Multi/Cable Corporation

Choosing Insulation & Jacketing Materials for Your Custom Cable

A guide from Multi/Cable

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INTRODUCTION

A custom-built cable can meet your specific wiring needs and integrate all the demands of your application. With an extensive range of materials and wire weights available, as well as advanced capabilities for coloring, striping, and printing, the options for your custom cable are virtually endless.

Each component in your cable can positively or negatively impact your application's performance—and therefore should be given the same careful consideration you'd give to the choice of that most critical cable element, the conductor.

In this guide, we'll discuss the material options for your cable's primary insulation and jacket, and important factors to consider when making your selections for each. Both insulation and jacketing are nonconductors that work to protect your cable: insulation protects from within, and jacketing protects from the outside. The materials you select should be dictated by the mechanical and electrical properties of your specific application, as well as the elements and processes they will be exposed to.

In most cases, the materials discussed here can be used for insulation and/or jacketing—however, there really are no one-size-fits-all materials. Thus, it's important to have a thorough understanding of how your custom cable will be used before you begin the selection process.

ABOUT INSULATION

A nonconductive material that is applied directly around the conductor, insulation performs several important functions. By preventing electrical leakage and guarding against interference, it helps to keep the cable's signal strong. And by protecting the conductor from outside environmental damage, the insulation is critical to the cable's effectiveness and safety, preventing short circuits and fire hazards.

In high-voltage cables, insulation reduces the risk of shock and electrocution.	**In shielded cables,** insulation acts a buffer between the conductor and shield.	**In multiconductor cables,** insulation prevents the conductor's current from coming into contact with other conductors.

While the most common insulators offer very high degrees of current resistance, there is no perfect insulating material. However, modern man-made cable insulations are designed to withstand voltage stresses as well as general wear and tear.

Insulation Material Properties to Consider

When selecting the primary insulation materials for your cable, you will first need to know the particulars of your application—what voltage is needed, how the cable will be used within the application, and what environment the cable will be used in. Then, consider the properties below to see if the material in question will meet your needs.

Electrical Properties	• Dielectric strength • Insulation resistance • Insulation power factors • Charging current • Arc resistance • Tracking susceptibility
Mechanical Properties	• Toughness and flexibility • Tensile, elongation and crushing strengths • Resistance to abrasion or moisture • Brittleness
Chemical Properties	• Moisture absorption • Resistance to oil, gas, acids and alkalis • Stability when exposed to sunlight, ozone, or flames
Thermal Properties	• Expansion and contraction • Softening and flow temperature • Compatibility with operating, ambient, or emergency overload and short circuit conditions

ABOUT JACKETING

Jacketing is the nonconductive outer layer of a cable that covers and protects the conductor, primary insulation, shields, and other components. Many of the same materials used for primary insulation can also be used as cable jacketing—e.g., nylon, neoprene, ethylene-propylene rubber, and polyurethane are typical choices.

While the jacketing material has little to no impact on a cable's electrical performance, this selection is crucial in ensuring the cable's suitability for the given application, as it can greatly impact the cable's durability and flexibility.

Jacketing is the cable's first line of defense against:

General Damage	Environmental hazards	Processes
• Oxidation • Abrasions • Wear & tear	• Chemicals or oil • Heat • Moisture • Harsh weather & temperatures	• Cable installation • Application assembly (soldering, etc.)

Jacketing Material Considerations

- What hazards will be present in the operating environment? (see above)
- Will the cable be handled frequently, flexed repeatedly, or exposed to frequent vibration?
- What temperature extremes (both high and low) will the cable be exposed to?
- What voltage does your application require?

When building a custom cable, you can also give some thought to its appearance. Color-coded jacketing can make cable identification easier (and thus make installation and troubleshooting faster). Colored jackets can also be used to enhance safety and to match your brand or desired color scheme.

CHOOSING THERMOPLASTIC VS. THERMOSET MATERIALS

Once you know the characteristics you'll require in your custom cable, you can decide whether you need thermoplastic or thermoset materials for your insulation and jacketing. This is a useful way to narrow down the available selection of plastics, and ensures your choices are a good fit for your application.

You may ultimately choose different materials for your insulation and jacketing, but if you find that your application's performance depends on, for example, utilizing a thermoset jacket, you will likely need to choose a thermoset insulation material as well.

The primary difference between these materials is how they respond to heat. Thermoplastics can be softened and melted into a liquid, allowing them to be re-molded as needed. Thermoset plastics have been crosslinked so that their shape is permanent—when exposed to heat, they will scorch and burn rather than melt.

