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# **PARTIAL DISCHARGE LOCATION**

## **Selected Topics**

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*IMCORP*

**ICC Meeting - Fall 2000**

# TOPICS

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- *TESTING PHILOSOPHY*
  - *Excitation Voltage*
  - *Test Voltage Level*
- *METHOD OF REFLECTOMETRY*
- *METHOD OF ARRIVAL TIME*
- *TESTING*
  - *Branched Circuits*
  - *On-line - Discussion of ON and OFF-Line*
- *Major Concerns - Answers*

# TESTING PHILOSOPHY

## ■ **PURPOSE:**

- *Reduce Service Failures - Improve Reliability*
- *Reduce Cost or Delay Capital Expenditure*

## ■ **TEST GOALS:**

- *Identify defects that may cause near-term service failures*
- *Characterize severity of defects to help prioritize corrective actions*
- *Constraint: Minimize likelihood of test-produced damage*
- *Other*

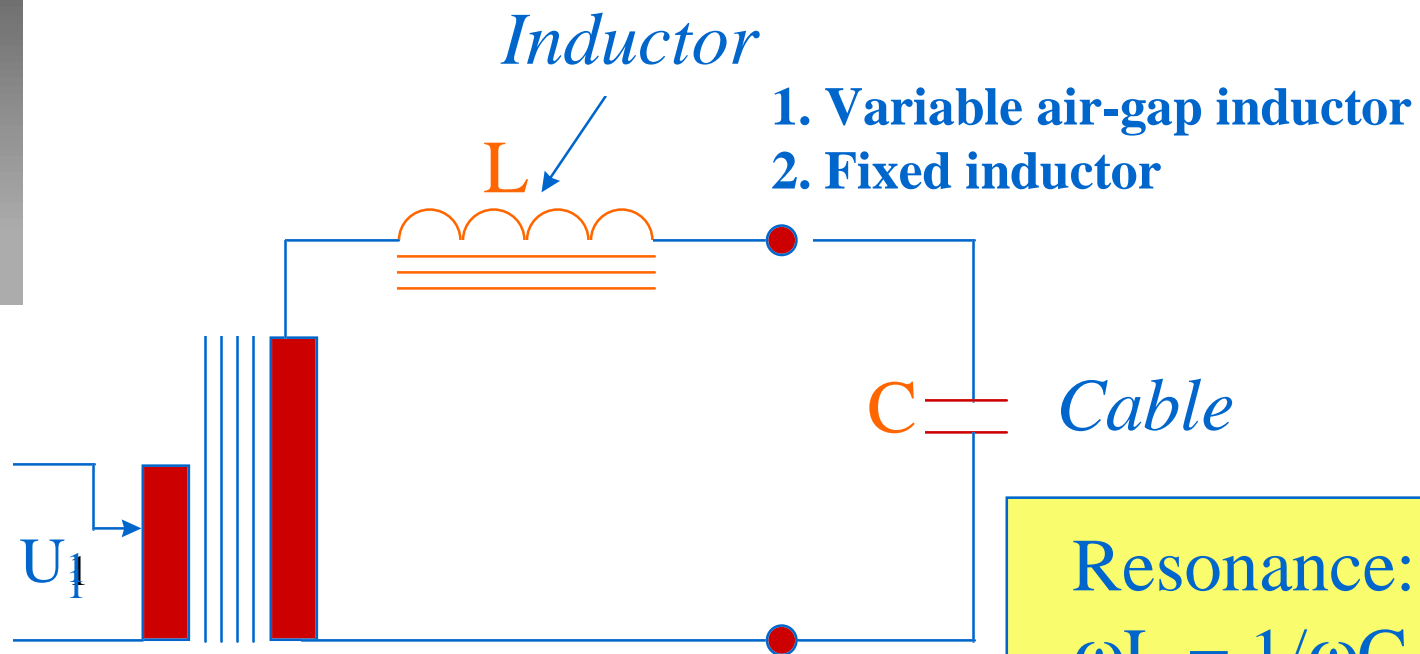
# TESTING PHILOSOPHY

## EXCITATION VOLTAGE

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- *Use 50/60Hz produced by resonant test set*
- *Ramp voltage slowly until PD is detected or max. test voltage is reached*
- *Dwell approx. 2 seconds (will be reduced to ~ 10 cycles).*
- *Reduce voltage to zero very rapidly.*

