DR-1230-1

DOE/SF/11556-T1
(DE85003521)

Energy

GEOTHERMAL

EAST MESA GEOTHERMAL PUMP TEST FACILITY (EMPTF)
Final Report

By
R. G. Olander
G. K. Roberts

November 28, 1984

MASTER

Work Performed Under Contract No. AC03-81SF11556

Barber-Nichols Engr. Co.
Arvada, Colorado

Technical Information Center
Office of Scientific and Technical Information
United States Department of Energy

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Printed Copy A03
Microfiche A01

Codes are used for pricing all publications. The code is determined by the number of pages in the publication. Information pertaining to the pricing codes can be found in the current issues of the following publications, which are generally available in most libraries: *Energy Research Abstracts (ERA)*; *Government Reports Announcements and Index (GRA and I)*; *Scientific and Technical Abstract Reports (STAR)*; and publication NTIS-PR-360 available from NTIS at the above address.

EAST MESA
GEOTHERMAL PUMP TEST FACILITY
(EMPTF)

Final Report
De-AC03-815SF11556

November 28, 1984

Prepared for:

Ray LaSala, CE-324
Department of Energy
Geothermal & Hydropower
1000 Independence Ave.
Washington, DC 20585

Prepared by:

R. G. Olander
G. K. Roberts
Barber-Nichols Engr. Co.
6325 W. 55th Ave.
Arvada, CO 80002

TABLE OF CONTENTS

1.0	<u>INTRODUCTION</u>
2.0	<u>SUMMARY</u>
3.0	<u>DISCUSSION</u>
3.1	HISTORY OF PROJECT
3.2	DESIGN SUMMARY
3.2.1	<u>EMPTF Design Parameters</u>
3.2.2	<u>Simulation of True Geothermal Environment</u>
3.2.3	<u>Pump Size Range</u>
3.2.4	<u>Hydraulic Turbine</u>
3.2.5	<u>Operation Support</u>
3.3	DOCUMENTATION FOR POTENTIAL USERS
3.4	FABRICATION AND INSTALLATION COMMENTS
3.5	ITEMS TO BE COMPLETED WITH FIRST PUMP INSTALLATION
APPENDIX A - GEOTHERMAL PUMP TEST FACILITY	

FIGURES:

Figure 1	EMPTF Facility
Figure 2	20" Test Well
Figure 3	Wellhead Gantry Hoist, Storage Areas
Figure 4	EMPTF Site Plan
Figure 5	Block Diagram EMPTF Test Well and Control Loop
Figure 6	Control Module
Figure 7	Assembled Pelton Wheel
Figure A1	East Mesa Geothermal Pump Test Facility Schematic
Figure A2	Test Pump Wellhead Cross Section

1.0 INTRODUCTION

In September 1981, Barber-Nichols was awarded contract number DE-AC03-81SF11556 for design and fabrication of a Geothermal Pump Test Facility at East Mesa (EMPFT) by the U.S. Department of Energy. The test facility, shown in Figure 1, provides the pump industry with a tool for in-the-well testing at typical operating conditions for submersible pumps while eliminating the risk of actual downwell geothermal field testing. The aim of this project was to produce a test facility for use by pump manufacturers to encourage research and development of electric submersible geothermal pumps.

2.0 SUMMARY

Barber-Nichols has completed the design, fabrication and installation of a geothermal pump test facility at the DOE geothermal site at East Mesa, California which is capable of testing 70 to 750 horsepower downwell pumps in a controlled geothermal environment. The facility consists of a skid-mounted brine control module, a 160 foot below ground test well section, a hydraulic turbine for power recovery, a gantry-mounted hoist for pump handling and a 3-phase, 480 VAC, 1200 amp power supply to handle pump electric requirements. Geothermal brine is supplied to the EMPTF from one of the facility wells at East Mesa.

The EMPTF is designed with a great amount of flexibility to attract the largest number of potential users. The 20-inch diameter test well, Figure 2, can accommodate a wide variety of pumps. The controls are interactive and can be adjusted to obtain a full complement of pump operation data, or set to maintain constant conditions to allow long-term testing with a minimum of operator support. The hydraulic turbine allows the EMPTF user to recover approximately 46% of the input pump power to help defray the operating cost of the unit. The hoist, shown in Figure 3, is provided for material handling and pump servicing and reduces the equipment that the user must supply for pump installation, inspection and removal.

