CRYSTAL HOT SPRINGS - SALT LAKE COUNTY

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INTRODUCTION

For more than 100 years, Crystal Hot Springs has provided geothermal water to a wide variety of community uses. At present, these uses include building heat for dormitories at the Utah State Correctional Facility, a commercial greenhouse next door to the prison and a fish farm nearby. Well known from pioneer times, this collection of geothermal springs and ponds are located 15 miles (24 km) south of Salt Lake City and should not be confused with Madsen's Crystal Hot Springs, another geothermal resource located about 70 miles north in Box Elder County. Unlike Madsen, which is highly saline, the Draper resource produces salts and sulfur mild enough for watering cattle, and meets state standard as a secondary drinking water source. However, dissolved oxygen and other water chemistry still require careful management to prevent pipe corrosion and mineralization. Current regional drought conditions have reduced geothermal flow. Still, with careful management, Crystal Hot Springs can support new commercial uses in addition to those in place.

GEOTHERMAL RESOURCES

Located adjacent to Interstate 15, Crystal Hot Springs is an artesian geothermal flow that fills a number of ponds and a small lake that scuba divers have measured at more than 50 ft (15 m) deep. In 2003, temperatures were reported at 195EF (91°C) in a 400-ft (122 m-) deep production well, consistent with other reports and investigations done over the years. Occasional well pump testing over the last 30 years consistently reports artesian flow at 600 to 1,000 gallons per minute (38 - 63 L/s). Pumping of geothermal well water causes a corresponding immediate decline in artesian flow. Elsewhere in Salt Lake Valley, groundwater measurements since about 1930 show a steady decline in water table of 15 to 40 ft (5 - 12 m)(Haradan, 2003). The primary cause of this decline is believed to be well pumping, although periods of apparent recharge coincide with high levels of annual precipitation.

Northern Utah is characterized as cold desert, with total annual precipitation seldom exceeding 15 inches (38 cm). Crystal Hot Springs is located at the south end of the Salt Lake Valley at about 4,550 ft (1,387 m) elevation above sea level. As such, winter low temperatures may reach 0ºF (-18ºC); while, summer high temperatures commonly reach 100ºF (38ºC) . Windy conditions are frequent, because mountains to the east and west form a funnel in whose path the springs lie, and there is little micro terrain or vegetation to block air flow. The area experiences about 270 sunny days per year, although conditions around nearby Traverse Ridge are known for storminess. Atmospheric humidity can descend to as little as 20 percent, relative. Soils are typically alkaline.

Crystal Hot Springs is within the municipal boundary of Draper City, a 400-square mile (1,037-km^2) geographic basin underlain by groundwater in unconsolidated deposits. Salt Lake Valley is bounded by the Wasatch Mountains on the east and the Oquirrh Mountains on the west. The Crystal Hot Springs geothermal system rises from the northern base of an east-west ridge known as the Traverse Range (Murphy and Gwynn, 1979). This feature is intermediate in elevation between the Wasatch Range to the east and the valley grabens to the north and south. A series of northeast striking normal faults, with a combined displacement of at least 3,000 feet (914 m) separate the Traverse Range from the Jordan Valley graben to the north. The spring system is located between two closely spaced range-front faults that are intersected by a north-northeast striking fault.

The Wasatch Mountain fault system exhibits predominately vertical movement, and represents the longest and most tectonically active geologic structure in Utah, with abundant evidence of surface rupturing events. The Wasatch fault is crosscut by numerous underlying, older faults and folds that complicate understanding of geothermal resources found on both slopes of the range. The entire region is also part of the Intermountain Seismic Belt and, as such, produces terrestrial heat flow averaging about 107 milliwatts per square meter (mW/m^2). In contrast, the adjacent Colorado Plateau region to the east exhibits average terrestrial heat flow of about 57mW/m^2.

The geothermal system is fed by mountain rain and snowfall that descend through fractured bedrock before returning to the surface by convection and artesian flow into overlying unconsolidated alluvium (Blackett and Wakefield, 2003). The Crystal Hot Springs resource is considered to be fault-controlled, with geothermal energy rising from normal heat flow of the Basin and Range province, rather than by cooling of igneous rock at depth (Murphy and Gwynn, 1979).

The surface expression of Crystal Hot Springs consists of several springs found within a 70-acre (28-ha) area that lies mostly within state prison property (Murphy and Gwynn, 1979). Some of the springs feed small ponds located at the eastern edge of the geothermal zone, while others are present at the bottom of Crystal Pond, a small lake at the western edge of the geothermal resource.

