SCE’s Perspective on Cable Failure and Diagnostics

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Topics of Interest to SCE

- Identify “Best Practices” for Pre-emptive Cable Replacement
- Integrate Real-time Temperature Monitoring into cable loading criteria. (Proof of Concept)
- Provide examples of Cable Failures at SCE

Identify “Best Practices” for Pre-emptive Cable Replacement

SCE Distribution Cable Design Timeline

Pilc Cable - Prior to 1968
- Paper insulated Oil filled design
- Thermal Limits Normal 80ºC & Emerg 110ºC

HMWPE - 1966 to 1972
- Solid Dielectric design
- Thermal Limits Normal 75ºC & Emerg 95ºC

XLPE - 1971 to 2000
- PE design - Crosslinked for improved thermal performance
- Thermal Limits Normal 90ºC & Emerg 130ºC

TR-XLPE - 1999 to 2002
- PE design - Crosslinked for improved thermal performance and tree retardant agent
- Thermal Limits Normal 90ºC & Emerg 130ºC

JCN TR-XLPE - 2002 to Present
- PE design - Crosslinked for improved thermal performance and tree retardant agent
- Thermal Limits Normal 90ºC & Emerg 130ºC

EPR Jacketed 1997 to Present
- Replacement for PILC cable
- Thermal Limits Normal 90ºC & Emerg 130ºC (Introduced in 1997 & Standardized in 2002)

Pre-Emptive Cable Replacement Program

- SCE has 46,000 conductor miles of underground MV Cables.
- SCE has replaced 133 conductor miles of MV Cables over past six years.
- SCE’s proposal for the next three years is to replace 750 conductor miles of MV Cables.
- SCE needs to improve its strategy to optimize selection of cables to be replaced.

Pre-Emptive Cable Replacement Program

- The current replacement criteria is based on:
  - Removing the oldest HMWPE and XLPE
  - Highest impact of system reliability
    - Based on Failure Rates
    - Based on SAIDI and SAIFI
  - Using expert knowledge within local districts
  - Using diagnostic tools to support replacement strategy

Proposed Cable Diagnostics Program

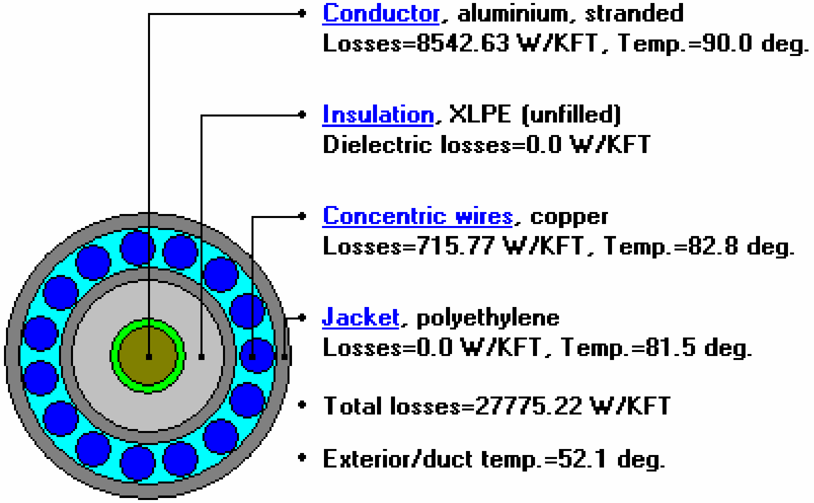
- Cable Diagnostics pilot scheduled to start in 2008.
- Cable Diagnostics Technologies Under Consideration:
  - VLF Tan Delta
  - Partial Discharge
  - Cable Rejuvenation
- Identify “best fit” for SCE’s Pre-Emptive Cable Replacement Program.
- Validate Diagnostic Technology by removing cable samples for testing.
- Projected use in the 2009 to 2011 cable replacement program.

