Material and Cable Testing to Ensure Long Life for Medium Voltage Cables

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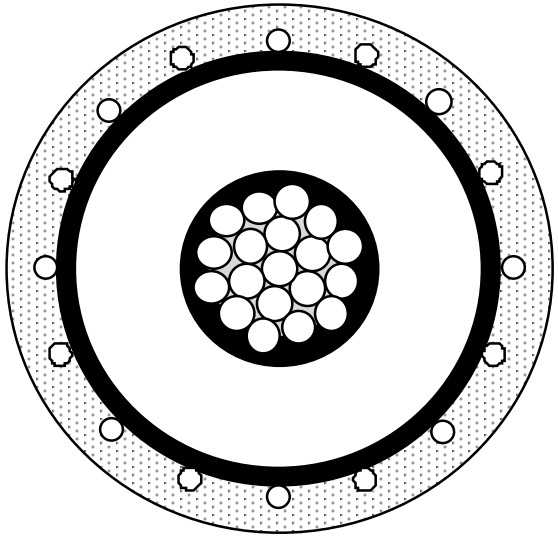
Long Life Medium Voltage Cables

Take Home Message:

- >40 year life expected
- To achieve long life requires:
  - Clean and smooth materials
  - Excellence in manufacturing
  - Excellence in installation
- Best performance with TR-XLPE and supersmooth shields

Background

- 1960s—Extruded HMWPE polymeric MV power cables
- Expectation for life was 20-30 years
- But, in reality, the life for HMWPE cables has a broad distribution, some failing with significantly shorter times, some still in use

