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Combustion Turbine Guidelines: Conventional and Advanced Machines

Volume 11: Alstom Model GT11N2 Repair Guidelines

1012704

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1012704

Technical Update, March 2007

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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, Siemens-Westinghouse, Alstom, and Mitsibishi 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, multi-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 (1004597)
- Volume 2: GE MS6001 Model B (1006429)
- Volume 3: GE MS7001 Model F/FA (1004341)
- Volume 4: GE MS7001 Model E/EA (1006503)
- Volume 5: Westinghouse Models W501 A thru D (1006509)
- Volume 6: Westinghouse W501 Model F (1008317)
- Volume 7: Coatings Guidelines (1006513)
- Volume 8: GE MS9001 Model E (1005032)
- Volume 9: Siemens V84.2 (1010476)
- Volume 10: Compressor Coatings Guidelines (1010394)
- Volume 11: Alstom GT11N2 (1012704)

Soon to be released:

- Volume 12: Alstom GT 24/26 (2007)
- Volume 13: Siemens V84.3 (2007)
- Volume 14: Siemens V94.3A (2007)
- Volume 15: GE MS9001 Model F/FA (2007)

By the end of 2007, the entire multi-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
REPAIR SPECIFICATION FOR ALSTOM MODEL GT11N2 FIRST STAGE TURBINE VANE SEGMENTS

1 SCOPE

1.1 Purpose

This specification covers the minimum requirements for the weld repair, heat treatment and application of thermal barrier coating for Alstom Model GT11N2 first stage turbine vane segments manufactured from the nickel base alloy Inconel 738LC (Ni - 16Cr - 8.5Co - 3.4Al - 3.4Ti - 2.6W - 1.7Mo - 0.9Cb – 0.11C – 0.055Zr – 0.0095B). Following repair, a thermal barrier coating (TBC) is applied to the gaspath surfaces, consisting of an MCrAlY type bondcoat and a ceramic topcoat, as described in Section 1.3. Vane segments repaired to these requirements should provide service life approaching that of new components. Forty-four (44) vane segments comprise a full set quantity.

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. It should be noted that Inconel 738LC has proven difficult to weld as part of refurbishment processing. For this reason, consideration should first be given to blending minor defects according to OEM blend limits or the blend limits in Table 1, reserving weld repair for the larger defects which cannot be successfully blended. A thermal barrier coating (TBC) is applied following repair to lower vane segment operating metal temperatures.

1.3 Vane Coating

The OEM standard for external coatings has been an MCrAlY overlay on all external surfaces exposed to the turbine hot gas flow. This metallic layer is reportedly applied by the vacuum plasma spray (VPS) process and is a NiCrAlY overlay designated as SV20. A partial coverage of a ceramic topcoat is then applied to the airfoil and platform by the Air Plasma Spray (APS) process. No internal diffusion coatings are applied as part of original component manufacture, and this document assumes the internal passages will not be coated during the repair / refurbishment process.

As part of the HP turbine blade refurbishment process, careful consideration must be made with regard to alternative airfoil coating systems to be applied. Industry experience has shown the High Velocity Oxy-Fuel (HVOF) process to be a viable and acceptable alternative to VPS in terms of bond-coat application. Alternative bond-coat chemistries may also be considered; however, careful consideration of comparative oxidation resistance and strain tolerance in cyclic service must be made (5.6.3). Deviation from the OEM ceramic topcoat application plan (coverage) may be considered, such as an upgrade to complete airfoil and shroud coverage rather

than partial coverage. However, care must be taken such that airfoil and shroud cooling holes are properly masked during coating and thus not restricted by the application of coating (Section 5.4.4).

2 DEFINITIONS & VANE ILLUSTRATIONS

2.1 Alstom GT11N2 First Stage Turbine Vane Segment

Figures 1-8 are photographs of various views of the first stage turbine vane segment. The vane is internally air cooled and is coated over the entire airfoil with a metallic overlay bond coat. A partial coverage of a ceramic thermal barrier topcoat is applied to the airfoil pressure and suction sides and the outer shroud gaspath surfaces. The vane is

assembled into the turbine vane carrier by use of an axial entry attachment or hookfit integrally cast on the vane segment outer shroud. Film cooling holes are used to lower surface metal temperature on both the inner and outer shrouds, and air introduced into the airfoil internal cavity exits through a combination of airfoil leading edge and pressure side film cooling holes as well as trailing edge slots. The flow of cooling air into the airfoil internal cavity is metered and controlled by impingement cooling inserts and outer shroud cover plates which are welded and brazed to the outer shroud of the vane segment casting.

NOTE: Proper refurbishment of the first stage vane segment requires disassembly of the impingement cooling insert and outer shroud cover plates to allow inspection of the airfoil internal cavity, as well as to avoid entrapment of media used during the refurbishment process. However, these sheet metal details are assembled during original manufacture by brazing to the vane casting outer shroud, such that grinding the attachment braze joints will destroy these parts and render them unsuitable for re-use. It thus may be necessary to identify or develop a source of replacement new sheet metal detail parts prior to attempting repair of the first stage vane segments.

2.2 Lot

A group of parts which is processed through the entire repair cycle at the same time and are 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 sub-groups for heat treatment, each sub-group shall constitute a lot.

2.3 E.D.M.

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

2.4 Linear Indications

Non-destructive testing indications with a length of three times the width or greater.

2.5 Non-linear Indications

Non-destructive testing indications with a length of less than three times the width.

2.6 Through-Going Indications.

Non-destructive testing indications appearing directly opposite each other and apparently extending through the thickness of the section.

2.7 L.P.T. Liquid Penetrant Test

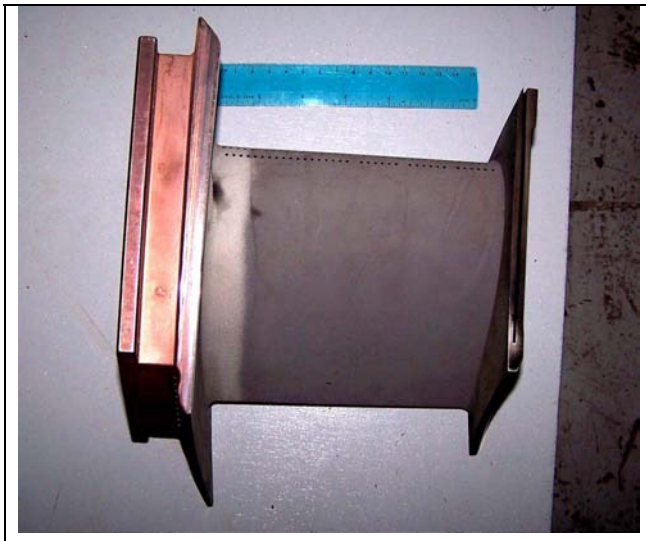


Figure 1-1
Overall View, Suction Side

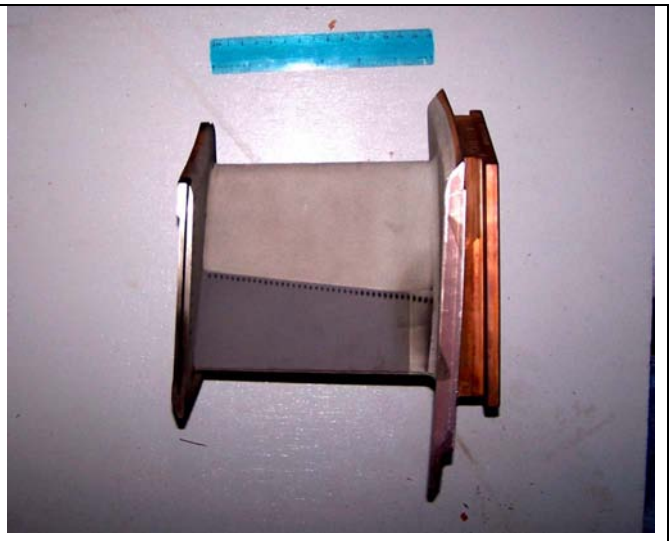


Figure 1-2
Overall View, Pressure Side



Figure 1-3
View of Outer Shroud



Figure 1-4
View of Inner Shroud

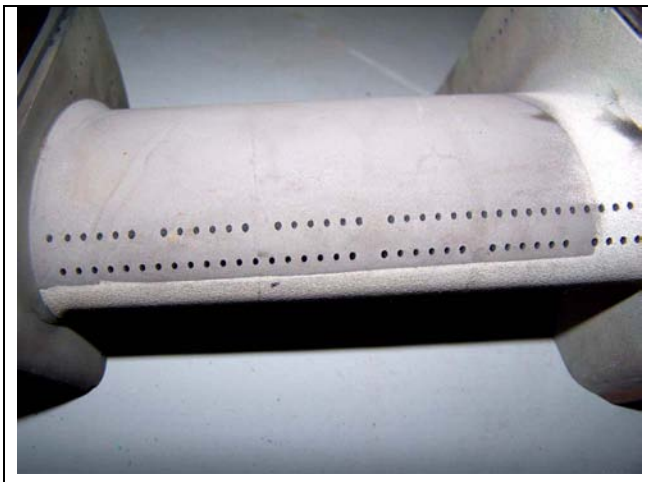


Figure 1-5
Leading Edge Film Cooling Holes

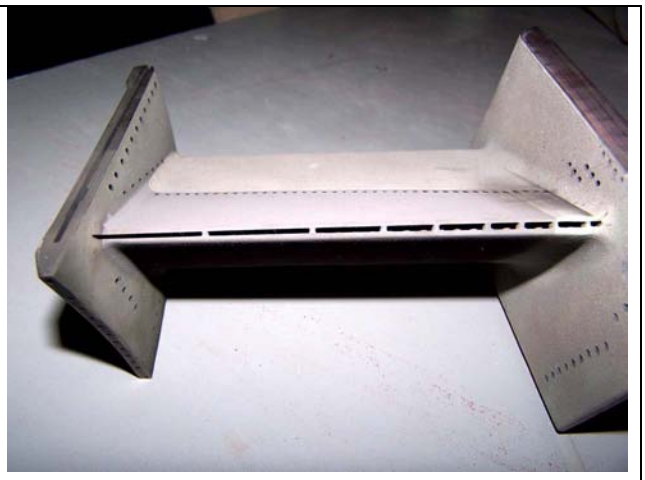


Figure 1-6
Trailing Edge Cooling Air Exit Slots

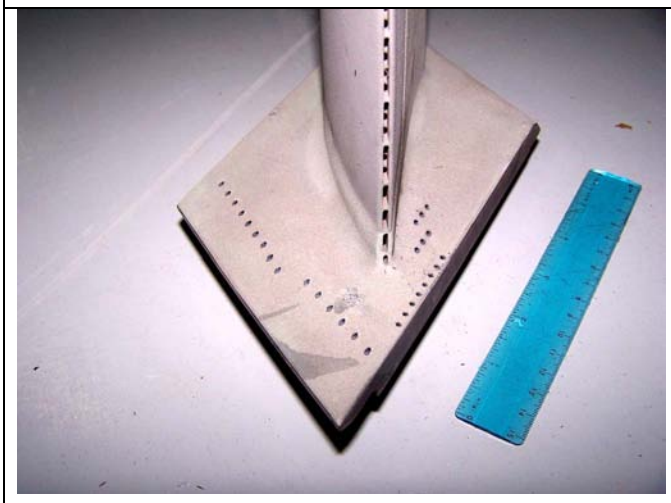


Figure 1-7
Outer Shroud Film Cooling Holes

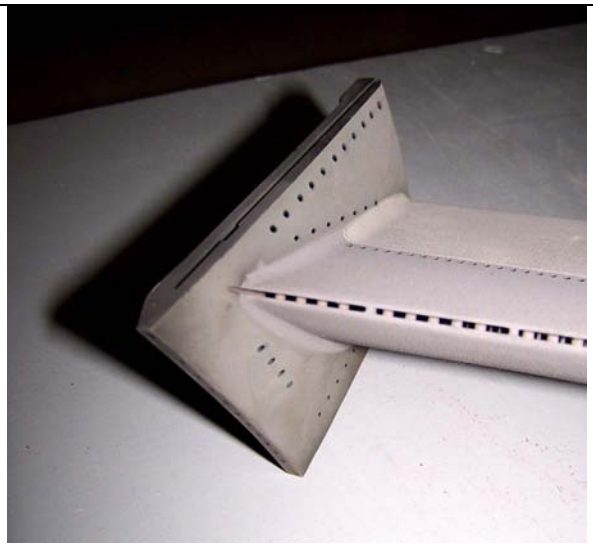


Figure 1-8
Inner Shroud Film Cooling Holes

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.

ASTM 1417

"Inspection, Liquid Penetrant"

ASTM E165

"Standard Practice for Liquid Penetrant Inspection Method"

Aerospace Material Specifications 5837F

“Nickel Alloy, Corrosion and Heat Resistant, Welding Wire 62Ni 21.5Cr 9.0Mo 3.7Cb (Mar 99)"

Aerospace Materials Specification 5887B

“Nickel Alloy, Corrosion and Heat Resistant, Bars, Forgings, and Rings 54Ni 22Cr 12.5Co 9.0Mo 1.2Al, Consumable Electrode or Vacuum Induction Melted Annealed (Jul 01)”

Aerospace Material Specifications 5878B

“Nickel Alloy, Corrosion and Heat Resistant, Sheet, Strip, and Plate 59Ni 22Cr 2Mo 14W 0.35Al 0.03La, Solution Heat Treated (Nov 02)”

ASNT Recommended Practice No. SNT-TC-1A

"Personnel Qualification and Certification in Nondestructive Testing"

ASTM B487

“Measurement of Metal and Oxide Coating Thickness by Microscopical Examination of a Cross Section”

ASTM C633 - 01

“Standard Test Method for Adhesion or Cohesive Strength of Thermal Sprayed Coatings”

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 5837C (Alternate 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 vane alloy, when pre-qualified by vendor and approved by the purchaser, may be allowed.. Braze, diffusion brazing, or other

alternative techniques, for repair of craze cracking, and other defects are not permissible in critical areas. They are permitted in non-critical areas of the segments, as defined in Figure 9, provided that the process used is identical to that used in the original process qualification (7.1.2).

NOTE Use of braze processes for repair of defects should be considered carefully, given the potential for braze re-melt during future repair heat treatments and the limited ductility inherent with braze filler materials. Depending on the braze filler material utilized, the employment of braze processing can potentially limit temperatures used in future heat treatments, and render the brazed areas of the vane incapable of being subsequently weld repaired.

5.2 Vane Blend/Weld Repair Limits

5.2.1 Unless approved otherwise, blending limits shall be per Table 1. Blends must have a depth to blended length ratio of 1:8 minimum and be smooth and gradual with no sharp edges remaining.

5.2.2 External and internal surface oxidation/corrosion/alloy depletion may be blended out (blend repaired) to the maximum depths stated in Table 1. All surfaces to be coated must be metallurgically clean and free of all oxide and residual coating.

Blend repaired areas shall be liquid penetrant test (LPT) inspected to the requirements of Section 5.3.

5.2.4 Unless approved otherwise, weld repairability limits shall be per Table 1. All defects to be weld repaired must be completely removed prior to welding.

5.3 Non-Destructive Testing Acceptance Limits

Critical and non-critical areas of the component are defined in Figure 9. Linear indications are permitted in the critical areas of the component up to 0.76 mm (0.030 inch) in length provided they are spaced by 5 times their length. Non-linear indications are permitted in critical locations up to 1.5 mm (0.060 inch) diameter, or up to a diameter equal to 25% of the local section thickness, whichever is smaller. Linear indications up to 1.5 mm (0.060 inch) long are permitted in non-critical areas of the component provided that they are spaced by at least 5 times their length. Non-linear indications in non-critical areas of the component are permitted up to 1.5 mm (0.060 inch). Non-linear indications in non-gas path areas are permitted up to 3.2 mm (0.125 inch). Airfoil (vane) material loss to due to erosion, corrosion, nicks or dents must not exceed 50 percent of wall thickness. No through going indications are permitted.

Table 1-1
ALSTOM GT11N2 FIRST STAGE VANE SEGMENT REPAIR LIMITS

DESCRIPTION	MAXIMUM LIMITS
Airfoil	
Surface Blend	Critical Areas (see Figure 9) - 0.75 mm (0.030 inch) deep or 20% of design wall thickness, whichever is less.
Non-Critical Areas (see Figure 9)	1.5 mm (0.060 inch) deep or 40% of design wall thickness, whichever is less.
Trailing Edge Blend	6.25 mm (0.250 inch) maximum depth x 25.4 mm (1.0 inch) maximum length.
Shroud Gas Path Blend	
Surface Blend	1.5 mm (0.060 inch) deep or 40% of design wall thickness, whichever is less.
Edge Blend	3.0 mm (0.120 inch) maximum depth x 25.4 mm (1.0 inch) maximum length.
Shroud Non-gas Path Blend	
Surface Blend	3.0 mm (0.120 inch) maximum depth.
Vane-to-Vane Joint Seal Slot Blend	
Sealing Surface Blend	0.75 mm (0.030 inch) maximum depth.
Edge Blend	1.5 mm (0.060 inch) maximum depth x 25.4 mm (1.0 inch) maximum length.
Airfoil Weld Repair Limits	
Axial Crack Repair	up to 33% of the airfoil chord at any radial plane.
Radial Crack Repair	no limit.
Shroud Weld Repair Limits	no limit.

NOTE Blends must have a depth to blended length ratio of 1:8 minimum and be smooth and gradual with no sharp edges remaining.

5.4 Dimensional Requirements

5.4.1 Gas path dimensions, axial and radial locations shall be within the range identified on the inspection forms attached as Appendix I.

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

5.4.3 Surface finish on the repaired components (after TBC application) shall be 4.6 microns (180 micro inches) Ra or better measured according to ANSI B46.1.

5.4.4 Cooling passages shall be restored to original dimensions. Unless otherwise approved, vane segments shall be flow tested to ensure that all cooling holes are open and flowing properly following the repair / recoating process (see Section 5.7). Flow testing with air and with impingement inserts installed is preferred. It is good practice to also flow test the vane segments during incoming inspection to determine the pre-repair flow patterns and whether blockage or

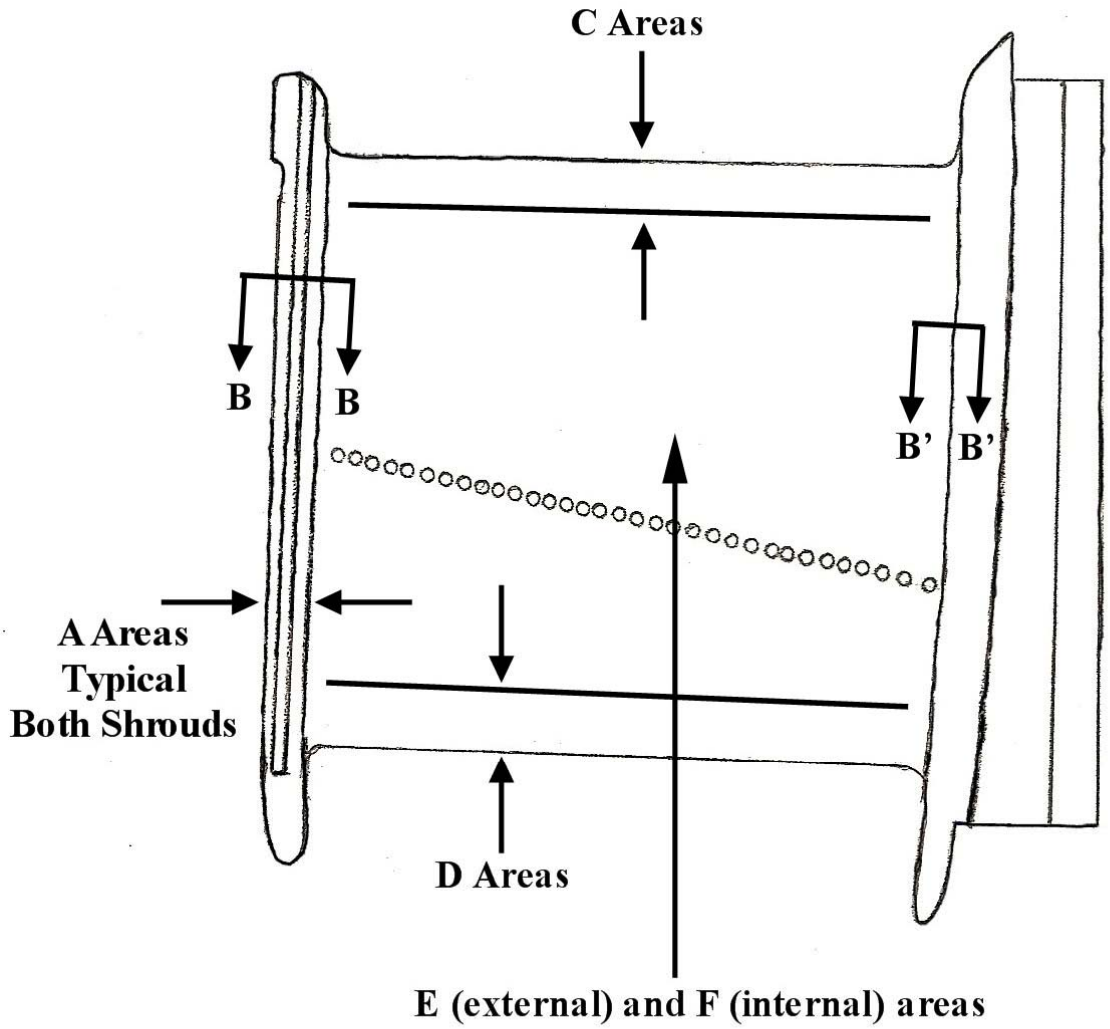
hole damage has occurred during service. Proper fit-up of vane impingement inserts is of vital importance, and the position / clearance of the inserts should be carefully noted prior to removing them for repairs. This will aid in refitting the inserts to the proper dimensions when re-installing them following repair.

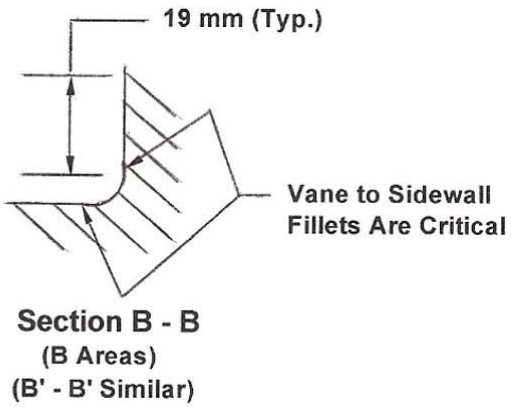
NOTE Omission of vane cooling passage flow testing following repair requires specific approval from the purchaser. Whenever omission is granted, the vane cooling holes must still be checked for blockage using properly sized gage wires or other approved procedure. In addition, the impingement inserts should be carefully inspected upon removal from the vanes with respect to integrity of impingement cooling holes.

5.4.5 The repaired vane segment shall properly fit a dimensionally correct vane carrier, or a fixture which accurately simulates the vane carrier.

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. Some important dimensions affecting form, fit and function are given in Appendix I.

Figure 1-9
ALSTOM GT11N2 FIRST STAGE VANE SEGMENT CRITICAL AREAS





ALSTOM GT11N2 FIRST STAGE VANE SEGMENT CRITICAL AREAS

Area A- All surfaces of the shroud except the airfoil fillet radius areas (B areas) are non-critical areas.

Area B- That portion of the airfoil and shroud starting at the line of tangency between the shroud and airfoil and extending parallel to the airfoil and shroud span for 19 mm (0.75 inch) around the whole airfoil contour are critical areas. (See Sections B – B and B' – B').

Area C- Critical area which includes the entire airfoil leading edge and extends 25 mm (1 inch) axially downstream of the leading edge on both pressure and suction sides.

Area D- Critical area which includes the entire airfoil trailing edge and extends 25 mm (1 inch) axially upstream of the trailing edge on both pressure and suction sides.

Area E- Airfoil surfaces not included in Areas B, C and D are non-critical areas.

Area F- Internal airfoil surfaces are critical in B, C and D areas and non-critical in E areas.

5.4.6 The minimum wall thickness between vane external airfoil surfaces and internal cooling passage surfaces is a critical dimension that can govern repair / replacement decisions. Recommendations for performing wall thickness measurements for these vanes are provided in Appendix I, Form I-C and, unless approved otherwise, these recommendations must be followed. Form I-D is included to record the results of wall thickness measurements. Some turbine OEM's provide guidance on minimum acceptable airfoil wall thickness for each vane design in their turbine instruction manuals. If no OEM wall thickness criteria are available, the values measured may be compared with those of a new vane and a judgment made on the severity of wall thinning and whether repairs are practical. Airfoil wall thickness shall be recorded at all locations where significant corrosion, erosion or foreign object damage has occurred. Omission of wall thickness measurements requires specific purchaser approval.

5.5 Microstructural Requirements

5.5.1 The re-cast layer on any E.D.M. surface shall not exceed 0.025 mm (0.001 inch).

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

5.5.3 The microstructure shall be comparable to new material. Un-serviced material in the fully heat treated condition may be used for comparison. Specifically, no continuous carbide films or needle phases shall be present after processing. Appendix III provides guidance on metallographic samples and their evaluation.

5.6 Thermal Barrier Coating Application Requirements

NOTE: This section assumes that turbine owners will elect to apply a full coverage TBC coating to the airfoil and shroud wall (gaspath) surfaces. The purchaser may elect to apply an MCrAlY overlay and a partial coverage ceramic topcoat similar to the original OEM coating plan. This section also assumes that the bondcoat will be applied by the High Velocity Oxy-Fuel (HVOF) process and the ceramic topcoat will be applied by the Air Plasma Spray (APS) process. Other processes (i.e., Low Pressure Plasma Spray for the bondcoat and Electron Beam – Physical Vapor Deposition for the ceramic topcoat) have also been used for applying TBC's on gas

turbine hot section components. The repair vendor should verify with the purchaser the scope of coating application desired before bidding or proceeding with the refurbishment process. It is recommended that all coating process procedures used be qualified by the first article qualification process as specified in paragraph 7.1.2.

5.6.1 Coverage. The coating shall cover all areas of the airfoil and shrouds that are exposed to the turbine hot gas flow (i.e., all gas path areas). Cooling holes shall be protected during the coating cycle using an appropriate masking compound. The method used shall prevent coat-down of cooling holes and shall be easily removed after coating. The base alloy shall be unaffected by the masking procedure, as demonstrated on a test coupon prior to process qualification. Procedures used shall be identical to those used in the original process qualification (7.1.2). Coatings shall be continuous over all areas where coating coverage is specified. For those areas where coating is not allowed, materials used for masking shall not have any deleterious effect on the base metal or the coating itself.

5.6.2 Surface Preparation. Surface preparation shall include cleaning and other operations required to insure proper coating adherence. Cracks, scale, and other surface discontinuities shall be removed by an approved process that may combine grinding, polishing, etching, and grit blasting. Intergranular attack and excessive metal removal due to etching is not permitted. Metallic shot may not be used for blasting. Blasting of close tolerance machined areas is not permitted. The surface preparation procedure used shall not impart any physical or microstructural damage to the part and shall satisfy all other aspects of this section. The cleaning process shall be capable of removing all grease, dirt, oils, oxidation products, and other foreign material that could impair the development of a satisfactory coating. Coating shall be performed within two (2) hours of surface preparation. Procedures used shall be identical to those used in the original process qualification (7.1.2).

5.6.3 Materials. Materials used to deposit the MCrAlY bondcoat and Yttrium stabilized Zirconium topcoat shall be approved by the purchaser. There can be a wide range of acceptable bondcoat compositions. Selection of the bondcoat should be based on the level of contaminants contained in both the fuels and ambient air. The level of aluminium in the bondcoat is an important consideration. Nominal compositions typically range from 8 to 12 weight percent. In general, coatings with higher aluminium levels tend to be more brittle, therefore the duty cycle of the engine (cycling or continuous duty) should also be considered when specifying aluminium content. It should also be recognized that the level of elements in coating powders delivered from manufacturers can typically vary by 1 to 2 percent from nominal values specified. Certificates of analysis for each lot of material used to coat components shall be maintained on file for a period of five years.

5.6.4 Appearance

Visual inspection of coating surface shall be performed without magnification. Areas of discoloration or suspect irregularities shall be examined at 5X magnification to establish conformance. Coating coverage shall be verified per the requirements based on visual (unaided) examination of coated parts and color changes.

5.6.5 Visual. Coating shall have a uniform matte surface texture and color and shall be 100% adherent with no evidence of spalling, chipping, cracking, flaking, pitting, or other indications of coating distress.

5.6.6 Defects. All part surfaces shall be free of foreign materials such as masking materials and glass beads that may have been used for surface improvement. Foreign material that has been fused by exposure to heat treating cycles is cause for rejection. Raised or positive coating defects such as ridges, plateaus, or other abrupt changes in coating thickness which are readily detectable by touch or sight are not permitted, subject to the limits specified in 5.6.7 and 5.6.8.

5.6.7 Acceptable Irregularities. Irregularities caused by casting defects or service degradation that are present in the surface prior to coating processing shall not be cause for rejection of the component.

5.6.8 Unacceptable Irregularities. Notwithstanding 5.6.7, irregularities or defects that expose base metal are not permitted. Coating cracks are not permitted. In addition, irregularities that are larger than 0.25 mm (0.010 inch) in any dimension are cause for rejection of the part.

5.6.9 Surface Finish. The surface finish on TBC coated surfaces shall be 4.6 microns (180 micro inches) Ra or better, measured according to ANSI B46.1. When post-coating surface improvement is necessary, care shall be exercised to limit the amount of coating removal, to avoid cracking, and to prevent damage or alteration of uncoated areas. Measurements of coating thickness shall be made after any surface improvement.

NOTE: If purchaser should elect to apply an MCrAlY overlay with a partial coverage of ceramic topcoat, it is recommended that the surface finish of the overlay be 2.5 microns (100 micro inches) Ra or better, measured according to ANSI B46.1. To meet this surface finish will typically require post-coating processing (e.g., wire peen or vibratory tumble).

5.6.10 Microstructural Requirements Metallographically prepared cross sections of coated and heat treated samples shall be examined using standard microscope techniques. Vacuum impregnated epoxy mounting materials and standard mechanical polishing techniques shall be used to prepare mounts for microscopic inspection. The specimen base metal shall be the same alloy as the components being coated and preferably from a representative scrap component. The samples shall be processed through the complete coating and heat treating cycle defined herein (6.2) and meet the requirements of 5.6.11, 5.6.12, 5.6.13 and 5.6.14.

