Arcing Damage to Aircraft Components and Wire at a Distance

2009 Aging Aircraft Conference

Lectromec

Why Examine Damage at a Distance?

- The damage that can be caused by electrical arcing from wires has been well documented.
- Items such as the chafing of a power wire against a grounded hydraulic line and the subsequent damage have previously been examined.
- When an arc occurs, some of the energy is used to ionize and heat the local gas. This ‘arc plume’ can cause damage to targets an inch away from the arcing event.
- Because this arc plume is ionized, this makes it possible for air to conduct electricity and therefore to arc directly from the power wire to a grounded target.

Lectromec

Why Examine Damage at a Distance?

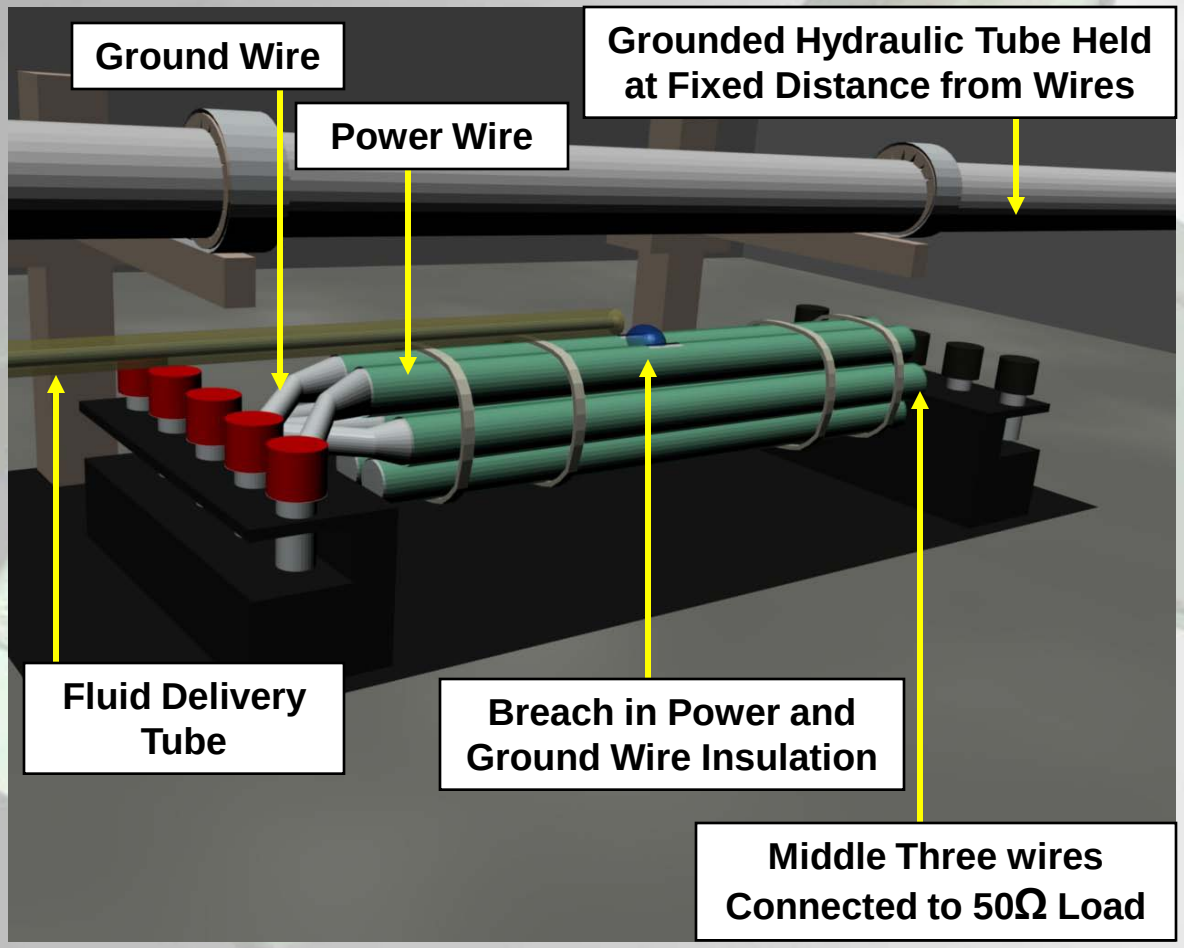
- Under normal circumstances, 115 volts is not able to jump a 0.01” gap. However, if arcing has been initiated by direct contact or a conductive media, the arc plume will allow a larger gap to be bridged.
- The purpose of these tests is to show the potential electrical energy transfer and damage to targets at a defined distances from arcing wires.
- Methods using both wet and dry initiation have been developed.

Lectromec

What Parameters Matter?

