Electrical Arc Ignition Testing of Spacesuit Materials

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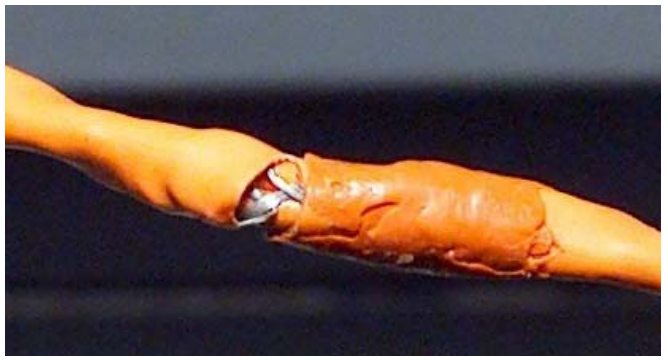
Background

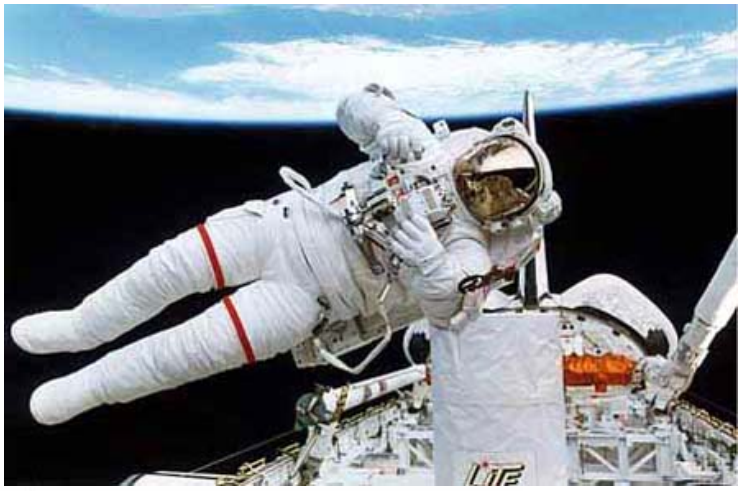
- Testing in response to frayed cable discovered during spacewalk
- Reliance on Apollo-era arc testing
  - Limited applicability to current materials
  - Significant changes in voltage and circuitry
  - Poor understanding of test configuration

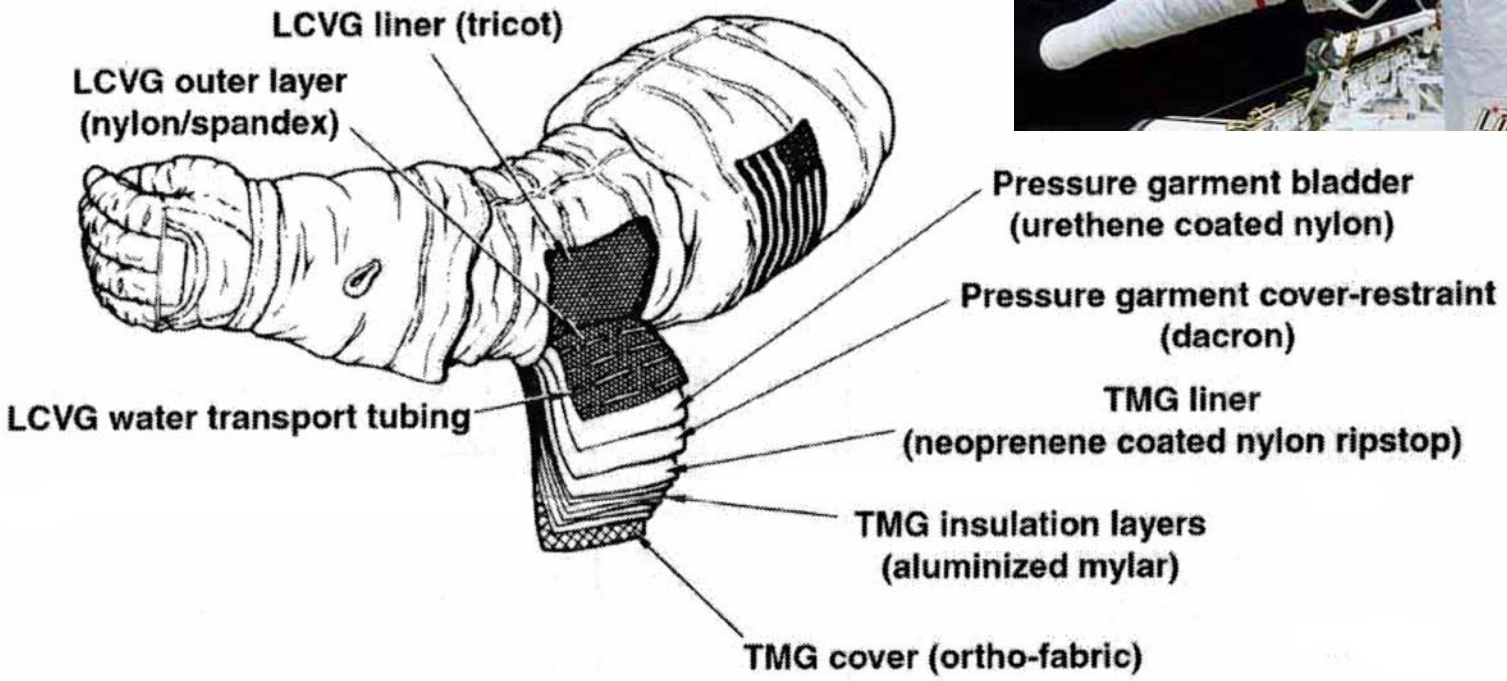


Test Objectives

- Gain better understanding of Apollo-era data
- Investigate new test methods
- Characterize minimum current levels necessary for combustion of EMU materials (at a given voltage)

