THE OREGON INSTITUTE OF TECHNOLOGY GEOTHERMAL HEATING SYSTEM - THEN AND NOW

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INTRODUCTION

Oregon Institute of Technology (OIT) is located on a hill, which gently slopes from the east to the west, in the northeast part of Klamath Falls. The campus has been using geothermal water, for its heating and domestic hot water needs, since it was relocated to this location in 1964. It has been in continuous operation for 35 years and now heats 11 buildings (~600,000 ft^2 / 55,700 m^2). It is the oldest of the modern geothermal district-heating systems, and due to the lack of experience with the design of large systems in the early-1960s, it has experienced some difficulties through the years. These difficulties have been resolved and the experience has provided a substantial body of information concerning the applicability of various materials and designs for low-temperature use.

The original system, which provided heating and domestic hot water for the five original buildings, consisted of constant-speed, water-lubricated lineshaft pumps located in well pits. The pumps were run manually according to the level in the storage tank. The distribution system consisted of direct-buried Schedule 40 carbon steel piping which was field insulated with "Foamglas" type insulation and covered with a "mastic" vapor barrier. The geothermal water was used directly in the buildings' mechanical heating systems; then, the effluent was disposed of to the surface through the storm drainage system than eventually emptied into Upper Klamath Lake. Cooling for the campus was accomplished by an electric-powered chiller.

Figure 1 shows a general layout of the OIT system as it is today. Geothermal water for the system is produced from three wells at a temperature of 192°F (89°C), which are located in the southeast corner of the campus. The wells are from 1300-1800 ft (400-550 m) in depth. The water is pumped individually from each well (total flow of all the wells is 980 gpm/62 L/s). The water is then collected in a 4000-gal (15-m^3) settling tank in the Heat Exchanger building before it is delivered to each building via gravity through the distribution system according to demand on the system. The settling tank (Figure 2) provides the necessary head for the gravity flow system and allows the fines from pumping to settle out of the water. The heat exchanger building also housed a fuel-oil boiler from the old campus as a backup; but due to lack of use, it was dismantled several years ago. The geothermal system saves approximately 11,000 bbl (1650 tonnes) of oil or $225,000 each year.

