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A Materials and Equipment Review of Selected U.S. Geothermal District Heating Systems

by

Kevin D. Rafferty

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DOE/ID/12693--3

DE89 017552

**A Materials and Equipment Review of Selected
U.S. Geothermal District Heating Systems**

Prepared for:

**U.S. Department of Energy
Idaho Operations Office
Idaho Falls, ID**

**Contract Number
DE-FG07-87ID 12693**

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July 1989

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INTRODUCTION

This collection of information was assembled for the benefit of future geothermal system designers and existing system operators. It is intended to provide insight into the experience gained from the operation of 13 major geothermal systems over the past several years.

Each chapter contains six or seven sections depending upon the type of system: Introduction, Production Facilities, Distribution, Customer Connections, Metering and Disposal. Some chapters, covering systems which incorporate a closed distribution design include a section on the central mechanical room.

Each section details the original equipment and materials installed in that portion of the system. Following each section is a discussion of the subsequent problems, solutions and modifications relating to the equipment.

The extent to which information was available varied from system to system. This is reflected in the length and level of detail of the chapters.

ACKNOWLEDGMENTS

Without the assistance of the following individuals, this report could not have been completed. Each generously contributed their time and expertise in an effort to assemble as complete a body of information as possible.

Kent Colahan, Utility Director, City of Klamath Falls, OR
Kevin Fisher, Geothermal Engineer, San Bernardino Water Dept., CA
Joe Dan Martinez, Utility Director, City of Pagosa Springs, CO
Louie Templeton, Geothermal Energy Mgr., City of Susanville, CA
Chuck Mickelson, P.E., City Engineer, City of Boise, ID
Dave Turner, Engineering Technician, City of Boise, ID
Dave Beckner, Geothermal Technician, San Bernardino Water Dept., CA
Bob Griffiths, P.E., Manager, Boise Warm Springs Water Dist., ID
Larry Osgood, P.E., Project Engineer, State Dept. of Public Works, ID
Owen Lockwood, P.E., Engineer, New Mexico State University, NM
Roger Wiltrout, Physical Plant Director, Oregon Institute of Tech., OR
Mike Lattin, P.E., Senior Civil Eng., Kennedy/Jenks/Chilton, Elko, NV
John Vietti, Facilities Director, Elko County School District, NV
Francis McKay, Owner, McKay Drilling, Reno, NV

In addition, the following individuals were instrumental in securing permission to reprint original drawings for the systems reviewed:

John Austin, P.E., CH2M Hill, Boise, ID
David Bomar, P.E., Balzhiser Hubbard Engineering, Eugene, OR
Bill Baker, P.E., Aspen Engineering, Reno, NV
Bill Petty, P.E., Petty and Associates, Reno, NV
Kevin Fisher, San Bernardino City Water Dept., San Bernardino, CA
Mike Lattin, P.E., Kennedy/Jenks/Chilton, Elko, NV

To the following individuals fell the task of converting a dizzying array of text, tables, diagrams and photos into a single coherent document. Their fine work is gratefully acknowledged:

Donna Gibson
Penny Lewis
Kathleen Moore
Cindy Caskey

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SUMMARY

Most of the systems included in this work have logged a minimum of 4 years operating experience. As such, they have encountered many of the problems likely to occur as a result of fluid chemistry and initial design. The purpose of publishing this information is to provide the operators of existing systems and designers of new systems with the input necessary to make informed decisions regarding equipment selection and system design.

Table 1 presents an introduction to the systems included in report.

Table 1
Information Summary - Systems Reviewed

System and Location	Years Operated	Resource Temp.	Peak Flow	Feet of Pipe
OIT Klamath Falls, OR	26	192°F	980	7,300
Klamath Falls City Klamath Falls, OR	5	218°F	1,000	14,000
Susanville, DOE Susanville, CA	5	174°F	700	19,000
Susanville, HUD Susanville, CA	4	155°F	300	10,000
San Bernardino Water District Susanville, CA	5	138°F	3,700	35,000
Pogosa Springs Pagosa Springs	6	140°F	600	15,000
NMSU Las Cruces, NM	6	142°F	230	N/A
Boise City Boise, ID	5	170°F	4,000	37,000
BWSWD Boise, ID	100	176°F	1,600	11,300
Boise Capital Mall Boise, ID	6	169°F	750	6,000
ECSD Elko, NV	2	190°F	290	11,300
Elko Heat Company Elko, NV	6	170°F	650	15,500
Warren Property Reno, NV	6	210°F	710	26,500

Production Facilities

There is great variation in the depth and temperature of production wells employed for these systems. Depth ranges from only 275 feet at Pagosa Springs to 3030 feet at the Capital Mall in Boise. Temperatures of 138° to 218°F are employed. With one exception (Pagosa Springs) all of the projects employ pumps to produce the

geothermal fluid. Several systems previously were able to operate for some of the year on the artesian head generated by the well. At present, however, only the two Elko, NV projects and Pagosa Springs, system have this capability.

Production well pumps, in general, have been the source of much system downtime. Specifically, difficulties have centered around shaft and bearing failures in lineshaft pumps. Two types of lineshaft pumps have typically been employed in geothermal applications: enclosed lineshaft and open lineshaft. Of these, the open shaft has been more subject to failure. In this design, the shaft and bearings are lubricated by the fluid flowing up the pump column. As a result, these components are exposed to the geothermal fluid. Shaft materials of both carbon and stainless steel have experienced failure in this application along with bearing materials of bronze and various elastomers (rubber).

The nature of the failure of these components has been attributed to a variety of modes, however, two causes are most common:

Deterioration of the bronze bearings as a result of fluids containing H_2S and

"dry" running of the top bearings (those above the static water level) at start up.

This latter effect may be particularly important in view of the relative success of water lubricated pumps in artesian wells. The Boise City, Boise Capital Mall and Elko Heat Company systems have all operated water lubricated pumps successfully and all have artesian wells. The water levels in these wells are of sufficient height to maintain the bearings in a fully lubricated state, thus avoiding "dry" running.

The most successful shaft and bearing arrangement for direct use wells has been the enclosed shaft, oil lubricated design. This system isolates the shaft and bearings from the geothermal fluid and maintains the lubrication on a constant basis. One system (Susanville) experimented with a water lubricated enclosed lineshaft arrangement initially, however, after several failures oil lubricated models were installed.

Of the 11 systems reviewed which use lineshaft pumps, 8 use oil lubricated designs. The OIT system has successfully operated such pumps in 192°F, 800 TDS fluid for as long as 15 years without major overhaul.

The pumps (bowl assemblies) themselves have proven more reliable than the shaft and bearing portion of the system. Few failures of the bowl assembly have been experienced. The only system to experience numerous, recent failures of the pump was NMSU. This is due to the production of large quantities of sand in that location. The OIT system experienced several failures of the bowl

assembly in the early years of operation. This was reportedly due to impellers becoming detached from the shaft. A change was made to keyed rather than collet connections (impellers-to-shaft) and no further problems were encountered.

Table 2
Production Facility Information Summary

Facility	No. of Well Pumps in System	Pump Type	Lube	Artesian	Variable Speed Drive	Frequency of Well Pump Failures	
						Early	Recent
OIT	3	ELS	Oil	No	FC	High	None
Klamath Falls City	2	ELS	Oil	No	FC	None	None
Susanville DOE	1	ELS	Oil	No	VFD	High	None
Susanville HUD	1	ELS	Oil	No	VFD	High	None
San Bernardino	2	ELS	Oil	Yes	VFD	None	None
Pagosa Springs	0	-	-	Yes	None	None	None
NMSU	1	ELS	Oil	No	None	High	Mod
Boise City	3	OLS	Water	Yes	None	High	None
BWSWD	2	ELS	Oil	Yes	None	Mod	Mod
Boise Capital Mall	1	OLS	Water	Yes	MSM	None	High
ECSD	1	Surface	-	Yes	VFD	None	None
Elko Heat Company	1	OLS	Water	Yes	None	None	None
Warren Property	2	ELS	Oil	No	None	High	None

ELS - Enclosed Lineshaft

VFD - Variable Frequency Drive

MSM - Multi Speed Motor

OLS - Open Lineshaft

FC - Fluid Coupling

MOD - Moderate

Regardless of the type of lineshaft design (oil or water lubricated) the bearings in the bowl assembly are always water lubricated. Of interest is the fact that leaded red bronze bearings, while the source of numerous failures in open lineshaft pumps, have demonstrated good success in bowl assembly bearings.

The most successful design for production well pumps in direct use systems includes: closed lineshaft, oil lubricated equipment with bowl assemblies consisting of leaded red bronze bearings, stainless steel shaft, keyed impeller connections and enameled cast iron impellers.

Submersible pumps were employed in only one of the systems reviewed (NMSU). Numerous failures occurred and such pumps are no longer used.

Other pump problems of note include headshaft seal failures in Boise and deterioration of threaded pump column connections at NMSU.

All of the original pumps in the Boise Capital Mall and Boise City system included teflon packing in the headshaft seal. Several incidents of shaft scoring occurred and the teflon was replaced with graphite impregnated material.

The NMSU operators have experienced ongoing problems with corrosion of carbon steel components in the system. One area in which this has been of greatest concern is threaded connections on well pump columns. Several solutions have been attempted including various coatings and the use of flanged rather than threaded connections. These efforts have been partially successful, however, carbon steel components continue to fail due to corrosion.

As indicated in Table 2 many of the systems employ variable speed drives of one type or another to regulate well pump output. The two most common are fluid couplings and variable frequency drives. The fluid coupling is a mechanical device installed between the electric motor and pump shaft. It is a relatively simple device which can generally be serviced by the local pump contractor. The only problem experienced by users of this equipment is periodic replacement of the thrust bearings.

Variable frequency drives are more energy efficient than fluid couplings. This efficiency, however, comes at the expense of much greater sophistication. Some operators have found it useful to purchase the optional self-diagnostic packages and factory operator training available from certain manufacturers.

The remaining production facility problems relate mainly to controls and system design.

The Susanville DOE system was originally designed as a pumped storage system. The well produced into a large storage tank. From here a booster pump supplied water to the system. Higher than normal energy use (the booster pump was designed for peak system flow and throttled to its control output) and level control problems resulted in the redesign to a variable speed well pump feeding directly into the system.

The OIT system also includes a well head tank. The three production wells produce into the tank which then feeds the campus system by gravity. The tank, which is vented to atmosphere permits oxygen to enter the system. This substantially increased the corrosion rate on the largely steel distribution system.

In recent years, much of the distribution system has been converted to fiber glass piping. The tank remains vented to atmosphere.

The Boise City system regulates flow to its distribution system by cycling its 3 production pumps. In addition, a large pneumatic valve throttles the flow in response to supply line pressure. A number of problems surfaced with the design. Initially pressure surges were experienced as different pumps were cycled on and off. Subsequent modifications included the installation of pressure relief valves and removal of stages from pumps to allow for closer matching of head at certain flows. Finally, the main throttling valve, designed for the system peak flow (4000 gpm), was somewhat oversized for the actual flow during initial operations. This resulted in "hunting" of the valve and system pressure variation. Control modifications which effectively reduced valve travel by 50% successfully addressed this situation.

Central Mechanical Plant

Central mechanical plants are included in 5 of the systems reviewed for this project. The central mechanical plant contains the main heat exchangers, circulating pumps, expansion tanks and controls for systems which employ closed type distribution systems. Closed systems are those in which the geothermal fluid does not flow through the distribution system to the customers. A closed loop is used to deliver the heat.

The equipment in these facilities has been quite successful with respect to fluid compatibility. No corrosion related failures have been reported.

Piping within mechanical plants consists of all steel in 3 of the systems, all copper in one and all fiber glass (epoxy adhesive joint) in the remaining plant. Isolation heat exchangers in all cases are constructed of 316 stainless steel plates and nitrile (Buna-N) gaskets. Control valves are typically of iron body, flanged construction with stainless steel trim.

Although no corrosion related problems have occurred, operational problems have surfaced.

The Klamath Falls system had difficulty with a pressure sustaining valve on the geothermal injection line. This valve, designed to regulate the peak system flow (800 gpm) exhibited erratic operation at the low flow under which the system was operated. Controls for the valve were disconnected and a manual valve is operated to perform this function.

Similarly, the Pagosa Springs system is operated manually though it is extensively instrumented with sensors and motorized valves for automatic operation. The low load imposed on the system is such that manual control results in more stable operation.

The ECSD system also experienced problems with very low load operation. The unstable operation which occurred under these conditions was not possible to address through manual means since the system was designed to operate unattended. As a result, a small, low load heat exchanger was installed. Controls were

modified such that the two main heat exchangers were out of the loop at low flows and supply water temperature was controlled only through the small heat exchanger.

Distribution System

Distribution networks for these systems fall into two general designs: open and closed. As discussed in the Central Plant section, the closed type distribution system includes central heat exchangers while the open system delivers the geothermal fluid directly to the customer. This is an important distinction since the open type design exposes the entire distribution system to the geothermal fluid.

As indicated in Table 3, a wide variety of piping materials has been applied to geothermal district heating systems. Of these, the most common is asbestos cement. This material, frequently used in municipal water systems is familiar to installers, relatively low cost, designed in such a way as to eliminate the need for expansion compensation devices and, as a non-metallic, is impervious to corrosion. Unfortunately, health related concerns regarding the asbestos content of this material have, for practical purposes, eliminated it from consideration for new projects. An important task for the future will be the identification of a substitute material capable of replicating the practical and economic advantages of AC pipe.

The San Bernardino system, which has to date employed largely pre-insulated AC pipe, recently installed a new extension using pre-insulated ductile iron piping which they manufacture themselves. Another system anticipating expansion is considering a fiber glass product which incorporates threaded connections.

Fiber glass piping has been used successfully in several systems. At Oregon Institute of Technology, the original direct buried steel piping was replaced with fiber glass piping after about 15 years. The original field installed asphalt coating, used to protect the pipe and insulation from moisture, failed and permitted exterior corrosion of the pipe to occur. The replacement fiber glass piping employed epoxy adhesive joints and was installed largely in concrete tunnels.

Table 3
Distribution Systems Equipment and Materials Summary

<u>System</u>	<u>Distribution Type</u>	<u>Geo. Pipe</u>	<u>Non-Geo Pipe</u>	<u>Customer Branch Lines</u>	<u>Isolation Valves</u>	<u>Comments</u>
OIT	Open	FG, STL	-	STL	G, BF	Ext. Corr. of Steel
Klamath Falls	Closed	STL	FG, STL	STL/CU	G	Failure of FG Connects
Susanville DOE	Open	AC, FG, PB	-	FG, PB, STL	BF	-
Susanville HUD	Open	PB	-	PB	-	Branch Line Fittings Leaks
San Bernardino	Open	AC, DI, PVC	-	STL, CU	G	-
Pagosa Springs	Closed	AC	AC	STL, CU	G, BF	By Pass Problems
NMSU	Closed	AC	AC	STL, CU	G, BF	-
Boise City	Open	AC, FG	-	STL	BF	Ext. Corr. of Iron Alloys. Crossover Valve Failures
BWSWD	Open	AC, STL	-	STL	GE	Ext. Corr.
Boise Cap. Mall	Open	STL, AC	-	STL	BF	-
ECSD	Closed	AC, STL	STL	STL	BF	-
Elko Heat Co.	Open	AC	-	STL, SS	G	Ext. Corr. Stl.
Warren Property	Closed	STL, CU	STL, FG	CU	G	-

FG - Fiber Glass	STL - Steel	AC - Asbestos Cement
PB - Polybutylene	DI - Ductile Iron	CU - Copper
PVC - Poly Vinyl Chloride	G - Gate	BF - Butterfly
SS - Stainless Steel (304)		

Open - No central Heat Exchangers, Geothermal Fluid Delivered Directly to Customers

Closed - Central Heat Exchangers

The Klamath Falls City system experienced a failure of the fiber glass portion of their system (~7,000 lf). Interestingly, this failure occurred not in piping exposed to the geothermal fluid, but on the closed loop portion of the system. The piping system employed a "key lock" type joining system. This connection method consisted of a bell and spigot arrangement with a flexible "key" to lock the joint together. When assembled, a groove on the male portion of the fitting aligned with a groove in the female portion of the fitting. A flexible key was inserted into these grooves to lock the connection axially. The failure involved the epoxy, used at the factory, to attach the grooved rings to each section of pipe. This epoxy failed allowing the connection to slip and ultimately leak. The piping itself experienced no failure.

Ductile iron was originally selected for replacement of the fiber glass. Consideration is also being given to retaining the fiber glass piping and repairing only the piping connections.

Aside from fiber glass and AC, the two remaining types of piping in common use for main lines are steel and polybutylene.

Steel has been used successfully in both the Klamath Falls system and Boise Capital Mall system for the conveyance of geothermal fluid. In addition, it is used in the ECSD, Klamath Falls and Warren Property systems on closed distribution loops. In both the Klamath Falls and Capital Mall systems, this piping is installed primarily in concrete tunnels and building mechanical spaces in order to permit access. The BWSWD system used a wrought iron alloy pipe for approximately 50 years. This pipe was removed during the system up grade in 1982.

Polybutylene was used successfully in the Susanville HUD system. This piping, in sizes of 2 to 8" has been in service for 5 years and has not required any repair. The entire system was assembled using thermal fusion connections.

Although the experience with various types of main line piping has been generally good, problems have occurred in some systems with such items as valves and temperature crossovers.

Two types of valves have been employed for isolation duty on these systems: gate and butterfly valves are the most common. These valves in many cases have experienced stem leakage and seizure. In addition, they tend not to be capable of 100% shut off after several years in service. As a result, two system operators have switched to resilient seated gate valves for new construction.

Butterfly type valves appear to be better suited to geothermal applications. The rotary motion (rather than reciprocating) is less prone to leakage. In addition, the resilient lining protects the valve body from exposure to the geothermal fluid. Most geothermal applications employ EPDM seats and "O" rings, 316 stainless steel shafts and discs in butterfly valves.

Only one system has thus far experienced problems with these valves. The Boise City system employed butterfly valves at various points around the system for temperature maintenance duty. These valves, installed between the supply and waste collection piping were designed to divert a small flow of hot water to waste in order to maintain adequate supply temperature in the distribution system. In some valves the resilient seat distorted in such a way as to cause an increase in resistance to movement of the disk. This resistance required the operator to apply more torque to open and close the valve. As a result, the geared operator on some valves failed.

These valves were replaced with automatic temperature activated valves which were installed in concrete valve boxes. Each valve station also included a water meter for monitoring of flows. These installations solved the problems with the direct buried manual valves and resulted in significantly reduced system flow requirements.

The Pogosa Springs system also included crossover valves in the design. These valves were of the constant flow variety. Unfortunately they were installed backwards and did not function properly. This situation was considered responsible for the "pressure creep" problems originally experienced with the system. The curious absence of an expansion tank on the closed loop system may also have contributed to this excess pressure problem. The crossover valves were re-installed properly and have functioned well since.

Customer Connections

The customer connection is the physical link between the building heating loop and the district system. In general, this connection contains isolation valves, metering (volume or energy), temperature and pressure instrumentation and in some cases a heat exchanger and/or temperature limiting valve. The components included in the customers connections vary according to district system type (open or closed) and sophistication.

The simplicity of the customer connections in most systems has resulted in few if any problems for most operators.

Customer branch lines however, have been the source of some problems. In the Susanville HUD system, field insulated polybutylene lines were used for all customers. Compression type fittings were used to join this piping. After startup, numerous leaks developed at these connections. It was later discovered that the fittings incorporated acetal components which were not recommended for use in continuously recirculating hot water systems. These fittings were replaced with brass and stainless steel components and the leakage was eliminated.

Exterior corrosion of steel service lines has occurred to a large extent in both the Elko Heat Company and Boise City systems. The operators of these systems have taken two different approaches to the problem.

At Elko, type 304 stainless steel piping with welded connections is used for branch lines new installations. Although considerably more expensive than carbon steel, corrosion problems have been completely eliminated.

At Boise, several solutions have been applied. These involve the use of fusion bonded epoxy coating on all ferrous components to be directly buried in the soil, high potential magnesium anodes with test stations and selected backfill material.

Metering

Most district heating systems which serve more than a few customers, must employ some means for apportioning costs. In addition, many systems install well head meters to track total production rates. In the systems reviewed for this report, both the equipment employed and the results obtained vary widely.

Well head metering is used in 8 of the systems. All of these are of the volume type, measuring total gallons supplied. As indicated in Table 4, a variety of meter types are used. Only two of the systems report difficulties with this instrumentation. The OIT system's paddle wheel type insertion meter was installed just down stream of a number of fittings. As a result accuracy is questionable.

The original turbine meter at the Boise City System #2 well failed after a short period of operation. The turbine wheel from this meter was discovered lodged in the piping at the system disposal point some 14,000 feet away. The turbine meter was replaced with a magnetic flow meter. In addition, piping modifications were made to accommodate a sufficient straight length of piping upstream of the meter.

The turbine meter installed at the BWSWD production facilities has been in service for approximately 35 years. In that time it has been rebuilt at the factory on only two occasions.

Customer metering is used on all but one of the systems. Meter output is of one of two types: volume or energy. In general, volume metering has been less trouble prone than energy metering.

Volume meters are considerably less complex than energy meters, and hence their greater reliability. Volume metering provides an incentive for customers to minimize flow requirements since billing rates are generally indexed to a specific Δt . Customers who

Table 4
Metering Summary

<u>System</u>	<u>Wellhead Metering</u>	<u>Type</u>	<u>Experience</u>	<u>Customer Metering</u>	<u>Type</u>	<u>Experience</u>
OIT	Yes	Insertion Paddle Wheel	Fair (Poor Installation)	None		
Klamath Falls	None	--	--	Yes	Energy	Good
Susanville DOE	Yes	Orifice	Good	Yes	Energy	Poor
Susanville HUD	None	--	--	Yes	Energy	Poor
San Bernardino	Yes	Insertion Paddle Wheel	Good	Yes	Energy	Good
Pagosa Springs	None	--	--	Yes	Energy	Fair
NMSU	Yes	Turbine	Good	Yes	Volume/ Turbine	Good
Boise City	Yes	Turbine Magnetic	Poor Good	Yes	Volume/ Turbine	Good
BWSWD	Yes	Turbine	Good	Yes	Volume/ Orifice	Good
Boise Capital Mall	Yes					
ECSD	None	--	--	Yes	Energy	Good
Elko Heat Co.	Yes	Ultrasonic	Good	Yes	Volume/ Turbine	Good
Warren Property	None	--	--	Yes	Energy	Fair

design their systems for higher Δt (lower flow rate) increase their savings and help minimize district system flow requirements. Three of the systems use turbine meters for volume metering.

One system (BWSWD) uses orifice plates for metering purposes. A constant pressure is maintained in the supply system and as a result, various orifice sizes can be used to regulate customer flow

rates. Of course the orifice plate method controls only the peak flow rate and does not address the total gallons used. This method does not provide the incentive to minimize use as discussed above.

Energy metering has been demonstrated to be a useful technique or a persistent problem depending upon the system in question.

In Susanville, most of the problems have been traced to poor installation practices. Meters were installed in orientations not recommended by the manufacturer (such as horizontal meters in vertical position). Oversizing of the flow meter portion of the instrumentation also appears to be a problem there. The results at Susanville suggest that it is equally important to consider the average and minimum flow rates in addition to the peak flow rate when sizing these meters. This is particularly true for space heating applications.

At the Warren Property system in Reno, installation practices again have given rise to problems. In this case the meters were installed in small concrete valve boxes at the edge of each property. These valve boxes tend to accumulate water particularly during the spring and summer months. This water penetrates the electronic integrating circuits and renders the display unreadable or in some cases the entire unit inoperable. In the drier locations of the system, however, these meters have performed well.

One experience which seems to be common to most operations using battery operated energy meters is that the "5 year" batteries seem to consistently last only 2-3 years. As a result, some systems favor AC power sources for the meters, or have switched to the less expensive 1 year batteries.

Disposal

Most operating systems currently use some type of surface disposal, though 4 are operating injection wells. Of note is the fact that half (4) of those currently disposing on the surface are planning for or are in the construction phase of injection wells. This movement toward injection is a result primarily of regulatory issues.

The Susanville systems have been operated for several years under temporary surface disposal permits. During this time, attempts have been made to complete an injection well which would be capable of serving both systems. One existing well was found to be incorrectly completed and two subsequent wells drilled for injection were incapable of accepting a sufficient flow. The motivation for injection is regulatory pressure from the local water quality control board.

In Klamath Falls and Boise, extensive geothermal development has resulted in measurable reservoir declines. This is particularly true in Boise where wells which previously flowed artesian no longer do so. As a result, system operators are working diligently toward injection.

In both cases, regulatory pressure again plays an important role. At Klamath Falls, a city ordinance requires that all wells currently discharging to the surface cease to do so by 1990. In Boise, no specific regulations have been enacted, however, the State Department of Water Resources is closely monitoring the situation and has hired an outside consultant to evaluate the reservoir.

The OIT system is currently in the testing phase on their 2,000 ft. injection well. As indicated in Table 5 the success of the well as an injector is still in question. Initial pump tests have not been encouraging.

Table 5
Disposal Data

System	Type of Disposal	Repository	Planning Injection	Injection Well Under Construc.	No. of Success Inj. Wells
OIT	Surface	Lake	Yes	Yes	1 ?
Klamath Falls	Injection	--	--	--	0
Susanville DOE	Surface	Drain Ditch	Yes	Yes	3
Susanville HUD	Surface	Drain Ditch	Yes	Yes	—
San Bernardino	Surface	River	No	No	0
Pagosa Springs	Surface	River	No	No	0
NMSU	Injection	--	--	--	1
Boise City	Surface	River	Yes	No	0
BWSWD	Surface	Storm Sewer Sanit. Sewer Irrig. Canal	No	No	0
Boise Cap. Mall	Injection	--	--	--	0
ECSD	Surface	Irrigation	No	No	0
Elko Heat Co.	Surface	Percolation Pond & River	No	No	0
Warren Property	Injection	--			0

For those systems currently operating injection wells, few problems have been encountered. The Capital Mall system experienced some minor pressure fluctuations on start up. These were traced to the main

throttling valve on the outlet of the injection pumps. Adjustments to the valve controller successfully addressed this problem. The three other systems with injection wells do not require injection pumps and have had no problems.

For the systems using surface disposal, the only common problem relates to pressure sustaining valves. These valves used to maintain a minimum back pressure on the system, have failed at 4 sites. The failures are generally related to embrittlement of valve diaphragms. Periodic monitoring and replacement has been successful in reducing the problem. Standard Buna-N material has demonstrated the shortest life. Ethylene propylene diene monomer (EPDM) offers improved performance and fluoroelastomer superior performance.

Conclusion

The systems reviewed in the course of this work have all experienced materials and/or equipment problems to some degree. For the most part, however, these difficulties have been overcome and the systems serve as a reliable energy source for their customers.

The experience gained from the combined 182 years of operation of these systems allows one to describe conceptually, the ideal geothermal district heating system from a materials and equipment perspective. In summary, this system would consist of:

- Production well pumps of the enclosed lineshaft, oil lubricated design with bowl assemblies containing enameled cast iron impellers with keyed shaft connections, leaded red brass bearings and stainless steel shafts.

- Production pumps equipped with a variable speed drive (preferably a multispeed motor or variable frequency drive).

- Production pumps feeding directly into the main production line (no wellhead storage tank).

- Open type distribution system with asbestos cement piping (or some similar substitute).

- Butterfly valves (EPDM/316 SS trim).

- Automatic temperature activated valves for crossovers if used).

- Customer branch lines of a non-metallic material.

- Volume metering for billing purposes.

- Surface disposal if regulatory authorities permit.

BOISE CAPITOL MALL SYSTEM

Introduction

The Capitol Mall system serves 8 buildings (~800,000 ft²) in the area of the Idaho State Capitol in Boise. This system originally constructed in 1982 is noteworthy for a number of reasons:

The deepest production well of any district system in the U.S.
A 2 speed production pump.
Injection pumps.

This system supplies geothermal fluid to the individual buildings from a 3030 ft. production well located slightly to the north of the service area. The well produces 750 gpm of 160°F fluid. A steel distribution system located largely in basements and underground tunnels delivers the fluid to the end users. Cooled fluid is delivered to the injection well where it is handled by one of two injection pumps.

The operators of the Capitol Mall system along with those of the other major systems in the area are currently developing a plan for addressing reservoir problems which have surfaced due to the extensive geothermal development since 1982. Some reservoir decline has been experienced.

Table 1.1 provides a summary of information on the Capitol Mall system.

Table 1.2 presents a summary of fluid chemistry of the Capitol Mall system.

Table 1.1

Boise Capitol Mall Geothermal District Heating System

Start Up Date	Winter 1982
Years of Operation	6
Number of Customers/ft ²	8/800,000 ft ²
Resource Temperature	169°F
Delivery Temperature /Δt	155°/30°
Peak Flow Capacity	750 gpm
Disposal Method	Injection Well
Customer Heat Exchangers	Yes
No. Production/Injection Wells	1/1
Rate Structure	None
Ownership	Public
Original Financing	
State of Idaho	\$ 1,758,000
Other	92,000
	<u>\$ 1,850,000</u>
Contact Person	Mr. Larry Osgood, P.E. State Dept. of Public Works 502 N. 4th Street Boise, Idaho 83720 (208) 334-3453
Engineer of Record	Larry Fettkether, P.E. CH2M Hill 700 Clearwater Lane Box 8748 Boise, Idaho 83707 (208) 345-5310

Table 1.2

Water Chemistry - Boise Capitol Mall System
(Austin, 1983)

Temperature	76°C
TDS	283 ppm
pH	8.9 mg/L
Specific Conductance	355 micromhos

<u>Constituents</u>	<u>mg/L</u>	<u>Constituents</u>	<u>mg/L</u>
Silica (SiO ₂)	88.00	Carbonate (CO ₃)	25.00
Calcium (Ca)	2.00	Sulfate (SO ₄)	32.00
Magnesium (Mg)	1.00	Phosphorus (P)	0.16
Sodium (Na)	83.00	Chloride (Cl)	10.00
Potassium (K)	1.70	Fluoride (F)	18.00
Bicarbonate	70.00	Nitrate (NO ₃)	1.00

Production Facilities

The Capitol Mall system is served by a single production well located to the northwest of the main service area. Completion is illustrated in Figure 1.1. This is the second well drilled for the project. The initial well is now used for injection. The present production well is slightly warmer and a better producer than the original well and as a result it is used for production.

Table 1.3 provides a summary of production facilities information.

Table 1.3

Capitol Mall Production Facilities Data

Flow head	750 @ 140
Setting Depth	74 ft
Size Bowls	10 in.
Number Stages	5
Manufacturer	Peerless
Horsepower	40
Variable Speed Drive	Yes
Drive Type	2 Speed Motor
Manufacturer	--
Lubrication	Water
Well Depth	3030'
Well Size	12" to 1286', 8" to 2510'
	Openhole (9 7/8) to ID
Temperature (°F)	162
Static Level	Artesian (30 psi)

The originally installed well pump is still in service. It is of water lubricated design with a two speed electric motor drive. Due to the artesian nature of the aquifer, a setting depth of only ft. is employed. The production well pump and associated equipment is located in a 460 ft² wellhead structure in a state parking lot. Details of the wellhead facilities appear in Figures 1.2 and 1.3.

As shown, the production well is completed for both artesian and pumped flow. The artesian connection includes a gate valve (installed during the well construction) and a silent type check valve.

The pumped outlet is equipped with an elastomeric type flexible coupling and butterfly valve. Downstream of the butterfly valve is an automatic control valve (also of the butterfly type) which is used to regulate system pressure.

Figure 1.1 Construction details - Capitol Mall Production Well.
(Castelin, 1988)

Both production outlets are connected to a small settling tank (750 gal.), the purpose of which is to trap sand and other particulates which may evolve from the well. A drain system, connected to the bottom of the tank, delivers blowdown flow to a series of six 55 gallon drums. These drums are equipped with 40 mesh screens to trap the particulate matter.

Production fluid to the system flows from the top connection on the settling tank through the wellhead flowmeter (described in detail in the controls section), a flexible coupling (elastomeric type) and a butterfly valve.

Below grade the Schedule 40 steel pipe is connected to a short length of ductile iron and then to the pre-insulated asbestos cement piping.

Table 1.4 presents a summary of the materials of construction of the production well pump. Table 1.5 presents the materials of construction for other major wellhead components.

Table 1.4

Production Pump Materials of Construction

Component	Material
Lineshaft	AISI 1045, Carbon Steel
Lineshaft Bearings	SAE 660, Bronze
Head Shaft/Impeller	ASTM A276, Type 416, Stainless Steel
Shaft Sleeves	ASTM A276, Type 416, Stainless Steel
Impellers	ASTM A48, Enameled Cast Iron
Bowl Bearings	Bronze
Shaft Seal	Teflon
Column	ASTM A53, Grade A, Carbon steel

Table 1.5

Materials of Construction - Major Wellhead Components
(Austin, 1982)

Butterfly Valves

Manufacturer
Materials

Dezurik, Figure 632

Body

Cast Iron

Seat

EPDM

Stem

316 SS

Disc

Cast Iron (Nickel Plated)

Check Valves

Manufacturer
Materials

Val-Matic, Series 1400

Body

Iron

Trim

Stainless Steel

Piping

ASTM (A-53 Grade B) Welded,
Schedule 40

Flexible Couplings (Bellows Type)

Manufacturer
Materials

Holz Spanflex

Tube

Hypalon w/Neoprene Cover

Flowmeter

Manufacturer
Materials

Badger Turbo Meter

Housing

Cast Iron

Rotor, Nose Cone

Kynar

Bearings

Ceramic

The production well is capable of operating in three different modes: artesian flow, low speed pump and high speed pump. The following paragraphs from the original specifications (Austin, 1982) describe the system operation:

"The production pump P-5 has a two speed electric motor. A local HI/LO/OFF/REMOTE switch shall be located in the pump station.

In the REMOTE position the pump shall be controlled by HI/LO/OFF/AUTO switching relay(s) in the Central

Monitoring and Control System. In the AUTO position pump speed shall be set in response to the pump flow signal as indicated below.

At high speed the pump shall have a capacity of 750 gpm with its pressure controlled discharge valve wide open. Responding to the pressure signal, the valve shall throttle the pump capacity to maintain the high speed differential pressure set point. Minimum pump flow at high speed is 425 gpm.

At 425 gpm capacity the pump shall go to low speed with its discharge valve in a full open position. Responding to the pressure signal, the valve shall throttle the pump capacity to maintain a new pressure set point. Minimum flow at low speed is 125 gpm.

At 125 gpm capacity the pump shall stop and the discharge valve shall close. Artesian geothermal water flow will then take place from a well casing discharge pipe into the supply system piping.

On rising flow conditions, the pump shall start on low speed at 150 gpm and switch to high speed at 475 gpm."

Flow signals are produced by the Badger flowmeter and pressure signals from a wellhead pressure transducer.

Problems/Solutions/Modifications (Osgood, 1988)

The production pump has been down for repairs only twice in the life of the system. On the first occasion, in 1987, the headshaft seal failed and scored the shaft. At this time the seal and shaft were replaced. During this work the seal material was changed from the original teflon to a graphite impregnated material.

In September 1988, the pump failed due to a shaft shear at one of the couplings. At this time all of the shaft and bearings were replaced. Due to the slow response of the manufacturer and the need to have the system in operation for the approaching cold weather, the parts were manufactured locally. When the pump was restarted a substantial increase in sand production was experienced. By December of 1988, most of the excess sand production had ceased but blowdown from the wellhead separator tank showed evidence of bronze particles - suggesting deterioration of the bearings. At this writing, this problem is being monitored.

The wellhead settling tank is blown down on a daily basis. Sand production is very small (less than 4 ft³ in 6 years). To the knowledge of the present operators (with the system only 2 years) no other service has been required of major wellhead components.

Distribution System

The Capitol Mall distribution system is composed primarily of carbon steel piping installed in the individual buildings and in underground tunnels. In addition, a small quantity of direct buried asbestos cement piping is used. Figure 1.4 presents a layout of the system.

A summary of the piping sizes and lengths employed in the system appears in Table 1.6. Table 1.7 provides information on the piping materials.

Figure 1.5 presents a detail of the typical direct bury techniques used for the asbestos cement portion of the distribution system. The steel piping installed in the existing basement and tunnel areas is generally supported as shown in Figure 1.6.

Table 1.6
Distribution System Piping - Lengths and Sizes

	<u>Sizes (in.)</u>	<u>Lengths (lf)</u>
Steel Piping (All Insulated)		
	8	2680
	6	440
	4	480
	3	1120
		<u>4720</u>
Pre-Insulated Asbestos Cement Pipe		
	8	270
	4	300
		<u>570</u>
Bare Asbestos Cement Pipe		
	8	360
	4	300
		<u>660</u>
Total Piping		5950

Figure 1.4 Capitol Mall System layout.
(Fettkether, 1982)

Figure 1.5 Typical pipe burial detail.
(Fettkether, 1982)

Figure 1.6 Typical hanger detail.
(Fettkether, 1982)

Table 1.7

Distribution System Piping Information - Materials
(Austin, 1982)

Steel Piping

Manufacturer	Schedule 40
Thickness	ASTM A53, Grade B,
Specifications	ASTM A106, Grade B
Connections	Welded
Insulation	Field Insulated Welded Fiber Glass

Asbestos Cement PVC

Manufacturer	Johns-Manville
Pre-Insulated Material	Class 150, ASTM C296, Type II
Carrier	12 Mil, PVC Meeting
Carrier Pipe Lining	ASTM C-541, ASTM D-2583
Insulation	Polyurethane k.18 25#/ft2
Jacket	Asbestos Cement, Class 1500 Sewer Pipe
Manufacturer	Independent Fitting
Uninsulated Material	As Carrier Pipe Above
Fittings	Cast Iron, ANSI A21.10
Lining	None
Gaskets	EPDM
Coating	Asphaltic (AWWA C110)

Expansion joints are used for accommodating expansion in the steel piping. A total of 16 such joints are installed in the system. These joints are of the stainless steel bellows type with flanged connections and were supplied by Metraflex (Model HP).

Problems/Solutions/Modifications

No problems have been experienced with the distribution system to date.

Customer Connections

The typical customer connection for Capitol Mall system customers appears in Figure 1.7. Since most of the buildings contained hot water systems, the retrofit consisted primarily of installing a plate heat exchanger and its associated equipment.

Figure 1.7 Typical customer connection diagram.
(Fettkether, 1982)

As shown, the connection includes two butterfly valves, two flexible couplings, a strainer and a control valve in addition to the heat exchanger.

The control valve typically responds to a signal from a supply water temperature sensor on the building side of the heat exchanger.

Table 1.8 presents information on the major mechanical components of the customer connections.

Table 1.8

Customer Connections Mechanical Equipment Summary
(Austin, 1982)

Heat Exchangers	
Type	Plate Type
Materials	316 Plates, BUNA-S Gaskets
Manufacturer	Tranter (Super Changer)
Flexible Couplings	
Type	Bellows
Materials	
Body	Cast Iron
Tube	Hypalon Neoprene Cover
Manufacturer	Holy Spanflex
Butterfly Valves	
Type	Wafer Mount, Resilient Lined
Seat	EPDM
Shaft Screws	316 SS
Disc	Nickel Coated, Cast Iron
Manufacturer	Dezurik (Figure 632), Keystone (Figure 100)
Control Valves	
Valve	As Above
Operation	Electronic, Handwheel Equipped
Manufacturer	Keystone (Figure 777)

Instrumentation in the customer connections consists of the usual pressure and temperature indicators. In addition, each customer is equipped with temperature and flow transducers. These transducers deliver a signal to a field processing unit and ultimately to the Central Monitoring and Control System serving the entire Capitol Mall area (JC85). As a result, central recording and monitoring of individual building energy use (Btu) flow rate and Δt is possible.

In addition to the heat exchanger type customer retrofit, two of the buildings in the original design employed stainless steel finned coils which used the geothermal water directly. In these buildings (L.B. Jordan and Central Services) cleanable type finned coils were installed upstream or in place of the existing steam coils in the central air handlers. The customer connection for these buildings was similar to that described above with the exception of the heat exchanger.

Problems/Solution/Modifications

Since the original construction, a heat exchanger has been added in the L.B. Jordan building to isolate the stainless steel coils from the geothermal fluid. Current operating personnel were not aware of the reason for this installation.

The operators currently have a program of gasket replacement for the isolation heat exchangers. Many of these units have developed gasket leaks during the 6 years of operation. The replacement gaskets are believed to be of Buna-N material.

Disposal

The Boise Capitol Mall System is one of the few systems to employ an injection well and the only one to use injection pumps.

Figure 1.8 presents a layout of the injection station for the system. The well is located east of the main service area as shown in Figure 1.3. The wellhead building contains 2 centrifugal pumps, a back pressure control valve and associated controls.

Table 1.9 presents material information on the two injection pumps.

Table 1.9
Injection Well Pump - Information Summary
(Austin, 1982)

	P-7	P-6
Flow Head	300 @ 75'	750 @ 360'
Gpm	1750	1750
Type	Single Stage, Centrifugal	3 Stage Single Suction Horizontal Split Case
Materials		
Case	Cast Iron (ASTM A48)	ASTM A48
Impeller	Cast Iron ASTM A48	ASTM A48
Seal	Graphic, Impregnated Asbestos	Graphite, Impregnated Asbestos
Shaft	AISI 1141	AISI 1040
Shaft Sleeve	AISI 416	AISI 416
Bearings	Ball Type	Ball Type
Horsepower	10	125
Manufacturer	Peerless	Peerless

The two injection pumps are installed parallel with the smaller unit providing base load operation. The following paragraphs from the original system specifications (CH2M Hill) provides an explanation of the operating sequence:

"The injection pump system has two pumps each with single speed electric motors. Local ON/OFF/REMOTE switches shall be located in the pump station. In the REMOTE position the pump shall be controlled by ON/OFF/AUTO switching relays in the Central Monitoring and Control System. In the AUTO position the operating pump shall be selected in response to the flow signal as indicated below.

The injection pump's discharge shall be throttled by a control valve. At a flow of 750 gpm the control valve shall be in the full OPEN position and Pump P-6 shall be operating. In response to a pressure control signal, the control valve shall throttle Pump P-6 to maintain a constant pump suction pressure. When the flow rate falls to 275 gpm Pump P-6 shall shut off, Pump P-7 shall start, and the control valve shall go to the full OPEN position. Again, in response to a pressure control signal, the control valve shall throttle Pump P-7 to maintain a constant pump suction.

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Pump P-6 shall start when the rising flow rate reaches 325 gpm. Pump P-7 shall START and STOP in response to outside air ambient temperature. START/STOP set points shall be adjustable, initially set to start Pump P-7 at 60oF on falling temperature and stop Pump P-7 at 65oF on rising temperature."

Figure 1.8 presents a diagram of the completion of the Capitol Mall injection well. This well was originally constructed with the intention of its use as a production well.

The injection pump throttling valve described above is installed downstream of the two pumps. This valve is described in Table 1.10. The air for the pneumatic operator is supplied from an adjacent building.

Table 1.10

Injection Wellhead Throttling Valve Information
(Austin, 1982)

Manufacturer	Fisher Controls Model 657-ET-3582
Type	Globe
Size	6"
Operator	Pneumatic
Materials	
Stem	316 SS
Plug	416 SS
Seat Ring	416 SS
Case	416 SS

Problems/Solutions/Modifications

Practice has demonstrated that the large injection pump (P-6) is rarely required. Injection pressure requirements even at peak flow are much less than originally expected.

The Fisher throttling valve has demonstrated very little stem leakage and has shown reliable operation. On initial system startup the valve did experience hunting problems. This was remedied by "fine tuning" the valve controller (Austin, 1988).

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6. P. Castelin, Senior Hydrogeologist, IDWR, Boise, ID Personal Communication, October 1988.
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BOISE CITY SYSTEM

Introduction

The Boise City system was developed as one of the projects sponsored by the USDOE "PON" program in the early 1980's. The city's system was completed in March of 1983 and was in full operation during the winter of 1983-1984.

Geothermal fluid for the Boise system is produced from one of three production wells located to the northeast of the service area. Originally the production wells were owned by a separate, private entity (Boise Geothermal Limited) founded expressly for this purpose. For several years, the city operated the wells under contract to Boise Geothermal Limited (BGL). Recently, the production facilities were purchased from BGL by the City of Boise. This gives the city complete control of the system.

Fluid is delivered to customers through an extensive distribution system consisting primarily of pre-insulated asbestos cement (AC) supply piping and uninsulated AC disposal piping. The distribution system includes piping which varies in size from 6 to 14 inch. Figure 2.1 presents the general layout of the distribution system.

Customers are billed based upon the volume of water use. The data is provided by hot water meters placed at each building. Currently the Boise City system employs surface disposal of the geothermal fluid. All waste water is collected in the uninsulated disposal system and delivered, through a diffuser, into the Boise River at the southwest corner of the service area.

Due to intensive geothermal development in the Boise area, a decline in the geothermal aquifer has occurred. This has resulted in the Idaho Department of Water Resources establishing a ground water management area around Boise. This designation places a moratorium expansion. The prospects for injection of the system waste fluid are being studied.

Table 2.1 provides a summary of information on the Boise City Geothermal System.

Table 2.1
Boise City System - Data Summary

Years of Operation	5
Number of Customers/ft ²	34/1.2 x 10 ⁶
Total Length of Piping	44,000
Resource Temperature (°F)	174
Delivery Temperature/Δt	100-174°F/Varies rates based on 50°Δt
Peak Flow Capacity	4250 gpm
Disposal Method	Surface
Customer Heat Exchanger	Yes
No. Prod/Inj. Wells	3/0
Rate Structure	<u>Summer</u> <u>Winter</u> <u>Per 100 Gal.</u>
490,000 gal/day first 49,000	\$.1725 .1532 " " "
next 441,000	.1642 .1451 " " "
over 400,000	.1562 .1373 " " "
Ownership	Public
Original Financing	(See Table 2)
Contact Person	Dave Turner Public Works Department Room 401 - City Hall 150 N. Capitol Blvd. P. O. Box 500 Boise, ID 83701 208-384-4292
Engineer of Record	Nathan H. Little, P.E. CH2M Hill Boise, ID
Contractor	Owyhee Construction P. O. Box 7095 Boise, ID 208-336-5025

Figure 2.1 Boise City System Distribution Layout.
(Lunis, 1986)

Table 2.2
Source And Application Of Funds

SOURCE OF FUNDS	Amount \$	Percent
Reimbursements (1)	34,885	0.51
Bonneville Power Administration (2)	120,750	1.78
DOE Public Buildings Program (3)	8,500	0.12
Interest Income	61,356	0.9
Boise Warm Springs Water District	256,700	3.79
Limited Partnership	2,000,000	29.59
City of Boise	148,529	2.19
Department of Energy	3,626,000	53.66
Economic Development Administration	500,000	7.39
TOTAL REVENUES	6,756,720	99.93
EXPENDITURES		
BWSWD Wells	228,357	1.75
BWSWD Geology	42,849	0.63
BWSWD Market/Rate Studies (1)	5,000	0.07
BWSWD Environmental Study	20,958	0.31
BWSWD Public Awareness	2,307	0.03
BWSWD Construction	1,038,182	15.36
BWSWD Administration	114,640	1.69
BWSWD Design/Engineering	249,010	3.68
Boise City Wells	2,020,877	29.9
Boise City Geology	34,364	0.5
Boise City Market/Rate Studies	20,348	0.3
Boise City Environmental Studies	62,774	0.92
Boise City Public Awareness	15,184	0.22
Boise City System Design/Engineering	278,532	4.12
Boise City Construction	2,445,702	36.19
Boise City Administration	287,936	4.26
TOTAL EXPENDITURES	6,867,020	99.93

NOTES: (1) BPA, Terteling Co., etc. transfers
 (2) Retrofit City Library Building and Fort Boise Community Center
 (3) Funds to study retrofit potential of other City-owned buildings.

All other costs excepting construction and wells are divided between BWSWD and Boise City on the ratios of 25% and 75%, respectively.

Note: The Boise City System was installed as part of a DOE "PON" Grant which also included specifications to the old Boise Warm Springs Water District System. This Table presents cost data for both systems (Lunis, 1986).

Fluid Chemistry Data for the Boise City District system is presented in Table 2.3.

Table 2.3

Boise City Geothermal System - Fluid Chemistry
(Little, 1982)

	Temperature	176°F	
	TDS	290 ppm	
	pH	8.2 mg/L	
<u>Constituents</u>	<u>mg/L</u>	<u>Constituents</u>	<u>mg/L</u>
Bi-Carbonate (HCO_3)	70.000	Aluminum (Al)	0.010
Silver (Ag)	<0.002	Arsenic (As)	<0.050
Boron (B)	0.140	Barium (Ba)	<0.200
Beryllium (Be)	<0.002	Bismuth (Bi)	0.010
Calcium (Ca)	2.000	Cadmium (Cd)	<0.020
Chloride (Cl)	10.000	Cobalt (Co)	<0.020
Carbonate (CO_3)	4.000	Chromium	<0.002
Copper (Cu)	0.080	Flouride (F)	18.000
Iron (Fe)	<0.010	Mercury (Hg)	<0.020
Potassium (K)	1.600	Lutetium (Li)	0.050
Magnesium (Mg)	0.050	Manganese (Mn)	<0.002
Sodium (Na)	100.000	Nickel (Ni)	0.020
Lead (Pb)	<0.020	Silica Dioxide	160.000
Tin (Sn)	<0.020	Sulfate (SO_4)	23.000
Strontium (Sr)	0.020	Titanium (Ti)	<0.020
Vanadium (V)	<0.002	Zinc (Zn)	<0.020
Zirconium (Zr)	<0.100		

Production Facilities

The Boise City System includes three production wells. These wells were all completed during the original construction in 1982. Table 2.4 presents a summary of information on the production wells.

