Extruded Underground Cable Failure and Testing

39th Annual Engineering Insurance Conference

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RSA

October 10, 2012

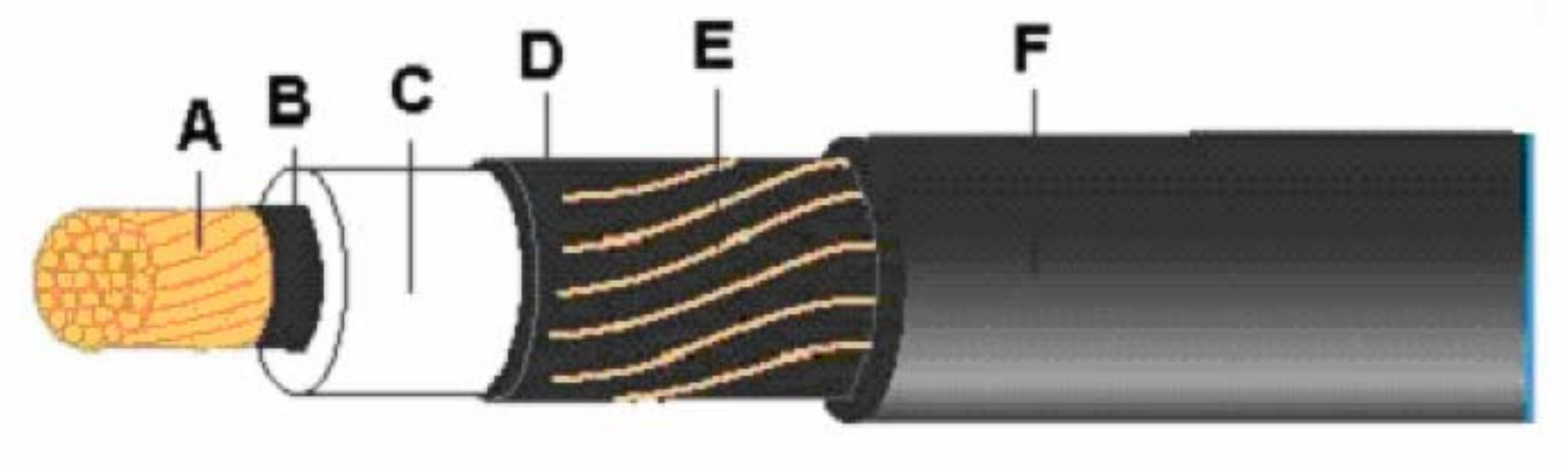
Agenda

- ✓*Extruded Underground Electrical Cable*
- ✓*Major Underground Cable Degradation*
- ✓*Needs for Underground Cable Testing*
- ✓*Cable Testing Technologies*
- ✓*Diagnostic Technologies for Aging Underground Cables*
- ✓*Standards of Cable Testing Technologies*
- ✓*Cable Repair and Rejuvenation*

Extruded Cable Application

- Power Distribution –Utilities, Heavy Industries, Institutes
- After Early 1970s All New Medium Voltage Cables –XLPE with Some EPR
- Cable Insulation Materials
  - XLPE- Cross Linked Polyethylene
  - EPR -Ethylene Propylene Rubber
- About 70% Underground Cables Are XLPE
- Underground: Conduit or Direct Buried

Typical Single Phase Underground Cable



A: Conductor

B: Conductor Shield

C: Insulation

D: Insulation Shield

E: Concentric Neutral

F: Jacket

Major Underground Cable Degradation

- **Most underground cables fail in:**
  cable neutral, conductor, insulation, insulation shield, lead sheath, outer jacket, splices and cable terminations.

- **Underground cable degradation processes:**
  corrosion, electrical trees, water trees, mechanical stress, mechanical damage, material degradation, animal damage, thermal runaway, embrittlement, loss of adhesion, partial discharge, tracking, overheating, thermal aging, and degraded seals.

- **Corrosion, electrical treeing and water treeing are the major root causes of underground cable failures.**

600MCM XLPE Underground Cable Failure in Hockey Arena

One phase 600MCM XLPE underground cable failed in one Hockey Arena. Root cause – water tree developed to electrical tree failure. Over $200,000 for a replacement of 700 meters cable.

XLPE Underground Cable Water Ingress Failure

- 500MCM aluminum XLPE underground cable failed
- $100,000 –fault locating, cable replacement, road repair and 2-week genset rental
- Root cause–water ingress; high level of sub-soil moisture;

Cable is water resistant, but not water proof!

