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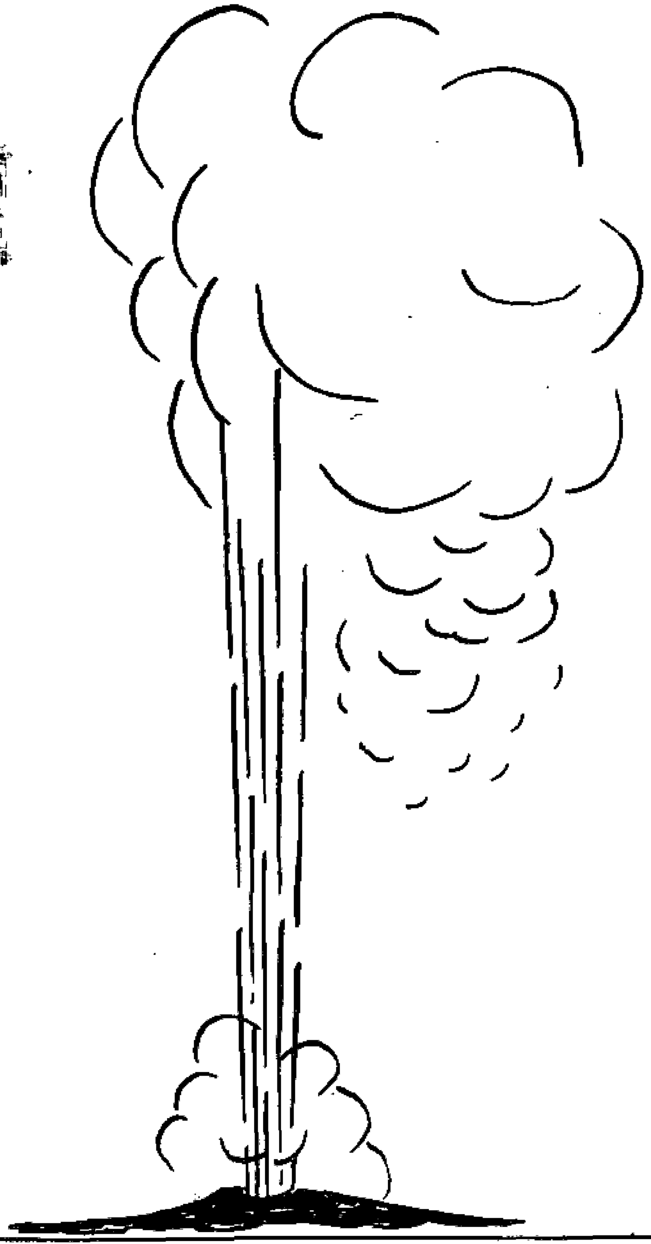

UTILIZATION OF GEOTHERMAL ENERGY IN THE MINING AND PROCESSING OF TUNGSTEN ORE

Quarterly Report

By
C. K. Lane
M. V. Erickson
G. D. Lowe

Work Performed Under Contract No. AC03-79ET27232

WESTEC Services, Inc.
San Diego, California

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C.K. Lane
M.V. Erickson
G.D. Lowe

WESTEC Services, Inc.
3211 Fifth Avenue
San Diego, CA 92103

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

TABLE OF CONTENTS (Continued)

LIST OF TABLES

ABSTRACT

The status of the engineering and economic feasibility study of utilizing geothermal energy for the mining and processing of tungsten ore at the Union Carbide-Metals Division Pine Creek tungsten complex near Bishop, California is reviewed. Results of geophysical data analysis including determination of assumed resource parameters are presented. The energy utilization evaluation identifies potential locations for substituting geothermal energy for fossil fuel energy using current technology. Preliminary analyses for local environmental and institutional barriers to development of a geothermal system are also provided.

SECTION 1

INTRODUCTION

1.1 STATEMENT OF OBJECTIVES

1.1.1 Overall Objectives

The overall objective of this study is to determine the engineering, economic and environmental feasibility of the utilization of low and moderate temperature geothermal heat from an area designated as valuable prospectively for geothermal resources in the mining and processing of tungsten ore at the Union Carbide - Metals Division facility near Bishop, California. A secondary objective is the development of engineering techniques in the direct use application of geothermal energy in anticipation that these techniques could be translated to other geothermal resource areas and applications.

1.1.2 Specific Objectives

The specific objectives of this study are as follows:

a) Prepare a preliminary geophysical evaluation of the geothermal resource within transportable range of the Union Carbide - Metals Division tungsten mining and processing complex at Pine Creek.

b) Develop a specific plan for early resource confirmation including a discussion of exploration techniques, reservoir parameters and well drilling and testing.

c) Conduct an engineering evaluation of the Pine Creek tungsten complex to identify those processes and systems which could directly utilize geothermal heat as a substitute for fossil fuel.

d) Conduct heat balance studies of the entire mill and mine to establish the technical feasibility of substituting geothermal heat for those mineral processing functions identified as compatible with the geothermal resource.

e) Determine the heat transfer methods for converting geothermal heat to process heat for those mineral processing functions identified as compatible with the geothermal resource.

f) Prepare cost estimates in terms of plant modification (capitalization) and operating costs for each alternative heat transfer approach considered to be technically feasible.

g) Determine the specific benefits of geothermal heat utilization in terms of reduced fossil fuel and electricity consumption and associated reduced energy costs.

h) Determine feasible approaches for transporting geothermal heat to the Pine Creek tungsten complex.

i) Determine the costs of transporting geothermal heat to the Pine Creek tungsten complex based on the selected heat delivery approaches.

j) Develop a conceptual design of a geothermal energy system that could supply process steam to the Pine Creek tungsten operation and if appropriate, concurrent generation of electrical power for plant use, utilizing parameters implied by the potential resource.

k) Provide an economic analysis of such a conceptual design comparing present and future conventional fuel costs, reduced fossil fuel and electricity costs, costs of mill modifications, and comparison of other unconventional alternatives, such as low-head hydro.

l) Provide an analysis of environmental and institutional factors related to such a geothermal application.

m) Provide a final report which addresses the feasibility of utilizing geothermal energy at the Pine Creek tungsten complex. If it is determined to be technically, economically and environmentally feasible to utilize geothermal heat, provide a specific plan of pilot experiments and/or detailed engineering requirements to accomplish this objective.

1.2 SCOPE OF FIRST QUARTERLY REPORT

This first quarterly report on the study of Utilization of Geothermal Energy in the Mining and Processing of Tungsten Ore documents the completion of the Start-up and Data Base Assembly Phases, and the progress to date in the Technical Approach and Approach Assessment Phases (as defined in Section 3). Section 4 evaluates the energy consumption for the Pine Creek tungsten complex for the potential application of geothermal energy. A description of the compiled geophysical data and its evaluation for determination of the geothermal resource parameters is contained in Section 5. Included in Section 6 is a preliminary evaluation of approaches to geothermal heat extraction methods of heat delivery to the mill, and identification of the processes and systems which can utilize geothermal heat within the Pine Creek tungsten complex. Section 7 provides a preliminary analysis of local environmental issues for development of a geothermal energy system, and Section 8 assesses the possible institutional barriers that would be associated with the project.

1.3 CONCLUSIONS AND RECOMMENDATIONS

Analysis of the initial geophysical data indicates a potential reservoir temperature of 116C, in the low to intermediate temperature range for geothermal utilization. Because of this indicated temperature, electrical generation is not considered feasible and the emphasis of the study has been appropriately focused on direct utilization of the geothermal energy.

The tungsten milling process is highly energy intensive, as indicated in the Energy Use Survey, Section 4. The extensive use of oil fired boilers to produce process steam is indicated as the area where replacement or augmentation of the fossil fuel with a geothermal heat source is most feasible, and therefore is the specific area where the study will concentrate. Additionally, the preliminary examination of less conventional energy alternatives shows that a potential exists for economic production of electricity from a small hydro unit at the complex. This potential is based on a complimentary combination of an elevated runoff of a reliable water source and the available altitude gradient that exists at the complex. Although this is not the main thrust of the study, a preliminary investigation and evaluation will be made of the hydroelectric generation potential as part of a hybrid geothermal heat utilization system.

SECTION 2

BACKGROUND

2.1 UNION CARBIDE CORPORATION — METALS DIVISION, BISHOP, CALIFORNIA OPERATIONS

2.1.1 General

Tungsten, one of the hardest of all metals and one of the strongest in tensile strength at high temperatures, has great industrial and national security value. Tungsten carbide is used for producing tools with extraordinary cutting ability. Tungsten is also an alloying component for steel, adding hardness. The compounds of tungsten are used in making automobile parts, fireproof cloth, pigments, X-ray screens, electric light bulbs, cutlery, electronic components, and dental and surgical instruments, as well as parts for lasers and military munitions.

More than a third of all tungsten ore in the United States is in California and Nevada. The largest mine, which is located near Bishop in Inyo County, California, has been operated by Union Carbide since 1937, providing the nation with its most important single source of the essential metal and the County with its largest private industry. More than 400 people (miners, skilled tradesmen, engineers, mill operators, and geologists) work at the Union Carbide Corporation's Bishop operation.

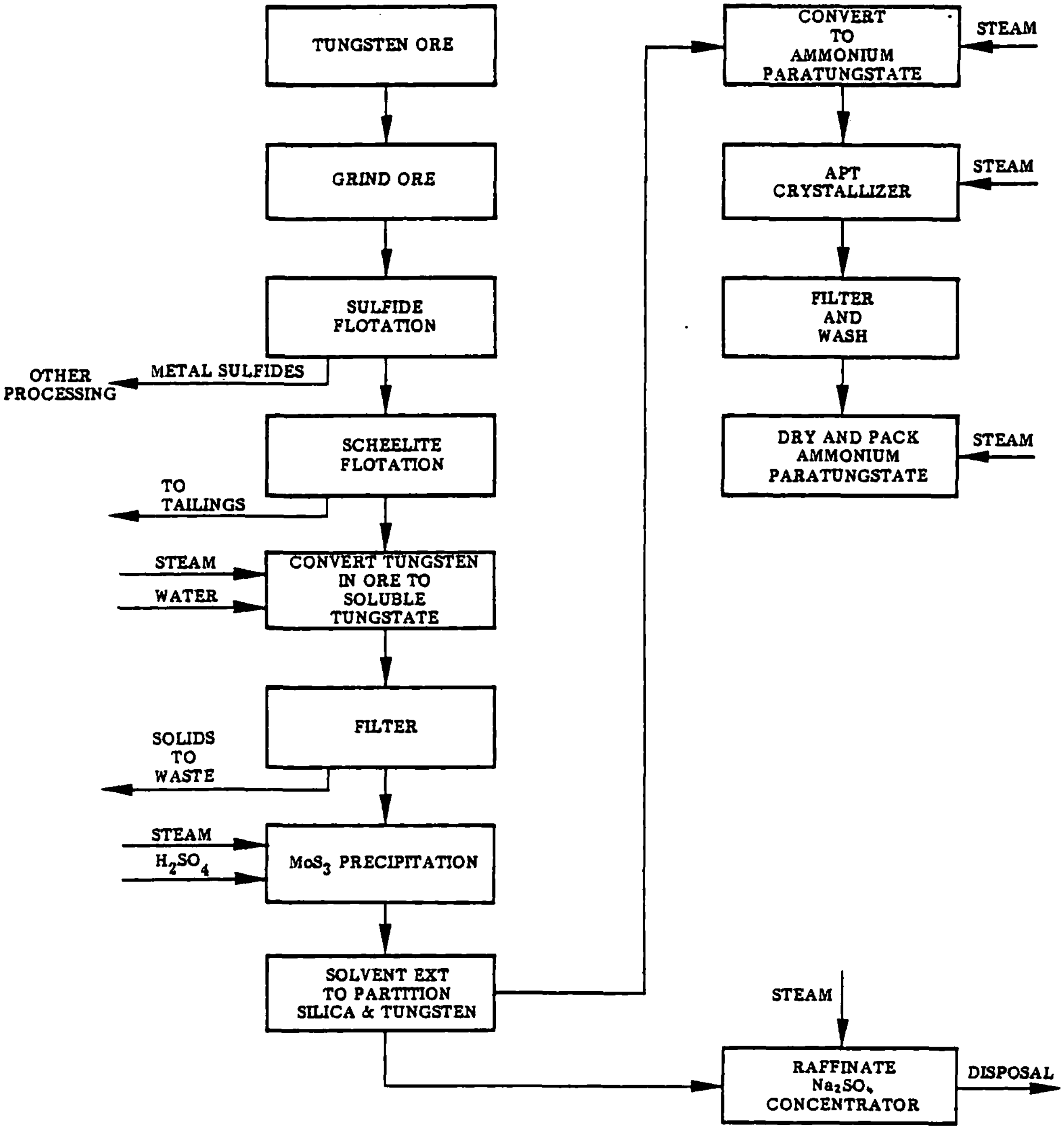
Beneath the Sierra Nevada Mountains, Union Carbide miners have excavated miles of tunnels which are connected by vertical shafts rising from the 8100-ft level to the 11,600-ft level. Ore from the mine is crushed, ground and chemically processed to a white sugar-like powder known as ammonium paratungstate. This is the main product Union Carbide ships from its Bishop operations. In addition to the principal tungsten mining, some molybdenum, an alloying metal, and copper also are mined, as well as small quantities of silver and gold.

2.1.2 Ammonium Paratungstate Process

Union Carbide owns patent rights to the ammonium paratungstate (APT) process (U.S. Patent Nos. 2,963,342 and 2,963,343). The APT process consists of a series of physical and chemical operations to extract tungsten from the raw ore and to produce a dry, solid product (see Figure 2-1). The raw ore from the mine is first crushed and ground to a small mesh size. The ground ore is then subjected to a series of aqueous flotations with chemical additives to remove heavy metal sulfides, resulting in a solution with a higher concentration of scheelite (tungsten bearing mineral).

The scheelite concentrate is then mixed with soda ash and water before being pressure digested in an autoclave. This operation puts the tungsten in solution so that it can be separated from the gangue (waste material) by filtration. This solution is filtered and the solids are sent to waste.

The tungsten-rich solution then goes through a series of proprietary solvent extraction operations which converts the tungsten to ammonium tungstate. This



SCHEMATIC FOR THE PROCESSING OF TUNGSTEN ORE

FIGURE 2-1

solution is processed in a crystallizer to produce solid ammonium paratungstate. The wet solids are then dried and packaged for shipment.

