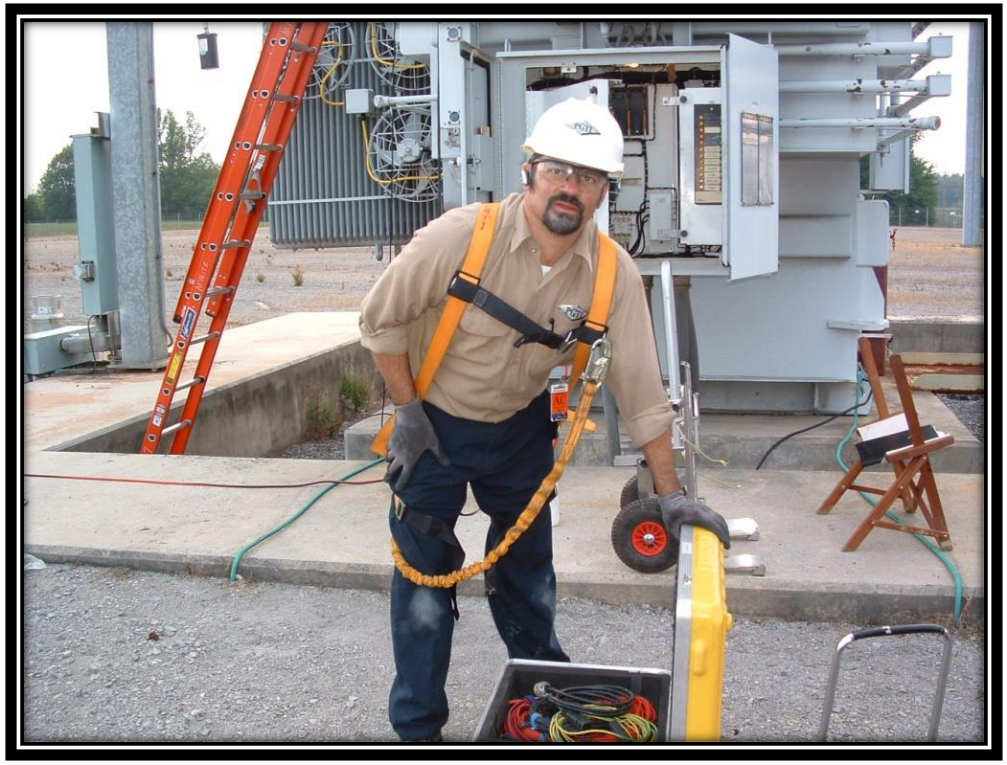
Electrical Predictive and Preventative Maintenance

Mose Ramieh III – CE Power

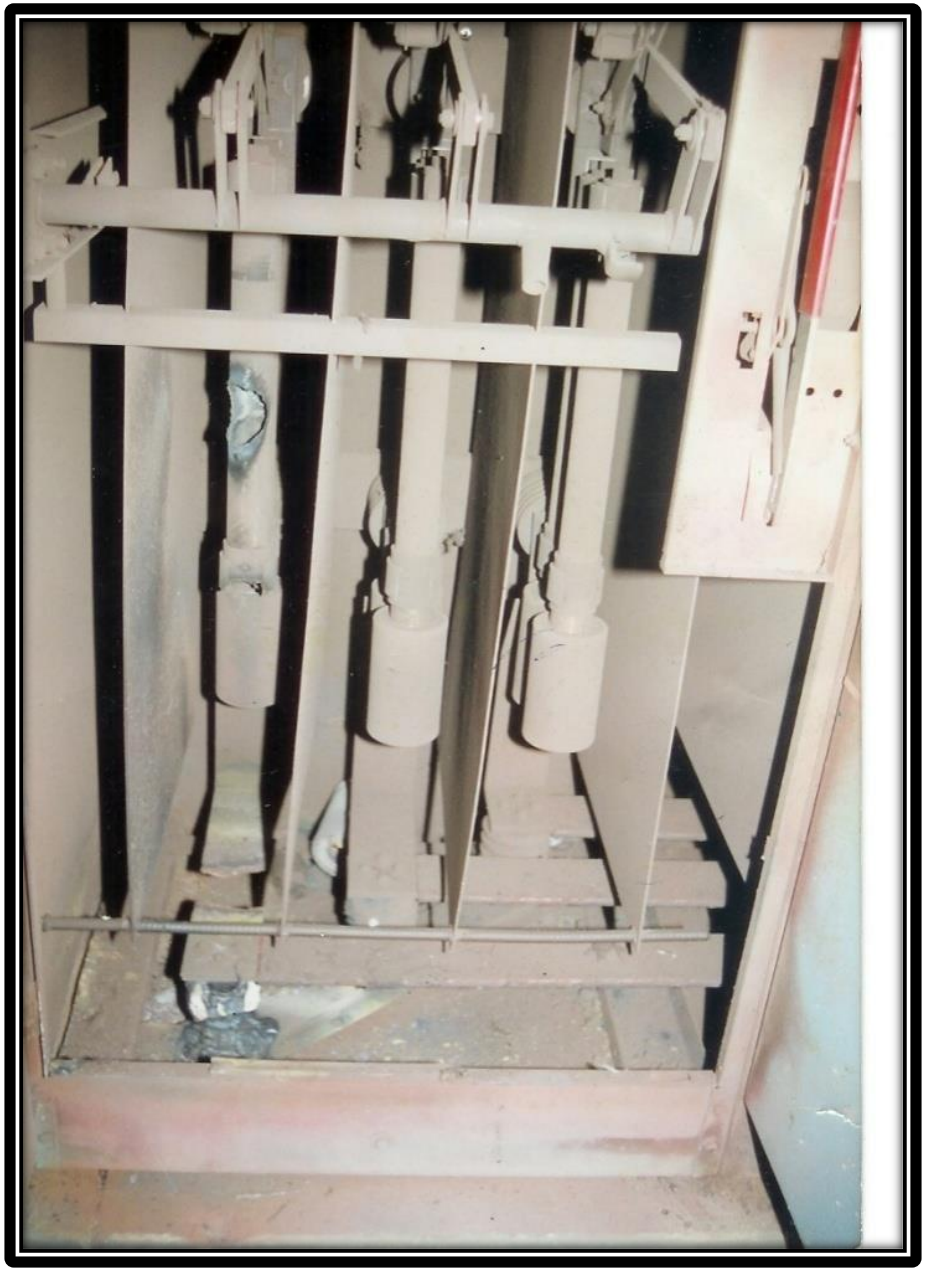


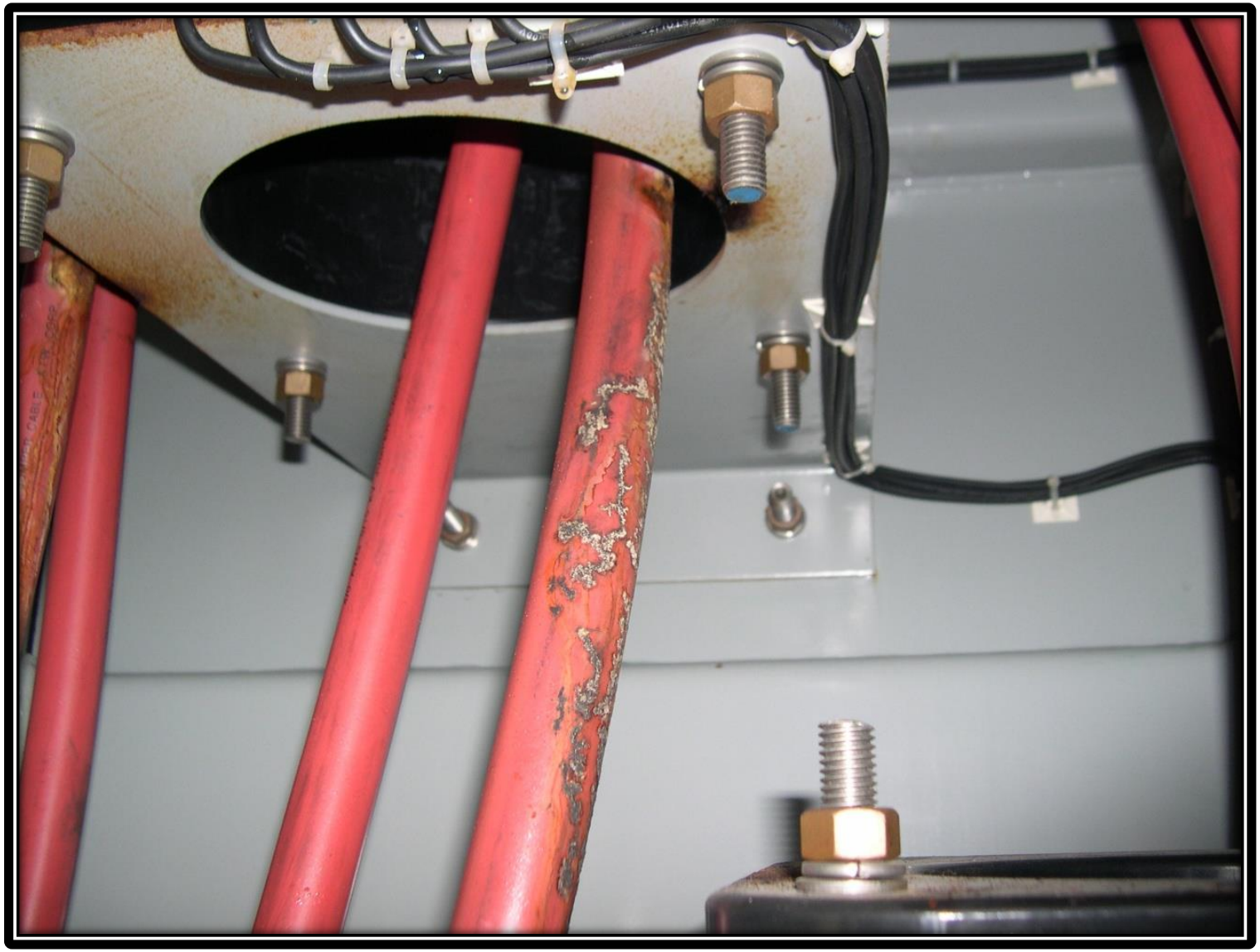
NETA™

Electrical and mechanical equipment is subject to failure, at the worst possible time, for no apparent reason.

- Mose Ramieh III

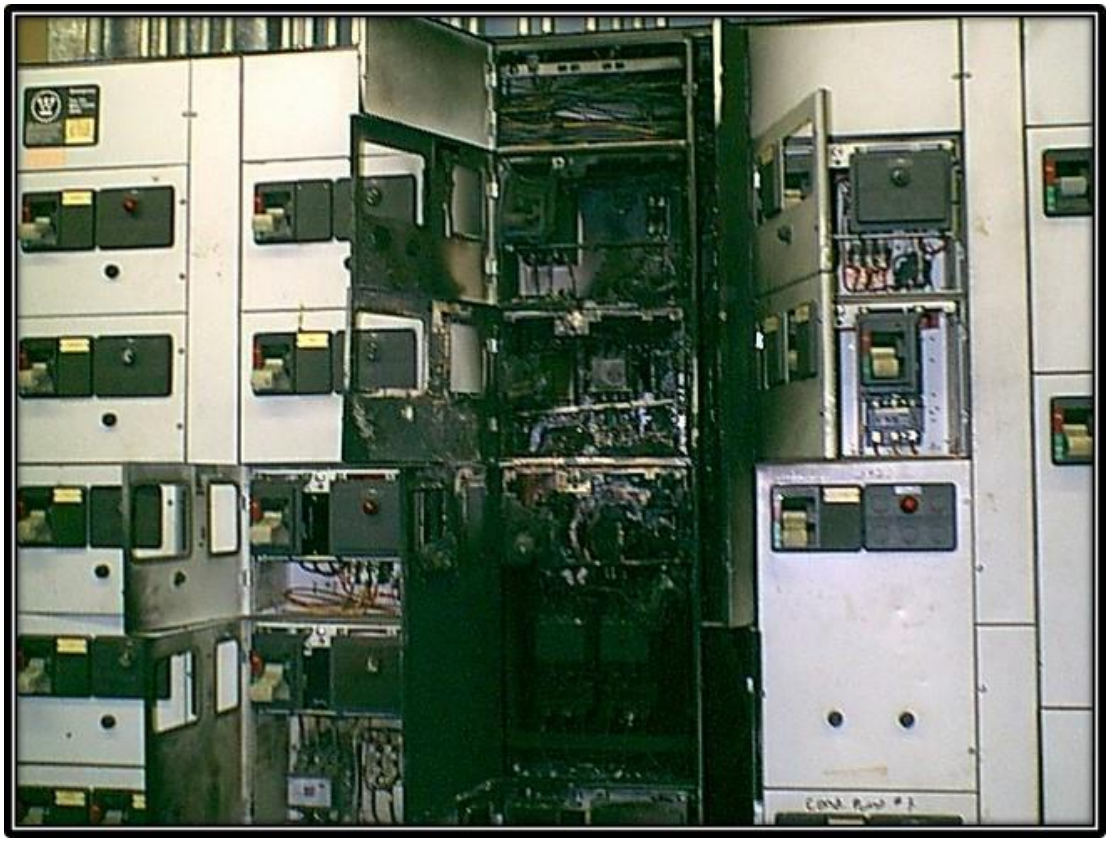

11.15.2004





There are two types of facilities...

