RELIABILITY AND DURABILITY EVALUATION OF PV CONNECTORS

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Acknowledgement:

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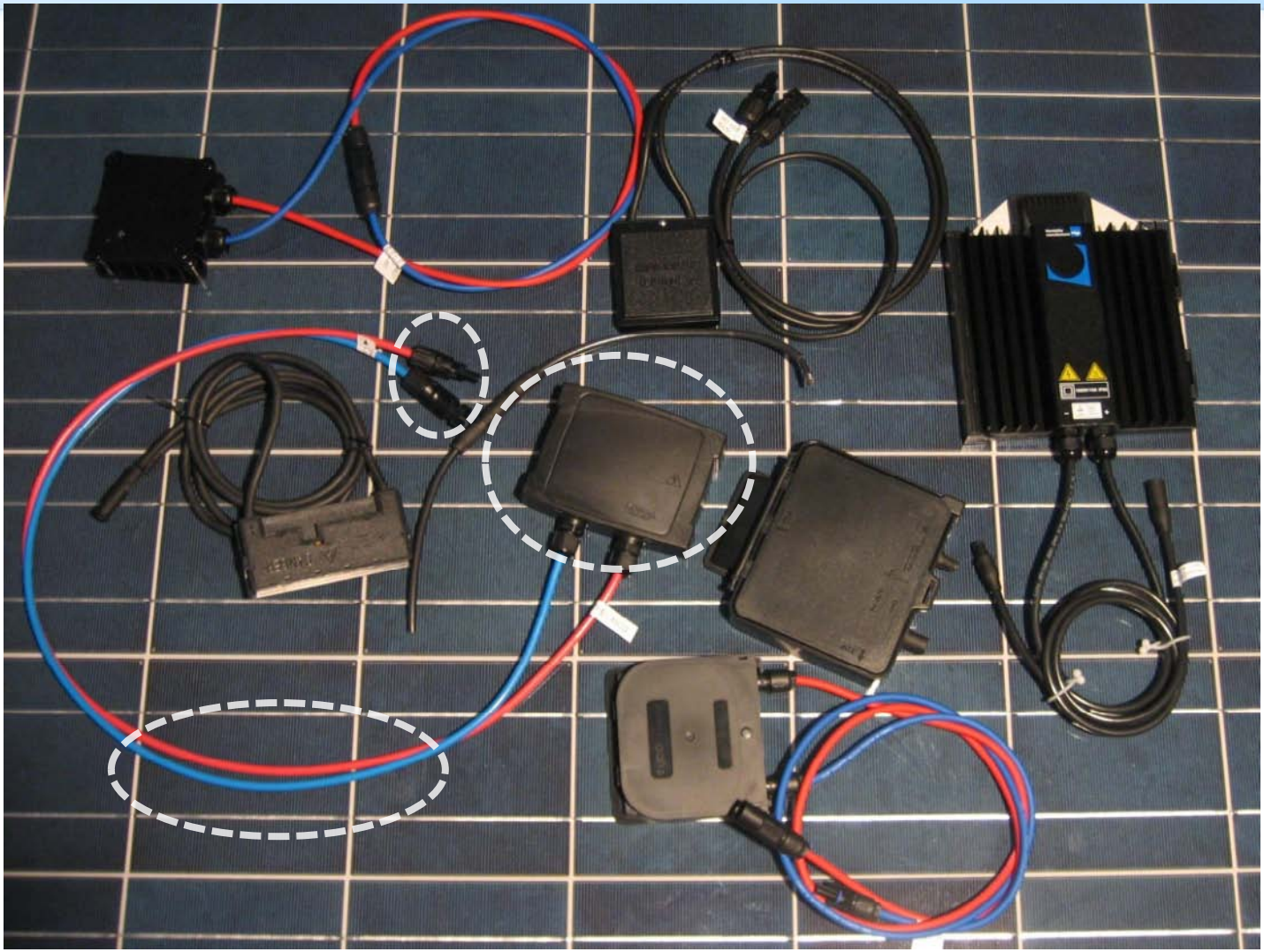
Thanks to Mr. Guido Volberg of TUV Rheinland for sharing his experience in connector testing

PV module supply chain: Polymeric components



Outline

PV Connectors

- Outdoor tests and results obtained @ ASU
  - Contact and cable resistance
- Indoor tests and results obtained @ TUV Rheinland
  - Contact resistance
- EN 50521 standard
  - A quick overview

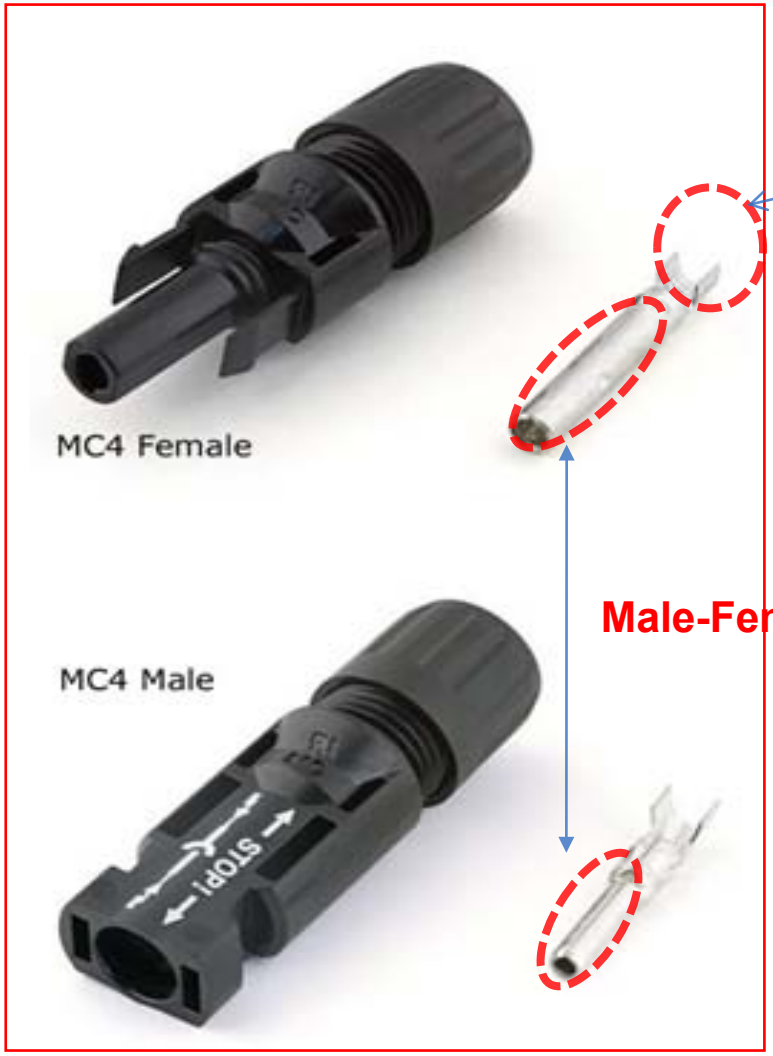
Why understanding PV connectors important

