TECHNICAL ARTICLE

CABLE INSULATION

WHAT IS CABLE INSULATION?

Insulation is an important non-conductive material that surrounds and protects the individual wires or cables. Some wire insulation is produced to resist electric current in electrical applications. Other types of insulation are used in dielectric applications for radio frequency cables.

Insulation resists electrical leakage, which prevents the wire's current from encountering other nearby wires and cables. It also preserves the material integrity of the wire by protecting against environmental threats such as water and heat. The longevity and effectiveness of a wire depend on its insulation.

Insulation resistance can be measured with a megohmmeter/ insulation tester without damaging the insulation, and data so obtained serves as a useful guide in determining the general condition of the insulation. Data obtained in this manner, however, may not give a true picture of the condition of the insulation. Clean, dry insulation having cracks or other faults might show a high value of insulation resistance but would not be suitable for use.

Dielectric strength is the ability of the insulator to withstand potential difference and is usually expressed in terms of the voltage at which the insulation fails because of the electrostatic stress. Maximum dielectric strength values can be measured by raising the voltage of a test sample until the insulation breaks down.

POPULAR TYPES OF INSULATION

There are many varieties of wire and cable insulation just like there are many types of wires and cables. The type of conductor insulation material varies with the type of installation. Characteristics should be chosen based on environment, abrasion resistance, arc resistance, corrosion resistance, cut-through strength, dielectric strength, flame resistant, mechanical strength, smoke emission, fluid resistance, and heat distortion. Depending on the application, insulation is generally produced from plastic, fluoropolymers or rubber materials. In the aerospace industry, fluoropolymers are typically used.

Fluoropolymers: A type of thermoplastic material which will soften, flow, or distort when subjected to adequate heat and pressure. These compounds are heated and extruded over the conductor. Similarly, the insulation on the finished product can be re-melted or softened, almost indefinitely, if exposed to heat. Some of the most common types of thermoplastic are polypropylene (PP), polyethylene (PE), polyvinylchloride (PVC) , polystyrene (PS), polyethylene theraphthalate (PET) and polycarbonate (PC). There are numerous types of Fluoropolymers that are used for wire insulation.

The following information shows the different types of wire insulations that are used in the aerospace industry.

Fluorinated Ethylene Propylene (FEP) is a material type that is a highly flame-resistant and commonly used in military applications. FEP is also used for foamed wire insulation for cables since FEP has a low melt temperature, low dielectric constant (good electrical properties) and high temp rating overall of +200°C. When foamed, it improves data transmission and is therefore widely used for cable jackets, especially for coax, like PIC's "S" cables.

E10224 is a good example for a data cable that uses a foamed dielectric, or insulation. A dual insulation can also be used, which is a solid inner insulation and foamed outer insulation. This design is used to get the inner wire OD down to a size to where a standard removal tool can be used to remove the wire's contact from a connector, such as a D-Sub connector. Refer to T12243 for an example.

Perfluoroalkoxy (PFA); with a temperature ratings range of -65°C to 250°C, PFA is suitable for high and low temperature applications. It has superior mechanical strength and its very low dissipation factor makes it an electrically efficient option. PFA is a more expensive material than FEP. This insulation is used in all of PIC's data cables that have a PTFE Tape jacket. The higher temp rating is required because the PTFE tape jacketed cable is run through an oven to cure the jacket and bond it to itself. A foamed PFA insulation would not work either as the added (injected) air in the PFA would heat up too much, causing a failure in the insulation (melting).

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Ethylene Tetrafluoroethylene Copolymer (ETFE) materials offer more strength and flexibility than PFA or FEP and, when irradiated, can become thermoset. Foaming the material reduces weight and improves data transmission. However, the materials lack the electrical advantages offered by FEP. ETFE is widely used in lead or hook-up wire for its abrasion resistance and therefore also widely used as an overall cable jacket, as in some of PIC's coax and data cables. It would not be used for any dielectric that requires high electrical performance cables such as Ethernet cables for instance. The temp rating is +150°C on standard ETFE.

Polytetrafluoroethylene (PTFE) is an extremely flexible, and water, oil, chemical, and heat resistant thermoplastic material. Its applications service a wide temperature range of -60°C to 200°C. PTFE has excellent electrical properties but can limit the lengths of cable runs due to the high melting point of the material and possibility of cracking after it's processed. A large portion of mil spec coaxial cables have a solid PTFE dielectric, but the super long lengths are not required as would be the case with manufacturing single wires, such as lead or hook-up wires. PTFE tapes are used on cables such as E50824. The tape not only serves as a binder, but also changes the Impedance of the pairs, thus allowing a reduction in their size (OD).

Expanded Polytetrafluoroethylene (ePTFE) – ePTFE is an expanded PTFE. The material has air injected into it during the extrusion process, similar to foaming. The amount of air injected into the material depends on the desired VOP target. The ePTFE material is used for its excellent electrical properties and its high temperature rating of +260° C.

Like a foamed FEP, a cable using an ePTFE dielectric can have the VOP range anywhere from 76% to 82% or higher. The higher the VOP however, the softer the material, which can lead to issues when bending a cable which might compromise the integrity of the insulation. Also, the softer the material, the better chance the material can migrate on the wire during the termination process into a connector or when bending or routing the cable through an aircraft.

SUMMARY

There are many different types of insulation. Each has its own functions, as well as some similar characteristics. We've outlined a few in this piece, and by no means is this an exhaustive list. When choosing the right type of insulation for an application, it is important to consider how long you need the cable to last, what the environment will be like, and how much protection your cable will need. It can affect the longevity of the cables and assure the safety of the cables in the installation.

At PIC Wire & Cable, we take pride in guiding our clients through the selection process step-by-step. Our experts understand what will work best for your specific interconnect project and can give you options tailored to your needs. From choosing the right cable for your needs to solving problems or concerns about other aspects of your interconnect application, let us handle it!

Figure 1: E6A5826 10G BASE-T CATEGORY 6a 4 PAIR (8-CONDUCTOR) ETHERNET CABLE INSULATION SHOWN

1. PTFE Tape Jacket - White (Laser Markable)
2. Silver-Plated Copper Braided Shield
3. Foil Shields
4. Foamed Fluoropolymer Insulation