Those that have HAD a failure...



And those that will...

IEEE 493-2007

Table 5-2—Percentage of failure caused from inadequate maintenance vs. month since maintained

Failure (months since maintained)	All electrical equipment classes combined (%)	Circuit breakers (%)	Motors (%)	Open wire (%)	Trans-formers (%)
Less than 12 months ago	7.4	12.5[a]	8.8	0[a]	2.9[a]
12 to 24 months ago	11.2	19.2	8.8	22.2[a]	2.6[a]
More than 24 months ago	36.7	77.8	44.4	38.2	36.4
Total	16.4	20.8	15.8	30.6	11.1

[a]Small sample size; less than seven failures caused by inadequate maintenance.


LOST
CONFUSED
UNSURE
UNCLEAR
PERPLEXED
DISORIENTED
BEWILDERED

Agenda

- Safety and Maintenance
- Types of equipment failures
- Non-Intrusive Predictive Options
- Somewhat Intrusive Predictive Options
- Intrusive Options

Electrical Maintenance & Safety

NFPA 70B, 70E, IEEE


05/27/03 M01 C47% 10:51:24

NFPA 70E

Standard for Electrical Safety in the Workplace

- Electrical Arc, Flash, and Blast
- Safe work practices
- Energized Electrical Work Permit
- Minimum PPE Requirements
- Make systems electrically safe prior to work
- Mechanical controls (IR Windows)

Article 110.4
Multiemployer Relationship

States:

On multiemployer worksites (in all industry sectors), more than one employer may be responsible for hazardous conditions that violate safe work practices.

Reasons for Electrical Predictive and Preventive Maintenance

Safety

- To minimize unsafe conditions
- Avoid personnel injuries
- Reliability Centered Maintenance is directed by safety first, then economics. When determined that safety is not a factor, then preventive maintenance is justified on economic grounds. IEEE 493-2007 Section 5.5

Economics

- To avoid future and more costly equipment failures.
- To avoid premature equipment failures.
- To avoid interruption of services to production and processes.

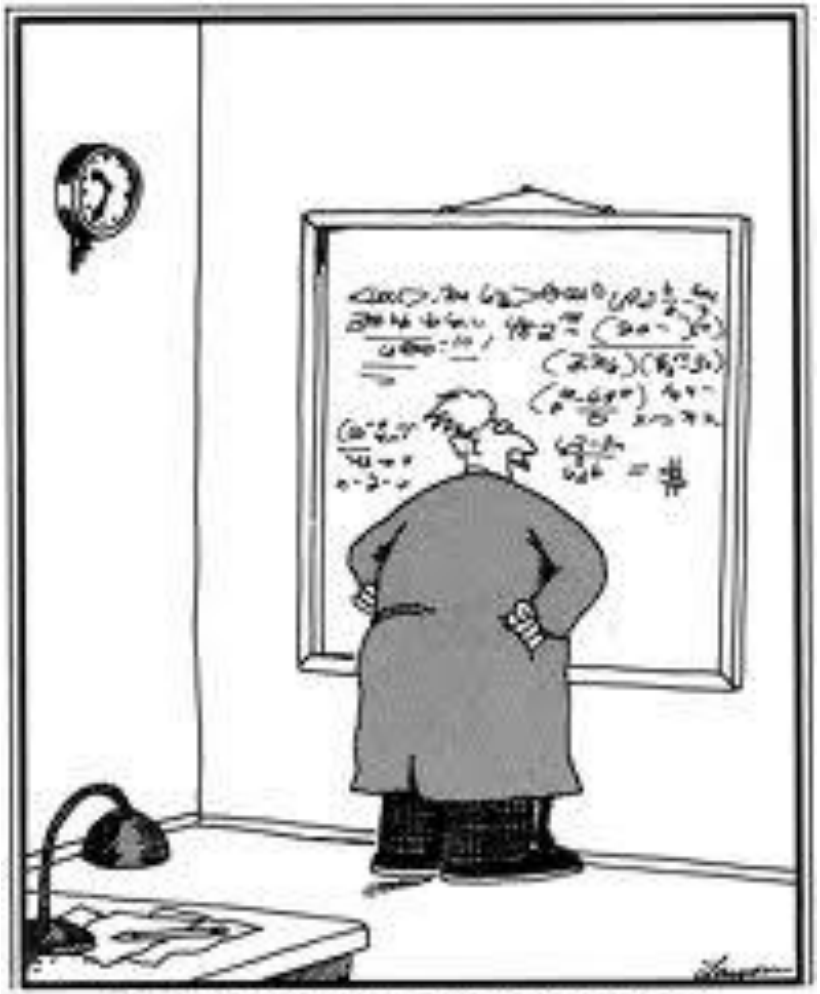
Legal & Contracts

- Avoid legal consequences and/or to meet legislated mandates (Codes & Standards)
- To comply with insurance company requirements.

Go Green

- Avoid environmental damage
- Accomplish equipment life cycle extension.

Downtime=Money!



Einstein discovers that time is actually money.

NFPA 70B

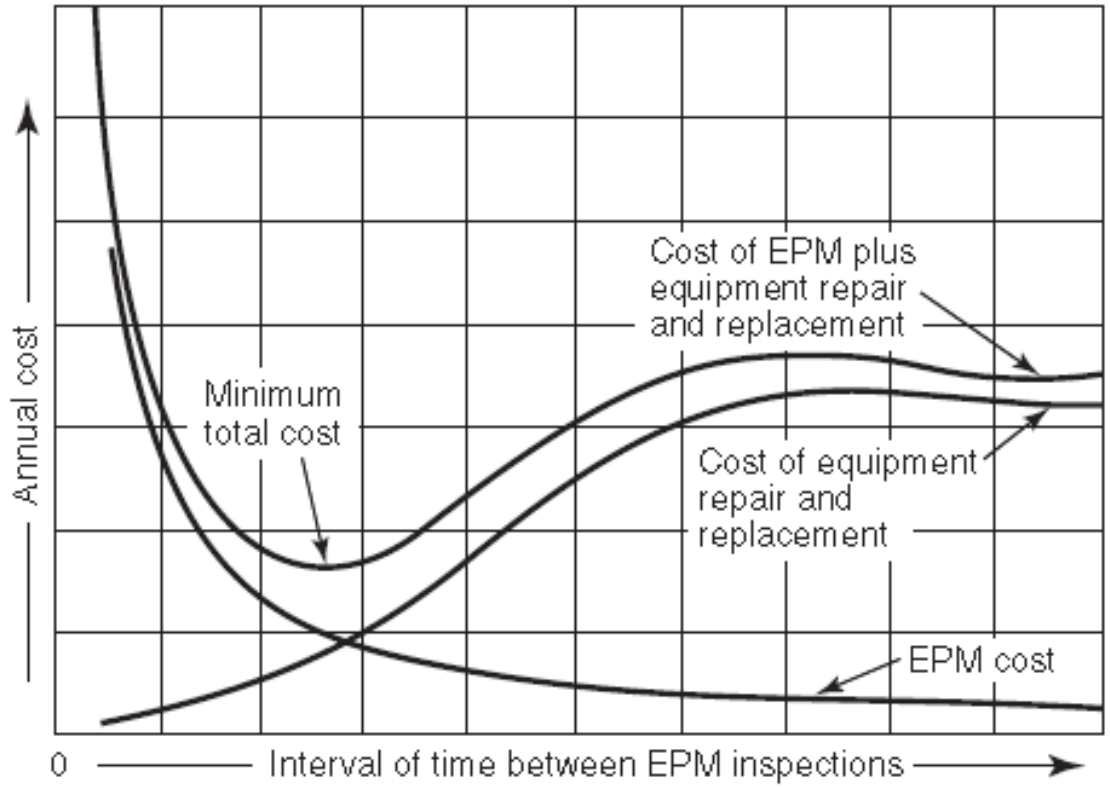
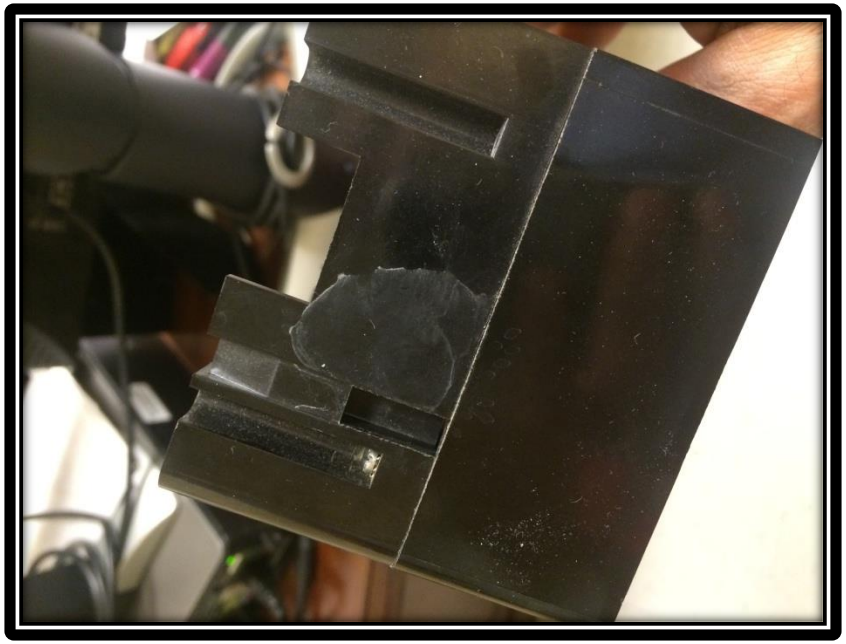
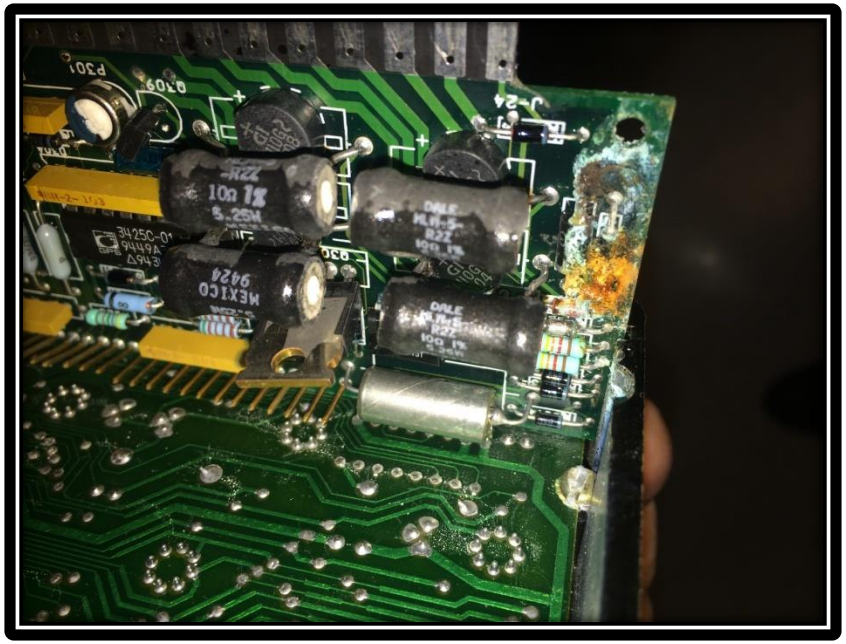


FIGURE 4.2.6 Effect of EPM Inspection Frequency on Overall Costs.

