Challenges of Rewinding Old and New High Voltage Generator Stators

Virtual Iris Rotating Machine Conference

June 24, 2021

Discussion

- New vs. Old Vintage Machines
- Overall Stator Rewind Technical Considerations
  - Rewind Reason / Failure Cause
  - Machine History & Condition Of Key Components
  - Specifications
  - Scheduled vs. Unscheduled (forced) Rewinds
- Rewind Case Studies

Considerations – Newer vs. Older

Newer Vintage

- Rewind Cause – normally one or a combination of:
  - Design concern
  - Material concern
  - Operational concern
- What is the root cause?
  - Specific – not a symptom
  - How can it best be corrected
- How can long-term reliable life best be achieved?

Older Vintage

- Rewind Cause – normally age deterioration of components. Possibly machine characteristic change to support system needs and/or process enhancements
- Were there any major technical deficiencies in the machine materials or design?
- Incorporation of new materials and technologies
- Is an Up-Rate desired?

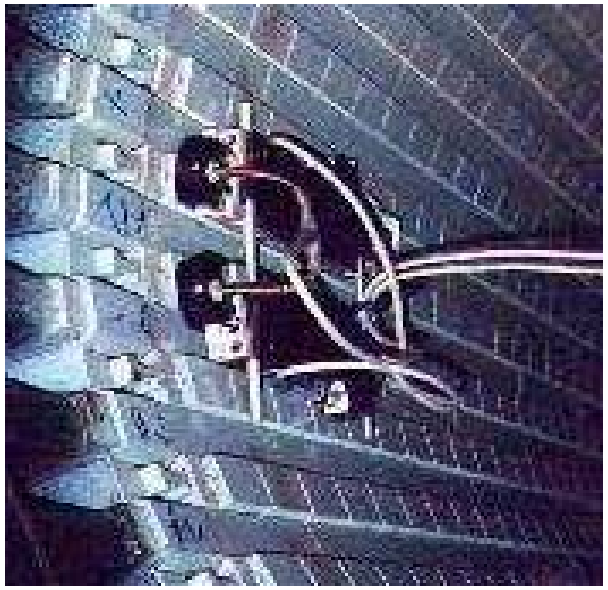
Specifications

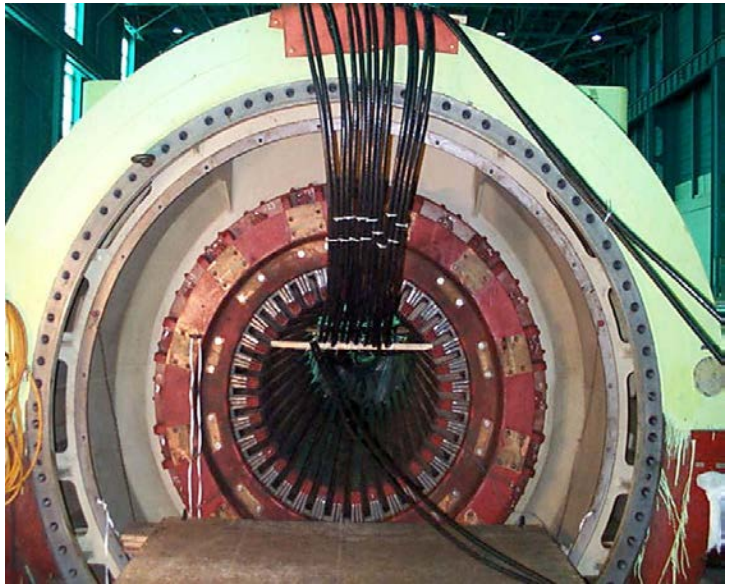
- The purpose of the specification is to clearly define the expectations and requirements for the project.
- The best time to develop specifications is before you need them!
- Overall Philosophy?
  - Process vs. Performance Specification
  - Clearly State Expectations and Requirements