5.6.11 Thickness. Bond coat thickness shall be 0.076 – 0.20 mm (0.003 - 0.008 inches) on all coated surfaces, except for airfoil-to-shroud fillet areas where a tolerance of 2x is permitted for the bondcoat. Ceramic topcoat thickness shall be 0.18 – 0.38 mm (0.007 to 0.015 inches) except for airfoil-to-shroud fillet areas where a tolerance of 1.5x is permitted for the topcoat. Feather coating thickness at the transition from coated to un-coated regions. Total thickness does not include the thickness of any interdiffusion zone between the MCrAlY layer and the component substrate. The thickness of the interdiffusion zone between the MCrAlY layer and the substrate shall not exceed 0.013mm (0.0005 inch). Coating thickness shall be measured in accordance with ASTM B487 and should be measured at 5 to 10 random locations on each metallographic specimen to establish an average thickness value

NOTE: If purchaser should elect to apply an MCrAlY overlay with a partial coverage of ceramic topcoat, it is recommended that the coating thickness range recommended above for the bondcoat be increased to 0.13 to 0.38 mm (0.005 to 0.015 inch). A 2x tolerance at airfoil-to-shroud fillets would typically be permitted.

5.6.12 Bondcoat Microstructure. The bondcoat microstructure shall be uniform and typical of the standard for the particular composition approved in the original coating process qualification

(7.1). No separation (delamination) along the bondcoat interface is allowed. The substrate / bondcoating interface shall have no interconnected voids at 500X magnification and be free of non-metallic inclusions in excess of 15% of the interface. The sum (volume percent) of bondcoat porosity and oxidation products shall be less than 4% in the airfoil and less than 5% in platform and fillet area. Clusters of pores greater than 0.025 mm (0.001 inches) in thickness shall be cause for rejection.

5.6.13 Ceramic Layer Microstructure. The thermal barrier layer shall have a minimum porosity level of 5% and a maximum porosity level of 20%. Clusters of pores greater than 0.051 mm (0.002 inches) in thickness shall be cause for rejection.

NOTE: In most cases, a maximum porosity level of 15% should be maintained. Certain turbine OEM's allow up to 20% porosity levels on specific components.

5.6.14 Coating / stripping process-related alloy depletion, oxidation, nitriding and intergranular attack of the base metal surface shall not exceed 0.025 mm (0.001 inch).

5.6.15 Bondcoat Strength. The room temperature tensile strength (adhesion) of the bondcoat to substrate interface shall be no less than 69 MPa (10,000 psi) as documented in testing during original process qualification (7.1.). Testing shall be performed in accordance with ASTM C633-01 using FM1000, EC2086 or EC2214 adhesive film. A minimum of three (3) tests shall be performed to verify consistency of the process.

5.6.16 Topcoat (Ceramic Layer) Strength. The room temperature tensile strength (adhesion) of the topcoat to bondcoat interface shall be no less than 10.4 MPa (1500 psi) as documented in testing during original process qualification (7.1.). Testing shall be performed in accordance with ASTM C633-01 using FM1000 adhesive film. A minimum of three (3) tests shall be performed to verify consistency of the process.

5.6.17 Parts that are improperly coated shall be recycled through the entire coating process beginning with stripping.

5.7 Cooling Passage Flow Test Requirements

Unless specifically waived by the purchaser, the cooling passage flow testing procedure / requirements specified in Appendix IV shall be followed / met.

NOTE: Proper functioning of the vane cooling system is of critical importance in advanced technology turbine vanes. For this reason, flow testing as described in Appendix IV is to be performed at (a) incoming inspection and (b) after all processing (i.e., following coating application).

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. Record vane serial numbers.

6.1.2 Advise purchaser immediately of any shipping damage.

6.1.3 Visually inspect each segment for the following:

- rubs and wear
- surface erosion loss
- cracks
- oxidation/corrosion
- impact damage
- blocked or damaged cooling holes
- loss of coating

Record the results on the form attached as Appendix II.

6.1.4. Flow test each vane segment per Appendix IV to determine the incoming flow rate and whether cooling hole blockage or hole damage has occurred during service.

6.1.5 Segment Disassembly. Carefully grind the outer shroud cover plate and impingement cooling insert attachment braze and weld joints and remove the insert from the vane cavity. Note if there is any interference or unusual difficulty encountered when removing the insert. Identify each cover plate and insert with the vane number or vane serial number from which it was removed. Cover plates and impingement inserts that were damaged during removal or service must be replaced with components that match OEM material and dimensional tolerances.

NOTE: Proper fit-up of impingement inserts is of vital importance in air-cooled turbine vanes. The position / clearance of the inserts should be carefully noted prior to removing them for vane repair. This will aid in refitting the inserts to the proper dimensions when re-installing them following repair / recoating.

6.1.6 Metallurgical evaluation (Optional). If excessive oxidation, corrosion, pitting, or other distress is noted, the taking of a metallographic sample for evaluation should be considered. The location where the sample is taken is critical in determining the physical and microstructural extent of the damage. In general, the location should be selected where the damage appears most extensive; however, consideration should also be given to reparability of the location where the sample is taken. Some generic guidance on metallurgical evaluation is given in Appendix III.

6.1.7 Clean the segments using grit blasting with 220 grit or finer aluminum oxide. Use this step to remove the ceramic topcoat layer by careful abrasive blasting. 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 since 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 which precedes a heat treatment.

6.1.8 Wax mask uncoated surfaces and remove the metallic airfoil coating (metallic TBC bondcoat) by a suitable chemical stripping process. Stripping of the coating shall be in accordance with an approved Process Description (7.1.2). Adequate precaution and masking shall be specified to ensure that the stripping procedure is not deleterious to the vane segments, including cooling holes. Control samples of Inconel 738LC shall be processed through any chemical stripping procedure (each stripping lot) and examined metallographically for intergranular attack, which shall not exceed the limits defined in 5.5.2. The use of coated samples taken from a vane from the set being repaired is strongly preferred for stripping control samples.

6.1.9 Verify coating removal using one of the two methods described below. If residual coating is indicated, the part must be recycled through the stripping procedure. Procedures used shall be identical to those used in the original process qualification (7.1.2).

6.1.9.1 Clean parts thoroughly to remove residue from chemical stripping. Lightly re-etch. Development of a dark residue indicates that coating remains.

6.1.9.2 Heat Tinting. Heat tinting using a low temperature thermal cycle (typically 427 °C to 649 °C (800 to 1200°F), but in no case higher than 815 °C (1500°F)) of relatively short duration (no longer than one-half hour) may be used to develop color differences between coated and uncoated areas for inspection.

6.1.10 Visually inspect both internal and external surfaces of 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 form attached as Appendix II. Results should be added to the forms completed in the visual inspection of 6.1.3, if practical. The intent is to document / map all service-induced vane segment defects on one set of damage assessment forms.

6.1.11 L.P.T all vane segments following the visual penetrant procedures outlined in ASTM Specification 1417 or the visual penetrant procedures in ASTM E165. 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. Results should be added to the forms completed in the visual inspection of 6.1.3, if practical. The intent is to document / map all service-induced vane segment defects on one set of damage assessment forms.

6.1.12 Dimensionally inspect each segment for gas path dimensions, axial and radial location 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 or dimensionally correct vane carrier in lieu of actual measurement, provided all dimensions identified on the Forms are checked by the Fixture.

6.1.13 Perform ultrasonic (UT) vane airfoil wall thickness measurements per the instructions on Form I-C in Appendix I. It is recommended that 20% of the vanes be inspected for airfoil wall thickness (i.e., 9 vanes from a complete set). Record wall thickness measurements on Form I-D.

NOTE: The recommendation of 20% should be increased when appropriate. For example, if it is known that the set of vanes is a “mixed” set (i.e., that set integrity has not been maintained, meaning that some segments have a different operating history than others in the set) it would be appropriate to increase the percentage so that a representative sampling of all operating histories was inspected. Likewise, all vanes that have significant distress that could result in wall thinning (corrosion, erosion, foreign object damage, etc.) should be inspected.

6.1.14 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.
- obtain written or verbal authorization to replace any core plugs.

6.2 Repair Procedure

6.2.1 Dress surfaces as required to remove any oxidation per the limits defined in Table 1. Thoroughly degrease components using approved solvent cleaner or other approved method such as steam cleaning or pressure spraying.

6.2.2 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 for disposition.

6.2.3 Solution anneal the vane segments in a vacuum, hydrogen or argon as follows:

1190 °C +/- 14 °C (2175 °F +/- 25 °F) for four (4) hours in a vacuum of 1 micron ($1.3x10^{-3}$ millibar) or better.

Inert gas quench to below 538°C (1000°F). Support parts using nickel base, iron base or coated graphite heat treat rack materials with the parts supported uniformly to prevent distortion. Avoid supporting the parts by any thin sections. Alternately, heat treatment at lower temperatures for the purpose of over-aging the microstructure prior to welding is permitted when approved by the purchaser. However, this approach will require full solution heat treatment as indicated above after completion of all welding (at paragraph 6.2.13).

6.2.4 L.P.T. all vane segments following procedures outlined in paragraph 6.1.11. Document the location and extent of any defects not identified in paragraph 6.1.11 using the form attached as Appendix II.

6.2.5 Prepare the areas of the segments to be weld repaired by grinding out the existing cracks and defects and L.P.T. to ensure 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). When specifically approved, sections may be removed for replacement with patches of matching alloy composition provided that, after the repairs are completed, the cooling hole configuration and airfoil contours are unchanged.

6.2.6 When requested, the purchaser shall be informed and allowed to inspect the components following weld preparation.

6.2.7 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).

6.2.8 Braze, diffusion brazing, or other alternative techniques, for repair of craze cracking, and other defects are not permissible in critical areas. They are permitted in non-critical areas of the segments, as defined in Figure 9, 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 the inherently lower ductility of the braze filler material.

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 L.P.T. the complete vane segment following procedures outlined in paragraph 6.1.11, using the acceptance criteria identified in Paragraph 5.3.

6.2.11 Parts that fail to meet the criteria of paragraph 5.3 may be recycled to repair any defects beginning at paragraph 6.2.5. Parts may be recycled to paragraph 6.2.3 for stress relief, at the vendor's option.

6.2.12 Thoroughly clean components using approved solvent cleaner or other approved methods such as steam cleaning or pressure spraying.

6.2.13 Vacuum heat treat the components to stress relieve the weldments / solution anneal the microstructure using the cycle used in the original process qualification (7.1.2). Unless otherwise specified / approved by the purchaser, the following parameters shall be employed:

1190 °C +/- 14 °C (2175 °F +/- 25 °F) for two (2) hours in a vacuum of 1 micron ($1.3x10^{-3}$ millibar) or better.

NOTE: This heat treatment step is not required if no welding was performed, and the full solution heat treatment step was previously performed at paragraph 6.2.3.

6.2.14 Immediately following heat treatment (if performed) and before any surface cleaning or blasting, liquid penetrant inspect the entire segment using the method outlined in paragraph 6.1.11 and acceptance criteria outlined in paragraph 5.3. Record the results on the forms attached as Appendix II.

6.2.15 Dimensionally check the vanes to ensure conformance to Paragraph 5.4 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.

6.2.16 Prepare vane segment surfaces for thermal barrier coating. Part cleaning, degreasing and grit blasting are a part of the coating process and are the responsibility of the repair vendor (unless coating is subcontracted by the purchaser). It is important that surface oxides, deposits and other contaminants be completely removed prior to coating. Preparation procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.17 Apply masking / stop off compounds as required to all no-coat areas. Component surfaces that are not to be coated shall be protected during the coating cycle using an appropriate mechanical mask or a suitable stop-off compound. The method used shall completely prevent coating build-up on the prohibited areas and be easily removed after coating. Procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.18 Apply the TBC bond coat. Coating shall be applied with a uniform build-up and without interruption. Control samples of IN-738LC shall be processed through the coating procedure (each coating lot) and examined metallographically to ensure compliance with paragraph 5.6.

NOTE Coating thermal cycles must be matched to the heat treatment for the alloy to develop appropriate mechanical properties. For this reason, coating shall be performed in conjunction with the heat treatment specified in paragraph 6.2.20.

6.2.19 When the coating process is complete, remove all mechanical masking and stop-off compounds.

6.2.20 Vacuum heat treat to diffuse the TBC bond coat and to restore the base material mechanical properties using the cycle used in the original process qualification (7.1.2). Unless otherwise specified / approved by the purchaser, the heat treatment shall be as follows:

1120 °C +/- 14 °C (2050 °F +/- 25 °F) for two (2) hours in vacuum, inert gas quench, followed by:

845 °C +/- 14 °C (1550 °F +/- 25 °F) for twenty-four (24) hours in vacuum or argon

NOTE Coating thermal cycles must be matched to the heat treatment for the alloy to develop appropriate mechanical properties. For this reason, TBC bond coating shall be performed in conjunction with the heat treatment specified in this paragraph.

6.2.21 Apply masking / stop off compounds as required to all no-coat areas. Component surfaces that are not to be coated shall be protected during the coating cycle using an appropriate mechanical mask or a suitable stop-off compound. The method used shall completely prevent coating build-up on the prohibited areas and be easily removed after coating. Procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.22 Prepare vane segment surfaces for the TBC ceramic top coat. Part cleaning, degreasing and grit blasting are a part of the coating process and are the responsibility of the repair vendor (unless coating is subcontracted). It is important that surface oxides, deposits and other contaminants be completely removed prior to coating. Coating shall be performed within two (2) hours of surface preparation. Preparation procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.23 Apply TBC ceramic top coat using only processes and coating compositions that have been specified or approved by the purchaser. Coating shall be applied with a uniform build-up and without interruption. Process control specimen for microstructural analysis fabricated from base material samples shall be included in each coating lot of vanes for process control. Evaluation of control specimens shall be the responsibility of the repair vendor (or coating vendor, if subcontracted). Unless specified / approved otherwise, the coating shall be in accordance with paragraph 5.6.

6.2.24 When the coating process is complete, remove all mechanical masking and stop-off compounds.

6.2.25 Remove excess coating from no-coat areas using a process identical to that used in the original process qualification (7.1.2).

6.2.26 Clean uncoated areas of the vane segments.

6.2.27 Visually inspect all coated areas using the methods and acceptance criteria outlined in 5.6. Light polishing may be performed to achieve the required surface finish. Wire brushes shall have austenitic stainless steel bristles.

6.2.28 Ensure that no blockage of cooling holes has occurred during processing by passing a wire gage or gaging balls of appropriate size through each cooling hole or by flow testing. See paragraph 5.4.4. It is preferable that flow testing be performed after core plugs are installed.

6.2.29 Perform surface finish inspections per the methods and criteria of 5.6. All coated parts shall be inspected. Record the results by segment serial number. Parts that are improperly coated shall be recycled through the entire coating process beginning with stripping. (See 6.1.7).

6.2.30 Thoroughly inspect all internal passages and plenums for cleanliness and install the impingement cooling inserts and cover plates. Inspect weld/braze joints per paragraph 5.3, non critical areas. Fit up and welding procedure shall be identical to those used in the original process qualification.

NOTE: Proper fit-up of impingement inserts is of vital importance in turbine vanes and the position / clearance of the inserts should have been carefully noted prior to removing them for vane repair (6.1.5). This will aid in refitting the inserts to the proper dimensions when re-installing them.

NOTE: If braze processing is utilized to attach the cooling inserts and cover plates, processes used shall be identical to those used in the original process qualification (7.1.2). Braze alloys and thermal processing shall be selected so as not to compromise any previously applied braze repairs. Extreme care must be utilized during detail part assembly and joining such that the thermal barrier coating is not damaged.

6.2.31 Flow test the vane segments per Appendix IV. Record the post-coating flow rates and results (pass/fail) by serial number.

Assembly Dimensional Inspection. Perform final dimensional inspection to ensure conformance

to Paragraph 5.4 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.

Ideally, this inspection will entail assembly of vane segments into a fixture that simulates the turbine vane carrier and can accommodate at least three (3) vane segments at a time. Inspect for the following:

Vane segments assemble / slide properly into the fixture without binding.

Excessive axial and radial mismatch (steps) between segments at the inner and outer shrouds.

Uniform vane segment joint gaps along their axial length and consistent joint gaps vane-to-vane.

Proper joint seal engagement in the mating grooves of adjacent segments.

6.2.33 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.

6.2.34 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.

6.2.35 Advise purchaser of the shipping date, route and carrier.

6.2.36 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 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 vanes (and/or other sample material identified by Purchaser) through the entire process for non-destructive 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 (7.1.1) and the Technical Review (7.1.2).

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

7.2 Documentation & 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 five 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 which shall contain:

a) a mapping of all defects identified at paragraph 6.1.3, 6.1.10, 6.1.11 and 6.2.4. (Use form attached as Appendix II)

b) a mapping of all repair locations (Use form attached as Appendix II)

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

d) a copy of final L.P.T. and flow check reports

e) a copy of the certificate of compliance

7.3 Acceptance and Disposition

7.3.1 All deviant parts shall be plainly labelled in a non-destructive 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

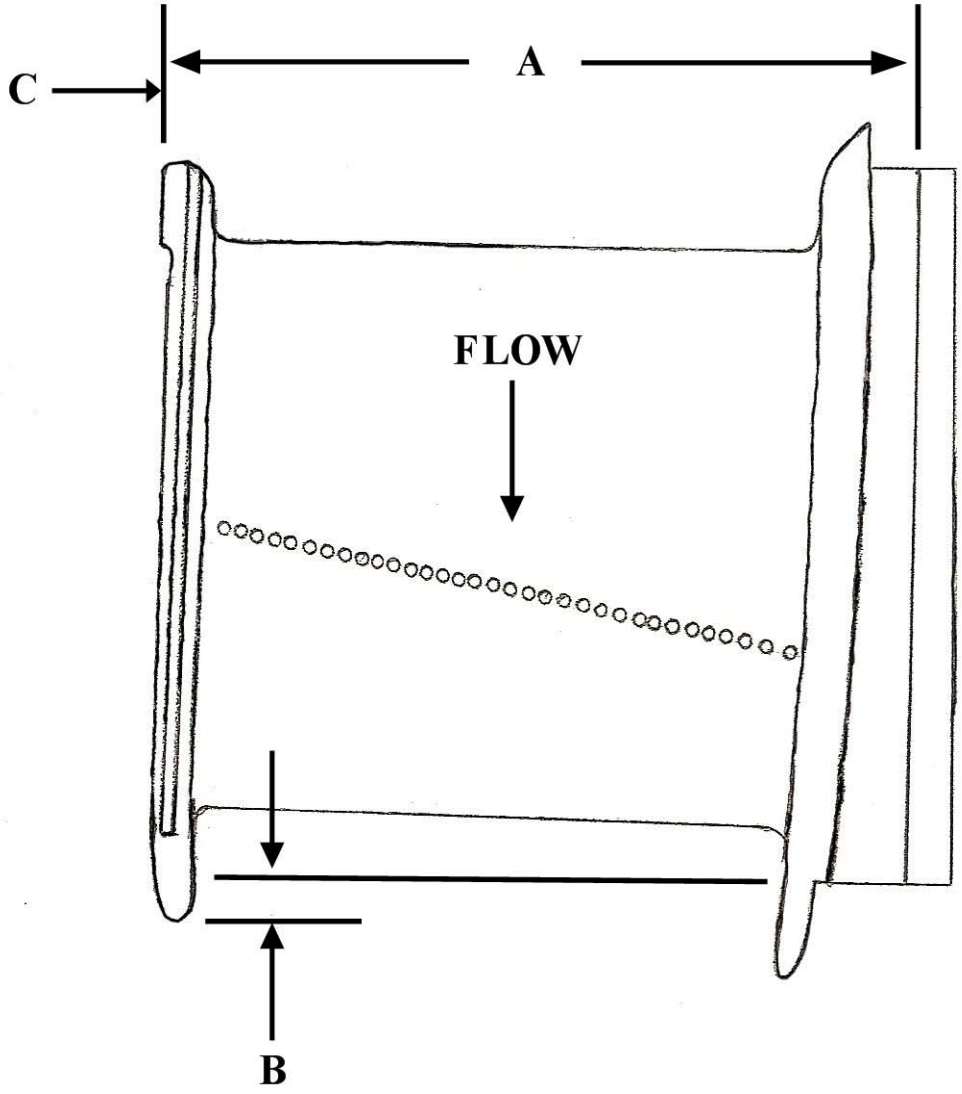
The purchaser shall be allowed reasonable access to inspect components at all times during the repair process.

APPENDIX I - DIMENSIONAL INSPECTION FORMS

FORM 1-A

ALSTOM GT11N2 FIRST STAGE VANE DIMENSIONAL INSPECTION FORM

OVERALL DIMENSIONS



NOTES:

1. Measure dimension A and B at the center and at both ends of the segment. Left and right ends are defined looking downstream.

2. Dimension C is a radius measurement and is to be measured at the left, center and right ends of the segment.

3. Checking fixtures or a dimensionally correct vane carrier may be used to check dimensions provided all dimensions shown are checked. Record results as Pass or Fail on Form 1-B.

FORM 1-B

ALSTOM GT11N2 FIRST STAGE VANE DIMENSIONAL INSPECTION FORM

OVERALL DIMENSIONS RECORD SHEET

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 Left					
C Center					
C Right					
Comments					

RECORDED DIMENSIONS ARE IN (Check one): ☐ mm ☐ Inches

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

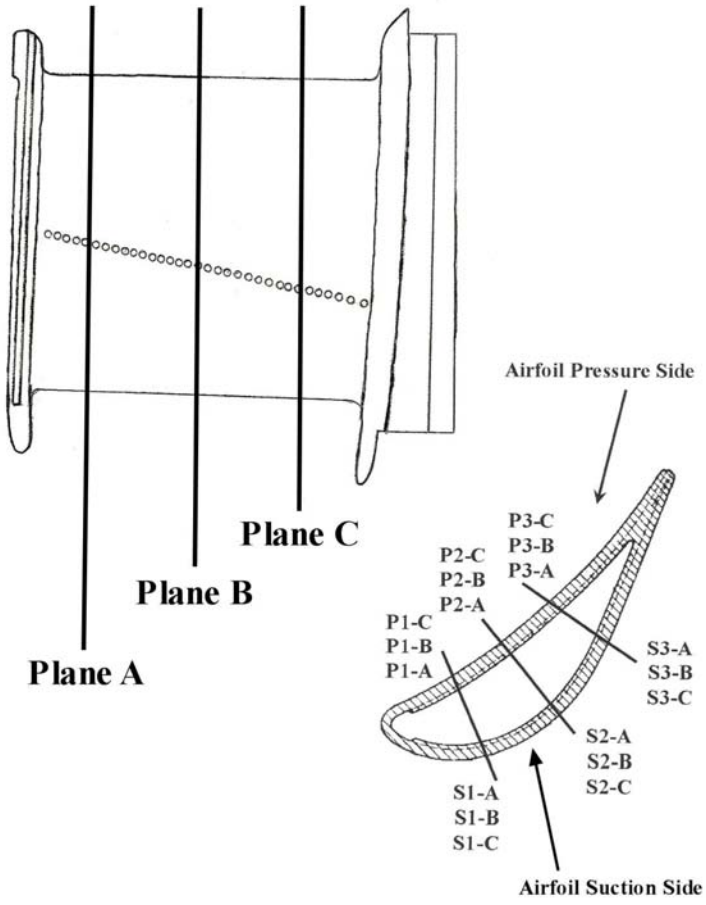
Segment numbers are counted clockwise looking in direction of flow. Number 1 is the first segment in the upper half on the left side.

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

FORM I-C

ALSTOM GT11N2 FIRST STAGE VANES

UT WALL THICKNESS INSPECTION INSTRUCTIONS



NOTES FOR ULTRASONIC WALL THICKNESS CHECKS:

Ultrasonic (UT) checks for vane airfoil wall thickness are recommended on 20 percent of the vanes to be repaired (i.e., 9 vanes from a full set). The sample size should be increased in some circumstances – see note at paragraph 6.1.14.

Eighteen (18) UT measurements are recommended on each vane airfoil: 9 measurements on the pressure side ("P") and 9 measurements on the suction side ("S"). Record measurements on Form I-D.

Vendor and purchaser may agree on alternate locations to more closely coincide with actual service degradation / wall thinning.

Radial locations are numbered A, B and C. The "A" locations are a radial distance of approximately 1 inch outboard of the inner shroud wall. Likewise, the "C" locations are a radial

distance of 1 inch inboard of the outer shroud wall. The “B” locations are at the approximate centerline between the inner and outer shroud walls.

Axial locations of measurements should be equally spaced along the chord of the internal cavity (as shown in Section X-X of the sketch). See Note 3 above.

Using the above terminology (as shown in Section X – X above), the measurement location designated as “P1-A” is on the pressure side surface at the axial center of the forward chamber and 1” inboard of the inner shroud wall. Likewise, the measurement location designated as “S3-C” is on the suction side surface at the axial center of the aft chamber and 1 inch inboard of the outer shroud wall.

FORM I-D

ALSTOM GT11N2 FIRST STAGE VANES

UT WALL THICKNESS INSPECTION RECORD SHEET

MEASUREMENT	**ALLOWABLE**		**SEG. #_____**	**SEG. #_____**	**SEG. #_____**
	MIN.	**MAX.**	**S/N**	**S/N**	**S/N**
			_____	_____	_____
PRESSURE SIDE MEASUREMENTS					
P1-A					
P1-B					
P1-C					
P2-A					
P2-B					
P2-C					
P3-A					
P3-B					
P3-C					
SUCTION SIDE MEASURMENTS					
S1-A					
S1-B					
S1-C					
S2-A					
S2-B					
S2-C					
S3-A					
S3-B					
S3-C					
Comments					

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

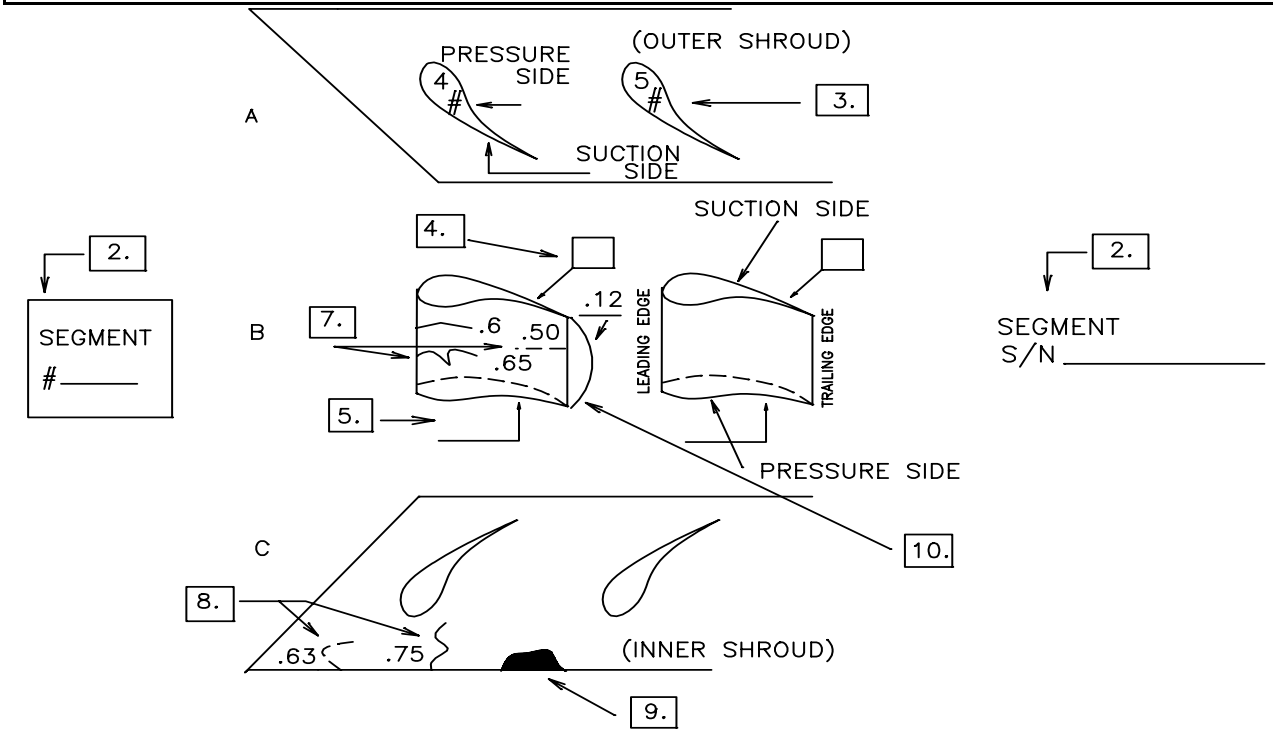
APPENDIX II - DAMAGE ASSESSMENT FORMS

FORM II-A

ALSTOM GT11N2 FIRST STAGE VANES

NOTES FOR VANE DAMAGE ASSESSMENT

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 -

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 cooling air holes below each vane.

