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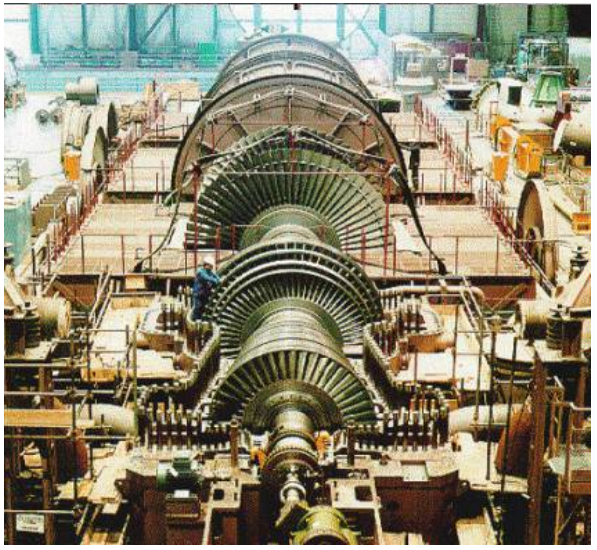
Steam Turbine-Generator Overhaul and Inspection Guidelines

EPRI product number 1014134

Overview

- Comprehensive guidelines addressing steam turbine-generator inspections and maintenance overhauls
- Critical industry review of all content, from written specifications to supporting software
- Annual updates reflecting industry operating experience, new technology and R&D advances
- Guidelines applicable at nuclear and fossil power plants worldwide



Unique Elements

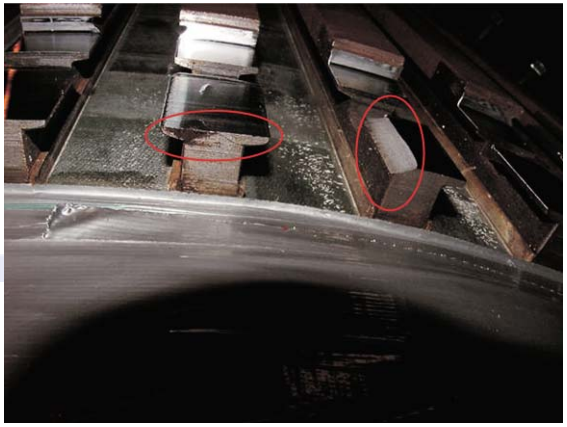
- Portable graphics
  - All charts, graphics, tables can be extracted for use in plant-specific procedures, manuals, reports, etc.
- Templates
  - Sample outage report
  - 17 condition assessment data sheets
  - 155 component-specific data sheets
  - RFQs (requests for quote) for equipment procurement
- Foreign material exclusion (FME) guidance
- Training support
  - Reference material for in-plant training and education of new personnel
  - Modular approach

Guideline Contents

- Seven volume, four CD set
- Volume 1 contains general guidance on *planning and conducting* turbine-generator maintenance overhauls and inspections
- Volumes 2-7 contain underlying technical guidance and tools *supporting* maintenance and overhauls

Volume	Content
1	General Practices
2	Repair Procedures
3	Balancing and Alignment
4	Component Procurement Specifications
5	Engineering Database for Large Steam Turbines
6/7	Blade/Disk Design Audit and Inspection Procedures

What's New?



2007 Updates

- Generator/exciter grinding procedure (Vol. 2)
- Turbine blade tuning criteria (Vol. 4)
- Excitation system purchase specification, with sample purchase RFQ (Vol. 4)
- Turbine bolting purchase specification, with sample purchase RFQ (Vol. 4)

Planned 2008 Updates

- Generator hydrogen seal best practices (Vol. 2)
- Turbine grit blasting procedure (Vol. 2)
- Updated commutator/collector ring procedure (Vol. 2)
- Turbine-generator alignment best practices (Vol. 3)

Where to Find It

Question	Volume
How do I determine which vendor is best for my needs?	1
What should I do to assess my unit before an outage?	1
What should I do to assess my unit during an outage?	1
How do I establish an effective outage plan and schedule?	1
How do I repair a collector ring or turbine diaphragm?	2
What precautions should I take in selecting and monitoring a vendor's repair work?	2
What documentation should I request from a vendor for a specific repair activity?	2

Where to Find It (continued)

Question	Volume
What are the advantages of high-speed vs. low-speed balancing?	3
How can misalignment affect unit operation?	3
What shim pad adjustments are needed to re-align my turbine rotor?	3
What could be causing vibration levels to exceed design specifications?	3
What information should I require from vendors in bid documents?	4
What types of penalty clauses should I include when purchasing new equipment?	4
What quality control checks should I require of vendors for new equipment?	4

