Challenges in Relating Accelerated Aging Results to Service Life

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Most test protocols are based on what is pragmatically possible

Protocols are designed to avoid "known" poor performance

Thus protocols are not designed to

- Distinguish if A is better than B
- Determine if C will last “x” years

The general assumption is that higher strength or longer times are better – how that relates to life is unclear

However, much of the data available to us come from such tests

Some Challenges / Concerns

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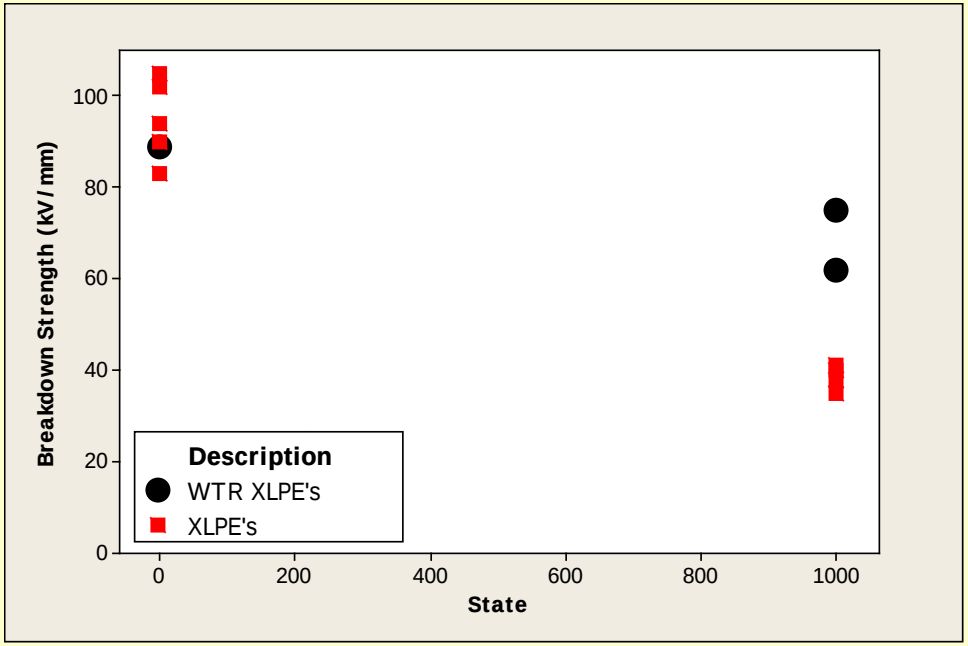
Aged Model Cable Tests

- Test Method
  - Voltage: 9 kV/50 Hz
  - Water: inside & outside
  - Inner temp: 85 °C
  - Outer temp: 70 °C
  - Ageing time: 1000 hours

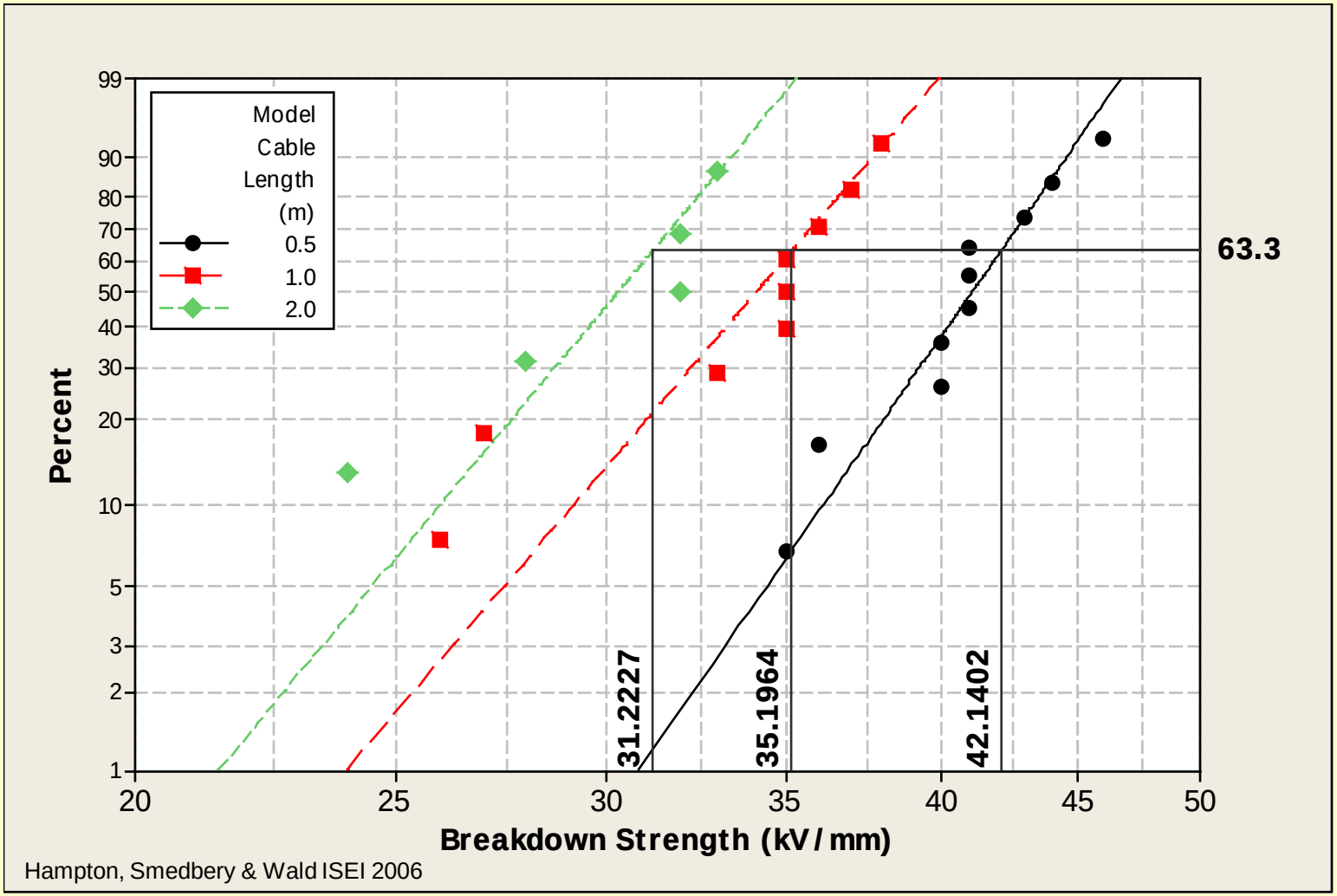
- Evaluation
  - AC breakdown stress
  - Number of trees
  - Size of trees



