Two Accelerated Wet Aging Tests for EPR Cables

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By

Ed Walcott, Bill Temple and John Smith III

General Cable

Outline

- Accelerated Water Treeing Test (AWTT)
- Accelerated Cable Life Test (ACLT)
- Differences between AWTT and ACLT
- Brief history and description of each test
- What they can tell us and what they cannot
  - Some examples

History of North American Tests

- Accelerated Water Treeing Test (AWTT)
  - A result of electrochemical water treeing
  - Resulted from early failures in the field on non-jacketed cables
  - Water filled pipes were first utilized in the 1970's to assess wet performance & water tree resistance of insulated cables
- Accelerated Cable Life Test (ACLT)
  - Resulted from a need for shorter test period than AWTT
  - A need to better determine cable life
  - Need for comparative testing of insulation systems

Differences in Wet Aging Tests

- AWTT
  - 3 Vg voltage stress
  - Water in pipes
  - Controlled insulation shield Temp in water
    - Achieves approx. 45 ˚C
  - Water in pipes not at a controlled temp
  - Retained ac voltage breakdown strength
  - Specified one year test

- ACLT
  - 3 or 4 Vg voltage stress
  - Water in tanks
  - Controlled conductor Temp in air or water
    - Achieves approx 15 ˚C less in water than location in air
  - Water temp in tank can be controlled to a set point

  Time to failure or retained breakdown strength
  - Test time only limited to number of samples used

1979
Accelerated Water Treeing Test (AWTT)

- Introduced in AEIC CS6 -79
  - For information only
  - Two methods
    - 1000 Hz for 30 days
    - 60 Hz for 120 days
  - 2 HVTT tests and tree count

1987
Accelerated Water Treeing Test (AWTT)

- AEIC CS6-87
  - 2 HVTT and after 120 days
    - Minimum withstand 260 volts/mil
  - 2 Impulse tests after 120 days for information only
  - Tree count after 120 days
  - 2 HVTT samples continued for 6 months and 1 year for information only

1996
Accelerated Water Treeing Test (AWTT)

- AEIC CS6 -96
  - 3 HVTT samples each required for 120, 180 and 360 days
  - No Impulse testing
  - Minimum withstand 300 volts/mil after 120 days
  - Tree count after 120 days

2005
Accelerated Water Treeing Test (AWTT)

- AEIC CS8 and ICEA S-94-649 (682)
  - 3 HVTT samples each required for 120, 180 and 360 days
  - Minimum withstand voltage for 120, 180 and 360 days
  - Tree count after 120 days
  - Tube setup defined more definitively
  - Material qualification
  - Manufacturer qualification

AWTT Test Protocol

- Per ICEA standards and AEIC specification for Qualification testing
- #1/0 AWG (19w), 175 mil wall 15 kV concentric neutral, no outer jacket
- Sample are preconditioned with 14 cycles (8h on, 16h off) at emergency overload
- Cables placed in tubes filled with tap water
- Tap water maintained in conductor
- 3 Vg applied continuously, load cycled to achieve an insulation shield temp in water of 45˚C ± 3˚C
- HVTT breakdowns on 3 samples after 120, 180 and 360 days

AEIC AWTT Setup

AWTT Results Overview

- AWTT – What can we learn from it?
  – Cable compliance with Industry standards
    - Manufacturers' capability to produce acceptable product
  – Compatibility of extruded core materials for EPR insulated cables
  – Water Tree Resistance of the insulation

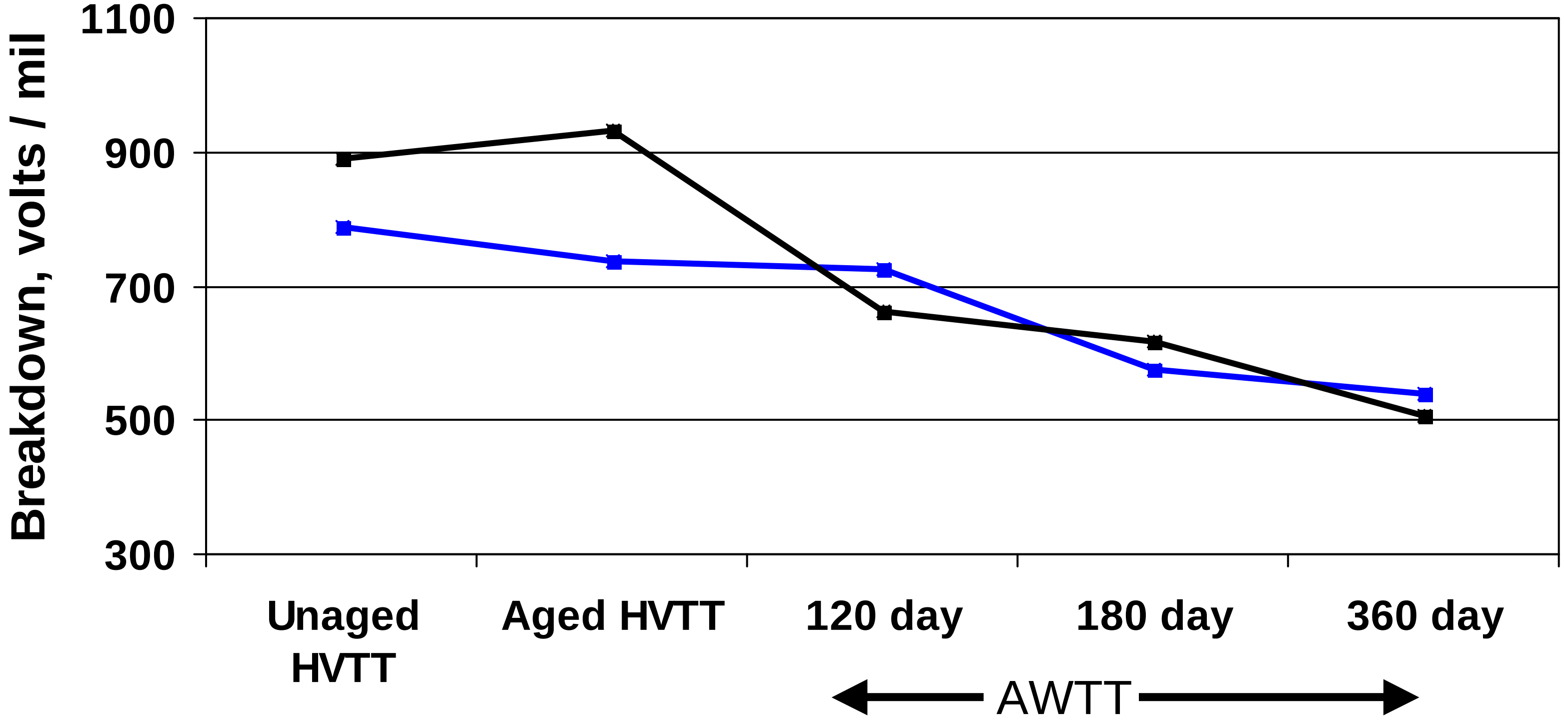
Diagnostic Tests Utilized for EPR Cables

