**GEOHERMAL HEATING RETROFIT AT
THE UTAH STATE PRISON
MINIMUM SECURITY FACILITY**

FINAL REPORT
March 1979—January 1986

Prepared by:
Case Lowe & Hart Inc. A/E
Ogden, Utah

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Administrative Services Division of Facilities
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MASTER

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ABSTRACT

This report is a summary of progress and results of the Utah State Prison Geothermal Space Heating Project. Initiated in 1978 by the Utah State Energy Office and developed with assistance from DOE's Division of Geothermal and Hydropower Technologies PON program, final construction was completed in 1984. The completed system provides space and water heating for the State Prison's Minimum Security Facility. It consists of an artesian flowing geothermal well, plate heat exchangers, and underground distribution pipeline that connects to the existing hydronic heating system in the State Prison's Minimum Security Facility. Geothermal water disposal consists of a gravity drain line carrying spent geothermal water to a cooling pond which discharges into the Jordan River, approximately one mile from the well site.

The system has been in operation for two years with mixed results. Continuing operation and maintenance problems have reduced the expected seasonal operation from 9 months per year to 3 months. Problems with the Minimum Security heating system have reduced the expected energy contribution by approximately 60%. To date the system has saved the prison approximately \$18,060. The total expenditure including resource assessment and development, design, construction, performance verification, and reporting is approximately \$827,558.

ACKNOWLEDGEMENTS

This report is a summary of the efforts of many people involved in the project since its inception in 1979. Their efforts have produced a viable geothermal heating system and provided a wealth of information for future development of geothermal resources. It is impossible to list all of the individuals involved but I would like to acknowledge their contribution to the success of this project.

The following people have been of great assistance to me in preparing this and previous reports and I would like to thank them individually.

Frank W. Childs

Senior Project Specialist
Energy Program Division
EG&G Idaho, Inc.

Lee Hathon, P.E.

Mechanical Engineer
Division of Facilities
Construction & Management
State of Utah

Ben C. Lunis

Senior Program Specialist
EG&G Idaho, Inc.

PON FINAL REPORT FORMAT

This report follows a general outline which has been developed for PON project final reports. The intent of the outline is to provide general uniformity in reporting format and content. Since the scopes of the projects vary, some sections of the general outline may not be applicable. This accounts for gaps in the section numbering because consistent numbering has been maintained for each subject which is presented. A list of PON projects which are expected to use this final report format follows. The DOE report number will be of the format: DOE/ET/XXXXX-N, where the X's are the last five digits of the contract number (given below) and N is determined by the number of reports issued by the subject contract.

<u>Contract Number</u>	<u>Project Name</u>	<u>Location</u>	<u>DOE Office</u>
DE-FC07-78ET27054	Monroe	Monroe, Utah	ID
DE-FC07-78ET27080	Haakon School	Philip, South Dakota	ID
DE-FC07-78ET28419	Diamond Ring Ranch	Haakon County, South Dakota	ID
DE-AC07-78ET28424	Ore-Ida Foods	Ontario, Oregon	ID
DE-FC07-78ET28441	St. Mary's Hospital	Pierre, South Dakota	ID
DE-FC07-79ET27027	Utah State Prison	Draper, Utah	ID
DE-FC07-79ET27028	Madison County	Rexburg, Idaho	ID
DE-FC07-79ET27030	Pagosa Springs	Pagosa Springs, Colorado	ID
DE-AC07-79ET27033	Elko Heat Company	Elko, Nevada	ID
DE-FC07-79ET27053	Boise	Boise, Idaho	ID
DE-AC07-79ET27055	Warm Springs State Hospital	W.S.S.H., Montana	ID
DE-AC07-79ET27056	Utah Roses, Inc.	Sandy, Utah	ID
DE-AC03-78ET27154	Klamath Falls	Klamath Falls, Oregon	SAN
DE-AC03-79ET27029	Moana, Reno	Reno, Nevada	SAN
DE-AC03-79ET27040	Susanville	Susanville, California	SAN
DE-AC03-79ET27045	El Centro	El Centro, California	SAN
DE-AC03-79ET27047	Aquafarms	Dos Palmas Area, California	SAN
DE-AC08-78ET27059	T-II-S Hospital	Marlin, Texas	NV
DE-FC08-79ET27058	Navarro College	Corsicana, Texas	NV

PROJECT REPORTS - UTAH STATE PRISON PON

1. Murphy, P. and Gwynn, J.W., "Geothermal Investigations at Crystal Hot Springs, Salt Lake County, Utah", Utah Geological and Mineral Survey Report of Investigation No. 139, October 1979 (DOE/ET/28393-16).
2. Terra Tek, Inc., "Environmental Report, Utah State Prison Geothermal Project", Report No. TR 80-25, March 1980.
3. Blair, C.K., "Utah State Prison Space Heating with Geothermal Heat - First Semi-Annual Report For the Period 14 March 1979 - 14 June 1980." July 1980 (DOE/IT/27027-1).
4. Specifications for a Geothermal Test Drilling Program at the Utah State Prison, Draper, Utah, June 1980.
5. Utah Energy Office, Utah State Prison Space Heating With Geothermal Heat - Second Semi-Annual Report for the Period June 1980 - December 1980, Report No. DOE/ET/27027-2, Cooperative Agreement No. DE-FC07-79ET27027, April 1981.
6. Utah Energy Office, Utah State Prison Space Heating With Geothermal Heat - Third Semi-Annual Report for the Period January 1981 - July 1981, Report No. DOE/ET/27027-3, Cooperative Agreement No. DE-FC07-79ET27027, November 1981.
7. Utah Energy Office, Utah State Prison Space Heating With Geothermal Heat - Resource Assesment Report, Crystal Hot Springs Geothermal Area, Report No. DOE/ET/27027-4, Cooperative Agreement No. DE-FC07-79ET27027, December, 1981.
8. CH₂M Hill (SLC), Geothermal Water Disposal, Report No. DOE/ET/27027-5, Cooperative Agreement No. DE-FC07-79ET27027, August, 1981.
9. CH₂M Hill (SLC), Preliminary Design, Report No. DOE/ET/27027-6, Cooperative Agreement No. DE-FC07-79ET27027, August, 1981.
10. Morrison-Knudsen Company, Inc., Utah State Prison Geothermal Well Test, Report No. DOE/ET/27027-7, Cooperative Agreement No. DE-FC07-79ET27027, August, 1981, September, 1982.
11. Case, Lowe, & Hart, Inc., Utah State Prison Space Heating With Geothermal Heat - Annual Report for the Period January 1982 - December 1982, Report No. DOE/ET/27027-8, Cooperative Agreement No. DE-FC07-79ET27027, June, 1983.
12. Case, Lowe, & Hart, Inc., Geothermal Heating Retrofit at the Utah State Prison Minimum Security Facility - Final Design Report, Report No. DOE/ET/27027-9, Cooperative Agreement No. DE-FC07-79ET27027, March, 1985.

DOE Direct-Use Geothermal PON Project

(No. 6)

1. Project Title: Utah State Prison Space Heating with Geothermal Heat (Utah Division of Facilities Construction and Management, DFCM).

Contract/Cooperative Agreement

2. Number: DE-FC07-79ET27027 (MOD A006, 12/20/85)
3. Former No.: None
4. Period: 03/14/79 to 01/31/86
5. Value: \$ 980,091
6. DOE Share: \$ 645,625 66%
7. Participant Share: \$ 334,466 34%
(include \$15,800 pre-award)

8. Project Application: Space and domestic hot water heat the minimum security building. The state replaced the existing control system and will expand the application if the resource is adequate.

9. Project Location: Utah State Prison; on I-15; 16 mi. S. of Salt Lake City.

10. Well Name/Loc: USP/TH-1

11. Peak Heat Load: 5.0 Million Btu/hr (design)
12. Annual Heat Load: 11.0 Billion Btu/yr (load Factor=25%)
13. Simple Payback (Cash): 15.5 Years

14. Project Status: Well USP/TH-1 was drilled to 1000 ft. The 180°F fluid was artesian flow tested using a natural CO2 lift at 300 gpm and 600 gpm for 34 days total. Construction contract was signed in June 1983. Construction was completed in July 1984. The artesian system uses calcite a settling tank, heat exchanger and disposal to the Jordan River. First season production approximately 3,200 million Btu.

15. Principal Investigators: Craig A Hibbert, Lee Hathon
16. Firm: Utah DFCM
17. Address: 4110 State Office Bldg.
Salt Lake City, UT 84114
18. Phone: 801-533-7769 (FTS DIR-DIAL)

Other Participants:

19. Firm/Activity: Case, Lowe and Hart, Inc. /Final Design
/performance verifications
20. Address: Suite 500 Kiesel Building, Ogden, UT 84401
21. Phone/Contact: 801-399-5821/Edward T. Case (FTS DIR-DIAL)

22. Firm/Activity: Morrison-Knudsen Co., Inc.
/CO2 Lift Flow Test
23. Address: Box 7808, Boise, ID 83729 (Two M-K Plaza)
24. Phone Contact: 208-345-5000/Leland L. (Roy) Mink
(FTS DIR-DIAL)
25. Firm/Activity: Terra Tek, Inc. /Resource Assessment
26. Address: 420 Wakara Way, Salt Lake City, UT 84108
27. Phone/Contact: 801-584-2400/Larry Owen (FTS DIR-DIAL)
28. Firm/Activity: CH2M Hill Central, Inc. /Preliminary Design
29. Address: Box 8748, Boise, ID 83707
(700 Clearwater Lane)
30. Phone/Contact: 208-345-5310/Larry Standley (FTS 554-1111)
31. Firm/Activity: Stephen L. Cornwall Co. /Construction
32. Address: Box 25413, Salt Lake City, UT 84125
(2813 So. 3600 West)
33. Phone/Contact: 801-943-6165/Stephen L. Cornwall
(FTS DIR-DIAL)

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1. INTRODUCTION

1.1. Objective

1.1.1. Department of Energy Project Opportunity Notice Program

The use of geothermal energy for district heat purposes by the private sector within the United States has been quite limited to date, yet there is a large potential market for thermal energy in such areas as industrial processing, agri-business, and space/water heating of commercial and residential buildings. Technical and economic information is needed to assist in identifying prospective direct heat users and to match their energy needs to specific geothermal reservoirs. Technological uncertainties and associated economic risks have influenced potential user perception of profitability to the point of limiting private investment in geothermal district heat applications.

In September, 1977, and April, 1978, the Department of Energy, Division of Geothermal Energy (now the Division of Geothermal and Hydropower Technologies), issued two program opportunity notices. These solicitations were part of DOE's national geothermal energy program plan, which had as its goal, the near term research and development of hydrothermal resources by the private sector. Encouragement was given to the private sector by DOE offering to share a portion of the front-end financial risk in a limited number of field experiment projects. After competitive evaluations, 22 PON projects were selected from the two project opportunity notice solicitations. This is the final project report for one of those PON projects.

1.1.2. Demonstration Project

Demonstration projects receiving financial support under the DOE'S PON program must resolve a number of technical and institutional problems ranging from resource exploration to retrofit and operation of the geothermal energy distribution system. The technology developed in these initial projects will be available to other industries and will serve to stimulate the development of geothermal energy at the commercial level.

Geothermal energy district heating systems are not widely used, but carry significant potential in terms of market size and utilization factor. Utilization of geothermal energy and district heating applications has been demonstrated successfully in other areas of the United States and also in other countries. The biggest load factors on a geothermal energy distribution system are

those associated with the space heating requirements that occur during seasonal peaks.

Other loads that contribute to the utilization factor include domestic hot water heating and specialized process loads. Typically, geothermal district heating systems connect a large number of users whose main heating requirements are space heating, therefore, providing a large seasonal peak in geothermal demand. It is the goal of the Utah State Prison space heating project to develop ways of providing for better system utilization to maximize the energy contribution of the geothermal source.

1.2. Background

In July, 1978 the Utah Energy Office, on behalf of the State of Utah, submitted a successful proposal to the Department of Energy (DOE) in response to a Program Opportunity Notice (PON) for Direct Utilization of Geothermal Energy Resources.

The Utah Energy Office PON proposal proposed to develop the Crystal Hot Springs geothermal resource located on private property adjacent to the Utah State Prison at the southern end of the Salt Lake Valley, Figure 1-1. The objective of the PON was to demonstrate the economic and technical feasibility of providing sufficient geothermal water for use in a variety of direct applications at suitable sites within the Utah State Prison complex. A geothermal well, heat exchange system, and injection disposal well were proposed to form the initial demonstration of providing geothermal water for space heating and domestic water heating for the Minimum Security Facility at the Prison.

The Minimum Security Facility is a 72,000 square foot building consisting of dorms, offices, a gymnasium, and a cafeteria. The facility was considered a good candidate for retrofit to geothermal energy for three reasons.

1. Due to its size and function, the facility consumes a large portion of the energy used at the Prison,
2. The facility's location as the nearest major prison building to the Crystal Hot Springs resource; a distance of only 400 meters, and
3. The building's existing space heating system was a hot water system and was considered to be relatively easy retrofit for a geothermal heating system.

The initial demonstration project, providing the minimum security facility with space and hot water heating, is intended to form the nucleus of a system which can

potentially be expanded to provide heat for the entire Prison.

In order to meet the objectives of the PON proposal, the Utah Energy Office programmed the project into three initial phases consisting of:

Phase I - Resource Assessment

1. Geophysical reconnaissance comprised of aeromagnetic and gravity surveys of the Crystal Hot Springs resource area.
2. Resource monitoring program to establish baseline thermal, hydraulic, and chemical characteristics of the Crystal Hot Springs resource area.
3. Selection of a drilling site on Prison property for a deep test well.
4. Short term flow testing program to assist in fixing a production well design and to provide information needed for completion of a preliminary heating system design.

Phase II - Resource Development

1. Selection of a site on Prison property for drilling a production well.
2. Detailed evaluation of well and reservoir characteristics.
3. Investigation of disposal alternatives.
4. Preliminary system design and economic and technical feasibility assessment.

Phase III - Construction and Inspection of Demonstration

1. Final system design.
2. System construction.
3. Commissioning and initiation of monitoring and performance verification program.

Work on the project began in March, 1979, with the writing of the environmental report and culminated with the startup of the heating system in September of 1984.

The total programmed cost for the project is \$980,091 with a cost share arrangement assigning \$645,625 to DOE and \$334,466 to the State of Utah.

FIGURE 1-1: Location Map

FIGURE 1-1: Location Map

1.3. Scope

The Utah State Prison Geothermal Space Heating Project was initiated in 1978 by the Utah Energy Office. It was conceived as a demonstration project developing the Crystal Hot Springs geothermal resource to provide space and domestic water heating for the Utah State Prison Minimum Security Facility. It was anticipated that the project would provide the nucleus of a system that could be expanded to provide heat and hot water for the entire prison complex.

For accounting and management purposes the project was divided into the following nine tasks:

Task 1 - Environmental Report

Task 2 - Resource Assessment

- Geophysical Reconnaissance
- Test Drilling
- Data Interpretation

Task 3 - Drilling Production Well

Task 4 - Investigate Disposal Alternatives

Task 5 - Construction and Demonstration of Operation

- Preliminary Design
- Final Design
- Construction
- Performance Verification

Task 6 - Reporting

Task 7 - Publicity

Task 8 - Project Management

Also, prior to construction, the heating system in the Minimum Security Facility was extensively upgraded in preparation for the geothermal heating retrofit.

The initial project scope was presented in a preliminary design report prepared by CH₂M Hill, Inc. in 1981. It consisted of a variable speed vertical turbine line shaft pump that circulated the geothermal water through underground pipelines, to the Minimum Security building. Two separate plate type heat exchangers in the existing equipment rooms were to transfer the geothermal energy to the existing heating systems. The spent geothermal water still pressurized by the pump, was piped to a cooling pond, then allowed to drain via gravity to the Jordan River.

The final design follows the same basic scheme with several modifications to improve performance and reduce costs. These modifications include allowing the well to flow artesian into a surge tank and pumping with a much smaller pump through the plate heat exchangers. The heat exchangers were moved to the well site so the underground pipelines will carry clean water, not geothermal water. Shell and tube type heat exchanger were added to heat domestic water. The spent geothermal water is drained by gravity to the cooling pond and the river.

1.3.1. Minimum Security Retrofit

It was determined that to properly utilize the geothermal energy in the building, it would be necessary to repair and upgrade the existing heating system in the Minimum Security Facility. The system was in very poor condition with large quantities of hot water leaking from corroded pumps and fittings. The temperature control system had been inoperable for approximately two years.

In September of 1982, a contract was let by DFCM in conjunction with the State Department of Social Services. The contract provided for a new temperature control system and new hot water heating pumps. Provisions were made for the future connection of the geothermal system.

The contract cost and associated design and administrative costs were part of the State of Utah's "in kind" matching funds for the geothermal heating project.

1.4. Project Summary

From 1978 through 1981, the geothermal resource at the State Prison was tested and analyzed. Test wells were drilled. One well, USP/TH-1, had adequate flow and temperatures to use as a production well.

In 1981, CH₂M Hill developed a preliminary design for using the well, USP/TH-1, to provide hot water for the prison's Minimum Security Building. In early 1982, the firm of Case, Lowe & Hart, Inc. A/E, (CLH), was selected to prepare the final design and necessary contract documents to place the project under construction.

Prior to completion of the final design, additional testing was performed on USP/TH-1 by Morrison-Knudsen (MK) with assistance from the University of Utah Research Institute (URRI). Also, the Minimum Security Facility upgrade was completed.

Construction began in July 1983 and was completed in May 1984. The system was officially started in September 1984 and operated through January 1985 when, due to mechanical and institutional problems, it was shut down.

When the system was prepared for startup in December 1985 problems were encountered with the well not starting on demand. A pressure and temperature log was run to assess the condition of the reservoir. The results indicated that the reservoir drawdown was higher than anticipated and that continued artesian flow was doubtful. Based on these results the State requested a time extension to place a pump in the well. This extension was granted by DOE in February 1986 and design work is proceeding on the addition of a down hole, vertical turbine pump to the system.