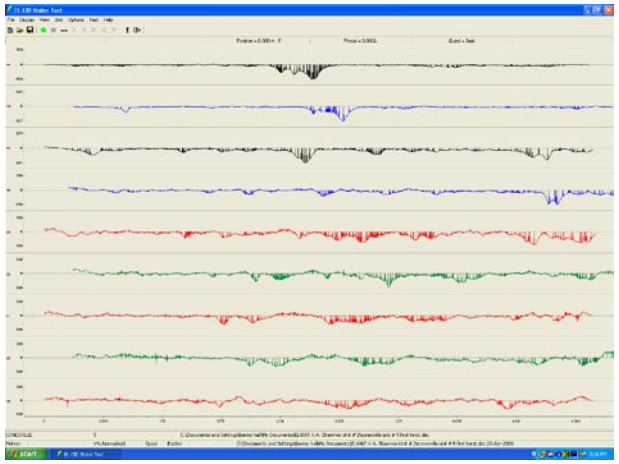
- Some Key Rewind Elements
  - Key Elements for Quality Stator Coils
    - Proven Qualified Insulation System
    - Advanced Materials
    - Optimized Design
  - Stator Core Iron Evaluation
  - Winding Process
    - Side filler
    - In process and final testing program
  - Vendor state key features like:
    - Ground Insulation Volts Per Mil (VPM)
    - Total Losses
    - Up Grades incorporated
- Division of Responsibilities (DOR)

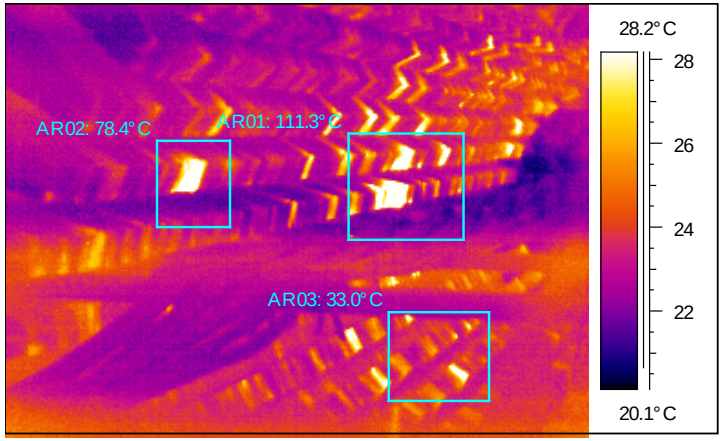
Stator Core Iron Integrity

- **Older vintage** machines should have maintenance reports to gain insight to the expected core condition but suitability for continued use should be considered and verified.
- **Newer Vintage** machines should have the core condition evaluated to insure the cause of the rewind did not compromise the long term reliability of the core.









Scheduled vs. Unscheduled Rewinds

- Estimated 40% - 50% of rewinds are unscheduled or forced outages.
- Scheduled rewinds can dramatically reduce total costs if properly planned and implemented
- Total Cost Impact ??? (30% to 60% ?)
    - Expediting
    - Lost Generation
    - Replacement Power
    - Contract Penalties
- Emergency Options

Case Study
Older Machine – Stator Rewind & Up Grade

Machine Information:

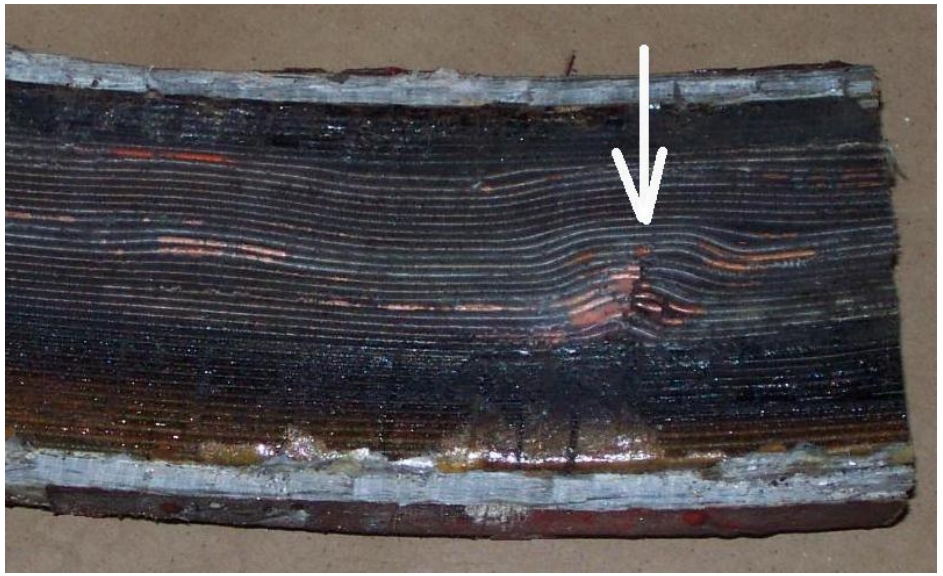
- ~ 40 year old generator
- Hydrogen Inner Cooled, 60 psig, 3 phase; 60 hertz, 3600 RPM,
- 493,280 MVA; 24 kV; 11,866 amps; 0.90 power factor

Reason for Rewind:

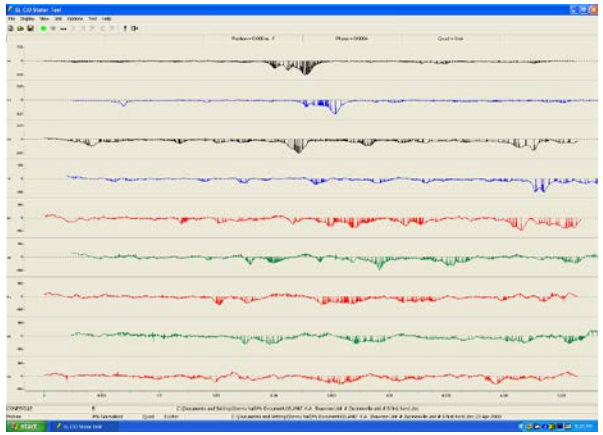
- Coil shorts in the end arms including latent manufacturing defects
- End winding vibration
- Ground insulation deterioration due to age
- Latent manufacturing defects

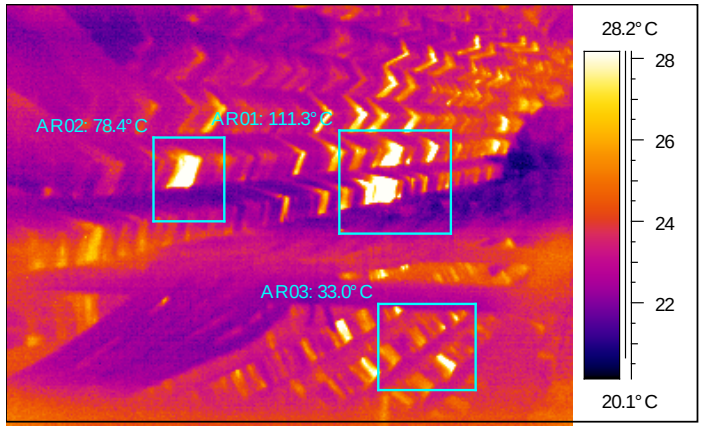
Issues:

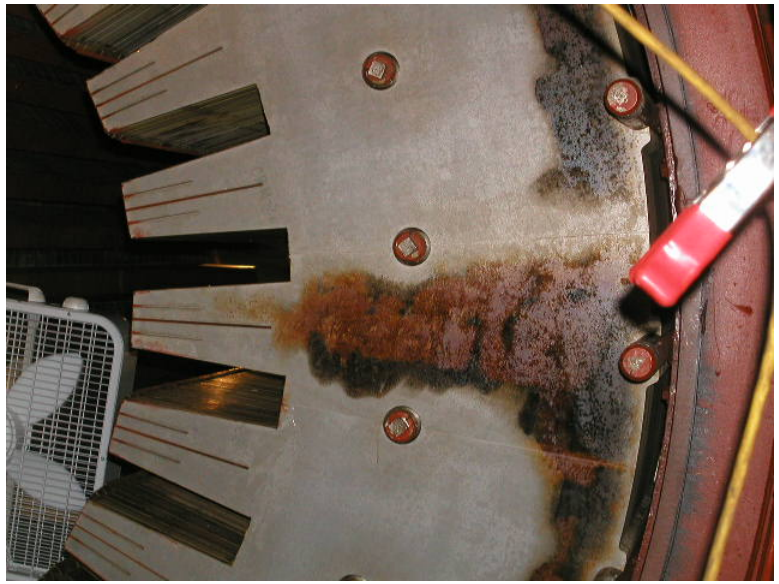
- High vibration in the stator end arms
- Fleet issue with lead group transpositions and broken / shorted strands
- “Surprise” with stator core condition



493 MVA Rewind – Case Study cont



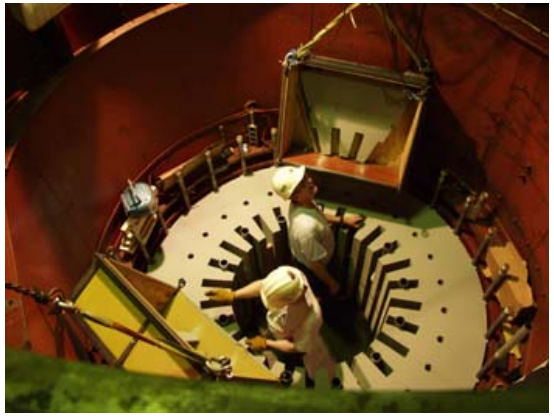




- Original El Cid test had multiple areas of concerns (areas under the curve)

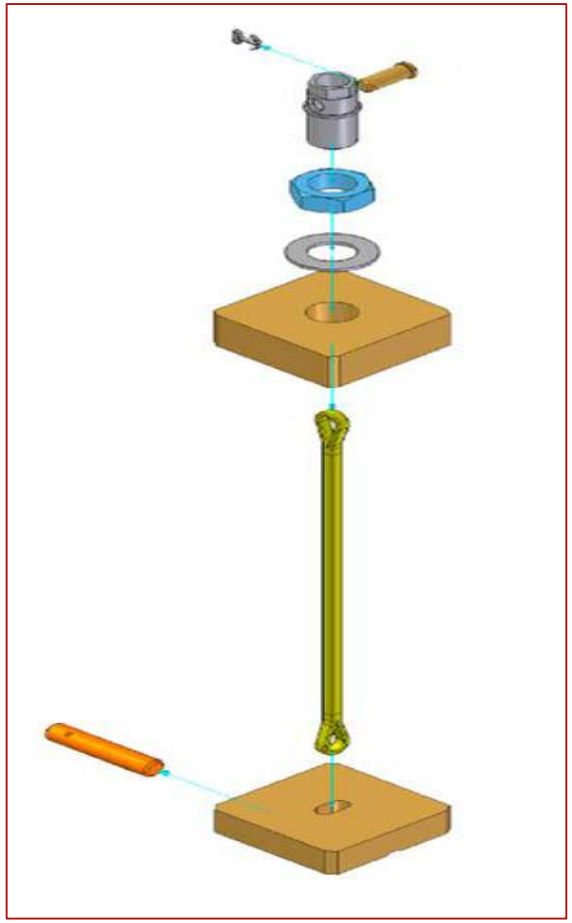
- Core Loop Test Numerous hot spots
  - 90 degrees C temperature spike in 2 minutes
  - 140 degrees C temperature spike in 10 minutes
  - Scheduled one hour test - had to be stopped after 10 minutes