Demonstrates compliance with Industry standards

Minimum ac Withstand Voltage Values V/mil (kV/mm)				
Prior to Cyclic Aging	After Cyclic Aging	After 120 Days of AWTT Aging	After 180 Days of AWTT Aging	After 360 Days of AWTT Aging
500(19.7)	500(19.7)	420(16.5)	340(13.4)	340(13.4)

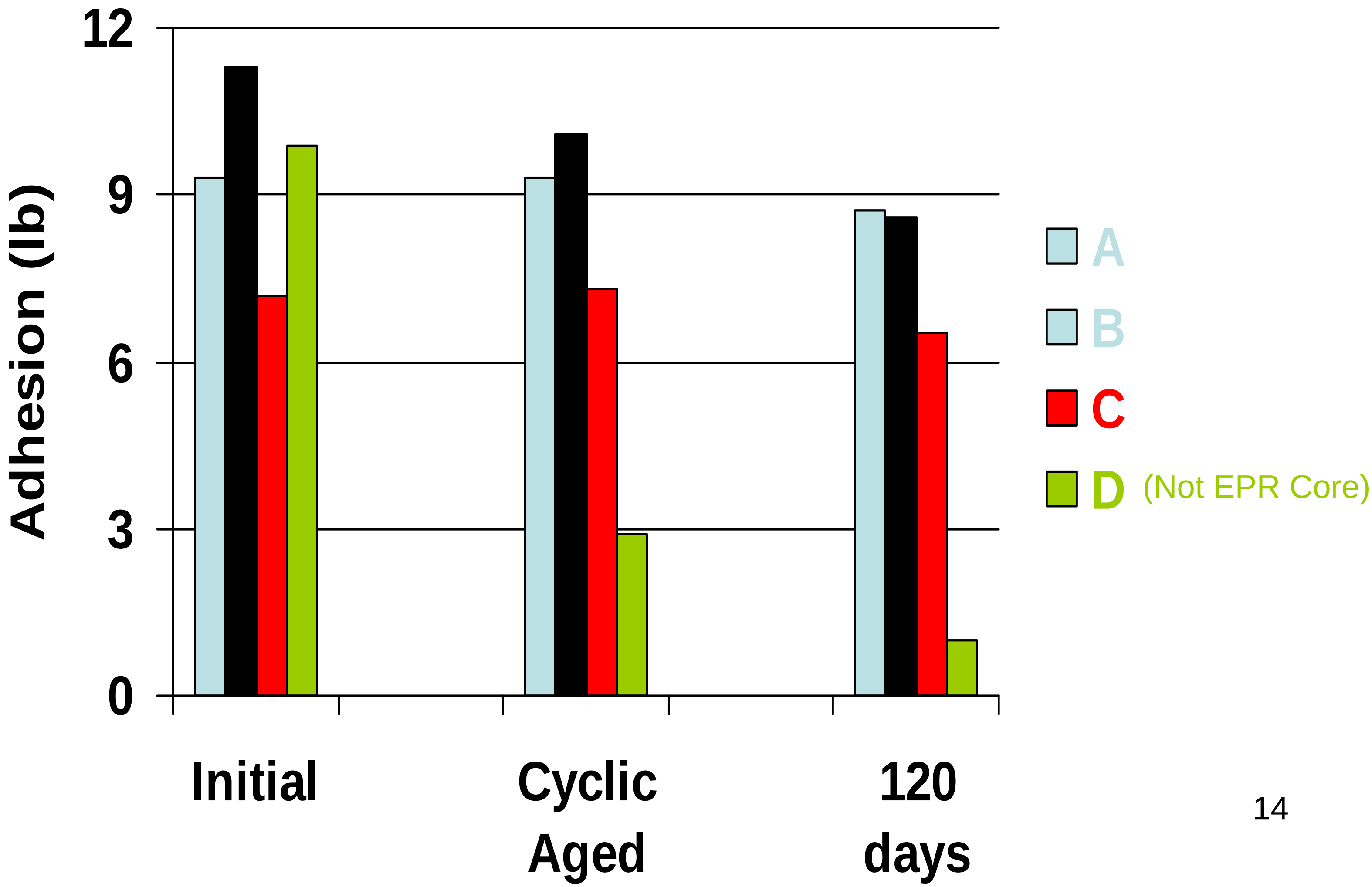
Typical EPR AWTT Trends

Weibull Eta values



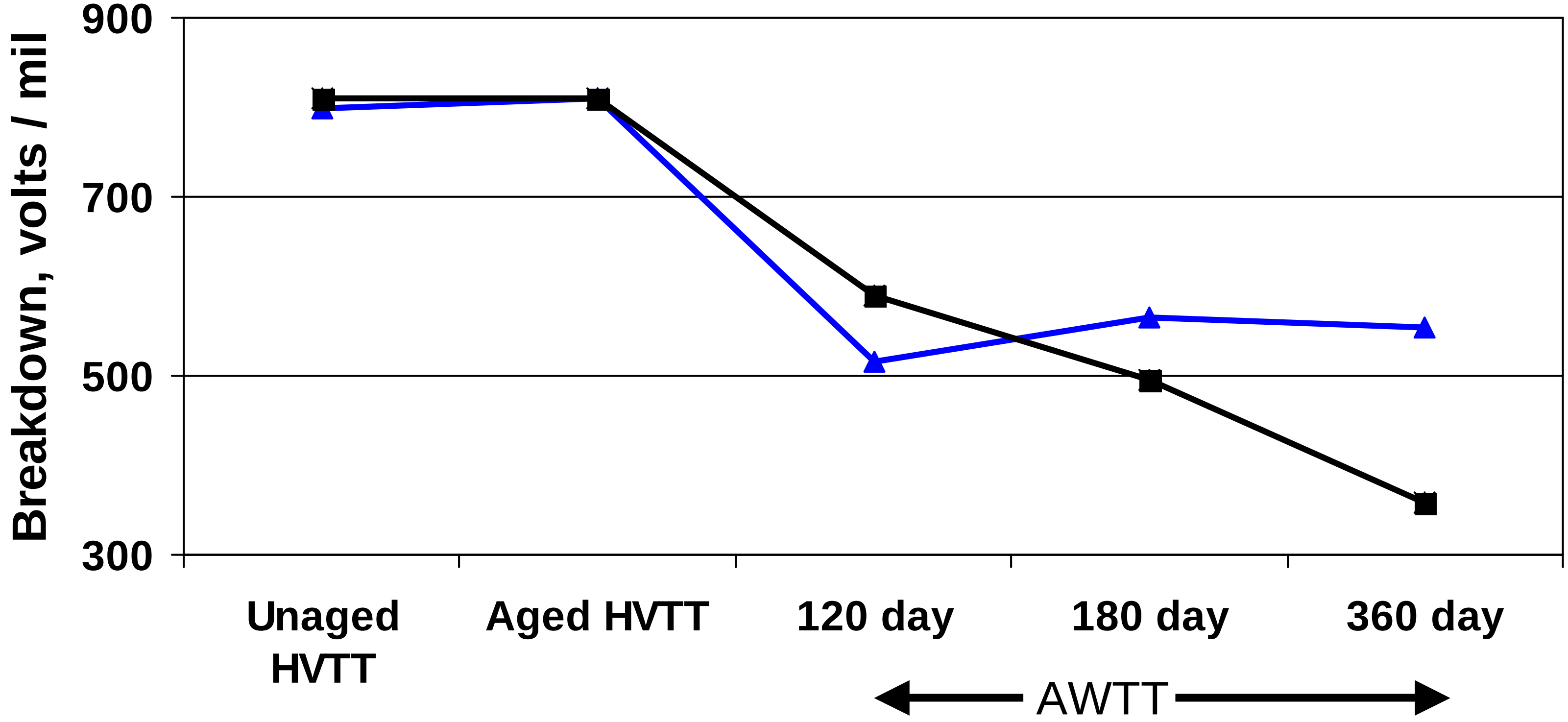
Diagnostic Tests Utilized for EPR Cables

- Extruded insulation shield adhesion stability



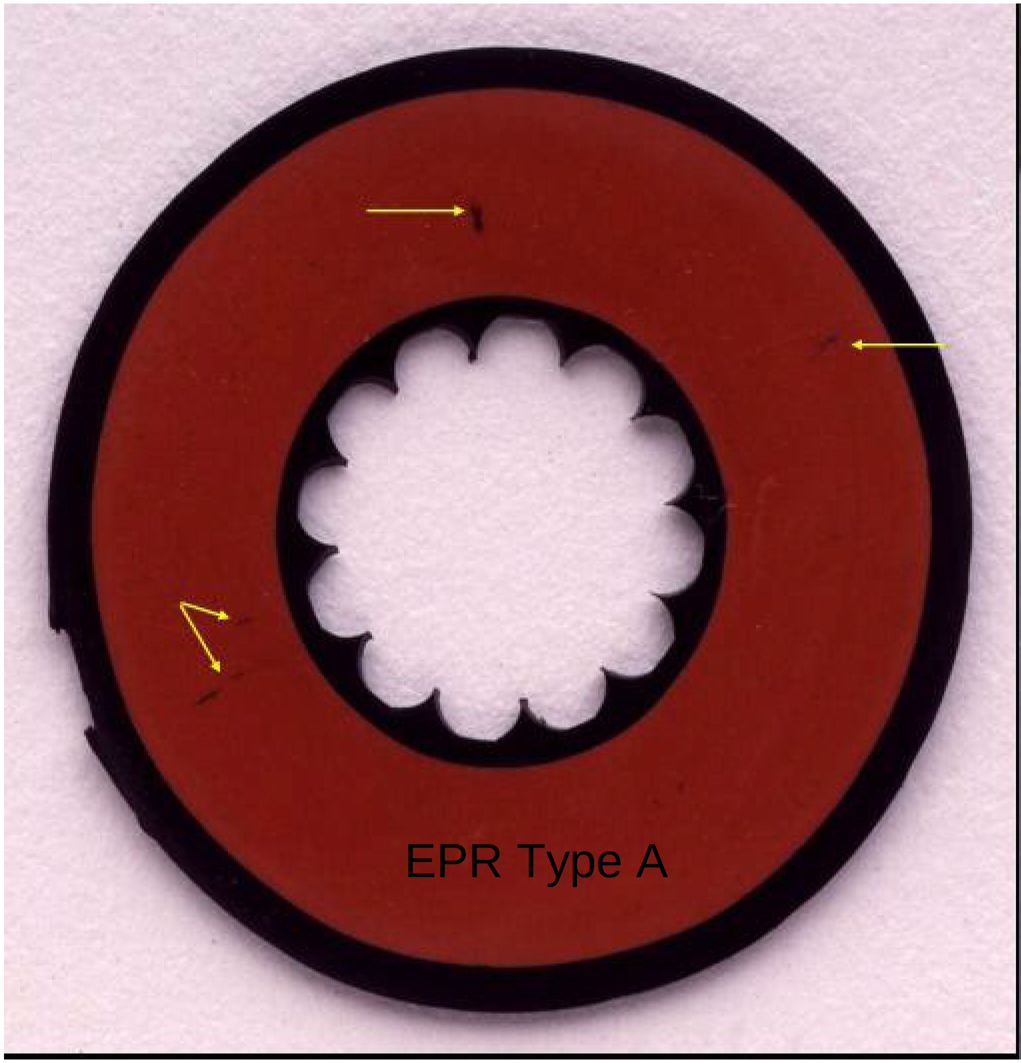
Diagnostic Tests Utilized for EPR Cables