Where to Find It (continued)

Question	Volume
Are there power plants near me that might have spare parts for my turbine-generator?	5
What plants have experience with the turbine modifications I'm planning for my next outage?	5
How can I assess how much turbine blade run time I have left based on differing blade failure mechanisms?	6/7
Which regions of the turbine blading are most susceptible to stress corrosion cracking?	6/7

Volume 1
General Practices Overview

- Technical guidance for both ***on-line*** and ***off-line*** turbine-generator condition assessments
- Pre-outage planning and bidding guidance
  - Task-oriented information addressing scaffolding, crane availability, lay-down area, safety, machine disassembly, special tools, etc.
- Unit shutdown best practices
  - Identify methods to reduce time required to bring unit from full speed to turning gear operation
- Oil flushing best practices
  - Techniques to reduce critical path time, such as flushing with minimal external piping and filtration
- Pre start-up checks and post-outage activities

Sample Content, Vol. 1

In-Service Condition Assessment

- Enables plant to monitor steam turbine-generator condition since last overhaul
- Addresses 17 systems/components
- Identifies risk-related recommendations for future outage work (color-coded)
  - **Green:** No perceived problems. System or component is expected to perform reliably until the next assessment.
  - **Blue:** No specific immediate or intermediate action necessary, but the issue is significant enough to be monitored.
  - **Yellow:** Work required at next convenient outage to avoid potential forced shutdown if not corrected.
  - **Red:** A specific component or system needs immediate attention. High risk of failure, causing loss of unit for an extended time.

Sample Content, Vol. 1
System/Component Data Sheets

Series	System or Component	Data Assembled and Reviewed
1	Maintenance History Summary	Record of modifications and upgrades
2	Turbine-Generator Vibration	Readings at minimum-maximum load, criticals
3	Bearing Metal and Oil Temperatures	Readings at minimum-maximum load
4	Section Performance Parameters	Readings at full load, valves wide open
5	Start-Up Operation	Record of starts, trips, service hours
6	Steam Purity	Frequency of tests, criteria, out-of-spec events
7	Lubricating Oil and EHC Analysis	Particle counts, presence of contaminates
8	Pump Start Tests	Frequency of tests, pressures, out-of-spec events
9	Valve Tightness Tests	Frequency of tests, criteria, sticking events
10	Turbine Trips and Tests	Record of trips, results, consequences
11	Turbine Monitoring Instrumentation	Readings at minimum-maximum load, calibrations
12	Generator-Exciter Condition	Readings, criteria, test results
13	Auxiliary System Operation	Readings, criteria, test results
14	Visual Inspection Results	HP, IP, LP inlets and exhausts
15	Checklist of Out-of-Limit Events	Record of unit upsets, actions, and consequences
16	Current Maintenance Plan	Record of inspections: last, next, frequency
17	Overall Condition Assessment	Summary with recommended actions

Sample Content, Vol. 1
Overall Condition Assessment Sheet

CONDITION ASSESSMENT SUMMARY					
Component or System	**Degradation**			**Good Condition**	**Comments**
	Severe	**Significant**	**Some**		
HP			X		Performance down 1% - monitor
IP			X		Performance down 1.5% - monitor
LP				X	
Generator			X		End windings may be loose. Vibration data has not been consistent.
Exciter		X			Exciter needs balancing. Insulation is very low on bearing.
Lube oil system	X				Particle count far exceeds specifications.
Seal oil system			X		Vacuum values trending toward higher end of acceptable criteria.
Controls		X			Overspeed trip too high. CV crack and intercept points need adjustment.
EHC/MHC system			X		Chloride count trending toward higher end of acceptable ppm.
Valves	X				Control valves and main stop valves are sticky. Last inspected three years ago.
TSI Instrumentation				X	
Recommendations: Both the lubricating oil and valves require attention. Refer to data sheet #5 and #7 for details. Based on their condition, the unit needs a weekend shutdown as soon as possible. Work is also required on the exciter and turbine controls. Refer to data sheets #12 and #13 for details. The urgency is not immediate, but this will require action before the currently scheduled intervals listed for these systems. Refer to sheet #16.					