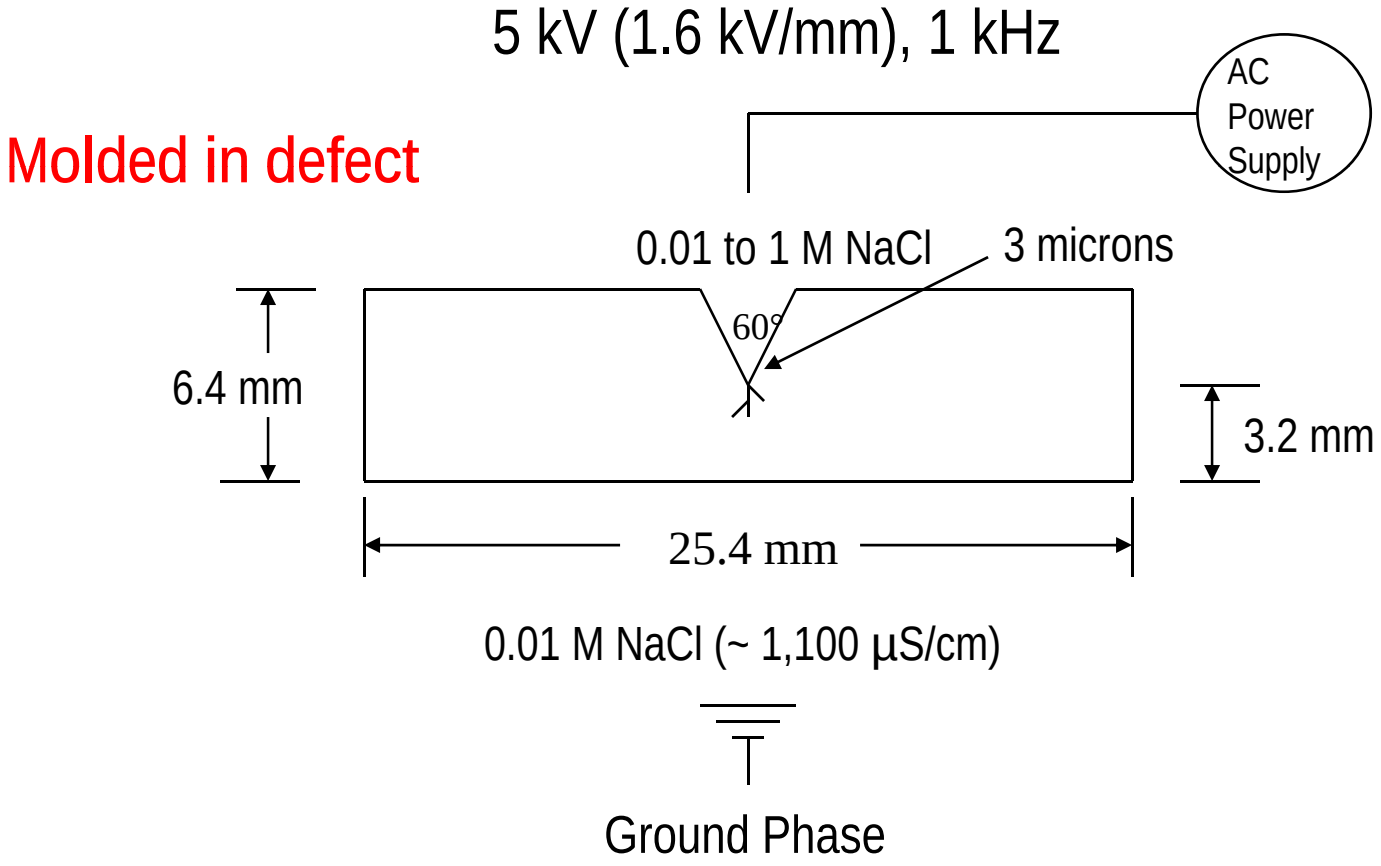


Why MV Cables Fail: Water Treeing

- Early HMW and XLPE cables (1960s and1970s)
  - Taped shields
  - No jackets
  - Criticality of cleanliness and smoothness was not recognized
  - HMW and XLPE susceptible to water treeing
- Reduce water treeing
  - Eliminate water
  - Clean insulation (minimize contamination)
  - Smoother, cleaner shields (no tapes, protrusions)
  - Strand fill
  - Jackets

Best---Use a Water Tree Retardant Compound

Ashcraft Water Tree Growth Test
ASTM D6097-00



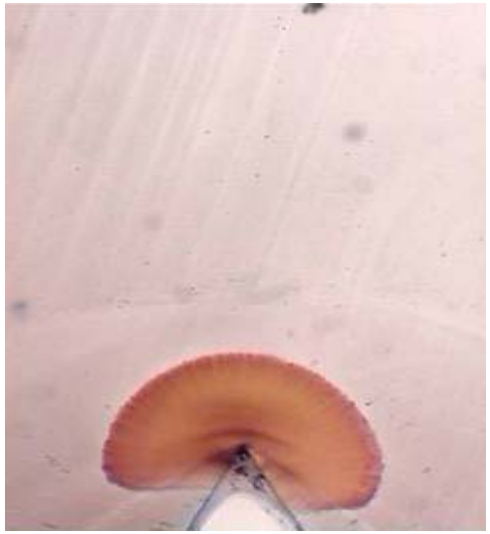
Water Tree Growth Test Results

ASTM D6097-00, 1.0 M NaCl

- Preconditioned in vacuum 7 days, 80C; 5 kV, 1 kHz, n=10, 30 days ambient

XLPE
1.209 ± 0.047 mm

TR-XLPE
0.288 ± 0.023 mm



40x Magnification

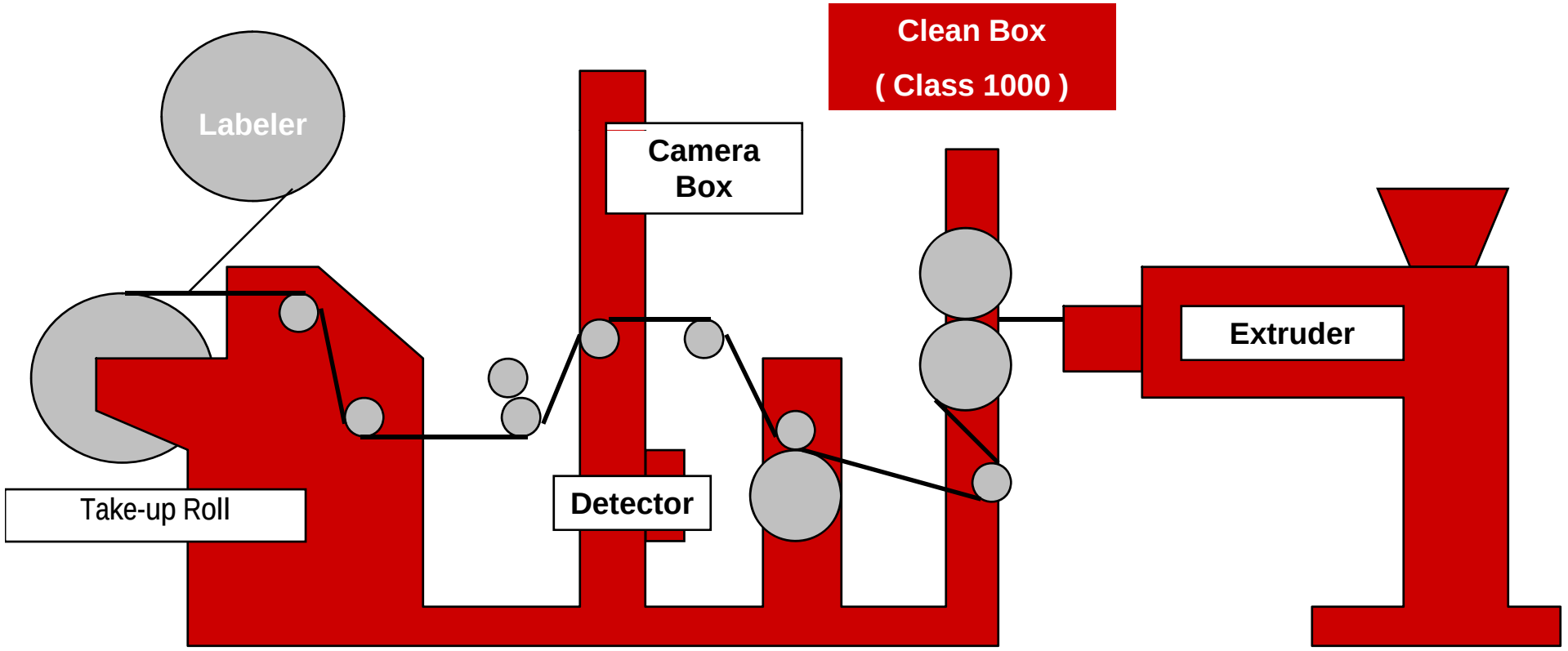
Causes:

- Water
- Divergent AC
- Contaminant
- Ions
- Time

Improvements in Materials and Processing

- Cleanliness of the Insulation
  - Materials
  - Materials handling
  - True Triple Extrusion, Dry Cure – void free
- Tree Retardant TR-XLPE Insulation
  - Virtually eliminated water treeing
  - Standard for MV XLPE cables
- Cleaner and Smoother Conductor Shield / Insulation Interface
  - Furnace black
  - Acetylene black Supersmooth shields
- Jackets
  - Toughness, reduced moisture ingress

Insulation Cleanliness:
Camera Tape Contamination Test System



Accelerated Aging via Laboratory Experiments

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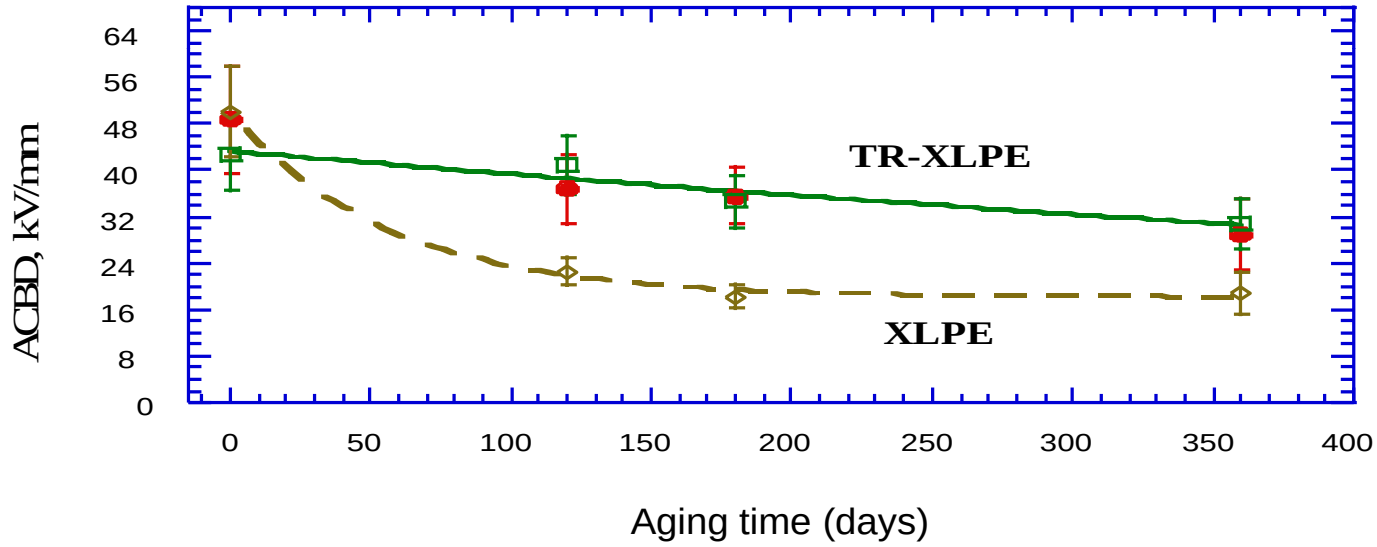
TR-XLPE Vs. XLPE
AWTT Performance

Values are averages of 6-7 manufacturers
Qualification tests

ANSI / ICEA S-94-649-2004 Specification
Accelerated Water Tree Test (AWTT)