# RESONANT TRANSFORMER

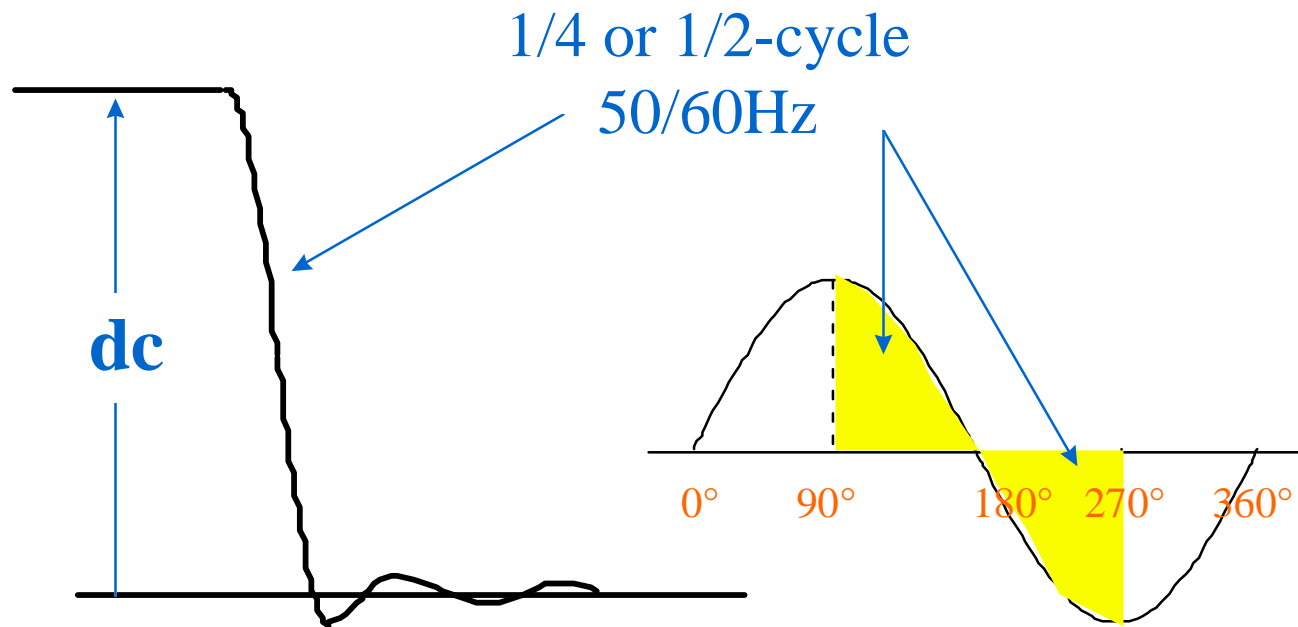


1.  $U_1$  is 50/60 Hz
2.  $U_1$  is variable frequency

Resonance:  
 $\omega L = 1/\omega C$

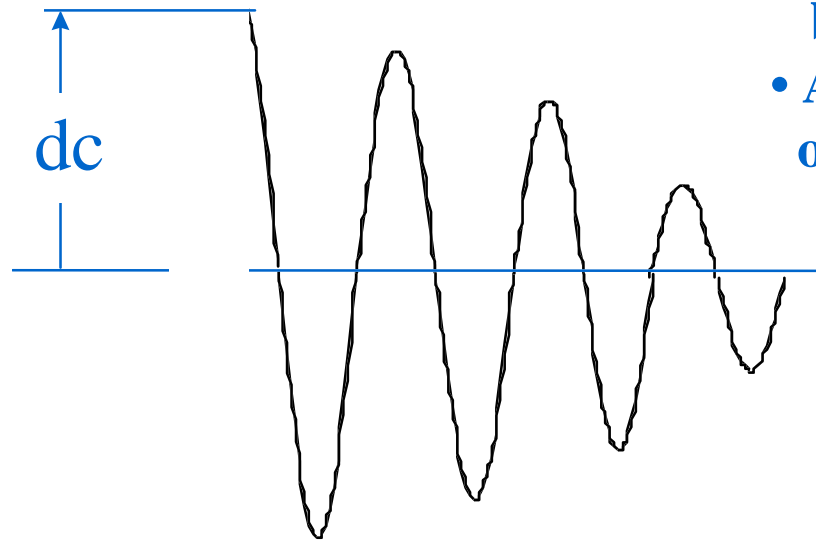
$\cancel{\omega}$   
 $\omega$

# PARTIAL WAVE - 50/60HZ



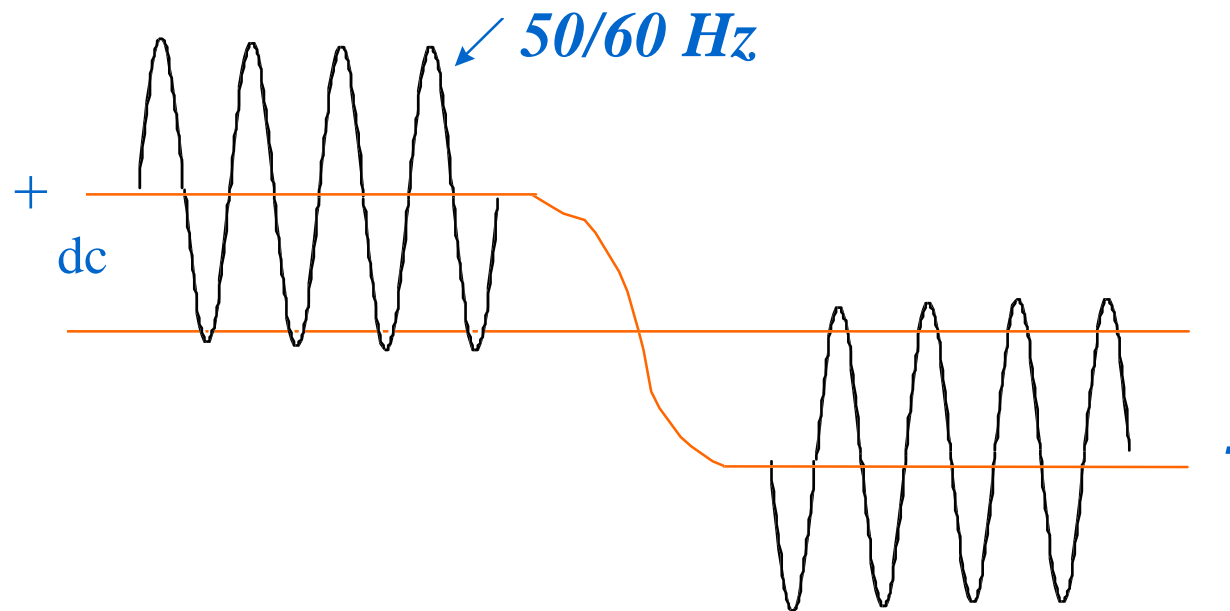
PD is detectable only in the quadrants shown

