Rotor Repair

API RECOMMENDED PRACTICE 687
FIRST EDITION, SEPTEMBER 2001

REAFFIRMED, MARCH 2015

energy API

AMERICAN PETROLEUM INSTITUTE

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Downstream Segment

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Chapter 1—Rotor Repair

1 Scope/Definition/Reference Standards

1.1 SCOPE

1.1.1 This recommended practice covers the minimum requirements for the inspection and repair of special purpose rotating equipment rotors, bearings and couplings used in petroleum, chemical, and gas industry services.

This recommended practice is separated into 7 specific chapters. Chapters 2 through 7 are to be used separately from each other and in conjunction with Chapter 1. Refer to Chapter 1, Section 2 for the process used to overhaul and refurbish a rotor.

Tutorial Discussion: The document covers equipment manufactured to the requirements of API 612 Special Purpose Steam Turbines, API 613 Special Purpose Gears, API 617 Special Purpose Centrifugal Compressors, API 619 Special Purpose Rotary Positive Displacement Compressors, API 671 Special Purpose Couplings, and Hot Gas Expanders used in FCCU Power Recovery and Nitric Acid Services.

Note: A bullet (•) at the beginning of a paragraph indicates that either a decision is required or further information is to be provided by the owner. This information should be indicated on the appropriate data sheets; otherwise it should be stated in the quotation request or in the order.

1.1.2 The basis of repair recommendations shall be to return dimensions required for spare parts interchangeability to the latest design fits and clearances and produce a safe reliable rotating element capable of at least 5 years of uninterrupted operation.

Note: Returning these dimensions to the latest design fits and clearances will allow the repair to:

a. Maintain interchangeability with other units.
b. Use existing spare parts.
c. Eliminate errors in manufacturing future spare parts that could be caused by undocumented dimensional changes.
d. Maintain its critical speed margins and torque transmission capabilities.

Notes:

1. Small bearing clearance changes can move rotor critical speeds and changes in shrink fits can adversely affect rotor dynamics.
2. The latest design fits and clearances may not be as originally designed by the original equipment manufacturer (OEM), since rerates and/or upgrades may have been incorporated into the machine design.

1.1.3 Components manufactured for the repair shall be designed and constructed for a minimum service life of 20 years and at least 5 years of uninterrupted operation and in accordance with the latest API standards and Appendix K.

Use of previously manufactured components (surplus, etc.) and their acceptance criteria should be mutually agreed upon by all parties involved.

1.1.4 Unless otherwise specified, the repair shop (vendor) shall assume order responsibility.

1.2 ALTERNATIVE PROCEDURES

The vendor may offer alternative procedures and designs. (See Chapter 1, paragraph 2.5 for proposal requirements).

Note: Any exception to this recommended practice shall be clearly stated in the proposal as required by Chapter 1, paragraph 12.2.

1.3 CONFLICTING REQUIREMENTS

In case of conflict between this recommended practice and the inquiry, the inquiry shall govern. At the time of the order, the order shall govern.

1.4 DEFINITION OF TERMS

The terms used in this recommended practice are defined in 1.4.1 through 1.4.28.

1.4.1 almen strips: Metallic strips used to determine the intensity of peening.

1.4.2 calibration: The set of operations which establish, under specified conditions, the relationship between values indicated by a measuring instrument, or measuring system, or values represented by a material measure, and the corresponding known values of a standard.

Notes:
1. The results of calibration permit the estimation of indication errors of the measuring system, material measure or the assignment of values to marks on an arbitrary scale.
2. The results of calibration may be recorded in a document sometimes called a calibration certificate. Calibration method is a defined technical procedure for performing a calibration.

1.4.3 hydrodynamic bearings: Bearings that use the principles of hydrodynamic lubrication. The bearing surfaces are oriented so that relative motion forms an oil wedge, or wedges, to support the load without shaft-to-bearing contact.

1.4.4 indications: A response or evidence of a discontinuity that requires interpretations to determine its significance.

1.4.5 "J" strips: Thin rotating labyrinth strips held in position by caulking or prick punching to the shaft or sleeve to provide pressure breakdown. These may also be referred to as "L" strips or "T" strips.

1.4.6 maximum allowable temperature: The maximum continuous temperature for which the original equipment manufacturer (OEM) or repair facility has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified maximum operating pressure.

1.4.7 maximum allowable working pressure: The maximum continuous pressure for which the OEM or repair facility has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified maximum operating temperature.

1.4.8 maximum continuous speed: The highest rotational speed (revolutions per minute) at which the machine, as built and tested, is capable of continuous operation with the specified fluid.

1.4.9 measurement accuracy: The smallest division on the measurement device.

1.4.10 observed inspection or test: Where the purchaser is notified of the timing of the inspection or test and the inspection or test is performed as scheduled even if the purchaser or representative is not present.

1.4.11 order responsibility: Refers to the responsibility for coordinating the technical aspects of the components included in the scope of the order. The technical aspects to be considered include but are not limited to such factors as testing, material test reports, conformance to specifications, and manufacturing of replacement components and coordination with subvendor shops.

1.4.12 owner: The final recipient of the equipment. The owner may delegate another agent as the purchaser of the inspection and repair services.

1.4.13 procedure qualification record (PQR): A PQR is a record of the welding data, variables, and results used to weld a test coupon in accordance with ASME Section IX.

1.4.14 protective coatings: Coatings used to prevent erosion or corrosion or for performance enhancement.

1.4.15 rerate: A change in the operating performance that may or may not require hardware changes. A rerate usually requires the addition of a data plate (nameplate).

1.4.16 residual unbalance: Refers to the amount of unbalance remaining in a rotor after balancing.

1.4.17 restoration coatings: Used to build up a surface to "original" or design dimensions.

1.4.18 special purpose application: An application for which the equipment is designed for uninterrupted, continuous operation in critical service, and for which there is usually no spare installed equipment.

1.4.19 stack: A term used to describe a built up rotor construction or a step in the assembly procedure, where a minimum of one major component is assembled on the shaft.

1.4.20 tolerance: The allowable variation in the measured parameter(s).

1.4.21 total indicator reading (TIR), also known as total indicator runout: The difference between the maximum and the minimum readings of a dial indicator or similar device, monitoring a face or cylindrical surface during one complete revolution of the monitored surface.

1.4.22 trip speed (revolutions per minute): The speed at which the independent emergency overspeed device operates to shut down a variable-speed prime mover.

1.4.23 truth bands: Locations on the component (such as a shaft) that are used to reference concentricity and or perpendicularity of a repaired location to the original geometric centerline of the component.

1.4.24 upgrade: An improvement in the equipment design, which may increase reliability, but does not result in a change in the performance.

1.4.25 vendor: The agency that supplies the inspection and repair services.

1.4.26 verified: When a vendor confirms that a requirement has been met.

1.4.27 welder qualification record (WQR): A written record of certification of the welder to the welding procedure specification (WPS) in accordance with ASME Section IX.

1.4.28 welding procedure specification (WPS): A written qualified welding procedure to provide direction for the welder or welding operator to assure compliance in accordance with ASME Section IX.

1.4.29 witnessed inspection or test: Where the purchaser is notified of the timing of the inspection or test and a hold is placed on the inspection or test until the purchaser or representative is in attendance.

1.5 REFERENCED PUBLICATIONS

1.5.1 This standard makes reference to American standards. Other international or national standards may be used as mutually agreed between owner and vendor provided it can be shown that these other standards meet or exceed the American standards referenced.

1.5.2 The editions of the following standards, codes, and specifications that are in effect at the time of publication of this standard shall, to the extent specified herein, form a part of this standard.

The applicability of changes in standards, codes, and specifications that occur after the inquiry shall be mutually agreed upon by the owner and the vendor.

API

Std 612	*Special-Purpose Steam Turbines for Refinery Services*
Std 613	*Special-Purpose Gear Units for Refinery Service*
Std 617	*Special Purpose Compressors for Refinery Service*
Std 619	*Rotary Type Positive Displacement Compressors for Petroleum, Chemical, and Gas Industry Services*
Std 670	*Vibration, Axial-Position, and Bearing-Temperature Monitoring Systems*
Std 671	*Special-Purpose Couplings for Refinery Service*
RP 683	*Quality Improvement Manual for Mechanical Equipment In Petroleum, Chemical, and Gas Industries*
RP 684	*Tutorial on the API Standard Paragraphs Covering Rotor Dynamics and Balancing: An Introduction to Lateral Critical and Train Torsional Analysis and Rotor Balancing*
Spec Q1	*Specification for Quality Programs*

AFBMA[1]

Std 4	*Tolerance Definitions and Gauging Practices, Including Radial and Internal Clearance*
Std 7	*Shaft and Housing Fits for Metric Radial Ball and Roller Bearings (Except Tapered Roller Bearings) Conforming to Basic Boundary Plans*
Std 9	*Load Ratings and Fatigue Life for Ball Bearings*
Std 11	*Load Ratings and Fatigue Life for Roller Bearings*
Std 20	*Radial Bearings of Ball, Cylindrical Roller and Spherical Roller Types, Metric Design: Basic Plan for Boundary Dimensions, Tolerances and Identification Code*

AGMA[2]

1010	*Appearance of Gear Teeth—Terminology of Wear and Failure*
1012	*Gear Nomenclature, Definitions of Terms With Symbols*
1328	*Cylindrical Gears—ISO System of Accuracy*
9002	*Bores and Keyways for Flexible Couplings (Inch Series)*

ANSI[3]

S2.19	*Mechanical Vibration—Balance Quality of Rigid Rotor—Part 1, Determination of Permissible Residual Unbalance*
Y14.5M	*Geometric Dimensioning and Tolerancing*

ASME[4]

B1.1	*Unified Inch Screw Threads (UN and UNR Thread Form)*
B1.20.1	*Pipe Threads, General Purpose (Inch)*
B17.1	*Keys & Keyseats*
Y14.2M	*Line Conventions and Lettering Boiler and Pressure Vessel Code, Section V, "Nondestructive Examination;" Section VIII, "Pressure Vessels;" and Section IX, "Welding and Brazing Qualifications"*

ASNT/SNT[5]

TC-1A	*Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing.*

ASTM[6]

A 6	*Specification for General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use*
A 275	*Method for Magnetic Particle Examination of Steel Forgings*
A 388	*Recommended Practice for Ultrasonic Examination of Heavy Steel Forgings*
A 515	*Specification for Carbon Steel Pressure Vessel Plates for Intermediate-and Higher-Temperature Service*
A 516	*Specification for Carbon Steel Pressure Vessel Plates for Moderate- and Lower-Temperature Service*
C 633	*Test Method for Adhesion or Cohesive Strength of Flame-Sprayed Coatings*

[1]Anti-Friction Bearing Manufacturers Association, 1235 Jefferson Davis Highway, Arlington, Virginia 22202.
[2]American Gear Manufacturers Association, 1500 King Street, Suite 201, Alexandria, VA 22314.
[3]American National Standards Institute, 11 West 42nd Street, New York, NY 10036.
[4]ASME International, 3 Park Avenue, New York, NY 10016-5990.
[5]American Society for Nondestructive Testing, Inc., 1711 Arlington Lane, P.O. Box 28518, Columbus, Ohio 43228-0518.
[6]American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

E 94	*Guide for Radiographic Testing*
E 125	*Reference Photographs for Magnetic Particle Indications on Ferrous Castings*
E 142	*Method for Controlling Quality of Radiographic Testing*
E 165	*Standard Practice for Liquid Penetrant Inspection Method*
E 709	*Standard Recommended Practice for Magnetic Particle Examination*
E 1316	*Standard Terminology for Nondestructive Examination*
E 1417	*Practice for Liquid Penetrant Examination*

ISO[7]

3448	*Standard Industrial Liquid Lubricants—ISO Viscosity Classification*

MIL Spec[8]

MIL-B-121	*NOT@ Barrier Material, Greaseproof, Waterproof, Flexible*
MIL2154 B	*Ultrasonic Testing*

NACE[9]

MR-01-75	*Sulfide Stress Corrosion Cracking Resistant Metallic Material for Oil Field Equipment Corrosion Engineer's Reference Book*

NEMA[10]

MG 1	*Motors and Generators*
SM 23	*Steam Turbines for Mechanical Drive Service*

SAE[11]

SAE-AMS S 13165	*Shot Penning of Metal Parts*

SSPC[12]

SP-6	*Commercial Blast Cleaning*

[7]International Organization for Standardization. ISO publications available from the American National Standards Institute, 11 West 42nd Street, New York, NY 10036.
[8]Manufacturers Standardization Society of the Valve and Fittings Industry, 127 Park Street, N.E., Vienna, Virginia 22180.
[9]NACE International (formerly the National Association of Corrosion Engineers), 1440 South Creek Drive, P.O. Box 218340, Houston, TX 77218-8340.
[10]National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1847, Rosslyn, VA 22209.
[11]SAE International, Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096-0001.
[12]Steel Structures Painting Council, 40 24th Street, Suite 600, Pittsburgh, PA 15222.

1.6 STATUTORY REQUIREMENTS

The owner and the vendor shall mutually determine the measures that must be taken to comply with any governmental codes, regulations, ordinances, or rules that are applicable to the equipment.

1.7 UNIT RESPONSIBILITY

The vendor who has order responsibility shall assure that all subvendors comply with the requirements of this recommended practice and all referenced standards.

2 Process for Overhauling and Refurbishing a Rotor

2.1 GENERAL

This section is intended to give the user guidance in defining the objectives, identifying the reference information needed, and setting the parameters of responsibility needed to properly evaluate the condition of special purpose rotors being considered for overhaul.

2.2 TYPICAL SEQUENCE OF EVENTS

The scope of repair may change as the result of inspections and tests performed on the rotor. A typical sequence of events for a rotor repair is:

Reference	Topic	Section
1.	Develop Initial Scope of Inspection/Repair/Upgrades	Ch 1, Sec 2 & App H
2.	Select Vendor Shop	Ch 1, Sec 3
3.	Transport to Vendor Shop	Ch 1, Sec 5
4.	Receiving Inspection	Ch 1, Sec 6
5.	Phase 1 Inspection of Assembled Rotor	Ch 1, Sec 7 & Chs 2–7, Sec 1
6.	Hold Point and Scope Evaluation	
7.	Phase 2 Inspection of Disassembled Rotor	Chs 2–7, Sec 2
8.	Hold Point and Scope Evaluation	
	Repairs/modifications completed	Ch 1, Sec 9 & Chs 2–7, Sec 3
	Reassembly and Balancing	Ch 1, Sec 10 & Chs 2–7, Sec 4
9.	Hold Point and Final Inspection	
10.	Preparation for Shipment	Ch 1, Sec 11
11.	Shipping/Storage Container	Ch 1, App J
12.	Documentation	Ch 1, Sec 12
13.	Post Shipment Review	Ch 1, Sec 4

2.3 OWNER SUPPLIED INFORMATION

● **2.3.1** The owner should identify the original edition of the API standard to which the rotor was supplied and also describe any exceptions or modifications that affected the "as built" configuration.

2.3.2 The owner should review the current operating conditions. If these conditions differ significantly from the original, a rerate should be considered.

● **2.3.3** The owner should provide the repair shop with a brief history of the rotor's service record since its last repair. Of particular importance would be the inclusion of details related to any unplanned outages of the machine and how the needed repair is related to in-service events. Any changes incorporated by previous repairs, such as changes of material, dimensions or operating parameters should also be provided.

● **2.3.4** The owner should briefly describe the internal environmental conditions in which the rotor is operating. If these conditions differ significantly from those used to design the present rotor, the owner should so advise. It is important to identify the presence of any corrosives such as H_2S, chlorides, or reactive chemicals such as Chlorine, not previously specified, which may adversely affect the rotor material.

● **2.3.5** The owner should provide the repair shop with general documentation related to the rotor. Documents such as the rotor materials, the use of any coatings, as built data sheet, previous repair records, general arrangement drawings, mass elastic diagrams, and rotor assembly drawings identifying probe track areas are appropriate and useful. The repair shop should be so advised if the rotor serves as a spare for more than one machine.

2.3.6 If the rotor has sustained severe damage, the owner should consider having a failure analysis performed. Fracture surfaces should be protected and not abrasively cleaned or otherwise modified. Broken components should not be reassembled due to potential damage to the fracture surface.

● **2.3.7** The owner should indicate why the rotor was sent in for repair and any time constraints for the repair.

2.3.8 The owner should obtain performance and mechanical data prior to unit shutdown for post turnaround comparison.

2.4 INITIAL SCOPE OF INSPECTION

● **2.4.1** Unless otherwise specified, all rotors shall be given a receiving and Phase I inspection. The owner should specify any additional work such as upgrades, rerates, or Phase II inspection.

2.4.2 Parts such as seal sleeves, thrust collars, locking nuts, turning gear, overspeed devices, timing gears, etc. that have been removed in the field should be included with the rotor for inspection. As appropriate, special tools and/or instructions required for disassembly/reassembly, should be sent in with the rotor.

2.4.3 The complete coupling assembly should be inspected by a qualified shop as determined by Appendix C 3.1.2. Unless otherwise specified, the coupling hub shall be removed from the shaft and blue checked by the repair shop. When available, matching ring and plug gauges should be supplied to this repair shop by the owner. Refer to Appendix C for coupling requirements.

Tutorial: The highly stressed coupling hub to shaft fit should be inspected whenever a rotor is repaired.

2.4.4 Unless otherwise specified, thrust collars shall be removed for inspection.

Tutorial: The highly stressed thrust collar to shaft fit should be inspected whenever a rotor is repaired.

● **2.4.5** The owner may elect to include inspection of the radial and/or thrust bearings as part of the initial inspection. The owner should define any special inspection requirements not included in Sections 7 and 8 of this standard.

● **2.4.6** The owner should specify, as outlined in Appendices G, H, and K, the required inspection activities. The repair vendor shall provide approximate dates of the witness and hold points.

2.5 UPGRADE ALTERNATIVES

2.5.1 After reviewing the data in paragraphs 2.3.1, 2.3.3, 2.3.4, 2.3.5, and 2.3.7, the desirability of incorporating improvements into the repaired rotor should be evaluated by the owner and vendor. Once the desired improvements are identified, the owner and vendor can develop the scope of repair.

● **2.5.2** When specified, mutually acceptable coatings shall be applied to the rotating and/or stationary components in the gas (flow) path to help prevent corrosion, erosion, or for performance improvement, in accordance with Appendix L.

2.5.3 Any change to the design that affects the nameplate data shall result in the issuance of a new data plate.

2.6 DEVELOPING THE SCOPE OF REPAIR

Tutorial Discussion: Information available at this point should give the owner a fairly good idea of the repair scope. Having received the inspection results and the vendor recommendations, as well as cost and lead time estimates, the owner should be well equipped to define the requirements.

2.6.1 In addition to the requirements of this recommended practice, RP 687, the scope of repair should define the owner's requirements expected from the resulting repair (such as operating performance, material performance and run time expected).

2.6.2 A root cause analysis should be considered prior to repairs of damaged areas to prevent possible reoccurrence.

2.6.3 Scope changes requested by the owner shall be responded to by the vendor in terms of cost and lead time impact. The vendor may offer alternative options for the owner's consideration, including expected technical and/or economic advantages.

● **2.6.4** The owner and vendor shall define any applicable inspection processes and acceptance criteria within the scope of repair. Reference to this recommended practice, RP 687, other standards, such as: API, owner, other organizations, or vendor, may be applied as acceptance criteria.

3 Selection of a Repair Shop

3.1 GENERAL

3.1.1 The repair shop (vendor) should be selected on the basis of the shop's ability to perform the scope of repair. This depends upon the repair shop's:

a. Facilities.

b. Engineering capability and support.

c. Experience repairing similar equipment.

d. Having a quality system in place similar to that recommended by API RP683 and further defined by API Specification Q1.

3.1.2 Qualification of a vendor is usually accomplished by having the vendor complete and submit a qualification survey form (reference Chapter 1, Appendix I). Initial and follow up on-site audits should be performed by the owner to ensure the vendor is capable of performing the required repair.

4 Communication

4.1 GENERAL

4.1.1 The success of a repair depends upon open communication. Communication is important in defining the needs and expectations of the owner to the vendor and to subvendors. Verbal instructions, recommendations and agreements should be confirmed in writing.

The owner and vendor should each have a designated person to coordinate communication.

The methods of communication should be defined before any repairs are initiated. Documentation supplied by the vendor shall be specified in the Vendor Drawing and Data Requirements (see Appendix G).

4.1.2 All written correspondence shall be identified with the following information:

a. The owner's corporate name.

b. The job/project number.

c. The equipment item number and service name.

d. The inquiry or purchase order number.

e. Any other identification specified in the inquiry or purchase order.

f. The vendor's identifying proposal number, shop order number, serial number, or other reference required to identify return correspondence completely.

4.2 MEETINGS

The complexity of a project or repair will usually determine how many of the following meetings should be planned. After the meetings are held, the meeting minutes shall be published by the vendor and distributed to the attendees or other personnel involved in the scope of the project.

a. After Phase I inspection of the rotor: a meeting should be held to review the repair scope, timetable, establish points of contact, and assign responsibilities for all parties.

b. Follow-up meetings may be required if deviations from the initial repair scope are found during the repair process.

c. In the case of rerates additional meetings such as a pre-award/coordination and project design audit may be required.

4.3 ELECTRONIC DRAWING AND DATA TRANSMITTAL

The project team shall utilize appropriate lines of communication, such as electronic drawing and data transmittal, to ensure that all members are kept informed. Examples are:

a. Facsimile transmissions.

b. Direct electronic links between computer aided design (CAD) systems.

c. Electronic mail including digital photography transmission.

d. Video and telephone conferencing.

4.4 POST-SHIPMENT REVIEW

Post-Shipment feedback is often missed but is needed to verify if requirements were met and to improve the quality of the next relationship. This review should occur within 8 weeks from shipment and may be accomplished by meeting, teleconferencing, video-conferencing, etc.

5 Transport to Vendor's Shop

5.1 GENERAL

5.1.1 The vendor shall provide a unique identification number to allow tracking of all owner components at the vendor's plant.

5.1.2 The owner shall identify all components with a common job related unique number such as a purchase order number or requisition number. Material shipped separately shall be identified with securely affixed, corrosion-resistant metal tags indicating the unique number. Crated equipment shall be shipped with duplicate packing lists, one inside and one outside of the shipping container. The packing list shall have the unique number and describe each item in the crate.

5.1.3 Rotors being returned for repair shall be adequately preserved to prevent any damage or environmental deterioration. Wrap each probe target area separately, using a barrier material such as MIL-B-121. Tape these areas and mark with the words, "Probe Area—Do Not Cut." The rotor shall be supported per the recommendations of 11.3.

Note: This barrier protection is for environmental protection for shipment. See 11.4 if a longer duration is required.

5.1.4 Shipping containers shall be designed for the specific rotor weight and configuration. Appendix J contains sample crating drawings. All containers shall be constructed to allow for lifting with a fork truck or crane.

5.1.5 Lifting points and lifting lugs shall be clearly identified on the equipment or equipment package. The recommended lifting arrangement shall be identified on boxed equipment.

5.1.6 All items which are exposed to environmentally sensitive material shall be decontaminated by the owner prior to shipment. When required, shipping documentation shall include Material Safety Data Sheets (MSDS). The owner should protect any failed or damaged sites for possible future failure analysis.

6 Receiving Inspection

6.1 RECEIVING OF ROTOR

6.1.1 The vendor shall assign personnel trained in the correct lifting procedures and equipment selection for moving rotors. Equipment and vehicles that are used for lifting and moving parts shall be maintained and exhibit current certifications of inspection and rating.

6.2 RECEIVING INSPECTION

6.2.1 The vendor shall make provisions for identification, verification, segregation, storage, maintenance, and release of all owner-supplied parts, materials, or items.

6.2.2 The vendor shall log in all owner-supplied materials upon receipt and verify against the received bill of lading and/or packing list.

6.2.3 The vendor shall photograph the "as received" condition of the shipping container, skid, box, etc.

6.2.4 Any apparent damage to the shipping container, skid, box, etc. is to be noted on a receiving record, photographed to clearly show details of any damaged areas and immediately reported to carrier, vendor representative, and owner representative.

Note: If shipping damage is present, a jointly agreed upon schedule shall be set to proceed to "As Received—Phase I Inspection" to determine what, if any, damage occurred to the rotor assembly as a result of shipping. Any damage due to shipping or handling must be resolved prior to proceeding. The owner will notify the vendor when work may proceed.

6.2.5 All owner-supplied material will be clearly marked with the vendor job number and/or owner reference number and clearly identified as "customer property."

6.2.6 Owner-supplied materials and items shall be stored in a location which will preserve the integrity of the material. Regular monitoring and checks will be performed by the vendor to detect effectiveness of storage procedure. Any deterioration will be reported to the owner representative.

7 Inspection of Assembled Rotor, Phase I

7.1 GENERAL

7.1.1 The following paragraphs 7.1.1.1, 7.1.1.2, and 7.2, are the general requirements for Phase I inspection of rotors. Additional specific requirements may be found in Section 1 of Chapters 2 through 7, as appropriate.

7.1.1.1 If bearings are provided with the rotor see Appendix E for inspection information.

7.1.1.2 If couplings are provided with the rotor see Appendix C for inspection information.

7.2 ROTOR INSPECTION

7.2.1 The vendor shall perform the following inspection in paragraphs 7.2.1.1 through 7.2.1.4, and 7.2.2 through 7.2.9 upon receipt of a rotor.

7.2.1.1 Conduct a careful visual inspection; clearly photograph in detail; and note on a sketch the size, location, and orientation (including any required physical reference point) of any erosion, corrosion and any unusual appearances or other damage resulting in loss or displacement of material, deposits, and buildup. Standardized sketches, forms, and tabulations are desirable. Examples are included in Appendix A of Chapters 2 through 7, as appropriate.

7.2.1.2 Take "as is" samples of any residues and deposits without further contamination of the sample. Return the sample to the owner, if requested, for laboratory analysis.

Note: If deposits are suspected to have caused damage such as cracks, corrosion, etc., the repair work may be delayed until a complete analysis is performed.

7.2.1.3 Identify and record dimensions from a distinct shaft feature; such as a shaft shoulder, etc., to the location of the axial and radial probe areas on each end of the rotor. If probe areas are not easily identified, the owner should be consulted. Afterwards, the probe areas must be adequately protected from damages such as rusting or scratches.

7.2.1.4 The vendor should notify the owner of any discrepancies noted in 7.2.1.1 and 7.2.1.2 to determine if failure analysis is necessary and/or special cleaning methods are required.

7.2.2 The vendor shall clean the rotor to remove dirt, rust and other foreign material using a procedure appropriate for the NDE methods to be used. Protective coatings, used to prevent erosion or corrosion or for performance enhancement, shall be cleaned with a non-abrasive media to prevent coating damage. The coating should not be removed for base metal inspection without owner approval.

When coatings or foreign material are to be removed from the component, caution should be used when applying abrasive cleaning methods to prevent damage to the component. The abrasives used are to be glass beads or a light abrasive at reduced blast pressure.

Annex A1.1 of ASTM E-165 gives typical cleaning methods and precautions that are suitable for LPI and may be suitable for other NDE methods.

Protect all critical areas such as journals, seal areas, probe areas, thermal gaps, rotating labyrinths, shaft ends, thin blades, and coupling surfaces during cleaning.

Do not use steam or water wash to clean a stacked assembled rotor that is not going to be disassembled or will be placed back into immediate service. Refer to Section 1 of Chapters 2 through 7, as appropriate, for additional recommendations.

Phase I visual inspection should include the condition of any protective coating(s).

Notes:
1. Blast cleaning may close cracks to detection by liquid penetrant inspection.
2. Cases of corrosion/stress corrosion cracking are known due to steam/water wash cleaning.

7.2.3 Non-destructive examination procedures as outlined in Chapter 1, Section 8, shall be used to determine the existence and location of any indications, such as cracks, on the rotor. Prior to NDE, residual magnetism shall be checked and recorded. Record the size, location, and orientation of any indications on a sketch or appropriate form. All non-magnetic components shall be fluorescent dye penetrant inspected. All ferro-magnetic components shall be wet magnetic particle inspected. The rotor shall be degaussed per the requirements of 8.2.4.2 prior to burnishing of vibration probe tracks and shipment.

Note: This step will not normally be done on rotors that must be disassembled. NDE will be carried out on individual components during Phase II inspection.

● **7.2.4** When specified, the chemistry and hardness of component(s) shall be determined.

7.2.5 Photograph the rotor in its cleaned condition. In addition, photos are to be taken of any unusual or abnormal condition, and a photo log shall be maintained for all work performed. Identification of all items, including equipment number and part name are to be clearly shown on all photographs.

7.2.6 Measure and record the following as received data in paragraphs 7.2.6.1 through 7.2.6.5 on worksheets designed for the particular rotor. Refer to Appendix A of Chapters 2 through 7, as appropriate, for typical worksheets. Unless otherwise specified in chapters 2 through 7, the accuracy (smallest division on the measurement device) of the measurements are as follows:

a. For radial runouts, the degree of accuracy is to be within ±3 µm (0.0001 inch).

b. For diameters, the degree of accuracy is to be within ±25 µm (0.001 inch).

c. For shaft fits, journals and coupling area diameters, the degree of accuracy is to be within ±3 µm (0.0001 inch).

d. For axial stack-up locations, the degree of accuracy is to be within ±40 µm (0.0016 inch).

e. For axial run-outs, the degree of accuracy is to be within ±13 µm (0.0005 inch).

f. For axial run-outs of shaft shoulders, thrust collar faces, and coupling flanges, the degree of accuracy is to be within ±3 µm (0.0001 inch).

7.2.6.1 Interstage seal sleeves, spacers, and other running clearance diameters.

7.2.6.2 Journal and shaft end seal area diameters (check both ends and center of each area for roundness and taper).

7.2.6.3 Depth, length, location, and type of any coatings, overlays, etc.

7.2.6.4 Shaft End for Coupling

On shaft ends with a threaded area for the nut, the threads should be checked for integrity and that the nut will properly screw onto the threads. Inspect for set-screw marks and the condition of the face of the shaft. On nuts with left handed threads mark direction of rotation or "L.H." if not previously marked.

On tapered shaft ends install the hub on the shaft to a line to line condition and verify that there is sufficient overhang of the hub on the shaft to accommodate the axial pull-up and verify that the retaining nut will bottom against the hub and not the shaft.

7.2.6.4.1 Tapered keyless shaft end—record minor and major diameters, length of taper, and percent of contact area as blued, using a ring gauge as outlined in the procedures per Appendix C. The standoff dimension of the ring gauge shall also be recorded. Inspect o-ring grooves for sharp edges or burrs. Inspect that hydraulic fluid holes are clean and the threads are in good condition.

7.2.6.4.2 Tapered keyed shaft end—record items in 7.2.6.4.1 and keyway dimensions including any metal distortion.

7.2.6.4.3 Straight keyed shaft end—record diameter, length of fit, and keyway dimensions.

7.2.6.4.4 Integrally flanged shaft end—record flatness, bolt circle diameter, bolt hole size, pilot diameter, and whether male or female.

7.2.6.5 Check all runouts with the shaft supported at the bearing journals on vee blocks as outlined in the procedures per Appendix "F".

7.2.6.5.1 Check and record mechanical runout on shaft fit areas, seal areas, axial faces of contact seal faces, bearing journals, integral coupling hubs, and all other running clearance areas. As a minimum, axial runout shall be recorded for both sides of the thrust collar (or the thrust collar shaft shoulder if the thrust collar is removed).

7.2.6.5.2 Electrical and mechanical runouts of each probe location shall be checked and continuously recorded and phase related as specified in Appendix F 4.0.

7.2.7 Weigh and record the static weight at each bearing journal and the total weight of the rotor using an appropriately sized scale having an accuracy of 95% or better.

7.2.8 If both bearing journals are round within 8 µm (0.0003 inches), perform a check balance of the rotor, using fully crowned half-keys in all exposed keyways. For double keyways that are equal in size and 180° apart, half-keys are not required. Record amounts and locations of imbalance and weights of all half-keys.

Note: Check balancing is not required on rotors with damages resulting in an obvious large unbalance.

7.2.9 The vendor shall notify the owner upon completion of Phase I Inspection. A copy of all Phase I documentation shall be submitted for the owner's use and records. The vendor shall evaluate the results of Phase I inspection and prepare the recommended job scope per Section 2.

8 Inspection Methods and Testing

8.1 GENERAL

● **8.1.1** The vendor shall make the following data available prior to shipment and maintained per 12.4.1.2.

a. Necessary or specified certification of materials, such as mill test reports.

b. Test data to verify that the requirements of the specification have been met.

c. Fully identified records of all heat treatment whether performed in the normal course of manufacture or as part of a repair procedure.

d. Results of quality control tests and inspections.

e. Details of all repairs.

f. When specified; final-assembly, maintenance, and running clearances.

g. Other data specified by the owner or required by the applicable codes and regulations. (Reference Paragraphs 1.7 and 9.1.)

Tutorial Discussion: Test data applies to such tests as inspection, NDE results, etc.

8.1.2 In addition to the requirements of Appendix D 1.2, the owner may specify the following:

a. Parts that shall be subjected to surface and subsurface examination.

b. The type of examination required, such as magnetic particle, liquid penetrant, radiographic and ultrasonic examination.

8.1.3 Components with protective coatings shall have the coating removed prior to NDE inspection. Before removal of the coating, the vendor must have authorization from the owner or the representative.

8.1.4 Components that require protective coatings after repairs or manufacturing shall be inspected prior to coating.

8.1.5 NDE personnel shall be qualified in accordance with ASNT TC-1A.

8.2 COMPONENT INSPECTION

8.2.1 General

8.2.1.1 When radiographic, ultrasonic, magnetic particle or liquid penetrant inspection is required or specified, the criteria in 8.2.2 through 8.2.4 shall apply unless other corresponding procedures and criteria have been specified. Cast iron shall be inspected in accordance with 8.2.4. Welds, cast steel, and wrought material may be inspected in accordance with 8.2.2 through 8.2.4.

Tutorial: Radiographic and ultrasonic inspection are not acceptable for cast iron.

Note: Items such as pitting, erosion, and corrosion may not show up as an indication using the NDE methods in this section. Visual examination and engineering judgement is generally required to evaluate the acceptability of the component.

8.2.1.2 The vendor shall review the design of the equipment and impose more stringent criteria than the generalized limits required in 8.2.2 through 8.2.4 if necessary.

8.2.1.3 Dispositions of indications larger than those acceptable for the applicable procedures in 8.2.2, 8.2.3, and 8.2.4 shall be mutually agreed upon between the vendor and the owner.

8.2.1.4 Refer to ASTM E 1316 for standard terminology used in nondestructive examinations.

8.2.2 Radiography

Radiography is generally not used to evaluate rotor components due to the complex geometry. The other techniques as outlined in this section are more suitable to evaluate the component.

8.2.3 Ultrasonic Inspection

8.2.3.1 Ultrasonic inspection shall be in accordance with Section V, Articles 5 and 23, of the ASME Code.

8.2.3.2 The acceptance criteria used for Ultrasonic Inspection shall be per MIL-STD-2154 Table 6 Class AA.

8.2.4 Magnetic Particle and Liquid Penetrant Inspections

8.2.4.1 Wet magnetic particle inspection shall be used and in accordance with ASTM E 709.

Comment: Generally for rotor components, the dry method is not used due to the problems with arcing on finish machined surfaces.

8.2.4.2 Demagnetize all components. Measure and record residual magnetism on all components. Maximum allowable residual magnetism is ±2.0 gauss, as measured with a digital gauss meter and Hall-type probe.

8.2.4.3 Liquid penetrant inspection shall be in accordance with Section V, Article 6, of the ASME Code. Ref. ASTM E 165. The sensitivity is to be Level 3 per ASTM E 1417.

8.2.4.4 Generalized acceptance criteria used for magnetic particle and liquid penetrant inspections shall be used in accordance with Table 1.8-1. This table lists the maximum acceptable size and distribution of indications.

Note: The criteria in Table 1.8-1 is applicable to many different components of the rotating equipment. Refer to Chapters 2 through 7 for specific application of the criteria.

8.2.4.5 All non-magnetic components shall be fluorescent dye penetrant inspected. All ferro-magnetic components shall be wet magnetic particle inspected.

Table 1.8-1—Generalized NDE Acceptance Criteria

Inspection Method	Type Indication	Severity		
		A	B	C
Magnetic Particle	non linear	1.6 mm ($^1/_{16}$ in.)	2.4 mm ($^3/_{32}$ in.)	3.2 mm ($^1/_8$ in.)
	linear	0.8 mm ($^1/_{32}$ in.)	1.2 mm ($^3/_{64}$ in.)	1.6 mm ($^1/_{16}$ in.)
and				
Liquid Penetrant	Number of indications per 645 mm (in.^{2})	2	2	3

General:
1. Crack like linear indications are cause for rejection
2. Two or more indications within 3*D* (where *D* is the length or maximum diameter of the larger of the indications) shall be considered a single indication whose size is the smallest diameter that can contain all indications in that group.
3. All indications greater than 0.4mm (0.015 in.) shall be reported.

Severity:
A: Applicable to rotating components with critical stress regions such as shaft journals, coupling hub regions, integral thrust collars, and fillet regions of the shafts and tie bolts.
B: High stressed rotating components such as tie bolts, coupling hubs, and shaft oil seals.
C: Moderately stressed areas of rotating components or high to moderately stressed stationary components such as shaft/rotor main bodies.

9 Repair Processes and New Component Manufacture

9.1 GENERAL

New material used for the repair of existing parts or the manufacture of replacement parts shall be equal to or better than the original for the intended service. Compatibility of the materials and the process in which they serve must be verified. The vendor shall consult with the owner on material selection and the owner shall approve the material. Materials exposed to a sour environment as defined by NACE MR-01-75 shall be in accordance with that standard.

Existing components may be repaired, as outlined in 9.2 to 9.5, or replaced when justified.

9.1.1 The owner reserves the right to purchase any new component from the rotating element OEM or any other supplier.

9.1.2 All drawings procedures and processes used in the repair or manufacture of any component shall be available for owner review.

9.1.3 All drawings and procedures shall be provided in the final Technical Data Manual per Section 12 and Appendix G, Paragraph 11.0.

9.1.4 When the damaged component(s) cannot be repaired satisfactorily, with approval from the owner, the vendor shall provide replacement component(s) as outlined in 9.7.

Note: It is suggested that damaged components not be disposed of until replacement components are available.

9.1.5 The supplier/repair shop of manufactured or repaired parts shall develop a Quality Plan for the owner's approval. Appendix K Quality Plan, and the appropriate Chapter 2 through 7, Appendix C Quality Plan, shall be used as the minimum requirements in developing the specific plan.

Note: It is recommended that the owner participate in key manufacturing and verification activities by means of observing or witnessing as appropriate to the importance of the equipment.

9.1.6 Failure analysis and redesign should be considered prior to replacing a component that failed unexpectedly or due to undetermined cause.

9.1.7 Unless otherwise specified, repaired keyways and replacement keys shall comply with AGMA 9002.

9.2 SHAFT RESTORATION

9.2.1 General

9.2.1.1 When approved by the owner, shaft areas may be repaired using any of the repair techniques outlined in 9.2.2 to 9.2.6. Refer to 9.3 for the repair of the coupling shaft end.

Note: Consideration must be given to the repair method selected for journal areas since balance machine rollers may cause damage to the coating or plating during balancing.

9.2.1.2 Re-establishing rotor centerline and reclaiming journals, based on excessive runout, is not recommended. This should only be considered after confirming that the rotor is thermally stable.

9.2.1.3 With any repair area, the location and the process used is to be reviewed to ensure that the area will adequately transmit the necessary torque and withstand the applied stresses.

9.2.1.4 When journals are to be restored, truth bands may be established to assure rotor concentricity and runout. The truth bands are to be located so that they will not be affected by the restoration technique. The final journal surface should be established to minimize rotor runout.

Note: Rotor unbalance is extremely sensitive to journal eccentricity. For example, journals on a 454 kg (1,000 lb) rotor running at 10,000 RPM which are offset from the shaft centerline by 5 μm (0.0002 in.), will result in an unbalance of 230 gm-mm (3.2 oz-in.)(90.8 gm-in.). This is eight times the maximum allowable residual unbalance allowed in Section 10.3.9.

9.2.2 Shaft areas (refer to 9.3.2 for coupling fits) can be restored by the following processes as per the procedures outlined in Appendix D:

a. Tungsten Inert Gas (TIG) Process.
b. Submerged Arc Welding (SAW) Process.
c. The High Velocity Oxygen Fuel (HVOF) Process.
d. The High Velocity Liquid Fuel (HVLF) Process.
e. The Intermittent Combustion Process.

Notes:
1. It is recommended not to use the MIG process since this process uses less amperage and is more susceptible to incomplete penetration and voids/porosity.
2. The description of each of the various techniques and comparisons of each process are outlined in Appendix D 2.0–3.0.

9.2.3 The damaged shaft area can be turned down resulting in an undersize shaft. The limitations of this repair method are described in Appendix D 4.0.

9.2.4 Unless otherwise specified, the shaft shall not be repaired by plating, metallizing, plasma spray, sleeving or straightening.

Note: Appendix D 5.0-D 9.0 outlines problems that can be encountered by using these repair techniques.

9.2.5 Unless otherwise specified, repaired shaft surface finish shall be a maximum of:

a. 0.4 μm (16 μinch) Ra in probe areas (preferably by burnishing).
b. 0.4 μm (16 μinch) Ra in journal and seal fit areas.
c. 0.8 μm (32 μinch) Ra for remaining parts of shaft.
d. See Paragraph 9.3.1 for coupling fits.

9.2.6 The finished fillet radii for all changes in shaft diameter shall be as large as practical with a minimum of 1.6 mm ($^1/_{16}$ in.).

9.3 COUPLING SHAFT END

9.3.1 Shaft ends for couplings shall conform to the requirements of API 671. Shaft surface finish shall be in the 0.4–0.8µm (16–32 µinch) Ra range.

Tutorial: Too smooth a surface finish can prevent adequate torque transmission between the hub and shaft. The 0.8 µm (32 µinch) finish on hydraulic fit shafts allows minute oil channels for the dilation oil to migrate to and from the oil inlet.

9.3.2 Unless otherwise specified, all shaft end coupling fit areas shall be repaired by the TIG or SAW welding process as outlined in Appendix D 2.0, using an owner approved weld procedure.

When repairing shaft ends the following recommendations should be considered:

1. Turn the area undersize, at least 0.050 in. below any keyway.
2. Perform a wet magnetic particle inspection and a UT inspection to verify shaft soundness.
3. Build up with weld using the TIG process.
4. Recut keyway at least 90° away from the previous location.
5. Remachine hydraulic ports in the same location (locate by Ultrasonic Inspection).

Notes:
1. The mechanical bond from flame spray or plating processes may not provide sufficient bond strength to adequately transmit the required torque.
2. Coatings exhibiting higher levels of porosity may result in other modes of failure.

9.3.3 Coupling shaft ends may be machined undersized to remove damaged areas. An engineering study should be performed to ensure the final shaft size is adequate for the intended duty, if this method is to be used.

9.3.4 Coupling shaft ends may be lapped to obtain proper contact per the methods outlined in Appendix C 7.0.

9.3.5 Integrally flanged shaft ends may be repaired by the weld procedures outlined in Appendix D 2.0, based upon an engineering evaluation.

9.3.6 Bolt holes for integrally flanged shaft ends may be machined oversize or have flanged bushings installed, based upon an engineering evaluation.

9.3.7 Faces for integrally flanged shaft ends may be skim cut to true up the faces, based upon an engineering evaluation.

9.4 THRUST COLLARS

9.4.1 As measured on the shaft, the axial total indicated runout of either face shall not exceed 12.7 µm (0.0005 in.). Both finished faces of the thrust collars shall have a surface finish of not more than 0.4 µm (16 µinches) Ra.

9.4.2 When the thrust collar exceeds the limits of 9.4.1 it shall be repaired by machining and grinding. If the additional stock furnished with the thrust collar for refinishing has been consumed, a new thrust collar shall be furnished. For integral collars, the Vendor shall consult with the Owner to determine alternate solutions to rotor shaft replacement such as:

a. Weld repair of the thrust collar by weld buildup in accordance with 9.3.2 and Appendix D 2.0.
b. Install a removable collar.

Note: For major thrust collar repairs, the maximum thrust load should be calculated to determine such factors as collar deflection and root stress. Collar deflection shall be within the operating tolerance of the thrust bearing.

9.5 SHAFT SLEEVES AND SPACERS

For rotors that do not require disassembly, the shaft sleeves and spacer may be repaired using the techniques outlined in 9.2.2 c, d, and e and Appendix D 3.0.

9.6 RADIAL RUNOUTS

9.6.1 Mechanical Runouts

9.6.1.1 The total indicated shaft runout (TIR) of the finished shaft shall be no more than 25 µm (0.001 in.) at any axial location with a maximum eccentricity of 13 µm (0.0005 in.).

Note: Correct methods of determining shaft TIR and interpretations may be found in Appendix F.

9.6.2 Vibration Probe Area Runouts

9.6.2.1 The shaft sensing areas to be observed by radial-vibration probes shall be concentric with the bearing journals. All shaft sensing areas (both radial vibration and axial position) shall be free from discontinuities, for a minimum of one probe-tip diameter on each side of the probe. These areas shall not be metallized or plated. The final surface finish shall be a maximum of 0.8 µm (32 µinch) Ra, preferably obtained by honing or burnishing. These areas shall be properly demagnetized to the levels specified in Paragraph 8.2.4.2 or otherwise treated so that the combined total electrical and mechanical runout does not exceed 25 percent of the maximum allowed peak to peak vibration amplitude, as specified in the applicable API specification, or the following value, whichever is greater:

a. For areas to be observed by radial vibration probes, 6 µm (0.25 mil).

b. For areas to be observed by axial position probes, 12 µm (0.5 mil).

Notes:
1. If all reasonable efforts fail to achieve the limits noted in 9.6.2.1, the vendor and the purchaser shall mutually agree on alternate acceptance criteria.
2. To prevent rusting on the probe surface areas during storage or in operation, a non-conductive coating, such as an epoxy, that does not affect the probe's electrical runout may be used.

9.6.2.2 Electrical and mechanical runouts of each probe location shall be checked and continuously recorded and phase related as specified in Appendix F 4.0.

9.7 NEW COMPONENT MANUFACTURE

9.7.1 New components supplied by the vendor, whether for as built replacement or for upgrade, shall conform to the latest edition of the applicable API standard. Refer to Section 3 of the subsequent chapters in this document for the number of the applicable API standard.

Note: Not all requirements of a later edition of the API standard may be practical.

9.7.2 The vendor shall review the owner provided information referred to in section 2.3.5 and determine if other data must be obtained to produce a component which will meet the requirements.

9.7.3 When OEM drawings are not available for reference, the vendor shall perform a "reverse" engineering process to establish the proper materials, heat treatment, dimensions and appropriate functional tolerances required to produce the new component.

Note: The vendor may find it necessary to obtain field measurements of equipment in service to verify or supplement the needed data.

9.7.4 It is recommended that the owner and vendor hold a design review meeting to assure the reverse engineering process has been properly conducted and documented.

10 Rotor Assembly and Balancing

10.1 GENERAL

● **10.1.1** When a rotor does not require additional work from the Phase I inspection, it shall be balanced in accordance with section 10.3. When specified, the rotor is to be high speed (at speed) balanced per section 10.6.

Note: Refer to API RP 684 for a tutorial on balancing.

10.1.2 When a coating has been applied to a journal, the rollers in the balance stand shall be run on a surface ground in the same set-up as the journal areas to assure concentricity.

Notes:
1. Running rollers on coated surfaces may cause cracking of the coating.
2. Running surfaces ground in a second set-up may not be concentric enough to maintain balance tolerance in the case/field.
3. Running the rollers on the transition from the coated surface to the uncoated surface will increase the potential for cracking.

10.1.3 All existing field accessible balance weights shall be removed. Field accessible balance holes shall not be used for balance corrections.

10.1.4 Consideration should be given to removing any other balance weights, particularly where there may be concerns that the weights could shift, become dislodged during service, or where components are removed from the rotor.

Tutorial: There are many special balance weights. They could be threaded weights peened into special balance holes, setscrew held bevel weights fitted into dovetailed grooves, or special clipped weights.

10.1.5 When balance weights are removed from the rotor, record weight, material, how attached, and phase angle reference to establish "zero."

10.1.6 Balance weights shall be compatible with disk material and suitable for the operating environment.

10.1.7 Balance weights on ancillary components such as couplings may be left in place since these components should have been individually balanced.

10.2 LOW SPEED COMPONENT BALANCING

10.2.1 Rotors to be balanced shall be rotated in a direction that is "normal" to reduce "windage" effects on the components mounted on the rotor-blading, vanes, etc.

10.2.2 Major Components of the rotating element, such as bare shaft, balance piston, impellers or disks shall be balanced prior to assembly in accordance with paragraph 10.2.11.

10.2.3 Component(s) that are to be protective coated shall be balanced prior to the coating application and then check balanced after the coating application.

Note: Consideration must be given to the type of coating and the patching application required to cover the balance corrections. Protective coating may be done for corrosion, erosion, anti-fouling considerations during operation.

10.2.4 Any requirements for spinning the components(s) to overspeed must be performed prior to installation onto the rotor.

10.2.5 When bare shafts are balanced, keyseats shall be filled with fully crowned half-keys, unless keys of equal size are used in the same axial plane, 180° apart, or are at a position that results in equalizing opposing imbalances. The balance machine reading prior to the initial balance correction to the bare shaft shall be recorded.

10.2.6 If components to be balanced are not phase reference marked, zero phase shall be at the component keyway (or locking pin or key block). If stage discs (elements) are not keyed or do not have a reference point, zero phase shall be permanently identified for use during the assembly balancing.

10.2.7 Components shall be balanced on mandrels with a surface finish not to exceed 0.4 µm (16 µinch) Ra that have no measurable eccentricity using an indicator graduated in 2.5 mm (0.0001 in.) increments.

a. Tapered spring mandrels shall not be used.
b. For keyed components, inside crowned half keys or an equivalent compensating moment are required for proper balance, since mandrels are typically not keyed.
c. The mandrel mass should not exceed 25% of the component mass.

10.2.8 The interference fit between a component and a mandrel shall not be less than 0.05 mm (0.002 in.) or one-quarter of the design fit between the component and the shaft, whichever is greater.

10.2.9 Components such as nuts, collars, thrust collars, coupling hubs, etc., may be balanced on a vertical balancing machine.

10.2.10 With the component mounted on the mandrel, it's axial and radial phase related runout(s) shall be recorded and not exceed 0.17 µm/mm (0.002 in./ft) T.I.R. of component diameter.

Note: This location should be at the same place as measured during disassembly and reassembly.

10.2.11 The balancing tolerances for the assembly shall also govern for the components. No balancing corrections are to be made on the indicator reference planes; or in critical areas.

The maximum allowable residual unbalance per plane (journal), measured at the journal, shall be defined as the greater of an eccentricity, *e*, of 0.43 µm (17 µinch) or by the following calculations:

In Metric units

$$U_{max} = 6350W/N\text{, gm-mm} \qquad (10\text{-}1)$$

In U.S. Customary units

$$U_{max} = 4W/N\text{, oz-in.} \qquad (10\text{-}2)$$

$$U_{max} = 113.4W/N\text{, gm-in.} \qquad (10\text{-}3)$$

where:

U_{max} = residual unbalance, in gram-millimeters (oz-in.)(gm-in.),

W = mandrel, with component, journal static weight load, in kilograms (lbs),

N = max. continuous speed, rpm.

Notes:
1. 4*W/N*, oz-in. = ~ ISO Grade 0.665 mm/sec
2. To go from, *e*, to oz-in.; one would multiply the eccentricity, *e*, e.g., 17 µinches by the journal weight in ounces (or) 0.000017 inches x (200 lbs x 16 oz/lb) = 0.054 oz-in. ALSO, one could take the balance tolerance in oz-in. and divide by the journal weight in ounces to get the eccentricity, *e* (often a balancing machine manufacturer's warranty) or 0.054 oz-in./3200 oz = 0.000017 in. or 17 µinches.

10.2.12 Major components such as turbine disks, impellers, etc., having a balance plane separation of 3% or less of the rotor's bearing journal span may be static balanced in lieu of dynamic balancing.

The maximum allowable residual unbalance for a component that is statically balanced only shall be defined as the greater of an eccentricity, *e*, of 0.43 µm (17 µinches) or by the following calculations:

In Metric units

$$U_{max} = 12{,}700\ W/N\text{, gm-mm}$$

In U.S. Customary units

$$U_{max} = 8\ W/N\text{, oz-in.}$$

$$U_{max} = 226.8\ W/N\text{, gm-in.}$$

where:

U_{max} = residual unbalance, in gram-millimeters (oz-in.)(gm-in.),

W = mandrel,withcomponent,totalweightload,in kilograms (lbs),

N = max. continuous speed, rpm.

10.3 LOW SPEED ASSEMBLY BALANCING

10.3.1 When the vendor's standard balance method is by high speed balancing in lieu of a sequential low speed balancing and high speed balancing is not specified, it may be used with the owner's approval. In all cases low speed component balance is required. The high speed balance shall be in accordance with 10.6.

10.3.2 Rotating components shall be multiplane dynamically balanced during assembly with the shaft. In the stacking sequence, the minimum number of components shall be added to achieve balance plane separation of at least 10% of the bearing (balancing) span. This shall be accomplished after addition of at least one major component for rotors that must stack from one end, and after typically no more than two major components for rotors that stack from the center out.

10.3.3 For an overhung rotor, the rotor is to be completely disassembled prior to any balancing. Each component (including the shaft) is to be balanced individually prior to rotor assembly. During the assembly balance, the components that are located between the balance supports are to be installed using the assembly balancing procedure outlined in paragraph 10.3.2 prior to any installation and balance of any component outside the balance supports.

Then, if possible, the lightest of the overhung components shall be installed and balanced, working up to the heaviest. The balance machine must have its program set up to correctly describe the overhung condition. Balance planes for such assemblies are often specified by the OEM and should be adhered to. If not otherwise specified, careful consideration should be given to selecting where to designate the balance planes and where the balance corrections will be made.

Notes:

1. Review prior balance correction plane locations for assistance in locating balancing planes if the OEM specifications are not available.

2. If the balance machine is programmed to allow a couple correction on the overhung component, a single or multi-stage overhung rotor can be balanced to the same criteria as outlined in these guidelines. If this configuration is not available from the balance machine options, then the balance machine must be configured manually to achieve a couple correction of the overhung component(s).

10.3.4 Rotor assemblies or rotors that have not been unstacked that are to be protective coated shall be balanced prior to the coating application and then check balanced after the coating application.

Note: Consideration must be given to the type of the coating and the patching application required to cover the balance corrections. Protective coating may be done for corrosion, erosion, anti-fouling considerations during operation.

10.3.5 Balancing corrections shall only be applied to components added to a maximum of 3 x U_{max}, as measured at the journals. When major components are added, the resulting unbalance of the assembly shall not exceed 3 x U_{max}. If the resultant unbalance exceeds 3 x U_{max}, (as measured at the journal); the reason for the excessive change in unbalance shall be determined and corrected when necessary. If 3 x U_{max} is not exceeded, the unbalance shall be corrected to that required by 10.3.9. No balancing corrections shall be made on the indicator reference planes, or other critical areas.

Note: It is important that components are properly balanced and that components in the "stacking sequence" be properly fitted to the main rotor. Therefore, a value of 3 x U_{max} balance tolerance has been established. This value has proven to be achievable in most cases. One shall ascertain why an increase has occurred. Higher imbalance can occur due to improper mounting or eccentricity of a component.

10.3.6 Unless otherwise specified, in the sequential balancing process, any half-keys used in balancing of the bare shaft from paragraph 10.2.5 shall continue to be used until they must be replaced with final keys and mating elements.

10.3.7 Weight of all half-keys used during final balancing of assembled element(s) shall be recorded, such as the coupling half-key.

10.3.8 Balance machine antifriction support rollers, within ±5% of the same nominal diameter as the rotor journals, shall not be used due to possible roller noise masking the balance readings.

10.3.9 Unless otherwise specified, the maximum permissible unbalance per plane (journal), measured at the journal, shall be defined by the following calculations:

In Metric units

$$U_{max} = 6350W/N, \text{ gm-mm}$$

In U.S. Customary units

$$U_{max} = 4W/N, \text{ oz-in.} \qquad \text{(or)}$$

$$U_{max} = 113.4W/N, \text{ gm-in.}$$

where

U_{max} = residual unbalance, in gm-mm (oz-in.)(or gm-in.),

W^* = journal static weight, in kg (lbs),

N = maximum continuous speed, in rpm.

Notes:

1. During sequential balancing W^* changes. "W" is the journal weight of each sequential assembly, and will increase during sequential "stacking."

2. There may be circumstances where the OEM's requirements are less.

3. The residual unbalance of U_{max} is ~ ISO Grade 0.665 mm/sec. *To determine ISO eccentricities, e; one must only divide the ISO Grade, mm/sec, by the balancing speed in rad/sec.*

$(\omega = \{2\pi/60\}N);$

e.g., $(0.665 \text{ mm/sec}) / [(2\pi / 60)(10{,}000 \text{ rpm})]$

$= e = 0.635\ \mu m$ *or* $25\ \mu$ *in. (0.000025 in.).*

10.3.10 For non-belt driven balance machines (i.e. rotor is driven with a jackshaft), after the addition of the first component, the jackshaft shall be rotated 180° and the residual unbalance checked again. If the unbalance values change to exceed the value in paragraph 10.3.9, the drive shaft is not balanced or pilot fit of drive shaft is incorrect. Error shall be corrected prior to proceeding.

10.3.11 Amount of residual unbalance and it's phase angle with relation to the established zero reference shall be recorded for the rotor before and after the addition of any component in the stacking sequence.

10.4 RESIDUAL UNBALANCE TESTING AND INSTALLATION OF TRIM PARTS

10.4.1 Residual unbalance testing per Chapter 1, Appendix A, shall be performed after the completion of all work, but prior to the installation of trim parts, such as the thrust collar assembly, coupling, etc., that may be removed for routine field maintenance.

10.4.2 After the installation of all trim parts such as the thrust assembly and coupling, the rotor's balance shall be checked to assure that it is still within the prescribed tolerance.

10.4.3 If the addition of components, such as coupling hubs, seal sleeves, thrust collars; exceeds U_{max} for the rotor, the unbalance problem shall be corrected appropriately. Component balance corrections of field removable parts must be approved by the owner.

10.4.4 Balance corrections on the coupling are not permitted. If it appears that the installation of the coupling resulted in an unbalance that exceeds the prescribed tolerance, the specifics shall be reviewed by the vendor to determine the cause of the problem. The vendor shall then contact the owner to determine the appropriate correction(s) to the problem.

Note: A coupling may have been balanced as an assembly and prior to an additional component balance of the hub, the previous balance method shall be reviewed.

10.4.5 When balance corrections are necessary on trim parts that are not keyed to the shaft, such as a hydraulically-mounted thrust collar, the individual trim parts shall be clearly match-marked to enable correct re-assembly in the field.

10.4.6 Unless otherwise specified, when balance corrections are made to the rotor trim parts an additional residual unbalance test will not be required when both of the following conditions are met:

a. The same balance machine is used for the trim corrections as was used for the residual unbalance test on the rotor, and the trim corrections are performed within 3 days of the residual unbalance test.

b. The documented unbalance indicated by the balance machine readouts and the residual unbalance test performed on the completed rotor agreed within 10%.

10.5 BALANCING EQUIPMENT AND DOCUMENTATION

10.5.1 The rotor balancing machine calibration shall be verified prior to balancing in accordance with the repair vendor's procedure.

10.5.2 Balance machines shall be capable of providing the following information:

a. Plane separation
b. Dynamic balance
c. Static/couple balance

10.5.3 Documentation of initial and final balance shall be provided.

10.5.4 After the final balancing has been completed, a residual unbalance check shall be performed and recorded as described in Appendix A.

10.6 HIGH SPEED (AT SPEED) BALANCE

Tutorial: Generally, compressor and turbine rotors do not require high-speed (or at speed) balancing. There are, however, conditions where high-speed balancing should be considered which may include, but not be limited to, the following:

a. Rotors which have exhibited high vibration as they pass through their critical speeds.

b. Rotors which accelerate slowly through their critical speeds.

c. Rotors which are running on or near a critical speed.

d. Rotors which are sensitive to unbalance.

e. Rotors for equipment in extremely critical services.

f. Rotors going to inaccessible locations, such as offshore.

g. Very long, flexible rotors.

h. Places where a critical rotor cannot be run in its intended casing prior to installation.

i. Rotors that have previously been high speed balanced and have not been disassembled.

A rotor dynamics analysis of the rotor and support system should have been performed prior to attempting a high-speed balance. This analysis will provide information about the predicted rotor mode shape as it passes through its critical speed(s) and about the best location for balance weights to minimize rotor vibration. Note that since the stiffness of the balancing machine bearing pedestals may vary significantly from the actual field installation, the critical speed, observed in the balancing machine, may differ significantly from that observed when the rotor is run in the field. A revised balancing speed may be required when this difference in pedestal stiffness results in high speed operation at or near a critical speed.

The rotor and balancing machine pedestal supports are placed in a vacuum chamber to reduce power required to turn the rotor at higher speeds and to reduce heating from windage. Specially manufactured oil film bearings *or job bearings are generally necessary to perform the balancing since the high speeds require journal bearings rather than anti-friction type used in low-speed balancing machines.*

Proper conditions of the rotor workpiece to remove bows and distortion prior to high-speed balancing is essential. This conditioning is accomplished by spinning the rotor up and down in speed until the unbalance readout and phase angle becomes stabilized. The time required for this stabilization will vary widely from rotor to rotor.

It is preferable that the rotor duplicate the normal running assembly when high speed balanced. The assembly should include coupling hub with moment simulator, thrust collars with locking collars, power take-off gears, overspeed trip assemblies, and tachometer rings for governor or speed switches, etc.

● **10.6.1** When specified, high-speed balancing (balancing in a high-speed balancing machine up to maximum continuous speed) shall be done. The procedure for this balancing shall be mutually agreed upon by the owner and the vendor.

Field accessible balance holes shall not be used for balance corrections.

Note: After high speed balance tag the rotor as having been high speed balanced. A rotor should not be low speed balanced after it has been high speed balanced.

10.6.2 Unless otherwise specified, the acceptance criteria for high speed balancing, with maximum pedestal stiffness at all speeds, measured on the bearing cap:

a. For speeds above 3000 rpm: shall not exceed the "greater" of 7400/N, mm/sec (291/N, in./sec) or 1 mm/sec (0.039 in./sec).

where

N = maximum continuous speed, rpm.

Or

b. For all speeds less than 3000 rpm; shall not exceed 2.5 mm/sec (0.098 in./sec).

Note: This residual unbalance is at all speeds (includes any criticals) and the force from this residual unbalance is $\leq$0.079 g's.

10.6.3 When high speed balance has been specified, the following information shall be provided, prior to High Speed balancing:

a. Latest low speed balance records.
b. Mechanical radial and axial runout checks of the rotor.
c. If applicable, transfer tapes showing contact-hydraulic fit coupling hub/shaft end.
d. Bearing/shaft clearances.
e. Location and thickness of any rotor coating(s). Verify that the probe tracks are not coated.
f. A plot of mechanical and electrical runout of shaft proximity probe tracks, obtained in vee-blocks. Plots at probe location and one probe diameter to either side of the primary probe location shall be provided.
g. Quality check of the rotor and any repairs (NDE including UT).
h. Procedures to install hardware items (thrust collars, couplings, etc.) as balance steps.
i. Critical speed and Amplification Factor as defined by analysis or prior testing.

● **10.6.4** The following shall be resolved by the owner and vendor before high speed balance:

a. Job type bearings should be used when specified.
b. Instrumented data during balancing. Data from 2 orthogonally mounted radial non-contacting vibration probes; in addition to the normal velocity sensors at each pedestal.
c. If specified for the third plane, an additional pair of radial non-contacting probes per b. above, in line (phase) with probes mounted at the bearings shall be placed at the location(s) expected to have maximum displacement in accordance with the rotor dynamic mode shape analysis. This requires a fixed set-up.
d. Confirmation of plans to record certain data during the balancing runs (Bode' and polar plots-direct and synchronous amplitude vs. frequency plots, embedded bearing temperature sensors).

● **10.6.5** When the High Speed Balance vendor, is not the repair vendor or owner, the High Speed Balance vendor may request information from the repair vendor and/or owner. Typical information requested generally includes:

a. Rotor history including repairs.
b. NDE-UT or wet magnetic particle inspection-by whom-certification of inspectors.
c. Inspection bureau involved.
d. Rotor manufacturer.
e. Type of Rotor—Integral or "built-up".
f. Rotor Speeds—Design, maximum continuous, trip.
g. Assembled rotor dimensional drawing.
h. Rotor Physical Data—weight, bearing span, journal weights, overall length, overall diameter.
i. Bearing Data—style, configuration, clearances, manufacturer, preload, journal diameter, maximum housing diameter, all dimensions.
j. Previous High Speed balance information, including critical speed information, analysis, etc.
k. Probe locations; correction planes.
l. Sequence of components—couplings (hub drive or standoff), thrust collars, trip assembly.
m. Witness testing requirement (when specified) along with the contact person.
n. Data required during balance.
o. Special considerations for setting mechanical trips in the bunker.

11 Preparation for Shipment and Storage

11.1 GENERAL

11.1.1 This section establishes basic container requirements for various levels of preservation and packaging for shipments, handling and storage. Rotors and components for all classes shall be placed in containers with covered tops. The basic differences in these containers are the material and the design for long term storage. The containers shall be designed per different classes as identified in 11.2.

11.1.2 The equipment shall be identified per owner's requirements. Material shipped separately shall be identified with securely affixed, corrosion-resistant metal tags indicating the owner's requirements. In addition, crated equipment shall be shipped with duplicate packing lists describing each item, one inside and one on the outside of the shipping container.

● **11.1.3** The owner will specify the term of storage and method of shipment (domestic or export). Unless otherwise specified, the repaired rotor shall be preserved for six months in a non-climate controlled indoor storage. For periods greater than six months, it is recommended that the rotor be stored vertically in a climate controlled environment or a purged container.

11.1.4 Containers shall be designed for the specific rotor weight and configuration. Appendix J contains sample crate and steel container drawings.

11.1.5 The container, whether supplied by the owner or vendor, shall comply with the requirements of this section and Appendix J.

11.1.6 The vendor shall protect the journals, vibration probe tracks, and coupling fit area from incidental mechanical damage.

11.1.7 All containers shall be constructed to allow for lifting with a fork truck or crane. Shipping weight and rotor weight, lifting points, and lifting lugs shall be clearly identified on the equipment or equipment package. The recommended lifting arrangement shall be identified on boxed equipment.

11.1.8 Unless otherwise specified, the vendor shall arrange shipment. The vendor shall be responsible for verifying that the mode of transport has the capacity for the shipment and that liability insurance coverage of the shipment is in force.

11.2 CONTAINERS

11.2.1 Shipping Classes

Three classes of packaging are established, Class #1: Transit Only, Class #2: Commercial Indoor (Up to 6 months), Class #3: Export.

11.2.2 Wooden Container Boxes

All materials of construction shall be of suitable grade of construction lumber and plywood strong enough to protect its contents from hazards of shipping and storage. Tops are to be removable. Heavy-duty nail or staple fasteners are to be used in the construction with a least two steel bands to fasten top and strengthen box. Wooden containers shall be designed for horizontal shipment and storage. For Class 2 and Class 3 containers consideration should be given to venting or desiccants.

Note: Some gears and overhung rotors may be supported with the shaft in the vertical position.

● 11.2.3 Steel

When specified, a steel rotor container shall be supplied. Steel rotor shipping containers shall have provisions for storage of a rotor in both a horizontal position and a vertical position. The placement of the runners should allow for a fork truck to be able to move the container and the rotor while placed in the horizontal position. Additionally, lugs should be provided to allow a crane to lift the container while the rotor is in the container. The container, valving, and connections shall be designed for a minimum of 0.35 bar (5 psig) pressure. The purge gas should be specified. Containers shall be cylindrical, horizontally split and the top is to be sealed, bolted and doweled to prevent movement and leakage. A typical steel container is shown in Appendix J, Figure 2 and may be used for all shipping classes. The pressure in the container is to be maintained during storage at a minimum of 0.07 bar (1 psig).

11.3 ROTOR SUPPORTS

11.3.1 Horizontal

Cradles shall be provided at rotor diameters that are not deemed critical to the rotor operation. Do not support rotors on bearing, probe or seal areas and at any exposed rotor blades or gear teeth. Compressor rotors can be supported on impeller outer diameters. Rotor retainers shall be used at the cradles to prevent any movement during transit. A material having a minimum thickness of 3 millimeters ($^1/_8$ in.), not Tetrafluoroethylene (TFE) or Polytetrafluoroethylene (PTFE), shall be used between the rotor and the cradle at the support areas. Recommended materials are micarta and mylar. Rotor shall be blocked to prevent axial movement.

Note: TFE and PTFE are not recommended as cradle support liners since they cold flow and impregnate into the surface.

11.3.2 Vertical

A cradle shall provide support at the rotor end and against a suitable circumferential surface such as impeller or turbine disc along with retainers on the rotor diameters and/or on a non-critical surface of the rotor to prevent movement. A material having a minimum thickness of 3.0 millimeters ($^1/_8$ in.) shall be used between the rotor and the cradle at the support areas. Recommended materials are micarta and mylar. Rotor shall be blocked to prevent radial movement.

11.4 PACKING

11.4.1 General

The rotor shall be protected with a corrosion barrier. Critical shaft areas such as journals, end seal areas, probe target areas, and coupling fit areas shall also be protected by a separate barrier material to protect against incidental mechanical damage.

Note: Some processes (Chlorine, Oxygen, etc.) may react with the corrosion barrier. Care should be taken in selecting the corrosion barrier for these applications.

Mark the probe target area barriers with the words "Probe Area—Do Not Cut." Loose components shall be dipped in wax or placed in plastic bags and contained by cardboard boxes. Loose boxes are to be securely blocked in the shipping container.

11.4.2 Class #1 (Commercial and Air Shipments), Appendix J, Figures 1 and 2

Interior plastic sheeting in wooden container boxes is not required.

11.4.3 Class #2 (Commercial Long Term—Indoor), Appendix J, Figures 1 and 2

All wooden container boxes are to have covered top with plastic sheeting. Overlap plastic sheeting around top a minimum of 30 cm (12 in.) all around, double over sheeting, and clamp in place by attaching cover. A minimum of 2 cm ($^3/_4$ in.) wide banding is to be used on all boxes.

11.4.4 Class #3 (Export and Commercial Long Term—Outdoor), Appendix J, Figures 2, 3, 4, and 5

All wooden container boxes are to have a plastic sheet vapor barrier securely stapled to the inside and top. Interior box walls and top to be lined with $^1/_8$ inch hard board or $^1/_4$ in. plywood for less than 4536 kg (10,000 pound) rotors and a minimum of $^1/_4$ in. plywood for boxes greater than 4536 kg (10,000 pounds). Liner shall wrap around and be nailed or stapled to exterior of the box wall and top. A minimum of 3 cm ($1^1/_4$ in.) wide banding is to be used on all container boxes.

12 Documentation

12.1 GENERAL

12.1.1 The information to be furnished by the vendor will be specified in 12.2 and 12.3. The supplier shall complete and return the Vendor Data Drawing Requirements form (see Appendix G) to the address or addresses on the inquiry or order. This form shall detail the schedule for transmission of drawings, data, and documentation as agreed to at the time of the order.

12.1.2 The data shall be identified on transmittal (cover) letters and in title blocks or title pages with the following information:

a. The purchaser/user's corporate name.
b. The job/Project number.
c. The equipment item number and service name.
d. The inquiry or purchase order number.

The vendor's identifying proposal number, shop order number, serial number, or other reference number required to identify return correspondence completely.

12.2 PROPOSALS

The vendor shall forward the proposal defining the scope of work with the initial inspection reports, price, and delivery sent to the owner to the address specified in the inquiry documents. The proposal shall include a statement that the repair scope and all documentation will be in accordance with this standard. If the scope and supplied data are not in strict accordance, the vendor shall include a list that details and explains each deviation. The vendor shall provide details to evaluate any proposed alternative repair procedures and scope. All correspondence shall be clearly identified in accordance with 12.1.2.

12.3 CONTRACT DATA

12.3.1 Technical Data shall be submitted in accordance with Appendix G and identified in accordance with 12.1.2. Any comments on the drawings or revisions of specifications that necessitate a change in the data shall be noted by the vendor. These notifications will result in the owner's issue of the completed, corrected purchase specifications.

12.3.2 The vendor shall submit progress reports to the purchaser at the intervals specified in the Vendor Data Drawing Requirements form (Appendix G).

12.4 DOCUMENT RETENTION

12.4.1 Vendor Requirements

12.4.1.1 Quality records shall be identified by vendor job number, OEM serial number, customer purchase order number, customer equipment identification number, and contract inquiry number. Control shall be by data, unique document number, and revision level.

12.4.1.2 Records shall be stored and maintained in such a way that they are readily retrievable. While in storage, quality records shall be protected from damage, loss, and deterioration due to environmental conditions. Records shall be maintained a minimum of 20 years. Records shall be made available for customer evaluation with reasonable notification.

12.4.2 Owner Requirements

The owner should update their equipment history file to reflect any changes to the rotor made during the repair. A change notice should be forwarded to the OEM by the owner to allow for the required revisions which could affect the future delivery of replacement spare parts.

APPENDIX A—PROCEDURE FOR DETERMINATION OF RESIDUAL UNBALANCE

A.1 General

This appendix describes the procedure to be used to determine residual unbalance in machine rotors. Although some balancing machines may be set up to read out the exact amount of unbalance, the calibration can be in error. The only sure method of determining is to test the rotor with a known amount of unbalance. See Figures 1.A-1 through 1.A-6.

A.2 Residual Unbalance

Residual unbalance is the amount of unbalance remaining in a rotor after balancing. Unless otherwise specified, residual unbalance shall be expressed in g-mm (g-in.).

A.3 Maximum Allowable Residual Unbalance

A.3.1 The maximum allowable residual unbalance, per plane, shall be calculated according to the paragraph from the standard to which this appendix is attached.

A.3.2 The static weight on each journal shall be determined by physical measurement. (Calculation methods may introduce errors.) Do NOT simply assume that rotor weight is equally divided between the two journals. There can be great discrepancies in the journal weight to the point of being very low (even negative on over-hung rotors). In the example problem, Figures 1.A-3 through 1.A-6, the left plane has a journal weight of 530.7 kg (1170 lbs). The right plane has a journal weight of 571.5 kg (1260 lbs).

A.4 Residual Unbalance Check

A.4.1 GENERAL

A.4.1.1 When the balancing machine readings indicate that the rotor has been balanced within the specified tolerance, a residual unbalance check shall be performed before the rotor is removed from the balancing machine.

A.4.1.2 To check the residual unbalance, a known trial weight is attached to the rotor sequentially in six equally spaced radial positions (60 degrees apart), each at the same radius. (i.e., same moment {g-in.}). The check is run at each balance machine readout plane, and the readings in each plane are tabulated and plotted on the polar graph using the procedure specified in A.4.2.

A.4.2 PROCEDURE

A.4.2.1 Select a trial weight and radius that will be equivalent to between one and two times the maximum allowable residual unbalance [e.g., if U_{max} is 488.4 g-mm (19. 2 g-in.), the trial weight should cause 488.4 to 976.8 g-mm (19.2 to 38.4 g-in.) of unbalance]. This trial weight and radius must be sufficient so that the resulting plot in A 4.2.5 encompasses the origin of the polar plot.

A.4.2.2 Starting at a convenient reference plane (i.e., ~ last heavy spot), mark off the specified six radial positions (60° increments) around the rotor. Add the trial weight near the last known heavy spot for that plane. Verify that the balance machine is responding and is within the range and graph selected for taking the residual unbalance check.

A.4.2.3 Verify that the balancing machine is responding linearly (i.e., no faulty sensors or displays) sufficient display near balance and within range at largest unbalance. If the trial weight was added to the last known heavy spot, the first meter reading should be at least twice as much as the last reading taken before the trial weight was added. Little or no meter reading generally indicates that the rotor was not balanced to the correct tolerance, the balancing machine was not sensitive enough, or that a balancing machine fault exists (i.e., a faulty pickup). Proceed, if all OK.

A.4.2.4 Remove the trial weight and rotate the trial weight to the next trial position (that is, 60, 120, 180, 240, 300, and 360 degrees from the initial trial weight position). Repeat the initial position as a check for repeatability on the Residual Unbalance Worksheet. All verification shall be performed using only one sensitivity range on the balance machine.

A.4.2.5 Plot the balancing machine amplitude readout versus angular location of trial weight (NOT balancing machine phase angle) on the Residual Unbalance Worksheet and calculate the amount of residual unbalance [refer to work sheets, Figures 1.A-3 and 1.A-6].

Note: The maximum reading occurs when the trial weight is placed at the rotor's remaining heavy spot; the minimum reading occurs when the trial weight is placed opposite the rotor's heavy spot (light spot). The plotted readings should form an approximate circle around the origin of the polar chart. The balance machine angular location readout should approximate the location of the trial weight. The maximum deviation (highest reading) is the heavy spot (represents the plane of the residual unbalance). Blank work sheets are Figures 1.A-1 and 1.A-2.

A.4.2.6 Repeat the steps described in A.4.2.1 through A.4.2.5 for each balance machine readout plane. If the specified maximum allowable residual unbalance has been exceeded in any balance machine readout plane, the rotor shall be balanced more precisely and checked again. If a balance correction is made in any balance machine readout plane, then the residual unbalance check shall be repeated in all balance machine readout planes.

A.4.2.7 For stack component balanced rotors, a residual unbalance check shall be performed after the addition and balancing of the rotor after the addition of the first rotor component, and at the completion of balancing of the entire rotor, as a minimum.

Notes:

1. This ensures that time is not wasted and rotor components are not subjected to unnecessary material removal in attempting to balance a multiple component rotor with a faulty balancing machine.

2. For large multi-stage rotors, the journal reactions may be considerably different from the case of a partially stacked to a completely stacked rotor.

Customer: ______
Job / Project Number: ______
OEM Equipment S / N: ______
Rotor Identification Number: ______
Repair Purchase Order Number: ______
Vendor Job Number: ______
Correction Plane (Left or Right) - use sketch ______ (plane)

Balancing Speed [ ] (rpm)
Maximum Rotor Operating Speed (N) [ ] (rpm)
Static Journal Weight Closest to This Correction Plane (W) [ ] (kg) [ ] (lbs)
Trial Weight Radius (R) - the radius at which the trial weight will be placed [ ] (mm) [ ] (in)

Calculate Maximum Allowable Residual Unbalance (Umax):
Si Units:
Umax = $\frac{(6350) \times (W)}{(N)}$ = $\frac{(6350) \times [\ ]}{[\ ]}$ = [ ] (g-mm)
Customary Units:
Umax = $\frac{(113.4) \times (W)}{(N)}$ = $\frac{(113.4) \times [\ ]}{[\ ]}$ = [ ] (g-in)
Calculate the trial unbalance (TU):
Trial Unbalance (TU) is between (1 x Umax) and (2 x Umax) (1 x) to (2 x) (Selected Multiplier is) [ ]
SI Units: [ ] to [ ] = [ ] (g-mm)
Customary units: [ ] to [ ] = [ ] (g-in)
Calculate the trial weight (TW):
Trial Weight (TW) = $\frac{Umax}{R}$ = $\frac{[\ ]\ \text{g-mm}}{[\ ]\ \text{mm}}$ or $\frac{[\ ]\ \text{g-in}}{[\ ]\ \text{in}}$ = [ ] (g)

Conversion Information:
1kg = 2.2046 lbs 1 ounce = 28.345 grams

Obtain the test data and complete the table:

Test Data

Position	Trial Weight Angular Location on Rotor (degrees)	Balancing Mach Readout Amplitude (grams)	Phase Angle (degrees)
1	0		
2	60		
3	120		
4	180		
5	240		
6	300		
Repeat 1	0		

Sketch the rotor configuration:

Rotor Sketch

PROCEDURE:
Step 1: Plot the balancing machine amplitude versus trial weight angular location on the polar chart (Figure 1.A-2) such that the largest and smallest values will fit.
Step 2: The points located on the Polar Chart should closely approximate a circle. If it does not, then it is probably that the recorded data it is in error and the test should be repeated.
Step 3: Determine the maximum and minimum balancing machine amplitude readings .
Step 5: Using the worksheet, (Figure 1.A-2), determine the Y and Z values required for the residual unbalance calculation.
Step 6: Using the worksheet, (Figure 1.A-2), calculate the residual unbalance remaining in the rotor.
Step 7: Verify that the determined residual unbalance is equal to or less than the maximum allowable residual unbalance (Umax).

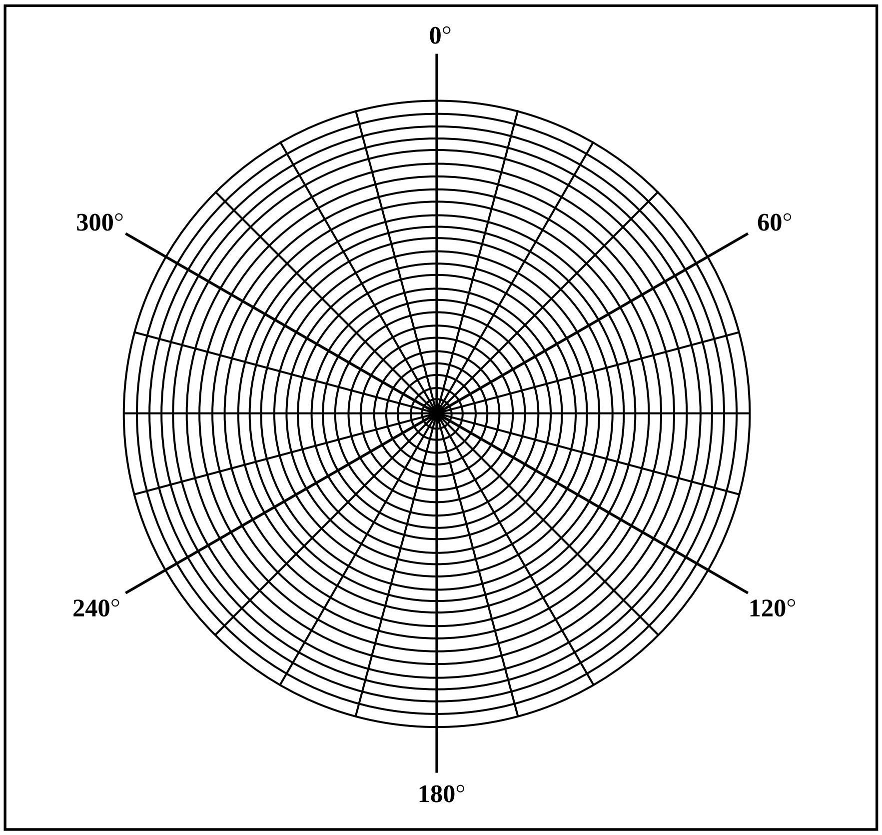
NOTES:
1) The trial weight angular location should be referenced to a keyway or some other permanent marking on the rotor. The preferred location is the location of the once-per-revolution mark (for the phase reference transducer).
2) The balancing machine amplitude readout for the Repeat of 1 should be the same as Position 1, indicating repeatability.
3) A primary source for error is not maintaining the same radius for each trial weight location.

Balanced By: ______ Date: ______
Approved By: ______ Date: ______

Figure 1.A-1—(Blank) Residual Unbalance Work Sheet

Customer: ______________________
Job / Project Number: ______________________
OEM Equipment S / N: ______________________
Rotor Identification Number: ______________________
Repair Purchase Order Number: ______________________
Vendor Job Number: ______________________
Correction Plane (Left or Right) - use sketch ______________________(plane)

RESIDUAL UNBALANCE POLAR PLOT



Rotor Rotation: ☐ CCW ☐ CW   Phase is layed out: ☐ CCW ☐ CW

Calculate Y and Z values:

Maximum amplitude value is:	☐	grams	Minimum amplitude value is:				☐ grams
Y = (Maximum - Minimum) / 2 (	☐	-	☐	)	/ 2	=	☐
Z = (Maximum + Minimum) / 2 (	☐	+	☐	)	/ 2	=	☐

Residual Unbalance Left in Rotor =	(TU)	x	(Y)	/	(Z)			
SI Units:	☐	x	☐	/	☐	=	☐	gm-mm
Customary Units:	☐	x	☐	/	☐	=	☐	gm-in

Allowable Unbalance Tolerance = Umax = ☐ gm-mm ☐ gm-in

RESULT: Residual unbalance left in the rotor is equal to or less than the allowable unbalance tolerance?

☐ As Received ☐ Final ☐ PASS ☐ Other: ☐ FAIL ______________

Balanced By: ______________________ Date: ______________________
Approved By: ______________________ Date: ______________________

Figure 1.A-2—(Blank) Residual Unbalance Polar Plot Work Sheet

Customer:	ABC Refining Co.	
Job / Project Number:	00 - 1234	
OEM Equipment S / N:	C - 1234	
Rotor Identification Number:	1234 - C - 4320	
Repair Purchase Order Number:	PO 12345678	
Vendor Job Number:	Shop - 00 - 1234	
Correction Plane (Left or Right) - use sketch	Left	(plane)

Balancing Speed	800	(rpm)		
Maximum Rotor Operating Speed (N)	6900	(rpm)		
Static Journal Weight Closest to This Correction Plane (W)	530.7	(kg)	1170	(lbs)
Trial Weight Radius (R) - the radius at which the trial weight will be placed	381	(mm)	15	(in)

Calculate Maximum Allowable Residual Unbalance (Umax):

Si Units:

$$\text{Umax} = \frac{(6350) \times (W)}{(N)} = \frac{(6350)}{6900} \times 530.7 = \boxed{488.4} \text{ (g-mm)}$$

Customary Units:

$$\text{Umax} = \frac{(113.4) \times (W)}{(N)} = \frac{(113.4)}{6900} \times 1170 = \boxed{19.2} \text{ (g-in)}$$

Calculate the trial unbalance (TU):

Trial Unbalance (TU) is between (1 x Umax) and (2 x Umax)

	(1 x)		(2 x)			
				(Selected Multiplier is)	1.6	
SI Units:	488.4	to	976.8	is	781.4	(g-mm)
Customary units:	19.2	to	38.5	is	30.8	(g-in)

Calculate the trial weight (TW):

$$\text{Trial Weight (TW)} = \frac{\text{Umax}}{R} = \frac{781 \text{ g-mm}}{381 \text{ mm}} \text{ or } \frac{31 \text{ g-in}}{15 \text{ in}} = \boxed{2.1} \text{ (g)}$$

Conversion Information:

1kg = 2.2046 lbs   1 ounce = 28.345 grams

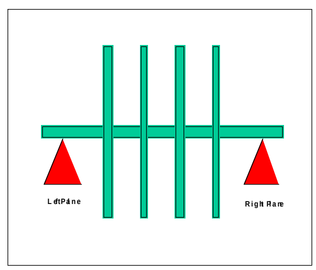
Obtain the test data and complete the table:

Test Data

Position	Trial Weight Angular Location on Rotor (degrees)	Balancing Mach Readout: Amplitude (grams)	Balancing Mach Readout: Phase Angle (degrees)
1	0	1.60	358
2	60	1.11	59
3	120	1.58	123
4	180	2.21	182
5	240	3.00	241
6	300	2.30	301
Repeat 1	0	1.58	359

Sketch the rotor configuration:

Rotor Sketch



PROCEDURE:

Step 1: Plot the balancing machine amplitude versus trial weight angular location on the polar chart (Figure 1.A-4) such that the largest and smallest values will fit.

Step 2: The points located on the Polar Chart should closely approximate a circle. If it does not, then it is probably that the recorded data it is in error and the test should be repeated.

Step 3: Determine the maximum and minimum balancing machine amplitude readings .

Step 5: Using the worksheet, (Figure 1.A-4), determine the Y and Z values required for the residual unbalance calculation.

Step 6: Using the worksheet, (Figure 1.A-4), calculate the residual unbalance remaining in the rotor.

Step 7: Verify that the determined residual unbalance is equal to or less than the maximum allowable residual unbalance (Umax).

NOTES:

1) The trial weight angular location should be referenced to a keyway or some other permanent marking on the rotor. The preferred location is the location of the once-per-revolution mark (for the phase reference transducer).

2) The balancing machine amplitude readout for the Repeat of 1 should be the same as Position 1, indicating repeatability.

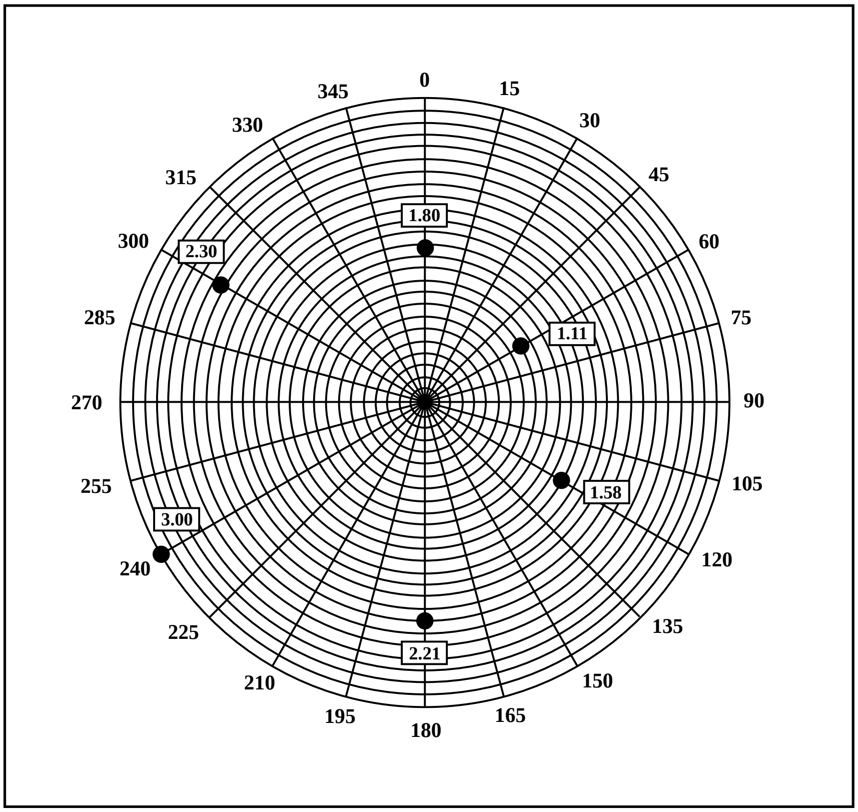
3) A primary source for error is not maintaining the same radius for each trial weight location.

Balanced By:	CJ, TR, & RC	Date:	5/24/00
Approved By:	CC	Date:	5/24/00

Figure 1.A-3—Sample Residual Unbalance Work Sheet for Left Plane

Customer:	ABC Refining Co.
Job / Project Number:	00 - 1234
OEM Equipment S / N:	C - 1234
Rotor Identification Number:	1234 - C - 4320
Repair Purchase Order Number:	PO 12345678
Vendor Job Number:	Shop - 00 - 1234
Correction Plane (Left or Right) - use sketch	Left (plane)

RESIDUAL UNBALANCE POLAR PLOT



Rotor Rotation: ☒ CCW ☐ CW   Phase is layed out: ☐ CCW ☒ CW

Calculate Y and Z values:

Maximum amplitude value is:	3.00	grams	Minimum amplitude value is:				1.11 grams
Y = (Maximum - Minimum) / 2 (	3.00	-	1.11	)	/ 2	=	0.9
Z = (Maximum + Minimum) / 2 (	3.00	+	1.11	)	/ 2	=	2.1

Residual Unbalance Left in Rotor =	(TU)	X	(Y)	/	(Z)	=		
SI Units:	781	X	0.95	/	2.06	=	359.3	g-mm
Customary Units:	31	X	0.95	/	2.06	=	14.1	g-in

Allowable Unbalance Tolerance = Umax = 488.4 g-mm 19.2 g-in

RESULT: Residual unbalance left in the rotor is equal to or less than the allowable unbalance tolerance? PASS

☐ As Received ☐ Final ☒ Other: w/o trim hardware

Balanced By:	CJ, TR & RC	Date:	5/24/00
Approved By:	CC	Date:	5/24/00

Figure 1.A-4—Sample Residual Unbalance Polar Plot Work Sheet for Left Plane

Customer:	ABC Refining Co.	
Job / Project Number:	00 - 1234	
OEM Equipment S / N:	C - 1234	
Rotor Identification Number:	1234 - C - 4320	
Repair Purchase Order Number:	PO 12345678	
Vendor Job Number:	Shop - 00 - 1234	
Correction Plane (Left or Right) - use sketch	Right	(plane)

Balancing Speed	800	(rpm)		
Maximum Rotor Operating Speed (N)	6900	(rpm)		
Static Journal Weight Closest to This Correction Plane (W)	571.5	(kg)	1260	(lbs)
Trial Weight Radius (R) - the radius at which the trial weight will be placed	203	(mm)	8	(in)

Calculate Maximum Allowable Residual Unbalance (Umax):

Si Units:

$$Umax = \frac{(6350) \times (W)}{(N)} = \frac{(6350) \times 571.5}{6900} = \boxed{525.9} \text{ (g-mm)}$$

Customary Units:

$$Umax = \frac{(113.4) \times (W)}{(N)} = \frac{(113.4) \times 1260}{6900} = \boxed{20.7} \text{ (g-in)}$$

Calculate the trial unbalance (TU):

Trial Unbalance (TU) is between (1 x Umax) and (2 x Umax)

	(1 x)	to	(2 x)	(Selected Multiplier is)	1.6	
SI Units:	525.9	to	1051.9	is	841.5	(g-mm)
Customary units:	20.7	to	41.4	is	33.1	(g-in)

Calculate the trial weight (TW):

$$\text{Trial Weight (TW)} = \frac{Umax}{R} = \frac{842 \text{ g-mm}}{203 \text{ mm}} \text{ or } \frac{33 \text{ g-in}}{8 \text{ in}} = \boxed{4.1} \text{ (g)}$$

Conversion Information:

1kg = 2.2046 lbs   1 ounce = 28.345 grams

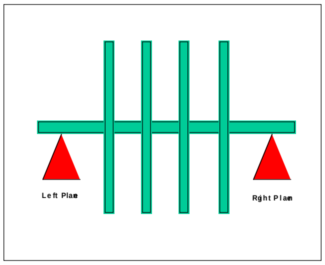
Obtain the test data and complete the table:

Test Data

Position	Trial Weight Angular Location on Rotor (degrees)	Balancing Mach Readout: Amplitude (grams)	Balancing Mach Readout: Phase Angle (degrees)
1	0	4.60	3
2	60	4.20	58
3	120	4.70	121
4	180	5.20	180
5	240	5.80	235
6	300	5.10	301
Repeat 1	0	4.60	2

Sketch the rotor configuration:

Rotor Sketch



PROCEDURE:

Step 1: Plot the balancing machine amplitude versus trial weight angular location on the polar chart (Figure 1.A-6) such that the largest and smallest values will fit.

Step 2: The points located on the Polar Chart should closely approximate a circle. If it does not, then it is probably that the recorded data it is in error and the test should be repeated.

Step 3: Determine the maximum and minimum balancing machine amplitude readings .

Step 5: Using the worksheet, (Figure 1.A-6), determine the Y and Z values required for the residual unbalance calculation.

Step 6: Using the worksheet, (Figure 1.A-6), calculate the residual unbalance remaining in the rotor.

Step 7: Verify that the determined residual unbalance is equal to or less than the maximum allowable residual unbalance (Umax).

NOTES:

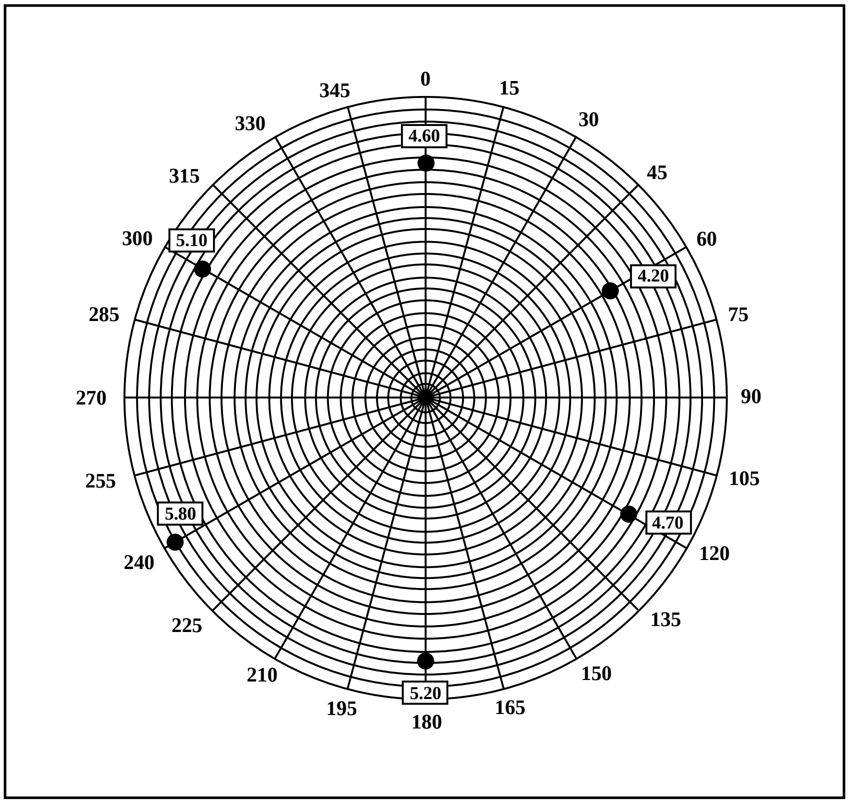
1) The trial weight angular location should be referenced to a keyway or some other permanent marking on the rotor. The preferred location is the location of the once-per-revolution mark (for the phase reference transducer).
2) The balancing machine amplitude readout for the Repeat of 1 should be the same as Position 1, indicating repeatability.
3) A primary source for error is not maintaining the same radius for each trial weight location.

Balanced By:	CJ, TR, & RC	Date:	5/24/00
Approved By:	CC	Date:	5/24/00

Figure 1.A-5—Sample Residual Unbalance Work Sheet for Right Plane

Customer:	ABC Refining Co.
Job / Project Number:	00 - 1234
OEM Equipment S / N:	C - 1234
Rotor Identification Number:	1234 - C - 4320
Repair Purchase Order Number:	PO 12345678
Vendor Job Number:	Shop - 00 - 1234
Correction Plane (Left or Right) - use sketch	Right (plane)

RESIDUAL UNBALANCE POLAR PLOT



Rotor Rotation: ☒ CCW ☐ CW

Phase is layed out: ☐ CCW ☒ CW

Calculate Y and Z values:

Maximum amplitude value is:	5.80	grams	Minimum ampltude value is:				4.20 grams
Y = (Maximum - Minimum) / 2 (	5.80	-	4.20	)	/ 2	=	0.8
Z = (Maximum + Minimum) / 2 (	5.80	+	4.20	)	/ 2	=	5.0

Residual Unbalance

Left in Rotor =	(TU)	x	(Y)	/	(Z)	=		
SI Units:	842	x	0.8	/	5	=	134.6	g-mm
Customary Units:	33	x	0.8	/	5	=	5.3	g-in

Allowable Unbalance Tolerance = Umax = 525.9 g-mm 20.7 g-in

RESULT: Residual unbalance left in the rotor is equal to or less than the allowable unbalance tolerance?

PASS

☐ As Received ☐ Final ☒ Other: w/o trim hardware

Balanced By:	CJ, TR & RC	Date:	5/24/00
Approved By:	CC	Date:	5/24/00

Figure 1.A-6—Sample Residual Unbalance Polar Plot Work Sheet for Right Plane

APPENDIX B—NON-DESTRUCTIVE EXAMINATION METHODS

B.1 General

Non-destructive examination is used to assure maximum reliability of equipment. The quality standards for materials have been set by various specifications and these standards must be met in repair activities. The individual in charge of major repairs to a component must make several choices among the variety of tests available as to which method of nondestructive examination offers the greatest sensitivity to indications. That individual also must be capable of correctly interpreting the results of those test methods.

One of the most critical concerns is that of correct interpretation. We tend to call anything that is noticed a “crack” or a “flaw.” The correct term is “INDICATION,” and it must be clearly understood that many “indications” are not flaws or cracks. A scratch or a pore may be irrelevant to the structural integrity or operation and should be left alone. Unnecessary and costly repairs are often performed in this regard.

Any indication should be investigated by polishing. If factory (OEM) acceptance criteria or standards are available, they should be consulted. Most acceptance criteria allow for a maximum size indication. Indications smaller than the criteria should not be repaired, unless in locations where the size criteria is not allowable.

The focus of NDE is to find those indications that are detrimental to the part or operation. The repair of non-relevant indications may cause more damage to the part than the indications could.

Many times it is better to leave well enough alone.

B.2 Liquid Penetrants

B.2.1 GENERAL

Cracks in wheel or impeller forgings probably have breathed; that is, they have opened and closed during heat cycles, drawing in moisture that has condensed in the cracks, forming oxides and filling cracks with moisture. This prevents penetration by crack detection solutions. To overcome this condition, all areas to be examined should be heated to about 120°C (250°F) and allowed to cool before application of the penetrant. These examinations require a smooth surface as any irregularities will trap penetrant and make it difficult to remove, thus giving a false indication or obscuring a real defect. Figure 1.B-1 illustrates the steps of using dye penetrant.

The vehicles for the penetrant, the cleaner and the developer are nonflammable. All three components should have low sulfur and chlorine content but after use on turbine blades (which are generally AISI 403 or 422 stainless steel) the penetrant and developer should be washed off with kerosene or some other solvent. Drinking water probably has more chlorine in it than the dye penetrant so don’t use ordinary water to wash the rotor. The reason for the concern about leaving a residue on the blading is that chlorine causes cracking in some stainless steels.

B.2.2 VISIBLE DYE PENETRANT

Liquid penetrant inspection is the most popular method for examining surface indications because of its simplicity. Penetrating oils containing a red dye are packaged in aerosol cans or bulk cans. The low surface property oil, when applied to a clean surface, penetrates surface indications such as cracks and pits. Indications are revealed by removing the excess oil and applying a developing powder. The indications are shown as a red line for cracks, red dots for pits, etc. This process works in aluminum, magnesium, bronze, tungsten carbide, plastics, ceramics, glass and other nonmagnetic solids. Furthermore, this process is not limited to non-magnetic materials, but the proper chemicals must be used for the materials being examined.

All penetrants are not created equal and some give better results than others. One should try several different brands and select the one that works best for your application. Because of the apparent simplicity, penetrants are frequently misused. Untrained personnel can over clean during excess penetrant removal and remove penetrant from the flaw. Also, too much developer can be applied which masks the indication.

B.2.3 FLUORESCENT DYE PENETRANT

In another technique, an ultraviolet light is used to view the surface. Fluorescent penetrating fluid is substituted for the visible dye penetrant. The same basic application procedures as described above are followed. After application of the penetrant fluid, visual inspection is done with ultraviolet light. The black light is not injurious to the eyes or skin but will make any of the fluorescent penetrating fluid glow in the dark. Other light, such as sunlight and electric lights should be excluded as much as possible. The “black light” causes the fluorescent fluid trapped in indications to glow in the dark. All indications should be circled with a chlorine free lumber marker, paint stick, or wax pencil.

Cracks and deep pinholes can usually be distinguished by the brilliance of the glow under the black light. On some occasions it is necessary to inspect the marked areas closely under ordinary light to determine the nature of the discontinuities or indications.

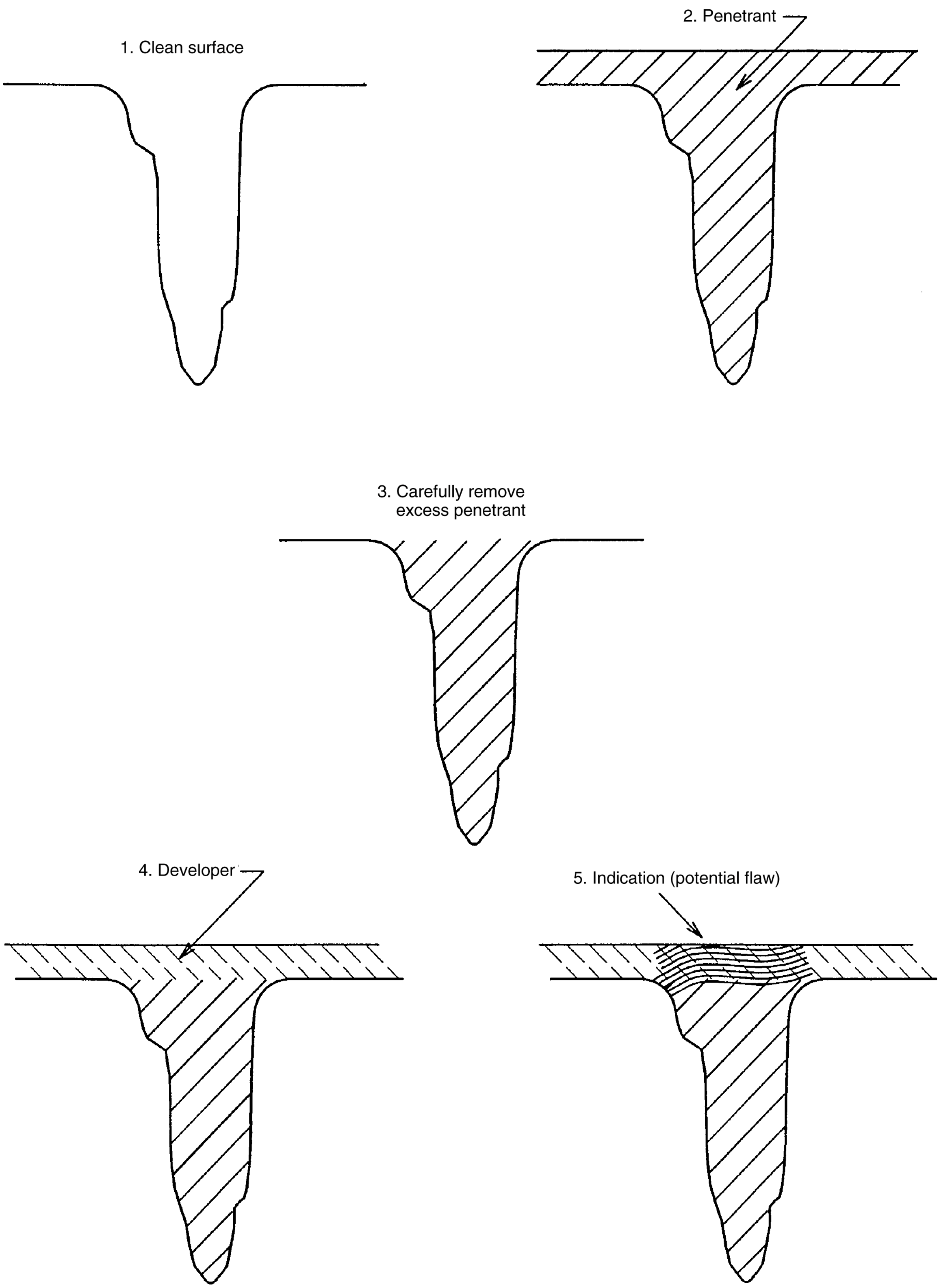


Figure 1.B-1—Steps in Liquid Penetrant Inspection

B.3 Magnetic Particle Inspection

Another method of checking for a defect is a magnetic particle check. This inspection method is used for detecting cracks and other discontinuities at or near the surface in ferromagnetic materials. There are two techniques, a dry one and a wet one.

B.3.1 DRY PROCESS

In the dry technique, finely divided magnetic particles are applied to the surface of a part that has been suitably magnetized. The particles are attracted to regions of magnetic nonuniformity associated with indications and discontinuities, thus producing indications either at or within $1^1/_4$ centimeters ($^1/_2$ in.), of the surface which are clearly visible. The magnetic particle power source requires 480 or 240 volt power. The high voltage input is changed to low voltage output by transformers located in the power source. The control box also contains selenium rectifiers to change the alternating current input to half-wave rectified current output. Heavy cables are used to connect the control box to the copper contact prods which are used to magnetize the material to be inspected. The contact prods can be mounted on a handle which maintains about 20 cm (8 in.) spacing or on handles for single prods. The handle is furnished with a control switch and cable to turn the current on. Magnetic particle powder can be applied with a rubber bulb or sprinkling. The dry process is preferable for rougher surfaces and sub surface indications. A maximum surface roughness for use of the process is 13 µm (500 µinch) Ra.

CAUTION: Prods can cause arc burns, and can also leave marks on the component.

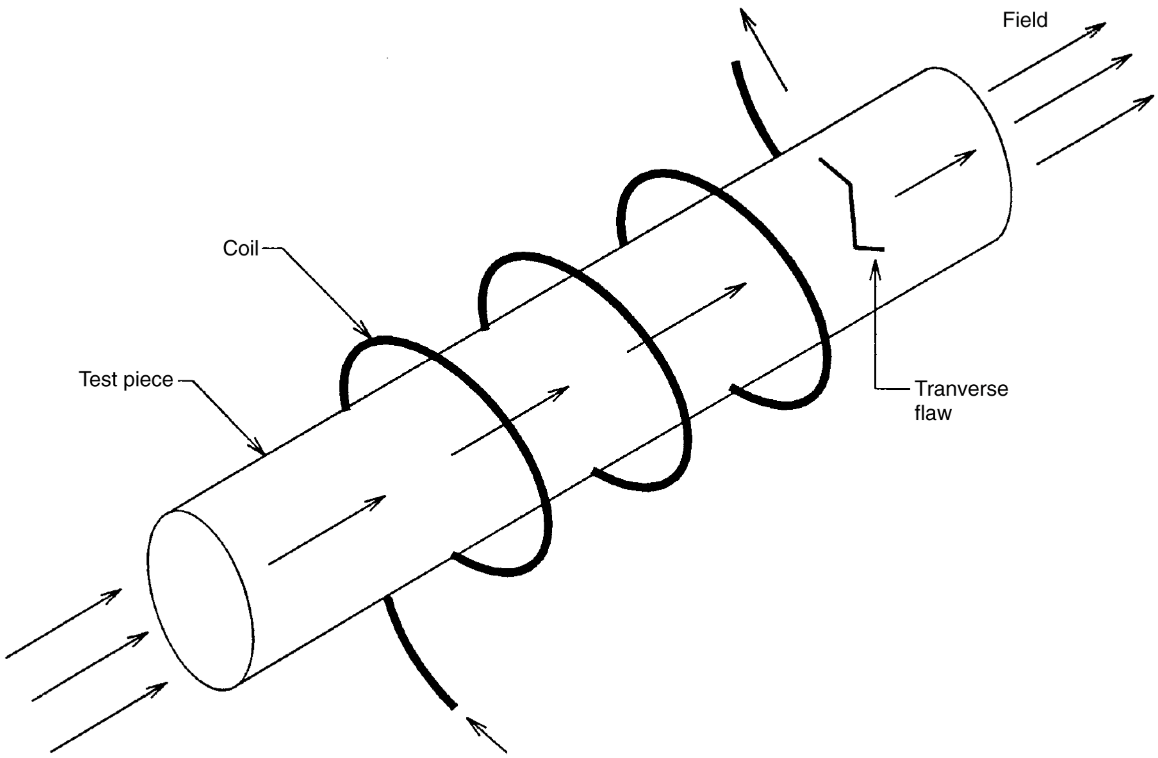
AC machines are also available, but alternating current field does not permit the detection of subsurface discontinuities. Only surface cracks or openings at the surface can be found by its use. The use of AC machines is not recommended. Direct current, on the other hand, penetrates more deeply into the cross-section giving maximum sensitivity for discontinuities lying below the surface. Deep-seated subsurface discontinuities can be found with the use of half wave direct current that cannot be found by ordinary direct current. Half-wave current consists of separate pulses of direct current with intervals during which no current at all is flowing. Each pulse lasts for $^1/_2$ cycle and the peak current is the same as the peak of the single phase alternating current which is being rectified. The average current, however, which is read on the DC meter, is only about a third of this peak current. Since power input and heating losses are more nearly a function of this average current, the system presents an advantage over either direct current, alternating current, or full-wave rectified alternating current in respect to size and cost of equipment necessary to produce comparable inspection results. Normally magnetizing currents of about 100 amperes per inch of prod spacing is required.

An important factor in successfully examining material regardless of the method of magnetization, is the selection of the proper level of magnetizing current. When the magnetizing current is too low, the magnetic field gradient around flaws is not of sufficient magnitude to reliably hold the magnetic particles in place. If the magnetizing current is too high, the magnetic field gradients may be of sufficient magnitude to attract and hold the magnetic particles even in flaw-free areas thereby masking genuine flaw indications. The optimum magnetizing current level and direction for finding various flaws is best verified by the use of the magnetic field indicator. The magnetic field, i.e., the lines of flux, tend to follow the path of least resistance and to squeeze around discontinuities which are parallel with the magnetic flux lines. Therefore, no magnetic particle indications occur when the flux lines are parallel to the indication. Indications only occur when the flux lines are interrupted. Generally, indications form when discontinuities are oriented between 45° to 90° in relation to the flux lines. Figure 1.B-2 shows some typical techniques.

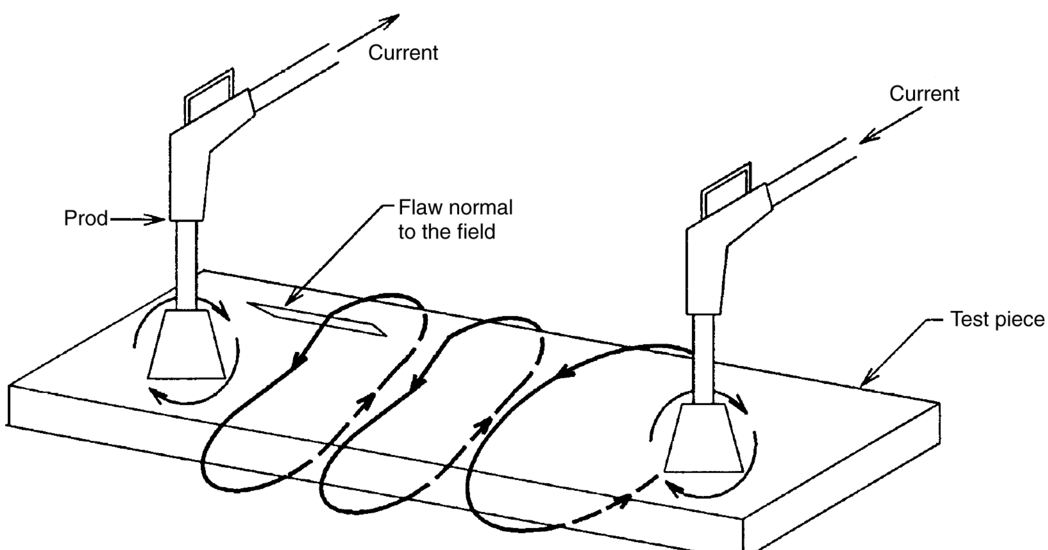
B.3.2 WET PROCESS

This process is similar to dry magnetic particle except the particles used in the wet-method are coated with a dye which causes them to fluoresce brilliantly when exposed to Ultraviolet or near Black light. The purpose of this dye is to provide maximum contrast between the indications and the background so that fine discontinuities can be observed more readily and quickly. The equipment required is not highly portable so the process is usually confined to shop applications with large tanks employed to “wet” the surfaces. Properly utilized, this is the ultimate test for metallurgical indications in a component. A maximum surface roughness for use of the process is 6.3 µm (250 µinch) Ra.

The application of magnetic particles for the wet method should be applied by either spraying or flowing it over the areas to be inspected or by dipping the part in an agitated bath of the inspection medium. In the “continuous” method the indicating medium is applied while the magnetizing force is present. With this method, the magnetizing field is at a maximum when the bath is applied. This provides the maximum sensitivity. A film of the inspection medium must cover all surfaces to be inspected at the time the magnetizing current is being applied. The magnetizing current must flow for a minimum period, usually about $^1/_2$ sec. If a high velocity flow bath is permitted after the magnetizing current has been removed, fine or weakly held indications may be washed away or obliterated. This is particularly true on highly finished or polished surfaces, but less critical on rough surfaces such as as-forged and as-cast.



Coil Around Test Piece



Use of Prods

Figure 1.B-2—Principles of Magnetic Particle Inspection

B.3.3 GENERAL

B.3.3.1 Cleaning Required for Both Processes

The materials to be inspected shall be dry and free of oil or other foreign material.

Note: Some liquid cleaning methods may result in an oil film that must be removed. After abrasive cleaning, all evidence of cleaning media, dust, oxide, or debris must be removed.

B.3.3.2 Precautions For Use of Magnetic Field

Since poor indications are produced when discontinuities are perpendicular to the current flow (parallel to the magnetic field) the parts shall be magnetized in at least two different directions approximately at right angles to each other. To produce satisfactory indications, the magnetic field in the part must have sufficient strength. For the indications to be consistent, this field strength must be sufficient to develop the pattern of the field indicator (pie gauge) over the entire area to be examined.

As this inspection method induces a magnetic field in the component, care must be taken to ensure that the component is demagnetized (degaussed) to a maximum level of ±2 gauss residual magnetism. If left magnetized, the components could be damaged. Residual magnetism in the shaft vibration probe track area could also adversely affect the vibration signal.

B.3.3.3 Surface Condition

Maximum sensitivity can only be achieved on a smooth surface. This is often not possible or practical. A light grinding of the suspect surface or in most cases just a good wire brushing brings about considerable improvement.

B.3.3.4 Spacing of Prods

For most applications, spacing of 15 to 20 centimeters (6 to 8 inches) are most effective.

B.3.3.5 Temperature of the Surface being Inspected

1. Wet magnetic particle work should not be performed on surfaces above 60°C (140°F).

CAUTION: Above this temperature may cause flashing of the penetrant.

2. Dry magnetic particle work should not be performed on surfaces above 315°C (600°F).

B.3.3.6 Orientation of indications

When using prod type contacts, elongated indications will be revealed on a line between the prods, and at small angles to that line. Indications at 90° to a line between the prods will not be indicated.

B.4 Ultrasonic Inspection

Ultrasonics is capable of economically revealing sub-surface discontinuities in a variety of materials and shapes. A piezoelectric crystal is excited with a high voltage pulse, causing the crystal to vibrate and emit a short pulse of sound introduced into the test material. The sound travels through the material and is reflected back to the crystal from the opposite side or from any location in the material where there is an abrupt change in acoustic impedance. The crystal converts the sound vibrations to electrical energy and the reflected pulse is displayed on a Cathode-Ray Tube (CRT). Signal amplitude and elapsed time are very important. Knowledge of the sound beam angle and elapsed time permits the flaw to be located. Ultrasonic inspection is particularly useful when only one surface of the test item is accessible, when heavy sections of material must be inspected for internal flaws, or when results must be immediately available. Another advantage of ultrasonic inspection is that reflections from indications can provide specific information regarding size and distance from the surface of the indication. Ultrasonic inspection has disadvantages too; (1) the test surface must be relatively smooth, and (2) the couplant used between the crystal and the material limits its use to under 55°C (130°F). Surface indications will not be detected because of near field signals.

B.4.1 STRAIGHT-BEAM TECHNIQUES

The straight-beam technique is accomplished by projecting a sound-beam into the test specimen perpendicular to the test surface to obtain reflections from the back surface or from discontinuities. The crystal in most cases acts as both transmitter and receiver of the sound-beam. The straight-beam technique is also used to inspect steel plate for laminar indications. This method works well on shafting material.

B.4.2 ANGLE-BEAM TECHNIQUES

The angle-beam technique is used to transmit sound waves into the test material at a predetermined angle to the test surface. Crystals that produce shear-waves are usually used for angle-beam testing. The sound-beam enters the test material at an acute angle and proceeds by successive zigzag reflections from the specimen boundaries. When interrupted by a discontinuity or boundary, the beam reverses directions and is reflected back to the crystal. Angle-beam techniques are used for testing welds, pipe or tubing, sheet and plate material, and for specimens of irregular shape.

B.5 Measuring Hardness

While hardness is not considered a fundamental property of matter, its consideration with regard to metals and alloys is of great engineering importance. With the hardness of a metal known, an insight is available into its tensile strength, ductility, yield point, resistance to abrasion, etc.

B.5.1 BRINELL SCALE

The term "hardness" is ambiguous; glass will scratch hardened steel, but would never do as a machine tool. The hardness data of any material is only valid when the particular type of hardness test is understood. There are several scales to indicate just how hard or soft a specific material is. One method was devised by Dr. J. A. Brinell of Sweden in 1900. He reasoned that the hardness of a metal could be determined by measuring the diameter of an impression made by a steel ball forced into the metal under definite static loads by means of hydraulic pressure. A scale of Brinell numbers is based on the diameter of the indentation, and the hardness of the metal on this scale also shows the approximate ultimate tensile strength.

B.5.2 ROCKWELL SCALE

Other hardness scales are the Rockwell series. This direct-reading hardness tester measures the "differential-depth" when first using a small primary load, a larger secondary load, and then returning to the primary or initial load. This system gives the advantage of eliminating any errors due to mechanical limitations of the tester (backlash, etc.) and errors caused by non-uniform surface imperfections of the specimen being tested. The two standard penetrators most often used are a 1.5 mm ($^1/_{16}$ inch) diameter hardened-steel ball which, when given a major load of 100 kgf, is called the "B" scale; and a diamond (Brale) penetrator which, when given a major load of 150 kgf, is called the "C" scale. There are 13 other arbitrary hardness scales that will define the hardness of almost any engineering material. To obtain the Rockwell hardness, an initial load of 10 kgf is applied (shown as "set" position on the dial). The major load is then applied, released, and the initial load is reapplied. The hardness number is read from either the red or black scale, depending on the type of penetrator and the load. A Rockwell number without a letter has no meaning because the scale is not defined.

B.5.3 CONVERSION OF SCALES

The hardness table in Figure 1.B-3 compares the equivalent hardness numbers for Rockwell "C" with Brinell numbers using a carbide ball with 3000 kgf load.

Example: A Brinell number of 237 is equal to 22 Rockwell "C".

B.6 Alloy Analyzer

To aid in determining the materials used in shafts, impellers for compressors and turbine wheels; etc.; an alloy analyzer is almost a "must" tool. An alloy analyzer is a microprocessor based instrument designed for rapid, nondestructive, on site verification of "type" and "elemental" composition of important materials used in turbomachinery. The total instrument weighs under twenty pounds, is battery operated, and the probe weighs about two and one half pounds. The operator need not have knowledge of metallurgy because industry standard names are displayed by the instrument and there is no interpretation involved. The microprocessor takes all the judgement out of data interpretation. The unit library comes from the factory loaded with about 200 alloys of Fe, Cu, Co, Ni, and Al bases. Up to 25 user-defined alloys may be added to the library. Very little sample preparation is necessary. Analysis time takes about two minutes. The analyzer provides a direct readout of alloy type and percent element concentration. For example, an identification measurement is performed on a specimen of AISI 4340, the display will indicate "4340" if the material is within specification. Accuracy is generally within ±0.5% for most of the common alloying materials. If no positive identification is made, the nearest match is shown on the screen. The analyzer probe can be used on surfaces up to 575°C (1000°F) with an adapter. There are several analyzer designs available.

Some identification trouble may be encountered with older forged steam turbine rotors where numerous "proprietary" alloys were used.

Figure 1.B-3—Equivalent Hardness Table

Brinell Hardness				Rockwell Hardness			RC Superficial Hardness Superficial Brake				
Diameter Ball 10 mm	Tungsten Carbide Ball 3000 KG	500 KG load	Diamond Pyramid Hardness (Victors)	A Scale 50 KG	B Scale 100 KG	C Scale 150 KG	15-N Scale 15-KG load	30-N Scale 30-KG load	45-N Scale 45-KG load	Tensile Strength (approx.) in 1000 psi	Brinell Diameter Ball 10 mm
3.35	331	55.1	350	68.1	—	35.5	78.0	55.4	37.8	166	3.35
3.40	321	53.4	339	67.5	—	34.3	77.3	54.3	36.4	160	3.40
3.45	311	51.8	328	66.9	—	33.1	76.7	53.3	34.4	155	3.65
3.50	302	50.3	319	66.3	—	32.1	76.1	52.2	33.8	150	3.50
3.55	293	48.9	309	65.7	—	30.9	75.5	51.2	32.4	145	3.55
3.60	285	47.5	301	65.3	—	29.9	75.0	50.3	31.2	141	3.60
3.65	277	46.1	292	64.6	—	28.8	74.4	49.3	29.9	137	3.65
3.70	269	44.9	284	64.1	—	27.6	73.7	48.3	28.5	133	3.70
3.75	262	43.6	276	63.6	—	26.6	73.1	47.3	27.3	129	3.75
3.80	255	42.4	269	63.0	—	25.4	72.5	46.2	26.0	126	3.80
3.85	248	41.3	261	62.5	—	24.2	71.7	45.1	24.5	122	3.85
3.90	241	40.2	253	61.8	100.0	22.8	70.9	43.9	22.8	118	3.90
3.95	235	39.1	247	61.4	99.0	21.7	70.3	42.9	21.5	115	3.95
4.00	229	38.1	241	60.8	98.2	20.5	69.7	41.9	20.1	111	4.00
4.05	223	37.1	234	—	97.3	20.0	—	—	—	—	4.05
4.10	217	36.2	226	—	96.4	18.0	—	—	—	105	4.10
4.15	212	35.3	222	—	95.5	17.0	—	—	—	102	4.15
4.20	207	34.4	218	—	94.6	16.0	—	—	—	100	4.20
4.25	201	33.6	212	—	93.8	15.0	—	—	—	98	4.25
4.30	197	32.8	207	—	92.8	—	—	—	—	95	4.30
4.35	192	32.0	202	—	91.9	—	—	—	—	93	4.35
4.40	187	31.2	196	—	90.7	—	—	—	—	90	4.40
4.45	183	30.5	192	—	90.0	—	—	—	—	89	4.45
4.50	179	29.8	188	—	89.0	—	—	—	—	87	4.50
4.55	174	29.1	182	—	87.8	—	—	—	—	85	4.55
4.60	170	28.4	178	—	86.8	—	—	—	—	83	4.60
4.65	167	27.8	175	—	86.0	—	—	—	—	81	4.65
4.70	163	27.1	171	—	85.0	—	—	—	—	79	4.70
4.80	156	25.9	163	—	82.9	—	—	—	—	76	4.80
4.90	149	24.8	156	—	80.8	—	—	—	—	73	4.90
5.00	143	23.8	150	—	78.7	—	—	—	—	71	5.00
5.10	137	22.8	143	—	76.4	—	—	—	—	67	5.10
5.20	131	21.8	137	—	74.0	—	—	—	—	65	5.20
5.30	126	20.9	132	—	72.0	—	—	—	—	63	5.30
5.40	121	20.1	127	—	69.8	—	—	—	—	60	5.40
5.50	116	—	122	—	67.6	—	—	—	—	58	5.50
5.60	111	—	117	—	65.7	—	—	—	—	56	5.60

APPENDIX C—MAIN DRIVE COUPLINGS

C.1 Scope

This Appendix is to cover the minimum requirements pertaining to the main drive coupling(s) for the train. These couplings have usually been specified utilizing the Special Purpose Coupling Specification, API 671. This Appendix may be used as a stand-alone type of document allowing it to be used separately from the remaining portions of this document, API 687, or along with the additional sections in this document.

C.1.1 GENERAL

Prior to performing maintenance on the coupling assembly, the manufacturer's drawing and information are to be consulted to assist with the procedures in this appendix. If no information is available from the manufacturer, the procedures outlined in this appendix can be used as a guide.

It is very important to note the coupling arrangement and how the coupling was installed prior to its removal. Observe for any parts that may be missing or assembled incorrectly which may be causing a problem that will be detected later during the disassembly and inspection.

On tapered shaft ends verify that there is sufficient overhang of the hub on the shaft to accommodate the axial pull-up and verify that the retaining nut will bottom against the hub and not the shaft.

A coupling assembly typically has three major components, a center assembly and two hubs. This appendix covers both the gear style and dry type with discs or diaphragms.

C.2 Disassembly

C.2.1 CENTER ASSEMBLY

When disassembling the center assembly, observe the coupling drawing's information pertaining to:

a. Bolts and nuts possibly being matched sets.

b. Match marks for proper orientation.

c. Placement of shims.

d. Thickness of shims for each end.

e. Installation of a pilot guard.

f. Installation of bolting and nuts.

g. Usage of methods to disengage the pilot fits.

h. Usage of hubs or integral flange.

Note: Some center sections are factory assembled and should not be disassembled. Manufacturer's instructions should be consulted.

C.2.2 HUBS

C.2.2.1 General

Prior to removing a hub from the shaft, the type of installation shall be known. Consult the manufacturer's drawing and information. In most situations, the coupling hub will be either a keyed style with one or two keys, a hydraulic fit with or without any keys or an integral flange. Prior to removing the hub, the axial placement of the hub on the shaft is to be measured for a positioning reference.

C.2.2.2 Non Hydraulic, Tapered or Straight, Hubs

When removing the hub from a straight or tapered shaft without hydraulic removal, the hub may require heating in order to remove it from the shaft. Puller holes are typically supplied in the hub for using a puller arrangement. A minimum of B-7 material and 2H nuts should be used in the puller assembly. The puller shall be capable of pulling the hub the entire distance without having to stop to reorient the puller assembly. This pulling distance for a straight bore is the entire length of the coupling hub. This pulling distance for a tapered fit hub is usually the axial pull-up distance utilized during the hub assembly process. The puller is to be utilized first with the force applied evenly utilizing the puller holes. If the puller will not remove the hub, then heat may be required in addition to the force from the puller. A heating torch or steam may be used. The manufacturer's information is to be consulted to ensure that the heat will not cause any damage. When a torch is used, the rotor shall be in a location where a flame is safe to use. When using a heating torch, a tip that will spread out the flame is typically used. Heat should be applied evenly to the outer area of the coupling hub. Do not allow the heat to be concentrated in one area. The heat shall be applied very quickly so that the heat does not soak into the shaft. Generally, the coupling hub will not have to be heated over 150 to 200°C (300 to 400°F). If the hub does not break loose with a few minutes of the hub being heated, then the hub will probably not come off due to the shaft heating. There will be some heat that the shaft absorbs and wet rags around the shaft may assist in minimizing the possibility of damage to other components on the shaft from the heat. Caution, when the hub has the flex members installed, do not heat in the location of these flex members.

CAUTIONS:

- *THE RELEASE FOR TAPER HUBS MAY BE SUDDEN AND NOISY. DO NOT STAND NEAR THE PATH OF THE COUPLING HUB BEING REMOVED.*
- *Excessive localized heat may damage coupling components.*

- *A torch shall be used in an area where it is safe to use.*
- *Wet rags will eventually dry and may burn.*
- *Do not heat the flexible members.*

C.2.2.3 Tapered Hydraulic Fit Bore

When removing a tapered hydraulic fit hub, the hub shall be expanded by using a hydraulic fluid pressurizing device. A hydraulic fluid pressure is used to expand the hub bore and another hydraulic fluid pressure device is typically used to control the movement of the hub axially on the shaft. The hub shall move approximately the axial pull-up distance. The manufacturer's procedure is to be followed, if available. The recommended maximum pressures are not to be exceeded. Excessive pressure may cause personal harm, shaft threads may be sheared, or the hub may be over stressed and damaged. If no procedure is available from the manufacturer, the following procedure can be used as a guide to remove the hydraulic fit coupling hub:

a. Remove the shaft end nut with a spanner wrench. Observe the correct direction for loosening.

b. Observe scribe marks (hub to shaft) for movement. If there is any movement, then the hub may have spun on the shaft.

c. Clean the connections on the hub or shaft for the hydraulic fluid pressure connections.

d. Use a depth micrometer to measure the installation position and record this measurement for reference.

e. Install a dial indicator to provide an indication of the amount and when the hub moves.

f. Install the hydraulic nut device onto the shaft end to control the hub movement during removal. This device is to control the coupling hub axial travel during removal.

g. Connect the hydraulic fluid pressurizing tools, one for expanding the hub and one for controlling the axial movement and bleed out any air from both systems.

h. Apply pressure to allow the nut to touch the coupling hub. This nut will provide a cushion for the impact of the coupling hub being removed suddenly. Close the valve to maintain about 700 kPA (100 PSIG). Observe for any leaks. Continue to slowly increase the pressure to about 4000 to 5500 kPA (600 to 800 PSIG) to provide for the cushioning.

i. Increase the pressure on the hub expanding hydraulic tool to about 700 kPA (100 PSIG). Observe for any leakage. Observe the dial indicator for any movement and watch the hydraulic pressure for the axial movement tool.

CAUTION: The release may be sudden and noisy. Do not stand near the path of the coupling hub being removed.

j. Slowly increase the pressure on the expanding hydraulic tool until the hub expands enough to allow it to be moved. The expanding pressure is to be increased in steps of a maximum of 70,000 kPA (10,000 PSIG) for each step. Each increase in pressure step is to be held for a minimum of 5 minutes before increasing to the next step. Typically, 280,000 kPA (40,000 PSIG) will be enough to expand the hub enough for removal. The hub will be released from its taper when the dial indicator indicates an axial movement and the axial hydraulic tool pressure increases. At this point, the hydraulic nut is holding the coupling hub from coming off of the taper shaft.

k. Slowly decrease the pressure from the axial hydraulic tool to let the hub slide down the taper. The hub expanding pressure may decrease as this axial movement occurs and may need to be increased to a maximum of the prior pressure. Continue to decrease the axial pressure until the hub is released from the taper. At this point, the hub can be rotated freely by hand. Typically, the hub will come off the taper very quickly and with a loud pop.

l. Record the pressures used for expanding of the hub and for the hub axial controlling pressure.

m. Remove the tools and the fittings and store properly.

PRECAUTIONS:

The hydraulic pressure is very high and is very dangerous. The hub will come off the taper with substantial force that MUST be stopped safely. The hydraulic pressurizing devices are not to be placed in line with the hub and are to be arranged so that a 90° elbow is used to keep the user out of the leak or removal path. Use the tooling and fittings as specifically designed for coupling hub removal and installation.

C.3 Inspection

C.3.1 GENERAL

The coupling model and serial number and any other unique part number are to be recorded. All of the components should have their condition, concerns, or indications recorded for future use. Photographs are very important to this documentation. Review of the inspection data should be done to determine acceptability for future service. Any situation that may affect form, fit, or function should be noted and reviewed. NDE inspections such as magnetic particle or dye penetration inspections may be used. If at any time there is a question of the integrity of any component, a qualified vendor may be consulted. Refer to API 671 for critical dimension locations.

Prior to cleaning of any components, notice the condition and any unusual indications. After the initial inspections, the coupling components are to be thoroughly cleaned to provide a complete inspection. Cleaning may consist of a solvent wash, with or without the use of a fine scouring pad type material. Cleaning by blasting may cause damage to the flexible members, damage to precision machined components, or allow for the leaving of particles that would interfere with the coupling's performance and torque capability. Multiple element discs or diaphragms are much more difficult to prevent debris from being trapped in between the discs or diaphragms compared to a single element. Care is to be used during the handling of the flexing discs or diaphragms to prevent them from being damaged. Some manufacturers use a special type paint that will show signs of damage. This paint is not to be removed unless by the manufacturer. The recommendations for the inspections as described in this section C 3.0, may be done in the field or the shop as the user chooses. Some of the inspections may be done using specialized equipment to positively determine some of the dimensions and concentricity. In order to perform a complete inspection, the coupling assembly may need to be completely disassembled. The complete disassembly shall be done at a shop that is knowledgeable in these techniques.

In general, the inspection is to include as a minimum, observance of/for:

a. Rusting, pitting or other corrosion damage.

b. Condition of the bolt holes (roundness).

c. Condition of grease for grease lubricated couplings.

d. Condition of each flange for any raised areas around the bolt holes or the flange edges from bolt damage or improper disassembly techniques.

e. Bent windage flanges (shrouds) (these may fail and introduce an imbalance that may result in a failure).

f. Residual magnetism (gauss).

g. Cracked welds.

h. Loose components.

i. Any distortion.

j. Cracks in the keyway area.

C.3.1.1 Inspection Intervals

A decision should be made on the intervals for the inspections and replacements of the coupling assemblies. It is recommended that whenever a rotor is removed from service, or any indications from C 3.1 a-j are discovered, then the spare coupling, if it exists, is to be placed into service and the removed coupling is to be inspected and repaired as necessary. When a spare coupling does not exist, coordination with a shop is beneficial to complete the inspections and necessary repairs in the required time. The decision on the extensiveness of the inspections are to be based on a minimum of:

a. The coupling style.

b. Previous history.

c. Known history from coupling manufacturer.

d. Plant requirements.

e. Operating information.

f. Time from last inspection and repair.

g. Results from the inspections from section C 3.1.

h. Coupling environment.

C.3.1.2 Selection of the Inspection/Repair Shop

This document may be used in the selection of the shop for the coupling inspection and possible repairs. The coupling is precisely designed, manufactured and balanced as an assembly. The repair shop's knowledge of the inspection and repairs required for couplings are to be reviewed by the user. The extensiveness of the inspections and repairs are to be mutually agreed upon. The inspection and repair shop may or may not be the same shop doing the rotor inspections and repairs.

C.3.2 GEAR STYLE COUPLINGS

A gear style coupling typically consists of a spacer assembly and a flexible assembly consisting of a hub and sleeve for each end. The center assembly may serve as a limited end float style to minimize the axial travel of a rotor. The assembly may be match marked for maintaining the desired balance quality. The inspection is to observe or perform, as a minimum:

a. Cracks in a tooth.
b. Broken tooth.
c. Fretting.
d. Electrical spark discharge.
e. NDE inspection of the hub(s), sleeve(s), and the teeth area.
f. Limited end float capability of minimizing the axial travel of the rotors.
g. Wear.
h. Corrosion, including the spacer bore due to moisture in the lube oil.

