PCIC EUROPE
PETROLEUM & CHEMICAL INDUSTRY COMMITTEE

18th PCIC Europe Annual Electrical and Automation Knowledge Sharing Event
www.pcic-europe.com

7-9 June 2022 - London, UK

EUR22_35
How Medium Voltage Cables Fail – Fundamentals to Ensure Long Cable Life

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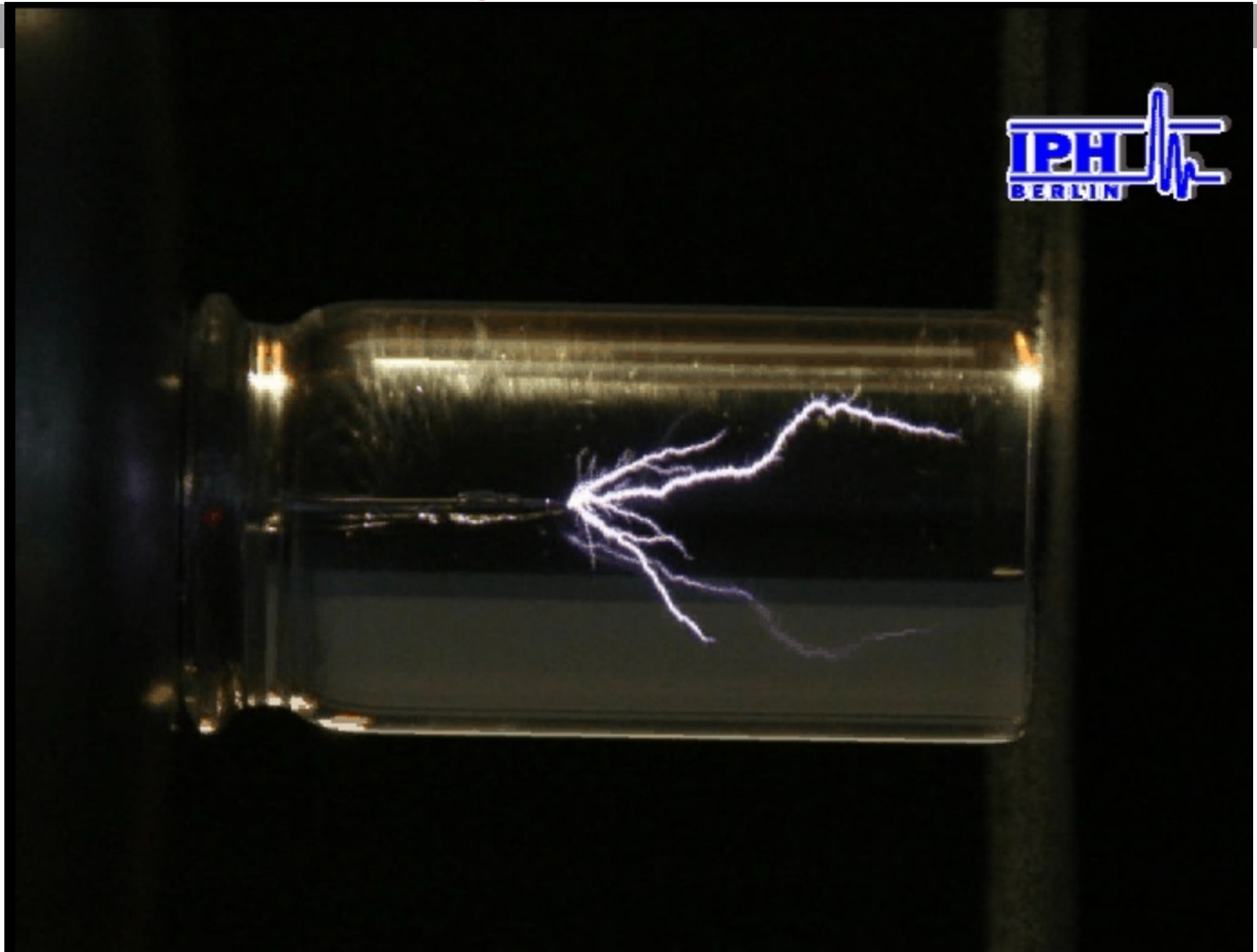
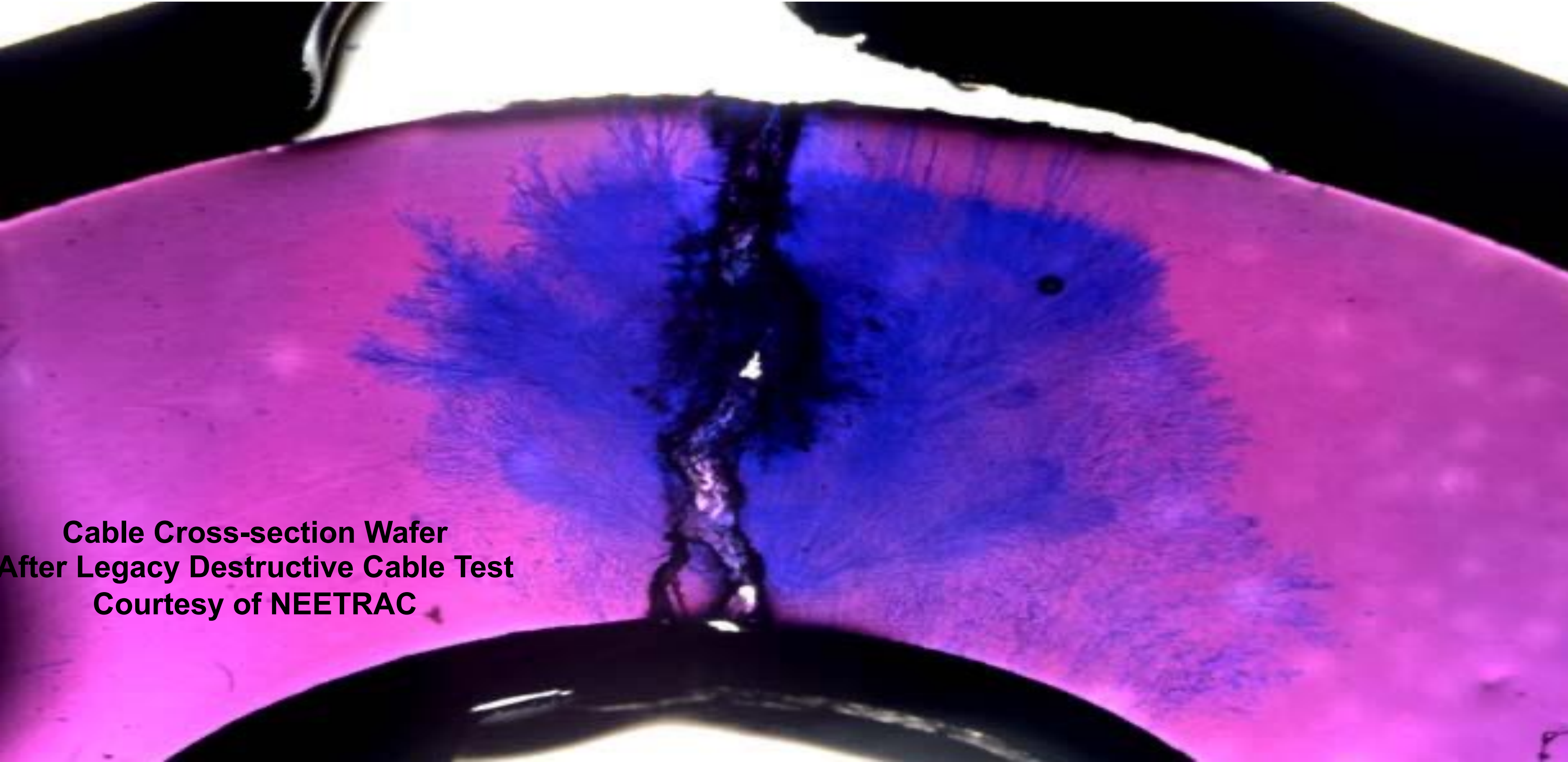
Video of Partial Discharge in Silicon