Major Underground Cable Degradation Process

- ***Corrosion***

- **Elevated chemicals, such as sulfate or chloride content, in the soil**

- **Soil having considerable capacity to hold moisture; Poor drainage; Moderate to heavy annual rainfall.**

- **Concentric neutral (CN) degradation –loss of protective shielding and lack of properly grounded current return path.**

Major Underground Cable Degradation Process

- ***Electrical Tree***

- **Occur at stress enhancements -material discontinuity, such as protrusions, contaminants, voids, or water trees subjected to electrical stress for extended time periods.**

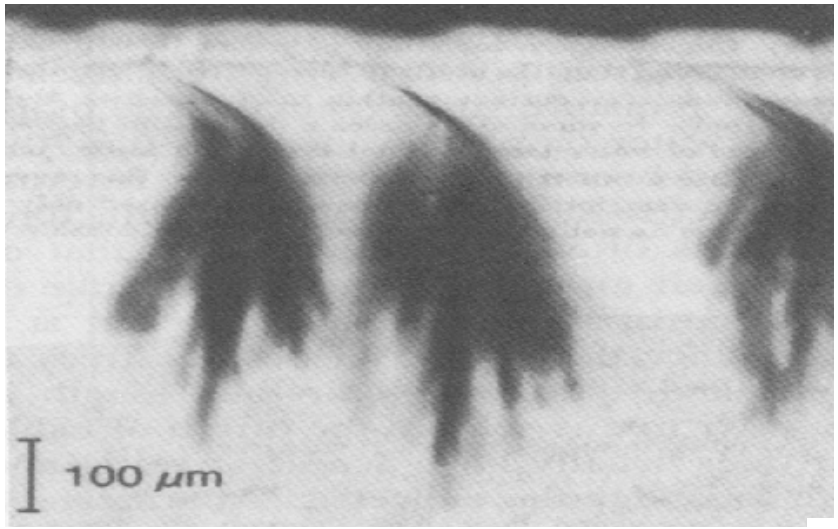
- **Insulation is damaged irreversibly, partial discharge may be present, and complete insulation breakdown may be only a question of time.**

Major Underground Cable Degradation Process

- ***Water Tree***

- **Water ingress during construction, installation or while in service in the moisture environment.**
- **Do not generate partial discharge; but can lead to electrical trees when subjected to high electrical stresses.**
- **Water treeing is an important form of degradation that can afflict older XLPE extruded cables.**

