EXPERIENCE THE POWER OF DOW INSIDE.

# Accelerated Aging Tests for MV Cables

## Educational Session
## Fall ICC – 2011
## Denver, CO

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# Underground Cables - Why Accelerated Testing?

- Utilities expectation for Long Cable Life (system reliability)
- Installation & Replacements Expensive… $$'s
- Short Term Tests Involve no 'Aging' & Do Not Indicate Performance in Presence of Water
- Utilities Interested in Gauging Performance Before Costly Installations in Moist Environments
- Early Problems Led to Improvements in Cable Standard/Specification Requirements
  - Contaminants, Protrusions (at shield interfaces),
    - Poor Cable Designs, Improper operations etc.
- Balance - Time, Costs, Conditions, while minimizing Operational risks to ensure system reliability

# What is "Accelerated Aging"?

- Cables Cores* energized @ elevated voltages and loads changed to reach target conductor temperatures
- Cores 'Aged' in presence of water
- Conditions 'Accelerate' cable (Insulation) degradation, providing clues to long term performance
- Cables monitored for performance over time
- Critical to evaluate degradation under moist / wet environments in underground systems.

*Cores - Cables without the Outer Jacket

# Most Common Accelerated Tests ..

**AWTT**
**One year Accelerated Water Treeing Test**

- North American Std.
- China (Optional)
- “Tube” Test
- Load cycling
- ACBD

**ACLT**
**Accelerated Cable Life Test**

- North American
- “Tank” Test
- Load cycling
- Mostly, ‘Time to Failure’ Test

**CENELEC**
**Two Year Aging Test**

- Europe
- “Tank” Test
- No ‘load cycling’
- ACBD

Also: High Frequency Test (On European CENELEC Standard)

# AWTT (Accelerated Water Treeing Test) Background

- AEIC Cable Engineering Committee (CEC) developed the AWTT in the early 1970s.
- Materials, manufacturing techniques and constructions for extruded underground power cables have improved significantly.
- Electric utilities still rely heavily on the results of accelerated laboratory tests.

# Objective：Accelerated Water Treeing Test (AWTT)

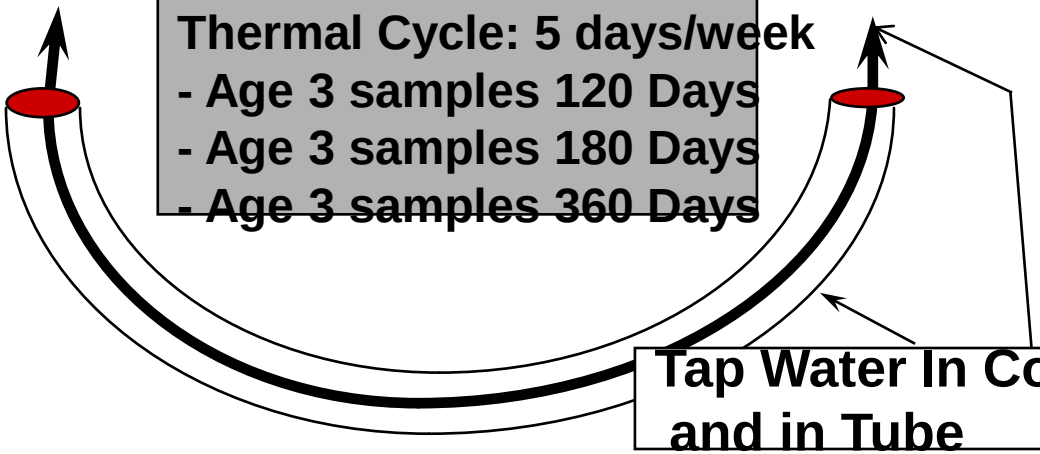
- Provide standardized qualification test method to give reasonable assurance that an extruded, medium-voltage cable design will meet minimum performance requirements in a wet environment.
- Test is designed to:
  - Accelerate operating conditions normally found in the field without creating failure mechanisms that do not occur in service.
  - Be relatively easy and economical to set up and run.
  - Provide results in a reasonable period of time.
  - Ensure that conductor shield, insulation and insulation shield compounds are compatible.
  - Ensure that manufacturer is capable of producing a well-made cable using materials being qualified.

