COP FLIGHT CONNECTOR AND WIRING

NEPP 2020 WORKSHOP

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OUTLINE

- CoP Charter/Scope
- Strategic Vectors (SVs)
- Technology Topics
  - Low Fluoride Wire Insulations
  - Development of a thermal model for wire bundles
  - Replacement of Copper Wiring with Carbon Nanotubes

NASA CONNECTORS AND WIRING COP CHARTER/SCOPE

- Provide a venue for technicians, engineers and scientists to engage in an open forum discussion for both current and future in the areas of manufacturing, connectors, wire, cable, materials, uses, design, fabrication processes and assemblies

- This community seeks knowledge capture through out the agency and to pass that knowledge on to current and future technical communities

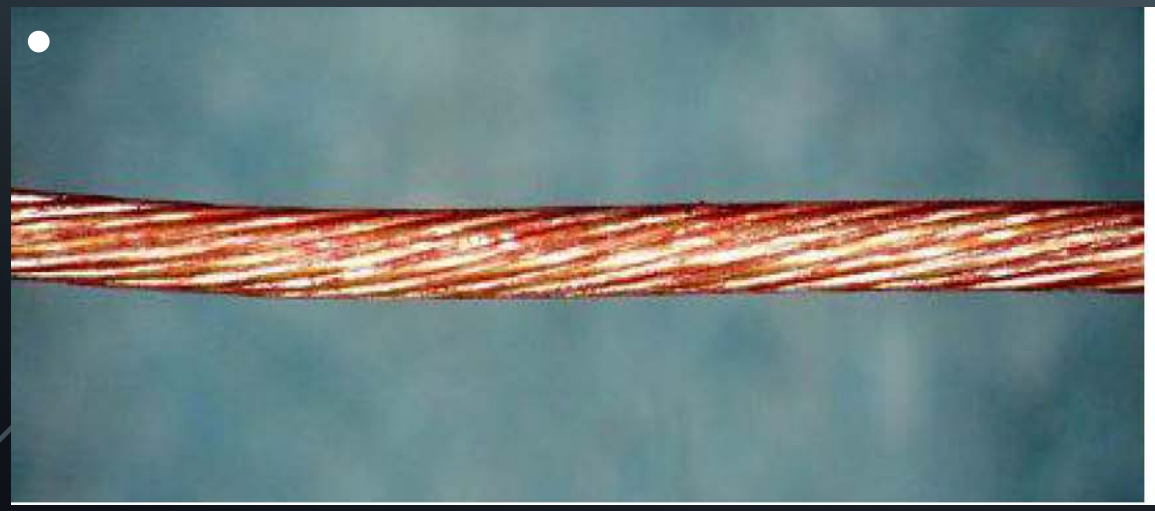
STRATEGIC VECTORS

- Near term SVs (3-5 years)
  - Nano Technology Connectors and Wiring
  - Specifications and Standards development
  - Audits and keeping up with Industry
  - Commercial Parts vs Space Grade Parts
- Long Term SVs (5-10 years)
  - High voltage/power electrical system development
  - Hybrid and all electrical aerospace systems

CONNECTOR AND WIRING TOPICS

LOW FLUORIDE XL-ETFE (TEFZEL) WIRING (AS22759/51)

- XL-ETFE Insulation off-gassing of HF is a known issue primarily affecting wiring and connectors sealed inside enclosures
  - Causes corrosion of wire conductors, terminations and connector components
  - See Technical Presentations under the CoP for details on the issue.
- HF off gassing is not a controlled parameter in qualified XL-ETFE wiring such as AS22759/33, LW XL-ETFE AG plated Cu
  - Extractable Fluoride has been measured as high as 1,000 ppm using AS4373 M608



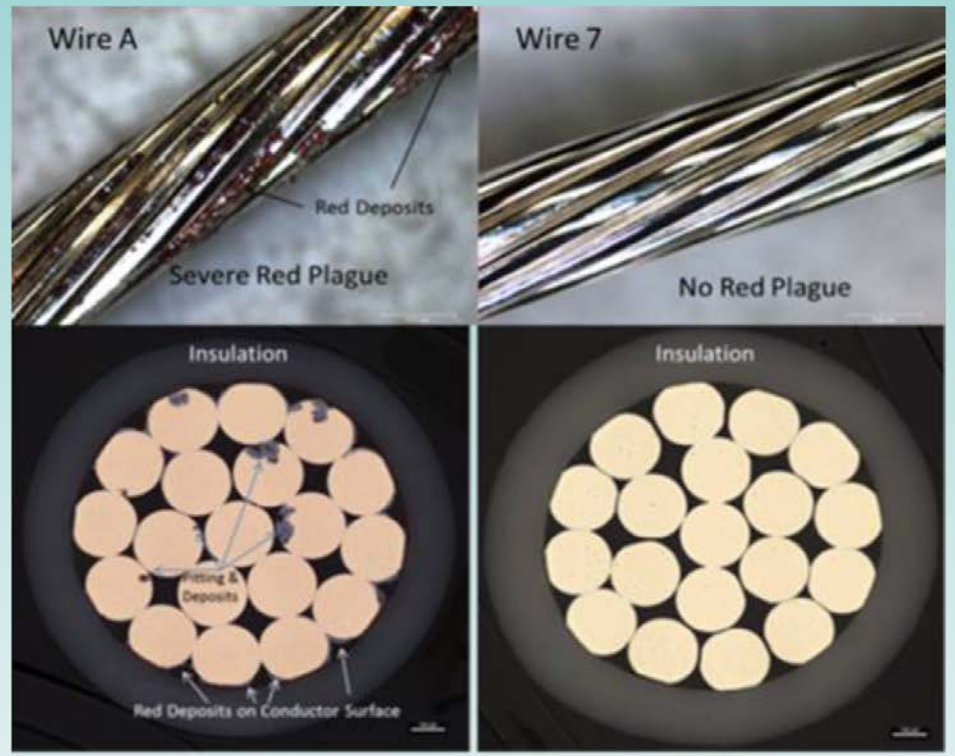
XL-ETFE/CONDUCTOR WIRE SAMPLE DESCRIPTIONS

(Wire 5: Nickel Plating; Wire A: Local Distributor)