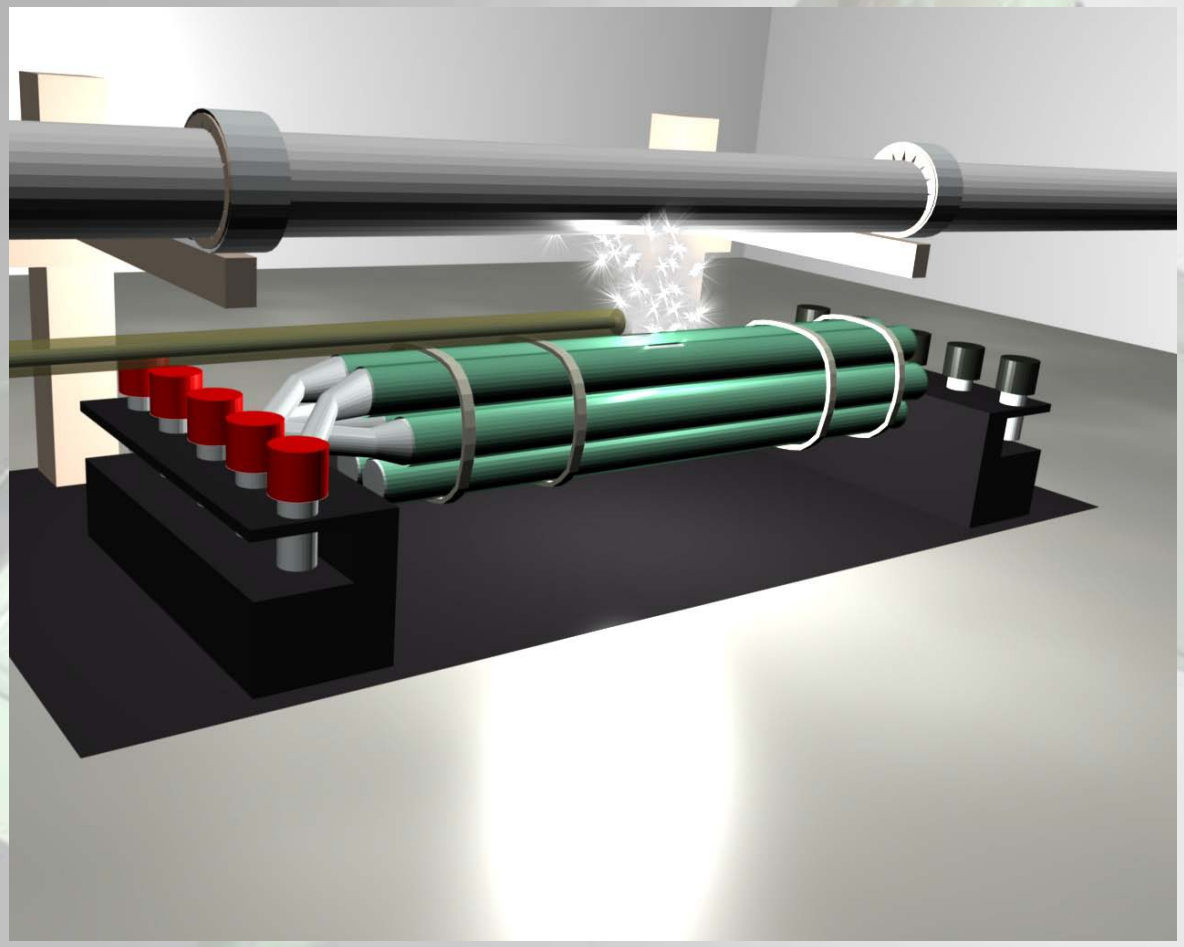
- Of the many variables that can exist in an arcing event, four have the greatest impact
  - Separation Distance
  - Fault Current
  - Circuit Protection (Duration)
  - Wire Type (Gauge, Insulation material and Construction)

Damage at a Distance with Wet Initiation Method



Lectromec

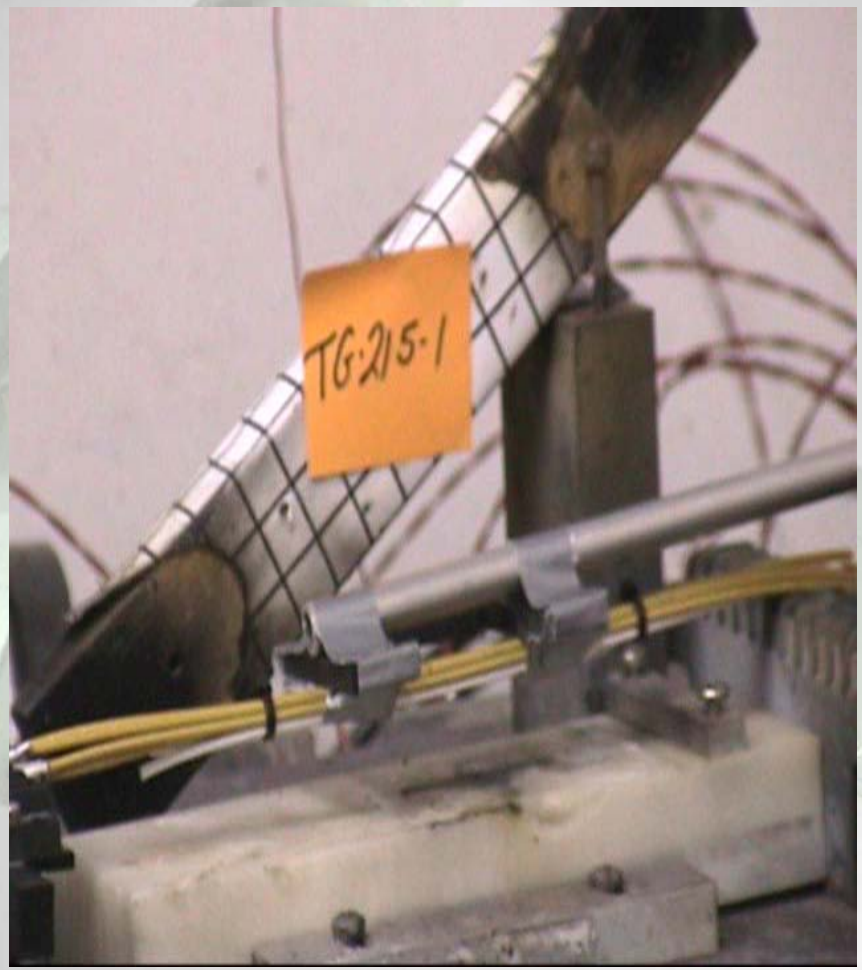
Damage at a Distance with Wet Initiation Method



Lectromec

Experiment

- 250 Amp Fault Current, 115VAC
- Polyimide Wire
- 14AWG
- 20Amp Thermal Circuit Breaker
- Separation distance: 0.385”