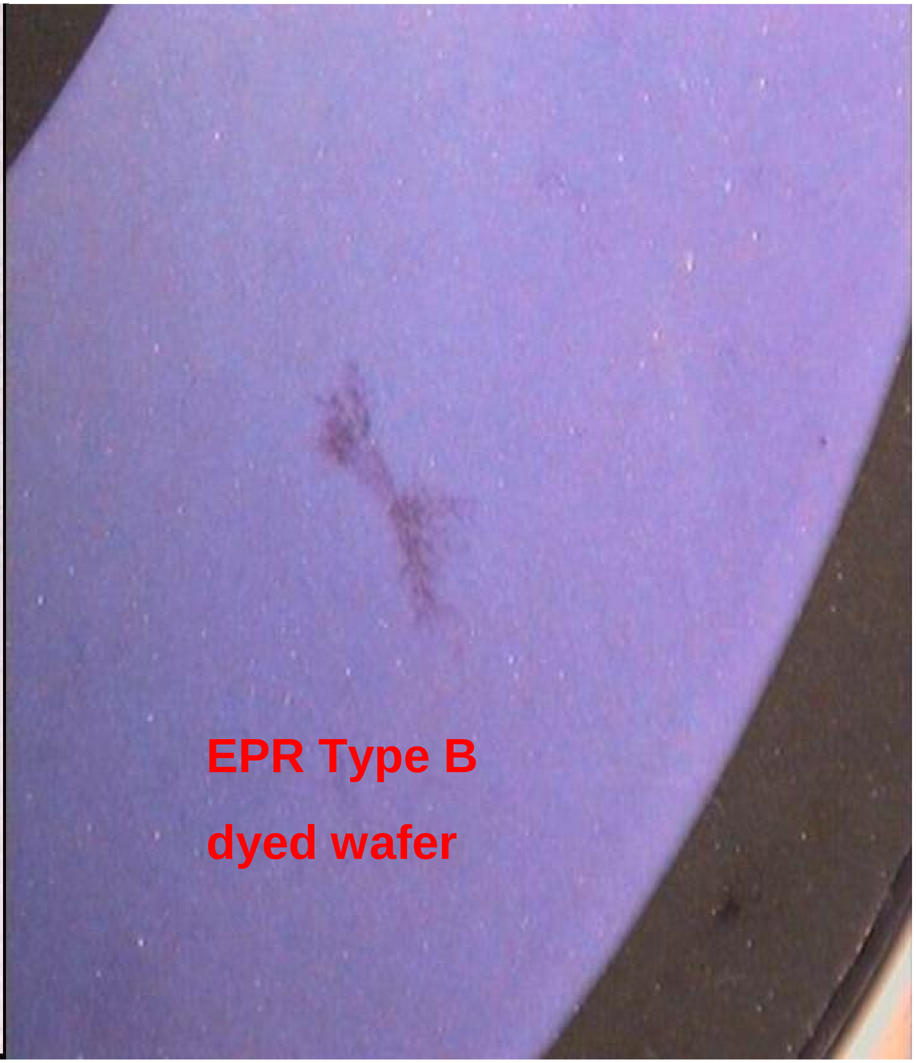
- Allows Intra-laboratory comparative analysis against other materials combinations (EPR with different conductor shields).



Diagnostic Tests Utilized for EPR Cables

- Water Treeing of EPR cables





AWTT Results Overview (Cont'd)

- AWTT – What it does not tell us!
  - Does not provide absolute predicted life
  - Inter-laboratory agreement as not been demonstrated
  - No correlation between HVTT breakdown strength and predicted cable life.
    - Higher HVTT values do not translate to longer life in service, i.e. EPR cables have lower breakdowns than TRXLPE cables but both have long service life.

