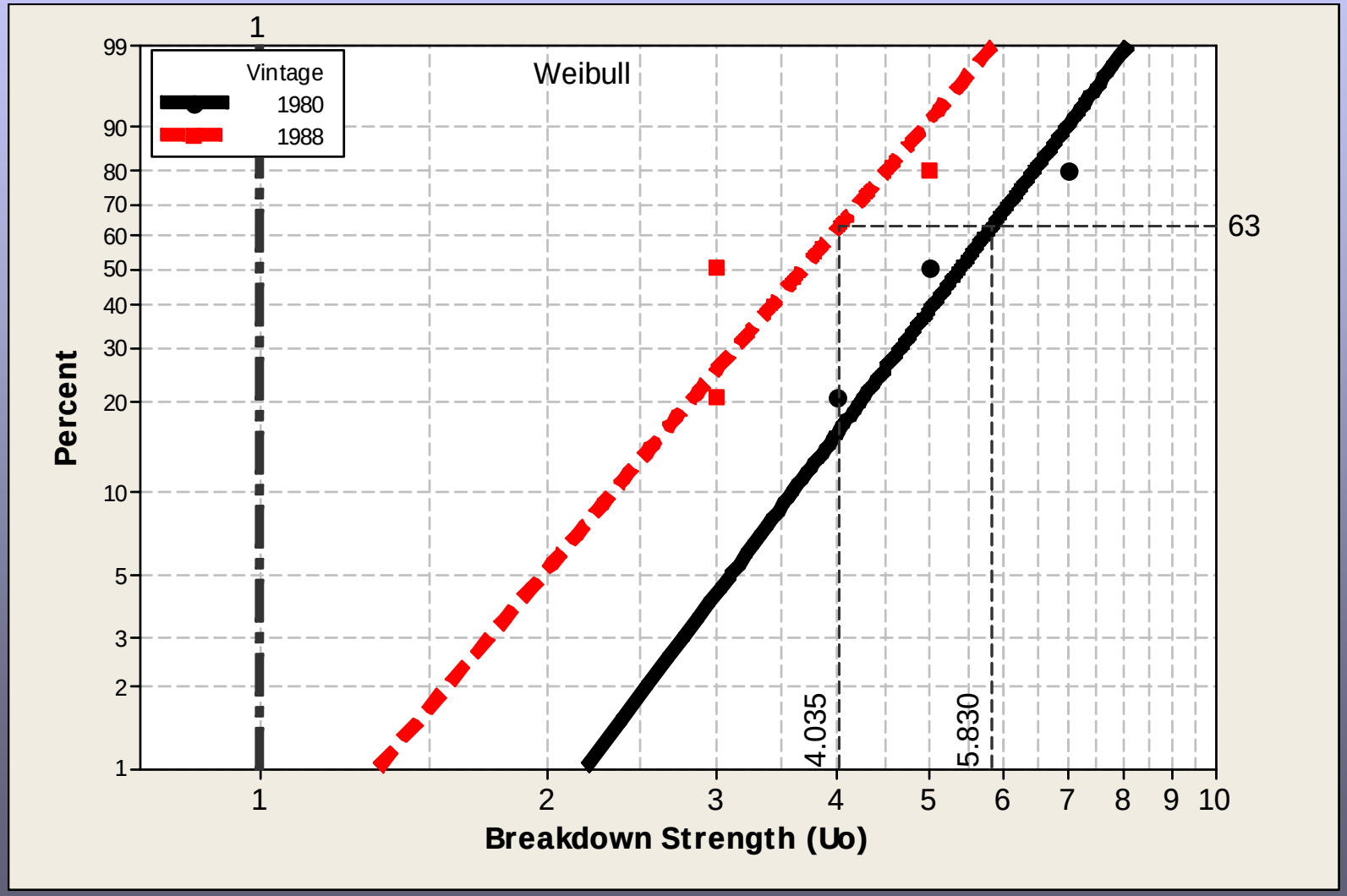
Upgrading Of Existing Approval Protocols to enable detailed assessment of Extruded MV Cable Performance

Nigel HAMPTON, Rick HARTLEIN
NEETRAC, Georgia Tech, USA,
nigel.hampton@neetrac.gatech.edu

