DIRECT UTILIZATION OF GEOTHERMAL ENERGY FOR HAAKON SCHOOL DISTRICT, SOUTH DAKOTA

FINAL REPORT January 1977—March 1985

Prepared by:
Hengel Associates
Rapid City, South Dakota

Under Subcontract to:
Haakon School District 27-1
Philip, South Dakota

For the:
U.S. Department of Energy
Idaho Operations Office
Under Contract No. DE-FC07-78ET27080

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DIRECT UTILIZATION OF GEOTHERMAL ENERGY
RESOURCES FOR SPACE HEATING
Final Report
January 1978 - May 31, 1982

By
Raymond J. Hengel
March 1985

Prepared by
HENGEL ASSOCIATES
115 St. Joseph Street
Rapid City, SD 57701

Under Subcontract to
Haakon School District 27-1
Philip, SD 57567

Sponsored by the
U.S. Department of Energy
Division of Geothermal and Hydropower Technologies
Washington, D.C. 20585
Under DOE-ID Contract DE-FC07-78ET27080

ABSTRACT

This report is a summary of a project which demonstrates the successful use of geothermal energy for service water and space heating of school, business and commercial buildings in the city of Philip, South Dakota. The project included a new well into the Madison limestone formation, a pipe line to the school and through the central business district to a treatment plant, the treatment plant and settling ponds, conversion of the existing space heating systems of the buildings to equipment suitable for heating with the geothermal energy and monitoring the system to determine operating characteristics and efficiency. The treated water is discharged into the north fork of the Bad River for use by down stream irrigators.

The project was jointly funded by the Haakon School District 27-1 and the Department of Energy (DOE) under its Project Opportunity Notice (PON) Program. It was substantially completed in November 1980.

ACKNOWLEDGEMENTS

Acknowledged are School District Board of Education members Darral Brooks, David Hansen, Charles Kroetch, Joe Gittings, Jim Hewitt, William Bruce, Kenneth McIlravy, Charles O'Connor, Pat Seager, Shirley Muck, Elsie Baye, Jack Hansen and Ronald Miglia for initiating and continuing the project; Dan Bjerke of Brady Engineering for his work on the barium chloride treatment process; Francis, Meador & Gellhaus for the well design; Northern Wyoming Drilling for drilling the well; Ramstad, Inc. for construction of the pipe line and the treatment plant; Wolff's Heating and Plumbing for retrofit of the school heating plant; Charles Maxon, Superintendent of Schools; Reed Drury, School Maintenance Chief; E. G. DiBello, A Crandell and Frank Childs of EG&G Idaho; R. N. Chappell and J. Lee of the U.S. Department of Energy; John Austin of CH2M Hill; and Dr. D. D. Carda, South Dakota School of Mines and Technology Mining and Engineering Experiment Station for their initiative, assistance and cooperation throughout the entire project. Roland Smit, the current Superintendent of Schools is continuing operation and monitoring of the system.

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 Meat 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-H-S Hospital	Marlin, Texas	NV
DE-FC08-79ET27058	Navarro College	Corsicana, Texas	NV

DOE DIRECT-USE GEOTHERMAL PON PROJECT

1. Project Title: Direct Utilization of Geothermal Energy for
Philip Schools
Haakon School District 27-1,
Philip, SD 57567

Contract Cooperative Agreement

2. Number: DE-FC07-78ET-27080
3. Former Number: None
4. Period: 05/10/78 to 08/01/85
5. Value: \$1,216,869 (\$1,210,649.60
to date)
6. DOE Share: \$945,569 (\$944,142.18 to date)
7. Participant Share:
School District Share: \$218,000 (214,442.61 to date)
Heating District Share: \$52,110 (\$52,110 to date)
8. Program Objectives: Provide low cost energy to heat the school
facilities; conservation of fossile fuel; conservation of
electrical energy; provide an energy source for other users
in future development stages; provide information to other
potential users of geothermal heat.
9. Project Location: Philip, South Dakota
10. Well name/location: Philip School #2, NE 1/4, SE 1/4,
Sec. 14, T.1N., R.20E., B.H.M.
11. Peak Heat Load: 8.4 Million Btu/hr.
12. Annual Heat Load: 17.8 Billion Btu/yr. (load factor
89.14%)
13. Simple Payback (Cash): 12.09 years
14. Project Status: Project commenced operation
November, 1980
15. Principal Investigator: Charles A. Maxon, Supt. of Schools
16. Firm: Haakon School District 27-1
17. Address: Box 117, Philip, SD 57567
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Other Participants:

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32. Address:	1823 West Main, Rapid City, SD 57702
33. Phone/Contact:	605/342-4105 / Al Foster
34. Firm/Activity:	Energy Drilling Specialists, Inc. / Drill Supervision
35. Address:	821 17th St., Suite 806, Denver CO 80202
36. Phone/Contact:	303/573-7011 / C. Lee Mueller
37. Firm/Activity:	Northern Wyoming Drilling Co. / Production Well Drilling
38. Address:	P. O. Box 487, Gillette, WY 82716
39. Phone/Contact:	307/682-9354 / Joe D. Banks
40. Firm/Activity:	Ramstad, Inc. / Transmission & Distribution Pipelines & Disposal System Construction
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43. Firm/Activity:	Wolff's Heating & Plumbing / Geothermal Conversion and Boiler Replacement
44. Address:	P. O. Box 71, Spearfish, SD 57783
45. Phone/Contact:	605/642-5755 / Julian Wolff

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INTRODUCTION

1.1 GENERAL

In early 1978 the U. S. Department of Energy, under its Project Opportunity Notice (PON) program, granted financial assistance for a project to utilize geothermal energy for space heating of the Haakon School District's buildings at Philip, South Dakota. The project included a new well into the Madison formation, conversion of the existing steam and electric heating systems to hot water systems using heat exchangers to transfer the heat from the corrosive geothermal water to the water used in the buildings heating systems, instrumentation to monitor quality and quantity of flow and to provide test data and information for future users of geothermal energy.

The new well was drilled to a depth of 4266 feet. It produced a flow of 340 gpm of water at 157 degrees F. A treatment plant using Barium Chloride was constructed to remove the sulfates containing Radium 226, and the water leaving the settling ponds was discharged into the North Fork of the Bad River. A district heating system was developed to heat nine business facilities in the central business district of the City of Philip, using the 130 degrees F water discharged from the school buildings. The existing heating systems of the school buildings and the business buildings were converted to utilize the geothermal energy. The barium chloride treatment system required some modification after use to prevent sulfates from precipitating in pipes between the treatment plant and the two-cell settling ponds.

The system has provided nearly all of the heat for the school buildings and the business buildings since it was placed in operation in November of 1980.

1.2 OBJECTIVES

The primary objective was to demonstrate the feasibility of utilizing the heat from water in the Madison limestone formation for heating the buildings and service water of the Haakon School district in Philip. Secondary objectives included:

- Providing information for other potential users of geothermal energy.

- Providing an energy source for other users whose plans were in the development stages.

- Conservation of fossil fuel and electrical energy.

1.2.1 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, agribusiness, 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 direct 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, 23 PON projects were selected from the two Project Opportunity Notice solicitations. This is the final report for one of those 23 PON projects.

1.2.2 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 plant on geothermal energy. 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.

Industrial application of geothermal energy is a relatively new concept, and carries significant potential in terms of market size and utilization factor. Utilization of geothermal energy in a process application, in comparison to space heating, has an inherent advantage in that it does not depend on climatic conditions, but rather process load energy requirements. The industrial geothermal system can usually be used to its full capacity most of the time, while space heating is subject to fluctuations.

Typically, in an industrial application, large loads are concentrated in a single facility. In contrast, a district heating system uses numerous, scattered, small loads, which increase distribution costs. Thus, the energy unit cost of industrial application is usually lower.

The Haakon School Project was initiated to demonstrate the feasibility of using the known geothermal resource of the water in the Madison formation for service water and space heating of existing buildings; retrofitting existing oil fired steam and electric heating systems to utilize lower temperature water; and developing methods of and systems for treating water of unacceptable quality to a state complying with water quality standards.

1.3 PRE-PROJECT BACKGROUND

The buildings of the Haakon School District 27-1 in Philip were heated by oil-fired steam, electricity or liquified petroleum heating systems. The cost of fuel oil and electrical energy had risen to a level which made alternative fuel an urgent consideration. The City of Philip had drilled a well into the Madison Limestone formation in 1962 and obtained a flow of 153 degree Fahrenheit water originally reported at 1,040 gallons per minute. The water was used to supplement the municipal water supply when necessary, but because of its temperature, dissolved solids and general poor quality, was discharged into the Grindstone Creek drainage when not required as a supplemental source. The School District Board of Education authorized and funded a feasibility study to determine if this source of energy could be used to heat their buildings and service water. Hengel, Berg & Associates, Architects-Engineers, of Rapid City, were retained to determine if Armory-High School, Elementary School, Vocational School and the music buildings at Philip could be heated with this water. The existing well was located at Lake Waggoner approximately three miles north of the school buildings, and was piped to discharge either into the water line from the treatment plant to the city, directly into Lake Waggoner or into the upper cooling-settling pond or into Grindstone Creek.

If water from this well was to be used, a safeguard would be required to insure that the municipal water supply would be protected at all times and well water would be available during any shortage of the normal supply.

The study investigated several methods of using the geothermal energy of water in the Madison formation.

- 1) Using water from the existing well and converting the existing heating system to use the raw water.
- 2) Extracting heat from the existing well water using heat exchangers and a secondary water circuit through the existing heating system enlarged to use the lower temperature medium.
- 3) Drill a new well and convert the existing heating system to use the raw water.
- 4) Drill a new well and extract heat from the water using heat exchangers and a secondary water circuit through the existing heating system enlarged to use the lower temperature medium.
- 5) Drill a new well and extract heat from the water using heat exchangers and a secondary circuit for each building, with a second steam-to-water heat exchanger using the existing steam boilers as a back-up source.

Amortization periods ranged from 12 to 22 years. The study recommended a search for outside funds.

1.4 PROJECT SCOPE

The initial scope of the project was to demonstrate the technical and economic feasibility of the direct utilization of geothermal energy for space and service water heating for the school building complex. Later it was expanded to include the business district. The project initially consisted of three phases.

Phase I: Obtain a source of water from a new well. This well would be drilled immediately adjacent to the school buildings.

Phase II: Convert the existing heating systems to utilize the lower temperature water from the heat exchangers.

Phase III: Construct a pipe line to dispose of the water after passing through the last heat exchanger.

A fourth phase was instituted to include a district heating system along the discharge pipeline through the downtown business district. Tests of water samples showed the presence of Radium 226 in the sulfates the water contained. The scope of the project was increased to include a barium chloride treatment system and plant to remove the sulfates.

1.5 GROWTH POTENTIAL

The initial intent of the project was to provide an alternative source of energy for heating the school district buildings in Philip. If the water supply was large enough to provide more energy than required for this purpose, the additional energy could be used to expand the size of the heating district and included additional buildings.

VICINITY MAP

FIGURE 1-1

SUMMARY

2.1 GENERAL

Plans and specifications for the well were prepared, bids for drilling were invited, a contract for drilling was awarded and the well was drilled to a depth of 4266 feet. An initial Artesian flow of 300 gallons per minute of 155 degrees F water was obtained. Modifications to the heating systems of the schools were designed, including replacement of the old steam boiler in the armory-high school with a new modular boiler. A discharge pipe line and a water treatment plant were designed and bids were invited for construction of both projects. Contracts were awarded for both projects and construction was completed in November, 1980, including connections for various buildings in the business heating district.

The well was permitted to flow at approximately 320 gpm for several days to bring the pipe and surrounding ground to a stabilized temperature. The water was introduced into the school heating systems in November and provided all of the heat required by the buildings for the remainder of the heating season. Only one business building in the heating district obtained heat from the system during the 1980-1981 heating season. During the 1981-1982 heating season, the school buildings were heated entirely by the geothermal system except for one 2-hour period when the boiler in the elementary building was operated to counteract excessive heat loss adjacent to leaky windows when the chill factor exceeded -55 degrees F. Six of the eight business district systems received more than 90% of the required heat from the geothermal system. Two of the business systems, which were not designed to provide 100% of the heat, obtained more than 75% of the required heat from the geothermal system.

The barium chloride treatment plant proved effective, but required some modifications due to precipitation of sulfates on the inner walls of the static mixer and the pipe. A second static mixer with different baffles was substituted for the first unit in an attempt to delay the reaction and reduce the deposits on the inner walls of the pipe. This was an improvement and reduced the rate of deposits, but accumulation of sulfates eventually reduced the cross sectional area of the discharge pipe to a condition which would not accommodate the flow. An open trough mixer was designed, constructed and installed outside the plant between the building and the settling ponds in the summer of 1982. It has functioned in a satisfactory manner, and the sulfates in the discharge to the river have been reduced.

An experiment was performed with an ion exchange system to remove the sulfates without the problem of deposits in the pipe. This system was effective during the initial flow, but quickly lost its effectiveness. It was not pursued because of the excessive cost of barium sulfate due to the short effective life of the medium.

2.2 ECONOMIC RESULTS

The economic results of this page are summarized as follows:

Total costs to June 30, 1982 are:

DOE	\$ 934,510.42
School District	214,112.61
Heating District	<u>52,110.00</u>
Total	\$1,201,063.03

Total annual heating load in BTUs are:

School District	5,351.21 x 10e6
Heating District	<u>4,183.93 x 10e6</u>
Total	9,535.14 x 10e6

\$/MM Btu (including Dissemination are):

School District	\$ 214.65
Heating District	12.45
Combined Total	125.93

Payback (including Dissemination of Information in years)are:

School District	29.50
Heating District	5.76
School & Heating District	20.82

Costs of Dissemination of Information to June 30, 1982 are:

DOE	\$ 15,623.60
School District	<u>2,552.40</u>
Total	\$ 18,176.00

CONCLUSIONS AND RECOMMENDATIONS

3.1 TECHNICAL

The entire geothermal site of the system operates automatically, provides all of the heat for space and water normally required for the School District buildings, and provides at least 75% of the heat required by the buildings in the business heating district. The treatment plant is now functioning satisfactorily, and the entire project is operating successfully. The plate heat exchangers operate efficiently and showed no signs of erosion or corrosion when inspected in July 1982 after about 1-1/2 years of operation. The filament wound fiberglass epoxy pipe has performed satisfactorily with no leaks, or visible erosion. Very little heat loss through the pipe itself was observed. General recommendations are as follows: Retain a qualified and experienced water well engineer to plan and monitor the well drilling for any geothermal project. As an example of this need, a drill stem, which was too small for the drilling loads, twisted off and was never recovered. Fortunately, the tools lost were by-passed and the drilling continued to a successful conclusion.

Thoroughly test any water treatment system required. After several weeks of operation, the flow through the system gradually decrease and could not be reestablished at the original rate by any control adjustments. Disassembly of the piping in the barium chloride treatment plant for removal of Radium 226 revealed extensive deposits of sulfates on the vanes of the static mixer, on the interior of the pipe and on every downstream item from the point at which the barium chloride solution was introduced into the system. The deposits could be removed, with some difficulty, by chipping and scraping, but the underground valves were not readily accessible, and the deposits on them either prevented or reduced their operation.

A static mixer with removable vanes was designed and installed in place of the original static mixer. This was intended to delay the precipitation of sulfates until the solution reached the settling pond. The deposits on the vanes were not as dense and hard as those which occurred on the original static mixer. However, the pipe downstream from the mixer continued to accumulate deposits until maximum flow could not be obtained.

An external, trough type baffle mixer was designed, constructed and installed between the treatment plant and the ponds. The barium chloride slurry was piped along and in contact with the 6 inch pipeline to insure that the slurry would not freeze.

Photographs of the mixer in operation indicate extensive turbulence and mixing. First tests of the amount of sulfates in the discharge from the settling ponds indicate that the mixer is effective and that the sulfates in the discharge water are being reduced and retained in the pond.

All contact areas of the filament wound epoxy pipe must be dry before making joints. Special care in keeping these contact areas dry is needed after testing earlier joints with water.

The barium chloride treatment plant requires the greatest expenditure of operator effort. Two small pumps supply the barium chloride slurry to the mixer through which the geothermal water flows. The controls for the rate of barium chloride slurry are manually operated. When the volume of geothermal fluid changes, the adjustments on the metering pumps have to be made manually. To insure that the Radium 226 is removed, a higher than necessary setting has been maintained. Regulations should be included in the district heating system contracts with building owners that include a clause requiring the building system to operate at the working pressure in the pipeline, or the building owner should provide a pressure reducing valve at his own expense. This would allow all users to operate at the most efficient pressure.

An ion exchange system was designed, installed and tested. This system, using a small quantity of water (diverted within the treatment plant) which passed through a vertical column containing the barium sulfate exchange media. Water was sampled after various quantities had passed through the system. These samples were tested for Radium 226 at the Idaho National Engineering Laboratory. Initial reports indicate that the system successfully removed the sulfates which contain the Radium 226 during the first part of the test, but as more geothermal water flowed through the system, the quantity of Radium 226 which remained in the sample increased. The size and the cost of the ion exchange system and the cost of barium sulfate precluded further consideration of this system.

All requirements for record keeping, including format, should be developed as early in the project as possible.

3.2. INSTITUTIONAL

Cooperation among the Department of Energy, E G & G Idaho, the Haakon School District Board of Education, the Heating District Directors and the design professionals was excellent from the standpoint of the Engineer.

3.3 ECONOMIC

Actual costs have been very close to the budget and the funds available from DOE, the Haakon School District and the Heating District. The 29 year payback is excessive, but fuel oil and electrical energy used for space heating has been replaced with geothermal energy. The barium chloride treatment system is and will be a continuing expense because of the need for barium chloride. However, it appears that the static mixer problem has been solved by the installation of the exterior, open trough type of mixer. A contingency fund for such items should have been included in the original budget.

PROJECT DESCRIPTION

4.1 GENERAL

The initial concept included the feasibility study. This project planned to include a source of geothermal water from the existing well through a new pipeline or a new well and conversion of the heating systems in the existing buildings to utilize the lower temperature water in space heating circuits. It also planned to include the primary pipeline circuit between the well, the buildings and the ultimate discharge point, and the well head and the lower end controls. Provisions for the District Heating System and the Radium 226 removal plant and settling ponds were added after the quantity and quality of the resource was determined. The School District buildings were to be supplied with geothermal water through a reverse return 2-pipe system from which the heat would be extracted by plate heat exchangers and the heat delivered to the various spaces by a secondary circuit using the existing steam heating system which would be converted to use the lower temperature water. The old boiler in the Armory High School was to be replaced with a new modular water boiler and the boiler in the Elementary School was to be refitted from steam to water. The boilers will provide a back-up to the geothermal system and can also be used as a supplement, if necessary.

