Docket No. 2020001-EI
Cross-Examination
Hearing Exhibit

Exhibit No.: 3

Proffered by: Public Counsel

Short title: St. Lucie 1 Generator Ground Fault Analysis

Witness(s): FPL- Coffey

St. Lucie 1 Generator Ground Fault Analysis

Gary Griffith, PGD Technical Services Leader

Randal Kerkes, Principal Technical Services Specialist

July 11th 2019

Agenda

St. Lucie 1 Generator Ground Fault

- **Executive Summary**
- **Fault Tree**
- **Siemens RCA Report**
  - Conclusion
  - Recommendations
- **EOSS**
  - Conclusion
  - Recommendations
- **Review of Forensic Analysis at Siemens Charlotte Innovation Lab**
  - Bottom Bar 17 Analysis
    - -- Picture of bar dissection with findings
    - -- Microscopic inspection of dissected bar specimens
    - -- Microscopic inspection of Insulation failure location
    - -- Review of Fourier-transform infrared spectroscopy (FTIR) data

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Executive Summary

St. Lucie Unit 1 Generator Ground Fault

When & Where did it Occur:
On 4/25/2019 at 09:18, St. Lucie Unit 1 experienced a stator ground fault

Repair:
Complete Stator winding replacement

What is the pain:
EFOR of ~59 Days, from 4/25/2019 to 6/22/2019
Lost generation of 1,375,775 MWh

What happened: Undetected Stator Winding Insulation failure (stator ground fault)
Most probable cause “Magnetic Termite”

Operational Risk:
No change is recommended to operational or maintenance plans for the remaining Siemens rewound units (PSL2, PBN 1, PBN 2, PTN 3, PTN 4). Details below. Maintaining a spare winding is not economical

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Bottom Bar 17 Forensic Analysis Report from Siemens

OPC EXH 3 FPL COFFEY 000004

St. Lucie Unit 1 Generator Ground Fault

- **Siemens Forensic Analysis – yielded the following:**
  - Siemens RCA Report Pending

Bottom Bar 17 Forensic Analysis Report from FPL EOSS

St. Lucie Unit 1 Generator Ground Fault Analysis

- **Participated in Siemens Forensic analysis / testing**
  - Elimination of most common failure modes, see Fault Tree
  - Fault channel is straight through the insulation system starting at the top of the bar insulation down to the conducting surface, indicating a classic “Magnetic Termite” failure
  - Ferrous material was introduced during the on site rewind process or during coil manufacturing
  - Ferrous material no longer present after the fault
- **Siemens performed major stator frame and core work on PSL 1 during rewind in 2012**
  - Complete restack with extensive grinding and welding
  - PSL 1 only unit in NEE fleet with this extent of frame and core modification coincident with a rewind activity

Bottom Bar 17 Forensic Analysis Report from FPL EOSS (continued)

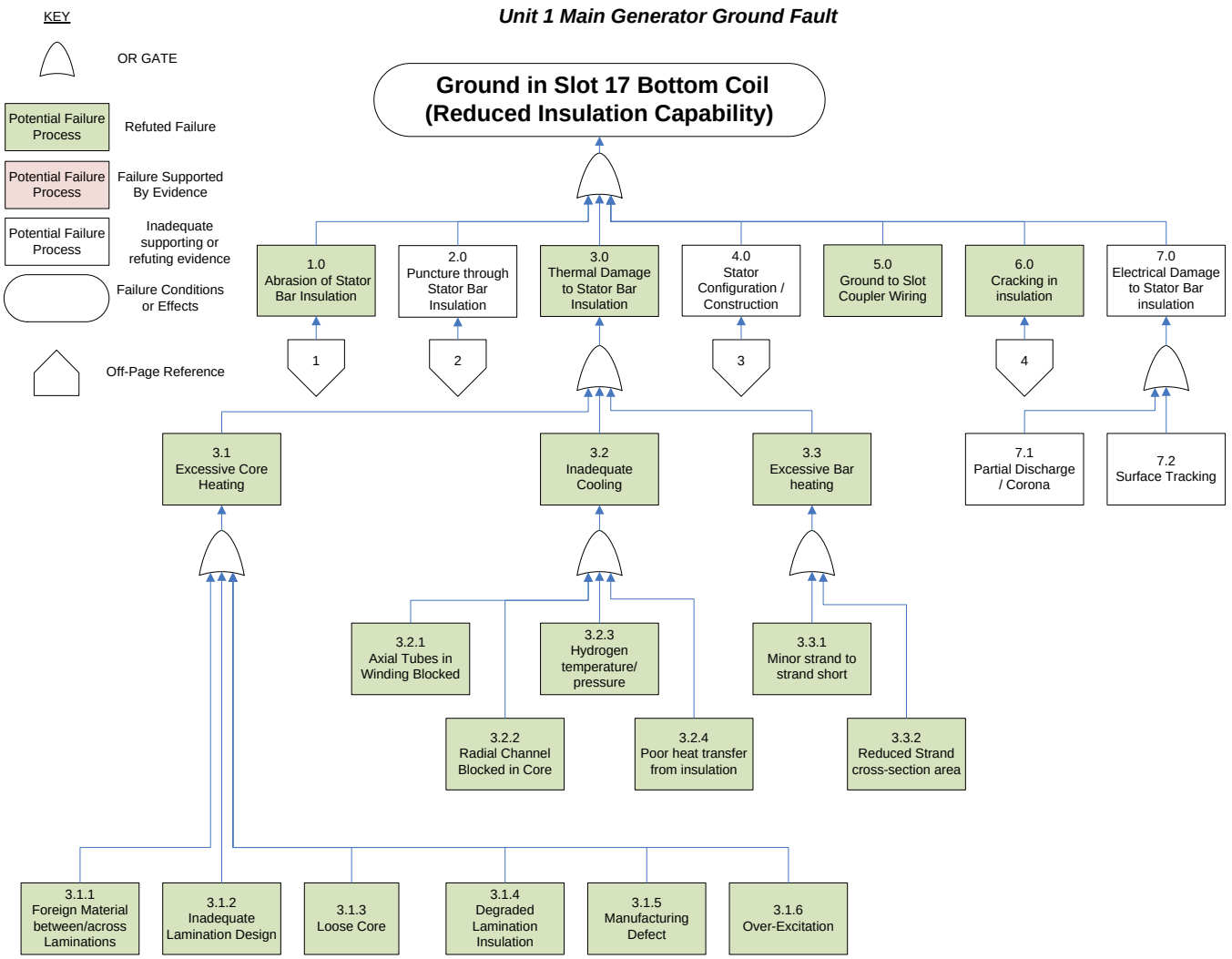
St. Lucie Unit 1 Generator Ground Fault Analysis

- **Additional Research - EPRI papers on "Magnetic Termite" failures with similar forensic evidence**
  - DTE Energy Fermi 2: GE Design (H2 In leakage to Stator Cooling Water)
  - Electrabel GDF Belgium Nuclear: Jeumont – Westinghouse Design (Stator Ground Fault)
- **Consulted with industry expert, Greg Stone (IEEE Fellow, IRIS Power)**
  - Agreed that "Magnetic Termite" is most likely failure mode
- **Based on the extent of core work performed during the 2012 rewind, the most likely root cause is an introduction of ferrous foreign material**