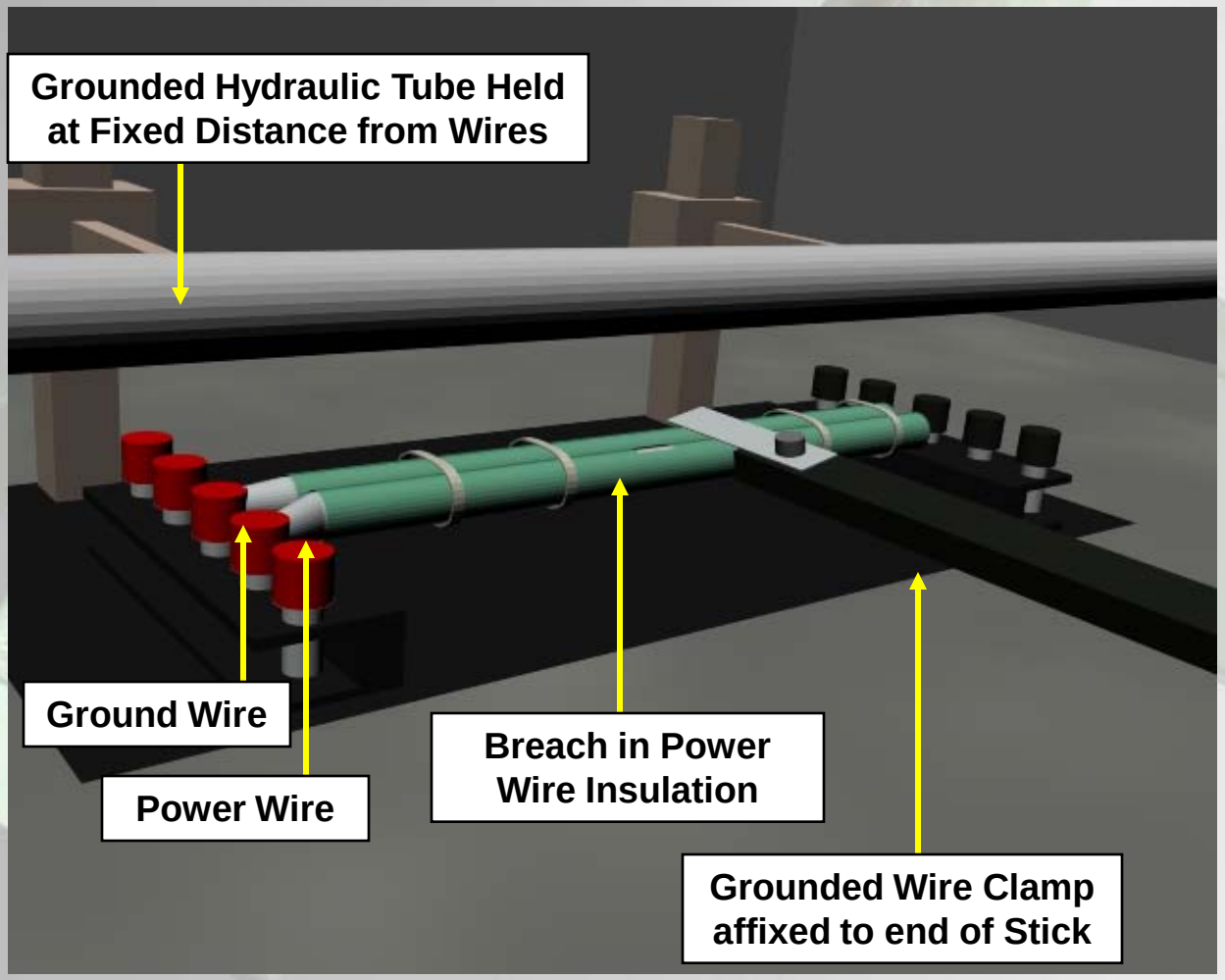
Lectromec

Results of Experiment

- Electrical Energy Transfer to Tube:
- 743 Joules [Top Pic] Extensive damage to the tube.
- [Bottom Pic] Damage to both active and passive wires (breach of passive wires)
- Scale 1mm x 1mm.