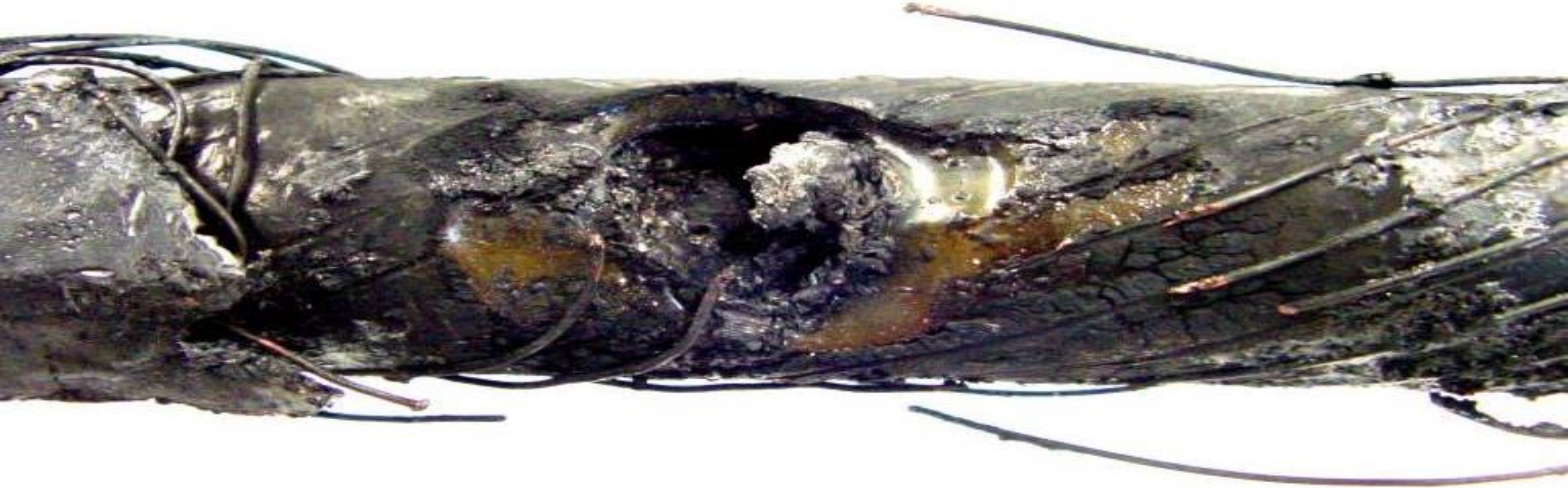


Cable Failure in Laboratory – Cross Section



PD Tracking on Cable Insulation

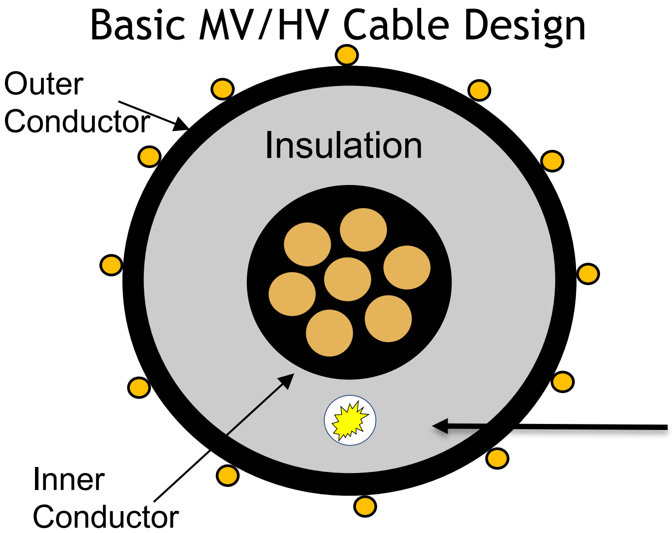
Cable Failure



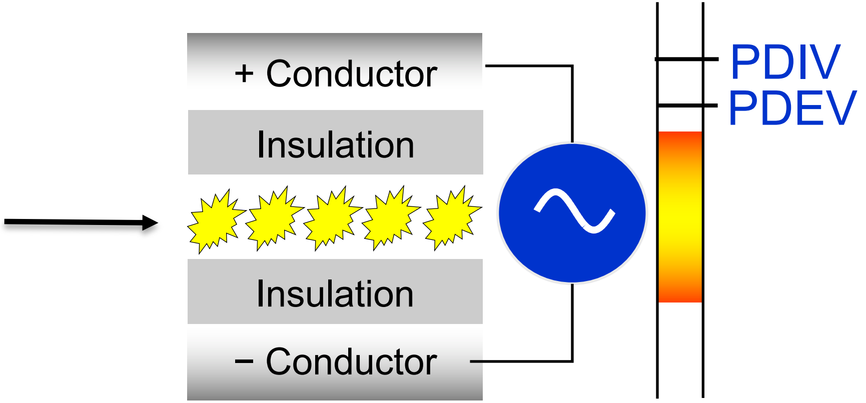