C.3.3 DRY STYLE COUPLINGS

A dry type coupling typically consists of a center assembly and a hub on each end. The design of the coupling will determine if the flexing discs or diaphragms are located on the spacer assembly or the hubs. The center assembly for a dry style coupling usually has several components: discs, or diaphragms, at each end and a torque tube separating the discs or diaphragms. The specific design of the coupling will determine how extensive the assembly is capable of being inspected. A visual examination is to include as a minimum the observance for:

a. Loosened paint or coating.
b. Scratches on the discs or diaphragms.
c. Dents in the discs or diaphragms.
d. Cracked discs or diaphragms.
e. Deformed discs or diaphragms.
f. Twisted components.
g. Corrosion.
h. NDE.

CAUTION: Some disc and diaphragm couplings have assemblies that are factory assembled. Refer to the manufacturer's instructions before disassembling the subassemblies.

C.3.4 HUBS

The hubs are to be observed for indications such as burrs, nicks, raised edges, the condition of any setscrew and puller holes, and the condition of the threads. The face of the hub should be flat and any raised areas are to be dressed with a hone. The "O" ring grooves for keyless style hubs should be inspected to ensure that there are no sharp edges that may produce stress riser areas on the shaft. The grooves are to be clean and free from any burrs. The holes for the hydraulic fluid are to be clean and the threads are to be checked. The flanges are to be inspected for flatness. Each keyway area is to be inspected for metal distortion and the entire hub is to have an NDE performed.

The hub bore dimensions are to be compared to the drawing and the shaft to ensure that the proper interference fit will result. The inspection of the hub bore is to include (see Figure 1.C-1):

a. Diameter.
b. Bore and pilot fits are concentric.
c. Sides of taper are straight, does not have a bulge or bow.
d. Keyway dimensions.
e. Piloting feature condition.

C.3.5 KEY(S) AND KEYWAY(S)

Key(s) are to be inspected for:

a. Fit into the hub and shaft.
b. Dimensions.
c. The key corners shall not interfere with the keyway corners.
d. Clearance of the key to the keyway is to provide for a snug side fit and 100 to 150 µm (0.004 to 0.006 in.) on the top of the key.
e. Evidence such as lines from overstressing.
f. For multiple key applications, the keys are marked for the keyway location.

The proper key is a stepped key that fills the entire void area of the shaft and the coupling hub. The key extension beyond the coupling keyway is to be contoured (crowned) to the shaft. This key design is critical to the balance quality. With approval of the owner, an equal mass designed key may be mutually agreed upon. Stress risers are to be avoided.

C.3.6 BOLTS/NUTS

It is recommended that the bolt and nut sets be replaced with a new set for final assembly whenever the spool piece has been removed. The bolts and nuts are typically obtained in weight matched sets and are not to be interchanged between sets.

When the coupling is being inspected separately, the manufacturer's drawing and information should be followed when available.

If no information exists from the manufacturer, the following should be considered for the bolt:

a. Shank condition for signs of wear.
b. Thread area for necking.
c. Thread damage.
d. Part of a balanced set or matched for a specific hole.

If no information exists from the manufacturer, the following should be considered for the nut:

a. Self locking feature condition.
b. Lack of a minimal resistance when installing on the bolt (consult drawing for minimal torque resistance).
c. Thread damage.
d. Part of a balanced set or matched for a specific hole.

The bolt and nut sets may have originally been matched marked for specific holes. It is recommended to modify this arrangement to provide for bolt sets and nut sets to be individually weight balanced as sets.

CAUTION: Most coupling connections use special bolting. Replacement hardware is to be per the manufacturer's recommendations. Common hardware will usually not maintain the balancing quality and the torque capability.

C.3.7 COUPLING GUARD

The coupling guard is to be inspected for its integrity and strength. Welds may have cracked due to resonance or windage. The drain from the guard is to be clean and open. If a vent is part of the assembly, it shall be clean and in good condition. Some coupling guards have seals that are to be inspected for their integrity and their dimensional condition.

C.3.8 SHAFT ENDS

Refer to Chapter 1, paragraph 7.2.6.4 for the shaft end inspections.

C.4 Checking Fit of Shaft Ends, Coupling Hubs, Gauges, and Lapping Tools

C.4.1 GENERAL

The hub bore surface finish is to be a maximum of 1.6 µm (63 µinch) Ra for keyed (tapered or straight) and 0.8 µm (32 µinch) Ra for keyless and a minimum of 0.3 µm (10 µinch) Ra. The hub bore should be dimensionally verified and recorded in accordance with the Figure 1.C-1 in this appendix.

Note: The shaft end is to be dimensionally verified per Chapter 1, paragraph 7.2.6.4.

C.4.2 TAPER APPLICATIONS

The resulting contact percentages of the components for taper applications are to be per Table 1.C-1.

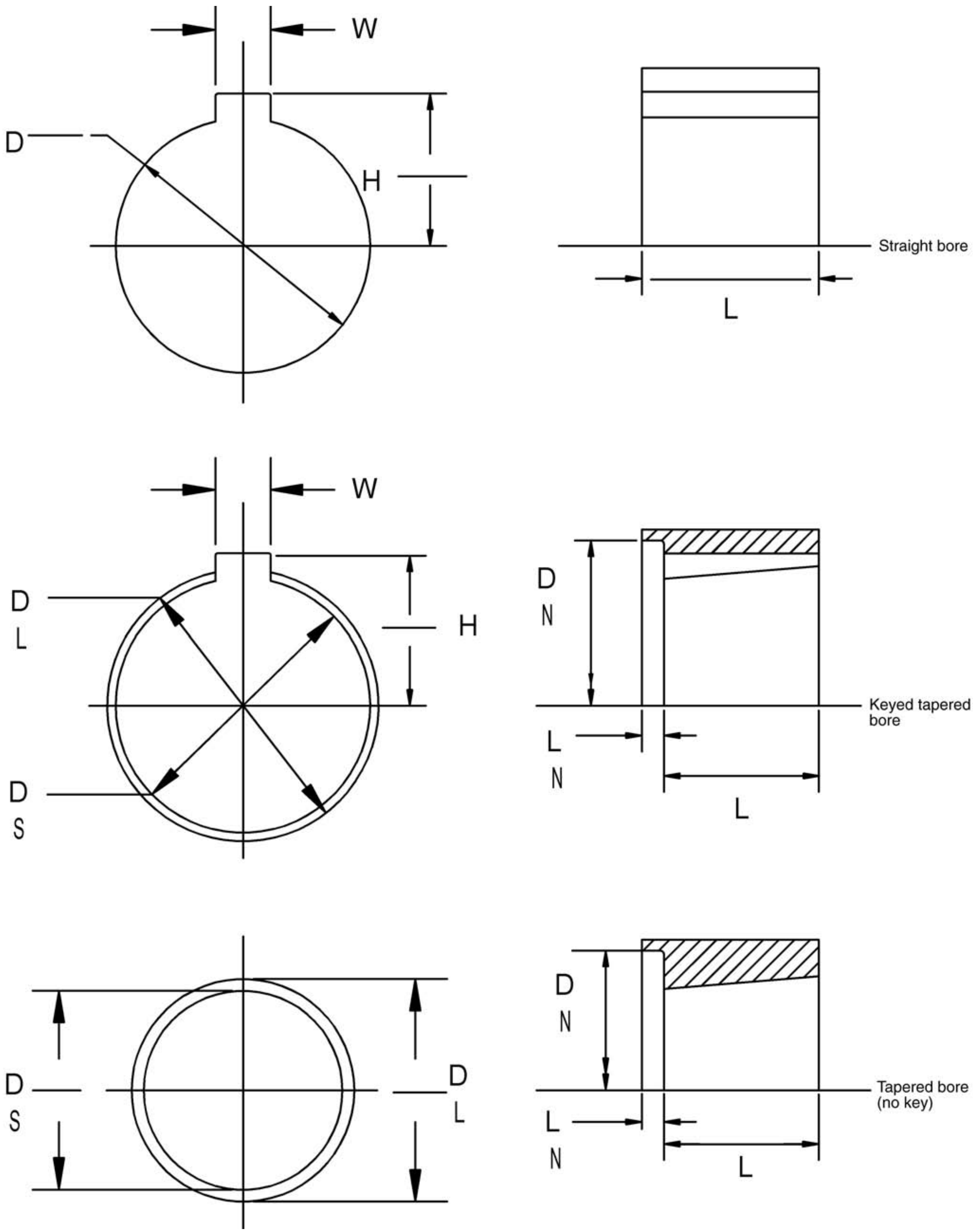


Figure 1.C-1—Hub Dimensional Measurements

Table 1.C-1—Minimum Contact

Components	Resulting Contact Minimum Percentages
Hub to shaft	75%
Gauge to Gauge, Lapping to Lapping, Gauge to Lapping	95%
Gauge to hub or shaft	85%

Notes:

1. Keyways, oil distribution grooves and "O" ring grooves are not included in the percentages.
2. The area around the keyway(s) are to be closely observed for high spots.
3. The length of these gauges should be verified that they are long enough to properly verify the entire area of the coupling hub bore and the shaft end taper area, and the lapping tools including the axial advancement.
4. Gauges are NOT to be used as a lapping tool.

C.4.3 STRAIGHT SHAFT ENDS AND STRAIGHT BORE COUPLING HUBS

These components are only able to be dimensionally verified and the surface finish verified.

C.5 Repair of Coupling Assembly

The coupling assembly should be repaired as mutually agreed upon by the owner and the repair shop. The hub bore should not be repaired by welding, plating, spraying, or sleeving.

Note: Welding may cause distortion of the bore or flange. Plating, spraying, or sleeving repairs may not provide for adequate torque transmission.

C.6 Bluing Procedures

This procedure will outline the basics in performing a bluing check.

C.6.1 GENERAL

a. All components, ring and plug gauges, shaft end, coupling hub bore, dilation holes distribution grooves, and "O" ring grooves are to be completely cleaned, free from oil, dirt, lint, solvent and any other foreign material, and dried.

b. All mating surfaces are to be free of burrs, nicks, or any other raised area.

c. Sharp corners shall be removed from keyways, grooves, and other areas that might damage the tools or cause errors in checking.

d. All "O" rings and back up rings are to be removed from the shaft end or coupling hub bore.

e. All components are to be at an equilibrium temperature.

f. Checking of components, other than the shaft ends should be done in a vertical position.

g. Verify the area percent contact between the ring gauge and the plug gauge with a bluing verification. This technique is described in section C.6.2. This contact area should be as great as practically possible.

h. Perform the bluing check on the shaft end with the ring gauge.

i. Perform the bluing check on the coupling hub bore with the plug gauge.

C.6.2 PROCEDURE

a. Place a thin coating of soft, non-drying, bluing sparingly and evenly onto the most convenient surface. The entire surface shall be covered with a thin uniform coating of the bluing. The coating is to be just thick enough to record contact on the mating surfaces. Excess bluing will cause erroneous readings.

b. Using the smaller part, carefully engage the mating tapers. Do not allow contact until the tapers are nearly fully engaged. Then push the pieces together and lightly tap.

> COMMENT: Perform this verification check in a vertical position, if possible.

c. Remove the smaller part by pulling straight back, being very careful not to upset the bluing.

d. Evaluate the degree of contact between tapers. The part being checked should have a very light coloring on the taper. Record this contact using transparent tape lift off. Record the serial numbers or the gauges on this document.

> COMMENT: Typically, the first check will have too much bluing on the mating part and will require removing the bluing from the checked part while leaving it on the part that the bluing was applied to. Redo the verification procedure.

e. Compare the results to the percentages from Table 1.C-1.

f. Inspect the transfer for indications of scratches, out of round areas, or flat areas. Do not expect to see a coating that looks as if it was painted. If this occurs, too much bluing was applied. If no contact is seen, it could be caused by either too light a coating of bluing or the tapers are not matched. Look closely for traces of the bluing at the ends. Indications on one end only suggest that the angle is incorrect. Indications on both ends suggest that the angle is correct but, the bluing may have been too light or the bore is barrel shaped.

g. After the bluing verification is completed, remove all bluing.

C.7 Lapping Taper Shaft End and Coupling Hubs

C.7.1 GENERAL

In order to correctly lap a tapered fit, a lapping ring tool and plug tool shall be used. It should be verified that the ring and plug lapping tools are long enough to properly lap the entire area of the coupling hub bore and the shaft end area. The shaft end area will be the coupling hub length plus the axial advancement. The lapping tools are NOT the same components that are used for the verification. The lapping tools are usually made from cast iron so that the lapping compound will embed into the soft material to allow the harder material to be lapped. The lapping tools are to be verified to the ring and plug gauges prior to the lapping process as described in section C 6.2. The shaft end to the hub bore will be required to be a minimum of 75%, so the contact area between the tools shall be more than 85%. If the verification does not have the minimum contact area percentage, then the lapping tools are not satisfactory and shall be replaced or reground by the manufacturer. If a lot of lapping is to be done, it is important to re-verify this contact area percentage partially through the process of lapping to ensure that the lapping tools are still good.

Notes:

1. THE COUPLING HUB IS NOT TO BE USED AS A LAPPING TOOL.
2. THE GAUGES ARE NOT TO BE USED AS LAPPING TOOLS.
3. Lapping processes will typically improve the contact area percentages by up to approximately 20%. Higher percentage improvements beyond these numbers will usually require regrinding of the components.
4. The length of the lapping tools shall extend beyond both ends of the finished taper for the shaft end or the coupling hub.

C.7.2 PROCEDURE

The procedure for the lapping process is:

a. All components, ring and plug lapping tools, ring and plug gauges, shaft end and coupling hub bore are to be completely cleaned, free from oil, dirt, lint and any other foreign material, and dried.

b. All “O” rings and back up rings are to be removed from the shaft end or coupling hub bore.

c. All components are to be at an equilibrium temperature.

d. All components, other than the shaft ends are to be in a vertical position.

e. Use the previously verified ring and plug gauges for the verifications of the ring and plug tools and for the verifications of the shaft end and coupling hub bore during the lapping processes.

f. Apply the lapping compound evenly to the lapping tool and work the compound into the tool.

g. The amount of contact area percentage will determine the coarseness of the lapping compound. The finishing lapping compound is to be approximate number 1000. Do not use a compound coarser than approximate number 200. It is recommended to start with the approximate number 1000 compound to determine just how much lapping will be required. At that time, the decision may be made to use a coarser compound.

h. Rotate the tool back and forth in an arc of approximately 45° while applying a slight forward push. Occasionally, remove the tool and reposition it onto the lapped area.

i. Repeat this process several times. When the entire lapped area appears to have a dull appearance move up to the next higher number (finer) lapping compound. Continue this process with progressively finer grits until completing the lapping process with the finishing compound. When stepping from one grit to the next, each component is to be completely cleaned to remove the previously applied compound.

Note: Refer to paragraph C.4.1 for surface finish requirements for coupling hubs and Chapter 1, paragraph 9.3.1 for shaft end surface finish.

j. Completely clean and dry all components prior to the contact area verification re-testing.

k. Retest the lapped area again with the gauge to determine the contact area percentage. If the proper contact area percentage is at least a minimum of 85%, then the lapping process is completed. If this verification is not sufficient, then more lapping is required or some other problem exists.

l. For hydraulic fit applications, make sure that the edges of the “O” ring grooves on the coupling hub bore or the shaft end are not sharp. This sharp corner can cause stress risers. If the edges are sharp and are re-dressed, then the contact area percentage shall again be re-verified.

C.8 Installation of Coupling Hub

C.8.1 GENERAL

All components are to be clean, free from oil, dirt, lint and any other foreign material, and dried. The components are to be visually observed to ensure that they are all ready for installation. The manufacturer’s drawing and information are to be reviewed for proper installation, orientation, positioning and axial advancement for a taper arrangement. See paragraph C.3.5 for keyway clearances. Two techniques shall be used to confirm the correct final location of the coupling hub. One technique is a dial indicator and the other is a depth micrometer. Record the dimensions for the reference positioning along with the final installed dimension. A split stop plate (ring) may be used to assist in the setting of the axial position. For applications with multiple keys, the keys along with the matching keyways are to be installed in the correct locations. For applications where the circumferential location of the coupling hub was used in performing a rotor assembly balance, the circumferential location of the hub is to be maintained.

C.8.1.1 Axial Advancement for Tapered Shaft Ends

C.8.1.1.1 General

The coupling hub shall be installed with a required amount of advancement in order to obtain the desired interference fit. The axial advancement is stated on the manufacturer's coupling drawing or information. This axial advancement is very critical and should not be less than the desired amount and should not be exceeded by more than 125 µm (0.005 in.). The shaft end may have a nut that tightens to the hub. For keyed applications, this nut may be required to assist in the advancing of the coupling hub onto the shaft and will be used to keep the hub from coming off during the cooling down time period. It should be verified that the coupling hub face, where the nut touches, will not allow the nut to "bottom out" on the shaft. The coupling hub face shall stick out past the end of the shaft end face more than the advancement so that the nut will be tight against the coupling hub face, not the shaft end face.

Note: Sometimes conflicting information may exist between the coupling manufacturer's information and the rotor manufacturer's information for pull-up that may need to be resolved.

C.8.1.1.2 Calculation of Hub Pull-up

Manufacturers information is to be reviewed for the proper pull-up.

If no information is given, this section may be used as a guide.

In order to calculate the amount of axial pull-up, several items are required:

a. Shaft taper (rate of change of diameter per unit of length)

b. Diametral interference fit between the hub and shaft

The equation to calculate the axial pull-up, Equation # 1 is:

$$\text{Axial advancement } (A) \text{ (mm)} = D \times I \; / \; T$$

where (Metric units)

D = diameter of the large bore (mm),

I = interference Rate (mm/mm),

T = shaft taper (mm/mm).

where (U.S. Customary units)

D = diameter of the large bore (in.),

I = interference Rate (in./in.),

T = shaft taper (in./ft).

Example:

D = 3.000 (in.)

I = 0.001 (in./in.)

T = 0.500 (in./ft)

A = 3.000 x 0.001 x 12 / 0.500

A = 0.072 (in.)

Figure 1.C-2 provides the advancement in a chart form for different tapers using an interference of 0.001 mm/mm (in./in.). Adjust for different interferences from this figure.

C.8.1.1.3 Reference Position for Tapered Shaft Applications

The first step is to determine the reference position of the hub on the shaft end utilizing components at an equilibrium temperature.

The hub is to be installed onto the shaft end and very lightly tapped with a small mallet to ensure it is squarely positioned and tight on the shaft. This position is the reference position and the final installed hub location is the axial advancement beyond this reference. Record the dimensions for the reference positioning. Do not rotate the hub onto the shaft in this dry condition to prevent damaging either component.

Note: For hydraulic fit applications, the "O" rings or back-up rings are not to be installed during this reference positioning.

C.8.2 APPLICATIONS REQUIRING HEATING FOR INSTALLATION OF NON-HYDRAULIC HUB

C.8.2.1 General

The required temperature to expand the coupling hub bore for installation is to be calculated. To allow for the cooling during handling, typically, the hub should be expanded between $1^1/_2$ and 2 times the interference fit. An upper limit temperature shall be established to prevent damaging the hub.

Note: A typical limitation of 260°C (500°F) is sufficient for installation of the hub, however, this temperature should be reduced due to temperature limitations of coatings, "O" rings or back up rings.

Methods of heating the coupling hub are (in order of preference):

a. Electric Oven Method

The best method to heat the hub for expansion is to gradually heat it up in an oven. The oven will heat the hub evenly and to the desired temperature.

b. Electric Induction Heater

This heater shall have a temperature probe and a demagnetizing feature. Rotate the hub periodically during the heating to heat the hub evenly.

c. Torch Method (flame)

A flame heating torch shall have a tip that will spread out the flame. Start with heat being applied evenly to the outside diameter and then proceed quickly to the hub bore area as evenly as possible. Do not allow the heat to be concentrated in one area. A temperature measuring device shall be used to verify the temperature.

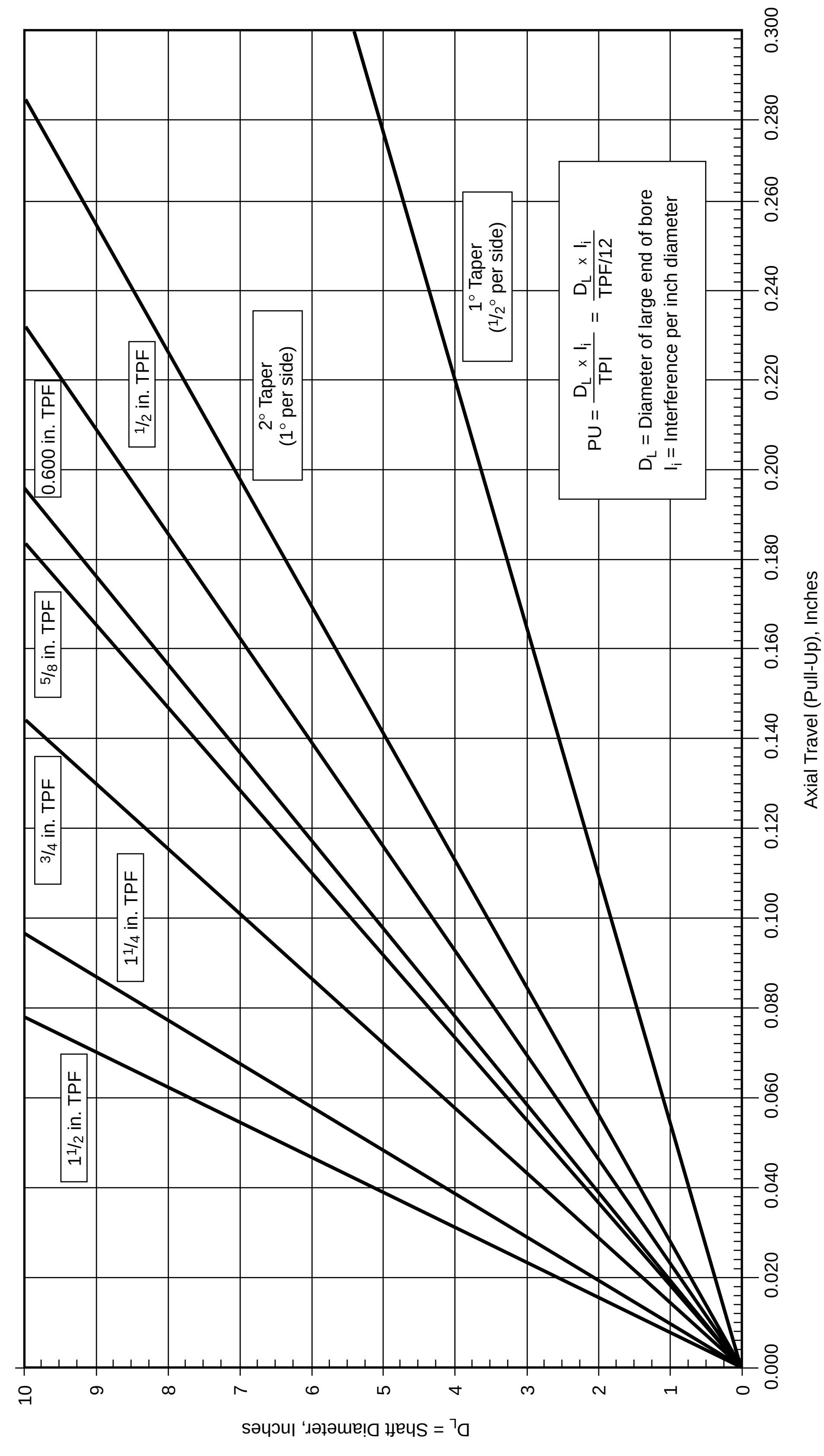


Figure 1.C-2—Axial Pull-Up Tapered Coupling Hubs for 0.001 in. (I) per in. Diameter Interference

C.8.2.2 Straight Shaft Ends

A gauge that has a dimension equal to the bore dimension plus $1^1/_2$ to 2 times the interference fit may be used as a go/no go gauge. This gauge will assist in the verification that the hub bore has expanded enough so that the hub can be installed onto the shaft without it sticking. Heat the coupling hub per one of the methods in section C.8.2.1.

C.8.2.3 Tapered Shaft Ends

Heat the coupling hub per one of the methods in section C.8.2.1. The verification of the hub bore expansion is to be determined with a caliper or a go/no go gauge. When the bore is properly expanded, install the hub onto the shaft end to the correct axial position. Verify the axial position of the coupling hub per paragraph 8.1.1.1 after cooling to ambient.

C.8.3 HYDRAULIC FIT APPLICATIONS

The coupling hub shall be expanded and advanced with hydraulic tools for the installation. The manufacturer's procedure is to be followed. The recommended maximum pressures are not to be exceeded so that personal harm will not occur and the hub will not be damaged. Excessive pressure may overstress the hub resulting in the hub being damaged. If no procedure is available from the manufacturer, the following procedure can be used as a guide to install the hydraulic fit coupling hub.

Note: After installation for hydraulic fit applications, the circumferential location of the hub is to be scribed and identified to the shaft end. This reference is used to verify any circumferential movement without removing the coupling hub.

a. All component contact percentages have been verified.

b. All components, including the oil passages, are to be clean and dried.

c. All hydraulic installation components including hoses and fittings are to be clean.

d. Determine the axial reference position per C.8.1.1.3, set the dial indicator (when space allows) and measure the standoff with a depth micrometer.

e. Remove the hub from the shaft end and install new "O" rings and back-up rings in the proper position. Lubricate these rings with the hydraulic fluid.

Notes:

1. To prevent extrusion of the "O" rings, the material for the "O" rings should have a Shore A durometer of 90. The back up rings should be split and the ends cut at a 45° angle and these ends do not overlap beyond the split. The position of the back up ring is to be positioned so that the "O" ring is placed closest to the higher pressure and the back up ring is on the lower pressure side.

2. The groove depth and width for "O" rings is critical and must be reviewed if repairs have been made to the shaft end or the hub bore.

f. Place the hub, with the "O" rings and back-up rings installed, onto the shaft end. Advance the coupling hub by hand and then lightly tap with the small mallet to ensure it is squarely positioned and firmly seated on the shaft. Usually the hub will not advance back to the axial reference position completely due to the installation of the "O" rings and back-up rings. The advancing tool is to be completely screwed onto the shaft end.

g. Attach the hydraulic tools and bleed out the air in the system.

PRECAUTIONS: The hydraulic pressure is very high and is extremely dangerous. Hydraulic pressurizing devices are not to be placed in line with the hub. The device should be arranged so that a 90° elbow is used to keep personnel out of the leak or removal path.

h. Increase the pressure on the axial advancing device to reach the reference position.

i. Gradually increase the expanding hydraulic tool pressure to each expanding pressure step per the manufacturer's recommendation. While expanding the hub for each step, increase the advancing tool pressure to advance the hub onto the shaft until the advancing stops. Typically the expanding increments are to be in increments of 35,000 kPA (5,000 PSIG). Hold at each pressure step for approximately one minute to allow the hub to evenly expand. Near the half way position, stop the advancing and let everything set for at least 5 minutes to allow the hub to fully expand. Continue to increase the expanding pressure until the axial position is reached. Typically, a maximum of 210,000 kPA (30,000 PSIG) will be necessary to expand the hub enough to properly position the hub.

Note: Continue to monitor the dial indicator's needle for movement. The dial indicator's needle should move smoothly as the coupling hub is advanced. If its movement is not smooth, then the hub could be contacting the shaft. Increase the expanding hydraulic pressure to assist in the axial traveling if it is not smooth.

j. When the final axial position has been reached, slowly release the expanding hydraulic pressure tool to zero by opening the valve on the hydraulic pump.

WARNING: Do not release the axial advancing hydraulic tool's pressure at this time.

No motion should be indicated on the dial indicator's needle.

k. Remove the high pressure expanding hydraulic tool and its fittings. The advancing hydraulic tool is still pressurized. Allow the hydraulic fluid to drain from the expanding connections for at least 30 minutes. More time may be necessary in very cold climate conditions or large coupling applications.

l. While waiting for the hub to relax, record the pressures used for the expanding of the hub and for the hub advancing pressure.

m. After at least 30 minutes, very slowly decrease the advancing hydraulic pressure while watching the dial indicator. If the indicator moves more than about 76 µm (0.003 in.), the repositioning is to be reviewed for adequate interference. If the advancement movement is unacceptable, then repeat the installation procedure and allow additional settling time. If the movement is less than the 76 µm (0.003 in.), remove the advancing tool.

n. Verify the proper advancement with a depth micrometer. If the coupling hub is outside the manufacturer's tolerance, the hub should be relocated.

COMMENT: THE POSITION OF THE COUPLING HUB IS VERY IMPORTANT.

o. When the advancement is correct, replace the advancing hydraulic tool with the coupling hub shaft end nut along with the proper setscrews.

Note: Do not place a load on the coupling hub for at least 12 hours, preferably 24 hours. This time period is to allow ALL the hydraulic fluid to escape from the shaft to hub fit.

C.9 Installation of Coupling Center Assembly

C.9.1 GENERAL

All components are to be clean. Review the manufacturer's drawing and information for the correct installation of the center assembly. The first step is to verify the distance between the shaft to shaft, and the flange to flange ends. The rotors should be in their proper position, typically against the active thrust bearings. For gearboxes, center each gear element in its axial float. For sleeve bearing motors, center the motor's rotor in the float. Measure the distance to be used in the shaft to shaft placement. When installing the center assembly, observe the match marks. The bolts are to be installed in the correct direction to allow for full engagement of the bolt shanks. The tightening torque and procedure will be stated on the manufacturer's drawing and information. Some bolts are match marked to the proper positioning. For some motor applications, an insulated coupling may be used and the insulation quality on final assembly should be verified.

Note: If the motor's mechanical center is not within the necessary tolerances with the magnetic center, a review of the setting position shall be done.

C.9.2 GEAR STYLE COUPLING

Gear style couplings require lubrication. This lubrication may be either grease or oil, per the design. If oil is to be used, make sure that the oil spray tubes/nozzles are clean, and are directed to the correct location of the coupling assembly.

For grease design, spread the required amount of grease as evenly as possible insuring that the grease is far back into the teeth area for each tooth.

The coupling assembly is to be axially floated to verify the proper axial freedom and positioning. This axial verification is to confirm the proper limited end float.

C.9.3 DRY STYLE COUPLING

Usually, the center assembly being used will have its actual overall length scribed on one of the flanges. Using this dimension plus the amount of pre-stretch, if required, determine the amount of shims necessary.

Record the thickness and the position of the shims for usage and for storage (if used).

C.10 Installation of Coupling Guard

All components are to be clean. Review the manufacturer's drawing and information for the correct installation of the coupling guard. If there is an oil drain make sure that it is open. The guard shall be rigid and not be capable of rubbing the coupling components. Seal the split line when necessary. If there is an oil vent, make sure that it is clean. If there are any windage baffles, make sure that they are rigid and properly positioned.

APPENDIX D—RESTORATION METHODS (OVERVIEW)

D.1 General

This appendix provides procedures for guidance in the repairing of shafts that require restoration. The methods that are outlined in this appendix are:

D.2.0 Weld Repair

D.3.0 Thermal Spray

D.4.0 Reducing (Turning Down) the Shaft

D.5.0 Plating

D.6.0 Shaft Straightening

D.7.0 Metallizing

D.8.0 Plasma Spray

The first decision is repair of the component versus manufacturing a new one. Many of the considerations in this decision are the same as for which repair process to use. Following is a list of things to consider when deciding what method of repair to use, especially when more than one method of repair is being contemplated:

a. Determination of the base material and the restoration material.

b. Limitations of the processes (thickness; environment of the part—chemical, thermal compatibility; machinability; mechanical bonding capabilities; velocities of steam/gas).

c. Concerns of using the technique for the application.

d. Durability/economics/risk.

e. Time constraints.

f. Experience using the technique in that shop and user's reference list.

g. Qualification of repair procedure and people.

h. Quality control procedures.

D.1.1 APPROVALS

Any repair procedure shall be approved by the owner prior to any repairs. All procedures shall be qualified per ASME or other standards, as applicable, that apply to the material and service. The methods to provide for quality assurance shall be reviewed prior to the repair process.

D.1.2 QUALITY ASSURANCE

Irrespective of which repair method is used, adequate methods must be used to verify a sound repair. This may include witnessing of operations, special inspection requirements, or special testing. For processes such as welding, flame spraying, and plating a test sample may be utilized to confirm important characteristics.

D.2 Weld Repair

D.2.1 GENERAL

The weld repair procedure shall be developed for the specific repair utilizing:

1. Guidelines from this RP 687.
2. Procedure qualification record (PQR).
3. Weld procedure specification (WPS).
4. Welder qualification record (WQR).

When applicable for the service, weld procedures shall be such as to maintain hardness requirements in the weld and heat affected zone per NACE MR O1-75.

Note: Consideration should also be given to pre-baking prior to weld for equipment in services such as hydrogen, chlorides, and hydrogen sulfide.

Depending upon base metal and the service, weld repairs may require additional qualification testing such as:

a. High Cycle Fatigue.

b. Low Cycle Fatigue.

c. Grain Size.

d. Stress Rupture.

e. Creep Strength.

f. Fatigue Crack Growth Rate.

g. Fracture Toughness.

h. Dilution of Chrome.

i. Hardness.

j. Soundness (Bend Test).

The repair procedure shall be approved by the owner prior to any weld repairs.

D.2.1.1 Qualifications

Welding operator(s) shall be qualified (WQR) to the applicable requirements and demonstrate current certification(s).

D.2.2 PREPARATION FOR WELDING

D.2.2.1 A sample of the base metal shall be analyzed and the correct weld procedure (WPS) specified.

D.2.2.2 Reclaim shaft centers and machine "truth bands" based on the work scope. Refer to Chapter 1, Section 9.2.1.4.

D.2.2.3 Premachine the area to be welded to ensure that the weld zone interface/heat affected zone will not lie at the resulting machined interface. Prior to welding, undercut the damaged shaft area a minimum of 1.5 mm (0.060 in.) radial. This ensures that the heat affected zone surface is not at the finished diameter, therefore no machining takes place on the interface between weld metal and base metal. A hardness measurement shall be taken on the undercut area.

D.2.2.4 Perform wet magnetic particle inspection and/or other appropriate NDE, as necessary, on the undercut area. The acceptance criteria is to be per Chapter 1, Table 1.8-1, or as mutually agreed.

D.2.2.5 Prior to additional undercutting of relevant defects located in D 2.2.3, the owner shall be notified for a review and approval of any additional undercutting necessary along with the revised weld repair procedures.

D.2.2.6 Clean the area to be welded to remove all dirt, oil, rust, or other foreign material that would impair the quality of the weld.

D.2.2.7 Set up the welding machine to ensure the voltage, amperage, travel speed, and the wire diameters are per the WPS.

D.2.3 WELDING

D.2.3.1 For a welding process that uses a flux, ensure that the flux is kept in a flux oven and has been held at the proper temperature prior to using.

D.2.3.2 Ensure that the area to be welded is preheated to the proper temperature. No welding shall be performed if the base metal temperature drops below the preheat temperature or exceeds the maximum interpass temperature.

D.2.3.3 Proceed to weld the area per the approved WPS. Ensure that the welds are kept clean and that the interpass temperature is maintained and, if possible, monitored during welding.

D.2.4 INSPECTION

D.2.4.1 Rough machine the welded area in order to perform the inspection process. Magnetic particle inspect (NDE) the welds to detect surface and sub-surface indications. Ultrasonic inspect the welds to detect any sub-surface slag inclusions and indications. Record any indications that fall outside of the weld procedure acceptance criteria. The acceptance criteria is to be per Chapter 1, Table 1.8-1, or as mutually agreed.

D.2.4.2 Prior to repair of relevant defects located in D.2.4.1, the owner shall be notified for a review and approval of any additional weld repair necessary along with the revised weld repair procedures.

D.2.5 INSTALLATION OF HEATING EQUIPMENT FOR POST WELD HEAT TREATMENT

D.2.5.1 Typical heating methods are by induction heating or heating elements. Heating elements should normally overlap the welded area by a minimum of 50 mm (2 in.).

D.2.5.2 The shaft area shall be insulated to preclude radical temperature gradients.

D.2.5.3 Heating elements should have one control and more than one temperature monitoring method per element. Thermocouples welded to the shaft are the most accurate method of temperature monitoring. Thermocouples should be made from calibrated wire.

D.2.6 POST WELD HEAT TREATMENT

D.2.6.1 Raise the temperature to 200 to 260°C (400 to 500°F) to ensure uniformity of the heating elements.

D.2.6.2 Raise the temperature to the final stress relieve temperature per the ramp rate specified in the WPS. The final stress relieve temperature should be at least 30K (50°F) below tempering temperature.

D.2.6.3 Maintain the temperature hold time per the WPS.

D.2.6.4 Lower the temperature, ramp rate, as specified in the WPS.

D.2.6.5 Best results are achieved by hanging the rotor in the vertical position during the post weld heat treatment.

D.2.6.6 Temperature monitoring equipment shall have current calibration records.

D.2.7 ROUGH MACHINE INSPECTION

Repeat the operations and necessary repairs as outlined in D.2.4. Additional welding may require an additional post weld heat treatment A hardness measurement shall be taken on the welded area.

D.2.8 FINAL MACHINING/GRINDING

Finish machine/grind the welded area with respect to a “truth band” area. The finish tolerances shall be concentric to the truth bands as follows:

a. Repaired journal 2.5 µm (0.0001 in.).

b. Other repaired areas (to the drawing tolerances).

D.2.9 FINAL INSPECTION

Dimensionally inspect and wet magnetic particle inspect (NDE) the finish machined welded area. All information is to be recorded.

D.3 Thermal Spray Repair

D.3.1 GENERAL

The repair procedure shall be approved by the owner prior to any repairs. Thermal spray repair procedures shall contain description of quality control checks on the composition, storage and handling of the spray powder, critical parameters and those to be monitored during the spraying process, and component preparation.

Important factors to consider in the selection and applications of coatings are:

a. Base metal temperature during coating application.
b. Bond strength.
c. Hardness (coating and base material).
d. Ductility.
e. Porosity of the coating material and potential for sub-coating corrosion.
f. Thickness.
g. Corrosion resistance superior to the base metal.
h. Wear / erosion resistance superior to the base metal.
i. Operating environment.
j. Angle of application nozzle to work surface.

PRECAUTIONS:

1. Coatings are typically brittle and may be damaged during shop procedures of rolling in bearing stands or while operating in a balancing machine with antifriction bearings. The repaired area may be damaged from the narrow area that the stands provide. The larger or heavier the rotor, the greater chance of damage to the coating area.
2. Coatings typically have coefficient of thermal expansions much different than the base metal. This difference may affect the application in areas where thermal stresses are prevalent. The selection of the coating is to be reviewed for the application.
3. Consideration should be given whether a "bake out" process is necessary to remove the imbedded gases or chemicals.
4. The base metal hardness may affect the ability to coat the shaft.
5. The operating environment may attack the coating binder(s).
6. The coating of inside diameters will result in a decrease in coating properties due to the angle of the application nozzle to the work surface. Coating of inside diameters with an aspect ratio greater than 1:1 inside diameter to length is not recommended. i.e., The bore length should not be greater than the inside diameter to be coated.

D.3.1.1 Comparisons of Processes

Different processes may affect the physical properties of the coating. Table 1.D-1 shows a comparison of some of the coating processes. The table compares particle velocities, porosity, coating thickness, surface finish, bond strength, temperature of substrate and hardness.

Note: Metallizing and plasma spray coatings are shown shaded in Table 1.D-1 for information only.

Table 1.D-1—Typical Properties of Various Thermal Spray Processes

	Metallizing	Plasma WC +13% %CO	Plasma CR_2O_3	HVOF	HVLF	Intermittent Combustion Process	Intermittent Combustion Process
Fuel	Acetylene			Various Gases	Kerosene	Acetylene	Mixed Gases
Particle Velocity (FPS)	300–500	500–1,000	500–1,000	1,800–2,600	2,240–3,350	2,100–2,500	3,000 +
% Porosity	8–10	6	4.5	< 2	< 2	< 1	< 1
Finished Thickness (mils)	30–40	8–10	5–8	7–25	7–30	3–10	3–10
Bond Strength* Per Standard ASTM Test (psi)	4,000	7,000–9,000	6,000–7,500	12,000	12,000	12,000	12,000
Bond Strength** Per Modified ASTM Test (psi)	NA	NA	NA	16,000	28,000	25,000	33,000
Hardness***—RC	35–40	65–68	58–70	72	72 plus	70	70
Substrate Temperature °F (during application)	Unfused 200–400 Fused 1,850–2,150	250–400	250–400	350	350	300	350

*ASTM C 633-79 test is limited to about 12,000 psi as epoxy fails; modified test uses brazing.
**Modified ollard test.
***Maximum hardness measured by diamond pyramid method and converted to RC.

Note: Metallizing and plasma spray coatings are shown shaded for information only and are not recommended.

D.3.1.1.1 Base Metal Temperature

The temperature of the base metal should remain at or below 180°C (350°F) to preclude any warpage, distortion, or other physical damage during application of the coating.

D.3.1.1.2 Bond Strength

This property is of considerable importance. The bond strength is the measurement of the "holding" of the coating to the base metal. The higher the bond strength, the better the resistance to rotational forces and/or torque stress. Bond strength is "officially" measured by the ASTM-633 tensile test in which the coating is applied to a 25 mm (1 in.) diameter round bar and a mating bar is epoxied to it. The limit of this test is the strength of the epoxy which is about 83,000 kPA (12,000 PSI). Test results cited showing coating strengths greater than 83,000 kPA (12,000 PSI) are not per the ASTM-633 specification. Several of the coatings are tested by brazing the mating bar to the coating and in this test, the strength exceeds 172,000 kPA (25,000 PSI).

Note: A rotating shaft may go through periods of boundary lubrication. The journal surface of a rotor rests metal-to-metal on the bearing before start-up. High shear forces are concentrated at that point of contact when the machine is first started.

D.3.1.1.3 Hardness

The hardness of the coating is important for an application where consideration must be given to galling and wear resistance. Hardness is not a measure of the strength of a coating.

D.3.1.1.4 Ductility

The ductility of the coating provides for the ability of the coating to deform without cracking. Most of the coatings do not have readily available ductility information. Coating ductility is generally much lower than the base metal ductility. The lack of ductility of the coating may cause a problem with applications which deform, such as disk to shaft and impeller eye locations. Generally, the harder or thicker the coating, the less ductile the coating will be. There are no recognized standards for determining the ductility of coatings. However coatings may be ranked by using bend tests. In this test a 1 in. wide x 6 in. long x $^1/_8$ in. thick steel coated coupon, is bent over a 1 in. round bar. The angle at which the coating cracks is a measure of its ductility.

D.3.1.1.5 Porosity

Porosity is the measure of voids in the material. A porous coating may result in corrosion of the base metal. The greater the porosity of a coating, the greater the possibility of a failure of the bonding of the coating. The coating's environment will dictate the maximum porosity allowable in a coating.

D.3.2 PREPARATION FOR COATING

● **D.3.2.1** When specified, the application and method for the coating shall be tested using a test coupon. The desired results and any restrictions during the coating process are to be mutually agreed upon between the owner and the coating repair shop. Typically coating microstructure is checked for hardness, porosity, bond strength, thickness, and contamination.

D.3.2.2 The base metal chemistry and hardness shall be determined.

D.3.2.3 Reclaim shaft centers and machine "truth bands" based on the work scope.

D.3.2.4 Premachine the area to be coated to assure that the spray coating/base metal interface will not lie at the resulting machined surface and all corrosion or damaged material have been removed. Prior to coating application, undercut the shaft area necessary for the type of coating to assure the required finish thickness. Each edge of the undercut shall have a smooth radius to the surface, as large as practical.

D.3.2.5 Perform wet magnetic particle inspection and/or other appropriate NDE, as necessary, on the undercut area. The acceptance criteria is to be per Chapter 1, Table 1.8-1, or as mutually agreed.

D.3.2.6 Prior to additional undercutting of relevant defects located in D.3.2.5, the owner shall be notified for a review and approval of any additional undercutting necessary along with the revised repair procedure.

D.3.2.7 Clean the area to be coated to remove all dirt, oil, rust, or other foreign material that would impair the quality of the coating.

D.3.2.8 The part to be appropriately masked and grit blasted to an agreed upon surface finish and quality.

D.3.2.9 Set up the spray coating machine to ensure that the process will be performed per the work instructions.

D.3.2.10 Spray build up the area to the dimension required.

D.3.3 FINAL MACHINING/GRINDING

Finish machine/grind the coated area with respect to a "truth band" area. The finish tolerances shall be concentric to the truth bands as follows:

a. Repaired journal 2.5 µm (0.0001 in.).

b. Other repaired areas (to the drawing tolerances).

D.3.4 FINAL INSPECTION

Dimensionally inspect and wet magnetic particle inspect, NDE, the finish machined welded area. All information is to be recorded.

D.3.5 HIGH VELOCITY FUEL PROCESSES

The high velocity spray process which are commercially available under various trade names, generates a velocity of the molten metallic stream. Since kinetic energy goes up as the square of the velocity, the metal powder impacts the item being sprayed with high energy. This means that the metal powder bonds with the base metal. The powder particles flatten as they impact the surface and the coating is built-up, layer by layer, to achieve a fully dense structure. The HVOF process uses a gas as the fuel and the HVLF process uses a liquid as the fuel.

HVOF/HVLF processes differ in their application methods in the following ways:

a. The applying device may be cooled by a different medium (air, water, etc.) This will affect the flame temperature which will, in turn, affect the temperature of the powder.

b. The base metal may be cooled by air, carbon dioxide, nitrogen, etc. This will keep the part from distorting due to heat, but may also have an affect on the quality of the coating, depending on which coating medium is used.

c. The powder may be injected in different locations in the flame stream to vary the amount of heat to which the powder is subjected.

d. The type of fuel may vary.

e. Mass flow meters may be used rather than pressure drop type flow meters to control powder, fuel and oxygen flow rates.

D.3.6 INTERMITTENT COMBUSTION PROCESSES

The intermittent combustion method of flame spraying is essentially an oxyacetylene powder method firing a very high velocity stream of particles at a rate of 4 to 8 times per second. Oxygen, acetylene, and powdered coating material suspended in nitrogen are metered into the combustion chamber. A spark detonates the mixture to create a hot, high-speed gas stream which makes the particles plastic while hurling them from the applicator. Successive detonations build up the desired thickness. The high noise levels, typically 150 dB during the application, requires a special sound attenuation area which may limit the size of the component to be coated.

Metallurgical properties of the base material remain unaltered. While temperature within the applicator may exceed 3300°C (6000°F), the part being coated remains below 180°C (350°F) to preclude warpage, distortion, or other physical change.

D.4 Reducing (Turning Down) the Shaft

This section is for the reduction of a diameter on a shaft and leaving the shaft at the reduced diameter. No build-up to the original diameter is to occur. It is important to understand that the reduction of the shaft diameter may affect items such as:

1. Bearing journals:
   The journal, thrust bearing, and / or seal rings for the bearing housing may have to be redesigned due to the smaller shaft.

2. Coupling shaft end:
   The coupling hub may have to be replaced and possible modifications to the remaining components of the coupling assembly due to the shaft to shaft dimension being modified.

3. Process seals:
   The seals may have to be redesigned due to the smaller shaft.

4. Other areas:
   The turned down dimension may affect the mating component.

5. Lateral or torsional rotor dynamics.

6. Torque capabilities.

7. The modification may affect the spare rotor, spare parts and component delivery due to the non-standard dimensions.

8. Add a thorough engineering analysis.

9. The equipment manufacturer may have standard dimensions that may provide for guidance in the finished diameter.

10. The preferred method is grinding.

D.4.1 The journal may be reduced if the scoring is more than 0.127 mm (0.005 in.) deep. Scratches or dents less than 0.127 mm (0.005 in.) deep do not require removing. Raised edges from scratches or dents are to be removed.

D.4.2 When necessary, reclaim shaft centers and machine "truth bands" based on the work scope. The truth bands shall be concentric within 2.5 µm (0.0001 in.) of the bearing journals.

D.4.3 The journal diameter should be reduced by the minimum amount required to clean and restore the journal surface.

D.4.4 As a guideline, for reference only, the maximum diameter reduction may be as shown below:

Original Diameter	Maximum Diameter Reduction
Less than 90 mm (3.6 in.)	7% of the original diameter
90 mm (3.6 in.) or greater	original diameter less 6 mm (0.25 in.)

Note: The maximum diameter reduction is influenced by many factors. It is cautioned against reducing the journal diameter by more that 6 mm ($^1/_4$ inch) or beyond that diameter which will increase the torsional shear stress 25% above the original design; whichever occurs first. These limitations preclude sleeving as a repair method, since a stable sleeve should have walls about 6 mm ($^1/_4$ in.) thick.

D.4.5 FINAL MACHINING/GRINDING

Finish machine/grind the area with respect to a “truth band” area. The finished surfaces shall be concentric to the truth band as follows:

a. Repaired journal 2.5 µm (0.0001 in.).

b. Other repaired areas (to the drawing tolerances).

D.4.6 FINAL INSPECTION

Dimensionally inspect and wet magnetic particle inspect (NDE) the finish machined welded area. All information is to be recorded.

D.5 Shaft Restoration By Plating

● When specified, components may be restored to original design size by chrome or nickel type plating. The application method, procedure, thickness, quality control checks, and acceptance criteria should be mutually agreed upon. Considerations should be given to: maximum thickness per step, maximum total thickness, maximum machining per each step, tank cleanliness, rate of application, baking of coating, and the location of the plating.

D.5.1 PRECAUTIONS

Typically, plating may result in premature failures due to items such as:

1. Fatigue of the interface.
2. Corrosion of base metal due to high porosity of the plating.
3. Improper application.
4. Stress corrosion cracking and hydrogen embrittlement.
5. Low bond strength.

D.6 Shaft Straightening

When specified, the restoring of the shaft straightness may be attempted by stress relieving, peening, or cold or hot straightening. The procedure used to straighten a shaft shall be mutually agreed upon by the owner and the repair shop.

Typically, shaft straightening is not preferred due to the following situations:

1. Low success rate for all diameters.
2. Shaft does not always maintain this restored straightness while in operation under load and temperature.
3. Smaller diameter shafts are more difficult to straighten than larger diameters.

Shaft straightening may be attempted by stress relieving the bare shaft while it is hanging in the vertical position. This process should be carried out twice to ensure that the stresses causing deformation have been eliminated. The temperature at which the stress relieving should take place is above any operating temperature and below the tempering temperature of the base material.

If straightening of the shaft by stress relieving is unsuccessful and the shaft is thermally stable, then the shaft may be machined to remove the bow. Dimensions are to be restored as outlined in Chapter 1, Section 9.2.

D.7 Metallizing

The metallizing process generates a low velocity molten metallic stream. Since the kinetic energy varies by the square of the velocity, the resulting impact of the metal powder has comparatively lower energy resulting in a low bond strength and high porosity. Therefore, metallizing is not recommended for shaft repair.

D.8 Plasma Spray

● When specified, components may be restored to original design size by plasma spray process. The plasma spray process feeds a powder and gas mixture into a high energy electric arc producing a molten metallic stream. The resulting impact of the metal powder has a low bond strength. Therefore, plasma spray is not recommended for shaft repair.

D.9 Sleeving

Sleeving is not recommended per D.4.4.

APPENDIX E—FLUID FILM BEARINGS

E.1 General

This appendix is to cover the minimum requirements pertaining to the bearings for the train. This appendix may be used as a stand alone type of document allowing it to be used separately from the remaining portions of this document, API 687, or along with the additional sections in this document.

E.2 Disassembly

Prior to removing the bearing assembly, the manufacturer's drawing and information are to be consulted to ensure the correct disassembly, inspection, and clearance check procedures that may be unique for the bearing assembly are followed. It is very important to note the arrangement and how the bearing assembly was installed prior to its removal. The assembly, as found, may have been assembled incorrectly which may be causing a problem that will be detected later during the inspection. Bearing assemblies typically have either RTDs or thermocouples for temperature sensing and these are very fragile. The bearing components and temperature sensors should be handled very carefully. Included in the bearings are end seals in the bearing housings that must be evaluated. Prior to disassembly it is recommended to match mark all components that may be disassembled and the orientation of the bearing in the case. Also note how long the bearing has been in use and any problems that may have occurred during that operating period.

Prior to disassembling the casing, it is recommended to perform the following checks:

a. A shaft lift check at each bearing to verify bearing clearance at shutdown.

b. Note rotor float and position of the shaft.

c. Note shaft direction of rotation relative to the journal and thrust bearings as they are installed. This may assist in analyzing abnormal wear and to verify proper placement of temperature sensors or direction of rotation for offset designs/pressure dams.

E.3 Inspection

E.3.1 INITIAL INSPECTION

All of the components should have their condition, concerns, or indications recorded for future use. Photographs can be very important to this documentation. Sketches of the abnormal wear patterns and probable causes are important as the inspections are completed. Review of the inspection data shall be done to determine acceptability for future service. Any situation that may affect form, fit, or function should be noted and reviewed. Samples of foreign object damage should be taken for possible analysis. Additional methods may be employed for further evaluation of the bearing assembly components. NDE inspections such as ultrasonic or dye penetrant inspections may be used to gain additional information. If at any time there is a question of the integrity of any component, a knowledgeable shop should be consulted.

Prior to any cleaning of any components, notice the condition and any unusual indications. After the initial inspections, the bearing assembly components are to be thoroughly cleaned to provide a complete inspection. A typical cleaning may consist of a solvent wash, with or without the use of a fine scouring pad type material.

E.3.2 VISUAL INSPECTION

All of the components should have their condition or indications recorded for future use. The bearing assembly should be visually inspected for abnormal wear conditions. Select a work area free from debris for disassembly of the bearing. Mark where sensors exit.

Observe as a minimum:

- General damage or wear to all parts such as:
  - Frosting due to current discharge
  - Fretting
  - Cracks
  - Rubbing
  - Heat discoloration
  - Brinelling/wire wooling
  - Wear
- Babbitt surface
  - Scoring/imbedding
  - Light scratches or polished areas are usually not worth correcting, but high spots should be removed
  - Cracks and missing babbitt must be repaired (no spot puddling allowed)
  - Pits
  - Imbedded dirt
  - Indications of loss of bond
  - Varnishing of babbitted surface due to overheating of oil
  - Indications of misalignment wear
- All oil inlet orifices and spray nozzles are to be open and free of any deposits
- RTDs or Thermocouple sensors and location
  - Placement of the temperature sensor
  - Inspect the wiring and the entry point into the bearing for any damage and sensor continuity

Most problems with bearings usually are not the bearing's fault. Investigate beyond the bearings themselves to determine the root causes. The bottom half may show wear as a polished area. This polished indication may be a normal effect due to start-up.

For examples of bearing failures, refer to *Tribology Handbook* by M. J. Neale and Appendix M.

E.3.2.1 Pivot Inspection

The pivots on tilt pad journal bearings and thrust bearings need to be evaluated. Both the pad pivot and the pad seat area need to be checked visually for wear and corrected if wear is evident. Pivot points may be susceptible to spalling, galling, or pitting that may result in increasing wear rates and/or clearance. The pads should move freely about the pivot. Any binding should be an indication of wear or damage that needs further investigation. In built up pivoting bearings watch match marks for proper orientation. If there is any doubt, return the bearings to a knowledgeable shop for verification.

The location where the pivot sets for journal bearings is critical to the proper bearing clearance. Any indentation in this area needs to be reviewed. Some style journal bearings have the pivot resting on the inside diameter of the bearing housing and inspection should be done to ensure that this housing has not been indented from the pivot.

For self equalizing thrust bearings, the leveling plates, rockers, and the base ring (at leveling plate pivot) are to be inspected. If the pivot areas show signs of wear they need to be repaired/replaced. If the parts do not show signs of excessive wear or damage, reassemble the bearing. Set the bearing, babbitt face down, on a clean, flat surface and confirm that all pads are firmly held in place. Place a load uniformly over the top of the bearing and confirm that all pads are firmly held in place. Then place your hands on the top of the bearing and verify that the bearing is free to tilt from side to side. Any binding should be an indication of wear or damage that needs further investigation.

E.3.3 NONDESTRUCTIVE TESTS

The babbitt must be bonded to the base metal. Ultrasonic testing of the babbitt bond is required. If the bearing has mechanical dovetails, ultrasonic testing may show indications from the dovetail. Dye penetrant inspection shall be performed to detect loose babbitt at the edges. Engineering judgment may be required to assess indications noted.

E.3.4 TEMPERATURE SENSING DEVICES

The RTDs or thermocouples are to be electrically inspected to verify their condition. Bad devices are to be replaced. Verify the color and number of wires are correct for the type of sensor required.

E.3.5 REPAIR OF BEARINGS

The bearing assembly shall be repaired as mutually agreed upon by the owner and the repair shop. The decision must be determined whether it is more effective to repair or replace the bearing. Spot puddling of defects shall not be allowed. Considerations that must be reviewed for repairs include items such as:

- Backing material.
- Backing thickness.
- Babbitt thickness.
- Babbitt composition.
- Temperature device replacement method.
- Knowledge of bearing dimensions, pressure dams or preload.

Repaired bearings shall be dimensional, ultrasonic and dye penetrant inspected.

Specific requirements of preload or pressure dam configuration shall be verified.

E.4 Dimensional Inspection of New or Reused Bearings

E.4.1 GENERAL

The following checks should be performed on components to assure the functionality of the bearing.

a. Verify that all pads heights are within 13 µm (0.0005 in.) of each other

b. Verify that reused thrust bearing pads are within 38 µm (0.0015 in.) thickness of new pads.

c. Verify that the direction of rotation is correct for the location of the temperature sensing device.

d. If the pads are offset pivots, verify that the direction of rotation is correct for the offset in the pads.

e. Verify that the assembly is put back together in the same manner by checking the match marks used in E.2.

f. Verify that all pads in the assembly move freely.

g. For directed lube, verify that the lube distribution ports are correct for the direction of rotation.

h. Verify that "O" rings are installed for designs requiring them.

i. Verify that wiring for the temperature sensing devices are properly routed, do not restrict pad movement, and will not be pinched during installation.

E.4.2 DIMENSIONAL CHECK

TUTORIAL: Babbitt thickness is usually around 1.5 mm (0.060 in.) thick on steel pad bearings and down to as little as 127 µm (0.005 in.) thick on bronze pad bearings. The thinner babbitt has improved fatigue strength *but can only be used with a bronze backing to provide the forgiveness needed should a break through the babbitt occur during operation. The thicker babbitt allows for imbedding of foreign particles, minimizing the potential scoring of the shaft.*

E.4.2.1 Tilt Pad Journal Bearings

For tilt pad journal bearings, the following checks should be recorded at a minimum of two axial locations:

a. Outer Shell

- Checked for roundness and size by measuring the outside diameter on either side of the horizontal split, from the top to the bottom, and at 45° from the split line.
- The outside diameter should be round within 76 µm (0.003 in.), depending upon size.

b. Bearing Case Bore

- Checked for roundness and size by measuring the inside diameter on either side of the horizontal split, from the top to the bottom, and at 45° from the split line.
- The bore is the average of readings taken around the bore.

c. Bearing Case to Outer Shell

- The fit should be 0 to 51 µm (0.000 to 0.002 in.) tight for proper support of the bearing.

d. Preload Check

- Using the shaft, or a mandrel of the same diameter as the shaft, blue each individual pad and observe for the location of the contact indications. The bearing should have a positive preload which would be indicated by the bluing showing on the center of the pad, not at each end of the pad. Figure 1.E-1 shows preload relationships.

E.4.2.2 Fixed Geometry Journal Bearings (Sleeve Bearings)

For fixed geometry bearings, the following checks should be recorded at a minimum of two axial locations:

a. Bearing Outside Diameter (unrestrained)

- Check bearing outside diameter on either side of the horizontal split line, from the top to the bottom, and at 45° from the split line.
- The outside diameter should be round within 76 µm (0.003 in.) on thick, 25 mm (1.0 in.) or thicker, walled bearings and up to 254 µm (0.010 in.) on thinner, 6.4 mm (0.250 in.) or less walled bearings. In between this range the tolerance should be linear.

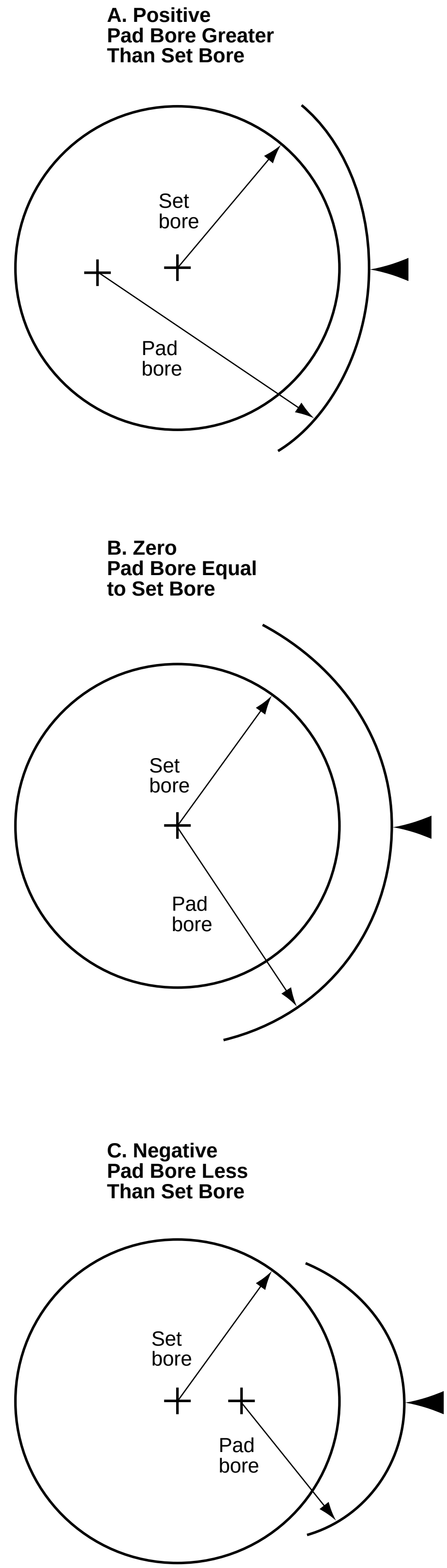


Figure 1.E-1—Preload Variations

b. Bearing Case Bore

- Bearing case bore is to be checked above and below the horizontal split line, from the top to the bottom, and at 45° from the split line.
- The bore is the average of readings taken around the bore.

c. Bearing Bore (unrestrained)

- Bearing bore is to be checked above and below the horizontal split line, from the top to the bottom, and at 45° from the split line.
- For round bearings and for bearings expected to be round when installed, the set bore is the average of all five readings.
- For elliptical bore bearings, the set bore is the minor diameter of an ellipse which is the inside diameter from top to bottom and such a bearing can only be used if it is sprung out at the horizontal joint or the major diameter is in the horizontal direction.

d. Bearing Case to Bearing Fit

- The fit should be 0 to 51 µm (0.000 to 0.002 in.) tight for proper support of the bearing.

e. Bearing Bore Concentricity

- Wall thicknesses on each end of the bearing is to be within 25 µm (0.001 in.).

With multi-lobe bearings, the bearing consists of more than one lobe and each lobe is cut from a different center. The bore of such bearings is much more difficult to evaluate and detailed drawings may be required to evaluate.

E.4.3 END SEALS

Each end seal bore should be measured and compared to the corresponding location on the shaft. The manufacturer's drawings and information are to be consulted for the proper clearance. If the end seal is fixed then the seal to shaft clearance should exceed the bearing bore clearance so the rotor does not contact the seal. If the end seal clearance is not per the design, the amount of oil flow through the bearing may be restricted or excessive oil flow may develop. With floating seals, this clearance can be kept tighter, but an alternate drain inside the bearing and upstream of the seal may be needed to get adequate oil flow through the bearing.

E.4.4 THRUST BEARINGS

E.4.4.1 Flat Face

The flat face bearing is a plain, turned babbitt face which theoretically does not produce a wedge oil film. An alteration of this type bearing is to add radial oil grooves which divide the thrust face into approximately equal pads. This flat face with radial oil grooves has a higher load capacity due to better lubrication and cooling. Flat face thrust bearings shall be inspected to assure uniform loading.

Inspections shall determine flatness and parallelism of the babbitted surface to the backing plate faces. Typical methods include:

a. Verification to surface plate using feeler gauge.

b. Verification to surface plate using height gauge.

E.4.4.2 Tapered Land

The tapered land bearing is similar to a flat face with radial oil grooves, except a portion of the pad surfaces taper such that the direction of rotation pulls oil into the flat face, resulting in a more efficient oil wedge. These bearings can have a simple taper from the leading edge to the flat land or they can have a compound taper where there is more taper at the I.D. than at the O.D. Tapered land thrust bearings shall be inspected to assure uniform loading.

Inspections shall determine flatness and parallelism of the babbitted surface to the backing plate faces and amount of taper. Typical methods include:

a. Verification to surface plate using feeler gauge.

b. Verification to surface plate using height gauge.

E.5 Journal Bearing Clearance Checks

E.5.1 TILT PAD JOURNAL BEARINGS

Tilt pad journal bearings shall be checked using one of the following techniques:

E.5.1.1 Lift Check

This check is performed with the bearing and rotor installed in the machine. For odd numbers of pads and load between pads tilt pad journal bearings the resulting lift will be greater than the set bore because the shaft moves between pads at some point in time. All manufacturers have correction charts for this effect. Typical correction factors are located in Table 1.E-1. The calculation of the actual bearing clearance is to be determined by the following formula:

$$ABC = LC \times CF$$

where:

ABC = Actual Bearing Clearance,

LC = Lift Clearance,

CF = Correction Factor.

The dial indicator used to measure the clearance should be located as close to the pivot center as practical. The typical diametral clearance for these bearings is 1.5 mm/m (0.0015 in.

Table 1.E-1—Lift Check Correction Factor

Number of pads	Load Orientation	Correction Factor
4	Between Pads	0.707
4	On Pad	1.00
5	On or Between Pads	0.894

per in.) of shaft diameter. The manufacturer's drawing and information is to be consulted for the clearance verification.

Note: Improper clearances may be caused by items such as:

a. Location and orientation of the dial indicator.

b. Components not installed with proper fit.

c. Improper preload.

d. Incorrect journal shaft size.

E.5.1.2 Bump Check

The bump check is similar to the lift check, except a mandrel is used in a vertical orientation to determine the amount of diametral clearance. This is a more accurate check of the clearance than a lift check.

E.5.1.3 Stepped Mandrel Check

A stepped mandrel is a machined shaft with steps of increasing diameter that the bearing is slid onto for the clearance verification. The steps should be at least the width of the bearing pads and in increments of 13 µm (0.0005 in.). The bearing minimum clearance is the difference between the last step the bearing fits on and the shaft diameter. Extreme care is to be used when sliding the bearing onto the next increasing diameter so that the babbitt is not scraped off. This clearance check is done with the bearing not installed and the bearing is strapped together tightly.

When using a stepped mandrel, the mandrel should be horizontally positioned. Since many tilt pad journal bearings have axial alignment capabilities, there is a tendency for the pads to lock up when advanced to a larger step on the mandrel. The split line bolts may be loosened prior to moving to the next step and then tightened when the bearing is over that step. The bearing should be rotated on the mandrel by hand. If it rotates freely it should be moved to the next step. This is done until a slight resistance is felt when the bearing is rotated.

E.5.1.4 Stack Height Check

With this technique, the thickness from the bearing outside diameter to the pad bore at the pivot point is measured. The bore diameter is then computed by subtracting twice the stack height from the housing averaged outside diameter. This is done for each pad and averaged to get the bearing set bore. A special set-up is required for this check, see Figure 1.E-2.

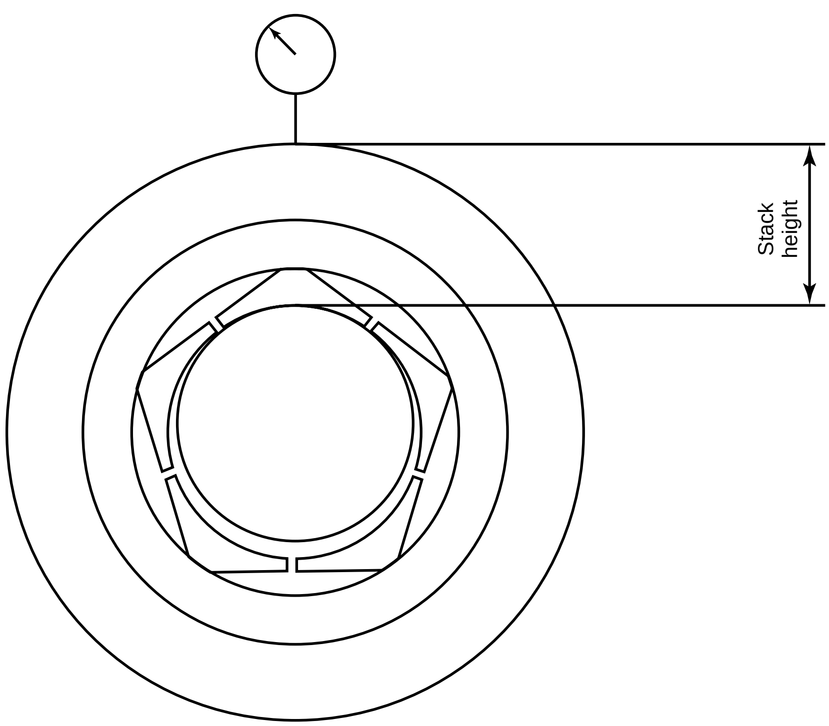


Figure 1.E-2—Stack Height Check

E.5.2 FIXED GEOMETRY JOURNAL BEARINGS (SLEEVE BEARINGS)

Fixed geometry journal bearings shall be checked using one of the following techniques:

E.5.2.1 Lift Check

For a fixed geometry journal bearing the resulting lift will be the diametral clearance. The dial indicator used to measure the clearance should be located as close to the bearing center as practical.

Note: Improper clearances may be caused by items such as:
a. Location and orientation of the dial indicator.
b. Components not installed with proper fit.
c. Incorrect journal shaft size.

E.5.2.2 Soft Solid Solder or Plastic Check

This method will give an approximation of the clearance between the bearing and the shaft. The soft, easily crushed material is to be placed axially for the full length of the bearing on the top of the shaft at 11:00, 12:00, and 1:00 and then the bearing upper half is to be carefully installed. The top half of the bearing housing is then installed and tightened. Remove the top half of the bearing housing and then carefully lift off the top half of the bearing shell. The thickness of this soft, easily crushed material is to be measured to determine the bearing clearance. The typical diametral clearance for these bearings is 1.5 mm/m (0.0015 in./in.) of shaft diameter. The manufacturer's drawing and information is to be consulted for the clearance verification.

E.6 Tutorial on Installation of Bearings In Casings

E.6.1 GENERAL

The following checks should be performed to assure the functionality of the bearing.

a. Verify that internal orifices or external orifice plates are installed when required.

b. Verify that the direction of rotation is correct.

c. Verify that all pads in the assembly move freely.

d. Verify that "O" rings are installed for designs requiring them.

e. Verify that wiring for the temperature sensing devices are properly routed, do not restrict pad movement, and will not be pinched during installation.

E.6.2 JOURNAL BEARING

Prior to installation of the bearing assembly, inspect the bearing cavity and cover for cleanliness. Remove any debris or dirt from the journal area, the bearing fit, and the oil sump areas of the bearing case. The rotor should be held in place by an overhead hoist.

Coat the journal and the bearing fit in the lower half of the casing with oil. Place the lower half of the bearing shell on top of the journal. Check alignment of the oil supply hole in the case with the position of the oil supply in the bearing shell.

Align the bearing fit in the case with the shell outside diameter and roll the bearing into the lower half of the case. It may be necessary to lift the rotor slightly to allow the bearing shell to roll in easily. Monitor the position of the temperature sensor lead wires when rolling in the bearing to ensure that the wire is not damaged.

Verify that the anti-rotation dowels in the bearing shell lower half are aligned with dowel holes in the shell upper half. Gently lower the top half of the bearing onto the lower half. Check for any stand off between the two bearing halves. Do not attempt to tighten the split line bolts if the two halves are not flush. Check for the cause of the stand off and correct. Install the bearing split line bolts and tighten securely.

It is recommended that a crush check be done to verify proper bearing to case fit. Place shims, 125 to 250 µm (0.005 to 0.0010 in.) thick along the case split line on either side of each bolt location. Lay a strip of plastigage or fuse wire parallel to the axis of the machine on top of the bearing shell. The typical standard design specification for the bearing shell crush is metal to metal to 50 µm (0.002 in.) interference. The manufacturer's drawing and information is to be consulted for this crush verification. The plastigage or fuse wire should be chosen such that the thickness of the shim at the case split line falls in the middle of the plastigage or fuse wire range.

Install the bearing cap or strap and tighten all split line bolts. After the bearing cap has been seated, remove the cap and inspect the plastigage or fuse wire. The plastigage or fuse wire should indicate a thickness equal to or less than the shim thickness used at the split line. The amount of interference is equal to the difference between the plastigage or fuse wire thickness and the shim thickness.

Once the proper crush is confirmed, the bearing clearance should be checked. Place the base of two dial indicators on a portion of the machine unaffected by rotor or bearing movement, such as the bearing case horizontal joint. Place an indicator stylus on the top of the shaft near the bearing. It is important that this stylus be placed near top dead center of the shaft to obtain an accurate reading. Place the other indicator stylus on the top of the bearing shell. Slowly lift the rotor, noting the shaft rise on the appropriate indicator. Be careful not to raise the rotor into an internal obstruction. Do not lift the rotor more than twice the set clearance.

Observe the indicator on the bearing as the shaft is slowly lifted. Once the bearing lifts, as indicated by the dial indicator, stop lifting the shaft. The lift is the difference between the two indicator readings. Note that the lift with tilt pad bearings will always be more than the actual bearing set clearance due to the shaft movement between the pads. Multiply the indicated lift clearance by the appropriate value in Table 1.E-1 to obtain the actual clearance.

After the clearance has been checked, install the bearing cap and tighten the split line bolts on the bearing cap.

E.6.3 THRUST BEARING

The method to determine the thrust bearing axial float is to install the bearing completely into the housing and the bearing housing is to be tightened. If the check is done with the top bearing housing removed, the reading will not be accurate and may be much larger than would be indicated. The rotor is to be thrusted back and forth with a steady force in each direction. With a dial indicator, observe the shaft movement, which is the amount that the shaft was thrusted from one direction to the other. This amount is the bearing axial float. If oil is on the thrust bearing pad faces, this axial float may be decreased due to the oil by about 25 µm (0.001 in.). This check should be done several times to verify that the rotor was thrusted as far as possible during the check. A verification of this axial float check is to use the eddy current position probes. Typically this axial float is between 250 µm and 380 µm (0.010 in. and 0.015 in.). Either shimming or grinding of the shim plate is used to adjust this axial float. The manufacturer's drawing and information is to be consulted for the axial float verification.

APPENDIX F—TOTAL INDICATOR READING

F.1 General

Dial indicators are one of the most commonly used tools in the inspection and quality control of repairs of turbomachinery rotors. They are available in a wide variety of types, graduations, and measuring ranges, and are commonly used to check shaft and component runout, for an accurate indication of the eccentricity (offset from the geometric centerline) of a shaft or component part. They are also used to verify the degree of roundness, face runout, and/or waviness of bearing journals and other components such as thrust collars, turbine disks, and compressor impellers. They are normally used in conjunction with a magnetic base holder during the inspection of rotors for ease in the rapid relocation of the indicator from one location to another.

F.2 Application of Indicators

As stated previously, there are many variations of dial indicators to suit their many applications. Probably one of the most commonly used indicators for turbomachinery rotor inspections is the horizontal dial test indicator, Figure 1.F-1, with a dial face graduated in 2.5 µm (0.0001 in.) increments. The measuring range of dial test indicators is typically limited to 1.0 mm (0.040 in.), which is more than adequate for the inspection of rotors and their components. The dial test indicators are also available with various length contact stylus that may be physically interchanged. However, it is of utmost importance that the contact stylus used for measurement is exactly the same length as the one that the indicator was calibrated for, as errors between 50% and 200% of the actual measured value can occur, depending on whether a longer or shorter contact stylus is used rather than the calibrated length. In general, it does not matter what type of indicator is used, as long as it will suit the application and is graduated to provide the necessary measurement resolution.

For example, when a balance mandrel is to be checked for excessive eccentricity, a resolution of 2.5 µm (0.0001 in.) is required, for any eccentricity that exceeds that amount is not acceptable. Therefore, an indicator with a face graduation in 10 µm (0.0004 inch) would not provide the necessary resolution.

Regardless of the type of indicator used, significant errors can also occur due to excessive inclination angle. For example, the contact stylus of a horizontal dial test indicator is basically horizontal, and the point of contact on the measurement surface should be parallel to the contact stylus as closely as possible, Figure 1.F-2. If the axis of the contact stylus forms a 45° angle with the measurement surface (45° inclination error), an error of 30% will occur (1-cos 45° = 0.293), Figure 1.F-3. Measurement error may also occur due to hysteresis in the indicator. Hysteresis may occur when the measurement surface is moved in two different directions, such as rotating a rotor forward, and then backwards, while attempting to make a single measurement. Finally, it should be noted that the best measurement accuracy is achieved when the measurement surface is moving away from the dial indicator, rather than towards the indicator.

F.3 Typical Indicator Measurements

F.3.1 TYPICAL ROTOR OR SHAFT SETUP

The rotor (or its shaft) is placed in vee blocks located at the bearing journals, and the shaft end is positioned against a backstop to prevent axial movement during rotation. The vee blocks are lined with a material such as micarta or nylon and lubricated with a heavy oil to prevent scoring of the journals. Further, the vee block widths should be equal to at least one-half of the journal diameter, so that the contact with the journals is not localized in one small area. The entire length of the vee block shall be used for support in the center of the journal. A ball bearing is typically placed between the shaft end

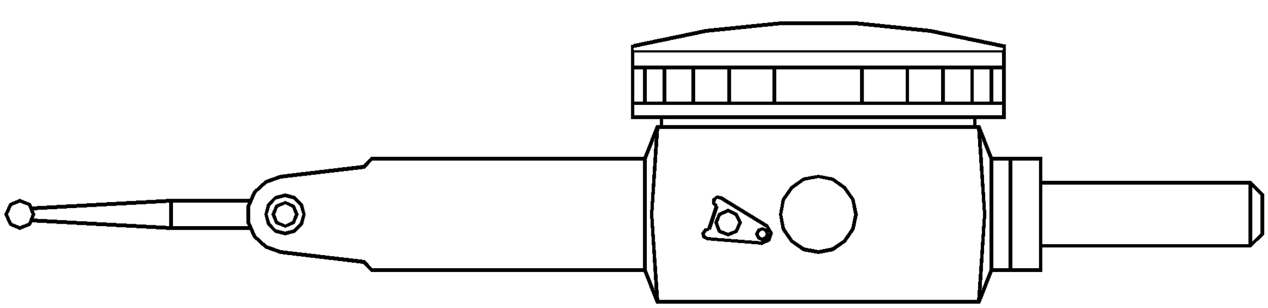
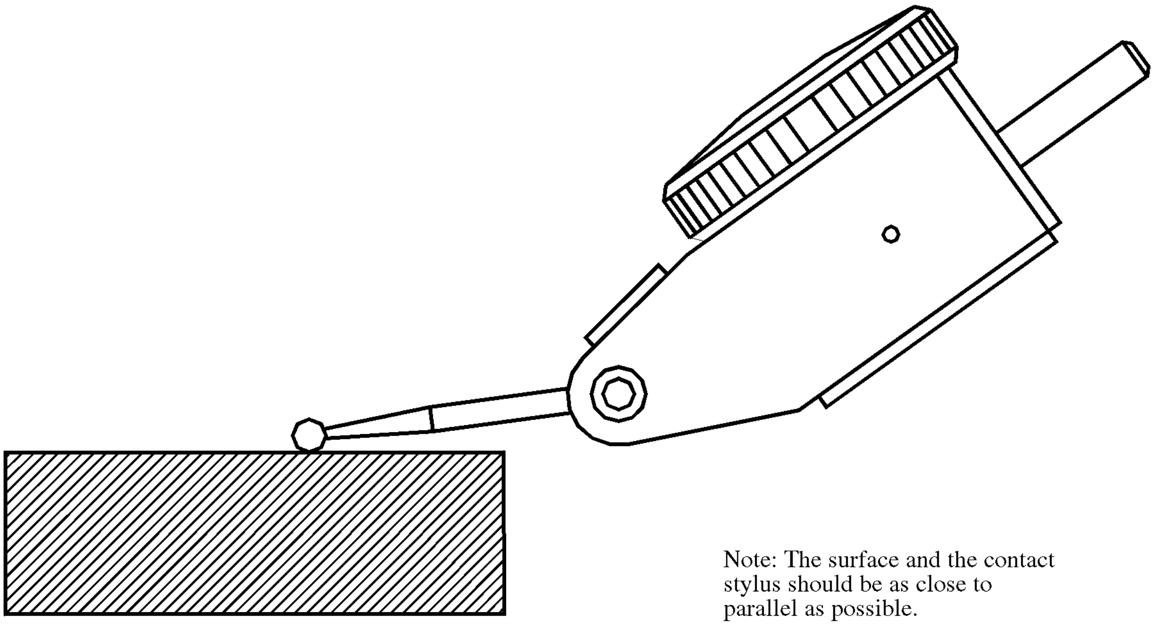
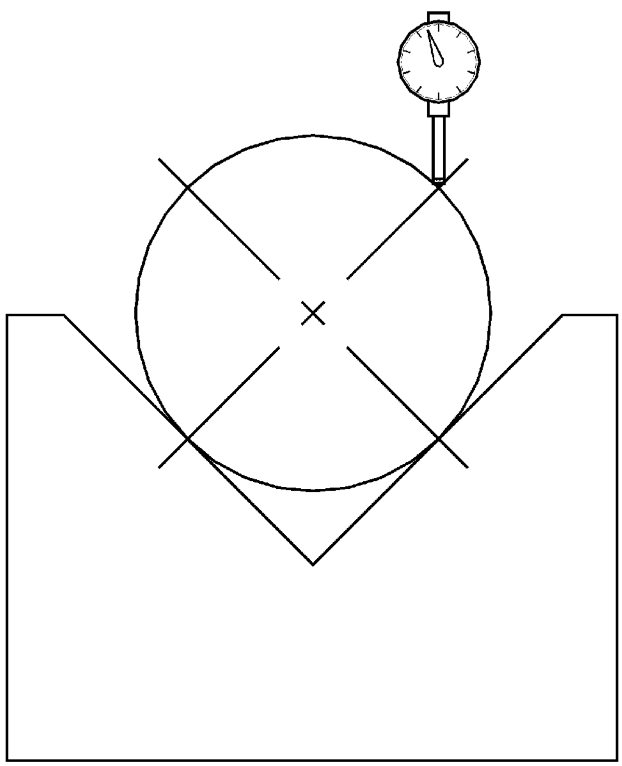


Figure 1.F-1—Typical Horizontal Dial Test Indicator



Note: The surface and the contact stylus should be as close to parallel as possible.

Figure 1.F-2—Proper Positioning of Contact Stylus



Note: Shown is an inclination error of 45° (indicator will reveal only 70% of true runout).

Incorrect positioning

Figure 1.F-3—Inclination Error

and the backstop to prevent the shaft face from contacting the backstop. The rotor or shaft is also generally placed in the vee blocks with the bearing journal opposite the backstop slightly higher than the journal nearest the backstop. In this manner, the rotor will tend to thrust towards the backstop during rotation, preventing axial movement during the measurements.

F.3.2 PHASE REFERENCE MEASUREMENT

Phase-referenced runout measurements are necessary to determine the shape of the shaft or component being measured. In practice, a "zero" reference is established and documented on the data sheet prior to taking any measurements. Typically the coupling (driven end) keyway centerline is used as the zero phase reference. If the coupling area is double-keyed or has no keyway, the thrust collar keyway shall be used as the zero reference; if this is also not possible, an arrow shall be stamped on the end of the shaft to show the plane of the zero phase reference. Runouts shall be recorded as viewed from the coupling (driven end) of the rotor. The indicator is then placed on the desired measurement surface in the same angular location as the zero reference, then the indicator is zeroed while at this location. The rotor or shaft is then turned in the direction of its normal rotation, and the maximum plus readings and their angular location on the measurement surfaces are noted and recorded (i.e., phase increases against normal rotation). A common way of temporarily marking the high spot is to use an indelible felt tip marker to place a dot at the high spot indicated by the indicator while the rotor is turned. The phase angle in degrees from the zero reference may either be determined by measurement, or by close visual estimation, as accuracy within approximately 10° is normally sufficient to analyze the basic shape of the rotor, shaft, or component being measured.

F.3.3 RADIAL RUNOUT MEASUREMENT

F.3.3.1 Purpose of Radial Runout Measurements

Radial runout measurements are primarily made to determine the eccentricity of the measured surface from the bearing journals diametral centerline. However, radial measurements may also be used to denote the degree of roundness of the surface. Note that if the indicator contact stylus is not perpendicular to one of the vee block faces, an out-of-round (or elliptical) condition may not be observed during the measurement, see Figure 1.F-4.

Note: When taking runout measurements the first measurement is to verify the roundness of the journals in the vee blocks.

F.3.3.2 Eccentricity Determination

When the surface is round, but not on the same centerline as the supported journals, the dial indicator will reveal only one high spot, and the readings will continually decline as the high spot moves away from the contact stylus until the low spot comes under the contact stylus. The low spot will also be

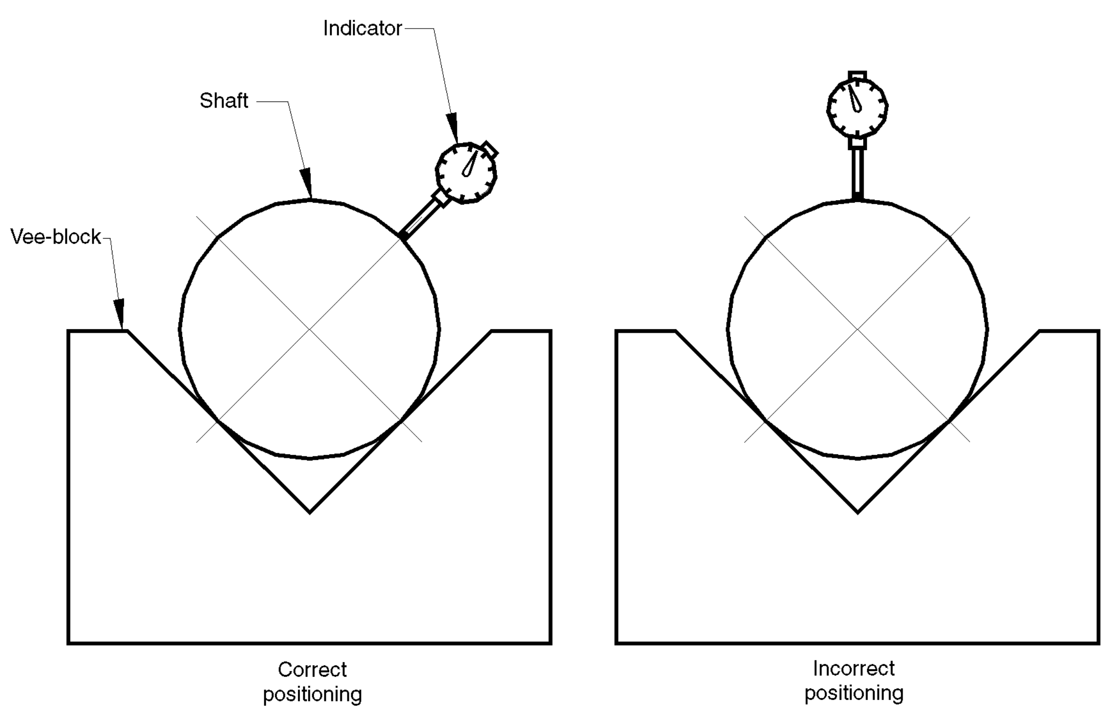


Figure 1.F-4—Roundness Measurement

180° from the high spot. Such a condition may be caused by a mechanical shaft bow, improper machining that results in the measurement area having a centerline that is different than that of the journals, or assembly stresses that result in a shaft bow. When an eccentric condition exists, and a distinctive maximum high spot can be determined, record the value of the maximum high spot and its phase angle.

F.3.3.3 Out-of-Roundness Determination

If the surface is not round, but is on the same centerline as the supported journals, the indicator will typically reveal two low spots that are 180° apart, and two high spots that are also 180° apart. Normally, there will be 90° between the high spots and the low spots. Such an elliptical condition is commonly referred to as "egg-shaped", and is commonly the result of machining errors. When an out of roundness condition exists, and a distinctive maximum high spot can be determined, record the value of the maximum high spot and its phase angle.

F.3.3.4 Eccentricity and Out-of-Roundness Determination

If the measured surface is not round, and also is not on the same centerline as the supported journals, there will still be two high spots that are 180° apart, however, one of these high spots may have a greater value than the other, depending on the relative magnitudes of the eccentricity and the out-of-roundness. When an elliptical condition exists, and a distinctive maximum high spot can be determined, record the value of the maximum high spot and its phase angle.

F.3.3.5 Surface Waviness Measurement

A surface may also have "waviness." In such a case the indicator reading will continually fluctuate as the rotor or shaft is turned, indicating numerous low and high spots. The differences between the low and high spots are usually very small, normally in the order of approximately 2.5 µm (0.0001 in.). A common cause of a "wavy" surface is grinder chatter that occurred when the surface was ground.

F.3.4 AXIAL RUNOUT MEASUREMENT

F.3.4.1 Purpose of Axial Runout Measurements

Axial runout measurements are primarily made to determine the perpendicularity of an axial face, such as an impeller suction eye face, a turbine disk face, or a thrust collar face, to the shaft's longitudinal centerline. However, axial runout measurements will also reveal face distortion and other conditions, as well.

Note: When taking axial runout measurements, a second indicator is required and is to be located to verify no axial travel.

F.3.4.2 Perpendicularity Measurement

If the axial measurement surface is flat and true, but is not perpendicular to the shaft's longitudinal centerline, the indicator will reveal only one high spot and one low spot, and the two will be 180° apart. In such a case, as with radial eccentricity, the indicator readings will continually decline as the high spot moves away from the contact stylus, until the low spot is contacted. One example could be a compressor impeller that is cocked on the shaft, as described in F.3.4.3. If the impeller's radial surface was machined true using the same setup as the face machining, and the radial eccentricity was also checked, the radial high spot should be 180° from the axial high spot. A cocked impeller often results in excessive assembly stresses. The impeller will also tend to straighten itself during operation, often while the rotor is in its influence of the bending critical, relieving the excessive assembly stresses and resulting in a significant change in balance.

F.3.4.3 Mis-Machined or Cocked Component Determination

A combination of axial and radial runout measurements, as mentioned in 3.4.2, may be used to determine a mis-machined component such as a suction eye on a compressor impeller. If the radial high spot on the outside diameter of the suction eye is less than 90° from the high spot on the suction eye face, the suction eye was likely mis-machined, and consequently, the runout measurements cannot be used to determine that the impeller is cocked on the shaft. Also, axial runout measurements of the hub faces at each end of the impeller bore may be compared to the suction eye face to aid in determining whether the impeller is cocked or not, however, since these faces are normally much smaller in diameter than the eye face, the runout readings will also be proportionally smaller. If the impeller is cocked on the shaft, the high spot on the suction side bore face should be at the same angular location as that of the eye face, and the high spot on the discharge side bore face should be 180° from that of the eye face. Similar analysis may be used for turbine disks, thrust collars, balance pistons, etc.

Note: Some impeller coverplates, especially those of riveted impellers, may distort when mounted due to a heavy interference fit on the shaft.

F.3.4.4 Distorted Face Determination

If an impeller or turbine disk is mounted perpendicular to the longitudinal shaft centerline, but the face is distorted, the dial indicator will usually reveal two high spots and two low spots. Similar to an out-of-round radial surface, the high spots will normally be 180° apart, and the low spots will also be 180° apart. Normally, the angular difference between a high and low spot will be 90°. This condition may be referred to as being "potato chipped," because the face is shaped liked a potato chip.

F.3.4.5 Disk Non-Parallelism Determination

Disks with faces that are machined on both sides can be checked for the parallelism of the faces using a dial indicator. If the disk faces are parallel, but the disk is cocked on the shaft, the high spots on the two faces will be of equal magnitude and will be 180° apart. If the disk faces are not parallel, but the disk is mounted true on the shaft, the high spots on the two faces may or may not be of equal magnitude, but they will be located less than 90° apart. With such machining errors, an outside micrometer can be used to measure the disk thickness in four locations, or every 90°, to verify the non-parallelism of the faces.

F.4 Vibration Probe Area Runout

F.4.1 RUNOUT MEASUREMENTS

The set-up and phase reference for the runout checks shall be as described in sections F.3.1.1 and F.3.2.

F.4.2 Electrical and mechanical runouts of each probe location shall be checked and continuously recorded and phase related as specified in F.4.1. The runouts shall be obtained by rotating the rotor through the full 360° rotation while supported in vee blocks at the journal centers. The runouts are to be measured with a noncontacting vibration probe and a mechanical runout indicator, both located at the centerline of each probe location and one probe tip diameter to either side.

● **F.4.3** When specified, the calibration curve for each probe system is to be determined using the actual shaft. A separate calibration curve is to be plotted for each probe location that may have different metallurgy due to different material permeability. The calibration curves are to consist of a minimum of ten points plotted on a graph with the displacement in increments of 0.25 mm (10 mils) versus the transducer's output voltage. During the measurements for the calibration curves, the probe travel is to be perpendicular to the shaft to obtain the most accurate measurements due to the curvature of the shaft. On target areas 75 mm (3 inches) or greater in diameter, the shaft end may be used.

Note: Using the actual shaft will provide the most accurate calibration curves possible. Errors may result from differences from the probe calibration test block vs. the actual shafting. The differences of concern are:

1. Material and heat-treating process.

2. Shaft diameters less than 75 mm (3 inches) may result in calibration errors due to the shaft curvature versus the flat block used as the reference.

APPENDIX G—VENDOR DATA DRAWING REQUIREMENTS (VDDR)

G.1 Phase I Inspection Schedule

a. The vendor shall supply a not to exceed time frame for the completion of the Phase I inspection.

b. When the customer has specified witness points, an inspection schedule shall be included with quotation/ proposal.

c. Unless otherwise specified, schedule shall be based on a normal work week without overtime.

d. Sufficient detail shall be provided to enable owner to plan the project witness activities.

e. Schedule shall be strictly followed in order for owner to establish completion of rotor inspection and repair.

G.2 Phase I Inspection Report

a. Upon completion of Phase I inspection, a detailed inspection report containing all initial inspection records, including NDE and dimensional inspection, as required by Sections 6 through 8, shall be sent to owner.

b. The detailed report shall be submitted for review and include the following as a minimum:

1. Proposed repair processes and procedures.
2. A list of required new components.
3. Upgrade alternatives and recommendations.
4. Associated schedules and costs.

G.3 Phase II Inspection Schedule

a. The vendor shall supply a not to exceed time frame for the completion of the Phase II inspection.

b. When the customer has specified witness points, an inspection schedule shall be included with quotation/ proposal.

c. Unless otherwise specified, schedule shall be based on a normal work week without overtime.

d. Sufficient detail shall be provided to enable owner to plan the project witness activities.

e. Schedule shall be strictly followed in order for owner to establish completion of rotor inspection and repair.

G.4 Phase II Inspection Report

a. Upon completion of Phase II inspection, a detailed inspection report containing all inspection records, including NDE and dimensional inspection, as required by Chapters 2 through 7, as appropriate, shall be sent to owner.

b. The detailed report shall be submitted for review and include the following as a minimum:

1. Proposed repair processes and procedures.
2. A list of required new components.
3. Upgrade alternatives and recommendations.
4. Associated schedules and costs.

G.5 Repair Schedule

a. The schedule for repairs shall be issued to include appropriate time for the repairs and/or replacement of components as defined by the scope of repair.

b. In the event of any schedule threatening setback or slippage, the owner shall be notified via the agreed upon means of communication between owner and repair shop.

G.6 Periodic Status Report

a. The repair vendor shall provide bi-weekly (or other frequency as agreed) status reports of the repair work.

b. As a minimum, the major components and milestone events shall be identified and tracked for progress.

c. The agreed upon witness points and corresponding dates should be included in each status report.

G.7 Weld Procedures

The repair shop shall have available for review all weld procedures as applicable to new components and to repaired components.

G.8 Rotor Disassembly Procedure

- A step-by-step procedure to disassemble the rotor, if specified, by the owner.

G.9 Rotor Stacking Procedure

Rotor stacking procedure, if required, shall conform to the applicable Chapter 2 through 7 for the specific type of rotor.

G.10 Special Procedures

As agreed between owner and repair shop, any special procedures shall be reviewed.

G.11 Technical Data Control

The purchaser and repair shop shall mutually agree upon the data to be provided in the final technical data manual. Typical data that might be included is:

a. All inspection reports, engineering dispositions of nonconformances, and photographs.

b. As Built dimensions and assembly clearances.

c. Certified mill test reports.

d. Residual unbalance reports per section 10.

e. Coupling bluing tapes per Appendix C.

f. Copies of all non-destructive inspection and acceptance criteria used for repair.

g. All drawings and procedures purchased for the repair or manufacture of any replacement component.

h. All correspondence and price quotes.

i. Quality control documentation and witness requirements conforming to Appendixes H and K.

G.12 Photography

a. Photographs taken shall be of sufficient quality to assure that any discrepancy is clearly seen. This may require an overall view and then detail views to highlight the discrepancy such that no question may arise in further reviews, even if the discrepancy has been removed or repaired. It is recommended that a 35 mm or a digital camera be used so that multiple copies and/or enlargements may be made.

b. Sufficient quantities of photographs shall be taken so that the repair shop and the owner may have their own copies as a minimum. Photographs shall be mounted on a sheet of paper with an explanation of the photograph either on or adjacent to the photograph.

G.13 Inspection Documentation

a. The vendor shall provide documentation that verifies conformance to each of the inspections required by the API standard applicable to the type of rotor being repaired or replaced.

b. The vendor shall submit a "Quality Assurance Plan for Rotor Repair" as defined by the Appendix K and the appropriate chapter appendix in this document that applies to the type of rotor being repaired. This plan shall be tailored as appropriate to correspond to the scope of repair agreed upon between owner and vendor.

c. The owner may use the forms included in this appendix as a convenient means of defining the general data requirements such as: specific documents required; the document media; quantities to be provided; schedules for submitting, reviewing and final issue.

ROTOR REPAIR VENDOR DRAWING AND DATA REQUIREMENTS

JOB NO. ________________________ ITEM NO. ______________
PURCHASE ORDER NO. _________ DATE ________________
REQUISITION NO. _______________ DATE ________________
INQUIRY NO. ___________________ DATE ________________
PAGE _______ OF _____ BY __________________________

FOR ____
SITE ____
SERVICE ____

REVISION ______________________ DATE ________________
UNIT ____
NO. REQUIRED ____________________________________

Proposal[a] Bidder shall furnish ________ copies of data for all items indicated by an X.

Review[b] Vendor shall furnish ________ copies and ________ transparencies of drawings and data indicated.

Final[b] Vendor shall furnish ________ copies and ________ transparencies of drawings and data indicated.
Vendor shall furnish ________ operating and maintenance manuals.

DISTRIBUTION RECORD

Final—Received from vendor
Final—Due from vendor[c]
Review—Returned to vendor
Review—Received from vendor
Review—Due from vendor[c]

Proposal	Review	Final	DESCRIPTION	Review—Due from vendor	Review—Received from vendor	Review—Returned to vendor	Final—Due from vendor	Final—Received from vendor
			1. Phase I Inspection Schedule					
			2. Phase I Inspection Report					
			3. Phase II Inspection Schedule					
			4. Phase II Inspection Report					
			5. Repair Schedule					
			6. Periodic Status Report					
			7. Weld Procedures					
			8. Rotor Disassembly Procedure					
			9. Rotor Stacking Procedure					
			10. Special Procedures					
			11. Technical Data Control					
			12. Photographs					
			13. Inspection Documentation					

[a]Proposal drawings and data do not have to be certified or “as-built.” Typical data shall be identified as such.
[b]Purchaser will indicate in this column the time frame for submission of materials using the nomenclature given at the end of this form.
[c]Bidder shall complete these columns to reflect his actual distribution schedule and include this form with his proposal.

Notes:

1. Send all drawings and data to ____
   ____
2. All drawings and data must show project, appropriation, purchase order, and item numbers in addition to the plant location and unit. One set of the drawings/instructions necessary for field installation must be forwarded with shipment in addition to copies specified above.

Nomenclature:

_________ S—number of weeks prior to shipment.
_________ F—number of weeks after firm order.
_________ D—number of weeks after receipt of approved drawings.

Vendor ____
Date ______________________ Vendor Reference No. ______________________
Signature ____
(Signature acknowledges receipt of all instructions)

APPENDIX H—AUDITORS CHECK LIST

H.1 General

This Appendix is a checklist to provide information for the owner and the vendor to aid in summarizing the scope of the rotor repair.

Repairs require clear owner / vendor communication and the assignment of responsibilities. The format of this checklist provides a summary of the items required and the parties responsible.

Each item on this checklist has a circle or a square to indicate whether the owner or vendor, respectively, is responsible for obtaining the information or performing the task. The owner must indicate, for each item, whether the item is to be witnessed, observed, or verified. Typically, inspections, processes or tests may be witnessed or observed while verification is the review of the results of the inspections, processes, tests, or other documentation so as to ensure that the requirements have been met.

AUDITORS CHECK LIST

Customer: ______________________

Job/Project Number: ______________________

Owner Equipment Identification Number: ______________________

OEM Equipment Serial Number: ______________________

Rotor Identification Number: ______________________

Repair Purchase Order Number: ______________________

Vendor Job Number: ______________________

Auditors Check List

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice			Date Inspected or Verified By	Status
			W	O	V		
Section 1							
N / A							
Section 2—Process for Overhaul and Refurbishment of a Rotor							
API STD Identified	O	2.3.1			X		
Operating Conditions	O	2.3.2			X		
Rotor History	O	2.3.3			X		
Environmental Conditions	O	2.3.4			X		
Rotor Documentation	O	2.3.5			X		
Failure Analysis	O	2.3.6			X		
Repair Reason	O	2.3.7			X		
Performance and Mechanical Data	O	2.3.8			X		
Additional Work	O	2.4.1			X		
Loose Parts/Special Tools Supplied	O	2.4.2			X		
Coupling Assembly, Ring/Plug Gauge	O	2.4.3			X		
Remove Thrust Collar	O	2.4.4			X		
Bearings To Be Inspected	O Y/N	2.4.5			X		
Data Sheets	O	2.4.6			X		
Upgrade Proposals	O/☐	2.5.1			X		
Coating Components	O/☐	2.5.2			X		
New Data Plate	☐	2.5.3			X		
Owner’s Requirements	O	2.6.1			X		
Root Cause Analysis	O/☐	2.6.2			X		
Documented Scope Changes	O/☐	2.6.3			X		
Applicable Inspection Processes	O/☐	2.6.4			X		

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
Section 3—Selection of a Repair Shop							
Qualification Survey Form	O/☐	3.1.2			X		
Section 4—Communication							
Meetings Documented	☐	4.2			X		
Post-Shipment Review	O/☐	4.4			X		
Section 5—Transport to Vendor's Shop							
Unique Tracking Number	☐	5.1.1			X		
Owner Supplied Material	O	5.1.2			X		
Preservation	O	5.1.3			X		
Containers	O	5.1.4			X		
Lifting Arrangement	O	5.1.5			X		
MSDS	O	5.1.6			X		
Section 6—Receiving Inspection							
Lifting Equipment Certification	☐	6.1.1			X		
Material Control	☐	6.2.1			X		
Receiving Log	☐	6.2.2			X		
Received Photographs	☐	6.2.3			X		
Shipment Damage	☐	6.2.4			X		
Customer Property	☐	6.2.5			X		
Storage	☐	6.2.6			X		
Section 7—Phase I Inspection							
Bearing Inspection	☐	7.1.1.1					
Coupling Inspection	☐	7.1.1.2					
Photo Log	☐	7.2.1.1					
Residue/Deposit Samples	☐	7.2.1.2					
Axial and Radial Dimension Inspection	☐	7.2.1.3					
Probe Locations	☐	7.2.1.3					
Discrepancies	☐	7.2.1.4					
Rotor Cleaning	☐	7.2.2					
Residual Magnetism	☐	7.2.3					
NDE	☐	7.2.3					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
Chemistry/Hardness	☐	7.2.4					
Photographs	☐	7.2.5					
Clearance Diameters	☐	7.2.6.1					
Seal Diameters	☐	7.2.6.2					
Coatings/Overlays	☐	7.2.6.3					
Coupling Fits	☐	7.2.6.4					
Runouts	☐	7.2.6.5					
Weight	☐	7.2.7					
Balance Check	☐	7.2.8					
Documentation	☐	7.2.9					
Section 8—Inspection Methods and Testing							
Data	☐	8.1.1			X		
Additional Work	O	8.1.2					
Remove Coating	O/☐	8.1.3					
Apply Coating	☐	8.1.4					
Qualifications	☐	8.1.5			X		
Review Design	☐	8.2.1.2					
Radiography	☐	8.2.2					
Ultrasonic Inspection	☐	8.2.3					
Magnetic Particle and Liquid Penetrant	☐	8.2.4					
Section 9—Repair and New Component Manufacture							
Drawing Review	☐	9.1.2			X		
Technical Data Manual	☐	9.1.3			X		
Quality Plan	☐	9.1.5			X		
Failure Analysis	☐	9.1.6			X		
Keyways and Keys		9.1.7					
Shaft Restoration—Additional Requirements In Quality Plan							
Rotor Centerline	☐	9.2.1.2					
Stress Analysis	☐	9.2.1.3			X		
Truth Bands	☐	9.2.1.4					
Restoration Processes	O/☐	9.2.2					
Machine Shaft Undersize	O/☐	9.2.3					
Shaft Surface Finish	☐	9.2.5					
Fillet Radii	☐	9.2.6					
Coupling Shaft End—Additional Requirements In Quality Plan							
Shaft End Requirements	☐	9.3.1			X		

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice			Date Inspected or Verified By	Status
			W	O	V		
Shaft End Welding	O/☐	9.3.2					
Shaft End Undersize	O/☐	9.3.3					
Shaft End Lap	O/☐	9.3.4					
Flanged Shaft Weld	O/☐	9.3.5					
Bolt Holes	O/☐	9.3.6					
Shaft End Face	O/☐	9.3.7					
Thrust Collar—Additional Requirements In Quality Plan							
Collar Runout/ Surface Finish	☐	9.4.1					
Collar Repair/Replace	O/☐	9.4.2					
Shaft Sleeve/Spacer—Additional Requirements In Quality Plan							
Sleeve/Spacer Repair	O/☐	9.5					
Shaft Radial Runouts							
Mechanical Runouts	☐	9.6.1					
Probe Area Runouts	☐	9.6.2					
New Component Manufacture—Additional Requirements In Quality Plan							
API Compliance	O/☐	9.7.1					
New Component Requirements	O/☐	9.7.2					
Reverse Eng. Process	☐	9.7.3					
Design Review	O/☐	9.7.4					
Section 10—Rotor Assembly and Balancing							
Rotor Balance	O	10.1.1					
Rotor Journal Coated	☐	10.1.2					
Field Balance Weight Removal	☐	10.1.3					
Balance Weight Removal	O/☐	10.1.4					
Record Balance Weights	☐	10.1.5					
Ancillary Components Balance Weights	☐	10.1.7					
Low Speed Component Balance—Additional Requirements In Quality Plan							
Balance Rotation	☐	10.2.1					
Major Component Balance	☐	10.2.2					
Coated Component Balance	☐	10.2.3					
Spin Components	☐	10.2.4					
Fully Crowned Keys	☐	10.2.5					
Phase Reference	☐	10.2.6					
Balance Mandrels	☐	10.2.7					
Interference Fit	☐	10.2.8					
Vertical Balance	☐	10.2.9					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
Phase Related Runouts	☐	10.2.10					
Balance Tolerances	☐	10.2.11					
Static Balance Tolerances	☐	10.2.12					
Low Speed Assembly Balance—Additional Requirements In Quality Plan							
Optional High Speed Balance	O/☐	10.3.1					
Rotating Component Balance	☐	10.3.2					
Overhung Rotor Balance	☐	10.3.3					
Coated Rotor Balance	☐	10.3.4					
Balance Corrections	☐	10.3.5					
Keys Used During Balancing	☐	10.3.6					
Weigh Half-Keys	☐	10.3.7					
Balance Machine Roller Diameter	☐	10.3.8					
Balance Tolerances	☐	10.3.9					
Rotate Jackshaft	☐	10.3.10					
Residual Unbalance/Phase Angle	☐	10.3.11					
Residual Unbalance Testing—Additional Requirements In Quality Plan							
Residual Unbalance Test	☐	10.4.1					
Installation of Trim Parts	☐	10.4.2					
Balance Corrections	☐	10.4.3					
Coupling Balance	☐	10.4.4					
Matchmarking of Trim Parts	☐	10.4.5/ 10.4.6					
Balance Equipment Documentation							
Balance Machine Calibration	☐	10.5.1					
Balance Machine Capability	☐	10.5.2					
Documentation	☐	10.5.3					
Residual Unbalance	☐	10.5.4					
High Speed Balance							
High Speed Balance Procedure	☐	10.6.1					
Acceptance Criteria	☐	10.6.2					
Pre-Balance Information	O/☐	10.6.3/ 10.6.4					
Rotor Records	☐	10.6.5					
Section 11—Preparation For Shipment and Storage							
Container Requirements	☐	11.1.1					
Equipment Identification	O/☐	11.1.2					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice			Date Inspected or Verified By	Status
			W	O	V		
Term of Storage and Method of Shipment	O/☐	11.1.3					
Container Design	☐	11.1.4/ 11.1.5					
Shaft Protection	☐	11.1.6					
Container Lifting Requirements	☐	11.1.7					
Shipment	☐	11.1.8					
Containers							
Shipping Classes	O/☐	11.2.1					
Wooden Box	O/☐	11.2.2					
Steel Container	O/☐	11.2.3					
Rotor Supports							
Horizontal Supports	☐	11.3.1					
Vertical Supports	☐	11.3.2					
Packing							
General	☐	11.4.1					
Class #1	O/☐	11.4.2					
Class #2	O/☐	11.4.3					
Class #3	O/☐	11.4.4					
Section 12—Documentation							
Vendor Data Drawing Requirements	O/☐	12.1.1					
Proposals	☐	12.2					
Technical Data	☐	12.3.1			X		
Progress Reports	☐	12.3.2			X		
Records Identification	☐	12.4.1.1			X		
Records Storage	☐	12.4.1.2			X		
Owner Records	O/☐	12.4.2			X		
Appendix A—Residual Unbalance Check							
See 10.4	☐						
Appendix B—Non-destructive Examination Methods							
See 8.2							
Appendix C—Main Drive Coupling							
Inspection	☐	C.3.0					
Fit Check	☐	C.4.0					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice			Date Inspected or Verified By	Status
			W	O	V		
Bluing	☐	C.6.0					
Lapping	☐	C.7.0					
Coupling Hub Installation	O/☐	C.8.0					
Coupling Center Assembly Installation	O	C.9.0					
Coupling Guard Installation	O	C.10.0					
Appendix D—Restoration Methods (Additional Requirements In Quality Plan)							
Repair Approval	O/☐	D.1.1					
Weld Repair	O/☐	D.2.0					
Thermal Spray Repair	O/☐	D.3.0					
Reducing the Shaft	O/☐	D.4.0					
Plating	O/☐	D.5.0					
Shaft Straightening	O/☐	D.6.0					
Appendix E – Fluid Film Bearings (Additional Requirements In Quality Plan)							
Initial Inspection		E.3.0					
Dimensional Inspection		E.4.0					
Clearance Checks		E.5.0					
Appendix F—Total Indicator Reading							
See 9.6							
Appendix G—Vendor Data and Drawing Requirements (See 12.1)							
Specify Data Requirements	O				X		
Phase I Inspection Schedule	☐	G.1.0					
Phase I Inspection Report	☐	G.2.0					
Phase II Inspection Schedule	☐	G.3.0					
Phase II Inspection Report	☐	G.4.0					
Repair Schedule	☐	G.5.0					
Status Reports	☐	G.6.0					
Weld Procedures (Refer to individual QC plans)	O/☐	G.7.0					
Disassembly Procedure	☐	G.8.0					
Stacking Procedure	☐	G.9.0					
Special Procedures	O/☐	G.10.0					
Technical Data	☐	G.11.0					
Inspection Documentation	☐	G.13.0					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
Appendix H—Auditor's Check List							
Complete	O/☐				X		
Appendix I—Selection Of Repair Shop							
See Section 3							
Appendix J—Containers							
See Section 11							
Appendix K—Quality/Manufacturing Plan							
Complete	O/☐				X		
Appendix L—Protective Coatings (Additional Requirements In Quality Plan)							
Evaluate Need for Coating	O/☐	L.1.0			X		
Selection of Coating	O/☐	L.1.3					
Compatibility with base material	☐	L.1.3.1			X		
Data Sheet Information	O/☐	L.1.3.1			X		
Gas and Deposit Analysis	O/☐	L.1.3.1			X		
Application of Multi-Layer Coating System for Operating Temperatures below 260°C (500°F)		L.2.0					
Clean Component	☐	L.2.2					
Mask off non-coated areas	☐						
Apply Base Coat	☐	L.2.3					
Cure Base Coat	☐	L.2.3					
Bond Strength Base Coat Coupon	☐	L.2.4					
Thickness Base Coat	☐	L.2.4/ L.2.10					
Burnish Base Coat	☐	L.2.5					
Resistivity Base Coat	☐	L.2.5					
Apply Second Base Coat	☐	L.2.6					
Cure Second Base Coat	☐	L.2.6					
Thickness Second Base Coat	☐						
Apply Intermediate Layer	☐	L.2.7					
Cure Intermediate Layer	☐	L.2.7					
Apply Top Coat Layer	☐	L.2.8					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
Cure Top Coat Layer	☐	L.2.8					
Total Coating Thickness	☐	L.2.9/ L.2.10					
Check for Surface Imperfections	☐	L.2.9					
Coating Surface Finish	☐	L.2.9					
Application of Multi-Layer Coating System for Operating Temperatures between 260°C and 565°C (500°F to 1050°F)		L.3.0					
Clean Component	☐	L.3.1					
Mask off non-coated areas	☐						
Apply Base Coat	☐	L.3.2					
Cure Base Coat	☐	L.3.2					
Bond Strength Base Coat Coupon	☐	L.3.3					
Thickness Base Coat	☐	L.3.3/L.3.7					
Burnish Base Coat	☐	L.3.4					
Resistivity Base Coat	☐	L.3.4					
Apply Top Coat Layer	☐	L.3.5					
Cure Top Coat Layer	☐	L.3.5					
Total Coating Thickness	☐	L.3.6/L.3.7					
Check for Surface Imperfections	☐	L.3.6					
Coating Surface Finish	☐	L.3.6					
Application of Multi-Layer Aerodynamically Smooth Coating to Resist Corrosion and Fouling up to 565°C (1050°F) on Axial Compressor Rotors in Air Service		L.4.0					
Clean Component	☐	L.4.1					
Mask off non-coated areas	☐						
Apply Base Coat	☐	L.4.2					
Cure Base Coat	☐	L.4.2					
Bond Strength Base Coat Coupon	☐	L.4.3					
Thickness Base Coat	☐	L.4.3/L.4.7					
Burnish Base Coat	☐	L.4.4					
Resistivity Base Coat	☐	L.4.4					
Apply Top Coat Layer	☐	L.4.5					
Cure Top Coat Layer	☐	L.4.5					
Total Coating Thickness	☐	L.4.6/L.4.7					
Check for Surface Imperfections	☐	L.4.6					
Coating Surface Finish	☐	L.4.6					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice			Date Inspected or Verified By	Status
			W	O	V		
Miscellaneous Considerations							
Coating Data	☐	L.5.1					
Rotor Balance	☐	L.5.2					
Evaluate Coating Thickness on Performance		L.5.3					
Cleaning Cautions	☐	L.5.4					
Rotor Supports	☐	L.5.5					
Thermal Treatments	☐	L.5.6					
Temperature Ramp Rate	☐	L.5.7					
Cure Temperature	☐	L.5.8					
Heat Cycle Temperature Charts	☐	L.5.9					
Coating Thickness	☐	L.5.10					
Drawing/Masking	☐	L.5.11					
Container	☐	L.5.12					
Shipping	☐	L.5.13					
Coating Restoration	☐	L.5.14					
Coating Requirements	☐	L.5.15					
Vibration Probe Areas	☐	L.5.16					

APPENDIX I—SELECTION OF A REPAIR SHOP CHECK LIST

I.1 General

This appendix may be used as a preliminary survey form filled out by the repair shop and submitted to the requester for the purpose of initial repair shop selection. All items of this survey may not be applicable, depending on the scope of repair requirements.

This appendix may also be used as a verification form by the owner on a continuing basis to allow first-hand verification of repair shop performance.

I.2 Instructions

I.2.1 OWNER'S REPRESENTATIVE

It is the responsibility of the owner's representative to fill out the survey form without bias and to judge each repair facility fairly and in a consistent manner.

I.2.2 REPAIR SHOP

The repair shop should fill out the form as completely and accurately as possible and submit to the owner. If an owner requests on-site verification, the repair shop should prepare by assembling all of the supporting documentation that supports the survey questions.

General Information (Attach separate sheets as necessary)

Name of Company:	Parent Company Name:
Registered Address:	Street Address:
President/ CEO:	
Manufacturing/Operations Manager:	Reports To:
Engineering Manager:	Reports To:
Quality Assurance Manager:	Reports To:
Contact Name/Title:	
Contact Telephone:	Contact Fax: E-Mail:
Contact Street Address:	
Alternate/After Hours Contact Name/Title:	
Alternate/After Hours Contact Telephone:	Alternate Contact Fax:
Alternate Contact Address:	
Recent (within 1 year) Management Changes:	
Company Mission/Vision:	

Primary Products or Principal Specialty of Shop

Product/Specialty	Main Characteristics	Annual Dollar Volume

Number of Full-Time Employees

	Contract	Non-Contract		Contract	Non-Contract	
Administration:			Engineering:			
Manufacturing:			Quality Assistance:			
Inspection/ Testing:			Purchasing:			
Field Service:						

Labor Management

Open Shop: Yes [ ] No [ ]	Union Shop: Yes [ ] No [ ]
Affiliation:	Contract Expires:
Shifts available for repair work:	

Code/Standards Experience
(Explain specifically which codes and standards your facility has experience with.)

AWS:	ANSI:	SSPC:
ASME: Type of PV Stamp:	API:	AGMA:
NACE:	ASTM:	Other:
Other:	Other:	Other:

Analytical Capabilities

Design Capability	Name of Computer Program	Version	Define In-house Capability or Name of Qualified Subvendor
Computer Aided Design			
Aerodynamic/Thermodynamic Analysis			
Gear Design			
Finite Element Analysis			
Rotordynamic Analysis			
Stress Analysis			
Vibration Analysis			
Computational Fluids Analysis			
Other:			

Manufacturing Facility and Capabilities

Road Limitations (weight, height, or width) to Repair Facility From Nearest Interstate Highway:				
Bldg. Bay:	Width (feet):	Length (feet):	Crane Capacity:	Hook Height (feet):
Bldg. Bay:	Width (feet):	Length (feet):	Crane Capacity:	Hook Height (feet):
Bldg. Bay:	Width (feet):	Length (feet):	Crane Capacity:	Hook Height (feet):
Climate Control: Yes [ ] No [ ] (describe):				
Spreader Bar: Yes [ ] No [ ] Capacity (lb.):				

Manufacturing Facility and Capabilities (Continued)

Welding Processes:	List Current Welding Procedures (WPSs) and Availability for Review	List Current Welder Qualification Records (WQRs) and Availability for Review
Plasma Arc Welding (PAW)		
Gas Metal Arc Welding (GMAW) or (GMAW-P)		
Gas Tungsten Arc Welding (GTAW) or (GTAW-P)		
Shielded Metal Arc Welding (SMAW)		
Submerged Arc Welding (SAW)		
Flux Cored Arc Welding (FCAW)		
Other Welding Processes:	**Written Procedures**	**Qualified Operators**
Torch Brazing (TB)	Yes [ ] No [ ]	Yes [ ] No [ ]
Induction Brazing (IB)	Yes [ ] No [ ]	Yes [ ] No [ ]
Furnace Brazing (FB)	Yes [ ] No [ ]	Yes [ ] No [ ]
Other Brazing (Specify)	Yes [ ] No [ ]	Yes [ ] No [ ]
Oxyacetylene Welding (OAW)	Yes [ ] No [ ]	Yes [ ] No [ ]
Other:		
Cutting Processes:	**Written Procedures**	**Qualified Operators**
Oxyfuel Gas Cutting (OFC)	Yes [ ] No [ ]	Yes [ ] No [ ]
Plasma Arc Cutting (PAC)	Yes [ ] No [ ]	Yes [ ] No [ ]
Air Carbon Arc Cutting (AAC)	Yes [ ] No [ ]	Yes [ ] No [ ]
Other:		
AWS Certified Welding Inspector on-site	Yes [ ] No [ ]	Yes [ ] No [ ]
Are Welding Rods/Wire Stored in Climate Controlled Storage Area?	Yes [ ] No [ ]	Yes [ ] No [ ]
Thermal Spraying Processes:	**Written Procedures**	**Qualified Operators**
Electric Arc Spraying (EASP)	Yes [ ] No [ ]	Yes [ ] No [ ]
Plasma Spray (PSP)	Yes [ ] No [ ]	Yes [ ] No [ ]
High Velocity Spraying (HVOF) [ ] (HVLF) [ ]	Yes [ ] No [ ]	Yes [ ] No [ ]
High Velocity Intermittent Combustion (HVIC)	Yes [ ] No [ ]	Yes [ ] No [ ]
Flame Spraying (FLSP)	Yes [ ] No [ ]	Yes [ ] No [ ]
Other:	**Written Procedures**	**Qualified Operators**
Plating	Yes [ ] No [ ]	Yes [ ] No [ ]
Babbitt	Yes [ ] No [ ]	Yes [ ] No [ ]

Manufacturing Equipment (Attach list if more convenient.)

Equipment Type	Description (capacity/size/weight/range)	Capabilities/ Accuracy	Last Calibration Date (if applicable)
Lathes			
Grinders			
Cylindrical			
Surface			
I.D.			
Multi-Purpose Machining Centers			
Milling Machines			
Vertical Boring Mill			
Horizontal Boring Mill			
Gear Cutters			
Shapers			
Hobbers			
Milling cutter			

Manufacturing Equipment (Attach list if more convenient.) (Continued)

Gear Finishing			
Shaving			
Grinding			
Lapping			
EDM Capability			
Special Purpose Tooling			
Lapping			
Honing			
Automated Peening			
Spline Machine			
Bucket Machines			
Thread Rolling			
Curvic Coupling Grinder			
Balance Machines At Speed: Yes [ ] No [ ]	Drive: Belt [ ] End [ ]	Max. Rotor Weight:	Min. Rotor Weight:
Bearing: Hard [ ] Soft [ ]		Maximum Sensitivity per Plane (in.-oz)	
Balance Machines At Speed: Yes [ ] No [ ]	Drive: Belt [ ] End [ ]	Max. Rotor Weight:	Min. Rotor Weight:
Bearing: Hard [ ] Soft [ ]		Maximum Sensitivity per Plane (in.-oz)	
Rotor Assembly/Disassembly Pit		Max. Rotor Weight:	Maximum Distance Between Journals:
Vee Block Rotor Runout Stand			
Overspeed pit for Impellers			

List All Manufacturing, Testing and Repair Work Being Sub-Contracted
(such as welding, heat treating, lab testing, balancing, coating, deposit analysis, etc.)

Type Operation	%	Length of Affiliation	Name and Address of Sub-Contractor

Heat Treat Capabilities

Describe: Oven size, temperature range, control system, recording capabilities, resistance blankets, induction heating, etc.

____

____

____

____

Oven available to heat components for assembly Yes [ ] No [ ] Largest Component Size/Weight:

Examination (non-destructive)

Type	In House or Contract	Standard Utilized/Number and Level of Trained Employees	List Written Procedures/ Acceptance Criteria
Ultrasound			
Eddy Current			
Radiographic			
Wet Magnetic Particle			
Intermittent			
Continuous			
Liquid Penetrant			
Post-Emulsifiable Fluorescent			
Solvent Removable Fluorescent			
Water Washable Fluorescent			
Post-Emulsifiable Visible Dye			
Solvent Removable Visible Dye			
Water Washable Visible Dye			
Plot Electrical and Mechanical Runout			
Hall Effect Gauss Meter			
3-D Coordinate Measuring			
Gear Checking Machine			
Overspeed Trip Set			
Material Analyzer			
Hardness Testing			
SEM (Scanning Electron Microscope)			
Optical Comparator			
Metallography			
Screw Rotor Mesh Check			
Surface Roughness			
Other:			
Other:			

Cleaning/Coatings

Decontamination Facilities	Yes [ ] No [ ]	
Steam Cleaning	Yes [ ] No [ ]	
High Pressure Water Wash	Yes [ ] No [ ]	
Abrasive Blasting Booth	Largest Component (LxWxH):	
Solvent Cleaning	Largest Component (LxWxH):	
Other:		
Erosion Coating System:	Describe:	
Corrosion Coating System:	Describe:	

	Yes	No	Explain
Management of the Quality System			
Has the top management stated and communicated a corporate quality policy?			
Are full time resources devoted to the quality system other than manufacturing quality control?			
Is a system in place to measure cost of non-conformance for the business unit?			
Is there a continuous improvement program and do you track long term trends and cost of non-conformance?			
Marketing Quality Assurance			
Does marketing/ sales have a documented process to communicate customer requirements to the repair facility?			
Does marketing/ sales process assure, compliance to customer requirements from the repair facility before technical and commercial commitments are made?			
Do you have a system/ process to accurately transfer customer driven change orders from marketing/ sales to the repair facility after an order?			
Is there a documented process in place for prompt communication between the repair facility and customer if non-conforming products/ materials/ delivery is discovered or suspected?			
Project Management Assurance			
Do you have a project management function that has total order responsibility including schedules, cost control, documentation and internal and external communication?			
Do project managers have experience with similar type of equipment?			
Does the same project manager follow the equipment through to installation and start-up if requested by owner?			
Are all repairs assigned to a project manager?			
Design Engineering Quality Assurance			
Do you have documented procedures for translation of customer specifications into internal company language?			

	Yes	No	Explain
Describe the formal design review process. Include:			
1. When design reviews are held.			
2. What functional areas are involved			
3. What design verification activities are used			
Is there a formal design review?			
Are design changes coordinated with the owner?			
Does a revised drawing and document procedure exist to assure that appropriate personnel are receiving current drawings and documents?			
Describe how changes result in revised procedures, drawings, travelers, etc., and how these changes are distributed to the appropriate personnel in a timely manner.			
Are obsolete drawings and specifications in production and inspection withdrawn from use?			
Is there an in-house engineering/technical support staff?			
Can failure analysis be done in-house?			
Supplier (Procurement) Quality Assurance			
Do you have a process of managing the quality of purchased goods and services?			
Are required references (drawings and specifications, special process control and inspection/ test requirements) given to the supplier with the P.O.?			
Are purchase order requirements available to receiving personnel to ensure correct material is received and any special instructions are followed?			
Is evidence of material and product inspection/ tests documented on appropriate records?			
Is appropriate segregation provided for raw, nonconforming, and accepted material pending inspection and / or test?			
Is there a process for control of non-conformance to assure effective supplier corrective action?			
Do you have and maintain an approved / acceptable supplier's list?			

	Yes	No	Explain
Is there a plan that provides for effective control and appraisal of characteristics which cannot be inspected upon arrival (for example, non-destructive testing, heat treat, chemical analysis)?			
Is there a plan that assures supplier's special processes (heat treating, welding, etc.) are currently qualified?			
Is manufacturing equipment calibrated/ maintained at established intervals?			
Manufacturing/Production Quality Assurance			
Is there a quality control program with a working manual and revision procedures?			
Are process instructions, procedure sheets, travelers, etc. utilized which contain requirements for manufacturing and inspection control?			
Are operator's and inspector's identification applied to documentation as required?			
Is the status of lots and/or items shown on tags, routing cards, move tickets, totebox cards, etc.?			
Are nonconforming items removed from normal channels and placed in appropriate isolation areas?			
Is rework conducted with authorized and documented procedures and subject to inspection/ test?			
Are corrective action forms and procedures utilized to prevent and/ or control recurrence of defects as appropriate?			
Does the final inspection and testing acceptance include verification of any in-process inspection and testing?			
Are inspection records completed and include (as appropriate) part and lot control number, customer, engineering changes, lot and sample size, characteristics inspected, quantity, etc.?			
Do items or materials released for manufacturing contain appropriate documentation of inspection/ test performance.			
Are personnel and/or equipment certifications conducted in conformance with applicable requirements?			
Are examination and equipment test and control records current and available for review?			
Are maintenance checks of equipment conducted and records maintained to verify status?			

	Yes	No	Explain
Material Storage Area, Packing and Shipping Quality Assurance			
Is acceptance for storage and release of material based on correct identification and authorized release by appropriate function?			
Do documented storage practices include control for correct location in area/ bin/ shelf per record; and adequate segregation and protection to prevent damage, intermingling and corrosion, and age sensitive material?			
Is there a process to ensure required enclosures and protection procedures are utilized before shipment?			
Do the procedures ensure product identification and protection during transient storage and installation?			
Measuring and Testing Equipment Quality Assurance			
Do records verify calibration and traceability to appropriate standards?			
Is test and measurement equipment calibrated within established intervals?			
Are items labeled, tagged, or otherwise identified as required to reflect serviceability date and date of next calibration?			
Do calibration records contain information required for controlling scheduling frequency?			
Is unqualified equipment identified to show its status and prevent its use?			
Are handling practices of test and measuring equipment in storage at points use adequate to ensure accuracy of devices is maintained?			
Field Quality Assurance			
Do you have a system that gathers and monitors data on product field history?			
Is there a corrective action system and are problems defined by this system assigned to a responsible party for corrective action?			
Do you have a field notification system that makes users of equipment aware of product enhancements or upgrades that could be used to improve the performance of existing equipment?			

	Yes	No	Explain
Quality Records System			
Are quality records protected and stored for a specified period of time in a fashion that allows retrieval of specific data?			
Human Resource Development and Training			
Do you have a means of identifying the need for training of all personnel?			
Do you have a training program for all personnel?			
Are all personnel given formal training in how their job performance influences product quality and customer satisfaction?			
Do you have a journeyman program for crafts personnel?			
Product Safety			
Do you have a process that addresses the safety aspects of the product or service?			
Does this process include provisions for product recall?			

COMPETITIVENESS

I. Describe the process and/ or methods used to improve your company's cost competitiveness position. (One page maximum.)

II. Do you measure Cost of Quality? _______ Y/N _______

III. Would you be willing to let your competitors visit your shop in order that they may also quote on the same repair? ___________________

FACILITIES/EXPENDITURES:

Average annual capital expenditures: amount __________ % of sales _________

Average annual maintenance costs: amount __________ % of sales _________

% of replacement value: __________________

How long have you been repairing this type of equipment? ________________________

Does this facility have a safety program/policy? __________________

Does this facility have an environmental program/policy?

____

Would you allow a shop inspection by the owner or a third party hired by the owner?

____

SERVICE PERFORMANCE

		Yes	No
A.	Electronic data transfer with supplier is possible?	______	______
B.	Photographic records provided?	______	______
C.	Field service is available within 24 hours?	______	______
D.	Supplier has appropriate product liability insurance? Elaborate:	______	______
E.	Do you have a warranty agreement on repairs? Submit a copy.	______	______
F.	Can you arrange safe transport of equipment to and from jobsite?	______	______
G.	Can you arrange for transportation insurance?	______	______

CUSTOMER SERVICE

Do you regularly monitor on time deliveries to customer request date. If yes, what percentage of your deliveries are on time?

____

____

____

____

QUALITY SYSTEM REGISTRATION

Indicate whether or not your Quality Assurance system is currently registered under ISO or ANSI/ASQC:

_____________ 9001 _____________ 9002 _____________ 9003 _____________ Other

(enclose a copy registration certificate, if available)

	Yes	No
Does your Q.A. system conform to API Q1?	______	______

BUSINESS INFORMATION

Number of years in business under the present name? ______________________________

Previous names: (please list) ______________________________

Type of ownership (partnership/ corporation, joint venture, other) ______________________________

Publicity traded: ________________ Privately held: ________________

Sales volume past three years: $____________ $____________ $____________

Current backlog $______________

Dunn and Bradstreet or other (name) rating: ________________

Do you have Liability Insurance? Yes _____ No _____ Amount/Incident ____________

Can you provide a copy of annual report? If so, please enclose. If not, what type of financial reports will you provide? Please enclose.

VENDOR/OWNER RELATIONSHIP

Have you sold any product to the owner in the past three years?

Yes _______ No _______

If yes,

Purchase Order Number	**Delivery Location**	**Description of Work**

REFERENCES

Company/Contact/ Location	**Telephone**	**Description of Repair Work Performed**

LIST ANY OTHER INFORMATION ABOUT YOUR COMPANY THAT YOU THINK IS RELEVANT

(include recent management changes, shop turnover in key positions, current legal involvements, associations with other repair shops or equipment manufacturers, etc.)

COULD YOU PREPARE WRITTEN OBJECTIVE EVIDENCE TO VERIFY RESPONSES GIVEN ON THIS QUESTIONNAIRE, IN 30 DAYS OR LESS, IF REQUIRED?