IEEE 493-2007
5.3.2 Causes of Electrical Failure




10Ω 1%
MEXICO
9424

IEEE 493-2007
5.3.2 Causes of Electrical Failure

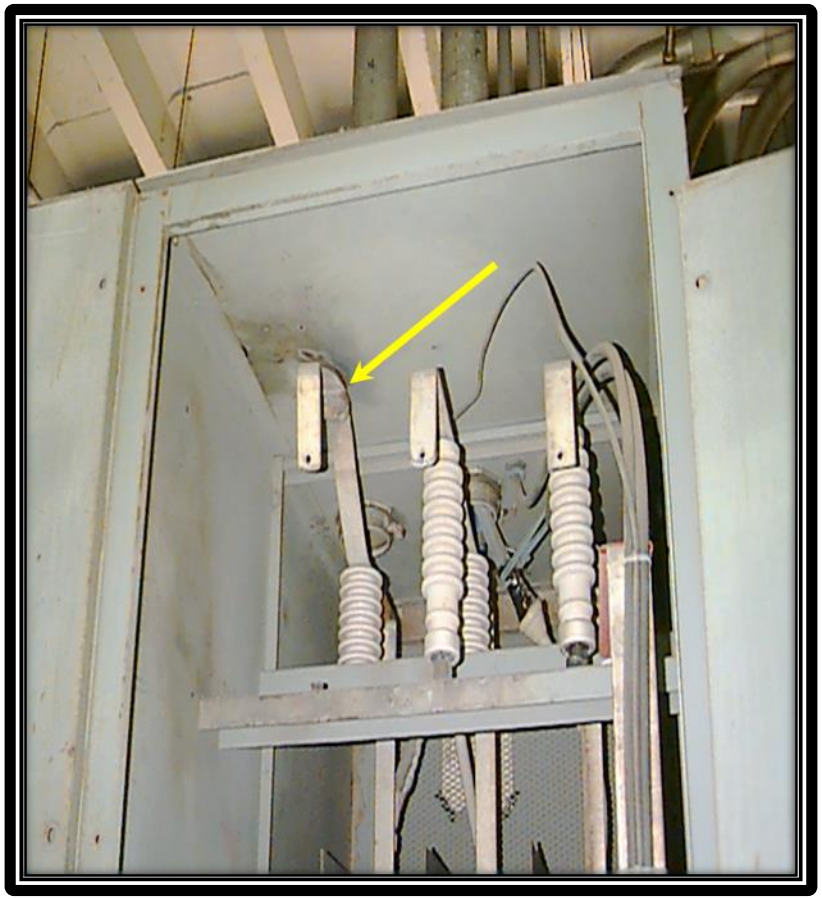
Insulation Failures

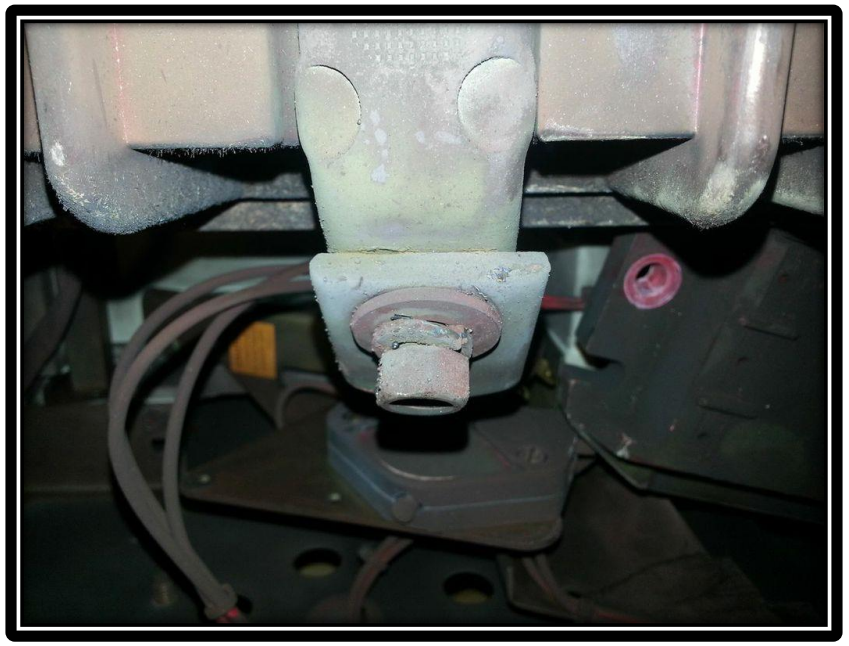
Component	Percentage of insulation failure
Transformers	84%
Circuit Breakers	21%
Disconnect Switches	15%
Insulated Switchgear Bus	95%
Bus duct	90%
Cable	89%
Cable Joints (splices)	91%
Cable Terminations	87%

Based on IEEE Gold Book Table 36

Mechanical Failures

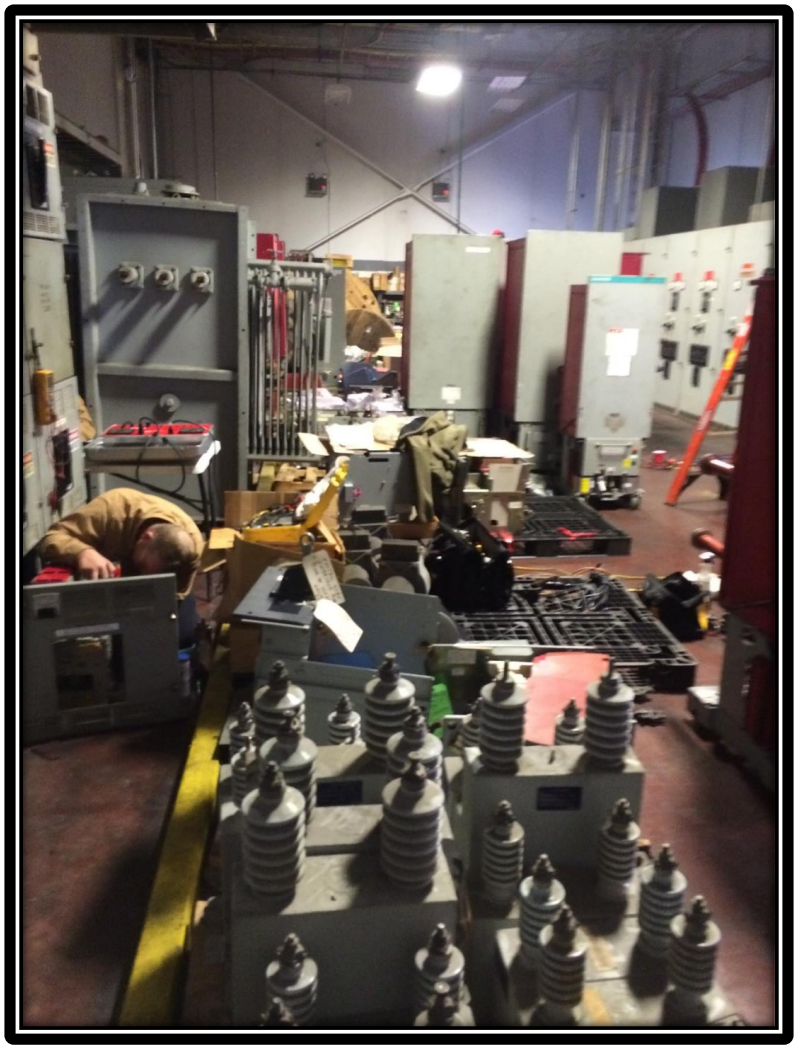
Mechanical Failures





Non-Invasive PdM

House Keeping



Walk Through Inspections


F1
F2
F3
CAUTION
CLOSED
OPEN
H1
H2
H3

What You Can’t See

What is Partial Discharge (PD)?

PD is a localized electrical discharge in an insulation system that does not completely bridge the electrodes

Phase to Phase
or
Phase to Ground

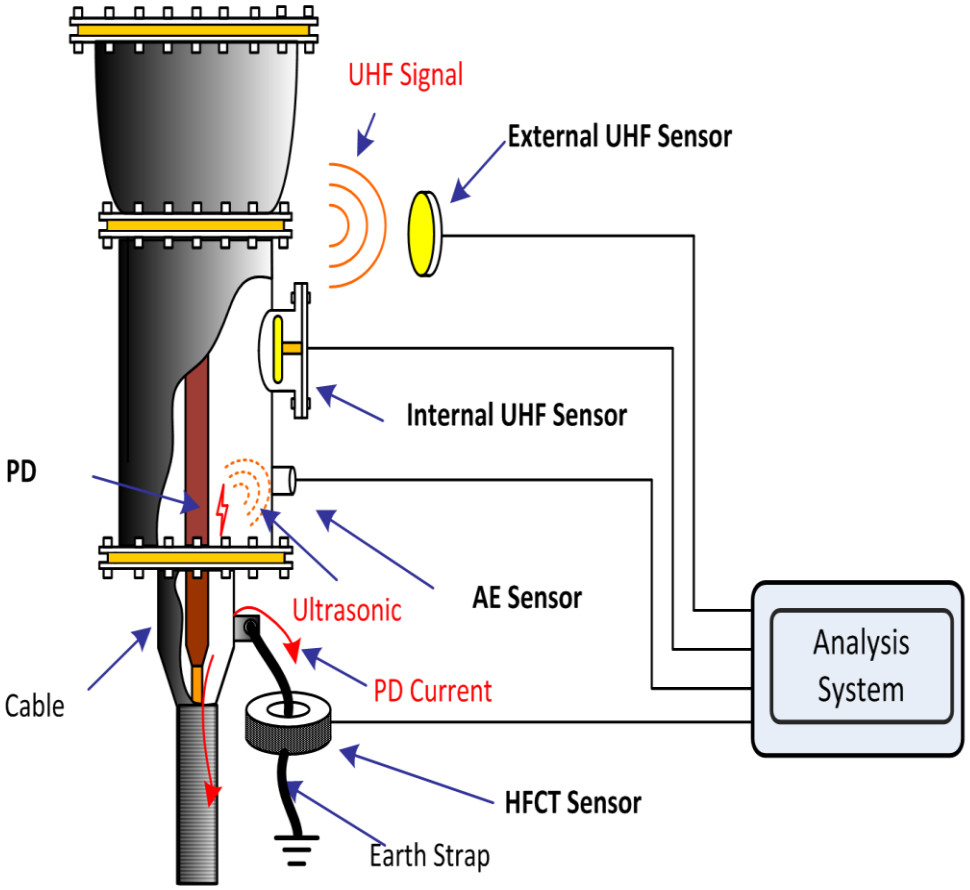
What is Partial Discharge ?

Partial Discharge Emission

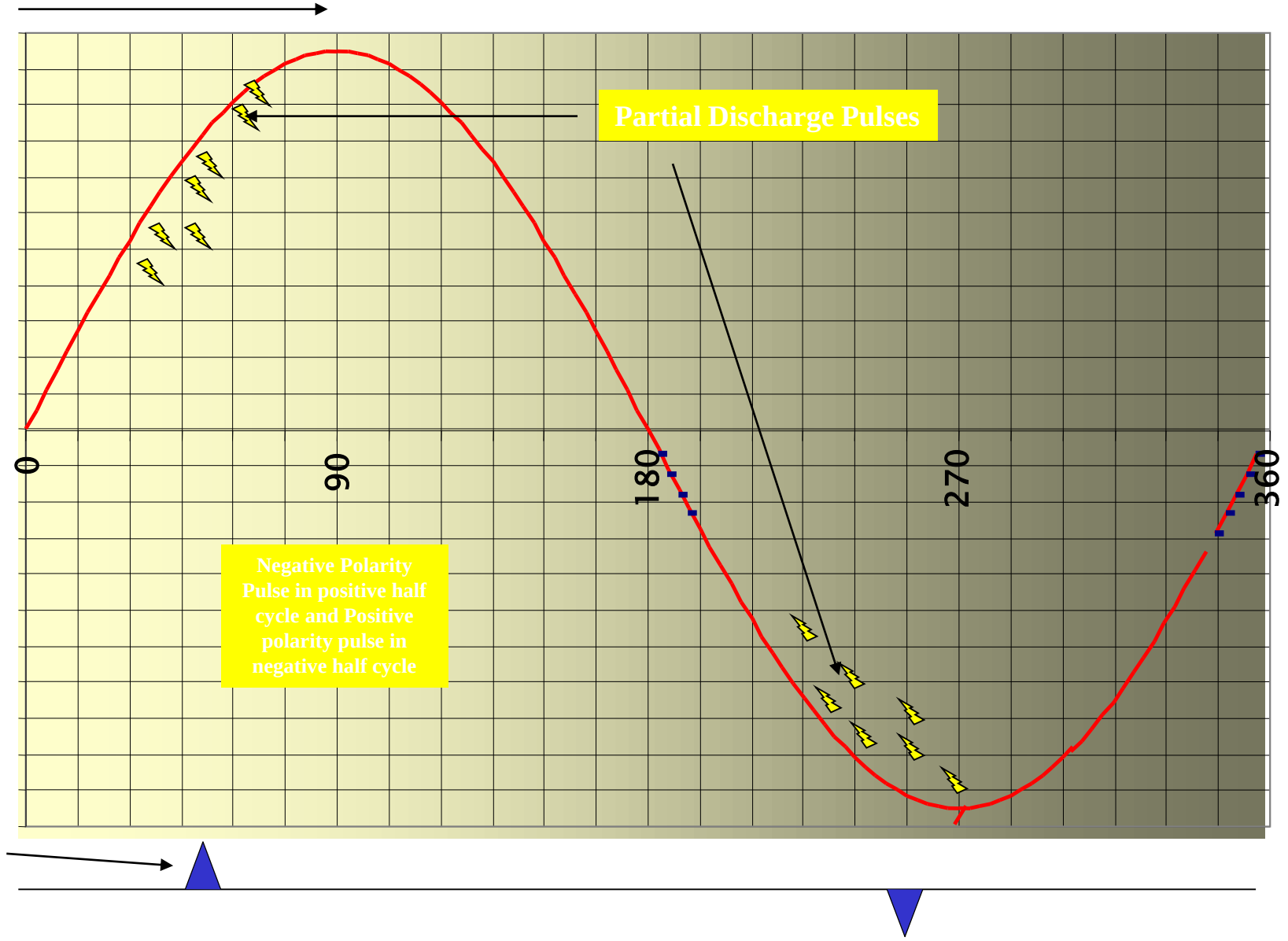
- Light
- Heat
- Odor (Ozone)
- Sound
- Electromagnetic pulse

