NEETRAC

National Electric Energy Testing, Research & Applications Center

A Research Center in the School of Electrical and Computer Engineering at the Georgia Institute of Technology

Breakdown of MV Cable Jackets under Impulse Conditions

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Background

- It has been suggested that URD circuits can experience abnormally high voltages between the neutral and the ground resulting from power system switching, faults, and lightning.
- The concern is that if these voltages are sufficiently high then they may cause puncture of the jacket.
- If the puncture is large enough then this may admit water
- The water would
  - Accelerate the growth of water trees
  - Cause corrosion of the neutral

Tasks

- Determine impulse characteristics of cable jackets
  - Breakdown levels
  - Evidence of time dependence
  - Probabilistic criteria

Subject of this presentation

- Model likely voltages across jacket
- Account for probabilistic nature of lightning and impulse failure
- Determine potential mitigation solutions

Test Objects

Geometry

- Plaques
  - – + simple to make & test, many materials,
  - – - not cable geometry
- Cables
  - – + replicates geometry & processing
  - – - terminations, length scaling, limited materials

Materials

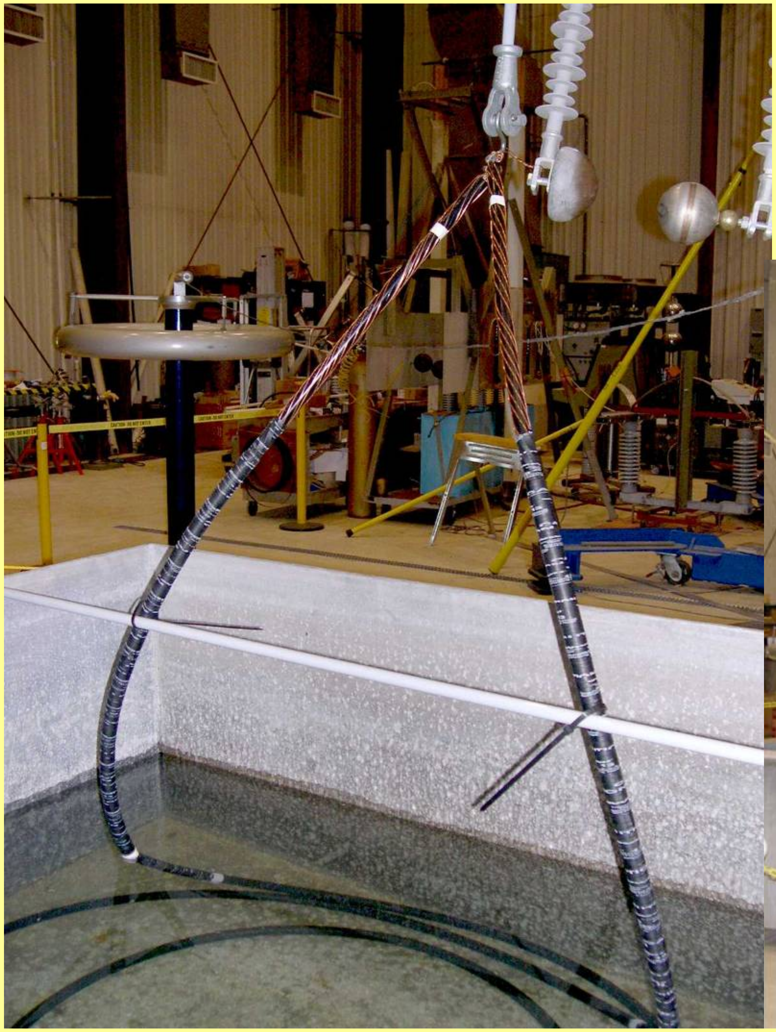
- Insulating
  - – LLDPE
    - Commercial
    - Manufacturers blend
  - – PVC
  - – HDPE
- Semiconducting

Test Program

- 1/0 175mil WTRXLPE 50mil LLDPE compounded ins jacket
- 20 samples
- Active lengths of 30 ft
- Three rates of voltage rise