Figure 1, EMPTF Facility
Showing: Wellhead, Control Module and Gantry Hoist

Figure 2, 20" Test Well

Figure 3, Wellhead, Gantry Hoist, Storage Areas

The test rig is complete as installed except for the test well wellhead, which must be configured to match a particular pump. The lack of a test pump has also resulted in a delay in final EMPTF operation-verification, and in the development of an operating and maintenance manual.

3.0 DISCUSSION

3.1 HISTORY OF THE PROJECT

The Department of Energy's experience with the development of geothermal downwell pumps and the need to develop large (700 hp) pumps indicated a requirement for a special pump test facility to duplicate in-the-well geothermal conditions. Most major pump manufacturers have low temperature pump testing capability at their facilities; however, since they use clean, cold water, they cannot be used to explore the unique problems of hot geothermal brine with its physical and chemical properties. In-the-well testing is very expensive, even if no major development problems are encountered, and presents a risk to both the pump and the well.

To enable manufacturers to test and develop geothermal pumps with geothermal brine and without the use of an actual well, Barber-Nichols has designed and built the EMPTF with its 160-foot-deep well test section for the DOE. The facility eliminates the cost and risk of installing a pump in an actual well, while providing true environmental testing.

The geothermal test facility at East Mesa, California was selected as the installation site for the EMPTF. It was chosen for two major reasons:

- 1) The area contains several producing geothermal wells.
- 2) The geothermal brines produced from those wells are thought to be representative of the types of brines encountered in production wells in the western United States.

The geothermal brines at the site average about 325°F and have a fairly moderate mineral content of approximately 2500 ppm total dissolved solids. The East Mesa brines, however, are saturated with CO₂ and if allowed to flash, considerable carbonate scaling can occur. This scaling effect is typical of western and West Coast brines, and although it is controllable, it can be particularly injurious to pumps and other downwell equipment. The EMPTF relies on temperature and pressure control to prevent brine flashing and avoid carbonate scale formation.

3.2 DESIGN SUMMARY

The primary design objective for the for the pump test facility was to provide a facility for testing large downhole pumps in a representative geothermal environment at a reasonable cost to the user.

The test rig consists of a simulated well for the test pump and a control module which contains all the required support equipment for pump testing. A gantry-type hoist has been provided to facilitate material handling and pump servicing. The site can accommodate the electrical power requirements of potential users from its 3-phase, 480 volt, 1200 amp electrical substation. Utility services include non-potable cooling water, compressed air and brine disposal. Support facilities for limited fabrication work, and material handling equipment are also located at the site. Figure 4 shows the relative locations of the EMPTF control module, test well, gantry hoist, utilities and access.

The test well consists of approximately 160 feet of 20-inch outside diameter, 0.5 inch wall casing cemented in place and bull plugged at the lower end to prevent brine loss, and ground water intrusion. The casing is coupled with buttress threads to prevent leakage at high temperature and pressure. The well is designed for 1500 gpm of brine flow at 450°F and 600 psi. The casing terminates in a 20-inch (nominal) flange at the surface. Since wellheads, pump casing and production tubing are unique to each pump installation, none of this equipment has been provided at the site. The user is

FIGURE 4

expected to furnish the wellhead, pump casing and production tubing for the particular pump under test. Field connections to the wellhead will be modified according to the user's specifications. In order to accommodate the widest variety of downwell pumps, there are very few restrictions on the wellhead design. The lower end of the wellhead must mate with a 20-inch, 900-pound raised face flange, the production tube must mate with a six-inch, 900-pound raised face flange, and the cable packoff and other wellhead penetrations must be capable of withstanding the maximum pressure and temperature conditions encountered in the wellhead. See Figure A2 in Appendix A for a typical wellhead schematic. Similarly, there are few design limitations on the pump casing and production tube. Maximum outside diameter for the pump casing is 13 3/8" to insure a low pressure drop at an annular flow rate of 1500 gpm between the pump casing and well casing, a larger pump casing can be accommodated at higher pressure drops.

The pump casing material can be very light schedule or wall thickness since it is not pressurized and no special couplings or threads are required. The production tubing can be sized to match the flow rates expected. In the well, the production tube should have sufficient wall thickness to contain the differential pressure between the pump suction and discharge. Above the well, the production tubing must have adequate wall thickness to contain the total pump discharge pressure. The production tube must eventually terminate in a six-inch, 900 pound raised face flange to mate with the field piping.

The brine control module is located near the well and contains all the equipment, controls and instrumentation required to maintain the test well. Additionally, a hydraulic turbine is provided to recover a substantial percentage of the pump power used.