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 -

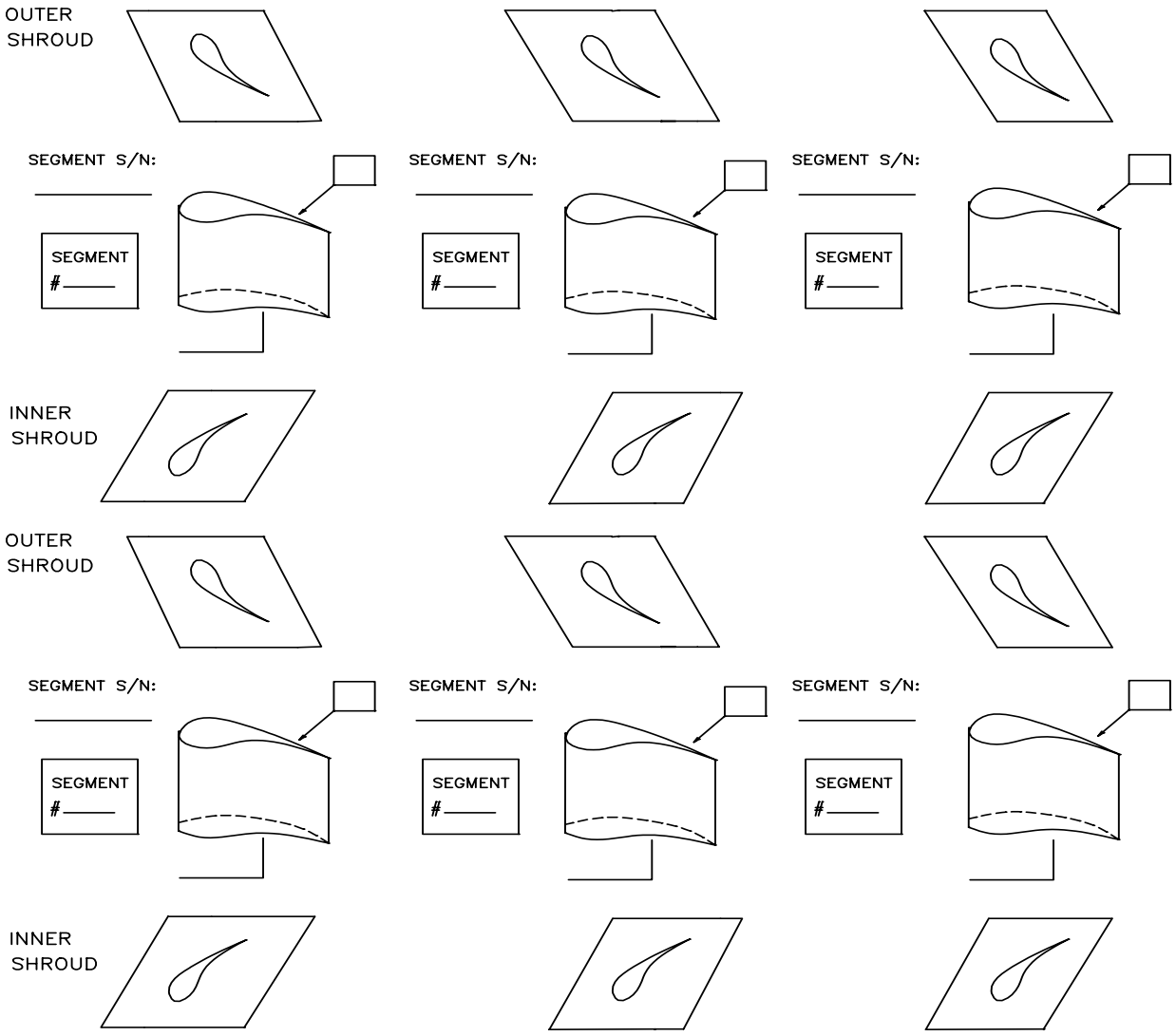
10.

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 100ths of inches.

FORM II-B

ALSTOM GT11N2 FIRST STAGE VANE SEGMENT

DAMAGE ASSESSMENT FORM



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

APPENDIX III - PROCEDURE FOR METALLURGICAL EVALUATION OF NOZZLE AND VANE SEGMENTS

SCOPE:

This procedure describes techniques to be used to characterize material degradation in both cobalt and nickel based nozzles / vanes and assess reparability. The removal of samples is semi-destructive, 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 0.16 mm (1/16") wafering blades and rotary air or electric hand tools. Appropriate personal protective gear should be worn at all times when using such tools.

Since samples removed must be repaired, the minimum material necessary should be removed. For leading and trailing edge locations, the sample geometry shown in Figure III-A is adequate for specimens in two orientations. For removal of samples from heavier locations such as side rails, a "boat" type specimen, as shown in Figure III-B, 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 (i.e., surfaces perpendicular to specimen plane). The depth of oxide scale and internal oxidation present should be measured. If the depth of attack exceeds 0.51 mm (0.020 inches) or 1/3 of the local section thickness, whichever is less, the nozzle or vane should be considered un-repairable by welding or brazing. Coupon type repairs may be possible if the oxidation damage is localized.

MICROSTRUCTURAL CONDITION:

Cobalt-Based Vanes

The microstructural condition should be examined in all sections. In particular, longitudinal sections should be examined for the presence of voids formed by thermo-mechanical 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.

Nickel-Based Vanes

All samples should be examined by optical microscopy for the presence of intergranular creep voids. Any vanes in which creep voids are identified are unserviceable. They may be repaired by Hot Isostatic Press rejuvenation.

All samples should be examined by optical microscopy for microstructural instabilities. Changes from new material microstructure can be identified by comparing airfoil samples with samples of un-serviced alloy of the same composition in the fully heat treated condition. 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.

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 2. By comparing the structures in these areas with that of new (un-serviced) material, 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.

Any deviations from normal microstructure should be noted.

FIGURE III-A - LEADING OR TRAILING EDGE SPECIMEN

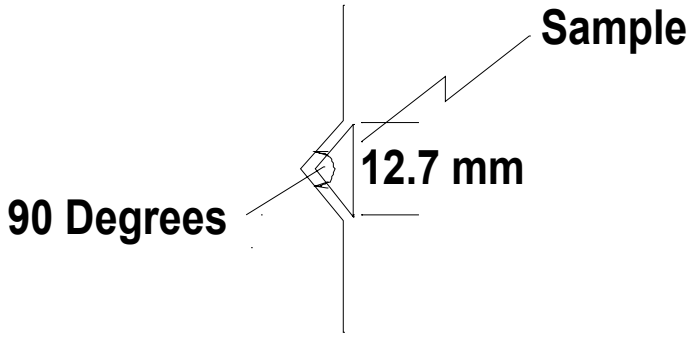
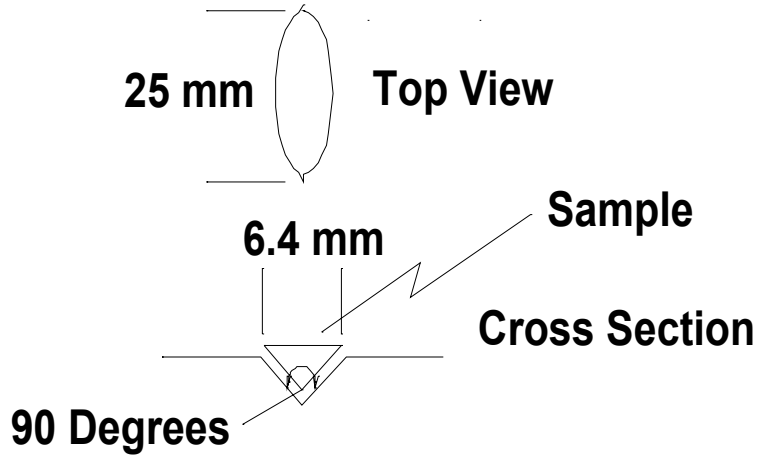


FIGURE III-B - "BOAT" SPECIMEN



APPENDIX IV - PROCEDURE FOR PERFORMING VANE COOLING PASSAGE FLOW TESTING

Introduction

This appendix provides procedures to be used by vane repair vendors for testing cooling passage flows prior to and after repair of air cooled gas turbine vanes. This is a quantitative test procedure in that cooling flow rates (kg/sec, lb/sec, cubic meters per minute, cubic feet per minute, etc.) or test stand pressures that are directly proportional to flow rate are measured and recorded. The purpose of this test is to determine if the vane cooling system has been affected by the repair and recoating processes. It is conducted by connecting a pressurized air supply to a vane / mounting fixture and measuring the total air flow through each vane. Results for each vane are recorded on Form IV-A herein.

NOTE: There are numerous air flow test stand configurations that are acceptable for use in conducting this testing. Some test stands measure and display flow directly in engineering units (kg/sec, lb/sec, SCFM, etc.). Others, such as those that use a critical flow nozzle, measure and display system pressures which, as long as the nozzle is maintained at choke flow, are directly proportional to flow. The method used should be reviewed and approved by the purchaser prior to testing. Any test system used must meet the accuracy requirement listed in Section C below.

B. Test Sequence Requirements

Vane flow testing is to be performed at (a) incoming inspection and (b) after completion of vane repair and re-coating. All testing is to be performed with vane segments fully assembled (all core plugs and cover plates installed).

C. Air Flow Test Instructions

Air Supply. Testing shall be performed using clean (pre-filtered) air at a regulated pressure. The regulator must be capable of maintaining constant inlet pressure to the orifice / flow nozzle within + / - 0.0141 kg/cm^2 (+ / - 0.2 psi).

Air Connection / Manifolding. The air supply system downstream of the flow orifice / nozzle (see item 3 below) must be leak-free. Any connection design geometry that provides a leak free system is acceptable, provided that the connection itself (a) does not impede air flow through the vane cooling system and (b) does not result in damage (scratches, dents, etc.) to the vane airfoil or shrouds.

Flow Measurements. Unless approved otherwise, the total air flow rate shall be measured by an orifice flow meter or flow nozzle designed and installed to produce an accuracy of + / - 1 percent. In order to obtain the required test accuracy, flow straighteners and compensation for test air temperature and pressure are required. Airflow may be recorded in engineering units (kg/sec, lb/sec, SCFM, etc.) or as a part inlet pressure or flow parameter that are directly proportional to airflow. Vendor shall obtain purchaser approval for the test stand configuration used and, for systems that do not display directly in engineering units, provide test system parameters that allow conversion of flow to engineering units.

Flow Criteria. Unless approved otherwise, the flow rate measured for each individual vane during the incoming air flow tests shall be used as a benchmark for the post coating flow tests.

Both Incoming and Post Coating flow rates shall be recorded by vane serial number on Form IV-A. The post coating flow rate for each vane shall be equal to the flow rate measured for that vane during the incoming air flow test within a tolerance of + / - 8 percent.

It is recognized that minimum to maximum flow rates measured across a full set of vanes typically vary by as much as + / - 12 percent from the nominal flow rate for the set. The central purpose of this testing is to determine if the repair and recoating process has resulted in blockages that lower flow for individual vanes by more that 8 percent from the values recorded during incoming inspection. It is reiterated that in the testing specified here, the flow recorded for each specific vane serial number at final inspection is compared to that recorded for the same serial number during incoming inspection.

It is also recognized that the incoming flow tests may reveal that some vanes exhibit abnormally low flow rates (i.e., more than 12 percent lower than the nominal for the set). When this occurs, efforts should be made to find and clear blockages, etc., that may have caused flow restrictions and the vanes retested. If the blockage cannot be cleared, the vanes should be set aside and held until a disposition can be obtained from the purchaser.

Vane Testing. All flow testing must be performed with the vane core plugs and cover plates installed. Connect vane to mounting fixture and air supply source and open supply line. Ensure that no air leaks are occurring in the system by conducting a soap / water solution “bubble” test at all connection locations downstream of the flow orifice / nozzle. Record the measured flow rate (or applicable system pressure for critical flow nozzle-based systems) on Form IV-A. Use the Comments section on the form to record any plugging / abnormal situations encountered or re-work / re-testing required.

Failures. Vanes that exhibit flow rates outside the criteria in item 4 above shall be considered as failures. The repair vendor may attempt to open any cooling holes that appear to be blocked / partially blocked by one or more of the following steps: (a) back-flushing with a cleaning medium such as water or steam; (b) soaking using petroleum-based solvents (or other approved solvents) followed by back-flushing; (c) probing of individual exit holes using appropriately sized wires; (d) other method approved by purchaser. Any vane in which cleaning / back-flushing was attempted must be re-tested and results recorded on Form IV-A. All vanes that cannot be cleared shall be separated from the remaining lot and held for purchaser disposition.

FORM IV-A

ALSTOM GT11N2 FIRST STAGE VANES

AIR FLOW TEST RECORD SHEET

VANE SERIAL NUMBER	INCOMING TESTS	POST COATING TESTS		COMMENTS
	MEASURED FLOW* (Or Pressure)	MEASURED FLOW* (Or Pressure)	RESULTS** (PASS OR FAIL)	

*Identify flow units measured (kg/sec, etc.) in this testing: _____

**The post coating flow rate must match the incoming flow rate within + / - 8 percent.

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

2
REPAIR SPECIFICATION FOR ALSTOM MODEL GT11N2 SECOND STAGE TURBINE VANE SEGMENTS

1 SCOPE

1.1 Purpose

This specification covers the minimum requirements for the weld repair, heat treatment and application of thermal barrier coating for Alstom Model GT11N2 second stage turbine vane segments manufactured from the nickel base alloy Inconel 738LC (Ni - 16Cr - 8.5Co - 3.4Al - 3.4Ti - 2.6W - 1.7Mo - 0.9Cb – 0.11C – 0.055Zr – 0.0095B). New vane segments supplied by the original equipment manufacturer are coated with a metallic MCrAlY type overlay coating, as described in Section 1.3. This specification addresses and assumes that the purchaser will opt to upgrade the gaspath coating to a thermal barrier coating (TBC) system to maximize component life. Vane segments repaired to these requirements should provide service life approaching that of new components. Sixty-six (66) vane segments comprise a full set quantity.

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. It should be noted that Inconel 738LC has proven difficult to weld as part of refurbishment processing. For this reason, consideration should first be given to blending minor defects according to OEM blend limits or the blend limits in Table 1, reserving weld repair for the larger defects which cannot be successfully blended.

1.3 Vane Coating

The OEM standard for external coatings has been an MCrAlY overlay on all external surfaces exposed to the turbine hot gas flow. This metallic layer is reportedly applied by the vacuum plasma spray (VPS) process and is a NiCrAlY overlay designated as SV20. As an optional upgrade, a ceramic topcoat can be applied over the metallic overlay coating by the Air Plasma Spray (APS) process, thus establishing a TBC system and effectively lowering base metal operating temperatures. No internal diffusion coatings are applied as part of original component manufacture, and this document assumes the internal passages will not be coated during the repair / refurbishment process.

As part of engineering the second stage vane refurbishment process, careful consideration must be made with regard to alternative airfoil coating systems and application methods to be utilized. Industry experience has shown the High Velocity Oxy-Fuel (HVOF) process to be a viable and acceptable alternative to VPS in terms of bond-coat application. Alternative bond-coat chemistries may also be considered; however, careful consideration of comparative oxidation resistance and strain tolerance in cyclic service must be made (5.6.3). As mentioned previously,

deviation from the OEM coating plan may be considered, such as an upgrade to a TBC system. However, care must be taken such that airfoil trailing edge and outer shroud cooling holes are properly masked during coating and thus not restricted by the application of coating (Section 5.4.4).

2 DEFINITIONS & VANE ILLUSTRATIONS

2.1 Alstom GT11N2 Second Stage Turbine Vane Segment

Figures 1-6 are photographs of various views of the second stage turbine vane segment. The vane is internally air cooled and coated by the OEM over the entire airfoil with a metallic overlay bond coat. The vane outer shroud possesses an integral blade path section which extends forward and forms the stationary tip shroud for the upstream first stage turbine blade. Cooling air is introduced onto the outboard and forward side of this blade path extension with the air guided aft by a cover plate mounted on the outboard side of the extension. This flow of cooling air then enters the gaspath through three (3) film cooling holes penetrating through the outer shroud, forward of the airfoil. Cooling air introduced into the airfoil internal cavity enters through an outer shroud cap assembly and exits through trailing edge slots.

NOTE: Proper refurbishment of the second stage vane segment requires disassembly of the cap assembly and the blade path extension cover plate mounted on the outer shroud to allow inspection of the airfoil internal cavity, as well as to avoid entrapment of media used during the refurbishment process. Careful grinding of the attachment welds/tabs during disassembly must be performed in order to ensure that these detail parts will be reusable after removal.

2.2 Lot

A group of parts which is processed through the entire repair cycle at the same time and are 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 sub-groups for heat treatment, each sub-group shall constitute a lot.

2.3 E.D.M.

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

2.4 Linear Indications

Non-destructive testing indications with a length of three times the width or greater.

2.5 Non-linear Indications

Non-destructive testing indications with a length of less than three times the width.

2.6 Through-Going Indications.

Non-destructive testing indications appearing directly opposite each other and apparently extending through the thickness of the section.

2.7 L.P.T.

Liquid Penetrant Test



Figure 2-1
Overall View, Pressure Side



Figure 2-2
Overall View, Suction Side



Figure 2-3
View of Outer Shroud



Figure 2-4
View of Airfoil Tip



Figure 2-5
View of Outer Shroud Cap Detail

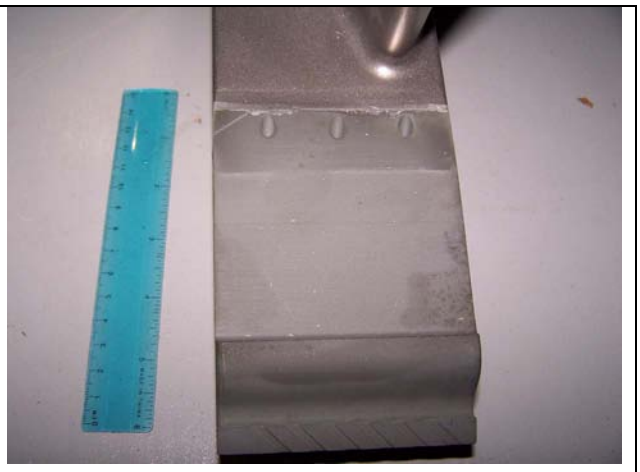


Figure 2-6
View of Outer Shroud Blade Path

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.

ASTM 1417

"Inspection, Liquid Penetrant"

ASTM E165

"Standard Practice for Liquid Penetrant Inspection Method"

Aerospace Material Specifications 5837F

“Nickel Alloy, Corrosion and Heat Resistant, Welding Wire 62Ni 21.5Cr 9.0Mo 3.7Cb (Mar 99)"

Aerospace Materials Specification 5887B

“Nickel Alloy, Corrosion and Heat Resistant, Bars, Forgings, and Rings 54Ni 22Cr 12.5Co 9.0Mo 1.2Al, Consumable Electrode or Vacuum Induction Melted Annealed (Jul 01)”

Aerospace Material Specifications 5878B

“Nickel Alloy, Corrosion and Heat Resistant, Sheet, Strip, and Plate 59Ni 22Cr 2Mo 14W 0.35Al 0.03La, Solution Heat Treated (Nov 02)”

ASNT Recommended Practice No. SNT-TC-1A

"Personnel Qualification and Certification in Nondestructive Testing"

ASTM B487

“Measurement of Metal and Oxide Coating Thickness by Microscopical Examination of a Cross Section”

ASTM C633 - 01

“Standard Test Method for Adhesion or Cohesive Strength of Thermal Sprayed Coatings”

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 5837C (Alternate 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 vane alloy, when pre-qualified by vendor and approved by the purchaser, may be allowed.. Braze, diffusion brazing, or other alternative techniques, for repair of craze cracking, and other defects are not permissible in critical areas. They are permitted in non-critical areas of the segments, as defined in Figure 7, provided that the process used is identical to that used in the original process qualification (7.1.2).

NOTE Use of braze processes for repair of defects should be considered carefully, given the potential for braze re-melt during future repair heat treatments and the limited ductility inherent with braze filler materials. Depending on the braze filler material utilized, the employment of braze processing can potentially limit temperatures used in future heat treatments, and render the brazed areas of the vane incapable of being subsequently weld repaired.

5.2 Vane Blend/Weld Repair Limits

5.2.1 Unless approved otherwise, blending limits shall be per Table 1. Blends must have a depth to blended length ratio of 1:8 minimum and be smooth and gradual with no sharp edges remaining.

5.2.2 External and internal surface oxidation/corrosion/alloy depletion may be blended out (blend repaired) to the maximum depths stated in Table 1. All surfaces to be coated must be metallurgically clean and free of all oxide and residual coating.

Blend repaired areas shall be liquid penetrant test (LPT) inspected to the requirements of Section 5.3.

5.2.4 Unless approved otherwise, weld repairability limits shall be per Table 1. All defects to be weld repaired must be completely removed prior to welding.

5.3 Non-Destructive Testing Acceptance Limits

Critical and non-critical areas of the component are defined in Figure 7. Linear indications are permitted in the critical areas of the component up to 0.76 mm (0.030 inch) in length provided they are spaced by 5 times their length. Non-linear indications are permitted in critical locations up to 1.5 mm (0.060 inch) diameter, or up to a diameter equal to 25% of the local section thickness, whichever is smaller. Linear indications up to 1.5 mm (0.060 inch) long are permitted in non-critical areas of the component provided that they are spaced by at least 5 times their length. Non-linear indications in non-critical areas of the component are permitted up to 1.5 mm (0.060 inch). Non-linear indications in non-gas path areas are permitted up to 3.2 mm (0.125 inch). Airfoil (vane) material loss to due to erosion, corrosion, nicks or dents must not exceed 50 percent of wall thickness. No through going indications are permitted.

Table 2-1
ALSTOM GT11N2 SECOND STAGE VANE SEGMENT REPAIR LIMITS

DESCRIPTION	MAXIMUM LIMITS
Airfoil	
Surface Blend	Critical Areas (see Figure 7) - 0.75 mm (0.030 inch) deep or 20% of design wall thickness, whichever is less.
Non-Critical Areas (see Figure 7)	1.5 mm (0.060 inch) deep or 40% of design wall thickness, whichever is less.
Trailing Edge Blend	6.25 mm (0.250 inch) maximum depth x 25.4 mm (1.0 inch) maximum length.
Shroud Gas Path Blend	
Surface Blend	1.5 mm (0.060 inch) deep or 40% of design wall thickness, whichever is less.
Edge Blend	3.0 mm (0.120 inch) maximum depth x 25.4 mm (1.0 inch) maximum length.
Shroud Non-gas Path Blend	
Surface Blend	3.0 mm (0.120 inch) maximum depth.
Vane-to-Vane Joint Seal Slot Blend	
Sealing Surface Blend	0.75 mm (0.030 inch) maximum depth.
Edge Blend	1.5 mm (0.060 inch) maximum depth x 25.4 mm (1.0 inch) maximum length.
Airfoil Weld Repair Limits	
Axial Crack Repair	up to 33% of the airfoil chord at any radial plane.
Radial Crack Repair	no limit.
Shroud Weld Repair Limits	no limit.

NOTE: Blends must have a depth to blended length ratio of 1:8 minimum and be smooth and gradual with no sharp edges remaining.

5.4 Dimensional Requirements

5.4.1 Gas path dimensions, axial and radial locations shall be within the range identified on the inspection forms attached as Appendix I.

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

5.4.3 Surface finish on the repaired components (after TBC application) shall be 4.6 microns (180 micro inches) Ra or better measured according to ANSI B46.1.

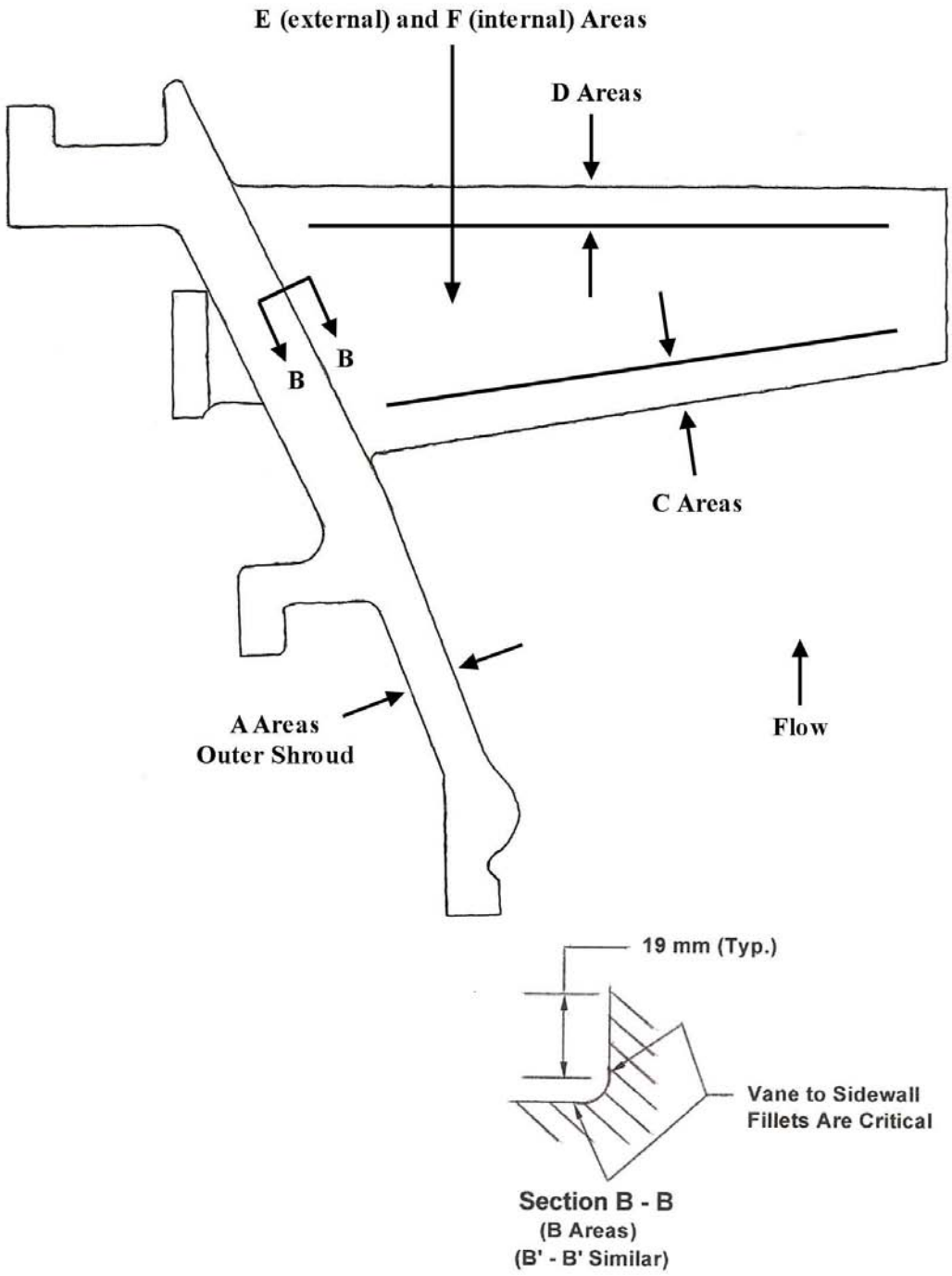
5.4.4 Cooling passages shall be restored to original dimensions. Unless otherwise approved, vane segments shall be flow tested to ensure that all cooling holes are open and flowing properly following the repair / recoating process (see Section 5.7). Flow testing with air and with the outer shroud cap assembly installed is preferred. It is good practice to also flow test the vane segments during incoming inspection to determine the pre-repair flow patterns and whether blockage or hole damage has occurred during service.

NOTE Omission of vane cooling passage flow testing following repair requires specific approval from the purchaser. Whenever omission is granted, the vane cooling holes must still be checked for blockage using properly sized gage wires or other approved procedure.

5.4.5 The repaired vane segment shall properly fit a dimensionally correct vane carrier, or a fixture which accurately simulates the vane carrier.

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. Some important dimensions affecting form, fit and function are given in Appendix I.

Figure 2-7
ALSTOM GT11N2 SECOND STAGE VANE SEGMENT CRITICAL AREAS



ALSTOM GT11N2 SECOND STAGE VANE SEGMENT CRITICAL AREAS

Area A- All surfaces of the shroud except the airfoil fillet radius areas (B areas) are non-critical areas.

Area B- That portion of the airfoil and shroud starting at the line of tangency between the shroud and airfoil and extending parallel to the airfoil and shroud span for 19 mm (0.75 inch) around the whole airfoil contour are critical areas. (See Section B – B).

Area C- Critical areas which includes the entire airfoil leading edge and extends 25 mm (1 inch) axially downstream of the leading edge on both pressure and suction sides.

Area D- Critical areas which includes the entire airfoil trailing edge and extends 25 mm (1 inch) axially upstream of the trailing edge on both pressure and suction sides.

Area E- Airfoil surfaces not included in Areas B, C and D are non-critical areas.

Area F- Internal airfoil surfaces are critical in B, C and D areas and non-critical in E areas.

5.4.6 The minimum wall thickness between vane external airfoil surfaces and internal cooling passage surfaces is a critical dimension that can govern repair / replacement decisions. Recommendations for performing wall thickness measurements for these vanes are provided in Appendix I, Form I-C and, unless approved otherwise, these recommendations must be followed. Form I-D is included to record the results of wall thickness measurements. Some turbine OEM's provide guidance on minimum acceptable airfoil wall thickness for each vane design in their turbine instruction manuals. If no OEM wall thickness criteria are available, the values measured may be compared with those of a new vane and a judgment made on the severity of wall thinning and whether repairs are practical. Airfoil wall thickness shall be recorded at all locations where significant corrosion, erosion or foreign object damage has occurred. Omission of wall thickness measurements requires specific purchaser approval.

5.5 Microstructural Requirements

5.5.1 The re-cast layer on any E.D.M. surface shall not exceed 0.025 mm (0.001 inch).

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

5.5.3 The microstructure shall be comparable to new material. Un-serviced material in the fully heat treated condition may be used for comparison. Specifically, no continuous carbide films or needle phases shall be present after processing. Appendix III provides guidance on metallographic samples and their evaluation.

5.6 Thermal Barrier Coating Application Requirements

NOTE: This section assumes that turbine owners will elect to apply a full coverage TBC coating to the airfoil and shroud wall (gaspath) surfaces. The purchaser may elect to apply an MCrAlY overlay only similar to the original OEM coating plan. This section also assumes that the TBC bondcoat or "stand-alone" MCrAlY overlay will be applied by the High Velocity Oxy-Fuel (HVOF) process, and the ceramic topcoat will be applied by the Air Plasma Spray (APS) process. Other processes (i.e., Low Pressure Plasma Spray for the bondcoat and Electron Beam – Physical Vapor Deposition for the ceramic topcoat) have also been used for applying TBC's on

gas turbine hot section components. The repair vendor should verify with the purchaser the scope of coating application desired before bidding or proceeding with the refurbishment process. It is recommended that all coating process procedures used be qualified by the first article qualification process as specified in paragraph 7.1.2.

5.6.1 Coverage. The coating shall cover all areas of the airfoil and shrouds that are exposed to the turbine hot gas flow (i.e., all gas path areas). Cooling holes shall be protected during the coating cycle using an appropriate masking compound. The method used shall prevent coat-down of cooling holes and shall be easily removed after coating. The base alloy shall be unaffected by the masking procedure, as demonstrated on a test coupon prior to process qualification. Procedures used shall be identical to those used in the original process qualification (7.1.2). Coatings shall be continuous over all areas where coating coverage is specified. For those areas where coating is not allowed, materials used for masking shall not have any deleterious effect on the base metal or the coating itself.

5.6.2 Surface Preparation. Surface preparation shall include cleaning and other operations required to insure proper coating adherence. Cracks, scale, and other surface discontinuities shall be removed by an approved process that may combine grinding, polishing, etching, and grit blasting. Intergranular attack and excessive metal removal due to etching is not permitted. Metallic shot may not be used for blasting. Blasting of close tolerance machined areas is not permitted. The surface preparation procedure used shall not impart any physical or microstructural damage to the part and shall satisfy all other aspects of this section. The cleaning process shall be capable of removing all grease, dirt, oils, oxidation products, and other foreign material that could impair the development of a satisfactory coating. Coating shall be performed within two (2) hours of surface preparation. Procedures used shall be identical to those used in the original process qualification (7.1.2).