Table 2.4
Boise City Production Wells Summary

	Well #2	Well #3	Well #4
Pump			
Flow/Head (gpm/ft)	1500 @ 240'	2000 @ 254'	750 @ 240'
Setting Depth (ft)	95	100	95
Size Bowls (in)	12	12	10
No. of Stages	5	5	7
Manufacturer	Peabody Floway	Peabody Floway	Peabody Floway
Model	12FKL/H	23FKH	20 DKM
Horsepower	125	200	50
Lubrication (shaft)	Water	Water	Water
Variable Speed Drive	No	No	No
Drive Type	--	--	--
Manufacturer	--	--	--
Well			
Well Depth (ft)	880	1897	1103
Well Size (in)	12" (pump area)	12" (pump area)	12" (pump area)
--	--	--	--
Temperature (oF)	163	172	176
Static Level (ft)	--	--	--
Drawdown (ft)	--	--	--

Each of the three wellheads is located in a separate concrete structure. The #2 wellhouse (Figure 2.2) is the largest and contains all of the electrical equipment, controls and monitoring apparatus for the three wells. This well is located between #3 (to the north 200 feet) and #4 (to the south 200 feet).

The original production pumps are described on the attached three sheets. Materials information is summarized in Table 2.5.

VERTICAL TURBINE PUMP TYPE 'A'

8" 125# ANSI-F.F. DISCH FLG.
8 3/4" 8-7/8" DIA HOLES
11 3/4" DIA. BOLT CIRCLE.
13 1/2" DIA. FLANGE
*BOLT HOLES STRADDLE VERTICAL C

MOTOR

MAKE Yaskawa
TYPE WP-1 NRR ☒ ☒
HP RPM 1770
PHASE 3 HERTZ 60
VOLTAGE 460
FRAME NO. 405 TP
TYPE COUPLING Threaded

PUMP

8" x 16 1/2" C.I. DISCH HD
1 1/2" LINE SHAFT 8" COL
None SHAFT TUBE
PROO LUBE X OIL LUBE
TYPE 12 FKL STAGE 5
1500 GPM 240 Ft. TDH
IMPELLER ☒ ☒
STRAINER ☒ ☒

MATERIAL

COL PIPE Steel
LINE SHAFT Steel
SHAFT TUBE None
BOWL SHAFT Stainless 416
SHAFT PACKING High-Temp Teflon

PUMP BOWL Cast Iron
IMPELLER Cast Iron
BEARINGS (BOWL) Cast Iron
BEARINGS (LINESHAFT) EDX-Neop
STRAINER Galv. Steel

NO. UNITS REQ'D. 1

FLUID Geothermal Water
SPEC. GRAVITY .98
VISCOSITY
TEMPERATURE 170 F
PH

CUSTOMER Boise Geothermal Inc.

ORDER NO.
SUPPLIER Sabol and Rice, Salt Lake

DWG. NO.
SERIAL NO.

VERTICAL TURBINE PUMP

TYPE 'X'

4- 12 - 1" DIA. HOLES

10" 125# ANSI -F.F. DISCH FLG.
12-1" DIA HOLES^a
14 1/4" DIA. BOLT CIRCLE
16" DIA. FLANGE
^aBOLT HOLES STRADDLE VERTICAL C

SOLE PLATE ☒ ☐
SIZE _____
" HOLES ON " O.S.C.
MATERIAL _____

MOTOR

MAKE Yaskawa
TYPE WP-1 NRR ☒ ☐
HP 150 RPM 1770
PHASE 3 HERTZ 60
VOLTAGE 460
FRAME NO. _____
TYPE COUPLING _____

PUMP

10" x 16 1/2" C.I. DISCH HD
1 1/2" LINE SHAFT 10" COL
None SHAFT TUBE
PROO LUBE ☒ OIL LUBE _____
TYPE 12FKH STAGE 5
2000 GPM 258 Ft. TDH
IMPELLER ☒ OPEN ☐ CLOSED
STRAINER ☒ ☐

MATERIAL

COL PIPE Steel
LINE SHAFT Steel
SHAFT TUBE None
BOWL SHAFT Stainless
SHAFT PACKING High Temp Teflon

PUMP BOWL Cast Iron
IMPELLER Bronze
SEARINGS (BOWL) Cast Iron
BEARINGS (LINE SHAFT) EPDM
STRAINER Galv. steel

REMARKS

NO. UNITS REQ'D 1

FLUID Geothermal Water
SPEC. GRAVITY 1.0
VISCOSITY _____
TEMPERATURE 170 F
PH _____

CLSTCIMER Boise Geothermal
ORDER NO. _____
SUPPLIER Sabol and Rice Inc.
DWG. NO. _____
SERIAL NO. _____

FLOWAY PUMPS, INC.

BOX 164

NOT TO BE USED FOR
CONSTRUCTION

By: _____ Date: _____

FLOWAY

Form 3-1024

VERTICAL TURBINE PUMP

TYPE 'A'

8" 125# ANSI-F.F. DISCH FLG.
8 3/4" 8-7/8" DIA HOLES
11 3/4" DIA. SOLT CIRCLE
13 1/2" DIA. FLANGE
*SOLT HOLES STRADDLE VERTICAL C

MOTOR

MAKE Yaskawa
TYPE WP-1 NRR
HP 50 RPM 1770
PHASE 3 HERTZ 60
VOLTAGE 460
FRAME NO. 326 TP
TYPE COUPLING Threaded

PUMP

8" x 16 1/2" C.I. DISCH HD
LINE SHAFT 8" COL
None SHAFT TUBE
PROO LUSE X OIL LUBE
TYPE 10 DKL STAGE 7
500 GPM 240 Ft. TDH
IMPELLER Standard
STRAINER 7-8

MATERIAL

COL PIPE Steel
LINE SHAFT Steel
SHAFT TUBE None
BOWL SHAFT Stainless 416
SHAFT PACKING High-Temp Teflon

PUMP BOWL Cast Iron
IMPELLER Cast Iron
BEARINGS (acw) Cast Iron
BEARINGS (LINESHAFT) EDM-Neopren.
STRAINER Galv. Steel

CUSTOMER Boise Geothermal Inc.

NO. UNITS REQ'D. 1

FLUID Geothermal Water
SPEC. GRAVITY .98
VISCOSITY
TEMPERATURE 170 F
PH

ORDER NO.
SUPPLIER Sabot and Rice, Salt Lake

DWG. NO.
SERIAL NO.

FLOWAY DIRECT INC

NOT TO BE USED FOR

Table 2.5

Materials of Construction - Original Boise City Production Pumps

<u>Components</u>	<u>Material</u>
Shaft	Carbon Steel C1045
Column	Carbon Steel
Shaft Enclosure	N/A
Bearings	EDM rubber
Bowls	Cast Iron
Impellers	Cast Iron (enameled)
Keys	N/A
Fasteners	304 SS
Collets	304 SS
Bowl Shaft	416 SS
Bowl Bearings	Cast Iron

All piping in the wellhead buildings is of carbon steel Schedule 40 construction with welded, flanged or grooved end type connections. Valves, with the exception of those installed directly on the wellheads during drilling are of the butterfly type with EPDM seats and 316 SS trim.

Figures 2.8, 2.9 and 2.10 present details of the original wellhead piping installations. Figure 2.8 presents a basic wellhead piping and control diagram. As shown, a pressure transducer located in City Hall delivers a signal by radio transmission to a receiver at the number two wellhead. The signal is received by a Uniface, Inc. (Belmont, CA) telemetry system and delivered through a Leeds and Northrup programmable controller (Figure 2.4) to a 10 inch pneumatic control valve which throttles to maintain a pressure of 65 psi at City Hall. The 4-20 ma output from the programmable controller is delivered to a transducer at the control valve which translates it into a proportional pneumatic signal for valve operation. A pump control center (Figure 2.5) responds to a signal from the Fisher/Porter flowmeter and stages the three pumps on and off according to system demand. The following excerpt from the original specifications (Fettkether, 1982) outlines the sequence of operation:

"Wellhead instrumentation consists of individual temperatures and pressure gauges at the three wellheads for operator convenience. Pressure gauges are placed on the well casing to monitor artesian pressure and at the pumped outlet for pump monitoring. In addition 12 inch, 7-day, circular chart recorders for monitoring system flow and output temperature are located in the #2 wellhouse.

Figure 2.2

#2 Wellhouse.

Figure 2.3

#3 Well pump.

Figure 2.4

Leeds and
Northrup
programmable
controller.

Figure 2.5 Pump control cabinet with flow chart recorder.

Figure 2.6 Well #4.

Figure 2.7 Wellhead pressure recorder.

Figure 2.8

Production Facilities Control Scheme.

Figure 2.9 Wellhead #2.
(Fettkether, 1982)

Figure 2.10 Wellhead #3.
(Fettkether, 1982)

8" LUGGED BUTTERFLY VALVE SUPPLIED & INSTALLED BY OTHERS

PUMP, SUPPLIED & INSTALLED BY OTHERS

1/2" GALV PACKING WATER DRAIN

0-30 PSIG

1/2" TYPE 32 W/ PLUG

8" BELLOWS TYPE FLEX CPLG W/ 300 LB FLGS (NOTE 1)

EXST 8" 250 LB GATE VALVE

100'-0" SEE NOTE 2

EXST 12" GATE VALVE

EXST WELL CASING

COMPACTED GRANULAR MATERIAL TO UNDISTURBED EARTH, 6" MIN

8" BELLOWS TYPE FLEX CPLG W/ 150 LB FLGS (NOTE 1)

COMBINATION AIR RELEASE VALVE

8" TYPE 79

THERMOMETER, SEE DETAIL 6H3

1" TYPE 32

DRILL & TAP OR INSTALL 2000 LB HALF CPLG

1" GALV DRAIN LINE

8" TYPE 21

1/2" TAP ON BACK SIDE

1/2" TYPE 32

8" TYPE 79

SCN 40 STL PIPE FLOOR SLEEVE W/ 1/4" PL SLEEP RING, SIZE TO FIT OVER FLANGES OR SPLIT AND WELD AROUND PIPE

8" DI

8" DI

THRUST BLOCK W/ 5.5 SQ FT BEARING AREA

NOTES:

1. BELLOWS TYPE FLEXIBLE COUPLINGS ARE NOT REQUIRED IF GROOVED END JOINTS ARE USED
2. FACE OF TOP FLANGE ON EXISTING 12" GATE VALVE IS USED FOR REFERENCE ELEVATION.

Figure 2.11

Wellhead #4.
(Fettkether, 1982)

<u>Flow (gpm)</u>	<u>Falling Flow</u>
3,500	Pump No. 4 OFF
2,000	Lag pump OFF, Pump No. 4 ON
1,500	Pump No. 4 OFF
500	Lead pump OFF, Pump No. 4 ON
	Pump No. 4 off when switched to OFF

There is a differential pressure relief valve installed between the discharge and suction sides of Pump No. 4. This valve will begin to open when the differential pressure across the pump reaches 70 psi. Its purpose is to maintain a minimum flow rate of approximately 200 gpm through Pump No. 4, even if the required flow to the pipeline is less than 200 gpm. This valve is installed on Pump No. 4 because only this pump will operate during low flow conditions. This valve is NOT a system safety pressure relief valve.

The normal operating position for all the main line system butterfly and gate valves is OPEN, with the one exception being the 10 inch butterfly valve in the bypass around the Fisher pressure control valve. This 10 inch butterfly valve is normally CLOSED. If a pump is operating, water will flow from the pump discharge and create a pressure which will close the check valves on any non-operating pumps and on the artesian bypass lines on Pumps No. 2 and No. 4. If artesian operation is desired, the pump discharge valves should be closed and the artesian bypass line valves left open.

Pressure Control System

A pressure sensor and transmitter are located on the geothermal water supply pipe in the City Hall service connection meter vault. Well casing and pump discharge pressure gauges have been installed to help determine if the pumps are operating normally and to determine system pressures. Thermometers have been installed to monitor the temperature of the geothermal water from each pump.

Well Pump Controls

The operation of each well pump is controlled by a HAND-OFF-AUTO switch located at the motor control center located at Pump Station No. 2. In addition, well pumps No. 3 and 4 can be controlled by ON-OFF-REMOTE switches at the respective pump stations.

In the AUTO mode (or AUTO and REMOTE modes for No. 3 and 4), the operation of the pumps is controlled by the flow measured at the flow meter in Pump Station No. 2. The control system also includes a manual lead/lag selector switch for pumps No. 2 and 3. The pumps are started in the sequence indicated in the following table."

Rising Flow

Flow (gpm)

600 or below	Pump No. 4 ON when switched to AUTO
601	Lead Pump ON, Pump No. 4 OFF
1,600	Pump No. 4 ON
2,100	Lag Pump ON, Pump No. 4 OFF
3,600	Pump No. 4 ON

The Lander Street Treatment Plant has the ability to remotely shut down the production well pumps.

Problems/Solutions/Modifications

The production facilities for this system have been the source of a number of operation problems. Most of the problems have been resolved and the three wells currently serve as a reliable source for the system.

The original production pumps employed cast iron bowl bearings. After a very short period of operation it was apparent that these bearings were not suitable for the application. In addition, the original top shaft packing material was teflon. This packing proved to be a problem.

The following memo describes some of the early pump difficulties and solutions:

"To: Chuck Mickelson
City Engineer
Public Works

From: Rich Rabe
Supervisor
Central Maintenance

Subject: Geothermal Pump #4 History
November 9, 1984

October 11, 1983:

Pump #4 failed with 169 hours. Pump was pulled by Widdison Turbine Service. Lineshaft bearings looked good although several lineshaft sleeves that had been locktightened on had slipped several inches (you could see where locktite had melted out of the sleeves). Pump bowl set was damaged beyond repair and top of bowl shaft was broken off; poor machine work on bowl shaft where it was reduced down to one inch, they had left a sharp 90° shoulder with no radius.

October 28, 1983:

Widdison Turbine Service reinstalled the #4 pump with bronze pump bowl bushings, proper shaft radius and shrunk on lineshaft sleeves. Teflon packing supplied by manufacturer had badly scored shaft so I supplied Widdison with a die formed pure graphite set of packing to reinstall.

January 1, 1984:

Don Purtell called in - #4 shaft broken again, 395.1 hours on pump.

January 10, 1984:

Widdison Turbine Service began pulling #4 pump; lineshaft couplings were hour glass shaped, had stretched and one coupling had broken. The bowl was removed and inspected and found to be in good condition.

January 16, 1984:

Widdison reinstalled pump with heavy duty couplings; wall thickness improved to .250 from .125", one bowl was removed from set; started pump at 3:30 PM.

June 25, 1984:

#4 pump shut off with 4092.4 hours and booster pump put on line.

November 1, 1984:

Shut off booster pump and started #4 pump; it ran about 10 minutes and quit pumping.

November 5, 1984:

Pulled the #4 pump. The shaft was broken 30 feet down flush with the coupling, approximately .500" from termination of the threaded end of the shaft.

November 6, 1984:

Reinstalled spare bowl set; bowl set shipped complete but was not assembled (?), threads were bad (improperly machined) on bell reducer on top of pump which attaches to bottom pipe section. Lineshaft bushings (rubber) and shaft sleeves were in good condition and old bowl set appears to be in usable condition although it has not yet been disassembled for inspection. When we reinstalled the new spare bowl set, we left off two 10

foot sections of lineshaft and pipe. The reason for this was that the last two pump failures appear to have been caused by excessive down thrust for the size of the lineshaft. In the last operating cycle of 3697 hours there was never more than 85 psi back pressure on the pump. By removing 20 feet of the lineshaft and piping, we also removed 20 feet of TDH on the pump and reduced the down thrust on the lineshaft. This also shows up in the amp draw of the motor which previously was 61 amps and is now 44 amps or about the same as a 35 hp motor.

Another problem we encountered was with the motor leads; one lead was badly burned although it megged good and was not open. These connections were made by Widdison Turbine Service.

Upon checking, the motor leads were found to be sized too small (size 10 AWG wire) connected to size 2 wire from the magnetic starter for the initial starting current of the motor. New wire was pulled from the motor starter to the motor and the motor was taken to L & K Electric where the proper size leads coming out of the motor were installed.

Rich Rabe "

The bowl bearings in the #2 pump were also replaced with bronze materials shortly after the work on the number 4 well. The #3 well, due to its very limited use still has the original cast iron bearings. The remaining materials in the #3 pump are the same as those used in the original construction (Turner, 1988).

Several modifications to the production pumps were made as a result of system pressure surges experienced as pumps were cycled on and off. (The staging of the pumps is such that #4 carries the base load. As the flow requirement increases #2 is brought on line. The #3 pump could be used if flow requirements exceeded the capabilities of #2 and #4. The current system load is such that the #3 pump is not required.) The first of these modifications involved equipping the butterfly valve at the outlet of pump #2 with an electric actuator. The actuator, (Figure 2.13) would open the valve slowly (starting at 33% open) over approximately 3 minutes on startup, thereby dissipating the excess head produced by pump #2 (compared to pump #4).

In addition to this measure, a pressure relief valve (Figure 2.14) was added to the main production line at the #2 wellhouse. This valve functions to direct flow from the main line if the pressure exceeds a preset value upstream of the main throttling valve. The diverted flow is delivered to the artesian outlet of the #2 well.

The components added included a 4 inch butterfly valve and a 4 inch OCV pressure relief valve. The OCV valve is equipped with an EPDM diaphragm and 316 SS trim.

Finally, two stages were removed from the #2 pump when it was pulled for bearing replacement (cast iron to bronze) in the summer of 1985. This reduced the pressure difference between the #2 and #4 pumps to approximately 26 psi at the 700 gpm flow rate. The pressure difference previously was approximately 85 psi at this flow rate (Turner, 1988).

In addition to addressing the pressure surges resulting from pump staging, the OCV valve also assisted in reducing pressure swings caused by the main throttling valve. During early system operation, it was discovered that this valve was "hunting". The result of this hunting was severe pressure variations in the delivery system downstream from the valve and at the wellhead above of the valve. At one time pressure swings at City Hall were on the order of 50 psi over a period of a few minutes and production pumps were operating at correspondingly variable outlet pressures (Turner, 1987). This operation was likely the result of oversizing of the valve compared to the system flow requirements. This valve was designed to control a peak flow of 4050 gpm. Adjustments to the programmable controller (which receives the pressure signal from downtown and controls the main throttling valve) proved an unsuccessful approach to dealing with the problem. The final solution involved an adjustment to the valve actuator which effectively reduced valve travel by 50%.

Early in the systems operation a small (450 gpm @ 120') surface centrifugal pump (Figure 2.12) was added in the #2 wellhouse. The pump, operating off the natural artesian head from the wells (#2 & #4), permitted the lineshaft pumps to be completely shut down during the warmer periods of the year. Operation of the smaller pump during these periods reduced electrical costs to the extent that the installation was payed back in approximately six months.

Wellhead flow was originally monitored by a turbine meter located in the 10 inch line leaving wellhouse #2. Shortly after start up of the system, this meter failed. The turbine wheel was discovered lodged in piping located at the system discharge point some 14,000 feet (pipeline route) from the production well. At that time, the turbine meter was replaced with a new magnetic type meter (Figure 2.12) which remains in service. Table 2.6 presents a summary of information on this meter.

Table 2.6

Information Summary - Boise City Wellhead Flow Meter

Manufacturer	Fischer-Porter
Model	10D146 Copax
Size	10 inch
Type	Magnetic
Materials	
Liner	Teflon
Electrode	Zirconium
Body	304SS - Epoxy Coated

This meter employs a remote signal conditioner/display which includes totalized flow (gallons) and instantaneous rate (% of peak flow) with LCD indicator. Along with the meter installation, piping modifications were also made in order to assure a sufficiently long enough upstream run of straight pipe to permit accurate flow sensing. This consisted of running a short riser to the roof of the wellhouse to accommodate the meter.

Distribution System

The layout of the distribution system is shown in Figure 2.1 in the introduction. The system is of the open type with geothermal fluid delivered directly to individual customers. The main distribution system is summarized in Table 2.7.

Figure 2.12

West side of #2 wellhouse showing magnetic flowmeter, main control valve and centrifugal pump.

Figure 2.13

East side of #2 wellhouse showing #2 well pump and butterfly valve electric actuator.

Figure 2.14

Pressure relief valve in #2 wellhouse.

Table 2.7

Boise City System Distribution Information Summary
(Little, 1982, Mickelson, 1984)

Supply Piping	Pre-insulated Asbestos Cement
Carrier Pipe	Class 150, AC Pressure Pipe ASTM C296 Type II, AWWA C400 Epoxy Lined
Insulation	Nominal 3/4" Polyurethane 1.8 lbs/ft ³ min.
Jacket	AC
Manufacturer	Johns-Manville
Collection Piping	Same as Carrier Pipe (non-insulated)
Manufacturer	Johns-Manville
Fittings	Cast Iron, Coal Tar Epoxy Coating Exterior, Class D Wall Thickness
	ANSI 21.10, EPDM Gaskets
Manufacturer	Trinity Valley, Tyler

Piping Size Breakdown

<u>Inches</u>	<u>Supply (lf)</u>	<u>Collection (lf)</u>
14	7419	--
12	4127	11964
10	863	5312
8	1800	1160
6	5710	5708
4	--	--
	<u>19919</u>	<u>24144</u>

All of this piping is direct buried. A typical trench detail appears in Figure 2.17.

Isolation valves located on the distribution system are of the butterfly type. These valves are located at strategic points to facilitate maintenance on the pipeline.

In addition to isolation duty, these valves were also employed in the original construction for crossover duty between the supply and return lines. These crossovers were placed at six points in the system to assure minimum flows were sufficient to maintain supply line temperature. These valves were also direct buried and were

TYPICAL SERVICE CONNECTION

NTS

5, 6, 7, 10, 11, 12, 13, 14, 15

Figure 2.15

Original pipeline details.
(Little, 1982)

Figure 2.16

Direct buried valve.
(Little, 1982)

Figure 2.17 Current customer branch line details. (Hightree, 1988)

all of 6 or 8 inch size. Figure 2.16 presents a detail of the original valve installation. A number of modifications have been made to these valves since the original construction. These modifications are discussed in the following section.

Table 2.8 presents an information summary of these valves.

Table 2.8
Boise City System Isolation Valve Data Summary
(Little, 1982)

Type	Butterfly, Resilient Seat
Manufacturer	Keystone, Figure 239
Sizes	4 to 14"
Number in Service	31
Materials	
Body	Cast or Ductile Iron
Seat	EPDM
Disk	316 SS
Stem	316 SS
Bearing	Teflon

Customer branch lines were originally connected to the main line with cast iron tees for those who contracted for service prior to line construction. For customers connected after original construction and for small services, saddle taps were employed. The original saddle taps were of cast iron construction with carbon steel bands and bolts. These were specified in the original plan to be protected by a coating of coal tar epoxy. Due to problems experienced with these taps (discussed below) later construction employed models with 316 SS bands and clamps and currently an epoxy coated, fabricated steel saddle (Romac FTS/420) with 316 SS nuts and bolts are used. Customer branch lines are primarily constructed of polybutylene material (Figure 2.15) up to 2" and AC for 3" to 6" sizes.

Table 2.9 provides a summary of information on this material.

Table 2.9

**Information Summary - Customer Branch Lines
(Little, 1982)**

Type	Polybutylene
Specification	ASTM D-3308, SDR9, 125 psi @ 180°F
Manufacturer	Rahn Plastics
Insulation (Supply Only)	Polyurethane Nominal 1 1/2"
Jacket	PVC SDR 35

Table 2.10

**Protective Coating Used for ferrous materials - Boise City System
(Hightree, 1988)**

Manufacturer	Pure-Cote Corporation
Type	Moisture Cured, Polyurethane/Tar Topcoat
Components	One
Color	Brownish Black
Solids by Volume	60.5%
Recommended Thickness	4-10 Mills Per Coat
Dry Time	Touch 6 hrs, Handle 24 hrs,
	Recoat 4-6 hrs (6 Mil)
Temperature	212°F (Wet Intermittent)

Original construction of the system included a small amount of carbon steel piping and fittings between the saddle tap and the polybutylene pipe (Figure 2.15). In newer construction all of this pipe and fittings are of 316 SS construction. In addition a polyurethane/tar coating is applied at installation.

Table 2.10 presents a summary of information on this coating.

Customer branch line isolation valves are direct buried. Current specifications call for two piece ball valves of 316 stainless steel body with a Teflon seat and 800 psi working pressure rating. Details of current customers connections appears in Figure 2.17.

Problems/Solutions/Modifications

Most of the problems experienced by the Boise City system have been associated with the distribution system. The most serious of these include:

- External corrosion of iron alloy fittings in direct buried applications.
- Failure of seats in resilient lined butterfly valves.
- Failure of butterfly valve operators.
- Failure of compression fittings used in customer connections.
- Excessive water use caused by constant flow crossover valves.
- Failure of angle valves used to connect air/vac valves.

The most difficult problem to deal with has been that of exterior corrosion. Attack of virtually all iron alloy materials has occurred although failure of malleable iron straps and bolts on service saddles appears to have caused the most difficulties. Although failure of the service saddles (Figures 2.18, 2.19 and 2.20), and resultant leaks has been the largest source of corrosion induced operational problems, the rate of corrosion discovered on other components has also been an area of major concern.

The original design called for coating of all direct buried ferrous materials with a coal tar epoxy similar to Tarmastic (Pittsburgh Coke Co.) or Bitumastic 505 (Koppers Co.) (Little, 1982). At service connections cathodic protection in the form of magnesium anodes was also specified. Details of these items appear earlier in this section (Figure 2.15).

Excavation of some of the original service connections reveals that the mastic coating was improperly applied (Turner, 1988). As a result of these discoveries and new recommendations from the city engineering consultant (CH2M Hill) exterior corrosion protection has been very carefully addressed in the most recent construction documents for system extensions.

The current design includes a very comprehensive approach to protection of ferrous materials including the following: (Hightree, 1988, Tenson, 1987)

- 1) The use of selective backfill. Current specifications are for the use of washed sand backfill. This is the result of analysis of several pieces of ferrous material removed from various parts of the system. This analysis revealed that the nature of the backfill material played an important role in the rate of exterior corrosion. The fill is specified as washed sand, 1/4 inch maximum size with 95% passing through a Number 4 sieve.

- 2) All fittings are required to have a fusion bonded epoxy coating. For those fittings on which it is not possible to obtain such a coating from the factory, the coating is applied locally prior to installation. The coating is specified as electrostatically applied to a thickness of 10 mils (I3) and suitable for most service at 180°F to be Molyngo 20/20 (Lynn Industrial Coatings, Inc.)
- 3) Existing piping or fittings encountered during repair which are not possible to coat with the above coating are coated with a combination polyurethane/tar (Metalogal PUR-TAR) manufactured by Pure-Cote Corporation (Pacimona, CA). Sandblasting to SR10 is specified prior to this coating.

A variety of service saddle designs has been employed in the system. The original saddles were cast iron with carbon steel straps and bolts. These were replaced with cast iron saddles equipped with stainless (316) straps and bolts (Figure 2.21). The current model (Figure 2.24) is a fabricated steel, epoxy coated model (Romac FTS-420).

A number of seat failures were experienced on the originally installed butterfly valves (Keystone Figure 239). These failures generally involved seat distortion and in some cases indications of embrittlement. The cause of the seat failure is unclear. Assuming that EPDM material was installed, as specified, the local fluid chemistry is very unlikely to have resulted in embrittlement of this material. Another possibility that these valves were damaged during installation. This type of valve does not require a gasket. The lip on the valve seat serves as the gasket. Installation of a gasket can result in seat distortion. In addition, it is possible that the valves could have been installed in the closed position. Such installation can result in seat distortion.

The resistance, to closure created by the distorted seats in these failed valves may have been related to the other failures experienced such as broken disk attaching bolts and actuator boxes.

The current specifications for system butterfly valves call for AWWA C504 Class 150B, cast iron body, EPDM seat, stainless steel disk and shaft and fluoroelastomer bearings. The operator is also specified to meet AWW C504 and employ traveling nut construction and 316 SS cover screws (Pratt Goundhog with MDT operator).

The customer connections for this system (<3") were installed using field insulated polybutylene piping. In the earliest installations a compression type fitting was used to join the polybutylene to steel piping. After a period of time these fittings had a tendency to "work out of" the compression coupling resulting in a leak. New installations have addressed this problem through the use of a new type of fitting. This design, (Figure 2.23) assembled at the factory consists of a brass nipple with a socket fusion

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Figure 2.18

Failed service
saddle.

Figure 2.19

Failed service
saddle.

Figure 2.20

Failed service
saddle.

Figure 2.21

Cast iron service saddles with stainless steel bands and bolts.

Figure 2.22

Newest style of service saddle - fabricated steel with fusion bonded, epoxy coating.

Figure 2.23

Steel to polybutylene adapter currently used. Shows clamp ring.

Figure 2.24

Failed butterfly valve
showing distorted seat.

polybutylene fitting bonded onto it. The bonding is done at the factory using a stainless steel band which is permanently crimped in place.

One of the first problems identified in the system operation was the excessive use of water for pipeline temperature maintenance. This was the result of the use of constant flow (butterfly) valves at the six crossover points in the system. Failure of some of these valves (Figure 2.27), as described above, precluded reduction of crossover flows in some cases. In addition, the constant flow approach was not temperature responsive.

The problem with these crossovers was addressed in a major retrofit program in 1987. The original butterfly crossovers, which were direct buried, were replaced with automatic temperature control valves placed in concrete vaults. Details and locations of these valves appear in Figure 2.28.

In addition to the automatic temperature valve, a water meter was also placed at each crossover. As a result the operators are able to monitor water use for system temperature maintenance more accurately. Table 2.11 provides a summary of the equipment installed at the temperature crossover points.

Figure 2.25

Newest cast iron fittings with fusion bonded, epoxy coating.

Figure 2.26

Failed angle valve originally used for attaching air vac valves.

Figure 2.27

Failed direct buried cross-over valves.

Figure 2.28 Crossover valve details.
(Tenson, 1987)

Table 2.11

**Temperature Control Crossover Connection Equipment
(Tenson, 1987)**

Temperature Control Valves	
Manufacturer	Jordan, Mark 80
Sizes	1 and 1 1/2"
Number	6
Type	Automatic, Self Powered, Remote Bulb
Materials	
Body	Cast Iron
Trim	316 SS
Isolation Valves	
Manufacturer	Saturn, 96-105
Type	Ball
Materials	
Body	316 SS
Seat	Teflon
Water Meter	
Manufacturer	Badger
Type	Nutating Disk
Materials	
Body	Bronze
Disk	-
Trim	316 SS
Piping	
	Threaded, Carbon Steel, ASTM A-53, Type E, Grade A, Sch. 80

Several of the angle valves used to attach the air/vac valves to the main line failed. These valves (Figure 2.26) were originally equipped with stainless steel seats. These seats were threaded into the bronze valve body. The failures of the valves all occurred at the same location. The stainless steel seat cracked and completely detached at a point flush with the bronze valve body. Since all of these valves were attached to the saddle using a corporation stop and nipple, replacement did not require draining of the system nor did failure affect the ability of the air/vac valve to function. The original valves were replaced with all bronze valves which have served well.

The operators of the Boise System are currently in the process of evaluating alternate piping materials. Although the AC pipe used since the system was installed has performed very well, its availability is rapidly diminishing. Due to concerns relating to the asbestos content, the piping is becoming nearly impossible to

buy. As a result, the newest extension on the Boise System employed fiber glass material with epoxy adhesive connections.

Metering

Customer metering on the Boise City System is currently based upon volume measurement. Each customer is supplied with a totalizing water meter which is read monthly by the district personnel to provide billing data. Table 2.12 describes the meter currently in use. Meters are typically installed in service vaults for individual customers.

Table 2.12

Boise City Hot Water Meters

Manufacturer	Badger Meter Inc.
Number of Meters	40
Sizes	5/8 to 4"
Large Meters	
Size	3 to 4"
Type	Turbine
Materials	
Body	Cast Iron
Rotor	Kynar/Ryton
Nose Cone	Kynar
Bearing	Ceramic
Head, Vans, Valve	316 SS
Gasket, O-Ring	Nitrile
Small Meters	
Size	5/8 to 1 1/2
Type	Nutating Disk, Model Scer-8
Materials	
Body	Bronze
Disk	Synthetic Hard Rubber
Trim	316 SS

Problems/Solutions/Modifications

These meters have been in service since the initial startup of the system. In general, the larger (turbine) meters have provided more reliable service than the smaller (nutating disk) meters. The smaller meters have reportedly exhibited a tendency to "wear out".

The City is currently switching to Hersey MTX Series 123 meters for customer connections in the 3/4" to 1 1/2" size. These meters are reportedly less expensive and employ sealed registers.

A meter test bench was recently acquired by the City for testing the accuracy of the meters on the geothermal system. The bench, located at the #2 well house, is currently being used to test all existing meters on the system. During this testing, one meter was discovered to have been shipped from the factory with an incorrect register. As a result, it was measuring only 14.7% of the actual flow.

The bench is also used to calibrate all new meters to be installed in the system.

For some customers (end of line or waste line users) Btu meters may be employed. At certain locations in the system, it is not possible to accurately predict or supply a constant water temperature. As a result, it would be more equitable for these customers to be equipped with Btu water meters. A manufacturer has not yet been chosen for these meters.

Disposal

The Boise City system currently employs surface disposal to the Boise river. The disposal point is located at the southwest corner of the service area. Figure 2.30 presents a view of the equipment located at the disposal point.

All of the equipment is located in an underground vault adjacent to the river. System effluent enters through a 12 inch butterfly valve and is then passed through a Water Specialties (Porterville, CA) turbine meter. This meter also provides a signal to a 12 inch circular 7-day chart recorder which monitors system flow. The outlet of the turbine meter is delivered to two pressure sustaining valves which maintain a system back pressure of approximately 30-35 psi. These valves are manufactured by OCV and are equipped with EPDM diaphragm and stainless steel trim.

From the underground vault, the flow is delivered to a "diffuser" located on the upstream face of a division canal in the river. (Figure 2.29) The diffuser assumed adequate mixing with the river water for chemical and thermal dilution.

Problems/Solutions/Modifications

The disposal system as it is presently configured has served the system in a fairly trouble free manner. Some difficulties have been experienced with the turbine meter. In addition, diaphragms have been replaced in the pressure sustaining valves.

Geothermal development in the Boise area during the last eight years has resulted in some reservoir water level decline. To address this situation, the City of Boise is moving toward a program of injection of the disposal fluid for their system.

Figure 2.29

Site of disposal
diffuser in the
Boise river.

Figure 2.30

Disposal station
vault showing
pressure sustaining
valves and flow
totalizer.

Figure 2.31

Flow recorder in
disposal vault.

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BOISE WARM SPRINGS WATER DISTRICT SYSTEM

Introduction

The Boise Warm Springs Water District (BWSWD) is the oldest continuously operating geothermal district heating system in the U.S. Started in the late 19th century, this district has served its largely residential customer base for nearly 100 years.

The system supplies its customers with approximately 170° fluid from two production wells located at the east end of the service area. The distribution system consists only of a geothermal water supply line (currently of asbestos cement material). Each end user (of which there are approximately 266) is responsible for his own fluid disposal arrangements. A variety of disposal methods is in use including: sanitary sewer, storm sewer, drainage ditch, infiltration wells and drain fields.

The primary means of metering for the system is via orifice plates, though a few hot water meters are employed. Table 3.1 provides a summary of information on the system.

Table 3.1
Information Summary - BWSWD System

Years of Operation	Approximately 100
Number of Customers/ft ³	266/680,000
Resource Temperature	176°F
Delivery Temperature/ Δt	170°F/Varies
Peak Flow Capability	1400 gpm
Disposal Method	Surface
Customer Heat Exchangers	Only Larger Users
Number Production/Injection Wells	2/0
Rate Structure	See Accompanying Table
Ownership	Public (Service District)
Original Financing	Unknown
1982 System Rebuild:	
Wells	\$ 228,357
Geology	42,849
Market/Rate Studies (1)	5,000
Environmental Study	20,958
Public Awareness	2,307
Construction	1,038,182
Administration	114,640
Design/Engineering	249,010
Total	<u>\$1,700,943</u>
 Contact Person	 Bob Griffiths, PE Boise Warm Springs Water Dist. 2440 Old Penitentiary Road Boise, ID 83707 (208) 342-3162
 Engineers of Record	
Transmission Main Replacement:	Nathan H. Little, PE CH2M Hill P. O. Box 8748 Boise, ID 83707 (208) 345-5310
Remaining 60% of Distribution:	R. H. Griffiths, PE 4421 Alpine Street Boise, ID 83705 (208) 345-3216

Table 3.2 presents a summary of the fluid chemistry for the two BWSWD wells.

Table 3.2

BWSWD Geothermal Fluid Chemistry

		Temperature TDS pH		176°F 290 ppm 8.2 mg/L	
BWSWD Well (a)				BWSWD Well (b)	
Constituents	mg/L			Constituents	mg/L
Aluminum (Al)	Trace			Silver (Ag)	<0.002
Nitrogen (N)	0.14			Nitrogen (N)	0.040
Barium (Ba)	<0.20			Barium (Ba)	<0.020
Calcium (Ca)	2.00			Calcium (Ca)	1.000
Chromium (Cr)	Trace			Chromium (Cr)	<0.002
Copper (Cu)	0.08			Copper (Cu)	<0.010
Flourine (F)	14.00			Flourine (F)	18.000
Arsenic (As)	<0.05			Bismuth (Bi)	0.010
Chloride (Ce)	10.00			Cadmium (Cd)	<0.020
Carbonate (CO ₃)	4.00			Cobalt (Co)	<0.020
Bicarbonate (HCO ₃)	70.00			Iron (Fe)	<0.010
Hydrogen Sulfide ³ (H ₂ S)	Trace			Manganese (Mn)	<0.000
Mercury (Hg)	<0.02			Nickel (Ni)	0.020
Sodium (Na)	90.00			Sodium (Na)	100.000
Potassium (K)	1.60			Lead (Pb)	<0.020
Lithium (Li)	0.05			Tin (Sn)	<0.020
Magnesium (Mg)	0.05			Titanium (Ti)	<0.000
Sulfate (SO ₄)	23.00			Vanadium (V)	<0.100
Strontium (Sr)	0.02			Zinc (Zn)	<0.000
Silicon Dioxide (SiO ₂)	160.00			Zirconium (Zr)	<0.100

a. United States Geological Survey.

b. Lawrence Livermore Laboratory, Chemical
Sample taken November 14, 1979.

Production Facilities

The BWSWD system is served by two production wells. Both wells are located in the same structure to the east of the system service area. The current production wells have been in service since the original development of the district in the late 1800's. In fact, the wellhead building was constructed using a portion of the original wooden derricks employed for drilling the wells in the 1890's. This building is on the National Register of Historic Places.

The production pumps currently installed in the wells are capable of producing a peak flow rate of 700 gpm each at a temperature of approximately 176°F. Table 3.3 provides a summary of information on the BWSWD production facilities.

Table 3.3
BWSWD Production Facilities Summary

	<u>West Well</u>	<u>East Well</u>
Flow/Head	800 gpm @ 238	800 gpm @ 238
Setting Depth	220	220
Size Bowls	8"	8"
No. Stages	4	4
Manufacturer	Layne	Layne
Horsepower	60	60
Variable Speed Drive	No	No
Lubrication (Shaft)	Oil	Oil
Well Depth	400 +	400 +
Well Size	16" to 130' 12" open hole below	16" to 150' 12" open hole below
Temperature	176°F	176°F
Static Level	Varies	Varies
Drawdown	Varies	Varies

These wells are located only 30 feet from each other (Figure 3.1) in the same building. Traditionally the West well has been the best producer and is used as the systems primary source.

Each of the two wells is equipped in a similar fashion. As shown in Figure 3.2. The pump discharges into the main production line through a pressure reducing valve. This valve, described in Table 3.4 is set to maintain a main line pressure of 12 psi. In addition to the pressure reducing valve, a pressure relief valve is placed upstream to guard against excessive back pressure on the pump. A resilient wedge type gate valve is located just downstream of the pressure reducing valve. This valve is used for isolation of the wellhead from the balance of the system if service should be necessary.

Figure 3.1 Production wellhouse showing proximity of West well (foreground) and East well (Background).

Figure 3.2 East wellhead showing typical components.

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Table 3.4

BWSWD Wellhead Pressure Reducing/Relief Valves

Manufacturer	ClaVal
Size	8"
Type	Pressure Reducing Valve
Materials	
Body	Cast Iron
Diaphragm	Viton
Shaft Piping	Stainless Steel

The two wells discharge into a 12 inch header which is connected to the 12 inch pre-insulated AC supply line just outside the wellhead building. As shown in Figure 3.2 this piping is all located in a trench below the concrete floor of the building. The trench is covered with grating and is fully accessible from the inside of the building. The main header is located under a wooden deck in front of the building. The piping is also fully accessible.

The control scheme for the production facility is, with the exception of the pressure reducing valves, completely manual. Pumps are started and stopped by hand and the pressure reducing valves are in complete control of system pressure.

Table 3.5

Wellhead Gate Valve Data

Manufacturer	
Size	6"
Type	Resilient Wedge Gate Valve
Materials	
Body	ASTM A126 Cast Iron, Class B
O-Rings	BUNA-N
Stem	Manganese Bronze, ASTM B-584-79
Wedge	Cast Ductile Iron, ASTM A5360-76
	Covered with BUNA-S
Stem Nut	Cast Bronze, ASTM B62-80

Wellhead instrumentation, with the exception of pressure gauges at each pump, consists only of a propeller type flowmeter located in the main discharge line from the facility. This meter is described in Table 3.6.

This meter is connected through a mechanical drive shaft (automobile speedometer cable) to a surface display. This display (Figure 3.4) indicates total flow in thousands of gallons on a counter type output.

Table 3.6

BWSWD Wellhead Flowmeter

Manufacturer	Sparling
Model	K-483
Type	Propeller, Remote Display
Years in Service	Mechanical Drive Shaft Operated 35

Table 3.7

BWSWD Production Pump Materials

Bowls	Cast Iron
Bowl Bearings	Leaded Red Bronze
Bowl Shaft	416 Stainless Steel
Impellers	Enameled Cast Iron
Shaft	Carbon Steel
Shaft Bearings	Bronze

Problems/Solutions/Modifications

Although the system has operated for approximately 100 years, the information available on operations for the first 80 to 90 years is sparse and unreliable. The following sequence presents a summary of the available information on the system production pumping equipment (Griffiths, 1988).

Figure 3.3 Sparling propeller flowmeter installed in main supply line.

Figure 3.4 Totalizing display from Sparling flowmeter.

1913	5-Stage Pump Set In West Well @144 Feet.
1914	5-Stage Pump Set In East Well @144 Feet.
1927	3-AM 7 Stage Pump With Additional 14 Feet Column and Variable Speed (Wound Rotor) Motor Set In East Well
1935	2-KH 8 Stage Pump With Additional 14 Feet Column Set In West Well
1943	New 3-KM 7 Stage Pump Installed In East Well New Leather Links For Motor/Pump Coupling On East Well
1954	New Pump 2-KH 3 Stage Installed In West Well
1982	New Pumps - Both Wells
1987	West Well Pump Fails Due To Cavitation Both Well Pumps Replaced

Little is known of the materials used in the early pumps. Most, according to the available data, were of the oil lubricated shaft design and included "marine bronze" bowl bearings.

From 1927 through 1982, the system included one constant speed motor and one variable speed motor. The variable speed motor was installed on the East well in 1927. The motor is pictured in Figure 3.5.

As shown, the motor was equipped with a hand wheel for adjustment of the brushes. This hand wheel was operated by prison trustees (the BWSWD wells are located just a few hundred yards from the Old Idaho State Penitentiary) who were stationed at the wellhead 24 hours a day. Employees of the Boise Water Corporation (the former operator of the system) had a gauge located in their office which indicated system pressure. Whenever the pressure strayed from the acceptable operating range, a call was placed to the Boise Water Corporation supervisor, who in turn called the prison operator who contacted the trustees and advised which way to adjust the pump speed (Griffiths, 1988).

During most of the 55 years this motor was in service, the variable speed pump was employed as the secondary source for the system. The constant speed pump (West well) was the base load source.

Most of the original pumps used from the early 1900's until 1982 were produced by two manufacturers - Byron Jackson and Fairbanks-Morse.

The difficulties with the variable speed drive motor were primarily related to the brushes and commutator surfaces. In addition, the flexible coupling between the pump and motor (the variable speed drive motor was of a solid shaft design) contained leather pads which required periodic replacement.

In 1982 both pumps were replaced during a major system upgrade which included replacement of the main supply line as well. The pumps installed at this time are summarized in Table 3.8.

Table 3.8
1982 Production Well Pumps - BWSWD
(Little, 1979)

	<u>West Well</u>	<u>East Well</u>
Manufacturer	Layne	Layne
Lubrication	Oil	Oil
Horsepower	60	60
Materials		
Bowls	Cast Iron	Cast Iron
Bowl Bearings	Leaded Red Bronze	Leaded Red Bronze
Bowl Shaft	416 SS	416 SS
Impellers	Enameled Cast Iron	Enameled Cast Iron
Line Shaft	Carbon Steel	Carbon Steel
Shaft Bearings	Bronze	Bronze
Flow/Head	1000 @200	1000 @200
Setting Depth	160	160

In 1987 the West well pump failed. The failure is believed to be the result of cavitation promoted by the drop in reservoir water levels recently experienced in the area. At this time both pumps were replaced with new pumps of the same manufacturer as the previous ones. In addition, the pump setting depth was lowered to 220 feet from the previous 160 feet to accommodate the new reservoir level. One of the pumps installed during the 1982 construction was repaired and retained as a spare.

The pressure reducing valves located at the outlet of both pumps have exhibited diaphragm lives of approximately 2 years. It is believed that these diaphragms are of BUNA-N construction. In an effort to increase the life of these components, the most recent replacement parts have been ordered in Viton material. The cost for a Viton diaphragm for a 10 inch valve is reportedly \$748.00.

Recently, all of the wellhead piping between the pressure reducing valves and the connection to the main AC supply pipe was replaced with new steel piping. The original cast iron, OS&Y, gate valves on the line were replaced with new resilient wedge gate valves as described in Table 3.5.

The wellhead flowmeter has been serviced several since its original installation in 1954 and twice since 1978. On each occasion, the meter was completely rebuilt. The procedures were performed in 1979 and 1986 (Griffiths, 1988).

Figure 3.5 Wound rotor type variable
speed motor installed in
1927.

Distribution

The BWSWD system operates an "open" type of distribution system. Geothermal fluid is delivered directly to the 239 individual residential customers through an insulated supply system. Each customer is then responsible for his own disposal arrangements. There is no collection or disposal side of the system. The distribution network is constructed primarily of asbestos cement main line and pre-insulated steel branch lines.

As in the case of the production facilities, little information is available on the early construction of the system. The original piping was of wrought iron alloy and cast iron with oakum and lead joints as shown in Figure 3.6. This pipe was asphalt coated on the interior and exterior. Branch lines were primarily of uninsulated, galvanized steel construction.

Some portions of the earliest piping were insulated with sawdust in the field. The technique involved placing a redwood box around the piping. The box was then filled with sawdust (Griffiths, 1988). Some of the original redwood materials have been found intact in recent construction work (Figure 3.7).

In 1937 the entire main line was replaced. The new material installed was 10 inch cast iron piping. This material served the system until 1982 when the entire main line was replaced with 10 and 12 inch pre-insulated asbestos cement material.

Since 1982 the district has had an ongoing program of branch line replacement. As of 1988 most of the original uninsulated galvanized branch piping has been replaced.

The 1982 construction included replacement of the system's main line from the production wells down Warm Springs Avenue to Idaho Street at 6th. This installation included a total of 11300 feet of 10 and 12 inch pre-insulated asbestos cement piping as detailed in Table 3.9.

This piping was installed adjacent to the existing 1937 cast iron line. The route is generally southwest from the production wells to Warm Springs Avenue then west along Warm Springs and East Idaho.

Table 3.9
1982 Main Line Replacement Piping Summary
(Little, 1981)

<u>Total Length Installed</u>	
10"	4800
12"	<u>6500</u>
Total	11300
Type	Pre-insulated, Epoxy Lined, Asbestos Cement
Manufacturer	Johns-Manville, Temptite
Materials	
Carrier	Class 150 Asbestos Cement Pressure Pipe
	Epoxy Lined
Insulation	Polyurethane, Nominal Thickness 1", 2#/ft ³
Jacket	Asbestos Cement, Class 1500
Gaskets	EPDM
Fittings	Cast Iron, Cement Lined, Class D Thickness
Manufacturer	Independent Fitting Company

Figure 3.8 shows details of various portions of the installation including the pressure reducing station located between Louisa Street and Hot Springs Drive. This station steps the main line pressure down from approximately 23 to 15 psi at which the line is maintained. The station is required to dissipate the pressure resulting from the elevation difference between the wells and the service area. As shown, the station includes three 8 inch gate valves and an 8 inch pressure reducing valve. All of the components are located in a below grade concrete vault.

The gate valves are of similar construction to the valves and used for isolation in the balance of the system. Table 3.10 presents a summary of information on these valves.

Table 3.10
Distribution System Valves - BWSWD System

Type	Iron Body, Gate Valve, Solid Wedge, Non Rising Stem
Manufacturer	Powell (Figure 1799)
Sizes in Service	3 - 12"
Materials	All Iron, Asbestos Packing
Class	125#

Figure 3.6 Original iron alloy piping showing oakum/lead coupling.

Figure 3.7 A piece of the original wooden material used for containing sawdust insulation around system hot water lines.

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The pressure reducing valve is an 8 inch, 125# model which was specified to have a cast iron body with stainless steel trim (Little, 1981). Clayton was specified as the manufacturer although it is reported that another manufacturer's product was installed (Griffiths, 1988).

Figure 3.8 also indicates the design used for branch connections to the main line. All of the branch lines on the BWSWD are 2 inch or less in size. It is believed that most of the connections were accomplished using the "alternate" approach with a saddle type connection. The original specifications called for a Rockwell No. 813 double stop saddle. These saddles are of all carbon steel and cast iron construction (Little, 1981).