The design temperature of the water leaving the school buildings was 130 degrees F. The supply and return lines were combined after leaving the last school building and continued as a single line to the first user in the district heating system. The piping then continued as a reverse return system through the heating district after which the lines were combined into a single transmission line to the treatment plant.

At the treatment plant, some of the water was diverted into a radiant panel floor heating system to heat the entire treatment plant before being recombined upstream from the point where barium chloride was introduced into the water to cause the sulfates bearing Radium 226 to precipitate.

The water containing the barium chloride slurry then flowed into the settling ponds where it was contained long enough to permit the sulfates to settle to the bottom. Water was then drawn off the top and discharged into the North Fork of the Bad River for use by downstream irrigators.

Figure 4-1 is a flow chart of the district heating system.

4.2 TASK BREAKDOWN

The project was planned in phases. The first phase was planning and drilling a new well. The second phase was the design and construction of the modifications to the heating systems of each building to use recirculating fresh water as the heating medium at the temperature obtainable from the geothermal resource. The third phase was the design and construction of the discharge pipe line and the treatment plant to remove the sulfates containing Radium 226 before discharging the water into the North Fork of the Bad River. The fifth phase was providing geothermal water to a heating district down the line from the school buildings, and the sixth phase was operation and monitoring of the entire system. Figure 4-2 shows the schedule for each task.

A feasibility study was prepared by Hengel, Berg & Associates and accepted by the Board of Education. The study indicated that a project would be successful if approximately 425 gallons per minute of 150 degree F water could be obtained. "Geothermal Applications of the Madison Aquifer System in South Dakota," dated 1977 by Dr. J. P. Gries of the South Dakota School of Mines and Technology indicated that the geothermal resource in the Haakon County area was suitable for space and water heating.

4.3 ORGANIZATION AND PARTICIPANTS

The project organizational structure is shown in Figure 4-3. The School District Board of Education was the project sponsor, and jointly with the Department of Energy funded the project. Hengel, Berg & Associates were the Engineers for the project, and with support from consultants, were responsible for the engineering. Plans and specifications for well drilling, pipe line and treatment plant construction and heating plant modifications were prepared and contractors were invited to bid on the construction. The superintendent of schools was the project director and monitored the system operation when completed. The Schedule of Events for this project follows in Table 4-1.

TABLE 4-1
SCHEDULE OF EVENTS

<u>DATE</u>	<u>EVENT</u>
June 1977	The feasibility study was completed. The School Board decided to proceed with the project. The search for funding initiated.
April 26, 1978	The Water Rights application was filed.
June 1, 1978	The DOE Cooperative Agreement was completed
June 1978	The Bad River Rural Water System was formed to be the second user of the water discharged from the heating system.
June 21, 1978	An organizational "Kick-off" meeting was held and the schedule was prepared.
July 10, 1978	The well design and the environmental report was started.
July 26, 1978	The Water Rights application was approved.
Aug. 25, 1978	The Environmental Impact Assessment report was completed.
Sept. 1978	Advertised for bids on drilling the well.
Oct. 11, 1978	The preliminary report on the Bad River Water System was prepared.
Nov. 8, 1978	The bids were opened for well drilling.
Nov. 16, 1978	The well drill rig was inspected by Maxon, DiBellow, Berg and drilling consultant W. J. McPeters who approved it.
Dec. 5, 1978	Drilling commenced at the driller's risk, as the contract had not been awarded nor had the performance bond been provided.
Dec. 14, 1978	Contract for drilling the well was awarded to Northern Wyoming Drilling Company.
Jan. 2, 1979	The Environmental Report was approved.
Jan. 5, 1979	The drill stem separated during drilling.
Jan. 6, 1979	The drill stem separated a second time during drilling.
Jan. 18, 1979	The well hole was re-drilled from 2,065 to 3,385 feet depth.
Feb. 1, 1979	Drilling Inspector C. Lee Mueller of Energy Drilling Specialists, Inc., reported on the drilling operation with recommendations for improvements.
Feb. 13, 1979	Drilling reached Madison formation limestone at 4,107 feet; 6-1/2 inch open bore hole was drilled to 4,266 feet in limestone and dolomite.
Feb. 21, 1979	5-1/2 inch o.d. well casing was set.

Feb. 24, 1979	Well flow testing was started under the direction of DiBello, Niemi and Goldman, all of EG&G Idaho, and Maxon and Berg. Initial flow was 138 gpm at 156 degrees F.
March 12, 1979	Flow reached 320 gpm. The decision was made to provide a back-up system in lieu of attempting to improve well.
April 23, 1979	A preliminary design conference on heating system was held at Idaho Falls.
June 21, 1979	A meeting was held in Rapid City between R. N. Chappell, DOE-Idaho, DiBello & Donovan, EG&G Idaho, Maxon, Haakon County School District 27-1, D. Carda, South Dakota School of Mines and Technology, Petersen, Berg & Hengel of Hengel, Berg & Associates to assess project problems. The design of heating system modifications was suspended for one to two weeks pending assessment of the Radium 226 problem.
June 29, 1979	A decision was made to proceed with the design; specifications were prepared for the plate heat exchangers.
July 1979	Bids were invited for plate heat exchangers.
Aug. 9, 1979	Design of systems was reviewed at Idaho Falls by Lee and Chappell, DOE-ID, DiBello and Crandal, EG&G Idaho, Austin of CH2M Hill, Maxon, Berg and Hengel.
Aug. 13, 1979	Bids were opened for plate heat exchangers.
Oct. 23, 1979	A contract was awarded to Western Mechanical Services, Inc. of Rapid City for heat exchangers manufactured by the American Heat Division of Alfa-Laval Thermal of Somerville, New Jersey.
Nov. 29, 1979	The narrative report on proposed water treatment method and system was prepared by D. Bjerke of the Brady Consultants.
Dec. 12, 1979	An agreement for right-of-way for pipe line under the railroad tracks of the Chicago and Northwestern Transportation Company was offered.
Dec. 31, 1979	A draft of the National Pollutant Discharge Elimination System permit application was sent to the United States Environmental Protection Agency in Denver.
Feb. 6, 1980	Subsurface soil exploration for the barium chloride treatment plant was completed by Francis, Meador & Gellhaus.

Feb. 27, 1980	Bids were opened for the Geothermal Conversion and Boiler Replacement and the Geothermal Distribution Pipeline and barium chloride treatment plant for the removal of Radium 226.
March 26, 1980	The National Pollution Discharge Elimination System Permit was issued.
April 18, 1980	The contract for the Geothermal Distribution Pipeline and the barium chloride treatment plant was awarded to Ramstad, Inc.
	The contract for the Geothermal Conversion and Boiler Replacement was awarded to Wolff's Heating & Plumbing.
April 1980	The final draft of the Discharge Permit for discharge of water after it has been treated to remove sulfates which contain Radium 226 was issued.
Oct. 15, 1980	Geothermal water started flowing through the pipeline to the barium chloride treatment plant.
Nov. 4, 1980	Geothermal water started flowing through piping into the school building heat exchangers, and system water flowed through the converted heating system.
Nov. 17, 1980	Final inspection of the Distribution Pipeline Project was conducted.
Dec. 3, 1980	Post final inspection was held.
Jan. 19, 1981	A Certificate of Substantial Completion was issued for the Pipeline Project and the Geothermal Conversion Project.
Jan. 23, 1981	Pressure increase and flow decrease were recorded at the heating district controls at the fire station.
Feb. 24, 1981	Minor problems of small leaks in heating system piping and balancing were being corrected.
	Deposits on static mixer vanes and pipe were found to be responsible for decreasing flow. Water from the city system replaced geothermal water as the source for the barium chloride slurry.
March 18, 1981	New water only decreased the rate of deposits in the static mixer, but did not stop them. Heating District systems were being converted to geothermal.

May 3,	1981	An ion exchange system was proposed for elimination of sulfate.
May 18,	1981	Plant piping was modified to include the barium sulfate ion exchange system.
		The ion exchange pilot system was installed, tested and removed by Dr. Miller, EG&G Idaho. It was not feasible.
Sept.	1981	Barium chloride treatment suspended due to pump failure and excessive deposits on pipe and valves.
Nov.	1981	Water analysis showed 92.4 pico curies per liter of Radium 226 in the effluent.
Dec. 16,	1981	Water analysis showed 30.0 pico curies per liter of Radium 226 in the effluent.
March 24,	1982	The design of the new, open trough static mixer was completed.
June	1982	Open trough static mixer was placed in operation during low flow summer operation when system was used only to heat service water.
July 13,	1982	Water analysis showed 1.2 pico curies per liter of Radium 226 in the effluent.
Sept. 3,	1982	Water analysis showed 10.0 pico curies per liter of Radium 226 in the effluent.
Sept. 3,	1982	Water analysis showed 10.0 pico curies per liter of Radium 226 in the effluent.
Sept.	1982	Geothermal flow increasing with demand for heating; all geothermal water flows through and is treated in the exterior, open trough static mixer.

4.4 COST BREAKDOWN

The project was jointly funded by the U. S. Department of Energy under its P. O. N. (\$936,199), the Haakon School District 27-1 (\$218,000) and Philip Geothermal, Inc. (\$52,110). Total cost to June 30, 1982: \$1,201,062.03.

The project financing was structured to allow D.O.E. and the Haakon School District to fund the new well, the transmission and distribution pipe line, the disposal system and the retrofit of the school buildings. Each heating district user was responsible for retrofitting his own building.

Actual project costs are shown in Table 31-1.

TASK	1977	1978	1979	1980	1981	1982
	JFMAMJJASONDJ	JFMAMJJASONDJ	JFMAMJJASONDJ	JFMAMJJASONDJ	JFMAMJJASONDJ	JFMAMJJASONDJ
FEASIBILITY STUDY FOR DIRECT UTILIZATION OR GEO- THERMAL WATER	*****					
ENVIROMENTAL IMPACT ASSESS- MENT OF GEOTHERMAL SYSTEM	*****	*****				
GEOTHERMAL DISTRIBUTION PIPELINE & BARIUM CHORIDE PLANT (DESIGN)	*****	*****	*****	*****		
NEW WELL (DESIGN)		*****				
GEOTHERMAL CONVERSION & BOILER REPLACEMENT (DESIGN)		*****	*****	*****		
PHILIP BUISNESS HEATING DISTRICT GEOTHERMAL (DESIGN)		*****	*****	*****	*****	
SUBMISSION OF PON		*				
WELL DRILLING & TESTING			-----+++++	+++++	+++++	+++++
HEAT EXCHANGERS (DESIGN)			*****			
GEOTHERMAL DISTRIBUTION PIPELINE & BARIUM CHORIDE PLANT				-----	+++++	+++++
GEOTHERMAL CONVERSION & BOILER REPLACEMENT				-----	+++++	+++++
PHILIP BUISNESS HEATING DISTRICT GEOTHERMAL					-----	+++++

LEGEND: PRE-CONSTRUCTION: ***, CONSTRUCTION: ---, OPERATION: +++

DESIGN, CONSTRUCTION, INSTALLATION & OPERATION SCHEDULE

FIGURE 4-2

FIGURE 4-3

- (1) South Dakota School of Mines & Technology
 (2) Francis, Meador & Gellhaus, Consulting Engineers
 (3) Brady Consultants, Consulting Engineers

(4) CH2M HILL

ORGANIZATIONAL STRUCTURE

RESOURCE ASSESSMENT

5.1 PRE-PROJECT ASSESSMENT

The reliability of flow and temperature of water from the Madison formation had been adequately established by records of wells in the vicinity. The City of Philip well was located approximately three miles north of the school buildings and 154 degree F water had been flowing continuously since it had been drilled. A pipe line carried the water into the city. The water would be available when not needed by the city to supplement water from the lake during dry periods when the water level in the lake was low. Either a new pipe line from the existing well or a new well would be required to provide an adequate supply of water for heating the school buildings. The heating systems in the buildings were suitable for conversion to heating using water of a lower temperature than the steam used in the existing systems.

The isothermal map (Figure 5-1) shows the recorded temperatures of water in the Madison formation and the contour map (Figure 5-2) shows the depth of the Madison formation.

5.2 PRE-DRILLING ASSESSEMENT

A feasibility study was prepared by Hengel, Berg & Associates and accepted by the Board of Education. The study indicated that a project would be successful if approximately 425 gallons per minute of 150 degree F water could be obtained. "Geothermal Applications of the Madison Aquifer System in South Dakota", dated 1977 by Dr. J. P. Gries of the South Dakota School of Mines and Technology indicated that the geothermal resource in the Haakon County area was suitable for space and water heating.

The decision to drill a new well rather than construct a new pipe line from the existing well was based in part on the following: The condition of the screen in the existing well was unknown and the well head piping was badly corroded; the water might be needed by the city at the same time it would be needed for heating; land adjacent to the school was available for the site of a new well and the cost of the pipe line and the cost of a new well were initially estimated to be similar.

After using the water to furnish heat for the school buildings, the discharge water would still be useful for additional heating, grain drying, commercial applications, use by the city or by other potential users for recreational or domestic purposes.

ISOTHERMAL MAP MADISON FORMATION

40 20 0 40 80

CONTOUR INTERVAL 10° F

FIGURE 5-1

DEPTH TO TOP OF MADISON

CONTOUR INTERVAL 1000 FT

FIGURE 5-2

5.3 DRILL SITE SELECTION

An open area on the school property northwest of the High School-Armory was available for the well. Experience gained from other wells into the Madison formation indicated that this location was far enough from the City's well to prevent any adverse effects on the flow of the city well. The elevation of the well head would be nearly level with the school buildings, and considerably above the downtown business district and the Bad River, a possible point of discharge.

5.4 POST-DRILLING ASSESSMENT

The site proved to be a fortunate location; it was approximately 225 feet from the high school mechanical equipment room; a minimum of right of way easements would be required for the pipe line; soil conditions were satisfactory for easy excavation for the pipe line; the elevation was adequate to recover any static head lost in school systems in order to supply water at adequate pressure to the district heating system without the use of pumps in the geothermal circuit and the water would still flow to and through the treatment plant before discharge.

5.5 OPERATIONAL ASSESSMENT

The system has operated successfully. The artesian flow is adequate to force water through the school systems heat exchangers and the pipe line to the district heating system. The difference in elevation between the well head and the district heating system has provided adequate head for each of the heating district members. The 154 degree F temperature of the water has been adequate for heating the school buildings and their service water, and the temperature of the water leaving the school site is approximately 130 degrees F. The heating district users have been able to obtain more heat than anticipated from the geothermal water. However, treatment of the geothermal water to remove the sulfates which contain Radium 226 without causing other problems such as deposits in the pipe, has been more difficult than anticipated.

The plate heat exchangers have operated satisfactorily. Each heat exchanger was disassembled in June 1982 after about one and one-half years of service for inspection and cleaning. The geothermal sides of the plates appeared absolutely clean, but a very thin film of particulate deposit could be wiped from the plates. The building heating system sides of the plates contained minor deposits from the existing piping. The service water heat exchangers geothermal sides were clean; the service water side of

the high school-armory heat exchanger had heavy deposits of iron oxide. The plates were easily washed with water before any of the deposits were allowed to dry.

The barium chloride treatment process effectively removed the sulfates which contained the Radium 226. However, the sulfates precipitated immediately after the introduction of the barium chloride and coated the static mixer vanes, the interior of the pipe and the downstream valves. Attempts to delay the precipitation were only partially successful. The substitute ion exchange method was not successful. The open trough static mixer located outside the building is successful. Tests of the discharge water since installation of the open trough mixer indicate that the amount of sulfates in the water was reduced.

Vertical discharge unit heaters furnished for the gymnasium did not have sound ratings in the manufacturer's literature submitted for approval and have an unacceptably high sound level. Attempts to reduce fan speed by changing motor controls have not yet proven successful. The supply water temperature is lower than that normally used in space heating operations, and equipment was operated at nearly maximum capacity. Test data should be required of all equipment before approval.

Figure 5-3 shows the barium chloride Radium 226 removal system.

BARIUM CHLORIDE RADIUM 226 REMOVAL PLANT SYSTEM

FIGURE 5-3

ENVIRONMENTAL ISSUES

6.1 GENERAL

An environmental impact assessment was completed August 25, 1978 and approved January 2, 1979. An addendum to the report was completed January 30, 1980. It included the method of treating the geothermal water to remove the Radium 226 contained in the sulfates present in the water. Initial considerations were: drilling the well or building a new pipe line, constructing a distribution pipe line, converting the existing heating systems from steam and electric energy to use the geothermal water, constructing the discharge pipe line, secondary or end use of the water, and final disposal of the water.

No unusual problems were anticipated during drilling. The drilling site was level and no excavation for the drill rig was necessary. Temporary settling pits for fluids used during drilling were constructed adjacent to the well site. Water for drilling was available from the Philip City water system. After completion of drilling, the sludge from the pits was removed and taken to the Philip city land fill. The pits were backfilled, top soil was replaced and the disturbed areas seeded with native grasses. Impact to surface and ground water was a prime concern. The well was cemented and cased from the top down to the top of the Madison formation. Blowout preventers were installed during drilling.

Pipe trenches were excavated, the pipe was installed as quickly as possible, and the trenches backfilled and the surface restored to the original condition. Noise of construction equipment was temporary, and much of the pipe line construction was performed during school vacation.

The problem of erosion of heating system components was kept to a minimum by selection of materials which would not be adversely affected by water of the quality expected.

The effect on the existing well was to be determined by monitoring flow, temperature, pressure and water quality of both the existing and the new well.

6.2 PRE-DRILL

The environmental report described the planned well construction. The depth to be approximately 4,100 feet; well casing depths and diameters to the top 1,000 feet, 10 3/4 inches; next 2,800 feet, 7 5/8 inches; next 300 feet, plus or minus to the top of the

Madison formation, 6 1/4 inches. The well drilling was to be supervised by a qualified engineer. Geological formations and other subsurface data were to be logged as drilling proceeded.

6.2.1 Geology

The Madison formation is porous or fractured limestone and dolomite. The formation is recharged naturally from rain and surface water at the higher elevations. Existing wells into the Madison formation in this vicinity are artesian. Flow and temperature were estimated at 1,000 gallons per minute and 150 degrees F respectively.

6.2.2 Hydrology

Production from this well was not expected to affect the flow from other wells in the vicinity, the closest of which was the City of Philip well approximately two and one half miles north and slightly east of this well site. Blowout preventers were used during drilling to minimize effect on other strata. Sumps in tight soils prevented escape of drilling fluids into other formations.

6.2.3 Natural Resources

Construction and operation of the project had no effect on mineral or energy resources.

6.2.4 Air Quality

Unassociated hydrogen sulfide was not present in previous Madison formation wells, and was not a factor in this well.

6.2.5 Noise

Temporary noise was generated during drilling and construction. Drilling occurred during December, January and February when windows and doors are normally closed. Residences were at least five hundred feet from the well, and the distance attenuated the noise to acceptable levels.

