



Voltage Rating vs Dielectric Thickness in Mil-Spec Wire

Introduction

In military and aerospace systems, reliable electrical performance under extreme environmental conditions is non-negotiable. Wire selection is often guided by Mil-Spec (MIL-W-22759, MIL-W-16878, etc.) standards that specify voltage ratings, insulation types, and environmental performance. A common misconception is that increasing dielectric thickness inherently improves voltage handling and overall wire performance. While thicker insulation can enhance certain properties, it is not universally better. Understanding the relationship between voltage rating, dielectric thickness, and practical application is critical for system reliability, maintainability, and safety.

Understanding Voltage Rating and Dielectric Thickness

The **voltage rating** of a wire indicates the maximum continuous voltage the insulation can withstand without failure. This rating is influenced by:

- **Dielectric strength of the insulation material** – measured in volts per mil (V/mil). Materials with higher dielectric strength can handle more voltage for a given thickness.
- **Insulation thickness** – thicker insulation generally increases the breakdown voltage, but not linearly.
- **Environmental factors** – temperature, humidity, vibration, radiation, and chemical exposure can all degrade dielectric performance.

Essential Insight:

Voltage rating = dielectric strength × thickness × safety factor

However, increasing thickness comes with trade-offs:

- Reduced **flexibility** and increased **bend radius**
- Higher **weight** in harnesses
- Potential **interference** with connector fit or routing in constrained assemblies
- Increased **manufacturing cost**



When Thicker Insulation Helps

Thicker insulation is beneficial in scenarios where:

1. **High voltage stress is present** – long runs or high voltage spikes require extra dielectric margin.
2. **Mechanical abrasion or environmental exposure** – thicker insulation provides added robustness against chafing, chemicals, or UV exposure.
3. **Safety-critical circuits** – redundant dielectric can reduce the risk of catastrophic failure.

Example: In high-power avionics or missile systems, where voltages exceed 600V, a thicker PTFE or crosslinked polyimide layer promotes safety and compliance with MIL-STD breakdown requirements.

When Thicker Insulation is Not Better

Excessive insulation can create new problems:

1. **Reduced flexibility and dynamic performance** – important for wires in turrets, landing gear, or rotating platforms.
2. **Heat dissipation issues** – thicker insulation can trap heat, affecting current carrying capacity and longevity.
3. **Connector incompatibility** – oversized insulation may prevent proper termination in standard Mil-Spec connectors.
4. **Diminishing returns** – beyond a certain thickness, breakdown voltage increases minimally while negative impacts escalate.

Optimizing Dielectric Thickness

Effective Mil-Spec wire selection balances voltage requirements with practical engineering constraints.

Factors to consider:

Factor	Consideration
Voltage rating	Select insulation that meets or slightly exceeds operating voltage
Environmental conditions	Include margins for temperature, chemicals, vibration



Factor	Consideration
Flexibility	Ensure bend radius and dynamic motion are within system limits
Weight and routing	Optimize thickness to reduce harness bulk and connector strain
Material choice	High dielectric materials (e.g., PTFE, polyimide) allow thinner layers while maintaining voltage rating

Rule of Thumb: Choose the minimum thickness required to achieve voltage rating while satisfying mechanical and environmental demands. Use thicker insulation only where voltage spikes, abrasion, or redundancy justify it.

Conclusion

The relationship between voltage rating and dielectric thickness in Mil-Spec wire is nuanced. While thicker insulation can improve dielectric strength, it is not always advantageous. System designers must evaluate electrical, mechanical, and environmental factors to select the optimal insulation. By balancing dielectric thickness with flexibility, weight, and reliability considerations, engineers can guarantee that military and aerospace systems achieve both safety and performance without unnecessary compromises.