Cable Jackets for Military Applications

By MilesTek

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From aircraft to radio communications, military applications require ruggedized cable assemblies to form a highly reliable network backbone. Custom wire harnessing, coaxial, Ethernet, and fiber optic cables are just a few brands of cabling employed to serve the multitude of operations. One commonality between these cables are their jackets that can be specially designed to protect all signal transmissions from external thermal, chemical, mechanical, and environmental stressors. Indoor and outdoor environments can cause the protective jacketing material to crack and crumble over time exposing the insulation and conductor and eventually rendering a cable installation nonfunctional. In data cables, even a degradation in cable performance can lead to intermittent connectivity and significant lags. Miles of fiber optic runs in aerial and burial installations can be expensive and difficult to troubleshoot, cable jackets are relied upon to ensure a consistent connection.

Common Jacket Materials

Different polymers can be leveraged for the jacket material depending upon the adverse conditions that the cable may be exposed to including: extreme temperatures for aerial applications, corrosive chemicals for industrial military applications, extensive flexing, and fire for indoor applications.

There are three general categories to describe the compounds employed in cable jackets: thermoplastics, thermoset, and thermoplastic elastomers (TPE) [or thermoplastic rubbers]. A **thermoplastic** is a plastic material that can be formed above a certain temperature and solidifies upon cooling. Thermoplastics are most often leveraged for their ease of manufacturing with the extrusion process often used to make cable jackets. **Thermosets**, as denoted by the name, are permanently set after the curing process. This is due to the cross-linked polymers in the plastic that form an irreversible chemical bond, making them ideal for high heat applications. **Thermoplastic elastomers**, now gaining momentum in automotive and medical applications, consist of both thermoplastic and elastomer (rubber) materials where elastomers are often thermosets. While this material also benefits from structural cross-linking, TPE can be molded and remolded without negatively affecting the material, making it both durable and providing the cable with a higher tensile strength.

Polyvinyl Chloride (PVC) is the most commonly used material for indoor and residential cabling as it is relatively inexpensive. Variants such as Plenum PVC (P-PVC) provide fire-retardant properties to this commonly used cable jacket material. Generally susceptible to oil exposure and excessive flexure PVC is normally not leveraged in industrial environments.

Polyethylene (PE) is most often leveraged in electrical cabling as insulation due to its excellent electrical properties with a low dielectric constant, and stable dielectric constant over frequency. While this is excellent for a cable insulator, it is not necessary for a cable jacket. Alternative thermosets such as Chlorinated Polyethylene (CPE), Chlorosulfonated Polyethylene (CSPE, or Hypalon), and Cross-linked Polyethylene (XLPE) provide much higher oil resistance in harsh petrochemical and industrial environments. Thermoplastic Linear Low-Density Polyethylene (LLPE) is an enhancement that allows for superior durability, UV resistance, and water permeability for direct burial applications such as in CCTV and CATV installations.

Polyurethane (PUR) is often chosen for cable jackets as it has good oxidation, oil, abrasion, and flame resistance. This material proves itself most valuable due to its exceptional flexibility and is therefore often leveraged in continuously flexed manufacturing applications and even for retractile cords.

Other thermosets such as **Ethylene Propylene Rubber** (EPR) and **neoprene** offer more options for ruggedized cable jackets with high resistance to cold temperatures (particularly EPR), and resistance to heat, abrasion, and oxidation. Neoprene is known for its extreme ruggedness, flame retardant, and self-extinguishing behavior and so is often leveraged in military handheld cordsets and power cables. **Nylon** is thermoplastic cable jacket that is often braided to be used in military cable harnessing, offers a thin tubing wall for increased flexibility while being abrasion resistant. Nylon jacketing is very susceptible to moisture ingress and so is not typically used in applications with outdoor exposure, or in a direct-burial application.