Chemistry tests in 1979 reveal silica, calcium, magnesium, sodium, and related minerals in concentrations below 230 parts per million (ppm). Chlorine was found to be higher, at 590 ppm. Total dissolved solids (TDS) registered 1,462 ppm in 1979, which is slightly lower than tests done more recently that found TDS at about 1,750 ppm. In contrast, pH was measured at 5.9 in 1979, somewhat more acidic than recent test results that ranged from 6.0 to 6.5. One test indicated pH at 7.6, total suspended solids (TSS) at 14 mg/L and TDS at 1,810 mg/L (Murphy and Gwynn, 1979). Well pumping tests in 1979 proved steady flow at 650 to 1,000 gpm (41-63 L/s) (Murphy and Gwynn, 1979). Water quality testing done for discharge permit approval indicated levels of arsenic, managanese, radium, potassium, various chlorides and radium slightly higher than found in Jordan River receiving waters. In 2003, a nearby well tested to a maximum flow of 1,100 gpm (69 L/s). However, neither of these tests examined the cone of depression, nor projected rates of recovery. Temperature gradient testing found an elliptical area 200 hundred yards (183 m) wide in which soil temperatures exceeded 190ºF. A roughly concentric area 600 yards (550 m) wide tested to at least 90ºF (32ºC) at a depth of 200 ft (61 m). It is believed, but not verified, that the Crystal Hot Springs resource is a limestone reservoir, resulting in production of CO_2 that may supply some corrosive effect in spite of best efforts to keep oxygen and other gases from entering at points in the mechanical system above ground.

GEOTHERMAL USES

Crystal Hot Springs has been commercially exploited since the late 1800s, supporting a brewery, stock watering, log floating, a recreational resort that burned down in the 1920s, beaver raising and a country inn. At present, geothermal water is used for production of fish for commercial sale, greenhouse production of cut flowers, and building heat at the prison. As such, Crystal Hot Springs may be one of the better examples of multiple-use development of geothermal energy in the region.

Prison Building Heat

In 1983, the Utah Department of Corrections installed a geothermal well and heat exchange equipment to supply space heat to Oquirrh 4, a minimum-security dormitory facility that also included a gymnasium, offices and a cafeteria. That equipment met winter season building heat requirements and year-round hot water needs for Oquirrh 4 until sometime during 1985, when corrosion resulted in severe pitting of stainless steel pipes. Mineral build-up also caused pump shaft failure. Both wells were abandoned in place, along with the original heat exchanger and related equipment. Since then, the discharge permit for one well has expired and its location has been lost to memory. Prison officials and Johnson Controls plan to eventually search for the missing well, determine if it can be rehabilitated, and verify whether or not lapsed water rights and state permits for pumping and discharge can be renewed.

In 2003, the State of Utah Department of Corrections contracted with Johnson Controls, a world-wide energy service company (ESCO) to re-establish a geothermal building heat and culinary water system in two phases. This new geothermal facility is part of a larger contract awarded to Johnson Controls for improved facilities management at the Draper prison, the largest correctional facility in the region. The overall contract improvements for energy, water and waste management services is worth $5.7 million. Energy control measures (ECMs) include the installation of more efficient lighting and motors, use of digital building climate controls and the two-phase geothermal system.

The Johnson Controls performance guarantee calls for annual savings of about $228,000 on energy improvements, and $175,000 in annual savings for improvements in water, sewer and solid waste handling. For performance comparison purposes, base year energy consumption at the prison complex totals 19.5 million kWh and 1.85 million therms (195 kJ) of natural gas for about 1.1 million square feet (102,000 m^2) of buildings (Johnson Controls, 2003).

Phase I of the geothermal portion of the project calls for supplying culinary hot water and building heat for the Oquirrh 4 complex. Built in 1987, each of the four units at Oquirrh 4 contains 9,714 square feet (902 m^2) of floor area. All units are constructed of hollow concrete masonry, built-up roof and single pane windows. These units were originally heated by ducted forced air coils supplied with steam from a campus distribution system fired by natural gas. That mechanical system is still in place, and can be supplied interchangeably by either campus steam or hot water from the geothermal-plate-and frame heat exchanger (Figure 1).

