The Accelerated Water Treeing Test (AWTT)

Background, Summary, Example Data, Pros & Cons

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Background

- **In early 1970's extruded cables began to fail unexpectedly.**

- **The reasons for the unexpected early failures are varied.**
  - **Improper installation practices**
  - **Inadequate cable designs (bare neutrals, inadequate neutrals, poor shield designs)**
  - **Inadequate insulation and shield compound cleanliness**
  - **Poor manufacturing and material handling practices**

Background

- **This sometimes-poor performance history led the electric utility and cable industries to develop accelerated test programs to evaluate cable performance.**
- **These tests are generally conducted at elevated temperatures and voltages over a period of several months. The idea is to establish, in a relatively short period, whether or not a cable can be expected to operate reliably in service.**
- **While no direct correlation between performance in the lab and performance in the field is established, the test conditions were believed to be sufficient to provide a general indication of the ability of a cable to survive in a moist environment.**

Background

- **Materials, manufacturing techniques and constructions for extruded underground power cables have improved significantly over the past 10 to 15 years.**
- **However, utilities are still cautiously uncertain about their expected life and rely heavily on the results of accelerated laboratory tests. This reliance is particularly important in view of the new cable insulation and shield materials that are being introduced into the marketplace.**
- **Cable manufacturers and insulation compound manufacturers use the results from accelerated aging tests to:**
  - **Evaluate**
  - **Qualify**
  - **Promote**

Background

- **At this point, there is no satisfactory method for using accelerated aging test data to accurately predict cable life in service:**
  - **Aging factors are incredibly complex**
  - **Aging mechanisms not completely understood**
  - **Field conditions vary significantly**

- ***The most commonly employed accelerated test in North America is the AWTT*. In this test, full size, extruded distribution cables are exposed to elevated temperatures and voltages in the presence of moisture.**

- **Primary performance indicators are impulse and ac breakdown data.**

AEIC AWTT Background

- **The group within the AEIC that deals with technical issues related to cable, the Cable Engineering Committee (CEC), developed the AWTT in the early 1970's.**

- **While the reason for the premature failures was not fully understood, they are believed to be the result of moisture migration into the insulation, which caused degradation (water treeing).**

- **The CEC already published a variety of cable specifications that contained qualification and production test requirements so the addition of a test to address this premature cable failure problem seemed like an appropriate task to undertake.**

AEIC AWTT Background

- **The AWTT procedure was published in AEIC CS5 and CS6 for many years.**
- **AWTT procedure now published in:**
  - **ANSI/ICEA S-94-649, "Standard for Concentric Neutral Cables Rated 5 Through 46 kV"**
  - **ANSI/ICEA S-97-682, "Standard for Utility Shielded Power Cables Rated 5 Through 46 kV"**
  - **Supplements (increased tree counting requirements) are published in AEIC CS8.**

AWTT Objective

The primary objective of the AWTT test is to provide a standardized qualification test method that will give reasonable assurance that an extruded, medium voltage cable design made by a given manufacturer will meet minimum performance requirements for operation in a wet environment.

To meet this objective, the 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 (1 year).
- Help assure that the conductor shield, insulation and insulation shield materials are compatible.
- Help assure that the manufacturer is capable of manufacturing a reasonably well made cable using the materials being qualified.

AWTT - Procedure

- A total of 21 samples are tested (1/0 AWG conductor, 175 mils of insulation, no jacket)
  - Six without aging
  - Six with thermal aging only
  - Nine with thermal and wet aging
  -
- Thermal conditioning is conducted in PVC tubes with the conductor at 130 Deg. C using conductor current. (Thermal load cycle for 14 days)
- New (unaged) and thermally conditioned samples subjected to ac breakdown and hot impulse tests.
- Dissipation factor measured on selected samples.
- Wet aging is accomplished with 3X rated voltage applied and conductor current sufficient to achieve approximately 60 Deg. C conductor temperature in water. Aging is conducted in tap water filled PVC tubes with tap water in the conductor strands. All wet aging samples are subjected to the thermal load cycle test before wet aging to thermally condition the samples (drive off excessive volatiles in the insulation).

AWTT - Procedure

- Three samples are removed after each aging period - 120, 180 and 360 days and subjected to an ac breakdown test.