Sample Content, Vol. 2
Repair Procedures

- Equally useful for on-site and off-site repairs
- Scope of Work
  - Defines tasks to be performed by utility or vendor
- References/Test Requirements
  - Defines prerequisites for the repair, such as materials needed, testing techniques, instructions for repair vendor
- Procedures
  - Provides numbered steps, supported by checklists and graphics as necessary
- Administrative/Report Requirements
  - Defines reports to be completed post-repair
  - Includes data sheet templates to be completed by vendor

Sample Content, Vol. 2

Example: Diaphragm Partition Repairs

Scope of Work (not comprehensive)

- Provide transportation to vendor repair facility.
- Remove all diaphragm hardware, place in a bag of sufficient strength, and tag the bag with the plant name, unit number, and diaphragm stage.
- Grit blast diaphragm using 220-grit aluminum oxide or equivalent.
- Perform an incoming inspection as outlined in Table 2-2.
- Perform a 100% diaphragm partition repair using 410 weld material, assuming a 5/8" cutback is required.
- Stress relieve the diaphragm as outlined in Table 2-4.
- Perform a final nondestructive evaluation/quality control, and record the diaphragm pitch, throat, and radial height data in Table 2-6.
- Perform a final outgoing inspection as outlined in Table 2-2.

Example: Diaphragm Partition Repairs

References/Test Requirements (not comprehensive)

- Air gap on contour convex side: <0.005" using a contour gauge.
- Exhaust edge thickness:
  - 0.040" ± 0.005" for the first stage high-pressure diaphragm.
  - 0.035" ± 0.005" for the first intermediate-pressure diaphragm.
  - 0.025" ± 0.005" for all other diaphragms.
- Radial height: Within 0.005"/in. with 0.060" maximum deviation from end to end.
- Edge straightness: Within 0.010"/in. with maximum 0.030" in 12" and 0.060" total as checked by a feeler gauge under a straight edge.
- Pitch: (3.1416) x radius/number of partitions per half

Sample Content, Vol. 2

Example: Diaphragm Partition Repairs

Procedure (not comprehensive)

1. Lay out diaphragm partition pitches on the inner and outer sidewall faces using a trammel, centerhead, dividers, and center punch.
2. Make a copper backing strip to match the diaphragm partition contour, based on drawing information or data from reverse engineering.

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20. Take final area check measurements. Set the throats at the X, Y, and Z positions +/-0.005" to satisfy area requirements. If throat requirements are not met, the partition should be cut out and re-welded with 410 filler wire.
21. Perform final inspection of diaphragm partitions with an inspection light from the admission side to reveal any minor grinding and blending corrections that may be necessary where the repair weld joins the original sidewall and partition contours.

Sample Content, Vol. 2
Example: Diaphragm Partition Repairs

Administrative and Report Requirements

- Repair vendor to provide data package, with all completed tables, to the driver
- Vendor instructs driver to hand carry data package to designated plant representative.

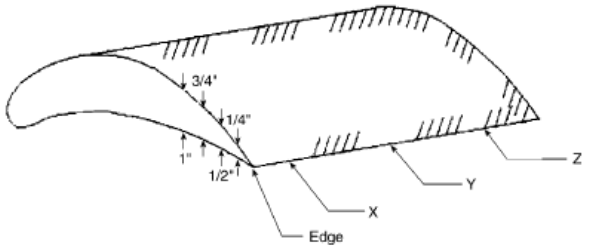
Table 2-3
Diaphragm Reverse Engineering Data

_____ Stage Diaphragm Reverse Engineering Data

Plant _____ Unit _____ Stage _____

Steam Path Dimensional Data					
Location	Steam Path Radius	Throat	Pitch	Setback B	Radial Height
Outer Wall					Eyebolt Size
@ X					
@ Y					Outside Diameter
@ Z					
Inner Wall					

Partition Section Thickness



Location	Section Thickness		
Edge	@X	@Y	@Z
@1/4" (6.35 mm)			
@1/2" (12.7 mm)			
@3/4" (19.05 mm)			
@1" (25.4 mm)			

Sample Content, Vol. 2

Example: Generator Rewind

Scope of Work (not comprehensive)

- Technical guidance for the rewind of a General Electric-manufactured, water-cooled generator stator with Micapal insulation.
- Rewind procedures assume that all new bars will be installed.
- Includes checklists for pre-outage work, outage work scope and demobilization.

