



Selecting Wire and Cable for Arctic and Extreme Cold Operations

Summary

Operations in Arctic and extreme cold environments impose unique challenges on wire and cable systems. Standard wiring solutions may fail due to reduced flexibility, insulation cracking, increased brittleness, and ice or snow exposure. This whitepaper outlines the critical factors for selecting wire and cable for low-temperature operations, emphasizing **cold-temperature flexibility, cracking resistance, and jacket embrittlement risks**. The goal is to support reliable, long-term performance in military, aerospace, maritime, and industrial applications where extreme cold is a factor.

Introduction

Extreme cold environments—such as the Arctic, high-altitude regions, and polar maritime zones—place extraordinary demands on electrical systems. Wire and cable must operate reliably in temperatures often below -40°C , where material properties change dramatically. Poor selection can lead to:

- **Loss of cold-temperature flexibility**, making installation and routing difficult.
- **Insulation and jacket cracking**, which can expose conductors and cause short circuits.
- **Jacket embrittlement**, reducing mechanical protection and increasing the risk of failure during bending, vibration, or ice impact.

Vital considerations for Arctic operations include maintaining flexibility, resisting cracking, and validating jacket integrity to prevent failures in mission-critical systems.

Temperature and Material Considerations

Conductor Materials

- **Copper:** Retains ductility at low temperatures if annealed, reducing conductor brittleness.
- **Aluminum:** Lightweight but less ductile; careful alloy selection is required to reduce risk of fracture in extreme cold.
- **Silver-plated copper:** Offers corrosion resistance and improved cold-weather performance.



Insulation Materials

Cold-temperature performance is critical to prevent **cracking and embrittlement**. Common Arctic-suitable insulations include:

Material	Low Temp Range	Cold Flexibility	Cracking Resistance	Jacket Embrittlement Risk
PTFE / FEP	-200°C to +260°C	Excellent	Very high	Very low
XLPE (Cross-linked Polyethylene)	-60°C to +90°C	Good, slightly stiffer at -40°C	Medium	Medium-low
PVC (Plasticized)	-40°C to +70°C	Moderate, becomes stiff below -40°C	Medium-low	High below -40°C
Polyurethane (PUR)	-50°C to +90°C	Very good	High	Low
Silicone Rubber	-60°C to +200°C	Excellent	High	Very low

Recommendation: For Arctic and extreme cold operations, prioritize materials that retain **flexibility at low temperatures** and resist **cracking and embrittlement**.

Jacket and Sheath Considerations

Cable jackets protect against mechanical stress and environmental hazards. In extreme cold, **embrittlement risk is a primary concern**.

- **Polyurethane jackets:** Maintain flexibility in sub-zero temperatures and resist tearing.
- **Fluoropolymer jackets (FEP, PTFE):** Excellent chemical and UV resistance, very low embrittlement risk.
- **Metallic armor:** Recommended for high-impact areas, prevents damage from ice and mechanical loads.
- **LSZH jackets:** Must be specially formulated to avoid brittleness below -40°C.



Mechanical and Installation Factors

Cold-Temperature Flexibility

Cables may become stiff and harder to bend in extreme cold. Always follow manufacturer specifications for **minimum bend radius at low temperatures**, considering the risk of insulation or jacket cracking.

Cracking and Embrittlement Risks

Repeated bending or vibration in sub-zero conditions can **initiate micro-cracks in insulation and jackets**, eventually leading to electrical failure. Measures to mitigate cracking include:

- Selecting high-flex, low-temperature materials.
- Avoiding tight bends or sharp angles during installation.
- Using strain reliefs and protective conduits in dynamic applications.

Moisture and Ice Management

Cold-temperature moisture exposure can exacerbate cracking if water freezes inside the cable. Overmolding, water-blocking tapes, and careful routing reduce the risk.

Connector and Termination Considerations

- Choose low-temperature-rated connectors and strain reliefs to prevent cracking.
- Metal shells preferred in Arctic conditions.
- Guarantee thermal contraction does not stress insulation or jacket.

Testing and Qualification

- **Cold bend testing:** Verifies cable maintains flexibility and does not crack at minimum expected temperatures.
- **Thermal cycling:** Confirms resistance to embrittlement and repeated contraction/expansion.
- **Insulation and jacket inspection:** Detect micro-cracks or surface degradation after cold exposure.



Recommendations

1. **Material Selection:** Prioritize insulation and jackets with **high cold-temperature flexibility and cracking resistance** (FEP, PTFE, PUR, silicone rubber). Avoid PVC below -40°C unless specially formulated.
2. **Mechanical Design:** Respect bend radius and minimize dynamic stress to reduce embrittlement risk.
3. **Environmental Protection:** Use overmolding, water-blocking, and protective conduits.
4. **Testing:** Perform cold bend and thermal cycling tests to validate cable performance in Arctic conditions.

Conclusion

In extreme cold environments, the selection of wire and cable materials is not merely a matter of meeting electrical requirements—it is critical to enhancing system reliability, safety, and longevity. This also requires careful attention to **cold-temperature flexibility, cracking resistance, and jacket embrittlement risks**. Low temperatures can significantly reduce flexibility, increase susceptibility to cracking, and accelerate jacket embrittlement, all of which can compromise both performance and mission success. By prioritizing materials with proven cold-temperature resilience, considering jacket compositions that resist brittle failure, and implementing best practices for bend radius and stress management, engineers can mitigate these risks effectively.

Ultimately, understanding and addressing the interplay between cold-temperature flexibility, cracking resistance, and embrittlement is essential for designing wiring systems that maintain integrity under the harshest conditions. Thoughtful material selection and rigorous testing empower designers to deliver cables that perform reliably when it matters most, protecting both equipment and personnel in extreme cold operations.