

KLAMATH FALLS GEOTHERMAL DISTRICT HEATING SYSTEM EVALUATION

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INTRODUCTION

The city of Klamath Falls, Oregon, is located near a geothermal resource that has provided heating for homes, businesses, schools, and institutions for many years. Almost 20 years ago, in 1977, Klamath Falls and Klamath County became interested in establishing a geothermal district heating system to extend the benefits of the geothermal resource to government buildings and businesses in downtown Klamath Falls.

The district heating system was constructed in 1981 to initially serve 14 government buildings with planned expansion to serve additional buildings along the route. The expectation at the time was that the system would have a high initial load and rapid expansion to full capacity. When the system feasibility was studied, the cost of natural gas was increasing rapidly; that trend was expected to continue, making geothermal energy highly attractive by comparison (Lienau, et al., 1977).

The promise of profitable operation has been elusive, even after fifteen years. More than once, financial and operational problems have resulted in serious consideration of shutting the system down. Challenges faced by the system have included:

- Initial opposition from other geothermal users to operating the system, resulting in a three year delay in system start-up to 1984,
- Failure of a portion of the distribution system piping after one season of operation, resulting in five years of downtime, reconstruction cost, and poor public perception of the system,
- Low-load factor, with the system operating at only about 15-20 percent of design capacity, and
- Low-natural gas cost, resulting in pressure to keep district heating energy costs low and leaving little incentive for new customers to connect.

While the district heating system has had more than its share of problems, there has been a strong underlying support for geothermal energy and the will to work through the problems.

- The initial opposition to system operation was resolved by extensive testing of the aquifer, requiring reinjection of geothermal fluids to stabilize well levels, and formation of a citizen Geothermal Advisory Committee to oversee geothermal development. That committee is now very supportive of the system,
- The perception of poor reliability after the pipeline failure has been eased by five years of reliable operation since system reconstruction in 1991, and
- The low load factor is being addressed by a system expansion effort, which has more than doubled the customers on the system.

The city began a marketing effort in 1992 to add more customers to the system. The initial focus was adding buildings along the pipeline because of the high cost of line extensions (Rafferty, 1993). The expansion effort got a huge boost from a community fund raising drive to extend the district heating mains to serve the Ross Ragland Theater, a community performing arts center. Most of the new connections and increased system load is served by that main extension. Geothermal heated sidewalks and crosswalks have been incorporated into a downtown redevelopment project along Main Street. The snowmelt system has generated considerable favorable press for the geothermal system and the city (Brown, 1995). Figure 1 shows the service area of the district heating system.

The Klamath Falls geothermal district heating system has been discussed in several publications. For more information, see Lienau, et al.,(1989 and 1991) or contact the Geo-Heat Center at Oregon Institute of Technology, Klamath Falls, Oregon.

Thanks to a great deal of hard work and perseverance, the Klamath Falls district heating system is back on track toward a bright future. It is important to keep it on track with reliable service and additional system expansion.

Need for System Evaluation

The winter of 1995 to 1996 was not a particularly severe winter, with no temperature excursions below 0°F. However, there were times that the district heating loop failed to maintain the differential pressure necessary to deliver design heating

