HYDROVISION INTERNATIONAL

-Refurbishing/Rewinding Motor/Generators- Critical Steps that Ensure Long-Term Reliability

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DONAKO

Energy Technology Excellence

DHR Hydro Services, Inc.

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Presentation Highlights

- Hydro Plant Reliability – Three Contributing Processes
- Motor/Generator Rewind – The Critical Element to Hydro Plant Reliability
- Motor/Generator Lifecycle
- The Rewind Process – Be Intentional, Use PM Protocols
  - DEDICATED PROJECT MANAGER
  - Tear Down Phase – Photos
  - Rebuild Phase – Photos
  - Factory/Manufacturing Inspections - Photos
- Generator/Motor Rewind Nightmares
- Generator/Motor Rewind Take Aways
- Questions

Hydro Plant Reliability – Three Contributing Processes

- Hydro plant reliability is the *fundamental* most important attribute sought after by all energy producers, water delivery owners and customers, whether private, public, or government.
- Securing Hydro Plant Reliability requires implementation of three critical processes:
    1. Scheduled Maintenance and Testing Protocols (Units, Transformers, Turbines, Plant Systems, etc.) with metric driven protocols.
    2. Asset Management/Condition Assessment Protocols (Units, Transformers, Turbines, Plant Systems, etc.)…Risk assessments, visual inspections, test data trending, Monitoring, operational metrics.

Hydro Plant Reliability – Three Contributing Processes

3. Motor/Generator Rewind – The Critical Element to Hydro Plant Reliability
   - -Four Subset Asset Classes: Stator Windings, Stator Core/Laminations, Rotor Field Poles, Excitation
   - -THE REWIND: 6 Critical Elements to Secure Motor/Generator Reliability/Life Cycle

Take Away 1

1. Specifications, astutely written with quality control metrics, testing parameters clearly defined, required visual and quality control inspections, “no repairs”, final acceptance performance testing, and defined warranty
2. On-site inspections at all factory/manufacturing locations – stator windings, stator core/laminations, field pole windings: likely at different factory locations
3. Knowledgeable Inspection of all on-site rewind activities
4. Recommend one day-shift only; 10-hour shift, 6-days/week rewind schedule; Repeat rewind supervisor/crew for multiple Rewinds
5. Final Performance Testing (heat run, vibration/balancing)
6. Warranty Period Inspections: 1-year (visual), 3-year (visual), & 5-year (visual & testing)

Motor/Generator Lifecycle

- Motor/Generator Asset Subclass Lifecycles:
    1. Stator Winding Replacement (coil/bar design): typically, every 30-35 years (13 – 15 kV) depending on voltage class
    2. Stator Core/Laminations Replacement (punched/laser cut): typically, every 70 – 75 years
    3. Rotor Field Pole Winding Replacement (reinsulated): typically, every 70 – 75 years
    4. Rotor Field Pole Amortisseur Windings Replacement for motors: Varies, depending on excessive starts, every 70 – 75 years
    5. Excitation Replacement; Limited Discussion

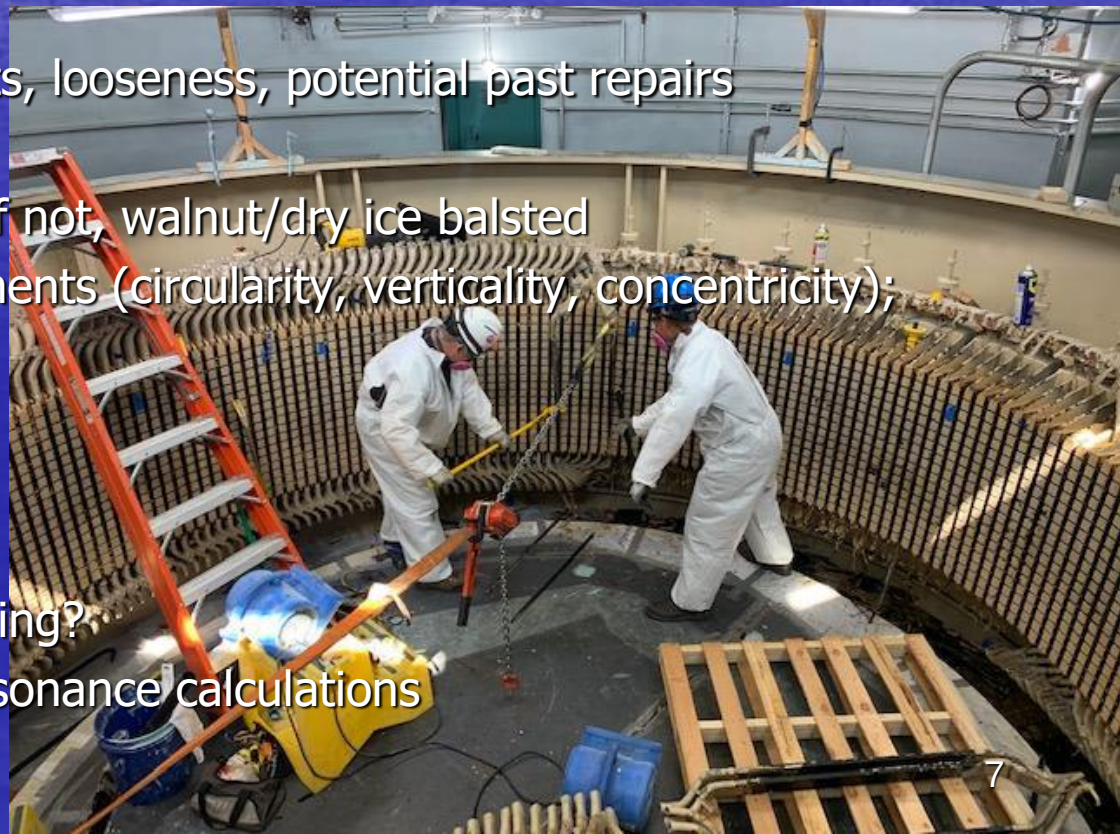
The Rewind Process – Be Intentional, PM Protocols Dedicated Project Manager