The system was operational for approximately 9 months during 1984 and 1985. Much of this time the energy contribution has been low, due mainly to operational problems with the Minimum Security heating system. Estimated savings to date are \$18,060, which accounts for 3,199 million Btu's of avoided energy consumption. Total cost for the project, including demonstration and reporting, is \$827,558.

2. CONCLUSIONS AND RECOMMENDATIONS

2.1. Technical

With the exceptions of resource concerns, the technical design, construction, and operation of the geothermal heating system is not too difficult. Greater attention must be paid to material selection than in normal hydronic heating systems but other design tasks are quite similar. The project has proven technically and economically feasible.

Technical problems in the Minimum Security heating system have caused more down-time and loss of performance than the geothermal system has. Greater attention should be paid to the existing system operation and maintenance. (See Institutional recommendations).

The combined effect of producing from two wells (USP/TH-1 and Utah Roses) has, as predicted, caused significant stress on the geothermal reservoir. The actual stress is greater than predicted causing the well USP/TH-1 to drop below satisfactory artesian flow. It will be necessary to install a down hole pump for continued production.

To date, the majority of the energy contributed to the Minimum Security building has gone to heat culinary water (see performance summary). This contribution would be increased if the new culinary water heat exchangers in the Minimum Security facility, which use geothermally heated water to heat the culinary water, were piped in series (instead of parallel) with the existing steam heat exchangers. This way, the culinary water would be heated first by geothermal and then, if necessary, by steam.

Greater care and emphasis should be placed on calibration and maintenance of controls, both in the geothermal system and in the existing building heating system.

The concept of maintaining a CO₂ blanket in the surge tank has apparently worked quite well. It seems to prevent aeration of the fluid which could lead to corrosion problems, and to prevent the loss of CO₂, reducing the scaling potential. Water quality problems were more apparent in the so called clean water, than in the geothermal water. Predicted scaling problems have not occurred, with only slight traces of scaling in the system. Greater attention to water treatment on the clean side of systems is recommended.

2.2. Institutional

Obtain user commitment and support early in the project. Verify that the user has the necessary resources and desire to operate and maintain system. This was not done in this project and has apparently led to resentment and frustration the part of the eventual end user, the State Prison's facility's staff. There is a possibility the system may be abandoned when its operation and maintenance is completely turned over to the Prison staff. Several of the staff members view the system as a burden and have expressed a desire to see it 'leave' the prison facility.

There is no advocate for the project at the State Prison. It is viewed as an added burden to an already over worked staff. The actual effort to operate and maintain the system is minimal and the savings potential great, but this does not appear to be a motivator. Recently some effort has been made by the State's Division of Facility Construction and Management to improve the situation, but progress has been slow.

The facility is well instrumented and would be a good teaching laboratory for a variety of Educational Institutions including universities and technical colleges. Joint operation of these facilities with such institutions has been suggested to the State of Utah.

Geotechnical testing and water chemistry, scaling, and corrosion testing, should be completed as early as possible. Also, if extra review during design is requested, the review should be carefully planned and expedited. Reviews during the early stages of design tend to cause fewer delays and should be used when possible.

3. PROJECT DESCRIPTION

The project is located at the Utah State Prison near Bluffdale, Utah, approximately 25 miles south of Salt Lake City. The Crystal Springs Resource Area is on the west end of the Prison complex, near the Prison's farm and dairy operations. There are several thermal ponds on private property adjacent to the prison, and several developments using the resource. The largest user is Utah Roses, which uses geothermal water from a pumped well to heat green houses. There are several smaller private operations that use either the pond water or discharge water from Utah Roses.

Figure 3-1 shows the relative locations of the resource and the Prison, and shows the path of the geothermal drainage line installed as part of this project.

3.1. Description of System

The complete Geothermal Space Heating system, Figure 3-3, can be divided into four sub-systems, 1) Energy extraction; 2) Energy transmission; 3) Energy utilization; 4) Geothermal water disposal.

The energy extraction system consists of the geothermal production well, well head piping, surge tank, circulating pump, heat exchangers, and controls. The well discharges the hot (180 degrees) geothermal water into the surge tank. The pump circulates the geothermal water from the tank through the plate heat exchanger, and into the disposal system.

The disposal system consists of a catch basin on the end of the surge tank, a buried gravity drain line, spray nozzles, and a cooling pond. The geothermal water is discharged from the heat exchangers into the catch basin and the drain line.

The drain line carries the water to a group of gravity fed spray nozzles which discharge into the cooling pond. From the pond, the cooled water is discharged into a swampy area on the bank of the Jordan River (see Figure 3-1).

The energy transportation system consists of circulating pumps and a buried distribution piping loop. The pumps circulate geothermally heated clean water from the plate heat exchangers, through the buried pipeline, to the Minimum Security building, then back to the heat exchangers.

The heated water is utilized directly in the Minimum Security building's hydronic space heating system. Two shell and tube heat exchanger in the building are used to heat culinary water. A piping crossover controlled by 3 way valves regulates the amount of geothermal heat used in the existing building system.

FIGURE 3-1: Site Plan

FIGURE 3-2: Schematic of Geothermal Heating System

3.2. Environmental Impact

Studies were conducted to determine potential adverse environmental effects resulting from implementation of the Utah State Prison Geothermal Project. The completed study indicated that only minor, temporary environmental effects will result.

The drilling and development occurred entirely on prison property; project efforts were integrated into planned prison facilities construction and rehabilitation activities. Direct use of land is approximately one acre (for wells, equipment building, and pipelines). Because the development is small and was integrated with prison construction plans, the aesthetic quality of the area was not diminished.

Temporary disruption of surface soil will occur during drilling of the wells and installation of pipelines. The surface impact was small compared to other prison construction activities conducted concurrently with the geothermal development.

Clearing of land for roads, drill sites, and piping resulted in slight impact to flora and fauna. These activities required only minimal removal of vegetation or displacement of fauna.

Discharging into the river has minimal effect on water quality or wildlife.

3.3. Project Schedule

Figure 3-3 depicts the major task accomplishments and when they were performed. Due to problems with securing water rights and discharge permits, and delays during final design and construction, the project was finished approximately two years after the initially conceived completion date.

3.4. Organization and Participation

Figure 3-4 represents the major participants in the project and their contributions. There are undoubtedly other participants which contributed to the completion of the project that are not presented here but the chart identifies the major players.

T
A
S
K

FIGURE 3-3: Progress Schedule

UTAH STATE PRISON – GEOTHERMAL PON PROJECT

FIGURE 3-4: Project Participants

3.5. Cost Breakdown

The following cost break down identifies the major tasks and their costs to date. For a more detailed analysis of actual construction costs see Section 8.4. The programmed amount was \$980,091 and was more than sufficient to see the project through completion. There are additional expenditures, mainly for the anticipated down hole pump, presently under consideration. The additional cost should be under \$30,000 and will still fall under the programmed budget.

1 - Environmental Report	\$10,348
2 - Resource Development	\$121,473
3 - Reservoir Analysis (includes well)	\$77,654
4 - Investigate Disposal Alternatives	\$6,148
5 - Design, Construction and Performance Verif.	\$517,114
6 - Reporting	\$27,794
7 - Publicity (technology transfer)	\$6,964
8 - Project Management	\$60,013

TABLE 3-1: Summary of Project Costs

4. RESOURCE ASSESSMENT

Preliminary resource assessment was conducted from early 1979 through 1980. A Resource Assessment Report, Utah Energy Office, 1981, offers detailed information gathered from the various assessment efforts. This section summarizes the progress and results of this early assessment effort.

Additional testing and monitoring was conducted later in the project after attention was focused on well USP/TH-1 as a production well. Those efforts are summarized in section 5 - Production Drilling, Logging, and Testing.

4.1. Description of Resource

The geothermal development was focused on the Crystal Hot Springs geothermal resource. The surface expression of the system is several warm water ponds located on private property adjacent to Prison property.

The geothermal system is a deep convective system located at the eastern margin of the Basin and Range physiographic province. The thermal springs are located north of an east-northeast trending horst that is perpendicular to the structural trend of Wasatch Front grabens. The horst, known as the Traverse Range, consists of highly fractured mid-Paleozoic quartzites and tertiary volcanics.

There are two separate aquifer systems; a shallow, confined to semi-confined, aquifer and a deep, artesian geothermal, aquifer containing water apparently heated at depth in the fractures of the quartzites. There is some interaction between the two systems, however, each has its own distinct waterbearing characteristics.

The shallow aquifer lies within the recent interbedded alluvium and lacustrine deposits and derives most of its recharge from surface sources such as rainfall, streams, canals, and irrigation. Several wells have been drilled into the shallow aquifer for domestic and irrigation water supplies. Many of these wells discharge warm waters indicating leakage of the deeper thermal aquifer into the shallow ground water system.

The deep aquifer (geothermal reservoir) occurs at a depth of 400 to 700 feet and consists of a fractured system within Tertiary volcanic rocks. Thermal water, upwelling along spur faults of the Wasatch Range, provides the shallow geothermal waters. Recharge is thought to occur through deep circulation within the range front faults.

Meteoric water enters the system in the adjacent ranges, circulates to depths of 3 Km, and is heated. The thermal fluids return to the surface along steeply dipping range front faults that bound the northern flank of the range. The thermal springs issue between two such faults that are buried beneath Tertiary and Quaternary age valley fill deposits. Highly fractured quartzite beneath the valley fill act as a near-surface reservoir for the thermal water targeted for development.

The surface expression is defined by several hot water spring discharges contained within a 70 acre area. At the center of the Crystal Hot Springs resource area springs issue to the surface through alluvium approximately 80 feet thick.

The maximum measured temperature at Crystal Hot Springs is 98°C, recorded in the bottom of the 410 foot Utah Roses well. The chemical quality of the thermal waters are excellent with total dissolved solids content between 1,500 - 1,700 ppm.

4.2. Geophysical Reconnaissance

The geophysical reconnaissance was designed to provide detailed subsurface structural information in the vicinity of thermal springs so an informed decision as to the locations of test and production holes could be made.

Considerable resource data had been gathered in the vicinity of Crystal Hot Springs under the DOE State-Coupled Geothermal Resource Assessment program. These previous investigations are described in detail by Murphy and Gwynn (1979). Initial resource models derived from this data were further developed during the geophysical reconnaissance investigations.

In the original PON proposal, the reconnaissance task consisted of detailed gravity and ground magnetic surveys in the immediate vicinity of the prison but, at the time the surveys were to be conducted, significant changes were made. The detailed gravity survey was maintained, but was tied to a more regional survey conducted under the State-Coupled Geothermal Resource Assessment program. The ground magnetics survey was dropped in favor of a detailed aeromagnetic survey being conducted under the same state coupled program.

These changes resulted in a superior geophysical survey at reduced cost to the PON and without significantly increasing the cost to the state coupled program. The results of these surveys, in particular the gravity survey, were a significant contribution to the data needed to select test hole sites.

4.2.1. Gravity Survey

Gravity surveys in the vicinity of the Utah State Prison were conducted during the Fall and early Winter of 1979 by Applied Geophysics, Inc. Area-wide coverage was obtained by using profiles that began on the Traverse Range to the south and ended on the valley floor to the north of the prison facility. This area-wide survey defined the major features of the gravity surface, providing a regional setting into which the more detailed gravity grid could be placed.

The gravity grid was centered on the prison and adjacent thermal springs and was designed to provide a detailed gravity surface for the area most likely targeted for drilling by the Utah State Prison PON Project. The grid consisted of 290 stations spaced 350 feet apart covering an area approximately 1.5 mi².

This data added much detail to a previously available gravity map produced in 1961 and provided detailed structural and geological information of the subsurface conditions beneath Crystal Hot Springs and the Utah State Prison.

The detailed survey revealed a complex faulted bedrock surface buried beneath the unconsolidated materials that are present at the surface. Normal range-front faults strike east-west through the area, breaking the bedrock into blocks, Figure 4-1. From south to north the depth to the top of the blocks generally increases. These fault blocks are internally faulted by north-northeast striking faults which results in a complex structured bedrock in the vicinity of the thermal springs.

Immediately beneath the springs, the bedrock is fractured quartzite and approaches to within 80 feet of the surface. The west, north and east of the springs, bedrock is encountered at depths on the order of 500 to 700 feet. North of the springs, in the vicinity of the State Prison farm, the fractured quartzite is present at approximately 250 to 300 feet in depth.

FIGURE 4-1: Inferred Faults

Faults in the vicinity of the Utah State Prison as interpreted from the residual gravity anomaly.

Figure 4-1 shows the inferred structural conditions beneath the thermal springs and the prison, as interpreted from gravity and drill hole data. It shows a number of tilted sub-surface blocks defined by the major fault planes. The thermal data reported by Murphy and Gwynn (1979) suggests the presence of elevated temperatures in blocks A and B. The data does not exclude the possibility of thermal water within the remaining blocks at depths beyond those penetrated by the drill holes.

4.2.2. Aeromagnetic Survey

The aeromagnetic survey was flown by Aerial Surveys of Salt Lake City, Utah, under subcontract to Applied Geophysics, Inc., of Salt Lake City, Utah, in November 1979. The area surveyed was 9.5 miles long in the north-south direction, 6 miles wide in the east-west direction and centered on the Crystal Hot Springs system. A mean terrain clearance of 500 feet was maintained.

The Aerial survey detailed the complex magnetic surface and was a significant improvement over the existing aeromagnetic data. The main feature identified by the survey is an east-west trending zone of magnetic highs, the most intense of which is immediately north of the Crystal Hot Springs system. The eastern end of the zone is adjacent to the Cottonwood Stock. North and south of the zone the magnetic surface is relatively flat, but not featureless.

Preliminary modeling of the magnetic data, resulted in an acceptable model of the bodies responsible for the observed magnetic surface, Smith (1980). According to Smith (1980), the magnetic anomaly results from a series of magnetically susceptible intrusive and extrusive bodies that trend east-northeast. These bodies extend from a minimum depth of 7500 feet to within 350 feet of the surface. The lower portions of the bodies are believed to be intrusives, while the upper levels may be either intrusive dikes and sills, or extrusive flows.

4.3. Test Hole Drilling

The geophysical investigations, together with available drill hole data, provided a reasonably detailed description of the subsurface structural conditions in the vicinity of Crystal Hot Springs. On the basis of this description, a zone was defined in which test holes would be drilled into the geothermal reservoir. This zone was identified as the area under Block B (Figure 4-1) located beneath Utah State Prison property. Interpretation of the gravity data identified an area north of the springs, in the vicinity of the State Prison farm, where the fractured quartzite was present at approximately 250 and 300 feet in depth. The zone was chosen for the following reasons:

1. The block consisted of the quartzite thought to be a reservoir rock and known to be present beneath the thermal springs.
2. The top of the block is present at a depth of less than 300 feet and was accessible to shallow drilling.
3. The block is adjacent to an area known to contain thermal water.
4. The property in question is owned by the State of Utah.

Potential targets some distance from the known thermal springs and at greater depth were also identified. They lie south of the northern range-front fault in the vicinity of prison's Maximum Security facilities.

Utah Geological and Mineral Survey began a search for a drilling contractor for the test hole drilling program in September 1980. Billings Drilling Company of Salt Lake City, Utah was eventually selected, and a contract was signed in September 1980. The drill rig used was rated to 1800 feet with 4-1/2 inch drill steel. The driller, Paul B. Billings, had considerable experience in drilling private and municipal water wells, as well as mineral exploration holes.

An existing thermal gradient monitoring well, (SF-1), was deepened from 270 feet to 500 feet. SF-1 penetrated 140 feet of quartzite, and upon completion flowed artesian at 30 gpm. A new test hole referred to as USP/TH-1 was drilled to a total depth of 1,000 feet. USP/TH-1 penetrated 640 feet of quartzite, and when completed flowed artesian at 600 gpm. This confirmed the bedrock model and the presence of significant quantities of thermal water within the fractured quartzite.

Results of the drilling program suggested that the quartzite is not homogeneously fractured and that the upper portion of the quartzite is relatively impermeable. Production from SF-1 originates from below 330 feet, while production from USP/TH-1 is primarily from below 600 feet.

4.4. Testing and Monitoring

The resource monitoring program was designed to enable determination of baseline thermal, hydraulic, and chemical characteristics in the vicinity of Crystal Hot Springs and to provide a history of these characteristics during resource development. A program for testing well USP/TH-1 was conducted to provide information required to aid in siting and design of a production well and to provide information for preliminary system design activities.

NOT FOR PUBLICATION
(U.S. GEOLOGICAL SURVEY)

STATIC TEMPERATURE PROFILE FOR
WELL USP/TH-1 (DEC. 1980)

FIGURE 4-2: Static Temperature Profile - Well USP/TH-1

4.4.1. Well Testing

The production characteristics of well USP/TH-1 were determined from a controlled 48 hour artesian flow test. Analysis of surface and drawdown/recovery data indicated a highly permeable reservoir of somewhat limited area. Long term production characteristics of well USP/TH-1 were estimated to be limited due to reservoir boundary effects. The well was considered capable of sustaining a flow rate of 100 gpm for 8 months with a drawdown of 275 feet. Production temperature at the wellhead averaged 179 degrees F during testing.

4.4.2. Monitoring

Thermal monitoring of gradient holes in the vicinity of Crystal Hot Springs was conducted throughout the resource assessment phase of the project. Figures 4-3 through 4-5 show the monitoring locations and summarize the characteristics of the wells and springs in the monitoring area.