# Description of Accelerated Water Treeing Test (AWTT) – Typically on 1/0 (53 sq.mm, 15 kV cable cores)

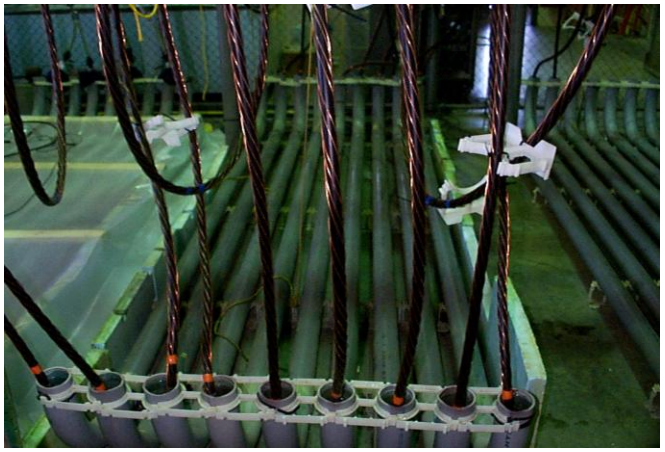
- All samples for wet aging are first subjected to thermal preconditioning to drive off excessive volatiles in the insulation.
- Wet aging is carried out with voltage stress applied.
- Conductor current is sufficient to achieve approximately 60 °C conductor temperature in water.
- Temperature of water in conduit is not controlled, unlike Accelerated Cable Life Test (ACLT).
- Aging is conducted with tap water in conductor strand interstices and conduit.
- Various diagnostic tests may be carried out.

# AWTT - Accelerated Water Treeing Test

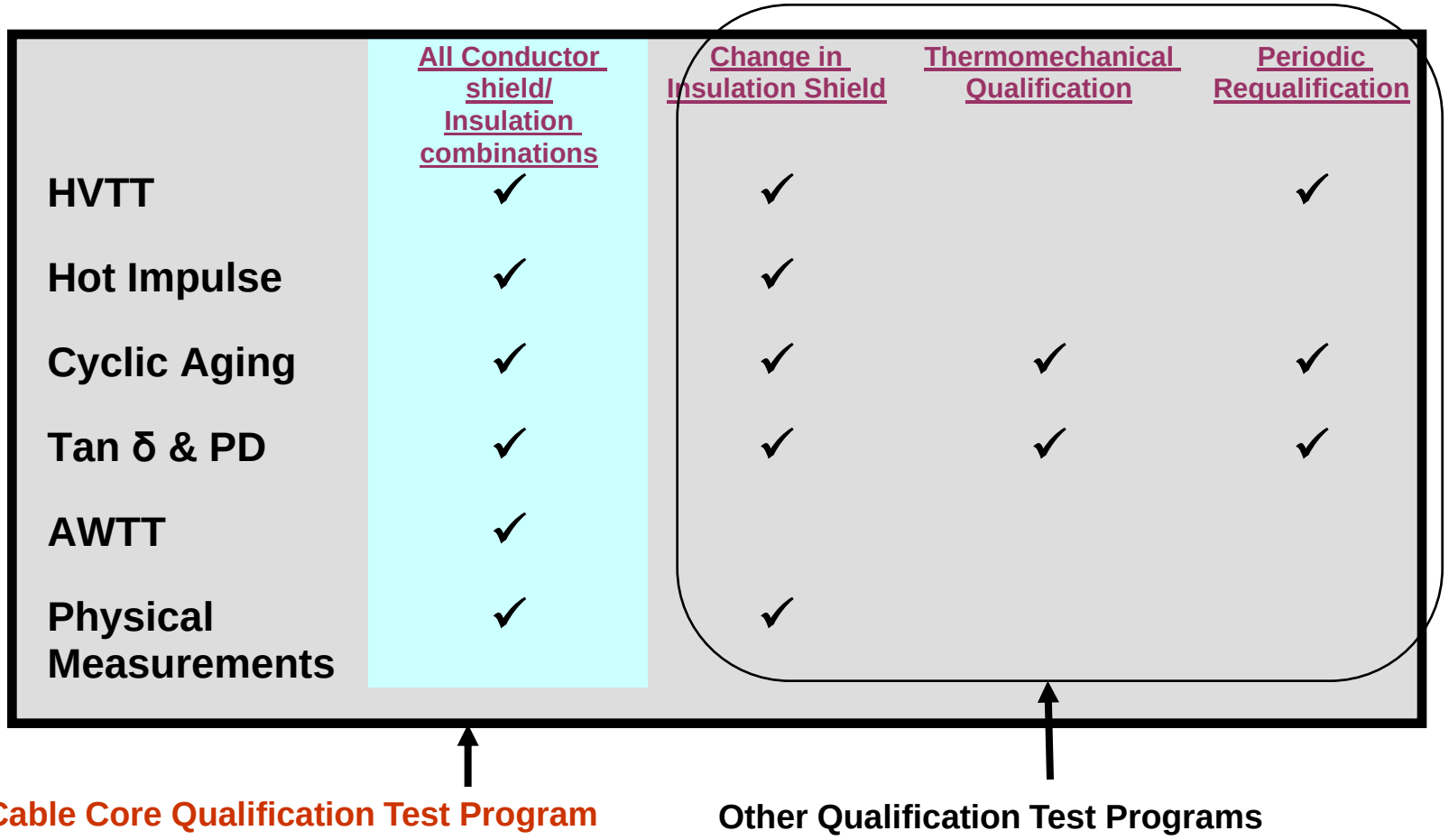
**9 Test Cable Samples**
**Aged at 6 kV/mm (Average Stress)**
**45 ºC on Cable Insulation Shield**
**Thermal Cycle: 5 days/week**
**- Age 3 samples 120 Days**
**- Age 3 samples 180 Days**
**- Age 3 samples 360 Days**



