EPRI

Combustion Turbine Guidelines: Conventional and Advanced Machines

Volume 5, Westinghouse Models W501A–D

Technical Report

Combustion Turbine Guidelines: Conventional and Advanced Machines

Volume 5, Westinghouse Models W501A–D

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Final Report, November 2001

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REPORT SUMMARY

For more than a decade, EPRI has been developing gas turbine hot section component repair and coating guidelines to assist utilities in the refurbishment of these critical and expensive parts. Utilities and repair vendors have used these guidelines to perform repairs on buckets (blades), turbine nozzles (vanes), combustion liners, and combustor transitions. Guidelines now exist for a variety of conventional and advanced General Electric and Westinghouse heavy frame gas turbines.

Background

During the early 1990s, EPRI was instrumental in developing repair and coating guidelines for several gas turbine engines. Repair vendors and utilities assisted in the development of the first set of guidelines, which included the General Electric MS7001 Model B and early versions of the Westinghouse Model W501. Newer, more advanced machines have found their way into domestic and international fleets throughout the 1990s and into the 2000s, including General Electric MS6001 Model B, MS7001 Model E/EA, MS7001 Model F/FA, and Westinghouse Models W501 D4/D5 and W50lF. Similar refurbishment criteria are needed for the newer machines. The EPRI program is ongoing and is now focused on developing repair and coating guidelines to meet this need. Updated and new volumes of this report will be issued periodically as the guidelines are completed for each machine.

Objectives

- To assemble repair and coating guidelines that utilities can use for the refurbishment of hot section components, including buckets (blades), nozzles (vanes), combustion liners, and combustor transitions
- To cover the minimum requirements for weld repair, heat treatment, damage and dimensional inspections, and quality assurance for gas turbine hot section components

Approach

Each repair guideline has been assembled in a standard format that includes scope, definitions, applicable documents, general requirements, technical requirements, processing requirements, and quality requirements. Contained within these sections is detailed information surrounding the minimum requirements for microstructural characterization, damage and dimensional inspection, stripping, mechanical properties, appearance, quality assurance, welding and coating procedures, and heat treatment. EPRI has worked closely with several repair vendors to develop and refine each guideline to ensure that the information contained in each is consistent with today's repair practices.

Results

A comprehensive, seven-volume set of repair and coating guidelines is being developed for utilities to employ for hot section component repairs. The set comprises the following:

Volume 1: GE MS7001 Model B

Volume 2: GE MS6001 Model B

Volume 3: GE MS7001 Model F/FA

Volume 4: GE MS7001 Model E/EA

Volume 5: Westinghouse Models W501 A through D

Volume 6: Westinghouse 501F

Volume 7: Coatings

By the end of 2002, the entire seven-volume set will be available for utilities and independent power producers to employ for hot section component repairs.

EPRI Perspective

Gas turbine owners/operators are encouraged to use these guidelines for hot section component repair and refurbishment. In many cases, gas turbine owners will be able to simply insert their company's name into the guidelines (where appropriate), print the guideline, attach it to a purchase order, and give the guideline directly to a repair vendor. Electronic copies of these repair guidelines are located on EPRIweb. Click on the Generation tab and go to 079.0 – Combustion Turbine & Combined Cycle O&M. EPRI is continuing to develop and update repair guidelines for hot section components.

Keywords

Combustion turbines
Combustion turbine O&M
Combustion turbine repair

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1
EPRI GUIDELINE 501BL520 – REPAIR GUIDELINE FOR UDIMET 520 WESTINGHOUSE W501 FIRST AND SECOND STAGE TURBINE BLADES

Revised April 2000

April 2000 Revisions: Guideline format/software converted to Microsoft Word®. Text added to allow extension of bucket repair limits and the use of advanced repair procedures using matching, or near matching, weld filler materials when qualified by the vendor and approved by the Purchaser.

> **Note**
> The use of repair procedures and guidelines supplied by the Original Equipment Manufacturer (OEM), if available, in conjunction with, and to supplement this guideline, is permitted and encouraged. However, Purchaser expects the requirements of this guideline to be met by the repair vendor as a minimum condition for acceptable repairs. Conflicts between this and any other guidelines should be brought to the Purchaser's attention for resolution.

1 Scope

1.1 Purpose

This guideline covers the minimum requirements for the weld repair and heat treatment of Westinghouse W501 First and Second Stage Blades manufactured from Udimet 520 (56Ni 19Cr 12.5Co 6.2Mo 3.0Ti 2.1Al; Alternative designation: U-520) alloy, uncoated or protected with a corrosion resistant coating. Blades repaired to these requirements should provide service life approaching that of new components.

1.2 Application

Weld repair of turbine blades is performed to repair physical damage such as rubbing, cracking, impact damage, and erosion. Heat treatments are required prior to welding to improve ductility and after welding to stress relieve weldments and to restore the appropriate microstructure. Straightening of deformed turbine blades is prohibited.

2 Definitions

2.1 Lot

A group of parts that is processed through the entire repair cycle at the same time and heat treated in the same furnace at the same time throughout the repair cycle. If a group of parts being repaired at the same time is split into two or more subgroups for heat treatment, each subgroup shall constitute a lot.

2.2 EDM

Electrical Discharge Machining (EDM) is a process in which metal is removed by an electrical spark in a dielectric fluid.

2.3 Linear Indications

Nondestructive testing indications with a length of three times the width or greater.

2.4 Nonlinear Indications

Nondestructive testing indications with a length of less than three times the width.

2.5 FPT

Fluorescent Penetrant Testing.

3 Applicable Documents

3.1 Guidelines

The following documents form a part of this guideline to the extent specified herein. Unless otherwise specified, the latest issue shall apply.

U.S. Military Specification MIL-I-6866B
“Inspection, Liquid Penetrant”

U.S. Military Specification MIL-STD-453C
“Inspection, Radiographic”

ASTM E165
“Standard Practice for Liquid Penetrant Inspection Method”

ASTM E94
"Standard Guide for Radiographic Testing"

ASTM E139
"Standard Practice for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials"

Aerospace Material Guidelines 5837C
"Wire, Welding, Alloy- 62Ni 21.5Cr 9.0Mo 3.7(Cb +Ta)" (July 1985)

ASNT Recommended Practice No. SNT-TC-1A
"Personnel Qualification and Certification in Nondestructive Testing"

ANSI B46.1
"Surface Texture"

3.2 Precedence of Documents

Specific requirements contained in purchase order instructions or drawings may be issued to supplement the requirements of this document. In cases of conflict, the purchase order shall take precedence followed by applicable drawings, followed by this document.

4 General Requirements

General requirements are typically addressed in Purchase Orders for component repairs.

5 Technical Requirements

5.1 Weld Repair Limits

No repair welding shall be performed outside of the limits identified in Figure 1-1 unless approved by the Purchaser.

5.2 Repair Materials

Unless qualified by the vendor and approved by the Purchaser, repairs shall be performed by gas tungsten arc welding or plasma transferred arc welding using AMS 5837C (Alternative designations: Inconel 625, Alloy 625, UNS N06625), Inconel 617, or Haynes 230 filler materials. Repair by advanced processes, such as laser powder fusion welding using filler materials that match (or more closely match) the blade alloy, when pre-qualified by the vendor and approved by the Purchaser, may be allowed.

5.3 Nondestructive Testing Acceptance Limits

Linear indications of less than 0.080 inch (2 mm) in length within ±30 degrees of the radial direction and 0.040 inch (1 mm) in all other directions are permitted within the weld repair limits, identified in Figure 1-1, provided they are spaced by five times their length. No linear indications are permitted at any other location in the component. No through-going indications are permitted. Nonlinear indications up to 0.030 inch (0.76 mm) diameter or up to a diameter equal to 25% of the local section thickness, whichever is less, are permitted.

5.4 Dimensional Requirements

5.4.1 Blade tip height dimensions shall be within the range identified on the forms attached as Appendix I.

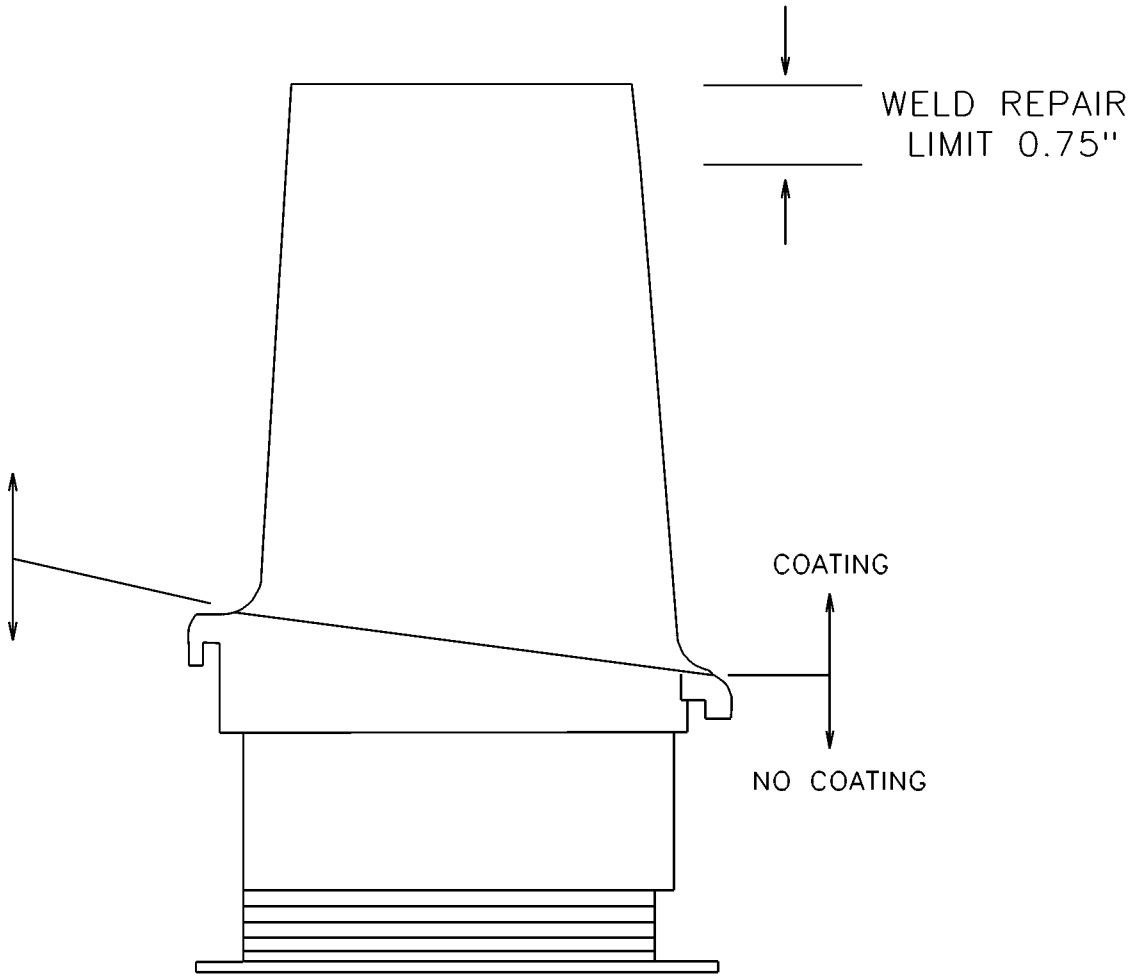
5.4.2 Airfoil profiles shall be restored to the same contours as new components using smooth blends between the original material and repaired areas.

5.4.3 Surface finish on the completely repaired airfoil shall be 80 micro-inches (2 microns) Ra or better, measured according to ANSI B46.1. Surface finish on the root form shall be maintained at 50 micro-inches (1.3 microns) Ra or better.

5.4.4 All cooling hole passages shall allow free and unobstructed passage of water. Upon receipt, all holes shall be checked on a typical blade in good condition and the diameters of each hole recorded to use as a target for others in the set. (If the nominal cooling hole sizes per OEM drawing requirement are known for the particular style blade being repaired, these values shall be used instead of the measured target values.) After processing, all cooling holes in each blade shall be checked for conformance with the target (±0.003 inch [76.2 microns]). Appropriately sized wires and metal balls can be used to verify hole sizes.

5.4.5 The minimum wall thickness at the leading and trailing edge cooling holes depends on the particular style blade. If OEM drawing requirements are known, these should be used as a standard for reconditioned blades. Otherwise, minimum wall thicknesses shall be 0.035 inch (0.89 mm) at the leading edge and 0.030 inch (0.76 mm) at the trailing edge.

Note
OEM-supplied dimensional information contained in manuals and other supporting documentation should be used as reference dimensions where available. In the absence of such information, new or undamaged components may be measured and appropriate tolerances applied.



1 Inch = 25.4 mm

Note
Weld repair limits shown at the blade tip and leading/trailing edges are those originally set by the OEM for repairs using solid solution strengthened weld fillers applied by GTAW or PTAW. Extended repair limits, when qualified by the vendor and specifically approved by the Purchaser, may be permitted.

Figure 1-1
Weld Repair and Coating Limits for W501 First and Second Stage Blades Manufactured from U520 Alloy

5.5 Mechanical Properties

Stress rupture bars of 0.160 inch (4.0 mm) minimum diameter removed from the airfoil of the blade (exclusive of the repair regions) in pairs shall meet the following requirements when tested according to ASTM E-139 at a temperature of 1475°F ±5°F (802°C ±3°C) using a minimum stress level of 50,000 psi (345 MPa):

Life (hours)	100 minimum
Elongation in 4D (%)	5 minimum
Reduction of area (%)	5 minimum

If the stress rupture bars fail these requirements, two more specimens shall be cut and tested to the same requirements. Failure of the second set of specimens shall subject the entire lot to rejection.

Note
Testing is preferably performed on a blade from the set being repaired. The same blade can be used to characterize the pre-repair condition of the material as specified in 6.1.8. If a blade cannot be sacrificed, Udimet 520 material from another source should be processed with the parts to qualify the process.

5.6 Microstructural Requirements

5.6.1 The thermal processing employed shall not result in grain growth.

5.6.2 Process-related alloy depletion, oxidation, nitriding, and intergranular attack at the surface of the components shall not exceed 0.001 inch (0.025 mm).

5.6.3 The re-casted layer on any EDM surface shall not exceed 0.001 inch (0.025 mm).

5.6.4 The microstructure shall be comparable to new material. The root section of an unrepaired blade may be used for comparison. In particular, no continuous grain boundary carbide films or needle phases shall be present after processing.

5.7 Coating Requirements

The coating shall meet the requirements specified by the Purchaser.

6 Processing Requirements

All process procedures applied during the repair of the components shall be the same as those used in the preparation of first article qualification samples and described in the process description as specified in paragraph 7.1.2.

6.1 Initial Inspection

6.1.1 Receive material and check for shipping damage. Check purchase order, material, and shipping papers to verify that the material received is correctly identified, fully accounted for, and that the repairs requested are reasonable for the parts received.

6.1.2 Advise Purchaser immediately of any shipping damage or errors in documentation.

6.1.3 Dimensionally inspect blades for:

- Tip height and angle (second stage) (10% of blades)
- Wall thickness to leading and trailing edge cooling holes (all blades)

Record results on the forms attached as Appendix I. Tip dimensions may be checked with a Fixture in lieu of actual measurements, provided all dimensions identified on the Forms are checked.

6.1.4 Visually inspect each blade for the following:

- Tip and seal rubs
- Impact damage
- Cracks
- Surface corrosion/erosion/coating loss

Record the results on the forms attached as Appendix II.

6.1.5 Clean blades using grit blasting with 220 grit aluminum oxide. Avoid excessive blasting, particularly on the root, and take necessary precautions to prevent blockage of cooling holes.

> **Note**
> Cooling passages can become filled with media during abrasive cleaning. It is imperative that the media be removed prior to any heat treatment because the passage can become permanently blocked by sintering of the media at high temperature. This may be minimized by preventing the media from getting into the passages by physical masking, by maintaining a positive flow of air through the passages during blasting, and by avoiding blasting into cooling passages. Any trapped media can be removed by thorough flushing of all passages after blasting. It is good practice to inspect the passages for flow after any abrasive cleaning step that precedes a heat treatment.

6.1.6 Nondestructively identify the alloy from which each blade is manufactured using X-ray fluorescence spectroscopy. If any alloy other than U-520 is identified, inform Purchaser immediately.

6.1.7 FPT all blades following procedures outlined in the U.S. Military Specification MIL-I-6866B using method Type 1, A, B, C, or D or following procedures outlined in ASTM E165 using method A, Type 1, 2, or 3 with a level 3 sensitivity penetrant. Document the location and extent of all cracks, dents, wear, corrosion/erosion, and missing material on the forms attached as Appendix II.

6.1.8 Select one blade for incoming destructive evaluation. This blade shall be typical of the condition and service history of the blades being repaired but may be a blade that is damaged beyond repair limits. Written authorization from the Purchaser permitting destructive examination of the blade selected must be obtained prior to proceeding with the examination. The condition of the surface and microstructure shall be characterized as identified in the procedure attached as Appendix III. The balance of the material from this blade shall be saved for use as control material, as specified in paragraph 6.2.1.

6.1.9 Prepare a detailed report outlining the repairs, heat treatment cycles, and procedures to be used and:

- Obtain written approval from the Purchaser for any proposed changes to this guideline
- Obtain written or verbal authorization from the Purchaser to proceed with the repairs

6.2 Blade Repair Procedures

6.2.1 Control material from the destructively examined blade or other Udimet 520 material specified by the Purchaser shall be processed with each lot of blades. Sufficient material must be included in each lot for tests required in 6.2.2 and 6.2.26.

6.2.2 Remove the coating by physical or chemical means, while ensuring no excessive base metal attack. Control samples of Udimet 520 alloy shall be processed through any chemical stripping procedure (each lot) and examined metallographically for intergranular attack, which shall not exceed the limits defined in 5.6.2. Each blade shall be examined for complete coating removal by heat tinting or etching.

6.2.3 Dress surfaces as required to remove oxidation, corrosion scale, and pitting to a maximum depth of 0.010 inches (0.25 mm) or 1/3 of the local section thickness, whichever is less. Thoroughly degrease components using trichloroethane or equivalent.

6.2.4 Solution anneal the blades at a temperature of 2050 ±15°F (1120 ±8°C) for a minimum of 2 hours in a vacuum of 1 micron of mercury (1.3×10^{-3} millibar), or better. Fixture parts using nickel or iron base fixture materials with the parts supported uniformly to prevent distortion. Avoid supporting the parts by any thin sections.

6.2.5 FPT all blades following procedures outlined in paragraph 6.1.7. Document the location and extent of any defects not identified in paragraph 6.1.7 using the forms attached as Appendix II.

6.2.6 Prepare the areas of the blades to be repaired by removing the existing cracks and defects using abrasive grinding and FPT to ensure that the cracks are completely removed. Areas with defects outside the repair limits specified in paragraph 5.1 can be blended to remove them within the manufacturer’s blending limits. Grinding tools and procedures to be used shall be identical to those used in the original process qualification (7.1.2).

6.2.7 After weld preparation, the Purchaser shall be informed and allowed to inspect the components.

6.2.8 Weld repair the components using gas tungsten arc or plasma transferred arc welding methods with filler metals identified in 5.2. Areas to be welded must be free of oxide, grease, dirt, and penetrant chemicals. All welds must be prepared using full penetration welds in the region being repaired. Weld repairs beyond the limits outlined in paragraph 5.1 are not allowed. Weld procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.9 Grind and polish the repaired areas to restore the original contours and dimensions. Restore any cooling holes plugged during repair to original dimensions. Grinding tools and procedures to be used shall be identical to those used in the original process qualification (7.1.2).

6.2.10 Check all cooling holes to ensure that they meet the requirements of 5.4.4. Record results (pass/fail) by serial number.

6.2.11 FPT the blades following procedures outlined in paragraph 6.1.7 to the acceptance limits in 5.3. Record results (pass/fail) by serial number and map the location of all repaired areas on the forms attached as Appendix II.

6.2.12 Parts that fail to meet the criteria of paragraph 5.3 may be recycled to repair any defects beginning at paragraph 6.2.6.

6.2.13 Radiograph all welded areas of the blades following the procedures outlined in U.S. Military Specification MIL-STD-453C or ASTM E94 to the acceptance limits defined in 5.3. Record results (pass/fail) by serial number.

6.2.14 Parts that fail to meet the criteria of paragraph 5.3 may be recycled to repair any defects beginning at paragraph 6.2.6.

6.2.15 Thoroughly degrease components using trichloroethane or equivalent.

6.2.16 Hot Isostatic Press (HIP) the blades (if determined necessary by destructive evaluation; see Appendix III). Fixture parts using nickel or iron base fixture materials with the parts supported uniformly to prevent distortion. Avoid supporting the parts by any thin sections. The blades shall be processed at a temperature of 2050 ±25°F (1120 ±15°C) for a minimum period of 2 hours at a minimum pressure of 15,000 psi (103 MPa). The inert gas used must contain no greater than 25 ppm impurities.

6.2.17 Immediately following HIP (if performed) and before any surface cleaning or blasting, liquid penetrant inspect the entire blade using procedures outlined in paragraph 6.1.7 and the acceptance limits defined in 5.3.

6.2.18 Thoroughly degrease components using trichloroethane or equivalent.

6.2.19 Coat airfoils of blades, as shown in Figure 9-1 and as specified by the Purchaser.

Note
Coating thermal cycles must be matched to the heat treatment for the alloy to develop appropriate mechanical properties. For this reason, coating may be performed before, during, or after the heat treatment specified in paragraph 6.2.21.

6.2.20 Thoroughly degrease components using trichloroethane or equivalent.

6.2.21 Vacuum heat treat the components, using the cycle used in the original process qualification (7.1.2) to restore the Udimet 520 properties to the minimum levels outlined in paragraphs 5.5 and 5.6 of this guideline.

Note
The Udimet 520 alloy developer recommends a heat treatment of:
4 hours at 2025°F (1107°C)/Gas quench to room temperature
24 hours at 1550°F (843°C)/Gas quench to room temperature
16 hours at 1400°F (760°C)/Gas quench to room temperature

6.2.22 Immediately following heat treatment and before any surface cleaning or blasting, liquid penetrant inspect the entire blade using procedures outlined in paragraph 6.1.7 and the acceptance limits defined in 5.3.

6.2.23 Clean blade shank and dovetail serrations using appropriate means such as blasting with glass beads. Light blasting pressures must be used to prevent any distortion of the serrations.

6.2.24 Flow check all cooling holes to ensure that all passages are open by passing water through the cooling air inlet. Each hole shall be flowing freely. Alternative flow tests may be employed if approved in writing by the Purchaser. Record the results (pass/fail) by serial number.

6.2.25 Dimensionally check all blades to ensure conformance with 5.4.1 and 5.4.5. Record the results on the forms attached as Appendix I. Tip dimensions may be checked with a Fixture in lieu of actual measurement, provided all dimensions identified on the Forms are checked by the Fixture.

6.2.26 Production Control Tests. Control material from each lot of blades shall be subject to the following qualification tests.

6.2.26.1 Mechanical Testing. After the final heat treatment, two stress rupture test bars of 0.160 inch (4.0 mm) minimum diameter will be machined from the test material for each lot and tested according to ASTM E-139. The sample material shall meet the requirements specified in 5.5. If necessary, a re-test of two specimens is permitted. Failure of the specimens to meet the minimum requirements shall subject the entire lot to rejection.

6.2.26.2 Metallography. Metallographic samples will be prepared from the test material after processing and examined for compliance with 5.6.1, 5.6.2, and 5.6.4.

6.2.27 Moment weigh and computer sequence blades and provide written documentation of the sequence by serial number. Net unbalance is to be documented.

6.2.28 Arrange a pre-shipment inspection with the Purchaser to:

- Review vendor's documentation, including heat treat charts and quality control test reports
- Visual inspection
- Deliver Purchaser copy of documentation

6.2.29 Package and ship parts in suitable containers that will prevent component contact and damage under rigorous handling conditions. All parts that are lost or damaged beyond repair shall be back charged up to the cost of replacement by OEM parts.

6.2.30 Advise Purchaser of information such as the shipping date, route, and carrier.

6.2.31 Issue final report outlining repair process used and containing all documentation required in paragraph 7.2.

7 Quality Requirements

7.1 Pre-Production Qualification

7.1.1 Vendor Audits. Prior to placing a blade repair order of any sort with a specific vendor, the vendor's facilities, quality control system, and general operation shall be audited for capability to adequately perform turbine component repair by representative(s) from the Purchaser's purchasing, quality control, and engineering organizations. Approval shall be granted for a period specified by the Purchaser but may be removed by the Purchaser for inadequate vendor performance at any time.

7.1.2 Technical Review and First Article Inspection. For each specific repair process, the vendor will be required to submit a description of the process to the Purchaser for review. The supplier will also be required to process two blades (and/or other sample material identified by the Purchaser) through the entire process for nondestructive and destructive examination, by the Purchaser, for compliance with the requirements of paragraph 5. Based on the results, the Purchaser will approve the process for use at the vendor. The vendor shall obtain written approval by the Purchaser for any change to the process and, at the Purchaser's option, shall be required to prepare an additional first article for approval.

7.1.3 Personnel Qualifications. Inspection personnel shall be qualified to ASNT Recommended Practice No. SNT-TC-3A Level II or III.

7.2 Documentation and Certification

7.2.1 Quality Control Tests. In-process and final quality control tests shall be performed, as identified in paragraph 6. Results of all required testing shall be recorded by blade serial number. A certified copy shall be given to the Purchaser's representative at the pre-shipment inspection.

7.2.2 Processing Records. Processing records shall be maintained in sufficient detail to indicate compliance with this guideline and to allow traceability by lot. A copy of these records shall be given to the Purchaser's representative at the pre-shipment inspection.

7.2.3 Certificate of Compliance. All processing and quality control records shall be reviewed by the vendor to verify compliance with this guideline and the purchase order. Any deviations shall be reported immediately to the Purchaser and may be cause for rejection. A document certifying that all aspects of this guideline and the purchase order have been met shall be signed by the responsible vendor representative and shall be presented to the Purchaser with the repair report. This document shall include:

a) Purchase order number

b) Purchaser guideline number

c) Purchaser drawing number

d) Blade serial numbers and final disposition

e) Heat treatment lots by serial number

f) A copy of all documents approving deviations from the requirements of this guideline

7.2.4 Records. All process control records and quality control test results shall be maintained on file by the vendor for a period of seven years. This information shall be made available to the Purchaser upon request.

7.2.5 Final Report. At completion of the repair process, a final report shall be issued and shall contain:

a) A description of the complete repair process

b) A mapping of all defects identified at paragraph 6.1.4, 6.1.7, and 6.2.5 (use forms attached as Appendix II)

c) A mapping of all repair locations (use forms attached as Appendix II)

d) A copy of all incoming, in-process, and final dimensional inspection forms (use forms attached as Appendix I)

e) A copy of final FPT and flow check reports

f) A copy of the moment weight/computer sequence report

g) A copy of the certificate of compliance

h) A copy of all production control test results

7.3 Acceptance and Disposition

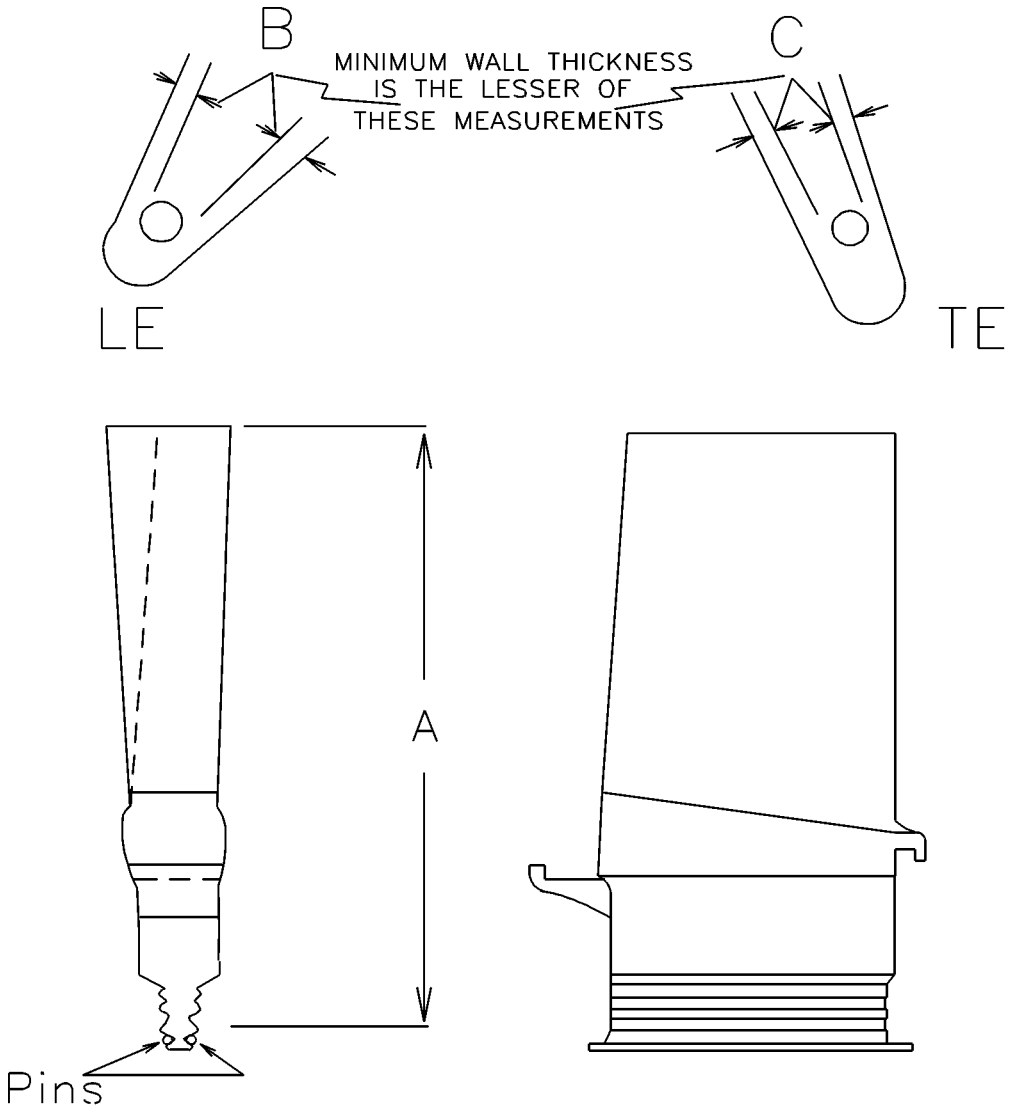
7.3.1 All deviant parts shall be plainly labeled in a nondestructive manner, isolated from the batch and held for Purchaser disposition.