No definitive root cause was identified due to the damage at the failure location

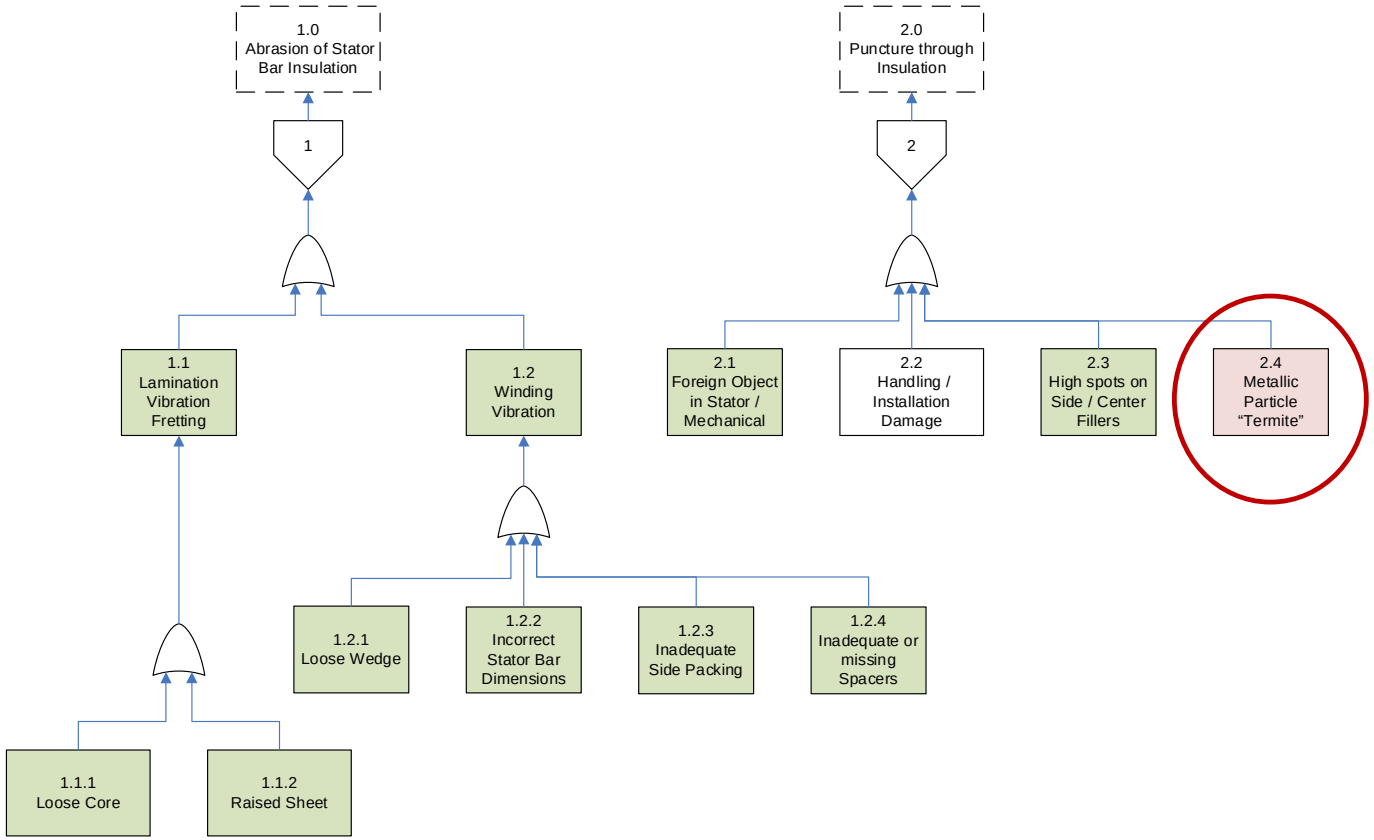
Fault Tree

St. Lucie 1 Generator Ground Fault



Fault Tree

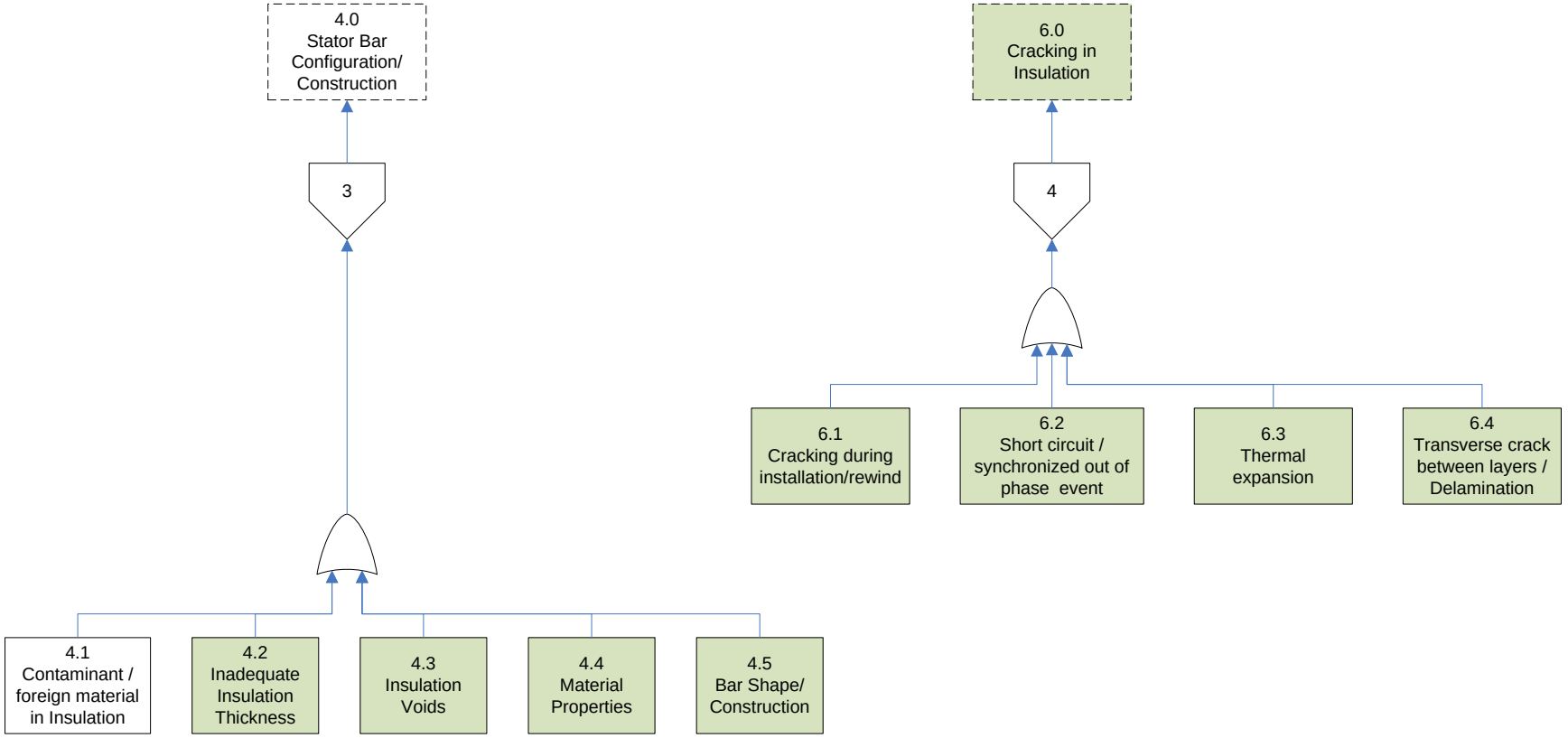
St. Lucie 1 Generator Ground Fault



By Elimination of possible failure modes the most probable and verified by 3rd party consultant is a "Magnetic Termite"