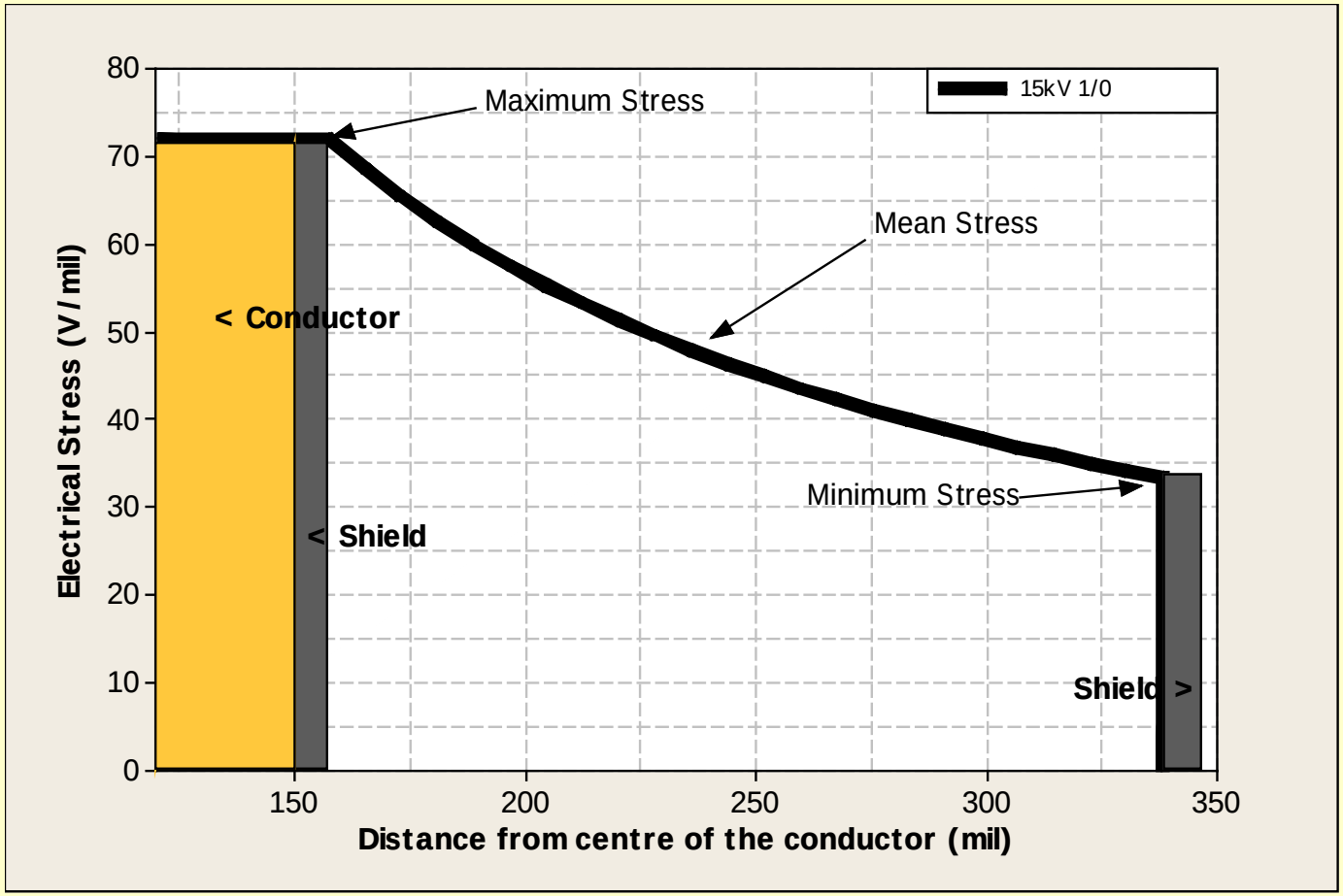
Hampton, Smedbery & Wald ISEI 2006

Aged Model Cable Data

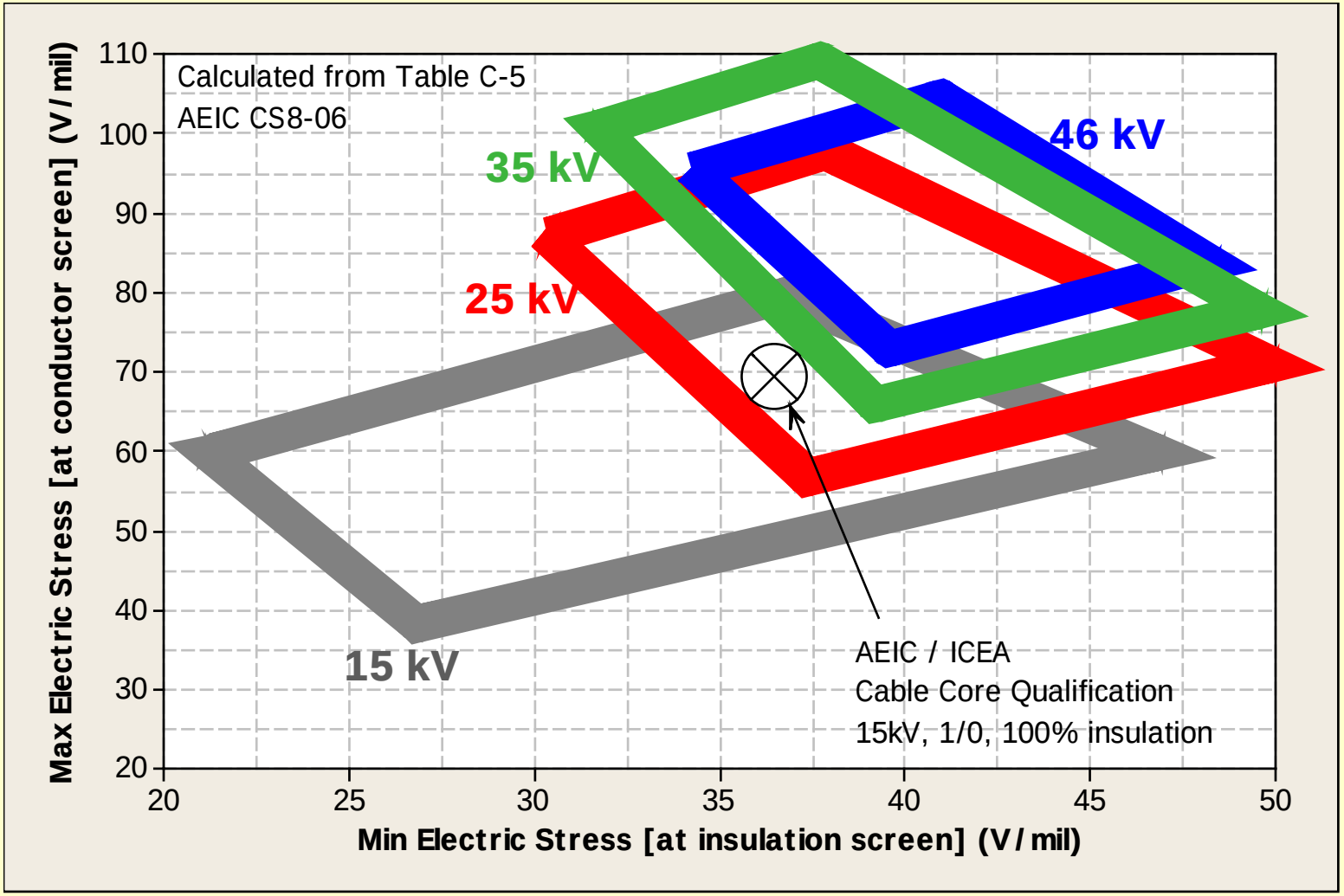
1000h at 75/80C with 6kV/mm applied



Min, Max & Mean Stresses



MV Stresses from AEIC / ICEA



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Impact on HV design methods