Crosslinking is the formation of bonds that join polymer chains together, making the material stronger and more heat-resistant. It can take place under high temperatures, high pressure, or through a chemical process such as vulcanization, as is common with polyethylene. A common (and sometimes required, depending on specifications) crosslinking technique is irradiation, used with PVC and ETFE, among others.

Because the curing process cross-links the polymer structures together, crosslinked materials are typically marked with an "XL."

Examples of Cross-Linked Materials	
XL-ETFE	Cross-Linked Extruded Ethylene
XLPE	Cross-Linked Polyethylene

Thermoplastics Melt when exposed to heat	**Thermoset Plastics** Burn when exposed to heat
Advantages	
• Can be re-shaped many times • Can be recycled • High impact resistance • Easy to strip, if needed	• Overall more durable • Better heat resistance • Higher chemical resistance • Greater flexibility • Better shrink-resistance
Disadvantages	
• Cannot withstand extreme heat	• Cannot be re-molded or recycled

AN OVERVIEW OF TYPICAL INSULATION & JACKETING MATERIALS

For both insulation and jacketing, plastics are the most common and least expensive material options. In the following pages, we'll provide an overview of the advantages and disadvantages of each material. They are organized into sections by construction:

A. Thermoplastics

B. Thermoset Plastics

C. Fluoropolymers

D. Textiles

Thermoplastics

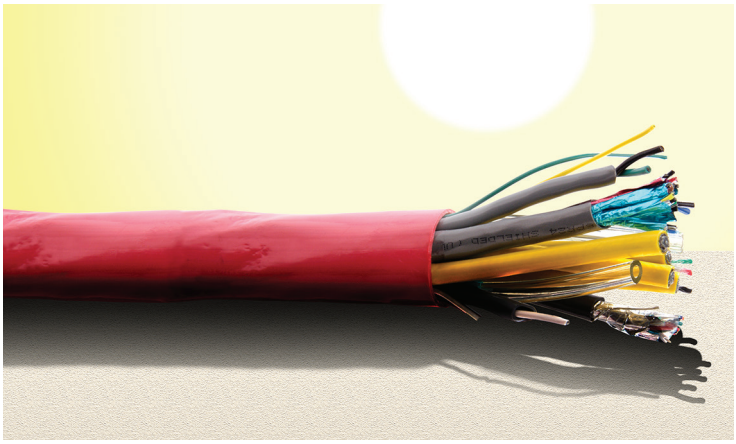
Nylon

Temperature Range: -40° to 150°C

Nylon generally carries a high temperature rating of 150°C for continuous service. However, its low temperature limit is dependent upon the wall thickness and the diameter of the cable construction: as both of these parameters increase, nylon becomes more susceptible to cracking or flexing at low temperatures. It is typically not flammable in wire and cable applications because of flame retardants that are added to the compound.

Advantages:	Disadvantages:
• Excellent abrasion resistance • Excellent weatherability • Chemical resistant • Flexible	• Poor dielectric strength • Moisture absorbent • May crack at low temperatures

Nylon is a good choice for: Additional coatings in thin-wall applications.



Polyethylene (PE)

Temperature Range: -65° to 80°C

Polyethylene is an excellent insulator, as well as an affordable option. When needed, it can be foamed to improve its electrical qualities, or cross-linked to improve its strength and resistance to abrasion and environmental stress cracking.

Both low-density polyethylene (LDPE) and high-density polyethylene (HDPE) have similar chemical and electrical properties—the major difference between them lies in the mechanical area. Polyethylene is stiff and inflexible at all densities, but even more so at higher densities, giving HDPE better cut-through and abrasion resistance. As it provides superior protection from environmental degradation, and has somewhat better fluid resistance, HDPE is an excellent jacketing material choice. LDPE, however, would not be recommended for thin-walled applications where mechanical abuse is anticipated.

On the other hand, LDPE can be an excellent insulation choice—it is a low-loss material with excellent moisture resistance and good resistance to breakdown under corona, and is often used in high-voltage applications.

Advantages:	Disadvantages:
• High dielectric strength • Low dielectric constant • Low dielectric loss at all frequencies • Excellent resistance to cold flow • Excellent weatherability • Good abrasion resistance • Low moisture absorption • Low cost	• Flammable

Polyethylene is a good choice for: Insulation on telephone signal and control cables, high-frequency electronic cables, high- and low-voltage power cables, line wire, neutral supported secondary and service drop cable.