6.2.6 Wildlife

The site was within the city limits and had a positive effect on wildlife through increased plant growth.

6.2.7 Terrestrial Ecology

Disturbance to vegetation and soils was confined to the well site and pipelines. All disturbed areas were restored to preconstruction or better condition.

6.2.8 Aquatic Ecology

Geothermal water from well flow tests was discharged into the nearby storm sewer which discharges into the Bad River. This river has intermittent flow, primarily in the spring. No long term adverse effects on stream life were anticipated and none occurred.

6.2.9 Land Use

The well site had been used for outdoor school activities on unimproved land and for overflow parking. The well house would occupy only a few hundred square feet near the south edge of the site and would not prevent future use of the site for pre-project activities. Pipe line trenches were kept in public right of way as much as possible and the surface was restored to pre-project or better condition.

6.2.10 Socioeconomic

The project was of short duration and provided very few jobs for local workers. Construction crews from outside the area used motel and temporary housing facilities. Their living expenses helped the local economy.

6.2.11 Energy

The project is expected to replace more than 95 percent of the fossil fuel used by the school, approximately 75 percent of the fossil fuel used by members of the Heating District, and 95 percent of the electrical energy used for space heating. (Electrical energy is used to heat the vocational building. Electrical powered circulating pumps are required to circulate space heating water. These were not previously a part of the steam heating system.)

6.2.12 Historical/Archaeological Sites and Natural Landmarks

None on the site or affected.

6.3 POST-DRILL

Flow tests and water samples taken from the well showed 99 ± 2 pico Curies of Radium 226 per liter in the water. The allowable effluent limitation daily average for thirty consecutive days for Radium 226 is 3 pCi/l with the maximum for any one day of 10 pCi/l. A treatment process for removal of Radium 226 involves the addition of barium chloride which removes the sulfates containing the Radium 226 by chemical coprecipitation. The sulfates would be retained in ponds sized to hold forty five years of precipitates. However, after thirty years, pond maintenance and disposal of the sludge would be accomplished. A treatment plant and two settling ponds was proposed.

Maximum reported concentrations of Radium 226 in various wells were:

Philip City well	158 pCi/l
Philip School well	132 pCi/l
Midland well	15 pCi/l

The EPA standard for drinking water is 5 pCi/l. In practice, an additional 5 pCi/l is allowable from background sources, so the allowable measured value for a sample is 10 pCi/l.

INSTITUTIONAL ISSUES AND PERMITS

7.1 GENERAL

A permit to drill the well was required from the State of South Dakota Water Rights Commission.

Authorization to discharge under the National Pollutant Discharge Elimination System (NPDES) was required by the United States Environmental Protection Agency.

The School District, a political subdivision of the state, owned the land on which the well was drilled and through which the upper part of the pipe line would pass. The pipe line was located in streets and alleys wherever possible. Initially, the line was located to cross railroad property, but necessity to provide a treatment plant and two settling ponds required additional property on which to locate the plant. The location selected avoided railroad property, but did require construction and maintenance easements from property owners. The School District obtained all easements.

The City of Philip did not require construction or building permits for either the pipe line or modifications to the heating plants of the school buildings.

7.2 PRIVATE

The distribution pipe line location passed through three parcels of private property. Ten foot wide construction and maintenance easements were obtained by the School District from the property owners.

7.3 CITY

The City of Philip provided easements for the pipe line along alleys and streets. Building permits were not required by the city.

7.4 COUNTY

No permits were required by Haakon County.

7.5 STATE

The State through the South Dakota Department of Water & Natural Resources, Joe Foss Building, Pierre, SD 57501, Office of Water Quality, telephone 605/773-3296, required a permit to drill the well, and through the Department of Environmental Protection required a permit to discharge the geothermal water into a waterway.

The application to drill a well was reviewed by the State Water Rights Commission, who held a hearing on the application and temporarily deferred action of the application because of the following concerns:

- 1) Secondary use of the water; after heat had been extracted, a consumptive use of the water should be established.
- 2) Depletion of the Madison Aquifer; the effect of wells flowing from the formation, the volume of flow and the effect of great volumes of flow on the Aquifer.
- 3) The number of permits to be allowed for geothermal heating. The possibility that a successful heating project may lead to numerous applications for water rights.

The permit for drilling the well and the right to remove water was issued on July 26, 1978 with the following conditions:

- 1) The well be valved and only the amount of water needed for the uses served could be removed.
- 2) Records be kept on the well pressure by a continuous recorder, and if the well was to be abandoned or the Permit cancelled, the well was to be plugged in accordance with the specifications of the Water Rights Commission.
- 3) Secondary uses be developed within five years and that the secondary users apply to the Commission for permits to cover their specific uses.

Future prospects of obtaining Madison well permits will probably depend on:

- 1) Finding consumptive uses for the water after heat extraction.
- 2) The results of monitoring projects such as this.
- 3) South Dakota's overall energy and water development plan.

The South Dakota Department of Transportation, Division of Highways, Pierre, SD 57501, required their permission to use the State storm sewer on a temporary basis for transmitting well water used in testing the well. They also requested a copy of a chemical analysis of the water if the storm sewer was to be used as a permanent part of the system.

7.6 FEDERAL

The United States Environmental Protection Agency, Region VIII, 1869 Lincoln Street, Denver, CO 80295, required an environmental impact assessment of the project. This was prepared and submitted on August 25, 1978 and ammended January 2, 1979. The Agency issued an Authorization to Discharge under the National Pollutant Discharge Elimination System on March 26, 1980.

PRODUCTION DRILLING AND LOGGING

8.1 SUMMARY

The first phase of the project was to drill a new well into the Madison formation on land owned by the Haakon School District adjacent to the school buildings in Philip, South Dakota. These are the buildings that will utilize the geothermal resource for space heating and domestic water heating.

Plans and specifications for the new well were prepared by Francis-Meador-Gellhaus, Inc., consulting engineers of Rapid City, South Dakota, reviewed by the Department of Energy and approved for bidding.

Bids for drilling the well were solicited and only one bid was received. The bidder's organization was investigated and his drilling equipment was inspected and found satisfactory for the work anticipated.

A contract was awarded to Northern Wyoming Drilling Company to drill the well who proceeded drilling at his own risk. He was unable to provide a performance bond and labor and material payment bond until the well was completed. Without the bond, a formal contract could not be entered into between the Haakon School District and Northern Wyoming Drilling Company. This placed the contractor in a zero cash flow position, and exposed the Haakon School District to a potential legal or financial problem.

The well was completed to a total depth of 4,266 feet (see Figure 8-1). The original plans required a 10-3/4 inch casing for the first 1,000 feet in depth, a 7-5/8 inch casing from the 1,000 foot depth to the 3,800 foot depth, and an open hole bore from the 3,800 to the 4,100 foot depth. To prevent future problems of sluffing encountered below the 3,800 foot depth, it was necessary to install a 5 inch o. d. flush joint casing inside the 7-5/8 inch casing. The bottom of this 5 inch o. d. casing extends to a depth of approximately 3,900 feet. The well was completed and flow testing started.

The initial attempt to measure the flow with a weir box was unsuccessful because the box had been designed for larger flows than were obtained. Preliminary testing using a stop watch and a 55 gallon drum indicated a maximum flow rate of approximately 320 gallons per minute of water at a temperature of 156 degrees F.

Flow tests using a free flow orifice indicates that the well is capable of sustaining a long-term Artesian flow rate of 300 gallons per minute.

FIGURE 8-1 HAAKON SCHOOL WELL DIAGRAM

From the water quality samples obtained and tested, the water quality of this well appeared to be similar to the water quality of the City of Philip well which is located 2-1/2 miles northeast of this well.

8.2 ORGANIZATION

The following organizations were involved in the drilling activities.

Engineers: Hengel, Berg & Associates, Rapid City, SD.

Well Consultants: Francis, Meador & Gellhaus, Inc.,
Rapid City, SD.

Consulting Geologist: Dr. J. P. Gries, South Dakota School
of Mines & Technology, Rapid City, SD.

Well Water Testing: Dr. D. D. Carda, South Dakota School of Mines
& Technology, Rapid City, SD.

Drilling Equipment Inspector: W. J. McPeters

Drilling Inspector: Ray Steadham, Energy Drilling Specialists,
821 17th St., Suite 806
Denver, Colorado 80202

Drilling Contractor: Northern Wyoming Drilling Co., P. O. Box 487,
Gillette, Wyoming.

8.3 DRILLER BIDDING, SELECTION AND CONTRACT

Bids were advertised in September of 1978 to be opened on October 26, 1978. Approximately 30 drillers were contacted to determine interest and six were invited to bid. At the appointed time on October 26, no bids were received and the bid date was changed to November 8, 1978. At that time, one bid of \$217,134.94 was received from Northern Wyoming Drilling Company.

The bidder's organization was investigated, and on November 16, 1978, his drilling equipment was inspected and approved by W. J. McPeters, a drilling consultant, E. G. DiBello of EG&G Idaho, the technical representative for the Department of Energy, Charles Maxon, Superintendent of the Haakon School District and R. O. Berg of Hengel, Berg & Associates, the Engineer.

A verbal award of contract was made to Northern Wyoming Drilling Company and a contract dated November 26, 1978 was prepared by Ralph A. Kemnitz, attorney for the School District. The contract was sent to Northern Wyoming Drilling Company and signed by Joe Banks, Vice-President of the company.

On November 29, 1978, Charles Maxon recieved a letter from Northern Wyoming Drilling Company stating that the required certificates of insurance had been sent to Dick Berg (The certificates had been received), and that the bond had been approved and should be delivered by December 1, 1978. A "Notice to Proceed" was not issued because the bond had not been received, but on December 1, 1978, Northern Wyoming Drilling Company's equipment arrived on the site and began rigging up for the drilling operation. Drilling commenced on December 5, 1978.

On December 6, 1978, the Department of Energy concurred with the award, subject to having a full time consultant on the site to protect the interests of the School District and the Department of Energy. Ray Steadham of Energy Drilling Specialists, Inc., of Denver, Colorado, was hired as the consultant. A Notice of Award of Contract was issued December 14, 1978, and the Contractor was directed to furnish the Performance Bond within ten days.

On December 15, 1978, Attorney Debbie Fischer notified Northern Wyoming Drilling Company that "....if you fail to execute said Bonds within 10 days from the date of the Notice, the Haakon School District will be entitled to consider all your rights arising out of their acceptance of you bid as abandoned and as a forfeiture of your bid bond....it is the position of the Haakon School District that you have been and will continue to proceed at your own risks in your drilling efforts....the School District disclaim any and all liability which may arise in connection with the drilling which has been completed and which will continue prior to issuance of the Performance Bond and the Payment Bond and the Notice to Proceed."

A Performance Bond and a Payment Bond dated February 26, 1979, was furnished to cover the project, and the contract was executed.

8.4 DRILLING SUMMARY (DRILLING REPORT)

Drilling commenced on December 5, 1978, without a contract for the well drilling.

By December 8, the 15 inch bore hole was 1,008 feet deep and ready for casing. No drilling problems were encountered in drilling the 15 inch bore hole. The 10-3/4 inch casing was installed and grouted on December 9.

Drilling should have resumed on December 10, but the well head valve did not arrive at the site until December 12. The well head valve and the blow out preventer were installed on top of the 10-3/4" casing and drilling was resumed. On December 13, drilling started on the 9-7/8 inch bore hole. The drilling summary is tabulated below:

TABLE 8-1
DRILLING SUMMARY

<u>DATE</u>	<u>DEPTH(feet)</u>	<u>DATE</u>	<u>DEPTH</u>
12-13-78	1,008	12-22-78	3,169
12-14-78	1,267	12-23-78	3,309
12-15-78	1,745	12-24-78	3,370
12-16-78	2,012	Shut down for Christmas	
12-17-78	2,557	12-26-78	3,398
12-18-78	2,846	12-27-78	3,503
12-19-78	2,978	12-28-78	3,503
12-20-78	3,052	12-29-78	3,503
12-21-78	3,117	12-30-78	3,543

The driller tripped out of the hole and shut down for Christmas on December 24. The viscosity of the drilling mud was 34 (satisfactory) but the formation "fell in" and removal of the drilling apparatus failed on December 29. Two days of work produced a successful removal on December 31 and drilling resumed that day.

The following information is from the February 1, 1979 report of E. Lee Mueller of Energy Drilling Specialists, Inc.:

From January 1 through January 4, the rig drilled from 3,627 to 3,725 feet, a total of 88 feet in 48-1/2 rotating hours for an average rate of penetration of 1.8 feet per hour. The low rate of penetration was due mainly to poor hole cleaning and poor quality of drilling mud. The hole cleaning problem can be attributed to inadequate hydraulics; poor mud quality is due to a poor mud surface cleaning system.

On January 3, the well was logged for correlation purposes. Additional drilling was necessary to reach the zone of interest. On January 5, the drill pipe failed when a 3-1/2 inch drill pin washed out and split the box to which it was connected. The fish was recovered and drilling continued on January 6 to a depth of 3,756 feet.

On January 6, another drill pipe failure occurred and twelve days were spent in an unsuccessful attempt to recover the fish. The well was then plugged back and a Dynadrill was used to kick off and drill a new hole from 2,065 feet to the then-present depth of 3,385 feet on the morning of February 1.

The two drill pipe failures in the 3-1/2 inch drill pipe appear to be a combination of improper joint make-up and running weights on the bit in excess of drill collar weight. The combination of these two improper drilling techniques caused wobbling in the drill string while rotating, which in turn caused washout and eventual failure in the connection. At re-drilling, the drill string was changed to 4-1/2 inch. Although the 4-1/2 inch drill string has not failed, there was strong concern that this string could be a potential problem since it was made of API Condition III inspected drill pipe. This grade of used pipe is rated at about 75 percent of new pipe.

The driller was operating with only one pump which further reduced the hydraulics from what was considered less-than-adequate. Another mechanical failure could have resulted in the loss of the hole.

The following Table lists reports of the drilling progress:

TABLE 8-2
DRILLING PROGRESS

<u>DATE</u>	<u>ACTIVITY</u>
1-22-79	Drilling at the 2,660 feet at the rate of 10 to 12 feet per hour; reached 2,701 feet at 1:30 p.m.
1-24-79	Drilling stopped at 2,701 feet; conditioning mud and cleaning mud pit; #2 pump not operating.
1-29-79	Drilling at 3,155 feet; estimate 6 to 7 days to reach 3,800 feet.
1-30-79	Drilling at 3,236 feet; solids up to 10%; not cleaning; #2 pump not operating, but should be back in operation today.
1-31-79	Drilling at 3,326 feet; 11% solids; #2 pump repaired and used to mix.
2- 1-79	Driller tripped out from 3,422 feet with some difficulty; some tight spots and possibly some cave-ins; bit changed; replacement bit is a re-run; 8% solids; Steadham said solids should not exceed 4%.
1- 2-79	Driller experienced trouble getting back down hole, but drilling at 3,427 feet at noon.
2- 3-79	Drilling at 3,715; Dr. Gries, Consulting Geologist visited well today.
2- 7-79	Casing set and grouted; Dr. Gries will monitor final 300 feet with samples every five feet.
2-13-79	Drill reached Madison limestone at 4,107 feet; drilling 6-1/2 inch open bore continued.
2-15-79	Liner and liner hanger will be delivered on 2-16-79; Steadham reports good bond on cement.
2-21-79	5-1/2 inch o. d. casing set.
2-24-79	Well head set.
2-24-79	Well flow testing started.

8.4.1 Wellhead Configuration Drilling

A well head valve and a blow-out preventer were installed at the well head after drilling a 15 inch bore hole to a depth of 1,008 feet and installing a 10-3/4 inch casing.

Wellhead configuration during flow testing consisted of the wellhead valve, a tee with a blind flange in which was installed a 1/2" x 4" schedule 40 nipple to which the recording pressure gage was attached, a 10" x 6" reducer welded to a 90 degree elbow and a gate valve in discharge line.

8.4.2 Final Wellhead Configuration

The final wellhead configuration is shown in Figures 15-1 and 15-2. It consists of: a wellhead valve; a tee with blind flange and nipple for the pressure gage; a 90 degree elbow; a gate valve; a reducing flange; a strainer; a temperature controlled motorized flow control valve; a flange, orifice plate and flange for differential pressure gage; a volume meter and a recording thermometer.

8.4.3 Drill Rig

Northern Wyoming Drilling Company used the following equipment in the drilling of the well:

Drawworks: Franks 500
Power: 2-671 GMC low block engines
Pump #1: Wheland 14000; Liner: 5-1/2"
Pump #2: FXZ; Liner: 5-1/2"
Drill String: 3-1/2"] 3.30 I.F. Drill Pipe
Drill Collars: 5-7/8" to 6" x 2-1/4" & 4-3/4"
for 7-5/8" casing.
Drill String after failure: 4-1/2" API Condition III
insp. pipe.

8.4.4 Drilling Fluid

The drilling mud properties are given in the following Table.

TABLE 8-3
MUD PROPERTIES

<u>DEPTH</u>	<u>WT</u>	<u>VIS</u>	<u>WL</u>	<u>PV</u>	<u>YP</u>
3370	9-3	34	8	10	6
3398	9-2	33	6	7	5
3503	9-3	34	7-8	9	4
3503	9-5	72	4-2	31	31
3503	9-6	90	3-8	36	44
3543	9-4	45	4-4	21	12
3627	9-5	64	3-8	30	27
3654	9-4	74	3-6	32	30
3701	9-5	64	3-2	40	42
3725	9-5	55	3-4	38	40
Failure & recovered fish					
3756	9-5	54	3-6	32	34
3756	9-5	55	3-8	30	34
Failure, fishing & re-drilling					

2065	9-5	50	10	22	7
2097	9-6	88	6	38	16
2193	9-6	74	10	30	15
2366	9-8	65	10	30	16
2597	9-8	50	9	28	18
2701	9-7	50	8-2	26	20
2701	9	55	7-2	30	21
2791	9	55	6-4	25	18

8.4.5 Drill Bits

The drill bits used are identified in Table 8-4.

TABLE 8-4
DRILL BITS

<u>NO.</u>	<u>TYPE</u>	<u>DEPTH OUT</u>
4	Smith J-2	3370
RR 5	Reed FP51J	3564
RR 6	Reed S21J	3654
7	Reed Y13J	3725
Re-drilling		
RR 11	Reed Y13J	2065
10	Reed Y13J	2183
11	Reed FP51J	

8.5 Completion Method

The completion methods are shown on Table 8-5.

TABLE 8-5
COMPLETION METHODS

<u>DEPTH</u>	<u>METHOD</u>
Surface to 1,040 feet	10-3/4" casing
1,040 to 3,725 feet	7-5/8" casing
3,725 to 3,900 feet	5" o. d. casing using liner hanger at the top of the casing and cement grout to 3,900 feet.
3,900 to 4,266 feet	6-1/2" open hole.