5.6.3 Materials. Materials used to deposit the MCrAlY bondcoat and Yttrium stabilized Zirconium topcoat shall be approved by the purchaser. There can be a wide range of acceptable bondcoat compositions. Selection of the bondcoat should be based on the level of contaminants contained in both the fuels and ambient air. The level of aluminium in the bondcoat is an important consideration. Nominal compositions typically range from 8 to 12 weight percent. In general, coatings with higher aluminium levels tend to be more brittle, therefore the duty cycle of the engine (cycling or continuous duty) should also be considered when specifying aluminium content. It should also be recognized that the level of elements in coating powders delivered from manufacturers can typically vary by 1 to 2 percent from nominal values specified. Certificates of analysis for each lot of material used to coat components shall be maintained on file for a period of five years.

5.6.4 Appearance. Visual inspection of coating surface shall be performed without mag-nification. Areas of discoloration or suspect irregularities shall be examined at 5X magnification to establish conformance. Coating coverage shall be verified per the requirements based on visual (unaided) examination of coated parts and color changes.

5.6.5 Visual. Coating shall have a uniform matte surface texture and color and shall be 100% adherent with no evidence of spalling, chipping, cracking, flaking, pitting, or other indications of coating distress.

5.6.6 Defects. All part surfaces shall be free of foreign materials such as masking materials and glass beads that may have been used for surface improvement. Foreign material that has been

fused by exposure to heat treating cycles is cause for rejection. Raised or positive coating defects such as ridges, plateaus, or other abrupt changes in coating thickness which are readily detectable by touch or sight are not permitted, subject to the limits specified in 5.6.7 and 5.6.8.

5.6.7 Acceptable Irregularities. Irregularities caused by casting defects or service degradation that are present in the surface prior to coating processing shall not be cause for rejection of the component.

5.6.8 Unacceptable Irregularities. Notwithstanding 5.6.7, irregularities or defects that expose base metal are not permitted. Coating cracks are not permitted. In addition, irregularities that are larger than 0.25 mm (0.010 inch) in any dimension are cause for rejection of the part.

5.6.9 Surface Finish. The surface finish on TBC coated surfaces shall be 4.6 microns (180 micro inches) Ra or better, measured according to ANSI B46.1. When post-coating surface improvement is necessary, care shall be exercised to limit the amount of coating removal, to avoid cracking, and to prevent damage or alteration of uncoated areas. Measurements of coating thickness shall be made after any surface improvement.

NOTE: If purchaser should elect to apply an MCrAlY overlay with a partial coverage of ceramic topcoat, it is recommended that the surface finish of the overlay be 2.5 microns (100 micro inches) Ra or better, measured according to ANSI B46.1. To meet this surface finish will typically require post-coating processing (e.g., wire peen or vibratory tumble).

5.6.10 Microstructural Requirements. Metallographically prepared cross sections of coated and heat treated samples shall be examined using standard microscope techniques. Vacuum impregnated epoxy mounting materials and standard mechanical polishing techniques shall be used to prepare mounts for microscopic inspection. The specimen base metal shall be the same alloy as the components being coated and preferably from a representative scrap component. The samples shall be processed through the complete coating and heat treating cycle defined herein (6.2) and meet the requirements of 5.6.11, 5.6.12, 5.6.13 and 5.6.14.

5.6.11 Thickness. Bond coat thickness shall be 0.076 – 0.20 mm (0.003 - 0.008 inches) on all coated surfaces, except for airfoil-to-shroud fillet areas where a tolerance of 2x is permitted for the bondcoat. Ceramic topcoat thickness shall be 0.18 – 0.38 mm (0.007 to 0.015 inches) except for airfoil-to-shroud fillet areas where a tolerance of 1.5x is permitted for the topcoat. Feather coating thickness at the transition from coated to un-coated regions. Total thickness does not include the thickness of any interdiffusion zone between the MCrAlY layer and the component substrate. The thickness of the interdiffusion zone between the MCrAlY layer and the substrate shall not exceed 0.013mm (0.0005 inch). Coating thickness shall be measured in accordance with ASTM B487 and should be measured at 5 to 10 random locations on each metallographic specimen to establish an average thickness value

NOTE: If purchaser should elect to apply an MCrAlY overlay with a partial coverage of ceramic topcoat, it is recommended that the coating thickness range recommended above for the bondcoat be increased to 0.13 to 0.38 mm (0.005 to 0.015 inch). A 2x tolerance at airfoil-to-shroud fillets would typically be permitted.

5.6.12 Bondcoat Microstructure. The bondcoat microstructure shall be uniform and typical of the standard for the particular composition approved in the original coating process qualification (7.1). No separation (delamination) along the bondcoat interface is allowed. The substrate / bondcoating interface shall have no interconnected voids at 500X magnification and be free of

non-metallic inclusions in excess of 15% of the interface. The sum (volume percent) of bondcoat porosity and oxidation products shall be less than 4% in the airfoil and less than 5% in platform and fillet area. Clusters of pores greater than 0.025 mm (0.001 inches) in thickness shall be cause for rejection.

5.6.13 Ceramic Layer Microstructure. The thermal barrier layer shall have a minimum porosity level of 5% and a maximum porosity level of 20%. Clusters of pores greater than 0.051 mm (0.002 inches) in thickness shall be cause for rejection.

NOTE: In most cases, a maximum porosity level of 15% should be maintained. Certain turbine OEM's allow up to 20% porosity levels on specific components.

5.6.14 Coating / stripping process-related alloy depletion, oxidation, nitriding and intergranular attack of the base metal surface shall not exceed 0.025 mm (0.001 inch).

5.6.15 Bondcoat Strength. The room temperature tensile strength (adhesion) of the bondcoat to substrate interface shall be no less than 69 MPa (10,000 psi) as documented in testing during original process qualification (7.1.). Testing shall be performed in accordance with ASTM C633-01 using FM1000, EC2086 or EC2214 adhesive film. A minimum of three (3) tests shall be performed to verify consistency of the process.

5.6.16 Topcoat (Ceramic Layer) Strength. The room temperature tensile strength (adhesion) of the topcoat to bondcoat interface shall be no less than 10.4 MPa (1500 psi) as documented in testing during original process qualification (7.1.). Testing shall be performed in accordance with ASTM C633-01 using FM1000 adhesive film. A minimum of three (3) tests shall be performed to verify consistency of the process.

5.6.17 Parts that are improperly coated shall be recycled through the entire coating process beginning with stripping.

5.7 Cooling Passage Flow Test Requirements

Unless specifically waived by the purchaser, the cooling passage flow testing procedure / requirements specified in Appendix IV shall be followed / met.

NOTE: Proper functioning of the vane cooling system is of critical importance in advanced technology turbine vanes. For this reason, flow testing as described in Appendix IV is to be performed at (a) incoming inspection and (b) after all processing (i.e., following coating application).

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. Record vane serial numbers.

6.1.2 Advise purchaser immediately of any shipping damage.

6.1.3 Visually inspect each segment for the following:

- rubs and wear
- surface erosion loss
- cracks
- oxidation/corrosion
- impact damage
- blocked or damaged cooling holes
- loss of coating

Record the results on the form attached as Appendix II.

6.1.4. Flow test each vane segment per Appendix IV to determine the incoming flow rate and whether cooling hole blockage or hole damage has occurred during service.

6.1.5 Segment Disassembly. Carefully grind the outer shroud cover plate attachment weld and remove the cover plate. Carefully grind the tab welds holding the outer shroud cap assembly in place over the airfoil cavity and remove the cap assembly. Note if there is any interference or unusual difficulty encountered when removing these detail parts. Identify each cover plate and cap assembly with the vane number or vane serial number from which it was removed. Cover plates and cap assemblies that were damaged during removal or service must be replaced with components that match OEM material and dimensional tolerances.

6.1.6 Metallurgical evaluation (Optional). If excessive oxidation, corrosion, pitting, or other distress is noted, the taking of a metallographic sample for evaluation should be considered. The location where the sample is taken is critical in determining the physical and microstructural extent of the damage. In general, the location should be selected where the damage appears most extensive; however, consideration should also be given to reparability of the location where the sample is taken. Some generic guidance on metallurgical evaluation is given in Appendix III.

6.1.7 Clean the segments using grit blasting with 220 grit or finer 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 since 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 which precedes a heat treatment.

6.1.8 Wax mask uncoated surfaces and remove the metallic airfoil coating by a suitable chemical stripping process. Stripping of the coating shall be in accordance with an approved Process Description (7.1.2). Adequate precaution and masking shall be specified to ensure that

the stripping procedure is not deleterious to the vane segments, including cooling holes. Control samples of Inconel 738LC shall be processed through any chemical stripping procedure (each stripping lot) and examined metallographically for intergranular attack, which shall not exceed the limits defined in 5.5.2. The use of coated samples taken from a vane from the set being repaired is strongly preferred for stripping control samples.

6.1.9 Verify coating removal using one of the two methods described below. If residual coating is indicated, the part must be recycled through the stripping procedure. Procedures used shall be identical to those used in the original process qualification (7.1.2).

6.1.9.1 Clean parts thoroughly to remove residue from chemical stripping. Lightly re-etch. Development of a dark residue indicates that coating remains.

6.1.9.2 Heat Tinting. Heat tinting using a low temperature thermal cycle (typically 427 °C to 649 °C (800 to 1200°F), but in no case higher than 815 °C (1500°F)) of relatively short duration (no longer than one-half hour) may be used to develop color differences between coated and uncoated areas for inspection.

6.1.10 Visually inspect both internal and external surfaces of 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 form attached as Appendix II. Results should be added to the forms completed in the visual inspection of 6.1.3, if practical. The intent is to document / map all service-induced vane segment defects on one set of damage assessment forms.

6.1.11 L.P.T all vane segments following the visual penetrant procedures outlined in ASTM Specification 1417 or the visual penetrant procedures in ASTM E165. 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. Results should be added to the forms completed in the visual inspection of 6.1.3, if practical. The intent is to document / map all service-induced vane segment defects on one set of damage assessment forms.

6.1.12 Dimensionally inspect each segment for locating diameters and axial and radial airfoil location and record the results on the forms attached as Appendix I. Locating (fit) diameters and radial and axial location may be checked with a fixture or dimensionally correct vane carrier in lieu of actual measurement, provided all dimensions identified on the Forms are checked by the Fixture.

6.1.13 Perform ultrasonic (UT) vane airfoil wall thickness measurements per the instructions on Form I-C in Appendix I. It is recommended that 20% of the vanes be inspected for airfoil wall thickness (i.e., 13 vanes from a complete set). Record wall thickness measurements on Form I-D.

NOTE: The recommendation of 20% should be increased when appropriate. For example, if it is known that the set of vanes is a "mixed" set (i.e., that set integrity has not been maintained, meaning that some segments have a different operating history than others in the set) it would be appropriate to increase the percentage so that a representative sampling of all operating histories was inspected. Likewise, all vanes that have significant distress that could result in wall thinning (corrosion, erosion, foreign object damage, etc.) should be inspected.

6.1.14 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.

- obtain written or verbal authorization to replace any core plugs.

6.2 Repair Procedure

6.2.1 Dress surfaces as required to remove any oxidation per the limits defined in Table 1. Thoroughly degrease components using approved solvent cleaner or other approved method such as steam cleaning or pressure spraying.

6.2.2 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 for disposition.

6.2.3 Solution anneal the vane segments in a vacuum, hydrogen or argon as follows:

1190 °C +/- 14 °C (2175 °F +/- 25 °F) for four (4) hours in a vacuum of 1 micron ($1.3x10^{-3}$ millibar) or better.

Inert gas quench to below 538°C (1000°F). Support parts using nickel base, iron base or coated graphite heat treat rack materials with the parts supported uniformly to prevent distortion. Avoid supporting the parts by any thin sections. Alternately, heat treatment at lower temperatures for the purpose of over-aging the microstructure prior to welding is permitted when approved by the purchaser. However, this approach will require full solution heat treatment as indicated above after completion of all welding (at paragraph 6.2.13).

6.2.4 L.P.T. all vane segments following procedures outlined in paragraph 6.1.11. Document the location and extent of any defects not identified in paragraph 6.1.11 using the form attached as Appendix II.

6.2.5 Prepare the areas of the segments to be weld repaired by grinding out the existing cracks and defects and L.P.T. to ensure 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). When specifically approved, sections may be removed for replacement with patches of matching

alloy composition provided that, after the repairs are completed, the cooling hole configuration and airfoil contours are unchanged.

6.2.6 When requested, the purchaser shall be informed and allowed to inspect the components following weld preparation.

6.2.7 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).

6.2.8 Braze, diffusion brazing, or other alternative techniques, for repair of craze cracking, and other defects are not permissible in critical areas. They are permitted in non-critical areas of the segments, as defined in Figure 7, 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 the inherently lower ductility of the braze filler material.

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 L.P.T. the complete vane segment following procedures outlined in paragraph 6.1.11, using the acceptance criteria identified in Paragraph 5.3.

6.2.11 Parts that fail to meet the criteria of paragraph 5.3 may be recycled to repair any defects beginning at paragraph 6.2.5. Parts may be recycled to paragraph 6.2.3 for stress relief, at the vendor's option.

6.2.12 Thoroughly clean components using approved solvent cleaner or other approved methods such as steam cleaning or pressure spraying.

6.2.13 Vacuum heat treat the components to stress relieve the weldments / solution anneal the microstructure using the cycle used in the original process qualification (7.1.2). Unless otherwise specified / approved by the purchaser, the following parameters shall be employed:

1190 °C +/- 14 °C (2175 °F +/- 25 °F) for two (2) hours in a vacuum of 1 micron ($1.3x10^{-3}$ millibar) or better.

NOTE: This heat treatment step is not required if no welding was performed, and the full solution heat treatment step was previously performed at paragraph 6.2.3.

6.2.14 Immediately following heat treatment (if performed) and before any surface cleaning or blasting, liquid penetrant inspect the entire segment using the method outlined in paragraph 6.1.11 and acceptance criteria outlined in paragraph 5.3. Record the results on the forms attached as Appendix II.

6.2.15 Dimensionally check the vanes to ensure conformance to Paragraph 5.4 and record the results on the form attached in Appendix I. Locating (fit) diameters and radial and axial airfoil location may be checked with a Fixture in lieu of actual measurement, provided all dimensions identified on the Forms are checked by the Fixture.

6.2.16 Prepare vane segment surfaces for thermal barrier coating. Part cleaning, degreasing and grit blasting are a part of the coating process and are the responsibility of the repair vendor (unless coating is subcontracted by the purchaser). It is important that surface oxides, deposits and other contaminants be completely removed prior to coating. Preparation procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.17 Apply masking / stop off compounds as required to all no-coat areas. Component surfaces that are not to be coated shall be protected during the coating cycle using an appropriate mechanical mask or a suitable stop-off compound. The method used shall completely prevent coating build-up on the prohibited areas and be easily removed after coating. Procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.18 Apply the TBC bond coat. Coating shall be applied with a uniform build-up and without interruption. Control samples of IN-738LC shall be processed through the coating procedure (each coating lot) and examined metallographically to ensure compliance with paragraph 5.6.

NOTE Coating thermal cycles must be matched to the heat treatment for the alloy to develop appropriate mechanical properties. For this reason, coating shall be performed in conjunction with the heat treatment specified in paragraph 6.2.20.

6.2.19 When the coating process is complete, remove all mechanical masking and stop-off compounds.

6.2.20 Vacuum heat treat to diffuse the TBC bond coat and to restore the base material mechanical properties using the cycle used in the original process qualification (7.1.2). Unless otherwise specified / approved by the purchaser, the heat treatment shall be as follows:

1120 °C +/- 14 °C (2050 °F +/- 25 °F) for two (2) hours in vacuum, inert gas quench, followed by:

845 °C +/- 14 °C (1550 °F +/- 25 °F) for twenty-four (24) hours in vacuum or argon

NOTE Coating thermal cycles must be matched to the heat treatment for the alloy to develop appropriate mechanical properties. For this reason, TBC bond coating shall be performed in conjunction with the heat treatment specified in this paragraph.

6.2.21 Apply masking / stop off compounds as required to all no-coat areas. Component surfaces that are not to be coated shall be protected during the coating cycle using an appropriate mechanical mask or a suitable stop-off compound. The method used shall completely prevent coating build-up on the prohibited areas and be easily removed after coating. Procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.22 Prepare vane segment surfaces for the TBC ceramic top coat. Part cleaning, degreasing and grit blasting are a part of the coating process and are the responsibility of the repair vendor (unless coating is subcontracted). It is important that surface oxides, deposits and other contaminants be completely removed prior to coating. Coating shall be performed within two (2) hours of surface preparation. Preparation procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.23 Apply TBC ceramic top coat using only processes and coating compositions that have been specified or approved by the purchaser. Coating shall be applied with a uniform build-up

and without interruption. Process control specimen for microstructural analysis fabricated from base material samples shall be included in each coating lot of vanes for process control. Evaluation of control specimens shall be the responsibility of the repair vendor (or coating vendor, if subcontracted). Unless specified / approved otherwise, the coating shall be in accordance with paragraph 5.6.

6.2.24 When the coating process is complete, remove all mechanical masking and stop-off compounds.

6.2.25 Remove excess coating from no-coat areas using a process identical to that used in the original process qualification (7.1.2).

6.2.26 Clean uncoated areas of the vane segments.

6.2.27 Visually inspect all coated areas using the methods and acceptance criteria outlined in 5.6. Light polishing may be performed to achieve the required surface finish. Wire brushes shall have austenitic stainless steel bristles.

6.2.28 Ensure that no blockage of cooling holes has occurred during processing by passing a wire gage or gaging balls of appropriate size through each cooling hole or by flow testing. See paragraph 5.4.4. It is preferable that flow testing be performed after cap assemblies are installed.

6.2.29 Perform surface finish inspections per the methods and criteria of 5.6. All coated parts shall be inspected. Record the results by segment serial number. Parts that are improperly coated shall be recycled through the entire coating process beginning with stripping. (See 6.1.7).

6.2.30 Thoroughly inspect all internal passages and plenums for cleanliness and install the outer shroud cap assemblies and cover plates. Inspect welds per paragraph 5.3, non critical areas. Fit up and welding procedure shall be identical to those used in the original process qualification.

6.2.31 Flow test the vane segments per Appendix IV. Record the post-coating flow rates and results (pass/fail) by serial number.

Assembly Dimensional Inspection. Perform final dimensional inspection to ensure conformance

to Paragraph 5.4 and record the results on the form attached in Appendix I. Locating (fit) diameters and radial and axial airfoil location may be checked with a Fixture in lieu of actual measurement, provided all dimensions identified on the Forms are checked by the Fixture.

Ideally, this inspection will entail assembly of vane segments into a fixture that simulates the turbine vane carrier and can accommodate at least three (3) vane segments at a time. Inspect for the following:

Vane segments assemble / slide properly into the fixture without binding.

Excessive axial and radial mismatch (steps) between segments at the airfoil tips and outer shrouds.

Uniform vane segment joint gaps along their axial length and consistent joint gaps vane-to-vane.

Proper joint seal engagement in the mating grooves of adjacent segments.

6.2.33 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.

6.2.34 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.

6.2.35 Advise purchaser of the shipping date, route and carrier.

6.2.36 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 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 vanes (and/or other sample material identified by Purchaser) through the entire process for non-destructive 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 (7.1.1) and the Technical Review (7.1.2).

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

7.2 Documentation & 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 five 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 which shall contain:

a) a mapping of all defects identified at paragraph 6.1.3, 6.1.10, 6.1.11 and 6.2.4. (Use form attached as Appendix II)

b) a mapping of all repair locations (Use form attached as Appendix II)

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

d) a copy of final L.P.T. and flow check reports

e) a copy of the certificate of compliance

7.3 Acceptance and Disposition

7.3.1 All deviant parts shall be plainly labelled in a non-destructive 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

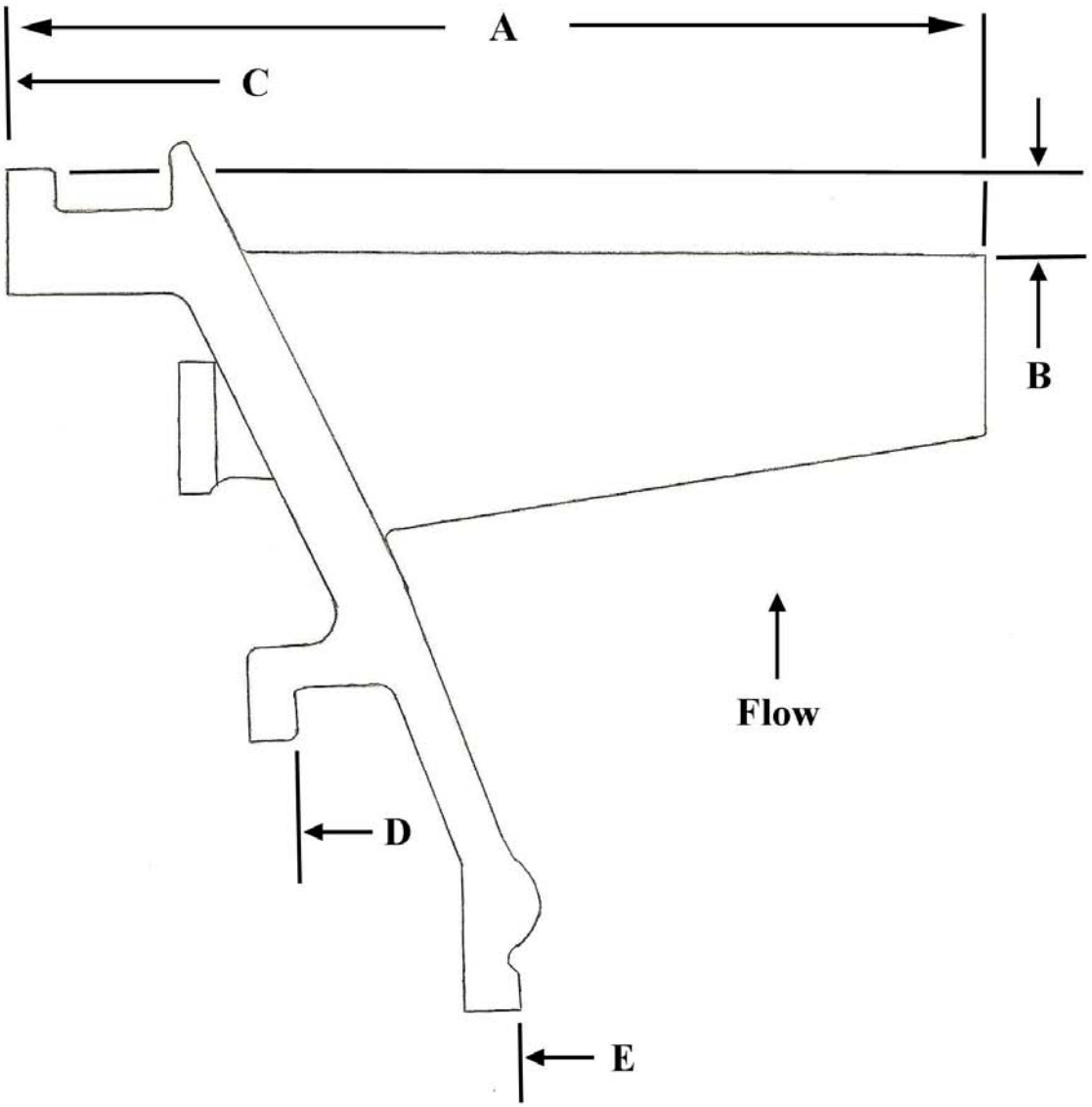
The purchaser shall be allowed reasonable access to inspect components at all times during the repair process

APPENDIX I - DIMENSIONAL INSPECTION FORMS

FORM 1-A

ALSTOM GT11N2 SECOND STAGE VANE DIMENSIONAL INSPECTION FORM

OVERALL DIMENSIONS



NOTES:

1. Measure dimension A at the center of the segment.

2. Dimensions C, D and E are radius measurements and are to be measured at the left, center and right ends of the segment.

3. Checking fixtures or a dimensionally correct vane carrier may be used to check dimensions provided all dimensions shown are checked. Record results as Pass or Fail on Form 1-B.

FORM 1-B

ALSTOM GT11N2 SECOND STAGE VANE DIMENSIONAL INSPECTION FORM

OVERALL DIMENSIONS RECORD SHEET

DIMENSION	**ALLOWABLE**		**SEG. #_____**	**SEG. #_____**	**SEG. #_____**
	MIN.	**MAX.**	**S/N** _____	**S/N** _____	**S/N** _____
A					
B					
C Left					
C Center					
C Right					
D Left					
D Center					
D Right					
E Left					
E Center					
E Right					
Comments:					

RECORDED DIMENSIONS ARE IN (Check one): ☐ mm ☐ Inches

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

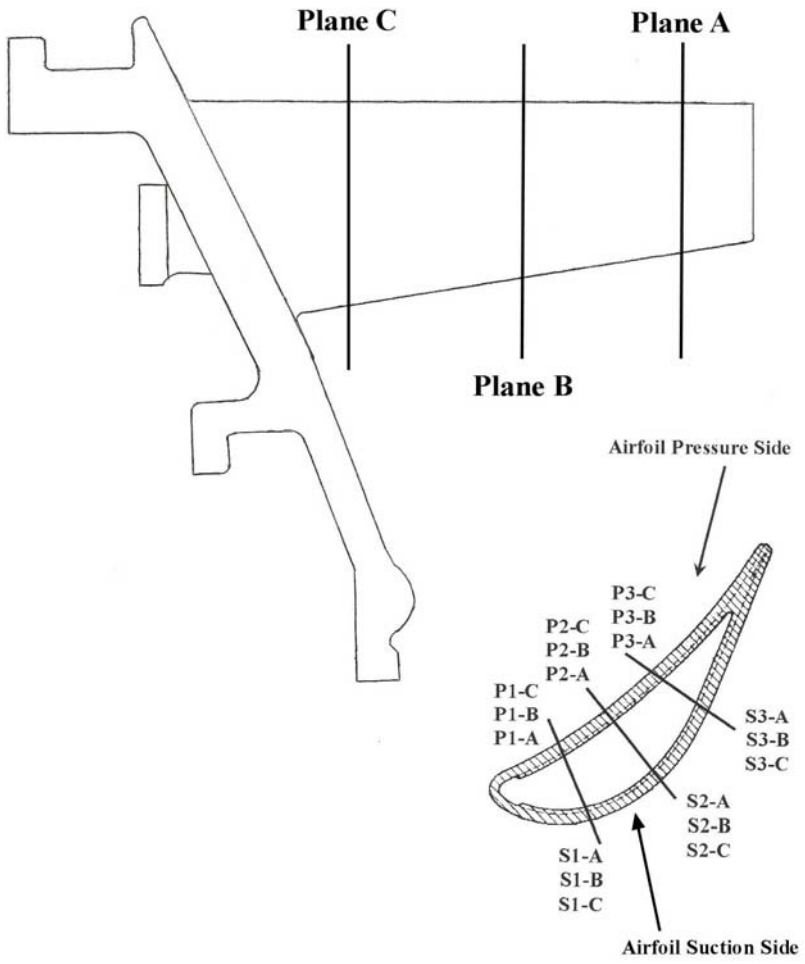
Segment numbers are counted clockwise looking in direction of flow. Number 1 is the first segment in the upper half on the left side.

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

FORM I-C

ALSTOM GT11N2 SECOND STAGE VANES

UT WALL THICKNESS INSPECTION INSTRUCTIONS



NOTES FOR ULTRASONIC WALL THICKNESS CHECKS:

Ultrasonic (UT) checks for vane airfoil wall thickness are recommended on 20 percent of the vanes to be repaired (i.e., 13 vanes from a full set). The sample size should be increased in some circumstances • see note at paragraph 6.1.14.

Eighteen (18) UT measurements are recommended on each vane airfoil: 9 measurements on the pressure side (“P”) and 9 measurements on the suction side (“S”). Record measurements on Form I-D.

Vendor and purchaser may agree on alternate locations to more closely coincide with actual service degradation / wall thinning.

Radial locations are numbered A, B and C. The “A” locations are a radial distance of approximately 1 inch outboard of the airfoil tip. Likewise, the “C” locations are a radial distance of 1 inch inboard of the outer shroud wall. The “B” locations are at the approximate centerline between the inner shroud wall and the airfoil tip.

Axial locations of measurements should be equally spaced along the chord of the internal cavity (as shown in the above sketch). See Note 3 above.

Using the above terminology, the measurement location designated as “P1-A” is on the pressure side surface at the axially forward region of the internal cavity and 1” inboard of the airfoil tip. Likewise, the measurement location designated as “S3-C” is on the suction side surface at the axially aft region of the internal cavity and 1 inch inboard of the outer shroud wall.

FORM I-D

ALSTOM GT11N2 SECOND STAGE VANES

UT WALL THICKNESS INSPECTION RECORD SHEET

MEASUREMENT	**ALLOWABLE**		**SEG. #_____** **S/N _____**	**SEG. #_____** **S/N _____**	**SEG. #_____** **S/N _____**
	MIN.	**MAX.**			
PRESSURE SIDE MEASUREMENTS					
P1-A					
P1-B					
P1-C					
P2-A					
P2-B					
P2-C					
P3-A					
P3-B					
P3-C					
SUCTION SIDE MEASURMENTS					
S1-A					
S1-B					
S1-C					
S2-A					
S2-B					
S2-C					
S3-A					
S3-B					
S3-C					
Comments					

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

APPENDIX II - DAMAGE ASSESSMENT FORMS

FORM II-A

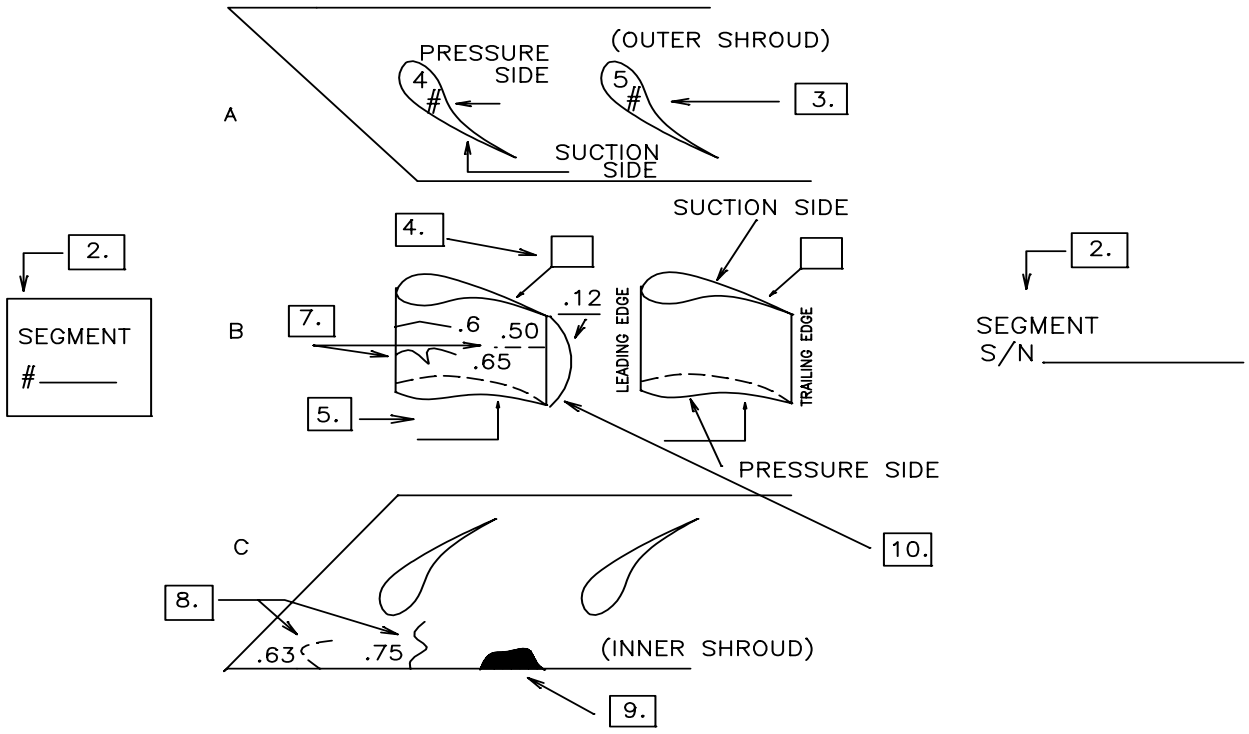
ALSTOM GT11N2 SECOND STAGE VANES

NOTES FOR VANE DAMAGE ASSESSMENT

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 -

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 cooling air holes below each vane.