TABLE 4.4.1.1. SUMMARY OF WELL TESTING RESULTS

and other related data

MONITORING LOCATIONS-CRYSTAL HOT SPRINGS AREA

FIGURE 4-3: Monitoring Locations

FIGURE 4-4: Results of Monitoring Program

Salt Lake County, Utah									
HOLE	IDENT.	DATE DRILLED	TYPE DRILL ₁	DEPTH FT.	MAX TEMP C°	ARTESIAN FLOW	TEMP DEPTH FT.	STATUS ₂	COMPLETION
UGMS Gradient	A	2/78	R/M	220	68.5	175 gpm	TD	M	Tertiary Seds
	B	2/78	R/M	245	35.5	NO	TD	M, G	Tertiary Seds
	C	2/78	R/M	280	76.0	NO	TD	G	Tertiary Seds
	D	3/78	R/M	237	74.2	NO	65	M	Paleozoic Qtz
	E	3/78	R/M	200	85.5	5-10 gpm	TD	M	Paleozoic Qtz
	F	3/78	R/M	250	33.0	NO	TD	M, G	Tertiary Seds
ASARCO		6/55	R, C/M	940	34.3	NO	150	A	Tertiary Volc
LEE			CT	825	24.5	NO	215	A	Tertiary Volc (?)
HALL		12/75	CT	290	45.0	NO	TD	W	Paleozoic Qtz (?)
STATE FORESTRY-1		4/78	R/M	280	80.4	12 gpm	TD		
		10/80	R/W	505	80.4	300 gpm	0	T	Paleozoic Qtz
* UTAH ROSES	-1	11/79	R/W	410	98.4	150 gpm	TD	P	Paleozoic Qtz
	-2	11/79	R/W	210	16	NONE	0	W	Tertiary Seds
	-3	10/80	R/W	175	14	NONE	0	W	Tertiary Seds
	-4	10/80	R/W	950	82	7100 gpm	0	I	Tertiary Seds
USP/TH-1		10/80	R/W	1005		800 gpm		T	Paleozoic Qtz

1. Method/Fluid
 R = Rotary
 C = Core
 M = Bentonite
 W = Water
 CT = Cable Tool

2. M = Monitor
 G = Gradient
 A = Abandoned
 W = Producing Water Well
 T = Test

P = Geothermal Production
 I = Geothermal Injection

TEMPERATURE PROFILES FOR GRADIENT HOLES
AND CULINARY WELLS (NOV.-DEC. 1980)

FIGURE 4-5: Temperature Profiles for Adjacent Wells

4.4.3. Results

Due to the limited scope of the test program and short duration of time under which the artesian flow testing was conducted, definitive statements about long-term reservoir productivity could not be made. Terra Tek, Inc., made the following recommendations in regards to future resource assessment efforts:

- 1) Due to the limited long-term production potential predicted for that portion of the resource, drilling of an additional well for production was not warranted at that time.
- 2) A long-term pump test of well USP/TH-1 should be conducted during a period when Utah Roses is not producing its well. This test is necessary to verify the predicted long-term drawdown characteristics and to assess any system recharge effects.
- 3) A test of the Utah Roses Well (or perhaps just careful monitoring) should be conducted to determine the effect of Utah Roses Production upon well USP/TH-1.
- 4) Current and future production requirements for Utah Roses should be established.

Several of these recommendations were completed in later production testing of well USP/TH-1. Extensive chemical monitoring was conducted and corrosion and scaling potential were evaluated. Results of these studies are detailed in the following section on production drilling and testing

4.5. Disposal Alternatives

When the results of the geophysical reconnaissance and reservoir analysis were complete, an effort was made to determine the most practical and cost effective method for disposal of the spent geothermal water. The primary methods evaluated were surface disposal to the Jordan river or nearby irrigation canals, or reinjection into the underground strata.

4.5.1. Surface Disposal

The surface expression of the Crystal Hot Springs Resource is characterized by a cumulative discharge of 650 to 1000 gpm of geothermal waters via a series of hot springs. The total natural discharge flows eventually to the Jordan River. Thus, the baseline condition is discharge of up to 1000 gpm of geothermal water, via surface drainage paths, to the Jordan River.

Observations of surface thermal spring discharge rates during periods of significant production by Utah State and Utah Roses indicates that spring discharge rates undergo substantial reductions. Thus, it can be argued that surface disposal of geothermal fluid would simply offset the decline in natural hot spring discharge rates due to operation of production wells. The chemical characteristics of hot spring fluids and production well fluids (less than 2000 ppm total dissolved solids) are essentially identical with the exception that production fluids, after passage through heat exchangers, would be somewhat cooler than the natural hot spring discharge.

4.5.2. Re-Injection

Subsurface disposal of spent geothermal fluids is only practical by using deep injection wells completed within the metaquartzite reservoir formation. Subsurface injection into overlying sediments is not feasible due to low permeabilities. Wells completed in andesite in adjacent areas bounding the northern portion of the geothermal resource also indicate very low permeability.

Technical difficulties with deep injection arise due to the potential for thermal contamination of production fluids by relatively cold injected fluids. Thermal breakthrough is a definite potential problem due to the very high fracture conductivities of the metaquartzite. Injection wells could be completed at much greater depths than production wells in an attempt to prevent thermal breakthrough. However, the cost of such wells would be prohibitively high and no guarantee could be made that a through-going fracture would not be intersected.

Because of the technical difficulty and expense of re-injection, the decision was made to pursue surface disposal permits and to design the system using surface disposal techniques.

4.6. Institutional Issues and Permits

There were basically three types of permits required to assure legal protection of water rights, easements, and discharge.

4.6.1. Water Rights

In 1978, an application was made to the State Engineer to appropriate water for production purposes. In early 1983 a permit was approved to use up to 700 gallons per minute from the reservoir.

4.6.2. Discharge and Disposal

In November of 1981, the Utah Energy Office was granted a surface disposal permit by the Utah Water Quality Board. This permit allowed for surface disposal of spent geothermal waters from the Crystal Hot Springs to the Jordan River via a pipeline.

In December 1981, the Department of Wildlife Resources determined the project would not degrade the Jordan River below a Class 3 fishery level and approved the discharge.

In March 1982 the Federal Environmental Protection Agency granted a 30-day discharge permit for further testing and in May 1983 granted a production discharge permit allowing discharge into the Jordan River from September to May of each year.

4.6.3. Property Easement

Most of the proposed project is located on State Prison property. However, one easement was required for the disposal line to pass under railroad tracks owned by the Denver & Rio Grande Western Railway Co. The easement was first requested in June 1982 and, after some modification required by the railway company, was granted in early 1983.

5. PRODUCTION DRILLING, LOGGING, AND TESTING

5.1. Drilling Program

The geophysical reconnaissance program provided the structural details needed to focus the exploration program on the most promising production targets available to the State Prison. The objective of the subsequent test hole drilling program was to establish the presence of significant quantities of thermal water and to provide holes that could be used for preliminary reservoir testing. These objectives were markedly different from the simple gradient hole drilling program envisioned in the original proposal, and represented an evolution of project scope that was influenced by: 1) the findings of the geophysical reconnaissance program, and 2) changes in the disposition of the land status in the vicinity of the springs adjacent to the Prison.

Two test holes were drilled; SF-1 an existing shallow hole was deepened and a new hole USP/TH-1 was drilled. After preliminary testing, USP/TH-1 was designated as the production well so progress during drilling USP/TH-1 is presented in this section instead of the test drilling section.

5.1.1. Drilling USP/TH-1

Drilling at the USP/TH-1 site began on the morning of October 13. A 14 inch hole was drilled to a depth of 40 feet, and a 12 inch casing was installed. The casing was grouted into place and was left to cure for 39 hours. On October 15, the driller penetrated approximately 3 feet of grout as drilling continued.

A 10 inch diameter hole was drilled from the bottom of the 12 inch casing to the top of the bedrock surface. Water was used as a drilling fluid until, at a depth of 95 feet, the hole began to cave in and the cuttings could not be cleaned from the hole. After reaching 120 feet, an inorganic polymer was used to increase the viscosity of the drilling fluid. Circulation of this fluid quickly cleaned the hole and drilling proceeded without major difficulty.

The bedrock surface was intersected at a depth of 268 feet and drilling continued to 278 feet. An eight inch, schedule 40, standard wall casing was installed from the surface to a total depth of 272 feet and grouted in place. The grout was placed on the morning of October 20 and was allowed to cure for approximately 44 hours. An eight inch diameter gate valve was installed on the eight inch casing, and a T assembly was fastened to the valve.

With the well-head assembly in place and approximately 90 feet of drill collars behind the bit, drilling continued to a total depth of 1000 feet. Water was used as a drilling fluid. While evidence of fluid loss was noticed in drilling the upper portions of USP/TH-1, major losses did not occur until a depth of approximately 625 feet. Large water losses continued from that point to total depth.

At the conclusion of drilling the geothermal fluid began to warm and decreased in density. After 4 days the fluid had warmed enough that the hole began to flow at rates of 600 to 1,000 gpm. As the liner could not be installed with the well flowing at these rates, cold water from a nearby fire hydrant was forced into the hole to control the flow. This method of well control worked well because the wellhead pressures were on the order of 5 to 10 psi. A reducer was fabricated to allow a fire hose line to be coupled to the well head assembly. After flowing cold water into the hole for 2 to 3 hours, the hole was chilled. The blind flange on the vertical leg of the well head assembly was removed and the liner installed.

The hole was completed with a six inch diameter slotted liner. During installation of the liner a tool failed, allowing 245 feet of the liner to drop into the hole. It was recovered after two days of fishing, apparently intact. The completed liner string was lowered into place and secured by using a K-packer.

Figure 5-1 represents the drilling log for USP/TH-1 with drilling rates, temperatures, and lithography. Figure 5-2 shows the completion schematic of the finished production well.

FIGURE 5-1: Drilling Log - USP/TH-1

Temperature log , drilling rate and lithologic profile of test well USP/TH-1

COMPLETION SCHEMATIC - WELL USP/TH-1

FIGURE 5-2: Production Well USP/TH-1

5.2. Testing

Testing of the resource began as early as October 1980 during drilling operations on both the existing State Forestry well SF-1 and USP/TH-1. An initial short term artesian flow test was conducted in October 1980 immediately after completion of USP/TH-1. The results of that test were used to predict long term reservoir performance and to plan further test efforts.

In June 1983 a longer term (30 day) artesian flow test was conducted on USP/TH-1 to more accurately model the resource and predict future performance and drawdown. During this test geochemical testing and corrosion testing were performed, and monitoring of adjacent wells and springs was continued. This longer term test was conducted in lieu of the recommended pumped flow test and provided a large amount of data that, for the most part, confirmed the previous predictions of reservoir performance.

The results and predictions of the testing efforts are presented in detail below. The monitoring locations are the same as those shown in Figure 4-3.

5.2.1. Reservoir Testing and Predicted Performance

The second artesian flow test was carried out by Morrison Knudsen Company (MK) during a 34 day test in May and June 1983. The testing sequence was based upon a plan submitted by Terra Tek, Inc. in January 1982. Its purpose was to further assess the reservoir's draw-down characteristics. Water chemistry and corrosion tests were also performed during the 34 day period.

The test consisted of a preliminary step draw-down test with increments of 100, 200, and 300 gpm flow rates. The well was allowed to recover overnight before the start of the constant rate production test. The well was allowed to flow at 300 gpm for a period of 20 days and then increased to 600 gpm for the remaining 14 days.

5.2.1.1. Predictions

The data predicted the well will flow at the design rate of 200 gallons per minute with a pressure decline of approximately 1.5 to 2.0 psi at the end of a 6 to 9 month heating season. This should result in a well head pressure of approximately 6.0 psi which will sustain the 200 gallon per minute rate. At a flow rate of 400 gpm there could be a pressure decline of approximately 2.5 psi at the end of six months. This predicted decline only accounts for Well USP/TH-1 flowing at 200 gpm rate.

FIGURE 5-3: Predicted Draw-Down for Well USP/TH-1

Transmissibility values and pressure response between the Utah Roses well and the Utah State Prison production well indicate a highly transmissive zone between these two wells. Because of this interaction between the wells, both of them producing at the same time will have a compounded impact on the reservoir. Draw-down in the Utah State Prison well should be approximately 3.5 psi for a 6 to 9 month heating season. Artesian flow at the 200 gallon per minute rate would be maintained. Flowing well head pressure would be approximately 4.5 psi at the end of the heating season.

Draw-down in the Utah Roses well will be approximately 7 psi with both wells producing a total of 460 gallons per minute. This would result in a standing water level draw-down to 12 feet below ground surface. As a result the Utah Roses system would have to rely on pumping for a geothermal water source.

If USP/TH-1 was shut down late in the season, and the well bore allowed to cool, a 4.2 psi drop in the reservoir pressure could result in the well not being able to self start because of a higher density water column and lower reservoir pressure affecting the CO₂ flash point. It may then be necessary to stimulate the flow through air lift or pumping until the well bore heats up sufficiently to self flow at the desired rate.

The predicted decline in the system would cause Spring CR-3 to dry up. This would cause an impact on water supply to the Western Pond and to a private facility utilizing geothermal waters located adjacent to the pond. This facility would need to consider developing an alternative water supply or possibly using waste water from either the Utah Roses or Utah State Prison facility in the future.

Recharge to the system will occur during the summer non-heating season. With 3 to 6 months of non-geothermal use, the system should recharge to within 80 to 100 percent of the original pre-production pressures, depending on length of the non-heating season. This assumes a production rate of up to 200 gpm for USP/TH-1 and up to 400 gallons per minute for Utah Roses.

5.2.2. Well Bore

A test, modified from EPA 5760/9-715001, to determine the capability of the 8" portion of the well bore to receive a pump was conducted in conjunction with inserting an air line into the well. The air line was fitted with decentralizer rings made up of 7-5/8" ØØ steel pipe prior to inserting it in the well. The rings were placed at 20 foot intervals throughout the full 253 foot length of the air line. Murray Plumbing monitored the placement of the air line and noted there was no interference in the way of obstructions or excessive friction in lowering the air line into the well.

It was concluded that the well bore within the 8" section of casing to a depth of 260' would not pose any problem in placement of a pump in the well. The 6" section of pipe was not checked for compatibility to receive a pump. It was the feeling of M-K that the possibility of having toplacea pump in the 6" portion of the hole is remote. The well appears to meet the design criteria of 200 gpm through artesian flow and calcite deposition was not detected in the lower portion of the 8" casing.

5.2.3. Chemical

Results of the water chemistry tests performed by the University of Utah Earth Science Laboratory for MK indicated a sodium chloride type water with a total dissolved solid content ranging from 1778 to 1898 ppm. Three surrounding wells exhibited similar water chemistry. A significant difference seen in non-thermal ground water supports the concept that the thermal water source is the deeper quartzites and the non-thermal source the overlying clay-rich sediments.

The chemical composition of water from both TH-1 and UR1 was relatively constant throughout the flow test period. When flow of TH-1 was stepped up to 600 gpm UR1 ceased to flow so samples were not collected after July 6. Thus, compositional changes in UR1 during the final stages of flow test cannot be documented.

Utah State Prison (TH-1) thermal water has a maximum measured temperature of 83°C. It is slightly acid with a sodium chloride character, and relatively dilute. Dissolved solids range from 1780 to 1900 ppm. The chemical composition of down-hole samples is consistent with that of surface samples collected at the pump head. Utah Roses (UR1) thermal water is similar in chemical character to TH-1.

Waters from Crystal Hot Springs and the State Forestry well, in the immediate vicinity of TH-1 and UR1, are similar in chemical character to the TH-1 and UR1 water and have maximum temperatures of 80°C and 86°C, respectively.

Other nearby thermal well waters have a chemical character similar to that of TH-1 and UR1 but are slightly cooler and more dilute, Figure 5-4. Temperatures range from 19° to 38°C with dissolved solids contents less than 1310 ppm.

Nonthermal ground water in the study area is distinctly different from that of the thermal water. It is slightly basic with a sodium-calcium bicarbonate and sulfate-chloride character in contrast to the sodium chloride character of the thermal water. The ground water is generally more dilute with dissolved solids content ranging from 260 to 1600 ppm.

The different chemical character suggests the thermal water has a different source than the local aquifer water, supporting previous conclusions (Utah Energy Office, 1981).

Ranges in Composition of Thermal and Nonthermal Water from Study Area.

		CRYSTAL HOT SPRINGS AREA					Nonthermal Ground water ^{1,4}
		Thermal Water					
		TH1	URI	SF1 ¹	CHS ¹	Other ¹	
Number of Samples		6	4	1	2	3 ²	16
Well Depth	m	306	125	85	Spring	82-88	37-257
Collection Temperature	°C	81-82	73-82	54	29-38 ³	19-38	13-17
pH		6.4-6.9	6.5-6.7	6.2	7.2-7.3	6.3-7.2	7.0-7.5
Na	mg/l	405-415	356-371	370	316-347	209-267	23-230
K	mg/l	63-65	55-58	55	47-53	18-39	<2.5-17
Ca	mg/l	142-155	136-153	139	124-146	59-143	40-200
Mg	mg/l	32-34	30-33	32	32-36	11-35	13-80
SiO ₂	mg/l	52-58	56-62	45	43-77	21-24	15-47
HCO ₃ ²	mg/l	423-457	391-461	480	350-480	230-400	190-500
SO ₄ ³	mg/l	64-69	61-66	62	74-94	45-129	33-440
Cl ⁴	mg/l	742-774	676-697	708	618-673	365-531	29-350
F	mg/l	1.9-2.6	1.8-2.8	2.4	2.3-2.5	0.8-1.8	0.2-1.1
Total Dissolved Solids	mg/l	1780-1900	1680-1690	1700	1560-1720	1000-1310	260-1600
(Measured)							
B		1.3-1.5	1.1-1.3	1.4	0.8-1.1	0.3-0.5	2.2-2.7
Li		1.26-1.53	1.06-1.22	1.58	0.93-1.34	0.31-0.53	<0.05-0.07
<u>Geothermometers</u>							
Quartz (cond. cooled) ⁶	°C	104-107	107-112	97	95-123	65-70	
Chalcedony ⁶	°C	74-78	78-83	67	64-95	33-3	
Alpha Cristobalite ⁶	°C	53-57	57-62	47	45-72	16-21	
Na-K-Ca (Mg Corrected) ⁷	°C	80-82	74-83	77	61-79	66-81	

¹ Unpublished data from R. H. Klauk (Utah Geological and Mineral Survey, 1982).

² Samples 15, 56, and 121.

⁴ Nonthermal ground water in the Jordan Valley is designated by Klauk et al. (1981) as water having temperatures of less than 18°C

⁵ Maximum measured temperature 80°C (Utah Energy Office, 1981).

⁶ Calculated using the methods of Fournier (1977).

⁷ Calculated using the methods of Fournier and Truesdell (1973, 1974) and Fournier and Potter (1979).