The initial decision was to hang the 5" o.d. pipe using a liner hanger at the top of the casing and an open hole packer at the bottom of the casing. The 6" open hole packer could not be forced into the 6-1/2" bore hole and was removed with considerable difficulty. The 5" o.d. casing was then grouted in place.

8.6 STIMULATION METHOD

Initial artesian flow of the well was less than 200 gpm. Flow tests indicated that the well was capable of sustaining long-term flow of 300 gpm, which was less than the 425 gpm desired.

Stimulation by acidizing was considered. The cost was estimated to be between \$37,000 and \$49,000, but stimulation funding was not included in the original cooperative agreement. The risk of damage to the casing or the cement grout and/or loss of tools in the hole was too great, and stimulation was not performed.

8.7 WELL LOGGING SUMMARY

Consulting Geologist John Paul Gries, PhD, provided the elevations of formation tops shown below and the description of sample cuttings below the casing set at 3,722 feet shown in Table 8-6.

TABLE 8-6
WELL LOGGING SUMMARY

<u>FORMATION</u>	<u>DEPTH (feet)</u>
Sharon Springs bentonite	1,078 to 1,087
Top of Niobrara	1,260
Top of Niobrara - Fort Hayes member	1,360
Base Niobrara	1,476
Top Greenhorn	1,742
Top Greenhorn limestone	1,812
"X" bentonite bed	1,968 to 1,971
First Dakota sand	2,078
Solid Dakota sand	2,112
Top Skull Creek Shale	2,418
Fall River-Lakota sandstones	2,556
Top Morrison shale	2,685
Top Sundance	2,694
Top Orange Sand (LAK member) Sundance	2,838
Top Opeche (?) redbeds	2,900
Top Minnelusa	2,980 or 2,996
Top Madison Limestone	3,800 or 3,875
Top Madison dolomite	3,965
Total depth	4,266

Sets of sample cuttings and electric logs are on permanent file at the Department of Geology, South Dakota School of Mines and Technology, Rapid City, South Dakota, and at the State Geological Survey, Vermillion, South Dakota.

The initial temperature of the well was 156 degrees F and its initial flow was 138 gpm.

WELL LOG by
JOHN PAUL GRIES
Consulting geologist
218 St. Charles Street
Rapid City, SD 57701

STATE So Dak		COMPANY	
COUNTY Haakon	FARM City of Philip	WELL NO. 2	
BLOCK	SURVEY		
SEC. 14			
T. 1 N	R. 20 E	TOTAL DEPTH	
		COMMENCED Dec 1972	
		COMPLETED	
ALTITUDE 2232 and PRODUCTION		REMARKS 550 FSL 1600 FSL Sample Set 646	

CASING RECORD		
10 3/4" @ 1000		
9 1/4" hole for 8 1/2" lower string		
SHOT	QUARTS	BETWEEN

FORM 186 - In stock and for sale by Ross-Martin Co., Tulsa

Logs are on public file at the Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, and at the State Geological Survey, Vermillion, South Dakota.

WELL LOG by
JOHN PAUL GRIES
Consulting geologist
218 St. Charles Street
Rapid City, SD 57701

Logs are on public file at the Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, and at the State Geological Survey, Vermillion, South Dakota.

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JOHN PAUL GRIES

Consulting Geologist

238 ST. CHARLES STREET

RAPID CITY, SOUTH DAKOTA

Description of sample cuttings below casing set at 3722 feet.

- 3722-25 cement, metal, trace brown dolomite and green shale
30 dolomite, very finely crystalline, dense, medium to dark brown;
some red and green shale
35 dolomite, same, and dolomite, medium to coarsely crystalline,
vitreous; some circulated sandstone and some green shale
40 same
45 limestone, very finely crystalline to slightly earthy, dolomitic
50 same
55 limestone, slightly dolomitic to very calcareous, light brown to
light pink, dense
60 limestone, same, and limestone, dense greenish gray; some red
fissile shale
65 limestone and dolomite as above, 2/3; shale, red, green, black 1/3
70 limestone and dolomite as above, 1/2; shale, dolomitic, 1/2
75 limestone, dolomitic, dense, medium brown
80 same
90 dolomite, finely crystalline, greenish gray to brown; some variegated sh.
95 dolomite as above, 1/2; shale greenish gray to red 1/2
3800 dolomite, as above, 2/3; shale, 1/3
20 limestone, finely crystalline, earthy brown to light brown, lithographic
30 limestone same and some slightly dolomitic; some shale
45 limestone, lithographic, 1/2; sandstone, red and white, poorly
sorted, 1/2
50 limestone, same, 1/3; sandstone same, 2/3
55 Limestone, same, 1/3; sandstone, same, 1/3; shale, greenish, 1/3
60 sandstone, poorly sorted, white, lavender, red-brown
65 sandstone, same, 1/2; dolomite, 1/4; shale, olive, 1/4
70 sandstone, 2/3; limestone and dolomite, 1/3; trace green shale
75 sandstone, 2/3; green shale, 1/3; trace dolomite
80 limestone, 1/3; sandstone, 1/3; shale, green, 1/3
95 same, and some limestone, very fine to lithographic, soft, nearly white
3900 limestone, very finely crystalline to lithographic, soft, white
10 limestone, same
15 limestone, same, trace of pinpoint porosity
65 limestone, same
70 limestone same, and some white to colorless, coarsely crystalline,
porous dolomite
80 limestone, 1/2; dolomite, coarsely crystalline, colorless, 1/2
85 limestone, dense, same, 1/2; dolomite, coarsely crystalline, porous 1/2
90 same, trace of porosity
95 dolomite, medium to coarsely crystalline, white to light gray, 2/3;
trace oolitic or peletic limestone, 1/3 dense limestone
4000 dolomite, coarsely crystalline, 1/2; limestone, dense, 1/2
05 limestone, dolomitic, very finely crystalline, white, 2/3; dolomite,
coarsely crystalline, some porosity
30 dolomite, fine to coarsely crystalline, coarse is rhombic, white to
light brown, with some intergranular porosity

JOHN PAUL GRIES

Consulting Geologist

238 ST. CHARLES STREET
RAPID CITY, SOUTH DAKOTA

- 4030-35 dolomite, fine to medium crystalline, brown; some dolomite medium to coarsely crystalline, porous
- 55 dolomite, fine to medium crystalline, brown, dense
- 70 dolomite, same, and dolomite medium crystalline, rhombic, some porous, some has interstices filled with white matrix
- 75 dolomite, fine to medium crystalline, gray brown to medium brown, glassy
- 80 dolomite, fine to medium crystalline, glassy, trace of porosity
- 85 dolomite, medium crystalline, nearly white with embedded rhombs of dolomite in limestone
- 90 dolomite, coarsely crystalline, rhombic, fairly porous
- 95 dolomite, same
- 4100 dolomite, very finely crystalline, light gray brown; some rhombic dolomite probably caved from above
- 10 dolomite, finely crystalline, gray brown, slightly earthy; dolomite fine to medium crystalline, rhombic, glassy, with trace of intergranular porosity
- 15 dolomite, finely crystalline, lgt gray to light brown, some porosity, $2/3$; dolomite, rhombic, porous, $1/3$
- 20 dolomite, finely crystalline, glassy, porous and non-porous; traces of oolitic dolomite, more or less porous
- 45 dolomite, finely crystalline, light gray brown, dense; probably with streaks of porous oolitic dolomite
- 70 dolomite, fine to medium crystalline, medium brown, glassy to rhombic, fair porosity in the rhombic dolomite
- 80 dolomite, fine to medium crystalline, medium brown, glassy to rhombic
- 90 dolomite, same, fair porosity
- 95 dolomite, same, plus some with open vug porosity
- 4205 dolomite, same, trace of porosity
- 20 dolomite, same, and some with vestigial oolitic structure, porous
- 35 dolomite, same, no vuggy porosity
- 50 dolomite, fine to medium crystalline, medium brown, glassy, rhombic, little or no porosity
- 55 dolomite, calcareous, finely crystalline, mealy, light brown
- 66 dolomite, same, tight.
- 4266 Total depth, driller

Logs are on public file at the Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, South Dakota, and at the State Geological Survey, Vermillion, South Dakota.

JOHN PAUL GRIES

Consulting Geologist

238 ST. CHARLES STREET
RAPID CITY, SOUTH DAKOTA

Record of electrical logs run by Birdwell

Induction electric log	1,000 - 3,677	Run January 1, 1979
Density, borehole compensated	1,000 - 3,677	
Induction electric log	3,700 - 4,264	Run February 14, 1979
Density, borehole compensated	3,720 - 4,264	
3-D Velocity (cement bond)	3,720 - 4,264	

Logs on public file at Department of Geology and Geological Engineering, School of Mines and Technology, Rapid City, and at State Geological Survey, Vermillion.

BIRDWELL

Induction Electric Log

COMPANY PHILIP SCHOOL

WELL PHILIP SCHOOL #2

FIELD PHILIP SCHOOL

COUNTY HAakon

STATE So. DAKOTA

LOCATION:

NE SE

OTHER SERVICES:

DEC GRS
CBL

SEC. 14 TWP. 1N RGE. 20E

PERMANENT DATUM GROUND LEVEL ELEV. 2432
LOG MEASURED FROM KB + 7 FT. ABOVE PERM. DATUM
DRILLING MEASURED FROM KB

ELEV. K.B. 2259
D.F. _____
G.L. 2232

DATE	<u>2/14/79</u>				
RUN NO	<u>ONE</u>				
DEPTH-DRILLER	<u>4266</u>				
DEPTH-LOGGER	<u>4264</u>				
BTM. LOG NTER.	<u>4257</u>				
TOP LOG NTER.	<u>3720</u>				
CASING-DRILLER	<u>758 @ 3723'</u>	@			
CASING-LOGGER	<u>3726'</u>				
BIT SIZE	<u>6 1/4</u>				
TYPE FLUID IN HOLE	<u>MUD</u>				
	<u>FULL</u>				
DENS.	<u>NA</u>	<u>71</u>			
pH	<u>NA</u>	<u>8.6 ml</u>		<u>ml</u>	
SOURCE OF SAMPLE	<u>Flowline</u>				
Rm @ MEAS. TEMP.	<u>1.0 @ 58 °F</u>	@	°F	@	°F
Rmt @ MEAS. TEMP.	<u>.61 @ 62 °F</u>	@	°F	@	°F
Rmc @ MEAS. TEMP.	<u>1.1 @ 62 °F</u>	@	°F	@	°F
SOURCE <u>Rmt</u>	<u>4595</u>				
Rm @ B. - T.	<u>.5 @ 174 °F</u>	@	°F	@	°F
TIME SINCE CIRC.	<u>6 HRS</u>				
MAX. REC. TEMP.	<u>174 °F</u>		°F		°F
EQUIP. LOCATION	<u>3029 LPR</u>				
RECORDED BY	<u>KGYNOLO</u>				
WITNESSED BY	<u>GRIS</u>				

FIELD
PRINT

SPONTANEOUS-POTENTIAL MILLIVOLTS	DEPTHS	RESISTIVITY OHMS M ² /M	CONDUCTIVITY MILLIMHOS/M = $\frac{1000}{\text{OHMS M}^2/\text{M}}$
<div style="text-align: center;"> $- \left \begin{array}{c} 13 \\ \longleftrightarrow \\ 1 \end{array} \right +$ </div>		0 AMP. 16" NORMAL	INDUCTION 6 COIL 40"
		16" NORMAL	
		40" INDUCTION RESISTIVITY

<p>SPONTANEOUS-POTENTIAL MILLIVOLTS</p> <p>10 - +</p>	<p>DEPTH SCALE 2" = 100'</p>	<p>0 100 0 100 0 40" INDUCTION RESISTIVITY 0 Amp 16" NORMAL 10 0 500 0 100 0 1000</p>	<p>INDUCTION 6 COIL 40"</p>
<p>SPONTANEOUS-POTENTIAL MILLIVOLTS</p> <p>10 - +</p>	<p>DEPTH SCALE 5" = 100'</p>	<p>0 100 0 100 0 40" INDUCTION RESISTIVITY 0 Amp 16" NORMAL 10 0 500 0 1000</p>	<p>INDUCTION 6 COIL 40"</p>

RESOURCE TESTING

9.1 GENERAL

The specific objective of the March 20-22, 1979 aquifer test was to determine the feasibility of stimulating the well to improve efficiency. An artesian flow of approximately 500 gallons per minute was desired. The objectives that were addressed are: 1) Determine local aquifer characteristics; 2) determine the specific capacity of the well; 3) estimate "long-term" well productivity and 4) estimate well losses.

W. L. Niemi and D. Goldman of EG&G, Idaho provided the following information:

A summary of the artesian flow testing is shown in Table 9-1. The results are indicative of an inefficient well, as shown by the rapid pressure drawdown, followed by stabilization, and rapid pressure recovery, following shut-in. The response is not a function of friction due to well and/or casing diameter. The pressure responses are characteristic of wells completed in the Madison limestone (Blankenagel and Howell personal communication).

The specific capacity (the productivity of a production well defined as the discharge of a well is expressed as the well discharge rate per unit of drawdown) of the well, determined after 10 minutes of flow, ranged from 2.74 gpm/psig (gallons per minute per pound per square inch) to 4.59 gpm/psig. The specific capacity decreased with increases in discharge rate, implying an inefficient well. This response appears to be typical of Madison Formation wells.

Local aquifer characteristics could not be determined nor "long-term" well productivity accurately estimated due to the failure of test rates to adequately stress the aquifer(s) penetrated, and the inefficiency of the well. The well appears to be capable of sustaining a long-term artesian flow rate of 300 gpm while maintaining sufficient wellhead pressure to allow for pressure drawdown resulting from unforeseen aquifer or well conditions. Test and geological data suggest negligible interference effects on either the city Madison well or the Little Scotchmen's well.

Stimulation of the well utilizing an acid mixture could improve flow rates by 20-30%. Post acidizing development should utilize air-lift pumping techniques. Stimulation would introduce problems of disposal of spent acid and larger volumes of water during development.

9.1 APPARATUS

The flow test apparatus consisted of the gate valve at the well-head, a manometer, a 4-inch orifice in the 6-inch discharge pipe, irrigation pipe, a radio (to relay flow rate information from discharge to wellhead), a thermocouple, and a Fluke digital readout.

Preliminary measurements, using a wier box, were unsuccessful because the box had been designed for larger flows than were obtained. The preliminary tests were made using a stop watch and a 55 gallon drum.

Haakon March 1979 Aquifer Test Results

Q ¹	IWHP ²	FWHP ³	t ⁴	t ⁵	t ^{1,6}	Temp
45	129 psig	120 psig	51	11	--	150°F
185	120	74.5	57	--	1.5	154
45	128	114	40	--	--	152
310	114	17.5	60	3	2	157
50	127	122	15	--	--	137
265	122	44	1500	5	1	157
345 ⁷	128	3	11	1.5	--	153
350 ⁸	121	3	60	--	--	158

1. Controlled artesian flow rate
2. Initial wellhead pressure in pounds per square inch gauge (psig)
3. Flow wellhead pressure at time (t) in psig
4. Time (in minutes) since artesian flow commenced
5. Time (in minutes) required for pressure stabilization
6. Time (in minutes) required for well to recover following shut-in
7. Uncontrolled artesian flow
8. Data reported by Haakon School District for March 23, 1979

TABLE 9-1

DISPOSAL DRILLING & LOGGING

10.1 GENERAL

A disposal well was not required.

DISPOSAL TESTING

11.1 GENERAL

Disposal of water after extraction of heat by the School District and the central Heating District consisted of discharging the water into the North Fork of the Bad River. Testing included water quality and temperature and methods of removal of sulfates containing Radium 226.

The discharged water was sampled and analyzed to determine the amount of Radium 226 remaining in the water after treatment.

APPLICATION ANALYSIS

12.1 GENERAL

The geothermal resource is used to heat space in buildings and service water for these buildings. The system was planned to include a well, a transmission pipe line to the school buildings, a primary geothermal circuit to plate heat exchangers, fresh water circulating loops from the flat plate heat exchangers, valves and controls, a transmission pipe line to the Heating District area, valves and controls to maintain pressure to the Heating District, a transmission pipe line to the treatment plant and settling ponds and the discharge line to the river.

The treatment plant to remove Radium 226 included a small building which houses the barium chloride treatment equipment consisting of tanks for mixing barium chloride slurry, pumps for injecting the slurry into the pipe line and a static mixer to mix the slurry with the pipe line water, two settling ponds and the piping and valves to control the discharge into the river.

The secondary piping circuits in each of the buildings to be heated included circulating pumps, new or modified existing standby or back-up heating equipment, new or modified existing terminal heating units and the controls to operate this equipment.

12.2 TECHNICAL

The school district's buildings were heated by the following systems.

12.2.1 Armory-high school

Steam fired boiler, auditorium unit ventilators with steam blast coils, finned tube radiation, classroom unit ventilators and unit heaters. Service water was heated by an oil fired water heater in the summer and by a steam-to-water tube bundle in a storage tank.

12.2.2 Elementary and middle school

Steam fired boiler, unit heaters, classroom unit ventilators, finned tube radiation, unit heaters and a forced air heating and ventilating system with steam coil. Service water was heated by shell and tube steam-to-water heat exchanger.

12.2.3 Vocational building

Electric resistance coils in forced air unit ventilators, base board electric resistance heaters and classroom-type electric resistance unit ventilators.

12.2.4 Music buildings

Liquified petroleum gas fired forced air unit heaters.

Several methods of using the geothermal energy of the water from the Madison formation had been investigated. The method used was a primary circuit of well water, a plate- type water-to-water heat exchanger, and a secondary closed circuit of conditioned water through the space heating terminal units. A separate plate heat exchanger was used for heating service (domestic) water.

12.3 ECONOMIC

The initial economic analysis of 1977 showed an average annual fuel oil consumption over the preceeding five years of 36,200 gallons. The Vocational Education Building had been occupied for only two years and the average annual cost of electricity to heat the building had been \$2,950. The small, frame music buildings were not considered in the initial analysis.

The posted price of fuel oil on June 1, 1977 was \$0.436 per gallon. Using a 5% annual inflation rate, the annual energy cost for heating the armory-high school building, the middle-elementary school building and the vocational education building was estimated at \$25,000 for the next ten years and \$28,000 for the next twenty years. These estimates were too low, as the price of fuel oil on March 20, 1980 was \$1.013 per gallon and on January 9, 1982 it was \$1.128 per gallon in the quantities purchased by the school district.

Based on the price of purchased energy in 1982, it is estimated that the annual saving due to the geothermal system was \$46,700.

An economic analysis is presented in Section 33, "System Economics".

OBTAINING USER COMMITMENT

13.1 GENERAL

The Haakon School District 27-1 Board of Education initiated a study of geothermal energy for heating their school buildings and were committed to the concept early in 1977.