Sample #	Wire Type	Color	Extractable F (ppm/g of insulation)	Antimony %
1	M22759/44-20-9	white	155	1.8
2	M22759/44-20-9	white	976	4.5
3	M22759/44-20-9	white	708	4.8
4	M22759/44-20-9	white	853	3.1
5	M22759/45-20-9	white	183	1.6
6	M22759/33-20-9	white	35	1.6
7	M22759/33-20-9	white	4	1.5
8	M22759/9-20 (PTFE)	white	3	0
9	M22759/44-20-9	white	307	4.7
10	M22759/44-20-9	black	30	2.2
11	M22759/44-20-9	white	711	3.6
A	M22759/44-20-9	white	1480	3.2

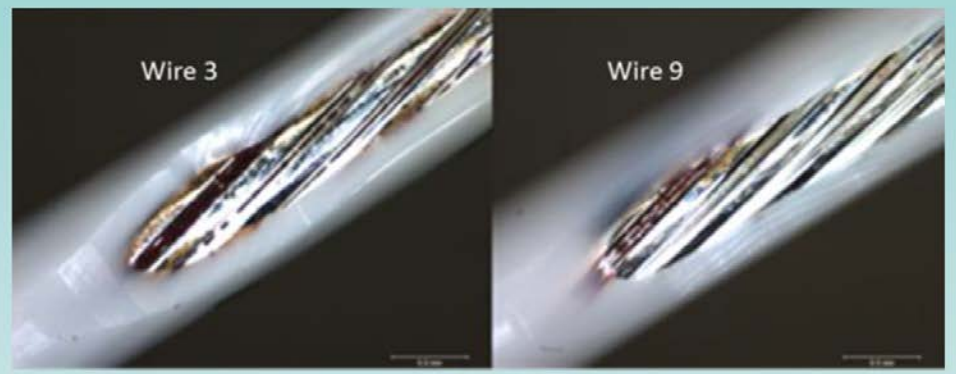
Extractable Fluoride (F): SAE AS4373 Method 608

STRIPPED LENGTHS AND CROSS-SECTIONS FOR HIGH (A) AND LOW (7) FLUORIDE WIRES PRODUCED BY MULTIPLE-WIRE RED PLAGUE TEST AFTER TWO WEEKS