The saddles and all other bare steel components of the system were protected in two ways from corrosion:

- 1) Exterior Coating
- 2) Cathodic Protection

Coating of all bare steel components was called for in the original specifications. The coating was specified to be applied in two coats to a thickness of 12 mil minimum. The product called for was Bitumastic 505 (by Koppers Co.). In addition, all branch connections were to be cathodically protected with a magnesium anode. Table 3.11 provides a summary of the anode specifications.

Table 3.11
BWSWD Branch Connection Anode Specifications
(Little, 1981)

Type		Standard Patented Magnesium Anoded ASTM AZ 634 Type III	
Weight		17#	
<u>Constituents</u>	<u>mg/L</u>	<u>Constituents</u>	<u>mg/L</u>
Aluminum	5.3 - 6.7%	Zinc	2.5 - 3.5%
Manganese	0.150	Silicon	0.300
Cadmium	0.050	Nickel	0.003
Iron	0.003	Other	0.300
Magnesium	Remainder

Figure 3.8 Installation details - 1982 construction.
(Little, 1981)

Figure 3.9 Undercrossing details.
(Little, 1981)

A test station was installed with each anode in order to allow monitoring of the below grade conditions. The test station included a terminal block with leads from the anode, protected piping, and unprotected piping.

Details of the installation and placement of the various cathodic protection components appear in Figure 3.8.

The route of the main pipeline required the crossing of an irrigation canal on Warm Springs Avenue. This crossing was accomplished by boring under the canal as detailed in Figure 3.9. A 30 inch steel casing was installed in which the AC pipe was installed on 4 X 4 wooden blocks. The casing installation was 36 feet long.

The district has had an ongoing program of branch line replacement since 1982. This program consists of replacing the original uninsulated galvanized branch material (Figure 3.10) with new pre-insulated steel piping (Figure 3.11). In most cases branch lines are 2 inch steel and customer lines are 1 inch steel. To date a total of 8200 lf of 2 inch branch lines have been replaced. Table 3.12 presents a summary of branch line replacement data.

Table 3.12
BWSWD Branch Line Replacement Data

Replacement Material	Pre-insulated Steel	
Connections	Threaded	
Carrier	Schedule 40 ASTM A120	
Insulation	Polyurethane 1" Nominal 1" Minimum Thickness, 2#/ft3	
Jacket	PVC	
Manufacturer	Thermacor (Thermafab)	
<u>Quantity Installed</u>		
<u>Year</u>	<u>1"</u>	<u>2"</u>
1982	415'	
1983		
1984	442'	1735'
1985		2677'
1986	296'	2629'
1987		
1988		
Totals

Figure 3.10 Original galvanized branch line material, severely corroded on the exterior.

Figure 3.11 Current branch line material - pre-insulated steel.

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Problems/Solutions/Modifications (Griffiths, 1988)

The above discussions relate primarily to the most recent modifications to the system. These were an effort to decrease the number and frequency of system leaks. Since replacement of the main line and much of the branch piping, the frequency of leaks has been substantially reduced.

The main pressure reducing valve (between Louisa and Hot Springs Drive) has been the source of some problems. These have related to the diaphragm and regulator. Recently, the original regulator on the valve was replaced with a Clayton regulator and performance has improved since. In addition, the diaphragm on this valve has exhibited the same general life expectancy (2 years) as the wellhead pressure reducing valves. To remedy this situation, the current replacement diaphragm has been ordered in Viton material.

Customer Connections

As with the balance of the BWSWD system, customer connections are of relatively simple design. A standard bronze body corporation stop (Mueller H-9979) is installed at the branch line connection. From this point, pre-insulated steel pipe (1 inch standard size), with threaded connections is used to deliver the geothermal fluid to the customers valve box. At the valve box a 1 inch bronze body ball valve (Grinnel) with teflon seat is used for a curb stop.

Connection to the customer's line is accomplished using an insulating compression type coupling (Figure 3.12). The systems branch line is protected by a magnesium anode installed as per Figure 3.8. In addition, all bare surfaces are coated with primer and wrapped with plastic tape, and then coated with "rain stop" asphalt roofing cement and then wrapped with 4 mil polyethylene.

Problems/Solution/Modifications

The early construction of the system employed largely uninsulated, unprotected galvanized piping of various sizes for customer branch lines. This piping suffered extensive exterior corrosion resulting in many leaks. The interior of the pipe, however, was reasonably well preserved in comparison. Some samples as old as 50 years still have the galvanized coating on the interior clearly visible whereas the exterior of the pipe is severely pitted (see Figure 3.10).

Most of this piping has been replaced with new pre-insulated (Thermacor) steel pipe. This piping employs polyurethane insulation and a PVC jacket. Curb stops in the older construction

were of a gate valve design with a round hand wheel. These valves presented two problems:

- 1) The round hand wheel frequently broke off requiring excavation for service.
- 2) The valves did not provide 100% shut off after several years of service.

The current construction employs a bronze body ball valve in place of these gate valves.

There has been some problems with the shearing off of corporation stops at the branch line. These have all occurred at the valve body where the threaded portion is connected (Figure 3.13). These failures are believed to be the result of insufficient allowance for expansion in the branch line construction.

It is reported that the material used for coating these bare metal surfaces becomes "baked and brittle" after a few years in service. Unless disturbed however, it remains in place on the piping and provides the required protection.

Metering

The BWSWD system was established prior to the time in which water meters were commonly available. As a result, the system does not employ meters in the conventional sense. Instead, each customer is equipped with an orifice plate located on the waste line from the house. The distribution system pressure is maintained at a constant 15 psi. Since most customers discharge to the surface (atmospheric pressure) this pressure difference results in a fairly predictable flow rate. Billing is based upon a fixed annual cost related to the size of the orifice used. The single most common size orifice is 3/16 inch, though sizes from 1/8 to 9/32 inch are available. Figure 3.14 details the typical installation of the orifice plate.

Water meters are used for a very small number of customers (approximately 14). Meters are only used for those customers which must employ a pump in their system on the geothermal side. The use of a pump would alter the pressure drop across the orifice plate, thereby rendering it unable to accurately meter the flow. For residential customer metering, Kent hot water meters are currently employed. Table 3.13 presents the details of these meters.

The State office building complex is also metered. At this location an "MVR" Hersey hot water meter is used. This is similar to the meters used in Elko (Elko Heat Company) and New Mexico (NMSU). Details of this meter appear in Table 3.13.

Figure 3.12 Insulating coupling used to connect system branch to customer's line.

Figure 3.13 Sheared off corporation stop.

Figure 3.14 Components included in the typical orifice installation.

Table 3.13

BWSWD Hot Water Meter Details

Residential Meters

Manufacturer	Kent (11), Neptune (2)
Type	Single Jet, Inferential
Sizes	3/4"
No. In Service	13
Materials	Not Available

Commercial Customer Metering

Manufacturer	Hersey (Model MHR)
Type	Turbine
Sizes	3"
No. In Service	1
Materials	
Case	Bronze
Rotor	Polypropylene
Shaft Bolts	Stainless Steel
Rotor Bearings	Graphite
"O" Rings	Silicone Rubber

Problems/Solutions/Modifications

The simplicity of the orifice plate, used for most customers, has resulted in very few operational problems over the years. The only difficulty experienced has been the occasional customer who removes or enlarges his orifice plate to obtain more flow from the system.

The use of water metering for residential customers has been somewhat less successful. The products of two manufacturers (Corad and Neptune) were used prior to the present meter. These meters were standard, positive displacement cold water units which predictably had very short lifetimes in the geothermal fluid. The meters currently in use have been in service for a maximum of approximately two years. As a result, no long time performance information is available.

The single large turbine type meter in use has performed well in the 10 years it has been in service. It was returned to the factory twice for service.

Disposal

Disposal for the BSWD system is entirely to the surface. Each customer is responsible for his own disposal arrangements and a variety of methods is employed. It is reported that approximately 40% is discharged to a drainage ditch and 20% to the sanitary sewer. Of the remainder, most discharge to the storm sewer. A few of the customers have constructed infiltration wells for disposal though this is rare.

Problems/Solutions/Modifications

This disposal system has been a trouble free operation for nearly 100 years. As with most other systems in Boise, the BSWD is coming under increasing regulation with regard to disposal. This is particularly true for those customers who discharge to the sanitary sewer. The City of Boise is considering imposing a charge on these customers for use of the sewer.

Figure 3.15
Currently used
meter for
residential
customers.

Figure 3.16
Previously used
Neptune meter.

Figure 3.17
Previously used
Corad meter.

on 12/1/10

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100-111-100

100-111-100

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2. Little, N.D., Contract Documents - BWSWD - Wells 1 and 2, CH2M Hill, Boise, ID, 1979.
3. Little, N.D., Contract Documents - BWSWD - Mainline Replacement CH2M Hill, Boise, ID, 1981.

SAN BERNARDINO SYSTEM

Introduction

The San Bernardino Geothermal District Heating system was developed from a project which was originally much smaller in scope.

In 1982 an existing well (Meeks and Daley #66) which produced 133°F fluid was obtained by the San Bernardino City Water Department. In early 1983 a pipeline was installed to deliver fluid from this well to the Water Treatment Plant where it was to be used for heating of a sewage digester. This system was dedicated April 5, 1983.

As a result of its successful operation, a study was commissioned to expand the use of the local geothermal fluid to a district heating system. The results of this study were positive. Funding was obtained from the California Energy Commission and additional system construction began in 1984. A second production well was also constructed in 1984. Currently the system serves a total of 20 customers representing 1,300,000 ft² of building area. Several extensions of the distribution system have been completed since the original construction.

Table 4.1 presents a summary of data on The San Bernardino Geothermal District Heating System.

Table 4.2 presents the geothermal resource fluid chemistry for the system.

Table 4.1
Information Summary - San Bernardino Geothermal System

Years of Operation	5
Number of Customers/ft	20 - 1,300,000 ft ²
Total Length of Piping (ft)	33,600
Resource Temperature (F)	133 to 138
Delivery Temperature/ Δt	133 to 138F (varies)
Peak Flow Capacity	3,700 gpm
Disposal Method	Surface
Customer Heat Exchangers	Yes
Number of Prod/Inj Wells	2/0
Rate Structure	75% of Natural Gas Rate
Ownership Public/Private	Public
Financing	N/A
Contact Person	Kevin Fisher Geothermal Resource Engineer Municipal Water Department 300 North "D" Street San Bernardino, CA 92401
Engineer of Record:	N/A
Contractor:	Municipal Water Department 300 North "D" Street San Bernardino, CA 92401 (714)384-5139

Table 4.2
Geothermal Fluid Chemistry - San Bernardino System (SBMWD, undated)

	TDS pH	290 ppm 8.6 mg/L	
<u>Constituent</u>	<u>mg/L</u>	<u>Constituent</u>	<u>mg/L</u>
Sodium (Na)	116.0	Boron (B)	2.20
Calcium (Ca)	9.0	Iron (Fe)	0.02
Magnesium (Mg)	1.0	Chloride (Cl)	82.00
Carbonate (CO ₃)	12.0	Sulphate	32.00
Bicarbonate (HCO ₃)	88.0	Nitrate	49.00
Total Hardness (as CaCO ₃)	4.4		

Production Facilities

The San Bernardino system originally operated from a single existing production well. At the outset, system requirements were small enough to allow the natural artesian head of this well to serve the load without the use of a production pump. As the system grew, a small 25 horsepower pump was added to this well. Later a second production well was constructed and finally a larger pump was added to the original well.

The system currently employs two production wells - the original Meeks and Daley #66 and the Mill and "D" well. Table 4.3 provides a summary of information on these wells.

Table 4.3

San Bernardino System Production Facilities Data

	<u>Meeks & Daley 66</u>	<u>Mill & "D"</u>
Flow (gpm)/Head (ft)	2,500 @ 160	1,200 @ 150
Setting Depth (ft)	150	150
Size Bowls (in)	16	12
No. of Stages	2	6
Manufacturer	Aurora	Ingersoll-Rand
Horsepower	150	125
Variable Speed Drive	Yes	Yes
Drive Type	VFD	VFD
Manufacturer	Mitsubishi	Toshiba
Lubrication	Oil	Oil
Well Depth (ft)	1100 (Now Filled in to 900)	931
Well Size (in)	18	16
Temperature (°F)	133	137
Static Level	7-14 psi shut-in	7-14 psi shut-in
Drawdown (gpm/ft)	60	45

The Meeks and Daley #66 well was constructed in 1966 by the Meeks and Daley Water Company. The following (SBMWD, undated) describes the construction of the well when it was acquired at the subsequent re-work.

"Meeks and Daley #66 was drilled by cable tool in 1966 to a total depth of 975 feet according to the drilling log. The proposed use of the well was for domestic and irrigation water. The well was backfilled from 1100 feet to 975 feet apparently in an effort to seal off strata containing elevated boron. The well was cased throughout the depth of the hole with 20 inch diameter

6 gauge casing, perforated at all hot and cold water bearing strata, using a Mills Mechanical Knife with a 2 1/2 by 3/8 inch blade.

In approximately 1977, the well began to flow artesian at a rate of 1,350 gpm, with a water temperature of 135 to 140F. Geothermal Surveys, Inc. attempted a thermal log in May, 1980. The results are shown in Table 4.4. The well could only be logged to a depth of 160 feet due to the artesian flow and the large diameter pump equipment set inside the casing."

Table 4.4

Temperature and Flow Test
Meeks and Daley #66
January 8, 1983
(SBMWD, undated)

Flow Rate GPM	Minutes at Flow Rates					
	5	10	15	20	25	30
500 Temperature (F)	127.00	128.00	128.00	128.00	129.00	131.00
Pressure (psi)	12.00	11.75	11.75	11.75	11.75	11.75
pH	8.25	8.25	8.30	8.22	8.25	8.30
1,000 Temperature (F)	130.60	129.90	129.80	129.90	130.00	130.00
Pressure (psi)	40.50	10.00	10.00	10.00	10.00	10.00
pH	8.25	8.25	8.25	8.35	8.62	8.62
1,500 Temperature (F)	130.70	131.00	131.00	131.00	131.00	131.00
Pressure (psi)	9.00	8.50	8.50	8.50	8.50	8.50
pH	8.30		8.62			8.62
2,000 Temperature (F)	131.20	131.10	131.00	131.00	131.00	131.00
Pressure (psi)	7.00	6.75	6.75	6.75	6.75	6.75
pH	8.82		8.82			8.82
2,500 Temperature (F)	131.00	131.00	131.00	130.90	130.90	130.90
Pressure (psi)	4.50	4.50	4.50	4.50	4.50	4.50
pH	8.88	8.88	8.86	8.86	8.80	8.86
<hr/>						
Static Start: Pressure:	12.5	psi	Start Temperature		110.0	F
Time to Sand Surge:	2.5	Hours	Start Time		10:30	A.M.
Well Seal Bag Pressure:	24.0	psi	Finish Time:		2:45	P.M.

SAN BERNARDINO CITY MUNICIPAL WATER DEPARTMENT

Figure 4.1

TYPICAL MUD ROTARY WELL DESIGN

N.T.S.

"Upon entering escrow for the purchase of Meeks and Daley #66, authorization was granted by Meeks and Daley Water Company for the Water Department to remove the existing pumping equipment, bail the well, and set equipment to conduct carbon dioxide vapor pressure testing.

The last week of December, 1982, the existing equipment was pulled from the well and the well was then bailed to a total depth of 945 feet from 857 feet. The carbon dioxide release test was then conducted on the well by setting a 35 gpm, 100 psi submersible pump 60 feet into the well which was flowing in excess of 1,000 gpm. The preliminary findings indicate a carbon dioxide vapor pressure of 8 to 9 psi.

In January, 1983, flow tests were conducted on the well. In order to conduct the flow and temperature tests, a valved 12-inch diameter pipe was inserted in the 20-inch diameter well casing and a well seal kit was inflated to control the artesian flows. Results of the first flow and temperature tests are displayed on Table 4.4. The temperature remained at 55°C at flows varying from 500 gpm up to 2,500 gpm."

In the summer of 1983 a 25 horsepower Peabody Floway 3 stage, 10 inch pump with a 25 horsepower motor and variable frequency drive, was installed in the Meeks and Daley well. This pump served the initial system customers until a second well (Mill and "D") was drilled in July of 1984. In July of 1985 the 25 horsepower pump was removed and replaced with a 150 horsepower unit as described in Table 4.5. This pump is still in service. The Mill and "D" Street well was completed in August of 1984. The completion is similar to Figure 4.1.

The Mill and "D" Street well contains a 125 horsepower Ingersoll-Rand turbine pump as described in Table 4.5. This pump was installed in January of 1985 and is still in service.

Figures 4.2 and 4.3 show the details of the wellhead for both production wells. The installations are very similar. Due to the artesian flow capabilities of the wells, both contain two production outlets, one for pumped flow and one for artesian flow. This is more apparent in Figure 4.2 showing the #66 well since the artesian flow line on the Mill and "D" well is below grade.

Figure 4.2

Meeks and Daley #66 Well.

Figure 4.3

Mill and "D" Street
Wellhead.

Block Diagram SAN BERNARDINO WATER DEPT.

MILL & D
INVERTER

MAIN PANEL

Well #66

MANUAL START/STOP
From Main PANEL

Whitman - Electric

Table 4.5

San Bernardino System - Production Pump Data

<u>Component</u>	<u>Material</u>
Pump Shaft	ASTM A108-61 GR 1045 (Carbon Steel)
Column	ASTM A120-65 (Carbon Steel)
Shaft Enclosure	Schedule 80 (Carbon Steel)
Shaft Enclosure Stabilizers	Neoprene
Shaft Bearings	SAE 660 Bronze
Pump Shaft	ASTM A276-63 410 or 416
Pump Shaft Bearings	Bronze
Bowls	Cast Iron
Impellers	Bronze or enameled Cast Iron
Collets	416 SS
Suction Cone Strainer	316 SS

Each well is equipped with check valves in both lines so that either line can be used to supply the system. At this time, the maintenance of adequate system pressure requires that at least one production well pump be in operation at all times. Artesian head does not supply sufficient pressure. An air/vac valve is located just upstream of the pump check valves in each case in order to allow for drain back and purging of the pump column. Relief ports are located on the casing to permit servicing of the wells.

Control of the production wells is fully automated and controlled by a programmable controller located at the Mill and "D" Street well. Figure 4.4 presents a block diagram of the original system. Communication between the wells by the controller is via a single pair of wires buried along the pipe line route.

The controller primarily functions to bring on the Meeks and Daley 66 well if the Mill and "D" well is unable to maintain sufficient pressure in the distribution system.

The original control system was manufactured by Electromatic and included, as shown in Figure 4.4, the main controller, one 4 channel transmitter, two 2 channel transmitters, three 2 channel receivers and a tachometer relay. Figure 4.5 shows the controls which were located at the Meeks and Daley well. This system was replaced in 1988.

In addition to the programmable controller for starting and stopping the wells, each is equipped with an electronic variable speed drive. Table 4.6 provides details of the two units.

Figure 4.5

Meeks and Daley Wellhead Controls
for Interfacing with Programmable Controller.

Figure 4.6

Mill and "D" Well Pressure Surge Equipment
Surge Tank (Left) - Air Tank (Right).

Figure 4.7

Air Compressor Servicing
Pressure Surge Equipment.

Table 4.6
Variable Speed Drive Units - San Bernardino System

	Meeks & Daley 66	Mill & "D"
Manufacturer	Mitsubishi	Toshiba
Model	--	433-100
HP Rating	150	150
Type	Pulse Width Modulated	Pulse Width Modulated
Input Signal	4-20 ma (Pressure)	4-20 ma (Pressure)
Voltage Input	460, 3 Phase	460, 3 Phase
Over Speed (60HZ)	No	Yes

Wellhead instrumentation is relatively sparse. Temperature measurements are regularly taken using a portable instrument. Both wellheads have permanently installed temperature instrumentation.

Pressure is monitored only at the Mill and "D" Street Well. This instrumentation (a Babcock 12 inch, 24 hour circular recorder) was added to monitor early pressure surge problems (see below) and is not currently in operation.

Water flow rate is the only parameter monitored continuously at both wells. In each case the same instrumentation is employed. The flow meter and auxiliary components are described in Table 4.7.

Table 4.7
Wellhead Flow Meters - San Bernardino System

Manufacturer	Signet Scientific
Flowmeter Model	MK-315
Type	Paddle Wheel, Insertion Type
Materials-	
Housing	Polypropylene
"O" Ring	Viton
Shaft	Titanium
Signal Conditioner	4-20 ma Output
Display	ACCUMU-Flow
Output	Instantaneous Flow - Analog
Totalized Flow	Pulse Counter, 7 Digit
Mounting	Remote (in VFD Cabinet)

Well pump speed is controlled by Omega digital set-point controllers. These controllers are used to set the desired system pressure at each wellhead.

Problems/Solutions/Modifications

The production facilities for the system have been largely problem free. Although the system has been in operation since 1982, growth has resulted in the necessity of replacing production equipment several times. As a result, the oldest pump has been in operation only 3 years.

The relatively benign fluid chemistry in conjunction with the use of variable speed drives and oil lubricated pumps also contributes to reliable system operation.

In late 1984, when the Mill and "D" well was first brought on line, the system was experiencing pressure surges on startup of the pump. Initially this problem was addressed through the use of an air cushion tank. Photographs of the air tank, surge tank and compressor appear in Figure 4.6 and 4.7. This system maintained a cushion of air pressure on the system at all times. On pump start, the air cushion absorbed the pressure surge. This system has now been disconnected and pressure surge problems are addressed through pump speed control via the variable frequency drives.

The original Electromatic programmable controller was replaced in 1988 with a unit manufactured by Toshiba. This controller is used to start and stop the two production pumps in response to system pressure and outside air temperature.

In 1988, the temperature of the Meeks and Daley well began to decline. The pumping equipment was removed and the well temperature logged and photographed. It was discovered that the upper 500 feet of casing had corroded to the extent that cold water infiltration was occurring. The well was lined with 18" x 1/4" casing and sealed using 8 sack of cement with 1 sack bentonite.

Distribution

The distribution system for San Bernardino is illustrated in Figure 4.8. The system was originally commissioned in April of 1983 and new piping has continuously been added since. At this writing, a new expansion has recently been constructed at the south end of the service area (Hospitality Lane).

Most of the system is constructed of direct buried asbestos cement piping with pre-insulated material for the supply line and uninsulated material for the disposal line (Figure 4.9). Some PVC is used for disposal lines and a small amount of steel piping is employed at bridge crossings. Table 4.8 provides a summary of piping information for the San Bernardino System.

Figure 4.8

Figure 4.9

Typical Burial Detail:

Figure 4.10
Typical Bridge
Crossing.

Figure 4.11
Close Up of Supports
on Typical Bridge
Crossing.

Figure 4.12
Typical Bridge
Crossing.

The current distribution system includes a number of bridge crossings. Most of these involve a design similar to that illustrated in Figures 4.10, 4.11 and 4.12. Steel piping is used for the crossings. This piping is schedule 40 carbon steel with grooved end connections. Flex type connections are used to accommodate some expansion and for increased flexibility to allow for bridge vibration. The steel piping is field insulated with fiber glass and covered with aluminum jacket material. As shown, the fabricated wide flange supports are welded directly to the bridge structure.

Table 4.8

Piping Summary - San Bernardino City Geothermal System

Supply Piping

Manufacturer	Thermal Pipe Systems (Johns-Manville)
Materials	Epoxy Lined, Class 150, Asbestos
Carrier	Cement, EPDM Gaskets
Insulation	Polyurethane, Nominal 1", 2#/Ft ³
Casing	Asbestos Cement, Class 1500, ASTM C-428
Fittings	Cast Iron (Cement Lined or Coal Tar, Epoxy Lined)
Manufacturer	Dayton

Disposal Piping

AC	Class 150, Asbestos Cement, Epoxy Lined
Fittings	As Above
Manufacturer	Certainfeed
PVC	1120, SDR 21, 200 psi, ASTM B2241
Fittings	Schedule 80, Solvent Welded

PIPING	SUPPLY			DISPOSAL		
	AC	DI	STEEL	PVC	AC	DI
14"	5000	--	--	1500	2000	1000
12"	9000	2000	1000	--	--	--
10"	2000	--	--	--	--	--
8"	3500	--	--	1500	--	--
6"	2000	--	--	2000	--	--
4"	--	--	--	800	--	--
3"	1500	--	--	--	--	--

In addition, approximately 800 lf of fiber glass pipe was used in the Santa Ana River crossing.

Figure 4.14 Typical Air/Vac Valve Installation.

Isolation valves throughout the system are of the gate type. Initially these were of standard, bronze seated, construction. More recent construction has employed resilient seated valves. Table 4.9 presents a summary of system gate valves. A detail of typical valve installation appears in Figure 4.13.

Table 4.9

System Gate Valve Summary - San Bernardino

Type	Gate, Iron Rising Stem
Manufacturer	Clow, Dresser
Materials	
Coating (External)	Coal Tar Epoxy
Packing	Double Recessed "O" Ring
Thrust Washers	85-5-5-5 Bronze
Stem Nut	Bronze
Wedge	Cast Iron or Bronze
Body	Cast Iron
Gasket	EPDM

Air vent valves are connected to the system as detailed in Figure 4.14. These are connected to the main line using pre-tapped, asbestos cement couplings. The bushing in the coupling is of bronze construction.

All fittings 3 inches and larger are of cast iron, cement lined construction. All cast iron fittings are coated on the exterior with coal tar epoxy.

Pipeline repairs are accomplished using two types of fittings depending upon the type of failure. For breaks in straight piping, a Dresser flexible coupling is used. For coupling failures, a band style repair clamp (R. R. Baker Company) is used.

Problems/Solutions/Modifications

Most of the distribution system in San Bernardino has been constructed of asbestos cement material. Due to health concerns regarding the asbestos content, this piping is no longer available to the district. As a result, the Hospitality Lane extension is being constructed with pre-insulated ductile iron piping.

This piping is being manufactured by the Water District. Standard ductile iron (Tyton joint) is purchased and assembled into a pre-insulated product using polyurethane insulation and PVC jacket materials. The cost of this piping is less than half that of pre-insulated fiber glass purchased from an outside source. In comparison to the previously purchased AC pipe, the cost is approximately the same.

Figure 4.15

Typical Customer Connection.

Some failures have occurred in the AC piping in the system. All of these have been related to either improper compaction or bedding.

Failures have also been experienced in the PVC piping used in small portions of the disposal network. These failures have typically involved fittings. Due to expansion of the pipe, solvent welded joints at these fittings have been "pushed in" resulting in leaks.

One section of steel piping failed at a bridge crossing. This failure is believed to be related to exposure of the exterior of the pipe to a sand slurry backfill at the bridge abutment.

Customer Connections

A typical customer connection for the San Bernardino system is illustrated in Figure 4.15. Each generally contains a Btu meter, pressure reducing valve, pressure sustaining valve, 4 shut off valves and 2 pressure gauges.

Most of the equipment is installed in below grade, prefabricated concrete vaults at the edge of the customers property. Each connection includes a pressure reducing valve to step distribution system pressure (~70 psi) down to a lower value for building operation. Most of the pressure reducing valves are set for approximately 50 psi. A pressure gauge is located just downstream of the pressure reducing valve to monitor building inlet pressure. The last item in the vault is a butterfly valve for shut off duty.

On the effluent line, a butterfly valve is located at the entrance to the valve box. This is followed by a short length of piping (usually carbon steel, flanged) just upstream of the flow sensor for the Btu meter. A pressure sustaining valve is located just downstream of the flow sensor. The function of this valve is to maintain a minimum pressure in the customers building heat exchanger to avoid evolution of CO₂ and subsequent scaling problems. Pressure sustaining valves are typically set for 28 psi, thereby allowing for a 22 psi pressure drop through the customers heat exchangers, piping and controls.

Table 4.10 presents a summary of the manufacturer and materials included.

When possible connections to the main distribution system are made during line installation with cast iron tee fittings with flanged branch connections (Figure 4.16). In cases of new customers added to existing lines, service saddles are employed. Two types of saddles are in use.

Table 4.10

Customer Connection Components Data - San Bernardino

Butterfly Valves**Manufacturer**

Crane, Keystone

Materials

Shaft

316 Stainless

Disc

Bronze or Stainless

Seat

EPDM

Pressure Sustaining, Reducing Valves**Manufacturer**Watts, Claval, Ames,
Imball (No longer Used)**Materials**

Body

Cast Iron

Diaphragm

EPDM

Seat, Spring, Stem

316 SS

Btu MeterSee Metering Section

In areas where the soil is known to be "hot" (aggressive), an epoxy coated cast iron saddle is used (Figure 4.17). The saddle is attached to the main line using stainless steel straps and bolts.

In areas where the soil is relatively non aggressive, a fabricated steel (epoxy coated) saddle with galvanized bolts are used (Figure 4.18). These saddles employ a flanged connection. The cast iron/stainless saddles use a threaded connection.

Problems/Solutions/Modifications

The only problem related to the customer connections has been with the pressure reducing and sustaining valves. Difficulties were experienced with the originally installed equipment. Since a change in manufacturers was initiated, no further problems have developed.

Metering

The San Bernardino System employs Btu meters for billing all customers. At present two types of meters from the same manufacturer are used.

For industrial type loads with a relatively constant flow rate, a Btu meter with a standard turbine type flow sensor, mounted with

Figure 4.16

Cast Iron Tees Used
For Original
Construction Branch
Connections.

Figure 4.17

Cast Iron Epoxy
Coated Service
Saddles for "Hot"
Soil Areas.

Figure 4.18

Epoxy Coated
Fabricated Steel
Service Saddles.

the axis of the turbine perpendicular to the flow is installed. The meters are less costly and for applications with little turn down they provide accurate flow measurement.

For space heating loads and similar applications, a turbine meter with the axis parallel to the flow is installed. This type of meter is more resistant to the characteristic "roll off" experienced by standard water meters at very low flow rates (relative to the rated flow).

Table 4.11 presents a summary of San Bernardino system Btu meter data.

Table 4.11

San Bernardino System Btu Meter Data

Manufacturer	Sanceboz
No of Meters in Service	30
Sizes	2 - 6"
Standard Model	Style MTR (250°F Max.)
Type	Axial Flow Turbine (Axis to Flow Perpendicular)
Materials	"High Quality" Plastic, Stainless Steel
High Turn Down Model	Style WP (300°F Max.)
Type	Axial Flow Turbine (Axis Parallel to Flow)
Materials	"High Quality" Plastic, Stainless Steel
Display	Sanceboz Model 323
Power Source	Total Btu/Total Gallons
Mounting	Battery
	Remote (Typically Basement or Vault Wall)
Temperature Probes	Platinum RTD, 4 Wire

Depending upon the size of the customers and the installation technique, the meters may be installed in an underground vault or in the customers mechanical room. In cases which the meter is installed in the vault, the electronic integration unit is encased in a plastic box for additional protection from moisture damage.

Problems/Solutions/Modifications

The system operators have had good success with the present Btu metering system. Aside from a normal failure rate and occasional recalibration, the only problems encountered have been the result

of moisture. Moisture build up in the underground vaults has promoted corrosion induced failure of the electronic integrator units in some cases. As a result, present practice is to avoid locating the units in the underground vaults.

The Water Department has acquired a meter (electronic integrator and RTD) testing unit from the manufacturer. This has significantly enhanced the in house diagnostic ability with regard to meters.

Electronic integrator batteries for the Btu meters have not lasted as long as suggested by the manufacturer. As in other systems, the "5 year" batteries have demonstrated a lifetime more in the range of two to three years.

Meters from two other manufacturers were used in the early development of the system. These units produced erratic data and are replaced as they failed with the Sonceboz units.

Disposal

The San Bernardino System uses surface disposal for spent geothermal fluids. All waste flow is directed to storm sewers and drainage canals which eventually connect to the Santa Ana River south of the city.

Fluid exits the system at a total of 6 points. Some of these points are located along the collection system and some at individual users. At each point, water flow meters are installed to monitor the total waste flow. In most cases, these meters are the same as those described in Table 4.11. In addition, some meters manufactured by Micrometer Corporation are employed. These units appear in Figure 4.19.

Problems/Solutions/Modifications

None

Figure 4.19

Micrometer Disposal Flow Meters.

San Bernardino References

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SUSANVILLE DOE DISTRICT HEATING SYSTEM

Introduction

The DOE system was officially dedicated on December 5, 1982 (Templeton, 1985). This system was designed to serve, at least initially, a group of publicly owned buildings located in the downtown area of the city. Figure 5.1 presents a layout of the system. To date, the customer base remains primarily municipal buildings, though a few commercial customers have been added.

The system operates from a single production well which delivers approximately 170°F fluid through an asbestos cement distribution system. Currently, disposal consists of both surface and injection. The system has been plagued by difficulties with disposal. An attempt to use an existing well was only partially successful. As a result, in order to achieve full operation, it was necessary to direct a portion of the waste flow to surface disposal. A recent attempt at drilling an injection well was again unsuccessful. The city is currently in the process of developing a third injection well.

The other major problem experienced with the system relates to the production pump. Two failures of the original water lubricated bearings were experienced before the system was changed over to an oil lubricated system.

Table 5.1 presents a summary of key information on the Susanville DOE system.

Table 5.1

Key Data - Susanville DOE District Heating System (Templeton, 1983; Templeton, 1985)

Start up date	Dec. 5, 1982
Years of operation	5
Number of customers, ft ²	10/300,000
Resource temperature	174°F
Delivery temperature, Δt	170°F/35°FΔt
Peak flow capability	700 gpm
Disposal method	Injection/surface
Customer heat exchangers	Yes
Number of production/injection wells	1/1
Rate structure	2/3 price of fuel oil
Ownership - public/private	Public
Original financing	
Bureau of Rec. - resource evaluation	\$1,300,000
U.S. Dept. of Energy - construction	2,039,499
California Energy Commission - line extension	40,000

	disposal study	59,000
	line extension	143,000
	line extension	14,000
City of Susanville - line extension		75,000
County of Lassen - line extension		62,000
	Total	\$3,732,499

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Engineer of Record:

Almont Koepf, P.E.
Koepf & Lange
Lafayette, CA

Construction:

Valley Engineers

In an effort to improve both reliability and flexibility of the system, a major modification to the distribution system was completed in 1984. This project, the "CEC pipeline", served to connect the DOE and HUD systems. In addition, the supply line (DOE system) was extended to serve two new customers and the disposal main was enlarged to permit flow to the new surface disposal site. The CEC line is shown on Figure 5.1.

Table 5.2 presents a summary of the Susanville resource chemistry.

Table 5.2

Susanville Resource Fluid Chemistry
(U.S. Department of Interior, 1982)

<u>Key Species</u>	<u>mg/l</u>	<u>Key Species</u>	<u>mg/l</u>
pH	8.1	Silicon, Si	---
TDS	810.0	Sodium, Na	205.0
Chloride, Cl	120.0	Calcium, Ca	32.0
Sulfate, SO ₄	294.0	Nitrate, NO ₃	---
Bicarbonate, HCO ₃	37.0	Potassium, K	6.0
Carbonate, CO ₃	1.0	Fluorine, F	---
Hydrogen Sulfide, H ₂ S	0.5	Iron, Fe	---
Ammonium ion, NH ₄	0.4	Boron, B	2.5
Oxygen, O ₂	---

Figure 5.1 Layout of System

Production

The DOE system is supplied from a single production well designated Susan-1. This well, completed in 1981, has served the system from initial start up, to date.

The following summary from an assessment of the geothermal resource underlying the City of Susanville and the disposal system for the geothermal waste water by Subir Sanyal (Sanyal, 1984) describes the drilling and completion of this well.

"Susan-1, a hot water production well, was drilled late in 1980 for the City of Susanville, California, as part of its general space heating project. This report presents a history of drilling, logging, completion and pump testing of this well. Susan-1 was drilled to 930 feet using local river water with a 17 1/2 inch bit from 50-540 feet, and a 12 1/2 inch bit from 540-927 feet. A 12 3/4 inch solid casing was set from surface to 350 feet, a slotted casing from 358-538 feet, and an 8 5/8 inch slotted casing from 520-925 feet.

Based on interpretations of drilling logs, formation logs, production logs and pump test data, the following stratigraphic sequence was identified in this well:

alluvial section	-	0-75 feet
lake beds(?)	-	75-280 feet
tuffs(?)	-	280-700 feet
lake beds(?)	-	700-750 feet
basaltic andesite	-	750-815 feet
lake beds(?)	-	815-895 feet
basalt	-	895-915 feet
lake beds(?)	-	915-930 feet

Drilling conditions were more severe than anticipated, resulting in numerous partial cave-ins of the uncased hole. Future drilling will require a modified casing and completion program.

Permeable zones in the interval 350-460 feet constitute the aquifer, within the probably tuff interval. Permeable zones appear to exist below 825 feet from mud return temperatures; this could not be confirmed because of the inability to run logs below this depth.

The transmissivity value from the pump test is on the order of 1.5×10^6 md feet/cp and agrees with that from the wells in the southern part of the city. The storativity value from the pump test is on the order of 3×10^{-5} ft/psi and is about one-tenth of that from the wells in the southern part of the city. Despite this, deliverability is comparable to that

of other thermal wells in the area, at 10.5-12.6 gpm/ft. Maximum flow temperature of 174°F is some 10°F above the temperature anticipated prior to drilling.

The observed high flow rates (up to 650 gpm for short intervals, and sustainable at 350 gpm with just over 30 feet of drawdown), high temperature (flow at 174°F, extrapolated equilibrium of at least 180°F), and high deliverability at least equal to the pre-drilling expectations, categorize Susan-1 as a successful geothermal well."

Figure 5.2 presents a cross section of Susan-1.

The production well pump was, for the first few years of operation, the cause of many problems. Modifications made to the production well pump and controls in 1985 were very successful (see discussion below) and no further difficulties have been experienced.

Table 5.3 provides a summary of original and current production well and pump information.

Table 5.3
Production Facilities Data Summary

	Original Design	Present Design
Flow/head (gpm/ft)	700 @ 290?	800 @ 290
Setting depth (ft)	153	153
Size bowls (in.)	10	10
Number of stages	9	9
Manufacturer	Peerless	Ingersol Rand
Horsepower (hp)	60	75
Variable speed drive	no	yes
Drive type	-	variable frequency
Manufacturer	-	Robicon
Lubrication (shaft)	water	oil
Well depth (ft)	925	925
Well size (in.)	12 3/4, 8 5/8	12 3/4, 8 5/8
Temperature (°F)	174	174
Static water level (ft)	201	201
Drawdown (ft)	60 @ 700	60 @ 700

The original production well pump was a lineshaft, water lubricated model. The water lubrication system was not the usual open lineshaft production fluid lubricated arrangement. This system employed an enclosed lineshaft with a pressurized, external ("clean water") water source (Templeton, 1988). This lubricating flow was admitted to the bearing tube through either of two paths, automatic or manual, as shown in Figure 5.3. Regardless of the control arrangement (automatic or manual), it is critical with this type of

Figure 5.2 Cross-section Susan-1 Production Well (Sanya1, 1984)

WATER FLUSH SYSTEM FOR BEARINGS
OF PUMP NO. 240007

Figure 5.3 Original Pump Bearing Water Flush Control System

system that lubrication flow be established at least 1½ minutes prior to pump start.

Table 5.4 presents a summary of the original production well pump materials of construction.

Table 5.4

Original Susanville DOE System Production Pump Materials

<u>Item</u>	<u>Material</u>
Bowls	Class 30 Cast Iron
Impellers	Class 30 Cast Iron
Bowl bearings	SAE 64 Bronze
Bowl lateral seal ring	Class 30 Cast Iron
Column pipe	Steel
Enclosing tube	Extra Heavy Wall Steel
Lineshaft	C1045 Steel
Lineshaft couplings	Steel
Pump bowl shaft	416 Stainless Steel
Top shaft	416 Stainless Steel
Tube nut assembly	Steel

The remainder of the production facilities consisted primarily of a 10,000 gallon steel storage tank and a 40 hp booster pump. The piping design of this system is shown in Figure 5.4, and an equipment key Table 5.5. The only major departure from this design was that PTR-1, the low load booster pump, was not installed (Templeton, 1988).

The basic control scheme operated as follows.

The production well pump was operated in an on/off sequence in response to a mechanical level control located in the 10,000 gallon storage tank. Valve CV1 is a pressure reducing/check valve, which is operated to maintain a constant downstream pressure (between the valve and the tank). Valve CV2 is an automatic vent valve. It opens on both pump shutdown and start up. Pump PTR-2 operated continuously to supply geothermal fluid to the distribution system.

Variable speed drives for both the booster pump and well pump were specified as alternatives to the basic system. Evidently, funding was not sufficient to cover these items and they were not installed.

Seven day circular recorders were included for system flow rate and temperature.

Table 5.5

Equipment Key for Figure 5.4 (Koepf, 1981)

<u>Item</u>	<u>Description</u>
PW1	Pump, well, turbine, existing this contract, connect, 800 gpm at 165' TDH, 1750 rpm, Nema B Motor.
TK1	Tank, surge and storage, insulated vertical cylinder, 10'D x 18'H, 10570 gallons, 8000 gallons working range.
PTR1	Pump, transfer, horizontal centrifugal, base mount, all iron, mechanical seal, 200 gpm at 120' TDH, 180°F, 1750 rpm, Nema B Motor.
CV1	Valve, combined flow control and check diaphragm type with pilot, 150# steel body, alloy steel or stainless steel trim, flanged, claval SG01 180°F water.
CV2	Valve, pump control diaphragm type with pilot solenoid valve (24V 1Ø), 150# steel, trim, flanged. Claval 61P-2A Series, 180°F water, close under pressure.
TH1	Thermometer, bimetallic, 3" dial type, stainless steel, 0-250°F.
TH2	Thermocouple element, threaded insert, 3XX stainless steel, 0-250°F range.
REC1	Recorder, 7 day, circular chart, 3 pens; PW1 flow distribution flow, distribution temperature. Square root extractors for flows.
PTR1	Pump, transfer, horizontal centrifugal base mount, all iron, mechanical seal, 100 gpm at 120' TDH, 180°F, 1750 rpm.
LS1A,B	Level switch, differential for pump control multiple float type, 180°F water, adjustable set. DPST. Magnatrol Model A103 Tandem.
LS2A,B	Level switch, high level and low level for alarm and shutdown. Multiple float type, 180°F water adjustable set. DPST. Magnatrol Model A103 Tandem.
STR1	Strainer, 125# iron body, 40 mesh, stainless steel screen, flanged.
STR2	Strainer, 125# iron body, 40 mesh, stainless steel screen, threaded.
V1	Valve, gate, bronze, 200#, threaded.

V2	Valve, butterfly, iron body, stainless steel trim, Buna-N gasket, 180°F water. Keystone 100.
V3	Valve, plug, all iron, lubricated, 125#, flanged, 180°F water.
V4	Valve, check, swing, 125# iron body, iron or steel trim, flanged, 180°F water.
V5	Valve, gate, 150# steel, steel trim, flanged.
V6	Valve, check, swing, iron body and trim, 125# threaded, 180°F water.
V7	Valve, globe, bronze, 200#, threaded, 180°F water.
EJ4 } EJ5 } EJ6 }	Expansion joint, pump discharge type, 125# rated 0.50" nominal maximum expansion, flanged.
PG2	Pressure gauge, 6" dial, stainless steel wetted part 0-15 psig. Provide blank face for level calibration.
DPSI	Differential pressure switch, range to match flows and orifice plate, 125 psi rated, 180°F water. Static "O"ring 24R3-KXX.
TS1	Temperature switch, 0-200°F, 125 psi rated, 180°F water Fenwall 2XX.
PT1	Pressure transmitter (level) for NFC1. 0-18 feet, 4-20 MA Signal.
PS1	Pressure switch, 0-15 psg range, adjustable, 180°F water, static "O" ring 4NN-KXX.
PT2	Pressure transmitter for VFC1, 0-100 psig, 4-20 MA Signal.

Table 5.6 presents a summary of the materials of construction and manufacturer's of major production facility components.

Table 5.6

Materials of Construction of Selected Product Facility Components

	<u>Materials</u>	<u>Manufacturers</u>
Valves (CV1 and CV2)	body - cast steel ASTM A216-WCB shaft & spring - stainless steel spool, seat retainer, diaphragm plate - ductile iron seat, bushing - bronze	Oil Capital Valve Co Clayton
Piping (mechanical room)	Schedule 40 steel welded	-
Valves (V5)	butterfly type body - cast iron disk, stem, screws - 316 SS "O" ring, packing - Buna-N seat - EPDM	Keystone
Expansion joints	Carrier 316 SS control rings - nickel iron	Flexonics
Storage tank	1/4 in. steel plate interior-epoxy coated (3 coats)	Nevada Tank & Casing
Booster pump (PTR-2)	end suction, centrifugal type shaft, sleeve - stainless steel 416, case impeller - cast iron class 30	Paco

Problems/Solutions

The production facility for this system has been the source of many operational difficulties.

One of the earliest problems concerned the mechanical float switch on the storage tank. This control was located on the top of the tank (18 ft high). During very cold weather, water vapor leaking from the tank vent tended to condense and freeze on the level switch control rod. Ultimately, this would result in loss of control over the tank water level. Depending upon whether a pump off or a pump on condition existed when the level control failed, a situation of loss of system flow or tank overflow would develop. The remedy for this occurrence was generally accomplished by climbing to the top of the tank and defrosting the level control rod (Templeton, 188).

This problem was eliminated in 1986 when use of the storage tank was discontinued.

The 8 in. gate valve on the inlet and outlet of the storage tank suffered the same fate as nearly all iron rising stem valves in other geothermal systems - seizure. Again, elimination of tank use eliminated this problem.

The pressure control, and automatic vent valves (CV1 and CV2) have experienced frequent failure of the copper pilot water lines. These lines, when removed, were discovered to have experienced severe wall thinning. In addition, a black scale was found on the interior surface of the tubing (Templeton, 1988). These symptoms are highly indicative of H_2S attack.

The major problem with the production facility on the DOE system has been the pump itself. The original pump failed during December of 1983 (second winter of operation). The failure required the replacement of the entire lineshaft and bearing assembly (approximately \$7,500).

In 1983, the bolts attaching the non-reversing ratchet to the motor shaft sheared off. This allowed the pump to back spin on shut down. It is unknown how long this situation existed since it was discovered only by chance when someone happened to be in the pump house during an off cycle. Since repair of the ratchet assembly approached the cost of a new motor, the latter choice was selected (Templeton, 1988).

In May of 1984, this pump failed again in a similar fashion to that of December 1983. At that time, a decision was made to convert the pump to an oil lubricated design. The oil lubricated pump was installed in October of 1984 (total cost \$8,900) and has been in service successfully since. The new pump appears in Figure 5.5.

The failure of the two water lubricated pumps may have been related to the design of the control system. Manufacturer's literature requires that the water lubrication flow be established at least 1½ minutes prior to pump start. If the system was installed as shown on the drawings (see Figure 5.5), it is unlikely that this 1½ minute period was allowed for.

In addition to the pump repairs, a major modification to the design of the production facility was implemented in 1986. At that time, the 40 hp booster pump, 10,000 gallon storage tank and valve CV2, were removed from the system, and the production well pump was equipped with a variable speed drive. The production well pump now feeds directly into the pipeline with system pressure controlled by adjusting the pump speed.

The following equipment list describes the items included in the production facility upgrade.

Type 'W' Standard

4 Holes
 4W - 1.00 Dia.
 6W - 1.13 Dia.
 8W - 1.13 Dia.
 10W - 1.25 Dia.

Motor

75 H.P. Vertical Hollowshaft
1800 R.P.M., 3Ø Phase, 60 Cycle, 480 Volts
 Mfg. US MOTORS
 Data 365 TP FRAME MODEL 6326
PREMIUM EFFICIENCY (94.2%)

Discharge Head — Type W

8WTOL-16 Discharge head, 8 " Discharge
 Flange matches 125# ANSI dimensions, flange holes straddle vertical centerline.

Shaft seal: ☐ Packing box, ☒ Oil lube, ☐ Mechanical seal

Column

8 " Column Pipe
1 1/4 " Diameter Lineshaft
☐ Open Lineshaft, ☒ Enclosed Lineshaft
2 " Enclosing Tube

Pump

9 Stage 10NK Bowl, Type H Impeller
800 USGPM, 290 Ft. T.D.H.
 Strainer: ☒ Yes ☐ No, Type 8" CONICAL

Materials

Bowls <u>CAST</u>	Column Pipe <u>8" STEEL</u>
Impellers <u>CAST</u>	Encls. Tube <u>STEEL</u>
Pump Shaft <u>1 1/2" SS</u>	Brg. Retainer <u>N/A</u>
Bowl Bearings <u>RUBBER</u>	Lineshaft Brgs. <u>BRZ</u>
Strainer <u>GALV</u> ^{10" SUCTION}	Lineshaft <u>CARBON STEEL</u>
Head <u>CAST</u>	Sleeve <u>N/A</u>

PROJECT: GEOTHERMAL PRODUCTION

FACILITY MODIFICATION

SUSANVILLE, CA

CUSTOMER: CITY OF SUSANVILLE

SUSANVILLE, CA 96130

DATE: AUGUST 1986

Figure 5.5 New Production Well Pump

Equipment List

- 1) Pump bowl, impeller, additional stage, shaft, oil tube, Ingersoll Rand 10NKH.
- 2) Motor: 460 volt, 3 phase, 60 cycle, 1,770 rpm, 75 hp US Motor.
- 3) Variable frequency A.C. motor speed drive to permit pump flow variation from 200 to 800 gpm, Analog speed indicator, 10 turn speed pot with manual/automatic switch, rated for 75 hp, Robicon Series 442 - Mark IV.
- 4) Variable frequency drive controller, inverse acting Barber-Coleman Model 520, analog loop controller.
- 5) Flow sensor and recorder; use existing orifice plates and Bristol 2408 Differential pressure transmitter, 0-800 gpm.
- 6) Ametek Meter 571ADC2LC and Transducer 57SN005A2SCS and a compatible Bristol Recorder.
- 7) Temperature sensor and recorder with 12 inch, 7 day chart, 0° to 200°F, Bristol 4330 series with valved coupling attachment.
- 8) Pressure sensor and recorder - with 0 to 80 psi, 12 inch, 7 day chart, Bristol 4330 series with valved coupling attachment.
- 9) 8 in. strainer, cast iron, Class 150, flanged coupled.
- 10) Additional set of pump bowls and impeller, same as used in Item #1, including shaft, oil tube, and appurtenances.
- 11) Combination air and vacuum release valve, Val-matic 102 DWS with threaded inlet.