**Tap Water In Conductor and in Tube**

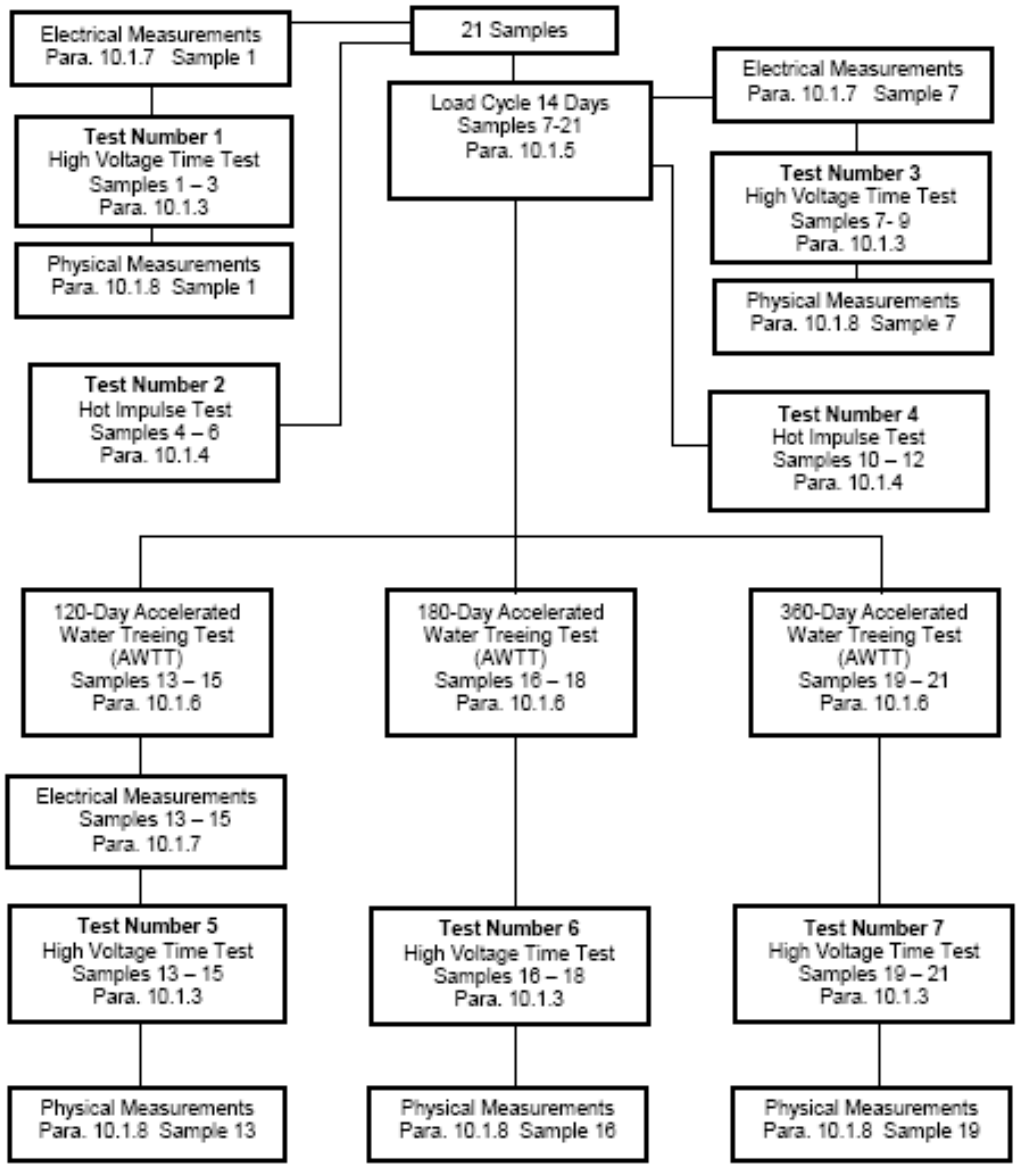


# ICEA/AEIC Qualification Test Program




Courtesy - NEETRAC

# Cable Core Qualification Test Program




Courtesy - NEETRAC

# ICEA S-94-649-2004

- Diagnostic Tests:
  - AC Voltage Breakdown:
    - Three samples each after 120, 180 and 360 days
    - 40 V/mil steps for five minutes each

| Insulation Type | Minimum ac Withstand Values V/mil (kV/mm) | | |
|---|---|---|---|
| | After 120 Days of AWTT Aging | After 180 Days of AWTT Aging | After 360 Days of AWTT Aging |
| Crosslinked Polyethylene | 300 (11.8) | Not Required | Not Required |
| Tree Retardant Crosslinked Polyethylene | 660 (26.0) | 580 (22.8) | 380 (15.0) |
| Ethylene Propylene Rubber | 420 (16.5) | 340 (13.4) | 340 (13.4) |