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 -

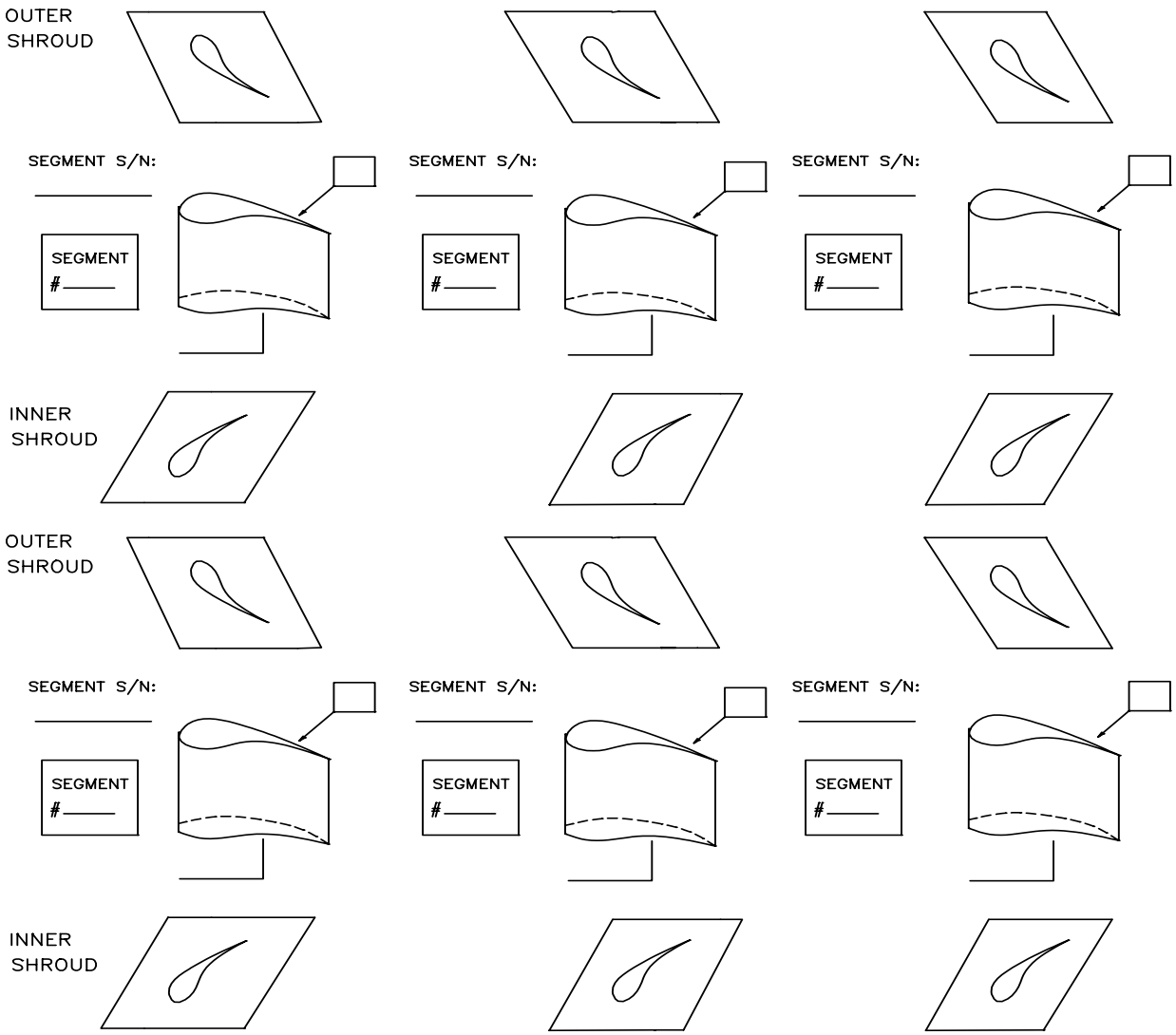
10.

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 100ths of inches.

FORM II-B

ALSTOM GT11N2 SECOND STAGE VANE SEGMENT

DAMAGE ASSESSMENT FORM



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

APPENDIX III - PROCEDURE FOR METALLURGICAL EVALUATION OF NOZZLE AND VANE SEGMENTS

SCOPE:

This procedure describes techniques to be used to characterize material degradation in both cobalt and nickel based nozzles / vanes and assess reparability. The removal of samples is semi-destructive, 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 0.16 mm (1/16") wafering blades and rotary air or electric hand tools. Appropriate personal protective gear should be worn at all times when using such tools.

Since samples removed must be repaired, the minimum material necessary should be removed. For leading and trailing edge locations, the sample geometry shown in Figure III-A is adequate for specimens in two orientations. For removal of samples from heavier locations such as side rails, a "boat" type specimen, as shown in Figure III-B, 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 (i.e., surfaces perpendicular to specimen plane). The depth of oxide scale and internal oxidation present should be measured. If the depth of attack exceeds 0.51 mm (0.020 inches) or 1/3 of the local section thickness, whichever is less, the nozzle or vane should be considered un-repairable by welding or brazing. Coupon type repairs may be possible if the oxidation damage is localized.

MICROSTRUCTURAL CONDITION:

Cobalt-Based Vanes

The microstructural condition should be examined in all sections. In particular, longitudinal sections should be examined for the presence of voids formed by thermo-mechanical 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.

Nickel-Based Vanes

All samples should be examined by optical microscopy for the presence of intergranular creep voids. Any vanes in which creep voids are identified are unserviceable. They may be repaired by Hot Isostatic Press rejuvenation.

All samples should be examined by optical microscopy for microstructural instabilities. Changes from new material microstructure can be identified by comparing airfoil samples with samples of un-serviced alloy of the same composition in the fully heat treated condition. 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.

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 2. By comparing the structures in these areas with that of new (un-serviced) material, 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.

Any deviations from normal microstructure should be noted.

FIGURE III-A - LEADING OR TRAILING EDGE SPECIMEN

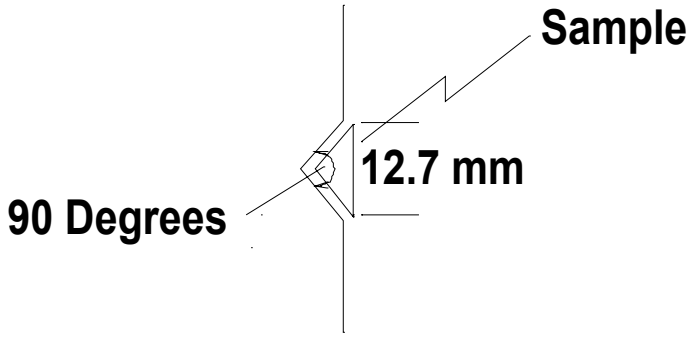
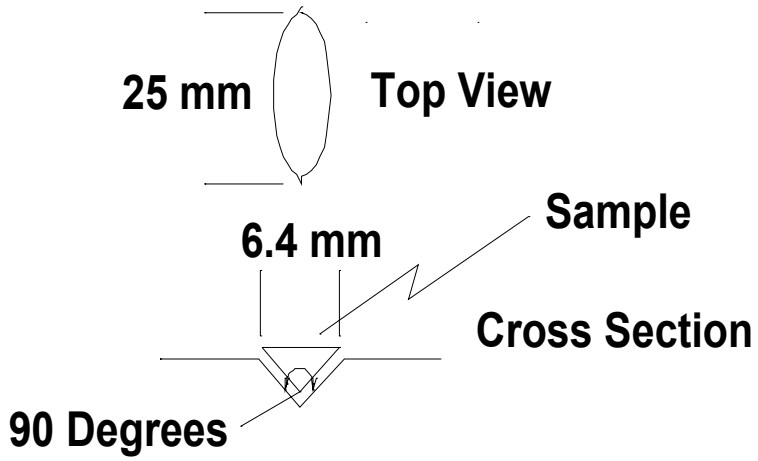


FIGURE III-B - "BOAT" SPECIMEN



APPENDIX IV - PROCEDURE FOR PERFORMING VANE COOLING PASSAGE FLOW TESTING

Introduction

This appendix provides procedures to be used by vane repair vendors for testing cooling passage flows prior to and after repair of air cooled gas turbine vanes. This is a quantitative test procedure in that cooling flow rates (kg/sec, lb/sec, cubic meters per minute, cubic feet per minute, etc.) or test stand pressures that are directly proportional to flow rate are measured and recorded. The purpose of this test is to determine if the vane cooling system has been affected by the repair and recoating processes. It is conducted by connecting a pressurized air supply to a vane / mounting fixture and measuring the total air flow through each vane. Results for each vane are recorded on Form IV-A herein.

NOTE: There are numerous air flow test stand configurations that are acceptable for use in conducting this testing. Some test stands measure and display flow directly in engineering units (kg/sec, lb/sec, SCFM, etc.). Others, such as those that use a critical flow nozzle, measure and display system pressures which, as long as the nozzle is maintained at choke flow, are directly proportional to flow. The method used should be reviewed and approved by the purchaser prior to testing. Any test system used must meet the accuracy requirement listed in Section C below.

B. Test Sequence Requirements

Vane flow testing is to be performed at (a) incoming inspection and (b) after completion of vane repair and re-coating. All testing is to be performed with vane segments fully assembled (all core plugs and cover plates installed).

C. Air Flow Test Instructions

Air Supply. Testing shall be performed using clean (pre-filtered) air at a regulated pressure. The regulator must be capable of maintaining constant inlet pressure to the orifice / flow nozzle within + / - 0.0141 kg/cm^2 (+ / - 0.2 psi).

Air Connection / Manifolding. The air supply system downstream of the flow orifice / nozzle (see item 3 below) must be leak-free. Any connection design geometry that provides a leak free system is acceptable, provided that the connection itself (a) does not impede air flow through the vane cooling system and (b) does not result in damage (scratches, dents, etc.) to the vane airfoil or shrouds.

Flow Measurements. Unless approved otherwise, the total air flow rate shall be measured by an orifice flow meter or flow nozzle designed and installed to produce an accuracy of + / - 1 percent. In order to obtain the required test accuracy, flow straighteners and compensation for test air temperature and pressure are required. Airflow may be recorded in engineering units (kg/sec, lb/sec, SCFM, etc.) or as a part inlet pressure or flow parameter that are directly proportional to airflow. Vendor shall obtain purchaser approval for the test stand configuration used and, for systems that do not display directly in engineering units, provide test system parameters that allow conversion of flow to engineering units.

Flow Criteria. Unless approved otherwise, the flow rate measured for each individual vane during the incoming air flow tests shall be used as a benchmark for the post coating flow tests.

Both Incoming and Post Coating flow rates shall be recorded by vane serial number on Form IV-A. The post coating flow rate for each vane shall be equal to the flow rate measured for that vane during the incoming air flow test within a tolerance of + / - 8 percent.

It is recognized that minimum to maximum flow rates measured across a full set of vanes typically vary by as much as + / - 12 percent from the nominal flow rate for the set. The central purpose of this testing is to determine if the repair and recoating process has resulted in blockages that lower flow for individual vanes by more that 8 percent from the values recorded during incoming inspection. It is reiterated that in the testing specified here, the flow recorded for each specific vane serial number at final inspection is compared to that recorded for the same serial number during incoming inspection.

It is also recognized that the incoming flow tests may reveal that some vanes exhibit abnormally low flow rates (i.e., more than 12 percent lower than the nominal for the set). When this occurs, efforts should be made to find and clear blockages, etc., that may have caused flow restrictions and the vanes retested. If the blockage cannot be cleared, the vanes should be set aside and held until a disposition can be obtained from the purchaser.

Vane Testing. All flow testing must be performed with the vane core plugs and cover plates installed. Connect vane to mounting fixture and air supply source and open supply line. Ensure that no air leaks are occurring in the system by conducting a soap / water solution “bubble” test at all connection locations downstream of the flow orifice / nozzle. Record the measured flow rate (or applicable system pressure for critical flow nozzle-based systems) on Form IV-A. Use the Comments section on the form to record any plugging / abnormal situations encountered or re-work / re-testing required.

Failures. Vanes that exhibit flow rates outside the criteria in item 4 above shall be considered as failures. The repair vendor may attempt to open any cooling holes that appear to be blocked / partially blocked by one or more of the following steps: (a) back-flushing with a cleaning medium such as water or steam; (b) soaking using petroleum-based solvents (or other approved solvents) followed by back-flushing; (c) probing of individual exit holes using appropriately sized wires; (d) other method approved by purchaser. Any vane in which cleaning / back-flushing was attempted must be re-tested and results recorded on Form IV-A. All vanes that cannot be cleared shall be separated from the remaining lot and held for purchaser disposition.

FORM IV-A

ALSTOM GT11N2 SECOND STAGE VANES

AIR FLOW TEST RECORD SHEET

VANE SERIAL NUMBER	INCOMING TESTS	POST COATING TESTS		COMMENTS
	MEASURED FLOW* (Or Pressure)	MEASURED FLOW* (Or Pressure)	RESULTS** (PASS OR FAIL)	

*Identify flow units measured (kg/sec, etc.) in this testing: _____

**The post coating flow rate must match the incoming flow rate within + / - 8 percent.

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

3
REPAIR SPECIFICATION FOR ALSTOM MODEL GT11N2 THIRD STAGE TURBINE VANE SEGMENTS

1 SCOPE

1.1 Purpose

This specification covers the minimum requirements for the weld repair and heat treatment of Alstom Model GT11N2 third stage turbine vane segments manufactured from the nickel base alloy Inconel 738LC (Ni - 16Cr - 8.5Co - 3.4Al - 3.4Ti - 2.6W - 1.7Mo - 0.9Cb – 0.11C – 0.055Zr – 0.0095B). New vane segments supplied by the original equipment manufacturer (OEM) are uncoated, i.e., they do not possess an oxidation/corrosion resistant airfoil coating or thermal barrier coating (TBC). This specification assumes that the purchaser will also not opt to apply an airfoil coating. Vane segments repaired to these requirements should provide service life approaching that of new components. Sixty-six (66) vane segments comprise a full set quantity.

NOTE: Should unusual operating conditions exist which result in abnormal airfoil surface oxidation or corrosion, such as poor air or fuel quality, application of a protective coating may be considered. Under these circumstances, determination of an optimum coating system and processing/quality requirements shall be agreed upon between Purchaser and Vendor.

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. It should be noted that Inconel 738LC has proven difficult to weld as part of refurbishment processing. For this reason, consideration should first be given to blending minor defects according to OEM blend limits or the blend limits in Table 1, reserving weld repair for the larger defects which cannot be successfully blended.

2 DEFINITIONS & VANE ILLUSTRATIONS

2.1 Alstom GT11N2 Third Stage Turbine Vane Segment

Figures 1-6 are photographs of various views of the third stage turbine vane segment. The vane segment airfoil is hollow, but does not possess any airfoil or shroud exit holes or slots. The airfoil is thus not internally cooled, i.e., cooling air does not flow into the airfoil cavity from the outer shroud and exit into the gas path through any airfoil or shroud cooling holes. The vane segment is also not coated by the OEM. The vane outer shroud possesses an integral blade path section which extends forward and forms the stationary tip shroud for the upstream second stage turbine blade.

NOTE: Although the vane segment is not air cooled, given the hollow nature of the airfoil, non-destructive measurement of airfoil wall thickness via ultrasonic (UT) inspection is a critical requirement of this specification. Also, inspection and diligence must be employed to avoid entrapment in the airfoil cavity of media used during the refurbishment process.

2.2 Lot.

A group of parts which is processed through the entire repair cycle at the same time and are 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 sub-groups for heat treatment, each sub-group shall constitute a lot.

2.3 E.D.M.

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

2.4 Linear Indications.

Non-destructive testing indications with a length of three times the width or greater.

2.5 Non-linear Indications.

Non-destructive testing indications with a length of less than three times the width.

2.6 Through-Going Indications

Non-destructive testing indications appearing directly opposite

each other and apparently extending through the thickness of the section.

2.7 L.P.T.

Liquid Penetrant Test



Figure 3-1
Overall View, Pressure Side



Figure 3-2
Overall View, Suction Side



Figure 3-3
View of Vane Leading Edge



Figure 3-4
View of Vane Trailing Edge

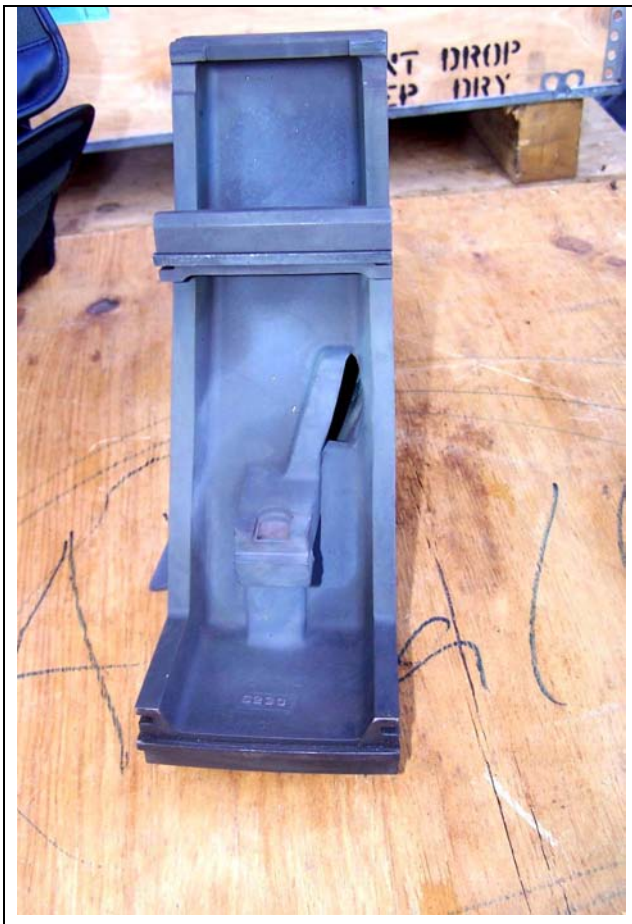


Figure 3-5
View of Outer Shroud



Figure 3-6
View of Airfoil Tip

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.

ASTM 1417

"Inspection, Liquid Penetrant"

ASTM E165

"Standard Practice for Liquid Penetrant Inspection Method"

Aerospace Material Specifications 5837F

“Nickel Alloy, Corrosion and Heat Resistant, Welding Wire 62Ni 21.5Cr 9.0Mo 3.7Cb (Mar 99)"

Aerospace Materials Specification 5887B

“Nickel Alloy, Corrosion and Heat Resistant, Bars, Forgings, and Rings 54Ni 22Cr 12.5Co 9.0Mo 1.2Al, Consumable Electrode or Vacuum Induction Melted Annealed (Jul 01)”

Aerospace Material Specifications 5878B

“Nickel Alloy, Corrosion and Heat Resistant, Sheet, Strip, and Plate 59Ni 22Cr 2Mo 14W 0.35Al 0.03La, Solution Heat Treated (Nov 02)”

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 5837C (Alternate 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 vane alloy, when pre-qualified by vendor and approved by the purchaser, may be allowed.. Braze, diffusion brazing, or other alternative techniques, for repair of craze cracking, and other defects are not permissible in critical areas. They are permitted in non-critical areas of the segments, as defined in Figure 7, provided that the process used is identical to that used in the original process qualification (7.1.2).

NOTE Use of braze processes for repair of defects should be considered carefully, given the potential for braze re-melt during future repair heat treatments and the limited ductility inherent with braze filler materials. Depending on the braze filler material utilized, the employment of braze processing can potentially limit temperatures used in future heat treatments, and render the brazed areas of the vane incapable of being subsequently weld repaired.

5.2 Vane Blend/Weld Repair Limits

5.2.1 Unless approved otherwise, blending limits shall be per Table 1. Blends must have a depth to blended length ratio of 1:8 minimum and be smooth and gradual with no sharp edges remaining.

5.2.2 External and internal surface oxidation/corrosion/alloy depletion may be blended out (blend repaired) to the maximum depths stated in Table 1.

Blend repaired areas shall be liquid penetrant test (LPT) inspected to the requirements of Section 5.3.

5.2.4 Unless approved otherwise, weld repairability limits shall be per Table 1. All defects to be weld repaired must be completely removed prior to welding.

5.3 Non-Destructive Testing Acceptance Limits.

Critical and non-critical areas of the component are defined in Figure 7. Linear indications are permitted in the critical areas of the component up to 0.76 mm (0.030 inch) in length provided they are spaced by 5 times their length. Non-linear indications are permitted in critical locations up to 1.5 mm (0.060 inch) diameter, or up to a diameter equal to 25% of the local section thickness, whichever is smaller. Linear indications up to 1.5 mm (0.060 inch) long are permitted in non-critical areas of the component provided that they are spaced by at least 5 times their length. Non-linear indications in non-critical areas of the component are permitted up to 1.5 mm (0.060 inch). Non-linear indications in non-gas path areas are permitted up to 3.2 mm (0.125 inch). Airfoil (vane) material loss to due to erosion, corrosion, nicks or dents must not exceed 50 percent of wall thickness. No through going indications are permitted.

Table 3-1
ALSTOM GT11N2 THIRD STAGE VANE SEGMENT REPAIR LI MITS

DESCRIPTION	MAXIMUM LIMITS
Airfoil	
Surface Blend Critical Areas (see Figure 7)	1.0 mm (0.040 inch) deep or 20% of design wall thickness, whichever is less.
Non-Critical Areas (see Figure 7)	1.5 mm (0.060 inch) deep or 40% of design wall thickness, whichever is less.
Trailing Edge Blend	6.25 mm (0.250 inch) maximum depth x 25.4 mm (1.0 inch) maximum length.
Shroud Gas Path Blend	
Surface Blend	1.5 mm (0.060 inch) deep or 40% of design wall thickness, whichever is less.
Edge Blend	3.0 mm (0.120 inch) maximum depth x 25.4 mm (1.0 inch) maximum length.
Shroud Non-gas Path Blend	
Surface Blend	3.0 mm (0.120 inch) maximum depth.
Vane-to-Vane Joint Seal Slot Blend	
Sealing Surface Blend	0.75 mm (0.030 inch) maximum depth.
Edge Blend	1.5 mm (0.060 inch) maximum depth x 25.4 mm (1.0 inch) maximum length.
Airfoil Weld Repair Limits	
Axial Crack Repair	up to 33% of the airfoil chord at any radial plane.
Radial Crack Repair	no limit.
Shroud Weld Repair Limits	no limit.

NOTE: Blends must have a depth to blended length ratio of 1:8 minimum and be smooth and gradual with no sharp edges remaining.

5.4 Dimensional Requirements

5.4.1 Gas path dimensions, axial and radial locations shall be within the range identified on the inspection forms attached as Appendix I.

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

5.4.3 Surface finish on the repaired components shall be 2.0 microns (80 micro inches) Ra or better measured according to ANSI B46.1.

5.4.4 The repaired vane segment shall properly fit a dimensionally correct vane carrier, or a fixture which accurately simulates the vane carrier.

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. Some important dimensions affecting form, fit and function are given in Appendix I.

5.4.5 The minimum wall thickness between vane external airfoil surfaces and internal cooling passage surfaces is a critical dimension that can govern repair / replacement decisions. Recommendations for performing wall thickness measurements for these vanes are provided in Appendix I, Form I-C and, unless approved otherwise, these recommendations must be followed. Form I-D is included to record the results of wall thickness measurements. Some turbine OEM's provide guidance on minimum acceptable airfoil wall thickness for each vane design in their turbine instruction manuals. If no OEM wall thickness criteria are available, the values measured may be compared with those of a new vane and a judgment made on the severity of wall thinning and whether repairs are practical. Airfoil wall thickness shall be recorded at all locations where significant corrosion, erosion or foreign object damage has occurred. Omission of wall thickness measurements requires specific purchaser approval.

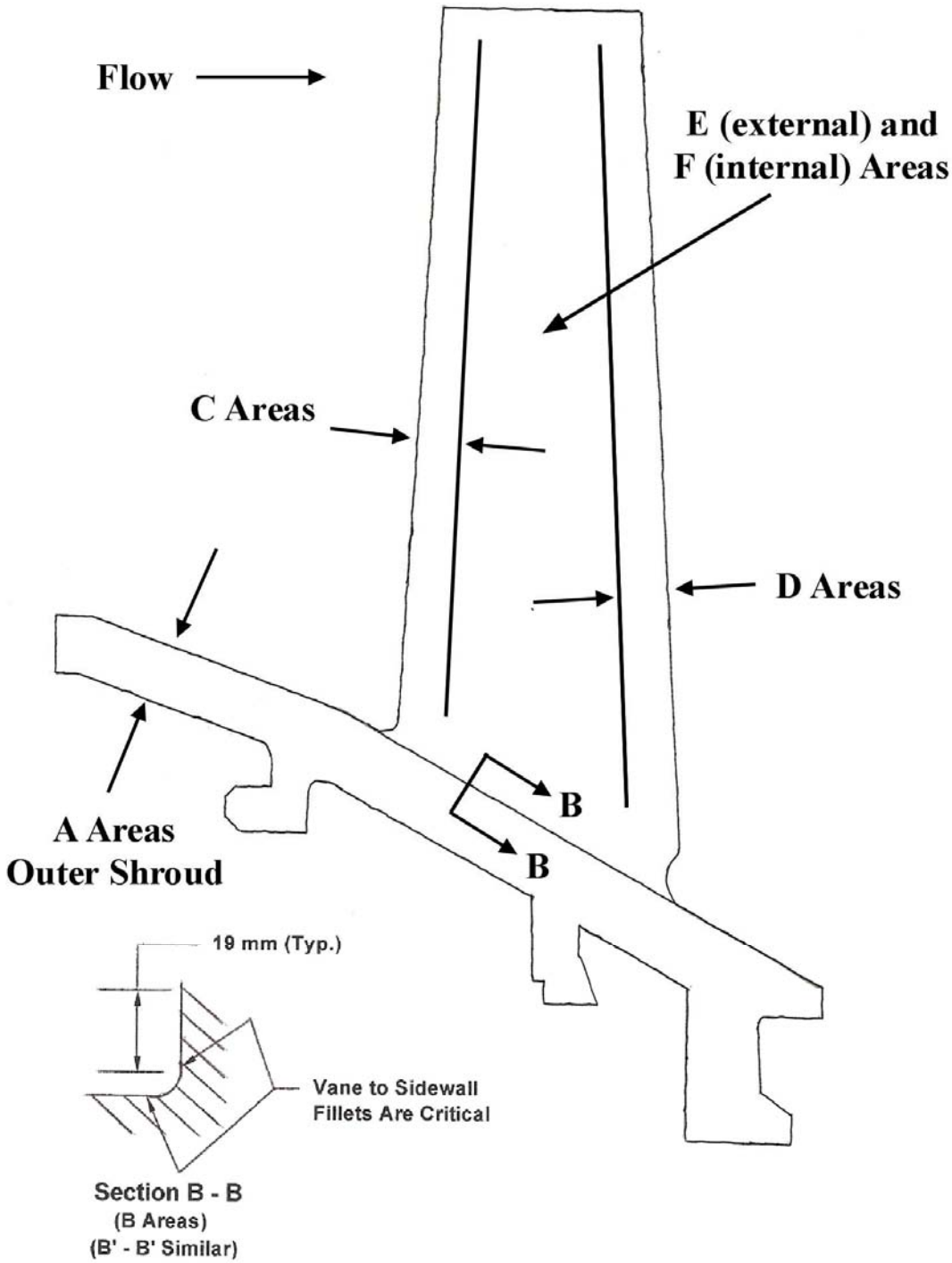
5.5 Microstructural Requirements

5.5.1 The re-cast layer on any E.D.M. surface shall not exceed 0.025 mm (0.001 inch).

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

5.5.3 The microstructure shall be comparable to new material. Un-serviced material in the fully heat treated condition may be used for comparison. Specifically, no continuous carbide films or needle phases shall be present after processing. Appendix III provides guidance on metallographic samples and their evaluation.

Figure 3-7
ALSTOM GT11N2 THIRD STAGE VANE SEGMENT CRITICAL AREAS



ALSTOM GT11N2 THIRD STAGE VANE SEGMENT CRITICAL AREAS

Area A- All surfaces of the shroud except the airfoil fillet radius areas (B areas) are non-critical areas.

Area B- That portion of the airfoil and shroud starting at the line of tangency between the shroud and airfoil and extending parallel to the airfoil and shroud span for 19 mm (0.75 inch) around the whole airfoil contour are critical areas. (See Section B – B).

Area C - Critical areas which includes the entire airfoil leading edge and extends 25 mm (1 inch) axially downstream of the leading edge on both pressure and suction sides.

Area D - Critical areas which includes the entire airfoil trailing edge and extends 25 mm (1 inch) axially upstream of the trailing edge on both pressure and suction sides.