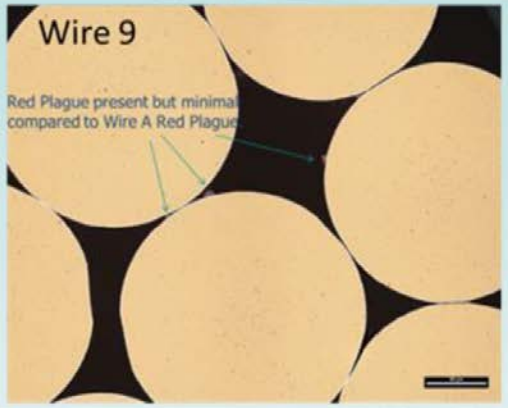


Severe Red Plague No Red Plague

STRIPPED LENGTHS AND CROSS-SECTIONS FOR MEDIUM FLUORIDE WIRES PRODUCED BY MULTIPLE-WIRE RED PLAGUE TEST AFTER TWO WEEKS



Low Amount of Red Plague Agrees with Small Increase In Voltage Drop Plots



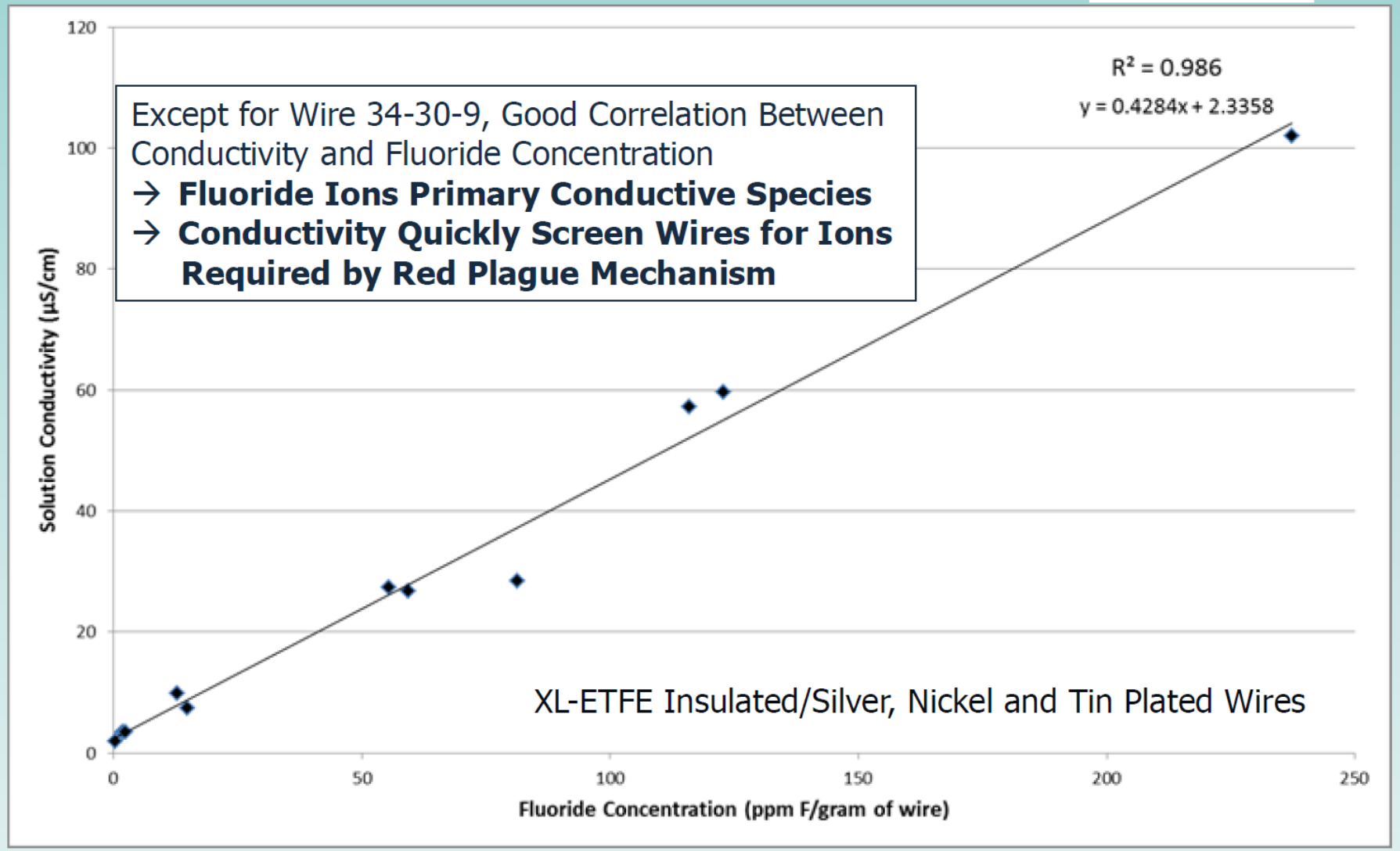
3 708 ppm
9 307 ppm
7 4 ppm
A 1480 ppm

LOW FLUORIDE XL-ETFE (TEFZEL) WIRING (AS22759/51)

- Testing has shown limiting fluoride to 20 ppm or less mitigates the HF corrosion issue (references to be placed on CoP under Technical Presentations)
- AS22759/50-54 (XL-ETFE silver plated conductors) requires the insulation to have less than 20 ppm of fluoride
  - Two qualified sources (TE Connectivity and Judd Wire)
  - Contacting wire distributors and the qualified vendors showed AS22759/51-54 are not in stock.
  - Wire vendors claim they are producing standard XL-ETFE wiring (AS22759/33) that produce less than 35 ppm of extractable Fluoride (it appears OEMs are requiring wire vendors to meet a low F PPM level)
  - Marmon Wiring is a qualified source of AS22759/33, XL-ETFE, LW, Ag plated conductor and they are willing to provide a certificate the wiring has 35 ppm or less extractable Fluoride
  - Run the two day conductivity test for measuring corrosion susceptibility (AS4373 M611)

CONDUCTIVITY VERSUS FLUORIDE CONCENTRATION OF ACCELERATED EXTRACTION TEST SOLUTIONS

Extraction: 90°C for 2 Days



Specification	Construction	NEMA 27500 Codes
AS22759/51	XL-ETFE, Low Fluoride, LW, Ag HS Cu Alloy	UA
AS22759/52	XL-ETFE, Low Fluoride, LW, Ag Cu Alloy	UB
AS22759/53	XL-ETFE, Low Fluoride, NW, Ag HS Cu Alloy	UC
AS22759/54	XL-ETFE, Low Fluoride, NW, Ag Cu Alloy	UD

References

- AIR4487B, Investigation of Silver-Plated Conductor Corrosion (Red Plague)
- ARP6229 Fluoride Offgassing in Fluoropolymer Insulations
- IPC-WP-113 Guidance for the Development and Implementation of a Red Plague Control Plan (RPCP)

CURRENT AND FUTURE POWER SCHEMES

- Legacy Voltages (High Voltage above 115VAC and 28VDC)
- 115 VAC (400Hz, three phase) Qualified AE-8 Components
- 230 VAC (400 Hz, three phase)
- 28 VDC, Qualified AE-8 Components
- 270 VDC (500-1200 amps) long runs the primary concern
- 230 VAC Variable frequency (50Hz-1KHz)
  - Impact of high frequency on insulation
- 540 VDC (± 270 VDC)
- What's Next
  - 48 VDC
  - 1000 – 5000 VAC, 1K -3k Hz (electric propulsion)
  - 400 to 800 VDC

SAE AIR 6198, Design Consideration for Aerospace Electrical Systems

Voltage Level	AC, Volt rms	DC, Volts
Voltage level 1	Up to 42.4VAC	Up to 60VDC
Voltage level 2	Up to 213VAC	Up to 300VDC
Voltage level 3	Up to 425VAC	Up to 600VDC
Voltage level 4	Up to 851VAC	Up to 1,200VDC
Voltage level 5	Up to 3,400VAC	Up to 4,800VDC
Voltage level 6	Above 3,400VAC	Above 4,800VDC

NASA/TM–2018-220114
NESC-RP-17-01264

Publicly Available

Re-Architecting the NASA Wire Derating Approach for Space Flight Applications

A physics-based thermal model of single wires and wire bundles was successfully developed and demonstrated

A test facility was developed for accurately measuring the thermal profile of single wires and wire bundles

Thermal model wire temperature predictions were validated based on comparing results with the experimental testing completed

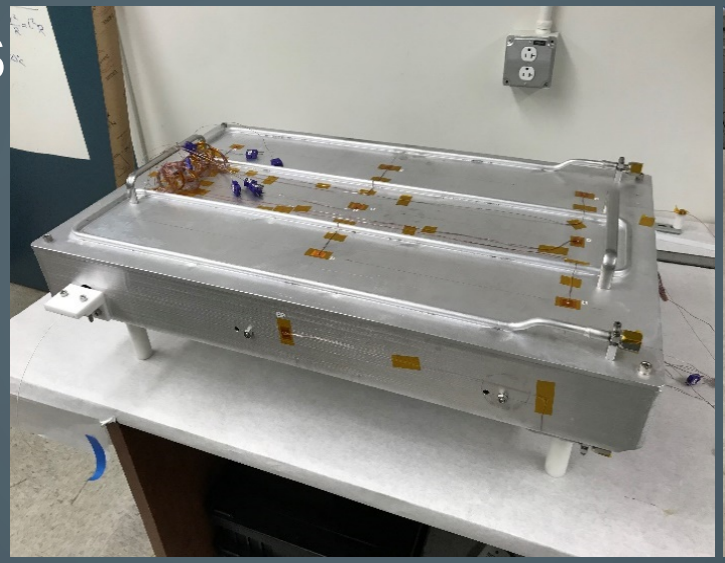
Thermal data was collected under vacuum and atmospheric conditions and varying environmental temperatures and currents

Test results correlated well with published wire bundle derating standards, JPL D-8208, and AS50881