Test Sample Materials





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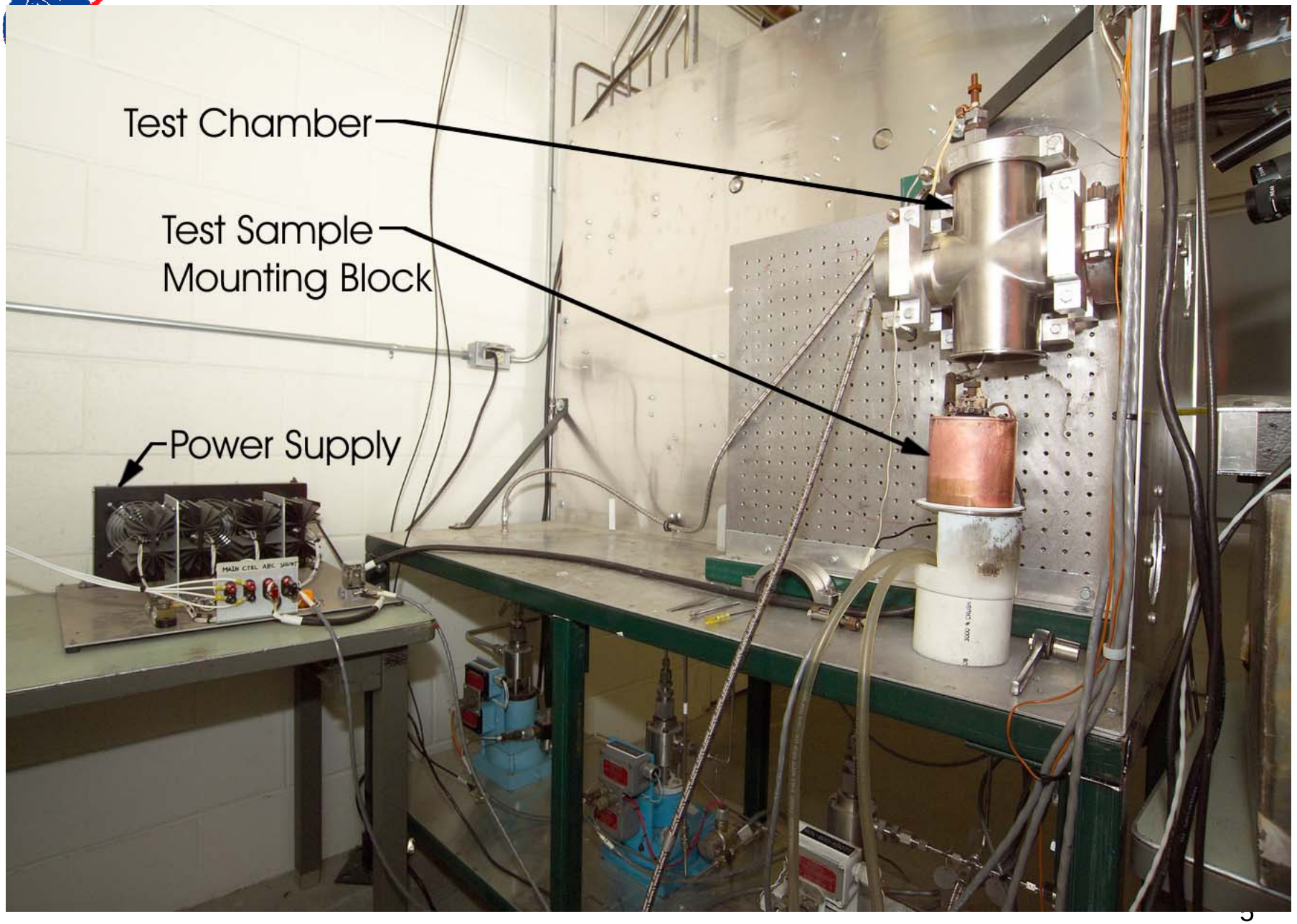
Test Chamber
Test Sample
Mounting Block
Power Supply

Test Methods

- Multiple location intermittent arcing (scratch) test
- Single location intermittent arcing (poke) test
- Single location wire-break arcing test

Scratch Test Objectives

- Simulate Apollo-era testing
- Determine configurational effects
- Test materials currently used in the EMU

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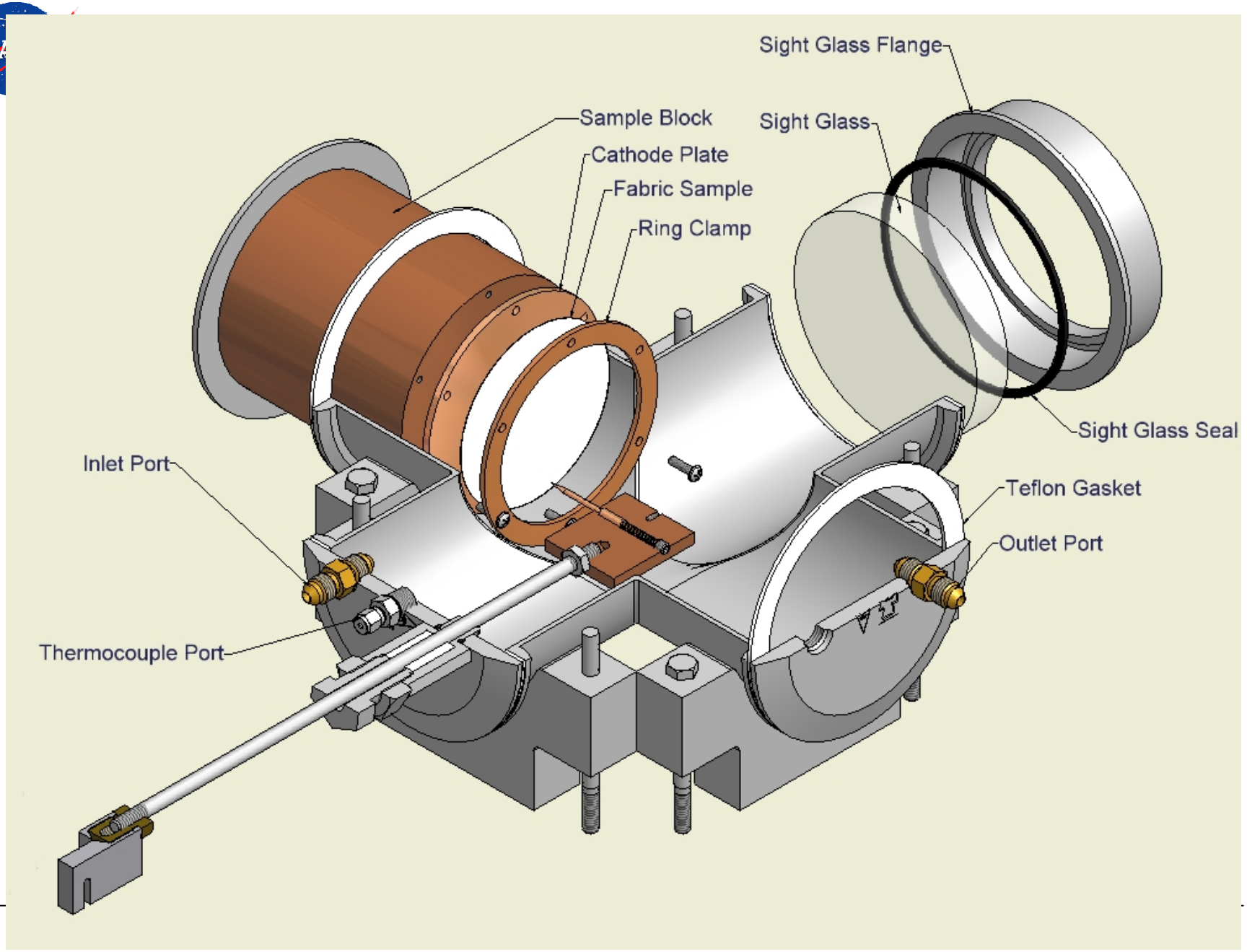
Sight Glass Flange
Sample Block
Sight Glass
Cathode Plate
Fabric Sample
Ring Clamp
Sight Glass Seal
Inlet Port
Teflon Gasket
Outlet Port
Thermocouple Port