Figure 1. ***Plate-and-frame heat exchanger (Bruce Munson, Johnson Controls).***

Phase I geothermal improvements refurbished one of the old geothermal wells, installed a line-shaft constant speed pump on the geothermal side, new heat exchange equipment, and variable speed drive for heat control on the building side (Figure 2). Among other things, the holding tank from the 1983 system was removed as part of effort to prevent air intrusion that is believed to contribute to corrosion and mineral deposition. The constant speed pump installed in Phase I is set at 240 gpm (15 L/s) on maximum capacity of 300 gpm (19 L/s). Entering water temperature is about 185EF (85ºC) . The system uses the existing coil and fan equipment from the original steam system. A variable-speed drive on the clean side governs the rate of heat exchange, with a 40EF (22ºC) drop in geothermal temperature being an efficiency goal. Actual discharge water temperature is about 160EF (71ºC) . Constant-speed pump pressure is applied to the geothermal side in order to prevent precipitation of minerals that might otherwise occur during periods of slack demand.

Figure 2. ***Heat exchange building with wellhead and pump in foreground.***

Johnson Controls avoided installing probes for flow measurement piping in order to reduce the number of potential places where air intrusion could occur. Instead, a sensor to measure geothermal heat is in place to calculate energy passing through the heat exchanger. Strainers that would normally be in place have also been omitted in order to reduce points of potential corrosion. Piping on the geothermal side is made of fiberglass-reinforced plastic, considered a good general alternative to stainless steel for chemical and temperature conditions at Crystal Hot Springs. The vertical turbine pump is located seven feet (2 m) down a 1,000-ft (305-m) deep well, and is a Bell and Gossett enclosed lineshaft, 12-in. (30-cm) conductor casing to 40 ft (12 m), 4-in. (10-cm) pump column, 6-in. (15-cm) Schedule 40 liner to 1,000 ft (305 m), slotted bull nose entry below pump bowls and impellers.

At the time Johnson evaluated the existing heating system at Oquirrh 4 (Figure 3), the heat recovery system was in poor condition, and variable air volume vanes were fixed in place and inoperable. Meanwhile, to meet air quality needs, 100 percent outside air is still used for both ventilation and winter heating. As such, there is no return air circuit, resulting in substantial heating system inefficiency. Thus, Johnson Controls estimates that use of geothermal heat probably saves more in natural gas for the Oquirrh 4 facility than its proportionate share of square footage served by the overall prison gas-fired steam facility. As is common with large institutional uses, general lack of sub-metering at the correctional facility prevents the accumulation of itemized data on cost savings.

Figure 3. ***Oquirrh 4 Complex.***

Thermostatic controls are set higher on the campus steam side to prevent heat from that system entering the Oquirrh 4 loop unless geothermal flow fails. During the first six months of geothermal system operation, natural gas-fired steam has been needed only once, when the geothermal pump failed due to ingestion of well debris left from the 1983 geothermal system. As expected, system controls made a smooth switch to campus steam heat when the geothermal pump failed.

Phase II geothermal development, planned for late 2004, calls for replacement of the fixed speed 10-horsepower (hp) (7 kW) geothermal well pump by a 25-hp (19-kW) variable-speed drive that can potentially deliver up to the full water right of 750 gpm (47 L/s). The practical expectation is for a base load of about 600 gpm (25 L/s). A second heat exchanger will also be added. This larger geothermal flow will continue to supply space heat for the Oquirrh 4 cell block, and will also supply the prison furniture shop, sewing shop, and Special Service Dormitory (SSD). Altogether, geothermal heat will eventually supply space heat and culinary hot water for a total of 252,350 square feet (23,440 m^2) of building area.

Under Phase II, geothermal input temperature is expected to reach 185ºF (85ºC) or higher, dropping to 165ºF (74ºC) at discharge during warm weather and 135ºF (57ºC) in winter. A variety of other improvements will be needed to ensure system performance, including fan/coil unit heaters in the prison industry buildings, upgraded insulation and thermostats in individual sections. Phase II improvements will continue to send the usual 200 gpm (13 L/s) discharge flow to prison fish ponds. However, discharge by buried pipe to the cooling pond will rise from about 40 to 400 gpm (2.5 to 25 L/s) or more. After Phase II geothermal improvements are operational, the existing back-up boiler will be considered for retrofit to better fit with the geothermal system.