- Electrical safety
  - Arcing
  - High voltage (worse in flat roof puddles!)
- Contact resistance
  - Energy loss (kWh/kW)
  - Lifetime reduction (higher operating temperature)
  - Worse in hot-sunny location rooftops

Connector types: Plug-in & Lockable

Source: www.civicsolar.com

Contact resistance



Cable coupling

Male-Female contact

Source: www.civicsolar.com

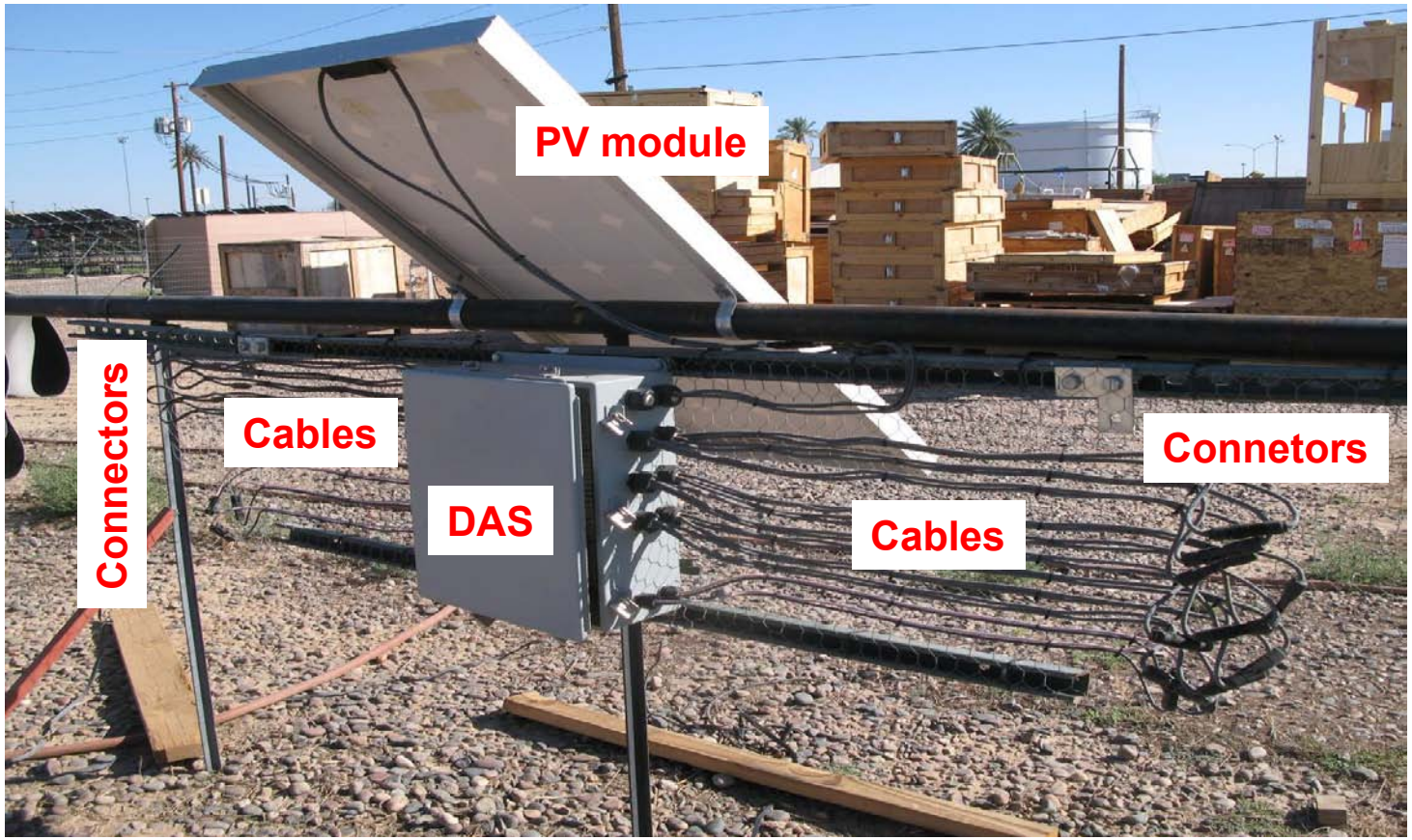
Field issues

Field issues

Outdoor connector test @ ASU

- 19 connectors tested
- 2 meter long cables used
  - 12 AWG (for 14 connectors)
  - 14 AWG (for 5 connectors)
- 3 manufacturers
- 4 connector types
  - 1 plug-in
  - 3 lockable
- 1 PV module
- Outdoor exposure started in Nov. 2005 and the initial resistance measured
- Outdoor exposure continued and the second time resistance measured in Jun. 2006
- Outdoor exposure continued and every 6 min resistance monitoring started in Dec. 2008