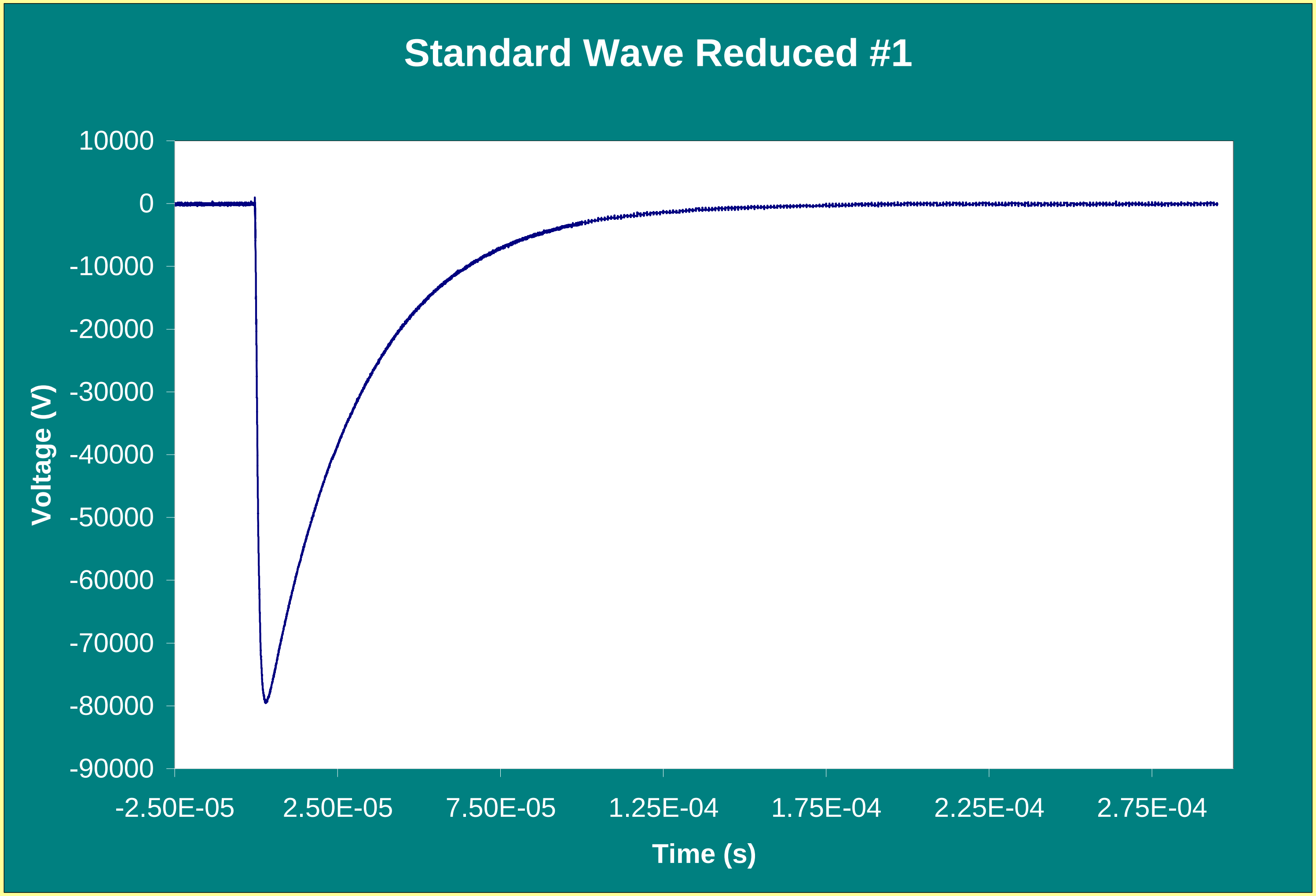
- Failure area located
- Postmortem dissection to determine jacket thickness at puncture location.