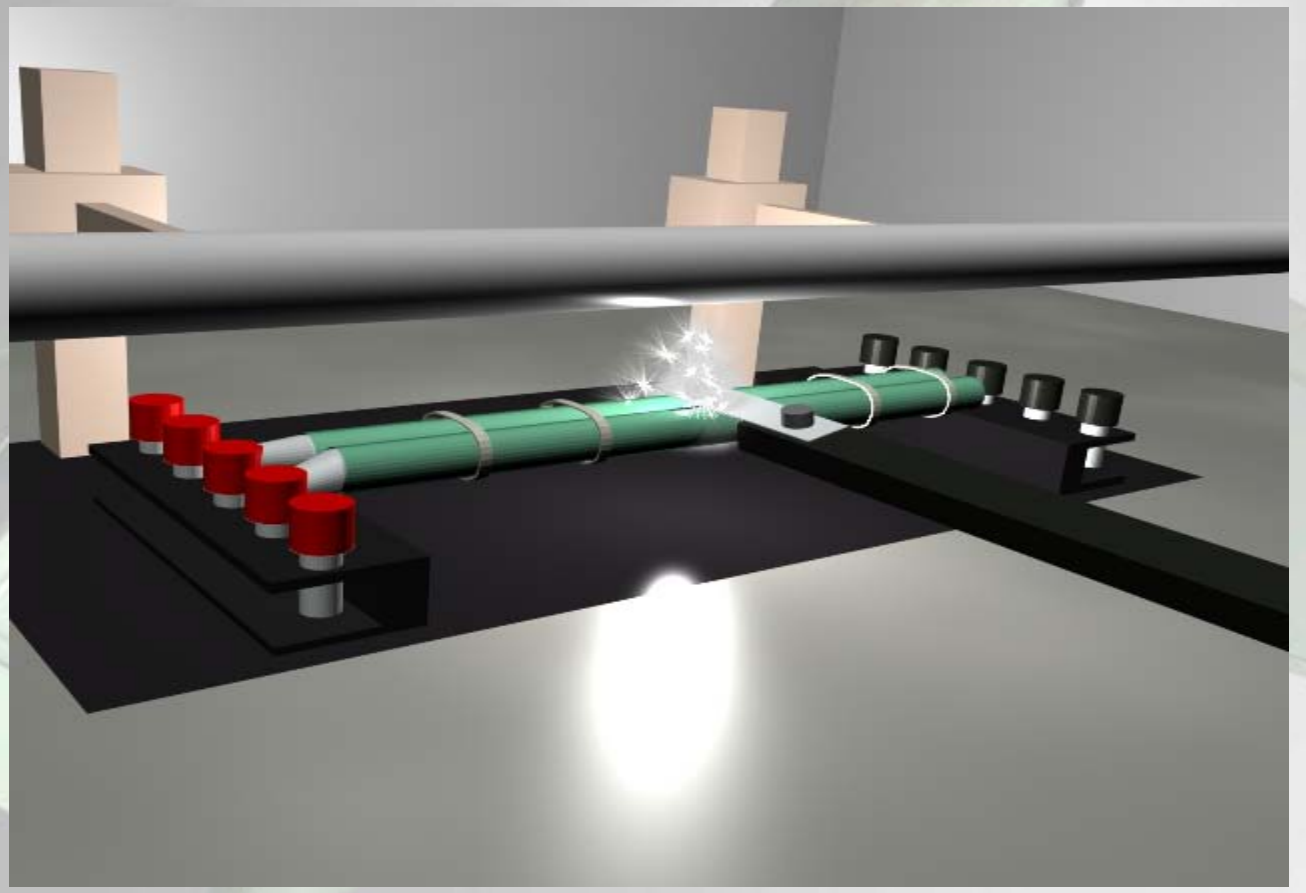
Lectromec

Damage at a Distance with Dry Initiation Method



Lectromec

Damage at a Distance with Dry Initiation Method



Lectromec

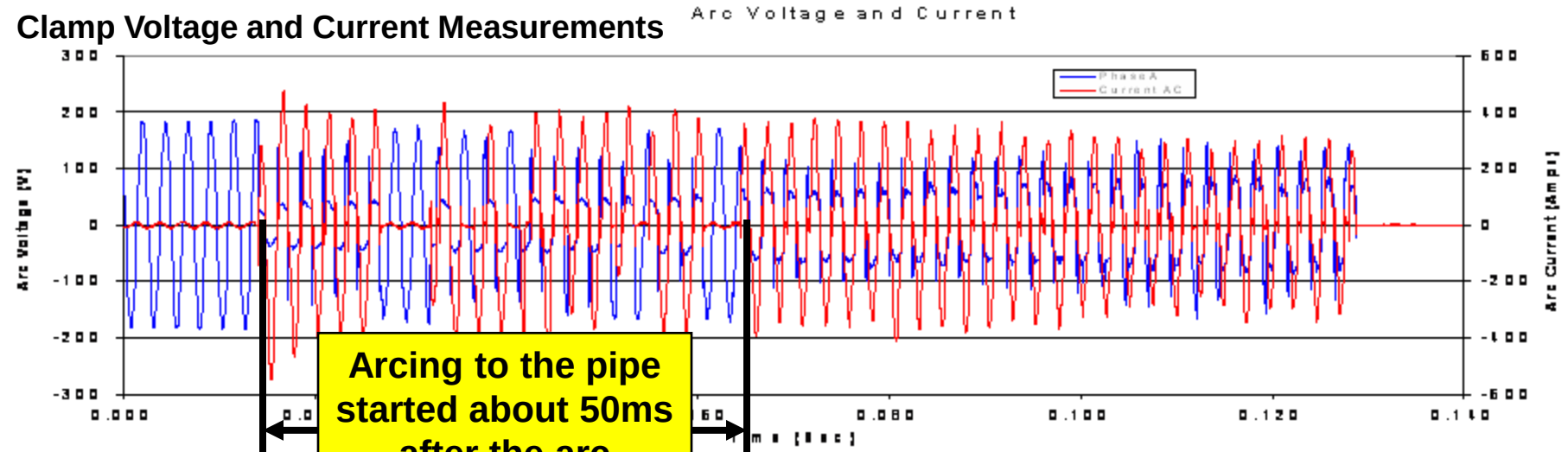
Experiment

- 500 Amp Fault Current
- Polyimide Wire
- 14AWG
- 15Amp Thermal Circuit Breaker
- Separation distance: 0.5”