The City of Philip also investigated limited use of the geothermal resource for various purposes, including heating their road oil tank and the city Fire Hall.

Early in 1979, a feasibility study of a geothermal heating system for the Philip business district was authorized and undertaken. Fourteen business and government buildings were included in the study, and of these, twelve appeared to have reasonable chances of successful use of the geothermal resource. The Philip Heating District was subsequently organized. See Table 13-1, 13-2, & 13-3.

Seven business buildings had their heating systems modified to utilize the water discharged from the school geothermal system and were connected to the heating district geothermal pipe lines. The city fire hall will also be connected, and provisions were made for certain other business buildings to obtain this energy in the future.

13.2 GENERAL STRATEGY USED

Conservation of fossil fuel and electricity with the resulting cost savings for space and water heating were the incentives for developing a geothermal heating district and utilizing this alternative source of energy. The successful completion of the new well provided this source of geothermal water for the school district. The 130 degree F water discharged from the school after the school had extracted heat for their buildings contained residual heat adequate for the heating district.

13.3 CONTACTS

The entire community was interested in the geothermal concept from the time the feasibility study was instituted. The school district Board of Education made the initial contact to start the project.

The school district space and water heating loads had been surveyed during the feasibility study and were confirmed with the exact type and rated capacity of each terminal unit. The method of conversion was developed and the cost of conversion for each unit was estimated.

The heating district feasibility study determined those interested in the concept and survey forms were composed and distributed to the interested parties. Included in the survey were information on the building type, use, dimensions, construction material and characteristics, insulation, heating equipment rating, type and quantity of fuel used, hours occupied and any proposed plans for modification or expansion.

13.3.1 Status of Project Definition

The project was defined as follows:

- 1) The School District would provide and operate the well, the distribution pipe line, valves and branch pipe connections for heating district members, the system controls, meters, gages, monitors, the treatment plant and its own heating systems.
- 2) Each member of the heating district would provide his own piping from the valved branch pipe connections to his building, and the modifications to heating systems necessary to utilize the geothermal energy.

Twelve buildings within a two block area adjacent to the proposed location of the discharge line from the school were studied to determine the feasibility of utilizing the geothermal energy. The preliminary study determined that eight of the buildings could use the geothermal water to provide a substantial portion of their heating requirements.

The heating requirement for each building was determined from the rated capacity of the installed heating equipment. The total amount of heat that could be extracted from the geothermal water by reducing the temperature of the water 20 degrees F was computed and prorated to the eight buildings in proportion to their existing installed heating capacity. The quantity of geothermal water required for each building was determined. Approximately sixty percent of the annual heating requirements for these buildings could be provided by the geothermal water available from the school.

A preliminary design and cost estimate was prepared for each building, and a preliminary design of a heating system was made. Preliminary selection of heating equipment indicated that thick copper coils in fan-coil systems with some variations and modifications would meet the requirements of each building.

An estimate was made of the cost of the supply line, return line, service lines, valves and all items of the district system. These costs were pro-rated to the buildings in the heating district in proportion to the quantity of water to be delivered to each. This was the basis on which the cost would be allocated. The estimated fuel saving for each heating district member was computed on the basis that sixty percent of the heat required would be provided by the geothermal system.

An estimate of the cost of operating the heating district was prepared. It included \$2,500 per year to be paid to the school district. Three per cent of the cost of the capital investment would be used to fund maintenance of all of the exterior pipe lines except the supply line, which would be maintained by the school district as part of its discharge line.

13.3.2 Commitment Requested

The School District was committed to the project and obtained permits from the City of Philip to construct the pipeline in city streets and alleys. The School District also obtained written easements from property owners for construction and maintenance of the pipeline for its entire length between the School District property and the treatment plant and obtained an option to purchase a site for the Barium Chloride Treatment Plant. Application was made for a permit to discharge the treated water into the North Fork of the Bad River. The School District obtained an extension of the Water Rights Permit from 1983 to 1990.

The heating district incorporated as Philip Geothermal, Inc., and entered a formal Agreement with the School District that each property owner member would install a service line from the distribution line to his building, modify his heating system to utilize the heat from water circulated in the distribution pipeline if the pipeline was constructed within one hundred feet of his building. This agreement would be null and void if a Department of Energy Grant for constructing the distribution system was not obtained.

13.4 RECOMMENDED STRATEGY

Install additional tees in the pipeline for future connection of buildings belonging to property owners along the line.

REDUCED FUEL COSTS FOR GEOTHERMAL SYSTEM WITH 15 - YEAR LIFE

USER	PHILIP MOTOR CO.	KEMNITZ LAW OFFICE	HANSON'S SUPER VALU	RINGERS	FIRST NATIONAL BANK
TYPE OF FUEL	OIL	OIL	OIL	OIL	PROPANE
YEAR					
1981	\$8,310	\$1,118	\$3,297	\$1,178	\$2,942
1982	\$8,941	\$1,204	\$3,547	\$1,267	\$3,165
1983	\$9,620	\$1,295	\$3,816	\$1,363	\$3,405
1984	\$10,350	\$1,393	\$4,106	\$1,466	\$3,663
1985	\$11,136	\$1,499	\$4,418	\$1,577	\$3,941
1986	\$11,981	\$1,613	\$4,753	\$1,697	\$4,240
1987	\$12,890	\$1,735	\$5,114	\$1,826	\$4,562
1988	\$13,868	\$1,867	\$5,502	\$1,965	\$4,908
1989	\$14,921	\$2,009	\$5,920	\$2,114	\$5,281
1990	\$16,054	\$2,161	\$6,369	\$2,274	\$5,682
1991	\$17,272	\$2,325	\$6,852	\$2,447	\$6,113
1992	\$18,583	\$2,501	\$7,372	\$2,633	\$6,577
1993	\$19,993	\$2,691	\$7,932	\$2,833	\$7,076
1994	\$21,510	\$2,895	\$8,534	\$3,048	\$7,613
1995	\$23,143	\$3,115	\$9,182	\$3,279	\$8,191

TABLE 13-1

OPERATING AND MAINTENANCE COSTS FOR
GEOTHERMAL SYSTEM WITH 15-YEAR LIFE^A

USER	PHILIP MOTOR CO.	KEMNITZ LAW OFFICE	HANSON'S SUPER VALU	RINGERS	FIRST NATIONAL BANK
YEAR					
1981	\$989	\$323	\$296	\$115	\$649
1982	\$1,048	\$342	\$314	\$122	\$688
1983	\$1,111	\$363	\$333	\$129	\$729
1984	\$1,178	\$385	\$353	\$137	\$773
1985	\$1,249	\$408	\$374	\$145	\$819
1986	\$1,324	\$432	\$396	\$154	\$868
1987	\$1,403	\$458	\$420	\$163	\$920
1988	\$1,487	\$485	\$445	\$173	\$975
1989	\$1,576	\$514	\$472	\$183	\$1,034
1990	\$1,674	\$545	\$500	\$194	\$1,096
1991	\$1,774	\$578	\$530	\$206	\$1,162
1992	\$1,880	\$613	\$562	\$218	\$1,232
1993	\$1,993	\$650	\$596	\$231	\$1,308
1994	\$2,113	\$689	\$632	\$245	\$1,389
1995	\$2,240	\$730	\$670	\$260	\$1,467

^AINFLATION FACTOR OF 6% A YEAR

TABLE 13-2

DISTRICT HEATING SYSTEM FINANCIAL FEASIBILITY

NAME	GALLONS PER MINUTE USE	PERCENTAGE OF TOTAL	ESTIMATED EXTERIOR COST BASED ON % OF MAIN PIPE- LINE & COMBINED INDIVIDUAL SERVICE LINE COSTS	ESTIMATED INDIVIDUAL INTERIOR COSTS	ESTIMATED ANNUAL OPERATING COSTS	ESTIMATED TOTAL COST	ESTIMATED FUEL COST SAVINGS	ESTIMATED ADJUSTED FUEL COST SAVINGS	ESTIMATED PAYBACK (YEARS)
KEMNITZ (oil)	14.00	7.9	3027	2662	288	5977	1254	966	10.1
BANK (propane)	26.00	15.8	6055	3356	577	9988	3118	2541	5.2
HANSON'S SUPER VALUE (oil)	12.75	7.2	2759	9603	263	12625	3111	2848	6.1
DOROTHY BROS. (propane)	30.9	17.4	6668	13819	635	20487	3226	2591	16
PHILIP MOTORS (oil)	42.0	24.1	9235	26775	880	36010	8059	7179	7.6
KENNEDY IMPLEMENT (propane)	37.1	20.9	8009	12217	763	20989	2924	2161	
FIRE HALL (propane)	7.0	3.9	1494	5000	142	6636	1000	858	15.6
RINGERS (oil)	5.0	2.8	1073	4660	102	5835	1120	1018	9.0

TABLE 13-3

SYSTEM LOADS

14.1 PEAK LOADS - BTUH

Armory - High School	1,868,600
Elementary School	762,000
Domestic Water Heating	521,000
Vocational Education	396,000
Band (Instrumental Music)	62,800
Vocal Music	68,000
Remodeled Old Elementary	150,000
Fire Station	200,000
Philip Motor Co.	1,040,000
Dorothy Brothers (Auto Dealership)	1,084,000
Kennedy Implement	900,000
Hanson's Super Value (Grocery)	309,000
Bank	490,000
Kemnitz Law Office	260,000
Ringer Appliance	140,000
Kennedy Building	150,000
Total	8,401,400

14.2 ANNUAL SPACE HEATING LOADS

Total annual space heating loads of all users: $17,811.27 \times 10^6$ Btuh.

14.3 LOAD FACTOR

Load factor for this report is defined as the ratio of the Peak System Hourly Capacity at flow of 320 gallons per minute of water at 150°F to the Peak Hourly Load: $9,422,940/8,401,400 = 0.8914$.

14.4 FUEL REPLACED

<u>BUILDING</u>	<u>OIL (GAL)</u>	<u>\$</u>	<u>LPG (GAL)</u>	<u>\$</u>	<u>ELEC (KWH)</u>	<u>\$</u>
Armory	30,748	34,684				
Elementary	12,408	13,996				
Music			7,843	5,325		
Vocational					166,610	9,630
Fire Station	5,000	5,640				
Philip Motors	13,790	15,555				
Dorothy Bros.	6,761	7,581				
Kennedy's	3,505	3,954				
Hanson's	5,000	5,640				
Bank			9,615	6,529		
Kemnitz's	1,401	1,580				
Ringer's	1,592	1,796				
Total	80,205	90,426	17,458	11,854	166,610	9,630

FIGURE 14-1
PEAK LOADS

TOTAL ANNUAL LOAD
ALL USERS = $\frac{17,811.27}{\times 10^6}$ BTU

FIGURE 14-2

ANNUAL LOADS

PRODUCTION SYSTEM DESIGN

15.1 SELECTION PROCESS

The artesian flow of the well delivered 300 gpm at 15 psi. The shut-in pressure was 125 psi. Based on experience with other wells in the Madison Formation, it appears that the well will sustain a long term flow of 300 gpm. The fire station and the discharge outlet are approximately 100 feet lower than the well head. Therefore, the artesian flow was adequate and a pump was not required to circulate the water through the school system, the heating district or the treatment plant.

Well head configuration and equipment, pipe line location and material, heat transfer system and equipment and treatment plant type, location and equipment were considered.

Well head equipment included a manual valve, a pressure gage, a thermometer, a flow meter, a motor operated flow control valve with remote controller, a vacuum breaker with vent, a pressure reducing valve, a strainer and related reducers, enlargers, elbows, tee with blind flange and taps for recording pressure gage. Black iron pipe was used to the point of departure from the well house where glass fiber filament wound epoxy pipe was used.

The glass fiber filament wound epoxy pipe was used throughout the pipe line because of its qualities to resist corrosion and pressure at the 150° F water temperature.

Plate type heat exchangers were selected for the school space and water heating because of their efficiency and availability in corrosion resisting materials. The existing space heating equipment was used wherever possible with modifications to operate at the temperature of the geothermal water rather than as previously as a steam or hot water system.

Treatment plant equipment consisted of tanks for mixing barium chloride slurry, metering pumps, a static mixer and a two-cell settling pond. Polyethylene pipes were embedded in the concrete floor slab to serve as heating elements of a radiant panel heating system.

15.2 DESIGN

The production system was designed to control the volume of water supplied to the transmission system in inverse relationship to the outdoor temperature.

15.2.1 GENERAL DESCRIPTION

Final well head configuration is shown in Figures 15-1 and 15-2. The well head valve from drilling operations was retained; a tee with a blind flange provided a place for taps for a pressure recorder and allowed for a future second connection.

FINAL WELLHEAD CONFIGURATION

FIGURE 15-1

FINAL WELL HEAD CONFIGURATION

FIGURE 15-2

15.2.2 CONTROLS

The outdoor reset thermostat control opens the valve when the outdoor temperature falls to 65°F allowing geothermal water to flow through the transmission and distribution pipe line. Each building has its own system controls.

15.2.3 MAJOR COMPONENTS

Major components at the well head consist of:

- 1) Outdoor reset thermostatic controller
- 2) Motorized Modular Flow Control Valve
- 3) Pressure gage
- 4) Temperature gage
- 5) Flow meter

15.2.4 ENERGY MONITORING SYSTEM

The energy monitoring system operates only when manually activated by loading the recorders with paper and pen. The flow meter records flow of geothermal water and the temperature gage records the temperature of the water.

15.2.5 ENVIRONMENTAL CONTROLS

Environmental controls consist of an electric space heater to heat the well head building in the event of a well shut down during low temperatures.

SECTION 16

DISPOSAL SYSTEM DESIGN

16.1 SELECTION PROCESS

Reinjection was rejected because of cost and untreated discharge was not allowed because of sulfates which contained Radium 226. A proven treatment system which would remove these sulfates was designed. It consisted of two vertical, cylindrical plastic tanks which were used to mix and as a reservoir for Barium Chloride slurry. A two cell settling pond with overflow type discharge structure allowed the water to flow into the discharge line for release into the North Fork of the Bad River. The downstream irrigators would take the water as a secondary use of the resource.

16.1 SELECTION PROCESS

Reinjection was rejected because of cost and untreated discharge was not allowed because of sulfates which contained Radium 226. A proven treatment system which would remove these sulfates was designed. It consisted of two vertical, cylindrical plastic tanks which were used to mix and as a reservoir for barium chloride slurry. A two cell settling pond with overflow type discharge structure allowed the water to flow into the discharge line for release into the North Fork of the Bad River. The downstream irrigators would take the water as a secondary use of the resource.

16.2.1 GENERAL DESCRIPTION

The treatment plant was designed to use a portion of the geothermal water to heat the building through a radiant floor system using polypropylene pipe embeded in the concrete floor slab. This water was then reintroduced into the main pipe line ahead of the point where barium chloride slurry was introduced into line. Barium chloride was mixed with water into a slurry in two cylindrical plastic reservoirs each having a small pump. These pumps were controlled to alternate pumping the slurry into the pipe line ahead of a static mixer designed to mix the slurry with the water in order to precipitate the sulfates which contained Radium 226. The water was piped to either cell of the two cell settling pond where the sulfates were allowed to settle to the bottom of the pond. Overflow structures allowed the water to flow into the discharge piping and into the North Fork of the Bad River. (Figure 16-1)

16.2.2 CONTROLS

Pump controls allowed precise but variable quantities of barium chloride slurry into the pipe line. Manually operated valves control water entering the settling ponds and discharging into the Bad River.

16.2.3 MAJOR COMPONENTS

The entire disposal system consists of:

- 1) The outfall pipe line from the last building using the resource to the treatment plant building
- 2) The treatment plant building
- 3) The barium chloride slurry system
- 4) The static mixer
- 5) The settling ponds
- 6) The discharge line

16.2.4 ENERGY MONITORING SYSTEM

There is no continuous monitoring, but a thermometer is in the pipe to determine temperature of water entering the plant. This enables the operator to determine if the energy remaining in the water is usable and available for future development.

16.2.5 ENVIRONMENTAL CONTROL AND MONITORING

Samples of the discharge water are taken periodically and analyzed for Radium 226 content. Adjustments in the barium chloride slurry are made if necessary to obtain changes in the precipitation rate.

SECTION 17

TRANSMISSION SYSTEM DESIGN

17.1 SELECTION PROCESS

The selection process involved the type of pipe to be used, the depth of burial, backfill material and insulation, if any.

The corrosive nature of impurities in the water indicated a plastic pipe should be used. The temperature of the water and the pressure involved indicated a pipe resistant to deformation by crushing at any time, but especially during construction and testing, was required.

Fiberglass reinforced epoxy pipe met all of the requirements better than any of the other plastic pipes investigated and the filament wound fiberglass reinforced epoxy pipe was selected.

17.2 DESIGN

A single pipe transmits water from the well to the first building, the Armory - High School Building; a two pipe reverse return system is used between the first building and the second building, the Elementary School Building; the return and supply are combined into a single pipe at the Elementary Building; this single pipe transmits water to the first building in the Philip Geothermal Heating District; a two pipe reverse return system is used throughout the heating district; at the Fire Station, the last building on the district system, the return and supply are again combined into a single pipe which transmits the water to the treatment plant. Thrust blocks were provided at changes in direction. The geothermal pipeline was placed in steel pipe casings at all street and highway crossings.

17.2.1 GENERAL DESCRIPTION

See figure 17-1. The length of the transmission line is approximately 5,277 feet. The minimum burial depth is 6-1/2 feet to the top of the pipe. The pipe is bedded in and covered with sand prior to the placement of compacted backfill. Tees were installed in the supply and return pipes for each user. The Geothermal District was willing to accept water at the temperature of the combined supply and return of the school buildings. The temperature of the water leaving the last District user was adequate to heat the treatment building with a radiant floor system.

The treatment procedure uses a barium chloride slurry pumped into the pipe line ahead of a stainless steel vaned static mixer. The barium chloride causes the sulfates to precipitate onto the walls of the pipes enroute to the settling ponds. Overflow fittings in each pond allow water from the top surface to flow into the discharge pipe which empties into the North Fork of the Bad River.

TRANSMISSION SYSTEM
FIGURE 17-1

17.2.2 CONTROLS

There are no controls on the transmission system pipeline.

17.2.3 MAJOR COMPONENTS

Major components are the pipe, pipe fittings, thrust blocks, steel casings and the backfilled ditch.

17.2.4 ENERGY MONITORING SYSTEMS

There are no energy monitoring systems which are part of the transmission pipeline. Thermometers at the end of the district heating system and at the treatment plant show the change of temperature between these two points. A remote temperature sensor was installed 6' downstream from the point where the supply and return lines were joined downstream from the Elementary School.

17.2.5 ENVIRONMENTAL CONTROL AND MONITORING

There are no environmental control or monitoring which are a part of the transmission pipeline.

