



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

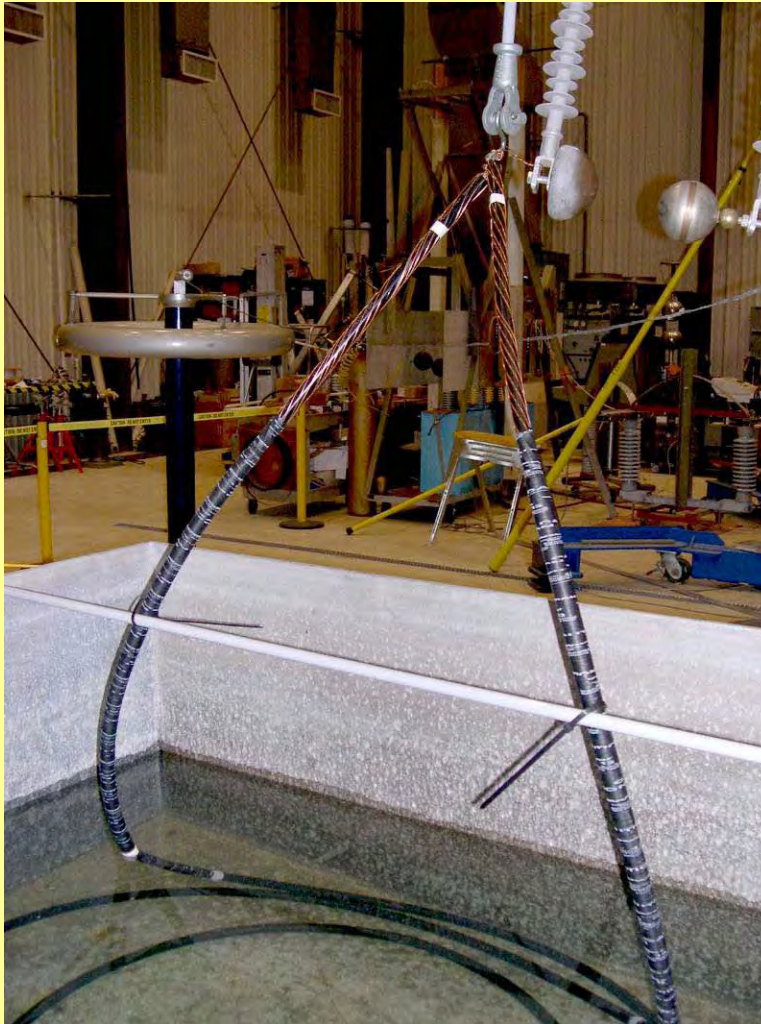
Test Program

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

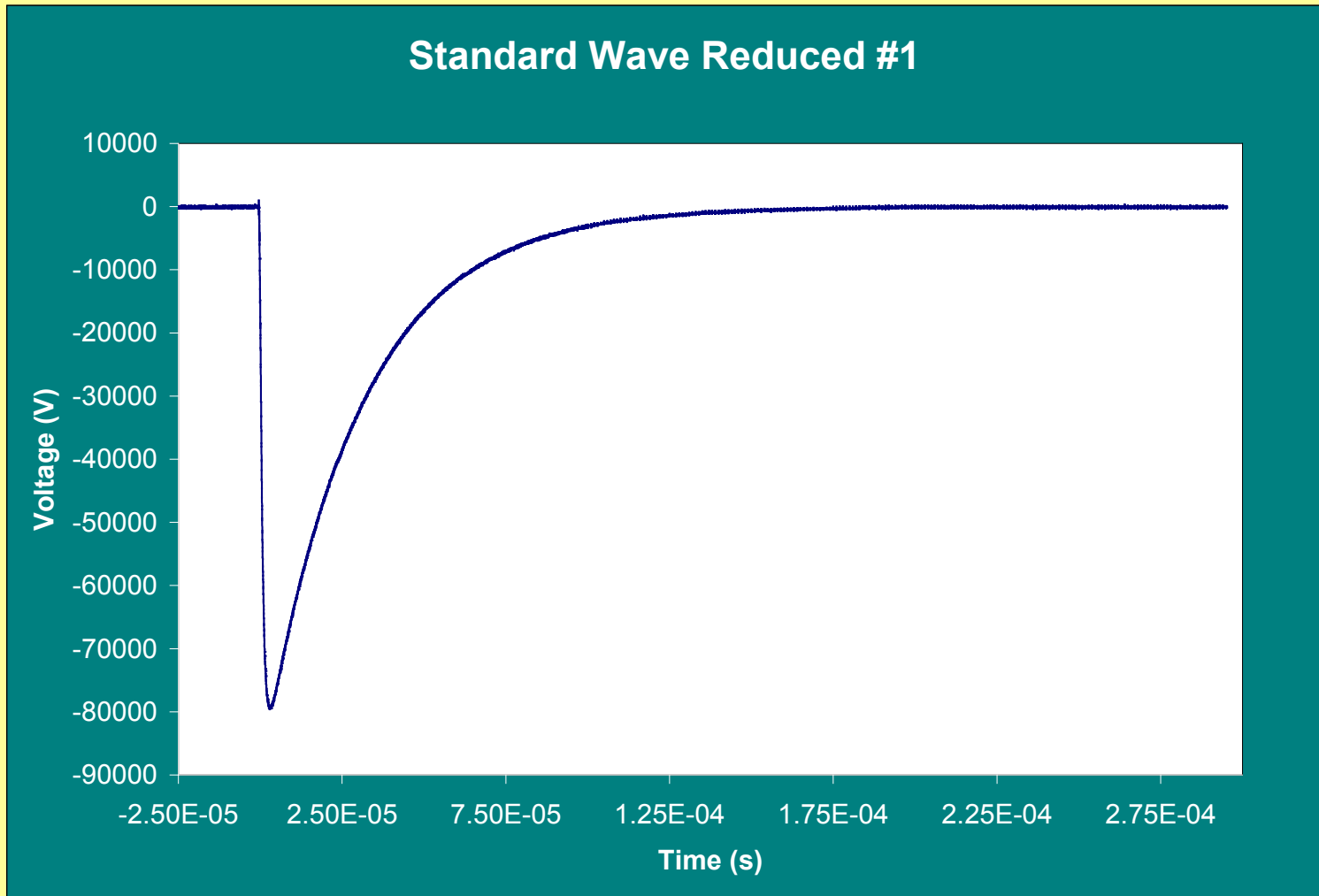
- Failure area located
- Postmortem dissection to determine jacket thickness at puncture location.