Typical PD Types

- Corona discharge
- Floating discharge
- Particle discharge
- Void discharge
- Surface discharge



PD Activity


Partial Discharge Pulses
0
90
180
270
360
Negative Polarity Pulse in positive half cycle and Positive polarity pulse in negative half cycle
TEV signal
(nano Secs)

Level I PD Detection Services

Application

- GIS
- MV switchgear
- Power cable
- Transformer

Detection Bandwidth

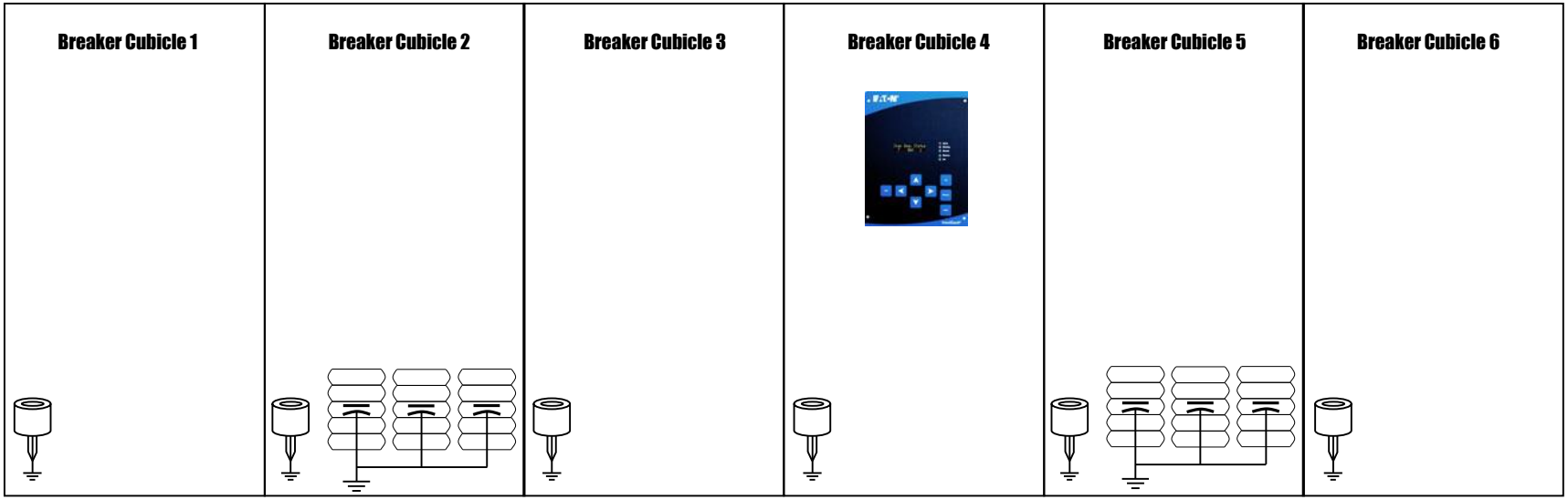
- TEV: 3MHz ~ 100MHz
- UHF: 300MHz ~ 1500MHz
- AE: 20kHz ~ 300kHz
- Ultrasonic:40kHz
- HFCT: 500kHz ~ 50MHz

Level I PD Detection Services

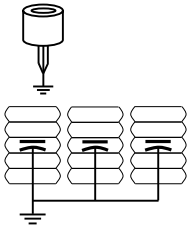
- UHF – Radio Frequency
- TEV – Transient Earth Voltage (capacitive)
- Ultrasonic (airborne acoustic)


TYPE HVL SWITCH
CATALOG NUMBERS
44036-340-XX, 44036-360-XX
SQUARE D COMPANY
SCHNEIDER ELECTRIC
E140591

Typical Retrofit Switchgear Application



LEGEND



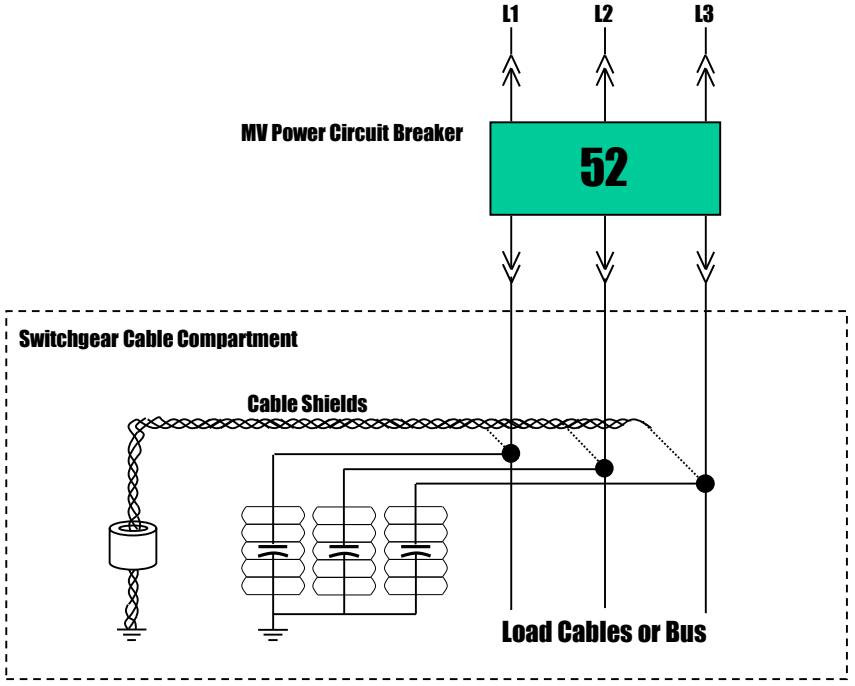
RFCT

Coupling Capacitors

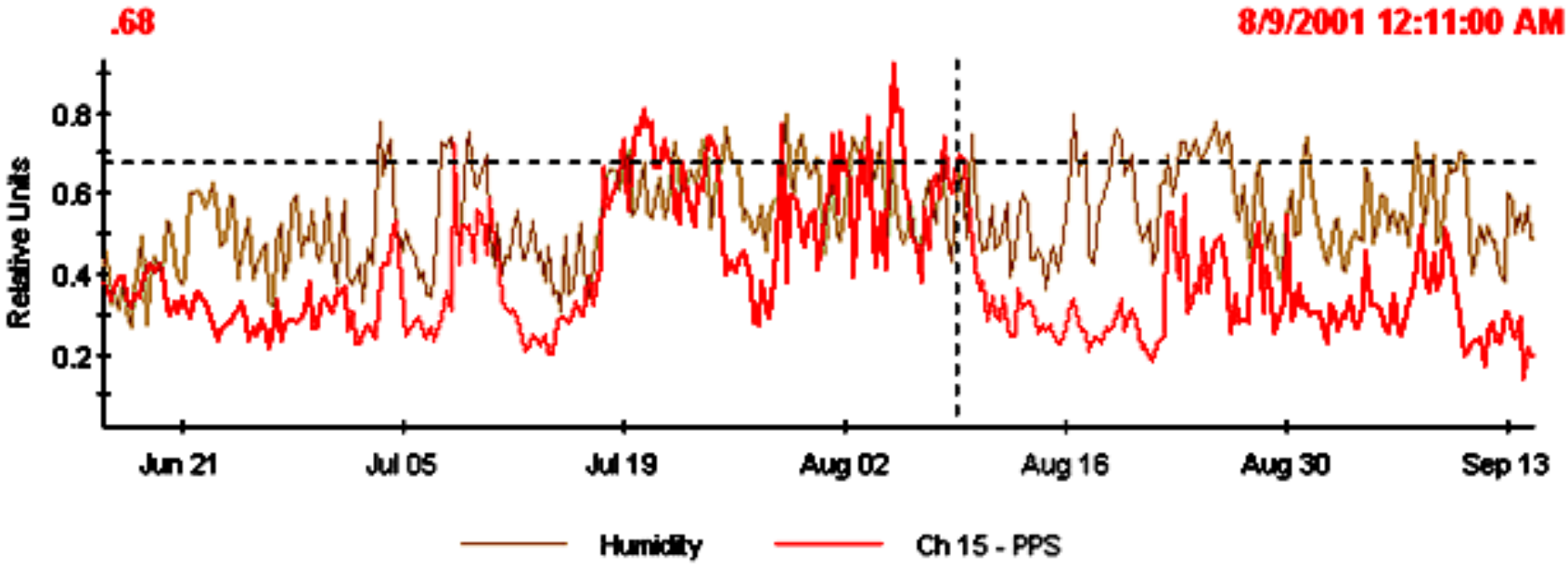
Sensor Selection Guideline

RFCT – One for every cable-set (in or out)

Coupling Capacitors – One set for every 3 structures



On-Line Partial Discharge Continuous Monitoring



Transformer Oil Samples

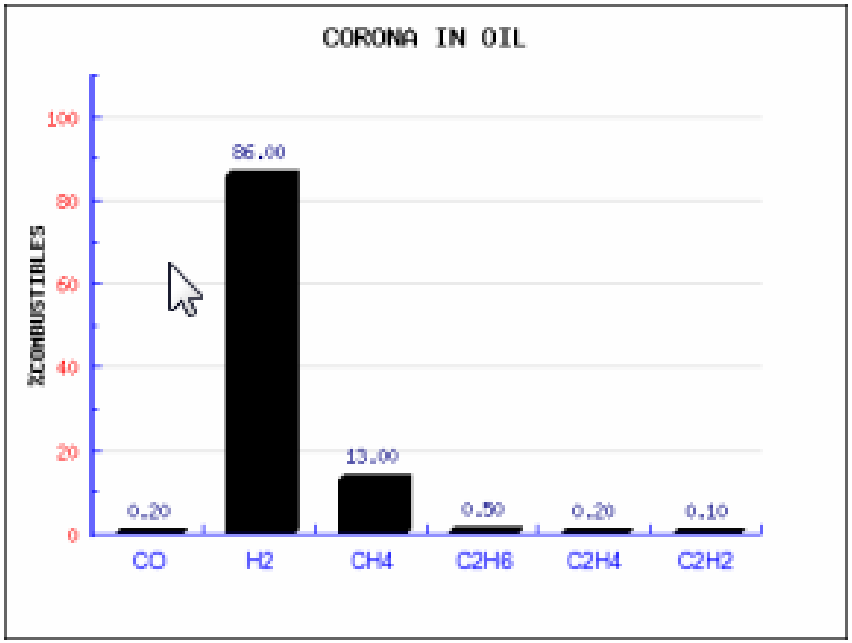


Fig.2. Identification of Corona or Partial Discharge Problem.