SECTION 18

DISTRIBUTION SYSTEM DESIGN

18.1 SELECTION PROCESS

Distribution system for this project is defined as the system between the transmission system and the users heating systems. The filament wound fiberglass reinforced epoxy pipe was selected for the same reasons it was selected for the transmission system. Butterfly valves were selected for the supply lines and eccentric valves for the return lines at each of the business district users.

18.2 DESIGN

The distribution system included two branch reverse return piping systems and supply and return pipes directly from the transmission system to the users. Valves were installed in the branch lines adjacent to the transmission system. The branches and supply and return lines were carefully designed to keep the friction losses nearly identical in each branch.

18.2.1 GENERAL DESCRIPTION

Distribution piping was installed by the pipeline contractor and extended from the transmission line to inside the users' buildings. Some pipe entered the building through a wall where a basement was available and other piping entered through the floor where appropriate.

18.2.2 CONTROLS

Control components, in addition to the manual valves on the supply and return pipes at each user's service entrance, are located in the well house and at the fire station which is the last user on the transmission system. A motor operated, modulating volume control valve located in the well house is controlled by an outdoor reset thermostat which increases the volume of water as the outdoor temperature decreases. At the fire station, which is approximately 100 feet lower than the well house, a second motor operated modulating volume control valve is located in the hot water return line from the heating district and a combination pressure relief-pressure sustaining valve is located in the hot water supply line from the heating district. The volume control valves maintain the proper quantity of water to the systems and the pressure sustaining valve at the lowest point in the distribution system maintains pressure to force the water through the various distribution and users' heating systems.

The control valve in the well house is set for full open at approximately 30 degrees and approximately 1/3 open at 60 to 65 degrees. Some flow is required to provide domestic hot water for the school.

18.2.3 MAJOR COMPONENTS

- 1) Tees in pipe line
- 2) Branch supply and return lines
- 3) Service supply and return lines
- 4) Service valves

18.2.4 ENERGY MONITORING SYSTEM

(NOT APPLICABLE)

18.2.5 ENVIRONMENTAL CONTROL AND MONITORING

(NOT APPLICABLE)

APPLICATION SYSTEMS DESIGN

19.1 SELECTION PROCESS

Haakon School District 27-1 is responsible for delivering water to each of the users, including their own buildings. Each user is responsible for the design of his own system. Design and retrofit for the School District buildings was performed under separate contracts. The School District used the geothermal water for both space and heating; the Heating District users heated space only.

The School District decided to retrofit their buildings, using the existing equipment wherever possible, augmenting the capacity with additional equipment or replacing equipment as a last resort. The old boiler in the armory-high school was to be replaced with a new modular boiler to serve as back-up to the geothermal system. The corrosive nature of the geothermal water and the greater efficiency of plate type heat exchangers led to their selection in lieu of the shell and tube type. Exchanger plates were available in a variety of corrosion resistant materials and alloys. Forty five days of testing polished metal coupons exposed to flowing geothermal water showed that 316 stainless steel was the most suitable material for use wherever geothermal water contacts metal.

Analysis was made comparing one central plate heat exchanger for the entire school complex with separate smaller exchangers for space heating and domestic water for the armory-high school, space heating and domestic water for the elementary, vo-ag, music and future expansion. Separate heat exchangers were selected to avoid shut down of the school system in the event of failure of the large heat exchanger.

The untreated geothermal water is used directly by the Heating District users. Only one user has a shell and tube heat exchanger.

19.2 DESIGN

Separate heat exchangers were used for space and water heating in each of the two systems for the school buildings. Specifications and performance criteria are shown on the following pages.

Schematic diagrams of the design of the system for the Elementary building is shown on Figure 19-1. The Armory - High School Building system is similar, but does not supply other buildings as does the Elementary building system (Vo-Ag, Music & Jr. High).

Treated water only is pumped through the heat exchanger and closed circuit heating systems. The existing steam system terminal units were modified to increase their capacity, and new, down flow fan coil units were added in the gymnasium. New fan coil units were also added in the vo-ag building to replace the electric resistance units and in the music building to replace the direct gas fired unit heaters.

Philip Elementary School Heating Schematic (Armory Building Similar)

FIGURE 19-1

19.2.1 GENERAL DESCRIPTION

Geothermal water flows through the heat exchangers when the outdoor air temperature falls to 65°F. Water for space heating is pumped through the heating system side of the heat exchanger and the space heating circuits. A separate pump pumps water through the domestic water circuit and its heat exchanger. A new eight unit modular hot water boiler provides augmenting and/or back up capacity in the armory-high school building. The existing steam boiler in the elementary was converted to hot water to provide augmenting and/or back up capacity for the elementary and auxiliary buildings.

19.2.2 CONTROLS

HVAC CONTROL SEQUENCES: GEOTHERMAL SYSTEM:

Geothermal Heat Exchangers: TCTE dual element proportioning thermostat with element in outside air and element in space heating supply water shall maintain space heating water temperature between 90 and 140 degrees F. at ratio of 1.5:1 with the outside air by modulating 3-way valve in heat exchanger and by-pass circuits.

Geothermal Pumps: TCTE remote element temperature controllers shall start space heating pumps P-1 (Armory) and P-4 (Elementary) when outside air temperature falls to 64 and stop the pump when it rises to 66 degrees F. TCTE low limit controller with element in space heating supply water shall stop the pump when water temperature falls below 65 degrees F.

Boilers: TCTE adjustable set point dual element proportioning temperature controller with element in outside air and element in space heating supply water shall start boiler and modulate valve to increase supply water temperature above 140 degrees F. at a ratio of 1.5:1 when outdoor air temperature falls below -10 degrees F. and geothermal system cannot maintain adequate water temperature.

Domestic Water Heating: TCTE in domestic water storage tank shall operate domestic water Geothermal pumps P-3 (Armory) and P-6 (Elementary) to start pump when tank water temperature falls to 115 degrees F. and stop pump when temperature reaches 120 degrees F. When Geothermal system cannot maintain tank water temperature of 105 degrees F., controller shall start pump P-2 (Armory) and P-6 (Elementary) to supply boiler water to tank heat exchanger until water temperature reaches 110 degrees F. at which time controller shall stop pump.

Space temperature Control Sequences: Existing Unit Ventilators with new water coils: Use existing thermostat controls.

New Unit Ventilators (UV): Connect existing thermostats to new unit ventilators. Modify controls to permit use and control of existing valve or to allow continuous flow of water through coil and operate face and by-pass dampers.

New Cabinet Unit Heaters (CUH): Armory: Connect existing thermostats to new cabinet unit heaters to operate fan on demand for heat.

Elementary School: Connect existing thermostats to new cabinet heaters to operate fan on demand for heat.

Band and Vocal Buildings: Provide new thermostats to operate fan on demand for heat.

Vocational Education Building: Provide new theromstats to operate fan on demand for heat.

New Unit Heaters (HUH) and (DCUH): Armory: Connect existing thermostat to new unit heaters to operate fans on demand for heat.

Vocational Education Building: Provide new thermostat to operate fans on demand for heat.

New Unit Heaters (DFUH): Armory: Provide new thermostat to operate fans on demand for heat. Provide a separate fan switch in parallel with the thermostat circuit for each row (east to west) to operate the fans.

Elementary School: Connect existing thermostat to operate fans on demand for heat. Provide fan switch in parallel with the thermostat to operate the fans.

New Base Board Radiation (BBR): Provide new control valve and new single temperature thermostat to open control valve on demand for heat for each room or space.

19.2.3 MAJOR COMPONENTS

Heat exchangers, pumps, boilers, exansion tanks, new unit ventilators, new cabinet unit heaters, new unit heaters, new baseboard radiation, new thermostats and control components.

19.2.4 ENERGY MONITORING SYSTEM

There is no specific energy monitoring system, but the outdoor reset thermostats prevent waste of energy when outdoor air is above 70°F.

19.2.5 ENVIRONMENTAL CONTROL AND MONITORING

(NOT APPLICABLE)

HEAT EXCHANGER SCHEDULE AND PERFORMANCE CRITERIA

UNIT NUMBER: HX-1

FUNCTION: Space Heating

LOCATION: Armory Boiler Room

GEO THERMAL CIRCUIT FLOW CHARACTERISTICS:

1. FLUID: Geothermal Brine, See Chemical Analysis which is a part of this spec.
2. FLOW RATE (GPM): 150 maximum
3. INITIAL TEMPERATURE: 155.0 degrees F.
4. LEAVING TEMPERATURE: Not to be less than 131 degrees F.
5. FOULING FACTOR: .05 minimum

SYSTEM WATER CIRCUIT FLOW CHARACTERISTICS:

1. FLUID: Treated boiler system water
2. FLOW RATE (GPM): 150 maximum
3. TEMPERATURE DIFFERENTIAL (ΔT): 24 degrees F. minimum
4. LEAVING WATER TEMPERATURE: 140 degrees F. or greater.
5. ADDITIONAL SURFACE AREA FOR FOULING: 5 percent

SYSTEM SIDE HEAT LOAD: 1,800,000 BTUH Minimum

HEAT EXCHANGER INFORMATION:

1. MATERIAL:
 - A. EXCHANGER: 316 stainless steel
 - B. GASKETS: To be compatible with the water analysis that is a part of this spec.
2. GEO THERMAL WATER CIRCUIT:
 - A. PRESSURE DROP (PSIG): 7.7 Estimated *
 - B. CONNECTION: Threaded (NPT)
3. SYSTEM WATER CIRCUIT:
 - A. PRESSURE DROP (PSIG): 7.7 Estimated, 10 psi Maximum
 - B. CONNECTION: Threaded (NPT)

MAXIMUM ALLOWABLE DIMENSIONS:

LENGTH: 24"
WIDTH: 20"
HEIGHT: 45"
(Includes frame) other dimensions will be considered on an approval basis by the engineer.

*Total pressure drop of HX-1 & HX-2 not to exceed 20 PSIG.

HEAT EXCHANGER SCHEDULE AND PERFORMANCE CRITERIA

UNIT NUMBER: HX-2

FUNCTION: Domestic Water Heating

LOCATION: Armory Boiler Room

GEO THERMAL CIRCUIT FLOW CHARACTERISTICS:

1. FLUID: Geothermal Brine, See Chemical Analysis which is a part of this spec.
2. FLOW RATE (GPM): 40 Estimated, 150 GPM Maximum
3. INITIAL TEMPERATURE: Discharge Temperature of HX-1 (131 degrees F. estimated)
4. LEAVING TEMPERATURE: Not to be less than 80 degrees F.
5. FOULING FACTOR: .05 Minimum

SYSTEM WATER CIRCUIT FLOW CHARACTERISTICS:

1. FLUID: Domestic Water
2. FLOW RATE (GPM): 13.3 Minimum
3. INITIAL TEMPERATURE: 65.0 degrees F.
4. LEAVING WATER TEMPERATURE: 125 degrees F. Minimum
5. ADDITIONAL SURFACE AREA FOR FOULING: 5 percent

SYSTEM SIDE HEAT LOAD: 400,000 BTUH Minimum

HEAT EXCHANGER INFORMATION:

1. MATERIAL:
 - A. EXCHANGER: 316 stainless steel
 - B. GASKETS: To be compatible with the chemical analysis that is a part of this spec.
2. GEO THERMAL WATER CIRCUIT:
 - A. PRESSURE DROP (PSIG): 7.0 (Estimated) *
 - B. CONNECTION: Threaded (NPT)
3. SYSTEM WATER CIRCUIT:
 - A. PRESSURE DROP (PSIG): 4.5 (Estimated), 5 PSIG Maximum
 - B. CONNECTION: Threaded (NPT)

MAXIMUM ALLOWABLE DIMENSIONS:

LENGTH: 24"
WIDTH: 15"
HEIGHT: 36"
(Includes frame) other dimensions will be considered on an approval basis by the engineer.

*Total pressure drop of HX-1 & HX-2 not to exceed 20 PSIG.

HEAT EXCHANGER SCHEDULE AND PERFORMANCE CRITERIA

UNIT NUMBER: HX-3

FUNCTION: Space Heating

LOCATION: Elementary School Boiler Room

GEOHERMAL CIRCUIT FLOW CHARACTERISTICS:

1. FLUID: Geothermal Brine, See Chemical Analysis which is a part of this spec.
2. FLOW RATE (GPM): 100 maximum
3. INITIAL TEMPERATURE: 155.0 degrees F.
4. LEAVING TEMPERATURE: Not to be less than 130 degrees F.
5. FOULING FACTOR: .05 Minimum

SYSTEM WATER CIRCUIT FLOW CHARACTERISTICS:

1. FLUID: Treated Boiler System Water
2. FLOW RATE (GPM): 100 maximum
3. TEMPERATURE DIFFERENTIAL (ΔT): 24 degrees F. Minimum
4. LEAVING WATER TEMPERATURE: 140 degrees F. or greater
5. ADDITIONAL SURFACE AREA FOR FOULING: 5 percent

SYSTEM SIDE HEAT LOAD: 1,180,000 BTUH Minimum

HEAT EXCHANGER INFORMATION:

1. MATERIAL:

- A. EXCHANGER: 316 stainless steel
- B. GASKETS: To be compatible with the water analysis that is a part of this spec.

2. GEOHERMAL WATER CIRCUIT:

- A. PRESSURE DROP (PSIG): 4.3 Estimated, 5 PSIG Maximum *
- B. CONNECTION: Threaded (NPT)

3. SYSTEM WATER CIRCUIT:

- A. PRESSURE DROP (PSIG): 4.3 Estimated, 5 PSIG Maximum
- B. CONNECTION: Threaded (NPT)

MAXIMUM ALLOWABLE DIMENSIONS:

LENGTH: 24"
WIDTH: 20"
HEIGHT: 45"
(Includes frame) other dimensions will be considered on an approval basis by the engineer.

*Total pressure drop of HX-3 & HX-4 not to exceed 15 PSIG.

HEAT EXCHANGER SCHEDULE AND PERFORMANCE CRITERIA

UNIT NUMBER: HX-4

FUNCTION: Domestic Water Heating

LOCATION: Elementary School Boiler Room

GEOHERMAL CIRCUIT FLOW CHARACTERISTICS:

1. FLUID: Geothermal Brine, See Chemical Analysis which is a part of this spec.
2. FLOW RATE (GPM): 10.0 Estimated, 100 Maximum
3. INITIAL TEMPERATURE: Discharge Temperature of HX-3
4. LEAVING TEMPERATURE: Not to be less than 105 degrees F.
5. FOULING FACTOR: .05 Minimum

SYSTEM WATER CIRCUIT FLOW CHARACTERISTICS:

1. FLUID: Domestic Water
2. FLOW RATE (GPM): 3.6 Minimum
3. INITIAL TEMPERATURE: 65.0 degrees F.
4. LEAVING WATER TEMPERATURE: 125.0 degrees F. minimum
5. ADDITIONAL SURFACE AREA FOR FOULING: 5 percent

SYSTEM SIDE HEAT LOAD: 117,000 BTUH Minimum

HEAT EXCHANGER INFORMATION:

1. MATERIAL:

- A. EXCHANGER: 316 stainless steel
- B. GASKETS: To be compatible with the water analysis that is a part of this spec.

2. GEOHERMAL WATER CIRCUIT:

- A. PRESSURE DROP (PSIG): 8.7 Estimated, 10 PSIG Maximum *
- B. CONNECTION: Threaded, (NPT)

3. SYSTEM WATER CIRCUIT:

- A. PRESSURE DROP (PSIG): 1.2 Estimated, 5 PSIG Maximum
- B. CONNECTION: Threaded (NPT)

MAXIMUM ALLOWABLE DIMENSIONS:

LENGTH: 24"
WIDTH: 15"
HEIGHT: 36"
(Includes frame) other dimensions will be considered on an approval basis by the engineer.

* Total pressure drop of HX-3 & HX-4 not to exceed 15 PSIG.

SECTION 20

PRODUCTION SYSTEM CONSTRUCTION

20.1 BIDDING, SELECTION AND CONTRACT

THERE WERE NO SIGNIFICANT CHANGES IN THE PRODUCTION SYSTEM.

Reports of well water analysis are shown in figures 20-1, 20-2, 20-3, 20-4 & 20-5 and are an indication of the substances which cause corrosion in normal heating system materials.

ENGINEERING & MINING EXPERIMENT STATION
of the
SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY

JOHN PAUL GRIFF

REPORT OF ANALYSIS

Rapid City, S. D. 1 March 1979, 19--

Mr. Philip High - School
Philip, SD 57567

The sample of water received from you has been analyzed and the results obtained are as follows:

Certificate No. 789887

Your sample No. #1

SUBSTANCE	mg/L	SUBSTANCE	mg/L
Total Dissolved Solids	1114	Calcium (Ca)	192
Volatile Dissolved Solids		Magnesium (Mg)	42
Total Suspended Solids	105	Sodium (Na)	16
Volatile Suspended Solids		Potassium (K)	8
		Iron (Fe)	0.16
Total Hardness	684	Manganese (Mn)	0.13
Carbonate Hardness	98		
Non-Carbonate Hardness	586		
		Chloride (Cl)	12
pH --- 7.4		Sulfate (SO ₄)	624
Alkalinity (Phenolph'n)	0	Silica (SiO ₂)	
Alkalinity (Met. Orange)	98	Nitrate (N)	.12
		Orthophosphate (PO ₄)	.01
Turbidity (J.U.) ---		Total Phosphate (PO ₄)	
Spec. Conductance ---			

REMARKS:

The Engineering and Mining Experiment Station assumes no responsibility as to the source of the above samples.

Analyst.

D. D. Carda, Research Associate

hb

1

FIGURE 20-1

ENGINEERING & MINING EXPERIMENT STATION
of the
SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY

REPORT OF ANALYSIS

Rapid City, S. D. March 1979, 19

Mr. Philip High School

Philip, SD 57567

The sample of water received from you has been analyzed and the results obtained are as follows:

Certificate No. 789888

Your sample No. #2

SUBSTANCE	mg/L	SUBSTANCE	mg/L
Total Dissolved Solids	1128	Calcium (Ca)	205
Volatile Dissolved Solids		Magnesium (Mg)	44
Total Suspended Solids	17	Sodium (Na)	15
Volatile Suspended Solids		Potassium (K)	8
		Iron (Fe)	0.03
Total Hardness	692	Manganese (Mn)	0.07
Carbonate Hardness	105		
Non-Carbonate Hardness	587		
		Chloride (Cl)	11
pH --- 7.5		Sulfate (SO ₄)	778
Alkalinity (Phenolph'n)	0	Silica (SiO ₂)	
Alkalinity (Met. Orange)	105	Nitrate (N)	.306
		Orthophosphate (PO ₄)	.032
Turbidity (J.U.) ---		Total Phosphate (PO ₄)	.058
Spec. Conductance ---			

REMARKS:

The Engineering and Mining Experiment Station assumes no responsibility as to the source of the above samples.