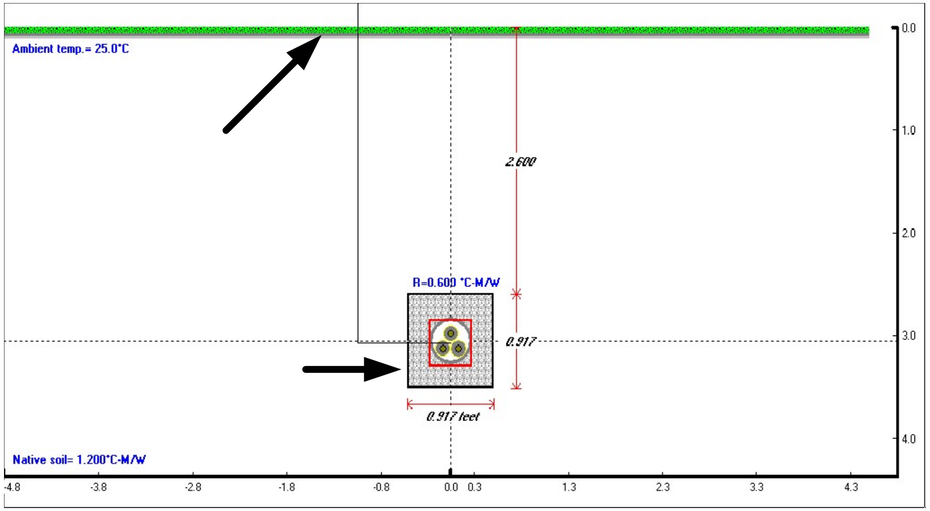
Goal: Refine/optimize cable replacement within target population

Existing Modeling Tools and Methods for Thermal Ratings

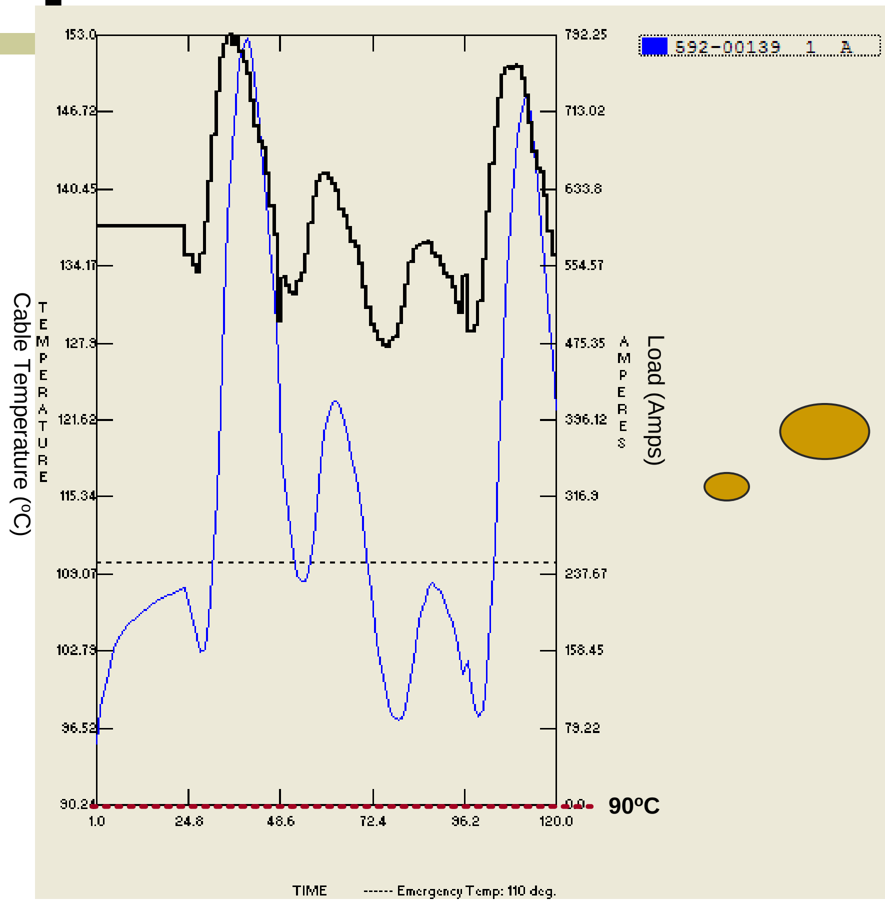
SCE's Existing Method for Rating Ductbanks and Cables

- SCE's DDS thermal limits are based on Steady State Analysis
- Assumptions (As an example):
  - Cable Design
    - TR-XLPE 220 mil Insulation
    - 1000kcmil, JCN
  - Cable Loading
    - Normal Rating 90ºC
    - Emergency Rating 130ºC
  - Ductbank Parameters
    - RHo 120
    - Earth Temp 25ºC
    - Ductbank Conf 1x1
    - Conduit 5" PVC
    - Encasement Concrete
    - Cover 30"