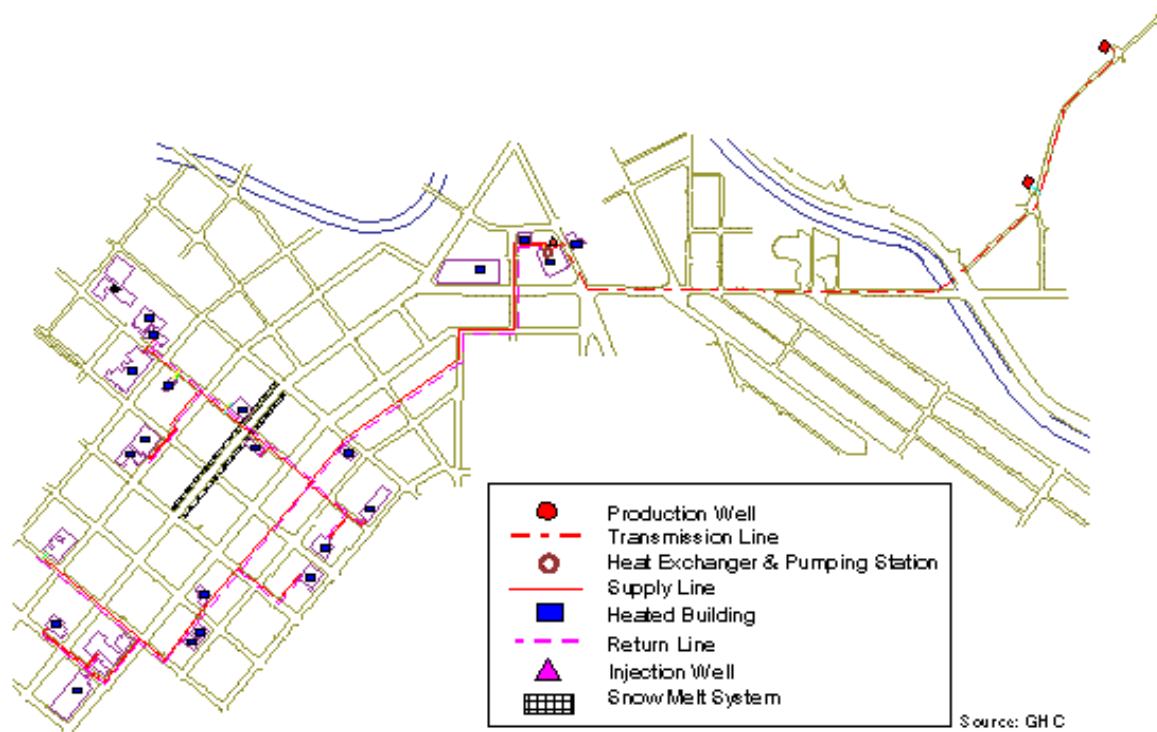


Figure 1. Klamath Falls geothermal district heating system location map, 1995.