7.3.2 Blades not meeting the requirements of this guideline, the purchase order, and referenced drawings shall be rejected.

7.4 Access

The Purchaser shall be allowed reasonable access to inspect components at all times during the repair process.

Appendix I - Dimensional Inspection Forms



NOTES:

1. Measure “A” on 10% of blades at incoming inspection. Pins to be installed in bottom serrations. Record pin diameter used on Form I-B.
2. Measure “B” and “C” at Leading and Trailing edge cooling holes on all blades at incoming and final inspection.
3. Measure “A” on all blades at final inspection.
4. Record dimensions on Form I-B.
5. Dimension “A” may be checked with a Fixture. Record results (pass/fail) on Form I-B.

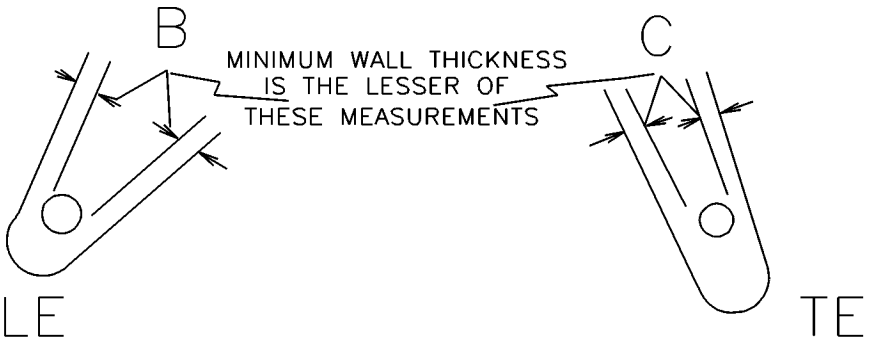
Form I-A
Westinghouse W501 First Stage Blade Dimensional Inspection Form

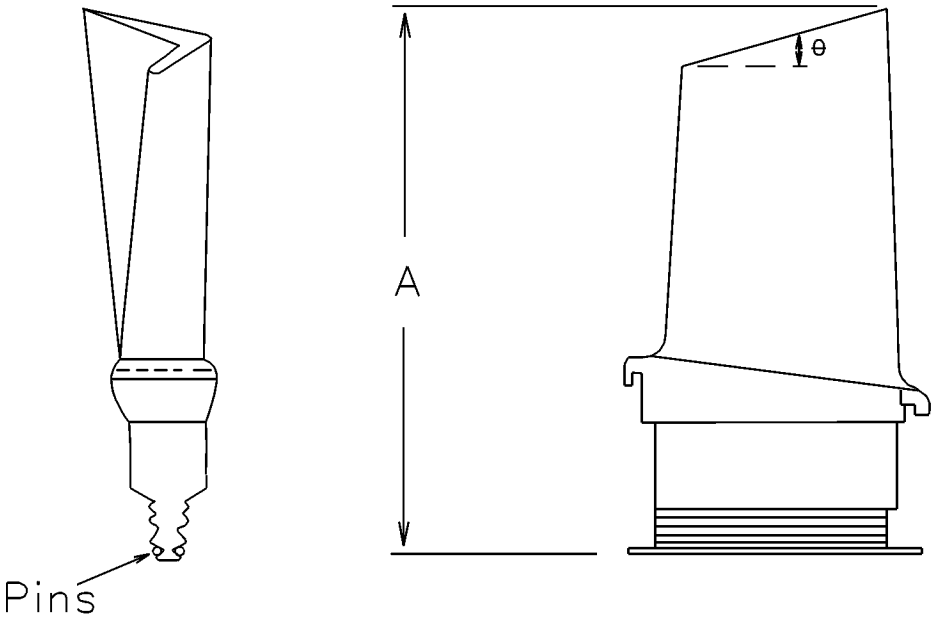
BLADE SERIAL NO.	DIMENSIONS (INCHES)		
	A	B	C
ALLOWABLE MIN.			
ALLOWABLE MAX.			

"A" Measurements made using pins of _____ inches diameter.

DATE:	**INSPECTED BY:**
OWNER:	**PLANT:**
UNIT DESIGNATION:	**TURBINE S/N:**
CHECK TYPE OF INSPECTION: ☐ **INCOMING;** ☐ **IN PROCESS;** ☐ **FINAL**	

Form I-B
Westinghouse W501 First Stage Blade Dimension Sheet





NOTES:

1. Measure A on 10% of blades at incoming inspection. Pins to be installed in bottom serrations. Record pin diameter used on Form I-D.
2. Measure B and C at Leading and Trailing edge cooling holes on all blades at incoming and final inspection.
3. Measure A and _ on all blades at final inspection.
4. Dimensions A and _ may be checked with a Fixture. Record results (pass/fail) on Form I-D.

Form I-C
Westinghouse W501 Second Stage Blade Dimensional Inspection Form

BLADE SERIAL NO.	A INCHES	B INCHES	C INCHES	_ DEGREES
ALLOWABLE MIN.				
ALLOWABLE MAX.				

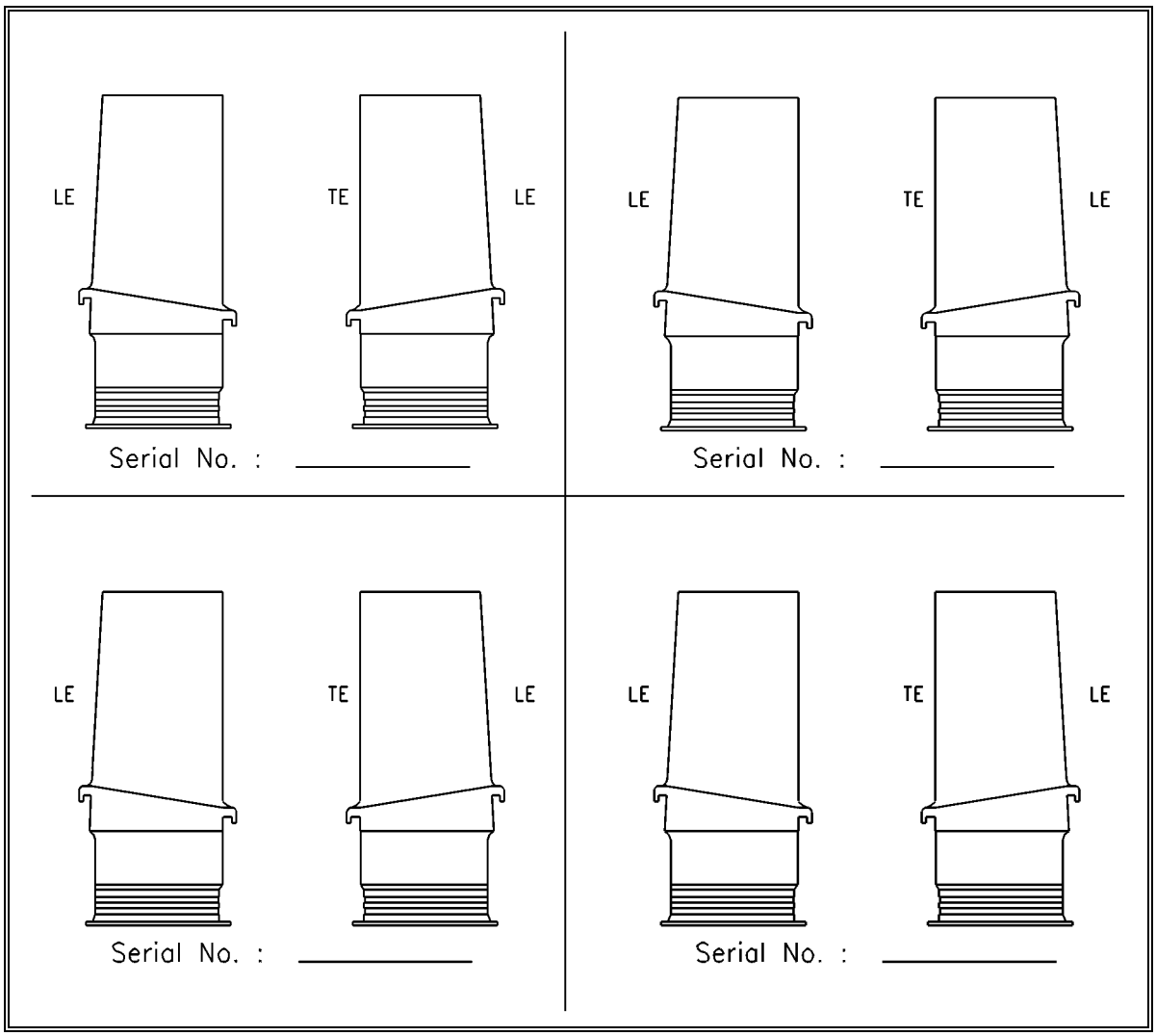
"A" Measurements made using pins of _____ inches diameter.

DATE:	**INSPECTED BY:**
OWNER:	**PLANT:**
UNIT DESIGNATION:	**TURBINE S/N:**
CHECK TYPE OF INSPECTION: ☐ **INCOMING;** ☐ **IN PROCESS;** ☐ **FINAL**	

Form I-D
Westinghouse W501 Second Stage Blade Dimension Sheet

Appendix II - Damage Assessment Forms

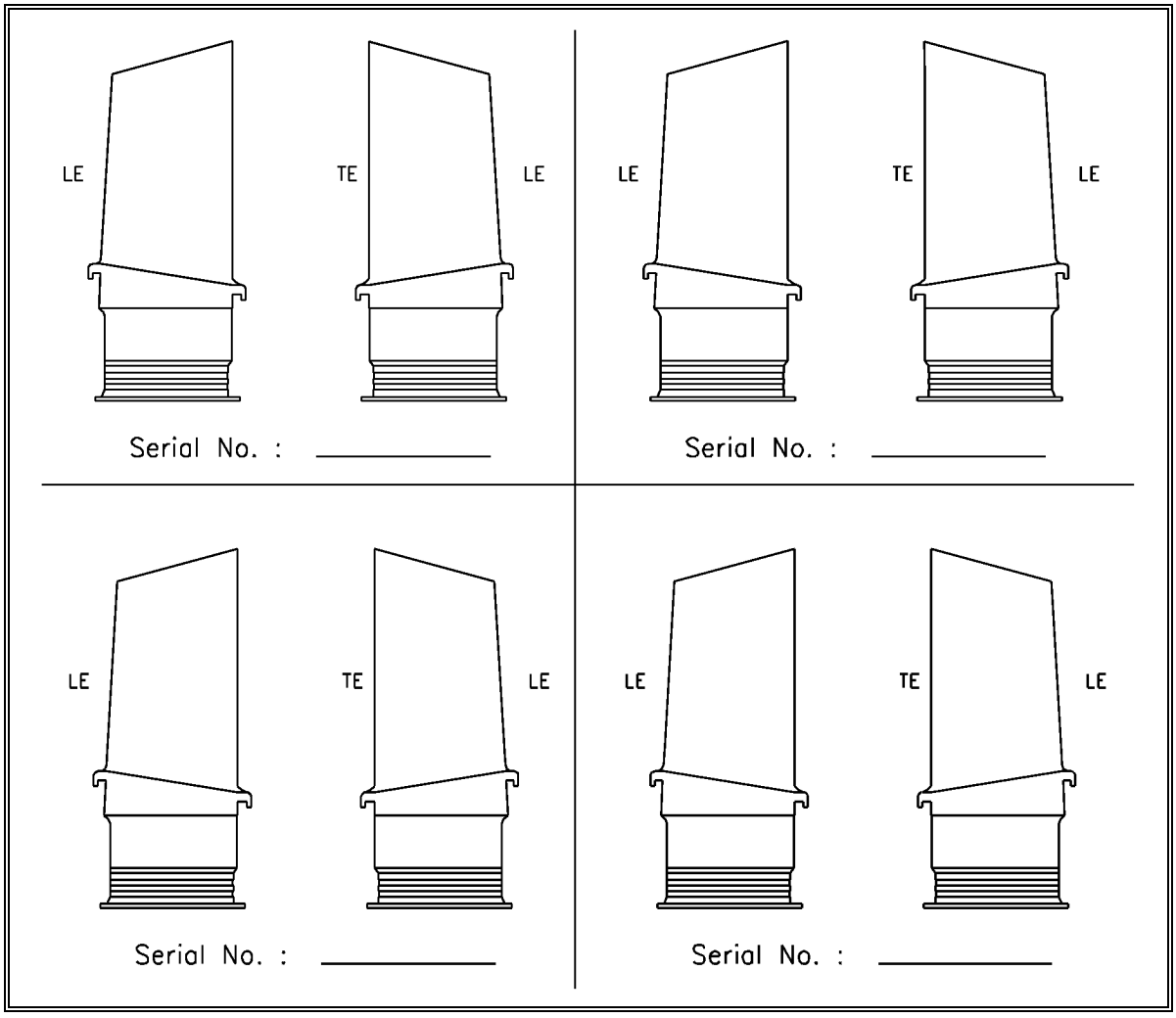
MAP LOCATION AND RECORD SIZE OF ALL DEFECTS.
KEY: CK = CRACK; D = DENT; MM = MISSING MATERIAL; C = CORROSION; E = EROSION; R = RUBBING (WEAR)
B = BLEND; RW = REPAIR WELD



DATE:	**INSPECTED BY:**
OWNER:	**PLANT:**
UNIT DESIGNATION:	**TURBINE S/N:**
CHECK TYPES OF INSPECTION: ☐ **INCOMING;** ☐ **IN PROCESS;** ☐ **FINAL;** ☐ **VISUAL;** ☐ **FPI**	

Form II-A
Westinghouse W501 First Stage Blade Damage Assessment Form

MAP LOCATION AND RECORD SIZE OF ALL DEFECTS.
KEY: CK = CRACK; D = DENT; MM = MISSING MATERIAL; C = CORROSION; E = EROSION; R = RUBBING (WEAR)
B = BLEND; RW = REPAIR WELD



DATE:	**INSPECTED BY:**
OWNER:	**PLANT:**
UNIT DESIGNATION:	**TURBINE S/N:**
CHECK TYPES OF INSPECTION: ☐ **INCOMING;** ☐ **IN PROCESS;** ☐ **FINAL;** ☐ **VISUAL;** ☐ **FPI**	

Form II-B
Westinghouse W501 Second Stage Blade Damage Assessment Form

Appendix III - Procedure for Metallurgical Examination of Turbine Blades During Repair

A. Selection of Sample Blade

1. The blade removed from the set for evaluation should be chosen to be as representative as possible of the balance of the set (that is, same service and manufacturing history).

2. Records should be made of replacement blades so they are not used in subsequent life assessments.

B. Surface Evaluation

1. Metallographic sections perpendicular to the blade surface should be examined from the upper, middle, and lower airfoil at the leading and trailing edges and any other areas that appear visually to have surface damage. Internal surfaces of cooled parts should be examined in addition to the external surfaces.

2. In uncoated blades, the total depth of environmental attack should be measured. This should include:

   i) The depth of any oxide layer

   ii) The depth of internal oxidation

   iii) The depth of the alloy depleted zone

   iv) The depth of intergranular attack

   v) An indication of the amount of metal lost due to corrosion/erosion

3. Uncoated blades should be considered reusable if the total depth of attack is less than 0.002 inches (0.05 mm). Blades with greater than 0.002 inches (0.05 mm) may also be used if the damage can be removed by dressing within the manufacturer's allowable limits prior to any heat treatments. For improved life, the use of a protective coating should be considered in such instances.

4. On coated blades, the remaining coating thickness, excluding any diffusion layer, should be compared in the best and worst sections of the blade. The original thickness of coating should be estimated based on the remaining thickness in the best area, and the depth of attack should be judged by the remaining thickness in the worst areas. Any internally oxidized material shall not be counted as part of the coating thickness.

5. Coating life should be considered exhausted if less than 1/3 of the original coating thickness remains unattacked. Such blades may be reused by removal and re-application of the protective coating. If base metal attack has occurred, the damaged areas must be removed by dressing within the manufacturer's allowable limits prior to re-coating. Blades with attack deeper than the manufacturer's allowable dressing limits are unrepairable.

6. In addition to the thickness, the coating phases should be examined. For an aluminide or modified Al coating, there should be a single phase beta (NiAl) structure. A-2-phase beta +

gamma prime, 2-phase gamma + gamma prime, or single phase gamma structure means the coating has exhausted its life, regardless of the thickness. For an overlay coating, the criteria depend upon the original coating structure. If this structure is initially a single beta phase, or CoAl, NiAl, then the same description for an aluminide applies. If the structure is initially a 2-phase structure, then the situation is more difficult. If the beta phase has disappeared, then the life of the coating is exhausted. If the volume fraction of beta is 50% less than original, then life is also exhausted.

C. Microstructural Evaluation

1. Sections from the upper, middle, and lower airfoil and root section of the blade and from any other location that appear visually to have been at higher temperature should be prepared for metallographic examination. Sections should be oriented in a direction parallel to the blade radial direction.

2. All samples should be examined by optical microscopy for the presence of intergranular creep voids.

3. Any blades in which creep voids are identified are unserviceable. They may be repaired by Hot Isostatic Press rejuvenation.

4. All samples should be examined by optical microscopy for microstructural instabilities. Changes from the new material microstructure can be identified by comparing airfoil samples with those from the root. In particular, the presence of acicular or plate-like phases, growth of grain boundary carbides especially forming a continuous film, and gamma prime aging, if visible, should be noted.

5. The microstructure of the gamma prime phase should be examined by an electron microscope technique. Samples should be prepared from the areas showing the most severe instability in Step 4 (usually the middle or upper airfoil) and from the root. Comparing the structures in these two areas, the degree of service aging can be identified. The diameter of the particles should be measured to determine the amount of particle growth that has occurred. In alloys with duplex gamma prime microstructures, the absence of fine secondary gamma prime particles and the agglomeration of the primary particles should be recorded, if it has occurred.

6. Any deviations from normal microstructure should be noted.

2
EPRI GUIDELINE 501AAVAN – REPAIR GUIDELINE FOR WESTINGHOUSE W501 FIRST STAGE VANE SEGMENTS MANUFACTURED FROM X-45 ALLOY

Revised April 2000

April 2000 Revisions: Guideline format/software converted to Microsoft Word®. Minor corrections/editing of text and forms.

> **Note**
> The use of repair procedures and guidelines supplied by the Original Equipment Manufacturer (OEM), if available, in conjunction with, and to supplement this guideline, is permitted and encouraged. However, Purchaser expects the requirements of this guideline to be met by the repair vendor as a minimum condition for acceptable repairs. Conflicts between this and any other guidelines should be brought to the Purchaser's attention for resolution.

1 Scope

1.1 Purpose

This guideline covers the minimum requirements for the weld repair and heat treatment of Westinghouse W501 A through B Series First Stage vane segments manufactured from X-45 alloy (57Co 25.5Cr 10Ni 7W 0.25C 0.01B). Vane segments repaired to these requirements should provide service life approaching that of new components.

> **Note**
> Alloy X-45 was employed in the earlier W501 models A, AA, and B machines and was cast in multiple airfoil segments (three vanes per segment). Some of these machines (generally model B) have been retrofitted with vanes made from ECY-768 alloy. This guideline applies to X-45 alloy vanes only.

1.2 Application

Weld repair of vane segments is performed to repair physical damage such as rubbing, cracking, impact damage, and erosion. Heat treatments are required prior to welding to improve ductility and after welding to stress relieve weldments and to restore the appropriate microstructure and properties.

2 Definitions

2.1 Lot

A group of parts that is processed through the entire repair cycle at the same time and heat treated in the same furnace at the same time throughout the repair cycle. If a group of parts being repaired at the same time is split into two or more subgroups for heat treatment, each subgroup shall constitute a lot.

2.2 EDM

Electrical Discharge Machining (EDM) is a process in which metal is removed by an electrical spark in a dielectric fluid.

2.3 Linear Indications

Nondestructive testing indications with a length of three times the width or greater.

2.4 Nonlinear Indications

Nondestructive testing indications with a length of less than three times the width.

2.5 FPT

Fluorescent Penetrant Testing (FPT).

3 Applicable Documents

3.1 Guidelines

The following documents form a part of this guideline to the extent specified herein. Unless otherwise specified, the latest issue shall apply.

U.S. Military Specification MIL-I-6866B
"Inspection, Liquid Penetrant"

Aerospace Material Guideline 5789B
"Wire, Welding 54Co 25.5Cr 10.5Ni 7.5W" (October 1987)

Aerospace Materials Guideline 5801B
"Wire, Welding 39Co 22Cr 22Ni 14.5W 0.07La" (January 1986)

ASTM E165
"Standard Practice for Liquid Penetrant Inspection Method"

ASNT Recommended Practice No. SNT-TC-1A
"Personnel Qualification and Certification in Nondestructive Testing"

ANSI B46.1
"Surface Texture"

3.2 Precedence of Documents

Specific requirements contained in purchase order instructions or drawings may be issued to supplement the requirements of this document. In cases of conflict, the purchase order shall take precedence followed by applicable drawings, followed by this document.

4 General Requirements

General requirements are typically addressed in Purchase Orders for component repairs.

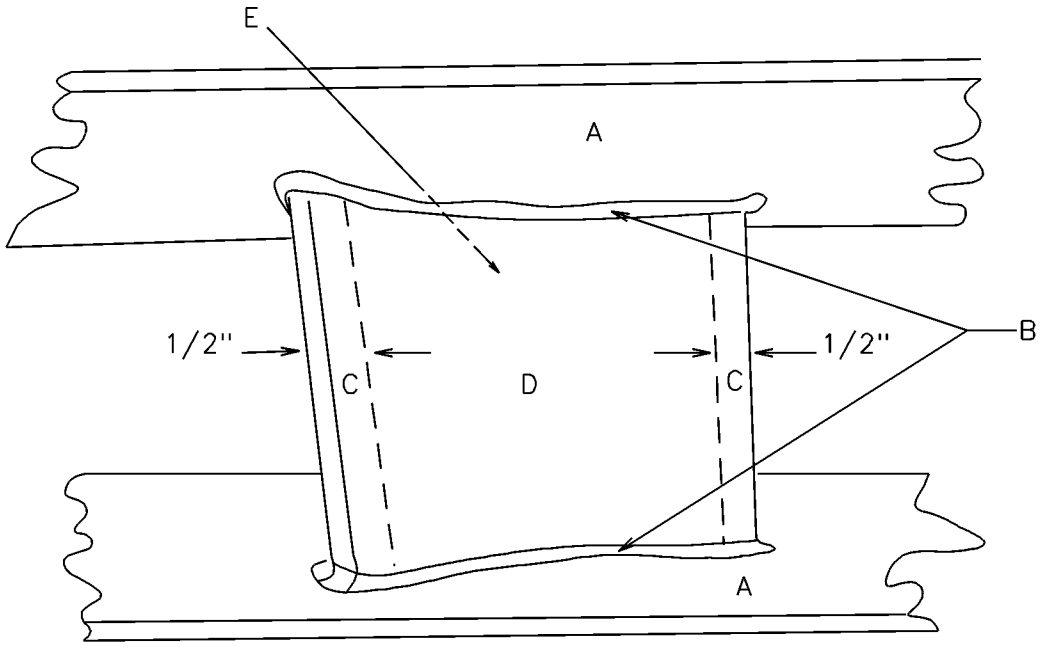
5 Technical Requirements

5.1 Repair Materials

Repairs shall be performed by gas tungsten arc welding or plasma transferred arc welding using AMS 5789B (Alternative designations: Stellite 31, X40, Haynes Stellite Alloy, No 31, UNS R30031) or AMS 5801B (Alternative designations: Haynes 188, HS 188, HA 188, UNS R30188) filler wire.

5.2 Nondestructive Testing Acceptance Limits

Critical and noncritical areas of the component are defined in Figures 2-1 and 2-2. Linear indications are permitted in the critical areas of the component up to 0.030 inch (0.76 mm) in length provided they are spaced by 5 times their length. Nonlinear indications are permitted in critical locations up to 0.060 inch (1.5 mm) diameter, or up to a diameter equal to 25% of the local section thickness, whichever is smaller. Linear indications up to 0.060 inch (1.5 mm) long are permitted in noncritical areas of the component provided that they are spaced by at least 5 times their length. Nonlinear indications in noncritical areas of the component are permitted up to 0.060 inch (1.5 mm). Nonlinear indications in non-gas path areas are permitted up to 0.125 inch (3.2 mm). No through-going indications are permitted.



1 Inch = 25.4 mm

Looking with Flow
(Upstream and Pressure Side)

Figure 2-1
Westinghouse W501 First Stage Vane Critical Areas – Pressure Side

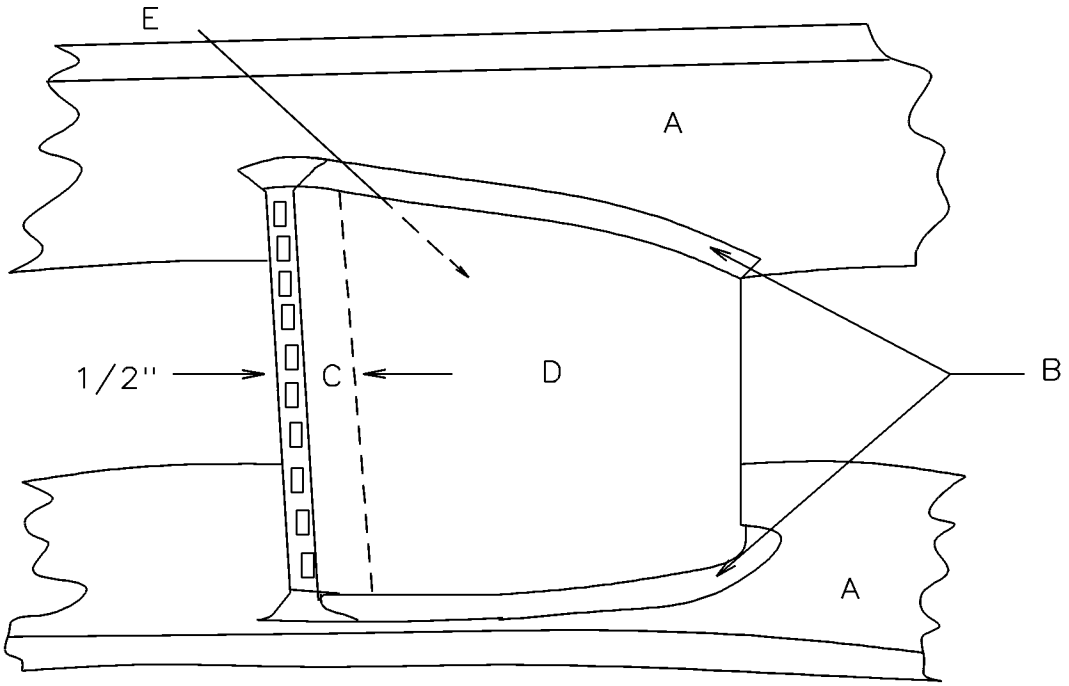
Area A All surfaces of the shroud except the airfoil fillet radius areas are noncritical areas.

Area B That portion of the airfoil starting at the line of tangency between the shroud and fillet radius and extending parallel to the airfoil span for 1/2 inch (12.7 mm) around the whole airfoil contour are critical areas.

Area C That portion of the airfoil leading edge (LE) or trailing edge (TE) beginning at the mid LE or TE radius line and extending 1/2 inch (12.7 mm) on both concave and convex airfoil surfaces and bounded on both outer and inner ends at the airfoil intercept with Area B are critical areas.