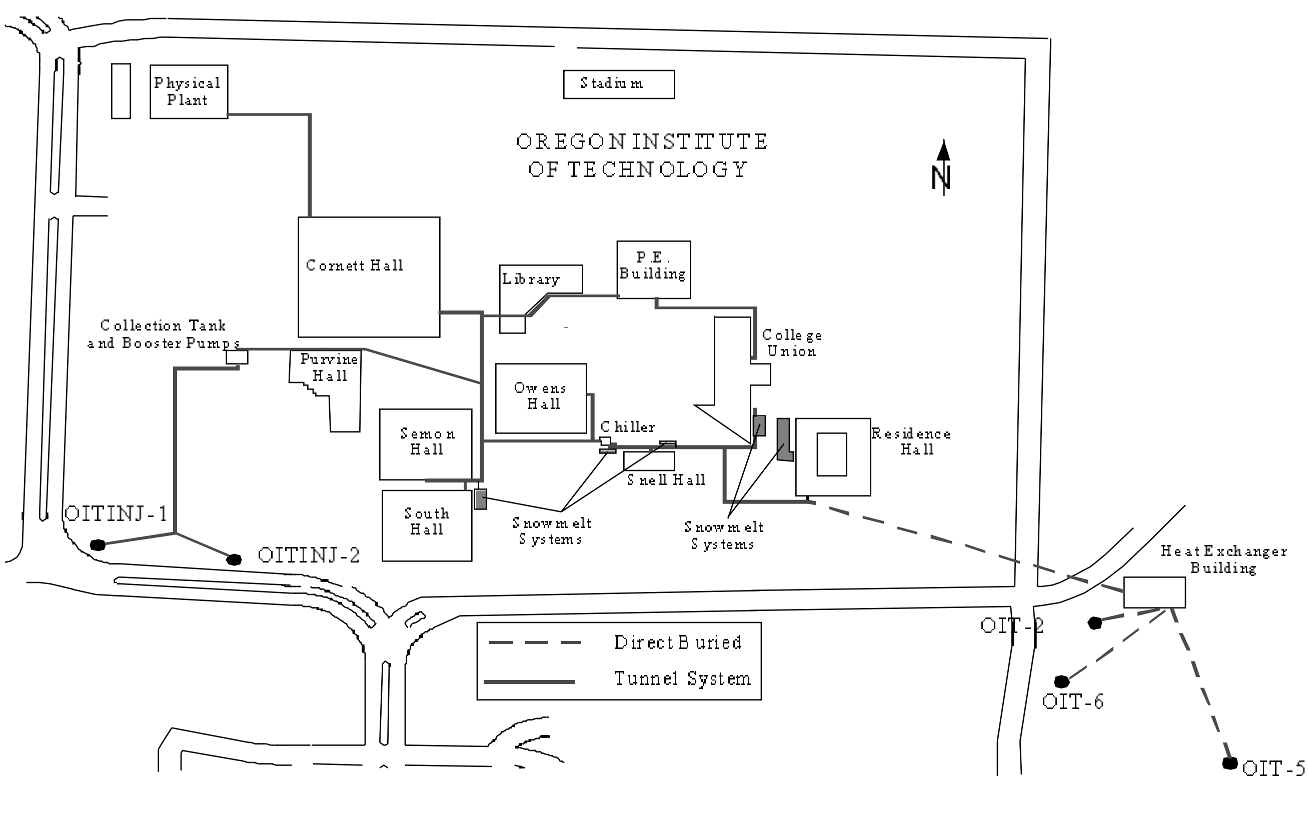

Figure 1. General layout of the OIT geothermal system.

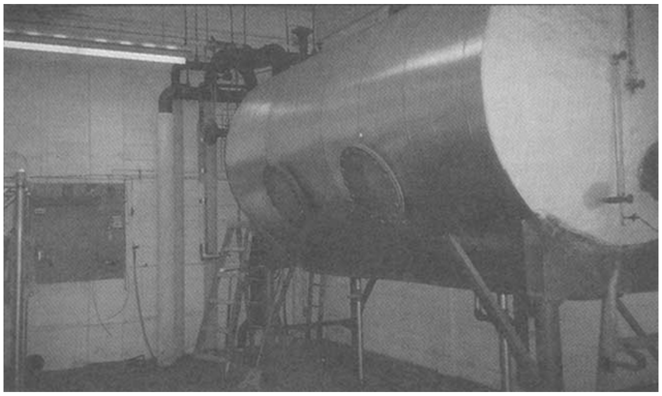

Figure 2. The 4000-gal (15-m^3) settling tank located in the Heat Exchanger building.

THE PROBLEMS ENCOUNTERED AND THE SOLUTIONS

Pumps

After approximately six years of operation, a major redesign of the pumping system was carried out. The original constant-speed, water-lubricated lineshaft pumps, were virtually the same as cold-water irrigation pumps and were located in wellhead pits. Placing the pumps in the pits didn't allow for air circulation which lead to overheating and condensation problems. The earlier pumps also didn't provide for the expansion of the piping in the well; therefore, the lineshaft had to be preheated to produce sufficient clearance before the pump was started. This meant one pump had to be kept running all the time. The pumps also experienced other failures. The original bronze impellers were attached to the shaft with collets and the failures occurred when the impellers detached from the shaft. The most serious problem was related to the failure of the shaft bearings. A number of bearing types were used, but none proved to have acceptable lifetimes. It was reported that the bronze bearings "burned up," and the rubber and teflon bearings "swelled."