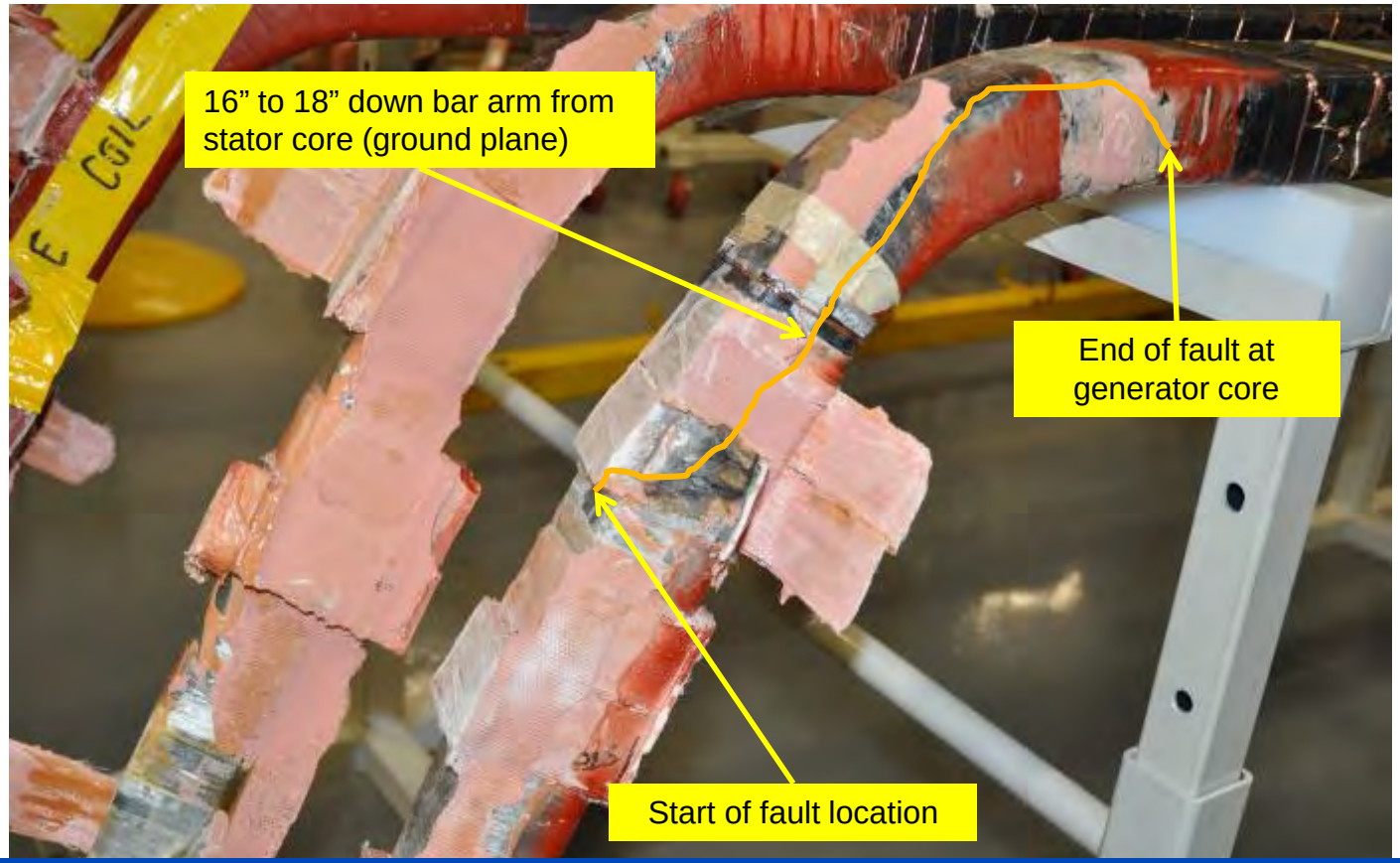
Fault Tree

St. Lucie 1 Generator Ground Fault



Review of Forensic Analysis at Siemens Charlotte Innovation Lab

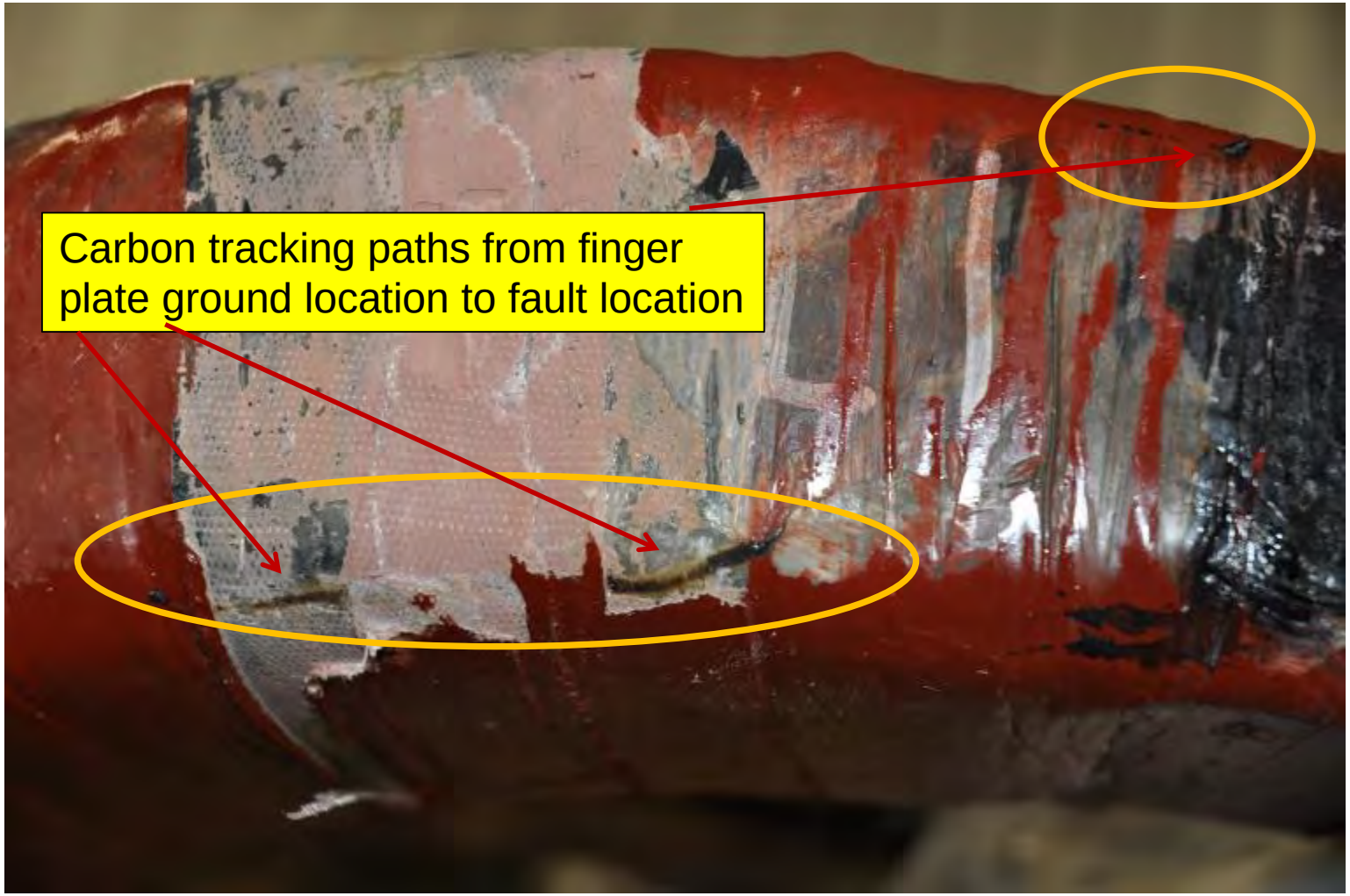