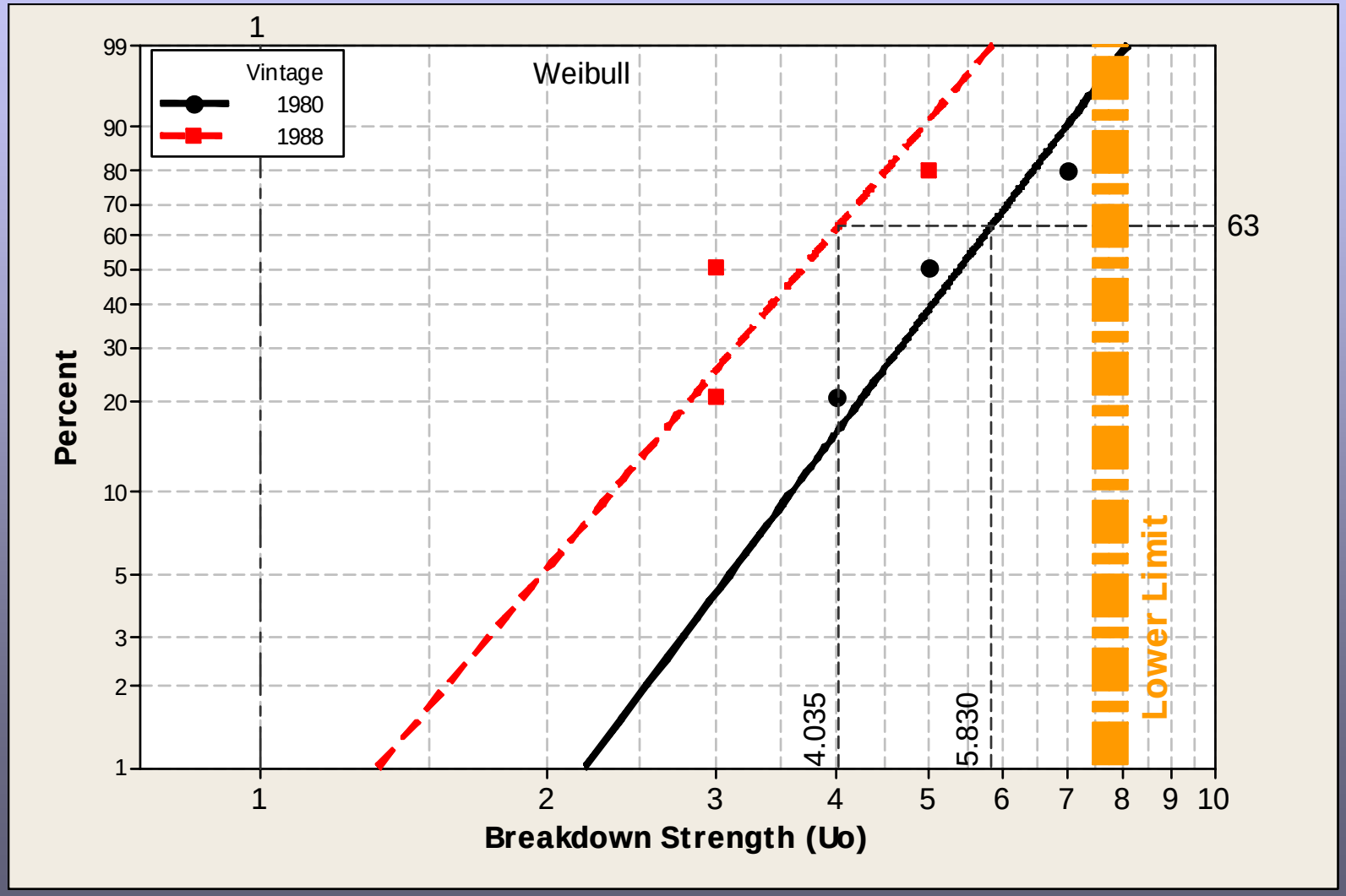
Background

- Cable users and cable manufacturers have derived significant benefit in system reliability from improved medium voltage (MV) cable quality.
- One of the important elements has been the use of recognised qualification tests CENELEC HD605, ICEA S-94-649 and IEEE 1407.
- These tests generally have well defined ageing and evaluation procedures.
- The associated “success criteria”, serve to discriminate and assure that cable users can be certain of minimum levels of cable performance.

Performance of Early Designs



Exclusion Limits



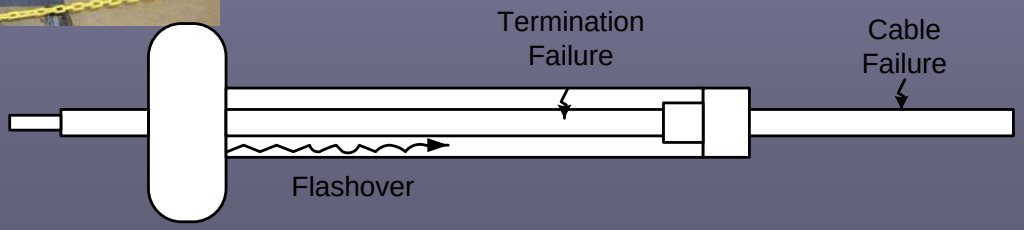
Present Issues