Cotton Scratch Test Video

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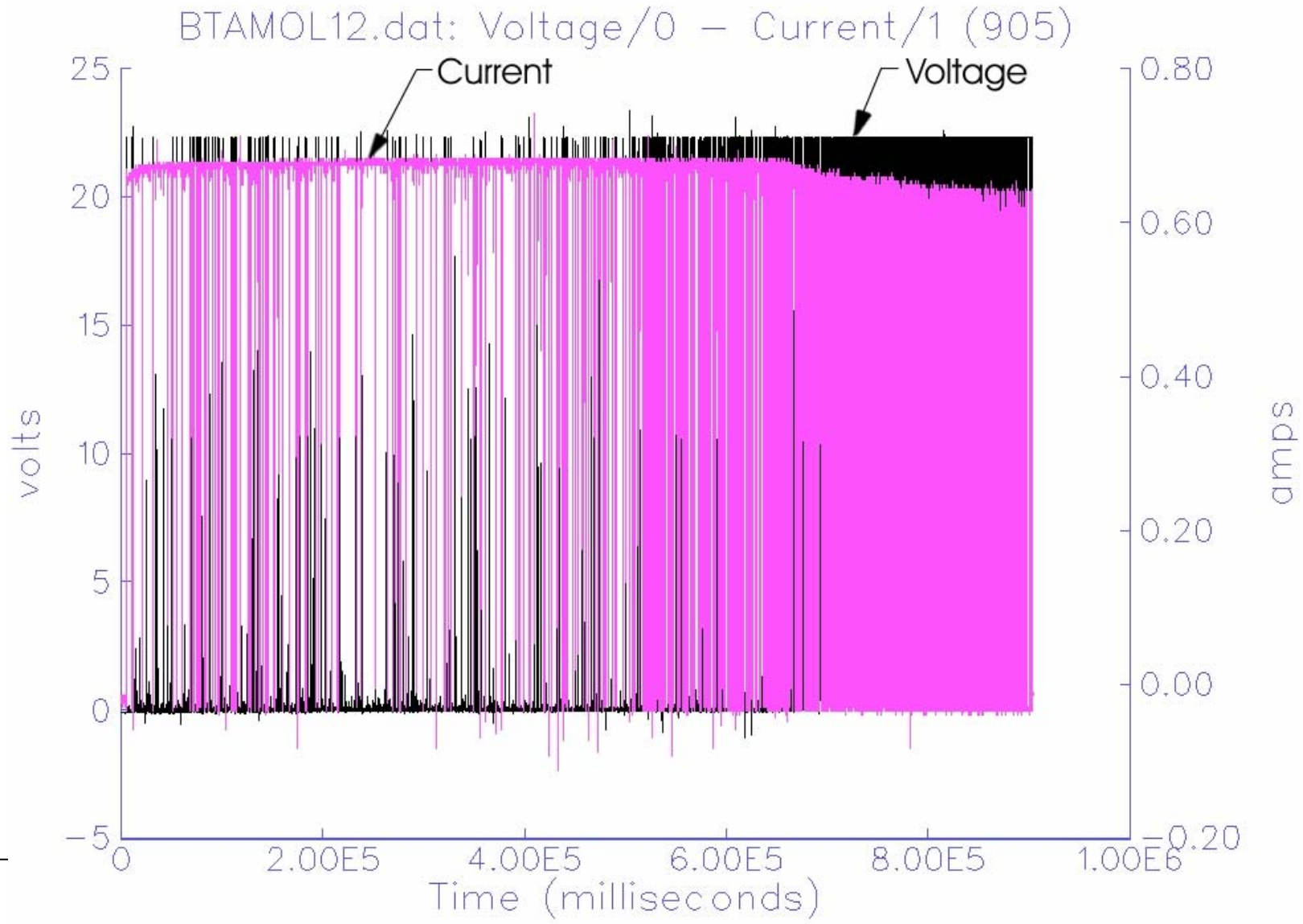
Scratch Test Results

- Testing yielded results similar to Apollo-era testing
- Frayed materials more reactive
- No distinguishable difference between horizontal samples and vertical samples
- Tests performed at 23.5 psia 100% O2, 22.5 V
  - 7 materials tested
  - Current required for ignition ranged from 0.8 A to 1.4 A