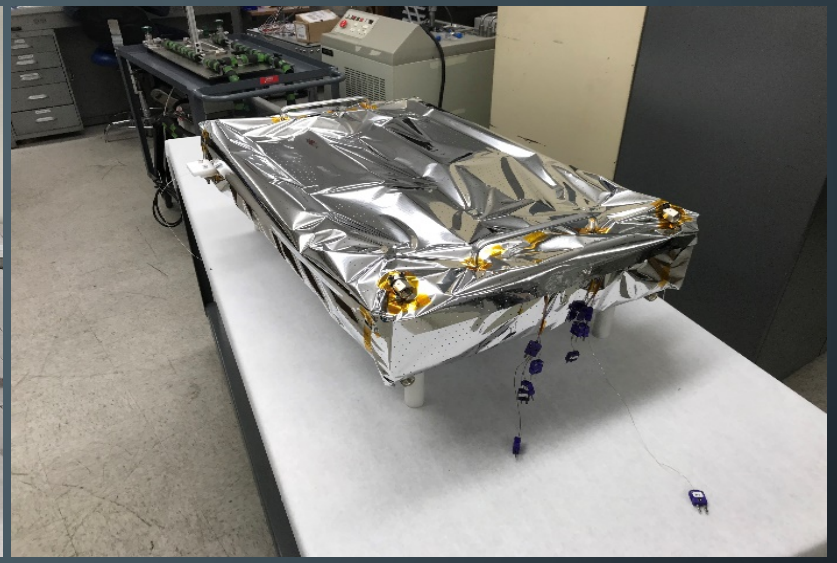
A regression model was also developed and correlated with the derating standards.