- Users are now wishing to understand more about the cables they use – they ask more than whether they pass / fail the criteria.
- Early cable systems tended to have low breakdown strengths, especially after aging. Thus it was relatively straightforward to achieve cable breakdowns.
- Improvements in the quality of cable has led to an increase in dielectric strength. This leads to the increased test issues.

Test Issues

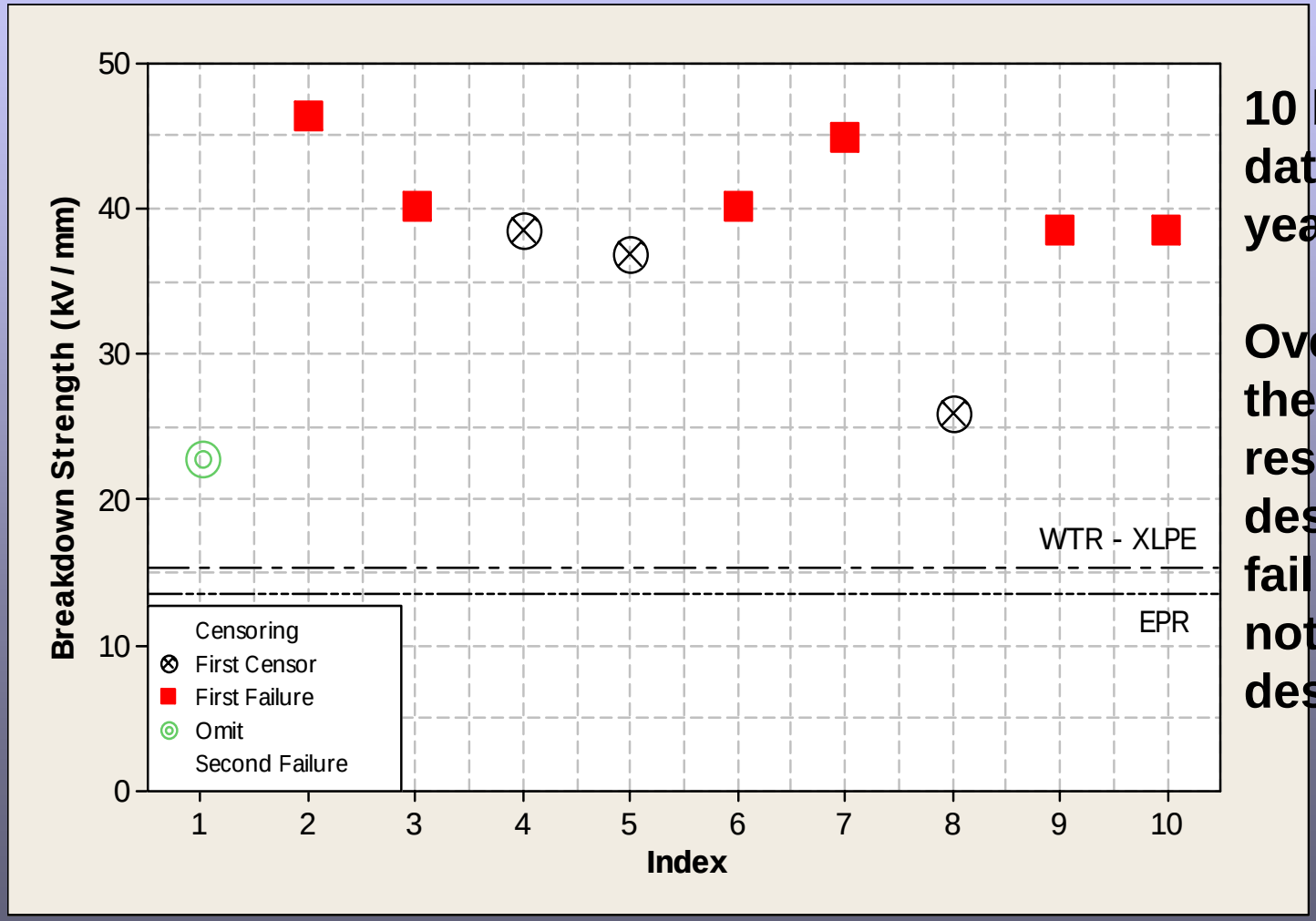
MV cables undergoing ac breakdown testing after long term wet ageing

Types of test results – schematic showing the types of failures under test



What are the consequences of these un expected failure modes?