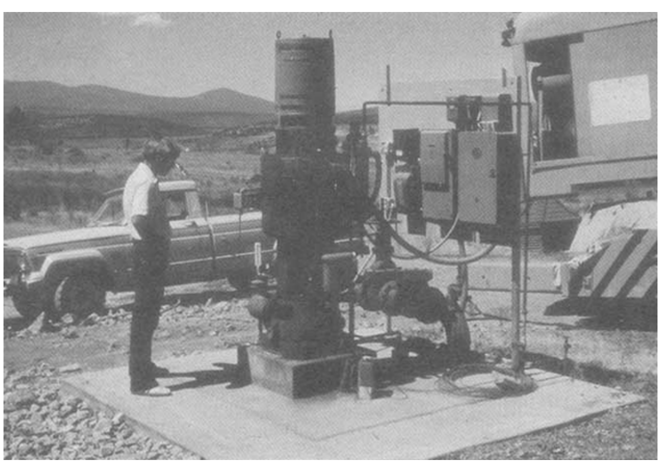

Figure 3. One of the pumps and variable-speed controllers with the housing removed.

During the redesign of the pumps, extra lateral bowls were installed to eliminate the need for shaft preheating. The impellers were attached with both keys and collets. At this point, it was also decided to isolate the bearings from the geothermal water using an oil-lubricated enclosed lineshaft arrangement. To help with the overheating and condensation problems, it was decided to raise the pumps to ground level and enclosed them in housing (Rafferty, 1989). Figure 3 shows one of the pumps with the housing removed.

Distribution System

The original distribution system consisted of direct-buried Schedule 40 carbon steel piping, field insulated with "Foamglas" insulation and covered with a "mastic" vapor barrier. This piping system suffered internal and exterior corrosion. The external corrosion was due to the expansion and movement of piping which caused the mastic vapor barrier to break. This failure allowed groundwater and salt water from deicing to come in contact with the piping, resulting in the external corrosion. After 14 years of service, an examination of the piping revealed an internal buildup of scale. The scale consisted of mainly silica and iron oxide with the iron oxide being closest to the pipe. In many places, the piping wall thickness was reduced to one-third of its original thickness. The fact that the main settling tank was vented to the atmosphere permitted oxygen to enter the system, which promoted the internal corrosion. The storm sewer system used for disposal of the effluent also encountered failures. This part of the system consisted of cast iron and carbon steel piping located in the buildings, galvanized culverts from the buildings to the main line, and concrete culverts in the main line. All of the failures occurred in sections with galvanized culverts. This could have been a result of dezincification (galvanized coating removed) and eventually corrosion of the unprotected steel surface (Rafferty, 1989).

In response to the piping failures, it was decided to construct a new distribution system and a dedicated collection system along with the construction of utility tunnels to connect all the buildings. The design of the tunnel (6 ft x 6 ft / 2 m x 2 m) provides access for maintenance personnel and space for other campus utilities. During construction the concrete was formed and poured in place to allow for forming around building foundations and utility pipes running at an angle to centerline (Figure 4). The floor of the tunnel is 8 in. (20 cm) thick and the sides 6 in. (20 cm) thick. The pipes are held to the side with pipe clamps and Unistrut hangers. In some cases, the tunnel also serves as a sidewalk; thus, snow-melting is enhanced due to the heat loss through the system. The cost of constructing the tunnel system (including excavation and backfill) was extremely high at about \$160/lf (\$525/m), which didn't include the cost of the piping. The cost of the piping varied from \$15/ft (\$50/m) for 6-in. (15-cm) diameter to \$22/ft (\$72/m) for 8-in. (20-cm) diameter pipe. When new extensions to the tunnel system were added, a 6-ft (2-m) diameter corrugated galvanized steel culvert was used instead of concrete. Its estimated cost was only 25 percent of the cost for concrete tunnels (Lund and Lienau, 1980).

Figure 4. View of the tunnel under construction.