Outdoor connector test setup @ ASU



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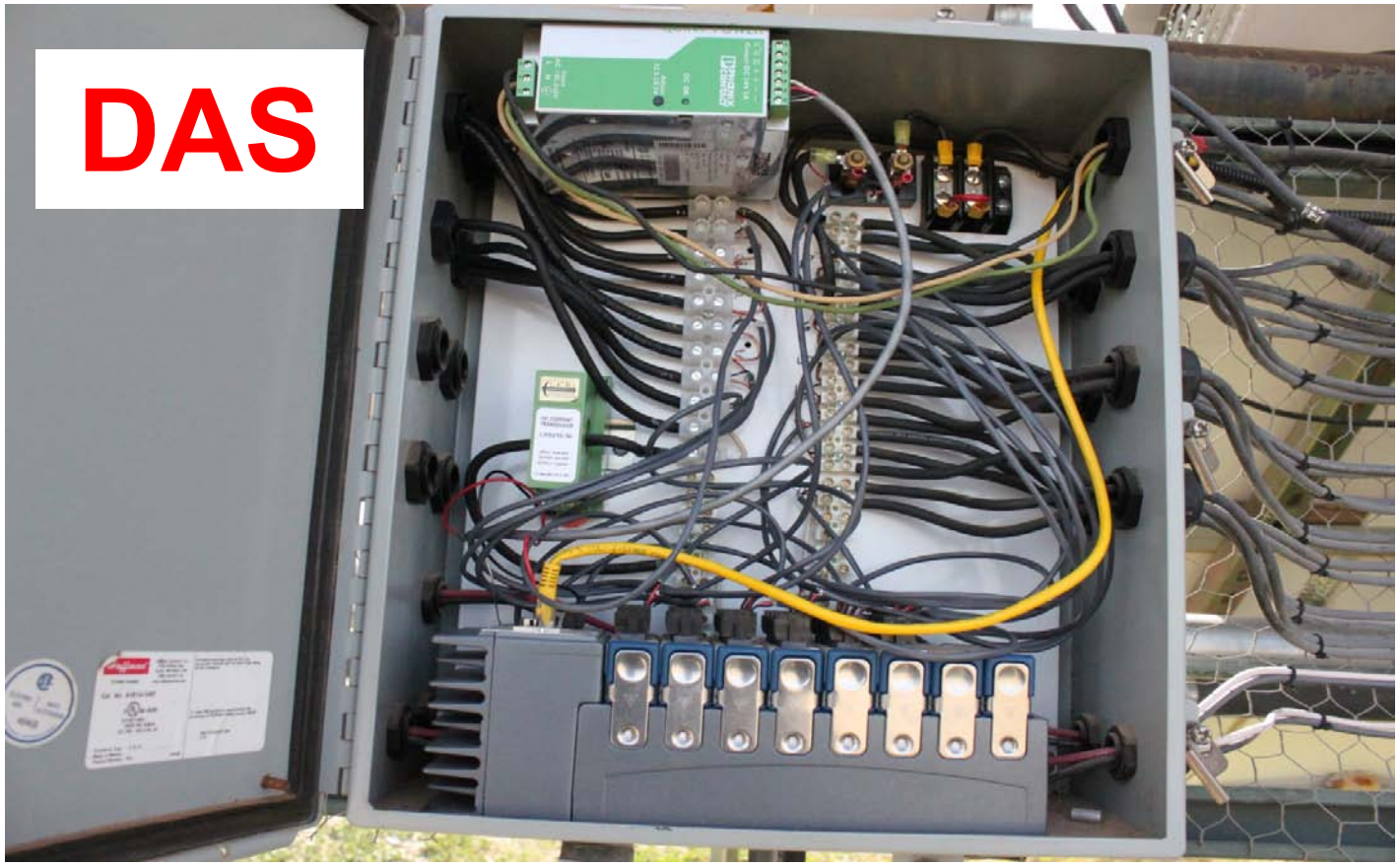
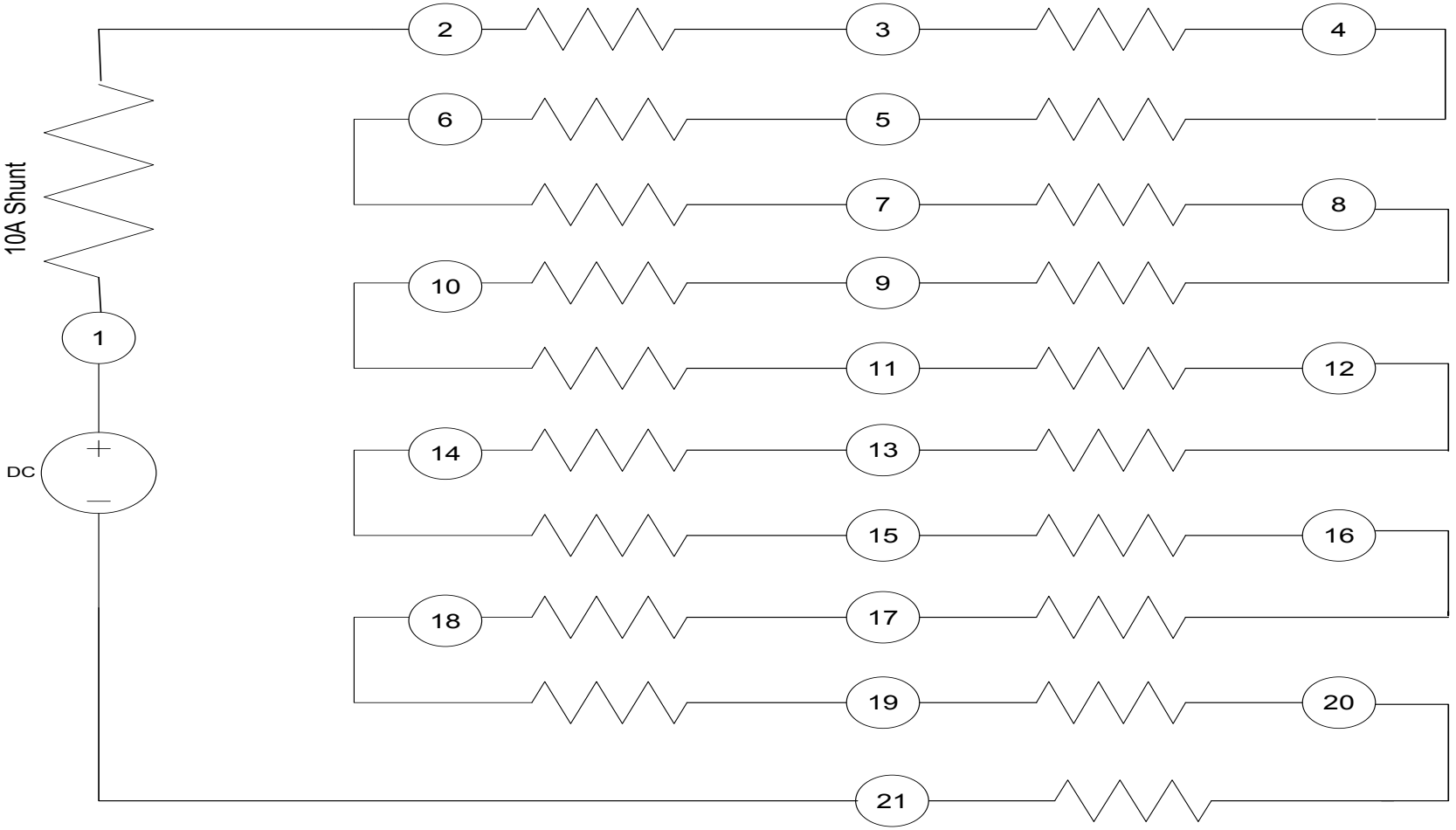
Outdoor connector test setup @ ASU



