


## Borescope Inspection Findings on Air-Cooled Generators with Spark Erosion and Partial Discharge


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## Introduction

- Spark Erosion and Partial Discharge Deterioration is a concern with large air-cooled generators: >200 MVA, 18/19 kV
- Units are failing or are having to be rewound with less than 10 years of service life, primarily due to the more serious and faster acting spark erosion failure mode


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## Introduction

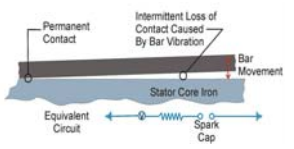
- A Borescope Inspection can help to assess the degree of stator winding deterioration due to spark erosion and partial discharge and help the owner to implement a timely, planned rewind before an in-service failure occurs. It can help to mitigate risk of a forced outage.
- Inspection results are based on more than a dozen borescope inspections in conjunction with detailed evaluations of stator bars removed from more than seven different units of this particular class of machine.


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## Spark Erosion

- Electrical arc between core and bar surface – high current
- Bars loose in slot
- Low surface resistance
- Occurs on any bar
- Higher rate on Top Bars





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### Spark Erosion

- Relatively Fast
- Penetrate through ground insulation
- Unplanned forced outage

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### Partial Discharge in Slot

- Occurs in cavity, void, or air pocket
- Voltage across the cavity exceeds breakdown voltage.

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### Partial Discharge in Slot

- PD in slot causes a 'bleaching' of the semi-conducting layers
- Occurs on higher voltage bars
- Can occur anywhere on bar

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### SE versus PD Comparison

- SE independent of bar voltage
- PD correlates with bar voltage

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## Spark Erosion Failure

- 18 kV, 226 MVA\*
- Commercial-8/2001\*
- Failed-12/2005\*
- 33,183 hours\*



\*Published Data: IRMC 2008

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## Bar Deterioration Comparison



- 15,000 service hours
- Level 1 and 2 SE




- 40,000 service hours
- All Levels of SE

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## Borescope Inspection

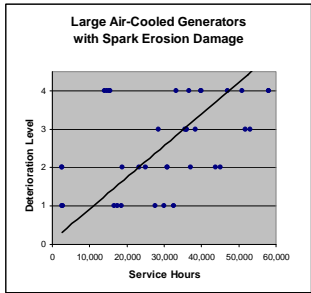
- NEC Teamed up with ATS – Advanced Turbine Support (.borescopeinspections.com)
- ATS - Perform over 1,000 borescope inspections every year-15 FT inspectors
- NEC/ATS inspected and evaluated more than a dozen units of this class for SE
- Correlated borescope findings with visual inspection of stator bars removed prior to rewind with new bars



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## Industry Statistics

- 40 Borescope Inspection Results
- Deterioration Level
  0. No Deterioration
  1. Minimal
  2. Moderate
  3. Critical
  4. Failure/Rewind




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### Level 1 SE Deterioration

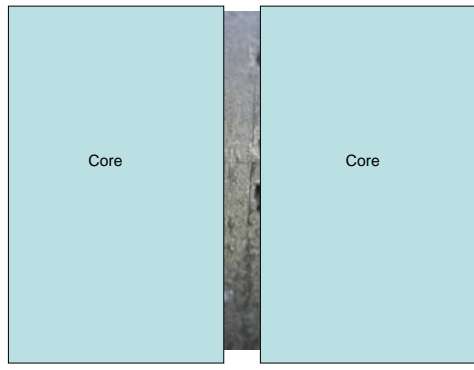
- Black circles near the edge of the vent duct spacer.

Dark spots – early stages of SE



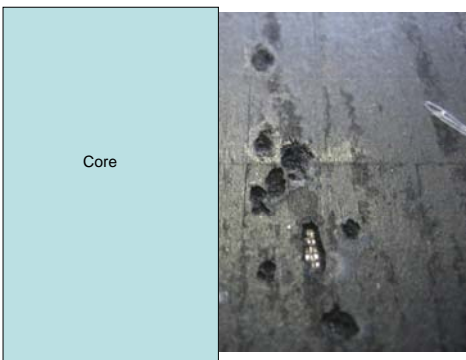
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### Level 1 SE Deterioration



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### Level 1 SE Deterioration



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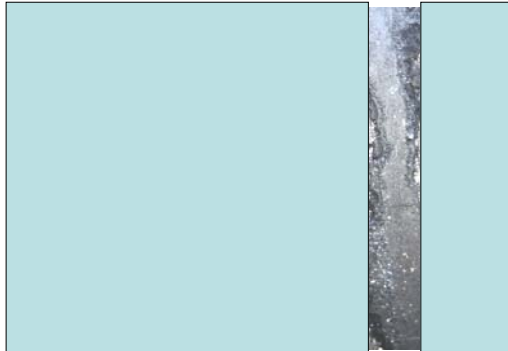
### Level 2 SE Deterioration

- Damage is more extensive near the vent duct edge
- Slag/Rough surfaces that have some depth




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### Level 2 SE Deterioration



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### Level 2 SE Deterioration



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### Level 3 SE Deterioration

- Slag/rough surface appearance over a large portion or all of the vent duct opening



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### Level 3 SE Deterioration



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### Level 3 SE Deterioration



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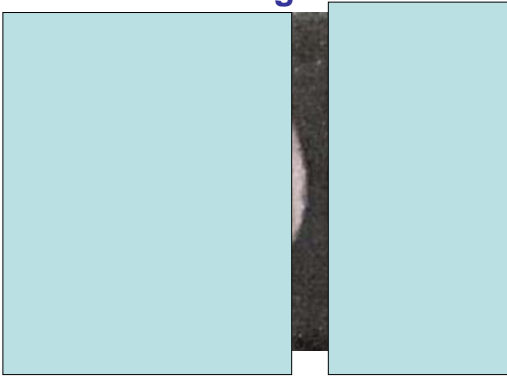
### Initial Stages of PD