Area E- Airfoil surfaces not included in Areas B, C and D are non-critical areas.

Area F- Internal airfoil surfaces are critical in B, C and D areas and non-critical in E areas.

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. Record vane serial numbers.

6.1.2 Advise purchaser immediately of any shipping damage.

6.1.3 Visually inspect each segment for the following:

- rubs and wear
- surface erosion loss
- cracks
- oxidation/corrosion
- impact damage

Record the results on the form attached as Appendix II.

6.1.4 Metallurgical evaluation (Optional). If excessive oxidation, corrosion, pitting, or other distress is noted, the taking of a metallographic sample for evaluation should be considered. The location where the sample is taken is critical in determining the physical and microstructural extent of the damage. In general, the location should be selected where the damage appears most extensive; however, consideration should also be given to reparability of the location where the sample is taken. Some generic guidance on metallurgical evaluation is given in Appendix III.

6.1.5 Clean the segments using grit blasting with 220 grit or finer aluminum oxide. Avoid excessive blasting.

NOTE: Internal cavities can become filled with media during abrasive cleaning. It is imperative that the media be removed prior to any heat treatment since the cavity can become permanently filled by sintering of the media at high temperature. This may be minimized by preventing the media from getting into the cavity by physical masking and by avoiding blasting into the cavity. Any trapped media can be removed by thorough flushing of cavities after blasting.

6.1.6 Visually inspect both internal and external surfaces of each segment for the following:

- rubs and wear
- trailing edge bowing
- surface erosion loss
- oxidation/corrosion
- impact damage
- cracks

Record the results on the form attached as Appendix II. Results should be added to the forms completed in the visual inspection of 6.1.3, if practical. The intent is to document / map all service-induced vane segment defects on one set of damage assessment forms.

6.1.7 L.P.T all vane segments following the visual penetrant procedures outlined in ASTM Specification 1417 or the visual penetrant procedures in ASTM E165. 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. Results should be added to the forms completed in the visual inspection of 6.1.3, if practical. The intent is to document / map all service-induced vane segment defects on one set of damage assessment forms.

6.1.8 Dimensionally inspect each segment for locating diameters and axial and radial airfoil location and record the results on the forms attached as Appendix I. Locating (fit) diameters and radial and axial location may be checked with a fixture or dimensionally correct vane carrier in lieu of actual measurement, provided all dimensions identified on the Forms are checked by the Fixture.

6.1.9 Perform ultrasonic (UT) vane airfoil wall thickness measurements per the instructions on Form I-C in Appendix I. It is recommended that 20% of the vanes be inspected for airfoil wall thickness (i.e., 13 vanes from a complete set). Record wall thickness measurements on Form I-D.

NOTE: The recommendation of 20% should be increased when appropriate. For example, if it is known that the set of vanes is a “mixed” set (i.e., that set integrity has not been maintained, meaning that some segments have a different operating history than others in the set) it would be appropriate to increase the percentage so that a representative sampling of all operating histories was inspected. Likewise, all vanes that have significant distress that could result in wall thinning (corrosion, erosion, foreign object damage, etc.) should be inspected.

6.1.10 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 Repair Procedure

6.2.1 Dress surfaces as required to remove any oxidation per the limits defined in Table 1. Thoroughly degrease components using approved solvent cleaner or other approved method such as steam cleaning or pressure spraying.

6.2.2 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 for disposition.

6.2.3 Solution anneal the vane segments in a vacuum, hydrogen or argon as follows:

1190 °C +/- 14 °C (2175 °F +/- 25 °F) for four (4) hours in a vacuum of 1 micron ($1.3x10^{-3}$ millibar) or better.

Inert gas quench to below 538°C (1000°F). Support parts using nickel base, iron base or coated graphite heat treat rack materials with the parts supported uniformly to prevent distortion. Avoid supporting the parts by any thin sections. Alternately, heat treatment at lower temperatures for the purpose of over-aging the microstructure prior to welding is permitted when approved by the purchaser. However, this approach will require full solution heat treatment as indicated above after completion of all welding (at paragraph 6.2.13).

6.2.4 L.P.T. all vane segments 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 form attached as Appendix II.

6.2.5 Prepare the areas of the segments to be weld repaired by grinding out the existing cracks and defects and L.P.T. to ensure 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). When specifically approved, sections may be removed for replacement with patches of matching alloy composition provided that, after the repairs are completed, the airfoil contours are unchanged.

6.2.6 When requested, the purchaser shall be informed and allowed to inspect the components following weld preparation.

6.2.7 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).

6.2.8 Braze, diffusion brazing, or other alternative techniques, for repair of craze cracking, and other defects are not permissible in critical areas. They are permitted in non-critical areas of the

segments, as defined in Figure 7, 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 the inherently lower ductility of the braze filler material.

6.2.9 Grind and polish the repaired areas to restore the original contours and 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 L.P.T. the complete vane segment following procedures outlined in paragraph 6.1.7, using the acceptance criteria identified in Paragraph 5.3.

6.2.11 Parts that fail to meet the criteria of paragraph 5.3 may be recycled to repair any defects beginning at paragraph 6.2.5. Parts may be recycled to paragraph 6.2.3 for stress relief, at the vendor's option.

6.2.12 Thoroughly clean components using approved solvent cleaner or other approved methods such as steam cleaning or pressure spraying.

6.2.13 Vacuum heat treat the components to stress relieve the weldments / solution anneal the microstructure using the cycle used in the original process qualification (7.1.2). Unless otherwise specified / approved by the purchaser, the following parameters shall be employed:

1190 °C +/- 14 °C (2175 °F +/- 25 °F) for two (2) hours in a vacuum of 1 micron ($1.3x10^{-3}$ millibar) or better.

NOTE: This heat treatment step is not required if no welding was performed, and the full solution heat treatment step was previously performed at paragraph 6.2.3.

6.2.14 Immediately following heat treatment (if performed) and before any surface cleaning or blasting, liquid penetrant inspect the entire segment using the method outlined in paragraph 6.1.7 and acceptance criteria outlined in paragraph 5.3. Record the results on the forms attached as Appendix II.

6.2.15 Dimensionally check the vanes to ensure conformance to Paragraph 5.4 and record the results on the form attached in Appendix I. Locating (fit) diameters and radial and axial airfoil location may be checked with a Fixture in lieu of actual measurement, provided all dimensions identified on the Forms are checked by the Fixture.

6.2.16 Vacuum heat treat to restore the base material mechanical properties using the cycle used in the original process qualification (7.1.2). Unless otherwise specified / approved by the purchaser, the heat treatment shall be as follows:

1120 °C +/- 14 °C (2050 °F +/- 25 °F) for two (2) hours in vacuum, inert gas quench, followed by:

845 °C +/- 14 °C (1550 °F +/- 25 °F) for twenty-four (24) hours in vacuum or argon

6.2.17 Immediately following heat treatment (if performed) and before any surface cleaning or blasting, liquid penetrant inspect the entire segment using the method outlined in paragraph 6.1.7

and acceptance criteria outlined in paragraph 5.3. Record the results on the forms attached as Appendix II.

6.2.18 Clean the segments using grit blasting with 220 grit or finer aluminum oxide. Avoid excessive blasting.

NOTE: Internal cavities can become filled with media during abrasive cleaning. It is imperative that the media be removed prior to any heat treatment since the cavity can become permanently filled by sintering of the media at high temperature. This may be minimized by preventing the media from getting into the cavity by physical masking and by avoiding blasting into the cavity. Any trapped media can be removed by thorough flushing of cavities after blasting.

6.2.19 Visually inspect the entire vane segment for the presence of defects using the acceptance criteria outlined in paragraph 5.3. Thoroughly inspect all internal passages and plenums for cleanliness

Final Dimensional Inspection. Perform final dimensional inspection to ensure conformance to Paragraph 5.4 and record the results on the form attached in Appendix I. Locating (fit) diameters and radial and axial airfoil location may be checked with a Fixture in lieu of actual measurement, provided all dimensions identified on the Forms are checked by the Fixture.

Ideally, this inspection will entail assembly of vane segments into a fixture that simulates the turbine vane carrier and can accommodate at least three (3) vane segments at a time. Inspect for the following:

Vane segments assemble / slide properly into the fixture without binding.

Excessive axial and radial mismatch (steps) between segments at the airfoil tips and outer shrouds.

Uniform vane segment joint gaps along their axial length and consistent joint gaps vane-to-vane.

Proper joint seal engagement in the mating grooves of adjacent segments.

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 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 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 vanes (and/or other sample material identified by Purchaser) through the entire process for non-destructive 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 (7.1.1) and the Technical Review (7.1.2).

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

7.2 Documentation & 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 five 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 which shall contain:

a) a mapping of all defects identified at paragraph 6.1.3, 6.1.6, 6.1.7 and 6.2.4. (Use form attached as Appendix II)

b) a mapping of all repair locations (Use form attached as Appendix II)

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

d) a copy of airfoil wall thickness inspection forms (use forms attached as Appendix I)

e) a copy of final L.P.T. report

f) a copy of the certificate of compliance

7.3 Acceptance and Disposition

7.3.1 All deviant parts shall be plainly labelled in a non-destructive 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

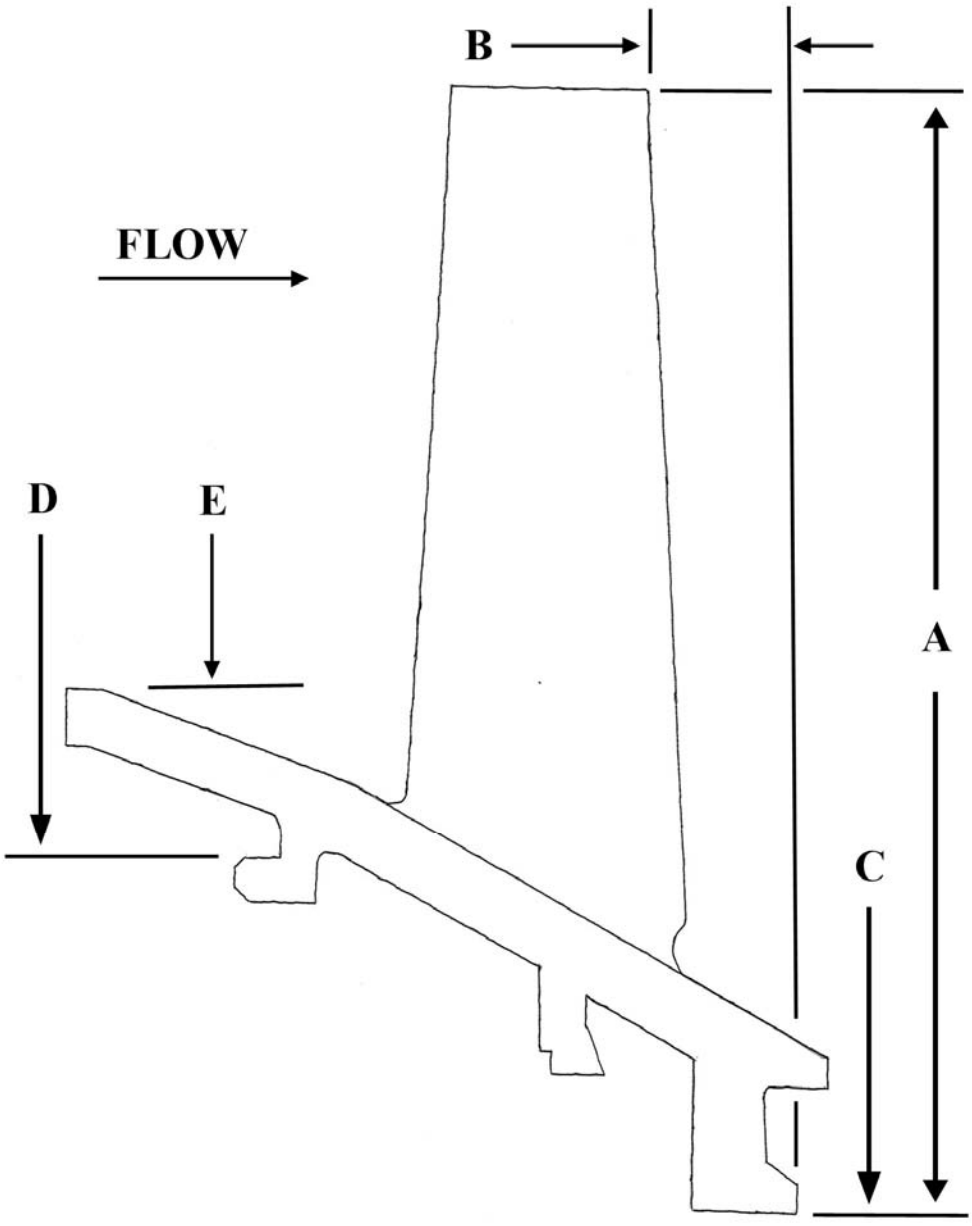
The purchaser shall be allowed reasonable access to inspect components at all times during the repair process.

APPENDIX I - DIMENSIONAL INSPECTION FORMS

FORM 1-A

ALSTOM GT11N2 THIRD STAGE VANE DIMENSIONAL INSPECTION FORM

OVERALL DIMENSIONS



NOTES:

1. Measure dimension A at the center of the segment.

2. Dimensions C, D and E are radius measurements and are to be measured at the left, center and right ends of the segment.

3. Checking fixtures or a dimensionally correct vane carrier may be used to check dimensions provided all dimensions shown are checked. Record results as Pass or Fail on Form 1-B.

FORM 1-B

ALSTOM GT11N2 THIRD STAGE VANE DIMENSIONAL INSPECTION FORM

OVERALL DIMENSIONS RECORD SHEET

DIMENSION	**ALLOWABLE**		**SEG. #_____** **S/N _____**	**SEG. #_____** **S/N _____**	**SEG. #_____** **S/N _____**
	MIN.	**MAX.**			
A					
B					
C Left					
C Center					
C Right					
D Left					
D Center					
D Right					
E Left					
E Center					
E Right					
Comments:					

RECORDED DIMENSIONS ARE IN (Check one): ☐ mm ☐ Inches

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

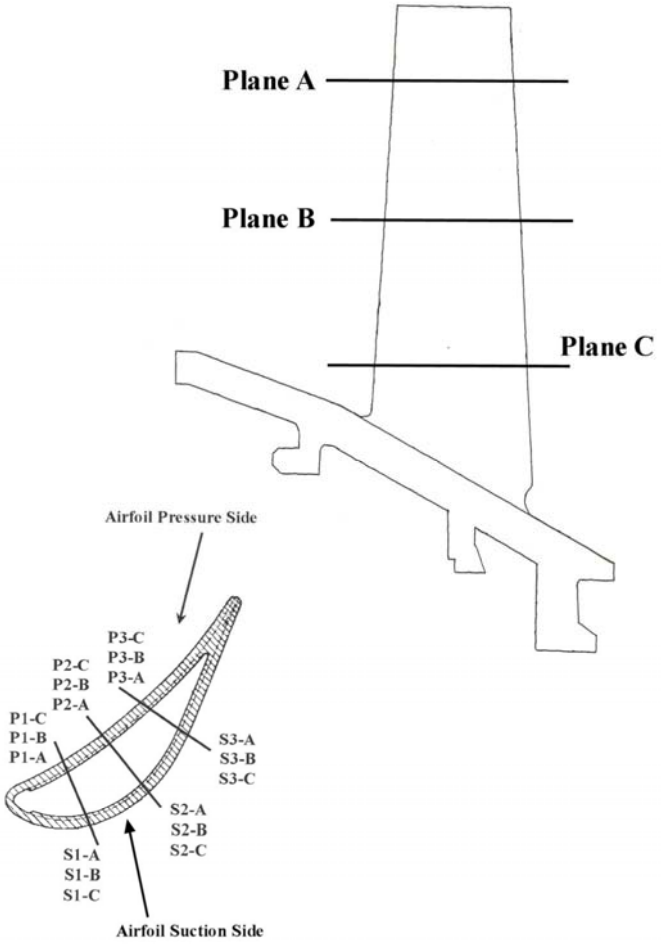
Segment numbers are counted clockwise looking in direction of flow. Number 1 is the first segment in the upper half on the left side.

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

FORM I-C

ALSTOM GT11N2 THIRD STAGE VANES

UT WALL THICKNESS INSPECTION INSTRUCTIONS



NOTES FOR ULTRASONIC WALL THICKNESS CHECKS:

Ultrasonic (UT) checks for vane airfoil wall thickness are recommended on 20 percent of the vanes to be repaired (i.e., 13 vanes from a full set). The sample size should be increased in some circumstances ─ see note at paragraph 6.1.14.

Eighteen (18) UT measurements are recommended on each vane airfoil: 9 measurements on the pressure side (“P”) and 9 measurements on the suction side (“S”). Record measurements on Form I-D.

Vendor and purchaser may agree on alternate locations to more closely coincide with actual service degradation / wall thinning.

Radial locations are numbered A, B and C. The “A” locations are a radial distance of approximately 1 inch outboard of the airfoil tip. Likewise, the “C” locations are a radial distance of 1 inch inboard of the outer shroud wall. The “B” locations are at the approximate centerline between the inner shroud wall and the airfoil tip.

Axial locations of measurements should be equally spaced along the chord of the internal cavity (as shown in the above sketch). See Note 3 above.

Using the above terminology, the measurement location designated as “P1-A” is on the pressure side surface at the axially forward region of the internal cavity and 1” inboard of the airfoil tip. Likewise, the measurement location designated as “S3-C” is on the suction side surface at the axially aft region of the internal cavity and 1 inch inboard of the outer shroud wall.

FORM I-D
ALSTOM GT11N2 THIRD STAGE VANES
UT WALL THICKNESS INSPECTION RECORD SHEET

MEASUREMENT	**ALLOWABLE**		**SEG. #_____** **S/N _____**	**SEG. #_____** **S/N _____**	**SEG. #_____** **S/N _____**
	MIN.	**MAX.**			
PRESSURE SIDE MEASUREMENTS					
P1-A					
P1-B					
P1-C					
P2-A					
P2-B					
P2-C					
P3-A					
P3-B					
P3-C					
SUCTION SIDE MEASURMENTS					
S1-A					
S1-B					
S1-C					
S2-A					
S2-B					
S2-C					
S3-A					
S3-B					
S3-C					
Comments					

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

APPENDIX II - DAMAGE ASSESSMENT FORMS

FORM II-A

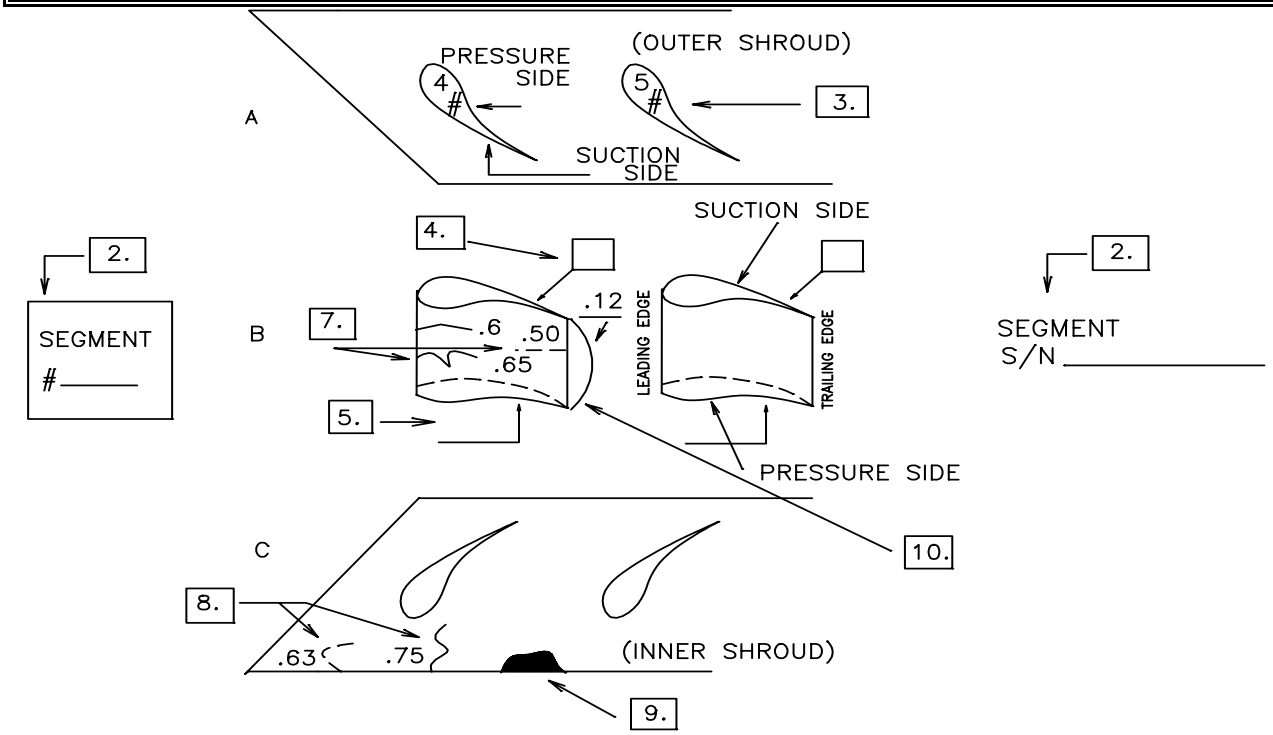
ALSTOM GT11N2 THIRD STAGE VANES

NOTES FOR VANE DAMAGE ASSESSMENT

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



3-8

GENERAL -

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.

17

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

3.

18

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

4.

19

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.

20

Show the number of plugged cooling air holes below each vane.

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.

21

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.

22

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.

23

Sketch area where pieces are broken off.

TRAILING EDGE BOWING -

10.

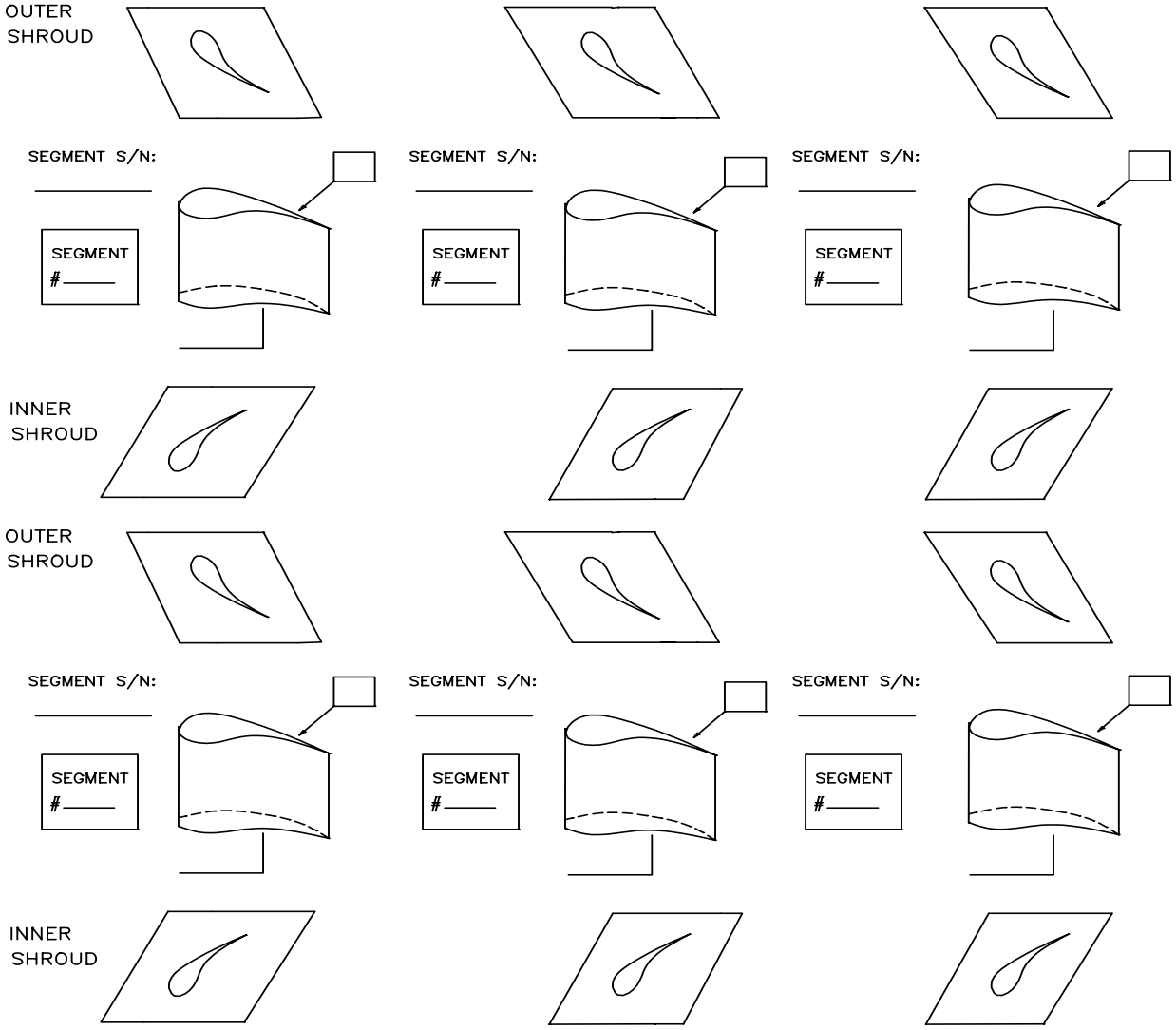
24

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 100ths of inches.

FORM II-B

ALSTOM GT11N2 THIRD STAGE VANE SEGMENT

DAMAGE ASSESSMENT FORM



3-9

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

APPENDIX III - PROCEDURE FOR METALLURGICAL EVALUATION OF NOZZLE AND VANE SEGMENTS

SCOPE:

This procedure describes techniques to be used to characterize material degradation in both cobalt and nickel based nozzles / vanes and assess reparability. The removal of samples is semi-destructive, 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 0.16 mm (1/16") wafering blades and rotary air or electric hand tools. Appropriate personal protective gear should be worn at all times when using such tools.

Since samples removed must be repaired, the minimum material necessary should be removed. For leading and trailing edge locations, the sample geometry shown in Figure III-A is adequate for specimens in two orientations. For removal of samples from heavier locations such as side rails, a "boat" type specimen, as shown in Figure III-B, 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 (i.e., surfaces perpendicular to specimen plane). The depth of oxide scale and internal oxidation present should be measured. If the depth of attack exceeds 0.51 mm (0.020 inches) or 1/3 of the local section thickness, whichever is less, the nozzle or vane should be considered un-repairable by welding or brazing. Coupon type repairs may be possible if the oxidation damage is localized.

MICROSTRUCTURAL CONDITION:

Cobalt-Based Vanes

The microstructural condition should be examined in all sections. In particular, longitudinal sections should be examined for the presence of voids formed by thermo-mechanical 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.

Nickel-Based Vanes

All samples should be examined by optical microscopy for the presence of intergranular creep voids. Any vanes in which creep voids are identified are unserviceable. They may be repaired by Hot Isostatic Press rejuvenation.

All samples should be examined by optical microscopy for microstructural instabilities. Changes from new material microstructure can be identified by comparing airfoil samples with samples of un-serviced alloy of the same composition in the fully heat treated condition. 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.

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 2. By comparing the structures in these areas with that of new (un-serviced) material, 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.

Any deviations from normal microstructure should be noted.

FIGURE III-A - LEADING OR TRAILING EDGE SPECIMEN

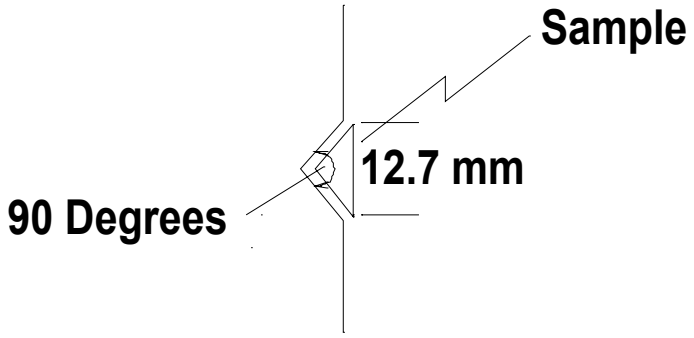
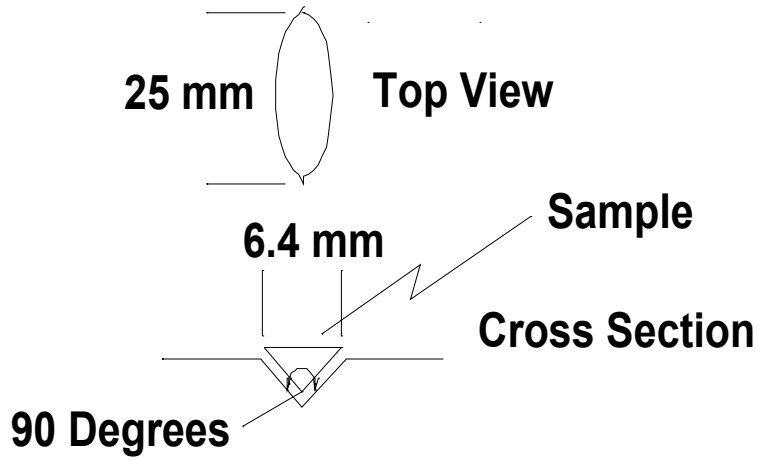


FIGURE III-B - "BOAT" SPECIMEN



4
REPAIR SPECIFICATION FOR ALSTOM MODEL GT11N2 FOURTH STAGE TURBINE VANE SEGMENTS

1 SCOPE

1.1 Purpose.

This specification covers the minimum requirements for the weld repair and heat treatment of Alstom Model GT11N2 fourth stage turbine vane segments manufactured from the nickel base alloy Inconel 738LC (Ni - 16Cr - 8.5Co - 3.4Al - 3.4Ti - 2.6W - 1.7Mo - 0.9Cb – 0.11C – 0.055Zr – 0.0095B). New vane segments supplied by the original equipment manufacturer (OEM) are uncoated, i.e., they do not possess an oxidation/corrosion resistant airfoil coating or thermal barrier coating (TBC). This specification assumes that the purchaser will also not opt to apply an airfoil coating. Vane segments repaired to these requirements should provide service life approaching that of new components. Thirty-two (32) vane segments comprise a full set quantity.

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. It should be noted that Inconel 738LC has proven difficult to weld as part of refurbishment processing. For this reason, consideration should first be given to blending minor defects according to OEM blend limits or the blend limits in Table 1, reserving weld repair for the larger defects which cannot be successfully blended.