Distribution System

The distribution system for the Susanville DOE system is constructed primarily of asbestos cement piping with a small amount of fiberglass and polybutylene material. In all cases, the supply line is insulated and the disposal line uninsulated. The original system was entirely direct buried type installation and included one bridge crossing, one road bore and one creek crossing. The total 13,710 lf of material originally installed consisted of the following (Koepf, 1981).

<u>Size</u>	<u>Insulated</u>	<u>Uninsulated</u>
8 in.	4,470	570
6 in.	280	3,110
4 in.	2,110	2,470
3 in.	350	350
	<u>7,210</u>	<u>6,500</u>

Table 5.7 presents a summary of piping employed in the Susanville system.

Table 5.7

Piping Summary, Susanville DOE system (Koepf, 1981)

Supply lines	
carrier	asbestos cement, class 150, pressure pipe ASTM C296
insulation	polyurethane, 2-3lb/ft ³ , k = .20
casing	asbestos cement, ASTM C42E, class 1500
Disposal lines	asbestos cement, class 150, pressure pipe, ASTM C296
Manufacturer	
supply	Johns-Manville
disposal	Johns-Manville
Fittings	
body	ductile iron
gasket	EPDM, rated for 200°F
lining	None
Manufacturer	Trinity Valley Iron and Steel
Branch connectors	Pre-threaded, asbestos cement couplings

The main supply line proceeds from the production facility north on Lassen Street (Figure 5.1) to the Susan River Bridge. The crossing was accomplished by hanging the line from the bridge structure as shown in Figures 5.6a and 5.6b. Flange transitions were employed to permit the use of Schedule 40 steel pre-insulated material for the crossing. The steel piping is protected by a buried magnesium anode located at the north end of the bridge. An expansion joint to accommodate the use of the steel piping is located at the north end of the bridge.

The main line proceeds north on Lassen Street to Mill Street, then east to the high school site. At this point, the line turns north again through the school grounds, then under Main Street to the original injection well located in Memorial Park.

All major laterals to the system were connected to the main line at concrete valve boxes as detailed in Figure 5.7. Isolation valves located in these boxes are all of the butterfly type, as are the valves located at individual customer branches. Table 5.8 summarizes the materials employed in these valves.

Figure 5.6a South End of Bridge Crossing (Koepf, 1981)

Figure 5.6b North End of Bridge Crossing (Koepf, 1981)

Table 5.8

Susanville DOE System Isolation Valves (Koepp, 1981)

Type	butterfly
Manufacturer	Keystone Figure 129
Materials	
body	cast iron
seat	EPDM
disk, stem, bolts	316 SS

The presence of these valve boxes at major laterals greatly facilitates maintenance and the connection of new branch lines.

A detail of the direct burial trench appears in Figure 5.8.

In 1984, a major modification was made to the disposal portion of the line and the supply line was extended to the south. Since this project was carried out largely with funding from the California Energy Commission, it is generally referred to as the "CEC" line.

The supply line extension was an effort to deliver services to two new customers (County shops and Mental Health Center). The modification of the disposal system was necessary to allow full operation of the system in view of the ongoing problems with system injection wells.

Due to the lack of success with the injection wells (both located at the north end of the system), it was decided to temporarily develop a surface disposal point on the south end of the system, while attempting to develop an injection well in the same area. In order to deliver the total system waste flow to this location, it was necessary to enlarge the disposal line toward the south, since it was originally designed to deliver flow toward the north.

To accomplish this, the existing 4 in. AC disposal line on Lassen Street was replaced with new 8 in. material. This line size increase was installed from the intersection of Lassen and Mill Streets, south past the production well, to the new surface disposal/injection well site on Hospital Lane, a distance of approximately 4,580 lf. This line was installed in the same manner as that described for the original construction. Piping material was uninsulated asbestos cement pressure pipe (Johns-Manville).

At the same time as the new disposal line construction, a new 6 in. supply line was installed in the same trench to serve two new customers on South Lassen Street. This line was constructed of pre-insulated fiber glass material as outlined in Table 5.9.

Figure 5.8 Typical Burial Detail (Koepp, 1981)

Table 5.9

Piping Material for 6 in. Supply Line - CEC Extension

Carrier pipe	-	epoxy resin fiberglass, 150 psi, 210°F rating, ASTM D2310, 30 ft lengths
Insulation	-	polyurethane, 2#/ft ³ k = .13, Mil-I-24172, 1.68" thickness
Jacket	-	PVC Class 12454-B, ASTM 1784 - Type 1, 10 in., 100 mils thickness
Fittings	-	fiberglass, epoxy type adhesive joint
Manufacturer	-	Rovanco

The fiberglass material was chosen primarily as a result of availability. Due to the short construction season in Susanville and the timing of the project funding, it was necessary to obtain the construction materials very quickly. The fiberglass manufacturer was the only one capable of meeting this schedule (Templeton, 1988).

In addition to the supply line extension and disposal line modifications, an interconnecting line was installed between the new disposal point and the HUD system. As originally conceived, this connection would consist of two lines; one insulated and one uninsulated. Unfortunately, available funding permitted only the installation of the uninsulated line.

The interconnecting piping is constructed of asbestos cement material similar to that installed in the balance of the system. The distance between the disposal point and the HUD connection valve box is approximately 800 lf.

This interconnection was completed just in time to allow operation of the HUD system on an emergency basis for the winter of 1984-85. Failure of the system pump resulted in a loss of hot water supply for the system. Using the new interconnection, the HUD system was operated successfully for the entire season on effluent from the DOE system. At the disposal point, flow was directed from the DOE disposal line through the interconnecting line, into the supply line for the HUD system. Waste flow from the HUD system was disposed of to the surface at the "North Drain", a ditch located near the southeast corner of the HUD service area.

This operation was successful largely due to the temperature difference between the systems. The DOE system operates on effluent temperatures comparable to the supply temperatures of the HUD system. As a result of this and HUD production pump capacity,

it is not possible for the HUD system to provide supply back up capacity to the DOE system.

The interconnecting line is now used primarily to deliver water flow from the HUD system to the disposal point.

Problems/Solutions (Templeton, 1988)

The distribution system has been relatively trouble free over the five years of operation.

Only two piping failures have occurred and both of those appear to be installation related.

Shortly after the original construction, a fracture occurred in an uninsulated disposal line near valve box 1. While repairing this fracture, it was discovered that the pipe penetration through the concrete valve box had been grouted. This effectively eliminated any "play" in the line between the fitting outside the box and the fitting inside. As a result, the fracture occurred. The line was repaired, the grouting removed and no similar failures have occurred.

A second failure in the disposal line occurred in 1983 (after one year of operation). This failure was located at a pipe coupling and was, evidently, the result of the gasket becoming deformed during pipe assembly. The joint was removed and repaired with a gasketed stainless steel clamp. One year later, the repair clamp failed. Upon disassembly, it was discovered that the gasket material used in the repair fitting was not suitable for the temperature conditions of the geothermal line. This gasket was replaced and the system has operated without incident since.

The only other difficulty experienced with the distribution system relates to the performance of the pressure sustaining valves at the disposal point. These valves have not provided consistent performance with regard to back pressure. Since they have not been disassembled to determine the cause of this inconsistent performance, it is not possible to provide an explanation.

Customer Connections

A typical customer retrofit is shown in Figure 5.9. Table 5.10 presents an accompanying equipment list. This diagram indicates the flow scheme for the retrofit of the County Jail facility.

Although officially, the district's responsibility ends at the shut off valves (V5), since the Btu meters are the property of the city and are frequently located indoors, this has resulted in the need to enter the customers building to effect repairs.

Table 5.10
Equipment Description for Figure 5.9 (Koepp, 1988)

<u>Item</u>	<u>Description</u>
HTX1	Heat exchanger, straight tube, 550 Btu/hr, 230 sq. ft. nominal, heat exchange area, arranged for counterflow geothermal side, temperature in 170°F, temperature out 140°F, 37 gpm (tube) hot water side, temperature in 130°F, temperature out 160°F, 37 gpm. Bell and gasket OC Series.
HTX2	Heat exchanger, U-tube, 130 Btu, 12 sq. ft. nominal exchange area, arranged for crossflow geothermal side temperature in 170°F, temperature out 140°F, 9 gpm (tube) hot water side temperature in 70°F, temperature out 130°F, 4.3 gpm. Bell and gasket WU Series.
BLR-1(E)	Existing Boiler, Burnham with Ray Burner.
TX 1(E)	Existing Tank, domestic hot water.
PHW 1(E)	Existing pump, hot water, 38.7 gpm at 20' TDH.
PHW 2(E)	Existing pump, hot water.
V2	Valve, check, swing, 150# bronze, threaded.
V3	Valve, needle, 130# iron body, threaded.
CV1	Control Valve, 3-way, motor operated, 1.5 IBBM flanged diverter type, Honeywell Valve V5013 Series, Linkage, motor actuated M644 Series, 160# seal off force.
T1	Thermometer, dial type, 3"Ø bimetalic stem, 0-250°F.
CV3	Temperature flow regulator, 125# rated, adjustable, direct acting, Robert Shaw RT 100 3x-XX, remote insertion bulb with threaded end.
TS1	Temperature switch, close drop temperature, 70 -150°F range nominal, Honeywell T 675 Series, threaded bulb.
TS22	Temperature switch, close loop temperature variable open/close 3-12 °F differential range, Honeywell 7673 Series.
ACE	4PR conductor signal cable.
AVV	Air vent valve, 125°F bronze, threaded.

The actual customer connection consists only of two butterfly valves. These items are the same as those used elsewhere in the system and are described in detail in Table 5.8.

Problems/Solutions

Although the problems experienced by the customers with their retrofits are not directly the responsibility of the district, these problems, nonetheless, influence the customer's attitude toward the system. As a result, the operators of the district have been involved from time to time with these problems.

Aside from the Btu meter difficulties, which will be discussed in the next section, retrofit problems have centered around two issues; temperature limiting valves and domestic hot water circuiting.

The temperature limiting valves are in the circuit to assure a low disposal temperature - typically 135°F. This maximum disposal temperature is required by the district. The self activated valves have experienced leaking around the packing. Eventually, this leaking results in seizure of the valve and loss of temperature control. Several manufacturers' models have met the same fate.

The second difficulty encountered was with the domestic hot water heating arrangement. As indicated in Figure 5.9, this arrangement uses the geothermal heat exchanger as an instantaneous water heater. Cold make-up water is passed through the heat exchanger and heated from 70 to 130°F. This hot water is then delivered to the existing storage tank. Since the boiler is no longer in the hot water loop under geothermal operation (as a result of CV1 valve), there is no source of heat to offset make-up losses from the storage tank. As a result, during extended periods of low usage, the storage tank would cool off. In addition, during periods of very high hot water consumption, which exceed the capacity of the heat exchanger, the temperature of the hot water out of the heat exchanger would fall below desirable levels. In order to address these problems, a recirculating pump was added to the circuit to provide additional heat to the storage tank during periods of low usage (Templeton, 1988).

Metering

Billing for customers connected to the district heating system was originally to be based upon two-thirds of the cost of fuel oil. As a result, each customer was equipped with a Btu meter to permit collection of energy consumption data.

Equipment from four different manufacturers is currently in service in the Susanville system. These manufacturers include:

D-K Enterprises
Ista
Kent
Hersey

In May of 1987, Gene Culver, of the OIT Geo-Heat Center, published a report (Culver, 1987) on the performance of the meters in both the Susanville HUD and DOE systems. The following is taken from that report.

"Btu Meters

The district heating system has had continuing problems with Btu and flow meters. If it is any consolation to the City, so has every other district heating system, geothermal or conventional, both in the US and abroad. Accurately metering hot water and Btu's is a difficult and costly undertaking.

As of July 1986, 41 meters had been installed; 18 Btu meters and 23 flow meters. The operational status was:

- 4 Btu meters apparently operating satisfactorily
- 2 Btu meters operating, but not correctly
- 2 flow meters operating, but not correctly
- 5 Btu meters not operating
- 4 Btu and 20 flow meters need calibration (HUD project)
- 3 Btu and 1 flow meter installed, but never used

Installation details are shown in Table 1.

By far the largest number are those needing calibration. These are the small meters installed at the "HUD" project residences.

Table 1

<u>Location</u>	<u>Size</u>	<u>Spec. Peak Flow</u>	<u>Spec. Min. Flow</u>	<u>Spec. Cont. Flow</u>	<u>Calc. Peak Flow</u>	<u>Orientation</u>	<u>Status</u>
Jail	3"	374 gpm	9.0	53.0	29	Vertical	not working
Annex	2"	110.	.8	57.5	36	Vertical	working, not correctly
Wash. School	3"	266.7	6.7	133.3	41	Vertical	not working
HS Shop	3"	266.7	6.7	133.3	40	Horizontal	working
HS Greenhouse	1"	30.8	.3	13.3			never used
HS Old JC	3"	266.7	6.7	133.3	38	Horizontal	working
HS 100	3"	266.7	6.7	133.3	50.6	Vertical	not working
HS 200	3"	266.7	6.7	133.3	54	Horizontal	not working
HS 300	3"	266.7	6.7	133.3	50	Vertical	working
Boy's Gym	3"	266.7	6.7	133.3	62	Vertical	working, not correctly
Girl's Gym	3"	266.7	6.7	133.3	39	Horizontal	working
Maint.	2"	110.	.8	57.5	16	Horizontal	never used
Dist. Off.	1"	30.8	.3	13.3	8	Horizontal	never used
Mem. Bldg.	3"	374.	9.0	53.0	29	Vertical	not working
Senior Center	2"	160.	5.0	-	12.3	Horizontal	working, not correctly
Parks & Rec.	1"	50.	1.0	-	?	Horizontal	working, not correctly
HUD SYSTEM							
1009 Orchard	3/4"	22.	1.0	11.0		Horizontal	all HUD meters work but need calibration
1017 Orchard	3/4"	22.0	1.0	11.0		Horizontal	
1021 Orchard	3/4"	22.	1.0	11.0	1.7	Horizontal	
701 Plumas	3/4"	22.	1.0	11.0		Horizontal	
704 Plumas	3/4"	22.	1.0	11.0		Horizontal	
728 Plumas	3/4"	22.	1.0	11.0		Horizontal	
739 Plumas	3/4"	22.	1.0	11.0		Horizontal	
1110 Modoc	3/4"	22.	1.0	11.0		Horizontal	
1209 Modoc	3/4"	22.	1.0	11.0		Horizontal	
729 Shasta	3/4"	22.	1.0	11.0		Horizontal	
738 Shasta	3/4"	22.	1.0	11.0		Horizontal	
745 Shasta	3/4"	22.	1.0	11.0		Horizontal	
777 Shasta	3/4"	22.	1.0	11.0		Horizontal	
801 Shasta	3/4"	22.	1.0	11.0		Horizontal	
812 Shasta	3/4"	22.	1.0	11.0		Horizontal	
841 Shasta	3/4"	22.	1.0	11.0		Horizontal	
861 Shasta	3/4"	22.	1.0	11.0		Horizontal	
864 Shasta	3/4"	22.	1.0	11.0		Horizontal	
? Shasta	3/4"	22.	1.0	11.0		Horizontal	
865 Shasta	3/4"	22.	1.0	11.0	2.4	Horizontal	
869 Shasta	3/4"	22.	1.0	11.0		Horizontal	
726 Sierra	3/4"	22.	1.0	11.0		Horizontal	
732 Sierra	3/4"	22.	1.0	11.0		Horizontal	
824 Sierra	3/4"	22.	1.0	11.0	3	Horizontal	
844 Sierra	3/4"	22.	1.0	11.0	3.3	Horizontal	

Two of the "not operating" meters, at the jail and Memorial Building, were Kent TM 230 3" Btu meters. These meters were installed in vertical pipes, whereas installation instructions call for horizontal installation only with 10 straight pipe diameters upstream and 5 straight pipe diameters downstream. Vertical installation was apparently done because of ease in plumbing and space restrictions, but unless there were some meter modifications or approval by the manufacturer, this should not have been allowed.

Louie Templeton arranged to have the meters replumbed according to manufacturer's instructions and smaller meters installed. Both meters appear to have been grossly oversized. The manufacturer recommended (telephone conversation 10/20/86) the 3" meter at the jail should have been a 1½" size, and the 3" meter at the Memorial Building should have been a 2" size. Both new meters are 2" and appeared to be operating satisfactorily as of December 1986.

Note that only one of the other five meters installed vertically is working and only one of the four installed horizontally is not working. All are ISTA meters and the manufacturer's representative says horizontal mounting is standard, but it is possible on some meters to make modifications to permit vertical mounting. These modifications cannot be detected except upon disassembly by a trained person. However, they may still have records on the meters if they can be identified. At the time of this writing, Louie Templeton is identifying the meters as to purchaser, purchase date, serial number, orientation and other details of installation. Hopefully, the manufacturer will be able to tell if the meters are installed correctly. This will take some time and their reply probably will not be received until after completion of this report.

Comparison of the meter specified peak flow with the system calculated peak flows suggest that these meters are grossly oversized and probably should have been 1 ¼" or 1 ½" meters. Flow meters typically fall off in accuracy at about 10% of rated continuous flow. A 2" ISTA meter Louie Templeton checked was very erratic below about five gpm or about 9% of rated continuous flow. If the same holds true for the 3" meter, it would be erratic below about 12 gpm. This is one-third to one-fifth the calculated peak flow for the buildings in which they are installed. The meters could be operating in this "erratic" range a significant portion of the time, depending on how the building control

systems react. At very low flows, the meters will register flows lower than actual, if they register at all.

The drawings for several of the school buildings call for an "ISTA Meter #188XX....80 gpm flow at 20 ft. loss max.". ISTA's model numbering system has changed, but this appears to correspond to a Model 20, 1½" meter. The meters are shown as being installed in 3" pipe runs on the drawings. Perhaps they were ordered based on pipe size rather than flow rates, a practice every flow meter manufacturer warns against.

At the schools, flow through the meters is typically controlled by two direct acting remote bulb temperature regulator valves; one for space heat and one for domestic water. During conditions where little building heating is required and domestic water load is relatively low, flows could be below the meter's accurate operating threshold. This can be checked by obtaining the turn down ratio of the valves from the manufacturer. A low turn down ratio (indicating the valve is "off" at 5% or so of rated flow) could permit satisfactory operation. A high turn down would permit flow through the valve too low to be accurately registered.

The best solution to the problem is to replace the meters and associated piping with the proper size and required straight runs. This will be expensive. There does not appear to be any place the large meters can be utilized except possibly the Litchfield facility and in the main pipeline system to monitor flows, injection into Richardson #1 and discharge to Ramsey ditch. Peak flows for satisfactory operation would be in the 100 to 250 gpm range and minimum flows greater than 7 gpm for the 3" meters.

Since accurate metering is obviously a requisite for customer satisfaction, it is highly recommended that all non-functioning or questionable meters be repaired or replaced with meters of known accuracy. Any new meters installed should be checked prior to installation.

The city has approximately 50 uninstalled ¾" meters that were ordered for the HUD project. Since the hook up numbers were less than expected, these are now available as spares and for future hook ups. Since they are only ¾", their use would be limited to smaller applications - probably residential and very small commercial. The meters have been assembled into

the standard HUD system hook up and metering module and, probably, cannot be returned or exchanged. Most of these are flow meters only but could be modified to Btu meters by adding the electronics package, temperature measuring devices and flow counter/sender. Cost for the conversion is about \$700 per unit.

Although installing Btu meters throughout the system might be desirable, the income from a HUD home hardly seems to justify the expense, at least now when the system is in a low income situation. The HUD homes are equipped with a temperature limiting valve which sets the discharge temperature at 130°F. Calculating the Btu's consumed is a relatively simple calculation since the inlet water temperature is known within close limits, the valve sets the discharge temperature within close limits and the flow is measured. A limited number of Btu meters are installed at typical homes to provide checks. Although there are certainly some errors in this type of metering, they are relatively small, if the discharge valve is checked regularly.

Louie Templeton reported that he had 11 meters installed at a cost of \$35,300, or \$3209 each including materials and labor.

In order to check flow meter accuracy, a test stand similar to a conventional city cold water meter test stand should be available. This can, in fact, be a conventional test stand, if it will accommodate the required sizes and straight run pipe lengths. The temperature sensors for the Btu meters can be checked using a high quality mercury in glass thermometer.

The city has an old cold water meter test stand they use for calibration of their domestic water meters. However, this stand is limited to 2" pipe sizes and corresponding flow rates; therefore could not check 3" meters over their full range. The unit is located in a CP National building (the previous owners of the water system) and does not have a supply of hot water available. There is a possibility of contamination if the unit is used with geothermal water (which is not chlorinated) and then used for domestic water. Use for both would require thorough cleaning and disinfecting, a time consuming job. It would be far better if they had a separate unit. Cost of a new calibration unit including tanks and conversion for hot water (high temp. gaskets, etc) could be \$15,000 to \$17,000."

DISPOSAL

The original disposal plan for the DOE system was based upon the use of an existing injection well, located in Veteran's Park at the north end of the system. During initial system testing, it was discovered that this well was completed in such a manner that injected fluid could rise up around the outside of the casing and exit at the surface. As a result, it was unusable.

Shortly thereafter, planning began to construct a well specifically for injection of the geothermal fluid. This well, Richardson 1, was located along the main distribution line route on Mill Street adjacent to the Susan River. It was only partially successful in that it was capable of accepting 150 gpm of the approximately 500 gpm peak system flow.

At this point, a contract was executed with GeothermEx Inc., a reservoir engineering firm, to study the problem and make recommendations. The following is taken from their final report (GeothermEx, 1984):

" Drilling and Completion of Richardson 1 Well

Well Richardson 1 was drilled and completed to 1,200 feet depth between October 14 and November 13, 1982. We have developed the lithology and well completion schematic shown in Figure 17 from driller's reports to the California Division of Oil and Gas. The well was drilled with air to 427 feet where circulation was stopped and a series of 5 temperature logs run in the open hole; the first, middle and last run are reproduced on Figure 17 (dates 10/20/82 and 10/21/82). The 8-5/8" slotted casing was then set on bottom, gravel packed to 310 feet, and the hole unloaded by blowing with water and air. It reportedly flowed at 30 gpm only when on airlift without the drilling string in the hole. A fluid sample was collected during this flow, and the resulting analysis (Appendix D) is the only chemical data available from the well. Drilling then continued with air to 440-450 feet, at which point drilling was resumed with mud because of well caving, rough drilling conditions and slow drilling rate. At 1,000 feet, drilling was suspended and a temperature log run (Figure 17, 11/3/82). At the total depth of 1,200 feet the 6-5/8" slotted and screened casing was hung inside the 8-5/8" casing. The top of this casing overlaps the bottom 20 feet of the 8-5/8" casing. Drilling below 440-450 feet was essentially without incident except for an apparent "total" lost circulation and a "jump" in

temperature between 870 and 880 feet (Templeton, 1984). The bit reportedly dropped several feet at this depth. The driller's log lacks clear reference to lost circulation zones, but does mention adding 3,000 gallons of water at 910-920 feet, "adding cold water often" at 1,130-1,140 feet and having 90-95% return at 1,200 feet.

After the 6-5/8" casing was set, the setter was removed from the drill string, the string lowered to 1,185 feet and about 6,600 gallons of clean water pumped into the hole. The string was then lifted to 640 feet according to the Waldrop drilling report or "540 ft (GR)" according to Juncal (1983), and the hole blown with air. Blowing pressure dropped from an initial 250 psi to a stable 100 psi within one-half hour, and at this pressure the hole produced 270 gpm, measured using a drum, for about 7-1/2 hours (Juncal, 1983; drillers report indicates "tested 300 gpm").

Depending upon several assumptions, the rough data indicate about 310 feet drawdown (134 psi) for the 270 gpm production rate, giving a productivity index of about 0.87 gallons per minute per foot (gpm/ft). Drawdown is not precisely known because of uncertainties about the stable rest level and density of the produced column of aerated water. In spite of these uncertainties this productivity index agrees well with the injectivity index we estimated during an injectivity test in this well in April, 1984."

Problems/Solutions

Again quoting from the GeothermEx final report:

"Richardson 1 has productivity and injectivity of about 0.85 gpm/feet, which is only 1/10 the productivity of the other thermal wells in the area. We consider the poor injectivity to be due to low reservoir transmissivity (about 260,000 md ft/cp, compared to 1.33 to 4.5×10^6 at several other thermal wells), plus a high positive skin factor (about 18). The high skin factor such as mud invasion in permeable zones, insufficient slots or perforations, excessive bridging by fine-grained sloughing material behind the casing, or casing collapse, etc. The exact nature of the "damage" is unknown.

Calculations indicate that the well damage causes a pressure increase of about 41 psi out of the total pressure increase of 61 psi for 120 gpm injection into the well. If the well were reworked or cleaned to completely remove the "damage", the injectivity index would be 2.5 gpm/ft, and 500 gpm of waste water could be injected at a wellhead pressure of about 73 psi. Normal line pressure might be sufficient to achieve this level. The damaged well would require a pump capable of generating at least 250 psi at 500 gpm.

Consideration of alternatives to allow a total of 500 gpm subsurface fluid disposal leads to preference for drilling a new injection well, at a site which has been chosen near Suzy 3, to supplement Richardson 1. Other alternatives, at the Richardson 1 well itself, include a work-over, an attempt to improve injectivity using acid stimulation, and installing a pump. All of these appear to involve expenses, risks and uncertainties somewhat higher than will be incurred by drilling a new well. An acid stimulation might be done using grant monies, and a test of a technique relatively untried in this kind of system, but found to be successful elsewhere."

As a result of the failure of the Richardson well, the city currently disposes of its waste flow on the surface.

Figure 5.10 provides a schematic of the disposal point piping and instrumentation. Basically, the disposal lines from the HUD system (through the 6" interconnecting line) and the DOE system are piped in such a way that flow can be delivered to the surface disposal point or the future injection well. In addition, a bypass line is provided to allow flow between the two systems. Regardless of whether the disposal flow is delivered to the surface or injection, it is passed through a pressure sustaining valve to maintain back pressure in the disposal line.

Instrumentation is provided for monitoring of totalized flows in the two surface disposal lines and the two injection lines.

A description of the equipment at the disposal point appears in Table 5.11.

A third injection well was drilled in the summer/fall of 1988. This well did not intersect fractured basalt as expected and produced less than 5 gpm during a bailer test. As of February 1989, the city is investigating several more disposal options.

Table 5.11

Disposal Point Equipment Description

Item	Description
V1	Valve butterfly, iron body, stainless steel shaft, tapping lugs, Buna-N gasket.
V2	Valve, gate, bronze, 200# rated, threaded.
V3	Valve, plug, all iron, lubricated, 125# rated, threaded.
CV1	Pressure sustaining, pressure reducing, and check valve, IBBM, 125# rated, water service to 180°F, adjustable pressure range, diaphragm type with pilot, flanged 700 gpm maximum flow rate, 4" nominal valve body, Clayton 92-02 or approved equal.
CV2	Same as CV1 except 400 gpm maximum flow rate.
CV3	Same as CV1 except 200 gpm maximum flow rate and 3" nominal valve body.
CV4	Same as CV1 except 350 gpm maximum flow rate and 3" nominal valve body.
AVV1	Air vent valve, iron body, stainless steel float mechanism, threaded.
YBV1	Vacuum breaker valve.
PI1	Pressure gauge, bourdon type, 4 1/2" dia. dial, stainless steel case and bourdon system, 0-100 psig range, water service to 180°F.
TI1	Temperature indicator, 4 1/2" dia. dial and stainless steel case, 0-200°F range.
EJ1	Expansion joint, 150# rated, flanged, total travel 2".
FM1-4	Flow meter and totalizer, microprocessor based digital display, user calibrated in field, nema 4 enclosure, 120V/10 input power, Data Industrial Model 900 or approved equal.
FE4	Flow sensor, low voltage pulse/impeller type, stainless steel body, sensor to fit 2" threaded pipe saddle welded to process pipe, Data Industrial Model 220SS or approved equal.
CV5	Same as CV1 except 400 gpm maximum flow rate.

References for Susanville DOE System

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7. Koepf, A., Specifications for Susanville - DOE Geothermal District Heating System, Koepf and Lange Engineers, Layfayette, CA. 1981.
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9. Original Project Submittal Data on file at City of Susanville.

SUSANVILLE HUD DISTRICT HEATING SYSTEM

Introduction

The HUD system is so named in recognition of the fact that the U.S. Department of Housing and Urban Development provided most of the funds for its development. This system was implemented primarily to serve a residential area (126 homes), to the east of the area served by the DOE system. Figure 6.1 indicates the location of the HUD system.

The design of the HUD system was able to capitalize on a number of factors to reduce the cost of the system. Primary among these were: the use of existing wells for production and injection; installation of main lines largely in unpaved alleys; and use of low cost polybutylene piping material.

Table 6.1 provides a summary of key HUD system data. Construction of the project began in summer, 1983 and was completed in the spring of 1984. Just after completion of the HUD system, the CEC project (see DOE system chapter) was completed. This timing was quite fortunate in that the production pump for the HUD system failed in December of 1984. Completion of the CEC line allowed the HUD system to operate through the winter on effluent from the DOE system.

Table 6.2 provides a summary of fluid chemistry for the HUD system production well (Naef Well).

Table 6.1

Key Data - Susanville HUD System

Start up date	Spring 1984
Years of operation	4
Number of customers/ft ²	25/30,000 ft ²
Resource temperature	158°F
Delivery temperature/ Δt	155°.45° Δt
Peak flow capability	300 gpm
Disposal method	surface (pursuing injection)
Customer heat exchangers	space heat - no/dhw - yes
Number of production/injection wells	1/0
Rate structure	2/3 the price of oil
Ownership public/private	public
Original funding	
US Dept. HUD (Innovative	
Community Energy Conservation	
Program)	\$800,000
FMHA	100,000
	<u>\$900,000</u>

Contact person:

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Geothermal Energy Manager
City Hall
66 N. Lassen
Susanville, CA 96130
(916) 257-7236

Engineer of record:

Almont Koepf, P.E.
Koepf and Lange
Lafayette, CA

Contractor:

Table 6.2

Susanville HUD Resource Fluid Chemistry

<u>Key Species</u>	<u>mg/l</u>
pH	8.1
TDS	810.0
Chloride, Cl	120.0
Sulfate, SO ₄	294.0
Bicarbonate, HCO ₃	37.0
Carbonate, CO ₃	1.0
Hydrogen Sulfide, H ₂ S	0.5
Ammonium ion, NH ₄	0.4
Oxygen, O ₂	---
Silicon, Si	---
Sodium, Na	205.0
Calcium, Ca	32.0
Nitrate, NO ₃	---
Potassium, K	6.0
Fluorine, F	---
Iron, Fe	---
Boron, B	2.5

Production Facilities

One of the aspects of the development of the HUD system was the opportunity to take advantage of an existing well for production purposes. This well, known as the Naef Well, was located in the heart of the area to be served by the system. It was originally drilled in 1930 as part of an attempt by a local saw mill to develop a source of cold water. Eventually, the mill sold the property on which the well is located to Mr. Naef, the present owner.

Figure 6.1 Distribution System Layout

Under an agreement between the city and Naef, this well is rented for a sum of approximately \$1,200 per year and serves as the production well for the system.

Table 6.3 presents a summary of the available information on this well. Due to the age of the well, little information on its drilling and construction is still in existence.

The production well pump, installed during construction of the system, was of similar design to that employed for the original DOE system pump. The arrangement consisted of an enclosed lineshaft vertical turbine pump with cold water lubrication of the shaft bearings. Materials of construction for this pump appear in Table 6.4.

Table 6.3
Susanville HUD System Production Facilities

	<u>Original Design</u>	<u>Present Design</u>
Flow/head (gpm/ft)	300 @ 160	300 @ 160
Setting depth (ft)	160 ?	220 ?
Size bowls (in.)	7	7
Number of stages	11	11
Manufacturer	Peerless	Peerless (7HxB)
Horsepower (hp)	20	20
Variable speed drive	yes	yes
Drive type	variable frequency	variable frequency
Manufacturer	Robicon (Barber-Coleman)	Robicon (Barber-Coleman)
Lubrication (shaft)	water	oil
Well depth (ft)	450	450
Well size (in.)	8 to 240'/7 to 374'	8 to 240'/7 to 374'
Temperature	158°F	158°F
Static level (ft)	46	46
Drawdown (ft)	100	100

Table 6.4

**Original Susanville HUD System
Production Pump Materials**

<u>Item</u>	<u>Material</u>
Bowls	Class 30 cast iron
Impellers	Class 30 cast iron
Bowl bearings	SAE 64 bronze
Bowl seal ring	Class 30 cast iron
Column pipe	Class 30 cast iron
Enclosing tube	Extra heavy wall steel
Lineshaft	C1045 steel
Lineshaft coupling	steel
Pump bowl shaft	416 stainless steel
Top shaft	416 stainless steel
Tube nut assembly	steel

This pump was designed to pump directly into the distribution system with pressure controlled primarily by the variable speed drive unit. Figure 6.2 provides a diagram of the production facilities for the HUD system as originally designed.

Valve CV2 serves as a combination pressure reducing and check valve on the main 6 in. production line. Valve CV1, on a 3 in. bypass line, is employed only for pump start up and shut down. Its function is to purge air from the column on start up and to allow air to enter the system on shut down.

Table 6.5 presents a summary of materials of construction for selected production facility equipment.

Table 6.5

Materials of Construcion - Wellhead Equipment

<u>Item</u>	<u>Material</u>	<u>Manufacturer</u>
Valves (CV1 and CV2)	body - cast steel ASTM A-216 WCB shaft & spring - stainless steel spool, seat retainer, diaphram plate - ductile iron seat, bushing - bronzes	Berrud, Cla-Val
Valves (V1)	type - gate, OS&Y body - cast iron trim - steel	Nibco
Piping	Schedule 40 steel welded	

Problems/Solutions

As in the case of the DOE system, the pressurized water lubricated bearings were not particularly successful. The original pump failed in December of 1984 after less than a year of operation. These bearings were replaced with an oil lubricated system in March of 1985 and this design has served the system without incident since.

During the period in which the pump was out of service, the system was operated with effluent from the DOE system supplied through the "CEC pipeline" (see Susanville DOE Chapter) which had been completed only a matter of months before.

The only other difficulty with the production facilities occurred prior to system construction during well testing. It was discovered that in order to achieve full capacity, the pump bowls would have to be lowered 60 ft. Extra column was added to accomplish this in 1982.

Distribution System

The distribution system for the HUD project is unique in that it is the only major geothermal district heating system to employ polybutylene piping for the large diameter supply and return mains.

As with the DOE system, the supply lines are insulated and return lines uninsulated. Table 6.6 provides a breakdown of the line sizes and associated installed quantity.

Table 6.6
HUD System Piping Size Breakdown

<u>Size</u>	<u>Insulated</u>	<u>Uninsulated</u>
6 in.	1,800 lf	1,020 lf
4 in.	300 lf	300 lf
3 in.	2,920 lf	3,980 lf
	<u>5,020 lf</u>	<u>5,300 lf</u>
Total installed length = 10,320 lf		

All of the piping was installed using the thermal fusion joining method. In the size range for this project, butt fusion joints were most common. For connection to valves and other pipe fittings specialized polybutylene "stub ends" and slip on flanges were used.

Table 6.7 presents key information on the piping material used in the HUD system.

Table 6.7
Piping Data - Susanville HUD System

<u>Insulated piping</u>	<u>Manufacturer</u>
carrier pipe - polybutylene SDR 11 ASTM D-3309 PB 4121 ₃	Rahn Western Pipe
insulation - polyurethane 2lb/ft ³ k = .20 Btu in/hr ft ² °F max.	
carrier pipe - PVC ASTM D2241 min. thickness	
6 in. - .134 in. 8 in. - .178 in. 10 in. - .165 in.	
<u>Uninsulated pipe</u> - polybutylene SDR 11 ASTM D-3309 PB 4121	Rahn Western Pipe

Pipe alignments for this system made wide use of existing unpaved alley ways and right of ways. In this way, pavement work was minimized.

In comparison to the DOE system, the HUD system was a relatively low budget project. As a result, the system contains no provisions for isolation of major branch lines or sections.

With the exception of the connection of the CEC and FMHA extensions, there are no valves in the system. The lack of such valves would require draining of the system to effect major repairs.

The CEC extension was connected to the HUD system in 1984. This connection, described in detail in the Susanville DOE system chapter, permits flow to take place between the two systems for back up purposes.

The FMHA extension was installed in 1985. This line was located near the southeast corner of the existing distribution system. Its purpose was to provide a means of delivery for system effluent to an area in which greenhouses could be located.

The extension consisted of 250 lf of 6 in. insulated supply line and 1,410 lf of 6 in. uninsulated line, located along the latter were three valve boxes with blind flanges for future connection. All of the piping installed in the FMHA extension was of asbestos cement construction with cast iron fittings similar to that used in the DOE system.

Problems/Solutions

No operational problems have been experienced with the polybutylene or asbestos cement portions of the distribution system. During construction, a problem did occur as a result of the installation procedure. This consisted of assembling the pipe at the surface, including all service and joint connections, and then lowering it into the trench. On at least one occasion, the polybutylene pipe failed (broke) at a service connection while lowering it into the trench (Templeton, 1988). Because the jacket and insulation material had been removed to install each service connection, only the bare polybutylene pipe remained at these points. As a result, any bending load applied during the installation of the pipe in the trench was concentrated at this point.

More careful support of the service connections during handling eliminated this problem.

Customer Connections

All customer service connections to the main distribution system were installed during the original construction phase. These taps were installed to serve all 126 homes in the area. Figure 6.3 illustrates the design of the service tap. In each case, 1 1/4 in. supply and return feeders were connected to a single 12 x 20 in. concrete valve box. Each valve box was designed to serve up to four residences.

Figure 6.3 Typical Service Line Installation (Koepf, 1982)

Physical connection to the distribution supply and return mains was accomplished using standard mechanical service saddles (Smith Blair Style 352) with PVC stiffeners. A short galvanized nipple and plug valve was attached to the service tap and the polybutylene branch line attached to the valve.

Of the two 1 1/4 in. polybutylene lines to each valve box, only the supply line was insulated. A field insulation technique was used. Prior to back filling the trench, the supply line was covered with lengths of closed cell, flexible insulation. This insulation was then wrapped in polyethylene and secured with bands.

As part of the original construction, 26 homes were provided with retrofits and connected to the system. A typical diagram of such a retrofit appears in Figure 6.4. Most of the central mechanical equipment for these retrofits was contained in a single box. These control boxes were prefabricated and installed in each of the retrofit homes. Table 6.8 provides details on this equipment.

Table 6.8

Customer Retrofit and Control Box Components (Koeppf, 1982)

<u>Item</u>	<u>Description</u>
VBR1	<u>Valve</u> , angle, baseboard radiator, integral temperature control, 125# rated, threaded.
R1	<u>Baseboard radiator</u> , cabinet enclosure, wall mount. See individual house schedule for exact unit. Water gpm varies, 160°F to 140°F, 65°F EAT.
RF1	<u>Unit ventilator</u> , cabinet, fan, 120V, 1/30 to 1/12 HP. See individual house schedule for exact unit. Water, gpm varies, 160°F to 135°F, air CFM varies, 65°F EAT. Unit mounted return air thermostat on fan and modulating thermostat with angle radiator valve.
HTX1	<u>Heat exchanger</u> , counterflow, copper tubes $q = 5.0 \text{ MBTUH}$ Tube side 3.0 gpm 130°F to 126°F, $\Delta h = 2'.0$ Shell side 1.0 gpm 100°F to 110°F, $\Delta h = 3'.0 \text{ max.}$ Young radiator model 201
PHW1	<u>Pump</u> , centrifugal 1.0 gpm 5.0' TDG 1750 rpm 1/30 HP 120V 10 125# bronze, threaded Grundfos UPS 20-42F (speed 1)

MTR1	<u>Water meter</u> , turbine type, bronze body, meter to include pulse output for future interface with Btu measuring system, totalizer up to 1,000,000 gallons and automatic reset to zero, meter to include 3/4" bronze couplings, Kent ESJ-Q
EM1	<u>Energy meter</u> but indicating, sensors, integrator, 125# rated, 0-5 gpm range, 70-200°F range, 1.0 psi loss, 1 watt at 120V 10 60 HZ. Kent AK.
CAB1	<u>Cabinet</u> , weather resistant, plywood backer, side hinged, 30" X 24" X 8", key lock handle or latch.
TS1	<u>Temperature switch</u> , surface mounted, 50 to 300°F range, SPST, General Electric, Model No. CT1000.
SR1	<u>Solid state relay/switch</u> , SPST, N.O., 5 amp max current, 120V, Delaval, #18670.
V1	<u>Valve</u> , Ball, 125# bronze, 3/4" FPT & 2 bolt flange connections (flange connection must be compatible with Grunfos pump).
V2	<u>Valve</u> , plug, air vent cock, bronze, threaded.
V3	<u>Valve</u> , plug or ball, 125# bronze, threaded.
V4	<u>Valve</u> , check, swing, 200# bronze, threaded.
V5 N.I.C.	<u>Valve</u> , plug, 1B, 175#, threaded.
V6	<u>Valve</u> , plug cock with compression ends.
CV1	<u>Control valve</u> , liquid expansion type, set point 130°F, 1 1/4 FPT, steel inlet coupling, brass body, iron outlet thermostat assembly, Sarco Thermoton Model FH-10.
CV2	<u>Flow Control Valve</u> , (flow limiting), 0-5 gpm range, 1.0 psi maximum loss, 180°F water, bronze, threaded. Griswold.

Using available head from the distribution system, geothermal water is delivered directly to the individual heating equipment in each home. A domestic hot water heat exchanger is placed in series with the hot water return line from the space heating equipment. In order to maintain an acceptable Δt on the system and minimize flow requirements, a special self-actuated temperature limiting valve

Figure 6.4 Customer Retrofit and Control Box (Koepp, 1982)

was included. The function of this valve was to maintain effluent temperatures for each house at or below a maximum value. In addition, flow control valves were included to maintain balanced flow to each dwelling.

A summary of the materials of construction of selected components used in the retrofits appears in Table 6.9.

Table 6.9
Selected Materials Used in HUD System Customer Retrofits

<u>Item</u>	<u>Material</u>	<u>Manufacturer</u>
Temperature limiting valves (CV1) body valve head and seat thermostat assembly	cast iron, Class 30 stainless steel brass	Sarco FH-10
Heat exchanger tubes, baffles, shell, sheet bonnets	brass cast iron	Young Radiator
Flow control valve body spring cup	gray cast iron, Class 30 stainless steel AISI 17-7 stainless steel AISI 3XX	Griswold
Circulating pump	bronze, bronze fitted	Grundfos

Problems/Solutions

Performance of the plumbing components used in the customer retrofits has been good despite the fact that these materials of construction were largely "standard".

The most significant problem which surfaced related to the small diameter polybutylene pipe fittings. The original joining method involved acetal fittings onto which the polybutylene piping was pushed. The pipe was then secured with an aluminum ring which was crimped in place. It was later discovered that this technique was not recommended by the manufacturer for recirculating hot water systems.

A number of leaks occurred in these fittings. The leaks may have been attributable to creep in the plastic materials or simply differential expansion between the acetal, polybutylene and aluminum (Templeton, 1988).

These fittings have largely been replaced with a new system consisting of brass fittings in place of the acetal, and copper crimp rings in place of the aluminum. This modification appears to have been successful.

As mentioned earlier, the geothermal water is passed directly through the individual heating equipment in each residence. Although no failure of the copper tubes in this equipment has occurred to date, problems have surfaced with the solder joints. Leaks have developed at silver solder joints (brazed joints) at return bends on the hot water coils (Templeton, 1988).

These leaks have been repaired, but are likely to continue to be a problem.

As noted earlier, each residence "control box" is equipped with a valve, the function of which is to regulate the return water temperature at or below a maximum value. Unfortunately, no temperature instrumentation was provided to calibrate these valves. As a result, their performance is unknown.

Metering

Metering for the HUD system is discussed in the metering section of the Susanville DOE system chapter.

Disposal

The original plan for disposal for the HUD system was based upon the use of one of the original "Suzy" series wells drilled during the resource confirmation work for the DOE system. Unfortunately, it was discovered that the completion of the well was not appropriate for injection purposes.

The next step was to deliver flow out of the system, near the FMHA extension line, to the "north drain" (a drainage ditch).

The current practice is to discharge through the CEC line to a common discharge point with the DOE System. The discharge station is described in the DOE System Chapter.

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WARREN PROPERTY SYSTEM

Introduction

The Warren Property system, located in Reno, Nevada, is unusual in that it is one of only two geothermal heating districts which serve exclusively residential customers. The system was originally developed to serve the first phase of the project, Warren Estates, a development of 69 homes on 1/2 acre lots. At the outset the system employed a single well with a 4 in. diameter downhole heat exchanger (dhe). The dhe supplied heat to a distribution loop consisting of pre-insulated fiberglass piping. In 1985, as a result of additional development (Manzanita Estates) the downhole heat exchanger was removed and the system converted to a surface plate heat exchanger design. Also at this time a second production well and an injection well were completed. A second distribution loop, this time using pre-insulated steel piping, was added in 1986. The central heat exchanger and circulation pump are located along with those for the Warren Estates loop in a mechanical building between the two subdivisions and adjacent to the production wells. Figures 7.5 and 7.6 illustrate the project layout.

A summary of key system information appears in Table 7.1.

Table 7.1

Warren Property - Key System Information.

Years of Operation	
- Warren Estates Loop	- 6 yrs.
- Manzanita Estates Loop	- 2 yrs.
Number of Customers/ft ²	- 169/500000 ft ² (at buildout)
Total Length of Piping	- 33,000 LF
Resource Temperature	- 210°F
Delivery Temperature/ΔT	- 165°F/55°F
Peak Flow Capacity	- 710 gpm (system requires only 450 gpm)
Disposal Method	- Injection
Customer Heat Exchangers	- No (Central heat Exchangers)
Number of Production/ Injection Wells	- 2/1
Rate Structure	- .70 x current natural gas rate
Ownership	- Private
Original Financing	- Not Available
Contact Person	- Francis McKay or Gordon McKay McKay Drilling 690 Starlight Circle Reno, Nevada 89509 (702)825-8692
Engineer of Research	- W. W. Baker, P.E. Aspen Engineering 63 Keystone Ave. Reno, Nevada 89503 (702)329-7133
Contractor	- McKay Drilling

Table 7.2 provides the details of the Warren System fluid chemistry.

Table 7.2

Warren Property System Fluid Chemistry (Remco, 1985)

	WE-1 05/11/82	WE-1 05/12/82	WE-1 02/18/83	WE-2 06/27/85
Temp °C	91.00	-	87.00	98.00
pH	8.23	8.20	8.18	8.30
Ca	26.00	30.00	24.20	27.00
Mg	0.00	0.10	0.04	0.10
Na	285.00	270.00	276.00	254.00
K	10.00	10.00	11.90	12.00
Cl	56.00	56.00	51.30	49.00
SO ₄	505.00	450.00	459.00	422.00
HCO ₃	6.00	0.00	0.00	0.00
F	5.20	4.60	5.57	5.00
B	-	-	2.45	2.20
As	.15	.13	-	.13
SiO ₂	-	116.00	127.00	110.00
TDS ²	1097.00	1046.00	1061.00	948.00

Production Facilities

The Warren property system operates two production wells, WE-1 and WE-2. The location of these wells in relation to the central plant is shown in Figure 7.5.

Well WE-1 was the first production well completed for the project (1982). Initially, this well was used in conjunction with a downhole heat exchanger to serve the development. Little information is available on the DHE installation. It was reportedly constructed of 4 inch diameter fiberglass pipe (McKay, 1988). This heat exchanger developed a leak in 1985 and was removed. At that time (1985), the system was changed over to a surface heat exchanger design. In support of the surface heat exchanger design and as a result of growth of the development, a second production well was completed along with an injection well. Temperature and lithologic logs, along with completion details appear in Figures 7.1 and 7.2.

Both wells produce temperatures in excess of 200°F with WE-2 slightly warmer (209°F) than WE-1 (200°F). Although initial pump tests on both wells produced similar results (see Table 7.3), in practice, WE-2 is capable of producing the entire peak requirement of 480 gpm while WE-1 produces only 260 gpm (McKay, 1988). Both wells employ the similar line shaft pumps. (See Table 7.3.)

Table 7.3
Warren Property Production Well Data (McKay, 1988)

	WE-1	WE-2
Flow/Head	450 gpm @ 180'	450 gpm @ 180'
Setting Depth	200'	200'
Size Bowls	10"	10"
No. Stages	5	5
Manufacturer	Ingersol Rand	Ingersol Rand
Horsepower	30	30
Variable Speed Drive	No	No
Drive Type	-	-
Manufacturer	-	-
Lubrication (shaft)	Water	Water
Well Depth (ft.)	833	685
Well Size (in.)	12"	12"
Temperature (°F)	200	200
Static Level (ft.)	102	110
Drawdown (ft.)	40' @ 450 gpm	23' @ 450 gpm

As a result operation of the system is such that WE-1 serves primarily summer duty and WE-2 primarily winter duty.

A summary of production pump materials appears in Table 7.4.

Table 7.4
Production Well Pump Material Summary WE-1, WE-2

<u>Component</u>	<u>Material</u>
Bowls	
Impellers	
Bowl Bearings	
Column Pipe	
Enclosing Tube	
Line Shaft	
Line Shaft Couplings	
Bowl Shaft

Figure 7.1 WE-1 Details
(REMC0, 1985)

Figure 7.2 WE-2 Details
(REMC0, 1986)

There is no automatic control system for the production well pumps. The pumps are manually started at the well head disconnect switches. Figure 7.3 presents a simplified sketch of the production facility piping. Piping from WE-2 to the central mechanical room is direct buried Schedule 40 carbon steel piping. This piping (275 ft.) was field insulated with polyurethane foam encased in a polyethylene wrap (McKay, F, 1988).