Polypropylene (PP)

Temperature Range: -30° to 105°C

Polypropylene has chemical and electrical properties similar to those of polyethylene, but is considerably harder, stiffer, and lower density than PE, with a somewhat lower dielectric constant than LDPE. Polypropylene also has a wider temperature range, making it a more versatile choice for applications that will be exposed to harsh weather.

Like polyethylene, polypropylene can be foamed to improve its electrical qualities.

Advantages:	Disadvantages:
• Excellent abrasion resistance • Excellent weatherability • Better fluid resistance than PE	• Flammable

Polypropylene is a good choice for: Thin-wall applications; multimedia, telecom, and optical fiber cables.

Polyurethane (TPU)

Temperature Range: -40º to 80ºC

Polyurethane is among the most durable material options and has outstanding “memory” properties—making it an ideal jacket material for retractile cords. It may also be used for jacketing when additional strength must be given to the entire cable assembly. It is not typically used as an insulating material.

However, because TPU is expensive, it is typically only specified when other jacket materials will not satisfy the requirements of the application.

While most polyurethanes are thermosets, it is generally only utilized in a thermoplastic construction for wire and cable applications. It may also be specially formulated to enhance its flame resistance.

Advantages:	Disadvantages:
• Unusually tough • Exceptional resistance to: - Oil - Radiation - Fungus - Oxidation - Ozone • Higher tensile strength and elongation than neoprene • More abrasion resistant than neoprene • Better low temperature flexibility than neoprene	• Poor resistance to: - Steam - High temperatures - Acids • High cost

TPU is a good choice for: Retractile cords and applications with continuous flexing; applications within the military, aerospace, and oil & gas industries; low-temperature applications.

Polyvinyl Chloride (PVC)

Temperature Range: -40° to 105°C, depending on specific compound

Polyvinyl Chloride is a thermoplastic that is specially compounded for general-purpose applications, allowing it to be used effectively in many environments. It is one of the most common insulation and jacketing materials for electronic cables.

Because of its potential to release toxic fumes when burning, safer low-smoke zero-halogen (LSZH) options should be used in applications where people are confined, such as shipboard or mass transit systems.

Advantages:	Disadvantages:
• Low cost & readily available • Flexible • Gas & vapor tight • Resistant to: - Abrasion - Acids - Flame - Gasoline - Moisture - Oils - Oxidation - Weather & sunlight	• Burns quickly • Emits hazardous halogens when burned • Loses flexibility at low temperatures

PVC is a good choice for: Primary insulation and/or jacketing in power distribution cables, building wiring, appliance wiring, flexible cords, high temperature wiring, industrial wiring, coaxial cables.

Thermoplastic Elastomer (TPE) or Thermoplastic Rubber (TPR)

Temperature Rating: -50° to 125°C

A TPE or TPR material is made from both plastic and rubber. They have the mechanical characteristics of thermoset rubbers, yet are thermoplastics—meaning they are flexible, can be re-molded, and can be recycled. In general, TPE / TPR materials are fairly durable and suitable for harsh weather; their low-temperature potential is among the best available. For applications where an extremely rugged cable jacket is required, however, polyurethane would be a better choice.

Advantages:	Disadvantages:
• Excellent electrical properties • Excellent ozone resistance • Good abrasion resistance • Low water absorption	• High cost • Inferior chemical resistance • Inferior heat resistance

TPE / TPR is a good choice for: Household appliances; automotive, medical, and robotics applications.

Thermoset Plastics

Cross-Linked Extruded Ethylene Tetrafluoroethylene (XL-ETFE)

Temperature Range: -100° to 150°C

Lightweight and small in size, ethylene tetrafluoroethylene is utilized as insulation when a wire's weight and diameter must be kept to a minimum. When cross-linked, this material offers excellent resistance to heat and

Advantages:	Disadvantages:
• Flame retardant • Moisture resistant • Stable at high temperatures	• Flexibility is somewhat reduced by cross-linking • Can be degraded by UV light

XL-ETFE is a good choice for: Aerospace and aviation applications.

Cross-Linked Polyethylene (XLPE)

Temperature Range: -40° to 105°C

The cross-linking process retains polyethylene's excellent insulating abilities, while improving its strength and resistance to abrasion and environmental stress cracking.

Advantages:	Disadvantages:
• Abrasion resistant • Chemical resistant • Retains strength at low temperatures	• Hardness is somewhat reduced by cross-linking

XLPE is a good choice for: Power cables, building wires, oil & gas applications, and insulation in medium- to high-voltage electrical wires.