Accelerated Cable Life Test (ACLT)

- Introduced in 1970’s to allow a statistical group of medium voltage cables samples to be tested in a common test medium
- 1981 Lyle & Kirkland IEEE Transactions Paper “An Accelerated Life Test for Evaluating Power Cable Insulation” ; MV cable tests started in ‘76
- Time-To-Failure has been the primary indicator of comparative cable life
- Compound and Cable Manufacturers have utilized the test to demonstrate cable life improvements since early 1980’s

Accelerated Cable Life Test (ACLT)

- EPRI RP 2713-02 1985-1993
  - Study the influence of electrical stress & temperature on wet cable laboratory aging
  - Correlate laboratory aging & field aging
  - Monitoring & Control of the aging parameters
  - Try to establish a relationship between Time-To-Failure & Remaining Breakdown Strength
- IEEE P1407 1998
  - Guide for Accelerated Aging Tests for Medium-Voltage Extruded Electric Power Cables Using Water-Filled Tanks

ACLT Protocol

- Generally #1/0 AWG (19w), 175 mil wall 15 kV; either core designs or cable designs
- Sample are preconditioned from 72-360 hrs @ 90˚C
- Cables placed in tanks filled with tap water (preferred)
- Tap water maintained in conductor
- 10-12 samples (16 ft to 23 ft) per tank
- Test voltage varies (3Vg, or generally,4Vg)
- Test temperature varies, load cycled (8h on, 16h off)
- Either time to failure or retained breakdown strength

Types of ACLT Protocols

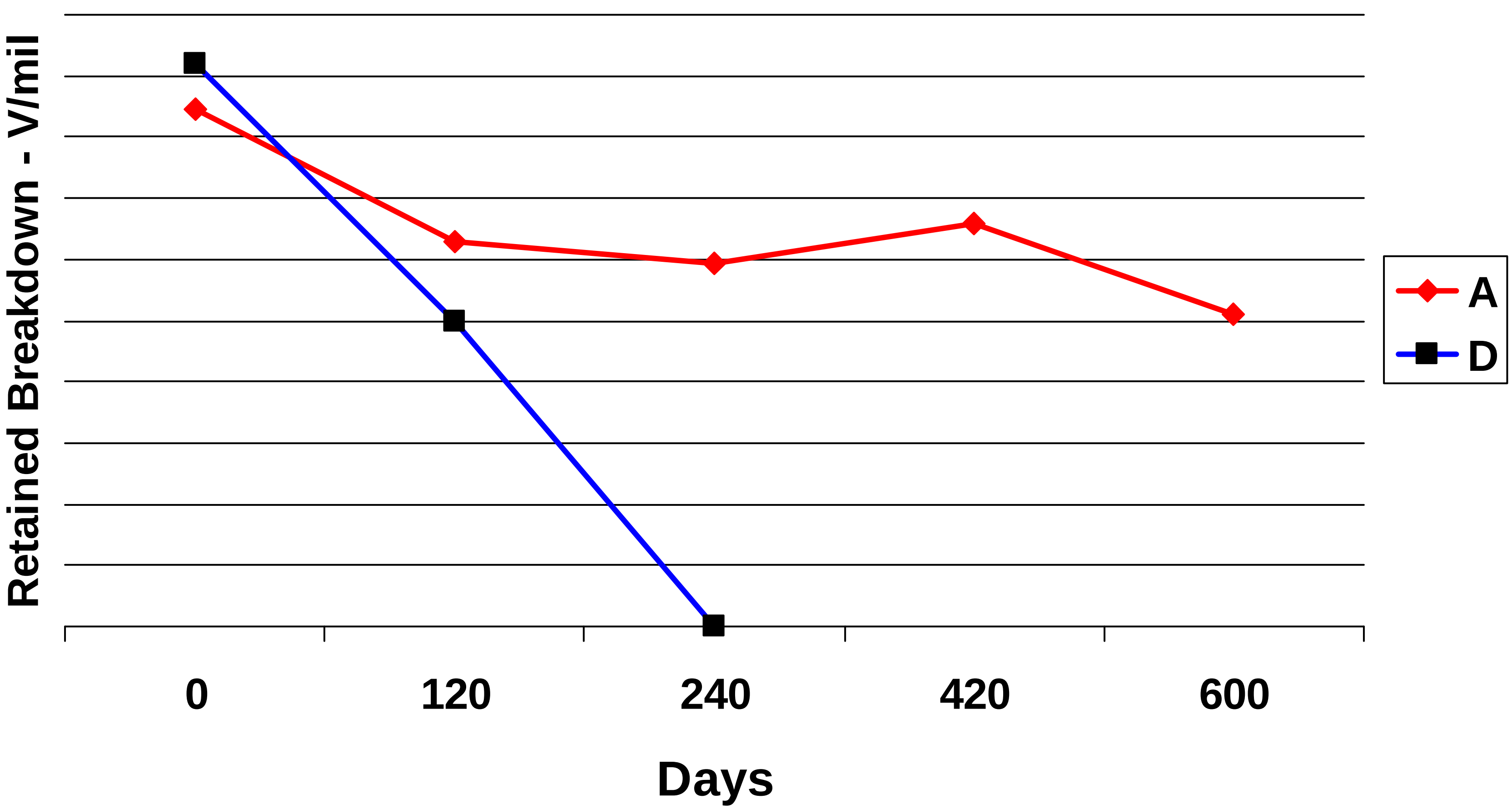
- Time to failure
  - Samples are subjected to a test protocol until all sample have failed.
    - 44, 41, 47, etc
  - Eta and Beta values established from Weibull analysis
    - Eta is the characteristic life when 63.2% of the units have failed
    - Beta is the slope of the Weibull plot and describes the type of failure mechanism
      - <1 infant mortality
      - =1 random failures
      - >1 wear out failures
- Retained ac voltage strength
  - Samples are subjected to a certain test protocol and at pre-designated time intervals some of the samples are removed and a HVTT is done.
  - Typical times (days) are
    - 120, 240, 420, 600, 1060