Water Trees in XLPE Cable Insulation

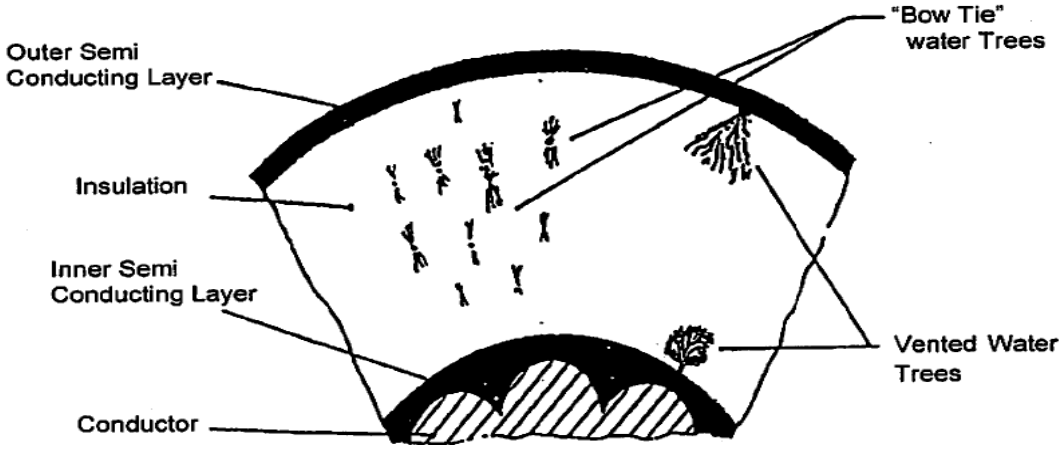


Water trees in XLPE cable insulation

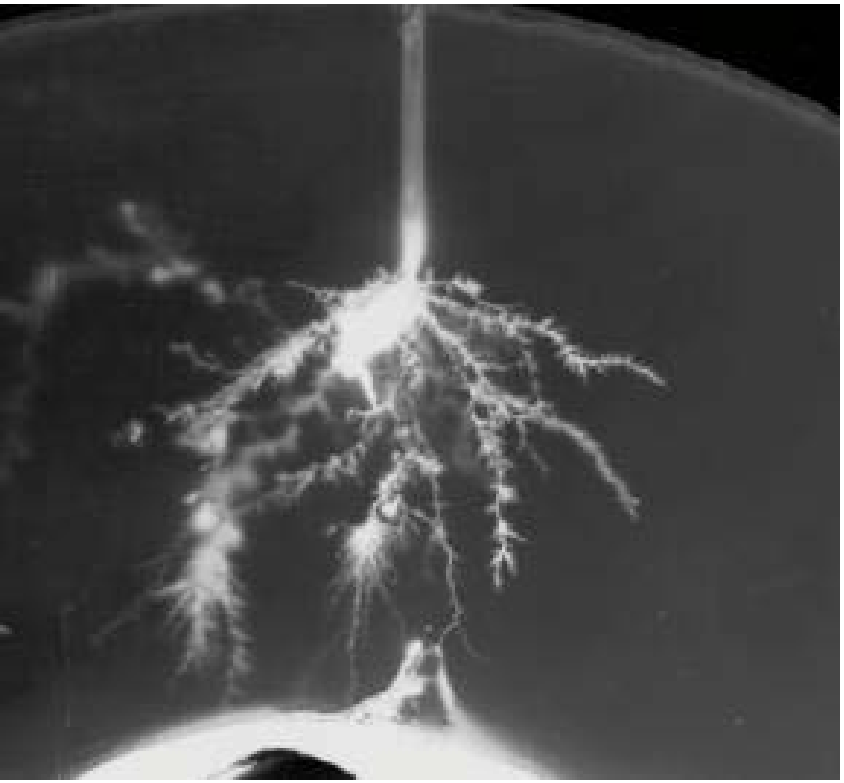
A tree-shaped collection of water-filled micro-voids.

Various configurations of water trees in extruded cables

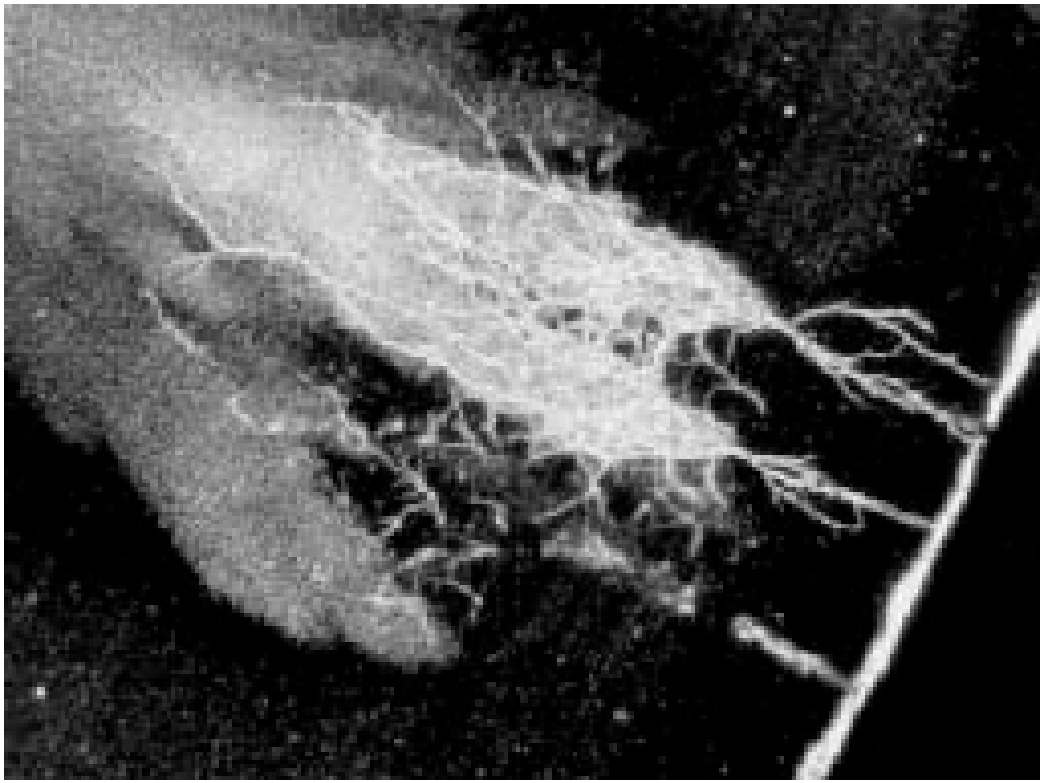
- ✓**Vented Water Trees**
- ✓**"Bow Tie" Water Trees**



Electrical Trees in XLPE Cable Insulation



Example of electrical tree in XLPE cable insulation



Electrical tree growing from water trees

Tree-like growths, consisting of non-solid or carbonized micro-channels.