Outdoor connector test setup @ ASU



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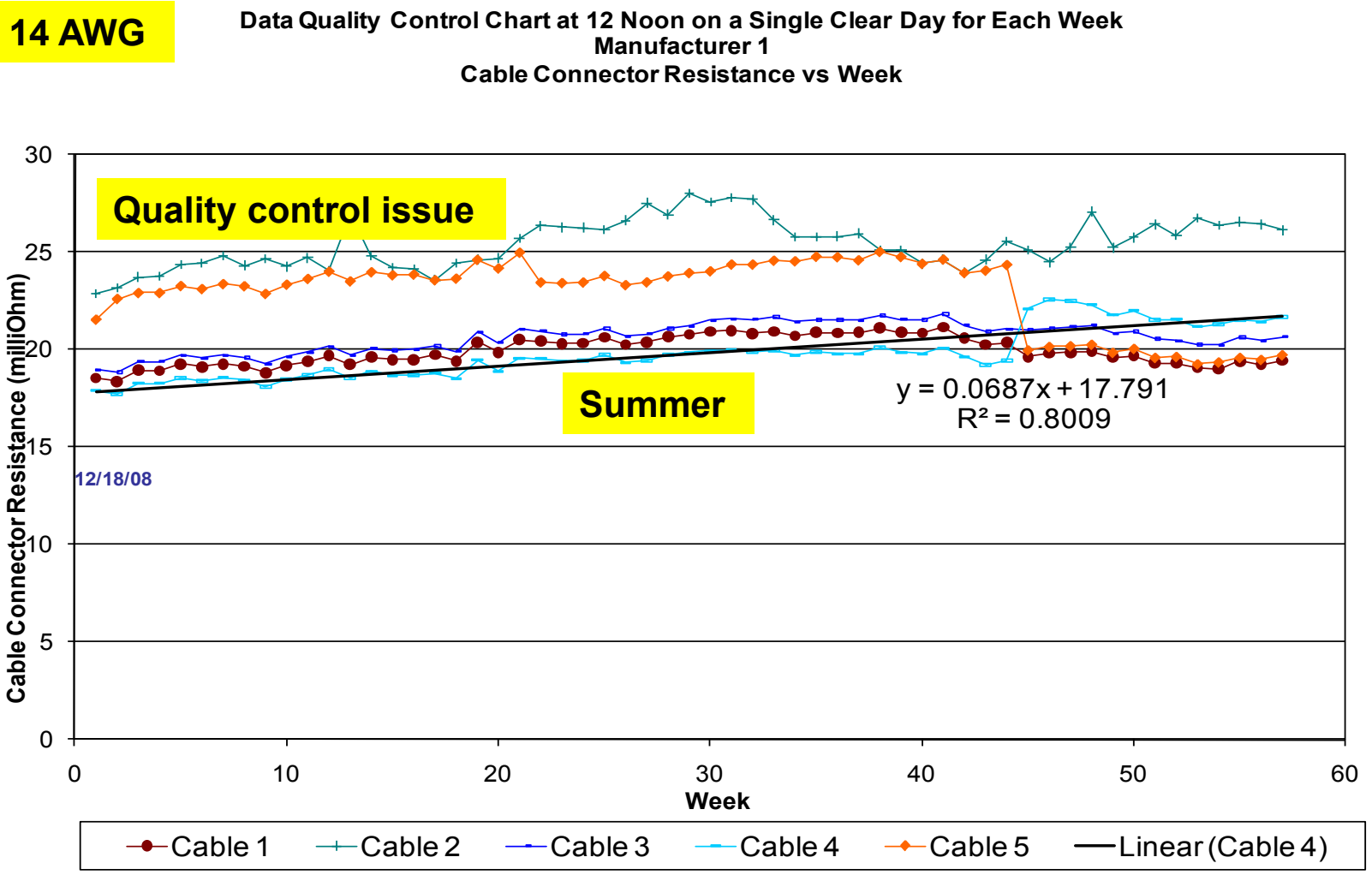
Outdoor connector test results @ ASU