$$E_{Design} = \frac{E_{Breakdown}}{K_{Thermal} K_{Age} K_{Safety}}$$

Breakdown Strength

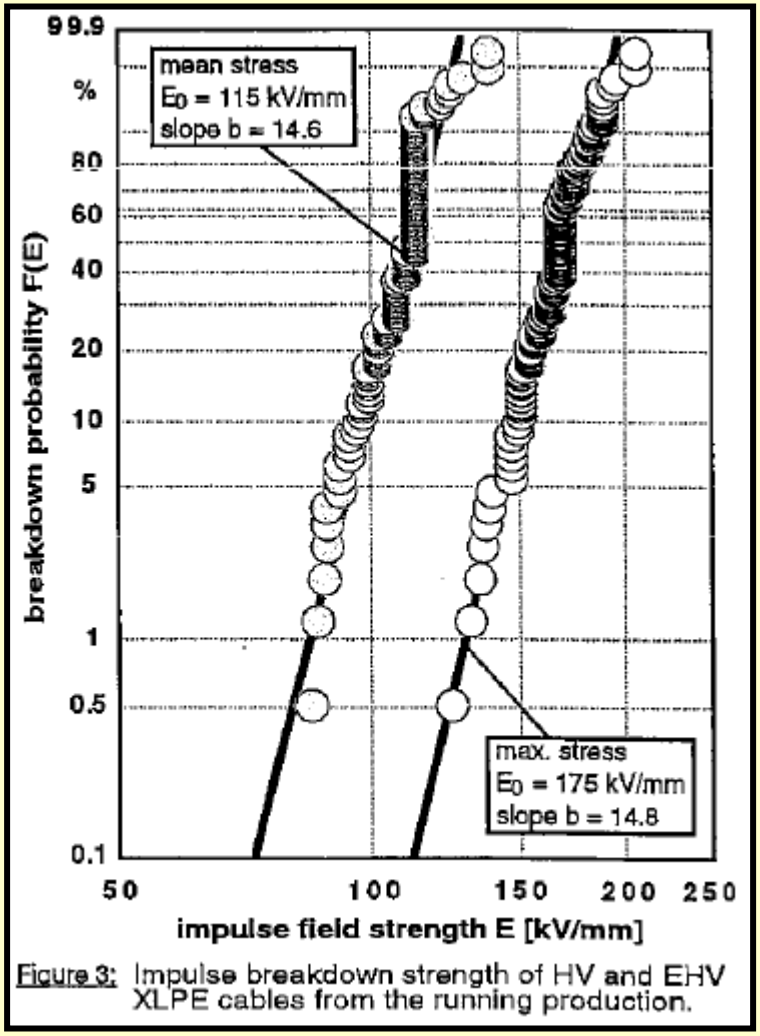

Figure 3: Impulse breakdown strength of HV and EHV XLPE cables from the running production.

Pesche Jicable 1995

Example - Uncertainty in Ageing Factor

$$k_1 = \sqrt[12]{\frac{30 \times 365 \times 24}{1}} = 2.83$$