 Analyst
 D. D. Carda, Research Associate

hb

2

FIGURE 20-2

ENGINEERING & MINING EXPERIMENT STATION
of the
SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY

REPORT OF ANALYSIS

Rapid City, S. D., April 3, 1979

Mr. Philip High School Attention: Chuck Maxon
Philip, South Dakota 57567

Dick Berg
Hengelberg and Associates
115 St. Joe
Rapid City, SD 57701

The sample of new well received from you has
been analyzed and the results obtained are as follows:

Certificate No. 789-950

Your sample No. 43

SUBSTANCE	mg/L	SUBSTANCE	mg/L
Total Dissolved Solids	1090	Calcium (Ca)	205
Volatile Dissolved Solids		Magnesium (Mg)	48
Total Suspended Solids	4.0	Sodium (Na)	13
Volatile Suspended Solids		Potassium (K)	7
		Iron (Fe)	.41
Total Hardness	710	Manganese (Mn)	
Carbonate Hardness			
Non-Carbonate Hardness			
		Chloride (Cl)	16
pH ---	7.29	Sulfate (SO ₄)	665
Alkalinity (Phenolph'n)		Silica (SiO ₂)	40.3
Alkalinity (Met. Orange)	115	Nitrate (N)	
		Orthophosphate (PO ₄)	
Turbidity (J.U.) ---		Total Phosphate (PO ₄)	
Spec. Conductance ---			

REMARKS:

The Engineering and Mining Experiment Station
assumes no responsibility as to the source of the above
samples.

Fletcher

Analyst

D. D. Carda, Research Associate

FIGURE 20-3

ENGINEERING & MINING EXPERIMENT STATION
of the
SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY

REPORT OF ANALYSIS

Rapid City, S. D., M. April 3, 1979

Mr. Philip High School Attn: Chuck Maxon
Philip, South Dakota 57567

Dick Berg
Hengelberg and Associates
115 St. Joe
Rapid City, SD 57701

The sample of new well been analyzed and the results obtained are as follows:

Certificate No. 739980

Your sample No. #4

SUBSTANCE	mg/L	SUBSTANCE	mg/L
Total Dissolved Solids	1116	Calcium (Ca)	205
Volatile Dissolved Solids		Magnesium (Mg)	48
Total Suspended Solids	7.6	Sodium (Na)	14
Volatile Suspended Solids		Potassium (K)	8
		Iron (Fe)	12
Total Hardness	710	Manganese (Mn)	
Carbonate Hardness			
Non-Carbonate Hardness			
		Chloride (Cl)	16
pH ---	7.70	Sulfate (SO ₄)	740
Alkalinity (Phenolph'n)		Silica (SiO ₂)	41.3
Alkalinity (Met. Orange)	116	Nitrate (N)	
		Orthophosphate (PO ₄)	
Turbidity (J.U.) ---		Total Phosphate (PO ₄)	
Spec. Conductance ---			

REMARKS:

The Engineering and Mining Experiment Station assumes no responsibility as to the source of the above samples.

Fletcher

Analyst

D. D. Carda, Research Associate

ENGINEERING AND MINING EXPERIMENT STATION
of the
SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY

REPORT OF ANALYSIS

date: 1 June 1979
Rapid City, SD 57701

TO: Dick Berg
Hengel Berg Associates
115 Saint Joseph Street
Rapid City, SD 57701

The sample of _____ received from you has
been analyzed and the results obtained are as follows:

Certificate Number _____

Your Sample Number _____

Cu	Ag	Pb	Zn	Cd	Hg	As	Se
<.1	<.25	<.75	<.02	<.05	<.005	<.05	<.005

The Engineering and Mining
Experiment Station assumes
no responsibility as to the
source of the above samples.

Analyst

D. D. Carda, Research Associate

hb

5

FIGURE 20-5

SECTION 21

DISPOSAL SYSTEM CONSTRUCTION

21.1 BIDDING, SELECTION AND CONTRACT

THERE WERE NO SIGNIFICANT CHANGES IN BIDDING, SELECTION AND CONTRACT.

21.2 AS-BUILT SYSTEM

21.2.1 GENERAL DESCRIPTION

A six inch diameter motionless mixer which mixed the barium chloride slurry with the geothermal water to precipitate the sulfates which contained the Radium 226 was installed in the pipeline in the disposal plant building. The sulfates precipitated immediately on the vanes and walls of the mixer, on the pipe walls and on the interior of the valves, impeding operation of the valves. The deposits reduced the cross sectional area of the pipe, thereby reducing the flow of water through the pipe.

The white sulfate deposits could be removed, but the removal process involved removing the mixer from the pipe and chipping and scraping the material from the interior of the mixer and that pipe which could be reached.

A new motionless (static) mixer which had removable vanes was designed in an attempt to delay the precipitation. Partial success was achieved, and the deposits were softer, easier to remove, but the mixer still had to be removed from the pipeline for cleaning.

The geothermal heating system had been operated without treatment of the water to remove the sulfates during September, October and November of 1981. Effluent samples of November 24, 1981, showed 92.4 3.3 pico curies per liter of Radium 226. Analysis of the effluent samples of December 16, 1981, showed 30.0 1.6 pico curies per liter after the water treated by the new mixer diluted the mixture in the settling ponds. However, due to the work required to clean the new mixer, additional improvements were sought.

An ion exchange system for removing the sulfates was investigated, a pilot system designed, constructed and operated. The system was rejected for the following reasons: efficiency diminished rapidly and the cost of the operation was excessive.

An open trough, baffled static mixer was designed for installation outside the building. The pipeline was rerouted to leave the treatment building above grade (in lieu of underground in the original

installation) and the slurry feed line was attached to the outside of the pipeline to prevent freezing. The slurry was discharged into the pipe immediately prior to entry of the trough. Figure 21-1.

The geothermal heating system had been operated without treatment of the water to remove the sulfates. The level of Radium 226 in the discharge water increased to unacceptably high values. The levels decreased gradually as the water treated by the new mixer diluted the mixture in the settling ponds.

21.2.2 CONTROLS

(THERE WERE NO SIGNIFICANT CHANGES IN THE CONTROLS)

21.2.3 MAJOR COMPONENTS

Open trough, static mixer.

21.2.4 ENERGY MONITORING SYSTEM

(THERE WERE NO SIGNIFICANT CHANGES IN THE ENERGY MONITORING SYSTEM)

21.2.5 ENVIRONMENTAL CONTROL AND MONITORING

Samples of the effluent were taken until the analysis showed that Radium 226 was below the maximum permissible discharge level of five (5) pico curies per liter. The sulfates removed would accumulate in the settling ponds with a Radium 226 accumulation of 0.06 curie per year. The ponds were designed to hold 138 cubic yards of surplus material which would allow approximately forty six years of sludge accumulation. The safe useful life of the ponds is considered to be thirty years.

Radium 226 is an alpha emitter for which very little shielding is required. The pond cannot be drained or the sludge allowed to dry, because dust from this sludge could carry the Radium 226. Sludge removal and disposition would have to be done every thirty years.

STATIC MIXER TROUGH
 BARIUM CHLORIDE TREATMENT PLANT - GEOTHERMAL SYSTEM
 HAAKON SCHOOL DISTRICT 27-1
 PHILIP, SOUTH DAKOTA

NOT TO SCALE
 HENGEL ASSOCIATES
 ARCHITECTS - ENGINEERS
 RAPID CITY, SOUTH DAKOTA
 MARCH 24, 1982

FIGURE 21-1

FIGURE 21-2

DIAGRAM OF FINAL VERSION OF BARIUM CHLORIDE TREATMENT PLANT

DIRECT UTILIZATION OF GEOTHERMAL ENERGY FOR THE PHILIP SCHOOLS

SECTION 22

TRANSMISSION SYSTEM CONSTRUCTION

22.1 BIDDING, SELECTION AND CONTRACT

One bid was received for the geothermal pipeline, which included the transmission system. The bid was above the estimate, but negotiations with the bidder reduced the price to an acceptable sum and the contract was awarded to Ramstad, Inc.

22.2 AS-BUILT SYSTEM

(NO SIGNIFICANT CHANGES WERE MADE IN THE SYSTEM)

22.2.1 GENERAL DESCRIPTION

The pipeline was tested by applying pressure of 225 to 250 pounds per square inch with water at temperatures of 140 to 150°F. This pressure was maintained for a minimum period of thirty (30) minutes, released and reapplied three times as a pulse test. After pulse testing, pressure of 250 psi was maintained for a minimum of four hours.

After testing the pipe and backfilling the trenches, the well was permitted to flow at an approximate rate of 320 gallons per minute for a period of several days to stabilize the temperature of the pipe and the surrounding material. The school used this flow of water for both space and water heating.

22.2.2 CONTROLS

(THERE WERE NO SIGNIFICANT CHANGES IN THE CONTROLS)

22.2.3 MAJOR COMPONENTS

(THERE WERE NO SIGNIFICANT CHANGES IN THE MAJOR COMPONENTS)

22.2.4 ENERGY MONITORING SYSTEM

(THERE WERE NO SIGNIFICANT CHANGES IN THE ENERGY MONITORING SYSTEM)

22.2.5 ENVIRONMENTAL CONTROL AND MONITORING

(THERE WERE NO SIGNIFICANT CHANGES IN THE ENVIRONMENTAL CONTROL AND MONITORING SYSTEMS)

SECTION 23

DISTRIBUTION SYSTEM CONSTRUCTION

23.1 BIDDING, SELECTION AND CONTRACT

The distribution system was included in the bid for the Geothermal Transmission System.

(THERE WERE NO SIGNIFICANT CHANGES FROM THE DESIGN IN THE DISTRIBUTION SYSTEM DURING CONSTRUCTION)

SECTION 24

APPLICATION SYSTEM CONSTRUCTION

24.1 BIDDING, SELECTION AND CONTRACT

Three bids were received. The apparent low bid contained several errors. Negotiations were conducted with Wolff's Heating and Plumbing and the contract was awarded to them.

(THERE WERE NO SIGNIFICANT CHANGES FROM THE DESIGN IN THE APPLICATION SYSTEM)

SECTION 25

SYSTEM MANAGEMENT AND ORGANIZATION

25.1 ORGANIZATIONS AND PARTICIPANTS

Figure 25-1 shows the final, overall project organization.

25.2 RESPONSIBILITIES

The Haakon School District 27-1 Board of Education, Superintendent and maintenance staff operate the system and provide geothermal water to Philip Geothermal, Inc., the heating district. Each user in the heating district is responsible for his internal system.

- (1) South Dakota School of Mines & Technology
 (2) Francis, Meador & Gellhaus, Consulting Engineers
 (3) Brady Consultants, Consulting Engineers

(4) CH2M HILL

FIGURE 25-1

SECTION 26

PRODUCTION SYSTEM PERFORMANCE

26.1 PERFORMANCE SUMMARY

During the 1980-1981 heating system, the school buildings were heated entirely by the geothermal system after it was placed in operation in November of 1980. Only one of the heating district's users obtained heat from the system, as the other users had not completed their retrofit. During the 1981-1982 heating season, the school buildings were heated by the geothermal system except for one 2-hour period when the boiler in the elementary building was operated to counteract excessive heat loss adjacent to leaky windows when chill factor exceeded -55°F . Six of the heating users obtained more than 90% of their heat from the geothermal system. Two user systems which were not designed to provide 100% of their heat did obtain more than 75% of their required heat from the geothermal system. The fire station had not yet been retrofitted.

Flow rates varied from approximately 30 gpm at 64°F outside ambient air temperature to 320 gpm at 20°F outside ambient air temperature.

26.2 DATA ACQUISITION

Data acquired on the production system includes:

- Quantity of water flowing is recorded on a conventional meter.
- Pressure can be continuously recorded by connecting a recording gage to the taps installed.
- Temperature and pressure are recorded manually from the thermometer and pressure gage.

Temperature and flow can be plotted against time to establish the quantity of heat in the water and monitor performance.

26.3 POST CONSTRUCTION MODIFICATION

The well house auxiliary heating system was modified after a leak caused minor flooding in the well house.

26.4 OPERATOR SATISFACTION

The production system has required very little operator effort and no maintenance. The flow meter in the well house must be read and the reading recorded. The production system operates automatically as controlled by the outdoor reset thermometer.

PRODUCTION RECORDS

WELL HOUSE STATION

Month: Feb. Year: 1981

DAY	HOURL	OUTSIDE AMBIENT AIR TEMP ° F	FLOW GPM	PRESSURE AHEAD OF MODULATING VALVE PSI	PRESSURE AT MOD. VALVE PSI	PRESSURE DOWNSTREAM FROM MOD. VALVE PSI	METER READING CUMMULATIVE GALLONS
2	3:05		240	68	54	52	42,174,400
3	6:20		220	75	62	62	42,377,900
3	3:15		330	30	18	12	42,455,000
4	6:30		320	35	22	18	42,764,400
4	3:30	36	330	32	18	12	42,925,800
5	6:25	10	330	30	18	12	43,220,900
5	3:20	24	320	30	18	12	43,388,200
6	6:15	12	330	30	20	14	43,686,600
6	3:30	36	330	30	20	14	43,859,000
9	6:20	2	320	40	24	20	45,068,200
9	3:50	8	330	30	20	18	45,297,600
10	6:30	-10	310	40	26	20	45,523,000
10	3:50	0	310	40	26	20	45,692,800
12	6:30	12	330	36	20	16	46,426,700
12	3:30	1	330	32	17	12	46,605,100
13	8:10	32	330	30	18	12	46,928,600
13	2:30	52	150	98	2	2	47,014,400
16	6:20	30	340	40	18	12	48,057,900
16	3:00	68	150	100	6	5	48,183,400
17	6:25	35	330	25	20	16	48,439,700
18	6:30	34	330	30	18	10	48,860,700
18	4:00	58	150	100	5	5	48,975,000
19	6:30	35	330	30	18	10	49,256,500
19	3:30	66	150	100	6	4	49,351,900

TABLE 26-1

SECTION 27

DISPOSAL SYSTEM PERFORMANCE

27.1 PERFORMANCE SUMMARY

Section 21 describes the modification to the disposal system. The performance of the disposal system had exceeded design assumptions, and after the open trough static mixer had replaced the closed, fixed van, cylindrical mixer and the removable vane mixer, performance returned to the anticipated levels. Temperature of the water entering the ponds is higher than anticipated. However, wildlife, including deer and wild turkey in the area congregate around the fenced ponds, and waterfowl use it, although it is near residences in the southwest part of Philip.

Barium chloride, which is purchased in paper bags containing approximately one cubic foot of material, must be manually emptied into the tanks and mixed. The two slurry pumps operate in conjunction with flow, and operate alternately.

The entire disposal system is extremely reliable, but the slurry pumps require attention and occasional cleaning. The open trough mixer has not required any cleaning to date.

27.2 DATA ACQUISITION

Records of analysis of the effluent is the only data collected. The samples are taken and analyzed to determine the level of Radium 226.

27.3 POST CONSTRUCTION MODIFICATION

Replacement of the in-line static mixers with the open trough, baffled mixer is described in Section 21.

27.4 OPERATOR SATISFACTION

Operator satisfaction is high for the entire geothermal heating system, but is probably lowest with respect to the disposal system which requires visual monitoring and manual labor to mix barium chloride slurry, maintain the slurry pumps and collect effluent samples at the discharge outlet.

SECTION 28

TRANSMISSION SYSTEM PERFORMANCE

28.1 PERFORMANCE SUMMARY

The transmission system has been in operation since November 1980 without any major problems. The modulating volume control valve located in the Fire Station at the outlet end of the district heating system did not operate in a completely satisfactory manner for a short period of time. Due to its distance from the well house, it was controlled by a separate outdoor reset thermostat rather than by the same outdoor reset thermostat which controls the modulating control valve in the pipe line at the well house. The valve would "hunt" (move between open and shut continuously). The pressure sustaining was not capable of maintaining adequate pressure during rapid volume fluctuations.

28.2 DATA ACQUISITION

A recording thermometer which records the temperature of water leaving the district heating system is installed in the Fire Station. The paper disk on which temperature is recorded is not changed at all times and temperatures are not continuously recorded.

28.3 POST CONSTRUCTION MODIFICATION

There has been no post construction modification to the transmission system.

28.4 OPERATOR SATISFACTION

Complete operator satisfaction has been marred by the fluctuations of the lower modulating valve. Changing set points on the outdoor reset thermostat improved performance.

SECTION 29

DISTRIBUTION SYSTEM PERFORMANCE

29.1 PERFORMANCE SUMMARY

Performance of the distribution system appears to vary yearly. The first full year of operation, performance was satisfactory. In 1982, the second full year of operation, users near the ends of the branches did not obtain the desired quantity of water. Changing the setting of the pressure sustaining valve to increase the pressure caused excessive pressure and leaks in plastic pipe joints in one of the user's internal systems.

Balancing the entire system to obtain the desired flow under all conditions of weather and occupancy is nearly impossible with the equipment and instruments currently available. A computerized energy management system with additional modulating volume and pressure modifying valves could possibly provide the necessary control, but the expense would not provide a reasonable payback period.

29.2 DATA ACQUISITION

NOT APPLICABLE

29.3 POST CONSTRUCTION MODIFICATION

NOT APPLICABLE

29.4 OPERATOR SATISFACTION

The School District operates the distribution system which delivers the geothermal water to the heating district users. Although the system is providing a larger percentage of the heating requirements than anticipated, operator satisfaction would be improved if user satisfaction was greater.

SECTION 30

APPLICATION SYSTEM PERFORMANCE

30.1 PERFORMANCE SUMMARY

The first full year of operation during the 1981-82 heating season, the systems exceed expectations and provided a larger percentage of the heating loads than were included in the feasibility studies. Users at the ends of the two branches have not always received the desired quantity of water. When the pressure sustaining valve set point is changed to provide higher pressure, and subsequently force more water into the branch circuits, leaks have developed in the plastic pipe joints in one of the user's internal systems.

There has been very little maintenance of the conventional heating systems. The shell and tube type heat exchanger in one user's system corroded and was replaced with the same type of copper tubes as those in the first exchanger. If another change is necessary, a stainless steel exchanger will replace the copper tube unit.

30.2 DATA ACQUISITION

Each user is responsible for collecting his own data. To date, the information provided by the users is shown in Section 14.4.

30.3 POST CONSTRUCTION MODIFICATION

One user added a shell and tube heat exchanger to his system to allow treated water to circulate throughout his system and reduce the rate of corrosion.

No other changes have been reported.

30.4 OPERATOR SATISFACTION

The only problems reported have been some leaks in the plastic pipe joints and a quantity of heat reduced from the initial year, but still exceeding the quantity anticipated.

Corrosion was known to be a problem prior to the start of this project. The experience with the fan coil units at the City's water treatment plant (which uses water from the Madison Formation) was well known, as these units had to be replaced at two or three year intervals.