# OSCILLATING WAVE (OSW)



- Frequency dictated by cable capacitance
- Attenuation depends on cable

# APDAC



**ALTERNATING POLARITY DC-BIASED AC**



# TEST VOLTAGE LEVEL

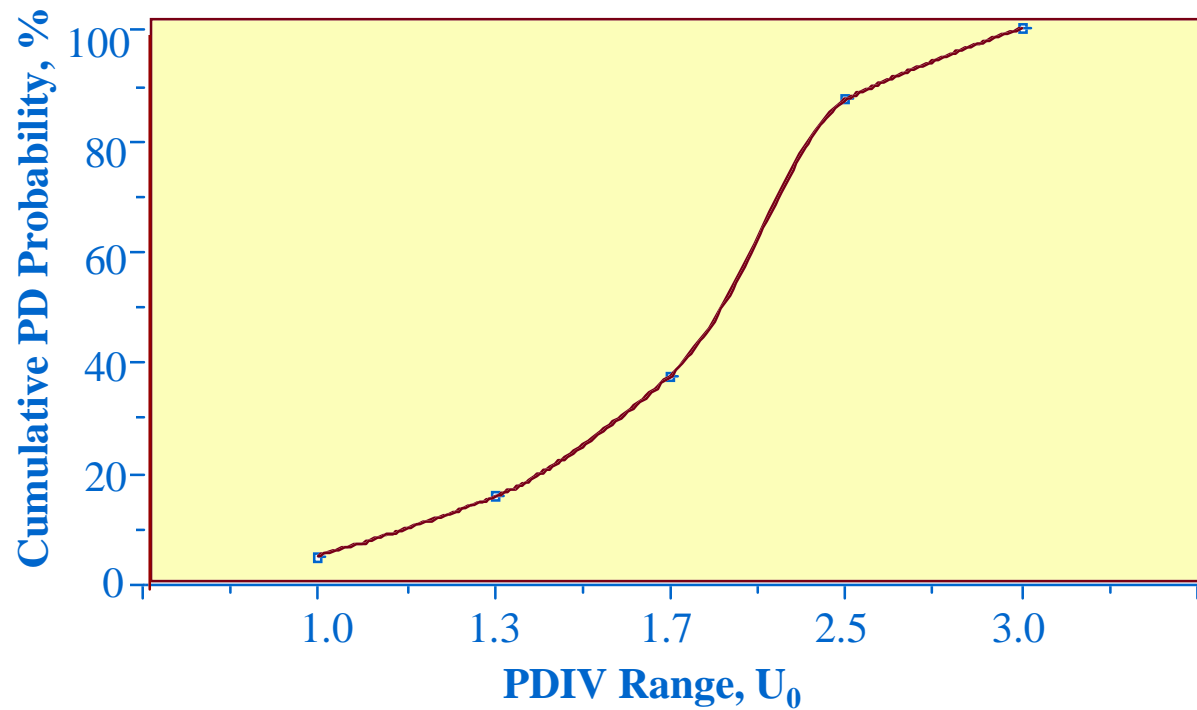
- *Decide after discussing with client*
- *Minimum:  $2U_0$  recommended*
- *Maximum:  $2.5 - 3.0U_0$*