Entire Data Plot



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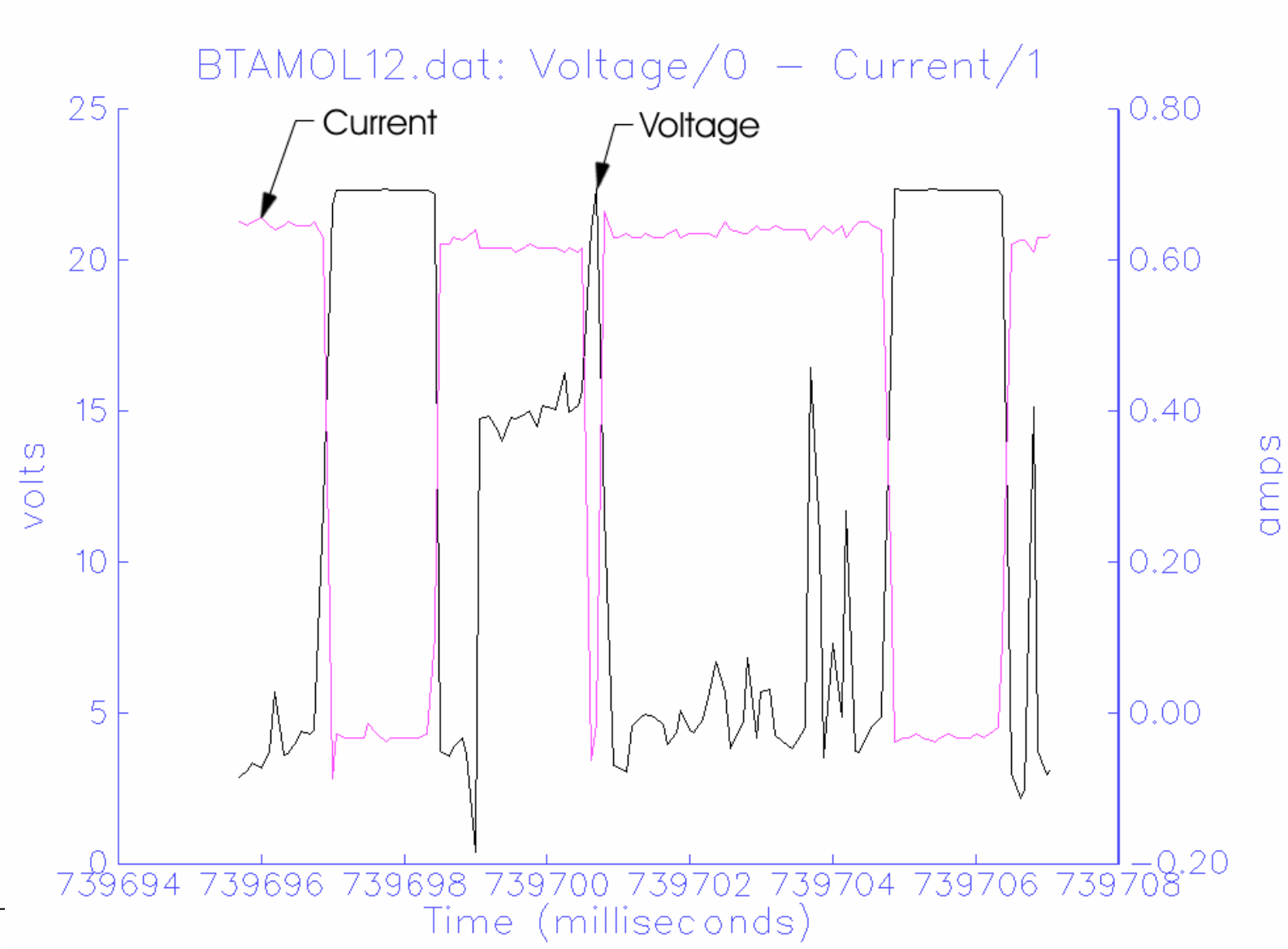
Closeup Data Plot



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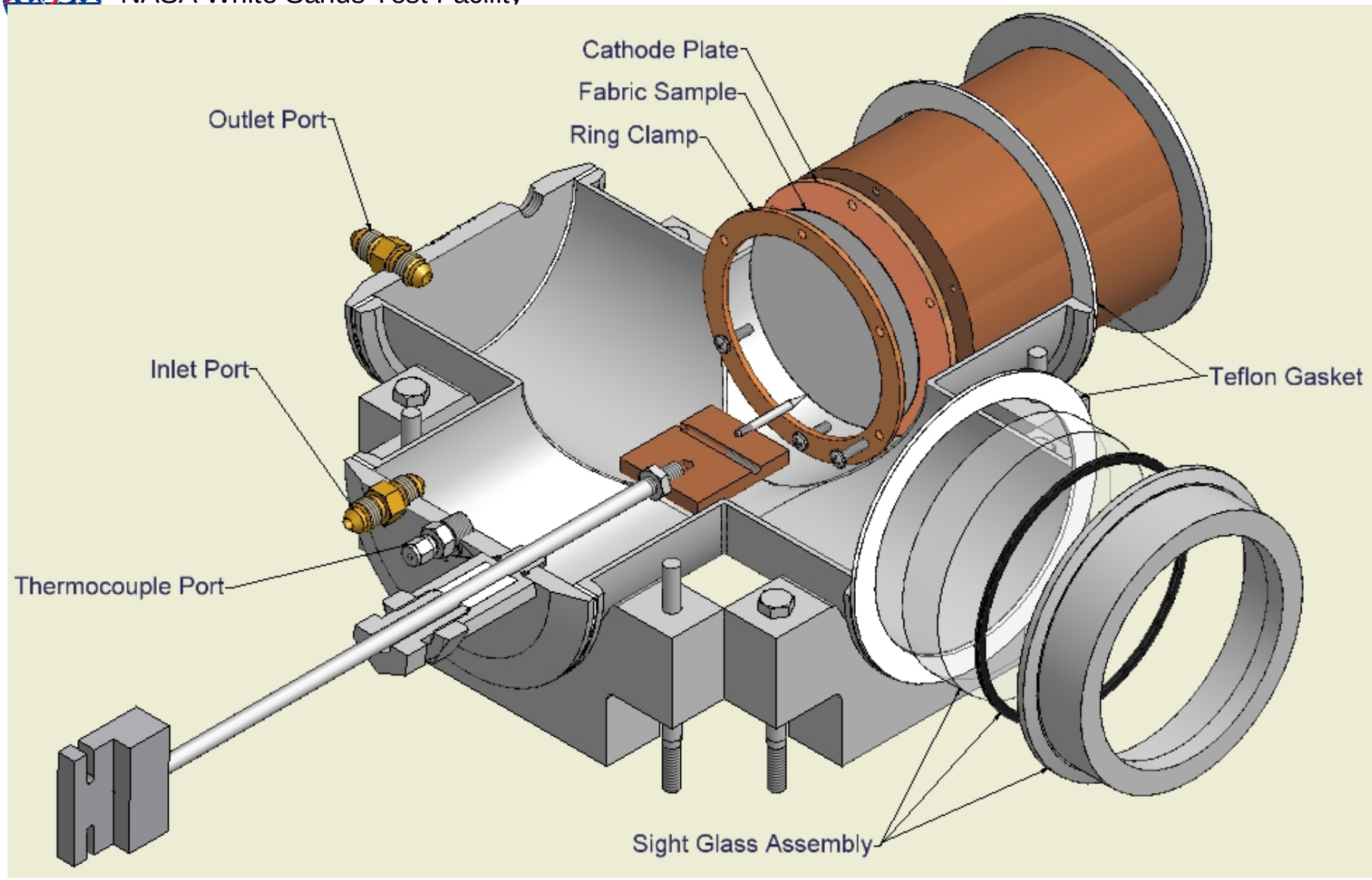
Scratch Test Problems