n (@ 30 yrs)	k_1
13	2.6
12	2.8
11	3.6

Life (yrs) (@ n=12)	k_1
20	2.7
30	2.8
40	2.9

The 14.4mm estimate
could be as high 17mm or as low as 13mm

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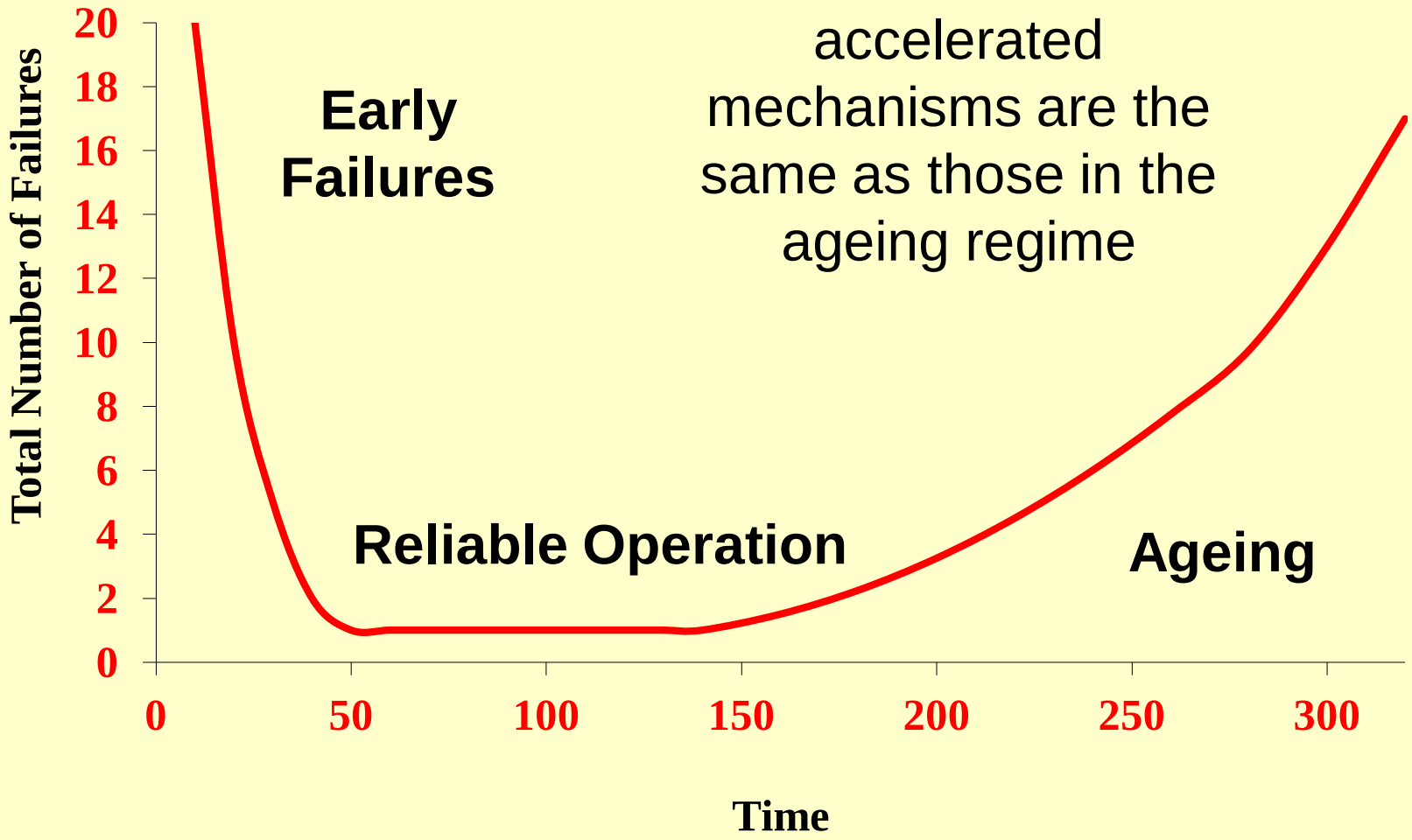
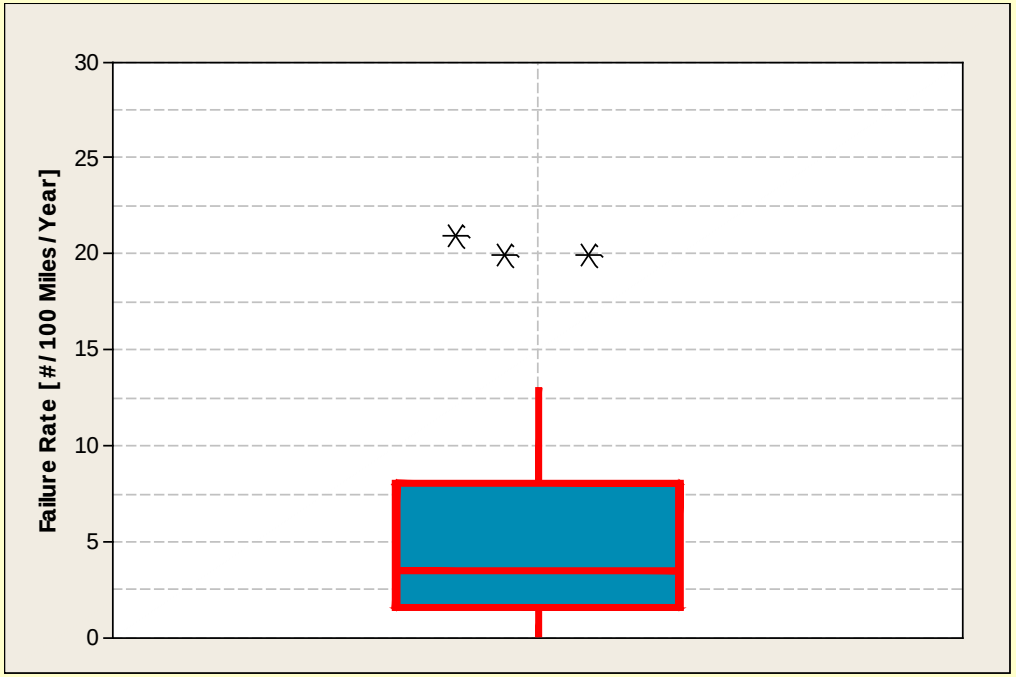
Bathtub Reliability Curve

