technical bulletin 021

Temperature Rating of Cables

The maximum temperature rating

The maximum temperature rating of Camesa cables, as listed in the catalog, is based on the following operating conditions:

- The maximum bore hole temperature is not greater than the cable rated temperature.
- The cable is operated under a normal tension profile.
- There are no unusual hole conditions or restrictions causing excessive tension.

There are three factors that will influence the temperature rating of a cable.

- The "nominal melting point" of the plastic used for insulating the conductor.
- The pressure exerted by armor wires on the core by normal loads
- The inner armor coverage

The nominal melting point

Plastics are called amorphous materials and as such do not have a specific melting point. Crystalline materials, such as metals and water, are characterized by the fact that they do have a very specific temperature at which they change from a solid state to a liquid state. Amorphous materials, like plastics, do not have a specific temperature at which they change from a solid material to a liquid state but just gradually become softer.

At their melting point temperature crystalline materials continue to absorbed heat, called heat of fusion, with out changing temperature until all the material has completely changed state. The temperature will then again rise as heat is added.

Amorphous materials under go different molecular bonding changes as they are heated and become softer. When these changes occur a certain amount of heat is absorbed with out a change of temperature , indicating the change in molecular structure. Arbitrary standards have been set on this heat absorption that is used to classify the "nominal melting point" of plastic materials.

The arbitrary melting point ratings of plastics is no more than a guide as to whether a plastic is qualified to be used in an electro-mechanical cable at its rated melting point. For example DuPont Teflon- FEP-100 has a nominal melting point of 510 F . This plastic is, however, so soft, it would not be suitable as total insulation on an EM cable rated at 300 F. There are no published specifications by plastic manufactures that clearly identify their plastics as being suitable for use in oil field cables. Special engineering testing and controlled field testing are required to qualify a plastic for these cables.

Core pressure

When there is tension on the cable the helical shape of the armor wires results in a significant pressure or "squeezing" of the cable core. This pressure on the core, if high enough, will result in the plastic being " squeezed" out between the gap in the adjacent inner armor wires (as shown in the picture below). This loss of plastic insulation will ultimately lead to an electrical failure.

The pressure on the core , as a function of cable tension, can be calculated. The equation is rather complicated but evaluating it for different cables and tension will illustrate the importance of special testing to qualify the temperature rating of a plastic.

$$cp = \left(4\left(\frac{nia\,\mathrm{Csc}\left[\frac{\pi}{nia}\right]\mathrm{Sin}[\alpha ia]\left(\mathrm{Cos}[\alpha ia]^2 - \frac{(cd-2\,dia-2\,doa)\,pr\,\mathrm{Sin}[\alpha ia]^2}{cd-dia-2\,doa}\right)}{(cd-2\,doa)\,(cd-dia-2\,doa)} + \frac{noa\,\mathrm{Csc}\left[\frac{\pi}{noa}\right]\mathrm{Sin}[\alpha oa]\left(\mathrm{Cos}[\alpha oa]^2 - \frac{(cd-2\,dia-2\,doa)\,pr\,\mathrm{Sin}[\alpha oa]^2}{cd-doa}\right)}{cd\,(cd-doa)}\right)\right) \Big/ \left(\pi\left(dia^2\,nia\,\mathrm{Cos}[\alpha ia]\left(\mathrm{Cos}[\alpha ia]^2 - \frac{(cd-2\,dia-2\,doa)\,pr\,\mathrm{Sin}[\alpha ia]^2}{cd-dia-2\,doa}\right) + doa^2\,noa\,\mathrm{Cos}[\alpha oa]\left(\mathrm{Cos}[\alpha oa]^2 - \frac{(cd-2\,dia-2\,doa)\,pr\,\mathrm{Sin}[\alpha oa]^2}{cd-doa}\right)\right)\right)$$

Core pressure is most important on the tool end of the cable where the temperature is the highest. The maximum tension in the cable at the tool end is the weak point pull out tension. The calculated core pressure, cp, at typical weak point pull out tensions (POT), that would be used with standard cables operating at a depth of 20,000 feet and a tool weight of 300 pounds are as follows:

ARMOR	K22	N22	N25	N29	N32	N38	N42
POT-lbs	1200	1200	1600	2700	2800	3500	4600
cp-psi/lb	4.00	4.10	3.10	2.49	1.98	1.43	1.14
cp – Tool-psi	1200	1230	930	747	594	429	342
cp-at POT-psi	4800	4920	4960	6723	5544	5005	5244

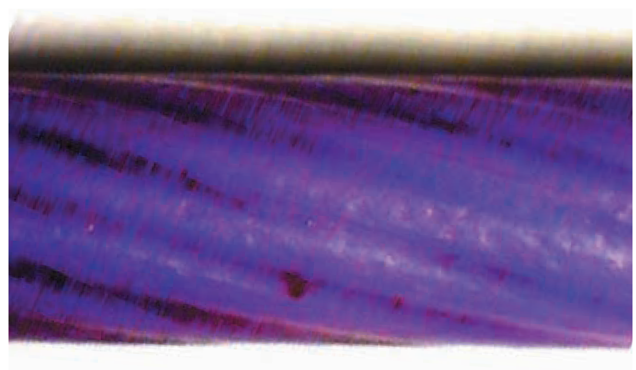
These calculations show that under normal operating conditions the pressure on the core from the tool weight is 1200 psi or less. When a cable is manufactured with the correct inner armor coverage, the core plastic will not be squeezed out at these core pressures at the maximum rated temperature of the cable. If on the other hand the tool becomes stuck and it becomes necessary to pull out of the rope socket, then the resulting 5,000 psi core pressure is likely to squeeze the core plastic out between the inner armor wires if the temperature is high enough. When a tool becomes stuck in a hole at or near maximum rated cable temperature, then after pulling out of the tool ,it can be expected that there will be some plastic squeezed out and it will be necessary to cut back the cable.

The inner armor coverage

The term “armor coverage” refers basically to how close the armor wires are together. If a layer of armor wires were to have 100% coverage, it would mean that all of the armor wires in that layer were touching their adjacent wires. If the coverage on either layer were 100%, the cable would be so stif f it could not be bent around a sheave wheel without forcing one of the wires out of the layer.
(See Technical Bulletin 17, Armor Coverage).

The inner armor coverage is the most important factor in determining the temperature rating of a cable. When there are large gaps between the armor wires the plastic is more easily squeezed out under cable tension. Two factors are carefully monitored during the manufacture of Camesa cables . The first is the inner armor coverage which is maintained between 98.0% to 99 % . On high temperature cables the coverage is kept above 98.5%. The other factor monitored in manufacturing is the uniformity of the spacing of the inner armor wires around the core.

The closing dye and following pinch rollers press the evenly spaced armor wires into the plastic core to insure they will stay evenly spaced during subsequent manufacturing operations (as shown in the picture below).



Conclusions

As new plastics become available, Camesa evaluates them by testing them under simulated tension and temperature conditions. If these new materials perform well in these simulated tests, then a limited number of cables are manufactured using the new material and their performance closely monitored. If there are no problems with the new materials in the initial field trials, then additional cables will be put into field service for continued evaluation.

By carefully choosing and testing all core plastic materials and precisely controlling the inner armor coverage and spacing, Camesa cables will operate at or above the maximum temperature rating for all routine operations.