Courtesy of General Cable

Cable Failure in a Joint

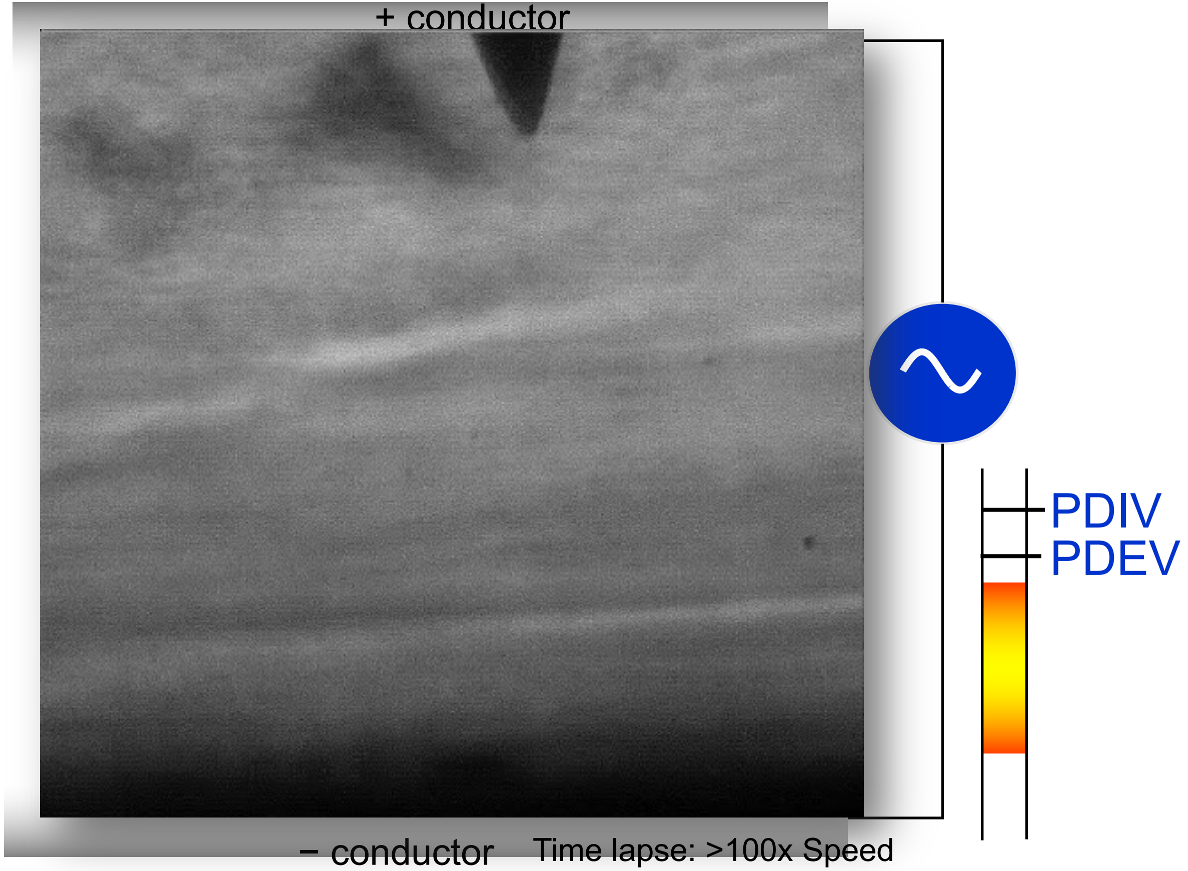
Theory of Partial Discharges in Cables



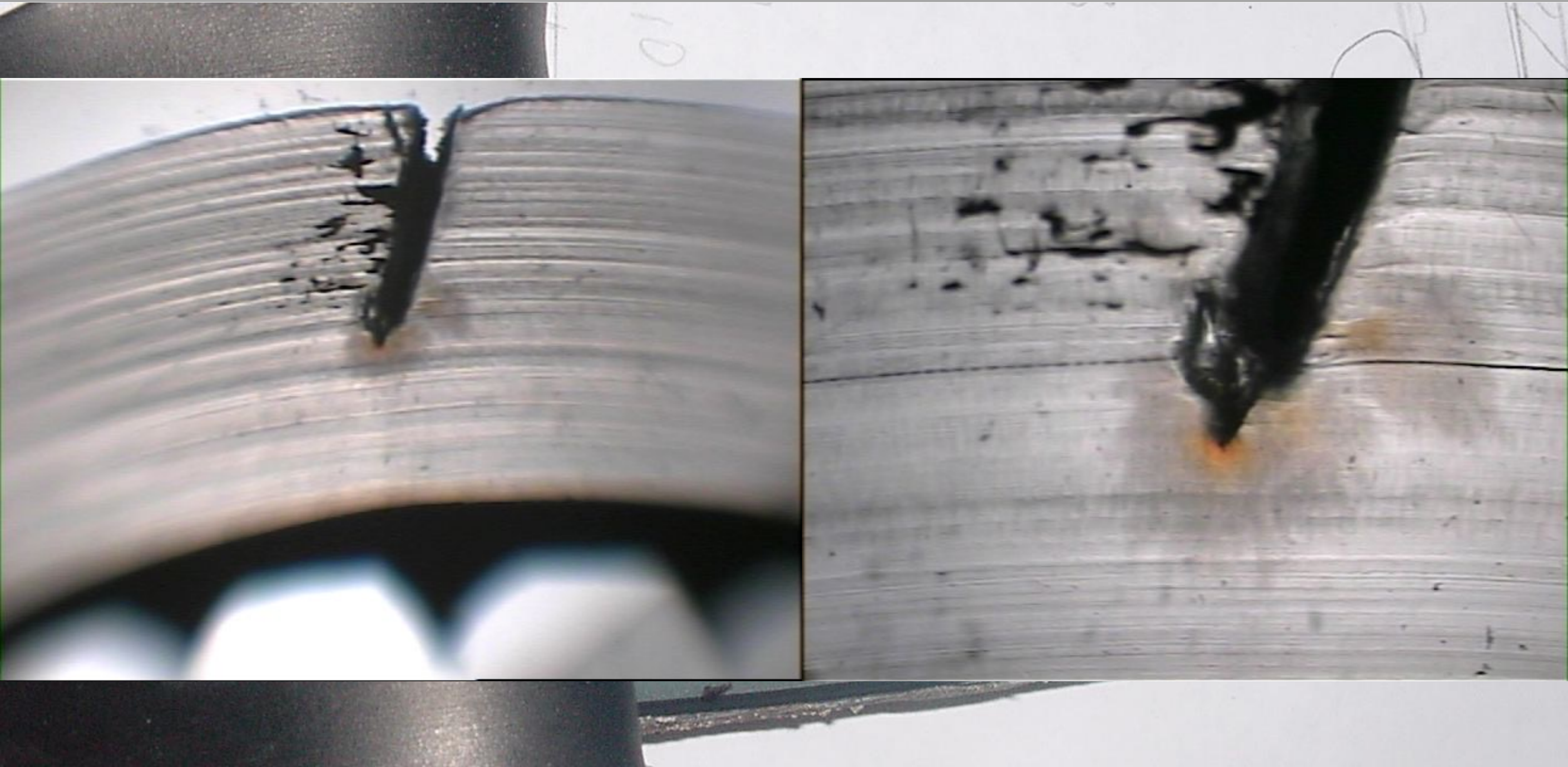
Gap (air/gas) "Void"



