ELECTRICAL SUBMERSIBLE PUMPS IN GEOTHERMAL ENVIRONMENTS

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ABSTRACT

The need for using artificial lift to produce geothermal fluids is a reality. Electrical submersible pumps represent a promising method of pumping these hot, hostile fluids. A description of the equipment which makes up an electrical submersible pump (E.S.P.) system is discussed along with considerations involved with geothermal applications. Areas of equipment development needed to improve reliability and extend the operating range are likewise presented.

INTRODUCTION

The economics of drilling and producing geothermal fields indicate the need for utilizing artificial lift methods to increase the production of geothermal fluids. Electrical submersible pumps have been used for many years in the petroleum industry for pumping fluids from hostile environments. It is only natural that their use be extended to the pumping of geothermal resources. The application to geothermal wells does present unique problems and is requiring the extension of the state of the art for submersible pumps in order to reliably operate in these hot environments.

The present state of the art for E.S.P.'s is found in petroleum industry applications. In recent years, submersible pumps have been successfully operating in oil wells with temperatures to 260^{o}F, producing depths to 12,000 ft. and flow rates through 1500 GPM. Oil well environments contain crude oil, water, and brine fluids as well as methane, CO_2, and H_2S gases. Submergence pressures experienced by the pumping equipment can be 3500 psi.

THE PUMPING SYSTEM

A submersible pumping installation is a system made up of several vital components. Technically speaking, the system takes electrical power and converts it into mechanical power via the electrical motor. The mechanical power is then coupled to the pump where it is converted to hydraulic power which does work on the fluid being lifted. A simple system block diagram can be constructed as in Figure 1.

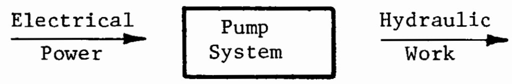
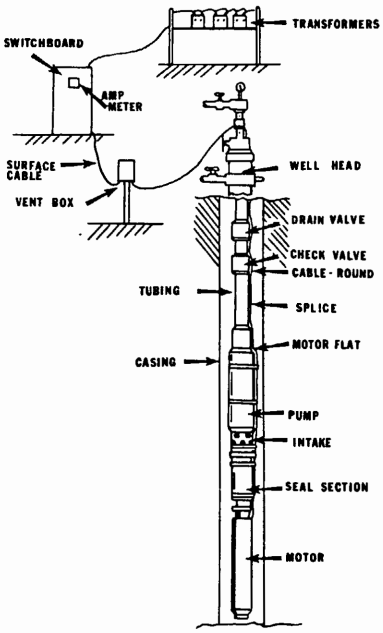


Figure 1

Figure 2 shows a typical submersible pumping system installation. The elements of the installation start at the electrical power distribution



SUBMERSIBLE PUMP INSTALLATION

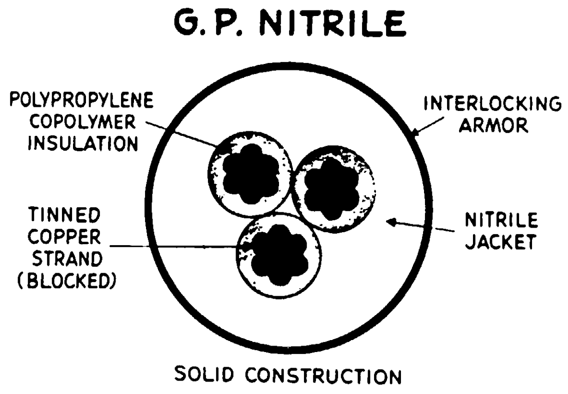
FIGURE 2

lines with the three phase transformer bank. The purpose, of course, of the transformers is to change the level of the voltage from the distribution value to the required surface value. The surface value is a function of the motor nameplate and the voltage drop in the downhole cable feeding the motor. Since each installation may have a different setting depth and, therefore, a different length of the downhole cable, several different secondary voltage taps are usually required.

The next element of the system is the motor controller. The function of the motor controller is threefold. First, the motor controller houses the power contactor which energizes or deenergizes the submersible motor. In effect, it turns on or off the pump. Secondly, the motor controller contains protection elements which should sense motor overload, well pump off, single phase conditions, and harmful levels of unbalanced voltage. Finally, the motor controller provides interfacing and coordination of shutdown and startup with auxiliary control devices such as pressure switches, tank levels, and remote commands.

Motor controller ratings depend upon the horsepower of the motor and the surface voltage. Because of the degree of the required protection and the uniqueness of the submersible motor characteristics, the submersible pump manufacturers design and manufacture motor controllers to the requirements of the specific application.