______ Yes ______ No

VERIFICATION BY RESPONSIBLE PARTIES

Repair Shop Representative/Title/Date

Repair Shop CEO/Date

Owner's Representative/Title/Date
(required for on-site verification only)

APPENDIX J—SHIPPING CONTAINERS

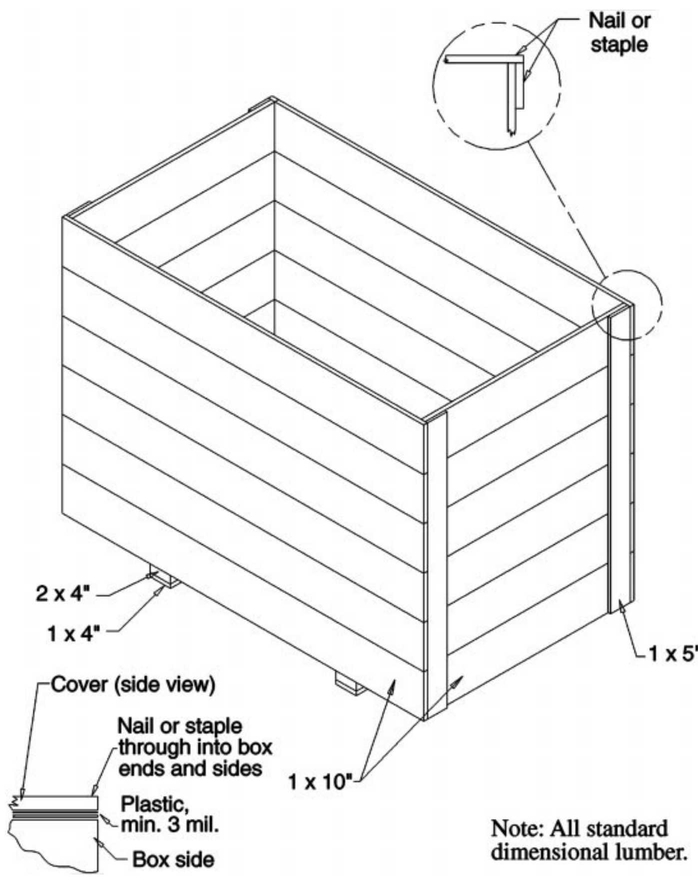


Figure 1.J-1—Commercial Shipment Boxing

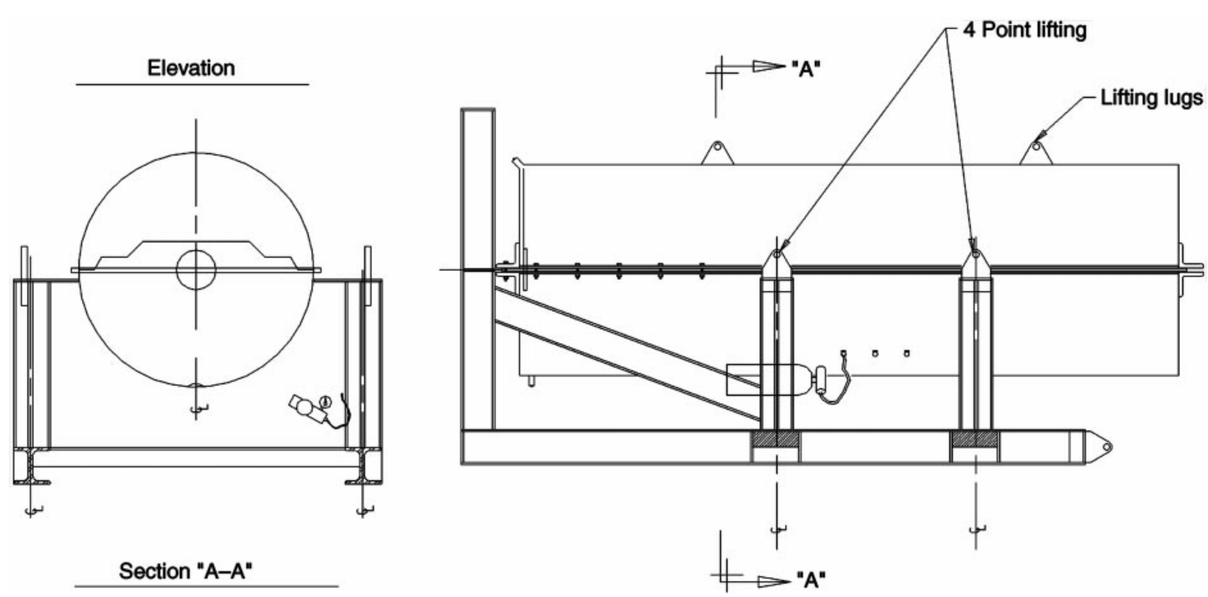


Figure 1.J-2—Steel Container

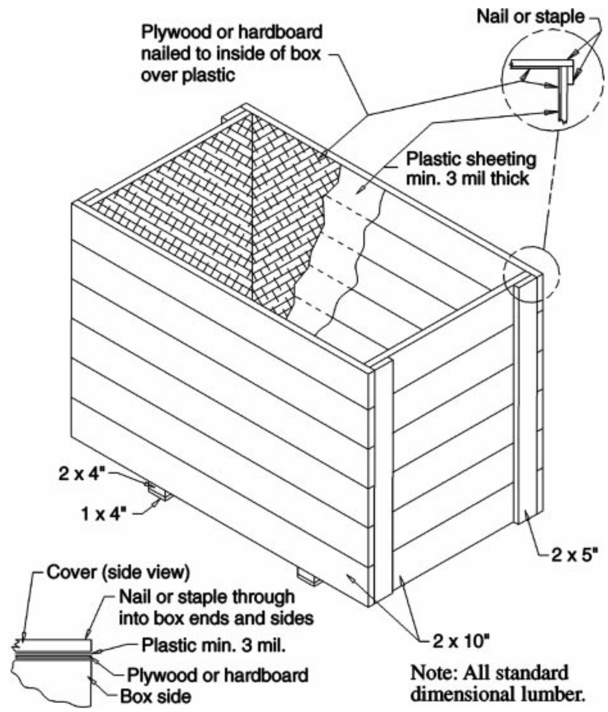


Figure 1.J-3—Commercial and Export Boxing, 905 Kg (2000 lbs) through 4530 Kg (1000 lbs)

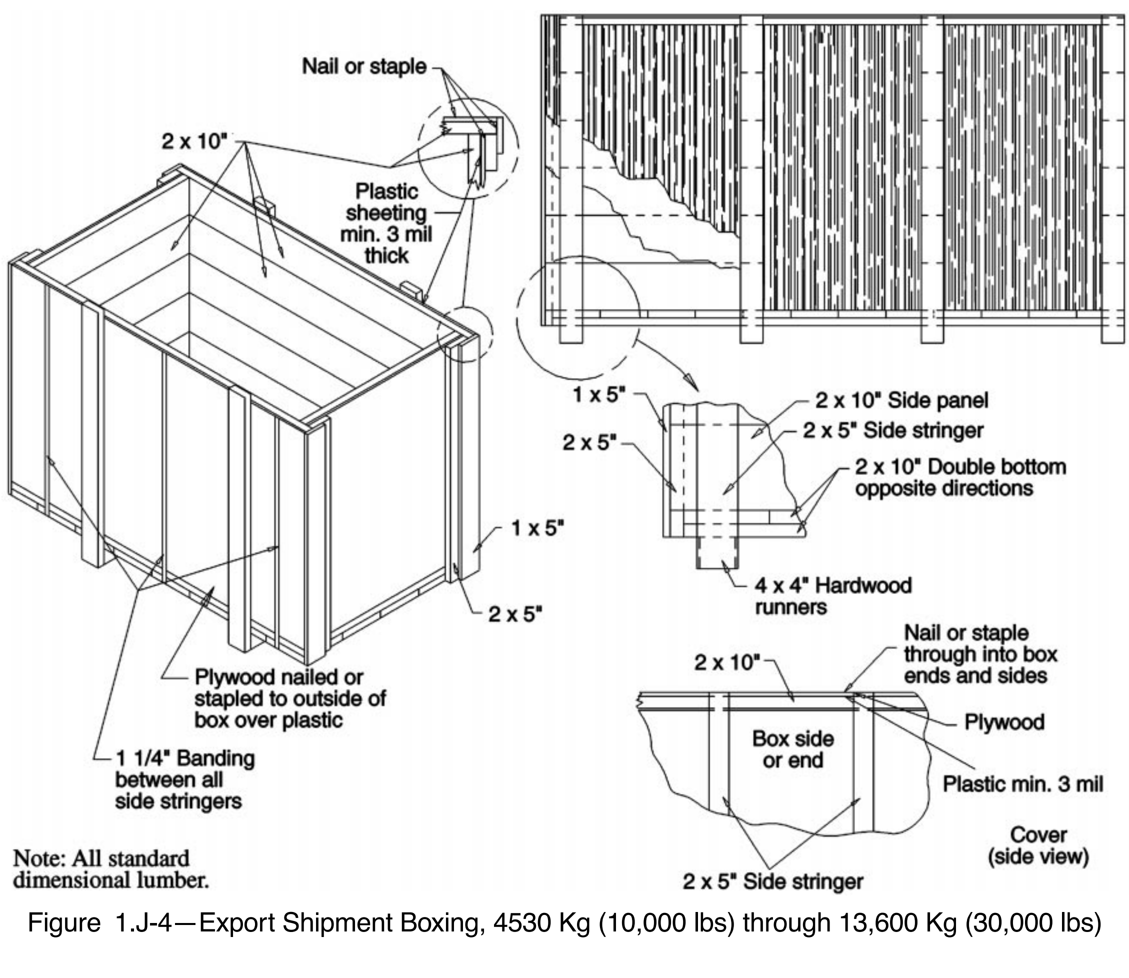


Figure 1.J-4—Export Shipment Boxing, 4530 Kg (10,000 lbs) through 13,600 Kg (30,000 lbs)

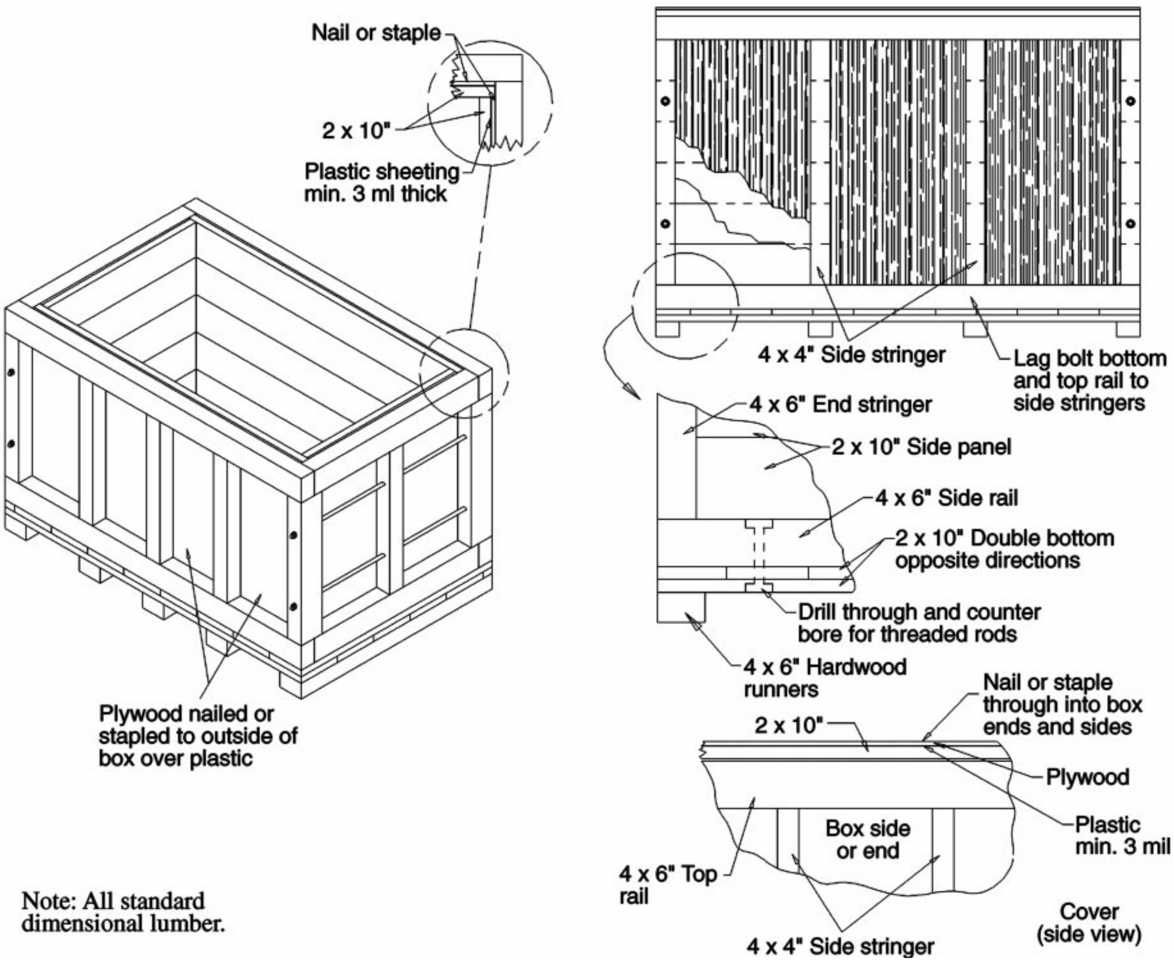


Figure 1.J-5—Commercial and Export Boxing, 13,600 Kg (30,000 lbs) and Over

APPENDIX K—QUALITY/MANUFACTURING PLAN

QUALITY/MANUFACTURING PLAN

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	SHAFT RESTORATION						(2)			
	Weld Restoration			9.2.2						
	Machine Truth Bands			D 2.2.2		D 2.2.2	Report			
	Undercut for Weld Preparation			D 2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	D 2.2.1			Certificate			
	Hardness Check			D 2.2.3			Report			
	Rough Dimensional Inspection			D 2.2.3		Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			8.2.4	ASTM E 709	8.2.4.4	Certificate			
	Weld Repair			D 2.3	WPS, PQR		WPS, PQR			
	Rough Machine					Mfg Requirement				
	Ultrasonic Inspect			8.2.3	ASME Section 5, Articles 5 & 23	MIL-STD-1254	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			8.2.4	ASTM E 709	8.2.4.4	Certificate			
	Post Weld Heat Treatment		H	D 2.5/2.6	Vendor Procedure		Chart			
	Final Rough Machine					Mfg Requirement				
	Ultrasonic Inspect			8.2.3	ASME Section 5, Articles 5 & 23	MIL-STD-1254	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			8.2.4	ASTM E 709	8.2.4.4	Certificate			
	Demagnetize			8.2.4.2		8.2.4.2	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Hardness Check			D 2.2.3		WPS	Report			
	Final Machine			D 2.8		D 2.8				
	Final Dimensional Inspection			D 2.9		Mfg Drawing	Report			
	Runout Inspect			9.6		9.6	Report			
	Thermal Spray Restoration			9.2.2						
	Machine Truth Bands			D 3.2.3		D 3.2.3	Report			
	Undercut for Thermal Spray Preparation			D 3.2.4		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	D 3.2.2			Certificate			
	Hardness Check			D 3.2.2			Report			
	Rough Dimensional Inspection			D 3.2.4		Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			D 3.2.5	ASTM E 709	8.2.4.4	Certificate			
	Thermal Spray Build-up (1)			D 3.2.10	Vendor Procedure					
	Final Rough Machine					Mfg Requirement				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			8.2.4	ASTM E 709	8.2.4.4	Certificate			
	Demagnetize			8.2.4.2		8.2.4.2	Certificate			
	Final Machine			D 3.3		D 3.2.10				
	Final Dimensional Inspection			D 3.4		Mfg Drawing	Report			
	Runout Inspect			9.6		9.6	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Reducing the Shaft Restoration			9.2.3						
	Final Machine Undersize			D 4.5		D 4.5				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			D 4.6	ASTM E 709	8.2.4.4	Certificate			
	Demagnetize			8.2.4.2		8.2.4.2	Certificate			
	Final Inspection			D 4.6		Mfg. Drawing	Report			
	COUPLING SHAFT END RESTORATION						**(2)**			
	Weld Restoration			9.3.2						
	Undercut for Weld Preparation			9.3.2 & D 2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	D 2.2.1			Certificate			
	Hardness Check			D 2.2.3			Report			
	Rough Dimensional Inspection			D 2.2.3		Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			8.2.4	ASTM E 709	8.2.4.4	Certificate			
	Weld Repair			D 2.3	WPS, PQR		WPS, PQR			
	Rough Machine					Mfg Requirement				
	Ultrasonic Inspect			8.2.3	ASME Section 5, Articles 5 & 23	MIL-STD-1254	Certificate			
	Dye Penetrant Inspect			8.2.4	ASTM E165	8.2.4.4	Certificate			
	Post Weld Heat Treatment		H	D 2.5/D 2.6	Vendor Procedure		Chart			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Final Rough Machine					Mfg Requirement				
	Ultrasonic Inspect			8.2.3	ASME Section 5, Articles 5 & 23	MIL-STD-1254	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			8.2.4	ASTM E 709	8.2.4.4	Certificate			
	Demagnetize			8.2.4.2		8.2.4.2	Certificate			
	Hardness Check			2.2.3		WPS	Report			
	Final Machine			D 2.8		D 2.8				
	Final Dimensional Inspection			D 2.9		Mfg Drawing	Report			
	Perform Bluing Check and Record Stand-off			C 6		Table C-1	Report			
	Reducing the Shaft End Restoration			9.3.3						
	Final Machine Undersize			D 4.5		D 4.5				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			8.2.4	ASTM E 709	8.2.4.4	Certificate			
	Demagnetize			8.2.4.2		8.2.4.2	Certificate			
	Final Inspection			D 4.5						
	Perform Bluing Check and Record Stand-off			C 6		Table C-1	Report			
	Lapping the Shaft End Restoration			9.3.4						
	Lap the Shaft End			C 7.0	C 7.2					
	Perform Bluing Check and Record Stand-off			C 6.0		Table C-1	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	SHAFT, NEW						**(2)**			
	Shaft Forging	AISI/ ASTM Spec No.	C,H,M,I	9.1		Compliance with AISI/ASTM Requirement	Report			
	Rough Dimensional Inspection					Mfg Requirement	Report			
	Vertical Stress Relieve		H		Vendor Procedure		Chart			
	Ultrasonic			8.2.3	ASME Sect V, Article 5 & 23	8.2.3.2	Certificate			
	Dimensional Stability Test				ASTM A472 (4)	ASTM A472	Report			
	Pre-Grind Dimensional And Runout					Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			8.2.4	ASTM E 709	8.2.4.4	Certificate			
	Demagnetize			8.2.4.2		8.2.4.2	Certificate			
	Electrical Runout Check						Report			
	Final Dimensional Inspection					Mfg Drawing	Report			
	Serial Number					Mfg Drawing	Certificate			
	Shaft End Taper			7.2.6	Appendix C	Table C-1	Transfer Tapes			
	PISTON, NEW						**(2)**			
	Balance Piston Forging	AISI/ ASTM Spec No	C, H	9.1		Compliance with AISI/ASTM Requirement	Report			
	Final Machine									

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			8.2.4	ASTM E 709	8.2.4.4	Certificate			
	Demagnetize			8.2.4.2		8.2.4.2	Certificate			
	Dimensional Inspection					Mfg. Drawing	Report			
	SHAFT SLEEVE AND SPACER RESTORATION						**(2)**			
	Thermal Spray Restoration			9.5						
	Undercut for Thermal Spray Preparation			D 3.2.4		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	D 3.2.2			Certificate			
	Hardness Check			D 3.2.2			Report			
	Rough Dimensional Inspection			D 3.2.4		Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			D 3.2.5	ASTM E 709	8.2.4.4	Certificate			
	Thermal Spray Build-up (1)			D 3.2.10	Vendor Procedure					
	Final Rough Machine					Mfg Requirement				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			8.2.4	ASTM E 709	8.2.4.4	Certificate			
	Demagnetize			8.2.4.2		8.2.4.2	Certificate			
	Final Machine			D 3.3		D 3.2.10				
	Final Dimensional Inspection			D 3.4		Mfg Drawing	Report			
	Reducing the Shaft Sleeve or Spacer Restoration			9.5						

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Final Inspection			D 4.5		Mfg. Drawing	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			8.2.4	ASTM E 709	8.2.4.4	Certificate			
	SHAFT SLEEVES, NEW						**(2)**			
	Sleeve Forging	AISI/ ASTM Spec No	C,H	9.1		Compliance with AISI/ASTM Requirement	Report			
	Final Machine									
	Wet Magnetic Particle Inspect (fluorescent, continuous method with central conductor)			8.2.4	ASTM E709	8.2.4.4	Certificate			
	Demagnetize			8.2.4.2		8.2.4.2	Certificate			
	Dimensional Inspection					Mfg. Drawing	Report			
	THRUST COLLAR RESTORATION						**(2)**			
	Undercut for Weld Preparation			D 2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	D 2.2.1			Certificate			
	Hardness Check			D 2.2.3			Report			
	Rough Dimensional Inspection			D 2.2.3		Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (Fluorescent, continuous method)			8.2.4	ASTM E 709	8.2.4.4	Certificate			
	Weld Repair			D 2.3	WPS, PQR		WPS, PQR			
	Rough Machine					Mfg Requirement				

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Ultrasonic Inspect			8.2.3	ASME Sect V, Articles 5 & 23	MIL-STD-1254	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			8.2.4	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Post Weld Heat Treatment		H	D 2.5/2.6	Vendor Procedure		Chart			
	Final Rough Machine					Mfg Requirement				
	Ultrasonic Inspect			8.2.3	ASME Sect V, Articles 5 & 23	MIL-STD-1254	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			8.2.4	ASTM E 709	8.2.4.4	Certificate			
	Demagnetize			8.2.4.2		8.2.4.2	Certificate			
	Hardness Check			2.2.3		WPS	Report			
	Final Machine			D 2.8		D 2.8				
	Final Dimensional Inspection			D 2.9		Mfg Drawing	Report			
	THRUST COLLAR, NEW						**(2)**			
	Material Certification Review	AISI/ ASTM Spec No	C,H	9.1		Compliance with AISI/ASTM Requirement	Report			
	Final Machine									
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			8.2.4	ASTM E 709	8.2.4.4	Certificate			
	Demagnetize			8.2.4.2		8.2.4.2	Certificate			
	Dimensional Inspection					Mfg. Drawing	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	OTHER SHAFT COMPONENTS						**(2)**			
	Outline other shaft component mfg. & inspection requirements during Phase I									
	COUPLING AND SPACER (5)						**(2)**			
	For New Components, Material Certification Review	AISI/ ASTM Spec No	C,H	9.1		Compliance with AISI/ASTM Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			8.2.4	ASTM E 709	8.2.4.4	Certificate			
	Demagnetize			8.2.4.2		8.2.4.2	Certificate			
	Dimensional Inspection					Compliance With Mfg Drawing	Report			
	Contact check ring & plug gauge/ lapping set			Appendix C		95% contact	Report			
	Contact check plug gauge to coupling Hub			Appendix C		85% contact	Report			
	For New Components, Check weight of coupling					Mfg drawing	Report			
	Coupling bolt clearance					API 671	Report			
	Component Balance					API 671	Report			
	Assembly Check Balance (6)					API 671	Report			
	TILTING PAD JOURNAL BEARING						**(2)**			
	Initial inspection			E 3.1/E 3.2		Mfg. drawing	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Individual Pad Ultrasonic Inspection			E 3.3	ASME Sect V, Article 5 & 23	8.2.3.2	Certificate			
	Individual Pad Dye Penetrant Inspection			E 3.3	ASTM E 165	8.2.4.2	Certificate			
	Thermocouple installation and operation			E 3.4		Mfg. drawing	Report			
	Dimensional check of components			E 4.1		Mfg. drawing	Report			
	Assembly check			E 5.1		Mfg drawing	Report			
	SLEEVE TYPE JOURNAL BEARING (3)						**(2)**			
	Initial inspection			E 3.1/E 3.2		Mfg. drawing	Report			
	Babbitt Ultrasonic Inspection			E 3.3	ASME Sect V, Article 5 & 23	8.2.3.2	Certificate			
	Babbitt Dye Penetrant Inspection			E 3.3	ASTM E 165	8.2.4.2	Certificate			
	Thermocouple installation and operation			E 3.4		Mfg. drawing	Report			
	Dimensional checks			E 4.2		Mfg. drawing	Report			
	Dam Geometry					Mfg. Drawing	Report			
	THRUST BEARING						**(2)**			
	Initial inspection			E 3.1/E 3.2		Mfg. drawing	Report			
	Babbitt Ultrasonic Inspection			E 3.3	ASME Sect V, Article 5 & 23	8.2.3.2	Certificate			
	Babbitt Dye Penetrant Inspection			E 3.3	ASTM E 165	8.2.4.2	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Thermocouple installation and operation			E 3.4		Mfg. drawing	Report			
	Dimensional checks			E 4.4		Mfg. drawing	Report			
	PROTECTIVE COATINGS (1)						**(2)**			
	Multi layer coating [Below 260°C (500°F)]			**L 2.0**						
	Clean surface			L 2.2/L 5.4	Mfg. Drawing					
	Protect Rotor Support Surfaces			L 5.5						
	Apply Base Coat			L 2.3/L 5.6						
	Cure Base Coat		H	L 2.3/L 5.6/ L 5.7/L 5.8/ L 5.9						
	Burnish Base Coat			L 2.5	ASTM D4541	L 2.5				
	Check resistivity			L 2.5						
	Apply second base coat layer			L 2.6/L 5.6						
	Cure second Base Coat			L 2.6/L 5.6/ L 5.7/L 5.8/ L 5.9						
	Check and record overall coating thickness at number and location specified by the purchaser			L 2.10/L 5.10		Mfg. Drawing	Report			
	Apply Intermediate coat (When required)			L 2.7/L 5.6						

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Cure Intermediate Coat		H	L 2.6/L 5.6/ L 5.7/L 5.8/ L 5.9						
	Check and record overall coating thickness at number and location specified by the purchaser			L 2.10/L 5.10		Mfg. Drawing	Report			
	Apply Top Coat			L 2.8/L 5.6						
	Cure Top Coat		H	L 2.8/L 5.6/ L 5.7/L 5.8/ L 5.9						
	Check and record overall coating surface finish and thickness at number and location specified by the purchaser			L 2.9/L 2.10/ L 5.10		L 2.9	Report			
	Shipment			L 5.12/L 5.13						
	Supply Touch-up Paint			L 5.14						
	Multi layer coating [Between 260°C–565°C (500°F–1050°F)]			**L 3.0**						
	Clean Surface			L 3.1/L 2.2/ L 5.4	Mfg. Drawing					
	Protect Rotor Support Surfaces			L 5.5						
	Apply Base Coat			L 3.2/L 5.6						
	Cure Base Coat		H	L 3.2/L 5.6/ L 5.7/L 5.8/ L 5.9						
	Burnish Base Coat			L 3.4	ASTM D4541	L 3.4				
	Check Resistivity			L 3.4						
	Check and record overall coating thickness at number and location specified by the purchaser			L 3.3/L 3.7/ L 5.10		Mfg. Drawing	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Apply Top Coat			L 3.5/L 5.6						
	Cure Top Coat		H	L 3.5/L 5.6/ L 5.7/L 5.8/ L 5.9			Report			
	Check and record overall coating surface finish and thickness at number and location specified by the purchaser			L 3.6/L 3.7/ L 5.10		L 3.6	Report			
	Shipment			L 5.12/L 5.13						
	Supply Touch-up Paint			L 5.14						
	Multi layer coating for axial compressors in air surface [Up to 565°C (1050°F)]			**L 4.0**						
	Clean surface			L 4.1/L 2.2/ L 5.4	Mfg. Drawing					
	Protect Rotor Support Surfaces			L 5.5						
	Apply Base Coat			L 4.2/L 5.6						
	Cure Base Coat		H	L 4.2/L 5.6/ L 5.7/L 5.8/ L 5.9						
	Burnish Base Coat			L 4.4	ASTM D4541	L 4.4				
	Check Resistivity			L 4.4						
	Check and record overall coating thickness at number and location specified by the purchaser			L 4.3/L 4.7/ L 5.10		Mfg. Drawing	Report			
	Apply Sealer Top Coat			L 4.5/ L 5.6						

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Cure Top Coat		H	L 4.3/L 5.6/ L 5.7/L 5.8/ L 5.9			Report			
	Check and record overall coating surface finish and thickness at number and location specified by the purchaser			L 4.6/L 4.7/ L 5.10		L 4.6	Report			
	Shipment			L 5.12/L 5.13						
	Supply Touch-up Paint			L 5.14						

DESCRIPTION/OPERATION

NOTES:

1) When specified, test coupon to be supplied in accordance with D 3.2.1.

2) All verifying document reports shall reference procedure and state drawing acceptance criteria.

3) Bearing halves held lightly together after doweling and round within 0.001". Sleeve bearing shall be round for bench check and in casing. No springing at horizontal joint.

4) 3 indicator bands inside heat shield and 2 outside the heat shield. For compressor shafts 600ºF, maximum inlet temperature for steam turbine shafts.

5) Coupling manufacturer to advise inspection steps performed during coupling overhaul or manufacture of new components.

6) Purchaser may specify alternate balance requirements as detailed in API 671.

LEGEND GENERAL	MATERIAL CERT	INSPECTION POINT
H.T. Heat Treatment PT Liquid Penetrant Inspection MT Magnetic Particle Inspection VT Visual Inspection UT Ultrasonic Inspection W/A Will Advise N/A Not Applicable	A Certificate Of Compliance C Chemical Analysis M Mechanical Properties H Heat Treat Charts I Impact	O Observation W Witness / Hold Pt * Vendor To Confirm That Requirement Has Been Met

Report: defines a vendor generated quality control inspection form/report that documents the actual dimensions.
Certificate: defines a certificate of conformance.
Chart: defines a continuous recording of the event.

APPENDIX L—ANTI-FOULING/CORROSION RESISTANT/PERFORMANCE IMPROVEMENT COATINGS

L.1 General

This appendix provides guidance for the specification and use of multi-layer, anti-fouling and corrosion resistant coatings for ferrous alloy components to be used in the gas path area on steam turbines, centrifugal, and axial compressor components in wet air, hydrocarbon and corrosive steam service. Custom formulated coatings can extend service life, minimize rework, enhance performance, and protect against hydrogen embrittlement.

Notes:

1. The user should evaluate the use of coatings vs. modification of metallurgy to reduce corrosion.

2. Coatings for resisting erosion and dimensional restoration of fits are covered in Appendix D.

L.1.1 HOW COATINGS WORK

Coatings are engineered to control corrosion and fouling. Coatings can delay the onset of performance deterioration as well as prevent corrosion of the base metal. Coating performance may be enhanced when the coated surfaces are maintained by an appropriate washing routine. Protective coating systems typically include several layers of coatings. These layers may include one or more of the following types of coatings: BARRIER coating, INHIBITING coating, and SACRIFICIAL coating.

Barrier coatings isolate the material under them from the environment.

Inhibiting coatings change the chemistry of the corrodants to reduce attack on the substrate. Ideally by the time the corrodant penetrates the inhibiting coating it is no longer corrosive to the base metal. Sacrificial coatings corrode in the place of the base metal.

Barrier, Inhibiting, and Sacrificial coatings.may be classified as Organic or Inorganic in nature.

L.1.1.1 Organic coatings are formed from an organic (hydrocarbon based) resin. Typical types of organic resins are epoxy, polyurethane, phenolic, fluoropolymer, etc. In addition to the resin, the coatings usually contain organic solvents to control solubility and application characteristics. These coatings form continuous, uniform films that have good resistance to chemicals. Volatile organic compounds (VOCs) are present in these coatings. These coatings have continuous operating temperature limitations of approximately 150 to 200°C (300 to 400°F).

L.1.1.2 Inorganic coatings consist of chromate/phosphate, phosphate, or silicate bases. While they are not as film forming as organic coatings, they can be formulated to provide barrier, inhibiting, and/or sacrificial protection. These coatings have a continuous operating temperature limitation of approximately 565°C (1050°F) for rotating equipment. Inorganic coatings are easy to apply and usually do not contain volatile organic compounds.

L.1.1.3 The use of a Organic or Inorganic coating depends upon the environment in which the coating will operate. For example, inorganic silicates do not withstand sulfuric acid whereas an organic fluoropolymer, does.

L.1.2 MULTI LAYER COATING SYSTEMS

To provide maximum protection, coatings are often used in multiple layers. (Similar to the primer and finish coat painting system used on cars and wood structures.) These multi layer systems have a base coat, intermediate coat, and top coat or barrier coat. The base coat is typically a sacrificial coating, the intermediate coat(s) is (are) typically an inhibitive coating, and the top coat is a barrier (sealant) coating. A description of each of these coatings follows.

L.1.2.1 A typical base coat is a galvanically sacrificial coating. It does not prevent corrosion, but redirects corrosion. When the base metal is exposed directly to the contaminants in the operating environment, the sacrificial coating corrodes in place of the exposed metal. The exposed substrate remains unaffected by the environment until the sacrificial coating has been depleted. Sacrificial coatings are more active than the base material and are made of active anodic metals such as zinc, aluminum, and cadmium.

L.1.2.2 A typical intermediate coat is an inhibiting coating and is able to prevent corrosion even when corrodants reach the base metal. Chemical in the inhibiting coating modify the corrodant. Changing the chemistry of the corrodant changes its effect upon the metal below. Instead of causing corrosion, these liquids actually help the metal produce it's own protective chemical film. Once the inhibitor is consumed, the coating is no longer effective.

L.1.2.3 A typical top coat is a barrier coating that prevents corrosion by keeping damaging liquids away from the base metal surfaces. Barrier coatings stop corrosion by keeping the base metal surface dry. As long as the barrier film is continuous and intact, corrosion will not occur. When barrier coatings fail due to erosion or loss of adhesion, the base metal becomes susceptible to corrosion because barrier coatings do not provide residual or lingering protection

Note: The use of a barrier coating as the only method of corrosion protection is not recommended. Multi-layer coating systems are preferred.

L.1.3 SELECTION OF COATING

L.1.3.1 The coating selection process should include an evaluation of the coating's compatibility with the base material and the suitability for the operating environment. The coating supplier should provide a blank engineering data sheet / information request to be completed by the purchaser to aid in selecting a coating that is compatible with the base material and suitable for the gas stream. An analysis of rotor flow path deposits should be performed to identify potential corrodants and foulants. Also, a pH analysis of the gas should be conducted to verify the gas acidity. The coatings reviewed in this tutorial are typically applied when the gas acidity is in the pH range of 3 to 9.

Note: Caustic can attack the aluminum in some coatings and cause coating damage.

L.2 Application of Multi-Layer Coating Systems To Resist Corrosion and Fouling for Operating Temperatures Below 260°C (500°F)

L.2.1 When operating temperatures are below 260°C (500°F) [with brief and infrequent excursions to 290°C (550°F)], the coating system typically consists of three (3) types of coatings applied with a spray gun in the order below to a clean metal surface. Note that each type of coating may require more than one application or layer. A cure or dry cycle is usually required between each layer. Curing is usually between 93°C and 345°C (200°F and 650°F). (See L.5.8.) This cure temperature should be provided so the user knows how hot the rotor will become during curing. This type of coating system is typically used on the low temperature stages of steam turbine, and centrifugal compressor rotors to help prevent corrosion and fouling. Refer to Figure 1.L-1 which illustrates the structure of this type of coating.

L.2.2 All salts, oils, greases, and organic contaminants must be removed from a part before the coating process begins. The inorganic base coat will not adhere to surfaces with organic contaminates such as oil, grease, etc. Equipment Manufacturers may specify the cleaning method to be used on some parts. The coating supplier will normally recommend procedures which may include chemical cleaning, thermal cleaning, and abrasive cleaning.

L.2.3 The base coat is typically a layer of aluminum- particulate held together with an inorganic phosphate binder which is then cured as required.

L.2.4 The bond strength of the base coat should be capable of at least 550 bar (8,000 psi) as measured in accordance with the procedures of ASTM C633 with a hardness of at least 85 to 90 on the Rockwell "B" scale and a thickness of at least 38 μm (0.0015 in.).

L.2.5 Following the cure cycle, the coating may be burnished with abrasive at low pressure to make the coating electrically conductive and galvanically sacrificial. Electrical Resistivity should be less than 15 ohms or less when measured with a conventional voltmeter using probes spaced 2.5 cm (1 in.) apart.

L.2.6 If the first layer of aluminum-filled inorganic coating is electrically conductive and galvanically sacrificial, a second base layer of, inorganic coating should be applied to it. This coat should also be cured as required. The purpose of this layer is to retard reaction of the initial layer with the operating environment.

L.2.7 When applied, the intermediate coating is typically an organic polymeric, ion-reactive layer. This layer retards the reaction between the base coats and the corrosive agents as well as inhibiting the formation of corrosion products. This layer also promotes interlayer adhesion. Cure as required.

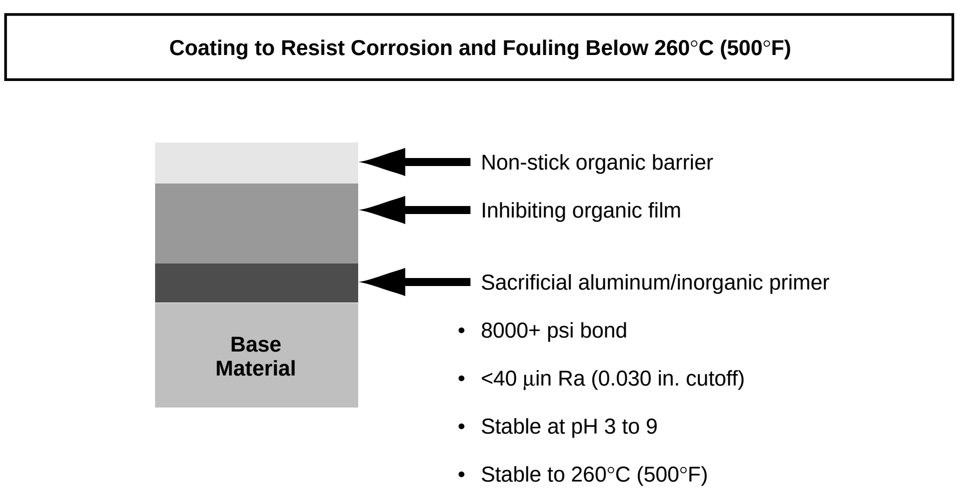


Figure 1.L-1—Coating to Resist Corrosion and Fouling Below 260°C (500°F)

L.2.8 The top coat is a layer of organic polytetrafluoroethane (PTFE-filled) which provides a non-porous barrier and lowers the coefficient of friction to resist fouling. Cure as required.

L.2.9 The coating should be applied to a combined thickness up to 150 µm (0.006 in.) without any runs, cracks, spallation, or any surface imperfections. The surface finish after coating, with the metal substrate finish of 63 Ra or less, should not exceed 40 Ra at a 760 µm (0.030 in.) cutoff as measured with a profilometer with digital circuitry.

Note: In practice, surface finish is calculated by measuring the motions of a stylus traveling across the surface. The condition of the surface is most often characterized by its average roughness (Ra) which is typically expressed in microinches. Any surface has short- or long-range variations. Short-range variation is called roughness. Long-range variation is called waviness. Cutoff is the filter that determines what constitutes roughness or waviness for a given surface. Cutoff is the distance that the stylus moves before the measuring device (the profilometer) averages all readings. A cutoff length of 760 µm (0.030 in.) is most often used, though a shorter distance 250 µm (0.010 in.) may be required when measuring highly curved surfaces. The length of each stylus measurement stroke must be at least 5 times the cutoff length. (Surface finish measurement methods and parameters are described in detail in ANSI/ASME B46.1.)

L.2.10 When the thickness of each coating layer is specified in addition to the overall coating thickness, actual thicknesses may be verified by measuring with magnetic or eddy current type thickness gauge(s) and recorded in the quality records.

L.3 Application of Multi-Layer Coating Systems To Resist Corrosion and Fouling for Operating Temperatures Between 260°C and 565°C (500°F to 1050°F)

L.3.1 When a higher temperature capability than the coating described in Section 2.0 is required, an inorganic coating system consisting of two (2) types of coatings applied in the following order to a clean metal surface (see paragraph L.2.2) should be used. This type of coating system is typically used on steam turbine and centrifugal compressor rotors to help prevent fouling. Refer to Figure 1.L-2 which illustrates the structure of this type of coating.

Note: Depending on the operating environment, this coating may be used below 260°C (500°F) but the coating described in L.2 is typically a better choice at the lower operating temperatures.

L.3.2 Similar to the coating system described in L.2, the base coat is sacrificial and typically a layer of an aluminum particulate held together with an, inorganic phosphate binder which is then cured as required.

L.3.3 The bond strength of the base coat should be capable of at least 550 bar (8,000 psi) as measured in accordance with the procedures of ASTM C633 with a hardness of at least 85 to 90 on the Rockwell "B" scale and a thickness of at least 38 µm (0.0015 in.).

L.3.4 Following the cure cycle, the coating is burnished with abrasive at low pressure to make the coating electrically conductive and galvanically sacrificial. Electrical Resistivity should be less than 15 ohms or less when measured with a conventional voltmeter using probes spaced 1 in. apart.

L.3.5 The top coat is typically a layer of inorganic chromate/phosphate (or sealer) which is then cured.

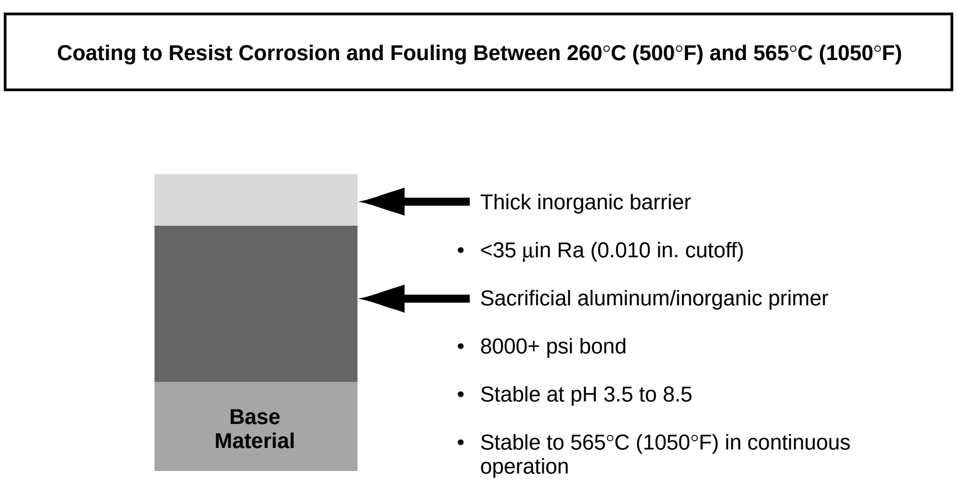


Figure 1.L-2—Coating to Resist Corrosion and Fouling Between 260°C (500°F) and 565°C (1050°F)

L.3.6 The coating should be applied to a combined thickness of between 13 and 127 µm (0.0005 and 0.004 in.) without any runs, cracks, spallations, or any surface imperfections. When the metal substrate has a finish of 63 Ra or less before coating, the roughness of the finished coating should not exceed 35 Ra at a cutoff of 250 µm (0.010 in.) cutoff as measured with a digital profilometer.

L.3.7 The specific thickness of each coating layer in addition to the overall coating thickness could be confirmed as discussed in paragraph L.2.10 earlier by measuring with magnetic or eddy current type thickness gauge(s) and recorded in the quality records.

L.4 Application of Multi-Layer Aerodynamically Smooth Coating To Resist Corrosion and Fouling Up To 565°C (1050°F) On Axial Compressor Rotors In Air Service

L.4.1 When an aerodynamically smooth surface finish is required and the operating temperatures do not exceed 565°C (1050°F) the coating system should consist of two (2) inorganic coatings applied in the following order to a clean metal surface (see paragraph L.2.2). Refer to Figure 1.L-3 which illustrates the structure of this type of coating.

Note: Aerodynamically smooth coatings are useful for limiting losses due to aerodynamic drag in axial flow compressors, even ones that are not susceptible to appreciable corrosion or fouling from particulates or hydrocarbons.

L.4.2 The base coat is typically a layer of aluminum particulate held together with an inorganic phosphate binder which is then cured as required. The coating is cured, and then mechanically burnished with the appropriate media to make it electrically conductive and galvanically sacrificial. This coating may be applied in multiple layers.

Note: Since the goal is a smooth coating, a different media from that used in L.2 and L.3 may be required.

L.4.3 The bond strength of the base coat should be capable of at least 550 bar (8,000 psi) as measured in accordance with the procedures of ASTM C633 with a hardness of at least 85 to 90 on the Rockwell "B" scale and a thickness of at least 38 µm (0.0015 in.).

L.4.4 Following the cure cycle, the coating is burnished with abrasive at low pressure to make the coating electrically conductive and galvanically sacrificial. Electrical Resistivity should be less than 15 ohms or less when measured with a conventional voltmeter using probes spaced 2.5 cm (1 in.) apart.

L.4.5 The top coat is typically a layer of inorganic chromate / phosphate (or sealer) which is then cured.

L.4.6 The coating should be applied up to a combined thickness from between 13 and 89 µm (0.0005 and 0.0035 in.) without any runs, cracks, spallations, or any surface imperfections. When the metal substrate has a finish of 63 Ra or less before coating, the roughness of the finished coating should not exceed 20 Ra at a 250 µm (0.010 in.) cutoff as measured with a digital profilometer.

L.4.7 The specific thickness of each coating layer in addition to the overall coating thickness should be confirmed as discussed in paragraph L.2.10 by measuring with magnetic or eddy current type thickness gauge(s) and recorded in the quality records.

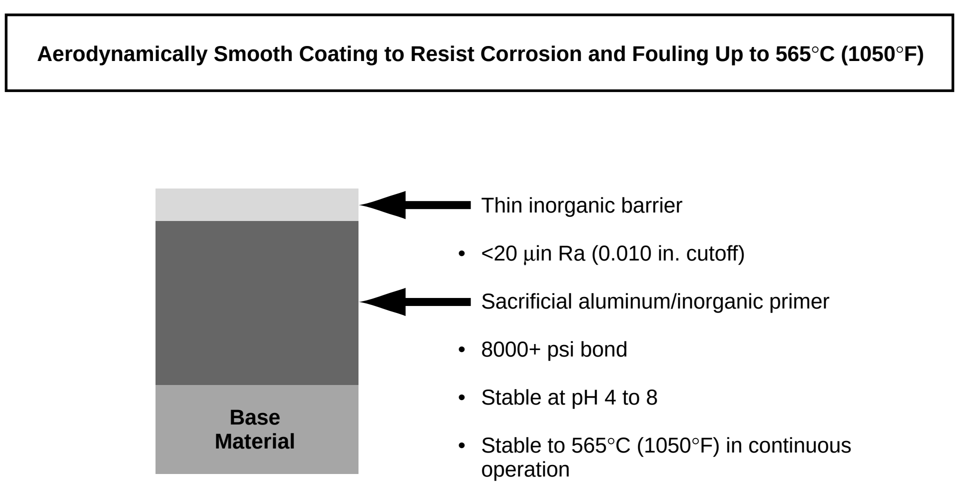


Figure 1.L-3—Aerodynamically Smooth Coating to Resist Corrosion and Fouling Up to 565°C (1050°F)

L.5 Miscellaneous Considerations

L.5.1 In qualifying a coating for a service, the manufacturer shall supply test data indicating the compatibility of the proposed coating with the base material and the coating's ability to operate under the proposed conditions.

L.5.2 Rotating elements should be balanced prior to coating. Rotor balance should be also conducted after coating for final balance corrections (including coating touch-up) made at balance shop.

L.5.3 On narrow gas passages, the affect of coating thickness on performance should be evaluated.

L.5.4 Caution should be used in cleaning the component in preparation for coating to assure no cleaning media enters any internal passages or prevents functioning of thermal gaps.

L.5.5 Surfaces used to support the rotor during coating and curing shall be protected to prevent damage.

L.5.6 Rotating elements should be continuously slow rolled during any thermal treatments.

L.5.7 Ramp rate of temperature in curing ovens should not exceed 75°C (175°F) per hour.

L.5.8 Maximum cure temperatures should be agreed upon prior to the start of coating in order to maintain dimensional/balance integrity.

L.5.9 Heat cycle temperature charts should be recorded and maintained.

L.5.10 Locations of coating thickness readings on intermediate layers as well as the completed system should be specified in the inquiry to the coating shop. All thickness readings should be maintained and submitted with completion of components.

L.5.11 Drawings and masking information should be sent to the coating shop as part of the quotation process. Care should be taken to prevent coating entrance into such areas as thermal gaps and balance holes.

L.5.12 A properly designed shipping container should be provided for transportation of components to and from the coating shop. Areas to be coated should be free from any support members to prevent damage to coated areas during transit.

L.5.13 All exposed non-coated metal surfaces must be preserved prior to shipment from the coating shop.

L.5.14 The coating shop shall provide a compatible touch-up material and directions for use for restoration of coating due to damage and/or removal of metal during the balance process.

L.5.15 Coatings should be applied in accordance with the requirements of the Quality Manufacturing Plan outlined in Appendix K.

L.5.16 Vibration probe areas shall be protected to prevent damage during handling of the rotor.

Table 1.L-1—Coating Application Summary

	Multi-Layer Coating Systems To Resist Corrosion and Fouling for Operating Temperatures Below 260°C (500°F)	Multi-Layer Coating Systems To Resist Corrosion and Fouling for Operating Temperatures Between 260 and 565°C (500 and 1050°F)	Multi-Layer Aerodynamically Smooth Coating To Resist Fouling Up To 565°C (1050°F) On Axial Compressor Rotors In Air Service
Base Layer	Aluminum filled, inorganic phosphate, ceramic primer. (This layer may be sacrificial.)	Sacrificial aluminum filled, inorganic phosphate	Sacrificial aluminum filled, inorganic phosphate
Second Base Layer (Optional)	Aluminum filled, inorganic phosphate	—	—
Intermediate Layer (Optional)	Inhibiting, organic polymeric, ion-reactive layer	—	—
Top Coat	Non-stick Organic polytetrafluoroethane (PTFE) filled	Inorganic chromate/phosphate	Thin inorganic chromate/phosphate
Total Coating Thickness	76 and 152 µm (0.003 and 0.006 in.)	13 and 127 µm (0.0005 and 0.004 in.)	13 and 89 µm (0.0005 and 0.0035 in.)

Table 1.L-2—Relative Comparison of Coating Capabilities

Final Surface Finish	With base metal of 63 microinches Ra or less, final finish should not exceed 40 Ra at a 760 µm (0.030 in.) cutoff	With base metal of 63 microinches Ra or less, final finish should not exceed 35 Ra at a 250 µm (0.010 in.) cutoff	With base metal of 63 microinches Ra or less, final finish should not exceed 20 Ra at a 250 µm (0.010 in.) cutoff
Create Aerodynamically Smooth Surface	⁕ ⁕ ⁕		⁕ ⁕⁕⁕
Limit Hydrocarbons Fouling	⁕⁕⁕⁕	⁕⁕	⁕⁕
Limit Mineral Fouling	⁕⁕⁕⁕	⁕⁕⁕	⁕
Low pH	⁕⁕⁕⁕	⁕⁕	
Wet (Aqueous Corrosion)	⁕⁕⁕⁕	⁕⁕⁕	
T >260°C (500°F)		⁕⁕⁕⁕	⁕⁕⁕⁕
Thin [<38 µm (0.0015 in.)]		⁕	⁕⁕⁕
Reduce Roughness of Surfaces with Roughness >63 Ra	⁕⁕⁕	⁕	⁕⁕

The number of ⁕ indicates the relative capability of each coating, with four ⁕ being the most capable.

APPENDIX M—EXAMPLES OF BEARING DAMAGE

SCORING OF BEARING SURFACE

(Figures 1.M-1a, 1.M-1b, and 1.M-1c)

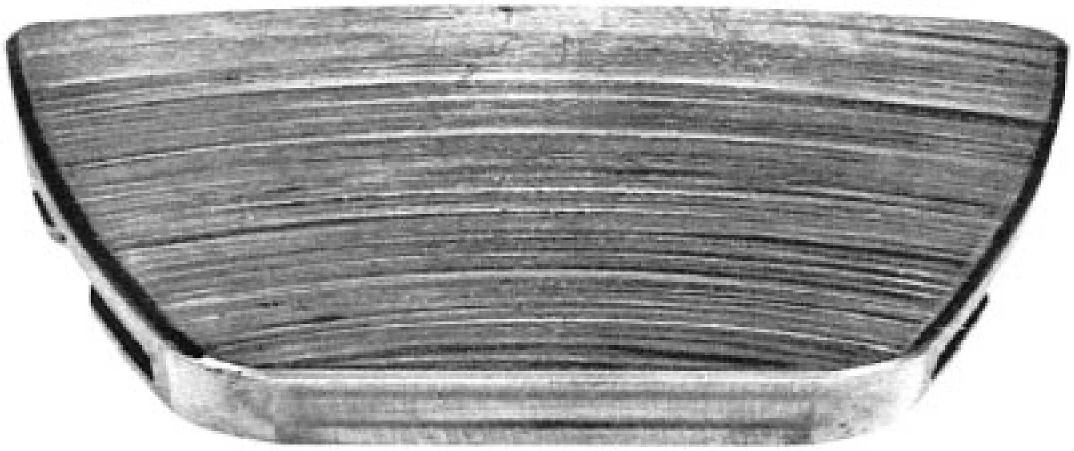
Description: Circumferential scratches may be a short arc on the surface, ending at the point the debris becomes embedded. The scratch may continue across the entire shoe surface.

Cause: Hard debris larger than the oil film passing through the oil film rough journal, rough collar or runner surface.

Rectification: Lubricating oil must be filtered. Clean the bearing assembly, and reservoir. Hand stone rough collar or runner surface.

Compliments of Kingsbury, Inc.

Figure 1.M-1a—Thrust Shoe Surface Abrasion



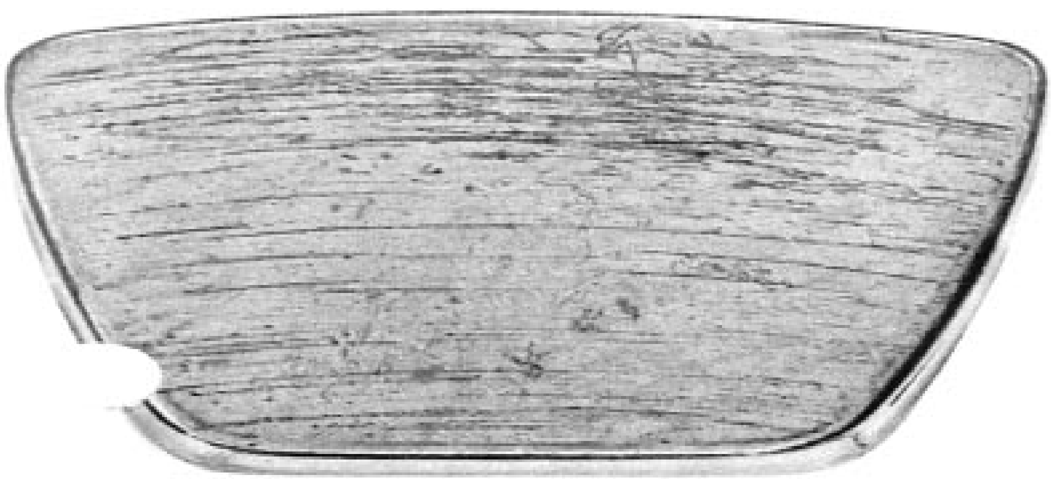
Description: Circumferential scratches continuous across the entire shoe surface.

Cause: At high speed, hard debris larger than the oil film passing through the oil film, rough journal, rough collar or runner surface.

Rectification: Lubricating oil must be filtered. Clean the bearing assembly, and reservoir. Hand stone rough collar or runner surface.

Compliments of Federal-Mogul RPB Inc. (Formerly Glacier RBP)

Figure 1.M-1b—Concentric Scoring of Thrust Pad



Description: Circumferential scratches may be a short arc on the surface ending at the point the debris becomes embedded. The scratch may continue across the entire shoe surface. Random radial and non-circumferential scratches

Cause: Dirt entering bearing at start-up.

Rectification: Lubricating oil must be filtered. Clean the bearing assembly and reservoir.

Compliments of Federal-Mogul RPB Inc. (Formerly Glacier RBP)

Figure 1.M-1c—Scoring of Pad

CORROSION

(Figures 1.M-2a and 1.M-2b)

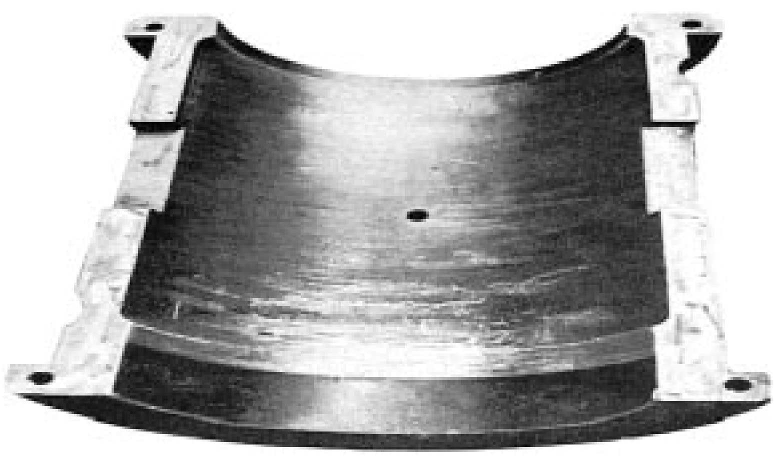
Description: Hard, dark brown or black film that forms on the Babbitt.

Cause: Formed in the presence of tin-based Babbitt, oil and salt water, beginning in the area of high temperature and pressure. Tin oxide eliminates the "*embedability*" properties of the Babbitt.

Rectification: Replace lube oil. Clean entire bearing assembly and flush oil piping, and reservoir with mineral spirits.

Compliments of Kingsbury, Inc.

Figure 1.M-2a—Tin Oxide Damage



Description: Hard, black film that on the Babbitt.

Cause: Corrosion of a marine turbine bearing which was formed in the presence of tin-based Babbitt, oil and salt water, beginning in the area of high temperature and pressure. Tin oxide eliminates the "*embedability*" properties of the Babbitt.

Rectification: Replace bearing, and lube oil. Clean entire bearing assembly and flush oil piping, and reservoir with mineral spirits. Eliminate water in the lube oil.

Compliments of Federal-Mogul RPB Inc. (Formerly Glacier RBP)

Figure 1.M-2b—Tin Oxide Damage

OVER TEMPERATURE

(Figures 1.M-3a, 1.M-3b, 1.M-3c, 1.M-3d, 1.M-3e, and 1.M-3f)

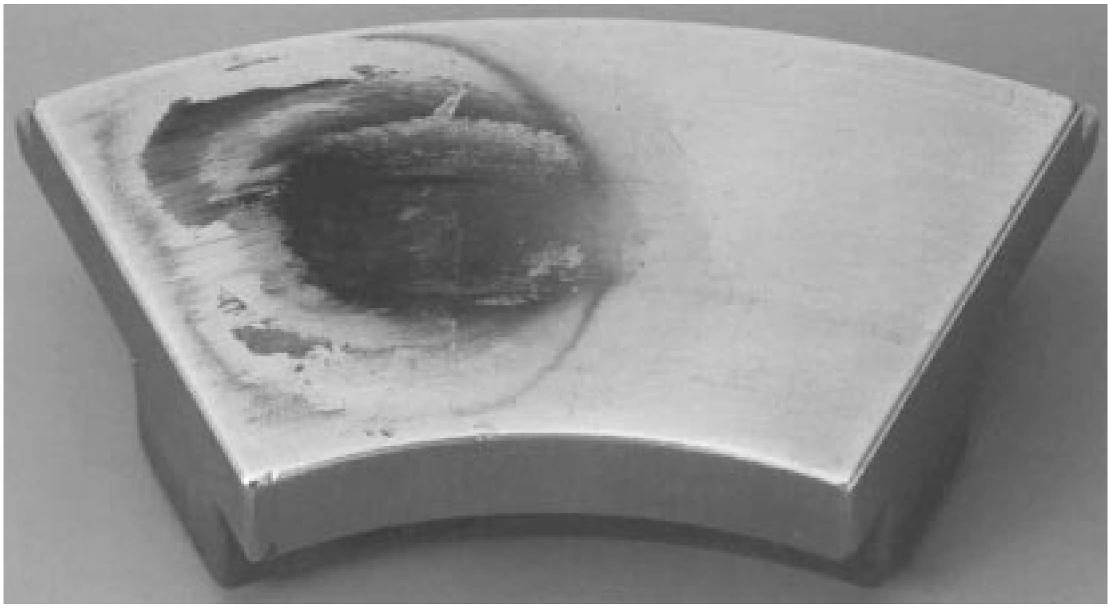
Description: Irregular shaped crystal shapes.

Cause: Repeated cycles of overheating produces surface deformation in materials which have different coefficients of thermal expansion in each crystal axis. The crystal size is large, approximately 0.20 inches.

Rectification: Eliminate overheating which may be caused by improper lubrication selection, inadequate lubrication supply, interrupted fluid film, improper bearing selection, poor collar, runner or journal surface finish, insufficient bearing clearance, excessive load, overspeed. Replace shoes.

Compliments of Kingsbury, Inc.

Figure 1.M-3a—Thermal Ratcheting



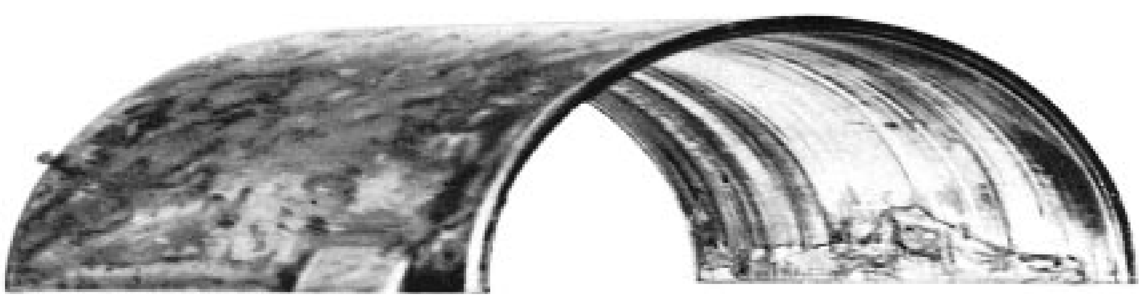
Description: Discoloration or blackened region on bearing.

Cause: Over heating causes oil additive package to "plate out". Typically begins in the area of highest temperature, at the 75-75 location.

Remedy: Eliminate overheating which may be caused by improper lubrication selection, inadequate lubrication supply, interrupted fluid film, improper bearing selection, poor collar, runner or journal surface finish, insufficient bearing clearance, excessive load, overspeed. Replace shoes.

Compliments of Kingsbury, Inc.

Figure 1.M-3b—Overheating, Oil Additives Plated Out



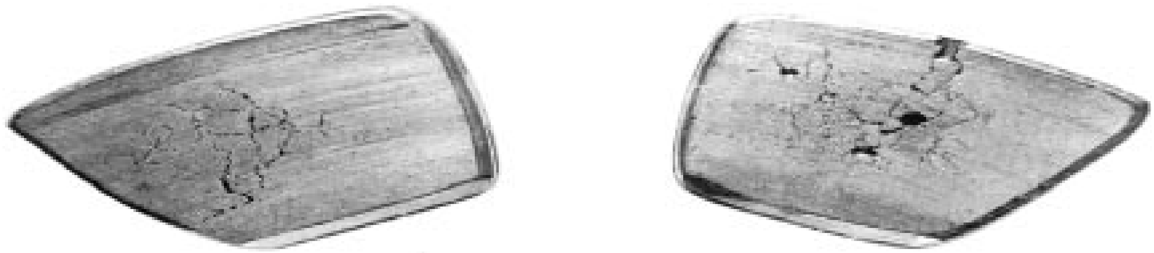
Description: Damage at bearing horizontal joint

Cause: Excessive interference causing bearing bore or housing distortion, or flimsy housing.

Rectification. Replace bearing. Determine interference fit and concentricity of bearing, and bearing housing bore.

Compliments of Federal-Mogul RPB Inc. (Formerly Glacier RBP)

Figure 1.M-3c—Overheating and Fatigue at Joint



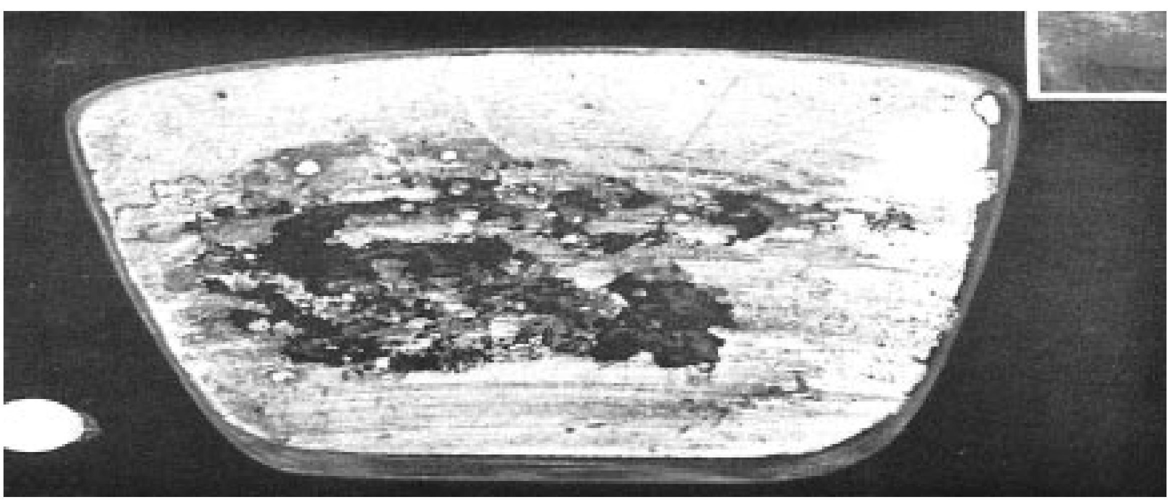
Description: Irregular cracks on bearing surface and possible extrusion. Note displacement of babbitt over edge of pad due to extrusion.

Cause: Overheating and subsequent reduction in material strength results in cracks forming as the result of normal and shear forces transmitted through the oil film. Wiping does not necessarily occur under such conditions.

Remedy: Eliminate overheating which may be caused by improper lubrication selection, inadequate lubrication supply, interrupted fluid film, improper bearing selection, poor collar, runner or journal surface finish, insufficient bearing clearance, excessive load, overspeed. Replace shoes.

Compliments of Federal-Mogul RPB Inc. (Formerly Glacier RBP)

Figure 1.M-3d—Cracking of Pad Due to Operation at Excessively High Temperatures



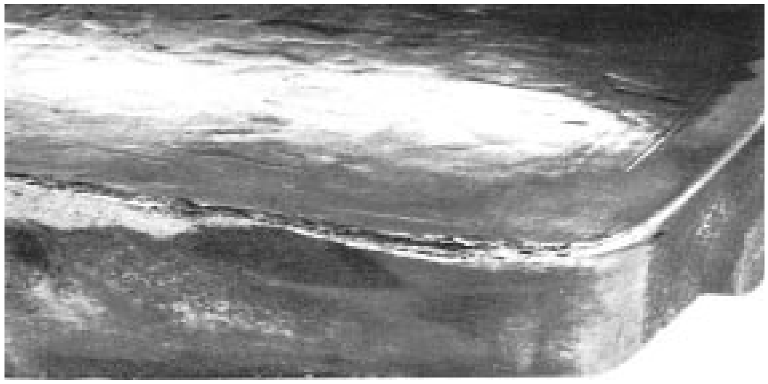
Description: Irregular cracks on bearing surface and possible extrusion

Cause: Overheating and subsequent reduction in material strength results in cracks forming as the result of normal and shear forces transmitted through the oil film. Wiping does not necessarily occur under such conditions.

Remedy: Eliminate overheating which may be caused by improper lubrication selection, inadequate lubrication supply, interrupted fluid film, improper bearing selection, poor collar, runner or journal surface finish, insufficient bearing clearance, excessive load, overspeed. Replace shoes.

Compliments of Federal-Mogul RPB Inc. (Formerly Glacier RBP)

Figure 1.M-3e—Cracking and Displacement of Pad Due to Overheating Under Steady Conditions



Description: Irregular shaped crystal shapes.

Cause: Repeated cycles of overheating produces surface deformation in materials which have different coefficients of thermal expansion in each crystal axis.

Rectification: Eliminate overheating which may be caused by improper lubrication selection, inadequate lubrication supply, interrupted fluid film, improper bearing selection, poor collar, runner or journal surface finish, insufficient bearing clearance, excessive load, overspeed. Replace shoes.

Compliments of Federal-Mogul RPB Inc. (Formerly Glacier RBP)

Figure 1.M-3f—Thermal Ratcheting Due to Thermal Cycling Through Excessive Temperature Range In Service

ELECTRICAL DISCHARGE PITTING

(Figures 1.M-4a, 1.M-4b, and 1.M-4c)

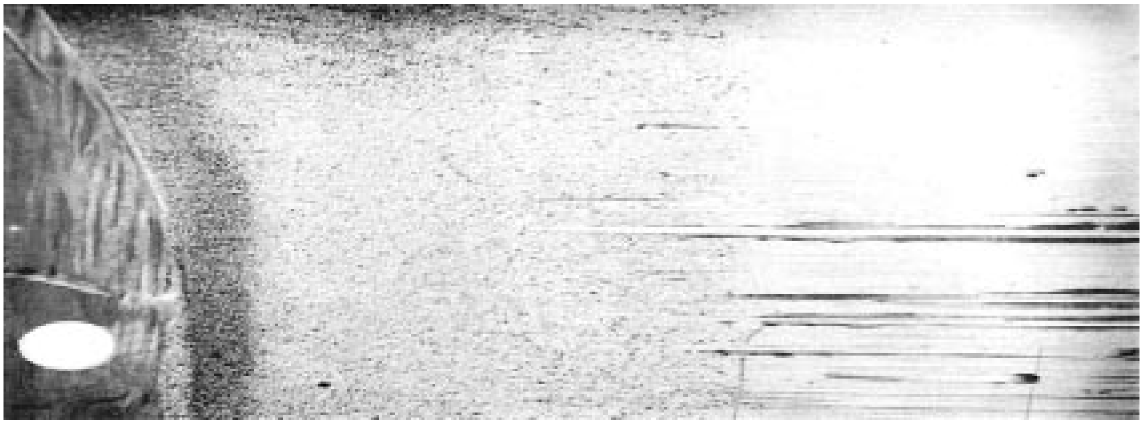
Description: The pits may be very small and difficult to observe with the unaided eye. Examination at low magnification (5–10X) reveals shiny, rounded pits from which metal has been removed by melting. The pit may appear as frosting or matt appearance as shown above or blackened due to oil deposits. The frosting may also appear on the mating rotating surface such as the journal or thrust collar. A clearly defined boundary exists between the pitted and unpitted regions. Pitting usually occurs where the oil film is thinnest. As pitting progresses, the individual pits lose their characteristic appearance as they begin to overlap.

Cause: Electrical pitting is caused by intermittent arcing between the stationary and rotating components. It may be electrostatic or electromagnetic in origin. If electrostatic in nature it can be attributed to charged lubricant, charged drive belts, or impinging particles If electromagnetic in nature it can be attributed to magnetization of rotating and/or stationary components or leakage currents from electric motors. May not occur in the region of thinnest oil film.

Rectification: Electrostatically based—install grounding brushes or straps. Bearing isolation is also recommended. Electromagnetically based—demagnetizing the affected components. Electric motors should be fitted with insulated bearings and couplings. Filter lubricating oil, clean and flush the entire bearing assembly and oil reservoir. Replace shoes. Examine and if necessary regrind journal. Consider reduced run time and inspect bearing.

Compliments of Kingsbury, Inc.

Figure 1.M-4a—Stray Shaft Currents/Electrical Pitting (Frosting)



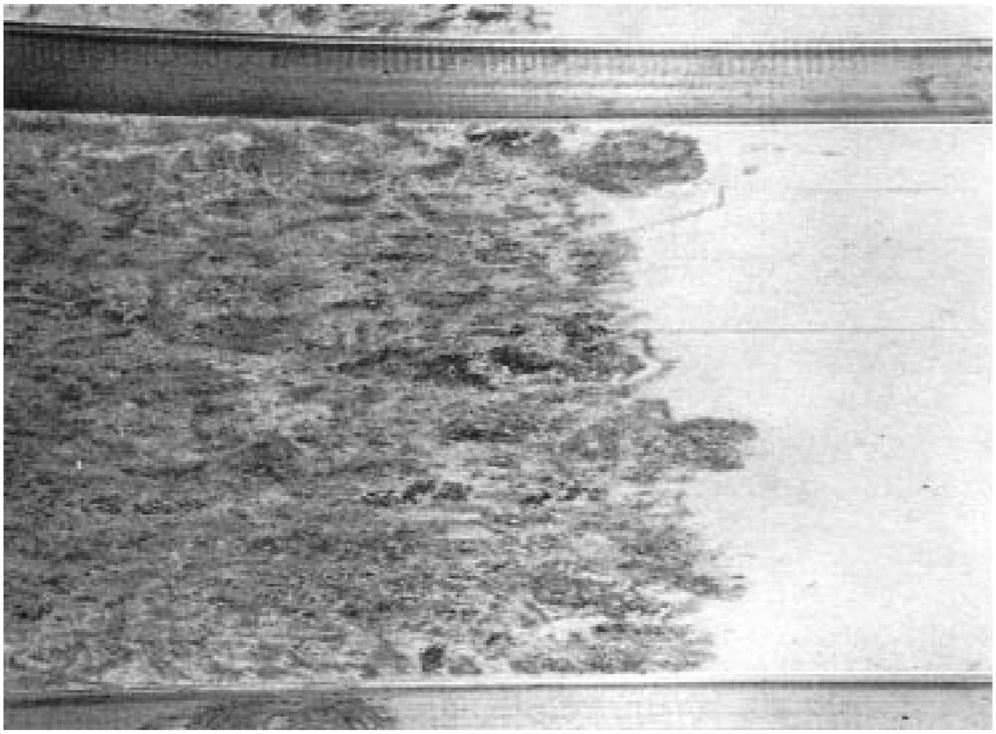
Description: The pits may be very small and difficult to observe with the unaided eye. Examination at low magnification (5–10X) reveals shiny, rounded pits from which metal has been removed by melting. The pit may appear as frosting or matt appearance as shown above or blackened due to oil deposits. The frosting may also appear on the mating rotating surface such as the journal or thrust collar. A clearly defined boundary exists between the pitted and unpitted regions. Pitting usually occurs where the oil film is thinnest. As pitting progresses, the individual pits lose their characteristic appearance as they begin to overlap.

Cause: Electrical pitting is caused by intermittent arcing between the stationary and rotating components. It may be electrostatic or electromagnetic in origin. If electrostatic in nature it can be attributed to charged lubricant, charged drive belts, or impinging particles. If electromagnetic in nature it can be attributed to magnetization of rotating and/or stationary components or leakage currents from electric motors. May not occur in the region of thinnest oil film.

Rectification: Electrostatically based—Install grounding brushes or straps. Bearing isolation is also recommended. Electromagnetically based—demagnetizing the affected components. Electric motors should be fitted with insulated bearings and couplings. Filter lubricating oil, clean and flush the entire bearing assembly and oil reservoir. Replace bearing. Examine and if necessary regrind journal. Consider reduced run time and inspect bearing.

Compliments of Federal-Mogul RPB Inc. (Formerly Glacier RBP)

Figure 1.M-4b—Fine Hemispherical Pitting and Scoring of Bearing



Description: The pits may be very small and difficult to observe with the unaided eye. Examination at low magnification (5–10X) reveals shiny, rounded pits from which metal has been removed by melting. The pit may appear as frosting or matt appearance as shown above or blackened due to oil deposits. The frosting may also appear on the mating rotating surface such as the journal or thrust collar. A clearly defined boundary exists between the pitted and unpitted regions. Pitting usually occurs where the oil film is thinnest. As pitting progresses, the individual pits lose their characteristic appearance as they begin to overlap.

Cause: Electrical pitting is caused by intermittent arcing between the stationary and rotating components. It may be electrostatic or electromagnetic in origin. If electrostatic in nature it can be attributed to charged lubricant, charged drive belts, or impinging particles If electromagnetic in nature it can be attributed to magnetization of rotating and/or stationary components or leakage currents from electric motors. May not occur in the region of thinnest oil film.

Rectification: Electrostatically based—Install grounding brushes or straps. Bearing isolation is also recommended. Electromagnetically based—demagnetizing the affected components. Electric motors should be fitted with insulated bearings and couplings Filter lubricating oil, clean and flush the entire bearing assembly and oil reservoir. Replace bearing. Examine and if necessary regrind journal. Consider reduced run time and inspect bearing.

Compliments of Federal-Mogul RPB Inc. (Formerly Glacier RBP)

Figure 1.M-4c—Stray Shaft Currents/Electrical Pitting (Frosting) Journal Bearing

FATIGUE

(Figures 1.M-5a, 1.M-5b,1.M-5c, 1.M-5d, and 1.M-5e)

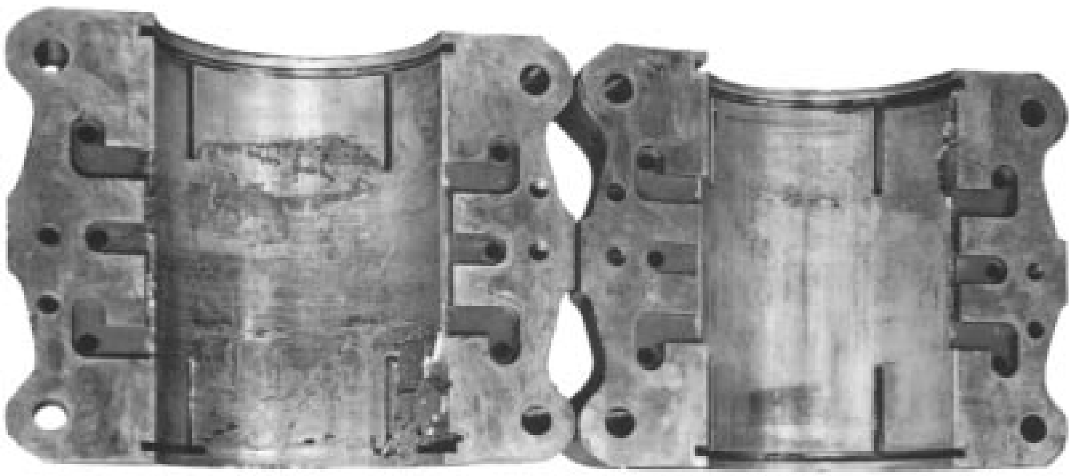
Description: Pieces of babbitt are spalled out or appear to be pulled away from the shoe backing.

Cause: Fatigue damage due to concentrated cyclic loading which involves repeated bending or flexing of the bearing. Damage occurs more rapidly with poor bond but will also occur with good bond. Cyclic loading may be caused by misalignment and consequential edge loading, journal eccentricity, imbalance, bent shaft, thermal cycling, vibration. High bearing temperature may also be a contributing factor since the fatigue strength of the babbitt decreases at elevated temperature.

Rectification: Determine cause of the cyclic loading and eliminate. Filter lubricating oil, clean and flush the entire bearing assembly and oil reservoir. Replace shoes.

Compliments of Kingsbury, Inc.

Figure 1.M-5a—Edge Load Pivoted Shoe Showing Babbitt Mechanical Fatigue



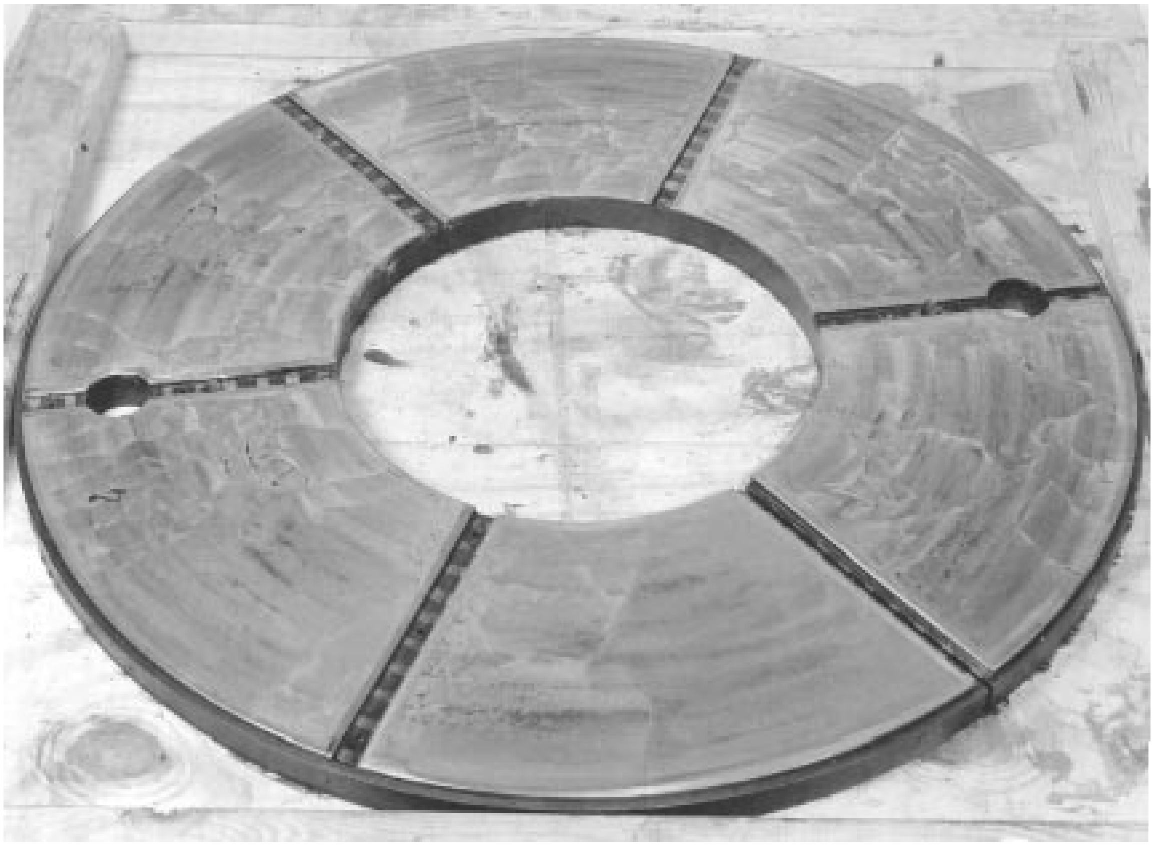
Description: Pieces of babbitt are spalled out or appear to be pulled away from the shoe backing.

Cause: Fatigue damage due to concentrated cyclic loading, which involves repeated bending or flexing of the bearing. Damage occurs more rapidly with poor bond but will also occur with good bond. Cyclic loading may be caused by misalignment and consequential edge loading, journal eccentricity, imbalance, bent shaft, thermal cycling, and vibration. High bearing temperature may also be a contributing factor since the fatigue strength of the babbitt decreases at elevated temperature.

Rectification: Determine cause of the cyclic loading and eliminate. Filter lubricating oil, clean and flush the entire bearing assembly and oil reservoir.

Compliments of Kingsbury, Inc.

Figure 1.M-5b—Edge Load Journal Shell with Babbitt Mechanical Fatigue



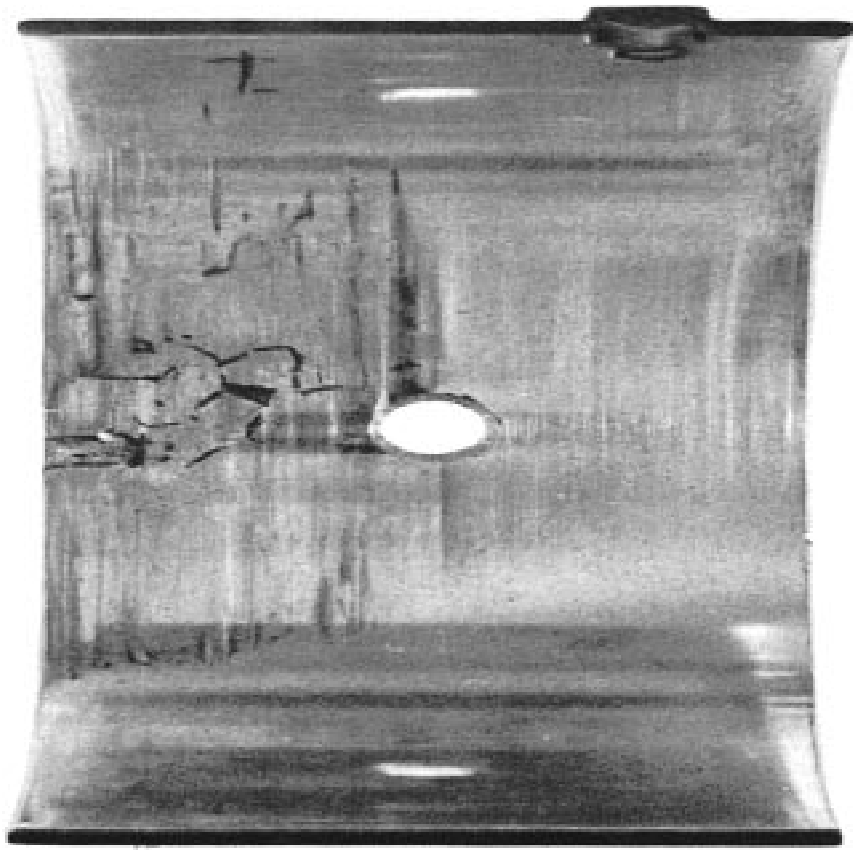
Description: Intergranular or hairline cracks in the Babbitt. The cracks may appear to open in the direction of rotation. Pieces of babbitt are spalled out or appear to be pulled away from the shoe backing. The cracks may reveal the backing.

Cause: Fatigue damage due to concentrated cyclic loading, which involves repeated bending or flexing of the bearing. Damage occurs more rapidly with poor bond but will also occur with good bond. Cyclic loading may be caused by misalignment, journal eccentricity, imbalance, bent shaft, thermal cycling, and vibration. High bearing temperature may also be a contributing factor since the fatigue strength of the babbitt decreases at elevated temperature.

Rectification: Determine cause of the cyclic loading and eliminate. Filter lubricating oil, clean and flush the entire bearing assembly and oil reservoir.

Compliments of Kingsbury, Inc.

Figure 1.M-5c—Babbitt Fatigue in a Thin Thrust Plate



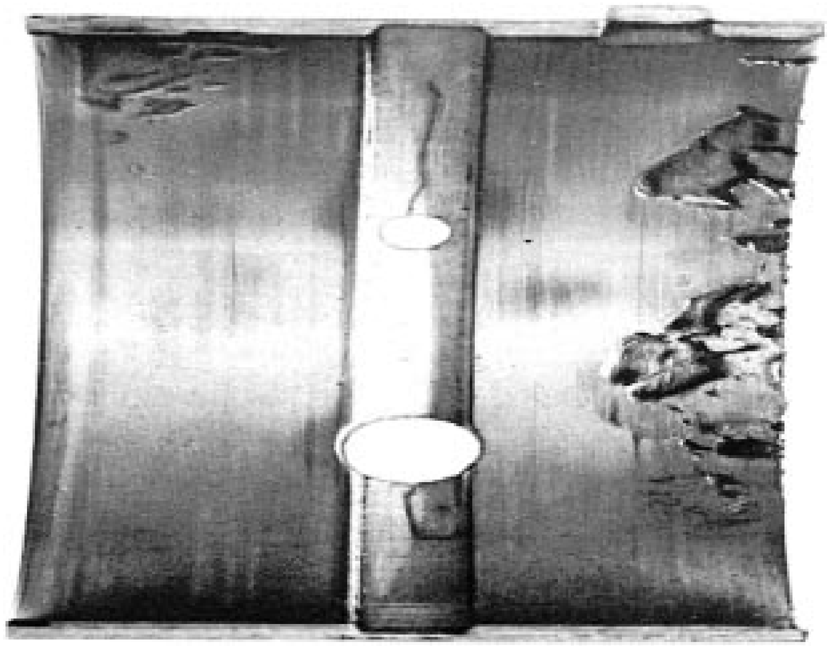
Description: Pieces of babbitt are spalled out or appear to be pulled away from the insert backing.

Cause: Fatigue damage due to concentrated cyclic loading which involves repeated bending or flexing of the bearing. Damage occurs more rapidly with poor bond but will also occur with good bond. Cyclic loading may be caused by misalignment and consequential edge loading, journal eccentricity, imbalance, bent shaft, thermal cycling, vibration. High bearing temperature may also be a contributing factor since the fatigue strength of the babbitt decreases at elevated temperature.

Rectification: Determine cause of the cyclic loading and eliminate. Filter lubricating oil, clean and flush the entire bearing assembly and oil reservoir. Replace insert.

Compliments of Federal-Mogul RPB Inc. (Formerly Glacier RBP)

Figure 1.M-5d—Babbitt Fatigue Cracking



Description: Pieces of babbitt are spalled out or appear to be pulled away from the insert backing.

Cause: Fatigue damage due to concentrated cyclic loading which involves repeated bending or flexing of the bearing. Damage occurs more rapidly with poor bond but will also occur with good bond. Cyclic loading may be caused by misalignment and consequential edge loading, journal eccentricity, imbalance, bent shaft, thermal cycling, vibration. High bearing temperature may also be a contributing factor since the fatigue strength of the babbitt decreases at elevated temperature.

Rectification: Determine cause of the cyclic loading and eliminate. Filter lubricating oil, clean and flush the entire bearing assembly and oil reservoir. Replace insert.

Compliments of Federal-Mogul RPB Inc. (Formerly Glacier RBP)

Figure 1.M-5e—Babbitt Fatigue Cracking

CAVITATIONS

(Figures 1.M-6a, 1.M-6b, 1.M-6c, and 1.M-6d)

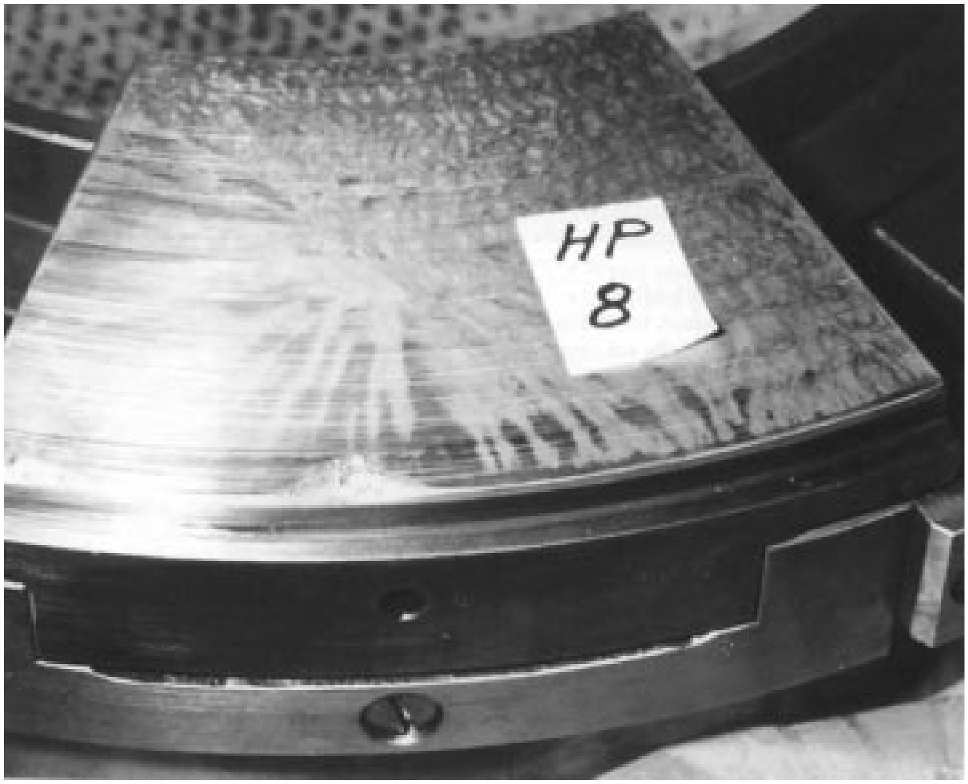
Description: Discrete irregularly shaped Babbitt voids which may or may not extend to the bond line. It may also appear as localized Babbitt erosion.

Cause: Cavitations damage. This is caused by the formation and implosion of vapor bubbles in areas of rapid pressure change.

Rectification: Based on the source, cavitations may be eliminated by: radiusing/chamfer sharp steps, modify bearing grooves, reduce bearing clearance, reduce bearing arc, eliminate flow restrictions downstream, increase lubricant flow, increase oil viscosity, lower bearing temperature, change oil feed pressure, use harder bearing materials. Filter lubricating oil, clean and flush the entire bearing assembly and oil reservoir. Replace shoes.

Compliments of Kingsbury, Inc.

Figure 1.M-6a—Thrust Shoe Cavitations Damage in Babbitt Face



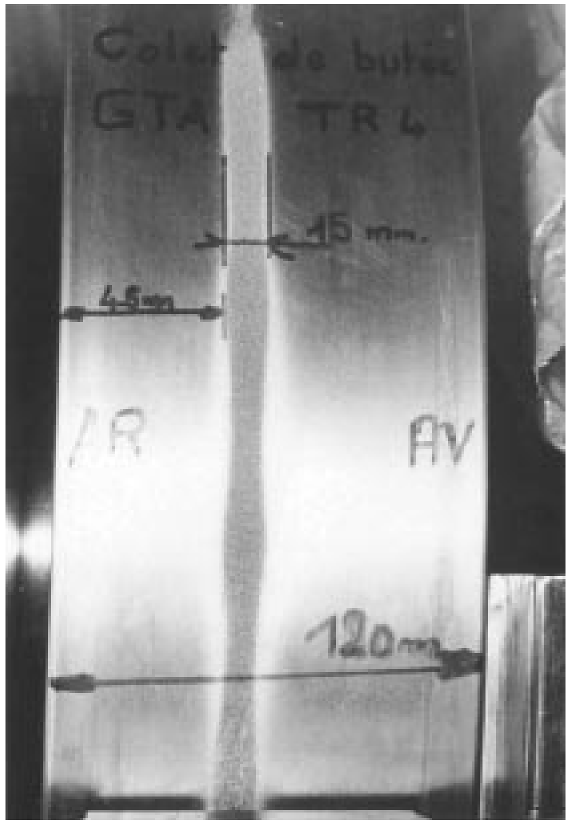
Description: Discrete irregularly shaped Babbitt voids which may or may not extend to the bond line. It may also appear as localized Babbitt erosion.

Cause: Cavitation damage. This is caused by the formation and implosion of vapor bubbles in areas of rapid pressure change. Damage often occurs at the outside diameter of thrust bearing pads due to the existence of higher velocities.

Rectification: Based on the source, cavitation may be eliminated by: radiusing/chamfer sharp steps, modify bearing grooves, reduce bearing clearance, reduce bearing arc, eliminate flow restrictions downstream, increase lubricant flow increase oil viscosity, lower bearing temperature, change oil feed pressure, use harder bearing, materials. Filter lubricating oil, clean and flush the entire bearing assembly and oil reservoir. Replace shoes.

Compliments of Kingsbury, Inc.

Figure 1.M-6b—Thrust Shoe Cavitation Towards Outside Diameter



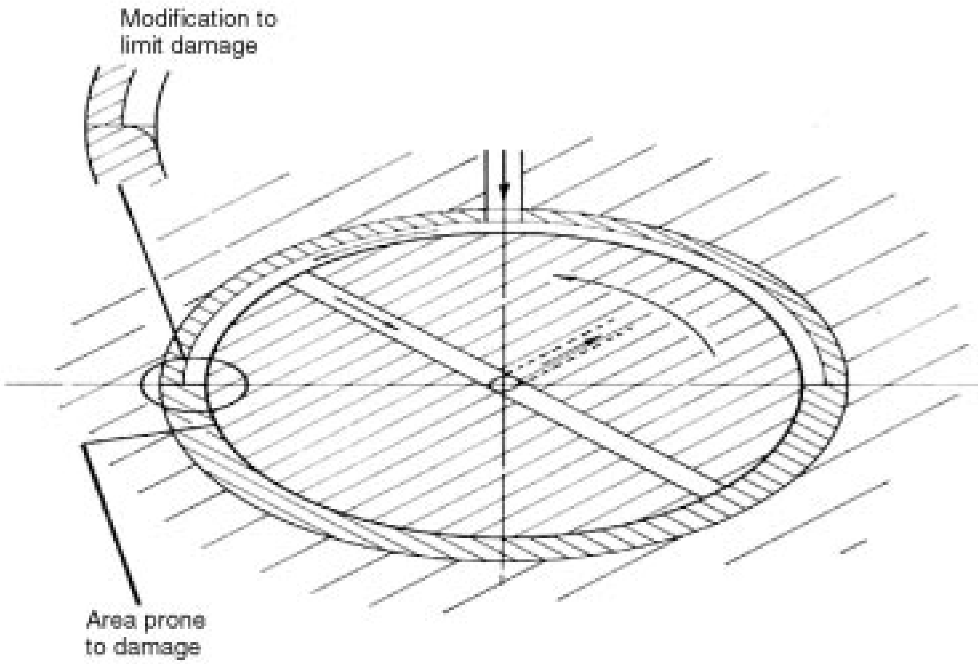
Description: Discrete irregularly shaped Babbitt voids which may or may not extend to the bond line. It may also appear as localized Babbitt erosion.

Cause: Cavitation damage. This is caused by the formation and implosion of vapor bubbles in areas of rapid pressure change. Although the babbitted surface is usually damaged more severely, the rotating collar, runner, or journal surface may also be affected.

Rectification: Based on the source, cavitation may be eliminated by: radiusing/chamfer sharp steps, modify bearing grooves, reduce bearing clearance, reduce bearing arc, eliminate flow restrictions downstream, increase lubricant flow, increase oil viscosity, lower bearing temperature, change oil feed pressure, use harder bearing, materials. Filter lubricating oil, clean and flush the entire bearing assembly and oil reservoir. Replace affected components.

Compliments of Kingsbury, Inc.

Figure 1.M-6c—Cavitation Damage on Outside Diameter of Collar



Description: Discrete irregularly shaped Babbitt voids which may or may not extend to the bond line. It may also appear as localized Babbitt erosion.

Cause: Cavitation damage. This is caused by the formation and implosion of vapor bubbles in areas of rapid pressure change. Damage often occurs at the outside diameter of thrust bearing pads due to the existence of higher velocities.

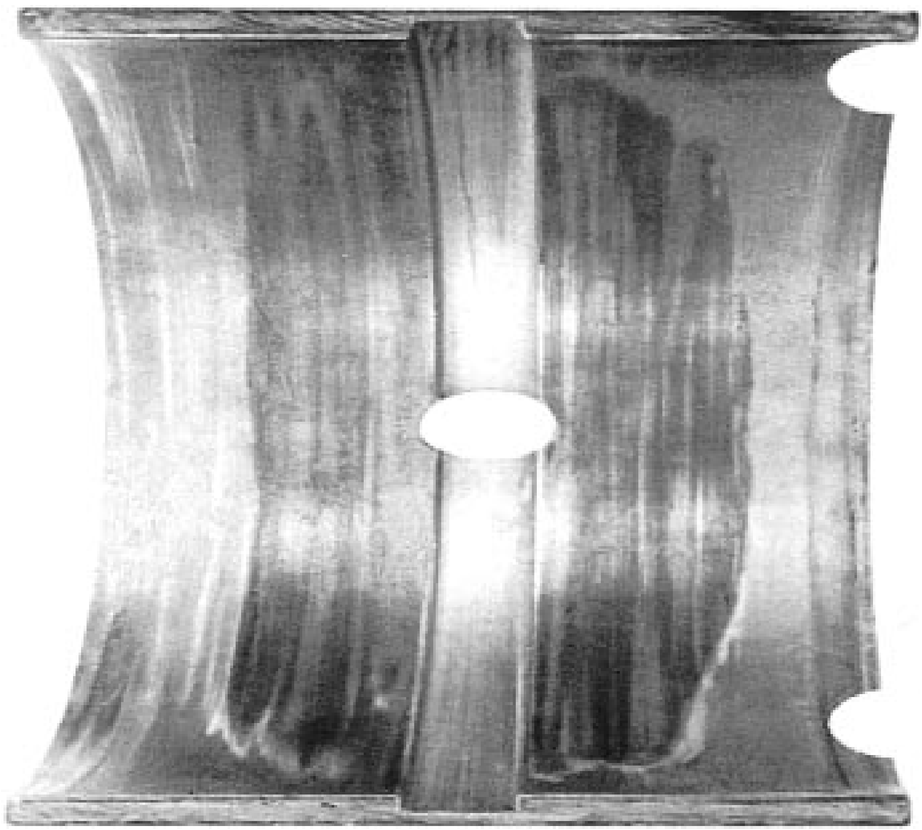
Rectification: Based on the source, cavitation may be eliminated by: radiusing/chamfer sharp steps, modify bearing grooves, reduce bearing clearance, reduce bearing arc, eliminate flow restrictions downstream, increase lubricant flow increase oil viscosity, lower bearing temperature, change oil feed pressure, use harder bearing, materials. Filter lubricating oil, clean and flush the entire bearing assembly and oil reservoir. Replace shoes.

Compliments of Federal-Mogul RPB Inc. (Formerly Glacier RBP)

Figure 1.M-6d—Modification of Groove to Limit or Reduce Cavitation Damage

WIPING OF BEARING SURFACE

(Figures 1.M-7a and 1.M-7b)



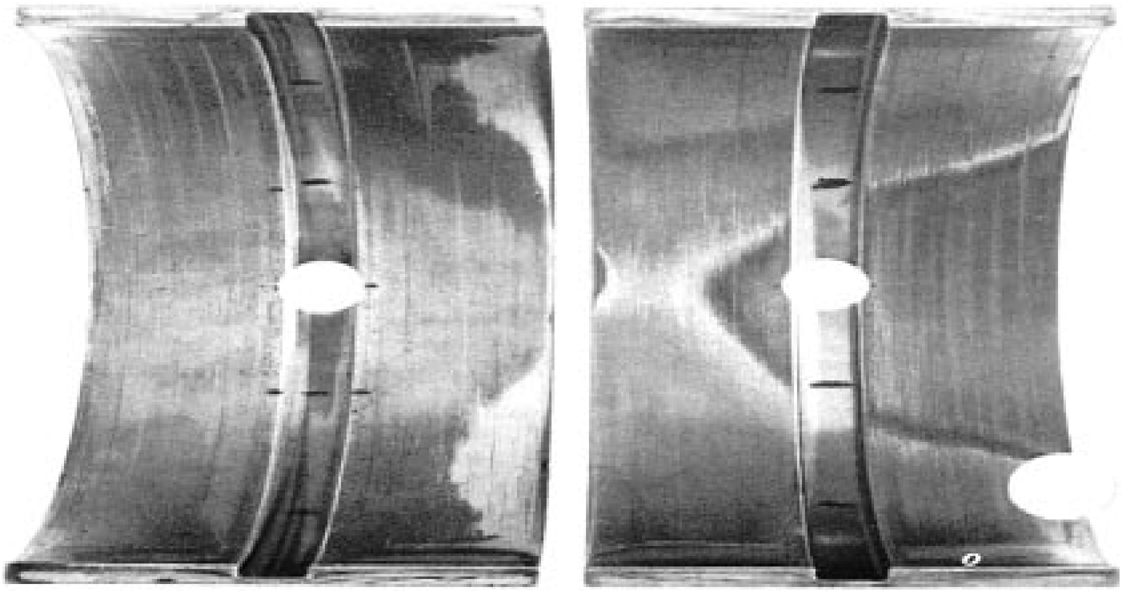
Description: Shinny smooth area where rubbing, smearing and/or melting is evident.

Cause: Inadequate running clearance in middle of the bearing with consequential overheating, inadequate oil supply or both. Improper alignment of components.

Rectification: Check bearing clearance, journal diameter and bearing inside diameter at various axial locations along the axis of the journal.

Compliments of Federal-Mogul RPB Inc. (Formerly Glacier RBP)

Figure 1.M-7a—Bearing Wiped Due to a Barreled Journal



Description: Shinny smooth area where rubbing, smearing and/or melting is evident.

Cause: Inadequate running clearance with consequential overheating, inadequate oil supply or both. Improper alignment of components.

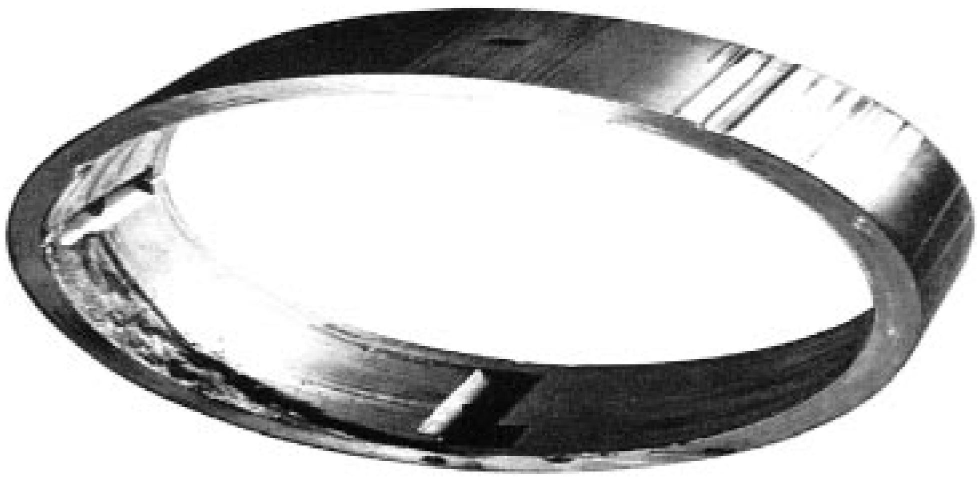
Rectification: Check bearing clearance at various axial locations along the axis of the journal.

Compliments of Federal-Mogul RPB Inc. (Formerly Glacier RBP)

Figure 1.M-7b—Uneven Wear of Bearing Due to Misalignment

WIRE WOOL

(Figures 1.M-8a, 1.M-8b, and 1.M-8c)



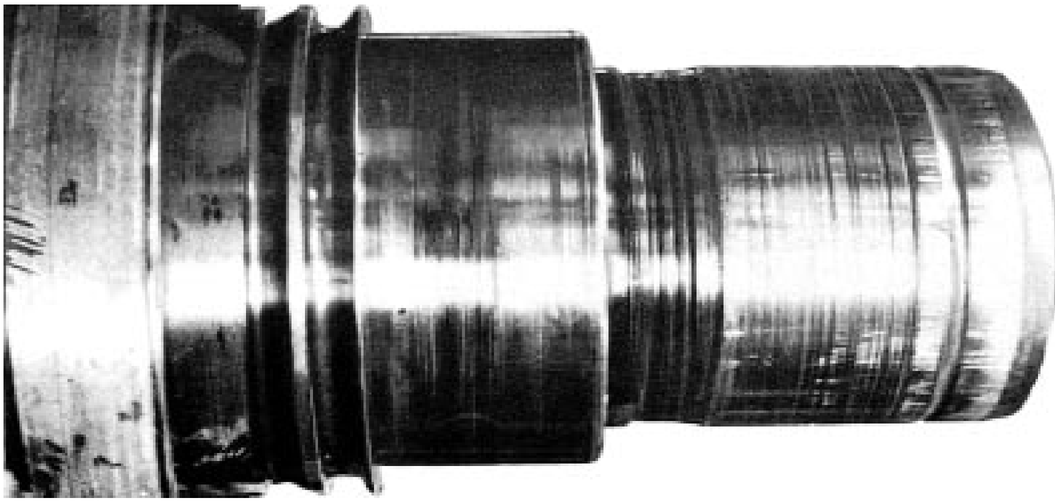
Description: Identified by extensive damage to both bearing and the journal and/or thrust collar with wear products from the shaft collected in the bearing housing where they look like wire wool. A black scab is also often present on the damaged surface, hence the alternative name “black scab failure.”

Cause: This failure occurs when a small particle of hard dirt gets embedded in the bearing material, but continues to rub against the steel counterface. At high speed the temperature generated by the frictional rub carburises the chromium in the steel in the presence of a hydrocarbon oil, producing hard chromium carbides that embed in the soft bearing material and act as cutting tools on the journal or thrust collar. The process continues by accretion of the embedded carbides and may result in a journal being turned completely through.

Rectification: One solution is to limit the chromium content of the steel to 1.5% where surface speeds are greater than 80 ft/sec. Shaft made of material such as 400 series stainless, 17-4 PH and 15-5 PH are susceptible to this phenomenon and should be coated in the journal area with an HVOF coating or welded. Cleanliness of the lube oil is also a major consideration. There have also been reports that lube oil with EP additives containing chlorinated paraffin increases susceptibility to wire wooling even on low chromium shafts, as the chlorine may acidify the oil and cause it to etch along any stringers in the shaft surface and possibly release small metallic slivers into the lube oil.

Compliments of Federal-Mogul RPB Inc. (Formerly Glacier RBP)

Figure 1.M-8a—Compressor Bearing with Formation of “Black Scab”



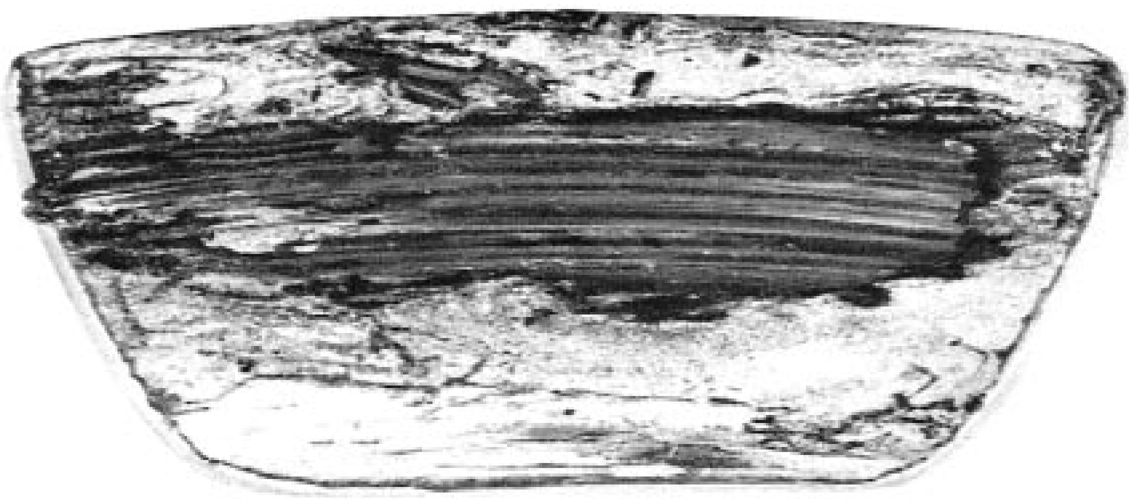
Description: Identified by extensive damage to both bearing and the journal and/or thrust collar with wear products from the shaft collected in the bearing housing where they look like wire wool. A black scab is also often present on the damaged surface, hence the alternative name “black scab failure.”

Cause: This failure occurs when a small particle of hard dirt gets embedded in the bearing material, but continues to rub against the steel counterface. At high speed the temperature generated by the frictional rub carburises the chromium in the steel in the presence of a hydrocarbon oil, producing hard chromium carbides that embed in the soft bearing material and act as cutting tools on the journal or thrust collar. The process continues by accretion of the embedded carbides and may result in a journal being turned completely through.

Rectification: One solution is to limit the chromium content of the steel to 1.5% where surface speeds are greater than 80 ft/sec. Shaft made of material such as 400 series stainless, 17-4 PH and 15-5 PH are susceptible to this phenomenon and should be coated in the journal area with an HVOF coating or welded. Cleanliness of the lube oil is also a major consideration. There have also been reports that lube oil with EP additives containing chlorinated paraffin increases susceptibility to wire wooling even on low chromium shafts, as the chlorine may acidify the oil and cause it to etch along any stringers in the shaft surface and possibly release small metallic slivers into the lube oil.

Compliments of Federal-Mogul RPB Inc. (Formerly Glacier RBP)

Figure 1.M-8b—13% Cr. Journal Running in Bearing Shown in Figure 1.M-7a Showing Severe “Machining” Damage



Description: Identified by extensive damage to both bearing and the journal and/or thrust collar with wear products from the shaft collected in the bearing housing where they look like wire wool. A black scab is also often present on the damaged surface, hence the alternative name “black scab failure.”

Cause: This failure occurs when a small particle of hard dirt gets embedded in the bearing material, but continues to rub against the steel counterface. At high speed the temperature generated by the frictional rub carburises the chromium in the steel in the presence of a hydrocarbon oil, producing hard chromium carbides that embed in the soft bearing material and act as cutting tools on the journal or thrust collar. The process continues by accretion of the embedded carbides and may result in a journal being turned completely through.

Rectification: One solution is to limit the chromium content of the steel to 1.5% where surface speeds are greater than 80 ft/sec. Shaft made of material such as 400 series stainless, 17-4 PH and 15-5 PH are susceptible to this phenomenon and should be coated in the journal area with an HVOF coating or welded. Cleanliness of the lube oil is also a major consideration. There have also been reports that lube oil with EP additives containing chlorinated paraffin increases susceptibility to wire wooling even on low chromium shafts, as the chlorine may acidify the oil and cause it to etch along any stringers in the shaft surface and possibly release small metallic slivers into the lube oil.

Compliments of Federal-Mogul RPB Inc. (Formerly Glacier RBP)

Figure 1.M-8c—”Black Scab”—Wire Wooling—Formation on Thrust Pad

CHAPTER 2—SPECIAL PURPOSE CENTRIFUGAL COMPRESSORS

CONTENTS CHAPTER 2

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Rotor Repair

Chapter 2—Special Purpose Centrifugal Compressors

1 Inspection of Assembled Rotor Phase I

1.1 GENERAL

This section describes the data to be recorded and the requirements of Phase I inspection of an assembled centrifugal compressor rotor. This section is to be used in addition to the requirements of Chapter 1, Section 7, Phase I inspection. In addition to the information supplied by Chapter 1, paragraph 2.3, the owner should identify the type of impeller construction. This construction method is critical to determine the inspection and repair methods.

Note: Brazed impellers require special techniques to inspect and repair. The inspection and repair methods are to be per Section 3.2.6.

1.2 DEFINITIONS

1.2.1 Major components are the impellers, balance piston, and the shaft keys that go with them (if any).

1.3 INSPECTION

1.3.1 The impeller construction method is to be identified on the inspection form. Typical impeller types are welded, brazed, cast, riveted, or machined.

1.3.2 In addition to the requirements specified in Chapter 1, Section 7, the inspections indicated in 1.3.3 through 1.3.11 shall be made:

1.3.3 Appendix A inspection forms and drawings or equal shall be used in recording the necessary information. These inspection forms and drawings may be modified by the vendor to represent the actual configuration of the rotor.

1.3.4 Measure and record impeller outside and suction eye diameters.

1.3.5 Measure gaps between all shrunk on parts. Generally the gap should be a minimum of approximately 0.10 mm (0.004 in.).

1.3.6 Measure and record axial runout for each impeller suction eye.

1.3.7 Measure and record axial stack-up dimensions, in a minimum of two circumferential locations referenced from the thrust collar shaft shoulder (or active side of the integral thrust collar), to each impeller (the gas path surfaces nearest the thrust collar) and to all other components that may be removed from the shaft. Each dimension is to be referenced and recorded from the same thrust location. One of the axial stack-up dimensions should be taken at the zero phase reference point and the second should be 90° apart.

1.3.8 For an open faced impeller, each blade's natural frequency shall be measured and recorded. This check is to determine that each blade, new or as it wears, does not operate in resonance. A Campbell diagram shall be provided (based on test data) showing the first fundamental blade natural frequency (corrected for operating speed) and harmful excitation frequencies. The exciting frequencies shall not intersect a blade natural frequency within ±10% of the operating speed range. The correction method is to be mutually agreed.

Notes:

1. This test and evaluation is required due to the free standing type of blading design for an open faced impeller. The blading for this type of impeller is more susceptible to high cycle fatigue than closed type impellers.

2. The correction for the blade's natural frequency is due to the blade stiffening at operating speed.

3. Grinding on a blade during balancing may change the blade's natural frequency.

1.3.9 Inspect for damaged, deformed, loose or missing rivets.

1.3.10 The NDE evaluation described in Chapter 1, Table 1.8-1, shall be a severity level of "A" for all components, excluding sleeves which shall be severity level "C."

1.3.11 Check hardness of any rubbed areas where metal has transferred.

Note: Particular attention should be paid to applications such as those susceptible to stress corrosion cracking, low temperature, materials with high impact requirements, etc.

1.4 INSPECTION REPORT

1.4.1 The vendor shall prepare an initial inspection documentation package (report) consisting of all of the information identified in Chapter 1, Section 7 and Section 1.3, as applicable.

1.4.2 The vendor shall not disassemble the rotor without the approval of the owner. The vendor may minimize the Phase I inspection if it is obvious that the rotor needs to be disassembled and a more detailed phase II inspection performed. Some reasons for disassembly include:

a. Shaft damage such as fretting, cracking, journal bearing/shaft end damage.
b. Thermally unstable rotor.
c. Impeller / flowpath damage requiring removal of impeller.
d. Severe corrosion / erosion.
e. Overspeed of rotor where yielding of material is a concern or evident.
f. Rerate requiring new components.
g. Shifting of components, loss of thermal gaps.
h. Bowed rotor, excessive runout or impeller runouts that are out of phase.
i. Balance level not repeatable in the shop or field.
j. Previous operating and overhaul history suggests full disassembly.
k. Over temperature history.

1.4.3 If the owner has authorized dismantling of the rotor, the vendor shall proceed to Section 2 and provide "as found" data for each component (impellers, balance pistons, etc.).

2 Rotor Disassembly Phase II

2.1 GENERAL

2.1.1 This section describes the data to be recorded and the requirements of Phase II inspection of a centrifugal compressor rotor disassembly.

2.2 DISASSEMBLY FOR PHASE II INSPECTION

● **2.2.1** When specified, or with owners approval as a result from Phase I inspection, the vendor shall dismantle the rotor completely.

2.2.2 Prior to dismantling, the requirements of paragraphs 1.3 are to be completed and recorded.

2.2.3 Match mark components and record location and orientation as required to assure proper reassembly.

2.2.4 Care must be exercised in the disassembly to prevent the damaging of components. Typically an interference fit exists between a rotor component and the shaft that requires heat to allow disassembly. A thorough understanding of the rotor construction and the interference fits is required to safely disassemble the rotor without causing component damage.

2.2.5 All major component(s) shall be uniformly heated for disassembly. In no case shall a component be more than 280 K (500°F) above the shop ambient temperature.

Notes:

1. Heating components for disassembly is a critical step. Heated components should be heated uniformly to minimize circumferential temperature variations that could cause permanent distortion. This heating may be accomplished by the use of two or more large (flare tip or rosebud) torches, however, care must be exercised to avoid a heat rate that is too rapid to maintain even heating. The differential temperature should be carefully monitored with temperature indicating temperature sticks without sulfur components or a non-contacting infrared surface temperature gun.

2. Impeller blades on open impellers are subject to rapid heating since there is no cover plate to act as a heat sink.

2.2.6 Unstacking of the rotor should be done in the vertical position.

2.2.7 All mating fits shall be visually inspected for signs of yielding, distress, fretting, galling, etc.

2.2.8 During disassembly, check and record axial dimensions between the thrust collar shaft shoulder (or active side of the integral thrust collar) to the face of the bore nearest the thrust collar on each impeller. Record data on a worksheet designed for the particular rotor as outlined in Appendix "B."

2.3 PHASE II INSPECTION

2.3.1 Carefully, abrasively clean the rotor components to base metal. See Chapter 1, Section 7.2.2 for cleaning methods and precautions. Chemical stripping may be required to adequately evaluate pitting due to corrosion.

Note: This will result in the removal of any protective coatings.

2.3.2 The vendor shall perform the following inspections in paragraphs 2.3.2.1 through 2.3.2.8 after the Phase II disassembly has been completed.

2.3.2.1 All interference fits shall be dimensionally inspected to determine the amount of interference remaining and if component rework is required to restore the design interference.

2.3.2.2 All mating fits shall be visually inspected for signs of yielding, distress, fretting, galling, etc.

2.3.2.3 Visually inspect and record the condition of each part removed. Measure and record all shaft and component sizes on a worksheet designed for the particular component, per Appendix "B" or equal. This data will be used to determine the roundness and taper of each component. This shall include:

a. Bare shaft fit sizes, overall length, and runouts (including thrust collar shoulder).
b. Impeller bore sizes and lengths, and widths of gas passages and land fit areas.
c. Measure and record impeller outside and suction eye diameters.
d. If the "as received" stacking dimensions appear to be incorrect, the stacking heights, at two locations, 90° apart of the impellers shall be determined. Record dimensions from

the outside hub face of the backplates to the inside gas passage face of the backplates (at the O.D. of the impellers).

e. Bore sizes and lengths of shaft spacers, seal sleeves, and impellers.

f. Balance piston bore size and length.

g. Thrust collar and thrust collar spacer(s) bore sizes and lengths.

h. Key clearances on all keyways.

1. With keys installed in keyways, measure from tops of keys to opposite side of shaft.
2. Measure across bore of components to bottoms of keyways.

Note: Item "2" above plus total component interference fit minus item "1" above, equals key clearance.

2.3.2.4 Remove and deburr area(s) of any previously installed balancing weight(s). The location and amount of each weight is to be recorded.

2.3.2.5 Unless otherwise specified, use applicable NDE procedures as outlined in Chapter 1, Section 8 after disassembly, to determine the existence of any indications. Record the size, location, and orientation of any indications on a sketch. All ferro-magnetic components shall be wet magnetic particle inspected.

2.3.2.6 The NDE evaluation described in Chapter 1, Table 1.8-1 shall be a severity level of "A" for all components, excluding sleeves which shall be severity level "C."

2.3.2.7 Photographs shall be taken per Chapter 1, Appendix G, of any component with any unusual or abnormal condition. A photo log should be maintained for all work performed.

2.3.2.8 Threaded areas of the shaft are to be visually inspected and dimensionally verified by a gauge. Inspect for setscrew marks, burrs, sharp corners, and galling.

Note: When a gauge is not available for checking the threads, the mating nut may be used with judgement.

2.4 EVALUATION OF PHASE II INSPECTION DATA

2.4.1 Review and evaluate all data and information to determine the acceptability of the resulting fits, clearances and runouts.

2.4.2 Component bore—If the latest design dimensions, clearances and fits are not available, the following criteria may be used as a guide in determining the acceptable taper and contact area.

2.4.2.1 For straight fit designs, the component bore should not exceed a taper of 0.3 μm/mm (0.0003 in./in.) of bore length.

2.4.2.2 Interference between wheel bore and shaft shall be sufficient for all speed and temperature transients. The actual required interference shall be determined by an engineering review prior to reassembly.

2.4.2.3 For hydraulic fit, tapered bore impeller designs, a bluing contact check shall be performed per Chapter 1, Appendix C with a minimum contact area of 80%. The impeller may be used for this verification as long as there are not any raised discontinuities in the shaft surface.

2.5 PHASE II RECOMMENDED JOB SCOPE

2.5.1 The vendor shall notify the owner upon completion of Phase II Inspection, provide a copy of all Phase II documentation, summarize the results of Phase II Inspection, and prepare the recommended job scope for approval.

3 Repair Processes and New Component Manufacture

3.1 GENERAL

3.1.1 In addition to the general repair processes and new component manufacturing requirements discussed in Chapter 1, Section 9, the following procedures and practices are recommended to accommodate the conditions and considerations unique to centrifugal compressor rotors. Components shall be repaired as outlined in 3.2 through 3.5, or new components supplied as outlined in 3.6.

Note: The repair techniques for brazed impellers are to be individually reviewed due to the possibility of additional damage to the impeller as the result of the temperature requirements during the repair process.

3.1.2 In order to minimize distortion problems in the final assembly, components having a straight, continuous bore and a bore length-to-diameter ratio of 0.75 or greater without a center relief, should have an engineering review. This engineering review is to determine the justification and criteria to incorporate a center relief and land fit concept on each end of the bore.

3.1.3 Rubs and pitting may be removed by machining after an engineering review.

3.2 IMPELLER RESTORATION

3.2.1 General

The acceptable repair methods for welded, machined, or cast impellers are outlined in 3.2.2 to 3.2.4. The acceptable repair method for riveted impellers is outlined in 3.2.5 and the acceptable repair method for brazed impellers is outlined in 3.2.6.

3.2.2 Impeller Seal Area(s)

Repairs to damaged impeller seal areas, typically caused from contact with labyrinth type seals, may be made using the repair methods outlined in 3.2.2.1, 3.2.2.2, and 3.2.2.3. Installation of wear rings (sleeves) shall not be used.

3.2.2.1 Weld Repair

Impeller seal areas may be repaired by the welding process outlined in Chapter 1, Appendix D.2 using an owner approved procedure. The repair procedure shall include the following steps:

a. Weld areas per Chapter 1, Appendix D 2.0.

b. Machine repaired area to finished size to a maximum surface finish of 1.6 µm (64 µinch) Ra.

c. Record impeller dimensions and runouts.

d. Ferromagnetic impellers shall be wet magnetic particle inspected and non-ferromagnetic impellers shall be liquid penetrant inspected per Chapter 1, paragraph 8.2.4.

e. Balance impeller as per Chapter 1, Section 10.

f. Spin test the impeller in accordance with requirements of API 617.

g. Repeat step d above.

h. Perform final dimensional checks and investigate any critical dimensional changes.

Notes:

1. Distortion may be minimized if the impeller is firmly attached to a thick plate prior to welding and stress relieving.

2. Due to distortion, when repairing the seal areas by welding, the impeller bore may be required to be welded also per the procedure outlined in 3.2.3.

3.2.2.2 Reducing (Turning Down) the Impeller Seal Area(s)

Impeller seal area(s) may be repaired by machining undersize the damaged area(s). No build-up to the original diameter is to occur. A minimum amount of material shall be removed. The seal area can be typically undercut a maximum of 760 µm (0.030 in.) on the radius or 10% of the radial thickness, whichever is less. Further undercutting requires detailed engineering analysis. The procedure is to include the following steps:

a. Transition from the undercut area to the adjacent areas should have a minimum of 1.5 mm (0.060 in.) radius with no visible lines or steps.

b. Surface finish shall be a maximum of 1.6 µm (64 µinch) Ra.

c. Ferromagnetic impellers shall be wet magnetic particle inspected and non-ferromagnetic impellers shall be liquid penetrant inspected per Chapter 1, paragraph 8.2.4.

d. Record impeller dimensions and runouts.

e. Balance impeller as per Chapter 1, Section 10.

f. Spin test the impeller in accordance with requirements of API 617.

g. Repeat step c above.

h. Perform final dimensional checks and investigate any critical dimensional changes.

i. Non standard, stationary labyrinth seals will be required to maintain design clearances. The seals should be manufactured such that the tooth height remains as original and the additional thickness should be in the body of the seal.

3.2.2.3 Thermal Spray Repair

Impeller seal area(s) may be repaired by using the thermal spray techniques outlined in Chapter 1, Appendix D.3 for the damaged area(s). A minimum amount of material shall be removed. The seal area can be typically undercut a maximum of 760 µm (0.030 in.) on the radius or 10% of the radial thickness, whichever is less. The finished coating thickness will be between 75 to 760 µm (0.003 to 0.030 in.), as per Chapter 1, Table 1.D-1, for the technique used. The procedure is to include the following steps:

a. Undercut the entire seal area(s) and record dimensions and runouts.

b. Ferromagnetic impellers shall be wet magnetic particle inspected and non-ferromagnetic impellers shall be liquid penetrant inspected per Chapter 1, paragraph 8.2.4.

c. Apply the thermal spray coating

d. Machine seal area to the finished dimension.

e. Repeat step b above.

f. Perform dimensional checks.

g. Balance impeller as per Chapter 1, Section 10.

h. Spin test the impeller in accordance with requirements of API 617.

i. Repeat step b above.

j. Perform final dimensional checks and investigate any critical dimensional changes.

Notes:

1. This repair shall not be used if the surface velocity of the coating is greater than 300 m/sec (1000 ft/sec).

2. Coating application should consider deformation as a result of assembly interference expansion during normal operation and overspeed testing.

3. This repair method shall not be used for rotating labyrinths or "J" strip seals.

3.2.3 Impeller Bore

Impeller bores should be repaired using the repair methods outlined in 3.2.3.1 to 3.2.3.3.

Due to the differences in the coefficients of thermal expansion and bore dilation, chrome or nickel plating shall not be used as a repair method for impeller bore buildup.

3.2.3.1 Weld Repair

Impeller bores may be repaired by the welding process outlined in Chapter 1, Appendix D.2 using an owner approved procedure. Repair procedure is to include the following steps:

a. Record angular position of keyways relative to a discharge blade and mark location on impeller backplate.

b. Generously radius all keyway(s) corners and chamfer the sides of the keyway(s) prior to welding.

c. Weld up keyway, impeller bore and as necessary the seal areas per Chapter 1, Appendix D.2.

d. Machine repaired areas. Impeller bore is to have a maximum surface finish of 0.8 µm (32 µinch) Ra. Repaired impeller seal areas and keyways are to have a maximum surface finish of 1.6 µm (64 µinch) Ra.

e. Ferromagnetic impellers shall be wet magnetic particle inspected and non-ferromagnetic impellers shall be liquid penetrant inspected per Chapter 1, paragraph 8.2.4.

f. Record impeller dimensions and runouts.

g. Balance impeller as per Chapter 1, Section 10.

h. Spin test the impeller in accordance with requirements of API 617.

i. Repeat step e above.

j. Perform final dimensional checks and investigate any critical dimensional changes.

Notes:

1. The face of the impeller at the bore may need to be welded to provide for the impeller final bore length to remain the same length as original.

2. Due to distortion, when repairing the bore by welding, the impeller seal areas may be required to be welded also per the procedure outlined in 3.2.2.

3.2.3.2 Thermal Spray Repair

Impeller bores may be repaired by using the thermal spray techniques outlined in Chapter 1, Appendix D.3. A minimum amount of material shall be removed. The finished coating thickness shall be per Chapter 1, Table 1.D-1, for the technique used. The procedure is to include the following steps:

a. Oversize the bore and record dimensions and runouts.

b. Ferromagnetic impellers shall be wet magnetic particle inspected and non-ferromagnetic impellers shall be liquid penetrant inspected per Chapter 1, paragraph 8.2.4.

c. Blank off the keyway area(s) and apply the thermal spray coating.

d. Machine bore.

e. Repeat step b above.

f. Perform dimensional checks.

g. Balance impeller as per Chapter 1, Section 10.

h. Spin test the impeller in accordance with requirements of API 617.

i. Repeat step b above.

j. Perform final dimensional checks and investigate any critical dimensional changes.

Notes:

1. This technique, depending on the application process, may result in minute chips at the edges, especially at the keyway. Chamfering may be necessary to prevent additional chipping.

2. Coating application should consider deformation as a result of assembly interference, and expansion during assembly, normal operation, and overspeed testing.

3. The angle of the applicator device used in the thermal spray process to build up the impeller bore are to be within the limits recommended by the process licensor. This may preclude thermal spraying impeller bores that have relatively small bores with long lengths.

● **3.2.3.3** When specified, an acceptable alternate repair method is to bore out the impeller oversize and manufacture a new oversize shaft. While technically acceptable, the economics must be carefully compared to the other repair techniques.

Note: For assembly and disassembly purposes on multistage rotors it may be necessary to perform this task on all the impellers.

3.2.4 Blade Repair

3.2.4.1 Minor cracking and/or mechanical damage to impeller blade may be blended out by grinding to a maximum of 10% of the blade thickness. The grinding of these indications is dependent on the impeller geometry, operating stresses, and type of construction. Any grinding beyond the defined limits require an engineering review and disposition.

3.2.4.2 Impeller blades may be repaired by welding process outlined in Chapter 1, Appendix D.2 using an owner approved procedure. The repair procedure shall be in accordance with 3.2.4.2.1 or 3.2.4.2.2.

Note: Successful blade weld repair is highly dependent on impeller geometry (such as thin cross sections), material selection, and construction.

3.2.4.2.1 Blade Repair

a. Weld areas per Chapter 1, Appendix D 2.

b. Remove damaged area by grinding or machining and to prepare the weld joint geometry.

c. NDE weld preparation, Ferromagnetic impellers shall be wet magnetic particle inspected and non-ferromagnetic impellers shall be liquid penetrant inspected per Chapter 1, paragraph 8.2.4.

d. Repair weld and if required, weld blade insert of proper material chemistry and physical properties.

e. Blend welded area to proper profile and surface finish.

f. NDE weld, Ferromagnetic impellers shall be wet magnetic particle inspected and non-ferromagnetic impellers shall be liquid penetrant inspected per Chapter 1, paragraph 8.2.4.

g. Perform post weld heat treatment process, as required.

h. Record parent material and weld hardness per Chapter 1, Appendix B.5 and Chapter 1, Appendix B.6.

i. Record impeller dimensions and runouts.

j. Ferromagnetic impellers shall be wet magnetic particle inspected and non-ferromagnetic impellers shall be liquid penetrant inspected per Chapter 1, paragraph 8.2.4.

k. Balance impeller as per Chapter 1, Section 10.

l. Spin test the impeller in accordance with requirements of API 617.

m. Ferromagnetic impellers shall be wet magnetic particle inspected and non-ferromagnetic impellers shall be liquid penetrant inspected per Chapter 1, paragraph 8.2.4.

n. Perform final dimensional checks and investigate any critical dimensional changes.

3.2.4.2.2 Blade Replacement for Open Style Impellers

TUTORIAL: Impeller blades may be replaced individually or as a complete set. Special fixture tools are required to control impeller distortion.

a. Weld areas per Chapter 1, Appendix D.2.

b. Remove damaged or all blades by machining and to restore hub to the original contour.

c. If required, repair weld hub and machine to final contour.

d. Ferromagnetic impellers shall be wet magnetic particle inspected and non-ferromagnetic impellers shall be liquid penetrant inspected per Chapter 1, paragraph 8.2.4.

e. Record parent material and weld deposit hardness per Chapter 1, Appendix B.5 and Chapter 1, Appendix B.6.

f. Record impeller hub dimensions and runouts.

g. Weld blades of proper material chemistry and heat treatment per Chapter 1, Appendix B.6.

h. Blend welded area.

i. Ferromagnetic impellers shall be wet magnetic particle inspected and non-ferromagnetic impellers shall be liquid penetrant inspected per Chapter 1, paragraph 8.2.4.

j. Machine final blade contour.

k. Ferromagnetic impellers shall be wet magnetic particle inspected and non-ferromagnetic impellers shall be liquid penetrant inspected per Chapter 1, paragraph 8.2.4.

l. Record impeller dimensions and runouts.

m. Balance impeller as per Chapter 1, Section 10.

n. Spin test the impeller in accordance with requirements of API 617.

o. Ferromagnetic impellers shall be wet magnetic particle inspected and non-ferromagnetic impellers shall be liquid penetrant inspected per Chapter 1, paragraph 8.2.4.

p. Perform final dimensional checks and investigate any critical dimensional changes.

q. Measure and record each blade's natural frequency in accordance with paragraph 1.3.8.

Notes:

1. Distortion may be minimized if the impeller is firmly attached to a thick plate prior to welding and stress relieving.

2. Due to distortion, the impeller bore may require welding per the section 3.2.3.

3.2.5 Riveted Impellers

For impellers that require the replacement of less than 6 rivets, or

5% of the total number, whichever is greater, the rivets may be replaced. For impellers requiring more than 5 rivet replacement, or 5%, the following steps shall be done:

a. Remove the damaged rivets.

b. Replace damaged rivets.

c. Check the tightness of adjacent rivets after the replacements of damaged rivets.

d. Ferromagnetic impellers shall be wet magnetic particle inspected and non-ferromagnetic impellers shall be liquid penetrant inspected per Chapter 1, paragraph 8.2.4.

e. Record impeller dimensions and runouts.

f. Balance impeller as per Chapter 1, Section 10.

g. Spin test the impeller in accordance with requirements of API 617.

h. Repeat step d above.

i. Perform final dimensional checks and investigate any critical dimensional changes.

Notes:

1. The reason why rivets require replacing should be investigated.

2. Riveted impellers that require extensive repairs should be reevaluated for replacement with welded construction.

3.2.6 Brazed Impellers

Braze repairs are not always successful. The impeller brazing repair should only be attempted using a qualified procedure and facility. A controlled atmosphere furnace, and load bearing and centering fixtures are required for the repair. The existing impeller material property requirements, including heat treatment and braze material, are to be incorporated in the procedures for the repair.

Rebrazing requires joint areas to be clean of grease, dirt, and foreign materials. Due to the high temperature necessary to braze an impeller, the impeller materials will be in the annealed condition after brazing so the complete impeller is to be quenched and tempered to the original heat treatment. Test bars of the same material chemistry of the disk and blades are to accompany the impeller through the heat treatment process for mechanical property verification. The procedure is to include the additional following steps:

a. Ferromagnetic impellers shall be wet magnetic particle inspected and non-ferromagnetic impellers or braze material shall be liquid penetrant inspected per Chapter 1, paragraph 8.2.4.

b. Disk to blade braze joints shall be ultrasonic inspected per Chapter 1, paragraph 8.2.3 to verify complete joint bonding.

c. Record impeller hardness, dimensions and runouts.

d. Balance impeller as per Chapter 1, Section 10.

e. Spin test the impeller in accordance with requirements of API 617.

f. Repeat step a.

g. Make a dimensional check and investigate any critical dimensional deviations.

3.3 PROTECTIVE COATINGS

● **3.3.1** Centrifugal Compressor impellers and / or seal areas may be coated for anti-fouling, erosion, and corrosion protection. Erosion coatings are generally applied by thermal spray process as outlined in Chapter 1 Appendix D.3. Corrosion and/or anti-fouling coatings are generally applied as outlined in Chapter 1 Appendix L. The coating type, method of application, and area to be coated shall be specified by the purchaser.

Note: These coatings are highly specialized and require special part preparation, mask tooling and handling to assure proper application and consistent quality. Improperly selected and/or applied coating can lead to rapid coating failure and the degradation of the base material properties of the coated component. A thorough engineering review of any coating application should be conducted prior to use.

3.3.2 When re-coating existing components all evidence of previous coatings shall be removed prior to recoating.

3.4 LABYRINTHS

3.4.1 “J” strips shall be repaired by straightening if possible and replaced as necessary. The replacement of “J” strips is to include the removal of the old strips and the replacement with new. The strips shall be final machined and the final dimensions shall be recorded. Caulking strip material should be in the annealed condition.

Note: For proper installation, the open end of the “J” is typically toward the higher pressure.

3.4.2 Integral seal teeth are generally remachined undersized and fitted with appropriate mating seals. Alternatively, seal teeth may be restored by repair welding per Chapter 1, Appendix D.2.

3.5 SHAFT SLEEVES, BALANCE PISTONS, AND SPACERS

While it may be technically acceptable to repair shaft sleeves, balance pistons, and spacers, the economics of repairing generally result in a new component replacement.

3.6 COMPONENT REPLACEMENT

3.6.1 Refer to Appendix C and Chapter 1, Section 9 for component replacement requirements.

● **3.6.2** When specified, fabricated impellers shall have their natural frequencies/ mode shapes measured and recorded. This check is to determine that the impeller does not operate in resonance. A Campbell diagram shall be provided (based on test data) showing the first fundamental blade natural frequency (corrected for operating speed) and harmful excitation frequencies. The exciting frequencies shall not intersect an impeller natural frequency within ±10% of the operating speed range. The correction method is to be mutually agreed.

4 Assembly and Balancing

4.1 PRE-ASSEMBLY REQUIREMENTS

4.1.1 Because major components are all coming together for the first time after repairs, the vendor shall assure that the following items are completed prior to assembly.

a. Verify that all specific requirements of the repair scope have been met.

b. Verify that correct axial positioning data is available.

c. Verify that all critical dimensions and runouts have been taken, recorded, and evaluated for final fits, locations, and clearances.

d. Verify that the requirements of Section 3 have been met on any new or repaired components.

4.1.2 All mating components should be thoroughly cleaned prior to assembly. Remove any foreign deposits, preservation materials, oil, etc. with an appropriate solvent.

4.1.3 Verify that all mating surfaces are clean and free of corrosion and burrs. Stone faces as necessary.

4.1.4 Verify that the keys have a tap fit in the shaft and a slip fit in the components, and that the top key clearances are 100 µm to 150 µm (0.004 in. to 0.006 in.).

4.1.5 The vendor shall record a complete set of phase-related bare shaft runouts prior to assembly. As a minimum, runouts shall be recorded at each location between the impellers and at one point outside of each bearing journal.

4.2 MULTISTAGE ROTOR ASSEMBLY

4.2.1 Rotors shall have the bare shafts and individual major components balanced prior to the rotor assembly per chapter 1, Section 10.2.

4.2.2 Rotor stacking and low speed assembly balance shall conform to the requirements of Chapter 1, paragraph 10.3, and the data recorded on Figures 2.D-1 through 2.D-3.

4.2.3 With shafts that have a common diameter for all impellers and sleeves, and the impellers can be installed on the shaft from either end, the components shall be assembled from the center of the rotor, outwards. When possible, the vendor shall plan the rotor assembly so that two-plane balance corrections may be applied on the major rotor components throughout the assembly (i.e., assemble two major components for each balancing step). On rotors having an odd number of major components, the single-plane balance step shall be either the first or last major component assembled.

4.2.4 All major components shall be uniformly heated for assembly on the shaft. Components shall be heated to provide an assembly clearance to the shaft of 1 µm/mm (0.001 in./in.) of shaft diameter, but in no case shall a component be more than 280 K(500°F) above the shop ambient temperature.

Notes:

1. Heating components (especially the impellers) for assembly is a critical step. In general, the differential temperature across an impeller should never exceed approximately 60 K (100°F) during the heating process, as permanent distortion may occur. This heating may be accomplished in a horizontal oven that has good temperature control. It can also be accomplished by the use of two or more large (flare tip or rosebud) torches, however, care must be exercised to avoid large heat input causing uneven heating. Care is also to be given to sections of different thicknesses to avoid excessive temperature differentials. When torches are used, the differential temperature should be carefully monitored with low sulfur temperature indicating sticks or a non-contacting infrared surface temperature gun.