Insulation PD on Accessory



Cut in Cable Insulation – with signs of water tree and PD



Less than ‘turn on’ voltage

‘Turn on’ exceeded

Significant voltage surge

Switching surge with proper protection

Switching surge with insufficient protection

IMCORP HV Laboratory Manchester, CT USA

Installation in the Field

10 Root Causes for Cable Failure

- Foreign Objects
- Non-Radial Cutbacks
- Contaminants
- Water Trees

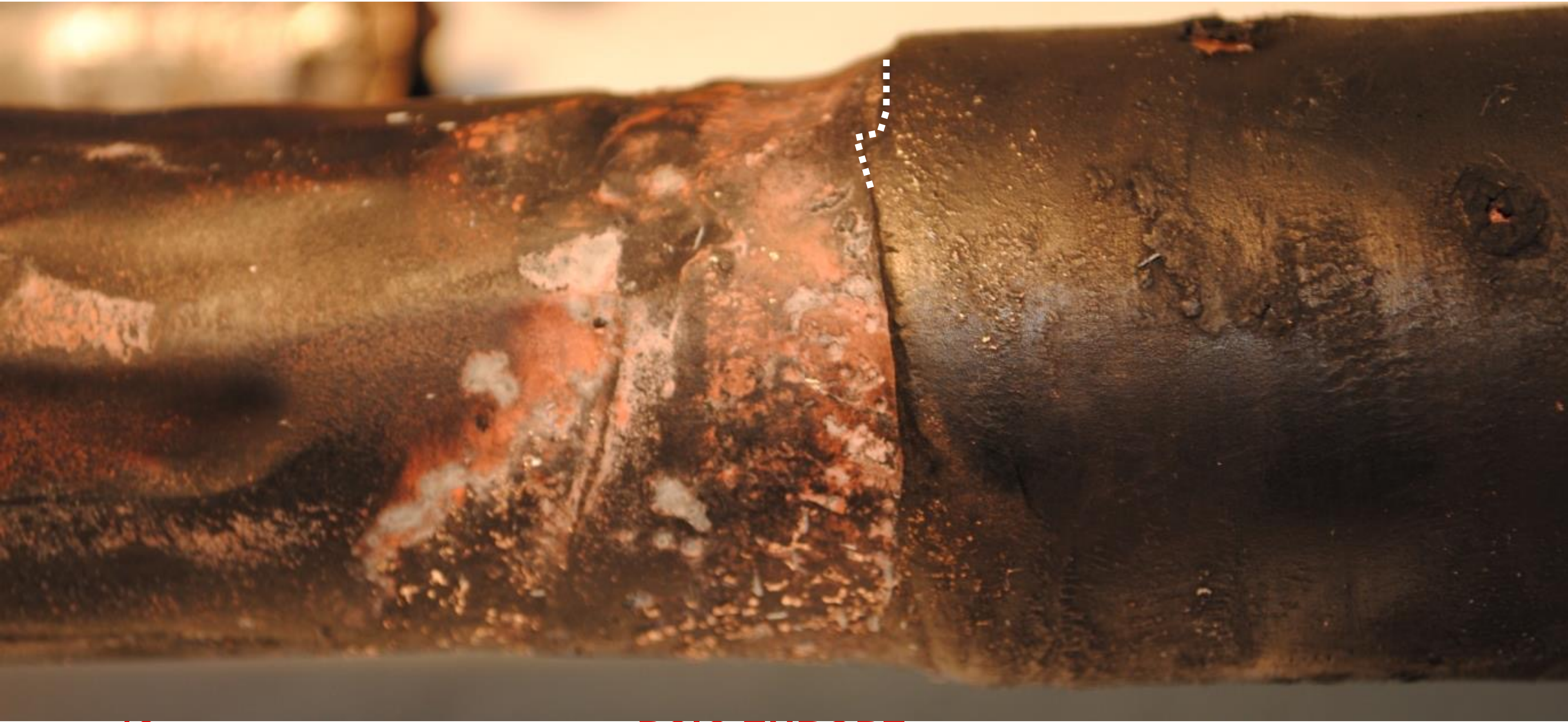
→ Stress Enhancement

- Insulation Voids
- Chem. / Semicon Damage
- Overheating
- Insulation cuts
- Insufficient Void Filler
- Incorrect Dimensions