NASA Test Apparatus

Temperature Controlled Shroud with Wire Bundle Test Article

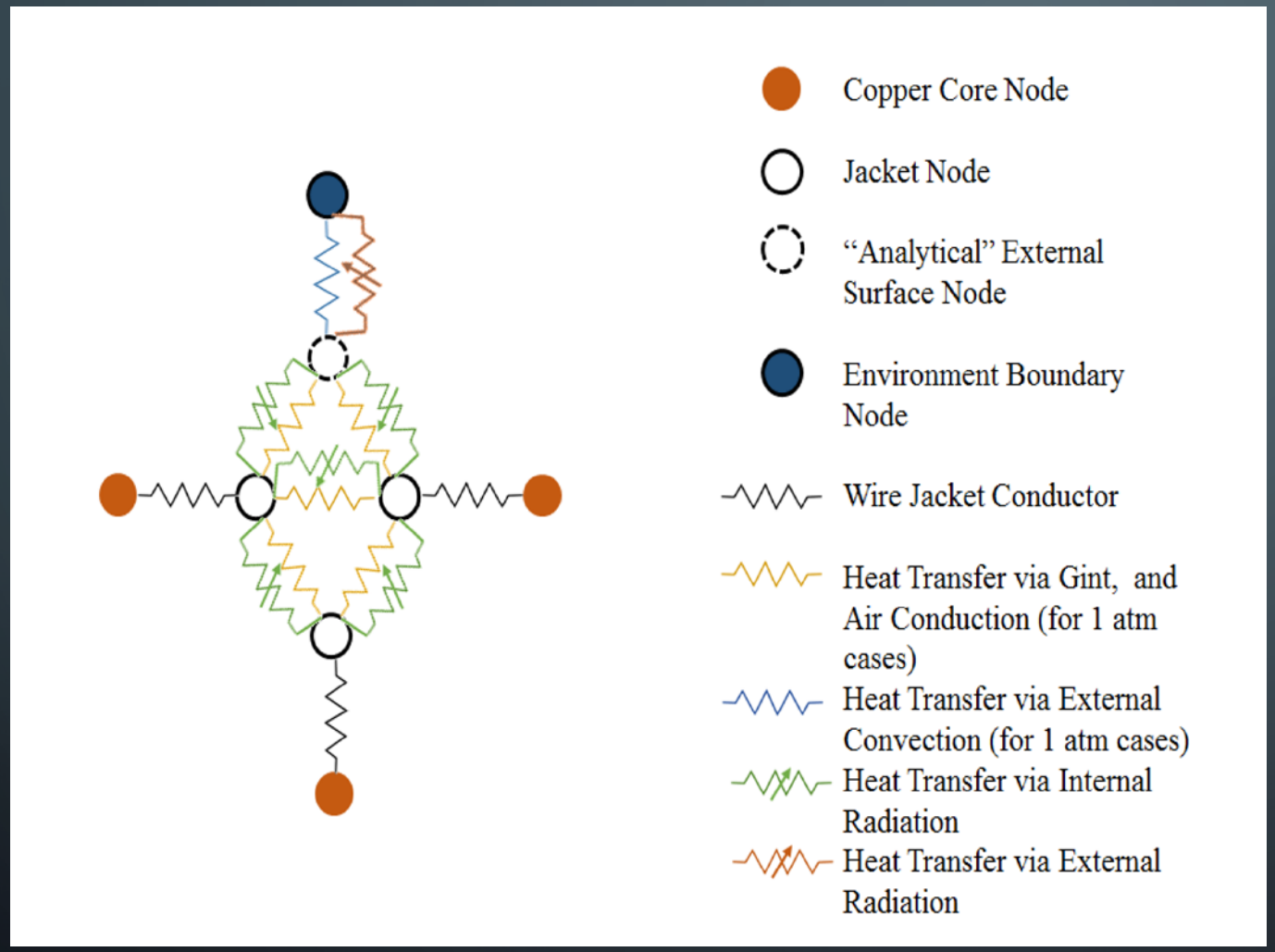


Shroud with Lid



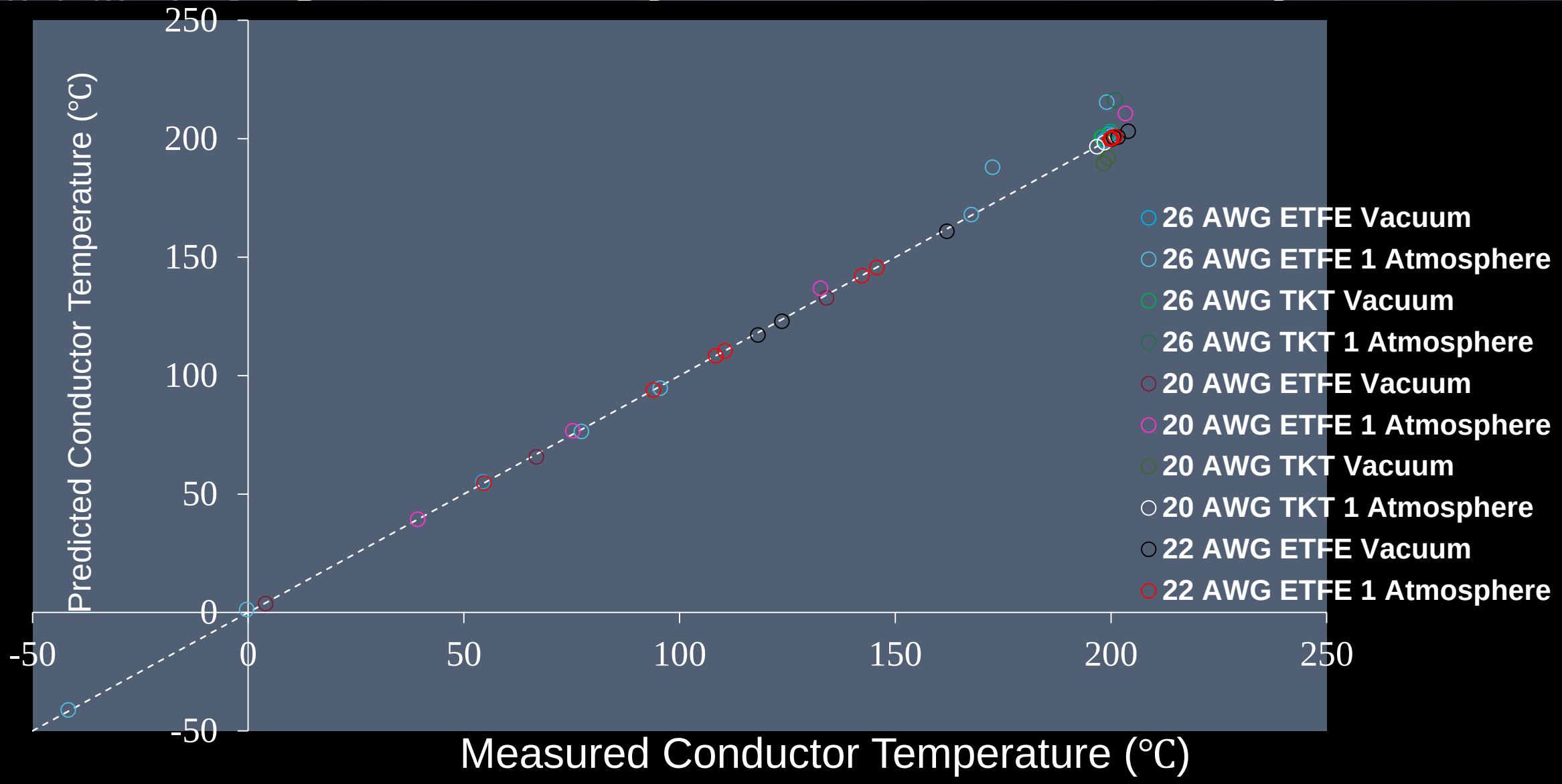
Shroud Insulated

Vacuum Chamber

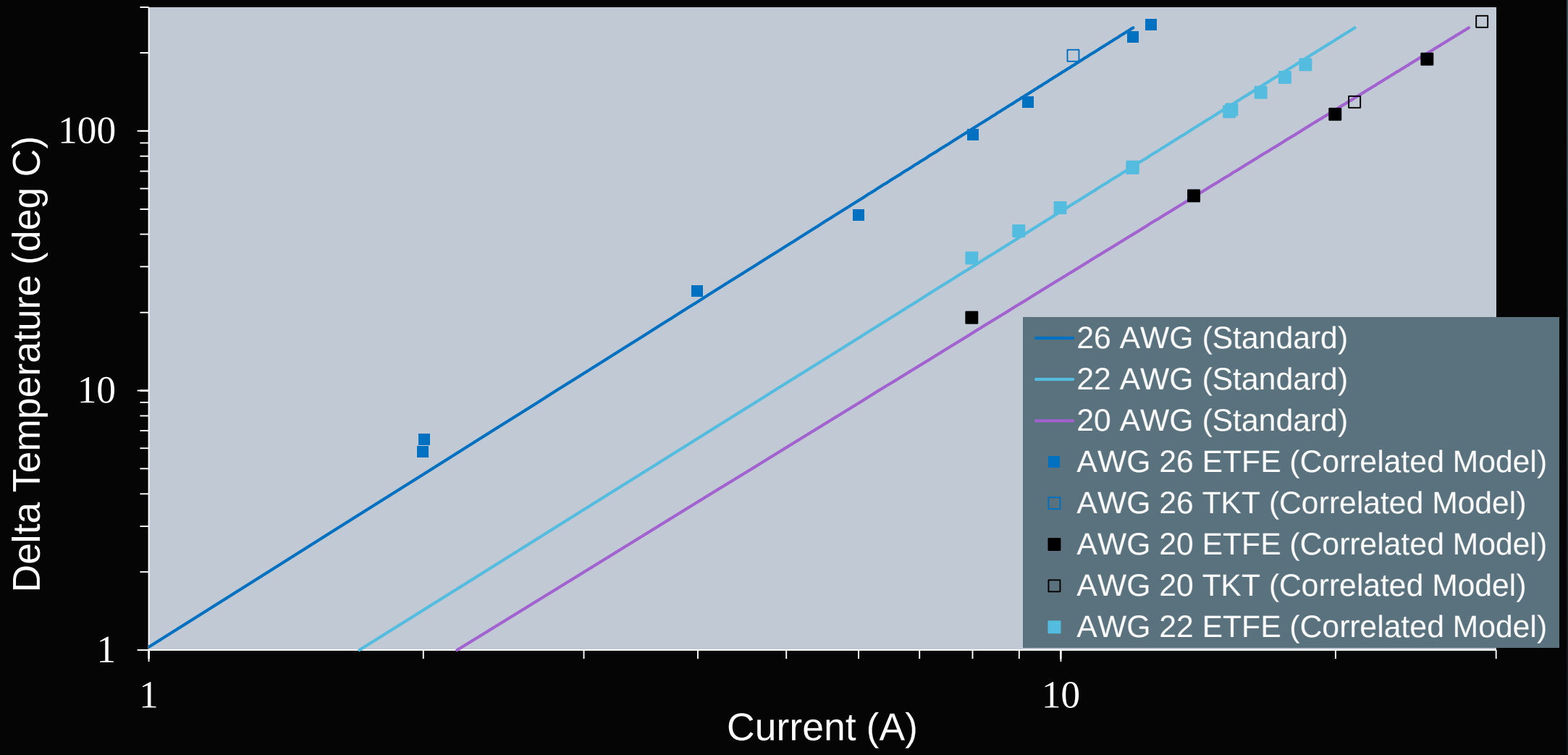


- Thermal impact of the wire insulation and shielding can be represented as a thermal resistance of a wire node to its environment
- Model needs to consider properties of the insulation such as emissivity and infrared transmissivity of materials,
- Insulation thickness, thermal resistance
- Contact with surrounding materials as the material responds to heating and cooling.