- Comments:

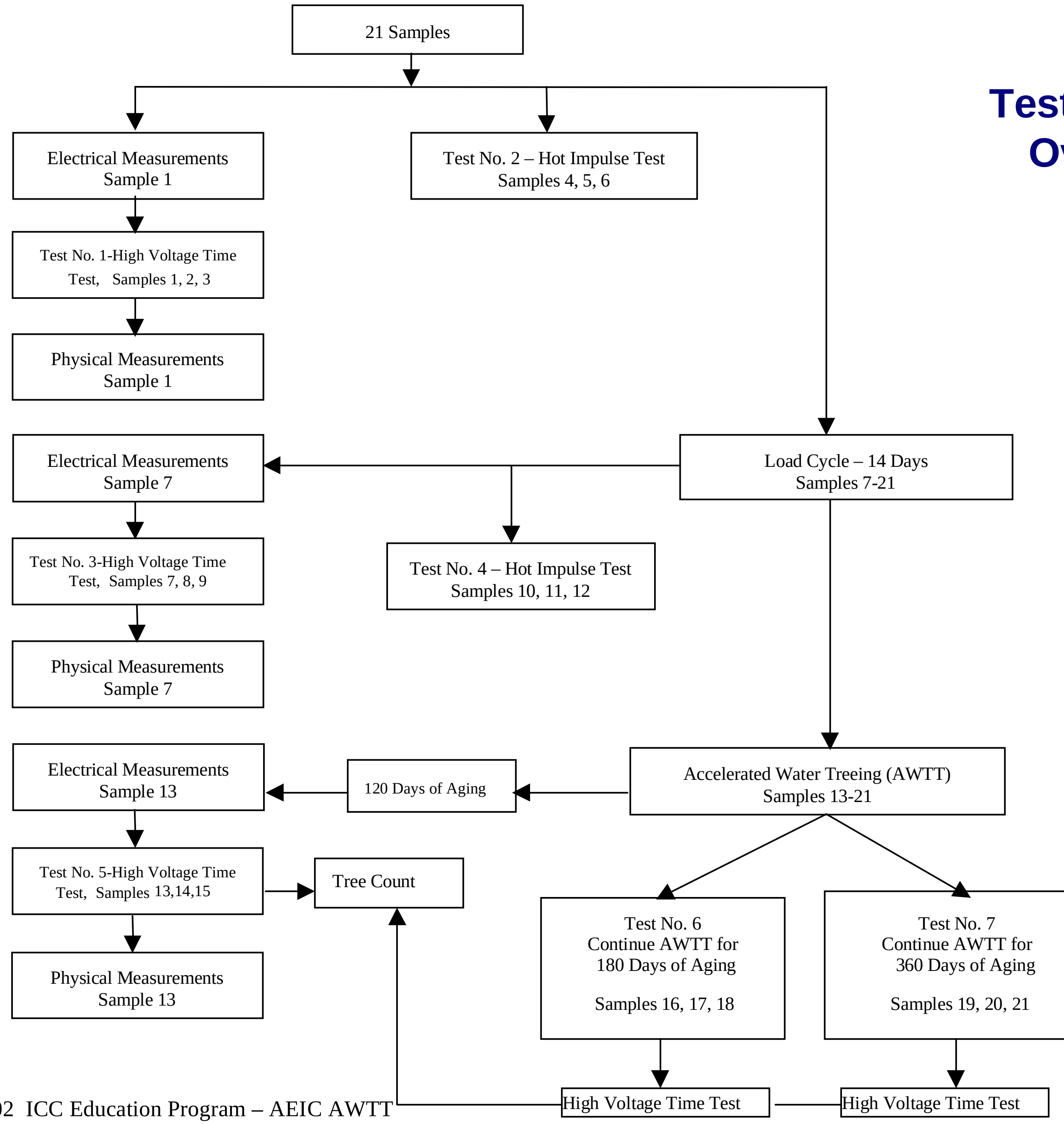
  - Test conditions are generally well defined.

  - Primary performance indicator is ac breakdown test results. (Impulse breakdown test also performed on new and thermally aged samples.)

