ICC Education Session

Cable Accessory Failure Analysis

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Outline

• Background
• Overall Process for an Effective Forensic Program
• Primary Modes of Failure
• Benefits of a Forensic Program
• Summary
Background – Significance of Problem

- Cable accessories have a significant infant mortality rate.
- Newly installed accessories account for 20% of accessory-related service interruptions.
- Workmanship is the Number 1 cause of failure representing nearly 50% of the total failures.
- The number of unknown causes of failure is high (about 20%) showing the need for more thorough forensic evaluations.
- Manufacturing defects represent 15% of the total failures.
### Analysis of Collated Data – Cable Accessories - Cause of Failure

<table>
<thead>
<tr>
<th>Fault Type</th>
<th>% of Total Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor workmanship</td>
<td>35</td>
</tr>
<tr>
<td>Manufacturing problem</td>
<td>5</td>
</tr>
<tr>
<td>Corrosion</td>
<td>10</td>
</tr>
<tr>
<td>Mechanical Damage</td>
<td>15</td>
</tr>
<tr>
<td>Event</td>
<td>20</td>
</tr>
<tr>
<td>Aging</td>
<td>25</td>
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<tr>
<td>Overload</td>
<td>30</td>
</tr>
<tr>
<td>Unknown</td>
<td>35</td>
</tr>
<tr>
<td>Moisture</td>
<td>40</td>
</tr>
<tr>
<td>Dielectric breakdown</td>
<td></td>
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<tr>
<td>Contamination</td>
<td></td>
</tr>
<tr>
<td>Overheat</td>
<td></td>
</tr>
<tr>
<td>Incorrect record</td>
<td></td>
</tr>
<tr>
<td>Maintenance failure</td>
<td></td>
</tr>
</tbody>
</table>

![Fault Type Graph](image-url)
Analysis of Collated Data – Failures by Accessory Vintage

Accessory Vintages - All Utilities

% of Total Failures

Vintage

- 1970-1975
- 1975-1980
- 1980-1985
- 1985-1990
- 1990-1995
- 1995-2000
- 2000-2005
- >2005

Joints
Terminations
Junctions
Analysis of Collated Data – Cause of Failure

Summary by Failure Type - All Utilities

- Overheat: 4%
- Dielectric breakdown: 10%
- Aging: 6%
- Corrosion: 4%
- Moisture: 4%
- Event: 3%
- Overload: 2%
- Manufacturing problem: 14%
- Contamination: 1%
- Mechanical Damage: 1%
- Maintenance failure: 2%
- Poor workmanship: 49%
Overall Process for an Effective Forensic Program

- Preservation of sample integrity
- Importance of sister components
- Collection of background information
- Obtain installation instructions
- Choose the right evaluation technique/document all findings
- Identify all installation errors/determine most probable root cause of failure
- Clearly and accurately report all findings/forward to the appropriate personnel
- Track results of examinations
Preservation of Sample Integrity

• Remove sufficient cable length on either side of failed component
• Label sample to clearly identify location of failure
• Seal cable ends and wrap component to protect from environment
• Keep associated components together
• Store in a dry location prior to performing analysis
Preservation of Sample Integrity

• If you do not know what you are doing **Do Not** attempt your own analysis
Importance of Sister Components

- Sister components are those installed at the same time of the failed component, likely by the same installer.
- Significant damage to failed component may prevent determining most probable root cause of failure.
- Sister components allow for easy detection of installation/workmanship errors if installed by the same personnel.
Sister Units

- Jacket Cutback
- Copper Tape Shield
- Ground Strap
- Constant Force Spring
- Jacket Cutback
Sister Units

Cut in Cable Insulation at Jacket Cutback
Sister Units

Cut in Tape Shield at Jacket Cutback

Copper Tape Shield intact
Collection of Background Information

- Events leading up to failure (weather, switching events, previous failures, etc.)
- Circuit diagram
- Number of re-closures on circuit after initial failure
- Available fault current
- Typical loading conditions
- Type of load being served
- Any additional information that may be helpful in determining the root cause of failure
Obtain Installation Instructions

• Obtain installation instructions for vintage of component to be evaluated
• A proper analysis of most failed components is the exact reverse of the installation instructions
• Check for function, not for detailed compliance
• A perfectly installed accessory may fail by means outside the installers control
Outside the Installers Control

- Termite Damage
- UV Aging
Outside the Installers Control

Over ¾ inch Total Insulation Shrinkback

12 Inches
Choose the Right Evaluation Technique

• Think before you cut
• Document all findings/observations through photographs
• Preserve failure site, Do Not make cuts directly through failure site
• Cuts should be made at locations 90 degrees on either side of failure site
• Cuts through failure site should only be made, if necessary, and once a detailed examination of the various mating interfaces has been made
X-Ray
Identify all Installation Errors/Determine Most Probable Root Cause of Failure