Once electrical power is connected to the system via the motor controller, it is transmitted to the motor through the downhole cable. This cable is a three conductor cable which can have several different physical configurations as well as utilizing different materials. Figure 3 shows the most common configuration used in oil well applications.



CABLE

FIGURE 3

Figure 4 shows two of the cables being presently used in geothermal applications. The lead sheath cable has the advantage of the qualities of lead being impervious to the environment. On the other hand, the lead sheath tends to stress crack with handling and is also very difficult to reliably splice.

The CL-81 cable uses a patented high temperature formula of EPDM rubber for the conductor insulation. Present cable applications of this configuration go as high as 300°F. Tests have been performed on the material at 500°F with encouraging results.

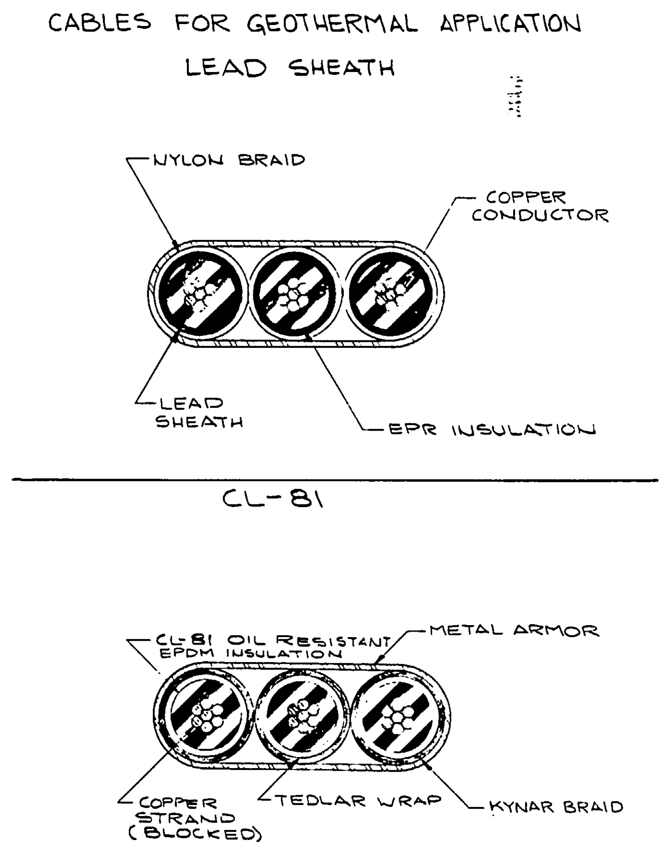


Figure 4

The downhole electrical power cable is connected to the submersible motor through an electrical connector commonly called a "pothead". This connector is usually a plug-in design and is constructed to prevent the well environment from leaking into the motor.

The submersible motor is a three phase, squirrel cage induction motor of very special design. This motor is commonly built in diameters of 4-1/2", 5-7/16", and 7-1/2" O.D.'s. Horsepower output can range from 15-750 hp. The length of these motors in single piece construction can be in excess of thirty feet. In tandem, they can exceed sixty feet.

The motor is filled with a highly refined insulating oil and therefore operated with a fluid in the gap between the rotor and stator instead of the air found in a typical surface motor. This fluid increases the dielectric strength of the electrical winding, lubricates the bearings of the motor, and provides for pressure equalization of the inside of the motor with the outside of the motor (well environment). In such a way, very little pressure differential is allowed to exist across the sealing joints and electrical connector of the motor.

Coupled to the submersible motor is another element of the system called the seal section. This seal plays three fundamental roles in the submersible system. First, the seal section contains the thrust bearing which carries the thrust of the pump. The seal section also allows for the expansion and contraction of the dielectric oil in the airgap of the motor which changes with motor temperature. Finally, the seal section allows the equalization of the internal pressure in the motor with the well pressure without allowing water, brine, hydrocarbons, precipitates, and other contaminants to enter the motor and break down the dielectric insulation properties within the motor. Figure 5 shows a cutaway of the internal parts of the seal. Separation of the well fluid from the motor fluid is accomplished by shaft seals and a series of U-tubes. Since the well fluid is heavier than the dielectric oil in the motor, it stays at the bottom of the U-tube and will not migrate into the motor unless all three shaft seals leak. Field experience with this design has been excellent.