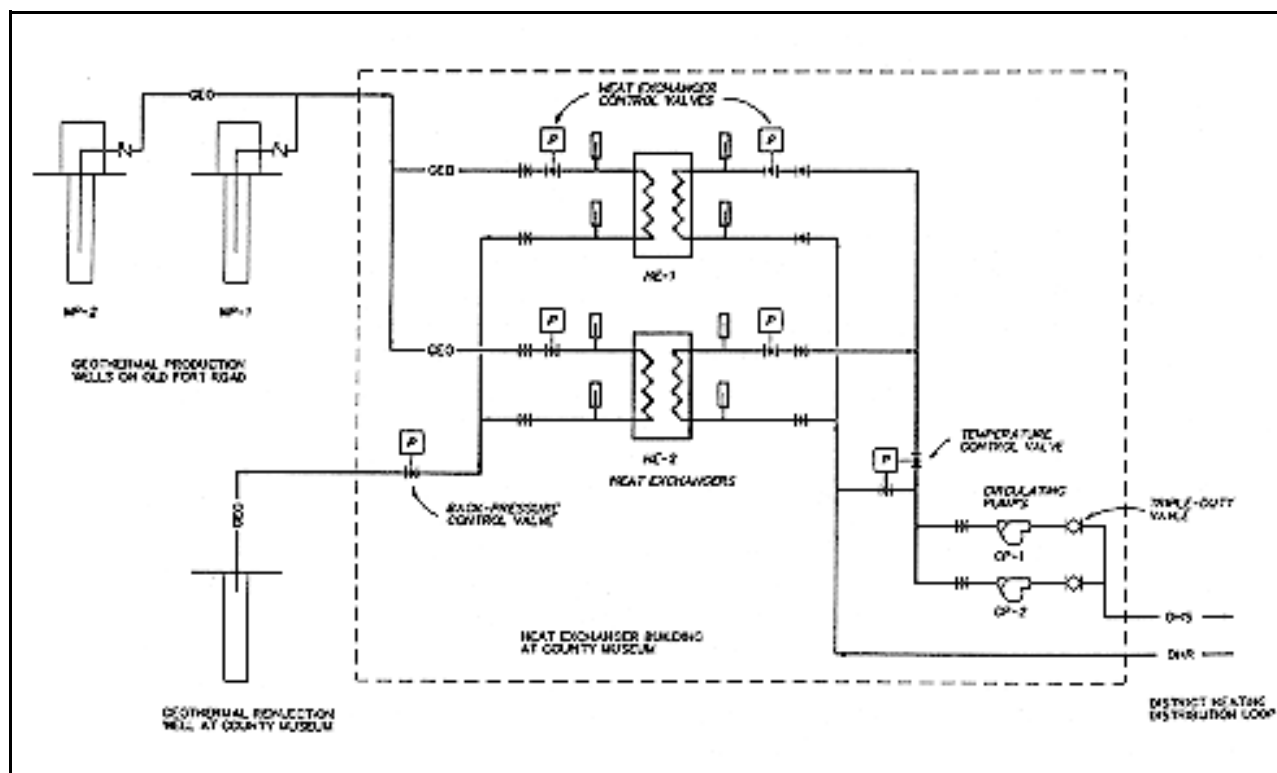


Figure 2. District heating system schematic.

capacity to many of the buildings. On one occasion, on a relatively mild night, the system circulation pump tripped out, leaving the customers with no heat. These incidents were little noticed by the district heating customers, but are indicative of problems that must be solved prior to another heating season or further expansion of the system. Questions to be addressed include:

- **System capacity:** What is the system heating capacity; what portion of the capacity is currently being used; how much further expansion is possible; and how can system capacity be increased if necessary?
- **System operation and controls:** How effective are existing automatic controls and operating procedures; how can they be improved to increase reliability and reduce operating costs?
- **System condition:** What is the condition of system facilities and equipment; what maintenance or improvements are necessary to provide continued reliable operation?

SYSTEM CAPACITY

Additional expansion is planned and is necessary for the financial stability of the district heating system. Yet, the operation of the system in the winter of 1995-1996 showed an apparent lack of capacity to meet currently connected loads. The apparent lack of capacity is primarily due to uncontrolled flow at several of the buildings and low system temperature differential (ΔT). This section discusses the effect of flow and ΔT on system capacity, the original design capacity of the Klamath Falls system, how much of that design capacity was used by the original system, the effect of system expansion, capacity improvements available with better flow control, and the system capacity limits.

Capacity, Flow and ΔT

Heating with water is based on circulating hot water to the heating equipment, transferring heat in the heating equipment to the heated space with resulting cooling of the water, and returning the water to the heat source to be reheated. The amount of heat delivered by the water depends on both the flow rate and the temperature change of the water. This can be expressed by the equation:

$$ENERGY (BTU/HR) = FLOW (GPM) \times \Delta T (F) \times 500$$

Flow is essentially fixed by the hardware selected in the design; for example pumps, pipes, control valves, heat exchangers, production wells, and reinjection well. As long as the equipment is maintained in good condition, the system will generally deliver the design flow. Any significant increase in the flow requires larger equipment and increased power to operate. The feasible increase in flow is limited by such things as pipeline size or well capacity that are too costly to economically increase.

Temperature change of the heating water (ΔT) is equally important to the delivery of heat. The ΔT is affected by physical constraints such as the temperature of the heat source, the temperature requirements of the heat load, and the sizing of the heat transfer device. However, the main cause of low ΔT or lower than design ΔT is failure to properly control heating water flow. Poor flow control will result in low ΔT , with the consequence of reduced thermal capacity and higher than necessary pumping costs.

Constant Flow-Variable ΔT : A boiler-based hydronic heating system is often designed for constant flow, with variable ΔT . The pump runs continuously, with a relatively constant flow. At the heating coils, 3-way valves direct the flow either through the coil when heating is required, or bypass the flow around the coil and back to the boiler and pump. If all of the heating coils happen to be operating at peak design conditions at the same time, then the overall system will operate at the design ΔT , and the boiler will operate at peak output to keep up with the load. If some or all of the heating coils are operating at less than full load, the flow remains constant, but the overall system ΔT and heat output decreases.

The constant flow-variable ΔT approach works fine for a single, small building. The boiler is sized to handle the peak output of the heating system, and works fine at reduced ΔT . Also, pumping cost is a relatively small part of the operation cost. However, this approach is not well suited for a district heating system:

- Pumping power is the most significant operating cost of a geothermal district heating system and is much greater with constant flow,
- Once a flow rate to a building is set, that in effect "locks up" a share of the total system capacity. With fixed, constant flow, there is no way to take advantage of building load diversity, and
- There is a tendency to over-specify the flow requirements of a building during design, committing more system capacity than the building really needs.