Impulse Characteristics of Jackets

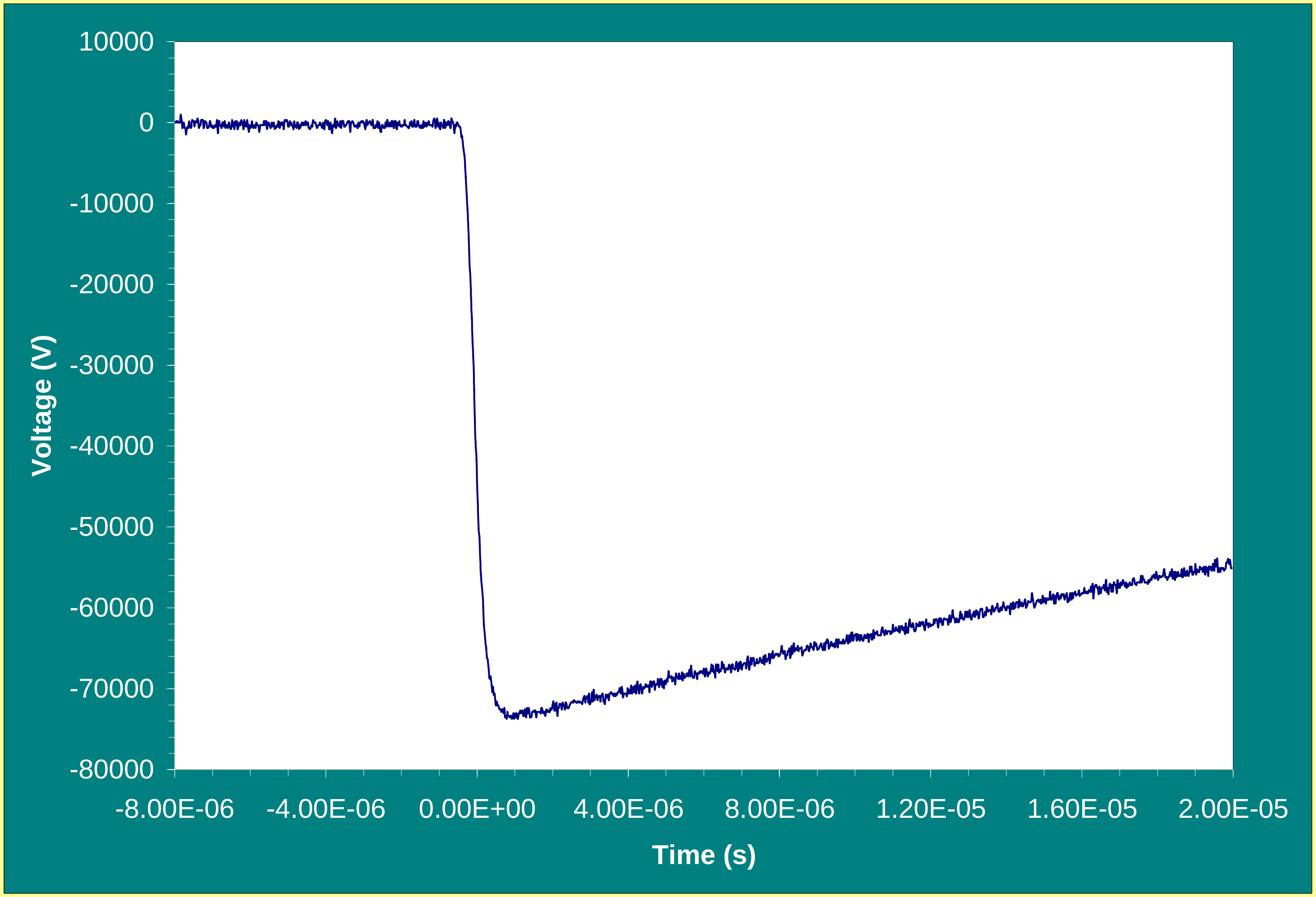


- Cables tested in water
- Impulse voltages applied to neutral wires

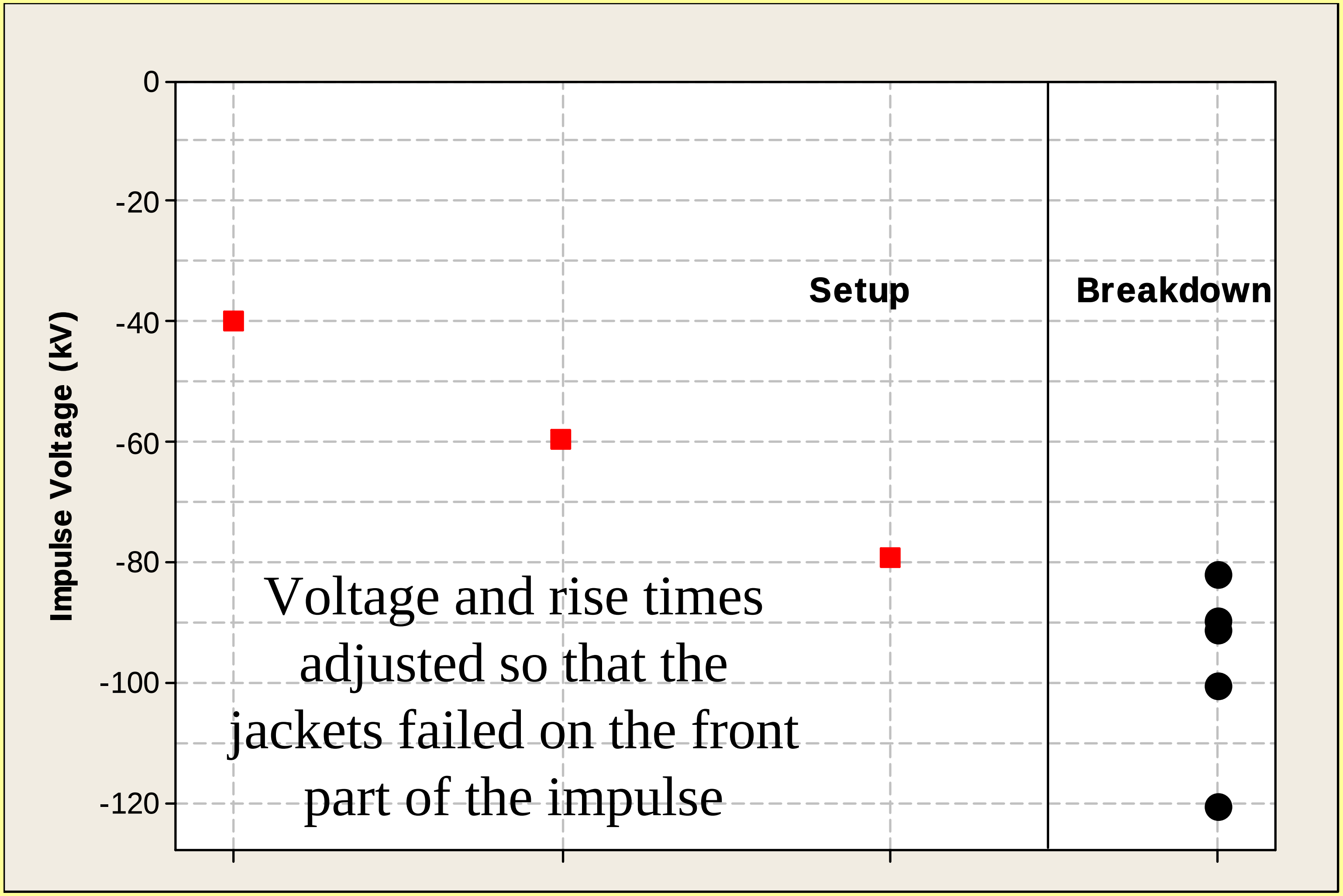
Impulse


Standard Wave Reduced #1
Voltage (V)
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
-70000
-80000
-90000
-2.50E-05
2.50E-05
7.50E-05
1.25E-04
1.75E-04
2.25E-04
2.75E-04
Time (s)