Impulse Characteristics of Jackets

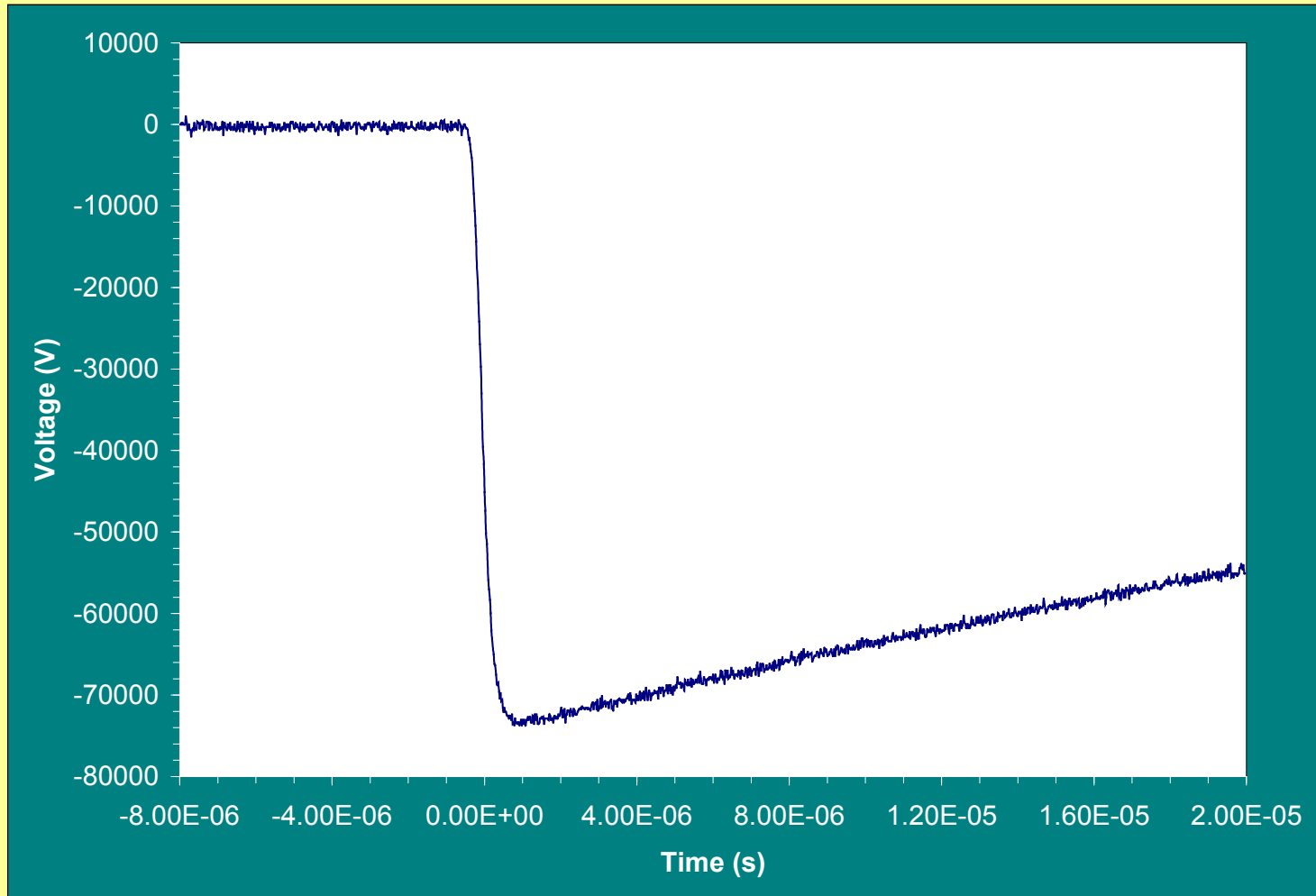
- Cables tested in water
- Impulse voltages applied to neutral wires