Single Wire Analysis – Results Summary

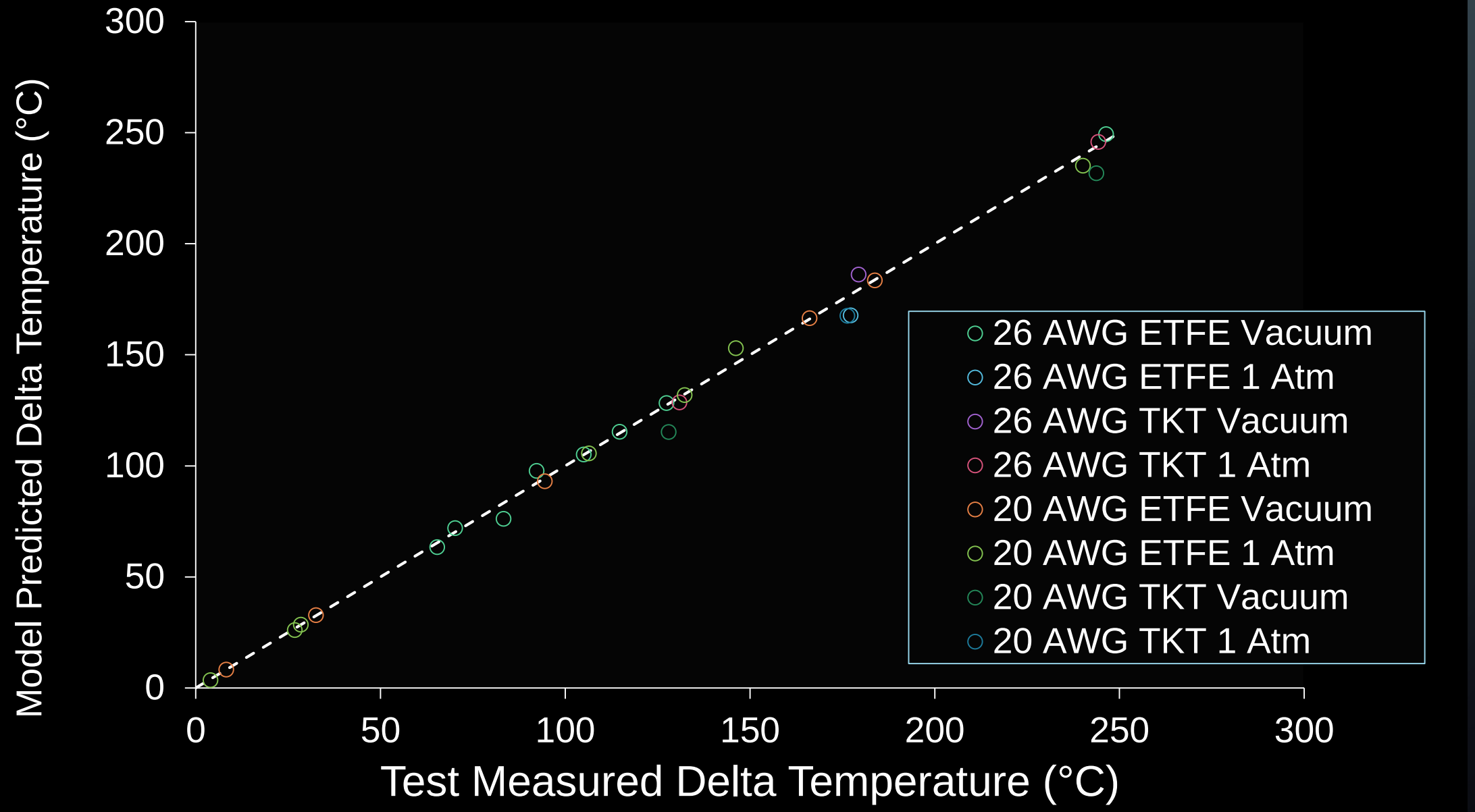


Single Wire Analysis – Results Summary – Comparison with Published Standard

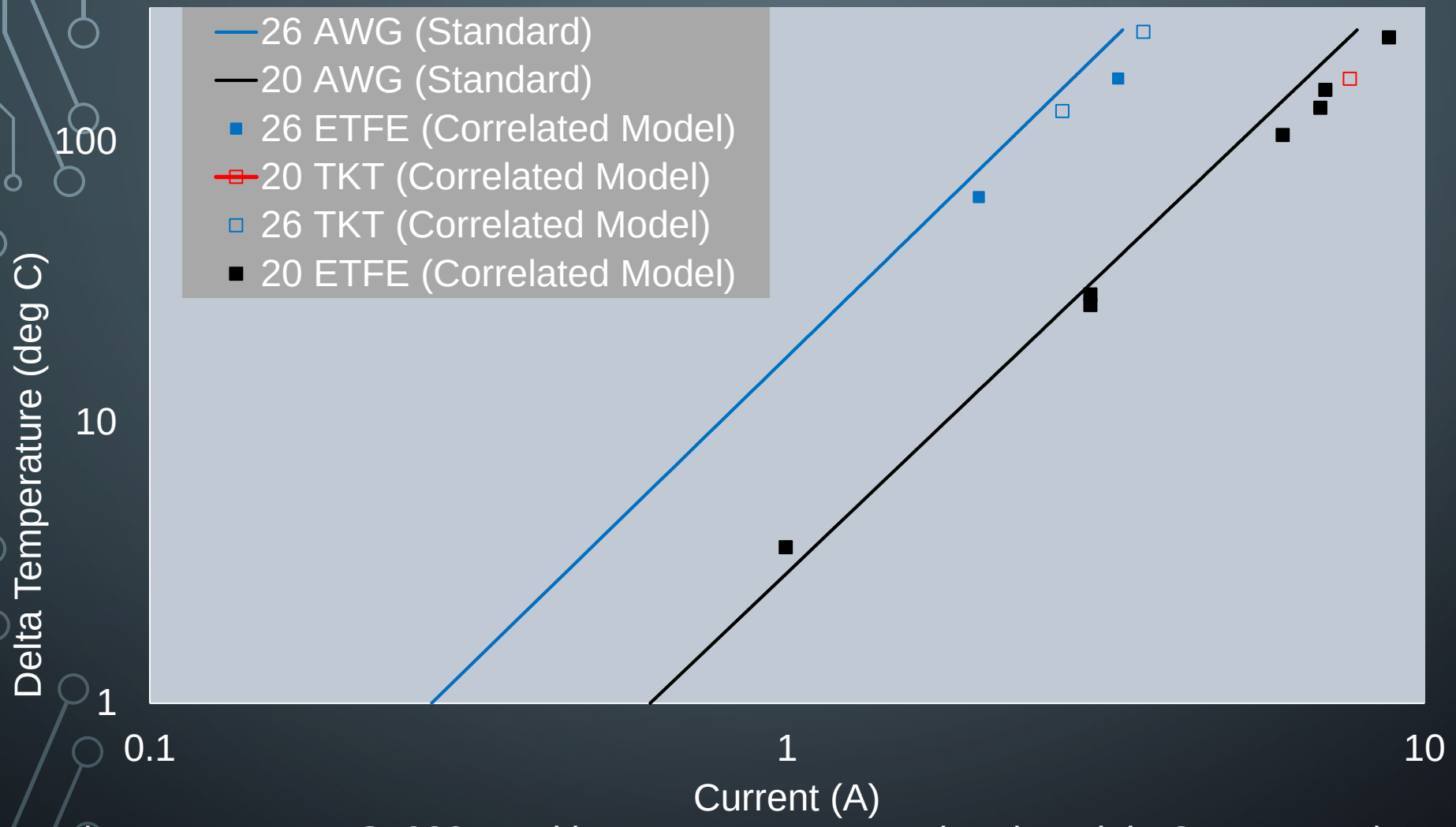


Note: Lines represent AS50881 and boxes represent correlated model. One atmosphere cases.

32 Wire Bundle Thermal Analysis – Results Summary



Wire Bundle Analysis – Results Summary – Comparison with Published Standard



Note: Lines represent AS50881 and boxes represent correlated model. One atmosphere cases.