- Not possible to determine which arc ignited material
- Arc energies vary widely from test to test and arc to arc
- Difficult to ensure that test sample material is in intimate contact with arcing event
- Configuration not realistic for inside spacesuit because of size of stylus

Poke Test Objectives

- Determine whether more severe to arc with wires or stylus
- Determine whether more severe to arc in single location (poke test) or multiple locations (scratch test)


Cathode Plate
Fabric Sample
Ring Clamp
Outlet Port
Inlet Port
Thermocouple Port
Teflon Gasket
Sight Glass Assembly

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Poke Test Results

- Poke test results consistent with scratch test results
  - No detectable difference between arcing in one location or multiple locations
- Tests showed that it is more severe to arc with a wire than a stylus
  - Wires are flammable and can burn in oxygen
  - Burning wires easily ignite test materials

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Poke Test Problems

- Not possible to determine which arc ignited material
- Arc energies vary widely from test to test and arc to arc
- Difficult to ensure that test sample material is in intimate contact with arcing event

Wire-break Test Objectives

- Reduce variability in tests
- Test all materials
- Determine whether ignition is dependent on voltage or current

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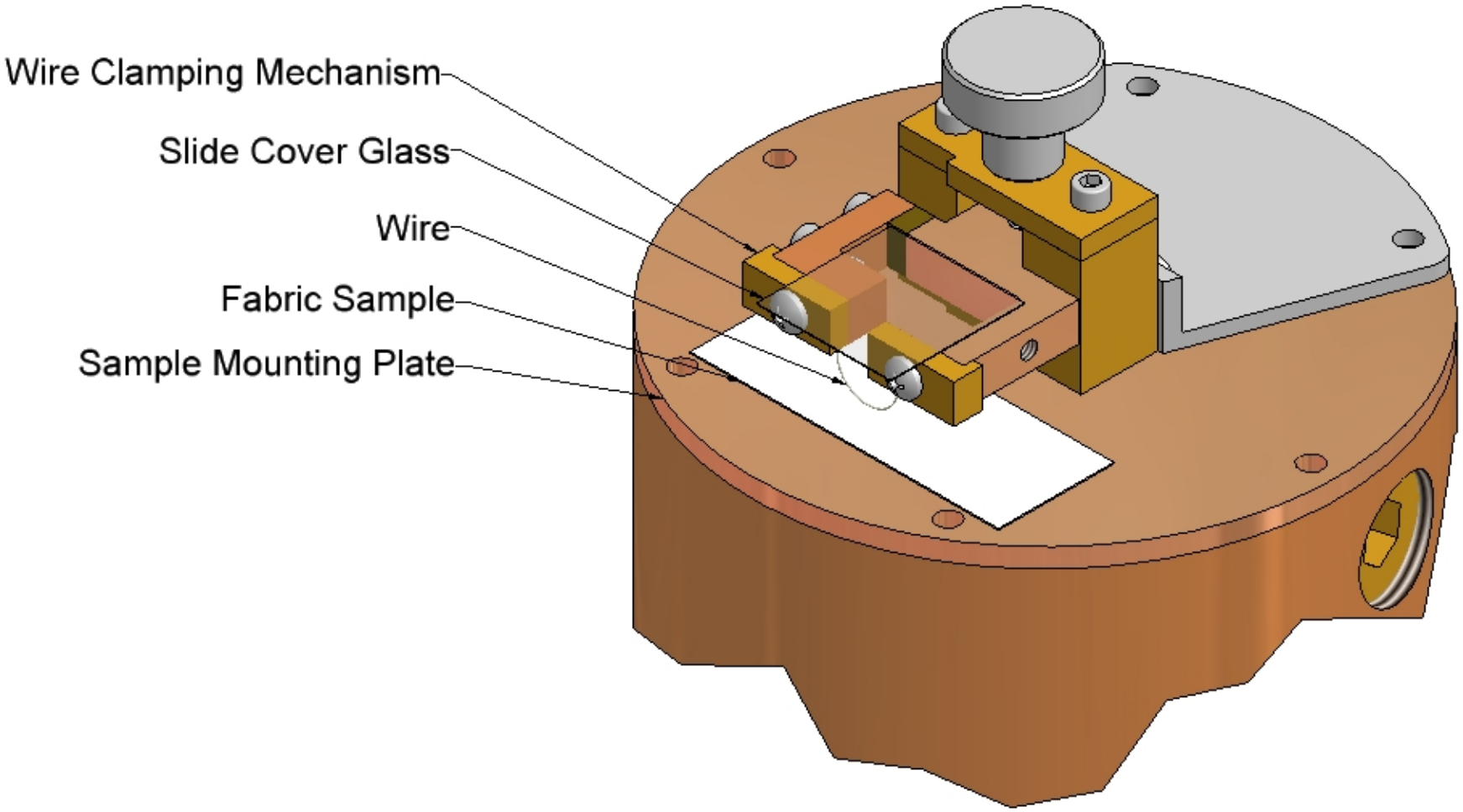
Wire Clamping Mechanism
Slide Cover Glass
Wire
Fabric Sample
Sample Mounting Plate