Area D All portions of the airfoil not included in Areas B or C are noncritical areas.

Area E All internal airfoil surfaces and insert seats are critical in the same B and C regions and noncritical in the D region.



1 Inch = 25.4 mm

Looking Against Flow
(Downstream and Suction Side)

Figure 2-2
Westinghouse W501 First Stage Vane Critical Areas – Suction Side

Area A All surfaces of the shroud except the airfoil fillet radius areas are noncritical areas.

Area B That portion of the airfoil starting at the line of tangency between the shroud and fillet radius and extending parallel to the airfoil span for 1/2 inch (12.7 mm) around the whole airfoil contour are critical areas.

Area C That portion of the airfoil leading edge (LE) or trailing edge (TE) beginning at the mid LE or TE radius line and extending 1/2 inch (12.7 mm) on both concave and convex airfoil surfaces and bounded on both outer and inner ends at the airfoil intercept with Area B are critical areas.

Area D All portions of the airfoil not included in Areas B or C are noncritical areas.

Area E All internal airfoil surfaces and insert seats are critical in the same B and C regions and noncritical in the D region.

5.3 Dimensional Requirements

5.3.1 Gas path dimensions, axial and radial location, and throat area shall be within the range identified on the inspection forms attached as Appendix I.

5.3.2 Gas path profiles shall be restored to the same contours as new components using smooth blends between the original material and repaired areas.

5.3.3 Surface finish on the repaired components shall be 80 micro-inches (2 microns) Ra or better, measured according to ANSI B46.1.

5.3.4 Cooling passages shall be restored to original dimensions.

Note
OEM-supplied dimensional information contained in manuals and other supporting documentation should be used as reference dimensions where available. In the absence of such information, new or undamaged components may be measured and appropriate tolerances applied.

5.3.5 The repaired vane segment shall properly fit a dimensionally correct blade ring.

5.4 Microstructural Requirements

5.4.1 The re-casted layer on any EDM surface shall not exceed 0.001 inch (0.025 mm).

5.4.2 Process-related alloy depletion, oxidation, nitriding, and intergranular attack at the surface of the components shall not exceed 0.001 inch (0.025 mm).

6 Processing Requirements

All process procedures applied during the repair of the components shall be the same as those used in the preparation of first article qualification samples and described in the process description as specified in paragraph 7.1.2.

6.1 Initial Inspection

6.1.1 Receive material and check for shipping damage. Check purchase order, material, and shipping papers to verify that the material received is correctly identified, fully accounted for, and that the repairs requested are reasonable.

6.1.2 Advise Purchaser immediately of any shipping damage.

6.1.3 Dimensionally inspect each segment for gas path dimensions, axial and radial location, and throat area and record the results on the forms attached as Appendix I. Gas path diameters and axial and radial location may be measured in a checking fixture in lieu of actual measurement, provided all dimensions identified on the forms are checked by the fixture.

Note
Throat area distortion during service has not historically been a problem with Westinghouse W501 vane segments. Throat area measurements should be made if there is any obvious bowing of the trailing edge or after any significant weld repair of the trailing edge. A fixture is required to hold adjacent segments to make these measurements. The throat area measurement forms are included herein for use if the measurements are deemed necessary or if specifically called for by the Purchaser.

6.1.4 Visually inspect each segment for the following:

- Rubs and wear
- Trailing edge bowing
- Surface erosion loss
- Oxidation/corrosion
- Impact damage
- Cracks
- Blocked or damaged cooling holes

Record the results on the forms attached in Appendix II.

6.1.5 Remove the core plugs, cover plates, and clean and inspect them. Fully open any blocked holes. Note if there is any interference or unusual difficulty encountered when removing the core plugs. Core plugs that were damaged during removal or service must be replaced with components that match OEM material and dimensional tolerances.

Note
A proper core design and fit of the core plugs within the vane cavity are critical to the proper functioning of the vane cooling system.

6.1.6 Examine a sample from the leading and trailing edge of one of the airfoils using the procedure attached in Appendix III. If the depth of the oxide scale or pitting exceeds 0.020 inches (0.51 mm) or 1/3 or the local section thickness, whichever is less, the vane should be considered unrepairable. Coupon type repairs are permissible, if the damage is localized.

6.1.7 Clean the segments using grit blasting with 220 grit aluminum oxide. Avoid excessive blasting and take necessary precautions to prevent blockage of cooling holes.

Note
Cooling passages can become filled with media during abrasive cleaning. It is imperative that the media be removed prior to any heat treatment because the passage can become permanently blocked by sintering of the media at high temperature. This may be minimized by preventing the media from getting into the passages by physical masking, by maintaining a positive flow of air through the passages during blasting, and by avoiding blasting into cooling passages. Any trapped media can be removed by thorough flushing of all passages after blasting. It is good practice to inspect the passages for flow after any abrasive cleaning step that precedes a heat treatment.

6.1.8 FPT all segments following procedures outlined in the U.S. Military Specification MIL-I-6866B using Type 1, A, B, C, or D or the procedures in ASTM E165 using Method A, Type 1, 2, or 3, using a level 3 sensitivity penetrant. Inspect both internal and external surfaces. Document the location and extent of all cracks, dents, wear, corrosion/erosion, and missing material on the form provided in Appendix II.

6.1.9 Prepare a report delineating condition of the components and outlining the repairs. At this point, the vendor must:

- Obtain written approval for any proposed changes to this guideline
- Obtain written or verbal authorization from the Purchaser to proceed with the repairs
- Obtain written authorization to replace any core plugs

6.2 Repair Procedure

6.2.1 If the vane segments have been coated, remove the coating by physical or chemical means, while ensuring no excessive base metal attack. Control samples of X45 alloy shall be processed through any chemical stripping procedure (each lot) and examined metallographically for intergranular attack, which shall not exceed the limits defined in 5.4.2. Each segment shall be examined for complete coating removal by heat tinting or etching.

6.2.2 Thoroughly degrease components using trichloroethane or equivalent. Dress surfaces as required to remove any oxidation or corrosion scale or pitting to a maximum depth of 0.020 inches (.51 mm) or 1/3 of the location section thickness, whichever is less.

6.2.3 Solution anneal the vane segments in vacuum, hydrogen, or argon at 2100°F ±15°F (1149°C ±8°C) for 4 hours. Fixture parts using nickel or iron base fixture materials with the parts supported uniformly to prevent distortion. Avoid supporting the parts by any thin sections.

> **Note**
> Based on the experience of the repair vendor, the processing and operational history of the vane segment in question, the microstructure of the vane as determined per paragraph 6.1.6, and the extent of the defects being repaired, it may be preferable to omit the solution anneal step. Purchaser approval must be obtained in this case.

6.2.4 Examine a sample from the trailing edge of one of the airfoils using the procedure attached in Appendix III.

6.2.5 FPT all vane segments following procedures outlined in paragraph 6.1.8. Document the location and extent of any defects not identified in paragraph 6.1.8 using the form attached as Appendix II.

6.2.6 Warm form at greater than 1400°F (760°C) deformed areas to restore the correct contour of airfoils that have bowed, bent, or warped during service and to correct throat opening.

6.2.7 Prepare the areas of the segments to be repaired by grinding out the existing cracks and defects and FPT to ensure that the cracks are completely removed. Grinding tools and procedures to be used shall be identical to those used in the original process qualification (7.1.2). Sections may be removed for replacement with patches of matching alloy composition provided that, after the repairs are completed, the cooling hole configuration is unchanged.

6.2.8 After weld preparation, the Purchaser shall be informed and allowed to inspect the components.

6.2.9 Weld repair the components using gas tungsten arc or plasma transferred arc welding methods. Areas to be welded must be free of oxide, grease, dirt, and penetrant chemicals. All areas must be welded using full penetration welds through the section being repaired. Weld procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.10 Braze, diffusion brazing, or other alternative techniques for repair of craze and other defects are not permissible in critical areas. They are permitted in noncritical areas of the segments, as defined in Figures 2-1 and 2-2, provided that the process used is identical to that used in the original process qualification (7.1.2).

Note
Braze repairs may make future weld repair of the vanes difficult, due to embrittlement in the brazed region.

6.2.11 Grind and polish the repaired areas to restore the original contours and dimensions. Restore any cooling holes plugged during repair to original dimensions. Grinding tools and procedures to be used shall be identical to those used in the original process qualification (7.1.2).

6.2.12 FPT the complete vane segment following procedures outlined in paragraph 6.1.8 using the acceptance criteria identified in paragraph 5.2.

6.2.13 Parts that fail to meet the criteria of paragraph 5.2 may be recycled to repair any defects beginning at paragraph 6.2.7. Parts may be recycled to paragraph 6.2.2 for stress relief, at the vendor's option.

6.2.14 Thoroughly degrease components using trichloroethane or equivalent.

6.2.15 After all repairs are complete, vacuum heat treat the vane segments at 2100°F ±15°F (1149°C ±8°C) for 4 hours, furnace cool at 10 to 45°F/min to 1800°F ±15°F (982°C ±8°C) and hold for 4 hours, furnace cool at 10 to 45°F/min to 1000°F (538°C), and gas quench to room temperature. Fixture parts using nickel or iron base fixture materials with the parts supported uniformly. Avoid supporting the parts by any thin sections.

6.2.16 Immediately following heat treatment and before any surface cleaning or blasting, FPT the entire segment using the method outlined in paragraph 6.1.8 and acceptance criteria outlined in paragraph 5.2. Record the results on the forms attached as Appendix II.

6.2.17 If the repaired vane segment is to be coated for further service, the coating should be applied at this time using a Purchaser-approved process.

6.2.18 Install the core plugs and cover plates and inspect welds per paragraph 6.2.12, noncritical areas. Fit-up and welding procedure shall be identical to those used in the original process qualification.

6.2.19 Flow check all cooling holes to ensure that all passages are open by passing water through the cooling air inlet. Each hole shall be flowing freely. Alternative flow tests may be employed if approved in writing by the Purchaser. Record the results (pass/fail) by serial number.

6.2.20 Dimensionally check the vanes to ensure conformance to paragraph 5.3 and record the results on the form attached in Appendix I. Gas path diameters and radial and axial location may be checked by a fixture in lieu of actual measurement, provided that all dimensions identified on the form are checked.

6.2.21 Arrange a pre-shipment inspection with the Purchaser to:

- Review documentation, including heat treatment charts, quality control test reports, and a mapping of repairs
- Perform visual inspection
- Deliver Purchaser copies of the documentation

6.2.22 Package and ship parts in suitable containers that will prevent component contact and damage under rigorous handling conditions. All parts that are lost or damaged beyond repair may be back charged up to the cost of replacement by original OEM parts.

6.2.23 Advise Purchaser of information such as the shipping date, route, and carrier.

6.2.24 Issue final report outlining repair process used and containing all documentation required in paragraph 7.2.

7 Quality Requirements

7.1 Pre-Production Qualification

7.1.1 Vendor Audit. Prior to placing a vane repair order of any sort with a specific vendor, the vendor's facilities, quality control system, and general operation shall be audited by the Purchaser for capability to adequately perform turbine component repair. Approval shall be granted for a period specified by the Purchaser but may be removed by the Purchaser for inadequate vendor performance.

7.1.2 Technical Review and First Article Inspection. For each specific repair process, the vendor will be required to submit a description of the process to the Purchaser for review. The supplier will also be required to process vane segments (and/or other sample material identified by the

Purchaser) through the entire process for nondestructive and destructive examination, by the Purchaser, for compliance with the requirements of paragraph 5. Based on the results, the Purchaser will approve the process for use at the vendor. The vendor shall obtain written approval by the Purchaser for any change to the process and, at the Purchaser's option, shall be required to prepare an additional first article for approval.

7.1.3 Personnel Qualifications. Inspection personnel shall be qualified to ASNT Recommended Practice No. SNT-TC-1A Level II or III.

7.2 Documentation and Certification

7.2.1 Quality Control Tests. In-process and final quality control tests shall be performed, as identified in paragraph 6. Results of all required testing shall be recorded by serial number. A certified copy shall be given to the Purchaser's representative at the pre-shipment inspection.

7.2.2 Processing Records. Processing records shall be maintained in sufficient detail to indicate compliance with this guideline and to allow traceability by lot. A mapping of the location, nature, and extent of repairs on each component shall be prepared and recorded by serial number. A copy of these records shall be given to the Purchaser's representative at the pre-shipment inspection.

7.2.3 Certificate of Compliance. All processing and quality control records shall be reviewed by the vendor to verify compliance with this guideline and the purchase order. Any deviations shall be reported immediately to the Purchaser and may be cause for rejection. A document certifying that all aspects of this guideline and the purchase order have been met shall be signed by the responsible vendor representative and shall be presented to the Purchaser with the final report. This document shall include:

a) Purchase order number

b) Purchaser guideline number

c) Purchaser drawing number

d) Serial numbers and final disposition

e) Heat treatment lots by serial number

f) A copy of all documents approving vendor requested deviation from the requirements of this guideline

7.2.4 Records. All process control records and quality control test results shall be maintained on file by the vendor for a period of seven years. This information shall be made available to the Purchaser upon request.

7.2.5 Final Report. At completion of the repair process, a final report shall be issued and shall contain:

a) A description of the complete repair process

b) A mapping of all defects identified at paragraph 6.1.4, 6.1.8, and 6.2.5 (use form attached as Appendix II)

c) A mapping of all repair locations (use forms attached as Appendix II)

d) A copy of all incoming, in-process, and final dimensional inspection forms (use forms attached as Appendix I)

e) A copy of final FPT and flow check reports

f) Throat area check forms (if used)

g) A copy of the certificate of compliance

7.3 Acceptance and Disposition

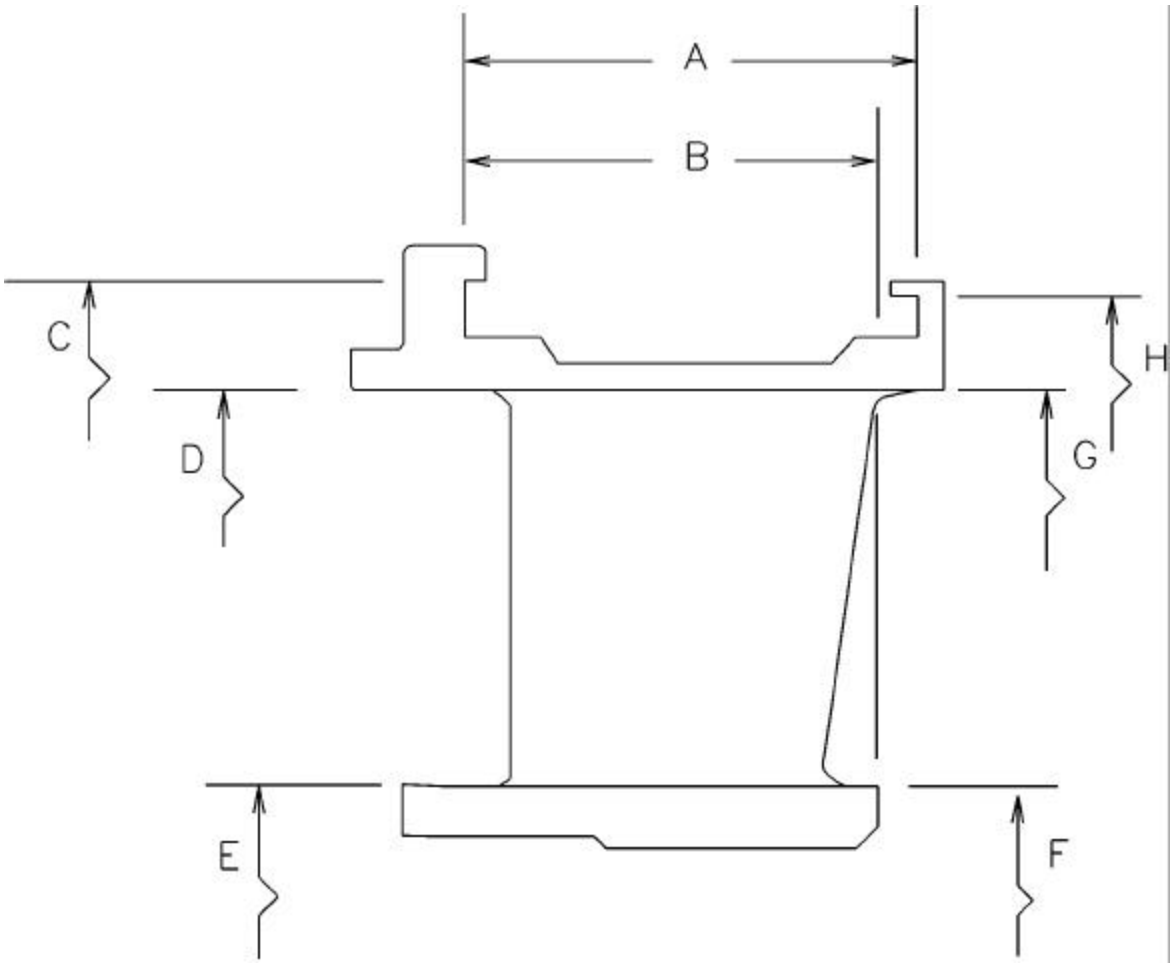
7.3.1 All deviant parts shall be plainly labeled in a nondestructive manner, isolated from the batch and held for Purchaser disposition.

7.3.2 Components not meeting the requirements of this guideline, the purchase order, and referenced drawings shall be rejected. Rejected parts shall be held for Purchaser disposition.

7.4 Access

The Purchaser shall be allowed reasonable access to inspect components at all times during the repair process.

Appendix I - Dimensional Inspection Forms



NOTES:

1. Measure dimensions A & B at center and both ends of segment.
2. C, D, E, F, G, and H are radial dimensions.
3. Record dimensions on Form I-B.
4. Checking Fixtures may be used in lieu of actual measurements, provided all dimensions identified are checked. Record results (pass/fail) on Form I-B.

Form I-A
Westinghouse W501 Multivane Segment Dimensional Inspection Form

3
EPRI GUIDELINE 501VANE – REPAIR GUIDELINE FOR WESTINGHOUSE W501 FIRST STAGE VANE SEGMENTS MANUFACTURED FROM ECY-768 ALLOY

Revised April 2000

April 2000 Revisions: Guideline format/software converted to Microsoft Word®. Minor corrections/editing of text and forms.

> **Note**
> The use of repair procedures and guidelines supplied by the Original Equipment Manufacturer (OEM), if available, in conjunction with, and to supplement this guideline, is permitted and encouraged. However, Purchaser expects the requirements of this guideline to be met by the repair vendor as a minimum condition for acceptable repairs. Conflicts between this and any other guidelines should be brought to the Purchaser's attention for resolution.

1 Scope

1.1 Purpose

This guideline covers the minimum requirements for the weld repair and heat treatment of Westinghouse W501 First Stage vane segments manufactured from the cobalt alloy ECY-768 (55Co 23.5Cr 10Ni 7W 3.5Ta 0.6C 0.2Ti 0.2Al). Both single airfoil and multiple airfoil segments are covered. Vane segments repaired to these requirements should provide service life approaching that of new components.

1.2 Application

Weld repair of vane segments is performed to repair physical damage such as rubbing, cracking, foreign object damage, and localized erosion. Heat treatments are required prior to welding to improve ductility and after welding to stress relieve weldments and to restore the appropriate microstructure and properties. The alloy ECY-768 has proven difficult to weld. For this reason, consideration should first be given to blending minor defects according to OEM blend limits, reserving weld repair for the larger defects that cannot be successfully blended.

2 Definitions

2.1 Lot

A group of parts that is processed through the entire repair cycle at the same time and heat treated in the same furnace at the same time throughout the repair cycle. If a group of parts being repaired at the same time is split into two or more subgroups for heat treatment, each subgroup shall constitute a lot.

2.2 EDM

Electrical Discharge Machining is a process in which metal is removed by an electrical spark in a dielectric fluid.

2.3 Linear Indications

Nondestructive testing indications with a length of three times the width or greater.

2.4 Nonlinear Indications

Nondestructive testing indications with a length of less than three times the width.

2.5 FPT

Fluorescent Penetrant Testing.

3 Applicable Documents

3.1 Guidelines

The following documents form a part of this guideline to the extent specified herein. Unless otherwise specified, the latest issue shall apply.

U.S. Military Specification MIL-I-6866B
“Inspection, Liquid Penetrant”

Aerospace Material Guidelines 5789B
“Wire, Welding 54Co 25.5Cr 10.5Ni 7.5W” (October 1987)

Aerospace Materials Guideline 5801B
“Wire, Welding 39Co 22Cr 22Ni 14.5W 0.07La” (January 1986)

ASTM E165
"Standard Practice for Liquid Penetrant Inspection Method"

ASNT Recommended Practice No. SNT-TC-1A
"Personnel Qualification and Certification in Nondestructive Testing"

ANSI B46.1
"Surface Texture"

3.2 Precedence of Documents

Specific requirements contained in purchase order instructions or drawings may be issued to supplement the requirements of this document. In cases of conflict, the purchase order shall take precedence followed by applicable drawings, followed by this document.

4 General Requirements

General requirements are typically addressed in Purchase Orders for component repairs.

5 Technical Requirements

5.1 Repair Materials

Repairs shall be performed by gas tungsten arc welding or plasma transferred arc welding using AMS 5789B (Alternative designations: Stellite 31, X40, Haynes Stellite Alloy No. 31, UNS R30031), AMS 5801B (Alternative designations: Haynes 188, HS 188, HA 188, UNS R30188), or MarM 918. The use of AMS 5801B is restricted to noncritical areas identified in Figures 3-1 and 3-2.

5.2 Nondestructive Testing Acceptance Limits

Critical and noncritical areas of the component are defined in Figures 3-1 and 3-2. Linear indications are permitted in the critical areas of the component up to 0.030 inch (0.76 mm) in length provided they are spaced by 5 times their length. Nonlinear indications are permitted in critical locations up to 0.060 inch (1.5 mm) diameter, or up to a diameter equal to 25% of the local section thickness, whichever is smaller. Linear indications up to 0.060 inch (1.5 mm) long are permitted in noncritical areas of the component provided that they are spaced by at least 5 times their length. Nonlinear indications in noncritical areas of the component are permitted up to 0.060 inch (1.5 mm). Nonlinear indications in non-gas path areas are permitted up to 0.125 inch (3.2 mm). No through-going indications are permitted.

5.3 Dimensional Requirements

5.3.1 Gas path dimensions, axial and radial location, and throat area shall be within the range identified on the inspection forms attached as Appendix I.

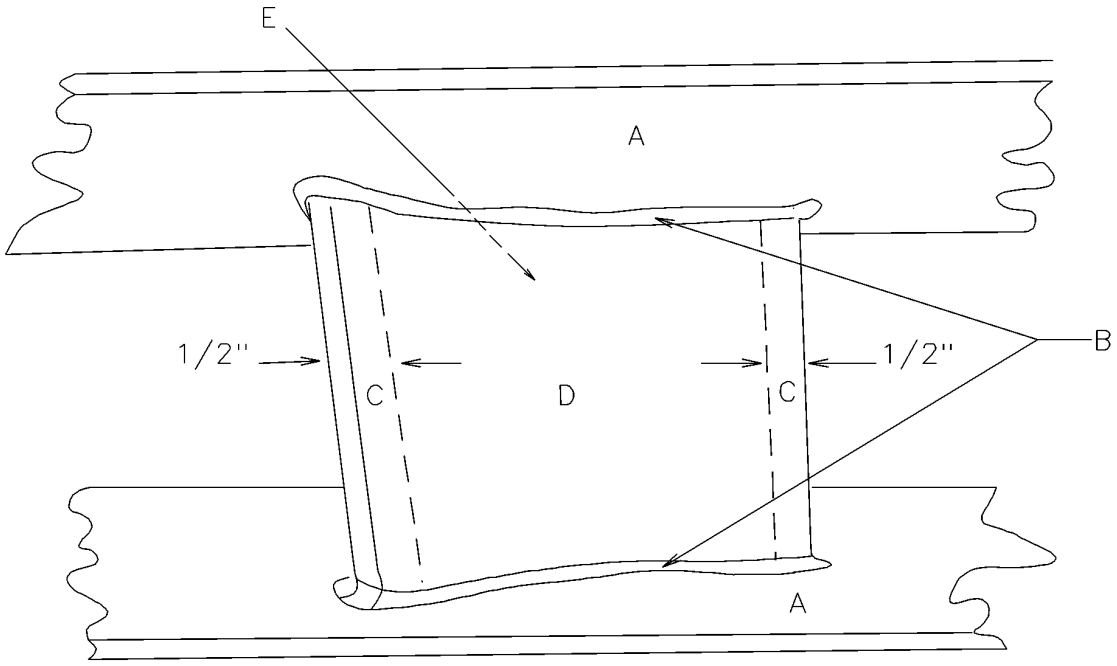


Figure 3-1
Westinghouse W501 First Stage Vane Critical Areas – Pressure Side

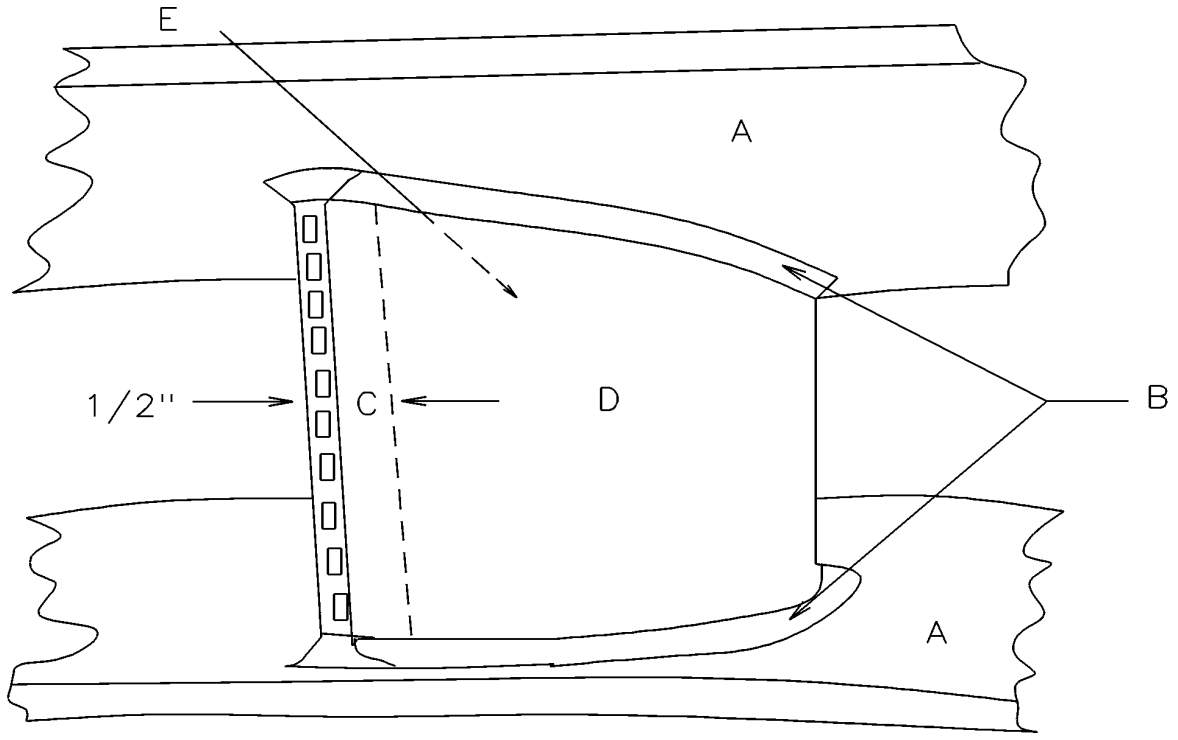
Area A All surfaces of the shroud except the airfoil fillet radius areas are noncritical areas.

Area B That portion of the airfoil starting at the line of tangency between the shroud and fillet radius and extending parallel to the airfoil span for 1/2 inch (12.7 mm) around the whole airfoil contour are critical areas.

Area C That portion of the airfoil leading edge (LE) or trailing edge (TE) beginning at the mid LE or TE radius line and extending 1/2 inch (12.7 mm) on both concave and convex airfoil surfaces and bounded on both outer and inner ends at the airfoil intercept with Area B are critical areas.

Area D All portions of the airfoil not included in Areas B or C are noncritical areas.

Area E All internal airfoil surfaces and insert seats are critical in the same B and C regions and noncritical in the D region.



1 Inch = 25.4 mm

Looking Against Flow
(Downstream and Suction Side)

Figure 3-2
Westinghouse W501 First Stage Vane Critical Areas – Suction Side

Area A All surfaces of the shroud except the airfoil fillet radius areas are noncritical areas.

Area B That portion of the airfoil starting at the line of tangency between the shroud and fillet radius and extending parallel to the airfoil span for 1/2 inch (12.7 mm) around the whole airfoil contour are critical areas.