St. Lucie 1 Generator Ground Fault Path



Fault Initiation at Endwinding Leading to Core Finger Plate

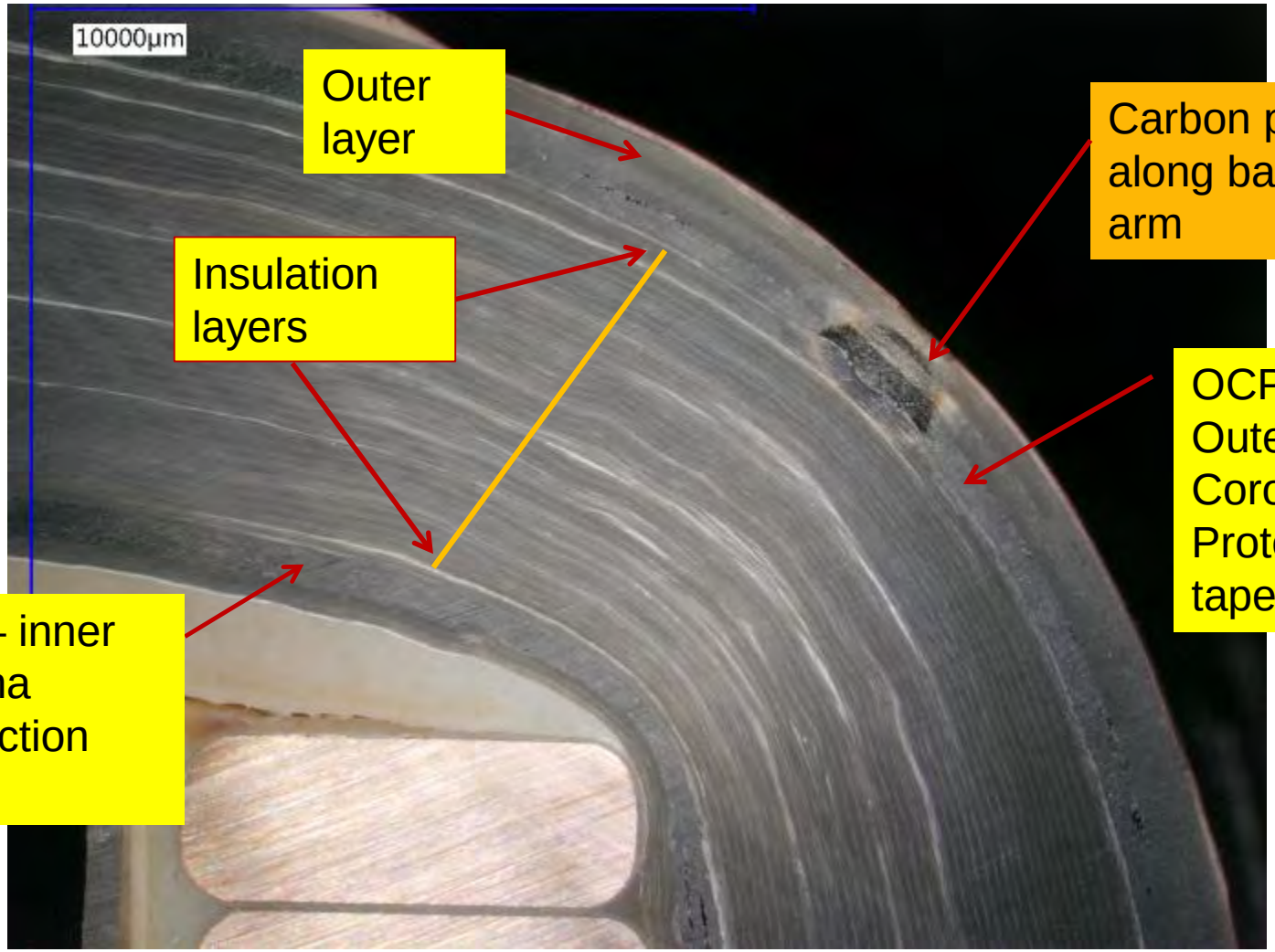
Review of Forensic Analysis at Siemens Charlotte Innovation Lab