- PD - damage to outer layers of tape
- Appearance is round




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### Intermediate Stages of PD



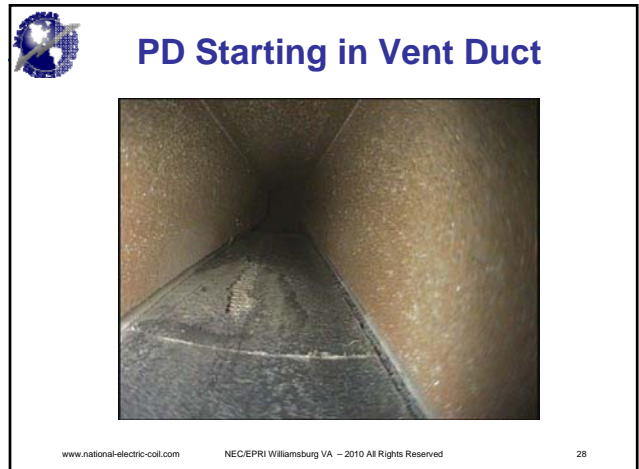
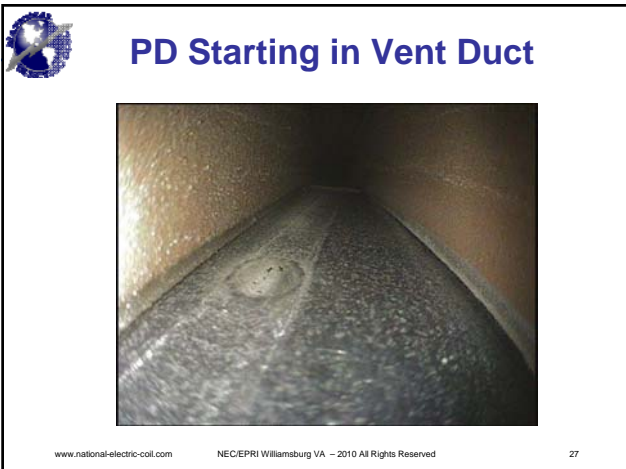
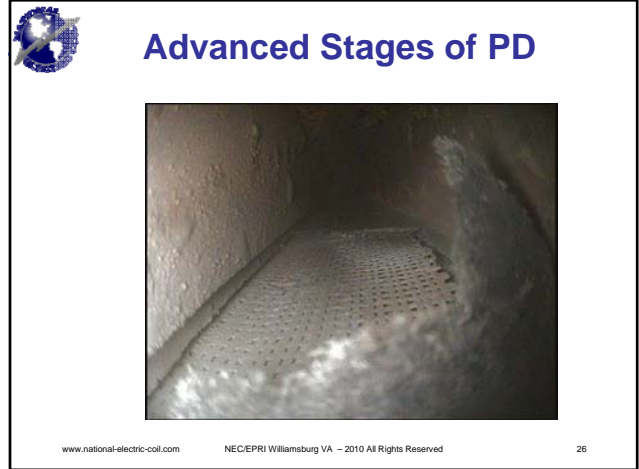
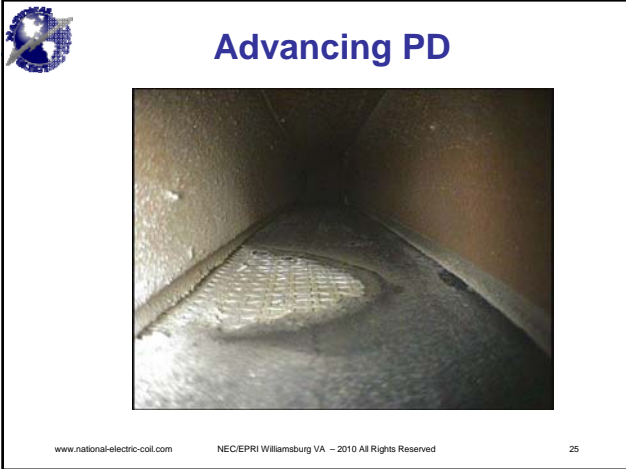
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### Intermediate Stages of PD



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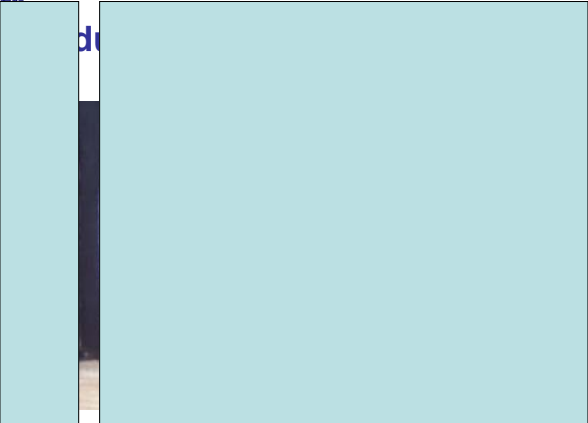
## Conclusions/Recommendations

- A borescope inspection is one of several important condition assessment tools to mitigate risk of a forced outage failure of the stator winding for this class of units
- Correlation of Service Hours is an important consideration
- EMI/PD testing may also be a benefit
- Plan for rewind
- Incorporate design improvements

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## Industry Failure at 33,000 hours



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## Questions?

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