Take Away 2

1) Generator/Motor Background/Knowledge
2) Specification Knowledge/Experience
3) Responsible for Tripple Constraint: Budget, Schedule, Quality
4) “Boots on the Ground” Capability
5) Communicator/Decision Maker/Accountability
6) Weekly Project Status Reports
7) May be “on-site” Inspector or Inspector Reports to PM

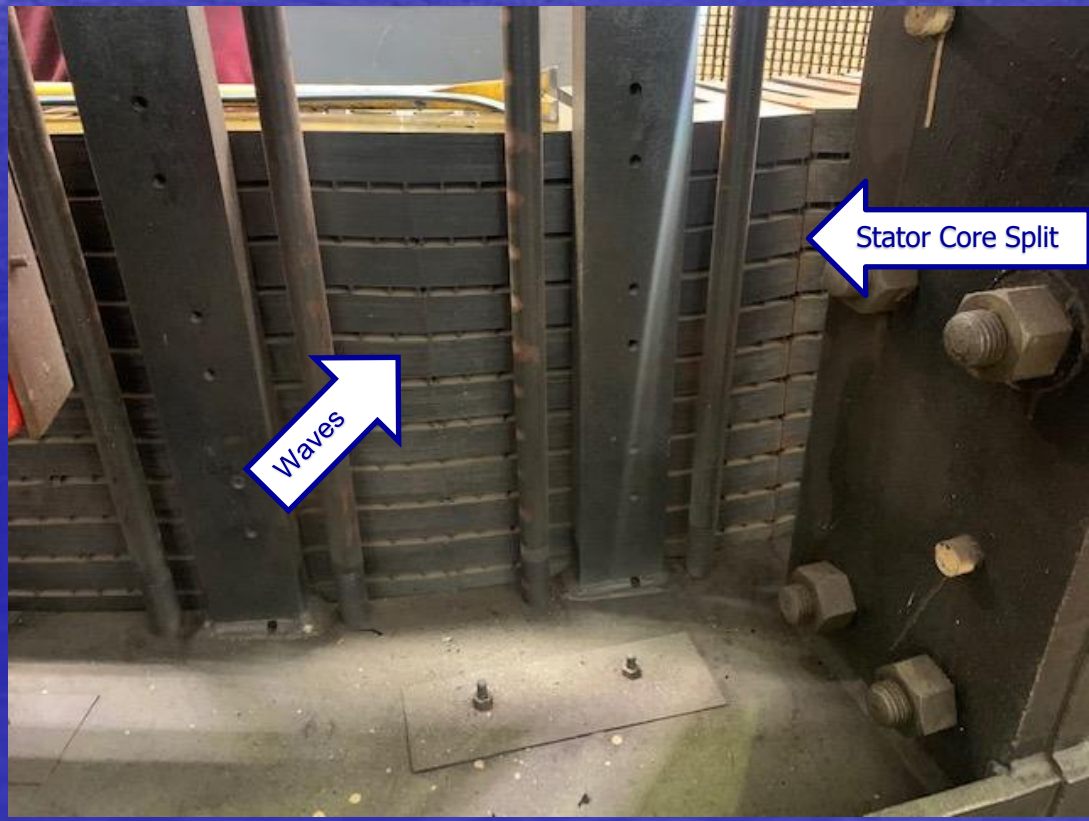
The Rewind Process – Be Intentional
Tear Down Phase

- Thorough Visual Inspection & Documentation Before Tear Down
  - Stator Windings
    - Existing Winding – confirm winding original design 1Y, 2Y, etc.
    - Winding Insulation – asphalt, mica B-stage, Mica VPI, etc.
    - Picture documentation
    - Look for winding hot spots, looseness, potential past repairs
  - Stator Core Laminations
    - Is Core being replaced? If not, walnut/dry ice balsted
    - As found Laser Measurements (circularity, verticality, concentricity); Magnetic Center
    - Core Hot spots?
    - Core back iron waves?
    - Segmented Core?
    - Core Fretting? Core Buckling?
    - Continuous Stacking – resonance calculations
    - Replace Through Bolts



The Rewind Process – Be Intentional
Tear Down Phase

- Stator Frame
  - Stator Core Upper and Lower Finger Press Plates
  - Jack Bolt Inspection
  - Sole Plate Inspection
  - Laser Measurements of Stator Frame (circularity, verticality, concentricity)
  - Frame Machining Required?
  - Frame Center – Movement?
  - Picture documentation
- Field Pole Windings
  - As Found Megger
  - As Found Pole Drop
  - Asbestos Insulation?
  - Rotor Dove Tail NDT
  - Amortisseur Winding
  - Laser Measurements