We need to show that accelerated mechanisms are the same as those in the ageing regime

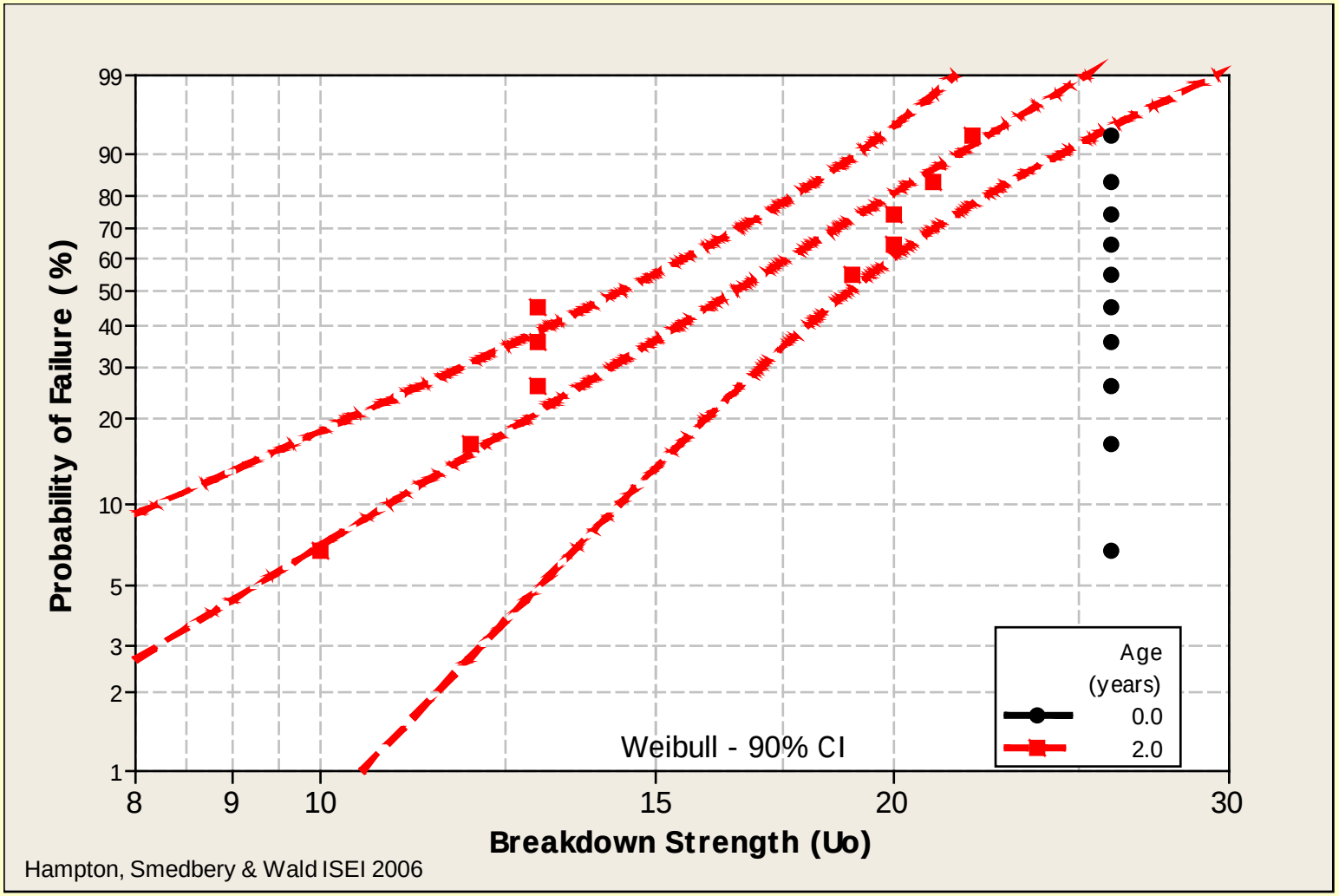


- We tend to track service failures as a lumped rate rather than a function of time



- ACLT results can potentially be related to service performance
- We define quality (AWTT, CENELEC) of accelerated tests by absolute breakdown strength & retained breakdown