St. Lucie 1 Generator Ground Fault



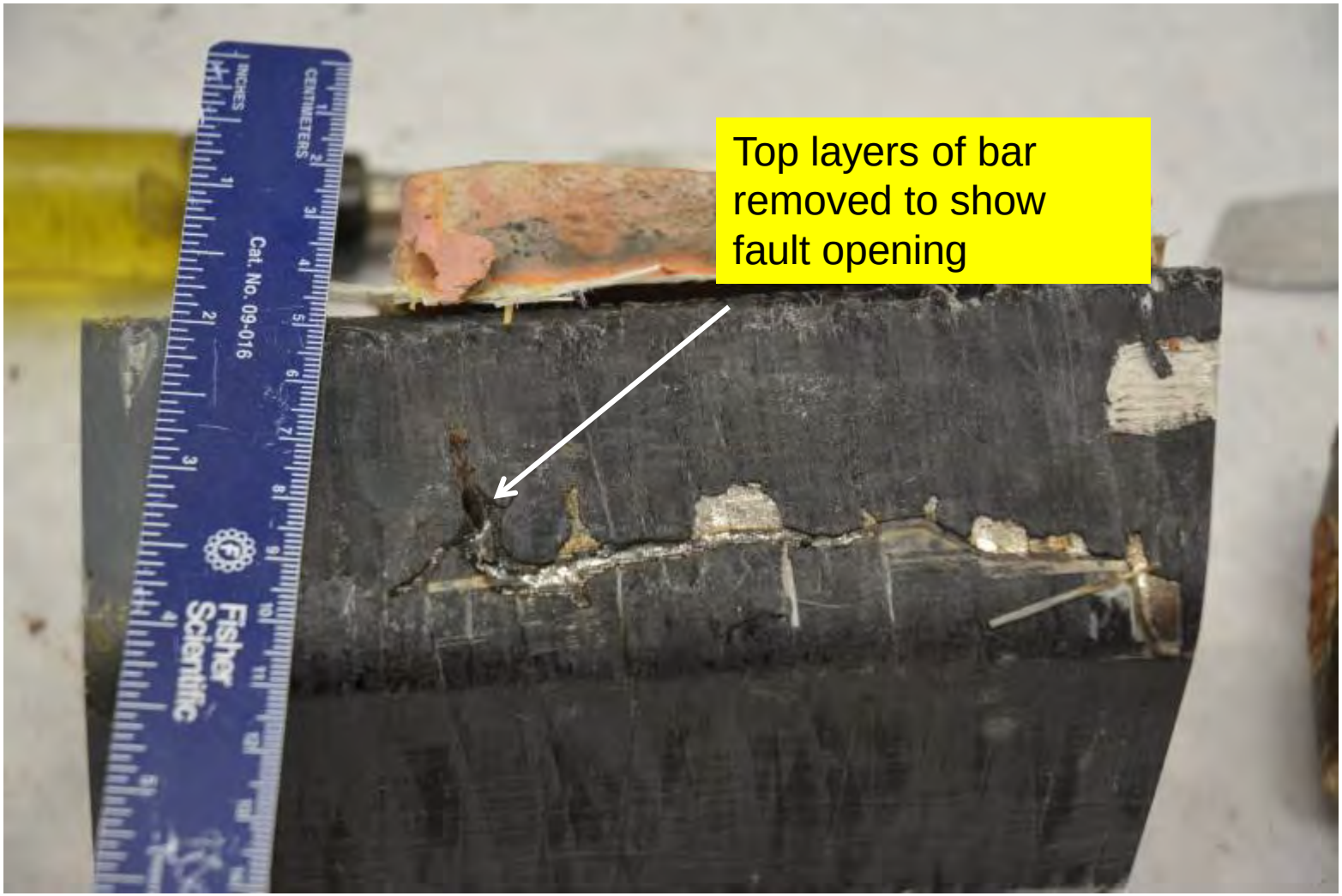
Review of Forensic Analysis at Siemens Charlotte Innovation Lab

St. Lucie 1 Generator Ground Fault



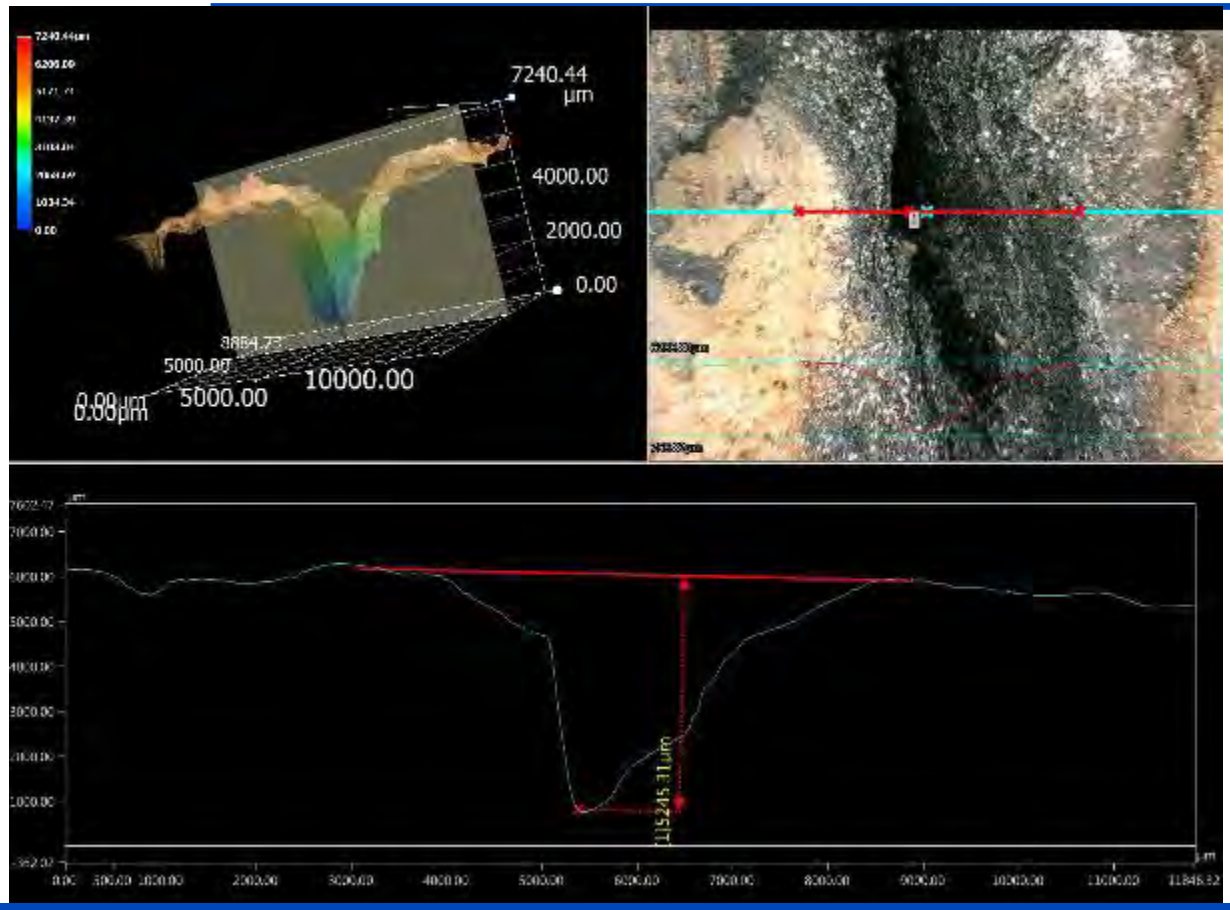
Review of Forensic Analysis at Siemens Charlotte Innovation Lab

St. Lucie 1 Generator Ground Fault



Review of Forensic Analysis at Siemens Charlotte Innovation Lab

St. Lucie 1 Generator Ground Fault



Failure straight down through insulation system

Failure mode characteristics of a Magnetic termite – 2.4 on refute matrix

Failure mode characteristics of a "Magnetic Termite" – 2.4 on fault tree
Magnetic Termite relatively long term failure mode

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EOSS Conclusions

St. Lucie 1 Generator Ground Fault Summary

- **EOSS Analysis concludes the failure mode is a "Magnetic Termite":**
  - Based on available evidence, the failure was caused by a "Magnetic Termite" introduced by a failure of FME process
  - PSL 1 only unit in NEE fleet with a complete core restack and extensive frame and core modifications coincident with a rewind
  - This is a know failure mode identified on two other units:
    - -- Electrabel, GDF Suez
    - -- DTE Energy
  - No known test / inspection to detect this failure mode
- **Recommendations**
  - No change to current NEE operational or maintenance plans
  - Ensure strict adherence to FME process during generator work

FME process adherence is critical to long term generator reliability

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Appendix

Inspection of bottom bars is extremely difficult

This is a Sanford STG which has the same endwinding support design as PSL-1

There is no practical method to inspect many areas of the winding for 'termite' activity, most of which may be under the top layer of the bar and thus invisible even if it was possible to inspect the whole winding