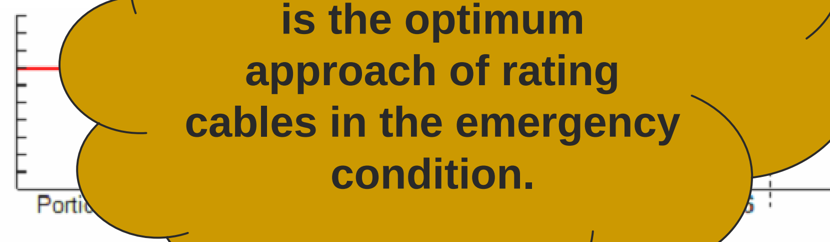
Examples of Thermal Transient Analysis Based on SCE 2005 Peak Loads



Based on 130% of normal current

Black – Ampacity

Blue - Temperature



The Transient Analysis is the optimum approach of rating cables in the emergency condition.

Case No 16

The load profile is based on SCE 2005 Summer Peak July 21, 2005 @ 2:00 PST

Based on 80% Residential and 20% CI, 100 customer @ 2625kW Peak load

Temperatures were modeled at 30% above normal ampacity rating.

Cables were preconditioned with a load factor of 1.0 for 24 hours than allowed to operate with a load factor that is based on the summer peak July 21, 2005 for 120 hours.

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Integrate Real-time Temperature Monitoring into cable loading criteria.

Avanti Circuit out of Shandin Substation

Distributed Temperature Sensing (DTS) System Proof of Concept

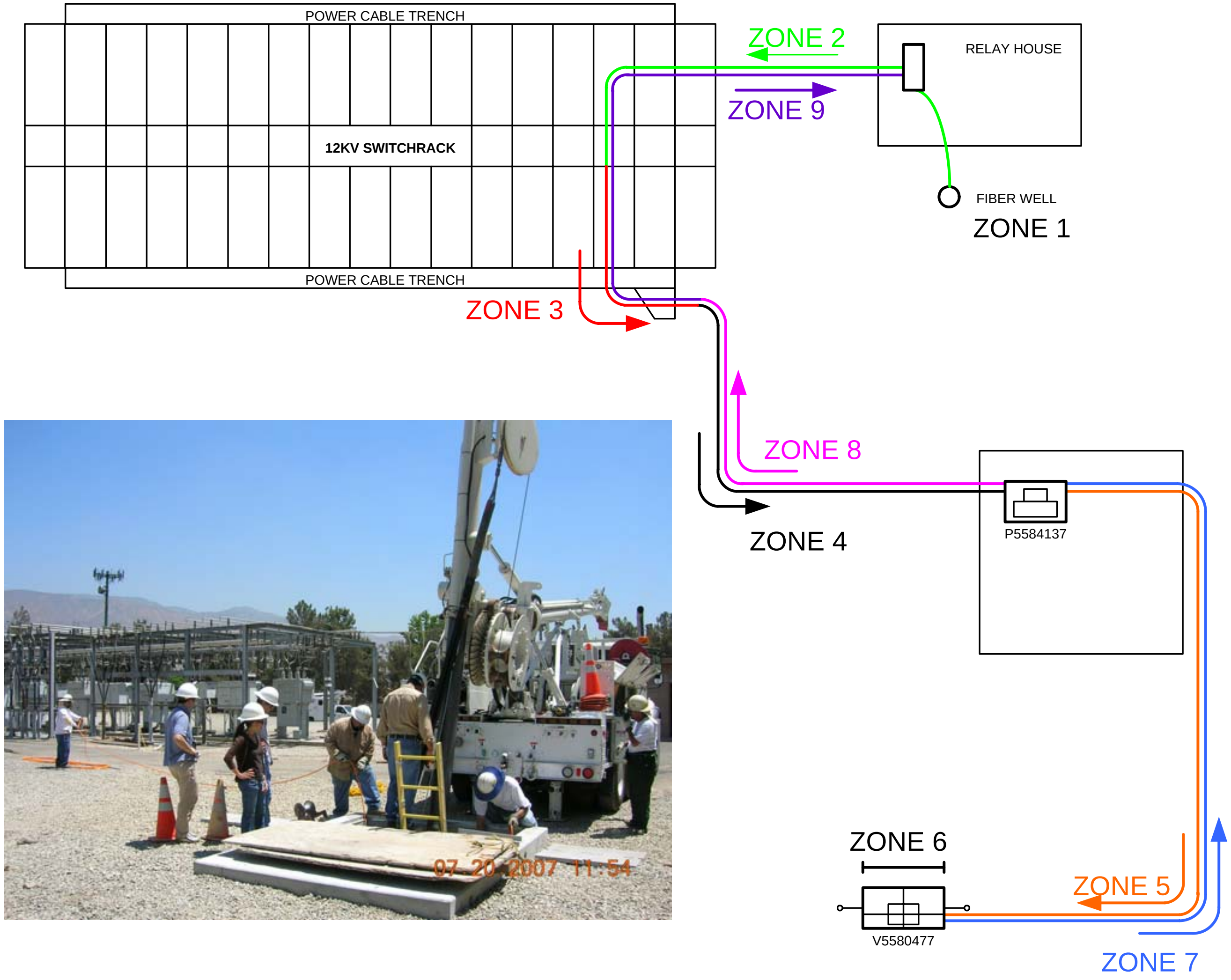
Integrate Real-time Temperature Monitoring as a Proof of Concept