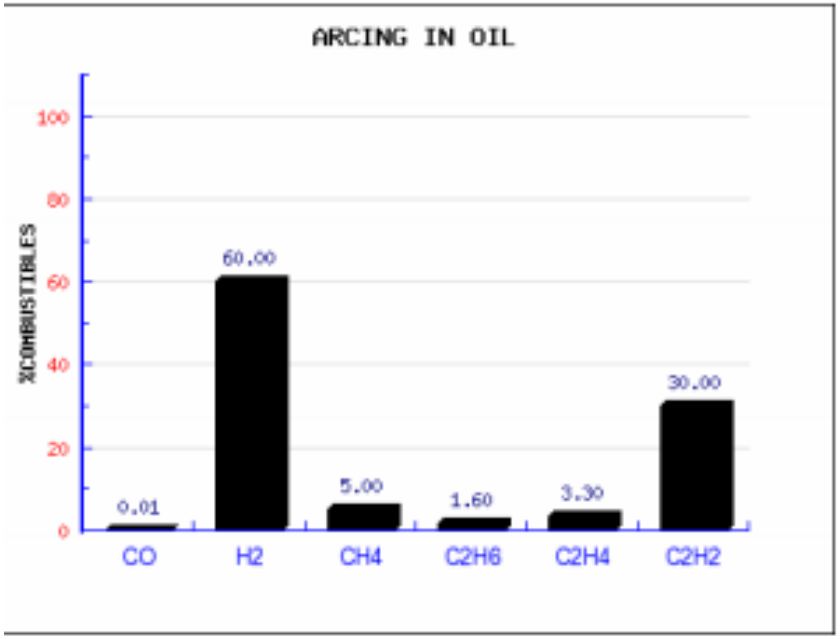
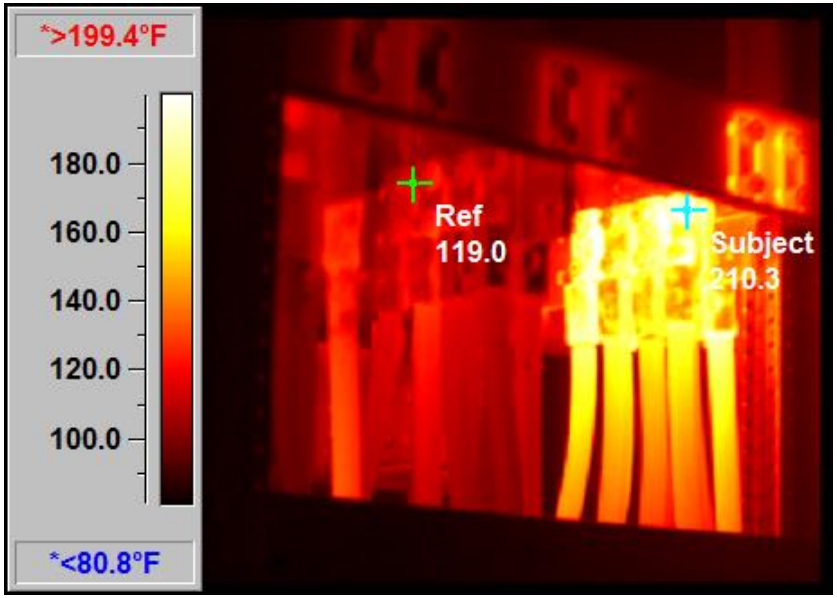
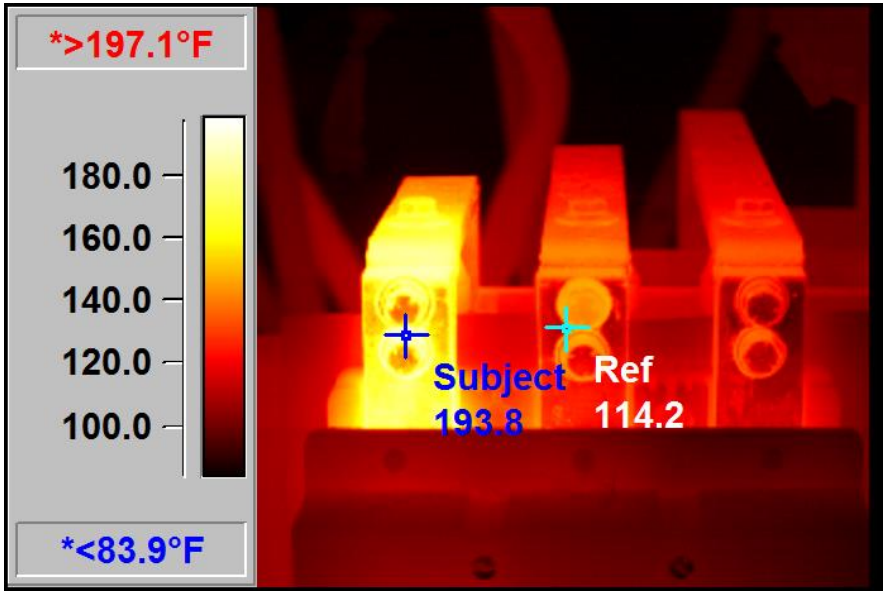


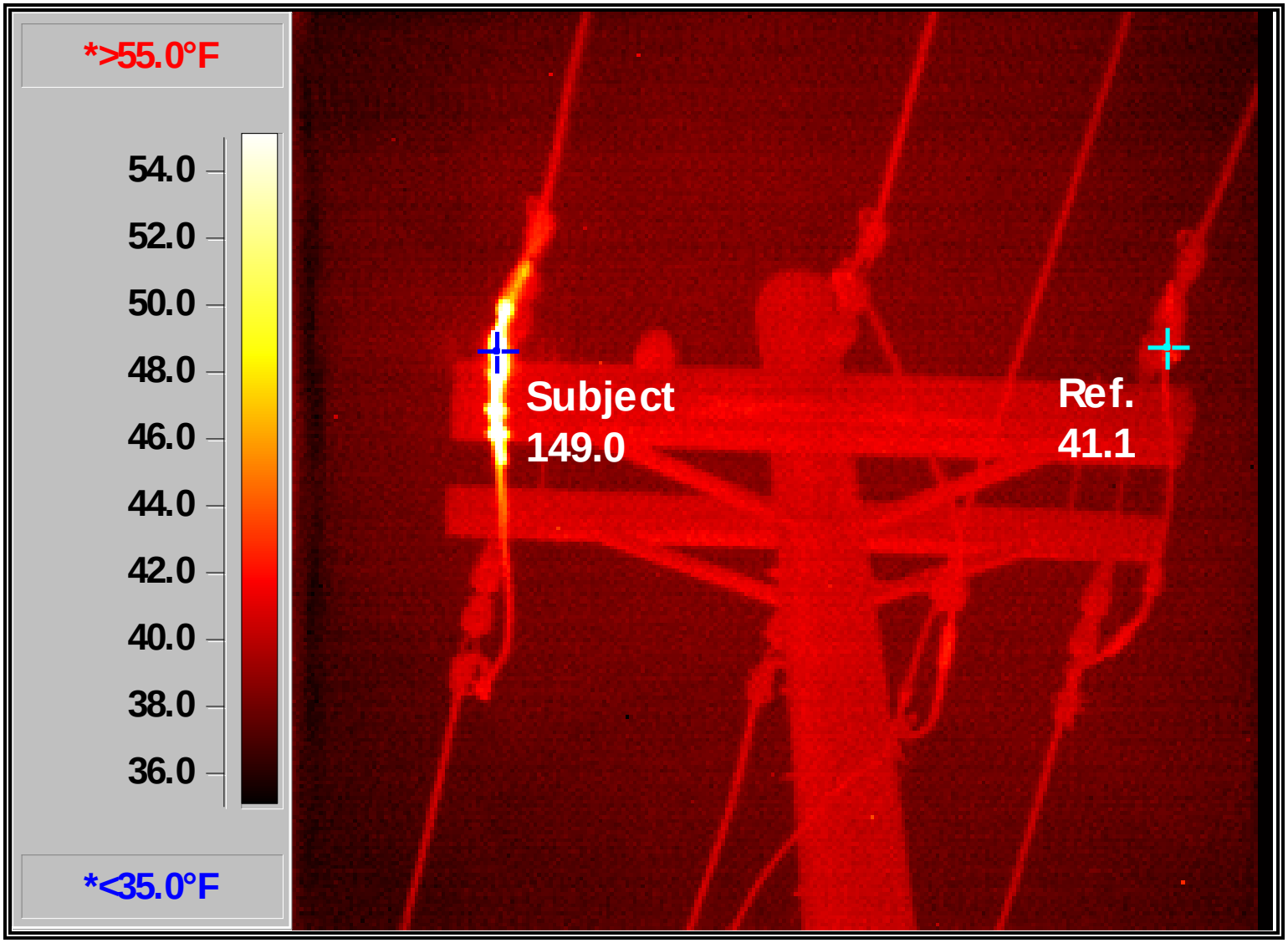
Fig.1. Identification of an Electrical Arc in Oil Problem.

Slightly Invasive PdM

Thermographic Surveys






*>55.0°F
54.0
52.0
50.0
48.0
46.0
44.0
42.0
40.0
38.0
36.0
*<35.0°F
Subject
149.0
Ref.
41.1


FLIR

Survey Hazards

IR Windows

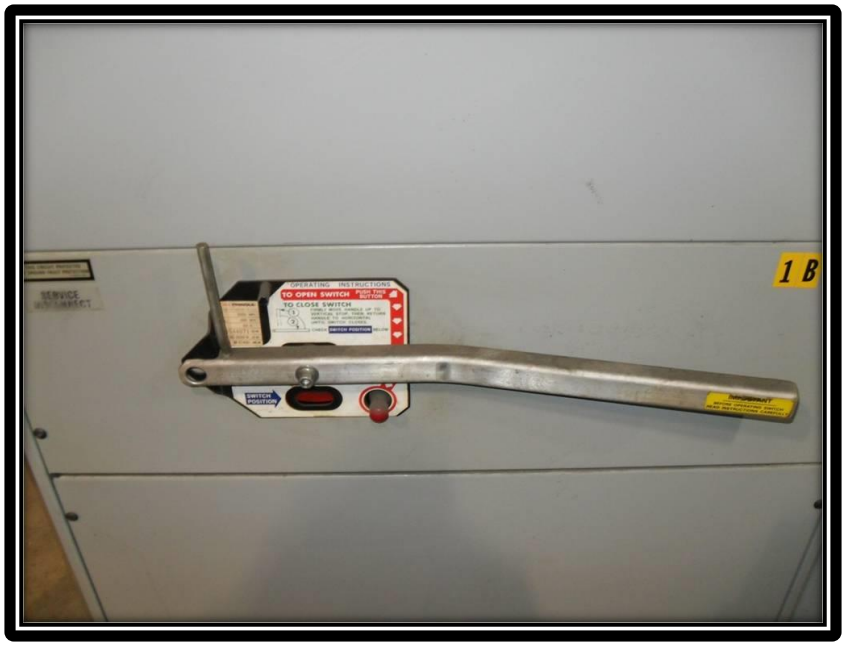

4160 VOLTS
Westinghouse
Arrogent
Medium Voltage
Motor Control
DANGER
HIGH VOLTAGE
4,160 VOLTS
LBC
5 KV FUSIBLE CONTACTOR
LOCATED WITHIN SWITCHGEAR "F" LINE
FEEDS 5KV SECONDARY CHILLED WATER
PUMP SCHMP #3

Short Outage PdM

IEEE 493-2007
5.3.2 Causes of Electrical Failure

- Dirt on moving parts can cause sluggishness and improper electrical equipment operations…
- Checking the mechanical operation of devices and manually or electrically operating any device that seldom operates should be standard practice.

Seldom Operated



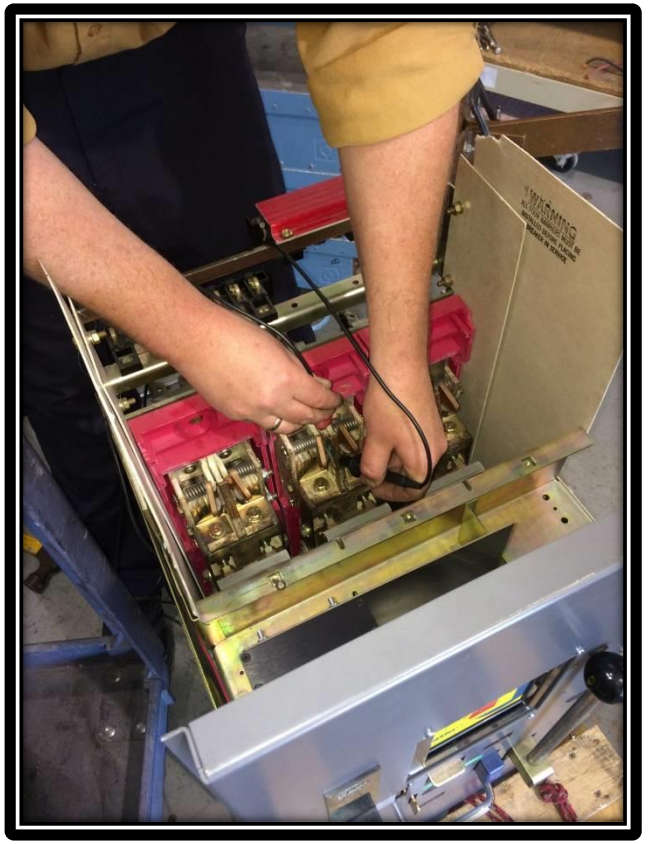
“Traditional” Outage PM

When to Test?
NETA MTS and NFPA 70B

- Monthly
  - Visual Inspections
  - Make notes regarding operating status and house keeping
- Annually
  - Thermographic Survey
  - Out of Service Maintenance
- 1-5 Years
  - Follow Manufacturer Guidelines
  - NETA Guidelines (Handouts Available)
  - Check with Insurance Carrier for additional Guidelines.