2. Impeller blades on open impellers are subject to rapid heating since there is no cover plate to act as a heat sink.

4.2.5 When components are coated, the temperature limitation of the coating must be reviewed for assembly considerations.

4.2.6 All major components shall be assembled with the shaft in the vertical position.

4.2.7 Major components should not be impacted with hammers, blocks of wood, etc., at any time during the assembly process.

4.2.8 After the addition of each stack allow the rotor to cool to approximately 50°C (120°F) and record the data required by 4.2.9, 4.2.10, 4.2.11, 4.2.12, and 4.2.13.

4.2.9 The vendor shall assure that the last components added are correctly located on the shaft according to the assembly data and/or drawing. Stacked dimensions shall conform to the inspected dimensions per paragraph 1.3.7, or have engineering justification for deviation. Major component positioning shall be within ±760 µm (0.030 in.) of the assembly reference dimension (normally measured from the thrust collar or the thrust collar shoulder), and within ±380 µm (0.015 in.) of the component-to-component dimension (normally measured from the discharge side gas passage-to-gas passage).

Specific types of seals or open impellers may require a tighter tolerance for the positioning of the components.

4.2.10 The minimum axial gap between all adjacent components after assembly shall be 100 µm (0.004 in.).

4.2.11 The vendor shall record phase-related runouts on the suction eyes, suction eye faces, and the shaft on both sides of the stack.

4.2.12 Suction eye axial face runouts must be within 25 µm (0.001 in.) of the face runouts measured when the impeller was on the balance mandrel, accounting for any phase angle differences. In no case shall the suction eye face TIR runouts exceed 0.13 µm/mm (0.0015 in./ft) of diameter.

4.2.13 The vectorial change in shaft runouts during each stack, comparing the before and after shaft runouts measured with a dial indicator adjacent to the last major component(s) stacked, shall not exceed 8 µm (0.0003 in.) TIR.

4.2.14 If, after each stack, the requirements of paragraph 4.2.13 have not been met, and/or the assembly stresses exceed the requirements of Chapter 1, paragraph 10.3.5, a "heat soak" process may be performed in accordance with 4.2.14a-d.

a. The exposed areas of the shaft shall be wrapped with an insulating material to avoid exposure to direct flame during the process.

b. Continuously rotate the rotor in a balance machine at 300 to 500 rpm during the entire process.

c. The impeller(s) that were last assembled shall be rapidly heated with a large (flare tip or rosebud) torch on the discharge side only, to a temperature of approximately 180°C to 200°C (350°F to 400°F). The rapid heat shall be applied near the bore area only after heating the entire discharge backplate to allow for expansion. The impeller temperature shall be monitored with low sulfur temperature indicating sticks or a non-contacting infrared surface temperature gun.

d. The rotor shall be continuously rotated in the balancing machine until its temperature is not more than 50°C (120°F).

4.2.15 If the rotor still does not meet the requirements of 4.2.13 and/or Chapter 1, paragraph 10.3.5, but the heat soak did result in a balance improvement of at least 25%, a second heat soak procedure may be performed per 4.2.14. If, after a second heat soak procedure, the rotor still does not meet the requirements of 4.2.13 and/or Chapter 1, paragraph 10.3.5, the components that were last assembled shall be removed for inspection and correction as required.

4.2.16 After performing a heat soak process, the vendor shall verify the axial positioning of the components per 4.2.9 and axial gap per 4.2.10.

4.2.17 Balance corrections after each successive stack shall be limited to the last major components stacked.

a. The corrections shall be made on the major components by grinding on the coverplate and backplate only. Metal removal shall be limited to a maximum of 15% of the original thickness. If necessary, the correction grind shall be spread out to limit thinning of the material, and/or the rims of the cover and backplate may be scalloped between the vanes to a maximum depth of 3% of the impeller outside diameter.

b. Grinding of the suction eye face is not permitted.

c. Grinding of rivet heads on riveted impellers is not permitted.

4.2.18 The overall stack dimension (normally from the first stage discharge wall of the gas passage to the last stage discharge wall) shall be within 760 µm (0.030 in.) of the inspected dimension per 1.3.7 or have engineering justification for deviation.

4.2.19 Perform residual unbalance testing per Chapter 1, paragraph 10.4.

4.3 OVERHUNG ROTOR ASSEMBLY

4.3.1 General

Impellers on overhung rotors can be thermally or hydraulically mounted.

4.3.2 Thermally mounted impeller

All major components shall be uniformly heated for assembly on the shaft. Components shall be heated to provide an assembly clearance to the shaft of 1 µm/mm (0.001 in./in.) of shaft diameter, but in no case more than 280 K (500°F) above the ambient shop temperature.

Note: Heating components (especially the impeller) for assembly is a critical step. In general, the differential temperature across an impeller should never exceed 30 K (50°F) during the heating process, as permanent distortion may occur. This heating may be accomplished in a horizontal oven that has good temperature control. It can also be accomplished by the use of two or more large (flare tip or rosebud) torches, however, care must be exercised to avoid large heat input causing uneven heating. Care is also to be given to sections of different thicknesses to avoid excessive temperature differentials. When torches are used, the differential temperature should be carefully monitored with low sulfur temperature indicating sticks. Impeller blades on open impellers are subject to rapid heating since there is no cover plate to act as a heat sink.

4.3.3 Hydraulic Fit Impeller

For general mounting procedures refer to the hydraulic fit application in Chapter 1, Appendix C.8.1 and 8.3.

4.3.4 When components are coated, the temperature limitation of the coating must be reviewed for assembly considerations.

4.3.5 Major components shall not be impacted with hammers, blocks of wood, etc., at any time during the assembly process.

4.3.6 After the addition of each component, record the data required by 4.3.7, 4.3.8, 4.3.9, and 4.3.10. For thermally mounted components allow the rotor to cool to approximately 50°C (120°F) before recording the data.

4.3.7 The vendor shall assure that the last components added are correctly located on the shaft. Stacked dimensions shall conform to the inspected dimensions per paragraph 1.3.7, or have engineering justification for deviation Major component positioning shall be within ±760 µm (0.030 in.) of the assembly reference dimension (normally measured from the thrust collar or the thrust collar shoulder), and within ±380 µm (0.015 in.) of the component-to-component dimension (normally measured from the discharge side gas passage-to-gas passage).

Note: Specific types of seals or open impellers may require a tighter tolerance for the positioning of the components.

4.3.8 The minimum axial gap between all adjacent components after assembly shall be 100 µm (0.004 in.).

4.3.9 When rotor components are thermally installed, vendor shall record phase-related runouts on the suction eye, suction eye face, and the shaft.

4.3.10 Suction eye axial face runouts must be within 25 µm (0.001 in.) of the face runouts measured when the impeller was on the balance mandrel, accounting for any phase angle differences. In no case shall the suction eye face TIR runouts exceed 0.17 µm/mm (0.002 in./ft) of diameter.

4.3.11 Balance corrections after the impeller mounting shall be as follows:

a. The corrections shall be made on the major components by grinding on the coverplate and backplate only. Metal removal shall be limited to a maximum of 15% of the original thickness. If necessary, the correction grind shall be spread out to limit thinning of the material.

b. Grinding of the suction eye face is not permitted.

c. Grinding of rivet heads on riveted impellers is not permitted.

d. Grinding on open faced impeller blades shall be only allowed within predefined limits and in conjunction with blade frequency requirements. Grinding on a blade during balancing may change the blade's natural frequency.

4.3.12 Residual unbalance testing per Chapter 1, Section 10.4.

4.4 FINAL INSPECTION

4.4.1 Perform dimensional and NDE inspections of the assembled rotor as required in Section 1.3.

4.5 DOCUMENTATION

4.5.1 Documentation for rotor re-assembly and/or balancing shall conform to the requirements of Chapter 1, Section 12.

APPENDIX A—DIMENSIONAL FORMS FOR PHASE I INSPECTION

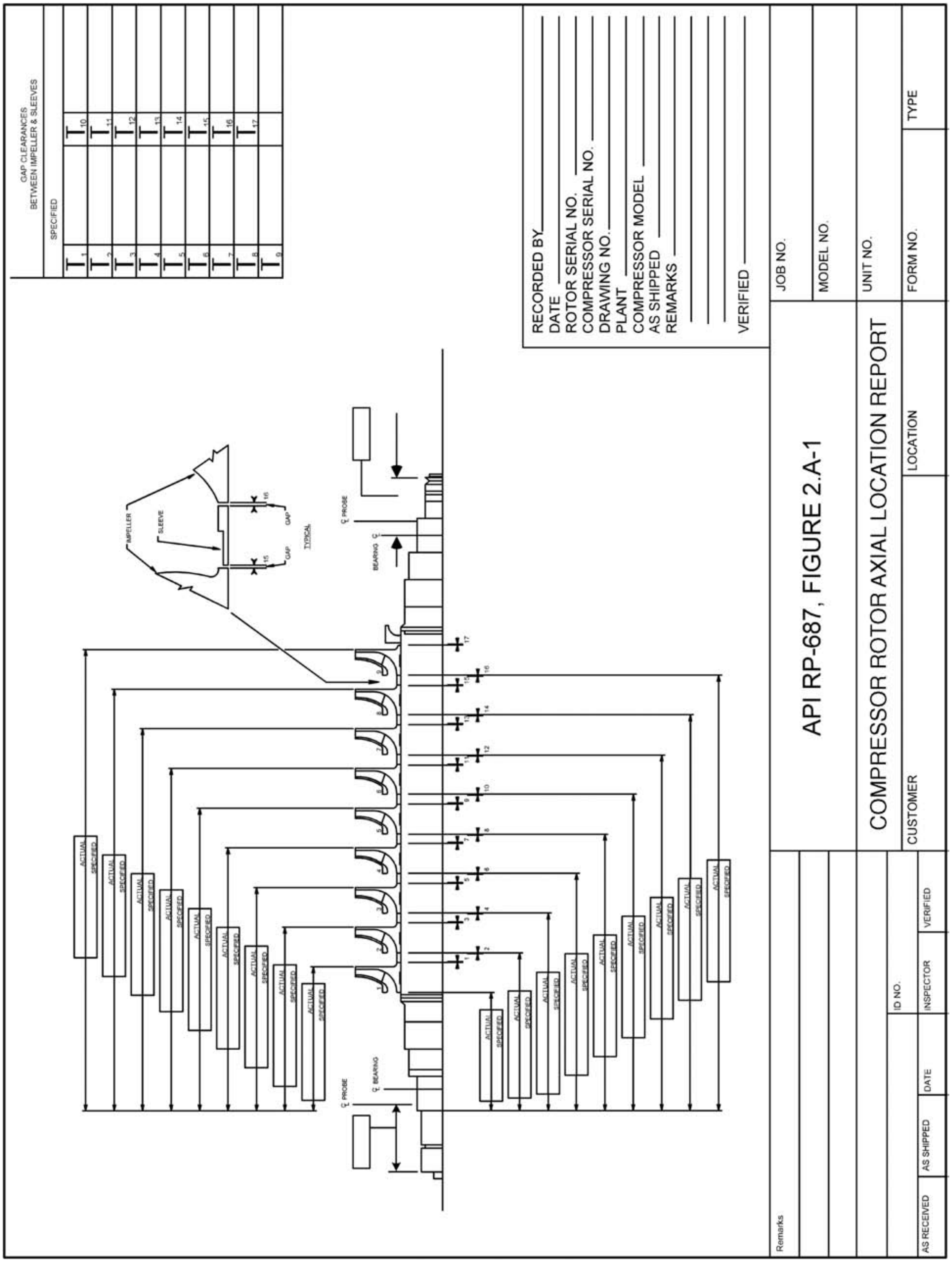


Figure 2.A-1—Compressor Rotor Axial Location Report

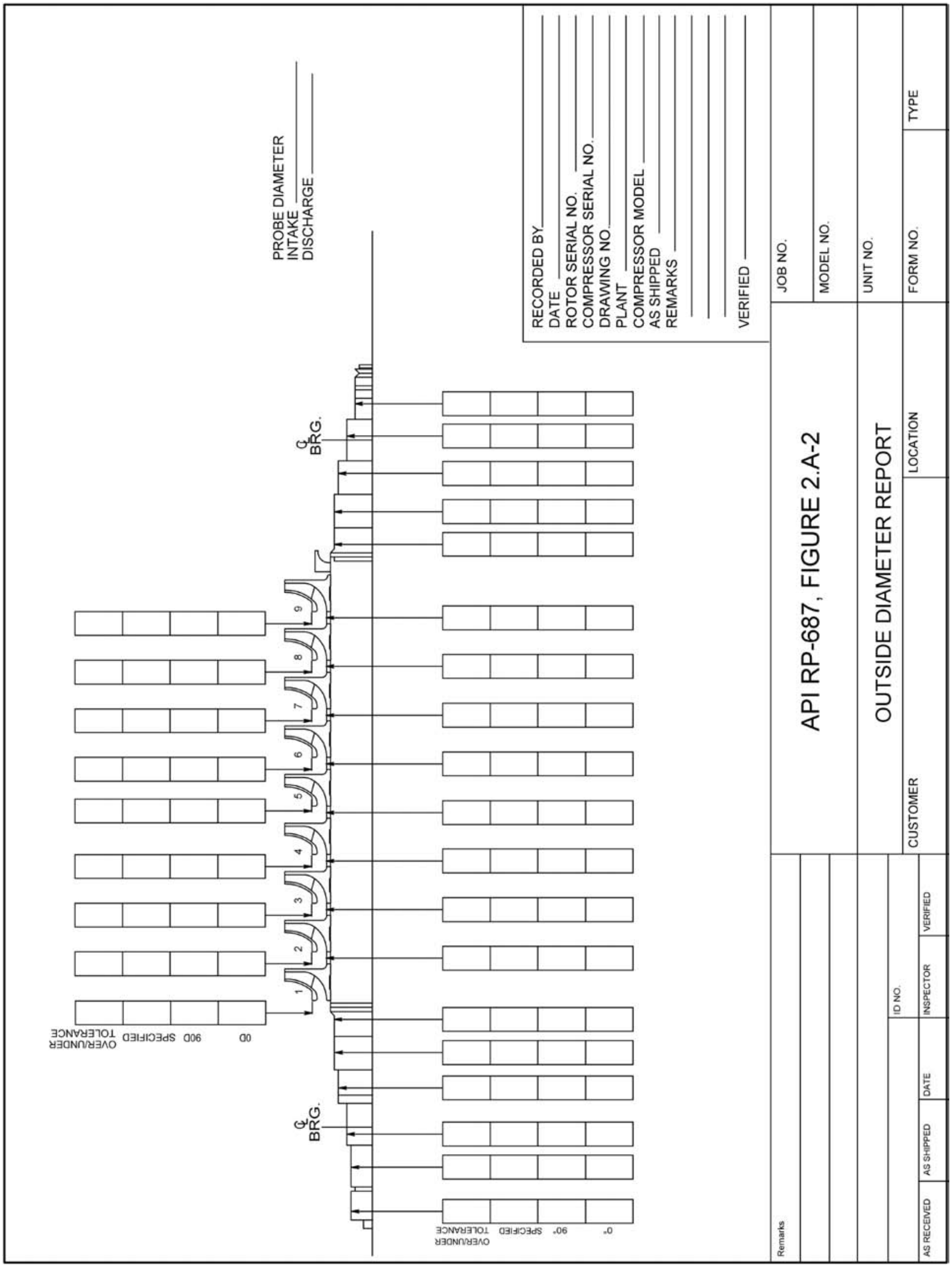


Figure 2.A-2—Outside Diameter Report

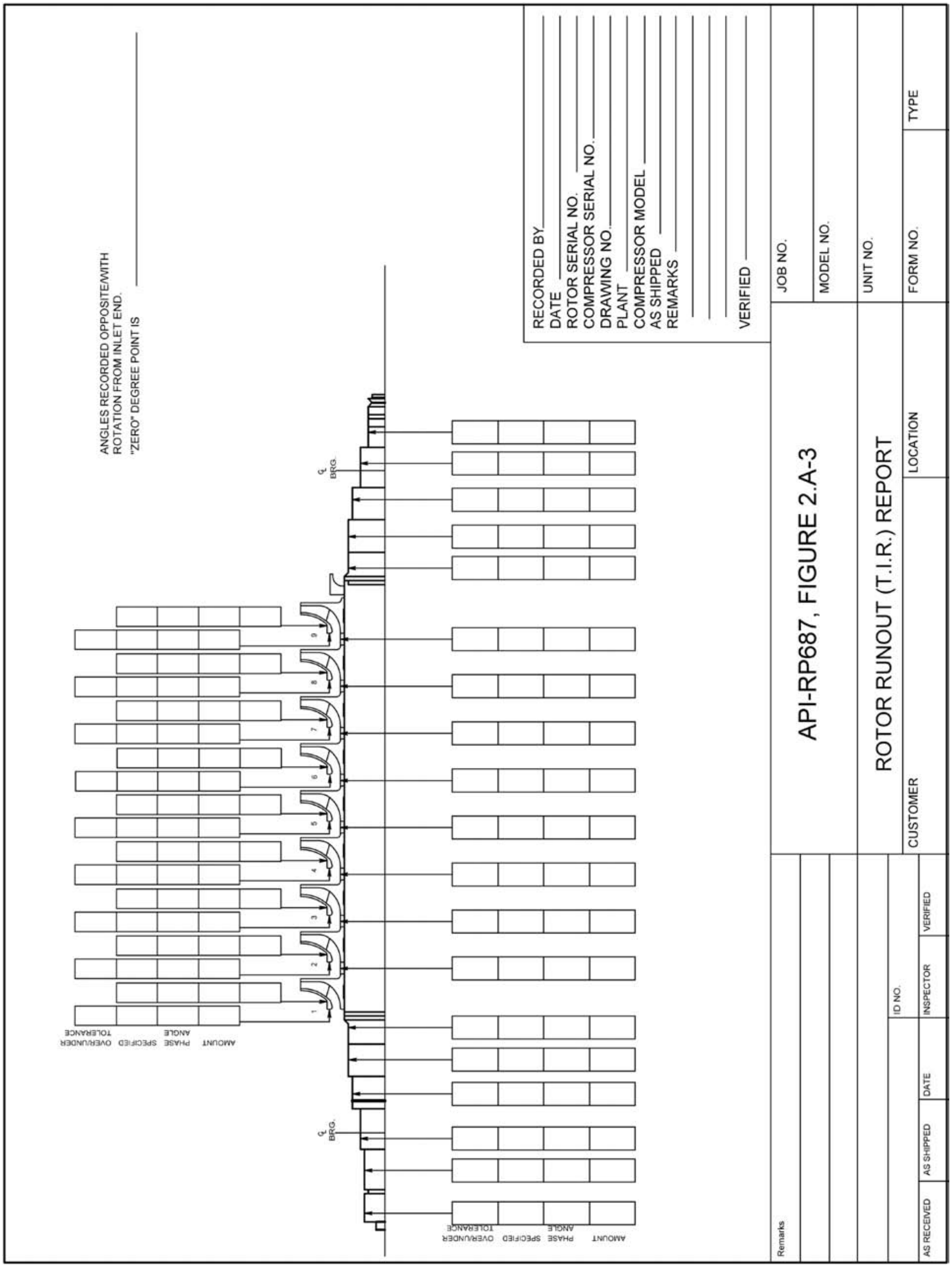


Figure 2.A-3—Rotor Runout (T.I.R.) Report

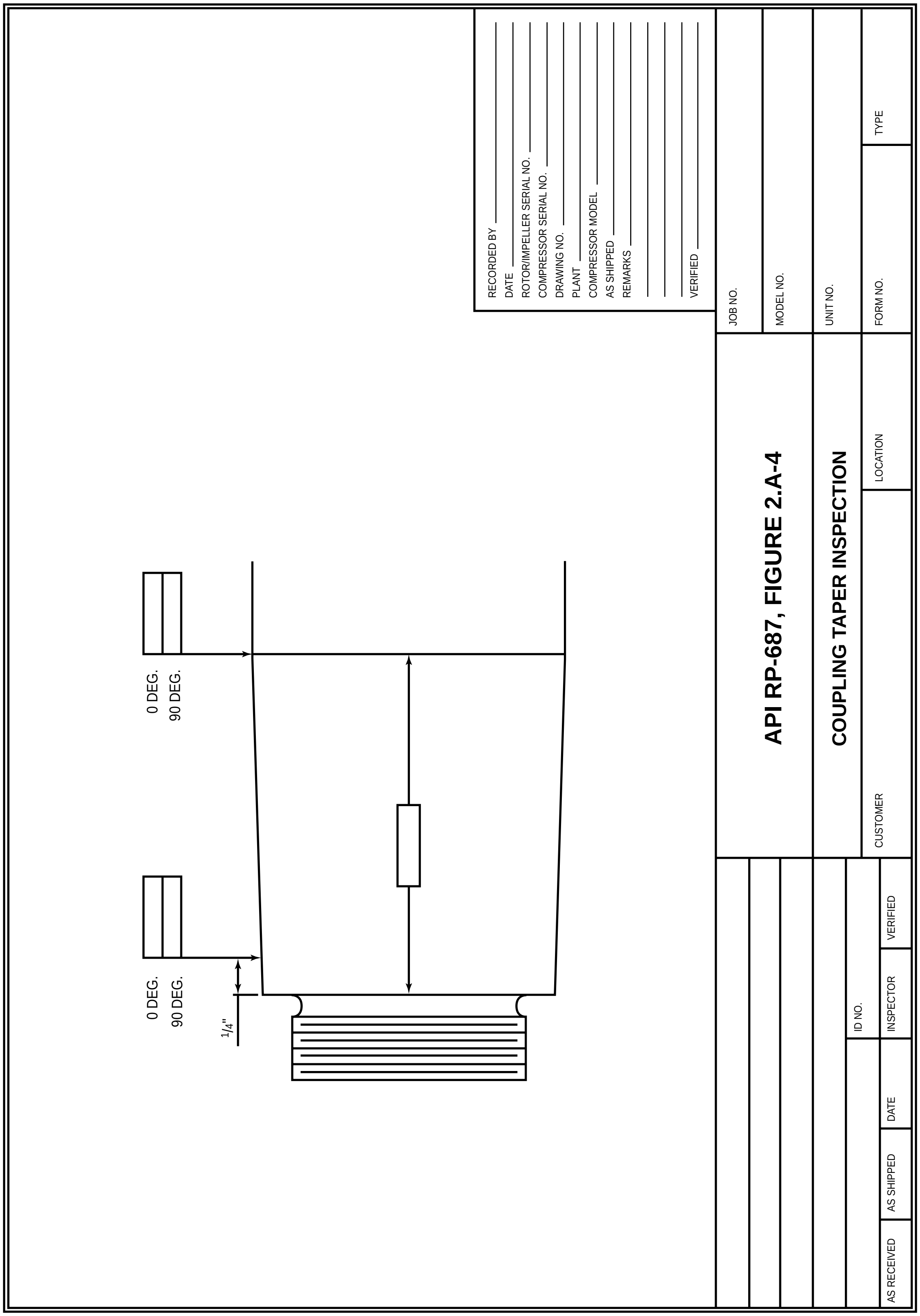


Figure 2.A-4—Coupling Taper Inspection

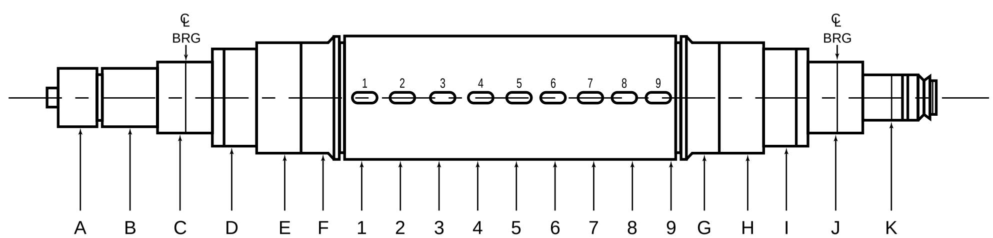
APPENDIX B—DIMENSIONAL FORMS FOR PHASE II INSPECTION

SHAFT DIAMETERS				
	SPECIFIED	0 DEG.	90 DEG.	OVER/UNDER TOLERANCE
A				
B				
C				
D				
E				
F				
G				
H				
I				
J				
K				

SHAFT RUNOUTS				
	SPECIFIED	0 DEG.	90 DEG.	OVER/UNDER TOLERANCE
A				
B				
C				
D				
E				
F				
G				
H				
I				
J				
K				

SHAFT DIAMETERS				
	SPECIFIED	0 DEG.	90 DEG.	OVER/UNDER TOLERANCE
1				
2				
3				
4				
5				
6				
7				
8				
9				

SHAFT RUNOUTS				
	SPECIFIED	0 DEG.	90 DEG.	OVER/UNDER TOLERANCE
1				
2				
3				
4				
5				
6				
7				
8				
9				



ANGLES RECORDED OPPOSITE/WITH
ROTATION FROM INLET END.
"ZERO" DEGREE POINT IS ____________________

RECORDED BY ____________
DATE ____________
ROTOR SERIAL NO. ____________
COMPRESSOR SERIAL NO. ____________
DRAWING NO. ____________
PLANT ____________
COMPRESSOR MODEL ____________
AS SHIPPED ____________
REMARKS ____________
____
____
____
VERIFIED ____________

			ID NO.	
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED

API RP-687, FIGURE 2.B-1

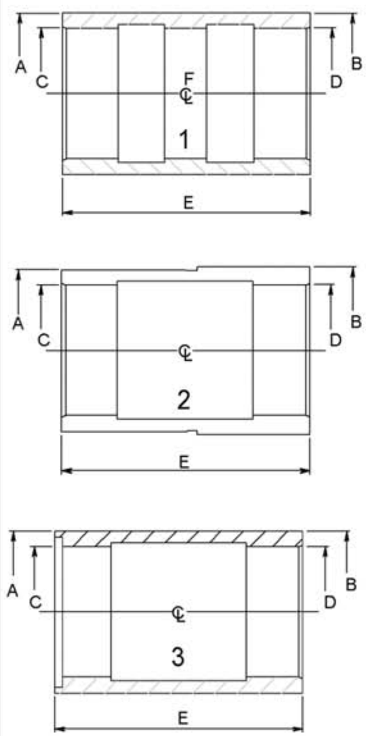
SHAFT INSPECTION

CUSTOMER	LOCATION

JOB NO.	
MODEL NO.	
UNIT NO.	
FORM NO.	TYPE

Figure 2.B-1—Shaft Inspection

IMPELLER SPACERS

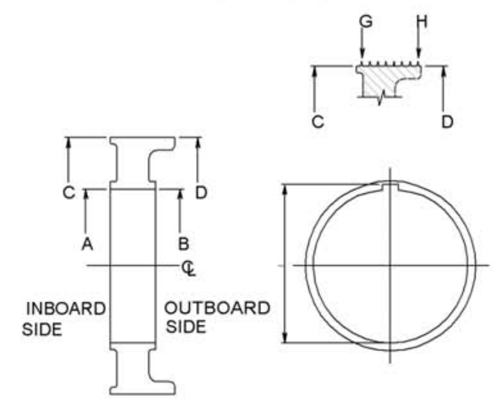


IMPELLER SPACER 1 2 3				BALANCE PISTON			
DIM.	0D	90D	SPECIFIED	DIM.	0D	90D	SPECIFIED
A				A			
B				B			
C				C			
D				D			
E				G			
F				H			
				I			

ACCEPT__________
REJECT__________

ACCEPT__________
REJECT__________

BALANCE PISTON



RECORDED BY__________
DATE __________
ROTOR SERIAL NO. __________
COMPRESSOR SERIAL NO.__________
DRAWING NO.__________
PLANT __________
COMPRESSOR MODEL __________
AS SHIPPED __________
REMARKS __________

VERIFIED __________

Remarks

ID NO.

AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED

API RP-687, FIGURE 2.B-2

IMPELLER SPACERS & BALANCE PISTON

CUSTOMER	LOCATION	JOB NO.	
		MODEL NO.	
		UNIT NO.	
		FORM NO.	TYPE

Figure 2.B-2—Impeller Spacers and Balance Piston

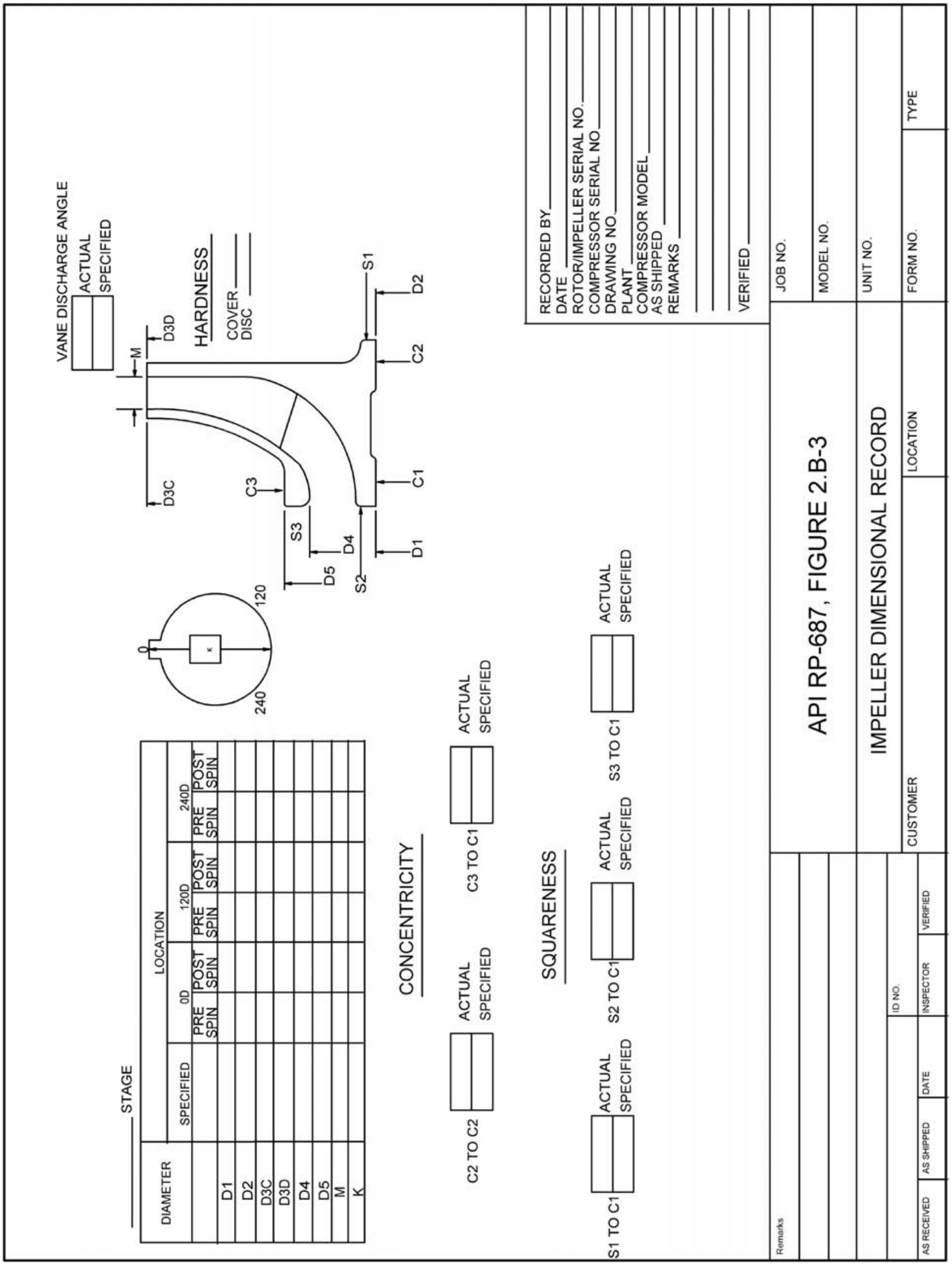


Figure 2.B-3—Impeller Dimensional Record

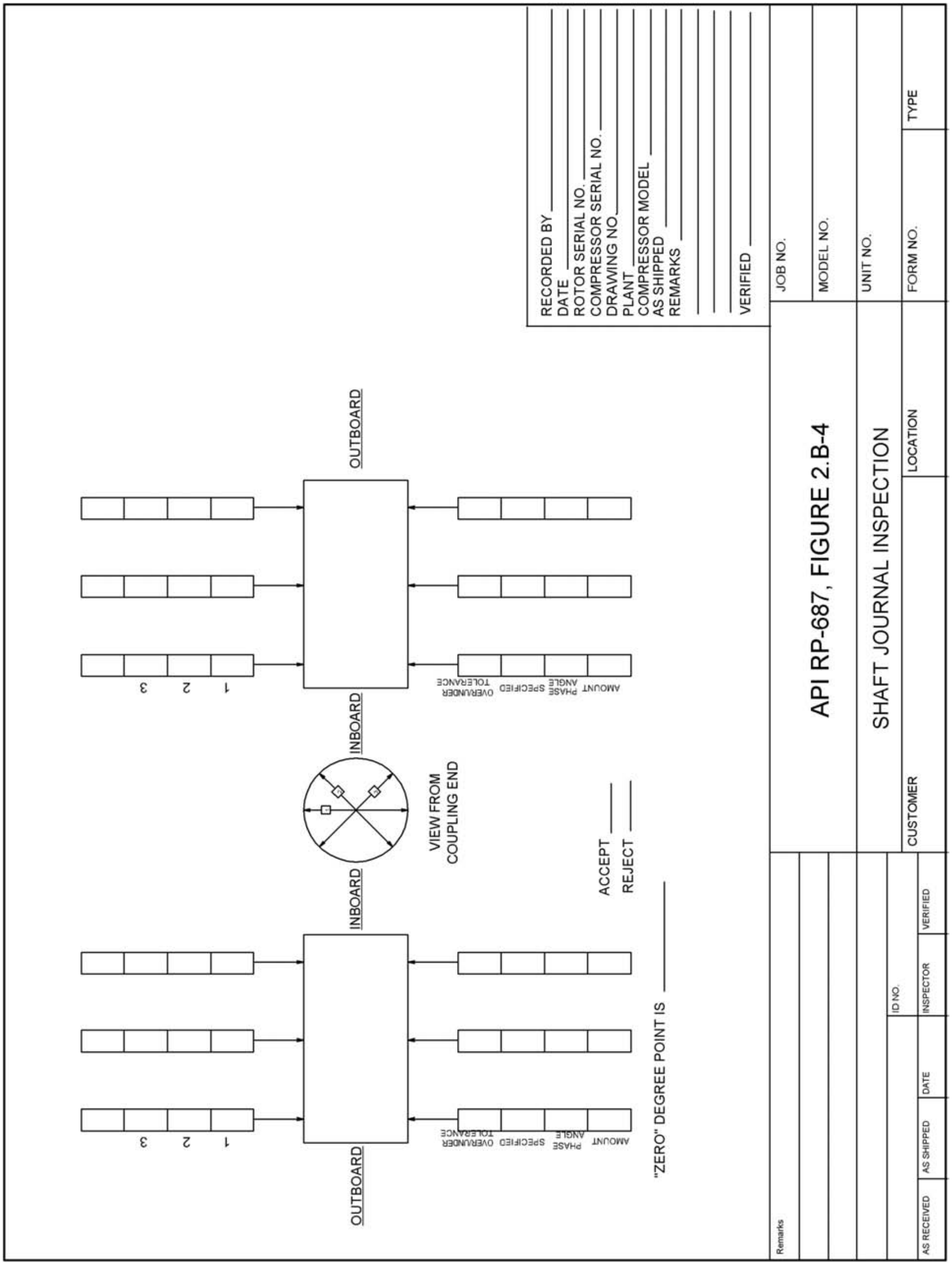
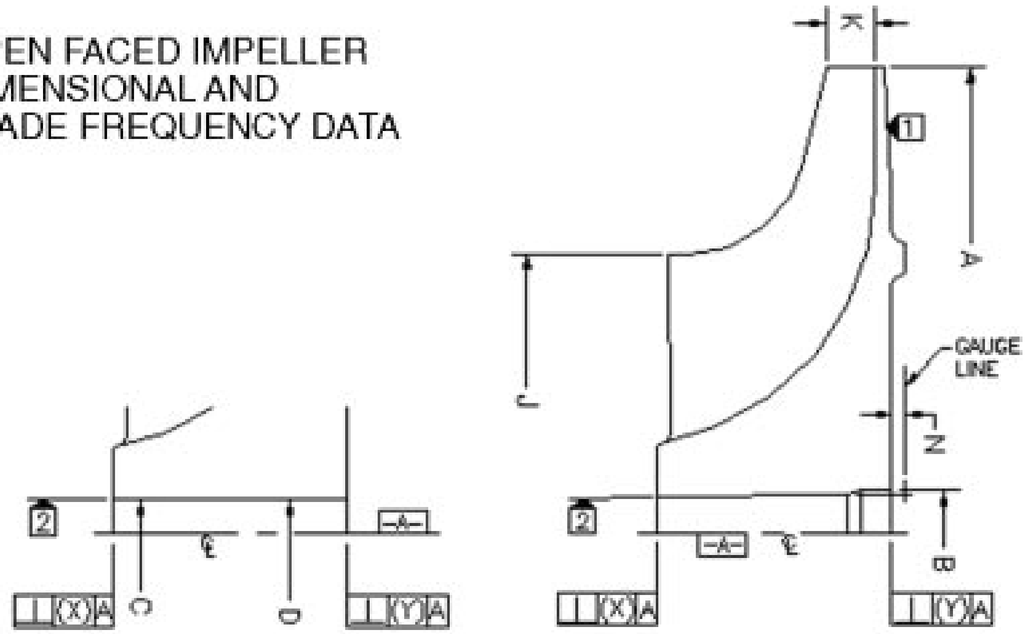


Figure 2.B-4—Shaft Journal Inspection

OPEN FACED IMPELLER DIMENSIONAL AND BLADE FREQUENCY DATA



Total Indicator Readings TYPE BORE: STRAIGHT TAPERED
Record at four (4) points 90° apart.

FINISH MACHINED — BEFORE & AFTER OVERSPEED			BLADE FREQUENCY		
Operation	Specified	Measured	Blade#	Specified	Measured
A 1–3			1		
A 2–4			2		
B 1–3			3		
B 2–4			4		
C 1–3			5		
C 2–4			6		
D 1–3			7		
D 2–4			8		
J			9		
N			10		
X			11		
Y			12		
K (AVE.)			13		
% Contact With Gauge			14		
1 Indicator Reading			15		
2 Indicator Reading			16		
			17		
			18		
			19		
			20		

	OPEN FACED IMPELLER DIMENSIONAL AND BLADE FREQUENCY DATA	
	API RP687, 2.B-5	

Figure 2.B-5—Open Faced Impeller Dimensional and Blade Frequency Data

STAGE										
SHAFT OD (1)										
IMPELLER ID(2) D1										
D2										
INTERFERENCE FIT (ACTUAL)										
INTERFERENCE FIT (SPECFIED)										
IMPELLER SPACER (3) C-1										
D										
F										
INTERFERENCE FIT (ACTUAL)										
INTERFERENCE FIT (SPECIFIED)										
KEY TO SHAFT (WIDTH) (4)										
KEY TO IMPELLER (WIDTH) (5)										
KEY TO IMPELLER (HEIGHT) (6)										
SIDES OF KEY TO ℄ OF SHAFT (7)										

(1) DIMENSIONS FROM SHAFT INSPECTION REPORT.
(2) DIMENSIONS FROM IMPELLER INSPECTION REPORT.
(3) DIMENSIONS FROM IMPELLER SPACER REPORT.
(4) TYPICALLY .000 TO .0015" TIGHT.
(5) TYPICALLY .000 TO .003 LOOSE.
(6) TYPICALLY .005 TO .013 CLEARANCE.
(7) TYPICALLY PARALLEL TO ℄ OF SHAFT .0005" PER INCH LENGTH OF KEYWAY.

Remarks					API RP-687, FIGURE 2.B-6		JOB NO.	
							MODEL NO.	
					INTERFERENCE FIT SUMMARY		UNIT NO.	
			ID NO.		CUSTOMER	LOCATION	FORM NO.	TYPE
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED				

Figure 2.B-6—Interference Fit Summary

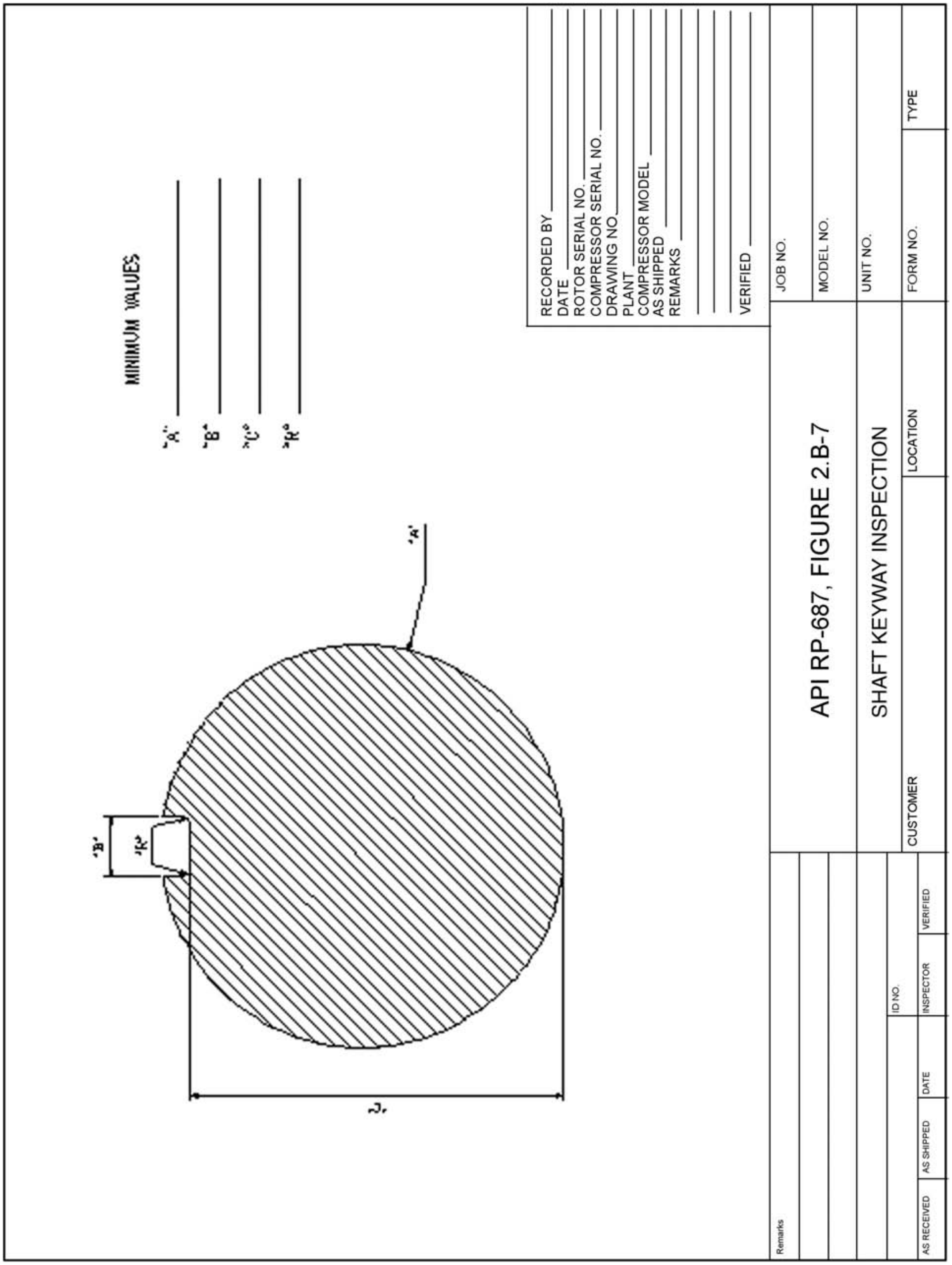
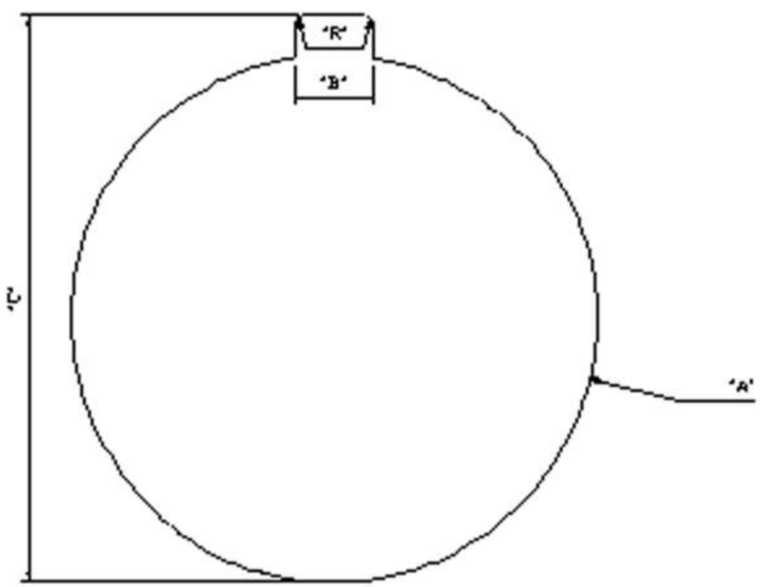


Figure 2.B-7—Shaft Keyway Inspection



MINIMUM VALUES

"A" ____________

"B" ____________

"C" ____________

"R" ____________

Note: Check for taper in the bore.

RECORDED BY ____________
DATE ____________
ROTOR SERIAL NO. ____________
COMPRESSOR SERIAL NO. ____________
DRAWING NO. ____________
PLANT ____________
COMPRESSOR MODEL ____________
AS SHIPPED ____________
REMARKS ____________

VERIFIED ____________

Remarks					API RP-687, FIGURE 2.B-8		JOB NO.	
							MODEL NO.	
					BORE KEYWAY INSPECTION		UNIT NO.	
			ID NO.					
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED	CUSTOMER	LOCATION	FORM NO.	TYPE

Figure 2.B-8—Bore Keyway Inspection

APPENDIX C—QUALITY/MANUFACTURING PLAN

QUALITY/MANUFACTURING PLAN

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	IMPELLER (NEW) (1)			**3.6**			**(2)**			
	Two or Three Piece Construction (Blades separate from cover or disc)									
	BLADING									
	FORGING OR PLATE STOCK	AISI/ ASTM Spec No	C,M,H			Compliance with AISI/ASTM Requirement	Report			
	Ultrasonic Inspection			Chap 1, 8.2.3	ASME Sect V, Article 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Blade Machining/Forming									
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Dimensional Inspection (3)					Mfg. Drawing	Certificate			
	FORGINGS (Cover and Disc) (Pancake Type Preferred)	AISI/ ASTM Spec No	C,M,H (4)			Compliance with AISI/ASTM Requirement	Certificate			
	Rough Machine					Mfg. Drawing				
	Ultrasonic Inspection			Chap 1, 8.2.3	ASME Sect V, Article 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Machining to contour									
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Dimensional Inspection					Mfg. Drawing	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	IMPELLER FABRICATION (1)									
	(Welded Impeller)									
	Weld Procedure Welders Qualification			Chap 1, D.2.1			WPS (5) WQR & PQR			
	Weld blade to cover; Dimensionally inspect (1)			Chap 1, D.2		Mfg. Drawing	Certificate			
	Stress Relieve/Heat Treat		H (4)			Mfg. Drawing	Chart			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Weld blade to disc; Dimensionally inspect (1)			Chap 1, D.2		Mfg. Drawing	Certificate			
	Stress Relieve/ Heat Treat		H (4)			Mfg. Drawing	Chart			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Final Machine					Mfg. Drawing	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection—Preoverspeed				API 617	Mfg. Drawing	Report			
	Balance			Chap 1, 10.2		Chap 1, 10.2.11	Report			
	Overspeed				API 617		Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Final Dimensional Inspection						Report			
	Coat (6)		A	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Coating process qualification (coupons) (6)		C,H	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Determine Impeller Natural Frequencies/Modes			1.3.8		1.3.8	Report			
	(Brazed Impeller)									
	Braze Procedure Braze Qualification				Vendor Procedure		Procedure			
	Braze Components Together		H (4)							
	Heat Treat		H (4)			Mfg. Drawing	Chart			
	Ultrasonic Inspection of Brazed Joint			Chap 1, 8.2.3	ASME Sect V, Article 5 and 23	Chap 1, 8.2.3.2	Certificate			
	Final Machine					Mfg. Drawing	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			
	Final Dimensional Inspection			Chap 1, D.2.9	Vendor Procedure	Mfg. Drawing	Report			
	Balance			Chap 1, 10.2		Chap 1, 10.2.11	Report			
	Overspeed				API 617		Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Final Dimensional Inspection						Report			
	Coat (6)		A	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Coating process qualification (coupons) (6)		C,H	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Determine Impeller Natural Frequencies/Modes			1.3.8		1.3.8	Report			
	INVESTMENT CAST IMPELLER									
	Investment Cast	AISI/ ASTM Spec No	C, M, H	Chap 1, 9.1		Compliance with AISI/ASTM Requirement	Report			
	X-ray Inspection			Chap 1, 8.2.2	Vendor Standard		Certificate			
	Heat Treat		H (4)			Mfg. Drawing	Chart			
	Final Machine					Mfg. Drawing	Report			
	Dimensional Inspection (3)					Mfg. Drawing	Certificate			
	Balance			Chap 1, 10.2		Chap 1, 10.2.11	Report			
	Overspeed				API 617		Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Coat (6)		A	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Coating process qualification (coupons) (6)		C,H	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Final Dimensional Inspection						Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	IMPELLER SEAL REPAIR			**3.2.2**			**(2)**			
	Weld Restoration			3.2.2.1/ Chap 1, D.2						
	Undercut for Weld Preparation			Chap 1, D.2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D.2.2.1			Certificate			
	Hardness Check			Chap 1, D.2.2.3		Report	Certificate			
	Rough Dimensional Inspection of Undercut Area			Chap 1, D.2.2.3	Vendor Procedure	Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.2.4/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Weld Repair			Chap 1, D.2.3	WPS, PQR, WQR		WPS, PQR, WQR			
	Rough Machine			Chap 1, D.2.4.1		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.4.1/ Chap 1, 8.2.3	ASME Sect V, Articles 5 and 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle Inspect			Chap 1, D.2.4.1/ Chap 1, 8.2.4.1	ASTM E709	Chap 1, 8.2.4.4	Certificate			
	Post Weld Heat Treatment		H	Chap 1, D.2.5/ Chap 1, D.2.6	Vendor Procedure		Chart			
	Final Rough Machine			Chap 1, D.2.7		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.7/ Chap 1, 8.2.3	ASME Sect V, Articles 5 and 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.7/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Hardness Check			Chap 1, D.2.7		Report	Certificate			
	Final Machine			3.2.2.1b/Chap 1, D.2.8		Chap 1, D.2.8				
	Wet Magnetic Particle Inspect (Fluorescent, continuous method)			Chap 1, D.2.9/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection			3.2.2.1c/ Chap 1, D.2.9		Mfg Drawing	Report			
	Balance			3.2.2.1e		Chap 1, 10.2.11	Report			
	Overspeed			3.2.2.1f	API 617		Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.2.2.1g/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			
	Final Dimensional Inspection			3.2.2.1h	Vendor Procedure	Mfg Drawing	Report			
	Thermal Spray Restoration			3.2.2.3/ Chap 1, D.3.0						
	Undercut for Thermal Spray Preparation			3.2.2.3a/ Chap 1, D.3.2.4		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D.3.2.2			Certificate			
	Hardness Check			Chap 1, D.3.2.2			Report			
	Rough Dimensional Inspection			Chap 1, D.3.2.4		Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.2.2.3b/ Chap 1, D.3.2.5/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Thermal Spray Build-up			3.2.2.3c/ Chap 1, D.3.2.9	Vendor Procedure	Chap 1, D.3.2.10				
	Final Rough Machine					Mfg Requirement				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.2.2.3e/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			
	Final Machine			3.2.2.3d/ Chap 1, D.3.3		Chap 1, D.3.3				
	Dimensional Inspection			3.2.2.3f/ Chap 1, D.3.4	Vendor Procedure	Mfg Drawing	Report			
	Balance			3.2.2.3g		Chap 1, 10.2.11	Report			
	Overspeed			3.2.2.3h	API 617		Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.2.2.3i/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			
	Final Dimensional Inspection			3.2.2.3j	Vendor Procedure	Mfg Drawing	Report			
	Reducing the Seal Area Restoration			3.2.2.2/ Chap 1, D.4.0						
	Machine Undersize			3.2.2.2 a and b/ Chap 1, D.4.5		Chap 1, D.4.5				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.2.2.2c/ Chap 1, D.4.6/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Dimensional Inspection			3.2.2.2d/ Chap 1, D.4.6		Mfg Drawing	Report			
	Balance			3.2.2.2e		Chap 1, 10.2.11	Report			
	Overspeed			3.2.2.2f	API 617		Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.2.2.2g/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Final Inspection			3.2.2.2h		Mfg. Drawing	Report			
	Design Clearances			3.2.2.2i						
	IMPELLER BORE REPAIR			**3.2.3**			**(2)**			
	Weld Restoration			3.2.3.1/ Chap 1, D.2						
	Record Angular Position of Keyways			3.2.3.1a						
	Undercut, Chamfer, and Radius for Weld Preparation			3.2.3.1b/ Chap 1, D.2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D.2.2.1			Certificate			
	Hardness Check			Chap 1, D.2.2.3		Report	Certificate			
	Rough Dimensional Inspection of Undercut Area			Chap 1, D.2.2.3	Vendor Procedure	Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.2.4/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Weld Repair			Chap 1, D.2.3	WPS, PQR, WQR		WPS, PQR, WQR			
	Rough Machine			Chap 1, D.2.4.1		Mfg Requirement				

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Ultrasonic Inspect			Chap 1, D.2.4.1/ Chap 1, 8.2.3	ASME Sect V, Articles 5 and 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.4.1/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Post Weld Heat Treatment		H	Chap 1, D.2.5/ 2.6	Vendor Procedure		Chart			
	Final Rough Machine			Chap 1, D.2.7		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.7/ Chap 1, 8.2.3	ASME Sect V, Articles 5 and 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.7/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			
	Hardness Check			Chap 1, D.2.7		Report	Certificate			
	Final Machine			3.2.3.1d/ Chap 1, D.2.8		Chap 1, D.2.8				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.2.3.1e/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection-Preoverspeed			3.2.3.1f/Chap 1, D.2.9		Mfg Drawing	Report			
	Balance			3.2.3.1g		Chap 1, 10.2.11	Report			
	Overspeed			3.2.3.1h	API 617		Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.2.3.1i/Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Final Dimensional Inspection			3.2.3.1j		Mfg Drawing	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Thermal Spray Restoration			3.2.3.2						
	Undercut and blank off keyway(s) for Thermal Spray Preparation			3.2.3.2a&c/ Chap 1, D.3.2.4		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D.3.2.2			Certificate			
	Hardness Check			Chap 1, D.3.2.2			Report			
	Rough Dimensional Inspection			Chap 1, D.3.2.4		Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.2.3.2b/ Chap 1, D.3.2.5/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Thermal Spray Build-up (1)			3.2.3.2c/ Chap 1, D.3.2.9	Vendor Procedure	Chap 1, D 3.2.10				
	Final Rough Machine					Mfg Requirement				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.2.3.2e/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			
	Final Machine			3.2.3.2d/ Chap 1, D.3.3		Chap 1, D 3.3				
	Dimensional Inspection			3.2.3.2f/ Chap 1, D.3.4	Vendor Procedure	Mfg Drawing	Report			
	Balance			3.2.3.2g		Chap 1, 10.2.11	Report			
	Overspeed			3.2.3.2h		API 617	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.2.3.2i/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			
	Final Dimensional Inspection			3.2.3.2j	Vendor Procedure	Mfg Drawing	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Reducing The Bore Area Restoration			3.2.3.3/ Chap 1, D.4						
	Machine Undersize			Chap 1, D.4.5						
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.4.6/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection			Chap 1, D.4.6		Mfg Drawing	Report			
	Manufacture New Shaft			3.2.3.3	Chap 1, App K					
	CLOSED STYLE IMPELLERS BLADE REPAIR			**3.2.4**			**(2)**			
	Blending			3.2.4.1						
	Weld Restoration			3.2.4.2.1a/ Chap 1, D.2						
	Welders Qualification			Chap 1, D.2.1.1			WQR			
	Machine for Weld Preparation			3.2.4.2.1b/ Chap 1, D.2.2.3						
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.2.4.2.1c/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Chemical Analysis of New Blade Material			3.2.4.2.1d		Mfg. Drawing	Certificate			
	Chemical Analysis of Base Material			3.2.4.2.1h/ Chap 1, D.2.2.1			Certificate			
	Base Material Hardness Check			3.2.4.2.1h		Mfg. Drawing	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Weld Blades			Chap 1, D.2	WPS, PQR	Mfg. Drawing	WPS, PQR (5)			
	Post Weld/ Heat Treat		H (4)	3.2.4.2.1g/ Chap 1, D.2.5/2.6		Mfg. Drawing	Chart			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Hardness Check			Chap 1, D.2.7		Report	Certificate			
	Final Machine					Mfg. Drawing				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection—Preoverspeed					Mfg. Drawing	Report			
	Balance			3.2.4.2.1k		Chap 1, 10.2.11	Report			
	Overspeed			3.2.4.2.1l	API 617		Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.2.4.2.1m/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Final Dimensional Inspection			3.2.4.2.1n			Report			
	OPEN STYLE IMPELLERS BLADE REPAIR			**3.2.4**			**(2)**			
	Blending			3.2.4.1						
	Weld Restoration			3.2.4.2.2a/ Chap 1, D.2						
	Welders Qualification			Chap 1, D.2.1.1			WQR			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Machine for Weld Preparation			3.2.4.2.2b&c/ Chap 1, D.2.2.3						
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.2.4.2.2d/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Chemical Analysis of New Blade Material			3.2.4.2.2g		Mfg. Drawing	Certificate			
	Chemical Analysis of Base Material			3.2.4.2.2e/ Chap 1, D.2.2.1			Certificate			
	Base Material Hardness Check			3.2.4.2.2e		Mfg. Drawing	Certificate			
	Weld Blades			Chap 1, D.2	WPS, PQR	Mfg. Drawing	WPS, PQR (5)			
	Post Weld/ Heat Treat		H (4)	Chap 1, D.2.5/ 2.6		Mfg. Drawing	Chart			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Hardness Check			Chap 1, D.2.7		Report	Certificate			
	Final Machine					Mfg. Drawing				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection—Preoverspeed					Mfg. Drawing	Report			
	Balance			3.2.4.2.2m		Chap 1, 10.2.11	Report			
	Overspeed			3.2.4.2.2n	API 617		Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.2.4.2.2o/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Final Dimensional Inspection			3.2.4.2.2p			Report			
	Determine Impeller Natural Frequencies/Modes (For Free Standing Blades)			3.2.4.2.2q		1.3.8	Report			
	RIVETED IMPELLER REPAIR			**3.2.5**			**(2)**			
	Remove/Replace Damaged Rivets			3.2.5a&b						
	Check Tightness of Adjacent Rivets Remove/Replace Damaged Rivets			3.2.5c						
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.2.5d/Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Dimensional Inspection			3.2.5e		Mfg Drawing	Report			
	Balance			3.2.5f		Chap 1, 10.2.11	Report			
	Overspeed			3.2.5g	API 617	Chap 1, 10.2.11	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.2.5h/Chap 1, Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Final Dimensional			3.2.5i		Mfg Drawing	Report			
	BRAZED IMPELLER REPAIR			3.2.6			(2)			
	Rebraze Impeller			3.2.6		Mfg. Procedure				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.2.6a/Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Ultrasonic Inspect			3.2.6b/Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Dimensional Inspection			3.2.6c		Mfg Drawing	Report			
	Balance			3.2.6d		Chap 1, 10.2.11	Report			
	Overspeed			3.2.6e	API 617		Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.2.6f/Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Final Dimensional Inspection			3.2.6g		Mfg Drawing	Report			
	J STRIP REPAIR			**3.4**			**(1)**			
	Straighten J Strip			3.4.1		Mfg Drawing	Report			
	Liquid Penetrant Inspect			Chap 1, 8.2.4.3	ASTM E 165	Chap 1, 8.2.4.4	Certificate			
	J STRIP NEW			**3.4**			**(2)**			
	“J” strip and caulking material		C,M	3.4.1						
	Remove old “J” strips and install new “J” strips with caulking material			3.4.1		Mfg. Drawing				
	Machine to size			3.4.1		Mfg. Drawing				
	Final Dimensional Inspection			3.4.1		Mfg. Drawing	Report			
	PRE-ASSEMBLY REQUIREMENTS			**4.1**			**(2)**			
	Axial Positioning Data			4.1.1b			2.A-1			
	Critical Dimensions and Runouts			4.1.1c			2.A-2,3,4/ 2.B-2,3,4,5,6, 7,8			
	Clean Mating Components			4.1.2						
	Clean Mating Surfaces			4.1.3						
	Key Clearances			4.1.4						
	Phase-Related Bare Shaft Runouts			4.1.5			2.B-1			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	MULTISTAGE ROTOR ASSEMBLY/LOW SPEED BALANCE			**4.2**			**(2)**			
	Interference Fit Summary			4.1.1c		Mfg Drawing	Report			
	Balance Machine Calibration			Chap 1, 10.5.1		Mfg Requirement	Report			
	Rotor Indication (stage by stage/complete)			4.2.8-4.2.13		4.2.8-4.2.13	Report			
	Rotor Balance (stage by stage/complete)			4.2.14-4.2.17/ Chap 1, 10.3		Chap 1, 10.3.9	Report			
	Residual Unbalance—Rotate U-Joint Drive			Chap 1, 10.3.10		Chap 1, 10.3.10	Report			
	Residual Unbalance/Sensitivity Check			4.2.19/ Chap 1, 10.4		Chap 1, App. A	Report			
	Residual Unbalance With Coupling			Chap 1, 10.4.3/ Chap 1, 10.4.4		Chap 1, 10.3.5	Report			
	Rotor Assembly—Final Dimensional			4.2.18 and 4.4.1		Mfg Drawing	Report			
	Rotor Assembly—Final Indication			4.4.1		Mfg Drawing	Report			
	Rotor Assembly—Gauss Level			4.4.1		Mfg Drawing	Report			
	Coat (6)		A	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Coating process qualification (coupons) (6)		C,H	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Rotor Balance (complete) after coating (6)			Chap 1, 10.3		Chap 1, 10.3.9	Report			
	Residual Unbalance—Rotate U-Joint Drive (6)			Chap 1, 10.3.10		Chap 1, 10.3.10	Report			
	Residual Unbalance/Sensitivity Check (6)			Chap 1, 10.4		Chap 1, App. A	Report			
	Residual Unbalance With Coupling (6)			Chap 1, 10.4.3/ Chap 1, 10.4.4		Chap 1, 10.3.5	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Rotor Assembly—Final Dimensional (6)			4.4.1		Mfg Drawing	Report			
	Rotor Assembly—Final Indication (6)			4.4.1		Mfg Drawing	Report			
	Rotor Assembly—Gauss Level (6)			4.4.1		Mfg Drawing	Report			
	Weight of Assembled Rotor			4.4.1		Mfg Drawing	Report			
	Prep For Shipment			Chap 1, 11						
	OVERHUNG ROTOR ASSEMBLY/ LOW SPEED BALANCE			**4.3**			**(2)**			
	Interference Fit Summary			4.1.1c		Mfg Drawing	Report			
	Balance Machine Calibration			Chap 1, 10.5.1		Mfg Requirement	Report			
	Rotor Indication (stage by stage/complete)			4.3.6-4.3.10		4.3.6-4.3.10	Report			
	Rotor Balance (stage by stage/complete)			4.3.11/ Chap 1, 10.3		Chap 1, 10.3.9	Report			
	Residual Unbalance—Rotate U-Joint Drive			Chap 1, 10.3.10		Chap 1, 10.3.10	Report			
	Residual Unbalance/Sensitivity Check			4.3.12/ Chap 1, 10.4		Chap 1, App. A	Report			
	Residual Unbalance With Coupling			Chap 1, 10.4.3/ Chap 1, 10.4.4		Chap 1, 10.3.5	Report			
	Rotor Assembly—Final Dimensional			4.4.1		Mfg Drawing	Report			
	Rotor Assembly—Final Indication			4.4.1		Mfg Drawing	Report			
	Rotor Assembly—Gauss Level			4.4.1		Mfg Drawing	Report			
	Coat (6)		A	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Coating process qualification (coupons) (6)		C,H	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Rotor Balance (complete) after coating (6)			Chap 1, 10.3		Chap 1, 10.3.9	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Residual Unbalance—Rotate U-Joint Drive (6)			Chap 1, 10.3.10		Chap 1, 10.3.10	Report			
	Residual Unbalance/Sensitivity Check (6)			Chap 1, 10.4		Chap 1, App. A	Report			
	Residual Unbalance With Coupling (6)			Chap 1, 10.4.3/ Chap 1, 10.4.4		Chap 1, 10.3.5	Report			
	Rotor Assembly—Final Dimensional(6)			4.4.1		Mfg Drawing	Report			
	Rotor Assembly—Final Indication (6)			4.4.1		Mfg Drawing	Report			
	Rotor Assembly—Gauss Level (6)			4.4.1		Mfg Drawing	Report			
	Weight of Assembled Rotor			4.4.1		Mfg Drawing	Report			
	Prep For Shipment			Chap 1, 11						

DESCRIPTION/OPERATION

NOTES:

1. Actual steps in Impeller fabrication depends on Impeller construction. Impeller shall be stress relieved and wet Magnetic Particle inspected after each complete weld, i.e., vanes to disc, disc/vanes, assembly to cover. No undercutting allowed.
2. All verifying document reports shall reference procedure state drawing acceptance criteria.
3. Dimensionally inspect each formed blade before welding to cover or disc.
4. Coupons from each cover and disc must accompany each cover and disc through all heat treating.
5. All WPS, WQR, and PQR shall be available to purchaser for review and approval prior to any welding.
6. Only applies to rotors specified to be coated.

LEGEND GENERAL	MATERIAL CERT	INSPECTION POINT
H.T. Heat Treatment PT Liquid Penetrant Inspection MT Magnetic Particle Inspection VT Visual Inspection UT Ultrasonic Inspection W/A Will Advise N/A Not Applicable	A Certificate of Compliance C Chemical Analysis M Mechanical Properties H Heat Treat Charts I Impact	O Observation W Witness / Hold Pt * Vendor To Confirm That Requirement Has Been Met

Report: Defines a vendor generated quality control inspection form/report that will satisfy industry standards or requirements outlined on purchase order.

APPENDIX D—INSPECTION FORMS FOR ASSEMBLY AND BALANCING

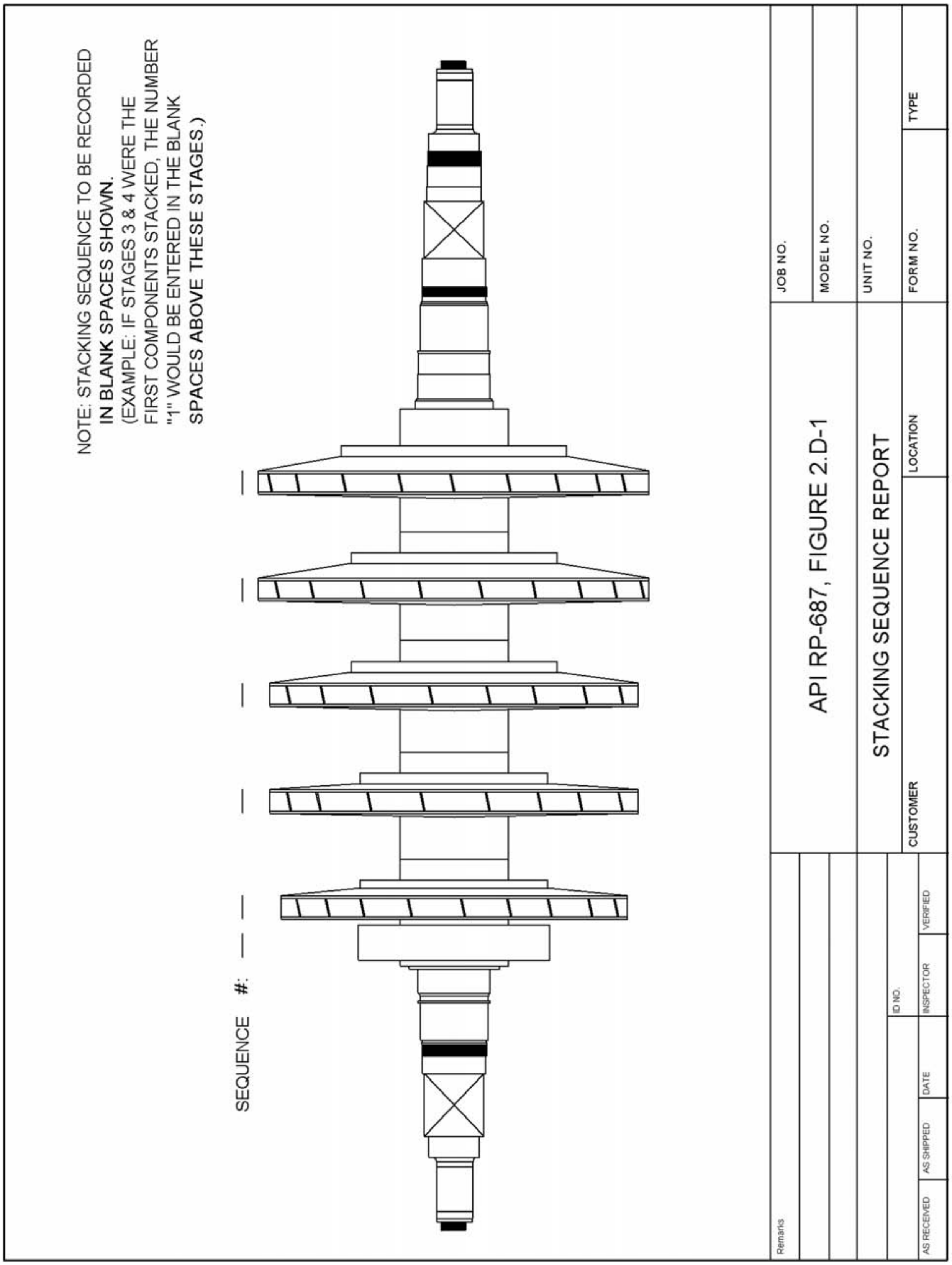


Figure 2.D-1—Stacking Sequence Report

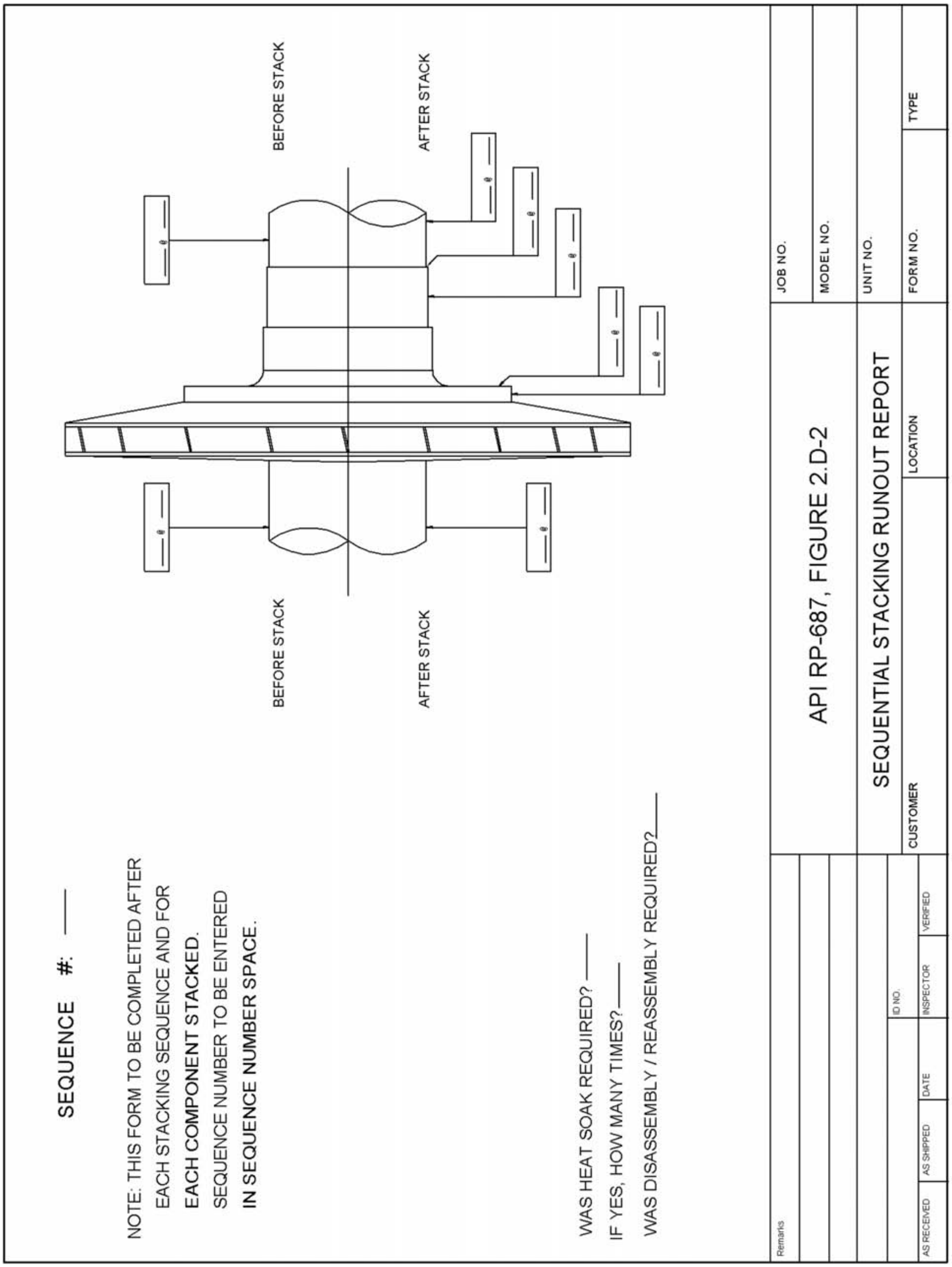


Figure 2.D-2—Sequential Stacking Runout Report

SEQUENCE NUMBER(S): ______________

NOTE: THIS FORM TO BE COMPLETED AFTER EACH STACKING SEQUENCE AND FOR EACH COMPONENT STACKED. SEQUENCE NUMBER TO BE ENTERED IN SEQUENCE NUMBER SPACE.

INITIAL BALANCE MACHINE READINGS: ☐ GRAMS ☐ OUNCES

LEFT PLANE ______________ AT ______________ DEGREES ON ______________ END.

RIGHT PLANE ______________ AT ______________ DEGREES ON ______________ END.

ROTOR AND SETUP DATA:

BEARING SPAN (MM/INCHES): ______________

BALANCE PLANE SEPARATION (MM/INCHES): ______________

LEFT PLANE RADIUS (MM/INCHES): ______________

RIGHT PLANE RADIUS (MM/INCHES): ______________

“ZERO” REFERENCE POINT IS: ______________

LEFT JOURNAL WEIGHT (Kg/Lbs): ______________

RIGHT JOURNAL WEIGHT (Kg/Lbs): ______________

MAX. CONTINUOUS OPERATING SPEED: ______________

BALANCE SPEED: ______________

FINAL BALANCE MACHINE READINGS: ☐ GRAMS ☐ OUNCES

LEFT PLANE ______________ AT ______________ DEGREES ON ______________ END.

RIGHT PLANE ______________ AT ______________ DEGREES ON ______________ END.

REMARKS				**API RP-687, FIGURE 2.D-3**		JOB NO.	
						MODEL NO.	
AS RECEIVED	DATE	ID NO.		**SEQUENTIAL STACKING BALANCE REPORT**		UNIT NO.	
AS SHIPPED	DATE	INSPECTOR	VERIFIED	CUSTOMER	LOCATION	FORM NO. 2.D-3	TYPE

Figure 2.D-3—Sequential Stacking Balance Report

APPENDIX E—AUDITORS CHECK LIST

E.1 General

This Appendix, along with Appendix H, Chapter 1, is a checklist to provide information for the owner and the vendor to aid in summarizing the scope of the rotor repair.

Repairs require clear owner/vendor communication and the assignment of responsibilities. The format of this checklist provides a summary of the items required and the parties responsible.

Each item on this checklist has a circle or a square to indicate whether the owner or vendor, respectively, is responsible for obtaining the information or performing the task. The owner must indicate, for each item, whether the item is to be witnessed, observed, or verified. Typically, inspections, processes or tests may be witnessed or observed while verification is the review of the results of the inspections, processes, tests, or other documentation so as to insure that the requirements have been met.

AUDITORS CHECK LIST

Customer: ______________________________

Job/Project Number: ______________________________

Owner Equipment Identification Number: ______________________________

OEM Equipment Serial Number: ______________________________

Rotor Identification Number: ______________________________

Repair Purchase Order Number: ______________________________

Vendor Job Number: ______________________________

Auditors Check List

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 2 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice			Date Inspected or Verified By	Status
			W	O	V		
Section 1—Inspection of Assembled Rotor Phase I							
Impeller Identification	☐	1.3.1					
Inspection Forms/Drawings	☐	1.3.3					
Diameter Measurements	☐	1.3.4					
Gap Measurements	☐	1.3.5					
Axial Runouts	☐	1.3.6					
Axial Stack-up	☐	1.3.7					
Natural Frequency	☐	1.3.8					
Rivet Inspection	☐	1.3.9					
NDE	☐	1.3.10					
Hardness Inspection	☐	1.3.11					
Inspection Report	☐	1.4					
Section 2—Rotor Disassembly Phase II							
Rotor Disassembly	☐	2.2.1					
Matchmark Components	☐	2.2.3					
Interference Fits	☐	2.2.4					
Heat Components	☐	2.2.5					
Rotor Unstacking	☐	2.2.6					
Mating Fits	☐	2.2.7					
Axial Dimensions	☐	2.2.8					
Clean Rotor	☐	2.3.1					
Interference Fits	☐	2.3.2.1					
Mating Fits	☐	2.3.2.2					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 2 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
Part Inspection	☐	2.3.2.3					
Shaft Dimensions	☐	2.3.2.3a					
Bore Dimensions	☐	2.3.2.3b					
Impeller Diameters	☐	2.3.2.3c					
Stacking Dimensions	☐	2.3.2.3d					
Spacers, Seals	☐	2.3.2.3e					
Balance Piston	☐	2.3.2.3f					
Thrust Collar	☐	2.3.2.3g					
Key Clearances	☐	2.3.2.3h					
Eliminate Weight(s)	☐	2.3.2.4					
NDE	☐	2.3.2.5/ 2.3.2.6					
Photographs	☐	2.3.2.7					
Threaded Areas	☐	2.3.2.8					
Review	☐	2.4.1					
Component Bore	☐	2.4.2					
Job Scope	☐	2.5.1					
SECTION 3 – Repair Process and New Component Manufacture							
Engineering Review	☐	3.1.2					
Machining	☐	3.1.3					
Impeller Seal Area Weld Repair	☐	3.2.2.1					
Impeller Seal Area Undersize Repair	☐	3.2.2.2					
Impeller Seal Area Thermal Spray Repair	☐	3.2.2.3					
Impeller Bore Weld Repair	☐	3.2.3.1					
Impeller Bore Thermal Spray Repair	☐	3.2.3.2					
Impeller Bore Oversize Repair	☐	3.2.3.3					
Impeller Blade Grind Repair	☐	3.2.4.1					
Impeller Blade Weld Repair	☐	3.2.4.2					
Riveted Impellers	☐	3.2.5					
Brazed Impellers	☐	3.2.6					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 2 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
Coating	O	3.3.1					
Recoating	☐	3.3.2					
J Strips	☐	3.4.1					
Seal Teeth	☐	3.4.2					
Spacers, Pistons, Spacers	☐	3.5					
Component Replacement							
Component Replacement Requirements	☐	3.6.1					
New Impeller Manufacture	☐	3.6.2					
Section 4—Assembly and Balancing							
Dimensional Verification	☐	4.1.1					
Mating Components	☐	4.1.2					
Mating Surfaces	☐	4.1.3					
Keyway Verification	☐	4.1.4					
Phase Related Runouts	☐	4.1.5					
Multistage Rotor							
Component Balance	☐	4.2.1					
Assembly Balance	☐	4.2.2					
Assembly Sequence	☐	4.2.3					
Heat Components	☐	4.2.4					
Coating Restrictions	☐	4.2.5					
Shaft Positioning	☐	4.2.6					
Rotor Cooldown	☐	4.2.8					
Position Verification	☐	4.2.9					
Axial Gaps	☐	4.2.10					
Phase Related Runouts	☐	4.2.11					
Suction Eye Runouts	☐	4.2.12					
Shaft Runout Changes	☐	4.2.13					
Balance	☐	4.2.14/ 4.2.15					
Axial Dimensions	☐	4.2.16					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 2 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
Balance Corrections	☐	4.2.17					
Overall Stack	☐	4.2.18					
Residual Unbalance	☐	4.2.19					
Overhung Rotor							
Thermally Mounted Impellers	☐	4.3.2					
Hydraulic Fit Impeller	☐	4.3.3					
Coating Restrictions	☐	4.3.4					
Rotor Cooldown	☐	4.3.6					
Position Verification	☐	4.3.7					
Axial Gap	☐	4.3.8					
Phase Related Runouts	☐	4.3.9					
Suction Eye Runouts	☐	4.3.10					
Balance Corrections	☐	4.3.11					
Residual Unbalance	☐	4.3.12					
Final Inspection	☐	4.4					
Documentation	☐	4.5					

CHAPTER 3—SPECIAL PURPOSE AXIAL COMPRESSORS

CONTENTS CHAPTER 3

Page

Figures

Rotor Repair

Chapter 3—Special Purpose Axial Compressors

1 Inspection of Assembled Rotor Phase I

1.1 GENERAL

This section describes the data to be recorded and the requirements for a Phase I inspection of an assembled axial compressor rotor. This section is to be used in addition to the requirements of Chapter 1, Section 7, Phase I inspection.

In addition to the information supplied by Chapter 1, paragraph 2.3, the owner should identify the type of rotor construction. This construction method is critical to determine the inspection and repair methods.

Tutorial Discussion: Axial compressor rotor assemblies may be classified by two fundamental characteristics: method of rotor construction and method of blade attachment. All rotors except disk-on-shaft and solid (one-piece) rotor construction include end (stub) shafts, which include bearing journals, probe surfaces, sealing features, and coupling hub attachment provisions.

The construction of the main rotor body that restrains the blading differs. The typical methods of rotor construction are shrink fit disk-on-shaft (similar to most centrifugal compressors), stacked disk with through tie bolts, drum rotors with studs or tie bolts, and solid rotors. Refer to Figures 3.1-1 through 3.1-5 for typical rotor configurations.

An axial dovetail, tangential fir tree, tangential T-slot, or radial entry with conical seat may be used to accomplish blade attachment to the rotor. Refer to Figures 3.1-1 through 3.1-5. Tangential designs typically include spacer pieces between blades to achieve the required pitch. All blade attachments include a blade location locking provision.

Other key features of an attachment design are blade attachment rigidity, whether blades may be removed individually or as a stage, and whether or not the rotor body must be disassembled to remove blades.

Note: Information developed from inspections of rotors that have not been cleaned has been invaluable in evaluating the overall condition of a compressor. Therefore, it is recommended to not perform on-line cleaning or post removal cleaning prior to inspection. If blade deposit analysis is to be performed by the vendor, rotor preservation should be limited to critical areas such as thrust collars, journals, probe areas, and shaft ends.

1.2 DEFINITIONS

1.2.1 airfoil: The part of the blade that converts mechanical energy to velocity and pressure.

1.2.2 axial entry blade: A blade which is assembled to the disk using axially machined grooves for each blade.

1.2.3 blade: A component which is attached to the disk or drum and includes the blade root, platform, and airfoil.

1.2.4 blade moment weight: A value that represents the combination of the blade weight and its center of gravity.

1.2.5 blade pan weight: The static weight of the blade.

1.2.6 chord length: The blade width or the distance from the leading edge to the trailing edge at a given radial height.

1.2.7 disk: A component which has blades attached at the outside diameter. May be separate from or integral with the shaft. Disks are used on disk-on-shaft or tie-bolt rotor designs.

1.2.8 disk-on-shaft rotor: An assembly which includes the compressor shaft and separate disks which are interference fitted to the shaft.

1.2.9 drum rotor: Consists of a hollow center section(s) to which the blades are attached and two stub shafts. Assembly of the rotor sections may be accomplished by using through tie bolts or localized studs.

1.2.10 major components: Major components are the shaft, drums, disks, stub shafts, sleeves, thrust collar, balance piston, tie bolts, nuts, and shaft keys.

1.2.11 platform: A blade feature located between the airfoil and the blade root or attachment.

1.2.12 radial entry blade: A blade which is assembled to the disk using a circumferentially machined groove for the blades.

1.2.13 solid rotor: A one piece rotor construction where blades are fitted into the integral forging.

1.2.14 tie-bolt rotor: A rotor assembly consisting of two stub shafts and multiple drums or disks held together by axial tie bolt(s).

1.3 INSPECTION

● **1.3.1** The blades are not to be removed from the rotor unless specifically instructed by the owner. However, blade removal and inspection of the disk attachment is recommended if blade removal is easily accomplished based on the design of the blade attachment. If the blades are removed, uniquely identify all blades to their corresponding stage and circumferential location for material tracking purposes. Deblading of the rotor should be done in the horizontal position. If blades are removed, refer to paragraph 2.2.9

Note: Certain rotor designs require disassembly to remove the blades. Where possible, blades should be removed during the Phase I inspection on rotor designs which do not require disassembly. The blade attachment area should be inspected on both the blades and disk, particularly if there is a history of corrosion or fretting. Removal of the blades from the rotor will facilitate removal of any protective coating and NDE of base metal.

1.3.2 In addition to the requirements specified in Chapter 1, Section 7, the following precautions and inspections in 1.3.3 through 1.3.11 shall be made.

1.3.3 Rotor is to be cleaned as described in Chapter 1, paragraph 7.2.2. Critical areas are to be protected and masked to prevent the cleaning media from entering the areas during cleaning. In addition to the critical areas identified in Chapter 1, paragraph 7.2.2 are the blading and disk to disk. Care must be taken to prevent damaging features such as thin rotor blade trailing edges, tips, and knife edge seals.

1.3.4 Appendix A inspection forms and drawings or equal shall be used in recording the necessary information. These inspection forms and drawings may be modified by the vendor to represent the actual configuration of the rotor.

1.3.5 The following dimensions are to be recorded if the rotor is to be unstacked or fitted with new blades or disks. This should be performed before deblading and after reblading to ensure the rotor will fit into the casing during assembly.

a. Identify and record the radius of the low and high blade from each stage to verify the blade to casing tip clearances.

b. Measure and record two axial and corresponding radial dimensions on one blade tip of each row of blades, referenced from the thrust collar shaft shoulder (or active side of the integral thrust collar).

c. Measure and record axial stack-up dimensions, in a minimum of two circumferential locations referenced from the thrust collar shaft shoulder (or active side of the integral thrust collar), to the face of each disk (nearest the thrust collar) and to all other components that may be removed from the shaft. Each dimension is to be referenced and recorded from the same thrust location. One of the axial stack-up dimensions should be taken at the zero phase reference point and the second should be 90° apart.

NOTE: The degree of accuracy is to be within:

a. ±25 μm (0.001 in.) on the radial dimensions

b. ±250 μm (0.010 in.) on the axial dimension for location of blade tip profiles.

c. ±250 μm (0.010 in.) on the axial dimension for location of the disks.

1.3.6 Measure axial gaps between all shrunk on parts. Generally the gap should be a minimum of approximately 0.10 mm (0.004 in.).

1.3.7 NDE the accessible areas of each blade, disk, and shaft per Chapter 1, paragraph 8.2.4.

1.3.8 The NDE evaluation described in Chapter 1, Table 1.8-1 shall be a severity level of “A” for all components, excluding sleeves which shall be severity level “C.”

Note: MT is not always conclusive for assembled equipment due to the difficulty in generating a magnetic flux in noncontinuous surfaces.

1.3.9 Inspect for circumferential slippage between tie-bolt rotor components by measuring the circumferential offset of a tie bolt. The maximum amount of offset, as indicated by opposite ends of the tie bolt, should be less than 1.7 mm (0.065 in.).

1.3.10 For disk-on-shaft and tie-bolt rotors, check and record axial dimensions in a minimum of two circumferential locations, between the thrust collar shaft shoulder (or active side of the integral thrust collar) to the face of the disks. Record data on an inspection form designed for the particular rotor as outlined in Appendix “A”. One of the axial stack-up dimensions should be taken at the zero phase reference point and the second should be 90° apart.

1.3.11 For tie bolt designs, determine each tie bolt stretch, without removing the tie bolts.

Each tie bolt shall be within ±25% of its initial stretch. In addition, the variation in stretch between each tie bolt shall not be more than ±15%. If a tie bolt stretch does not meet these requirements, disassemble in accordance with paragraph 2.2.6 and perform a Phase II inspection per 2.3.

Note: In order to determine a change in bolt stretch, previous assembly records are to be reviewed.

1.4 INSPECTION REPORT

1.4.1 The vendor shall prepare a Phase I inspection documentation package (report) consisting of all of the information identified in Chapter 1, Section 7, and Section 1.3, as applicable.

1.4.2 The vendor shall not disassemble the rotor without the approval of the owner. The vendor may minimize the phase I inspection if it is obvious that the rotor needs to be disassembled and a more detailed phase II inspection performed. Some reasons for disassembly include:

a. Shaft damage such as fretting, cracking, journal bearing/shaft end damage.

b. Thermally unstable rotor.

c. Drum / disk / blade damage requiring removal.

d. Severe corrosion / erosion.

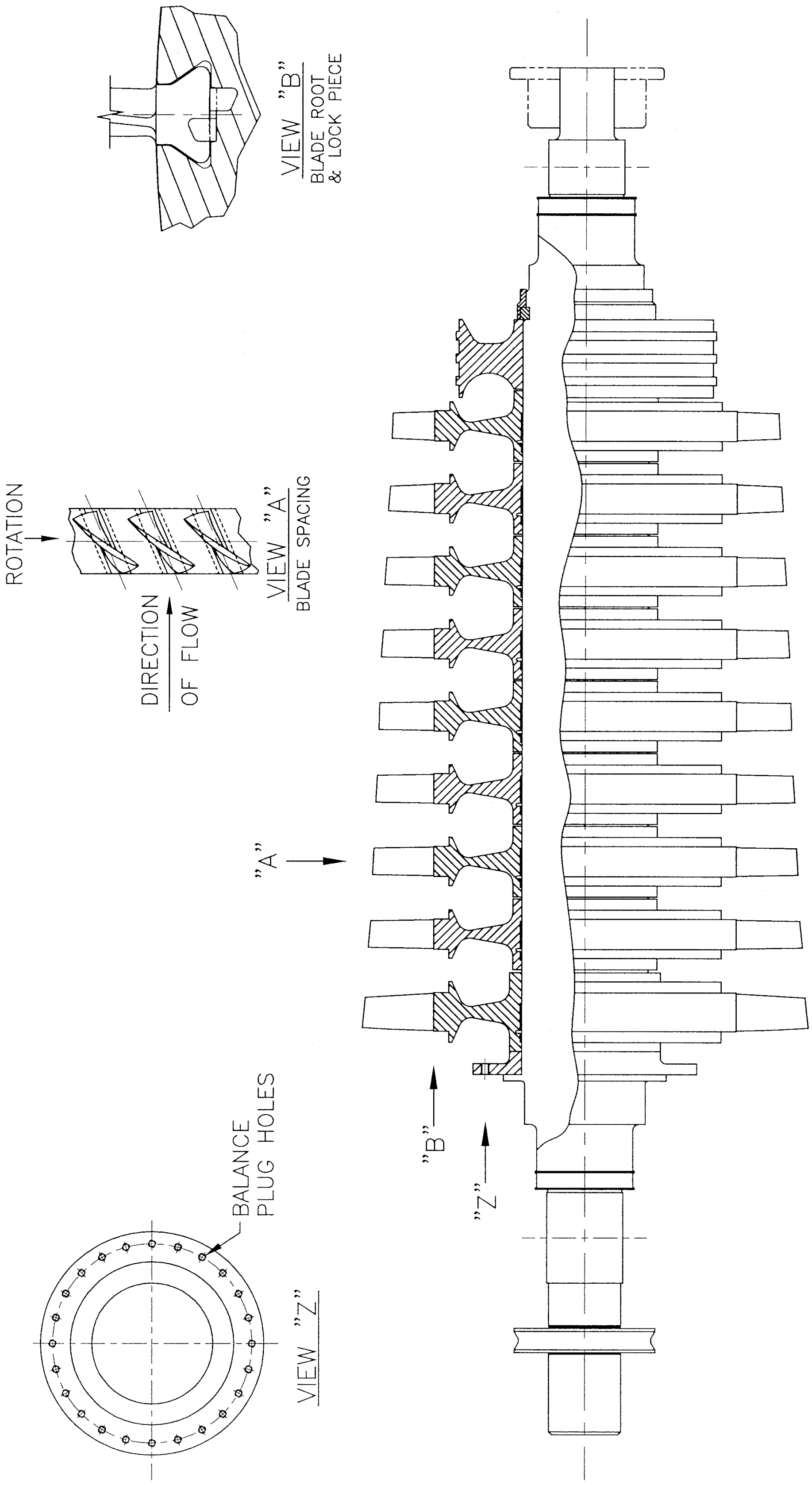


Figure 3.1-1—Disk on Shaft Construction

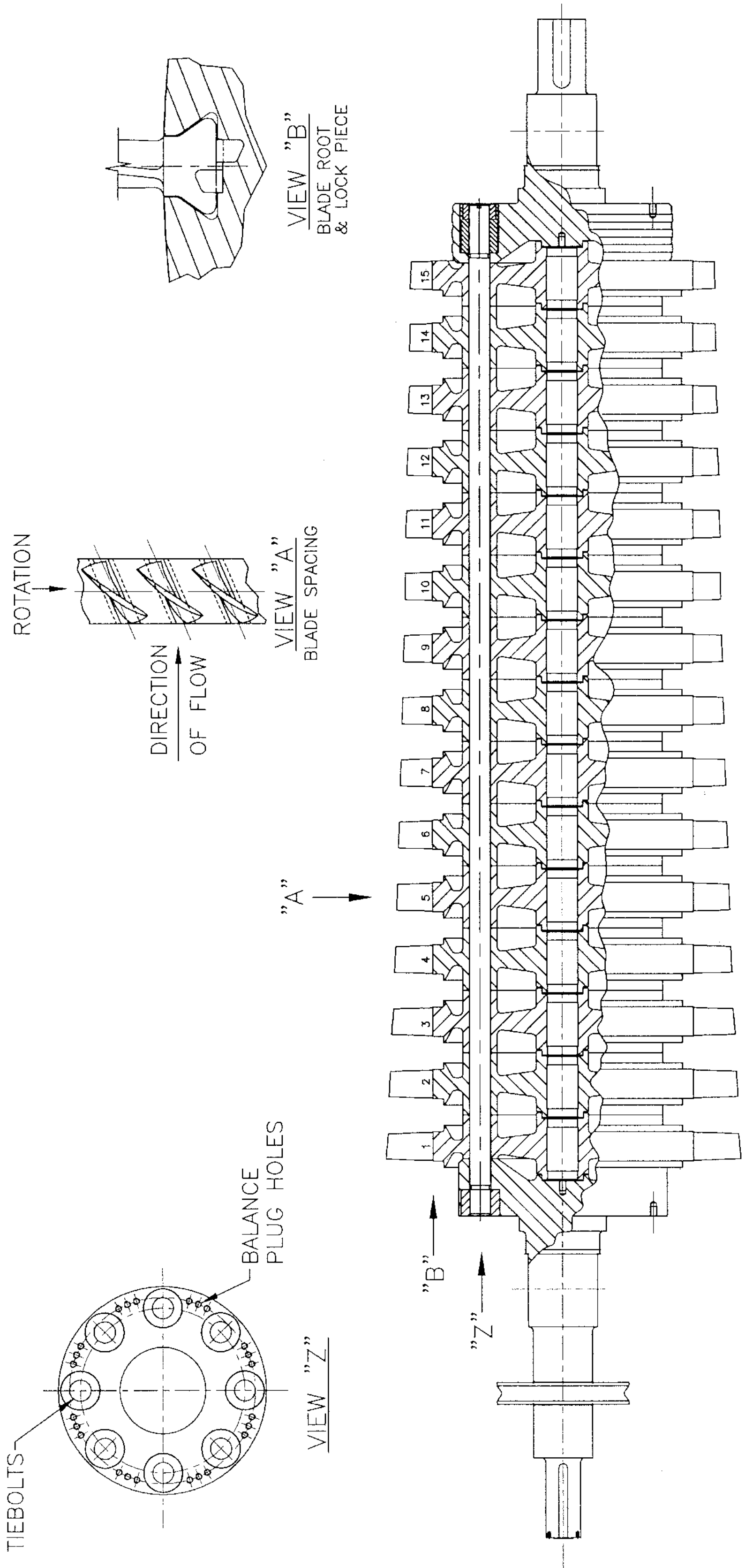


Figure 3.1-2—Tie Bolt Rotor Construction

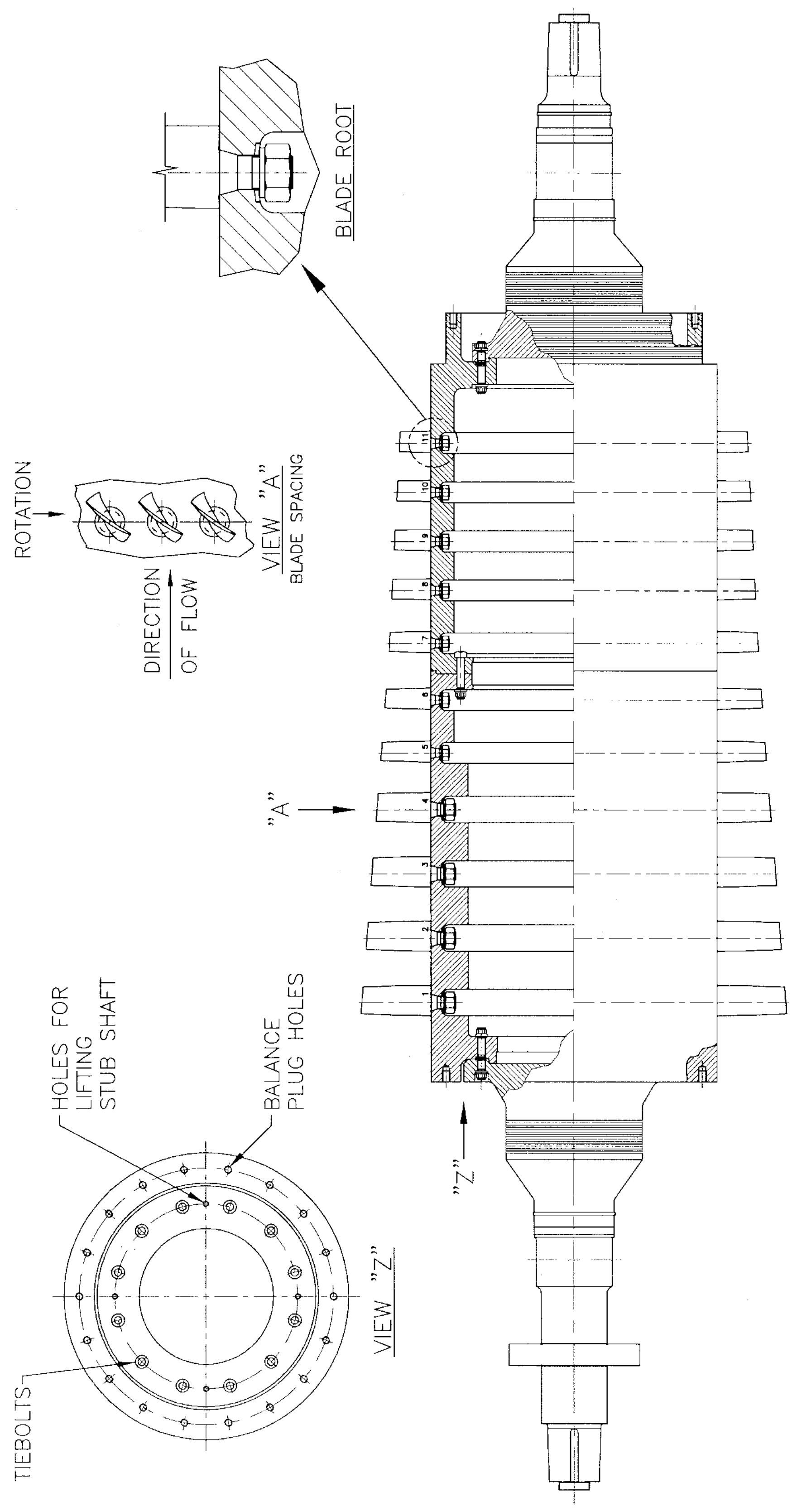


Figure 3.1-3—Drum Construction

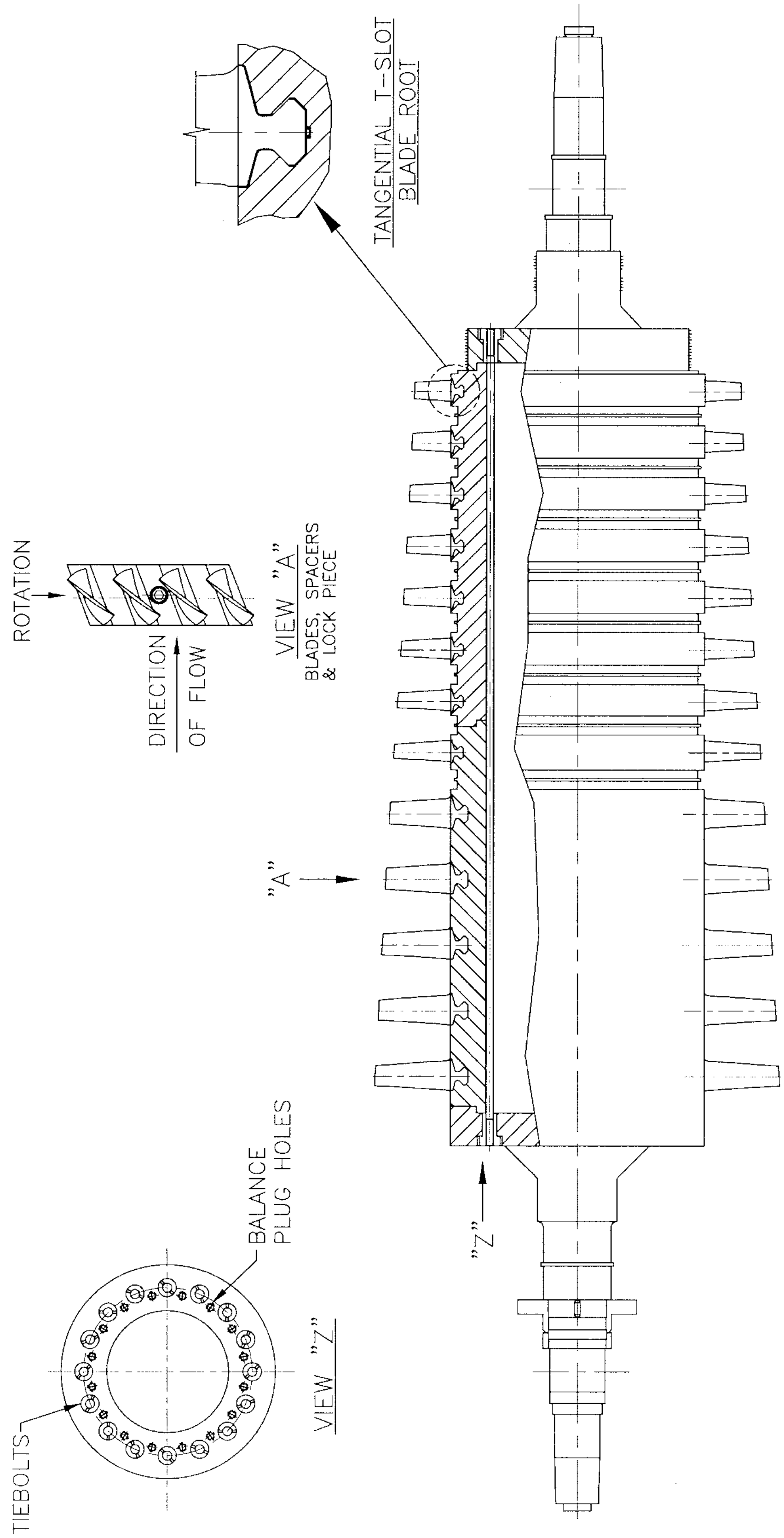


Figure 3.1-4—Drum/Tie-Bolt Rotor Construction

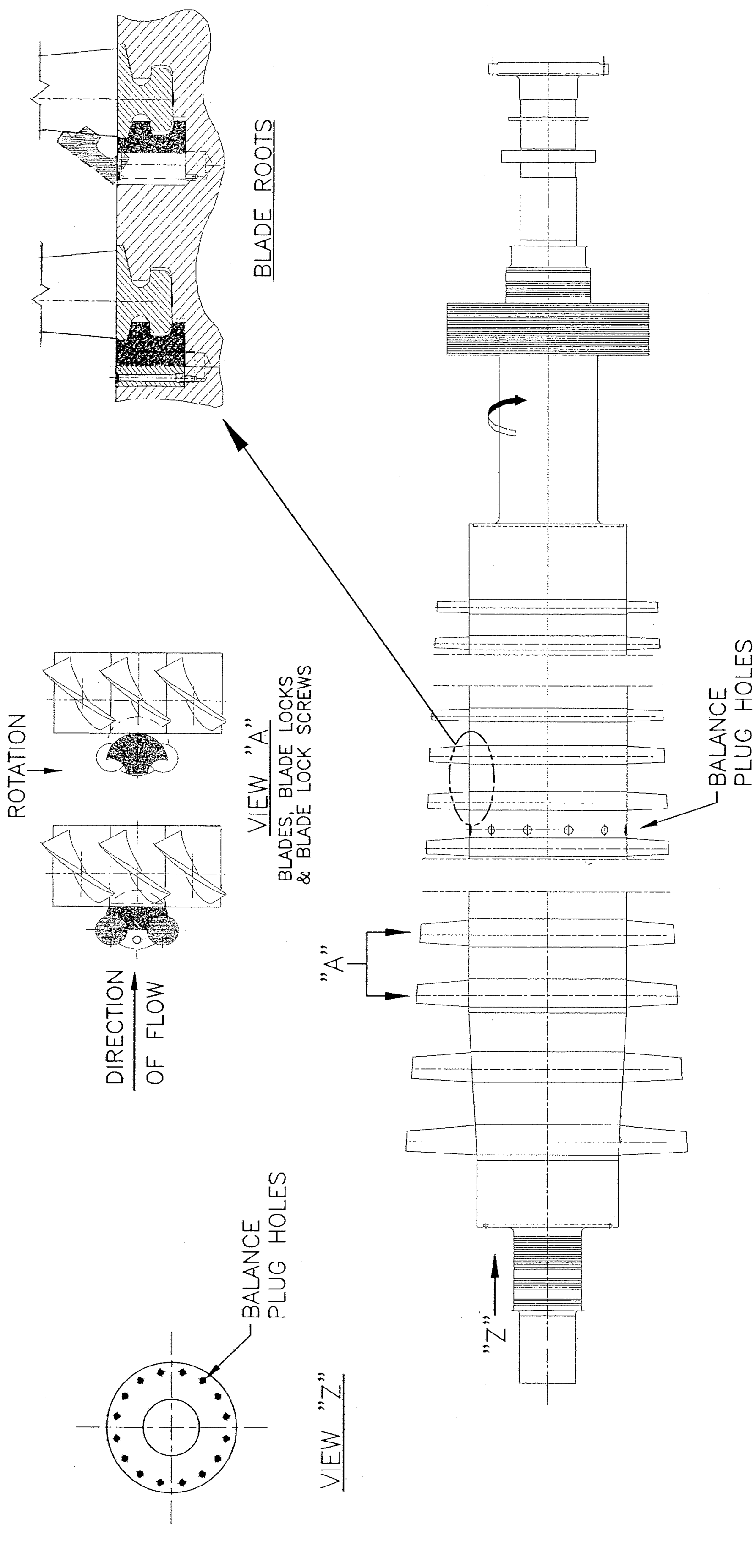


Figure 3.1-5—Solid Rotor Construction

e. Overspeed of rotor where yielding of material is a concern or evident.

f. Rerate requiring new components.

g. Shifting of components, loss of thermal gaps.

h. Circumferential twist or slippage of tie-bolt rotor components.

i. Bowed rotor, or rotor with excessive runout or runouts that are out of phase.

j. Balance level not repeatable in the shop or field.

k. Previous operating and overhaul history suggests full disassembly.

l. Loss of tie bolt stretch.

m. Over temperature history.

1.4.3 If the owner has authorized dismantling of the rotor, the vendor shall proceed to Section 2 and provide "as found" data for each component (disks, stub shafts, etc.).

2 Rotor Disassembly Phase II

2.1 GENERAL

This section describes the data and requirements for a Phase II inspection and disassembly of an axial compressor rotor.

2.2 DISASSEMBLY FOR PHASE II INSPECTION

● **2.2.1** When specified, or with the owners approval, as a result from Phase I inspection, the vendor shall dismantle the rotor to the extent specified.

2.2.2 Prior to dismantling, the requirements of paragraph 1.3 are to be completed and recorded.

2.2.3 Match mark components and record location and orientation as required to assure proper reassembly.

2.2.4 Care must be exercised in the disassembly to prevent damaging components. Often rotor disks, stub shafts and shafts have interference fits between components that require heat to allow disassembly. A thorough understanding of the rotor construction and the interference fits is required to safely disassemble the rotor without causing component damage.

2.2.5 Unstacking of the rotor should be done in the vertical position.

2.2.6 Tie-Bolt Rotor Disassembly (Figures 3.1-2 and 3.1-4)

2.2.6.1 Before disassembly of a tie-bolt rotor configuration, measure and record stack height (overall length of the components restrained by the tie-bolts and tie bolt length). After disassembly remeasure, calculate, and record the stack compression and tie-bolt stretch.

2.2.6.2 For stacked rotors utilizing tie bolts, the tie bolt removal detensioning should be done with caution. Detensioning is rotor specific and has been accomplished thermally, hydraulically or mechanically. The appropriate procedures, tooling and/or fixtures are to be used. For multiple tie bolt configurations, it is recommended to detension the tie bolt(s) in diagonal pairs and in several steps versus detensioning one at a time.

CAUTION: Improper detensioning may cause the rotor to deform, allowing binding and buckling of the components, or overstressing of the remaining bolts.

2.2.7 Rotors with Shrunk on Components (Figure 3.1-1)

2.2.7.1 All major component(s) shall be uniformly heated for disassembly. In no case shall a component be more than 280K (500°F) above the shop ambient temperature.

Note: Heating components for disassembly is a critical step. Heated components should be heated uniformly to minimize circumferential temperature variations that could cause permanent distortion. This heating may be accomplished by the use of two or more large (flare tip or rosebud) torches, however, care must be exercised to avoid a heat rate that is too rapid to maintain even heating. The differential temperature should be carefully monitored with temperature indicating temperature sticks without sulfur components or a non-contacting infrared surface temperature gun.

2.2.8 Drum Rotor Disassembly (Figure 3.1-3)

2.2.8.1 For conical seat blade attachments:

a. Number each blade from a reference point prior to disassembly so that they may be returned exactly as they were removed.

Since there is no blade angular location feature, special tooling is required to verify and set the blade angle.

b. Once consistent angles have been verified, and if special tooling is not available, a method to aid reassembly is to scribe a line across the blade platform and drum to establish the angular setting of each blade. If angles are not consistent, an Engineering review and disposition are required.

2.2.9 Blade Disassembly

2.2.9.1 Remove blades with the following cautions:

1. Axial blades are retained in a variety of methods. Care must be taken to determine the method of retention and the appropriate removal procedure to prevent damage to the blades or disks.
2. Blade retention hardware is not re-usable.

3. To prevent damaging the coating, care must be taken when removing coated blades that are not to be recoated. Do not impact the blade near or on the coated areas.

2.2.10 Remove and deburr area(s) of any previously installed balancing weight(s). The location and amount of each weight is to be recorded.

2.2.11 Blades that have been removed and appear to be reusable shall be cleaned in accordance with 1.3.3. The coating is not required to be removed for these procedures at this time.

2.3 PHASE II INSPECTION

2.3.1 Carefully, abrasively clean the rotor components to base metal. See Chapter 1, paragraph 7.2.2 for cleaning methods and precautions. Chemical stripping may be required to adequately evaluate blade pitting due to corrosion.

Note: This will result in the removal of any protective coatings.

2.3.2 The vendor shall perform the following inspections in paragraphs 2.3.2.1 through 2.3.2.9 after the Phase II disassembly has been completed.

2.3.2.1 All interference fits shall be dimensionally inspected to determine the amount of interference remaining and if component rework is required to restore the design interference.

2.3.2.2 All mating fits shall be visually inspected for signs of yielding, distress, fretting, galling, etc.

2.3.2.3 Visually inspect and record the condition of each part removed. The rotor blades and disks shall be inspected for signs of distress, rubbing, over temperature, distortion, attachment fretting, erosion and corrosion. Any evidence of erosion, corrosion or component distress should be photo documented. Inspection is required by an experienced individual that is knowledgeable with axial compressors and the particular process application, since this type of equipment can be subjected to highly corrosive and erosive environments.

2.3.2.4 Dimensional Inspections:

Measure and record all shaft and component sizes on a worksheet designed for the particular component, per Appendix “B” or equal. This data will be used to determine the roundness and taper of each component. This shall include:

a. Bare shaft or stub shaft fit sizes in critical regions such as journal and seal regions, coupling fits, disk and sleeve fits, overall length, and runouts (including thrust collar shoulders).

b. Disk bore sizes, lengths, roundness, face runouts, and outside diameter runout for disk rotors. Rotor to shaft or disk pilot fit dimensions.

c. The stacking heights of individual components, at 90° intervals.

d. Bore sizes and lengths of shaft spacers, seal sleeves, etc.

e. Balance piston bore size and length.

f. Thrust collar and thrust collar spacer(s) bore sizes and lengths.

g. Key clearances on all keyways.

1. With keys installed in keyways, measure from tops of keys to opposite side of shaft.
2. Measure across bore of components to bottoms of keyways.

Note: Item “2” above plus total component interference fit minus item “1” above, equals key clearance.

h. Tie bolts and nuts shall have the thread condition and size verified with thread gauges.

i. Tie bolt runout.

j. Rotor disk blade attachments(slots) shall be checked for wear by dimensional inspection of the attachment with Go/No go gauging.

k. Rotor disk or spacers should be checked against master gauges to determine adequate tooth fit up and stacking heights. The inspection techniques and the acceptance criteria shall be mutually agreed.

l. In cases where the blades have been removed from the disk or drum, the loaded faces and the fillet areas of the blade groove must be visually inspected for mechanical damage, corrosion damage or foreign material that may have entered the blade groove or transferred from the blade root.

m. For tie bolt rotors, measure and record the radial runouts and disk rim face runout with respect to the stacking face for each disk.

n. Stub shaft radial and face runout readings shall be measured and recorded.

2.3.2.5 Unless otherwise specified in job scope, use applicable NDE procedures as outlined in Chapter 1, Section 8 after disassembly, to determine the existence of any indications on the components to be reused or subject to failure analysis. Record the size, location, and orientation of any indications on a sketch. All ferro-magnetic components shall be wet magnetic particle inspected. Non ferro-magnetic components shall be fluorescent dye penetrant inspected.

2.3.2.6 The NDE evaluation described in Chapter 1, Table 1.8-1 shall be a severity level of “A” for all components, excluding blade and blade to disk attachments and sleeves. Blade and disk attachment areas shall report any visible indication. Sleeves shall be inspected to a severity level “C.”

2.3.2.7 Photographs are to be taken per Chapter 1, Appendix G, of any component with any unusual or abnormal condition. A photo log should be maintained for all work performed.

2.3.2.8 Threaded areas of the shaft and tie-bolts are to be visually inspected and dimensionally verified by screwing on a gauge. Inspect for set screw marks.

Note: When a gauge is not available for checking the threads of thrust collar and coupling retaining nuts, the mating nut may be used with judgement.

2.3.2.9 Nuts that have locking features shall be replaced if the breakaway torque is less than 20% of the new torque value.

2.4 EVALUATION OF PHASE II INSPECTION DATA

2.4.1 Review and evaluate all data and information to determine the acceptability of the inspections, resulting fits, clearances, and runouts.

2.4.2 Component bores

If the latest design dimensions, interferences, clearances and fits are not available, the following criteria may be used as a guide in determining the acceptable taper and contact area.

2.4.2.1 For straight fit designs, the component bore should not exceed a taper of 0.3 μm/mm (0.0003 in./in.) of bore diameter.

2.4.2.2 Interference between disk bore and shaft shall be sufficient for all speed and temperature transients. The actual required interference shall be determined by an engineering review prior to reassembly.

2.4.2.3 For hydraulic fit, tapered bore disk designs, a blue contact check shall be performed per Chapter 1, Appendix C with a minimal contact area of 80%. The disk may be used for this verification as long as there are not any raised discontinuities in the shaft surface.

2.4.3 For tie-bolt construction, an engineering evaluation of the bolting stretch, thread condition, visual and dimensional inspection, and surface condition is to be performed.

Note: Tie bolt threads are typically rolled threads.

2.4.4 Evaluate the blades for reuse, based upon the guidelines given in 3.6.

2.5 PHASE II RECOMMENDED JOB SCOPE

2.5.1 The vendor shall notify the owner upon completion of Phase II Inspection, provide a copy of all Phase II documentation, summarize the results of Phase II Inspection, and prepare the recommended job scope for approval by the owner.

2.5.2 Fasteners with galling resistant coatings that are to be reused shall be recoated. The coating is to be an extreme pressure anti-seize coating suitable for the application.

2.5.3 Coated blades that are to be reused are to be stripped of any coating and NDE.

3 Repair Processes and New Component Manufacture

3.1 GENERAL

3.1.1 In addition to the general repair processes and new component manufacturing requirements discussed in Chapter 1, Section 9, the following procedures and practices are recommended to accommodate the conditions and considerations unique to axial compressor rotors. Components should be repaired as outlined in 3.2 through 3.10 or new components supplied as outlined in 3.11.

3.1.2 In order to minimize distortion problems in the final assembly, components having a straight, continuous bore and a bore length-to-diameter ratio of 0.75 or greater without a center relief, should have an engineering review. This engineering review is to determine the justification and criteria to incorporate a center relief and land fit concept on each end of the bore.

3.1.3 Repairs to damaged rotor seal areas (disks, drums, or shafts), typically caused from contact with labyrinth type seals, may be repaired per the methods in Chapter 1, paragraph 9.2.

3.1.4 Pilot fits may be restored by weld repair per Chapter 1, Appendix D.2. Pilot fits may also be restored by machining, installing a patch ring by shrink fit, and then machining to final size. The ring material should be similar to the disk with respect to mechanical and thermal properties. The thickness of the ring should be between 3 to 6 mm ($^1/_8$ to $^1/_4$ inch) thick. Due to the differences in the coefficients of thermal expansion, chrome or nickel plating shall not be used as a repair method for fit buildup.

3.1.5 Rubs and pitting on disk faces may be removed by machining after an engineering review.

3.2 INTEGRAL ROTORS

Integral rotor disk(s) may be repaired by welding as outlined in Chapter 1, Appendix D.2. Disk weld repair shall be accomplished by partially or completely machining the outside diameter of the disk and building back up by welding.

3.3 BUILT UP ROTORS

3.3.1 Repair of the shaft under the disk(s) shall be per Chapter 1, Appendix D.2.

3.4 DISK BORE

3.4.1 Disk bores should be repaired using the repair methods outlined in 3.4.1.1 to 3.4.1.4.

Due to the differences in the coefficients of thermal expansion and bore dilation, chrome or nickel plating shall not be used as a repair method for disk bore buildup.

3.4.1.1 Weld Repair

Disk bores may be repaired by the welding process outlined in Chapter 1, Appendix D.2 using an owner approved procedure. Repair procedure is to include the following steps:

a. Record angular position of keyways.

b. Generously radius all keyway(s) corners and chamfer the sides of the keyway(s) prior to welding.

c. Weld up keyway, disk bore and as necessary seal areas per Chapter 1, Appendix D.2.

d. Machine repaired areas. Disk bore is to have a maximum surface finish of 0.8 µm (32 µinch) Ra. Repaired disk seal areas and keyways are to have a maximum surface finish of 1.6 µm (64 µinch) Ra.

e. Wet magnetic particle inspect per Chapter 1, paragraph 8.2.4.

f. Record disk dimensions and runouts.

g. Balance disk as per Chapter 1, Section 10.

Note: The face of the disk at the bore may need to be welded to provide for the disk final bore length to remain the same length as original.

3.4.1.2 Thermal Spray Repair

Disk bores may be repaired by using the thermal spray techniques outlined in Chapter 1, Appendix D.3. A minimum amount of material shall be removed. The finished coating thickness shall be per Chapter 1, Table 1.D-1, for the technique used. The procedure is to include the following steps:

a. Oversize the bore and record dimensions and runouts.

b. Wet magnetic particle inspect per Chapter 1, paragraph 8.2.4.

c. Blank off the keyway area(s) and apply the thermal spray coating.

d. Machine bore.

e. Repeat step b above.

f. Perform dimensional checks.

g. Balance disk as per Chapter 1, Section 10.

Notes:

1. This technique, depending on the application process, may result in minute chips at the edges, especially at the keyway. Chamfering may be necessary to prevent additional chipping.

2. Coating application should consider deformation as a result of assembly interference, and expansion during assembly, normal operation, and overspeed testing.

3. The angle of the applicator device used in the thermal spray process to build up the disk bore are to be within the limits recommended by the process licensor. This may preclude thermal spraying disk bores that are relatively small with long lengths.

● **3.4.1.3** When specified, an acceptable alternate repair method is to bore out the disk oversize and manufacture a new oversize shaft. While technically acceptable, the economics must be carefully compared to the other repair techniques.

Note: For assembly and disassembly purposes it may be necessary to perform this task on all the disks.

● **3.4.1.4** When specified, bore out the disk oversize and HVOF or HVLF spray the bore per Chapter 1, Appendix D.3.5. The metal powder used for build up shall have been previously applied and demonstrated in similar applications.

3.5 BLADE ATTACHMENT ON ROTOR

3.5.1 Blade attachment areas may be machined oversize to remove corrosion pitting or mechanical damage if supported by engineering analysis. Corrosion pitting greater than 76 µm (0.003 in.) deep would require an engineering evaluation. After machining, new blades with a matching oversized attachment are required.

3.5.2 After removing from the shaft, rotor disk(s) may be repaired by welding as outlined in Chapter 1, Appendix D.2. Disk weld repair shall be accomplished by machining the outside diameter of the disk below the blade attachment area and to a point below the area to be repaired and building back up by welding. For built up rotors the disk shall be removed from the shaft and weld repaired.

Note: Weld repair in the blade attachment area of a drum rotor is not recommended due to distortion.

3.5.3 Except for conical fits, all blade attachment areas shall be peened. All material external corners shall be chamfered or radiused to prevent material roll over. Peening intensity and media depend upon base material, compressive layer depth desired and material thickness. The compressive layer induced shall be checked by using Almen strip.

Note: Peening increases resistance to stress corrosion cracking and resistance to fatigue cracking via inducing a compressively stressed layer at the material's surface.

3.5.4 If the blade attachment area had been previously coated, and the coating appears to have been effective, then it shall be recoated in accordance with the requirements of Chapter 1, Appendix L.

3.6 BLADE REPAIR

3.6.1 Minor damage to blade airfoils may be repaired without significantly adverse effects to the blades' mechanical integrity or aerodynamic performance. Figure 3.3-1 includes material removal limits to be used during the repair of damaged blades. This figure is applicable to all airfoil designs and blade root designs. Material removal beyond the limits provided by Figure 3.3-1 may be possible after completion of an engineering review. If an engineering review is not completed, blades requiring rework beyond the limits of Figure 3.3-1 should be scrapped.

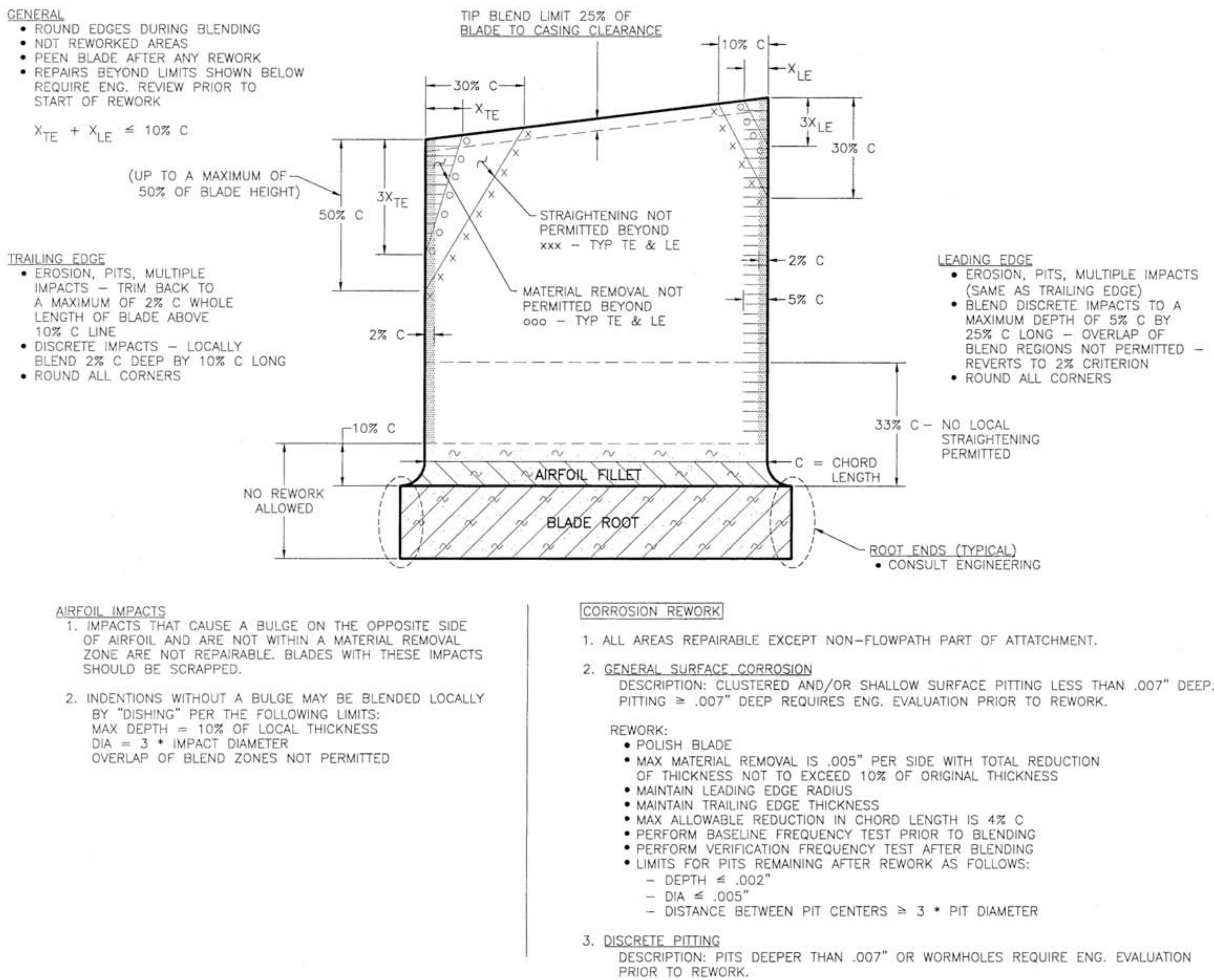


Figure 3.3-1—Blade Rework Limits

3.6.2 The cause of cracking should be identified prior to any repair. If caused by foreign object damage, cracking may be repaired as outlined below. If caused by other than a foreign object damage, or in a location other than the leading edge, an engineering analysis should be performed. Typical causes of cracks are vibration of thin sections which have developed due to erosion, pitting corrosion, blade rubbing on casing, blade operating in a resonant condition, and stress corrosion cracking.

Blade damage due to tip rubs may be reworked by reducing the blade length such that rubs do not reoccur. The hardness of the remaining base metal shall be checked to confirm all damaged material has been removed. After repairing, NDE inspect per Chapter 1, Section 8, with acceptance criteria per 2.3.2.6.

Note: Tip rubs may be caused by casing distortion, foreign objects, and operating conditions. The root cause of the rub should be determined in establishing the new blade height and resultant tip / casing clearance.

3.6.3 After rework, NDE per Chapter 1, Section 8, with acceptance criteria per 2.3.2.6. After completion of rework and all testing, the blades should be peened and coated, as required.

3.6.4 Weld repair of axial compressor blades is not recommended due to blade air foil shape, configuration and the thin edges.

3.6.5 Depending upon the severity of airfoil rework, the blades' natural frequencies could change significantly. Therefore, when polishing or trimming rework is performed, a baseline frequency response shall be obtained by test prior to the start of rework. A sample size of 25% of the blades per stage is adequate for developing a baseline if the variation of frequencies within the sample is within a 2% bandwidth. Otherwise, all of the blades in a stage should be tested. All reworked blades shall be frequency tested. Blades whose frequencies change more than (±2%) from the baseline shall be verified as suitable for service by comparison to a Campbell diagram. The Campbell diagram shall be provided based on test data and showing the blades' natural frequencies for the four lowest frequency modes (corrected for operating speed and temperature), and harmful excitation frequencies. The exciting frequencies caused by upstream and downstream stator vanes, inlet struts, and one through six times rotor speed shall be indicated and shall not intersect a blade dynamic natural frequency within ±10% of the operating speed range.

Notes:

1. This test and evaluation is required due to the free standing, non-shrouded type of blading typically used in an axial compressor.

2. The correction for the blade's natural frequency is due to the blade stiffening at operating speed and softening at operating temperature.

3.6.6 All blades are to be peened. Peening intensity and media depend upon base material, compressive layer depth desired and material thickness. The compressive layer induced shall be checked by using Almen strip.

Note: Peening increases resistance to stress corrosion cracking and resistance to fatigue cracking via inducing a compressively stressed layer at the material's surface. In general, the peening intensity is set by the section thickness. If the intensity is too high, the component's edge can distort. Thus the airfoil peening intensity is governed by the thickness of the blades' trailing edge. The blade root is generally peened to a higher intensity than the blade.

3.7 PROTECTIVE COATINGS

● **3.7.1** Axial blades and disks may be coated for anti-fouling, erosion and corrosion protection. Erosion coatings are generally applied by thermal spray process as outlined in Chapter 1, Appendix D.3. Corrosion and/or anti-fouling coatings are generally applied as outlined in Chapter 1, Appendix L. The coating type, method of application, and area to be coated shall be specified.

Note: These coatings are highly specialized and require special part preparation, mask tooling and handling to assure proper application and consistent quality. Improperly selected and/or applied coating can lead to rapid coating failure and the degradation of the base material properties of the coated component. A thorough engineering review of any coating application should be conducted prior to use.

3.7.2 When re-coating existing components all evidence of previous coatings shall be removed prior to recoating.

3.8 TIE-BOLTS

3.8.1 The body of the tie-bolts are not to be repaired except for minor skim turning (generally less than 0.005 in. deep), blending or stoning of the tie-bolt body to eliminate localized, minor galling or scoring.

3.8.2 Rotor tie-bolts are highly stressed, therefore, thread repair is to be limited to minor deburring and chasing of the threads with the appropriate die.

Note: Tie-bolt threads may be a special class, special form, or rolled threads. Caution must be taken when chasing these threads to assure that the appropriate thread class and form is used. A standard thread die cannot be used on a special thread class, special form or rolled threads.

3.8.3 If the tie-bolts are not straight within the assembly clearance of the disks or drums that they pass through, they should be replaced and not welded or machined. Tie-bolts may be cold press straightened if the vendor has successfully demonstrated the capability on previous equipment or test pieces.

3.9 LABYRINTH SEALS

3.9.1 "J" strips shall be repaired by straightening if possible and replaced as necessary. The replacement of "J" strips is to include the removal of the old strips and the replacement with new. The strips shall be final machined and the final dimensions shall be recorded. Caulking strip material should be in the annealed condition.

Note: For proper installation, the open end of the "J" is typically toward the higher pressure.

3.9.2 Integral seal teeth are generally remachined undersized and fitted with appropriate mating seals. Alternatively, seal teeth may be restored by repair welding per Chapter 1 Appendix D.2.

3.10 SHAFT SLEEVES AND SPACERS

While it may be technically acceptable to repair shaft sleeves and spacers, the economics of repairing generally result in a new component replacement.

3.11 COMPONENT REPLACEMENT

3.11.1 Refer to Appendix C and Chapter 1, Section 9 for component replacement requirements.

3.11.2 New Blade Manufacture

The manufacture of new blades shall account for any machining performed in the blade attachment region and any design improvements.

3.11.2.1 Prior to blade manufacturing, manufacture "root" samples based on the blades previously removed from the disk and trial fit root samples to the disks to confirm proper engagement.

3.11.2.2 All blade root (dovetail), platform, and fillet to the airfoil areas are to be peened. On 250 m/sec (825 ft/sec) or faster applications the airfoil fillet to tenon region shall be peened. Peening intensity and media depend upon base material, compressive layer depth desired and material thickness. The compressive layer induced shall be checked by using Almen strip.

Note: Peening increases corrosion resistance and resistance to fatigue cracking via inducing a compressively stressed layer at the material's surface. In general, the peening intensity is set by the section thickness. If the intensity is too high, the component's edge can distort. Thus the airfoil peening intensity is governed by the thickness of the blades' trailing edge. The blade root is generally peened to a higher intensity than the blade.

4 Assembly and Balancing

4.1 PRE-ASSEMBLY REQUIREMENTS

4.1.1 Because major components are all coming together for the first time after repair, the vendor shall ensure that the following items are completed prior to assembly.

a. Verify that all specific requirements of the repair scope have been met.

b. Verify that correct axial positioning data is available.

c. Verify that all critical dimensions and runouts have been taken, recorded, and evaluated for final fits, locations, and clearances.

d. Verify that the requirements of section 3 have been met on any new or repaired components.

e. Verify that all the parts are laid out in their proper order (numbered blades, tie bolt & nut assemblies, etc.) and that all assemblies line up to their original match marks.

4.1.2 All mating components should be thoroughly cleaned prior to assembly. Remove any foreign deposits, preservation materials, oil, etc. with an appropriate solvent.

4.1.3 Verify that all mating surfaces are clean and free of corrosion and burrs. Stone faces as necessary. Perform a trial fit of nuts to tie bolts.

4.1.4 Verify that the keys have a tap fit in the shaft and a slip fit in the components, and that the top key clearances are 100 µm to 150 µm (0.004 in. to 0.006 in.).

4.1.5 The vendor shall record a complete set of phase-related bare shaft runouts prior to "disk on shaft" assembly, or prior to assembling blades to integral rotors or stacked drum/disk rotors. As a minimum, runouts shall be recorded at each location between the blade rows and at one point outside of each bearing journal.

4.1.6 Proper placement of blading will minimize residual unbalance and the subsequent grinding corrections to the disk. Generally the depth of the correction should be limited to approximately 3 mm, ($^1/_8$ in.).

Note: To minimize grinding on disks the following should be considered.

1. All blades with an airfoil length of 150 mm (6 in.) or less may be pan-weighed.
2. All blades with an airfoil length greater than 150 mm (6 in.) should be moment-weighed.
3. Consideration also needs to be given to variations in blade thickness and locking blade weight when distributing blades.

4.1.7 For blades that have been moment weighed, the circumferential distribution of the blades shall be determined with a computer program designed for the purpose of minimizing resultant unbalance.

4.1.8 New rotor blade locking hardware shall be used (tabs, belleville or locking washers, self locking nuts, etc.).

4.1.9 The rotor components are to be protected during the assembly process to prevent damaging the components.

Note: Coated blades are easily damaged and are to be individually protected.

4.1.10 Prior to balancing, determine the appropriate balance correction regions.

Balancing corrections shall be made on the disks by grinding on the face of the disk dedicated for balance correction or by adding balance weights in a balance groove. Corrections on the disk faces adjacent to the blade root areas (which is normally also the indicator plane), the blade attachment, or other critically stressed regions of the disk is not permitted.

Metal removal on the disk faces shall be limited to guidelines given in 4.1.6. If necessary, the correction grind shall be blended to prevent stress risers and spread out to limit thinning of the disk material.

4.2 DISK ON SHAFT ROTORS (FIGURE 3.1-1)

4.2.1 Rotors shall have the bare shafts and individual major components balanced prior to the rotor assembly per Chapter 1, Section 10.2.

4.2.2 Rotor stacking and low speed assembly balance shall conform to the requirements of Chapter 1, paragraph 10.3 and the data recorded on Figures 3.D-1 through 3.D-3.

Disks are to be bladed and the bladed disk assemblies are to be balanced per Chapter 1, paragraph 10.2 prior to the assembly onto the rotor. For axial admission blading, balance correction should first be made by moving blades. Grinding of the disks should be done after efforts have been exhausted in relocating blading to achieve the balance tolerance.

4.2.3 With shafts that have a common diameter for all blade disks and sleeves, and the disks may be installed on the shaft from either end, the components shall be assembled from the center of the rotor, outwards. When possible, the vendor shall plan the rotor assembly so that two-plane balance corrections may be applied on the major rotor components throughout the assembly (i.e., assemble two major components for each balancing step). On rotors having an odd number of major components, the single-plane balance step shall be either the first or last component assembled.

4.2.4 All major components shall be uniformly heated to provide an assembly clearance to the shaft of 1µm/mm (0.001 inches/inch) of shaft diameter, but in no case more than 260 K (500°F) above the shop ambient temperature. Rabbet fits may be locally heated.