Phase I of the geothermal performance contract calls for capital expenditures of $519,000 intended to produce guaranteed annual energy savings of $68,944 in deferred natural gas cost. Those savings are tempered by an expected base increase of $1,068 in additional annual electricity charges for pumping geothermal fluid and electronic controls. Geothermal improvements are projected to have a payback period of 7.6 years, and a predicted equipment life of 17 years. In contrast, the overall performance contract has a combined estimated payback period of 15 years. Phase II geothermal improvements are expected to cost a total $1,523,611, and should produce annual natural gas savings of $123,813, offset by an increase in electricity cost of $69,145 for pumping geothermal water. Phase I became operational in January of 2004, providing initial monthly savings of $17,000 in deferred natural gas costs.

Bluffdale Flowers

In 1981, Utah Roses established a commercial greenhouse using 450 gpm (28 L/s) of geothermal water pumped from a 1,000-ft (305-m) deep well on property located immediately adjacent to the prison. That facility was sold and renamed Bluffdale Flowers in 1998. In the interim, some 250,000 sq ft (2.3 ha) of greenhouse space was constructed for raising roses and other ornamental flowers (Figure 4).

Figure 4. ***Interior of Bluffdale Flowers greenhouse with finned-tube heating system.***

In 1983, at about the same time the prison was developing its first attempt at geothermal building heat in 1983, Utah Roses used U.S. Department of Energy funding to install a geothermal production well at a commercial greenhouse located in Sandy City, about five miles north of Crystal Hot Springs. Well depth eventually reached 5,000 ft (1,524 m), but produced only about 200 gpm (13 L/s) of water at 120ºF (49ºC) and was therefore abandoned. Eventually, the entire greenhouse operation in Sandy was also abandoned and operations were consolidated at the Crystal Hot Springs site.

At present, Bluffdale Flowers uses a 40-hp (30-kW) lineshaft pump running at constant speed to supply geothermal water from a well depth of about 200 ft (61 m) (Figure 5). Space heat is provided through plate-and-frame heat exchangers showing an intake temperature of about 190EF (88ºC) and discharge temperature of 140EF (60ºC) (Figure 6). There is no back-up heat system, and indoor greenhouse temperatures on winter nights may descend to near freezing. A brief experiment with by-passing the heat exchanger caused rapid mineral fouling of capillary piping. Discharge water travels by 8-in. (20-cm) pipe to Crystal pond where it cools to about 80EF (27ºC) before traveling about 1,000 ft (305 m) by open ditch to a Hi-Tech Fisheries, a downstream user of geothermal water (described below).

For several years, attempts were made to re-inject spent geothermal water for aquifer recharge. However, artesian effect and slow permeability resulted in surface leakage and pump failure. After deliberation, the State of Utah Division of Water Rights was persuaded to grant a permit for surface discharge of spent fluid. As such, even though greenhouse use of heat-exchanged water is a “non-contact” use of the geothermal resource, surface disposal exposes the fluid to chemical alteration. Geothermal pumping is limited to the cool months of September to May each year during the hours of 4:00 p.m. to 8:00 a.m.

Figure 5. ***Lineshaft pump at Bluffdale Flowers (Jack Kaleel).***

Figure 6. ***Plate-and-frame heat exchanger (Stan Goldberg).***

The state-issued discharge permit requires semi-annual water tests for metals, including cadmium, copper, lead, mercury, radium and others. Some concern has been raised regarding tests of discharge water that show TDS at 1,700 ppm, close to the state maximum limit of 2,000 ppm, and pH readings as low as 5.9.

Bluffdale Flowers is in the process of expanding greenhouse space from 250,000 to 500,000 sq ft (2.3-4.6 ha). To provide winter space heat, discharge water at about 140EF(60ºC) will be re-heated using natural gas boilers to about 180EF (82ºC) and circulated through that additional space before discharging en-route to Hi-Tech Fisheries further downstream.

Water rights total about 1.95 cubic feet per second (55 L/s), which would allow Bluffdale Flowers to augment geothermal flow by running the idled re-injection pump in reverse, resulting in a potential doubling of geothermal flow to about 900 gpm (57 L/s)

Bluffdale Flowers managers note that artesian flow is substantially lower in 2004, compared to recent years, as evidenced by the fact that natural ponds are nearly empty during early summer. Ordinarily, these ponds would actually deepen as summer progresses, due to cessation of greenhouse and prison use of geothermal water during previous cool months. Informal discussion among various parties in the area suggest that persistent regional drought conditions account for a large fraction of diminished geothermal spring flow. More recently, discussion has focused on the possible role of prison geothermal pumping as a cause of spring flow reduction for other geothermal users. These concerns add interest to the widespread belief that water rights have been over-appropriated by the State Engineer. As noted above, regular groundwater monitoring in Salt Lake indicates that wells have caused a steady decline in water table across several decades (Haradan, 2003).