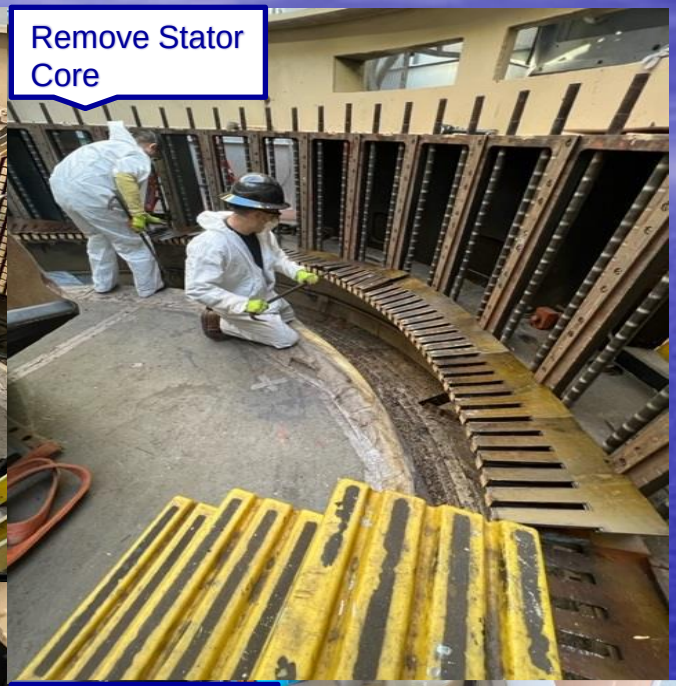


The Rewind Process – Be Intentional
Tear Down Phase - Stator

As Found Stator Core Laser Measurements

Remove Stator Winding

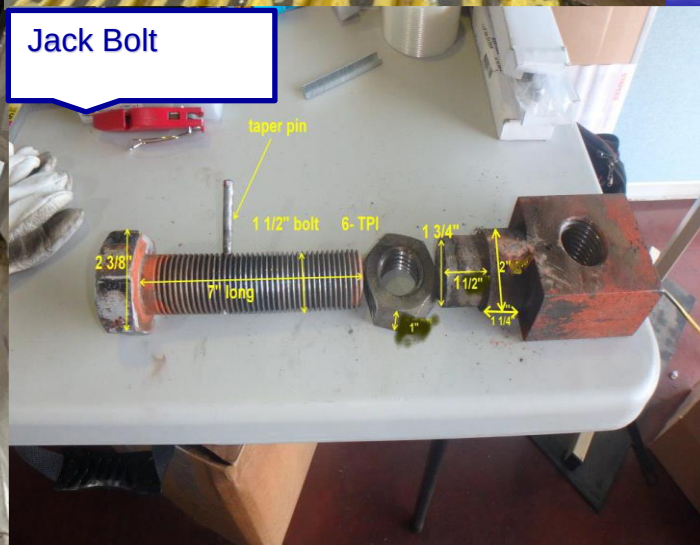
Remove Stator Core



Remove Through-bolts

Remove Finger Press Plates

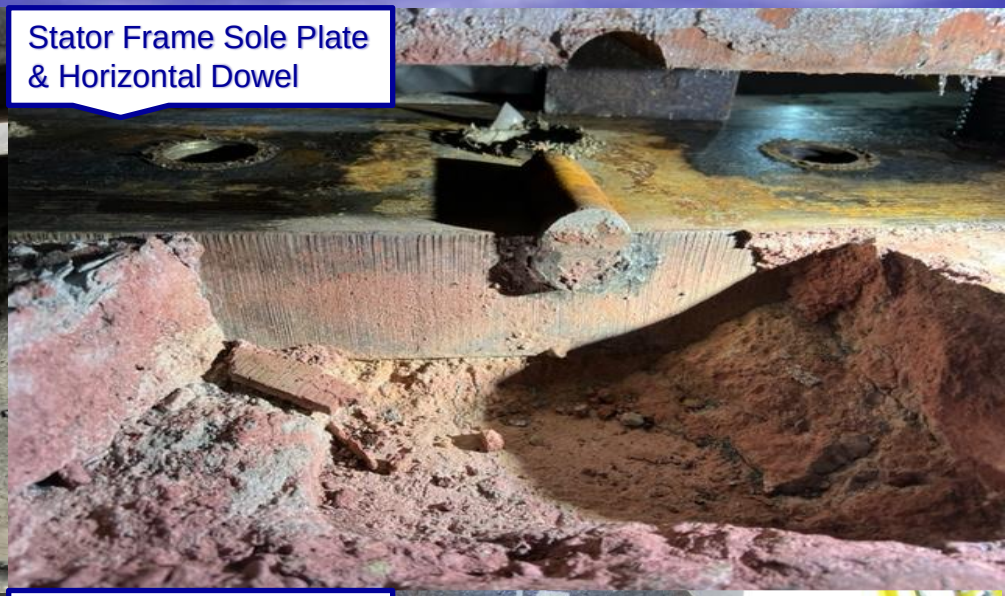