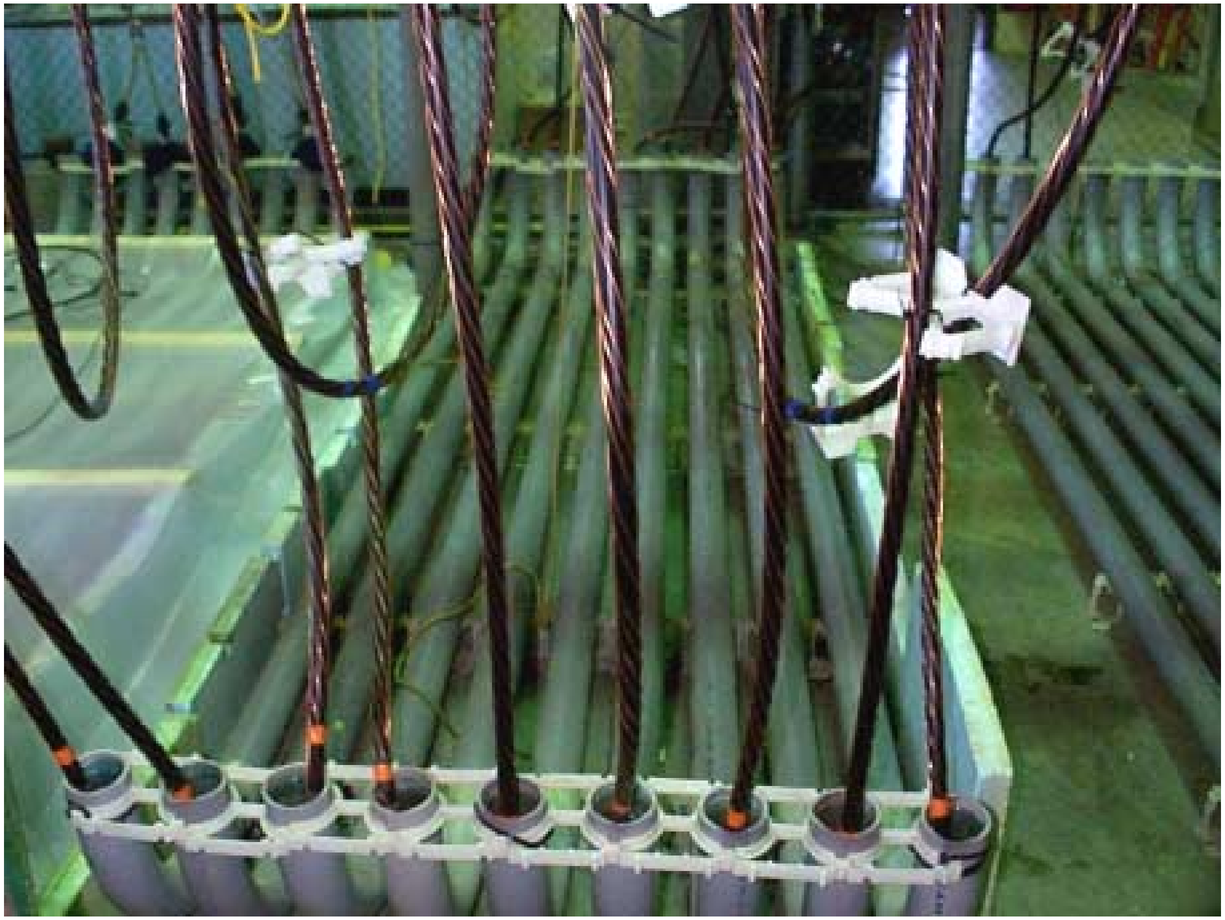
Test Protocol Summary

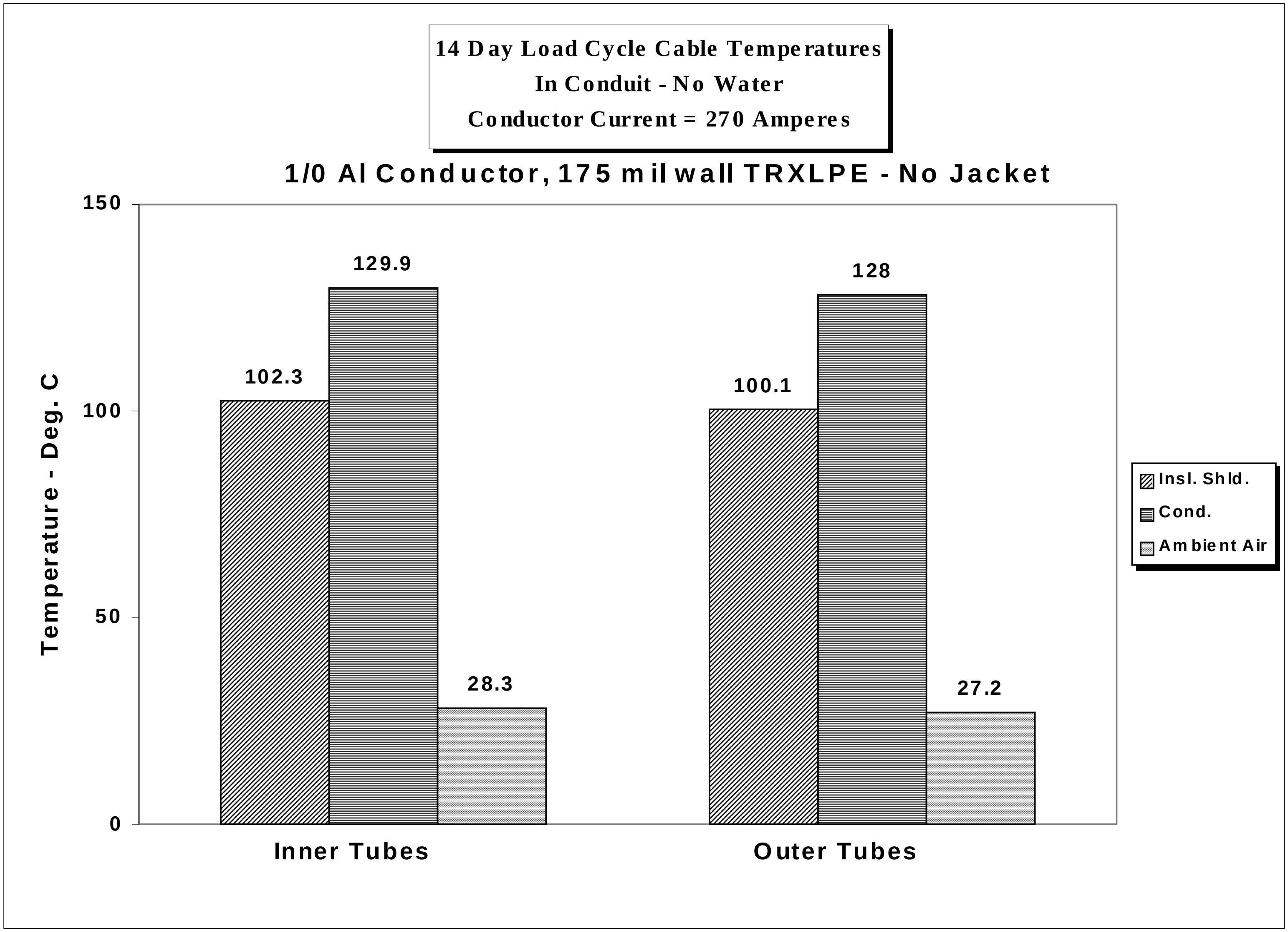
Test Characteristic	**AWTT**
Well Defined Protocol?	Yes
Aging Period	1 Year
Water Type	Tap
Voltage	3 Times Vg
Maximum Aging Temperature	45 ± 3 ºC on Ins. Shld. in water (60 °C on conductor)
Aging Environment	PVC Tubes
Time at Elevated Temperature	8 hours out of 24 hours
Number of Labs that Perform the Test?	Many
Primary Performance Indicator	AC Breakdown
Defined Performance Limits?	Yes
Severity of Test Parameters	Moderate