Lectromec

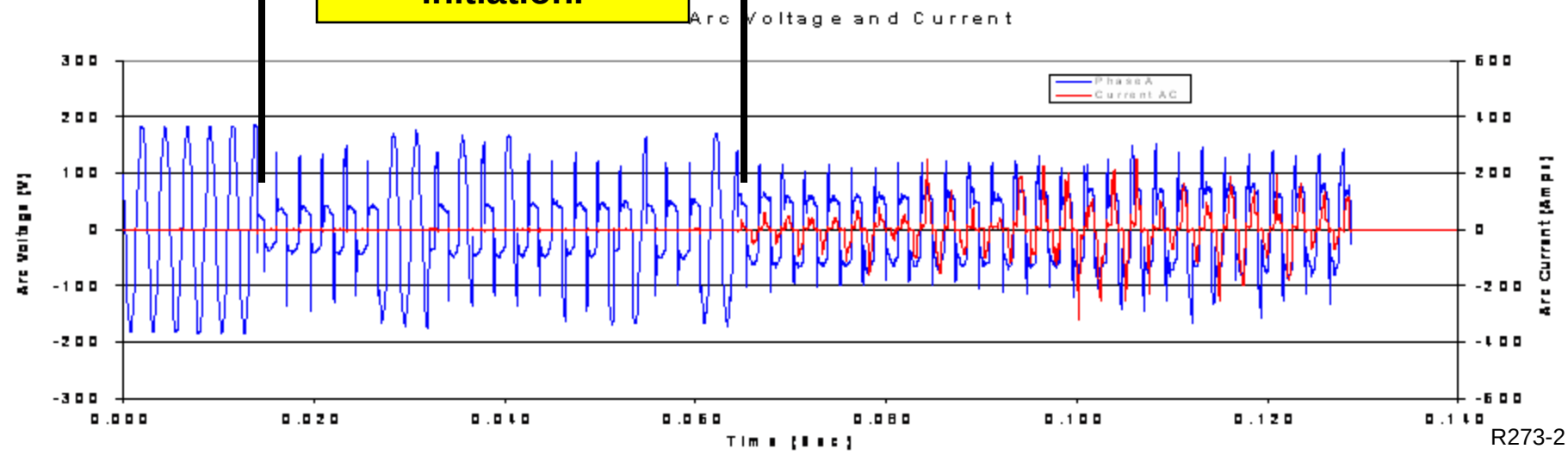
Results of Experiment

Clamp Voltage and Current Measurements



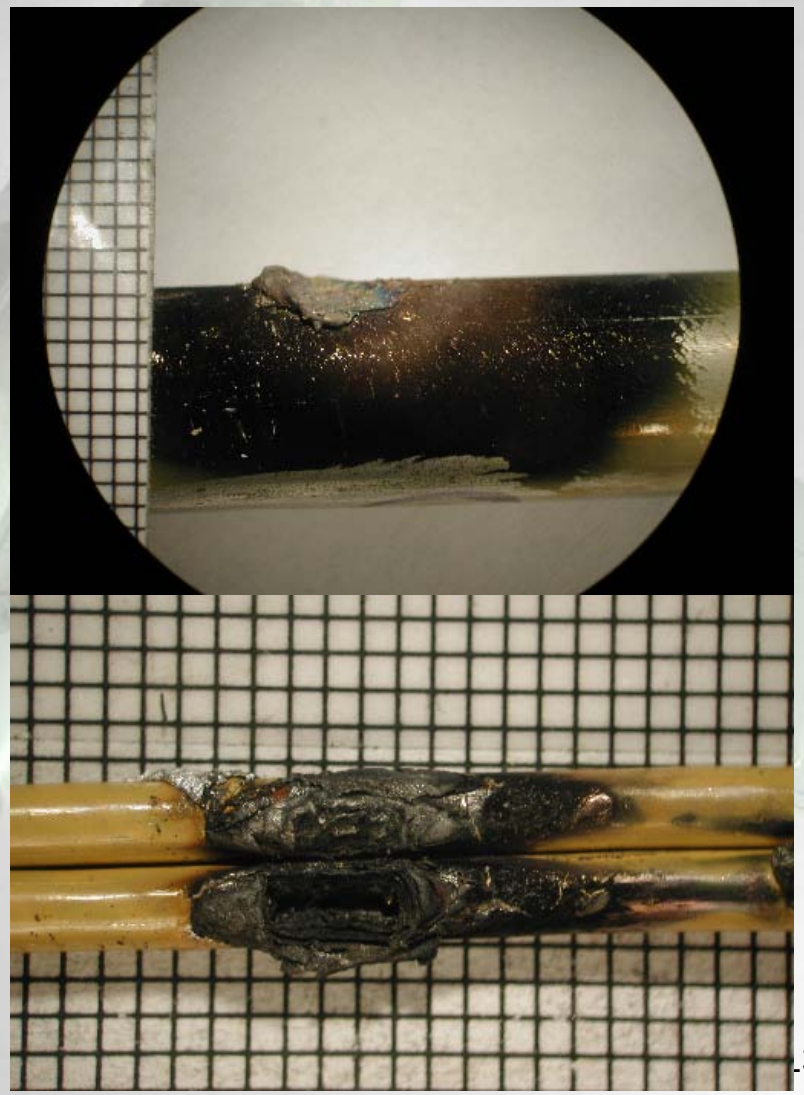
Arcing to the pipe started about 50ms after the arc initiation.

Pipe Voltage and Cu



Results of Experiment (cont.)

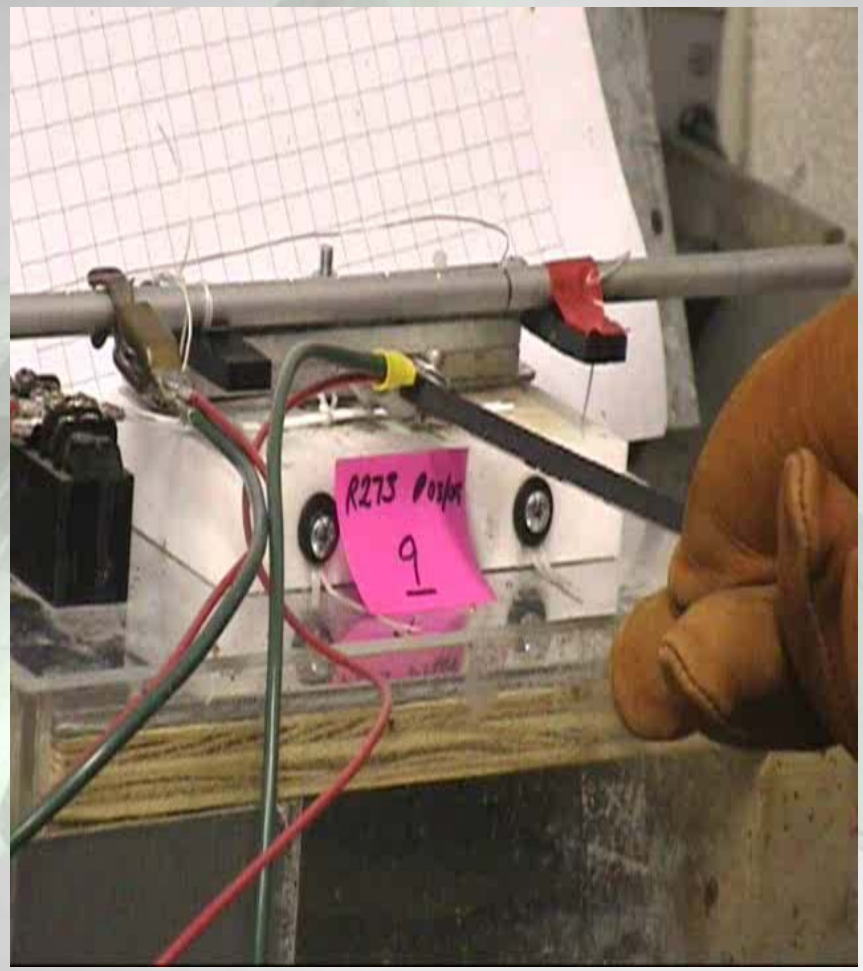
- Electrical Energy Transfer to Tube: 362 Joules
- [Top Pic] Extensive damage to the tube (6mm x 6mm damage area). No tube penetration.
- [Bottom Pic] Some damage to the passive wire, but no breach to conductor.
- Scale 1mm x 1mm.