- Identification of all installation errors should be documented to enhance training efforts
- Multiple errors may have contributed to the failure
- Determine most probable cause by process of elimination through a detailed analysis of the available evidence

“When you have eliminated the impossible, whatever remains, however improbable, must be the truth”

Sherlock Holmes – In the Sign of the Four
Clearly and Accurately Report all Findings

- Report should identify most probable cause of failure and all installation errors observed
- Share report with all parties to reduce or prevent future occurrences
- Discuss product defects with manufacturer to improve processes
- Discuss installation errors with training personnel or installers to eliminate installation errors
- If installation errors are the result of unclear installation instructions revise instructions

As-Built of termination used in report
Track Examination Results

• Results of examinations should be tracked in a database
• A database will help responsible personnel to observe and take appropriate action when trends in installation errors or manufacturing defects are evident
Common Failure Modes

- Workmanship
- Manufacturing Defects
- Design Issues
Workmanship

Cut in Cable Insulation
Workmanship

- Nicks in Conductor Strands
- Cuts in Conductor Strands
Workmanship

Lower Cold Shrink Tube Incorrectly Installed at Upper End of Termination

Black Stress Control Tube

Electrical Activity off Insulation Shield Cutback
Workmanship

Incomplete Shrink Down of Dual Layer Tube Leading to Failure

Puncture
Workmanship

Discharge between Inner Stress Control Tube and Cable Insulation Caused by Incomplete Shrink Down
Workmanship

Discharge between Inner Stress Control Tube and Dual Layer Tube Caused by Incomplete Shrink Down and Failure to Keep Stress Control Tube Hot
Workmanship

- No Mastic between Solder Blocks
- Lack of Bond between Mastic and Jacket
- Corrosion Deposits
- Water Migrated Past End Seal
Workmanship

Puncture at Knife Cut in Cable Insulation

Discharge between Stress Control Tube and Insulation Shield
Workmanship

Interface Tracking from Surface Contamination
Workmanship

Dirt Deposits and Lack of Bond

Water
Workmanship

Contamination between Insulating Tube and Stress Control Tube
Workmanship

Stress Relief Mastic Across Entire Cable Interface
Workmanship

Brown Discoloration of TRXLPE caused by Overheating Compression Connector

No Wire Brush Marks on Conductor in Area of Crimp Down
Workmanship

Deformation of Insulation

Thermal Damage to Joint Body

Transition of Insulation Color Away from Connector
Workmanship

No Wire Brush Marks on Conductor

Wire Brush Marks on Conductor
Workmanship

Brown Discoloration of TRXLPE caused by Overheating Compression Connector

Thermal Damage

Tool Cuts in Conductor Strands
Workmanship

Area of Crimpdown in Connector Body

Aluminum Oxides

Arc Pit in Connector Body
Workmanship

Melting of Arc Quenching Probe

Bent Probe
Workmanship
Workmanship

Soldier Block Located over Dual Layer Tube

Ground Strap

Corrosion Deposits
Workmanship

- Cut in Cable Insulation
- Dielectric Puncture
- Start of Penciling on Cable Insulation
- Thin Area of Insulation Wall In Line With Failure
Workmanship

Note that Cut Aligns with Centerline of Puncture

Fault Channel

Electrical Treeing
Workmanship

Bracket Cutting into Cable

Open Neutrals Arcing to Bracket

Failure Site
Workmanship

Compression Lug Vaporized
Workmanship/Manufacturing

- Knife Cuts Created During removal of Joint Body
- Sanding Marks
- Folds/Wrinkles in Copper Tape
- White Bedding Tape
Manufacturing Defect

- Puncture Site
- Area of Discoloration
- Puncture Site
Manufacturing Defect

- Insulation
- Conductor Shield
- Puncture in Conductor Shield
- Void in Insulation
Manufacturing Defect

Fault Channel in Joint Insulation

Metal Contaminant
Design Issues

Surface Tracking on Cable Insulation

Erosion of Stress Control Tube
Design Issues

Corrosion on Conductor

Moisture Entry Point

Path of Moisture
Design Issue
Design Issue

Complete Break in Sheath

Failure Site

Stress Cracking
Design Issue - UV Aging

Surface Tracking and Erosion

Stress Cracking
Benefits of a Failure Analysis Program

- Improve Training
- Reduce outages
- Increase in revenue
- Reduce need for expensive diagnostic testing
Summary

- Surveys and data analysis show cable accessory failures make up a large percentage of in-service outages.
- About 20% of accessory failures have no known cause, indicating a need for more detailed forensic analysis.
- About 15% of accessory failures can be attributed to manufacturing defects, indicating a need for tighter control of manufacturing processes.
- Surveys and data analysis show the need for improved training of cable accessory installers.

Utility Survey Showing System Failure Causes
Summary

All evidence points to improved TRAINING as the single most cost effective means of improving system reliability.