The basic brine control loop is pictured in Figure 5 and a more detailed process and instrumentation diagram is shown as Figure A1 in Appendix A.

FIGURE 5

BLOCK DIAGRAM
EMPT F TEST WELL
&
CONTROL LOOP

The brine control loop and test well are filled with the two plunger pumps. The well is filled directly through the pump discharge piping. The control loop piping is filled through the accumulator/tailstock vessel. Fresh brine can be continually added to the control loop and a corresponding spent brine flow is discharged from the accumulator vessel during testing. Fresh brine can be injected at rates between 4 gpm and 50 gpm at maximum temperatures and pressures of 350°F and 600 psi.

Brine temperature is maintained by an air-cooled heat exchanger which is used to reject the heat developed by the pump. Pump suction temperature is measured and compared to a preset required temperature, the differential temperature is used to adjust the temperature control valve which increases or decreases brine flow to the heat exchanger. Flow to the heat exchanger comes from the pump discharge line, bypasses the main control loop, runs through the heat exchanger and enters the accumulator vessel. In the accumulator vessel, the cooler side stream flow is mixed with the main test loop flow and returned to the pump suction. Maximum flow conditions for the heat exchanger are 150 gpm at 450°F and 1845 psi.

Test well pump suction pressure, brine level and brine inventory are maintained in the accumulator vessel. The maximum capacity of the vessel is 700 gallons. The level in the accumulator is compared to a predetermined set point, the vessel horizontal centerline. The differential level is used to control the brine level control valve which increases or decreases brine flow to the disposal facility to maintain a nominal brine inventory of 350 gallons in the vessel. Maximum flow conditions to the disposal facility are 50 gpm at 450°F and 600 psi. Brine pressure is maintained by a nitrogen blanket above the liquid level in the accumulator. A regulator maintains a preset pressure and vents or injects nitrogen as the accumulator level fluctuates. Pressure is maintained at the pump suction pressure required. Maximum pres-

sure and temperature conditions for the accumulator vessel are 600 psi and 450°F.

Brine flow is controlled by the pintle valve on the hydraulic turbine and a flow control valve located in the pump discharge piping. The flow control valve will automatically maintain a constant pump discharge flow rate for endurance testing or it can be manually varied to produce pump characteristic curves.

The EMPTF was designed with instrumentation, controls and automatic safety shutdowns to allow endurance testing of a pump with a minimum of operator support. Typically, a few hours per day of surveillance is all that should be required. The test rig is equipped with a centrally located "status" panel which indicates current operating conditions and any overrange conditions, alarms or shutdowns which have occurred. Conditions which can be preset to run for extended periods of time are pump discharge flow rate, suction pressure, suction temperature, brine level, fresh brine, flow rate and spent brine discharge rate. The test loop is monitored for various upset conditions including pump discharge over or under pressure, pump suction over or under temperature, accumulator vessel high or low level, accumulator vessel over or under pressure and excessive hydraulic turbine speed. If any of these conditions are present, an alarm horn is sounded, the status panel is set which indicates which parameter is out of bounds and the system is automatically shut down. An operator must respond to restart the system and clear all failure indicators.

Instrumentation for the pump test loop (including the test well) and the control loop consists of visual indicators (bordon-tube gauges and bi-metal thermometers) and recording instruments for the important pump parameters. Recording instruments are 24-hour continuous chart recorders which monitor pump discharge flow rate, discharge pressure, suction pressure and suction temperature. Flow rate is measured indirectly as the pressure drop across an ASME flow orifice of known diameter. For detailed information

on the type and location of all the test loop controls and instrumentation, refer to schematic diagram Figure A1 in Appendix A.

The EMPTF facility includes a track-mounted gantry hoist for pump servicing and material handling. The hoist is located above the test pump and is capable of lifting a maximum load of 30,000 pounds, 47 feet above the test well. The hoist track extends 15 feet beyond the test well and the hoist will lift up to 10,000 pounds at its maximum travel.

3.2.1 EMPTF Design Parameters

The following lists contain a quick reference for maximum operating conditions of the EMPTF pump test loop and ancillary hardware. Note that where maximum temperatures and pressures are listed for a given location, they are to be taken as simultaneous conditions. Listed maximum pressures may be exceeded as long as there is a corresponding drop in operating temperature and vice versa.