Heat Exchangers

In the original design, the geothermal water was used directly in each of the building mechanical systems. This “once through” approach eliminated the need for circulation pumps in the buildings. The direct use of the geothermal fluids caused problems due to the corrosive nature of the water. The original chemical analysis of the water failed to consider the effect of H_2S (hydrogen sulfide) and NH_4 (ammonia) on the copper and copper alloys used in the mechanical system. There were a number of different types of failures identified that occurred as a result of using the water directly. The most important ones are listed below:

- Failure of the 50/50 tin/lead solder connections,
- Rapid failure of 1% silver solder,
- Wall thinning and perforation of copper tubing was a common occurrence,
- Control valve failures where plug (brass) was crimped to the stem (stainless steel). The threaded ones experienced no problems, and
- Control valve problems associated with packing leakage.

To address these problems, it was decided to isolate the geothermal water from the building heating systems using plate heat exchangers. Based on an analysis study, heat exchangers with 316 stainless steel plates with Buna-N gaskets were selected. The stainless steel heat exchanger used to heat the campus swimming pool failed within the first three years of operation. This failure occurred on the pool’s water side of the heat exchanger, probably as a result of the high chorine content. The pool’s heat exchanger was eventually replaced with titanium plates (Rafferty, 1989).

Some of the building systems utilize two loops through the heat exchanger. The College Union building plate heat exchanger, shown in Figure 5, utilizes two loops. The first loop provides 1,350,000 Btu/hr (1,350 MJ/hr) using the geothermal water at 100 gpm (6.3 L/s) and the building water at 54 gpm (3.4 L/s). The building water is then circulated through finned-tube pipe heat convectors located along the outside walls of the building. The second loop provides 30,000 Btu/hr (30 MJ/hr) using geothermal water at 25 gpm (1.4 L/s) and building water at 12 gpm (0.65 L/s). The building water is then circulated through reheat coils, which provides heating through a forced-air system for the interior of the building (Lund and Lienau, 1980).

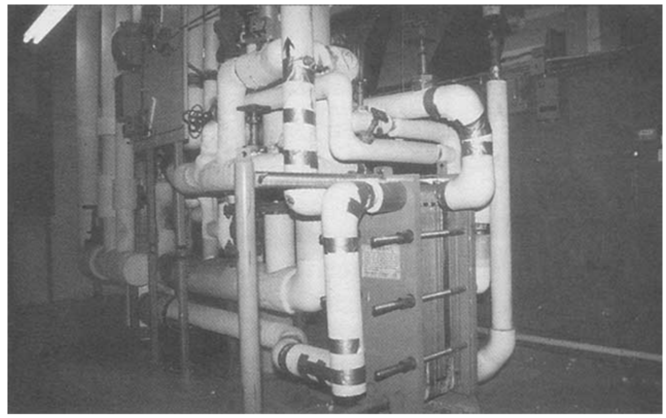

Figure 5. The College Union heat exchanger.

Fluid Disposal

Discharge to the surface was the original approach for disposal of the geothermal effluent. Although surface discharge is the simplest and least expensive option, there were several possible potential problems. The discharge temperature of the waste effluent was still quite high (135°F/57°C-winter and 170°F/77°C-summer) when it was delivered to the ditch. This method presented a safety hazard. A local city ordinance was passed which banned surface disposal and required all operations in the city to establish an injection program by 1990. OIT now has two injection wells to compile with the ordinance. The first injection well was drilled using standard mud-rotary techniques, and the second well used a combination of methods with air drilling in the injection zone. During the initial pumping test of the first injection well, the maximum obtainable pumping rate was only 200 gpm (12.6 L/s). It was believed that a considerable amount of drilling mud had invaded fractures in the primary production zones. The well was acidized (13% hydrochloric acid, 3% hydrofluoric acid) twice; this increased the capacity from 200 to 400 gpm (12.6 to 25.2 L/s). Analysis of test data indicated that the aquifer was still clogged with drilling mud at about 25 times the effective radius of the well. The maximum injection rate was estimated to be 600 gpm (37.8 L/s). The second injection well easily handles 1,000 gpm (63 L/s) and could possibly accept as much as 2,500 gpm (158 L/s) at 50 psi (3.4 bar) injection pressure is allowed at the wellhead. This well is being used as the primary injection well. Experience with these injection well suggest that air drilling can be quite beneficial in terms of subsequent well performance (Lienau, 1989).

