KLAMATH FALLS GEOTHERMAL DISTRICT HEATING SYSTEMS

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INTRODUCTION

The city of Klamath Falls, Oregon, geothermal district heating system was constructed in 1981 to initially serve 14 government buildings with planned expansion to serve additional buildings along the route. After a difficult start-up period, the system has provided reliable service since 1991. For more information on the system development, see Lienau, et al., (1989 and 1991).

The district heating system was designed for a thermal capacity of 20 million Btu/hr (5.9 MWt). At peak heating, the original buildings on the system utilized only about 20 percent of the system thermal capacity, and revenue from heating those buildings was inadequate to sustain system operation. This led the city to begin a marketing effort in 1992 to add more customers to the system (Rafferty, 1993).

Since 1992, the customer base has increased substantially, with the district heating system serving several additional buildings and extensive areas of sidewalk snowmelt. Figure 1 shows the service area of the district heating system.

In the winter of 1998 to 1999 the district heating system served the highest load ever, with peak loads estimated at 50 to 60 percent of the original design capacity. The system showed some strain under the load, with operational difficulties related to capacity, controls, and equipment failures. System upgrade and maintenance work is scheduled for the summer of 1999 to improve system capacity, control, and reliability.

BUILDING HEATING

The original and continuing primary purpose of the district heating system is to serve building space heating requirements. The original buildings connected to the system included:

- County Museum
- Fire Station
- Post office
- City Hall
- City Hall Annex
- County Library
- County Courthouse
- Old County Jail
- Veteran's Memorial Building (County offices)
- County Annex

The courthouse, jail, and Veteran's buildings were all extensively damaged by an earthquake in 1993 (Lienau & Lund, 1993). The earthquake damage caused the loss of that building space for County government use, and the loss of the heating revenue for the district heating system. These buildings were subsequently demolished and replaced.

The HVAC system controls in the County Library were upgraded in 1996, resulting in a 50% reduction in the heating costs; from about $12,000 to $6,000 per year. That was good for the County, but reduced revenue for the district heating system.

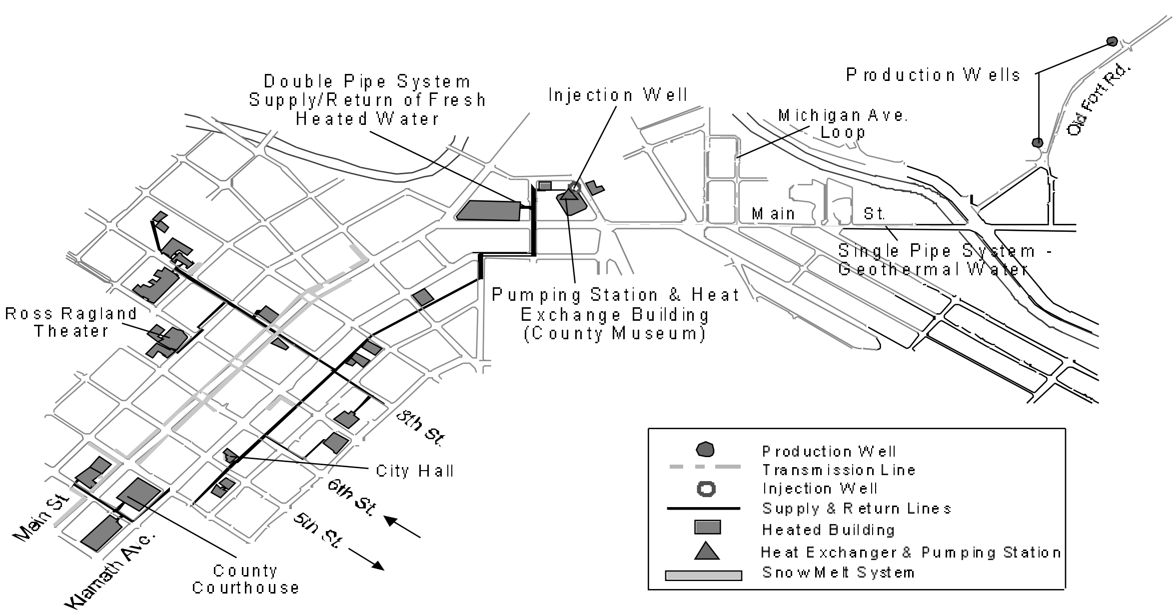

Figure 1. Map of Klamath Falls geothermal district heating system.

New facilities added to the district heating system in1993 through 1997 included:

- Christ Lutheran Church (served off the geothermal production main)
- Balsiger Building (replacing heating from a private geothermal well)
- Eagles Club
- Gospel Mission
- Ross Ragland Theater
- First Presbyterian Church
- First Baptist Church
- Sacred Heart Catholic Church (complex of 4 buildings)
- South Valley State Bank
- US Bank
- Pacific Linen (commercial laundry)

New in 1998:

- Klamath County Government Center building. This building is a renovation of the old County Annex building with a significant new addition. The construction included a complete new HVAC system.