Exerts from EPRI Papers – Support Evidence

Fermi 2 – Issue manifested as an In leakage of H_2 Stator Cooling Water

DTE Energy

Fan baffle and cruciform removed

Failure under end winding supports similar to St. Lucie Unit 1

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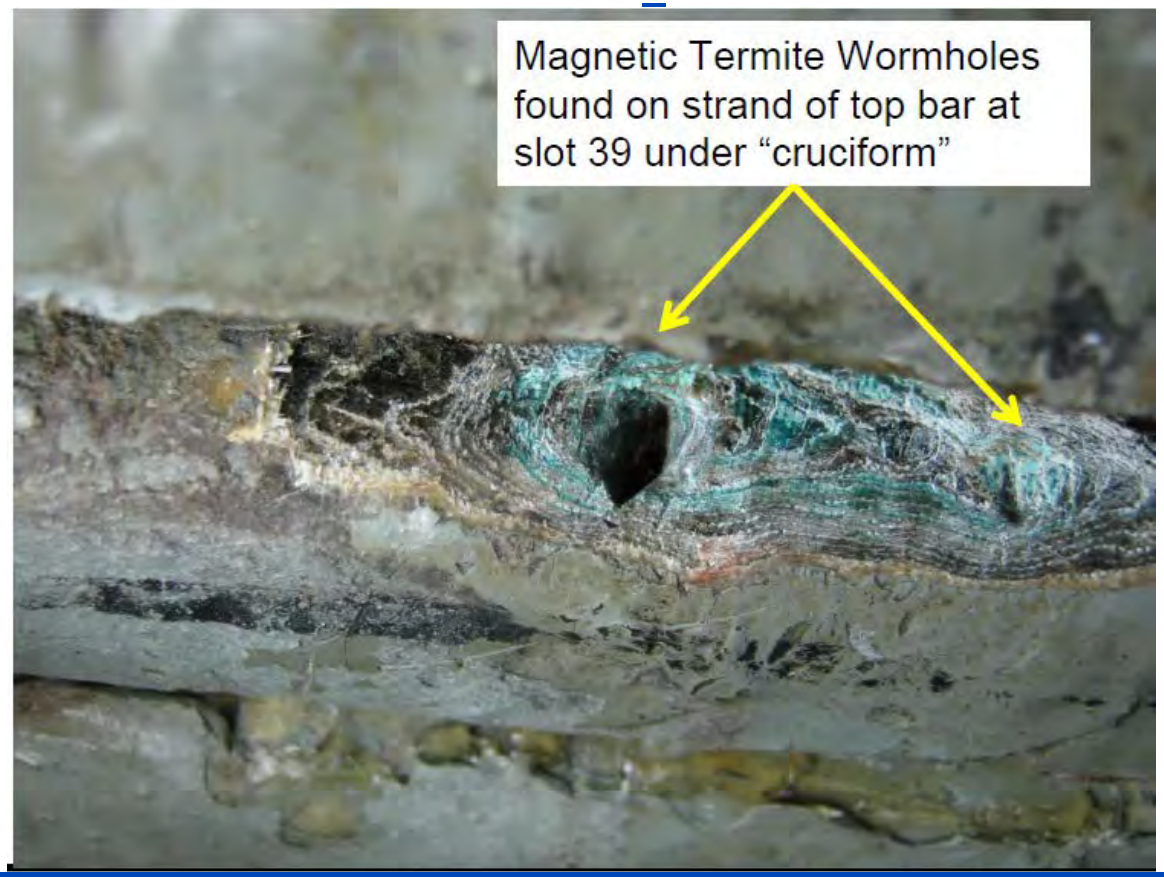
Exerts from EPRI Papers – Support Evidence

Fermi 2 – In leakage of H_2 Stator Cooling Water

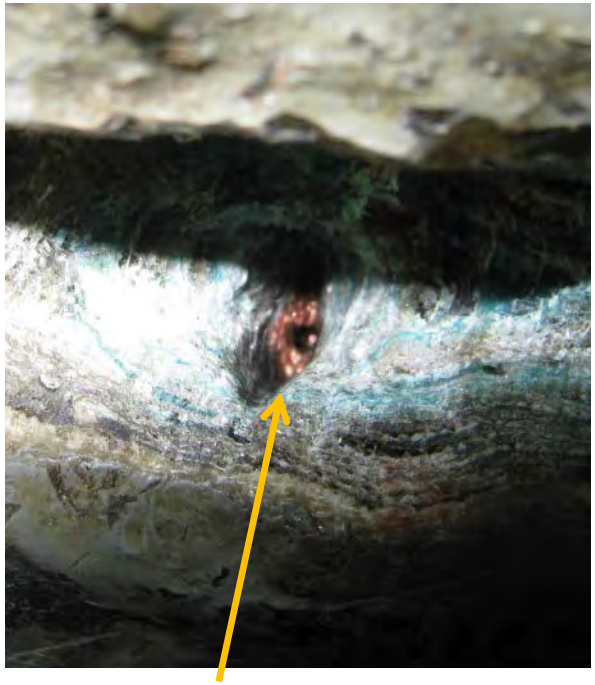


Failure opening in insulation similar to St. Lucie Unit 1

Excerpts from EPRI Papers – Supporting Evidence

Fermi 2 – In leakage of H_2 Stator Cooling Water

Particle is approx. 2.39 X 0.613 mm



Magnetic Termite – worm hole

Failure opening in insulation similar to St. Lucie Unit 1 but, since there was no electrical fault, the particle was recovered

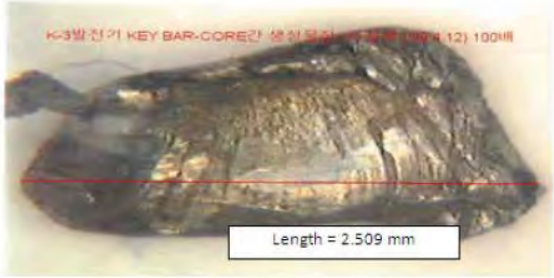
Excerpts from EPRI Papers – Supporting Evidence

Fermi 2 – In leakage of H_2 Stator Cooling Water

Termites found at Kori

DTE Energy

Particles from KoRi generator [lo carbon steel]



Magnetic termites failure mode documentation

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Excerpts from EPRI Papers – Supporting Evidence