# ACLT – Accelerated Cable Life Test

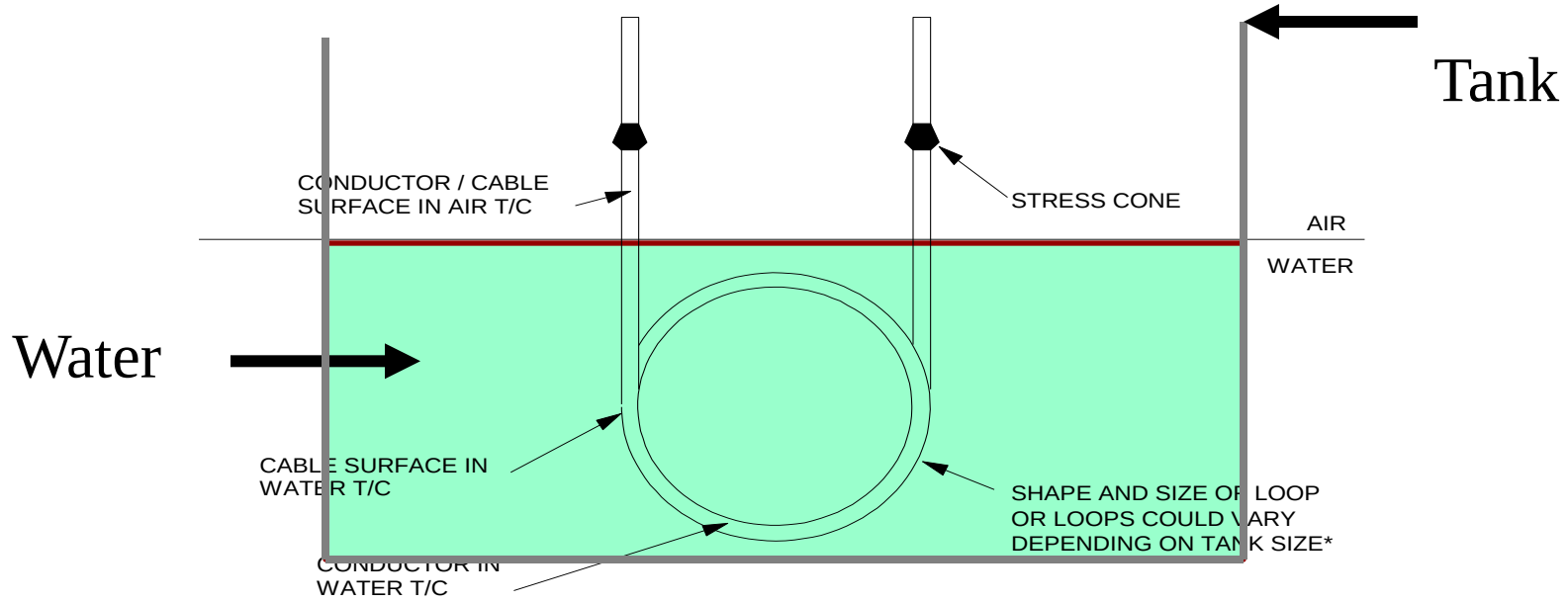
- Done in water tanks,
- Typically with 12 cable core coils
- Tested until all 12 samples fail
- Test Conditions can vary…
  - Conductor Temp. …..23, 45, 75 or 90 C
  - Applied Voltage Stress…1, 2, 3 or 4 Uo
  - Hence, 1,1 thru 4,4 Conditions
- Variations exist ..
  - Time to failure, Fixed time (ACBD) etc.

# ACLT - Accelerated Cable Life Test

Cable Cores Aged in Water Tanks

- **Typically 12 cable core coils used; Aged to Failure**
- **Conductor Temp. & Voltage Stress Range Varied**
  - **$23^0$ C & 1x$V_0$ (Ref.to 1,1) ..To.. $90^0$ C & 4x$V_0$ (4,4)**