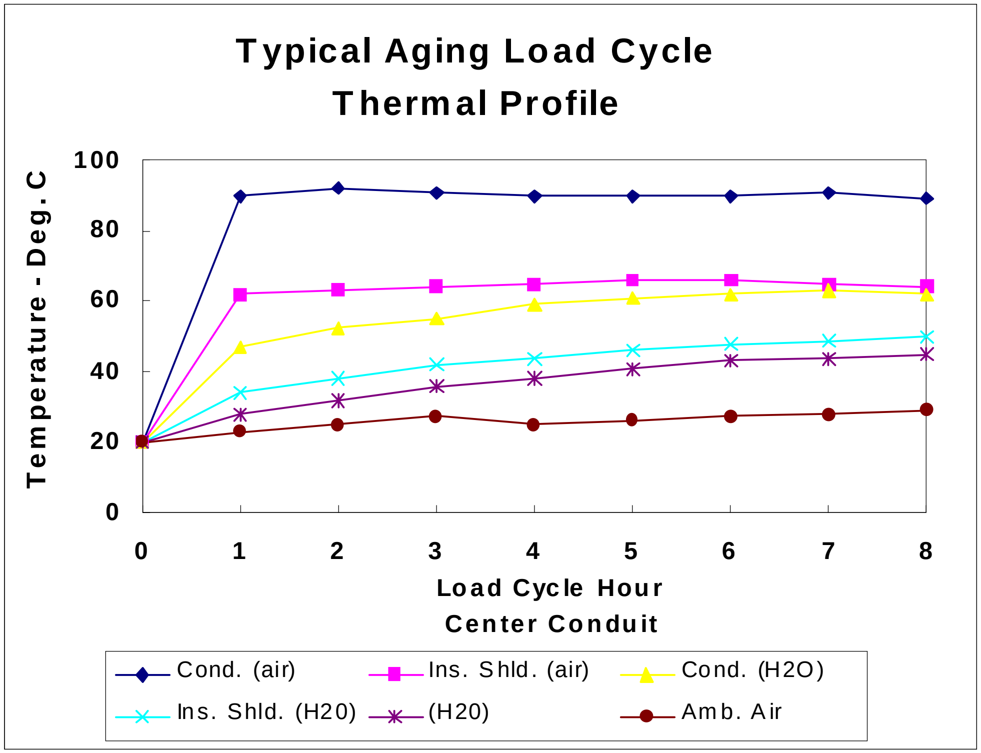
Test Protocol Overview



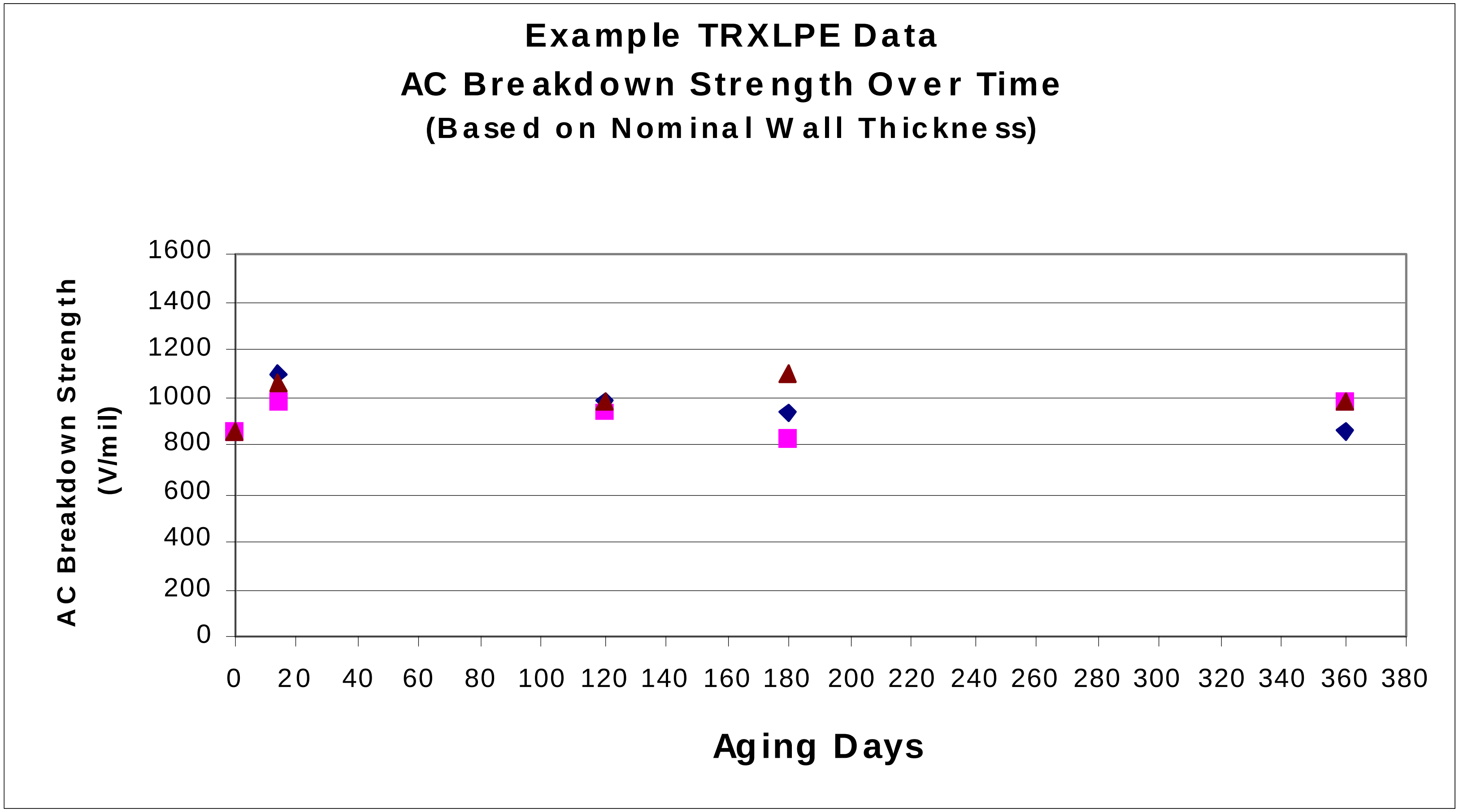
AWTT - Procedure

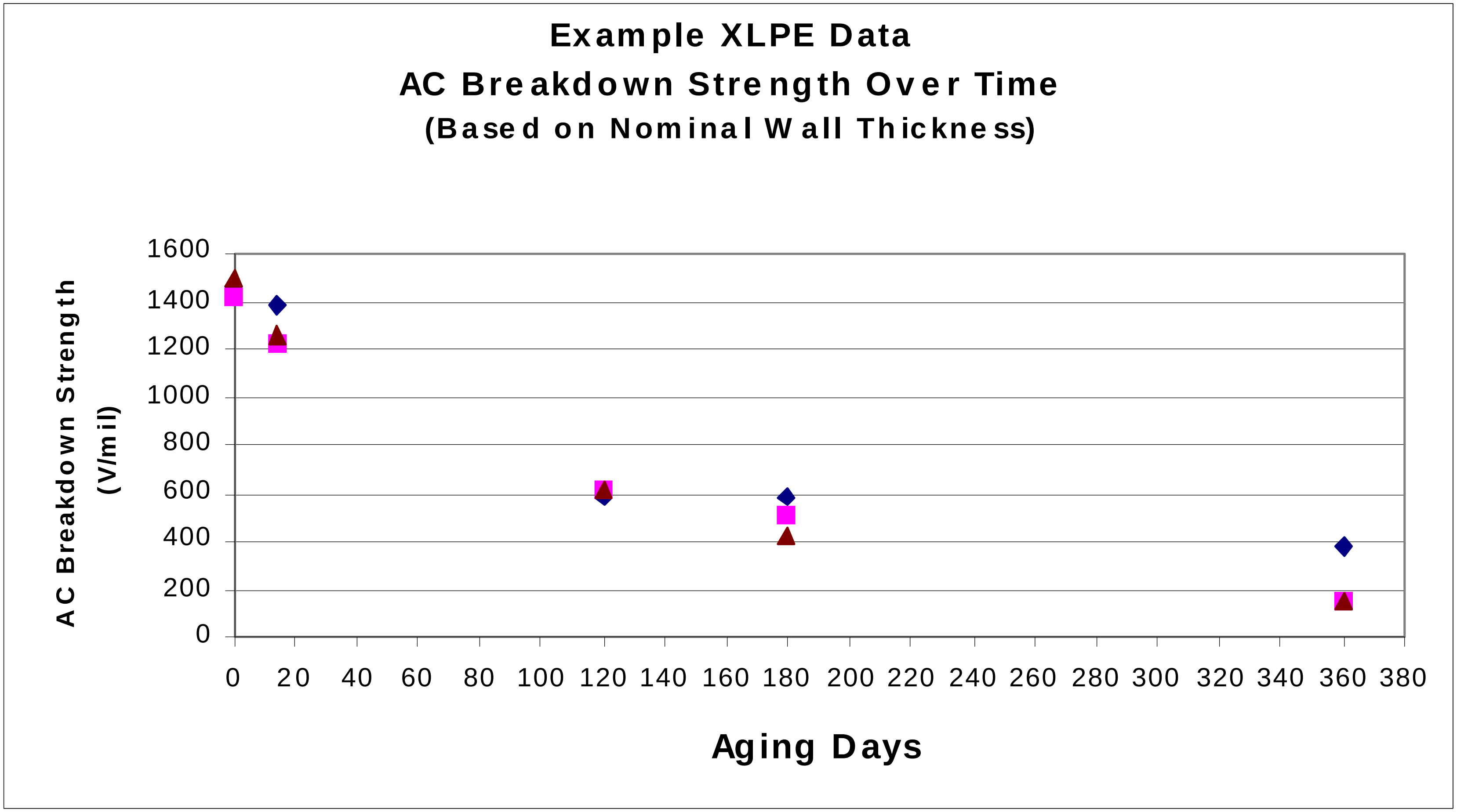



14 Day Load Cycle Cable Temperatures
In Conduit - No Water
Conductor Current = 270 Amperes
1/0 Al Conductor, 175 mil wall TRXLPE - No Jacket
Temperature - Deg. C
150
100
50
0
129.9
102.3
28.3
128
100.1
27.2
Inner Tubes
Outer Tubes
Insl. Shld.
Cond.
Ambient Air