14 AWG



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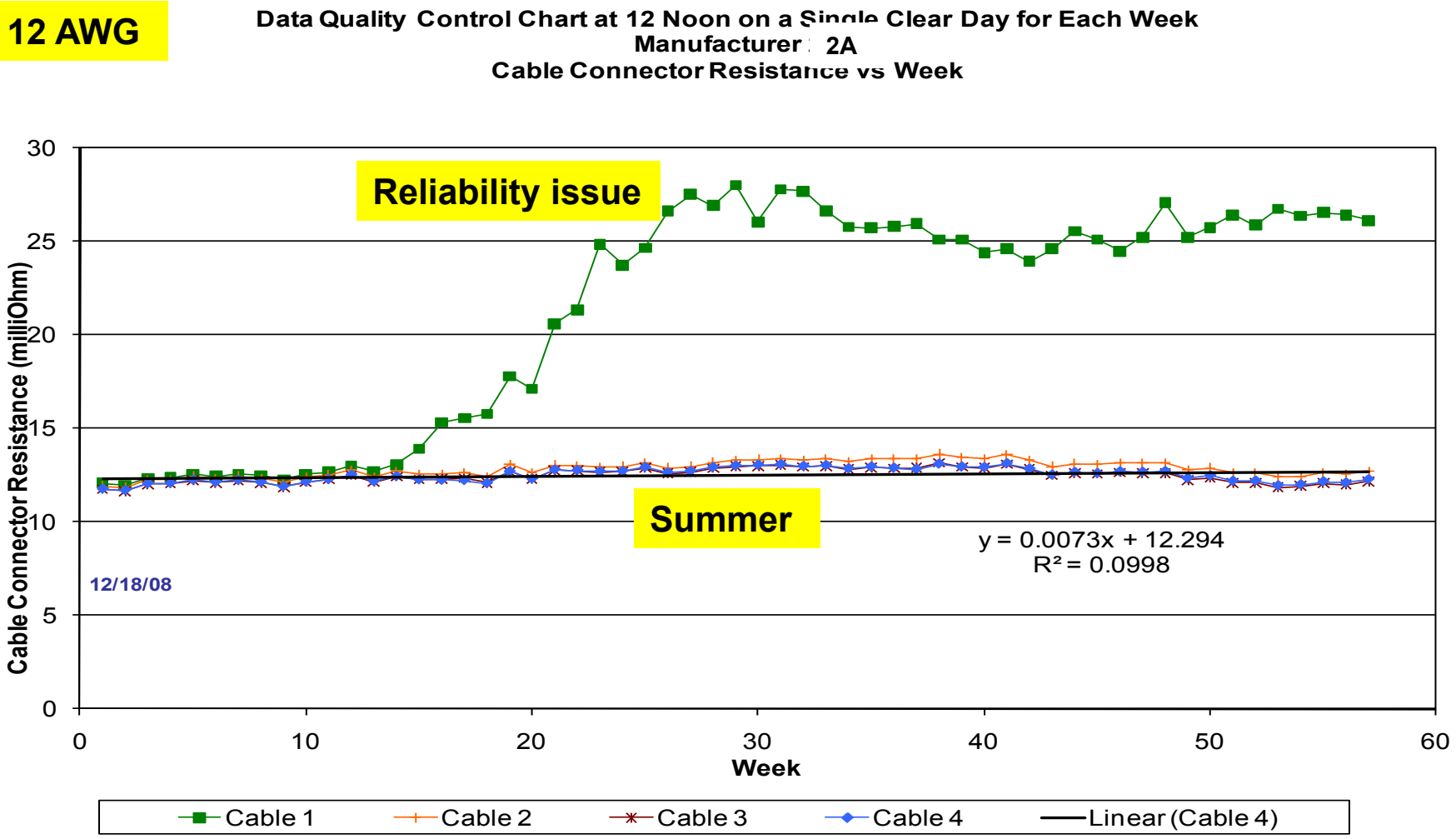
Outdoor connector test results @ ASU

12 AWG



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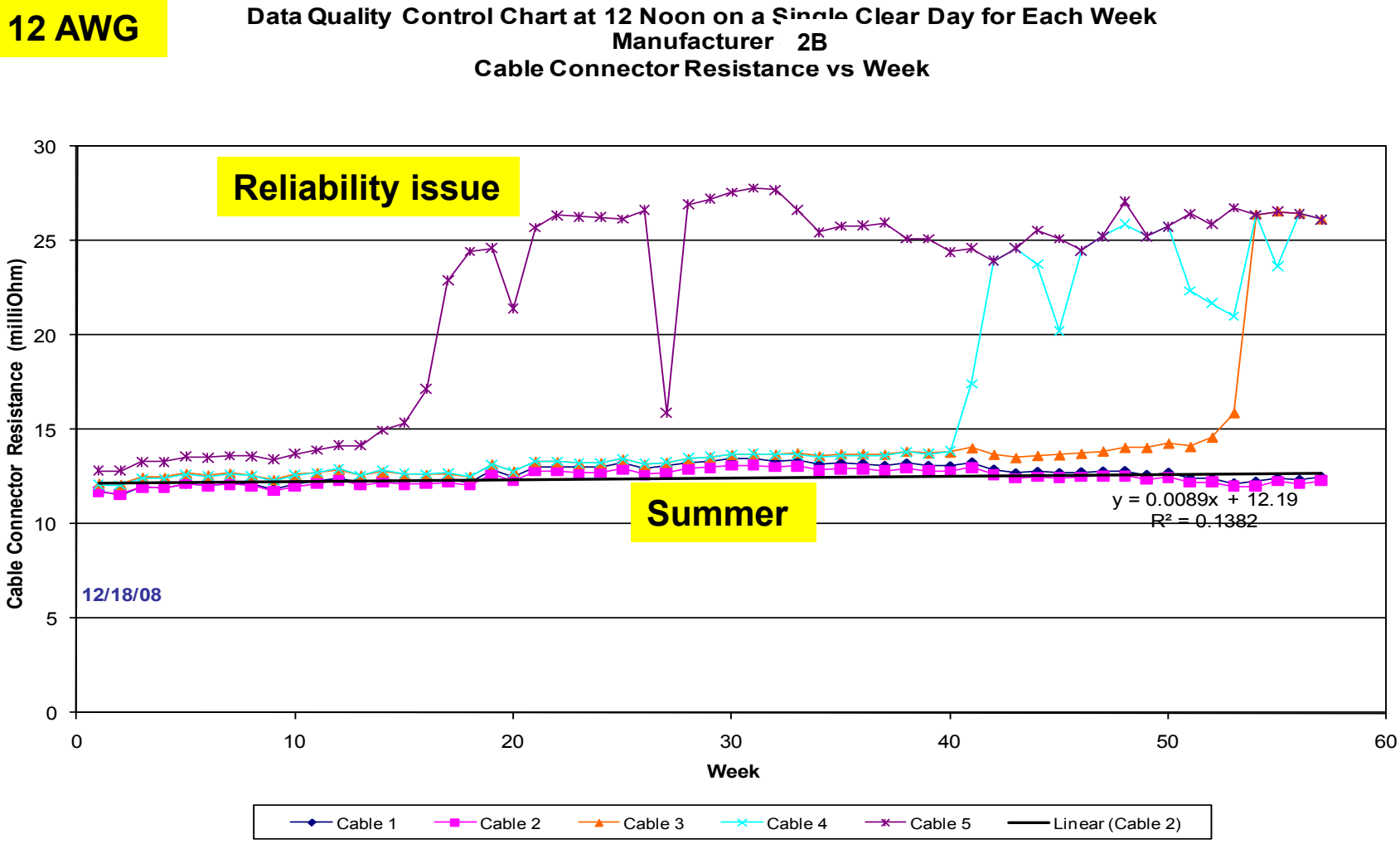