FIGURE 5-4: Chemical Composition of Surrounding Wells

5.2.4. Scale Potential

When utilizing geothermal water, detailed consideration must be given to the possibility of scale formation. Understanding the factors that control mineral deposition allows design modifications so that mineral deposition occurs at noncritical parts in the geothermal system.

Scale was actively depositing from the Utah State Prison well (TH-1) production fluid during the testing period. X-ray analysis of the scale, precipitated at the surface, showed it composed of calcite (CaCO_3). Calcite is not deposited from a solution by simple cooling if a constant concentration of carbon dioxide (CO_2) is maintained. However, loss of CO_2 from the solution will induce calcite deposition according to the simplified reaction

CO_2 is lost from the solution in response to pressure decline as the liquid flows to the surface. Analysis of gas released from TH-1 water shows predominantly CO_2 with lesser amounts of methane (CH_4) and hydrogen sulfide (H_2S). Scale production may occur at the location where the CO_2 gas is released. System operation has shown little scale deposition in the system until the water is released to the atmosphere in the disposal system.

5.2.5. Corrosion

The corrosion tests were performed by EG&G Idaho and consisted of exposing two sets of corrosion coupons to the geothermal water (Appendix B). The tests indicate that the 300 series stainless steels were the recommended materials for heat-exchangers and critical applications. The carbon steels and cast iron are acceptable if suitable corrosion allowances are made. Copper and brass were in general not acceptable due to heavy corrosion and scale formation.

Two sets of corrosion coupons were exposed in the geothermal fluids at the Utah State Prison. One set was left in the well for the full duration of the test, 815 hours. The other set was left in the well for 485 hours, removed and visually inspected by the test engineers, and then immersed in the discharge ditch for 330 hours. This latter procedure was not in accordance with earlier plans and procedures and makes the results of the latter test suspect. This test is referred to as the aerated test.

The coupons were first examined in the as-returned condition using a low power stereo microscope (ca. 10 to 70 power magnification). They were then cleaned and examined at 10 and 400 power magnification.

The coupons were weighed before and after exposure to the geothermal environments. The weight loss data are presented in terms of average general corrosion penetration into the base metals, even though pitting corrosion may have been the major form of attack. Because of the manner in which the aerated test was conducted, the weight loss data were "adjusted" to delete the corrosion experienced during the time spent in the well.

The alloys may be conveniently grouped into three categories according to corrosion damage. The groupings for the aerated and non-aerated tests are given in the Table 5-1. These groupings are discussed below.

1. Non-Aerated Corrosion Test

The 1018 carbon steel and the gray cast iron would be acceptable if given a proper corrosion allowance. However, cast iron is not commonly used in thin sections, and may be applicable to thick sections such as pumps and valves if carefully monitored.

Copper, admiralty brass and red brass show sulfide scale formation. For this reason, they should be given extensive tests in a heat exchanger configuration before being given serious consideration for such service.

Titanium and the austenitic stainless steels suffered almost no corrosion attack. For the most part, a slight superficial attack was the maximum damage, and this was minor. Care must be taken in the use of austenitic stainless steels, since there is a tendency for these to undergo stress corrosion cracking in hot, chloride bearing, oxygenated solutions.

2. Aerated Corrosion Tests

When aerated geothermal fluids are considered, e.g., holding pond conditions, the materials suffered much more corrosion attack. Scaling was much more evident on the coupons exposed in the aerated water. The following conditions are noted:

Considerable care must be used in considering 1018 carbon steel or gray cast iron, since a substantial corrosion allowance must be made. Cast iron is not commonly used for tube and shell or plate type heat exchangers; however, this material is used for pumps and valves, and suitable corrosion allowances must be included in the specification of this material.

AISI Type 410 stainless steel is frequently used in pump shaft material. The use of this material for such applications in aerated geothermal fluids is not recommended. The same material appears to have performed satisfactorily in the non-aerated geothermal fluid.

The propensity for austenitic stainless steel to undergo stress corrosion cracking increases as the temperature, chloride concentration, and oxygen concentration of the geothermal fluids increases. While stress corrosion cracking tests were not run, one must consider the potential for such attack.

Classification of Alloys in Terms of Corrosion Resistance*

<u>NON AERATED GEOTHERMAL FLUID</u>	<u>AERATED GEOTHERMAL FLUID</u>
<u>Recommended</u>	<u>Recommended</u>
Titanium	Titanium
AISI Type 304 Stainless Steel	AISI Type 304 Stainless Steel
316	316
317L	317L
<u>Acceptable</u>	<u>Acceptable</u>
Gray Cast Iron	Gray Cast Iron
AISI Type 1018 Carbon Steel	AISI Type 1018 Carbon Steel
AISI Type 410 Stainless Steel	<u>Not Acceptable</u>
Admiralty Brass	AISI Type 410 Stainless Steel
Red Brass	Copper
<u>Not Acceptable</u>	Admiralty Brass
Copper	Red Brass

*For thin section applications in Utah State Prison Geothermal Fluids. Criteria for classification are minimum average penetration as determined from weight loss and from extent of pitting attack.

TABLE 5-1: Results of Corrosion Testing

6. SYSTEM DESIGN

On April 5, 1982, Case, Lowe & Hart, Inc., was chosen to prepare the final design. CH₂M Hill's preliminary design report was used for conceptual design and to determine CL&H's scope of work.

The design process was divided into three stages; 1) Development of schematic drawings and preliminary cost estimates of several possible designs; 2) Production of working drawings of the selected design and alternates; and 3) Preparation of final drawings and specifications. At critical times in each step the design was reviewed by the State of Utah's (DFCM) and by DOE, represented by EG&G Idaho.

On July 1, 1982, CL&H was issued a formal notice to proceed. To facilitate design analysis, the system was divided into four sections. Well head configuration including well head piping and flow control; gravity disposal system; clean water distribution system including circulating pumps and buried pressure piping; and interconnection with existing building system.

On July 13th, a design conference was held at the prison to discuss the design procedure and direction. Representatives were there from DFCM, CL&H, Department of Social Services and prison maintenance.

Among the items discussed were the routing of the gravity discharge line, the basic design philosophy and the need for upgrading of the Minimum Security building's heat system.

The design philosophy required the system to be as simple and basic as possible to reduce first-cost and maintenance. The design was to be flexible enough that if necessary, additional equipment could be added after initial construction.

6.1. Preparation of Schematics

Based upon the conference discussions, a schematic diagram, Figure 6-1, of the entire system was drawn and given to DFCM.

In a meeting on August 11th between CL&H and DFCM, the schematic design was discussed. The gravity disposal system, clean water distribution system, and connection to existing heating system, were generally acceptable as presented.

A major area of concern was the well head configuration due to possible scaling of the well bore and heat exchangers. Alternate schemes to deal with this were discussed. CL&H prepared schematics of a basic system design plus three alternate well head schemes to deal with the scaling problem. The basic system design was to provide for scale removal on a periodic basis by mechanical or chemical means.

These schematics were prepared and preliminary cost estimates were made for each alternate. The pros, cons, and unknowns for each scheme were listed on each drawing and were submitted to DFCM and EG&G. These schematics appear in Appendix A, labeled Figure 2 through 6.

After review by DFCM and DOE, two of the design schemes were chosen to be the basis of the final design. The sand bed scale trap was removed from both configurations (Appendix figures 2 and 5). The base bid consisted of allowing the well to flow artesian into the surge tank and pumping the water through the plate heat exchangers. The additive bid item used a deep well pump, set at approximately 275 feet, to pump the fluid through the heat exchangers.

FIGURE 6-1: System Schematic

6.2. Working Drawings

After acceptance of the schematics work began on the detailed design of the system. The purpose of working drawings is to present, based on the schematics, detailed drawings and specifications describing the work and specifying the materials, workmanship and equipment required. The working drawings represented a preliminary construction bid package containing general contractual requirements, detailed drawings and specifications.

There were six areas where additional detailed engineering and design work was required:

1. Equipment Sizing
2. Material Selection
3. Connection to Existing Systems
4. Gravity drainage system
5. Controls and Instrumentation
6. Down hole well pump

Each area was studied in detail in an attempt to achieve the best possible design. Throughout the process many decisions were made based on information contained in the preliminary design report and results of the water chemistry and corrosion tests. Extensive use was made of information published on other geothermal heating systems and components. Much of the system was designed using accepted engineering methods for design of low temperature hydronic heating systems.

6.2.1. Equipment Sizing:

The preliminary design by CH₂M Hill and the schematic drawing phase produced approximate sizes and capacities for most of the mechanical equipment. As more accurate information on anticipated demands and expected flow rates became available, it was necessary to refine the selection parameters.

A detailed study was made of the Minimum Security building's heating systems and expected heating and hot water loads. This, along with a conservative geothermal well flow rate was used to size the plate heat exchangers and circulating pumps.

The plate heat exchangers and geothermal pumps are sized based on expected heating loads. To minimize pressure drops and provide flexibility, two heat exchangers piped in parallel were used. This allows one to be cleaned or repaired without shutting down the system. Each unit is sized to provide 50% of the maximum heat transfer.

The clean water circulating pumps and loop are sized based on estimated design flows and calculated pressure drops. Part of the buried distribution pipe line is oversized to enable future expansion of the system.

The culinary water shell and tube heat exchangers are designed based on expected demands for each system. They are sized with larger heat transfer surface to compensate for the lower heating water temperature (130° - 170° F).

6.2.2. Material Selection:

The critical materials selected were those that would be exposed to the geothermal water. The water chemistry report and corrosion test results were used to determine suitable materials. The corrosion test results (Table 5-1) indicate that, in general the 300 series stainless steels, 316 SS in particular, are good choices for critical materials.

6.2.3. Description of Existing System:

The space and hot water heating system in the Minimum Security building is divided into two separate sections. One section, with the equipment located in an equipment room below the kitchen, supplies the north end of the building including the gym and cafeteria. The other section, located in an equipment room at the south east corner of the building, supplies the south end of the building including the office and administration areas. The systems are completely separate, sharing only control air and high pressure steam from the prison's central steam plant.

Each equipment room contains two manually controlled heating water circulating pumps, each sized to meet two thirds of full load heating requirements. The water is heated in shell and tube heat exchangers by steam supplied from the prison's central boiler plant. The water temperature is automatically reset according the outside air temperature. The colder the outside temperature, the hotter the heating water.

Domestic hot water (DHW) is primarily used for showers and dishwashing. Each equipment room contains a large hot water storage tank. Water is heated by circulating it through a shell and tube steam heat exchanger. An aquastat mounted in the tank controls a circulating pump to regulate the storage temperature. The water is circulated through the building by several small recirculating pumps. A booster heater in the kitchen supplies 180° F rinse water for dishwashing.

6.2.4. Connection to Existing System:

The connection between the geothermal system and the existing system was designed according to primary-secondary pumping system principles contained in Bell and Gossett's engineering manual: "Design of Primary-Secondary Pumping Systems". The geothermal clean water pumps and circulating loop are the primary loop, the existing heating system is the secondary loop.

Study of the Minimum Security building heating system and the calculated clean water loop flow rates enabled a crossover between the systems to be sized. Three-way valves on the return side of the existing system control the amount of water drawn from the primary loop. This water is circulated through the building and returned to the primary loop.

The valves are regulated to maintain an existing loop supply temperature, selected by the existing outside air reset controller. Only after the maximum amount of water is drawn from the clean water loop (100 gpm each equipment room) is the steam converter allowed to supply additional heat.

The culinary hot water heat exchangers were placed in series on the primary loop, downstream of the space heat system. The supply temperature for the culinary water is lower than the temperature required for space heating, 120°F versus 120+°F, so a lower clean water return temperature can be obtained, enabling a lower geothermal water discharge temperature.

6.2.5. Gravity Drainage System:

To get the discharged geothermal water from the well site to the Jordan River, it was necessary to provide a drainage system. There is sufficient elevation drop between the two so a gravity system consisting of open ditches and buried pipe was considered. Due to possible ground fog, Prison authorities objected to open ditches so the design was changed to buried pipe with manholes for access. A 10" concrete pipe was used to provide excess capacity for future expansion.

To get to the river, it is necessary to cross a large irrigation canal and tracks of the Denver and Rio Grande Western Railroad (D&RGW). The original scheme was to cross both at the same location utilizing an existing D&RGW crossing. This was rejected by the railroad for unstated reasons so separate crossings for the canal and railroad were designed.

Before discharging to the river, the water had to be cooled to 80° F or less. The first idea was to use natural draft cooling towers. However, after further investigation, it was decided a cooling pond with spray inlets would meet the cooling requirements at approximately the same cost. The cooling pond requires less maintenance and has a longer life expectancy. There was an existing pond at the discharge site that could be re-worked without extensive grading or fill.

6.2.6. Controls and Instrumentation:

The design strategy for the control system was to keep it as simple and automatic as possible, yet sophisticated enough to provide optimum use of the geothermal resources.

Pneumatic controls are used wherever possible because, in the designer's experience, pneumatic controls are more reliable and are easier to service and maintain.

The major items requiring automatic control are: geothermal water flow from the well and flow rate through the heat exchanger, the on/off operation of the clean water circulating pumps, the 3-way crossover valve regulating the flow of primary water into the Minimum Security Building's heating system, and the pumps that circulate culinary water through new shell and tube heat exchangers in the Minimum Security Building.

Due to the surges caused by CO₂ evolving from the well water, and the location within the system of the surge tank, the flows from the well and through the heat exchangers require separate flow regulating devices.

Flow from the well had to be regulated to maintain an adequate water level in the surge tank. The logical choice was a float type level controller regulating a valve on the well discharge.

Several methods of controlling the flow rate through the heat exchangers were looked at, the two most promising being a variable speed pump controlled by discharge temperature, or a flow control valve controlled by discharge temperature. Due to the cost and complexity of a variable speed pump, a flow control valve similar to the one used to regulate flow from the well was used. The valve is placed on the discharge side of the heat exchanger, maintaining an over pressure on the geothermal water to minimize the evolution of CO₂.

A variable speed drive was also considered for the alternate down hole pump but was rejected for the same reasons. The final method of control was similar to the base bid, one flow control valve on the heat exchanger discharge.

The 3-way crossover valve connecting the geothermal system to the existing system is controlled so that the geothermally heated water is completely utilized before heat can be added to the system by steam. To accomplish this, the valve was specified with a spring range that assures it's completely open before the existing steam valve opens. Both valves are controlled by the same existing reset controller.

Instrumentation was required to monitor the performance of the system and record the energy contribution from the geothermal source. It's necessary to monitor and record the supply and return temperatures and the flow rate of the clean water loop. By measuring the clean water side the actual contribution to the building is determined rather than the resource use. High quality industrial type process equipment was specified to meet these requirements.

6.3. Final Design

The working drawings were delivered to DOE and DFCM for review in November, 1982,. In a meeting on December 16, 1982, their comments were discussed and several small changes in the design were agreed upon. These changes were incorporated into the construction documents and the complete design package was delivered to DFCM in January 1983.

The final design of the geothermal system can be divided into four major sections, Extraction, Transmission, Utilization, and Disposal. In addition, Control and Instrumentation systems are included. The sections are defined as follows:

Extraction -

The energy extraction system consists of five major components: 1) Production well-Utah State Prison/TH-1; 2) Well head piping; 3) Surge tank; 4) Geothermal pump; 5) Plate heat exchangers.

Transmission -

The major components of the transmission system are: 1) Two circulating pumps; and 2) A buried steel and fiberglass reinforced plastic (FRP) pipe circulating loop.

Utilization -

The energy utilization system consists of: 1) The piping crossover in the Minimum Security Building equipment rooms, and 2) The domestic hot water heating system.

Disposal -

The disposal system consists of four major components: 1) A concrete catch basin attached to the surge tank; 2) A buried concrete drain line; 3) A system of spray nozzles for cooling; and 4) A cooling and retention pond with outlet to the Jordan River.

6.3.1. Energy Extraction System

6.3.1.1. Production Well USP/TH-1

The production well USP/TH-1, Figure 5-2, was drilled in October 1980. Originally drilled as a test well, its predicted performance was enough to use it as a production well. It consists of 281 feet of 8" steel casing above 20 feet of 6" casing and 700 feet of 6" slotted steel liner for a total depth of 1000 feet.

6.3.1.2. Well Head

The well was originally topped with an 8" cast iron gate valve at existing grade and various instrumentation and flow testing ports above the gate valve. Everything above the gate valve was removed and replaced with new equipment and fittings.

A new 8" steel gate valve, Figure 6-2, is located immediately above the original valve, insuring positive shut-off of the well. An 8" riser with a 6" saddle tee extends approximately 4 feet above the cast iron gate valve. The riser is topped with a 3" steel gate valve and blind flange to allow instrument placement. The 6" saddle tee, with a 6" steel gate valve, provides the water path to the surge tank. The water flows through a 6" isolation butterfly valve, a 6" V-ball flow control valve, valve V1 Figure 6-2, a second butterfly valve, and into the surge tank. There is a 4" bypass around the control valve. A concrete slab poured around the well provides a base for pipe support.

The 8" riser is Schedule 40 mild steel. The remaining metal pipe carrying geothermal water is Schedule 10S stainless steel pipe with 304 ASSA 376.19 butt welded fittings and service flanges.

All valves exposed to the geothermal water, except the gate valves, are type 316 stainless steel construction with Viton or teflon seats. The gate valves are Class 150 cast steel with full Stellite trim.

6.3.1.3. Surge Tank

The water from the well flows directly to the concrete surge tank, Figure 6-2. The tank located approximately 10 feet from the well head, is insulated with foam insulation and earth berming. The use of a surge tank accomplishes two goals.

First, it eliminates the surging inherent in the water flow from the well. Internal concrete baffle walls reduce the effects of this surging and hinder the flow of particulates from the tank inlet to the pump suction inlet.

Second, the tank maintains a carbon dioxide "blanket" over the water. Water chemistry tests indicate calcium carbonate (the primary scale forming material) will precipitate only when the carbon dioxide dissolved in the water leaves solution. The blanket appears to reduce the evolution of carbon dioxide and prevents aeration, reducing the corrosion and scaling potential of the water.