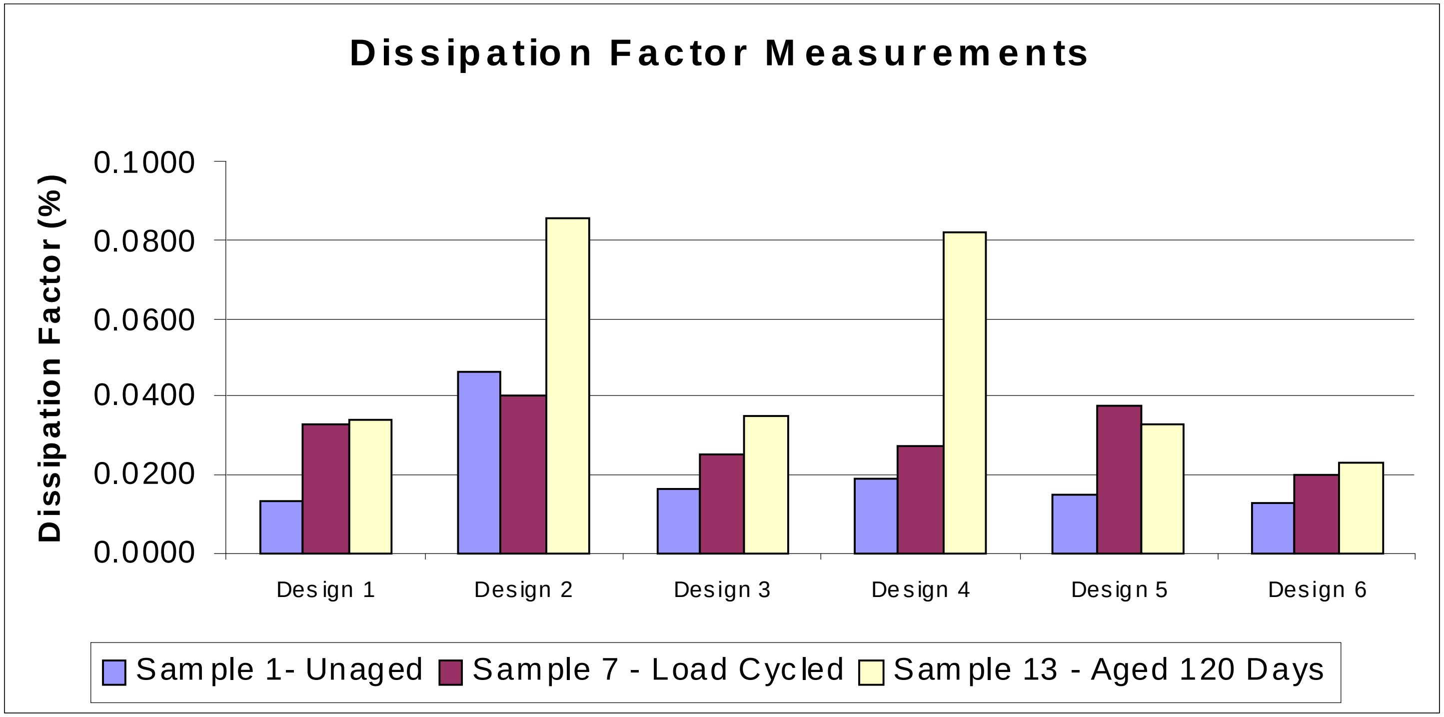


Typical Aging Load Cycle
Thermal Profile
Temperature - Deg. C
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
Load Cycle Hour
Center Conduit
Cond. (air)
Ins. Shld. (air)
Cond. (H2O)
Ins. Shld. (H20)
(H20)
Amb. Air