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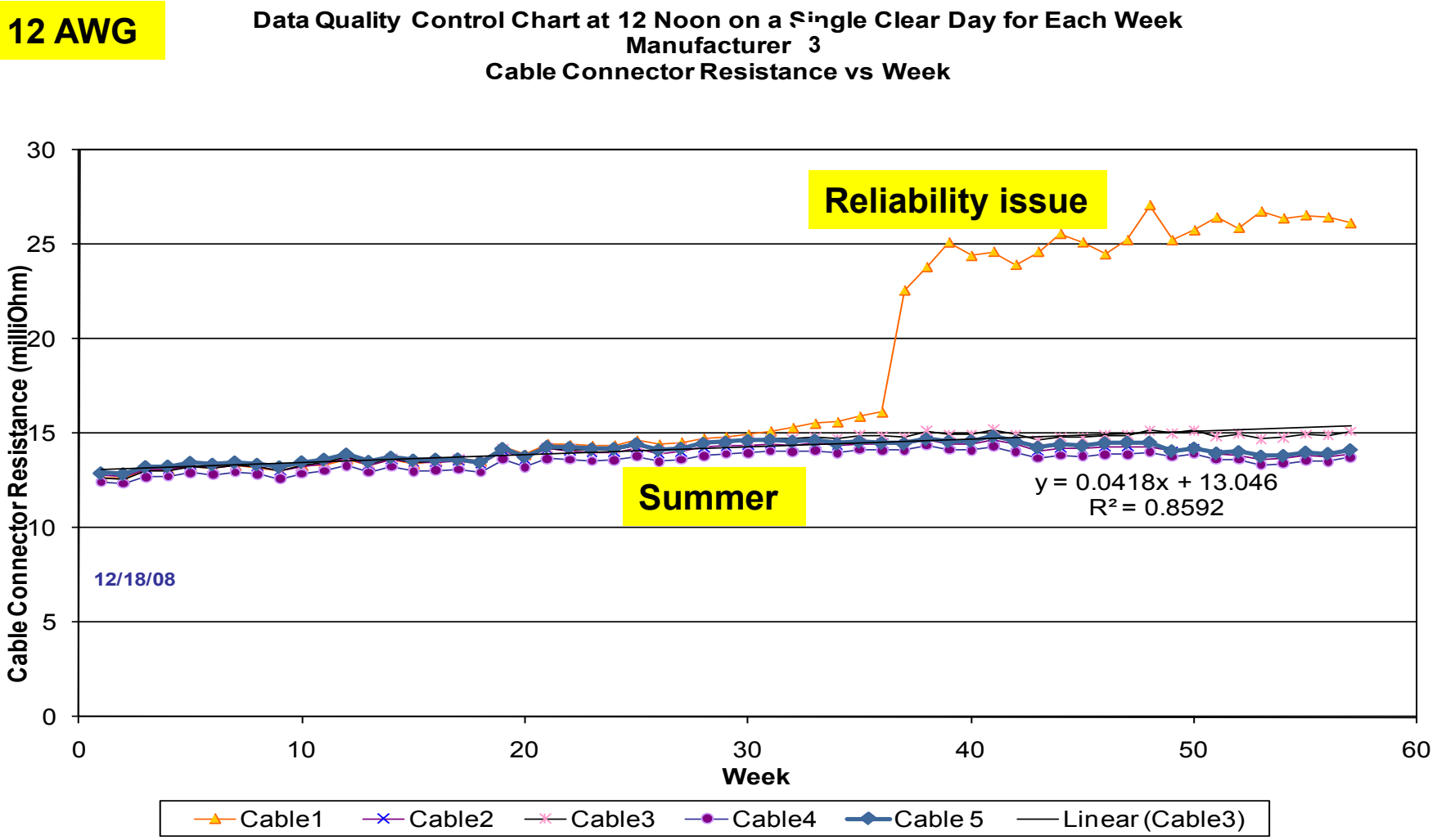