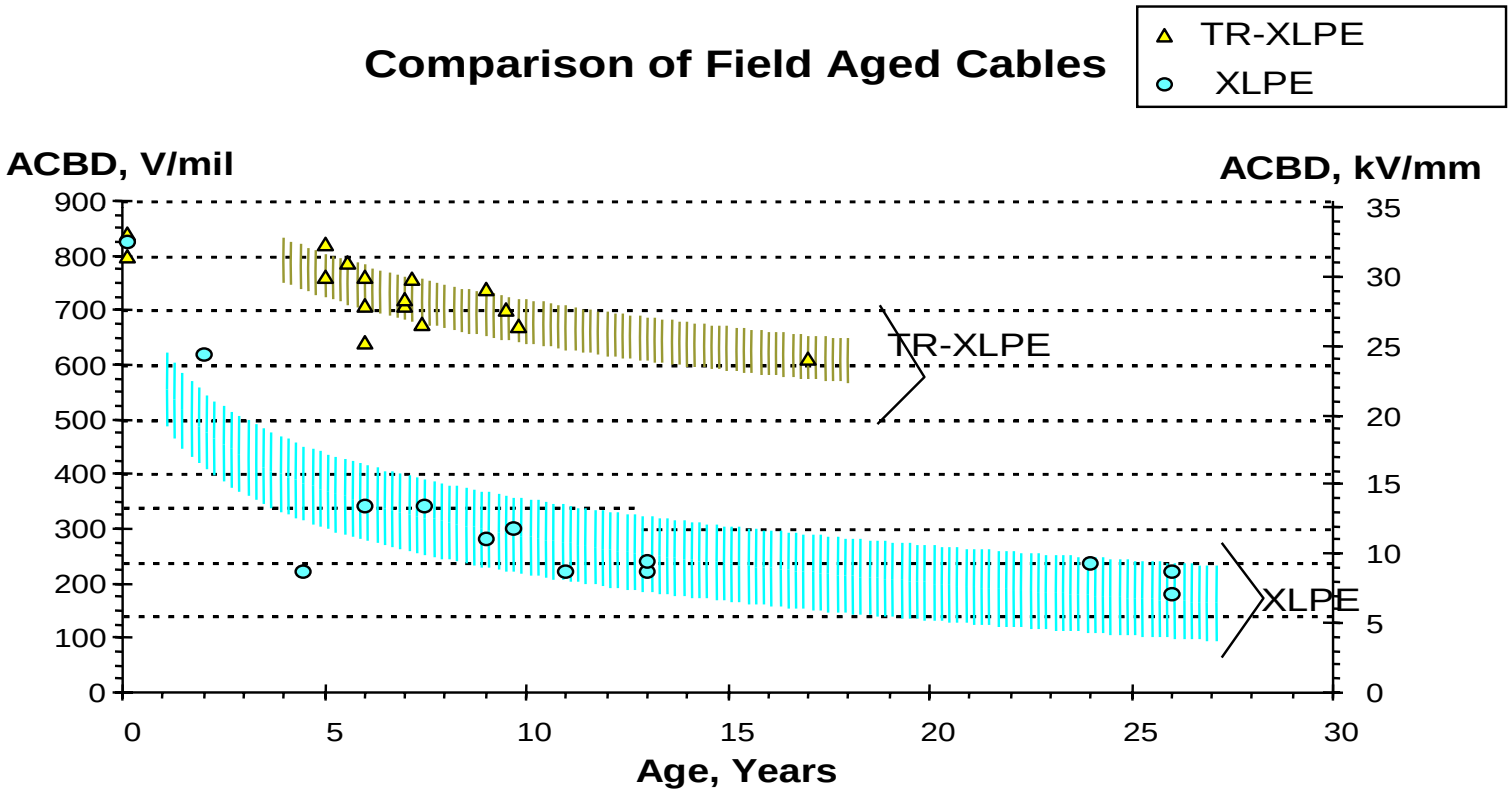


Acceleration of failure modes by water, temperature, and electrical stress

Accelerated Lab Tests vs. Field Aged

- Acceleration of failure modes by temperature, water, and electrical and mechanical stress (and frequency)
- Are the accelerating factors the same for lab vs. field?