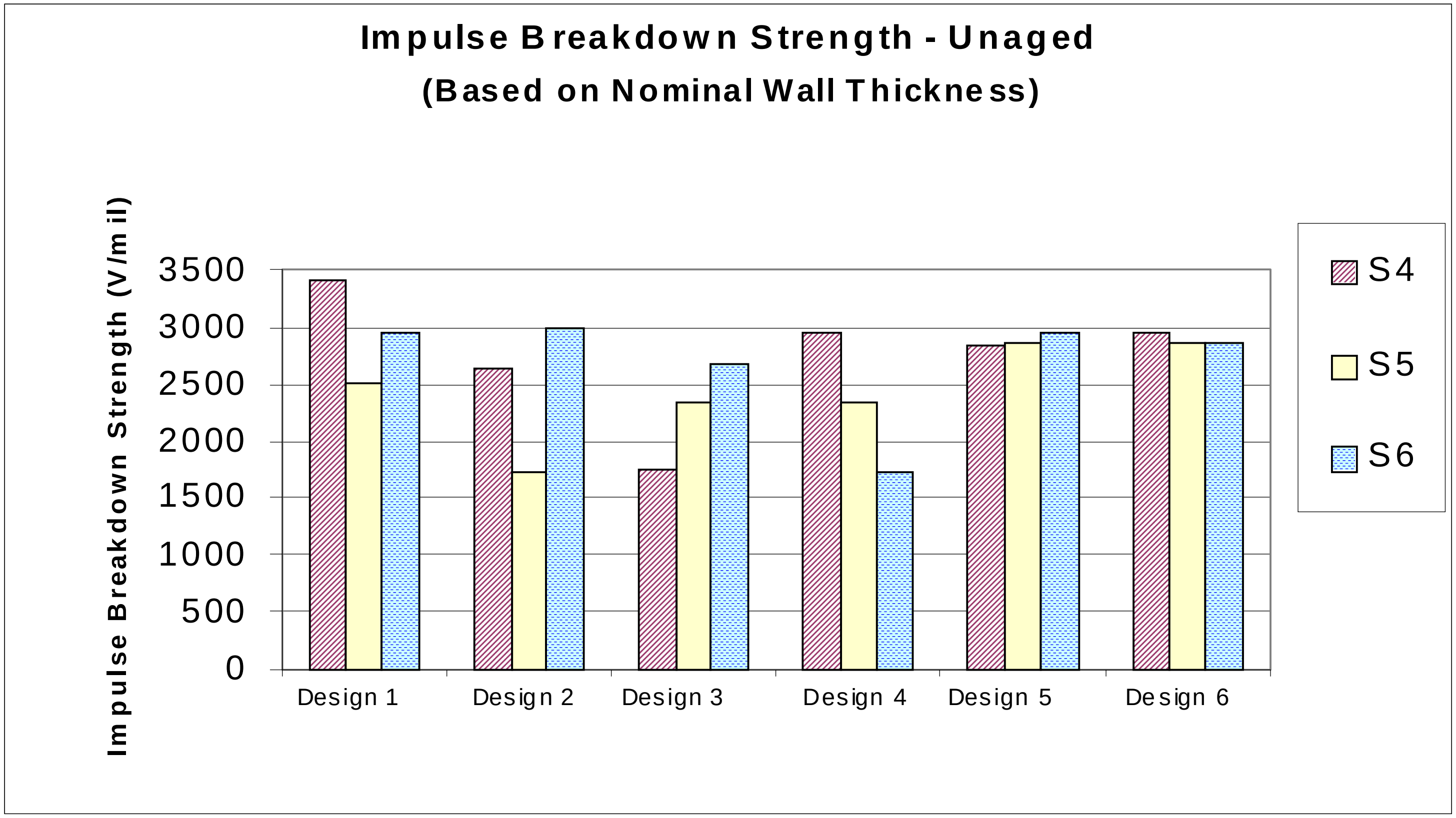

Example TRXLPE Data
AC Breakdown Strength Over Time
(Based on Nominal Wall Thickness)
AC Breakdown Strength (V/mil)
1600
1400
1200
1000
800
600
400
200
0
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380
Aging Days


Example XLPE Data
AC Breakdown Strength Over Time
(Based on Nominal Wall Thickness)
AC Breakdown Strength (V/mil)
1600
1400
1200
1000
800
600
400
200
0
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380
Aging Days

Example Dissipation Factor Data



Example Impulse Breakdown Data



Performance Requirements

- Impulse Breakdown Strength
  - New: XLPE: 1,200 V/mil, EPR: 800 V/mil
  - After thermal aging: XLPE: 1,200 V/mil, EPR: 800 V/mil
  -
- AC Breakdown Strength
  - New: XLPE: 620 V/mil, EPR: 500 V/mil
  - After thermal aging: XLPE: 620 V/mil, EPR: 500 V/mil
  - 120 days: XLPE: 260 V/mil, EPR: 300 V/mil
  - 180 days: XLPE & EPR: no requirement!
  - 360 days: XLPE & EPR: no requirement!

Interpreting AWTT Data

- Assure that all appropriate cable construction parameters are the same when comparing results from the AWTT.
- For AWTT, results from different labs *should* be comparable.
- Be aware that the accelerated tests conditions are truly accelerated.
- Current performance requirements for qualification using the AWTT need to be increased.
- Examine multiple data sets – one data set does not establish a firm benchmark.

Pros and Cons - AWTT

Table 2
Pros and Cons for AWTT

Pros	Cons
✓ Test protocol well established, allowing for good confidence when comparing different data sets ✓ Provides for basic, tangible performance requirements for ac and impulse dielectric strength in a relatively short period of time ✓ The test is conducted by a wide variety of laboratories so a broad data base of test results is available ✓ Does a relatively good job of identifying poor insulation or shield compounds or poor manufacturing processes in a relatively short period of time	✓ The number of ac breakdown samples for each time period is relatively small ✓ The total aging time is one year which may be somewhat short when projecting life in service ✓ The primary data provided is ac breakdown strength over time, which is only indirectly related to cable life