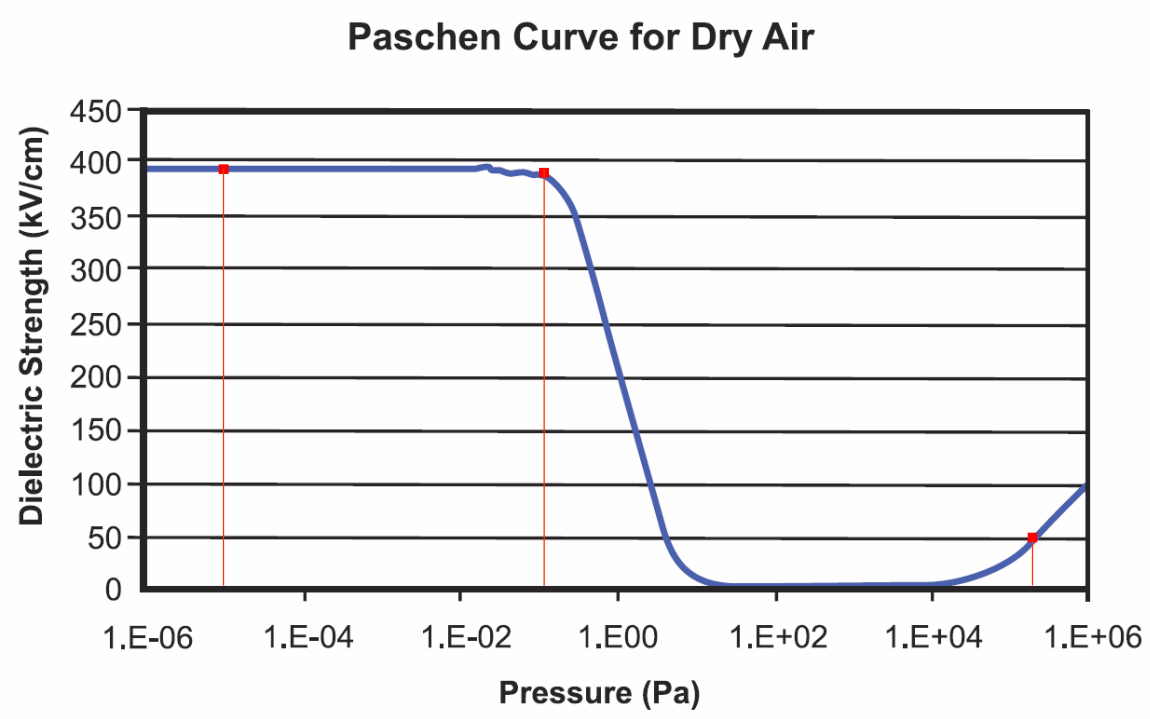
Circuit Breaker Testing

Circuit Breaker Testing

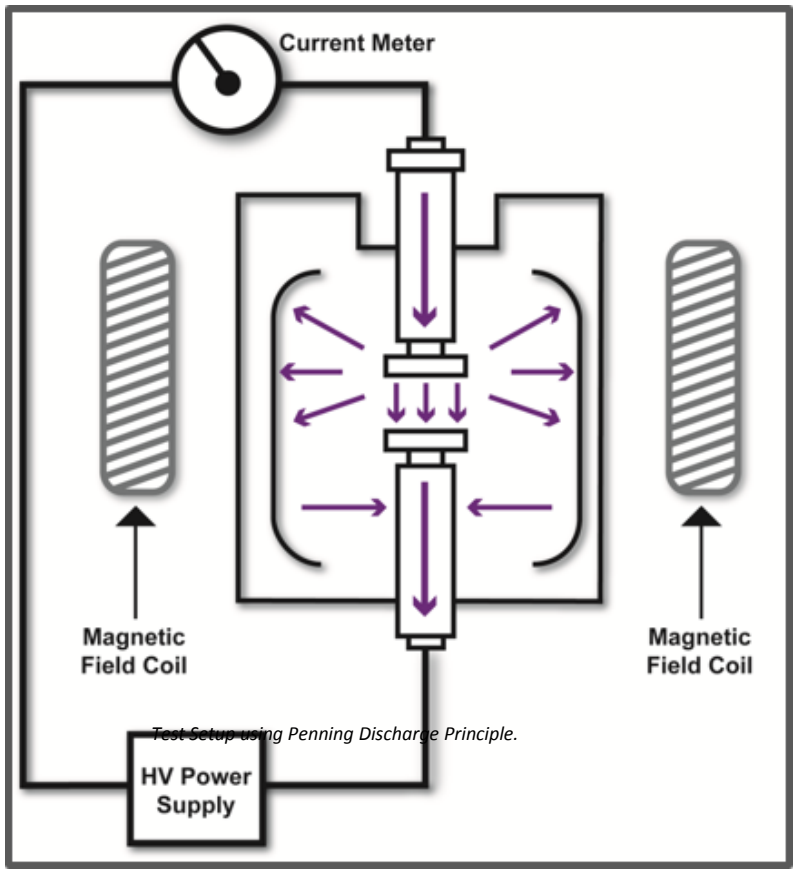


“New” Vacuum Breaker Technology

Breakdown Voltage



Penning Diagram and Field Testing



Test Setup using Penning Discharge Principle.

NFPA 70E Chapter 2 Safety Related Maintenance Requirements

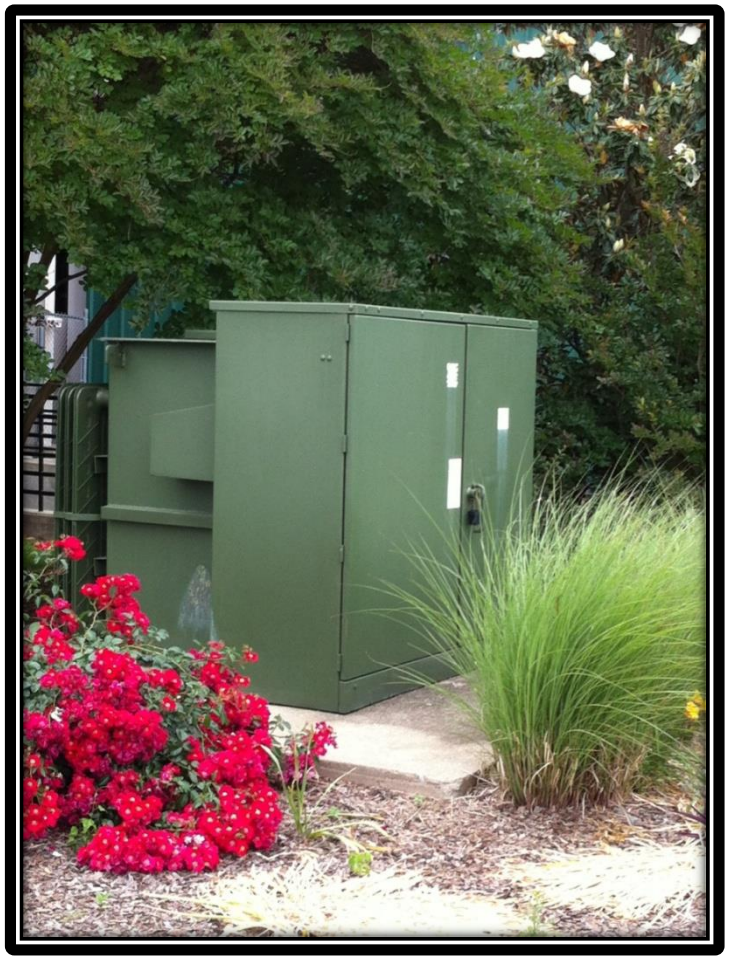
- **Qualified Persons** to conduct maintenance.
- Over-current devices **shall be maintained**.
- House keeping, House keeping

NFPA 70E Chapter 2 Safety Related Maintenance Requirements

"Failure to properly maintain protective devices can have an adversely effect on the arc flash hazard analysis incident values."

Circuit Breaker Testing

Transformer Testing

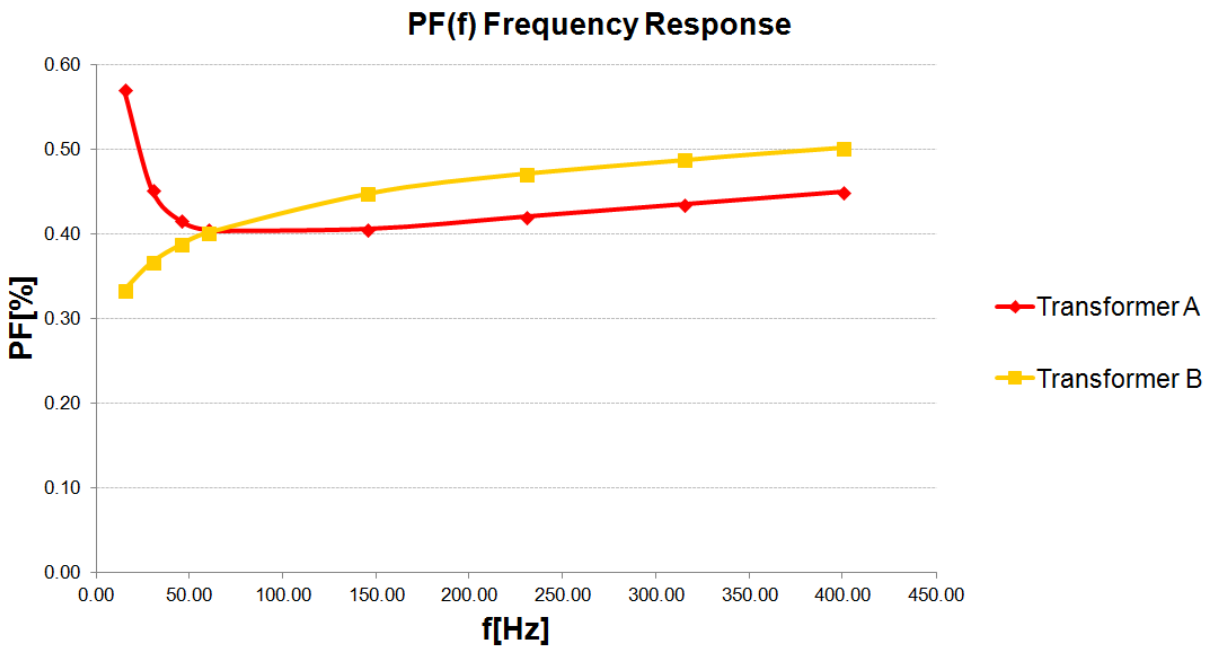


Transformer Testing

- Insulation Resistance
- Winding Resistance
- Turns Ratio Test
- Power Factor (60Hz)
- Leakage Reactance
- On Load Tap Changer

Power Factor vs Frequency

So How Can We Detect the Water?



OMICRON

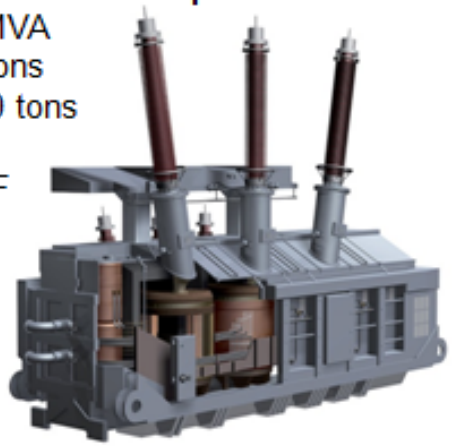
Besides.....The Moisture is All in the Paper!!