2.1.3 Energy Utilization

The Pine Creek tungsten operation is entirely dependent on fuel oil for the production of process steam and on electrical energy for prime movers. The processing mill operates 24 hours per day, seven days per week. Operational steam demand for the complex is 64,000 lb/hr which is presently generated with package boilers utilizing 3,355,000 gallons of fuel oil per year. The total electrical demand of the facility is 36 million killowatt hours per year.

The existing steam system is of the "once-through" design with no condensate return system. This is due in part to the direct injection of approximately 46,000 lb/hr of steam into the process. Another 5000 lb/hr are consumed in the mine for space heating and hot water; the remaining steam usages cannot justify a condensate return system.

SECTION 3

STUDY METHODOLOGY

3.1 SCOPE OF WORK

This section discusses the study methodology that has been developed to accomplish the technical objectives of the study as outlined in Section 1. A Study Implementation Plan showing work flow is provided at the end of this section and is labeled Figure 3-1. This diagram provides identification of study phases, key tasks, project schedule and deliverables and is keyed to the task descriptions that follow.

3.1.1 Start-up Phase

This task includes project assignment and detailed briefing on the objectives of the study for individual study team members. During this phase, the project management and DOE representatives established procedures for contract technical management, monitoring and reporting.

3.1.2 Data Base Assembly Phase

This phase consists of six primary tasks (D-1 through D-6), each of an information/data collection nature.

Task D-1: Survey of Energy Use in Mine and Mill

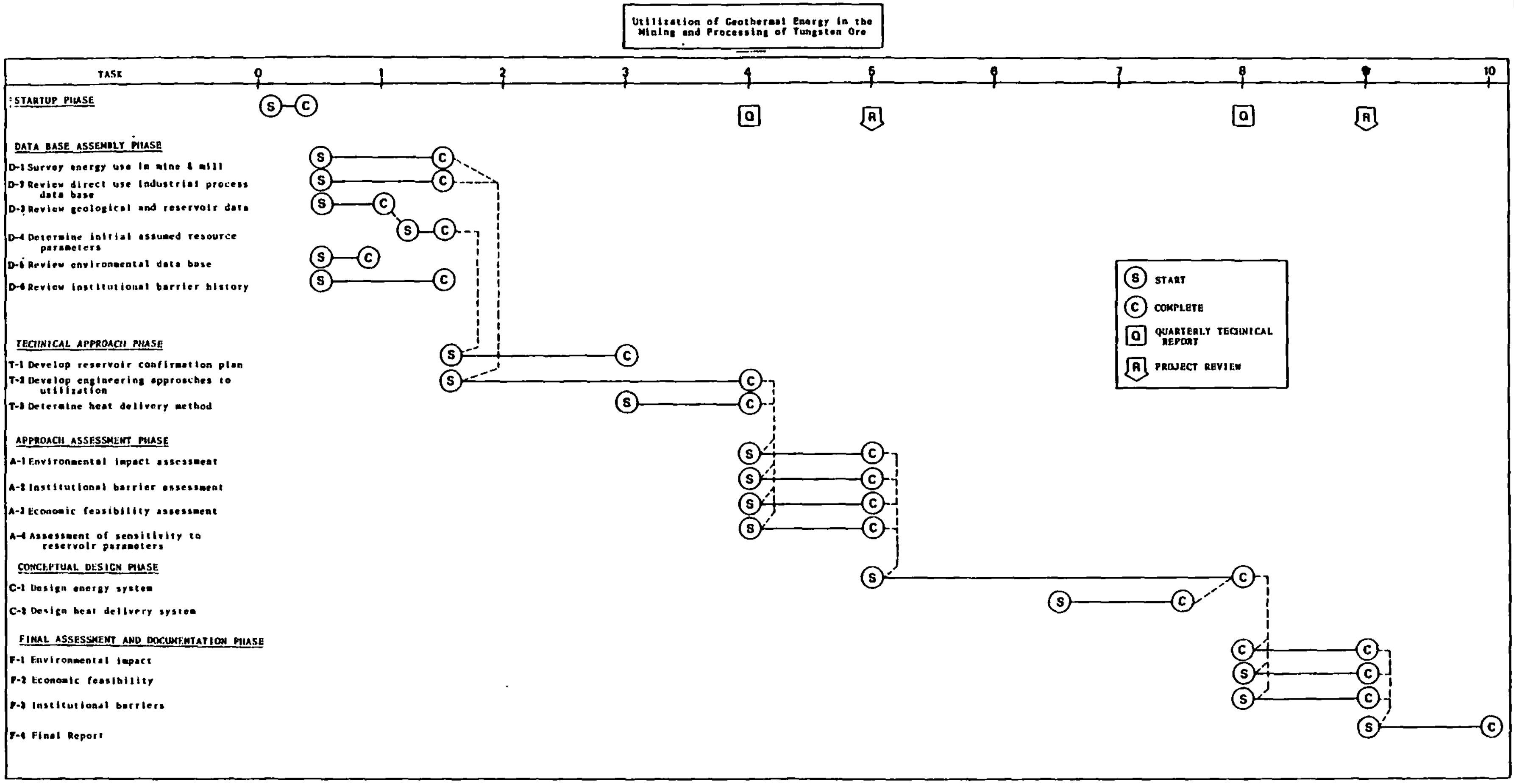
This task involves the conduct of a comprehensive energy survey to quantify energy use in the tungsten extraction process and other systems in the mine and mill, and to identify those elements which could directly utilize geothermal heat as a substitute for fossil fuel.

Task D-2: Review of Industrial Processing Direct Use Data Base

The study will utilize the data base available from previous DOE-sponsored engineering and economic studies in the industrial direct use field and research the additional application techniques required for the site-specific application.

Task D-3: Review of Available Area Geological and Reservoir Data

Because of the proximity of the Mono-Long Valley KGRA and conventional mineral resources, a considerable body of information exists which will be helpful in developing a viable reservoir confirmation plan. This information will also be directly applicable to the immediate follow-on task of determining the initial geothermal resource parameters to be used in the technical approach phase.



STUDY METHODOLOGY

FIGURE 3-1

Task D-4: Determination of Initial Geothermal Parameters to be Used in Technical Approach Phase

Based on a review of the available area geological and implied reservoir data, initial reservoir parameters will be determined.

Task D-5: Review of Available Environmental Data Base

Because the Mono-Long Valley KGRA is partially located on Federal land including some National Forest land, environmental statements were published as early as 1973 by the Department of the Interior to support the geothermal leasing program. This and other available data will be assembled and analyzed to determine additional environmental data baseline requirements.

Task D-6: Review of Institutional Barrier History for Mono and Inyo Counties

This task includes a literature search and review for identification of possible institutional barriers for geothermal development concerning Inyo County, the location of the Pine Creek tungsten complex. It is expected that the institutional barriers for this location will be similar to those already identified for Mono County.

3.1.3 Technical Approach Phase

This phase consists of three tasks (T-1 through T-3) with a Technical Approach Plan as a final product. The purpose is to focus on those geothermal application approaches appropriate to the energy requirements of the Pine Creek complex with due regard for probable resource parameters.

Task T-1: Develop a Reservoir Confirmation Plan

The reservoir confirmation plan will be developed as a four-phase effort:

Phase I: Geochemical evaluation of existing surface emanations and utilization of surface geophysical exploration techniques.

Phase II: Drilling of an exploratory well and conduct of borehole geophysical surveys and geochemical studies.

Phase III: Development of data models to allow predictions for additional test well drilling.

Phase IV: Development of reservoir parameters and determination of economic viability.

Task T-2: Development of Engineering Approaches for Heat Utilization

This task is to select specific state-of-the-art application techniques from those available in the literature and to develop the additional application techniques required for geothermal heat utilization within the Pine Creek complex.

Task T-3: Determine Geothermal Heat Delivery and Distribution Methods

This task will identify methods to minimize transportation and distribution costs and define the minimum geothermal heat demand rates required for a cost effective system.

3.1.4 Approach Assessment Phase

This phase consists of four concurrent tasks (A-1 through A-4) which evaluate the Technical Approach Plan to ensure that it is appropriate for further development in the conceptual design phase.

Task A-1: Environmental Impact Assessment

This task is basic to acceptance by local government and the rural-oriented community and will identify adverse impacts that can be attenuated by appropriate conceptual design work.

Task A-2: Institutional Barrier Assessment

This task will identify institutional barriers and allow early focus on resolution of problems.

Task A-3: Economic Feasibility Assessment

This task to test the viability of the technical approach will be an initial economic evaluation of the potential for using geothermal heat based on the developed application techniques.

Task A-4: Assessment of Sensitivity to Reservoir Parameter Changes

The Technical Approach Plan will be reviewed for sensitivity to reasonable changes in the parameters of the geothermal reservoir.

3.1.5 Conceptual Design Phase

The input to this phase is the Technical Approach Plan as modified by the environmental, economic, institutional barrier and reservoir parameter change assessments. There are two tasks, C-1 and C-2, which will result in a completed Conceptual Engineering Plan as a product.

Task C-1: Conceptual Design of Geothermal Energy System

Utilizing parameters implied by the potential resource, a conceptual design of a geothermal energy system that could utilize steam in the Pine Creek tungsten extraction operation will be developed. If appropriate, some concurrent generation of electrical power will be included.

Task C-2: Design of Heat Delivery and Distribution System

This task includes route, material, insulation and sizing parameter selection for geothermal fluid transmission to the Pine Creek complex and return of the fluid to the reservoirs.

3.1.6 Final Assessment and Documentation Phase

The final phase of the study effort is an assessment of the conceptual engineering plan divided into four tasks (F-1 through F-4), to document environmental acceptance, economic feasibility, and institutional compatibility.

Task F-1: Final Environmental Impact Assessment

The work will be the same as in the approach assessment phase but will investigate only those elements that have changed since the completion of the Technical Approach Phase.

Task F-2: Final Economic Feasibility Assessment

Using a model of the conceptual system and reservoir heat pricing data, a final test of economic viability will be made.

Task F-3: Final Institutional Barrier Assessment

The work will be the same as in the Approach Assessment Phase but will investigate only those elements that have changed since the completion of the Technical Approach Phase.

Task F-4: Final Report

The final technical report, supplemented with engineering drawings will provide a full review of the study results. Contingency plans will be included for a possible follow-on field experiment which might be required to demonstrate technical viability. Delivery of the final report is scheduled for 10 months after contract award and the report preparation will take one month.

3.2 STUDY METHODOLOGY DIAGRAM

The study approach as described in Section 3.1 is depicted graphically as a work flow diagram with identification of schedule and product deliverables in Figure 3-1.

SECTION 4

ENERGY SURVEY AND DATA REVIEW

4.1 ENERGY USE SURVEY

4.1.1 Background

A detailed engineering survey of the mill was conducted to identify which processes could potentially utilize geothermal heat as a substitute for fossil fuel generated heat. The survey concentrated on development of a model for the mill steam usage, since the primary opportunity to substitute geothermal heat for fossil fuel energy will be in the reduction of fired steam production.

4.1.2 Present Energy Consumption

The Pine Creek tungsten complex relies solely on purchased electricity for prime movers and fuel oil for the production of process steam. A survey was completed of current energy consumption at the Pine Creek tungsten complex to evaluate the potential for utilizing geothermal energy.

4.1.2.1 Electrical Consumption

Electricity for Union Carbide's tungsten complex is produced at a hydroelectric power generation plant approximately twenty-eight miles from Union Carbide's facilities and purchased from Southern California Edison (SCE). Power from the SCE plant is carried via a 55,000 V transmission line and is transformed onsite to 12,480 V for delivery.

Large pieces of rotating machinery including ball and rod mills, compressors and pumps are used in the mill for the processing of tungsten ore. An electrical use survey at the Pine Creek tungsten complex, listing major pieces of equipment and their electrical requirements, is shown in Table 4-1. Approximately 36 million kilowatt hours are required for the continuous operation of the mill at a cost of 3.7 cents per kilowatt hour. The feasibility of electrical production onsite will be investigated for unconventional alternatives such as geothermal or small scale hydro generation facilities.

4.1.2.2 Steam Consumption

Large amounts of steam and clean water are needed for processing tungsten ore. The mine cuts across several water bearing fractures which results in a drainage of 7-8000 GPM that collects at the lowest level of the mine. From there it is pumped to a water clarifier which supplies water for process use and the water required for process steam.

Three oil fired boilers provide process steam to the Pine Creek tungsten complex. Steam consumption to the mill is supplied through a 240 psi steam header with pressure reducing stations to throttle the steam to the pressure levels required for

TABLE 4-1

UNION CARBIDE ELECTRICAL SURVEY SUMMARY

EQUIPMENT	AMPS	VOLTS	KVA	KW
B&W Boiler M.C.C. 107 Main	70	460	56	46
B&W Boiler Fan 100 HP	62	460	49	41
Agitators, Filters, M.C.C. 108 Main	50	465	40	24
Digester M.C.C. 109 Main	29	465	23	13
Digester M.C.C. 15 HP	3	465	2.4	.6
Boilers M.C.C. 110 Main	115	465	92	79
Boilers Water Pump 40 HP	265	465	21	19
Boilers Water Pump 60 HP	55	465	44	38
Edwards Roaster M.C.C. 111 Main	140	465	113	106
Edwards Roaster Scrubber Fan	45	465	36	35
Stripper Column Fan 75 HP	48.5	465	39	32
Rafmate Main	400	465	322	261
Crystalizing Circulation Pump 60 HP	67	465	54	40
Evap. Pump Dr. 75 HP	50	465	33	33
Water Reclaimer 60 HP	66	465	53	47
Slurry Agitation Dr. 60 HP	50	465	40	33
Batch Mixing M.C.C. 112 Main	130	465	105	78
30 Transfer Pump	38	460	30	25
Agitator M.C.C. 114 Main	92	460	73	51
Agitator 40 HP	16	465	7	2
Batch Mix 40 HP	35	465	28	22
Main 3000 AMP	1320	470	1075	784
Apt Main, 600 AMP (3 M.C.C.'s)	135	465	109	71
Crusher Area one M.C.C.	80	470	65	57
Crusher Area two M.C.C.	100	470	81	73
Crusher Area Jaw Crusher 150 HP	110	470	88	88
Crusher Area Cone Crusher 150 HP	140	470	112	95
Ball & Rod Mill M.C.C. #2 Main	300	460	239	186
Cyclone Feed Pump #1	140	460	112	97
Cyclone Feed Pump #2	140	460	112	97
Floats M.C.C. #3 Main	230	465	185	128
Floats M.C.C. #4 Main	210	440	160	112
Floats 20 HP (9 Units)	14	460	11	8
Air Blower 25 HP	14	460	11	9
M.C.C. 101 Main	85	465	68	40
Wolframite M.C.C. 102 Main	270	465	218	180
6x5 Ball Mill 100 HP	110	465	89	75
5x6 Ball Mill 60 HP	80	465	64	46
M.C.C. 106 Main	200	465	161	97
Air Compressor	110	470	80	80
Air Compressor	135	465	628	53
Vacuum Pumps 30 HP (4)	22	465	18	14
Floats 20 HP (10 units)	22	465	18	12

various process stages. Seventy-two percent (46,000 lb/hr) of the produced steam is used for direct injection into the ore process stream. The steam is injected for three reasons:

- To provide the heat required to carry out the chemical reactions.
- To provide dilution of the process stream.
- Due to the corrosive nature and the fouling tendencies of the slurries being processed, direct injection is economical.