Area C That portion of the airfoil leading edge (LE) or trailing edge (TE) beginning at the mid LE or TE radius line and extending 1/2 inch (12.7 mm) on both concave and convex airfoil surfaces and bounded on both outer and inner ends at the airfoil intercept with Area B are critical areas.

Area D All portions of the airfoil not included in Areas B or C are noncritical areas.

Area E All internal airfoil surfaces and insert seats are critical in the same B and C regions and noncritical in the D region.

5.3.2 Gas path profiles shall be restored to the same contours as new components using smooth blends between the original material and repaired areas.

5.3.3 Surface finish on the repaired components shall be 80 micro-inches (2 microns) Ra or better, measured according to ANSI B46.1.

5.3.4 Cooling passages shall be restored to original dimensions.

5.3.5 The repaired vane segment shall properly fit a dimensionally correct blade ring.

Note
OEM-supplied dimensional information contained in manuals and other supporting documentation should be used as reference dimensions where available. In the absence of such information, new or undamaged components may be measured and appropriate tolerances applied.

5.4 Microstructural Requirements

5.4.1 The re-casted layer on any EDM surface shall not exceed 0.001 inch (0.025 mm).

5.4.2 Process-related alloy depletion, oxidation, nitriding, intergranular attack, or intercarbidic oxidation at the surface of the components shall not exceed 0.001 inch (0.025 mm).

6 Processing Requirements

All process procedures applied during the repair of the components shall be the same as those used in the preparation of first article qualification samples and described in the process description as specified in paragraph 7.1.2.

6.1 Initial Inspection

6.1.1 Receive material and check for shipping damage. Check purchase order, material, and shipping papers to verify that the material received is correctly identified, fully accounted for, and that the repairs requested are reasonable.

6.1.2 Advise Purchaser immediately of any shipping damage.

6.1.3 Dimensionally inspect each segment for gas path dimensions, axial and radial location, and throat area and record the results on the forms attached as Appendix I. Gas path diameters and radial and axial location may be checked with a Fixture in lieu of actual measurement, provided all dimensions identified on the Forms are checked by the Fixture.

Note
Throat area distortion during service has not historically been a problem with Westinghouse W501 vane segments. Throat area measurements should be made if there is any obvious bowing of the trailing edge or after any significant weld repair of the trailing edge. A fixture is required to hold adjacent segments to make these measurements. The throat area measurement forms are included herein for use if the measurements are deemed necessary or if specifically called for by the Purchaser.

6.1.4 Visually inspect each segment for the following:

- Rubs and wear
- Trailing edge bowing
- Surface erosion loss
- Oxidation/corrosion
- Impact damage
- Cracks
- Blocked or damaged cooling holes

Record the results on the appropriate form attached as Appendix II.

6.1.5 Remove the core plugs, cover plates, and clean and inspect them. Fully open any blocked holes. Note if there is any interference or unusual difficulty encountered when removing the core plugs. Core plugs that were damaged during removal or service must be replaced with components that match OEM material and dimensional tolerances.

Note
A proper core design and fit of the core plugs within the vane cavity are critical to the proper functioning of the vane cooling system.

6.1.6 Examine a sample from the leading and trailing edge of one of the airfoils using the procedure attached in Appendix III. If the depth of oxide scale or pitting exceeds 0.020 inches (0.51 mm) or 1/3 of the local section thickness, whichever is less, the vane should be considered unrepairable. Coupon type repairs are permissible, if the damage is localized.

6.1.7 Clean the segments using grit blasting with 220 grit aluminium oxide. Avoid excessive blasting and take necessary precautions to prevent blockage of cooling holes.

Note
Cooling passages can become filled with media during abrasive cleaning. It is imperative that the media be removed prior to any heat treatment because the passage can become permanently blocked by sintering of the media at high temperature. This may be minimized by preventing the media from getting into the passages by physical masking, by maintaining a positive flow of air through the passages during blasting and by avoiding blasting into cooling passages. Any trapped media can be removed by thorough flushing of all passages after blasting. It is good practice to inspect the passages for flow after any abrasive cleaning step that precedes a heat treatment.

6.1.8 FPT all segments following procedures outlined in the U.S. Military Specification MIL-I-6866B using Type 1, A, B, C, or D, or the procedures in ASTM E165 using method A, Type 1, 2, or 3, using a level 3 sensitivity penetrant. Inspect both internal and external surfaces. Document the location and extent of all cracks, dents, wear, corrosion/erosion, and missing material on the form attached as Appendix II.

6.1.9 Prepare a report delineating condition of the components and outlining the repairs. At this point, the vendor must:

- Obtain written approval for any proposed changes to this guideline
- Obtain written or verbal authorization from the Purchaser to proceed with the repairs
- Obtain written authorization to replace any core plugs

6.2 Repair Procedure

6.2.1 If the vane segments have been coated, remove the coating by physical or chemical means, while ensuring no excessive base metal attack. Control samples of ECY-768 alloy shall be processed through any chemical stripping procedure (each lot) and examined metallographically for intergranular attack, which shall not exceed the limits defined in 5.4.2. Each segment shall be examined for complete coating removal by heat tinting or etching.

6.2.2 Dress surfaces as required to remove any oxidation to a depth of 0.020 inches (0.51 mm) or 1/3 of the local section thickness, whichever is less. Thoroughly degrease components using trichloroethane or equivalent.

6.2.3 Solution anneal the vane segments in a vacuum, hydrogen, or argon at 2300°F ±15°F (1260°C ±8°C) for 10 hours. Argon quench to below 1000°F (538°C). Fixture parts using nickel or iron base fixture materials with the part supported uniformly to prevent distortion. Avoid supporting the parts by any thin sections.

> **Note**
> Based on the experience of the repair vendor, the processing and operational history of the vane segment in question, the microstructure of the vane as determined per paragraph 6.1.6, and the extent of the defects being repaired, it may be preferable to omit the solution anneal step. Purchaser approval must be obtained in this case.

6.2.4 Examine a sample from the trailing edge of one of the airfoils using the procedure attached as Appendix III.

6.2.5 FPT all vane segments following procedures outlined in paragraph 6.1.8. Document the location and extent of any defects not identified in paragraph 6.1.8 using the form attached as Appendix II.

6.2.6 Cold or warm forming to straighten deformed airfoils is not permitted. Segments that are bowed, bent, or warped beyond the acceptable limits are to be marked and set aside. The Purchaser shall be notified in writing.

6.2.7 Prepare the areas of the segments to be repaired by grinding out the existing cracks and defects and FPT to ensure that the cracks are completely removed. Grinding tools and procedures to be used shall be identical to those used in the original process qualification (7.1.2). Sections may be removed for replacement with patches of matching alloy composition provided that, after the repairs are completed, the cooling hole configuration is unchanged.

6.2.8 After weld preparation, the Purchaser shall be informed and allowed to inspect the components.

6.2.9 Weld repair the components using gas tungsten arc or plasma transferred arc welding methods. Areas to be welded must be free of oxide, grease, dirt, and penetrant chemicals. All areas must be welded using full penetration welds through the section being repaired. Weld procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.10 Braze, diffusion brazing, or other alternative techniques for repair of craze and other defects are not permissible in critical areas. They are permitted in noncritical areas of the segments, as defined in Figures 3-1 and 3-2, provided that the process used is identical to that used in the original process qualification (7.1.2).

Note
Braze repairs may make future weld repair of the vanes difficult, due to embrittlement in the brazed region.

6.2.11 Grind and polish the repaired areas to restore the original contours and dimensions. Restore any cooling holes plugged during repair to original dimensions. Grinding tools and procedures to be used shall be identical to those used in the original process qualification (7.1.2).

6.2.12 FPT the complete vane segment following procedures outlined in paragraph 6.1.8, using the acceptance criteria identified in Paragraph 5.2.

6.2.13 Parts that fail to meet the criteria of paragraph 5.2 may be recycled to repair any defects beginning at paragraph 6.2.7. Parts may be recycled to paragraph 6.2.2 for stress relief, at the vendor's option.

6.2.14 Thoroughly degrease components using trichloroethane or equivalent.

6.2.15 After all repairs are complete, heat treat the vane segments in vacuum, argon, or hydrogen at 2100°F ±15°F (1149°C ±8°C) for 2 hours. Argon quench to below 1000°F (538°C). Fixture parts using nickel or iron base fixture materials with the parts supported uniformly. Avoid supporting the parts by any thin sections.

6.2.16 Immediately following heat treatment and before any surface cleaning or blasting, liquid penetrant inspect the entire segment using the method outlined in paragraph 6.1.8 and acceptance criteria outlined in paragraph 5.2. Record the results on the forms attached as Appendix II.

6.2.17 If the repaired vane segment is to be coated for further service, the coating should be applied at this time using a Purchaser-approved process.

6.2.18 Install the core plugs and cover plates and inspect welds per paragraph 6.2.12, noncritical areas. Fit-up and welding procedure shall be identical to those used in the original process qualification.

6.2.19 Flow check all cooling holes to ensure that all passages are open by passing water through the cooling air inlet. Each hole shall be flowing freely. Alternative flow tests may be employed if approved in writing by the Purchaser. Record the results (pass/fail) by serial number.

6.2.20 Dimensionally check the vanes to ensure conformance to Paragraph 5.3 and record the results on the form attached in Appendix I. Gas path diameters and radial and axial location may be checked with a Fixture in lieu of actual measurement, provided all dimensions identified on the Forms are checked by the Fixture.

6.2.21 Arrange a pre-shipment inspection with the Purchaser to:

- Review documentation, including heat treatment charts, quality control test reports, and a mapping of repairs
- Perform visual inspection
- Deliver Purchaser copies of the documentation

6.2.22 Package and ship parts in suitable containers that will prevent component contact and damage under rigorous handling conditions. All parts that are lost or damaged beyond repair may be back charged up to the cost of replacement by original OEM parts.

6.2.23 Advise Purchaser of information such as the shipping date, route, and carrier.

6.2.24 Issue final report outlining repair process used and containing all documentation required in paragraph 7.2.

7 Quality Requirements

7.1 Pre-Production Qualification

7.1.1 Vendor Audits. Prior to placing a vane repair order of any sort with a specific vendor, the vendor's facilities, quality control system, and general operation shall be audited by the Purchaser for capability to adequately perform turbine component repair. Approval shall be granted for a period specified by the Purchaser but may be removed by the Purchaser for inadequate vendor performance.

7.1.2 Technical Review and First Article Inspection. For each specific repair process, the vendor will be required to submit a description of the process to the Purchaser for review. The supplier will also be required to process vane segments (and/or other sample material identified by the Purchaser) through the entire process for nondestructive and destructive examination, by the Purchaser, for compliance with the requirements of Paragraph 5. Based on the results, the Purchaser will approve the process for use at the vendor. The vendor shall obtain written

approval by the Purchaser for any change to the process and, at the Purchaser's option, may be required to prepare an additional first article for approval.

7.1.3 Personnel Qualifications. Inspection personnel shall be qualified to ASNT Recommended Practice No. SNT-TC-1A Level II or III.

7.2 Documentation and Certification

7.2.1 Quality Control Tests. In-process and final quality control tests shall be performed, as identified in Paragraph 6. Results of all required testing shall be recorded by serial number. A certified copy shall be given to the Purchaser's representative at the pre-shipment inspection.

7.2.2 Processing Records. Processing records shall be maintained in sufficient detail to indicate compliance with this guideline and to allow traceability by lot. A mapping of the location, nature, and extent of repairs on each component shall be prepared and recorded by serial number. A copy of these records shall be given to the Purchaser's representative at the pre-shipment inspection.

7.2.3 Certificate of Compliance. All processing and quality control records shall be reviewed by the vendor to verify compliance with this guideline and the purchase order. Any deviations shall be reported immediately to the Purchaser and may be cause for rejection. A document certifying that all aspects of this guideline and the purchase order have been met shall be signed by the responsible vendor representative and shall be presented to the Purchaser with the repair report. This document shall include:

a) Purchase order number

b) Purchaser guideline number

c) Purchaser drawing number

d) Serial numbers and final disposition

e) Heat treatment lots by serial number

f) A copy of all documents approving vendor requested deviation from the requirements of this guideline

7.2.4 Records. All process control records and quality control test results shall be maintained on file by the vendor for a period of seven years. This information shall be made available to the Purchaser upon request.

7.2.5 Final Report. At completion of the repair process, a final report shall be issued and shall contain:

a) A description of the complete repair process

b) A mapping of all defects identified at paragraph 6.1.4, 6.1.8, and 6.2.5 (use form attached as Appendix II)

c) A mapping of all repair locations (use form attached as Appendix II)

d) A copy of all incoming, in-process, and final dimensional inspection forms (use forms attached as Appendix I)

e) A copy of final FPT and flow check reports

f) A copy of throat area check forms (if used)

g) A copy of the certificate of compliance

7.3 Acceptance and Disposition

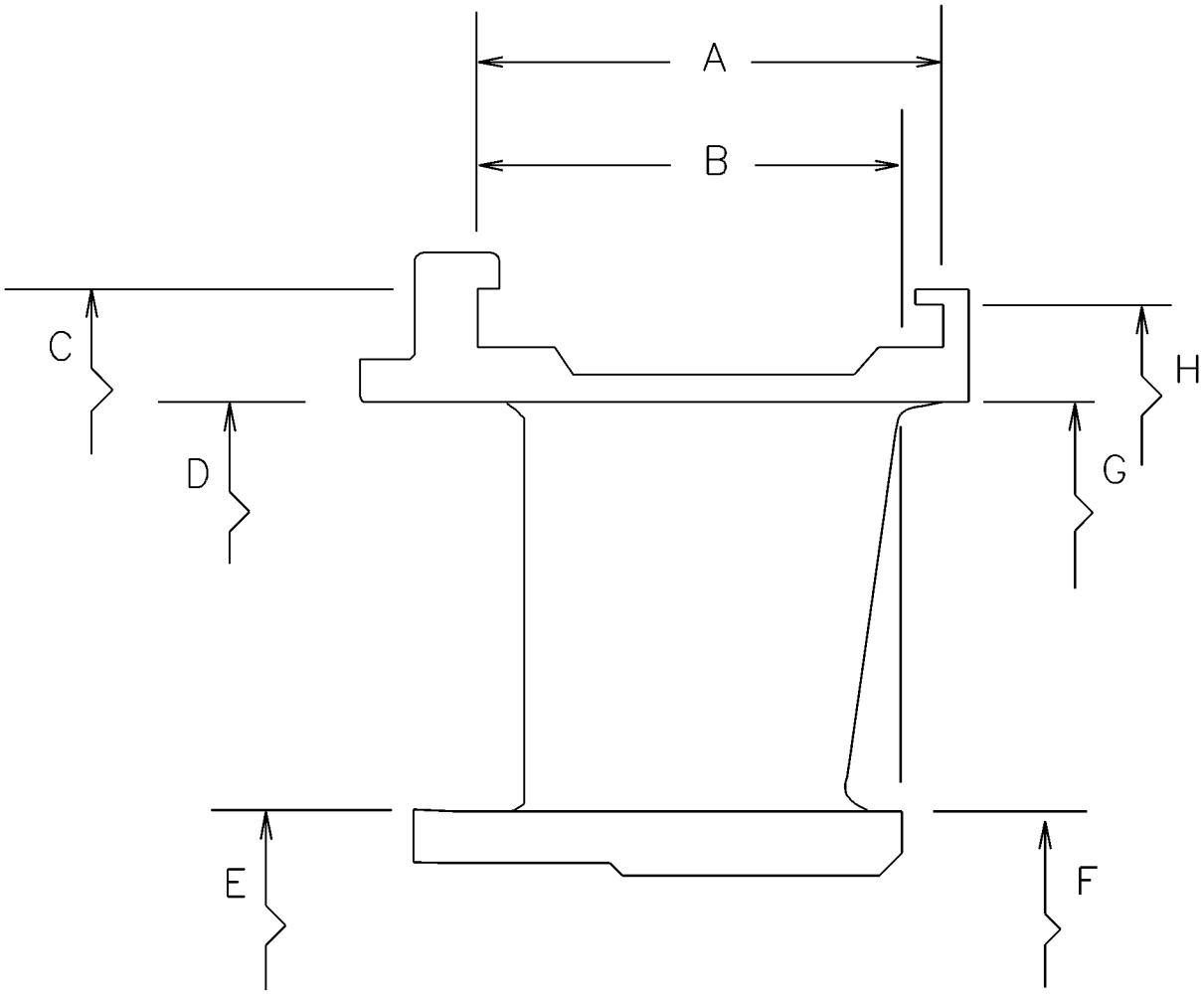
7.3.1 All deviant parts shall be plainly labeled in a nondestructive manner, isolated from the batch and held for Purchaser disposition.

7.3.2 Components not meeting the requirements of this guideline, the purchase order, and referenced drawings shall be rejected. Rejected parts shall be held for Purchaser disposition.

7.4 Access

The Purchaser shall be allowed reasonable access to inspect components at all times during the repair process.

Appendix I - Dimensional Inspection Forms



NOTES:

1. Measure dimensions A and B at center and both ends of segment.
2. C, D, E, F, G, and H are radial dimensions.
3. Record dimensions on Form I-B.
4. Checking Fixtures may be used in lieu of actual measurements, provided all dimensions identified are checked. Record results (pass/fail) on Form I-B.

Form I-A
Westinghouse W501 Multivane Segment Dimensional Inspection Form

DIMENSION	ALLOWABLE		SEG. #_____ S/N _____	SEG. #_____ S/N _____	SEG. #_____ S/N _____
	MIN.	MAX.			
A Left					
A Center					
A Right					
B Left					
B Center					
B Right					
C					
D					
E					
F					
G					
H					

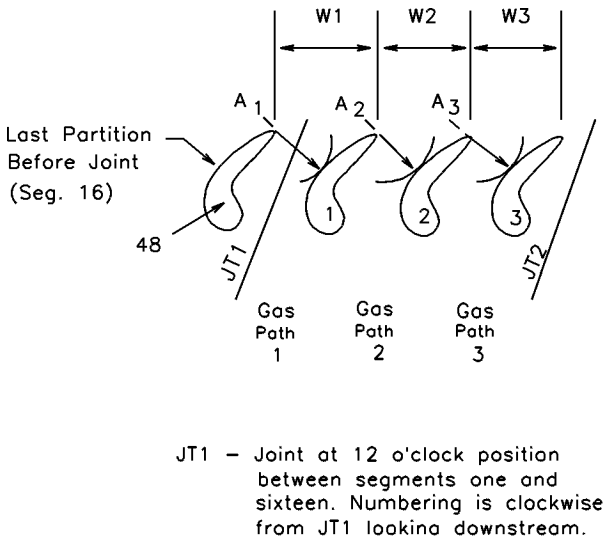
DIMENSION	ALLOWABLE		SEG. #_____ S/N _____	SEG. #_____ S/N _____	SEG. #_____ S/N _____
	MIN.	MAX.			
A Left					
A Center					
A Right					
B Left					
B Center					
B Right					
C					
D					
E					
F					
G					
H					

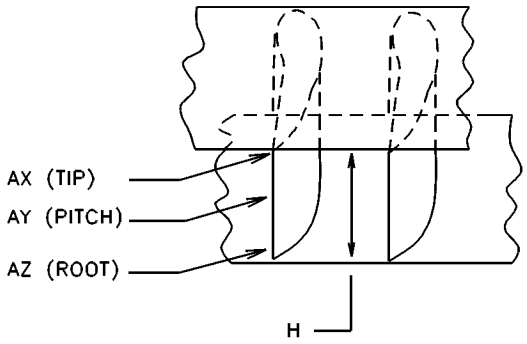
NOTE: "Left" and "Right" dimensions are defined looking downstream.

DATE:	**INSPECTED BY:**
OWNER:	**PLANT:**
UNIT DESIGNATION:	**TURBINE S/N:**

CHECK TYPE OF INSPECTION: ☐ **INCOMING;** ☐ **IN PROCESS;** ☐ **FINAL**

Form I-B
Westinghouse W501 Multivane Segment Dimension Sheet





NOTES:

1. Record dimensions on Forms I-D and I-E.
2. If blade ring or fixture is not available, you can take dimensions on only those passages that contain no joint (Nos. 2 and 3 above, etc.).
3. $W1_{AX}$ = Pitch dimension for Gas Path 1 measured at tip checking diameter.
4. $W2_{AY}$ = Pitch dimension for Gas Path 2 measured at pitch checking diameter.
5. H = Radial height of throat measured at the midpoint between trailing edges on the same plane as the trailing edges.
6. A_1X = Throat dimension measured at tip checking diameter for Gas Path #1.
7. $A_{37}Y$ = Throat dimension measured at pitch checking diameter for Gas Path #37.
8. $A_{22}Z$ = Throat dimension measured at root checking diameter for Gas Path #22.

Form I-C
Westinghouse W501 First Stage Vanes Multivane Gas Path Area Check Form

SEG. SERIAL NO.	PATH #	WAX	WAY	H	AX	AY	AZ	PATH AREA
	1 (JT1)							
	2							
	3							
	4 (JT2)							
	5							
	6							
	7 (JT3)							
	8							
	9							
	10 (JT4)							
	11							
	12							
	13 (JT5)							
	14							
	15							
	16 (JT6)							
	17							
	18							
	19 (JT7)							
	20							
	21							
	22 (JT8)							
	23							
	24							

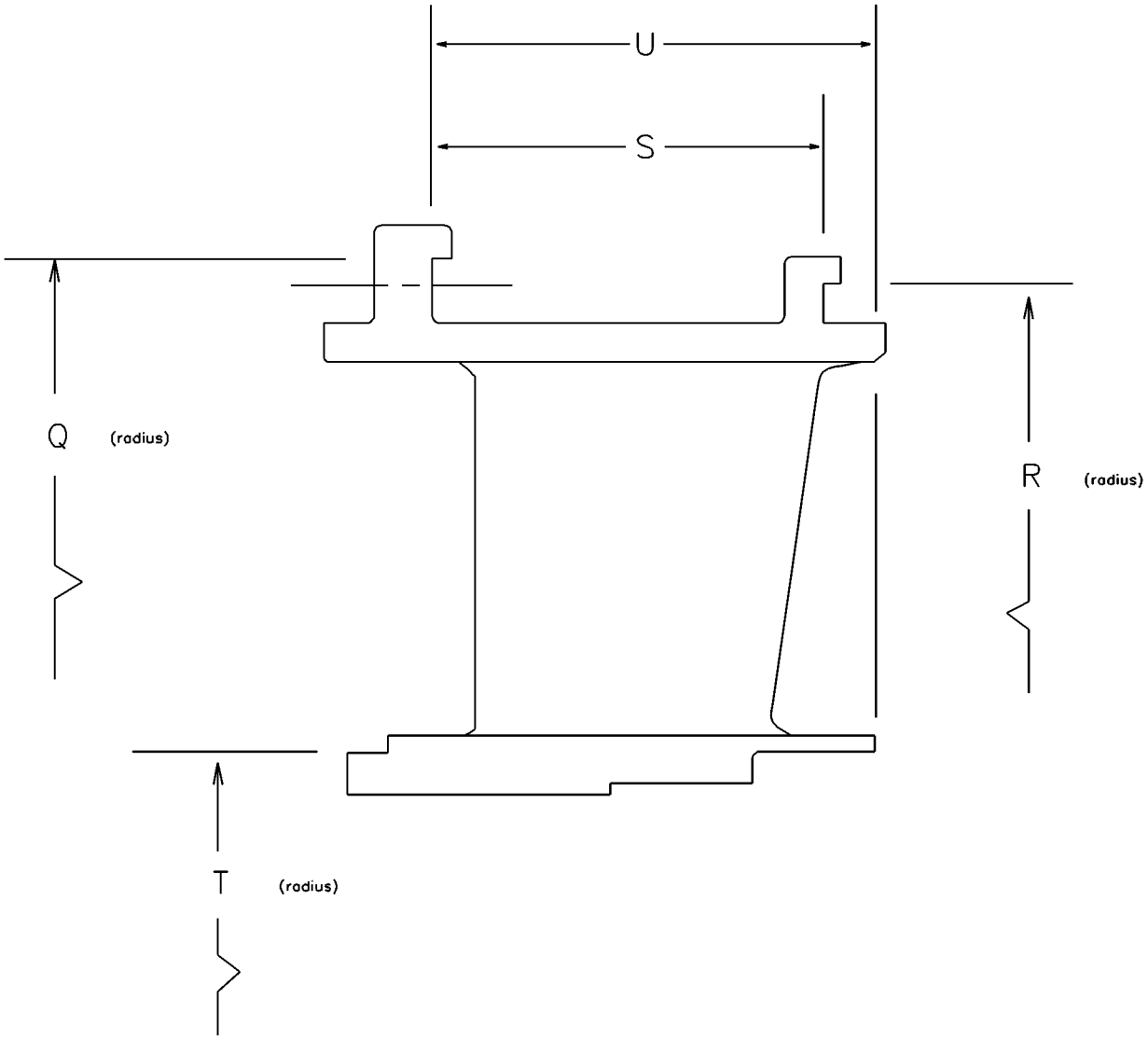
INSPECTED BY:	**CHECKED BY:**
DATE:	**DATE:**
OWNER:	**PLANT:**
UNIT DESIGNATION:	**TURBINE S/N:**

Form I-D
Westinghouse W501 Multivane First Stage Segments Gas Path Area Check Dimension Sheet

SEG. SERIAL NO.	PATH #	WAX	WAY	H	AX	AY	AZ	PATH AREA
	25 (JT9)							
	26							
	27							
	28 (JT10)							
	29							
	30							
	31 (JT11)							
	32							
	33							
	34 (JT12)							
	35							
	36							
	37 (JT13)							
	38							
	39							
	40 (JT14)							
	41							
	42							
	43 (JT15)							
	44							
	45							
	46 (JT16)							
	47							
	48							

INSPECTED BY:	CHECKED BY:
DATE:	DATE:
OWNER:	PLANT:
UNIT DESIGNATION:	TURBINE S/N:

Form I-E
Westinghouse W501 Multivane First Stage Segments Gas Path Area Check Dimension Sheet



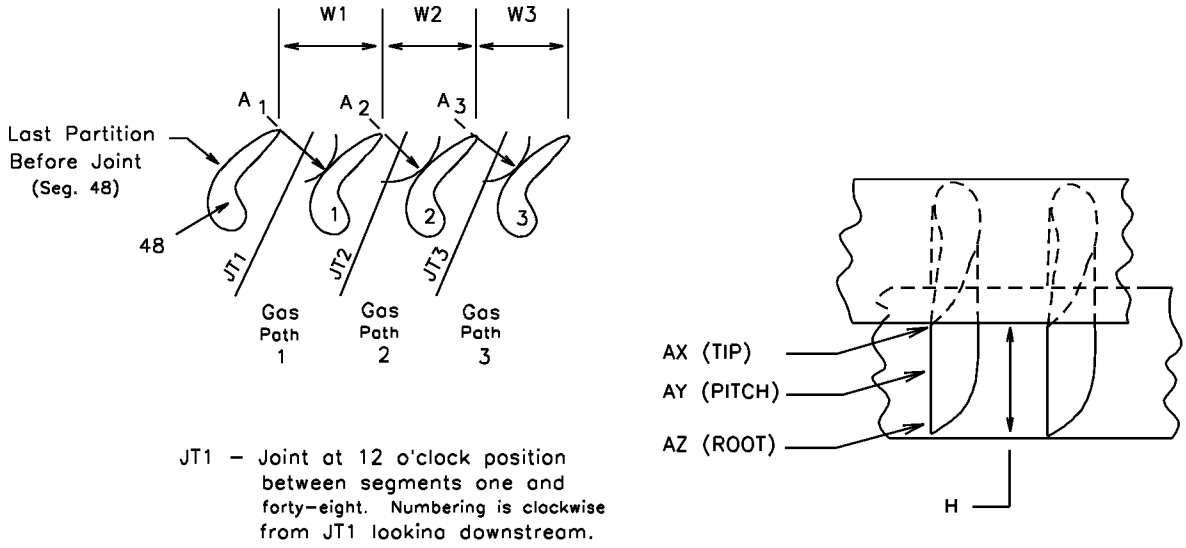
"Q", "R", and "T" are radial dimensions. Check concentricity of "R" and "T" with respect to "Q". Record dimensions on Form I-G. Checking Fixtures may be used in lieu of actual measurements, provided all dimensions identified are checked. Record results (pass/fail) on Form I-G.

Form I-F
Westinghouse W501 First Stage Vanes Single Vane Segment Dimensional Inspection Form

		DIMENSIONS - INCHES						
		Q	R		S	T		U
		RADIUS						
SEG NO.	SERIAL NO.		RADIUS	ECCENTRICITY WRT/Q		RADIUS	ECCENTRICITY WRT/Q	
MINIMUM								
MAXIMUM								

DATE:	INSPECTED BY:
OWNER:	PLANT:
UNIT DESIGNATION:	TURBINE S/N:
CHECK TYPE OF INSPECTION: ☐ INCOMING; ☐ IN PROCESS; ☐ FINAL	

Form I-G
Westinghouse W501 First Stage Vanes Single Vane Segment Dimension Sheet



NOTES:

1. Record dimensions on Forms I-I and I-J.
2. A fixture to secure adjacent segments is required to shop-check gas paths on these vanes.
3. $W1_{AX}$ = Pitch dimension for Gas Path 1 measured at tip checking diameter.
4. $W2_{AY}$ = Pitch dimension for Gas Path 2 measured at pitch checking diameter.
5. H = Radial height of throat measured at the midpoint between trailing edges on the same plane as the trailing edges.
6. A_1X = Throat dimension measured at tip checking diameter for Gas Path #1.
7. $A_{37}Y$ = Throat dimension measured at pitch checking diameter for Gas Path #37.
8. $A_{22}Z$ = Throat dimension measured at root checking diameter for Gas Path #22.