A constant flow system often results in low ΔT at full load and even lower ΔT at part load. This results in unnecessarily high pumping costs, and limits the thermal capacity of the system.

Constant ΔT -Variable Flow: A better approach for district heating is to design for constant ΔT -variable flow. Features of this approach include:

- Flow is controlled at the point of heat use by 2-way control valves; when no heat is needed, no flow is permitted,

- System-wide ΔT is constant or even increases at part load; flow is variable depending on load and ΔT ,
- A variable flow system provides better allowance for load diversity; flow capacity not needed at a particular building at a particular time is available to be used elsewhere,
- Variable flow results in reduced pumping power cost; pumping power is proportional to the cube of the flow, a 50% reduction in flow can produce an 88% reduction in power use, and
- Proper flow control results in better heat transfer in heat exchangers and primary-secondary pumping loops.

Design Capacity

The Klamath Falls geothermal district heating system was designed with a thermal capacity of 20 million Btu/hr on both the production side and the distribution side of the heat exchangers.

Table 1. Klamath Falls District Heating Design Capacity

	Flow	Temperature F			Heat
<u>Pump</u>	<u>gpm</u>	<u>Supply</u>	<u>Return</u>	<u>ΔT</u>	<u>Btu/hr</u>
Production					
WP-1	500				
WP-2	500				
Maximum	1000	210	170	40	20 x 10 ⁶
Distribution					
CP-1	1000				
CP-2	500				
Maximum	1000	180	140	40	20 x 10 ⁶

Original System Operation

The building heating systems in the original system were designed for constant flow-variable ΔT . In addition to the main circulation pumps in the heat exchanger building, each connected building had a circulation pump connected in series.

Table 2 shows the design flow, ΔT , and heat load of the original buildings. The design values are based on the balance valve flow schedule in the construction drawings, and 40°F ΔT . The fire station is included in the total heat load, but not the flow, because its return flow is pumped back into the system supply main. The total projected load was about 90 percent of the system design capacity.

Also shown on Table 2 is the measured or estimated maximum monthly average flows, heat load, and ΔT of each of the buildings and the overall system. Flow rate and average load are calculated from the monthly meter readings for total BTUs and gallons, divided by the estimated hours between

available. Buildings showing no flow were never connected to the system.

As shown, the metered maximum month heating load was substantially less than the design basis. The flow is less than the design flow only due to operation of the smaller circulation pump, CP-2. Since the smaller pump is unable to supply the total design flow, the system worked because each building had a booster pump, operating in series with the main loop circulation pump. The maximum observed system load is based on the highest system ΔT recorded in the daily logs, in January 1991.

Table 2. Klamath Falls District Heating System: Heating Load For Original Buildings

Building	Original Design			Maximum Month		
	Flow gpm	ΔT °F	Load MBH	Flow gpm	ΔT °F	Load MBH
Fire Station	-	-	529	-	-	286
Employment	46	40.0	920	0	0.0	0
Post Office	198	40.0	3,960	36	20.0	360
City Annex	30	40.0	600	22	7.7	85
City Hall	72	40.0	1,440	68	6.2	211
Vet. Memorial	82	40.0	1,640	21	14.5	152
Courthouse	201	40.0	4,020	157	7.1	557
Library	107	40.0	2,140	35	28.3	501
County Annex	25	40.0	500	29	8.4	122
Vet Services	16	40.0	320	0	0.0	0
State Offices	100	40.0	2,000	0	0.0	0
Total	877	41.2	18,069	368	12.3	2,274
Maximum observed				368	24.0	4,421

Table 2 illustrates how a constant flow approach, which does not account for building heating system over-sizing and building load diversity, can result in a system ΔT and useable capacity that is much lower than design.

System Expansion

Significant expansion to the district heating system began in November 1993 with the opening of the new distribution pipeline extension to the Ross Ragland Theater. In planning for connection of new customers, it was decided that the new connections would not include booster pumps. Instead, the main circulation pumps would be operated to provide a minimum of 5 psi differential pressure at the building connection. The building heating system conversions were designed to provide the required heating at that differential pressure and a ΔT of 40°F. Controls were included to maintain the required minimum ΔT over the entire operating range, and shut off flow when no heating is required.