Electrabel GDF Suez – Belgian Nuclear Unit

Bottom bar failure

Excerpts from EPRI Papers – Supporting Evidence

Electrabel GDF Suez – Belgian Nuclear Unit

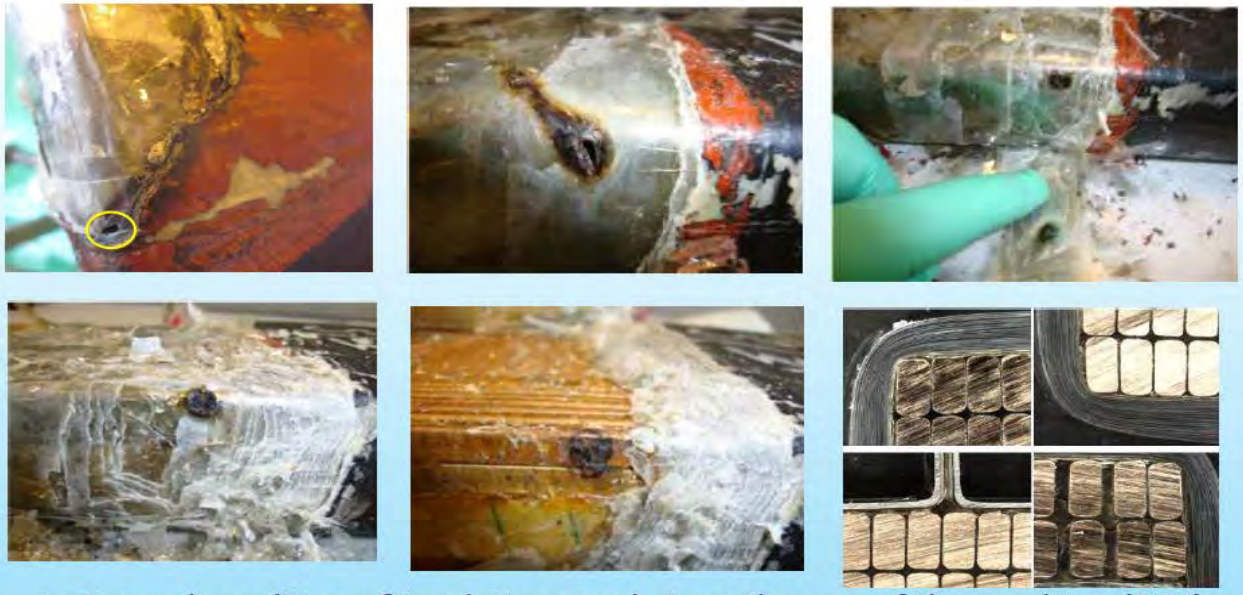
Failure mode identical to St. Lucie Unit 1 – tracking from insulation opening to ground over stator bar insulation

Excerpts from EPRI Papers – Supporting Evidence

Electrabel GDF Suez – Belgian Nuclear Unit

Electrabel
GDF SUEZ

RCA - BAR AUTOPSY BY LABORELEC



- General condition of insulation good given the age of the machine (37Y)
- Correct alignment and impregnation of insulation layers
- Breakdown channel goes straight through insulation layers
- No traces of partial discharge activity between insulation layers
- No foreign materials found

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Exact failure mode as St. Lucie Unit 1

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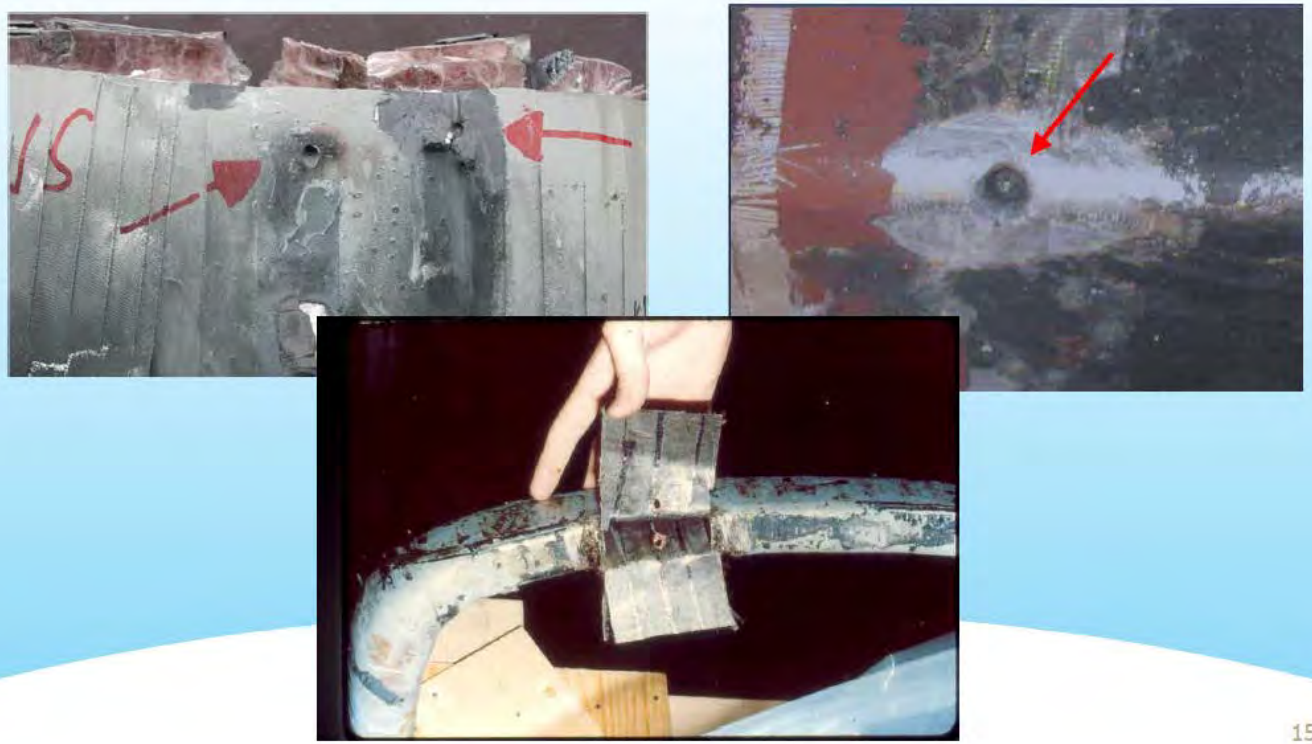
Excerpts from EPRI Papers – Supporting Evidence

Electrabel GDF Suez – Belgian Nuclear Unit

Electrabel
GDF SUEZ

RCA – EXTERNAL CONSULTATION

- Other examples of insulation failure caused by magnetic termites



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Excerpts from EPRI Papers – Supporting Evidence

Electrabel GDF Suez – Belgium Nuclear Unit

Electrabel GDF SUEZ

RCA – EXTERNAL CONSULTATION

- **Different parties were consulted to present their hypotheses based on pictures provided, discussion and lab visits.**
  - Thomas Hillfer (Alstom Birr, head of insulation competence center)
  - Gregg Stone (IEEE fellow, IRIS power)
  - Stefan Lanz (freelancer, former head of insulation CC Alstom/ABB Birr)
  - Siemens-Westinghouse engineering
- Independently all 4 experts pointed out the presence of a **'magnetic termite'** as the most probable cause of the defect.
- Magnetic termite = **metallic object** (1-2 mm) trapped locally, wearing out the insulation due to a combined effect of magnetic attraction (field around bar) and 50 Hz vibration due to eddy currents induced.
- **Origin** of the particle is **unknown**.
- **Propagation time** is **not clear**: according to some experts it can take many 10.000 OH, according to others 1 or 2 years can already be enough.