The tank is constructed from 8" cast-in-place concrete. It is 18 feet long, 7 feet wide, and 9 feet high with two separate compartments connected by overflow pipes. Finished grade is approximately 4 feet above the bottom of the tank. One end of the tank is used as a catch basin for the geothermal water discharged from the heat exchangers. The water level in the tank is maintained at approximately 4 feet.

The water is drawn from the tank through two 6 inch ductile iron pipe spools cast in the tank wall. The pipes penetrate the adjacent equipment building wall and connect to the geothermal pump suction lines. The spools are located in the lower third of the tank to maintain the maximum possible suction head but not pick up sediment from the tank bottom.

The tank can be drained and is accessed for cleaning and maintenance through sealed manholes in the top and fiberglass reinforced plastic steps cast in the tank wall.

6.3.1.4. Geothermal Pump

One five-horsepower geothermal water pump, pump P1 Figure 6-3, is located in a pit in the Geothermal Heating Equipment building. The pit is on the west wall within 2 feet of the surge tank. Provision was made for a second pump but it was not installed due to cost considerations.

The pump draws water from the surge tank, circulates it through the plate heat exchangers and discharges it into the catch basin on the south end of the tank. It pumps 220 gpm of geothermal water at 42 feet of head and is all iron construction.

FIGURE 6-2: Well Head Piping and Surge Tank

6.3.1.5. Plate Heat Exchangers

The heat exchangers are the primary energy extraction equipment. They transfer heat from the geothermal water to the 'clean' hydronic heating water.

Two heat exchangers, Figure 6-3, are piped in parallel, one-half of the total flow through each. They are constructed of embossed stainless steel plates clamped together and held in a steel frame. The fluids are circulated between alternate plates in a counter flow path.

These heat exchangers provide large heat transfer area in a very small package. Each has 370 square feet of transfer surface and measures approximately 4 feet by 6 feet by 2 feet. They are sized to heat 200 gpm of hydronic water from 133° F to 175° F using 220 gpm of 180° F. geothermal water.

Each heat exchanger is equipped with pressure gauges on the geothermal water inlet and outlet to monitor the pressure drop through the unit. This enables monitoring of scale build-up to indicate when cleaning is required. They are designed to be easily dismantled and manually cleaned. Ports for chemical cleaning were added in case manual cleaning is not adequate.

6.3.2. Transmission System

6.3.2.1. Circulating Pumps

The 'clean' hydronic water from the plate heat exchangers is supplied to the Minimum Security Building by two pumps circulating the water through the buried pipeline, pumps P2 in Figure 6-3.

The pumps, located in the geothermal equipment building, are designed to run individually or together depending on the load requirement. With one pump running the design flow rate is 170 gpm and increases to 200 gpm when both are operating.

The pumps are standard base-mounted pumps, a type commonly used for hydronic heating systems. They operate at 3500 rpm with 10 H.P. motors and are approximately 70% efficient at design load.

Equipment associated with the pumping system includes an expansion tank with automatic water makeup, an air separator, suction diffusers, pressure gauges and valves.

FIGURE 6-3: Extraction and Transmission System

6.3.2.2. Circulating Loop

Buried 6" and 4" diameter pipes carry the heating water from the equipment building to the Minimum Security building mechanical rooms. The supply and return pipes are 6" to a point within the prison's security zone. They reduce to 4" with a 6" x 4" x 4" tee. The 6" pipe and tee are installed to give the system added capacity for future expansion.

The 6" lines are Schedule 40 steel with 2" of field applied foam glass insulation jacketed with PVC. The 4" lines are fiberglass reinforced plastic pipe with 2 inches of factory applied urethane foam insulation, jacketed with 100 mill PVC.

6.3.3. Energy Utilization

6.3.3.1. Piping Crossover

The clean heating water from the heat exchangers is used directly in the building hydronic system. In each mechanical room, a piping crossover, consisting of supply and return lines, is attached to the existing system immediately before the steam heat exchangers. A three-way automatic valve, valves V3 and V4, Figure 6-4, controls the amount of geothermally heated water that crosses over into the building's heating system.

6.3.3.2. Domestic Hot Water:

When the water leaves the space heating system, it is used to heat domestic hot water for showers and kitchen use. By placing the domestic water heating system downstream it is possible to lower the temperature of the water returning to the plate heat exchangers.

Two shell and tube heat exchangers, H2 and H3, Figure 6-4, are used to transfer heat from the hydronic water to the domestic water. They were designed with large heat transfer areas to achieve the lowest possible return temperature for the hydronic water. Domestic water is pumped from the existing storage tanks, through the heat exchangers and back to the storage tanks.

FIGURE 6-4: Utilization System

6.3.4. Disposal System

6.3.4.1. Catch Basin and Drain Line

After leaving the heat exchangers, the geothermal water is discharged into a catch basin on the south end of the surge tank. The water flows from the tank through a 12" ductile iron pipe into a manhole located approximately 15 feet south of the tank, Figure 6-3. It flows by gravity through a 10" concrete pipe to a cooling pond near the Jordan River, 1-1/4 mile away.

The line runs through the prison's dairy and along the west edge of a prison cornfield. Before reaching the river the line crosses under a large irrigation canal and the tracks of the Denver and Rio Grande Western Railroad (see Figure 3-2). After crossing the railroad a PVC plastic pipe carries the water down the river bluff to the cooling pond.

6.3.4.2. Cooling Pond and Spray Nozzles

The cooling pond is located on the flood plain of the river below a 30 foot river bluff. It has approximately 9,750 square feet of surface and varies from 2 to 4 feet deep. A system of 7 spray nozzles manifolded with PVC pipe are used to evaporatively cool the water. The elevation drop of the river bluff provides the pressure necessary to operate the spray nozzles.

The water flows from the pond through a concrete discharge structure to a swampy area of the riverbank.

6.3.5. Controls

6.3.5.1. Well Head:

The 6" V-ball flow control valve on the well head discharge piping is controlled by a float-type level controller mounted on the surge tank, Figure 6-2. The controller regulates the well flow rate to maintain a preset water level (approximately 4 feet) in the tank. The controller and valve are pneumatic and use compressed air from the equipment building.

6.3.5.2. Plate Heat Exchanger:

The flow rate of geothermal water through the heat exchangers is regulated by a 4" V-ball flow control valve. The valve is controlled by a temperature controller sensing the geothermal discharge water temperature, Figure 6-3. The controller is set to maintain a 135° F discharge temperature and can be adjusted.

6.3.5.3. Clean Water Circulating Pumps:

The circulating pumps are controlled by outside air temperature sensors. When the temperature is below approximately 60° F one pump is on. When the temperature drops to around 25° F the second pump starts. When the temperature drops below about 10° F both pumps are shut down because the temperature of the return water could be higher than 180°F (see Section 7.1.1).

6.3.5.4. Heating Water:

Geothermally heated water flow in the Minimum Security building is regulated by 3-way mixing valves in the two mechanical equipment rooms. The valves are controlled by existing heating water reset controllers. These controllers adjust the water supply temperature depending on outside air temperatures. The valves are sequenced so that the valves are open to full geothermal flow before the steam valve on the heating water converter opens.

6.3.5.5. Domestic Hot Water:

The domestic hot water temperature is regulated by operating a small circulating pump which circulates domestic water from the storage tank through the heat exchangers. The pump is controlled by a differential temperature controller which operates the circulating pump any time a large enough temperature difference exists between the storage tank and the geothermally heated water.

6.3.6. Instrumentation

Instrumentation consists of an industrial quality flow meter and temperature sensors installed on the geothermal clean water circulating loop, Figure 6-3. These devices, combined with logic circuits, provide a Btu output which is recorded on a digital recorder.

The primary element in the flow meter is an orifice plate. The temperature sensors are resistance type thermometers (thermistors) in instrument wells immersed in the return and supply flow streams.

A four channel strip chart recorder provides a continuous record of clean water flow rate, supply, return, and outside air temperatures.

6.4. Alternates

Several alternate systems and subsystems were considered during the design process. These alternates were narrowed to two before working drawings were prepared. One, the base system is described in preceding sections. The alternate consisted of a down-hole pump to be installed if artesian flow proves inadequate. Provisions for power were made in the base design for the installation of a 20 H.P. shaft driven pump on the production well.

The pump would have been piped directly to the heat exchangers, eliminating the surge tank. The balance of the system would remain unchanged.

7. PROJECTED ECONOMICS

7.1. System Model

Many of the estimates and numbers used in the economic evaluation were derived from a computer model of the system. The model was developed in-house by Case, Lowe, & Hart, Inc. during the schematic and working drawing phase of the final design.

The model is based upon system equations derived from design operating conditions and control strategies. These equations give the operating status of the system depending upon outside air temperatures and culinary water consumption patterns.

A temperature bin method was used to estimate yearly performance. Outside air temperatures are divided into 5° F temperature "bins". Annual hourly occurrence of these bin temperatures is obtained from Air Force engineering weather data from AFM 88-8. These data are a compilation of years of hourly temperatures recorded at Hill Air Force Base. The data were manipulated to account for the slight change in location. By combining the average frequency of occurrence of each bin with the operating status, a yearly estimate of energy flows was calculated.

7.1.1. Discussion:

The system model was used to estimate yearly performance of the system depending upon the control strategies and setpoints. It indicated a strong correlation between the control setpoints and the yearly contribution of energy from the geothermal source.

The most critical section of the control system is the existing heating hot water temperature reset control in the Minimum Security building (see Section 6.3). This control regulates the water temperature supplied to the heating system based on outside air temperature. As the ambient temperature decreases, the heating water temperature increases to help meet the heating load.

This reset control is critical due to the upper limit of approximately 175°F on the geothermal heating supply water. When the controller calls for heating supply water in the building above 180-190°F, the return water temperature rises above the 175°F limit and the geothermal can no longer be used for space heating. If the return temperature exceeds 180°F, it will heat the geothermal water before it is discharged.

While it is necessary to increase the heating water temperature to counteract the heat loss, the lower this temperature can be and still heat the building, the greater the contribution from the geothermal can be.

7.1.2. Actual Economics

The measured economic performance to date has been substantially less than predicted. This is due to deviations from planned operation of the Minimum Security heating system (see economic performance summary). It appears the system model is still applicable if operation and maintenance problems with the existing system are corrected. The following economic projections are based on the model, actual performance is summarized in Section 9.2 - Performance Summary.

7.2. Capital Costs

The capital costs can be divided into eight general categories based on the original funding allocation from DOE and the State of Utah. Several categories include funding for items not essential to the completion of the project, but are due to the demonstration nature of the project. These include numerous reports, conferences and dissemination of information.

The following sections summarize the costs by category and give some indication of what the money was actually spent on. The total expenditures to date including the construction contract are \$827,558.

7.2.1. Environmental Report:

The total expenditure in this category was \$10,348. This was spent on an Environmental Report which assessed the impact of the project on the local surroundings.

7.2.2. Resource Development:

Total expenditure was \$121,473 and included the geophysical reconnaissance, drilling of test wells which included the production well USP/TH-1 and interpretation of the data.

7.2.3. Reservoir Analysis:

Total expenditure was \$77,654. This was used to fund a reservoir test and interpret the data in an attempt to estimate reaction of the geothermal reservoir to the withdrawal of brine. Part of this amount was spent after system startup when the well experienced delayed start up due to pressure declines in the reservoir.

7.2.4. Disposal Alternatives:

As the project progressed, the need to investigate an alternative to reinjection became apparent. This investigation cost \$6,148.

7.2.5. Design and Construction:

A total of \$517,114 was spent in this category. This includes \$16,166 for preliminary design work, \$48,739 for final design which included preparation of a construction bid package and construction supervision, \$392,500 for the actual construction, and \$59,759 for performance verification.

7.2.6. Reporting:

Reporting costs totaled \$27,794. This was spent on biannual progress reports, design and construction report, and the final project report.

7.2.7. Technology Transfer:

A total of \$6,964 has been spent to distribute information about the project. This includes publicity costs and costs incurred in presenting information at geothermal conferences.

7.2.8. Project Management:

Total expenditures to date are \$60,013 and account for the efforts by the State of Utah in managing the project.

7.3. Operation and Maintenance Costs

Operation costs can be divided into two categories; utility costs for operating pumps and equipment, and labor costs for routine operation and inspection. Maintenance costs can also be broken down into two categories; routine maintenance and repair or replacement of malfunctioning equipment. These costs are estimated based on projected requirements to keep the system in good operating condition. Routine maintenance costs to date have been substantially less than predicted due to deferral of maintenance tasks by the operating agency.

7.3.1. Operation Costs:

The system controls are designed so that very little manual operation is required. Daily or weekly observation is required to insure proper operation. Yearly start-up and shut-down periods are also required.

Assuming a weekly inspection lasting approximately one hour, a one week start-up period, and 2 day shut down, approximately 80 manhours of labor are required at a cost of \$25 per hour, resulting in a \$2,000 operation labor cost.

The estimated utility costs for operating the pumps and equipment are derived from the system model and current utility rates. Only the cost of operating the equipment in the geothermal equipment building was considered.

The pumps power consumption was estimated to be 11.6 KW at full load. This was calculated using a theoretical brake horsepower equation based upon pump capacity and pressure. A pump efficiency of 70% was used. A flat consumption of 1 kilowatt (KW) was used to account for miscellaneous electrical consumption.

With the control system operating as specified, the pumps operate approximately 6,700 hours per year, using 77,720 KW hours of electricity. With the miscellaneous electrical use a total of 84,420 KW hours, or 288 million Btu's, is used per year.

Current Utah Power and Light schedules show electricity at the prison costs \$.0383 per kilowatt hour. This gives a first year operating cost for utilities of \$3,233.

The total estimated operating costs for the project, labor and utilities, is \$5,233 per year (1985 base).

7.3.2. Maintenance Cost:

These costs are the most difficult to estimate. The frequency of routine maintenance for pumps, controls and most mechanical equipment can be determined from suggested maintenance intervals published by the equipment manufacturers. The frequency of maintenance required due to scaling and adverse effects of the geothermal water can only be estimated but, so far, have been less than originally expected. Cleaning and descaling is necessary only once each operating season.

Approximately 100 manhours at \$20 per hour for routine mechanical maintenance and cleaning and 10 hours at \$50 per hour for controls and instrumentation maintenance is required. This gives a cost of \$2,500 per year for routine maintenance.

The cost of replacing and repairing broken equipment can only be estimated based on experience with similar non-geothermal systems. To achieve a life expectancy of twenty years, each pump may require \$150 per year in addition to routine maintenance. The controls and electrical equipment could require up to \$500 per year of non-routine maintenance resulting in approximately \$1,000 per year for repairs or replacement of equipment.

The total estimated maintenance cost for the project, labor and materials, is \$3,500 per year.

7.4. Fuel Savings

The following savings are estimated based on projected performance and not on actual results.

7.4.1. Direct Energy Savings:

Direct energy savings refer to the energy that is actually supplied to the building from the geothermal system. This includes energy used for space heat and culinary hot water.

The system model described above gives a yearly value of estimated energy contribution from geothermal. The model will account for various control strategies but assumes the system is performing as designed. Depending upon the actual control setpoints, the model gives a range of savings varying 25% from best to worst case. The model estimates the geothermal heating systems will supply 8,500 to 11,500 million Btu per year to the Minimum Security Building depending on the control setpoints. Seventy to 80% of this is used for space heat and the remainder (1,230 million Btu) is used to heat culinary water. This accounts for 65 to 90% of the total direct energy (excluding electricity) used by the Minimum Security Facility.

7.4.2. Avoided Fuel Costs:

The totals mentioned above as "direct energy used" refer to the end use amount. In order to deliver 8,500 million Btu's to the building, the prisons central heating plant could burn more than twice that amount of fuel. Boiler losses, transmission loss, condensate and flashing losses must all be considered.

It was estimated based on recent studies of the central plant, that the overall plant efficiency is approximately 50%. To be on the conservative side, an overall plant efficiency of 65% was used. With planned upgrading and maintenance, the plant should be capable of this efficiency.

If 8,500 million Btu's are delivered to the Minimum Security Facility by the geothermal system, 13,075 million Btu's of gas will be saved. If 11,500 million Btu's are delivered, 17,692 million Btu's will be saved.

At August 1985 prices, the local gas utility, Mountain Fuel Supply Company, charges the prison \$3.26 per million Btu's in the winter and \$2.87 in the summer. An average cost for the operating season is \$3.13. The avoided fuel costs generated by the geothermal project range from \$40,925 to \$55,375 for the 1985-86 heating season.

With proper monitoring and control of the system, the savings should approach the higher figures. If the system is not maintained and operated properly, the system could actually increase the energy consumption of the Minimum Security building.

7.5. Results

Capital Cost

Resource Development:	\$199,127
Environmental Reports and Disposal Studies:	\$ 16,496
Design:	\$ 64,905
Construction:	\$392,500
State Project Administration:	\$ 60,013

Total Project Costs
(Excluding Demonstration Costs): **\$733,041**

Reporting:	\$ 34,758
Performance Verification:	\$ 59,759

Total Capital Costs: **\$827,558**

Operation and Maintenance Cost

Yearly Operation Costs:	\$ 6,500
Maintenance Costs:	\$ 3,500

Total Estimated Operation and Maintenance Costs: **\$10,000**

Fuel Savings

Direct Energy Savings
(Million Btu's per Year): 8,500 - 11,500

Avoided Fuel Costs:

1) Million Btu's per Year	13,075 - 17,692
2) Dollars per Year	<u>\$40,925 to \$55,375</u>

TABLE 7-1: Estimated Costs and Savings

The estimated first year savings range from \$41,000 to \$55,400 depending on the assumptions used to model the system operation. With proper operation and maintenance the savings should approach the top number. For the life cycle cost analysis, a savings of \$50,000 per year (1985 base) is used.

7.6. Economic Analysis:

The following life cycle cost analysis are included to show the effects of fuel and Operation and Maintenance (O&M) cost escalation on the project.

The initial costs and saving were estimated in previous sections. Fuel escalation rates were chosen based on estimates published by DOE. The energy escalation rates are expressed in amounts above general inflation. It was assumed that the non-energy related O&M costs, \$5,500, escalated at rates only slightly higher than the general inflation rate.