Lectromec

Experiment using TKT insulated wire

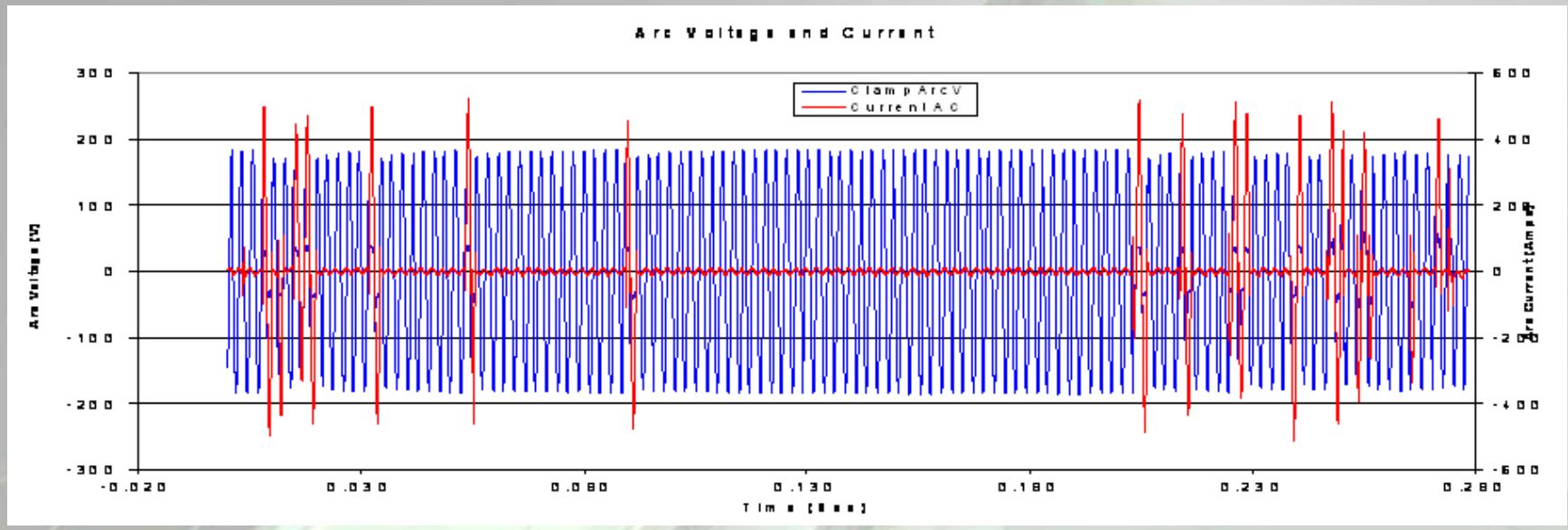
- 500 Amp Fault Current
- TKT Wire
- 16AWG
- 15Amp Thermal Circuit Breaker
- Separation distance: 0.5”