493 MVA Rewind – Case Study



493 MVA Rewind – Case Study

- Eliminated Lead group transpositions by incorporating 900 deg. Roebel inside the coil
- Addressed end winding vibration by upgrading the cone and radial tie system
- Advanced monitoring added using new fiber optic sensors



493 MVA Rewind – Case Study

Project Schedule and Facts

- Eliminated lead group transposition – upgrading to 900º coil roebel.
- Upgraded End Winding Support System
- Over 100,000 lamination segments 26 gauge, C5 core plate with Rembrantin coating
- Schedule Elements
  - Schedule Stator Core Restack With New Laminations - 54 Days
  - Total project duration for restack and rewind – 96 days

135.5 MVA - Case Study

Newer Machine – Stator Rewind & Design Optimization

Equipment:

- ~ 8 year old generator – CT application
- Inner Air Cooled; 135,500 kVA; 3600 RPM

Reason for Rewind:

- Stator coil ground fault
- TE core damage
- Repair Stator Core
- Clean and Refurbish the Rotor & Exciter

Issues:

- Stator Coil Failure
- TE Core Iron Damage
- Rotor Contamination
- High Internal Operating Temperature
- Partial Discharge / Corona

Coil Failure and Core Iron Damage

Corona / Partial Discharge

Existing filler and Blocking

(fire hose & sausages)

Stator Coil Roebel Configuration

- Circulating current losses are minimized by increasing the Roebel transpositions in the coil

	End Arm	Slot	End Arm		
Top Original	90	360	90	**Total**	**540**
Bottom Original	90	540	90	**Total**	**720**
NEC Top Coil	180	540	180	**Total**	**900**
NEC Bottom Coil	180	540	180	**Total**	**900**