ACLT Setup

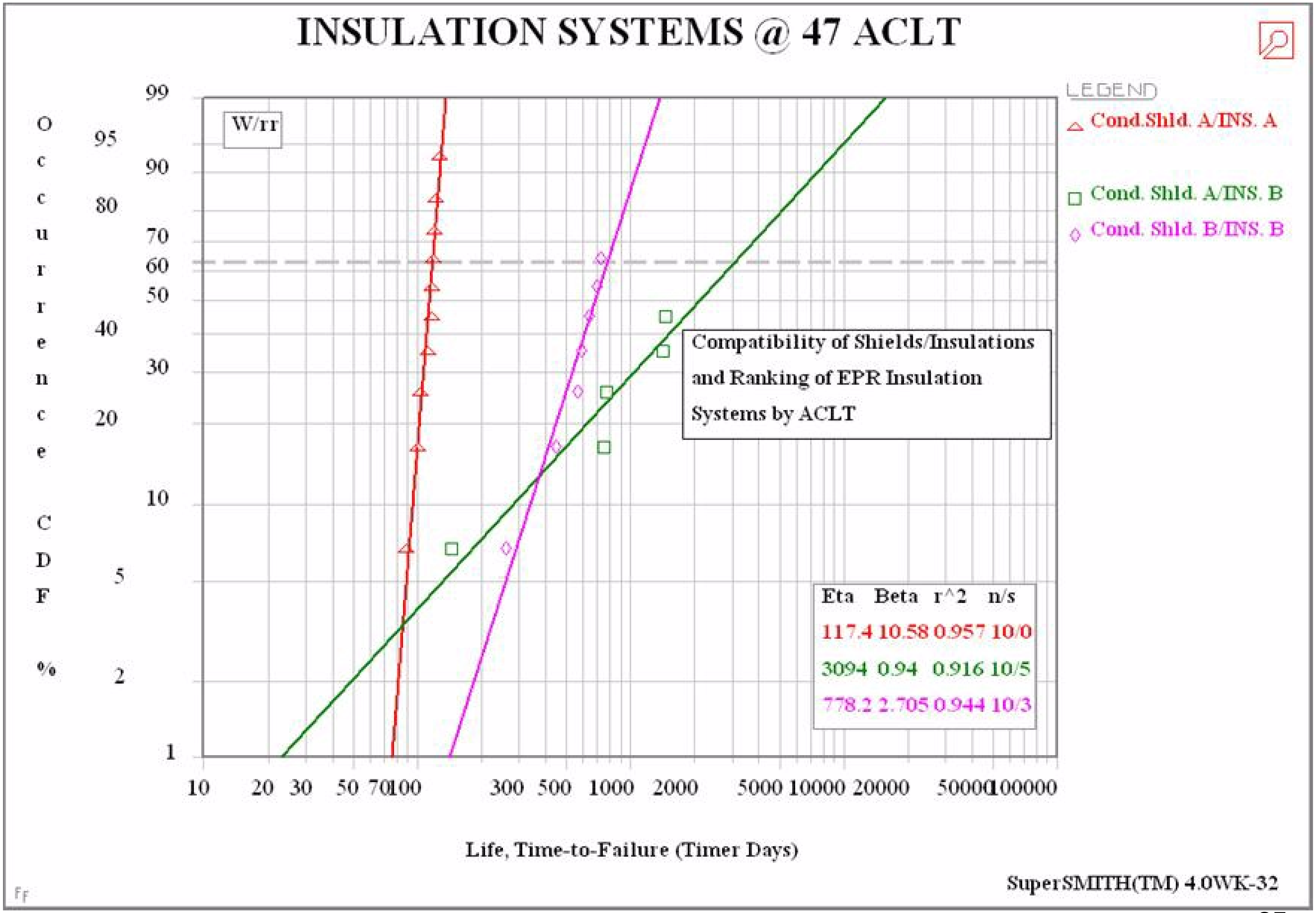
ACLT Results Overview

- ACLT – What can we learn from it?
  - Study the influences of operating conditions on cable life
  - Compatibility of extruded cable core materials
  - Breakdown strength stability from retained ac breakdown tests
  - Relative ranking between similar types of insulations
  - Distinctions (ranking) between EPR insulations can be more easily seen at a higher stress/lower temperature than at higher stress/high temperature.
  - EPR insulations with equal life performance cannot be distinguished using ACLT