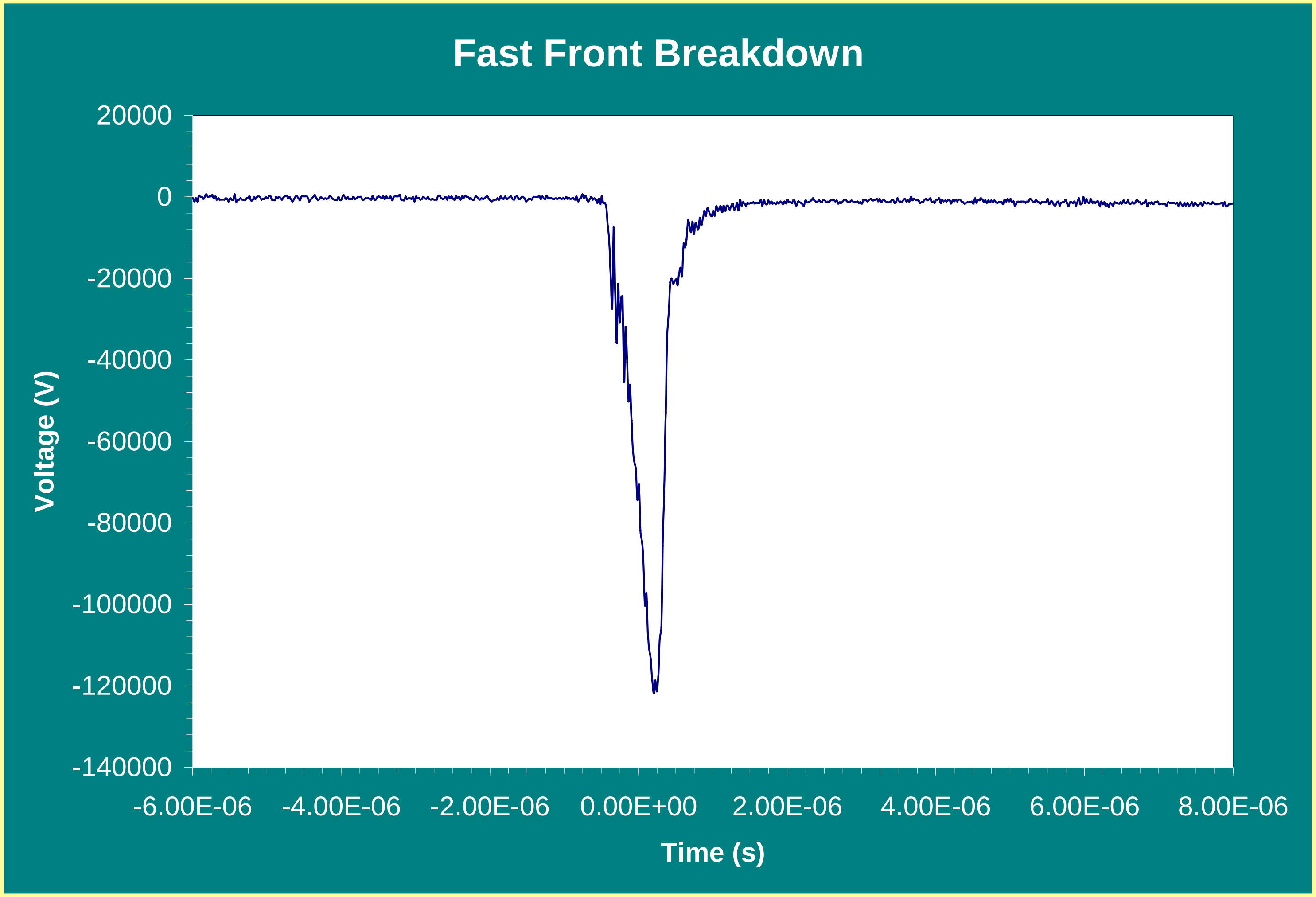
Impulse Waveforms – no reflections



Setup and Breakdown Sequence

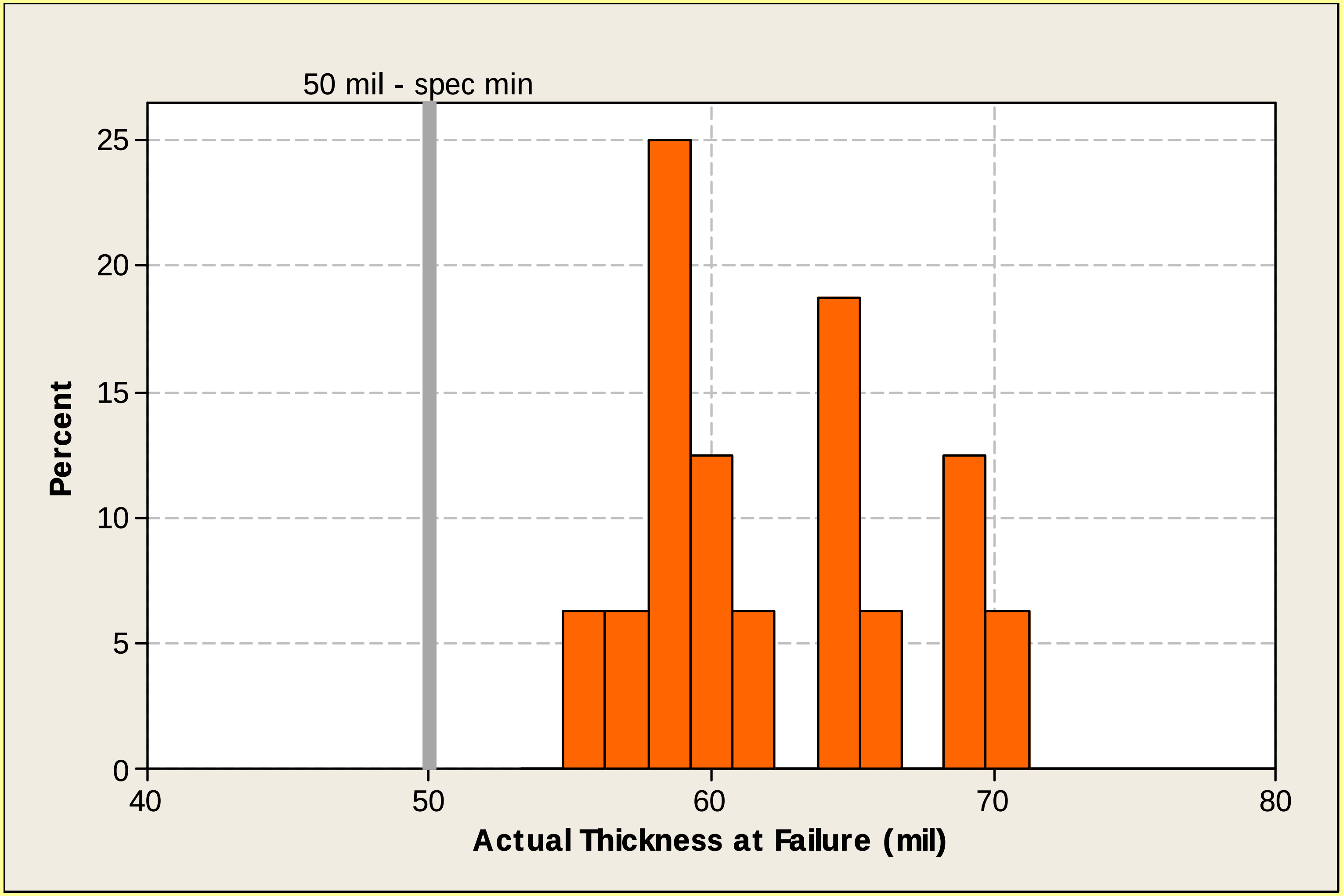


Breakdown under Impulse

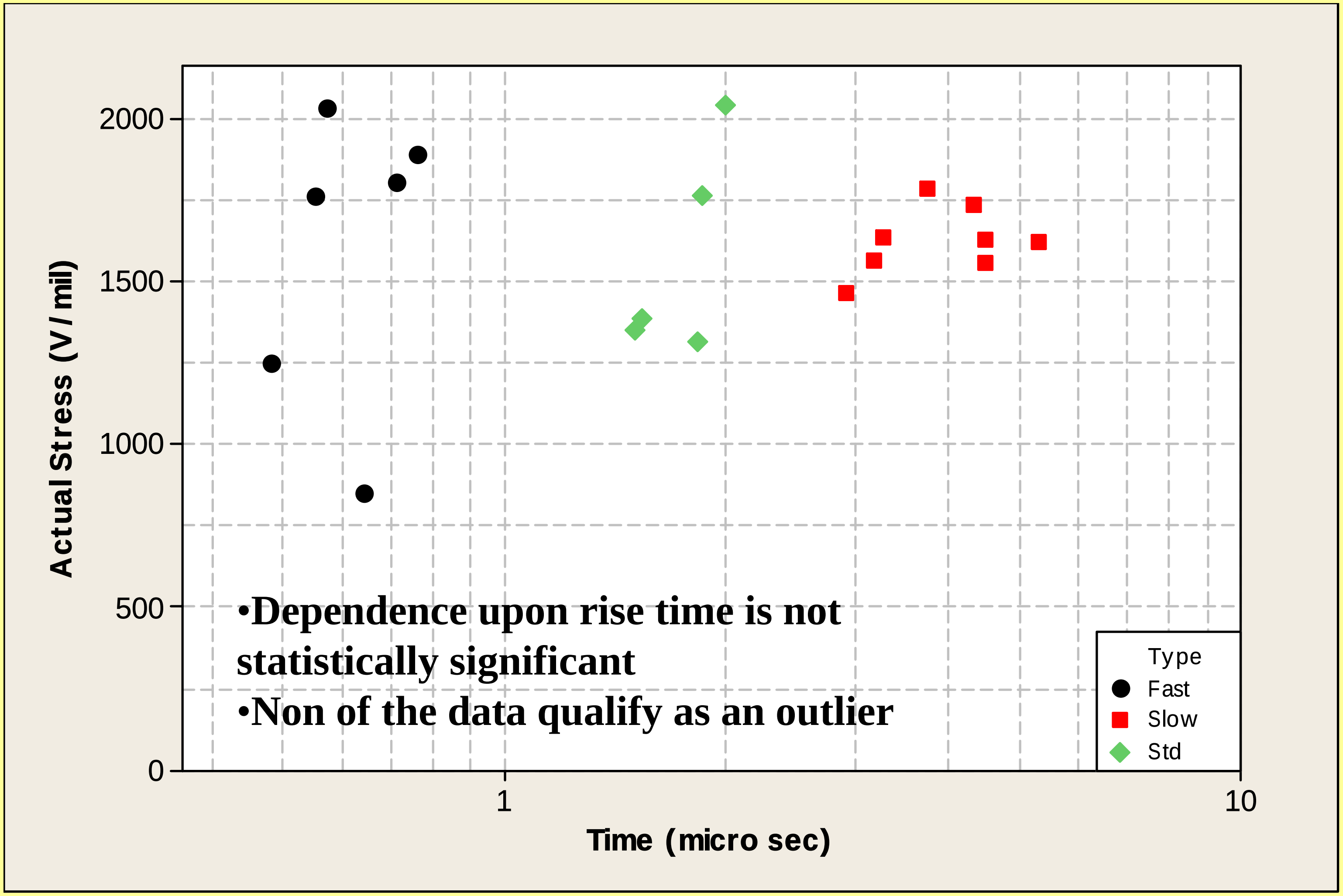


Failure Locations Disected

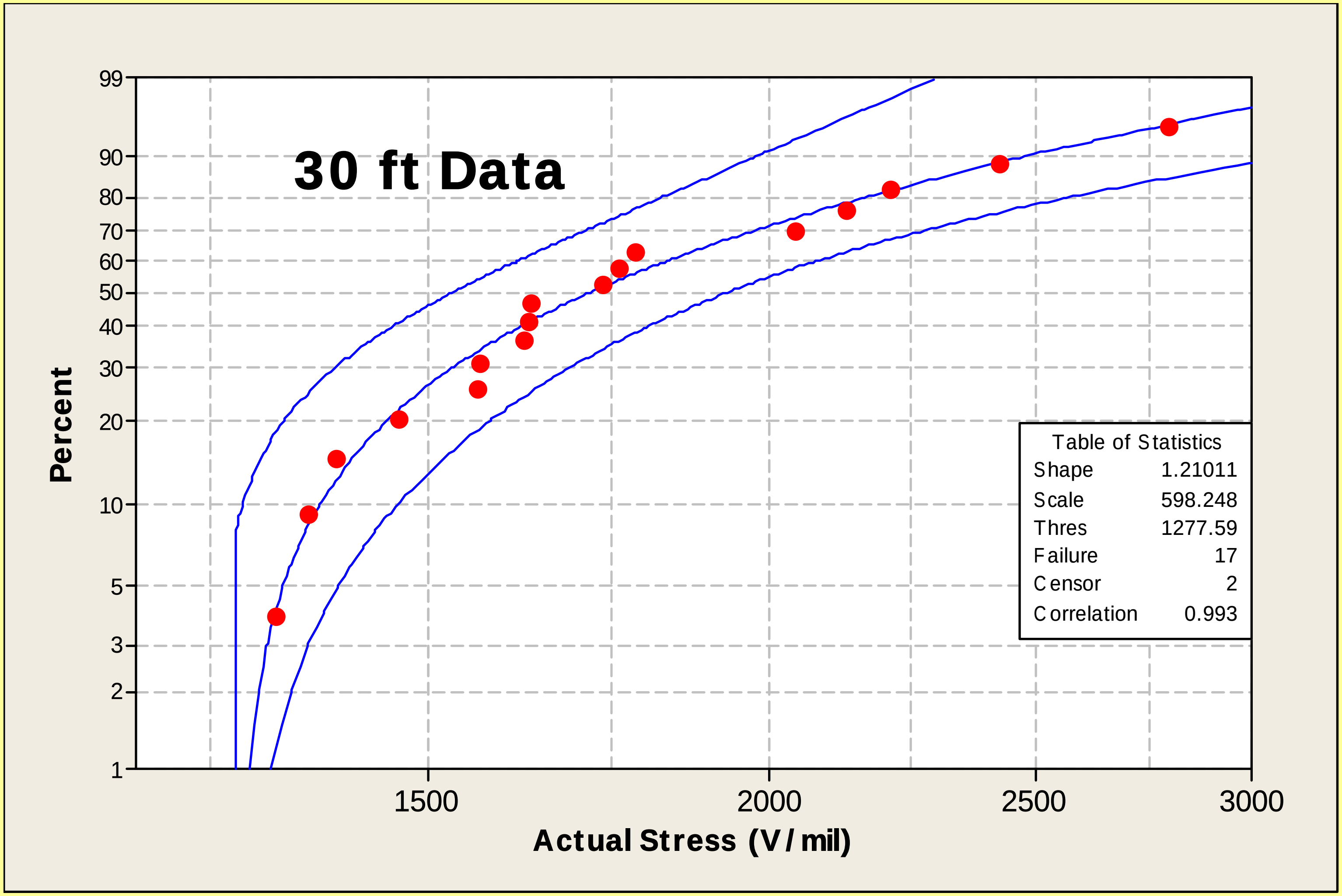
Thicknesses at Failure