2 DEFINITIONS & VANE ILLUSTRATIONS

2.1 Alstom GT11N2 Fourth Stage Turbine Vane Segment

Figures 1-4 are photographs of various views of the fourth stage turbine vane segment. Vane segments are cast as two airfoil clusters, or doublets. Vane segment airfoils are solid (not hollow), and are therefore not air cooled, nor do the airfoils act to channel cooling air radially inward to feed wheelspace regions. The vane segment is also not coated by the OEM. Additionally, the vane outer shroud possesses an integral blade path section which extends forward and forms the stationary tip shroud for the upstream third stage turbine blade.

2.2 Lot.

A group of parts which is processed through the entire repair cycle at the same time and are 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 sub-groups for heat treatment, each sub-group shall constitute a lot.

2.3 E.D.M.

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

2.4 Linear Indications.

Non-destructive testing indications with a length of three times the width or greater.

2.5 Non-linear Indications.

Non-destructive testing indications with a length of less than three times the width.

2.6 Through-Going Indications

Non-destructive testing indications appearing directly opposite

each other and apparently extending through the thickness of the section.

2.7 L.P.T.

Liquid Penetrant Test



Figure 4-1
Overall View, Leading Edge



Figure 4-2
Overall View, Trailing Edge



Figure 4-3
View of Outer Shroud

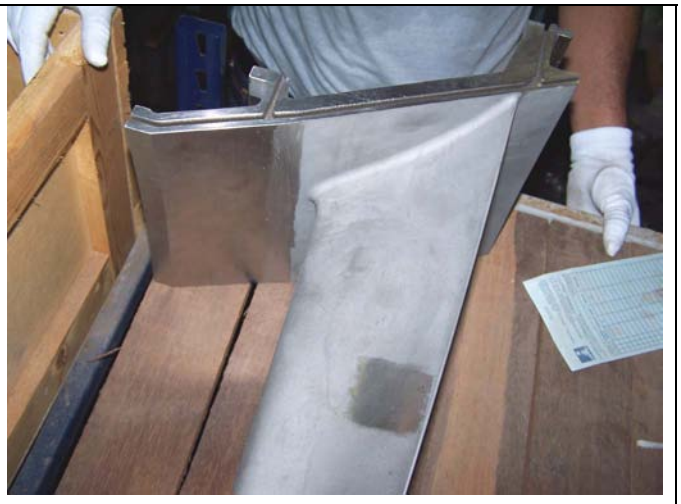


Figure 4-4
View of Outer Shroud Blade Path

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.

ASTM 1417

"Inspection, Liquid Penetrant"

ASTM E165

"Standard Practice for Liquid Penetrant Inspection Method"

Aerospace Material Specifications 5837F

“Nickel Alloy, Corrosion and Heat Resistant, Welding Wire 62Ni 21.5Cr 9.0Mo 3.7Cb (Mar 99)"

Aerospace Materials Specification 5887B

“Nickel Alloy, Corrosion and Heat Resistant, Bars, Forgings, and Rings 54Ni 22Cr 12.5Co 9.0Mo 1.2Al, Consumable Electrode or Vacuum Induction Melted Annealed (Jul 01)”

Aerospace Material Specifications 5878B

“Nickel Alloy, Corrosion and Heat Resistant, Sheet, Strip, and Plate 59Ni 22Cr 2Mo 14W 0.35Al 0.03La, Solution Heat Treated (Nov 02)”

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 5837C (Alternate 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 vane alloy, when pre-qualified by vendor and approved by the purchaser, may be allowed.. Braze, diffusion brazing, or other alternative techniques, for repair of craze cracking, and other defects are not permissible in critical areas. They are permitted in non-critical areas of the segments, as defined in Figure 5, provided that the process used is identical to that used in the original process qualification (7.1.2).

NOTE Use of braze processes for repair of defects should be considered carefully, given the potential for braze re-melt during future repair heat treatments and the limited ductility inherent with braze filler materials. Depending on the braze filler material utilized, the employment of braze processing can potentially limit temperatures used in future heat treatments, and render the brazed areas of the vane incapable of being subsequently weld repaired.

5.2 Vane Blend/Weld Repair Limits

5.2.1 Unless approved otherwise, blending limits shall be per Table 1. Blends must have a depth to blended length ratio of 1:8 minimum and be smooth and gradual with no sharp edges remaining.

5.2.2 External and internal surface oxidation/corrosion/alloy depletion may be blended out (blend repaired) to the maximum depths stated in Table 1.

Blend repaired areas shall be liquid penetrant test (LPT) inspected to the requirements of Section 5.3.

5.2.4 Unless approved otherwise, weld repairability limits shall be per Table 1. All defects to be weld repaired must be completely removed prior to welding.

5.3 Non-Destructive Testing Acceptance Limits.

Critical and non-critical areas of the component are defined in Figure 5. Linear indications are permitted in the critical areas of the component up to 0.76 mm (0.030 inch) in length provided they are spaced by 5 times their length. Non-linear indications are permitted in critical locations up to 1.5 mm (0.060 inch) diameter, or up to a diameter equal to 25% of the local section thickness, whichever is smaller. Linear indications up to 1.5 mm (0.060 inch) long are permitted in non-critical areas of the component provided that they are spaced by at least 5 times their length. Non-linear indications in non-critical areas of the component are permitted up to 1.5 mm (0.060 inch). Non-linear indications in non-gas path areas are permitted up to 3.2 mm (0.125 inch). Airfoil (vane) material loss to due to erosion, corrosion, nicks or dents must not exceed 50 percent of wall thickness. No through going indications are permitted.

Table 4-1
ALSTOM GT11N2 FOURTH STAGE VANE SEGMENT REPAIR LIMITS

DESCRIPTION	MAXIMUM LIMITS
Airfoil	
Surface Blend Critical Areas (see Figure 5)	1.0 mm (0.040 inch) deep or 30% of design wall thickness, whichever is less.
Non-Critical Areas (see Figure 5)	1.5 mm (0.060 inch) deep or 40% of design wall thickness, whichever is less.
Trailing Edge Blend	6.25 mm (0.250 inch) maximum depth x 50.8 mm (2.0 inch) maximum length.
Shroud Gas Path Blend	
Surface Blend	1.5 mm (0.060 inch) deep or 40% of design wall thickness, whichever is less.
Edge Blend	3.0 mm (0.120 inch) maximum depth x 25.4 mm (1.0 inch) maximum length.
Shroud Non-gas Path Blend	
Surface Blend	3.0 mm (0.120 inch) maximum depth.
Vane-to-Vane Joint Seal Slot Blend	
Sealing Surface Blend	0.75 mm (0.030 inch) maximum depth.
Edge Blend	1.5 mm (0.060 inch) maximum depth x 25.4 mm (1.0 inch) maximum length.
Airfoil Weld Repair Limits	
Axial Crack Repair	up to 33% of the airfoil chord at any radial plane.
Radial Crack Repair	no limit.
Shroud Weld Repair Limits	no limit.

NOTE: Blends must have a depth to blended length ratio of 1:8 minimum and be smooth and gradual with no sharp edges remaining.

5.4 Dimensional Requirements

5.4.1 Gas path dimensions, axial and radial locations shall be within the range identified on the inspection forms attached as Appendix I.

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

5.4.3 Surface finish on the repaired components shall be 2.0 microns (80 micro inches) Ra or better measured according to ANSI B46.1.

5.4.4 The repaired vane segment shall properly fit a dimensionally correct vane carrier, or a fixture which accurately simulates the vane carrier.

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. Some important dimensions affecting form, fit and function are given in Appendix I.

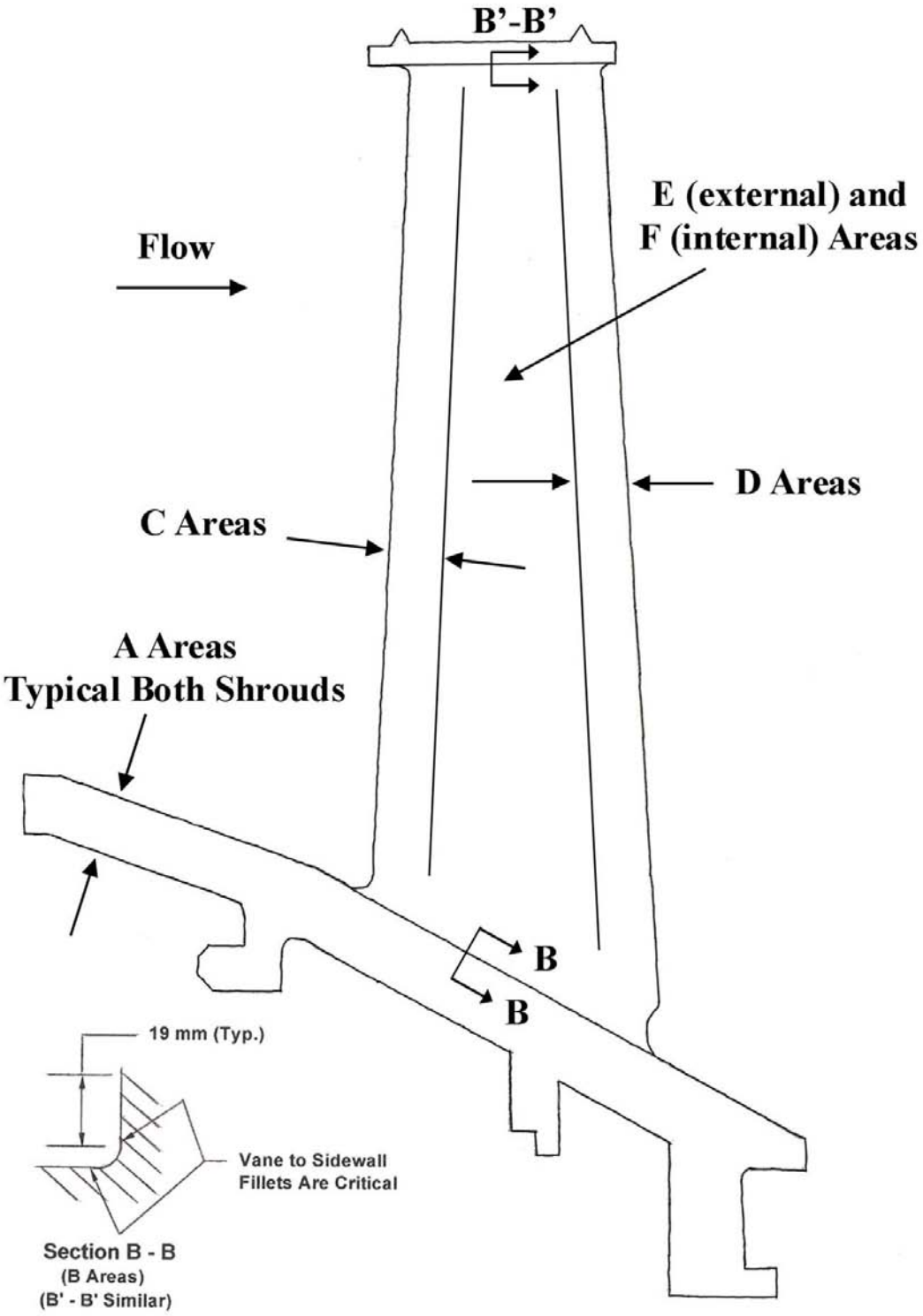
5.5 Microstructural Requirements

5.5.1 The re-cast layer on any E.D.M. surface shall not exceed 0.025 mm (0.001 inch).

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

5.5.3 The microstructure shall be comparable to new material. Un-serviced material in the fully heat treated condition may be used for comparison. Specifically, no continuous carbide films or needle phases shall be present after processing. Appendix III provides guidance on metallographic samples and their evaluation.

Figure 4-5
ALSTOM GT11N2 FOURTH STAGE VANE SEGMENT CRITICAL AREAS



ALSTOM GT11N2 FOURTH STAGE VANE SEGMENT CRITICAL AREAS

Area A- All surfaces of the shroud except the airfoil fillet radius areas (B areas) are non-critical areas.

Area B- That portion of the airfoil and shroud starting at the line of tangency between the shroud and airfoil and extending parallel to the airfoil and shroud span for 19 mm (0.75 inch) around the whole airfoil contour are critical areas. (See Section B – B).

Area C - Critical areas which includes the entire airfoil leading edge and extends 25 mm (1 inch) axially downstream of the leading edge on both pressure and suction sides.

Area D - Critical areas which includes the entire airfoil trailing edge and extends 25 mm (1 inch) axially upstream of the trailing edge on both pressure and suction sides.

Area E- Airfoil surfaces not included in Areas B, C and D are non-critical areas.

Area F- Internal airfoil surfaces are critical in B, C and D areas and non-critical in E areas.

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. Record vane serial numbers.

6.1.2 Advise purchaser immediately of any shipping damage.

6.1.3 Visually inspect each segment for the following:

- rubs and wear
- surface erosion loss
- cracks
- oxidation/corrosion
- impact damage

Record the results on the form attached as Appendix II.

6.1.4 Metallurgical evaluation (Optional). If excessive oxidation, corrosion, pitting, or other distress is noted, the taking of a metallographic sample for evaluation should be considered. The location where the sample is taken is critical in determining the physical and microstructural extent of the damage. In general, the location should be selected where the damage appears most extensive; however, consideration should also be given to reparability of the location where the sample is taken. Some generic guidance on metallurgical evaluation is given in Appendix III.

6.1.5 Clean the segments using grit blasting with 220 grit or finer aluminum oxide. Avoid excessive blasting.

6.1.6 Visually inspect both internal and external surfaces of each segment for the following:

- rubs and wear
- trailing edge bowing
- surface erosion loss
- oxidation/corrosion
- impact damage
- cracks

Record the results on the form attached as Appendix II. Results should be added to the forms completed in the visual inspection of 6.1.3, if practical. The intent is to document / map all service-induced vane segment defects on one set of damage assessment forms.

6.1.7 L.P.T all vane segments following the visual penetrant procedures outlined in ASTM Specification 1417 or the visual penetrant procedures in ASTM E165. 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. Results should be added to the forms completed in the visual inspection of 6.1.3, if practical. The intent is to document / map all service-induced vane segment defects on one set of damage assessment forms.

6.1.8 Dimensionally inspect each segment for locating diameters and axial and radial airfoil location and record the results on the forms attached as Appendix I. Locating (fit) diameters and radial and axial location may be checked with a fixture or dimensionally correct vane carrier in lieu of actual measurement, provided all dimensions identified on the Forms are checked by the Fixture.

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 specification.
- obtain written or verbal authorization from the purchaser to proceed with the repairs.

6.2 Repair Procedure

6.2.1 Dress surfaces as required to remove any oxidation per the limits defined in Table 1. Thoroughly degrease components using approved solvent cleaner or other approved method such as steam cleaning or pressure spraying.

6.2.2 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 for disposition.

6.2.3 Solution anneal the vane segments in a vacuum, hydrogen or argon as follows:

1190 °C +/- 14 °C (2175 °F +/- 25 °F) for four (4) hours in a vacuum of 1 micron ($1.3x10^{-3}$ millibar) or better.

Inert gas quench to below 538°C (1000°F). Support parts using nickel base, iron base or coated graphite heat treat rack materials with the parts supported uniformly to prevent distortion. Avoid supporting the parts by any thin sections. Alternately, heat treatment at lower temperatures for the purpose of over-aging the microstructure prior to welding is permitted when approved by the purchaser. However, this approach will require full solution heat treatment as indicated above after completion of all welding (at paragraph 6.2.13).

6.2.4 L.P.T. all vane segments 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 form attached as Appendix II.

6.2.5 Prepare the areas of the segments to be weld repaired by grinding out the existing cracks and defects and L.P.T. to ensure 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). When specifically approved, sections may be removed for replacement with patches of matching alloy composition provided that, after the repairs are completed, the airfoil contours are unchanged.

6.2.6 When requested, the purchaser shall be informed and allowed to inspect the components following weld preparation.

6.2.7 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).

6.2.8 Braze, diffusion brazing, or other alternative techniques, for repair of craze cracking, and other defects are not permissible in critical areas. They are permitted in non-critical areas of the segments, as defined in Figure 5, 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 the inherently lower ductility of the braze filler material.

6.2.9 Grind and polish the repaired areas to restore the original contours and 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 L.P.T. the complete vane segment following procedures outlined in paragraph 6.1.7, using the acceptance criteria identified in Paragraph 5.3.

6.2.11 Parts that fail to meet the criteria of paragraph 5.3 may be recycled to repair any defects beginning at paragraph 6.2.5. Parts may be recycled to paragraph 6.2.3 for stress relief, at the vendor's option.

6.2.12 Thoroughly clean components using approved solvent cleaner or other approved methods such as steam cleaning or pressure spraying.

6.2.13 Vacuum heat treat the components to stress relieve the weldments / solution anneal the microstructure using the cycle used in the original process qualification (7.1.2). Unless otherwise specified / approved by the purchaser, the following parameters shall be employed:

1190 °C +/- 14 °C (2175 °F +/- 25 °F) for two (2) hours in a vacuum of 1 micron ($1.3x10^{-3}$ millibar) or better.

NOTE: This heat treatment step is not required if no welding was performed, and the full solution heat treatment step was previously performed at paragraph 6.2.3.

6.2.14 Immediately following heat treatment (if performed) and before any surface cleaning or blasting, liquid penetrant inspect the entire segment using the method outlined in paragraph 6.1.7 and acceptance criteria outlined in paragraph 5.3. Record the results on the forms attached as Appendix II.

6.2.15 Dimensionally check the vanes to ensure conformance to Paragraph 5.4 and record the results on the form attached in Appendix I. Locating (fit) diameters and radial and axial airfoil location may be checked with a Fixture in lieu of actual measurement, provided all dimensions identified on the Forms are checked by the Fixture.

6.2.16 Vacuum heat treat to restore the base material mechanical properties using the cycle used in the original process qualification (7.1.2). Unless otherwise specified / approved by the purchaser, the heat treatment shall be as follows:

1120 °C +/- 14 °C (2050 °F +/- 25 °F) for two (2) hours in vacuum, inert gas quench, followed by:

845 °C +/- 14 °C (1550 °F +/- 25 °F) for twenty-four (24) hours in vacuum or argon

6.2.17 Immediately following heat treatment (if performed) and before any surface cleaning or blasting, liquid penetrant inspect the entire segment using the method outlined in paragraph 6.1.7 and

acceptance criteria outlined in paragraph 5.3. Record the results on the forms attached as Appendix II.

6.2.18 Clean the segments using grit blasting with 220 grit or finer aluminum oxide. Avoid excessive blasting.

6.2.19 Visually inspect the entire vane segment for the presence of defects using the acceptance criteria outlined in paragraph 5.3.

Final Dimensional Inspection. Perform final dimensional inspection to ensure conformance to Paragraph 5.4 and record the results on the form attached in Appendix I. Locating (fit) diameters and radial and axial airfoil location may be checked with a Fixture in lieu of actual measurement, provided all dimensions identified on the Forms are checked by the Fixture.

Ideally, this inspection will entail assembly of vane segments into a fixture that simulates the turbine vane carrier and can accommodate at least three (3) vane segments at a time. Inspect for the following:

Vane segments assemble / slide properly into the fixture without binding.

Excessive axial and radial mismatch (steps) between segments at the airfoil tips and outer shrouds.

Uniform vane segment joint gaps along their axial length and consistent joint gaps vane-to-vane.

Proper joint seal engagement in the mating grooves of adjacent segments.

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 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 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 vanes (and/or other sample material identified by Purchaser) through the entire process for non-destructive 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 (7.1.1) and the Technical Review (7.1.2).

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

7.2 Documentation & 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 five 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 which shall contain:

a) a mapping of all defects identified at paragraph 6.1.3, 6.1.6, 6.1.7 and 6.2.4. (Use form attached as Appendix II)

b) a mapping of all repair locations (Use form attached as Appendix II)

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

d) a copy of final L.P.T. report

e) a copy of the certificate of compliance

7.3 Acceptance and Disposition

7.3.1 All deviant parts shall be plainly labelled in a non-destructive 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.

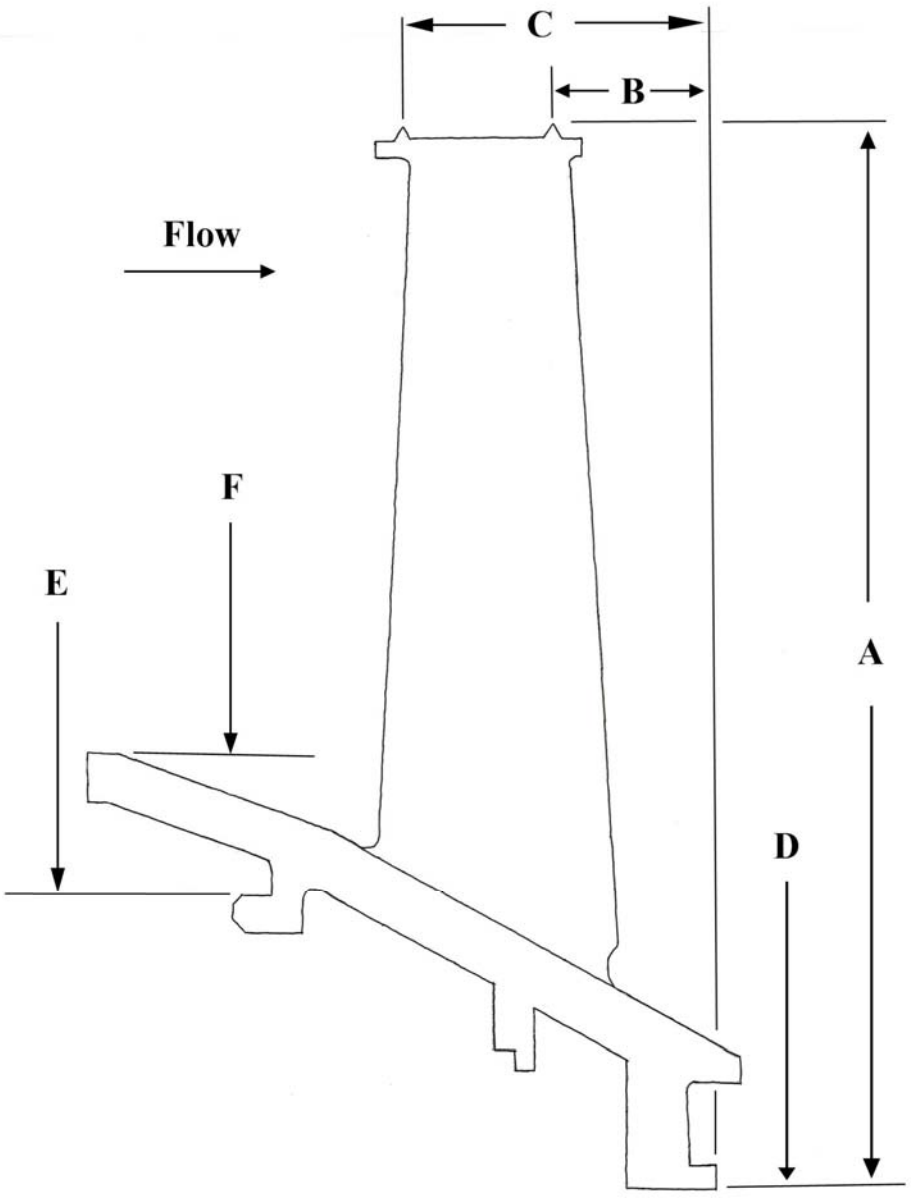
The purchaser shall be allowed reasonable access to inspect components at all times during the repair process.

APPENDIX I - DIMENSIONAL INSPECTION FORMS

FORM 1-A

ALSTOM GT11N2 FOURTH STAGE VANE DIMENSIONAL INSPECTION FORM

OVERALL DIMENSIONS



NOTES:

1. Measure axial drop dimension C and and radius dimension F at the center of the segment.

2. Dimensions A, D and E are radius measurements and are to be measured at the left, center and right ends of the segment.

3. Checking fixtures or a dimensionally correct vane carrier may be used to check dimensions provided all dimensions shown are checked. Record results as Pass or Fail on Form 1-B.

FORM 1-B
ALSTOM GT11N2 FOURTH STAGE VANE DIMENSIONAL INSPECTION FORM
OVERALL DIMENSIONS RECORD SHEET

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 Left					
D Center					
D Right					
E Left					
E Center					
E Right					
F					
Comments:					

RECORDED DIMENSIONS ARE IN (Check one): ☐ mm ☐ Inches

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

Segment numbers are counted clockwise looking in direction of flow. Number 1 is the first segment in the upper half on the left side.

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

APPENDIX II - DAMAGE ASSESSMENT FORMS

FORM II-A

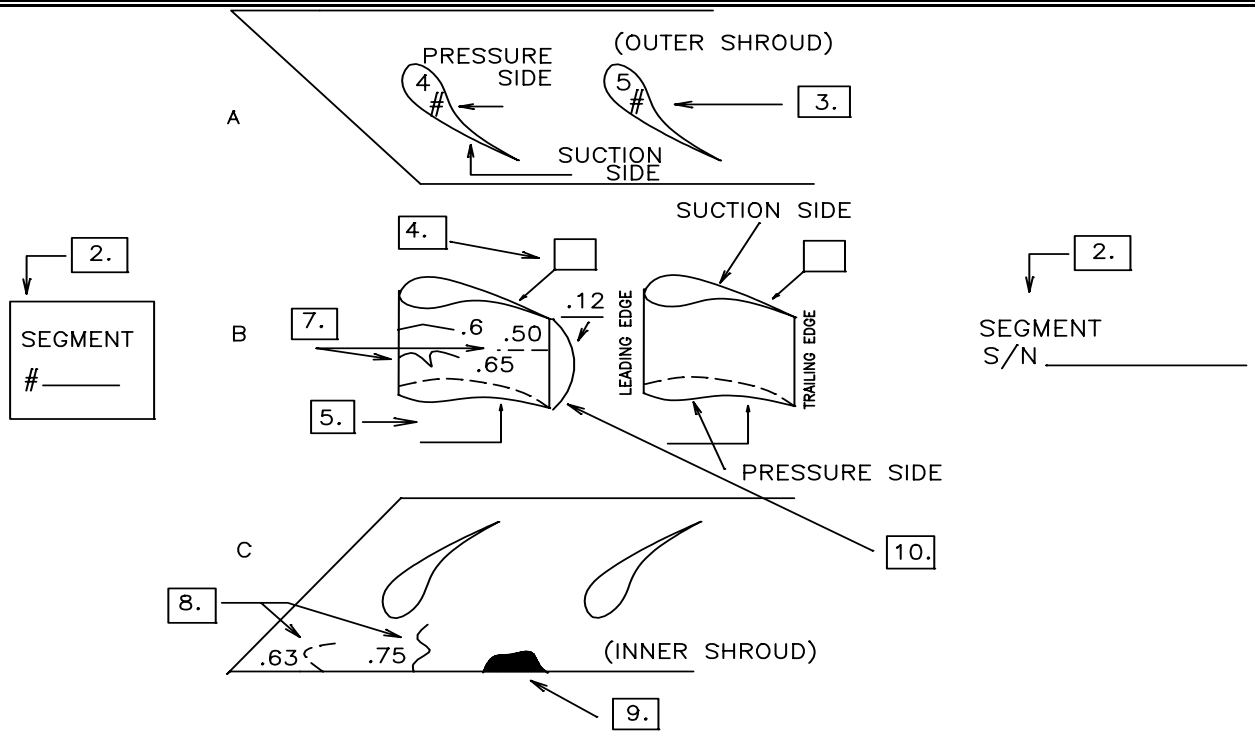
ALSTOM GT11N2 FOURTH STAGE VANES

NOTES FOR VANE DAMAGE ASSESSMENT

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 -

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 cooling air holes below each vane.

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 -

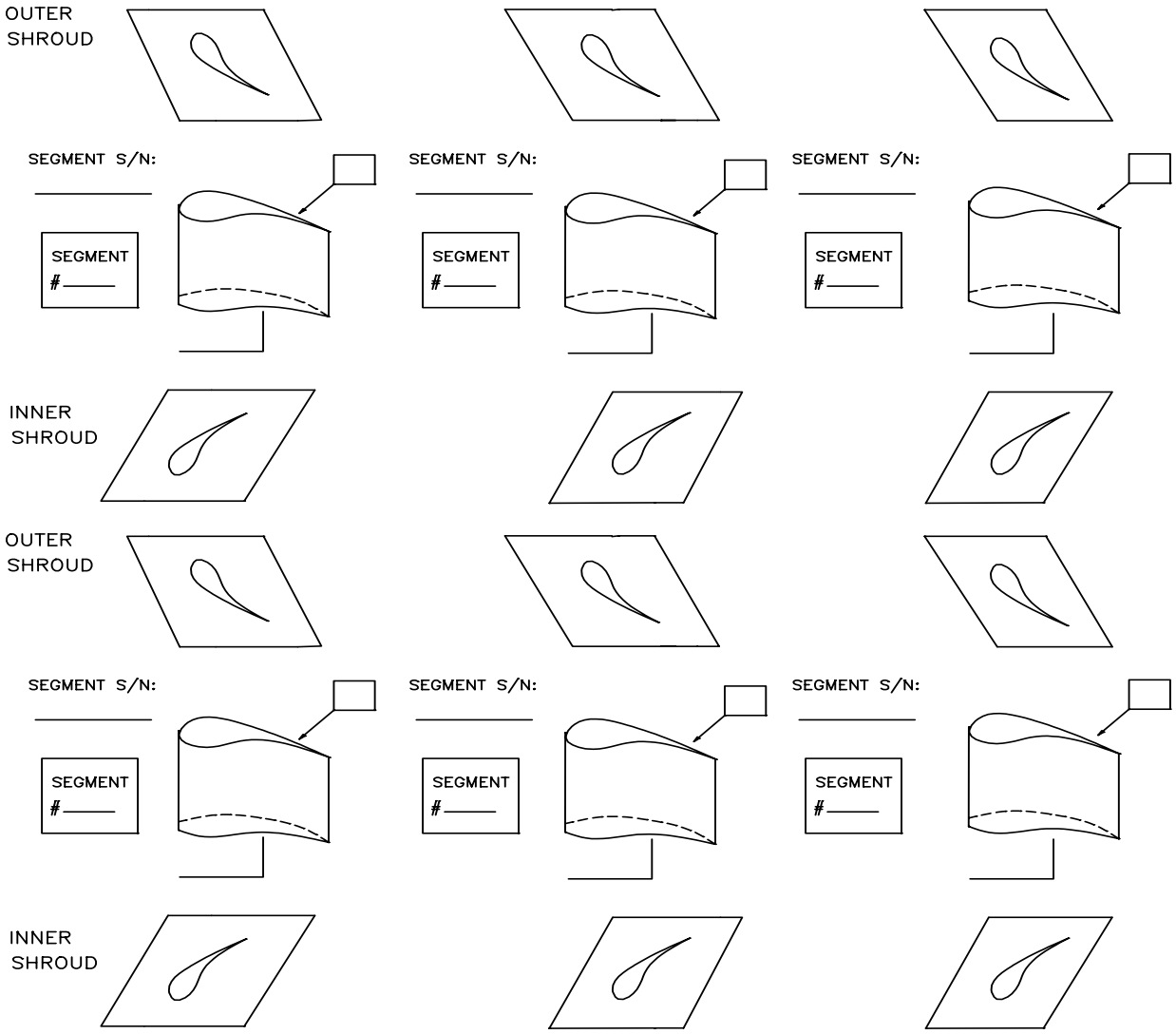
10.