References/Test Requirements (not comprehensive)

- IEEE, ANSI, NEMA, OSHA, UL standards
- Unit wiring diagrams and stator winding drawings
- Latest revision of GE technical information letter (TIL-1098), *Inspection of Generators with Water Cooled Stator Windings*

Sample Content, Vol. 2

Example: Generator Rewind

Disassembly Procedure (not comprehensive)

1. Maintain equipment clearances or have rewind personnel indicate any clearance discrepancies as needed to support the work scope.
2. Prepare bushing box for rewind. Depending on the machine configuration, the phase connections may need to be stripped in this area.
3. Release the stator for work. Implement suitable foreign material exclusion controls.
4. Take measurements on the end winding/turn areas. Make a gauging template to assist with fitting of the replacement bars.
5. Sample for asbestos-contaminated material (ACM), and then remove the wedges, top ripple springs, filler, and any side ripple springs.
6. Remove the end nose rings.
7. Strip back and unsolder the phase connections.
8. Saw cut the series loops and ties. Keep loose material and dust from accumulating in the machine.
9. Cut the Teflon hoses and unbraze the connections to the distribution headers.
10. Remove the top and bottom bars along with any filler or old conforming material.

Sample Content, Vol. 2
Example: Generator Rewind

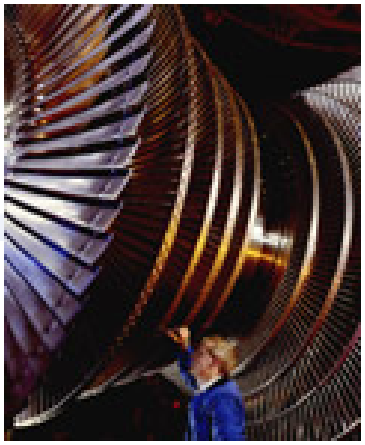
Administrative and Report Requirements (not comprehensive)

- Reports
  - Clearly address commercial terms in vendor proposals.
- Materials and equipment
  - List of required materials
  - List of expendable items
  - List of required tools and equipment
- Safety-related information
  - Lighting and ventilation
  - Worker qualifications
  - Personal protective equipment

Normally required rewind materials (partial list)

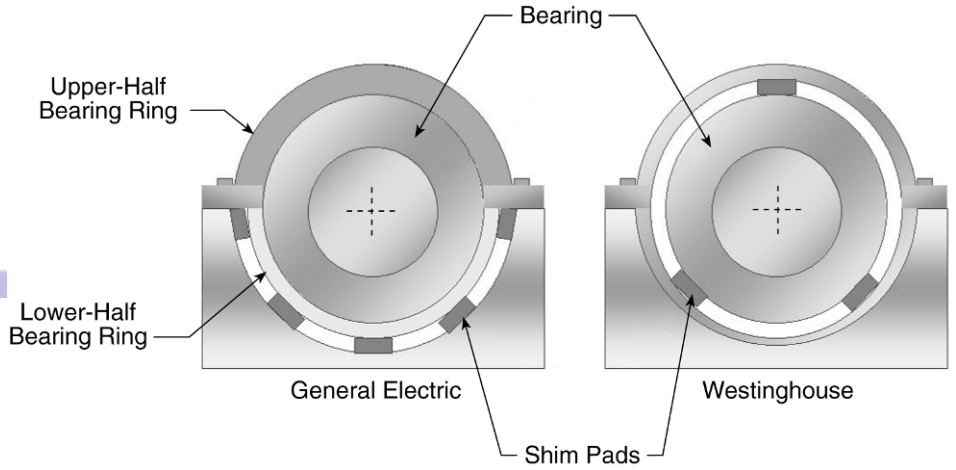
Item No.	Description
1	Adhesive, epoxy
2	Bars, bottom – phased
3	Bars, bottom – standard
4	Bars, top – phased
5	Bars, top – standard
6	Bar seal
7	Blocks “A”
8	Blocks “B”
9	Blocks, conforming space
10	Blocks, series loop
11	Bolts, T
12	Bond, Barco

Sample Content, Vol. 3
Balancing and Alignment



- Procedures, test requirements and report requirements for slow-speed and high-speed balancing of turbine, generator and exciter rotors
- Primers
  - Vibration: fundamentals, causes, measurement and instrumentation
  - Alignment: disassembly data, tight wire alignment, set points, clearance and alignment checks
- Includes TGAlign software for turbine-generator alignment
  - Installation instructions
  - Users manual

Sample Content, Vol. 3
TGAlign Software



- Determines optimum coupling alignment for a turbine-generator rotor system
- Input
  - Number/diameter of couplings
  - Rim/face alignment measurements
  - Alignment and move limits
  - Distance between bearings
  - Shim pad location for each bearing
- Output
  - Bearing position changes for optimum alignment
  - Specific shim pad adjustments to achieve bearing position
- Benefits
  - Reduces potential for calculation errors
  - Minimizes number of bearings to be moved
  - Minimizes potential for turbine rubs and startup vibration
  - Includes manual mode to permit bearing-by-bearing analysis

