FOSSIL FUEL-FIRED PEAK HEATING FOR GEOTHERMAL GREENHOUSES

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INTRODUCTION

Greenhouses are a major application of low-temperature geothermal resources. In virtually all operating systems, the geothermal fluid is used in a hot water heating system to meet 100% of both the peak and annual heating requirements of the structure. This strategy is a result of the relatively low costs associated with the development of most U.S. geothermal direct-use resources and past tax credit programs which penalized systems using any conventional fuel sources.

Increasingly, greenhouse operations will encounter limitations in available geothermal resource flow due either to production or disposal considerations. As a result, it will be necessary to operate additions at reduced water temperatures reflective of the effluent from the existing operations. Water temperature has a strong influence on heating system design.

Greenhouse operators tend to have unequivocal preferences regarding heating system equipment. Many growers, particularly cut flower and bedding plant operators, prefer the "bare tube" type heating system. This system places small diameter plastic tubes under the benches or adjacent to the plants. Hot water is circulated through the tubes providing heat to the plants and the air in the greenhouse. Advantages include the ability to provide the heat directly to the plants, low cost, simple installation and the lack of a requirement for fans to circulate air. The major disadvantage of the system is poor performance at low (<140°F) water temperatures, particularly in cold climates. Under these conditions, the quantity of tubing required to meet the peak heating load is substantial. In fact, under some conditions, it is simply impractical to install sufficient tubing in the greenhouse to meet the peak heating load.

Forced-air heating equipment (unit heaters, fan coil units, etc.) is very effective at low temperature operation. Unfortunately, many growers strongly resist using it. In these cases, the use of cascaded geothermal fluid to provide a portion of the heating requirements (base load) along with a conventionally-fueled peak heating system may be an effective strategy.

Due to temperature occurrences in most western geothermal locations, a base load system (geothermal) designed for approximately 60% of the peak load can actually meet 95+% of the annual eating requirements. As a result, a facility with limited geothermal flow can expand, use the heating system of choice and still achieve substantial energy savings with a base load/peak load heating system design. In addition, the fossil-fueled peak load system offers a no-cost emergency backup in the event of a failure in the geothermal system.

CONVENTIONAL GREENHOUSE HEATING SYSTEMS

Conventional greenhouse heating systems can take a wide variety of configurations (unit heater, fan coil unit, bare tube, finned pipe, etc.). Two system types, however, are most common: fan coil and bare tube. The fan coil heating units, as the name implies, include a fan for moving the air and a coil or heat exchanger for transferring heat from the water to the air. Several designs are available with some off-the-shelf units optimized for performance at low (<120°F) temperatures. Custom designed units are also sometimes used.

Bare tube systems consist of a large quantity of bare tubing, usually of polyethylene, polybutylene or EPDM, distributed throughout the greenhouse. Bare tube systems, in comparison to fan coil systems, are characterized by low equipment cost and zero fan energy consumption and simple installation practices. This makes the bare tube system especially attractive to greenhouse growers. The tubing system permits do-it-yourself installation, another feature attractive to developers. At low water temperature, bare tube systems require substantial quantities of tubing to meet 100% of the peak heating requirement in cold climates. Figure 1 presents system costs for a 1-acre house in a moderately cold (0°F outside design temperature) climate.

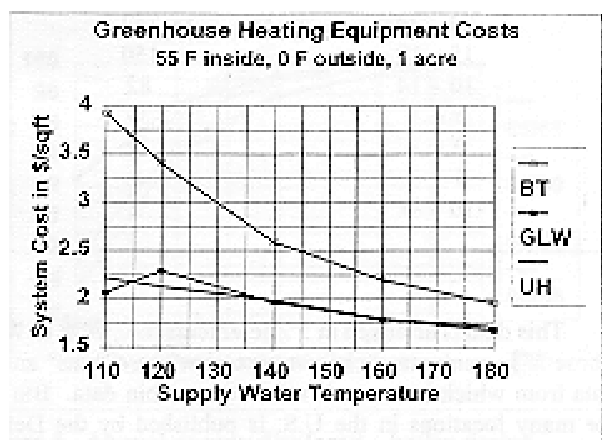

Figure 1. Greenhouse heating equipment costs.

It is apparent that the low-temperature unit heater (GLW) and the standard unit heater (UH) systems are more capable of economically dealing with low supply water temperatures than the bare tube system (BT). The reason for the high costs of the bare tube system at low temperatures is best illustrated with an example. Again using the 1-acre house of Figure 1, at a supply water temperature of 180°F, 106,000 feet of tubing would be required to meet the peak load. At a 110ºF supply water temperature, this figure is 397,000 ft. This means that for the example greenhouse, tubes would have to be spaced at intervals of less than 1 1/2 inches (over the entire floor area) to meet the load at the lower temperature.