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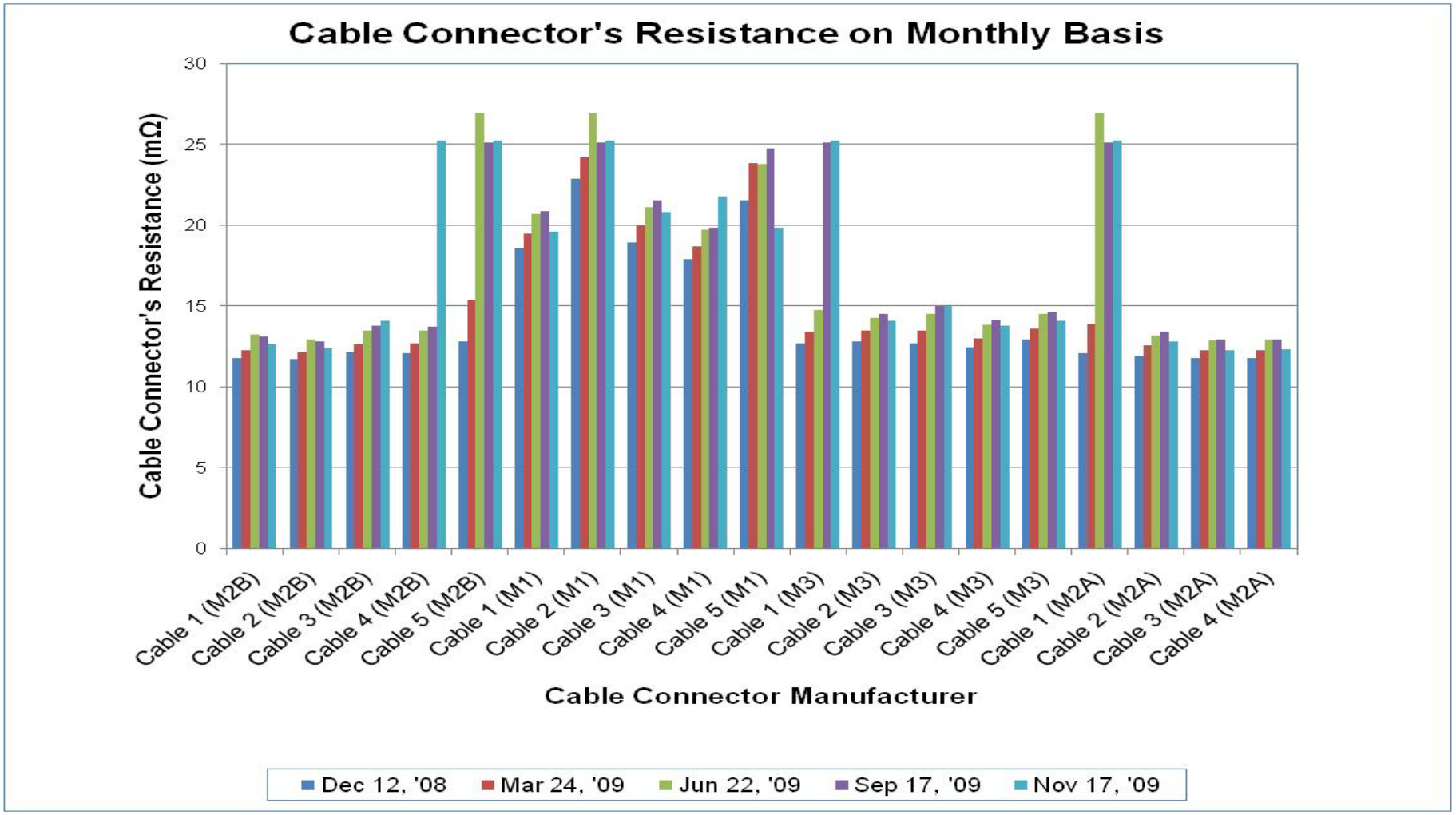

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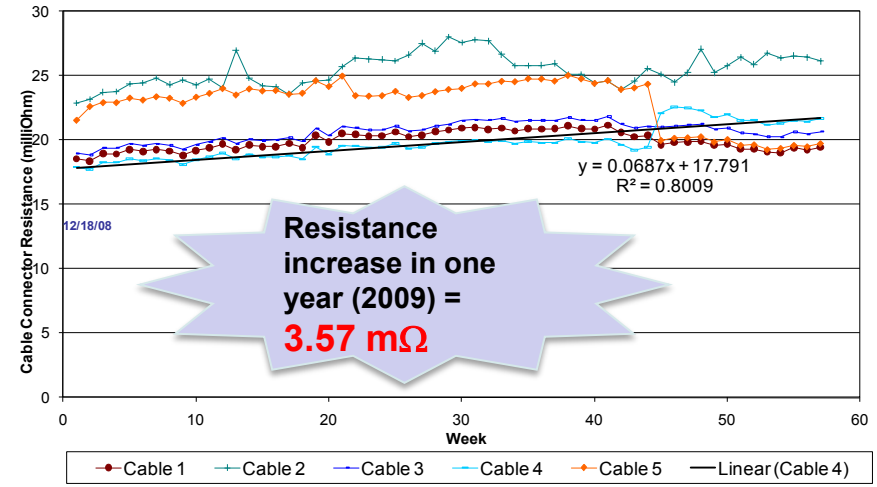

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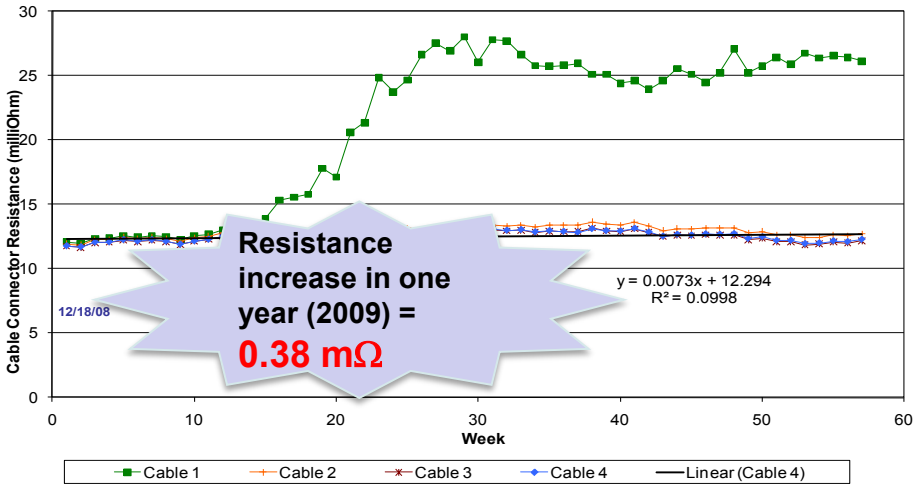

