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TITLE: EXAMINATION OF INSULATION WEAR MODES IN GEOTHERMAL LOGGING CABLES

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EXAMINATION OF INSULATION WEAR MODES IN GEOTHERMAL LOGGING CABLES

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ABSTRACT

The wear mode of the Tetrafluoroethylene (TFE) insulation used on an electrical logging cable is described. The cable examined in this study was used repeatedly in various harsh geothermal environments. Considering the amount of abuse the cable was subjected to, the TFE performed very well. Grooves were formed on the outside of the insulation as a result of the fluid pressure and the loading from the inner layer of metal armor. Also, indentations on the inside of the insulation were caused by the insulation molding to the conductor strands. If this mode of wear were to continue, the conductors would eventually protrude from the insulation and short out against each other or the cable armor.

INTRODUCTION

Cables for geothermal applications exist in two forms, electrical logging cables and nonelectrical cables. Electrical logging cables not only provide the mechanical support for geophysical tools and instruments but they transmit power to and receive signals from downhole instruments. These signals are used to measure many important downhole parameters such as temperature, pressure and flow rate and their changes. For this reason all of the components of a logging cable must be able to withstand the hostile geothermal environment as well as the forces and loads applied to the cable.

Two types of electrical logging cables are used for geothermal applications. The first type is a multi-conductor cable consisting of several conductors which are each individually wrapped with insulation then covered with one or two outer layers of a high-strength metal armor. The second type is a coaxial cable which consists of a center core conductor wrapped with insulation, covered with a conducting shield and an outer layer of armor.

Thus far, experimental work has been conducted on several types of wireline materials which can withstand hostile geothermal environments and are likely candidates for the outer cable armor (Vaughn and others, 1981). Also, four types of coaxial cables have been examined experimentally under load at high temperature and pressure (Smith and others, 1981). However, no references could be found on the type of mechanical wear or resistance to wear of the insulation used in multiconductor cables typically used in wireline operations.

Two of the common types of insulation used in geothermal cables are Perfluoralkoxyethylene (PFA) and Tetrafluorethylene (TFE) Teflons. The assessment of the wear modes to the TFE insulation on a cable that has been used downhole is examined in this paper. In order to better understand this mode of wear, a new cable will be used for comparison.

BACKGROUND

The multiconductor cable examined consists of two layers of galvanized improved Plow Steel armor surrounding a standard 7-conductor cable with TFE insulation. The outside layer of armor has an overall diameter of 1.110 cm consisting of 18 strands of wire each with a diameter of 0.150 cm. The inner layer of armor also has 18 strands of wire each with a diameter of 0.107 cm and an overall diameter of 0.808 cm. A cigarette paper configuration wrap is used to seal the insulation around the conductors. Also, a TFE braid around the 7-conductor core is used as a bedding for the metal armor and provides an extra layer of insulation material to resist damaging the TFE insulation and electrical conductors. A cross-sectional view of the whole cable is shown in Fig. 1 which is a photomicrograph obtained using a Scanning Electron Microscope (SEM). All other figures were obtained on an SEM.

This particular cable was used primarily at the Fenton Hill Site (FHS) geothermal wells where the bottom-hole temperature is 320°C at a depth of 4600 m (Helmick and others, 1982). The geofluid in these wells is classified as Corrosivity Class IV (Ellis, 1983). Other locations where the cable was used include mostly Class IV geofluids, however one well was identified as Class I, which is the worst possible case for corrosion. The cable was used for approximately 125 runs downhole with a nominal 4000-lb load. It is still in use with no apparent electrical or mechanical degradation.