**FIGURE 4**
**DUMMY USED FOR**
**TEMPERATURE MEASUREMENTS**

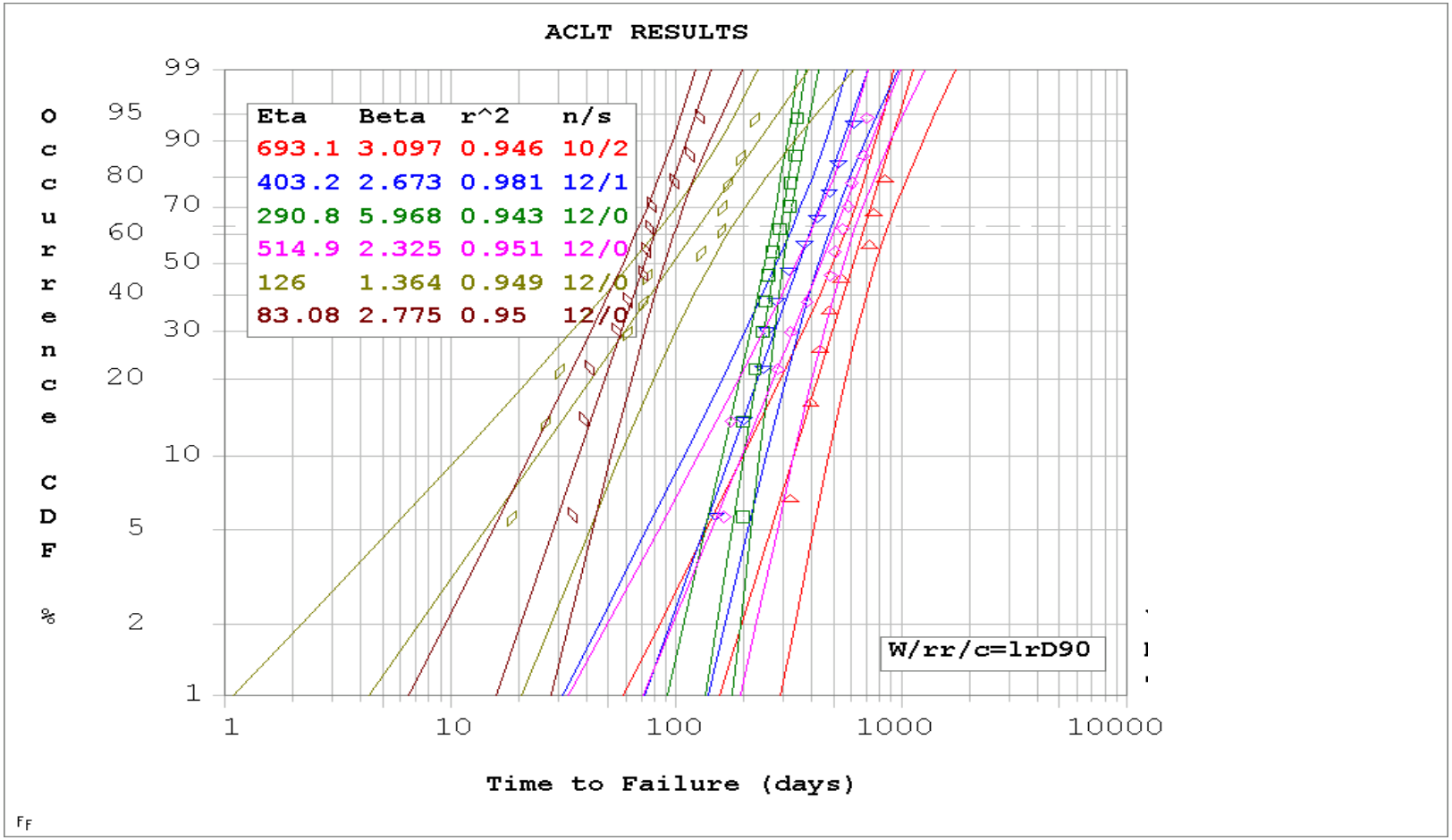



TC - Thermocouple

* Not Less Than Minimum Bending Radius