Note: Heating components (especially the disks) for assembly is a critical step. In general, the differential temperature across a disk should never exceed 30 K (50°F) during the heating process, as permanent distortion may occur. This may be accomplished in a horizontal oven that has good temperature control. It can also be accomplished by the use of two or more large (flare tip or rosebud) torches, however, care must be exercised to avoid large heat input causing uneven heating. Care is also to be given to sections of different thicknesses to avoid excessive temperature differentials. When torches are used, the differential temperature should be carefully monitored with low sulfur temperature indicating sticks or a non-contacting infrared temperature gun.

4.2.5 When components are coated, the temperature limitation of the coating must be reviewed for assembly considerations.

4.2.6 All major components shall be assembled with the shaft in the vertical position.

4.2.7 Major components shall not be impacted with hammers, blocks of wood, etc., at any time during the assembly process.

4.2.8 After the addition of each stack, allow the rotor to cool to less than 50°C (120°F) and record the data required by 4.2.9, 4.2.10, 4.2.11, 4.2.12, and 4.2.13.

4.2.9 The vendor shall assure that the last components added are correctly located on the shaft according to the assembly data and/or drawing. Stacked dimensions shall conform to the inspected dimensions per paragraph 1.3.4 and 1.3.5, or have engineering justification for deviation. Major component positioning shall be within ±760 µm (0.030 in.) of the stacked dimensions recorded per paragraph 1.3.4 and 1.3.5.

Major component positioning shall be within ±250 µm (0.010 in.) of the component to component dimension (normally measured from the inlet face of one disk to the inlet face of the next disk.

4.2.10 The minimum axial gap after assembly between adjacent, shrunk fit components shall be 100 µm (0.004 in.).

4.2.11 The vendor shall record phase-related runouts on the faces of the disks just below the blades, and the shaft on both sides of the stack.

4.2.12 Disk rim axial face runout must be within 25 µm (0.001 in.) of the face runouts measured when the disk was on the balance mandrel, accounting for any phase angle differences. In no case shall the rim axial TIR's exceed 0.13 µm/mm (0.0015 in./ft) of diameter.

4.2.13 The vectorial change in shaft runouts during each stack, comparing the before and after shaft runouts measured with a dial indicator adjacent to the last major component(s) stacked, shall not exceed 8 µm (0.0003 in.) TIR.

4.2.14 If, after a stack, the runout requirements of 4.2.13 have not been met, and/or the assembly stresses exceed the requirements of Chapter 1, paragraph 10.3.5, a "heat soak" process may be performed in accordance with 4.2.14 a-d.

a. The exposed areas of the shaft shall be wrapped with an insulating material to avoid exposure to direct flame during the process.

b. Continuously rotate the rotor in a balance machine at 300 to 500 rpm during the entire process.

c. The component shall be rapidly heated with a large (flare tip or rosebud) torch on both sides to a temperature of 180°C to 200°C (350°F to 400°F). Rapid heat shall be applied near the bore area only after heating the disk to allow for expansion. Metal temperature shall be monitored with low sulfur temperature indicating sticks or a non-contacting infrared surface temperature gun.

d. The rotor shall be allowed to continuously rotate in the balancing machine until its temperature is not more than 50°C (120°F).

4.2.15 If the rotor still does not meet the requirements of 4.2.13 and/or Chapter 1, paragraph 10.3.5, but the heat soak did result in a balance improvement of at least 25%, a second heat soak procedure may be performed per 4.2.14. If, after a second heat soak procedure, the rotor still does not meet the requirements of 4.2.13 and/or Chapter 1, paragraph 10.3.5, the components that were last assembled shall be removed for inspection and correction as required.

4.2.16 After performing a heat soak process, the vendor shall verify the axial positioning of the components per 4.2.9 and axial gap per 4.2.10.

4.2.17 Balance corrections after each successive stack shall be limited to the last major components stacked and comply with the requirements of 4.1.10.

4.2.18 Check and record blading dimensions to confirm agreement with those recorded prior to disassembly per paragraph 1.3.5, or have engineering justification for deviation.

4.2.19 The overall stack dimension (normally from the forward face of the first disk to the forward face of the last disk) shall be within 0.8 mm (0.031 in.) of the inspected dimension per 1.3.5 or have engineering justification for deviation.

4.2.20 Perform residual unbalance testing per Chapter 1, paragraph 10.4.

4.3 INTEGRAL ROTORS (FIGURE 3.1-5)

4.3.1 Measure and record rotor runouts and dimensions as outlined in 1.3 and Chapter 1, paragraph 7.2.6.

4.3.2 Balance the rotor (less blading) in accordance with Chapter 1, paragraph 10.2.

4.3.3 During the blading operations, the rotor should be sequentially balanced in accordance with the requirements of Chapter 1, paragraph 10.3. For axial admission blading, balance correction should only be made by moving blades. Blading shall be assembled from the center of the rotor, outwards. When possible, the vendor shall plan the blading assembly so that two plane balance corrections may be applied throughout the assembly. On rotor having an odd number of stages the single plane balance step shall be either the first or last row of blading assembled.

4.3.4 Check and record blading dimensions to confirm agreement with those recorded prior to disassembly per paragraph 1.3.5, or have engineering justification for deviation.

4.3.5 Perform residual unbalance testing per Chapter 1, paragraph 10.4.

4.4 TIE BOLT ROTORS (FIGURES 3.1-2 AND 3.1-4)

4.4.1 Tie bolt stack rotor designs do not allow for sequential stacking and balancing between major components.

4.4.2 Prior to stacking the rotor, prepare a rotor stacking chart for all components to be assembled. The rotor stacking chart shall be generated based upon the individual component inspection data. The stacking orientation is intended to minimize both the radial and axial run out of the assembled rotor components.

4.4.3 Prior to the rotor stacking, check the alignment of the tie bolts (rotor studs) within the disks, stub shafts for shaft ends for freedom of assembly while providing the required fastening. All tie bolts must be of the same material and matched in length and diameter within the design tolerance.

4.4.4 Trial fit each component to be assembled to each other to assure proper fit up. This may necessitate a step beyond mechanical inspection to include a trial assembly with bluing or equivalent.

4.4.5 Alignment dowels are often used to align components. Locate and fit up any special tooling required for the rotor stacking.

4.4.6 Prestack the rotor in the vertical position and check the alignment of the tie bolt holes within the disks and stub shafts for shaft ends for freedom of assembly while providing the required fastening.

4.4.7 Install the rotor tie bolts, studs and nuts. All rotor assemblies have a defined procedure and sequence of tensioning the tie bolts. Tie bolt tensioning should generally be done in three or four steps of increasing load and preferably in opposite pairs. Some rotor assemblies require special hydraulic tooling for simultaneous torquing of a defined fraction of the full quantity of through bolts. Some rotor designs may require over torquing the bolting in order to achieve a setting of the stack prior to establishing the final setting. Measure and record the resultant stretch in the tie bolts and evaluate with the manufacturer's recommendation.

4.4.8 Major components requiring heating to allow assembly shall be uniformly heated. The required amount of and maximum heating of the components shall be calculated and submitted to the owner for approval prior to the rotor build.

Note: Heating components for assembly is a critical step. In general, the differential temperature across a disk should never exceed 30 K (50°F) during the heating process, as permanent distortion may occur. This heating may be accomplished in a horizontal oven that has good temperature control. It can also be accomplished by the use of two or more large (flare tip or rosebud) torches, however, care must be exercised to avoid large heat input causing uneven heating. Care is also to be given to sections of different thicknesses to avoid excessive temperature differentials. When torches are used, the differential temperature should be carefully monitored with low sulfur temperature indicating sticks or a non-contact infrared surface temperature gun.

4.4.9 When a coated rotor disk or blades is used, the temperature limitation of the coating must be reviewed for assembly considerations.

4.4.10 All major components shall be assembled in the vertical position.

4.4.11 Major components should not impacted with hammers, blocks of wood, etc., at any time during the assembly process.

4.4.12 After the use of heat for each component added, the vendor shall assure that the tie bolt holes are properly aligned and that there is no space between mating faces outside the tie bolt circle.

4.4.13 After all disks and stub shafts have been assembled, the tie bolts shall be installed and properly torqued.

4.4.14 The vendor shall record phase-related runouts on the faces of the disks just below the blades, and the thrust collar.

Disk rim axial face runout must be within 25 µm (0.001 in.) of the face runouts measured when the disc was bench inspected, accounting for any phase angle differences. The rim axial TIR's should not exceed 0.17 µm/mm (0.002 in./ft) of diameter.

4.4.15 The vendor shall record phase-related radial runouts on the seal lands (or truth bands) and the shaft ends.

Seal land radial runout (TIR) must be within 0.1 µm/mm (0.0012 in./ft) of disk diameter. Shaft end TIR should not be more than 25 µm (0.001 in.).

4.4.16 The rotor disk position and overall stack rotor length shall be within 0.5 mm (0.020 in.) of the inspected dimensions per 1.3.5 minus any face machining done or have engineering justification for deviation.

4.4.17 Stacked rotors will generally require a machining/grinding or "truing up" of the journals, vibration probe areas, thrust faces and coupling fits and faces.

Note: Truing up of the shaft ends which contain the journals, vibration probe areas, thrust faces and coupling fits and faces will require the use of non-standard components. If interchangeability is required, journal and shaft ends should be oversized per Chapter 1, Section 9.

4.4.18 The tie bolt rotor shall be balanced in accordance with Chapter 1, paragraph 10.3.4 and 10.3.6 through 10.3.11. This balancing should be done as a three plane balance operation.

4.4.19 For rotors with loose blade designs, the balance speed shall be sufficient to seat the blades.

4.4.20 After balancing per 4.4.18, the rotor should be sequentially bladed and balanced in accordance with the requirements of Chapter 1, paragraph 10.3. When possible, the vendor shall plan the blading assembly so that two plane balance corrections may be applied throughout the assembly. On a rotor having an odd number of stages the single plane balance step shall be either the first or last row of blading assembled. Blading shall be assembled from the center of the rotor, outwards.

For axial admission blading, balance correction should first be made by moving blades. Resequence the blades if the unbalance exceeds 25 grams at the correction radius (10 in. radius would be 250 gm-in.). Grinding of the disks should be done after efforts have been exhausted in relocating blading to achieve the balance tolerance.

For non-axial entry blading, grinding is required on the disks.

4.4.21 Check and record blading dimensions to confirm agreement with those recorded prior to disassembly per paragraph 1.3.5, or have engineering justification for deviation.

4.4.22 Measure and record the axial movement of each blade.

4.4.23 Verify the locking clips are tight against the disks, and they have not chipped any disk coating. LPI bent area of each locking clip to confirm they have not cracked during installation.

TUTORIAL NOTE: Locking clips which are not tight against the disk may hit the adjacent stationary stators when the rotor is installed in the casing.

4.4.24 Perform residual unbalance testing per Chapter 1, paragraph 10.4.

4.5 DRUM ROTORS WITH CONICAL FIT BLADES (FIGURE 3.1-3)

TUTORIAL: Drum rotors require the conical fit blades to be installed prior to assembly of the drum halves or stub shaft ends. A drum half may be integral with one stub end or bolted. Drum assembly of the blades, drum and stubs is best performed in the vertical direction.

4.5.1 Measure and record the depth of conical blade fits in the drum with plug gauge tool.

4.5.2 Blade nuts are to be pan weighed. Variation to be within 1 gram of each other for each individual row.

4.5.3 Measure and record blue check of the blade conical fit to the rotor body per Chapter 1, Appendix C.6. Contact to be a minimum of 75%.

4.5.4 Install blades with new nuts and spring washers and set the blade position to the proper leading edge blade angle with a gauge tool or to the scribe line defined at disassembly. Torque nut to predefined torque levels.

4.5.5 Measure and record blade leading and trailing edge clearances to the drum surface, minimum clearances to be 250 µm (0.010 in.).

Note: This clearance is to prevent stresses due to the blade touching the drum surface.

4.5.6 All blade frequencies are to be measured and recorded. A Campbell diagram shall be provided (based on test data) showing the first fundamental blade natural frequency (corrected for operating speed) and harmful excitation frequencies. The exciting frequencies shall not intersect a blade natural frequency within ±10% of the operating speed range. The correction method is to be mutually agreed.

4.5.7 Stub shaft shall be installed to the drum with bolts, washers and nuts. Certain designs may require thermal heating of the pilot fit for installation. Torque bolts to the predetermined torque.

4.5.8 If rotor has second half drum, install drum onto first drum and locate to the match marks. Drum may require thermal heating of the pilot fit for installation. Install bolts, washers and nuts and torque to predetermined torques.

4.5.9 Final stub shaft shall be installed to the drum with bolts, washers and nuts. Stub may require thermal heating of the pilot fit for installation. Torque bolts to the predetermined torque.

4.5.10 Measure and record rotor runouts and dimensions as outlined in Chapter 1, paragraph 7.2.6.

4.5.11 Machine new blade tips to the required diameters and angles.

Note: Single blade installations in existing blade rows may be milled to the exact size.

4.5.12 Check and record blading dimensions to confirm agreement with those recorded prior to disassembly per paragraph 1.3.5, or have engineering justification for deviation.

4.5.13 Balance to be completed in accordance with Chapter 1, paragraph 10.3.

a. The corrections shall be made on the drum axial ends.

b. Grinding on the blades is not permitted.

c. Balance screw holes are not to be used.

d. This rotor design does not allow sequential balancing during blade installation.

4.5.14 Perform residual unbalance testing per Chapter 1, paragraph 10.4.

4.6 REASSEMBLY OF PARTIALLY DISASSEMBLED ROTORS

4.6.1 General

This section outlines the procedures required for rotors that have had disks or blading removed.

4.6.1.1 Prior to the addition of any additional disks or blades, the rotor shall be balanced per Chapter 1, paragraph 10.2. Rotors should be initially balanced without the removable overhung components (thrust collars, coupling hubs, turning gears, etc.). These components are to be added after the assembly balance is completed per Chapter 1, paragraph 10.3.

Note: Partially debladed rotors need to be assessed as to whether the balance weights should be removed. Removal of balance weights depends upon:

a. Number of stages of blades removed.

b. Balance of the rotor in the partially debladed condition.

c. Location of the balance weights with respect to the residual unbalance in the rotor.

d. Number of resonances that the rotor must pass through.

If the balance weights are removed, record their weight and locations so they can be replaced in their original location, if required.

4.6.2 Disk-On Shaft Rotors

4.6.2.1 The remaining disks and blading shall be installed and inspected as outlined in paragraph 4.2

4.6.3 Integral Rotors

4.6.3.1 For integral constructed rotors, install, and inspect blading in accordance with paragraph 4.3.

4.6.4 Tie Bolt Rotors

4.6.4.1 For tie bolt constructed rotors, install, and inspect blading in accordance with 4.4.19 through 4.4.23.

4.6.5 Reblading of Partially De-Bladed Row

4.6.5.1 Prior to the reinstallation of additional blades into a row that had been partially debladed, insure that the blades which have not been removed are reusable and that they are properly seated into the row.

4.6.5.2 Add the remaining blades.

4.6.5.3 Balance the rotor per chapter 1, paragraph 10.3.

4.6.5.4 Perform residual unbalance testing per Chapter 1, paragraph 10.4.

4.7 ROTOR TIP GRINDING

4.7.1 Many rotors require a grinding or “truing up” of the rotor blade tips. The final blade tip dimensions are to be in accordance with the dimensions developed from the Phase II inspection.

4.7.2 Blade tip grinding requires that the following operations be performed and precautions be taken:

a. Loose blading must be shimmed to prevent movement or chatter during the grinding operation.

b. Protect any airfoil coatings.

c. Long blading may require temporary support. The support materials must not damage the blading or coatings (if used).

d. The grinding is generally performed without coolants to prevent the coolant or grinding debris from entering the rotor cavities. Many coolants can be corrosive to high temperature metallurgies during operation.

e. Rotor grooves and cavities should be masked to prevent debris accumulation in these areas. Rotor journals need to be protected from airborne debris.

f. The rate of the grinding should be low to prevent blade chatter, movement or coating damage.

4.8 FINAL INSPECTION

4.8.1 Perform dimensional and NDE inspections of the assembled rotor as required in paragraph 1.3.

4.9 DOCUMENTATION

4.9.1 Documentation for rotor re-assembly and/or balancing shall conform to the requirements of Chapter 1, Section 12.

APPENDIX A—DIMENSIONAL FORMS FOR PHASE I INSPECTION

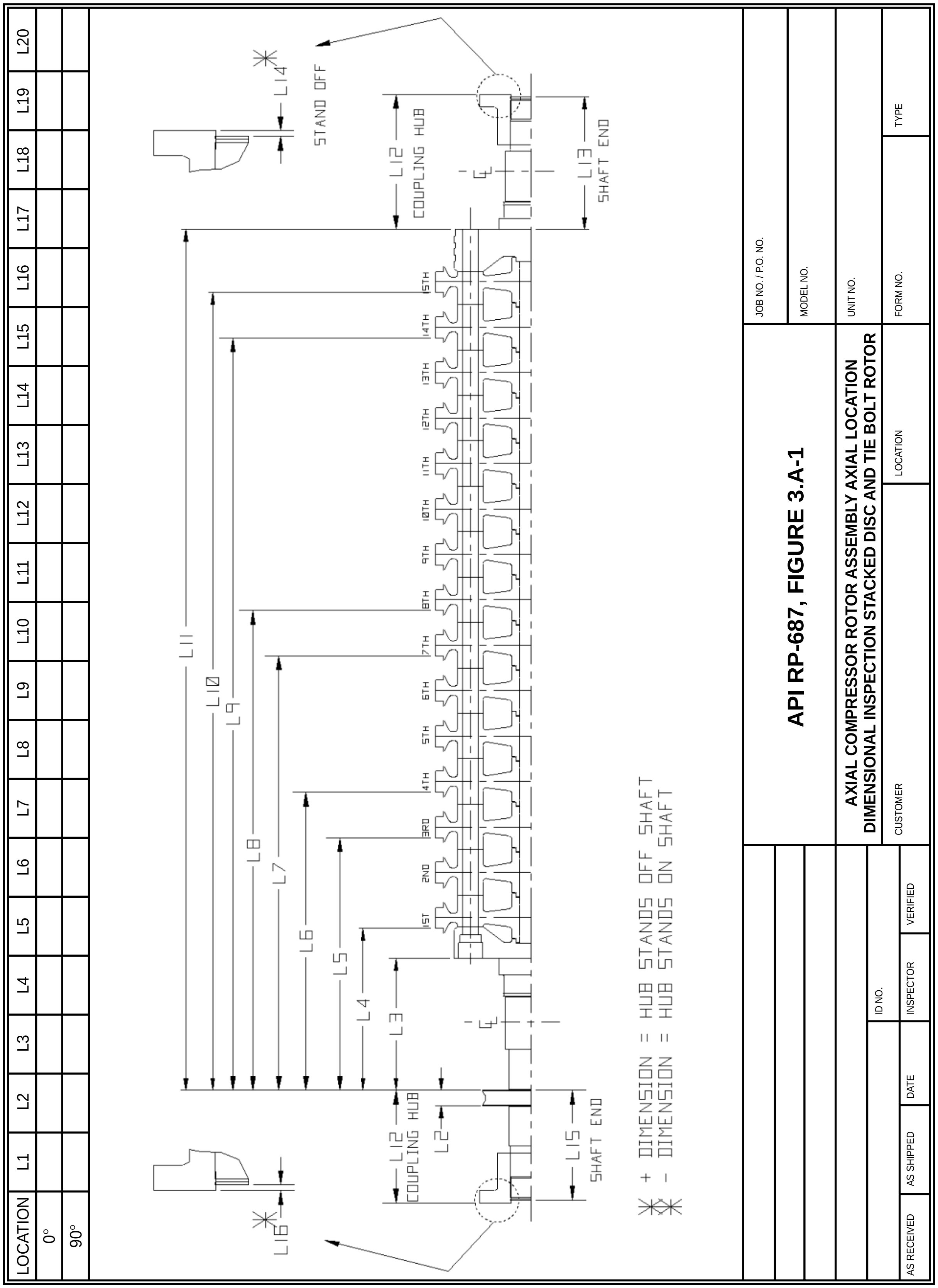
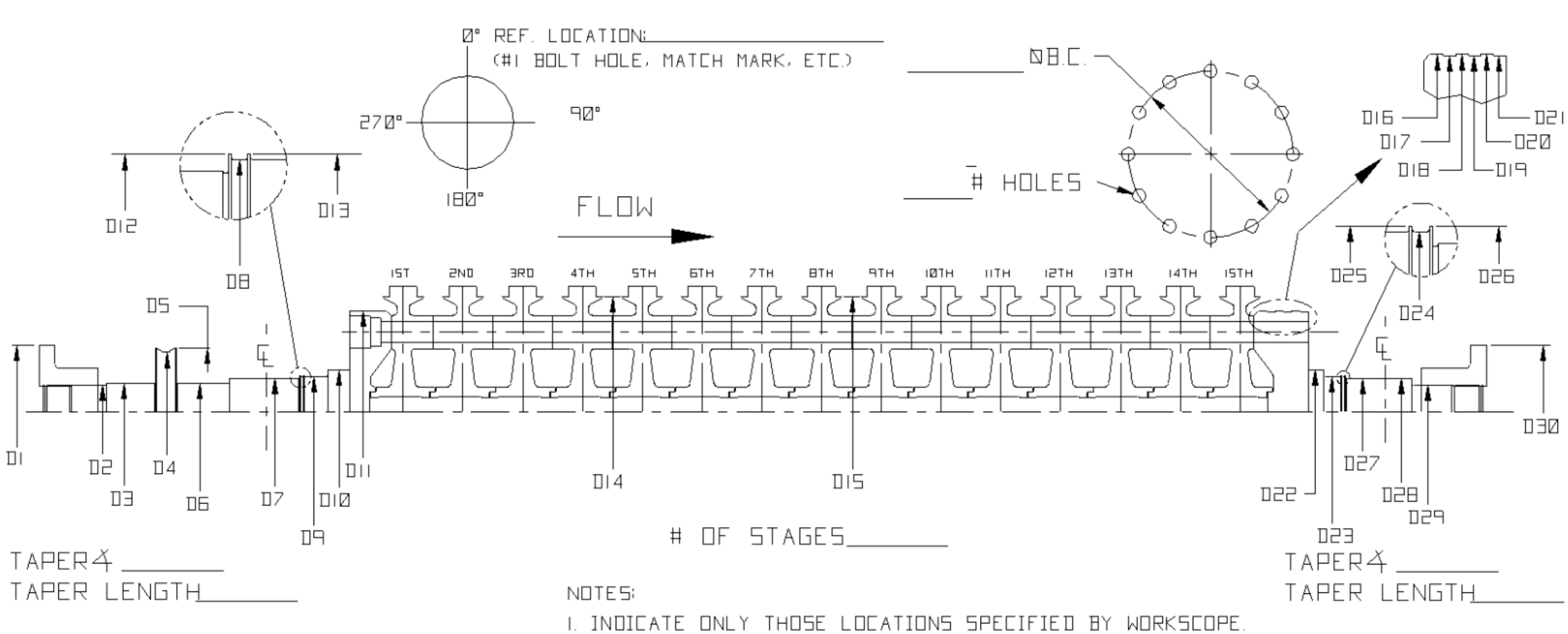


Figure 3.A-1—Axial Compressor Rotor Assembly Axial Location Dimensional Inspection Stacked Disc and Tie Bolt Rotor

LOCATION	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20
0°–180°																				
90°–270°																				

LOCATION	D21	D22	D23	D24	D25	D26	D27	D28	D29	D30	D31	D32	D33	D34	D35	D36	D37	D38	D39	D40
0°–180°																				
90°–270°																				



NOTES:
1. INDICATE ONLY THOSE LOCATIONS SPECIFIED BY WORKSCOPE.

API RP-687, FIGURE 3.A-2

AXIAL COMPRESSOR ROTOR ASSEMBLY DIAMETER DIMENSIONAL INSPECTION STACKED DISC AND TIE BOLT ROTOR

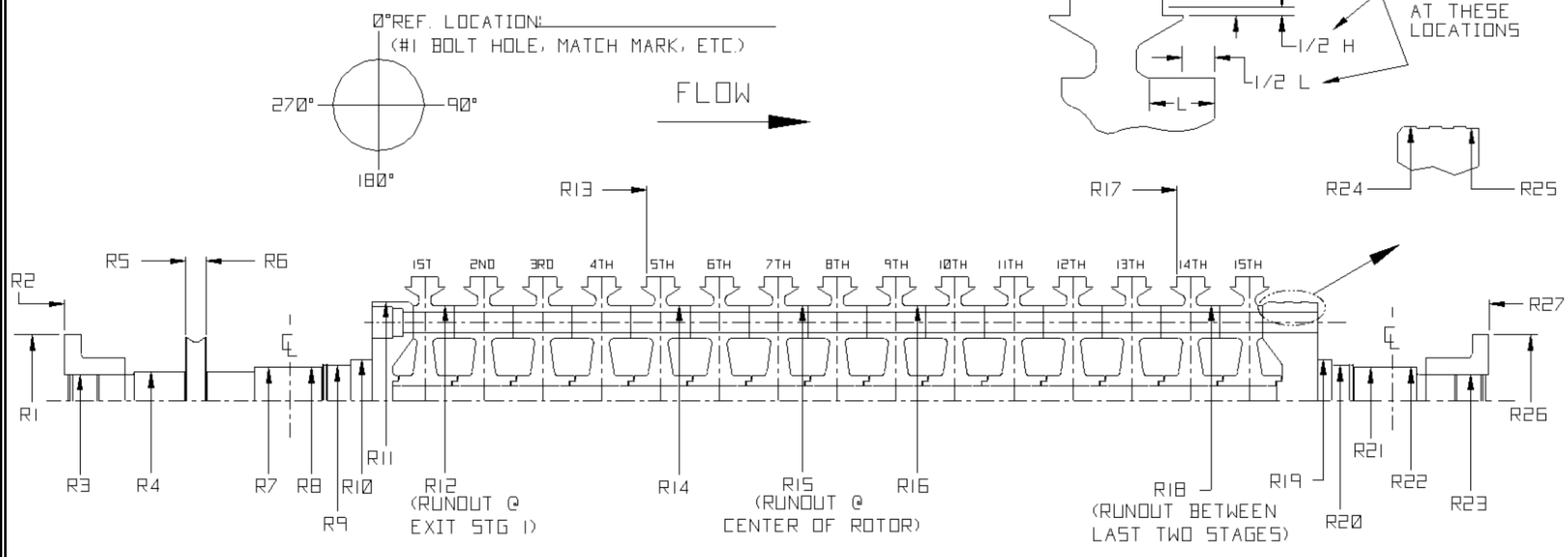
JOB NO. / P.O. NO.	MODEL NO.	UNIT NO.	FORM NO.	TYPE
CUSTOMER	LOCATION	ID NO.		
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED

Figure 3.A-2—Axial Compressor Rotor Assembly Diameter Dimensional Inspection Stacked Disc and Tie Bolt Rotor

LOCATION	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23	R24	R25	R26	R27	R28	R29	R30
TIR																														
MAX POSITIVE																														
ANGLE OF MAX POSITIVE																														

NOTES:

1. RECORD ALL RUNOUTS IN TENTHS OF A MIL (i.e. 5 = .0005).
2. MARK RUNOUT BOXES WITH AN (X) IF AN ERRONEOUS MEASUREMENT IS TAKEN DUE TO MACHINING MARKS, WEAR, RUB MARKS, ETC.
3. INDICATE ONLY THOSE LOCATIONS SPECIFIED BY WORKSCOPE.



OF STAGES ________

API RP-687, FIGURE 3.A-3

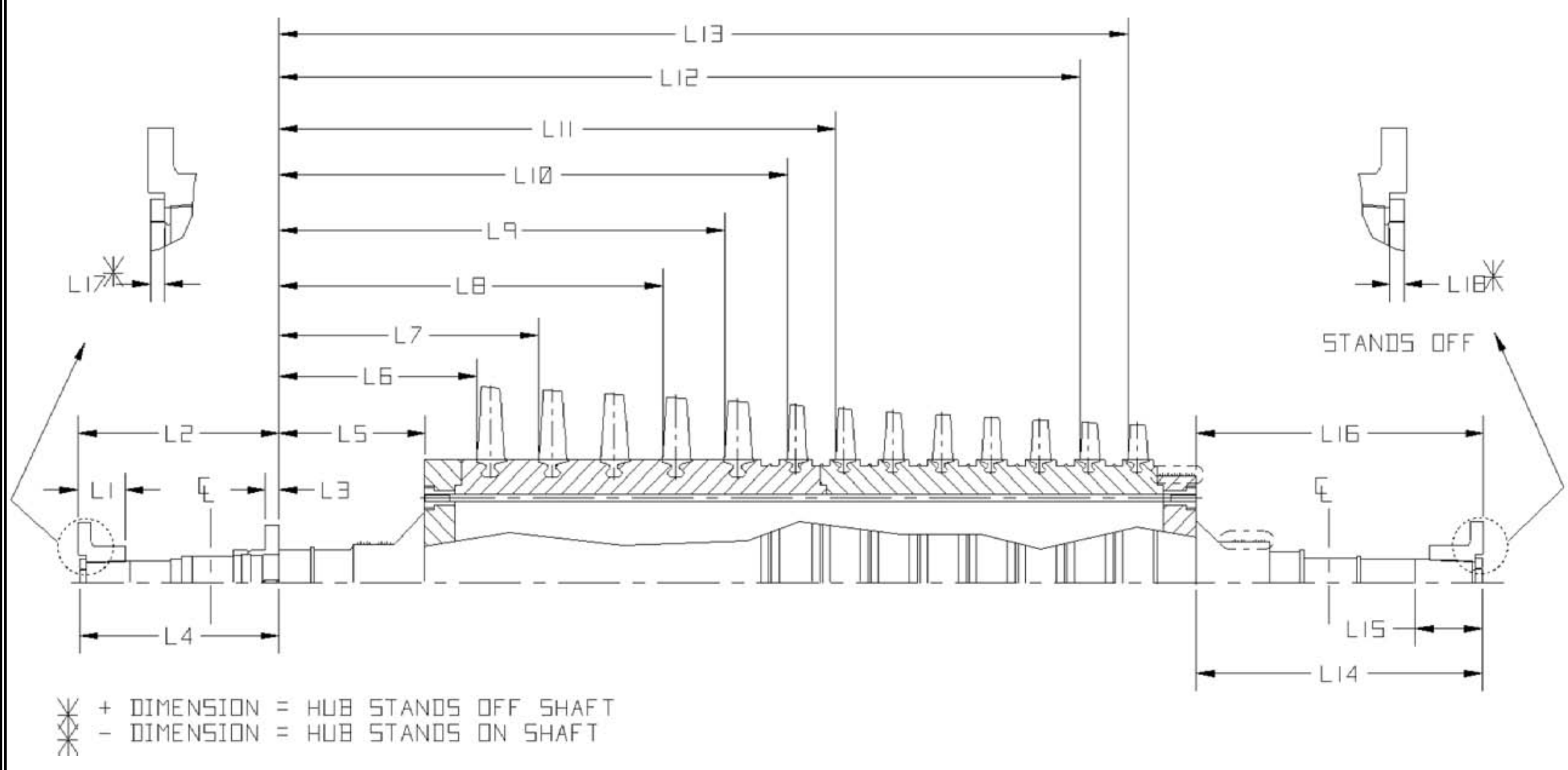
AXIAL COMPRESSOR ROTOR ASSEMBLY RUNOUT INSPECTION STACKED DISC AND TIE BOLT ROTOR

			ID NO.	
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED

JOB NO. / P.O. NO.	MODEL NO.	UNIT NO.	
CUSTOMER	LOCATION	FORM NO.	TYPE

Figure 3.A-3—Axial Compressor Rotor Assembly Runout Inspection Stacked Disc and Tie Bolt Rotor

LOCATION	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15	L16	L17	L18	L19	L20
0°																				
90°																				



API RP-687, FIGURE 3.A-4

AXIAL COMPRESSOR ROTOR ASSEMBLY AXIAL LOCATION DIMENSIONAL INSPECTION DRUM/TIE BOLT ROTOR

JOB NO. / P.O. NO.

MODEL NO.

UNIT NO.

ID NO.

AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED	CUSTOMER	LOCATION	FORM NO.	TYPE

Figure 3.A-4—Axial Compressor Rotor Assembly Axial Location Dimensional Inspection Drum/Tie Bolt Rotor

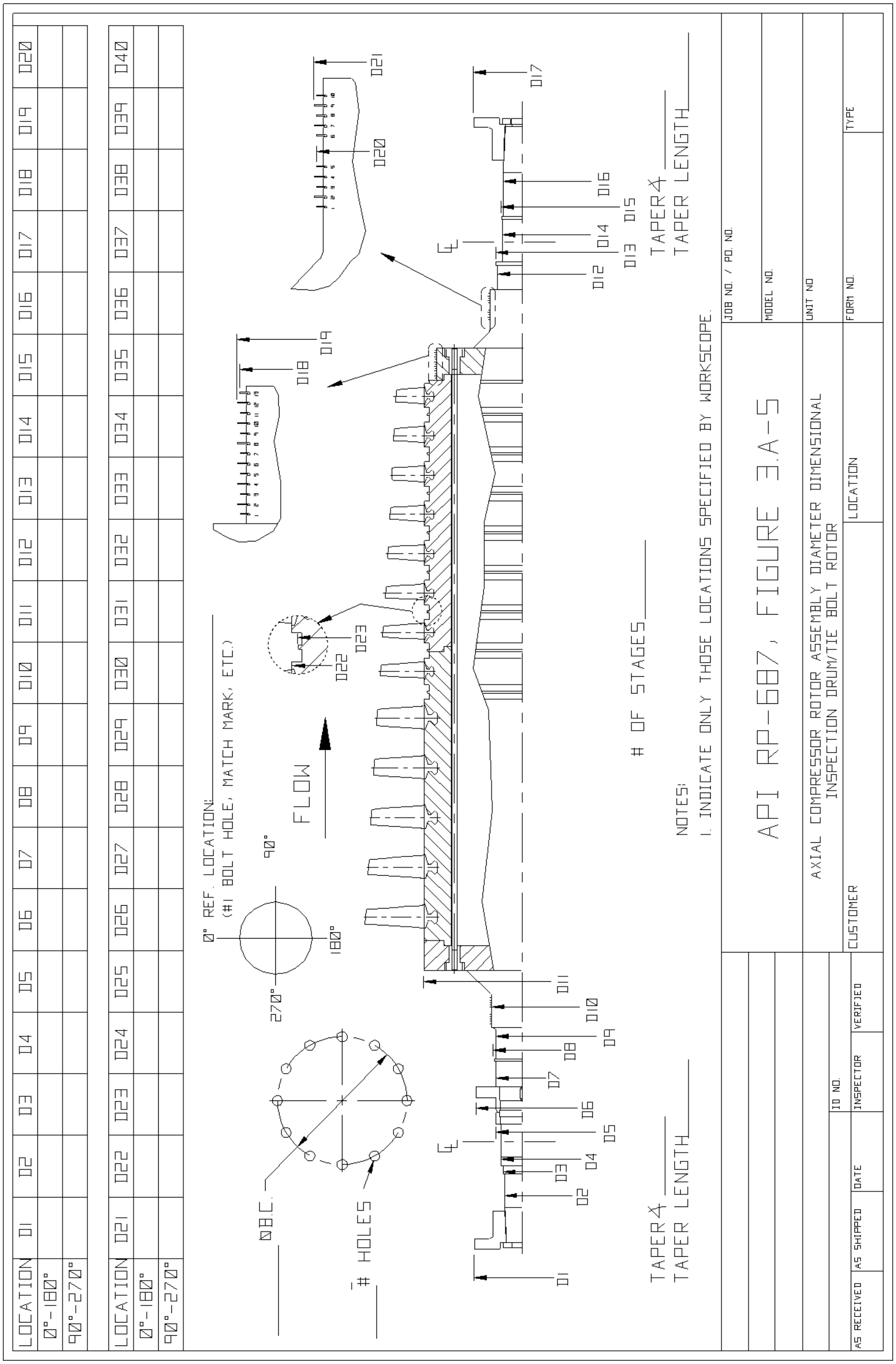


Figure 3.A-5—Axial Compressor Rotor Assembly Diameter Dimensional Inspection Drum/Tie Bolt Rotor

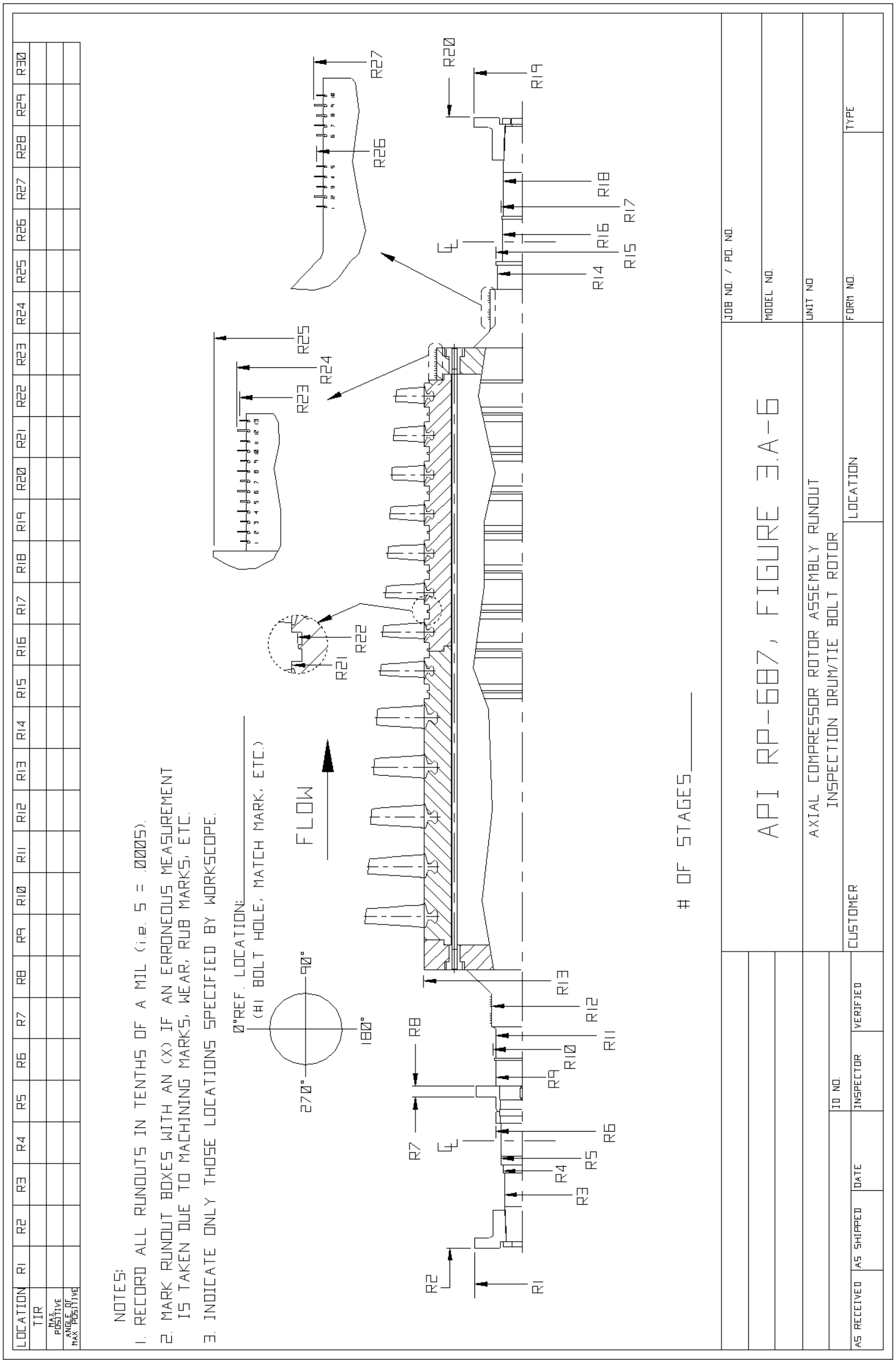


Figure 3.A-6—Axial Compressor Rotor Assembly Runout Inspection Drum/Tie Bolt Rotor

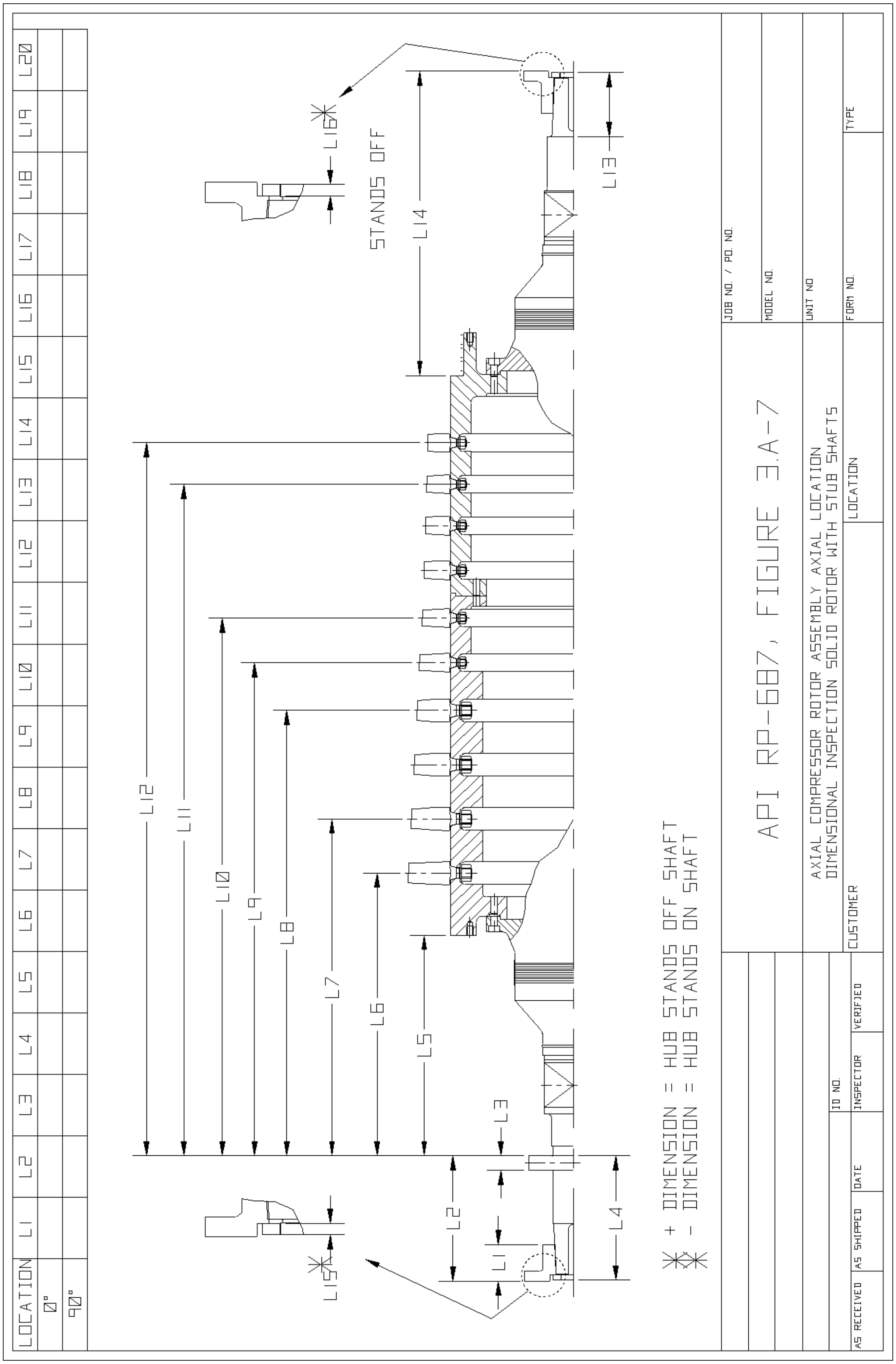
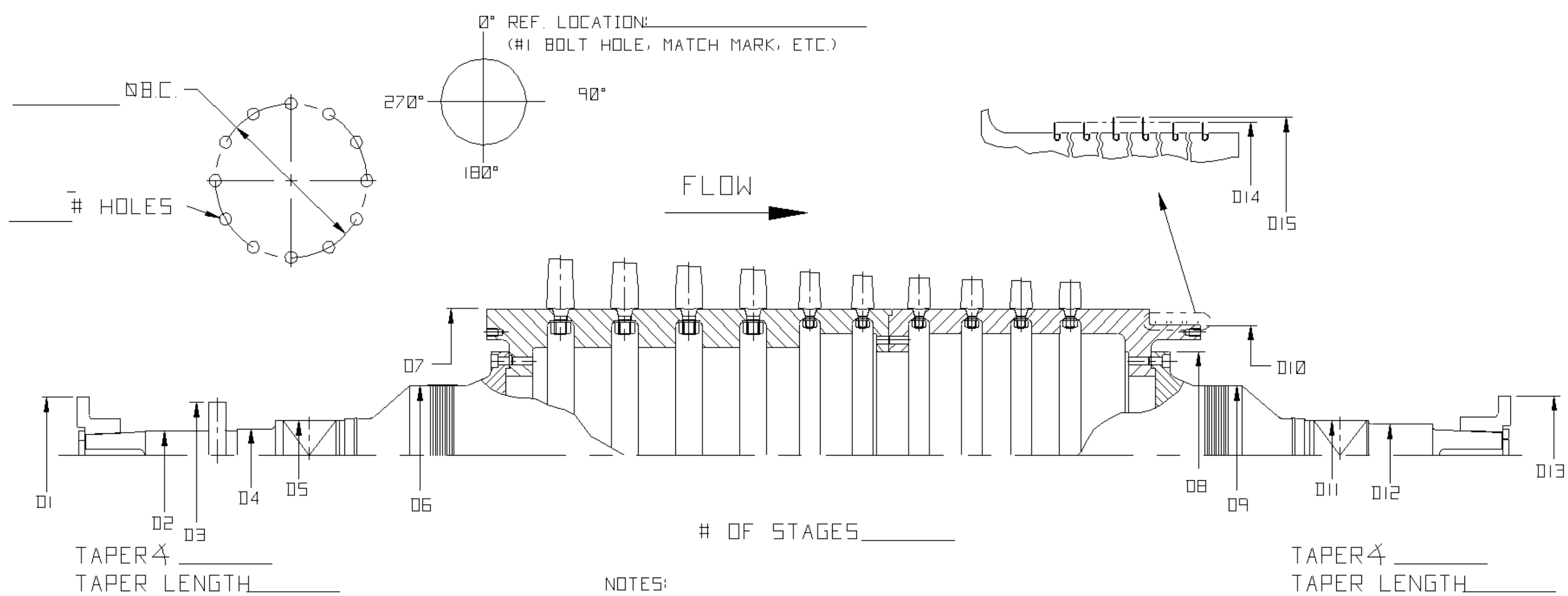


Figure 3.A-7—Axial Compressor Rotor Assembly Axial Location Dimensional Inspection Solid Rotor with Stub Shafts

LOCATION	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20
0°-180°																				
90°-270°																				

LOCATION	D21	D22	D23	D24	D25	D26	D27	D28	D29	D30	D31	D32	D33	D34	D35	D36	D37	D38	D39	D40
0°-180°																				
90°-270°																				



NOTES:
1. INDICATE ONLY THOSE LOCATIONS SPECIFIED BY WORKSCOPE.

					API RP-687, FIGURE 3.A-8		JOB NO. / PO. NO.		
							MODEL NO.		
			ID NO.		AXIAL COMPRESSOR ROTOR ASSEMBLY DIAMETER DIMENSIONAL INSPECTION SOLID ROTOR WITH STUB SHAFTS		UNIT NO		
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED	CUSTOMER	LOCATION	FORM NO.	TYPE	

Figure 3.A-8—Axial Compressor Rotor Assembly Diameter Dimensional Inspection Solid Rotor with Stub Shafts

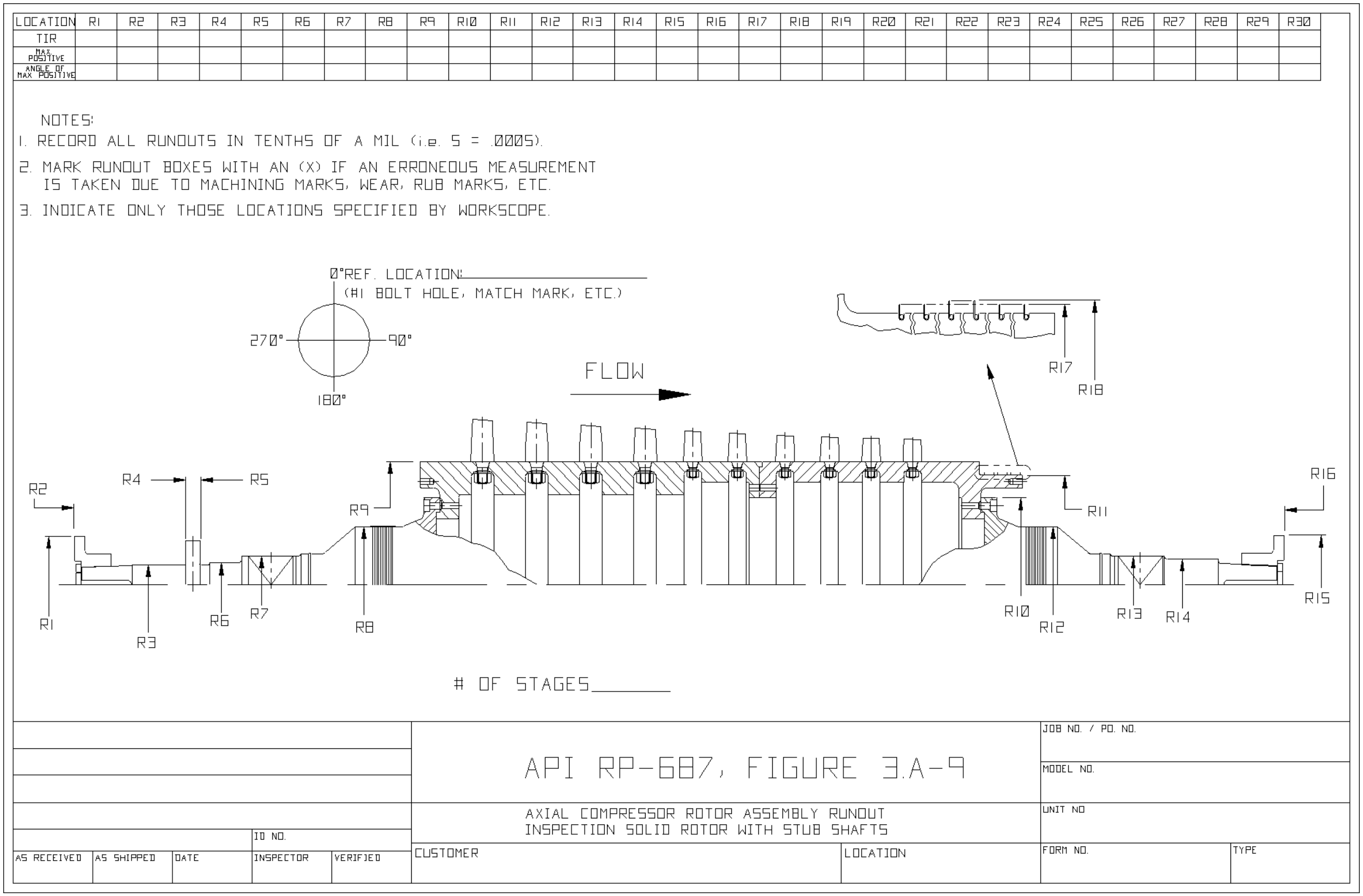


Figure 3.A-9—Axial Compressor Rotor Assembly Runout Inspection Solid Rotor with Stub Shafts

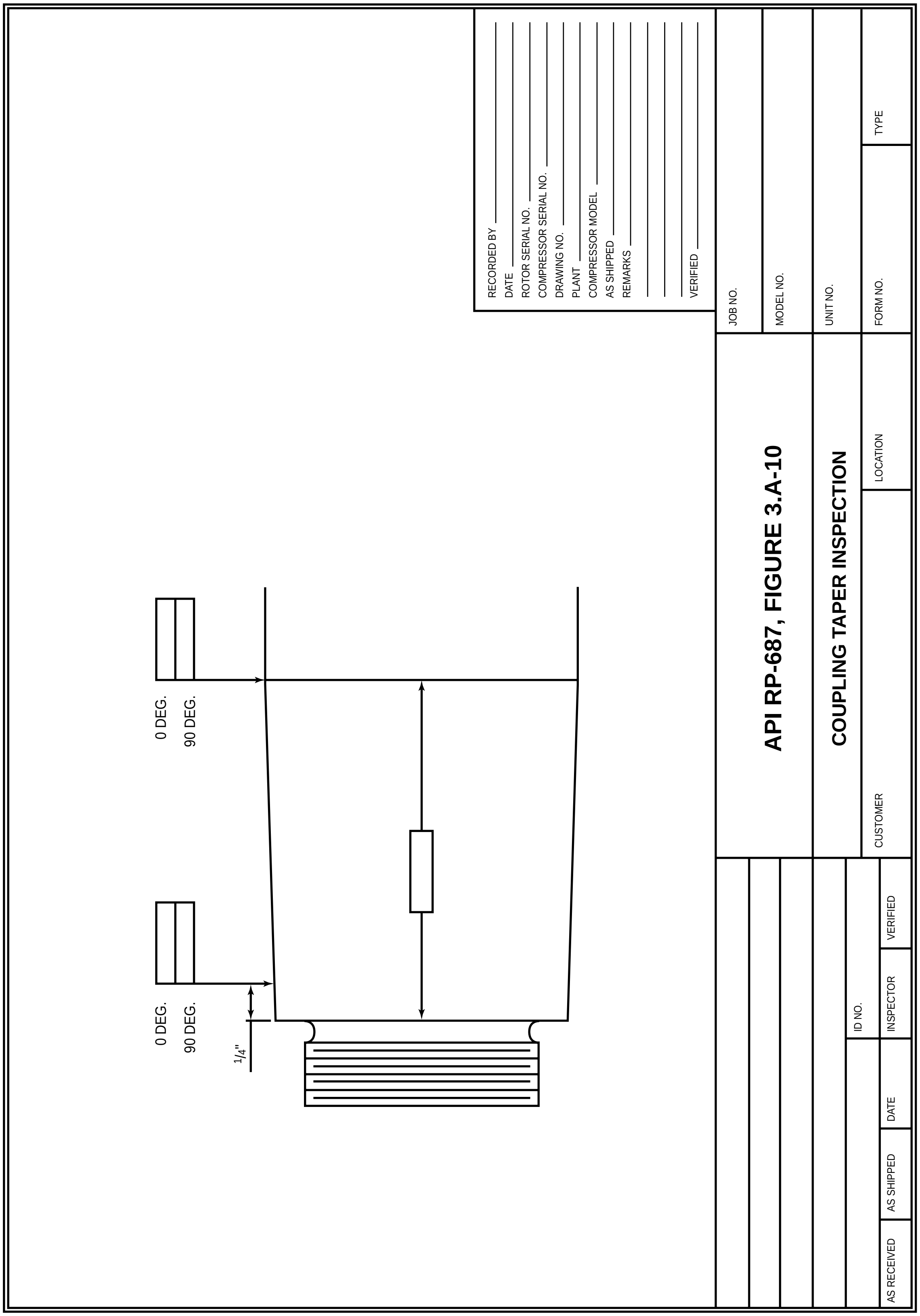


Figure 3.A-10—Coupling Taper Inspection

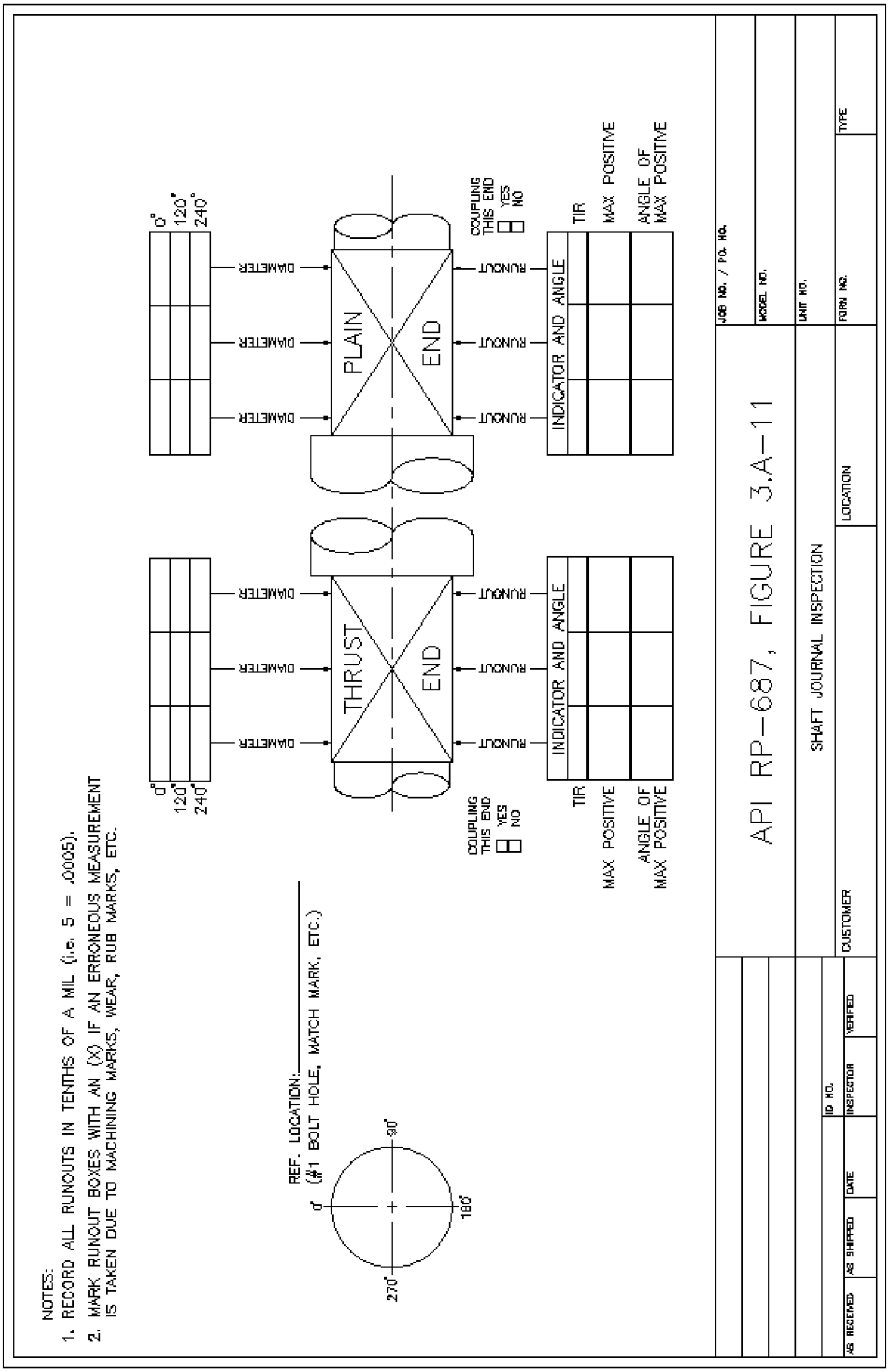
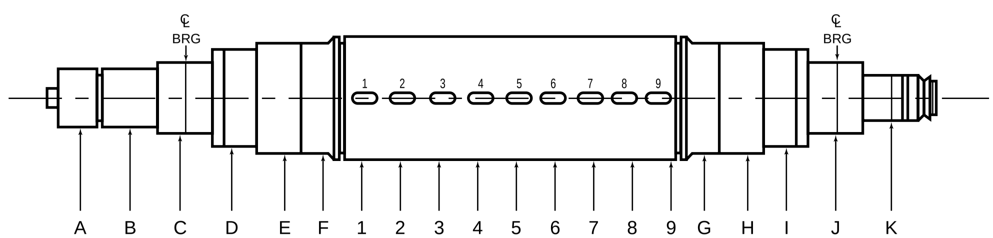


Figure 3.A-11—Shaft Journal Inspection

APPENDIX B—DIMENSIONAL FORMS FOR PHASE II INSPECTION

SHAFT DIAMETERS					SHAFT RUNOUTS				
	SPECIFIED	0 DEG.	90 DEG.	OVER/UNDER TOLERANCE		SPECIFIED	0 DEG.	90 DEG.	OVER/UNDER TOLERANCE
A					A				
B					B				
C					C				
D					D				
E					E				
F					F				
G					G				
H					H				
I					I				
J					J				
K					K				

SHAFT DIAMETERS					SHAFT RUNOUTS				
	SPECIFIED	0 DEG.	90 DEG.	OVER/UNDER TOLERANCE		SPECIFIED	0 DEG.	90 DEG.	OVER/UNDER TOLERANCE
1					1				
2					2				
3					3				
4					4				
5					5				
6					6				
7					7				
8					8				
9					9				



ANGLES RECORDED OPPOSITE/WITH
ROTATION FROM INLET END.
"ZERO" DEGREE POINT IS ____________________

RECORDED BY ____________
DATE ____________
ROTOR SERIAL NO. ____________
COMPRESSOR SERIAL NO. ____________
DRAWING NO. ____________
PLANT ____________
COMPRESSOR MODEL ____________
AS SHIPPED ____________
REMARKS ____________

VERIFIED ____________

API RP-687, FIGURE 3.B-1

SHAFT INSPECTION

JOB NO.
MODEL NO.
UNIT NO.
ID NO.
CUSTOMER
LOCATION
FORM NO.
TYPE

AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED

Figure 3.B-1—Shaft Inspection

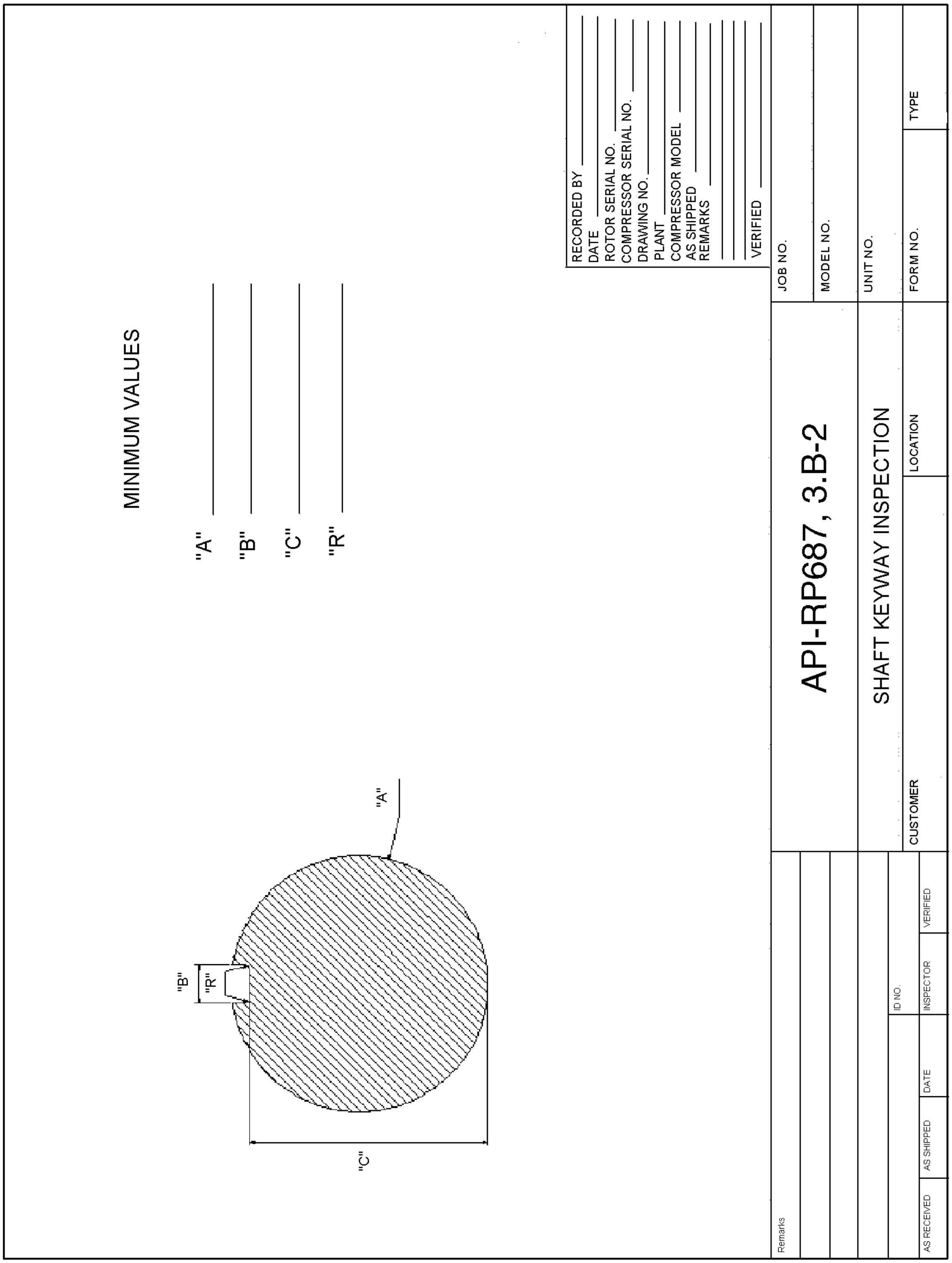


Figure 3.B-2—Shaft Keyway Inspection

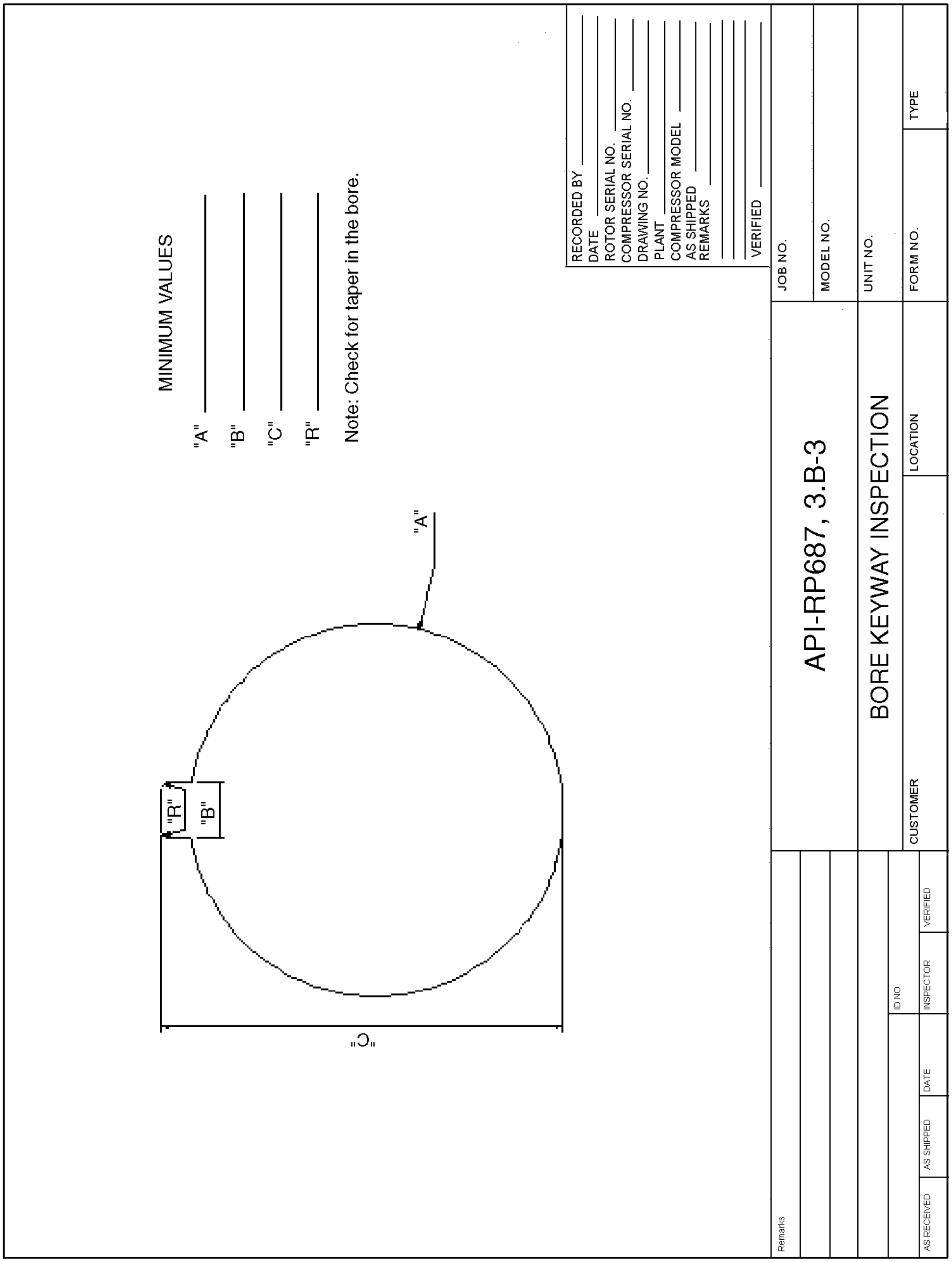


Figure 3.B-3—Bore Keyway Inspection

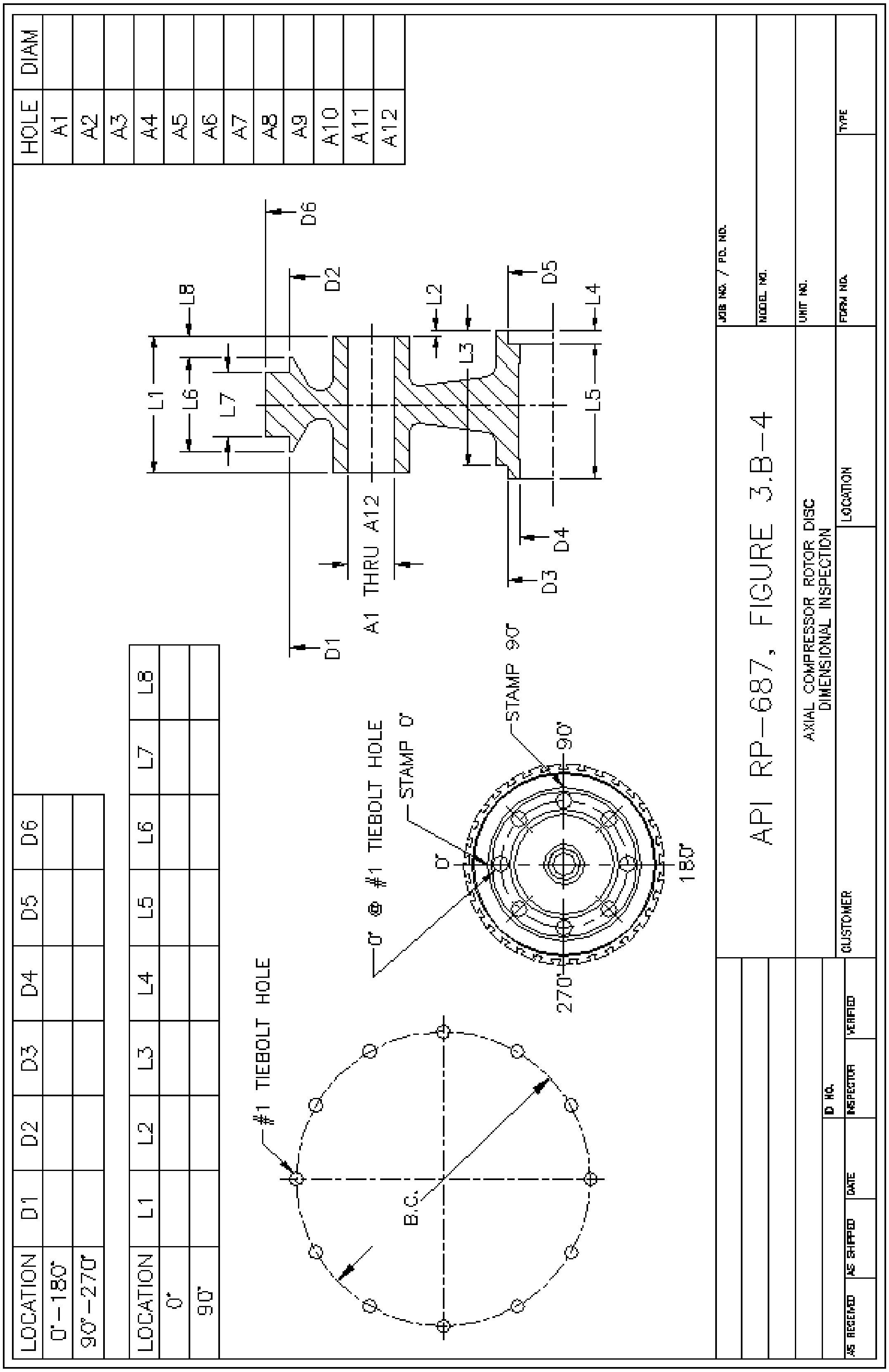


Figure 3.B-4—Axial Compressor Rotor Disc Dimensional Inspection

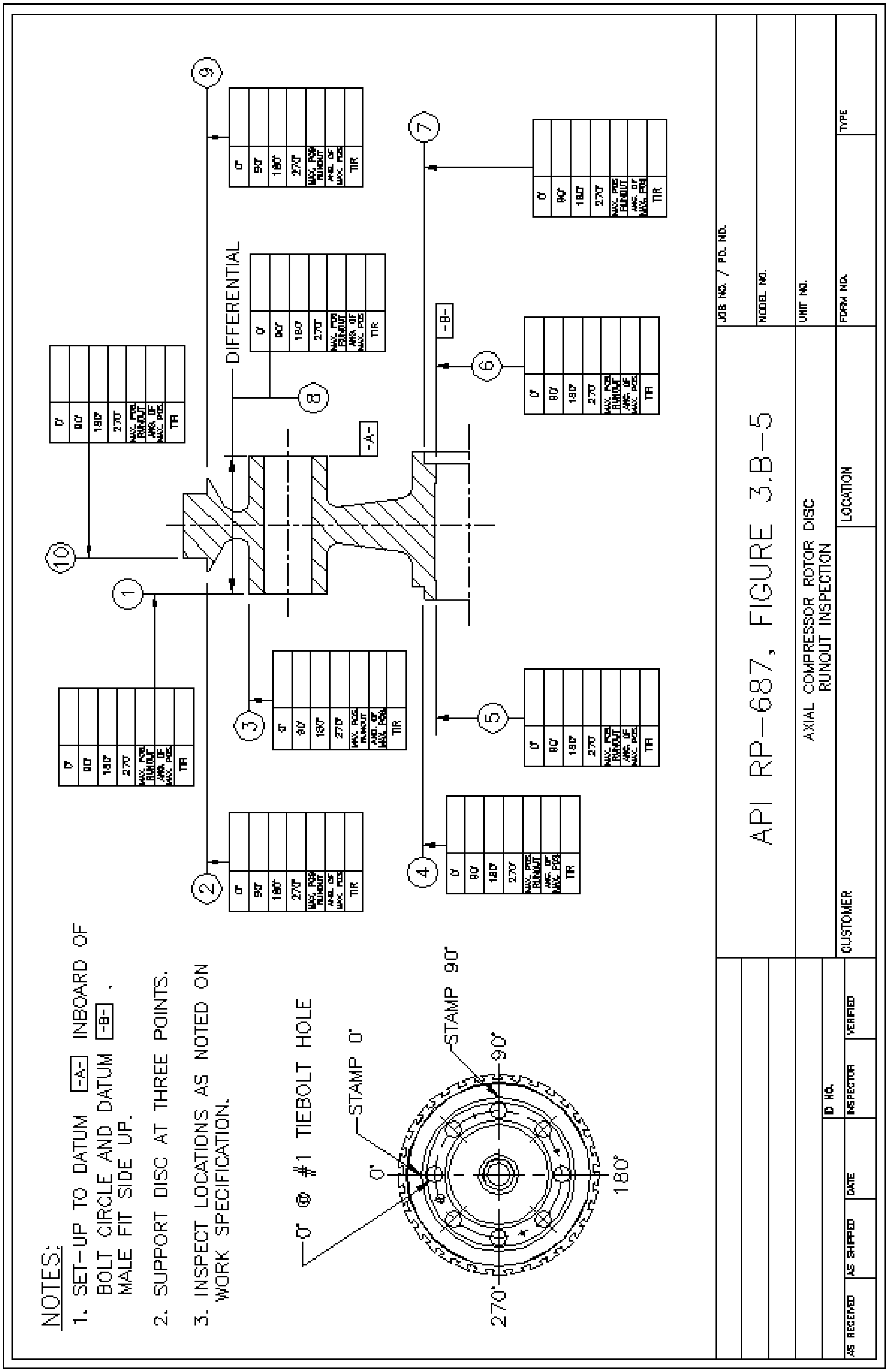


Figure 3.B-5—Axial Compressor Rotor Disc Runout Inspection

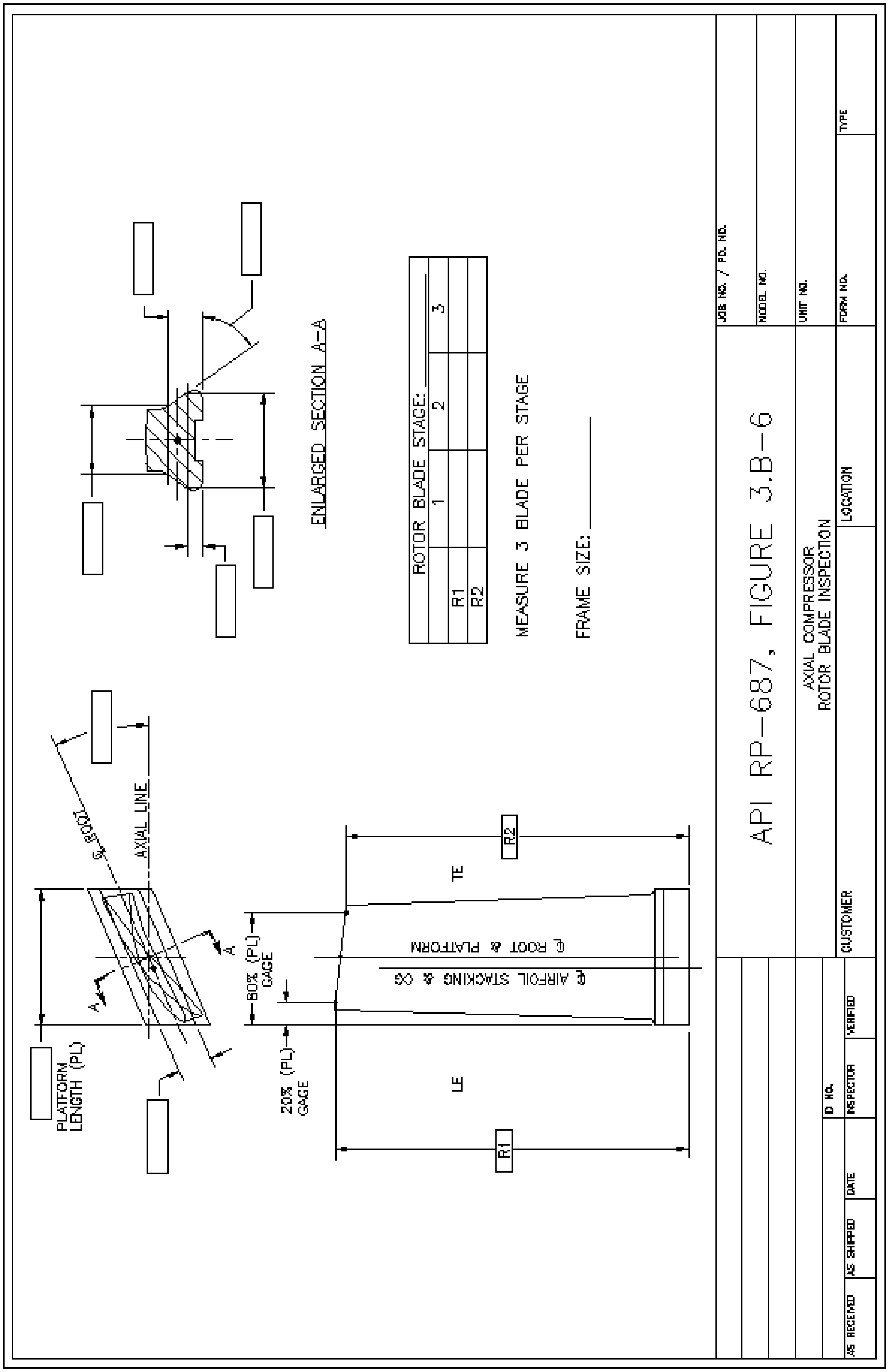


Figure 3.B-6—Axial Compressor Rotor Blade Inspection

STAGE										
SHAFT OD (1)										
DISC ID (2) D1										
D2										
INTERFERENCE FIT (ACTUAL)										
INTERFERENCE FIT (SPECIFIED)										
DISC SPACER (3) C-1										
D										
F										
INTERFERENCE FIT (ACTUAL)										
INTERFERENCE FIT (SPECIFIED)										
KEY TO SHAFT (WIDTH) (4)										
KEY TO DISC (WIDTH) (5)										
KEY TO DISC (HEIGHT) (6)										
SIDES OF KEY TO ℄ OF SHAFT (7)										

(1) DIMENSIONS FROM SHAFT INSPECTION REPORT.

(2) DIMENSIONS FROM DISC INSPECTION REPORT.

(3) DIMENSIONS FROM DISC SPACER REPORT.

(4) TYPICALLY 0.000 TO 0.0015" TIGHT.

(5) TYPICALLY 0.000 TO 0.003 LOOSE.

(6) TYPICALLY 0.005 TO 0.013 CLEARANCE.

(7) TYPICALLY PARALLEL TO ℄ OF SHAFT 0.0005" PER INCH LENGTH OF KEYWAY.

API RP-687, FIGURE 3.B-7

AXIAL COMPRESSOR INTERFERENCE FIT SUMMARY

			ID NO.	
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED

JOB NO.			
MODEL NO.			
UNIT NO.			
CUSTOMER	LOCATION	FORM NO.	TYPE

Figure 3.B-7—Axial Compressor Interference Fit Summary

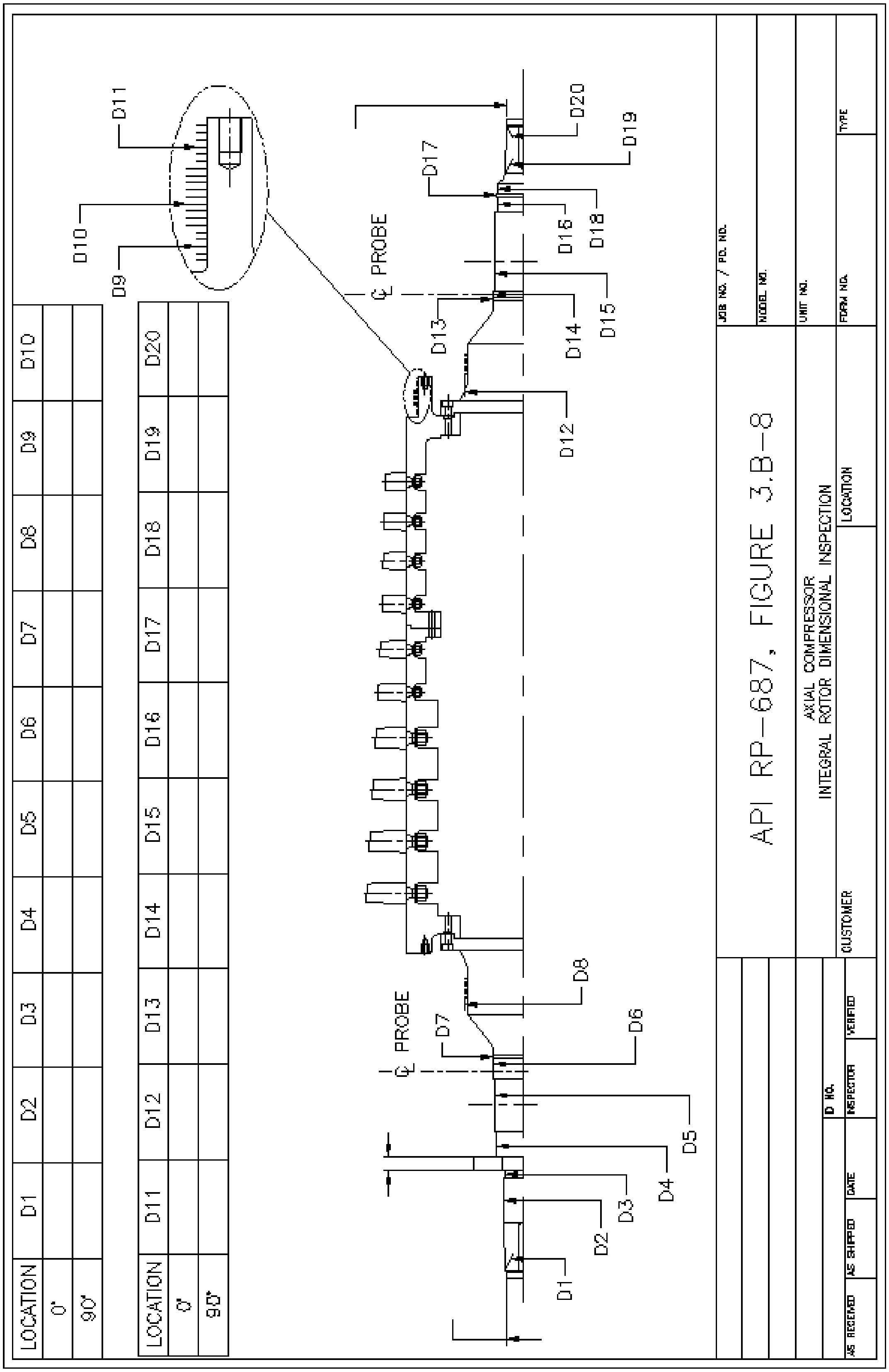


Figure 3.B-8—Axial Compressor Integral Rotor Dimensional Inspection

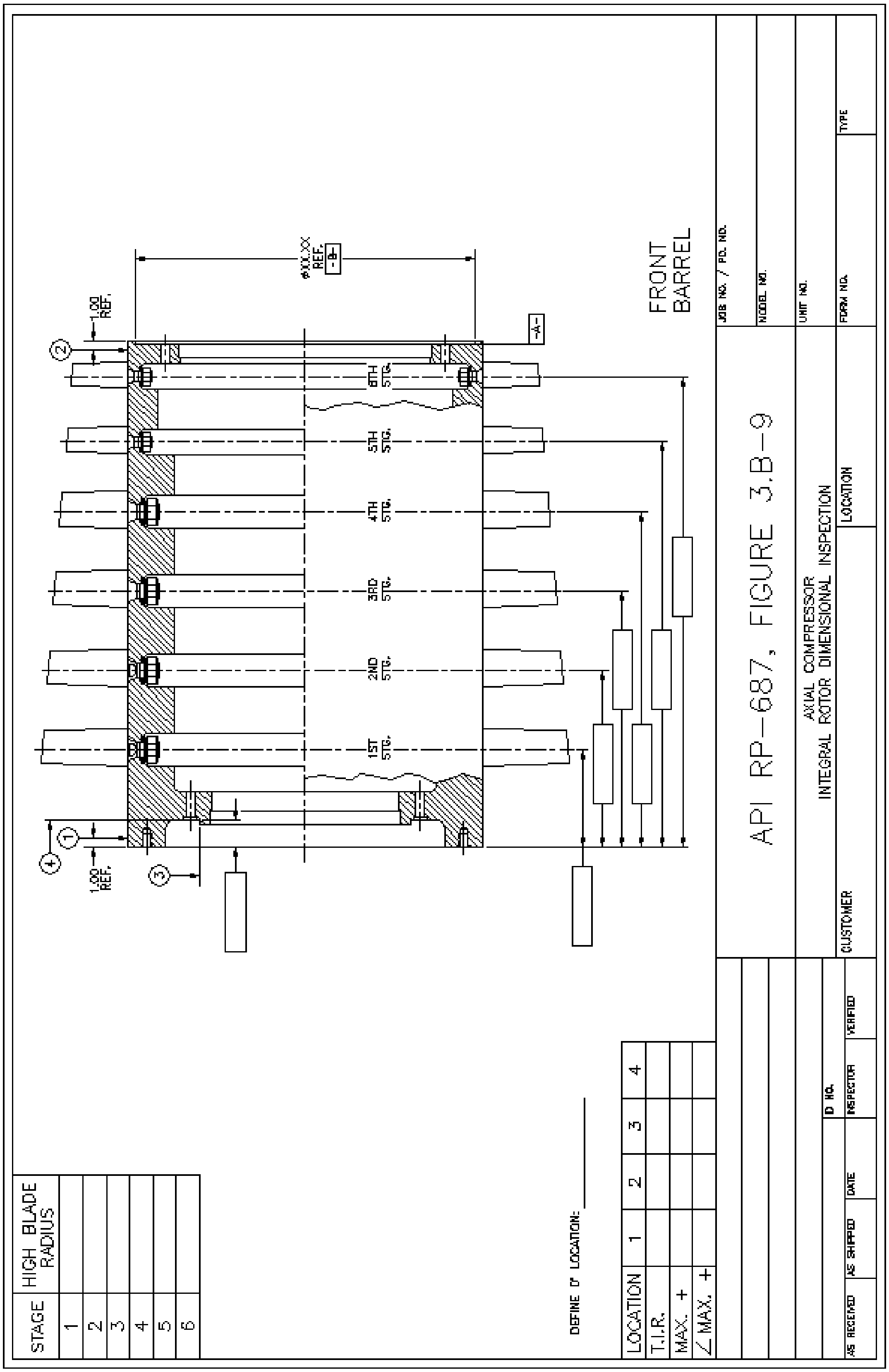


Figure 3.B-9—Axial Compressor Integral Rotor Dimensional Inspection

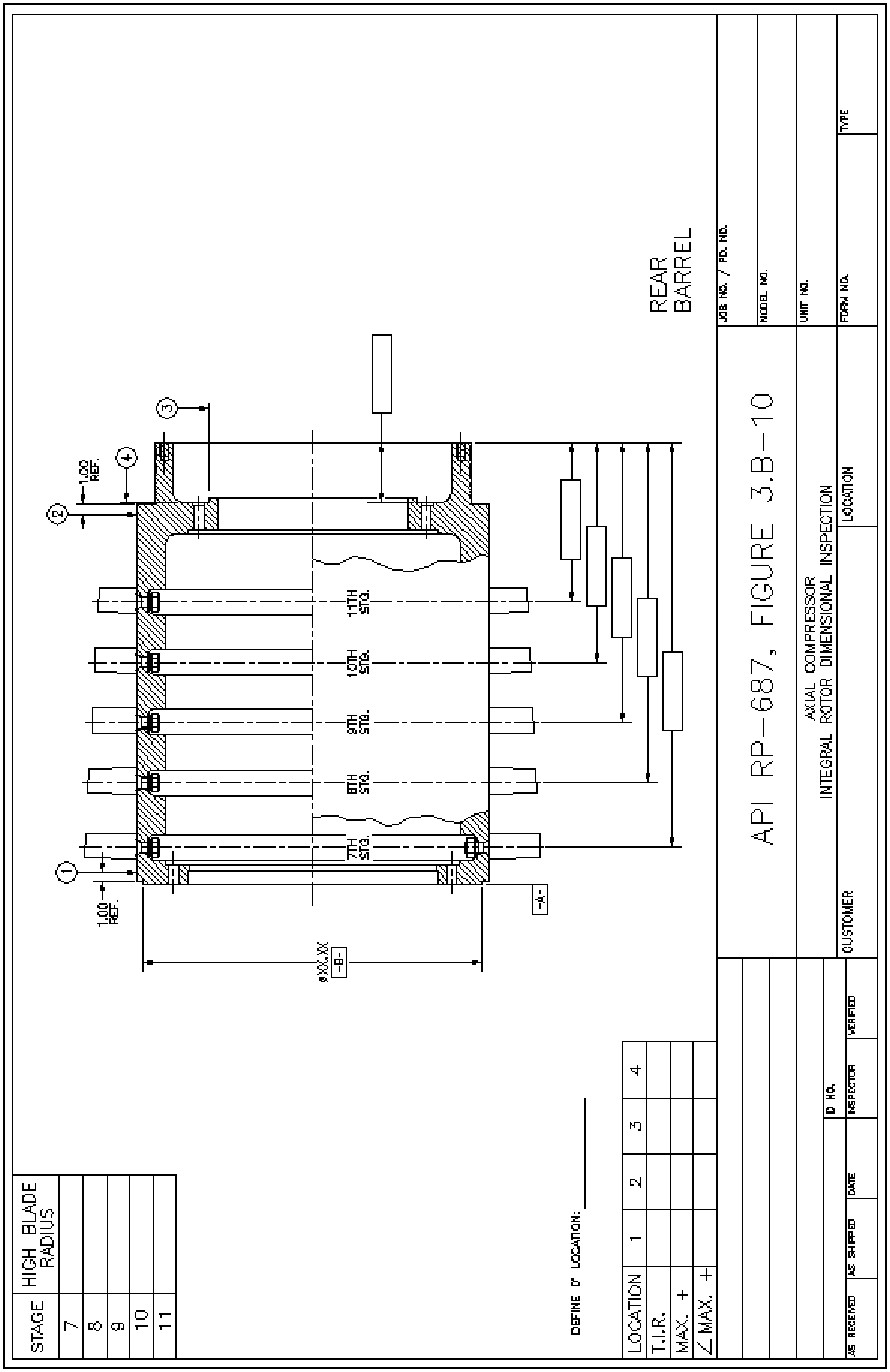


Figure 3.B-10—Axial Compressor Integral Rotor Dimensional Inspection

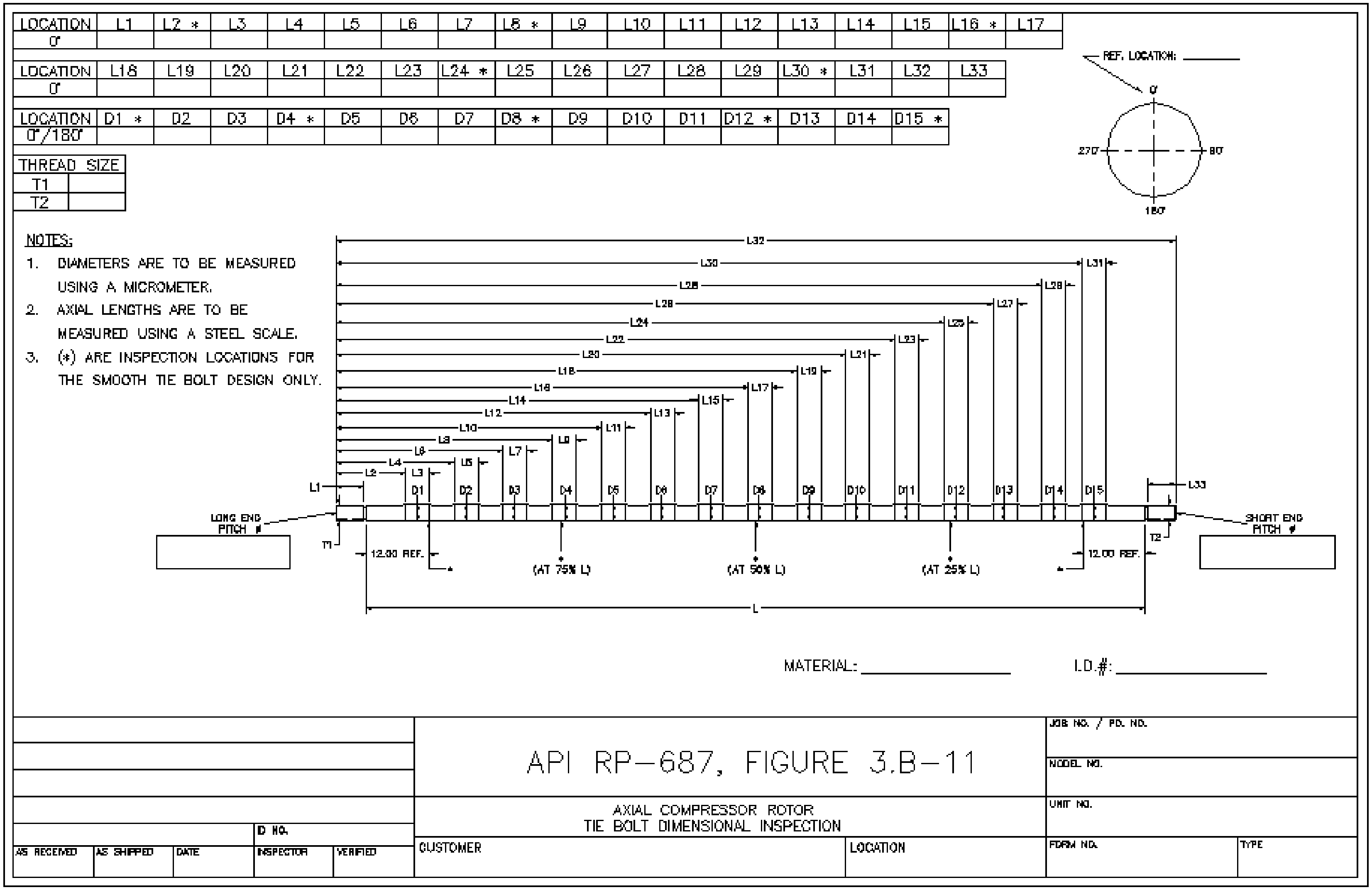


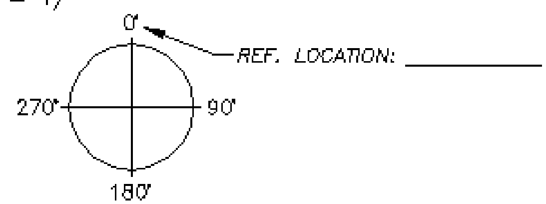
Figure 3.B-11—Axial Compressor Rotor Tie Bolt Dimensional Inspection

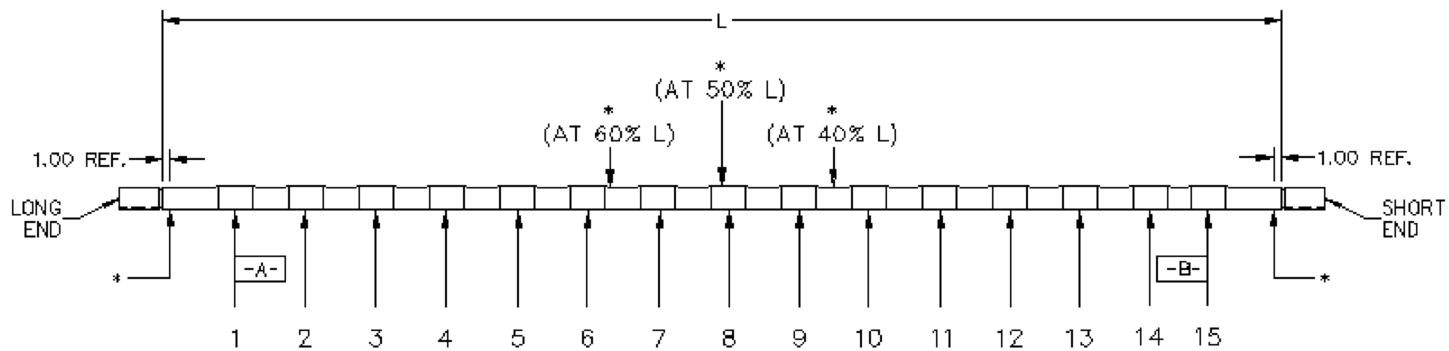
LOCATION	1*	2	3	4	5	6*	7	8*	9	10*	11	12	13	14	15*	16	17
T.I.R.																	
MAX +																	
∠ MAX +																	

ALL READINGS ARE IN TENTHS (0.0001" = 1)

NOTES:

1. SETUP WITH –A– AND –B– IN "V" BLOCKS.
2. (*) ARE INSPECTION LOCATIONS FOR THE SMOOTH TIE BOLT DESIGN ONLY.
3. INDICATE ONLY THOSE LOCATIONS SPECIFIED BY WORKSCOPE.





I.D.#: ___________

API RP–687, FIGURE 3.B–12

AXIAL COMPRESSOR ROTOR
TIE BOLT RUNOUT INSPECTION

								JOB NO. / PO. NO.
								MODEL NO.
			D NO.					UNIT NO.
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED	CUSTOMER	LOCATION	FORM NO.	TYPE

Figure 3.B-12—Axial Compressor Rotor Tie Bolt Runout Inspection

APPENDIX C—QUALITY/MANUFACTURING PLAN

QUALITY/MANUFACTURING PLAN

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	DISK OR DRUM MANUFACTURE (NEW)			**3.11**						
	Forgings—Material Certification Review	AISI/ ASTM Spec No.	C,H,M	Chap 1, 9.1		Compliance with AISI/ASTM Requirement	Report			
	Rough Machine					Mfg. Drawing				
	Ultrasonic Inspection			Chap 1,8.2.3	ASME Sect V Article 5 & 23	Chap 1,8.2.3.2	Certificate			
	Machining to contour					Mfg. Drawing				
	Stress Relieve/Heat Treat		H			Mfg. Drawing	Chart			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Final Machine, Including Blade Roots					Mfg Requirement	Report			
	Dimensional Inspection (including Blade Root Fit)					Mfg. Drawing	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			
	Blade Attachment Peening verify intensity with Alem strip		A		Mfg Drwg	Mfg Drwg	Report			
	Balance			Chap 1, 10.2		Chap 1, 10.2.11	Report			
	Coat (3)		A	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Coating process qualification (coupons) (3)		C,H	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	BLADE MANUFACTURE—NEW			**3.11**						
	Forgings, Bar Stock and/or envelope forgings	AISI/ ASTM Spec No.	C,H,M	Chap 1, 9.1		Compliance with AISI/ASTM Requirement	Report			
	Ultrasonic Inspection			Chap 1, 8.2.3	ASME Sect V, Article 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Dimensional Inspect airfoils and roots of all blading					Mfg. Drawing	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			
	Shot peen dovetails (roots), platform and tenon verify intensity with Almen Strips			3.11.2.2		Mfg Drawing	Report			
	Positive Material identification (PMI) each blade	AISI/ ASTM Spec No.					Certificate			
	Coat (3)		A	Chap 1, App L/ Chap 1, App K		Coating Procedure				
	Coating process qualification (coupons) (3)		C,H	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	TIE BOLT MANUFACTURE (NEW)			**3.11**						
	Forging	AISI/ ASTM Spec No.	C,H,M	Chap 1, 9.1		Compliance with AISI/ASTM Requirement	Report			
	Ultrasonic Inspection			Chap 1,8.2.3	ASME Sect V Article 5 & 23	Chap 1,8.2.3.2	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Roll threads					Mfg Requirement	Report			
	Verify thread profile and lead with “go/ no go” gauge & check with nut					Mfg Requirement	Report			
	Final Machined Dimensions					Mfg Requirement	Report			
	Wet Magnetic Particle Inspect			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize as applicable			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			
	Positive Material identification (PMI)	AISI/ASTM Spec No.					Certificate			
	Coat Threads		A							
	ROTOR SEAL AREA REPAIR			**3.1.3**			**(1)**			
	Weld Restoration			Chap 1, 9.2/ Chap 1, D.2						
	Undercut for Weld Preparation			Chap 1, D.2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D.2.2.1			Certificate			
	Hardness Check			Chap 1, D.2.2.3		Report	Certificate			
	Rough Dimensional Inspection of Undercut Area			Chap 1, D.2.2.3	Vendor Procedure	Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.2.4/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Weld Repair			Chap 1, D.2.3	WPS, PQR, WQR		WPS, PQR, WQR			
	Rough Machine			Chap 1, D.2.4.1		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.4.1/ Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Wet Magnetic Particle Inspect			Chap 1, D.2.4.1/ Chap 1, 8.2.4.1	ASTM E709	Chap 1, 8.2.4.4	Certificate			
	Post Weld Heat Treatment		H	Chap 1, D.2.5/ Chap 1, D.2.6	Vendor Procedure		Chart			
	Final Rough Machine			Chap 1, D.2.7						
	Ultrasonic Inspect			Chap 1, D.2.7/ Chap 1, 8.2.3						
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.7/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Hardness Check			Chap 1, D.2.7		Report	Certificate			
	Final Machine			Chap 1, D.2.8		Chap 1, D.2.8				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.9/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			
	Final Dimensional Inspection			Chap 1, D.2.9		Mfg Drawing	Report			
	Thermal Spray Restoration			Chap 1, 9.2/ Chap 1, D.3						
	Undercut for Thermal Spray Preparation			Chap 1, D.3.2.4		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D.3.2.2			Certificate			
	Hardness Check			Chap 1, D.3.2.2			Report			
	Rough Dimensional Inspection			Chap 1, D.3.2.4		Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.3.2.5/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Thermal Spray Build-up (1)			Chap 1, D.3.2.9	Vendor Procedure	Chap 1, D.3.2.10				
	Final Rough Machine					Mfg Requirement				

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Final Machine			Chap 1, D.3.3		Chap 1, D.3.3				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection			Chap 1, D.3.4		Mfg Drawing	Report			
	Reducing the Seal Area Restoration			Chap 1, D.4						
	Machine Undersize			Chap 1, D.4.5		Chap 1, D.4.5				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.4.6	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection			Chap 1, D.4.6		Mfg Drawing	Report			
	J STRIP REPAIR			**3.9**			**(1)**			
	Straighten J Strip			3.9.1		Mfg Drawing	Report			
	Liquid Penetrant Inspect			Chap 1, 8.2.4.3	ASTM E 165	Chap 1, 8.2.4.4	Certificate			
	J STRIP NEW			**3.9**			**(2)**			
	"J" strip and caulking material		C,M	3.9.1						
	Remove old "J" strips and install new "J" strips with caulking material			3.9.1		Mfg. Drawing				
	Machine to size			3.9.1		Mfg. Drawing				
	Final Dimensional Inspection			3.9.1		Mfg. Drawing	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	LABYRINTH SEALS (integral with shaft)			**3.9**						
	Weld Restoration			3.9.2/Chap 1, D.2						
	Undercut for Weld Preparation			Chap 1, D 2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D 2.2.1			Certificate			
	Hardness Check			Chap 1, D 2.2.3			Report			
	Rough Dimensional Inspection			Chap 1, D 2.2.3		Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.2.4/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Weld Repair			Chap 1, D 2.3	WPS, PQR		WPS, PQR			
	Rough Machine			Chap 1, D.2.4.1		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.4.1/ Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Dye Penetrant Inspect			Chap 1, 8.2.4	ASTM E165	Chap 1, 8.2.4.4	Certificate			
	Post Weld Heat Treatment		H	Chap 1, D 2.5/ Chap 1, D.2.6	Vendor Procedure		Chart			
	Final Rough Machine			Chap 1, D.2.7		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.7/ Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.7/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Hardness Check			Chap 1, D 2.7		Report	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Final Machine			Chap 1, D 2.8		Chap 1, D 2.8				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.9/ Chap 1, 8.2.4.1		Chap 1, 8.2.4.4				
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2				
	Dimensional Inspection			Chap 1, D 2.9		Mfg Drawing	Report			
	PILOT FIT REPAIR			**3.1.4**			**(1)**			
	Weld Restoration			Chap 1, D.2						
	Undercut for Weld Preparation			Chap 1, D.2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D.2.2.1			Certificate			
	Hardness Check			Chap 1, D.2.2.3		Report	Certificate			
	Rough Dimensional Inspection of Undercut Area			Chap 1, D.2.2.3	Vendor Procedure	Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.2.4/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Weld Repair			Chap 1, D.2.3	WPS, PQR, WQR		WPS, PQR, WQR			
	Rough Machine			Chap 1, D.2.4.1		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.4.1/ Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle Inspect			Chap 1, D.2.4.1/ Chap 1, 8.2.4.1	ASTM E709	Chap 1, 8.2.4.4	Certificate			
	Post Weld Heat Treatment		H	Chap 1, D.2.5/ Chap 1, D.2.6	Vendor Procedure		Chart			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.7/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Hardness Check			Chap 1, D.2.2.3		Report	Certificate			
	Final Machine			Chap 1, D.2.7		Chap 1, D.2.8				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.9/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection			Chap 1, D.2.9		Mfg Drawing	Report			
	Patch Ring Repair			3.1.4						
	Review Patch Ring Material Properties			3.1.4			Certificate			
	Rough Machine			3.1.4		Mfg Requirement				
	Install Ring And Final Machine			3.1.4						
	Final Dimensional Inspection			3.1.4			Report			
	TIE BOLT REPAIR			**3.8**			**(1)**			
	Blend Damaged Areas			3.8.1		Mfg. Req'ts				
	Dimensional Inspection			3.8.3			Report			
	DISK BORE REPAIR			**3.4**			**(1)**			
	Weld Restoration			3.4.1.1/ Chap 1, D.2						
	Undercut for Weld Preparation			3.4.1.1b/ Chap 1, D.2.2.3		Mfg Requirement	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Chemical Analysis of Base Material		C	Chap 1, D.2.2.1			Certificate			
	Hardness Check			Chap 1, D.2.2.3		Report	Certificate			
	Rough Dimensional Inspection of Undercut Area			Chap 1, D.2.2.3	Vendor Procedure	Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.2.4/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Weld Repair			Chap 1, D.2.3	WPS, PQR, WQR		WPS, PQR			
	Rough Machine			Chap 1, D.2.4.1		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.4.1/ Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle Inspect			Chap 1, D.2.4.1/ Chap 1, 8.2.4.1	ASTM E709	Chap 1, 8.2.4.4	Certificate			
	Post Weld Heat Treatment		H	Chap 1, D.2.5/ 2.6	Vendor Procedure		Chart			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.7/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Hardness Check			Chap 1, D.2.7		Report	Certificate			
	Final Machine			3.4.1.1 d/ Chap 1, D.2.8		Chap 1, D.2.8				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.4.1.1e/ Chap 1, D.2.9/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Dimensional Inspection			3.4.1.1f/ Chap 1, D.2.9		Mfg Drawing	Report			
	Balance			3.4.1.1 g		Chap 1, 10.2.11	Report			
	Thermal Spray Restoration			3.4.1.2/ Chap 1, D.3						
	Undercut for Thermal Spray Preparation			3.4.1.2a/ Chap 1, D.3.2.4		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D.3.2.2			Certificate			
	Hardness Check			Chap 1, D.3.2.2		Report	Certificate			
	Rough Dimensional Inspection			Chap 1, D.3.2.4		Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.3.2.5/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Thermal Spray Build-up (1)			3.4.1.2c/ Chap 1, D.3.2.9	Vendor Procedure	Chap 1, D.3.2.10				
	Final Rough Machine					Mfg Requirement				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			3.4.1.2e/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Final Machine			3.4.1.2f/ Chap 1, D.3.3		Chap 1, D.3.3				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection			Chap 1, D.3.4		Mfg Drawing	Report			
	Balance			3.3.1.2g		Chap 1, 10.2.11	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	BLADE ATTACHMENT ON ROTORS			**3.5**						
	Reducing the Blade Attachment Area Restoration			3.5.1/ Chap 1, D.4		Engineering Review				
	Machine Undersize			Chap 1, D.4.5						
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.4.6/ Chap 1, 8.4.2.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Shot peen blade attachment areas and verify intensity with Almen Strips			3.5.3		Mfg Drawing	Report			
	Final Dimensional Inspection			Chap 1, D.4.6		Mfg Drawing	Report			
	Balance			Chap 1, 10.2		Mfg. Drawing	Report			
	Coat (3)		A	3.5.4/Chap 1, App L/Chap 1, App K		Coating procedure	Report			
	Coating process qualification (coupons) (3)		C,H	3.5.4/Chap 1, App L/Chap 1, App K		Coating procedure	Report			
	Weld Restoration			3.5.2/Chap 1, D.2						
	Undercut for Weld Preparation			Chap 1, D.2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D.2.2.1			Certificate			
	Hardness Check			Chap 1, D.2.2.3		Report	Certificate			
	Rough Dimensional Inspection of Undercut Area			Chap 1, D.2.2.3	Vendor Procedure	Mfg Requirement	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.2.4/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Weld Repair			Chap 1, D.2.3	WPS, PQR, WQR		WPS, PQR			
	Rough Machine			Chap 1, D.2.4.1		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.4.1/ Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Dye Penetrant Inspect			Chap 1, 8.2.4.3	ASTM E165	Chap 1, 8.2.4.4	Certificate			
	Post Weld Heat Treatment		H	Chap 1, D.2.5/ 2.6	Vendor Procedure		Chart			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.7/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Hardness Check			Chap 1, D.2.7		Report	Certificate			
	Final Machine			Chap 1, D.2.8		Chap 1, D.2.8				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.9/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Shot peen blade attachment areas and verify intensity with Almen Strips			3.5.3		Mfg Drawing	Report			
	Dimensional Inspection			Chap 1, D.2.9		Mfg Drawing	Report			
	Balance			Chap 1, 10.2		Chap 1, 10.2.11	Report			
	Coat (3)		A	3.5.4/Chap 1, App L/Chap 1, App K		Coating procedure	Report			
	Coating process qualification (coupons) (3)		C,H	3.5.4/Chap 1, App L/Chap 1, App K		Coating procedure	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	BLADING REPAIR			**3.6**			**(1)**			
	Grind, Straighten, Polish			3.6.1 & 3.6.2		Mfg. Req'ts				
	Dimensional Inspection			3.6.1 & 3.6.2			Report			
	NDE Inspect			3.6.3/ Chap 1, 8.2.4		2.3.2.6/ Chap 1, 8.2.4.4	Certificate			
	Shot peen blade attachment areas and verify intensity with Almen Strips			3.6.3/ 3.6.6		Mfg Drawing	Report			
	Coat (3)		A	3.6.3/Chap 1, App L/Chap 1, App K		Coating procedure				
	Coating process qualification (coupons) (3)		C,H	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Blade Natural Frequency			3.6.5		3.6.5				
	Dimensional Inspection					Mfg. Drawing	Report			
	PRE-ASSEMBLY REQUIREMENTS			**4.1**						
	Axial Positioning Data			4.1.1b			2.A-1			
	Critical Dimensions and Runouts			4.1.1c			3.A-2, 3, 4, 5, 6, 7, 8, 9, 10, 11/ 3.B-2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12			
	Clean Mating Components			4.1.2						
	Clean Mating Surfaces			4.1.3						
	Key Clearances			4.1.4						

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Phase-Related Bare Shaft Runouts			4.1.5			3.B-1			
	New Locking Hardware			4.1.8						
	Protect Rotor Components			4.1.9						
	DISK ON SHAFT ROTOR ASSEMBLY/LOW SPEED BALANCE			**4.2**			**(2)**			
	Blue Check Coupling Fit			Chap 1, App C.6			Report			
	Balance Machine Calibration			Chap 1, 10.5.1		Mfg Requirement	Report			
	Component Balance all Major Sub Assemblies			4.2.1/ Chap 1, 10.2						
	Interference fit Summary			4.1.1c						
	Blade Weight or moment weight			4.1.6			Report			
	Sequentially Assemble and Low Speed Balance Rotor			4.2.2/4.2.3/4.2.4/ 4.2.5/4.2.6/4.2.7/ 4.2.14/4.2.15/ 4.2.17		4.2.8–4.2.13/ 4.2.16/4.2.19				
	Residual Unbalance—Rotate U-Joint Drive			Chap 1, 10.3.10		Chap 1, 10.3.10	Report			
	Residual Unbalance/Sensitivity Check			4.2.20/ Chap 1, 10.4		Chap 1, App. A	Report			
	Residual Unbalance With Coupling			Chap 1, 10.4.3/ Chap 1, 10.4.4		Chap 1, 10.3.5	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Rotor Assembly—Final Dimensional			4.2.19/ 4.8.1		Mfg Drawing	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Rotor Assembly—Locate and mark high blade tip			4.8.1		Mfg Drawing	Report			
	Rotor Assembly—Gauss Level			4.8.1		Mfg Drawing	Report			
	Coat (3)		A	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Coating process qualification (coupons) (3)		C,H	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Rotor Balance (complete) after coating (3)			Chap 1, 10.3		Chap 1, 10.3.9	Report			
	Residual Unbalance—Rotate U-Joint Drive (3)			Chap 1, 10.3.10		Chap 1, 10.3.10	Report			
	Residual Unbalance/Sensitivity Check (3)			Chap 1, 10.4		Chap 1, App. A	Report			
	Residual Unbalance With Coupling (3)			Chap 1, 10.4.3/ Chap 1, 10.4.4		Chap 1, 10.3.5	Report			
	Rotor Assembly—Final Dimensional (3)			4.8.1		Mfg Drawing	Report			
	Rotor Assembly—Final Indication (3)			4.8.1		Mfg Drawing	Report			
	Rotor Assembly—Gauss Level (3)			4.8.1		Mfg Drawing	Report			
	Weight of Assembled Rotor			4.8.1		Mfg Drawing	Report			
	Prep For Shipment			Chap 1, 11						
	INTEGRAL ROTOR ASSEMBLY/ LOW SPEED BALANCE			**4.3**			**(2)**			
	Blue Check Coupling Fit			4.4.4			Report			
	Balance Machine Calibration			Chap 1, 10.5.1		Mfg Requirement	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Rotor Indication (stage by stage/ complete)			4.3.1			Report			
	Rotor Balance (stage by stage/ complete)			Chap 1, 10.2/ Chap 1, 10.3		Chap 1, 10.3.9	Report			
	Residual Unbalance—Rotate U-Joint Drive			Chap 1, 10.3.10		Chap 1, 10.3.10	Report			
	Residual Unbalance/Sensitivity Check			4.3.5/ Chap 1, 10.4		Chap 1, App. A	Report			
	Residual Unbalance With Coupling			Chap 1, 10.4.3/ Chap1, 10.4.4		Chap 1, 10.3.5	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Rotor Assembly—Final Dimensional			4.8.1		Mfg Drawing	Report			
	Rotor Assembly—Locate and mark high blade tip			4.8.1		Mfg Drawing	Report			
	Rotor Assembly—Gauss Level			4.8.1		Mfg Drawing	Report			
	Coat (3)		A	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Coating process qualification (coupons) (3)		C,H	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Rotor Balance (complete) after coating (3)			Chap 1, 10.3		Chap 1, 10.3.9	Report			
	Residual Unbalance—Rotate U-Joint Drive (3)			Chap 1, 10.3.10		Chap 1, 10.3.10	Report			
	Residual Unbalance/Sensitivity Check (3)			Chap 1, 10.4		Chap 1, App. A	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Residual Unbalance With Coupling (3)			Chap 1, 10.4.3/ Chap 1, 10.4.4		Chap 1, 10.3.5	Report			
	Rotor Assembly—Final Dimensional (3)			4.8.1		Mfg Drawing	Report			
	Rotor Assembly—Final Indication (3)			4.8.1		Mfg Drawing	Report			
	Rotor Assembly—Gauss Level (3)			4.8.1		Mfg Drawing	Report			
	Weight of Assembled Rotor			4.8.1		Mfg Drawing	Report			
	Prep For Shipment			Chap 1, 11						
	TIE BOLT ROTOR ASSEMBLY/LOW SPEED BALANCE			**4.4**			**(2)**			
	Interference Fit Summary			4.1.1c		Mfg Drawing	Report			
	Stack Rotor Per Stacking Chart			4.4.2		Mfg Drawing	Report			
	Tighten Tie Bolts, Record Stretch And Rod Length			4.4.3–4.4.13		Mfg Drawing	Report			
	Grind Journals, Thrust Faces, Coupling Fits and Vibration Probe Tracks			4.4.17		Mfg Drawing				
	Dimensionally Inspect Rotor						Report			
	Blue Check Coupling Fit			4.4.4			Report			
	Rotor Indication			4.4.14–4.4.16		4.4.12-4.4.16	Report			
	Balance Machine Calibration			Chap 1, 10.5.1		Mfg Requirement	Report			
	Rotor Balance (stage by stage/ complete)			4.4.18-4.4.20/ Chap 1, 10.3		Chap 1, 10.3.9	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Residual Unbalance—Rotate U-Joint Drive			Chap 1, 10.3.10		Chap 1, 10.3.10	Report			
	Residual Unbalance/Sensitivity Check			4.4.24/ Chap 1, 10.4		Chap 1, App. A	Report			
	Residual Unbalance With Coupling			Chap 1, 10.4.3/ Chap 1, 10.4.4		Chap 1, 10.3.5	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Rotor Assembly—Locate and mark high blade tip			4.8.1		Mfg Drawing	Report			
	Rotor Assembly—Final Indication			4.8.1		Mfg Drawing	Report			
	Rotor Assembly—Gauss Level			4.8.1		Mfg Drawing	Report			
	Weight of Assembled Rotor			4.8.1		Mfg Drawing	Report			
	Prep For Shipment			Chap 1, 11						
	DRUM ROTOR ASSEMBLY/LOW SPEED BALANCE			**4.5**			**(2)**			
	Dimensional Inspect blade fits			4.5.1			Report			
	Blue inspection of fit			4.5.3			Report			
	Install blades—dimensional on blade clearances			4.5.4/ 4.5.5			Report			
	Measure blade frequencies			4.5.6			Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Interference Fit Summary			4.1.1c		Mfg Drawing	Report			
	Stack Rotor per Stacking Chart					Mfg Drawing	Report			
	Tighten Tie Bolts, Record Stretch And Rod Length					Mfg Drawing	Report			
	Grind Journals, Thrust Faces, Coupling Fits, and Vibration Probe Tracks					Mfg Drawing				
	Dimensionally Inspect Rotor						Report			
	Blue Check Coupling Fit						Report			
	Rotor Indication (stage by stage/ complete)			4.5.7-4.5.12		4.5.7-4.5.12	Report			
	Balance Machine Calibration			Chap 1, 10.5.1		Mfg Requirement	Report			
	Rotor Balance (stage by stage/ complete)			4.5.13/ Chap 1, 10.3		Chap 1, 10.3.9	Report			
	Residual Unbalance—Rotate U-Joint Drive			Chap 1, 10.3.10		Chap 1, 10.3.10	Report			
	Residual Unbalance/Sensitivity Check			4.5.14/ Chap 1, 10.4		Chap 1, App. A	Report			
	Residual Unbalance With Coupling			Chap 1, 10.4.3/ Chap 1, 10.4.4		Chap 1, 10.3.5	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Rotor Assembly—Final Dimensional			4.8.1		Mfg Drawing	Report			
	Rotor Assembly—Locate and mark high blade tip			4.8.1		Mfg Drawing	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Rotor Assembly—Gauss Level			4.8.1		Mfg Drawing	Report			
	Coat (3)		A	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Coating process qualification (coupons) (3)		C,H	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Rotor Balance (complete) after coating (3)			Chap 1, 10.3		Chap 1, 10.3.9	Report			
	Residual Unbalance—Rotate U-Joint Drive (3)			Chap 1, 10.3.10		Chap 1, 10.3.10	Report			
	Residual Unbalance/Sensitivity Check (3)			Chap 1, 10.4		Chap 1, App. A	Report			
	Residual Unbalance With Coupling (3)			Chap 1, 10.4		Chap 1, 10.4.3/ 10.4.4	Report			
	Rotor Assembly—Final Dimensional (3)			4.8.1		Mfg Drawing	Report			
	Rotor Assembly—Final Indication			4.8.1		Mfg Drawing	Report			
	Rotor Assembly—Gauss Level			4.8.1		Mfg Drawing	Report			
	Weight of Assembled Rotor			4.8.1		Mfg Drawing	Report			
	Prep For Shipment			Chap 1, 11						
	PARTIALLY BLADED ROTOR ASSEMBLY/LOW SPEED BALANCE			**4.6**			**(2)**			
	Balance Rotor			4.6.1/ Chap 1, 10.2/ Chap 1, 10.3						
	Disk-On Shaft Rotors			4.6.2/ 4.2						

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Integral Rotors			4.6.3/ 4.3						
	Tie Bolt Rotors			4.6.4/ 4.4.19–4.4.23						
	Reblading of Partially De-Bladed Row			4.6.5						

DESCRIPTION/OPERATION		
NOTES:		
1) All verifying document reports shall reference procedure and state drawing acceptance criteria.	2) All WPS, WQR, and PQR shall be available to purchaser for review and approval prior to any welding. 3) Only applies to rotors specified to be coated.	
LEGEND GENERAL	**MATERIAL CERT**	**INSPECTION POINT**
H.T. Heat Treatment PT Liquid Penetrant Inspection MT Magnetic Particle Inspection VT Visual Inspection UT Ultrasonic Inspection W/A Will Advise N/A Not Applicable	A Certificate Of Compliance C Chemical Analysis M Mechanical Properties H Heat Treat Charts I Impact	O Observation W Witness / Hold PT * Vendor To Confirm That Requirement Has Been Met
Report: defines a vendor generated quality control inspection form/report that will satisfy industry standards or requirements outlined on purchase order.		

APPENDIX D—INSPECTION FORMS FOR ASSEMBLY AND BALANCING

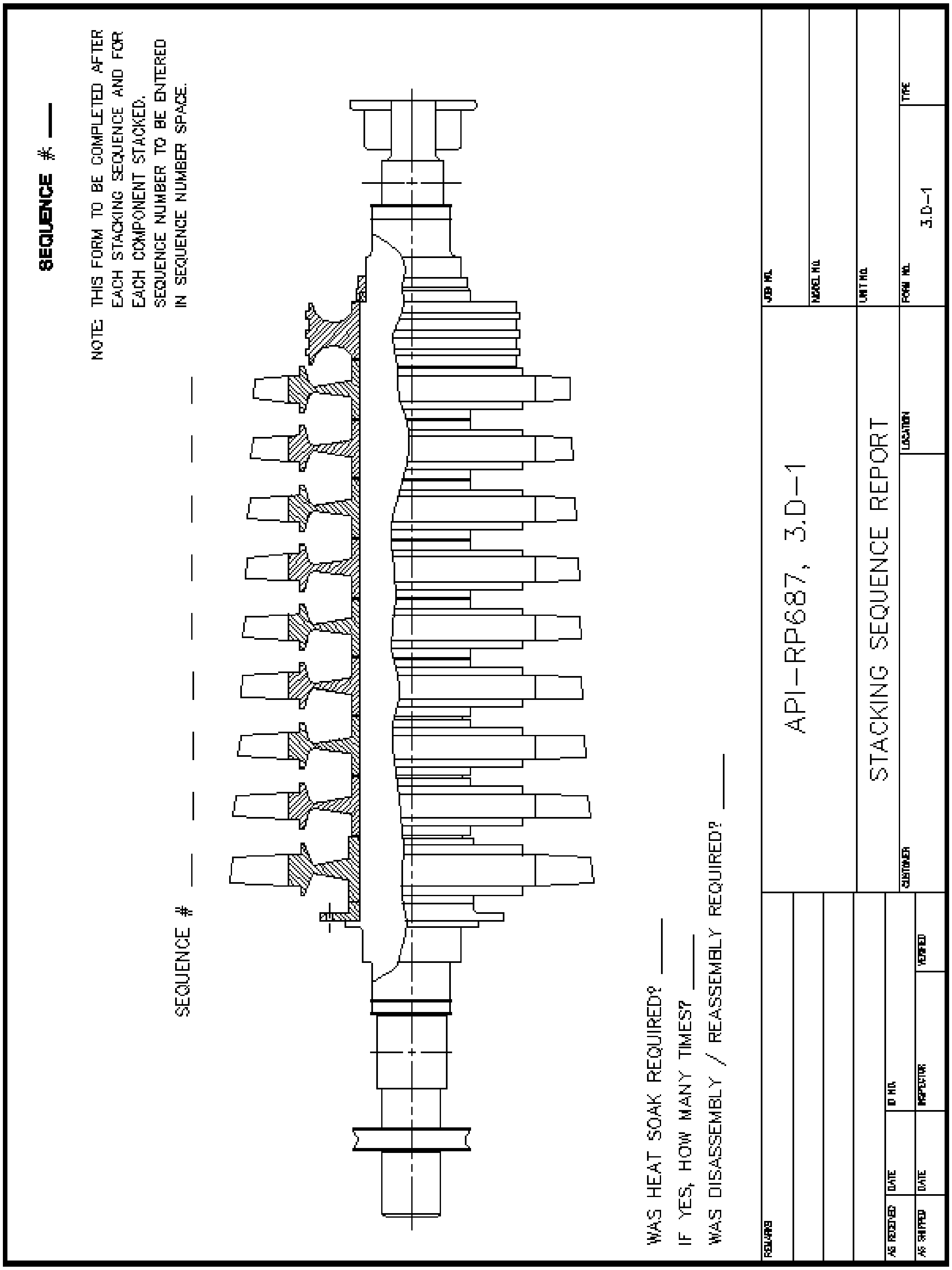
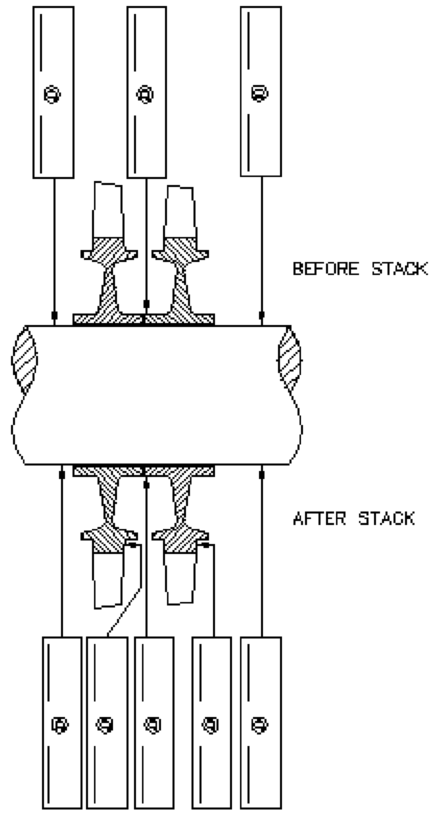


Figure 3.D-1—Stacking Sequence Report

SEQUENCE #: ___

NOTE: THIS FORM TO BE COMPLETED AFTER EACH STACKING SEQUENCE AND FOR EACH COMPONENT STACKED.
SEQUENCE NUMBER TO BE ENTERED IN SEQUENCE NUMBER SPACE.



WAS HEAT SOAK REQUIRED? ___
IF YES, HOW MANY TIMES? ___
WAS DISASSEMBLY / REASSEMBLY REQUIRED? ___

API-RP687, 3.D-2

SEQUENTIAL STACKING RUNOUT REPORT

REMARKS			
AS RECEIVED	DATE	ID NO.	
AS SHIPPED	DATE	INSPECTOR	VERIFIED
CUSTOMER	LOCATION		
JOB NO.	MODEL NO.	UNIT NO.	
FORM NO. 3.D-2	TYPE		

Figure 3.D-2—Sequential Stacking Runout Report

SEQUENCE NUMBER(S): ______________

NOTE: THIS FORM TO BE COMPLETED AFTER EACH STACKING SEQUENCE AND FOR EACH COMPONENT STACKED. SEQUENCE NUMBER TO BE ENTERED IN SEQUENCE NUMBER SPACE.

INITIAL BALANCE MACHINE READINGS: ☐ GRAMS ☐ OUNCES

LEFT PLANE ______________ AT ______________ DEGREES ON ______________ END.

RIGHT PLANE ______________ AT ______________ DEGREES ON ______________ END.

ROTOR AND SETUP DATA:

BEARING SPAN (MM/INCHES): ______________

BALANCE PLANE SEPARATION (MM/INCHES): ______________

LEFT PLANE RADIUS (MM/INCHES): ______________

RIGHT PLANE RADIUS (MM/INCHES): ______________

"ZERO" REFERENCE POINT IS: ______________

LEFT JOURNAL WEIGHT (Kg/Lbs): ______________

RIGHT JOURNAL WEIGHT (Kg/Lbs): ______________

MAX. CONTINUOUS OPERATING SPEED: ______________

BALANCE SPEED: ______________

FINAL BALANCE MACHINE READINGS: ☐ GRAMS ☐ OUNCES

LEFT PLANE ______________ AT ______________ DEGREES ON ______________ END.

RIGHT PLANE ______________ AT ______________ DEGREES ON ______________ END.

REMARKS				**API RP-687, FIGURE 3.D-3**		JOB NO.	
						MODEL NO.	
AS RECEIVED	DATE	ID NO.		**SEQUENTIAL STACKING BALANCE REPORT**		UNIT NO.	
AS SHIPPED	DATE	INSPECTOR	VERIFIED	CUSTOMER	LOCATION	FORM NO. 3.D-3	TYPE

Figure 3.D-3—Sequential Stacking Balance Report

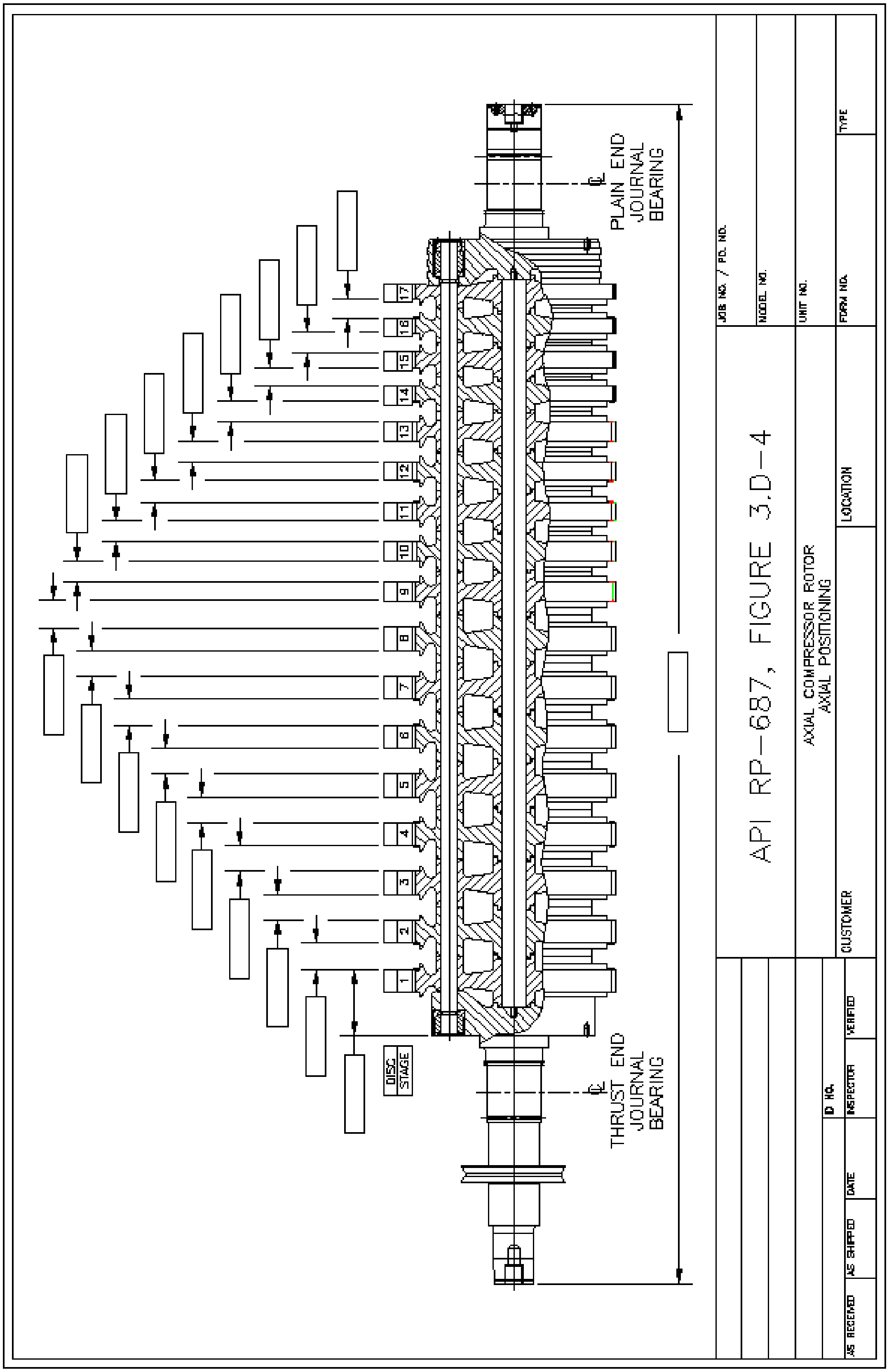


Figure 3.D-4—Axial Compressor Rotor Axial Positioning

APPENDIX E—AUDITORS CHECK LIST

E.1 General

This Appendix, along with Appendix H, Chapter 1, is a checklist to provide information for the owner and the vendor to aid in summarizing the scope of the rotor repair.

Repairs require clear owner/vendor communication and the assignment of responsibilities. The format of this checklist provides a summary of the items required and the parties responsible.

Each item on this checklist has a circle or a square to indicate whether the owner or vendor, respectively, is responsible for obtaining the information or performing the task. The owner must indicate, for each item, whether the item is to be witnessed, observed, or verified. Typically, inspections, processes or tests may be witnessed or observed while verification is the review of the results of the inspections, processes, tests, or other documentation so as to insure that the requirements have been met.