Form I-H
Westinghouse W501 First Stage Vanes Single Vane Segment Gas Path Area Check Form

SEG. SERIAL NO.	PATH #	WAX	WAY	H	AX	AY	AZ	PATH AREA
	1 (JT1)							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							
	11							
	12							
	13							
	14							
	15							
	16							
	17							
	18							
	19							
	20							
	21							
	22							
	23							
	24							

{PRIVATE **}INSPECTED BY:**	**CHECKED BY:**
DATE:	**DATE:**
OWNER:	**PLANT:**
UNIT DESIGNATION:	**TURBINE S/N:**

Form I-I
Westinghouse W501 Single Vane First Stage Segments Gas Path Area Check Dimension Sheet

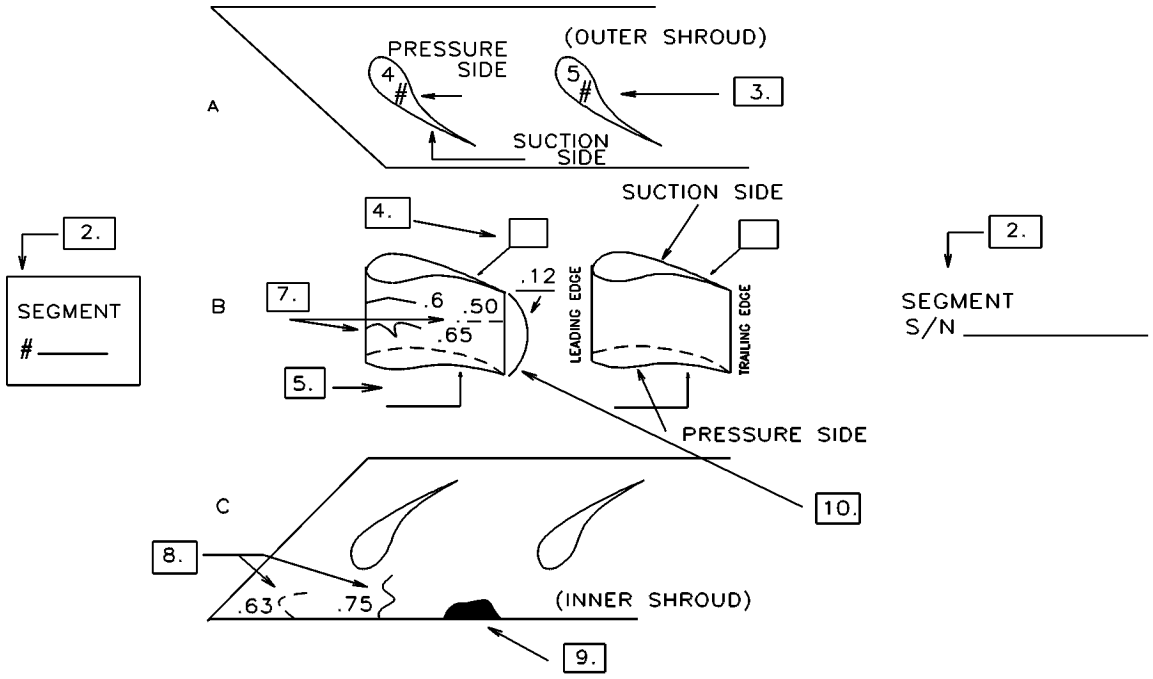
SEG. SERIAL NO.	PATH #	WAX	WAY	H	AX	AY	AZ	PATH AREA
	25							
	26							
	27							
	28							
	29							
	30							
	31							
	32							
	33							
	34							
	35							
	36							
	37							
	38							
	39							
	40							
	41							
	42							
	43							
	44							
	45							
	46							
	47							
	48							

INSPECTED BY:	**CHECKED BY:**
DATE:	**DATE:**
OWNER:	**PLANT:**
UNIT DESIGNATION:	**TURBINE S/N:**

Form I-J
Westinghouse W501 Single Vane First Stage Segments Gas Path Area Check Dimension Sheet

Appendix II - Damage Assessment Forms

MAP LOCATION AND RECORD SIZE OF ALL DEFECTS
KEY: CK = Crack; D = Dent; MM = Missing Material; C = Corrosion; E = Erosion; R = Rubbing (Wear); RW = Repair Weld; RB = Repair Braze; N = No Defects/No Repair Required



GENERAL -

1. Vane airfoils are numbered clockwise from the 12 o'clock position when viewed in the direction of turbine flow. Vane segments are numbered in the same manner. Sketch shows multivane segment. Single vane forms are completed in like manner.

2. Enter segment number and serial number (S/N) in appropriate block.

3. Enter vane airfoil number in appropriate space in outer shroud sketch.

4. Indicate type of repair made on vane airfoil in box at upper left of vane for final inspection record. RW = Repair Weld; RB = Repair Brazed; N = No Repair Required.

NOTE: IT IS CRITICAL THAT ANY BRAZED VANES BE RECORDED ON THE FINAL INSPECTION RECORD.

5. Show the number of plugged trailing edge cooling air holes below each vane. (Air cooled vanes only).

CRACKING, MISSING MATERIAL, WEAR, DENTS, ETC. -

6. Draw in cracks and label length of each crack. For other damage, draw in damage and label using the key symbols. Damage in the junction (fillet) area between shroud and vane should be shown on the shroud sketches along the vane outline and labeled with an "F" to indicate fillet (e.g., CK-F, etc.).

7. For vane cracks (B), use solid lines for pressure side cracking and dashed lines for suction side cracking. Show other damage in similar fashion and identify using key symbols.

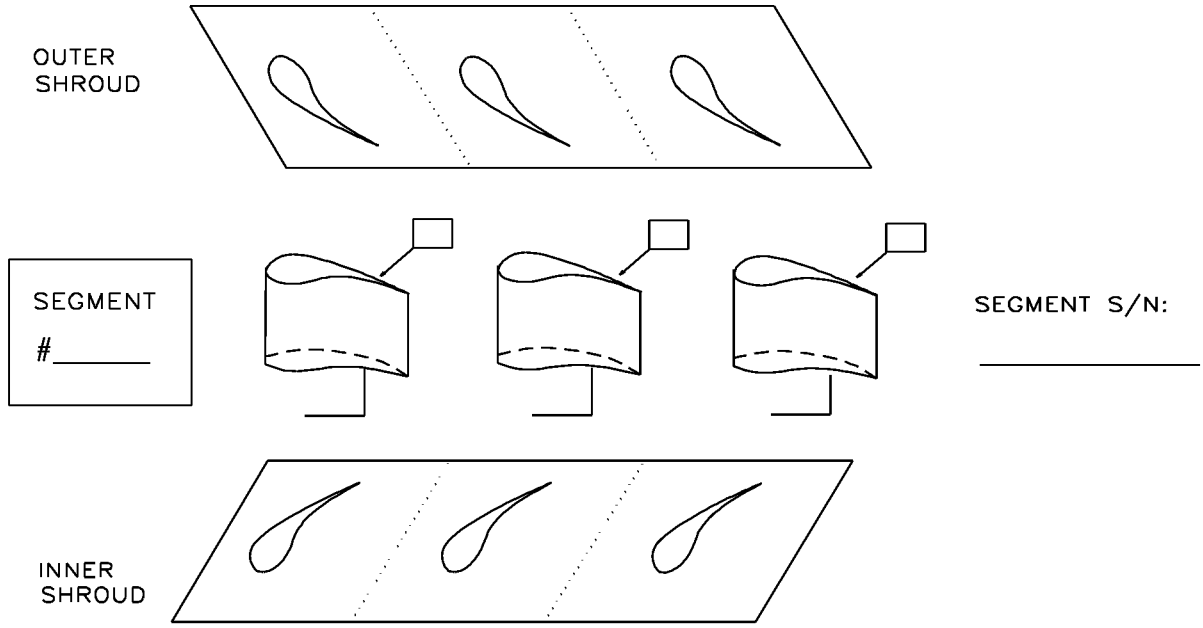
8. For inner (C) and outer (A) shroud, use solid lines for gas path side cracks and dashed lines for external side cracks. Show other damage in similar fashion and identify using key symbols.

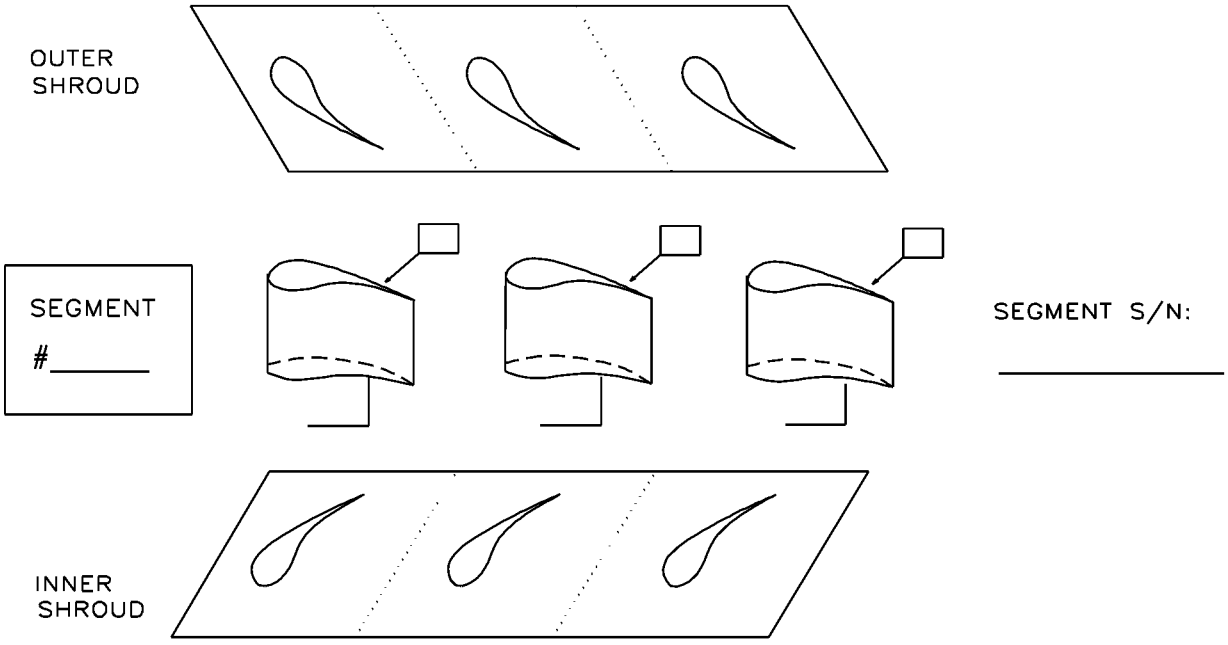
9. Sketch area where pieces are broken off.

TRAILING EDGE BOWING –

10. Show trailing edge bowing on sketch of vane (B) - line to the left to indicate bowing to pressure side. Line to the right to indicate bowing to suction side. Indicate amount of bowing in 100 ths of inches.

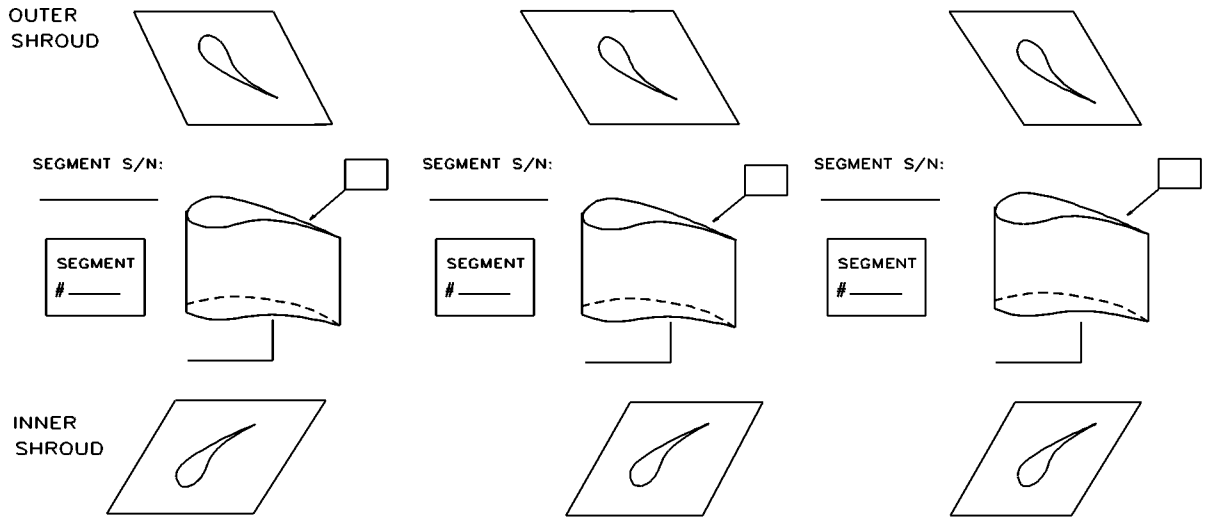
Form II-A
Westinghouse W501 Turbine Vanes Notes for Vane Damage Assessment

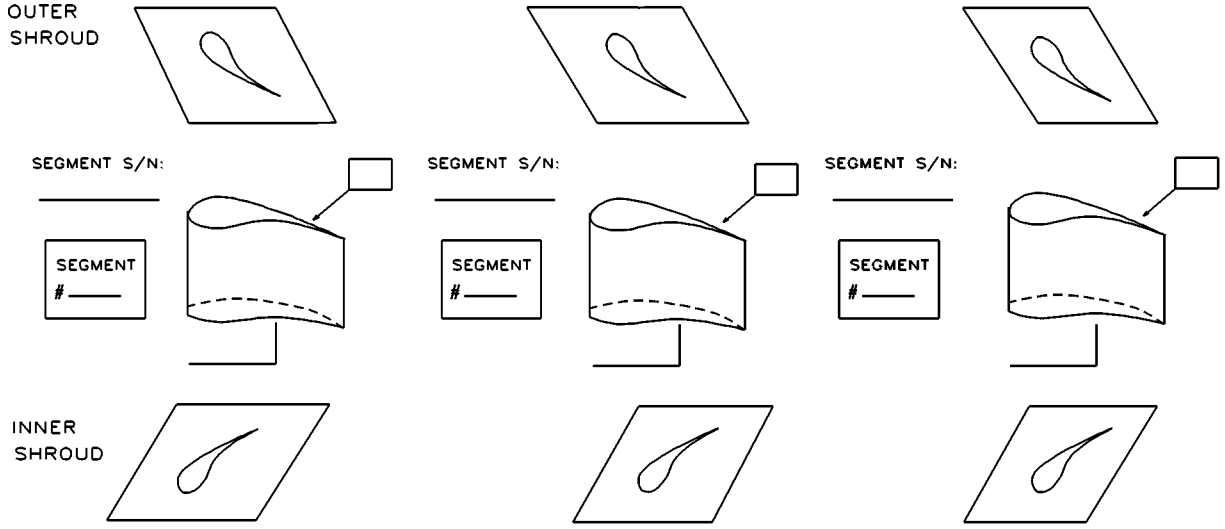




DATE:	**INSPECTED BY:**
OWNER:	**PLANT:**
UNIT DESIGNATION:	**TURBINE S/N:**
CHECK TYPES OF INSPECTION: ☐ INCOMING; ☐ IN PROCESS; ☐ FINAL; ☐ VISUAL; ☐ FPI	

Form II-B
Westinghouse W501 Multivane Segment Damage Assessment Form





DATE:	**INSPECTED BY:**
OWNER:	**PLANT:**
UNIT DESIGNATION:	**TURBINE S/N:**
CHECK TYPES OF INSPECTION: ☐ INCOMING; ☐ IN PROCESS; ☐ FINAL; ☐ VISUAL; ☐ FPI	

Form II-C
Westinghouse W501 Single Vane Segment Damage Assessment Form

Appendix III - Procedure for Metallurgical Evaluation of Nozzle and Vane Segments

Scope

This procedure describes techniques to be used to characterize material degradation in cobalt alloy nozzles or vanes and assess repairability. The removal of samples is semidestructive, in that the areas from which samples are removed must be repaired by welding. Thus, such examinations are normally carried out in conjunction with repairs.

Selection of Sample Locations

Degradation of gas path material in stationary nozzles and vanes is seldom uniform due to the presence of combustor patterns. Generally, the more severely damaged areas are evident visually by oxidation patterns. Specimens should be removed from areas showing the most severe damage, as well as areas showing average damage. Samples are typically removed from both leading and trailing edge locations before any abrasive cleaning or heat treatments are performed.

Removal of Samples

Samples are removed using 1/16 inch (1.6 mm) wafering blade and rotary air or electric hand tools. Appropriate personal protective gear should be worn at all times when using such tools.

Because samples removed must be repaired, the minimum material necessary should be removed. For leading and trailing edge locations, the sample geometry shown in Figure 3-3 is adequate for specimens in two orientations. For removal of samples from heavier locations such as side rails, a “boat” specimen, as shown in Figure 3-4, is suitable.

Preparation of Samples

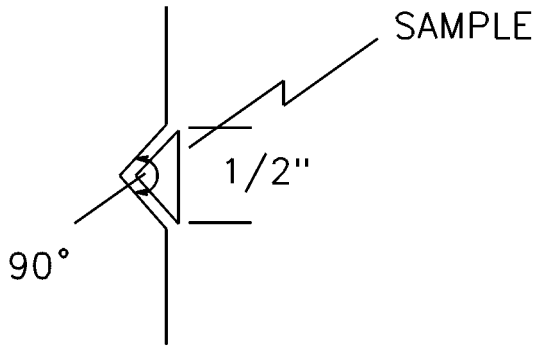
Sections of the samples removed from each location should be prepared for optical metallography in the transverse and longitudinal directions.

Surface Condition

Surface condition should be examined in the transverse sections (that is, surfaces perpendicular to specimen plane). The depth of oxide scale and internal oxidation present should be measured. If the depth of attack exceeds 0.020 inches (0.51 mm) or 1/3 of the local section thickness, whichever is less, the nozzle or vane should be considered unrepairable by welding or brazing. Coupon type repairs may be possible if the oxidation damage is localized.

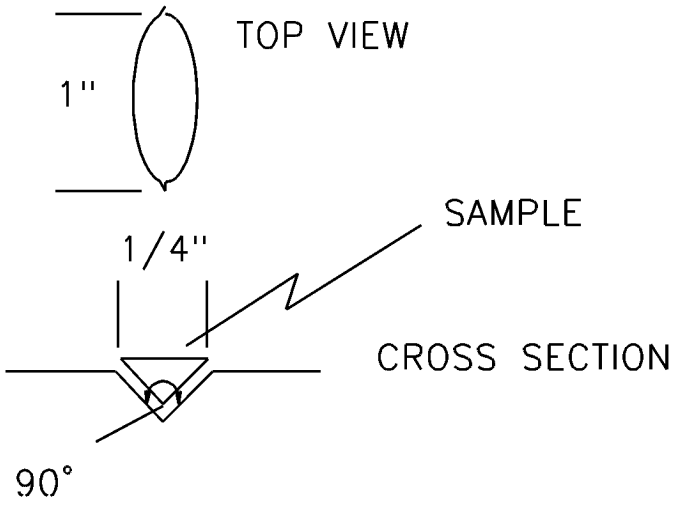
Microstructural Condition

The microstructural condition should be examined in all sections. In particular, longitudinal sections should be examined for the presence of voids formed by thermomechanical fatigue at high temperatures. If greater than 5% of the grain boundary area is occupied by voids, the component should be considered unrepairable by welding. Coupon repair may be possible if it can be demonstrated that the damage is localized. The microstructure should be examined for the formation of irreversible grain boundary carbide formation, which may affect weldability after heat treatment.



1 Inch = 25.4 mm

Figure III-A
Leading or Trailing Edge Specimen



1 Inch = 25.4 mm

Figure III-B
"Boat" Specimen

4
REPAIR SPECIFICATION FOR WESTINGHOUSE W501 MODELS B, D24, D4, AND D5 COMBUSTOR BASKETS

Note
The use of repair procedures and specifications supplied by the Original Equipment Manufacturer (OEM), if available, in conjunction with, and to supplement this specification, is permitted and encouraged. However, Purchaser expects the requirements of this specification to be met by the repair vendor as a minimum condition for acceptable repairs. Conflicts between this and any other specifications should be brought to Purchaser's attention for resolution.

1 Scope

1.1 Purpose

This specification covers the minimum requirements for the weld repair, heat treatment, and application of thermal barrier and hardface coatings for Westinghouse W501 Models B, D24, D4, and D5 combustor baskets manufactured from Hastelloy X (49Ni 22Cr 18Fe 9Mo 1.5Co 0.5W) alloy. Baskets repaired to these requirements should provide service life approaching that of new components.

1.2 Application

Weld repair of combustor baskets is performed to repair physical damage such as cracking, impact damage, and erosion. Pre-weld heat treatments are not routinely required for combustor basket repair but may be required prior to welding to improve ductility. Thermal barrier coatings are applied to the internal surfaces of combustor baskets to reduce component metal temperatures. Hardface coatings are applied at basket contact locations to reduce wear and fretting.

2 Definitions

2.1 Heat Treatment Lot

A group of parts that is processed in the same furnace at the same time shall constitute a heat treatment lot. If a group of parts being repaired at the same time is split into two or more subgroups for heat treatment, each subgroup shall constitute a lot.

2.2 Linear Indications

Nondestructive testing indications with a length of three times the width or greater.

2.3 Nonlinear Indications

Nondestructive testing indications with a length of less than three times the width.

2.4 Through-Going Indications

Indications appearing directly opposite each other and apparently extending through the thickness of the section.

2.5 LPT

Liquid Penetrant Testing.

3 Applicable Documents

3.1 Specifications

The following documents form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue shall apply.

U.S. Military Specification MIL-I-6866B
“Inspection, Liquid Penetrant”

ASTM E165
“Standard Practice for Liquid Penetrant Inspection Method”

ASNT Recommended Practice No. SNT-TC-1A
“Personnel Qualification and Certification in Non-destructive Testing”

AMS 5536K
“Sheet, Strip, and Plate, 47.5 Ni 22Cr 1.5Co 9.0 Mo 0.6W 18.5 Fe” (Hastelloy X)

AMS 5542K
“Sheet, Strip, and Plate, 72Ni 15.5Cr 0.95(Cb + Ta) 2.5Ti 0.70Al 0.70 Fe” (Inconel X750)

AMS 5798C
“Wire, Welding, Alloy 47.5Ni 22Cr 1.5Co 9.0Mo 0.60W 18.5Fe” (Hastelloy X)

Purchaser specification COMBTBC
"Specification for Application of Thermal Barrier Coatings on Industrial Gas Turbine Combustion Components"

3.2 Precedence of Documents

Specific requirements contained in purchase order instructions or drawings may be issued to supplement the requirements of this document. In cases of conflict, the purchase order shall take precedence followed by applicable drawings, followed by this document.

4 General Requirements

General requirements are typically addressed in Requests for Proposals or Purchase Orders (as applicable) for component repairs.

5 Technical Requirements

5.1 Repair Materials

5.1.1 Weld repairs shall be performed using AMS 5798C weld filler material (Alternative designation: Hastelloy X, UNS N06002).

5.1.2 Materials for replacement basket ring (shell) sections, dome assembly, wiggle strips, and reinforcement bands shall conform to AMS 5536K (Alternative designation: Hastelloy X).

5.1.3 The forward flange on later model Westinghouse baskets is an assembly composed of 300 series stainless steel (flange portion) and carbon steel (neck portion). Earlier model flange assemblies are composed entirely from carbon steel. Replacement materials shall be equivalent to those provided by the gas turbine OEM.

5.1.4 Materials for replacement crossfire tube flanges shall conform to AMS 5536K (Alternative designation: Hastelloy X).

5.1.5 Materials for replacement spring clips shall conform to AMS 5536K (Alternative designation: Hastelloy X). Inconel X750 (AMS 5542K) heat treated to full hardness may be used in lieu of Hastelloy X for spring clips when approved by the Purchaser. Spring clips shall be attached using one spot weld below each spring leaf. Replacement of individual spring clip leaves on the outboard set of clips is permissible; however, should removal of the entire spring clip assembly (inner and outer clips) be required, the entire assembly shall be replaced with new components. The contact areas (forwardmost areas, approximately 2.125 inches [54 mm]) of the outer spring clip surfaces are to be coated with a wear-resistant hardface coating applied by a thermal spray process (see Appendix III). Powder materials used for hardface coatings applied by thermal spraying shall be chrome carbide within a nickel matrix. The powder composition

and thermal spray process used for applying the coating shall be identical to those used in the preparation of the original process qualification (7.1).

5.1.6 Materials and application methods for basket internal thermal barrier coating (TBC) systems shall be in accordance with Purchaser specification COMBTBC "Specification for Application of Thermal Barrier Coatings on Industrial Gas Turbine Combustion Components." Unless otherwise specified, the extent of coating coverage shall be equivalent to that provided by the original equipment manufacturer.

5.2 Nondestructive Testing Acceptance Limits

Linear indications are permitted to 0.030 inch (0.76 mm) in length provided they are spaced by 5 times their length. Nonlinear indications separated by 2 times the diameter of the largest indication are permitted up to 0.060 inch (1.6 mm) diameter, or up to a diameter equal to 25% of the local section thickness, whichever is smaller. No through-going indications are permitted.

5.3 Dimensional Requirements

5.3.1 Dimensions shall conform to those identified on the forms and illustrations attached as Appendix I and Appendix III. Proper dimensions shall be verified prior to the application of internal Thermal Barrier Coating (TBC).

Note
OEM-supplied dimensional information contained in manuals and other supporting documentation should be used as reference dimensions where available. In the absence of such information, new or undamaged components may be measured and appropriate tolerances applied.

Note
This specification addresses baskets for several W501 models. Some models have 16 combustion chambers while others have only 14. Therefore, to cover all possible configurations, the forms provided in Appendix I include space for recording data for 16 baskets. When recording information for models comprised of 14 baskets, mark through the unneeded spaces.

5.3.2 Repaired areas penetrating into the basket gas path (internal) surfaces following repair (that is, prior to the surface preparation required for the application of internal TBC) shall be ground smooth to remove any surface irregularities or abrupt changes in geometry to ensure that no stress risers exist that would limit the life of the basket TBC. Any bulging, warped, or bent areas shall be restored to their original contours prior to the application of the internal TBC.

5.4 Microstructural Requirements

5.4.1 Process-related alloy depletion, oxidation, nitriding, and intergranular attack at the surface of the components (such as that can occur from heat treating furnace atmospheres) shall not exceed 0.001 inch (0.025 mm).

5.4.2 All hardface coatings applied by thermal spraying shall be crack-free. The sum (volume percent) of total porosity plus oxidation products shall be less than 4%. No delamination at the coating/substrate interface is allowed.

5.5 Attachment Spot Weld Requirements

All spot welds used for joining basket component parts shall be 0.250 inch (+0.000/-0.030 inch [6.35 +0.0/-0.76 mm]) diameter. The spot welds shall have a minimum tensile strength of 2000 psi (13.8 MPa) as demonstrated on a minimum of three tensile test specimens during the original process qualification (7.1). At least one of the specimen layers being joined for the process qualification shall be from a used (serviced) component. Any change in spot welding equipment or weld parameters shall be preceded by re-testing spot weld strength using the same procedures used during the original process qualification.

6 Processing Requirements

All process procedures applied during the repair of the components shall be the same as those used in the preparation of first article qualification samples and described in the process description as specified in paragraph 7.1.

6.1 Initial Inspection

6.1.1 Receive material and check for shipping damage. Check purchase order, material, and shipping papers to verify that the material received is correctly identified, fully accounted for, and that the repairs requested are reasonable.

6.1.2 Advise Purchaser immediately of any shipping damage.

6.1.3 Dimensionally inspect each combustion basket for the following:

- Forward (fuel nozzle) flange thickness/wear
- Crossfire tube flange axial location and cylindricity
- Overall length
- Spring clip assembly diameter
- Aft end diameter and cylindricity

Record the results on the forms attached as Appendix I. Checking Fixtures may be used in lieu of actual measurements, provided that all dimensions identified are checked.

6.1.4 Visually inspect each basket for the following:

- Cracks
- Thermal distress/distortion

- Corrosion/erosion
- Dents
- Missing material
- Wear
- Loss of thermal barrier coating

Record the results on the inspection forms attached as Appendix II.