MV Qualification – 2 year data

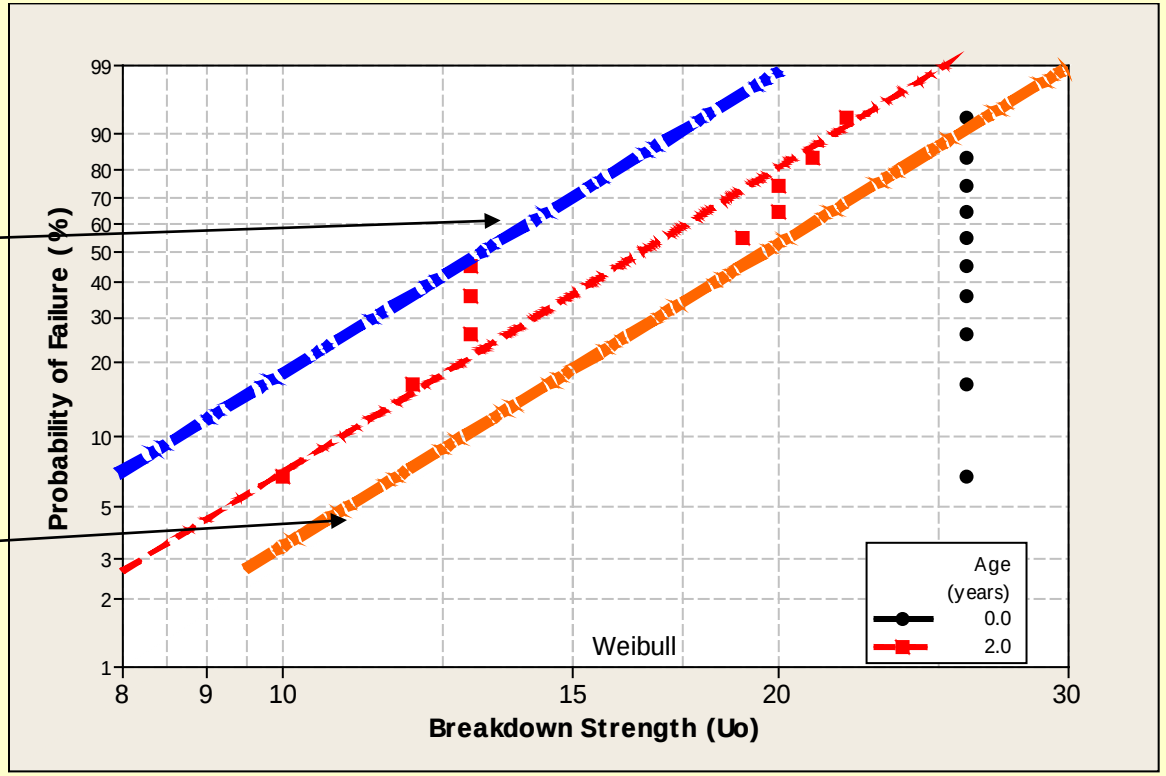


Qualification – adjustment

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

Longer, Larger

Shorter, Smaller



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