CLIMATE CONSIDERATIONS

The rationale behind using different base load and peak load heating systems lies partly in the annual temperature profile.

Table 1. Annual Temperature Occurrences (Bin Data) Klamath Falls, OR

Outside Temperature (ºF)	Hours/Year
95 - 99	1
90 - 94	39
85 - 89	124
80 - 84	235
75 - 79	313
70 - 74	373
65 - 69	468
60 - 64	551
55 - 59	658
50 - 54	783
45 - 49	826
40 - 44	931
35 - 39	1044
30 - 34	1132
25 - 29	675
20 - 24	352
15 - 19	150
10 - 14	82
5 - 9	39
0 - 4	17
-5 - -1	6
-10 - -6	2

This data is arranged in 5º increments (i.e., 70º F to 74º F). These 5º increments are known as temperature "bins" and the data from which it comes is referred to as bin data. Bin data for many locations in the U.S. is published by the Defense Department in Engineering Weather Data, AFM 88-29, 1978.

The rate at which heat must be supplied to a structure (Btu/hr) to offset heat loss is directly related to the temperature difference between the outside air and the temperature inside the structure. The so-called peak load is calculated at an outside temperature referred to as the design outside temperature. This is a value below which only 1% of the hours in a typical winter occur. Conventional practice in the U.S. for geothermal systems is to design the system for 100% of the peak load.

The amount of energy required to heat a building (on annual basis) is determined by the number of hours occurring at outside temperatures less than the temperature maintained in the structure. The quantity of annual energy required at a particular temperature bin is determined by the number of hours at that bin and the temperature difference between it and the inside temperature of the structure. Summing the number of hours at various outside temperatures permits the development of a cumulative heating requirement curve similar to that in Figure 2. This particular plot was developed for an inside temperature of 60º F using the weather data from Table 1.

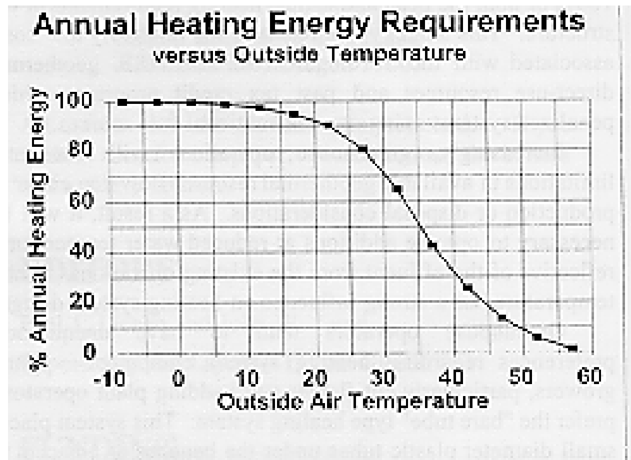

Figure 2. Cumulative heating requirement curve.

Because the base load system continues to operate in parallel with the peaking system, the percentage of annual energy captured by the base load system is greater than the value indicated in Figure 2. For example consider a base load system designed for 60% of the peak load (24ºF outside temperature). Figure 2 indicates that 85% of the annual heating needs occur above this temperature. In reality, a 60% sized system could capture 97.2% of the annual requirements in this climate.

It is clear that due to the nature of temperature occurrences, the base load heating system capable of meeting only half the peak heating requirement and still meets more than 90% of the annual heating energy needs of a structure.

PEAKING EQUIPMENT CAPITAL COSTS

Two broad approaches are available for the use of conventionally-fired peak heating equipment in a hot water greenhouse heating system: individual unit heaters and central peaking boiler.

Individual unit heaters offer the advantage of zero floor space requirements (since they can be hung from the ceiling). Because each unit requires accessory equipment (flue pipe, thermostat, distribution "poly tube", fuel line, electrical connection, etc.), the cost of a given amount of heating capacity is relatively high in comparison to the boiler approach.

The central boiler approach involves the installation of a peaking boiler downstream of the geothermal heat exchanger. The boiler's function is to boost the supply water temperature to the heating equipment during the peak load period. The higher water temperature allows a down-sized tubing system to provide the required capacity to meet the space heating requirement. Because only a single piece of equipment (along with its accessory components) is required, the cost of a given heat output is much lower than for the unit heater equipment cited above. Figure 3 provides cost data for both propane and oil-fired heating equipment. Oil-fired equipment costs include a double wall, fuel storage tank.