Jack Bolt



The Rewind Process – Be Intentional
Tear Down Phase – Core Lift

Lift Stator Frame

Stator Frame Sole Plate & Horizontal Dowel

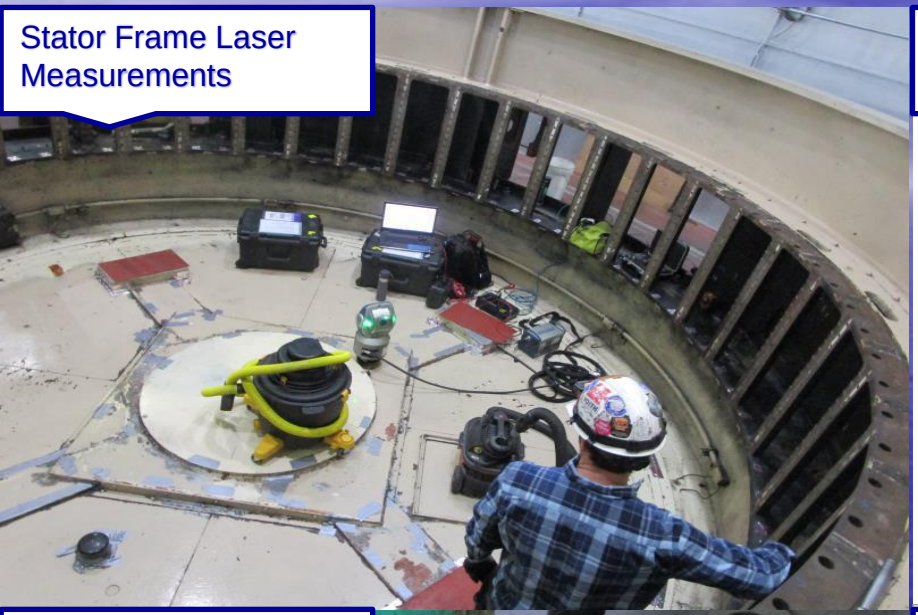


Cleaning Stator Frame Sole Plate

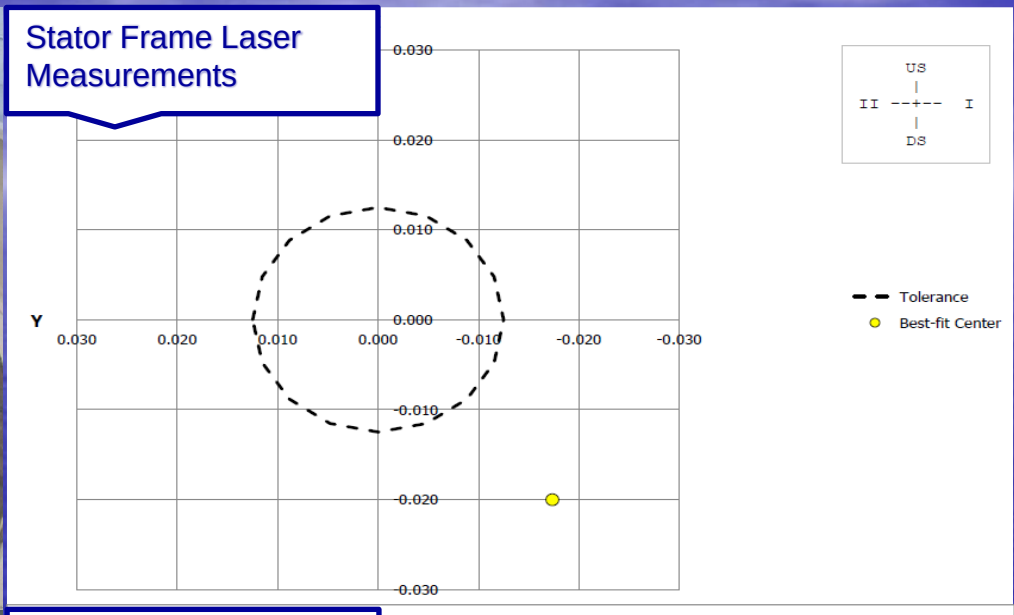
Stator Frame Sole Plate Cleaned and Lubricated