Field performance of TR-XLPE and XLPE



15-35 kV cables, Retention of ACBD Strength

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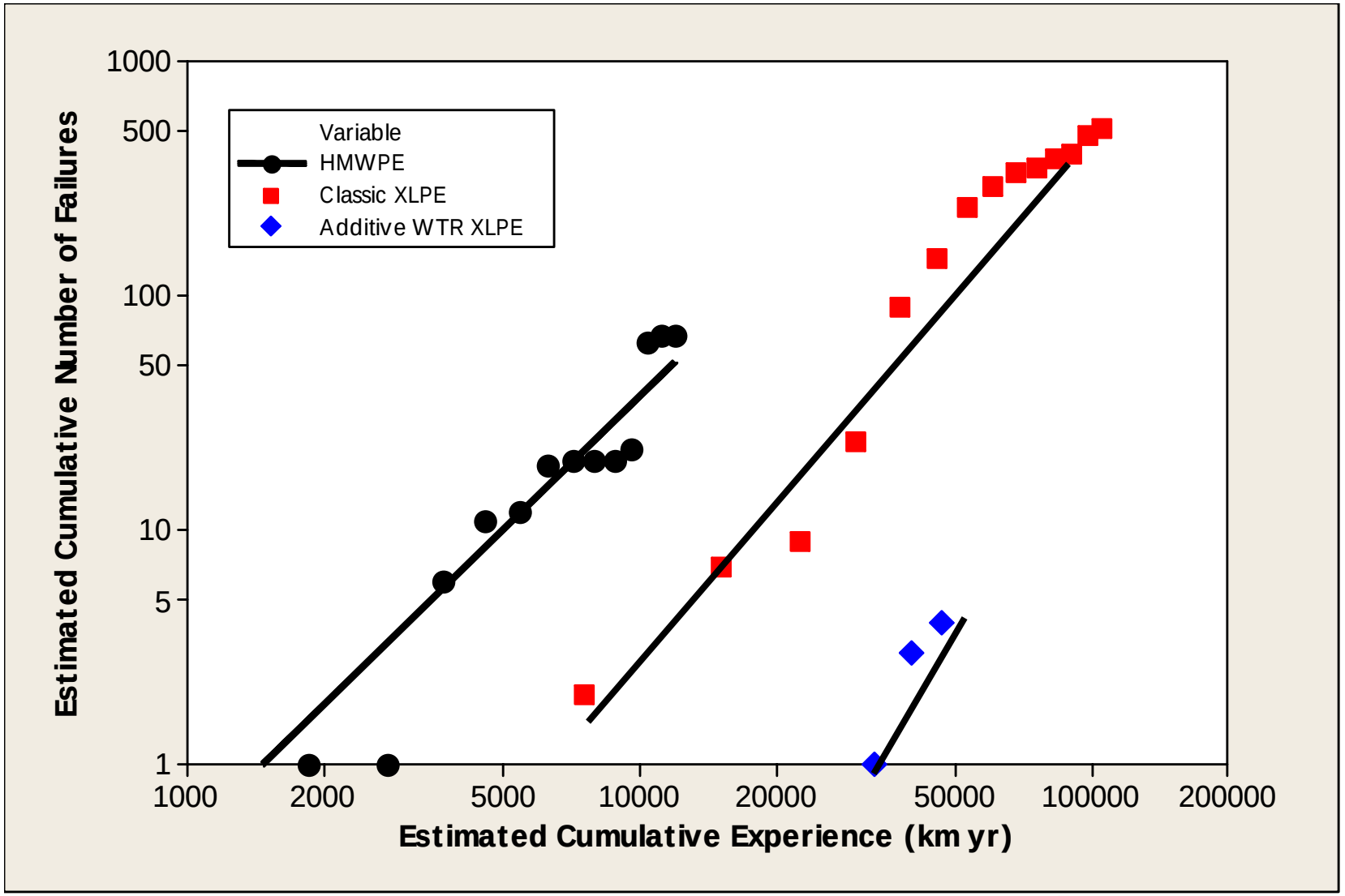
Failure Data for Three Generations of MV Cables at TXU

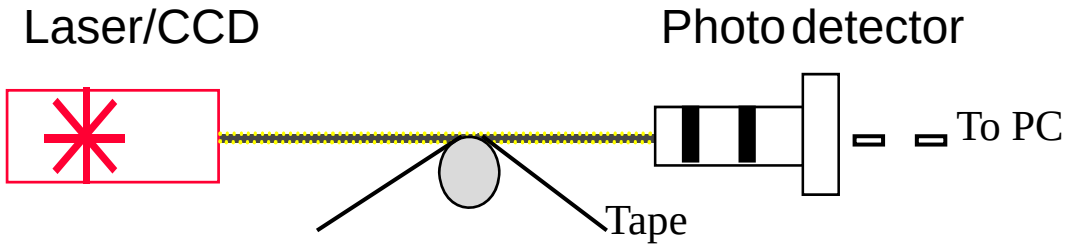


Semicons: Critical Attributes

- Semicon surface smoothness
- Ionic cleanliness
- Conventional semicons made from furnace blacks (oils)
  - Continually being made with better smoothness and lower ionic content
- “Supersmooth” semicons made from acetylene black (C2H2)
  - Cleanest and smoothest semicons
  - Preferred for distribution cables at majority of North America utilities