The addition of new buildings requiring a 5 psi pressure differential, in parallel with the original buildings with booster pumps and no flow control, made it necessary to operate the

larger circulation pump CP-1 at all times. The smaller pump, CP-2, cannot meet even light winter loads, and can meet the summer hot water loads only if the service valves to the buildings without flow control are manually closed.

Table 3 shows the buildings currently connected to the system, with the estimated flow, ΔT , and peak heating load. The flows and loads in Table 3 are estimates based on rough flow measurements in June 1996, building heat load calculations, building system temperature monitoring, and meter readings. For buildings with metered monthly usage, a peak load of about 1½ times the maximum month average was used unless better information was available. The estimated loads are an attempt to allocate the observed system-wide peak load to individual buildings. They do not necessarily reflect the building design peak load or the relative total energy use or energy billings of the buildings.

Table 3. Klamath Falls District Heating System: Existing Heating Loads

Building	Existing Conditions			Improved ΔT		
	Flow gpm	ΔT °F	Load MBH	Flow gpm	ΔT °F	Load MBH
Fire Station ³	-	-	429	-	-	429
Post Office ²	270	4.0	540	27	40.0	540
City Annex	30	8.0	120	6	40.0	120
City Hall	75	8.5	320	16	40.0	320
Vet. Memorial ¹	0	0.0	0	0	40.0	0
Courthouse ¹	0	0.0	0	0	40.0	0
Library	60	20.0	600	30	40.0	600
County Annex	33	11.0	180	9	40.0	180
Subtotal Original	468	9.4	2,189	88	49.8	2,189
Balsiger	50	40.0	1,000	50	40.0	1,000
Eagles	10	40.0	200	10	40.0	200
Pacific Linen	125	24.0	1,500	75	40.0	1,500
US Bank	15	40.0	300	15	40.0	300
Snowmelt ³	-	-	500	-	-	500
SVS Bank	24	40.0	489	24	40.0	489
Sacred Heart	127	22.0	1,400	70	40.0	1,400
1st Baptist	50	40.0	1,000	50	40.0	1,000
Ross Ragland	31	40.0	620	31	40.0	620
1st Presbyterian	20	40.0	390	20	40.0	390
Subtotal New Connections	452	32.7	7,399	345	42.9	7,399
Total System	920	20.8	9,588	433	44.3	9,588
Maximum Observed	850	16.0	6,800			
<ol style="list-style-type: none"> 1. The Courthouse complex and Veterans Memorial building were on the system at the start of the system expansion, but were badly damaged by an earthquake. Those buildings have been demolished or are not heated. 2. The Post Office shows a substantially higher flow than metered due to an un-metered bypass valve. 3. The snowmelt system does not affect total flow because it works off of water pumped from, and returned to, the district heating return main. The load, however affects system-wide ΔT. Likewise, the Fire Station flow is returned to the supply main. 						

The district heating system operated during the 1995 - 1996 heating season with only one heat exchanger on line. Under those conditions, the calculated system-wide peak flow of 920 gpm is more than the larger pump, CP-1 can deliver. The maximum observed system load is based on the highest recorded ΔT , in February 1996, at the maximum calculated pump capacity.

Table 3 shows that the estimated and observed system peak load is one third to one half of the design thermal capacity. However, the system flow requirement is at or beyond the pumping capacity. To further increase heat delivery, either the flow or the system wide ΔT must be increased.

System Performance Improvement with Flow Control

The second part of Table 3 shows the conditions if the flow to the currently uncontrolled buildings is controlled to provide a 40°F ΔT . The result is considerably reduced total system flow which frees system capacity for additional expansion, and reduces pumping costs.

Capacity Limits

With improvements to the system ΔT and improvements to the system operation and control, it should be feasible to expand the connected load to about double the existing load. Since the system expansion will not happen in one year, there will be opportunity to observe system performance with each stage of expansion and adjust the projected limit accordingly.

The ultimate potential service capacity within the constraints of the existing wells and pipelines is limited by the flow and ΔT capabilities of the production and distribution systems. The limiting factor in overall capacity is currently the production system, most notably the flow acceptance of the reinjection well. Without additional development of the well, the system is limited to close to the original design capacity of 1000 gpm (20×10^6 Btu/hr).