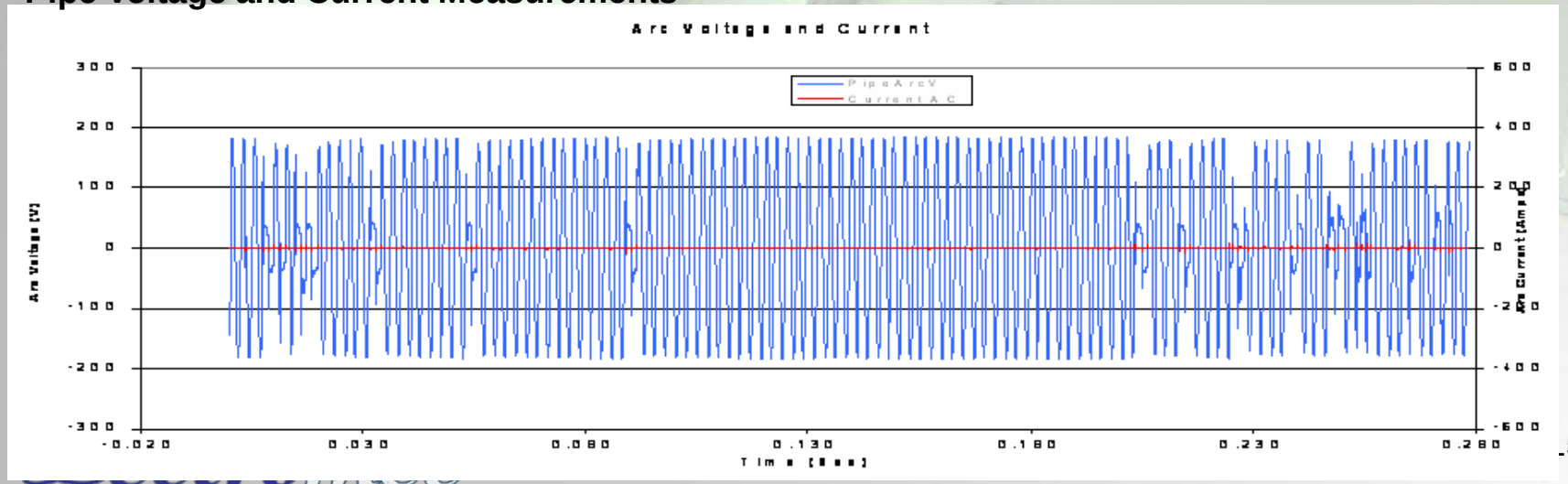
Lectromec

Results of Experiment

Clamp Voltage and Current Measurements

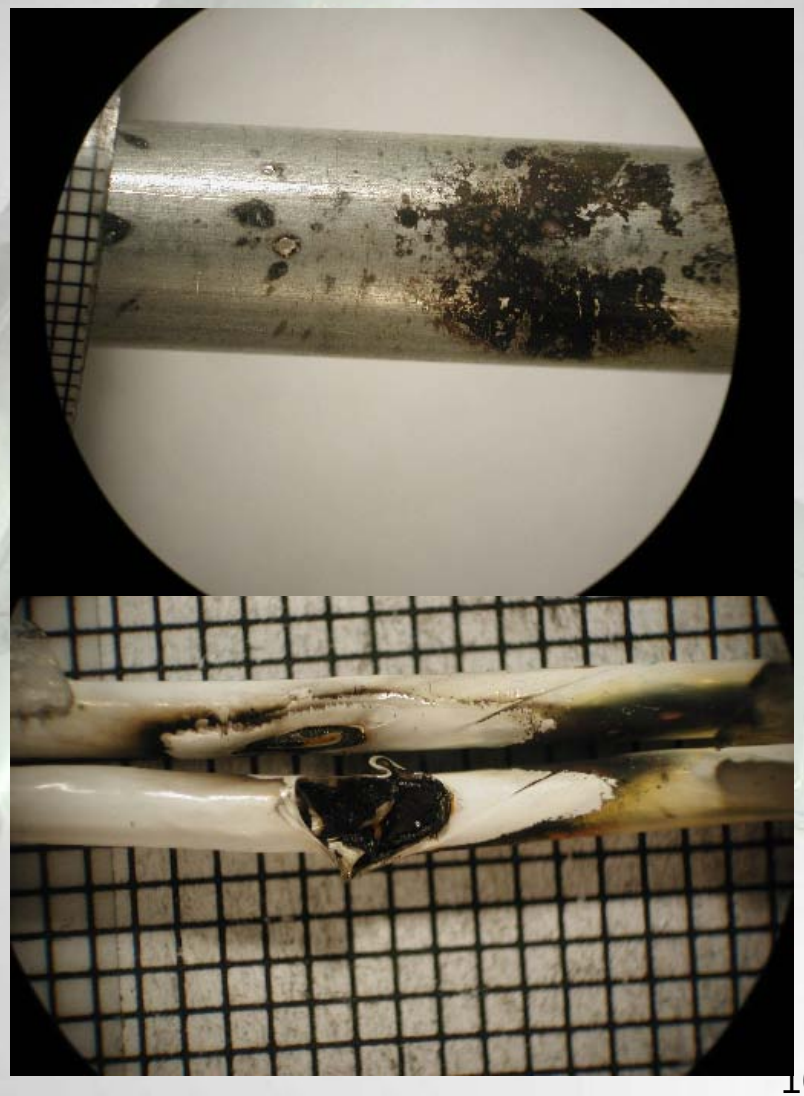


Pipe Voltage and Current Measurements



Results of Experiment (cont.)

- Electrical Energy Transfer to Tube: 0.0 Joules
- [Top Pic] Wide damage pattern will only minor scaring.
- [Bottom Pic] Breach of top layer of Teflon, but no damage to other layers.
- Scale 1mm x 1mm.