Problems/Solutions/Modifications

The only problems experienced thus far with the production well pump has been failure of the line shaft bearings. This occurred on one occasion for each pump. In each case this failure occurred immediately following a power outage. Originally the pump controls were arranged to allow for automatic restart in such instances (following an outage). When the pump attempted to start approximately half the bearings were "dry" due to the 100' static level and 200' setting depth. It is thought, by the operator, that this led to insufficient lubrication of the rubber bearings and subsequent vibration and failure (McKay, F, 1988). In one case, the pump shaft and section of column were twisted off by the dry bearing resistance.

After the failures, all bearings in the pumps were replaced. In addition, the pump motor control was modified for manual restart after shut down. Prior to starting the pumps, water is flushed down the column to "wet" the bearings and prevent dry operation.

Central Mechanical Room

The central mechanical room for the Warren property system is located between the two main service areas for the development as shown in Figure 7.5. The building contains heat exchangers, circulating pumps, expansion tanks, and controls for the two main loops.

The operation of the equipment is much the same as other systems which employ a closed loop for distribution. Geothermal water from the production wells is delivered to the plate heat exchanger in the central mechanical room. Modulating 3-way valves control the flow to (or past) the heat exchangers according to system load requirements. On the loop side of the exchangers, circulating pumps supply the individual loops with hot water. Each loop includes an expansion tank for pressure control.

Table 7.5 provides information on the loop heat exchangers. Although each loop serves a different number of residences (Warren Estates 69 homes, Manzanita 100 homes) both heat exchangers are of the same design (materials surface area, etc.).

Figure 7.3 Production Well Head Piping Diagram

Temperature control is maintained by Honeywell 3-way, motorized valves. These valves respond to aquastats located in the supply water line in the mechanical room to maintain a temperature of 160°F.

Table 7.5

Loop Heat Exchangers Data - Warren Property System

Geothermal Water	In/Out (°F)	200°/113°
Loop Water	In/Out (°F)	110°/164°
Flow Rates	Geo/Loop (gpm)	200/300
Heat Transfer Area	(ft ²)	395.6 ft ²
No. Plates		-
Plate Material		304 SS
Gasket Material		Nitrile
Manufacturer		Tranter
Duty		7.9 X 10 ⁶ btu/hr

Figure 7.4 provides a diagram of the major components of the Manzanita Estates loop. The Warren Estates loop is identical with the exception of the circulating pump horsepower.

All piping in the central mechanical room (loop and geothermal) is constructed of 4" copper (ASTM B-280 ACL). Connections are primarily brazed using copper/phosphorous filler material (AWS BWP-2).

Valves used in the mechanical room are all of the gate type. They appear to be of standard bronze body, rising stem construction. Most connections are of the sweat type. The manufacturer is Toyo (Red White) Figure 207A Class 125.

Circulating pumps are manufactured by Gould. The Manzanita loop includes two 7.5 hp pumps and the Warren loop two 5 hp pumps. All pumps are standard bronze fitted construction and rated for 80' head. Only one pump is required for normal operation with the second for standby. All pumps are constant speed.

The Honeywell 3-way control valves (one per loop) are of iron body, flanged connection construction. It is reported that these contain stainless steel trim materials (McKay, G., 1988).

Central mechanical room instrumentation consists only of rudimentary temperature and pressure gauges at key points on the loop. No continuous recording is employed for btu or flow rate in the mechanical area. Production line (geothermal) temperature and

Figure 7.4 Meter Room Piping (Aspen, 1986)

pressure is monitored through connections to a telephone auto dialer. Should either values fall below a preset limit, the auto dialer calls the operator and notifies him of the problem.

One novel aspect of this system is the ability to "backwash" the heat exchangers. Backwashing is performed periodically based on pressure drop across the units.

Problems/Solutions/Modifications

The system has been largely trouble free. The only equipment replacement or service required was related to the circulating pump seals (McKay, F., 1988), (McKay, G., 1988), (Flynn, 1988), (Baker, 1988).

Distribution System

The Warren property system is really two separate systems: the first of which (Warren Estates) was installed in 1982 and the second (Manzanita Estates) installed in 1985. With regard to central mechanical equipment, as discussed above, both systems are nearly identical. In the distribution area, however, each is unique.

Warren Loop

The Warren loop was installed in 1982. This loop was constructed entirely of pre-insulated fiberglass piping material for both supply and return lines. Figure 7.5 presents a layout of the system. Table 7.6 presents a summary of piping information for the Warren loop.

Table 7.6

Piping Information Summary - Warren Loop

Total Installed Length		-	6" - 1100
		-	4" - 3200
		-	3" - 2800
		-	2" - 5350
Total		-	12450 (6225 ft. Trench)
Piping Type	Carrier	-	FRP, (Ameron 1600, 210 ⁰ max)
	Insulation	-	Nominal 1" polyurethane (w 16/ft ³ k = .13)
	Jacket	-	PVC
Connections	Connections	-	Epoxy Adhesive (Quick Lok)
Supplier		-	Rovanco (Ameron Carrier Pipe)

Figure 7.5 Warren Estates Distribution Layout
(Dinter Engineering, 1981)
Scale: 1" = 150'

All of the piping in the Warren loop is direct buried. Installed under the streets, the piping serves a total of 69 properties in the loop. A total of 34 2-inch branch lines deliver fluid to the individual lots. The 2-inch lines are all connected to the main distribution lines using tee fittings. No saddle taps were employed. Most branch lines serve two lots (Baker, 1988).

From the 2" fiberglass branch lines, 1 1/2" lot connection lines deliver water to a buried 2' x 3' precast concrete valve box at each lot. This valve box contains the supply and return shut off valves for each residence in addition to the btu meter.

Isolation and crossover valves are located at each major lateral in the system. These valves are located in prefabricated 2' x 4' concrete vaults, equipped with traffic covers. All of these boxes are located in the street. Isolation valves in all instances are Keystone Figure 228 resilient seated butterfly type. Balancing valves are located at strategic locations to assure minimum flow in the system at all times. The balancing (or crossover) valves are of the same design as the shutoff valves with the exception of having the additional feature of memory stop.

Manzanita Loop

The Manzanita loop was installed in 1986. This loop is constructed entirely of pre-insulated steel piping with welded connections. Figure 7.6 presents a layout of the system. A summary of piping information appears in Table 7.7.

Table 7.7

Piping Summary - Manzanita Loop

Total Installed Length		- 8"	320
		- 6"	4360
		- 4"	4460
		- 3"	3180
		- 2"	1690
		- 1 1/2"	6600
Total		-	20610 lf (10305 ft. Trench)
Piping Type	Carrier	-	Carbon Steel, Schedule 30
	Insulation	-	Polyurethane 3.5 lb/ft ³
	Jacket	-	Polyurethane
	Integral Leak Detection System Equipped		
Connections	Welded		
Manufacturer	Ecopipe

Figure 7.6 Manzanita Estates Distribution Layout
Scale: 1" = 180'

In addition to the piping, all valves and fittings were supplied by Ecopipe. No information was available on the details of the balance of the distribution system equipment.

With the exception of piping materials, the branch line arrangement to each valve box is the same as that employed in the Warren loop.

Problems/Solutions/Modifications

When the Warren loop was originally constructed it included only a small circulation pump (1 1/2 hp) to maintain a minimum loop flow rate. Individual homeowner pumps were employed to provide the primary circulation requirements. Since each home was custom built, pump details varied. As a result flow balancing was nearly impossible. In some cases, reverse flow actually occurred in the system (Baker, 1988).

To address this situation, two types of modifications were made: larger main circulation pumps were installed in the central mechanical room, and certain system crossover connections were modified to eliminate looping in the distribution lines. These modifications were largely successful. A few homeowners still employ their own circulation pumps despite the fact that this is no longer necessary (Baker, 1988).

Customer Connections and Metering

Customer connections for the Warren system consist only of a concrete valve box located at the corner of each property. The valve box contains two 1 1/2" ball valves and a btu meter. Batt type fiber glass insulation is placed over the lines in the valve box and the btu totalizing unit is placed on top of the insulation. Table 7.8 provides details on the btu meter used in the Warren system.

Table 7.8

Warren Property Btu Meter Information

Manufacturer	- D. K. Enterprises
Model	- 323
Size	- 1 1/2"
Number of Meters	- 169 (when all lots are occupied)

Problems/Solutions/Modifications

The only problem experienced with the metering is that of moisture. The meters, as described above, are installed in buried concrete valve boxes. Due to the extensive use of irrigation and the sloping nature of the development, these boxes tend to accumulate water. As a result, the meters are constantly exposed to moisture. This results in premature failure of the electronic unit.

As yet, no solution has been found for this problem, though it maybe advisable to move the btu meters out of the valve boxes and into the residences with a remote display unit in the outside of the building.

Disposal

All geothermal fluids produced in the Warren property system are disposed of in an injection well. This well is located approximately 1500 feet east of the central mechanical room.

Fluid is delivered from the mechanical room to the injection well through a direct buried, 6" Schedule 40 carbon steel pipe line. Expansion loops are located along the route.

A totalizing flow meter, manufactured by Water Specialties, Porterville, California, (#871060), is installed in the injection line just outside the mechanical room wall.

The following description of the injection well completion and testing are taken from "Drilling, Completion and Testing: Warren Estates Geothermal Well WE-3" by REMCO - Earth Sciences Division, Reno, Nevada, published in August 1985.

Casing and Cementing

"Figure 7.7 illustrates the completed well. After reaming the pilot hole to a diameter of 17.5 inches, the 12-inch diameter casing was set to a total depth of 1090 feet. The ends were butt-welded and centralizing straps were welded at approximately 30 feet intervals. Water was circulated in the hole for several hours prior to cementing.

Approximately 34 cubic yards of 17 sack neat cement were pumped through the mud pump, into the casing, and up the annulus of the well. The cement contained approximately 2% bentonite to reduce shrinkage during and after the curing process. After pumping for approximately 90 minutes the first returns of cement were observed in the discharge stream. Pumping continued for several minutes to insure a complete seal. When the cementing was completed, the surface

casing was removed and the cement fell back to a point approximately 15 feet below the surface of the ground. A "top-job" was completed the next day bringing the cement to the surface."

Injection Testing

"A six-inch diameter, 0.188-inch wall, welded steel injection pipeline was installed from WE-2 and WE-1 to WE-3. The six-stage, diesel-powered turbine pump set for the pump test of WE-2 was used to supply injection fluids for the test. Testing began on August 3rd and continued through August 6th.

On the morning of August 3rd, a 72-hour injection test of WE-3 was initiated at a flow rate of 450 gpm and an engine speed of 1100 rpm. These rates remained constant throughout the test. Water levels were monitored in both WE-2 and WE-3. Monitoring of WE-1 was abandoned because that well had to be pumped intermittently to supply Unit 1 with heat.

After 72 hours of continuous injection at 450 gpm, the water level in WE-2 was 1 foot above the static water level of 110 feet. This was due to the pressure wave from WE-3 increasing the hydraulic head within the aquifer. This indicates the wells are hydraulically connected. This was not unexpected, as the welder for the pipeline noted he could arcweld using the water between the wells to complete the electrical circuit.

Throughout the test the water levels in WE-3 were monitored. These data show the water level increasing as a logarithmic function of time. At the end of 72 hours the water level was at 14 feet 11 inches, an increase over the static level of 103 feet. Using this methodology, this gives an injectivity of 8500 gal/day/ft. This is approximately 1/3 of the transmissibility of 22,690 gal/day/ft., which is consistent for injection into confined aquifers. In addition to the injection test, a recovery test of WE-3 was performed. This test gives an injectivity value of 8000 gal/day/ft. which is in good agreement with the injection test value. Noting that the overall average production from the aquifer will be approximately 200 gpm, not the 450 gpm maximum flow rate, the static water level after 20 years continuous pumping would be 51 feet below the surface. These calculations suggest that the Warren Estates can inject the fluids produced for space heating over the lifetime of the project.

Figure 7.7 Injection Well Details

Temperature of the injected fluids was 210°F during the test. This is the same temperature measured during the pump test of WE-2. Although this injection test was too short to accurately predict long term effects, it appears that there is little flow from WE-3 to WE-2. Further monitoring of production temperatures over long periods of time will provide the information necessary to evaluate interference effects between the production and injection wells."

Problems/Solutions/Modifications

None.

References

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PAGOSA SPRINGS

Introduction (Martinez, 1988)

The town of Pagosa Springs, along with Archuleta County and School District 50, applied for, and received a total of approximately 1.4 million dollars of U.S. Department of Energy grants to test the aquifer, drill production wells and design and build a geothermal utilization system. The project began in the spring of 1978 and was completed in December of 1982. The original design called for the utilization of a 2,000 gallon per minute flow of geothermal fluid from the wells to serve 63 residential, 54 commercial and 10 public users. This design incorporated two production wells operating simultaneously, a closed-loop distribution system consisting of 2 plate-type heat exchangers, 4 circulating pumps, and 17,600 feet of supply and return lines with associated automatic controls and accessories. Monitoring and control of the system was to be done with a micro-computer to be located at Town Hall.

Due to the necessity of drilling additional wells in order to tap higher temperatures and production capabilities within the aquifer, along with construction cost increases, it was necessary to cut back on the original design by eliminating 1 heat exchanger, 2 circulating pumps, 6,200 feet of pipeline and some of the control associated with the automatic operation of the system. At a later date the town received additional funding of \$44,000 dollars which was used to construct 2,500 feet of line to serve a low-to-medium income area in town.

The town also experienced difficulties in obtaining the production permits and water rights necessary for full utilization of the system even with the modified design. It became necessary to enter into several heating seasons during which data was collected while operating under an "interim production testing permit" issued by the State of Colorado.

The system has operated at several flow rates from one well, PS-5, and has determined that a production rate of 450 gallons per minute can serve the 6 businesses, 3 schools, Town Hall, a church and part of the County Courthouse, all of which are on line at this time, and still be able to expand its coverage by probably 70 to 100 percent. At this flow rate, it is the Town's opinion that no damaging effects have been caused to other well owners.

Negotiations are currently underway with the owners of geothermal wells in an attempt to purchase water rights from the Pagosa Springs Aquifer. The acquisition of these rights would enable the Town to utilize the aquifer more efficiently and hopefully to ensure continuous use from this aquifer for at least 100 years.

The State of Colorado, through the office of the State Water Engineer and the District Court in Archuleta County has awarded the Town Production Permits and Conditional water rights for 450 gallons per minute from production wells PS-3 and PS-5. The issuance of these permits will allow the Town to proceed with its efforts in securing more geothermal customers.

Table 8.1 presents a summary of key information regarding the Pagosa Springs System. Fluid chemistry appears in Table 8.2.

Table 8.1

Key Data - Pagosa Springs Geothermal District Heating System

Years of Operation	6
Number of Customers	11
Total Length of Piping	15,000
Resource Temperature	140°F
Delivery Temperature, Δt	135°/25°F
Peak Flow Capability	1,400 gpm
Disposal Method	Surface (River)
Customer Heat Exchangers	No (Central Heat Exchanger)
Number of Production/Injection Wells	2/0
Rate Structure	\$.38/Therm
Ownership Public/Private	Public
Original Financing	
USDOE	\$ 1,213,000 (81.5%)
City/County	274,620 (18.5%)
TOTAL	\$ 1,487,620

Contact Person:

Joe Dan Martinez
 Manager, Water Dept.
 Town of Pagosa Springs
 Box 265
 Pagosa Springs, CO 81147
 (303) 264-4151

Engineer of Record:

Eric Will, Kurt Mahnken
 Hydro-Triad, Ltd.
 12687 W. Cedar Dr., Suite 100
 Lakewood, CO 80226
 (303) 989-1264

Contractor:

Roseberry Plumbing & Heating

Table 8.2

Fluid Chemistry
Pagosa Springs Geothermal District Heating System (Anliker, 1981)

KEY SPECIES

pH	6.70	
Chloride	160.00	mg/l
Sulfate	1520.00	mg/l
Carbonate	0.00	mg/l
Bicarbonate	810.00	mg/l
Ammonia	Not Reported	
Hydrogen Sulfide	>5.00	mg/l*

OTHER SPECIES

Calcium	240.00	mg/l
Magnesium	22.00	mg/l
Sodium	640.00	mg/l
Potassium	87.00	mg/l
Iron	0.07	mg/l
Silica	61.40	mg/l
Nitrate (as N)	0.09	mg/l
Alkalinity (as CaCO ₃)	670.00	mg/l
Total Dissolved Solids at 356°F	3160.00	mg/l
Conductivity	4270.00	mho/cm

*Measured during Radian site visit

Production Facilities

Table 8.3 presents a summary of the production facilities included in the Pagosa Springs System. At the present time only well PS-5 is connected to the transmission line. Well PS-3 is not connected, but is located only a matter of feet from the line.

Table 8.3

Pagosa Springs Geothermal System - Production Facilities

	<u>PS-3</u>	<u>PS-5</u>
Flow/head	600 (artesian)	800/90'
Setting Depth	N/A	Surface
Size bowls (in.)	N/A	N/A
Number of Stages	N/A	1
Manufacturer	N/A	Paco
Horsepower	N/A	25
Variable Speed Drive	N/A	No
Drive type	N/A	N/A
Lubrication	N/A	N/A
Well Depth	300	274
Well Size	9 5/8 to 232, 8 3/4 open to 300	Same
Temperature (°F)	131	149
Static level	artesian	artesian
Drawdown	N/A	N/A

Due to the artesian nature of these wells, production well pumps were not required. However, in order to allow for sufficient flow at the pressure drop imposed by the system equipment, surface pumps were included in the original design. Table 8.4 presents a summary of materials information on the surface pump originally specified for well PS-5.

Table 8.4

Materials Summary - Surface Pump - Well PS-5 (Roseberry, 1982)

Casing	Gray Cast Iron	ASTM AAB Class 30
Impeller	Gray Cast Iron	ASTM AAB Class 30
Wear Rings	Stainless Steel	AISI 316
Shaft	Stainless Steel	AISI 303
Shaft Sleeves	Stainless Steel	AISI 316
Mechanical Seal		
Seat	Ni Resist	
Washer	Carbon	
Elastomer	Buna-N	
Metal Parts	Brass	
Spring	Stainless Steel	AISI 316

This was a horizontal, split case, centrifugal with a capacity of 800 gm @90'TDH. Figure 8.1 presents a layout of the well head equipment at Well PS-5.

Figure 8.1 Well PS-5 Equipment Layout (Original Design)
(Roseberry, 1982)

The actual installation involved the location of the strainer upstream of the pump and outside the small "pump house".

The production well head is a fairly simple arrangement consisting only of 2 iron gate valves. The piping converts to fiberglass material (Bondstrand 2000) at the upper flange of the second gate valve. Above this, a tee delivers the production stream to the strainer through the branch connection. The run connection of the tee is attached to a short length of vertical pipe which forms a gas trap. An automatic air vent periodically vents the trapped gases.

From the pumphouse Schedule 40 steel piping connects to the buried, 10" asbestos cement line which delivers the fluid to the mechanical room.

Figure 8.2 shows a detail of the construction of Well PS-3.

Figure 8.2 Well PS-3 Completion Detail (Lunis, 1986)

Problems/Solutions

During the early startup and testing of the system a vibration problem developed with the booster pump after approximately 6 months of operation (Lunis, 1986). The pump was repaired under warranty by the manufacturer.

Due to the very low initial load on the system, it was discovered that use of the booster pump was not necessary. The artesian

pressure of the well provided sufficient head for operation of the system under these conditions. As a result, the booster pump is not currently connected to the system (see Figure 8.3).

Another minor difficulty was associated with the strainer. The original maintenance plan involved periodic blowdown of the strainer (Figure 8.4) on a regular basis. Because some of the city maintenance workers were reluctant to deal with the hot water well, this procedure was not regularly attended to. In fact, it is reported (Martinez, 1988) that the strainer was not blown down for a period of several years. At that time a decreasing flow rate was becoming apparent. The city geothermal superintendent investigated the situation and discovered the cause (plugged strainer). The staff was instructed in the proper operation of the blow down valve and the problem has not reoccurred.

There has been some deterioration of the exposed fiberglass piping in the well head area (Figure 8.5). This piping has lost entirely the outermost layer of resin. This has exposed the reinforcing material which has begun to fray and weather. Plans are in place to have a factory representative examine this piping.

The automatic air vent valve is of standard brass and steel construction. Despite its constant exposure to geothermal fluid and air, it has functioned well since startup of the system.

The lack of production well pumps in this system has resulted in a greatly reduced down time and maintenance expense compared to the other systems evaluated in this report.

Central Mechanical Room

The basic design of the Pagosa Springs System is very similar to that of the Klamath Falls City System. The geothermal water is delivered to a central heat exchanger and heat is distributed to customers via a closed-loop distribution system.

The central mechanical room, as depicted in Figure 8.6 includes the central heat exchanger, circulating pumps, control and city water cross connection (for make up and pressurization).

Geothermal fluid from the production well enters the building and is passed through the main plate heat exchanger. A control valve, located on the exit side of the heat exchanger controls the flow rate.

All of the geothermal fluid piping inside the mechanical room is of fiberglass construction with flanged and epoxy adhesive type connections. Instrumentation taps employ a fiberglass saddle (Figure 8.6) containing a threaded bushing. This saddle is joined to the O.D. of the pipe with adhesive. Flanges are used to accommodate butterfly valves and connections to equipment.

An instrumentation design appears in Figure 8.6. Original design was based upon the use of a micro-computer for remote monitoring and control of the system (from the Town Hall). Due to budget difficulties, this arrangement was not installed. Instead the system is set up for local monitoring and control with standard electro-mechanical controls.

The following paragraphs detail the original control sequence and equipment: (Roseberry, 1982)

"CONTROL & INSTRUMENTATION

Schedule

PI	Local Pressure Indicator, Weksler Ea14, 0-200 psi loop, 0-100 psi geothermal
TE	Temperature Element, XacTohm RTD UE-2½
TI	Local Temperature Indicator, Weksler 3A04 3", 0-200 degrees Farenheit
TR	Temperature Recorder, COW Ohmic SCT-1345-1-100, 0-1 vdc output
TIC	Temperature Controller, Unviersal 61011, RTD input, 4-20 ma output
FE	Flow Élement, Robison Halpern 153A-P210-D-E-V31-W pressure differential transmitter, 0-1 vdc output
FI	Local Flow Indicator, Kent series 2000 turbine meter with local readout
FR	Flow Recorder, Ken RFT rate of flow transmitter, 0-1 vdc output
FRC	Flow Controller, Kent RFT to Cow Ohmic SC-1455 relay
FAH	Flow Alarm High, Cow Ohmic SC-1455 relay
FSHH	Flow Switch Hi Hi, Cow Ohmic SC-1455 relay
FS	Flow Switch, McDonnel Miller FS7-4V, spdt
TDR	Time Delay Relay, Mars/Line 32366 time delay relay
SS	Selector Switches, Centerlab JV-9000 series
IL	Indicator Panel Lights, Allen Bradley bulletin 800T with green lens
HOA	Hand Off Auto Switches, Allen Bradley 800T-B60
OCA	Open Close Auto Switches, Allen Bradley 800T-B60
AL	Alarm Light, Red Dot VX-21 with VGLR red lens and guard

SEQUENCE OF OPERATION

Temperature Control

Temperature at the loop supply is maintained at a variable set point by a Demco 10" 2155-5120319 butterfly valve with a reverse proportional 5065-1367392 actuator. A Universal 61011 panel mounted set point controller receives a signal from RTD-6 and positions the valve to maintain a constant loop supply temperature.

Figure 8.3

Interior of Well House
S-5 showing disconnected
booster pump.

Figure 8.4

Exterior of Well House
S-5 showing Production
Well and strainer.

Figure 8.5

Closeup view of UV
degraded fiberglass
piping at well head PS-5.

Figure 8.6 Central Mechanical Room Instrumentation and Piping Diagram (Lunis, 1986)

Circulating Pump Control

Circulation of loop water is maintained by a Cow Ohnmic SC-1455 dual relay. The relay receives a signal from FRC (Kent RFT Transmitter) and at the variable set point will turn on pump #2 when system load reaches flow in excess to pump #1 capabilities. If pump #1 should fail, pump #2 will then be started by FS-1 Flow Switch. SS-1 Selector switch allows selection of lead, lag and sequencing of pumps. Each pump has manual control with a hand-off-auto switch and a time delay relay to keep pumps from searching. The panel contains provisions for future addition of relays, switches, etc. to allow for operation of four pumps. See block wiring diagram.

Well Pump Control

Well pump shall start with circulating pumps automatically through an interlock with the circulation pumps. Each pump has manual control with a hand-off-auto switch and a time delay relay to keep pumps from hunting. Also a remote disconnect and hand-off-auto switch at the pump.

Recording Controls

The following read outs will be provided to a terminal strip mounted on a 12" isolated panel for computer interlock by owner.

1. Total Loop Flow, 0-1 vdc signal from FM-1 to terminals 1 & 2.
2. City Make Up Water, 0-1 vdc signal from FM-2 to terminals 3 & 4.
3. Hi Alarm, dry contacts from R-2 Relay to terminals 5 & 6.
4. Hi Hi Alarm, dry contacts from R-2 Relay to terminals 7 & 8.
5. Loop Supply Temperature, 0-1 vdc signal form TM-1 to terminals 9 & 10.
6. Geothermal Supply Temperature to HX-1, 0-1 vdc signal to terminals 11 & 12.
7. Geothermal Leaving Temperature from HX-1, 0-1 vdc signal to terminals 13 & 14.
8. Loop Return Temperature to HX-1, 0-1 vdc signal to terminals 15 & 16.
9. Loop Supply Temperature from HX-1, 0-1 vdc signal to terminals 17 & 18.
10. Total Geothermal Flow from PDT, 0-1 vdc signal to terminals 19 & 20.

Figure 8.7

Major Plate Heat
Exchanger

Figure 8.8

Main Loop Circulating
Pumps

Figure 8.9

Geothermal Piping in
Central Mechanical Room
showing instrumentation
saddle type taps.

Miscellaneous Control

A high flow alarm light is panel mounted to indicate high flow on make up. A Hi Hi flow switch is interlocked to control panel power and will turn all pumps off on city water make up Hi Hi flow. System emergency cut in valve will maintain loop water pressure at set point and a safety relief valve is provided for loop pressure safety control. All motors are protected by thermal overloads in the motor control center and control panel valves are fused internally in the control panel."

The loop supply water temperature is maintained by the main control valve downstream of the heat exchanger on the geothermal side. Circulation pumps are sequenced according to a signal from the loop flow meter. City water is cross connected to maintain a minimum low pressure of 60 psi.

The circulation loop piping is constructed entirely of Schedule 40 steel with welded connections. Main lines are 10" diameter. Table 8.5 presents key data on the main loop circulation pumps.

Table 8.5

Key Data - Loop Circulation Pumps

Manufacturer	Paco
Capacity	500 gm @ 160'
Type	Vertical, in-line
Materials	Bronze fitted
Seal	Mechanical
Seat	Ni-Resist
Washer	Carbon
Spring	Stainless Steel
Metal Parts	Brass (ASTM B-62)

Table 8.6 summarizes the key data relating to the main plate heat exchanger. Currently only one of these units is installed. However, the piping is arranged to accommodate a second unit if system growth warrants.

Table 8.6

Main Plate Heat Exchanger Data

Geothermal Water	in/out (°F)	140/113.9
Loop Water	in/out (°F)	107/136
Flow Rates	Geo/Loop (gpm)	1000/900
Pressure Drop	Geo/Loop (psi)	14.9/12.4
Heat Transfer Area		2650.5 ft ²
No. of Plates		326
Material		316SS
Gasket Material		NBR (Buna-N)
Manufacturer		Tranter

Problems/Solutions

The original design called for the use of 2 plate heat exchangers and four circulation pumps for a total loop flow rate of 2,000 gpm. Due to budget problems only half of this equipment was actually installed. In addition, the micro-computer based control system was deleted.

Despite this, the system has operated in a highly reliable manner. The current load is easily handled by a single circulation pump. In fact, plans are in place to down size one of the loop pumps since current operation requires that the original 500 gpm pump be throttled to reduce its capacity to system requirements.

Although only a single heat exchanger was installed, its capacity is far greater than that required by the system. In fact, during the site visit for this report, entering loop temperature and leaving geothermal temperature were equal according to the instrumentation. As a result of the extensive surface area available, fouling if any, inside the heat exchanger has not affected operation. The plate heat exchanger has not been opened for service in the 6 years the system has been operating.

Due to legal agreements, the system is presently operated at a maximum flow rate of 1.0 cfs (450 gpm) from the production well. If necessary, this flow is throttled back using hand valves. In the presence of automatic controls, this may seem a waste of manpower. Given the design of the system however, manual control is likely to produce the most stable operation. As with the Klamath Falls system, there is substantial excess capacity in the system. The main control valve was designed to handle a peak flow rate of 1,000 gpm. It is unlikely that this valve could accurately function at the low flow presently in use. As a result manual control of the system is appropriate until such time or growth demands higher flows.

Figure 8.10 Distribution System Layout

The only maintenance required thus far in the central mechanical room has been replacement of circulation pump seals. These items have exhibited a service life of approximately 3-4 years.

The automatic make up line to the system (city water connection) has been disconnected and is manually operated. The concern of the operating personnel is that the flow capacity of this line (4") could result in a substantial quantity of water use should a major piping failure occur.

An interesting aspect of this system is the lack of expansion tanks on the main circulating loop.

Distribution System

The layout of the distribution system for Pagosa Springs appears in Figure 8.10.

As with other portions of the project, the size of the distribution network was considerably scaled back in comparison to the original construction.

The final installation included 15,000 of piping supply compared to the 34,000 initially planned for.

All of the buried piping on the system is of epoxy lined, asbestos cement construction. Supply piping is insulated and return lines uninsulated. Table 8.7 presents a summary of the piping included in the system.

Table 8.7

Pagosa Springs Piping Summary

Insulated	6"	1,500 LF
	8"	3,250 LF
	10"	2,950 LF
Type		Class 150 AC Carrier, polyurethane insulation, AC jacket
Manufacturer		Johns-Manville (Temptite)
Uninsulated	6"	1,500
	8"	3,250
	10"	2,375
Type		Class 150 AC
Manufacturer		Johns-Manville
Fittings		Cast iron, gasketed, 250 psi

A burial detail is shown in Figure 8.11. Most piping was installed in unpaved alleyways and streets. As with most systems, supply and return lines were installed in a common trench.

Manholes containing air release valves are located at the high points on each of the main loops (East and West of the system). In addition, manholes are located at the ends of the East and West loops. In each of these a crossover is located as shown in Figure 8.12. These crossovers were installed to allow a minimum flow rate to pass from supply to return thus maintaining system distribution temperature.

With the exception of the "Methodist Church" loop, installed in 1985, there are no isolation valves in the system. Valving, located in the central mechanical building, is provided so that either of the loops can be shut down. Buried gate valves were included in the Methodist Church line extension. These valves were equipped with valve boxes and extension stems. The valves are of cast iron construction with iron trim. Specifications for these valves and system piping appear at the end of this chapter.

Problems/Solutions

During initial start up of the system leaks were discovered in a number of places. All of these leaks occurred at the couplings. Evidently, "rolling" of the gaskets occurred during construction. This is generally a result of improperly drawing together of the pipe and coupling or of inadequate lubrication or both. All of these leaks were repaired and none have reoccurred.

Another problem which surfaced early on related to system pressurization. This manifested itself as a slow upward pressure creep in the entire distribution system. This increase in pressure continued until the relief valves opened to vent the build up. Investigation resulted in the discovery that the flow control valves, located on the crossovers, in the end of the system were improperly installed. This was corrected and the problem eliminated.

Customer Connections/Metering

Although there were some preliminary drawings prepared for generic retrofits, actual installations are highly varied and rarely conform to these drawings.

A number of the customers are connected to the system with the components shown in Figure 8.13. There are no pressure regulating valves and as a result, the customer systems operate at pressures similar to those of the distribution system. (60 psi supply).

Figure 8.11 Typical Burial Detail (Hydro Triad, 1981)

Figure 8.12 Typical Crossover Station (Hydro Triad, 1981)

Figure 8.13 Typical Customer Connection

The connection consists only of two ball valves for isolation duty, a water meter for flow totalization and a temperature limiting valve for maintaining an adequate and predictable system Δt .

The temperature limiting valve currently in use is a 24 volt, motorized, two-way valve coupled to an aquastat mounted on the return line. These units are typically set to maintain a 110°F exit water temperature.

Table 8.8 offers a summary of the water meter data.

Table 8.8

Pagosa Springs Hot Water Meter Data

Manufacturer	- Kent
Type	- Single jet, inferential
Sizes	- 1" - 4"
Number of meters	- 6
Materials	- Not available

Problems/Solutions

As with many other systems, metering has been a difficulty in Pagosa Springs. Early in the operation of the system an attempt was made to use Btu meters for billing purposes. It is reported (Martinez, 1988) that six of these meters were installed and none worked properly. No information is available on the manufacturer of these meters.

The present arrangement is detailed above. The use of temperature control valves for assuring an adequate system Δt is common. Such valves are employed in the Klamath Falls, Susanville and Elko Heat Company systems.

The arrangement currently used in the Pagosa Springs system is somewhat different however. The aquastat/motorized valve approach is more expensive and likely to be less responsive than the self-actuated valves employed in the other systems. For this reason it is recommended that the operators of the Pagosa System consider the use of the self contained valves. These devices offer the advantages of reduced equipment costs and system complexity accompanied by increased performance.

In addition, it may be useful to consider the use of a small bypass line (around the temperature limiting valve) in order to increase the responsiveness of the system. Such a bypass will allow the temperature sensing element to "feel" the exit temperature on a continuous basis.

The general approach and controls used in building retrofits has also proven to be a problem in Pagosa Springs. The following is taken from a letter from Kevin Rafferty of the Geo-Heat Center to Joe Dan Martinez of the City of Pagosa Springs:

"In order to attract new customers, it is necessary for existing customers to be able to demonstrate a successful track record. It is in this area where Pagosa Springs seems to have a problem. Based on the buildings I had the opportunity to tour, operational problems appear to be entirely a result of the retrofit of the buildings, and not the fault of the district system.

The county courthouse is a good example. The upper portion of this building, which is connected to the district, is served by two air handlers, each of which contains a single water coil. River water is passed through these coils in the summer for cooling purposes and hot water from the district system in the winter for heating purposes. A manual piping switchover is performed to change from heating to cooling or vice versa.

The controls employed on each of these air handlers appear to be needlessly complex. Each unit has associated with it two thermostats (one for heating and one for cooling) and four control valves (two for heating and two for cooling). If my understanding of the system is correct, I see no reason why the installation could not have been accomplished with only a single thermostat and control valve for each unit. The presence of the six additional control valves and two thermostats adds unnecessary cost and complexity to the system, making it more difficult to maintain and operate. This complexity has resulted in unsatisfactory performance of the system.

In addition to the control problem, this retrofit also reportedly included exposed, uninsulated piping running up the side of the building. This practice, now corrected with insulation, can cause excessive heat loss to the hot water before it reaches the heating equipment. As a result, the heating equipment could be unable to supply proper temperature to the space. The piping could also be susceptible to freeze damage.

These problems, present in varying degrees in the other buildings on the district system, have a negative effect upon customer attitude. Despite the fact that the buildings are the real problem, dissatisfaction with the district system in general can result.

For this reason, it is critical to the growth and survival of the district system that the town play a role in assuring that building retrofits are accurately accomplished. Depending upon local preference, this role could be advisory or regulatory in nature."

Disposal

The Pagosa Springs System employs surface disposal to the San Juan River. The river is located within 200 yards of the central mechanical room. Effluent from the system is delivered to the discharge point through a buried uninsulated 10" PVC line. This line discharges into a small pond above a fiberglass weir structure. Discharge from the weir flows directly into the San Juan River.

Problems/Solutions

As expected this method of discharge is quite trouble free, the only problem encountered thus far has been with the measuring weir. The initial structure was constructed of steel. As a result of the constant exposure to air and geothermal fluid this arrangement quickly failed. The original materials were replaced with a custom made fiberglass weir. This unit has served well.

Plans are in place to install a level recording instrument on the weir so that totalized flows may be obtained.

There is some evidence of deterioration of the 10" PVC at the outfall. Exit temperatures of the system are higher than expected as a result of the low load on the system. Despite this, no failure of the piping has occurred.

SELECTED SPECIFICATIONS (Roseberry, 1983)

ASBESTOS-CEMENT PIPE

Description:

The work shall include furnishing and installing the different sizes of pipe and fittings as shown on drawing.

Materials:

All pipe and couplings shall be manufactured and tested in accordance with "AWWA Standard for Asbestos-Cement Pressure Pipe for Water and Other Liquids", AWWA C-400.

UNINSULATED PIPE - Epoxy-lined asbestos-cement pressure pipe of the sizes indicated on the plan drawings and shall be Class 150, such as the type pipe manufactured by Johns-Manville with the trade name of "Transite" or a similar type as supplied by Rovanco Corporation.

INSULATED PIPE - Epoxy-lined asbestos-cement pressure pipe, such as the type pipe manufactured by Johns-Manville, with the trade name of "Temp-Tite", or a pre-insulated epoxy-lined asbestos-cement pressure pipe manufactured by Ravanco Corporation, of the sizes indicated on the plan drawings.

COUPLINGS shall be the same class as the pipe. Manufacturer shall furnish rubber-ring gasket lubricant for each quantity of pipe furnished. The rubber rings shall be of uniform solid cross-section and conform to ASTM D-1869 "Rubber Rings for Asbestos-Cement Pipe."

FITTINGS - All fittings shall be cast-iron pressure fittings with a pressure rating of 250 psi and "Ring-Tite" bells conforming to AWWA Standard C-110.

The contractor shall furnish certification, by the manufacturer of the pipe to be furnished on this project, that the pipe and fittings comply with the applicable specifications.

TS-4 MECHANICAL

Gate Valves:

The gate valves shall be furnished in sizes as shown on the drawings and be equipped with manual operators. The gate valves to be used for buried service shall have the axis of the leaf horizontal when the leaf is in the installed position. The gate valve shall be equipped with valve boxes and extension stems for square nut operation. They should be equal to Nibco Class 125 iron body and iron trim gate. Catalog No. F-619-N. flanged.

Figure 8.14 Pagosa Springs System Disposal Point Showing Well

TS-2 STEEL PIPE

Description:

The work shall include the furnishing and installing of the different diameters of steel pipe as shown on drawings.

Materials:

All steel pipe 6 inches and larger shall be fabricated and tested in accordance with "AWWA Standard for Steel Water Pipe 6 inches and Larger", AWWA C200-75. Pipe less than 6 inches shall be Schedule 40.

All fittings shall be in accordance with "AWWA Standard for Steel Water Pipe Fittings", AWWA C208-59.

All flanged sections, as called for in the plans, shall conform with "AWWA Standard for Steel Pipe Flanges", AWWA C207-55.

Construction:

All field welding of steel pipe shall be in accordance with "AWWA Standard for Field Welding of Steel Water Pipe", AWWA C206-75.

Trenching to be in accordance with the provisions of Section TS-3.

All exposed steel that is to be buried shall be given two coats of CA-1200 Mastic cold coating, or equal, as manufactured by Protecto Wrap Company, Denver, Colorado.

All pipe shall be stored and handled according to the manufacturer's recommendations.

Pagosa References

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ELKO COUNTY SCHOOL DISTRICT SYSTEM

INTRODUCTION

The Elko County School District (ECSD) geothermal district heating system was dedicated on Oct. 14, 1986. The system has been continuously operating since that time delivery the heating needs of a number of municipal users including;

Junior High School
High Schools
Centennial Gym
School District Administration offices
County Hospital
City Hall
Convention Center

Development of the system was an outgrowth of an unexpectedly high temperature well originally drilled to serve a loop heat pump system at the new Junior High School. This well, expected to be of relatively low temperature instead produced 190°F fluid. As a result, the district system was implemented.

A single well capable of flowing approximately 300 gpm serves the system. This well, due to artesian conditions is able to meet system requirements a majority of the time without the need of a pump. During peak load periods a surface pump supplies the required flow. Central heat exchangers are employed and a closed loop distributes heat to the end users. In addition, individual customer heat exchangers are employed.

Table 9.1

Key Data - Elko County School District Geothermal System.

Years of Operation	2
Number of Customers/ft ²	4/n/a
Total Length of Piping	11260 lf
Resource Temperature	190°
Delivery Temperature/ Δt	180°/100° (Δt is for entire system-individual buildings vary)
Peak Flow Capability	290 gpm
Disposal Method	Surface (River/Irrigation)
Customer Heat Exchangers	Yes (also Central Heat Exchanger)
Number of Production/ Injection Wells	1/0
Rate Structure	None - Users contribute to system maintenance fund.
Ownership Public/Private	Public

Original Financing

USDOE - \$ 250,000
Participants - 1,250,000
\$1,500,000

Contact Person:

Mr. Steve Bowers
Elko County School District
1092 Burns Road
Elko, NV 89801
(702)738-5196

Engineer of Record:

William Petty, P.E.
Petty and Associates
960 Matley Lane, Suite 4
Reno, NV 89502
(702)329-5177

Table 9.2**Fluid Chemistry - ECSD Geothermal System (Bugenig, 1985)**

Key Species

<u>Constituent</u>	<u>PPM</u>
pH	645.00
Chloride	18.00
Sulphate	71.00
Carbonate	0.01
Bicarbonate	500.20
Ammonia	Not available
Hydrogen Sulfide	0.60

Other Species

Fluoride	1.86
Calcium	68.90
Potassium	180.00
Magnesium	12.50
Sodium	36.50
Iron	1.80
Silica	77.80
TDS	645.00

The system is operated for the mutual benefit of the existing users and there is no formal rate structure according to the Interlocal Agreement. Each user contributes annually to an O&M fund which is

used to pay system expenses. The school district acts as operator for the central mechanical room and distribution system.

This system is particularly noteworthy in terms of heat extraction. The design Δt for the distribution loop is 100° (180° supply - 80° return). This level of performance is achieved by cascading individual use such as space heating to domestic hot water. In addition, certain individual systems capable of operating at very low temperatures are placed in series with the main distribution loop return line. These include the municipal pools and the loop heat pump system at the Junior High School.

Production Facilities

The ECSD system operates from a single production well located adjacent to the Junior High School. This well (Figure 9.1) has a shut in pressure of 25 psi and will, as a result of artesian flow, meet system requirements most of the time without the use of a pump. Table 9.3 presents a summary of production facility information.

Table 9.3

ECSD Geothermal System - Production Facilities Data

Flow Head	300 gpm @ 75'
Setting Depth	Surface
Size Bowls (in)	N/A
Number of Stages	2
Manufacturer	Bell and Gossett
Horsepower	10 hp
Variable Speed Drive	Yes
Drive Type	Variable Frequency
Lubrication	N/A
Well Depth	1970'
Well Size	10 (to 1000'), 8" (to FD)
Temperature	190°
Static Level	25.5 psi Shut in
Drawdown	22.8 psi @ 294 gpm

Under peak conditions a pump is required to provide adequate flow through the main heat exchangers. A surface pump was selected for this duty. Due to the elevation (5000') and the high temperature of the fluid (190°F) there is the potential for a very low available net suction condition. To address this, the designer selected a pump designed specifically for such applications. As shown in Figure 9.2 this unit contains two impellers. The first, of a propeller type configuration feeds the second or main impeller.

ELKO JR. HIGH SCHOOL WELL CONSTRUCTION & LITHOLOGIC LOG

Figure 9.1 Production Well Details (Bugenig, 1985)

Figure 9.2 Section View of Production Pump

Table 9.4

Materials Summary Surface Pump

Case	Cast Iron
Impeller	
Shaft	
Seal	Mechanical
Manufacturer	Bell & Gassett
Model	B-17 Combination 358

The pump is controlled from the central mechanical room located in the Junior High School. A variable speed drive, with loop supply water temperature as the control input, determines the speed of the production pump. Control of the pump will be discussed in greater detail in the Control Mechanical Section. During most of the year the pump is not in operation; however, the production stream is directed through the pump at all times. Figures 9.3 and 9.4 present a layout of the production well head area.

All of the components are located in a concrete vault at the well head. Piping is all Schedule 40 carbon steel with grooved end (Victaulic Style 07) flex type connections. Although valves are indicated as gate type on the original drawings, butterfly valves were actually installed with the exception of the existing 12" gate on the top of the well casing. Table 9.5 provides a summary of valves materials.

Figure 9.3 Production Well Vault Plan (Petty, 1985)

Figure 9.4 Production Well Vault Section (Petty, 1985)

Table 9.5

Well Head Valve Materials - ECSD System (Vietti, 1988)

Body	Cast iron
Seat	Buna-N
Stem	316 SS
Disc	Bronze
Manufacturer	Victaulic

Piping from the production well to the central mechanical room, a distance of approximately 80 ft is of direct buried, preinsulated steel construction. This is the same as the material employed for construction of the main system distribution loop and is described in Table 9.9 of the Distribution System Section.

Problems-Solutions/Modifications

None

Central Mechanical Room

The central mechanical room for the ECSD system is located in the Junior High School. This area contains all of the mechanical equipment and controls for the main distribution loop. Figure 9.5 presents a piping and control schematic for the mechanical room. The following, from the original construction documents (Petty, 1985) describes the sequence of operation.

"Temperature Control Panel - 3 (TCP-3)

General: Panel disconnect switch closed energizes the Btu meters and the domestic hot water temperature controls.

Domestic hot water: Controller 3 modulates temperature control valve TCV-1 to maintain 120 degrees F. Supply water at temperature sensor TS-1. Circulating pump 3 de-energized opens flow switch FS-1. Closing normally closed valve TCV-1.

Temperature Control Panel-4

General: Panel disconnect switch closed energizes temperature controller 4. Variable frequency drives 1 and 2, and pressure control valves 1-4.

Figure 9.5
Central Mechanical Room Flow and Control Scheme
(Petty, 1985)

Heat exchanger pressure control: Panel mounted pressure switch 5 positioned to the lead heat exchanger opens pressure control valves PCV 1 and 2 for HX-1B or PCV 3 and 4 for HX-1A. Pressure at differential pressure controller PC-1 exceeding 20 psi opens the pressure control valves to the lag heat exchanger pressure dropping below 4 psi at PC-1 closes the valves to the lag heat exchanger.

Heat exchanger temperature control: Temperature controller 4 modulates normally closed temperature control valve TCV-3 to maintain the main supply temperature of 180 degrees F. At temperature sensor TS-2. TCV-3 position at 100% open, starts well pump P-3. TCV-3 positions at 5% open stops P-3. The TCV-3, S.P.D.T. floating aux switch increases pump P-3 rpm at the 80% open valve position and decreases P-3 rpm at the 50% open position via variable frequency drive VFD-1. Water flow at flow switch PS-2 ceasing shuts TCV-3 and de-energizes P-3.

Main distribution flow and pressure control: Communications module 6 increases or decreases circulating pump P-4. Rpm to maintain a 7 psi differential pressure across the supply and return lines at the centennial gym heat exchangers. The rpm of P-4 is controlled by variable frequency drive VFD-2."

The major components originally included in the mechanical room consisted of:

- 2 Plate Heat Exchangers (in parallel)
- Loop Circulating Pump and Variable Speed Drive
- Expansion Tank
- Operating Controls
- Main Loop Btu and Flow Meter
- Variable Speed Drive for Well Pump

Geothermal fluid from the production well is delivered to the two main loop heat exchangers to maintain loop temperature. Depending upon system load, one or both heat exchangers may be in service. Originally, staging of the heat exchangers was accomplished by a controller sensing differential pressure (loop side) across the lead heat exchanger. This controller operated valves PCV-1 through 4 which directed flow through the two main heat exchangers (HX-1A and HX-1B). As the pressure drop exceeded a preset value the second heat exchanger was brought on line. Loop supply water temperature is controlled under low load by a two-way valve located on the geothermal disposal line (TCV-3). This valve modulates to control the artesian flow from the well. When this valve has modulated to the full open position, the variable speed drive controlling the well pump is enabled. From this point to design

flow the loop supply water temperature is controlled by the variable flow from the well pump. Table 9.6 presents key information concerning the loop heat exchanger.

Table 9.6
ECSD Loop Heat Exchanger Data

Number of Units	2 (parallel)
Geothermal water in/out (°F)	190°/90°
Loop water in/out (°F)	80°/180°
Flow (gpm)	150
Pressure drop	13.6
Area (Ft ²)	820
Number of Passes	4
Number of Plates	129
Gasket material	Nitrile
Plate material	316 SS
Manufacturer	American Viacarb Inc.

All automatic control valves in the main mechanical room (PCV's and TCV-1) are butterfly type and were originally equipped with electric motor actuators. Materials employed in these valves are detailed in Table 9.7.

Table 9.7
Control Valve Materials - ECSD System

Type	Butterfly
Seat	EPDM
Stem	416 SS
Disc	Aluminum Bronze
Manufacturer	Keystone 22B

Instrumentation originally located in the main mechanical room consisted of:

- Loop Btu Meter
- Geothermal Water Meter
- Standard Pressure and Temperature Gages

The Btu meter located on the loop side of the heat exchangers is used to monitor the total quantity of heat provided by the system and to provide a check on the accuracy of the Btu meters located in the individual user buildings.

The geothermal flow totalizing meter located on the main disposal line provides information regarding the total usage of geothermal fluid. Table 9.8 provides information on these meters.

Table 9.8

ECSD Mechanical Room Meters

Btu Meter

Size	4"
Manufacturer	Sonceboz
Model	323 WP
Displays	Total Btu Total gallons
Intergrater Mounting	Remote
Power Source	115 V

Water Meter

Size	4"
Manufacturer	Rockwell
Model	W-1000DR
Display	Total gallons

Materials

Case	Bronze
Rotor	Thermoplastic
Trim	Stainless Steel

Loop flow is handled by a 20 horsepower circulating pump. This pump is controlled by a variable speed drive whose input is differential pressure. A differential pressure control at the end of the loop (currently located in the Centennial gym) transmits a signal to the variable speed drive via a dedicated phone line to maintain a 5 psi difference between the supply and return lines (at the gym). Variable flow is promoted by the use of all 2-way control valves in the customer buildings.