Cable Jacket Materials		
Polymer		Type of Synthetic Material
PVC	Polyvinyl Chloride	Thermoplastic
P-PVC	Plenum Polyvinyl Chloride	Thermoplastic
PE	Polyethylene	Thermoplastic
CPE	Chlorinated Polyethylene	Thermoset
XLPE	Cross-linked polyethylene	Thermoset
LLDPE	Linear Low-Density Polyethylene	Thermoplastic
FRPE	Flame Retardant Polyethylene	Thermoplastic
CSPE or Hypalon	Chlorosulfonated Polyethylene	Thermoset
EPR	Ethylene Propylene Rubber-Insulated	Thermoset
PUR	Polyurethane	Thermoset
Nylon	Polyamide	Thermoplastic
Neoprene	Neoprene	Thermoset
PTFE	Polytetrafluoroethylene (Teflon)	Thermoplastic
ETFE	Ethylene tetrafluoroethylen	Thermoplastic

Jacket Features

Plenum and Riser Rated

While a basic PVC jacket would suffice for general purpose cables routed indoors without the need for fire retardancy, many applications call for a more rugged design. Plenum spaces, or areas that facilitate airflow often for heating, ventilation, and air conditioning (HVAC) purposes are ideal places to route bundles of Ethernet cables through a building and out of reach of employees and equipment. These spaces also happen to be an ideal path for fire to spread undeterred through an entire building. Cables are also installed in vertical risers, or enclosed spaces with upward and downward routed wiring, to allow for connectivity between floors. Vertical installations can be a fire hazard and require fire retardants jackets, still, they do not pose as much of a risk as plenum ducts since they generally do not have any forced air circulation. Plenum and riser rated cables are employed in bases, offices, and buildings typically must submit the cable design to an independent test laboratory such as underwriter's laboratories (UL) in order to have their performance verified and obtain an approval listing for their cables. Thermoplastics such as **P-PVC**, fire retardant polyethylene (**FRPE**), and thermosets such as **PUR**, **Neoprene**, and **EPR** have strong fire resistant properties and can be leveraged for plenum and riser rated cable jackets.

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Fire Retardant Cable Ratings				
Fiber Optic Rating	**Twisted Pair Rating**	**Coaxial Cable Rating**	**Common Term**	**Standards**
OFNP OFCP	CMP MPP	CATVP	Plenum	NFPA-262 UL-910
OFNR OFCR	CMR MPR	CATVR	Riser	UL-1666
OFNG OFCG	CMG MPG	CATVG	General Purpose	UL-1581
OFN OFC	CM	CATV	General Purpose	UL-1581
N/A	CMX	CATVX	Limited Use (Residential)	UL-1581

OFN: Optical Fiber Nonconductive
OFC: Optical Fiber Conductive
CM: Communications Cable
MP: Multipurpose Cable
CATV: Cable Television (Coax)

Low Smoke Zero Halogen

Plenum cables can often employ halogens such as fluorine, chlorine, bromine, and iodine for their fire retardant capabilities. When under combustion, the highly reactive halogen-based cable jackets release toxic gases that are dangerous and can be lethal when certain quantities are inhaled. For instance, fluorine is employed in a wide variety of cable jackets but will react with virtually every element of the periodic table forming a host of toxic gases. When burned, Low Smoke Zero Halogen (LSZH) cables can self-extinguish, emit limited smoke, and do not release any highly reactive halogens.

Oil, UV, Moisture, and Chemical Resistance

Depending upon the environment, a cable jacket can be exposed to a host of elements that cause performance degradation and a shortened life cycle. Depending upon the material, plasticizers can be added to the thermoplastic and TPE materials to allow for low-temperature (cold) flexibility, impact and abrasion resistance, as well as resistance to oils and chemicals. For instance, thermoplastic polyurethane elastomers (TPU) can be combined with PVC to achieve a higher abrasion resistance, oil resistance, and low-temperature flexibility. If plasticizers that are not oil resistance are employed, oil ingress can cause migration and dispersion of the plasticizers causing the cable jacket to melt, swell, or crack.