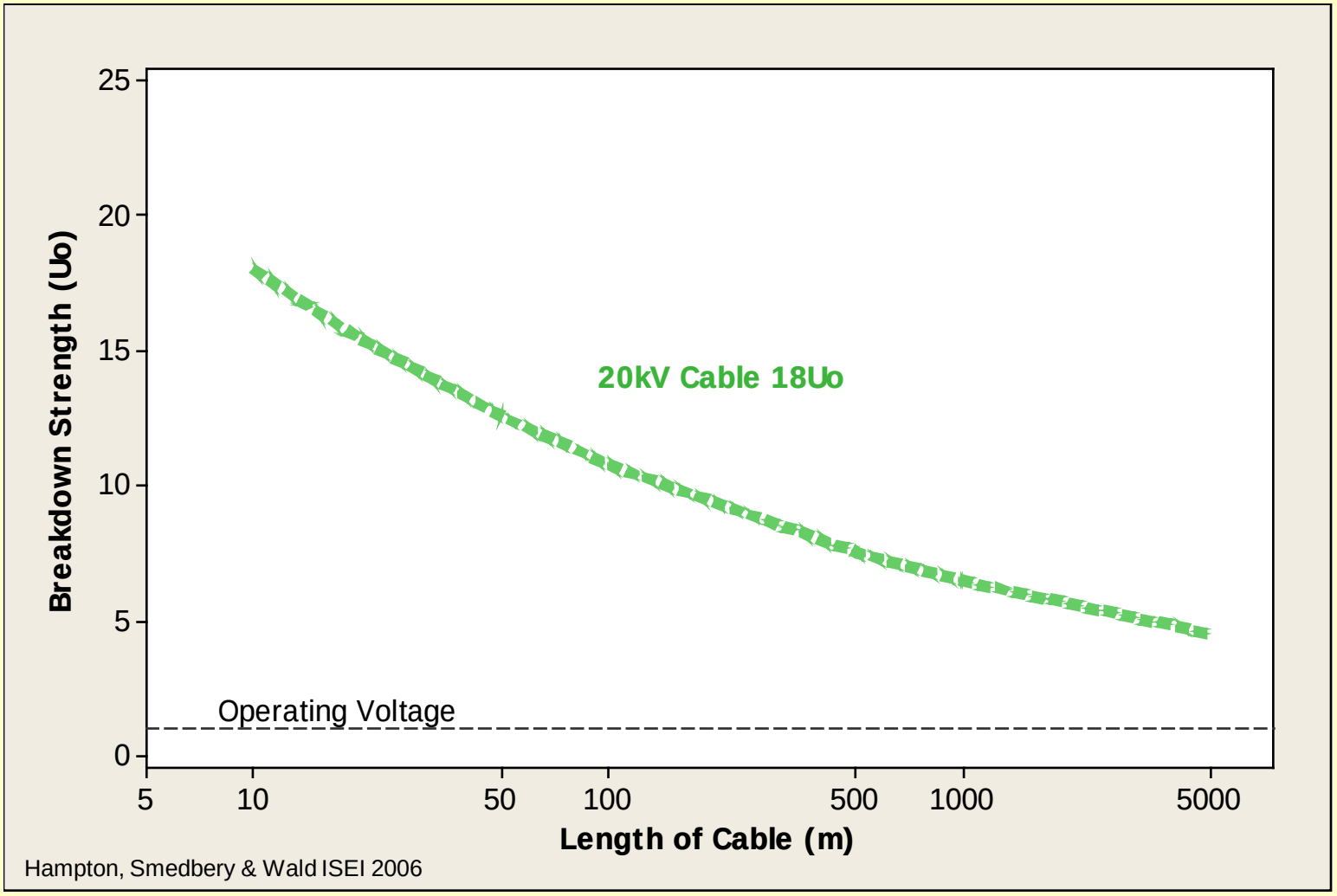
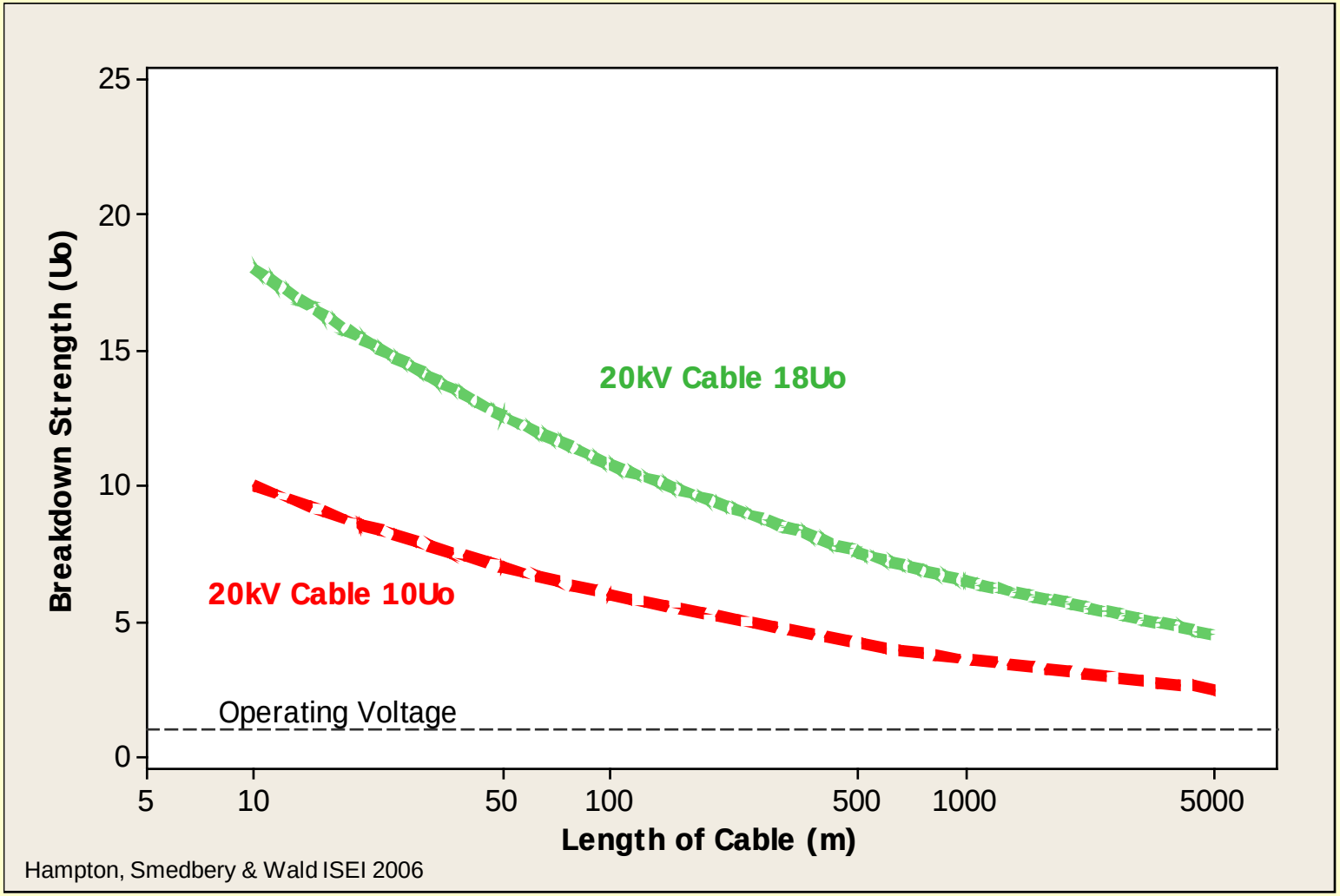
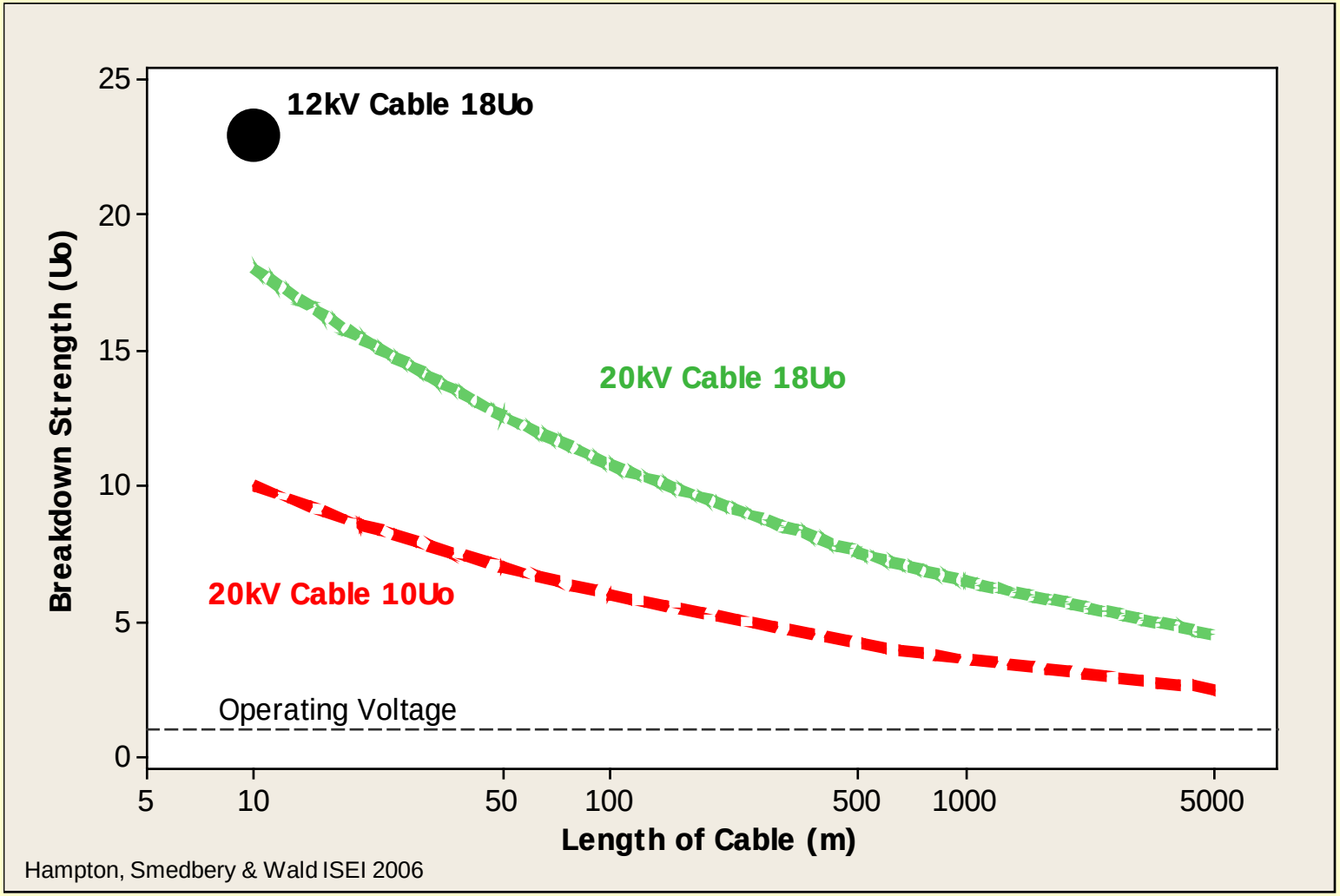
How does length change things



What if only have the min req



What if we qualified a small cable



Conclusions

- Data from existing protocols are useful
- Data need to be handled carefully

Open Issues

- How do both test and service data get considered
- How are accessory interactions included
- How does the full test experience get included

Thank You