All piping in the mechanical room, including geothermal supply and return lines are of Schedule 40 carbon steel grooved end construction.

Problems/Solutions/Modifications

As discussed above, the staging of the two main loop heat exchangers was accomplished based on a signal from a differential pressure controller. This method was discovered to be inaccurate

and unstable. As a result, an insertion type flow transducer was installed in the loop piping at the outlet of the pump. The signal from this flow transducer is used via a solid state controller to stage the heat exchangers. In addition, the output from the transducer is delivered to a flow meter which displays rate, and an 8" circular chart recorder.

This new instrumentation consists of a Flow Research FL 1000 meter, a TR 400 insertion type flow transducer and a Dickeson Model EL-8 circular recorder. The installation of the new flow monitoring equipment has resulted in more stable operation and the ability to analyze system performance via the circular recorder.

A small problem also related to the operation of the heat exchangers was discovered. At very low loop flows (less than about 40 gpm) the system supply water temperature became quite unstable. This was a result of the inability of the control valve and heat exchanger to function smoothly at very small heating requirements. The problem manifested itself as "hunting" of the supply water temperature at times reaching swings of 25°F. In order to address this situation, the existing actuator on the main control valve was replaced with a new magnetic type actuator (Staefa). In addition, a third smaller plate heat exchanger with its own control valve was added for very low load duty. With the installation of this unit, both of the main plate heat exchangers (1A and 1B) would be out of the loop at low loads. The new smaller plate heat exchanger is designed to handle a peak flow rate of 40 gpm and is of similar construction to the original heat exchangers (Vietti, 1988).

The final major modification in the central mechanical room involved the main loop controls. As originally installed, these controls consisted only of operating controls. There was no allowance for monitoring or shutting down the system if various operating parameters departed grossly from set points. This lack of shut down allowance became apparent during a situation which involved a leak in the loop piping. Since the control of the loop circulation pump was based only on differential pressure, as the leak reduced system pressure, the control system interpreted this as a need for increased loop pump speed. This resulted in the variable speed drive running the loop pump up to 100% speed. The intermittent flow in the partially filled pipe (as result of the leak) in conjunction with the full pump speed subjected the loop piping to repeated water hammer shocks.

As a result of this incident, John Vietti of the ECSD developed a sophisticated control system based primarily on relay logic to provide for system shut down and error mode monitoring. These added controls detect and allow for correction or shut down of the system in the event of:

- A) Low loop suction pressure
- B) Failure of well pump variable speed drive
- C) Failure of loop pump variable speed drive
- D) Low loop flow rate
- E) High geothermal discharge temperature (effluent)
- F) Low loop supply water temperature
- G) Data fail (loss of dedicated phone line to differential pressure control in gym building)

In the event that any of these conditions result in a shut down of the system an auto dialer was also installed which automatically calls Vietti (at home or at the office) notifying him of the situation. The auto dialer unit is also equipped with a microphone in the mechanical room. This allows an individual to call the auto dialer and listen in on the mechanical room. An experienced operator can deduce how the system is operating by interpreting sounds in the mechanical room.

An 8" circular recorder was also added to monitor loop supply water temperature in order to analyze performance of the system.

The water meter located on the geothermal effluent line has encountered problems due to higher than expected temperatures. Under design conditions, an effluent temperature for the system of 80-90°F was expected. This is frequently achieved. However, under certain conditions the temperature rises to 120°F or so. At these temperatures the water meter tends to "lock up". As a result, it is planned to replace this low temperature Rockwell meter with a Sonceboz hot water meter (similar to the type used in the balance of the system).

Distribution System

The layout of the distribution system is shown in Figure 9.6. The piping is entirely of preinsulated welded schedule 40 steel. Table 9.9 presents a summary of key distribution system information.

Figure 9.6 Distribution System Layout (no scale)

Table 9.9

ECSD System Distribution Information

Piping Length	5"	7060 LF
	4"	2960
	3"	0
	2"	1240
	Total	11260 LF

Type Schedule 40 carbon steel carrier pipe ASTM A53 Grade B
 Insulation 1" polyurethane (Tryner 9501 Isocyanurate)
 Jacket - fiberglass 110 mil

Connections - Welded

Supplier - Sigma Pipe

Since this system employs a central heat exchanger, none of the loop piping is exposed to the geothermal fluid. As a result, the buried steel piping would be subject only to external corrosion arising from soil moisture.

All user branch lines are connected to the main loop piping via a buried concrete valve box. The connections in all of these boxes employ grooved end type piping (Victaulic 2610 flex) connections. Isolation valves on the main loop piping and at the user branch connections are of the butterfly type with grooved end connections. A description of these valves appear in Table 9.5 in the production facilities section of this chapter.

Expansion allowance in the distribution system is accommodated entirely by the use of "L" and "Z" bends in the layout. The supplier for the system piping shows no expansion loops as part of the bid.

Drain valves are located at each isolation point in the system to facilitate maintenance on the piping.

Problems/Solutions/Modifications

None

Customer Connections/Metering

All of the users on the system were connected at approximately the same time and retrofits were designed by the same consultant. As a result, the basic piping scheme and equipment is common to all.

Differences between individual buildings lie mainly in details necessary to accommodate the retrofit of their specific systems.

The retrofit of the Convention Center provides a good example. As with all users on the system, retrofit of the building, from the valve box on was the responsibility and the property of the building owner. Piping from the valve box to the building wall was of the same material as that employed for the main system loop (See Table 9.9).

Figure 9.7 presents a piping detail of the retrofit. The following from the original construction documents (Petty, 1985) describes the sequence of operation:

"Building Heating

Outdoor temperature controller T-2 at 65°F starts circulating pump 2 (CP-2) and allows temperature controller 4 (TC-4), to modulate normally closed valve TCV-1, and maintain the heating water return temperature set point at temperature sensor 1 (TS-1). The heating water return temperature set point shall reset by an adjustable reset ratio to outside air temperature sensed at sensor 3 (TS-3).

Domestic Water Heating

Temperature controller T-1 at 120°F starts circulating pump 1 (CP-1), and allows temperature controller 3 (TC-3) to modulate normally closed temperature control valve 2 (TCV-2) and maintain 140°F at temperature sensor 4 (TS-4). Temperature reaching 140°F at T-1 stops CP-1 and closes TCV-2."

All buildings use available head from the distribution loop to provide flow through their building exchangers and control valves. Loop water enters the building and is generally directed to the space heating exchanger first. All valves are of the two way type so as to accommodate the use of constant temperature variable flow in the main distribution loop.

The main loop fluid is passed through the space heating exchanger and if there is a call for domestic hot water, the fluid is cascaded to the domestic hot water heat exchanger before entering the return line.

An equipment list for this particular retrofit appears in Table 9.10.

All users are equipped with Btu meters for monitoring of energy usage. In some cases separate meters are provided for space and domestic hot water users. All of the meters are manufactured by Sonceboz.

Figure 9.7 Retrofit Detail-Convention Center (Petty, 1985)

Table 9.10
Equipment Schedule

<u>Item</u>	<u>Description</u>
HX-3	Heat Exchanger (supplied by owner), American Vicarb Model V-4 plate heat exchanger. .316 SS, 0.6 mm plates w/nitrile gaskets. 235 MBH-primary - 145°F EWT, 140°F LWT. Secondary - 5.4 gpm, 50°F EWT, 140°F LWT.
HX-4	Heat Exchanger (supplied by owner), American Vicarb Model V-13 plate heat exchanger. .316 SS, 0.6 mm plates w/nitrile gaskets. 1660 MBH-primary - 85 gpm, 180°F EWT, 140°F LWT. Secondary - 85 gpm, 130°F EWT, 170°F LWT.
TCV-1	Temperature Control Valve. 2 1/2" - 60 CV.
TCV-2	Temperature Control Valve. 1" - 7.0 CV.
TCV-3	Temperature Control Valve. 3/4" - 3.5 CV.
FCV-1	Flow Control Valve. Bell and Gosset Model S-2-1/2".
FCV-2	Flow Control Valve. Bell and Gosset Model CB-Series. Balance valve.
BM-1	Btu Meter System - Sonceboz. Model 323 Mtr. 2" water meter (0.37-132 gpm rating), integrator, 115 vac. Btu (U.S. readout, 2 temperature), sensors with 1/2" NPT wells and cables, rated for use up to 250°F service.
CP-1	Heating Loop Circulating Pump. Bell and Gosset Model 90-40T, size 2' A, 1750 rpm, 1 1/2 hp, 85 gpm at 36 ft. of W.C.
CP-2	Domestic Hot Water Circulating Pump. Bell and Gosset Model PR-Bronze. 1" flange, 1/6 hp, 1750 rpm, 5.4 gpm at 16.5 ft. of W.C.
UH-1	Unit Heater. Modine Model H586 - horizontal delivery, 45 MBH.

As mentioned at the outset the system is noteworthy in terms of its operating Δt on the main distribution loop (100° peak). This is achieved through a number of methods. The use of cascading (from space heating to domestic hot water) at individual buildings is one approach. The most significant contribution however lies in the cascading of individual users. This occurs at two locations in the system.

At the municipal pool all heating for the 3 pools and the building is accomplished entirely with return water from the high school, hospital, school district office and gym. Because the pools are operated at only 85° or so, they are very effective loads for increasing the overall system Δt . Only the domestic hot water heat exchangers at the pool are supplied with primary loop supply water. Under peak conditions, the pools place a load of 2,620,000 Btu/hr on the system offering the potential of lowering the loop return temperature by approximately 17.5°F. In the event that there is no load or little load at the pools a pressure sustaining valve is used to bypass around the heat exchanger to assure that a minimum main distribution loop flow is maintained.

Heat exchangers in the pool are of 316 SS (plates) and nitrile (gaskets) construction. The operators of this system should be aware that 316 plates have failed due to putting in at least one other pool application. This is believed to be the result of high chlorine concentration in the water.

In addition to the municipal pool, the junior high school loop heat pump system is also placed in service with the distribution loop return line. This system operates at temperatures close to those of the swimming pool.

The high system Δt achieved through this cascading is preserved at part load due to the use of all two way valve controls on the user system.

Problem/Solution/Modifications

This is one of the few systems which has experienced no difficulty with its metering equipment. Although the metering output is not used directly to bill the end users, the data we used for monitoring of system performance, and apportioning of pumping costs.

The only equipment related modifications have involved temperature instrumentation and pipe circuiting at the pool.

The original temperature instrumentation consisted of alcohol in glass thermometers at all users. Due to separation of the alcohol in virtually all of these units, they have been replaced with dial type thermometers.

At the pool, it was discovered that under certain conditions, the temperature of the main distribution loop return water was too low to accomplish the necessary heat input to the pools. To remedy this situation, a temperature sensitive two way valve was added. The purpose of this valve is to maintain a preset minimum return water temperature at the pool.

Disposal

The present disposal system for the ECSD system is a combination of two different surface methods. The primary approach consists of delivering the fluid to a city operated treatment plant effluent line. During the spring, summer and fall, this line delivers the effluent from the treatment plant and the geothermal system to the golf course where it is used for irrigation. During the winter months the city effluent is delivered to percolation ponds for disposal.

In the event there is a failure of the cities effluent line, the effluent from the geothermal system is delivered to a storm drain at the junior high school. This is accomplished by the use of a pressure relief valve. Should the pressure in the geothermal effluent line rise above 45 psi, the pressure relief valve opens to initiate flow to the storm drain. The normal pressure required to accommodate flow into the cities effluent line is 25 psi.

The disposal line is reportedly (Vietti, 1988) constructed of two different piping materials. From the central mechanical room to the west side of the street in front of the junior high school, the line is of fiberglass construction. From that point to the connection with the water effluent line it is of asbestos cement construction. No details on the type or manufacturer of this piping is available.

Table 9.11 provides details of the pressure relief valve located at the storm drain connection of the effluent line.

Table 9.11

ECSD Pressure Sustaining Valve Data - Effluent Line

Size	4"
Manufacturer	OCV (Oil Capital Valve Co.)
Model	108
Materials:	
Body	Cast iron ASTM A-126
Shaft, Spring	Stainless steel
Diaphragm, "O"rings	Buna-N

An injection well was constructed for this system. It was located at the junior high school approximately 300 ft from the production well. The completed depth of this well was 350 ft, considerably less than the 1970 ft production well. Unfortunately testing revealed that this well would be capable of accepting only 50 gpm of sustained flow. As a result other options for disposal were developed.

Problems/Solutions/Modifications

None.

References for ECSD System

1. Bugenig, D., Report On Drilling and Testing Results - Elko Junior High School Well, William E., Nark Inc., Reno NV. February 12, 1985.
2. Vietti, J., Facilities Superintendent, ECSD, personal communication, Elko, NV, 1988.
3. Petty, W., Construction Documents - ECSD Geothermal System, Petty and Associates, Reno, NV, 1985.

ELKO HEAT COMPANY SYSTEM

Introduction

The Elko Heat Company System serves the downtown business district of Elko, Nevada. This system is noteworthy in terms of its private ownership and largely private business customer base. In addition, the growth experienced over the years (from 3 initial customers to 14 today) is evidence of an effective marketing strategy. This is in sharp contrast to most other geothermal district heating systems which are owned by and primarily servicing public sector entities.

The Elko Heat Company (EHC) System was initiated in 1977 with resource evaluation work. This led to production well drilling in 1981 and finally system start up in late 1982.

A single production well produces the 175°F fluid for the system. As with the Elko School District system, this well is able to meet system requirements during most of the year with natural artesian flow. Geothermal fluid is delivered directly to individual customers with heat transfer provided by plate heat exchangers. Metering is based upon water volume rather than energy. An effluent collection line delivers the system waste water to a cooling pond from which it is discharged into the Humboldt River.

Table 10.1 presents a summary of key system information on the Elko Heat Company System.

Table 10.1

Elko Heat Company System - Key Information

Years of Operation	6
Number of Customers/ft ²	14/250,000 ft ²
Total Length of Piping	15,500'
Resource Temperature	177°F
Delivering Temperature/ Δ t	170°/Variable
Peak Flow Capability	650 gpm
Disposal Method	Surface (cooling pond to river)
Customer Heat Exchanger	Yes
Number of Production/Injection Wells	1/0
Rate Structure	\$1.25/1000 gal
Ownership Public/Private	Private
Original Financing:	
DOE	\$ 827,404.00 43.6%
Elko Heat Co.	789,765.00 41.6%
Customer Retrofits	281,000.00 14.8%
Total	<u>\$1,898,169.00 100%</u>

Contact Person:

Mike Lattin, P.E.
Kennedy/Jenks/Chilton
421 Court Street
Elko, NV 98901
(702)738-2121

Engineer of Record: Same as above

Contractor Pipe Line: Owyhee Construction
Box 5095
Boise, ID 53705
(208)536-5025

Production/Disposal: Canyon Construction
P.O. Box 2347
Elko, NV 98901

Table 10.2

Elko Heat Company - Water Chemistry Data

ELEMENT	(PPM)	ELEMENT	(PPM)
Sodium (Na)	109.000	Gold (Au)	<0.100
Potassium (K)	38.000	Arsenic ((As)	<0.625
Calcium (Ca)	64.000	Antimony (Sb)	<0.750
Magnesium (Mg)	13.000	Bismuth (Bi)	<2.500
Iron (Fe)	0.290	Uranium (U)	<6.250
Aluminum (Al)	<0.625	Tellurium (Te)	<1.250
Silicon Dioxide (SiO ₂)	66.000	Tin (Sn)	<0.125
Titanium (Ti)	<0.125	Tungsten (W)	<0.125
Phosphorus (P)	<0.625	Lithium (Li)	0.240
Strontium (Sr)	2.750	Beryllium (Be)	<0.005
Barium (Ba)	<0.625	Boron (B)	0.900
Vanadium (V)	<1.250	Zirconium (Zr)	<0.125
Chromium (Cr)	<0.050	Lanthanum (La)	<0.125
Manganese (Mn)	<0.250	Cerium (Ce)	<0.250
Cobalt (Co)	<0.025	Thorium (Th)	<2.500
Nickel (Ni)	<0.125	Total Dissolved	
Copper (Cu)	1.000	Solids (TDS)	582.000
Molybdenum (Mo)	<1.250	Sulfate (SO ₄)	71.000
Lead (Pb)	<0.250	Chloride (Cl)	10.000
Zinc (Zn)	0.300	Flourine (F)	2.000
Cadmium (Cd)	<0.063	(Hydrogen Ion	
Silver (Ag)	<0.050	Concentration) (Ph)	8.200
Bicarbonate (HCO ₃)	502.000		

Note: High Mg values indicate mixing may be occurring between Geothermal fluids and colder ground waters.

* Samples taken during May flow test and analyzed by EG&G Idaho, Inc.

Production Facilities

The Elko Heat Company uses a single well located to the west of the main service area. The well is 858' deep and produces 177°F fluid, with a shut-in pressure of 60 psi. It is capable of satisfying most flow requirements without the use of a production pump. However, a small line shaft pump is installed in the well for very cold weather.

A summary of production facilities data for the system appears in Table 10.3.

Table 10.3

Elko Heat Company Production Facility Summary

Flow	650
Setting Depth	60'
Size Bowls	10"
Number of Stages	2
Manufacturer	Bryon Jackson
	Model 10 gpm
Horsepower	15
Variable Speed Drive	No
Drive Type	---
Lubrication	Water
Well Depth	868
Well Size	16" to 242 6 5/8 to 820
Temperature	177°F
Static Level	60 psi
Drawdown	---

Figure 10.1 presents the details of the production well completion. This well presented a number of difficulties during the drilling and completion phase of the project. These problems are detailed in earlier reports. (Chilton Engineering, 1983; Lunis, 1986).

Figure 10.1 Production Well Completion Detail

Production
Facility Plan
(Lattin, 1981)

Figure 10.2b Production Facility Elevation (Lattin, 1981)

Figure 10.3 Well thread showing production line connections.

Figure 10.4
Main production line showing magnetic flow meter and exit from well house.

Figures 10.2a and 10.2b show the equipment details in the production facility. The well head connection is typical of most lineshaft pumps equipped for artesian applications. There are two connections for the production line to the well head; one for artesian flow operation and one for pumped operation. The connection for pumped operation receives flow from the pump column. Wafer type check valves are installed in each line to prevent backflow. In addition to these connections, a third line is connected to the casing. This line which includes a 12" iron gate valve is employed during maintenance or repair operations on the well so as to bleed off the artesian flow.

The production well pump is a lineshaft, water lubricated, two stage, model. It is employed only during peak system flows (usually during January) and is idle for most of the year. The original design called for operation of this pump to be controlled from a pressure switch: on at 35 psi off at 85 psi, production line pressure.

Figures 10.3, 10.4 and 10.5 present internal views of the production building.

Table 10.4 presents some details of the production pump materials of construction.

Table 10.4

Elko Heat Company Production Pump Materials

<u>Item</u>	<u>Material</u>
Bowls	Cast Iron Class 30
Impellers	---
Bowl Bearings	High Lead Bronze
Column Pipe	Steel
Bowl Shaft	416 SS
Line Shaft	416 SS
Line Shaft Bearings	High Lead Bronze
Bowl/Shaft Connection Type	Key
Strainer	316 SS
Shaft Couplings	416 SS

The well pump is connected to the production line via a gate valve and wafer type check valve. A similar arrangement exists on the artesian flow line. All piping in the well house is schedule 40 carbon steel with flanged connections. Table 10.5 presents a summary of the materials included in the well head and valves.

Table 10.5
Well Head Valve Materials

<u>Gate Valves</u>	<u>Material</u>
Body	Cast Iron
Shaft	Bronze
Seat	Bronze
Manufacturer	
<u>Check Valves</u>	
Body	Cast Iron
Seat	Bronze
Disc	Bronze
Manufacturer	

Instrumentation originally included in the well house (Figure 10.5) consisted of continuous monitoring of pressure and temperature and instantaneous and totalized flow.

Figure 10.5 Well Head Instrumentation and Controls

Pressure and temperature transducers located just downstream of the flow meter transmitted signals to a 12" Taylor (Model # 76JT 3005,3) circular chart recorder

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Flow rate information is processed by a Mapco ultrasonic flow meter (Model 9000-3379 with 6" flow tube). Signals from the flow transducers are delivered to the processing unit located on the wall. This unit processes the input and indicates instantaneous rate on a LCD display. In addition, a second output is delivered to a totalizing counter (Taylor # 83-S-215 7 digit non-resetting) located adjacent to the processor (Figure 10.5).

The main production line leaves the well head building through the concrete floor in a 10" steel line (Figure 10.4). This line connects to the 10" asbestos cement line just outside the building. A 10" gate valve with a flanged connection on one side (steel) and a gasketed bell connection on the other side (AC) is used for the transition between the two types of piping.

Problems/Solutions/Modifications (Lattin, 1983)

Modifications in the production area have been of a relatively minor nature.

The ultrasonic flowmeter was originally supplied with epoxy encapsulated sensors. These failed and were replaced with stainless steel models.

Due to the manpower requirements for monitoring and chart replacement, the continuous recording of wellhead data on the circular chart recorder and digital totalizer has been discontinued.

The combination air/vacuum release valves originally installed in the wellhead area have been removed.

The well pump is manually controlled rather than using the automatic pressure controller.

A leak developed on one of the 2" "kill" port stubs on the well casing. In order to repair this, it was necessary to saw cut a portion of the concrete floor in the wellhead building.

Distribution System

Due to the growth of this system a number of pipeline extensions have been added since the original construction. In all cases the piping is of asbestos cement material with the supply line insulated and the disposal line uninsulated. The total length of piping currently in the system amounts to 15,500 lf (7,750 ft of trenches). All piping is direct buried. Table 10.6 presents a summary of distribution piping information.

From the production well, which is located west of the main service area, an 8" supply line runs east to the downtown area. In addition, a 6" line runs west to serve the Sewage Treatment Plant.

Table 10.6
Elko Heat Company Distribution Piping Summary

INSTALLED LENGTH		
Supply	8	4570
	6	1450
Return	10	920
	8	4570
	6	1450
PIPE MATERIAL		
Supply Carrier	- Class 150 Asbestos Cement Pressure Pipe	
Insulation	- Polyurethane	
Casing	- Asbestos Cement	
Disposal Lines	- Class 150 Asbestos Cement Pressure Pipe	
Manufacturer	- John Manville	
Fittings	- Body	- Cast Iron
	Gasket	- EPDM
	Lining	- Cement
Branch Connections	- Pre-threaded asbestos cement couplings. Saddle Tap fittings, carbon steel bands and bolts.	

Six inch branch lines in the downtown area deliver fluid to the customer areas.

Much of the piping was installed directly under the existing streets in a direct burial as detailed in Figure 10.6a and 10.6b.

Due to the location of the service lines and end users, it was necessary in a number of places to bore under state highways and railroad tracks. Instead of making a transition to steel and suspending the steel pipe in the bore casing an alternate method was chosen. This consisted of running the AC pipe through the casing and then backfilling the casing full of sand. This method was employed in all three rail crossings and for the crossing of highways (Lattin, 1988).

Isolation gate valves are located in a number of key locations of the system. A detail of their installation appears in Figure 10.7.

These valves, as shown, were all installed in a direct burial fashion with cast iron valve boxes. Table 10.7 presents a summary of information on these valves.

Figures 10.6a and 10.6b Pipe Buried Details
(Lattin, 1981)

Figure 10.7 Distribution Gate Valve Detail
(Lattin, 1981)

Table 10.7

Elko Heat Company System Gate Valve

Type	- Gate
Materials	- Body - Cast Iron
Stem	- Bronze
Seat	- Bronze
Manufacturer	- Kennedy
Class	- 125

Temperature regulation of the distribution system was allowed for in the original system through the use of cross over valves between the supply and return lines at strategic points.

Problems/Solutions/Modifications (Lattin, 1988)

The most significant problem experienced with the distribution system has been the failure of numerous threaded piping connections. This occurred most commonly at the customers branch line connections and at air/vacuum release valves located throughout the system.

Initially, customer branch piping consisted of carbon steel lines. Supply lines were insulated with 1½" polyurethane insulation and covered with a PVC jacket, return lines were uninsulated but coated with Koppers Super Service and wrapped (double) with 10 mil PVC tape. These lines were typically less than 3 inches in size.

Several failures occurred in the customer lines, at threaded connections, at least one of which was inside the customer building. These failures have been at least partially attributed to the use of poor quality (foreign manufacturer) piping in the installation. At the location of the first failure the schedule 80 foreign manufactured piping was replaced with U.S. manufactured carbon steel pipe (ASTM A 53 Gr B). This piping has performed well and is still in service.

On one occasion an attempt was made to employ CPVC piping with solvent joints. This piping failed (at the joint) within a matter of hours and no attempt has been made to use CPVC since.

Customer branch lines for new installations are of 304 stainless steel in all cases. This piping is installed using welded connections. All piping from the mains to the customer heat exchanger is of stainless material. This piping has experienced no failures.

In addition to the threaded fitting difficulties some carbon steel service saddle components have also failed. These items included primarily bands. Current practice calls for stainless steel bands for this application.

Operation of the crossover valves installed to maintain system temperatures has proven to be unnecessary. Customer requirements are sufficient to maintain system flow rates such that delivered temperatures seldom fall below 170° at the end of the line (well temperature 177°).

Isolation valves throughout the system were originally of standard construction (cast iron with bronze trim). These valves are still in service and functional. A regular exercising schedule prevents stem seizure. During maintenance procedures on the lines, however, it was discovered that these valves are no longer capable of 100% shut off. Since they are still in service and buried it is not clear whether deterioration of the seat area is due to use or corrosion. To address this situation, valves installed in new construction are of the rubber seated gate variety.

Customer Connections/Metering

Most customers on the system employ a plate type heat exchangers (316 ss/nitrile gaskets) to isolate their system from the geothermal fluid. Two customers use the fluid directly. The Vogue Laundry (Figure 10.8) uses the water (after softening) for washing purposes. The Pioneer Building uses the water directly in its cast iron radiator system.

Since each customer is responsible for his own building retrofit, individual designs vary, however Figure 10.9 depicts a typical system.

The major components are shut off valves on the supply and return, strainer, hot water meter and temperature limiting valve.

On the early systems the shut off valve was of standard cast iron bronze trim construction. Newer systems which have been partially installed with grooved end piping, include butterfly type valves.

Table 10.8

Elko Heat Company - Hot Water Meter Data

Number of meters in service	- 14
Sizes	- 1½" - 4"
Type	- Hot water, totalizing, multi jet, turbine
Display	- Total gallons (or meter)
Manufacturer	- Hersey Model MVR
Materials - Body	- Bronze
Rotor	- Polypropylene
Thrust bearings	- Tungston-carbide & sapphire
Shaft/bolts	- Stainless steel
"O" rings	- Silicone rubber
Rotor bearings	- Graphite

These meters are all placed on the supply water side of the customer connection (Figure 10.8)

Strainers are placed upstream of all hot water meters. These are of standard bronze or iron body (depending upon line size) construction with stainless steel screens. Strainers are not those manufactured by the meter company.

Newer installations include temperature limiting valves to assure low system effluent temperatures. These valves are similar in configuration to those employed in other geothermal district heating systems.

Table 10.9

Elko Heat System - Customer Temperature Limiting Valves

Type	- Self activated, remote bulb, two-way, direct acting
Materials - Body	- Bronze (to 2"), iron (>2")
Seat	- Stainless Steel
Plunger	- Stainless Steel
Stem	- Monel
Manufacturer - Powers	
Model - No. 11	

Problems/Solutions/Modifications (Lattin, 1988)

No problems have been experienced with the customer connections.

Of note is the fact that the temperature limiting valves used in this application appear to have no difficulty with stem leakage which has been a problem in other systems. In addition, they can be equipped with an optional thermometer mounted on the valve body. This eliminates the necessity of extra instrumentation for calibration purposes.

Disposal

The Elko Heat Company uses a surface disposal system. This disposal facility, as shown in Figure 10.11 was originally designed as a percolation/evaporation pond. This pond is located to the south of the main service area.

Geothermal fluid is delivered from the service area through a buried 10" AC line to the disposal facility. A valve house is located on the north side of the pond. The valve house contains a system pressure sustaining valve and bypass. In addition, a means is provided to direct all or a portion of the flow to a spray header for cooling purposes. A plan view of the valve house appears in Figure 10.12. Gate valves are of the same construction used in the balance of the system. The pressure sustaining valve is a Clayton Model 91-01. Table 10.10 provides a summary of its materials of construction.

Table 10.10

Elko Heat Company Pressure Sustaining Valve Data

Manufacturer	-	Clayton Model 91-01
Materials - Body	-	Cast iron ASTM-A-126
Trim	-	Stainless steel
Spool, Seat Retainer	-	
Diaphragm Plate	-	Ductile Iron
Diaphragm	-	BUNA-N
"O" ring	-	BUNA-N

The pond itself is approximately four feet deep and 1.5 acres in area. Waste fluid for the system enters at approximately 130°F.

Figure 10.8 Vogue Laundry connection showing gate type shut-off valves, strainer and hot water meter.

Figure 10.9 Retrofit of furniture store in Elko—not temperature limiting valve.

Figure 10.10 Typical Hot Water Meter

Hot water meters (Figure 10.10) provide the billing basis for all customers on the system. Rates are indexed to a price per gallon for the hot water. Table 10.8 provides information on the meters used throughout the system.

Figure 10.11 Disposal/Cooling Pond Plan
(Lattin, 1981)

Figure 10.12 Disposal Valve Station Plan
(Latin, 1981)

Problems/Solutions/Modifications (Lattin, 1988, Lunis, 1986)

As discussed above, the original plan was for the pond to serve a percolation/evaporation function to dispose of the system waste flow. After several months of operation the pond overflowed and began discharging fluid to the Humboldt River. Analysis of the local soils revealed an impervious layer of cemented sands at a depth of about 16-18' below the pond. This layer prevented percolation from occurring at an acceptable rate. As a result, the pond now serves primarily a cooling function prior to discharging fluid to the river.

The only difficulty experienced with the mechanical equipment at the disposal facility has been the periodic replacement of the diaphragm in the pressure sustaining valve. The diaphragm has demonstrated a service life of about three years.

Elko Heat Company System References

1. Gordon, S., Elko Heat Company, "Symposium on Operating Geothermal District Heating Systems", Oregon Institute of Technology, April 25, 1985.
2. Lattin, M., Construction Documents - Elko Heat Company Geothermal System, Chilton Engineering, Elko, NV, 1981
3. Lunis, D. C., Geothermal Direct Use Program Opportunity Notice Projects - Lessons Learned, USDOE Idaho Operations Office, Idaho Falls, ID, 1986.
4. Lattin, M., Kennedy/Janks/Chilton Engineering, Elko, NV, Personal Communication, 1988.

NMSU SYSTEM

Introduction

The geothermal system serving the New Mexico State University campus was designed and implemented under sound and unusual conditions. Due to relatively low funding levels, the system was conceived, designed and constructed largely by NMSU faculty, staff and students. As a result, the normal project sequence of design drawing, specification development, bidding and submittal evaluation was eliminated.

Although this procedure resulted in a highly successful geothermal system, the level of documentation available is considerably less than for other systems reviewed for this report. Fortunately a very detailed report was completed on the system in 1984. This report authored by those closest to the design and construction of the system details the startup and initial 3 years of operation. The report: New Mexico State University Campus Geothermal Demonstration Report by Roy A. Cunniff, Kevin P. Fisher and Prasan Chintawongvanich is the basis of this chapter. Aside from occassional comments regarding the performance of the system since 1984, this chapter consists entirely of an edited version of the above report.

The system provides domestic hot water to eleven user complexes of university buildings, including the dormitories, student athletic facilities, and the natatorium complex which contains two swimming pools. Currently, the system also provides space heating for 30,000 square feet in two buildings. Formal dedication was April 21, 1982, following a seven-month construction program and a three-month operational check-out period. This construction was the culmination of a progressive series of studies, feasibility and research followed by a detailed geothermal aquifer evaluation. Design and construction were initiated after determination was made that on a long-term basis, the aquifer could supply the necessary quantity of water at sufficient temperature.

In August, 1979, NMSU drilled the first geothermal production well to a depth of 850 feet (NMSU PG-1). Subsequent limited flow testing showed evidence of 200 gpm potential, with well-head water temperature of 142°F. A second shallow production well was drilled later in 1979 to serve as the heating source for the University Center and President's house. This well (NMSU PG-2) is 600 feet deep and produces water at 118°F.

This project was constructed using \$829,000 construction funding from a special appropriation of the New Mexico Legislature, \$70,000 of New Mexico funding for a new disposal well, supplemented by \$336,000 from U.S. Department of Energy for well drilling and project management.

The overall system operation is illustrated in Figure 11.1. Either of two production wells in the well field can supply the required production rate of 100-200 gpm, at a temperature of 141-145°F, to the primary heat exchangers after the dissolved CO₂ has been stripped off by the gas separator. The gas separator is located at the well head and the heat exchangers are 6,200 feet away, adjacent to the main campus domestic water storage tank.

Water from the main campus tank is heated in the primary heat exchangers and then supplied through 6,000 feet of buried pipeline to the hot water storage tank for distribution to system users. This storage tank is located on the main campus, adjacent to two of the primary users of domestic hot water.

The cooled geothermal fluid is routed to the disposal wells located one-half mile from the heat exchangers, and reinjected into the geothermal aquifer. The hot water storage tank provides domestic hot water at a peak flow rate of up to 400 gpm, and provides a short-term storage capability in the event of temporary system outages. The system components have been sized to provide a built-in capacity for future expansion. The system controls and instrumentation are an integral part of the NMSU Campus Energy Management System (EMS) which is designed to provide remote monitoring and centralized computer control of energy consumption.

SYSTEM OVER-VIEW

Figure 11.1 NMSU Campus Geothermal System

Table 11.1 provides a summary of data on the NMSU System. Typical water chemistry appears in Table 11.2.

Table 11.1

Key Data - NMSU Geothermal System

Years of Operation	-	6
Number of Customers, ft ²	-	32
Total Length of Piping	-	Not Available
Pressure Temperature	-	142°F - 145°F
Delivery Temperature, Δt	-	141°/65° Δt
Peak Flow Capability	-	230 gpm
Disposal Method	-	Injection
Customer Heat Exchanger	-	No (central heat exchanger)
Number of Production/ Injection Wells	-	2/2
Rate Structure	-	Not Available
Ownership Public/Private	-	Public

Original Financing:

Total Cost of NMSU Campus Geothermal Project
and Fund Source

<u>CATEGORY</u>	<u>NEW MEXICO</u>	<u>NMSU</u>	<u>DOE</u>	<u>TOTAL</u>
Basic Research	\$ 30,000		\$ 70,000	\$ 100,000
Development	54,000		126,000	180,000
Demonstration and Application	954,000		336,000	1,290,000
Disposal Well	70,000			70,000
New Deep Production Well	90,000	(to be determined)		90,000
System Expansion (Breland & O'Donnell)		122,000	120,000	242,000
	\$1,198,000	\$122,000	\$652,000	\$1,972,000

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Table 11.2
Water Chemistry - NMSU System

<u>Name</u>	<u>ppm</u>	<u>Name</u>	<u>ppm</u>
ph	6.30	Sulfate (So ₄)	250.00
EC	3.11	Iron, (Fe)	2.80
Sodium, (Na)	488.00	Manganese (Mn)	0.11
Potassium, (K)	54.00	Fluorine (F)	1.30
Calcium (Ca)	143.00	CO ₂	374.00
Magnesium (Mg)	18.60	H ₂ S	0.15
Chloride (Cl)	584.00	Nitrogen (N ₂)	14.50
Carbonate (CO ₃)	0.00	Oxygen (O ₂)	0.04
Bicarbonate (HCO ₃)	620.00		

Production Facilities

There are five current wells of significance in the Geothermal Demonstration System. Two of them, PG-1 and PG-3 are production wells, and OW-1 is an observation well which was completed to assess the hydrology of the geothermal aquifer. The remaining two wells are the old golf course well, which was repaired for use as a disposal well, and the new disposal well GD-2, which was completed in October 1982, as a supplement to the Geothermal Demonstration System. The relative location of these wells appears in Figure 11.2.

A study of geothermal well yield of the production wells PG-1 and PG-3 was established by a series of well testings conducted during the period of December 1981 - April 1982. On the basis of relevant data assessed from pumping tests of PG-1 and PG-3, the result of well yields of the production wells is detailed in the following sections.

PG-1

Controlled testing of this well using a 100-hp submersible pump produced some useful indicators of possible aquifer parameters.

The saturated thickness of the alluvial deposits is from the water table to at least 1,200 feet. Water table is roughly 250 feet below ground surface. Water temperature is 142°F at the well-head. Static water level is 328 feet. Using a 100-hp pump, the well yield was measured to be 365 gpm at 526 feet of total drawdown depth. This is 365 gpm for 198 feet of net drawdown, or a specific yield of 1.8 gpm/foot of drawdown. It should be noted, however, that the observed specific yield in sustained operations was only 1.3 gpm/foot of drawdown.

Figure 11.2 Production Well Location

Table 11.3

Construction Highlights

WELLFIELD EXPANSION

- * PG-3 completed January, 1981
- * Observation Well completed November, 1980
- * Pumps installed July 1981, and February, 1982

DISPOSAL

- * Disposal Pipeline installed October, 1981
- * Old Golf Course Well renovated as disposal well, December, 1981
- * New Disposal Well completed October, 1982

SYSTEM FACILITIES

- * Pump Houses completed June, 1980, and March, 1981
 - * Transmission Power Line completed June, 1982
 - * Buried Pipelines completed August, 1981
 - * Gas Separator completed September, 1981
 - * Heat Exchanger Building completed October, 1981
 - * Hot Water Storage Tank completed January, 1982
 - * Four complexes retrofitted January, 1982
 - * Partial System Use January, 1982 (six months ahead of schedule)
 - * Tunnel Pipeline completed February, 1982
 - * Retrofit completed March, 1982
 - * Swimming Pools on-line March, 1982
 - * System Tests
 - Gas Separator (September, 1981)
 - Heat Exchanger (November, 1981)
 - Disposal Well (December, 1981)
 - Hot Water Storage Tank (January, 1982)
 - Full System (January - March, 1982)
 - * Instrumentation (April, 1982)
 - * Dedication (April, 1982)
-

The maximum available drawdown for PG-1 is 522 feet, less 50 feet for dissolved gas control, or a net usable drawdown of 472 feet.

PG-3

The geothermal fluid temperature is 145°-146°F. This slightly hotter fluid probably is the result of casing off the cooler zone from 700 to 750 feet of depth. This well contains a shutter-type screen, which has 34 percent more screen opening than does the slotted pipe screen in PG-1. Using a 100 hp pump, the well yield was 194 gpm at 144 feet of net drawdown. Static water level is 382 feet. Specific yield was 1.34 gpm/foot of drawdown. During sustained usage, the well yield was roughly 1.05 gpm per foot.

This well contains 220-230 cc of CO₂ per liter of fluid. This is roughly 5 percent higher than for PG-1.

Realistic production temperature for this well was 145°F at 300 gpm. During the combined pumping tests, this well continued to produce 145°F fluid at a two-well combined flow rate of 600 gpm. The conclusion reached was that the temperature in PG-3 is probably independent of PG-1 pumping rate. Probable reason for this phenomenon is that the sub-surface geothermal fluid migration (or flow) was believed to be South-to-South-West. Hence, PG-3 effectively is "uphill" from PG-1, and is intercepting the hotter strata. It is possible that PG-3 would show a decline in temperature if PG-1 was pumped at its optimum yield of 564 to 782 gpm.

The following table (Table 11.4) illustrates original well yields and temperatures. If the estimated yield, and estimated temperature at optimum yield are correct, the combined flow rate at optimum would be 1000 gpm, at an average temperature of 138°F.

Table 11.4
Actual and Theoretical Yield,
NMSU Geothermal Wells

	<u>Tested GPM</u>	<u>Optimum GPM</u>	<u>Tested Temp °F</u>	<u>Temp @ Optimum °F</u>
PG-3	330	294	146	146
PG-1	365	782	142	(135)
Combined	600	(1000 est)	145 (PG-3) 139 (PG-1)	144 (PG-3) 135 (PG-1)

Separator Tank

The final design parameters were as follows:

- (1) An epoxy coated interior, steel tank, 12 feet in diameter and 6 feet long will satisfy the minimum requirements. This tank will be buried with the 12-foot axis vertical. Figure 11.5 is a simplified drawing of this installation. The tank will be insulated with 2-inches of polyurethane foam sprayed on before burial. Vapor barriers will be Diathon or equivalent.
- (2) The tank will be installed adjacent to the pump house for well PG-1, and located approximately 30 feet to the west, alongside Geothermal Road. Taking advantage of natural terrain features, the elevation will minimize burial depth requirements for the gas separator discharge lines which must exit approximately eleven feet below normal grade.
- (3) To facilitate location of controls, for insulation purposes, and for physical security, the tank will be enclosed by an equipment well on one end. This well is 12 feet deep, and 12 feet long. Access will be through a roof hatch. The bottom and three side walls will be pre-cast (tilt-slab) concrete, coated with a vapor barrier before installation. The fourth wall, abutting the gas separator tank, will be concrete block. All pumps, pneumatic valves, connections to both wells, and gas separator inlet and outlet pipes will be located in the equipment well. In addition, an inspection port for the gas separator will be accessible from the equipment well.
- (4) Concerning controls, Figures 11.5 and 11.6 are schematics of the system, depicting major controls. Not depicted are manual isolation valves, check valves, and other minor system controls.

Figure 11.3 PG-1 Completion Detail

DEPTH (FT)

0
50
100
150
200
250
300
325
350
400
450
500
550
600
650
700
750
800
850
870

Ground Surface

382'
Water Level
in Casing

10" Dia.

730'

Gravel Pack

750'

Screen

860'

870'

Figure 11.4 PG-3 Completion Details

Figure 11.5 Gas Separator Details

Figure 11.6 Gas Separator Controls

Table 11.5
PRODUCTION WELL PG-1 HISTORY

August 1979	Well was drilled as NMSU, a test well, and later redesignated production well NMSU-PG-1, (LRG-521). Well was drilled to 870 feet, and was completed to 850 feet, with cement plug in bottom.
February 1980	24-hour pump test.
June 1981	50 hp Peerless pump set in well.
July 1981	Ten-day controlled pump test and aquifer evaluation.
18-19 Dec 1980	48-hour flow test.
18-18, 22 Dec 1980	Test for dissolved gas in water.
July 1981	Combined flow test of PG-1 and PG-3 at 500 gpm. PG-1 pumped mud and sand for 45 minutes after which the 50 hp Peerless pump failed.
August 1981	The 100 hp pump was moved to PG-1, from PG-3. 365 gpm was pumped with little or no sand.
February 1982	Set new 100 hp pump in PG-3.
April 1982	Combined flow test of PG-1 and PG-3. PG-1 produced 225 gpm and PG-3 produced 275 gpm.
17 May 1982	Installed 100 hp pump failed. Break in screen in PG-1 at 803 feet, detected by down-hole video camera.
June 1982	Well repairs, to seal off defective screen section.
7-10 July 1982	Pump test using 80 hp pump and 100 hp motor. (265 gpm and with much sand)
1-8 August 1982	Air jetting to remove sand.
24-25 August 1982	Pump test of new performance pump (60 hp, 265 gpm)
30 September 1982	The 60 hp TRW-REDA pump failed after 30 hours.

18 November 1982 Installed a new Johnston, vertical shaft turbine pump.

March 1983 PG-1 pump column was penetrated by corrosion, and the production rate declined to 100 gpm.

23 March 1983 Switched the operation to PG-3. The Johnston pump was removed for repair. 80% of threaded portion of column pipe showed evidence of severe corrosion resulting from H₂S attack.

7-9 April 1983 Airjetted to remove sand for 20 hours.

12 April 1983 TV logged for PG-1. Log showed significant evidence of screen plugging with carbonate build-up, and gravel pack probably gone at 740 feet of depth.

June-July 1983 Metallurgical testing and examination of failed pump column confirmed sulfide (hydrogen) embrittlement was the primary cause of failure.

August 1983 Well was treated with sodium hypochlorite to control suspected anerobic bacterial action, and hydrochloric acid to dissolve carbonate pump in the screen section. Well was bailed for 24 hours after chemical treatment.

September 1983 Repaired Johnston pump was reset, using flanged column pipe epoxy coated on interior and exterior surfaces. Special pump section sand screen also was installed. A planned 3-day test pumping was terminated early because excessive sand production plugged the pump and sand screen. Pump subsequently was removed and stored at NMSU.

December 1983 Using a contractor supplied pump, conducted a special 24-hour flow test designed to measure sand production and H₂S control measures. The chemical treatment resulted in a significant reduction in H₂S. Sand production at first appeared to be controllable at production rates of 200 gpm. After the pump was removed, however, inspection of the well indicated that at least 17 feet of sand had infiltrated the

well. Equilibrium draw-down values showed evidence of a progressive pumping resistance as the test continued, which is consistent with the sand infiltration, and effective loss of useful screen.

Table 6
PRODUCTION WELL PG-3 HISTORY

January 1981	Well was drilled as NMSU-PG-3 (LRG-520), a test well, and in February 1982, was designated LRG-521-S, a production well supplement to PG-1 (LRG-521). Well was drilled to 930 feet, and completed to 870 feet, with open-hole completion.
25-27 January 1981	48-hour flow test and analysis of water samples.
January 1981	Combined flow test of PG-1 and PG-3 at 400 gpm. Each well produced 200 gpm
July 1981	Combined flow test of PG-1 and PG-3 at 500 gpm.
August 1981	The 100 hp pump was moved from PG-3 to PG-1.
February 1982	PG-3 redesignated - see above.
April 1982	New 100 hp pump installed; flow tested at 320 gpm.
April 1982	Combined flow test of PG-1 and PG-3 at 500 gpm. PG-1 produced 225 gpm and PG-3 produced 275 gpm.
May 1982	Pump failure. Tear down inspection was inconclusive. Operator decided that the lower section (870 to 930) of open hole was likely source of sand, even though no evidence existed that this well produced sand.
June 1982	Well repairs, cement plug installed in bottom to seal open hole.

July 1982	Flow tested using 100 hp pump; well could not produce more than 175 gpm.
August 1982	Air jetted for 5 days to re-develop well after attempt made to loosen cement plug.
25-26 August 1982	New permanent pump was installed (60 hp). Production rate 185 gpm at 70 psig well head pressure. Well was placed in service as a backup well.
27 September 1983	After 2,400 hours of operation, well head pressure had declined to 35 psig. Operator decided to shut down the pump.
October 1983	Controlled testing indicated pump still retained at least 85% of capability. Decision made to continue operation.
26 April 1984	Pump performance still slowly declining, and is now only 60 gpm at 30 psig well head pressure. Pump has more than 7,000 hours of operation. Well was taken out of service temporarily, to preserve remaining pump life for use during a scheduled 10-day steam outage planned for mid-May, 1984.

Problems/Solutions/Modifications

Concerning PG-1, two years of production experience has clearly shown that a geothermal well completed with a screen section in the water-bearing fine sand strata can cause severe operational problems, which are covered in more detail in the next section. As to PG-3, the drilling record and subsequent methodical research, indicates the well in its most productive zone (770 to 780 feet of depth), probably intersected a fault gouge of a relatively recent fault which occurred after the Santa Rosa alluvial sequence was deposited. This well was completed as an open hole, gravel packed. However, after the premature failure of the first well pump in that well, the system operator chose to fill the open hole with a cement plug "to stop sand formation."

The cement filled in the looser aggregate located at the fault zone, and production was severely curtailed.

In February, 1980, a seismic experiment was conducted by detonating explosives in the DT-1 well, which was located about 15 feet from PG-1. DT-1 was destroyed by dynamite. From the written report of this experiment, at least four separate charges were detonated. (This seismic experiment was not known by the project geothermal team until November, 1980.)

In June, 1980, a permanent pump was set in PG-1, and a controlled 10-day pumping test was conducted. A marked change in specific yield was noted. Drawdown stabilized at 474 feet (or a drawdown of 152 feet for a 200 gpm flow rate). This is a specific yield of 1.3 gpm per foot of drawdown, or 30 percent larger than the February test. It would seem evident that the dynamite charges possible loosened the gravel pack, and also possibly fractured the screen which is the damage detected by video camera in April, 1982.

During the period July - November, 1980, a series of flow tests were conducted on PG-1. In aggregate, a total of perhaps 500 hours of well pumping was conducted. Drawdown and specific yield parameters remained unchanged from the July 1980 values.

When the dynamite experiment was discovered, the project geothermal team attempted to determine the possibility of damage to PG-1. From the written report filed by the seismic researchers to the New Mexico Oil Conservation Division (OCD), the deepest charge was detonated at or near 550 feet. By pressuring the well to 125 psi, the water level was depressed to 610 feet. Since no loss of air pressure was detected, the assumption appeared valid that the casing was intact to at least that depth. One worrisome factor, however, was that the damaged DT-1 well casing, exposed 15 feet away, had observable movement when air pressure was increased or decreased.

In June, 1981, after the permanent pump was installed in PG-3, a combined flow test was conducted on the two wells. PG-3 was pumped at 275 gpm, and PG-1 was pumped at 280 gpm with rates up to 320 gpm. This test was designed to stress the aquifer as much as practical to assess the effects of the interference between the wells. During the test, PG-1 suddenly started producing large amount of mud and sand, which persisted for 45 minutes. The 50 hp Peerless pump subsequently failed, and the test was terminated.

In August, 1981, the 100 hp TRW-REDA pump was relocated from PG-3 to PG-1. A series of controlled flow tests were made, with the flow gradually increased from 150 to 320 gpm. Only small amounts of sand were produced at any time.

From September, 1981, through May, 1982, the TRW-REDA pump in PG-1 was operated for roughly 2,500 hours. The pump failed in May, 1982, and in the late stages, sand production showed an increasing trend.