Needs for Underground Cable Testing

- **Serious dielectric property deterioration when the underground conduit and cable are exposed to corrosive/wet conditions.**
- **Age and size of most installed underground distribution cables for utilities and heavy industry is increasing.**
- **A sudden power outage, causing unexpected downtime and production losses.**
- **Losses of cables due to deterioration could be a claim. Replacement of complete cable line is very expensive. The business interruption loss could be significant.**
- **Cable users and utilities search for diagnostic tools that will locate cables and accessories in weakened condition (likely to fail). This leads to proactive maintenance measures to replace, repair or rejuvenate cable prior to failure.**

Cable Testing Technologies

- **Meggering: mainly for cable terminals**
- **High Potential (Hi-pot)**
  - **Hi-pot test (DC or AC): higher than rated voltage**
  - **DC Hi-pot Test: stresses the insulation by resistivity, and may cause the water tree failure. Only used for new cable and installation.**
  - **Very Low Frequency (VLF -0.01-1 Hz) Hi-pot Test: stresses the cable insulation by permittivity. Withstand is preferred over DC Hi-pot testing to avoid water tree deterioration.**
- **Diagnostic Test with VLF: dissipation factor (DF), differential dissipation factor, harmonic loss current, and dielectric spectroscopy.**
- **Partial Discharge Measurement (PD)-Diagnostic test**
- **Time Domain Reflectometer (TDR): non-destructive. Also called "cable radar".**

Diagnostic Technologies for Aging Underground Cables

***For medium voltage XLPE cables where water treeing is considered to be the major aging and deterioration factor, following tests are suggested*:**

- **TDR –Corrosion Condition**
  - **Locate splices and terminators if any;**
  - **Check corrosion and concentric neutral;**
  - **When the neutral is more than 50% corroded, further inspection should be carried out to see if the corrosion is localized (PD) or widespread (DF).**
- **Partial Discharge Measurement (PD) –Electrical Trees**
  - **Detect small electric sparks or discharges in defects in the insulation, or at interfaces or surfaces, or between a conductor and a floating metal component.**
  - **Capable of detecting 300 meters long underground cables from each splice.**
- **VLF DF Test –Water Trees**
  - **VLF Dissipation Factor (DF)-Diagnostic: detect overall condition/ water treeing in XLPE cables.**

Standards of Cable Testing Technologies

IEEE Underground Cable Test Standards:

- **DC Hi-pot Test**
  - **IEEE Standard 400.1, Guide for Field Testing of Laminated Dielectric, Shielded Power Cable Systems Rated 5 kV and Above with High Direct Current Voltage**
- **Partial Discharge Measurement (PD)**
  - **IEEE Standard 400.3, Guide for Partial Discharge Testing of Shielded Power Cable Systems in a Field Environment .**
- **VLF Withstand and DF Test**
  - **IEEE Standard 400.2, Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF)**
  - **IEEE Standard 400.2 -2012 Draft, IEEE P400.2/D1; with more recent database for diagnostic patterns and comparison**