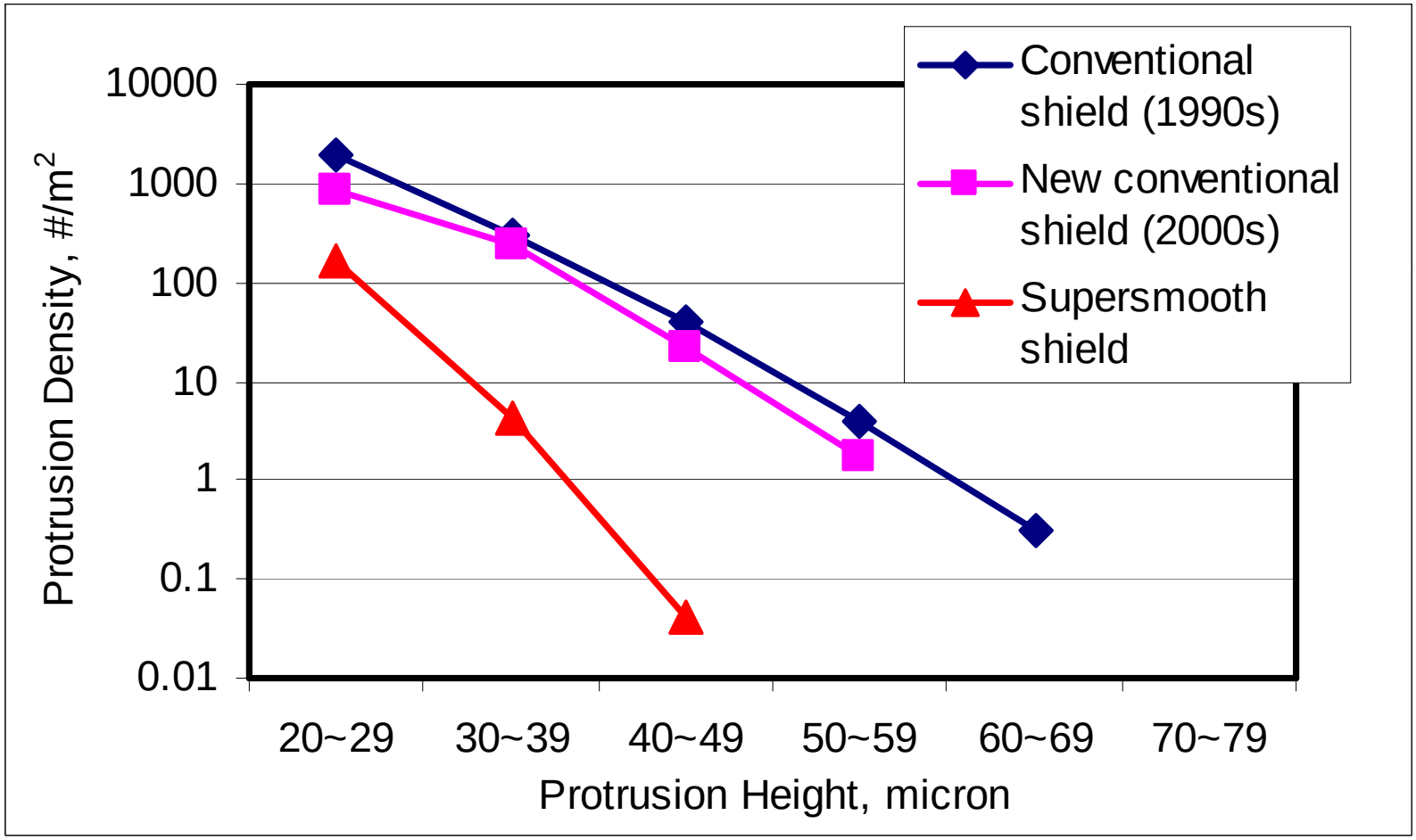
Semicon Smoothness Detection Technologies

- Laser or CCD camera in profiling mode -- counts protrusions and sizes their actual height
  - SEED: Surface Excellence Evaluation Device (Laser)
  - SSA : Surface Smoothness Analyzer (CCD)



Profiling Mode

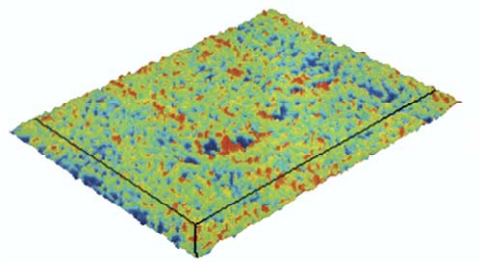
Surface Smoothness of Semicon Shields



Conductor Shield

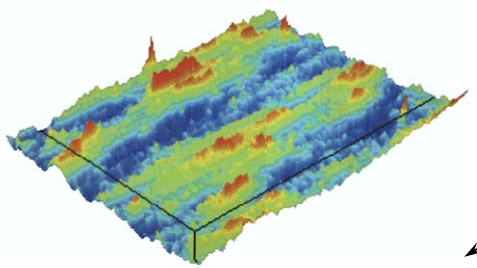
Semicon Micro-Smoothness via Interferometric Microscopy