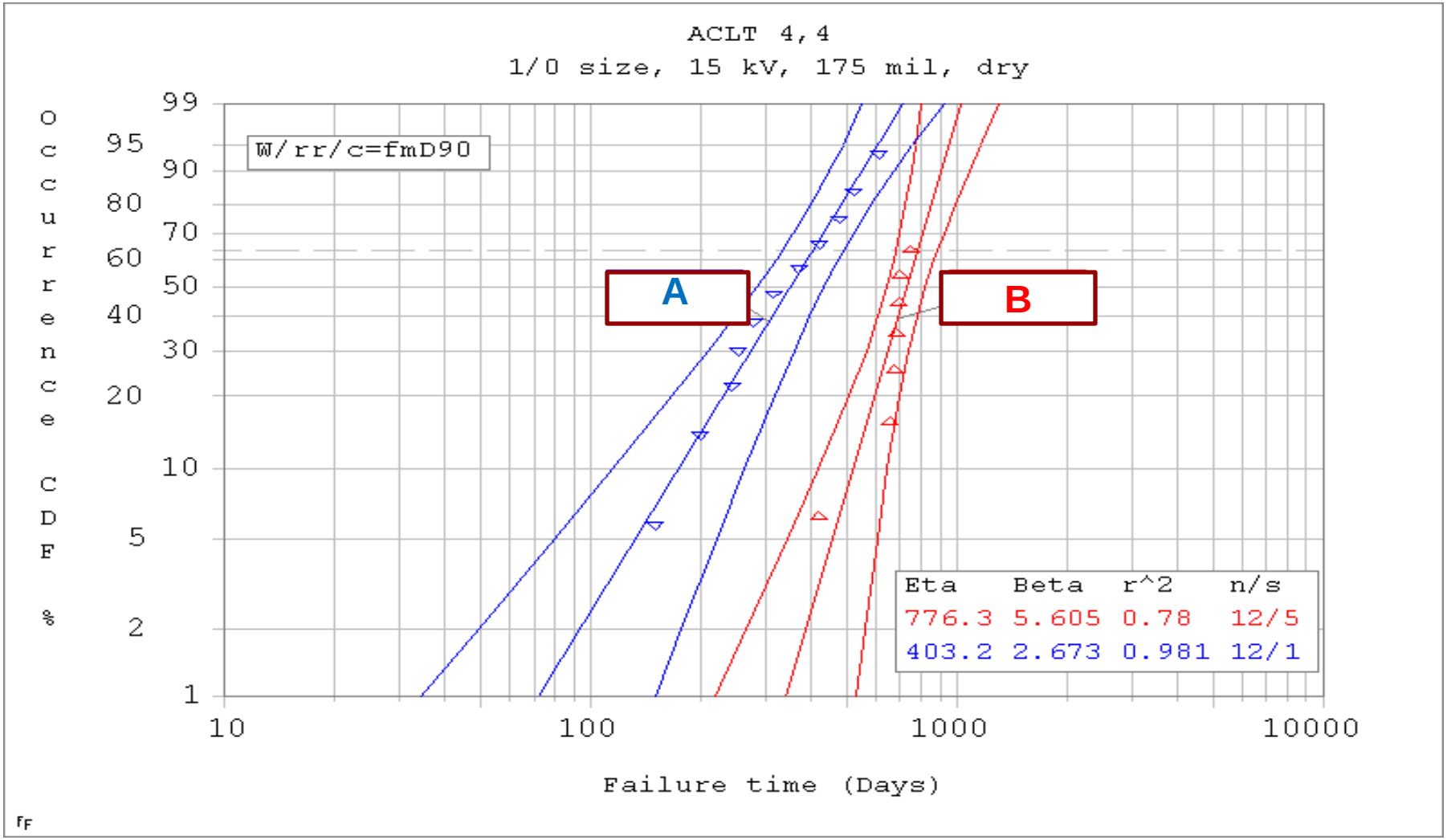
Courtesy- GCC

# ACLT - Typical Test Results




Better

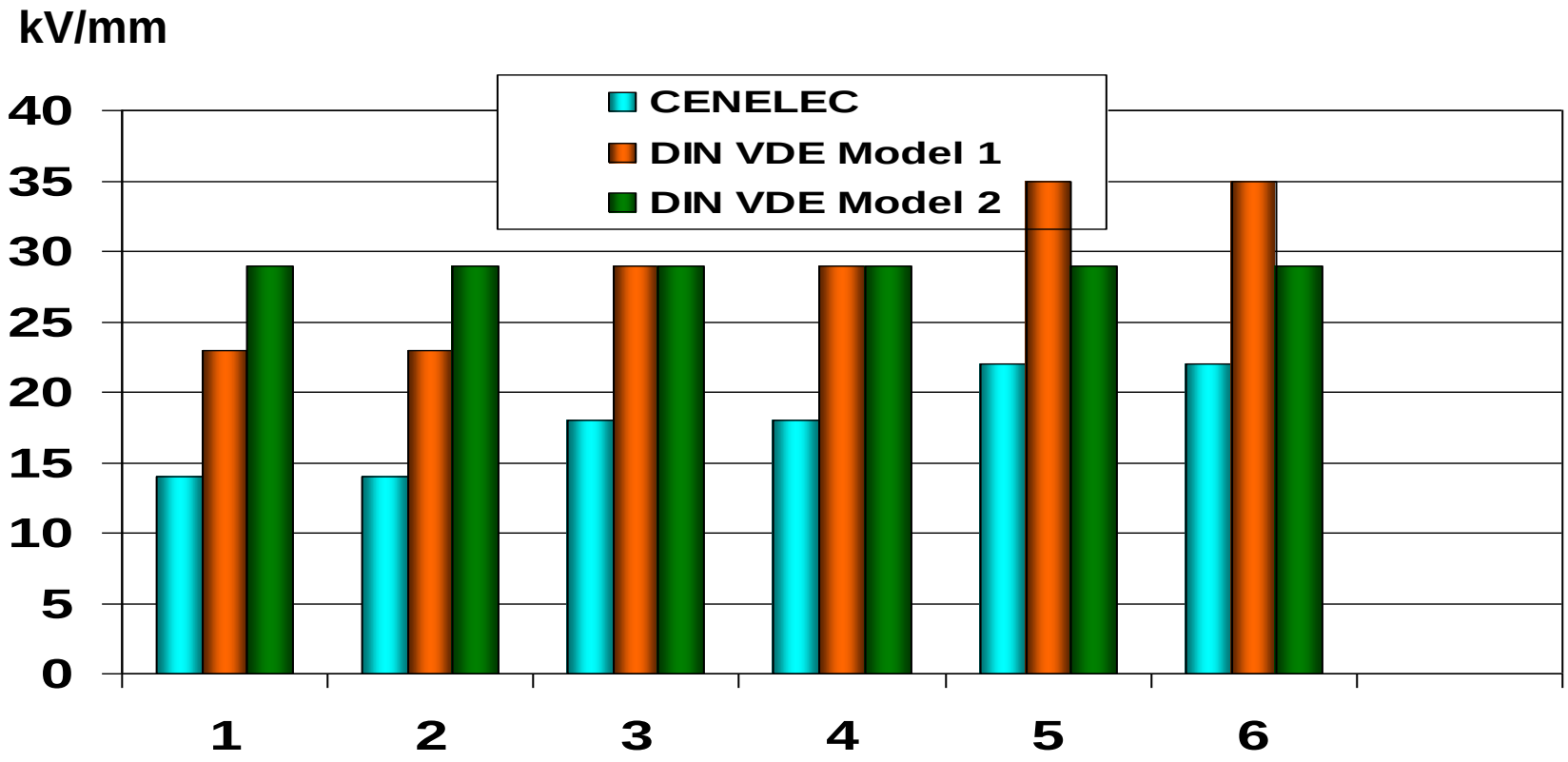
# Typical 44 ACLT Data – Two Cable Types