Ethylene Propylene Diene Monomer (EPDM) Rubber

Temperature Range: -50° to 150°C

A versatile synthetic rubber, EPDM offers excellent flexibility even at high and low temperature extremes. It is a better choice than silicone in cables which may be dragged, run over, stepped on, and otherwise at risk of abrasions. EPDM is also a better choice than neoprene when resistance to heat, light, and/or ozone is critical.

Advantages:	Disadvantages:
• High durability • Excellent abrasion resistance • Excellent moisture resistance • Excellent UV resistance • Excellent flexibility	• Flammable • Inferior chemical resistance

EPDM rubber is a good choice for: Medium-voltage power cables, appliance wiring, high-voltage applications, outdoor applications.

Neoprene

Temperature Range: -20° to 90°C

Neoprene is a thermoset material that, after undergoing vulcanization, can withstand harsh temperature extremes and rugged environments without negatively impacting performance.

Advantages:	Disadvantages:
• Flame retardant • Durable & long-lasting • Excellent abrasion resistance • Good chemical resistance	• Inferior electrical properties

Neoprene is a good choice for: Military and oil & gas applications.

Silicone

Temperature Range: -80° to 180°C

A thermoset material that is heat- and flame-resistant, silicone is also quite soft and pliable. Due to this flexibility, it may be used as jacketing in situations where a cable must be routed through a tight space.

Advantages:	Disadvantages:
• Flame retardant • Excellent flexibility • Excellent UV resistance	• Inferior abrasion resistance • Inferior chemical resistance

Silicone is a good choice for: High-voltage cables; aerospace, automotive, medical and military applications.

Fluoropolymers

Highly stable fluoropolymers are commonly used for cable insulation and jacketing in a wide range of applications. In general, they reduce friction and have excellent resistance to heat and corrosion. Depending on their construction, fluoropolymers may be either thermoplastics or thermosets.

The materials listed in this section are fluoropolymer of tetrafluoroethylene (TFE), which has outstanding electrical properties, excellent fluid resistance, very high resistance to chemicals and temperature, and the ability to remain flexible at very low temperatures. TFE's polymers are attacked only by alkali metals such as barium, sodium, potassium, and by fluorine at high temperatures and pressures.

Of the fluoropolymers listed here, ETFE is known by the trade name Tefzel, while FEP, PFA, and PTFE are all known by the trade name Teflon®.

Extruded Ethylene Tetrafluoroethylene (ETFE)

Temperature Range: -100° to 150°C

Advantages:	Disadvantages:
• Flame retardant • Excellent chemical resistance • Excellent UV resistance • High corrosion resistance • Lightweight • Flexible • Stronger than FEP, FPA, and PTFE	• Electrical properties are somewhat inferior to FEP

ETFE is a good choice for: Electrical and fiber optic wires; applications within the aerospace, aviation, medical industries.

Fluorinated Ethylene Propylene (FEP)

Temperature Range: -65° to 200°C

Advantages:	Disadvantages:
• Flame retardant • Excellent abrasion resistance • Excellent chemical resistance • Excellent UV resistance • Excellent weatherability	• Less durable than ETFE • Less flexible than ETFE, PFA, and PTFE • Mechanical and electric properties deteriorate faster under adverse conditions than TFE

FEP is a good choice for: Plenum cables and a wide range of applications, including aerospace, aviation, electronics, military, oil & gas, and more.

Perfluoroalkoxy (PFA)

Temperature Range: -100° to 250°C

Advantages:	Disadvantages:
• Low dissipation factor makes it electrically efficient • Flame retardant • Excellent chemical resistance • Better anti-stick properties than PTFE • Better chemical resistance than PTFE	• High cost • Less scratch resistant than PTFE • Less flexible than ETFE

PFA is a good choice for: Thermocouple wire and high-temperature applications in OEM appliances and the aerospace, military, oil & gas industries.

Polytetrafluoroetheylene (PTFE)

Temperature Range: -60° to 200°C

Advantages:	Disadvantages:
• Flame retardant • Excellent abrasion resistance • Excellent chemical resistance • Excellent UV resistance • Excellent weatherability	• Less durable than ETFE • Less flexible than ETFE, PFA, and PTFE • Mechanical and electric properties deteriorate faster under adverse conditions than TFE

PTFE is a good choice for: Coaxial cables, OEM appliances, and applications within the aerospace, oil & gas, and military industries.

Textiles

For challenging applications that face extreme temperatures, textiles are often an ideal solution for cable insulation and jacketing. Lightweight, flexible, and able to withstand the highest temperatures, today's textiles have been formulated for use in the most demanding environments.

Although it is less common for dielectric insulation, cotton may also be used in wire and cable.