6.1.5 Clean service deposits and thermal barrier coatings (including the internal TBC base coat) from internal and external surfaces with 120, or finer, grit aluminum oxide. Ensure that the TBC base coat has been completely removed to permit proper adhesion of new base coat during re-coating (following repair). Avoid excessive blasting.

6.1.6 LPT all the baskets following procedures outlined for visual penetrant inspection in U.S. Military Specification MIL-I-6866B or the procedures in ASTM E165. Document the location and extent of all cracks, dents, wear, corrosion/erosion, and missing material on the damage assessment forms attached as Appendix II. Results should be added to the forms completed in the visual inspection of 6.1.4, if practical. The intent is to document/map all service-induced basket defects on one set of damage assessment forms.

6.1.7 Prepare a report delineating condition of the components and outlining the repairs. At this point, the vendor must:

- Obtain written approval for any proposed changes to this specification
- Obtain written authorization from Purchaser to proceed with the repairs

6.2 Repair Procedure

> **Note**
> Not all of the steps outlined below will be required for each repair. The appropriate steps should be performed as required. It is also not intended that the steps be performed sequentially; in practice, the steps would be carried out in parallel (that is, weld prep for all steps, degreasing for all steps, welding etc.).

6.2.1 Correct Distortion. Distortion exceeding allowable limits can be repaired by cold straightening or replacement of individual basket shell ring sections.

6.2.2 Remove Spring Clips (as required for replacement or heat treatment).

6.2.2.1 All spring clips exhibiting dimensions outside of allowable limits or wear in excess of 25% of nominal thickness shall be replaced. When removal of the spring clip assembly (whether Hastelloy X or Inconel X750) is required, the old assembly may not be reused (that is, the spring clip assembly must be replaced with a new assembly).

6.2.2.2 Remove the internal and external spring clips by machining or grinding to separate the spot welds.

6.2.2.3 LPT the aft basket shell in the region from which the spring clips have been removed.

6.2.3 Heat Treatment

Note
Heat treatment should not be required for most repairs. It may be used at the vendor's option to improve weldability in instances where the Hastelloy X alloy has been embrittled by service exposure but should only be used after welding difficulties have been encountered. Thermal Barrier Coating, including bond coat, must be removed prior to heat treatment. Heat treatment may be carried out on the whole basket or individual parts as required.

6.2.3.1 If the spring clip alloy is Inconel X750, remove the spring seals prior to heat treatment per section 6.2.2. When removal of the spring clip assembly (whether Hastelloy X or Inconel X750) is required, the old assembly may not be reused (that is, the spring clip assembly must be replaced with a new assembly).

Note
Heat treatment of Inconel X750 spring clips will reduce spring resiliency and damage their ability to seal.

6.2.3.2 Unless specifically approved otherwise, remove the forward flange assembly.

Note
Heat treatment of the 300 series stainless/carbon steel flange assembly can result in deleterious grain growth in the microstructure of the assembly. Some industry experience indicates that the grain growth during component heat treatments may not be to the level that would result in an unserviceable component. However, the conservative approach is to remove the assembly prior to heat treatment. It is recommended that any approval of heat treatment without flange removal be granted based on testing/microstructural inspection during the original process qualification (7.1).

6.2.3.3 Strip thermal barrier coating (TBC), including bond coat, using the same procedures applied during the preparation of first article qualification samples and described in the process description as specified in paragraph 7.1. Special care should be exercised to ensure that the TBC bond coat is completely removed so that proper adhesion of the replacement bond coat will result during re-coating.

6.2.3.4 Thoroughly degrease parts using approved solvent cleaner or other approved methods such as steam cleaning or pressure spraying.

6.2.3.5 Fixture forward (upstream) and aft (downstream) end of the basket at four points with a Hastelloy X cross brace to prevent distortion during heat treatment. Other methods, such as proper positioning and support fixturing to ensure proper support within the heat treating furnace, may be permitted (in lieu of cross bracing) when approved by the Purchaser and shown to be acceptable during the original process qualification (7.1).

6.2.3.6 Solution anneal the baskets in vacuum, hydrogen, or argon atmosphere at 2150°F ±15°F (1175°C ±8°C) for 1/2 hour, followed by rapid cooling to less than 1000°F (550°C) in less than 15 minutes. Support parts using approved fixture materials (that is, the same fixture materials approved during the first article qualification, paragraph 7.1) with the parts supported uniformly to prevent distortion. Avoid supporting the parts by any thin sections.

6.2.4 Weld Repair

6.2.4.1 Cracking, wear, and erosion on the basket rings, basket dome, basket seams and forward (fuel nozzle) flange may be repaired by gas tungsten arc welding or plasma transferred arc welding to restore the damaged area. Spring clip damage above the allowable limits (6.2.2.1) and crossfire tube flanges must be repaired by replacement of the affected part. Replacement of individual spring clip leaves is permitted (see 5.1.5).

6.2.4.2 Prepare the areas of the basket to be repaired by grinding out the existing cracks and defects and performing LPT to ensure that the cracks are completely removed. All oxidation and traces of residual coating shall be removed from the surfaces adjacent to the repair areas. Grinding tools and procedures to be used shall be identical to those used in the original process qualification (7.1).

6.2.4.3 After weld preparation, and when specifically requested, Purchaser shall be informed and allowed to inspect the components.

6.2.4.4 Thoroughly degrease parts using approved solvent cleaner or other approved methods such as steam cleaning or pressure spraying.

6.2.4.5 Weld repair the components using gas tungsten arc or plasma transferred arc welding methods. Areas to be welded must be free of oxide, grease, dirt, and penetrant chemicals. All areas must be welded using full penetration welds through the section being repaired. Weld procedures used shall be identical to those used in the original process qualification (7.1).

6.2.4.6 Machine, grind, and polish the repaired areas to restore the original contours and dimensions. Tools and procedures used shall be identical to those used in the original process qualification (7.1). Repaired areas penetrating into the basket gas path (internal) surfaces following repair shall be ground smooth to remove any surface irregularities or abrupt changes in geometry to ensure that no stress risers exist that would limit the life of the basket TBC to be applied following repair.

6.2.4.7 LPT any repaired areas of the basket that will be inaccessible after replacement of basket rings and assembly of the forward flange and spring clips (if removed). Follow procedures outlined in paragraph 6.1.6, using the acceptance criteria identified in Paragraph 5.2.

6.2.4.8 Parts that fail to meet the criteria of paragraph 5.2 may be recycled to repair any defects beginning at paragraph 6.2.4.2. Parts may be recycled to paragraph 6.2.3 to improve weldability, at the vendor’s option.

6.2.5 Crossfire Tube Flange (Marmon Flange) Replacement

6.2.5.1 Excessive cracking, wear, and erosion on the crossfire tube Marmon flanges must be repaired by replacing the crossfire tube flange. Minor crossfire tube assembly damage may be corrected by repair welding in the affected areas.

6.2.5.2 Remove the damaged flange, ensuring that sufficient residual material remains to attach the new flange. All traces of oxidation and residual coating shall be removed from the surfaces adjacent to the joint area. Grinding tools and procedures used shall be identical to those used in the original process qualification (7.1).

6.2.5.3 Thoroughly degrease parts using approved solvent cleaner or other approved methods such as steam cleaning or pressure spraying.

6.2.5.4 Join the replacement cross fire tube flange to the basket crossfire sleeve using gas tungsten arc or plasma transferred arc welding methods. Areas to be welded must be free of oxide, grease, dirt, and penetrant chemicals. All areas must be welded using full penetration welds through the section being joined. Weld procedures used shall be identical to those used in the original process qualification (7.1).

Note
It is strongly recommended that a fixture be employed to ensure proper dimensional location of the replacement crossfire Marmon flange.

6.2.5.5 Machine, grind, and polish the internal surfaces to restore the original contours and dimensions. External unmachined surfaces do not require blending. Tools and procedures to be used shall be identical to those used in the original process qualification (7.1).

6.2.6 Body Shell Section (Body Ring) Replacement

Note
Refer to Appendix III for shell ring component details and attachment criteria.

6.2.6.1 Cracking, distortion, wear, and erosion on the basket shell sections (body rings) can be repaired by replacing the affected part. Model B, D24, and D4 baskets consist of seven body shell sections. W501 Model D5 baskets consist of six shell sections (see forms in Appendix II). In conjunction with body shell section replacement, the wiggle strips and reinforcement bands associated with the specific ring to be replaced must also be replaced with new components. Details of the shell component parts and their attachment criteria are illustrated in Appendix III.

6.2.6.2 Prepare the section of basket ring to be replaced by removing the spot welds securing the affected section and shell component parts (wiggle strips/reinforcing bands). Smooth and blend the remaining shell rings above and below the ring to be replaced to restore original contours and finish. LPT the remaining shell rings above and below the ring to be replaced to ensure that no cracks or other defects exist. All traces of oxidation and residual coating shall be removed from the surfaces adjacent to the repair areas. Grinding tools and procedures used shall be identical to those used in the original process qualification (7.1).

6.2.6.3 Basket shell ring sections shall be formed and machined to match the section to be replaced.

6.2.6.4 Thoroughly degrease parts using approved solvent cleaner or other approved methods such as steam cleaning or pressure spraying.

6.2.6.5 Join the basket ring by spot welding the wiggle strips, basket ring, and reinforcing bands per Appendix III. Areas to be welded must be free of oxide, grease, dirt, and penetrant chemicals. Weld procedures used shall be identical to those used in the original process qualification (7.1).

6.2.6.6 Machine, grind, and polish the affected areas as required to restore the original contours and dimensions. Tools and procedures used shall be identical to those used in the original process qualification (7.1).

6.2.7 Spring Clip (Aft Seal) Replacement

6.2.7.1 Cracking, excess wear, distortion, and/or erosion on the spring seal clips may be repaired by replacement of the entire seal clip assembly or replacement of individual spring clip leaves.

6.2.7.2 Replacement spring seal clips shall be formed and machined to match the existing seals and be in accordance with 5.1.5. Inconel X750, in lieu of Hastelloy X, may be employed for spring clip material if specified by the Purchaser. Spring clip hardface coatings shall be applied in the contact area to minimize wear of the spring clips. Spring clip hardface coating shall meet the microstructural requirements of 5.4.2. Process procedures used to apply hardface coatings shall be the same as those employed in the original process qualification (7.1).

6.2.7.3 Remove the existing external and internal spring clips by removing the spot welds attaching them to the basket aft shell ring. LPT the aft shell ring in the area where the spring clips were removed to ensure that no cracks or other defects exist. All traces of oxidation, residual coating, or other foreign material shall be removed from the surfaces adjacent to the repair areas. Grinding tools and procedures used shall be identical to those used in the original process qualification (7.1).

6.2.7.4 Thoroughly degrease parts using approved solvent cleaner or other approved methods such as steam cleaning or pressure spraying.

6.2.7.5 Attach the spring seal clip assembly to the aft end basket ring by spot welding. Internal and external spring clips shall be staggered (partially overlapped) to match the seal clip geometry provided by the original equipment manufacturer. All spot welds shall be 0.250 inch +0.000/0.030 inch (6.35 mm +0.00/-0.76 mm) diameter spaced at one spot weld below each spring leaf. Areas to be welded must be free of oxide, grease, dirt, and penetrant chemicals. Weld procedures used shall be identical to those used in the original process qualification (7.1).

6.2.7.6 Check concentricity of spring clip assembly with the basket aft inside diameter (ID). The spring clips shall be concentric with the aft ID within 0.100 inches (2.54 mm). Checking fixtures

may be used in lieu of actual measurements and recorded as “Pass” or “Fail” on the forms attached in Appendix I. Parts that fail to meet this requirement may be recycled for replacement beginning at paragraph 6.2.7.1.

6.2.8 Forward Flange Assembly (Fuel Nozzle Flange) Replacement

6.2.8.1 Distortion, cracking, or excessive wear and erosion of the forward flange assembly may be repaired by replacing the flange assembly.

6.2.8.2 Remove the damaged flange assembly ensuring that sufficient residual material remains to attach the new flange. FPI to ensure that the cracks are completely removed. All traces of oxidation and residual coating shall be removed from the surfaces adjacent to the joint area. Grinding tools and procedures to be used shall be identical to those used in the original process qualification (7.1).

6.2.8.3 Thoroughly degrease parts using approved solvent cleaner or other approved methods such as steam cleaning or pressure spraying.

6.2.8.4 Join the replacement forward flange assembly to the basket dome extension using gas tungsten arc or plasma transferred arc welding methods. Areas to be welded must be free of oxide, grease, dirt, and penetrant chemicals. Flange connection shall be made using full penetration welds through the section being joined. Weld procedures used shall be identical to those used in the original process qualification (7.1). Replacement flange materials shall be in accordance with paragraph 5.1.3.

6.2.8.5 Check and record concentricity (run-out) of forward flange assembly with respect to the aft end inside diameter (See Appendix I). The maximum allowable run-out is 0.010 inch (0.25 mm).

Note
Machining of the forward flange assembly may be used to restore concentricity when only minor corrections are required. When run-out exceeds approximately 0.050 inch (1.27 mm), the problem is typically caused by distortion in the basket shell. In these cases, removal and replacement of distorted basket shell sections per 6.2.6 is required.

6.2.8.6 Machine, grind, and polish the internal surfaces to restore the original contours and dimensions. External unmachined surfaces do not require blending. Tools and procedures to be used shall be identical to those used in the original process qualification (7.1).

6.2.9 Apply Thermal Barrier Coating (TBC)

6.2.9.1 Prior to application of the TBC, inspect, record, and ensure that the basket meets all dimensional requirements of paragraph 5.3 (record information on forms in Appendix I) and LPT each basket using the method outlined in 6.1.6 and acceptance criteria in 5.2. Record the LPT results on the forms attached as Appendix II.

6.2.9.2 Prepare internal (substrate) surfaces and reapply a thermal barrier coating to internal surfaces of the baskets according to Purchaser Specification COMBTBC "Specification for Application of Thermal Barrier Coatings on Industrial Gas Turbine Combustion Components." Unless otherwise specified, the extent of coating coverage shall be equivalent to that supplied by the original equipment manufacturer.

6.3 Final Inspection

6.3.1 After completion of the repair, Purchaser shall be informed and allowed to witness final inspection of the components.

6.3.2 If residue resulting from repairs has not been removed, thoroughly degrease parts using approved solvent cleaner or other approved methods such as steam cleaning or pressure spraying.

6.3.3 Arrange a pre-shipment inspection with Purchaser to:

- Review documentation, including dimensional and damage assessment record forms (see Appendices I and II), heat treatment charts, quality control test reports, and a mapping of repairs
- Perform visual inspection
- Deliver Purchaser copies of the documentation

6.3.4 Package and ship parts in suitable containers that will prevent component contact and damage under rigorous handling conditions. All parts that are lost or damaged beyond repair may be back charged up to the cost of replacement with original OEM parts.

6.3.5 Advise Purchaser of information such as the shipping date, route, and carrier.

6.3.6 Issue final report outlining repair process used and containing all documentation required in paragraph 7.2.

7 Quality Requirements

7.1 Pre-Production Qualification

7.1.1 Vendor Audits. Prior to placing a repair order of any sort with a specific vendor, the vendor's facilities, quality control system, and general operation shall be audited by Purchaser for capability to adequately perform turbine component repair. Approval shall be granted for a period specified by Purchaser, but may be removed by Purchaser for inadequate vendor performance.

7.1.2 Technical Review. For each specific repair process, the vendor will be required to submit a process plan to Purchaser for review. The process plan shall describe directly, or by reference to controlling specifications, all steps to be performed during the repair process. The vendor shall

also identify allowable limits for the dimensions identified in Appendix I. After review and acceptance by Purchaser, the process plan shall be fixed and all parts shall be processed according to that plan. The plan shall identify all tooling and fixtures to be used in the repair and inspection of the components. The vendor shall obtain written approval by Purchaser for any change to the process.

7.1.3 First Article Inspection. At Purchaser's option, the vendor shall be required to prepare a first article for approval prior to the acceptance of a process plan or any changes to the plan. The supplier will be required to process baskets (and/or other sample material identified by Purchaser) through the entire process for nondestructive and destructive examination, by Purchaser, for compliance with the requirements of paragraph 5. Approval of vendor's process will be based on the results of this inspection, the Vendor Audit and the Technical Review.

7.1.4 Personnel Qualifications. Inspection personnel shall be qualified to ASNT Recommended Practice No. SNT-TC-1A Level II or III.

7.1.5 Calibration. Tooling shall be calibrated on a periodic basis and records of calibration shall be maintained by the vendor.

7.2 Documentation and Certification

7.2.1 Quality Control Tests. In-process and final quality control tests shall be performed, as identified in paragraph 6. Results of all required testing shall be recorded by serial number. A certified copy shall be given to Purchaser's representative at the pre-shipment inspection.

7.2.2 Processing Records. Processing records shall be maintained in sufficient detail to indicate compliance with this specification and to allow traceability by lot. A mapping of the location, nature, and extent of repairs on each component shall be prepared and recorded by serial number. A copy of these records shall be given to Purchaser's representative at the pre-shipment inspection.

7.2.3 Certificate of Compliance. All processing and quality control records shall be reviewed by the vendor to verify compliance with this specification and the purchase order. Any deviations shall be reported immediately to Purchaser and may be cause for rejection. A document certifying that all aspects of this specification and the purchase order have been met shall be signed by the responsible vendor representative and shall be presented to Purchaser with the repair report. This document shall include:

a) Purchase order number

b) Purchaser specification number

c) Purchaser drawing number

d) Serial numbers and final disposition

e) Heat treatment lots by serial number

f) A copy of all documents approving vendor requested deviation from the requirements of this specification

7.2.4 Records. All process control records and quality control test results shall be maintained on file by the vendor for a period of seven years. This information shall be made available to Purchaser upon request.

7.2.5 Final Report. At completion of the repair process, a final report shall be issued and shall contain:

a) A description of the complete repair process

b) A mapping of all defects identified at paragraph 6.1.3 and 6.1.6 (use forms attached as Appendix II)

c) A mapping of all repair locations (use forms attached as Appendix II)

d) A copy of all incoming, in-process, and final dimensional inspection forms (use forms attached as Appendix I)

e) A copy of final LPT identified at paragraph 6.2.9.1 (use forms attached as Appendix II)

f) A copy of the certificate of compliance

7.3 Acceptance and Disposition

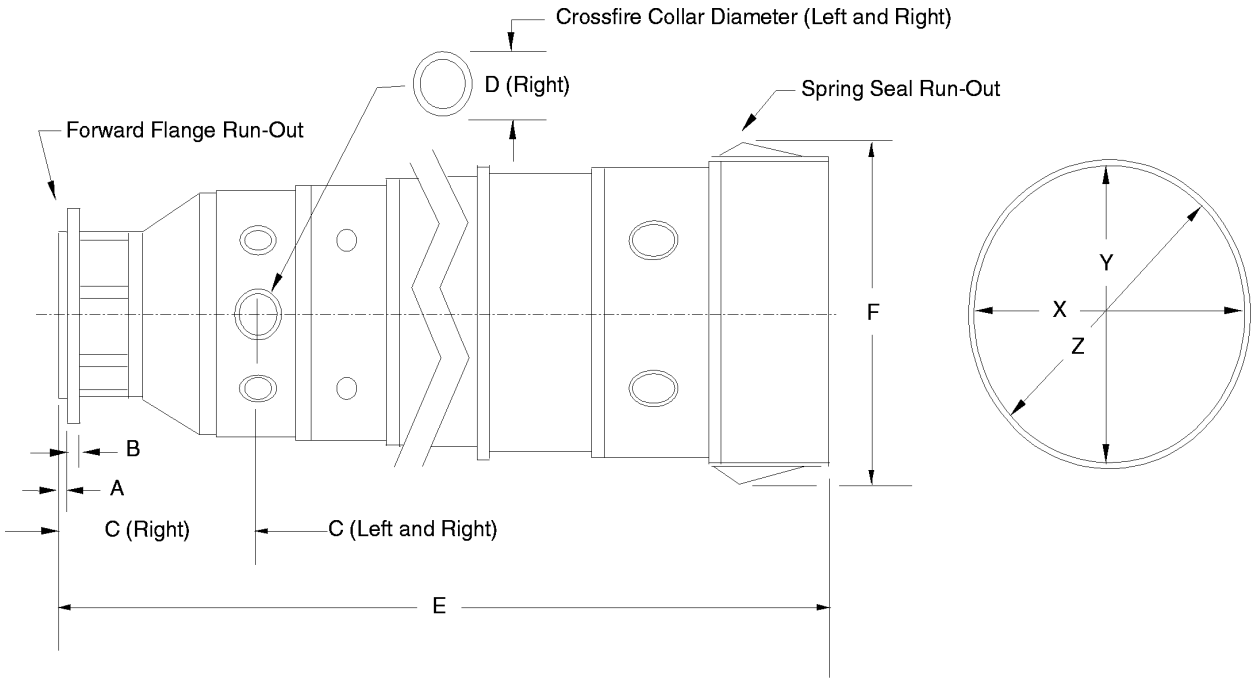
7.3.1 All deviant parts shall be plainly labeled in a nondestructive manner, isolated from the batch and held for Purchaser disposition.

7.3.2 Components not meeting the requirements of this specification, the purchase order, and referenced drawings shall be rejected. Rejected parts shall be held for Purchaser disposition.

7.4 Access

Purchaser shall be allowed reasonable access to inspect components at all times during the repair process.

Appendix I - Dimensional Inspection Forms



NOTES:

1. RECORD DIMENSIONS A THRU F ON FORM I-B.
2. RECORD AFT DIAMETERS (X, Y & Z), FORWARD FLANGE AND SPRING SEAL RUNOUTS ON FORM 1-C

Form I-A
Westinghouse W501 Models B, D24, D4, and D5 Combustor Baskets Dimensional Inspection Form

BASKET MODEL (CHECK ONE): ☐ B ☐ D24 ☐ D4 ☐ D5

Chamb No.	Serial No.	A Min / Max	B Min / Max	Crossfire Locations		Crossfire Collar Diameters		E	F
				C Left	C Right	D Left	D Right		
Allowable Limits									
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									

DATE	INSPECTED BY:
OWNER	PLANT
UNIT DESIGNATION	TURBINE S/N
CHECK TYPE OF INSPECTION: ☐ INCOMING; ☐ IN PROCESS; ☐ FINAL	

Form I-B
Westinghouse W501 Combustor Basket Dimension Sheet

BASKET MODEL (CHECK ONE): ☐ **B** ☐ **D24** ☐ **D4** ☐ **D5**

CHAMB No.	SERIAL No.	AFT END DIAMETERS			RUN-OUT OF FORWARD FLANGE WITH RESPECT TO AFT INSIDE DIAMETER	RUN-OUT OF AFT SEAL WITH RESPECT TO AFT INSIDE DIAMETER*
		X	Y	Z		
ALLOWABLE LIMITS						
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						

*** Use of checking fixtures and notation of "Pass" or "Fail" is permissible for aft seal run-out.**

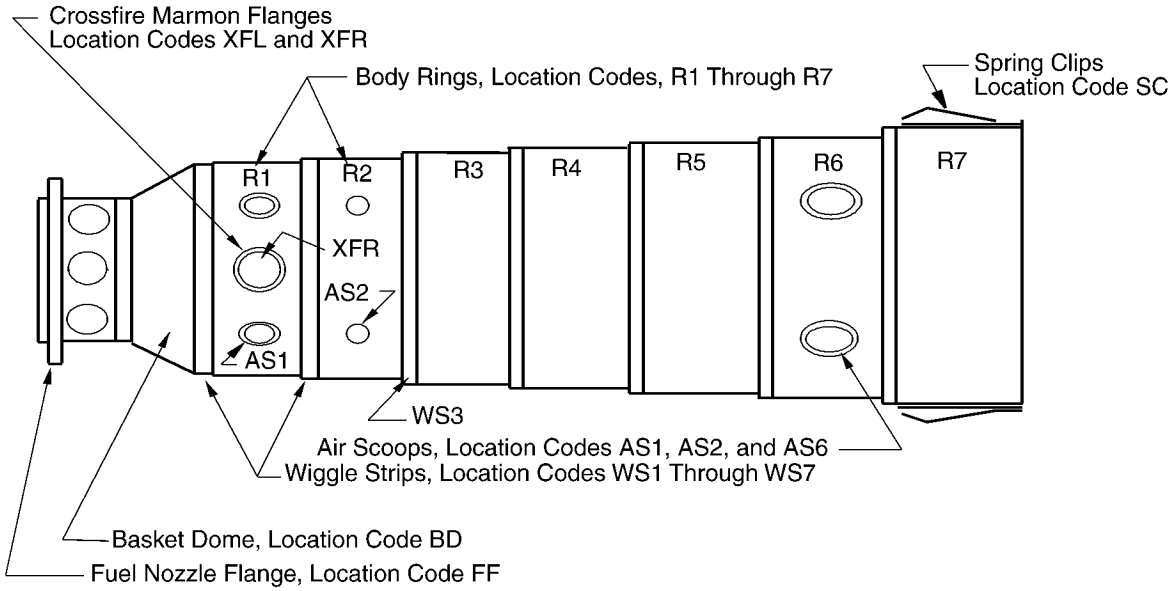
DATE	INSPECTED BY
OWNER	PLANT
UNITE DESIGNATION	TURBINE S/N
CHECK TYPE OF INSPECTION: ☐ **INCOMING;** ☐ **IN PROCESS;** ☐ **FINAL**	

Form I-C
Westinghouse W501 Combustor Basket Dimension Sheet – Forward Flange Concentricity, Aft End Diameters, and Aft Seal Concentricity

Appendix II - Damage Assessment Forms

RECORD BASKET DEFECTS, LOCATIONS & DISPOSITION ON FORM II-C USING THE CODES SHOWN BELOW

W501 Basket Models B, D24, and D4



DEFECT CODES			
BU	Burned *	PH	Plugged Cooling Holes
CO	Corroded*	DT	Distortion*
CR	Cracked**	BR	Broken*
BK	Buckled*	BT	Bent*
H	Hot Spots*	CL	Loss of Thermal Barrier Coating*
W	Wear***		
M	Missing*		

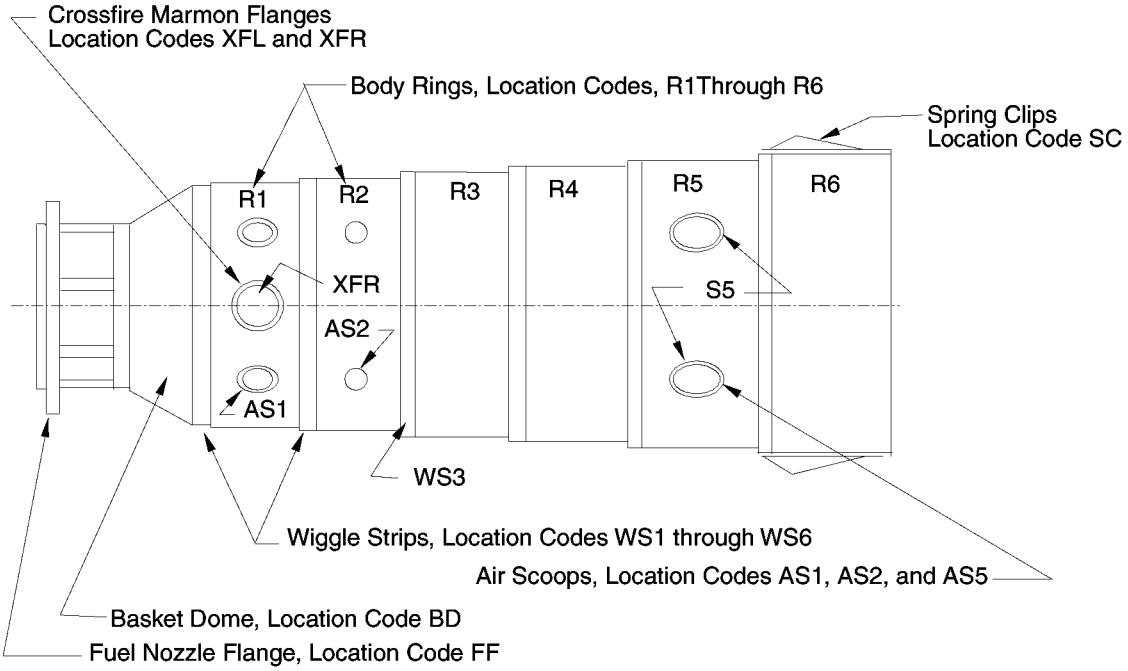
* Record the area of these types of defects in the "Size" column of Form II-C (e.g., ½" x 2").
** Record the length of cracks in the "Size" column of Form II-C.
*** Record the depth of wear in the "Size" column of Form II-C.