If production capacity is available, either by increased production or fossil fuel peaking, the district heating distribution system could support a peak load of about 27×10^6 Btu/hr. Additional development beyond that load would be feasible if selected large users were on interruptible service, supplementing the geothermal heat with their standby heating source at peak heating load. Peaking with fossil fuels is economically attractive because a geothermal system sized for 75 percent of the peak load will provide more than 95 percent of the annual energy requirement.

SYSTEM CONTROLS AND OPERATION

The main controls for the district heating system are located in the heat exchanger building. The control system was designed to monitor the temperatures, pressures, and flows of the district heating loop and the geothermal production system; and to automatically control loop circulation pump operation, loop supply and return temperature, production well pump operation and speed, heat exchanger operation, and geothermal system back pressure. Figure 2 shows the system piping and control schematic.

Circulation Pumps

The district heating loop is circulated by two pumps: CP-1, rated 1000 gpm; and CP-2, rated 500 gpm. The controls were intended to operate the pumps automatically in response to system load, as indicated by the loop return temperature. At less than 50 percent of design capacity, the smaller pump was to operate. At greater than 50 percent of capacity, the larger pump was to operate. Since system start-up, the pump controls have always been operated manually, and it is unknown if the automatic controls would or could work as designed.

With expansion of the system, new connections were designed for variable flow-constant ΔT control at the buildings, with no booster pump. Existing buildings are also being converted to that approach. As the original control system is not designed for that operation, the pump controls should be upgraded. Recommended changes include:

- Install an additional large circulating pump to provide backup operation at full load, and
- Use an adjustable frequency drive to vary the pump speed to match system flow; control the pump speed to maintain the required system pressure differential.

Temperature Control

The control system was designed to maintain the district heating supply temperature at a constant 180°F by controlling geothermal production and the flow through the heat exchanger. On decreasing temperature, the system was intended to increase the geothermal production. On increasing temperature the system would reduce production, then modulate a 3-way valve to bypass district heating water flow around the heat exchanger.

The only portion of the temperature control that is currently functional is the control of the 3-way valve. Geothermal production is controlled manually. This provides reasonable, although not very precise, control as long as there is adequate geothermal production to meet the system heating demand. With manual control, the district heating system temperature drops during periods of high heating demand when the geothermal flow is inadequate to meet the demand. When system load is low, the geothermal reinjection temperature increases. This, on occasion, has resulted in the entire system shutting down due to a high temperature alarm.

Production Well Control

The temperature control system was intended to control operation and modulate the speed of the production well pumps in response to system load, as indicated by district heating supply temperature. A leased phone line was used to transmit a START/STOP signal and an analog SPEED signal to the well pump controls and receive back a RUNNING signal. On decreasing district heating supply temperature (increasing load), the controls would first modulate the lead pump to full speed, then start the lag pump and modulate the two pumps together. On increasing temperature, the speed of

both pumps would be reduced, then the lag pump would stop and the lead pump speed would be modulated to match load.

The automatic well pump controls reportedly worked satisfactory at system start-up, with a single pump in operation. There was some flow instability that was attributed to the low system load and problems with the back-pressure control valve. The well pumps have been controlled manually since start-up, and the automatic control is currently not functional due to problems with the telemetry link.

Repair or upgrade of the well pump automatic control is needed to provide reliable district heating supply temperature control. The more the system load grows, the more important automatic well pump control becomes. For stable operation, the control system should respond to more complete information on system operation than just supply temperature. The pump control should respond very slowly to changes in load, increasing flow in small increments, and waiting for the system to stabilize before making another change. As this cannot be done by the existing controls, they should be replaced by a control system that can, such as a digital control (DDC) system.

Heat Exchanger Control

The flow to the two heat exchangers is designed to be coordinated with well pump operation. Automatic valves allow flow through one heat exchanger when one well pump is on, and both heat exchangers when both pumps are on. Since operation of both well pumps at once is currently never needed, the system forces all the district heating loop flow through a single heat exchanger. Modification of the control system to allow parallel operation of both heat exchangers will improve heat transfer and reduce pumping cost.

