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# 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 applications 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 290°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<sub>2</sub>, and H<sub>2</sub>S 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.

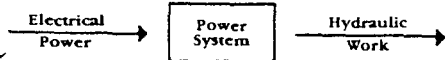
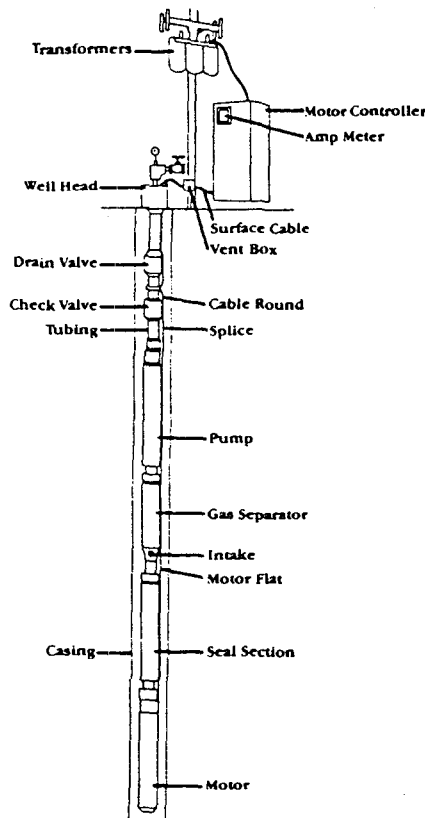


Figure 1.

Figure 2 shows a typical submersible pumping system installation. The elements of the installation start at the electrical power distribution lines with the three phase transformer bank. The purpose, of course, of the transformer 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.



SUBMERSIBLE PUMP INSTALLATION

Figure 2.

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 pro-

tection 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. This type configuration, round with interlocking armor, may be used in geothermal operations, with considerations being placed on operating temperatures. For those wells in excess of 180 - 200°F, polynitrile would not be used.

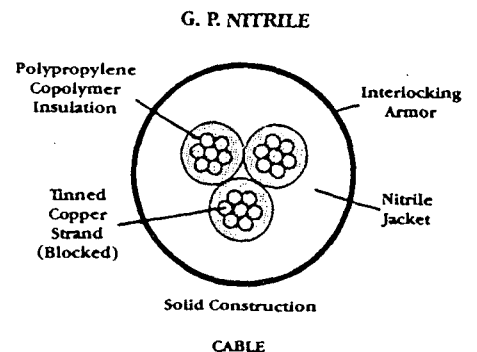


Figure 3.

Figure 4 shows two of the cables which have been used in geothermal applications. The CL83 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. The CL400 cable uses a high temperature formula of EPDM for the conductor insulation. This cable has been designed for those applications with operating

temperatures in excess of 400°F.

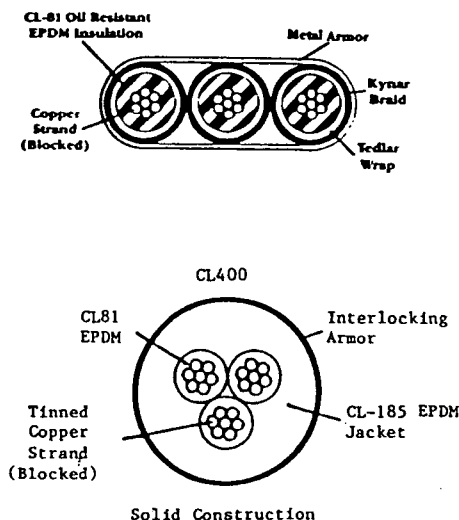


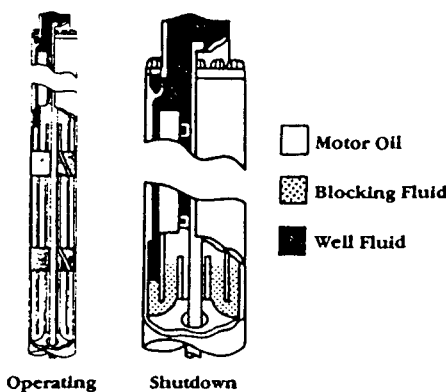
Figure 4.

The submersible motor is a three phase, squirrel cage induction motor of very special design. This motor is commonly built in diameters of 4½ in., 5¾ in., 6 in. and 7½ in. 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 equipment). 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 migrate into the motor. Three separate, independent seal chambers are used. In the event the top mechanical seal leaks, the well fluid would then flow to the second chamber and

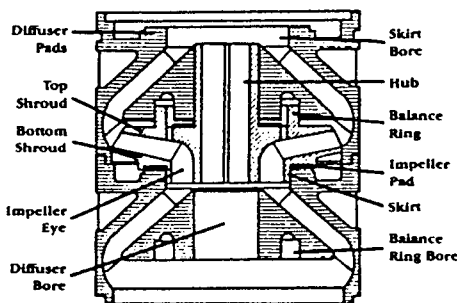
be trapped in the U-tube of that chamber. All these mechanical seals would have to fail to allow moisture and contaminants into the motor.



TYPE B SEAL OPERATION

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.



TYPICAL STAGE NOMENCLATURE

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°F. Other applications such as power generation source wells involve ambient well temperatures between 300°F and 400°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 soluble gases such as CO<sub>2</sub> and H<sub>2</sub>S.

Modification of a standard electrical submersible pump is necessary for geothermal operation in environments with temperatures in excess of 250°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 EPOM's seem to have considerable promise for utilization at temperatures to 400°F. The use of these EPOM'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

Electrical submersible pumps have been utilized in different applications related to geothermal sources. Some of these applications have been lower temperature "greenhouse" wells, produced fluids pumped through a series of pipes where heat is extracted for heating of greenhouses, while several installations involved operation at temperatures from 280°F through 360°F. Other installations involve well tests, the hottest application being approximately 360°F. Testing of wells where operating temperatures exceeded 350°F, flow rates typically at 1300 GPM with lift requirements in excess of 1300 ft. have also been conducted.

The run life performance of electrical submersible pumps in these environments has improved. 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 those temperatures.