TEST PUMP MAXIMUM CONDITIONS

Maximum Pump Power	750 hp
Maximum Suction Pressure	600 psig
Maximum Suction Temperature	450°F
Maximum Discharge Pressure	1845 psig
Maximum Discharge Temperature	450°F
Maximum Pump Flow Rate	1500 gpm
Maximum Head Rise at Maximum Suction Pressure and Temperature Limits	1245 psid (3500 ft)

TEST WELL DESIGN PARAMETERS

Test Well Casing OD	20.0 inches
Test Well Casing ID	19.0 inches
Test Well Length	160 feet
Maximum Pump Length	145 feet
Maximum Pump Casing Length	155 feet
Maximum Pump Casing OD	13 3/8 inches
(For Maximum Pump Flow rate)	
Lower Wellhead Mating Flange	20"-900# R.F.
Production Tube Mating Flange	6"-900# R.F.

SIDE STREAM FLOW PARAMETERS

Fresh Brine Injection	Maximum Flow Rate	50 gpm
	Maximum Temperature	Depends on Well
	Maximum Pressure	600 psig
Spent Brine Discharge	Maximum Flow Rate	50 gpm
	Maximum Temperature	450°F
	Maximum Pressure	600 psig
Heat Exchanger Bypass	Maximum Flow Rate	150 gpm
	Maximum Temperature	450°F
	Maximum Pressure	1845 psig

DATA ACQUISITION SPECIFICATIONS

Continuous 24-hour of 7-day mechanical chart recorders are provided for the following:

Test Pump Suction Pressure
Test Pump Discharge Pressure
Test Pump Suction Temperature
Test Pump Flow Rate*

* Measured as ASME Flow Orifice Differential Pressure

AVIALABLE SERVICES

Raw Brine:

Maximum Flow Rate	50 gpm
Nominal Temperature	330°F
Maximum Pressure	600 psig
Nominal Mineral Content (TDS)	2500 gpm

Cooling Water:

Maximum Flow Rate	15 gpm
Maximum Temperature	100°F

Compressed Air:

Maximum Delivery	90 cfm
Maximum Pressure	100 psig

Pump Electric Power

3-phase
480 volts
1200 amps

Auxiliary Electric Power

Single-phase
120 volt
15 amp

HOIST SPECIFICATIONS

Maximum Load at Wellhead	30,000 lbs
Maximum Lift at Wellhead	47 feet
Maximum Travel	15 feet
Load at Maximum Travel	10,000 lbs

3.2.2 Simulation of True Geothermal Environment

The EMPTF is designed to simulate a true downwell geothermal environment with the advantage of being able to control brine temperatures and pressures. The test well and control loop are charged with geothermal brine that is similar in temperature and chemical content to most producible western brines. During operation, fresh brine can be continually injected into the control loop to insure that the brine does not degrade with time. No attempt is made to alter the brine constituents other than to strain the brine at the control module inlet to eliminate large suspended particles. For this reason the pump will be exposed to as severe an operating environment as if it were installed in an actual geothermal well. Facility users should be prepared to supply all protective devices normally used in downwell geothermal applications.

The test well is also designed to simulate the actual field conditions encountered at typical geothermal installations. The well terminates in a 20-inch, 900-pound raised face flange which can accept the user's wellhead. Wellhead design and fabrication is the responsibility of the user; however, the suitability of the wellhead must be verified by Barber-Nichols before it will be accepted for installation. As in a typical field application, the pump must be installed in its own casing to insure that sufficient brine flow passes the motor for cooling. The pump casing also acts as a flow barrier to direct return brine flow down the annulus between the pump casing and the 20-inch well casing to the pump suction. Further details of the pump well interface are discussed in Section 3.2 above, and a sketch of a typical wellhead is included as Figure A2 in Appendix A.

3.2.3 Pump Size Range

The EMPTF will accept submersible pumps ranging in size from 70 to 750 horsepower. Maximum horsepower is limited by the heat rejection capacity of the air-cooled heat exchanger. The test loop and control loop are sized to handle flow rates ranging

from 80 gpm to 1500 gpm without modification. Maximum pump head rise at maximum suction pressure and temperature limits is 1245 psig.

Physical dimensions of the pump are governed by test well geometry. The maximum recommended length of the pump assembly, including motor and protector, is 145 feet. This limit is designed to allow sufficient turning area to initiate brine flow up to the pump suction. The maximum recommended pump casing diameter is 13 3/8" to allow the 1500 gpm maximum flow within the annulus to the pump suction. Both the length and diameter recommended limits may be exceeded if necessary with appropriate changes in operating limits.