ACLT Retained Breakdown
3Vg/75˚C
Different EPR Insulations



Ranking of Conductor Shields/ EPR Insulations Systems by ACLT



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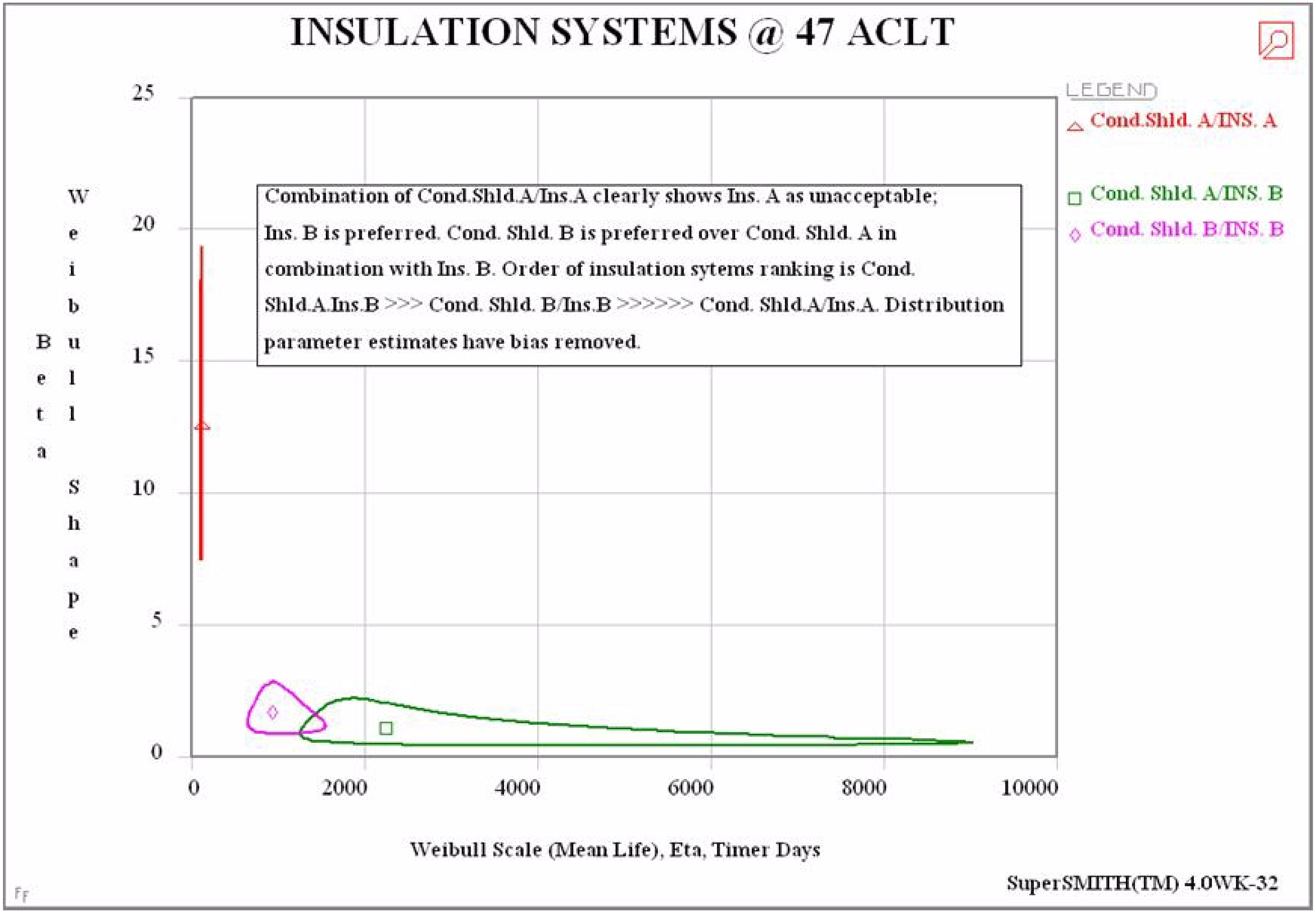
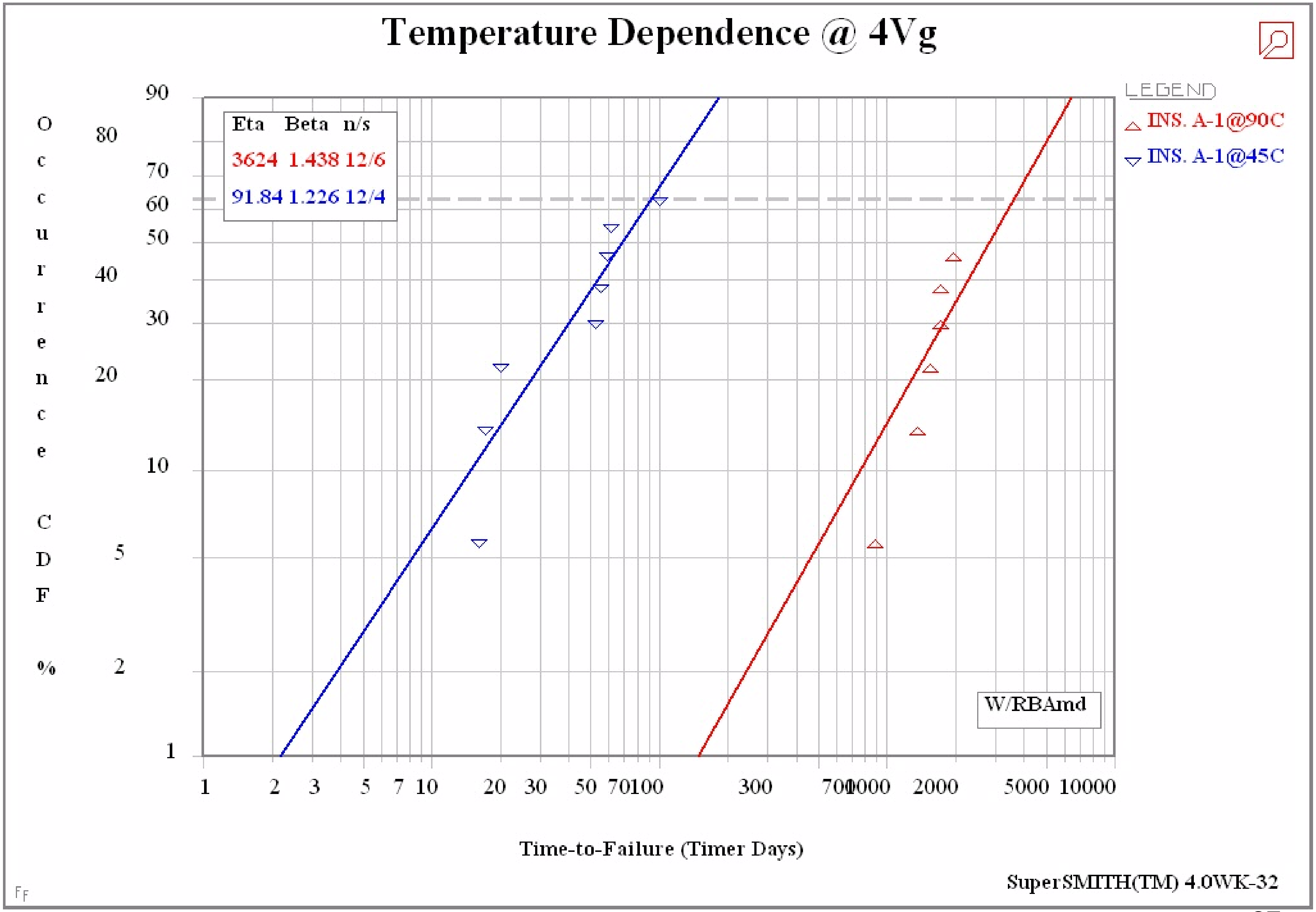
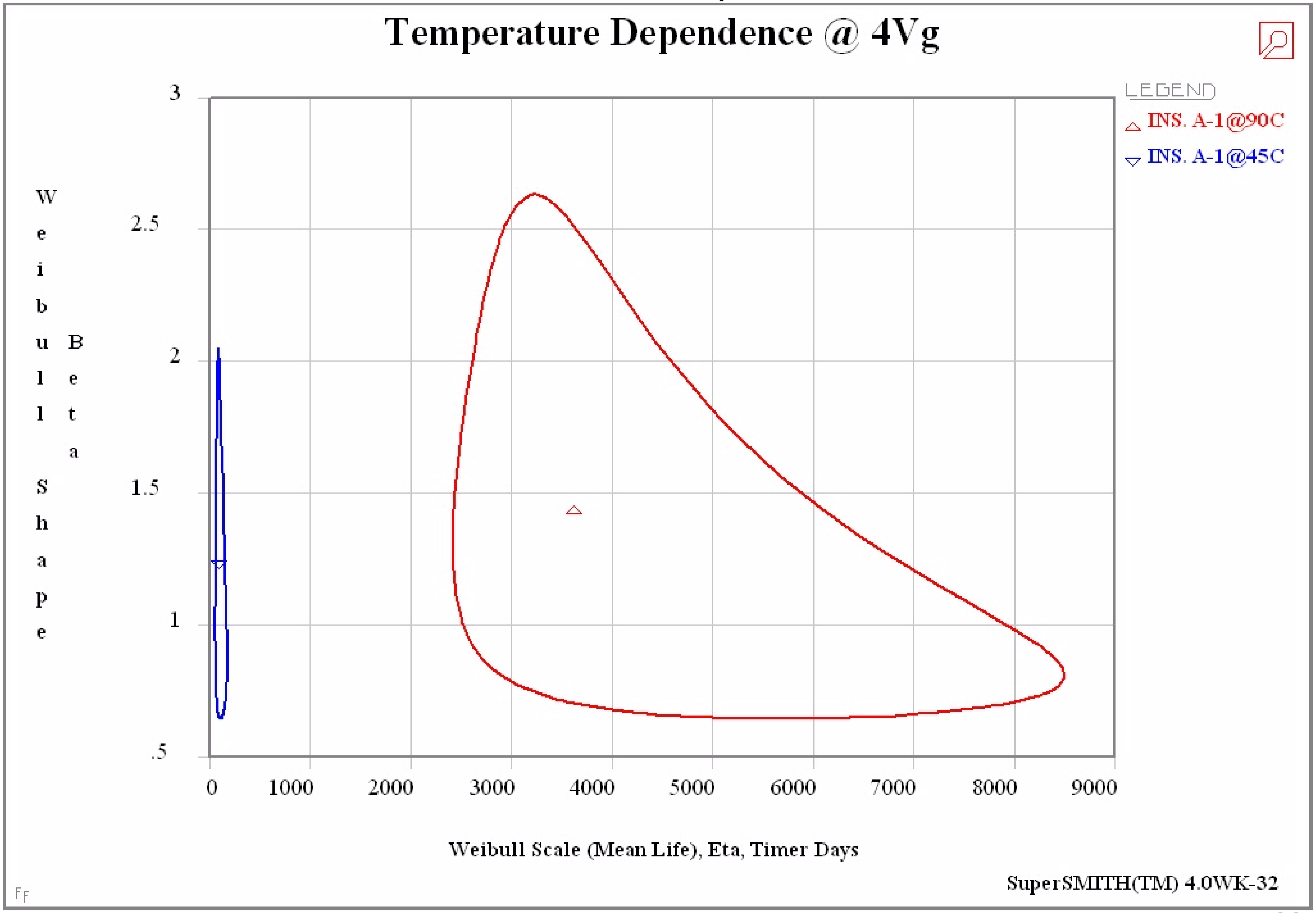