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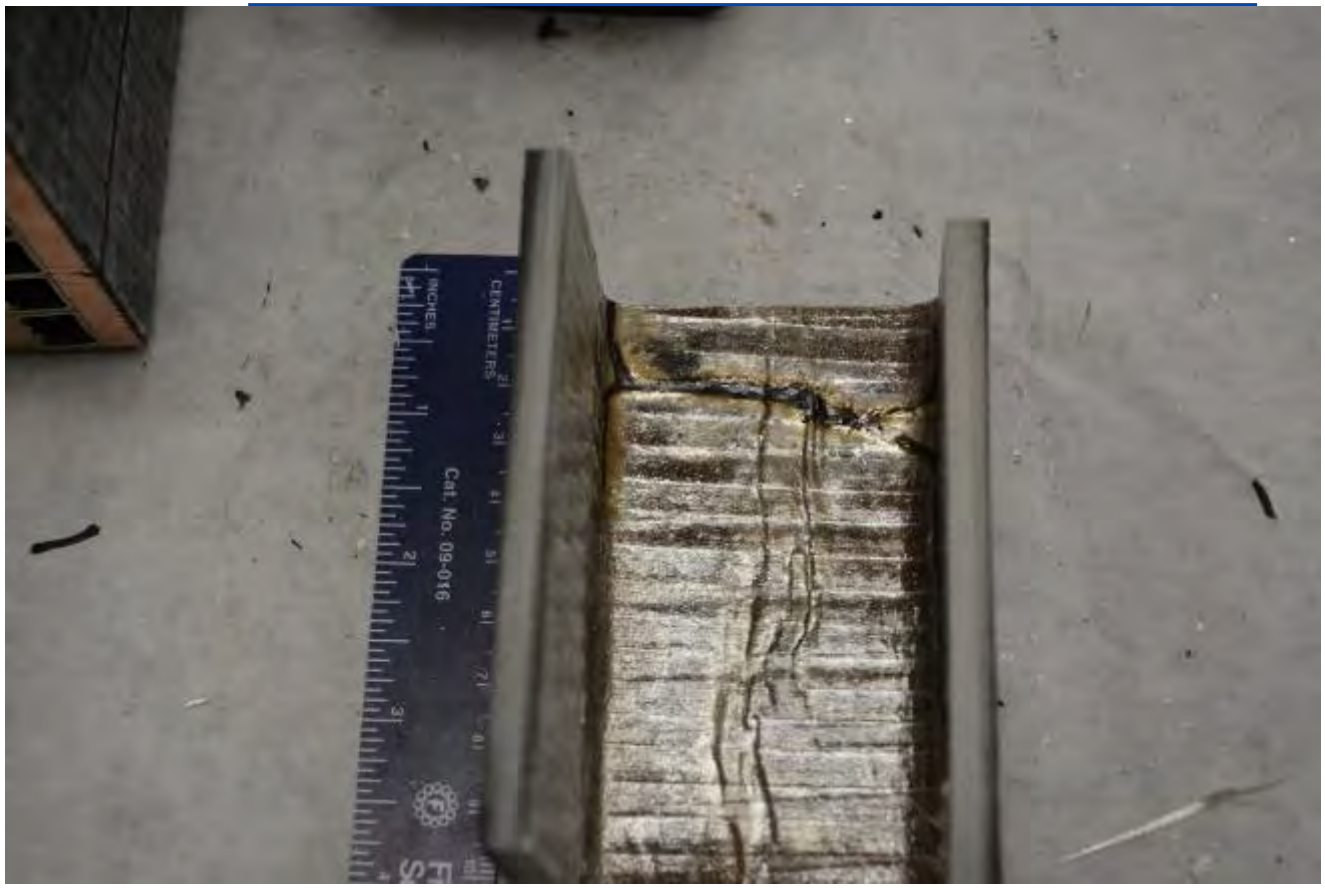
Review of Forensic Analysis at Siemens Charlotte Innovation Lab

St. Lucie Generator Ground Fault

Separated insulation from ICP layer – Forensic process evaluating specimen for failure mode – none NOTED AT THIS TIME

Review of Forensic Analysis at Siemens Charlotte Innovation Lab

St. Lucie Generator Ground Fault



FAULT OPENING STRAIGT DOWN DID NOT FOLLOW TAPE EDGS AS A NORMAL FAILURE MODE WOULD

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Review of Forensic Analysis at Siemens Charlotte Innovation Lab

St. Lucie Generator Ground Fault

Discharge site to ground – Stator Core Finger Plate

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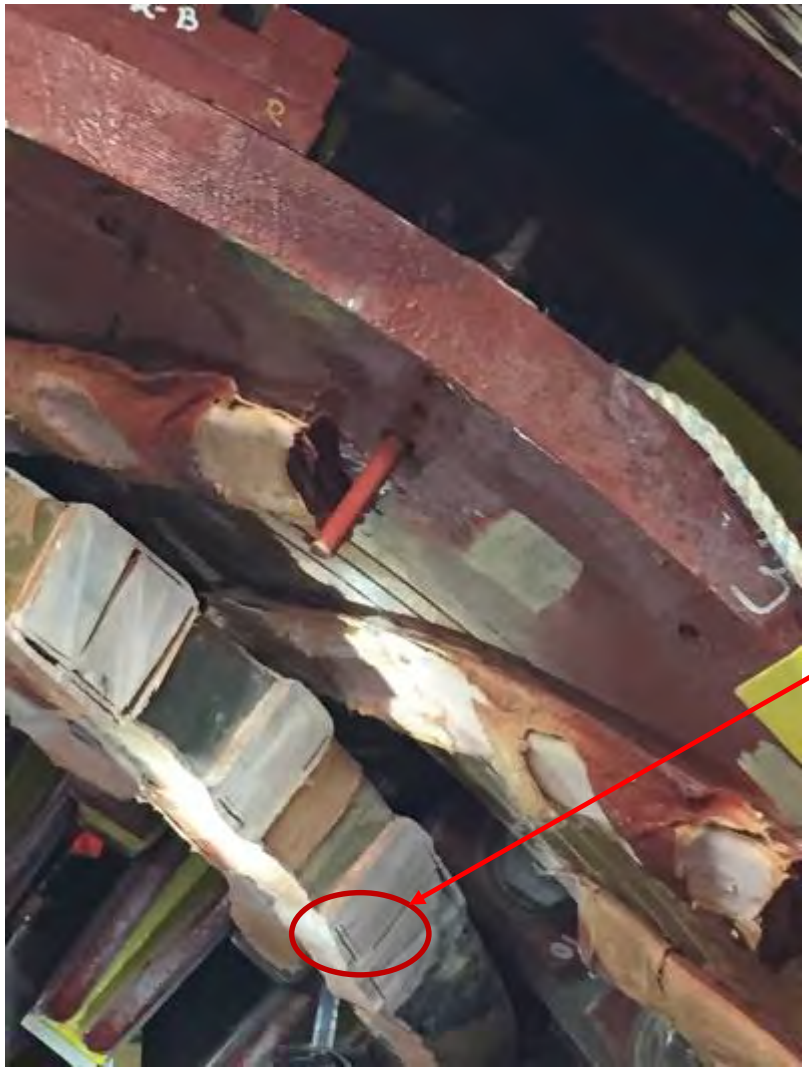
St. Lucie 1 Generator Coil Removal

Review of Forensic Analysis at Siemens Charlotte Innovation Lab

St. Lucie 1 Generator Coil Removal

Review of Forensic Analysis at Siemens Charlotte Innovation Lab

St. Lucie Generator Ground Fault



Extraction of Bottom Bar 17 - Fault location under blocking
Hidden from view by blocking