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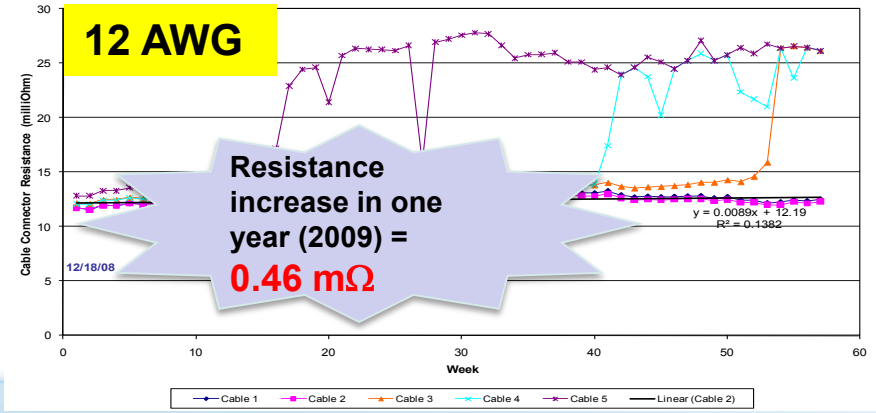

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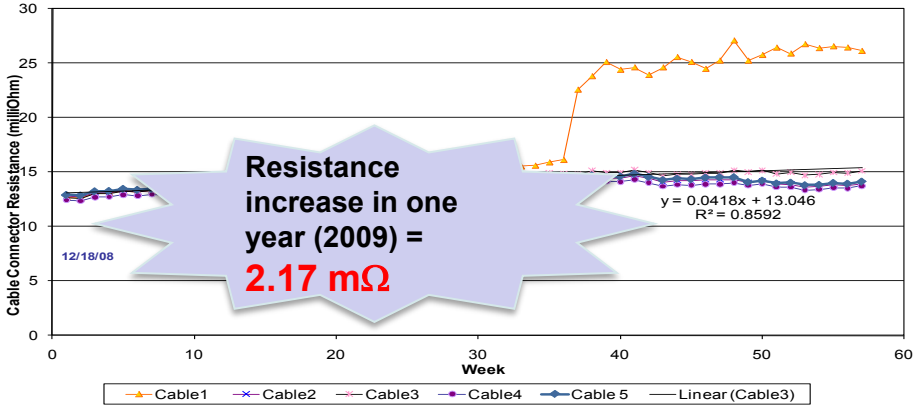

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Outdoor connector test results @ ASU

All the connectors passed the wet megger test at 500 V_{dc} in Nov. 2010!

Indoor connector test results @ TUV Rheinland
EN 50521: Contact resistance increase after stress test

STRESS TEST	PRJECT 1	PRJECT 2
BEFORE: 50 mechanical operating cycles test	2.5mm²: 2.60 mΩ	2.5mm² = 0.82 mΩ 6.0mm² = 0.49 mΩ
AFTER: 50 mechanical operating cycles test	2.5mm²: 2.62 mΩ	2.5mm² = 0.99 mΩ 6.0mm² = 0.51 mΩ
AVERAGE INCREASE (Group B): 6.6%	0.8%	12.4%
BEFORE: Temperature rise and dry heat tests	2.5mm²: 2.00 mΩ 6.0mm²: 1.36 mΩ	2.5mm² = 0.82 mΩ 6.0mm² = 0.46 mΩ
AFTER: Temperature rise and dry heat tests	2.5mm²: 2.01 mΩ 6.0mm²: 1.40 mΩ	2.5mm² = 0.91 mΩ 6.0mm² = 1.10 mΩ
AVERAGE INCREASE (Group C): 38.4%	1.7%	75.1%
BEFORE: Thermal cycling, damp heat and corrosion tests	6.0 mm²: 1.32 mΩ	2.5mm² = 0.75 mΩ 6.0mm² = 0.50 mΩ
AFTER: Thermal cycling, damp heat and corrosion tests	6.0 mm²: 1.45 mΩ	2.5mm² = 1.07 mΩ 6.0mm² = 1.82 mΩ
AVERAGE INCREASE (Group D): 81.6%	9.8%	153.3%

EN 50521 Tests

DESCRIPTION
Initial sample/specimen activity
Select Samples for testing
Perform Incoming Inspection
Perform pre-conditioning of all test specimens
Mechanical test (Group A)
Visual and dimensional check
Marking durability test
Polarisation test
Termination test
Contact retention test
Cable anchorage test
Mechanical strength impact test
Low temperature mechanical strength test
Insertion and withdrawal force test
Coupling device effectiveness test

EN 50521 Tests

Service life test (Group B)
Initial contact resistance measurement
Mechanical operation
Final contact resistance measurement
Contact earth measurement
Bending test
Thermal test (Group C)
Initial contact resistance measurement
Temperature rise test
Dry heat test
Visual and dimensional check
Final contact resistance measurement

EN 50521 Tests

Climatic test (Group D)
Initial contact resistance measurement
Thermal cycle test
Damp heat test ***(& Humidity freeze test??)***
Dielectric strength tests
Corrosion test
Final contact resistance measurement
Degree of protection test (Group E)
Test finger access test
Manufacturer IP Code test (ingress)
Dielectric test

EN 50521 Tests

Insulation material test (Group F)
Weather resistance test
Dielectric strength test
Outer housing insulation flammability test
Glow-wire test #1 (650°C)
Active parts insulation flammability test
Glow-wire test #2 (750°C)

Planned future work

- Outdoor: Continuous monitoring of connector contact resistance
- Outdoor: Continuous monitoring of connector temperature using thermocouples
- Indoor: Measure connector contact resistance before and after TC500, DH2000, HF30 and dry heat tests for the same type of connectors as that of outdoor's
- Compare the outdoor connector results with indoor connector results
- Potentially determine the acceleration factor based on the indoor and outdoor test results

Thanks for your attention!