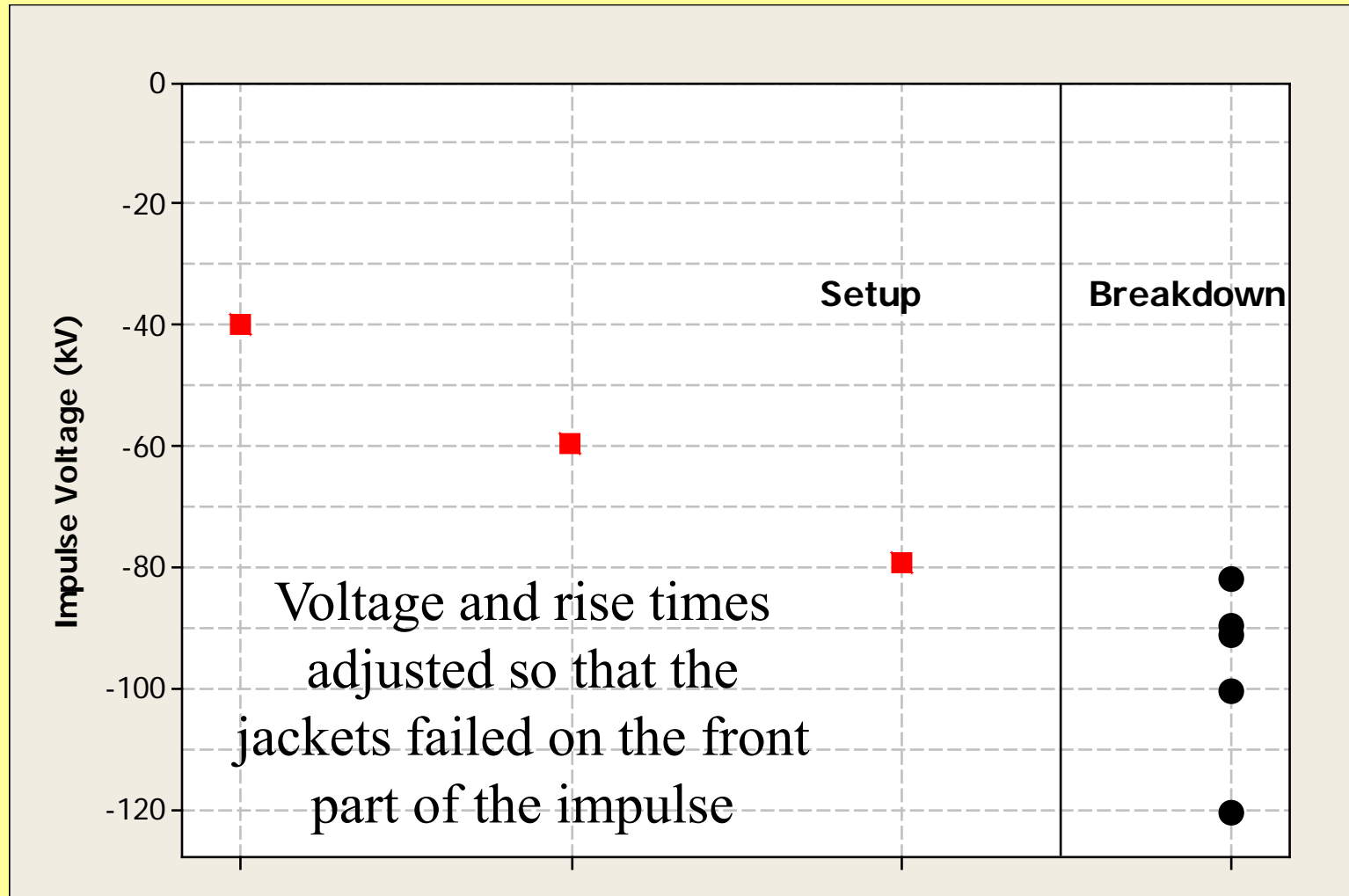
Impulse



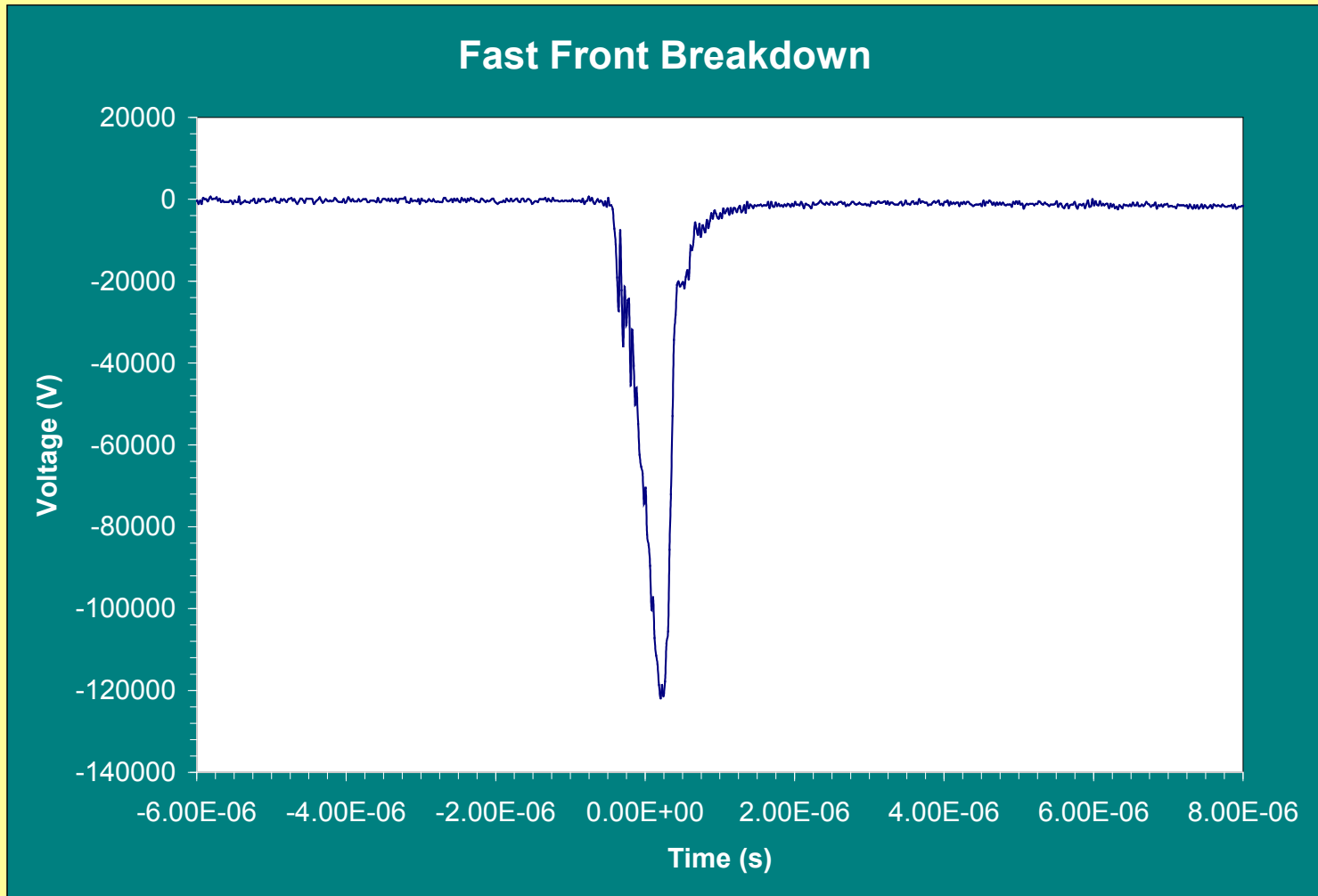
Impulse Waveforms – no reflections