# European CENELEC Test

- Two year wet aging protocol
- Test Conditions & Pass Criteria in later slides
- Most European countries follow this for MV (6-30 kV) cables
- 12 Cable samples tested –
  - 6 evaluated after one year and 6 after two…
- German Standards (VDE) use the same test, but, higher requirements

# European CENELEC (& German VDE)-Two Year Tank Test Minimum Requirements)




**CENELEC:**
2 @ 14kV/mm
2 @ 18; 2 @ 22

**VDE-Model 1**
2 @ 23 kV /mm
2 @ 29 ; 2 @ 35

**VDE Model 2**
All 6
@ 29 kV / mm

# North American and European Accelerated Cable Tests

## Key test conditions

| Standard | Aging Voltage | Aging Time | No. of Samples per Aging Period | Temp. (C) | Nature of Thermal Conditions |
|---|---|---|---|---|---|
| CENELEC HD620 (50 Hz) | $3U_0$ | 360d &720 d<br><br>0d &180d often used for information | 6 | 40 (water) | Constant |
| CENELEC HD620 (500 Hz) | $3U_0$ | 3000 hr | 6 | 40 (water) | Constant |
| ANSI/ICEA S-94-649 (AWTT) | $3U_0$ | 0, 120, 180, & 360 d | 3 | 45 (ins. shield in water) | Load cycled (5d/wk) |

# Test Criteria & requirements for CENELEC and AWTT Cable Tests

| Standard | Success Criteria | | |
|---|---|---|---|
| CENELEC HD620 (50 Hz) | All 6 (100%) samples > 14 kV/mm<br>Min 4 (66%) samples > 18 kV/mm<br>Min 2 (33%) samples > 22 kV/mm<br>Some utilities / countries (eg Germany) require higher levels | | |
| CENELEC HD620 (500 Hz) | All 6 (100%) samples > 14 kV/mm<br>Min 4 (66%) samples > 18 kV/mm<br>Min 2 (33%) samples > 22 kV/mm | | |
| ANSI/ICEA S-94-649 (AWTT) | XLPE<br>min value<br>• 0 days: 24.4 kV/mm<br>• 120 days: 11.8 kV/mm<br>• 180 days: Not required<br>• 360 days: Not required | Tree Retardent XLPE<br>min value<br>• 0 days: 26 kV/mm<br>• 120 days: 26 kV/mm<br>• 180 days: 22.8 kV/mm<br>• 360 days: 15 kV/mm | EPR<br>min value<br>• 0 days: 19.7 kV/mm<br>• 120 days: 16.5 kV/mm<br>• 180 days: 13.4 kV/mm<br>• 360 days: 13.4 kV/mm |

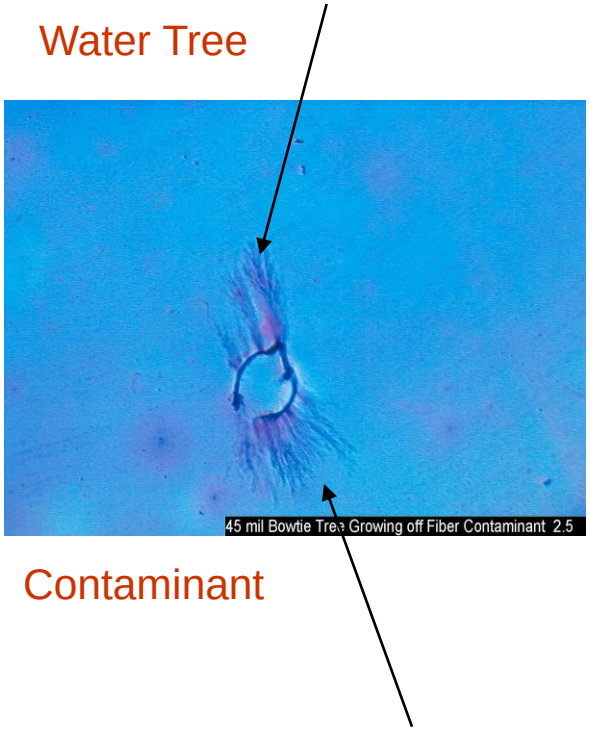
# ‘Other’ notable ‘Accelerated Aging’ test protocols

- EPRI / CTL  Low Temperature (ambient)  tank test program

- NEETRAC ‘Full’ Design Cable Aging Protocol
  - (Full, commercial cable designs, including outer jackets aged in water tanks…w/o water in conductor…to closely simulate operating conditions