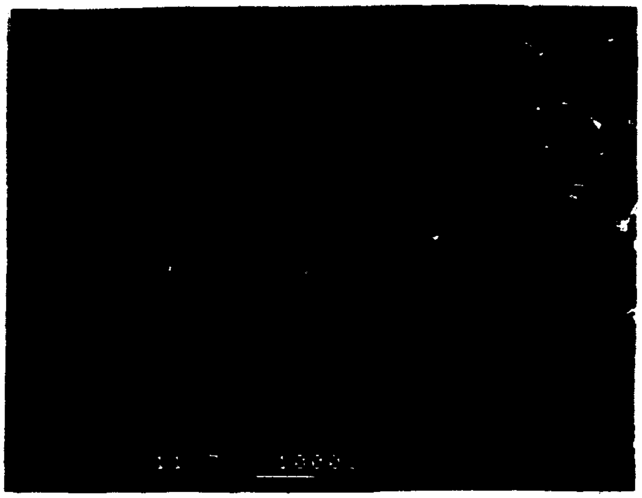

Figure 1. Cross-sectional view of the whole cable.

DISCUSSION

Figure 2 shows a cross-sectional view of the inside core of conductors. This core has never been wrapped with an outer armor, therefore it hasn't been subjected to any mechanical loads. Some of the conductor fibers have been removed to show the indentations caused by the Teflon molding to the conductors. As a comparison, Fig. 3 illustrates the results from the cable that has been used downhole. The indentations on the used cable are only slightly more developed. Also, as can be seen, the spaces between the seven individually wrapped conductors disappear and the

Figure 3. Cross-sectional view of conductor core from used cable.

insulation takes on a hexagonal shape around the center conductor. Figures 4 and 5 are side views of the new and used cable, respectively. The method of wrapping the Teflon around the conductors is quite apparent in both cases. Figure 5 demonstrates the effect the outer cable armor has on the Teflon. The unwrapped core has no deformation whereas on the used cable grooves have developed from the force applied by the outer armor. These grooves are fairly uniform with a diameter equal to the diameter of the inner layer of cable armor, approximately 0.107 cm, with the depth of the grooves about 0.015 cm.

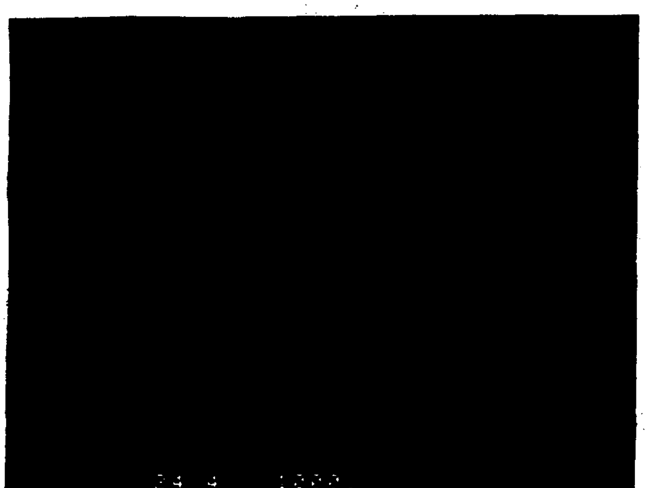

Figure 2. Cross-sectional view of conductor core from unused cable.

Figure 4. Side view of TFE insulator on unused cable.

The deformation on the used cable can be attributed to the large hydrostatic pressure it has been repeatedly subjected to, and also the tensile loads measured as high as 4000 lbs at the wellhead sheave. Considering how much the cable has been used, the incremental wear is relatively small. However, this mode of wear will eventually cause the conductor wires strands to get so close to the surface of the insulation that they would begin to touch each other or the inner cable armor and short out.

SUMMARY

Logging cables with TFE insulation possess excellent characteristics that resist the harsh environment to which they are exposed. The TFE insulation was examined from both internal and external surfaces. Deformation on the inside surface of the insulation was caused by the Teflon being molded to the electrical conductor strands. Deformation formed on the external surface on the insulation was caused by the inner layer of metal armor. The particular cable examined was used 125 times downhole and shows no indications of electrical degradation and no further mechanical wear.

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Figure 5. Side view of deformation to the TFE insulation on used cable.