



Cable Jacket Materials for Harsh Environments

Summary

Harsh environments—military operations, aerospace, industrial manufacturing, and outdoor infrastructure—expose cables to extreme stressors, including high temperatures, moisture, chemicals, UV radiation, and mechanical wear. Selecting the correct cable jacket material is critical to prevent failures, extend cable life, and assure operational safety. This whitepaper explores common cable jacket materials, compares their performance in harsh conditions, and provides guidelines for selecting the optimal jacket for challenging applications.

Introduction

Cables are the backbone of critical systems, transmitting power, signals, and data under demanding conditions. The cable jacket, the outermost protective layer, shields the internal conductors from environmental stressors and mechanical damage. Improper jacket selection can lead to premature failures, safety hazards, and operational downtime. A careful analysis of environmental conditions and material properties is essential for validating long-term performance.

Environmental Challenges

Harsh environments challenge cable performance in multiple ways:

Environmental Factor	Impact on Cable Jackets
Temperature Extremes	Thermal expansion, embrittlement, melting, insulation breakdown
UV Radiation	Surface cracking, accelerated degradation
Moisture / Water	Hydrolysis, swelling, electrical leakage, conductor corrosion
Chemicals / Oils	Dissolution, swelling, cracking, embrittlement
Abrasion / Mechanical Stress	Jacket wear, conductor exposure, insulation compromise



Environmental Factor	Impact on Cable Jackets
Fire / Flame	Combustibility, smoke, toxicity

Selecting a material resistant to these stressors promotes reliable cable operation.

Common Cable Jacket Materials

Polyvinyl Chloride (PVC)

- **Properties:** Flexible, flame-retardant, cost-effective
- **Advantages:** Chemical resistance, UV tolerance, widely available
- **Limitations:** Limited temperature range (-40°C to 105°C), can become brittle in cold
- **Applications:** General-purpose indoor/outdoor wiring, control cables

Polyurethane (PUR)

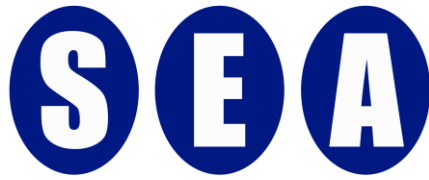
- **Properties:** Rubber-like flexibility, abrasion-resistant
- **Advantages:** Excellent mechanical toughness, oil/chemical resistance, UV stable
- **Limitations:** Moderate chemical resistance compared to fluoropolymers
- **Applications:** Industrial machinery, mobile equipment, robotics, harsh outdoor use

Low Smoke Zero Halogen (LSZH)

- **Properties:** Halogen-free, low smoke, flame-retardant
- **Advantages:** Safety in confined spaces, fire compliance
- **Limitations:** Moderate chemical and UV resistance, lower mechanical toughness
- **Applications:** Public transport, tunnels, data centers, safety-critical areas

Fluoropolymers

- **FEP (Fluorinated Ethylene Propylene):** Extreme temperature (-200°C to 200°C), excellent chemical resistance, moderate flexibility, self-extinguishing
- **ETFE (Ethylene Tetrafluoroethylene):** High chemical and UV resistance, tough, moderate flexibility, self-extinguishing



- **Applications:** Aerospace, chemical plants, military, solar farms, extreme temperature environments

Composite Jackets

- **Properties:** Multi-layer materials (PVC + TPU, fluoropolymer blends)
- **Advantages:** Customized performance for chemical, thermal, and mechanical protection
- **Limitations:** Cost varies depending on layer complexity
- **Applications:** Military, aerospace, subsea, and high-performance industrial cables

Comparative Performance of Jacket Materials

Material	Temp Range	Chemical Resistance	UV / Weather	Mechanical / Abrasion	Flexibility	Flammability / Smoke	Applications
FEP	-200°C to 200°C	Excellent	Excellent	Moderate	Moderate	Excellent	Aerospace, military, chemical plants
ETFE	-200°C to 150°C	Excellent	Excellent	Good	Moderate	Very Good	Aerospace, solar farms, outdoor chemical exposure
PVC	-40°C to 105°C	Good	Moderate	Moderate	High	Moderate	General-purpose, wiring harnesses
PUR	-40°C to 125°C	Very Good	Excellent	Excellent	High	Moderate	Industrial machinery, robotics, outdoor
LSZH	-40°C to 125°C	Good	Moderate	Moderate	High	Excellent	Confined spaces, tunnels, data centers



Material	Temp Range	Chemical Resistance	UV / Weather	Mechanical / Abrasion	Flexibility	Flammability / Smoke	Applications
Composite	-60°C to 200°C	Excellent to Very Good	Excellent	Excellent	Moderate-High	Excellent	Military, aerospace, subsea, multi-threat environments

Pivotal Insights:

1. Fluoropolymers (FEP, ETFE) dominate chemical and temperature resistance.
2. PUR and composites excel in abrasion and mechanical toughness.
3. LSZH and fluoropolymers provide superior fire safety and smoke control.
4. PVC is cost-effective and flexible but limited for extreme conditions.

Performance Comparison of Cable Jacket Materials for Harsh Environments

Axes / Parameters:

1. Temperature Range
2. Chemical Resistance
3. Abrasion Resistance
4. Flexibility
5. UV / Weather Resistance
6. Flame / Smoke Performance
7. Moisture Resistance

Legend / Materials:

- **FEP** – Fluorinated Ethylene Propylene
- **ETFE** – Ethylene Tetrafluoroethylene
- **PVC** – Polyvinyl Chloride



- **PUR** – Polyurethane
- **LSZH** – Low Smoke Zero Halogen
- **Composite** – multi-material / hybrid jacket

Example Performance Levels (0–5 scale, 5 = best):

Material	Temp	Chem	Abras	Flex	UV	Flame/Smoke	Moisture
FEP	5	5	3	3	5	4	5
ETFE	4	4	4	3	4	3	4
PVC	3	3	3	3	3	2	3
PUR	3	3	5	5	3	3	4
LSZH	3	3	3	4	3	5	3
Composite	4	4	5	4	4	4	4

Failure Modes from Improper Jacket Selection

- **Cracking / Embrittlement:** Cold temperature or UV exposure
- **Swelling / Softening:** Chemical or water exposure
- **Abrasion Damage:** Vibration, dragging, or mechanical wear
- **Thermal Degradation:** Heat-induced melting or loss of flexibility
- **Flammability Hazards:** Non-compliant jackets in fire-prone areas

Material Selection Guidelines

1. Identify **environmental stressors** (temperature, chemicals, UV, mechanical stress).
2. Balance **mechanical toughness, flexibility, and chemical resistance** with cost constraints.
3. Consider **safety requirements**, such as LSZH for low-smoke applications.



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4. Evaluate **composite solutions** for multi-threat environments.
 5. Regular **inspection and predictive maintenance** extends cable life.

Conclusion

Selecting the appropriate cable jacket material is **critical** for operational reliability in harsh environments. Fluoropolymers provide unmatched chemical and temperature resistance, PUR and composites excel in mechanical durability, and LSZH guarantees fire safety in confined spaces. Proper material selection, combined with ongoing inspection and maintenance, mitigates failure risk, establishes safety, and prolongs service life of cables in extreme conditions.