AUDITORS CHECK LIST

Customer: ______________________________

Job/Project Number: ______________________________

Owner Equipment Identification Number: ______________________________

OEM Equipment Serial Number: ______________________________

Rotor Identification Number: ______________________________

Repair Purchase Order Number: ______________________________

Vendor Job Number: ______________________________

Auditors Check List

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice			Date Inspected or Verified By	Status
			W	O	V		
Section 1—Inspection of Assembled Rotor Phase I							
Deblade Rotor	O/☐	1.3.1					
Clean Rotor	☐	1.3.3					
Inspection Forms/Drawings	☐	1.3.4					
Casing Tip Clearance	☐	1.3.5a					
Axial/Radial Dimensions	☐	1.3.5b					
Axial Stack-up	☐	1.3.5c					
Axial Gaps	☐	1.3.6					
NDE	☐	1.3.7/1.3.8					
Circumferential Offset	☐	1.3.9					
Axial Dimensions	☐	1.3.10					
Tie Bolt Stretch	☐	1.3.11					
Inspection Report	☐	1.4					
Section 2—Disassembly and Inspection of Rotor							
Rotor Disassembly	O/☐	2.2.1					
Matchmark Components	☐	2.2.3					
Interference Fits	☐	2.2.4					
Rotor Unstacking	☐	2.2.5					
Tie-Bolt Rotor							
Stack Dimensions	☐	2.2.6.1					
Remove Tie Bolt(s)	☐	2.2.6.2					
Rotors with Shrunk on Components							
Heat Components	☐	2.2.7.1					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
Drum Rotor							
Blade Identification	☐	2.2.8.1a					
Angle Consistency	☐	2.2.8.1b					
Blade Disassembly	☐	2.2.9					
Eliminate Weight(s)	☐	2.2.10					
Clean Blade(s)	☐	2.2.11					
Clean Rotor Components	☐	2.3.1					
Interference Fits	☐	2.3.2.1					
Mating Fits	☐	2.3.2.2					
Part(s) Inspection	☐	2.3.2.3					
Shaft Dimensions	☐	2.3.2.4a					
Bore Dimensions	☐	2.3.2.4b					
Stacking Heights	☐	2.3.2.4c					
Spacers, Seals	☐	2.3.2.4d					
Balance Piston	☐	2.3.2.4e					
Thrust Collar	☐	2.3.2.4f					
Key Clearances	☐	2.3.2.4g					
Thread Dimensions	☐	2.3.2.4h					
Tie Bolt Runout	☐	2.3.2.4i					
Blade Slots	☐	2.3.2.4j					
Disk, Spacers	☐	2.3.2.4k					
Blade Groove Inspection	☐	2.3.2.4l					
NDE	☐	2.3.2.5/ 2.3.2.6					
Photographs	☐	2.3.2.7					
Threaded Areas	☐	2.3.2.8					
Nuts	☐	2.3.2.9					
Review	☐	2.4.1					
Component Bore	☐	2.4.2					
Engineering Evaluation	☐	2.4.3					
Blade Reusability	☐	2.4.4					
Job Scope	☐	2.5.1					
Fasteners Coating	☐	2.5.2					
Blade Coating	☐	2.5.3					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
SECTION 3—Repair Processes and New Component Manufacture							
Engineering Review	☐	3.1.2					
Rotor Seal Areas	☐	3.1.3					
Pilot Fits	☐	3.1.4					
Disk Faces	☐	3.1.5					
Integral Rotors							
Disk Weld Repair	☐	3.2					
Built Up Rotors							
Shaft Repair	☐	3.3.1					
Disk Bore Weld Repair	☐	3.4.1.1					
Disk Bore Thermal Spray Repair	☐	3.4.1.2					
Disk Bore Oversize Repair	☐	3.4.1.3					
Disk Bore HVOF/ HVLF Repair	☐	3.4.1.4					
Oversize Blade Attachment Areas	☐	3.5.1					
Disk Weld Repair	☐	3.5.2					
Peen Blade Attachment Areas	☐	3.5.3					
Blade Attachment Areas Recoating	☐	3.5.4					
Blade Undersize Repair	☐	3.6.1					
Identify Cause of Blade Damage	☐	3.6.2					
NDE	☐	3.6.3					
Natural Frequency	☐	3.6.5					
Peen Blades	☐	3.6.6					
Coatings	☐	3.7.1					
Re-Coating	☐	3.7.2					
Tie-Bolt Body Repair	☐	3.8.1					
Tie-Bolt Thread Repair	☐	3.8.2					
Tie-Bolt Straightened	☐	3.8.3					
J Strips	☐	3.9.1					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
Seal Teeth	☐	3.9.2					
Sleeves, Spacers	☐	3.10					
Component Replacement							
Component Replacement Requirements	☐	3.11.1					
New Blade Manufacture	☐	3.11.2					
SECTION 4—Assembly and Balancing							
Dimensional Verification	☐	4.1.1					
Mating Components	☐	4.1.2					
Mating Surfaces	☐	4.1.3					
Keyway Verification	☐	4.1.4					
Phase Related Runouts	☐	4.1.5					
Blade Positioning	☐	4.1.6					
Circumferential Distribution	☐	4.1.7					
Blade Locking Hardware	☐	4.1.8					
Protect Components	☐	4.1.9					
Balancing Corrections	☐	4.1.10					
Disk on Shaft Rotors							
Component Balance	☐	4.2.1					
Assembly Balance	☐	4.2.2					
Assembly Sequence	☐	4.2.3					
Heat Components	☐	4.2.4					
Coating Restrictions	☐	4.2.5					
Shaft Positioning	☐	4.2.6					
Rotor Cooldown	☐	4.2.8					
Position Verification	☐	4.2.9					
Axial Gaps	☐	4.2.10					
Phase Related Runouts	☐	4.2.11					
Disk Rim Runouts	☐	4.2.12					
Shaft Runout	☐	4.2.13					
Balance	☐	4.2.14/ 4.2.15					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice			Date Inspected or Verified By	Status
			W	O	V		
Axial Dimensions	☐	4.2.16					
Balance Corrections	☐	4.2.17					
Blade Dimensions	☐	4.2.18					
Overall Stack	☐	4.2.19					
Residual Unbalance	☐	4.2.20					
Integral Rotors							
Rotor Measurements	☐	4.3.1					
Balance Rotor	☐	4.3.2					
Blade Operations	☐	4.3.3					
Blade Dimensions	☐	4.3.4					
Residual Unbalance	☐	4.3.5					
Tie Bolt Rotors							
Rotor Stacking Chart	☐	4.4.2					
Tie Bolt Alignment	☐	4.4.3					
Trial Assembly	☐	4.4.4					
Rotor Stacking Tools	☐	4.4.5					
Pre-stack Rotor	☐	4.4.6					
Tie Bolt Tensioning	☐	4.4.7					
Heat Components	☐	4.4.8					
Coating Restrictions	☐	4.4.9					
Component Assembly	☐	4.4.10					
Align Tie Bolt Holes	☐	4.4.12					
Install Tie Bolts	☐	4.4.13					
Disk Rim Runouts	☐	4.4.14					
Seal Land Runouts	☐	4.4.15					
Rotor Disk	☐	4.4.16					
Machining/Grinding/“Truing Up”	☐	4.4.17					
Balance	☐	4.4.18					
Loose Blade Designs	☐	4.4.19					
Blade Assembly	☐	4.4.20					
Blade Dimensions	☐	4.4.21					
Axial Movement	☐	4.4.22					
Locking Clips	☐	4.4.23					
Residual Unbalance	☐	4.4.24					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
Drum Rotors with Conical Fit Blades							
Conical Blade Fits	☐	4.5.1					
Blade Nuts	☐	4.5.2					
Blue Contact Check	☐	4.5.3					
Blade Positioning	☐	4.5.4					
Blade Clearances	☐	4.5.5					
Natural Frequencies	☐	4.5.6					
Install Stub Shaft	☐	4.5.7					
Install Drum	☐	4.5.8					
Install Final Stub Shaft	☐	4.5.9					
Rotor Measurements	☐	4.5.10					
Blade Tips	☐	4.5.11					
Blade Dimensions	☐	4.5.12					
Balance	☐	4.5.13					
Residual Unbalance	☐	4.5.14					
Reassembly of Partially Disassembled Rotors							
Balance Rotor	☐	4.6.1.1					
Disk-On Shaft Rotors	☐	4.6.2					
Integral Rotors	☐	4.6.3					
Tie Bolt Rotors	☐	4.6.4					
Reblading Of Partially De-Bladed Row	☐	4.6.5					
Blade Reusability	☐	4.6.5.1					
Add Blades	☐	4.6.5.2					
Balance Rotor	☐	4.6.5.3					
Residual Unbalance	☐	4.6.5.4					
Blade Tip Measurements	☐	4.7.1					
Blade Tip Grinding	☐	4.7.2					
Final Inspection	☐	4.8					
Documentation		4.9					

CHAPTER 4—SPECIAL PURPOSE STEAM TURBINES

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Rotor Repair

Chapter 4—Special Purpose Steam Turbines

1 Inspection of Assembled Rotor Phase I

1.1 GENERAL

This section describes the data to be recorded and the requirements of Phase I inspection of an assembled steam turbine rotor. This section is to be used in addition to the requirements of Chapter 1, Section 7, Phase I inspection.

Tutorial:

Rotors: Steam turbine rotors are of either solid forging or shrunk on disk (built-up) construction. The integral (solid) rotor design is applied over 250 mps (825 fps) blade tip speed or when stage inlet steam temperature exceeds 440°C (825°F). Below these requirements, built-up rotor construction is permitted.

Blading: Steam turbine blading designs include different types of fastening the blade to the disk. Examples include axial, radial and circumferential entry, as shown in Figure 4.1-1. Also, blades may incorporate shrouding at the tip of the blade. This may be mechanically fastened with peened tenons or may be integral with the blade. Some designs do not require any shrouding or dampening devices such as lacing wires.

1.2 DEFINITIONS

1.2.1 airfoil: The part of the blade which is exposed to steam velocity and/or pressure and converts this energy to mechanical work.

1.2.2 axial entry blade: A blade which is assembled to the disk using axially machined grooves for each blade.

1.2.3 blade, also referred to as "bucket": A component which is attached to the disk and includes the blade root, platform, and airfoil. The blade may be free standing or shrouded and may incorporate other mechanical features for damping.

1.2.4 blade moment weight: A value that represents the combination of the blade weight and its center of gravity.

1.2.5 blade pan weight: The static weight of the blade.

1.2.6 disk: A component which has blades attached at the outside diameter. May be separate from or integral with the shaft.

1.2.7 disk-on-shaft rotor: An assembly which includes the turbine shaft and separate disks which are interference fitted to the shaft.

1.2.8 erosion shield: A material attached to the inlet side of the blade airfoil section to minimize the damage from moisture particle impact.

1.2.9 finger root blade: A blade which is assembled to the disk using a circumferentially machined groove in the outside diameter of the disk. The blade root consists of two or more "fingers" which fit in the disk's machined grooves. The blade is attached to the disk using one or more axial pins.

1.2.10 integral shroud: A design where the blade and shroud are manufactured in one piece.

1.2.11 lacing (tie) wire: Wire located on the tip of the blade or another location on the airfoil to group blades.

1.2.12 major components: Major components are blades, turbine disks, bladed disks, and the shaft keys that go with them.

1.2.13 platform: A blade feature located between the airfoil and the blade root.

1.2.14 radial entry blade: A blade which is assembled to the disk using a circumferentially machined groove for the blades with an entry slot.

1.2.15 shroud: A component which is located on the tip of the blade and may span several blades to form groups. Shrouds may be integral to the blade or otherwise fastened to the blade with "peened" tenons or rolled in lacing wire.

1.2.16 solid rotor: A rotor in which the disks are forged integral with the turbine shaft.

1.2.17 tenon: The mechanical feature which is integral with the blade tip which secures the shroud to the blade when peened.

1.3 INSPECTION

1.3.1 In addition to the requirements in Chapter 1, Section 7, the following precautions and inspections in 1.3.2 through 1.3.16 shall be made.

1.3.2 Appendix A inspection forms and drawings or equal shall be used in recording the necessary information. These inspection forms and drawings may be modified by the vendor to represent the actual configuration of the rotor.

1.3.3 Measure and record axial stack-up dimensions in a minimum of two circumferential locations, referenced from the thrust collar shaft shoulder (or active side of the integral thrust collar), to the rim of each disk and its flow path surface closest to this collar and to all other components that may be

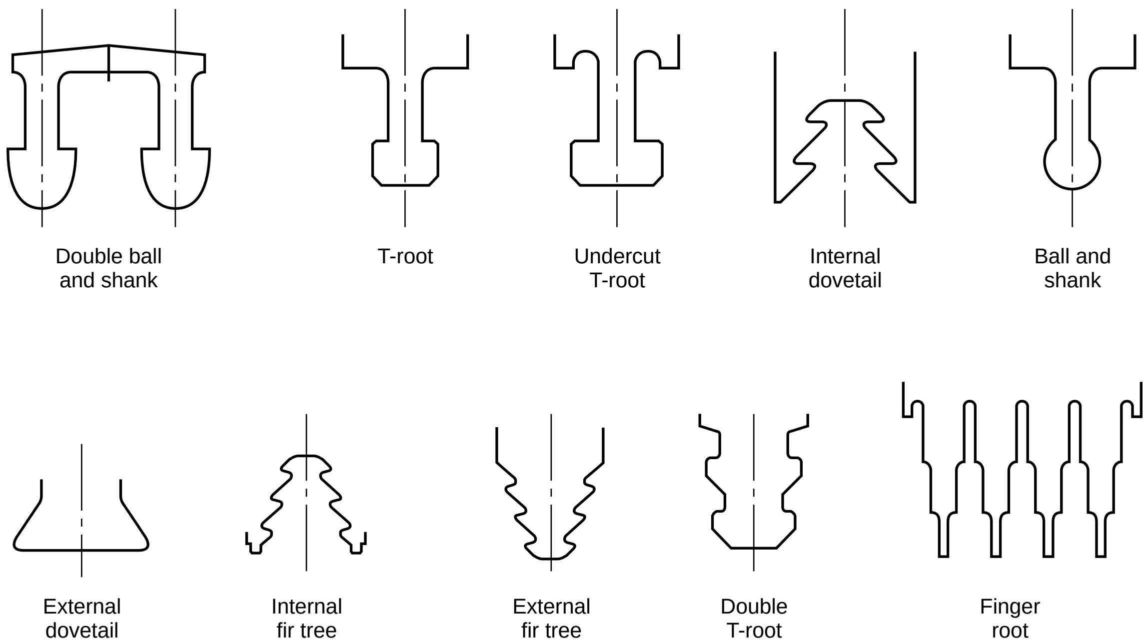


Figure 4.1-1—Examples of Blade to Disk Fasteners

removed from the shaft. The flow path reference surface may be the leading edge of the shroud or the leading edge of the blade platform for shrouded blades or the leading edge of the blade adjacent to the platform for free standing blades. Each dimension is to be referenced and recorded from the same thrust location. One of the axial stack-up dimensions should be taken at the zero phase reference point and the second should be 90° apart.

1.3.4 Measure and record the axial runout of rim of each disk and the leading edge of each shroud.

1.3.5 Measure axial gaps between all shrunk on parts. Generally the gap should be a minimum of approximately 0.10 mm (0.004 in.).

1.3.6 Remove mechanical overspeed trip mechanism and inspect for degradation. For bolt/pin styles, the dimensional setting and configuration of the device is to be recorded for reassembly purposes.

1.3.7 Visually inspect the flow path area and record any damage including corrosion, corrosion pitting, erosion, cracks, thin leading and trailing edges and damage from foreign objects or any obstruction to flow.

1.3.8 Confirm that the shrouds and lacing devices are all contacting the blades as they should, and if an interlocking design, confirm such a fit. Check for elongated lacing wire holes in the airfoil and reduction in the diameter of the lacing wire where the wire contacts the airfoil. Record any damage.

1.3.9 NDE the accessible areas of each blade, shroud, tenon and blade root per Chapter 1, paragraph 8.2.4.

1.3.10 The NDE evaluation described in Chapter 1, Table 1.8-1 shall be a severity level of “A” for all components except for blade and blade to disk attachments where all visible indications shall be reported.

1.3.11 Inspect blade erosion shields for cracks or separation per Chapter 1, paragraph 8.2.4 using Liquid Penetrant Inspection.

1.3.12 In addition to the NDE requirements of Chapter 1, paragraph 8.2.4, designs incorporating blade tenons which have suspected damage may be ultrasonically inspected per Chapter 1, paragraph 8.2.3.

1.3.13 Inspect disk surfaces for defects such as cracks and erosion in the steam balance holes, balance weight grooves/dovetails and also for corrosion pitting and general quality of surface finish.

1.3.14 Check hardness of severely rubbed areas including disk surfaces and shrouding.

1.3.15 Inspect the accessible areas of any mounting rings, locking nuts, and keys for damage or distortion.

1.3.16 Do not remove disks from the shaft nor flow path components unless instructed by the owner.

1.4 INSPECTION REPORT

1.4.1 The vendor shall prepare an initial inspection documentation package (report) consisting of all of the information identified in Chapter 1, Section 7 and Section 1.3, as applicable, including recommendations for removal of blades for disk groove and blade root inspection.

1.4.2 The vendor may minimize the phase I inspection if it is obvious that the disk on shaft rotor needs to be disassembled and a more detailed Phase II inspection performed. Some reasons for disassembly include:

a. Shaft damage such as fretting, cracking, bearing journal/ shaft end damage.

b. Thermally unstable rotor.

c. Disk/flow path damage requiring repair or removal.

d. Severe corrosion/erosion.

e. Over speed of rotor where yielding of material is a concern or evident.

f. Rerate requiring new components.

g. Shifting of components, loss of thermal gaps.

h. Bowed rotor, or rotors with excessive runout, or runouts which are out of phase.

i. Balance level not repeatable in the shop or field.

j. Previous history suggesting full disassembly is warranted.

k. Over temperature history.

1.4.3 If the owner has authorized dismantling of the rotor, the vendor shall proceed to Section 2 and provide "as found" data for each component such as disks, balance pistons, etc.

2 Rotor Disassembly Phase II

2.1 GENERAL

This section describes the data to be recorded and the requirements of Phase II inspection of a steam turbine rotor disassembly. Phase II inspection may require partial or total unstacking of built up rotors and possibly deblading of built-up and integral rotors.

2.2 DISASSEMBLY FOR PHASE II INSPECTION

● **2.2.1** When specified, or with owner's approval as a result from Phase I inspection, the vendor shall dismantle the rotor to the extent specified.

● **2.2.2** The owner shall specify if the rotor blades are to be removed from the rotor disks for shrouded or peened designs.

2.2.3 Prior to dismantling, the requirements of paragraphs 1.3.3, 1.3.4, and 1.3.5 are to be completed and recorded.

2.2.4 Matchmark components and record location and orientation as required to assure proper reassembly.

2.2.5 Care must be exercised in the disassembly to prevent the damaging of components. Often rotor disks and shafts have interference fits between the components that require heat to allow disassembly. A thorough understanding of the rotor construction and the interference fits is required to safely disassemble the rotor without causing component damage.

2.2.6 Unstacking of the rotor should be done in the vertical position.

2.2.7 All major component(s) shall be uniformly heated for disassembly. In no case shall a component be more than 280 K (500°F) above the shop ambient temperature.

Note: Heating components for disassembly is a critical step. Heated components should be heated uniformly to minimize circumferential temperature variations that could cause distortion. As permanent distortion may occur. This heating may be accomplished by the use of two or more large (flare tip or rosebud) torches, however, care must be exercised to avoid a heat rate that is too rapid to maintain even heating. The differential temperature should be carefully monitored with temperature indicating temperature sticks without sulfur components or a non-contacting infrared surface temperature gun.

2.2.8 All mating fits shall be visually inspected for signs of yielding, distress, fretting, galling, etc.

2.2.9 During disassembly, check and record axial dimensions between the thrust collar shaft shoulder (or active side of the integral thrust collar) to the face of the bore nearest the thrust collar on each impeller. Record data on a worksheet designed for the particular rotor as outlined in Appendix "A".

2.2.10 Blade Disassembly

2.2.10.1 Prior to disassembly of the blading, the following shall be recorded and sketched as appropriate:

a. Total number of blades.

b. Number of blades per grouping (packet).

c. Number and location of groupings.

d. Diameter of lacing (tie) wires.

e. Location and features of locking/loading blades and the method of fastening to the rotor.

f. Width, thickness, overhang, and profile of shroud bands.

2.2.10.2 Identify the type of blade fastening and method of assembly. Develop a work plan to address blade removal. This plan shall include specific items such as removal of locking blade(s) or block(s) and the salvage of damaged blades for future investigation.

This plan shall be used to minimize damage to the disks due to deblading.

Note: Blade removal usually commits to the installation of new blades and locking components in the disk.

2.2.10.3 Coated blades that are to be reused are to be stripped of any coating.

2.3 PHASE II INSPECTION

2.3.1 Carefully, abrasively clean the rotor components to base metal. See Chapter 1 paragraph 7.2.2 for cleaning methods and precautions. Chemical stripping may be required to adequately evaluate pitting due to corrosion.

Note: This will result in the removal of any protective coatings.

2.3.2 The vendor shall perform the following inspections in paragraphs 2.3.2.1 through 2.3.2.8 after the Phase II disassembly has been completed.

2.3.2.1 All interference fits shall be dimensionally inspected to determine the amount of interference remaining and if component rework is required to restore the design interference.

2.3.2.2 All mating fits shall be visually inspected for signs of yielding, distress, fretting, galling, etc.

2.3.2.3 Visually inspect and record the condition of each part removed. Measure and record all shaft and disk component interface size on a worksheet designed for the particular component per Appendix "B" or equal. This data will be used to determine the roundness and taper of each component. This shall include:

a. Bare shaft fit sizes, overall length, and runouts (including thrust collar shoulder).

b. Bore and bore length for all turbine disks. Also record the setback dimension from the HP side of the turbine disk to the leading edge of the shroud.

c. The stacking heights of individual components, at 90° intervals.

d. Radial and axial runouts of the individual components.

e. Bore sizes and lengths of shaft spacers, interstage sleeves, etc.

f. Balance piston bore size and length.

g. Thrust collar and thrust collar spacer(s) bore sizes and lengths.

h. Key clearances on all keyways,

1. With keys installed in keyways, measure from tops of keys to opposite side of shaft.

2. Measure across bore of components to bottoms of keyways.

Note: Item "2" above plus total component interference fit minus item "1" above, equals key clearance.

2.3.2.4 Remove and deburr area(s) of any previously installed balancing weight(s). The location and amount of each weight is to be recorded.

2.3.2.5 Unless otherwise specified, use applicable NDE procedures as outlined in Chapter 1, Section 8 after disassembly, to determine the existence of any indications on the components to be reused or subject to failure analysis. Record the size, location, and orientation of any indications on a sketch. All ferro-magnetic components shall be wet magnetic particle inspected.

2.3.2.6 The NDE evaluation described in Chapter 1, Table 1.8-1, shall be a severity level of "A" for all components except for blade and blade to disk attachments where all visible indications shall be reported.

2.3.2.7 Photographs are to be taken per Chapter 1, Appendix G, of any component with any unusual or abnormal condition. A photo log should be maintained for all work performed.

2.3.2.8 Threaded areas of the shaft are to be visually inspected and dimensionally verified by screwing on a gage. Inspect for setscrew marks.

Note: When a gauge is not available for checking the threads, the mating nut may be used with judgement.

2.4 EVALUATION OF PHASE II INSPECTION DATA

2.4.1 Review and evaluate all data and information to determine the acceptability of the inspections, resulting fits, clearances and runouts.

2.4.2 Component bore

If the latest design dimensions, are not available, the following criteria may be used as a guide in determining the acceptable taper and contact area.

2.4.2.1 For straight fit designs, the component bore should not exceed a taper of 0.3 µm/mm (0.0003 in./in.) of bore length, with a maximum of 25.4 µm (0.001 in.).

2.4.2.2 Interference between wheel bore and shaft shall be sufficient for all speed and temperature transients. The actual required interference shall be determined by an engineering review prior to reassembly.

2.4.3 Evaluate the blades for reuse, based upon the guidelines given in 3.7.

2.4.4 For hydraulic fit, tapered bore disk designs, a blue contact check shall be performed per Chapter 1, Appendix C with a minimal contact area of 80%. The disk may be used for this verification as long as there are not any raised discontinuities in the shaft surface.

2.5 PHASE II RECOMMENDED JOB SCOPE

2.5.1 The vendor shall notify the owner upon completion of Phase II Inspection, provide a copy of all Phase II documentation, summarize the results of Phase II Inspection, and prepare the recommended job scope for approval by the owner.

2.5.2 Coated blades that are to be reused are to be stripped of any coating and NDE.

3 Repair Processes and New Component Manufacture

3.1 GENERAL

3.1.1 In addition to the general repair processes and new component manufacturing requirements discussed in Chapter 1, Section 9, the following procedures and practices are recommended to accommodate the conditions and considerations unique to steam turbines. Components shall be repaired as outlined in 3.2, through 3.10, or new components supplied as outlined in 3.11.

3.1.2 In order to minimize distortion problems in the final assembly, components having a straight, continuous bore and a bore length-to-diameter ratio of 0.75 or greater without a center relief, should have an engineering review. This engineering review is to determine the justification and criteria to incorporate a center relief and land fit concept on each end of the bore.

3.1.3 Repairs to damaged rotor seal areas (disks or shafts), typically caused from contact with labyrinth type seals, may be repaired per the methods in Chapter 1, paragraph 9.2.

3.1.4 The rotor shall be checked and corrected for a thermal bow in accordance with paragraph 3.1.4.1 through 3.1.4.4.

Tutorial: It is quite common that turbine rotors arrive at the shop with thermal bows as a result of being shutdown while the rotor is hot. It is reasonable to assume that the rotor was properly balanced at a previous time. Therefore, no work should be accomplished that would alter the original balance state before reasonable attempts are made to re-establish the original rotor centerline, after which the repairs can be carried out under controlled conditions.

Notes:

1. This procedure is not required for built up rotors that will be disassembled.

2. This procedure will be done after removal of damaged blading/shrouding and/or repair of damaged journals.

3.1.4.1 Continuously roll the rotor in a balance machine at 300 to 500 rpm during the entire process.

3.1.4.2 The shaft interstage seal areas and the turbine disks shall be gradually heated with one or two large (flare tip or rosebud) torches to a temperature of approximately 180°C to 200°C (350°F to 400°F). Rotor temperatures shall be monitored with temperature indicating temperature stick or a non-contacting infrared surface temperature gun to assure that the differential temperatures of the rotor do not exceed approximately 55 K (100°F).

3.1.4.3 The rotor shall be continuously rotated in the balancing machine until its temperature is not more than 50°C (120°F).

3.1.4.4 If the initial heat soak procedure results in an eccentricity change of at least 25%, a second heat soak procedure should be performed to assure stability of the rotor centerline. The eccentricity change as a result of the second heat soak procedure should not exceed 25% as compared to the value prior to the second heat soak.

3.1.5 Rubs on disk faces may be removed by machining after an engineering review.

3.1.6 Pitting on disk faces may be removed by machining or cleaned by abrasive blasting after an engineering review.

3.2 INTEGRAL ROTOR

Integral rotor disk(s) may be repaired by welding as outlined in Chapter 1, Appendix D.2. Disk weld repair shall be accomplished by partially or completely machining the outside diameter of the disk and building back up by welding.

3.3 DISK ON SHAFT ROTOR

3.3.1 Repair of the shaft under the disk(s) shall be per Chapter 1, paragraph 9.2 and Quality/Manufacturing Plan, Chapter 1, Appendix K.

3.4 DISK

3.4.1 Disk bores that are oversized may be restored by the methods outlined in 3.4.1.1, to 3.4.1.4. An engineering evaluation is required to determine which method to use.

Due to the differences in the coefficients of thermal expansion and bore dilation, chrome or nickel plating shall not be used as a repair method for impeller bore buildup.

3.4.1.1 Weld Repair

Disk bores may be repaired by the welding process outlined in Chapter 1, Appendix D.2 using an owner approved procedure. Repair procedure is to include the following additional steps:

a. Record angular position of keyways.

b. Generously radius all keyway(s) corners and chamfer the sides of the keyway(s) prior to welding.

c. Weld up keyway, disk bore and as necessary seal areas per Chapter 1, Appendix D.2.

d. Machine repaired areas. Disk bore is to have a maximum surface finish of 0.8 μm (32 μinch) Ra. Repaired disk seal areas and keyways are to have a maximum surface finish of 1.6 μm (64 μinch) Ra.

e. Wet magnetic particle inspect per Chapter 1, paragraph 8.2.4.

f. Record disk dimensions and runouts.

g. Balance disk as per Chapter 1, Section 10.

Note: The face of the disk at the bore may need to be welded to provide for the disk final bore length to remain the same length as original.

● **3.4.1.2** When specified, bore out the disk oversize and weld build up the shaft per Chapter 1, Appendix D.2. or HVOF/HVLF spray the shaft per Chapter 1, Appendix D.3.5. While technically acceptable, the economics must be carefully compared to the other repair techniques.

Note: For assembly and disassembly purposes it may be necessary to perform this task on all the disks.

● **3.4.1.3** When specified, bore out the disk oversize and manufacture a new oversize shaft. While technically acceptable, the economics must be carefully compared to the other repair techniques.

Note: For assembly and disassembly purposes it may be necessary to perform this task on all the disks.

● **3.4.1.4** When specified, bore out the disk oversize and HVOF or HVLF spray the bore per Chapter 1, Appendix D.3.5. The metal powder used for build up shall have been previously applied and demonstrated in similar applications.

3.5 STEAM BALANCE HOLES

Steam balance holes shall be polished and radiused to a 0.4 µm (16 µinch) or better finish.

3.6 BLADE ATTACHMENT ON ROTOR

3.6.1 Blade attachment areas may be machined oversize to remove corrosion pitting or mechanical damage if supported by engineering analysis. After machining disk(s), new blades with a matching oversized attachment are required.

3.6.2 After removing from the shaft, rotor disk(s) may be repaired by welding as outlined in Chapter 1, Appendix D.2. Disk weld repair shall be accomplished by machining the outside diameter of the disk below the blade attachment area and building back up by welding. For built up rotors the disk shall be removed from the shaft and weld repaired.

Note: Minor weld repair such as for blade locking pin hole does not require removal of the disk from the shaft.

3.7 BLADING

3.7.1 The cause of cracking should be identified prior to any repair. If caused by foreign object damage, cracking may be repaired as outlined in 3.7.2. If caused by other than a foreign object damage, an engineering analysis should be performed. Typical causes of cracks are vibration of thin sections which have developed due to erosion, pitting corrosion, high thermal transients, blade operating in a resonant condition, and stress cracking.

In general, minor cracking/tears on leading or trailing edges up to 6% of the chord length with a maximum of 4 mm ($^1/_8$ in.) may be repaired by grinding. Refer to Figure 4.3-1 for recommended blade rework limits. If the cracking is more severe or in other locations, then an engineering evaluation shall be performed to determine if there are any other repair alternatives. After grinding NDE inspect per Chapter 1, Section 8, with acceptance criteria per 2.3.2.6.

Note: In determining the extent of repair, consideration needs to be given to aerodynamic performance, blade loading, defect location, tip speed, and operating steam conditions (moist steam region).

3.7.2 Foreign object damage may be repaired by straightening, grinding (feathering) and polishing. If any cracks appear as a result of this process, the limits of 3.7.1 apply. After repairing, NDE inspect per Chapter 1, Section 8, with acceptance criteria per 2.3.2.6.

Note: Moisture erosion should not be ground or polished, if erosion is excessive, blading should be replaced.

3.7.3 Weld repair

Depending upon the operating stresses, blade metallurgy and degree of distress, worn, damaged or eroded blades may be repaired by the welding processes, as outlined in Chapter 1, Appendix D.2 using an owner approved procedure.

All blade weld repairs should include the following basic steps;

a. Grind back or undercut the damaged area

b. Weld build-up per the qualified procedure.

c. Re-contour the blade profile

d. Heat treat as required to restore the metallurgical requirements.

e. Clean and perform NDE as per Chapter 1, Section 8.

f. Dimensionally check all blade critical fits, repair as required.

3.8 PROTECTIVE COATINGS

● **3.8.1** Steam turbine blades, disks, and seal areas may be coated for anti-fouling, erosion and corrosion protection. Erosion coatings are generally applied by thermal spray process as outlined in Chapter 1, Appendix D.3. Corrosion and / or anti-fouling coatings are generally applied as outlined in Chapter 1, Appendix L. The coating type, method of application, and area to be coated shall be specified by the purchaser.

Note: These coatings are highly specialized and require special part preparation, mask tooling and handling to assure proper application and consistent quality. Improperly selected and/or applied coating can lead to rapid coating failure and the degradation of the base material properties of the coated component. A thorough engineering review of any coating application should be conducted prior to use.

3.8.2 When re-coating existing components all evidence of previous coatings shall be removed prior to recoating.

3.9 LABYRINTH SEALS

3.9.1 "J" strips shall be repaired by straightening if possible and replaced as necessary. The replacement of "J" strips is to include the removal of the old strips and the replacement with new. The strips shall be final machined and the final dimensions shall be recorded. Caulking strip material should be in the annealed condition.

Note: For proper installation, the open end of the "J" is typically toward the higher pressure.

3.9.2 Integral seal teeth are generally remachined undersized and fitted with appropriate mating seals. Alternatively, seal teeth may be restored by repair welding per Chapter 1, Appendix D.2.

3.10 SHAFT SLEEVES AND SPACERS

Although some shaft hardware may be repaired (sleeves and spacers), the economics of repairing generally result in a new component replacement.

3.11 COMPONENT REPLACEMENT

3.11.1 Refer to Appendix C and Chapter 1, Section 9 for component replacement requirements.

3.11.2 New Blade Manufacture

The manufacture of new blades shall account for any machining performed in the blade attachment region and any design improvements.

3.11.2.1 Prior to blade manufacturing, manufacture "root" samples based on the blades previously removed from the disk and trial fit root samples to the disks to confirm proper engagement.

3.11.2.2 All blade root (dovetail), platform, and fillet to the airfoil areas are to be peened. On 250 m/second (825 ft/sec) or faster applications the airfoil fillet to tenon region shall be peened. Peening intensity and media depend upon base material, compressive layer depth desired and material thickness. The compressive layer induced shall be checked by using Almen strip.

Note: Peening increases corrosion resistance and resistance to fatigue cracking via inducing a compressively stressed layer at the material's surface. In general, the peening intensity is set by the section thickness. If the intensity is too high, the component's edge can distort. Thus the airfoil peening intensity is governed by the thickness of the blades' trailing edge. The blade root is generally peened to a higher intensity than the blade.

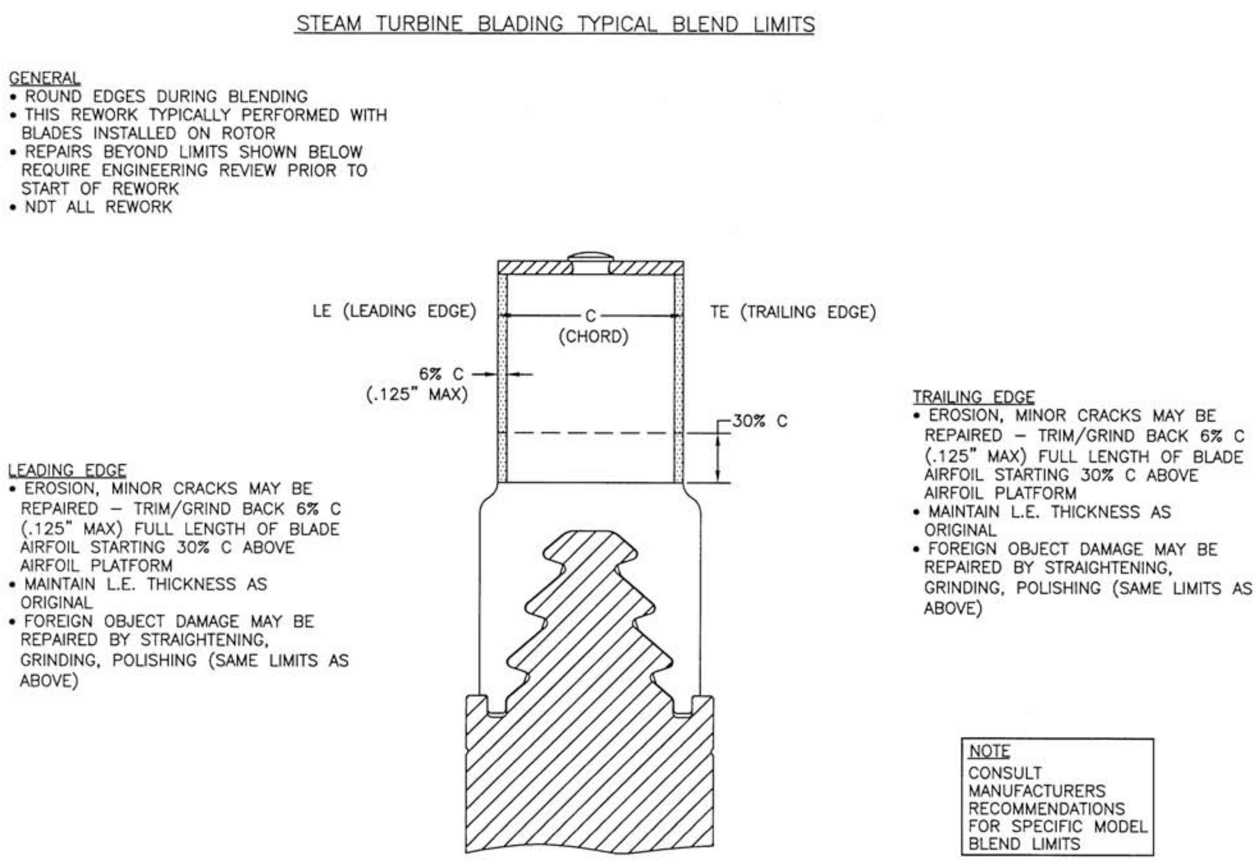


Figure 4.3-1—Rotor Blade Rework Limits

4 Assembly and Balancing

4.1 PRE-ASSEMBLY REQUIREMENTS

4.1.1 Because major components are all coming together for the first time after repairs, the vendor shall assure that the following items are completed prior to assembly:

a. Verify that all specific requirements of the repair scope have been met.

b. Verify that correct axial positioning data is available.

c. Verify that all critical dimensions and runouts have been taken, recorded, and evaluated for final fits, locations, and clearances.

d. Verify that the requirements of Section 3 have been met on any new or repaired components.

4.1.2 All mating components should be thoroughly cleaned prior to assembly. Remove any foreign deposits, preservation materials, oil, etc. with an appropriate solvent.

4.1.3 Verify that all mating surfaces are clean and free of corrosion and burrs. Stone faces as necessary.

4.1.4 Verify that the keys have a tap fit in the shaft and a slip fit in the components, and that the top key clearances are 100 µm to 150 µm (0.004 in. to 0.006 in.).

4.1.5 The vendor shall record a complete set of phase-related bare shaft runouts prior to assembly. As a minimum, runouts shall be recorded at each location between each disk and at one point outside of each bearing journal.

4.1.6 Proper location of blading will minimize residual unbalance and the subsequent grinding corrections to the disk. Generally the grinding depth of the balance corrections should be limited to approximately 3 mm ($^1/_8$ in.).

Note: To minimize grinding on disks the following should be considered.

1. All blades with an airfoil length of 150 mm (6 inches) or less may be pan-weighed.

2. All blades with an airfoil length greater than 150 mm (6 inches) should be moment-weighed.

3. Consideration also needs to be given to variations in blade thickness and locking blade weight when distributing blades.

4.1.7 For blades that have been moment weighed, the circumferential distribution of the blades shall be determined with a computer program designed for the purpose of minimizing resultant unbalance.

4.1.8 New rotor blade locking hardware shall be used (pins, notch blocks, filler pieces, etc.).

4.1.9 The rotor components are to be protected during the assembly process to prevent damaging the components.

4.1.10 When components are coated, the temperature limitation of the coating must be reviewed for assembly considerations. Such as when heating components during assembly.

4.1.11 Removable overspeed trip assemblies should be bench tested and calibrated for the proper trip speed.

Note: If rotor is to be high speed balanced, trip setting may be verified during that procedure.

4.1.12 Prior to balancing, determine the appropriate balance correction regions.

Balancing corrections shall be made on the disks by grinding on the face of the disk dedicated for balance correction or by adding balance weights in a balance groove. Corrections on the disk faces adjacent to the blade root areas (which is normally also the indicator plane), the blade attachment, or other critically stressed regions of the disk is not permitted.

Metal removal on the disk faces shall be limited to guidelines given in 4.1.6. If necessary, the correction grind shall be blended to prevent stress risers and spread out to limit thinning of the disk material.

4.2 DISK ON SHAFT ROTOR

4.2.1 Rotors shall have the bare shafts and individual major components balanced prior to the rotor assembly per Chapter 1, Section 10.2.

4.2.2 Rotor stacking and low speed assembly balance shall conform to the requirements of Chapter 1, paragraph 10.3, and the data recorded on Figures 4.D-1 through 4.D-3.

a. Bladed Disk assemblies are to be balanced per Chapter 1, paragraph 10.2 prior to the assembly onto the rotor.

b. If blades have not been installed on the disks, the disk(s) shall be assembled onto the shaft, perform runout checks, blades installed in accordance with 4.1.7 when applicable, check balanced, shrouded, assembly balanced per 4.2.19, and continue stack balancing in accordance with Chapter 1, paragraph 10.3.

Note: The rotor design and the shop practice will determine whether the blades will be installed onto the disk before or after the disk is installed onto the rotor.

4.2.3 Shroud installation, tenon peening, tie wire or lacing wire installation shall be in accordance with paragraph 4.5.

4.2.4 With shafts that have a common diameter for all turbine disks, and the disks can be installed on the shaft from either end, the components shall be assembled from the center of the rotor, outwards. The vendor shall plan the rotor assembly so that two-plane balance corrections may be applied on the major rotor components throughout the assembly (i.e., assemble two major components for each balancing step). On rotors having an odd number of major components, the single-plane balance step shall be either the first or last major component assembled.

4.2.5 All major components shall be uniformly heated for assembly on the shaft. Components shall be heated to provide an assembly clearance to the shaft of 1 µm/mm (0.001 in./in.) of shaft diameter, but in no case more than 280 K (500°F) above the ambient shop temperature. For high interference applications higher temperatures may be required with engineering review.

Note: Heating components (especially the disks) for assembly is a critical step. In general, the differential temperature across a disk should never exceed 30 K (50°F) during the heating process, as permanent excessive distortion may occur. This may be accomplished in a horizontal oven that has good temperature control. It can also be accomplished by the use of two or more large (flare tip or rosebud) torches, however, care must be exercised to avoid large heat input causing uneven heating. Care is also to be given to sections of different thicknesses to avoid excessive temperature differentials. When torches are used, the differential temperature should be carefully monitored with low sulfur temperature indicating sticks or a noncontact infrared surface temperature gun.

4.2.6 All major components shall be assembled with the shaft in the vertical position.

4.2.7 Major components shall not be impacted with hammers, blocks of wood, etc., at any time during the assembly process.

4.2.8 After the addition of each stack allow the rotor to cool to approximately 50°C (120°F) and record the data required by 4.2.9, 4.2.10, 4.2.11, 4.2.12, and 4.2.13.

4.2.9 The vendor shall assure that the last components added are correctly located on the shaft according to the assembly data and/or drawing. Stacked dimensions shall conform to the inspected dimensions per paragraph 1.3.3, or have engineering justification for deviation. Major component positioning shall be within ±400 µm (0.015 in.) of the assembly reference dimension (normally measured from the thrust collar or the thrust collar shoulder), and within ±200 µm (0.008 in.) of the disk-to-disk dimension (normally the distance between the high pressure edges of the shroud band and compensated for allowable axial runout/distortion of the disc face).

4.2.10 Unless otherwise specified, the minimum axial gap between all adjacent disks and interstage sleeves, after assembly, shall be 100 µm (0.004 in.).

4.2.11 The vendor shall record phase-related runouts on the faces of the disks just below the turbine blades, and the shaft on both sides of the stack.

4.2.12 Disk rim axial face runouts must be within 25 µm (0.001 in.) of the face runouts measured when the disk was on the balance mandrel, accounting for any phase angle differences. In no case shall the disk face TIR runouts exceed 0.13 µm/mm (0.0015 in./ft) of diameter.

4.2.13 The vectorial change in shaft runouts during each stack, comparing the before and after shaft runouts measured with a dial indicator adjacent to the last major component(s) stacked, shall not exceed 8 µm (0.0003 in.) TIR.

4.2.14 If, after a stack, the requirements of 4.2.13 have not been met, and/or the assembly stresses exceed the requirements of Chapter 1, paragraph 10.3.5, a "heat soak" process may be performed in accordance with 4.2.14 a-d.

a. The exposed areas of the shaft shall be wrapped with an insulating material to avoid exposure to direct flame during the process.

b. Continuously rotate the rotor in a balance machine at 300 to 500 rpm during the entire process.

c. The disk(s) that were last assembled shall be rapidly heated with a large (flare tip or rosebud) torch to a temperature of approximately 180°C to 200°C (350°F to 400°F). The rapid heat shall be applied near the bore area only after heating the entire disk to allow for expansion. The disk temperature shall be monitored with low sulfur temperature indicating sticks or a non-contacting infrared surface temperature gun.

d. The rotor shall be allowed to continuously rotate in the balancing machine until its temperature is not more than approximately 50°C (120°F).

4.2.15 If the rotor still does not meet the requirements of 4.2.14 and/or Chapter 1, paragraph 10.3.5, but the heat soak did result in a balance improvement of at least 25%, a second heat soak procedure may be performed per 4.2.14. If, after a second heat soak procedure, the rotor still does not meet the requirements of 4.2.14 and/or Chapter 1, paragraph 10.3.5, the components that were last assembled shall be removed for inspection and correction as required.

4.2.16 After performing a heat soak process, the vendor shall verify the axial positioning of the components per 4.2.9 and axial gap per 4.2.10.

4.2.17 Balance corrections after each successive stack shall be limited to the last major components stacked and comply with the requirements of 4.1.12.

4.2.18 The overall stack dimension (normally from the high pressure edge of the first stage shroud band to the high pressure edge of the last stage shroud band) shall be within 0.4 mm (0.016 in.) of the inspected dimension per 1.3.3 or have engineering justification for deviation.

4.2.19 Residual unbalance testing per Chapter 1, paragraph 10.4.

4.3 INTEGRAL ROTORS

4.3.1 Measure and record rotor runouts and dimensions as outlined in 1.3 and Chapter 1, paragraph 7.2.6.

4.3.2 Balance the rotor (less blading) in accordance with Chapter 1, paragraph 10.2.

4.3.3 Sequentially assemble and low speed balance the rotor in accordance with the requirements of Chapter 1, paragraph 10.3, assembling from the center of the rotor outwards. Blading shall be installed in accordance with 4.1.7 and check balanced. Resequence the blades if the check balance exceeds 25 grams at the correction radius (10 inch radius would be 250 gm-in.). The blades are then to be shrouded, machined, and assembly balanced per 4.3.5. When possible, the vendor shall plan the blading/shrouding assembly so that two plane balance corrections may be applied throughout the assembly. On rotors having an odd number of stages, the single plane balance step shall be either the first or last row of blading assembled.

Note: The effort of resequencing is to minimize the amount of grinding done on the disks.

4.3.4 Shroud installation, tenon peening, tie wire or lacing wire installation shall be in accordance with Section 4.5.

4.3.5 Residual unbalance testing per Chapter 1, paragraph 10.4.

4.4 REASSEMBLY OF PARTIALLY DISASSEMBLED ROTORS

4.4.1 This section outlines the procedures required for rotors that have had disks or blading removed.

4.4.2 Prior to the addition of any additional disks or blades, the rotor shall be balanced per Chapter 1, paragraph 10.2. After balancing proceed with the assembly balance per the applicable section as related to the rotor construction.

Partially debladed rotors need to be assessed as to whether the balance weights should be removed. Removal of balance weights depends upon:

a. Number of stages of blades removed.

b. Balance of the rotor in the partially debladed condition.

c. Location of the balance weights with respect to the residual unbalance in the rotor.

d. Number of resonances that the rotor must pass through

e. Condition of the balance weights and the locking hardware.

If the balance weights are removed, record their weight and locations so they can be replaced in their original location, if required.

4.5 SHROUD INSTALLATION, TENON PEENING, LACING (TIE) WIRE INSTALLATION

4.5.1 Shroud Installation

The installation of blade shrouds and peening of the blade tenons require considerations such as:

a. The peening of the tenons shall be done using a qualified procedure and personnel. The shroud shall have the same material properties as the “as received” shroud. (See 4.5.2.)

Note: Some shroud material may harden in service and should be accounted for when selecting material properties of new shroud material.

b. Ensure that the shroud grouping (blade packet) is consistent with the as received condition per Section 2.2.10.1.

c. Peening of the tenon should be done by utilizing a formed tool. The energy to form the tenon may be delivered with an automatic device or a hammer and form tool. An automatic device is preferred to provide consistency.

d. Clearance between the tenon and the shroud hole is required. This clearance may typically be 125 µm (0.005 in.) per side.

e. Wide airfoils are to be machined, during blade manufacturing, so that the blade tips match the curvature of the shroud.

f. The base of the tenon shall have a generous radius and the shroud ID shall be radiused so that the shroud does not contact at the tenon radius.

g. The peened side of the tenon holes in the shroud shall be chamfered and sharp edges removed.

h. Verify that the edge of the shroud hole does not interfere with the radius of the tenon at the top of the blade airfoil.

i. The installed blades shall be used as a template for locating the holes into the shroud.

j. Machine the hole in the shroud to the correct pitch. Surfaces must be deburred and finished to a minimum surface finish of 1.6 µm (64 µinch) Ra.

k. Prior to installation, NDE inspect the shroud in accordance with Chapter 1, paragraph 8.2.4. No indications are allowed.

l. When fitting of the shroud to the blading, no deflection of the blading is allowed.

m. Silver soldering of the shroud to the tenon is not allowed.

n. Roll the shroud to the required radius curvature corresponding to the outside diameter created by the blade tips.

o. Check fit of shroud holes to blade tenons. If the shroud does not fit, determine cause and correct with the manufacturing of a new shroud.

p. Peen the tenons in accordance with “a”. Confirm that the shroud is in contact with the blade tip and is not otherwise distorted. Tenons with a diameter larger than 16 mm ($^5/_8$ in.) may require stress relieving after peening.

q. After completion of all shrouding installation, but prior to balancing, trim the shroud to the required width, DO NOT MACHINE INTO AIRFOIL.

Note:

1. Trimming of the shroud should typically allow a minimum of 250 mm (0.010 in.) of overhang of the shroud past the edges of the airfoil.

2. The runout and location of the shroud’s leading edge is important to the efficiency and performance of the machine.

r. Verify that there is clearance of approximately 1.6 mm ($^1/_{16}$ in.) between the ends of shroud sections.

s. NDE inspect peened tenons in accordance with Chapter 1, paragraph 8.2.4. No indications are allowed. A dimensional inspection of the peened tenons should be performed.

4.5.2 Tenon Peening Qualification Procedure

If an approved peening procedure using the same material and geometry does not exist, prior to the tenon peening process, a test peening shall be completed. Procedure for qualifying the tenon peening process shall include the following to assure consistent results:

a. Manufacture six “peening samples” from the same metallurgy and material properties of bar stock used to manufacture the blades. The samples shall have the tenon geometry machined into them including diameter, height, fillet radius and surface finish.

b. Manufacture a shroud sample using the same type of material used for the final shroud including the hole tenon with all design features such as through diameter, corner radius adjacent to the top of blade, top of tenon hole chamfer and surface finish.

c. Peen the tenon to the shroud using the peening process which will be used for peening of the rotor. If an automatic peening machine is used, record all settings including but not limited to working pressure and travel.

d. MPI the peened tenon to check for cracks resulting from excessive work hardening.

e. Section all samples of the peened connection and mount for microscopic examination and “microhardness” inspection along the axis of the tenon. Check for proper “fill” of the tenon hole in the shroud and that the shroud is in acceptable contact with the top of the peening sample block (where the top of the airfoil will be).

f. Peened tenons shall not have feathered edges.

g. Confirm finished tenon height and diameter are within specification requirements.

4.5.3 Lacing (Tie) Wire Installation

4.5.3.1 Prior to the installation of the lacing (tie) wire, the diameter of the hole in the blading, or the groove in the integral shroud, and the diameter of the wire are to be measured and recorded and verified.

4.5.3.2 Ensure that the blade grouping is consistent with the as received condition per paragraph 2.2.10.1. The grouping of the blading is to be documented.

4.6 FINAL INSPECTION

4.6.1 Perform dimensional and NDE inspections of the assembled rotor as required in paragraph 1.3.

4.7 DOCUMENTATION

4.7.1 Documentation for rotor re-assembly and/or balancing shall conform to the requirements of Chapter 1, Section 12.

APPENDIX A—DIMENSIONAL FORMS FOR PHASE I INSPECTION

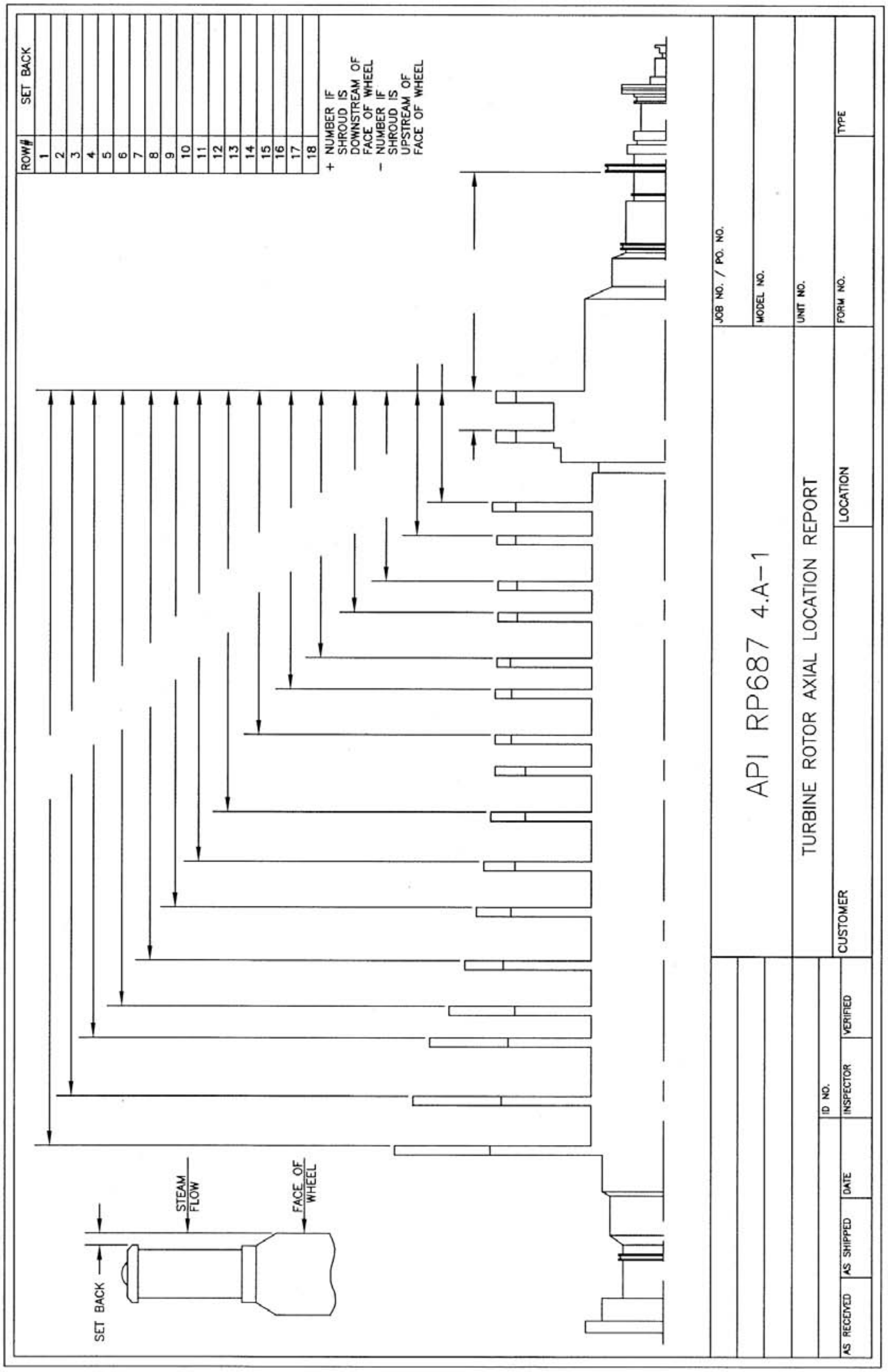


Figure 4.A-1—Turbine Rotor Axial Location Report

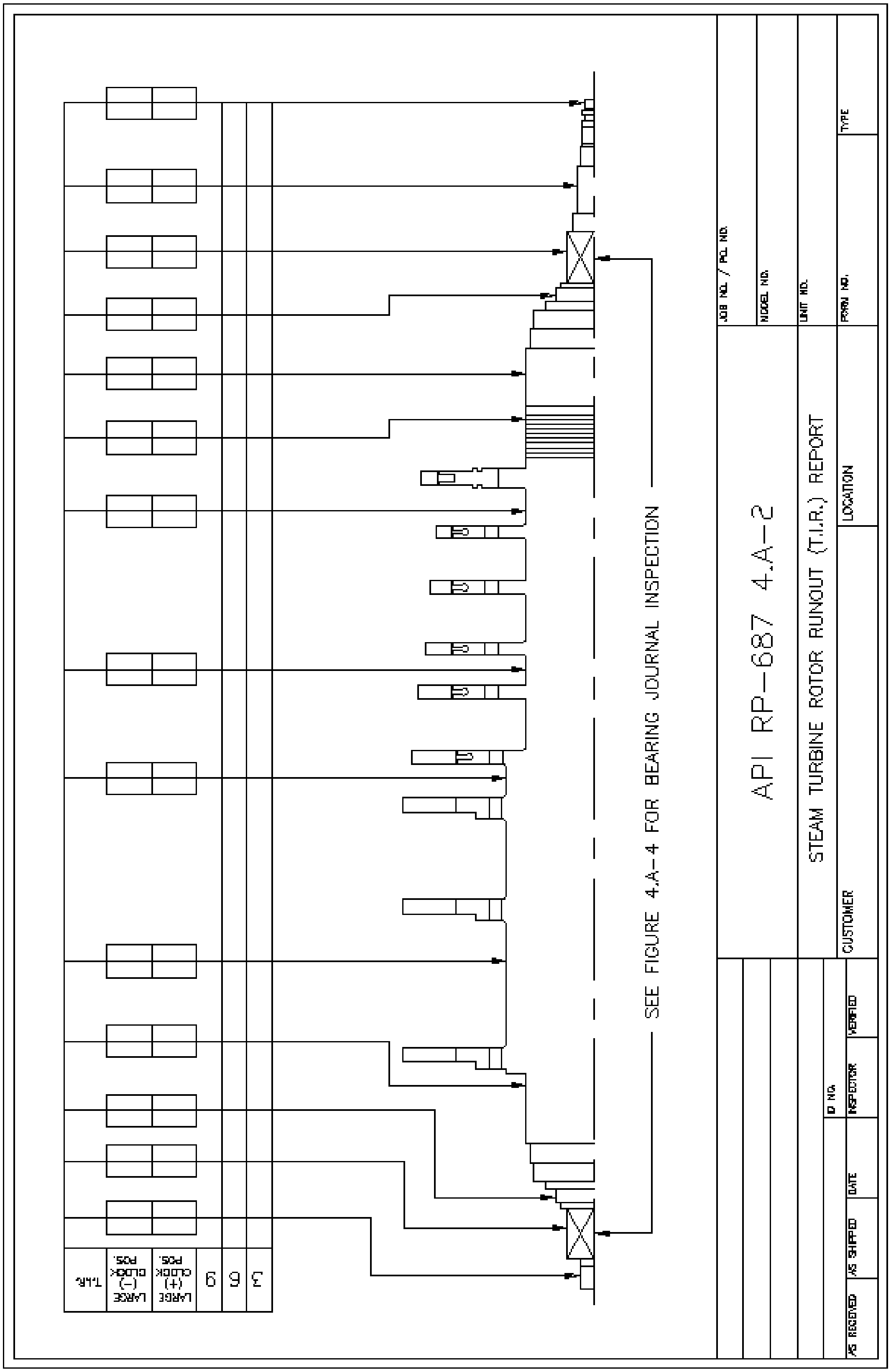


Figure 4.A-2—Steam Turbine Rotor Runout (T.I.R.) Report

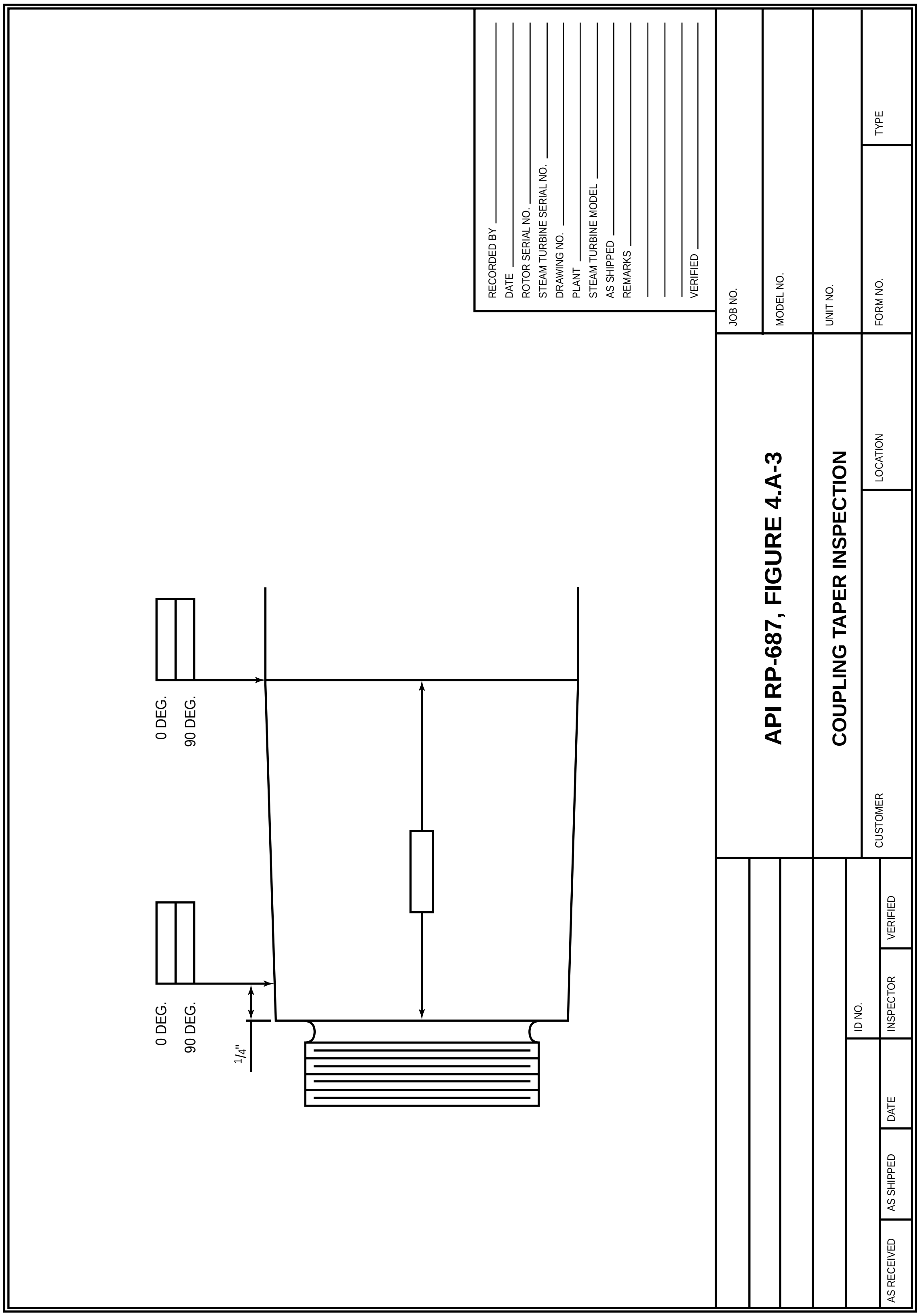


Figure 4.A-3—Coupling Taper Inspection

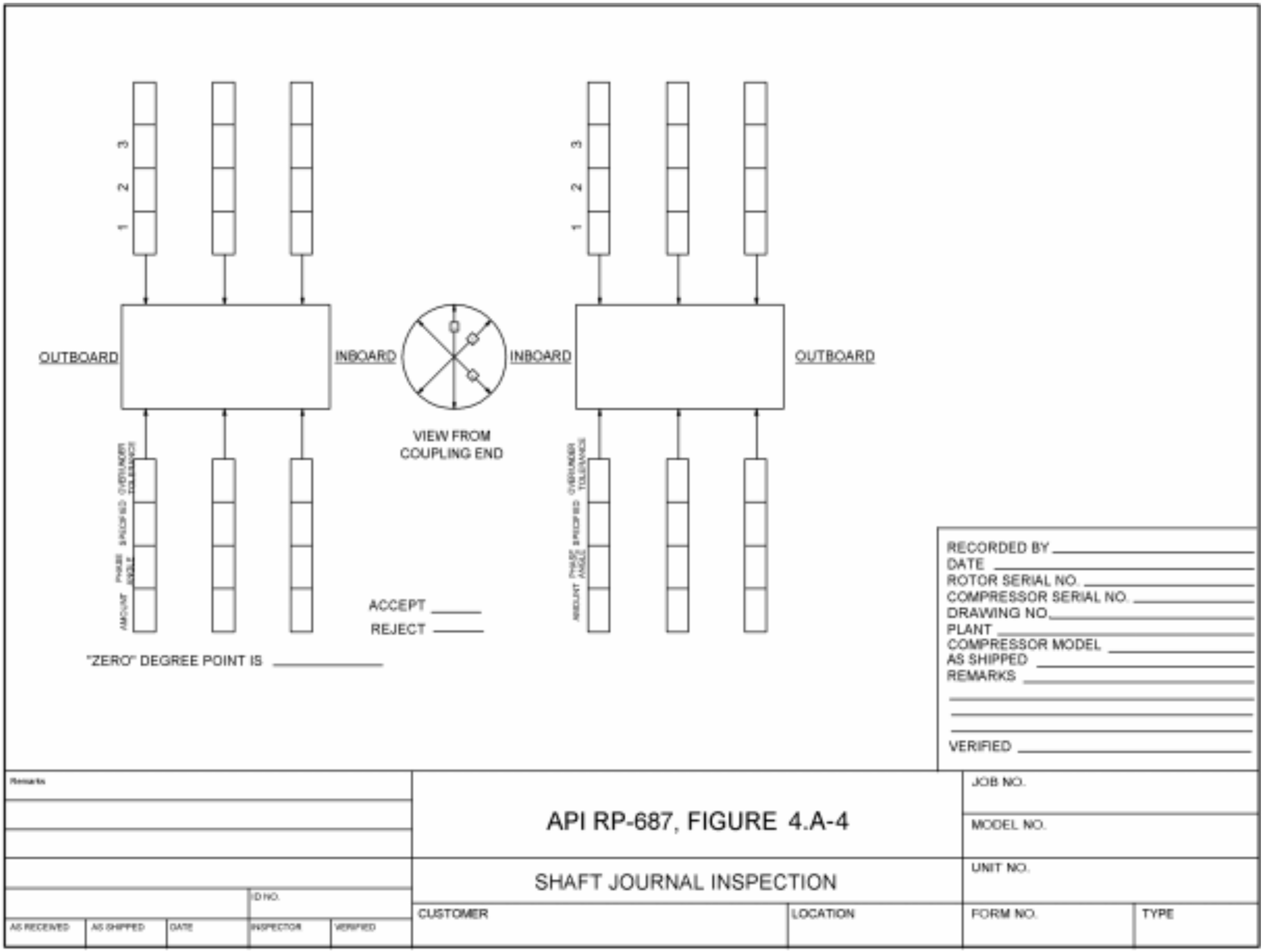


Figure 4.A-4—Shaft Journal Inspection

APPENDIX B—DIMENSIONAL FORMS FOR PHASE II INSPECTION

SHAFT DIAMETERS

	SPECIFIED	0 DEG.	90 DEG.	OVER/UNDER TOLERANCE
A				
B				
C				
D				
E				
F				
G				
H				
I				
J				
K				

SHAFT RUNOUTS

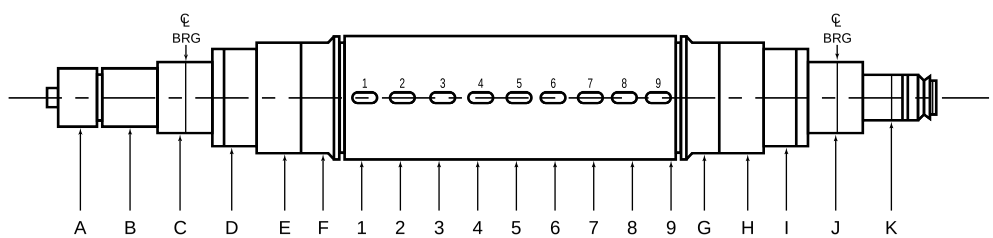
	SPECIFIED	0 DEG.	90 DEG.	OVER/UNDER TOLERANCE
A				
B				
C				
D				
E				
F				
G				
H				
I				
J				
K				

SHAFT DIAMETERS

	SPECIFIED	0 DEG.	90 DEG.	OVER/UNDER TOLERANCE
1				
2				
3				
4				
5				
6				
7				
8				
9				

SHAFT RUNOUTS

	SPECIFIED	0 DEG.	90 DEG.	OVER/UNDER TOLERANCE
1				
2				
3				
4				
5				
6				
7				
8				
9				



ANGLES RECORDED OPPOSITE/WITH
ROTATION FROM INLET END.
"ZERO" DEGREE POINT IS ____________

RECORDED BY ____________
DATE ____________
ROTOR SERIAL NO. ____________
STEAM TURBINE SERIAL NO. ____________
DRAWING NO. ____________
PLANT ____________
STEAM TURBINE MODEL ____________
AS SHIPPED ____________
REMARKS ____________
VERIFIED ____________

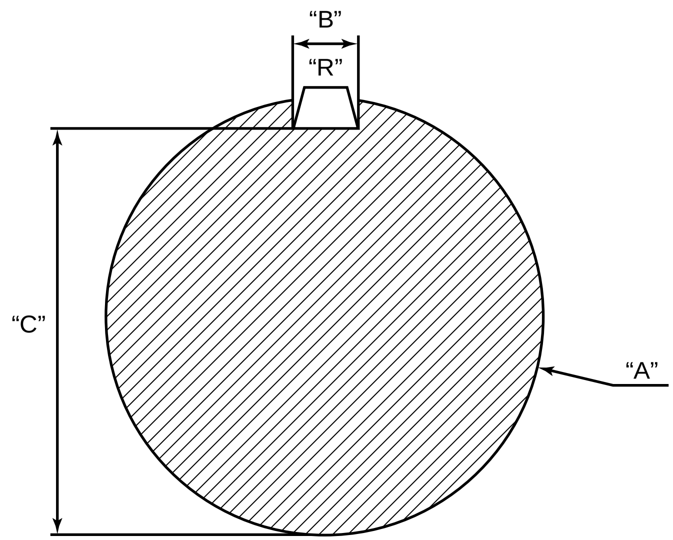
API RP-687, FIGURE 4.B-1

SHAFT INSPECTION

			ID NO.	
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED

JOB NO.			
MODEL NO.			
UNIT NO.			
CUSTOMER	LOCATION	FORM NO.	TYPE

Figure 4.B-1—Shaft Inspection



MINIMUM VALUES

"A" ____________________

"B" ____________________

"C" ____________________

"R" ____________________

RECORDED BY ____________________
DATE ____________________
ROTOR SERIAL NO. ____________________
STEAM TURBINE SERIAL NO. ____________________
DRAWING NO. ____________________
PLANT ____________________
STEAM TURBINE MODEL ____________________
AS SHIPPED ____________________
REMARKS ____________________
____
____
____
VERIFIED ____________________

		ID NO.		
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED

API RP-687, FIGURE 4.B-2

SHAFT KEYWAY INSPECTION

CUSTOMER	LOCATION

JOB NO.	
MODEL NO.	
UNIT NO.	
FORM NO.	TYPE

Figure 4.B-2—Shaft Keyway Inspection

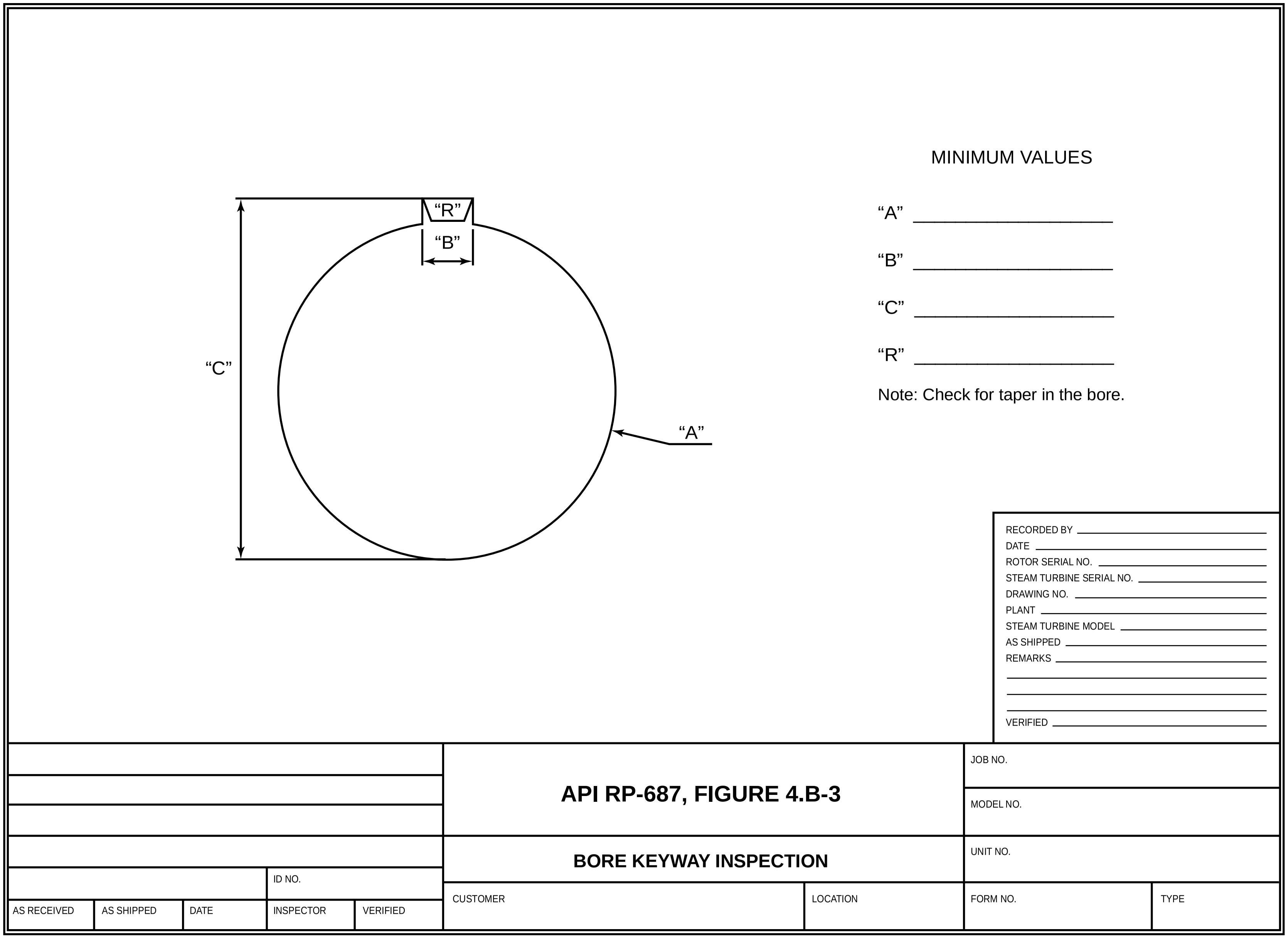


Figure 4.B-3—Bore Keyway Inspection

STAGE										
SHAFT OD (1)										
DISC ID (2) D1										
D2										
INTERFERENCE FIT (ACTUAL)										
INTERFERENCE FIT (SPECIFIED)										
DISC SPACER (3) C-1										
D										
F										
INTERFERENCE FIT (ACTUAL)										
INTERFERENCE FIT (SPECIFIED)										
KEY TO SHAFT (WIDTH) (4)										
KEY TO DISC (WIDTH) (5)										
KEY TO DISC (HEIGHT) (6)										
SIDES OF KEY TO ℄ OF SHAFT (7)										

(1) DIMENSIONS FROM SHAFT INSPECTION REPORT.

(2) DIMENSIONS FROM DISC INSPECTION REPORT.

(3) DIMENSIONS FROM DISC SPACER REPORT.

(4) TYPICALLY 0.000 TO 0.0015" TIGHT.

(5) TYPICALLY 0.000 TO 0.003 LOOSE.

(6) TYPICALLY 0.005 TO 0.013 CLEARANCE.

(7) TYPICALLY PARALLEL TO ℄ OF SHAFT 0.0005" PER INCH LENGTH OF KEYWAY.

					API RP-687, FIGURE 4.B-4		JOB NO.	
							MODEL NO.	
					INTERFERENCE FIT SUMMARY		UNIT NO.	
			ID NO.		CUSTOMER	LOCATION	FORM NO.	TYPE
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED				

Figure 4.B-4—Interference Fit Summary

APPENDIX C—QUALITY/MANUFACTURING PLAN

QUALITY/MANUFACTURING PLAN

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	TURBINE DISK (NEW) (1)			**3.11**			**(2)**			
	Forgings—or Plate Stock									
	Material Certification Review	AISI/ ASTM Spec No.	C,H,M	Chap 1, 9		Compliance with AISI/ASTM Requirement	Report			
	Rough Machine					Mfg. Drawing				
	Ultrasonic Inspection			Chap 1,8.2.3	ASME Sect V Article 5 & 23	Chap 1,8.2.3.2	Certificate			
	Machining to contour					Mfg. Drawing				
	Stress Relieve/Heat Treat		H			Mfg. Drawing	Chart			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Final Machine, Including Blade Roots					Mfg Requirement	Report			
	Dimensional Inspection (including Blade Root Fit)					Mfg. Drawing	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Blade Attachment Peening verify intensity with Alem strip		A		Mfg Drwg	Mfg Drwg	Report			
	Balance			Chap 1, 10.2		Chap 1, 10.2.11	Report			
	Positive Material identification (PMI)	AISI/ ASTM Spec No.					Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Coating process qualification (coupons)		C,H	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Coat (when specified)		A	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	BLADE MANUFACTURE (NEW)			**3.11**						
	Prepare Manufacturing Drawings from Samples taken from Rotor, if Required (includes standard, oversize, undersize blades, locking blades, shrouding stock (not rolled or machined for tenons), lacing/tie wires, etc…)			3.11.2						
	Manufacture “root samples” for verifying fit of blades to disk			3.11.2.1						
	Check Fit of Root Samples to Disk			3.11.2.1			Certificate			
	Manufacture Tenon peening samples, as Required, for peening qualification			4.5.2			Report			
	Qualify Tenon Peening Procedure			4.5.2			Report			
	Forgings, Bar Stock and/or envelope forgings	AISI/ ASTM Spec No.	C,H,M	Chap 1, 9.1		Compliance with AISI/ASTM Requirement	Report			
	Ultrasonic Inspection			Chap 1, 8.2.3	ASME Sect V, Article 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Manufacture blades in accordance with detail manufacturing drawings. Including oversize/undersize blades, locking blades and other necessary components					Mfg Drawing				
	Dimensional Inspect airfoils and roots of all blading					Mfg. Drawing	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Shot peen dovetails (roots), platform and tenon verify intensity with Almen Strips			3.11.2.2		Mfg Drawing	Report			
	Positive Material identification (PMI) each blade	AISI/ ASTM Spec No.					Certificate			
	Coating process qualification (coupons)		C,H	Chap 1, App L/ Chap 1, App K		Coating procedure	Report			
	Coat (when specified)		A	Chap 1, App L/ Chap 1, App K		Coating Procedure	Report			
	THERMAL BOW			**3.1.4**			**(1)**			
	Initial Runout Readings			3.1.4		Mfg. Drawing	Report			
	Heating Procedure			3.1.4.1, 3.1.4.2, 3.1.4.3		Mfg. Req'ts				
	Second Runout Readings			3.1.4.4		Mfg. Drawing	Report			
	Heating Procedure			3.1.4.2, 3.1.4.3		Mfg. Req'ts				
	Final Runout Readings			3.1.4.4		Mfg. Drawing	Report			
	DISK FACE RUBBING			**3.1.5**			**(1)**			
	Machine To Remove Rub			3.1.5		Mfg. Req'ts				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Hardness Check			Chap 1, B.5			Report			
	Final Dimensional Inspection			3.1.5		Engineering Review	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	DISK FACE PITTING			**3.1.6**			**(1)**			
	Clean or Machine to Remove Pitting			3.1.6		Mfg. Req'ts				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Final Dimensional Inspection			3.1.6		Engineering Review	Report			
	INTEGRAL ROTOR DISK REPAIR			**3.2**			**(1)**			
	Machine for Weld Preparation			Chap 1, D.2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D.2.2.1			Certificate			
	Hardness Check			Chap 1, D.2.2.3			Report			
	Weld Prep Dimensional Inspection			Chap 1, D.2.2.3		Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Weld Repair			Chap 1, D.2.3	WPS, PQR		WPS, PQR			
	Rough Machine			Chap 1, D.2.4.1		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.4.1/ Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.4.1/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Post Weld Heat Treatment		H	Chap 1, D.2.5/ Chap 1, D.2.6	Vendor Procedure		Chart			
	Final Rough Machine			Chap 1, D.2.7		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.7/ Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.7/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Hardness Check			Chap 1, D.2.7		WPS	Report			
	Final Machine (Profile & Blade Roots)			Chap 1, D.2.8		Chap 1, D 2.8				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.9/ Chap 1, 8.2.4	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection (Including Blade Root Fit)			Chap 1, D.2.9		Mfg Drawing	Report			
	BUILT UP ROTOR			**3.3**			**(1)**			
	SHAFT REPAIR			3.3.1						
	Refer To Chapter 1, Appendix K For Shaft Repair			3.3.1						
	DISK REPAIR			**3.4**			**(1)**			
	DISK BORE WELD REPAIR			3.4.1.1						
	Undercut for Weld Preparation			Chap 1, D.2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D.2.2.1			Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Hardness Check			Chap 1, D.2.2.3			Report			
	Rough Dimensional Inspection			Chap 1, D.2.2.3		Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.2.4/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Weld Repair			Chap 1, D.2.3	WPS, PQR		WPS, PQR			
	Rough Machine			Chap 1, D.2.4.1		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.4.1/ Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.4.1/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Post Weld Heat Treatment		H	Chap 1, D.2.5/ Chap 1, D.2.6	Vendor Procedure		Chart			
	Final Rough Machine			Chap 1, D.2.7		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.7/ Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.7/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2				
	Hardness Check			Chap 1, D.2.2.7		WPS	Report			
	Final Machine			Chap 1, D.2.8		Chap 1, D.2.8				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.9/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection			Chap 1, D.2.9		Mfg Drawing	Report			
	SHAFT WELD/HVOF or HVLF OVERSIZING			3.4.1.2						
	Machine Bore Oversize And True			3.4.1.2						
	Build Up Shaft, Refer To Chapter 1, Appendix K For Shaft Repair			3.4.1.2			Report			
	NEW SHAFT OVERSIZING			3.4.1.3						
	Machine Bore Oversize And True			3.4.1.3						
	Machine New Shaft, Refer To Chapter 1, Appendix K For Shaft Repair			3.4.1.3			Report			
	DISK BORE THERMAL SPRAY REPAIR			3.4.1.4						
	Machine Bore Oversize and True Build Up Shaft, Refer to Chapter 1, Appendix K for Shaft Repair			3.4.1.4						
	STEAM BALANCE HOLE REPAIR			**3.5**			**(1)**			
	Polish and Radius			3.5						
	Final Dimensional Inspection			3.5			Report			
	BLADE ATTACHMENT REPAIR			**3.6**			**(1)**			
	BLADE GROOVE REPAIR			3.6.1						
	Final Machine Oversize			Chap 1, D.2.8		Chap 1, D.2.8				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.9/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Final Dimensional Inspection			Chap 1, D.2.9		Mfg Drawing	Report			
	DISK OUTSIDE DIAMETER REPAIR			3.6.2						
	Machine for Weld Preparation			Chap 1, D.2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D.2.2.1			Certificate			
	Hardness Check			Chap 1, D.2.2.3		Report	Certificate			
	Rough Dimensional Inspection			Chap 1, D.2.2.3		Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.2.4/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Weld Repair			Chap 1, D.2.3	WPS, PQR, WQR		WPS, PQR			
	Rough Machine			Chap 1, D.2.4.1		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.4.1/ Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.4.1/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Post Weld Heat Treatment		H	Chap 1, D.2.5/ Chap 1, D.2.6	Vendor Procedure		Chart			
	Final Rough Machine			Chap 1, D.2.7		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.7/ Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.7/ Chap 1, 8.2.4	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2				
	Hardness Check			Chap 1, D.2.7		Report	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Final Machine			Chap 1, D.2.8		Chap 1, D.2.8				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.9/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection			Chap 1, D.2.9		Mfg Drawing	Report			
	BLADING REPAIR			**3.7**			**(1)**			
	Grind/Polish To Remove Cracking/ Tears/FOD			3.7.1 & 3.7.2						
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection			3.7.1 & 3.7.2		3.7.1 & 3.7.2	Report			
	BLADE WELD REPAIR			3.7.3						
	Machine for Weld Preparation			Chap 1, D.2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D.2.2.1			Certificate			
	Hardness Check			Chap 1, D.2.2.3		Report	Certificate			
	Rough Dimensional Inspection			Chap 1, D.2.2.3		Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.4.4/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Weld Repair			Chap 1, D.2.3	WPS, PQR, WQR		WPS, PQR			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Recontour Blade Profile			3.7.3c/Chap 1, D.2.4.1		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.4.1/ Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.4.1/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Post Weld Heat Treatment		H	Chap 1, D.2.5/ Chap 1, D.2.6	Vendor Procedure		Chart			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.7/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Hardness Check			Chap 1, D.2.7		WPS	Report			
	Dimensional Inspection			Chap 1, D.2.9		Mfg Drawing	Report			
	J STRIP REPAIR			**3.9**			**(1)**			
	Straighten J Strip			3.9		Mfg Drawing	Report			
	Liquid Penetrant Inspect			Chap 1, 8.2.4	ASTM E 165	Chap 1, 8.2.4.4	Certificate			
	J STRIP NEW			**3.9**			**(1)**			
	"J" strip and caulking material		C,M	3.9						
	Remove old "J" strips and install new "J" strips with caulking material			3.9		Mfg. Drawing				
	Machine to size			3.9		Mfg. Drawing				
	Final Dimensional Inspection			3.9		Mfg. Drawing	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	PRE-ASSEMBLY REQUIREMENTS			**3.9**			**(1)**			
	Axial Positioning Data			4.1.1b		4.A-1				
	Critical Dimensions and Runouts			4.1.1c		4.A-2, 3, 4 4.B-2, 3, 4				
	Clean Mating Components			4.1.2						
	Clean Mating Surfaces			4.1.3						
	Key Clearances			4.1.4						
	Phase-Related Bare Shaft Runouts			4.1.5		4.B-1				
	New Locking Hardware			4.1.8						
	Protect Rotor Components			4.1.9						
	DISK ON SHAFT ROTOR ASSEMBLY/ LOW SPEED BALANCE			**4.2**			**(2)**			
	Blue Check Coupling Fit			4.4.4			Report			
	Component Balance All Major Subassemblies			4.2.1/Chap 1, 10.2		Chap 1, 10.3.9	Report			
	Interference Fit Summary			4.1.1c		Mfg Drawing	Report			
	Balance Machine Calibration			Chap 1, 10.5.1		Mfg Requirement	Report			
	Weigh or moment weigh blades			4.1.6						
	Sequentially assemble and low speed balance the rotor			4.2.2/4.2.4/ 4.2.5/4.2.6/ 4.2.7/4.2.14/ 4.2.15/4.2.17		4.2.8/4.2.9/4.2.10/ 4.2.11/4.2.12/ 4.2.13/4.2.16/ 4.2.18	Report			
	Positive Material identification (PMI) each shroud, lacing and tie wire	AISI/ ASTM Spec No.					Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Shroud, tie wire and lacing wire Installation			4.2.3/4.5		Mfg Requirement	Report			
	Final Machine			4.5.1 q		Mfg Drawing	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			4.5.1 s	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection			4.5.1		Mfg Drawing	Report			
	Residual Unbalance—Rotate U-Joint Drive			Chap 1, 10.3.10		Chap 1, 10.3.10	Report			
	Residual Unbalance/Sensitivity Check			4.2.19/Chap 1, 10.4		Chap 1, App. A	Report			
	Residual Unbalance With Coupling			Chap 1, 10.4.3/ Chap 1, 10.4.4		Chap 1, 10.3.5	Report			
	Rotor Assembly—Final Dimensional			4.6.1		Mfg Drawing	Report			
	Rotor Assembly—Final Indication			4.6.1		Mfg Drawing	Report			
	Rotor Assembly—Gauss Level			4.6.1		Mfg Drawing	Report			
	Coat (3)		A	Chap 1, App L/ Chap 1, App K		Coating Procedure	Report			
	Coating process qualification (coupons) (3)		C,H	Chap 1, App L/ Chap 1, App K		Coating Procedure	Report			
	Rotor Balance (complete) after coating (3)			Chap 1, 10.3		Chap 1, 10.3.9	Report			
	Residual Unbalance—Rotate U-Joint Drive (3)			Chap 1, 10.3.10		Chap 1, 10.3.10	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Residual Unbalance/Sensitivity Check (3)			Chap 1, 10.4		Chap 1, App. A	Report			
	Residual Unbalance With Coupling (3)			Chap 1, 10.4.3/ Chap 1, 10.4.4		Chap 1, 10.3.5	Report			
	Rotor Assembly—Final Dimensional (3)			4.6.1		Mfg Drawing	Report			
	Rotor Assembly—Final Indication (3)			4.6.1		Mfg Drawing	Report			
	Rotor Assembly—Gauss Level (3)			4.6.1		Mfg Drawing	Report			
	Weight of Assembled Rotor			4.6.1		Mfg Drawing	Report			
	Prep for Shipment			Chap 1, 11						
	INTEGRALLY FORGED ROTOR ASSEMBLY/LOW SPEED BALANCE			**4.3**			**(2)**			
	Interference Fit Summary			4.1.1c		Mfg Drawing	Report			
	Blue Check Coupling Fit			Chap 1, App C.6			Report			
	Balance Machine Calibration			Chap 1, 10.5.1		Mfg Requirement	Report			
	Rotor Indication (stage by stage/ complete)			4.3.1			Report			
	Balance bare rotor			4.3.2			Report			
	Weigh or moment weigh blades			4.1.6						
	Sequentially assemble and low speed balance the rotor			4.3.3/Chap 1, 10.3		Chap 1, 10.3.9	Report			
	Positive Material identification (PMI) each shroud, lacing and tie wire	AISI/ ASTM Spec No.					Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Shroud, tie wire and lacing wire Installation			4.3.4, 4.5		Mfg. Require-ment	Report			
	Final Machine			4.5.1q		Mfg Drawing	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			4.5.1s/Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection			4.5.1 s		Mfg Drawing	Report			
	Residual Unbalance—Rotate U-Joint Drive			Chap 1, 10.3.10		Chap 1, 10.3.10	Report			
	Residual Unbalance/Sensitivity Check			4.3.5/Chap 1, 10.4		Chap 1, App. A	Report			
	Residual Unbalance With Coupling			Chap 1, 10.4.3/ Chap 1, 10.4.4		Chap 1, 10.3.5	Report			
	Rotor Assembly—Final Dimensional			4.6.1		Mfg Drawing	Report			
	Rotor Assembly—Final Indication			4.6.1		Mfg Drawing	Report			
	Rotor Assembly—Gauss Level			4.6.1		Mfg Drawing	Report			
	Coat (3)		A	Chap 1, App L/ Chap 1, App K		Coating Procedure	Report			
	Coating process qualification (coupons) (3)		C,H	Chap 1, App L/ Chap 1, App K		Coating Procedure	Report			
	Rotor Balance (complete) after coating (3)			Chap 1, 10.3		Chap 1, 10.3.9	Report			
	Residual Unbalance—Rotate U-Joint Drive (3)			Chap 1, 10.3.10		Chap 1, 10.3.10	Report			

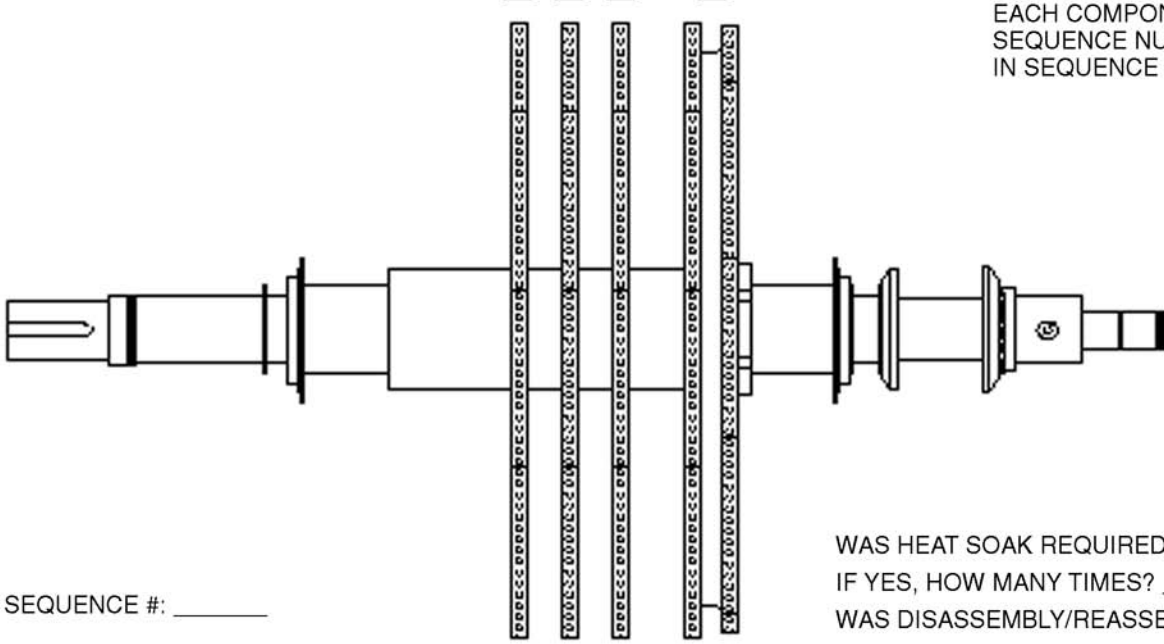
Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Residual Unbalance/Sensitivity Check (3)			Chap 1, 10.4		Chap 1, App. A	Report			
	Residual Unbalance With Coupling (3)			Chap 1, 10.4.3/ Chap 1, 10.4.4		Chap 1, 10.3.5	Report			
	Rotor Assembly—Final Dimensional (3)			4.6.1		Mfg Drawing	Report			
	Rotor Assembly—Final Indication (3)			4.6.1		Mfg Drawing	Report			
	Rotor Assembly—Gauss Level (3)			4.6.1		Mfg Drawing	Report			
	Weight of Assembled Rotor			4.6.1		Mfg Drawing	Report			
	Prep for Shipment			Chap 1, 11						

DESCRIPTION/OPERATION		
NOTES:		
1) All verifying document reports shall reference procedure and state drawing acceptance criteria.	2) All WPS, WQR, and PQR shall be available to purchaser for review and approval prior to any welding. 3) Only applies to rotors specified to be coated.	
LEGEND GENERAL	**MATERIAL CERT**	**INSPECTION POINT**
H.T. Heat Treatment PT Liquid Penetrant Inspection MT Magnetic Particle Inspection VT Visual Inspection UT Ultrasonic Inspection W/A Will Advise N/A Not Applicable	A Certificate of Compliance C Chemical Analysis M Mechanical Properties H Heat Treat Charts I Impact	O Observation W Witness / Hold Pt * Vendor To Confirm That Requirement Has Been Met
Report: defines a vendor generated quality control inspection form/report that will satisfy industry standards or requirements outlined on purchase order.		

APPENDIX D—INSPECTION FORMS FOR ASSEMBLY AND BALANCING

NOTE: THIS FORM TO BE COMPLETED AFTER EACH STACKING SEQUENCE AND FOR EACH COMPONENT STACKED. SEQUENCE NUMBER TO BE ENTERED IN SEQUENCE NUMBER SPACE.

SEQUENCE # __ __ __ __



SEQUENCE #: _______

WAS HEAT SOAK REQUIRED? _______

IF YES, HOW MANY TIMES? _______

WAS DISASSEMBLY/REASSEMBLY REQUIRED? _____

REMARKS					**API RP-687, FIGURE 4.D-1**		JOB NO.	
							MODEL NO.	
					STACKING SEQUENCE REPORT		UNIT NO.	
			ID NO.					
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED	CUSTOMER	LOCATION	FORM NO.	TYPE

Figure 4.D-1—Stacking Sequence Report

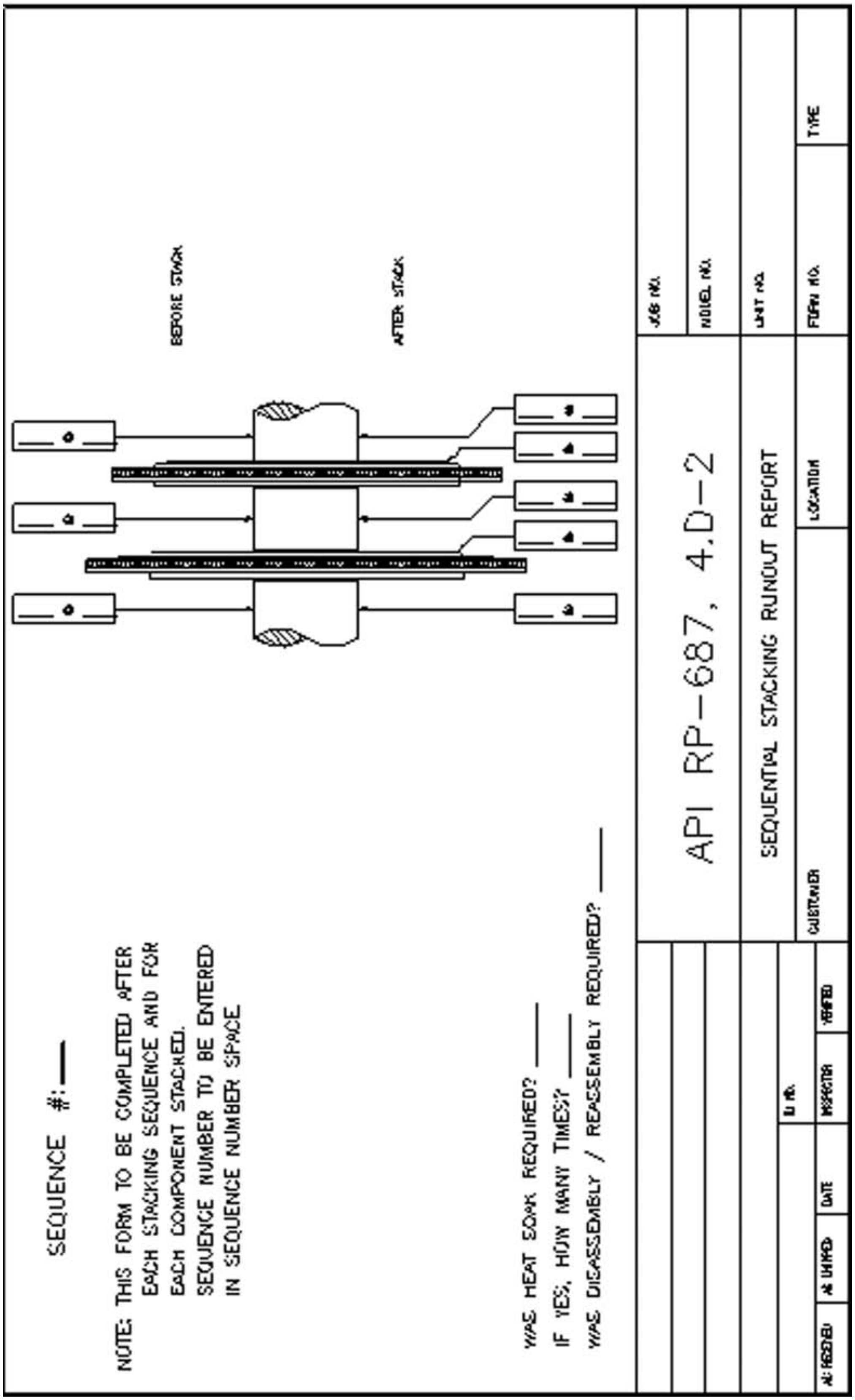


Figure 4.D-2—Sequential Stacking Runout Report

NOTE: THIS FORM TO BE COMPLETED AFTER EACH STACKING SEQUENCE AND FOR EACH COMPONENT STACKED. SEQUENCE NUMBER TO BE ENTERED IN SEQUENCE NUMBER SPACE.

SEQUENCE NUMBER(S): ______________

INITIAL BALANCE MACHINE READINGS: ☐ GRAMS ☐ OUNCES

LEFT PLANE ______________ AT ______________ DEGREES ON ______________ END.

RIGHT PLANE ______________ AT ______________ DEGREES ON ______________ END.

ROTOR AND SETUP DATA:

BEARING SPAN (MM/INCHES): ______________

BALANCE PLANE SEPARATION (MM/INCHES): ______________

LEFT PLANE RADIUS (MM/INCHES): ______________

RIGHT PLANE RADIUS (MM/INCHES): ______________

"ZERO" REFERENCE POINT IS: ______________

LEFT JOURNAL WEIGHT (Kg/Lbs): ______________

RIGHT JOURNAL WEIGHT (Kg/Lbs): ______________

MAX. CONTINUOUS OPERATING SPEED: ______________

BALANCE SPEED: ______________

FINAL BALANCE MACHINE READINGS: ☐ GRAMS ☐ OUNCES

LEFT PLANE ______________ AT ______________ DEGREES ON ______________ END.

RIGHT PLANE ______________ AT ______________ DEGREES ON ______________ END.

REMARKS				API RP-687, FIGURE 4.D-3		JOB NO.	
						MODEL NO.	
				SEQUENTIAL STACKING BALANCE REPORT		UNIT NO.	
AS RECEIVED	DATE	ID NO.					
AS SHIPPED	DATE	INSPECTOR	VERIFIED	CUSTOMER	LOCATION	FORM NO. 4.D-3	TYPE

Figure 4.D-3—Sequential Stacking Balance Report

APPENDIX E—AUDITORS CHECK LIST

E.1 General

This Appendix, along with Appendix H, Chapter 1, is a checklist to provide information for the owner and the vendor to aid in summarizing the scope of the rotor repair.

Repairs require clear owner / vendor communication and the assignment of responsibilities. The format of this checklist provides a summary of the items required and the parties responsible.

Each item on this checklist has a circle or a square to indicate whether the owner or vendor, respectively, is responsible for obtaining the information or performing the task. The owner must indicate, for each item, whether the item is to be witnessed, observed, or verified. Typically, inspections, processes or tests may be witnessed or observed while verification is the review of the results of the inspections, processes, tests, or other documentation so as to ensure that the requirements have been met.

AUDITORS CHECK LIST

Customer: ______________________________

Job/Project Number: ______________________________

Owner Equipment Identification Number: ______________________________

OEM Equipment Serial Number: ______________________________

Rotor Identification Number: ______________________________

Repair Purchase Order Number: ______________________________

Vendor Job Number: ______________________________

Auditors Check List

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
SECTION 1—Inspection of Assembled Rotor Phase I							
Inspection Forms/Drawings	☐	1.3.2					
Axial Stack-up	☐	1.3.3					
Wheel/Shroud Axial Runouts	☐	1.3.4					
Axial Gaps	☐	1.3.5					
Overspeed Trip Mechanism	☐	1.3.6					
Flow Path Inspection	☐	1.3.7					
Shroud Lacing Wire Inspection	☐	1.3.9					
NDE	☐	1.3.10-1.3.13					
Hardness Inspection	☐	1.3.14					
Surface Area Inspection		1.3.15					
Inspection Report	☐	1.4					
SECTION 2—Rotor Disassembly Phase II							
Rotor Disassembly	O/☐	2.2.1					
Deblade Rotor	O	2.2.2					
Matchmark Components	☐	2.2.4					
Interference Fits	☐	2.2.5					
Rotor Unstacking	☐	2.2.6					
Heat Components	☐	2.2.7					
Mating Fits	☐	2.2.8					
Axial Dimensions	☐	2.2.9					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
Pre-Deblading	☐	2.2.10.1					
Work Plan	☐	2.2.10.2					
Reusable Blades	☐	2.2.10.3					
Clean Rotor	☐	2.3.1					
Interference Fits	☐	2.3.2.1					
Mating Fits	☐	2.3.2.2					
Shaft Dimensions	☐	2.3.2.3a					
Disk Bore Dimensions	☐	2.3.2.3b					
Stacking Heights	☐	2.3.2.3c					
Axial Runouts	☐	2.3.2.3d					
Spacers, Sleeves	☐	2.3.2.3e					
Balance Piston	☐	2.3.2.3f					
Thrust Collar	☐	2.3.2.3g					
Key Clearances	☐	2.3.2.3h					
Eliminate Weight(s)	☐	2.3.2.4					
NDE	☐	2.3.2.5 / 2.3.2.6					
Photographs	☐	2.3.2.7					
Threaded Areas	☐	2.3.2.8					
Review	☐	2.4.1					
Component Bore	☐	2.4.2					
Blade Reusability	☐	2.4.3					
Blue Contact Check	☐	2.4.4					
Job Scope	☐	2.5.1					
Blade Reusability	☐	2.5.2					
SECTION 3—Repair Processes and New Component Manufacture							
Engineering Review	☐	3.1.2					
Seal Areas	☐	3.1.3					
Thermal Bows	☐	3.1.4					
Disk Rubs	☐	3.1.5					
Disk Pitting	☐	3.1.6					
Integral Rotor							
Disk Weld Repair	☐	3.2					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice			Date Inspected or Verified By	Status
			W	O	V		
Disk on Shaft Rotor							
Shaft Repair	☐	3.3.1					
Engineering Evaluation	☐	3.4.1					
Disk Bore Weld Repair	☐	3.4.1.1					
Disk Bore Oversize Repair Method #1	☐	3.4.1.2					
Disk Bore Oversize Repair Method #2	☐	3.4.1.3					
Disk Bore Oversize Repair Method #3	☐	3.4.1.4					
Steam Balance Holes	☐	3.5					
Blade Attachment Areas Oversize Repair	☐	3.6.1					
Disk Weld Repair	☐	3.6.2					
Identify Blade Failure Mode	☐	3.7.1					
Foreign Object Damage	☐	3.7.2					
Blade Weld Repair	☐	3.7.3					
Coatings	☐	3.8.1					
Re-Coating	☐	3.8.2					
J Strips	☐	3.9.1					
Seal Teeth	☐	3.9.2					
Sleeves, Spacers	☐	3.10					
Component Replacement							
Component Replacement Requirements	☐	3.11.1					
New Blade Manufacture	☐	3.11.2					
SECTION 4—Assembly and Balancing							
Dimensional Verification	☐	4.1.1					
Mating Components	☐	4.1.2					
Mating Surfaces	☐	4.1.3					
Keyway Verification	☐	4.1.4					
Phase Related Runouts	☐	4.1.5					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
Blade Attributes	☐	4.1.6					
Circumferential Distribution	☐	4.1.7					
Locking Hardware	☐	4.1.8					
Protect Components	☐	4.1.9					
Coating Restrictions	☐	4.1.10					
Overspeed Trip Mechanism	☐	4.1.11					
Balance Corrections	☐	4.1.12					
Disk on Shaft Rotor							
Component Balance	☐	4.2.1					
Assembly Balance	☐	4.2.2					
Shroud/Wire Installation	☐	4.2.3					
Assembly Sequence	☐	4.2.4					
Heating Components	☐	4.2.5					
Shaft Positioning	☐	4.2.6					
Rotor Cooldown	☐	4.2.8					
Position Verification	☐	4.2.9					
Axial Gaps	☐	4.2.10					
Phase Related Runouts	☐	4.2.11					
Disk Rim Runouts	☐	4.2.12					
Shaft Runout Changes	☐	4.2.13					
Balance	☐	4.2.14 / 4.2.15					
Axial Dimensions	☐	4.2.16					
Balance Corrections	☐	4.2.17					
Overall Stack	☐	4.2.18					
Residual Unbalance	☐	4.2.19					
Integral Rotors							
Rotor Measurements	☐	4.3.1					
Balance Rotor	☐	4.3.2					
Assembly Sequence	☐	4.3.3					
Shroud/Wire Installation	☐	4.3.4					
Residual Unbalance	☐	4.3.5					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
Reassembly of Partially Disassembled Rotors							
Balance Rotor	☐	4.4.2					
Install Shroud	☐	4.5.1					
Peen Blade Tenons	☐	4.5.1					
Peening Qualification Procedure	☐	4.5.2					
Wire Pre-Installation Data	☐	4.5.3.1					
Verify Blade Packet	☐	4.5.3.2					
Final Inspection	☐	4.6					
Documentation	☐	4.7					

CHAPTER 5—SPECIAL PURPOSE GEARS

CONTENTS CHAPTER 5

Chapter 5—Special Purpose Gears

1 Inspection of Assembled Rotor Phase I

1.1 GENERAL

This section describes the data to be recorded and the requirements of Phase I inspection of the gear assembly and / or pinion. This section is to be used in addition to the requirements of Chapter 1, Section 7, Phase I inspection.

1.2 DEFINITIONS

Refer also to Figure 5.1-1.

1.2.1 addendum: The portion of the tooth involute above the pitch line.

1.2.2 backlash: The amount of clearance between the non-contacting flanks of meshing gear teeth.

1.2.3 contact: The area on the tooth flank that has rubbed against the mating tooth after a gearset has rolled through mesh.

1.2.4 dedendum: The portion of the tooth involute below the pitch line.

1.2.5 double helical: A rotor that has two sets of teeth, both right hand and left hand lead, usually with a groove between them.

1.2.6 lead or helix: The angle between the tooth and the centerline of the rotor. It may be either "right hand" or "left hand". A right hand helix inclines downhill to the right.

1.2.7 pitch line, pitch diameter, or pitch circle of the gear teeth: Used interchangeably. It is the theoretical diameter about which only rolling action occurs and is generally half way up the tooth flank.

1.2.8 profile, flank, or involute: Used interchangeably and is the curved side (one working and one non-working) of the tooth.

1.2.9 rider rings, also called thrust collars: Rings that are mounted on a single helical pinion to rub on the sides of the gear. They transmit the axial force of the gear teeth without conventional thrust bearings.

1.2.10 root diameter: The circle that coincides with the bottom of the tooth spaces.

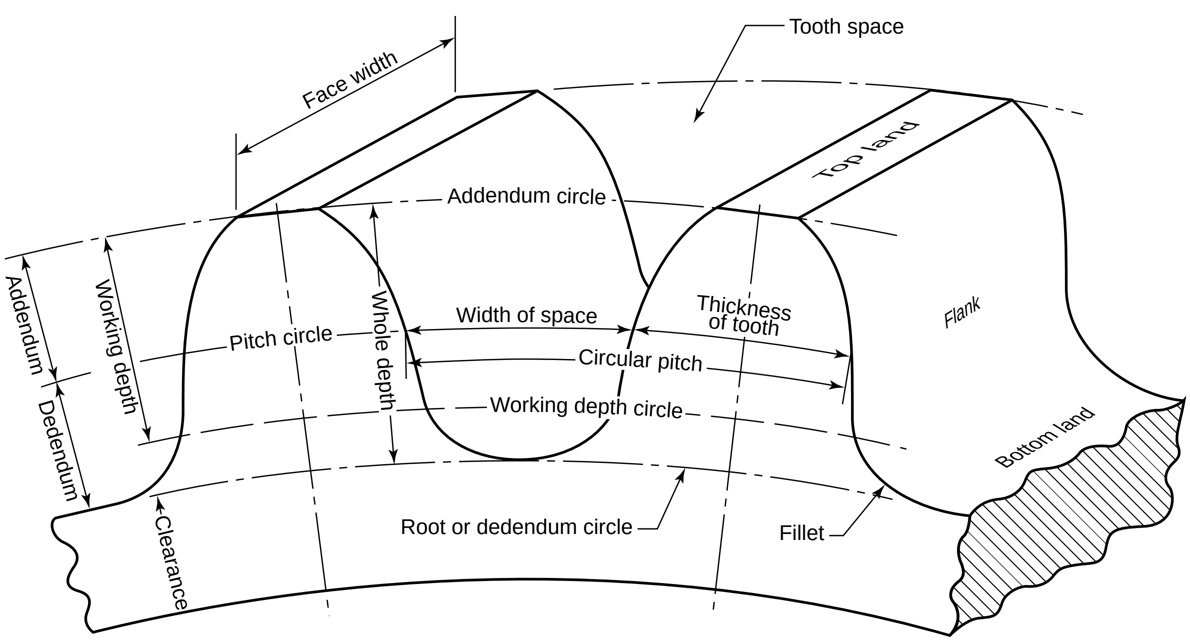


Figure 5.1-1—Gear Nomenclature

1.2.11 single helical: A rotor that has one set of teeth with only a right hand lead or a left hand lead inclined to the centerline of the gear.

1.2.12 tooth spacing: The distance from the flank of one tooth to the corresponding flank of the next, measured along the pitch line.

For further definitions of gear tooth terminology please refer to AGMA Standard 1012, *Gear Nomenclature, Definition of Terms with Symbols*.

1.3 INSPECTION

1.3.1 The following paragraphs shall be used in exception to or in addition to the paragraphs from Chapter 1, Section 7. The exception to paragraph shall be referenced.

1.3.2 Cleaning of the gear or pinion shall be conducted per Chapter 1, paragraph 7.2.2 except that blasting (shot, bead, sand, etc.) shall not be used as a cleaning method on gear teeth.

Note: Cleaning of the gear teeth with solvents and soft wire brushes is acceptable.

1.3.3 The direct current (DC) wet magnetic particle inspection method shall be used for NDE of gear elements. Evaluation shall be per severity level A, of Chapter 1, Table 1.8-1 and paragraph 8.2.4.4.

1.3.4 Non-integral rotors (two pieces or more) shall not be separated (unstacked) unless otherwise specified.

Note: Separation of a toothed element from its shaft compromises the dimensional integrity of the pitch line to the bearing journals.

1.3.5 Surface hardness of the teeth shall be measured on the top land (outside diameter) or either end of the teeth and recorded as described by the worksheet in Appendix A. The device used for hardness testing must not deform the working surface.

1.3.6 The gear element inspection shall include measurement(s) and the charting of tooth spacing, pitch line runout, profile and lead in accordance with ANSI/AGMA ISO 1328. Generally a quality level of 4 is satisfactory for special purpose gearing.

Note: It is important to identify any geometric modifications such as crowning, lead correction or profile adjustment that was made to the gear teeth to enhance performance. This information is used in the evaluation of tooth contact checks.

1.3.7 The mating gear elements shall receive a tooth contact check and the resultant contact pattern shall be recorded by tape lifts. Refer to API 613, Fourth Edition, paragraph 2.5.2.2 for a description of this process. This check shall be performed at a minimum of three randomly selected places around the circumference of the larger element, i.e., about every 120°.

1.3.8 The mating gear elements of double helical gears shall receive an axial stability check as defined by API 613, Fourth Edition, paragraph 2.5.2.3 and the results shall be recorded on the form provided in Appendix A or equivalent.

1.3.9 The mating gear elements of the gear set shall receive a backlash check. A double helical gear set is to be checked with the pinion centered on the gear.

Tutorial: Backlash is not as important as the condition of the tooth flank. In certain applications, such as reversing loads, a minimum amount of backlash is important. In applications where the load does not reverse, a larger amount of backlash is acceptable.

1.3.10 Dimensional and runout checks of gear rotors and their mounted components such as thrust collars, rider rings, axial probe targets, etc. shall be conducted and recorded as defined by Chapter 1, paragraph 7.2.6.

1.3.11 Vendor shall use terminology from the AGMA specification 1010, Appearance of Gear Teeth—Terminology of Wear and Failure to clarify and describe the gear teeth condition. This information is to be identified on the Phase I inspection report.

1.3.12 Review the check balance from Chapter 1, paragraph 7.2.8 for residual unbalance. Unbalance amounts resulting in a gear eccentricity larger than 0.00127 mm (50 µinches) should be thoroughly investigated prior to balance corrections.

1.4 INSPECTION REPORT

1.4.1 The vendor shall prepare an initial inspection documentation package (report) consisting of all of the information identified in Chapter 1, Section 7 and Section 1.3, as applicable.

2 Rotor Disassembly Phase II

2.1 GENERAL

The gear/shaft assembly shall not be disassembled.

Note: Dismounting and remounting of the finished gear to the shaft could result in perpendicularity and concentricity values no longer within the allowable tolerance requirements.

3 Repair Processes and New Component Manufacture

3.1 GENERAL

In addition to the general repair processes and new component manufacturing requirements discussed in Chapter 1, Section 9, the following procedures and practices are recommended to accommodate the conditions and considerations unique to gear elements.

CAUTION: Special purpose gearing requires repair shops that have the capability to measure and machine to the close tolerances required.

3.2 SHAFT RESTORATION

Damaged shaft areas may be repaired using any of the repair techniques discussed in Chapter 1, paragraphs 9.2.2 through 9.2.6. The following precautions apply:

a. Do not weld repair when damage is immediately adjacent to the tooth area, as distortion or deformation detrimental to future operating performance could occur.

b. Locate truth bands, one left and one right of the toothed area, which are verified to be concentric to the pitch line of the teeth, within the limits established in API 613, Fourth edition, paragraph 2.5.2.1 and which will not be affected by any restoration technique.

c. Any journals that are restored shall be finish machined concentric to the truth bands and thus concentric to the pitch circle. The total indicated runout of the repaired journal(s) with relation to both truth bands shall be no more than 12 µm (0.0005 in.) for speeds up to 12,000 feet per minute (FPM) pitch line velocity (PLV) and 7.6 µm (0.0003 in.) for speeds greater than 12,000 FPM PLV.

d. Gear shafting shall not be straightened.

Note: The runout tolerance requirements are probably not attainable by any straightening operation.

3.3 TOOTH RESTORATION

3.3.1 Regrinding

When the wet magnetic particle inspection results are satisfactory and the verification of tooth spacing, pitch line runout, profile and/or lead (refer to Figures 5.3-1 through 5.3-4) has detected non-conforming results, or if the contact check has shown an unacceptable pattern, one or both elements may receive corrective re-machining by means of tooth grinding.

Note: Regrinding may be an acceptable process for case hardened or through hardened gears.

CAUTION: Re-grinding will increase backlash and should not be considered for applications that are backlash sensitive. In applications where case hardening is utilized, re-grinding reduces case depth and possibly the strength rating. When available, the original case hardening records should be checked and ratings should be re-calculated based on the anticipated reduction of case depth to verify that performance parameters are maintained. Backlash sensitive applications can be synchronous motors, power recovery applications, or other applications with reversing torque directions.

3.3.2 Recutting

When the wet magnetic particle inspection results are satisfactory; but, the surface finish, tooth spacing, pitch line runout, profile and/or lead errors are such that more than approximately 0.13 mm (0.005 in.) must be removed from the tooth flank, elements which are through hardened may be restored by use of a process referred to as “re-cutting the gear and over-sizing the pinion”. As with regrinding, the wet magnetic particle inspection must be satisfactory for the element to be re-cut. An appropriate tooth finishing process such as grinding, shaving, or lapping shall be applied to the recut gear.

Note: Briefly described, the process involves a reduction of the outside diameter of the gear, followed by re-forming of the teeth to their original depth, thus establishing a new root diameter and a renewed involute profile. A new pinion is manufactured with its outside diameter and root diameter increased by an amount equal to the reduced diameters of the gear.

CAUTION: Re-cutting a gear tends to reduce the root bending stress capacity of the teeth, thus the ratings of the modified teeth must be checked to verify that they still meet the original performance requirements.

3.3.3 Weld repair of gear teeth is unacceptable.

3.3.4 Gear elements shall be re-balanced after any restoration process has been performed. Refer to Chapter 1, Section 10 and Section 4 of this chapter.

3.3.5 Verification of tooth spacing, pitch line runout, profile, and lead shall be performed and documented following the restoration process. Approval criteria shall be consistent with the original as built requirements, or upgraded requirements if the owner has specified an upgrade.

3.4 REPLACEMENT OF RIDER RINGS (“THRUST COLLARS”) ON SINGLE HELICAL GEAR SETS

3.4.1 General.

In lieu of internally installed load carrying thrust bearings in the gear housing, occasionally, single helical gear sets may be equipped with a set of collars mounted on the pinion at each end of the teeth. When the gear set is placed in mesh, the collars straddle the gear and “ride” the side of the gear, transferring the thrust forces through the gear rim to the gear’s thrust bearing. If the pinion teeth require corrective action, the rider rings must be removed and replacement collars must be produced and installed.

Note: The rider rings may be mounted with an interference fit only, or in combination with split rings.

3.4.2 Rider Rings

The replacement rider rings should be made of the same material and heat treatment as the original equipment. (Usually, they are case hardened by the nitriding process.) The thrust faces should have an additional 50 µm to 100 µm (0.002 in. to 0.004 in.) for the final grinding of the thrust faces. NDE inspection of the material should be performed as described in Chapter 1, paragraph 8.2.4. The bore should be sized to produce an interference fit equivalent to the original equipment fit. The OEM information is highly recommended, but if it is not available, the repair shop shall establish the required in-service interference and thrust angles, accounting for the generated thrust load and interference losses due to thermal and centrifugal effects.

3.4.3 Assembly

Typically, the mounted interference will be of a magnitude that requires that the pinion to be chilled and the rider rings be warmed to reduce the required installation force. The collar(s) shall be mounted dry, i.e., do not use lubricants to aid in the pressing step. The dry installation provides a high coefficient of friction between the collar and the pinion shaft.

3.4.4 Perform a NDE inspection on the assembly per Chapter 1, paragraph 8.2.4.

3.4.5 Grinding the Thrust Faces. Measure and record the linear span from face to face and the angle of the thrust faces on the gear (typically at least 0°30' to as much as 5°30'). Grind the thrust faces of the rider rings to establish the required axial clearance at the matching angle. The angles must match within ±0°0'40".

3.4.6 Contact and Axial Clearance Checks

Set the gear and pinion in a gear set checking stand on true centers. Apply soft bluing to the collar thrust faces. Axially move the pinion back and forth, bumping the gear thrust faces. Remove the pinion and check the transfer pattern. Record by lifting a tape and label appropriately. Rotate the gear approximately 60° and repeat the process, continuing until six places have been checked and recorded. The contact pattern should be a consistent “ellipse” and preferably heavier toward the outside of the collar. Once during the contact check also record the axial distance movement. The axial clearance should be within the OEM tolerance, or 125 µm to 200 µm (0.005 in. to 0.008 in.).

3.5 NEW COMPONENT MANUFACTURE

3.5.1 New components shall be manufactured in compliance with API 613, utilizing the latest edition. The vendor shall recommend upgrades as practical.

Notes:

1. Since there will not normally be a casing available for mechanical testing, the owner must rely on accurate verification of results attained at each significant milestone in the process.

2. Not all requirements of a later edition of API 613 may be practical or possible.

3.5.2 New components shall be manufactured and supplied in accordance with Appendix C and Chapter 1, Section 9.

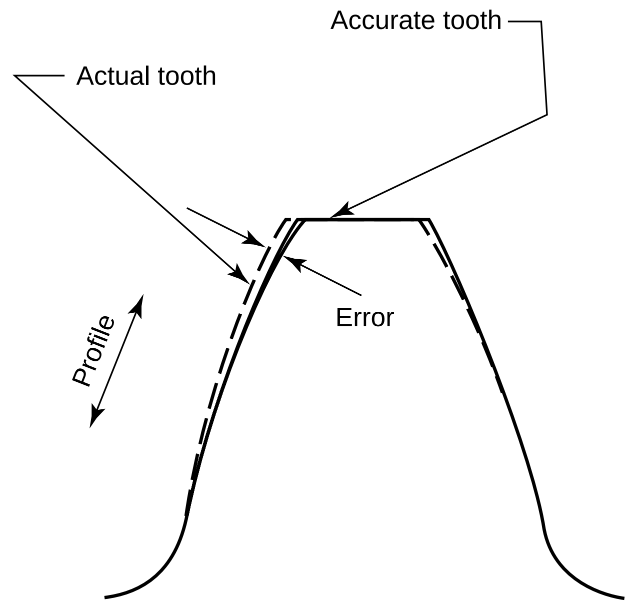


Figure 5.3-1—Gear Tooth Profile

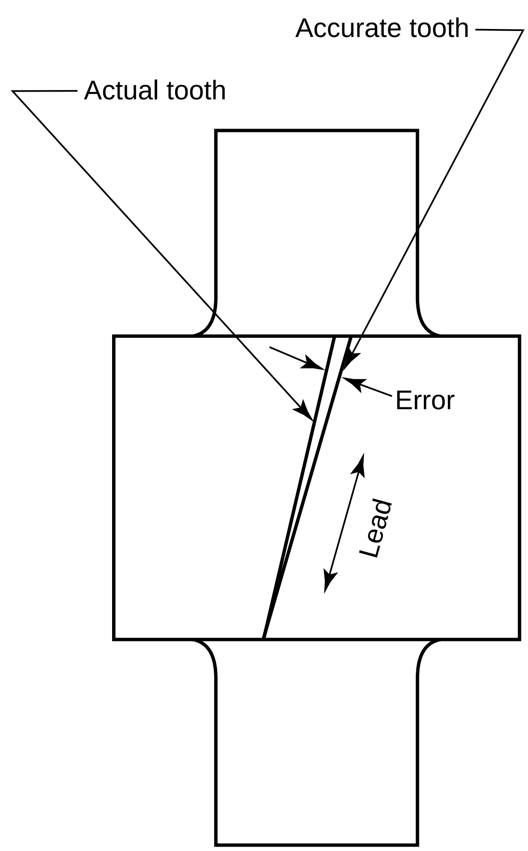


Figure 5.3-2—Gear Tooth Lead

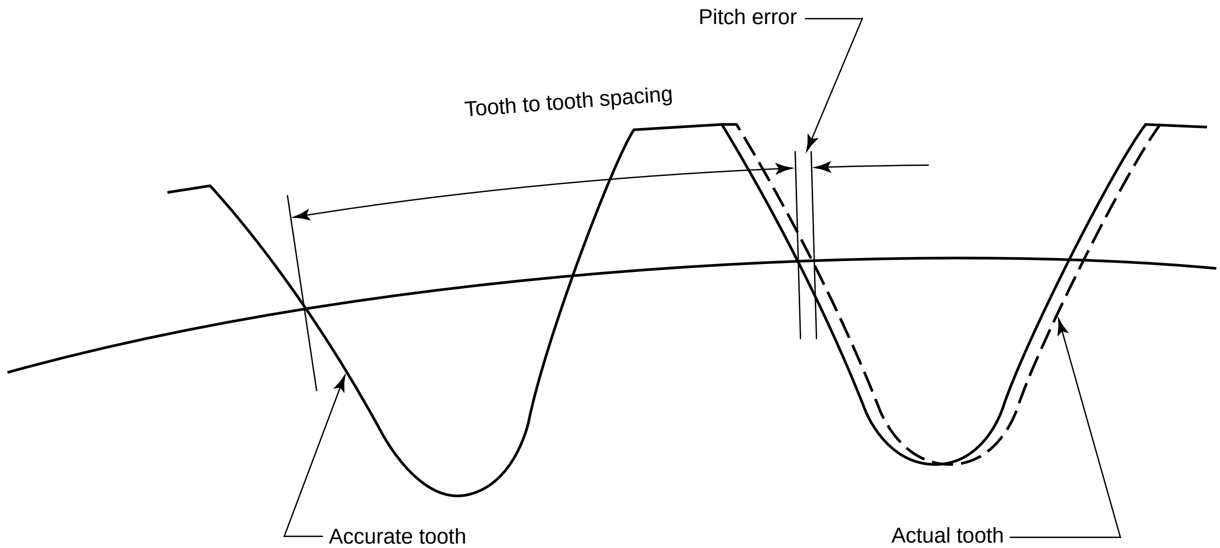


Figure 5.3-3—Gear Tooth Spacing

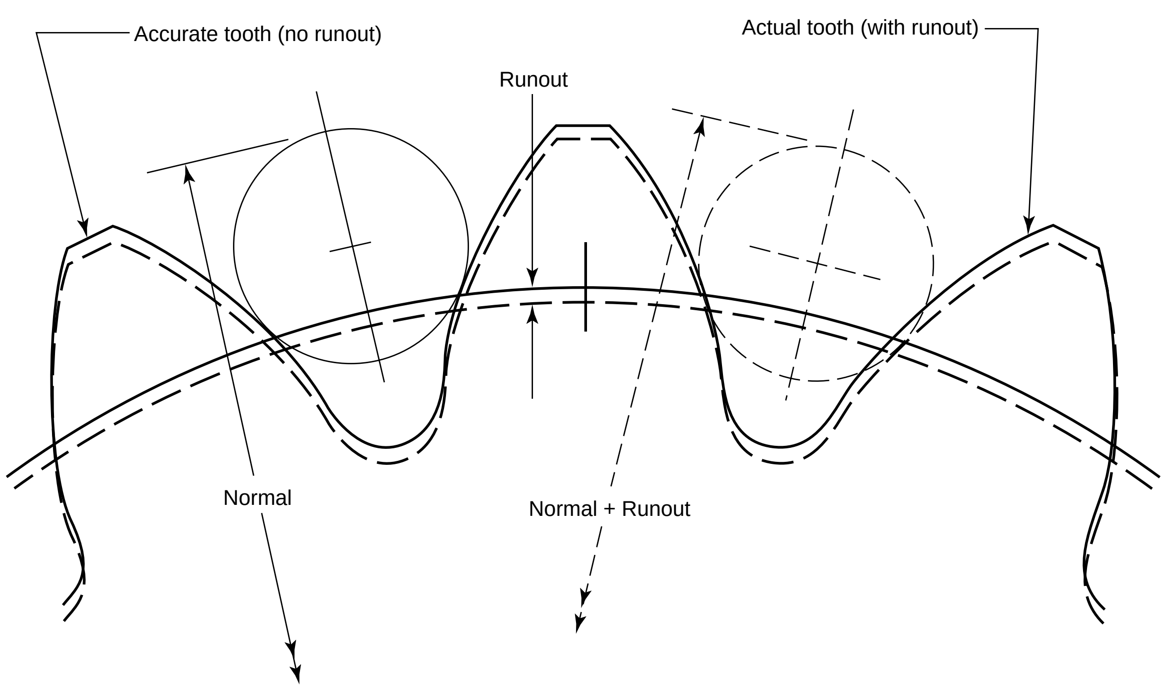


Figure 5.3-4—Pitchline Runout

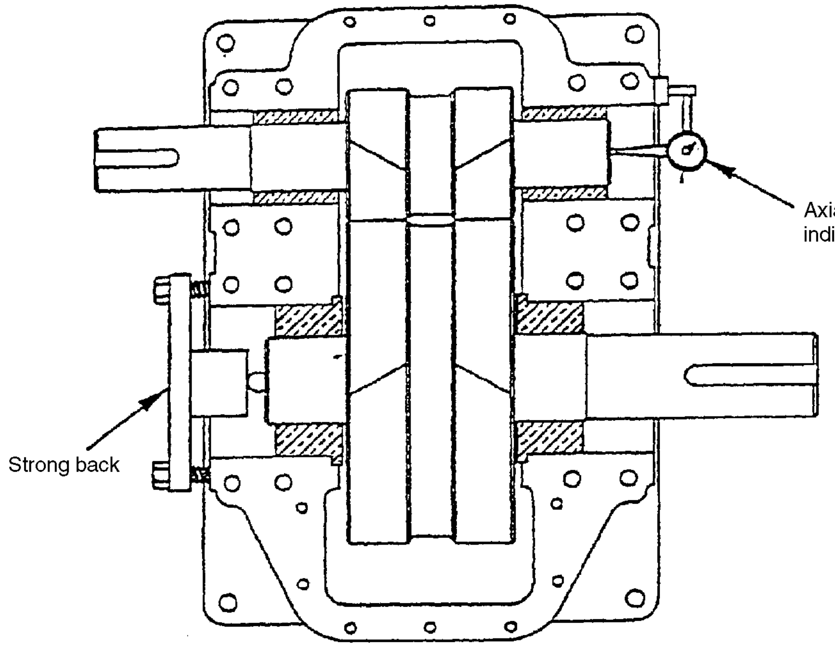


Figure 5.3-5—Apex Wobble

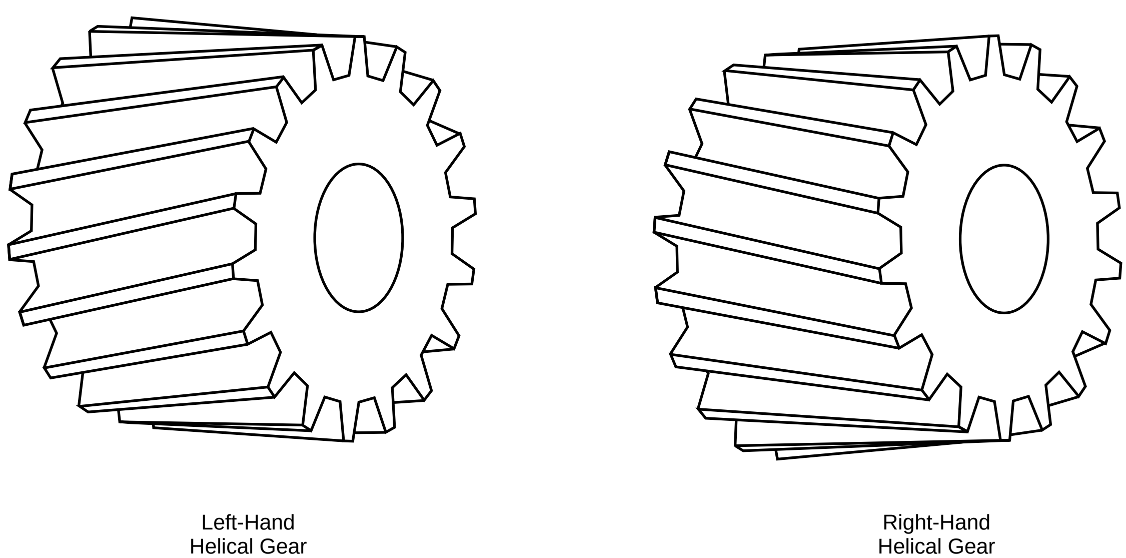


Figure 5.3-6—Hand of Helix

4 Assembly and Balancing

4.1 GENERAL

A repaired gear and pinion shall be considered as a matched set and should be permanently marked as such and identified for traceability with the repair vendor's and owner's unique identification numbers and the date of repair. "Assembly" for the purposes of this section, assumes the gear housing is not available, thus consists of the performance of the required pre-assembly and assembly activities using devices that accurately substitute for and simulate the role of the housing.

4.2 PRE-ASSEMBLY

4.2.1 The repaired gear and pinion shall be checked for contact and backlash on a contact checking stand. Refer to API 613 Fourth Edition, June 1995, Section 2, paragraph 2.5.2.2 for a description of the proper techniques and acceptance criteria.

4.2.2 Results of the contact check shall be documented by means of tape lifts, as described in API 613 Fourth Edition, June 1995, Section 2, paragraph 2.5.2.2.

4.2.3 For double helical gears, the repaired gear and pinion shall be checked for axial stability of the mesh. Refer to API 613 Fourth Edition, Section 2, paragraph 2.5.2.3 and Figure 5.3-5 for a description of the proper techniques and acceptance criteria.

Note: The slow rotation method must be used if a housing is not available for testing.

4.3 ASSEMBLY

4.3.1 Refer to Section 3.4 for assembly of rider rings. No other components are typically assembled to gear shafts.

4.4 BALANCING

4.4.1 General

Each gear shall be balanced per Chapter 1, paragraph 10.2 with additional specific requirements as described in paragraph 4.4.2.

4.4.2 Balance corrections shall be performed as follows:

a. On gears that operate below the first critical speed, corrections shall be made outboard of the bearing journals, if possible. If this is not possible, then the corrections may be made on the wing end faces of the gear.

b. The corrections shall be made by drilling and/or grinding. If drilled corrections are used, the bottoms of the drilled holes shall be dressed with a radiused drill point to eliminate undue stress risers.

c. When corrections are made on the wing faces of the gear, they shall be made at a minimum distance from the root of the gear teeth of 1.75 times the tooth depth.

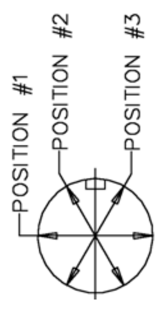
4.5 FINAL INSPECTION

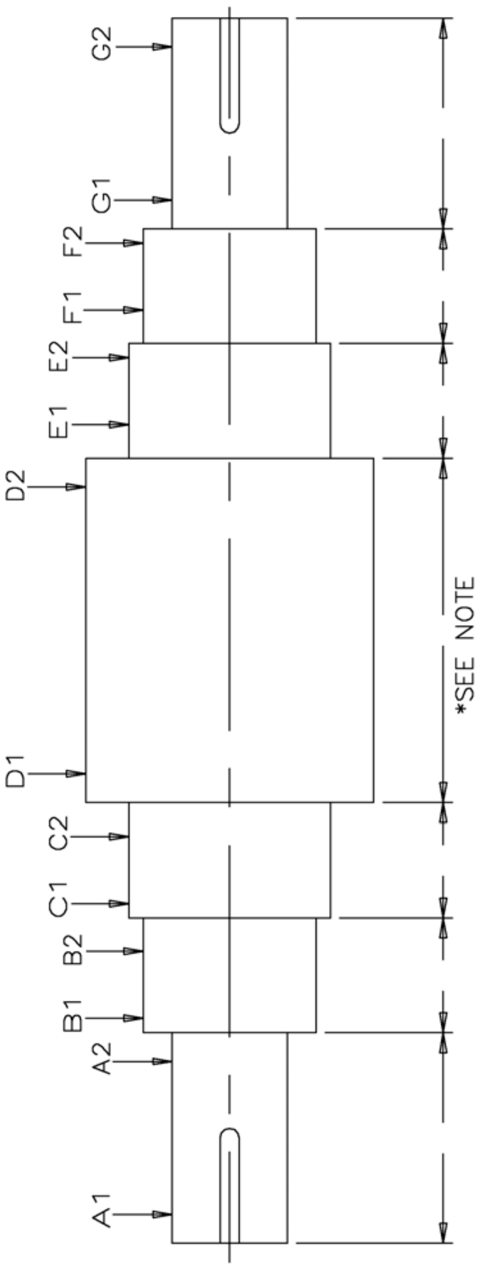
4.5.1 Perform dimensional and NDE inspections of the assembled rotor as required in Section 1.3.