New and under construction for 1999:

- Howard's Body Shop
- Klamath County Courthouse. This is a new replacement for the earthquake damaged and demolished original courthouse.
- Addition to the Ross Ragland Theater. This addition will increase the heated floor space from about 12,000 ft^2 to about 22,000 ft^2 The total heating load is expected to remain about the same due to added insulation and improved heating system controls in the original building.

As of the winter of 1998 - 1999, the estimated design peak load for the buildings on the district heating system is about 8 $x10^6$ Btu/hr (2.3 MWt).

DESIGN OF THE COUNTY GOVERMENT CENTER BUILDING HEATING SYSTEM

The new county buildings are the first on the geothermal district heating system with efficient use of the system incorporated in the original design. Important features of the heating system design include:

- Heating coils are selected for low flow and high water-side temperature drop (delta-T).
- Heating water control valves are mostly 2-way valves, resulting in a variable heating water flow and a high heating water system delta-T.
- Heating water pumps are controlled by adjustable frequency drives, minimizing pumping energy use and accommodating the variable heating water flow.
- The building heating water supply temperature is aggressively reset to a lower temperature at higher outside air temperatures and lighter building heating demand.
- Lower temperature loads, such as the sidewalk snowmelt system, are served from the heating water return, increasing overall delta-T.
- The control valve on the district heating water supply is closely controlled to meet building heating loads while minimizing the flow and maximizing the delta-T.

Figure 2. Klamath County Government Center Building.

The beneficial result of these design features is the maintenance of high system delta-T, meeting the heating demand with the minimum flow from the district heating system. The high delta-T benefits the geothermal district heating system all the way back to the production wells. Operation of the system at high delta-T reduces pumping costs, improves performance of heat exchangers, and increases the energy delivery capacity of the system.

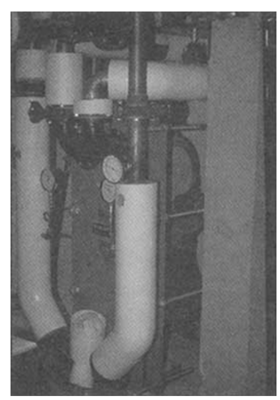

Figure 3. Government Center district heating heat exchanger.

The city does not guarantee uninterrupted service, as is the case with other utilities, from the district heating system; consequently the county building heating system includes a back-up boiler. The controls in the County Government Center building monitor the status of the district heating system and automatically operate the back-up boiler to supplement the heat available from the district heating system or to provide complete back-up heating. The controls compare the supply temperature available from the district heating system with the set-point temperature for the building heating water system. If the district heating system is colder than the required building heating water temperature, the district heating control valve is closed to prevent heat loss from the building system. Once the district heating system is returned to service, the controls initiate an automatic warm-up sequence to purge the cold water from the system piping. After the district heating supply temperature returns to normal and is adequate to meet the building heating demand, the boiler shuts off automatically.

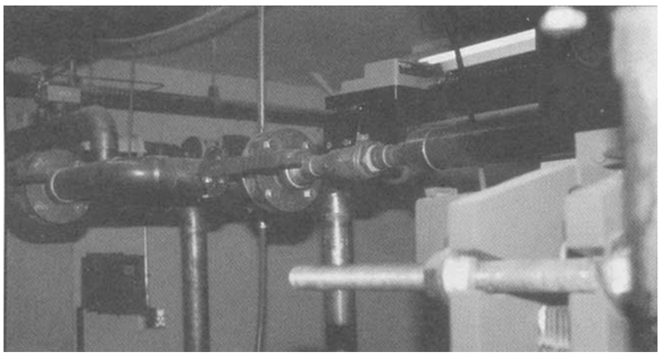

Figure 4. Klamath County Government Center district heating flow control valve. Good flow control is vital for efficient operation.

Over the 1998 to 1999 heating season, the district heating system experienced more than the ususal number of service interruptions from power outages, control problems, and production well problems. In all cases, the boiler controls provided automatic, uninterrupted heat to the building, while minimizing boiler run time.

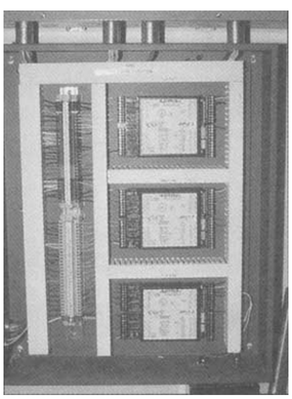

Figure 5. Government Center heating water, boiler, and snowmelt controls.