3.2.4 Hydraulic Turbine

The EMPTF is equipped with a hydraulic turbine to recover some of the energy produced by pumping a fluid in a closed loop. The pump imparts two types of energy, recoverable work energy generated by raising the fluid pressure and non-recoverable thermal energy which is the result of pump inefficiency. In a typical pump installation, the work energy is dissipated across a throttle valve and thermal energy is dissipated across a heat exchanger. In keeping with the design objective of providing the EMPTF facility for a reasonable cost, Barber-Nichols designed and developed a high efficiency pelton-type hydraulic turbine to recover a substantial percentage of the work energy. The fluid energy is converted to electrical energy which is returned to the local power utility to defray a portion of the operating cost.

The hydraulic turbine is directly coupled to an induction generator with a generating capacity of 450 kW. This direct coupling combination reduces losses within the turbine-generator combination and increases the cost savings. For a typical installation assuming a combined pump/motor efficiency of 60% and known generator and turbine efficiencies of 96% and 80% respectively, it is possible to recover 46% of the total input power. In terms of dollar savings, a typical 680 horsepower pump requires 846 kW of input power for every hour of operation. This results in a power cost

Figure 6, Control Module Showing Hydraulic Power Turbine, 350 kW Generator & Accumulator Vessel

of \$36,500 per month of continuous operation using a nominal power power cost of \$0.06/kW-hr. The power recovery turbine is capable of saving the user \$16,800 of this total cost and reducing the power bill to \$19,700 per month of continuous operation.

The pelton wheel turbine is mounted on the top of the accumulator vessel. High pressure brine from the pump discharge is piped directly to the turbine inlet pintle valve which serves the dual purpose of regulating pump flow rate and directing the incoming brine stream to the pelton wheel buckets. The present pintle valve configuration will accommodate a maximum brine flow rate of 750 gpm, for applications involving higher flow rates, the excess is bypassed through a conventional throttle valve. This bypass is also used for short-term and intermittent testing or for test conditions that require variable pump flow rates. After impacting the turbine buckets, the brine falls through the tailstock portion of the accumulator vessel. This large open area allows the spent brine to fall cleanly away from the turbine and results in the turbine's high efficiency. The brine then passes over baffled deaeration trays in the upper portion of the accumulator vessel. This removes entrained gases from the brine that could be detrimental to pump operation. Figure 6 shows a view of the pelton wheel housing, pintle valve and accumulator vessel. The generator is shown behind and above the turbine housing. A photograph of the assembled pelton wheel is shown in Figure 7.

3.2.5 Operating Support

Barber-Nichols will supply operators for manning the GPTR during testing, performing routine and special maintenance on the GPTR and to support test pump installation and removal. Additionally, Barber-Nichols will provide design support for special test hardware that interfaces the user's pump to the test rig and will give final approval for installation of user-supplied equipment.

At pump installation, the user will be required to furnish all special equipment and personnel to accomplish that effort. Barber-Nichols personnel will be available for support only and

Figure 7
Assembled Pelton Wheel

can assume no responsibility for the installation of the user's equipment. Once the pump is installed, Barber-Nichols will prepare the EMPTF for testing and begin test operations. The user should have people on hand until they are satisfied that their equipment is performing as expected. When the equipment is performing satisfactorily, Barber-Nichols will assume operation of the EMPTF and will conduct tests according to the user's pre-arranged test plan. Barber-Nichols will maintain personnel at the site for periodic monitoring of endurance tests and for the more intensive testing required to produce head-flow data or other information requiring variable pump flow conditions. As with pump installation, Barber-Nichols personnel are available in a support capacity for servicing and removing the test pump.

3.3 DOCUMENTATION FOR POTENTIAL USERS

Present documentation for potential users consists of a User's Manual included as Appendix A of this report. The User's Manual contains a complete description of the EMPTF, its operating limits, data acquisition specifications, hoist specifications and user interface information. Also included are a piping and instrumentation diagram showing the types and locations of the various pressure, temperature and flow instruments, and a sketch depicting the test well with a typical wellhead.

Other user documentation planned for the future is a complete operating and maintenance manual. Unfortunately, since the EMPTF has never been run due to a lack of a test pump, the information required to complete this manual has been unobtainable.

3.4 FABRICATION AND INSTALLATION COMMENTS

The EMPTF control module, including the hydraulic power turbine, module-mounted piping, instrumentation and controls, was fabricated and assembled at Barber-Nichols' facility in Arvada, Colorado. The control module contains some unique structural features that allow for ready access to all major components while keeping the overall package dimensions small enough to en-

able easy truck transportation. Before shipment to the East Mesa site, all module piping and components were pressure checked, and the action of controls and instruments was verified.