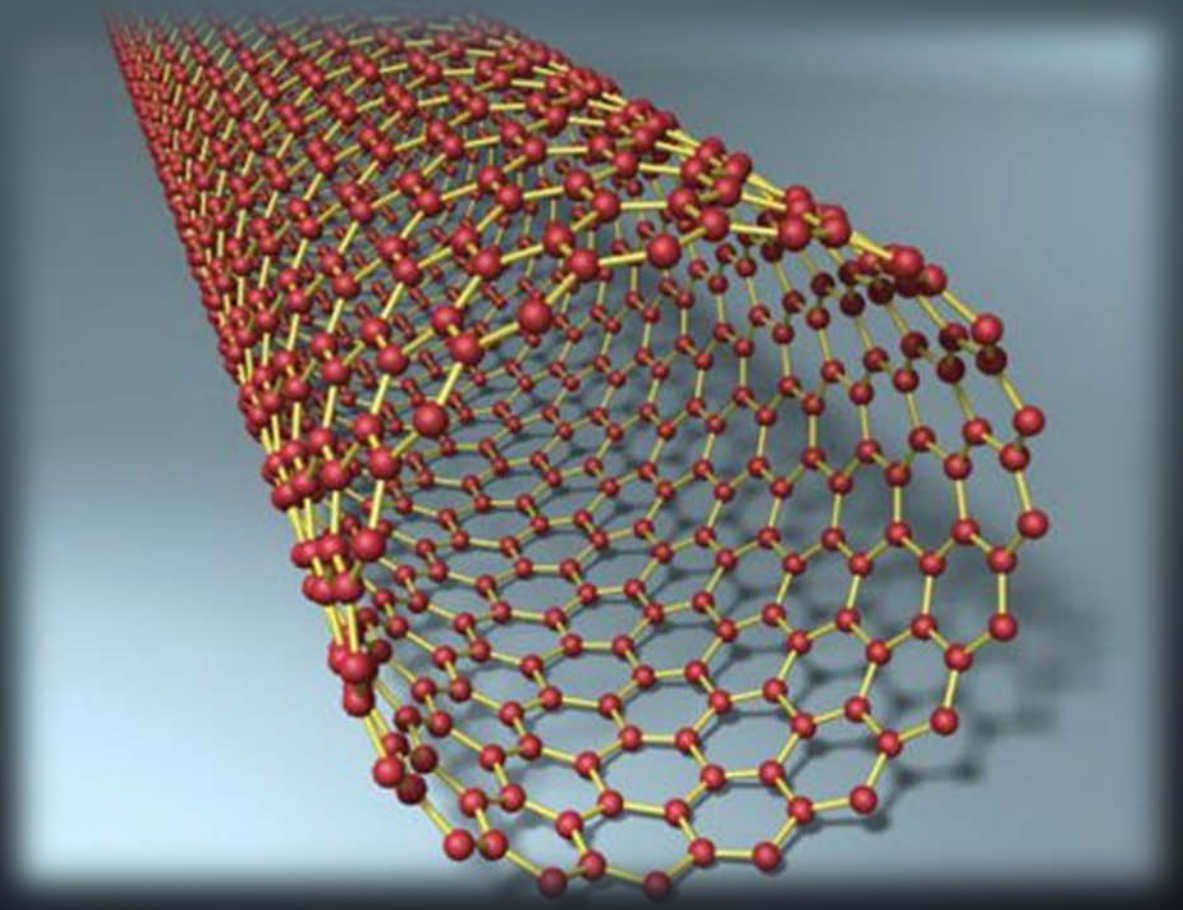
Thermal modeling of wires need to consider these parameters

- Wire type, dimensions and number of cores (e.g. AWG size, single, double, triple, quad).
- Insulation type, shielding and jacket thickness (thermal resistance).
- Wire core (conductor diameter and material).
- Current (DC, AC, heat losses).
- Bundle configuration e.g. contact conduction with neighboring wires or air convection at the bundle perimeter
- Environmental conditions (air temperature, pressure, enclosure).