Back-pressure Control

Both of the production wells supply geothermal water hotter than the boiling temperature at the system altitude of 4,100 ft. The operation log for WP-2 shows temperatures as high as 228°F. The geothermal water is prevented from flashing to steam in the piping by a control valve which maintains a 25 psi back-pressure on the system. The control valve is a line-size, commercial-duty, 8-inch butterfly valve. This valve is not the most appropriate selection for the service, since most of the time the system operates at near minimum geothermal flow, requiring the valve to operate almost completely closed. This operation mode is hard on the valve and does not allow proper control.

At system start-up, the back-pressure control was extremely unstable. That instability was reduced by manual throttling of an isolation valve, and restricting the sensitivity of the control. This has worked acceptably at the low, fairly constant, geothermal flow with manual well pump control. It is unknown if the controls can work automatically over the entire design flow range.

Back-pressure control is a difficult control service, with the valve required to operate over a wide flow range, controlling hot fluids that can flash to steam or cause

cavitation on the downstream side of the valve. The valve should be designed for the high temperature and cavitation, and sized to be at least 20 percent open at minimum flow. If a butterfly valve is used it should be an industrial quality valve, typically one or two sizes smaller than line-size.

Flow Measurement

The control system was designed with flow measurement on the geothermal water ahead of the injection well and at each heat exchanger, and on the district heating loop both at the supply and return. The flow meters are paddle-wheel type, inserted through a packing gland and ball valve into the bottom of the pipe. The flow meters only lasted for a short time, and sediment in the bottom of the pipes tended to fill in around the probe, making them near impossible to remove. Currently, none of the original six flow meters are functional.

Flow metering is valuable for tracking geothermal water usage and monitoring system operation and energy delivery. Installation of two new flow meters is recommended, one on the geothermal flow and one on the district heating loop. The meters should be industrial quality, rated for the temperature and service, with good turn-down. Vortex meters or magnetic flow meters would meet those requirements. Either the meters or the control system should have the ability to totalize both flow and BTUs.

Pneumatic vs. Electronic Controls

The existing control system is a pneumatic system, with electrical switches and relays as necessary to interface with the control panel switches, lights, and motor starters. Within the limitations of the designed control strategy, the pneumatic controls are working fairly well. However, the air compressor and control air dryer are in questionable condition, and much of the original control system is not functional or is in need of improvement.

The current state-of-the-art in control systems is electronic direct digital controls (DDC). Such a system can provide better, more accurate control, automatic logging of system operation parameters and alarms, automatic dial-out of critical alarms, and ability to provide dial-in access to adjust control set-points and operation. A DDC control system is being used successfully on the sidewalk snowmelt project. The district heating control system could be converted to fully electronic control, including valve actuators, or the existing pneumatic actuators could be used.

A properly operating control has the potential to improve system reliability and reduce operation and maintenance costs. Controls must be high quality, designed to be reliable in a hot, humid environment.

EVALUATION OF SYSTEM CONDITION

This section reviews the condition and maintenance needs of the district heating equipment and facilities. The system consists generally of geothermal production, geothermal transmission, the heat exchanger facility, and district heating distribution.

Production

Geothermal water is produced by two production wells. Production well pumps are vertical line shaft pumps, oil lubricated, with variable-speed fluid coupling drives. The pumps are rated for 500 gpm each, and are powered by 50 hp motors. The upper well supplies water at about 226°F, and the lower well supplies water at about 206°F. The pumps have provided excellent reliability, with no major maintenance requirement over the past 15 years. One drive motor has been rewound.

The well pumps are started manually at the well house and the speed is adjusted manually by adjusting the length of the control linkage. The automatic temperature control valve on the fluid drive oil cooler is not working, so the cooling water flow must be started and adjusted manually. The drip oiler for the pump line shaft is also checked on starting the pump and daily while operating.

Aside from repairing or replacing the non-functional controls, the only immediate maintenance need is repairing oil leaks in the pump and fluid drive. The pumps should be inspected by a qualified pump service company. The fluid drives used to control pump speed have been reliable, but are getting old, are expensive to repair, and are relatively inefficient. When any significant maintenance is required on the fluid drives, replacement of the drives by adjustable frequency electric motor control is recommended. An adjustable frequency drive will provide better control, better efficiency, and better reliability than the fluid drives.