The hydraulic power turbine was assembled in its housing at Barber-Nichols to verify the dimensional fit of all the internal components, and the housing and seal assemblies were pressure checked. The turbine housing represented a critical engineering challenge. Typically, these devices are used in low pressure or partial vacuum installations for which the main criteria of the housing design are to provide sufficient clearance for low windage loss, rotor operation and a large enough area to allow for the free-fall of spent fluid away from the buckets. To accommodate the high pressure and high temperature conditions, a cylindrical pressure vessel design was used as opposed to the conventional rectangular housing. To reduce potential windage loss, the turbine was mounted eccentrically to the axis of the vessel and the side clearance was kept at a minimum. Two pintle valve parts were fabricated in the cylindrical wall of the vessel furthest from the turbine. The pintle valve nozzle must be far enough from the impingement point to allow full development of the brine jet profile, yet vessel diameter has to be conserved to keep the wall thickness reasonable. The brine jets must strike the turbine buckets at a precise location and at an oblique angle in order to achieve high turbine efficiencies. The layout and fabrication of these parts were very carefully controlled and the welded assembly was frequently checked for dimensional tolerances during manufacture. The pelton wheel uses a double-hung mounting configuration so that bearing surfaces on both sides of the wheel are available to take the radial forces produced by the turbine wheel. The bearings are mounted within their own housings to protect them from the corrosive brine environment and to provide an enclosed area for bearing lubrication. Two shaft seals are required for this mounting approach and Barber-Nichols developed special cartridge-type seal assemblies capable of sealing against both high pressure fluid and high pressure vapor for this application. A rectangular hatch located near the top of the cylindrical housing provides access to the turbine for installation, removal and inspection. Seal and

bearing housings are accessible through cover plates on the housing and walls. In order to prevent leakage, the gasketed sealing surfaces were kept as small as possible. This means the turbine must be completely disassembled for installation and removal. The turbine wheel and its buckets are separate castings. The wheel is installed on its shaft in the housing and the buckets are individually bolted in place. In order to minimize the cost of the turbine/housing assembly, conventional pipe fittings were used where ever possible and machining was kept to a minimum.

The test well was fabricated at the East Mesa installation. The initial 24-inch diameter, 160-foot-long well bore was cut dry by a piling bore drilling rig. The 20-inch well casing was installed in the bore hole using buttress-threaded coupling to join the sections and a fabricated bull plug was used to seal the lower end. After the casing was lowered into the bore, it was held in place by a workover rig while a special cement was pumped into the annulus between the casing and the bore to insulate and seal the test well. The cement used was G+40 which is a high temperature application cement consisting of class G Portland cement and 40% silicon flour in a fine matrix with pea sand as the aggregate. After the well had been set, a 20-inch, 900-pound blind flange was used to cap the top and the well was pressure and leak checked.

The gantry hoist installed at the site takes advantage of an existing structure that was located near the test well. Additional structure and support bracketry was designed and fabricated by Barber-Nichols. The brackets were fabricated at Barber-Nichols' Arvada facility and shipped to the site for final installation and assembly.

Additional work performed by Barber-Nichols at the East Mesa site included all field piping for brine supply to the control module, brine disposal, cooling water, compressed air and a module to test well piping runs. All hot field piping, and hot piping and components on the control module were insulated with aluminum jacketed rigid fiberglass insulation.

3.5 ITEMS TO BE COMPLETED WITH FIRST PUMP INSTALLATION

The facility has been idle since its installation and has been completed with the result that a few tasks remain unfinished. The most important of these remaining tasks is to take the EMPTF through a "shake-down" run. This is necessary to verify that all the Barber-Nichols support equipment, controls and instrumentation will perform satisfactorily during actual pump test conditions.

While the EMPTF has been idle, all the components subject to potential damage have been removed and placed in storage. The items currently in storage include all recording instrumentation, the power recovery turbine assembly, the control loop, pneumatic and electronic controls, and the wellhead instrumentation and controls. These items will need to be reinstalled before a pump test can be made. The control loop and plunger pumps must also be reconditioned. Additionally, the field piping between the control module and the test pump must be completed; however, final connections cannot be made until a wellhead is available.

As a consequence of not having a pump available for test or to perform a "shake-down" run, the EMPTF operating and maintenance manual has not been completed. This manual is provided to potential users and others, and should reflect actual operating experience with the EMPTF to be of the most use.