The power costs (\$3,233 first year), were escalated according to DOE's estimates. However, the DOE estimates were calculated before the recent drop of inflation rates from 12% to 6%. If the rate remains low i.e., 4-8%, the figures given by DOE are no longer valid. To demonstrate the effect of this, calculations were also made based on the designer's estimates of fuel escalation. These calculations are marked as supplementary calculations.

The following tables, Tables 7-1 through 7-4, summarize the estimated life cycle costs of the project based on various assumptions. Tables 7-1 and 7-2 use DOE's published energy escalation rates with actual capital costs and non-demonstration capital costs respectively. Tables 7-3 and 7-4 use the Author's estimates of energy escalation rates and the same capital costs.

LIFE CYCLE COST ANALYSIS
Utah State Prison Geothermal Heating System

Alternate #1: Department of Energy 'Energy Price Escalation Rates' for Region 8 - Denver. All rates are given as differential rates with respect to inflation. Initial costs include all costs incurred to date including demonstration costs.

Escalation Rates -	0-5 Years	>6 Years
Natural Gas	4.95	2.84
Electricity	-4.05	-3.91
Maintenance	1.00	3.00

DESCRIPTION	First Cost \$	Worth at Year End			
		5 Years	10 Years	20 Years	25 Years

Initial Costs :					
Resource Development	199127	-199127	.....	.....	.....
Environmental Report	16496	-16496	.....	.....	.....
Design	64905	-64905	.....	.....	.....
Construction	392500	-392500	.....	.....	.....
Administration (local)	60013	-60013	.....	.....	.....
Reporting	34758	-34758	.....	.....	.....
Performance Verif.	59759	-59759	.....	.....	.....

TOTAL	827558	-827558	-827558	-827558	-827558

Operation Costs :					
Labor (First year cost)	2000	-10000	-20000	-40000	-50000
Energy (Electricity)	3233	-14908	-27065	-35224	-41908

TOTAL	5233	-24908	-47065	-75224	-91908

Maintenance Costs :					
Routine (1st year cost)	2500	-12753	-26702	-45450	-67183
Repair & Replace (Annual)	1000	-5101	-10681	-18180	-26873

TOTAL	3500	-17854	-37383	-63630	-94057

Energy Savings:					
Natural Gas	50000	276006	612918	1058716	1571515

*Net worth at end of year \$\$ ==>		-594313	-299088	92304	557993
*Net present worth with					*
*discount factor of :	5.00%	-465660	-234344	72322	437202
*	10.00%	-369022	-185710	57313	346470

TABLE 7-2: Life Cycle Cost - Version 1

LIFE CYCLE COST ANALYSIS
Utah State Prison Geothermal Heating System

Alternate #1a: Department of Energy 'Energy Price Escalation Rates' for Region 8 - Denver. All rates are given as differential rates with respect to inflation. Initial costs include only costs directly related to construction i.e., no demonstration costs.

Escalation Rates	0-5 Years	>6 Years
Natural Gas	4.95	2.84
Electricity	-4.05	-3.91
Maintenance	1.00	3.00

DESCRIPTION	First Cost \$	Worth at Year End			
		5 Years	10 Years	20 Years	25 Years

Initial Costs :					
Resource Development	199127	-199127	.....	.....	.....
Environmental Report	16496	-16496	.....	.....	.....
Design	64905	-64905	.....	.....	.....
Construction	392500	-392500	.....	.....	.....
Administration (local)	60013	-60013	.....	.....	.....
Reporting	0	0	.....	.....	.....
Misc.	0	0	.....	.....	.....

TOTAL	733041	-733041	-733041	-733041	-733041

Operation Costs :					
Labor (First year cost)	2000	-10000	-20000	-40000	-50000
Energy (Electricity)	3233	-14908	-27065	-35224	-41908

TOTAL	5233	-24908	-47065	-75224	-91908

Maintenance Costs :					
Routine (1st year cost)	2500	-12753	-26702	-45450	-67183
Repair & Replace (Annual)	1000	-5101	-10681	-18180	-26873

TOTAL	3500	-17854	-37383	-63630	-94057

Energy Savings:					
Natural Gas	50000	276006	612918	1058716	1571515

*Net worth at end of year \$\$ ==>		-499796	-204571	186821	652510
*Net present worth with					
*discount factor of :	5.00%	-391604	-160287	146379	511259
*	10.00%	-310334	-127023	116001	405157

TABLE 7-3: Life Cycle Cost - Version 1a

LIFE CYCLE COST ANALYSIS
Utah State Prison Geothermal Heating System

Alternate #2: Energy escalation rates estimated based on local utility company projections and historical trends. All rates are differential WRT inflation. Initial costs include all costs incurred to date including demonstration costs.

Escalation Rates		0-5 Years	>6 Years			
Natural Gas		7.00	5.00			
Electricity		-2.00	-1.00			
Maintenance		1.00	3.00			

DESCRIPTION	First Cost \$	Worth at Year End			
		5 Years	10 Years	20 Years	25 Years

Initial Costs :					
Resource Development	199127	-199127	.....	.....	.....
Environmental Report	16496	-16496	.....	.....	.....
Design	64905	-64905	.....	.....	.....
Construction	392500	-392500	.....	.....	.....
Administration (local)	60013	-60013	.....	.....	.....
Reporting	34758	-34758	.....	.....	.....
Performance Verif.	59759	-59759	.....	.....	.....

TOTAL	827558	-827558	-827558	-827558	-827558

Operation Costs :					
Labor (First year cost)	2000	-10000	-20000	-40000	-50000
Energy (Electricity)	3233	-15531	-29854	-42807	-55125

TOTAL	5233	-25531	-49854	-82807	-105125

Maintenance Costs :					
Routine (1st year cost)	2500	-12753	-26702	-45450	-67183
Repair & Replace (Annual)	1000	-5101	-10681	-18180	-26873

TOTAL	3500	-17854	-37383	-63630	-94057

Energy Savings:					
Natural Gas	50000	287537	675036	1306231	2111814

*Net worth at end of year \$\$ ==>		-583406	-239759	332237	1085075 *
*Net present worth with					*
*discount factor of :		5.00%	-457114	-187857	260316 850184 *
*		10.00%	-362249	-148871	206293 673746 *

TABLE 7-4: Life Cycle Cost - Version 2

LIFE CYCLE COST ANALYSIS
Utah State Prison Geothermal Heating System

Alternate #2a: Energy escalation rates estimated based on local utility company projections and historical trends. All rates are differential WRT inflation. Initial costs include only costs directly related to construction i.e. no demonstration costs.

Escalation Rates	0-5 Years	>6 Years
Natural Gas	7.00	5.00
Electricity	-2.00	-1.00
Maintenance	1.00	3.00

DESCRIPTION	First Cost \$	Worth at Year End			
		5 Years	10 Years	20 Years	25 Years

Initial Costs :					
Resource Development	199127	-199127	.....	.....	.....
Environmental Report	16496	-16496	.....	.....	.....
Design	64905	-64905	.....	.....	.....
Construction	392500	-392500	.....	.....	.....
Administration (local)	60013	-60013	.....	.....	.....
Reporting	0	0	.....	.....	.....
Misc.	0	0	.....	.....	.....
TOTAL		733041	-733041	-733041	-733041

Operation Costs :					
Labor (First year cost)	2000	-10000	-20000	-40000	-50000
Energy (Electricity)	3233	-15531	-29854	-42807	-55125
TOTAL		5233	-25531	-49854	-82807

Maintenance Costs :					
Routine (1st year cost)	2500	-12753	-26702	-45450	-67183
Repair & Replace (Annual)	1000	-5101	-10681	-18180	-26873
TOTAL		3500	-17854	-37383	-63630

Energy Savings:					
Natural Gas	50000	287537	675036	1306231	2111814

*Net worth at end of year \$\$ ==>		-488889	-145242	426754	1179592
*Net present worth with					
*discount factor of :		5.00%	-383057	-113801	334373
*		10.00%	-303561	-90184	264981
					732434

TABLE 7-5: Life Cycle Cost - Version 2a

The tables indicate that with a 20 year life the net present value of the system, using a 10% discount rate, varies from \$57,313 to \$264,981 depending on the assumptions used. With a 25 year life the net present values increase to \$346,470 or \$732,434.

Many factors, such as escalation rates and unpredictable performance variations, will affect the project's payback. The area with the highest potential impact on savings is operation and maintenance. If sufficient effort and finances are allocated (approximately \$10,000 per year) the system should perform at, or above, these estimates and could have a life expectancy well in excess of 20 years.

If, on the other hand, operation and maintenance procedures are allowed to degrade, the performance of the system will decrease and the system will cost more to operate than it will save.

8. CONSTRUCTION

8.1. Design Documents

The bid package consisted of drawings, specifications, and general conditions. The drawings and specifications present the final design of the system and specify all materials and their installation. The general conditions give detailed instructions and rules for the contractor to follow during construction, including pay requests, performance bonds, payment of sub-contractors, etc.

The bid package was organized to provide for a base bid and three additive alternates. The base bid included all items necessary for an operational system. The alternates provided for, 1) A down hole pump; 2) An increase in the distribution pipeline size from 4" to 6" to a point within the security perimeter (for future additions); and 3) Electrical service to an unrelated automobile service island. The package was broken into base bid and additive alternates to allow more detailed cost analysis and accounting.

8.2. Bidding and Selection

The bid package was released for bid in April, 1983, by the State of Utah Division of Facilities Construction and Management (DFCM). Advertisements for bid were placed in two local papers, the Salt Lake City Tribune and the Deseret News. These advertisements ran for approximately two weeks. They included instructions to potential bidders; where to pick up bid packages, and the deadline for submitting bids. Bid opening was scheduled for April 19, 1983.

A total of twelve qualified bids were received. The base bid prices ranged from \$350,000 to \$497,000. Six of the twelve bids were less than \$375,000, indicating the low bid of \$350,000 was competitive and was a valid price. The low bid was submitted by Stephan L. Cornwall Company of Salt Lake City, Utah. Since they were qualified contractors, DFCM awarded the contract to Cornwall based on their based bid and alternates 2 and 3. The total bid price, with both alternates, was \$359,300.

Although the contractor was prepared to begin work immediately, the State delayed giving a notice to proceed until the final EPA discharge permit was granted. The permit was received June 17, 1983. The contractors notice to proceed was sent immediately thereafter. A pre-construction meeting was held on June 23 and construction began the next day. The official ground breaking ceremony was held on July 12, 1983.

8.3. Construction

8.3.1. Equipment Building

The Geothermal Equipment building is located twenty feet east of the well head. It houses most of the equipment associated with the Extraction and Transmission systems. It also contains all the instrumentation, controls, and electrical equipment, and was designed for future expansion.

8.3.1.1. Description

The building is constructed of 8 inch brick walls with insulated or grouted cores. The floor is concrete slab on-grade, the roof is wood rafters with asphalt shingles and sheet rock ceiling. The roof and north wall structure were designed to allow future expansion to the north should the geothermal system be expanded.

The building contains approximately 330 square feet and is divided into two rooms. The geothermal equipment room contains most of the Extraction System equipment including the geothermal pump and the plate heat exchangers. The second room contains the Transmission System pumps and controls, the Instrumentation, the Extraction System controls, and the electrical equipment.

8.3.1.2. Progress During Construction

Construction on the building began in August, 1983. The shell was completed in early November and the finish work in December. There were no significant changes made or problems encountered during construction of the equipment building.

8.3.2. Energy Extraction System

8.3.2.1. Progress During Construction

The surge tank was the first component to be installed. Construction on the tank was started Aug. 18, 1983 and, with the exception of the insulation, was complete by Sept. 20. The insulation was applied in December.

The pump was delivered early and was installed by November 1983. The well head piping was started in early November and completed before December.

The plate heat exchangers were delivered to the site on Dec. 13, after a substantial delay in delivery. They were installed by Dec. 27.

There were no significant changes made during construction and the only significant problem encountered was in delivery of the plate heat exchangers. They twice failed the factory's final pressure test causing a delay in installation of approximately two months. While the contractor could not install the heat exchangers, other work was being done. The actual delay of the project due to this problem was minimal.

8.3.3. Transmission System

8.3.3.1. Progress During Construction

Work on the buried pipeline began in August 1983 and was completed in early November. There was a slight delay in testing the lines due to a possible leak in previously installed pipe. The pumps and accessories were installed in November.

The only significant change during construction was made by the contractor without approval from the Engineer or Owner. The change was made at the manhole where the transmission line changes direction, is reduced to 4", and the pipe material changes from steel to FRP. The design shows the transition from steel to FRP occurring outside the manhole meaning all pipe in the manhole was steel. The contractor made the transition from steel to FRP inside the manhole so that FRP pipe is exposed to additional stress and possible mechanical damage. The change was not noticed until after installation and was never accepted as correct.

There were two minor problems encountered in laying the underground pipe line.

The first was a conflict in the route of the line with an existing, unknown, storm sewer. The transmission line was moved laterally 5 feet, requiring the contractor to cut and patch asphalt in a parking lot. The contractor was given an extra \$1,275 for the work.

The second problem occurred in a section of line installed prior to construction on the geothermal project. The line was installed by a contractor working on site improvements at the prison. Two 6" steel pipes approximately 60 feet long were installed under a roadway, scheduled to be paved during the site improvements, to minimize cutting and patching of the road when the geothermal project, then in final design stages, was installed.

The contractor who installed the lines did not cap or test them. When the geothermal contractor uncovered them to make his connections, the lines were corroded and full of debris. After the connections were made pressure tests were conducted, the first two tests indicating a small leak in the line. Since no leaks were found in the new, and as yet exposed, sections, it was assumed the leak was in the previously installed section. A third test was run, and over a period of twenty four hours, there was no loss of test pressure indicating the leak had either sealed itself or the first two tests were faulty. Since digging up the line would be expensive the State decided to leave it buried and hope the leak does not re-appear.

8.3.4. Energy Utilization

8.3.4.1. Progress During Construction

The piping crossovers, domestic hot water heat exchangers and accessories were installed in November 1983. The electrical and controls were connected in December. There were no significant changes made during construction.

The only significant problem encountered during installation was a disagreement between sub-contractors as to who was responsible for electrical connection of the mechanical equipment. The problem was worked out internally and caused little, if any, delay.

8.3.5. Disposal System

8.3.5.1. Progress During Construction

Construction on the concrete drain line began in early July, 1983, installation proceeded slowly, but was substantially complete by late August. Construction on the spray piping began in August. Heavy rains hampered the work, causing earth slippage on the river bluff that destroyed a section of pipe. The damaged section was replaced and the installation was completed in September.

The only changes made were to solve problems encountered during construction and are discussed in detail below.

There were several problems during construction on the disposal system. The most serious was a hard-pan layer encountered during excavation for the drain line.

The hard pan is a fairly plastic, extremely tough soil layer approximately three feet below the surface. Standard excavating equipment was useless in removing the material. After determining the elevation of the the hard pan, the civil engineer raised the grade on the drain line to clear most of the layer. However, some sections of line still had to be installed in or below the hard-pan layer. After careful consideration, dynamite was use to blast the layer into pieces small enough to handle. The contractor was compensated for the additional effort with a change order totaling \$10,834.

Heavy rains caused minor problems with the plastic spray line installed down the river bluff. An earth slippage destroyed a section of line on the bluff. It appeared that the slippage would continue so the line was re-routed to avoid further problems. The cost of this was included in the hard-pan change order.

The rains also caused minor problems with the construction of the cooling pond.

8.3.6. Instrumentation

8.3.6.1. Progress During Construction

The instrumentation was installed in January, 1984 approximately two months behind schedule. Once installation was begun, the work went quickly with few delays. There were no significant changes made during construction.

Almost all the problems associated with the instrumentation were caused by delays in ordering and delivery of equipment. The equipment was supplied and installed by the control contractor who apparently did not order the proper equipment in a timely manor.

The contractor was repeatedly warned about procuring the equipment and installing it on time. The contractor began installing equipment only after being threatened with removal from the job.

One problem not identified until startup was with the paper in the chart recorder. It was not supplied with the correct units and scales and had to be reordered. There were other problems with calibration and operation of the instrumentation and controls that were only resolved with numerous warnings to the contractor that he was in danger of being removed from the job and being sued for failure to perform.

8.4. Summary of Construction Costs

The following is an estimated breakdown of construction costs for the project. The costs are based on itemized payment requests submitted by the general contractor.

Equipment Building	
Excavation & Backfill	\$2,448
Concrete	\$5,000
Masonry	\$6,000
Roofing	\$1,000
Misc. Iron & Steel	\$500
Damproofing	\$2,000
Electrical	\$3,000

Total	\$19,948

Energy Extraction	
Site Work	\$5,000
Exterior Piping	\$21,000
Interior Piping	\$28,000
V-Ball Control Valves	\$7,000
Heat Exchangers	\$18,000
Pump	\$4,000
Surge Tank	\$4,000
Insulation	\$2,500
Electrical	\$3,000
Controls	\$11,000

Total	\$103,500

Transmission	
Pumps	\$8,000
Buried Mains	\$58,775
Mechanical Equip.	\$4,000
Electrical	\$4,000
Controls	\$4,000

Total	\$78,775

Utilization	
Piping	\$15,000
Pumps	\$1,000
Heat Exchangers	\$4,000
Insulation	\$2,000
Controls	\$7,000

Total	\$29,000
Disposal	
Drain Line	\$86,834
Spray Nozzles	\$1,300
Cooling Pond	\$15,000

Total	\$103,134
Instrumentation	\$15,000
Electrical	
Transformers	\$6,757
Line Connections	\$5,000
Change Order (Temp. Power)	\$9,823

Total	\$21,580
Miscellaneous	
Bonding & Insurance	\$7,000
 TOTAL CONSTRUCTION COST	 <u>\$377,937</u>

9. OPERATION AND PERFORMANCE

9.1. Summary of Operation

9.1.1. Start-up

The initial system start-up occurred in February, 1984. All mechanical systems, pumps, valves, etc., worked as intended. There were several problems with controls and instrumentation, mostly due to improper installation and calibration. There were similar problems in the existing Minimum Security heating system. The controls were not fully operational until May, just prior to seasonal shut-down.

Because of the control problems, little useful operational data was collected until seasonal start-up in September, 1984.