- The objective of this proof of concept project is to:
  - Validate assumptions in existing thermal models
  - Provide a better understanding of thermal transients and their effect on ductbank loading.
  - Predict thermal transients
  - Operate cabling system by Dynamic Rating
  - Identify hotspots in cabling system – Project possible failure sites.

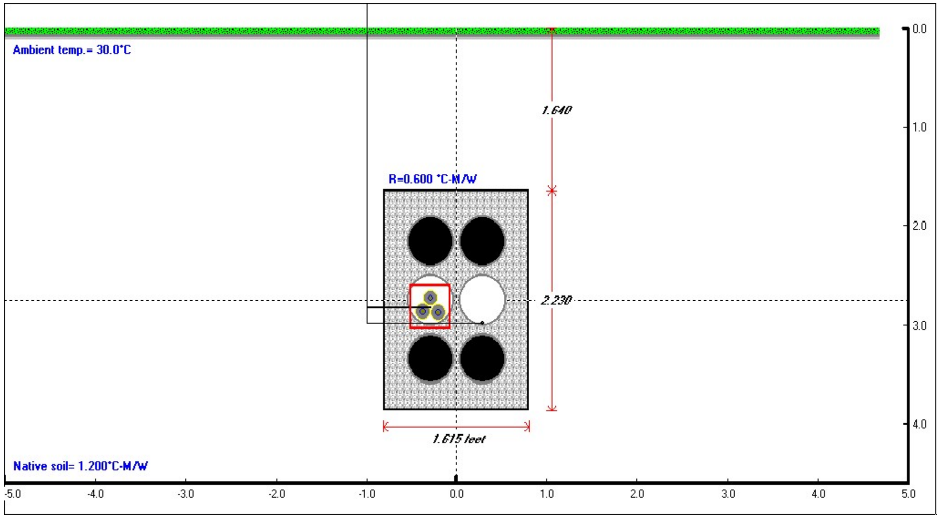
Distributed Temperature Sensing (DTS) System - Proof of Concept

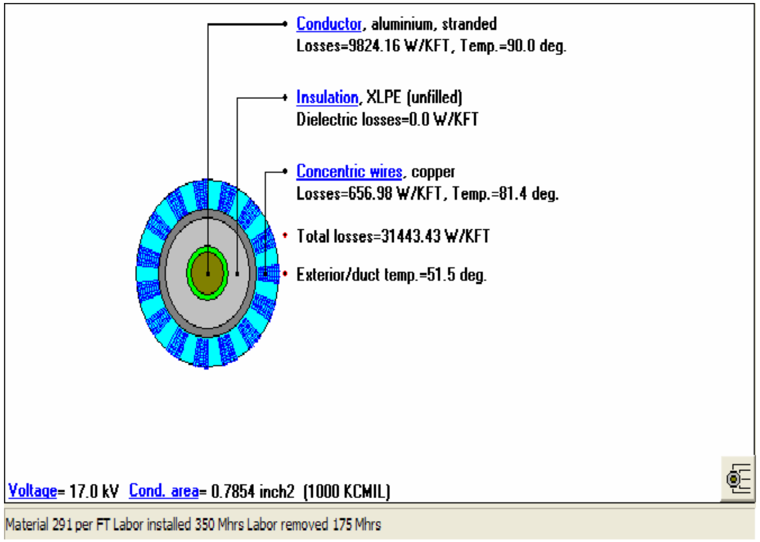
- Investigating the use of temperature data to forecast future thermal transients
- Import temperature data into modeling program
- Help manage cable loading as an operations tool.