Supersmooth



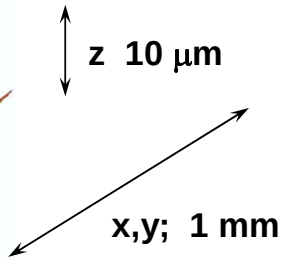
Ra = 0.2 μm
Rq = 0.3 μm

Conventional



Ra = 1.0 μm
Rq = 1.2 μm

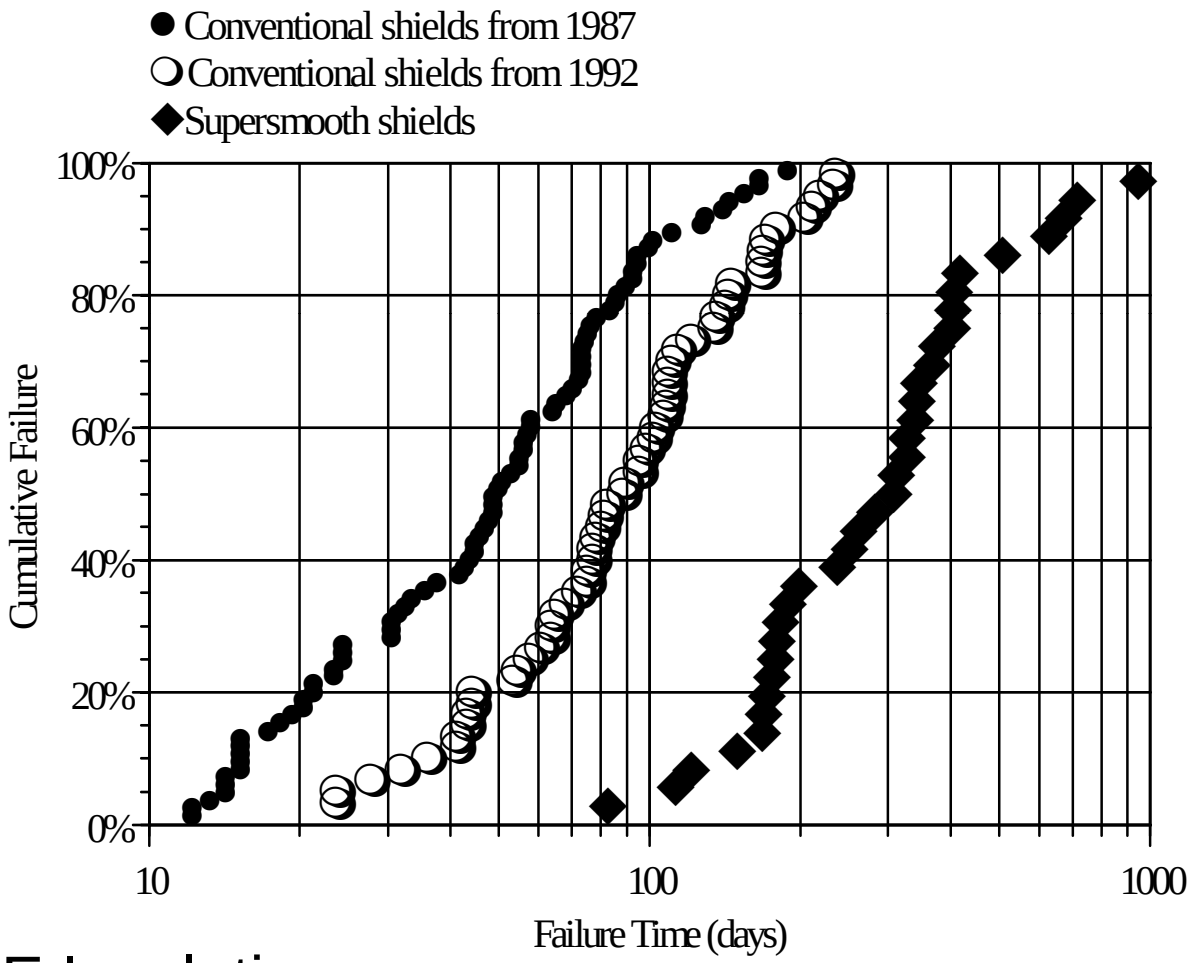
Scale



Ra = Average Roughness
Rq = RMS Roughness

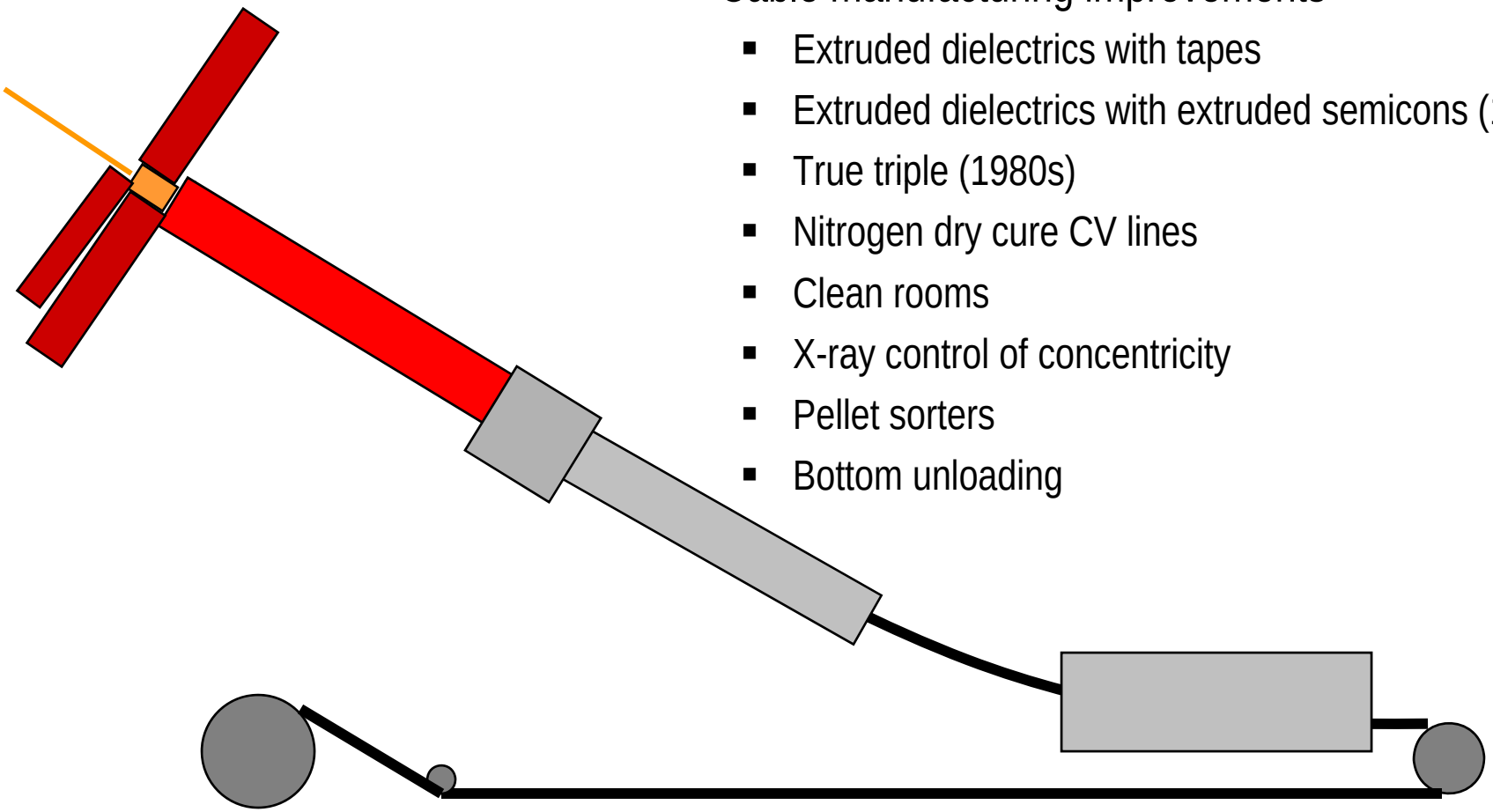
Instrument: Wyko RST Plus

Accelerated Cable Life Tests in Wet Aging



XLPE Insulation

Cable Manufacturing



- Cable manufacturing improvements
  - Extruded dielectrics with tapes
  - Extruded dielectrics with extruded semicons (1+2)
  - True triple (1980s)
  - Nitrogen dry cure CV lines
  - Clean rooms
  - X-ray control of concentricity
  - Pellet sorters
  - Bottom unloading

Conclusions

- Materials are constantly improving
  - Insulations are cleaner
  - Semicons are smoother with lower ionic content
  - Manufacturing is improved
- Today's cables have long life (>40 years)
  - Many XLPE cables in service for >30 years
  - TR-XLPE (the standard in NAA) in service for 25 years
  - Very few failures
- Best cable performance achieved with TR-XLPE and supersmooth shields
- Long term wet aging specifications are required to differentiate amongst materials

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Thank you