EPR Insulation Systems Differentiated by ACLT Conductor Temperature



Hypothesis Testing: EPR Insulation Systems Differentiated by ACLT Conductor Temperature:



ACLT Results Overview

- ACLT – What it does not tell us!
  - Absolute predicted life
  - Inter-laboratory agreement as not been demonstrated
  - Should not compare dissimilar insulation types such as EPR and TRXLPE in same protocol
  - Difficult to differentiate between good performing EPR cable systems

What can be learned from accelerated wet aging testing of EPR cables?

- Cable compliance with Industry standards
  - Manufacturers' capability to produce acceptable product
- Compatibility of extruded core materials for EPR insulated cables
- Water tree resistance of the insulation
- Study the influences of operating conditions on cable life
- Breakdown strength stability from retained ac breakdown tests
- Relative ranking between similar types of insulations
- Distinctions (ranking) between EPR insulations can be more easily seen at a higher stress/lower temperature than at higher stress/high temperature
- EPR insulations with equal life performance cannot be distinguished using ACLT

What cannot be learned from accelerated wet aging testing of EPR cables?

– Does not provide absolute predicted life
– Inter-laboratory agreement has not been demonstrated
– No correlation between HVTT breakdown strength and predicted cable life.
  - Higher HVTT values do not translate to longer life in service, i.e. EPR cables have lower breakdowns than TRXLPE cables but both have long service life.
– No correlation between Time-to-Failure and predicted cable life.
– Cannot compare dissimilar insulation types such as EPR and TRXLPE