Distributed Temperature Sensing (DTS) System – Proof of Concept



Avanti Circuit out of Shandin Steady State Thermal limits at 90^{o}C and 130^{o}C





	Power Cable Conductor Temperature	Calculated Ampacity	Calculated Fiber Temperature inside power conduit	Calculated Fiber Temperature in adjacent spare conduit
Normal Rating - Power Cable	90^{o}C	636.6	51.5^{o}C	46.7^{o}C
Emergency Rating - Power Cable	130^{o}C	750	76.6^{o}C	69.2^{o}C

Failure Mechanism

Failure Mechanisms

- High molecular weight polyethylene (HMWPE)
  - Treeing
  - Thermal Stresses
  - Corrosion of (CN)
  - Manufacturing Defects and Impurities
  - Transient Overvoltages
- Cross-linked Polyethylene Cable
  - Treeing
  - Thermal Stresses
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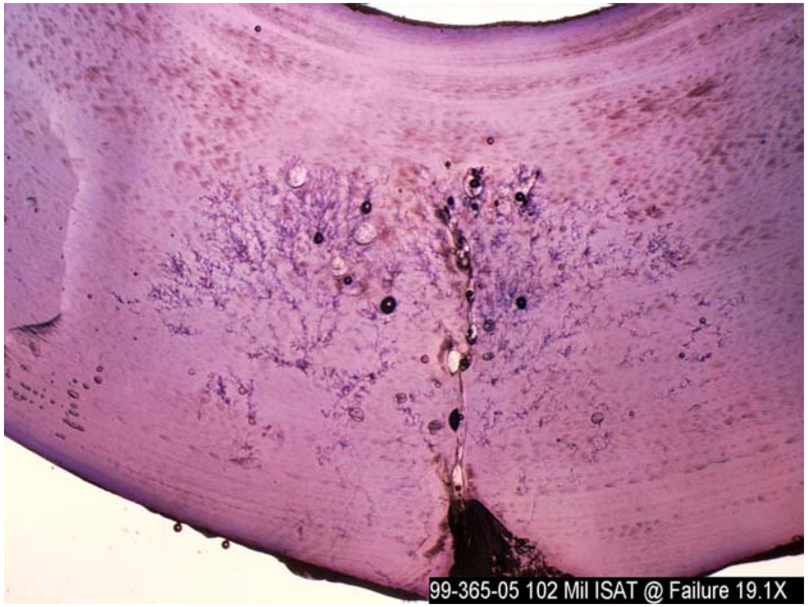
Understanding Failure Mechanism may lead to more effective diagnostic tools

Treeing - Failure Mechanism

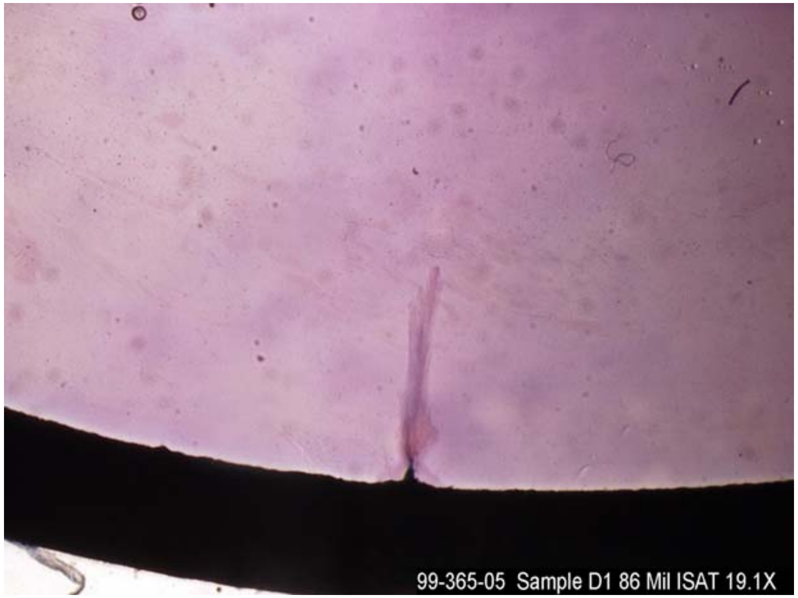


#2 AWG HMW vintage cable which failed in Ridgecrest. Water treeing more than 50% through the insulation