NEW ADDITIONS TO THE SYSTEM

Snowmelt System

The newest additions to the OIT system are two sections of sidewalk snowmelting located by the Residence Hall. This brings the total amount of sidewalk snowmelting to 2,300 ft^2 (214 m^3). The other sections include the wheelchair ramp in front of South Hall and a couple of stairwells (Figure 6) leading to upper sections of the campus. All systems utilize 5/8-in. (1.6 cm) diameter cross-linked polyethylene tubing (PEX). The wheelchair ramp has four loops with the tubing spaced 10 in. (25 cm) apart. The stairs has three loops with the tubing tied to the existing stairs. Figure 7 shows the placement of tubing on a stairwell before the form work was added. The systems should be able to maintain a slab surface temperature of 38°F (3°C) at -5°F (-21°C) air temperature and 10 mph (16 km/h) wind when the entering 50/50 propylene glycol/water temperature is144°F (62°C). Each stair section uses a brazed-plate heat exchanger to isolate the glycol-filled snowmelt loop. The new snowmelt systems installed have slab temperature sensors which will activate the system when the outside air is 30°F (-1°C)(Geothermal Pipeline, 1994).

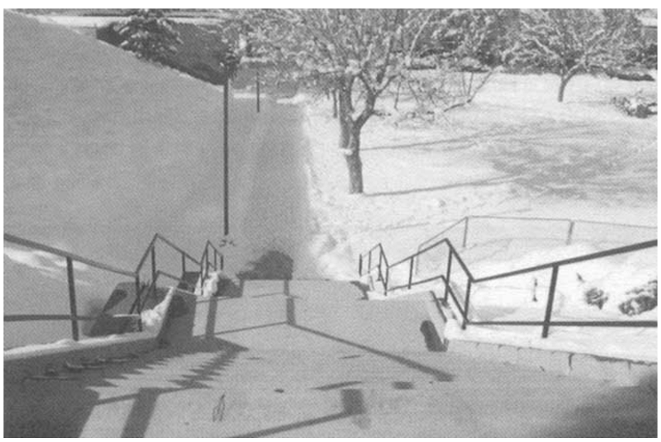

Figure 6. One of the stairwell leading to the College Union.

Figure 7. Placement of the snowmelt tubing before the formwork was added.

Purvine Hall

Purvine Hall utilizes the geothermal waste effluent from the rest of the campus for its space heating and domestic hot water heating. The temperature of the effluent as it enters the building is around 155°F (68°C) and leaves at a temperature of around 130°F (54°C). The main components of heating system include a 4,000-gal (15-m^3) storage tank, circulation pumps and heat exchangers. On the building heating side, space heating is accomplished by 54 variable air volume terminals equipped with hot water coils (Fields, 1989).

Absorption Chiller

A lithium-bromide absorption chiller was installed in 1980. It has a nominal 312 ton (1095 kW) capacity; but due to the low temperature of the water entering the system (192°F/ 89°C), it only produces 150 tons (526 kW) of cooling. The chiller requires 685 gpm (37.8 L/s) of geothermal fluid and only takes a 20°F (11°C) delta T out of the water. Recorded installation cost for the chiller was $171,300. The geothermal chiller supplies a base cooling load to five campus buildings or 277,300 ft^2 (25,800 m^2). The original electrical centrifugal chiller is now being used for peaking above the capacity of the absorption chiller. Since the geothermal water is used directly in the generator tubes of the absorption chiller there is a potential for corrosion to occur. The generator tubes are constructed of 90-10 cupro-nickel; but, no failures have occurred in the past 18 years (Lund and Lienau, 1980). Due to the low efficiency and high water usage, the absorption chiller will be replaced this summer with a centrifugal water chiller.

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