→ Voids

Stress Enhancement, Voids → PD / Electrical Tree — Cable System Failure

Cable Failure – due to installation error

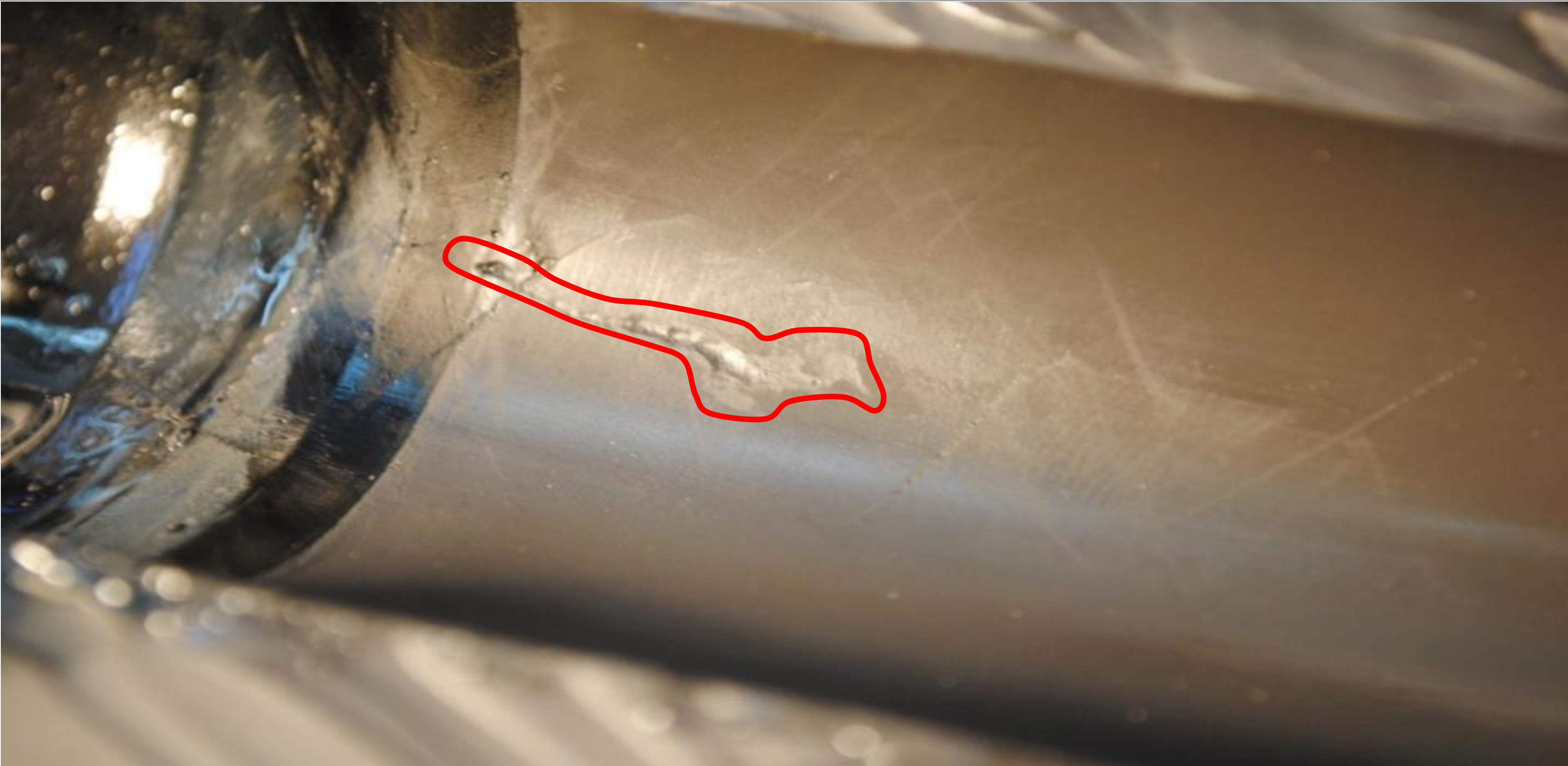


Installation Error on Semicon cutback

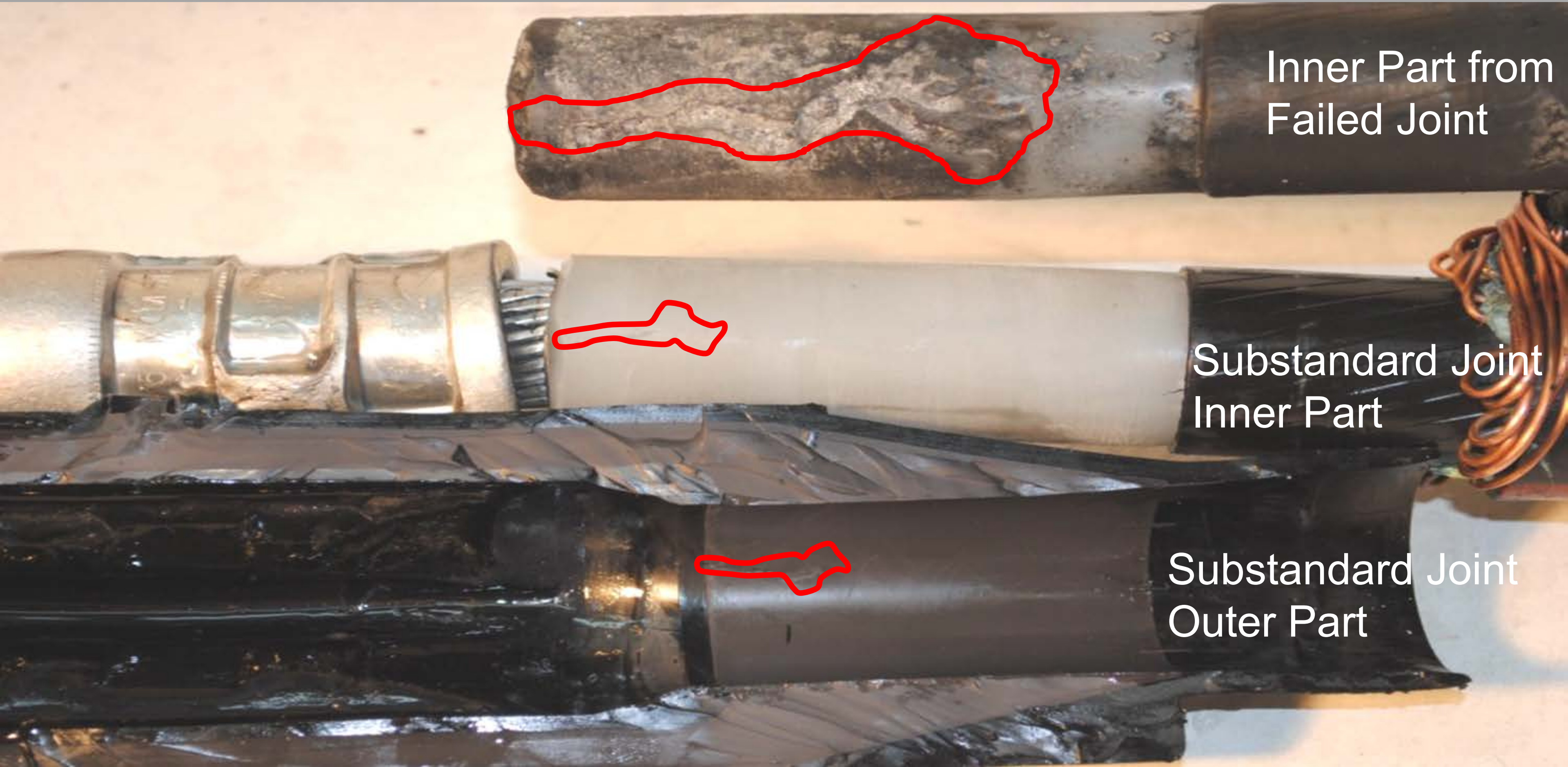
Cable Damage caused by Installation Error