## ■ Rationale

*Consider maximum transient voltage that may exist on system: geographic location and system protection.*

# CUMULATIVE PD PROBABILITY, 2500km, EXTRUDED CABLE



*DATA BASED ON 960 PD EVENTS IN CABLES*

At 1.0  $U_0$ , less than 3% of PD events can be identified.

# TEST VOLTAGE LEVEL

- *PDIV varies with type of excitation voltage:*
  - With sinusoidal VLF, PDIV may be as high as 2.5 times that at 50/60Hz.
- *Where PD is detected with 50/60Hz voltage, no PD may seem to exist at the same voltage level in PD tests with other types of excitation voltage.*

# PRINCIPLES OF PD TESTING

## PD Site Location

- *Reflectometry (off-line)*

- *Arrival-Time*

- *Non-branched (2-termination) system*

- *Off-Line*

- *On-Line*

- *Branched system:*

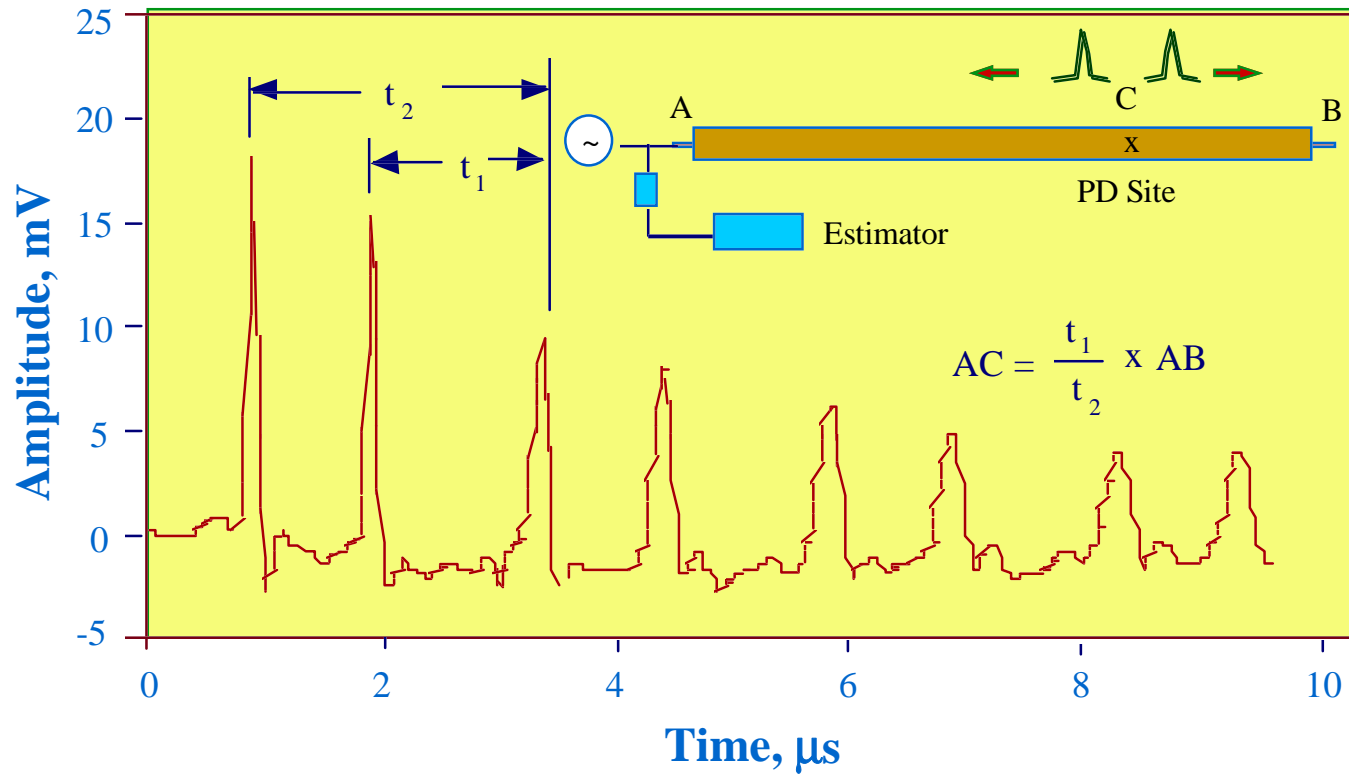
- *Off-Line*

- *On-Line*

- *Frequency-Domain Testing*

IMCORP  
Technologies

# REFLECTOMETRY



# TEST REPORT

## Joint and PD Locations

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PD

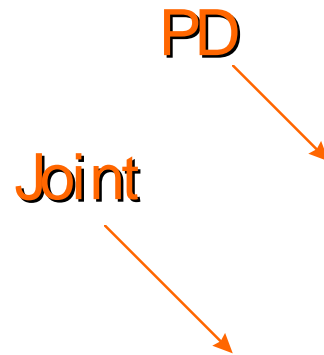


Joint

# TEST REPORT

## Joint and PD Locations

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# PHASE RESOLVED PD DISPLAY

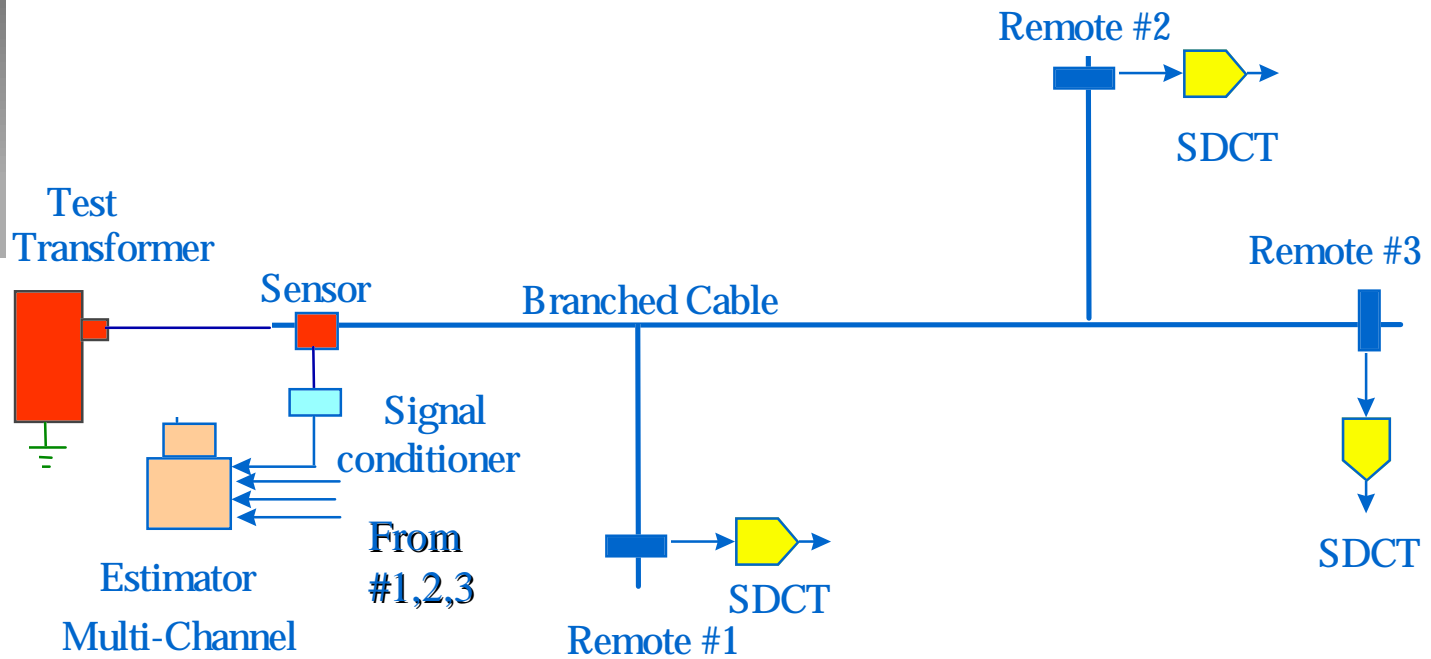
## PD in Termination

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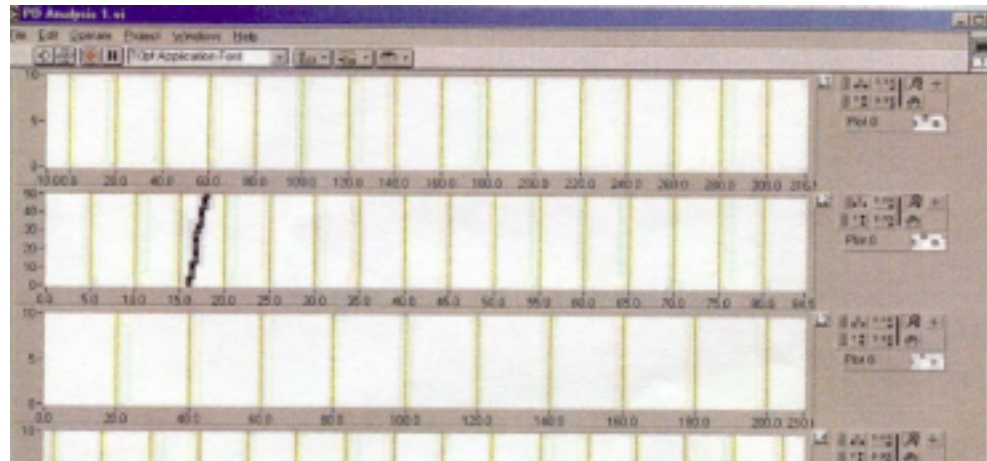