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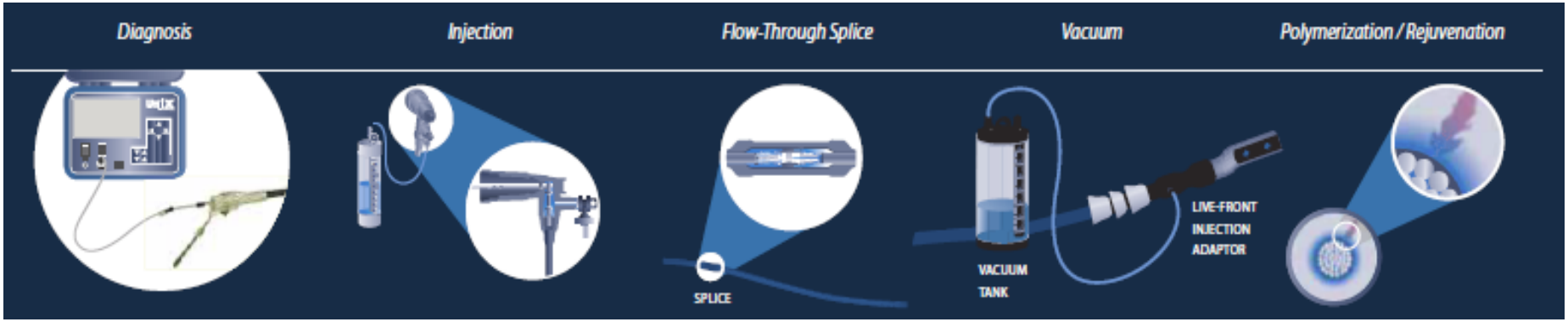
Cable Repair and Rejuvenation

- ❑ **Concerning on aging underground cable with poor dielectric property for continued services**

- ❑ **Options:**

•Section repair, splices or terminators
•Replace old cable with new cable
•Rejuvenate aging cable in situ

- ❑ **CableCure**



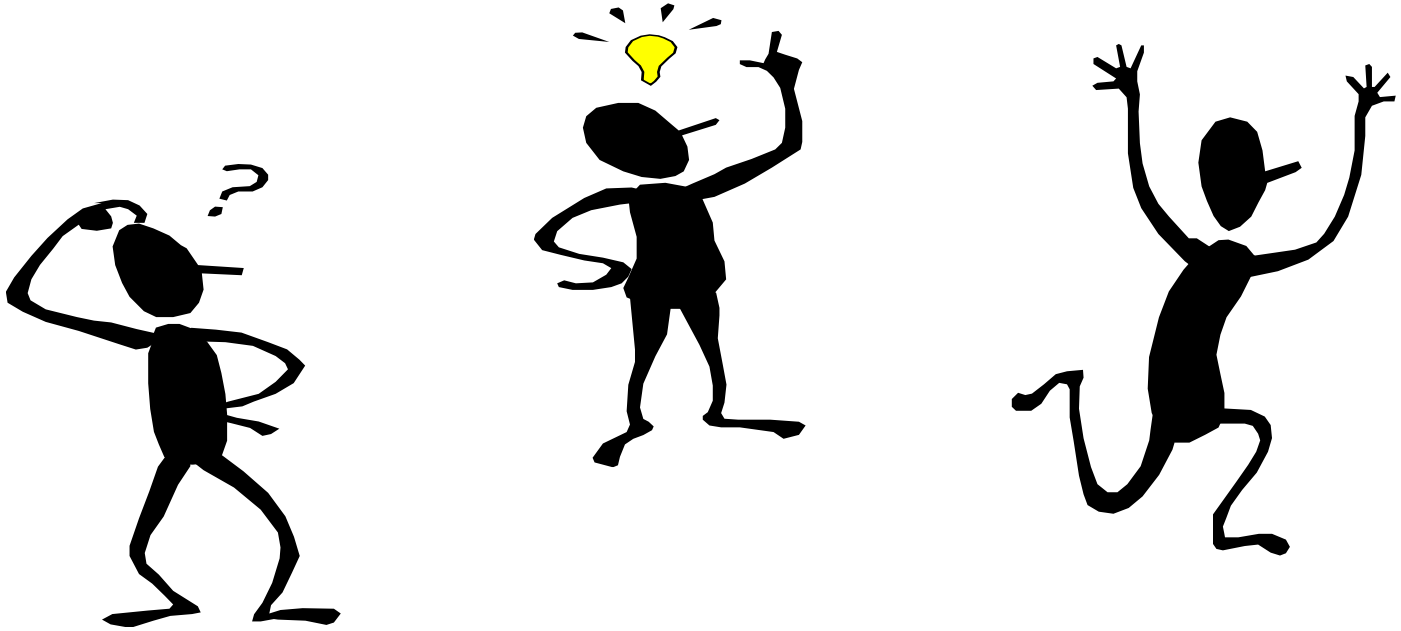
Cost of such a cable repair may be up to 50% of the cable replacement.

Special Appreciation to

Dr. John Densley (Chair of IEEE 400.2 Technical Committee)

For Guidance on Underground Cable Testing

Questions & Answers



Thank You!