4.6 DOCUMENTATION

4.6.1 Documentation for rotor re-assembly and/or balancing shall conform to the requirements of Chapter 1, Section 12.

APPENDIX A—DIMENSIONAL FORMS FOR PHASE I INSPECTION





MIC ALL DIAMETERS AND RECORD.

	A1	A2	B1	B2	C1	C2	D1
POSITION #1							
POSITION #2							
POSITION #3							

	D2	E1	E2	F1	F2	G1	G2
POSITION #1							
POSITION #2							
POSITION #3							

EXAMPLE:

A1 @ POSITION #1 – PERPINDICULAR TO KEYSEAT
@ POSITION #2 – 30 DEGREES LEFT OF KEYSEAT
@ POSITION #3 – 30 DEGREES RIGHT OF KEYSEAT

*NOTE:

PROVIDE MIC OR CALIPER DIMENSION OF THE DISTANCE BETWEEN THE BEARING SHOULDERS, HUB, OR TRUING BANDS. (ANY FEATURES THAT CONTROL LINEAR POSITION OF ELEMENT.)

REMARKS					
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED	ID NO.

API RP-687, FIGURE 5.A-1

ROUNDNESS AND TAPER CHECK

CUSTOMER	LOCATION	FORM NO.	TYPE
JOB NO.	MODEL NO.	UNIT NO.	

Figure 5.A-1—Roundness and Taper Check

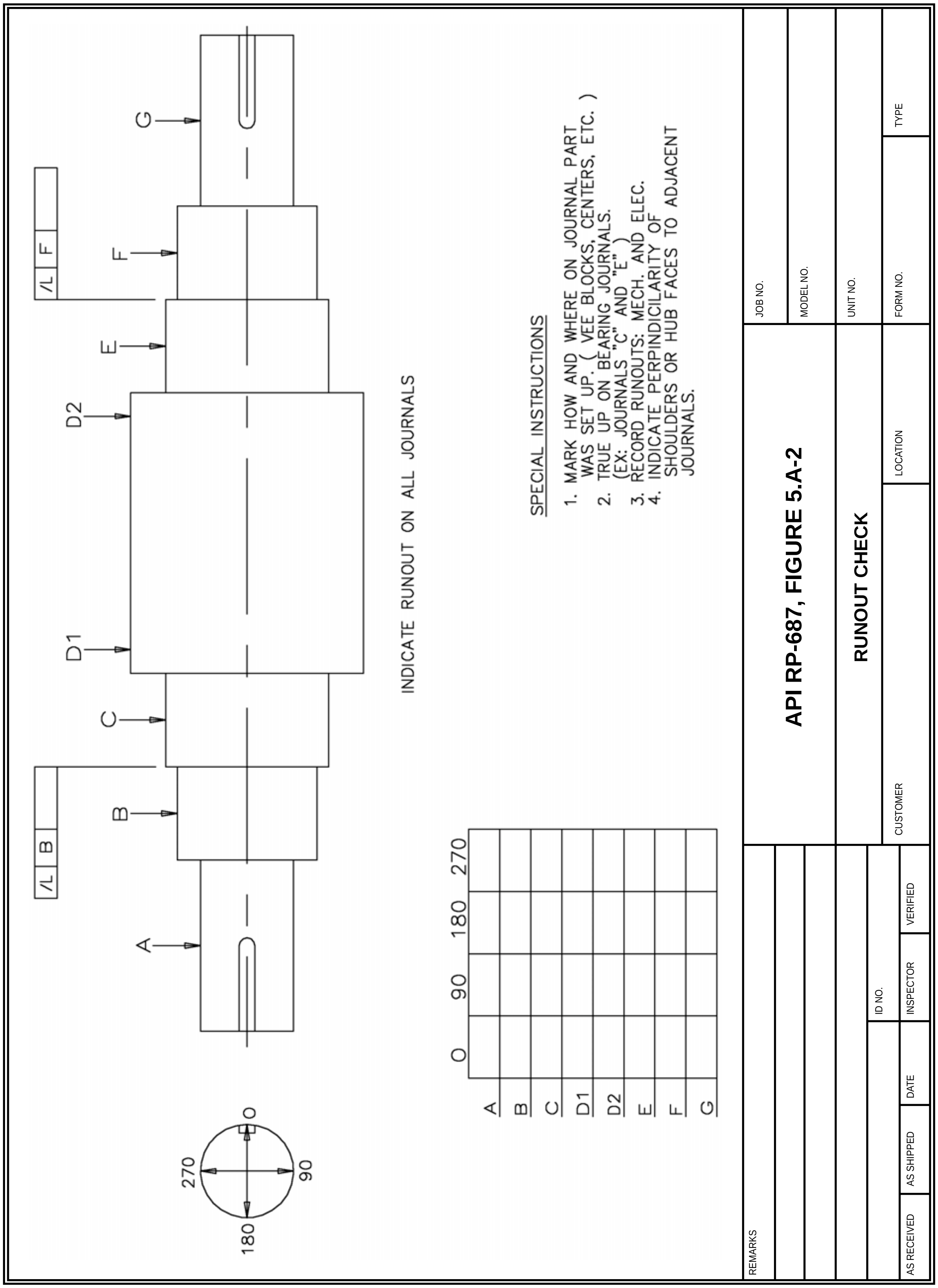
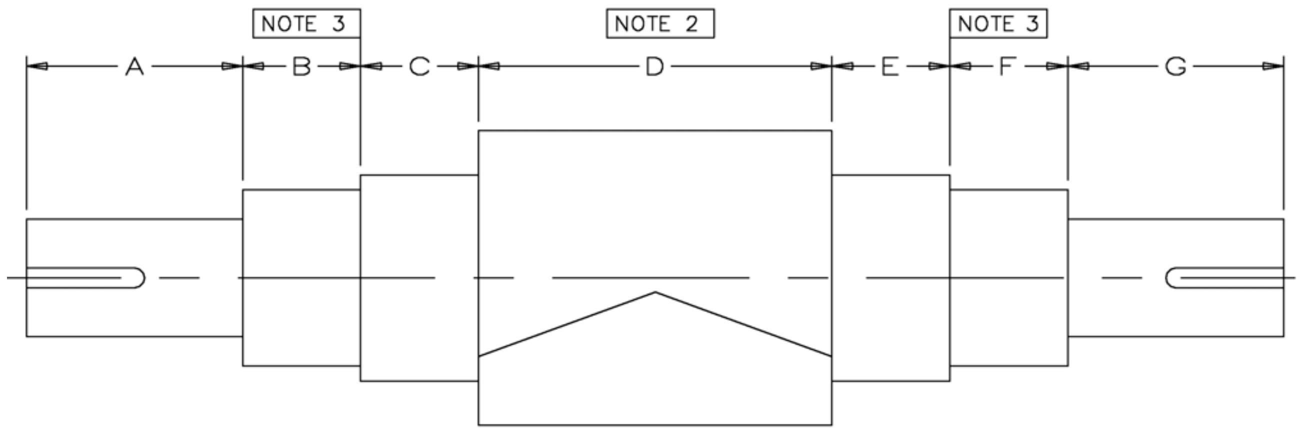


Figure 5.A-2—Runout Check



MEASURE LINEAR AND GEOMETRIC DATA AND RECORD:

RECORD JOURNAL LENGTH

A		
B		/L B
C		
D		
E		
F		/L F
G		

NOTES AND INSTRUCTIONS:

NOTE #2: PROVIDE MIC OR CALIPER DIMENSION OF THE DISTANCE BETWEEN THE BEARING SHOULDERS, HUBS, TRUING BANDS. (ANY FEATURES THAT CONTROL LINEAR POSITION OF ELEMENT.)

NOTE #3: INDICATE PERPINDICULARITY OF THE SHOULDERS OF HUB FACES AND ADJACENT JOURNALS:
EXAMPLE:

SHOULDER "B" /L TO JOURNAL "B" WITHIN .0005 /L B .0005

SHOULDER "F" /L TO JOURNAL "F" WITHIN .001 /L F .001

REMARKS

ID NO.

AS RECEIVED | AS SHIPPED | DATE | INSPECTOR | VERIFIED

API RP-687, FIGURE 5.A-3

LINEAR AND GEOMETRIC DATA

CUSTOMER | LOCATION

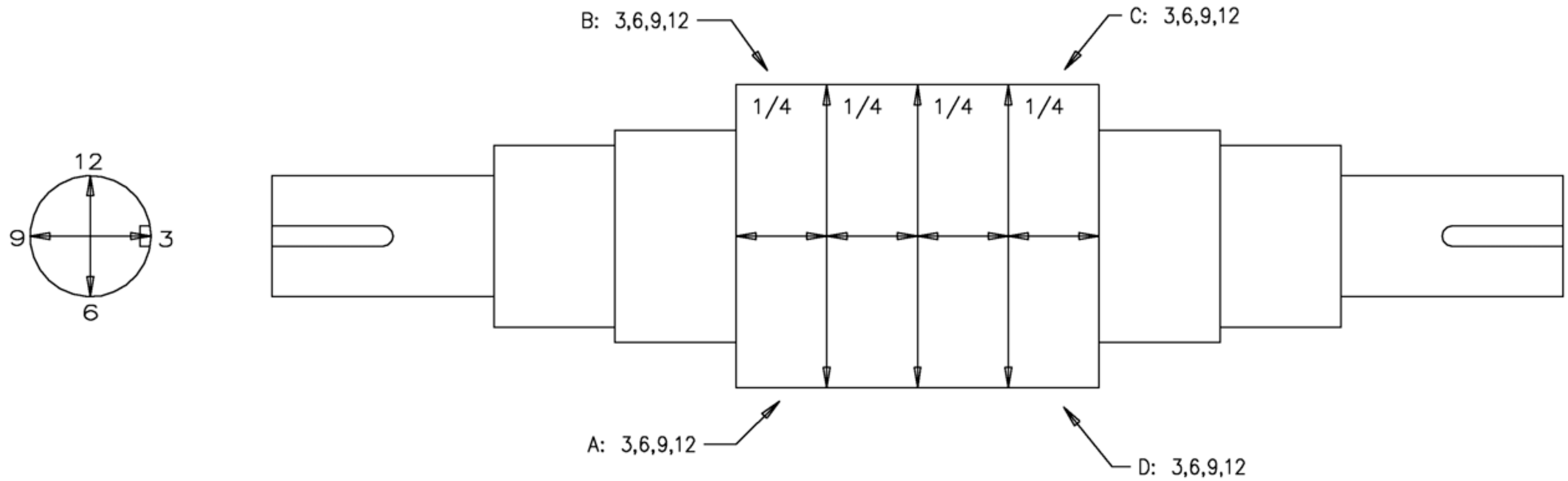
JOB NO.

MODEL NO.

UNIT NO.

FORM NO. | TYPE

Figure 5.A-3—Linear and Geometric Data



OBSERVE AND RECORD GENERAL TOOTH DATA AS FOLLOWS:

1) CHECK AND RECORD HARDNESS OF GEAR TEETH, AT TIPS, AT MARKED LOCATIONS.

	3	6	9	12
A				
B				
C				
D				

EXAMPLE:

"A" END OF TOOTH AT PITCH LINE, "B" TOP OF TOOTH 1/4 OF FACE
"C" TOP OF TOOTH 3/4 OF FACE, "D" OPPOSITE "A" AT PITCH LINE

REMARKS					API RP-687, FIGURE 5.A-4		JOB NO.	
							MODEL NO.	
					GENERAL OBSERVATIONS		UNIT NO.	
			ID NO.					
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED	CUSTOMER	LOCATION	FORM NO.	TYPE

Figure 5.A-4—General Observations

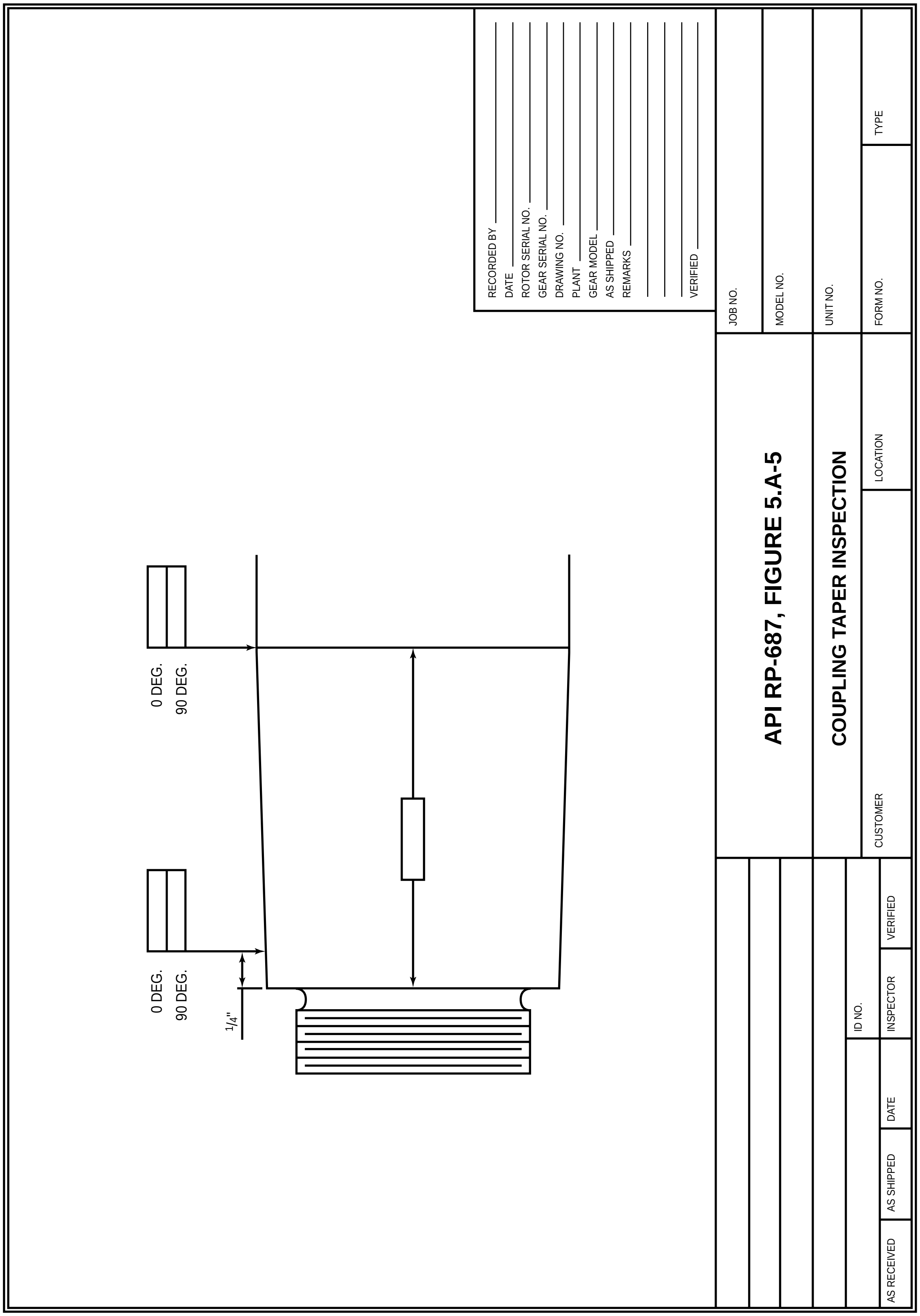


Figure 5.A-5—Coupling Taper Inspection

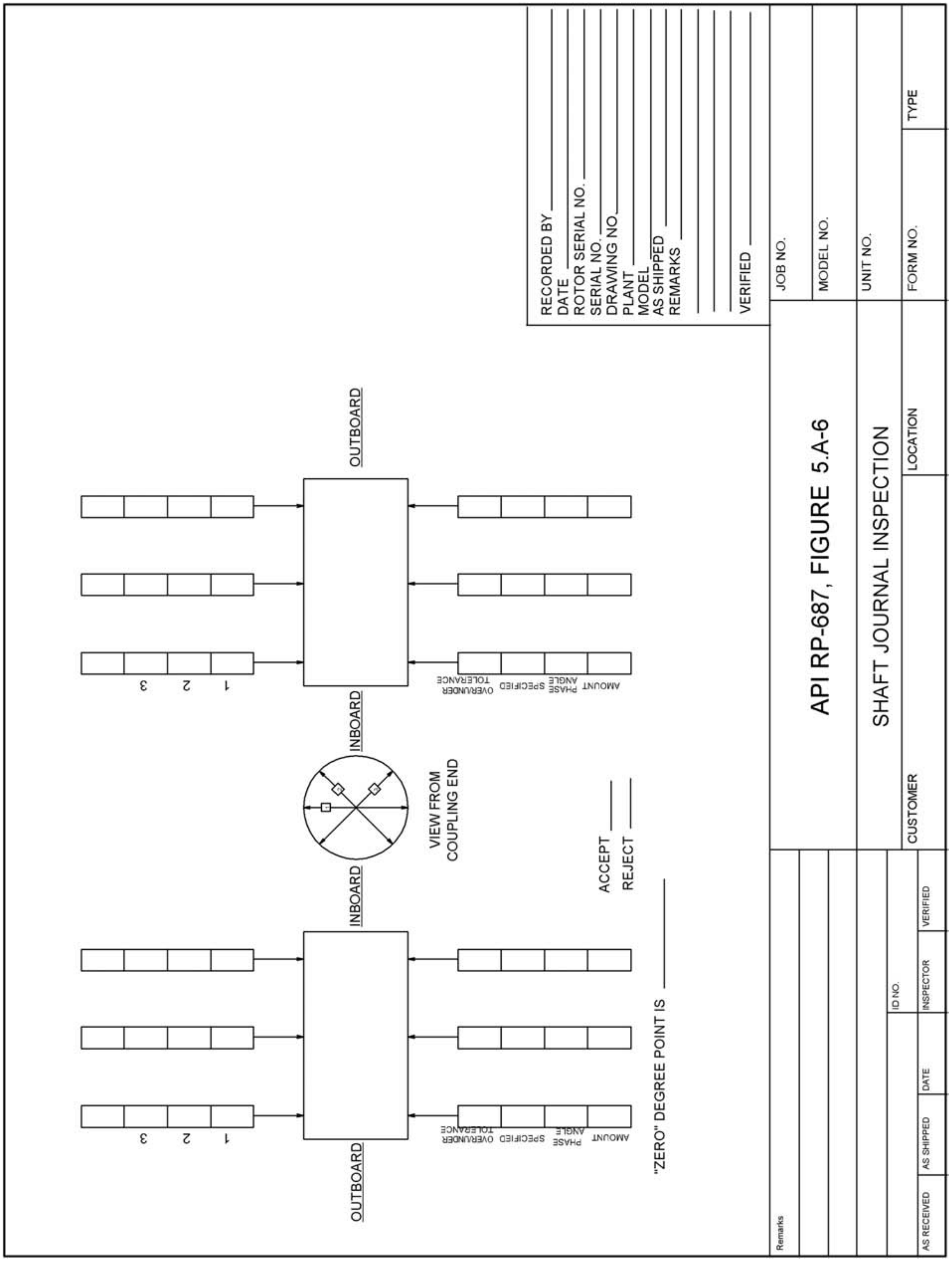


Figure 5.A-6—Shaft Journal Inspection

APPENDIX B—DIMENSIONAL FORMS FOR PHASE II INSPECTION

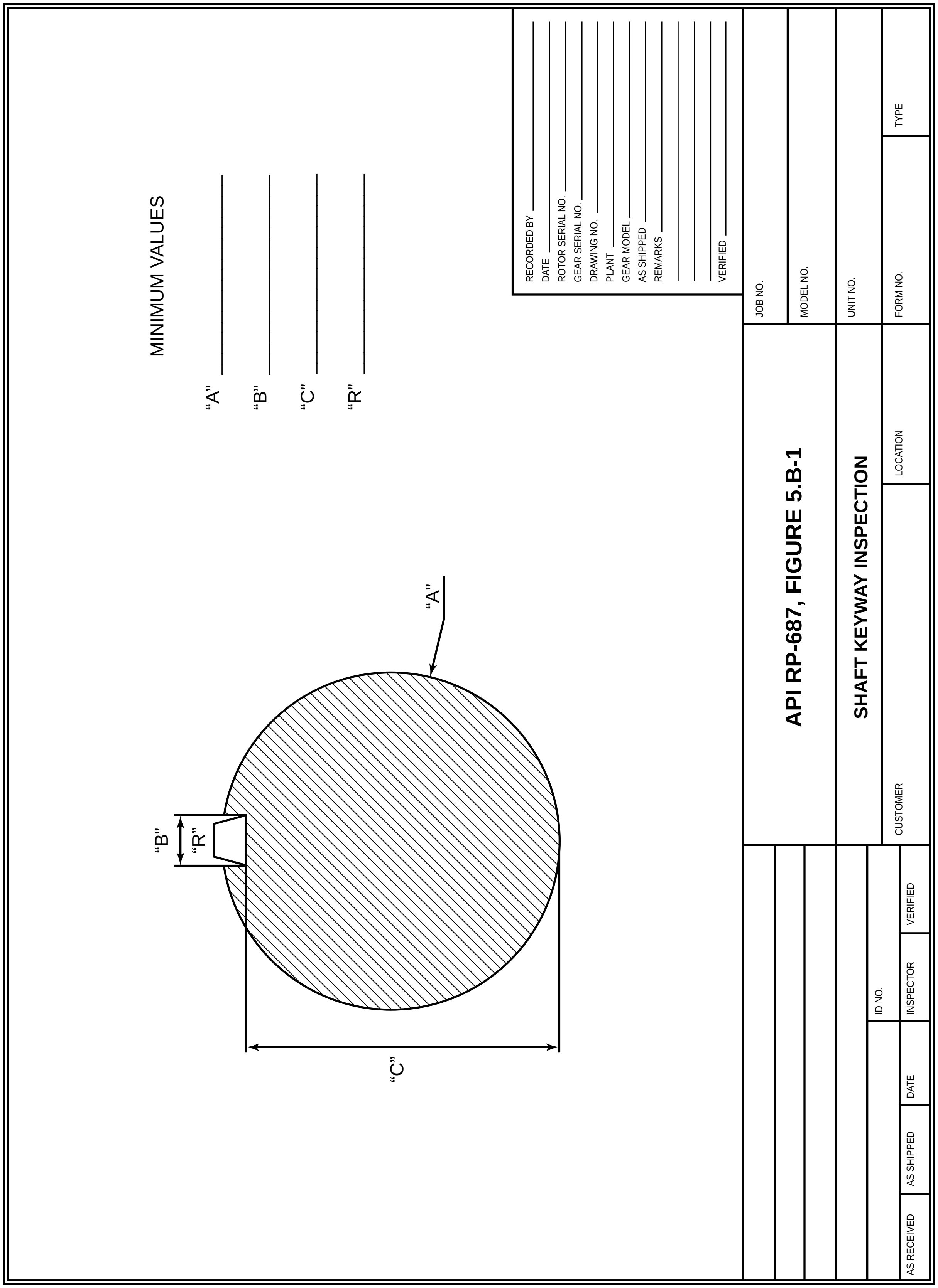
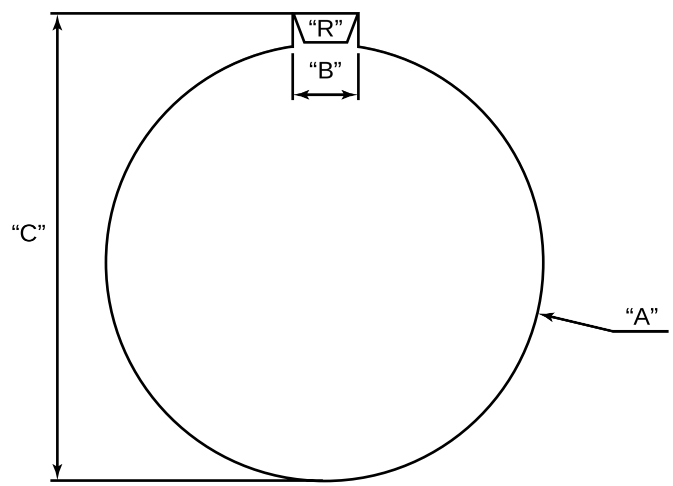


Figure 5.B-1—Shaft Keyway Inspection



MINIMUM VALUES

"A" ____________________

"B" ____________________

"C" ____________________

"R" ____________________

Note: Check for taper in the bore.

RECORDED BY ____________________
DATE ____________________
ROTOR SERIAL NO. ____________________
GEAR SERIAL NO. ____________________
DRAWING NO. ____________________
PLANT ____________________
GEAR MODEL ____________________
AS SHIPPED ____________________
REMARKS ____________________
____
____
____
VERIFIED ____________________

API RP-687, FIGURE 5.B-2

BORE KEYWAY INSPECTION

		ID NO.		CUSTOMER	LOCATION	JOB NO.	MODEL NO.	UNIT NO.	
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED			FORM NO.	TYPE	

Figure 5.B-2—Bore Keyway Inspection

APPENDIX C—QUALITY/MANUFACTURING PLAN

QUALITY/MANUFACTURING PLAN

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	SHAFT RESTORATION			**3.2**						
	Ch. 1 App. K as specified plus the following:									
	Concentricity/Runout Inspection			3.2.c		API 613, 4th	Report			
	Pitch Line Runout and Lead Inspection			1.3.6		API 613, 4th	Report			
	Contact/Backlash Inspection			4.2.1		API 613, 4th	Report			
	Balancing			4.4		Ch. 1, Sec. 10	Report			
	TOOTH RESTORATION			**3.3**						
	Regrinding/Recutting			3.3.1/3.3.2						
	Dimensional Inspect: Profile, Lead, Tooth Spacing, & Pitch Line Runout				Vendor appd.	As specified, PO	Report			
	Wet Magnetic Particle Inspection (fluorescent, continuous method)			Ch. 1, Sec. 8.2.4.1	ASTM E709	Chap 1, 8.2.4.4	Report			
	Demagnetize			8.2.4.2	Vendor Procedure	8.2.4.2	Certificate			
	Balancing			4.4/Chap 1, 10.2		Ch. 1, 10.2.11	Report			
	REPLACEMENT RIDER RINGS (“THRUST COLLARS”)			**3.4**			**(1)**			
	Collar Material	AISI / ASTM #	C, H	Ch. 1, 9		AISI / ASTM	Report			
	Case Hardening (Coupon)		Surface and Core Hard-ness, Case Depth	3.4.2	Vendor appd.	As specified	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Interference Fit Inspection			3.4.2	Engr. Calcs.	Mfg. Drawing	Report			
	Mount Collar on Shaft			3.4.3		Mfg. Drawing				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 3.4.4/ 8.2.4.1	ASTM E709	Chap 1, 8.2.4.4	Report			
	Final Grind			3.4.5		Mfg. Drawing				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E709	Chap 1, 8.2.4.4	Report			
	Demagnetize			Chap 1, 8.2.4.2		8.2.4.2	Certificate			
	Dimensional Inspect			3.4.5		Mfg. Drawing	Report			
	Contact and Axial Clearance Inspection			3.4.6	Engr. Calcs	Mfg. Drawing	Report			
	NEW COMPONENT (PINION)			**3.5**						
	Material	AISI / ASTM Spec No.	C, Grain Size, Jominy Hard-enability	Chap 1, 9.1		Compliance with AISI/ASTM Requirement	Report			
	Heat Treatment		H, M, I		Vendor appd.	Mfg Requirement	Report			
	Rough Machine					Mfg. Drawing				
	Ultrasonic Inspection			Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Report			
	Finish Turn and Grind					Mfg. Drawing				
	Journal Runout					Mfg Requirement	Report			
	Hob Teeth					Mfg. Drawing				
	Case Hardening, If Required (Coupon)		Surface and Core Hardness, Case Depth	3.4.2	Vendor appd.	As specified	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Journal Runout					Mfg Requirement	Report			
	Finish Teeth				Vendor appd.	Mfg. Drawing				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspect: Profile, Lead, Tooth Spacing, and Pitch Line Runout				Vendor appd.	As specified, PO	Report			
	Electrical / Mechanical Runout Inspection			Chap 1, 9.6			Report			
	Balancing, Machine Calibration, Residual Unbalance/Sensitivity Check			4.4			Report			
	Final Dimensional Inspection			4.5		Mfg Drawing	Report			
	NEW COMPONENT (GEAR)			**3.5**						
	SHAFT									
	Shaft Forging	AISI / ASTM Spec No.	C,H,M,I	Chap 1, 9		Compliance with AISI / ASTM Requirement	Report			
	Rough Dimensional Inspection					Mfg Requirement	Report			
	Vertical Stress Relieve		H		Vendor Procedure		Chart			
	Ultrasonic			Chap 1, 8.2.3	ASME Sect V, Article 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Dimensional Stability Test				ASTM A472 (4)	ASTM A472	Report			
	Pre-Grind Dimensional and Runout					Mfg Requirement	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.2	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	GEAR BLANK									
	Material	AISI / ASTM #	C, Grain Size, Jominy Hard-enability			Mfg Requirement	Certificate			
	Heat Treatment		H, M, I		Vendor appd.	Mfg Requirement	Report			
	Rough Machine					Mfg. Drawing				
	Ultrasonic Inspection			Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Report			
	Finish Machine					Mfg. Drawing				
	For Case Hardened Teeth									
	Hob Teeth					Mfg. Drawing				
	Case Hardening, (Coupon)		Surface and Core Hardness, Case Depth	3.4.2	Vendor appd.	As specified	Report			
	ASSEMBLY									
	Mount Gear On Shaft and Machine Journals and Truing Bands			4.3		Mfg. Drawing				
	Journal Runout					Mfg Requirement	Report			
	Hob Teeth (Through Hardened)					Mfg. Drawing				
	Journal Runout					Mfg Requirement	Report			
	Finish Teeth				Vendor appd.	Mfg. Drawing				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspect: Profile, Lead, Tooth Spacing, and Pitch Line Runout				Vendor appd.	As specified, PO	Report			
	Electrical / Mechanical Runout Inspection			Chap 1, 9.6			Report			
	Balancing, Machine Calibration, Residual Unbalance/Sensitivity Check			4.4			Report			
	Final Dimensional Inspection			4.5		Mfg Drawing	Report			
	Weight of Assembled Rotor			4.5		Mfg Drawing	Report			
	Prep For Shipment			Chap 1, 11						
	PRE-ASSEMBLY REQUIREMENTS			**4.2**			**(2)**			
	Contact / Backlash Inspection			4.2.1	API 613, 4th	Mfg Requirement	Report			
	Axial Stability Inspection (double helical)			4.2.3	API 613, 4th	API 613, 4th	Report			

DESCRIPTION/OPERATION

NOTES:

1) All verifying document reports shall reference procedure and state drawing acceptance criteria.

2) All WPS and WPQR shall be available to purchaser for review and approval prior to any welding.

LEGEND GENERAL	MATERIAL CERT	INSPECTION POINT
H.T. Heat Treatment PT Liquid Penetrant Inspection MT Magnetic Particle Inspection VT Visual Inspection UT Ultrasonic Inspection W/A Will Advise N/A Not Applicable	A Certificate of Compliance C Chemical Analysis M Mechanical Properties H Heat Treat Charts I Impact	O Observation W Witness / Hold Pt * Vendor To Confirm That Requirement Has Been Met

Report: defines a vendor generated quality control inspection form/report that will satisfy industry standards or requirements outlined on purchase order.

"Vendor appd.": Means the vendor has a procedure for the applicable activity, which has been reviewed and approved by the owner.

APPENDIX D—INSPECTION FORMS FOR ASSEMBLY AND BALANCING

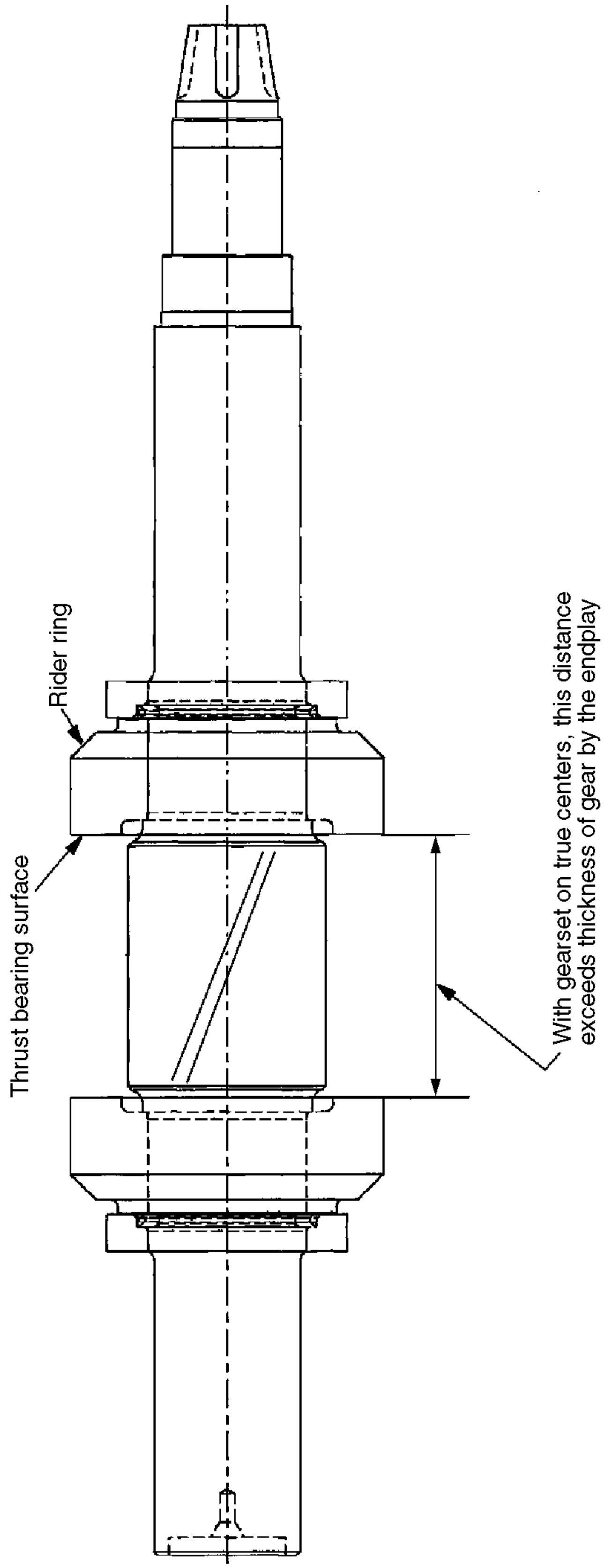


Figure 5.D-1—Rider Ring Assembly

APPENDIX E—AUDITORS CHECK LIST

E.1 General

This Appendix, along with Appendix H, Chapter 1, is a checklist to provide information for the owner and the vendor to aid in summarizing the scope of the rotor repair.

Repairs require clear owner / vendor communication and the assignment of responsibilities. The format of this checklist provides a summary of the items required and the parties responsible.

Each item on this checklist has a circle or a square to indicate whether the owner or vendor, respectively, is responsible for obtaining the information or performing the task. The owner must indicate, for each item, whether the item is to be witnessed, observed, or verified. Typically, inspections, processes or tests may be witnessed or observed while verification is the review of the results of the inspections, processes, tests, or other documentation so as to insure that the requirements have been met.

AUDITORS CHECK LIST

Customer: ______________________________

Job/Project Number: ______________________________

Owner Equipment Identification Number: ______________________________

OEM Equipment Serial Number: ______________________________

Rotor Identification Number: ______________________________

Repair Purchase Order Number: ______________________________

Vendor Job Number: ______________________________

Auditors Check List

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice			Date Inspected or Verified By	Status
			W	O	V		
Section 1—Inspection of Assembled Rotor Phase I							
Clean Gear/Pinion	☐	1.3.2					
NDE	☐	1.3.3					
Hardness Inspection	☐	1.3.5					
Inspect Gear Elements	☐	1.3.6					
Tooth Contact Check	☐	1.3.7					
Axial Stability Check	☐	1.3.8					
Backlash Check	☐	1.3.9					
Gear Rotors	☐	1.3.10					
Gear Teeth Condition	☐	1.3.11					
Residual Unbalance	☐	1.3.12					
Inspection Report	☐	1.4					
SECTION 2—Rotor Disassembly Phase II							
N/A							
SECTION 3—Repair Processes and New Component Manufacture							
Shaft Repair	☐	3.2					
Tooth Restoration							
Gear Grind Repair	☐	3.3.1					
Gear Cut Repair	☐	3.3.2					
Balance Gear	☐	3.3.4					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
Gear Verification	☐	3.3.5					
Rider Rings	☐	3.4.2					
Interference Fit	☐	3.4.3					
NDE	☐	3.4.4					
Grind Thrust Faces	☐	3.4.5					
Clearance Checks	☐	3.4.6					
New Component Manufacture	☐	3.5					
SECTION 4—Assembly and Balancing							
Identify Matched Set	☐	4.1					
Contact Check	☐	4.2.1/ 4.2.2					
Backlash Check	☐	4.2.1					
Axial Stability Check	☐	4.2.3					
Rider Rings Assembly	☐	4.3.1					
Balance	☐	4.4.1					
Balance Corrections	☐	4.4.2					
Final Inspection	☐	4.5					
Documentation	☐	4.6					

CHAPTER 6—SPECIAL PURPOSE EXPANDERS

CONTENTS CHAPTER 6

Figures

Rotor Repair

Chapter 6—Special Purpose Expanders

1 Inspection of Assembled Rotor Phase I

1.1 GENERAL

This section describes the data to be recorded and the requirements of a Phase I inspection of an assembled gas expander rotor. This section is applicable to both overhung and between bearing axial expander rotors. This section is not applicable to radial gas expanders. This section is to be used in addition to the requirements of Chapter 1, Section 7, Phase I inspection.

In addition to the information supplied by Chapter 1 paragraph 2.3, the owner should identify the type of rotor construction. This construction method is critical to determine the inspection and repair methods.

If possible, the owner should identify the rotor materials of construction or the use of any coatings.

Tutorial: There are several types of rotor construction used for gas expanders: between bearing integral rotor, between bearing built up rotor, single and multi stage overhung rotors. The overhung rotors are essentially all of a built up construction with either a single or multiple tie bolt disk retention. The built up between bearing designs can utilize shrunk on disks or a stacked rotor construction with single or multiple tie bolts. High temperature stacked rotors usually have the disk to disk or disk to shaft located via component piloting, curvic couplings, radial guide pins or keys. Refer to Figures 6.1-1 through 6.1-5 for typical rotor configurations.

1.2 DEFINITIONS

1.2.1 airfoil: The part of the blade which is exposed to gas velocity and/or pressure and converts this energy to mechanical work.

1.2.2 axial entry blade: A blade which is assembled to the disk using axially machined grooves for each blade.

1.2.3 blade: A component which is attached to the disk and includes the blade root, platform and airfoil and may be free standing or shrouded and may incorporate other mechanical features for damping.

1.2.4 blade moment weight: A value that represents the combination of the blade weight and its center of gravity.

1.2.5 blade pan weight: The static weight of the blade.

1.2.6 built-up rotor: An assembly which includes the expander shaft(s) and separate disks. See Figures 6.1-1, 6.1-2, 6.1-3, and 6.1-5.

1.2.7 curvic coupling: A curvic coupling has teeth on each component's face that engage axially, joining two shafts, end to end, used for torque transmission and to allow for differential thermal growth between adjacent components.

1.2.8 chord length: The blade width or the distance from the leading edge to the trailing edge at a given radial height.

1.2.9 disk: A feature which has blades attached at the outside diameter. May be separate from or integral with the shaft.

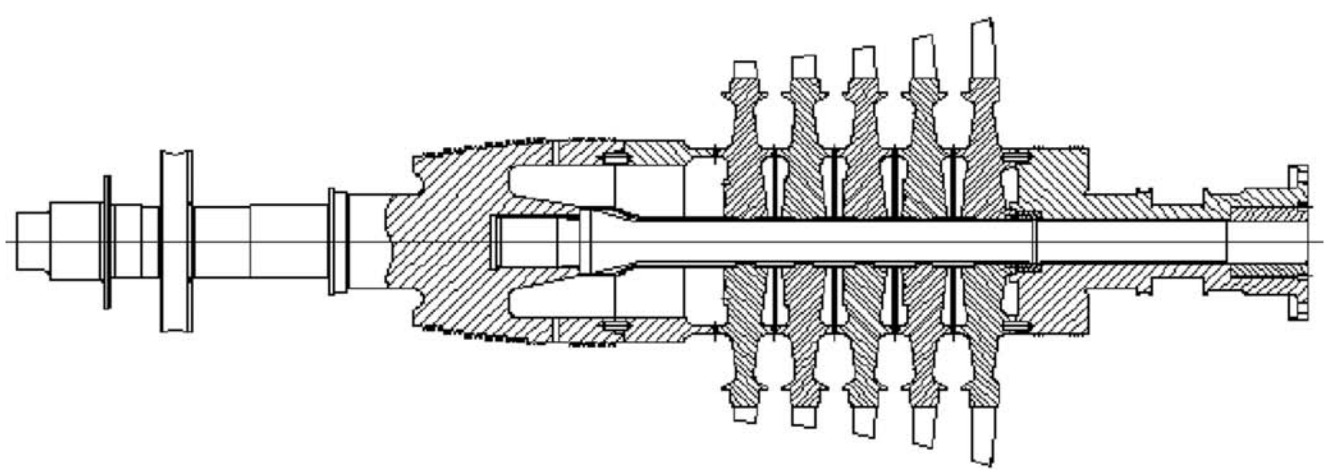


Figure 6.1-1—Multistage Tie Bolt Stacked Expander Rotor

1.2.10 disk-on-shaft rotor: An assembly which includes the expander shaft and separate disks which are interference fitted to the shaft.

1.2.11 integral shroud: A design where the blade and shroud are manufactured in one piece.

1.2.12 major components: Major components are rotor blades, disks, stub shafts, sleeve, spacer pieces, and tie bolts.

1.2.13 physical vapor deposition (PVD): PVD coatings are applied by melting and evaporating a coating material with a high heat energy source (such as an electron beam) in an evacuated chamber. The parts to be coated are heated and rotated on a spindle in the vacuum chamber above the streaming vapor generated by the molten prealloyed coating source. The coating vapor condenses or solidifies on the surfaces of the parts to be coated. Coating thickness and properties are determined by the coating source, power input and time of exposure. The coated parts are generally heat treated after coating to obtain the best base material and coating properties.

1.2.14 pack process: Pack coatings are applied by immersing or embedding the parts to be coated into a blended powder mixture of the active coating species. The powder mixture is packed around the parts to allow a proper transfer of the desired coating. The "pack" is heat treated at specific temperatures, pressures, atmospheres and times to allow the coating to diffuse into and/or on the surface of the parts to be coated.

1.2.15 platform: A blade feature located between the airfoil and the blade root.

1.2.16 radial entry blades: Assembled to the disk using a circumferentially machined groove for the blades.

1.2.17 shroud: A component which is located on the tip of the blade and may span several blades to form groups. Shrouds may be integral to the blade or otherwise fastened to the blade with "peened" tenons or rolled in lacing wire.

1.2.18 solid rotor: A rotor in which the disks are forged integral with the expander shaft. See Figure 6.1-4.

1.2.19 spigot fit: A locating fit in which one component fits into its mating component. Also called pilot or rabit fit.

1.2.20 tenon: A mechanical feature which is integral with the blade tip which secures the shroud to the blade when peened.

1.2.21 tie-bolt rotor: Assembly consisting of an arrangement in which the shaft is fastened to the disk(s) using axial tie bolt(s). See Figures 6.1-1, 6.1-2, and 6.1-3.

1.3 INSPECTION

1.3.1 Unless otherwise specified, all blades for overhung rotor construction are to be removed for the Phase I inspections, see note 1.

Refer to paragraph 2.2.11.2 for precautions in the removing of unshrouded blades.

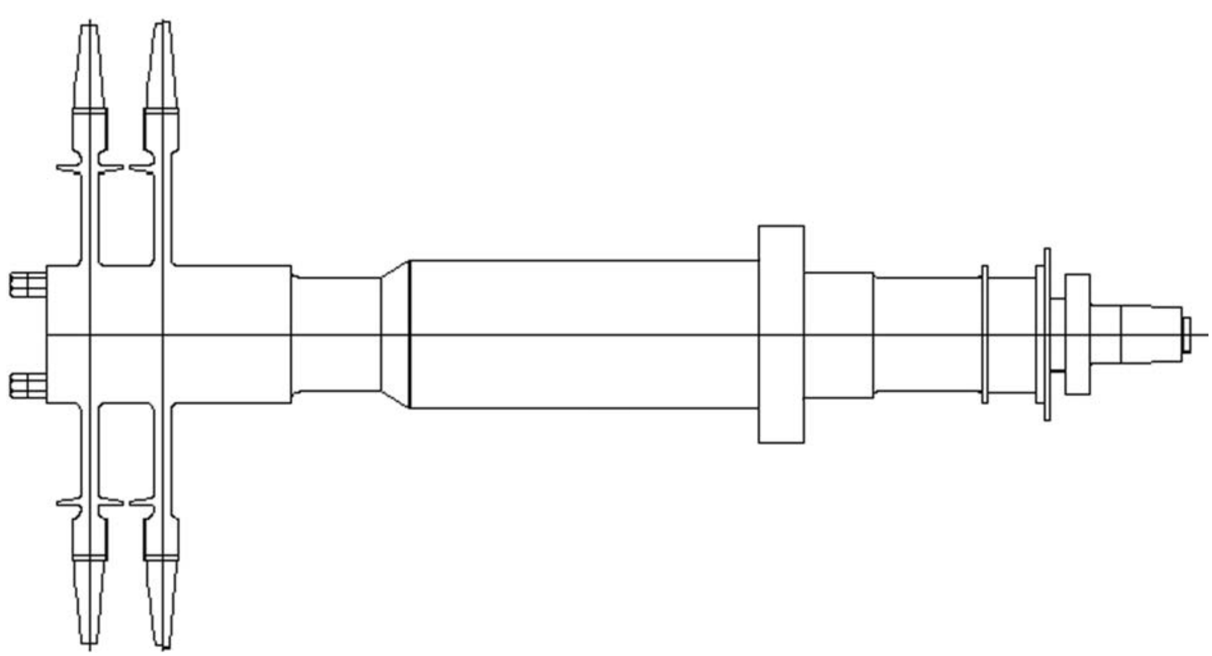


Figure 6.1-2—Overhung, 2 Stage, Multi Tie Bolt Expander Rotor

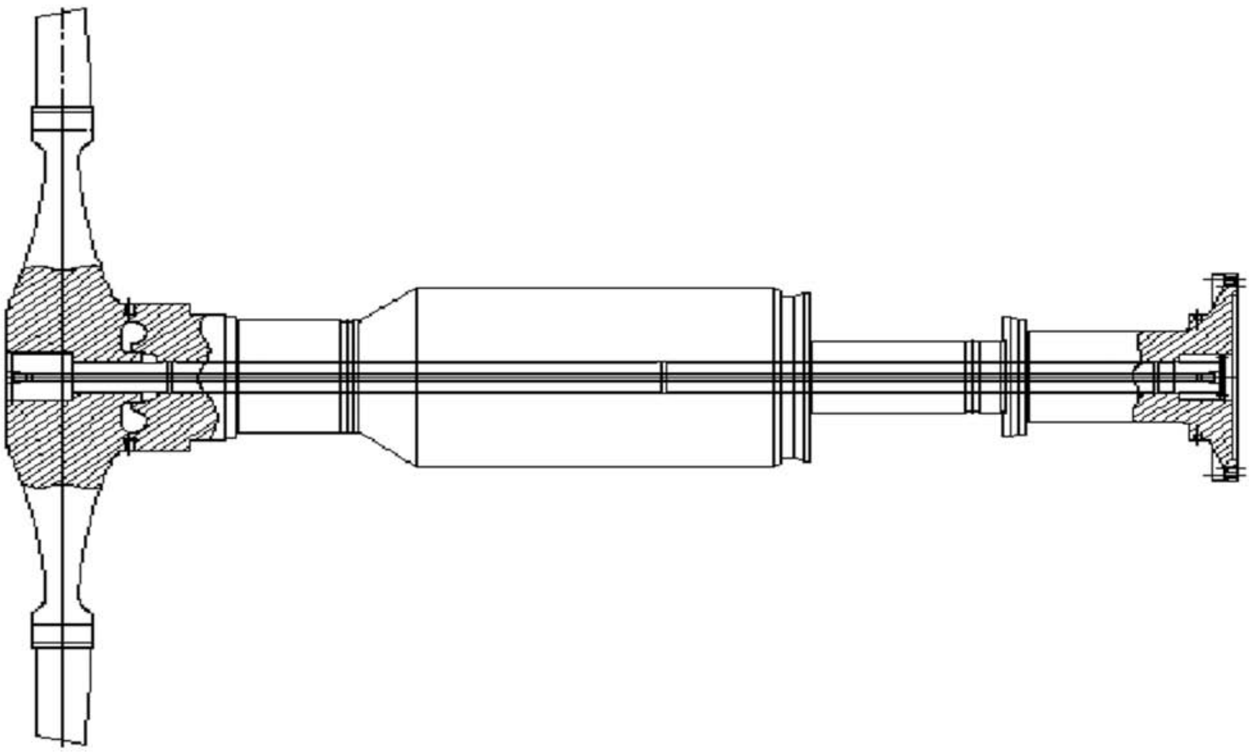


Figure 6.1-3—Overhung, Single Stage, Single Tie Bolt Expander Rotor

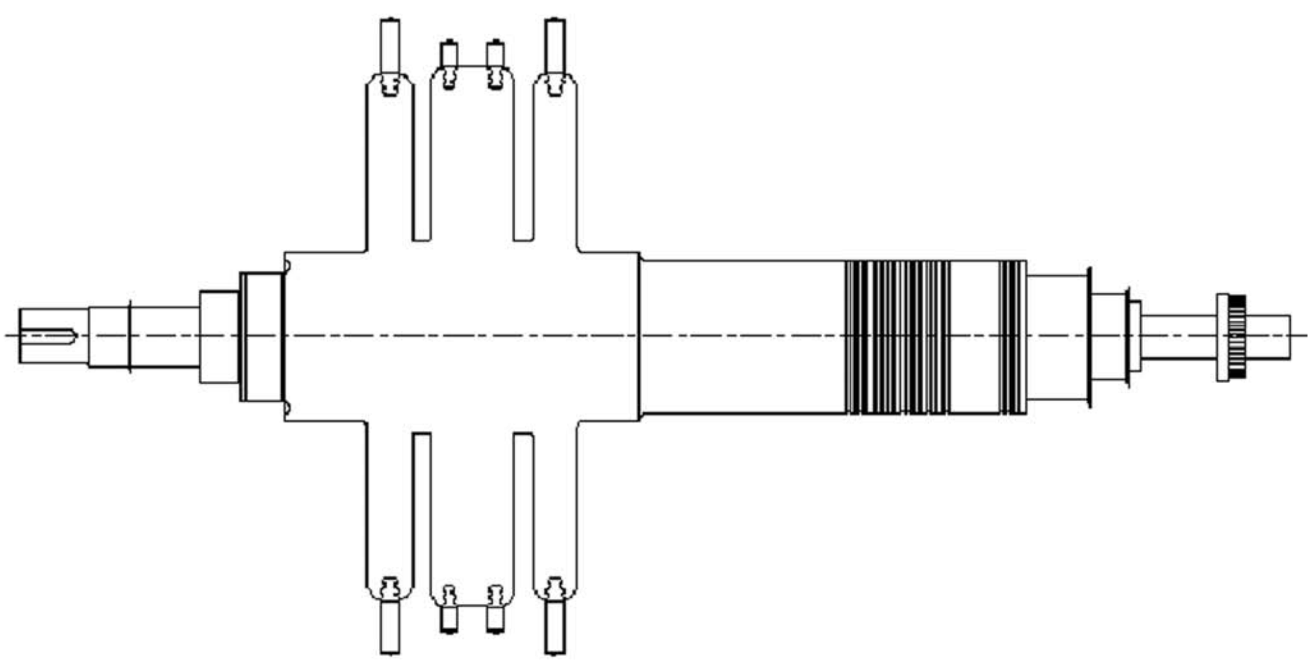


Figure 6.1-4—Multistage, Double Flow, Integral Expander Rotor

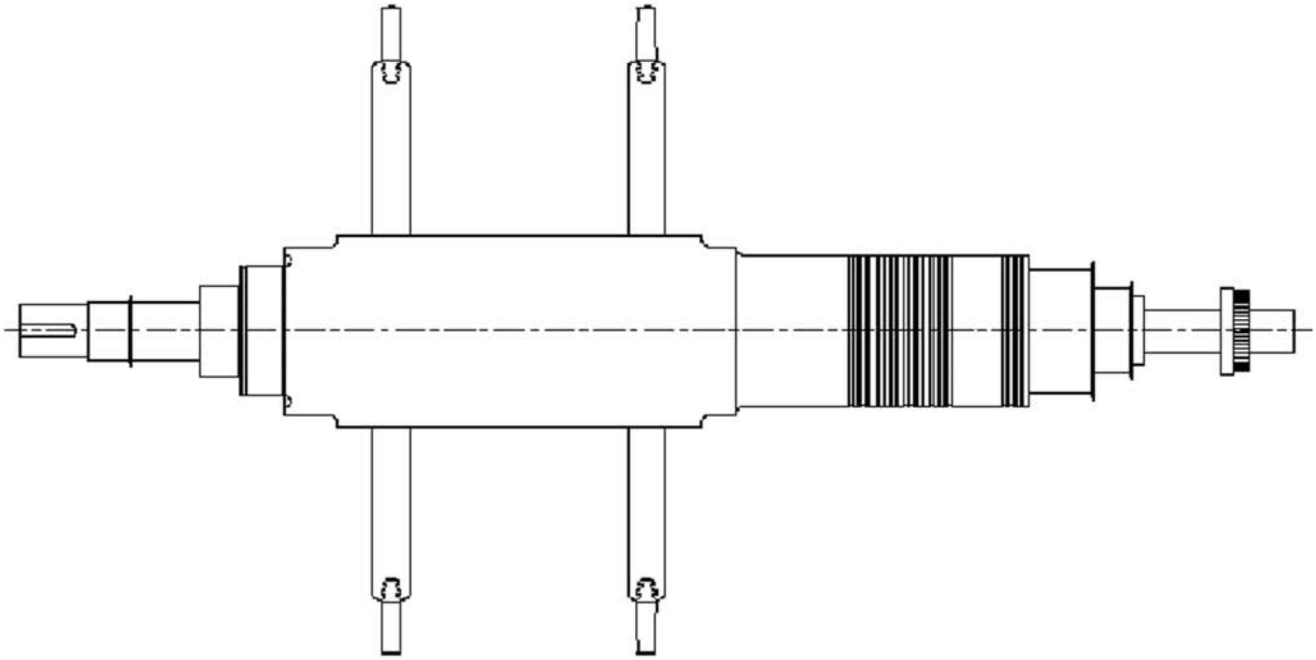


Figure 6.1-5—Multistage, Built Up, Expander Rotor

Removed blades are to be uniquely identified to their corresponding stage and circumferential location for inspection review.

Notes:

1. Removal of blading from other rotor designs (shrouded or peened attachments) may result in damage to the blading or the disk root areas.

2. Certain designs require rotor disassembly to remove the blades.

1.3.2 In addition to the requirements specified in Chapter 1, Section 7, the following precautions and inspections in 1.3.3 through 1.3.14 shall be made.

1.3.3 Rotor is to be cleaned as described in Chapter 1, paragraph 7.2.2. Expander rotors typically require abrasive cleaning of the disks due to the high temperature scales and corrosion products that tenaciously adhere to the rotor disk(s) surfaces. Critical areas are to be protected and masked to prevent the cleaning media from entering the areas during cleaning. In addition to the critical areas identified in Chapter 1, paragraph 7.2.2 are the blading, curvic coupling interfaces, disk to disk thermal gaps and cooling holes and passages. Care must be taken to prevent damaging features such as thin rotor blade trailing edges, squealer tips, and knife edge seals.

1.3.4 Appendix A inspection forms and drawings or equal shall be used in recording the necessary information. These inspection forms and drawings may be modified by the vendor to represent the actual configuration of the rotor.

1.3.5 The following dimensions are to be recorded if the rotor is to be unstacked or fitted with new blades or disks. This should be performed before deblading and after reblading to ensure the rotor will fit into the casing during assembly.

a. Identify and record the radius of the low and high blade from each stage to verify the blade to casing tip clearances.

b. Measure and record two axial and corresponding radial dimensions on one blade tip of each row of blades, referenced from the thrust collar shaft shoulder (or active side of the integral thrust collar).

Note: The degree of accuracy is to be within:

a. ±25 μm (0.001 in.) on the radial dimensions

b. ±250 μm (0.010 in.) on the axial dimension for location of blade tip profiles.

1.3.6 For curvic coupling rotors, measure and record rotor diameters on each side of a curvic coupling or component stack.

1.3.7 Measure and record axial stack-up dimensions, in a minimum of two circumferential locations, referenced from the thrust collar shaft shoulder (or active side of the integral thrust collar), to each rotor disk assembly and to all other components that may be removed from the shaft such as sleeves, balance pistons. For blading, refer to 1.3.5. Each dimension is to be referenced and recorded from the same thrust location. One of the axial stack-up dimensions should be taken at the zero phase reference point and the second should be 90° apart.

1.3.8 The rotor run out check shall include the radial run out on both sides of any curvic coupling fit and disk face runout on both sides of all of the disks and shall be recorded.

1.3.9 Blades that have been removed and appear to be reusable shall be visually inspected, cleaned in accordance with 1.3.3, NDE per 1.3.11, and evaluated for reuse. The coating is not required to be removed for these procedures at this time.

1.3.10 The rotor blades and disks shall be inspected for signs of distress, rubbing, over temperature, distortion, attachment fretting, erosion, and corrosion.

Note: Inspection is required by an experienced individual that is knowledgeable with expanders and the particular process application, since this type of equipment can be subjected to highly corrosive and erosive environments.

1.3.11 NDE the accessible areas of each blade, disk, tenon, shroud, and shaft per Chapter 1, paragraph 8.2.4.

1.3.12 The NDE evaluation described in Chapter 1, Table 1.8-1, shall be a severity level of "A" for all components, excluding sleeves which shall be severity level "C."

1.3.13 Remove mechanical overspeed trip mechanism and inspect for degradation. For bolt/pin styles, the dimensional setting and configuration of the device is to be recorded for reassembly purposes.

1.3.14 For tie bolt designs, determine each tie bolt stretch, without removing the tie bolts.

Each tie bolt shall be within ±25% of its initial stretch. In addition, the variation in stretch between each tie bolt shall not be more than ±15%. If a tie bolt stretch does not meet these requirements, disassemble in accordance with paragraph 2.2.9 and perform a Phase II inspection per 2.3.

Note: In order to determine a change in bolt stretch, previous assembly records are to be reviewed.

1.4 INSPECTION REPORT

1.4.1 The vendor shall prepare an initial inspection documentation package (report) consisting of all of the information identified in Chapter 1, Section 7 and Section 1.3, as applicable.

1.4.2 The vendor shall not disassemble the rotor without the approval of the owner. The vendor may minimize the phase I inspection if it is obvious that the rotor needs to be disassembled and a more detailed phase II inspection performed. Some reasons for disassembly include:

a. Shaft damage such as fretting, cracking, journal bearing/shaft end damage.
b. Thermally unstable rotor.
c. Rotor disk damage requiring removal of the disk.
d. Severe corrosion.
e. Overspeed of rotor where yielding of material is a concern or evident.
f. Rerate requiring new components.
g. Shifting of components, loss of thermal gaps or uneven curvic coupling clearance or mating diameters.
h. Circumferential twist or slippage of tie-bolt rotor components.
i. Bowed rotor, or rotors with excessive runout or runouts that are out of phase.
j. Balance level not repeatable in the shop or field.
k. Previous operating and overhaul history suggests full disassembly is warranted.
l. Loss of tie bolt stretch.
m. Over temperature history.

1.4.3 If the owner has authorized dismantling of the rotor, the vendor shall proceed to Section 2 and provide "as found" data for each component (blades, disks, shaft, sleeves, etc.).

2 Rotor Disassembly Phase II

2.1 GENERAL

This section describes the data to be recorded and the requirements of Phase II inspection of an expander rotor disassembly.

2.2 DISASSEMBLY FOR PHASE II INSPECTION

● **2.2.1** When specified, or with the owners approval, as a result from Phase I inspection, the vendor shall dismantle the rotor to the extent specified.

● **2.2.2** The owner shall specify if the rotor blades are to be removed from the rotor disks for shrouded or peened designs.

2.2.3 Prior to dismantling, the requirements of paragraph 1.3 are to be completed and recorded.

2.2.4 Matchmark components and record location and orientation as required to assure proper reassembly.

2.2.5 Care must be exercised in the disassembly to prevent the damaging of components. Often rotor disks, stub shafts and shafts have interference fits between the components that require heat to allow disassembly. A thorough understanding of the rotor construction and the interference fits is required to safely disassemble the rotor without causing component damage.

2.2.6 All interference fits shall be dimensionally inspected and recorded to determine the amount of interference remaining and if component rework is required to restore the design interference.

2.2.7 All mating fits shall be visually inspected for signs of yielding, distress, fretting, galling, etc.

2.2.8 Unstacking of the rotor should be done in the vertical position.

2.2.9 Tie-Bolt Rotor Disassembly

2.2.9.1 Before disassembly of a tie-bolt rotor configuration, measure and record stack height (overall length of the components restrained by the tie-bolts) and tie bolt length. After disassembly re-measure, calculate and record the stack compression and tie-bolt stretch.

2.2.9.2 For stacked rotors utilizing tie bolts, the tie bolt removal detensioning should be done with caution. Detensioning is rotor specific and has been accomplished thermally, hydraulically or mechanically. The appropriate procedures, tooling and/or fixtures are to be used. For multiple tie bolt configurations, it is recommended to detension the tie bolt(s) in diagonal pairs and in several steps versus detensioning one at a time.

CAUTION: Improper detensioning may cause the rotor to deform, allowing binding and buckling of the components, or overstressing of the remaining bolts.

2.2.10 Rotors with Shrunk on Components

2.2.10.1 All major component(s) shall be uniformly heated for disassembly. In no case shall a component be more than 280K (500°F) above the shop ambient temperature.

Note: Heating components for disassembly is a critical step. Heated components should be heated uniformly to minimize circumferential temperature variations that could cause distortion. This heating may be accomplished by the use of two or more large (flare tip or rosebud) torches, however, care must be exercised to avoid a heat rate that is too rapid to maintain even heating. The differential temperature should be carefully monitored with temperature indicating temperature sticks without sulfur components or a non-contacting infrared surface temperature gun.

2.2.11 Blade Disassembly

2.2.11.1 Identify the type of blade fastening and method of assembly. Develop a work plan to address blade removal. This plan shall include specific items such as removal of locking blade(s) or block(s) and the salvage of damaged blades for future investigation.

This plan shall be used to minimize damage to the disks due to deblading.

Note: Blade removal usually commits to the installation of new blades and locking components in the disk.

2.2.11.2 Unshrouded Blades

Remove unshrouded blades with the following cautions:

1. Expander blades are retained in a variety of methods that may include lock pins, wires, lock plates, rivets, or staking. Care must be taken to determine the method of retention and the appropriate removal procedure to prevent damage to the blades or disks.

2. Blade retention hardware is not re-usable.

3. To prevent damaging the coating, care must be taken when removing coated blades that are not to be recoated. Do not impact the blade near or on the coated areas.

2.2.11.3 Shrouded Blades

Prior to disassembly of the blading, the following information shall be recorded and sketched as appropriate:

a. Total number of blades.

b. Number of blades per shroud group (packet).

c. Number and location of groupings.

d. Diameter of tie wires.

e. Width, thickness, overhang, and profile of shroud bands.

2.2.12 Blades that have been removed and appear to be reusable shall be cleaned in accordance with 1.3.3. The coating is not required to be removed for these procedures at this time.

2.3 PHASE II INSPECTION

2.3.1 Carefully, abrasively clean the rotor components to base metal. See Chapter 1, paragraph 7.2.2 for cleaning methods and precautions. Chemical stripping may be required to adequately evaluate blade pitting due to corrosion.

Note: This will result in the removal of any protective coatings.

2.3.2 The vendor shall perform the following inspections in paragraphs 2.3.2.1 through 2.3.2.10 after the Phase II disassembly has been completed.

2.3.2.1 All interference fits shall be dimensionally inspected to determine the amount of interference remaining and if component rework is required to restore the design interference.

2.3.2.2 All mating fits shall be visually inspected for signs of yielding, distress, fretting, galling, etc.

2.3.2.3 Visually inspect and record the condition of each part removed. The rotor blades and disks shall be inspected for signs of distress, rubbing, over temperature, distortion, attachment fretting, erosion and corrosion. Any evidence of erosion, corrosion or component distress should be photo documented.

Note: Inspection is required by an experienced individual that is knowledgeable with expanders and the particular process application, since this type of equipment can be subjected to highly corrosive and erosive environments.

2.3.2.4 Dimensional Inspections

Measure and record all shaft and component sizes on a worksheet designed for the particular component, per Appendix “B” or equal. This data will be used to determine the roundness and taper of each component. This shall include:

a. Bare shaft fit sizes in critical regions such as journal and seal regions, coupling fits, disk and sleeve fits, overall length, and runouts (including thrust collar shoulders).

b. Disk bore sizes and lengths for shrunk on disk rotors. Rotor to shaft or disk pilot fit dimensions.

c. The stacking heights of individual components, at 90° intervals.

d. Radial and axial runouts of the individual components.

e. Bore sizes and lengths of shaft spacers, seal sleeves, etc.

f. Balance piston bore size and length.

g. Thrust collar and thrust collar spacer(s) bore sizes and lengths.

h. Key clearances on all keyways.

1. With keys installed in keyways, measure from tops of keys to opposite side of shaft.

2. Measure across bore of components to bottoms of keyways.

Note: Item “2” above plus total component interference fit minus item “1” above, equals key clearance.

i. Tie bolts and nuts shall have the thread condition and size verified with thread gauges.

j. Tie bolt runout.

k. Rotor disk blade attachments(slots) shall be checked for wear by dimensional inspection of the attachment with Go/No go gauging.

l. Rotor disk, spacers or shaft should be checked in accordance with Appendix B drawings. Curvic couplings should be checked in accordance with Appendix F.

m. Check radial keys or pins for distortion and fit.

n. For tie bolt rotors, measure and record the radial runouts and disk rim face runout with respect to the stacking face for each disk.

o. Stub shaft radial and face runout readings shall be measured and recorded.

2.3.2.5 Unless otherwise specified in job scope, use applicable NDE procedures as outlined in Chapter 1, Section 8 after disassembly, to determine the existence of any indications on the components to be reused or subject to failure analysis. Record the size, location, and orientation of any indications on a sketch. All ferro-magnetic components shall be wet magnetic particle inspected. Non ferro-magnetic components shall be fluorescent dye penetrant inspected.

2.3.2.6 The NDE evaluation described in Chapter 1, Table 1.8-1 shall be a severity level of “A” for all components, excluding blade and blade to disk attachments and sleeves. Blade and disk attachment areas shall report any visible indication. Sleeves shall be inspected to a severity level “C”.

2.3.2.7 Photographs are to be taken per Chapter 1, Appendix G, of any component with any unusual or abnormal condition. A photo log should be maintained for all work performed.

2.3.2.8 Threaded areas of the shaft and tie-bolts are to be visually inspected and dimensionally verified by screwing on a gauge. Inspect for set screw marks.

Note: When a gauge is not available for checking the threads of thrust collar and coupling retaining nuts, the mating nut may be used with judgement.

2.3.2.9 Nuts that have locking features shall be replaced if the breakaway torque is less than 20% of the new torque value.

2.3.2.10 Cooling passages are to be inspected for restrictions or corrosion.

2.4 EVALUATION OF PHASE II INSPECTION DATA

2.4.1 Review and evaluate all data and information to determine the acceptability of the inspections, resulting fits, clearances and runouts.

2.4.2 Component bores

If the latest design dimensions, interferences, clearances and fits are not available, the following criteria may be used as a guide in determining the acceptable taper and contact area.

2.4.2.1 For straight fit designs, the component bore should not exceed a taper of 0.3 μm/mm (0.0003 in./in.) of bore diameter.

2.4.2.2 Interference between disk bore and shaft shall be sufficient for all speed and temperature transients. The actual required interference shall be determined by an engineering review prior to reassembly.

2.4.2.3 For hydraulic fit, tapered bore disk designs, a blue contact check shall be performed per Chapter 1, Appendix C with a minimal contact area of 80%. The disk may be used for this verification as long as there are not any raised discontinuities in the shaft surface.

2.4.3 For curvic coupling designs, refer to Appendix F.

2.4.4 For tie-bolt construction, an engineering evaluation of the bolting stretch, thread condition, visual and dimensional inspection, and surface condition is to be performed.

Note: Tie bolt threads are typically rolled threads.

2.4.5 Evaluate the blades for reuse, based upon the guidelines given in 3.6.

2.5 PHASE II RECOMMENDED JOB SCOPE

2.5.1 The vendor shall notify the owner upon completion of Phase II Inspection, provide a copy of all Phase II documentation, summarize the results of Phase II Inspection, and prepare the recommended job scope for approval by the owner.

● **2.5.2** Coated blades that are to be reused are to be stripped of any coating, NDE, and recoated in accordance with the requirements of Chapter 1, Appendix D.3. The coating type, method of application, and area to be coated shall be specified.

3 Repair Processes and New Component Manufacture

3.1 GENERAL

3.1.1 In addition to the general repair processes and new component manufacturing requirements discussed in Chapter 1, Section 9, the following procedures and practices are recommended to accommodate the conditions and considerations unique to expander rotors. Components shall be repaired as outlined in sections 3.2 through 3.11, or new components supplied as outlined in 3.12.

3.1.2 In order to minimize distortion problems in the final assembly, components having a straight, continuous bore and a bore length-to-diameter ratio of 0.75 or greater without a center relief, should have an engineering review. This engineering review is to determine the justification and criteria to incorporate a center relief and land fit concept on each end of the bore.

3.1.3 Repairs to damaged rotor seal areas (disks or shafts), typically caused from contact with labyrinth type seals, may be repaired per the methods in Chapter 1, paragraph 9.2.

3.1.4 Pilot fits may be restored by weld repair per Chapter 1, Appendix D.2. Pilot fits may also be restored by machining, installing a patch ring by shrink fit, and then machining to final size. The ring material should be similar to the disk with respect to mechanical and thermal properties. The thickness of the ring should be between 3 to 6 mm ($^1/_8$ to $^1/_4$ in.) thick. Due to the differences in the coefficients of thermal expansion, chrome or nickel plating shall not be used as a repair method for fit buildup.

3.1.5 Rubs and pitting on disk faces may be removed by machining after an engineering review.

3.2 INTEGRAL ROTOR

Integral rotor disk(s) may be repaired by welding as outlined in Chapter 1, Appendix D.2. Disk weld repair shall be accomplished by partially or completely machining the outside diameter of the disk and building back up by welding.

3.3 BUILT UP ROTOR

3.3.1 Repair of the shaft under the disk(s) shall be per Chapter 1, Appendix D 2.0.

3.4 DISK BORE

3.4.1 Disk bores that are oversized may be restored by the methods outlined in Chapter 1, Appendix D.2. The bore may also be ground true and the corresponding disk fit area on the shaft increased by welding per 3.3.1 to establish proper interference fit. An engineering evaluation is required to determine which method to use.

Note: For assembly and disassembly purposes on multistage rotors, it may be necessary to perform this task on all disks.

3.4.1.1 Weld Repair

Disk bores may be repaired by the welding process outlined in Chapter 1, Appendix D.2 using an owner approved procedure. Repair procedure is to include the following steps:

a. Record angular position of keyways.

b. Generously radius all keyway(s) corners and chamfer the sides of the keyway(s) prior to welding.

c. Weld up keyway, disk bore and as necessary seal areas per Chapter 1, Appendix D.2.

d. Machine repaired areas. Disk bore is to have a maximum surface finish of 0.8 µm (32 µinch) Ra. Repaired disk seal areas and keyways are to have a maximum surface finish of 1.6 µm (64 µinch) Ra.

e. NDE per Chapter 1, paragraph 8.2.4.

f. Record disk dimensions and runouts.

g. Balance disk as per Chapter 1, Section 10.

Note: The face of the disk at the bore may need to be welded to provide for the disk final bore length to remain the same length as original.

● **3.4.1.2** When specified, an acceptable alternate repair method is to bore out the disk oversize and manufacture a new oversize shaft. While technically acceptable, the economics must be carefully compared to the other repair techniques.

Note: For assembly and disassembly purposes it may be necessary to perform this task on all the disks.

3.5 BLADE ATTACHMENT ON ROTOR

3.5.1 Blade attachment areas may be machined oversize to remove corrosion pitting or mechanical damage if supported by engineering analysis. Corrosion pitting greater than 0.08 mm (0.003 in.) deep would require an engineering evaluation.

Typically new blades with a matching oversized attachment are required.

3.5.2 After removing from the shaft, rotor disk(s) may be repaired by welding as outlined in Chapter 1, Appendix D.2. Disk weld repair shall be accomplished by machining the outside diameter of the disk below the blade attachment area and building back up by welding. For built up rotors the disk shall be removed from the shaft and weld repaired.

Note: Minor weld repair such as for blade locking pin hole does not require removal of the disk from the shaft.

3.6 BLADE REPAIR

3.6.1 General

Many expander blades are coated for erosion or corrosion resistance and require stripping the coating prior to any airfoil repair, and then require subsequent re-coating. The removal of the coating must be done carefully to prevent blade erosion or corrosion damage. Coating removal is very specific to the type of coating. Coatings are often removed via abrasive cleaning, chemical stripping or a combination of both.

Significant rotor blade repair is not a general practice to expander blading due to the critical nature of the blading, the specialty materials used, low tolerance to damage, high stress and often high operating temperature of the expanders.

Minor blade restoration and repair is acceptable providing that the repairs to do not compromise the structural integrity of the blading and is limited to the lower stressed regions of the airfoil. Repair or restoration of the critical attachment region shall not be performed.

The repair or refurbishment methods outlined in Section 3.6.2 may be considered after approval from the owner.

3.6.2 Repairs to Damaged Blades

3.6.2.1 Blending and Reprofiling

Foreign object damage maybe repaired by straightening, grinding (feathering) and polishing.

Blade airfoil distress such as minor nicks, dents, dings, corrosion pits, erosion gouges, etc. can be blended out of the blade by localized grinding and polishing. The maximum depth of the blending shall be limited to less than 10% of the minimum local airfoil thickness. The blade chord length (at the radial location of the defect) shall not be reduced by more than 5% of the nominal length.

All blending shall be smooth and continuous with no sharp edges or corners remaining after blending. The blending should be done over an area at least 4X larger than that of the damage to be blended. Upon completion of the local blending, the area shall be polished to a 0.8 μm (32 μinch) Ra or better surface finish.

After all rework has been performed, NDE inspect per Chapter 1, Section 8, with acceptance criteria per Severity Level A, and perform final dimensional inspection.

Blending and polishing in the attachment region of a blade is not permitted.

3.6.2.2 Weld repair

Depending upon the operating stresses, blade metallurgy and degree of distress, worn, damaged or eroded blades may be repaired by the welding processes, as outlined in Chapter 1, Appendix D.2 using an owner approved procedure. Weld repairs will be limited to low stressed regions of the airfoil or platform regions. Weld repairs are often limited to the outer $^1/_3$ of the airfoil region in critically stressed blade applications. No other weld repair of blades is recommended.

Because of the special metallurgies (stainless steel, super alloy or nickel base) used in most expanders, the repair procedures are very specific and should be reviewed and approved by the owner prior to commencing a weld repair. All blade weld repairs should include the following steps:

a. Grind back or undercut the damaged area

b. Perform NDE of undercut area until defect is completely removed

c. Solution heat treat the rotor blading.

d. Weld build-up per the qualified procedure.

e. Re-contour the blade profile.

f. Clean blade.

g. Perform NDE as per Chapter 1, Section 8.

h. HIPing (Hot Isostatic Pressing) of the weld repaired blades should be considered with any weld repair.

i. Heat treat as required to restore the metallurgical requirements.

j. Dimensionally check all blade critical fits, repair as required.

k. NDE the entire blade to the original quality requirements after all repairs have been completed.

3.7 PROTECTIVE COATINGS

● **3.7.1** Expander blades are often coated for additional erosion and corrosion protection. Erosion coatings are generally applied by thermal spray processes as outlined in Chapter 1 Appendix D.3. Corrosion coatings are generally limited to the attachment region and applied via Physical Vapor Deposition (PVD) or the Pack processes. The coating type, method of application, and area to be coated shall be specified by the purchaser. To insure coating integrity, the blades shall be thermally heat cycled in an oven to operating temperature prior to installation on a disk.

Note: These coatings are highly specialized and require special part preparation, mask tooling and handling to assure proper application and consistent quality. Improperly selected and/or applied coating can lead to rapid coating failure and the degradation of the base material properties of the coated component. A thorough engineering review of any coating application should be conducted prior to use.

3.7.2 The entire expander rotor disks are generally not coated due to the part geometric complexity. Erosion coatings have been applied to the disc faces and outer attachment region on a limited basis. These coatings are applied by thermal spray processes as outlined in Chapter 1 Appendix D.3. Disk coatings are highly specialized and require special part preparation, mask tooling and handling to assure proper application and consistent quality.

3.7.3 When re-coating existing components all evidence of previous coatings shall be removed prior to recoating.

3.8 TIE BOLTS

3.8.1 The body of the tie-bolts are not to be repaired except for minor skim turning (generally less than 0.005 in. deep), blending or stoning of the tie bolt body to eliminate localized, minor galling or scoring.

3.8.2 Rotor tie bolts are highly stressed, therefore, thread repair is to be limited to minor deburring and chasing of the threads with the appropriate die.

Note: Tie bolt threads may be a special class, special form, or rolled threads. Caution must be taken when chasing these threads to assure that the appropriate thread class and form is used. A standard thread die cannot be used on a special thread class, special form or rolled threads.

3.8.3 If the tie-bolts are not straight within the assembly clearance of the disks or drums that they pass through, they should be replaced and not welded or machined.

Note: It is recommended that tie-bolts should not be cold press straightened since this could introduce additional stresses.

3.8.4 Fasteners with galling resistant coatings shall be recoated. The coating is to be an extreme pressure anti-seize coating suitable for the application.

3.9 LABYRINTH SEALS

3.9.1 "J" strip seal teeth shall be repaired by straightening if possible and replaced as necessary. The replacement of "J" strips is to include the removal of the old strips and the replacement with new. The strips shall are final machined and the final dimensions shall be recorded. Caulking strip material should be in the annealed condition.

Note: For proper installation, the open end of the "J" is typically toward the higher pressure side.

3.9.2 Integral seal teeth are generally remachined undersized and fitted with appropriate mating seals. Alternatively, seal teeth may be restored by repair welding per Chapter 1, Appendix D.2.

3.10 SHAFT SLEEVES AND SPACERS

While it may be technically acceptable to repair shaft sleeves and spacers, the economics of repairing generally result in a new component replacement.

3.11 CURVIC COUPLING

3.11.1 Repairs to, or manufacture of Curvic Couplings should be done in shops which have the special grinding machines necessary to produce the coupling.

3.11.2 The number of times the curvic coupling teeth can be reground is limited only by the geometry of the components and stack height. Generally stack height is the limit, since the overall length of the rotor and the individual components in the rotor change as the teeth are reground. As material is removed the axial position of the various components is changed and the axial clearance is reduced. Even if a small amount of material is removed, for example 0.010 per face, on a rotor with five discs and stub shafts, there will be 12 curvic faces with a total loss of 0.120 in. in overall length. Regrindings can often be in the 0.030 range per face. Rotor repositioning in the casing and/or reworking stationary components is usually required.

3.11.3 Reground Curvic Couplings shall be inspected in accordance with Appendix F.

3.12 COMPONENT REPLACEMENT

3.12.1 Refer to Appendix C and Chapter 1, Section 9 for component replacement requirements.

3.12.2 New Blade Manufacture

The manufacture of new blades shall account for any machining performed in the blade attachment region and any design improvements.

3.12.2.1 Prior to blade manufacturing, manufacture "root" samples based on the blades previously removed from the disk and trial fit root samples to the disks to confirm proper engagement.

3.12.2.2 All blade root (dovetail), platform, and fillet to the airfoil areas are to be peened. On 250 m/sec (825 ft/sec) or faster applications the airfoil fillet to tenon region shall be peened. Peening intensity and media depend upon base material, compressive layer depth desired and material thickness. The compressive layer induced shall be checked by using Almen strip.

Notes:

1. Peening increases corrosion resistance and resistance to fatigue cracking via inducing a compressively stressed layer at the material's surface. In general, the peening intensity is set by the section thickness. If the intensity is too high, the component's edge can distort. Thus the airfoil peening intensity is governed by the thickness of the blades' trailing edge. The blade root is generally peened to a higher intensity than the blade.

2. Peening has been found beneficial for expander materials, even at higher operating temperatures.

4 Assembly and Balancing

4.1 PRE-ASSEMBLY REQUIREMENTS

4.1.1 Because major components are all coming together for the first time after repairs, the vendor shall assure that the following items are completed prior to assembly.

a. Verify that all specific requirements of the repair scope have been met.

b. Verify that correct axial positioning data is available.

c. Verify that all critical dimensions have been taken, recorded, and evaluated for final fits, locations, and clearances.

d. Verify that the requirements of Section 3 have been met on any new or repaired components.

e. Verify that all the parts are laid out in their proper order (numbered blades, tie bolt, and nut assemblies, etc.) and that all assemblies line up to their original match marks.

4.1.2 All mating components should be thoroughly cleaned prior to assembly. Remove any foreign deposits, preservation materials, oil, etc. with an appropriate solvent.

4.1.3 Verify that all mating surfaces are clean and free of corrosion and burrs. Stone faces as necessary.

4.1.4 Lubricants are not to be used on any rotor blading, or disk. Many lubricants or anti seize compounds can cause corrosion damage or embrittlement due to the expander's high operating temperatures.

4.1.5 Verify that the keys have a tap fit in the shaft and a slip fit in the components, and that the top key clearances are 100 µm to 150 µm (0.004 in. to 0.006 in.).

4.1.6 The vendor shall record a complete set of phase-related bare component runouts prior to assembly. As a minimum, runouts shall be recorded at each location where a disk or sleeve fits and at one point outside of each bearing journal.

4.1.7 Proper location of blading will minimize residual unbalance and the subsequent grinding corrections to the disk. Generally the grinding depth of the balance correction should be limited to approximately 3 mm ($^1/_8$ in.).

Note: To minimize grinding on disks the following should be considered.

a. All blades with an airfoil length of 100 mm (4 in.) or less may be pan-weighed.

b. All blades with an airfoil length greater than 100 mm (4 in.) should be moment-weighed.

c. Consideration also needs to be given to variations in blade thickness and locking blade weight when distributing blades.

4.1.8 For blades that have been moment weighed, the circumferential distribution of the blades shall be determined with a computer program designed for the purpose of minimizing resultant unbalance.

4.1.9 New rotor blade locking hardware shall be used rivets, lock plates, springs, pins, wire, etc.).

4.1.10 The rotor components are to be protected during the assembly process to prevent damaging the components.

Note: Coated blades are easily damaged and are to be individually protected.

4.1.11 Removable overspeed trip assemblies should be bench tested and calibrated for the proper trip speed.

If rotor is to be high speed balanced, trip setting may be verified during that procedure.

4.1.12 Prior to balancing, determine the appropriate balance correction regions.

Balancing corrections shall be made on the disks by grinding on the face of the disk dedicated for balance correction or by adding balance weights in a balance groove. Corrections on the disk faces adjacent to the blade root areas (which is normally also the indicator plane), the blade attachment, or other critically stressed regions of the disk is not permitted.

Metal removal on the disk faces shall be limited to guidelines given in 4.1.7. If necessary, the correction grind shall be blended to prevent stress risers and spread out to limit thinning of the disk material.

4.2 DISK ON SHAFT ROTOR

Refer to Figure 6.1-5.

4.2.1 Rotors shall have the bare shafts and individual major components balanced prior to the rotor assembly per Chapter 1, paragraph 10.2.

4.2.2 Rotor stacking and low speed assembly balance shall conform to the requirements of Chapter 1, paragraph 10.3 and the data recorded on figures in Appendix D.

a. Bladed Disk assemblies are to be balanced per Chapter 1, paragraph 10.2 prior to the assembly onto the rotor.

b. If blades have not been installed on the disks, the disk(s) shall be assembled onto the shaft, perform runout checks, blades installed as applicable, shrouded, check balanced, assembly balanced per 4.2.19, and continue stack balancing in accordance with Chapter 1, paragraph 10.3.

Note: The rotor design and the shop practice will determine whether the blades will be installed onto the disk before or after the disk is installed onto the rotor.

4.2.3 Shroud installation and tenon peening shall be in accordance with paragraph 4.6.

4.2.4 With shafts that have a common diameter for all discs and sleeves, and the discs can be installed on the shaft from either end, the components shall be assembled from the center of the rotor, outwards. When possible, the vendor shall plan the rotor assembly so that two plane balance corrections may be applied on the major rotor components throughout the assembly (i.e., assemble two major components for each balancing step). On a rotor having an odd number of major components, the single plane balance step shall be either the first or last major component assembled.

4.2.5 All major components shall be uniformly heated. Components shall be heated to provide an assembly clearance to the shaft of 1 µm/ mm (0.001 in./in.) of shaft diameter, but in no case more than 280 K (500°F) above the ambient shop temperature. For high interference applications higher temperatures may be required with engineering review.

Note: Heating components (especially the disks) for assembly is a critical step. In general, the differential temperature across a disk should never exceed 30 K (50°F) during the heating process, as permanent distortion may occur. This heating may be accomplished in a horizontal oven that has good temperature control. It can also be accomplished by the use of two or more large (flare tip or rosebud) torches, however, care must be exercised to avoid large heat input causing uneven heating. Care is also to be given to sections of different thicknesses to avoid excessive temperature differentials. When torches are used, the differential temperature should be carefully monitored with temperature indicating temperature sticks or a non-contact infrared surface temperature gun.

4.2.6 When a coated rotor disc or blades is used, the temperature limitation of the coating must be reviewed for assembly considerations.

4.2.7 All major components shall be assembled with the shaft in the vertical position.

4.2.8 Major components should not be impacted with hammers, blocks of wood, etc., at any time during the assembly process.

4.2.9 After the addition of each stack allow the rotor to cool to approximately 50°C (120°F) and record the data required by 4.2.10, 4.2.11, 4.2.12,4.2.13, and 4.2.14.

4.2.10 The vendor shall assure that the last components added are correctly located on the shaft according to the assembly data and/or drawing. Stacked dimensions shall conform to the inspected dimensions per paragraph 1.3.7, or have engineering justification for deviation. Major component positioning shall be within ±760 µm (0.030 in.) of the assembly reference dimension (normally measured from the thrust collar or the thrust collar shoulder to the inlet side of the rotor blade or shroud), and within ±200 µm (0.008 in.) of the disk-to-disk dimension (normally the distance between the high pressure edges of the shroud band).

4.2.11 Unless otherwise specified, the minimum axial gap between all adjacent disks and interstage sleeves, after assembly, shall be 100 µm (0.004 in.).

4.2.12 The vendor shall record phase-related runouts on the faces of the disks just below the expander blades, and the shaft on both sides of the stack.

4.2.13 Disk rim axial face runouts must be within 25 µm (0.001 in.) of the face runouts measured when the disk was on the balance mandrel, accounting for any phase angle differences. In no case shall the disk face TIR runouts exceed 0.13 µm/mm (0.0015 in./ft) of diameter.

4.2.14 The vectoral change in shaft runouts during each stack, comparing the before and after shaft runouts measured with a dial indicator adjacent to the last major components(s) stacked, shall not exceed 8 µm (0.0003 in.) TIR.

4.2.15 If after each stack, the requirements of paragraph 4.2.14 have not been met, a "heat soak" process may be performed in accordance with a-c:

a. The exposed areas of the shaft shall be wrapped with an insulating material to avoid exposure to direct flame during the process.

b. Continuously rotate the rotor in a balance machine at 300 to 500 rpm during the entire process.

c. The disk(s) that were last assembled shall be rapidly heated with a large (flare tip or rosebud) torch to a temperature of approximately 180°C to 200°C (350°F to 400°F) The rapid heat shall be applied near the bore area only after heating the entire disk to allow for expansion. The disk temperature shall be monitored with temperature indicating temperature sticks or a non-contacting infrared surface temperature gun. The rotor shall be allowed to continuously rotate in the balancing machine until its temperature is not more than approximately 50°C (120°F).

4.2.16 If the rotor still does not meet the requirements of 4.2.15 and/or Chapter 1, paragraph 10.3.5, but the heat soak did result in a balance improvement of at least 25%, a second heat soak procedure may be performed per 4.2.15. If, after a second heat soak procedure, the rotor still does not meet the requirements of 4.2.15 and/or Chapter 1, paragraph 10.3.5, the components that were last assembled shall be removed for inspection and correction as required.

4.2.17 After performing a heat soak process, the vendor shall verify the axial positioning of the components per 4.2.10 and axial clearances or gaps per 4.2.11.

4.2.18 Check and record blading dimensions and throat openings to confirm agreement with those recorded prior to disassembly per paragraph 1.3.5, or have engineering justification for deviation.

4.2.19 Balance corrections after each successive stack shall be limited to the last major components stacked and comply with the requirements of 4.1.12.

4.2.20 The overall stack dimensions (normally from the high pressure edge of the first stage blade or shroud to the high pressure edge of the last stage blade or shroud) shall be within 0.4 mm (0.016 in.) of the inspected dimension per 1.3.7 or have engineering justification for deviation.

4.3 INTEGRAL ROTORS

Refer to Figure 6.1-4.

4.3.1 Measure and record rotor runouts and dimensions as outlined in 1.3 and Chapter 1, paragraph 7.2.6.

4.3.2 Balance the rotor (less blading) in accordance with Chapter 1, paragraph 10.2.

4.3.3 For free standing blades, sequentially assemble and low speed balance the rotor in accordance with the requirements of Chapter 1, paragraph 10.3. Balance correction should only be made by moving blades. Blading shall be assembled from the center of the rotor, outwards. When possible, the vendor shall plan the blading assembly so that two plane balance corrections may be applied throughout the assembly. On rotors having an odd number of stages, the single plane balance step shall be either the first or last row of blading assembled.

4.3.4 Sequentially assemble and low speed balance the rotor in accordance with the requirements of Chapter 1, paragraph 10.3, assembling from the center of the rotor outwards. Blading shall be installed in accordance with 4.1.7 and check balanced. Resequence the blades if the check balance exceeds 25 grams at the correction radius (10 inch radius would be 250 gm-in.). The blades are then to be shrouded, machined, and assembly balanced per 4.2.19. When possible, the vendor shall plan the blading/shrouding assembly so that two plane balance corrections may be applied throughout the assembly. On rotors having an odd number of stages, the single plane balance step shall be either the first or last row of blading assembled.

Note: The effort of resequencing is to minimize the amount of grinding done on the disks.

4.3.5 Blade tip or shroud machining shall be in accordance with section 4.7.

4.4 TIE BOLT ROTORS

Refer to Figures 6.1-1, 6.1-2, 6.1-3.

4.4.1 Tie bolt rotors can be assembled in a variety of ways that include:

a. Disk face to disk face—with spigot fit.
b. Disk face to disk face—with Curvic couplings.
c. Disk face to disk face—with Radial pinning.

The general stacking requirements and procedures are the same for all of the above rotor designs.

4.4.2 Except for some overhung designs, tie bolt rotor designs may not allow for sequential stacking and balancing between the addition of major components.

4.4.3 Rotors utilizing curvic couplings at the disk to disk or disk to shaft interfaces shall have been inspected per Appendix F.

4.4.4 Prior to stacking the rotor, prepare a rotor stacking chart for all components to be assembled. The rotor stacking chart shall be generated based upon the individual component inspection data. The stacking orientation is intended to minimize both the radial and axial run out of the assembled rotor components.

4.4.5 Prior to the rotor stacking, check the alignment of the tie bolts within the disks and stub shafts for proper clearance. All tie bolts must be of the same material and matched in length and diameter within the design tolerance.

4.4.6 Alignment dowels are often used to align components. Locate and fit up any special tooling required for the rotor stacking.

4.4.7 For designs that utilize radial pins or keys for disk positioning, check to assure proper fit of these components.

4.4.8 Sequentially assemble the wheels, spacer pieces, and stub shafts in the correct orientation as defined by the stacking chart and the rotor assembly drawing. If possible, during each subsequent component assembly confirm that the combined rotor runout satisfies the requirement of that stage.

4.4.9 Major components requiring heating to allow assembly shall be uniformly heated. The required amount of and maximum heating of the components shall be calculated and submitted to the owner for approval prior to the rotor build. Rabbet fits may be locally heated. Components shall be heated to provide an assembly clearance to the shaft of 1 µm/mm (0.001 in./in.) of shaft diameter, but in no case more than 280 K (500°F) above the shop ambient temperature.

Note: Heating components for assembly is a critical step. It can be accomplished by the use of two or more large (flare tip or rosebud) torches, however, care must be exercised to avoid a heat rate that is too rapid to maintain even heating. When torches are used, the differential temperature should be carefully monitored with low sulfur temperature indicating sticks or a non-contact infrared surface temperature gun.

4.4.10 Install the rotor tie bolts, studs and nuts. All rotor assemblies have a defined procedure and sequence of tensioning the tie bolts. Tie bolt tensioning should generally be done in three or four steps of increasing load and in opposite pairs. Some rotor assemblies require special hydraulic tooling for simultaneous torquing of a defined fraction of the full quantity of through bolts. Some rotor designs may require over torquing the bolting in order to achieve a setting of the stack prior to establishing the final setting.

Measure and record the resultant stretch in the tie bolts and evaluate against the specified value.

4.4.11 All major components shall be assembled with the shaft or shaft ends in the vertical position.

4.4.12 Major components should not impacted with hammers, blocks of wood, etc., at any time during the assembly process.

4.4.13 Allow the rotor to cool to less than 50°C (120°F) and record phase-related runouts on the faces of the disks just below the blades, and the shaft on both sides of each disk and stub shafts.

Disk rim axial face runout must not exceed 0.32 µm/mm (0.0015 in./ft) of diameter.

4.4.14 The rotor disk position and overall stack rotor length shall be with in 0.5 mm (0.020 in.) of the inspected dimensions per 1.3.7 minus any face machining or have engineering justification for deviation.

4.4.15 Stacked rotors, other than overhung designs, will generally require a machining/grinding or "truing up" of the journals, vibration probe areas, thrust faces and coupling fits and faces.

Note: Truing up of the shaft ends which contain the journals, vibration probe areas, thrust faces and coupling fits and faces will require the use of non-standard components. If interchangeability is required, journal and shaft ends should be oversized per Chapter 1, Section 9.

4.4.16 The tie bolt rotor shall be balanced in accordance with Chapter 1, paragraph 10.3.6 through 10.3.11.

4.4.17 For overhung rotors, the balance corrections shall be made on the overhung disk. The corrections are to be made in the rim region. Balance corrections shall not be made on the blades, blade attachment regions, or neck region of the disk.

4.4.18 For rotors with loose blade designs, the balance speed shall be sufficient to seat the blades.

4.4.19 For unbladed rotor assemblies, balance the bare rotor per Chapter 1, paragraph 10.2. The rotor shall then be sequentially bladed and balanced in accordance with the requirements of Chapter 1, paragraph 10.3. When possible, the vendor shall plan the blading assembly so that two plane balance corrections may be applied throughout the assembly. On a rotor having an odd number of stages the single plane balance step shall be either the first or last row of blading assembled. Blading shall be assembled from the center of the rotor, outwards.

For axial admission blading, balance correction should first be made by moving blades. Resequence the blades if the unbalance exceeds 25 grams at the correction radius (10 inch radius would be 250 gm-in.). Grinding of the disks should be done after efforts have been exhausted in relocating blading to achieve the balance tolerance.

For non-axial entry blading, grinding is required on the disks.

4.4.20 For bladed rotor disks, upon completion of the rotor build, machine the rotor per paragraph 4.4.15 and then balance the rotor per Chapter 1, paragraphs 10.3.6 through 10.3.11.

Notes:

1. The rotor build for this style rotor does not allow for the sequence balancing criteria as described in Chapter 1, paragraph 10.3.

2. The rotor design and the shop practice will determine whether the blades will be installed onto the disk before or after the disk is installed onto the rotor.

4.4.21 Check and record blading dimensions and throat area to confirm agreement with those recorded prior to disassembly per paragraph 1.3.5, or have engineering justification for deviation.

4.4.22 For rotors with loose blade designs, measure and record the axial movement of each blade and tip movement in the circumferential direction.

4.4.23 Blade tip machining, when required, shall be in accordance with Section 4.7.

4.5 REASSEMBLY OF PARTIALLY DISASSEMBLED ROTORS

4.5.1 This section outlines the procedures required for rotors that have had disks or blading removed.

4.5.2 Prior to the addition of any additional disks or blades, the rotor shall be balanced per Chapter 1, paragraph 10.2. After balancing proceed with the assembly balance per the applicable section as related to the rotor construction.

Note: Partially debladed rotors need to be assessed as to whether the balance weights should be removed. Removal of balance weights depends upon:

a. Number of stages of blades removed.

b. Balance of the rotor in the partially debladed condition.

c. Location of the balance weights with respect to the residual unbalance in the rotor.

c. Number of resonances that the rotor must pass through.

d. Condition of the balance weights and the locking hardware.

If the balance weights are removed, record their weight and locations so they can be replaced in their original location, if required.

4.6 SHROUD INSTALLATION

4.6.1 Shroud Installation

The installation of blade shrouds and peening of the blade tenons require considerations such as:

a. The peening of the tenons shall be done using a qualified procedure and personnel. The shroud shall have the same material properties as the "as received shroud." (See 4.6.2.)

Note: Some shroud material may harden in service and should be accounted for when selecting material properties of new shroud material.

b. Ensure that the shroud grouping (blade packet) is consistent with the as received condition per section 2.2.11.

c. Peening of the tenon should be done by utilizing a formed tool. The energy to form the tenon may be delivered with an automatic device or a hammer and form tool. An automatic device is preferred due to consistency.

d. Clearance between the tenon and the shroud hole is required. This clearance may typically be 125 µm (0.005 in.) per side.

e. Wide airfoils are to be machined, during blade manufacturing, so that the blade tips match the curvature of the shroud.

f. The base of the tenon shall have a generous radius and the shroud ID shall be radiused so that the shroud does not contact at the tenon radius.

g. The peened side of the tenon holes in the shroud shall be chamfered and sharp edges removed.

h. Verify that the edge of the shroud hole does not interfere with the radius of the tenon at the top of the blade airfoil.

i. The installed blades shall be used as a template for locating the holes into the shroud.

j. Machine the hole in the shroud to the correct pitch. Surfaces must be deburred and finished to a minimum surface finish of 1.6 µm (64 µinch) Ra.

k. Prior to installation, NDE inspect the shroud in accordance with Chapter 1, paragraph 8.2.4. No indications are allowed.

l. When fitting of the shroud to the blading, no deflection of the blading is allowed.

m. Silver soldering of the shroud to the tenon is not allowed.

n. Roll the shroud to the required radius curvature corresponding to the outside diameter created by the blade tips.

o. Check fit of shroud holes to blade tenons. If the shroud does not fit, determine cause and correct with the manufacturing of a new shroud.

p. Peen the tenons in accordance with "a". Confirm that the shroud is in contact with the blade tip and is not otherwise distorted. Tenons diameter larger than 16 mm ($^5/_8$ in.) may require stress relieving after peening.

q. Verify that there is approximately a 1.6 mm ($^1/_{16}$ in.) clearance between the ends of shroud sections.

r. NDE inspect peened tenons in accordance with Chapter 1, paragraph 8.2.4. No indications are allowed. A dimensional inspection of the peened tenons should be performed.

4.6.1.1 After the shroud has been installed, final machine the shroud band per 4.7, as required, prior to balancing.

4.6.2 Tenon Peening Qualification Procedure

If an approved peening procedure using the same material and geometry does not exist, prior to the tenon peening process, a test peening shall be completed. The procedure for qualifying the tenon peening process shall include the following to assure consistent results:

a. Manufacture six "peening samples" from the same metallurgy and material properties of bar stock used to manufacture the blades. The samples shall have the tenon geometry machined into them including diameter, height, fillet radius and surface finish.

b. Manufacture a shroud sample using the same type of material used for the final shroud including the hole tenon with all design features such as through diameter, corner radius adjacent to the top of blade, top of tenon hole chamfer and surface finish.

c. Peen the tenon to the shroud using the peening process which will be used for peening of the rotor. If an automatic peening machine is used, record all settings including but not limited to working pressure and travel.

d. MPI the peened tenon to check for cracks resulting from excessive work hardening.

e. Section all samples of the peened connection and mount for microscopic examination and "microhardness" inspection along the axis of the tenon. Check for proper "fill" of the tenon hole in the shroud and that the shroud is in acceptable contact with the top of the peening sample block (where the top of the airfoil will be).

f. Peened tenons shall not have feathered edges.

g. Confirm finished tenon height and diameter are within specification requirements.

4.7 FINAL MACHINING

4.7.1 Shroud Machining

After completion of shroud installation, machine the shrouds to the proper axial position and final geometry. Longer rotor blades may require additional support to prevent tool chatter. Common support methods include soft wedges, plaster, low melting point metals, foam, rubber, etc. Care should be taken to prevent blade damage.

DO NOT MACHINE INTO AIRFOIL.

Notes:

1. Trimming of the shroud should typically allow a minimum of 250 μm (0.010 in.) of overhang of the shroud past the edges of the airfoil.

2. The runout and location of the shroud's leading edge is important to the efficiency and performance of the machine.

4.7.1.1 Before and after rework dimensional and runout inspections shall be performed, documented and submitted to the owner for approval.

4.7.2 Rotor Blade Tip Grinding

4.7.2.1 Many rotors require a grinding or "truing up" of the rotor blade tips. The final blade tip dimensions are to be in accordance with the dimensions developed from the Phase II inspection.

4.7.2.2 Blade tip grinding requires that the following operations be performed and precautions be taken:

a. Loose blading must be shimmed to prevent movement or chatter during the grinding operation.

b. Protect any airfoil coatings.

c. Long blading may require temporary support. The support materials must not damage the blading or coatings (if used)

d. The grinding is generally performed without coolants to prevent the coolant or grinding debris from entering the rotor cavities. Many coolants can be corrosive to high temperature metallurgies during operation.

e. Rotor grooves and cavities should be masked to prevent debris accumulation in these areas. Rotor journals need to be protected from airborne debris.

f. The rate of the grinding should be low to prevent blade chatter, movement or coating damage.

4.8 FINAL ROTOR BALANCING

4.8.1 Upon completion of the rotor build, grinding and/or machining, the final rotor assembly balance and residual unbalance check shall be performed in accordance with Chapter 1, Section 10.

4.8.2 When Balancing, material removal must be such as to prevent damage to the rotor critical components.

4.8.3 For overhung rotors, the balance corrections shall be made on the overhung disk. The corrections are to be made in the rim region. Balance corrections shall not be made on the blades, blade attachment regions, or neck region of the disk.

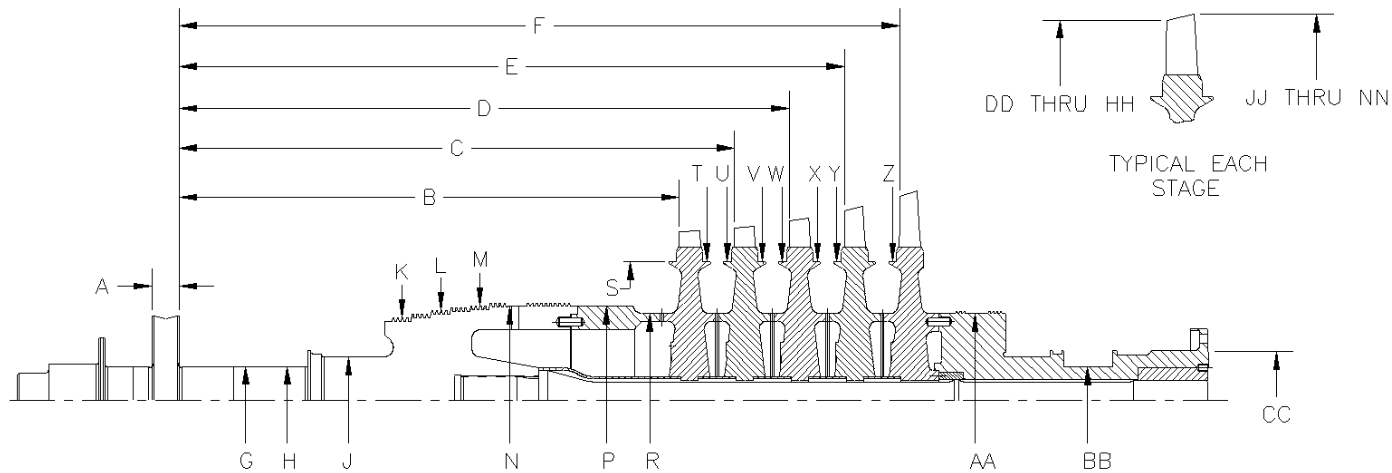
4.9 FINAL INSPECTION

4.9.1 Perform dimensional and NDE inspections of the assembled rotor as required in Section 1.3.

4.10 DOCUMENTATION

4.10.1 Documentation for rotor re-assembly and/or balancing shall conform to the requirements of Chapter 1, Section 12.

APPENDIX A—DIMENSIONAL FORMS FOR PHASE I INSPECTION

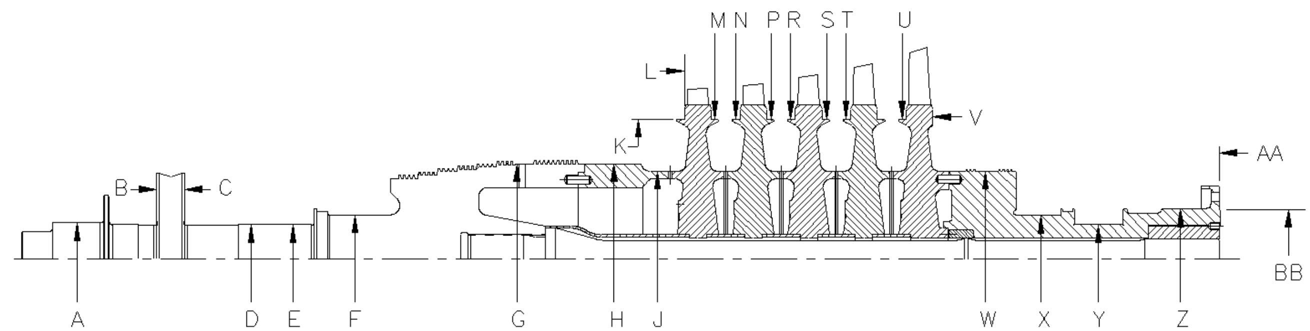


	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V
0°–180°																			
90°–270°																			

	W	X	Y	Z	AA	BB	CC	DD	EE	FF	GG	HH	JJ	KK	LL	MM	NN		
0°–180°																			
90°–270°																			

REMARKS	API RP-687, FIGURE 6.A-1	JOB NO. / PO. NO.
		MODEL NO.
ID NO.	TITLE MULTI STAGE STACKED EXPANDER ROTOR ROTOR DIMENSIONS	UNIT NO.
AS RECEIVED / AS SHIPPED / DATE / INSPECTOR / VERIFIED	CUSTOMER / LOCATION	FORM NO. / TYPE

Figure 6.A-1—Multistage Stacked Expander Rotor Dimensions



	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	BB
0°																									
90°																									
180°																									
270°																									

REMARKS	API RP-687, FIGURE 6.A-2		JOB NO / PO NO.
			MODEL NO.
ID NO.	TITLE MULTI STAGE STACKED EXPANDER ROTOR ROTOR RUNOUT (TIR)		UNIT NO.
AS RECEIVED / AS SHIPPED / DATE / INSPECTOR / VERIFIED	CUSTOMER	LOCATION	FORM NO. / TYPE

Figure 6.A-2—Multistage Stacked Expander Rotor Runout (TIR)

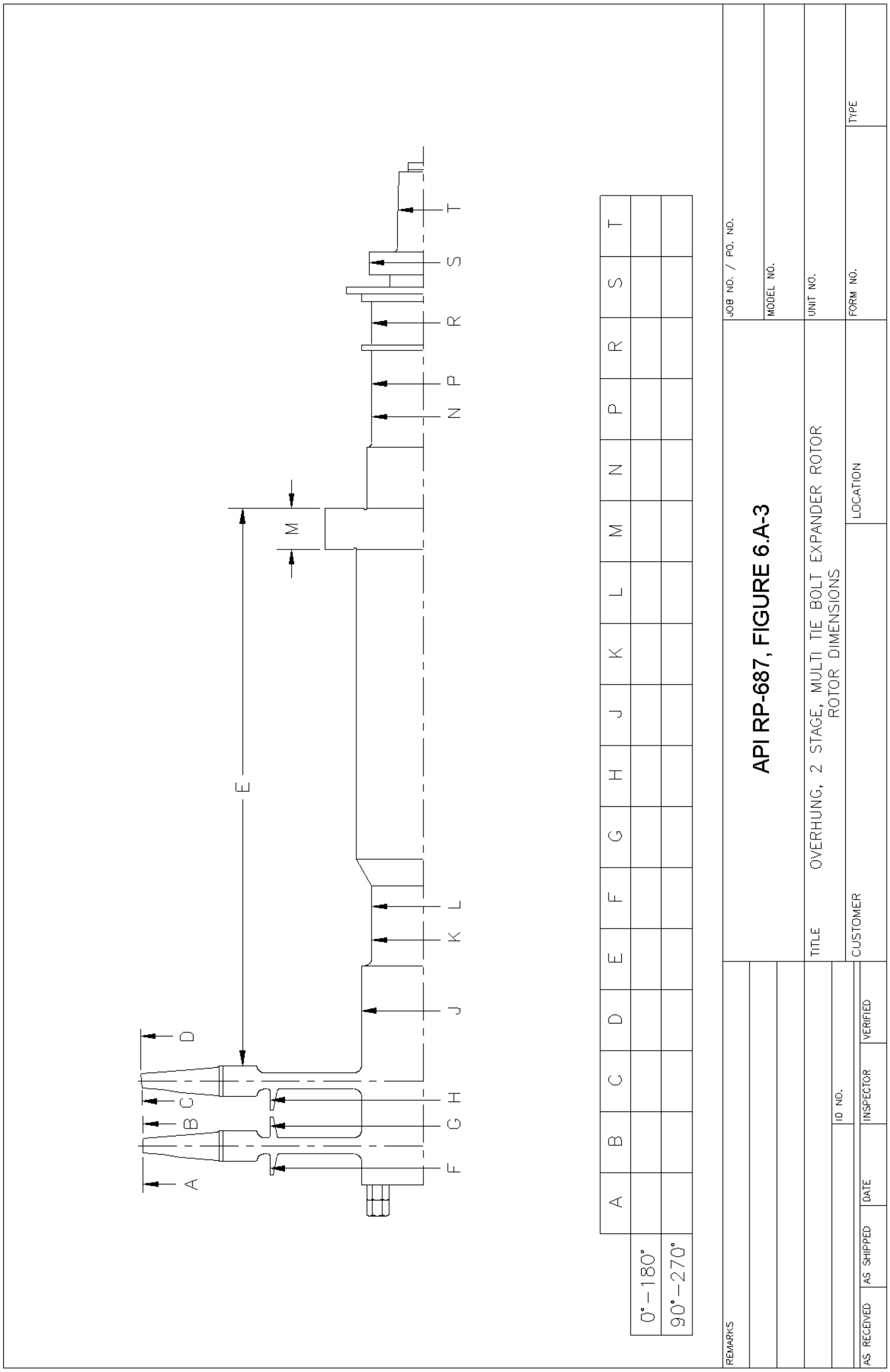
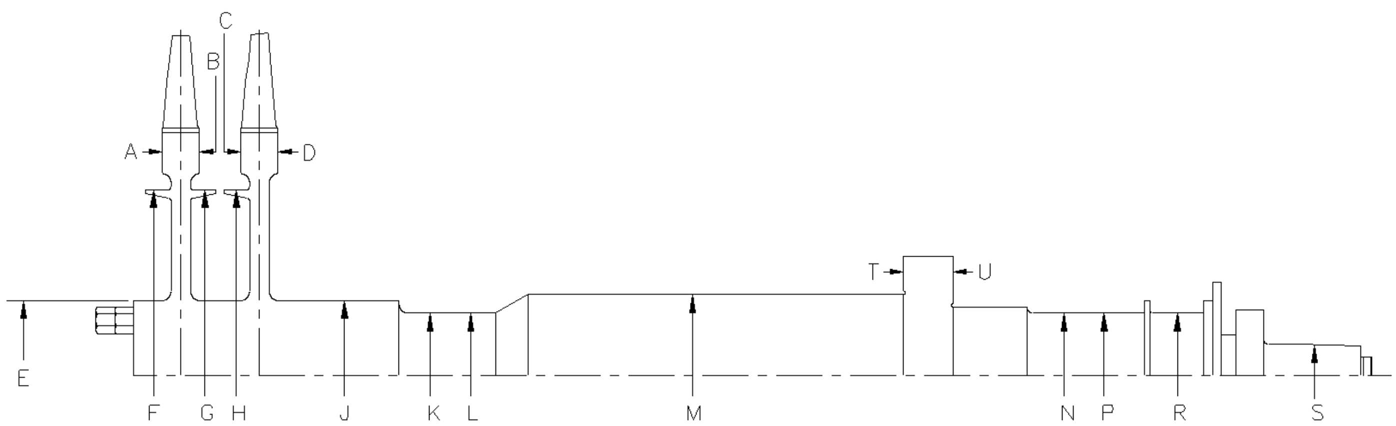


Figure 6.A-3—Overhung, 2 Stage, Multi Tie Bolt Expander Rotor Dimensions



	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	
0°																			
90°																			
180°																			
270°																			

REMARKS	API RP-687, FIGURE 6.A-4	JOB NO. / PO. NO.
		MODEL NO.
ID NO.	TITLE OVERHUNG, 2 STAGE, MULTI TIE BOLT EXPANDER ROTOR ROTOR RUNOUT (TIR)	UNIT NO.
AS RECEIVED / AS SHIPPED / DATE / INSPECTOR / VERIFIED	CUSTOMER / LOCATION	FORM NO. / TYPE

Figure 6.A-4—Overhung, 2 Stage, Multi Tie Bolt Expander Rotor Runout (TIR)

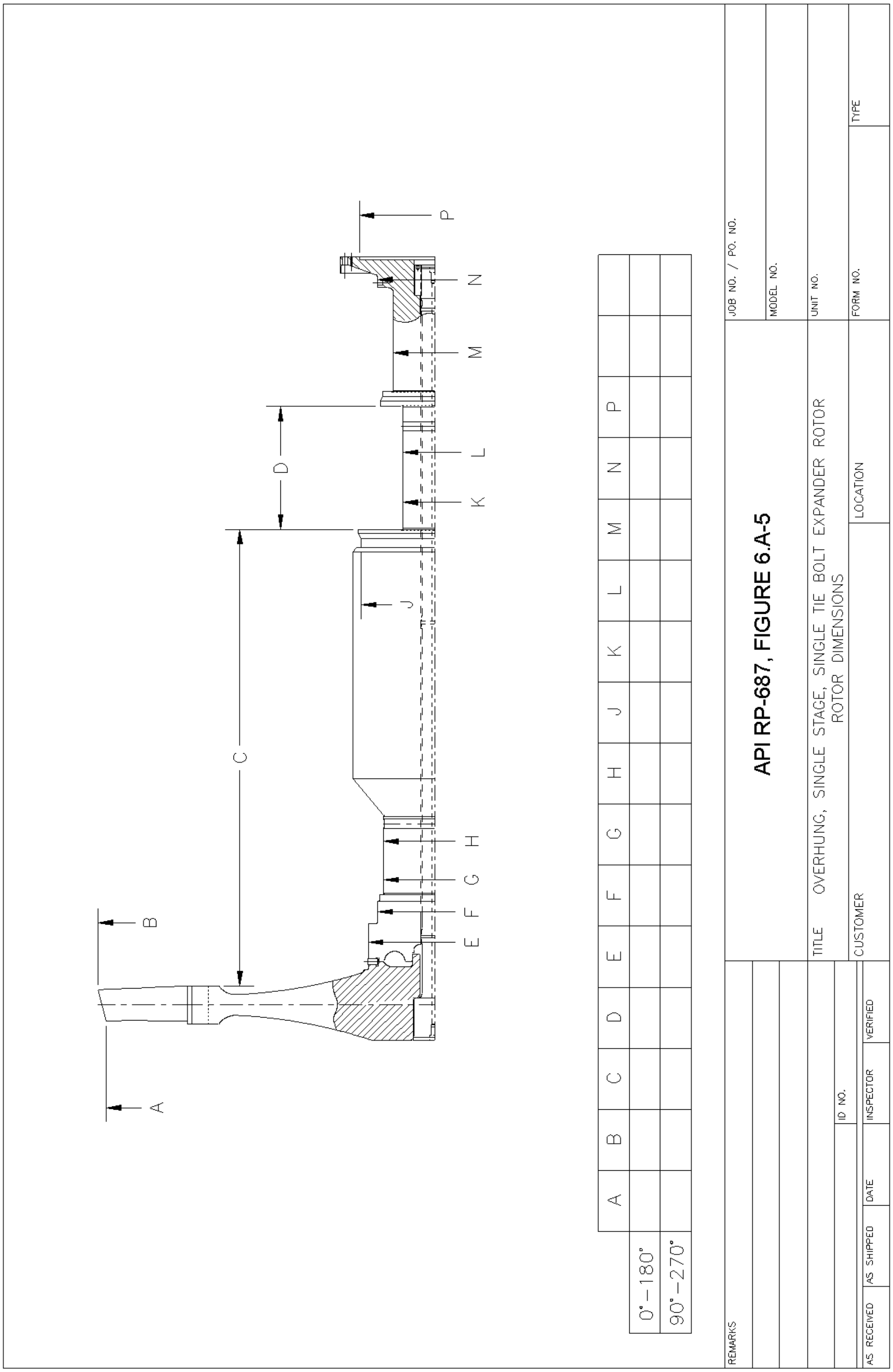
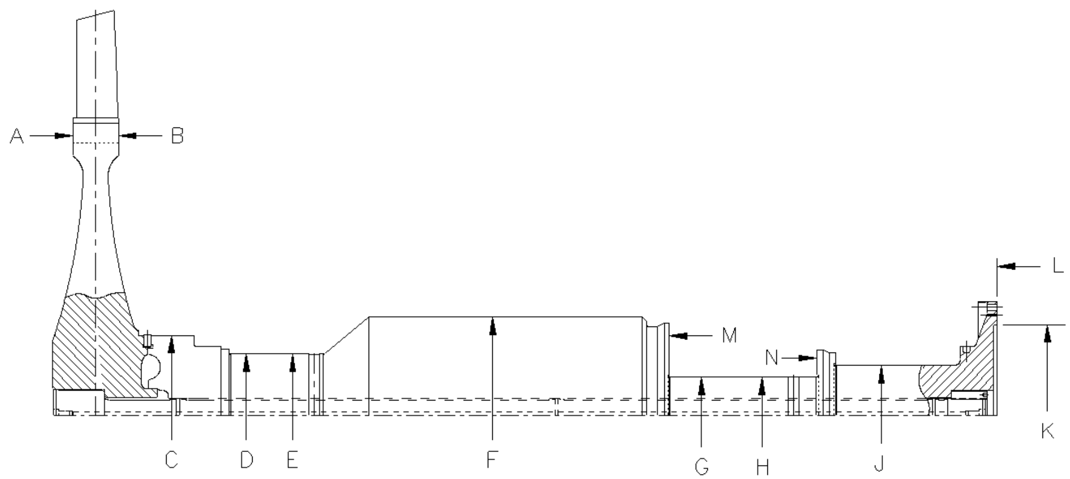


Figure 6.A-5—Overhung, Single Stage, Single Tie Bolt Expander Rotor Dimensions



	A	B	C	D	E	F	G	H	J	K	L	M	N			
0°																
90°																
180°																
270°																

REMARKS

ID NO.

AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED

API RP-687, FIGURE 6.A-6

TITLE OVERHUNG, SINGLE STAGE, SINGLE TIE BOLT EXPANDER ROTOR ROTOR RUNOUT (TIR)

CUSTOMER

LOCATION

JOB NO. / PO. NO.

MODEL NO.

UNIT NO.

FORM NO.

TYPE

Figure 6.A-6—Overhung, Single Stage, Single Tie Bolt Expander Rotor Runout (TIR)

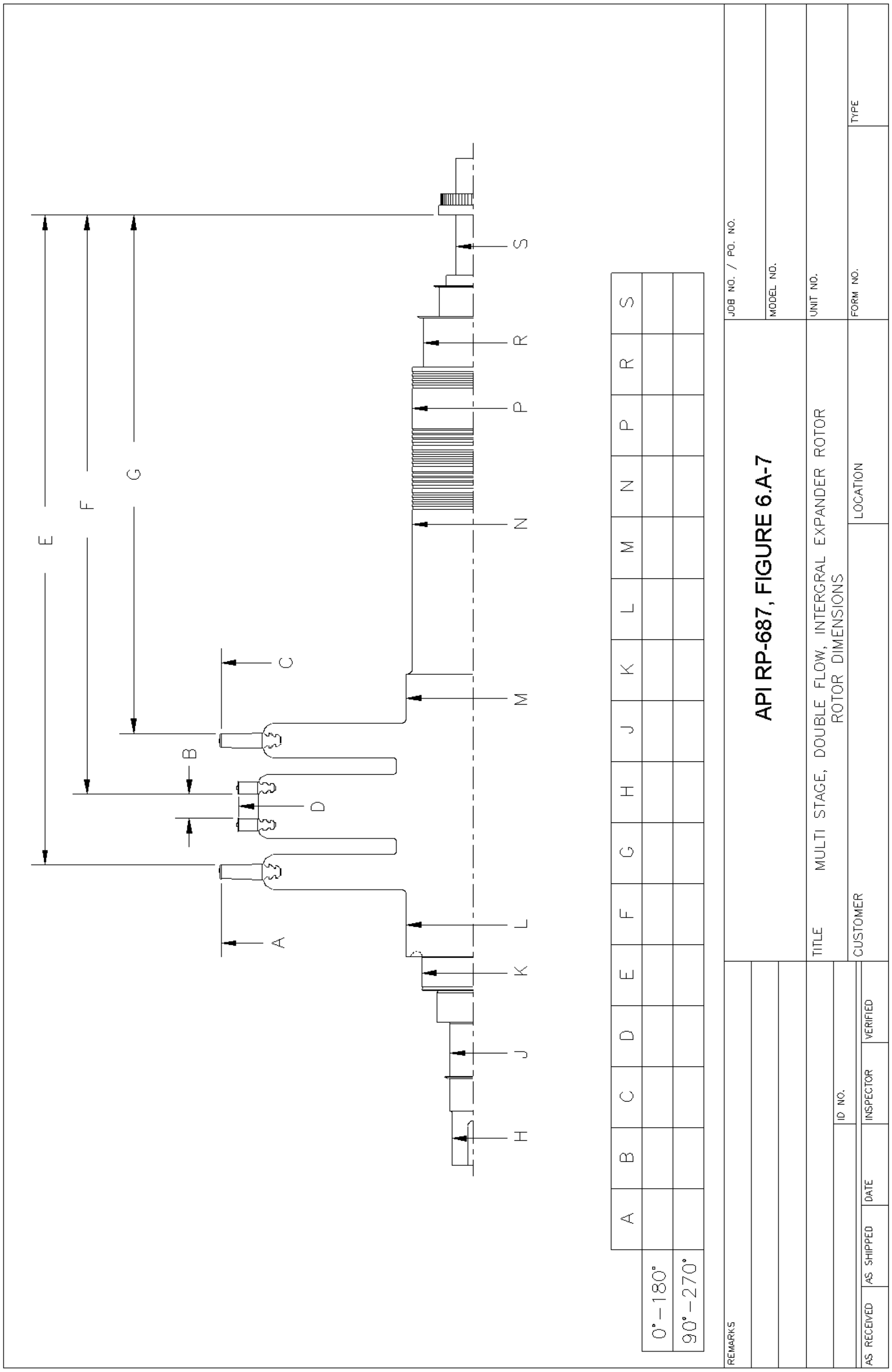
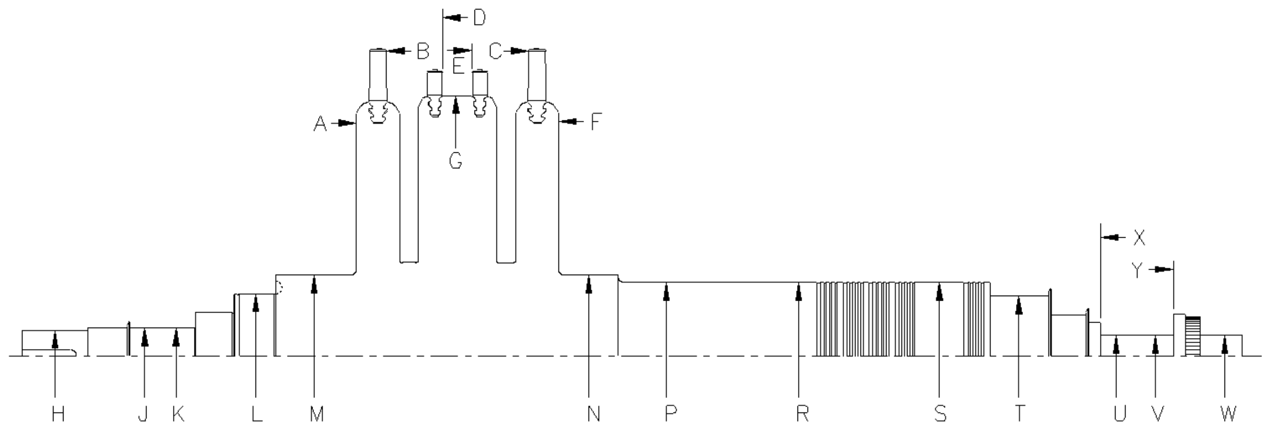


Figure 6.A-7—Multistage, Double Flow, Integral Expander Rotor Dimensions



	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y
0°																						
90°																						
180°																						
270°																						

REMARKS	API RP-687, FIGURE 6.A-8	JOB NO / PO NO.
		MODEL NO.
ID NO.	TITLE MULTI STAGE, DOUBLE FLOW, INTERGRAL EXPANDER ROTOR ROTOR RUNOUT (TIR)	UNIT NO.
AS RECEIVED / AS SHIPPED / DATE / INSPECTOR / VERIFIED	CUSTOMER / LOCATION	FORM NO. / TYPE

Figure 6.A-8—Multistage, Double Flow, Integral Expander Rotor Runout (TIR)

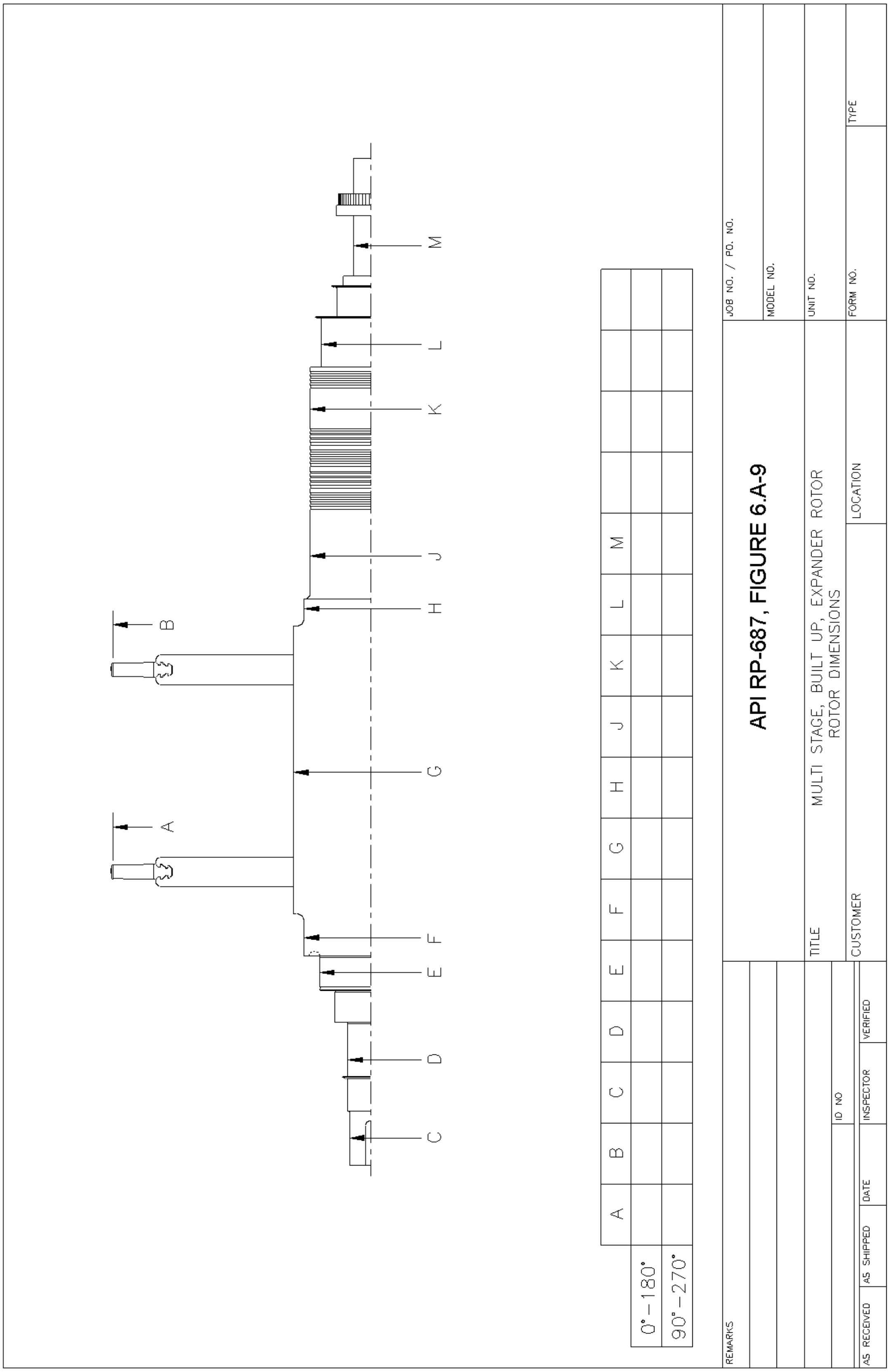
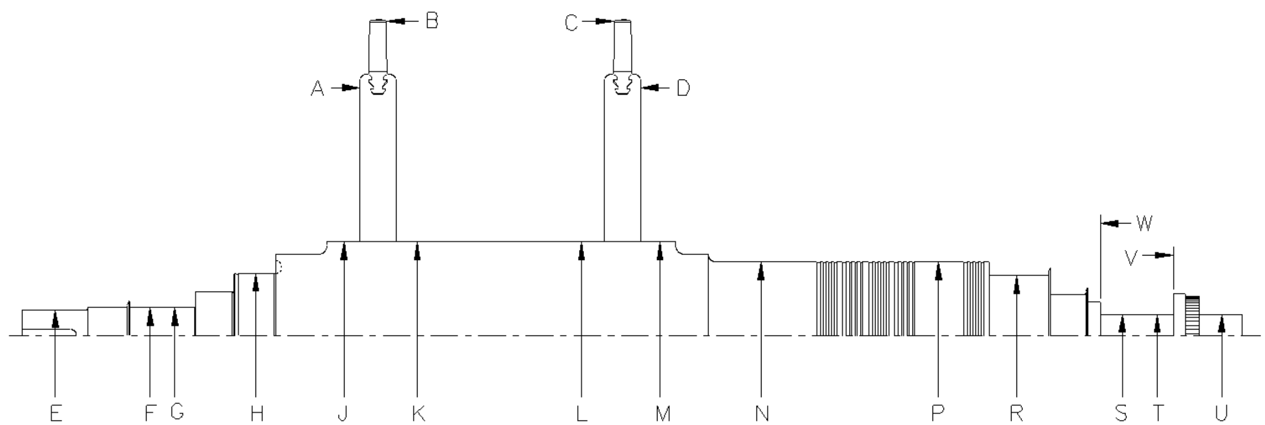


Figure 6.A-9—Multistage, Built Up, Expander Rotor Dimensions



	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V	W
0°																				
90°																				
180°																				
270°																				

REMARKS	API RP-687, FIGURE 6.A-10		JOB NO. / PO. NO.
			MODEL NO.
	TITLE MULTI STAGE, BUILT UP, EXPANDER ROTOR ROTOR RUNOUT (TIR)		UNIT NO.
ID NO.	CUSTOMER	LOCATION	FORM NO. / TYPE
AS RECEIVED / AS SHIPPED / DATE / INSPECTOR / VERIFIED			

Figure 6.A-10—Multistage, Built Up, Expander Rotor Runout (TIR)

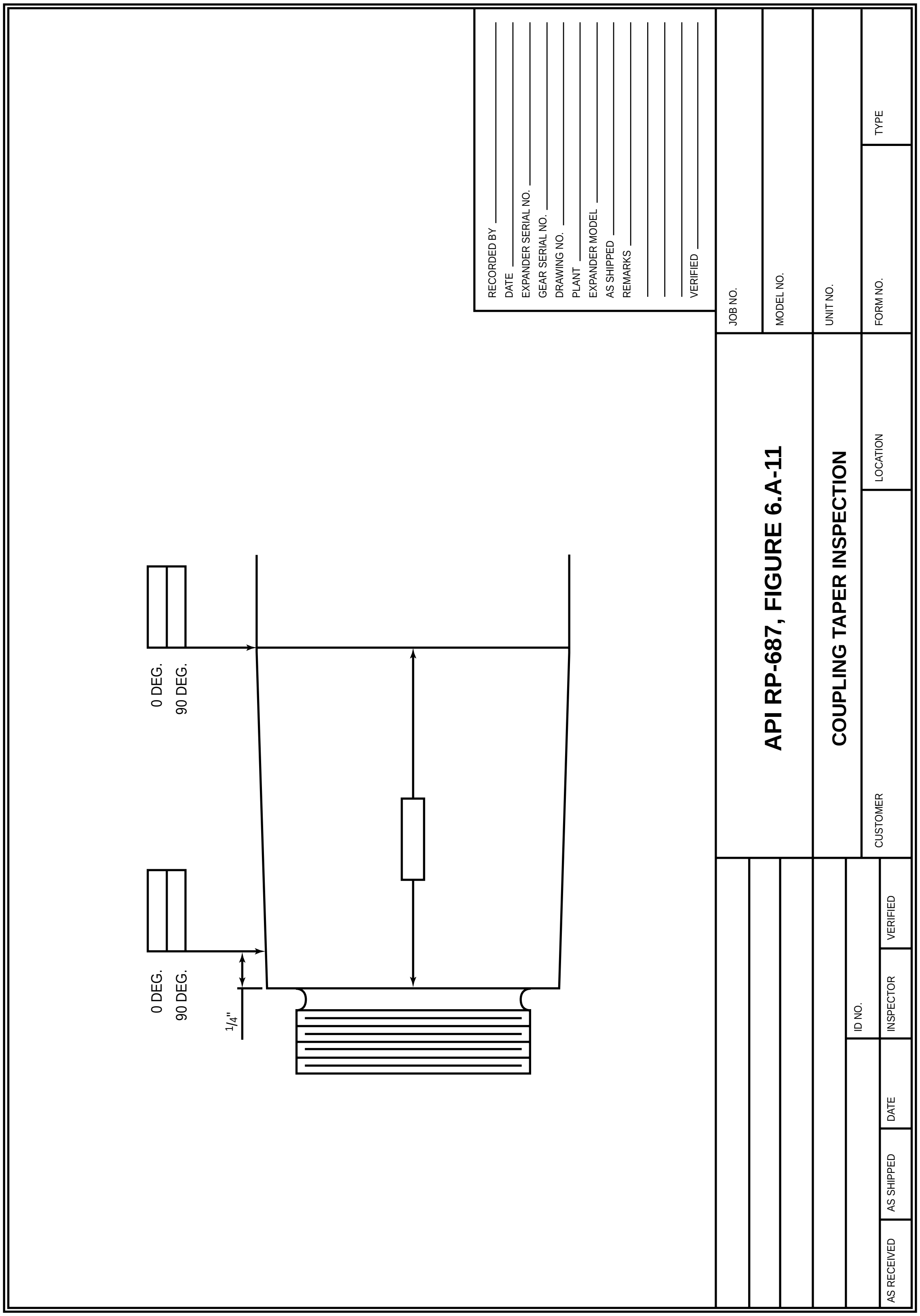


Figure 6.A-11—Coupling Taper Inspection

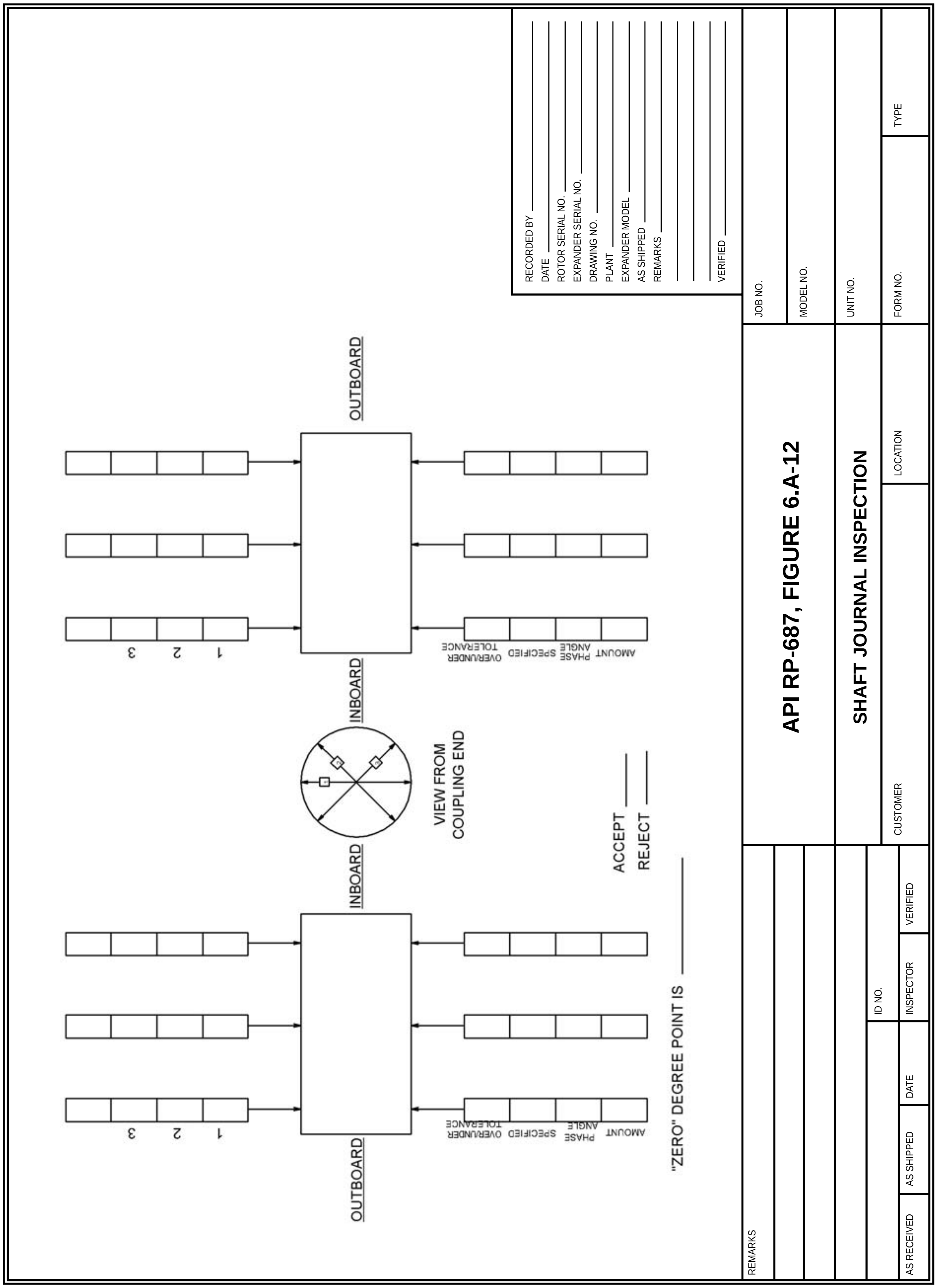


Figure 6.A-12—Shaft Journal Inspection

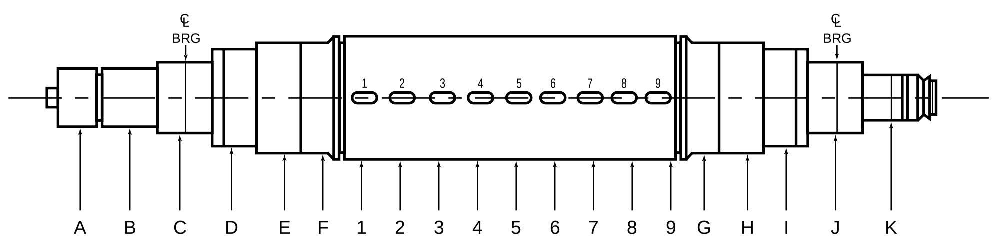
APPENDIX B—DIMENSIONAL FORMS FOR PHASE II INSPECTION

SHAFT DIAMETERS	SPECIFIED	0 DEG.	90 DEG.	OVER/UNDER TOLERANCE
A				
B				
C				
D				
E				
F				
G				
H				
I				
J				
K				

SHAFT RUNOUTS	SPECIFIED	0 DEG.	90 DEG.	OVER/UNDER TOLERANCE
A				
B				
C				
D				
E				
F				
G				
H				
I				
J				
K				

SHAFT DIAMETERS	SPECIFIED	0 DEG.	90 DEG.	OVER/UNDER TOLERANCE
1				
2				
3				
4				
5				
6				
7				
8				
9				

SHAFT RUNOUTS	SPECIFIED	0 DEG.	90 DEG.	OVER/UNDER TOLERANCE
1				
2				
3				
4				
5				
6				
7				
8				
9				



ANGLES RECORDED OPPOSITE/WITH ROTATION FROM INLET END.
"ZERO" DEGREE POINT IS ____________

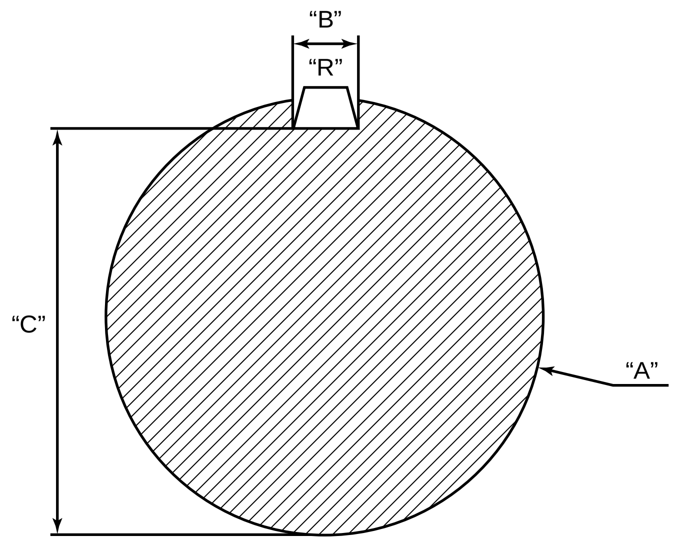
RECORDED BY ____________
DATE ____________
ROTOR SERIAL NO. ____________
EXPANDER SERIAL NO. ____________
DRAWING NO. ____________
PLANT ____________
EXPANDER MODEL ____________
AS SHIPPED ____________
REMARKS ____________
____
____
____
VERIFIED ____________

API RP-687, FIGURE 6.B-1

SHAFT INSPECTION

JOB NO.	MODEL NO.	UNIT NO.	FORM NO.	TYPE
CUSTOMER	LOCATION	ID NO.		
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED

Figure 6.B-1—Shaft Inspection



MINIMUM VALUES

"A" ____________

"B" ____________

"C" ____________

"R" ____________

RECORDED BY ____________
DATE ____________
ROTOR SERIAL NO. ____________
EXPANDER SERIAL NO. ____________
DRAWING NO. ____________
PLANT ____________
EXPANDER MODEL ____________
AS SHIPPED ____________
REMARKS ____________
____
____
____
VERIFIED ____________

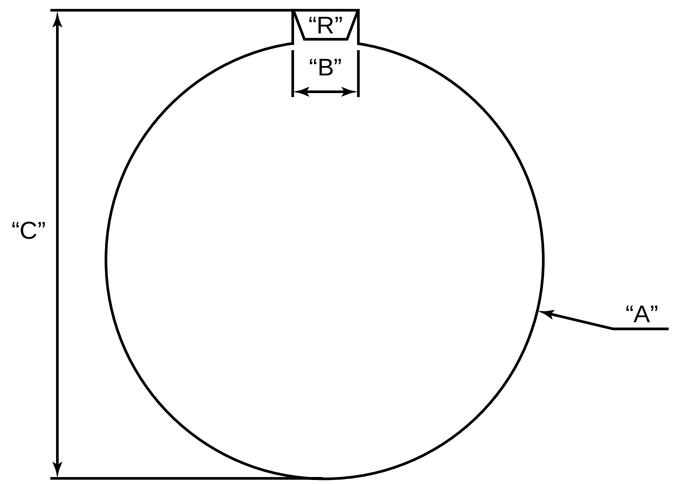
API RP-687, FIGURE 6.B-2

SHAFT KEYWAY INSPECTION

			ID NO.	
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED

JOB NO.			
MODEL NO.			
UNIT NO.			
CUSTOMER	LOCATION	FORM NO.	TYPE

Figure 6.B-2—Shaft Keyway Inspection



MINIMUM VALUES

"A" ____________________

"B" ____________________

"C" ____________________

"R" ____________________

Note: Check for taper in the bore.