APPENDIX A
GEOTHERMAL PUMP TEST FACILITY
USER'S MANUAL

INTRODUCTION

Barber-Nichols has completed fabrication and installation of a large-scale geothermal pump test facility (EMPTF) for the Department of Energy under contract number DE-AC02-81SF11556. The EMPTF installed at the East Mesa geothermal test facility near Holtville, California presents a unique opportunity for manufacturers of submersible downwell geothermal pumps and equipment to gain operating experience testing in a true geothermal environment without the attendant cost and risk associated with "in-the-well" testing.

The EMPTF provides a controllable geothermal testing environment for electrically driven downwell pumps up to 750 hp and 150 feet long. Using geothermal brine from the DOE test site wells, a wide variety of downwell operating conditions can be achieved. Well temperature, pressure and flow rate can be varied to obtain pump performance characteristics, or the facility may run at pre-set conditions to evaluate pump endurance. The system is designed to run continuously with a minimum of operator supervision utilizing data recorders, automatic controls and automatic safety shutdowns.

PUMP TEST RIG DESCRIPTION

The geothermal pump test rig configuration consists of a simulated well with appropriate equipment for controlling the operating conditions of the test pump. The flow loop for the pump is closed in typical pump test loop configurations. Provisions are incorporated into the support equipment to inject the test loop with a steady flow of fresh brine to maintain the proper brine chemistry with time. The closed loop configuration allows brine temperatures of up to 450° to be achieved even though the brine source temperatures at East Mesa are limited to approximately 350°. The simulated well

allows testing of a complete pump assembly including associated equipment such as potheads, cable and packoffs. The well is installed in the ground while above surface piping and a module with support equipment form the remainder of the test loop. The primary function of the surface support equipment is to control the operating environment and operating point of the pump. Figure A1 is a schematic of the complete pump test rig with its support equipment.

The simulated test well starts with 165 feet of 20-inch bore casing cemented into the ground. An adaptor sits on top of the 20-inch casing which allows attachment of a user-provided wellhead. The pump is installed with production tubing attached to the wellhead. The pump and production tubing must be located within a pump casing of the appropriate size. The well casing is also attached to the wellhead and forms a flow barrier that directs return flow down the annulus between the 20-inch bore and the pump casing to the mouth of the casing. With the casing of greater length than the pump and production tubing, the inlet flow will come upward past the pump motor to the pump inlet to provide motor cooling. Pump discharge flow is taken from the wellhead through a six-inch pipe to the support skid for control and conditioning.

The support skid contains appropriate valves and pumps for filling the rig with brine and supplying a steady flow of brine to the loop. A heat exchanger cools a portion of the brine flow in response to a temperature control loop to maintain a preset operating temperature for the brine supplied to the pump. Pump flow is set and maintained by a controlled throttle valve. To reduce the power consumed by the pump testing, a hydraulic turbine has been installed that generates electric power from the pump discharge flow. During endurance testing, a large percentage of the input pumping horsepower can be recovered and returned to the power lines. The turbine generates electrical power by being coupled to an induction generator which eliminates the need for synchronizing or any of the special synchronous generator protective switch gear. Suction pressure for the pump is set by controlling the pressure in the tail stock. The tail stock plays a

dual role in the test rig. First it allows the pelton-type hydraulic turbine to work in a vapor space, thereby achieving high efficiencies, and second it provides a plenum or expansion tank for the water in the closed test loop. The brine passes through a set of deaeration trays before it is accumulated in the tail stock and returned to the pump.

The test loop is equipped with appropriate condition and parameter sensors and a shutdown monitor to allow unattended operation. If loop pressures, temperatures or brine level in the tail stock are not within the preset limits, the rig automatically shuts down. In keeping with the objective for allowing unattended operation, pump flow rate, suction pressures and operating temperatures are all recorded on 24-hour Barton recorders.