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AWG Size	Diameter (in.)	% of Flight Wire Cross Sectional Area	Approximate Current Required to Break Wire (A)
34	0.0063	1550	9.00
38	0.004	625	5.00
39	0.0035	479	3.80
40	0.0031	375	3.00
41	0.0028	306	2.60
42	0.0025	244	2.30
43	0.0022	189	1.80
44	0.002	156	1.50
45	0.0018	127	1.30
46	**0.0016**	**100**	1.10
47	0.0014	77	0.90
48	0.0012	56	0.83
49	0.0011	47	0.70
50	0.001	39	0.63
51	0.00088	30	0.50
52	0.00078	24	0.45
54	0.00062	15	0.35

Cotton Wire-Break Test Video

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High Speed Cotton Wire-break Test Video

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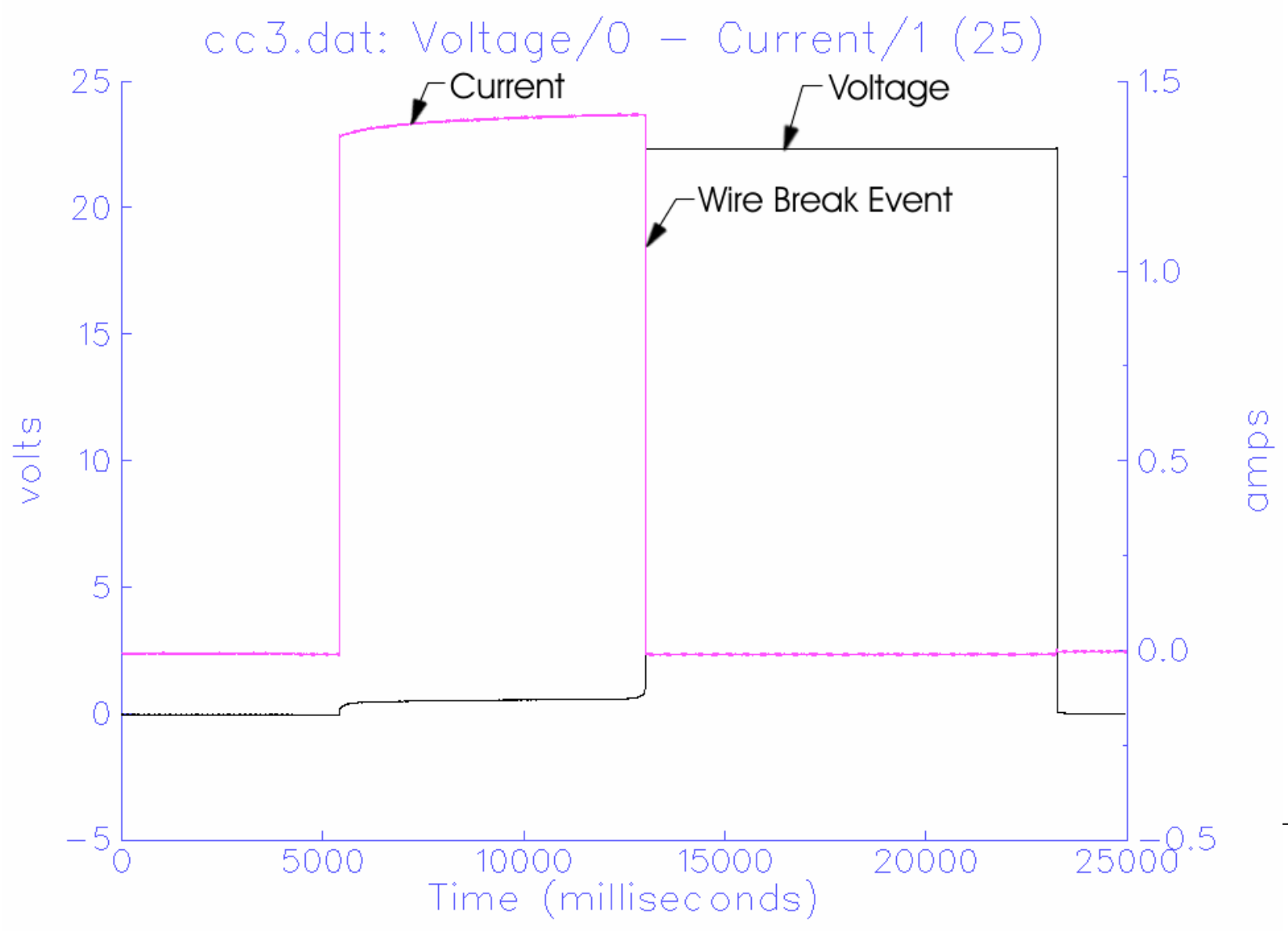
Typical Data Plot