# Appendix
# Additional Slides for Background

# Contamination
## *The Problem*

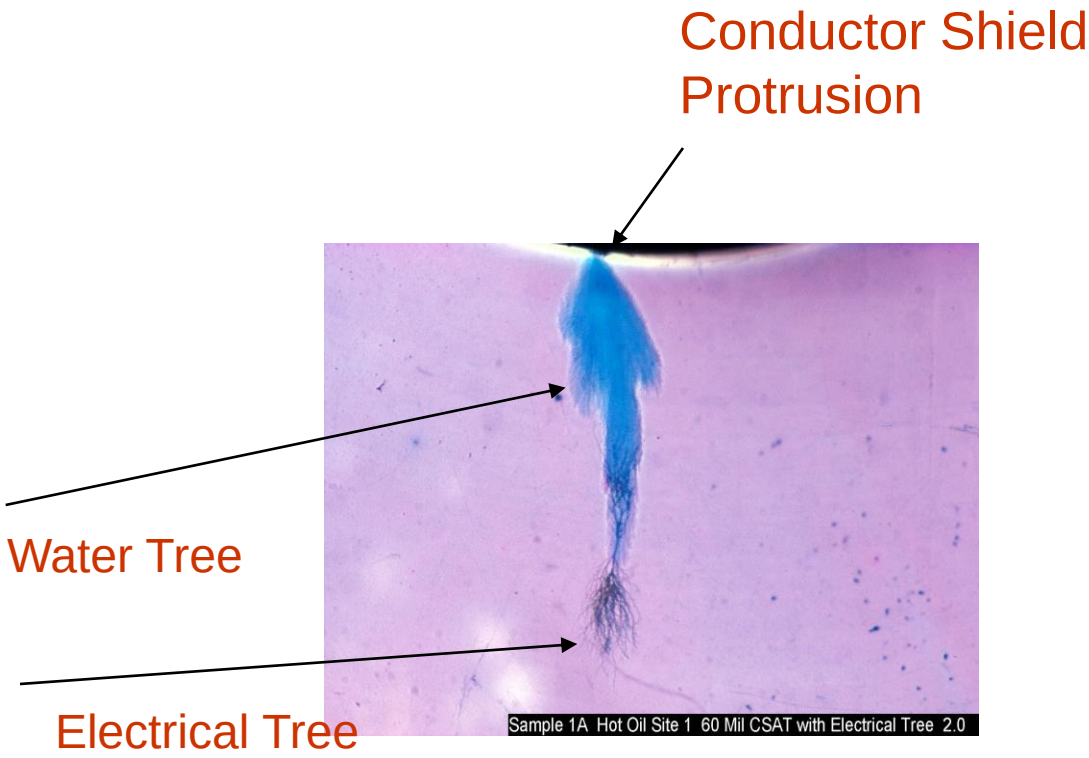



- In the early days, insulation compounds contained significant contamination.
- This contamination caused localized voltage stresses enhancement that that lead to water tree growth, electrical tree growth – and failure!

Courtesy - NEETRAC

# Conductor Shield Protrusions & Impurities

## *The Problem*




- Conductor shield protrusions enhanced localized stress. Ions in the compound contributed to the problem:
  - → water tree growth
  - → electrical tree growth
  - → failure

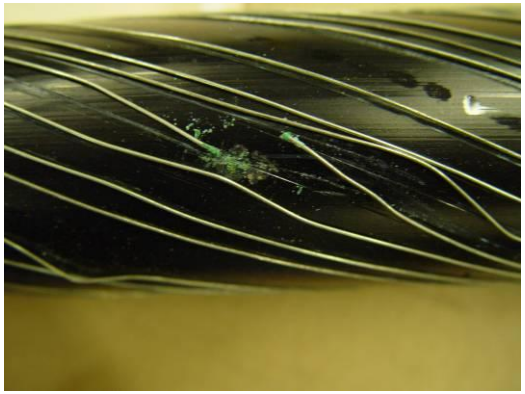
Courtesy - NEETRAC

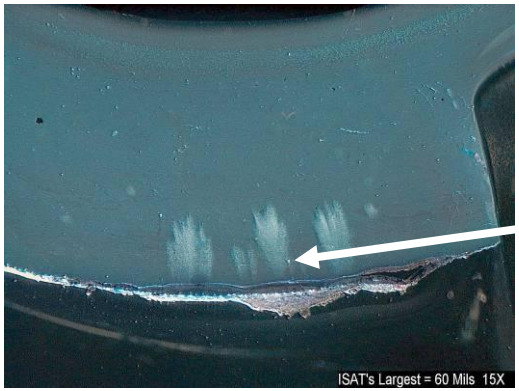
# Poor Cable Designs

## *The Problem*

- No jacket – Corroded Neutral Wires
- Taped Insulation shields
- Inadequate neutral wires

No Jacket – Corroded Neutral Wires






Courtesy - NEETRAC

# Improper Cable Operation


Overloading (Overheating)

(Causes cable deformation)

Chemical Exposure

(Causes cable degradation)

Courtesy - NEETRAC