The Rewind Process – Be Intentional
Tear Down Phase – Laser Measurements

Stator Frame Laser Measurements

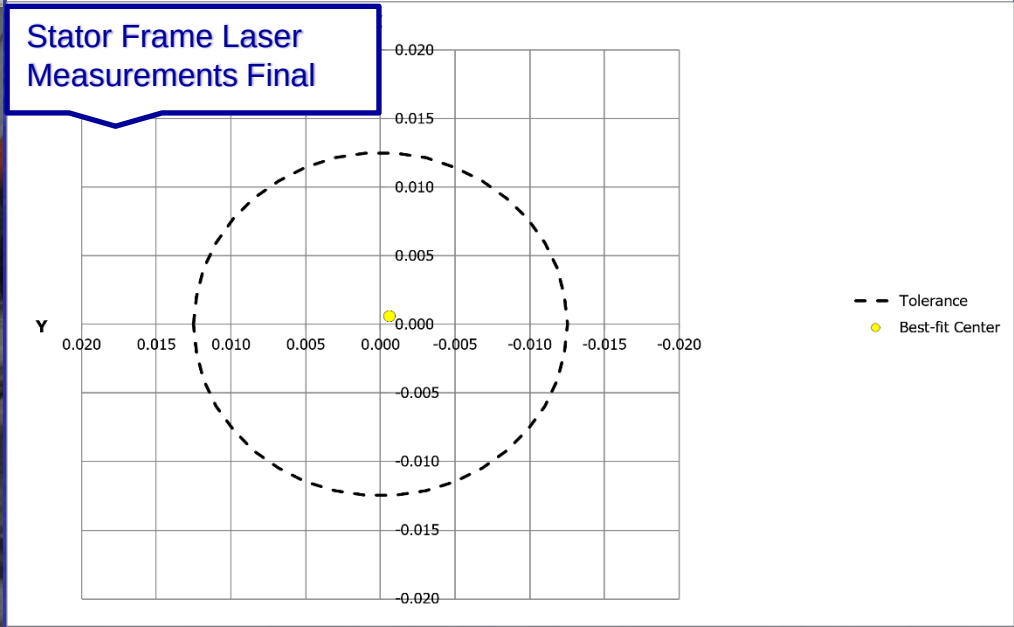


Stator Frame Laser Measurements



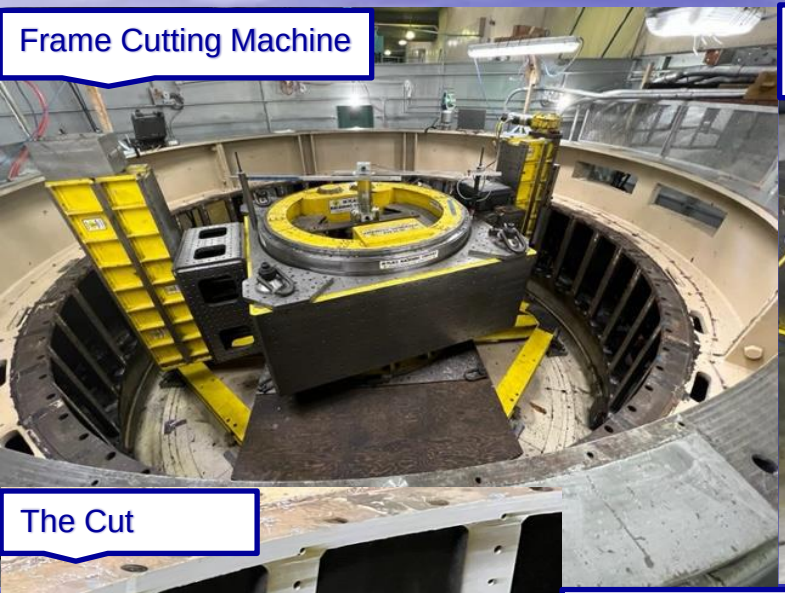
Move Stator Frame to Best Fit Center

Stator Frame Laser Measurements Final



The Rewind Process – Be Intentional
Tear Down Phase – Stator Frame Machining

Frame Cutting Machine



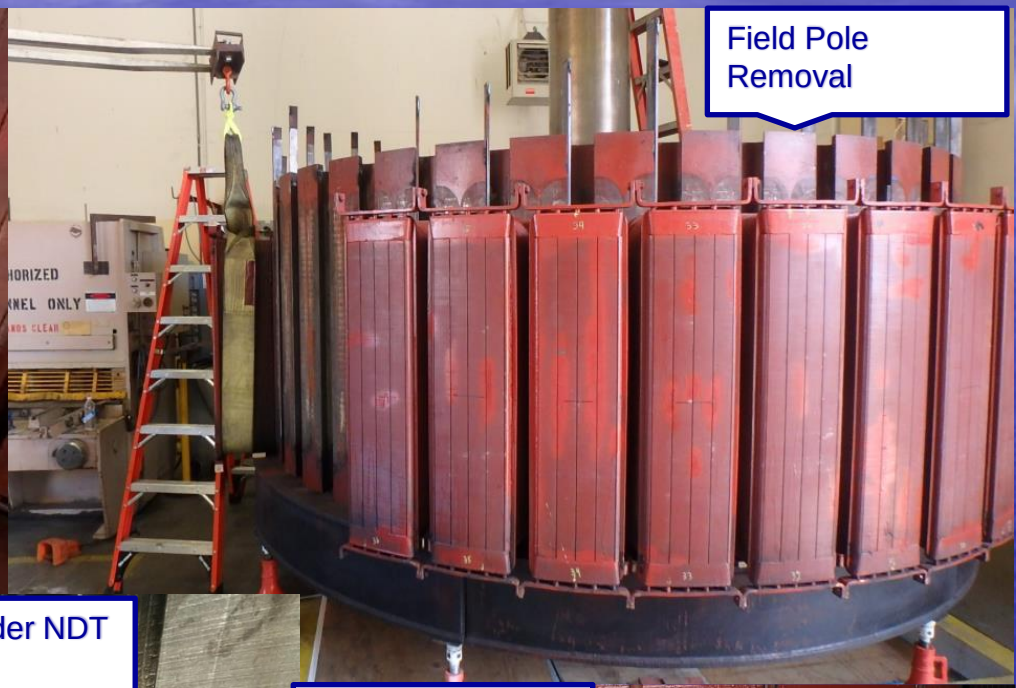
Frame Cutting Machine
Two Cutters

The Cut

Final Cut

Cut 1: 20 mils; Cut 2: 15 mils; Cut 3: 15 mils;
Cut 4: 10 mils; Cut 5: 10 mils; Cut 6: 10 mils
Cut 7: 5 mils; Cut 8: 5 mils; Cut 9: 5 mils
Final Laser measurements of Stator Frame:
All tolerances were achieved
Circularity: .0023; tolerance: .0125
Verticality: .0023; tolerance: .0125
Concentricity: .008; tolerance: .0125

The Rewind Process – Be Intentional
Tear Down Phase – Rotor Field Poles



The Rewind Process – Be Intentional
Rebuild Phase – Stator Core

Install new laminations

Stator Core Press

Stator Core Loop Test

Final Stator Laser Measurements

	Measured	Tolerance
Circularity	.0084	.0125
Verticality	.0124	.0125
Concentricity	.0010	.0125