After the break in the screen section was detected, repairs were made by cementing the lowest 50 feet of the screen section. A new test pump was acquired, and a controlled flow test was conducted. In spite of a one-third decrease in screen section, no observable changes were noted in specific yield or drawdown. In retrospect, this was not a good sign because it suggested the bulk of the production was from the apparently undamaged screen section.

This could be true only if the gravel pack was deteriorated so that higher than desired screen intake velocities were being used. If the screen inlet velocity exceeds 0.1 fps, channeling can occur in the formation and the gravel pack. This test pumping produced excessive amounts of sand, so the pump was removed and the well was air-jetted for five days. This air-jetting removed large amounts of sand.

A new 60 hp REDA pump was reinstalled in September, 1982. This pump had a casting flaw and failed after 60 hours of operation. During the short period of operation, the well did not produce significant amounts of sand.

A new Johnston vertical shaft turbine pump was installed in November, 1982, and operated successfully for 3,500 hours. In late March, 1983, a noticeable increase in sand production was noted. Controlled testing indicated that the well was producing excessive sand at a flow rate of 220 gpm, the desired production rate, but that the sand formation was greatly reduced if production rate was held below 150 gpm. Because production had declined, the pump was removed and inspected. Inspection of the pump and pump column revealed several problems as follows:

- a. The first three joints above the pump in the pump column were leaking badly at the couplings. This situation resulted in first a loss of well head pressure, and subsequently a loss in production. Just before the pump was pulled, production had declined to 150 gpm.
- b. Sand had eroded the pump bearings at the top stage, which allowed the throttle bushing to be eroded. Hence, water was able to enter the oil tube, and cause severe corrosion of the pump shaft and bearings. No other damage had resulted to the pump.
- c. Almost 80 percent of the pump column couplings showed evidence of erosion, in the threaded portion of the column pipe.

Based on the inspection, the pump was rebuilt, using hard-faced bearings above and below the throttle bushing, and similar hard-faced bearings installed every five feet on the pump shaft. The threaded and coupled column was replaced by flanged fittings with O-rings for the lowest 160 feet of pump column. The column pipe was coated with epoxy on exterior and interior surfaces. When the pump was reinstalled. A special sand screen was installed on the pump suction, consisting of 6.5 feet of #10 Johnson stainless steel wire screen. This special sand screen would help eliminate all sand larger than 0.010 inches, which is now able to enter the regular well screen which has perforations 0.0625 inches. Moreover, the well pumping rate was to be controlled to a lower production rate of 150-165 gpm, which appeared to cause less sand to be pumped during controlled testing in March.

The well was again air-jetted for five days, and excessive amounts of sand were removed. The air-jetting produced some gravel believed to be representative of the original gravel pack. Accordingly, a new TV log was acquired. This log showed major plugging of the well screen (an estimated 65-75 percent of the screen was plugged with carbonate deposits) and some slot enlargement. A strong likelihood was noted that the gravel pack apparently no longer was intact at the 740-750 foot horizon.

The well condition on the resulted in a decision to attempt to solve the problem by deepening the well to a sand-free horizon, and a bid invitation was advertised. In mid-June, the bids were open and no responsive bids were received.

At this point, only two options were apparently available. Drill a new well, or attempt to treat the well with chemicals to clean the screen section and also attempt hydrogen sulfide abatement. The least costly choice was well treatment, coupled with design changes on the pump and pump column to make them as sand and hydrogen sulfide resistant as possible. The well was treated with hydrochloric acid to dissolve the carbonate, in the hope that the increase in screen openings would result in lower screen inlet velocity, and less sand production. For hydrogen sulfide abatement, the well was treated with sodium hypochlorite, to test the theory that hydrogen sulfide was caused by anaerobic bacterial action.

A controlled flow test was conducted in December, 1983, in which a tightly controlled 24-hour step flow test was conducted to see if the sand could be pumped out, and to determine if the chemical treatment was effective. That test indicated the well would likely produce an excessive amount of sand.

The data for pH and conductivity measurements indicate that much of the chemical residues from the acid treatment of PG-1 in August, 1983, were still in the aquifer supplying water to PG-1 at the beginning of the flow test. However, these chemical residues were not found at the end of the flow test. Initially, pH of the solution was 6.5. The pH continued to decrease during pumping until it reached a minimum of 6.0 after four hours of pumping. Then, the pH of the solution increased gradually to a maximum of 6.8 after 12 hours of pumping; thereafter, the pH gradually decreased to 6.5 at the end of the flow test. Conductivity of the solution, however, started out as low as 2840 umhos at the beginning. It rapidly increased to the maximum of 7,200 umhos after 4 hours of pumping; thereafter, the conductivity gradually decreased to a stable level of 3,170 umhos at the end of the flow test.

A total of 10 water samples were taken during the flow test at a rate of one sample every two hours.

In reviewing the data from these chemical analysis, it is seen that there is a slight elevation in the levels of Na, Ca, Mg, Cl, SO₄, and Fe. However, the trend of the levels of the elevated chemical species decreased toward the original (1980) measured levels as pumping progressed. This suggests that even after 300,000 gallons of pumping, there still were traces of the chemical residues left from the acid treatment of PG-1 in August, 1983. The chemical analysis of PG-1 (#10) is essentially similar to the original water (1980) and also is similar to the water sample obtained from PG-3 at the end of the flow. Within limits of analysis uncertainty, the end samples are representative of original water quality.

In light of the chemical analysis, treatment with sodium hypochlorite to abate the suspected anaerobic bacteria in PG-1 probably was not as effective as desired. This tentative conclusion results from comparing the new analysis to recorded levels of H₂S in PG-1. Using sampling and analytical methodology for the period 15 March through December 1983 tends to indicate the H₂S level was reduced by approximately 50% as a result of the chemical treatment. However, data acquired by Carl Bernhardt in 1980, using a very sophisticated sampling technique, and an elaborate and tightly controlled gas chromatograph process produced measured values only one-half the current values. Because of the widely different techniques used in 1980 and 1983, direct comparison of the results is not possible. Initially at least, the chemical treatment of PG-1 decreased the H₂S level in the well to less than 20% of the level existing before the treatment. Additional measurements of PG-1 verified an apparent permanent reduction in H₂ levels.

A large volume of sand was produced during the December, 1983, 24-hour test, and an inspection after the pump was removed indicated that sand had filled in some 16 to 17 feet of the well, in only 24 hours of pumping.

If the 16 to 17 feet of fill in the well represents larger particles of sand, this is an unacceptable level of sand in-migration. If this rate continued (which is not likely for reasons explained as follows) the screen section would sand-in totally in 6-7 days of pumping operation. Assuming the sand was originating uniformly at every level from 700 to 795 feet (the current perforated screen section), the continued passage of sand would stop as the screen section filled with sand, because the reduced screen inlet area would act to reduce well production. However, the TV log acquired after the jetting operation in May 1983, showed evidence of a zone of silty fine sand at roughly 750 feet of depth. Perhaps this zone (which was detected during the original drilling), is the major producer of sand, and possibly the well would not produce as much sand if the well bore became filled above that depth. If this occurred, however, the screen would then be only 50 feet deep, and flow rates possibly would be significantly reduced.

The presence of the fill in the well, together with the large volume of sand which was intercepted by the Y-Strainer, and that quantity passed through to the holding pond is a worrisome sign. It is important to note the well was airjetted extensively in May, 1983, to remove sand. Then, after the chemical treatment, the well was bailed for a lengthy period. These two procedures under normal circumstances should have acted to reduce or eliminate sand in the immediate vicinity of the well bore. However, the December, 1983, test produced the largest amount of sand production ever noted.

In reviewing the sand particle sizes, it is useful to summarize as follows: The original well screen had 1/16-inch slots, which is 1.5875 mm. The sieve analysis showed that the Y-Strainer intercepted only 0.074 to 0.84 mm sand. Hence, particles larger than 0.84 mm, but smaller than 1.5875 mm could represent the material left in the well. However, if some of the slots are in fact enlarged as detected in the previous TV log, it is possible even larger sand particles exist in the well. Note also that the lithology log of the formation shows the following:

- (1) For the 750-foot zone, 30 percent is sand smaller than 1.0 mm. Another 25 percent is sand in the size range 1.5 to 4 mm.
- (2) For the 800-foot zone, 10 percent is sand smaller than 1.0 mm, and another 30 percent is in the size range 1.0 to 2.0 mm.
- (3) Based on these lithology analysis, upwards of 30 percent of the formation consists of size ranges which would pass through the well screen, and are large enough to be intercepted by the Y-strainer. Another 25 to 30 percent is small enough to pass through the Y-strainer, but too large to be carried out of the well.
- (4) If enlarged well screen slots exist, which is true to some extent, even larger particles could enter the well bore.

A major conclusion for the detailed analysis of the sand content of the well, Y-strainer, and holding pond is that the gravel pack probably has deteriorated to the point that sand production likely will increase.

Because of the large amount of sand now present, and the fact that this sand has returned after every attempt to clean out the well, a detailed engineering study was conducted to see if a down-hole sand eductor would work. After considerable research, a conclusion was reached that the 10-inch well diameter is too small to permit the educator to operate.

The repaired Johnston pump will be reset in the well so as to have a back-up well ready for service.

Production Well PG-3

This well was drilled and completed in early 1982. An inspection of the completed well showed that the well had a gradual deviation which reached an off-set of one diameter at 280 feet of depth. Below that depth, unknown deviation existed. However, from the deviation log which was run on the pilot hole before the main hole was reamed out to final diameter, the pilot hole deviated almost continuously from the surface to total depth (T.D.) of 941 feet, and total deviation was 10.1 feet at T.D. It is likely that the completed well follows the same deviation, which is in a southwesterly azimuth.

After the initial well pump failed at 1,000 hours, the system operators attributed the failure to sand production. This well did not have a history of sand; and the factory tear-down of the failed pump found no evidence of sand erosion. Nevertheless, the operator decided to set a cement plug to seal the lowest section of open hole (830 to 940 feet). A down-hole video camera showed that the open-hole portion was open before the cementing action.

The new pump was installed, and a controlled pumping test was started on July 14, 1983. The test was suspended after two hours. From test data, the well was only capable of an estimated sustained yield of 150 gpm at 144°F, and only 186 gpm at maximum drawdown, at water temperature of 144°F. At maximum production of 195 gpm, the pump was at incipient cavitation. Flowing temperature was 2°F cooler than earlier production. Apparently, a significant portion of the original production was from the open hole. Formation logs on this well were examined, and this water production probably is from the 865-930 feet of depth.

It was recommended that the cement plug be drilled, and a gravel pack inserted. Instead, the operator tried to break the cement plug by inserting 870 feet of 4-inch column, and attempting to force the plug loose. After this operation, the well was air-jetted for five days. A second down-hole video camera revealed the plug was still intact.

In spite of this loss of production, PG-3 has remained a usable well. In fact, because of the sand and hydrogen sulfide problem in PG-1, the former back-up well (PG-3) has been the primary well. The down-sized replacement pump in PG-3 had operated more than 7,000 hours, and has been submersed in the well for 20 months as of the end of April, 1984.

Problems/Solutions/Modifications

The New Mexico State University Geothermal Demonstration System has continued to perform well overall, although a well pump failure occurred during aquifer testing. Following the early failure of the Peerless 50 hp vertical shaft turbine pump in PG-1 in June, 1981, the 100 hp submersible TRW-REDA pump was moved from PG-3 to

PG-1 for a series of controlled tests. The results of testing showed that, with the TRW-REDA pump, PG-1 could produce a flow of clean water up to 365 gpm. Following the test results, a decision was made to purchase a new 100 hp TRW-REDA pump which was installed in PG-3 in February, 1982. During the two-year monitoring period, a total of four additional pump failures occurred, as well as major problems with PG-1.

Distribution System

A design of the campus geothermal system appears in Figure 11.7. The geothermal portion of the distribution system consists only of a single, pre-insulated, 6-inch direct buried line connecting the gas separator with the central heat exchanger. This line proceeds to the heat exchanger building located adjacent to the 4 million gallon downstream cold water storage tank.

At this point cold water from storage is passed through the heat exchanger and raised to a temperature of approximately 140°F. This water is then delivered through another direct buried, 6-inch, pre-insulated asbestos cement line to the 60,000 gallon hot water storage tank on the campus. The distance between the heat exchanger building and hot water storage tank amounts to some 6,200 lf.

Domestic hot water is delivered to the campus through a combination of tunnel installed piping and direct buried piping. Five pumps located at the 60,000 gallon tank provide for system pressurization and recirculating needs.

All of the buried piping for the system was, as described above, pre-insulated asbestos cement. Table 11.7 provides key information in this material.

Table 11.7

PRE-INSULATED ASBESTOS CEMENT PIPING - NMSU SYSTEM

Carrier Pipe:	
Size	6"
Material	Asbestos Cement Class 150 AWWAC-400
Insulation:	Polyurethane K = .16
Jacket	Asbestos Cement Class 1500
Manufacturer:	Johns-Mansville

Plate heat exchangers are used in three locations in the NMSU system: Primary Domestic Hot Water, Outdoor Pool and Indoor Pool.

The primary exchangers generate the domestic hot water which serves all of the end users. This domestic hot water is also the fluid from which heat is transferred for the two swimming pools. Details of these heat exchangers appears in Table 11.8.

The Distribution System is made up of three major elements, the heat exchangers (primary and pool), the hot water storage tank, and the tunnel pipeline.

The final design for the system used a total of five small pumps. The distribution system is divided into two main loops, with two pumps per loop. This type of design allows pump maintenance, without a hot water outage, by operating only one pump on each loop.

Also, previous design showed a floating suction pump inlet in the tank. This pump suction device was designed to provide draw-down of the presumably hotter water strata in the upper part of the tank.

The final design incorporated a unique arrangement in which the tank inlet is connected to a perforated tube running the entire length of the tank. A similar perforated tube is used for the tank outlet. As a result, thermal layering is minimized and outlet flow rate is always within two degrees of inlet temperature. Figures 11.8 and 11.9 show the final hot water storage tank design.

The pipeline from the hot water storage tank to end users is divided into a north and south loop, as indicated in Table 11.9

Table 11.8

HEAT EXCHANGER DATA

Primary Heat Exchangers	HOT SIDE	COLD SIDE	
Fluid Circulated	Water	Water	
Unit Flow Rate	200.000	200.000	gpm
Specific Heat	0.999	0.999	BTU/lb. °F
Specific Gravity	0.992	0.994	
Thermal Conductivity	0.363	0.360	BTU/hr. ft.
Inlet Temperature	140.000	65.000	°F
Outlet Temperature	75.000	129.880	°F
Pressure Drop	4.490	4.620	psig
Heat Exchanged	6448521.0		BTU/hr.
Plates Per Unit: 217			

Outdoor Pool Heat Exchanger

Fluid Circulated	Water	Water	
Unit Flow Rate	50.000	110.000	gpm
Specific Heat	0.999	0.999	BTU/lb. °F
Specific Gravity	0.992	0.997	
Thermal Conductivity	0.363	0.351	BTU/hr. ft.
Inlet Temperature	125.000	72.600	°F
Outlet Temperature	90.000	88.450	°F
Pressure Drop	2.250	9.990	psig
Heat Exchanged	868268.6		BTU/hr.
Plates Per Unit: 44			

Indoor Pool Heat Exchanger

Fluid Circulated	Water	Water	
Unit Flow Rate	15.000	35.000	gpm
Specific Heat	0.999	0.999	BTU/lb. °F
Specific Gravity	0.991	0.996	
Thermal Conductivity	0.364	0.353	BTU/hr. ft. °F
Inlet Temperature	125.000	77.000	°F
Outlet Temperature	92.000	91.090	°F
Pressure Drop	1.800	7.500	psig
Heat Exchanged	245639.1		BTU/hr/unit
Heat Transfer Area	13.1 sq/ft per unit		
Plates Per Unit: 16			

MATERIALS:

Plates	316SS
Gaskets	NBR
Nozzles	316L
Frame	CS Epoxy Painted
Bars	Hard CR Plated CS
Bolts	ZN Plated CS

MANUFACTURER:

Tranter

Figure 11.8 Hot Water Storage Tank End View

Figure 11.9 Hot Water Storage Tank Side View

Table 11.9

North Loop

Pan American Center
Garcia Hall
Women's Residence Center
Rhodes, Garrett, Hammil

South Loop

Alumni Hall
Activity Center
Natatorium (Indoor Pool/Outdoor Pool)
Regents
Breland Hall (conversion in process)
O'Donnell Hall (conversion in process)

The south loop requires six-inch welded steel pipe with separately installed insulation. The north loop requires a combination of six-inch buried pre-insulated pipe, and four-inch welded pipe with separately installed insulation in the utility tunnel. The south loop pipeline was over-sized to fill the high Natatorium load, including both swimming pools, as well as provide capacity for future expansion. O'Donnell and Breland Hall will be served by this south loop.

The circulating pumps for the north and south loops are located at the hot water storage tank. A small high capacity, low head three-hp pump is used to assure a positive suction pressure for the primary circulating pumps. Dual five-hp pumps are installed for the south loop, and dual 7.5-hp pumps are installed for the north loop. Even though the south loop has a higher load requirement, the north loop has a greater amount of head to overcome.

Problems/Solutions - Distribution

Primary Heat Exchangers

Tests were conducted 31 March 1982 to determine the temperature of domestic hot water at various flow rates for a constant geothermal flow rate of 275 gpm. At 75 gpm the delivered temperature was 140°F and at 235 gpm it was 137°F. The temperature drops sharply above this rate, 130°F for 300 gpm, and 120°F for 340 gpm. These heat exchangers have been tested extensively at various flow rates, and have given excellent performance. Figure 11.10 depicts the results of a controlled flow test to assess both the heat exchanger performance as well as the heat loss in the 6,200 feet of insulated pipeline from the heat exchanger building to the hot water storage

Figure 11.10 Heat Exchanger Flow Test Result

tank. As can be noted, a constant rate of geothermal of 245 gpm produced only a 4°F temperature loss in the sweet water arriving at the storage tank. At very high (300 gpm) flow rates the exchanger was able to provide 133°F water at the storage tank. Even at low flow rates (25 gpm) the system was able to deliver 130°F water to the storage tank.

Summarizing the data in another way, at the constant flow rate of 240 gpm and 141.5°F, the heat exchangers provided 0.5 to 1.0°F approach temperature at cold side flow rates of 200 gpm. Even with a cold side flow rate of 300 gpm, the exchangers delivered an approach temperature of 9°F.

Hot Water Storage Tank

Several tests were performed during the period of February - March, 1982, to determine the performance of the hot water storage tank. The heat retention tests of the storage tank which were conducted in February, 1982, show that the storage tank performed better than originally estimated. Testing of the emergency back-up supply of the storage tank which was carried out by a simulated heat exchanger or well pump outage on March 19, 1982, indicates that the system could provide the reserved hot water for limited duration emergencies. Figure 11.11 depicts the tank water temperature stratification after shut-down tests of 64 hours.

System Maintenance

Based on experience gained installing and operating the system, preventative maintenance procedures and schedules have been developed. The results of inspections and the resulting recommendations are given for the primary heat exchangers, and the swimming pool heat exchangers.

Primary Heat Exchangers

Purpose: To disassemble and clean the two primary exchangers. Both exchangers have had at least 2,000 hours of operation. The North exchanger previously was disassembled and cleaned at 500 hours, the South exchanger was left uncleaned for a comparison.

Inspection Results: Both exchangers are in excellent condition. No corrosion was detected. Both exchangers had a deposition, consisting of a soft silica/carbonate material, and the thin coating wiped off easily with a damp cloth. The stainless steel plates had a minor stain of iron, which did not appear to penetrate the stainless steel surface. Both exchangers had a rather substantial build-up of sand on the domestic (cold) water side. This sand problem results from the fact that the inlet is from the bottom of the large water tank.

NMSU GEOTHERMAL PROJECT
Temperature Stratification
Hot Water Storage Tank

22 February 1982

(64 Hours Lock-up Condition)

Figure 11.11 Water Temperature Stratification Test Results

Recommendations:

- 1) If technically feasible, replace the Y-strainer screen with a finer mesh screen. This could keep most of the sand out of the exchanger.
- 2) The large four-million gallon tank possibly is overdue for cleaning.
- 3) Based on conditions found, it would be appropriate to clean each exchanger annually. The exchangers possibly could be used for a longer time period; however, the deposition of the silica/carbonate material may degrade the performance of the heat exchangers since this deposited coating increases the resistance to heat transfer (i.e., it decreases the overall heat transfer coefficient). Also, the sand build-up can result in excessive pressure drop. In addition, the sharp-edged sand grains will scratch the stainless plates, which could lead to accelerated corrosion.

Upon disassembly after 1,500 hours of operation, the outdoor pool exchanger contained a large amount of debris on the swimming pool side. Foreign matter, included feathers, hair, leaves, grass, and one large-sized pebble roughly 1-inch long by 1/4 inch wide and thick. No visible corrosion existed, but the debris buildup undoubtedly was causing excessive pressure drop. It is noted that this exchanger interrupts pool water just before the water reaches the pool. In this mode, the heat exchanger is acting as a final filter. The indoor pool exchanger contained no foreign matter, and was free of visible corrosion.

Post Construction Modification

- 1) The outdoor pool exchanger should be disassembled and cleaned prior to each scheduled service, or at the end of service as was done this time. If a future decision is made to operate the pool over an entire winter season, the exchanger should be cleaned at the end of each 60-day cycle.
- 2) Based on inspection results, the indoor pool exchanger should be cleaned twice a season; at the end of spring, and during the Christmas break.
- 3) Install a Y-strainer between the pool circulation system and the heat exchanger.
- 4) Increase the heat transfer area of the outdoor pool exchanger by adding 8 plates, at \$60 per plate. Results were an increased efficiency, and ability to extract up to 825,000 Btu per hour, plus facilitating reinjection of the cooled hot side water into the domestic water system at 95°F rather than the

unacceptability high 105°F previously used. Additional plates also provide capability to provide up to 1.5 million Btu per hour for cold start-up.

Metering

Metering is used in the NMSU system only for the purpose of monitoring performance. Flow meters with totalizing capability are located at each production well, at the outlet of the hot water storage tank and at the disposal side of the main heat exchangers. The output of the flow meter at the main heat exchangers and at the hot water storage tank is fed to Btu meter for monitoring of energy savings.

All flow meters are of the inline turbine type. Table 11.10 summarizes key data on these meters.

Table 11.10

NMSU Geothermal System - Metering Data

Meter Type	-	Turbine
Materials		
Body	-	Bronze
Rotor	-	Polypopylene
Shaft/Bolts	-	Stainless steel
Rotor Bearings	-	Graphite
Manufacturer	-	Hersey model MHR
Sizes	-	4" and 6"
Temperature Probes	-	No information
Btu electronic	-	Hersey model 7003/1010
Display	-	Total Btu/total gallons

Disposal

There are two disposal wells, NMSU #4 (the old golf course well) and CD-2 LRG-3648 (the new disposal well). The golf course well originally was completed in 1962. It was in service for ten years, during which time trees and shrubs did not grow properly. The well was shut-in in 1972, and the pump was removed in 1977. The well was repaired and brought to operation as a disposal well in January, 1982. The new disposal well GD-2 was drilled in September, 1982, to provide an additional capacity to the existing golf course well. A history of each well, which briefly summarizes the results of test and performance during the construction and operation phases, is given in Table 11.11.

Table 11.11
Golf Course Well History

1961 - 1962	Well drilled and completed.
1971	Well taken out of production.
1977	Pump removed.
February 1981	Trial injection of 100,000 gallons of domestic water. Controlled injection tests at 300 and 550 gpm.
13 July 1981	Well approved as disposal well for gravity flow only, by the Director, Oil Conservation Division of the Energy and Minerals Department, State of New Mexico.
1 August - 4 September 1981	Six weeks of low-flow rate pumping test conducted.
September 1981	Reinjection test conducted at 225 gpm.
December 1981	New well casing, and screen liner installed.
January 1982	Additional testing conducted to verify the new well casing and repairs. Reinjection tests conducted at rates up to 300 gpm.
February 1982	Well placed into geothermal service as a disposal well.

Golf Course Well

The golf course well was abandoned in 1971 as excessive mineralization was causing harm to the golf course vegetation. Based on previous research, a Disposal Order was issued by the New Mexico Oil Conservation Division which allowed testing of this well as a disposal well. Gravity reinjection only was initially allowable, and verification of disposal facilities was necessary before placing the well in service.

The well was pumped for six weeks using the 3.5-hp pump from the PG-2 well. Water temperature and conductivity values were logged, and at the end of the pumping period, water samples were taken for detailed analysis.

A reinjection test was conducted over a 5-day period for a total of 115 hours. This test indicated that the planned reinjection rate of 225-250 gpm would be feasible.

After the well repairs were completed, additional tests were conducted to verify conditions and to assure the integrity of the repairs.

An initial test at a flow rate of 300 gpm caused water to overflow from the well. The cause of this overflow was unknown, although it was suspected that a temporary bridge had formed during the repair operations. Because of this problem, the casing liner was sealed at the well head. This change also permitted the system to use the drop of 130 feet in elevation between the production and disposal wells (less an estimated 15 feet of friction losses) as the injection motive force to assure injection without the need for an injection pump. Moreover, this design completely isolated the geothermal spill. Instead, if the well were blocked, system flow would cease, and automatic controls would shut down the production well pumps.

After design changes were incorporated, a 3-hour flow test was conducted. Changes in static water level were measured by differential pressure and flow rates were monitored by installed system flow meters at the Gas Separator tank and Heat Exchanger complex. The test was designed to assure that the well would accept up to 50 percent more flow than the system design flow rate of 200 gpm. Because automatic flow by-pass controls had not yet been installed, manual controls were used to set and control the flow at $\pm$ 10-15 gpm of the desired rate. From this limited test, it appeared that the well would safely accept the planned 250 gpm disposal rate.

Subsequent testing at varying flow rates over a 30-day period validated the conclusion from these earlier tests. During all but two of the tests, the water level rise in the well bore at 300 gpm was not noticeable. However, on two tests, the water level rose to -142 feet, and then slowly dropped to -165 feet. This lack of stable behavior was unexplainable, and dictated continuous monitoring. Because the behavior of this well could mean early failure, a new disposal well (GD-2) was planned for a location adjacent to the Heat Exchanger Building, which is underlain by the geothermal aquifer, and which would facilitate disposal operations.

This new disposal well was drilled as a New Mexico funded project, with funding provided through the Geothermal Demonstration Fund. The well, NMSU GD-2 LRG-3648, was designed to dispose of 200-250 gpm of geothermal water after the heat has been extracted.

The completed well was drilled, tested, and connected to the geothermal system in a 4-month period starting August 1, 1982.

This well has been in service as a disposal well since December 1, 1982. As part of the drilling program, additional information has become available which helps document the nature and extent of the geothermal anomaly for follow-up commercialization.

The New Mexico State University disposal well (NMSU GD-2 LRG-3648) is located at 330 feet from the Westline, 1,000 feet from the Northline, Section 27, Township 23S, Range 2E, in Dona Ana County, New Mexico. The well is located at a ground level of 4,000 feet above the mean sea level, approximately 1/4 mile east of highway I-15 in Las Cruces, New Mexico. New Mexico State University owns the land and mineral resources under the land at the site of the well.

Completion Method

The pilot hole was spudded on 23 September, 1982, and was drilled to 991 feet of total depth (TD). The drilled pilot hole was 7 7/8-inch diameter to 520 feet and 6 1/2-inch diameter to 991 feet TD. Suite of geophysical logs was acquired, and the pilot hole was packed with gravel before jetting water samples at 240, 840 and 468 feet of depth. The hole was enlarged to 14 3/4-inch diameter to 486 feet of depth.

On 21-22 October 1982, casing of type A/20 Kaiser prime steel of 0.322-inch wall thickness and 8.625-inch diameter was set from a level one foot above the ground surface to 370 feet, 380 to 390 feet, and 470 to 477 feet. Screen section was set with perforated zones from 370 to 380 feet and 390 to 470 feet of depth. The screen used was 8.625-inch diameter Johnson Type 316L stainless steel with 0.60 slot and 1 1/2 by 3-inch collars.

The bottom hole was sealed by a cement plug from 467 to 486 feet of depth using 20 sacks of cement. Colorado Silica gravel 0.079 to 0.132-inch was packed in the section from 347 to 486 feet. Cement from the surface to 347 feet of depth consisting of approximately 200 sacks of cement was emplaced using a cement pump. Cement bonding was verified by good cement return.

A schematic diagram of the completed well is shown in Figure 11.12.

NMSU GD-2, LRG 3648

Figure 11.12 GD-2 Completion Details

This new well, GD-2, is one of the first geothermal reinjections in New Mexico drilled specifically for the purpose of reinjection. As no prior history was available, a literature search was conducted to determine if any guidelines existed. Only one known controlled experiment has been conducted in which field and laboratory data were acquired, analyzed and compared. As reported in ASTM STP 735, American Society for Testing and Materials, Proceedings of the Second Symposium on Water for Subsurface Injection, Woodward Clyde, consultant reported on "Some Factors Contributing to Decreased Well Efficiency During Fluid Injection." This report served as a standard for the activities taken to develop NMSU GD-2.

Woodward and Clyde reported that compaction caused by vibration in the gravel-packed-aquifer model tended to decrease permeability by as much as 35 percent in the gravel pack, and 45 percent in the aquifer material. This decrease results from compaction of the gravel is a result of surging action from well development procedures and the alternate injection and pumping tests. Based on this concern, the NMSU research team made a decision to proceed with a very careful well development.

Initially, the well was to be developed by a modest amount of air-jetting, followed by a 24-hour pumping test. Air jetting was initially very limited, and served mainly to provide samples for laboratory analysis. When the test pump was installed, the small pump could produce only 107-125 gpm, and well development was being hindered.

A new fixture was designed and installed for the air jetting, and consisted of a 4-inch diameter tube emplaced within 5 feet of well bottom. The 1.5-inch air line was set inside this larger tube, with a U-shaped end nozzle. This fixture kept the air from being directed into the well screen; instead, it was directed upwards so as to force water in a vertical flow path. The entire fixture was then raised by successive stages until the entire screen section had been jetted. This procedure was followed for almost two weeks of intermediate jetting, and jetted volume increased to approximately 250 gpm.

All the geothermal fluid produced by pumping and air jetting was routed through a 4-inch temporary pipeline to Tortugas Arroyo, and impounded within a small earthen dam, where it recharged the aquifer by natural percolation. As estimated volume of one acre foot of water was produced.

After the well had been developed by air jetting, it was then connected with a segment of 6-inch permanent disposal pipeline. The wellhead was installed, and temperature and pressure ports were installed. An air release valve also was installed so that air could be removed during initial filling of the pipeline and the well. The initial inflow test was set at a rate of 220-240 gpm, and the well accepted this flowrate by gravity reinjection. This initial test was for a 24-hour duration.

Based on the successful development program, a decision was made to forego further well development activities at that time. Now that a baseline has been established for natural-information reinjection, future disposal operations can be monitored. If the well shows a decline in reinjection volume, or a build-up in wellhead pressure, the well can be acidized and cleaned out. Subsurface formation of the injection zone contains a large percentage of carbonates, and hydrochloric acid in suitable concentrations would be an effective acidizing agent.

Decline in reinjection volumes also could result from either air entrainment or gas binding caused by the release of dissolved gases. Concerning the dissolved gases, the NMSU geothermal system provides for separation of most of the free CO_2 prior to reinjection. Moreover, by reinjecting into an aquifer which is the same chemical composition as the geothermal water, and assuring that the reinjected fluid is slightly warmer than the natural ground water will tend to minimize the gas binding problem. The air entrainment problem is more difficult to solve. Although care was exercised in filling the pipeline to minimize air entrainment, it is possible that small air bubbles could become lodged in the well screen or aquifer. These air bubbles could be caused by the so-called Jamin effect, or could result from distortion of bubbles when they are forced through the capillary openings of the aquifer.

To minimize or eliminate air entrainment, the simplest (but most costly) solution is to install a reinjection pipe column, with a controllable butterfly valve near the bottom of the injection pipe. Modification of the well by this fixture would appear to be a useful future test if reinjection volume declines, or if wellhead pressure starts to rise. In the interim, care should be exercised by system operators to assure a slow and careful filling of the pipeline, and to vent the well carefully during future start-up operations.

Table 11.12
GD-2 LRG-3648 History

<u>Date</u>	<u>Action</u>
23-24 September 1982	A pilot hole was drilled to 991 feet of depth. Jetted water samples validated conclusion that the geothermal aquifer extended to the target zone, and was the same quality as production wells.
22-23 October 1982	Set casing, screen, and gravel pack.
27 October 1982	Well development. Jetted water samples were obtained 468 feet of depth.
November 1982	Field connection of the new disposal well to the geothermal system.
1-15 December 1982	Controlled reinjection tests. Gravity injection conducted at an average rate of 220-240 gpm.
1 December 1982	Well placed into service as primary disposal well, with the old golf course well (GD-1) as backup.

KLAMATH FALLS DISTRICT HEATING SYSTEM

Introduction

Planning for the Klamath Falls District Heating system began in the mid 1970's with the completion of preliminary feasibility studies (Lienau, 1981). Based on the favorable results of these studies, a USDOE Field Experiment Contract was obtained for the design and construction of the system. During the design process a three phase approach was developed. The first phase consisted of supplying heat to 14 domestic government buildings. Subsequent phases would expand the customer base to most of the downtown commercial district (Phase II) and, finally, a large residential area (Phase III). To date, only Phase I has been completed.

Construction of this portion of the system was completed in September 1981 (though acceptance of the system by the city did not occur until 1983) and included two production wells, injection well, transmission line, central heat exchanger and control building, and the downtown distribution loop. Key information on the system appears in Table 12.1.

Two major problems have prevented successful operation and expansion of this system:

- 1) political difficulties with existing well owners,
- 2) failure of a portion of the distribution loop piping.

Political difficulties began before the system construction. Existing well owners, concerned that operation of the city's system would negatively impact their wells, successfully spearheaded the passage of a city ordinance favorable to their point of view. This ordinance required that any geothermal fluid produced be returned to the same well. This effectively eliminated any possibility of operating the city system for a period of approximately 2½ years while litigation proceeded. A full discussion of these issues appears in Lienau, 1986.

In the spring of 1984, the ordinance was modified to allow "experimental" operation of the system. This continued until the summer of 1984.

During the following winter (1984-85), the second major system problem surfaced (Lienau, 1986). Leaks began to occur at the connections in the fiberglass portion of the piping system. Initially, a repair program was implemented. However, it was quickly discovered that these failures were occurring throughout the loop and acceptable operation was not possible.

In February, 1985 the system was shut down and subsequently it was decided that all of the fiberglass piping would be replaced.

Table 12.1

Key Data - Klamath Falls Downtown District Heating System

Years of operation	5
Number of customers, ft ²	14, approximately 400,000
Total length of piping	15,000 lf
Resource temperature	210°F
Delivery temperature, Δt	180°F, 40°FΔt
Peak flow capability	1,000 gpm
Disposal method	Injection well
Customer heat exchangers	No (central heat exchanger)
Number of production/injection wells	2 production/1 injection
Rate structure	\$.30/therm
Ownership public/private	Public
Original financing	See sub-table below
USDOE	\$1,547,183 66.4%
City of Klamath Falls	584,786 25.1%
Klamath County	150,000 6.4%
State of Oregon	50,000 2.1%
	<u>\$2,331,969 100.0%</u>

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Currently, the city is in litigation for the replacement of this piping.

Since completion of the downtown loop and transmission line, two other small district systems have been tied into the main transmission line.

The Michigan Street system serves a residential area to the north of the transmission line. To deliver heat to this system, a fraction of the flow in the main line is shunted through a heat exchanger and then back into the line. Since there are only eight houses currently connected to the system, the impact on the temperature delivered to the main loop heat exchanger is small. As in the case of the main loop, this system employs a central heat exchanger and secondary loop to deliver heat to the customer.

The Mills Addition system is connected to the main transmission line only for emergency backup purposes. This system uses, as its primary source of heat, water which was previously wasted to the storm sewer. A number of existing geothermal systems in this area of the city were previously operated on a "pump and dump" basis. The Mills Addition system was implemented in an effort to collect this fluid, extract any useful heat and then deliver it to an injection well. Toward this end, the fluid is collected in a gathering system, passed through a heat exchanger and then delivered in a separate line to the injection well used by the main system. A secondary loop delivers heat to the customers. Emergency backup for this system is provided by a second heat exchanger connected to the main transmission line. This system is not currently operated due to legal difficulties with a nearby facility which was collecting heat from the storm sewer system. Since this heat is no longer available, an agreement must be reached with this facility before the system can be operated.

Table 12.2 presents a summary of the fluid chemistry for the Klamath Falls system.

Table 12.2

Fluid Chemistry - Klamath Falls Downtown
District Heating System (Ellis, 1981)

Key Species	mg/l
pH	8.60
TDS	795.00
Chloride, Cl	51.00
Sulfate, SO ₄	330.00
Bicarbonate, HCO ₃	20.00
Carbonate, CO ₃	15.00
Hydrogen Sulfide, H ₂ S	1.50
Ammonium ion, NH ₄	1.30
Oxygen, O ₂	0-0.02
Silicon, Si	48.00
Sodium, Na	205.00
Calcium, Ca	26.00
Nitrate, NO ₃	4.90
Potassium, K	4.30
Fluorine, F	1.50
Iron, Fe	0.30

Production Facilities

Table 12.3 presents a summary of the production facilities employed by the City District Heating System.

Table 12.3

**City of Klamath Falls Production Facilities Summary
(Sammel, 1984)**

	Well #1	Well #2
Flow/head (gpm/ft)	500 @ 280	500 @ 280
Setting depth (ft)	300	300
Sizes (bowls)(in)	10	10
Number of stages	8	8
Manufacturer	Aurora	Aurora
Horsepower (hp)	50	50
Var. speed drive	yes	yes
Drive type	fluid coupling	fluid coupling
Manufacturer	Nelson	Nelson
Lubrication (shaft)	oil	oil
Well depth (ft)	367	900
Well size (in)	12	12
Temperature (°F)	218°	212°
Static water (ft)	76	60
Drawdown (ft)	1.5 @ 680 gpm (Forcella, 1984)	4.5 @ 540 gpm (Forcella, 1984)

A full discussion of the control system for the production pumps is presented in the Central Mechanical Room section of this chapter. The originally specified control sequence follows: (Balzhiser, 1980)

"Sequence of Operation:

1. Product Well Pumps (WP-1, WP-2)
 - a. Pumps controlled from Hand-Off-Auto switch at Control Panel.
 - b. Speed controller: set from temperature of discharge water from heat exchanger on the secondary loop. Transmission by telemetry equipment. Provide operator at speed controller. Coordinate with pump manufacturer.
 - c. Pumps modulated and controlled in sequence to provide lead-lag operation.
 - d. Lead pump alternated manually from control panel.

- e. Pump capacity controlled through proportional integral receiver controller to increase flow with an increase in heating water demand (from signal to V-1).
- f. Provide electric motor operator for each pump.
- g. Pump operation:
 - 1. Lead pump on as load increases from 0 to 50%.
 - 2. At 50% load, both pumps operational - each supplying equal flow to satisfy the heating load.
 - 3. With a total load reduction to 30%, lag pump shuts off with lead pump handling the load.
 - 4. Interlock valves V-2 and V-4 to open with lead pump.
 - 5. Interlock valves V-3 and V-5 to open with lag pump.
 - 6. Provide manual valve control switch-over to allow either set of valves to operate with either pump.
 - 7. Automatic valve V-6 modulates to maintain 25 psi upstream.

2. Heating Water Supply:

- a. Automatic valve V-1 controlled to maintain 180°F supply water temperature.
- b. Valve fails to by-pass.

3. Heating Water Pumps (CP-1, CP-2)

- a. Controlled from Hand-Off-Auto switches at central panel.
- b. Auto position:
 - 1. CP-2 runs continuously.
 - 2. When heating water return drops to 135°F, CP-1 starts and CP-2 shuts down.
 - 3. When heating water return temperature rises to 145°F, CP-2 starts and CP-1 shuts down.
 - 4. Provide high limit in heating water supply set at 190°F to shut down pumps and alarm.

- 4. Exhaust Fan (EF-2): Fan controlled by roof thermostat to maintain set point. Fan starts on rise in temperature."

Based on the experiences at nearby OIT, pump materials for the city system production wells were selected to match those of the campus. As a result, the units were specified to include extra lateral bowls, oil lubricated shaft bearings and a variable speed drive. Table 12.4 presents a summary of materials employed. A detail of the well head appears in Figure 12.1.

Figure 12.1 (Balzhiser, 1980)

Table 12.4

Klamath Falls System
Production Well Pump Materials (Ref. 8)

Item	Material	Specifications
Shaft	Stainless steel	AISI 410
Column	Steel	ASTM A102
Shaft enclosure	Steel	ASTM A53 Grade A
Bearings	Leaded red brass	83%Cu, 5%Sn, 7%Pb, 5%Zn
Bowls	Cast iron	ASTM A-48 Class 35
Impellers	Leaded red brass	83%Cu, 5%Sn, 7%Pb, 5%Zn
Keys	Stainless steel	AISI 316
Fasteners	Stainless steel	AISI 316
Collet	Stainless steel	AISI 316

Figure 12.2

Problems/Solutions

No problems have been experienced with the production wells or pumps to date (Colahan, 1988).

Distribution System

A layout of the Klamath Falls distribution system appears in Figure 12.2. The system consists of two major portions:

- 1) transmission line,
- 2) distribution loop.

The transmission line employs two types of installation methods; direct buried and concrete tunnel. The entire 4,040 foot length is composed of eight inch pre-insulated Schedule 40 steel piping with a fiberglass jacket.

From the production wells to Point A (Figure 12.2), this line is direct buried. Expansion joints are located in vaults along the route. The expansion joints are of the controlled flexing type with 304 SS carrier. A detail of the burial trench appears in Figure 12.3.

At Point A, the line passes under a state highway and across a canal bridge. The road bore was installed with a 20 inch steel casing in which the 12 inch OD pre-insulated line was located. A detail of this installation appears in Figures 12.4a and 12.4b.

For the bridge crossing, the pre-insulated line was hung from the bridge structure with spring loaded, roller type hangers.

At the west side of the bridge, the line passes through the canal berm and enters the concrete tunnel. The tunnel is located, for the most part, under the sidewalk system. It proceeds for a distance of 2,290 feet to the system mechanical room. The same type of expansion joints are used in the tunnel as were used in the direct buried portion of the line. A cross section of the tunnel construction appears in Figures 12.5a and 12.5b. The tunnel was designed to accommodate a second eight inch transmission line to provide for system growth.

Isolation valves throughout the piping system are of the resilient lined butterfly type. These valves were specified with EPDM seats for general duty and Viton for geothermal service in early construction (Balzhiser, 1980). Later construction employed all EPDM seats. Table 12.5 presents a summary of valve data.

Figure 12.3 (Balzhiser, 1980)

Table 12.5

Klamath Falls System Valve Data (Ref. 8)

Type	Butterfly, resilient lined
Manufacturer	Victaulic, Keystone (Fig. 228)
Body	Cast iron
Stem	316 SS
Seat	EPDM (late design) Viton (early design)
"O" ring	EPDM
Disc	316 SS, Ni Resist Iron
Bolts	316 SS

FIGURE 2a
ALAMEDA STREET PIPE GUIDE SPACING DETAIL
 NO SCALE

Figure 12.4a (Balzhiser, 1980)

FIGURE 4b
PIPE GUIDE DETAIL
 NO SCALE

Figure 12.4b (Balzhiser, 1980)

Figure 12.5a
(Balzhiser, 1980)

TUNNEL SECTION @ SIDEWALKS
SINGLE FORMED WALLS
CONTRACTORS OPTION

Figure 12.5b
(Balzhiser, 1980)

TUNNEL SECTION IN STREET
SINGLE FORMED WALLS
CONTRACTORS OPTION

TRENCH DETAIL - NON-SURFACED
 NO SCALE
 FOR DIMENSION & NOTES, SEE (2/15)

Figure 12.6a (Balzhiser, 1980)

Figure 12.6b (Balzhiser, 1980)

In the central mechanical room, the geothermal fluid is passed through the heat exchangers and directed to the injection well. A full discussion of the mechanical room appears in the following section. Heat is then delivered to customers through a two pipe closed loop system connected to the secondary side of the exchanger.

All of the secondary loop is direct buried piping. Approximately 4,400 feet of the total is ten inch pre-insulated Schedule 40 steel similar to the transmission line. Sizes less than ten inch (8,280 lf) are pre-insulated FRP piping of the key-lock type mechanical joining system. Trench details for the secondary loop piping appear in Figures 12.6a and 12.6b.

The steel portion of the secondary loop employs both vault installed expansion joints and direct buried expansion loops. Expansion joints are similar to those employed in the transmission line. Expansion loops employ oversized insulation and jackets to avoid failures in the jacket. Jacket failures were the source of piping problems on the nearby OIT campus.

As shown in Figure 12.7, the steel piping in both the transmission line and distribution loop is protected by magnesium anodes buried at various points along the route.

Figure 12.7 (Ref. 11)

The fiberglass portion of the secondary loop, a total of approximately 8,280 lf, was composed of an FRP carrier pipe, polyurethane insulation and a fiberglass casing. This piping employed a keyed type mechanical joint for both fittings and pipe connections. All piping connections were field insulated with polyurethane insulation and protected with three layers of polyethylene sheeting secured by straps as shown in Figure 12.8.

Table 12.6 summarizes the different types of piping employed in the distribution system.

Table 12.6

Klamath Falls Distribution System Piping Summary
(Colahan, 1988), (Balzhiser/Hubbard, 1980), (Ref. 11)

<u>Application</u>	<u>Carrier</u>	<u>Insulation Material</u>	<u>Jacket</u>	<u>Joining Method</u>	<u>Supplier</u>
Transmission line direct bury	Sch 40 steel ASTM A53	polyurethane $k = .12, 3$ $1.81b/ft^3$, 1 1/2" min.	fiberglass 180 mil	weld	Perma Pipe
Transmission line tunnel	Sch 40 steel ASTM A53	polyurethane $k = .12, 3$ $1.81b/ft^3$, 1 1/2" min.	fiberglass	weld	Perma Pipe
Secondary loop direct bury	Sch 40 steel ASTM A53	polyurethane $k = .12, 3$ $1.81b/ft^3$, 1" min.	fiberglass	weld	Perma Pipe
Secondary loop direct bury	Fiberglass Epoxy resin ASTM D-2310 D-2242 D-2996	polyurethane $k = .12, 3$ $1.81b/ft^3$, 1" min.	fiberglass	key lock mechanical	Fiberglass Resources

Problems/Solutions

The most difficult problem encountered with the Klamath Falls system was a failure of the joining system employed on the fiberglass piping in the secondary loop. As discussed above, this piping used a mechanical, key lock (Kwik-Key by Fiberglass Resources) joining system. A detail of a typical joint is shown in Figure 12.9. This is a slip together joint with an O ring seal. Axial movement is limited by the presence of the flexible key.

PREINSULATED PIPE INSULATION-DETAIL

1/2" SCALE

Figure 12.8 (Balzhiser, 1988)

Figure 12.9 (Ref. 11)

The failure of the Klamath Falls system was the result of the lock ring portion of the joint becoming detached from the piping. The lock rings were attached, by the manufacturer, with an epoxy adhesive. This adhesive was evidently improperly manufactured or applied. In any case, failure of the epoxy permitted axial movement in the joint. Eventually, this resulted in leaks at these locations.

Initially, the failed fiberglass joints were repaired with "Dresser" type couplings and short lengths of ductile iron pipe. This quickly became impractical due to the large number of leaks which developed (Colahan, 1988).

The existing fiberglass material will be replaced entirely with ductile iron when the City secures funding for the construction (Colahan, 1988).

The original specification for the loop piping called for the Kwik-Key product. An alternate bid was requested based on the use of epoxy joint piping (Balzhiser, 1980). Since the added labor associated with the epoxy joints raised the bid (above the Kwik-Key), the mechanical joint system was installed. The selection of the fiberglass material over the steel piping for the secondary loop was based strictly on costs (Colahan, 1988). With installation considered, the fiberglass material resulted in lower overall cost than steel in sizes less than ten inches.

An additional problem surfaced as a result of the leaks in the fiberglass piping. A lack of isolation valves in the system resulted in the necessity of draining the fiberglass system each time a leak occurred. This resulted in difficulty with customer systems (due to direct connections) and substantial time delays. The new distribution loop will include a much larger number of isolation valves (Colahan, 1988).

Aside from the failure of the fiberglass joining system, no other problems have been experienced with the distribution system (Colahan, 1988).

The magnesium protection anodes located along the direct buried steel portion of the system have not been unearthed and checked to date (Colahan, 1988).

Central Mechanical Room

The central mechanical room for the Klamath Falls system contains the main plate heat exchangers, circulating pumps, expansion tank and control system for the district. A flow scheme for this portion of the system appears in Figure 12.10.

As indicated, there is no temperature activated valve control for the geothermal fluid. The only automatic control valve on the geothermal side of the circuit is a pressure control valve set to maintain a constant 25 psi back pressure (upstream). Geothermal flow control is maintained by the variable speed drives at the production wells.

The system employs two heat exchangers, each capable of transferring 10×10^6 Btu/hr. A summary of key data concerning these units appears in Table 12.7.

Figure 12.10 (Balzhiser, 1980)

Table 12.7

Heat Exchanger Data - Klamath Falls City System (Ref. 8)

Duty	10 x 10 ⁶ Btu/hr
Temperatures - geothermal loop	210°F in, 170°F out 140°F in, 180°F out
Plate material	316 SS
Gasket material	Paracril (nitrile rubber)
Manufacturer	APV

Automatic, two position valves interlock these heat exchangers with the main circulating pumps so that only one heat exchanger is on line when only one pump is on line. Both heat exchangers operate when both pumps are on line.

