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# Insulation Selection for Electromechanical Cables

As oil & gas horizontal wells are drilled deeper and horizontal sections are longer than ever before, electromechanical cables are being subjected to more extreme down hole conditions. Longer exposure time to higher average temperatures, faster turnaround time from plug and perforating operations, and loosening outer armor cables while rubbing on horizontal sections of casing are just a few of the conditions a wireline must survive in today's oilfield. One of the most important components in any wireline, the insulation, is tasked with protecting the conductor copper wire from arcing to the steel armor wires while providing a dielectric barrier from the electromagnetic fields produced by the flowing current within. In addition to fulfilling this critical function, an insulation must also be able to withstand the ambient heat from bottom hole temperatures in an oil or gas well and resist the innate compressional forces from the inner steel armor layer. With the crucial job of delivering the electricity to instrumentation at stake, it is important to understand and choose the correct insulation for your specific wireline application.

## Temperature Ratings

The plastics surrounding the conductor must be able to withstand the expected down hole temperatures from the formation when placed in a well. If the plastic melts, and the copper conductor makes contact with the armor wires, the cable will short and be rendered useless. Plastic manufacturers rate their plastic's resistance to heat at continuous and intermittent exposure rates. For example, a plastic rated to 500°F continuous and 550°F intermittent would be able to resist temperatures up to 500°F without any noticeable degradation of the plastic and 550°F for short periods before seeing permanent deterioration or melting of the plastic. Temperatures above 550°F would result in complete failure. Different plastics inherently possess varying levels of heat resistance and are therefore selected according to their required working temperatures. For a more detailed explanation of plastic properties and heat, please refer to the Camesa Technical Bulletin Number 21.

## Dielectric Properties

The most important function of insulation in an electromechanical cable is to insulate the copper conductor from the steel armor wires. As electricity flows through the copper conductor of a wireline, an electromagnetic field is created and interacts with the steel armor wires. This electromagnetic field has the potential to impede the electrical current flowing through the copper conductor powering the logging tool at the end of the wireline. The measurement of this potential impedance is called the capacitance. In order to decrease the capacitance between a conductor and the steel armor wires, a dielectric material must be used. A dielectric is an electrical insulator that can be polarized by an applied electric field. When a dielectric is placed in an electric field, electric charges do not flow through the material thus reducing the potential to impede the electrical current running through the conductor. Plastics are considered a dielectric material and have varying levels of capacitance resistant properties which is why they are used as electrical insulators.

## Hardness

The third requirement of an insulator in an electromechanical cable is that it possesses the physical properties to resist the mechanical forces placed on it during its use. Not only must it be able to resist the bending forces placed on it when spooled from a drum and through a series of sheaves, but it must also be able to resist the compressional forces exerted on it by the inner armor wires. As a cable is lowered into a well, the weight of the tool string and of the cable elongate the helical shape of the individual wires which in turn reduces the inner radius of the cable causing the inner armor wires to "squeeze" the solid inner conductor compressing the core (See Technical Bulletin 21). The plastic insulation's ability to resist this mechanical compression can be

**Durometers of various common materials**

| Material | Durometer | Scale |
|---|---|---|
| Bicycle gel seat | 15-30 | 00 |
| Chewing gum | 20 | 00 |
| Sorbothane | 40 | 00 |
| Sorbothane | 30-70 | A |
| Rubber band | 25 | A |
| Door seal | 55 | A |
| Automotive tire tread | 70 | A |
| Hydraulic O-ring | 70-90 | A |
| Hard rollerskate wheels | 98 | A |
| Ebonite rubber | 100 | A |
| Solid truck tires | 50 | D |
| Hard hat (typically HDPE) | 75 | D |

predicted by its hardness and may be defined as the plastic's resistance to permanent indentation. This hardness can be measured through the Shore Durometer scale and is expressed numerically relative to other materials of similar application and hardness with higher numbers representing greater degrees of "hard". For example, a solid truck tire would rate as 50, FEP (a common wireline insulation material) would be 55 and a typical hard hat would rate 75 as a measure of hardness on the Shore Durometer D Scale.

## Ridging

One of the dangers in selecting an insulation that is too soft for the expected compressional forces is a phenomenon known as ridging. Excessive core compression, which is commonly seen in horizontal pump down applications, can result in "ridging" on the insulation surrounding the copper conductor. Ridging, as seen in Figure 1, can cause permanent outer armor looseness and in extreme cases can cause electrical shorts in the cable. Plastics are an excellent choice for insulating electrical cables as they possess many of the features desirable for insulating and protecting conductors. Different grades of plastics are used for specific purposes and each grade has specific advantages and disadvantages in relation to being used as an insulation material. The catalog temperature ratings of Camesa' cables apply for the bottom hole temperatures of ordinary oil/gas well logging situations. "Ordinary" Here refers to situations in which borehole temperature increases with depth to a maximum at the bottom of the borehole. Temperature ratings should be lowered when the cable is used in highly deviated wells, in producing or geothermal wells with high temperatures nearer the surface. Currently Camesa offers cables rated for 300°, 420°, 500° & 600° Fahrenheit environments. For low temperature applications, Polypropylene is used as an insulation material and is capable of withstanding ambient well temperatures up to 300°F continuously. In environments that consistently see temperatures up to 420°F, a plastic called FEP is used ,and in environments that see 500°F, either a plastic called PFA or a combination of plastics called FEP & ETFE are used.

**Figure 1**

## Hardness vs. Dielectrics

As mentioned above, an acceptable temperature resistance is only one of the three qualities a plastic must possess in order to successfully insulate an electromechanical cable. Hardness and dielectric properties must still be considered. FEP & PFA are primarily designed as insulating plastics, thus they have good dielectric properties but are relatively soft and do not resist ridging from the inner armor wire when exposed to core compression forces like those present in horizontal wells. ETFE is designed as a jacketing plastic with very favorable hardness characteristics that resist ridging but has very poor dielectric properties that increase the capacitance of the conductor within it. An ideal plastic insulation for horizontal applications would be a plastic with the dielectric properties of FEP or PFA and the hardness of ETFE. This is why the Camesa FT code insulation was developed (F=FEP, T=ETFE). This double extruded insulation combines the positive dielectrics of the FEP plastic with an outer layer of ETFE giving it favorable hardness to resist ridging from the inner armor wire layer. While the single PFA insulated conductor is still preferred in vertical higher temperature wells and limited horizontal applications, the FEP/ETFE insulated wireline is the preferred insulation for horizontal pump down applications including plug and perforating operations. Empirical evidence has proven that a single extruded PFA insulation does not resist the ridging that commonly occurs during horizontal pump down operations as well as FEP/ETFE insulation. Therefore, in order to maximize your wireline's workable life span, it is critical that you select an insulation that is best suited for the wireline operations that you intend to subject your cable to.

| Plastic Type | PFA | ETFE | FEP |
|---|---|---|---|
| Max. Suggested Working Temp. | 500°F | 500°F | 400°F |
| Shore D (Hardness) | 60 | 67 | 55 |
| Dielectric Strength (D149) | >80 | 70 | >80 |