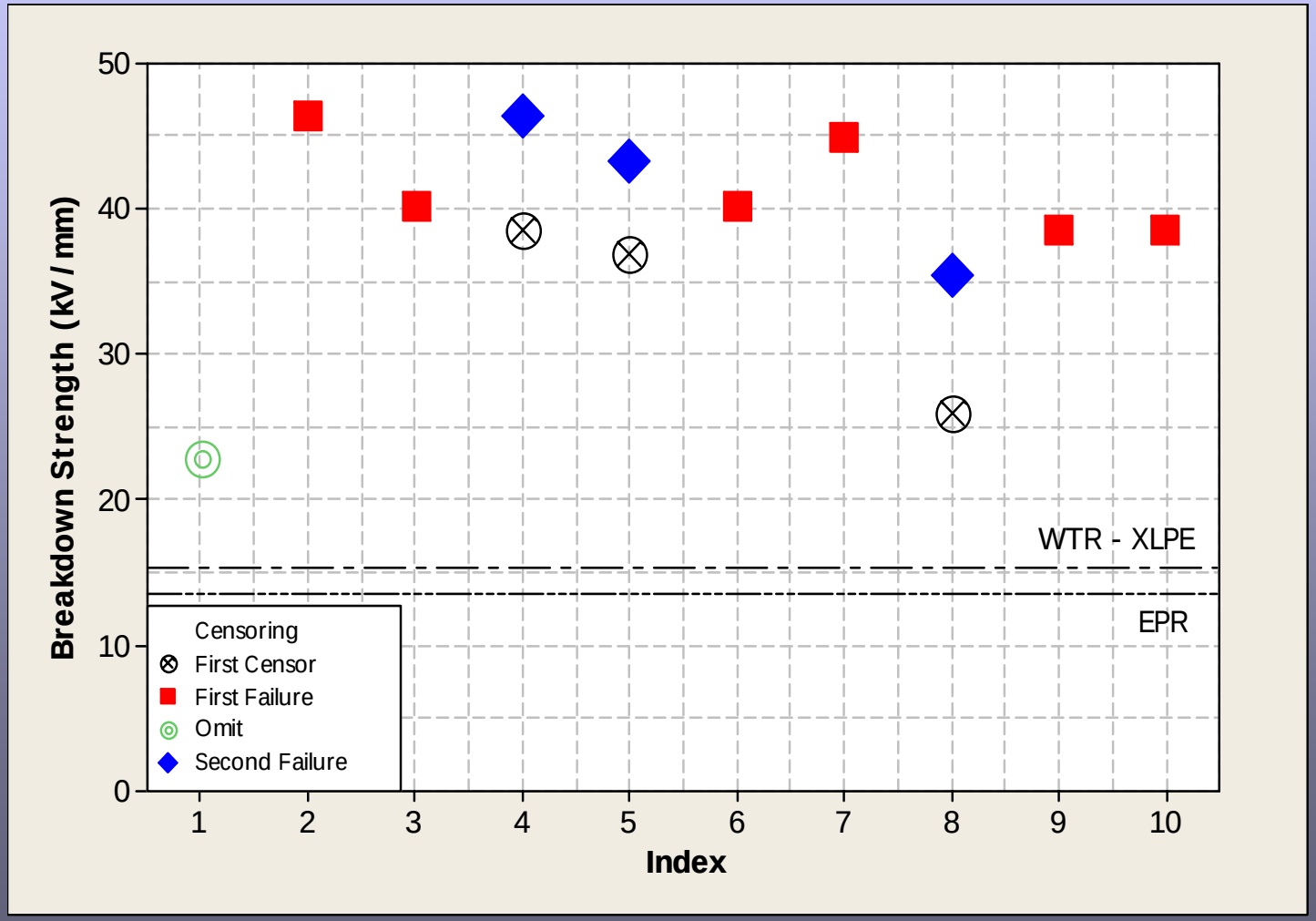
Test Data 1



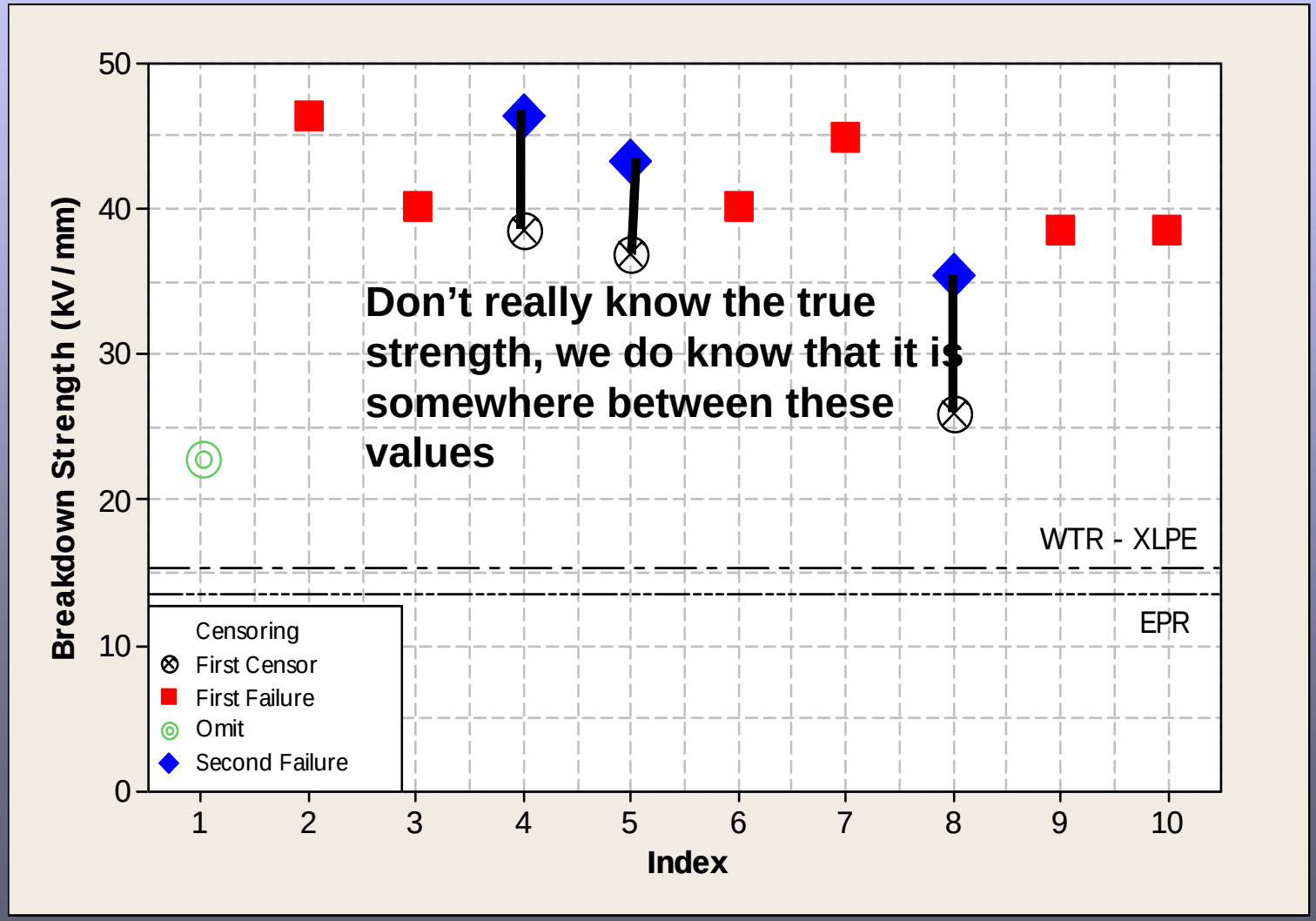
10 breakdown data after one year of ageing.

Overall 60% of the first tests resulted in the desired type of failure; 40% did not fail as desired.

Test Data 2


Breakdown Strength (kV / mm)
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
Index
WTR - XLPE
EPR
Censoring
First Censor
First Failure
Omit
Second Failure

Test Data 3


Breakdown Strength (kV / mm)
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
Index
Don't really know the true strength, we do know that it is somewhere between these values
WTR - XLPE
EPR
Censoring
First Censor
First Failure
Omit
Second Failure

Options for Data Analysis

	Breakdown Strengths for selected treatments (kV/mm)			
	a	**b**	**c**	**d**
Failures	***10***	***10***	***6***	***6***
Censors	***0***	***0***	***4***	***4***
1	23	23	>23	>23
2	47	47	47	47
3	40	40	40	40
4	38	47	>38	>38 <47
5	37	43	>37	>37 <43
6	40	40	40	40
7	45	45	45	45
8	26	35	>26	>26 <35
9	39	39	39	39
10	39	39	39	39