In summary, as shown in Figure 12.10, a pair of valves on the loop side of the exchangers modulate to maintain a supply water temperature of 180°F. The pneumatic signal to these valves is also delivered to a pressure transducer. This transducer sends a signal, via telephone lines, to an actuator located at the production wells. This actuator then varies the speed of the production pumps.

A control console in the central mechanical room monitors key pressures and temperatures and offers operator control of certain components as follows (Balzhiser, 1980):

<u>System</u>	<u>Start/Stop</u>	<u>Failure</u>	<u>Temperature</u>	<u>Flow</u>
1. Well Pump 1	C,L	L,A		
2. Well Pump 2	C,L	L,A		
3. CP-1	C,L	L,A		
4. CP-2	C,L	L,A		
5. Control Compressor	C,L	L,A		
6. Well Water Supply			L	L
Well water Return			L	
Heating Supply		L,A	L	
Heating Return			L	L
Heating Supply-Return				A
Sump Pump		L,A		

NOTE: C = control
L = indicator light
A = alarm

Problems/Solutions (Colahan, 1988)

The only problems experienced to date with the central mechanical room relate to the operation of the system under very low load. The problem areas have been associated with production well pump capacity control and back pressure valve performance.

At the production well, it was discovered that the automatic controls would not modulate down to a flow low enough for system operation. For initial operation, flow requirements amount to only 100 gpm, compared to the 1,000 gpm peak for which the system was designed. Although the system would function at higher flows, local existing well owners are very sensitive to the impact of the city's wells on their systems. As a result, the automatic controls have been disconnected and the production pump set to 100 gpm manually. The automatic controls will be re-connected when system growth results in higher flow requirements.

The back pressure regulating valve in the central mechanical room also performed poorly at low flow rates. Severe hunting was encountered. The controls contractor modified the control system; however, this was only marginally effective since the basic problem was that the valve was oversized for the flow it was handling. This valve was subsequently disconnected and a nearby gate valve is now used for back pressure control. Since the system operates at what amounts to a constant flow rate (100 gpm), the manual control of pressure has been successful. As with the production well controls, the automatic valve will be re-connected when system flow requirements rise.

Customer Connections

Due to the use of a central heat exchanger, the customer connections employed on the Klamath Falls system are very simple. Each consists only of pressure and temperature instrumentation, two isolation valves and a Btu meter. No individual pressure control valves are located at the buildings.

Problems/Solutions (Colahan, 1988)

No problems have been experienced with the materials present in the customer connections.

Operational problems have been experienced, however. These were the result of frequent draining and filling of the distribution loop during 1984-85 heating season in connection with repair of the leaks in the fiberglass piping. Coordination between the distribution system operator and the end users was difficult (even with only 14 buildings on line) during the draining and filling of the system. This was compounded by a lack of isolation valves in the system. It was frequently the case that customer systems were inadvertently drained or air bound during work on the distribution

loop. As a result of this, new customers connected to the system may be required to use heat exchangers to avoid problems in servicing the distribution loop.

Metering

Energy metering is employed on all buildings connected to the system. However, due to the limited number of users currently connected to the main loop, the output from energy meters is not used for billing purposes. The present billing method involves apportioning the total operating costs among the buildings connected according to the floor area. When sufficient users are connected to the system, billing will be based on the originally established price of \$0.32 per therm.

Since these meters have not, to date, been utilized, no data is available on their reliability or accuracy. Table 12.8 presents key data relating to the meters employed.

Table 12.8

Klamath Falls System Energy Meter Data (Balzhiser, 1980)

Water Meter

Manufacturer	Kent TM 230 (actually Sonceboz type 314)
Type	turbine
Body Material	cast iron
Rotor Assembly Material	Ryton, 316 SS

Temperature Sensors

Manufacturer	Rho Sigma
Type	thermistor

Totalizer

Manufacturer	Rho Sigma
Display	gallons, Btu
Mounting	remote, wall

Disposal

The Klamath Falls system employs a single injection well for the district heating system. This well is located (see Figure 12.2) adjacent to the central mechanical room. In fact, the system was laid out to take advantage of this well (which was already in existence at the time of construction) for injection purposes.

The museum well, as it was previously known, was drilled in May, 1975, and was used only as a downhole heat exchanger well (to heat the county museum) until construction of the district heating

system. Figure 12.11 presents key data on the well. The temperature profile was taken during a "no load" injection test.

Originally 1,235 feet deep, the well has filled in to approximately 1,180 feet. At completion, it was slightly artesian (2 psi shut in) and was capable of producing 188 gpm of 188°F water at full artesian flow (Sammel, 1984). The artesian head in recent years had dropped below the surface. A maximum temperature of 199°F has been measured in the well.

Injection tests of the well have been run at flow rates as high as 960 gpm. The most recent tests ran for 29 days at a rate of approximately 700 gpm. Well head pressure at this flow rate varied from 39 to 43 psig (Sammel, 1984).

This well currently accepts injection fluid from the main downtown district heating system and the Mills Addition collection/district heating system. In addition, a downhole heat exchanger serving the county museum is still in service in the well.

Figure 12.11 (Sammel, 1984)

In order to avoid problems which might arise due to the thermal affects on adjacent wells, the injection temperature for the city district system was selected to exceed that of the surrounding wells. In this manner, the only thermal effect which could occur

would be one of increasing rather than decreasing temperature. It is primarily for this reason that a Δt of only 40°F is achieved by the district system. If thermal impact on other wells was not a consideration, the system would likely have been designed for a much greater Δt .

Problems/Solutions (Colahan, 1988)

Only one minor problem has been experienced with this well. When the Mills Addition injection line was installed at the well head, the systems (both Mills Addition and the downtown system) were not in operation. After the well head plumbing for the connection was completed, the downtown system was re-started while the new injection line (for the Mills Addition system) was pressure tested. Since the downtown system injects fluid which is in excess of the static well temperature, expansion takes place in the well casing when the system is in operation. As a result, when the crew returned to the well head to connect the injection line flange to the well head flange, it was discovered that they were no longer in alignment.

The well head connection was re-piped with a flexible stainless steel line between the casing flange and the injection line flange to allow for casing expansion and contraction.

Michigan Street System

The Michigan Street System (see Fig. 12.2) was constructed with funds from HUD in 1982. This system was an effort to extend the heating district into a low income residential area. Because many of the homes in this area are rental units (in which the tenants pay the heating bills), only a small fraction of the total number of homes (8 out of approximately 120) have been connected.

Since this system is much smaller in size and constructed largely of the same materials as the main system, it will be discussed only briefly.

As mentioned in the Introduction to the chapter, the Michigan Street system is connected to the primary transmission line for the main downtown system. Figure 12.12 indicates the method by which this connection was made. Fluid is pumped from the transmission line through the central plate heat exchanger and back into the transmission line by one of two geothermal circulating pumps (all iron trim).

The heat exchanger (316 SS plates, Buna-N gaskets), along with all other mechanical equipment, is located in an underground concrete vault. This type of installation was employed as a result of the lack of available surface space for a mechanical room. The vault is located under the sidewalk adjacent to the main transmission line.

Figure 12.13 presents the sectional view of the mechanical vault. Electrical equipment (starters, manual controls, etc) is located in a steel enclosure above ground. The only indications of the presence of the vault are the electrical cabinet and the two 8 inch ventilation ducts.

Figure 12.14 presents a flow schematic of the Michigan Street mechanical system. A full description of the operating sequence follows: (Balzhiser, 1980)

"Sequence of Operation

1. Circulating Pumps CP-1, CP-2 (Heating Water Pumps):
 - a. Match operation for each pump. One pump is used for standby operation.
 - b. Controlled from Hand-Off-Auto switch located in above ground mounted control cabinet. Cabinet and switches provided by Electrical Contractor. Coordinate.
 1. Auto position: pump operates continuously subject to proof of water flow. Provide flow switch with time delay to allow pump starting.
2. Circulating Pumps Cp-3, CP-4 (Geothermal Water Pumps):
 - a. Match operation for each pump. One pump is used in above ground mounted control cabinet. Cabinet and switches provided by Electrical Contractor. Coordinate.

Auto position: pump runs continuously subject to full flow bypass condition on three-way valve. Pump to shut down anytime three-way valve goes to full bypass. Pump to activate when valve starts modulating to open condition. Note: built in time delay is provided with starting equipment to run pump minimum of two minutes each time it is activated. Coordinate with Electrical Contractor. Provide proof of water flow switch with time delay to bypass above timer and shut pump off if water flow is not established.

3. Modulating Three-Way Heating Water Valve:

- a. Controlled by 120 volt electric control motor to maintain 150°F LWT on downstream side of valve.
- b. Fail Position: full flow open to heat exchanger."

In summary, a three-way valve on the loop side of the heat exchanger modulates to maintain a 150°F supply water temperature. With this valve in the full bypass position, the geothermal pump shuts down. At anything less than full bypass position, the geothermal pump is in operation. The heat exchanger was designed for the following duty:

Heating load	5.76×10^6 Btu/hr
Geothermal flow	160°F in, 120°F out
Loop flow	110°F in, 150°F out

Figure 12.14 (Balzhiser, 1980)

The distribution system for the Michigan Street area consists of the following:

1026'	4 inch
1440'	3 inch
3792'	2 inch
3734'	3/4 inch

All of the two through four inch piping is direct buried, pre-insulated fiberglass material (Rovanco Insul-8). Although originally specified as Kwik-Key type connections, the actual installation employed epoxy type adhesive joints. Based on the experience with the Kwik-Key material in the downtown loop, it is fortunate that epoxy joints were used. Individual branch lines to homes (3/4 inch) were constructed of field insulated polybutylene (Rahn PB4121 SDR 13.5) piping. This material was specified to employ thermal fusion joints; however, actual installation is reported to have been accomplished with stainless steel hose clamps (Colahan, 1988).

These individual branch lines (3/4 inch) were insulated with flexible closed cell foam insulation. Branch lines were connected to precast meter boxes at the property line. These boxes contain supply and return ball valves, water meter and temperature probes. In some cases, output from the water meter and temperature probes is run through a 3/4 inch conduit buried along with the branch lines and connected to the totalizer located at the dwelling. In the remaining installations, the totalizer is located in the meter box.

Problems/Solutions

Only two problems have surfaced with the operation of the Michigan Street system. The first of these relates to the service life of the batteries in the Btu meters (totalizers). These "5 year" batteries have only lasted an average of 2 years. As a result of this performance and the significant price difference between the one year and five year models, only the one year batteries will be used in the future (Colahan, 1988).

The second problem relates to mechanical vault ventilation. The current system consists of an exhaust fan discharging through an 8-inch steel ventilation pipe. Ventilation air is delivered through a second 8-inch line. This system does not seem to maintain an acceptable level of moisture in the vault.

Mills Addition System

The Mills Addition system, completed in 1987, is the latest addition to the Klamath Falls heating district. As mentioned earlier, this system is connected to the main transmission line only for emergency back up purposes. The primary source of heat is

"waste" flow from a number of existing private geothermal systems in the Main Street/East Main Street area of the city.

Specifically, waste water from a total of seven existing geothermal systems is collected, delivered to a 2,000 gallon holding tank and passed through a heat exchanger to provide heat to a closed loop distribution system. Effluent from the heat exchanger is delivered through an uninsulated line to the injection well. This system employs the same injection well as the main downtown loop system.

A complete description of the sequence of operation for this system follows:

"Sequence of Operation"

1. Circulating pumps CP-1, CP-2 (Geothermal Water Pumps):

a. Match operation for each pump. Pumps run simultaneously.

b. Controlled from Hand-Off-Auto switch located in above ground mounted control cabinet. Cabinet and switches provided by Electrical Contractor. Coordinate.

1. Auto position: pump runs continuously subject to full flow bypass condition on three-way valve. Pumps to shut down anytime three-way valve goes to full bypass. Pump to activate when valve starts modulating to open condition. Note: built in time delay is provided with starting equipment to run pump minimum of two minutes each time it is activated. Coordinate with Electrical Contractor. Provide proof of water flow switch with time delay to bypass above timer and shut pump off if water flow is not established.

2. Circulating Pumps CP-3, CP-4 (Heating Water Pumps):

a. Match operation for each pump. Pumps run simultaneously for parallel operation.

b. Controlled from Hand-Off-Auto switch located in above ground mounted control cabinet. Cabinet and switches provided by Electrical Contractor. Coordinate.

1. Auto position: pumps operate continuously subject to proof of water flow. Provide flow switch with time delay to allow pump starting.
 2. On position: pumps run continually.
 3. Off position: pumps inoperative.
3. Circulating Pumps CP-5, Cp-6 (Geothermal Waste Water Pumps):
- a. Match operation for each pump. One pump is used for standby.
 - b. Controlled from Hand-Off-Auto switch located in above ground mounted control cabinet. Cabinet and switches provided by Electrical Contractor. Coordinate.
 1. Auto position: pump runs continuously subject to level switches in tank. Low level, pump shuts off; high level, pump activates.
 2. Off position: pump inoperative.
 3. On position: pump operates if water is above low level switch in tank.
4. Modulating Three-Way Heating Water Valve:
- a. Controlled by 120 volt electric control motor to maintain 170°F LWT on the downstream side of valve.
 - b. Fail position: full flow open to heat exchanger."

As shown in Figure 12.15, waste water drains to the holding tank, and as long as the level is above the minimum position, the waste water pump delivers flow to the heat exchanger. Effluent from the heat exchanger passes into the injection as described above. On the loop side of the heat exchanger a three way valve modulates to maintain a 151°F supply water temperature. As is the case of the Michigan Street system, a condition of full bypass at the three way valve serves to shut down the waste water pump. The waste water pump can also be activated by a high level switch in the holding tank. Circuiting is such that HE-1 can provide any peaking necessary in the event of low waste water flows.

In the emergency back up mode, loop flow would pass only through HE-1. In this mode the system would function in the same manner described for the Michigan Street system.

Figure 12.15 (Balzhiser, 1980)

Table 12.9 presents a summary of information relating to the heat exchangers.

Table 12.9
Heat Exchanger Data - Mills Addition System
Klamath Falls

	Heat Exchanger 1	Heat Exchanger 2
Duty	10×10^6 Btu/hr	2.75×10^6 Btu/hr
Geothermal Temp.	200°F in, 160°F out	174°F in, 145°F out
Loop Fluid	140°F in, 180°F out	140°F in, 151°F out
Plate Material	316 SS	316 SS
Gasket Material	Buna-N	Buna-N
Manufacturer	APV	APV

The collection system is constructed of all pre-insulated fiberglass piping as described in Table 12.10.

Table 12.10
Mills Addition Geothermal Piping Summary

Carrier Pipe	Fiberglass w/expoxy liner (.0200" min.) MIL-SPEC P28584 A and P222454 expoxy resin joint system.
Insulation	Polyurethane, $k = .13$, 21b/ft ³
Jacket	PVC, high impact class 12454-B, ASTM 1784, Type 1, Grade 1

This piping employs only bell and spigot adhesive type joining. Due to the location of the system from which the flow is collected, much of the collection piping was located in the concrete tunnel housing the main transmission line for the downtown loop. The remainder of the collection system is direct buried type installation.

The collection system piping terminates at the central mechanical vault. As in the case of the Michigan Street system, this mechanical equipment (heat exchangers, circulating pumps, holding tank, expansion tank, etc) are located in an underground concrete vault. In this instance, the vault is located below a traffic island at the intersection of Main Street and East Main Street (just across the street from the Michigan Street vault). Due to

the very limited space in the vault, all piping including geothermal is of the carbon steel, grooved end, mechanical type joint.

After passing through the heat exchanger, the waste geothermal water is pumped through an uninsulated fiberglass line to the injection well. The line is located, for the most part, in the main transmission line tunnel.

The distribution loop for the Mills Addition system is of pre-insulated, adhesive joint, direct buried fiberglass piping. Customer branch lines are pre-insulated copper. Specifications for all piping appear in the Appendix.

Due to funding limitations, the extent of the distribution loop was considerably reduced.

Actual construction included only about one-third of the originally planned piping.

Problems/Solutions

The major problem for this system has been legal. Prior to the construction of the collection system, the waste geothermal fluid was simply disposed of in the storm sewer system. As a result, storm sewer system temperatures in the immediate area were extremely high. An enterprising local business man took advantage of this heat by placing a heat exchanger in the system outfall.

Once the system was in place, this heat was no longer available at the outfall. As a result of this, legal difficulties developed which prevented operation of the system.

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OIT SYSTEM

Introduction

The Oregon Institute of Technology system is the oldest of the modern systems surveyed for this report (the Boise Warm Springs Water District has operated since the 1890's). It was originally constructed in 1964 and has been in continuous service since. As a result of the lack of experience with the design of large geothermal district heating systems in the early 1960's, a great many difficulties have been experienced with the system over the years. These problems, for the most part, have been resolved and, as a result, have provided a substantial body of information concerning the applicability of various materials and designs for low temperature direct use.

Figure 13.1 OIT Distribution System Layout
(Carson, et al., 1986)

A general layout of the campus system appears in Figure 13.1. Geothermal fluid is produced from three wells located on the hill above the campus. This fluid is collected in a 4000 gallon settling tank and delivered to the individual buildings via gravity through a distribution system containing both direct buried steel (original design) and pre-insulated fiberglass piping in a concrete tunnel system (newer design). The fluid is either used directly in the building heating system (original design) or passed through heat exchangers (newer design) and then disposed of on the surface. An injection well is currently under construction.

Two of the more novel applications of the campus resource have involved the operation of an absorption chiller for space cooling and the use of system effluent for an aquaculture project.

Table 13.1 provides an outline of key information on the OIT system.

Table 13.2 presents a typical chemical analysis of the fluid from the three production wells.

Table 13.1

Key Information - OIT Geothermal System

Years of operation	24 years
Number of customers, ft ²	Number of customers n/a, 600,000 ft ²
Total length of piping	Approximately 7,000 lf
Resource temperature	193°F
Delivery temperature, Δt	190°F, 55°
Peak flow capability	980 gpm
Disposal method	Surface (injection well under construction)
Customer heat exchangers	Yes
Number of production/injection wells	3 production, 1 injection
Rate structure	n/a
Ownership - public/private	Public
Original financing/cost	n/a
Contact person(s)	Roger Wilrout, Director of Physical Plant, or Paul Lienau, Director of Geo-Heat Center, Oregon Institute of Technology, 3201 Campus Drive, Klamath Falls, OR 97601

Table 13.2

Typical Fluid Chemistry - OIT Resource (Ellis, 1981)

Key Species	mg/l
pH	8.60
Chloride, Cl	51.00
Sulfate, SO ₄	330.00
Bicarbonate, HCO ₃	20.00
Carbonate, CO ₃	15.00
Hydrogen Sulfide, H ₂ S	1.50
Ammonium ion, NH ₄	1.30
Oxygen, O ₂	0 - 0.02
TDS	795.00
Silica, Si	48.00
Sodium, Na	205.00
Calcium, Ca	26.00
Nitrate, NO ₃	4.90
Potassium, K	4.30
Fluorine, F	1.50
Iron, Fe	0.30

Production Facilities

Table 13.3

OIT Production Facilities
Production Well and Pump Data (Campbell, 1988)

	Well #2	Well #5	Well #6
Flow/Head (gpm/ft)	130/637'	500/400'	350/650'
Setting depth (ft)	440	440	440
Size (bowls)(in)	7RM	10RL	8RH
Number of stages	35	12	26
Manufacturer	Aurora	Aurora	Aurora
Horsepower (hp)	50	75	75
Var. speed drive	yes	yes	yes
Drive type	fluid coupling	fluid coupling	fluid coupling
Lubrication (shaft)	oil	oil	oil
Well depth (ft)	1288'	1716'	1800'
Well size (in)			
Temperature (°F)	193	193	193
Static water (ft)	332	358	359
Drawdown (ft)	7-10'	7-10'	7-10'
		12"-480'	12"-416'
		10"-815'	10"-848'
		8"-TD	8"-1150'
			6"-TD

Control Scheme

The basic control scheme for the production wells is illustrated in Figure 13.2. The three production wells produce to a common settling tank located along with the back-up boiler in a "heat exchange" building. Flow into the tank is modulated by two control valves which respond to a level controller signal. Flow from the tank drains by gravity to the campus according to demand on the system. Since the outlet of the production line is throttled (by the two tank control valves), production line pressure is controlled by varying the pump speed through use of fluid coupling type speed control. The fluid couplings respond to a pressure signal from the production line. A Barber Coleman actuator is used. Change in pressure causes a pressure sensing bellows to expand or contract, rotating a shaft which controls the scoop tube on the fluid coupling.

Figure 13.2 Production Facilities Control Scheme

Problem/Solutions

Unfortunately, the pressure range of the controller is above the level the production line requires. As a result, this control method results in unnecessary high pressure operation which wastes pump energy. Flow control is also exercised through cycling of the three production pumps (Masl, Gibson, 1987). As a result, the fluid couplings are employed more for "soft starting" the pumps rather than speed and flow control.

The use of fluid couplings was not a part of the original design. These units were installed after about five years of operation as part of a major re-design of the production pumping system. The fluid couplings were installed along with the settling tank control valves (described earlier) in an effort to automate the system to a greater extent. Prior to this, the pumps were manually operated (on-off) according to tank level. This involved a significant manpower requirement.

The original production pump design consisted of constant speed, water lubricated lineshaft pumps, virtually the same as cold water irrigation pumps. At the surface, the electric motors were located in well head "pits" or cellars.

A review of the original specifications for the campus construction indicates that, although an oil lubricated enclosed lineshaft pump was specified (Skidmore, 1963), a water lubricated system was apparently installed. The original pump specifications appear at the end of this chapter.

This design proved unsuitable for a number of reasons.

The well head pits were poorly ventilated, which resulted in motor overheating and moisture condensation problems (Campbell, 1988). In addition, servicing the well head piping was difficult. Efforts at improving the ventilation proved only marginally successful and a decision was made to raise the well heads and enclose them in above ground wood frame structures, which are still in use today.

The major difficulty with the early pumps was their lack of allowance for operation in the water temperature and chemistry present. This was manifested in two primary areas (Campbell, 1988):

- 1) lack of sufficient bowl "lateral", and
- 2) use of water lubricated bearings.

The lack of sufficient bowl "lateral" resulted in the necessity to preheat the lineshaft prior to starting the pump. This preheating ensured that sufficient clearance between the impeller and bowl was developed prior to start up. This procedure was not only labor intensive but required that one pump always be in operation to provide preheat water flow to start up a second pump. During the system re-design in the late 1960's to early 1970's, extra lateral

bowls were installed, which eliminated the necessity for preheating (Campbell, 1988).

In addition to the lack of lateral in the bowls, the bronze impellers were attached to the shaft with collets. A number of failures occurred which involved impellers becoming detached from the shaft (Mitchell, 1980). It was thought that differential expansion between the bronze impeller and the stainless steel collet and shaft was the source of this problem. During the system upgrade, new pumps with keyed and colleted connections were installed.

The most serious difficulty with the early pumps related to shaft bearing failures. Due to the general lack of experience in pumping hot water in the early 1960's, an experimental approach was embarked upon. Basically, this consisted of using standard cold water equipment and learning, through experience, how long it would last. Three types of bearings were employed:

- 1) "cutlass" rubber
- 2) teflon
- 3) bronze

None of these materials demonstrated acceptable lifetimes. Though no actual records of the failures are available, it is reported that the bronze bearings "burned up" and the rubber and teflon bearings "swelled." A number of lineshaft failures (twist offs) also occurred in the original pumps and these were most likely related to the bearing problems.

After unsuccessful experimentation with water lubricated bearings, it was decided that isolating the bearings from exposure to the geothermal fluid through the use of an oil lubricated, enclosed lineshaft assembly would be the best approach. This modification was made along with the other changes during the system upgrade in the early 1970's.

In summary, a major pumping system re-design was carried out at OIT after approximately five to six years of operation. This upgrade included the following major items:

- o raising the discharge head assembly to grade level and eliminating well head pits,
- o installing fluid coupling type variable speed drives,
- o installing new oil lubricated enclosed lineshaft assemblies,
- o installing new "extra lateral bowls," and
- o changing from collet to key and collet impeller connections.

These changes were extremely successful. OIT's production well pumps have now been in service for 15 to 17 years with no service to the bowls or shaft assemblies. The only maintenance required has been periodically replacing the thrust bearing in the variable speed drive units.

Due to the multiple well arrangement, the system has inherent back-up capability. As a result, the back-up boiler has not had occasion to operate in over 20 years.

A summary of current production pump construction materials appears in Table 13.4.

Table 13.4

OIT Production Well Pump Materials (Layne and Bowler, 1971)

<u>Item</u>	<u>Material</u>	<u>Specifications</u>
Shaft (pump)	Stainless steel	AISI 416
Column	Carbon steel	ASTM A53 Grade A
Shaft enclosure	Carbon steel	ASTM A53 Grade A
Bearings	Leaded red bronze	(83% Cu, 5% n, 7% Pb, 5% Zn)
Bowls	Cast iron	ASTM A-48 Class 35
Impellers	Leaded red bronze	(83% Cu, 5% Sn, 7% Pb, 5% Zn)
Keys	Stainless steel	AISI 416
Fasteners	Stainless steel	AISI 303
Collet	Carbon steel	ASTM A-108 Grade B1113

(Layne and Bowler, 1971)

There is one curious paradox in the production pump experience at OIT. Although the bronze water lubricated bearings were unsuccessful in the lineshaft assembly, the same material has been very successful in the bowl bearings. Even with the use of an enclosed oil lubricated lineshaft, the bowl bearings are lubricated by the fluid being pumped. As a result, the bronze bowl bearings are exposed to the geothermal fluid. The only apparent explanation for this lies in the relative size of the bowl bearings to the shaft bearings. The larger bowl bearings surface area may provide sufficiently reduced loading to extend the life of the material.

In addition, there appears to be no dissimilar metal difficulty with the bronze impeller and stainless steel collet/key connection. The same type of contact is suspected of contributing to the failure of some control valves elsewhere on the campus as will be discussed below.

Distribution System

The distribution system at OIT was originally direct buried Schedule 40 carbon steel piping. This piping was field insulated with "Foamglas" type insulation and covered with a "mastic" vapor barrier. Specifications for the original steel piping appear at the end this chapter. Portions of this system are still in

service. Geothermal supply water was delivered directly to the individual buildings through the steel piping network. This water was used directly in the building heating system and then discharged to the campus storm sewer system, which provided the disposal portion of the distribution system.

As a result of numerous failures in both the insulated supply piping and the storm sewer system, this design is gradually being replaced by a new distribution/disposal network. Table 13.5 presents a summary of key distribution system piping data. The new system consists of pre-insulated fiberglass piping (see appendix for specifications) located in a concrete tunnel system below the campus.

Table 13.5
Piping Summary - OIT Geothermal Distribution System

	<u>Direct Buried Steel</u>	<u>Pre-Insulated Fiberglass in Tunnel</u>
Length in service	Approx. 3900 lf	Approx. 3400 lf
Sizes	8, 6, 4, 3	8, 6, 4
Material	Sch. 40 ASTM A-53, A120	See Table 13.6
Supplier		Rovanco, Thermal Pipe Systems
Connection Method	Welded	Epoxy adhesive bell & spigot joint

Problems/Solutions

The original buried steel piping system suffered both internal and external corrosion. Examination of a section of this piping after approximately 14 years of service revealed an internal build-up of scale approximately 1/16" to 1/4" thick. This scale consisted mostly of silica and iron oxide with the iron oxide located closest to the pipe wall. Tubercles were also present under which the wall thickness had been reduced by up to one-third of its original thickness (Mitchell, 1980). This corrosion was no doubt promoted by the fact that the main settling tank (at the head of the campus) is vented to atmosphere and, thus, permits oxygen to enter the system.

The numerous failures of the insulated steel distribution system have most often occurred in sections of pipe located adjacent to or beneath campus sidewalks. In addition, the failures are most common at elbows. It is concluded from this that expansion and movement of the piping caused failure of the mastic vapor barrier. This permits salt water (from sidewalk de-icing) to contact the

steel piping, resulting in corrosion failure (Ellis, 1981). Most of the remaining direct buried steel piping is straight run sections located under parking lots and undeveloped areas which are not exposed to de-icing salt.

In addition to the failures in the supply piping system, a number of failures in the storm sewer system were also experienced. This system is constructed of a combination of cast iron and carbon steel piping (in the buildings), direct buried galvanized culvert (from the buildings to the main campus line) and concrete culvert (main line). All of the failures occurred in the buried galvanized culvert. These failures were likely the result of a combination of dezincification (removal of the galvanized coating) and subsequent corrosion of the unprotected steel surface in the presence of the oxygen rich atmosphere.

In response to these failures, a program was implemented in the late 1970's to construct a new distribution system and a dedicated geothermal collection system. A dedicated collection system would eliminate storm sewer corrosion problems and also facilitate separation of the geothermal water from general storm sewer flow. This offered the advantage of subsequent cascaded uses.

To date, the areas indicated in Figure 13.3 have been completed. Funding is expected within the next few years to complete the tunnel installation. These tunnels are typically located beneath the campus sidewalks. Since the tunnels were installed some 15 to 20 years after the campus was constructed, it was not possible to locate as many utilities in them as might be the case for new construction. However, most sections contain geothermal supply and return lines, chilled water supply and return lines and fire protection with limited use for telephone lines. Details of the concrete tunnel construction appears in Figures 13.4 and 13.5.

Although performance of this system is excellent, its cost is extremely high. Based on the most recent construction, it appears that construction of the tunnel (without piping) amounts to approximately \$300 per linear foot for a 6' x 6' size. In an effort to reduce this cost, an alternate construction technique was recently employed. An extension of the tunnel to a newly constructed building employed a six foot diameter, corrugated, galvanized steel culvert (see appendix for specifications). Exact figures for the cost of this method are not available since it was bid as part of the building construction package; however, it is estimated to be only 25% of the cost of the concrete approach.

All of the piping located in the tunnel system is of the pre-insulated fiberglass type as detailed in Table 13.6.

Figure 13.3 Status of Tunnel Construction

- A. Geothermal Carrier Pipe
- B. 4" ϕ PVC perforated pipe
- C. Excavation limits
- D. Drain gutter

Figure 13.4 Crossection of Tunnel

Figure 13.5 Photograph of Tunnel Interior

Table 13.6
Pre-Insulated Piping

	<u>Rovanco</u>	<u>Thermal Pipe Systems</u>
Carrier pipe	Bondstrand 4000	A.O. Smith green thread
Insulation	Polyurethane	Polyurethane
Jacket material	PVC 1120	PVC ASTM-D-3034
Application	Geothermal supply pipe	Collection system piping

All piping lengths are joined by epoxy type, bell and spigot, adhesive joints. Connections to valves and transitions to steel piping employ fiberglass flanges joined to the pipe with epoxy.

No difficulties have been experienced with this piping despite the fact that, in both cases, it was installed by crews with no experience in fiberglass installation.

All valves in the distribution and at building connections are of cast iron, gate type with outside stem and yoke. These valves employ bronze stems. Leakage around the packing is a common problem and, as a result, many of these valves are no longer operable. Newer construction employs all butterfly type valves for isolation duty. These valves (a specification appears in the appendix) should provide greatly improved performance due to less leakage and superior materials.

As mentioned earlier, the installation of a dedicated collection system for geothermal effluent (see appendix for specifications) provided the opportunity for cascaded use of the fluid. This opportunity has been incorporated into the design of the newest building on the campus (equipment specifications appear in the appendix). As shown in Figure 13.6, flow from the exiting five buildings on the collection system is delivered to a 4000 gallon storage tank in the new building. This "waste" water, at approximately 130°F, is then used to heat the 40,000 square foot classroom structure. Overflow from the tank and exit water from the building is directed to the existing storm sewer discharge point.

In order to avoid corrosion problems, the storage tank in the new building, along with most of the piping, was constructed of reinforced fiberglass. This building came on line in February 1988, and has operated very satisfactorily.

Figure 13.6 Geothermal Piping Schematic New Classroom Building

Customer Connections

The original design for the OIT system involved direct use of the geothermal fluid in individual building heating equipment. This was based on a chemical analysis from which it was erroneously determined that the concentration of constituents in the geothermal fluid was not substantially different from water used in most hydronic systems. Unfortunately, the analysis failed to consider the effects of H_2S and NH_4 on the copper and copper alloys in the system. It is also probable that these items were not included in the water analysis. Due to a large number of equipment failures, an ongoing modification program is in place to convert all buildings to indirect (heat exchanger) type connections. For the most part, these indirect connections involve plate and frame type heat exchangers constructed of 316 SS plates and medium nitrile rubber (Buna-N) type gaskets, though there is one titanium plate unit on the campus.

Under the original design, geothermal fluid was delivered directly to the individual buildings under sufficient pressure to overcome the resistance of the mechanical system. The fluid was then discharged to the storm sewer system after use. This once through approach eliminated the need for main loop circulating pumps. Smaller pumps serving circuits which employed a supply water reset schedule were used. These pumps were generally of "all iron" construction and demonstrated acceptable life.

Problems/Solutions

Problems associated with the direct use of the geothermal fluid were promoted by the use of ordinary construction materials for building heating equipment. These materials consisted primarily of Type L copper piping, 50/50 solder and copper alloy (brass and bronze) valves (Skidmore, 1963).

A number of different corrosion failure modes were identified through experience and analysis provided by Radian Corporation under contract to USDOE. Among the more important of these modes are: (Mitchell, 1980)

- 1) Failure of 50/50 solder connections. This type of connection failed frequently. It was determined through analysis of specimens that the nature of the failure was de-plumbification or selective removal of the lead from the tin/lead matrix. This leaves a low strength sponge like structure which quickly fails. This mode of failure was particularly severe when the flow in the piping was toward the annulus of the joint (Mitchell, 1980).
- 2) Even more rapid failure of 1% silver solder was experienced at another Klamath Falls site with very similar water chemistry. In this case, the silver solder was completely removed in a period as short as 27 months (Ellis, Mitchell, 1979).
- 3) A similar failure mechanism was experienced with a bronze pump impeller. In this case, the zinc was removed from the alloy, resulting in a similar effect as discussed above. This dezincification was believed to be a result of the relatively high zinc content (13%) of this particular alloy (Ellis, 1981). Alloys composed of lower zinc content have experienced no dezincification.
- 4) Wall thinning and perforation of copper tubing was a common occurrence, particularly at connections between copper and steel piping (fan coil headers, valve connections, etc.). The failure of the copper was primarily due to the presence of H_2S in the water. The hydrogen sulfide attack was compounded at the steel connections by dissimilar metal (galvanic) corrosion. Corrosion rates in the copper were determined by analysis to be as high as 5.4 mils per year (Ellis, 1981).
- 5) Control valve problems were the result of two different failure modes. The first of these involved valve plugs becoming detached from the operating stem. This failure occurred in only those valves where the plug (brass) was crimped to the stem (stainless steel). This is believed

to be the result of both H_2S attack of the brass and galvanic corrosion. In control valves where the plug was threaded to the stem, the same materials experienced no failure (Mitchell, 1980).

- 6) A second control valve problem was associated with packing leakage. This leakage resulted in deposition of previously dissolved materials on the stem upon evaporation of the geothermal fluid. Sufficient accumulation of this material resulted in seized stems and inoperative valves. Upon disassembly, it was discovered that all bronze body valves were coated with a thin layer of black scale. This scale was identified as copper sulfide, which is a product of corrosion of the copper component by H_2S gas. This deposit was also found inside all copper piping which was removed for analysis. Due to the much greater thickness of the valve bodies compared to the piping, this corrosion had no effect upon valve operation.

In order to eliminate these problems, a program of isolation heat exchanger retrofit was implemented beginning in about 1980. Since that time, all of the major campus addition construction projects have incorporated plate and frame heat exchangers. In addition, heat exchangers have been retrofitted to three of the existing buildings and plans are being formulated for installation of heat exchangers in the remaining buildings.

As mentioned earlier, these units employ primarily 316 stainless steel plates and Buna-N gaskets. A typical specification appears in the appendix. One titanium plate heat exchanger is employed. This unit was installed in early 1979 when material analysis studies were still incomplete. In retrospect, the designer's choice of titanium was conservative since subsequent experience has demonstrated 316 SS to be acceptable. However, this information was unavailable at that time.

Two 316 SS plates in the swimming pool heat exchanger failed due to pitting in less than three years (Masl, Gibson, 1987). This pitting occurred on the pool water side of the plates and was no doubt a result of the high chlorine content of the water. It is likely that these plates will have to be replaced with titanium in order to avoid repeated failures.

Under the original design, the controls consisted largely of two way modulating valves. These served to throttle the geothermal water according to system requirements. In most buildings, the geothermal flow was cascaded from the perimeter system (finned tube) and domestic hot water heating to ventilation system hot water coils, resulting in a system Δt at 60° to $70^\circ F$. This approach, although beset by corrosion problems, was quite effective at achieving a large system Δt and minimizing flow requirements.

FIGURE

RETROFIT HEAT EXCHANGER CONTROLS

Figure 13.7 Typical controls installed with retrofit heat exchangers.

Problems in achieving acceptable system temperature drops were experienced in buildings which received retrofitted heat exchangers. The control scheme employed is illustrated in Figure 13.7. Heat exchangers were generally selected for the following conditions:

Geothermal	190° - 130°F
Building loop	100° - 155°F

Despite this, exit water temperature (geothermal) as high as 180°F were observed, indicating only a 10°F Δt . In addition, severe valve "hunting" was experienced. These difficulties were traceable to two primary causes: 1) controller sensor placement, and 2) control valve sizing.

In an effort to assure low geothermal effluent temperatures, the control design was based upon maintaining a constant building loop return water temperature. A sensor in the return water signaled a controller whose output operated the two-way valve located on the geothermal supply line to the heat exchanger. The theory was that maintaining a low building loop return temperature would naturally result in a low geothermal effluent temperature as a result of the design of the heat exchanger.

The basic flaw in this design was that it placed the entire mass of the building loop between the sensor and the control valve. As the sensor in the return water called for heat, the control valve would begin to open. This would result in an almost immediate rise in supply water temperature. However, before this increase could arrive at the return water sensor, it would have to travel through the entire building loop. This resulted in very unstable operation manifested in the "hunting" mentioned above. This situation was exacerbated by the oversizing of the control valves.

A program is currently underway to modify this design by switching to a supply water sensor (to eliminate the time lag of the present system) and throttling back the main geothermal line entering the building to reduce the effect of the oversized valve. The throttling solution is less effective than reducing the size of the control valve; however, it is also considerably less expensive.

A final comment on the use of plate heat exchangers at OIT relates to the original selection. As indicated by the temperatures discussed earlier, these units were chosen on the basis of a 30° approach. This approach could easily have been reduced to 15° or even 10° for a very reasonable incremental cost at the time of original design. This would have resulted in significantly reduced flow requirements (approximately 25%) and production pumping energy. Unfortunately, adding additional plates to existing exchangers is much more costly after installation.

Absorption Chiller

In addition to providing space, pool and domestic hot water heating needs, the OIT geothermal system also supplies a portion of campus cooling needs through an absorption chiller.

This machine, installed in 1980, is a nominal 312 ton unit (Rafferty, 1986). However, due to the relatively low input water temperature of 193°F, this unit produces only 150 tons of capacity. This requires 600 gpm of 190°F fluid and extracts only a 20° Δt. A full discussion of this unit can be found in Rafferty, 1986.

Although there have been no difficulties with the machine to date, the potential exists for corrosion of the generator tubes. Geothermal fluid is used directly in the tubes, which are

constructed of 90-10 cupro-nickel. It is likely at some point that failure of these tubes will occur as a result of the H_2S in the fluid.

Metering

No individual building energy metering is employed on the campus. A flow meter is used to monitor total flow in the main line just downstream from the settling tank.

Unfortunately, the placement of this meter is likely to compromise the accuracy of its output. Approximately 2 diameters upstream are 2 tees and a gate valve. The manufacturer's literature for the insertion paddle wheel element calls for 10 diameters of straight pipe upstream in order to assure a uniform flow profile at the meter.

Table 13.7 presents a summary of information on this meter.

Table 13.7
Wellhead Flow Meter - Information Summary

Transducer	- Insertion paddle wheel
Manufacturer	- BPN-Potoflow, 8 in series
Display	
	- Remote type, instantaneous flow rate (analog)
	Totalized flow - 6 digit counter, continuous
	Rate recorder, thermal printer
Manufacturer	- BPN Associates, Inc., #NTRR101N

Disposal

Surface discharge is the present method of disposal used by the system. Geothermal waste water, along with storm sewer flow, is discharged to a ditch at the lower (west) end of the campus. This ditch proceeds approximately one mile to Lower Klamath Lake.

Although, from an operational standpoint, surface discharge is the simplest and least expensive approach, it does present several potential problems.

Safety Hazard. Although the winter effluent temperature is as high as 130° to 140°F, ambient temperatures result in rapid cooling. Due to the operation of the absorption chiller,

however, summer effluent temperatures are approximately 160° to 170°F. Temperatures of this magnitude in an open ditch present a potential injury/liability hazard.

Conflict with Local City Ordinance. As a result of moderately declining reservoir levels (approximately 1 foot per year), a city ordinance banning surface discharge was passed. This ordinance requires all operations within the city to embark on an injection program by 1990. As a result, the campus is currently constructing an injection well.

In response to this ordinance, a 2,000 foot injection well was drilled in late 1988. Flow testing of the well is currently in progress. Initial results of the testing are not encouraging.

A novel use of a small portion of the campus effluent was developed by the Geo-Heat Center some years ago. Effluent was directed to an aquaculture facility which successfully raised several species. This project initially began as a small experimental pond which raised juvenile freshwater prawns. The success of this effort resulted in the construction of two large half acre ponds in 1980. Each of these ponds was supplied with 160 gpm of 130°F effluent at peak conditions.

These ponds were successfully used to raise both prawns and rainbow trout. The trout raised for the Oregon Department of Fish and Wildlife were found to be capable of growth rates nearly three times that experienced at the hatchery.

Unfortunately, future funding for the project became uncertain and the OIT administration decided to fill in the ponds and construct a parking lot.

Specifications

Original Direct Buried Steel Piping (approximately 1964)(Skidmore, 1963)

Piping Materials

Heating hot water mains: Schedule 40 black steel pipe and butt welding fittings with electric-arc welded joints.

Heating Main Insulation

1. General: All below grade heating water mains shall be insulated with either factory wrapped Pittsburgh Corning Foamglas or Z-Crete. Either system shall be furnished and installed in accordance with manufacturer's standards by a factory authorized installer. Main beneath building floor to mechanical room shall also have this insulation.
2. Foamglas Insulation:
 - a. Thickness: Pipes up to and including five inch shall have 1 1/2 inch Foamglas; six inch and larger pipes shall have two inch Foamglas.
 - b. Expansion Loops: Oversized Foamglas shall be used on all expansion loops and all loops shall be encased in concrete.
 - c. Drain: A continuous four inch concrete tile drain in a gravel bed shall be run in all trenches.
 - d. Sand Bed: The insulated mains shall be laid on sand bed of three inch minimum thickness and backfill to a point three inches over main shall also be sand.
 - e. Finish: Add "Finish coating shall consist of coal tar Pittcote #50, Koppers #50 or Koppers Pittchem 101. The glass fabric shall be impregnated with coal tar Glassphalt Inc., or Twinsburg Miller."

Geothermal Supply Piping and Valves (approxmiately 1980)(Amundson, 1980)

Liquid Heat Transfer Piping

Pipe:

1. Steel pipe shall be Schedule 40, black, ASTM Spec. A-120.
2. Copper pipe shall be type "L" hard drawn, ASTM Spec. B-88.

3. Geothermal water piping shall be filament wound epoxy equal to Bondstrand Insul-8 300 system type with integral urethane foam insulation and PVC jacket, meeting Ameron Bondstrand specifications for Series 2000 pipe, fittings and flanges.
4. Fittings for filament wound piping shall be filament wound epoxy meeting same specifications as pipe.
5. Gate valve for geothermal water use, 6" and 8"; flanged, 200 lb. WOG, all iron, rising stem, similar and equal to Lunkenheimer, Fig. 1587.

Geothermal Collection Piping (approximately 1985)(Amundson, 1985)

Pipe and Pipe Fittings

1. Factory fabricated pipe assembly consisting of service pipe, insulation, and jacket.
2. Joining Method:
 - a. Bell and spigot with field supplied thermal setting epoxy resin.
 - b. In conformance with manufacturer's recommendations.
 - c. When joining to steel pipe:
 Flange connections only. Steel flange 150 lb. flat faced.
 Anchor steel pipe within five feet of connection.
3. Piping: (contractor's option)
 - a. Rovanco "Insul-8 System 250" with FRP carrier. Two PCF Polyurethane foam insulation. 110 mil PVC jacket.
 - b. Bondstrand Series 2000. FRP Carriers, 2 PCF Polyurethane foam insulation. 110 mil PVC jacket.
 - c. Ric-will Dual-Gard 250. FRP Carriers, 2 PCF Polyurethane foam insulation. 110 mil PVC jacket.

Most Recent Campus Construction (1987)(SRG, 1986)

Geothermal Water Storage Tank

Tank shall be filament wound glass-fiber-reinforced thermoset resin constructed in accordance with ASTM D3299-81. Tank shall be designed for 250°F temperature and working pressure of 14.9 psig. Tank shall be factory insulated with 2 pcf density polyurethane foam, K factor of 0.13, 90 to 95% closed

cell content and in conformance with MIL 1-24172 and ASTM C 591. Insulation shall be a minimum of 1 1/2 inches thick. Provide outer glass-fiber reinforced jacket to enclose insulation. Tank to be supported above grade on legs or frame. Bottom of tank shall be dome or cone shaped. Tank shall have dome top. Provide flanged pipe connection, manhole access and site gauges. Tank size as shown on drawings. Corrosion Controllers, Inc., Harrington Plastics or approved.

Geothermal Water Specialties

1. Strainers: "Y" pattern, iron body, with blow-off connection and 0.45 inch perforated stainless steel screen. Install strainers in manner to permit access for cleaning and screen removal.
2. Valves: Valve type and style to be as listed below. Valves shall contain no bronze parts. Apollo, Crane, Demco, Grinnell, Hammond, Jenkins, Kennedy, Lukenheimer, Milwaukie, Nibco or approved. Jenkins numbers are listed.
 - a. 2 inch and smaller; Bell: No. 8421
 - b. 2 1/2 inch and larger, Butterfly, Lug: No. 231
Butterfly, Wafer: No. 221
3. Pumps: End suction base mounted, flexible coupling, mechanical seals, suitable for hot water service at head and capacity stated on drawings. Cast iron casing, all iron fitted with 316 SS impeller, roller bearing, 1750 or 1150 rpm standard frame motor. Impeller diameter not to exceed 90% of the volute tongue diameter. Horsepower to be not less than indicated on drawings and not less than will be required at any point of the impeller curve. Provide pressure gauge trappings on suction and discharge flanges. Bell & Gossett, Paco, Taco, Armstrong, Federal and Aurora approved. Mount in a manner to allow disassembly of pump and motor without disturbing piping. Provide coupling and shaft guard to meet requirements of State Safety Code.

Geothermal Piping

Piping in Utilidor, Underground Inside Building and Concealed Locations Inside Building: Provide pre-insulated piping system. Carrier pipe and fittings shall be Bonstrand Series 2000 filament wound fiberglass reinforced plastic designed to withstand 250°F and 150 psi rated. Pipe to be in conformance with MIL-SPEC P28584A and P22245A. Insulation shall completely fill the annular space between the carrier pipe and outer jacket. The outer jacket shall be high impact, seamless PVC Class 12454-B compound conforming to ASTM 1784, Type 1, Grade 1. Piping shall have factory installed water-tight end

seals. Additional end seals shall be provided where piping must be field cut. Fittings shall be filament wound fiberglass reinforced plastic and joined with piping using a thermosetting epoxy resin. Pipe manufacturer shall provide PVC fitting and joint covers, foam insulation mixing kit and joint tape for field insulation of fittings and joints. Specialized tools required for installation of piping shall be provided by pipe manufacturer. Pipe manufacturer shall instruct Contractor on proper assembly and installation of piping. The pipe manufacturer shall provide to the Architect certification signed by the Contractor that such instruction has been provided.

<u>Nominal Pipe Size (in.)</u>	<u>Carrier Wall Thickness (in.)</u>	<u>Min. Insulation Thickness (in.)</u>	<u>Min. Jacket Thickness</u>
2	0.140	1.81	70
3	0.140	1.25	70
4	0.180	1.75	80
6	0.180	1.68	100
8	0.200	1.68	120

Butterfly Valves

1. General: Cast-iron body; stainless steel 316-disk, stem and screws; EPDM resilient seat, Buna-N "O" ring and stem packing; acetal bushing; 150 psig and 200° rating.
2. Features: Refer to Section 15100 HVAC Basic Materials and Methods - "Class B" pipe and fittings for connection to pipe and system.
3. Manufacturers: Keystone Fig. 100-060 Wafer Style BF or equivalent. Jenkins, W. C Norris, Lunkenheimer or Demco.

Utilidor

The utilidor shall be constructed of galvanized corrugated steel pipe. The utilidor shall be six feet in diameter, 10 gauge with 2 2/3 inch by 1/2 inch corrugations. The pipe shall be made from zinc coated iron or steel sheets which shall conform to ASTM Designation A444 and/or AASHTO M-218. The manufacturer of the sheets shall submit a guarantee providing that metal furnished shall conform to specification requirements and sheet shall bear an identification brand. Rivets shall conform to ASTM Designation A31 Grade A and shall be zinc coated. For bolted pipe seams, bolts shall conform to ASTM Designation A563 Grade C. For connecting bands and miscellaneous fasteners, bolts and nuts shall conform to ASTM Designation A307 Grade A. Bolts and nuts shall be zinc coated. Field joints of pipe shall preserve the pipe alignment and have neoprene gasket to make a water-tight seal. Couplers shall be made of the same zinc coated metal as the pipe. Couplers shall be corrugated bands not less than 12 inches wide. The ends of couplers shall overlap and be

connected by galvanized angles, 2 inches by 2 inches by 3/16 inch fastened with 1/2 inch diameter galvanized bolts; or may have integrally or separately formed flanges or slots connected with 1/2 inch diameter.

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