# ARRIVAL-TIME BRANCHED CABLES



# TESTING 4-TERMINAL CIRCUIT



# PD-LOCATION



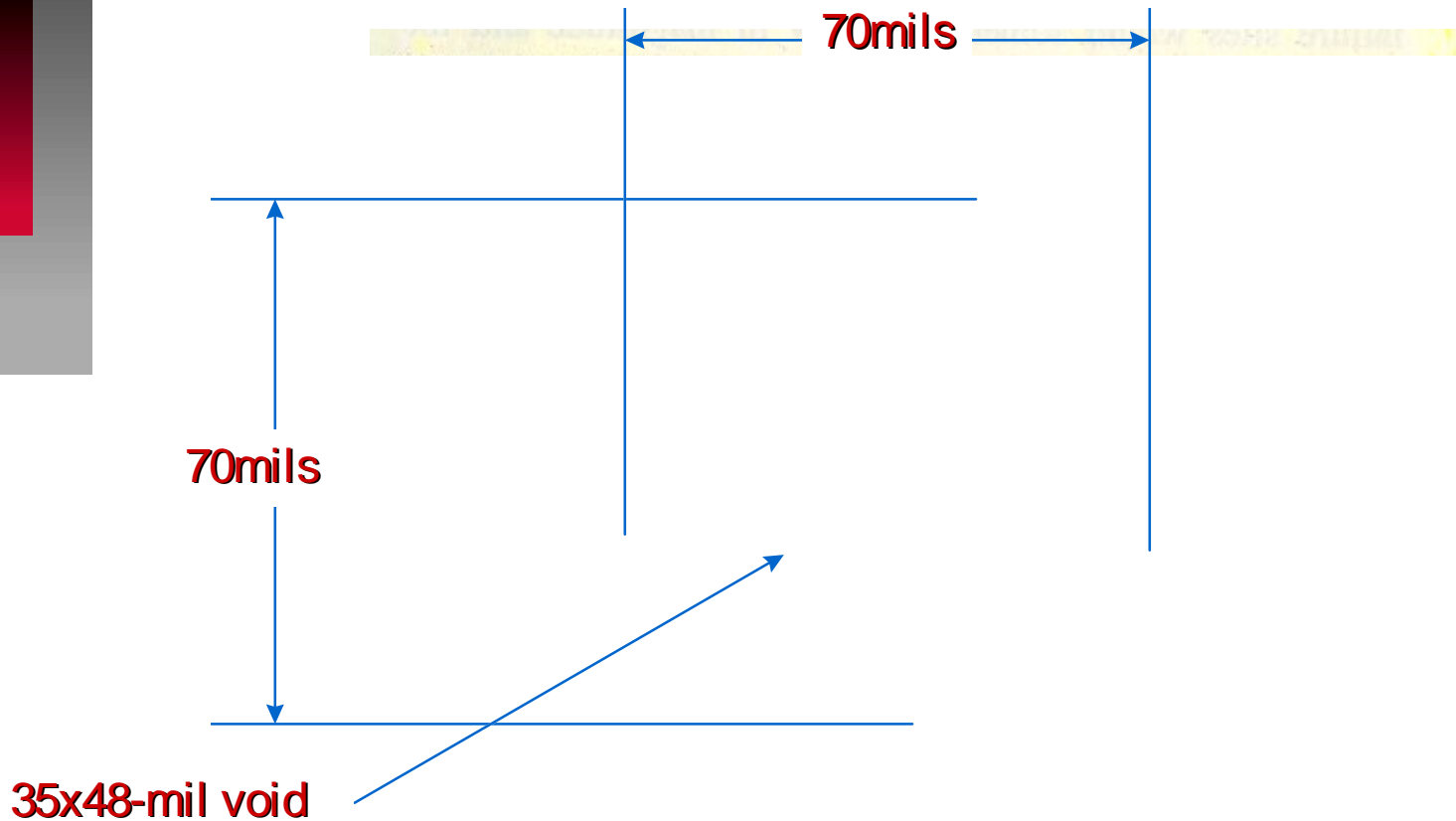
# PD TESTING - Major Concerns

- Is PD test able to locate water trees?
  - All trees?
  - Some trees?

*See McBride et al.*

- Does PD testing unduly deteriorate or fail
  - Good cables?
  - Defective cables? - Effect of high dc or thumping
- How effective is ON-LINE testing?
- How effective is PD testing of PILC cables?
- Are PD test results obtained by different methods identical?

# McBride et al. (Georgia Power Res., and EPRI) - IEEE Trans. on Power Del. 4/94



## McBride et al. (Georgia Power Res., and EPRI) - IEEE Trans. on Power Del. 4/94

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- Inspection of these wafers revealed a large void (35 mils wide and 48 mils high) in the center of the (70 mils diameter and 70 mils high) water tree.
- There was significant evidence of PD within the interior of the water tree, with darkened areas near the tips of the tree. This was clearly the site of the PD activity.
- Cable failures near large water trees have occurred in ac breakdown tests...

## McBride et al. (Georgia Power Res., and EPRI) - IEEE Trans. on Power Del. 4/94

- Seven cables failed while active PD sites were monitored (at higher voltage than PDIV).
- With the exception of two samples (out of the remaining 7 samples with PD) all other cable failures occurred at the PD inception voltage while (PD site) locations were being performed... Failures were associated with the PD sites.
- The duration of sustained PD ranged from 2 to 80 minutes prior to failure.
- The theory that PD above operating voltage results in failure at operating voltage is not supported by this data.