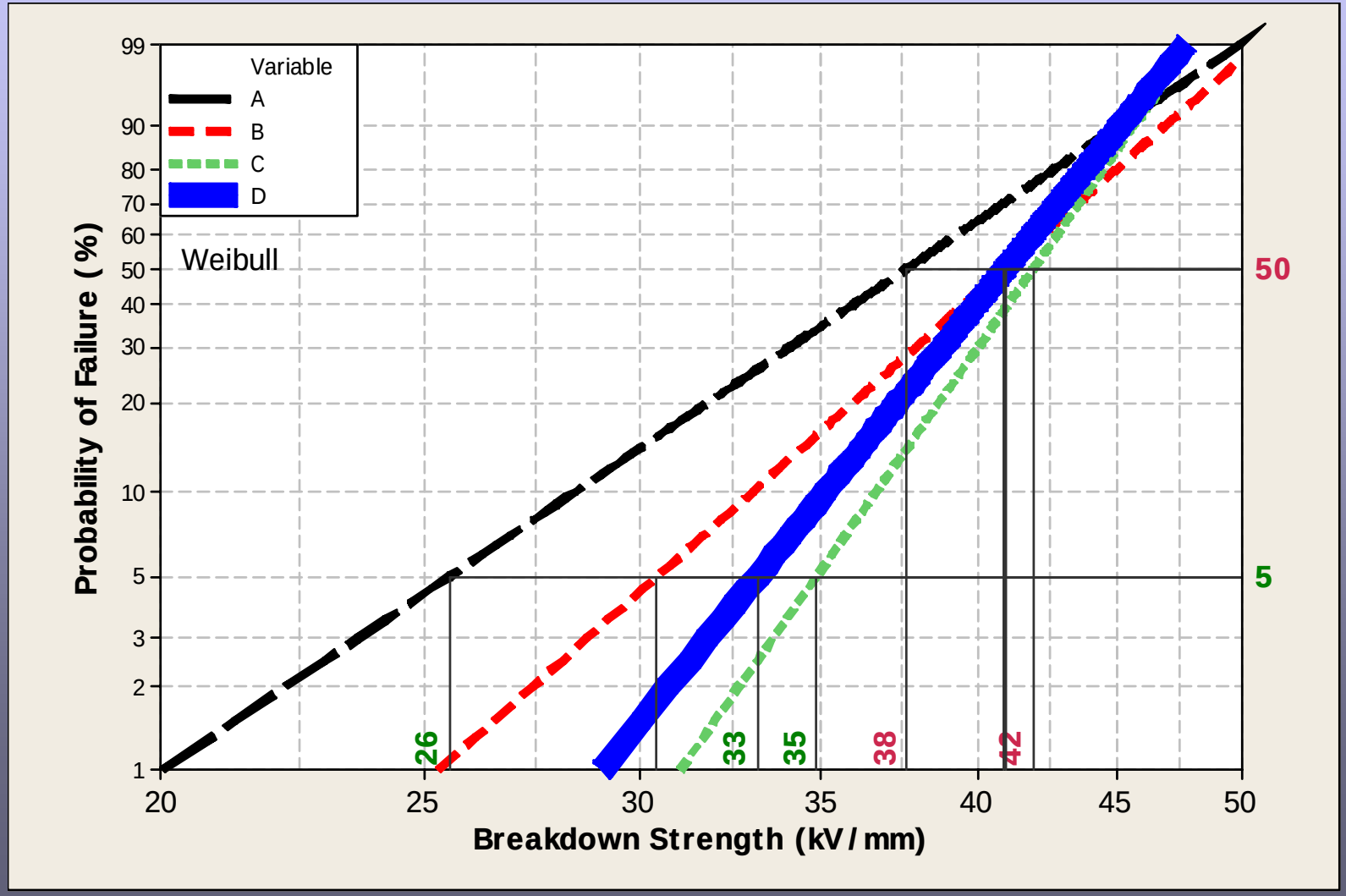
a) first tests as 'real' failures

b) first and any second retests as 'real' failures

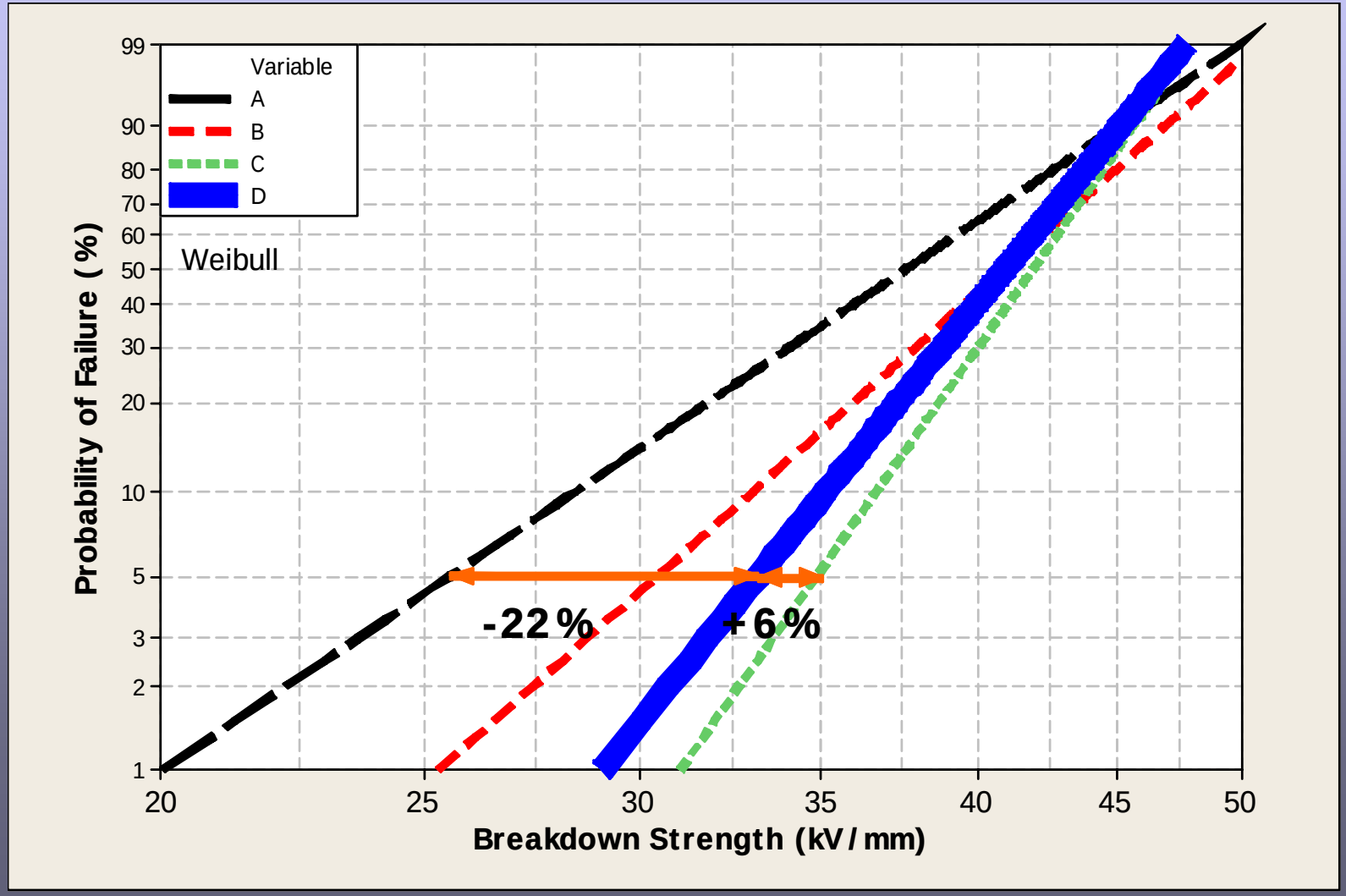
c) censored first tests and omitted data as simple censors – no retests included

d) omitted data as simple censored and first censor and second failure data as intervally censored data

Analysis of the different options



Analysis of the different options



If Censors are a fact of life – how do we protect ourselves against them?