Model Input Requires Detailed Wiring Parameters to create an Accurate Model

- Conductor alloy
- Conductor resistance at RT (20C)
- Resistance change over temperature (Alpha)
- Insulation material by layer and average thickness
- Insulation thermal resistance
- Insulation thermal coefficient Expansion
- Insulation emissivity
- Conductor resistance change due to thermal aging

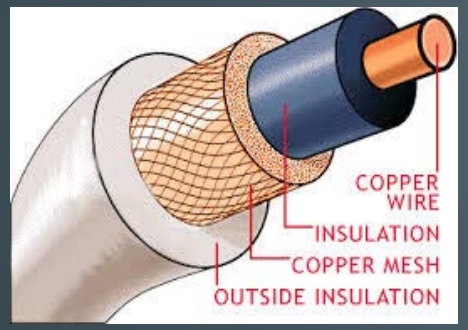
REPLACEMENT OF COPPER WIRING WITH CARBON NANOTUBES



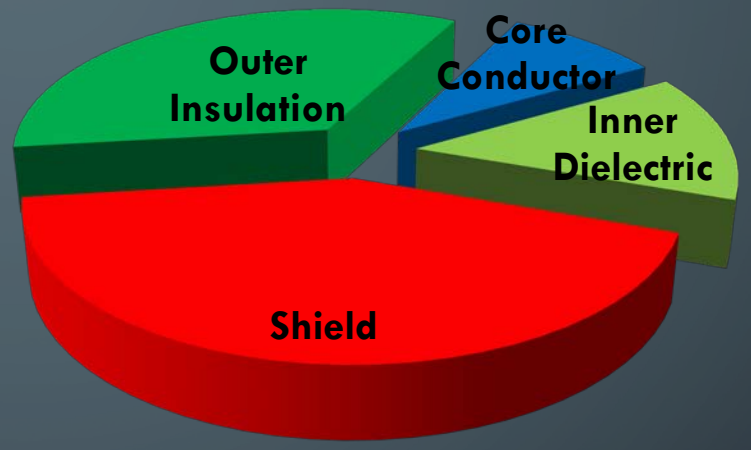
WHY CONSIDER A CARBON BASED WIRE CONDUCTOR?

- Weight Reduction
  - Typical carbon based cable weight savings can be 70-30% weight of copper depending on cable type and electrical requirements
  - Replacement of copper on an aircraft could reduce weight by several thousand pounds
  - Programs have spent up to a $1M to save a pound of weight on an aircraft design
- Reliability Improvement Impacting Safety and Aircraft Availability
  - Improved flex life and lower stiffness
  - Primary cause of wiring failures is conductor breakage
  - Aircraft designs can violate cable bend radius design requirements causing wiring failures and even aircraft mishaps

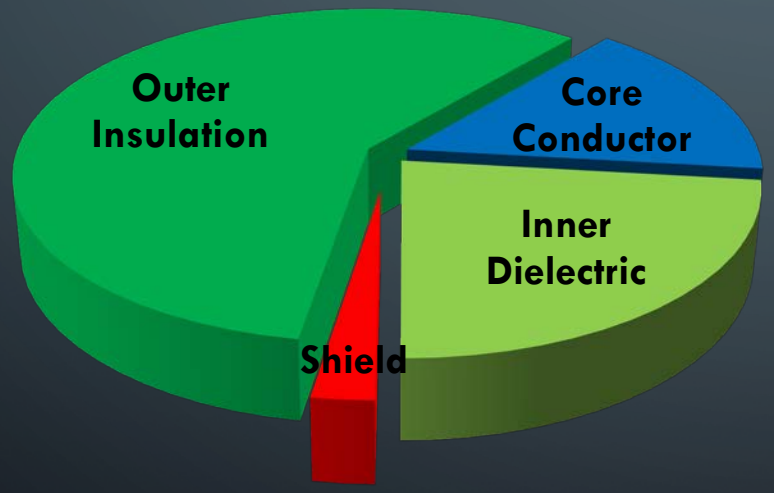
COPPER REPLACEMENT WEIGHT SAVINGS



Copper Based Coax Cable



CNT Shield Coax Cable



Copper based coax cable 8.5 lbs. /1,000 Ft
CNT shield based coax cable 5 lbs /1,000 Ft.
41% weight savings with shield
All CNT coax cable 4.32 lbs. /1,000 Ft.
51% weight savings
Up to 70% for other cable types

KEY FINDINGS

- Carbon based fibers, including CNT based fibers, available at TRL/MRL 8 as replacement for copper conductors in high frequency aircraft shielding applications
- Metalized non-conductive carbon fiber (Kevlar) has about 10% conductivity of nickel plated copper
- TRL 8 CNT fiber is about 4% the conductivity of nickel plated copper
- Cost of metalized carbon fiber is about 5 times the cost of copper
- Cost of TRL 8 CNT 5 to 10 times the cost of copper
- Carbon based wiring offers significant weight savings and enhanced flexibility over copper
- CNT is 10 times lower in weight compared to copper
- Metalized carbon conductor is about 5 times lower in weight than copper.
- As a drop-in replacement for copper conductor, CNT is at TRL 2 or 3

STATUS OF CNT DEVELOPMENT

- Specification completed and published as MIL-DTL-32630 under NAVAIR sponsorship
- Qualification by several vendors expected
- Platform applications identified
- Will have a QPL
- Applications: Controlled impedance and shielded twisted pair 27500 cables
- DLA interested in using qualified carbon based conductors in MIL-DTL-17
- Develop application specs to address shielding
  - AA 59569 with additional requirements

SUMMARY

- Develop carbon based conductors (CNT and metalized carbon fibers)
- Develop thermal and current derating model for wiring in cooperation with the NESC
- Need to develop wiring components for new high voltage/energy systems
- CoP Flight Connector and Wiring CoP meets the 4th Tuesday each month at 1500 (EST)