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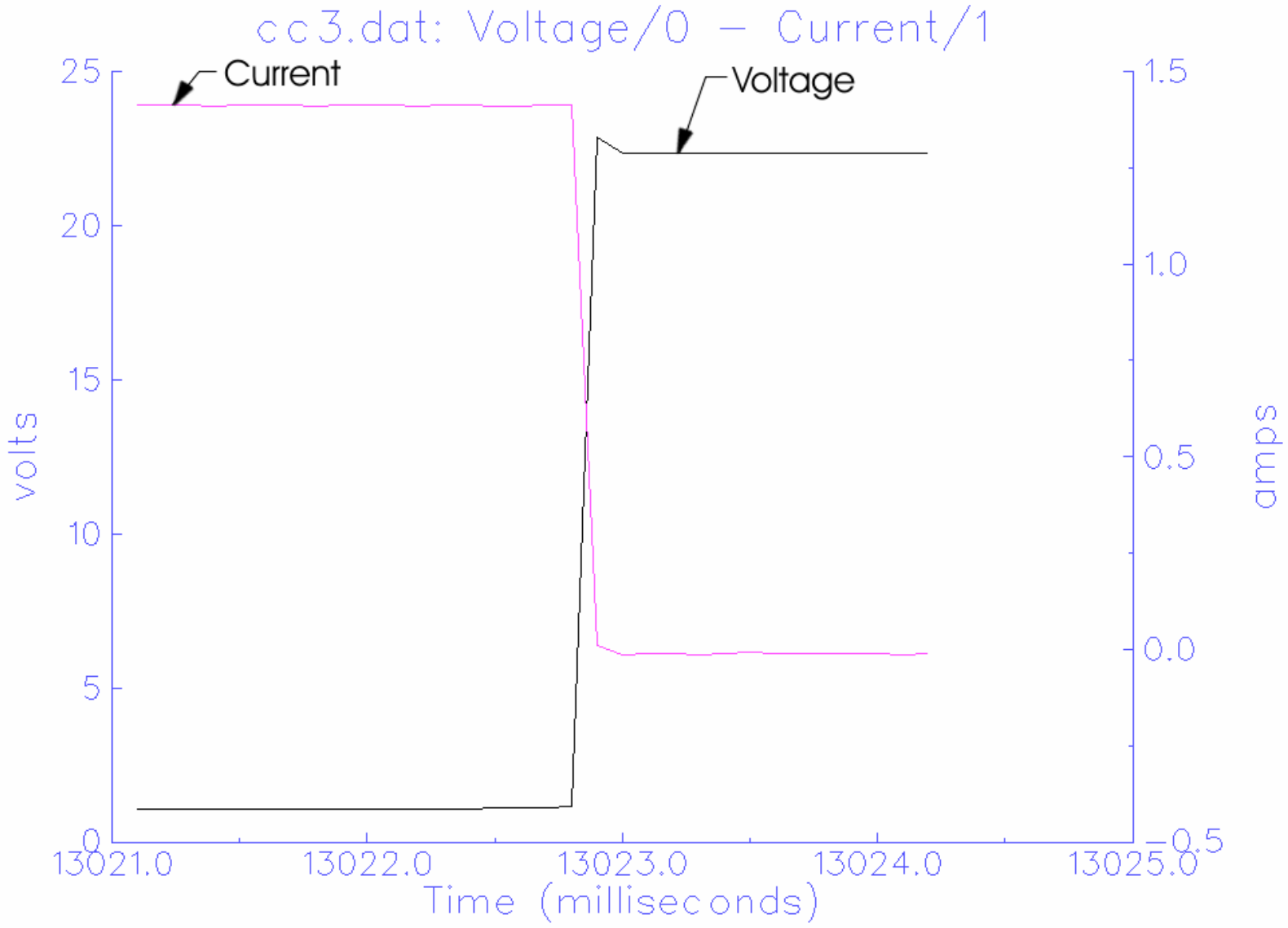
Closeup Data Plot



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Wire-break Test Results

- Much more severe than scratch and poke tests
- Test conditions
  - 23.5 psia 100% O2, 22.5 V
  - 50 psia 50% O2 and 50% N2, 15 V
- Several materials failed testing at the lowest possible current, ~0.3 A
- Current required for ignition for most materials ranged from <0.3 A to 0.97 A

Wire-Break Test Results (cont.)

- Gore-Tex only ignited under much more severe conditions
  - 100% O2, 54 psia
  - Zigzag wire configuration

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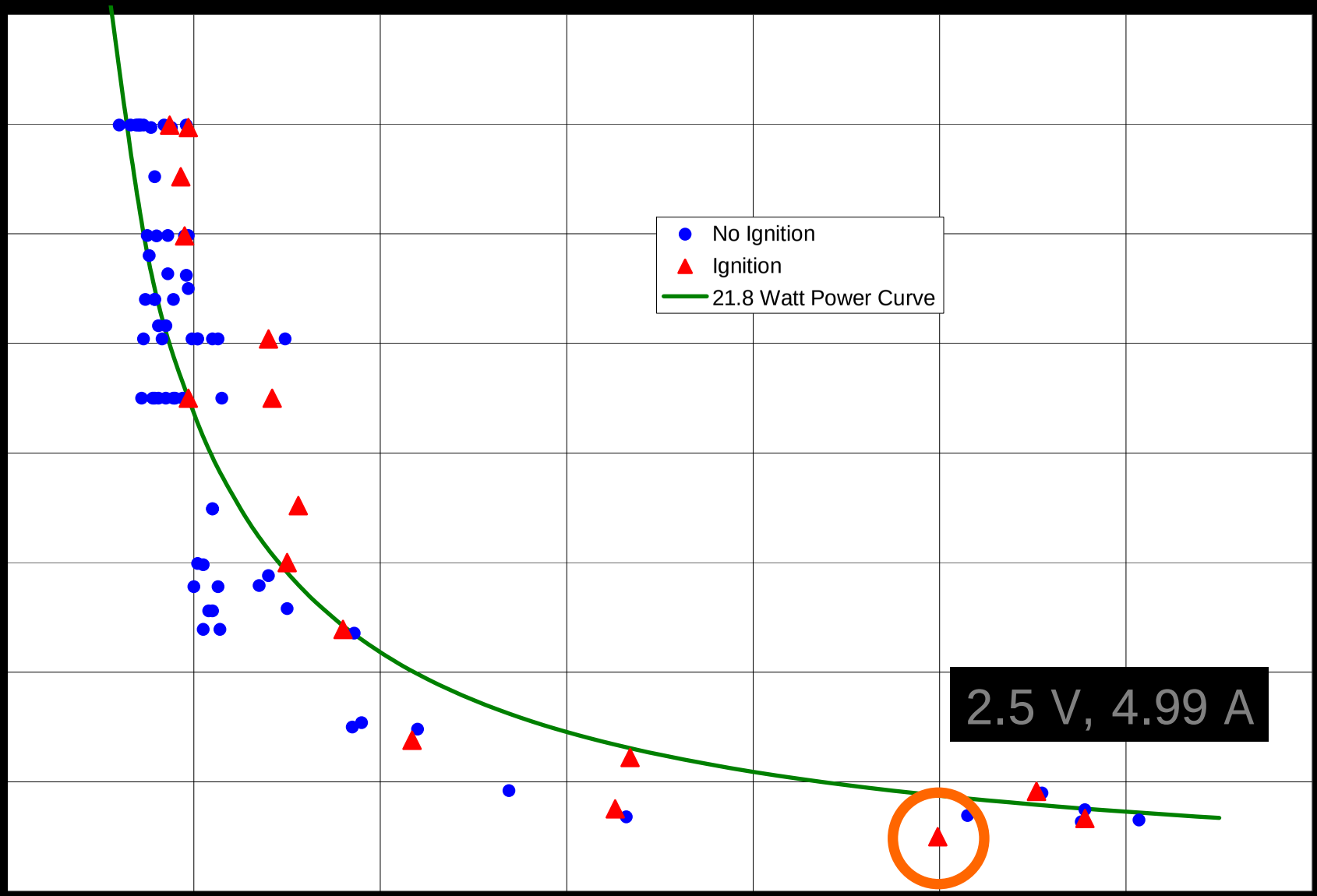
Wire-break Tests vs. Scratch Tests