9.1.2. Operation

When the system was started in the Fall of 1984, it operated with few problems through December. Periodic visits were made to collect data and monitor the operation.

The system was apparently operating as intended but was not contributing the expected amount of energy. An investigation showed the prison maintenance staff had bypassed the Minimum Security system's automatic controls. As a result, steam was used when the geothermally heated water could have carried the entire heating load.

By manually controlling the steam system, the maintenance staff greatly reduced the energy supplied from geothermal heat. They apparently received several complaints from inmates of cold conditions. The most effective response was to increase the heating supply water temperature to 200+ °F. The controls would remain in that state regardless of the actual heating requirements. Problems similar to this occurred several times during the operation of the system.

It's not clear why the system was manually controlled. The maintenance staff claimed the controls, installed in 1983 under a separate contract, did not work properly. However, little effort was made to correct them. As long as the inmates were not complaining, little effort was made to determine why the building was cold. The maintenance staff apparently has little time for anything other than "crises maintenance".

The geothermal system remained in operation until January, 1985, when due to operational problems, it was shut down. Again, delays in repairs caused the system to remain inoperable until May, when seasonal shut-down was required.

In December, 1985 the majority of the system was ready for start up but could not due to well problems. The well did not start for more than a week after it was opened. When it did start, the flow was quite weak, less than 250 gpm maximum. It flowed this way for several weeks until minor problems with one of the valves required shutting in the well for approximately two weeks. When it was opened it again did not start for several weeks. Since that time there have been continuing problems repairing a broken pipe, (Section 9.4.1.2), and the system has not been started to date.

9.1.3. Maintenance

During the first four months of operation, September through December, the system required little maintenance. The maintenance responsibility belonged to the prison maintenance department, but they were unaware of it for much of the period. Items such as pump lubrication and strainer blow-down were neglected but fortunately caused no failures or detectable damage.

As mentioned above, there were maintenance problems in the Minimum Security heating system. The maintenance staff was apparently over-worked before the geothermal system was installed. They have a continuing problem retaining enough properly trained people to adequately maintain the prison's aging heating systems.

9.1.4. Significant Events

The following events all occurred in a relatively short time span. They appear to be related, but just how is not clear. The dates are approximate and the causes given are best guesses, based on the information available.

9.1.4.1. Pump Failure:

The mechanical seal on the geothermal water pump, pump P1, Figure 6-3, showed signs of leakage as early as March, 1984. The leak was minor and did not require fixing until December, 1984. The pump was under warranty so the contractor was notified of the problem. A factory authorized service representative was sent to the prison to make the necessary repairs and, if possible, determine the cause of failure.

He felt the leak was caused by scale build up on the mechanical shaft seal. The scale apparently formed when geothermal water was present but the pump was not operating. This allowed the scale to build up on stationary surfaces and, when the pump was turned on, it scratched the surfaces of the seal causing the leak.

The pump was removed and repaired at the service company's shop. They replaced the pump and it has been working correctly since.

9.1.4.2. Pipeline Break

Sometime during the first week of January, 1985, a break occurred in the buried transmission pipeline. It was noticed that the system was making up water at a high rate, indicating a leak in the system. The prison maintenance staff found the break shortly after noticing the high make up rate.

The break occurred in a section of exposed FRP pipe in the manhole where the transmission line changes from steel to FRP. The break was in the FRP return line at the flange connecting the FRP pipe to the steel line. The cause of the break is not known for certain, but it appeared that stresses from expansion and contraction of the line were concentrated at the flange. However, the possibility of freezing has not been ruled out. The pipe was not installed according to design (see discussion in section 8.3.3) which may, or may not, have contributed to the break.

The system was under warranty so the contractor was notified and instructed to repair the break. It was repaired, in accordance with factory recommendations, by placing a fiberglass patch over the affected area but was never tested. In January, 1986 when the system was refilled there were still minor leaks at or near the patch. These were apparently repaired, but since the well is not flowing, the system has not yet been refilled.

9.1.4.3. Existing System Problems

Problems with the existing building system were the most significant reason for poor performance of the geothermal system. The problems were numerous, mainly affecting the controls. For example, an equipment room flooded, causing the control air compressor to fail, which caused all heating controls to fail to full heat. It took several weeks to get a replacement installed and operating. Occasionally untrained personnel would adjust the controls causing serious performance problems.

9.1.4.4. Well Failure

To date, the most serious problem encountered has been the failure of the well to flow artesian. This was recognized as a potential problem early in the design, but with the strong artesian flow experienced during testing, it was decided to rely on artesian flow as long as possible. It appears that the stress placed on the reservoir by the pumping of the Utah Roses well, UR-1, is greater than was estimated during testing (Appendix C).

A project is presently underway to place a down hole pump in the well to insure adequate flow for a proposed expansion to the system.

9.2. Performance Summary

9.2.1. Technical

With the exception of the existing heating system, the system performed as expected. There were a few minor difficulties, such as the pipeline break and the well problems, but nothing of great consequences. Most of the problems experienced with the existing heating system were caused by inadequate or improper operation and maintenance. The energy contribution was adversely affected by manual override of controls and periodic break downs in the Minimum Security Facility. The geothermal system experienced a few technical problems which are discussed in detail in the Operational Summary section of this report.

The concept of maintaining a carbon dioxide 'blanket' in the surge tank apparently worked quite well. There was very little indication of scaling in the tank or equipment. The only noticeable scaling took place at the cooling pond outflow where heavy scaling was apparent.

A well bore test conducted in January, 1986, (Appendix C) showed the 6" portion of the well bore clean and unobstructed. The 8" section was not tested due to problems getting the gauge ring past the bottom gate valve, but there is no reason to expect scaling there if none is present in the 6" section.

There was sufficient data available from the chart recordings to accurately define energy flow rates for more than 10 weeks of 'typical' operation. Hourly data show an energy contribution pattern that closely follows domestic hot water consumption patterns. By manually bypassing the heating controls, the energy contribution to the space heating system was greatly reduced.

From observing the hourly variations in energy flow rates, Figure 9-1, it appears the majority of energy used was used to heat culinary water. The graphs clearly show the change in energy contribution from a low point at about 5 AM to a high during the afternoon hours. According to projected performance, (Section 7.1) the contribution from geothermal to space heating should decrease when ambient temperature increases, not increase as the charts show.

Figure 9-2 shows the system performance over a ten week period. The graph shows the average energy flow rate, in 1000 Btu/Hour, and the ambient temperature in degrees F. The graph indicates little, if any, long term correlation between the flow rate and ambient temperature. Based on system modeling results and control strategies there should be a definite reverse correlation between the two. As the temperature drops the energy flow rate should increase. The graph shows several periods where the ambient temperature and energy flow rate increase rise and fall in close unison. This lack of correlation supports the assumption that the energy was used mainly to heat culinary water.

Average Daily Flow Rates

FIGURE 9-1: Typical Daily Energy Flow Rates

FIGURE 9-2: 1984 Summary of Geothermal Energy Contribution

9.2.2. Institutional

The institutional performance of the project has been fraught with problems. The prison maintenance staff is already over worked and has time for crises maintenance only. They appeared to be resentful of the project.

They are still dissatisfied with the system and as a result provide little or no maintenance or operation. The savings potential does not appear to motivate the staff to maintain and operate the system. It is a concern to both the State Division of Facilities Construction and Management, and the design firm, that once the system is completely turned over to the prison maintenance staff it may be abandoned.

There is a project currently in design that may improve the outlook for the system. A new prison housing facility is going to be constructed on top of the distribution line from the well head to the Minimum Security Facility. The designers of this project have been instructed to utilize the geothermal in the new building. Perhaps with a new facility the maintenance staff can be convinced of the benefits of the geothermal system and operate and maintain it properly.

9.2.3. Economic

The economic performance is difficult to accurately define due to unknowns in the boiler plant efficiency. In this discussion the plant efficiency was estimated to be 65%, the same figure used in previously published performance projections.

For the 10 week period analyzed in detail, the direct energy savings totaled 2,099 million Btu. With a boiler plant efficiency of 65%, the estimated avoided energy consumption (or total savings) equaled 3,229 million Btu. From Sept. 1984 to Nov. 5, 1984 natural gas cost the prison \$3.63 per million Btu. From Nov. 6, 1984 through April 1985 gas cost \$3.70 per million Btu. The total estimated dollar savings, for the 10 week period, was \$11,917.

It is estimated that the system operated approximately 8 weeks prior to October and that the performance was similar although the recording instruments were not operating. The estimated contribution from geothermal during this period was 1.100 million Btu for an avoided energy total of 1,692 million Btu. This results in a dollar savings of approximately \$6,143.

Figure 4 depicts the energy and dollar savings for the entire 18 week period. The cumulative Energy Contribution is shown as direct energy contributed to the Minimum Security building, that is, no plant efficiency factor is included.

CUMULATIVE ENERGY CONTRIBUTION - 1984

CUMULATIVE DOLLAR SAVINGS - 1984

FIGURE 9-3: Cumulative Savings - 1984

9.3. Data Acquisition

The data used for performance evaluation was recorded by a 4 channel chart recorder. The recorded variables are; outside air temperature, Minimum Security supply and return temperatures, and clean water flow rate. Periodic readings were made of the geothermal water supply and return temperatures as well as manual checks of the recorded data with mercury thermometers.

There were numerous periods where the chart recorder's pens went dry and some data was lost. Very little data was available on the Minimum Security's heating system due to problems with access to the equipment rooms.

9.3.1. Calculations

The data was manually transcribed from the chart recordings to a digital format. Values were taken at 30 minute intervals for each variable and input to a microcomputer spread sheet program. Although more data was available, only 10 weeks worth was deemed adequate to analyze. These data were manipulated to give energy flow rates for the entire 10 week period. Where the recorder pens failed, values were interpolated.

9.3.2. Presentation

The results are presented in graphical form in preceding sections and in graphs and tables in Appendix D. There are several graphs shown, plotting geothermal energy contribution, in 1000 Btu/hour or million Btu total, ambient air temperature, in degrees F, or dollars total, all versus time.

Figure 9-1, Typical Daily Energy Flow Rates, presents the hourly flow rate averaged over a weeks period. The data was assembled by averaging the weekly flow rate for each individual 30 minute period and shows the variation over typical 24 hour periods.

Figure 9-2, Summary of Geothermal Energy Contribution, is a summary of all 10 weeks worth of usable data. The data points are daily averages derived from the half hour data. The flat portions of the curves represent the interpolated data when recorder pens went dry.

Figure 9-3, Cumulative Savings, shows the cumulative savings in energy and dollars for the entire 18 week period the system operated. The energy savings are direct savings with no plant efficiency factor; the dollar amounts were calculated using the then current natural gas costs and including a 65% efficiency factor for plant efficiency.

The graphs in Appendix D, labeled 1984 Weekly Sum - Three Hour Averages, present the weekly summary for each of the 10 weeks. The data points are three hour averages derived from the 30 minute data. These graphs represent 95% of the recorded data. Flat portions of the graphs represent periods when one or more recorder pens failed and the values were interpolated.

9.4. Post Construction Changes

9.4.1. Technical

To date the only changes to the system have been the addition of a backup geothermal pump and the relocation of the sensor for the geothermal water discharge temperature controller.

After the failure of the first pump's seals, a packed type pump was installed. The pump was placed in the pit adjacent to the existing pump. Provisions were made in the original design for electrical service and suction piping for an additional pump.

The sensor was relocated to the clean water discharge side of the plate heat exchanger. This was done to provide better control of the geothermal water flow through the heat exchanger.

9.4.2. Institutional

There have been no significant institutional changes since construction was completed.

9.5. Operator Satisfaction

Technically, the responsible operating agency has been the prison facilities department. However, they have shown little interest in operating or maintaining the system. The geothermal system has been repeatedly blamed for malfunctions in the Minimum Security Facility's heating system. There has been no evidence to support this claim but the maintenance staff still has a very pessimistic view of the system.

The system, with the exception of the pipeline break, has been fairly free from operational problems and seems to require little more than periodic inspection from the maintenance staff.

SCHEME #1 (BASIC)

Geothermal water, through artesian or CO₂ gas induced flow, is discharged into a closed, non-pressurized concrete surge tank. The well flow is regulated by a level control in the tank and a regulating valve at the well head,².

The water is pumped from the bottom of the surge tank through the heat exchanger by a horizontal, base-mounted pump³ in an adjacent dry pit. The flow through the heat exchanger is regulated by a volume control valve⁴ on the heat exchanger discharge. The flow rate is controlled to maintain a constant outlet temperature of the heating hot water.

The geothermal water discharged from the heat exchanger is then bubbled through a sand/gravel bed⁵ to trap any dissolved solids in the water.

Gases from both concrete tanks are vented through a tall stack⁶.

Discharge is then by gravity to the cooling pond and then the river⁷.

WELL HEAD SCHEME #1 (BASIC)

PROS

1. Simple & Direct
2. Lowest 1st Cost
3. Lowest Electric Power User

CONS

1. Scale will probably have to be removed on a regular basis as part of normal operating procedure.

UNKNOWN

1. Scaling rate of well piping, & heat exchanger.
2. Level control valve & system unproved.
3. Scale trap untried or not proven.

Fig. 2

SCHEME #1A (MODIFIED BASIC)

In this Scheme, a combined gravel and sand bed scale trap⁵ is used to remove the dissolved solids before the water is pumped through the heat exchanger.

The system is controlled in the same manner as Scheme #1.

WELL HEAD SCHEME #1A (BASIC W/ SCALE TRAP 1E)

PROS

1. Simple & Direct
2. Low 1st Cost
3. Low Electric Power Use
4. Scheme #1 could be modified to this Scheme easily.

CONS

1. Plugging of sand bed.
2. Scaling and related problems may still be present. May occur in discharge line or heat exchanger.

UNKNOWN'S

1. Transfer of hot fluid through scale trap may not remove any dissolved solids.

Fig.3

SCHEME #2 (CHEMICAL TREATMENT)

The basic system elements are the same as in Scheme #1 with the addition of a chemical feed system and larger heater exchanger pump.

The chemical feed system consists of a storage tank¹ for the chemical, a small pump² to inject the chemical approximately 255 feet³ into the well and a controller that regulates the chemical flow rate according to the well flow rate.

The larger pump⁴ is used to maintain higher pressure on the geothermal water as it passes through the heat exchanger. This is to keep the carbon dioxide in solution to reduce the formation of scale in the heat exchanger.

<u>PROS</u>	<u>CONS</u>	<u>UNKNOWN</u>
1. Basically simple & low cost. 2. Scale build-up on well casing would be reduced. 3. Chemical feed could be easily added to Scheme #1 or #1A. 4. Increased exchanger pressure could be used for Scheme #1.	1. Chemical feed system adds to operating & maintenance cost. Chemical cost estimated at \$3.00 per day. 2. Misoperation of chemical feed system might damage well or other process equipment. 3. Electric power cost would be somewhat increased because of higher heat exchanger pressure.	1. The amount of reduction in scaling which will actually occur - due to chemical treatment & higher exchanger pressures is not known. It could be considerable.

Fig. 4

SCHEME #3 (DEEP WELL PUMP)

Geothermal water is pumped from the well by a line shaft, deep well pump¹. The pump is set at approximately 520 feet². The pump is designed to pressurize the water before any carbon dioxide leaves solution. This will require a minimum pump head (based on preliminary design report), of 244 PSIG. This pump pressure must be maintained at all flow rates.

The flow rate is controlled by a variable speed motor³ on the well pump.

The water is pumped directly to the heat exchanger. It is discharged from the heat exchanger through a pressure regulating valve⁴ set at approximately 110 PSIG. The water then passes through a sand bed scale trap⁵ and is discharged to the drainage system⁶.

PROS

1. Would probably eliminate scaling problems.

CONS

1. High first cost.
2. High Electric power use.
3. High pump maintenance cost.

UNKNOWN

1. If pump can be purchased for small diameter high lift variable speed application.
2. Might be necessary to set pump at about 200 ft. to match Utah Roses's System. This would reduce cost & power use but would operate above well CO₂ flash point according to preliminary design might add to pump maintenance and scaling problems.

Fig. 5

APPENDIX A

Design Schematics

SCHEME #4 (CO₂ REINJECTION)

This process is based on experimental data gathered at other wells.

Well water is lifted by injecting carbon dioxide into the well approximately 250 feet down. This is to increase well head pressure and reduce scaling of the well bore.

The water is piped directly through the heat exchanger and into a pressurized flash tank² to separate the gases from the well water.

The gases, mostly carbon dioxide, are dried and filtered³ then compressed and reinjected⁴ into the well.

The water is piped from the separator tank to a sand bed scale trap⁵ and discharged into the drainage system⁶.

- PROS
1. New data on a CO₂ injection would be obtained. Might be 1st use of this type of system applied to actual use of geothermal energy other than demonstration test.
 2. Could be low power user (compressor power only).

- CONS
1. High cost R&D effort with no guarantee of success for this application.
 2. Maintenance costs high.
 3. CO₂ make-up requirements and costs unknown.
 4. Development time to usable system would be much longer.
 5. Very skilled operation and maintenance would be needed for continuing reliable plant operation.

- UNKNOWN
1. Pressure obtained at well head will it develop adequate flow through heat exchanger?
 2. Compressor & driver sizes & type best for warm, corrosive gas use.
 3. CO₂ usage for start-up.

Fig. 6

RECEIVED

NOV 9 1982

CASE, LOVE & HART
Architects/Engineers

INTEROFFICE CORRESPONDENCE

Date: October 28, 1982
To: Frank W. Childs
From: Richard L. Miller *RLM*
Subject: CORROSION AND MATERIALS SELECTION FOR GEOTHERMAL SYSTEM AT
UTAH STATE PRISON - RLM-2-83

Two sets of corrosion coupons were exposed in the geothermal fluids at the Utah State Prison. One set was left in the well for the full duration of the test, 815 hours. The other set was left in the well for 485 hours, removed and visually inspected by the test engineers, and then immersed in the discharge ditch for 330 hours. This latter procedure was not in accordance with earlier plans and procedures and makes the results of the latter test suspect. This test is referred to as the non-aerated test.

The coupons were first examined in the as-returned condition using a low power stereo microscope (ca. 10 to 70 power magnification). The coupons were then cleaned and examined at 10 and 400 power magnification. The results of these examinations are attached.