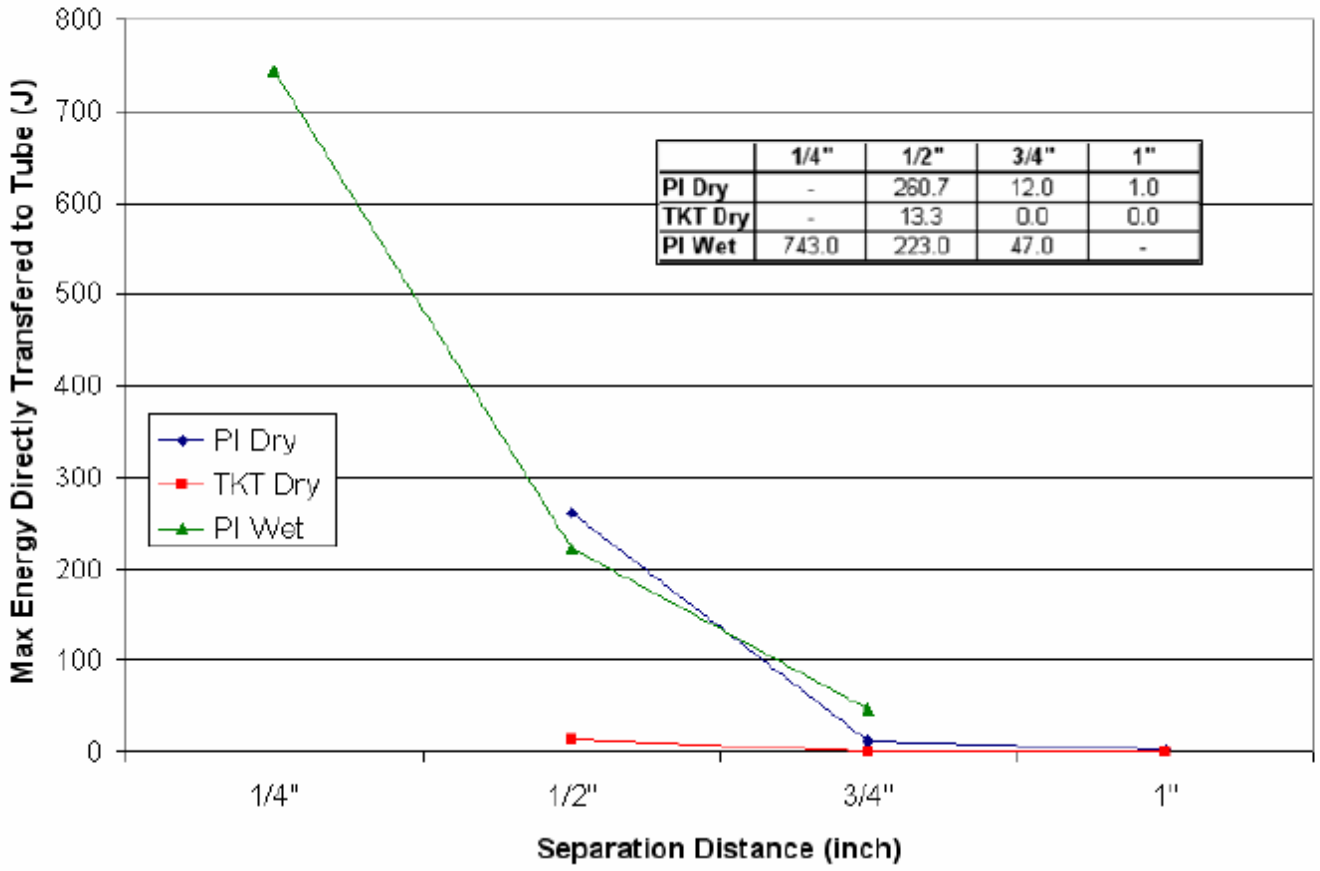


Lectromec

Test Set-Up						Arc Details			Tube Damage			
Test #	Initiation Method	Target Distance (inch)	Active Wire	Fault Current (A)	Circuit Protection	CB trip (y/n)	# Arcing 1/2 Cycles	Arcing - Energy Dissipated (J)	Damage Qualitative	Energy to Tube (J)	# of 1/2 Cycles before Arcing to Tube	Peak Current to the Pipe (A)
1	Dry - Clamp	0.5	PI-14	250	15 A	Y	463	1375	Moderate	260.7	42	150
2	Dry - Clamp	0.5	PI-14	250	15 A	N	171	901	Slight	147.4	60	145
3	Dry - Clamp	0.5	PI-14	500	15 A	N	86	934	Heavy	190	32	312
4	Dry - Clamp	0.5	PI-14	500	15 A	Y	93	857	Slight	28.2	25	151
5	Dry - Clamp	0.5	PI-14	500	20 A	Y	121	1312	Slight	49.8	25	100
6	Dry - Clamp	0.5	TKT-16	250	15 A	N	23	81	None	0		
7	Dry - Clamp	0.5	TKT-16	250	15 A	N	98	348	None	0		
8	Dry - Clamp	0.5	TKT-16	500	15 A	N	31	264	None	0		
9	Dry - Clamp	0.5	TKT-16	500	15 A	N	46	420	Slight	13.2	13	323
10	Dry - Clamp	0.75	PI-14	250	15 A	N	280	1442	None	0.8	108	19
11	Dry - Clamp	0.75	PI-14	250	15 A	N	357	1844	None	0.4	107	16.4
12	Dry - Clamp	0.75	PI-14	500	15 A	N	52	547	Slight	12	22	270
13	Dry - Clamp	0.75	PI-14	500	15 A	Y	69	735	Slight	0.6	24	22
14	Dry - Clamp	0.75	TKT-16	250	15 A	N	36	145	None	0		
15	Dry - Clamp	0.75	TKT-16	250	15 A	N	15	53	None	0		
16	Dry - Clamp	0.75	TKT-16	500	15 A	N	35	348	None	0		
17	Dry - Clamp	0.75	TKT-16	500	15 A	N	8	80	None	0		
18	Dry - Clamp	1	PI-14	500	15 A	Y	96	1049	None	1	54	47
19	Dry - Clamp	1	PI-14	500	15 A	Y	45	520	Slight	0.1		
20	Dry - Clamp	1	TKT-16	250	15 A	N	45	152	None	0		
21	Dry - Clamp	1	TKT-16	500	15 A	N	25	229	None	0		
22	Dry - Clamp	1	TKT-16	500	15 A	N	26	239	None	0		
23	Wet	0.25	PI-14	250	20A	Y	778	4475	Penetration	743	9	189
24	Wet	0.5	PI-14	250	20A	Y	826	4701	Penetration	223	27	133
25	Wet	0.75	PI-14	250	20A	Y	875	5579	Slight	47	32	46

Lectromec

Direct Transfer of Energy for Different Separation Distances and Insulation Types



	1/4"	1/2"	3/4"	1"
PI Dry	-	260.7	12.0	1.0
TKT Dry	-	13.3	0.0	0.0
PI Wet	743.0	223.0	47.0	-

Lectromec

Conclusions

- For Polyimide wire in which arcing has been initiated it is possible to have repeated ½ cycles of arcing across a 3/8” or ½” gap and transfer significant energy.
- When the gap is increased to ¾” or 1” the likelihood of bridging the gap is reduced, normally arcing is non-continuous, and the current and energy transferred is reduced
- For TKT wire arcing is sporadic limiting the arc plume therefore reducing the probability of direct arcing at a ½” and greater.

Lectromec

Lectromec History

- Technology and Engineering firm
  - Specializing in aircraft wiring testing, wire management services, research and design.
  - Lectromec's laboratory is equipped to test and analyze electrical systems of various types for a variety of industries.
  - Particular attention to Lectromec's forté is understanding the electrical and physical properties of wiring insulation and the ill effects of damaged wiring.
  - Facilities include: A Wet / Dry Arc Track Station, Machine Shop, Chemistry Lab, Wire Storage Room, Accelerated Aging Test Apparatus, Polyimide Database, Hi-Pot Station, DelTest™ Station, Humidity Chambers, a Technical Library and a Graphics / Art Station.

Lectromec