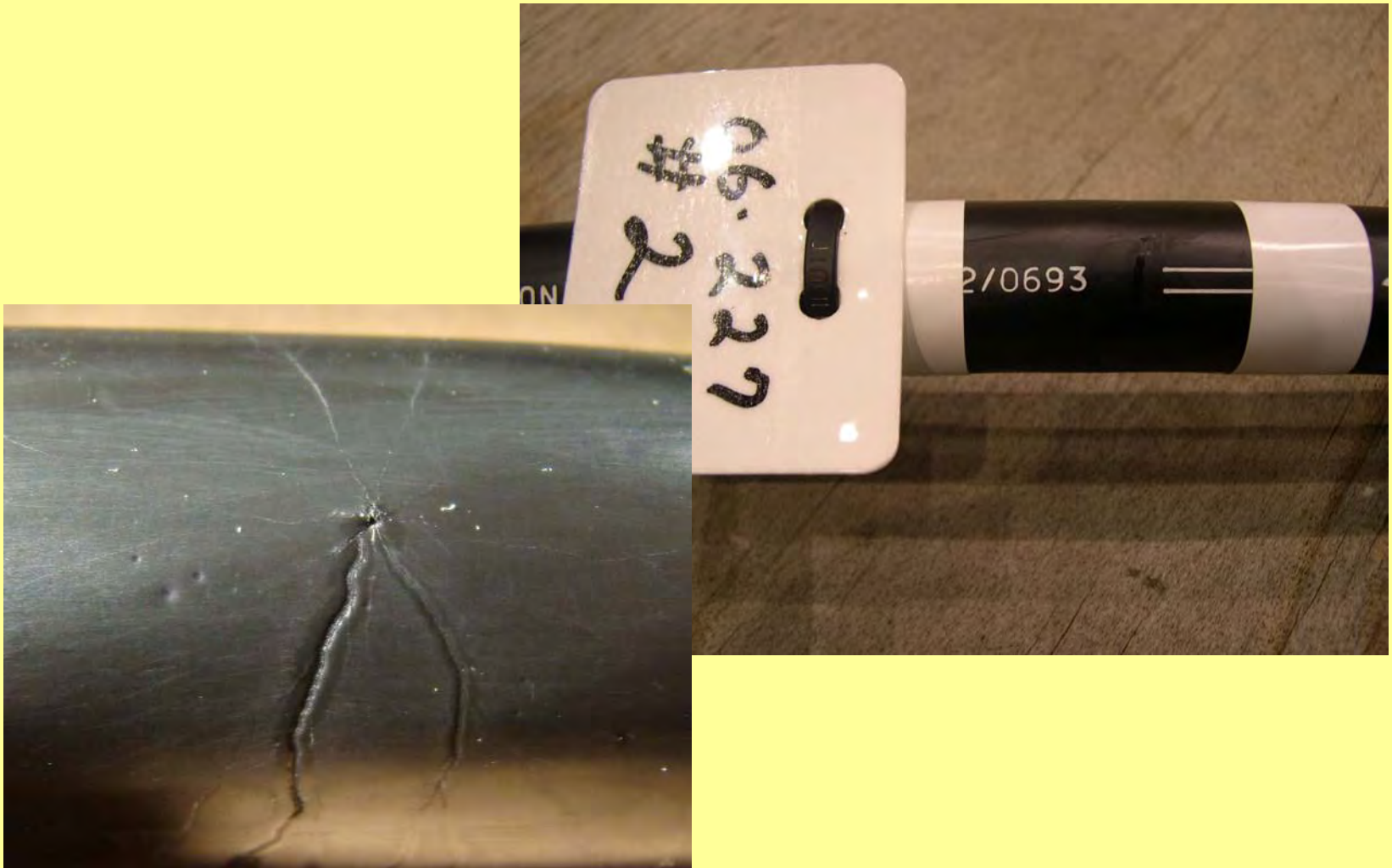
Setup and Breakdown Sequence



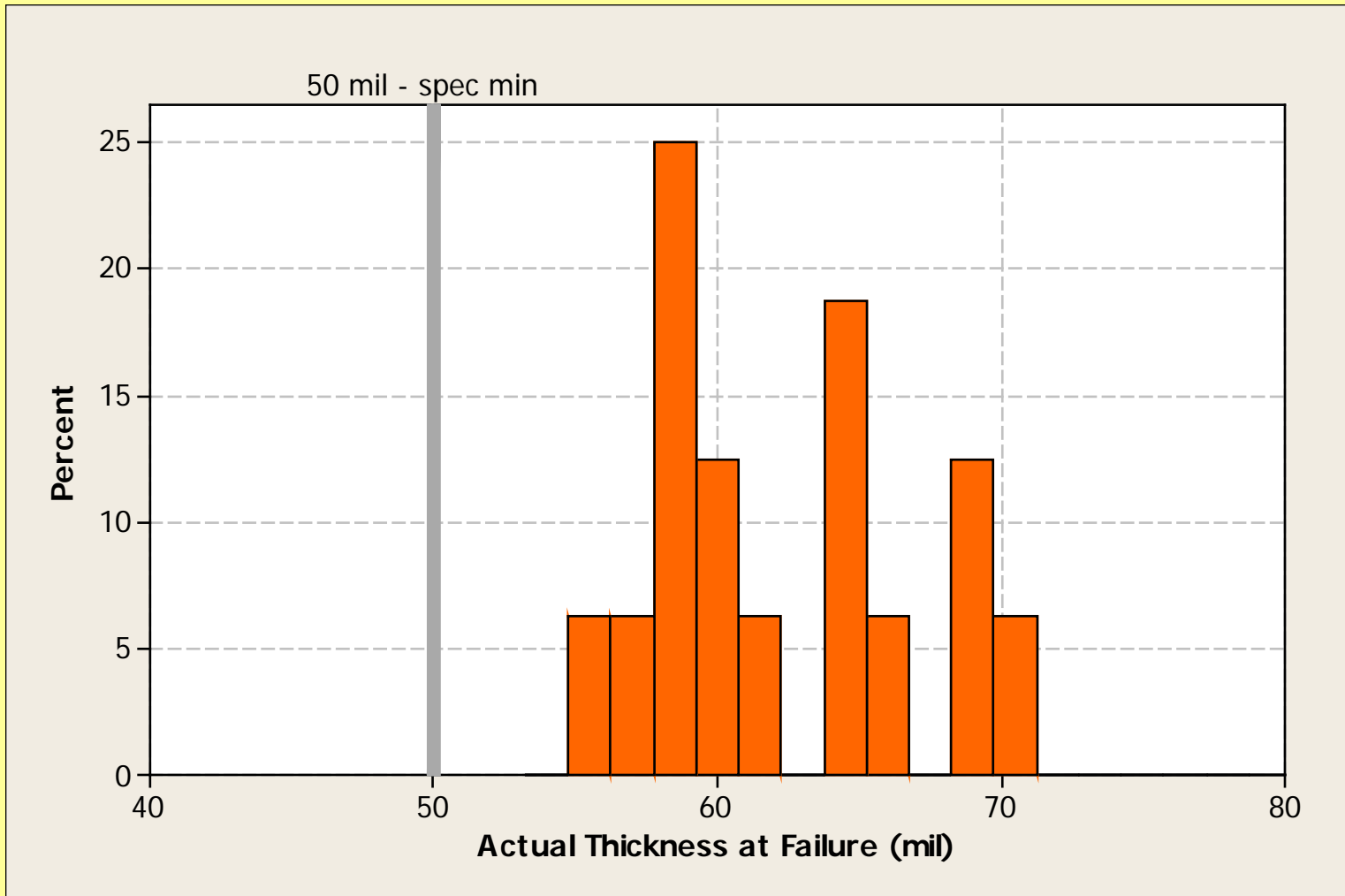
Breakdown under Impulse