Other Commercial Geothermal Uses

In the past, a number of aquaculture operations have used discharge water from either the prison, Bluffdale Flowers or directly from Crystal Pond, the largest of several ponds fed by Crystal Hot Springs. The most successful of these downstream geothermal users is Hi-Tech Fisheries, a 25-year old commercial producer of tropical fish based around Crystal Pond. Hi-Tech is a contract operator on behalf of Utah Corrections Industries, an enterprise of the state prison system. As such, the land, water rights and facilities are largely state-owned. Labor is provided by prison inmates.

Crystal Pond varies widely in size, up to about 3.0 acres (12 ha), but currently covers only about 1.0 acre (0.4 ha) in surface area due to persistent regional drought conditions. The pond was once host to a large variety of fish but is presently occupied only by a few hardy species of low-value fish that help control mosquitoes. Hi-Tech Fisheries uses discharge water from Bluffdale Flowers and from the prison geothermal facility to feed Crystal Pond, which is also supplied by artesian springs. Discharge water from Bluffdale Flowers leaves that facility at about 140EF (60ºC) , and travels through a succession of 8-in. (20-cm) piping, open ditches and intermittent ponds before arriving at Hi-Tech at an acceptable temperature of about 80EF (27ºC) . Discharge water from the prison geothermal facility travels entirely by pipe to Hi-Tech. Together, this flow moves successively through covered greenhouse space totaling about 4,500 sq ft (418 m^2), occupied by some 80 fish propagation tanks that vary in size from 200 to 1,000 gallons (760-3,786 liters) (Figure 7). Many of the fish originate from Africa's Lake Malawi, where water conditions are similar to those produced at Crystal Hot Springs. At times, this facility has also produced a variety of vegetables for commercial sale, including corn, tomatoes, squash and peppers. Propagation of aquarium plants for retail sale was also tried for a time, but proved unsuccessful.

During cold weather, geothermal water may arrive at fish tanks at temperatures as low as 60EF (16ºC), only marginally viable for fish propagation. In the past year, Hi-Tech also reports that combined inflow to Crystal Pond is down by about 50 percent from average years, resulting in the pond's lowest water level in 30 years. As a result, Hi-Tech currently re-circulates its own outfall water back into Crystal Pond in order to maintain adequate supply to the fish tanks. Concern has been raised by Hi-Tech that declining water supply may also be due, in part, to recent re-establishment of prison geothermal use, and recommends that consideration be given to circulating additional prison geothermal discharge water through Hi-Tech before final outfall to wetlands or the Jordan River.

Figure 7. Fish propagation tanks (Hi-Tech Fisheries).

At present, about 200 gpm (13 L/s) of geothermal outflow from the prison goes directly to Hi-Tech. The remaining 40 gpm (2.5 L/s) is sent to a cooling pond that is planned for eventually serving new wetland development. About 450 gpm (28 L/s) of geothermal discharge flows toward Hi-Tech from Bluffdale Flowers, although an unknown amount is lost to evaporation and seepage along that path. Hi-Tech does not directly measure the combined total of inflow to Crystal Pond from these various sources. Discharge water from Hi-Tech Fisheries ordinarily travels about 800 ft (244 m) in a ditch to a collector canal running through farm fields before either percolating fully into soil or reaching the Jordan River.

Original plans called for discharge of geothermal water from the prison to percolate into the soil through open ditches, with no significant surface flow off-site. However, the need for mosquito abatement resulted in re-direction of geothermal water through a buried 14-in. (36-cm) concrete pipe running about 1.5 miles (2.4 km) before entering a cooling pond. The pond is designed to overflow into the Jordan River through a culvert running under the Bangerter Highway, reaching the river at a temperature close to ambient.

UDOT Wetland Development

The Utah Department of Transportation (UDOT) plans to take geothermal discharge water, in combination with other surface flow, to create a new wetland in the area below the lowest pond at Crystal Hot Springs. This end-use of geothermal water helps fulfill UDOT need for wetland creation to offset loss of wetland caused by highway development elsewhere. As such, geothermal water is expected to reach ambient temperature before entering the river, having dissipated heat through a combination of at least three different beneficial uses and passing through thousands of feet of ditches and piping before disposal.