RECORDED BY ____________________
DATE ____________________
ROTOR SERIAL NO. ____________________
EXPANDER SERIAL NO. ____________________
DRAWING NO. ____________________
PLANT ____________________
EXPANDER MODEL ____________________
AS SHIPPED ____________________
REMARKS ____________________
VERIFIED ____________________

API RP-687, FIGURE 6.B-3

BORE KEYWAY INSPECTION

AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED	CUSTOMER	LOCATION	FORM NO.	TYPE

ID NO.

JOB NO.

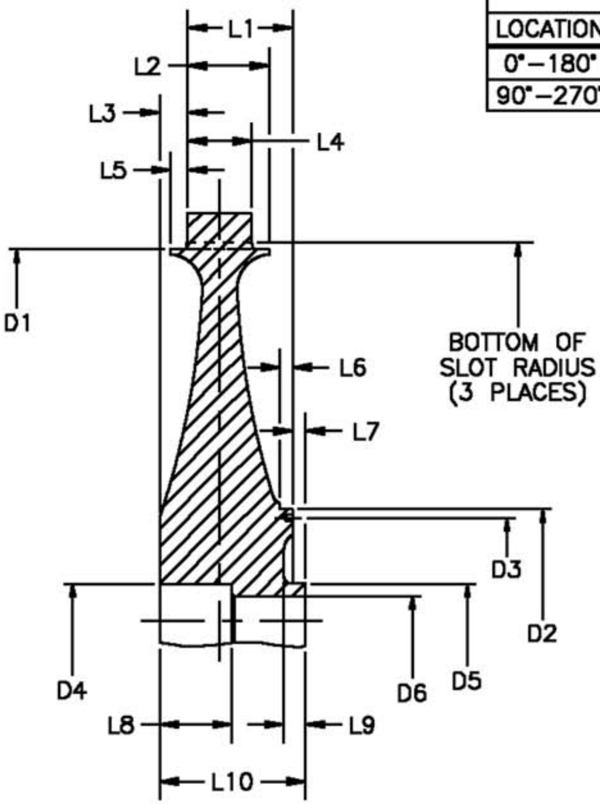
MODEL NO.

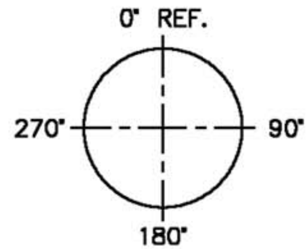
UNIT NO.

Figure 6.B-3—Bore Keyway Inspection

INSPECTED DISC DIAMETERS											
LOCATION		D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
0°–180°											
90°–270°											

INDICATE MEASUREMENT METHOD USED





BOTTOM OF SLOT RADIUS	
S1	
S2	
S3	

INSPECTED DISC LENGTHS										
LENGTH	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10
0°										
90°										

REMARKS

API RP-687, FIGURE 6.B-4

EXPANDER DISC DIMENSIONS INSPECTION

JOB NO. / P.O. NO.

MODEL NO.

UNIT NO.

ID NO.

AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED	CUSTOMER	LOCATION	FORM NO.	TYPE

Figure 6.B-4—Expander Disc Dimensions Inspection

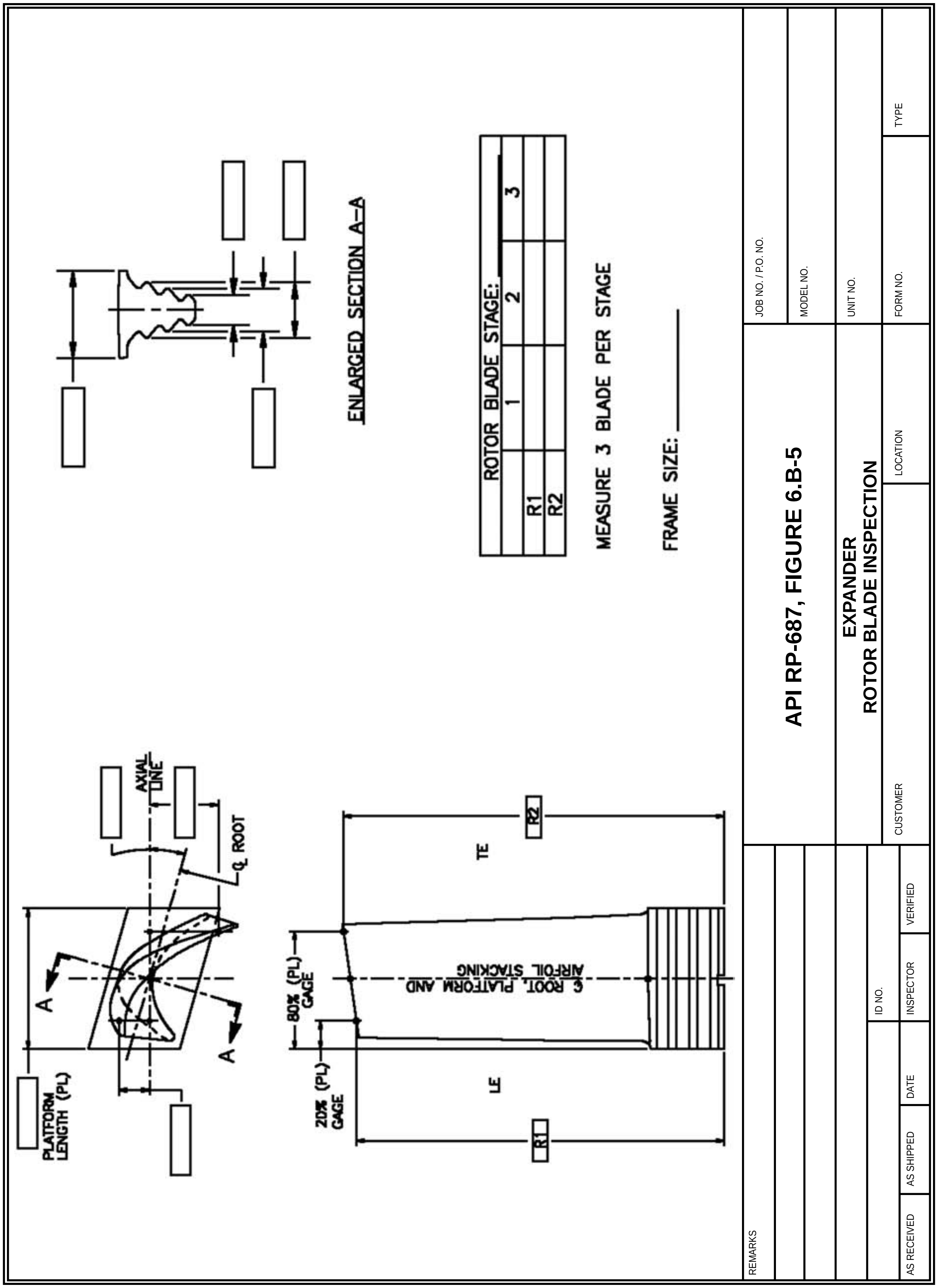


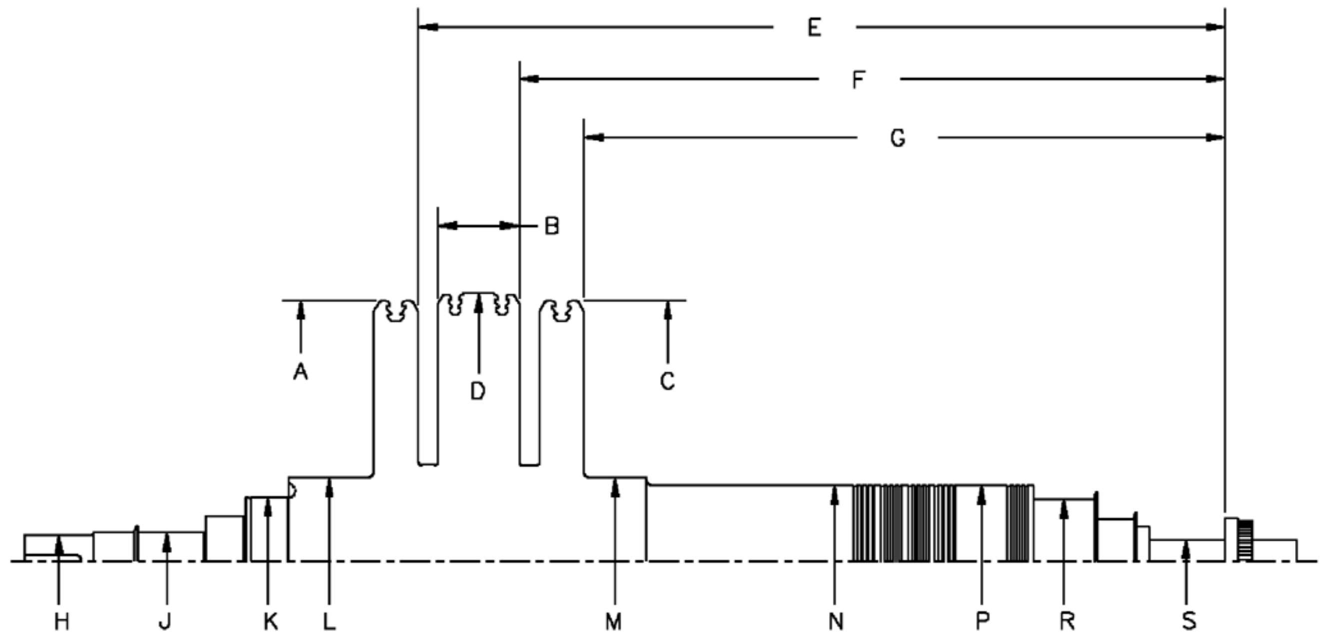
Figure 6.B-5—Expander Rotor Blade Inspection

STAGE										
SHAFT OD (1)										
DISC ID(2) DI										
INTERFERENCE FIT (ACTUAL)										
INTERFERENCE FIT (SPECFIED)										
SEAL SLEEVE (3)										
INTERFERENCE FIT (ACTUAL)										
INTERFERENCE FIT (SPECIFIED)										

(1) DIMENSIONS FROM SHAFT INSPECTION REPORT.
(2) DIMENSIONS FROM DISC INSPECTION REPORT.
(3) DIMENSIONS FROM SEAL SLEEVE REPORT.

REMARKS					API RP-687, FIGURE 6.B-6		JOB NO. / P.O. NO.
							MODEL NO.
					EXPANDER INTERFERENCE FIT SUMMARY		UNIT NO.
			ID NO.				
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED	CUSTOMER	LOCATION	FORM NO. / TYPE

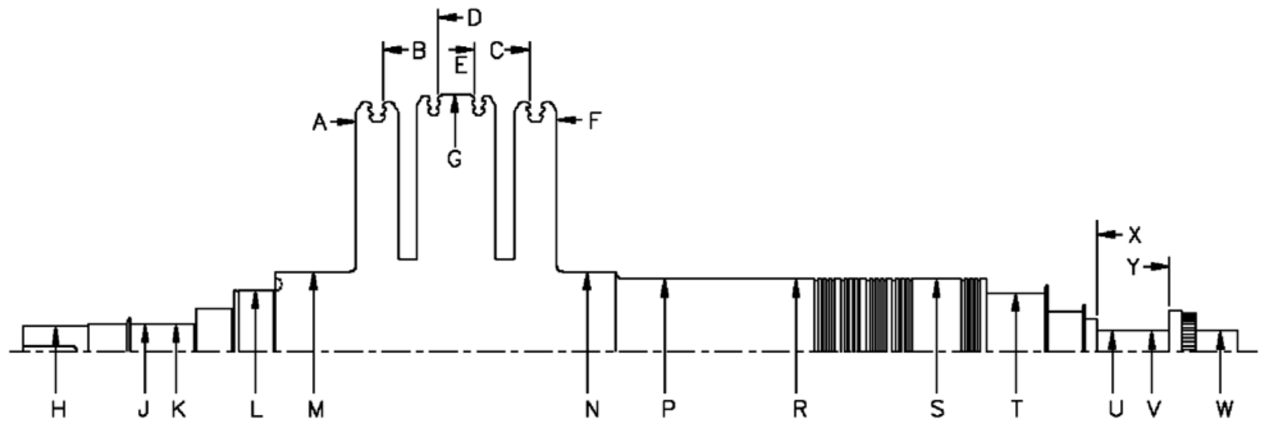
Figure 6.B-6—Expander Interference Fit Summary



	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S
0°–180°																
90°–270°																

REMARKS	**API RP-687, FIGURE 6.B-7A**	JOB NO. / P.O. NO.
		MODEL NO.
	MULTI-STAGE, DOUBLE-FLOW, INTEGRAL EXPANDER ROTOR DIMENSIONS	UNIT NO.
ID NO.	CUSTOMER	LOCATION
AS RECEIVED / AS SHIPPED / DATE / INSPECTOR / VERIFIED		FORM NO. / TYPE

Figure 6.B-7A—Multi-Stage, Double-Flow, Integral Expander Rotor Dimensions



	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y
0°																						
90°																						
180°																						
270°																						

REMARKS

ID NO.

AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED

API RP-687, FIGURE 6.B-7B

MULTI-STAGE, DOUBLE-FLOW, INTEGRAL EXPANDER ROTOR RUNOUT (TIR)

CUSTOMER

LOCATION

JOB NO. / P.O. NO.

MODEL NO.

UNIT NO.

FORM NO.

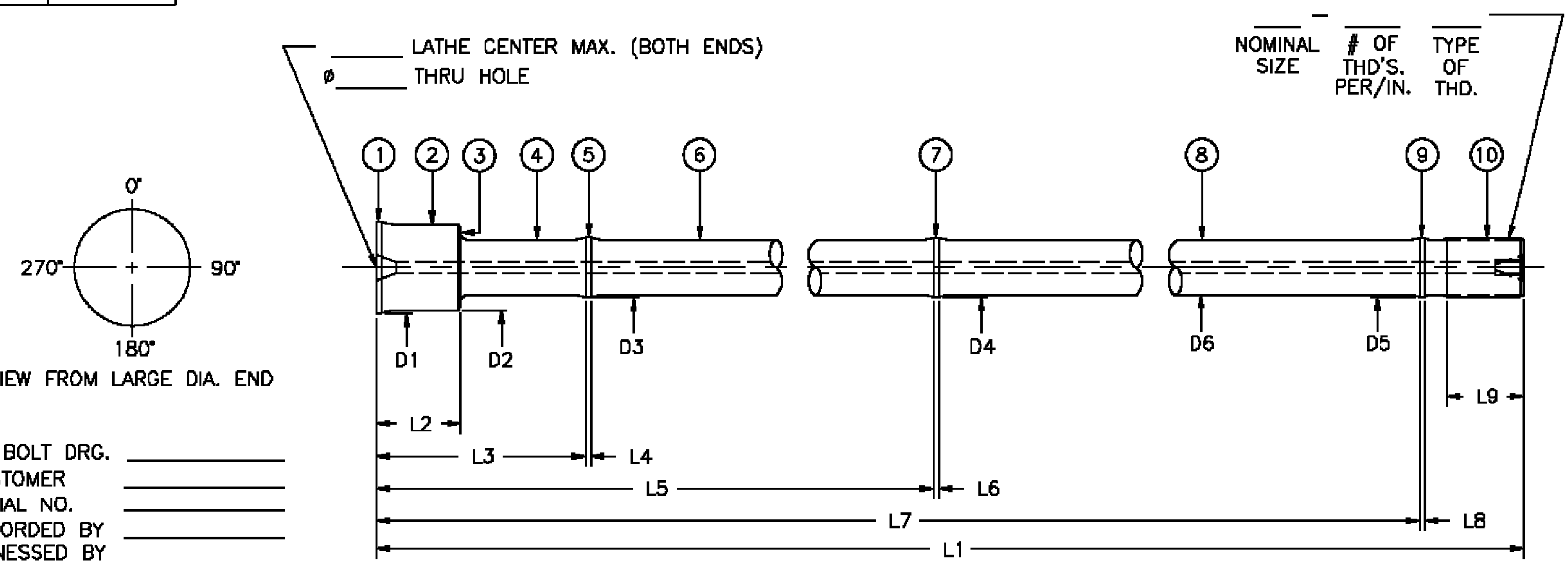
TYPE

Figure 6.B-7B—Multi-Stage, Double-Flow, Integral Expander Rotor Runout (TIR)

L1	
L2	
L3	
L4	
L5	
L6	
L7	
L8	
L9	

LOCATION	1	2	3	4	5	6	7	8	9	10
0°										
90°										
180°										
270°										
MAX.IR										
<MAX.IR										

DIMENSION	0°–180°	90°–270°
D1		
D2		
D3		
D4		
D5		
D6		



TIE BOLT DRG. ______
CUSTOMER ______
SERIAL NO. ______
RECORDED BY ______
WITNESSED BY ______
DATE ______

REMARKS					API RP-687, FIGURE 6.B-8		JOB NO. / P.O. NO.	
							MODEL NO.	
					EXPANDER TIE BOLT INSPECTION		UNIT NO.	
			ID NO.					
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED	CUSTOMER	LOCATION	FORM NO.	TYPE

Figure 6.B-8—Expander Tie Bolt Inspection

APPENDIX C—QUALITY/MANUFACTURING PLAN

QUALITY/MANUFACTURING PLAN

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	DISK MANUFACTURE (NEW)			**3.12**			**(2)**			
	Forgings—Material Certification Review	AISI / ASTM Spec No	M,C,H,(4)	Chap 1, 9.1		Compliance with AISI / ASTM Requirement	Report			
	Rough Machine					Mfg. Drawing				
	Submerged Ultrasonic Inspection			Chap 1, 8.2.3	ASME Sect V, Article 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Machining to contour					Mfg. Drawing				
	Stress Relieve/ Heat Treat—as applicable		H			Mfg. Drawing	Chart			
	Wet Magnetic Particle (fluorescent, continuous method) or Liquid Penetrant Inspect for non-magnetic materials			Chap 1, 8.2.4.1	ASTM E 709 ASTM E 165	Chap 1, 8.2.4.2	Certificate			
	Final Machine, Including Blade Roots					Mfg. Drawing				
	Wet Magnetic Particle (Fluorescent, continuous method) or Liquid Penetrant Inspect for non-magnetic materials			Chap 1, 8.2.4.1	ASTM E 709 ASTM E 165	Chap 1, 8.2.4.4	Certificate			
	Shot Peen Blade Attachment Region confirm intensity with Alem strip									
	Dimensional Inspection including 100% of all blade roots					Mfg. Drawing	Certificate			
	Check all blade roots with "go/no go" gauge					Mfg. Require	Certificate			
	Demagnetize—as applicable			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Positive Material identification (PMI) each blade	AISI/ ASTM Spec No.					Certificate			
	Coat—as applicable		A	Chap 1, App K		Coating Procedure	Report			
	Coating process qualification (coupons)		C,H	Chap 1, App K		Coating Procedure	Report			
	BLADE MANUFACTURE (NEW) – Bar Stock			**3.12**						
	Prepare Manufacturing Drawings from Samples taken from Rotor, if Required (includes standard, oversize, undersize blades, locking blades, shrouding stock (not rolled or machined for tenons,) etc…			3.12.2.1						
	Manufacture “root samples” for verifying fit of blades to disk, when required			3.12.2.1						
	Check Fit Of Root Samples To Disk			3.12.2.1						
	Manufacture Tenon peening samples, as Required, for peening qualification			4.6.2						
	Qualify Tenon Peening Procedure			4.6.2						
	Bar stock	AISI/ ASTM Spec No.	M,C,H,(4)	Chap 1, 9		Compliance with AISI/ASTM Requirement	Report			
	Ultrasonic Inspection			Chap 1, 8.2.3	ASME Sect V, Article 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Manufacture blades in accordance with detail manufacturing drawings. Including oversize/undersize blades, shrouding, locking blades and other necessary components					Mfg Drawing				

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Wet Magnetic Particle (fluorescent, continuous method) or Liquid Penetrant Inspect for non-magnetic materials			Chap 1, 8.2.4	ASTM E 709 ASTM E 165	Chap 1, 8.2.4.4	Certificate			
	Demagnetize as applicable.			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection Of All Blades									
	Check all blade roots with “go/no go” gauge					Mfg. Require	Certificate			
	Shot peen roots, platform and tenon as applicable with Almen Strips			3.12.2.2		Mfg Drawing	Report			
	Positive Material identification (PMI) each blade	AISI/ ASTM Spec No.					Certificate			
	Coat—as applicable		A	Chap 1, App K		Coating Procedure	Report			
	Coating process qualification (coupons)		C,H	Chap 1, App K		Coating Procedure	Report			
	BLADE MANUFACTURE (NEW) – Forgings			**3.12**						
	Prepare Manufacturing Drawings from Samples taken from Rotor, if Required (includes standard, oversize, undersize blades, locking blades, shrouding stock (not rolled or machined for tenons,) etc…			3.12.2.1						
	Manufacture “root samples” for verifying fit of blades to disk, when required			3.12.2.1						
	Check Fit of Root Samples To Disk			3.12.2.1						
	Manufacture Tenon peening samples, as Required, for peening qualification			4.6.2						
	Qualify Tenon Peening Procedure			4.6.2						

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Forgings	AISI/ ASTM Spec No.	M,C,H,(4)	Chap 1, 9		Compliance with AISI/ASTM Requirement	Report			
	Ultrasonic Inspection of each forging			Chap 1, 8.2.3	ASME Sect V, Article 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Manufacture blades in accordance with detail manufacturing drawings. Including oversize/undersize blades, shrouding, locking blades and other necessary components					Mfg Drawing				
	Wet Magnetic Particle (fluorescent, continuous method) or Liquid Penetrant Inspect for non-magnetic materials			Chap 1, 8.2.4.1	ASTM E 709 ASTM E 165	Chap 1, 8.2.4.4	Certificate			
	Demagnetize as applicable.			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection of all blades									
	Check all blade roots with “go/no go” gauge					Mfg. Require	Certificate			
	Shot peen roots, platform and tenon as applicable with Almen Strips			3.12.2.2		Mfg Drawing	Report			
	Positive Material identification (PMI) each blade	AISI/ ASTM Spec No.					Certificate			
	Coat as applicable		A	Chap 1, App K		Coating Procedure	Report			
	Coating process qualification (coupons)		C,H	Chap 1, App K		Coating Procedure	Report			
	BLADE MANUFACTURE (NEW)—Castings			**3.12**						
	Prepare Manufacturing Drawings from Samples taken from Rotor, if Required (includes standard, oversize, undersize blades,) etc…			3.12.2.1						

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Manufacture "root samples" for verifying fit of blades to disk, when required			3.12.2.1						
	Check Fit of Root Samples To Disk			3.12.2.1						
	Castings	AISI/ ASTM Spec No.	M,C,H, (4)	Chap 1, 9.0	Compliance with AISI/ASTM Requirement	Report				
	Radiographic Inspection			Chap 1, 8.2.2						
	Hot Iso-static Pressing (HIP)		H							
	Manufacture blades in accordance with detail manufacturing drawings. Including oversize/undersize blades, and other necessary components					Mfg Drawing				
	Wet Magnetic Particle (fluorescent, continuous method) or Liquid Penetrant Inspect for non-magnetic materials			Chap 1, 8.2.4.1	ASTM E 709 ASTM E 165	Chap 1, 8.2.4.4	Certificate			
	Demagnetize as applicable.			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection of All Blades									
	Check all blade roots with "go/no go" gauge					Mfg. Require	Certificate			
	Shot peen roots, platform and tenon as applicable with Almen Strips			3.12.2.2		Mfg Drawing	Report			
	Positive Material identification (PMI) each blade	AISI/ ASTM Spec No.					Certificate			
	Coat—as applicable		A	Chap 1, App K		Coating Procedure	Report			
	Coating process qualification (coupons)		C,H	Chap 1, App K		Coating Procedure	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	TIE BOLT MANUFACTURE (NEW)			**3.12**						
	Forgings	AISI/ ASTM Spec No.	C,H,M	Chap 1, 9		Compliance with AISI/ASTM Requirement	Report			
	Ultrasonic Inspection			Chap 1,8.2.3	ASME Sect V Article 2 & 2.3	Chap 1,8.2.3.2	Certificate			
	Roll threads					Mfg Requirement	Report			
	Verify thread profile and lead with "go / no go" gauge & check with nut					Mfg Requirement	Report			
	Final Machined Dimensions					Mfg Requirement	Report			
	Wet Magnetic Particle (fluorescent, continuous method) or Liquid Penetrant Inspect for non-magnetic materials			Chap 1, 8.2.4.1	ASTM E 709 ASTM E 165	Chap 1, 8.2.4.4	Certificate			
	Demagnetize as applicable			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	BLADE REPAIR (1)			**3.6**			**(2)**			
	Blending and Reprofiling Restoration			**3.6.2.1**						
	Strip coated blades with applicable Stripping Procedure			3.6.1		Mfg. Requirement	Certificate			
	Blend and Reprofile			3.6.2.1 and Figure 6.3-1		Engineering Review	Certificate			
	Wet Magnetic Particle (fluorescent, continuous method) or Liquid Penetrant Inspect for Non-magnetic Materials			3.6.2.1/Chap 1, 8.2.4.1	ASTM E 709 ASTM E 165	Chap 1, 8.2.4.4	Certificate			
	Final Dimensional Inspection			3.6.2.1		Mfg. Drawing	Report			
	Shot peen roots, platform and tenon as applicable with Almen Strips			3.12.2.2		Mfg Drawing	Report			
	Coat—as applicable		A	Chap 1, App K		Coating Procedure	Report			
	Coating process qualification (coupons)		C,H	Chap 1, App K		Coating Procedure	Report			
	Thermal (heat) cycle for coating integrity		3.7.1							

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Weld Restoration (2)			**3.6.2.2/Chap 1, D.2**						
	Strip coated blades with applicable Stripping Procedure			3.6.1		Mfg. Require-ment	Certificate			
	Solution Heat Treat		H	3.6.2.2 c.			Chart			
	Blend and Reprofile			3.6.2.1		Engineering Review	Certificate			
	Undercut for Weld Preparation			Chap 1, D.2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D.2.2.1			Certificate			
	Hardness Check of base material			Chap 1, D.2.2.3		Report	Certificate			
	Rough Dimensional Inspection			Chap 1, D.2.2.3	Vendor Procedure	Mfg Requirement	Report			
	Wet Magnetic Particle (fluorescent, con-tinuous method) or Liquid Penetrant Inspect for non-magnetic materials			Chap 1, 8.2.4	ASTM E 709 ASTM E 165	Chap 1, 8.2.4.4	Certificate			
	Weld Repair			Chap 1, D.2.3	WPS, PQR, WQR		WPS, PQR, WQR			
	Post Weld Heat Treatment / HIP if required		H	Chap 1, D.2.5/ Chap 1, D.2.6	Vendor Proce-dure		Chart			
	Recontour blade			Chap 1, D.2.7		Mfg Requirement				
	Dimensional Inspection of airfoil			Chap 1, D.2.7		Mfg. Drawing	Report			
	Radiographic or Ultrasonic Inspect			Chap 1, 8.2	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle (fluorescent, con-tinuous method) or Liquid Penetrant Inspect for non-magnetic materials			Chap 1, D.2.7/ Chap 1, 8.2.4.1	ASTM E 709 ASTM E 165	Chap 1, 8.2.4.4	Certificate			
	Final Machine			Chap 1, D.2.8		Chap 1, D 2.8				

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Wet Magnetic Particle (fluorescent, continuous method) or Liquid Penetrant Inspect for non-magnetic materials			Chap 1, D.2.9/ Chap 1, 8.2.4	ASTM E 709 ASTM E 165	Chap 1, 8.2.4.2	Certificate			
	Demagnetize as applicable			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Final Dimensional Inspection			Chap 1, D.2.9/ 3.6.2.2 j.		Mfg. Drawing	Report			
	Check all blade roots with “go/no go” gauge					Mfg. Require	Certificate			
	Shot peen roots, platform and tenon as applicable with Almen Strips			3.12.2.2		Mfg Drawing	Report			
	Coat Blades		A	Chap 1, App K		Coating Procedure	Report			
	Coating process qualification (coupons)		C,H	Chap 1, App K		Coating Procedure	Report			
	Thermal (heat) cycle for coating integrity			3.7.1						
	Patch Ring Repair			**3.1.4**						
	Review Patch Ring Material Properties			3.1.4			Certificate			
	Rough Machine			3.1.4		Mfg Requirement				
	Install Ring And Final Machine			3.1.4		Chap 1, D 2.8				
	Final Dimensional Inspection			3.1.4			Report			
	DISK REPAIR			**3.4**			**(1)**			
	DISK BORE WELD REPAIR			3.4.1.1/Chap 1, D.2						
	Undercut for Weld Preparation			Chap 1, D.2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D.2.2.1			Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Hardness Check			Chap 1, D.2.2.3		Report	Certificate			
	Rough Dimensional Inspection			Chap 1, D.2.2.3	Vendor Procedure	Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluores-cent, continuous method)			Chap 1, D.2.2.4/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Weld Repair			Chap 1, D.2.3	WPS, PQR, WQR		WPS, PQR, WQR			
	Rough Machine			Chap 1, D.2.4.1		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.4.1/ Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle Inspect (fluores-cent, continuous method)			Chap 1, D.2.4.1/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Post Weld Heat Treatment		H	Chap 1, D.2.5/ 2.6	Vendor Proce-dure		Chart			
	Final Rough Machine			Chap 1, D.2.7		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.7/ Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle Inspect (fluores-cent, continuous method)			Chap 1, D.2.7/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			
	Hardness Check			Chap 1, D.2.7		WPS	Report			
	Final Machine			Chap 1, D.2.8		Chap 1, D 2.8				
	Wet Magnetic Particle Inspect (fluores-cent, continuous method)			Chap 1, D.2.9/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection			Chap 1, D.2.9		Mfg Drawing	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	SHAFT WELD OVERSIZING			3.4.1						
	Machine Bore Oversize and True			3.4.1						
	Weld Build Up Shaft, Refer To Chapter 1, Appendix K For Shaft Repair			3.4.1			Report			
	NEW SHAFT OVERSIZING			3.4.1.2						
	Machine Bore Oversize And True			3.4.1.2						
	Machine New Shaft, Refer To Chapter 1, Appendix K For Shaft Repair			3.4.1.2			Report			
	BLADE ATTACHMENT REPAIR			**3.5**			**(1)**			
	BLADE GROOVE REPAIR (MACHINING)			3.5.1						
	Final Machine Oversize			Chap 1, D.4.5		Chap 1, D 4.5				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.4.6/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Final Dimensional Inspection			Chap 1, D.4.6		Mfg Drawing	Report			
	DISK OUTSIDE DIAMETER REPAIR (WELD)			3.5.2/Chap 1, D.2						
	Machine for Weld Preparation			Chap 1, D.2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D.2.2.1			Certificate			
	Hardness Check			Chap 1, D.2.2.3		Report	Certificate			
	Rough Dimensional Inspection			Chap 1, D.2.2.3	Vendor Procedure	Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.2.4/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Weld Repair			Chap 1, D.2.3	WPS, PQR, WQR		WPS, PQR, WQR			
	Rough Machine			Chap 1, D.2.4.1		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.4.1/ Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.4.1/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Post Weld Heat Treatment		H	Chap 1, D 2.5/ Chap 1, D.2.6	Vendor Procedure		Chart			
	Final Rough Machine			Chap 1, D.2.7		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.7/ Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.7/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Hardness Check			Chap 1, D.2.7		WPS	Report			
	Final Machine			Chap 1, D.2.8		Chap 1, D 2.8				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.9/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Dimensional Inspection			Chap 1, D.2.9		Mfg Drawing	Report			
	J STRIP REPAIR			**3.9**			**(1)**			
	Straighten J Strip			3.9		Mfg Drawing	Report			
	Liquid Penetrant Inspect			Chap 1, 8.2.4.3	ASTM E 165	Chap 1, 8.2.4.4	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	J STRIP NEW			**3.9**						
	"J" strip and caulking material		C,M	3.9.1						
	Install "J" strips with caulking material			3.9.1		Mfg. Drawing				
	Machine to size			3.9.1		Mfg. Drawing				
	Final Dimensional Inspection			3.9.1		Mfg. Drawing	Report			
	LABYRINTH SEALS (integral with shaft)			**3.9**						
	Weld Restoration			3.9.2/Chap 1, D.2						
	Undercut for Weld Preparation			Chap 1, D.2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D.2.2.1			Certificate			
	Hardness Check			Chap 1, D.2.2.3			Report			
	Rough Dimensional Inspection			Chap 1, D.2.2.3		Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.2.4/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Weld Repair			Chap 1, D 2.3	WPS, PQR		WPS, PQR			
	Rough Machine			Chap 1, D.2.4.1		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.4.1/ Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Dye Penetrant Inspect			Chap 1, 8.2.4	ASTM E165	Chap 1, 8.2.4.4	Certificate			
	Post Weld Heat Treatment		H	Chap 1, D.2.5/ Chap 1, D.2.6	Vendor Procedure		Chart			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Final Rough Machine			Chap 1, D.2.7		Mfg Requirement				
	Ultrasonic Inspect			Chap 1, D.2.7/ Chap 1, 8.2.3	ASME Sect V, Articles 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.7/ Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Hardness Check			Chap 1, D.2.7		Report	Certificate			
	Final Machine			Chap 1, D.2.8		Chap 1, D 2.8				
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, D.2.9/ Chap 1, 8.2.4.1		Chap 1, 8.2.4.4				
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2				
	Dimensional Inspection			Chap 1, D.2.9		Mfg Drawing	Report			
	Pre-Assembly Requirements			**4.1**						
	Axial Positioning Data			4.1.1b		6.A-1, 3, 5, 7				
	Critical Dimensions and Runouts			4.1.1c		6.A-1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12/ 6.B-2, 3				
	Clean Mating Components			4.1.2						
	Clean Mating Surfaces			4.1.3						
	Key Clearances			4.1.5						
	Phase-Related Bare Shaft Runouts			4.1.6		6.B-1				
	New Locking Hardware			4.1.9						
	Protect Rotor Components			4.1.10						

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	DISK ON SHAFT ROTOR ASSEMBLY/LOW SPEED BALANCE			**4.2**			**(2)**			
	Component Balance All Major Subassemblies			4.2.1/Chap 1, 10.2		Chap 1, 10.3.9	Report			
	Interference Fit Summary			4.1.1c		Mfg Drawing	Report			
	Balance Machine Calibration			Chap 1, 10.5.1		Mfg Requirement	Report			
	Weigh or moment weigh blades			4.1.7						
	Sequentially assemble and low speed balance the rotor			4.2.2/4.2.4/4.2.5/ 4.2.6/4.2.7/4.2.8/ 4.2.15/4.2.16/ 4.2.19		4.2.9/4.2.10/4.2.11/ 4.2.12/4.2.13/ 4.2.14/4.2.17/ 4.2.18/4.2.20	Report			
	Shroud Installation as applicable			4.2.3/4.6						
	Tip grind Blades as applicable			4.7.2						
	Rotor Final Balance			4.8						
	Residual Unbalance—Rotate U-Joint Drive			Chap 1, 10.3.10		Chap 1, 10.3.10	Report			
	Residual Unbalance/Sensitivity Check			Chap 1, 10.4		Chap 1, App. A	Report			
	Residual Unbalance With Coupling			Chap 1, 10.4.3/ Chap 1, 10.4.4		Chap 1, 10.3.5	Report			
	Rotor Assembly—Final Dimensional			4.9		Mfg Drawing	Report			
	Rotor Assembly—Locate and mark high blade tip			4.7.2		Mfg Drawing	Report			
	Rotor Assembly—Final Indication			4.9		Mfg Drawing	Report			
	Rotor Assembly—Gauss Level			4.9		Mfg Drawing	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Weight of Assembled Rotor			4.9		Mfg Drawing	Report			
	Prep for Shipment			Chap 1, 11						
	INTEGRAL ROTOR ASSEMBLY/LOW SPEED BALANCE			**4.3**			**(2)**			
	Interference Fit Summary			4.1.1c		Mfg Drawing	Report			
	Blue Check Coupling Fit			Chap 1, App C.6			Report			
	Balance Machine Calibration			Chap 1, 10.5.1		Mfg Requirement	Report			
	Rotor Indication (stage by stage/ complete)			4.3.1			Report			
	Balance Bare Rotor			4.3.2			Report			
	Weigh or Moment Weigh Blades			4.1.7						
	Sequentially Assemble and Low Speed Balance the Rotor			4.3.3/4.3.4/ Chap 1, 10.3		Chap 1, 10.3.9	Report			
	Positive Material Identification (PMI) Each Shroud, Lacing and Tie Wire	AISI/ ASTM Spec No.								
	Install Shroud and Peen			4.3.4/4.3.5/4.6		Mfg Requirement	Report			
	Tip Grind Blades/Final Machine			4.7						
	Wet Magnetic Particle Inspect (fluores-cent, continuous method)			4.6.1r/Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2		Chap 1, 8.2.4.2	Certificate			
	Rotor Final Balance			4.8						
	Residual Unbalance—Rotate U-Joint Drive			Chap 1, 10.3.10		Chap 1, 10.3.10	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Residual Unbalance/Sensitivity Check			Chap 1, 10.4		Chap 1, App. A	Report			
	Residual Unbalance With Coupling			Chap 1, 10.4.3/ Chap 1, 10.4.4		Chap 1, 10.3.5	Report			
	Rotor Assembly—Final Dimensional			4.9		Mfg Drawing	Report			
	Rotor Assembly—Locate and mark high blade tip			4.7.2		Mfg Drawing	Report			
	Rotor Assembly—Final Indication			4.9		Mfg Drawing	Report			
	Rotor Assembly—Gauss Level			4.9		Mfg Drawing	Report			
	Weight of Assembled Rotor			4.9		Mfg Drawing	Report			
	Prep for Shipment			Chap 1, 11						
	TIE BOLT ROTOR ASSEMBLY/LOW SPEED BALANCE			**4.4**			**(2)**			
	Interference Fit Summary			4.1.1c		Mfg Drawing	Report			
	Stack Rotor Per Stacking Chart			4.4.4/4.4.8		Mfg Drawing	Report			
	Tighten Tie Bolts, Record Stretch And Rod Length			4.4.10		Mfg Drawing	Report			
	Grind Journals, Thrust Faces, Coupling Fits, and Vibration Probe Tracks			4.4.15		Mfg Drawing				
	Dimensionally Inspect Rotor						Report			
	Blue Check Coupling Fit						Report			
	Rotor Indication			4.4.13, 4.4.14		4.4.13, 4.4.14	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Balance Machine Calibration			Chap 1, 10.5.1		Mfg Requirement	Report			
	Balance Bore Rotor			4.4.2/4.4.19			Report			
	Weigh or Moment Weigh Blades			4.1.7						
	Rotor Balance (stage by stage/ complete)			4.4.16/4.4.17/ 4.4.18/4.4.19/ 4.4.20/Chap 1, 10.3		Chap 1, 10.3.9	Report			
	Tip grind Blades (multistage)			4.4.23/4.7.2		Mfg Drawing				
	Rotor Final Balance			4.8		Chap 1, 10.3.9	Report			
	Residual Unbalance—Rotate U-Joint Drive			Chap 1, 10.3.10		Chap 1, 10.3.10	Report			
	Residual Unbalance/Sensitivity Check			Chap 1, 10.4		Chap 1, App. A	Report			
	Residual Unbalance With Coupling			Chap 1, 10.4.3/ Chap 1, 10.4.4		Chap 1, 10.3.5	Report			
	Rotor Assembly—Final Dimensional			4.9		Mfg Drawing	Report			
	Rotor Assembly—Locate and mark high blade tip			4.7.2		Mfg Drawing	Report			
	Rotor Assembly—Final Inspection			4.9		Mfg Drawing	Report			
	Rotor Assembly—Gauss Level			4.9		Mfg Drawing	Report			
	Weight of Assembled Rotor			4.9		Mfg Drawing	Report			
	Prep For Shipment			Chap 1, 11						

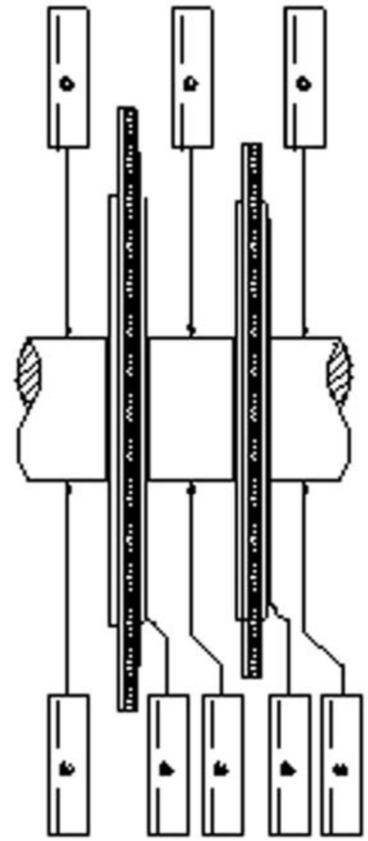
Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date

DESCRIPTION/OPERATION		
NOTES:		
1) Actual steps in blade repair depend on blade construction. 2) All verifying document reports shall reference procedure and state drawing acceptance criteria.	3) All WPS and WPQR shall be available to purchaser for review and approval prior to any welding. 4) Mechanical properties at room temperature and at elevated temperature.	
LEGEND GENERAL	**MATERIAL CERT**	**INSPECTION POINT**
H.T. Heat Treatment PT Liquid Penetrant Inspection MT Magnetic Particle Inspection VT Visual Inspection UT Ultrasonic Inspection W/A Will Advise N/A Not Applicable	A Certificate of Compliance C Chemical Analysis M Mechanical Properties H Heat Treat Charts I Impact	O Observation W Witness / Hold Pt * Vendor To Confirm That Requirement Has Been Met
Report: defines a vendor generated quality control inspection form/report that will satisfy industry standards or requirements outlined on purchase order.		

APPENDIX D—INSPECTION FORMS FOR ASSEMBLY AND BALANCING

SEQUENCE #: _________

NOTE: THIS FORM TO BE COMPLETED AFTER EACH STACKING SEQUENCE AND FOR EACH COMPONENT STACKED. SEQUENCE NUMBER TO BE ENTERED IN SEQUENCE NUMBER SPACE.



WAS HEAT SOAK REQUIRED? ________

IF YES, HOW MANY TIMES? _______

WAS DISASSEMBLY/REASSEMBLY REQUIRED? _______

REMARKS					API RP-687, FIGURE 6.D-1		JOB NO.	
							MODEL NO.	
					SEQUENTIAL STACKING RUNOUT REPORT		UNIT NO.	
			ID NO.		CUSTOMER	LOCATION	FORM NO.	TYPE
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED				

Figure 6.D-1—Sequential Stacking Runout Report

NOTE: THIS FORM TO BE COMPLETED AFTER EACH STACKING SEQUENCE AND FOR EACH COMPONENT STACKED. SEQUENCE NUMBER TO BE ENTERED IN SEQUENCE NUMBER SPACE.

SEQUENCE NUMBER(S): ____________

INITIAL BALANCE MACHINE READINGS: ☐ GRAMS ☐ OUNCES

LEFT PLANE ____________ AT ____________ DEGREES ON ____________ END.

RIGHT PLANE ____________ AT ____________ DEGREES ON ____________ END.

ROTOR AND SETUP DATA:

BEARING SPAN (MM/INCHES): ____________

BALANCE PLANE SEPARATION (MM/INCHES): ____________

LEFT PLANE RADIUS (MM/INCHES): ____________

RIGHT PLANE RADIUS (MM/INCHES): ____________

“ZERO” REFERENCE POINT IS: ____________

LEFT JOURNAL WEIGHT (Kg/Lbs): ____________

RIGHT JOURNAL WEIGHT (Kg/Lbs): ____________

MAX. CONTINUOUS OPERATING SPEED: ____________

BALANCE SPEED: ____________

FINAL BALANCE MACHINE READINGS: ☐ GRAMS ☐ OUNCES

LEFT PLANE ____________ AT ____________ DEGREES ON ____________ END.

RIGHT PLANE ____________ AT ____________ DEGREES ON ____________ END.

REMARKS				**API RP-687, FIGURE 6.D-2**		JOB NO.	
						MODEL NO.	
				SEQUENTIAL STACKING BALANCE REPORT		UNIT NO.	
AS RECEIVED	DATE	ID NO.					
AS SHIPPED	DATE	INSPECTOR	VERIFIED	CUSTOMER	LOCATION	FORM NO. 6.D-2	TYPE

Figure 6.D-2—Sequential Stacking Balance Report

APPENDIX E—AUDITORS CHECK LIST

E.1 General

This Appendix, along with Appendix H, Chapter 1, is a checklist to provide information for the owner and the vendor to aid in summarizing the scope of the rotor repair.

Repairs require clear owner/vendor communication and the assignment of responsibilities. The format of this checklist provides a summary of the items required and the parties responsible.

Each item on this checklist has a circle or a square to indicate whether the owner or vendor, respectively, is responsible for obtaining the information or performing the task. The owner must indicate, for each item, whether the item is to be witnessed, observed, or verified. Typically, inspections, processes or tests may be witnessed or observed while verification is the review of the results of the inspections, processes, tests, or other documentation so as to insure that the requirements have been met.

AUDITORS CHECK LIST

Customer: ______________________________

Job/Project Number: ______________________________

Owner Equipment Identification Number: ______________________________

OEM Equipment Serial Number: ______________________________

Rotor Identification Number: ______________________________

Repair Purchase Order Number: ______________________________

Vendor Job Number: ______________________________

Auditors Check List

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice			Date Inspected or Verified By	Status
			W	O	V		
SECTION 1—Inspection of Assembled Rotor Phase I							
Deblade Rotor	☐	1.3.1					
Clean Rotor	☐	1.3.3					
Inspection Forms/Drawings	☐	1.3.4					
Blade Dimensions	☐	1.3.5					
Curvic Coupling Rotors	☐	1.3.6					
Axial Stack-up	☐	1.3.7					
Rotor Runouts	☐	1.3.8					
Reusable Blades	☐	1.3.9					
Inspect Rotor Components	☐	1.3.10					
NDE	☐	1.3.11/ 1.3.12					
Degradation Inspection	☐	1.3.13					
Tie Bolts Stretch	☐	1.3.14					
Inspection Report	☐	1.4					
SECTION 2—Rotor Disassembly Phase II							
Rotor Disassembly	O/☐	2.2.1					
Deblade Rotor	O	2.2.2					
Matchmark Components	☐	2.2.4					
Interference Fits	☐	2.2.5/ 2.2.6					
Mating Fits	☐	2.2.7					
Rotor Unstacking	☐	2.2.8					
Tie-Bolt Rotor							
Stack and Tie Bolt Dimensions	☐	2.2.9.1					
Tie Bolt Detensioning	☐	2.2.9.2					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
Rotors with Shrunk on Components							
Heat Components	☐	2.2.10.1					
Blade Removal Plan	☐	2.2.11.1					
Unshrouded Blades	☐	2.2.11.2					
Shrouded Blades	☐	2.2.11.3					
Reusable Blades	☐	2.2.12					
Clean Rotor	☐	2.3.1					
Interference Fits	☐	2.3.2.1					
Mating Fits	☐	2.3.2.2					
Visual Inspection	☐	2.3.2.3					
Shaft Dimensions	☐	2.3.2.4a					
Disk Bore Dimensions	☐	2.3.2.4b					
Stacking Heights	☐	2.3.2.4c					
Radial and Axial Runouts	☐	2.3.2.4d					
Spacers, Seals	☐	2.3.2.4e					
Balance Piston	☐	2.3.2.4f					
Thrust Collar	☐	2.3.2.4g					
Key Clearances	☐	2.3.2.4h					
Thread Dimensions	☐	2.3.2.4i					
Tie Bolt Runout	☐	2.3.2.4j					
Blade Attachments	☐	2.3.2.4k					
Tooth Fit Up, Stacking Heights, Rotor Disk, Spacers, Shafts, or Curvic Couplings	☐	2.3.2.4l					
Distortion Check	☐	2.3.2.4m					
Tie Bolt Rotors	☐	2.3.2.4n					
Stub Shaft	☐	2.3.2.4o					
NDE	☐	2.3.2.5/ 2.3.2.6					
Photographs	☐	2.3.2.7					
Threaded Areas	☐	2.3.2.8					
Nuts	☐	2.3.2.9					
Cooling Passages	☐	2.3.2.10					
Review	☐	2.4.1					
Component Bore	☐	2.4.2					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
Curvic Coupling	☐	2.4.3					
Tie-Bolt	☐	2.4.4					
Evaluate Blades	☐	2.4.5					
Job Scope	☐	2.5.1					
Reusable Blades	☐	2.5.2					
SECTION 3—Repair Processes and New Component Manufacture							
Engineering Review	☐	3.1.2					
Seal Areas	☐	3.1.3					
Pilot Fits	☐	3.1.4					
Disk Faces	☐	3.1.5					
Integral Rotor							
Disk Weld Repair	☐	3.2					
Built Up Rotor							
Shaft Repair	☐	3.3					
Engineering Evaluation	☐	3.4.1					
Disk Bore Weld Repair	☐	3.4.1.1					
Disk Bore Oversize Repair	☐	3.4.1.2					
Blade Attachment Areas Oversize Repair	☐	3.5.1					
Disk Weld Repair	☐	3.5.2					
Blade Blending & Reprofiling Repair	☐	3.6.2.1					
Blade Weld Repair	☐	3.6.2.2					
Blade Protective Coatings	O	3.7.1					
Disk Protective Coatings	O	3.7.2					
Re-coating Protective Coatings	O	3.7.3					
Tie-Bolt Body	☐	3.8.1					
Tie-Bolt Thread Repair	☐	3.8.2					
Tie-Bolt Straightened/ Replaced	☐	3.8.3					
Fasteners Coating	☐	3.8.4					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
J Strips	☐	3.9.1					
Seal Teeth	☐	3.9.2					
Sleeves, Spacers	☐	3.10					
Curvic Coupling Repair Shops	☐	3.11.1					
Curvic Coupling Teeth	☐	3.11.2					
Reground Curvic Coupling	☐	3.11.3					
Component Replacement							
Component Replacement Requirements	☐	3.12.1					
New Blade Manufacture	☐	3.12.2					
SECTION 4—Assembly and Balance							
Dimensional Verification	☐	4.1.1					
Mating Components	☐	4.1.2					
Mating Surfaces	☐	4.1.3					
Keyway Verification	☐	4.1.5					
Phase Related Runouts	☐	4.1.6					
Blade Positioning	☐	4.1.7					
Circumferential Distribution	☐	4.1.8					
Locking Hardware	☐	4.1.9					
Protect Components	☐	4.1.10					
Overspeed Trip Mechanism	☐	4.1.11					
Balance Corrections	☐	4.1.12					
Disk on Shaft Rotor							
Component Balance	☐	4.2.1					
Assembly Balance	☐	4.2.2					
Shroud Installation	☐	4.2.3					
Assembly Sequence	☐	4.2.4					
Heat Components	☐	4.2.5					
Coating Restrictions	☐	4.2.6					
Shaft Positioning	☐	4.2.7					
Rotor Cooldown	☐	4.2.9					
Position Verification	☐	4.2.10					
Axial Gap	☐	4.2.11					
Phase Related Runouts	☐	4.2.12					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice			Date Inspected or Verified By	Status
			W	O	V		
Disk Rim Runouts	☐	4.2.13					
Shaft Runout Changes	☐	4.2.14					
Balance	☐	4.2.15/ 4.2.16					
Axial Dimensions	☐	4.2.17					
Blade Dimensions	☐	4.2.18					
Balance Corrections	☐	4.2.19					
Overall Stack	☐	4.2.20					
Integral Rotor							
Rotor Measurements	☐	4.3.1					
Balance Rotor	☐	4.3.2					
Free Standing Blades	☐	4.3.3					
Shrouded Blades	☐	4.3.4					
Tie Bolt Rotor							
Curvic Face Inspection	☐	4.4.3					
Rotor Stacking Chart	☐	4.4.4					
Tie Bolt Alignment	☐	4.4.5					
Rotor Stacking Tools	☐	4.4.6					
Radial Pins/Keys	☐	4.4.7					
Assembly Sequence	☐	4.4.8					
Heat Components	☐	4.4.9					
Tie Bolt Tensioning	☐	4.4.10					
Shaft Positioning	☐	4.4.11					
Phase Related Runouts	☐	4.4.13					
Rotor Dimensions	☐	4.4.14					
Machining/Grinding/ “Truing Up”	☐	4.4.15					
Balance	☐	4.4.16					
Overhung Designs	☐	4.4.17					
Loose Blade Design	☐	4.4.18					
Blade Assembly	☐	4.4.19					
Bladed Rotor Disks	☐	4.4.20					
Blade Dimensions	☐	4.4.21					
Loose Blade Design	☐	4.4.22					
Blade Tip Machining	☐	4.4.23					
Reassembly of Partially Disassembled Rotors							
Balance	☐	4.5.2					
Install Shroud	☐	4.6.1					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice			Date Inspected or Verified By	Status
			W	O	V		
Peen Blade Tenons	☐	4.6.1					
Peening Qualification Procedure	☐	4.6.2					
Machine Shrouds	☐	4.7.1					
Grind Rotor Tip	☐	4.7.2					
Assembly Balance	☐	4.8.1					
Material Removal	☐	4.8.2					
Overhung Design	☐	4.8.3					
Final Inspection	☐	4.9					
Documentation	☐	4.10					

APPENDIX F—INSPECTION OF CURVIC COUPLINGS

Curvic Couplings are precision face splines used for joining two or more members together to form a single operating unit. The teeth provide accurate centering of components, maintain alignment despite differential growth between members, and provide high torque transmission capability. To achieve this, it is critical to insure precision quality and uniformity of mating components utilizing the Curvic Couplings. This procedure highlights some of the essential inspections that should be performed to assure proper operation of the Curvic couplings. These inspections are applicable to both new and used Curvic couplings.

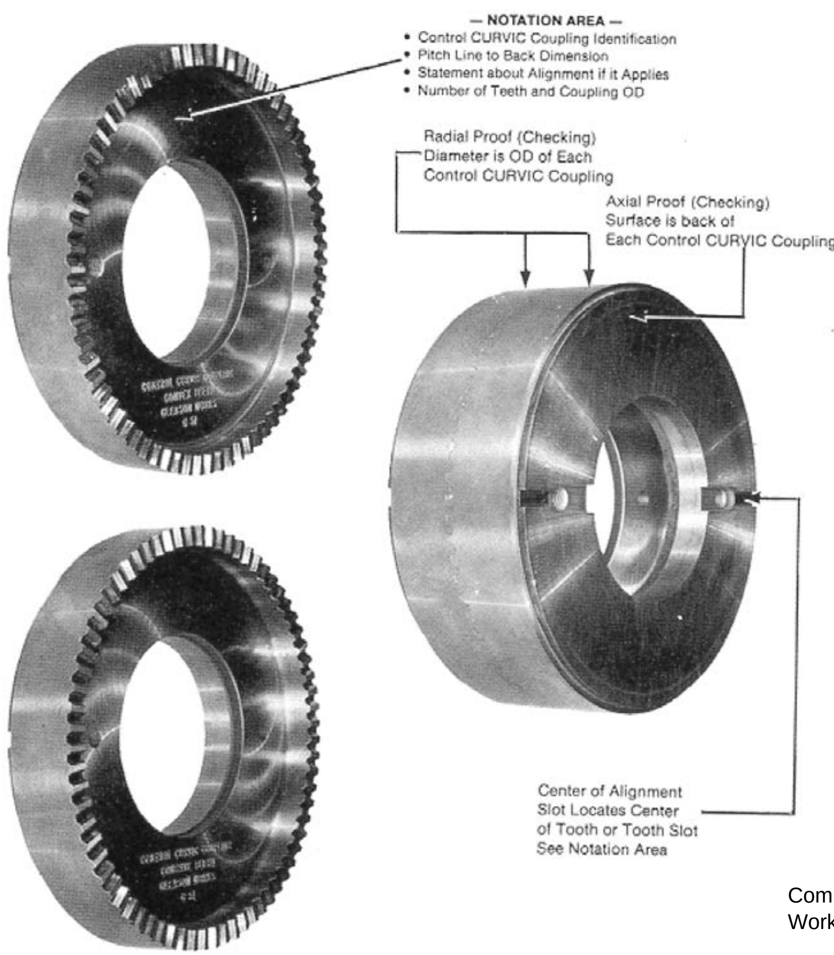
Control couplings, or master gauges, must be utilized to assure a proper inspection of the Curvic tooth profiles and contact. The master gauges serve as a standard against which all the couplings can be checked to assure uniform quality, contact and interchangeability. The inspection of two job components to each other does not assure proper coupling operation. The following Figure 6.F-1 shows typical master gauges and the important design features.

Curvic coupling inspection should include contact/bearing pattern, tooth spacing, stacking height/tooth size, radial runout, axial runout, and alignment of teeth in relation to a gauge plane.

Inspections

Alignment of teeth in relation to a gauge plane—For designs that have an indexing requirement (example: rotor discs that have multiple tie bolts), the Control Master Curvic gauging will have a reference slot or hole milled into the end face for positioning to the actual part. The reference feature on both master gauge and component must be aligned prior to the following inspections.

Tooth contact/bearing pattern and tooth spacing—To check the tooth contact/bearing pattern and spacing, the teeth of the Control Curvic coupling are first painted with a thin coating of red gear marking compound. The mating teeth are given a thin coating of Prussian blue. The two parts are mated together and lightly tapped or vibrated to assure part contact.



Compliments of Gleason Works—Rochester, N.Y.

Figure 6.F-1—Curvic Coupling Master Gauges

The *tooth contact/bearing pattern* is inspected by observation. The pattern of the contract shows whether or not the teeth are mating properly. The contact area on an individual tooth should be rectangular in shape and should extend along the length of the tooth as can be seen in Figure 6.F-2.

The bearing contact should be centrally located along the tooth length/radially. The minimum length of contact should be 75% of the overall tooth length.

The width (dimension H) of the contact is dependent upon the individual tooth design. Most Curvic Coupling designs utilize a rectangular contact pattern as shown in Figure 6.F-2. Occasionally, a line contact pattern is used. A contact check of the Master Gauges will define the desired contact pattern.

Contact at the outer extremes of the Curvic teeth on the end of the Curvic teeth, or in any fillet radius area, is unacceptable.

The checking of contact patterns from in-service components to each other is not acceptable since the wear of the faces can show mis-leading and improper contact. For example, worn teeth could indicate 100% contact but function improperly.

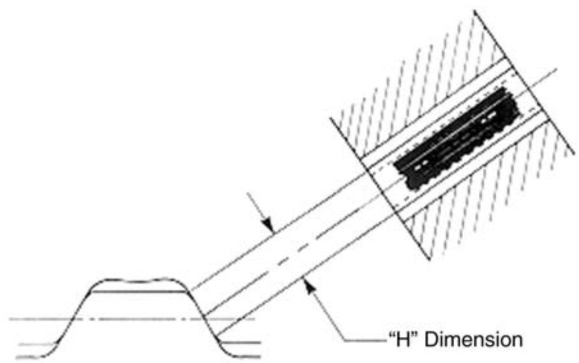
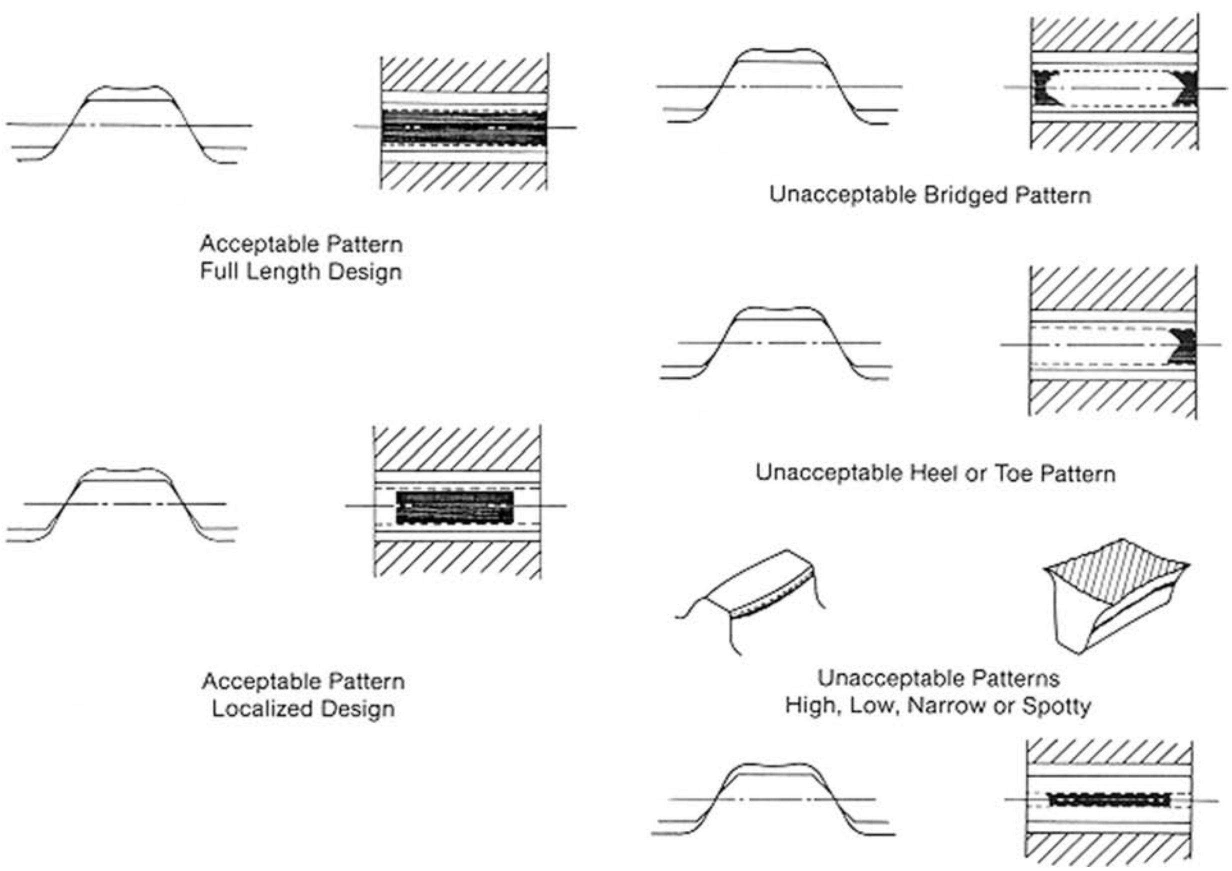


Figure 6.F-2—Contact Area of Tooth

Figure 6.F-3 shows examples of acceptable and unacceptable tooth contact. Poor tooth contact is an indication of a problem that may include:

- Improper or mismatching of the grinding wheels used to manufacturer the tooth profile.
- Improper pressure angles.
- Excessive chamfer.



Compliments of Gleason Works—Rochester, N.Y.

Figure 6.F-3—Examples of Curvic Coupling Contact Patterns

- Tooth wear.
- Tooth galling or fretting.

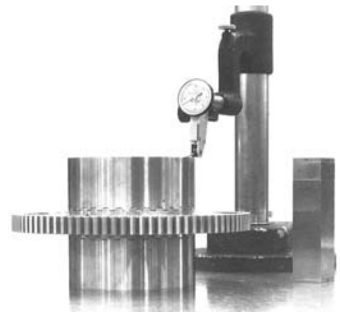
Tooth spacing is checked during the same visual observation. A lack of contact on a tooth indicates a tooth spacing problem. A bearing pattern should be visible on a minimum of 90% of the total number of teeth and there should be no two unmarked adjacent teeth.

Stacking Height/Tooth Size—The stacking height and tooth size are checked via the Control Curvic gauging. The tooth size (thickness and height) will determine the stacking height of the components. The stack height is the axial length of the production part plus the height of the Control Curvic. For parts with a Curvic coupling on both sides, two Control Curvic gauges are required.

The stacking height must be uniform around the entire circumference of the parts within ±0.0005 inches of the average height. The actual stack height dimension shall be recorded for use in the rotor stacking calculations.

Radial Runout—The actual part radial run out is also checked with the Control Curvic gauging. The Control Curvic gauge(s) is mounted to the part to be inspected. The Control Curvic gauges have an indicating (proof) diameter on each gauge that is used as the reference to check the radial run out of the part to the gauge.

The radial run out of the actual part should generally be controlled to less than 0.002 in. TIR.



Compliments of Gleason Works—Rochester, N.Y.

Figure 6.F-4—Stack Height Measurement of a Double-Sided Curvic Coupling Disk

Axial Runout—The actual part axial run out is also checked with the Control Curvic gauging in a similar manner as the radial run out. The Control Curvic gauge(s) is mounted to the actual part. The indicating (proof) faces on the master gauge are then used as the reference to check the axial run out of a plane through the Curvic pitch circle.

The axial run out of the Curvic pitch circle plane should generally be controlled to less than 0.001 in. TIR.

Quality Assurance Requirements—All inspection dimensions shall be recorded. Contact patterns shall be photo documented.

CHAPTER 7—POSITIVE DISPLACEMENT ROTARY SCREW TYPE COMPRESSORS

CONTENTS CHAPTER 7

Rotor Repair

Chapter 7—Positive Displacement Rotary Screw Type Compressors

1 Inspection of Assembled Rotor Phase I

1.1 GENERAL

Since there are few removable components on a screw type compressor, a Phase I inspection does not apply. Inspection is done as a Phase II inspection.

Tutorial: There are two major classifications of rotary screw type compressors, "Dry" and "Oil-Flooded".

The rotors of dry compressors typically have hydrodynamic radial and thrust bearings along with timing gears to drive the driven rotor. A process seal is utilized on each shaft end for each rotor. Typically, the oil-flooded compressors have hydrodynamic or antifriction bearings and balance pistons. There are no timing gears. Hydrodynamic radial and antifriction thrust ball bearings are common although other combinations are used. Oil between the lobes acts as a sealant to prevent recirculation losses, provides cooling and provides an oil film as the driver rotor drives the driven rotor.

1.2 DEFINITIONS

1.2.1 lobes: The compressing segments of the shaft, normally consisting of 4 convex and 6 concave regions.

1.2.2 interlobes: Areas between the lobe concave and convex surfaces.

1.2.3 peripheral lobe seals: Thin ribbon strips on the top surface of the lobes.

1.2.4 axial seals: The close clearance circumferential and radial seals at the lobe ends.

1.2.5 timing gears: A high precision gear set capable of transmitting torque and maintaining interlobe clearances.

2 Rotor Disassembly and Inspection Phase II

2.1 GENERAL

This section describes the data to be recorded and the requirements of Phase II inspection of a screw rotor disassembly. This section is to be used in addition to the requirements of Chapter 1, Section 7.

Notes:

1. The major removable components possibly removed at the compressor disassembly are timing gears, thrust collar, distance ring, shaft end seals and balance piston (if applicable).

2. The rotors are machined and checked as a set and should not be intermixed between other sets of rotors.

2.2 PHASE II INSPECTION

2.2.1 Care must be exercised in the disassembly to prevent the damaging of components. Often rotor disks, stub shafts and shafts have interference fits between the components that require heat to allow disassembly. A thorough understanding of the rotor construction and the interference fits is required to safely disassemble the rotor without causing component damage.

All interference fits shall be dimensionally inspected to determine the amount of interference remaining and if component rework is required to restore the design interference.

All interference fits shall be visually inspected for signs of yielding, distress, fretting, galling, etc.

2.2.2 Prior to disassembly, the timing gears shall be permanently match marked, on noncritical surfaces, to each other and to the shaft for future reference.

Note: If the timing gears have been removed during this disassembly, the proper orientation shall be verified during assembly.

2.2.3 With the timing gear assembled onto its respective shaft, measure and record the gear pitch diameter, face runout, pitch diameter runout for each timing gear, backlash, and gear contact bluing check. The degree of accuracy must be within ±12.7 μm (0.0005 in.).

2.2.4 Lobe tip and axial, circumferential, and radial end seal strips shall be visually inspected for deterioration and damage, record findings. All rotor seals are critical to compressor efficiency and should be carefully inspected for damage due to rubbing or foreign material.

Note: An allowable wear limit on the oil flooded lobe tip seals is about 0.3% of rotor diameter before repair is required. Dry compressor rotors should be returned to original configuration and dimensions to minimize recirculation losses.

2.2.5 Inter-lobe surface conditions shall be visually inspected for deterioration and damage, record findings. The surface condition report shall include the approximate percentage amount, size and location of inter-lobe wear, corrosion, erosion, pitting, and plating condition when present.

2.2.6 Rotor inter-lobe surface can be cleaned with a bead blasting process, all other surfaces shall be protected with heavy tape. Axial balance correction holes on rotor lobes are to be mechanically cleaned. Cleaning of the remaining rotor exterior surfaces shall be conducted per Chapter 1, Section 7.2.2.

2.2.7 If applicable, rotor center cooling passages are to be chemically or mechanically cleaned of any foreign material or build-up.

2.2.8 Visually inspect and record the condition of each part removed. Measure and record all shaft and component sizes on a worksheet designed for the particular component per Appendix “A” and “B” or equal. This data will be used to determine the roundness and taper of each component. This shall include:

a. Bare shaft fit sizes, overall length, and runouts (including thrust collar shoulder).

b. Bore sizes and lengths of shaft spacers, seal sleeves, etc.

c. Balance piston bore size and length.

d. Thrust collar and thrust collar spacer(s) bore sizes and lengths.

e. Key clearances on all keyways.

1. With keys installed in keyways, measure from tops of keys to opposite side of shaft.

2. Measure across bore of components to bottoms of keyways.

Note: Item “2” above plus total component interference fit minus item “1” above, equals key clearance.

2.2.9 Remove and deburr area(s) of any previously installed balancing weight(s). The location and amount of each weight is to be recorded.

2.2.10 The timing gears shall only be mechanically or solvent cleaned, DO NOT BLAST CLEAN GEAR TOOTH SURFACES.

Note: The timing gears are furnished as a machined set with very close tolerances; therefore, timing gears should not be intermixed between sets. Replacement gears are to be a matched set.

2.2.11 Unless otherwise specified, use applicable NDE procedures as outlined in Chapter 1, Section 8 on all disassembled components to determine the existence of any indications. Record the size, location, and orientation of any indications. All ferro-magnetic components shall be wet magnetic particle inspected.

2.2.12 The NDE acceptance criteria shall be per severity level B, Chapter 1, Table 1.8-1 for the lobes and severity level A for other areas.

2.2.13 Photographs are to be taken per Chapter 1, Appendix G, of any component with any unusual or abnormal condition. A photo log should be maintained for all work performed.

2.2.14 If applicable, measure and record balance piston diameter and axial location. Record visual condition.

2.2.15 Timing Gears

Remove gear lock nut, gear, female gear hub (if applicable), and keys. Locking pins may need to be removed by drilling.

CAUTION: Approximately 120 to 150°C (250 to 300°F) may be required to remove the gear or female hub. Apply uniform heat to the gear. Do Not overheat in localized spots as this may change the material heat treatment or distort teeth profile.

2.2.16 Thrust Collar and Distance Ring

Remove the thrust collar, key and distance ring. Approximately 125 to 150°C (250 to 300°F) heat may be required to remove thrust collar. Record distance ring thickness and thrust collar dimensions.

2.2.17 Shaft and Lobes

Record lobe tip seal strip diameters at the suction, two middle sections and discharge ends. This measurement is to be taken on all lobes of the rotor to establish seal wear patterns.

2.2.18 Seal Strips

Record axial seal strip dimensions for all lobe locations.

2.2.19 Rotor Profiles

Record assembled rotor male to female lobe profiles in a checking fixture to establish proper valley and lobe clearances.

2.2.20 Shaft Threads

Threaded areas of the shaft are to be visually inspected and dimensionally verified by a gauge or mating nut. Inspect for set screw marks.

Note: When a gauge is not available for checking the threads, the mating nut may be used with judgement.

2.3 INSPECTION REPORTS

2.3.1 The vendor shall prepare an initial inspection documentation package (report) consisting of all of the information identified in Chapter 1, Section 7 and paragraph 2.2, as applicable.

2.4 EVALUATION OF PHASE II INSPECTION DATA

2.4.1 Review and evaluate all data and information to determine the acceptability of the resulting fits, clearances and runouts.

2.4.2 For hydraulic fit, tapered bore disk designs or couplings, a blue contact check shall be performed per Chapter 1, Appendix C with a minimal contact area of 80%. The disk or coupling may be used for this verification as long as there are not any raised discontinuities in the shaft surface.

2.5 PHASE II RECOMMENDED JOB SCOPE

2.5.1 The vendor shall notify the owner upon completion of Phase II Inspection, provide a copy of all Phase II documentation, summarize the results of Phase II Inspection, and prepare the recommended job scope for approval by the owner.

3 Rotor Repair and New Component Manufacture

3.1 GENERAL

In addition to the general repair processes and new component manufacturing requirements discussed in Chapter 1, Section 9, the following procedures and practices are recommended to accommodate the conditions and considerations unique to Rotary Screw Compressors. Components shall be repaired as outlined in 3.2, 3.3, and/or 3.4, or new components supplied as outlined in 3.5.

3.2 LOBE PROFILE RESTORATION

3.2.1 Lobe profile restoration may be accomplished by mechanical blending, chemical plating as defined in Chapter 1, Appendix D.5 and welding. Lobe profiles may be repaired using the methods described in 3.2.2 to 3.2.5.

Notes:

1. Plating is used on many original dry screw male and female lobes due to their complex geometries for erosion protection from liquids and particles.

2. Plating is not used on oil flooded rotors since the power is transmitted directly between the rotors.

3. For new rotors having plating, the plating is normally chrome, with a thickness of approximately 7.5 µm (0.003 in.), and is plated to the final dimensions without remachining the lobe profiles.

3.2.2 When the original profile is damaged and has been plated, the plating shall be removed prior to repairs.

3.2.3 Mechanical Blending

Minor scratches can be removed with a fine abrasive cloth (240 grit). Localized damaged areas can be blended by light grinding for areas 5 to 7.5 cm (2 to 3 inches) in diameter at a maximum depth range of 0.64 to 1.25 mm (0.025 to 0.050 in.).

3.2.4 Chemical Plating:

Damaged areas on the lobe profile may be removed by remachining to a maximum depth of 0.25 mm (0.010 inch), using a special geared milling machine. Remaining localized lobe damage may be removed by blending to restore satisfactory geometry. Electroless chemical plating is then applied and no additional profile machining is performed.

Notes:

1. Rotary screw compressor rotors require special tooling to remachine and establish the proper profile.

2. When localized areas are damaged beyond the plating limit, localized welding may be required.

3. When the lobe profile has not been restored to design dimensions, due to the restoration limitations, there may be a loss of performance and efficiency with an increase in the discharge temperature. An engineering evaluation should be considered to determine the effects of the restoration limitations.

3.2.5 Welding:

When the lobe profile damage exceeds the limitations of 3.2.3 and/or 3.2.4, welding may be considered. Welding shall be in accordance with Chapter 1, Appendix D.2.

Note: Small volume welds may not require post weld stress relieving.

3.3 LOBE SEAL STRIP RESTORATION

3.3.1 General

Tutorial: Dry rotary screw compressor rotors have two types of seals.

1. Periphery seal strips, located on the outer diameter of the male and female lobes are machined in the lobe during the profile machining operation.

2. Circumferential and radial axial seals, located on both the inlet and discharge ends of the male and female rotor.

Notes:

1. Proper seal geometry is required to minimize excess internal recirculation.

2. Seal heights are established to a specific dimension depending on the rotor size.

3.3.2 Damaged seal strips shall be restored by the following method:

a. Remove damaged seal strips by hand grinding or machining to the parent material removing all hardened material inflicted by the rub.

b. Weld seals for the complete lobe axial length using approved weld procedures per Chapter 1, Appendix D.2.

c. Final lobe profile and tapered outer diameter is to be machined using a special geared milling machine and lathe.

d. Axial end seals are to be machined to the proper profile and size.

Note: Small volume welds may not require post weld stress relieving.

3.4 OTHER COMPONENT RESTORATION

3.4.1 Timing Gears

Damage to the gear teeth or excessive dimensional deviation requires gear replacement. Recutting of the gear teeth and/or weld repair to the gear is unacceptable.

3.4.2 Distance Ring (Thrust collar axial locating spacer ring)

The distance ring properly locates the rotors in the compressor housing. The clearance between the end of the rotor and the casing at the discharge end may be adjusted by changing the thickness of the ring. This ring is to be replaced if damaged. If rotors are to be installed in a different housing, final thickness is to be established at compressor assembly.

3.4.3 Balance Piston

While it may be technically acceptable to repair balance pistons, the economics of repairing generally result in a new component replacement.

3.5 COMPONENT REPLACEMENT

3.5.1 Refer to Appendix C and Chapter 1, Section 9 for component replacement requirements.

4 Assembly and Balancing

4.1 GENERAL

The special Rotary Screw rotor balance defined in this section is in addition to the general balance processes defined in Chapter 1, Section 10.

4.2 PRE-ASSEMBLY

4.2.1 Because major components are all coming together for the first time after repairs, the vendor shall assure that the following items are completed prior to assembly.

a. Verification that all specific requirements of the repair scope have been met.

b. Verification that all critical dimensions and runouts have been taken, recorded, and evaluated for final fits, locations, and clearances.

c. Verification that the requirements of Section 3 have been met on any new or repaired components

4.2.2 Before assembly, make sure that surfaces and oil passages are clean. Remove any burrs and stone down any rough spots on the rotors.

4.2.3 Interference fit attachments on sleeves, thrust collar, and timing gear and hub require uniform heating (usually oven) to about 120 to 150°C (250 to 300°F) above the ambient shop temperature for installation.

4.2.4 Verify that keys have a tap fit in the shaft and a slip fit in the components, and that the top key clearances are 100 µm to 150 µm (0.004 in. to 0.006 in.).

4.3 ROTOR ASSEMBLY

4.3.1 Shaft seal sleeves are to be installed, if applicable. Measure and record final sleeve diameters.

Note: Some designs require final sleeve diameters to be machined after assembly. Machining process must be completed prior to final inspection.

4.3.2 Install male timing gear or female timing gear hub, key and lock nut, secure lock nut with locking device. Measure and record timing gear pitch diameter, perpendicular runout and pitch diameter runout.

4.3.3 If existing distance ring (thrust collar spacer) is being replaced, measure axial dimension and machine to measured size. The distance ring must be flat and parallel within 5 µm (0.0002 in.).

Note: If the rotor may be used in another case, the distance ring should be left oversize for final machining so as to axially locate the rotor properly.

4.3.4 Install the thrust collar and key. Measure and record the thrust collar runouts as defined in Chapter 1, paragraph 7.2.6.5.1.

4.3.5 Measure and record assembled rotor runouts defined in Appendix D.

4.3.6 Ensure that the match marks identified in paragraph 2.2.2 are properly oriented.

4.4 BALANCE

Balance assembled rotors as defined in Chapter 1, Section 10 with the following additions:

4.4.1 Component Balance

Unless otherwise specified, each rotor less timing gear and thrust collar, each timing gear shall be component balanced per Chapter 1, Section 10.2. Balance records shall be supplied for each component.

4.4.1.1 Rotors

Shaft balance corrections shall be made by removing material on the rotor lobe ends. Drill holes may be used in the lobe axial direction for large balance corrections.

4.4.1.2 Timing Gears

Balance corrections to be made to the male timing gear and female hub on the internal hub corners, balance corrections are <u>NOT</u> to be made on the gear teeth ring area.

4.4.2 Assembled Rotor Balance

Each rotor is to be assembled and balanced as an assembly.

Balance corrections are to be made on the assembled components at the locations defined in the component balance section, paragraph 4.4.1

4.4.2.1 Record all balance measurements.

4.5 FINAL INSPECTION

4.5.1 Perform dimensional and NDE inspections of the assembled rotor as required in Section 2.2.

4.6 DOCUMENTATION

4.6.1 Documentation for rotor re-assembly and/or balancing shall conform to the requirements of Chapter 1, Section 12.

APPENDIX A—DIMENSIONAL FORMS FOR PHASE I INSPECTION

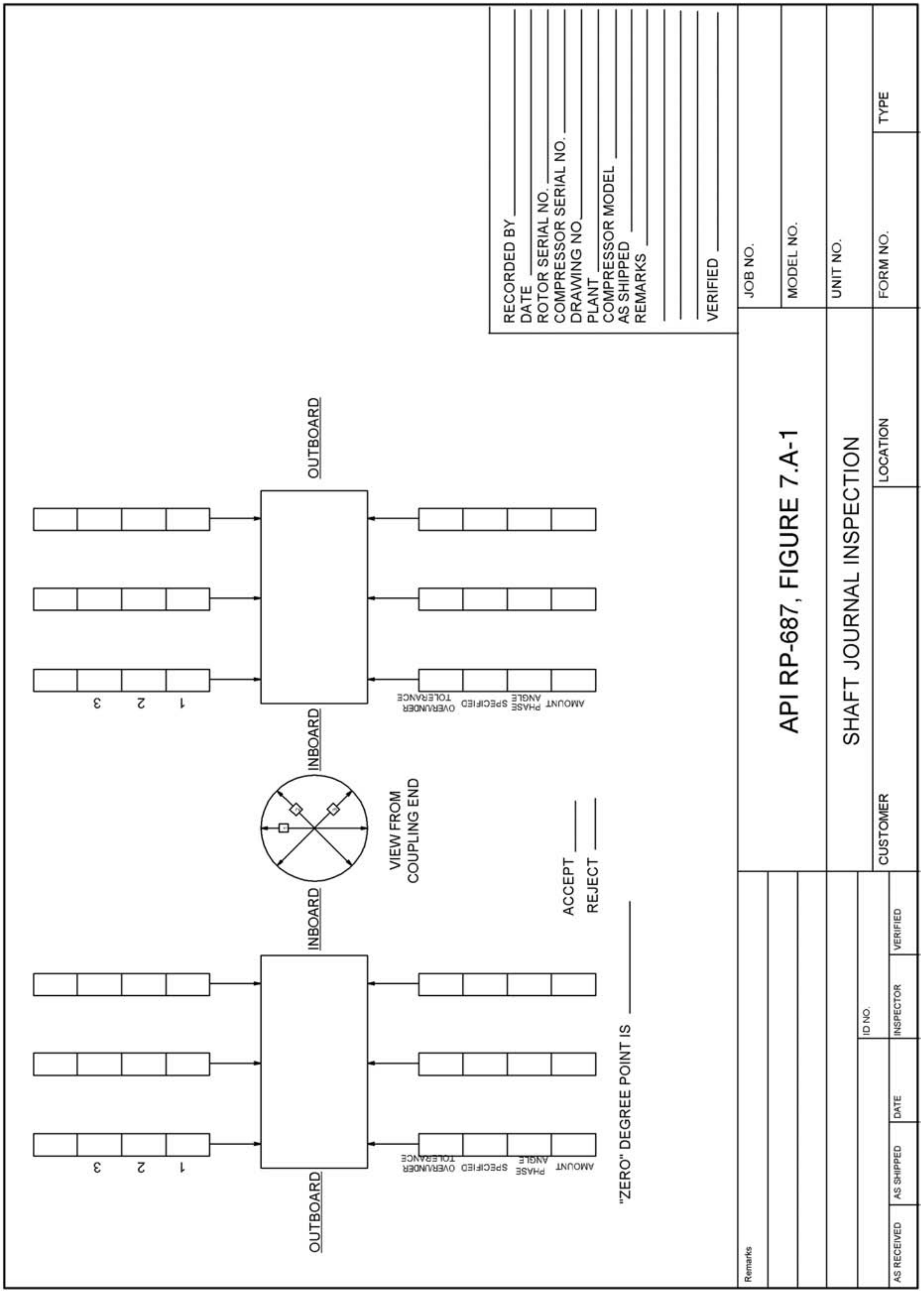


Figure 7.A-1—Shaft Journal Inspection

APPENDIX B—DIMENSIONAL FORMS FOR PHASE II INSPECTION

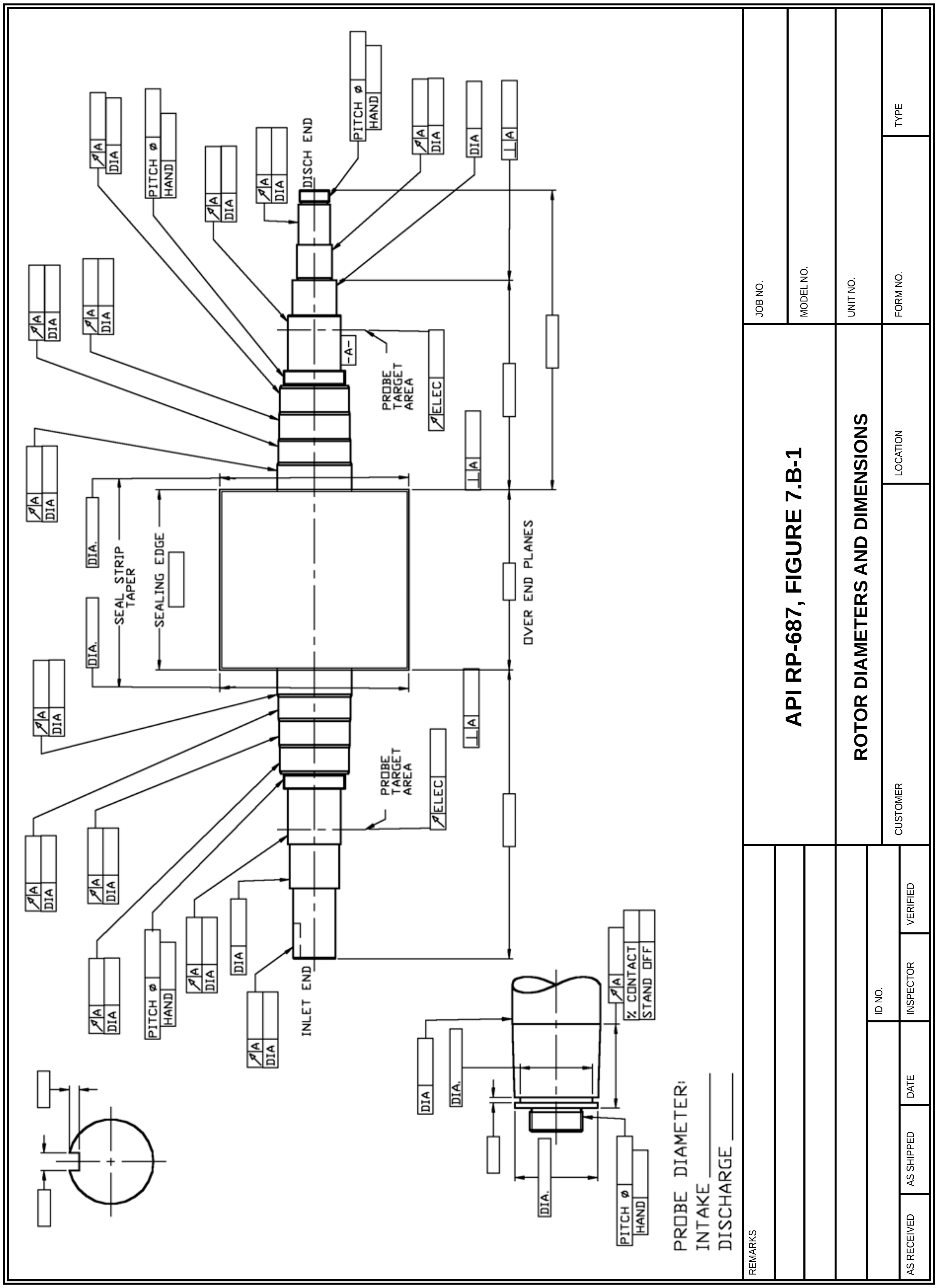


Figure 7.B-1—Rotor Diameters and Dimensions

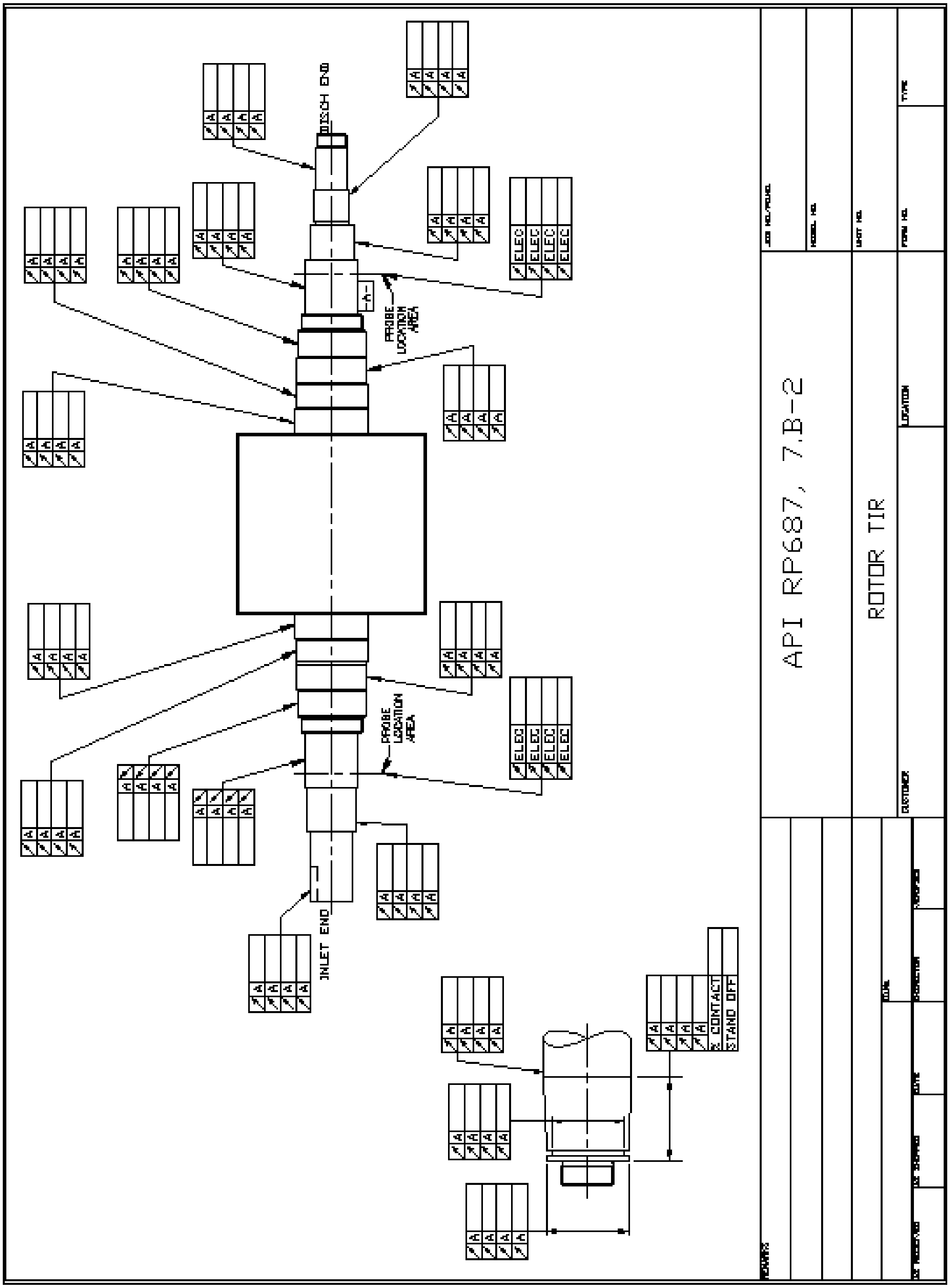


Figure 7.B-2—Rotor TIR

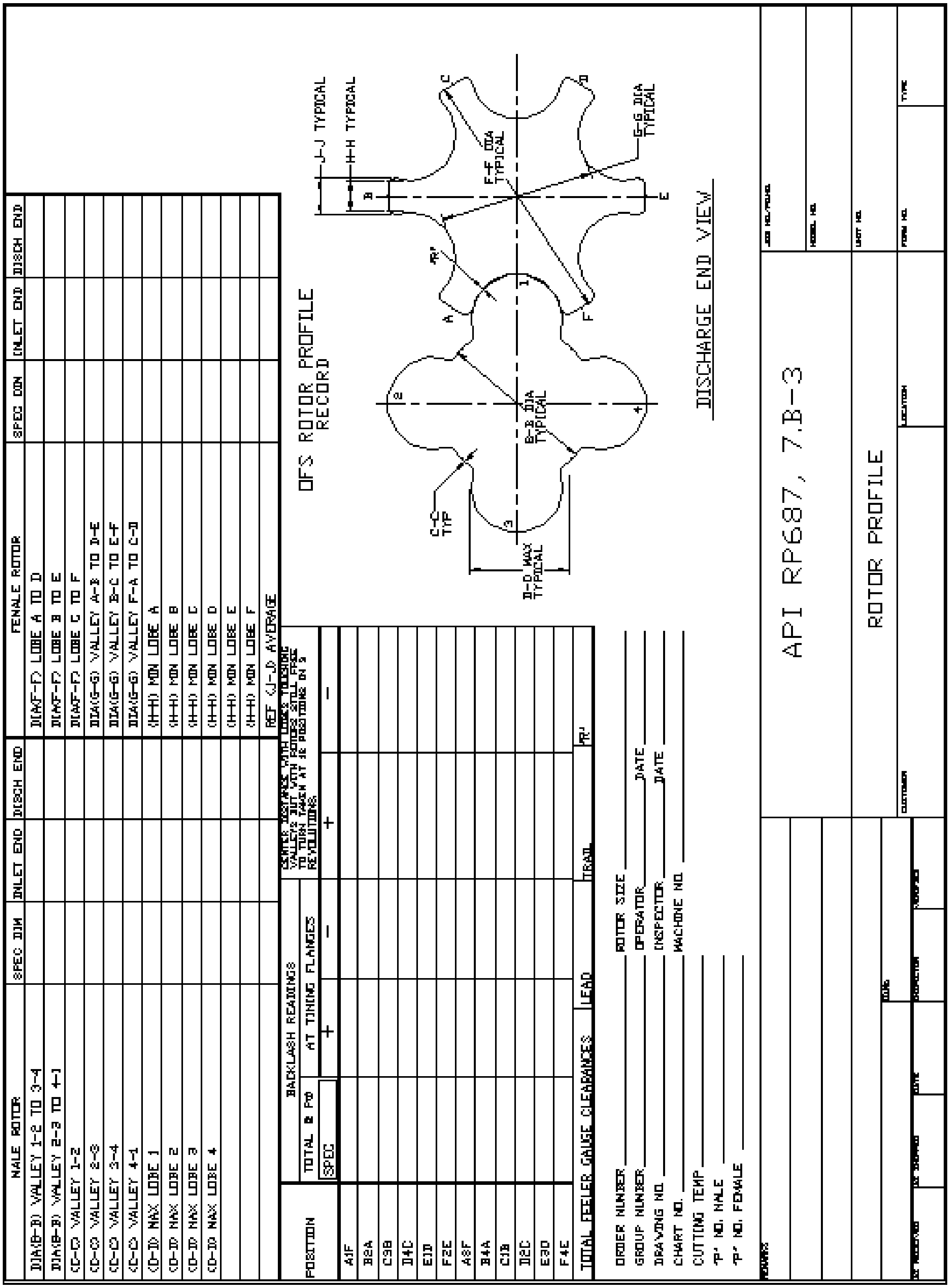
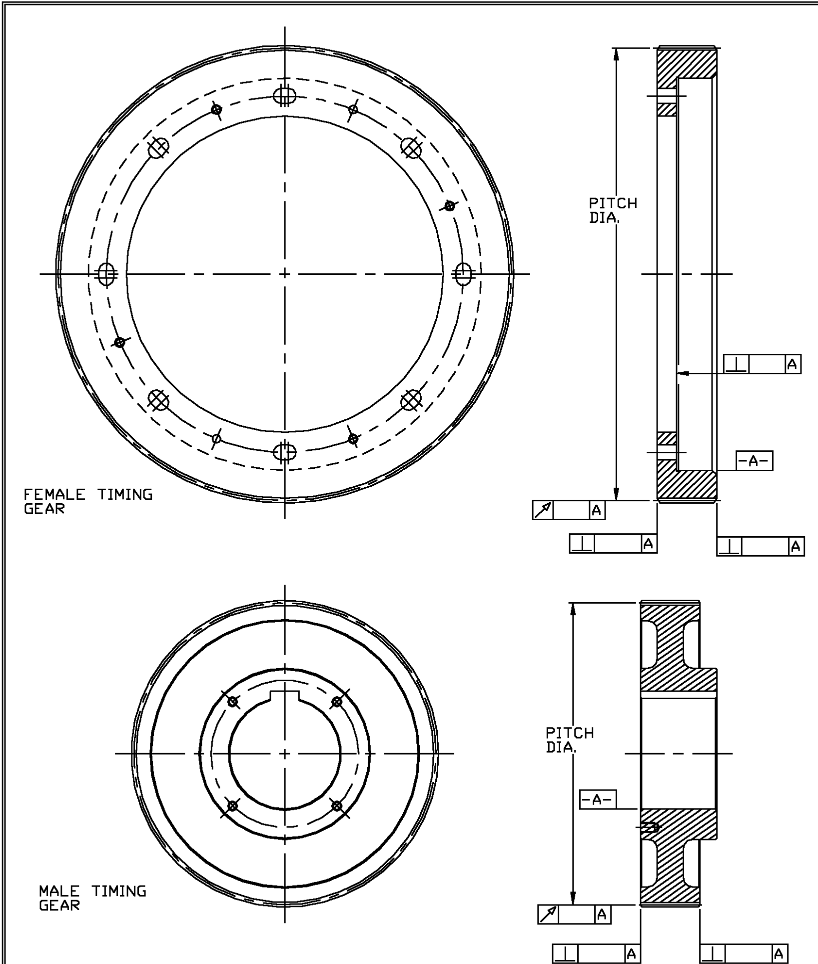


Figure 7.B-3—Rotor Profile



NUMBER	CHARACTERISTIC	SPECIFICATION	ACTUAL
1	PITCH DIAMETER		
	A) MALE GEAR		
	B) FEMALE GEAR		
2	PITCH LINE RUNOUT		
	A) MALE GEAR		
	B) FEMALE GEAR		
3	PERPENDICULARITY (MALE GEAR)		
	A) OUTBOARD FACE		
	B) INBOARD FACE		
4	PERPENDICULARITY (FEMALE GEAR)		
	A) OUTBOARD FACE		
	B) MOUNTING FACE		
	C) INBOARD FACE		
5	PITCH LINE RUNOUT (FEMALE GEAR TO HUB)		
	EST. LEAST ACHIEVABLE		
6	COMPOSITE PITCH LINE RUNOUT		
7	BACKLASH		
	A) MINIMUM		
	B) MAXIMUM		

REMARKS

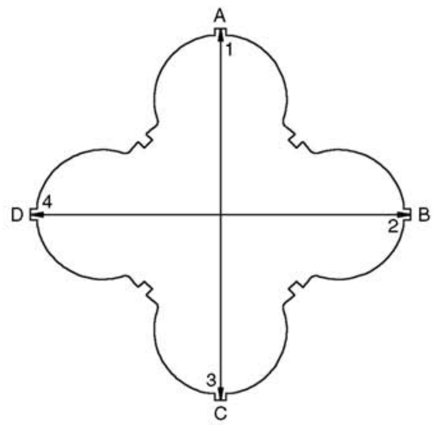
API RP-687, FIGURE 7.B-4

TIMING GEARS SET

ID.No.				
AS RECEIVED	AS SHIPPED	DATE	INSPECTOR	VERIFIED

JOB NO./PO.NO.			
MODEL NO.			
UNIT NO.			
CUSTOMER	LOCATION	FORM NO.	TYPE

Figure 7.B-4—Timing Gears Set



MALE ROTOR "P" No. ______

PRINT DIAMETER, inches ______

AC-1 ______

AC-2 ______

AC-3 ______

AC-4 ______

BD-1 ______

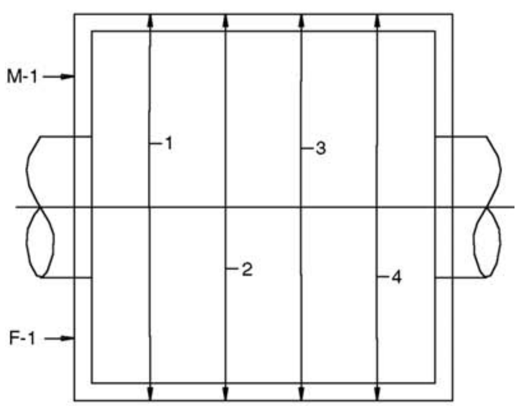
BD-2 ______

BD-3 ______

BD-4 ______

PRINT LENGTH, inches ______

M-1 ______



FEMALE ROTOR "P" No. ______

PRINT DIAMETER, inches ______

AD-1 ______

AD-2 ______

AD-3 ______

AD-4 ______

BE-1 ______

BE-2 ______

BE-3 ______

BE-4 ______

CF-1 ______

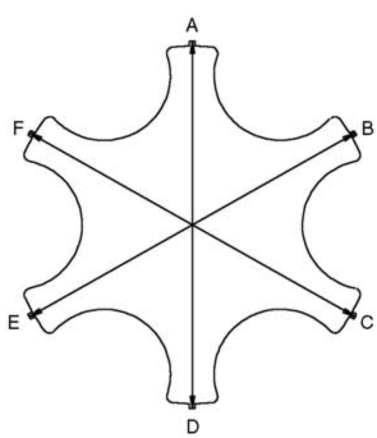
CF-2 ______

CF-3 ______

CF-4 ______

PRINT LENGTH, inches ______

F-1 ______



JOB NO. / P.O. NO.

MODEL NO.

UNIT NO.

FORM NO.

TYPE

API RP-687, FIGURE 7.B-5

ROTOR BODY CHART/OVER SEAL STRIPS

LOCATION

CUSTOMER

REMARKS

ID NO.

VERIFIED

INSPECTOR

DATE

AS SHIPPED

AS RECEIVED

Figure 7.B-5—Rotor Body Chart/Over Seal Strips

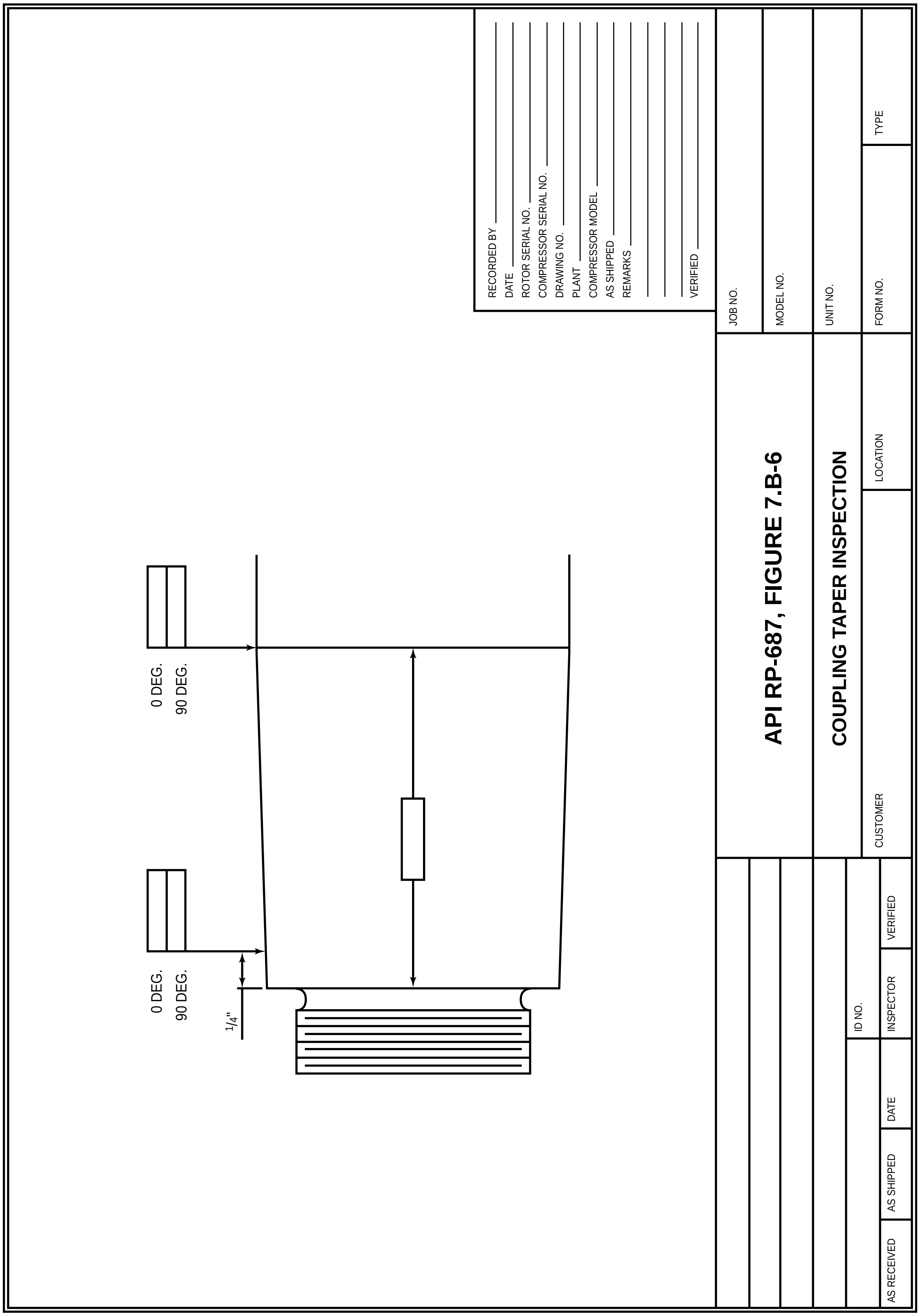


Figure 7.B-6—Coupling Taper Inspection

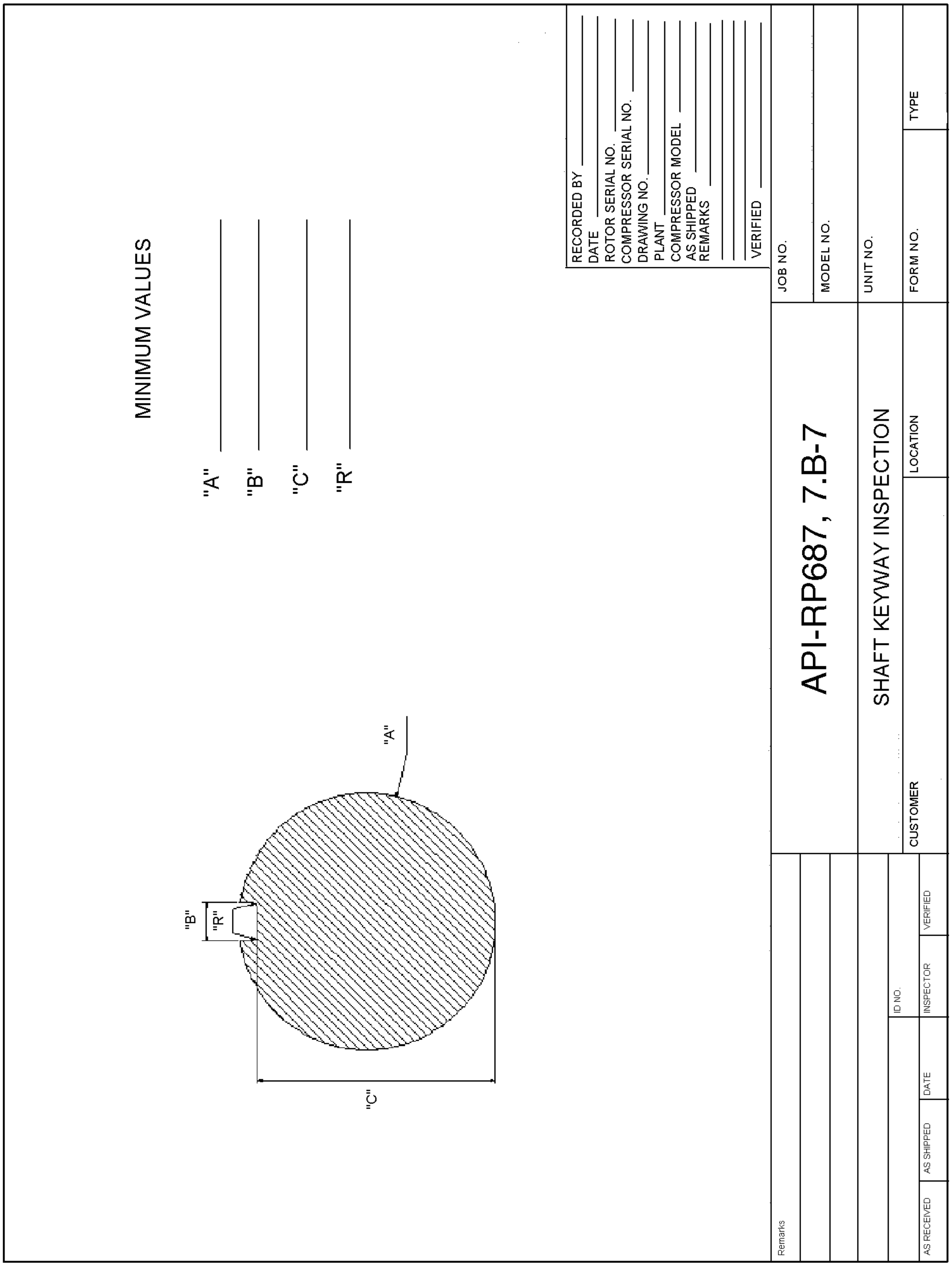


Figure 7.B-7—Shaft Keyway Inspection

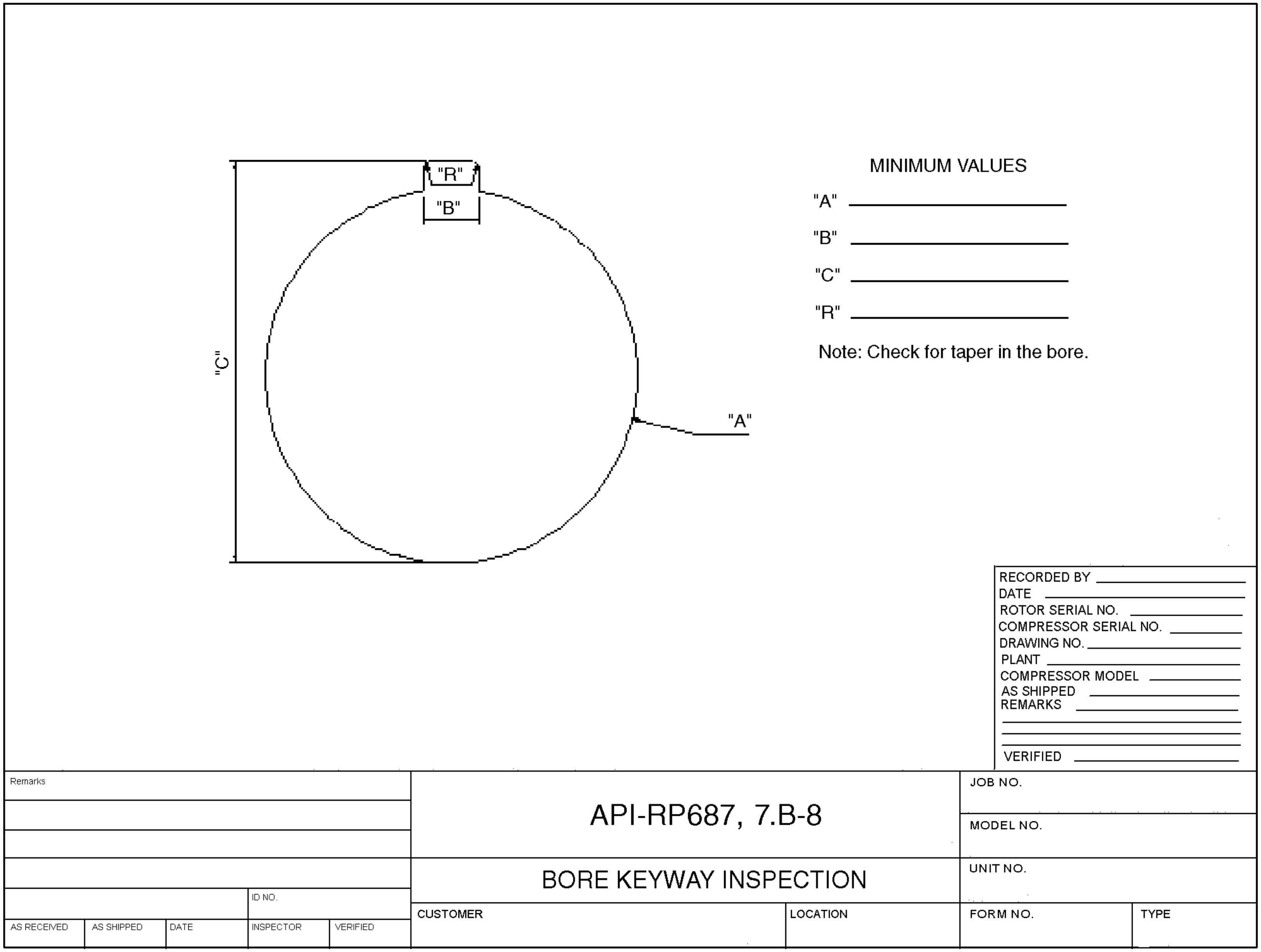


Figure 7.B-8—Bore Keyway Inspection

APPENDIX C—QUALITY/MANUFACTURING PLAN

QUALITY/MANUFACTURING PLAN

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	SHAFT (NEW)			**3.5/Chap 1, 9.7**						
	Shaft	AISI / ASTM Spec No.	C,M,H	Chap 1, 9.7		Compliance with AISI / ASTM Requirement	Report			
	Ultrasonic Inspection			Chap 1, 8.2.3	ASME Sect V Article 5 & 23	Chap 1, 8.2.3.2	Certificate			
	Final Machined Dimensions					Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			
	Serial Number					Mfg Drawing	Certificate			
	ROTOR LOBE PROFILE RESTORATION (1)			**3.2**			**(2)**			
	Mechanical Blending			3.2.3						
	Visually inspect			3.2.2	Vendor Procedure	No Discontinui-ties	Report, Photo-graphs			
	Hand Blend or Lightly Grind			3.2.3	Vendor Procedure	Mfg. Drawing	Report			
	Dye Penetrant Inspection (Non-Ferrous Materials)			Chap1, 8.2.4.3	ASTM E 165	Chap 1, 8.2.4.4	Certificate			
	Wet Magnetic Particle Inspection (Ferrous Materials)			Chap1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize (with MPI only)			Chap1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Final Dimensional Inspection			Chap1, D.2.9	Vendor Procedure	Mfg Drawing	Report			
	Balance			Chap1, 10.2		10.2.11	Report			
	Runout Inspect			Chap 1, 9.6		Chap 1, 9.6	Report			
	Chemical Plating (Dry Screw Units Only)			3.2.4						
	Visually Inspect			3.2.2	Vendor Procedure					
	Undercut for Plating Preparation			3.2.4	Vendor Procedure	Mfg Drawing	Report			
	Wet Magnetic Particle Inspect (Fluores-cent, continuous method) for ferrous material			Chap 1, D.3.2.5/Chap 1, 8.2.4.1	ASTM E 709	8.2.4.4	Certificate			
	Apply Plating			3.2.4	Vendor Procedure		Certificate			
	Visual Inspection				Vendor Procedure	No Discontinuities	Report, Photo-graphs			
	Final Dimensional Inspection			Chap 1, D.2.9	Vendor Procedure	Mfg Drawing	Report			
	Balance			Chap 1, 10.2		Chap 1, 10.2.11	Report			
	Runout Inspect			Chap 1, 9.6		Chap 1, 9.6	Report			
	Weld Restoration (Dry Screw Units Only) (3)			3.2.5						
	Undercut for Weld Preparation			Chap 1, D.2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D.2.2.1			Certificate			
	Hardness Check		C	Chap 1, D.2.2.3		Report	Certificate			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Rough Dimensional Inspection of Undercut Area			Chap 1, D.2.2.3	Vendor Procedure	Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Weld Repair			Chap 1, D.2.3	WPS, PQR		WPS, PQR (4)			
	Dye Penetrant Inspect			Chap 1, 8.2.4.3	ASTM E165	Chap 1, 8.2.4.3	Certificate			
	Hardness Check			Chap 1, D.2.2.3		Report	Certificate			
	Machine to Final Dimension and Profile				Vendor Procedure	Mfg. Drawing	Report			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Demagnetize			Chap 1, 8.2.4.2	Vendor Procedure	Chap 1, 8.2.4.2	Certificate			
	Final Dimensional Inspection			Chap 1, D.2.9	Vendor Procedure	Mfg Drawing	Report			
	Balance			Chap 1, 10.2		Chap 1, 10.2.11	Report			
	Runout Inspect			Chap 1, 9.6		Chap 1, 9.6	Report			
	PERIPHERAL ROTOR SEAL STRIP RESTORATION (1)			**3.3**			**(2)**			
	Weld Restoration			3.3/ Chap 1, D.2						
	Undercut for Weld Preparation			Chap 1, D.2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chap 1, D.2.2.1			Certificate			
	Hardness Check		C	Chap 1, D.2.2.3		Report	Certificate			
	Rough Dimensional Inspection of Undercut Area			Chapter 1, D.2.2.3	Vendor Procedure	Mfg Requirement	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Weld Repair			Chap 1, D.2.3	WPS, PQR		WPS, PQR (4)			
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chap 1, 8.2.4.1	ASTM E 709	Chap 1, 8.2.4.4	Certificate			
	Machine to Final Dimension and Profile			3.4.2c & d	Vendor Procedure	Mfg. Drawing	Report			
	Final Dimensional Inspection			Chap 1, D.2.9	Vendor Procedure	Mfg Drawing	Report			
	Balance			Chap 1, 10.2		Chap 1, 10.2.11	Report			
	Runout Inspect			Chap 1, 9.6		Chap 1, 9.6	Report			
	AXIAL ROTOR SEAL STRIP RESTORATION (1)						**(2)**			
	Weld Restoration			3.4						
	Undercut for Weld Preparation			Chapter 1, D.2.2.3		Mfg Requirement	Report			
	Chemical Analysis of Base Material		C	Chapter 1, D.2.2.1			Certificate			
	Hardness Check		C	Chapter 1, D.2.2.1		Report	Certificate			
	Rough Dimensional Inspection of Undercut Area			Chapter 1, D.2.2.3	Vendor Procedure	Mfg Requirement	Report			
	Wet Magnetic Particle Inspect (Fluorescent, continuous method)			Chapter 1, 8.2.4.1	ASTM E 709	Chapter 1, 8.2.4.4	Certificate			
	Weld Repair			Chapter 1, D.2.3	WPS, PQR		WPS, PQR (4)			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Wet Magnetic Particle Inspect (fluorescent, continuous method)			Chapter 1, 8.2.4.1	ASTM E 709	Chapter 1, 8.2.4.4	Certificate			
	Machine to Final Dimension and Profile			3.4.2 c	Vendor Procedure	Mfg. Drawing	Report			
	Final Dimensional Inspection			Chapter 1, D.2.9	Vendor Procedure	Mfg Drawing	Report			
	Balance			Chap 1, 10.2		Chap 1, 10.2.11	Report			
	Runout Inspect			Chap 1, 9.6		Chap 1, 9.6	Report			
	ROTOR ASSEMBLY/LOW SPEED BALANCE			**4.3**			**(2)**			
	Interference Fit Summary					Mfg Drawing	Report			
	Balance Machine Calibration			Chap 1, 10.5.1		Mfg Requirement	Report			
	Rotor Indication						Report			
	Rotor Balance			Chap 1, 10.3		Chap 1, 10.3.9	Report			
	Residual Unbalance—Rotate U-Joint Drive			Chap 1, 10.3.10		Chap 1, 10.3.10	Report			
	Residual Unbalance/Sensitivity Check			Chap 1, 10.4		Chap 1, App. A	Report			
	Residual Unbalance With Coupling			Chap 1, 10.4.3/ Chap 1, 10.4.4		Chap 1, 10.3.5	Report			
	Rotor Assembly—Final Dimensional			4.5.1		Mfg Drawing	Report			
	Rotor Assembly—Final Indication			4.5.1		Mfg Drawing	Report			
	Rotor Assembly—Gauss Level			4.5.1		Mfg Drawing	Report			

Drawing Number	Description/ Operation	Material Spec	Material Cert	API 687 Reference Paragraph	Reference Procedure	Acceptance Criteria	Verifying Document	W/O/* Point	Sign Off	Date
	Weight of Assembled Rotor			4.5.1		Mfg Drawing	Report			
	Prep For Shipment			Chap 1, 11						

<table>
<tr><th colspan="3">DESCRIPTION/OPERATION</th></tr>
<tr><th colspan="3">NOTES:</th></tr>
<tr><td>1) Repairs other than minor blending would normally not be done on cast iron rotors.

2) All verifying document reports shall reference procedure and state drawing acceptance criteria.</td><td colspan="2">3) Due to the moderate cost of new rotors on flooded screw compressors, new rotors are normally recommended in lieu of weld repair.

4) All WPS, WQR, and PQR shall be available to purchaser for review and approval prior to any welding.</td></tr>
<tr><td>LEGEND GENERAL</td><td>MATERIAL CERT</td><td>INSPECTION POINT</td></tr>
<tr><td>H.T. Heat Treatment
PT Liquid Penetrant Inspection
MT Magnetic Particle Inspection
VT Visual Inspection
UT Ultrasonic Inspection
W/A Will Advise
N/A Not Applicable</td><td>A Certificate of Compliance
C Chemical Analysis
M Mechanical Properties
H Heat Treat Charts
I Impact</td><td>O Observation
W Witness / Hold Pt
* Vendor To Confirm That Requirement Has Been Met</td></tr>
<tr><td colspan="3">Report: defines a vendor generated quality control inspection form/report that will satisfy industry standards or requirements outlined on purchase order.</td></tr>
</table>

APPENDIX D—INSPECTION FORMS FOR ASSEMBLY AND BALANCE

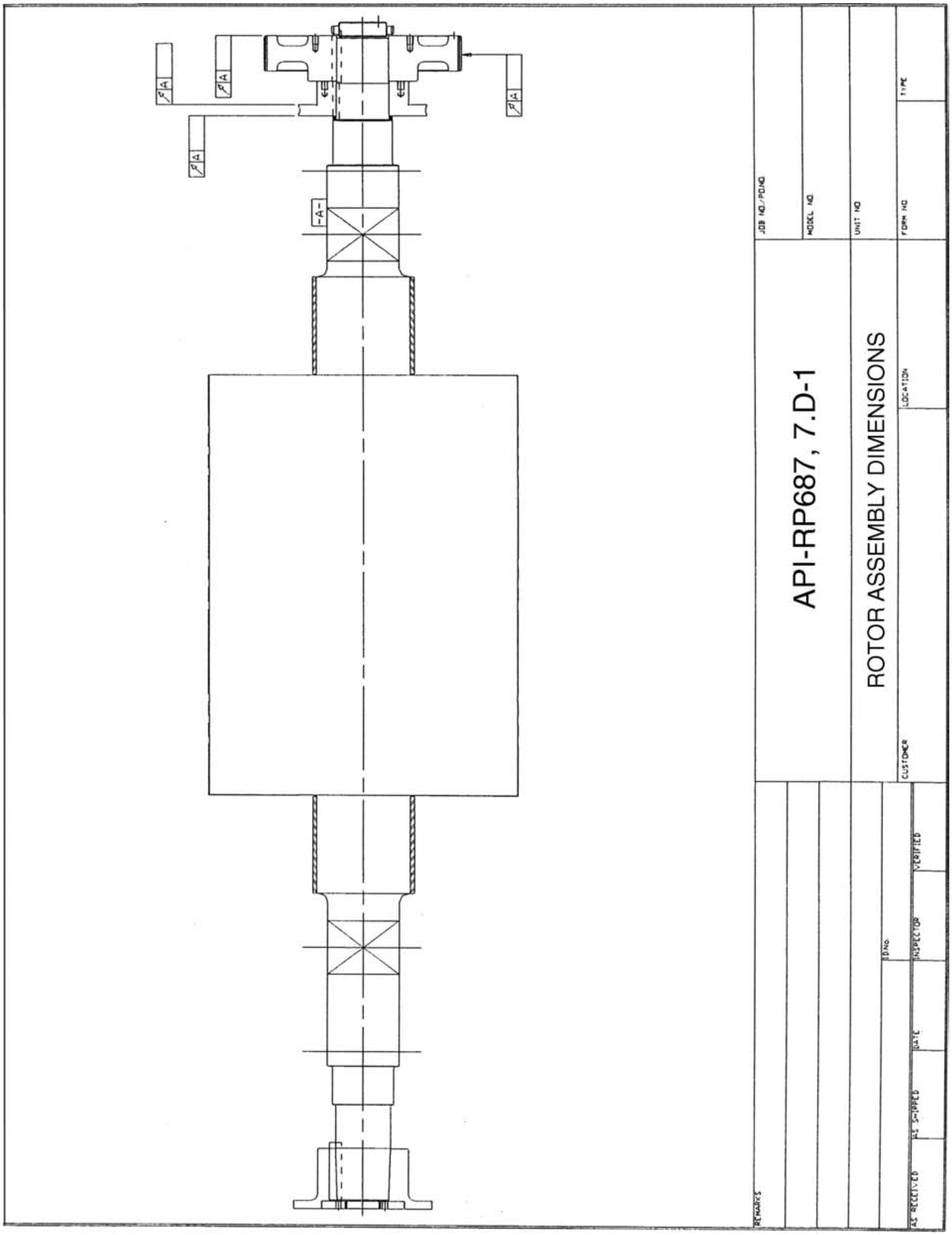


Figure 7.D-1—Rotor Assembly Dimensions

APPENDIX E—AUDITORS CHECK LIST

E.1 General

This Appendix, along with Appendix H, Chapter 1, is a checklist to provide information for the owner and the vendor to aid in summarizing the scope of the rotor repair.

Repairs require clear owner/vendor communication and the assignment of responsibilities. The format of this checklist provides a summary of the items required and the parties responsible.

Each item on this checklist has a circle or a square to indicate whether the owner or vendor, respectively, is responsible for obtaining the information or performing the task. The owner must indicate, for each item, whether the item is to be witnessed, observed, or verified. Typically, inspections, processes or tests may be witnessed or observed while verification is the review of the results of the inspections, processes, tests, or other documentation so as to insure that the requirements have been met.

AUDITORS CHECK LIST

Customer: ______________________________

Job/Project Number: ______________________________

Owner Equipment Identification Number: ______________________________

OEM Equipment Serial Number: ______________________________

Rotor Identification Number: ______________________________

Repair Purchase Order Number: ______________________________

Vendor Job Number: ______________________________

Auditors Check List

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice W	O	V	Date Inspected or Verified By	Status
SECTION 1							
N/A							
SECTION 2—Rotor Disassembly and Inspection Phase II							
Interference Fits	☐	2.2.1					
Match Mark Timing Gears	☐	2.2.2					
Timing Gear Measurements	☐	2.2.3					
Lobe, Seal Strips	☐	2.2.4/ 2.2.5					
Clean Rotor	☐	2.2.6/ 2.2.7					
Shaft Dimensions	☐	2.2.8a					
Spacers, Sleeves	☐	2.2.8b					
Balance Piston	☐	2.2.8c					
Thrust Collar	☐	2.2.8d					
Key Clearances	☐	2.2.8e					
Eliminate Weight(s)	☐	2.2.9					
Clean Timing Gears	☐	2.2.10					
NDE	☐	2.2.11/ 2.2.12					
Photographs	☐	2.2.13					
Balance Piston	☐	2.2.14					
Remove Timing Gears	☐	2.2.15					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice			Date Inspected or Verified By	Status
			W	O	V		
Thrust Collar, Distance Ring	☐	2.2.16					
Lobe Seal Strip Dimensions	☐	2.2.17/ 2.2.18					
Rotor Profiles	☐	2.2.19					
Threaded Areas	☐	2.2.20					
Inspection Report	☐	2.3					
Review	☐	2.4.1					
Blue Contact Check	☐	2.4.2					
Job Scope	☐	2.5.1					
SECTION 3—Rotor Repair and New Component Manufacture							
Pre-Lobe Profile Repair	☐	3.2.2					
Lobe Blending Repair	☐	3.2.3					
Lobe Plating Repair	☐	3.2.4					
Lobe Weld Repair	☐	3.2.5					
Seal Strip Repair	☐	3.3.2					
Replace Timing Gears	☐	3.4.1					
Distance Ring Thickness	☐	3.4.2					
Replace Balance Piston	☐	3.4.3					
Component Replacement	☐	3.5					
SECTION 4—Assembly and Balancing							
Dimensional Verification	☐	4.2.1					
Clean Rotor	☐	4.2.2					
Interference Fits	☐	4.2.3					
Keyway Verification	☐	4.2.4					
Install Sleeves	☐	4.3.1					
Install Timing Gears	☐	4.3.2					
Distance Ring Measurements	☐	4.3.3					

Auditors Check List (Continued)

Note: Information to be supplied or completed by: O owner ☐ vendor

Item	O/☐	API 687 CH. 1 REF.	Witnessed or Observed or Verified (W/O/V) Indicate Choice			Date Inspected or Verified By	Status
			W	O	V		
Install Thrust Collar & Key	☐	4.3.4					
Rotor Runouts	☐	4.3.5					
Orient Match Marks	☐	4.3.6					
Component Balance	☐	4.4.1					
Balance Corrections	☐	4.4.1.1/ 4.4.1.2					
Balance Rotor	☐	4.4.2					
Final Inspection	☐	4.5					
Documentation	☐	4.6					

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