The County Government Center building includes about 37,000 ft^2 of conditioned floor space and about 10,000 ft^2 of heated sidewalks. The peak heating design load for the building and sidewalks was estimated to be 2.4×10^6 Btu/hr (0.7 MWt), requiring a peak flow rate from the district heating system of 120 gpm at 40°F delta-T, based on a 180°F supply temperature from the district heating system and 140°F return temperature. The peak measured load in February, 1999 (after installation and setup of the meter) was 1.3×10^6 Btu/hr (0.38 MWt) with a peak flow of 50 gpm. Annual energy consumption is estimated to be about 1.8×10^9 Btu (520 MWht).

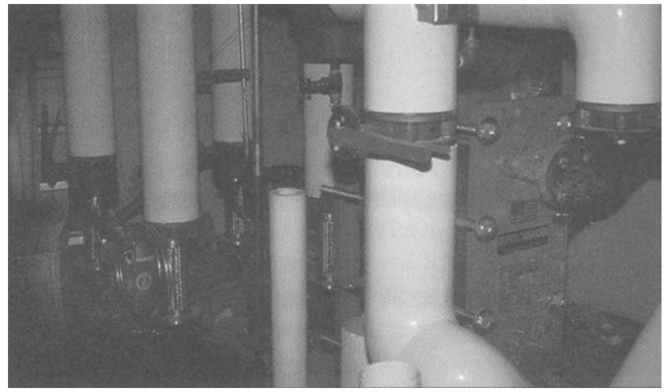

Figure 6. Government Center snowmelt heat exchanger.

Performance of the building heating system has been excellent, exceeding design expectations. Typical district heating return water temperature is 110°F when the snowmelt system is operating in the IDLING mode; and 120°F when the snowmelt system is off or operating in the higher temperature MELT mode. This return temperature is well below the design 140°F, and reflects the capability of the heating system to operate in a higher than design delta-T. The performance of the system can be attributed to a combination of system design, conservative heat exchanger sizing, and careful design and programming of the Alerton DDC control system.

SIDEWALK SNOWMELT

Geothermally heated sidewalks and crosswalks have been incorporated into a downtown redevelopment project along Main Street, starting with the 800 block in 1995. (Brown, 1995). That snowmelt system has been extended to cover nine blocks of sidewalks and crosswalks, from 2nd Street to 11th Street. The heated sidewalk and crosswalk area currently served by the city snowmelt system is about 51,000 ft^2. Anticipated additions to the city system in 1999 will bring the total area to about 60,000 ft^2.

Several snowmelt systems have also been installed separate from the main City snowmelt system, served from the district heating system through a building heating system or directly from the district heating mains. These installations include the County Government Center building, the Basin Transit bus transfer station, Sacred Heart Catholic Church, City Hall, City Hall Annex, South Valley Bank, and KOTI. The installed area of these systems is about 19,000 ft^2. About 15,000 ft^2 of additional private snowmelt system area is anticipated for 1999.

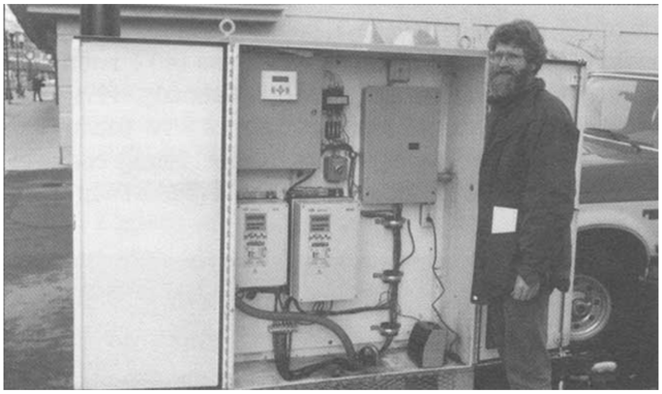

Figure 7. Klamath Falls snowmelt system control panel with author Brian Brown, P.E., consulting engineer.

The sidewalks are heated by circulation of a heated antifreeze solution through a network of polyethylene tubes imbedded in the sidewalks or in a sand or slurry base under the sidewalks. The solution is heated through a heat exchanger from the building heating water system or the district heating water. Where feasible, the heat is extracted from the return water side of the heating system to increase the overall district heating system delta-T.

Figure 8. Snowmelt tubing in slurry backfill under sidewalks.

Most of the snowmelt systems are designed for a heat output of 60 to 80 Btu/h·ft^2 of heated sidewalk. That design heat output is adequate for convenience snow melting under most conditions in Klamath Falls. It will not keep the sidewalk above freezing in extremely cold conditions, or keep up with high snowfall rates. Figure 9 shows the slush accumulation after a heavy snowfall this past winter. Figures 10 and 11 shows a section of sidewalk after the system had a chance to catch up. The sidewalk beyond does not yet have the snowmelt system installed. The trees are protected with styrofoam insulation to keep them from budding in the winter during system operation.