Install Stator Coils

High Voltage Testing Throughout Rewind

The Rewind Process – Be Intentional
Rebuild Phase Stator Winding

Coil-to-coil tying

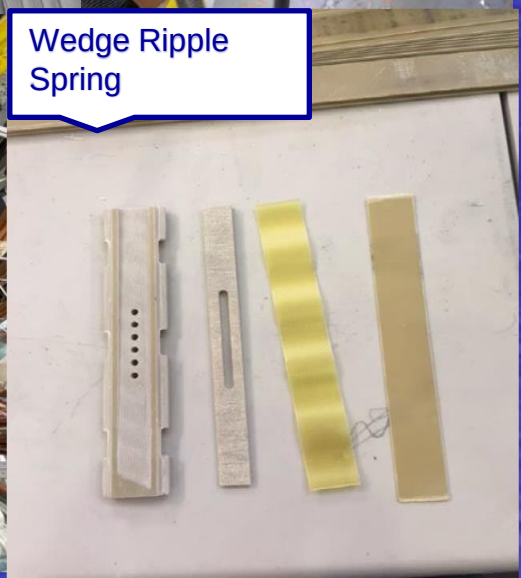
Surge Ring tying

Ripple Spring
Side Packing

Coil Resistance
Measurements

Closing the Lap

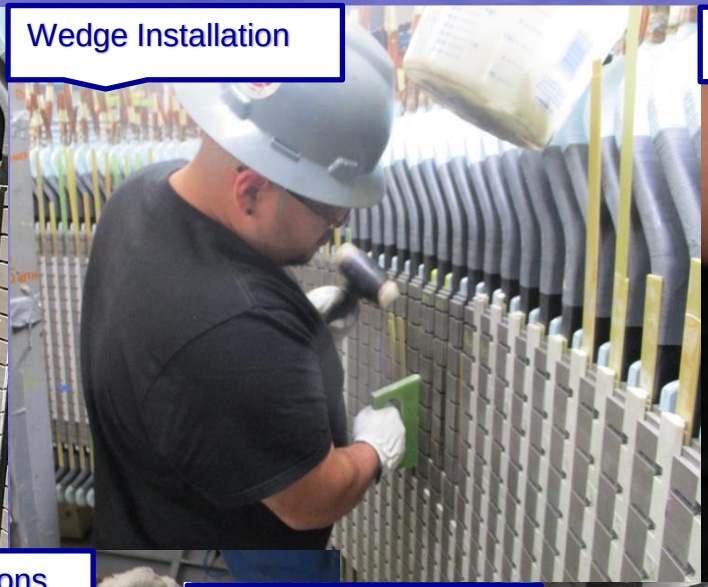
Wedge Ripple
Spring



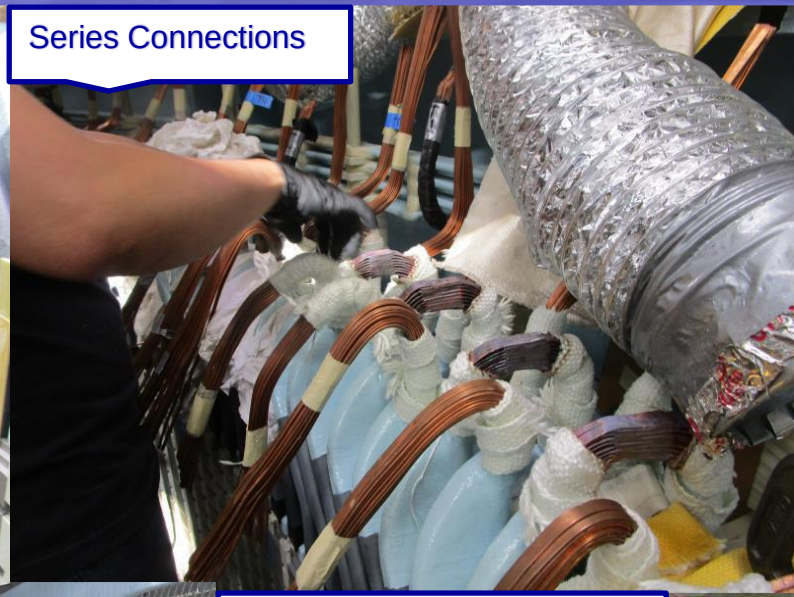
The Rewind Process – Be Intentional
Rebuild Phase Stator Winding