Crystal Springs Fisheries

A second aquaculture facility is also using geothermal waters in the area–Crystal Springs Fisheries, located just outside the Correctional Facility. Spring water at 80°F (27°C) feed 12,000 ft^2 (1,115 m^2) of indoor fiberglass tanks and raceways under three greenhouses covering a little less than an acre (0.4 ha). These consist of 200 tanks at 150 gal (568 liters), 350 at 250 gal (946 liters) and 14 raceways. Between 667 and 833 gpm (42 and 53 L/s) are used on the average with approximately double this during peak periods. Approximately half a million cichlids (tropical fish from Africa) are raise annually.

SUMMARY

Crystal Hot Springs will continue to provide water and energy for community uses into the foreseeable future. Further study of resource hydrogeology could assist with long term planning for further economic development and help prevent conflicts between users and their respective water rights. There is ample supply of geothermal water for development of additional uses of Crystal Hot Springs, particularly with more careful delivery of outfall water from one use to the next.

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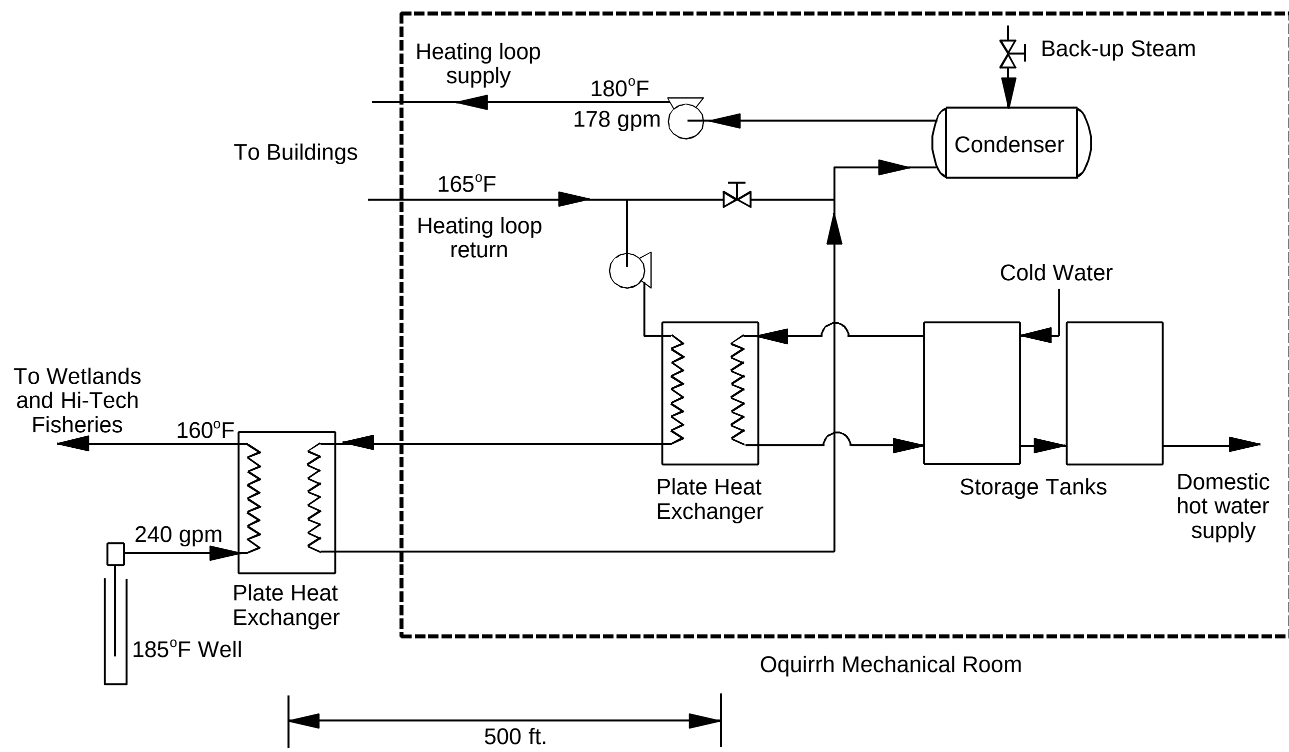

Schematic of the Utah Department of Corrections heat supply system to the Oquirrh building complex.