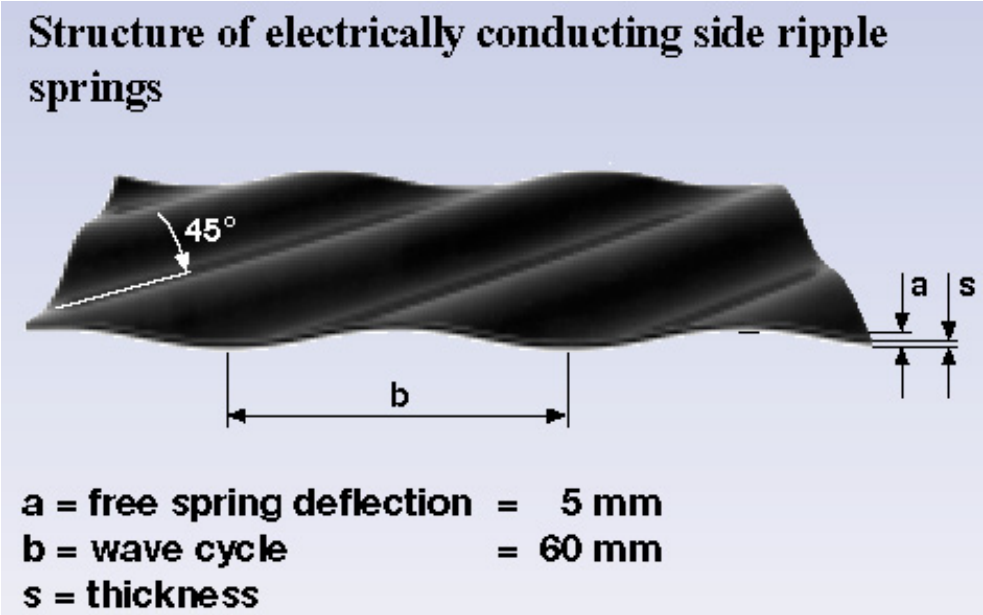
Maximize Copper Content

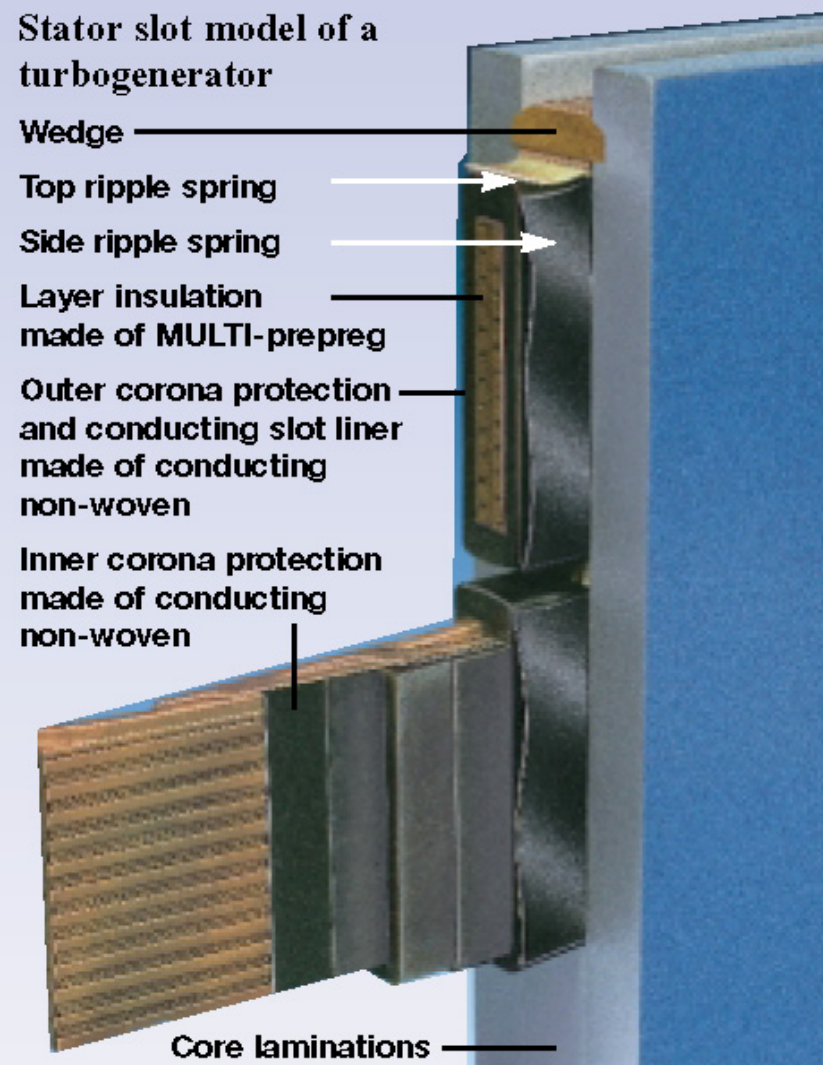
- Improve I2R losses
  - Top coil – Added ~ 10 %
  - Bottom Coil – Added ~ 4%
- Improve Eddy Current Losses
  - Changed strand configuration making strands smaller but adding more total strands

Ground Wall Insulation Volts Per Mil (VPM)

- As Found ~ 72.5 vpm
- NEC Insulation 67.5 vpm

Improved OCP & Side Ripple





- Krempel semi-conductive side ripple springs
  - Proven track record
  - Resistance to steady state pounding forces
  - Maintains sideways load on coil and continuous contact with core iron