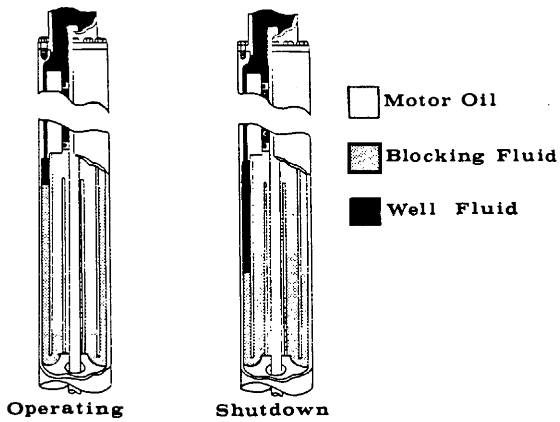


Figure 5

The final element of the submersible system is the pump. Figure 6 shows an internal cross section of a typical pump. The pump, of course, is of the centrifugal design and is made up of a number of stages. Each stage is comprised of an impeller and diffuser. The impeller is fixed to the shaft, and therefore rotates. The diffuser is fixed to the pump housing. The submergence pressure primes the first stage. As the impeller turns, the vanes apply centrifugal force to the fluid which then undergoes a pressure change which causes flow. The diffuser picks up the fluid from the circumference of the impeller converting kinetic energy into pressure and redirecting the fluid upward and inward to the impeller eye of the next stage. As the fluid progresses through each succeeding stage, a greater pressure is obtained.

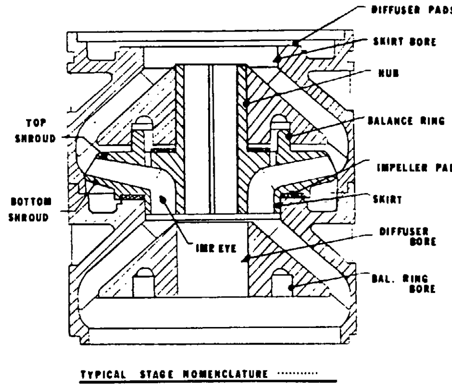


Figure 6

GEOTHERMAL ENVIRONMENTAL CONSIDERATIONS

The geothermal environment is one which is somewhat different than oil industry applications and can be either milder or tougher depending upon several factors. The primary run-life criteria is environmental temperature. Some "greenhouse" geothermal applications comprise pumping water or brine at temperatures as low as 180^{o}F. Other applications such as power generation source wells involve ambient well temperatures between 300^{o}F and 400^{o}F and fluids having precipitates which must be kept under pressure. In most cases, corrosion is a potential problem because of brine content as well as the presence of soluable gases such as CO_2 and H_2S.

Modification of a standard electrical submersible pump is necessary for geothermal operation in environments with temperatures in excess of 250^{o}F. Critical elements of the pumping system in the hotter environments include elastomers used for sealing, cable materials, oils used in motors, thrust bearing surfaces, bearing materials and tolerances, and mechanical seal considerations.

With regard to elastomeric materials, a considerable amount of engineering analysis and investigation has been centered toward modification of Vitons and EPR to withstand these high temperatures. Specially compounded EPDM's seem to have considerable promise for utilization at temperatures to 400°F. The use of these EPDM's in o-rings, packing material, cable insulation, and bellows enable the extension of the ESP operating range. The upper limit at present is thought to exist between 350°F-400°F.

EXISTING GEOTHERMAL INSTALLATIONS

To date, there have been only a handful of electrical submersible pumps operating in geothermal wells. Some of these applications have been lower temperature "greenhouse" wells while several installations involve operation at temperatures from 280°F through 360°F. Several pumps are presently installed in Idaho at Raft River's 5 Megawatt Power Demonstration Plant. These pumps are typically 1300 BPD pumps with as large as 650 hp. motors capable of 1325 head ft. of lift. Temperatures are in the 280°F-300°F range. Other installations involve well tests, the hottest application being approximately 360°F.

The run life performance of electrical submersible pumps in these hot environments has only been marginal. However, improvement in materials and designs are presently in progress by at least a couple of manufacturers. A realistic evaluation of operating potential in temperatures in the 300°F-400°F range would indicate that technology exists with the aid of modifications gained through experience to operate successfully at these temperatures.

SUMMARY

The use of electrical submersible pumps in geothermal applications is relatively new. Operation in environment temperatures to 250°F is state of the art. Presently, modified units are operating at temperatures to 300°F in Raft River, Idaho. At least one test unit has operated at ambient temperatures of approximately 360°F for a period of about one month without failure.

Material research is ongoing to provide increased temperature capabilities for E.S.P.'s. Progress in improved elastomeric materials has been made and application of improved materials is in process. As further field experience is obtained, necessary modification will be made which will result in a viable pump for geothermal fluids at temperatures to 400°F.

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