A general schematic for mill steam usage as related to the Ammonium Paratungstate (APT) process is shown in Figure 4-1.

Raffinate, a byproduct of the APT process, is treated in a highly energy intensive process that removes and concentrates sodium sulfate prior to disposal. The process does not require direct steam injection (see Figure 4-2) but uses nearly twenty percent of the mill's produced steam for waste treatment.

The steam usage in the Pine Creek complex was evaluated to determine where geothermal fluid could replace fuel oil as an energy input. Because the processing of tungsten ore is highly energy intensive, a reduction in fuel oil required per pound of steam produced could result in substantial savings.

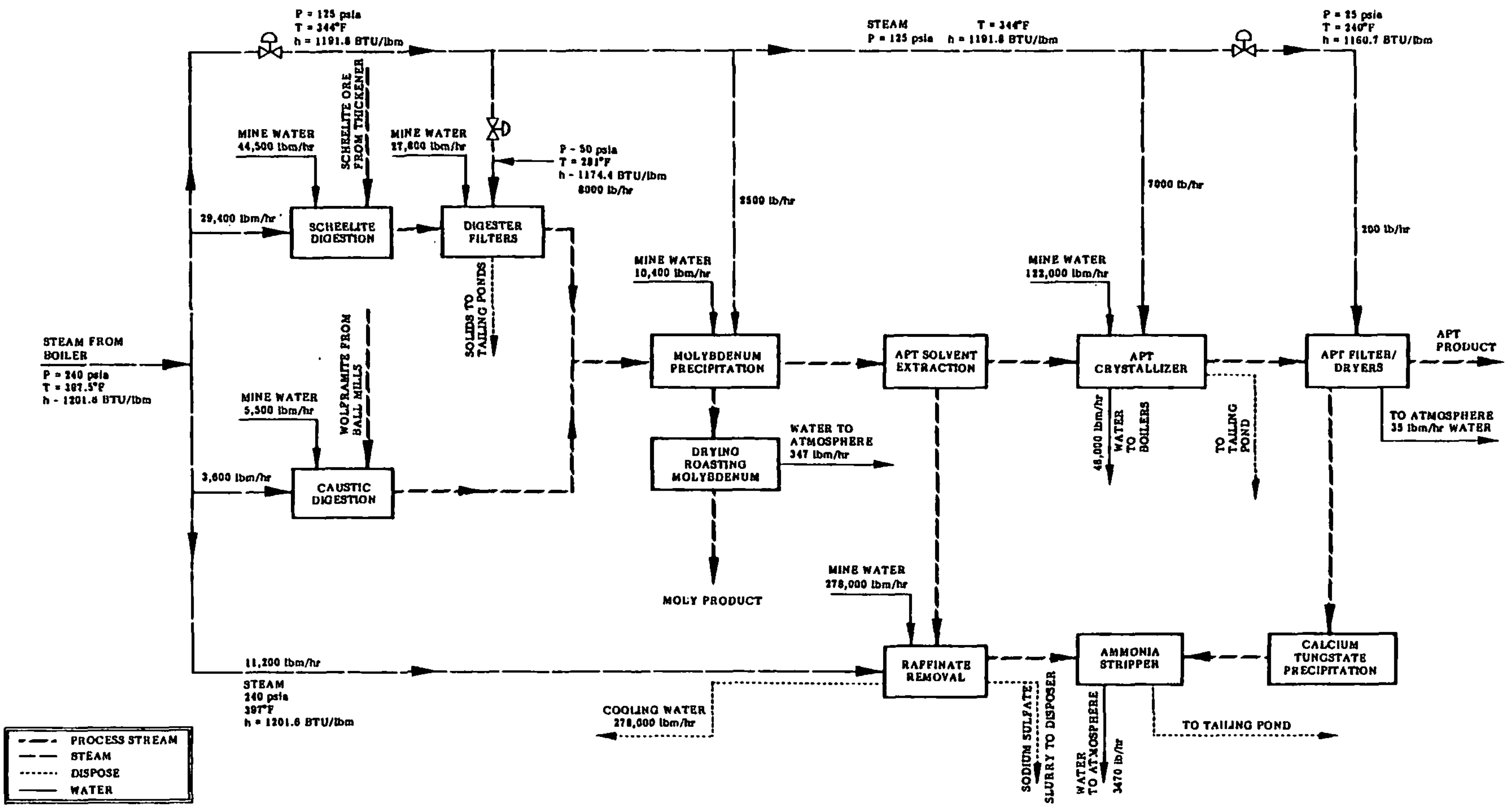
4.1.3 Geothermal Applications at the Pine Creek Tungsten Complex

4.1.3.1 Introduction

Energy is available in geothermal brine as heat. Therefore, applications for geothermal energy utilization will be analyzed in terms of economic and technical feasibility of direct or indirect heat conversion. End uses were evaluated for geothermal application based on the present source of energy use, its impact on the total energy consumption, its adaptability to using geothermal brine with available equipment, and its practicality for adapting to geothermal energy.

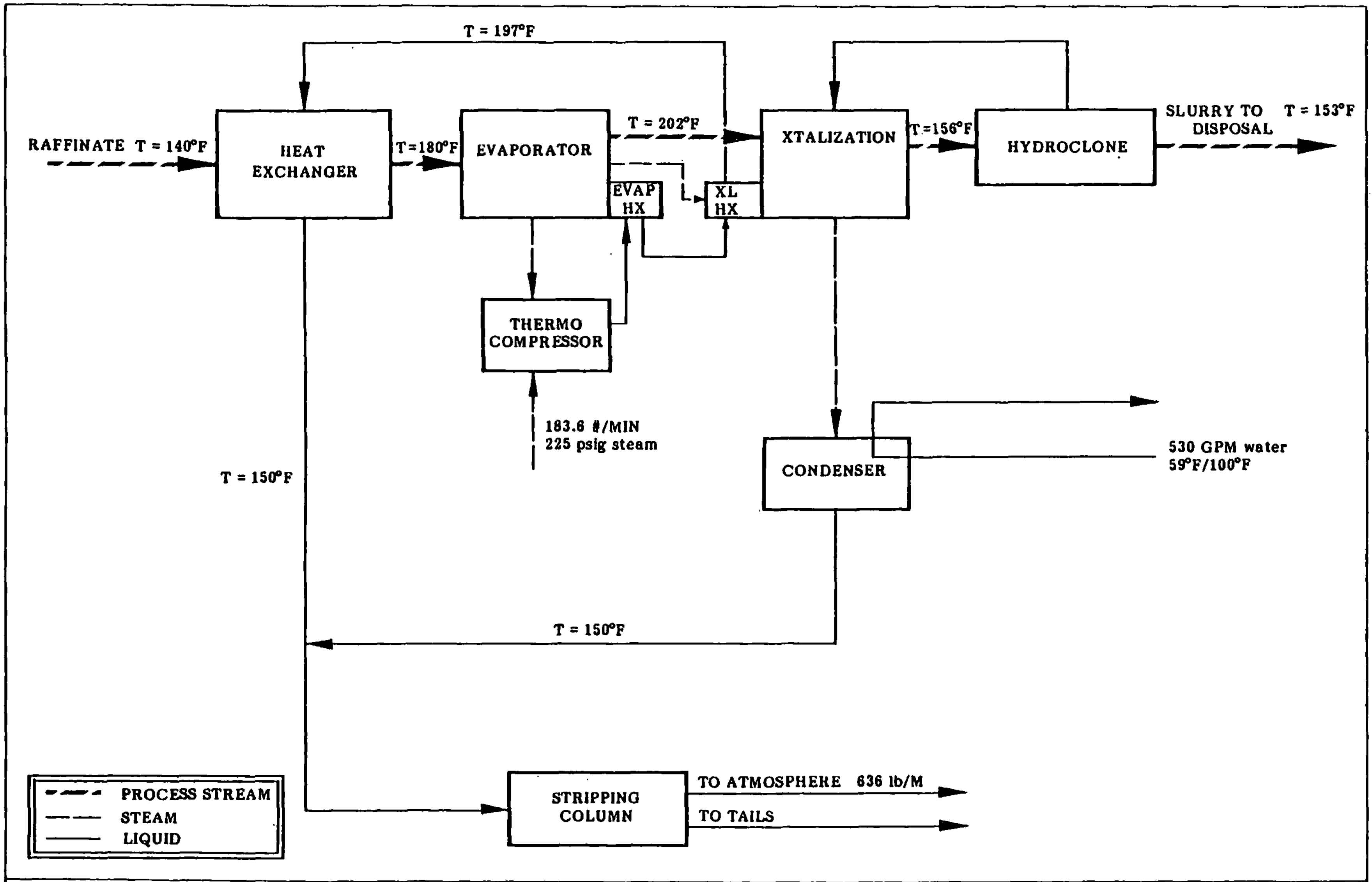
Process steam for the Pine Creek tungsten complex is presently supplied through a 240 psia steam header. As a large portion of this steam is directly injected into the process stream, geothermal brine cannot be used in direct applications because the predicted reservoir temperature is cooler than the required temperature for direct injection of 397F.

The highest potential for geothermal applications will be in utilizing brine through heat exchangers to preheat water to the boilers, to provide space heating, and to heat additives prior to their introduction into the process stream. Because of the relatively clean geothermal fluid expected in the area, which will make solid deposition insignificant, the minimum temperature allowed for reinjection will be 0C. Cascading heat requirements as shown in Figure 6-2 will improve system efficiency by utilizing a large portion of the heat contained in the brine before disposal. Portions of the plant energy cycle which already use indirect heating via heat exchangers can be replaced with alternate heat exchangers using a lower temperature fluid while maintaining the same heat transfer rate.



MODEL FOR MILL STEAM USAGE

FIGURE 4-1



RAFFINATE TREATMENT

FIGURE 4-2

4.1.3.2 Boiler Water Preheat

Using the data supplied by Union Carbide, it was determined that a substantial decrease in fuel consumption would occur if the incoming water was preheated via geothermal fluid. If make up water from the mine at 44F is preheated in a counterflow heat exchanger with an efficiency of .8, an inlet temperature to the boiler of 200F can be obtained saving 156 Btu/lb water. Currently, 72 percent (132,000 GPD) of the water entering the boiler is preheated to 140F by passing through the APT crystallizer. With the remaining 28 percent (53,000 GPD) of the incoming mine water to the boiler utilizing geothermal preheat, 2.9×10^6 Btu/hr of conventional fossil fuel energy can be replaced. This is a thirteen percent reduction in the amount of energy supplied by fuel oil for the make up water. The brine exit temperature can be between 180-200F, making it possible to extract more energy for space heating or alternate uses. Specific applications will be discussed in more detail as the project continues.

4.1.3.3 Space Heating

Space heating is the most versatile use for the heat extracted from geothermal fluid. High reservoir temperatures are not required nor is the technology complicated. Geothermal water ranging from 48-114C is currently being used to heat homes and commercial establishments in Klamath Falls, Oregon, and Reykjavik, Iceland. The water is used for space heating by circulating it through very large radiators, or by transferring the heat to a closed system supplied with clean municipal water. Current space heating at the Pine Creek tungsten complex is accomplished with a fuel oil-fired furnace for the office buildings, and 6000 lb/hr of steam at 240 psia for the mill and change room. This space heating requirement can be replaced or augmented with geothermal fluid via a different distribution system as the temperatures required for space heating are compatible with the geothermal resource.

4.1.3.4 Current Heat Exchangers

There are currently two heat exchangers at the Pine Creek tungsten complex that utilize steam to heat the process stream in the APT crystallization portion of the cycle. Each of these heat exchangers uses 3500 lb/hr of steam at 130 psi, with a heat transfer rate of 3.1×10^6 Btu/hr. Heat exchangers are also used in processing raffinate, a waste byproduct of the ammonium paratungstate process, which use steam at the rate of 11,200 lb/hr.

Major equipment modifications would be necessary to replace the current exchangers using geothermal heat. A larger heat exchanger or several heat exchangers in series will be required, but will be acceptable if the overall heat transfer rate remains constant. Liquid - liquid heat exchangers will be evaluated for their economic and technical feasibility for this application.

Scaling is expected to be a minimal problem as initial water analysis and a geologic review of the area indicate that there will be a low percentage of dissolved solids in the geothermal fluid because of the expected reservoir temperature and the geology of the area. If the heat in the geothermal fluid is extracted prior to entry to the tungsten mill, the problems associated with geothermal heat extraction (see Section 6) such as solid deposition can be confined to one location.

4.2 REVIEW OF ENERGY DATA

A review was made of the direct use industrial process data available from previous DOE sponsored engineering and economic studies to evaluate the application techniques of geothermal energy to the Pine Creek project. The practical methods of geothermal heat extraction, transmission, storage, and delivery to the tungsten mill were made in the review process, as well as the materials being used for geothermal applications. This review process was done to enhance the knowledge of application techniques for the technical feasibility of utilizing geothermal energy to replace conventional forms of energy at the Pine Creek mill. Additional information concerning the review of direct use industrial process data can be found in Section 6 of this report.