SECTION 31

CONSTRUCTION COSTS

31.1 PRODUCTION SYSTEM

The production system costs were divided into the well drilling, the well house which the School District provided with their staff and the initial part of the Geothermal Distribution Pipe which completed the piping, fittings, instrumentation and controls in the well house.

Production system costs: \$345,593.65

Costs for the entire Demonstration Project are shown Table 31-1, the Financial Voucher Summary of June 30, 1982. All costs other than Well Drilling, Heat Exchangers, District Piping and Treatment Plant and School Retrofit were pro-rated to each of these according to the relationship of each to their total.

The well drilling bid tabulation (non-pro-rated production system cost) is shown in Table 31-2.

31.2 DISPOSAL SYSTEM

The disposal system, transmission system and distribution system were bid as a single contract. The contractor's breakdown of costs as shown in his application for final payment is shown in Table 31-3. There is an unresolved discrepancy between the cost shown in Table 31-3 and that shown in Table 31-1 for these three systems which were bid under the title of Geothermal Distribution Pipe Line.

The non-pro-rated disposal system costs: \$111,963.00

31.3 TRANSMISSION SYSTEM

31.4 DISTRIBUTION SYSTEM

The costs of the transmission and distribution systems cannot be separated at this time. They were included in the bid for the Geothermal Distribution Pipe Line.

The non-pro-rated, combined transmission and distribution systems cost: \$326,167.00

31.5 APPLICATION SYSTEM

The cost of the application system for the school district is shown in the contractor's application for final payment, Table 31-4. There is an unresolved discrepancy between the cost shown in Table 31-4 and that shown in Table 31-1 for this system.

The non-pro-rated school district retrofit costs: \$334,205.23.

Each user in the Heating District modified his own heating system at his own expense and with his own contractor or labor. The application system costs of the Heating District users is not known at the date of this report.

FINANCIAL VOUCHER SUMMARY (MODIFIED)

Project PHILIP SCHOOL DEMONSTRATION PROJECT - DE FC07-78ET27080

As of June 30, 1982

	FUNDING AVAILABLE	TOTAL COSTS CHARGED*	DOE FUNDING AVAILABLE	COSTS CHARGED TO DOE TO DATE	HAAKON FUNDING AVAILABLE	COSTS CHARGED HAAKON TO DATE	HEATING DISTRICT FUNDING AVAILABLE	COSTS CHARGED HEATING DIST. TO DATE
PROGRAM MANAGEMENT	20,166	23,534.84	-0-	-	20,166	23,534.84	-0-	
ENVIRONMENTAL REPORT	2,000	844.44	762	761.42	1,238	83.02	-0-	
SUPPLIES, COMMUNICATIONS, PRINTING	1,200	1,507.13	-0-	-	1,200	1,507.13	-0-	
TRAVEL & SUBSISTENCE	1,600	995.57	-0-	-	1,600	995.57	-0-	
PROFESSIONAL SERVICES - Design, Const.Obs. Technical Assist.	76,374	74,913.22	51,374	49,878.53	25,000	25,034.69	-0-	
WELL DRILLING	311,517	311,515.91	264,755	264,754.84	46,762	46,761.07	-0-	
STANDARD WATER TESTS	1,195	765.58	956	638.15	239	127.43	-0-	
CONSTRUCTION	-	-	-	-	-	-	-	
Heat Exchangers	13,600	13,600.00	10,880	10,880.00	2,720	2,720.00	-0-	
District Piping & Treatment Plant	438,635	438,130.00	310,742	311,423.35	74,593	74,596.65	52,110.00	52,110.00
School Retrofit	331,479	329,000.00	294,728	294,728.00	36,751	34,272.00	-0-	
Testing & Recording Equipment	7,653	3,603.32	6,122	2,901.42	1,531	701.90		
Attorney & Legal Fees	1,000	1,555.91	-0-	-	1,000	1,555.91	-0-	
DISSEMINATION OF INFORMATION	-	-	-	-	-	-	-	
Monitoring and Reporting	5,200	2,552.40	-0-	-	5,200	2,552.40	-0-	
Workshop & Seminars	5,250	8,176.47	5,250	8,176.47	-0-	-	-0-	
TOTAL	1,216,869	1,210,694.60	945,569	944,142.18	218,000	214,442.61	52,110.00	52,110.00

*Total of Costs Charged to DOE + Costs Charged to Haakon + Costs Charged to Heating District

TABLE 31-1

Northern Wyoming Drilling Co.

MAIN OFFICE:

Loy C. Banks, President
P.O. Box 487
Gillette, Wyoming 82716
Phone: (307) 682-9354

MONTANA OFFICE:

S. D. (Buck) Hulse
V.P. Drilling & Production
P.O. Box 308
Chinook, Montana 59523
Phone: (406) 265-8246

November 8, 1978

BID SCHEDULE

<u>NO.</u>	<u>ITEM</u>	<u>UNIT</u>	<u>UNIT PRICE</u>	<u>AMOUNT</u>	<u>TOTAL PRICE</u>
1.1	Mobilization	Lump Sum	20,000.00	Lump Sum	20,000.00
1.2	15" Dia. Bore Hole	L.F.	29.00/ft.	1,000 ft.	29,000.00
1.3	9 7/8" Dia. Bore Hole	L.F.	29.00/ft.	2,800 ft.	81,200.00
1.4	6 1/2" Dia. Bore Hole	L.F.	29.00/ft.	300 ft.	8,700.00
1.5	10 3/4" Dia. Casing	L.F.	15.659/ft.	1,000 ft.	15,659.00
1.6	7 5/8" Dia. Casing	L.F.	10.235/ft.	2,900 ft.	29,681.50
1.7	Electronic Logging	Lump Sum	6,754.00	Lump Sum	6,754.00
1.8	Cement Grouting	Lump Sum	15,140.44	Lump Sum	15,140.44
1.9	Well Head Fittings	Lump Sum	5,500.00	Lump Sum	5,500.00
1.10	Well Head Valve	Lump Sum	5,500.00	Lump Sum	5,500.00
1.11	TOTAL BID - ITEM 1				\$ 217,134.94
1.12	Rig Time	Hr.	\$ 160.00		
1.13	Standby Time	Hr.	\$ 160.00		

Respectfully Submitted:

Joe D. Banks
Signature

P. O. Box 487 - Gillette, WY
Address 82716

Vice President
Title

November 8, 1978
Date

Not Applicable
License Number (if applicable)

NOTE- NO CORPORATE SEAL
(SEAL - If bid is by a corporation)

CHANGE ORDER: Provide 5" o.d. casing inside
7-5/8" casing at cost of: \$60,169.00

TOTAL CONTRACT PRICE, INCLUDING CHANGE ORDER: \$277,303.94

TABLE 31-2

CONTRACTOR'S BREAKDOWN OF GEOTHERMAL DISTRIBUTION PIPE LINE (INCLUDES TRANSMISSION, DISTRIBUTION AND DISPOSAL SYSTEMS)

CONTINUATION SHEET

AIA DOCUMENT G703

PAGE OF PAGES

AIA Document G702, APPLICATION AND CERTIFICATE FOR PAYMENT, containing Contractor's signed Certification is attached.

In tabulations below, amounts are stated to the nearest dollar.

Use Column I on Contracts where variable retainage for line items may apply.

APPLICATION NUMBER:

APPLICATION DATE:

PERIOD FROM:

TO:

ARCHITECT'S PROJECT NO:

A	B	C	D	E	F	G		H	I
ITEM No.	DESCRIPTION OF WORK	SCHEDULED VALUE	WORK COMPLETED			TOTAL COMPLETED AND STORED TO DATE (D+E+F)	% (G÷C)	BALANCE TO FINISH (C-G)	RETAINAGE
			Previous Applications	This Application					
				Work in Place	Stored Materials (not in D or E)				
1.	Bond, Ins. & Mobilisation	15,000.00	15,000.00			15,000.00	100	0.00	
2.	Main Hot Water Supply	245,000.00	240,100.00	4900.00		245,000.00	100	0.00	
3.	Valves, etc. for Polymer Pipe	9,000.00	9,000.00			9,000.00	100	0.00	
4.	Main Hot Water Return Line	45,000.00	45,000.00			45,000.00	100	0.00	
5.	Treatment Building	26,000.00	25,500.00	500.00		26,000.00	100	0.00	
6.	Piping in Well House & Firehall	25,000.00	25,000.00			25,000.00	100	0.00	
7.	Grade Settling Ponds	17,130.00	17,130.00			17,130.00	100	0.00	
8.	Install Inter-pond Piping	35,000.00	35,000.00			35,000.00	100	0.00	
9.	Seal Treatment Ponds	8,000.00	8,000.00			8,000.00	100	0.00	
10.	Chain Link Fence	9,000.00	9,000.00			9,000.00	100	0.00	
11.	Polymer Pipe Loop	4,000.00		4000.00		4,000.00	100	0.00	
		438,130.00	428,730.00	9400.00		438,130.00		0.00	

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G703 — 1978

TABLE 31-3

CONTRACTOR'S BREAKDOWN OF COSTS FOR THE GEOTHERMAL CONVERSION AND BOILER REPLACEMENT (THE SCHOOL DISTRICT APPLICATION SYSTEM)

CONTINUATION SHEET

AIA DOCUMENT G702A

PAGE 2 OF 2 PAGES

AIA Document G702, APPLICATION AND CERTIFICATE FOR PAYMENT, containing
CONTRACTOR'S signed Certification is attached.

APPLICATION NUMBER: Final

In tabulations below, amounts are stated to the nearest dollar.

Use Column I on Contracts where variable retainage for line items may apply.

ARCHITECT'S PROJECT NO:

ITEM No. A	DESCRIPTION OF WORK B	SCHEDULED VALUE C	WORK COMPLETED		STORED MATERIALS F	TOTAL COMPLETED AND STORED TO DATE G(D+E+F)	AND %	BALANCE TO FINISH H(C-G)	RETAINAGE I
			Previous Applications D	This Application E					
1.	Job planning, bond & insurance	8,000.00	8,000.00			8,000.00		None	
2.	Unit heaters and radiation	50,000.00	50,000.00			50,000.00		None	
3.	Remove piping	5,000.00	5,000.00			5,000.00		None	
4.	Undergroung piping	8,000.00	8,000.00			8,000.00		None	
5.	Valves	12,000.00	12,000.00			12,000.00		None	
6.	Pipe and fittings	80,000.00	80,000.00			80,000.00		None	
7.	Insulation	35,000.00	32,971.00	2,029.00		35,000.00		None	
8.	Temperature control	28,029.00	28,029.00			28,029.00		None	
9.	Geo pipe, fittings & valves	55,000.00	55,000.00			55,000.00		None	
10.	Hangers	8,000.00	8,000.00			8,000.00		None	
11.	Wiring	13,000.00	13,000.00			13,000.00		None	
12.	Boiler installation	29,000.00	29,000.00			29,000.00		None	
13.	Change order No. 2	3,176.23	-0-	3,176.23		3,176.23		None	
14.	Letter (11-19-80) 2-pressure gauges	489.32	0	489.32		489.32		None	
15.	Error in orig mathematics	710.00	0	710.00		710.00		None	
	SUB TOTAL OR TOTAL	334,205.23 335,404.55	329,000.00	5,205.23 6,404.55		334,205.23 335,404.55		None	

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TABLE 31-4

SECTION 32

OPERATING AND MAINTENANCE COSTS

32.1 SUMMARY

The date of this section of the report is June 1985; the transmission, distribution and disposal systems were placed in operation November 17, 1980; the shcool district heating systems commenced operation immediately; one of the heating district users had been testing his system during the testing periods of the transmission and distribution systems; the other users commenced operation as soon as their systems had been converted to use the geothermal water. All district heating users were operating on the geothermal system during the 1981-1982 heating season.

The only information obtained on fuel saved and operating and maintenance costs has been by telephone report without written confirmation.

It is anticipated that use of the geothermal water in conventional heating equipment such as standard weight copper or steel finned tube radiation and coils in fan coil units will require replacement after shorter periods of use than when used with treated or non-corrosive fluids. Those systems using copper tubes in shell and tube heat exchangers can anticipate replacing heat exchangers in three to five years. Stainless steel shell and tube exchangers will have a longer life at the cost of reduced efficiency. Plate heat exchangers of the proper plate material will have an indefinitely long life, but the initial cost is much higher than the initial cost of shell and copper tube heat exchangers.

Table 32-1 shows the estimated useful life of major components and their estimated replacement cost based on 1985 dollars.

Table 13-2 shows the estimated operating and maintenance costs as estimated during planning of the project. Records of actual costs of operation and maintenance for all of the users were not available at the time of this report.

32-2 OPERATING COSTS

System operating costs of the School District only were available at the time of this report, and are shown below:

ITEM	COST (\$)
1. Barium chloride for treatment	4,500
2. Electrical energy at treatment plant	2,500
3. Electrical energy at other locations	400
4. Labor to operate treatment plant	1,300
5. Labor at other parts of the systems (estimate)	520
<hr/>	
TOTAL	9,220

32-3 MAINTENANCE COSTS

System maintenance costs were not available at the time of this report.

32.3.1 ROUTINE MAINTENANCE

Routine maintenance consists of cleaning and adjusting the two barium chloride slurry pumps, inspecting annually the plate-type heat exchangers and cleaning them when necessary, adjusting controls when necessary and lubricating the school's circulating pumps. There have been some minor leaks in the school buildings internal piping which the contractor repaired under the one year warranty.

No leaks have been detected in the transmission or distribution pipe lines.

An operational and maintenance check list is shown in Table 32-2.

32.3.2 MAJOR COMPONENT REPAIR OR REPLACEMENT

An estimate of the useful life expectancy and replacement cost of major component of the systems is shown in Table 32-1.

DIRECT UTILIZATION OF GEOTHERMAL ENERGY
FOR PHILIP SCHOOLS

USEFUL LIFE AND REPLACEMENT COSTS
FOR MAJOR SYSTEM COMPONENTS

<u>COMPONENT</u>	<u>USEFUL LIFE</u> <u>YEARS</u>	<u>REPLACEMENT COST</u> <u>1985 DOLLARS</u>
Geothermal Production Well	20/25	716,298
Well House and Fire Station Piping	15/20	53,905
Treatment Plant Building & Plant Piping	40/50	152,342
Transmission & Distribution Piping	40/50	1,132,776
Disposal Ponds & Piping	30/35	200,637
Application System (Geothermal Retrofit)	40/50	1,250,539

Note: Projections are based on the construction cost index from bid date to June 1985 and at an annual inflation rate of 2% from June 1985 to the end of the useful life period.

HAAKON SCHOOL DISTRICT 27-2

OPERATIONAL & MAINTENANCE CHECK LIST

START OF SPACE HEATING SEASON

1. Inspect and clean if necessary, all plate type heat exchangers.
2. Clean all strainers, including those in well house, fire station and treatment plant.
3. Check all gages, meter and recorders for calibration and operation.
4. Change chart on temperature recorder at fire station.
5. Inspect all systems piping for leaks.
6. Inspect berms around ponds for erosion and repair as necessary.
7. Inspect outlet for erosion and repair as necessary.
8. Inspect control system for correct operation and set points.
9. Inspect back-up heating system, including boilers.
10. Operate all valves through their entire range.

DAILY MAINTENANCE

1. Read and record well house volume meter and thermometer.
2. Inspect well house piping.
3. Inspect heating piping in buildings.
4. Inspect barium chloride pumps and slurry.

WEEKLY MAINTENANCE

1. Inspect well house piping and gages.
2. Clean and adjust pressure sustaining valve.
3. Inspect ponds and discharge outlet.

MONTHLY MAINTENANCE

1. Inspect berms and ponds; remove weeds.
2. Collect sample of effluent and send to laboratory.

TABLE 32-2

SECTION 33

SYSTEM ECONOMICS

33.1 CAPITAL COSTS

The total cost of the Haakon School District Direct Utilization of Geothermal Energy System was \$1,210,694.60 excluding the cost of conversion and retrofitting the buildings of Philip Geothermal, Inc.

Costs charged were: U.S. DOE	\$ 944,142.18
Haakon School District 27-1	214,442.61
Philip Geothermal, Inc.	<u>52,110.00</u>

Total cost of project: \$1,210,694.79

33.2 OPERATING AND MAINTENANCE COSTS

The School District maintains and operates the production system (well), transmission system (single pipe lines), distribution system (reverse return pipe lines), disposal system and their own building heating systems. The annual cost to operate the production, transmission, distribution and disposal systems is:

1. Barium Chloride	\$ 4,500
2. Utilities	2,900
3. Labor (estimated)	<u>1,820</u>
4. Operating Cost	\$ 9,220.00

Philip Geothermal, Inc. pays the School District \$2,500 annually for the first five years of the contract; this amount increases \$500 each year for the next five years at the end of which the contract is open for renegotiation. To date, annual income is:

Philip Geothermal Inc.,	\$ 2,500.00
-------------------------	-------------

Net annual operating cost: \$ 6,720.00

The estimated operating and maintenance costs for five of the heating district users are shown in Table 13-2.

33.3 FUEL SAVINGS

The total fuel saved during 1983 was reported as $13,600 \times 10^6$ btu as listed below:

<u>USER</u>	<u>NO. 2 FUEL OIL</u> <u>138,690 BTU/GAL</u>	<u>PROPANE</u> <u>95,475</u> <u>BTU/GAL</u>	<u>ELECTRICITY</u> <u>3,413</u> <u>BTU/ KW</u>
School District Buildings	6,590.6	748.8	568.6
Philip Motor Co.	1,912.5		
Kemnitz Law Office	194.3		
Hanson's Super Market	693.5		
Ringer's Appliance	220.8		
First National Bank		918.0	
Dorothy Brothers	937.7		
Kennedy Implement	486.1		
Fire Station	693.5		

The cost of fuel saved in 1983 was reported as shown in Table 33-1.

33.4 CUSTOMER BILLING

Philip Geothermal, Inc., the heating district, makes an annual payment to the School District as previously described. No billing is necessary.

33.5 ANALYSIS

The simple payback for the School District's contribution of \$214,442.61 at the annual net savings of \$56,915 is 3.77 years; the simple payback of the total cost of \$1,210,694.60 at the annual combined saving of the School District and the other users of \$111,890 is 12.09 years.

FUEL SAVINGS FOR 1983

USER	ESTIMATED COST \$	REPORTED COST \$	DIFFERENCE \$	% OF EST.
School District Buildings	82,507	63,635	-18,872	-22.87
Philip Motor Co.	9,620	15,555	5,935	61.60
Kemnitz Law Office	1,295	1,560	265	20.46
Hanson's Super Market	3,816	5,640	1,824	47.80
Ringer's Appliance	1,363	1,796	433	31.77
First National Bank	3,165	6,529	3,364	106.29
Dorothy Borthers	3,226	7,581	4,355	135.00
Kennedy Implement	2,924	3,954	1,030	35.23
Fire Station	1,000	5,640	4,640	464.00
TOTAL		111,890		

TABLE 33-1