Ceramic Fiber

Temperature Range: Up to 1205°C, depending on composition

When extremely high temperatures are required, ceramic fiber is often the best choice—and sometimes the only choice. Usually a yarn braided of alumina and silica threads, it covers each conductor as a primary insulation, and can also be used as the outer jacketing.

Ceramic fiber's inferior moisture and abrasion resistance can be improved by pairing it with a mica wrap or covering it with metallic shielding.

Advantages:	Disadvantages:
• Flame retardant • Excellent abrasion resistance • Excellent chemical resistance • Excellent UV resistance • Excellent weatherability	• Less durable than ETFE • Less flexible than ETFE, PFA, and PTFE • Mechanical and electric properties deteriorate faster under adverse conditions than TFE

Ceramic fiber is a good choice for: High-heat applications, such as kilns and industrial plants.

Fiberglass

Temperature Range: Up to 482°C

Fiberglass is used as both an insulation and a jacketing material. Depending on its construction, fiberglass may be a thermoplastic or a thermoset.

Advantages:	Disadvantages:
• Flame retardant • Excellent abrasion resistance • Excellent chemical resistance • Excellent UV resistance • Excellent weatherability	• Less durable than ETFE • Less flexible than ETFE, PFA, and PTFE • Mechanical and electric properties deteriorate faster under adverse conditions than TFE

Fiberglass is a good choice for: High-heat applications, including ovens, furnaces, kilns, etc.; applications within aluminum processing and the aerospace industry.

Mica

Temperature Range: 0° to 500°C

Mica is a natural, non-toxic material available in a non-adhesive tape that can be wrapped around a cable's conductor(s) for primary insulation. Mica's temperature resistance is among the best available from primary insulation materials. Because it is non-combustible, releases no toxins, and can act as a barrier that both delays and reduces toxic fumes during a fire, mica is most commonly used when fire resistance is critical.

Advantages:	Disadvantages:
• Flame retardant • Excellent abrasion resistance • Excellent chemical resistance • Excellent UV resistance • Excellent weatherability	• Less durable than ETFE • Less flexible than ETFE, PFA, and PTFE • Mechanical and electric properties deteriorate faster under adverse conditions than TFE

Mica is a good choice for: High-heat applications, high-voltage applications, emergency equipment (e.g., emergency lighting), critical applications within hospitals, industrial plants, communication centers, railways, airports, etc.

APPENDIX: MATERIAL DATA FOR THE MOST COMMON INSULATION & JACKETING MATERIALS

Table 1.1: Typical Properties of Multi/Cable Insulations for Multi Conductor Cables

	PVC	Polyethylene (Unfilled)		Polypro-pylene (Unfilled)	Nylon	Fluorocarbon	
		Low density	High density			TFE	FEP
Specific Gravity	1.35	0.920	0.947	0.902	-	2.18	2.16
Ultimate Tensile Strength, psi	3000	2200	3400	5000	8000	3500	3000
Ultimate Elongation, %	200	625	250	200	200	300	250
Rated Max Temp, °C	105	75	95	105	120	260	200
Rated Min Temp, °C	-40	-65	-65	-40	-40	-65	-65
Volume Resistivity, ohm-cm	8 x 10	1 x 10	1 x 10	1 x 10	1 x 10	1 x 10	1 x 10
Dielectric Constant, 1k hz	5.0	2.25	2.32	2.22	4.5	2.0	2.1
Dissipation Factor	0.10	0.0002	0.0002	0.0003	0.04	0.0002	0.0003

ABOUT MULTI/CABLE

Multi/Cable Corporation is a leading manufacturer of multi conductor, multi-pair / triad and specialty composite wire and cable. Since 1975, we have supplied customers around the world with cables for their most critical applications.

- Cross matching to other manufacturer part numbers available
- Low minimum order quantities
- Competitive pricing
- Quick turnarounds

The Custom Cable Advantage

Put our in-house engineering and manufacturing capabilities to work for you. Custom cable manufacturing allows you to determine physical and electrical tolerances, define the components that best fit your application, combine various functions into one cable, and specify the exact quantity and lengths required. You can even brand your own company information on the cable jacket.

Industries Served Include:

- Aerospace
- Agriculture
- Audio / Broadcasting
- Automobile
- Communications
- Defense
- Food Processing
- Medical Instrumentation
- Oil Refining
- Petroleum
- Private Label Manufacturing
- Robotics
- Transportation
- Utilities
- Wire Harnessing

HAVE QUESTIONS?

Talk to one of our experts today! Call (860) 589-9035

Request a quote via our website: www.multicable.com

We'll get back to you within one business day.

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