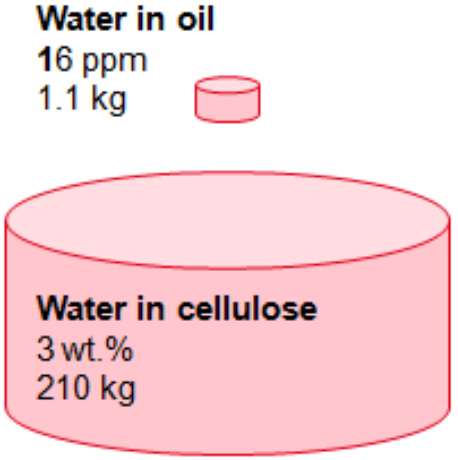
Moisture distribution

- Moisture exchange between cellulose and oil
  - Increasing temperature: water goes to the oil
  - Decreasing temperature: water goes back to the cellulose
- Most of the moisture is contained in the cellulose
- Thus it is important to know the water content of the cellulose, not of the oil

Moisture distribution example

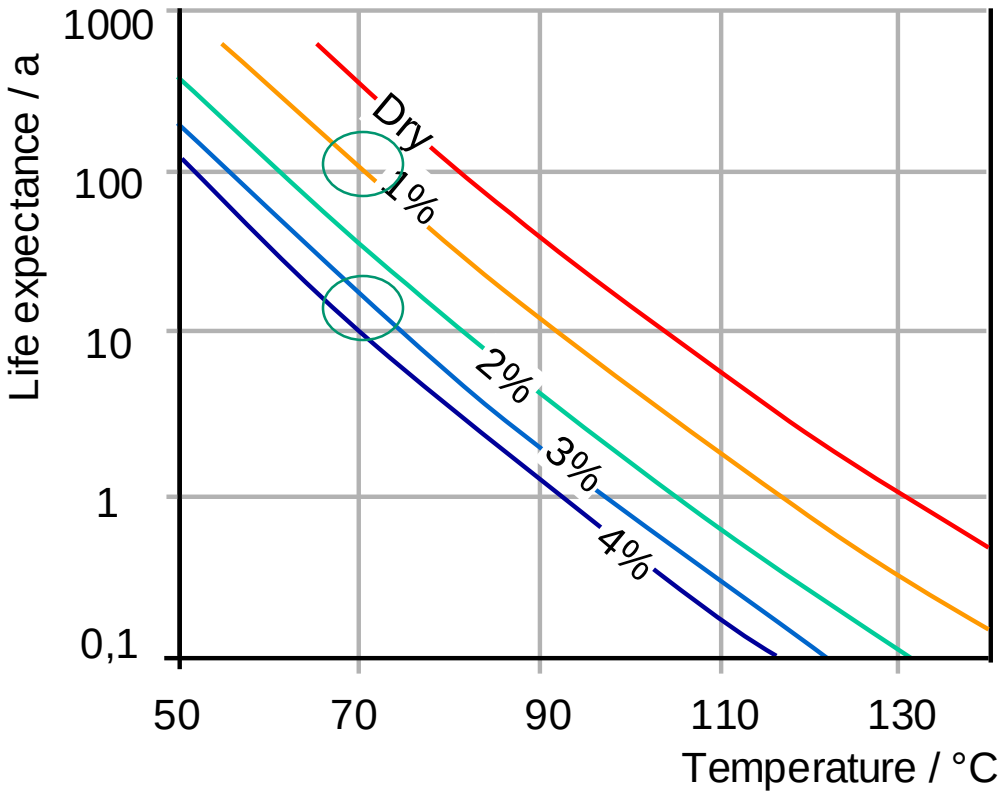
- Power: 150 MVA
- Cellulose: 7 tons
- Mineral oil: 70 tons
- Temperature: 40 °C / 104 °F





Catch it Early or Pay Big $'s Later

Effect:
High temperature and moisture content will dramatically lower the mechanical strength of paper insulation

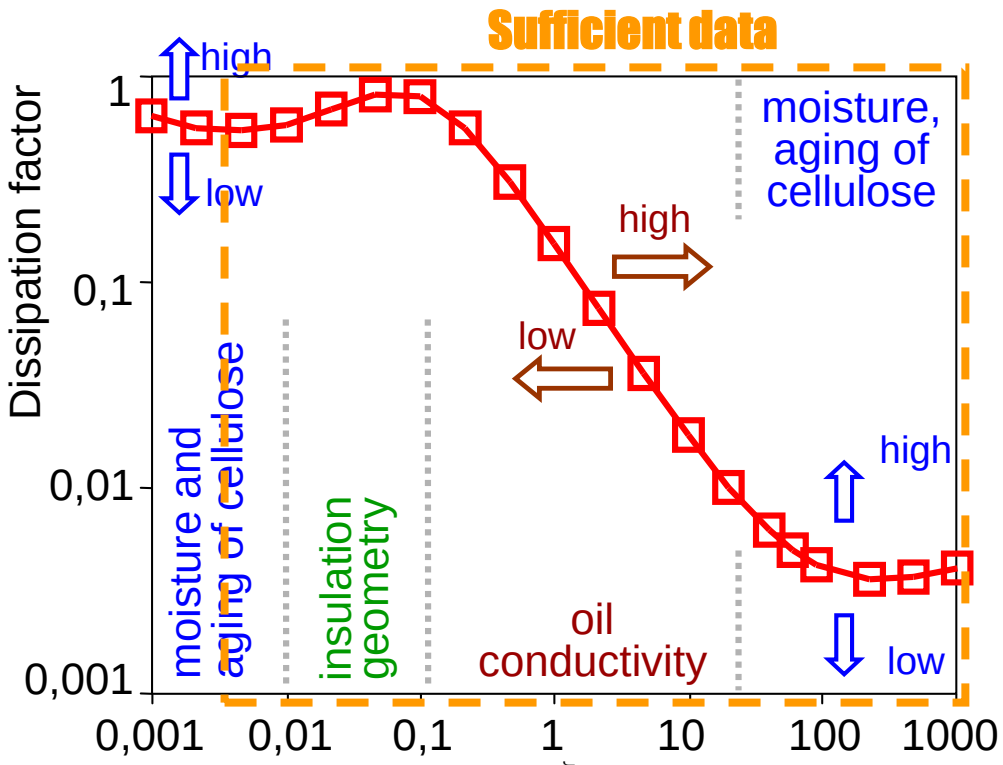


Risks:

- **Lower the expected life of transformer**
- **Run transformer at lower rating**

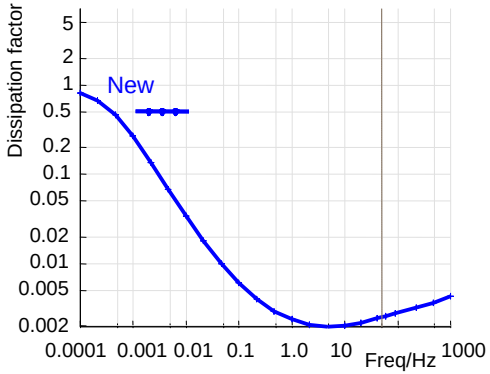
L. E. Lundgaard, "Aging of oil-impregnated paper in power transformers", IEEE Transactions on Power Delivery, Jan. 2004

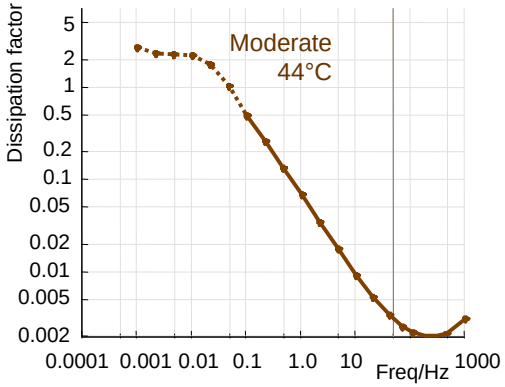
Dielectric Frequency Response

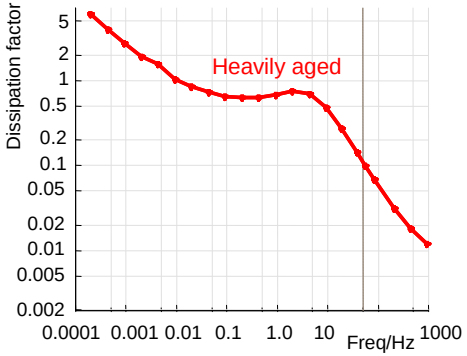


Typical:

- **Dry transformer or low temperature -> 0,1 mHz, 2:50 hours**
- **Moderate wetness / temperature -> 1 mHz, 22 min**
- **Wet transformer or hot temperature -> 0,1 Hz, 5 min**



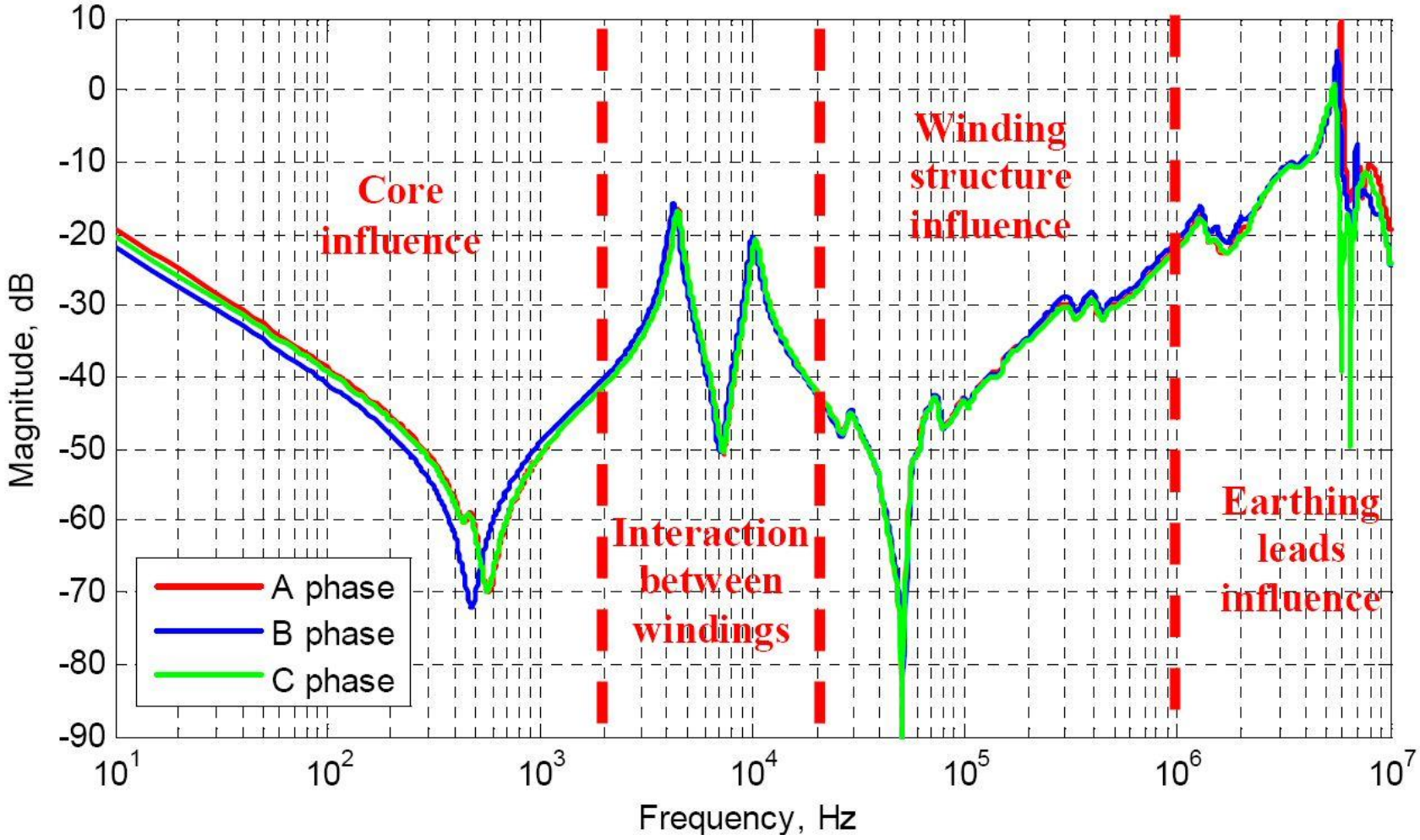




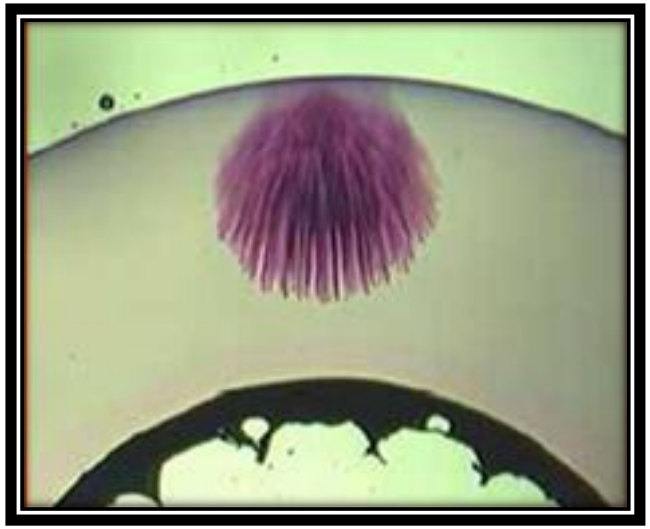
Transformer Tests

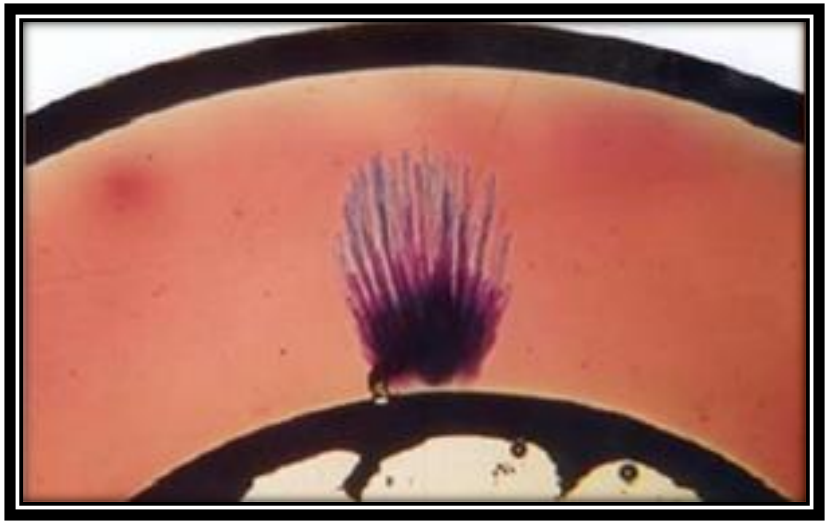
Dielectric	Thermal	Mechanical
DGA	DGA	SFRA
Oil Screen	Oil Screen	Leakage Reactance
PF/TD CAP	IR	PF/TD CAP
Exciting Ima	DC Winding RES	Exciting Ima
TTR		DC Winding RES
DFR		
Partial Discharge		