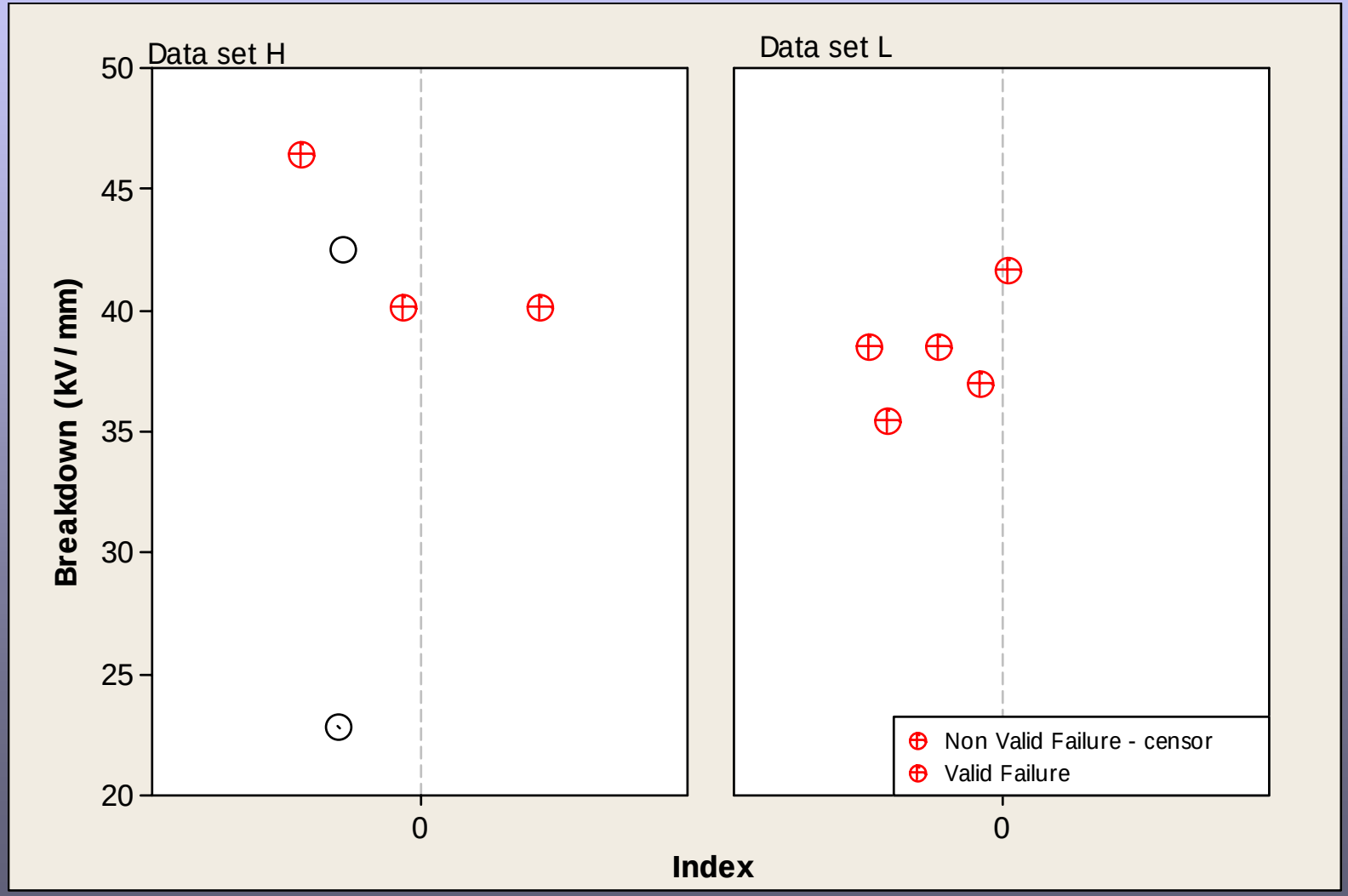
How Many Samples to Age?

ICEA and CENELEC protocols require a min of three & six "good" cable breakdowns.

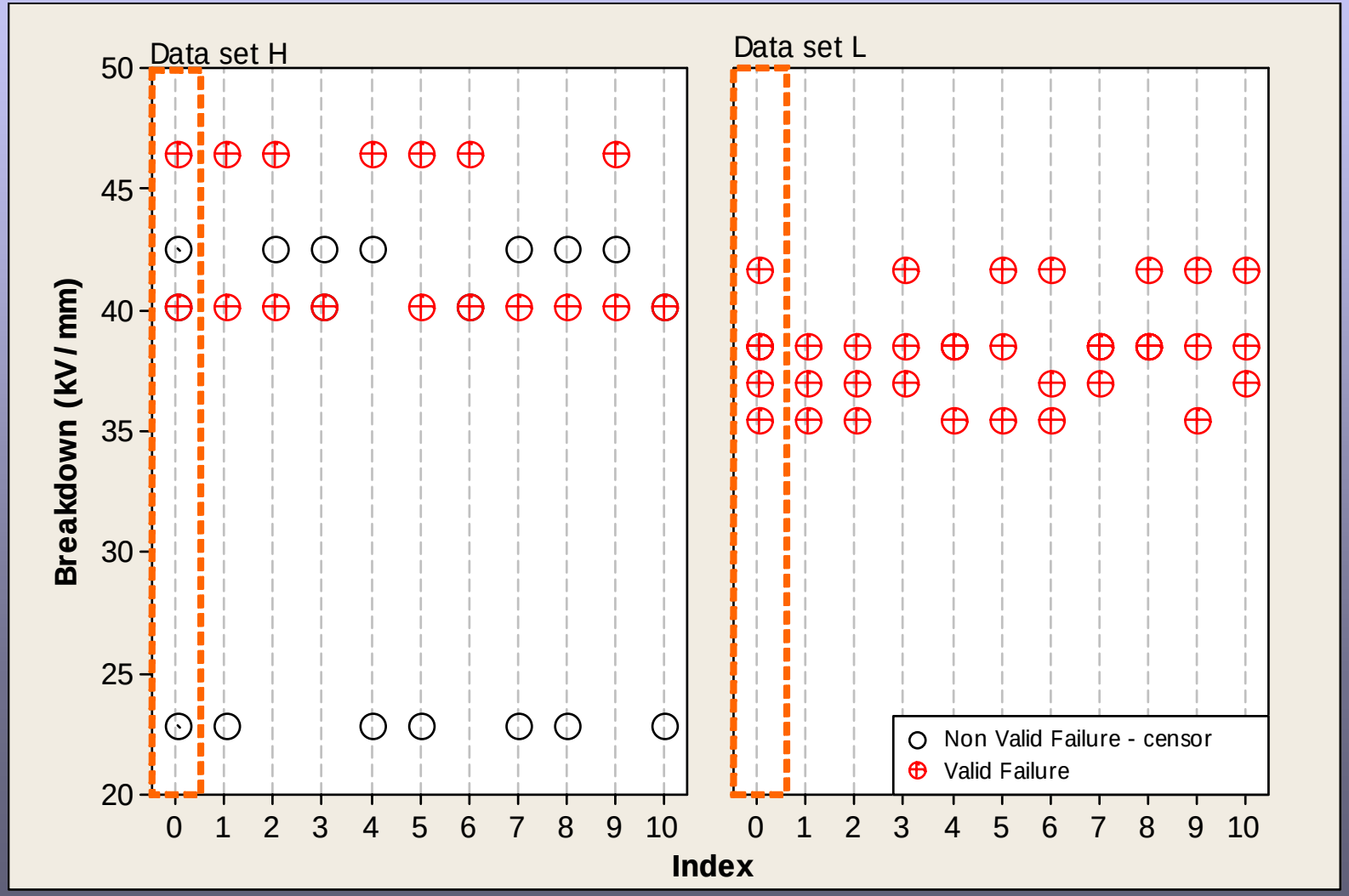
Years ageing	Portion Censored (%)	Number of final failures required / Number of test samples to be aged to normally achieve the required failures
0	35	3 / 5 6 / 9
1	30	3 / 5 6 / 8
2	30	3 / 5 6 / 8
5	5	3 / 4 6 / 7

Consequence of testing too few samples?