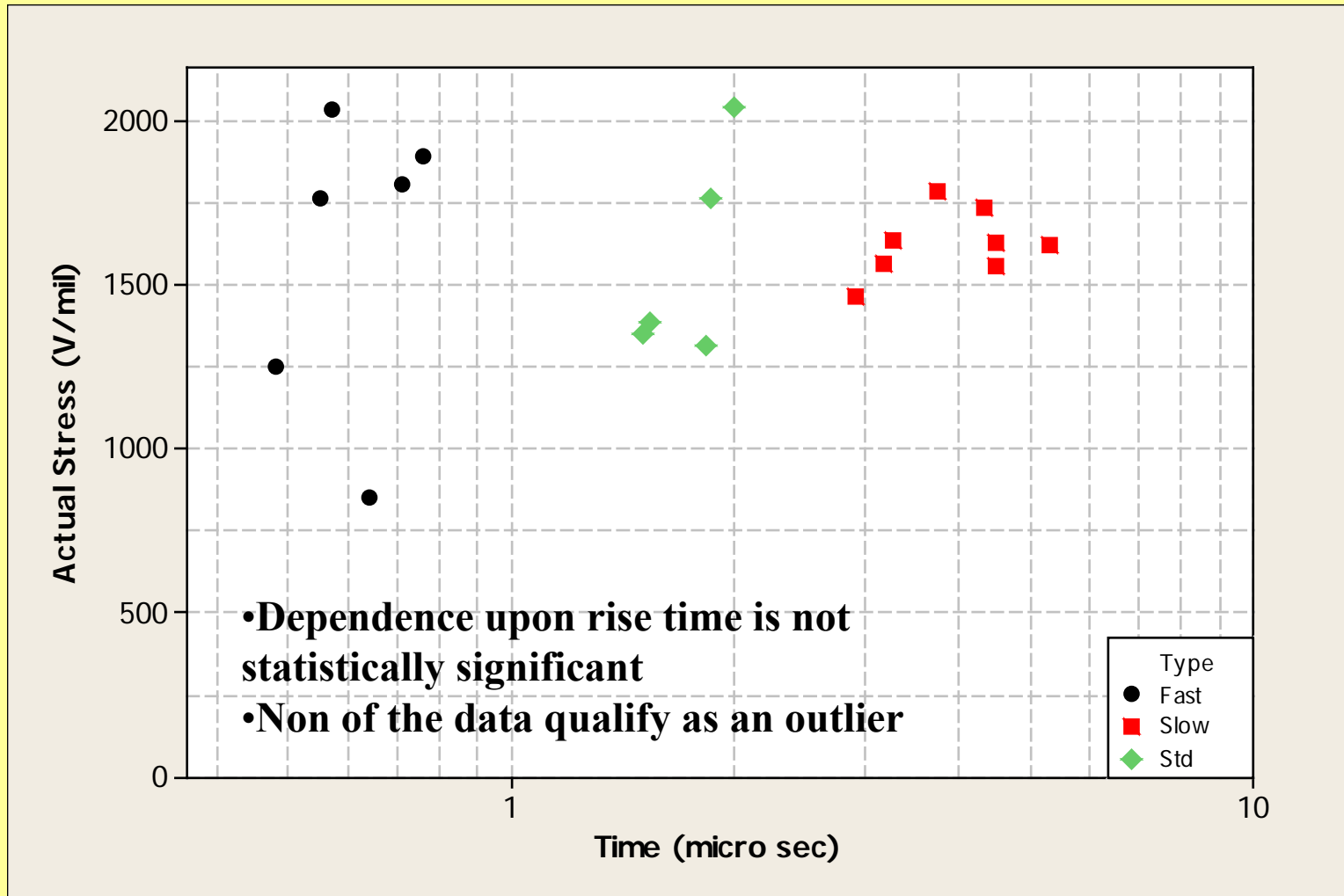
Failure Locations Disected



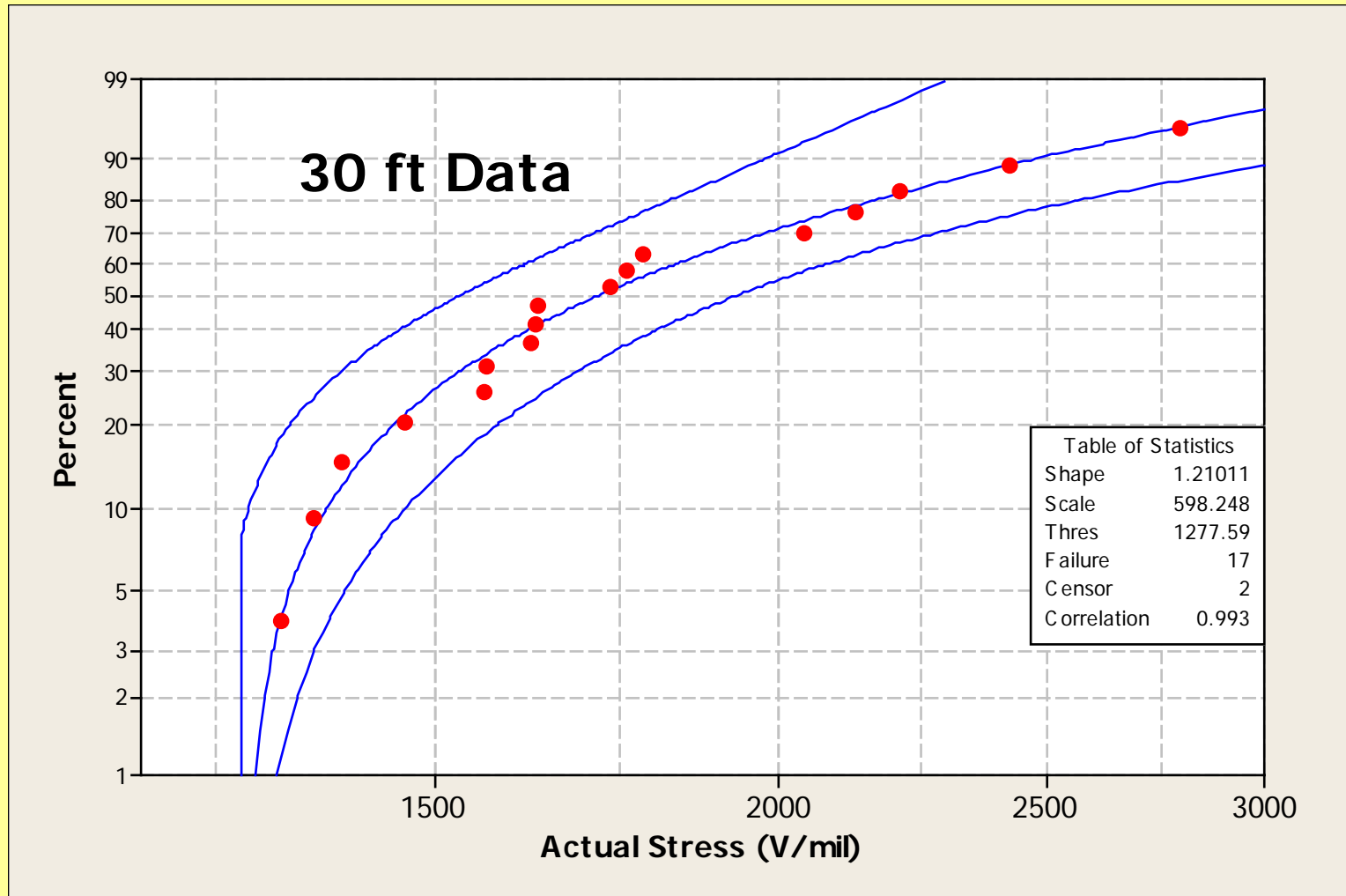