SECTION 5

THE GEOTHERMAL RESOURCE

5.1 INTRODUCTION

A search of published literature and the files of public agencies was conducted to establish the basis for interpreting the geology, geophysics and hydrogeochemistry in the vicinity of the Pine Creek Mine. These searches, together with a groundwater sampling and analysis program, are the basis for the following review of geologic data.

5.2 REVIEW OF GEOLOGIC DATA

The Pine Creek Tungsten Mine is developed within a pendant of Paleozoic metasedimentary rocks which cap portions of the Sierra Nevada batholith. This pendant has been exposed through erosion along the uplifted Eastern Sierra escarpment. Associated with the faults which created this escarpment are several geothermal features: the Long Valley Caldera hydrothermal system and the Bishop Tuff, scattered hot springs (particularly, Keough Hot Spring), and water chemistry anomalies. In addition, the Pine Creek Tungsten Mine and Mill are located within a prospective geothermal resource area identified on the National Oceanic and Atmospheric Administration (NOAA, 1971) Map of Geothermal Energy Resources of the Western United States, prepared by the National Geophysical and Solar-Terrestrial Data Center. The same area, however, was not classified as a potential geothermal resource area in a latter edition of this map published with U.S. Geological Survey Circular 790 (Muffler, 1979).

The geology of the region and water chemistry anomalies in the vicinity of the Pine Creek Mine have been investigated by Bateman (1965). As shown in Figure 5-1 (see pocket at end of report), Pine Creek Mine is located near the upper end of the alluvium-filled glacial canyon of Pine Creek. Glacial deposits, particularly lateral moraines, extend outward from the mouth of Pine Creek Canyon into Round Valley. Round Valley is a structurally depressed block filled with interbedded alluvium and pyroclastic deposits of the Bishop Tuff. No bedrock outcrops are present in Round Valley, but gravity data indicated that the alluvial fill of the valley is relatively shallow.

The western side of Round Valley follows the base of Wheeler Crest and the front of the Sierra Nevada mountain range (Figure 5-1). Groundwater discharges as springs along the range front. Some of these springs are directly associated with faults, whereas others apparently are not. Springs within the Sierra block in the vicinity of the Pine Creek Mine discharge from joints in the bedrock. Groundwater in Round Valley occurs at moderate depths (30+ meters), and has been intercepted by several wells.

Analysis of waters from several springs and wells in the vicinity of the Pine Creek Mine is available in the published literature and from the files of the California Department of Water Resources, southern district. Table 5-1 lists the available analyses and the sampled locations are shown in Figure 5-1. Three of these samples were from Sierra frontal springs while the remaining seven were from wells in Round Valley. Application of the Na-K-Ca geothermometer (Fournier and Truesdell, 1973) to

Table 5-1

GROUNDWATER QUALITY ANALYSES IN THE VICINITY OF THE PINE CREEK MINE-OBTAINED FROM LITERATURE AND AGENCY SEARCH

LOCATION (date collected)	TEMP-ERA-TURE °C	pH	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	Cl mg/l	F mg/l	NO_3 mg/l	B mg/l	SiO_2 mg/l	TDS	REF-ER-ENCE	TEMPERATURE °C Na-K-Ca Geotherm-ometer	REMARKS
04S/29E 36R01 (11-8-59)	10	7.6	6.9	0.6	9.2	0.7	0.3	0.2	0.9	—	19	63	USGS WSP 1535-I	10.7	Perennial spring along Sierra Front
05S/30E 14E01 (11-8-59)	8.3	6.5	6.8	0.1	6.1	0.9	0.2	0.1	0.2	—	20	55	USGS WSP 1535-I	18.2	Perennial spring along Sierra Front
05S/30E 26H01 (11-8-59)	"Cold"	6.7	6.2	0.8	10.0	1.2	0.2	0.1	1.0	—	16	63	USGS WSP 1535-I	14.9	Perennial spring along Sierra Front
06S/31E 14G01 (03-02-70)	—	7.4	23.0	3.0	62.0	6.0	7.0	0.3	1.8	0.00	—	343	Cal. DWR Bull. 130-70	27.3	Well in Rovena
06S/31E 20H01 (06-25-60)	—	7.4	27.0	2.0	29.0	2.0	16.0	0.4	3.1	0.06	11.0	284	Cal. DWR WDIS File	31.0 Ave. 29.4	Residential Well
(02-09-61)	—	6.6	26.0	2.0	35.0	2.0	18.0	—	3.9	0.03	13.0	181	Cal DWR WDIS File	27.7	
06S/31E 21D01 (07-14-55)	—	7.2	9.0	3.0	39.0	3.0	14.0	0.4	1.0	0.02	—	210	Cal. DWR WDIS File	27.3 Ave. 28.8	Round Valley School Well
(02-09-61)	—	6.9	14.0	3.0	40.0	3.0	14.0	0.1	4.1	0.02	18.0	282	Cal. DWR WDIS File	30.4	
06S/31E 22B01 (07-14-55)	—	7.4	7.0	2.0	19.0	3.0	3.0	0.4	1.5	0.00	—	140	Cal. DWR WDIS File	27.0 Ave. 19.6	Residential Well (Possibly same as South Schober Well)
(02-08-61)	—	7.5	7.0	1.0	18.0	2.0	2.0	0.1	4.1	0.01	21.0	64	Cal. DWR WDIS File	12.3	
06S/31E 23N01 (02-09-61)	—	7.1	10.0	2.0	35.0	1.0	2.0	0.2	5.3	0.01	42.0	133	Cal. DWR WDIS File	20.0	Residential Well
06S/31E 26E01 (02-09-61)	—	7.1	6.0	1.0	19.0	1.0	0.0	0.0	0.9	0.01	30.0	74	Cal. DWR WDIS File	10.3	Residential Well
06S/31E 31J01 (07-14-55)	22.2	7.3	21.0	1.0	14.0	0.0	3.0	0.5	0.0	0.00	—	145	Cal. DWR WDIS File	24.1	Residential Well

these available Round Valley Spring analyses shows hypothetical rock-water equilibrium temperatures for most of the groundwaters from Round Valley to be 10C higher than those from the Sierra Frontal springs (Table 5-1).

The closest water analysis shown in Table 5-1 is ten kilometers from the Pine Creek Mine. Thus, to obtain more locally pertinent data, groundwater analyses were obtained from personnel at the mine. These analyses were for specific constituents of interest to pollution control agencies, and therefore did not include constituents which are of direct use for this study. However, discussion of the hydrologic features of the Pine Creek Mine with Union Carbide officials yielded the following potentially significant information:

- "Warm" water discharges into a portion of the mine in a drift about 500 meters from the entrance to the Easy Going Tunnel, the mine's main entrance.
- A "warm" spring is present along Gable Creek, about 1.5 kilometers upstream from its confluence with Pine Creek (2.5 kilometers west of the mine portal).
- Wells at Rovana and the Round Valley School are about 120 meters deep whereas the well at the California Conservation Corp camp is about 366 meters deep (Figure 5-1).
- No supporting geophysical data covering the vicinity of Pine Creek Mine are available.

5.3 DATA COLLECTION PROGRAM

Based on the foregoing, a hydrologic data collection program was designed and implemented by WESTEC Services with the cooperation of Union Carbide specifically for this project. Briefly, the program was formulated to investigate actual temperature, hypothetical rock-water equilibrium temperature, and hot water/cold water components in the warm waters of the Pine Creek Mine. In addition, the program investigated mixing proportions of hot water/cold water and hypothetical rock-water equilibrium temperatures, as well as possible hot water component source characteristics of groundwaters in Round Valley.

Groundwater sampling points (shown in Figure 5-1) were selected on the basis of mapped locations of springs and wells and on interpretations from existing geologic maps. Emphasis was given to collecting water from the following sources:

a) Warm and cold groundwater from inside the Easy Going Tunnel.

b) Warm groundwater from the Gable Creek warm spring.

c) Groundwater from various types of Sierra frontal springs.

d) Groundwater from sources located above and below the Bishop Tuff in Round Valley.

e) Miscellaneous springs and wells.

Samples from each locality were analyzed in the field for temperature, pH, bicarbonate and silica (see Table 5-2). Field determination for iron, nitrate, ammonia and dissolved oxygen were attempted, but could not be accurately analyzed due to the extremely aerated condition of the water being sampled.

Replicate samples were obtained from each locality for additional analysis by an outside laboratory. These analyses will include determinations of all pertinent dissolved chemical species. In addition, five samples are being analyzed for tritium content for groundwater age estimation, and nine samples are being analyzed for deuterium and oxygen-18 content to aid in determining water-rock reactions and heating relations. Results of the laboratory analyses will be available in late March 1980.

The preliminary plan called for sampling for analysis of carbon^{13} and carbon^{14} for groundwater dating and for analysis of oxygen^{18} in dissolved sulfate for SO_4 and H_2O equilibrium relations. However, based on the results of field testing, these latter two analyses were abandoned. Specifically, field determinations of bicarbonate indicated such low concentrations as to preclude the feasibility of collecting samples for C^{13} and C^{14} (up to 3000 liters would have been required for C^{14} dating) because of the necessity to avoid atmospheric contamination. Similarly, in addition to sample contamination from milling activities, sulfate was too low to feasibly collect.

The locations of groundwater sampling sites are shown in Figure 5-1. Concentrations of field determined constituents (primarily silica) are considered tentative, and are used as a basis for the interpretation of geothermal resource temperatures presented in Section 5.4. More refined interpretations will be made following completion of the laboratory analyses.

Interpretation of the geothermal character of groundwaters in the project area was originally intended to emphasize the results of analyses of water samples from various depth ranges, particularly in Round Valley. This was believed to be possible because of the previously mentioned shallow (122 meters) and deep (366 meters) wells which reportedly occur in Round Valley. The shallow wells receive water from above and within the upper portion of the Bishop Tuff, whereas the deep well was believed to receive water from below the Bishop Tuff. However, upon site investigation and interviews with the personnel at the California Conservation Corporation (CCC), it was learned that the "deep" well which the CCC owns may be only about 60 meters deep, not 366 meters. The resolution of these conflicting statements will be possible after a review of pertinent well logs on file at the California Department of Water Resources.

5.4 DETERMINATION OF GEOTHERMAL RESOURCE TEMPERATURE

A major objective of the data collection program described above was to determine probable reservoir temperatures for the hot water component contributing to the thermal character of local groundwaters. Since groundwater recharge in the Pine Creek Mine area is primarily through infiltration of snow melt water (total precipitation in the project watershed is approximately 85 percent snowfall) (Bateman, 1965), any groundwater showing a temperature significantly above 0C must have been heated by some means or another. Two obvious non-geothermal modes exist whereby the temperature of newly infiltrated snow melt may be increased: solar heating before

TABLE 5-2

LOCATIONS AND ANALYSES OF WATER SAMPLES COLLECTED

Map Designation Figure 1	Sample Location	Location Name	Temp °C	pH	SiO_2 (mg/l)	HCO_3^- (mg/l)
A	06S/31E 31R01	"Basco" Spring	12.3	5.1	15.0	4
B	07S/30E 8C01	Easy Going Warm Spring	19.9	5.8	16.5	0
C	06S/30E 31R01	Easy Going Cold Spring	7.6	5.0	10.5	1
D	07S/30E 9Q01	Gable Creek Spring	13.4	5.0	13.5	3
E	07S/30E 8A01	Mill Spring	8.3	4.9	10.5	9
F	06S/31E 19G01	Rovana Water Supply Well	12.7	4.8	13.5	15
G	06S/30E 26C01	Rovana Water Supply Spring	13.4	4.9	13.5	3
H	06S/31E 21E01	Round Valley School Well	12.9	5.0	16.0	12
I	06S/31E 27Q01	CCC Well	15.0	4.9	17.0	10
J	05S/30E 31N01	Mile Post 333.5 Spring	5.6	5.0	17.0	5
K	05S/30E 26H01	Ainsely Spring	13.9	4.9	16.5	3
L	06S/30E 1L01	Wells Meadow Main Spring	11.3	4.8	14.0	3
M	06S/31E 17B01	C-BAR-O Ranch Well (40 acres)	11.6	5.1	13.0	9
N	06S/31E 5H01	North Schober Well	10.7	5.1	80.0	3
O	06S/31E 22B01	South Schober Well	9.0	5.1	24.0	7
P	07S/31E 20G01	Buttermilk Spring	11.8	5.1	20.5	7

infiltration (probably a significant factor) and frictional heating from flowing through fractures (a very minor factor). These two phenomena could account for a temperature increase of several degrees. Any groundwater temperatures higher than several degrees above freezing, however, must be accounted for by geothermal heating.

Rearrangement of the water quality data in Table 5-2 brackets the samples into three temperature categories (Table 5-3). The category of temperatures lower than 10C approximately corresponds to waters whose temperature can be accounted for by non-geothermal heating. The category of temperatures higher than 15C would almost certainly require geothermal heating. The 10 to 15C temperature category indicates some degree of geothermal heating or a combination with other heating types.

Accepting the above temperature categories and causes as representative of the natural waters, mixing models developed by the U.S. Geological Survey (Fournier, 1977; Fournier and Truesdell, 1973, 1974; Fournier, White and Truesdell, 1974) can be applied to determine the temperature of the hot water fraction.

The mixing model used in this investigation assumes that infiltrating cold groundwater mixes with hot water presumably derived from depth to produce the observed warm water. Thus, in this model it is assumed that the enthalpy of the hot water that mixes with the cold water is the same as the initial enthalpy of the deep hot water. Thus:

$$(H_{cold})(x) + (H_{hot})(1 - x) = H_{spring}$$

where H_{cold} = enthalpy of the cold water,

H_{hot} = enthalpy of the presumed hot water source,

H_{spring} = enthalpy of the observed warm water,

x = fraction of cold water in the mixture, and

$1 - x$ = fraction of hot water in the mixture.