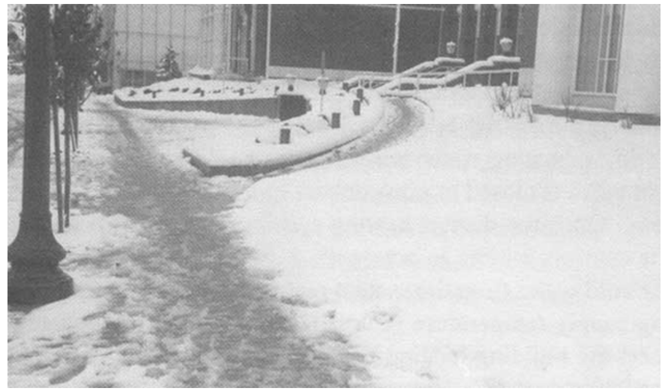

Figure 9. Slush accumulation after a heavy snowfall.

Figure 10. Clear sidewalk after snowfall. Tree well is protected from heat by insulation. Sidewalk beyond is not heated.

Figure 11. Basin Transit transfer station snowmelt.

The snowmelt systems have become a significant portion of the total district heating system load, with an estimated design peak load of about 4 x10^6 Btu/hr (1.2 MWt).

SYSTEM GROWTH AND CAPACITY

The peak load under normal design winter conditions for currently connected users is estimated to be about 60% of design system capacity, or 12 x10^6 Btu/h (3.5 MWt). The peak load is not precisely known, since the system has not had flow and energy monitoring. With improved controls and monitoring on-line for the '99-'00 heating season we will be better able to track system operation and project system reserve capacity.

Without system flow and energy instrumentation, evaluation of system load and reserve capacity has been based on general observations of system performance. Operation in the '95-'96 heating season indicated pump flow capacity concerns in the district heating closed loop, primarily due to poorly controlled flow at many of the users and the resulting low system delta-T. Improved flow control at three of the larger users improved that situation, and there were no capacity problems in the '96-'97 and '97-'98 heating seasons.

In the '98-'99 heating season the circulation pump still showed adequate capacity, maintaining more than 15 psi pressure differential between the district heating supply and return at the far end of the system. The system delta-T remained lower than design, with a typical delta-T of about 13°F and maximum delta-T of about 24°F; compared to the design delta-T of 40°F. This indicates that more work on flow control is necessary.

The system was designed to operate both production wells at design capacity, but that has never been necessary. Typically the lower, cooler (206°F) well is operated in the mild seasons and the hotter (226°F) upper well is used in the colder part of the winter. In December, 1998 the temperature dropped to -10°F, the coldest it has been for several years. Under those conditions, the upper well was unable to maintain the desired district heating supply temperature of 180°F. That may be partially due to fouling on the heat exchangers, but it also indicates a need to either increase the pumping capacity of the upper well, or begin operating both wells to meet the peak heating loads.

OPERATION AND IMPROVEMENTS

The district heating system has run close to nonstop since 1993, with short or partial shutdowns for system connections or maintenance. Extensive system maintenance is planned during a system shutdown in the summer of 1999. Planned work includes:

- Replacement of all critical isolation valves to facilitate future maintenance
- Installation of a second large circulation pump on the closed-loop system with an adjustable frequency speed control
- Improved control of flow to connected buildings
- Rehabilitation of the upper geothermal well pumps and replacement of the Nelson fluid drives with a larger motor and adjustable frequency speed control. Pump capacity will be increased 60%, from 500 gpm to 800 gpm.
- Cleaning of the main heat exchangers and addition of about 50% more plates
- Replacement of the system controls with digital programmable logic controller (PLC) based controls, with radio telemetry between the heat exchanger building, the remote pump stations, and the system manager's office
- Installation of new magnetic flow meters for geothermal and closed loop flow and energy measurement
- Cleaning and painting exposed pipe and fittings in tunnels and vaults
- Improved ventilation of expansion joint vaults and the production pipeline tunnel to reduce moisture accumulation and corrosion
- Maintenance of the pipeline cathodic protection systems

The planned system maintenance and improvements will improve the reliability and capacity of the district heating system to meet the existing and planned heating load. The improved flow control and adjustable speed pumping are also anticipated to reduce the electrical cost of operating the system by about 75 percent.

CONCLUSIONS

The city of Klamath Falls geothermal district heating system has experienced considerable growth in the past few years. Additional expansion is scheduled for 1999, and there is considerable additional interest in hooking onto the system. System maintenance and control system improvements scheduled for 1999 will make the system more reliable and less expensive to operate. This combination should help the district heating system make the transition from a subsidized experiment in renewable energy to a fully self-sustaining utility.

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