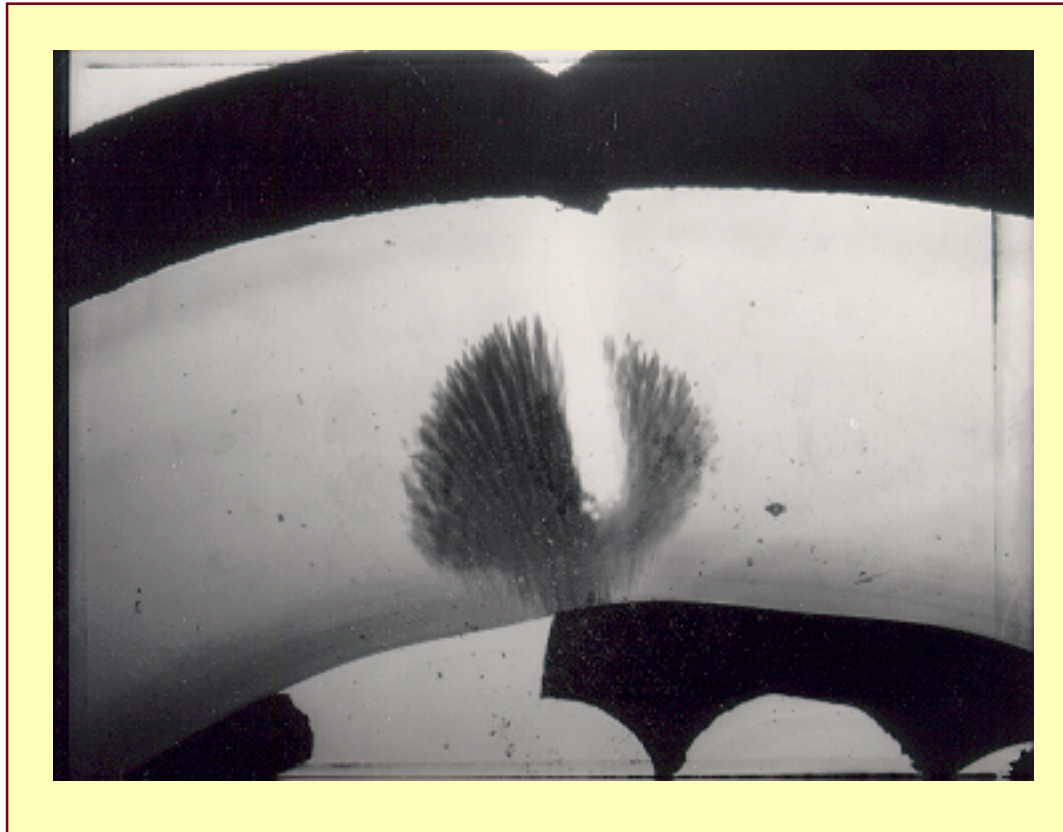


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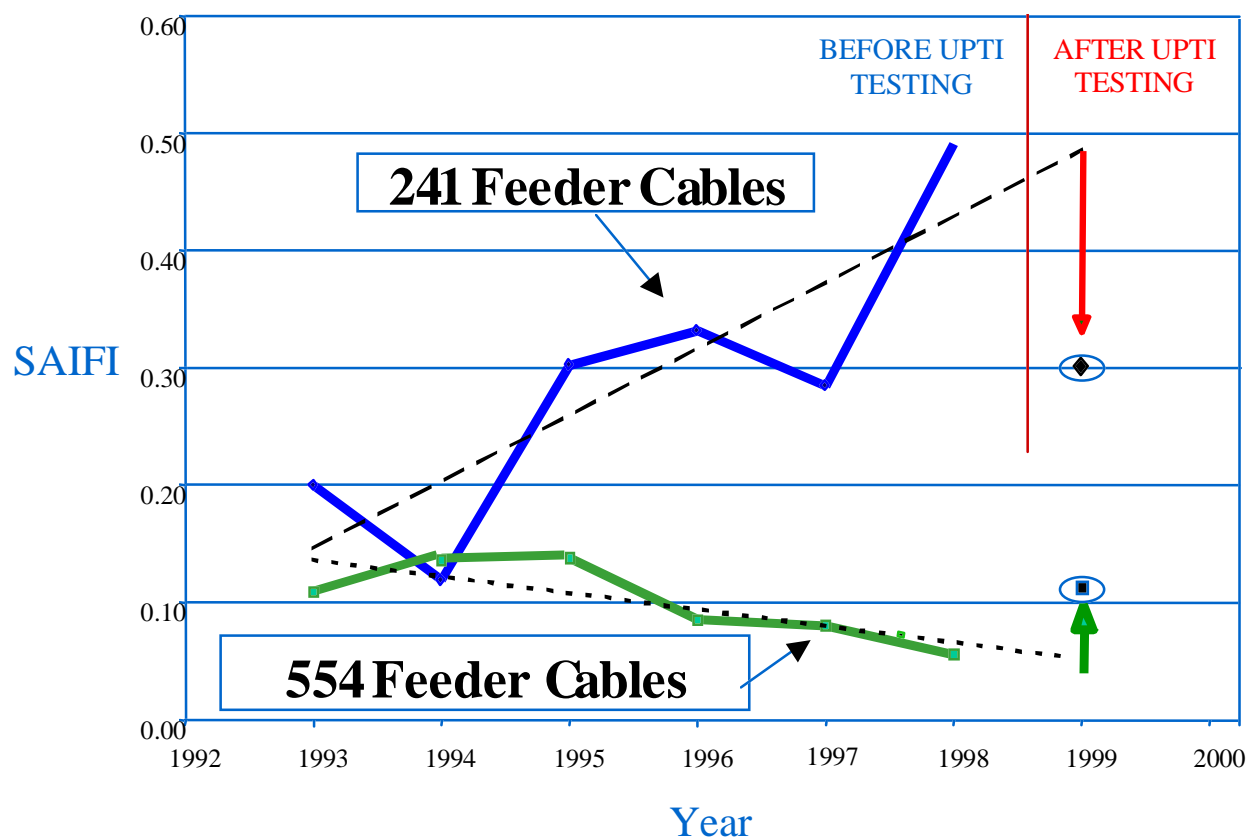
- Very few cables contained active PD sites near operating voltage. No PD above 1-3pC was detected in any of the test cables (61 samples) when energized at operating voltage. (PDIV = 8 - 35kV).
- Most PD sites were detected at twice operating voltage or higher.
- The (pC) level of the PD at a site could not be correlated with the likelihood of a failure at or near the site.

# **BREAKDOWN AT PD SITE THROUGH VENTED WATER TREE**



# IMPROVED RELIABILITY

Peter Daly, San Francisco, Jan. 20, 2000



NOTE: Only 40% of Recommended Repair Was Completed