The silica content of a groundwater sample is related to its enthalpy, and therefore can be used in a similiar fashion:

$$(Si_{cold})(x) + Si_{hot}(1 - x) = Si_{spring}$$

where Si_{cold} = silica content of cold water,

Si_{hot} = silica content of presumed hot water source,

Si_{spring} = silica content of observed warm water, and

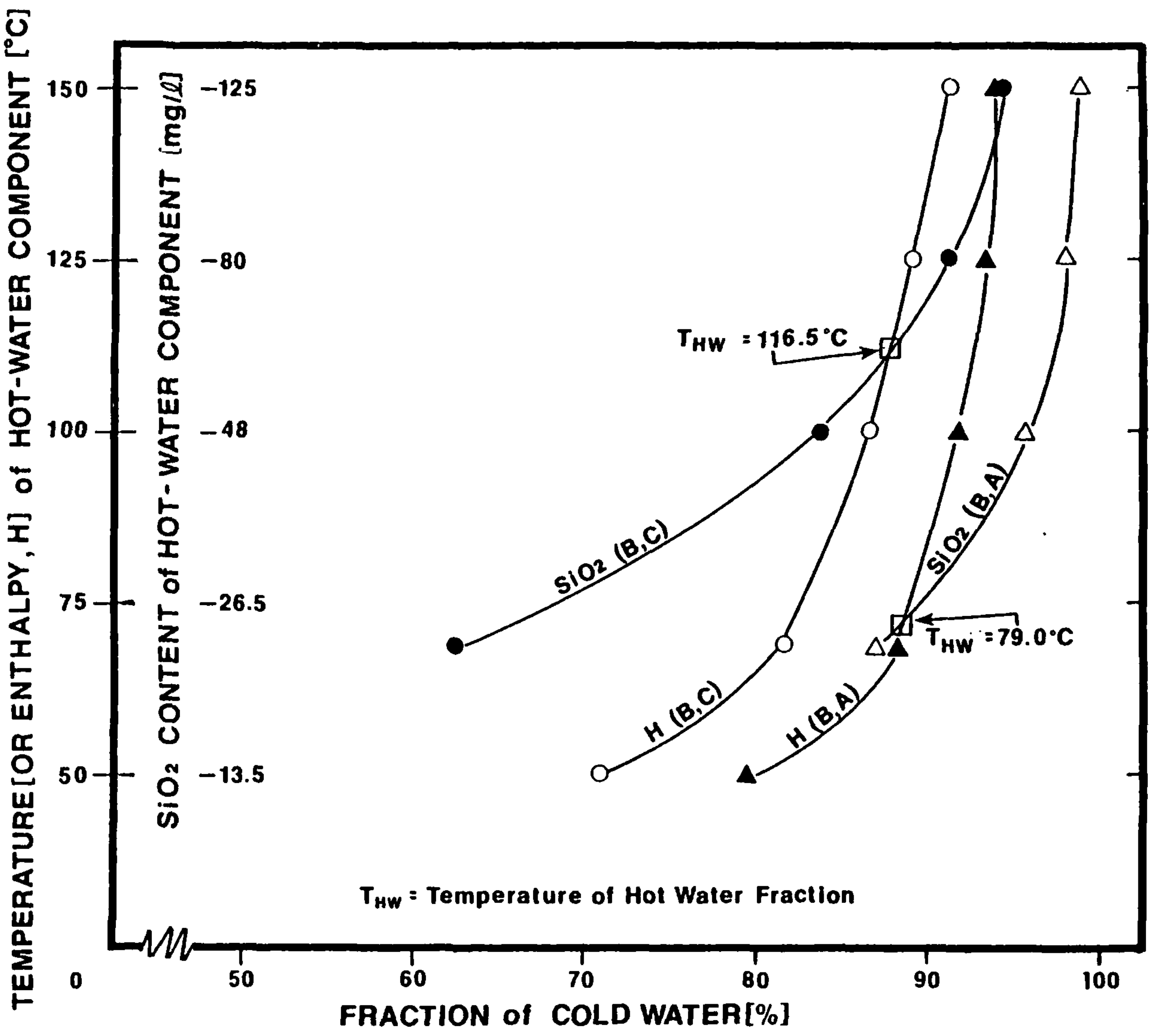
x and $1 - x$ are as in previous equation.

Figure 5-2 is a graphical solution of the above two equations based on Fournier and Truesdell's (1974) methodology, for two sets of spring waters. These two sets were

TABLE 5-3

GROUNDWATER QUALITY DATA (FROM TABLE 5-2) ARRANGED BY TEMPERATURE CATEGORY

	Less Than 10C	10 to 15C	Greater Than 15C
	Sample C (7.6C; 10.5 mg/l SiO_2)	Sample A (12.3C; 15.0 mg/l SiO_2)	Sample B (19.9C; 16.5 mg/l SiO_2)
	Sample E (8.5C; 10.5 mg/l SiO_2)	Sample D (13.4C; 13.5 mg/l SiO_2)	
	Sample J (5.6C; 10.5 mg/l SiO_2)	Sample F (12.7C; 13.5 mg/l SiO_2)	
	Sample O (9.0C; 24 mg/l SiO_2)	Sample G (13.4C; 13.5 mg/l SiO_2)	
		Sample H (12.9C; 16.0 mg/l SiO_2)	
		Sample I (15.0C; 17.0 mg/l SiO_2)	
		Sample K (13.9C; 16.5 mg/l SiO_2)	
		Sample L (11.3C; 14.0 mg/l SiO_2)	
		Sample M (11.6C; 13.0 mg/l SiO_2)	
		Sample N (10.7C; 80 mg/l SiO_2)	
		Sample P (11.8C; 20.5 mg/l SiO_2)	
Number of Samples	1	11	4
Average Temperatures	19.9C	12.6C	7.6C



PRELIMINARY GRAPHICAL INTERPRETATION OF RESERVOIR TEMPERATURE

FIGURE 5-2

selected for this preliminary analysis based on the spatial proximity of the springs and an assumed mixing of hot and cold waters at depth. One of these pairs of waters is the Easy Going Warm Spring (spring B in Table 5-2) and the Easy Going Cold Spring (spring C in Table 5-2). The interpretation of cold water fraction relative to temperature and silica content of the hot water fraction represents a mixture of groundwater from the coldest temperature group (Table 5-3) with a hot water at 116.5C to produce the water observed as discharge at the Easy Going Warm Spring. This mixture would consist of approximately 89 percent cold water.

The second pair of groundwaters used on Figure 5-2 is the Easy Going Warm Spring and Basco Spring (spring A on Table 5-2). Basco Spring is within the lower temperature category in Table 5-3. A mixture consisting of groundwater with the temperature and silica content of Basco Spring plus a hot water fraction with a temperature of 79.0C would be necessary to produce the observed warm spring waters.

Based on the foregoing preliminary data and calculations, the temperature of the Pine Creek area geothermal resource appears to lie between roughly 79C and 116.5C. Additional geochemical studies, derived from the results of pending laboratory analyses, will hopefully narrow this potential temperature range as well as provide information on the hot water component source waters.

SECTION 6

GEOTHERMAL ENERGY UTILIZATION

6.1 ENGINEERING APPROACH

The information from available geothermal direct use projects was evaluated to determine the feasibility of applying techniques that could be used in the Pine Creek project especially as to materials used, heat exchange methods, piping systems, heat delivery methods, heat storage, and application techniques for a geothermal energy system. Specific end uses which appear to have the highest potential for geothermal application at the Pine Creek complex are industrial process heat in the tungsten plant, and space heat and domestic water supply heat for the office buildings. The review of industrial data was viewed with these specific end uses in mind.

6.1.1 Geothermal Fluid Production/Reinjection

The energy survey has revealed that approximately 9.53×10^{10} BTU/yr of energy presently provided at the Pine Creek mill by conventional fossil fuels is potentially replaceable by geothermal energy. Given the preliminary resource temperature of 240F (116C) as surmised in Section 5, this would require a geothermal brine flow of at least 400 gpm to satisfy the heat requirements of both the tungsten plant and the office buildings. This flow is based on the assumption that all of the heat in the brine is used between the temperatures of 240F and 180F. Flows of this nature would require the use of a pump in the geothermal supply system.

For the brine fluid production flow, a downhole pump is most suitable. A pump placed in the production well will not only provide the necessary fluid flow, but will pressurize the brine transmission system to prevent brine flashing from taking place in the production pipeline. Flashing brine is a major cause of scale buildup in geothermal systems. Pressuring the fluid will also prevent dissolved gases from coming out of the brine solution. Dissolved gases in the brine reduce the heat transfer ability of the fluid and promote further scaling.

There are basically two types of pumps used for geothermal fluid production: the shaft driven downhole pump and the submersible downhole pump and motor.

The lineshaft pumps are rather limited in the depth at which the pump can be placed. The maximum practical depth for pumping brine with lineshaft pumps is around 1000 feet although shallower depths are more common. The reliability of the shaft bearings becomes questionable as the depth and temperature are increased. Shaft bearings are lubricated by either the brine being pumped, lube oil, or fresh water. Brine used for lubrication has resulted in scale buildup and ultimate seizure of bearings. Lube oil may be used if it can be tolerated in the brine stream, however this oil could reduce heat transfer properties of the brine. Lubricating with fresh water, although costly, has been quite successful. An advantage to the lineshaft type of pump, however, is that the motor is located at grade level -- easy to access and maintain.

The submersible type downhole pump, with both pump and motor down in the well hole, are preferred for deep wells over the lineshaft type because they are less expensive to purchase and install, and less sensitive to both deviating wells and poor assembly conditions. Submersible pumps, which have for the most part come out of the oil and gas industry needs, are being modified for the geothermal industry. The scaling and corrosive nature of geothermal brine, as well as the generally high temperatures encountered in brine fluids, has demanded a change in construction materials of submersible pumps from those materials used in the oil and gas industry. Tests have been conducted on submersible pumps at Raft River, Idaho and East Mesa, California. Problems have so far centered around brine leakage into the motor protector assembly. Further investigation shall be made into suitable materials for these pumps especially in relation to the expected chemical makeup of the Pine Creek geothermal fluid.

Pumps that have been used for brine reinjection have included multi-stage centrifugal, vertical turbine, and positive displacement type pumps. Due to the low NPSH available for most reinjection pumps, vertical multi-stage centrifugal (turbine) pumps have been used. There has been mixed reviews on the use of this type of pump for geothermal brine service. Discharge pressures are in the order of 300 to 400 psig.

Positive displacement pumps with discharge pressures of 400 to 500 psig range have been successfully used for filtered geothermal brine. Multi-staged centrifugal pumps with discharge pressures up to 600 psi will work if provided with proper NPSH. Some pumping arrangements have used a head tank which feeds brine to a single-stage centrifugal pump which in turn provides suction pressure to a multi-stage centrifugal unit.

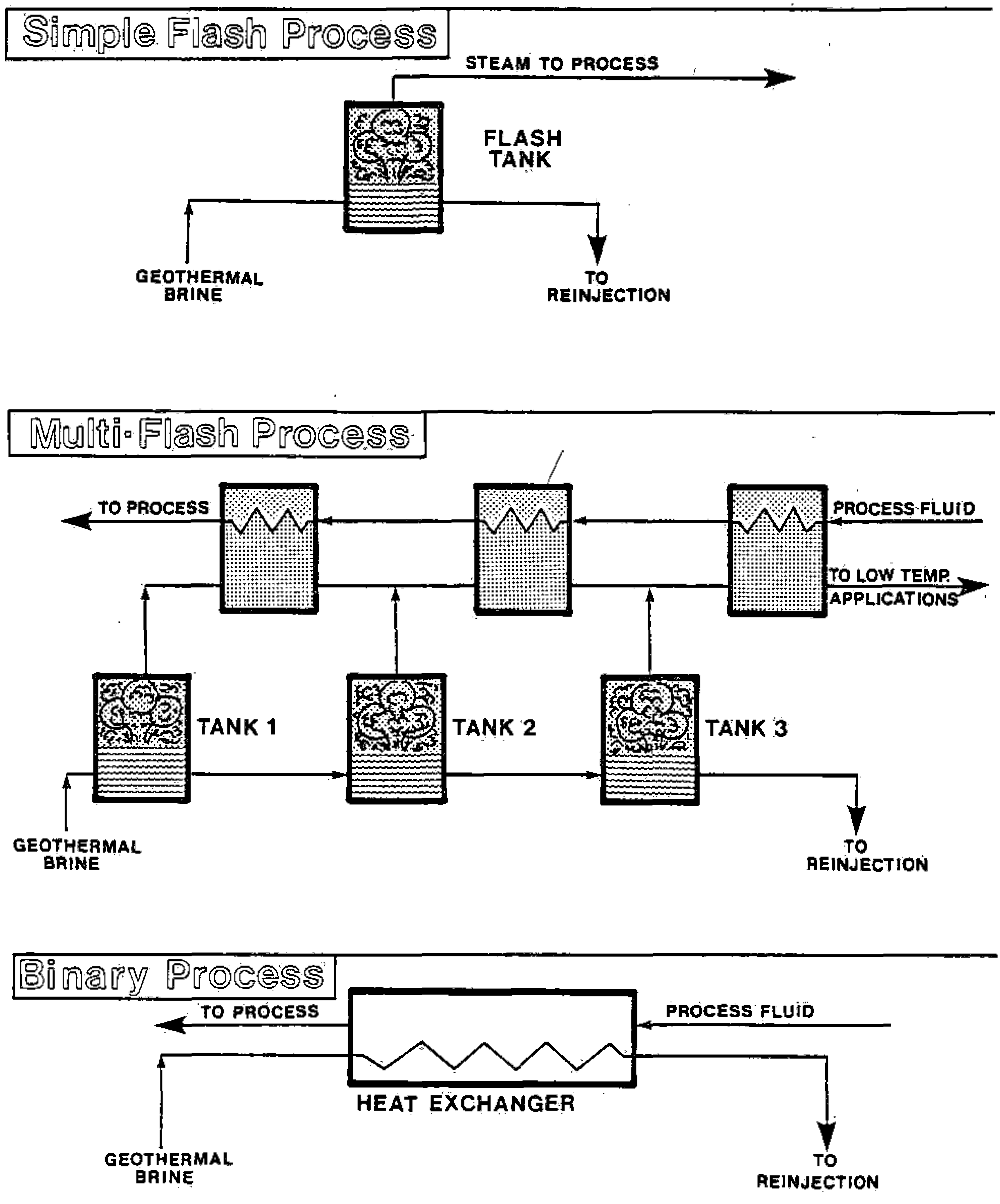
6.1.2 Geothermal Heat Extraction

There are various factors which affect the method of geothermal heat extraction for both electric and non-electric use: the quantity and nature (steam, water) of the heat required, environmental effects, capital costs, operating and maintenance costs, as well as other mitigating factors specific to each project.