Sample Content, Vol. 4

Component Procurement Specifications

- Outlines information needed to assess a vendor quote beyond price and schedule
- Enables fair comparison of competing proposals
- Defines criteria to ensure final product is delivered and installed to agreed design and performance specifications
- Ensures the latest technological improvements are incorporated into design
- Provides sufficient information to non-OEM vendors to develop competitive bids

Sample Content, Vol. 4

Low-Pressure Rotor Procurement RFQ

- Sample template for bid package or RFQ
- Form and checklists to be returned with bid
  - Pricing information
  - Warranties and penalties
  - General acceptance criteria
  - Technical criteria associated with the forging, rotating parts, and stationary parts
  - Transport of the parts
  - Post-delivery activities of inspection, alignment, balancing, and testing performance

Sample Content, Vol. 4
Low-Pressure Rotor Procurement RFQ

- **Warranties and Penalties** (example content)
  - In the event that the supplier does not provide the documentation indicated in this specification, the supplier shall pay $X,XXX for each document not supplied.
  - In the event that the unit does not meet the supplier's guarantee of increased output in kW, the liquidated damage penalty associated with the plant's not achieving this load increase at rated reactor conditions shall result in a payment of $XXXXX per kW for each kW not attained.

Sample Content, Vol. 4

Low-Pressure Rotor Procurement RFQ

- **General Acceptance Criteria** (example content)
  - The rotors shall be warranted for a 30 calendar-year life based on the unit's being operated in accordance with the supplier's recommendations.
  - The rotating and stationary blades shall be warranted for [five years, 40,000 hours, or 1000 start-stop cycles] life (whichever comes first), assuming that the unit is operated in accordance with the recommended instructions.
  - The replacement low-pressure rotors shall result in an increase of net generation (improvement in generator output) of [1% or 5,000 kWe].

Sample Content, Vol. 4

Low-Pressure Rotor Procurement RFQ

- **Technical Criteria** (example content)
  - The L-0 and L-1 stages should be designed so that the unit can operate up to 10" Hg back pressure without flutter (vibration due to aero-elastic instability of the blades).
  - If free-standing blades are used, the L-0 and L-1 should be designed to operate under the same back-pressure criteria, but these blades should also be mix-tuned to reduce the potential for flutter at speed and under load.

Part	Acceptable Material
Blades	AISI 630 (17-4PH), AISI 410, AISI 403, Jethete M-152
Covers	AISI 630 (17-4PH), AISI 410, AISI 403
Pins	AISI H11, ASTM A193GRB16
Tie wires	AISI 630 (17-4PH), AISI 316
Cross-keys	Type M252 Austenitic Steel Rod
Notch/bucket	Ti-6Al-4V or Equivalent

Sample Content, Vol. 5

Steam Turbine Database

- Global database of large steam turbines
  - Location, operational data, nameplate rating, manufacturer, status
- More than 3,000 global entries for units larger than 70 MW
- Units operating with last-stage blades greater than 23 inches
- Units mapped to turbine vendors: GE, Westinghouse, ABB, Siemens, GEC, MAN, MHI

- User value
  - Identifies plants with like steam turbine units
  - Helps locate spare parts at plants with same turbine model
  - Captures experience with turbine modifications at other plants

Sample Content, Vol. 6/7

Blade Design Audit and Inspection

- Helps engineers diagnose blade damage during shutdown
- Permits future run-time estimations based on current condition and failure probability
  - Failure mechanisms: low-cycle fatigue, high-cycle fatigue, stress corrosion cracking, solid particle erosion
  - Library of failure probability curves for each mechanism
- Supports maintenance process
  - Planning and pre-bidding: provide input to generic blade procurement specification
  - Turbine inspection: indicate regions susceptible to fatigue, creep, cracking
  - Condition assessment: assess crack initiation from resonant vibration; produce interference diagram to compare against natural frequencies

Sample Content, Vol. 6/7

Blade Designs Addressed

- HP/IP blade designs and unit configurations
  - GE G3D Unit with a 33.5-inch last-stage blade
  - GE D3 Unit with a 26-inch last-stage blade
  - Westinghouse BB44 first-stage reheat blade
  - GE G3 Unit with a 30-inch last-stage blade
  - GE G2 Unit with a 33.5-inch last-stage blade
- LP blade designs
  - Westinghouse 31-inch L-0 blade
  - GE 33.5-inch L-0 blade
  - GE 20.9-inch L-1 blade
  - GE 43-inch L-0 blade
  - Westinghouse 23-inch L-0 blade
  - GE 26-inch L-0 blade
  - GE 17.4-inch L-1 blade

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