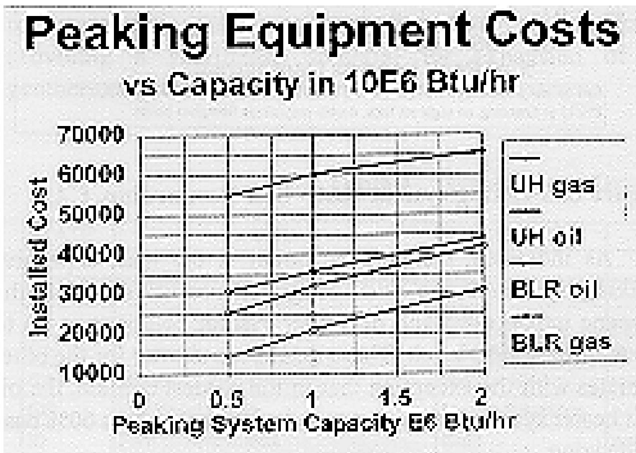

Figure 3. Peaking equipment costs.

CONTROLS AND OPERATIONAL CONSIDERATIONS

The object of the peaking equipment is to provide the capacity difference between the structure's requirement and the capacity of the base load (geothermal) system. This task must be accomplished in such a way as to produce even heat output and without compromising the performance of the base load system.

Peaking with individual unit heaters is a simple process with regard to controls. Each individual unit is equipped with a thermostat which initiates operation of the unit when additional capacity is required in the zone that it serves.

For the boiler design, the situation is somewhat more complex. This results from the boiler being incorporated into the heating loop. Because the boiler changes the temperature of the supply water, it not only influences the output of the terminal equipment but also the capacity of the geothermal heat exchanger.

As the supply water temperature rises, the output of the terminal equipment rises. At the same time, the temperature of the return water rises as well.

The rise in return temperature occurs at a rate less than the supply water increase due to the higher output of the terminal equipment (which results in an increasing system delta T). However, the rising return water temperature erodes the capacity of the geothermal heat exchanger to the extent that its capacity at the peak condition (0°F outside) is approximately 50% or less of its capacity prior to the initiation of boiler operation.

This results in two important impacts on the economics of the boiler approach: in a given application, the boiler must be sized larger than the unit heater equipment, and fuel use for the same peaking load is higher for the boiler approach.

Figures 4 and 5 show the annual heating energy displaced by base load systems sized for 50 - 90% of the peak load at four different inside temperature settings (day/night) for the Klamath Falls, OR climate. Figure 4 is based upon unit heater systems and Figure 5, the boiler design.

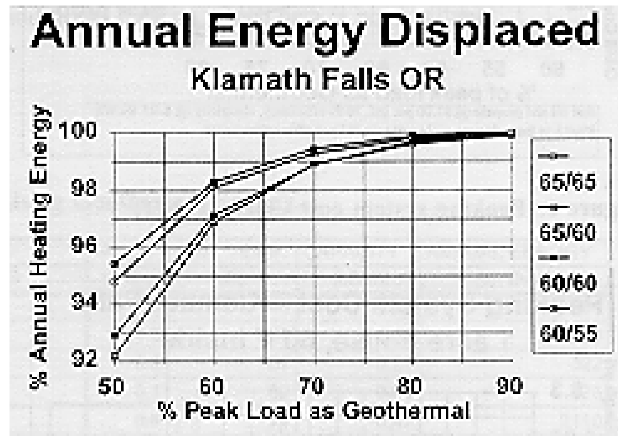

Figure 4. Annual energy displaced - unit heater system.

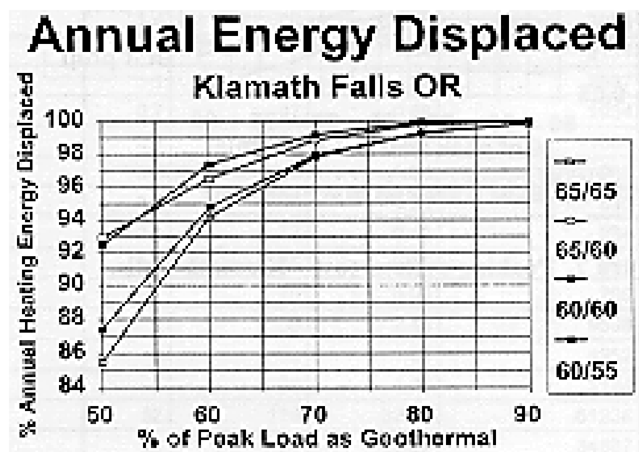

Figure 5. Annual energy displaced - boiler design.