Stress - Time Characteristics of Jackets



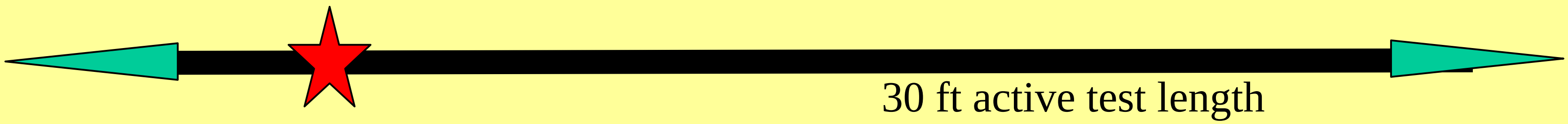
Weibull Analysis Probability



Test Reality vs Model Requirements

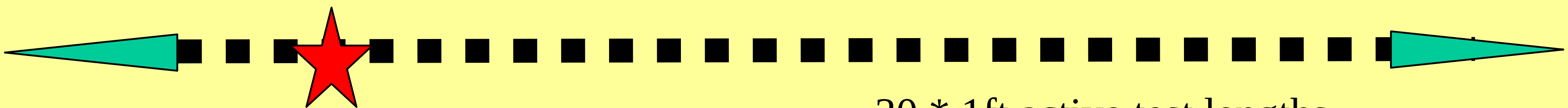
- Modeling of voltages is carried out on small length scales – 1 ft to 1 m
- Testing is not possible on these short lengths
  - Aberration from end effects due to cable cutting
  - Termination failures
  - Not possible to sample a reasonable population of defects
- Practical compromise tests 30ft of cable with hand taped terminations
- All tests resulted in jacket puncture – no termination failures