Side Packing

Wedge Installation



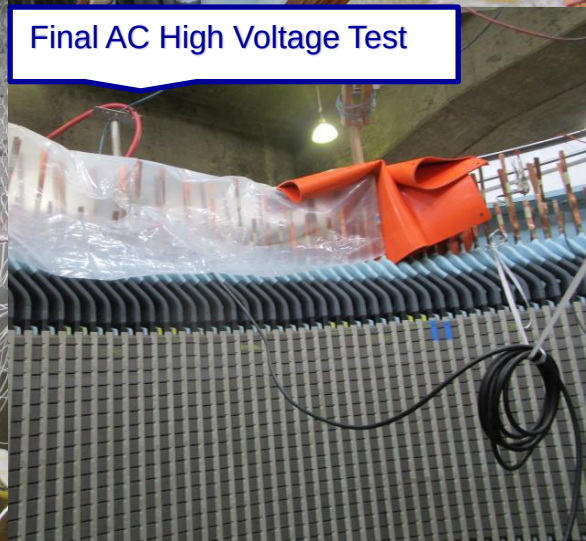
Series Connections



Pole Group Jumper Connections

Line & Neutral Leads

Final AC High Voltage Test



The Rewind Process – Be Intentional
Coil Factory/Manufacturing Inspections

Coil Manufacturing

4–turn Coil

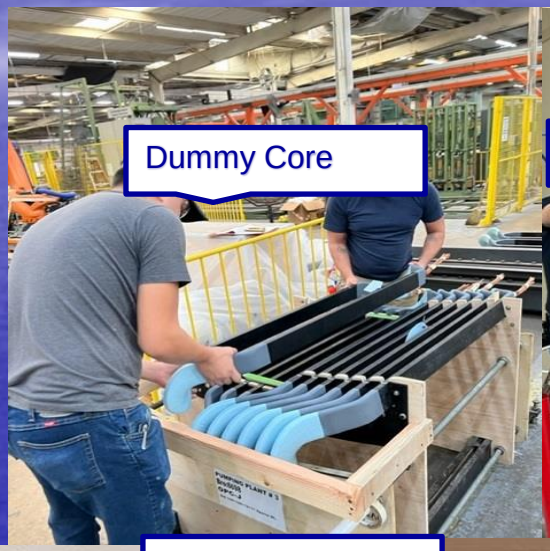
Coil Form Press

Coil mica tape

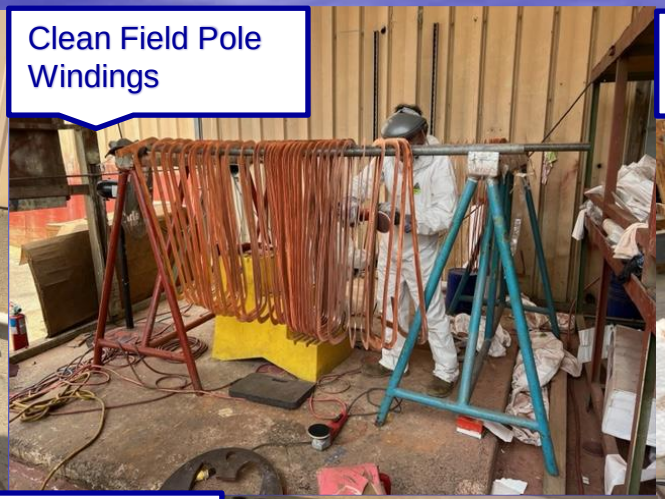
Coil Prior to VPI

VPI

The Rewind Process – Be Intentional
Coil Factory/Manufacturing Inspections



The Rewind Process – Be Intentional
Field Pole Factory/Manufacturing Inspections



The Rewind Process – Be Intentional
Lamination Factory/Manufacturing Inspections

29 gage non-electrical oriented steel M-15

400 Ton Programable Punching Machine

Punch Die

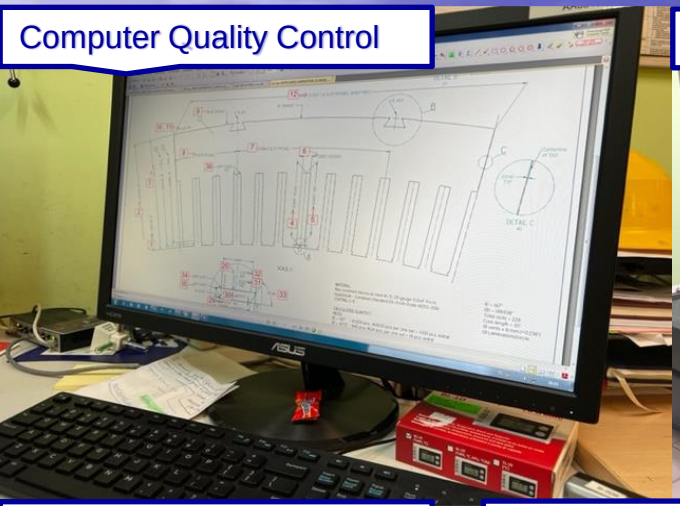
Punched Laminations

Punched Laminations

Deburr & C-5 Varnish Insulation

The Rewind Process – Be Intentional
Factory/Manufacturing Inspections

Computer Quality Control



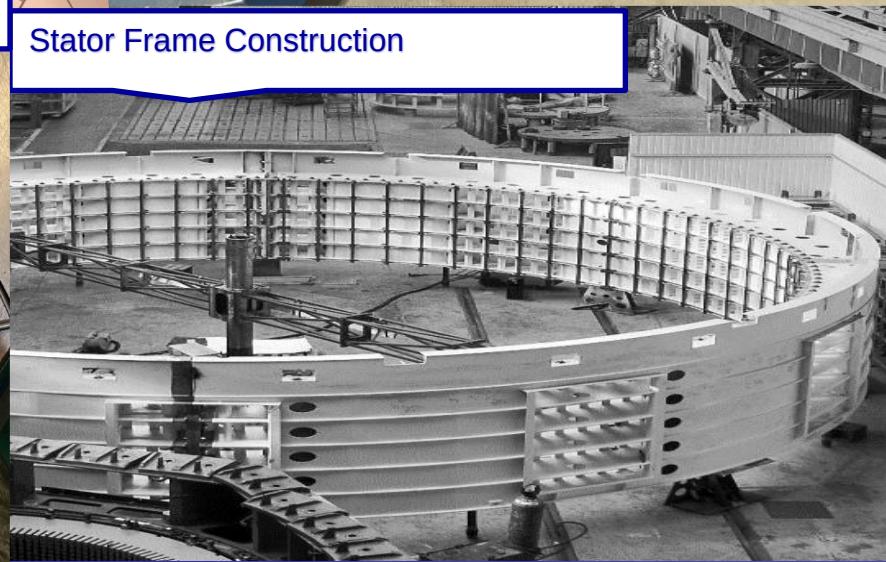
Computer Quality Control

Programable Laser Cutting Vent Plates

Vent Lamination

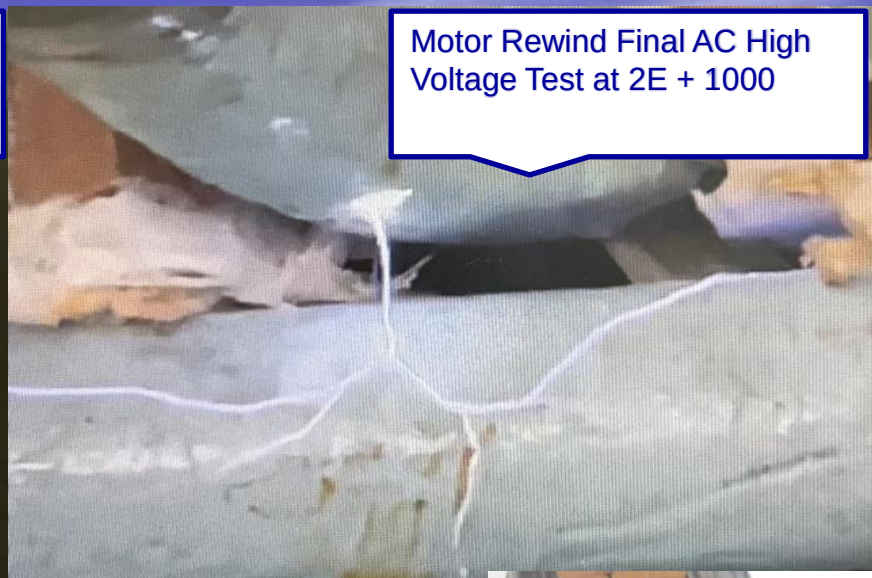
Quality Control: Burr Test, Varnish Thickness, Franklin Test, Bend Test, Solvent Test, Cross Hatch Test

Stator Frame Construction

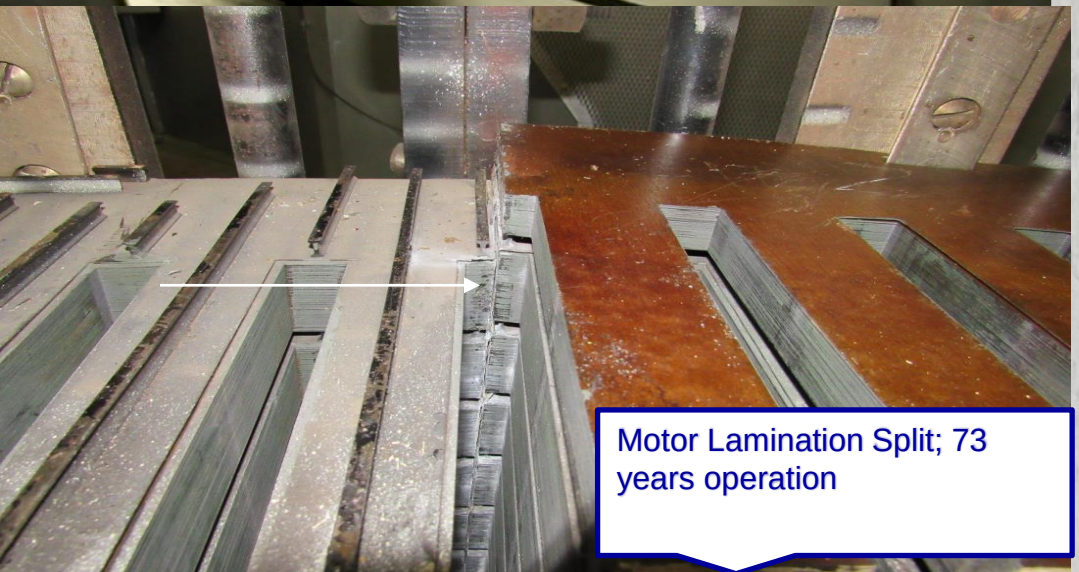


Generator/Motor Nightmares

Generator Stator Frame 10 years in operation; 250MVA



Motor Rewind Final AC High Voltage Test at 2E + 1000



Motor Lamination Split; 73 years operation

Generator/Motor Rewind
Take Aways

The 6 Critical Elements to Secure Motor/Generator Reliability/Life Cycle:

1) Specifications, well written with quality control metrics, testing parameters clearly defined, required visual and quality control inspections, final acceptance performance testing, “no repairs”, and defined warranty
2) On-site inspections at all factory/manufacturing locations – stator windings, stator core/laminations, field pole windings: likely at different factory locations
3) Inspection of all on-site rewind activities – on-site for full shift/ 6-days/week
4) Recommend one day-shift only; 10-hour shift, 6-days/week rewind schedule
5) Final Performance Testing (heat run, vibration/balancing)
6) Warranty Period: 1-year, 3-year, & 5-year inspections

Project Management Skill Set:

1) Specification Experience
2) Generator/Motor Background/Knowledge
3) Responsible for Tripple Constraint: Budget, Schedule, Quality
4) “Boots on the Ground” Capability
5) Communicator/Decision Maker/Accountability
6) Weekly Project Status Reports
7) May be “on-site” Inspector or Inspector reports to PM

QUESTIONS

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