For the direct heat (nonelectric) use of geothermal heat for the Pine Creek complex, the heat is required in the form of steam and hot water, as described in the energy survey section of this report. A search of the open literature has revealed that there are basically three methods of geothermal heat extraction from a liquid dominated geothermal reservoir: (1) single-flashed steam; (2) the multi-flash process; and (3) the binary process.

6.1.2.1 Single-Flash Steam Process

The single-flash steam method is simple in nature but requires the largest amount of geothermal brine for the least amount of extracted heat compared to the other two methods. This system involves the geothermal brine entering a tank where the pressure is lowered to flash the fluid into steam (see Figure 6-1). The system basically requires a flash tank and pumps to move the fluid. Although this method produces clean steam, typically used in a turbine-generator system to produce electricity, a large brine flow is required. To get an idea of the brine flows required in this method, to produce one pound of flashed steam, approximately 34 pounds of 240F brine would be needed in a flash tank at atmospheric pressure. Steam required at the Pine Creek mill is of the order of 64,300 lbs/hr at 400F, well above the 240F brine



HEAT EXTRACTION METHODS

FIGURE 6-1

temperature estimated at the mill site reservoir. To produce this quantity of steam at 212F would require a brine flow of approximately 4860 gpm, about five or six good flowing geothermal production wells.

Because of the large geothermal brine production needed to produce steam at even atmospheric pressure, the use of a single flash method is not technically feasible for the predicted resource temperatures at Pine Creek.

6.1.2.2 Multi-Flash Steam Process

The multi-flash process, also known as the feed and bleed method, is similar to the single-flash method (see Figure 6-1). Geothermal brine is flashed in succeeding tanks each of a lower pressure. The resulting steam from each flash tank is used for process heat purposes. This method produces the highest amount of heat extracted for a given brine quantity as compared to the other two methods. But this also requires a capital investment in a number of flash tanks and condensing units which could become a maintenance burden, depending upon the scaling problems encountered. Because of the higher efficiency of this system for steam production when it is in proper working condition, this method could be applicable to the Pine Creek mill process for preheating the boiler feedwater and other various process heat requirements if a somewhat higher than 240F reservoir was found. However, at the presently predicted temperature, steam production by multi-stage flashing as with single-stage flashing is technically infeasible.

6.1.2.3 Binary Process

The binary process requires the use of a heat exchanger(s) and a secondary medium, be it liquid or gas. In this process, heat from the geothermal brine (primary fluid) is transferred to the secondary medium. In some cases this secondary fluid is isobutane, which, when vaporized, is used in a Rankine cycle to produce electricity. In other cases the secondary fluid is water, which, when heated, is used in various applications from vegetable cooking to space heating.

The secondary medium for the Pine Creek project would most likely be water. The heat from the geothermal brine would be transferred to the fresh mine runoff water via heat exchangers. This clean heated water could be used for the boiler feedwater preheat, and space and domestic hot water requirements for the plant buildings. An advantage to the binary process is that the geothermal brine would remain in its own separate loop, pressurized to keep the fluid in liquid phase. Although this process would require a higher geothermal brine flow than the multi-flash method, (but less flow than the single-flash method), less scaling would result because the brine would remain pressurized. Conventional shell-and-tube heat exchangers could be utilized without the need for flash tanks, mist eliminators, and vacuum pumps.

6.2 CONCLUSION

Steam generated from a 240F reservoir would be of too low a pressure to be used for direct injection into the Pine Creek process but heat from the brine could be used to preheat supply water to the boiler as well as to heat water for space heating and domestic hot water. Utilizing the heat from the brine transferred to clean water via heat exchangers for these low temperature applications appears to be the most feasible method of geothermal heat use at this time. An economic evaluation will weigh heavily in the final engineering method of geothermal heat extraction.

6.3 HEAT DELIVERY METHODS

Once heat from the geothermal brine has been extracted, it must be delivered to the point of eventual use. Assuming that the geothermal well site is located on the grounds of the plant, problems associated with heat transportation can be minimized. Methods of delivering the tungsten geothermal heat to the points of end use were analyzed as to the piping system required and materials of construction. At this point in the study it is assumed that the geothermal brine will be kept in the liquid phase and exchange heat with mine runoff water, which will then in turn be delivered to the Pine Creek mill area for process heat, space heat, and domestic hot water uses.

6.3.1 Piping System

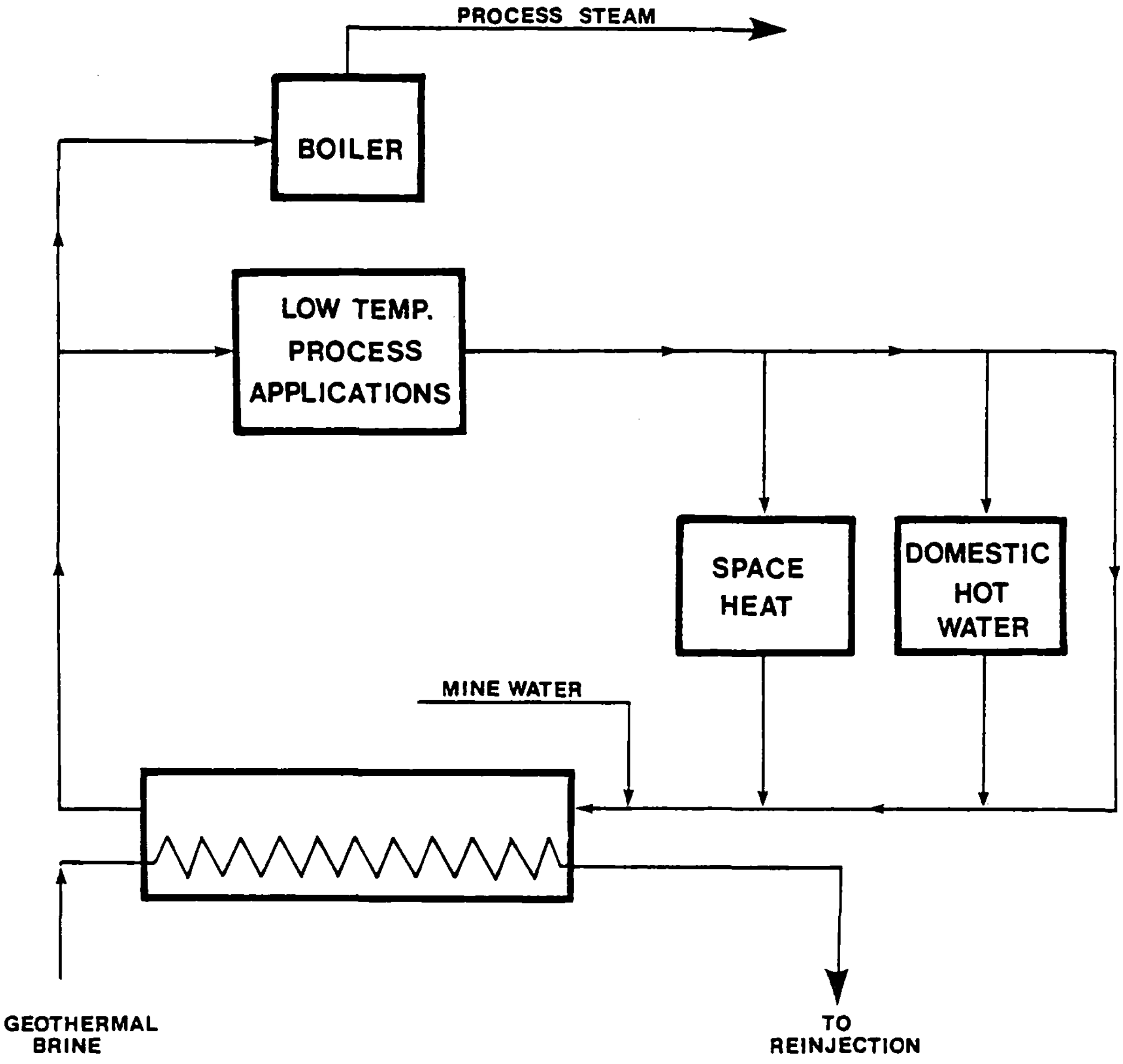
Heat for the Pine Creek complex is required for process applications and also for space heat and domestic hot water use. Mine runoff water heated in the boiler is for the most part consumed in the mill process, with only a relatively small amount rejected to the tailings pond. Heat for other process applications, while presently using steam from the boiler, could possibly be supplied by geothermally-heated hot water instead. The hot water rejected from these low temperature process applications could be used for space heating the office buildings and for heating domestic supply water.

Heat for the Pine Creek complex would have to be transported from the geothermal resource to the mill area. If it is assumed that the geothermal plant is on the grounds of the mill, which appears to be a reasonable assumption geologically, then heat transportation would be a short distance (a few hundred yards at most).

A preliminary design for the Pine Creek mill suggests the use of a two-pipe hot water system. This system would entail one supply pipe of hot water for preheated boiler supply and low temperature process applications, and one return pipe of rejected water from low temperature process applications and office buildings use.

Figure 6-2 is a diagram showing the two-pipe hot water system. The geothermal brine exchanges heat with the water taken from the tungsten mine. This geothermally preheated mine water is used to make process steam in the existing mill boiler and also for low temperature process applications. Hot water from the low temperature processes can be cascaded to provide space heat and to heat domestic water. The heat remaining in this water would be returned to the geothermal facility to be used to preheat mine makeup water prior to entering the heat exchanger.

The system as shown on Figure 6-2 is of a conceptual nature at this time. Future work will include refining this approach to supplying heat to the tungsten mill. Once again economics play a large part in any design and will be a determining factor in the Pine Creek geothermal system.



Heat Supply System

FIGURE 6-2

6.3.2 Storage

In large scale district distribution systems, daily demand fluctuations are a regular occurrence. To provide a ready supply of fluid for the daily peak demands, storage tanks are employed.

Although the steam demand for the Pine Creek tungsten process is rather constant, heat demands for other end uses are prone to daily fluctuations. Both process heat for the mill and space heat for the office buildings may require daily changes in heat demand. Thus a storage tank will be employed to handle demand fluctuations of the geothermally heated hot water on a day-to-day basis. An insulated storage tank will provide a reservoir of hot water for increases in demand whenever they may occur.

6.3.3 Materials Evaluation

6.3.3.1 Pipe Materials

A preliminary investigation into the different types of pipe materials indicates quite a wide variety from which to choose. The basic criteria in choosing the best pipe-insulation conduit combination would be: (1) the pipe must meet the requirements of the heat transfer medium, i.e., the pipe must not be adversely affected by the medium's temperature, pressure, or chemistry; (2) the insulation must properly limit thermal losses or gains; (3) if placed underground, some form of encasement must protect the pipe and insulation from external loads and the underground environment; and (4) the cost-benefit ratio for the pipe-insulation conduit combination must be examined in relation to the medium being transferred.

There are, of course, many other factors to be considered such as heat transfer characteristics, thermal expansion, creep strength, and corrosion protection. Some of the different types of pipe materials are listed in Table 6-1, which gives a brief description of the characteristics of each.

Mild steel is the most commonly used material in prefabricated pipe and conduit casing because of its relatively low cost, availability, and ease of fabrication. Carbon steel pipe for brine transmission has been successfully used in the past. Proper precautions must be taken, however, to prevent pitting and crevice corrosion especially by geothermal brine. High salinity geothermal fluids will cause high uniform corrosion as well as localized corrosion.

Preinsulated pipe using non-metallic materials of the asbestos-cement or fiberglass reinforced plastic (FRP) type appears to be popular for geothermal district heating systems. Preinsulated pipe, very simply, is a prefabricated pipe usually from 10 feet to 13 feet in length, which contains an inner core (copper, asbestos-cement, steel, or PVC) insulating material around this core (polyurethane foam or calcium silicate), and an outer casing (asbestos-cement or PVC). Because all of the components are packaged into a pipe spool at the factory, the cost per unit length is relatively inexpensive. Besides this main advantage, the prefabricated system is fast and easy to install.

While preinsulated pipe has certain advantages which make it suitable for district distribution systems, it may not be suitable for the Pine Creek mill situation.

Table 6-1

PIPING MATERIALS

FERROUS METALS

Cast Iron	- Widely used in water and sewer lines - High resistance to atmospheric and soil corrosion - Are comparatively brittle but have acceptable strength
Wrought Iron	- Highly corrosion resistant - Expensive
Low Carbon Steel	- Widely used in various applications - Good for low and medium pressure steam & water - Rather economical - Easy to weld - Low corrosion resistance
Stainless Steel	- Highly corrosion resistant - Very expensive

NON-FERROUS METALS

Note: The use of these materials is confined to within buildings. They are not used extensively in underground mains for thermal conveyance systems.

Copper	- Widely used for indoor plumbing - Good corrosion resistance - Highly expensive
Aluminum	- Lightweight - Good corrosion resistance
Brass, Bronze	- Suitable for low and medium temperature service

NON-METALLIC MATERIALS

Asbestos-cement	- Often used in water lines - High resistance to corrosion - Low friction losses - Good strength - Highly brittle - Sizes up to 36 in., pressures up to 200 psi, temperatures up to 200F
Concrete	- Used for large water mains and sewer lines - High flow coefficient - Corrosion resistant - Can withstand significant external loads
Fiberglass Reinforced Plastic (FRP)	- Temperatures up to 300F - Corrosion resistant - Low friction losses - Lightweight - Easy to install - Good strength
Thermoplastics	- Temperatures up to 200F - Pressures up to 100 psia - Relatively low strength
Thermosetting Resins	- Can be used as liner for other pipe materials - Good corrosion resistance - Good for low temperature water service

First of all, preinsulated pipe is good for long straight runs where its ease of installation saves greatly in cost. In the Pine Creek project this is not required if it is assumed that the well is at the mill site. In addition, pipe materials of the asbestos-cement variety are limited to maximum working temperatures of around 200F. FRP pipe can take temperatures up to 300F but requires more time for installation because each spool must be glued together.

It appears that for the Pine Creek mill, carbon steel pipe would suffice for both the brine loop and the freshwater loop with proper insulation. Carbon steel pipe is relatively inexpensive, readily available, and holds up surprisingly well in geothermal applications. There has been extensive use of carbon steel pipe in all types of brine, and carbon steel can handle a wide range of temperature and pressure conditions.