PD Tracking caused by Installation Error

Installation Error > 2 years old

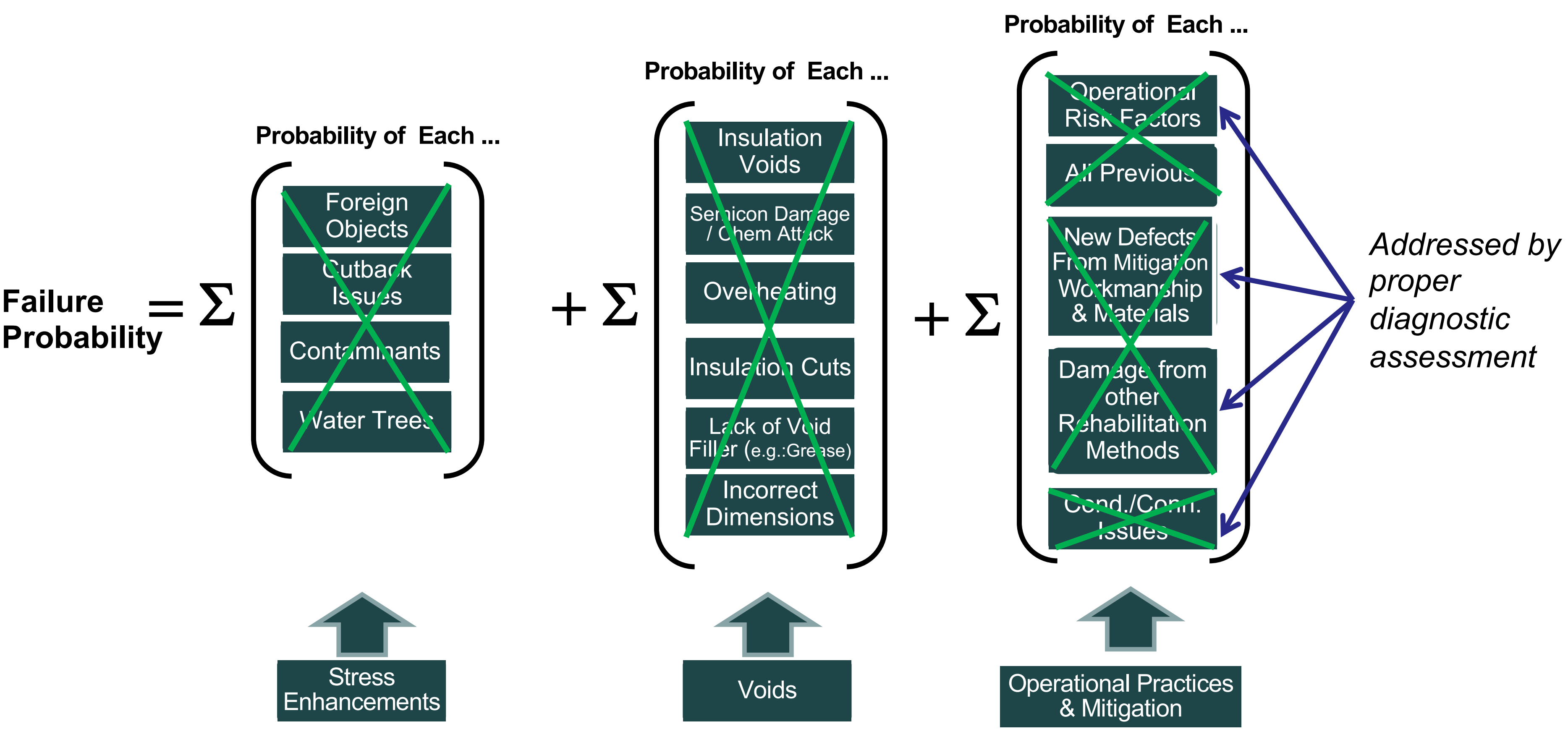


Installation Error > 2 years old



Installation Error on Cable End Termination

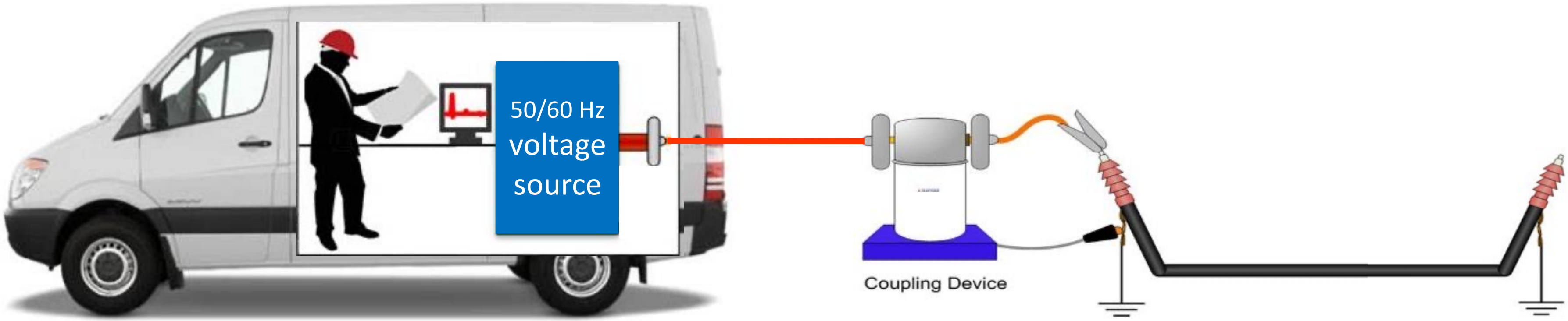
Reasons for Cables to fail



Cable & Accessory International Standards

	Factory QC Standard	Test Frequency	Test Sensitivity	Threshold (for 50/60 Hz)
Terminations	IEC 60502-4 IEEE 48	50/60 Hz 50/60 Hz	≤ 10 pC ≤ 5 pC	U ≤ 1.73 Uo U ≤ 1.5 Uo
Joints	IEC 60502-4 IEEE 404	50/60 Hz 50/60 Hz	≤ 10 pC ≤ 5 pC	U ≤ 1.73 Uo U ≤ 1.5 Uo
Separable Connectors	IEC 60502-4 IEEE 404	50/60 Hz 50/60 Hz	≤ 10 pC ≤ 3 pC	U ≤ 1.73 Uo U ≤ 1.3 Uo
Medium Voltage Cables	IEC 60502-2 ANSIICEA S-97/94-682/649	50/60 Hz 50/60 Hz	≤ 10 pC ≤ 5 pC	U ≤ 1.73 Uo U ≤ 4.0 Uo*
High Voltage Cables **EHV Cables**	IEC 60840-4 ANSIICEA S-108-720	50/60 Hz 50/60 Hz	≤ 10 pC ≤ 5 pC	U ≤ 1.5 Uo** U ≤ 2.0 Uo