Failure Lengths



30 ft active test length

One failure

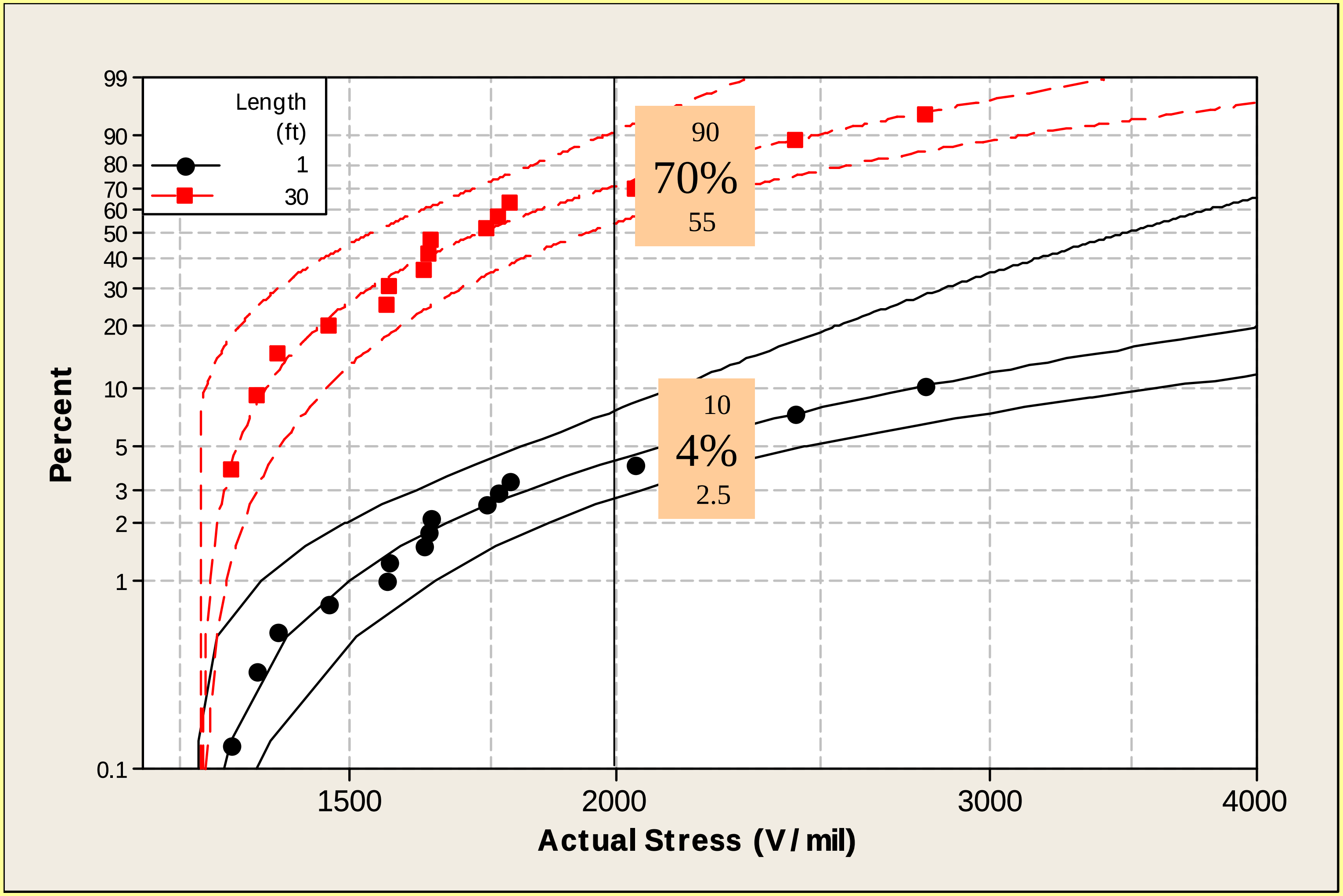


30 * 1ft active test lengths

One failure
And
29 passes

- Modeling is typically carried out on length scales quite different to one used for measurements.
- Censoring enables the measured data to be re cast in suitable lengths

Jacket Failure for Different Length Scales



Different Cable Sizes

- Breakdown stress of a jacket depends upon the volume of a jacket

$$\alpha_{actual} = \alpha_{ref}\left(\frac{V_{ref}}{V_{actual}}\right)^{1/\beta}$$

- Generally the breakdown stress (V/mil) decreases as the volume increases
- Thus
  - Breakdown stress for a 50 mil jacket on a 1/0 cable will be higher than on a 1000kcmil cable
  - Breakdown stress (V/mil) for a 50 mil jacket will be higher than a 80 mil jacket

Conclusions

- Breakdown strength of insulating LLDPE jackets has been determined experimentally
- For fully compounded LLDPE jackets in 15 kV 1/0 cable at the 30 ft length scale
  - Breakdown stress threshold is 1200 V/mil (approx)
  - Breakdown stress for 50% failure is in the range 1500 – 1900 V/mil
- Modeling based on these results should take account of
  - Appropriate lengths and jacket sizes
  - Probabilistic nature of the failure
- Correlation with other cable sizes needs to account for differences in jacket volume

Outstanding Issues

- Performance of other jacket materials / production techniques
- Influence of aging on jacket performance
- Neutral configuration – wires, vs foil
- Practical impact - is the hole large enough to cause concern

Acknowledgements

- The authors recognise
  - The NEETRAC Management Board for permission to share these data
  - Southwire for providing the test cable