CONCLUSIONS

The report which is summarized in this article examined the economics of fossil-fuel peaking for three different climates (Helena, MT; Klamath Falls, OR and San Bernardino, CA) representing very cold, moderate and warm climates. Figures 6, 7 and 8 present the results for these climates. Costs shown are expressed in $/ft² of greenhouse floor area and include capitalization of the equipment, fuel costs and maintenance for the fossil-fuel peaking system.

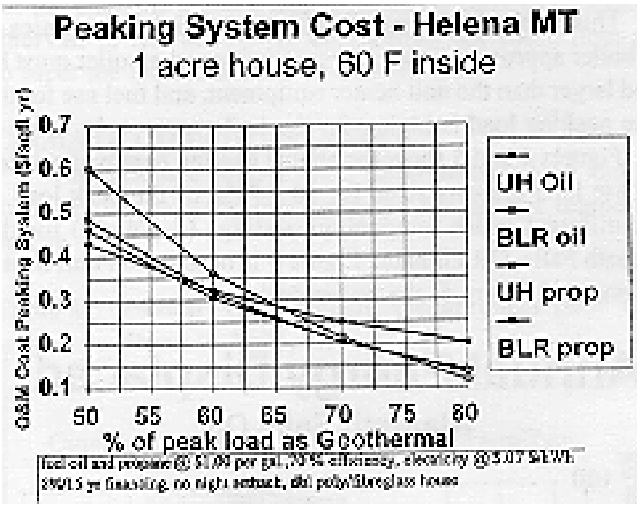

Figure 6. Peaking system cost - Helena, MT.

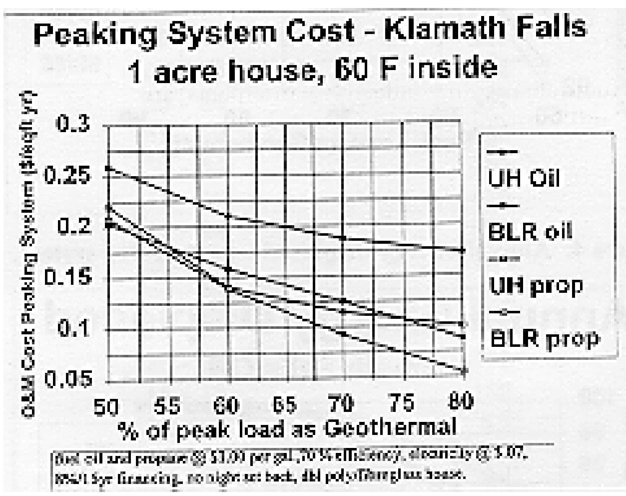

Figure 7. Peaking system cost - Klamath Falls.

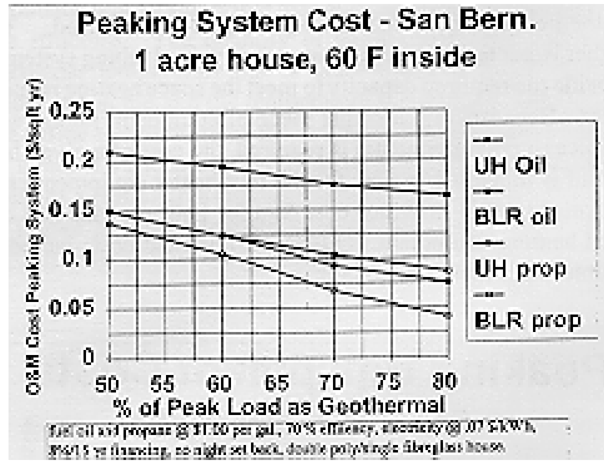

Figure 8. Peaking system cost - San Bernardino, CA.

As indicated, the propane boiler is the least expensive peaking system for a wide range of conditions, with the propane unit heaters and oil boiler system competitive up to the 65% base load level. These results are similar for the other climates with the exception that in the coldest climate, the oil unit heater system is the least cost design at less than 60% base load sizing.

It is unlikely that a base load/peak load system would be used in place of a 100% geothermal system if the decision was based solely on costs. In most, if not all, cases, the base load/peak load system will have both higher operating cost and capital cost than a geothermal system designed to meet 100% of the peak. In cases where there is limited geothermal flow available and the grower wishes to use a system which is difficult to apply at low water temperatures, the use of fossil fuel peaking permits the use of the growers preferred system for a reasonable increment in operating costs.