Thicknesses at Failure



Stress - Time Characteristics of Jackets



Weibull Analysis Probability



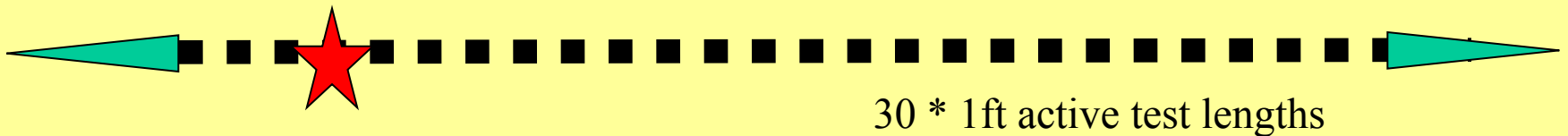
Test Reality vs Model Requirements

- 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



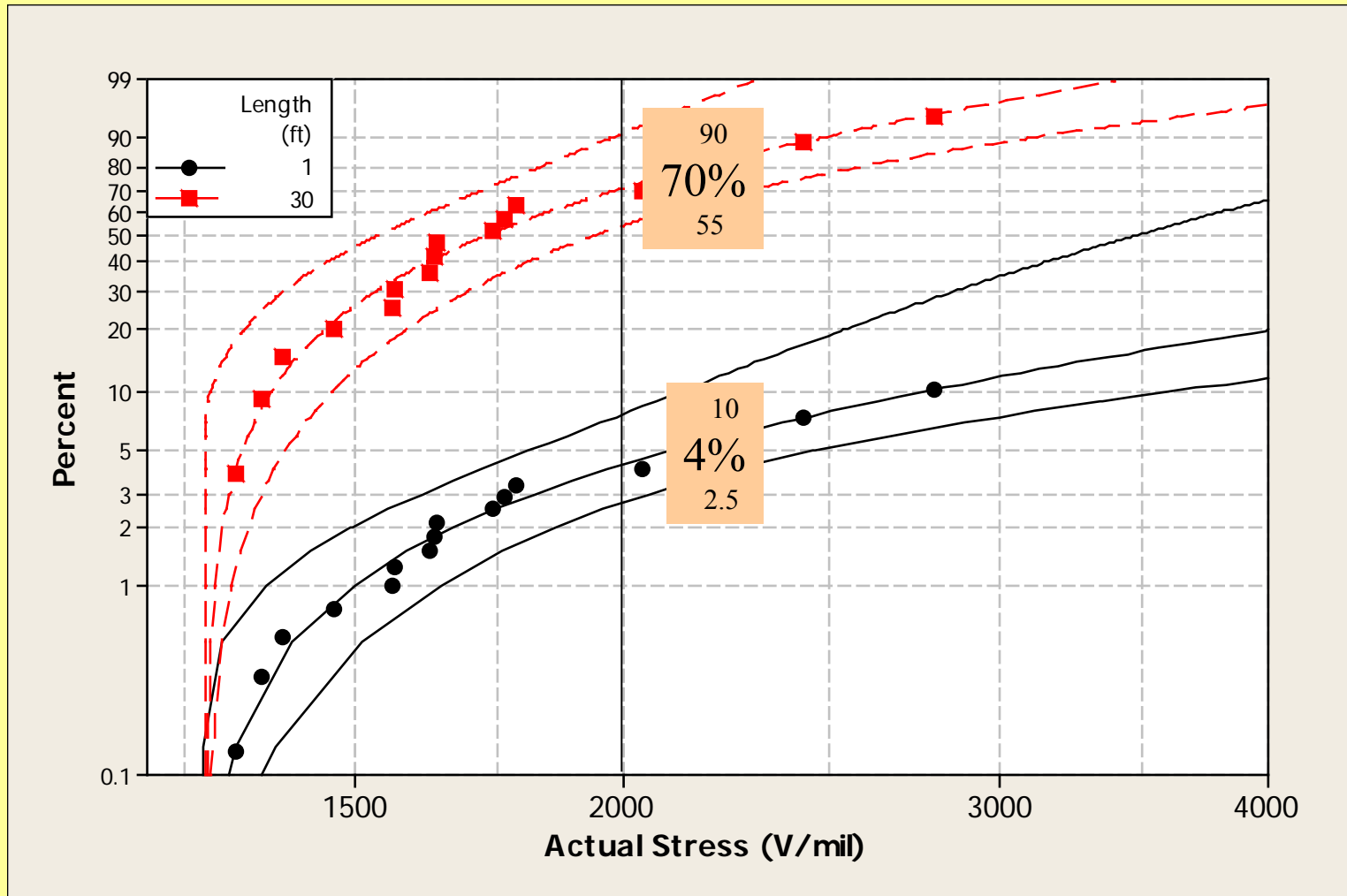
One failure



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

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