The General Curve Structure



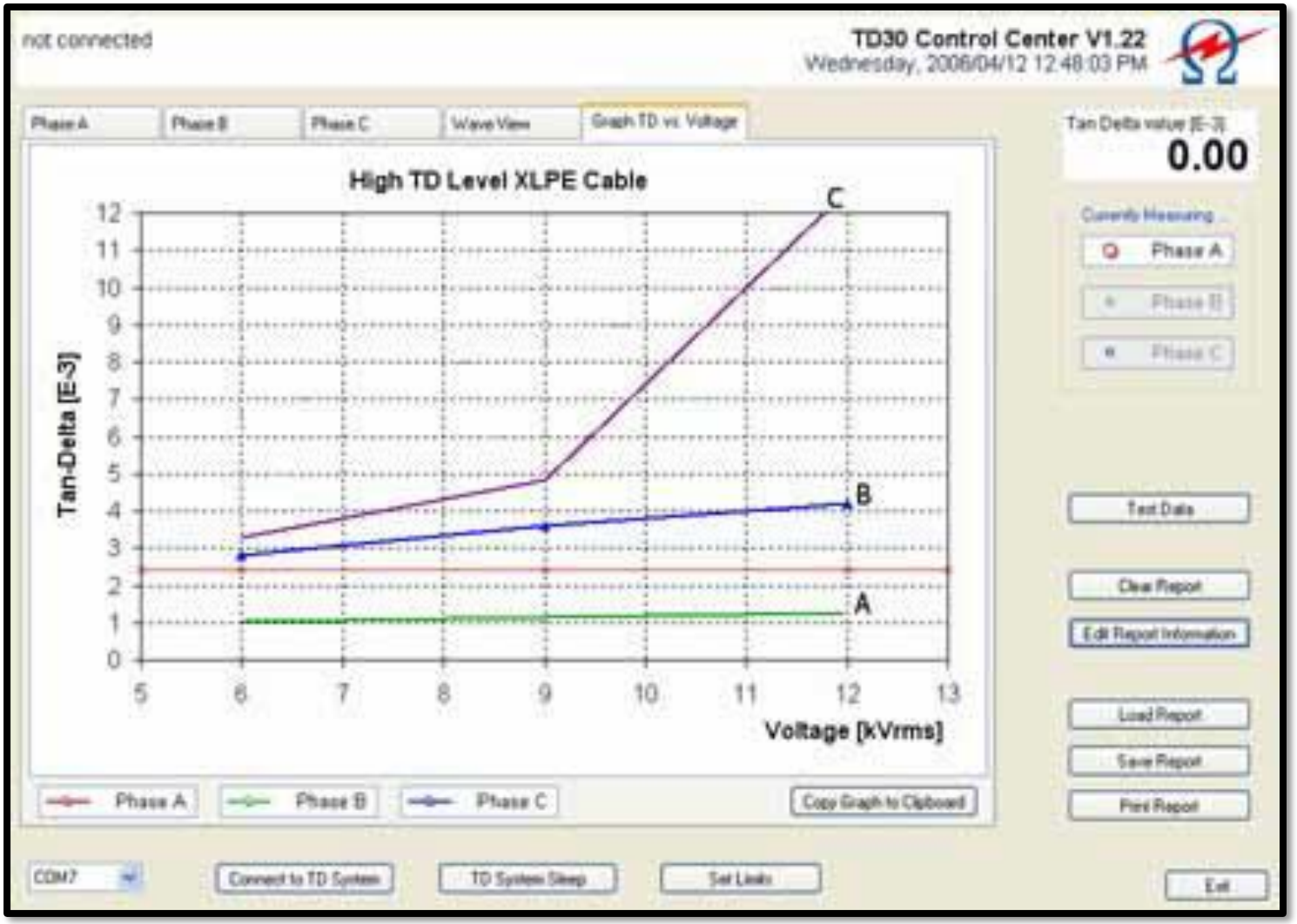
Cable Testing





VLF Cable Testing

VLF Cable Test Results



Protective Relays and Meters

- **Monthly**
  - Visual Inspection
  - Record and Reset Targets
- **Annually**
  - Pick up Test and Time Electromechanical Relays
  - Verify Setting of Solid State
- **1-5 Years (Out of Service)**
  - Pick Up Test
  - Timing Test
  - Verify Operational Scheme

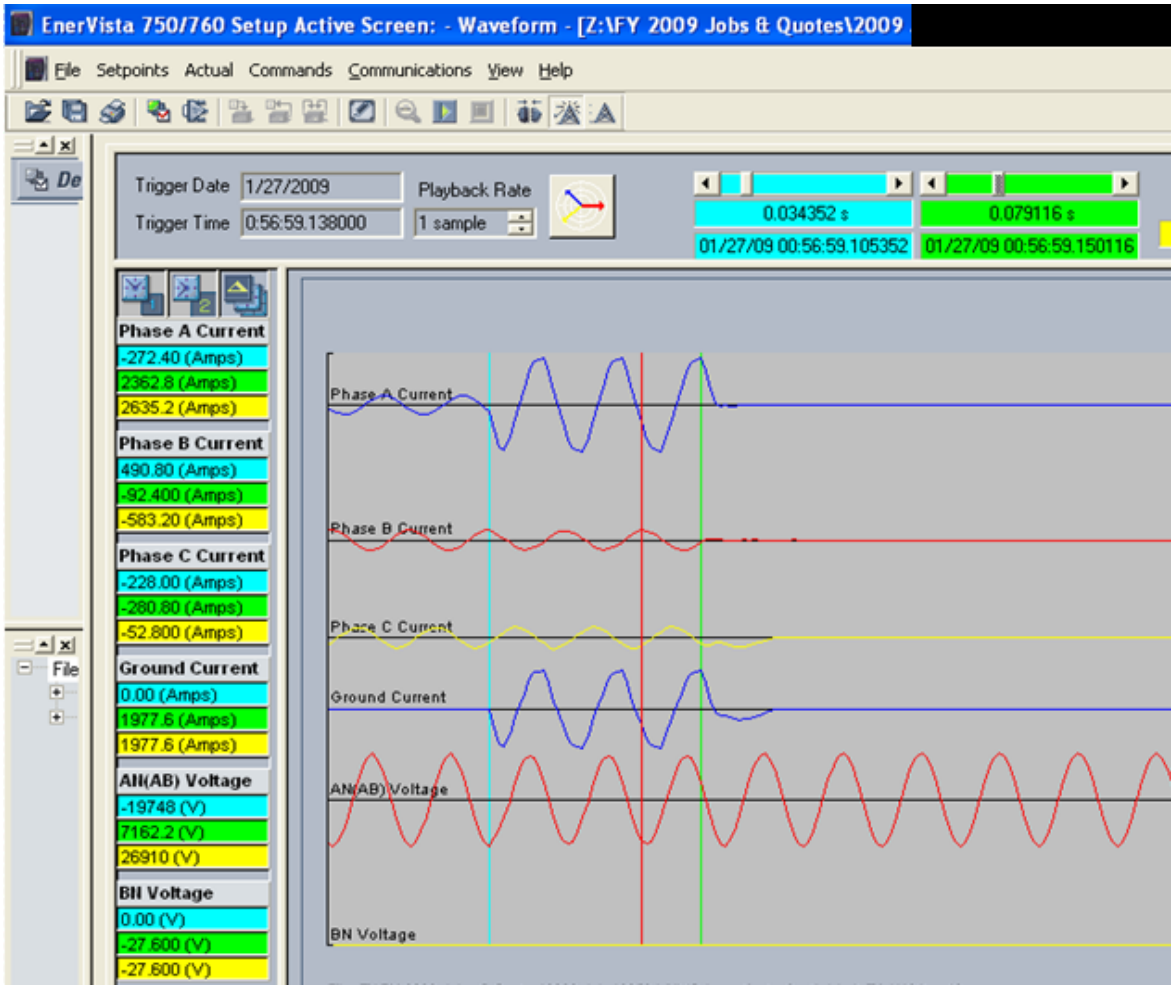
Dayton Power & Light – Killen Station

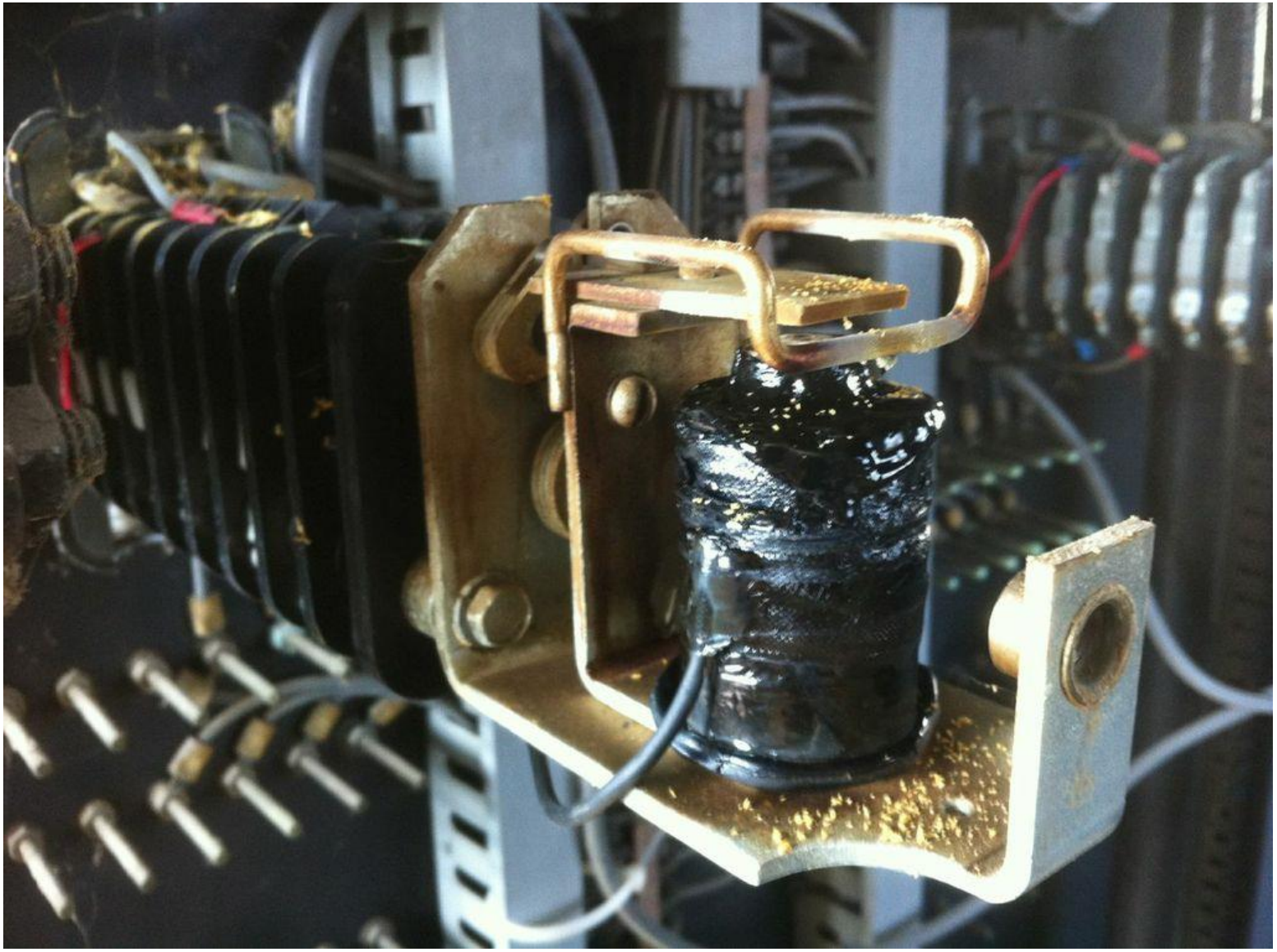
- Existing Electro-Mechanical Relays (124); CEPS provided NERC/FERC testing.
- Scope of Work included engineering, design, material, installation, and commissioning.
- Material scope included SEL 300G, 387E.

BEFORE

AFTER

Data and Oscillographic Records





Questions?
Answers