USER INTERFACE INFORMATION

Users of this facility will have to provide typical support equipment for their pump plus interface hardware to adapt the test well to their particular pump. Support equipment would include transformers, motor starters and electrical material to interface with the 1200 amp, 480 volt bus. Installation of the pump itself in the simulated well will require the user to supply a wellhead that meets system requirements and interfaces between the test rig and the user's pump. Figure A2 shows a typical wellhead in dotted outline that would mate the pump to the simulated and associated piping. The user would supply the production tube and fittings required to support the pump in the well and would also supply the pump casing for testing of the pump. Figure A2 shows the pump casing hung from a flange sandwiched at the interface between the well and the wellhead. The casing does not have to support any pressure or structural load and can be fabricated from tubing or pipe. This casing should be long enough to enclose the pump motor and direct the flow around the motor for proper cooling. Total length of the pump casing that can be accommodated in the well is 155 feet. The packoff used in the wellhead will have to be designed to work at higher pressures than in a typical well installation. To achieve required downwell pressures, the pressure

at the top of the well is as high as the suction since the setting depth does not allow the normal pressure reduction achieved by the gravity head present in an actual well. Thus the packoff must be designed to meet these high pressures.

Operation and running the pump test rig will be performed initially by Barber-Nichols personnel. Once the test rig and pump have been checked out and the pump is operating at a desired point for endurance running, the operators will leave the rig and start a daily regime of periodic monitoring. During installation and removal of the pump, the user must supply the necessary equipment and personnel. Barber-Nichols personnel will be available to support the pump installation and removal. Design support will be provided for the special test hardware that interfaces the user's pump to the test rig and a final approval by Barber-Nichols will be required prior to installation of the user-supplied equipment.

A gantry-mounted hoist is provided at the site to support the installation and pulling of the test pump. The hoist has the capability of lifting a 30,000-pound, 40-foot test section above the well. Additionally, the hoist may travel laterally 15 feet with a maximum load capacity of 10,000 pounds. Also available at the East Mesa test site are two fork lifts, a small mobile crane, stick welding machines and limited machine shop capability to support pump testing activities.

TEST PUMP MAXIMUM CONDITIONS

Maximum Pump Power	750 hp
Maximum Suction Pressure	600 psig
Maximum Suction Temperature	450°F
Maximum Discharge Pressure	1845 psig
Maximum Discharge Temperature	450°F
Maximum Pump Flow Rate	1500 gpm
Maximum Head Rise at Maximum Suction Pressure and Temperature Limits	1245 psid (3500 ft)

TEST WELL DESIGN PARAMETERS

Test Well Casing OD	20.0 inches
Test Well Casing ID	19.0 inches
Test Well Length	160 feet
Maximum Pump Length	145 feet
Maximum Pump Casing Length	155 feet
Maximum Pump Casing OD	13 3/8 inches
(For Maximum Pump Flow rate)	
Lower Wellhead Mating Flange	20"-900# R.F.
Production Tube Mating Flange	6"-900# R.F.

SIDE STREAM FLOW PARAMETERS

Fresh Brine Injection	Maximum Flow Rate	50 gpm
	Maximum Temperature	Depends on Well
	Maximum Pressure	600 psig
Spent Brine Discharge	Maximum Flow Rate	50 gpm
	Maximum Temperature	450°F
	Maximum Pressure	600 psig
Heat Exchanger Bypass	Maximum Flow Rate	150 gpm
	Maximum Temperature	450°F
	Maximum Pressure	1845 psig

DATA ACQUISITION SPECIFICATIONS

Continuous 24-hour of 7-day mechanical chart recorders are provided for the following:

Test Pump Suction Pressure
Test Pump Discharge Pressure
Test Pump Suction Temperature
Test Pump Flow Rate*

* Measured as ASME Flow Orifice Differential Pressure)

AVAILABLE SERVICES

Raw Brine:

Maximum Flow Rate	50 gpm
Nominal Temperature	330°F
Maximum Pressure	600 psig
Nominal Mineral Content (TDS)	2500 gpm

Cooling Water:

Maximum Flow Rate	15 gpm
Maximum Temperature	100°F

Compressed Air:

Maximum Delivery	90 cfm
Maximum Pressure	100 psig

Pump Electric Power

3-phase
480 volts
1200 amps

Auxiliary Electric Power

Single-phase
120 volt
15 amp

HOIST SPECIFICATIONS

Maximum Load at Wellhead	30,000 lbs
Maximum Lift at Wellhead	47 feet
Maximum Travel	15 feet
Load at Maximum Travel	10,000 lbs

BARBER-NICHOLS			ENGINEERING	Arvada, Colorado 80002
TITLE EAST MESA GEOTHERMAL PUMP TEST FACILITY SCHEMATIC				
SIZE	CODE IDENT NO.	DRAWING NO.		
	57377	FIGURE A1

CROSS-SECTION TEST PUMP WELL-HEAD
(USER SUPPLIED COMPONENTS SHOWN AS
DASHED LINES.)

FIGURE A2