The coupons were weighed before and after exposure to the geothermal environments. The weight loss data are presented in terms of average general corrosion penetration into the base metals, even though pitting corrosion may have been the major form of attack. Because of the manner in which the non-aerated test was conducted, the weight loss data were "adjusted" to delete the corrosion experienced during the time spent in the well.

The alloys may be conveniently grouped into three categories according to corrosion damage. The groupings for the aerated and non-aerated tests are given in the attached table. These groupings are discussed below.

Non-Aerated Corrosion Test

The 1018 carbon steel and the gray cast iron would be acceptable if given a proper corrosion allowance. However, cast iron is not commonly used in thin sections, and may be applicable to thick sections such as pumps and valves if carefully monitored.

Copper, admiralty brass and red brass show sulfide scale formation. For this reason, they should be given extensive tests in a heat exchanger configuration before being given serious consideration for such service.

Date: October 28, 1982
To : Frank W. Childs
Page: 2

Titanium and the austenitic stainless steels suffered almost no corrosion attack. For the most part, a slight superficial attack was the maximum damage, and this was minor. Care must be taken in the use of austenitic stainless steels, since there is a tendency for these to undergo stress corrosion cracking in hot, chloride bearing, oxygenated solutions.

Aerated Corrosion Tests

When aerated geothermal fluids are considered, e.g., holding pond conditions, the materials suffered much more corrosion attack. Scaling was much more evident on the coupons exposed in the aerated water. The following conditions are noted:

Considerable care must be used in considering 1018 carbon steel or gray cast iron, since a substantial corrosion allowance must be made. Cast iron is not commonly used for tube and shell or plate type heat exchangers; however, this material is used for pumps and valves, and suitable corrosion allowances must be included in the specification of this material.

AISI Type 410 stainless steel is frequently used in pump shaft material. The use of this material for such applications in aerated geothermal fluids is not recommended. The same material appears to have performed satisfactorily in the non-aerated geothermal fluid.

The propensity for austenitic stainless steel to undergo stress corrosion cracking increases as the temperature, chloride concentration, and oxygen concentration of the geothermal fluids increases. While stress corrosion cracking tests were not run, one must consider the potential for such attack.

Additional Recommendations

Because of the aggressive nature of the geothermal fluid at the Utah State Prison, the use of corrosion test coupons placed in the flow loop over the life of the facility is strongly recommended. The coupons should be evaluated on a timely and periodic basis to judge the nature of the corrosion and scale of the heat exchanger and other parts of the system. Designs for such monitoring systems are available in ASTM D2688-70 and ASTM G 4-74, as well as in corrosion engineering handbooks and textbooks.

bar

Attachments:
As Stated

cc: J. E. Flinn JEF
D. W. Keefer DWK/har
G. E. Korth
~~M. B. Sanders~~
Central Files
R. L. Miller File

TABLE 1

Classification of Alloys in Terms of Corrosion Resistance*

NON-AERATED GEOTHERMAL FLUID

Recommended

Titanium

AISI Type 304 Stainless Steel

316

317L

Acceptable

Gray Cast Iron

AISI TYPE 1018 Carbon Steel

AISI Type 410 Stainless Steel

Admiralty Brass

Red Brass

Not Acceptable

Copper

AERATED GEOTHERMAL FLUID

Recommended

Titanium

AISI Type 304 Stainless Steel

316

317L

Acceptable

Gray Cast Iron

AISI Type 1018 Carbon Steel

Not Acceptable

AISI Type 410 Stainless Steel

Copper

Admiralty Brass

Red Brass

*For thin section applications in Utah State Prison Geothermal Fluids. Criteria for classification are minimum average penetration as determined from weight loss and from extent of pitting attack.

NON-AERATED GEOTHERMAL FLUID

ALLOY	CORROSION PENETRATION $\mu\text{m}/\text{A} - \text{mpy}$	PIT DENSITY ₂ PITS/ cm^2	PIT DEPTH μm		OBSERVATIONS
			Average	Maximum	
Titanium	0.76 - 0.03	none	none	none	Minor initiation of general corrosion. Excellent material from corrosion point of view.
304 SS	5.6 - 0.22	none	none	none	Minor superficial corrosion initiated. Excellent material from corrosion point of view.
316 SS	0.36 - 0.01	none	none	none	No evidence of corrosion. Excellent material from corrosion point of view.
317 SS	0.66 - .03	none	none	none	No evidence of corrosion. Excellent material from corrosion point of view.
410 SS	1.58 - 0.06	none	none	none	Minor general corrosion. Appears to be useful in non-aerated water.
1018 Carbon Steel	62.4 - 2.46	dense	10	20	Acceptable for thick members if corrosion allowance is made.
Cast Iron	123 - 4.8	NM	NM	NM	No original surface remaining; may be dense pitting or selective leaching of iron from carbon matrix. Acceptable for thick members if corrosion allowance is made.
Copper	284 - 11.1	75	25	50	Dense sulfide and carbonate scale. Severe pitting and general corrosion. Not generally acceptable.
Admiralty Brass	24.6 - 0.97	none	none	none	Dense sulfide and carbonate scale. General corrosion only. Acceptable for heat exchangers in non-aerated water.
Red Brass	76.3 - 3.0	none	none	none	Dense sulfide and carbonate scale. Evidence of crevice corrosion is minor. No definite pits seen. Acceptable for heat exchange in non-aerated water.

AERATED GEOTHERMAL FLUID

ALLOY	PENETRATION $\mu\text{m}/\text{A} - \text{mpy}$	PIT DENSITY ₂ PITS/ cm^2	PIT DEPTH μm		OBSERVATIONS
			Average	Maximum	
Titanium	0 - 0	none	none	none	400x-Initiation of general corrosion. Appears to be an excellent material for heat exchanger application from the corrosion point of view.
304 SS	0 - 0	none	none	none	Heavy carbonate scale. Minor general attack. Appears to be an excellent material for heat exchangers from the corrosion standpoint.
316 SS	0.02 - 0.0007	none	none	none	Carbonate scale, not tightly bound. Appears to be an excellent heat exchanger material from the corrosion standpoint.
317 SS	.03 - 0.0012	none	none	none	Heavy carbonate scale. No evidence of corrosion. Appears to be an excellent heat exchanger material from the corrosion standpoint.
410 SS	0 - 0	.2	NM	12	Heavy calcite scale. Original surface largely gone. Should not be used in critical applications, e.g., pump shafts, in aerated water.
1018 Carbon Steel	210 - 8.2	general	2	NM	Calcite scale. What appears to be broad shallow pitting may be heavy localized general corrosion. Not acceptable for heat exchanger, unless carefully monitored and adequate allowance made in design specifications.
Gray Cast Iron	315 - 12.4	general	NM	NM	Heavy Calcite scale. Corrosion that appears to be general pitting may be selective leaching of iron from the graphite matrix. Acceptable for thick members if carefully monitored and adequate corrosion allowance is made in design specifications.

NM: Not measured

AERATED GEOTHERMAL FLUID

ALLOY	CORROSION PENETRATION $\mu\text{m}/\text{A} - \text{mpy}$	PIT DENSITY ² PITS/ cm^2	PIT DEPTH μm		OBSERVATIONS
			Average	Maximum	
Copper	0 - 0	12	NM	6	Heavy sulfide and carbonate scale. Crevice and pitting corrosion easily identified. General corrosion is severe. Not acceptable for heat exchanger application.
Admiralty Brass	16.8- 0.66	20	NM	2.5	Heavy sulfide and carbonate scale. Crevice and pitting corrosion. General corrosion is severe. Not acceptable for heat exchanger application.
Red Brass	211.3- 8.3	44	30	40	Heavy sulfide and carbonate scale. Crevice and pitting corrosion is extensive. General corrosion is severe, no original surface remaining. Not acceptable for heat exchanger application.

NM: Not measured

APPENDIX B

Material Testing

APPENDIX C

Post Production Testing

Mark Case,
Mechanical Engineer
Case, Lowe & Hart

January 10, 1986

Submitted by: Jay C. Hauth, P.E.
Tetonia Engineering Co.
4596 Creekview Dr.
Salt Lake City, UT 84107

Ref: Reservoir/production status,
Well USP-TH1, Crystal Hot Springs
Salt Lake County, Utah

This report summarizes the current status of the production characteristics of the referenced well as of January, 1986, and contains recommendations regarding resource utilization.

Introduction

The USP-TH1 well is a low-temperature geothermal production well located on the Utah State Prison grounds. Its intended use is for space heating, and is producing from the Crystal Hot Springs resource. The well has been used for space heating flowrate of approximately 220 GPM, although intermittently, for a total of six months. The well was tested by Morrison-Knudson during the summer of 1982 at a producing temperature of 190 deg. F at artesian flowrates from 300-600 GPM, with wellhead pressures of 3-5 psig. Based on that test data, it was decided to allow the well to flow artesian for the initial stages of utilization and determine if a pump would be needed for long-term production.

At one point during the 84-85 season, the well would not produce, mandating a system shutdown. Again, in December, 1985, the wellhead was opened up and the well would not produce. At this point, Case, Lowe & Hart retained Tetonia Engineering to evaluate the situation, and make recommendations regarding pump installation.

On the first site visit on January 2, 1986, the well was in production at approximately 200 GPM. According to Jay Schelin of UT/DFCM, the wellhead had been opened before Christmas of 1985, and although the well would not produce at that time, the fluid level was noted as being in the wellhead right at the flow tee. The wellhead was left open, and sometime within the next week or so, the well started producing.

Several tasks were performed to evaluate the well's and reservoir's status. First, the test report by M-K was reviewed and that data compared with current production conditions. A discussion was had with Murray Harmon of Utah Roses to determine the characteristics of their production. Based on the above, and also the lack of downhole information, a recommendation was made (submitted in draft form to Mark Case/Case, Lowe & Hart and Lee Hathon/UT/DFCM) to run a pressure/temperature survey on the well, and at the same time run gauge rings in the hole to observe wellbore obstructions, if any. The survey and gauge ring work was performed on January 8, 1986 by Otis logging and Sperry-Sun instrumentation for a cost of approximately \$3100.

Conclusions, recommendations, and detailed discussion follow.

Conclusions

1. A decline in reservoir pressure of several psi has been observed from the 1982 flowtest to current conditions. This has resulted in loss of maximum production of 600+ GPM to around 250 GPM with artesian flow, that is, when the well will flow. This appears to be seasonally related to production from the reservoir during the winter months, particularly by Utah Roses. There is now scarcely enough pressure with an unheated wellbore to start artesian production.

2. A decline in production temperature has been noted from 190 deg. F from the 1982 flowtest to 180 deg. F currently. It is clear from the recent temperature survey that hotter fluids are entering the wellbore at 600 ft. than 800 ft. This differential could be as much as 10 deg. F or more. It appears that the well produces preferentially from the hotter zone initially, and upon reduction of pressure in this zone, starts producing cooler fluids from deeper in the formation. This is a common phenomenon observed in long-term production, and has been noted in the Utah Roses production well. It could indicate the presence of cooler reservoir recharge fluids.

3. The inability of the well to flow immediately on demand can be expected to continue on an annual basis, due mainly to the seasonal pressure/temperature decline. Although the annual pressure and temperature recharge appears sufficient to maintain the reservoir in a suitably useable condition, the seasonal effects will limit the well's production capabilities during the winter months without pumping.

4. There is no sand fill in the well: TD remains at 1000 ft., and the slotted 6" liner is scale free. The lower master valve on the wellhead would not permit entry of a 7.315" gauge ring to determine scale buildup in the upper 250 ft. of 8" casing.

5. Reservoir response to production is largely unknown, and a monitoring program will be necessary to track behavior, as well as aid in development of a reservoir utilization strategy. There may very well be an as-yet undetermined overall pressure decline in the reservoir due to long-term production.

6. Static wellhead pressure as high as 25+ psig has been observed previously, however that pressure declines rapidly to the normal low production pressures of 2-5 psig. This would have been representative of a non-condensable gas cap, mostly carbon dioxide. More recently, though, the gas cap has not been noted, indicating a reduction of production fluid gas content.

7. Scale formation has not been evident in the surface equipment. This could be related to the apparent reduction in carbon dioxide.

Recommendations

1. Install a production pump in the USP-TH1 well. In order to ensure production on demand, a pump will be necessary. There is likely to be expanded use of this well for heating purposes, and the well already has apparently reduced production from the 1982 flowtest. The pump will not have very much head to overcome to supply brine to the existing holding tank, and no additional pressure would be needed if the existing system is used. The pump should be sized for 200-300 GPM with a drawdown of 40-80 ft. Serious consideration should be given to a variable-speed drive on the motor which would be controlled by the tank level controller. This would allow maximum use of existing equipment, and would reduce the annual number of pump starts, and thus pump maintenance.

2. Establish a reservoir monitoring program wherein downhole pressure and production temperature are monitored on a year-round basis. Further, a cooperative agreement might be made with Utah Roses to share reservoir data which would help both producing parties in long-term development planning.

3. If production temperatures decline substantially, consider filling the lower 200-250 ft. of the well with sand. This would allow the hotter, upper zone to flow, while blocking the cooler production. If this were done, and found to be unacceptable, the sand could be removed by jetting with nitrogen and coiled tubing.

4. Perform a long-term pump test on the well. This was recommended in the "Resource assessment report, Crystal Hot Springs Area", prepared by the Utah Energy Office in 1981. Also, M-K intended to perform a pump test in 1982, but did not. Keshav Goyal, a reservoir engineer retained to review the 1982 flowtest report also recommended longer-term testing at relatively high flowrates.

5. If the well is killed at any time to install a pump, remove the cast iron gate valve used as the lower master valve. The valve is apparently not a full-bore valve or has internal mechanical problems. This valve should be replaced with a full-bore steel gate valve such as the upper master valve, which has stellite trim.

Downhole logging

On approval of Mark Case/Case, Lowe & Hart, and Lee Hathon/UT-DFCM, the well was logged on 1-8-86. The services used were Otis E-line logging, and Sperry-Sun instrumentation, both of Evanston, Wyoming. Gauge rings of 7.315" and 5.935" were brought to location for gauging the 8" (7.981" i.d.) and 6" (6.065" i.d.) casing strings. Sperry-Sun provided a surface-readout combination pressure/temperature tool, and a backup tool which was identical to the surface-readout tool, except that it recorded the data downhole on magnetic tape. Subsequent review of the data indicates that both tools were operating within a close range, and the data from the surface-readout tools is used for reporting. The well was shut-in approximately two hours before commencing operations.

The 7.315" gauge ring would not pass through the lower master valve after repeated attempts, and this operation was aborted. Minor scale deposition has been noted from previous activity on this well down to 220 ft. depth., however current conditions are not known.

Next, the 5.935" gauge ring was run into the hole to TD @ 1000 ft. This run hit a slightly tight spot at 255 ft., indicating the start of the 6" liner hanger. The ring ran smoothly to TD and back, indicating that there is no fill whatsoever, and the 6" slotted liner is clean.

Sperry-Sun was rigged up, and run into the hole with no significant problems. Stops were made every 100 ft. going down, allowing enough time for the tools to equilibrate, about 3-5 min. per stop. After the bottom-hole data was obtained, the tool was brought up to 800 ft. and the well was put into production at an estimated 200-250 GPM, the maximum available. The well was flowed for 26 minutes to see if any significant drawdown occurred. A temperature increase of 2 deg. F at 800 ft. was noted during production, indicating likely production from this zone. The well was then shut-in to possibly observe some minor buildup. The pressure data from this very short flowtest cannot realistically be analyzed for reservoir parameters as the pressure response recorded is approximately 1 psi, and the data appears somewhat scattered.

After establishing shut-in pressure stability, the well flow was started again, and the tool was lowered back to TD. The hole was then logged at 100 ft. intervals coming up to surface. At this point, Otis and Sperry-Sun were rigged down and released.

Temperature Data (fig. 1):

The USP-TH1 well exhibits temperature reversal from 600 ft. depth to TD, both shut-in and on production. This has been noted from previous temperature surveys. Comparing the static run (going down), and the production run (coming up), the temperature differential noted is 4-5 deg. F. The production temperature from 700 ft. to TD is lower than static temperature, indicating cooler water entering the wellbore from 700 ft. to TD. Also, during the short production run with the tool set at 800 ft., the temperature increased from 174-176 deg. F. Although this is a slight change, the instrumentation is capable of this resolution, and the data strongly indicates some production entering the wellbore at 800 ft. With the well flowing, the temperature coming up increases from 175 to 180 deg. F in the 700-600 ft. interval. From 600 ft. to surface, the production temperature is essentially isothermal at 180-181 deg. F.

It is a possibility that the cooler fluids entering the wellbore are reservoir fluids that have been recently recharged into the system, and have not fully reached formation temperature. Certainly, Utah Roses' production is drawing in recharge fluids, but without established reservoir flow patterns, it is difficult to make definitive predictions of reservoir temperature performance.

Further verification of the well's behavior is subject to the availability of longer-term production and reservoir monitoring records.

Pressure Data (fig. 2):

The overall pressure gradient is .42 psi/ft. Some minor variations between the shut-in "static" profile and the flowing profile are seen, due to the variance in temperature between these conditions. No measurable gradient change is observed that would represent significant gas lift occurrence.

The data recorded during the production run with the tool set at 800 ft. shows a pressure response less than 1 psi. Certainly, the magnitude of pressure effects from wellbore temperature (fluid density) variations are at least as large as any reservoir response here, and the tool had resolution of .25 psi. No attempt is made to evaluate reservoir parameters with this data, which appears scattered at best. Any reservoir engineering work of substance would have to be based on much longer periods of production.

Fig. 1.

Fig. 2.

- - Going in hole
- ⊙ - Coming out of hole
- ◓ - Both

APPENDIX D

Performance Log

1984 WEEKLY SUM - 3 HOUR
AVERAGE

1984 WEEKLY SUM - 3 HOUR
AVERAGE

1984 WEEKLY SUM - 3 HOUR
AVERAGE

1984 WEEKLY SUM - 3 HOUR
AVERAGE

1984 WEEKLY SUM - 3 HOUR
AVERAGE