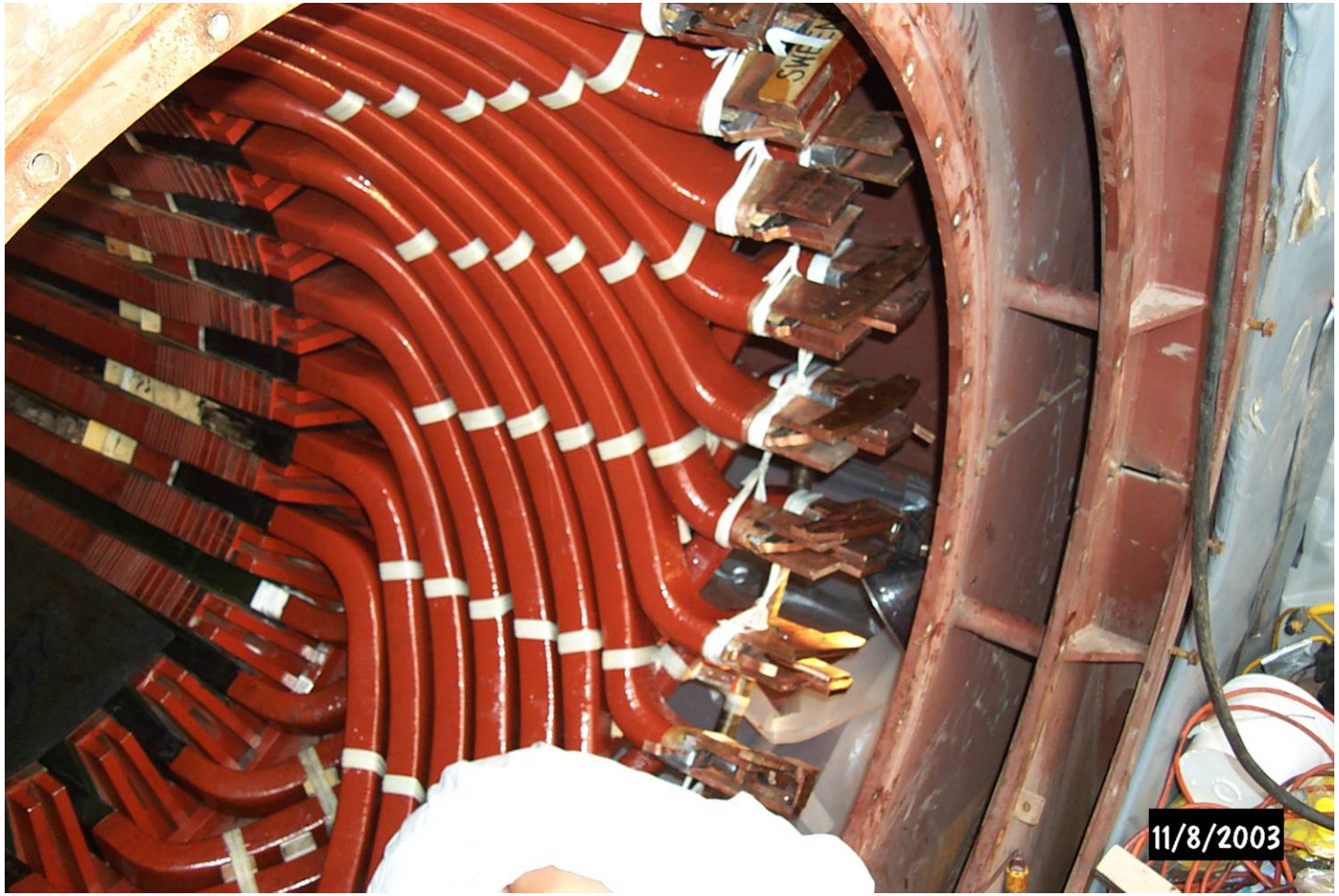
Optimize Slot, End Winding Basket and Detectors

- No fire hoses in slots or sausages in end arms. Upgraded end winding support system - more effective blocking and ties
- Improve slot Compression – Add Side & Top Ripple
- Reposition air RTD's to provide more accurate hot air temperature readings
- Reposition slot RTD's to provide more accurate readings

Blocking

Core Iron Repair

Turbine End Connections



Summary

- Both old and new vintage generators can be effectively rewound to provide long term reliable operation
- The considerations and planning for older -vs- newer machines may be different depending upon the age, design, and failure cause.
- Two very important key elements for rewind success are:
  - Clear understanding of the failure and cause
  - Practical Specification (Technical Value -vs- Volume)

Questions

W. Howard Moudy
Director of Operations
National Electric Coil
hmoudy@national-electric-coil.com
724-787-4967
www.National-Electric-Coil.com