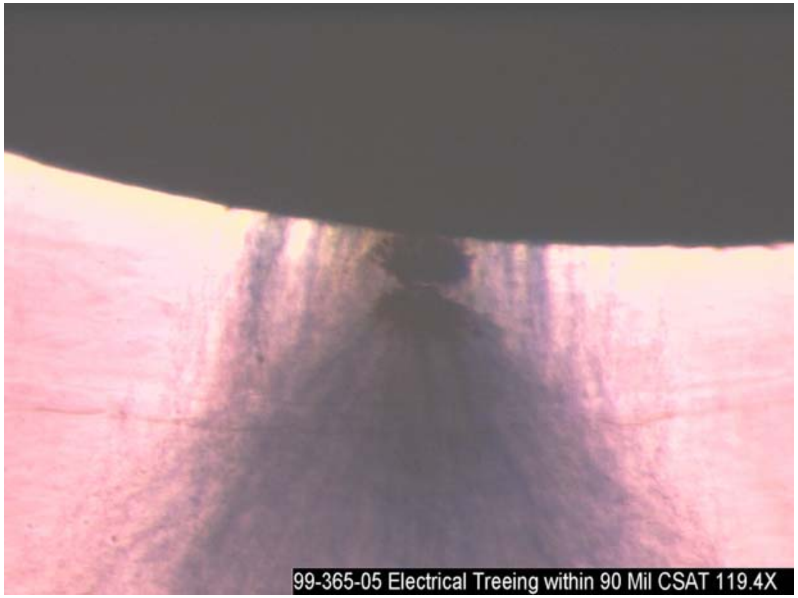
- #2 AWG XLPE cable from Fullerton. Water treeing more than 40% through the insulation.

Source: DAE, Improving the performance of underground cable.

Treeing Failure Mechanism



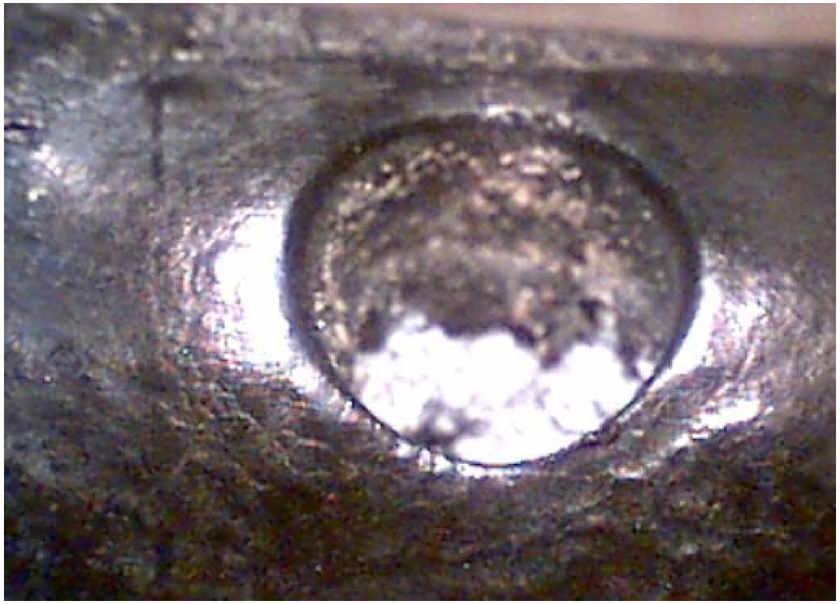
Water Tree Initiating through the insulation shield



Electrical Tree Initiating through the conductor shield

Corrosion and Impurities – Failure Mechanism

Arcing on the Semi-conducting Shield



Blown hole through the cable

Any Questions