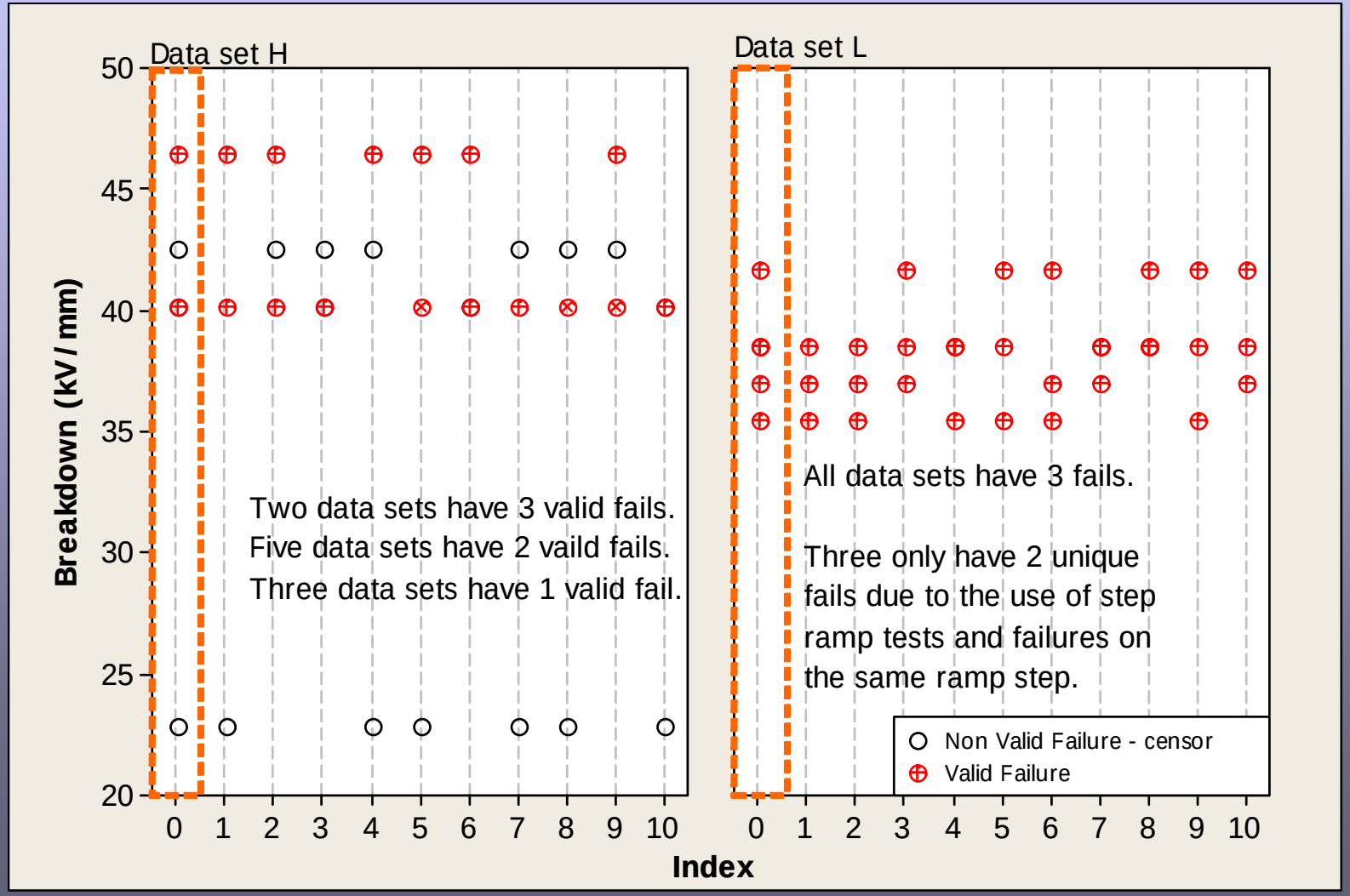
Number of Tests Required 1



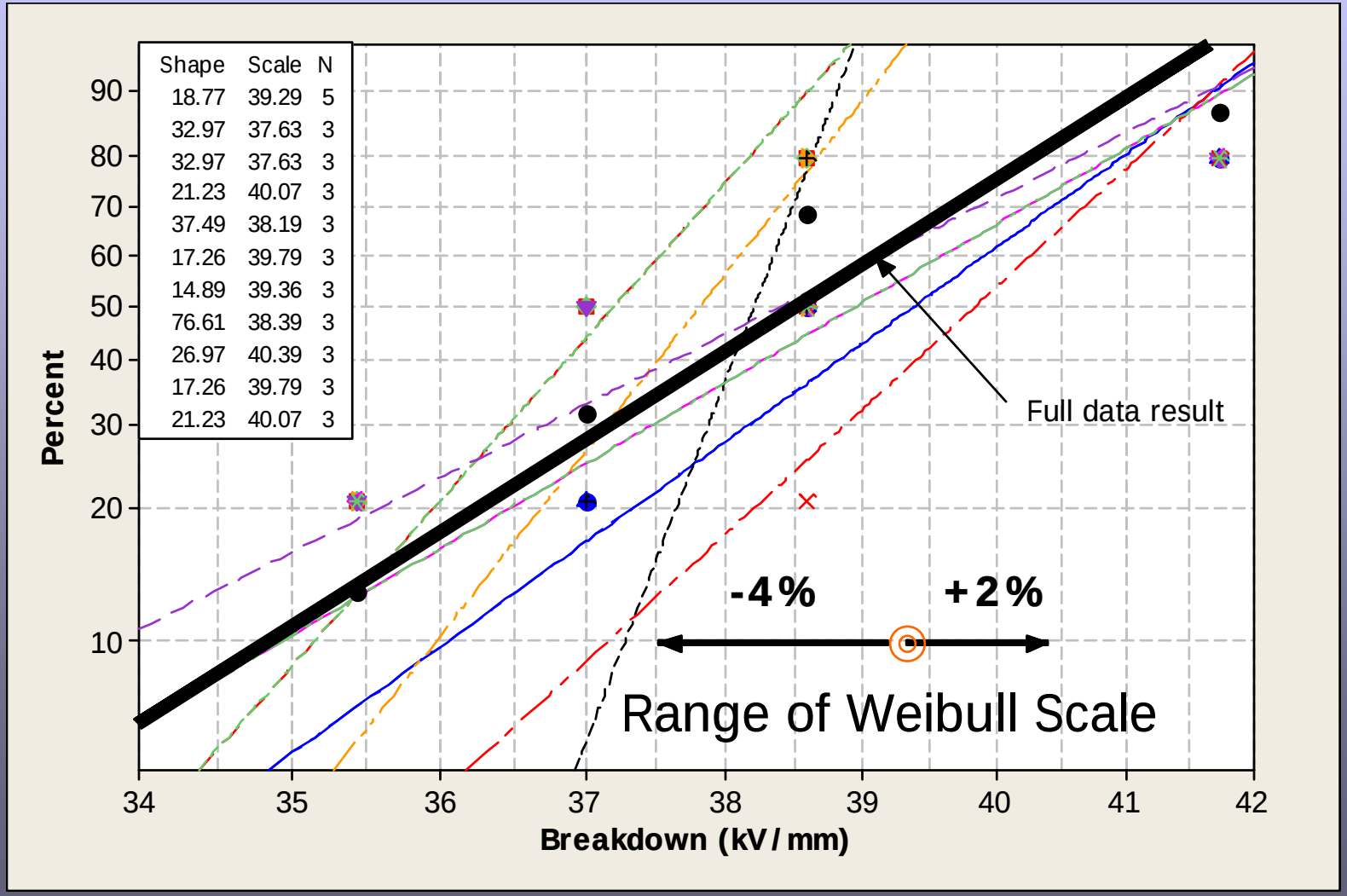
Number of Tests Required 2



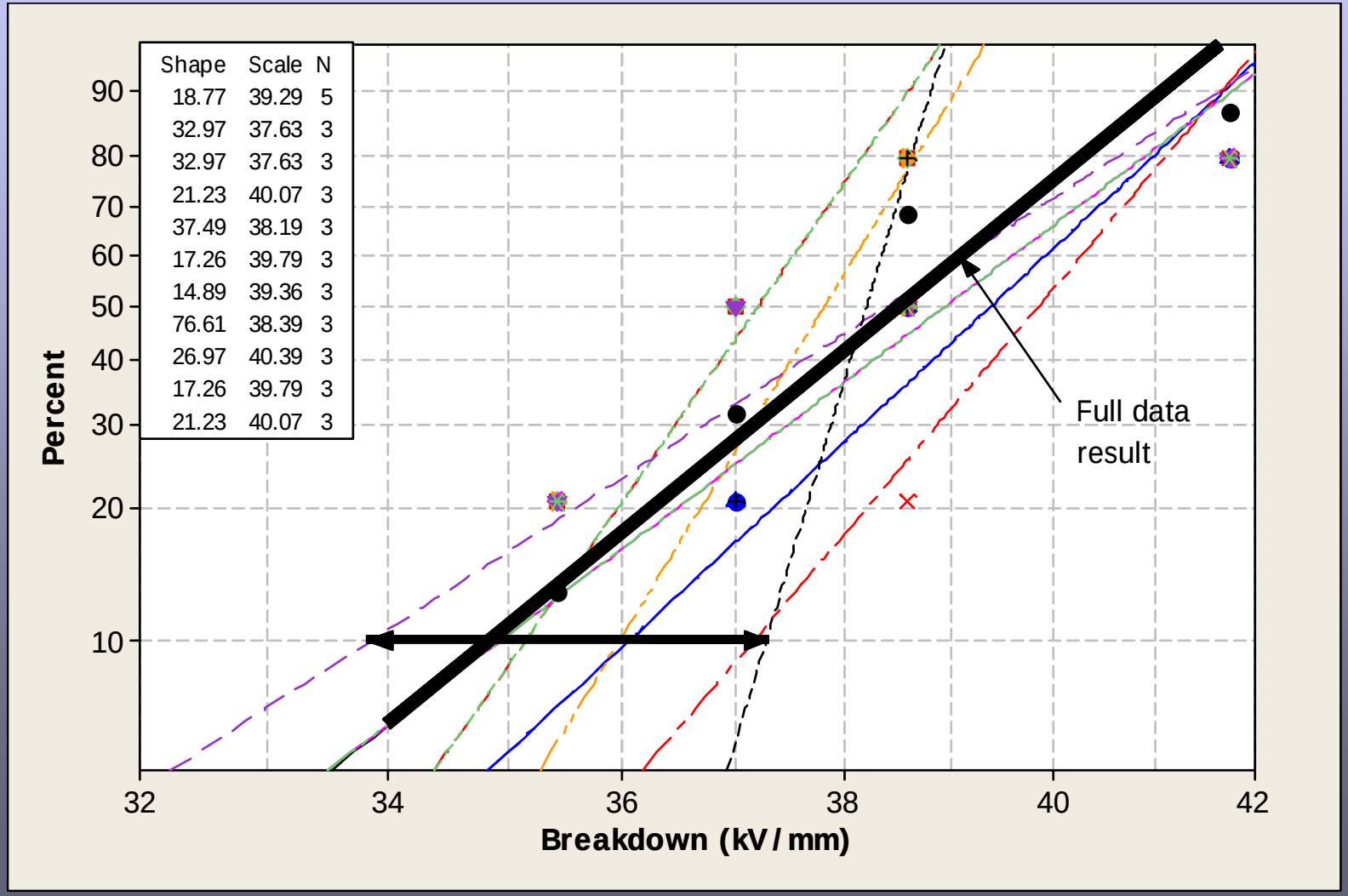
Number of Tests Required 3



Analysis of Separate Groups 1



Analysis of Separate Groups 2



Conclusions 1

A number of changes could be made to the standard approval protocols to make then better suited to determining the performance of the cables; these include:

- Increased number of samples in the ageing phase to allow for the potential censored data when the final breakdowns are completed
- Treat termination failures and flashovers as censored data
- When a censored result occurs, test a spare aged sample in preference to retesting a shortened length sample

Conclusions 2

A number of changes could be made to the standard approval protocols to make then better suited to determining the performance of the cables; these include:

- Subsequent tests on spare aged sample treated as a failure with the first censored data being a Right Censored Data (exact strength not known above this value)
- Use smaller voltage / time steps, retaining the same overall rate of rise, to reduce data with tied strengths
- Prior to a test program it is critically important to assess the size of the expected difference is sufficiently large to be detectable by the chosen sample sizes