DISPOSTION CODES	
WR	Weld Repair
R	Replace
B	Blend
O	Other (Explain)

Form II-A
Westinghouse W501 Models B, D24, and D4 Combustor Basket Damage Assessment Form Instructions

RECORD BASKET DEFECTS, LOCATIONS & DISPOSITION ON FORM II-C USING THE CODES SHOWN BELOW

W501 MODEL D5 BASKET



DEFECT CODES			
BU	Burned *	PH	Plugged Cooling Holes
CO	Corroded*	DT	Distortion*
CR	Cracked**	BR	Broken*
BK	Buckled*	BT	Bent*
H	Hot Spots*	CL	Loss of Thermal Barrier Coating*
W	Wear***		
M	Missing*		

* Record the area of these types of defects in the "Size" column of Form II-C (e.g., ½" x 2").
** Record the length of cracks in the "Size" column of Form II-C.
*** Record the depth of wear in the "Size" column of Form II-C.

DISPOSTION CODES	
WR	Weld Repair
R	Replace
B	Blend
O	Other (Explain)

Form II-B
Westinghouse W501 Model D5 Combustor Basket Damage Assessment Form Instructions

BASKET MODEL (CHECK ONE): ☐ **B** ☐ **D24** ☐ **D4** ☐ **D5**

CHAMBER NO.:		**BASKET SERIAL NO.:**		
DEFECT CODE	**LOCATION CODE**	**SIZE (INCHES x INCHES) (OR INCHES ONLY FOR CRACKING)**	DISPOSITION CODE	**COMMENTS**
DATE:				**INSPECTED BY:**
OWNER:				**PLANT:**
UNIT DESIGNATION:				**TURBINE S/N:**
CHECK TYPE OF INSPECTION:		**☐ INCOMING;**	**☐ IN PROCESS;**	**☐ FINAL**

Form II-C
Westinghouse W501 Models B, D24, D4, and D5 Combustor Basket Damage Assessment Form

Appendix III - Basket Repair Illustrations

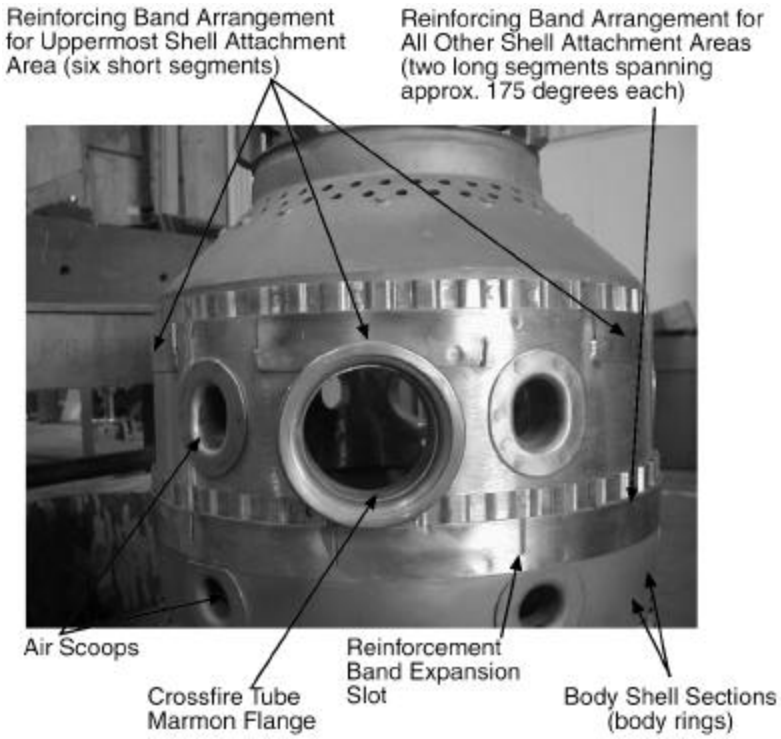
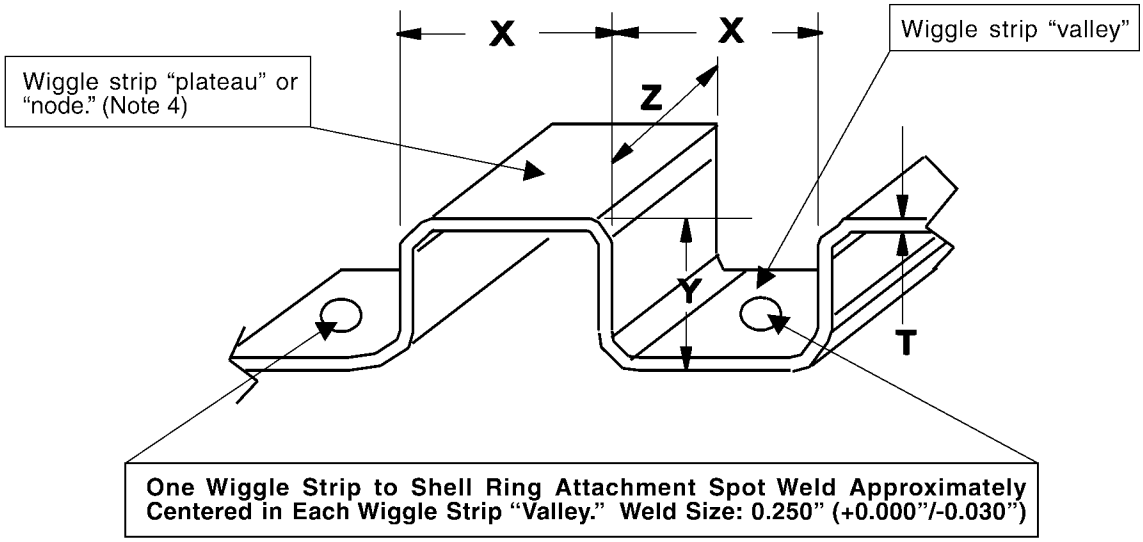


Figure III-A
Basket Shell (Ring) Section Nomenclature

WIGGLE STRIP GEOMETRY



X (INCHES)	Y (INCHES)	Z (INCHES)	T (INCHES)
0.314	0.125 Note 1	1.25	0.027 or 0.045 Note 2

1 Inch = 25.4 mm

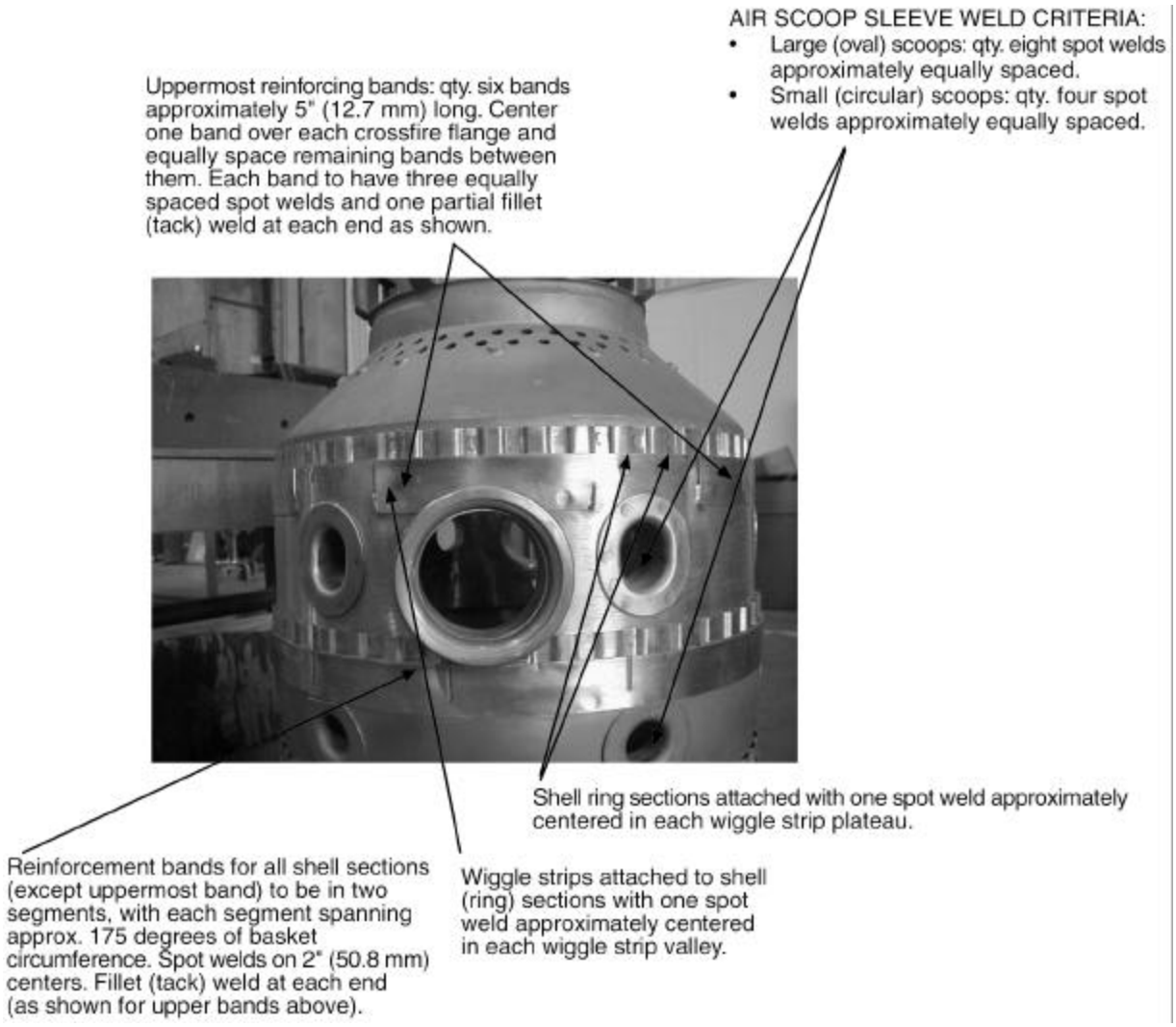
WIGGLE STIP GEOMETRY NOTES:

1. Wiggle strip height (Y): For the first wiggle strip (i.e., strip between basket dome and Ring 1), it is sometimes necessary to increase the height to 0.150 inches to allow for mismatch between dome extension and Ring 1.
2. Wiggle Strip Thickness (T): All wiggle strips except the aft-most strip are to be 0.027 inches thick. The aft-most strip (i.e., strip between Rings 6 and 7 on Models B, D24 and D4, or between Rings 5 and 6 on Model D5) is to be 0.045 inches thick.
3. All wiggle strips to be fabricated from Hastelloy X.
4. There are typically 36 wiggle strip "nodes" around the entire basket circumference.

NOTES ON BASKET REINFORCEMENT BAND GEOMETRY

1. All reinforcement band material to be 1 inch wide X 0.045 to 0.050 inches thick Hastelloy X.
2. Several designs have been used successfully relative to the spacing and size of the expansion slots on reinforcement strips. Unless approved otherwise, repair vendor should match the expansion slot size and spacing provided on the specific basket to be repaired.

Figure III-B
Body Shell Section Component Details



NOTE: ALL ATTACHMENT SPOT WELDS 0.250 inch (+0.000/-0.030 inch [6.35 +0.0/-0.76 mm])

Figure III-C
Body Shell Attachment Weld Details

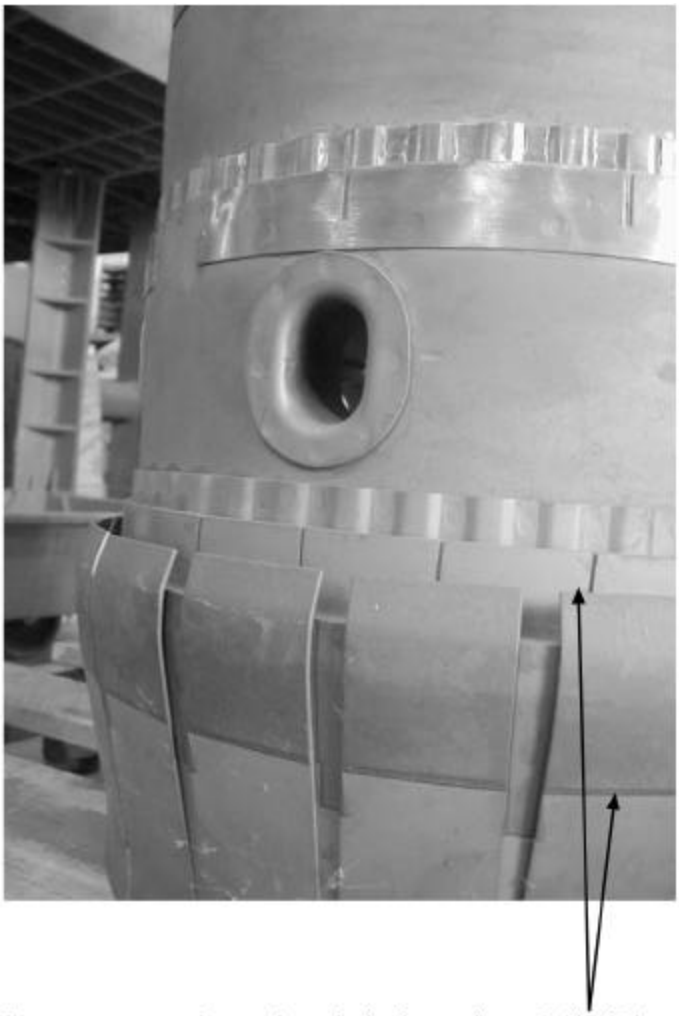


Figure III-D
Hardfacing of Basket Spring Clips

5
REPAIR SPECIFICATION FOR WESTINGHOUSE W501 MODELS D4 AND D5 COMBUSTOR TRANSITIONS

1 Scope

1.1 Purpose

This specification covers the minimum requirements for the weld repair, heat treatment, and application of thermal barrier and hardface coatings to Westinghouse W501 Models D4 and D5 combustor transitions manufactured from Hastelloy X alloy (49Ni 22Cr 18Fe 9Mo 1.5Co 0.5W) or IN-617 alloy (54Ni 22Cr 12.5Co 9Mo 1Al 0.3Ti). Transitions repaired to these requirements should provide service life approaching that of new components.

Note
While this specification addresses both Hastelloy X and IN-617 alloys, the vast majority of W501 D4 and D5 transitions are manufactured from Hastelloy X alloy. In terms of repair requirements, the only difference in processing is in the composition of weld filler alloys; that is, Hastelloy X transitions are weld repaired using Hastelloy X filler alloy and IN-617 transitions are weld repaired using IN-617 filler alloy.

Note
The application of hardface coatings at transition contact locations is typically not required on W501 Model D4 transitions and is typically considered an option for the Model D5. Operating experience on specific applications typically determines whether the additional expense of applying these coatings is justified. Therefore, the repair vendor is to determine the requirements, if any, for hardface coatings with the Purchaser prior to bidding and/or beginning repairs.

1.2 Application

Weld repair of combustor transitions is performed to repair physical damage such as wear, cracking, impact damage, and erosion. Heat treatments are required prior to welding to improve ductility and after welding to stress relieve weldments and to restore the appropriate microstructure (in many cases, one or both of the heat treatments may be omitted; refer to section 6.2). Thermal barrier coatings (TBCs) are applied to the internal surfaces of the transition piece to reduce metal temperatures. Hardface coatings are applied at transition contact locations to minimize wear and fretting.

2 Definitions

2.1 Lot

A group of parts that is processed through the entire repair cycle at the same time and heat treated in the same furnace at the same time throughout the repair cycle. If a group of parts being repaired at the same time is split into two or more subgroups for heat treatment, each subgroup shall constitute a lot.

2.2 Linear Indications

Nondestructive testing indications with a length of three times the width or greater.

2.3 Nonlinear Indications

Nondestructive testing indications with a length of less than three times the width.

2.4 Through-Going Indications

Indications appearing directly opposite each other and apparently extending through the thickness of the section.

2.5 LPT

Liquid Penetrant Testing.

3 Applicable Documents

3.1 Specifications

The following documents form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue shall apply.

AMS 5798C
“Wire, Welding, Alloy 47.5Ni 22Cr 1.5Co 9.0Mo 0.60W 18.5Fe”

U.S. Military Specification MIL-I-6866B
“Inspection, Liquid Penetrant”

ASTM E165
“Standard Practice for Liquid Penetrant Inspection Method”

ASNT Recommended Practice No. SNT-TC-1A
"Personnel Qualification and Certification in Nondestructive Testing"

Purchaser specification COMBTBC
"Specification for Application of Thermal Barrier Coatings on Industrial Gas Turbine Combustion Components"

3.2 Precedence of Documents

Specific requirements contained in purchase order instructions or drawings may be issued to supplement the requirements of this document. In cases of conflict, the purchase order shall take precedence followed by applicable drawings, followed by this document.

4 General Requirements

General requirements are typically addressed in the Request for Quotation or Purchase Order (as applicable) for component repairs.

5 Technical Requirements

5.1 Repair Materials

5.1.1 Repairs shall be performed by gas tungsten arc welding or plasma transferred arc welding using Hastelloy X filler material for Hastelloy X transitions and IN-617 filler material for IN-617 transitions.

5.2 Nondestructive Testing Acceptance Limits

Linear indications are permitted to 0.030 inch (0.75 mm) in length provided they are spaced by 5 times their length. Nonlinear indications separated by two times the diameter of the largest indication are permitted up to 0.060 inch (1.6 mm) diameter, or up to a diameter equal to 25% of the local section thickness, whichever is smaller. No through-going indications are permitted.

5.3 Dimensional Requirements

5.3.1 Dimensions shall be recorded as specified and conform to those identified on the forms attached as Appendix I.

Note
Dimensional inspection requirements shown in Appendix I are divided into several forms according to (a) the locations where measurements are required (for example, forward end and aft end) and (b) the type of measurements to be recorded (for example, linear, diametrical, and body panel thickness). The linear and diametrical dimensions at the forward end and aft end of the transition, while shown on separate forms, are interrelated due to the mounting arrangement employed in the

gas turbine itself; that is, measurements made from reference planes at the forward end are dependent on the fixed location of the aft end, and vice versa. *Therefore, it is a mandatory requirement to fix the location of the transition piece assembly at both the forward and aft ends before recording dimensions at either end.* Fixtures designed specifically for each transition model (D4/D5) are typically employed by repair vendors to simplify these measurements and to ensure the relationship of both the forward and aft ends with respect to each other. Many variations on fixture design are acceptable, and vendor-furnished forms associated with specific fixtures may be used in lieu of those shown in Appendix I. However, the fixtures/forms used shall record all of the critical dimensions shown on the forms in Appendix I and must be the same as those used during the original repair process qualification (7.1).

Note
OEM-supplied dimensional information contained in manuals and other supporting documentation should be used as reference dimensions where available. In the absence of such information, new or undamaged components may be measured and appropriate tolerances applied.

Note
This specification addresses transitions for both the D4 and D5 models. The D4 model has 16 combustion chambers while the D5 has only 14. Therefore, to cover both configurations, the forms provided in Appendix I include space for recording data for 16 transitions. When recording information for the D5 model, mark through the unneeded spaces.

5.3.2 Following repair, proper fit-up of combustor transitions is to be checked through the use of a fixture that replicates the first stage turbine vane assembly (See 6.2.15).

5.3.3 Repaired areas penetrating into the transition gas path (internal) surfaces following repair (that is, prior to the surface preparation required for the application of internal TBC) shall be ground smooth to remove any surface irregularities or abrupt changes in geometry to ensure that no stress risers exist that would limit the life of the transition TBC. Any bulging, warped, or bent areas shall be restored to their original contours prior to the application of the internal TBC.

5.4 Microstructural Requirements

5.4.1 Repair process related alloy depletion, oxidation, nitriding, and intergranular attack at the surface of the combustor transition (such as that can occur from heat treating furnace atmospheres) shall not exceed 0.001 inch (0.025 mm).

5.4.2 All hardface coatings applied by thermal spraying shall be crack-free. The sum (volume percent) of total porosity plus oxidation products shall be less than 4%. No delamination at the coating/substrate interface is allowed.

6 Processing Requirements

All process procedures applied during the repair of the components shall be the same as those used in the preparation of first article qualification samples and described in the process description as specified in paragraph 7.1.2.

6.1 Initial Inspection

6.1.1 Receive material and check for shipping damage. Check purchase order, material, and shipping papers to verify that the material received is correctly identified, fully accounted for, and that the repairs requested are reasonable.

6.1.2 Advise Purchaser immediately of any shipping damage.

6.1.3 Dimensionally inspect each transition for the following (See Appendix I):

- Overall length
- Body panel thickness
- Forward flange thickness and concentricity
- Forward support bracket distortion
- Aft seal area distortion
- Aft throat (picture frame opening) distortion
- Component wear

Record the results on the forms attached as Appendix I. Checking Fixtures may be used in lieu of actual measurements, provided that all dimensions identified on the forms are checked. (See note following 5.3.1.)

> **Note**
> Following repair, proper fit-up of combustor transitions is to be checked through the use of a fixture that replicates the first stage turbine vane assembly (See 6.2.15). Therefore, it is critical to determine at incoming inspection the extent of any distortion that may require removal/refitting or replacement of the aft ("picture") frame, forward flange assembly, forward supports, or body panels.

6.1.4 Visually inspect each transition for the following:

- Cracks
- Corrosion/erosion
- Hot spots/oxidation
- Dents/distortion
- Missing material

Record the results on the inspection form attached as Appendix II.

> **Note**
> This specification addresses transitions for both the D4 and D5 models. The D4 model has 16 combustion chambers while the D5 has only 14. Therefore, to cover both configurations, the forms provided in Appendix II include space for recording data for 16 transitions. When recording information for the D5 model, mark through the unneeded spaces.

6.1.5 Clean the transitions by grit blasting using 120 grit or finer aluminum oxide. Avoid excessive blasting.

6.16 Remove/strip any remaining thermal barrier coating (including base coat) left following grit blasting. The stripping of transition piece internal thermal barrier coatings shall be in accordance with Purchaser specification COMBTBC "Specification for Application of Thermal Barrier Coatings on Industrial Gas Turbine Combustion Components."

6.1.7 LPT the transitions following procedures outlined in U.S. Military Specification MIL-I-6866B or the procedures in ASTM E165. Document the location and extent of all cracks, dents, wear, corrosion/erosion, and missing material as directed on the form attached as Appendix II. Results should be added to the forms completed in the visual inspection of 6.1.4, if practical. The intent is to document/map all service-induced transition piece defects on one set of damage assessment forms.

6.1.8 Prepare a report delineating condition of the components and outlining the repairs. At this point, the vendor must:

- Obtain written approval for any proposed changes to this specification
- Obtain written or verbal authorization from the Purchaser to proceed with the repairs

6.2 Transition Repair Procedure

6.2.1 Any straightening required to correct transition distortion shall be performed prior to final heat treatment.

6.2.2 Thoroughly degrease the transition piece bodies using an approved solvent cleaner or other approved method such as steam cleaning or pressure spraying.

6.2.3 Solution anneal the transition piece bodies in vacuum, hydrogen, or argon atmosphere at 2150°F ±15°F (1175°C ±8°C) for 1/2 hour, followed by rapid cooling to less than 1000°F (550°C) in less than 15 minutes. Fixture parts using approved fixture materials with the parts supported uniformly to prevent distortion. Avoid supporting the parts by any thin sections. Unless approved otherwise, fixture materials used shall be identical to those used in the original process qualification (7.1.2).

> **Note**
> Depending upon the transition microstructure, length of service, and level of repairs required, solution annealing of transitions prior to weld repair may not be necessary. Repair vendor shall obtain approval from Purchaser for omitting the pre-weld heat treatment.

6.2.4 Prepare the areas of the transitions to be repaired by grinding out the existing cracks and defects and performing LPT to ensure that the cracks are completely removed. Grinding tools and procedures to be used shall be identical to those used in the original process qualification (7.1.2). Body panels, forward flange assembly, forward support brackets, and aft frame may be removed for replacement with parts of matching alloy composition.

6.2.5 When specifically requested, the Purchaser shall be informed and allowed to inspect the components after weld preparation.

6.2.6 Weld repair the transitions using gas tungsten arc or plasma transferred arc welding methods and the filler alloys specified in 5.1.1. Areas to be welded must be free of oxide, grease, dirt, and penetrant chemicals. All areas must be welded using full penetration welds through the section being repaired. Weld procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.7 Grind and polish the repaired areas to restore the original contours and dimensions. Non gas path unmachined surfaces do not require blending. Tools and procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.8 LPT each transition following procedures outlined in paragraph 6.1.7, using the acceptance criteria identified in Paragraph 5.2.

6.2.9 Parts that fail to meet the criteria of paragraph 5.2 may be recycled to repair any defects beginning at paragraph 6.2.4. Transitions may be recycled to paragraph 6.2.3 for stress relief, at the vendor's option.

6.2.10 Thoroughly degrease the transitions using an approved solvent cleaner or other approved method such as steam cleaning or pressure spraying.

6.2.11 After all repairs are complete (which includes both weld repairs and any cold straightening required to correct distortion), heat treat the transitions at 2150°F ±15°F (1175°C ±8°C) for 1 hour in vacuum, hydrogen, or argon atmosphere followed by rapid cooling to less than 1000°F (500°C) in less than 15 minutes. Fixture parts using approved fixture materials with the parts supported uniformly. Avoid supporting the parts by any thin sections. Unless approved otherwise, fixture materials used shall be identical to those used in the original process qualification (7.1.2).

Note
Depending upon the level of repairs required and transition microstructure, post weld heat treatment of transitions may not be necessary. Repair vendor shall obtain approval from Purchaser for omitting the post weld heat treatment.

6.2.12 Immediately following heat treatment and before any surface cleaning or blasting, LPT the transition using the method outlined in 6.1.7 and acceptance criteria in 5.2. Record the results on the forms attached as Appendix II.

6.2.13 Thoroughly degrease the transitions using an approved solvent cleaner or other approved method such as steam cleaning or pressure spraying.

6.2.14 Dimensionally check the transitions and record the results on the form attached as Appendix I. Checking Fixtures may be used in lieu of actual measurements, provided that all dimensions identified on the form are checked.

6.2.15 Following the dimensional check, a fixture replicating the first stage turbine vane assembly shall be used to check that the transitions will fit up properly into the vane assembly when re-installed into the gas turbine. If fixtures were used to complete the dimensional check (6.2.14) and if those fixtures have the capability to check overall fit-up of the transition to the turbine vane assembly, the intent of this paragraph may be considered to be met. Purchaser or Purchaser's designated representative shall be informed and allowed to inspect fit-up of the transition pieces into the first stage vane fixture.

6.2.16 If specified by Purchaser (see note following paragraph 1.1), prepare surfaces and install hardfacings at transition contact surfaces. Techniques used for wear protection shall be those approved in the original process qualification (7.1.2). Any wear protection method installed by welding shall be inspected by LPT following procedures outlined in paragraph 6.1.7 and using the acceptance criteria identified in Paragraph 5.2. All hardface coatings applied by thermal spraying shall meet the criteria identified in 5.4.2.

6.2.17 Reapply a thermal barrier coating to internal surfaces of the transitions according to Purchaser Specification COMBTBC "Specification for Application of Thermal Barrier Coatings on Industrial Gas Turbine Combustion Components." Unless otherwise specified, the extent of coating coverage shall be the same as that applied by the OEM.

6.2.18 Arrange a pre-shipment inspection with the Purchaser to:

- Review documentation, including heat treatment charts, quality control test reports, and a mapping of repairs
- Perform visual inspection
- Deliver Purchaser copies of the documentation

6.2.19 Package and ship parts in suitable containers that will prevent component contact and damage under rigorous handling conditions. All parts that are lost or damaged beyond repair may be back charged up to the cost of replacement with original OEM parts.

6.2.20 Advise Purchaser of the shipping date, route, and carrier.

6.2.21 Issue final report outlining repair process used and containing all documentation required in paragraph 7.2.

7 Quality Requirements

7.1 Pre-Production Qualification

7.1.1 Vendor Audits. Prior to placing a repair order of any sort with a specific vendor, the vendor's facilities, quality control system, and general operation shall be audited by the Purchaser for capability to adequately perform turbine component repair. Approval shall be granted for a period specified by the Purchaser but may be removed by the Purchaser for inadequate vendor performance.

7.1.2 Technical Review and First Article Inspection. For each specific repair process, the vendor will be required to submit a description of the process to the Purchaser for review. The supplier will also be required to process transitions (and/or other sample material identified by the Purchaser) through the entire process for nondestructive and destructive examination, by the Purchaser, for compliance with the requirements of paragraph 5. Based on the results, the Purchaser will approve the process for use at the vendor. The vendor shall obtain written approval by the Purchaser for any change to the process and, at the Purchaser's option, shall be required to prepare an additional first article for approval.

7.1.3 Personnel Qualifications. Inspection personnel shall be qualified to ASNT Recommend Practice No. SNT-TC-1A Level II or III.

7.2 Documentation and Certification

7.2.1 Quality Control Tests. In-process and final quality control tests shall be performed, as identified in paragraph 6. Results of all required testing shall be recorded by serial number. A certified copy shall be given to the Purchaser's representative at the pre-shipment inspection.

7.2.2 Processing Records. Processing records shall be maintained in sufficient detail to indicate compliance with this specification and to allow traceability by lot. A mapping of the location, nature, and extent of repairs on each component shall be prepared and recorded by serial number. A copy of these records shall be given to the Purchaser's representative at the pre-shipment inspection.