6.3.3.2 Insulation

An ideal material for insulation service should be: (1) capable of withstanding repeated wetting and drying without serious deterioration; (2) noncorrosive to pipe materials when wet; (3) a nonconductor of electricity; (4) vermin proof; and (5) chemically and physically stable at operating temperatures.

Insulation materials basically fall into four temperature ranges—cryogenic (below to -150F), low temperature (-150F to 250F), moderate temperature (250F to 1200F), and high temperature (above 1500F). Insulation types include calcium silicate, fibrous and cellular glasses, urethane foam, rock and mineral wools, expanded perlite, ceramic brick, and various fibers (mineral, ceramic, oxide, carbon). Physical forms of insulation can be loose-fill, flexible, rigid, reflective, and formed in place; forms can be foam, blocks, blankets, granular, mats, boards, and tape.

Of the abundant variety of materials from which to choose, fiberglass, calcium silicate, and polyurethane foam appear to be the most widely used in geothermal applications (See Table 6-2).

TABLE 6-2

PROPERTIES OF GEOTHERMAL INSULATING MATERIALS

	Calcium Silicate	Fiberglass	Urethane Foam
Temp. range	100F to 1500F	-120F to 650F	-250F to 225F
Conductivity, K Btu-in/hr-ft^2-°F	0.33 to 0.72	0.15 to 0.54	0.11 to 0.14
Density, lb/ft^3	10.0 to 14.0	0.60 to 3.0	1.6 to 3.0
Compressive strength lb/in^2 @ % deformation	100 to 250 @ 5%	0.02 to 3.4 @10%	16 to 100 @5%
Relative cost	high	low	low

Polyurethane foam is an organic plastic which is confined to the low-temperature application range. This material comes in blocks, boards, flexible sheets, or can be foamed in place. It has also been widely used in preinsulated pipe for low temperature geothermal brine service. Polyurethane has a very low conductivity factor, making it one of the best materials in this category. Unfortunately, permeability to water vapor has been a problem with polyurethane foam in cryogenic service. Water vapor penetrates the foam and deposits ice when it freezes, destroying the insulation properties.

Fiberglass is formed from fine, resilient glass fibers. It has been used in service up to 650F in temperature. Fiberglass most popularly comes in blankets, semi-rigid boards, and molded sections. In blanket form, fiberglass is easy to install around pipes and tanks. Although fiberglass does not have the compressive strength of either polyurethane foam or calcium silicate, it does have excellent thermal resistivity and is relatively cheaper than calcium silicate for moderate temperature use.

Calcium silicate is a mixture of lime and silica reinforced with organic and inorganic fibers. It is used up to 1500F temperatures. It comes in boards and blocks, and quarter-round and half-round segments for pipes. Because of its rigidity, this material has a higher resistance to mechanical abuse than most insulating materials. A typical aluminum jacketing around the insulation provides protection against weather and other damage.

6.3.3.3 Conduit

Conduit envelopes protect pipe and insulation against wetness, corrosive soils, and mechanical loads. The two basic types of conduit are: (1) poured field constructed type; and (2) prefabricated type. Both types can be either pressure tight or non-pressure tight. Many of the poured envelopes incorporate a combination cement-insulation or insulating cement which is poured around the pipes. Others use a hydrocarbon envelope of a natural granular asphaltic material of high resin content, or asphalt contained in a metal jacket surrounding the pipe.

Because field constructed conduits are more costly than factory prefabricated conduit sections, which can be easily assembled at the site, examination of the prefabricated conduit types is in order.

Prefabricated pressure tight steel conduit can be made of either smooth or corrugated steel. The pipe is surrounded with preformed insulation and then the conduit is placed around it with a drain space in between. A coupling is welded to join two sections of conduit; a protective coating, enamel or mastic is used to seal the joints. Sealed asbestos-cement conduits are similar in configuration to the prefabricated steel type except asbestos-cement is used for both the pipe and outer casing. Joints are made with compression type couplings and O-rings for sealing. Epoxy lining and polyurethane foam insulation is also used.

Also similar to this configuration is fiber-reinforced plastic conduit using FRP pipe with polyurethane insulation. Sections are joined by use of a bonding cement or mastic.

6.3.3.4 Heat Exchanger Materials

In the binary heat extraction process, well site heat exchanger(s) would be called upon to transfer heat between the geothermal reservoir fluid (estimated at approximately 240F, 116C) and the freshwater taken from the Pine Creek mine (at approximately 39F, 4C).

A wide variety of materials can be used for heat exchangers. Tube materials range from mild steel and copper alloys, to expensive titanium. Mechanically, these materials have high strength combined with excellent ductility so that they can be handled with reasonable care without bending, kinking, becoming dented or otherwise damaged.

Copper alloys are prone to chemical attack by copper embrittlement due to the H_2S (hydrogen sulfide) in the geothermal brine. The cracking of some copper-based alloys exposed to ammonia or its derivatives also may occur.

Titanium and titanium-based alloys tested on geothermal fluids have shown excellent results in resistance to corrosion, impingement, and cavitation damage. Titanium is relatively expensive and experiences with cheaper carbon steel material have been quite positive.

Tests have been conducted on heat exchanger tube materials under experimental conditions at a Heber Reservoir site. Results taken from tests at Heber's Nowlin No. 1 Well have shown that carbon steel or titanium tubes can be considered for service at Heber if proper precautions are taken to prevent excessive exposure to air (oxygen) during start-up, shutdown, and maintenance operations. Tests performed at an East Mesa geothermal well site have also shown positive results utilizing carbon steel tubes. After formation of a tenacious layer of magnetic iron oxide, corrosion appeared to have ceased. No signs of pitting or flaking of the oxide were apparent. Copper nickel (90:10) proved to function satisfactorily in lower temperatures but in hotter temperatures corrosive attack was excessive. Titanium tubes showed no signs of corrosion or other damage.

Further investigation shall be made into possible construction materials for heat exchangers with emphasis on the economic effects encountered.

SECTION 7

REVIEW OF ENVIRONMENTAL DATA BASE

7.1 INTRODUCTION

As a preliminary step towards full assessment of the environmental impact of geothermal development in the Pine Creek area, a search of previously prepared documents pertaining to the resources and constraints of the area has been conducted. The types of literature sought were land use plans, environmental assessments or baseline environmental studies, previous environmental impact reports (EIRs) or environmental impact statements (EISs), or any environmental documents pertaining to Inyo County, and more specifically, the Pine Creek region. The following agencies were contacted in order to obtain the information:

1. State of California, Department of Water Resources, Sacramento, California (916-445-9248).

2. Inyo County, California, County Services, Planning Department, Bishop office (714-873-5891); Independence office (714-873-2411).

3. United States Department of Agriculture, United States National Forest Service, Inyo National Forest, Bishop office (714-873-5841); White Mountain Office (714-873-4207).

4. United States Department of the Interior; Bureau of Land Management (BLM), California State Office (916-484-4253); Bishop Office (714-872-4881).

7.2 SUMMARY OF LITERATURE

The above-mentioned agencies supplied the reports, surveys and documents, and referred WESTEC Services to other possible sources of information. The following list describes documents that have been reviewed to date and found to be specifically applicable to the Pine Creek area.

1. State of California, Department of Water Resources, Bulletin No. 121, Southern Lahontan Area Land and Water Use Survey, 1961, August, 1965.

This report has not been updated since the initial Bulletin was published. Portions of Mono, San Bernardino, Kern, and Los Angeles Counties, and all of Inyo County were surveyed to discern changes in land and water uses for these areas. The objective of the investigation was to acquire information to determine present and future water requirements for the counties. The areas of investigation included climatic conditions, cultural development, water supply, and descriptions of the hydrographic units that were studied. In addition to showing present land use, this report also presents a narration of historical land use development and an estimate of the present levels of water use.

2. State of California, Department of Water Resources, Bulletin No. 126, Fish Slough Dam and Reservoir, Feasibility Investigation, October, 1964.

This investigation focused on the feasibility of construction of a dam and reservoir at Fish Slough in Inyo and Mono Counties. After an investigation of all engineering, geologic, and seismic factors involved, it was found that construction of a dam at Fish Slough site was not feasible due to safety considerations. The report contains a description of the area including water supply (precipitation, runoff, water rights, water quality), recreation (present and potential uses), geologic investigations, and seismic studies.

3. United States Department of Agriculture, National Forest Service, Pacific Southwest Region, Final Environmental Statement, Land Management Plan for the Mammoth-Mono Planning Unit, U.S. Government Printing Office, 1979.

This environmental statement covers the Mammoth-Mono Planning Unit (MMPU), which includes parts of Madera and Fresno Counties west of the Sierra crest, and ranges south to the Inyo County line. The purpose of the report was to provide a data base for the selection of one of several proposed management plans for the National Forest lands within the MMPU. The plan will either replace or continue the Multiple Use Management Plan, which remains in effect until the unit plan is selected. The selected plan will set the general direction for functional and project plans until the year 2000, and will be open-ended to allow for changing needs. The purpose of this plan is to resolve management problems and to respond to physical, biological, social, and economic changes that have occurred since the Multiple Use Management Plan was approved in 1970. One of the major issues to be resolved is the need to provide suitable land for geothermal development commensurate with maintaining other resources. Six alternatives were discussed in entirety, followed by a comprehensive evaluation of these alternatives. An extensive resource analysis summary is also included.

4. United States Department of the Interior, BLM, 1979, Water Quality Management Report, No. 208, October.

A portion of this report focuses on the effects of mining operations on the water quality of the Bishop Resource area, Pine Creek, Deep Canyon Creek, and the Owens Valley. For each area, a description of the area, the effect on beneficial uses of water, and identified information needs are included.

5. United States Department of the Interior, BLM, 1979, "Aquatic Habitat Inventories," Form 6671-5, September.

This report identifies the aquatic habitat of Pine Creek and includes a description of the bank and stream, pollution information, sediment source, riparian vegetation, the boundaries of fish habitat, spawning habitat quality and boundaries, access to the stream, and improvement or alteration suggestions. The stream habitat survey summary and analysis is included, as well as a water quality analysis and vertebrate locality record.

6. United States Department of Agriculture, Forest Service, White Mountain Ranger District, 1971, Environmental Survey, Pine Creek Tungsten Mine, Union Carbide Corporation, February.

The survey report contains an analysis of the interrelationship of the operation of the Pine Creek Tungsten Mine of Union Carbide Corporation and the resources and management of the Inyo National Forest, California Region. Specific attention in this report focused on proposed expansion of the mill tailing disposal site. The Union Carbide Mill is on private land, yet much of the associated surface activities involve National Forest land under special use permit, or mining and millsite claims. Therefore, the impact survey was prepared to analyze the effects of this proposed expansion upon the Pine Creek canyon area. The survey includes physical characteristics of the area; resource values and coordination requirements including outdoor recreation, water and soil, air quality, wildlife and fish, range, timber, land use, and effect on the local community and individuals; the Regional Forest Service Administration and protection aspects; and an analysis and recommendation section. Maps, photographs, and a chart of the treatment of Pine Creek tungsten ore are included in the appendix.

7. Inyo County Planning Department, 1979, Seismic Safety Element of the Inyo County General Plan, April.

The topography of Inyo County consists generally of longitudinal mountains and basins formed by the elevation and subsidence of massive blocks of crustal earth; therefore, the entire land surface of Inyo County is one of seismic origin, a process still on-going. To create an awareness of this situation, to guide the County Board of Supervisors and Planning Commission in formulating decisions on development, and to identify, appraise, and reduce some of the hazards of an earthquake, in addition to other reasons, this Seismic Safety Element was prepared. The Element contains information such as the location and occurrence of various physical seismic hazards in Inyo County, dam information and an implementation and policy plan is described. Maps, figures, and tables are included in the appendix.

8. Inyo County Planning Department, 1979, Scenic Highway Element of the Inyo County General Plan, February.

The purpose of the Scenic Highway Element is to develop, maintain, and protect the scenic resources observed from highways and to provide the basis for the preparation of a specific scenic corrior plan for eligible roads and highways. In addition, the Element is a specific plan which addresses policies that are intended to protect the scenic highway corridor. Included in the report are goals, objectives, policies, standards for corridor protection, and implementation. A specific scenic highway system for the General Plan is also included.

7.2.1 Known Data Sources Not Yet Reviewed

Other possible relevant information sources were identified; WESTEC Services is currently in the process of obtaining them. Inyo County is presently revising their Open Space and Conservation Element of the General Plan and a completed draft should be available by February 28, 1980. In addition, Natelson Company, a private consulting firm in Los Angeles, is preparing a joint Geothermal Element of the General

Plan for Mono and Inyo Counties, with a specific element for each County which should be available by Fall 1980.

Environmental statements which support the geothermal leasing program have been prepared by the Department of the Interior beginning in 1973. The Bureau of Land Management State office in Sacramento is presently reviewing those statements that pertain to Inyo County, and will forward them to WESTEC.

Due to the Pine Creek Tungsten Mine operation, Union Carbide in Bishop has prepared and assembled environmental documents. WESTEC is in the process of obtaining this information for review.

7.3 CONCLUSION

The literature search has revealed relevant information on the environmental aspects of developing a geothermal energy system for the Pine Creek tungsten complex. The compiled data base will function as the starting point for further environmental analysis and identification of measures that would be appropriate to mitigate any adverse environmental impacts for the area. Evaluation of additional documents will be synthesized with this data review to provide a final environmental assessment for this feasibility study.

SECTION 8

INSTITUTIONAL BARRIERS ASSESSMENT

8.1 INTRODUCTION

As a part of the contract effort, a preliminary search of literature concerning potential institutional barriers to geothermal development in Inyo and Mono Counties was conducted. Regulations of these counties were selected as pertinent to the initial review, since the site of the potential geothermal application, the Bishop-Pine Creek facility, is located in Inyo County and one potential resource area is the Mono-Long Valley KGRA (Known Geothermal Resource Area) situated in Mono County. Additionally, it was assumed that geothermal exploration and development might also be feasible within Inyo County, which is farther from the selected KGRA but closer to the actual operation of the mine.

It was initially expected that barriers identified in the literature concerning Mono County would also apply to Inyo County. As detailed in the following discussion, that assumption may be incorrect only when making a comparative analysis of those regulations presently in effect in the two counties.