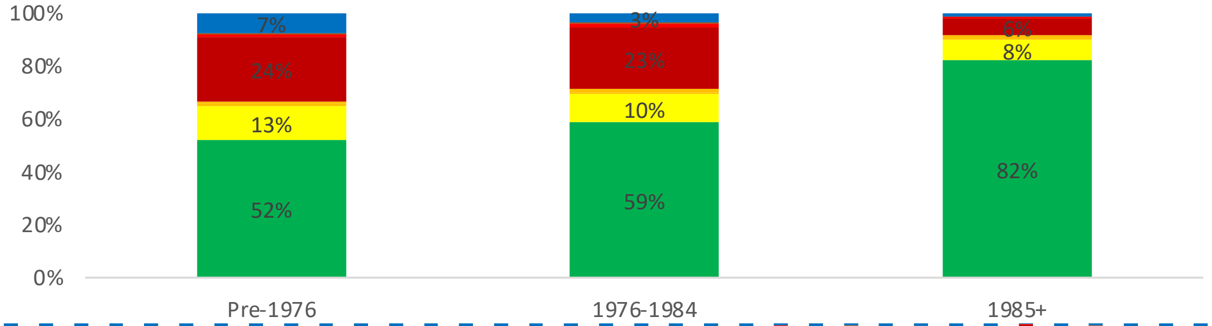
Testing Cables

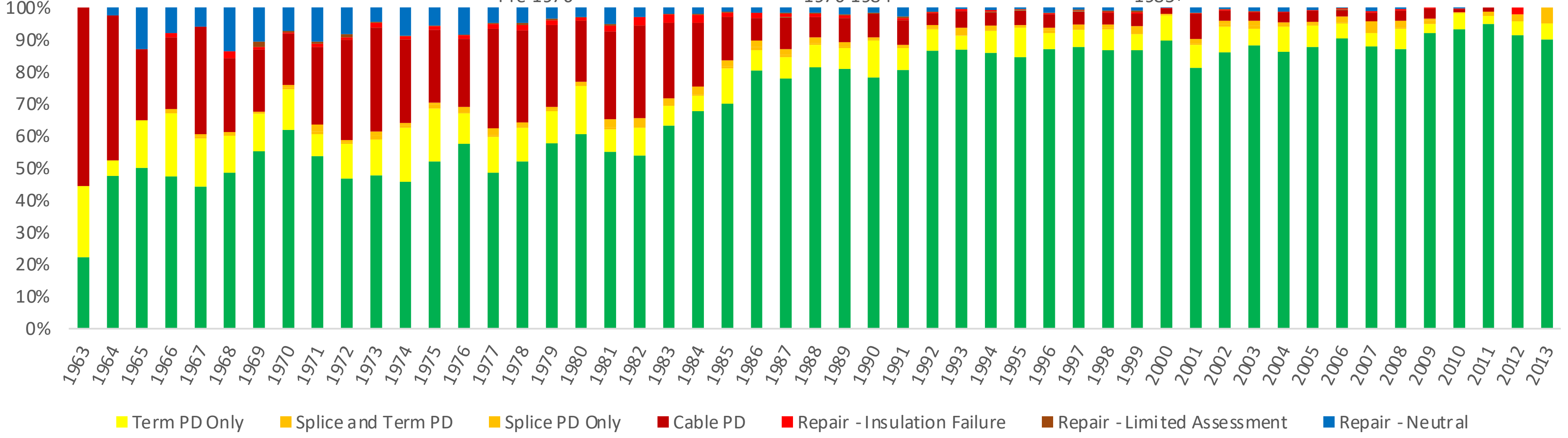


Test Van with Equipment

Cable under test

Performance by Vintage (> 52.000 km) - aged Utility Subset





Workmanship Issue on Open Air End Termination

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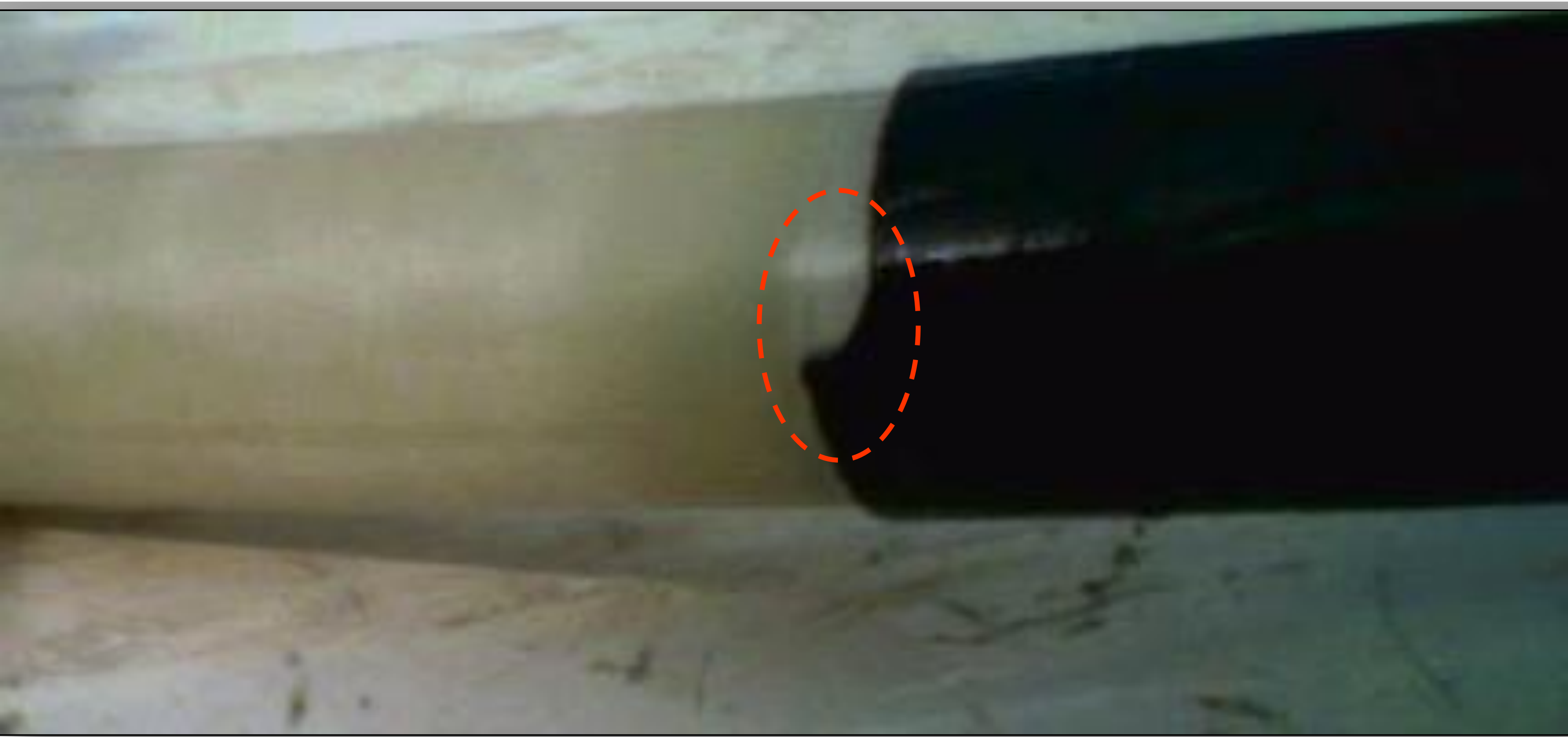
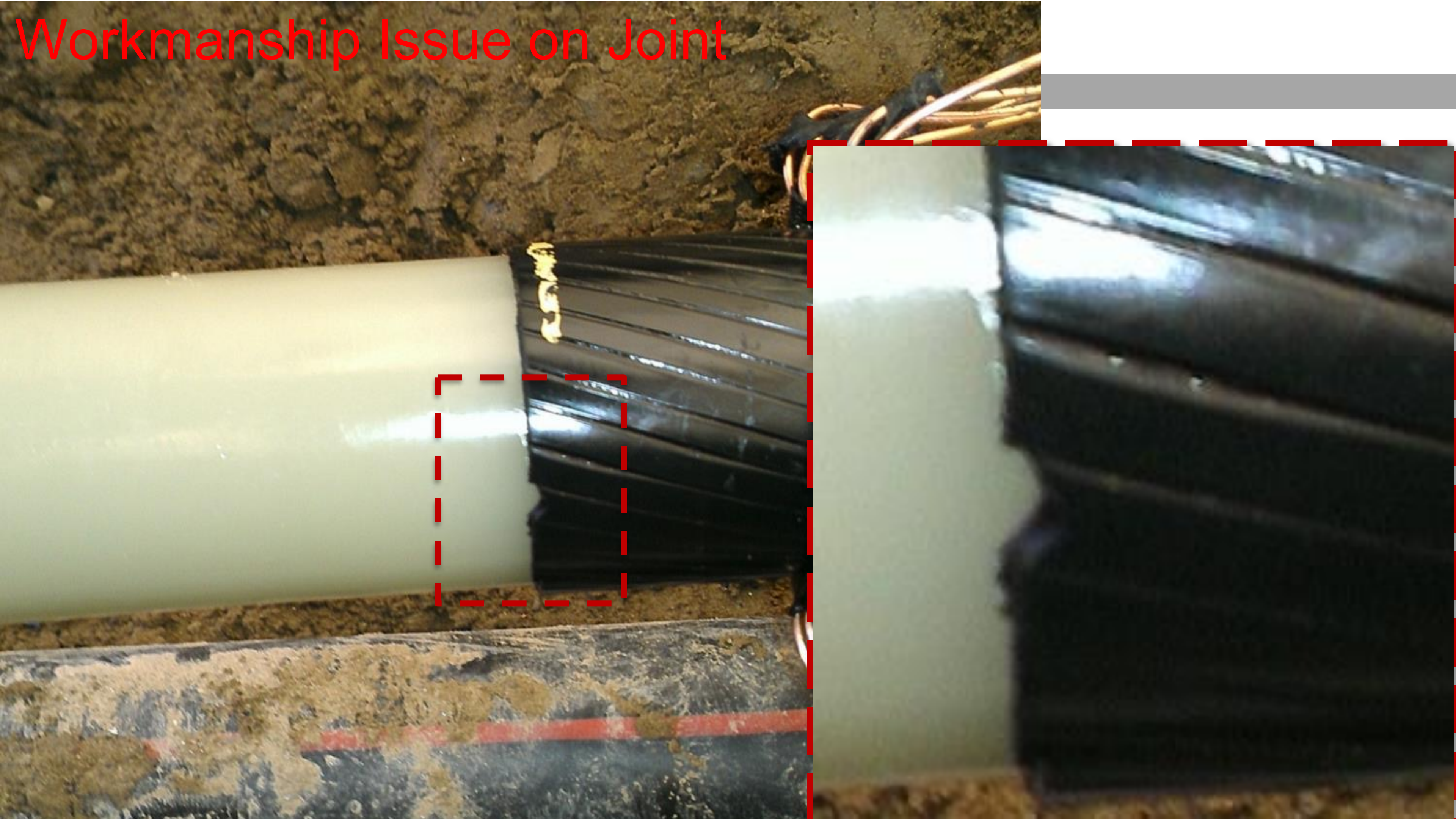


Workmanship Issue on Separable Connector

Workmanship Issue on Joint



Workmanship Issue on Joint

Workmanship Issue on Joint

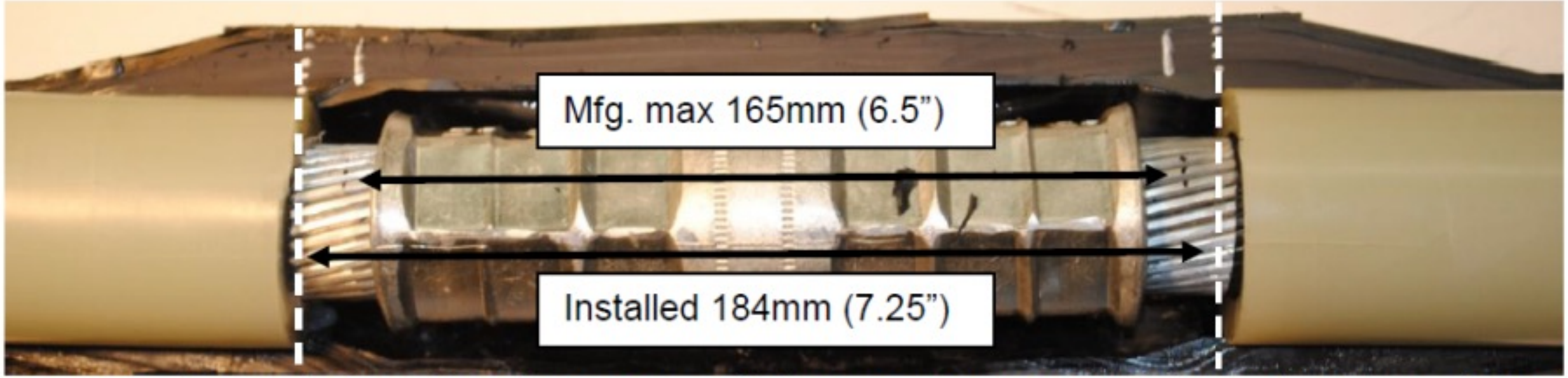


Figure 6: Insulation cutback out of specification. See attached instruction Step D1 "Check" distance that requires the joint assembly to be rebuilt if the dimension is longer than 165mm. Note: This issue was typical for all 5 dissected joints.

Conclusions

- >99% of issues are caused by improper Workmanship
- Partial Discharges (PD) is the dominant failure mode of MV cables
- Issues with Partial Discharges can be indentified with proper testing
- IEC / IEEE need to be followed for testing (sensitivity and voltage)
- Identified and located issues must be adressed
- Proper workmanship can be achieved through training and QA/QC