Cable Environments

Often the least stressful environment, communications rooms, defense switched networks, and distribution networks located in residential areas require cabling that meets the minimum, general purpose standards and are typically composed of PVC. Military air, naval, and army bases with intraoffice and intrabuilding Ethernet cabling routed in enclosed plenum spaces with forced airflow as well as vertical shafts require plenum and riser rated (CMP/CMR) cabling. It is critically important to mitigate any damage to personnel and equipment in the case of a fire outbreak. The image in **Figure 1**, depicts a technician connecting a United States Forces Japan (USFJ) communications network to support nonstop communications for Humanitarian Assistance/Disaster Relief to northern Japan after the Fukushima disaster--this was a reliable alternative to the original satellite communications that were not stable. The communications capabilities ultimately enabled the reopening of Sendai Airport, the delivery of 3,629 tons of relief cargo, and the safe departure for 7,713 people [1]. For these types of networks, generally thermoplastics such as Teflon are leveraged as they more cost-effective to use where there is practically no exposure to harsh chemicals, UV, or moisture and fire is the only real threat posed.

Figure 1: The Defense Switched Network (DSN) line supported communication during the Fukushima disaster.
Source: http://www.pacaf.af.mil/News/Article-Display/Article/593463/yokota-comm-named-best-in-air-force/

Often fiber optic, direct burial cabling can be exposed to moisture ingress, extreme temperatures, gnawing rodents, and even unintentional digging up from construction machinery. To protect from these factors, thermosets such as PUR jackets are employed for their extreme ruggedness and high cut, abrasion, and chemical resistance in order to protect the buffered fibers and dielectric material. During the manufacturing process, a gel can also be injected below the cable jacket to fill the cracks and crevices and ultimately impede the flow water thereby increasing the life expectancy of the cable. Water ingress in combination with extreme cold is a main cause of damage from these cables as the water expansion from freezing temperatures can not only cause fissures in the jacketing material but also push against the fibers causing microbends and increasing optical loss [2]. **Figure 2** depicts a fiber optic installation with a trench being dug in Afghanistan for a nearby camp to provide a secure strategic communications line, a channel for web-based logistics systems, and allow for the recovery of line-of-sight tactical equipment [3].

Figure 2: A direct burial fiber optic backbone for nearby Camp John Prat in Afghanistan provides a secure communication line as well as added bandwidth for web-based logistics.
Source; http://www.afcent.af.mil/News/Features/Display/Article/223375/deployed-comm-airmen-dig-it/

Cables for avionic installations such as fiber optic, coax, Ethernet, and cable harnesses face some of the most stringent requirements as they are often met with temperature extremes. The enclosed space with little ventilation presents not only a dangerous fire hazard, but also chemical hazard as the fumes from the cabling can also harm the occupants of a manned aircraft. LSZH-PUR or LSZH-Olefin cables are utilized to minimize the smoke, ash, and dangerous halogen gas emissions. Cables such as Ethernet, 1553B twinaxial, and firewire have to perform in high vibrational, extreme temperature cycling, low-fume-toxicity, and high reliability environments. Oftentimes, PUR cable jackets are used for their high-energy radiation resistance and ability to withstand high temperatures over long periods of time. Aside from their excellent thermal properties, they have extraordinary corrosion and abrasion resistance, a practical concern when bundles of aircraft wiring are constant rubbing against each other due to environmental vibrations.

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Cabling in aircraft are exposed to vibrations, ozone, and corrosive chemicals and often need inspection to ensure optimal performance.
Source: http://www.navair.navy.mil/index.cfm?fuseaction=home.NAVAIRNewsStory&id=5594

Conclusion

Military standards such as MIL-DTL-87104A for coaxial cable assemblies, MIL-PRF-85045/8A for ground tactical fiber optic cables, and MIL-DTL-32546 for high speed data cables call for an increase in the ruggedness of a cable assembly. Poor interconnections can adversely affect mission critical systems and are often difficult to troubleshoot. Cable jackets are the first line of defense for an entire assembly, poor construction and implementation can deteriorate the outer jacket and the insulation and inner conductors quickly thereafter. The choice of plasticizer combined with specific thermoplastics and thermosets strike a balance between cost-effectiveness and optimal performance in a particular environment.

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