8.2 DISCUSSION

Conversations with planning officials in each county indicate a local willingness to accept geothermal development, but there is a marked contrast regarding the extent to which the counties are disposed toward regulating that development (Dehart; Sandy, 1980). Furthermore, the counties have differing attitudes as to the jursidictional authority which the Federal and State government possess over local development of geothermal energy.

8.2.1 Mono County Regulations

To date County officials have not adopted any regulations dealing specifically with geothermal development. Their reasoning has been that until activity increases in the area, there is neither the need nor sufficient information on which to make an informed opinion. Despite forecasts over the past several years of increased geothermal activity, very little actual exploration and no significant development has occurred. A recent DOE-funded project at Mammoth Lakes for space heating utilized existing wells which had previously been shut-in and, therefore, required no additional permitting. Conditional use permits have been required for those exploratory activities undertaken to date. Those activities include shallow temperature gradient testing and continue through utilization. The Mono County Planning Department and ultimately the Planning Commission have local responsibility for processing any environmental impact report (EIR). Such reports may be dispensed with (i.e., a negative declaration prepared) in the case of geophysical surveys and temperature gradient holes.

8.2.2 Inyo County

In contrast to Mono County, Inyo County has adopted a detailed ordinance governing geothermal development within its boundaries. The Geothermal Ordinance of the County of Inyo (Inyo County, 1974), adopted in 1973, is patterned after the ordinance in effect in Imperial County, California (Imperial County, 1971). It is supplementary to regulations governing conditional use permits, i.e, an applicant must comply with all conditional use permitting requirements as well as these geothermal regulations. The ordinance is broken down into seven chapters, the first stating the general purpose and intent of the ordinance. Salient points of the remaining six chapters are discussed below.

8.2.2.1 Definitions Under the Ordinance

A distinction is drawn between a geothermal exploratory and a geothermal production project, the former encompassing non-major surface-disturbing activities ranging from geological, geophysical studies and surveys through observation and exploratory wells to temporary test facilities. An observation well is one utilized strictly for temperature monitoring pruposes, not exceeding four inches in diameter and drilled no deeper than 500 feet.

A geothermal production project encompasses those activities which will result in construction of permanent structures and significant alteration to the landscape (Ord. 239, Section 53.25). Interestingly, the definition of a geothermal well includes previously abandoned wells so that presumably a conditional use permit would be required before utilizing these wells again. That does not appear to be the case in Mono County which would require a new permit under these circumstances.

8.2.2.2 Unlawful Acts

This chapter (Ch. 19.12) simply states that no geothermal activity can be carried on without first obtaining a conditional use permit from the County and without complying with all applicable local, State, and Federal laws and regulations.

8.2.2.3 Permits

Chapter 19.16 specifies those items which must be contained in an application for a geothermal exploration project and for a production project. This regulation requires the applicant to submit proof of project approval by the State Division of Oil and Gas as well as approval by the County health department and regional water quality control board. Setting out requirements which address specific concerns associated with geothermal exploration and development appears to have three distinct advantages over the conventional conditional use application: (1) it assists the County planning in evaluating a particular project; (2) it potentially eliminates the need for an applicant to respond to non-germane questions; and (3) it advises an applicant as to those other agencies she or he must contact before securing final approval.

Once the application for a particular project has been satisfactorily completed, the matter is scheduled for hearing before the Planning Commission. This body is the final arbiter on the decision whether to issue a permit. All permits are issued contingent upon acceptance of any additional requirements imposed by the Planning Commission and of the conditions set forth in the subsequent chapter (Section 8.2.2.4).

8.2.2.4 Conditions

The conditions outlined in Chapter 19.20 of the Inyo Geothermal Ordinance fall within two basic categories: environmental concerns and the general "terms and conditions" to development. Under the first category, potential environmental impacts in the areas of waste disposal, noise, air pollution, aesthetics, and land use are noted. With respect to land use, as in Mono and Imperial Counties, the applicant requesting project approval must make an effort to minimize the effect of geothermal development on the all important agricultural use of land. In addition, the applicant/operator is required to participate in any subsidence and earth movement prevention and detection program in effect.

Under the second category, the general terms and conditions associated with an Inyo County geothermal project primarily involve bonding and insurance requirements. The provision dealing with bonding requirements follows a similar provision found in the Imperial County ordinance. It requires the operator of any well or production project to file a $50,000 indemnity bond for each well drilled or for any abandoned well re-entered. The purpose of requiring a bond is to ensure that any costs incurred by Inyo County in repairing damage caused by a geothermal operator can be recouped through sums recovered under the indemnity bond. The Inyo County indemnity bond requirement does not exempt the applicant from filing a similar bond imposed by the State of California Division of Oil and Gas (for the protection of the state). The bonding requirements differ, however, in that the State of California imposes only a $25,000 per well bond and allows a blanket bond of $100,000 to be submitted (as does Imperial County) to cover all of an applicant's well operations (California Public Resources Code (CA. PUB. RES. CODE), Section 3728, 1975). State regulations also permit a cash bond to be filed in lieu of an indemnity bond (CA. PUB. RES. CODE, Section 3728.5, 1975). Duplication of bonding requirements by designating the county or State as the responsible agency is seemingly one institutional barrier which may be overcome by joint cooperation between State of California and Inyo County officials.

A second important condition for permit compliance is insurance of a different type. Section 19.20.070 of the Ordinance requires the applicant to submit evidence of insurability against liability in tort arising from geothermal activities for a minimum of one million dollars ($1,000,000). This is in response to the County's obvious interest in seeing that an operator has adequate coverage to reimburse anyone who has been injured or whose property has been damaged as a result of geothermal operations.

Finally, this chapter requires an operator to supply data (excluding proprietary information) which will assist the County in the development of a Geothermal Element to the Inyo County General Plan. Recently, IMAGE, a regional body which includes both Inyo and Mono Counties, was awarded a grant to develop a Geothermal Element. Work on the project has already begun.

8.2.2.5 Standards

Under the Inyo County ordinance, standards applicable to geothermal project are broken down into planning, drilling, and production categories. The following paragraphs describe these standards.

8.2.2.5.1 Planning Standards

Planning standards relate to siting geothermal wells with the objective of minimizing the impact of drilling on agricultural land and preventing any interference with irrigation and drainage patterns. The applicant is required to site wells at specified minimum distances from designated categories of development, such as residences (500 ft) and schools (2640 ft). On the site itself, sumps and ponds must be designed and constructed in accordance with prescribed minimum criteria under the supervision of a registered civil engineer. Before beginning any construction, the operator must submit a soils investigation report for approval.

8.2.2.5.2 Drilling Standards

These standards relate more to drillsite conditions with which the operator must comply than to the drilling program which is under the purview of state or federal officials. (This is in turn dependent upon who the surface manager of the property is.)

One set of standards establishes noise level curves. The Planning Commission determines which differing noise levels will apply for a particular project. Noise levels are measured at the parcel boundary and not at the nearest sensitive receptor. In addition, site preparation, equipment removal or delivery, and racking up drillpipe are generally restricted to daylight hours (7 am to 7 pm) in order to mitigate noise impacts.

A second set of standards details reporting requirements which are filed with the County surveyor for the subsidence and earth movement detection programs (required under Section 19.20.080).

Finally, and most unique to Inyo County's geothermal ordinance, is a requirement that the operator participate in a hot springs protection program. Unfortunately, the ordinance does not define what qualifies as a "hot spring." This lack of definition is particularly crucial vis-a-vis the Pine Creek mine operation. To date, two sites, one inside the mine, the other nearby, have been identified for this study as having potential for geothermal resource development because of their proximity to warmer than average springs (see Section 5). If these springs are considered "hot," and if the identified sites were ultimately selected, compliance with the County's program would be mandatory.

Since the ordinance fails to give an explicit definition, a literature search of definitions of "hot springs" was undertaken. A Geological Survey report (Waring, 1965) states that strictly construed, any spring with an average temperature noticeably above the mean annual temperature of the air at the same locality qualifies as thermal or hot. A more restrictive interpretation has been taken by European sources which classify only those springs having temperatures higher than about 20C as commercially exploitable. The generally accepted standard of a thermal spring in the United States is a spring whose temperature is at least 15F above the mean annual ambient temperature at its locality.

The annual ambient temperature in and around the Pine Creek mine facility is approximately 60F. The temperature of the water at the two sites identified is roughly 68F. Therefore, these springs would be classified as thermal under the first, more liberal definition, but would not qualify under either of the latter definitions.

Assuming the hot springs program is applicable to a project, the ordinance provides that the operator must locate all known or possible hot springs in the project vicinity, file reports and maps detailing specified information about the springs and monitor the springs at specified time intervals. A further program to return the springs to their "original state" is mandated in the event there is a determination of permanent adverse effects.

The literature search for institutional barriers also uncovered a state measure proposed for the protection of hot springs. Thermal springs are defined as "any natural or artificial spring outlet whose average temperature is at least 15F above the mean annual temperature of the air at the same locality." Assembly Bill No. 1219 (Egeland) introduced in the California Legislature on March 23, 1979, provides for the "protection of naturally occurring thermal springs from the adverse effects of geothermal resources." The stated purpose of the bill is twofold:

(1) To require the State Oil and Gas Supervisor,
    a. to grant geothermal development permits only when there is demonstrable evidence that such development would not adversely affect the integrity of significant thermal springs; and
    b. to prohibit the granting of such permits under specified circumstances.

(2) To require the Department of Conservation to identify those thermal springs of importance and to conduct a survey with recommended actions of the kinds of activities which could impair the present use and integrity of such springs.

The bill, which would amend Division 3 of the Public Resources Code relating to geothermal resources, was referred to the Committee on Resources, Land Use and Energy for consideration. In November 1979, the Committee dropped this proposal from further consideration. Indications are that the bill, as presently written, will not be reintroduced in the 1980 session. Nevertheless, it points out a potential institutional consideration/constraint related to regulatory compliance and evidence of some concern in the environmental community that geothermal development should not invariably proceed at the expense of detrimentally affecting significant hot springs.

8.2.2.5.3 Production Standards

The third set of standards outlined in the Inyo County ordinance relates to geothermal production projects and assumes prior compliance with earlier chapters on drilling and planning requirements. It addresses few topics and does not go into great detail on these. Other than continued compliance with the subsidence program, the standards set forth are concerned strictly with surface activities, e.g., siting of power lines and pipelines on existing rights-of-way, landscaping and off-street parking.

Lastly, it dictates that a building permit be secured for all construction work associated with the project.

8.2.2.6 Enforcement

Under this final chapter, County officials are given the authority to investigate project sites and activities to ensure compliance. Any phase of work may be inspected prior to further work. The operator may also be required to submit additional data as necessary to satisfy officials that the project work is being carried out properly. Overall responsibility for enforcement of this chapter resides in the Inyo County Planning Department.

8.3 JURISDICTIONAL OVERLAP

A major portion of the land in both Mono and Inyo Counties is managed by the federal government under the U.S. Forest Service and the Bureau of Land Management (BLM). Approximately 81 percent of the land in Mono County is managed by the federal government, while that in Inyo County is 90 percent federally-managed. Roughly 90 percent of the Mono-Long Valley KGRA, designated initially for this study as the geothermal resource area, is under federal control (Jet Propulsion Laboratory, 1976).

Under this set of facts, the issue of the interface between local government and federal government in geothermal resource development on federal lands is raised. The federal government takes the not too surprising position that local government has no regulatory permitting authority over lands under its jurisdiction. The policy of Mono County of requiring conditional use permits only for non-federal land and of finding no present need to adopt a special geothermal energy ordinance for lands within its boundaries appears consistent with the federal assessment. Inyo County, on the other hand, takes the position that federal, state, and private lands all fall within its regulatory jurisdiction (Jet Propulsion Laboratory, 1976). Therefore, local regulations, such as the geothermal ordinance, are applicable and compliance is mandatory. While, as a practical matter, would-be geothermal developers may elect to comply with both federal and local regulations, a needless duplication of effort may result.

8.4 SUMMARY AND CONCLUSION

A review of the institutional barrier history for Mono and Inyo Counties was undertaken. The literature search did not uncover a great deal of information pertaining to institutional barriers. This may be due, in part, to the lack of geothermal development in these counties to date. It was assumed that constraints to geothermal development identified for Mono County would equally apply to Inyo County, the county in which the Bishop-Pine Creek operation is located. However, with respect to constraints imposed by local governmental regulations, substantive differences did appear.

A focused comparative analysis of the permitting requirements of Inyo and Mono Counties was performed. Special emphasis was directed to the "Geothermal Ordinance of the County of Inyo" which is patterned after the County of Imperial's "Terms and Conditions for Initial Geothermal Development." The major distinction between these two ordinances is the provision in the Inyo County ordinance for identification and protection of hot springs which occur with some frequency in Inyo County. It was noted, however, that no definition of a hot spring is included in the ordinance. Therefore, an investigation was made into definitions given the term by other authorities, including one cited in a recent legislative proposal introduced into the State of California Assembly. This investigation was undertaken to determine whether potential geothermal sites near two springs identified for the Bishop-Pine Creek operation would fall within the mandate of the Inyo County ordinance. It was concluded that under two of the three definitions given (see Section 8.2.2.5.2), compliance would not be required.

Finally, the first quarterly project effort discussed the potential jurisdictional regulatory overlap between local government and federal government, since the federal government is the principal surface manager of land in both Mono and Inyo Counties. The conclusion is that there is no apparent jurisdictional conflict in Mono County which defers, where possible, to federal permitting regulations. In contrast, Inyo County requires compliance with its ordinances relating to geothermal energy activities for all land, federal, state and private, within its jurisdictional boundaries.

8.5 RECOMMENDATIONS

For the following contract quarter, it is recommended that the literature search on institutional barriers be continued. Further discussion, if appropriate to the study's direction, should be given to the area of the potential jurisdictional conflict between federal and state agencies concerned with geothermal development and Inyo County. It would appear that if the Pine Creek facility utilizes a resource located in Inyo County, resolution of this potential institutional barrier would be helpful to avoid duplication of permitting requirements. Finally, it may be appropriate to explore the effect, if any, of the passage of California Assembly Bill 2644, designed to expedite exploration of geothermal resources within the state, on Inyo County's conditional use permitting requirements.

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