Geothermal Transmission Pipeline

Geothermal flow from the production wells is conveyed to the heat exchanger building through an 8-inch pre-insulated steel pipeline, about 4400 feet long. About one-third of the pipeline is direct buried, the rest is enclosed in a concrete pipe tunnel.

Tapping of the line for a service connection in 1993 revealed that the interior of the pipe is in excellent condition with minimal corrosion. The exterior of the pipe, where enclosed in the fiberglass carrier pipe and urethane foam insulation should also be in good condition. Corrosion is most likely to be a problem at fittings, expansion joints and pipe anchors, where the steel can be exposed to soil moisture or water.

As far as we know, corrosion has not yet compromised the integrity of the geothermal pipeline. It is, however, a potential time bomb if not addressed. The pipeline should be thoroughly inspected for corrosion, and the cathodic protection system anodes should be dug up for inspection and renewal. Any corrosion problems must be corrected as soon as possible to maintain system reliability and to prevent more costly problems in the future.

Heat Exchanger Building

The heat exchanger building houses the heat exchangers, circulation pumps, and controls for the district heating system. Flow from the geothermal water pipeline enters the heat

exchanger building, flows through a strainer, flows through the heat exchangers, through a back-pressure valve, and into the reinjection well. On the secondary side of the heat exchangers, clean city water is circulated through the heat exchangers and to the distribution system by two circulating pumps: CP-1 and CP-2.

Heat Exchangers: The heat exchangers are plate-and-frame heat exchangers with 316 SST plates. Each heat exchanger is designed for 10×10^6 Btu/hr heat transfer at 500 gpm, with 8 psi pressure drop. The heat exchangers have provided good service. They have been cleaned only once, in 1994. As the district heating load increases, more frequent cleaning will be needed to maintain performance. By comparison, the heat exchangers on the geothermal system at the hospital are cleaned annually. Capacity of the heat exchangers can be increased, if needed, by adding more plates.

Valves: Control valves and manual isolation valves in the geothermal and district heating loops are line size, commercial quality rubber-lined butterfly valves. The manual valves have provided good service and appear to be in good condition. The back pressure valve should be replaced with a higher quality valve, more appropriately sized, as discussed in the controls evaluation previously. The temperature control valve is a 3-way valve consisting of two linked butterfly valves. The stem seals are leaking badly, and the valves should be repaired or replaced.

Pumps: The circulating pumps have provided good service and are in good condition. Pumps CP-1 and CP-2 are vertically mounted split-case pumps, rated for 1000 gpm and 500 gpm respectively. As previously noted in the discussion of system controls, addition of a third pump is recommended to provide standby capacity at design load, with adjustable speed control to reduce pumping energy cost.

Ventilation: The heat exchanger building is extremely hot inside due to the high heat gain from the hot water, and limited ventilation. Recorded temperatures in the basement of the building have exceeded 116°F. This high temperature is hard on equipment and maintenance personnel. Heat gain can be reduced by insulating the heat exchangers, bare piping and the air separator tank. Temperature and humidity in the building can be reduced by increasing the ventilation rate, adding exhaust fans and additional air intakes.

District Heating Distribution Piping

The district heating distribution is a closed loop system, with both supply and return pipelines. Almost half of the original system length was 10-inch, pre-insulated steel pipe. The rest of the piping, 8-inch and smaller, was key-lock fiberglass pipe. The fiberglass pipe joints failed after the first heating season due to defective epoxy on the factory-glued joints. The fiberglass pipe was entirely replaced with pre-insulated ductile iron pipe.

As with the geothermal pipeline, the piping should be inspected for external corrosion, particularly in the expansion joint vaults for the steel pipe and in the customer service vaults.

CONCLUSIONS

The district heating system is currently operating at one third to one half of design thermal capacity. However, the distribution system is near hydraulic capacity due to uncontrolled flow at several buildings. With improved flow control resulting in increased system ΔT , the system can support significant additional expansion.

The district heating system is currently functioning adequately and reliably on mostly manual control. Control improvements would improve operation and reliability and reduce operating cost.

The system is basically mechanically sound. Maintenance is needed, especially in the area of corrosion control to keep the system sound.

Although the district heating system is not yet financially self-supporting, this study recommends additional investment in the system. The payback from that investment will come in the form of operational cost savings, continued reliability and community support, and ability to increase revenue with further system expansion.

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