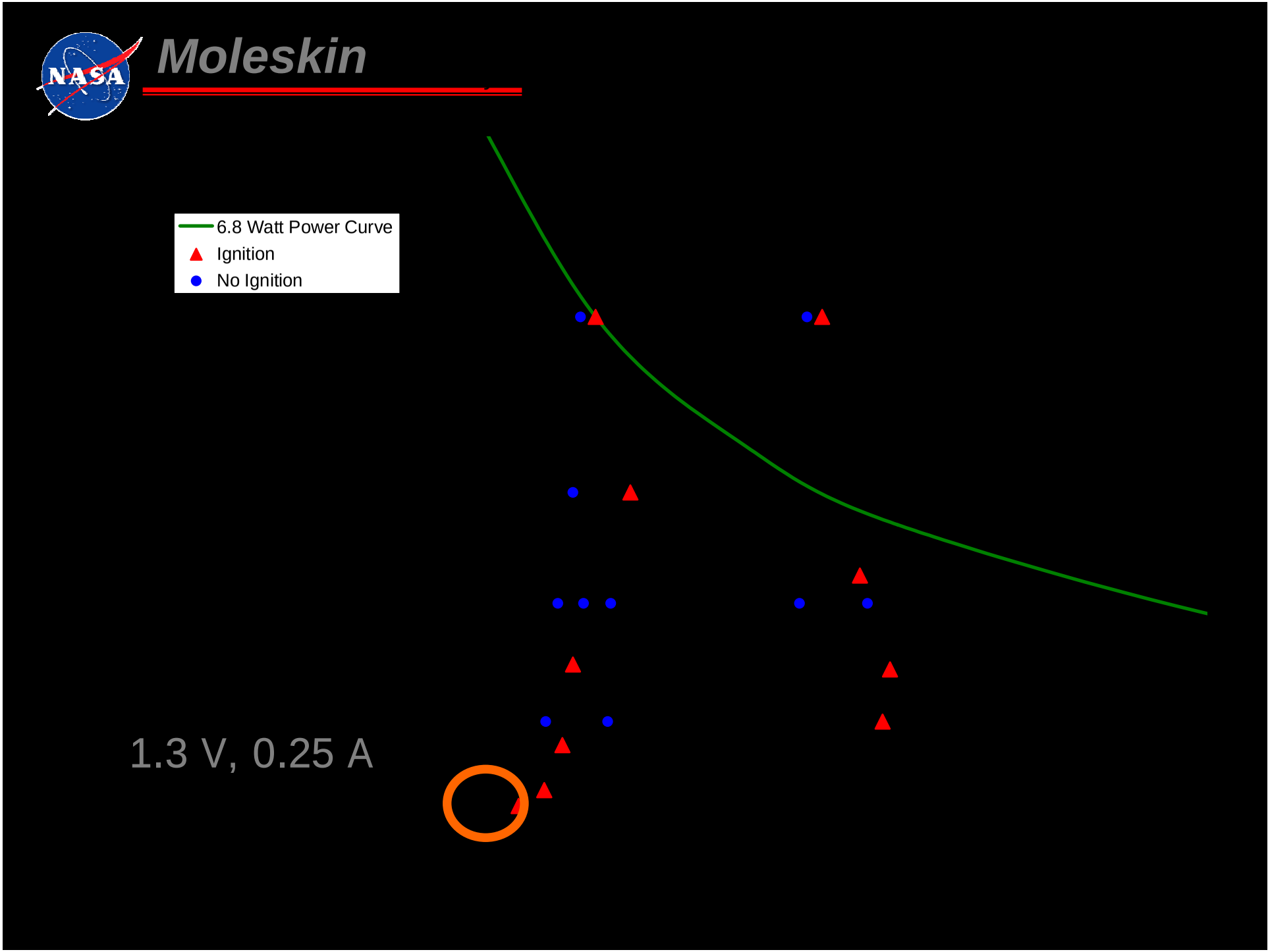
23.5 psia 100% O2, 22.5 V

Material	Wire Test Available Current at Ignition (A)	Scratch Test Available Current at Ignition (A)
Generic cotton	0.36	0.95
Moleskin	0.3	0.8
UCN (shiny side)	0.70	1.4
Nylon/Lycra Comm Cap	0.59	1.3
Astronaut undergarment	0.64	1.4
LCVG spandex	0.53	1.4
LCVG tricot	0.49	1.3

Urethane-coated Nylon



Moleskin



	Material	Surface Characteristics
Best	Interface cable Gore-Tex® sleeve	Smooth
	Urethane-coated nylon suit bladder (fabric side)	Smooth
	PVC	Smooth
	Interface cable polyurethane jacket	Smooth
	Urethane-coated nylon suit bladder (shiny side)	Smooth
	Astronaut longhandle undergarment	Fuzzy
	CCA cap spandex (nylon & Lycra® knit fabric)	Smooth
	LCVG garment (multifilament nylon / spandex knit 1106 treated with 3% TCHDE solution)	Smooth
	LCVG garment inner liner (nylon tricot treated with 3% TCHDE solution)	Smooth
	Cotton flocked Rucothane® glove bladder	Fuzzy
	TCU assembly (Capilene® – hollow fiber polyester treated with 3% TCHDE solution) (gray)	Fuzzy
	Kerlix dressing	Fuzzy
	Generic cotton	Fuzzy
Worst	Moleskin	Fuzzy

Conclusions

- Wire-break test is worst-case
- Fuzzy materials generally easier to ignite
- Current appears to have greater effect than voltage
- Controlling risk must include both
  - Physical isolation of easy to ignite materials
  - Limiting current and voltage

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