7.2.3 Certificate of Compliance. All processing and quality control records shall be reviewed by the vendor to verify compliance with this specification and the purchase order. Any deviations shall be reported immediately to the Purchaser and may be cause for rejection. A document certifying that all aspects of this specification and the purchase order have been met shall be signed by the responsible vendor representative and shall be presented to the Purchaser with the repair report. This document shall include:

a) Purchase order number

b) Purchaser specification number

c) Purchaser drawing number

d) Serial numbers and final disposition

e) Heat treatment lots by serial number

f) A copy of all documents approving vendor requested deviation from the requirements of this specification

7.2.4 Records. All process control records and quality control test results shall be maintained on file by the vendor for a period of seven years. This information shall be made available to the Purchaser upon request.

7.2.5 Final Report. At completion of the repair process, a final report shall be issued and shall contain:

a) A description of the complete repair process

b) A mapping of all defects identified at paragraph 6.1.4, 6.1.7, and the final LPT (use forms attached as Appendix II)

c) A mapping of all repair locations (use forms attached as Appendix II)

d) A copy of all incoming, in-process, and final dimensional inspection forms (use forms attached as Appendix I)

e) A copy of the certificate of compliance

7.3 Acceptance and Disposition

7.3.1 All deviant parts shall be plainly labeled in a nondestructive manner, isolated from the batch and held for Purchaser disposition.

7.3.2 Components not meeting the requirements of this specification, the purchase order, and referenced drawings shall be rejected. Rejected parts shall be held for Purchaser disposition.

7.4 Access

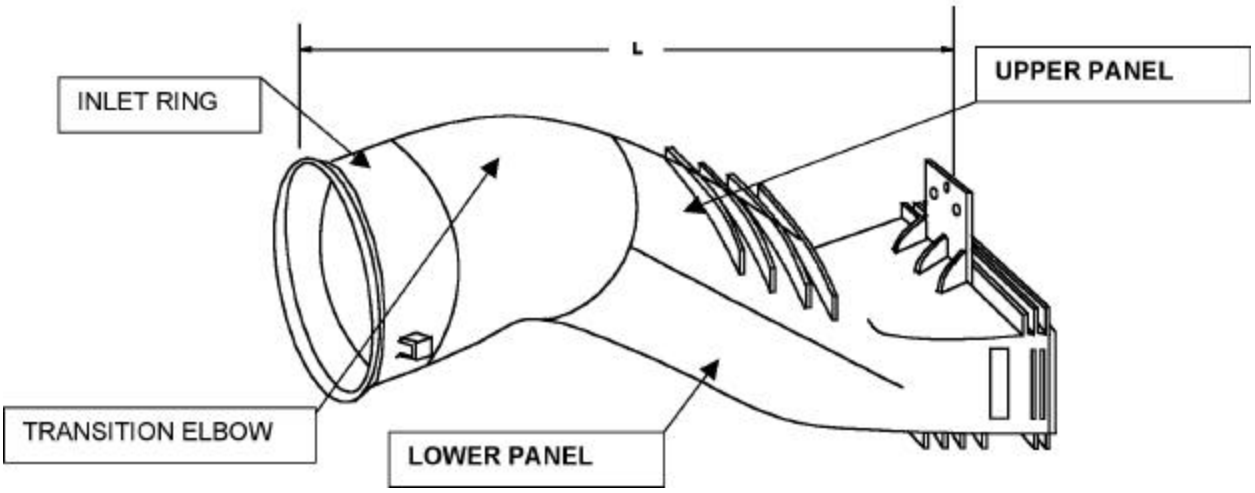
The Purchaser shall be allowed reasonable access to inspect components at all times during the repair process.

Appendix I - Dimensional Inspection Forms

Note

Dimensional inspection requirements shown in Appendix I are divided into several forms according to (a) the locations where measurements are required (e.g., forward end, aft end, etc.) and (b) the type of measurements to be recorded (e.g., linear, diametrical, body panel thickness, etc.). The linear and diametrical dimensions at the forward end and aft end of the transition, while shown on separate forms, are inter-related due to the mounting arrangement employed in the gas turbine itself; i.e., measurements made from reference planes at the forward end are dependent on the fixed location of the aft end, and vice-versa. Therefore, it is a mandatory requirement to fix the location of the transition piece assembly at both the forward and aft ends before recording dimensions at either end. Fixtures designed specifically for each transition model (D4/D5) are typically employed by repair vendors to simplify these measurements and to ensure the relationship of both the forward and aft ends with respect to each other. Many variations on fixture design are acceptable and vendor-furnished forms associated with specific fixtures may be used in lieu of those shown in Appendix I. However, the fixtures/forms used shall record all of the critical dimensions shown on the forms in Appendix I and must be the same as those used during the original repair process qualification (7.1).

MODEL No. (Check One): ☐ D4 ☐ D5



Dimension L taken along the transition centerline from the face of the forward flange to the aft face of the aft bracket. Body panel labeling is for panel thickness measurements that are to be recorded on Form I-B. Panel reinforcing rib design varies between models (D4 design shown dotted on Upper Panel).

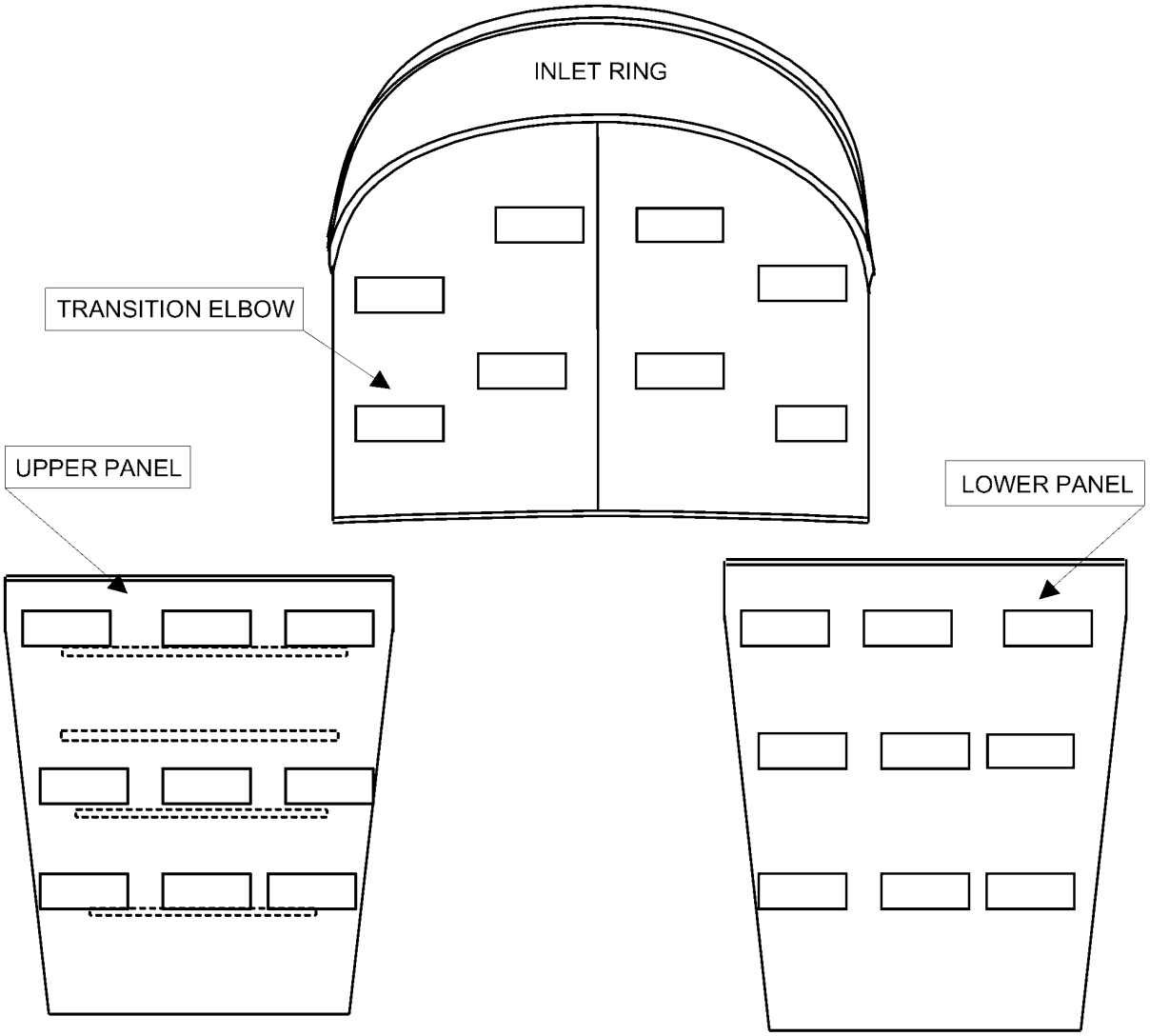
Chamber No.	Trans. Serial No.	L
ALLOWABLE LIMITS		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		

DATE:	INSPECTED BY:
OWNER:	PLANT:
UNIT DESIGNATION:	TURBINE S/N:
CHECK TYPE OF INSPECTION: ☐ INCOMING; ☐ IN PROCESS; ☐ FINAL	

Form I-A
W501 Models D4 and D5 Combustor Transition Dimensional Inspection Form

TRANSITION BODY PANEL THICKNESS CHECKS
(DUPLICATE THIS FORM FOR EACH TRANSITION)

RECORD BODY THICKNESS AT LOCATIONS INDICATED BY THE RECTANGLES AS A MINIMUM. RECORD THICKNESS AT ANY OTHER LOCATION WHERE DAMAGE (SUCH AS DENTS OR EROSIONS) HAS OCCURRED.



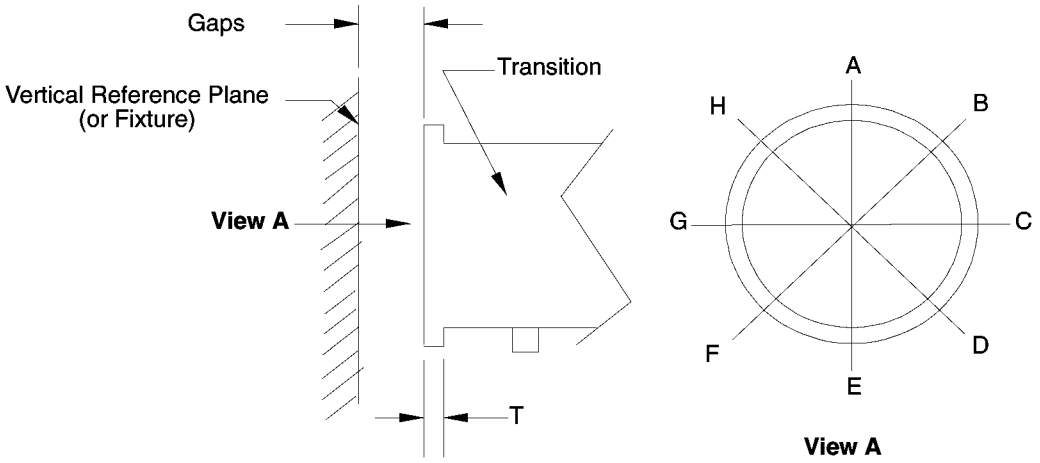
CHAMBER NUMBER _____ **TRANSITION SERIAL NUMBER**_____

DATE:	**INSPECTED BY:**
OWNER:	**PLANT:**
UNIT DESIGNATION:	**TURBINE S/N:**
CHECK TYPE OF INSPECTION: ☐ **INCOMING;** ☐ **IN PROCESS;** ☐ **FINAL**	

Form I-B
W501 Models D4 and D5 Combustor Transition Dimensional Inspection Form

MEASUREMENTS AT FORWARD THROAT & FORWARD FLANGE
(DUPLICATE THIS FORM FOR EACH TRANSITION)

MODEL No. (Check One): ☐ **D4** ☐ **D5**



CHAMBER No. _____ **TRANSITION SERIAL NO.** _____

DIMENSION	INSIDE DIAMETERS	GAPS	FLANGE THICKNESS "T"
ALLOWABLE LIMITS			
A			
B			
C			
D			
E			
F			
G			
H			

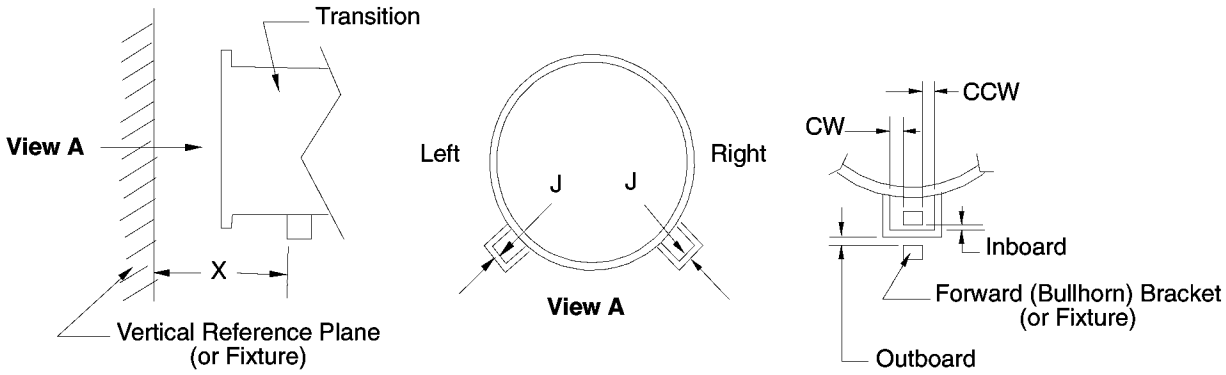
DATE:	**INSPECTED BY:**
OWNER:	**PLANT:**
UNIT DESIGNATION:	**TURBINE S/N:**

CHECK TYPE OF INSPECTION: ☐ **INCOMING;** ☐ **IN PROCESS;** ☐ **FINAL**

Form I-C
W501 Models D4 and D5 Combustor Transition Dimensional Inspection Form

MEASUREMENTS AT FORWARD (BULLHORN) BRACKETS
(DUPLICATE THIS FORM FOR EACH TRANSITION)

MODEL No. (Check One): ☐ **D4** ☐ **D5**



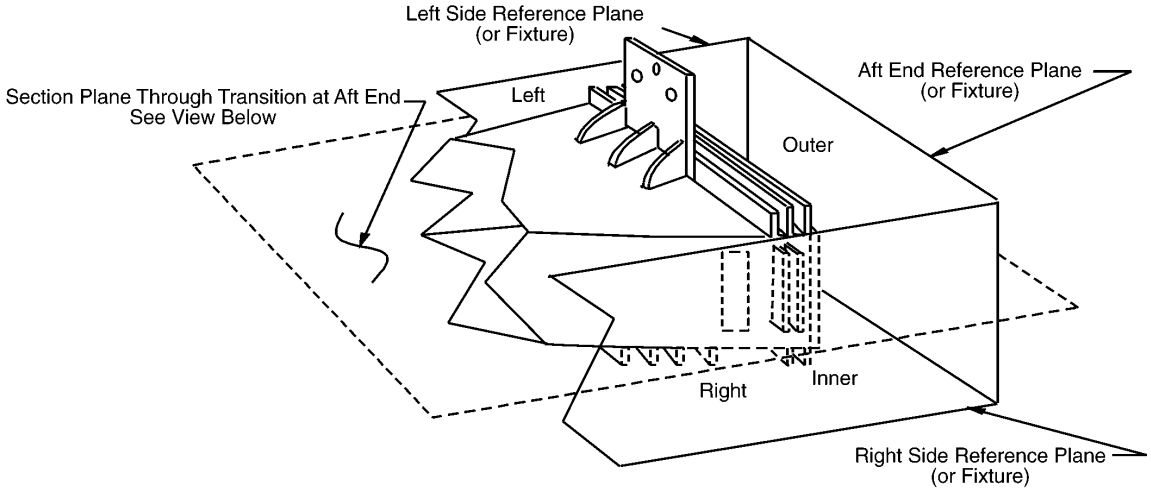
CHAMBER No. _____ **TRANSITION SERIAL NO.** _____

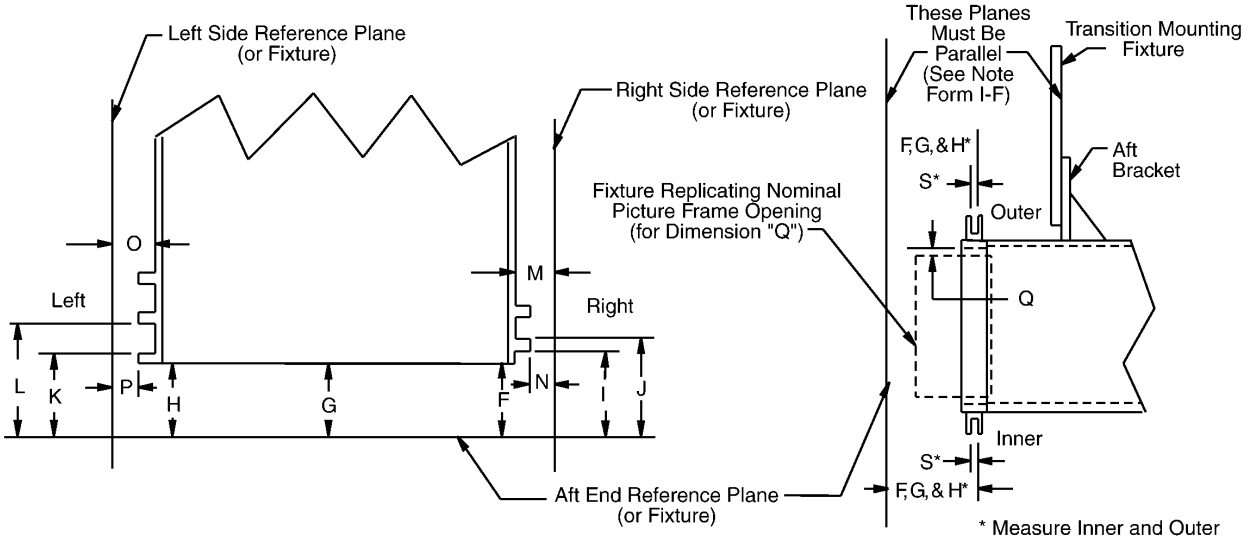
	ALLOWABLE LIMITS	LEFT		RIGHT	
X					
J					
BRACKET ROTATION		**CW**	**CCW**	**CW**	**CCW**
BRACKET RADIAL OFFSET		**INBOARD**	**OUTBOARD**	**INBOARD**	**OUTBOARD**

DATE:	**INSPECTED BY:**
OWNER:	**PLANT:**
UNIT DESIGNATION:	**TURBINE S/N:**
CHECK TYPE OF INSPECTION: ☐ **INCOMING;** ☐ **IN PROCESS;** ☐ **FINAL**	

Form I-D
W501D4 and D5 Combustor Transition Dimensional Inspection Form

MEASUREMENTS AT AFT END
RECORD MEASUREMENTS ON FORMS I-F AND I-G





SEE NOTE ON FORM I-F FOR TRANSITION MOUNTING REQUIREMENT FOR AFT MEASUREMENTS
DIMENSION Q TO BE MEASURED AT INNER & OUTER AND LEFT & RIGHT AFT FRAME LOCATIONS

Form I-E
W501D4 and D5 Combustor Transition Dimensional Inspection Form

MEASUREMENTS AT AFT END
MEASURMENTS CONT'D. ON FORM I-G

(DUPLICATE THIS FORM FOR EACH TRANSITION)

MODEL No. (Check One): ☐ **D4** ☐ **D5**

NOTE FOR TRANSITON MOUNTING FOR AFT END MESUREMENTS

TO RECORD ALL MEASUREMENTS THE TRANSITION AFT BRACKET MUST BE MOUNTED TO A RIGID FIXTURE PLATE THAT IS PARALLEL TO THE AFT END REFERENCE PLANE AND PERPENDICULAR TO THE LEFT AND RIGHT SIDE REFERENCE PLANES

PICTURE FRAME FACE TO AFT REFERENCE PLANE		**F**	**G**	**H**
	INNER			
	OUTER			

FLOATING SEAL CLEARANCE	**INNER**			
	OUTER			

SIDE SEAL AXIAL LOCATIONS	**I**	**J**	**K**	**L**

SIDE SEAL CLEARANCES	**M**	**N**	**O**	**P**

DATE:	**INSPECTED BY:**
OWNER:	**PLANT:**
UNIT DESIGNATION:	**TURBINE S/N:**
CHECK TYPE OF INSPECTION: ☐ **INCOMING;** ☐ **IN PROCESS;** ☐ **FINAL**	

Form I-F
W501D4 and D5 Combustor Transition Dimensional Inspection Form

MEASUREMENTS AT AFT END (CONTINUED)
(DUPLICATE THIS FORM FOR EACH TRANSITION)

MODEL No. (Check One): ☐ **D4** ☐ **D5**

CHAMBER No. _____ **TRANSITION SERIAL NO.** _____

FLOATING SEAL AXIAL SLOT WIDTH S		**INNER**	**OUTER**
	S LEFT		
	S RIGHT		

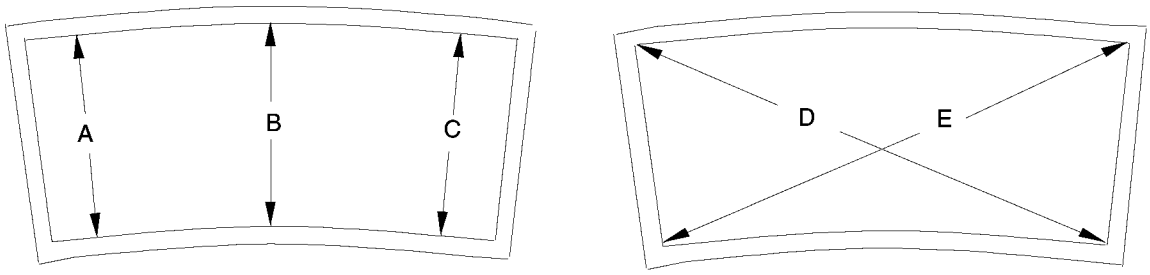
PICTURE FRAME MISMATCH		**INNER (Min. / Max.)**	**OUTER (Min. / Max.)**
	Q		
PICTURE FRAME MISMATCH		**LEFT (Min. / Max.)**	**RIGHT (Min. / Max.)**
	Q		

DATE:	**INSPECTED BY:**
OWNER:	**PLANT:**
UNIT DESIGNATION:	**TURBINE S/N:**
CHECK TYPE OF INSPECTION: ☐ **INCOMING;** ☐ **IN PROCESS;** ☐ **FINAL**	

Form I-G
W501D4 and D5 Combustor Transition Dimensional Inspection Form

MEASUREMENTS AT AFT END THROAT

MODEL No. (Check One): ☐ **D4** ☐ **D5**



DIMENSIONS A AND C MEASURED ONE (1) INCH INBOARD OF THEIR RESPECTIVE AFT SIDE FRAMES

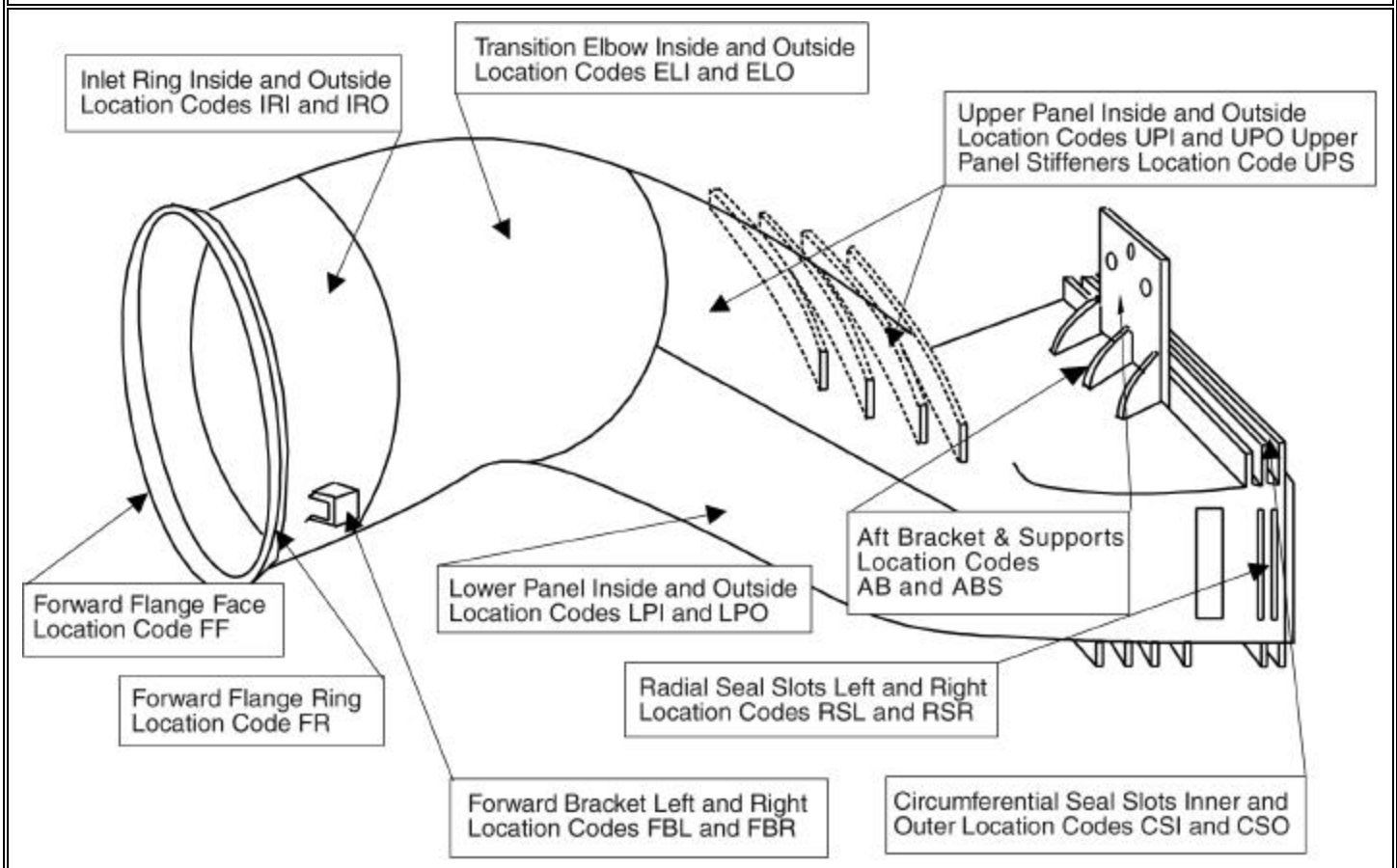
Chamber No.	Trans. Serial No.	A	B	C	D	E
Allowable Limits						
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						

DATE:	**INSPECTED BY:**
OWNER:	**PLANT:**
UNIT DESIGNATION:	**TURBINE S/N:**
CHECK TYPE OF INSPECTION: ☐ **INCOMING;** ☐ **IN PROCESS;** ☐ **FINAL**	

Form I-H
W501D4 and D5 Combustor Transition Dimensional Inspection Form

Appendix II - Damage Assessment Forms

RECORD INSPECTION RESULTS ON FORMS II-B & C USING THE LOCATION AND DEFECT CODES BELOW



DEFECT CODES	
CR	Cracks
H	Hot Spots
E	Erosion/Corrosion
D	Dents / Distortion
MM	Missing Material
W	Wear / Fretting
O	Other (Define)

Form II-A
W501D4 and D5 Combustor Transition Damage Assessment Form Instructions

IF CHAMBER NUMBERS ARE UNKNOWN, MARK OUT & RECORD BY SERIAL NO. ONLY

Chamber No.	TP Serial No.	Cracks (State Location Code and Length)	Other Defects (State Location & Defect Codes, Size and Shape)
1			
2			
3			
4			
5			
6			
7			
8			

DATE:	INSPECTED BY:
OWNER:	PLANT:
UNIT DESIGNATION:	TURBINE S/N:

CHECK TYPE OF INSPECTION: ☐ INCOMING; ☐ IN PROCESS; ☐ FINAL

Form II-B
W501D4 and D5 Combustor Transition Damage Assessment Form (Chambers 1–8)

IF CHAMBER NUMBERS ARE UNKNOWN, MARK OUT & RECORD BY SERIAL NO. ONLY

Chamber No.	TP Serial No.	Cracks (State Location Code and Length)	Other Defects (State Location & Defect Codes, Size and Shape)
9			
10			
11			
12			
13			
14			
15			
16			

DATE:	INSPECTED BY:
OWNER:	PLANT:
UNIT DESIGNATION:	TURBINE S/N:

CHECK TYPE OF INSPECTION: ☐ INCOMING; ☐ IN PROCESS; ☐ FINAL

Form II-C
W501D4 and D5 Combustor Transition Damage Assessment Form (Chambers 9–16)

Target:

Combustion Turbine & Combined Cycle O&M

About EPRI

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