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 100ths of inches.

FORM II-B

ALSTOM GT11N2 FOURTH STAGE VANE SEGMENT

DAMAGE ASSESSMENT FORM



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

APPENDIX III - PROCEDURE FOR METALLURGICAL EVALUATION OF NOZZLE AND VANE SEGMENTS

SCOPE:

This procedure describes techniques to be used to characterize material degradation in both cobalt and nickel based nozzles / vanes and assess reparability. The removal of samples is semi-destructive, 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 0.16 mm (1/16") wafering blades and rotary air or electric hand tools. Appropriate personal protective gear should be worn at all times when using such tools.

Since samples removed must be repaired, the minimum material necessary should be removed. For leading and trailing edge locations, the sample geometry shown in Figure III-A is adequate for specimens in two orientations. For removal of samples from heavier locations such as side rails, a "boat" type specimen, as shown in Figure III-B, 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 (i.e., surfaces perpendicular to specimen plane). The depth of oxide scale and internal oxidation present should be measured. If the depth of attack exceeds 0.51 mm (0.020 inches) or 1/3 of the local section thickness, whichever is less, the nozzle or vane should be considered un-repairable by welding or brazing. Coupon type repairs may be possible if the oxidation damage is localized.

MICROSTRUCTURAL CONDITION:

Cobalt-Based Vanes

The microstructural condition should be examined in all sections. In particular, longitudinal sections should be examined for the presence of voids formed by thermo-mechanical 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.

Nickel-Based Vanes

All samples should be examined by optical microscopy for the presence of intergranular creep voids. Any vanes in which creep voids are identified are unserviceable. They may be repaired by Hot Isostatic Press rejuvenation.

All samples should be examined by optical microscopy for microstructural instabilities. Changes from new material microstructure can be identified by comparing airfoil samples with samples of un-serviced alloy of the same composition in the fully heat treated condition. 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.

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 2. By comparing the structures in these areas with that of new (un-serviced) material, 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.

Any deviations from normal microstructure should be noted.

FIGURE III-A - LEADING OR TRAILING EDGE SPECIMEN

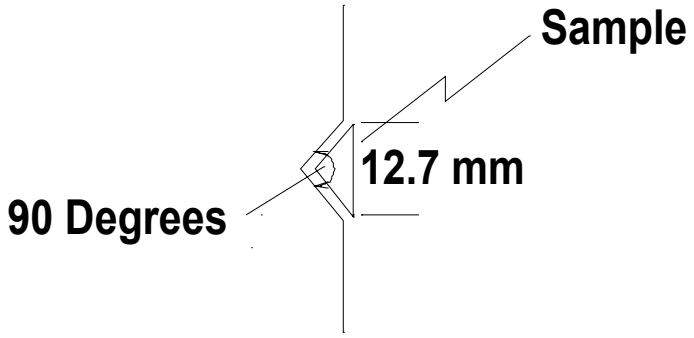
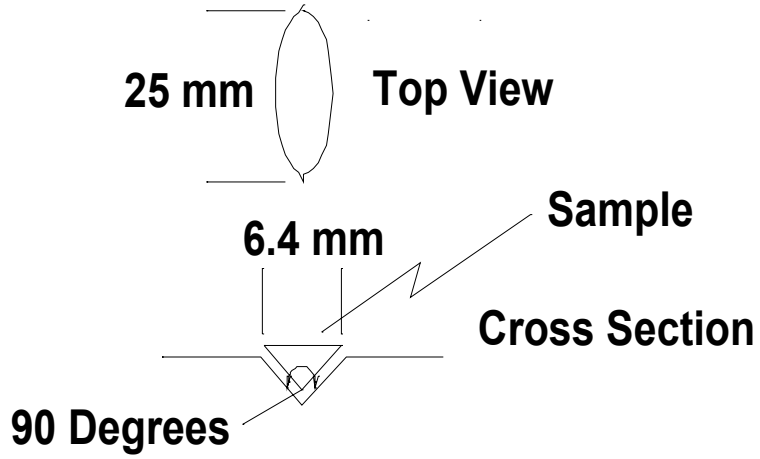


FIGURE III-B - "BOAT" SPECIMEN



5
REPAIR SPECIFICATION FOR ALSTOM MODEL GT11N2 FIRST STAGE TURBINE BLADES

1 SCOPE

1.1 Purpose

This specification covers the minimum requirements for the repair and heat treatment of ALSTOM Model GT11N2 First Stage Turbine Blades manufactured from Inconel 738LC alloy (Ni -16Cr – 8.5Co - 3.5Al – 3.5Ti – 2.6W – 1.8Mo – 1.75Ta – 0.9Cb - 0.11C – 0.055Zr – 0.0095B). A thermal barrier coating is applied to the blade airfoil and platform following repair to reduce metal temperatures and protect the substrate from oxidation and hot corrosion. Blades repaired to these requirements should provide service life approaching that of new components. Sixty blades comprise a full set of first stage turbine blades.

NOTE: Original production of this engine did not include thermal barrier coating (TBC) of the first stage blade. The scope of coating for the early models consisted of an MCrAlY-type overlay on the external airfoil surfaces that are exposed to the hot gas flow. Recently the OEM, began to apply a TBC over the MCrAlY on production engines. This document assumes that turbine owners will elect to adopt the latest standard and apply a TBC coating during the repair process outlined here. However, the repair vendor should verify with the purchaser the scope of coating application desired before bidding or proceeding with the refurbishment process.

1.2 Application

Weld repair and blending of turbine blades is performed to repair physical damage such as rubbing, cracking and impact damage. Heat treatments are required prior to welding to improve ductility and after welding to stress relieve weldments and to restore the appropriate microstructure. Heat treatments associated with protective coatings are typically performed in conjunction with the blade postweld heat treatment. It should be noted that weld repair of IN738LC has proven difficult. For this reason, consideration should first be given to blending minor defects according to OEM blend limits or the blend limits in Table 1, reserving weld repairs for larger defects that cannot be blended. Straightening of deformed turbine blades is prohibited.

2 DEFINITIONS & BLADE ILLUSTRATIONS

2.1 ALSTOM Model GT11N2 First Stage Blade

Figures 1 and 2 are photographs of the blade pressure side and suction side respectively. Figure 3 shows a leading edge view of the blade, and Figure 4 is a picture of the trailing edge of the blade with cooling air exit slots. Figure 5 is a picture of the bottom of the blade root, showing the cooling air entrance points, and Figure 6 is a picture of the tip of the blade. The GT11N2 first stage blade has a leading-edge radial flow passage with air leaving at the tip of the blade, and a

serpentine passage with air leaving at both the tip and the trailing edge. Internal turbulators are cast in to enhance heat transfer.

2.2 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 sub-groups for heat treatment, each sub-group shall constitute a lot.

2.3 E.D.M.

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

2.4 Linear Indications

Non-destructive testing indications with a length of three times the width or greater. It is generally agreed that linear defects less than 0.38mm (0.015 inches) in length cannot be confirmed using conventional non-destructive testing techniques.

2.5 Non-linear Indications

Non-destructive testing indications with a length of less than three times the width.

2.6 Through-Going Indications

Non-destructive testing indications appearing directly opposite each other and apparently extending through the thickness of the section.

2.7 F.P.I.

Fluorescent Penetrant Inspection



Figure 5-1
OVERALL VIEW OF GT11N2 1st STAGE BLADE, PRESSURE SIDE



Figure 5-2
OVERALL VIEW OF GT11N2 1st STAGE BLADE, SUCTION SIDE

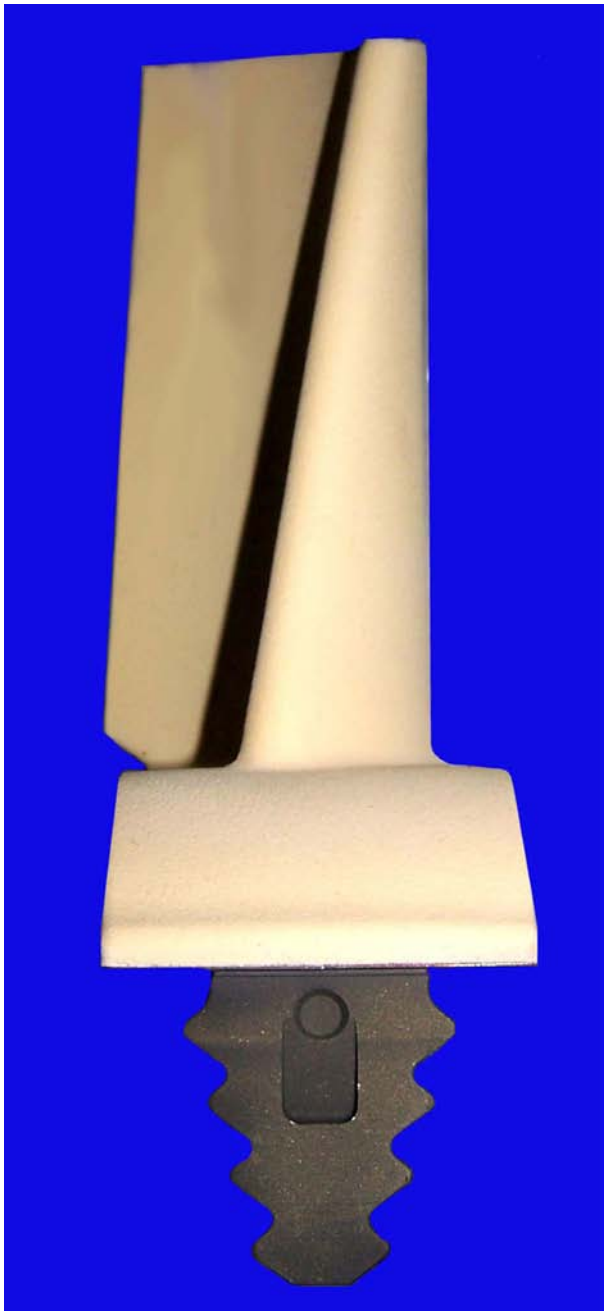


Figure 5-3
LEADING EDGE VIEW OF GT11N2 1st STAGE BLADE

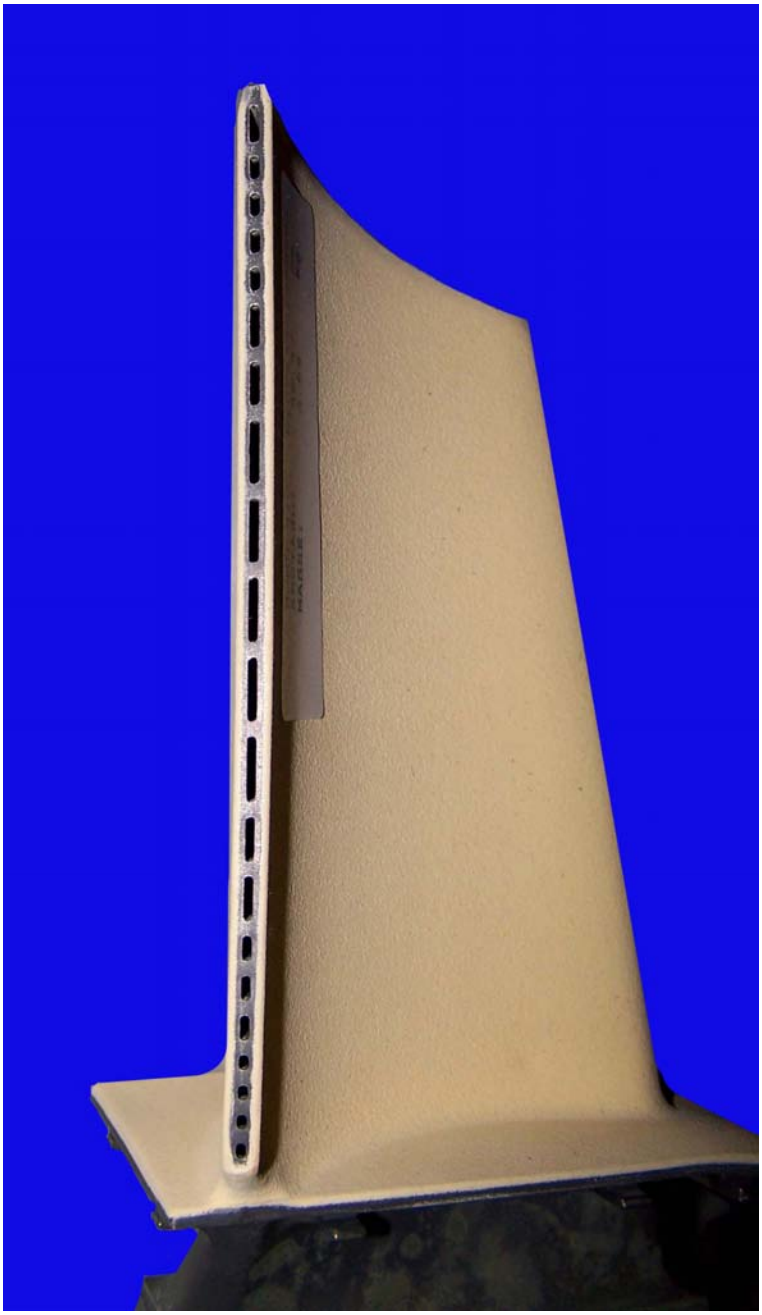


Figure 5-4
VIEW OF GT11N2 1st STAGE BLADE SHOWING AIRFOIL TRAILING EDGE COOLING HOLES



Figure 5-5
View of GT11N2 1st Blade Root Showing Cooling Air Entry Points



Figure 5-6
View of GT11N2 1st Blade Tip Showing Cooling Air Exit Points

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.

ASTM 1417

"Inspection, Liquid Penetrant"

ASTM 1742

"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 Specifications 5837C

"Wire, Welding, Alloy- 62Ni 21.5Cr 9.0Mo 3.7(Cb +Ta)"

ASNT Recommended Practice No. SNT-TC-1A

"Personnel Qualification and Certification in Nondestructive Testing"

ANSI B46.1

"Surface Texture"

Aerospace Material Specifications 2430

"Shot Peening, Automatic"

Purchaser document BUCKTBC

"Specification for Application of Thermal Barrier Coatings on Industrial Gas Turbine Blades/Buckets Using HVOF (Bondcoat) and APS (Topcoat) Thermal Spray Processes".

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 for the repair / re-coating of gas turbine components are typically supplied in the Request for Proposal or Purchase Order, as applicable.

5 TECHNICAL REQUIREMENTS

5.1 Repair Materials

Unless qualified by the vendor and approved by the purchaser, repairs at the blade tip shall be performed by gas tungsten arc welding or plasma transferred arc welding using AMS 5837C

(Alternate designations: Inconel 625, Alloy 625, UNS N06625), Waspaloy or Haynes 230 filler materials. Weld procedures and filler materials for repairs at the blade platform periphery require specific purchaser approval (see Note below). Repairs in structural areas (e.g. airfoil below the tip) using advanced processes (such as laser powder fusion welding or micro plasma arc welding) and that employ filler materials that match (or more closely match) the blade alloy, when pre-qualified by vendor and approved by the purchaser, are allowed. Braze repair is not addressed in this specification and it may not be used without specific purchaser approval.

NOTE: Experience is still being gained with respect to the level of damage and the damage mechanisms at the blade platform periphery. The experience gained to date indicates that little to no platform damage is typical in this stage; however, guidance is offered in this document to address platform repairs if they are required on a specific set of blades. The solid solution weld fillers listed for repairs at the tip should be acceptable for minor nicks and dents along the platform edges that are within the allowable areas shown in Figure 7. Selecting the appropriate filler material for more serious damage, such as through wall cracking along the platform edges, should be accompanied by an analysis to determine the stress / temperature distribution and damage mechanism. At this juncture, purchaser has not completed a detailed analysis of this blade design, however, it is expected that, if it proves to be needed, this document will be updated in the future in order to recommend filler materials for more serious damage along the platform periphery.

5.2 Blade Blend/Weld Repair Limits.

5.2.1 Unless approved otherwise between purchaser and supplier, minor defects may be blended (blend repaired) within the limits stated in Table 1. The blends must have a depth to length ratio of 1:8 minimum, and be smooth and gradual with no sharp edges remaining.

5.2.2 Surface oxidation/corrosion/alloy depletion on the airfoil surface may be blended out to the maximum depths outlined in Table 1. All surfaces to be coated must be metallurgically clean and free of all oxide and residual coating.

Blend repaired areas shall be fluorescent penetrant inspected to the requirements of 5.3.

Unless approved otherwise between purchaser and supplier, weld repair limits shall be per

Figure 7. All defects to be weld repaired must be fully removed prior to welding.

5.3 Non-Destructive Testing Acceptance Limits

Linear indications of less than 1mm (0.040 inch) in length within ± 30 degrees of the radial direction and 0.76mm (0.030 inch) in all other directions are permitted within the weld repair limits identified in Table 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. Non-linear indications up to 0.76mm (0.030 inch) diameter or up to a diameter equal to 25% of the local section thickness, whichever is less, are permitted.

5.4 Dimensional Requirements

5.0.1 Tip height and squealer tip thickness dimensions shall be within the range identified on the forms attached as Appendix I.

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.

5.4.2 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 Cooling air exit and bleed hole sizes. Upon receipt the repair vendor shall check cooling air exit and bleed holes / slots on a typical blade in good condition and record the sizes for use as targets for others in the set. (If the nominal cooling / bleed hole sizes per OEM drawing requirement are known, these values shall be used instead of the measured target values.) Any cooling / bleed holes blocked during repair shall be restored to original dimensions and shall be checked for conformance with the target.

5.4.4 The minimum wall thickness (ligaments) between airfoil surfaces and internal cooling passages are critical dimensions that can govern repair / replacement decisions. The OEM typically provides some guidance on minimum acceptable ligaments for each blade design in the turbine instruction manuals. As specified in the forms in Appendix I, these ligaments are to be checked, recorded and compared to the minimum values recommended by the OEM. If recorded values closely approach the minimum values recommended by the OEM, vendor shall notify purchaser and obtain a repair / replace decision. Because more than one first stage blade design / cooling passage geometry may be operating in the GT11N2 fleet, specific minimum values are not included in the Appendix I forms. Ligament thickness shall be recorded at all airfoil locations where significant corrosion, erosion or foreign object damage has occurred.

NOTE: At this juncture, a generic method for recording blade wall thickness is specified in Appendix I, Form I-D. Specific locations on the blade airfoil for recording wall thickness are not currently specified. However, vendor and purchaser may agree on specific airfoil locations where wall thickness must be recorded. If no OEM wall thickness criteria are available, the values measured may be compared with those of a new blade and a judgment made on the severity of wall thinning and whether repairs are practical.

5.5 Mechanical Properties

It is typically recommended that stress rupture bars be removed from the airfoil of a blade from the set being repaired and tested according to ASTM E-139. However, due to the limited wall (ligament) thickness available in the airfoil of the GT11N2 first stage blade, removal of specimens of a size to accommodate stress rupture testing is not practical. With this being the case, a thorough metallurgical analysis should be performed on a blade sacrificed from the set to be repaired. The metallurgical analysis should include electron microscopy (SEM or TEM) of the microstructural morphology of airfoil sample material that has been processed through the entire repair and heat treating processes. The size and morphology of the gamma prime phase as well as that of carbides should be determined and compared to that of new (un-serviced) IN738 material in the fully heat treated condition. A specimen extracted from the root of a blade may be used for this purpose. This metallurgical evaluation is recommended in lieu of stress rupture testing for this blade design. The assumption here is that, if heat treatments applied during the repair process result in a blade microstructure that is essentially equivalent to that of new IN738 material, then the blade mechanical properties should closely approach that of new IN738 material. Some guidance on metallurgical review of sample material is provided in Appendix III. Microstructural requirements are listed in paragraph 5.6.

5.6 Microstructural Requirements

5.6.1 The hold times and temperatures employed during thermal processing shall be held to minimum levels in order to minimize grain growth.

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

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

5.6.4 The microstructure shall be comparable to new material. The root section of an un-repaired blade may be used for comparison. Specifically, no continuous carbide films or needle phases shall be present after processing.

5.7 Coating Requirements

The blade external protective coating shall be a duplex coating system consisting of a MCrAlY overlay bondcoat and a ceramic thermal barrier topcoat (TBC) on the airfoils and platforms. Figure 3 outlines the extent of coating coverage. The OEM utilizes the Low Pressure Plasma Spray (LPPS) process to apply the bondcoat, however, it is anticipated that some repair vendors will request approval to apply the bondcoat using the High Velocity Oxy-Fuel (HVOF) process. The ceramic topcoat is applied using the Air Plasma Spray (APS) process. If the HVOF (bondcoat) and APS (topcoat) processes are to be used, the coating shall be performed according to purchaser specification BUCKTBC “Specification for Application of Thermal Barrier Coatings on Industrial Gas Turbine Blades / Buckets Using HVOF (Bondcoat) and APS (Topcoat) Thermal Spray Processes”. If the bondcoat is applied by LPPS, the coating process procedures and quality control requirements for the bondcoat shall be defined by the vendor and approved by the purchaser. All coating process procedures and quality control requirements, including those used for the stripping of existing coatings, shall be qualified per the first article qualification procedures specified in paragraph 7.1.2. .

NOTE: The TBC specification referenced above (BUCKTBC) specifies a surface finish after coating of 125 microinches Ra.. Obtaining either of these finishes will require that a post coating finishing process (typically sanding) be used to smooth the surface that will exist after the APS coating application process. Vendor should define / verify this item with purchaser before bidding or beginning the coating process.

5.8 Cooling Passage Flow Test Requirements

Unless otherwise specified or approved, the cooling passage flow testing procedure / requirements specified in Appendix IV shall be followed / met.

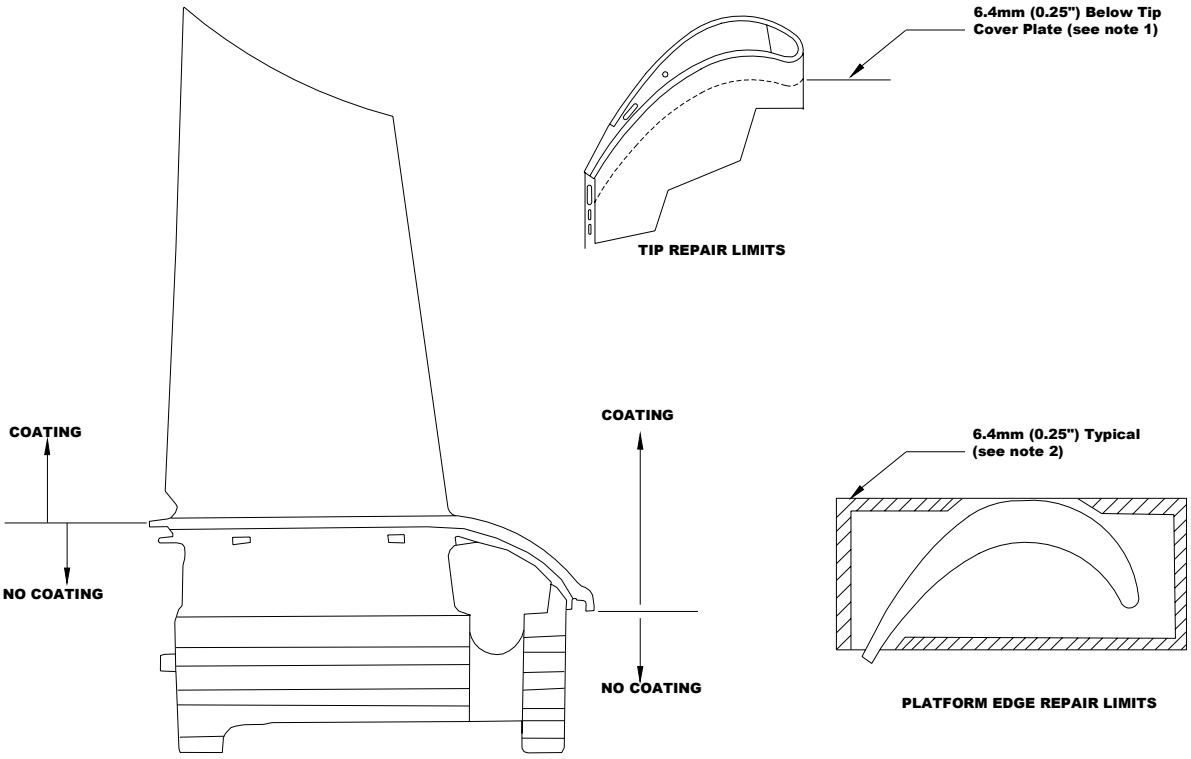
NOTE: Proper functioning of the blade cooling system is of critical importance in advanced technology turbine blades. For this reason, flow testing as described in Appendix IV is to be performed at (a) incoming inspection and (b) after all processing (i.e., following coating application).

Table 5-1
GT11N2 Row 1 Blade Blend Limits

DESCIPTION	MAXIMUM BLENDING LIMITS
AREA: Upper 1/3 of Airfoil	
1. Tip Blend	max depth to top of tip cap X 25.4mm (1.0") maximum length.
2. Surface Blend	0.76mm (0.030") deep or 25% of design wall thickness, whichever is less
3. Trailing Edge Blend	4.1mm (0.170") maximum depth x 25.4mm (1.0") maximum length.
AREA: Lower 2/3 of Airfoil	
1. Surface Blend	0.5mm (0.020") deep or 10% of design wall thickness, whichever is less.
2. Trailing Edge Blend	1.5mm (0.06") maximum depth x 25.4mm (1.0") maximum length.
AREA: Blade Shank and Root	
1. Surface Blend	0.25mm (0.010") deep on shank and root end faces.
2. Root Blend	0.12mm (0.005") deep maximum. None on load bearing surfaces or fillet radii.

Note: All blends must have a depth to length ratio of 1:8 minimum, and shall be smooth and gradual with no sharp edges remaining.

Figure 5-7
ALSTOM MODEL GT11N2
1st STAGE BLADE WELD REPAIR LIMITS & COATING COVERAGE
NOTES FOR THIS FIGURE BEGIN BELOW AND CONTINUE ON THE NEXT PAGE



NOTES

1. In the tip area, the entire squealer tip wall may be repaired / rebuilt. From a structural standpoint, repair of radial cracks may extend into the airfoil down to 6.4mm (0.25 inches) below the tip cover plate. However, the following is offered as guidance when attempting to weld in the airfoil below the tip cover plate:

Welding a through wall crack from one side will require argon backing. Any welding process used should be qualified before production repairs are attempted and all welds in the airfoil below the tip cover plate should be radiographed after the post weld heat treatment (see 6.2.12).

Attempting to repair damage below the tip cover plate is expected to be problematic. Repairs of this nature should be reviewed on a case-by-case basis with the purchaser and would only be attempted in an effort to prevent retirement of blades that would otherwise be acceptable for extended service.

The crosshatched areas in Section A – A show the locations where platform repairs are allowed, however, the welding procedures and filler materials used for platform repairs require specific purchaser approval (SEE 5.1). In general, repairs along the edges may extend into the platform to a depth of 6.4mm (0.25 inches); however, in no case should the repairs encroach into the airfoil

to platform fillet areas. This will limit repairs to less than 6.4mm (0.25") in areas where fillets are near the edges (as shown at mid-chord on suction side and at the trailing edge).

Blade coating shall be an approved duplex coating system consisting of a MCrAlY overlay bond coat and a ceramic thermal barrier top coat (TBC) on the airfoil and platform. The internal cooling passage coating is not normally replaced during repair. See paragraphs 1.3 and 5.7.

The TBC coating should extend around the radius on the forward (leading edge) end of the platform. Otherwise, platform coating should not extend below the platform top surface (i.e., no coating on platform axial edges).

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. Record blade serial numbers.

6.1.2 Advise purchaser immediately of any shipping damage.

6.1.3 Dimensionally inspect blades for:

- tip height (inspect all blades)
- squealer wall thickness (inspect 10% of lot)

Record the results using the forms attached as Appendix I. Tip height dimensions may be checked with a fixture provided the fixture allows actual dimensions to be recorded (i.e., pass / fail type results are not acceptable).

6.1.4 Visually inspect each blade for the following:

- tip rubs
- foreign object damage
- cracks
- surface oxidation, corrosion, erosion and coating loss

Record the results using the forms attached as Appendix II.

6.1.5 Non-destructively identify the alloy from which each blade is manufactured. If any alloy other than IN738 is identified, inform purchaser immediately.

6.1.6 Perform incoming blade cooling passage flow testing per Appendix IV. Record results by serial number. Inform purchaser and obtain disposition for any blades that exhibit cooling passage / exit hole blockage.

6.1.7 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 one which is damaged beyond repair limits. 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. Based on this evaluation, Recommendations / Decisions should be made for the blade set concerning repair/replace decisions. The balance of the material from this blade shall be saved for use as control material, as specified in 6.1.8.

6.1.8 Control material from the destructively examined blade or other IN738 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 5.5, 6.1.11 and 6.2.25. The control material for testing of paragraph 6.2.25 shall be processed through all thermal processing cycles (preweld heat treatment, postweld heat treatment, coating diffusion heat treatments and aging heat treatments).

6.1.9 Clean blades using grit blasting with 220 grit aluminum oxide. If the blades are thermal barrier coated (TBC), use this step to remove the ceramic topcoat layer by careful abrasive blasting. Avoid excessive blasting, particularly on the root, and ensure that the cooling passages are not plugged.

NOTE: Cooling passages can become filled with media during abrasive cleaning. It is imperative that the media be removed prior to any heat treatment since the passages 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.

Mask all internal surfaces and uncoated external surfaces to prevent base metal attack from stripping solutions.

Remove the coating by physical and chemical means, while ensuring no excessive base metal attack. Control samples of IN738 alloy shall be processed through any chemical stripping procedure (each stripping lot) and examined metallographically for surface attack, which shall not exceed the limits defined in 5.6.2. The use of coated IN738 material from a scrap blade from the set being repaired is strongly preferred for stripping control samples.

NOTE: The stripping procedures used to remove coatings on thin wall, serpentine cooled turbine blades is especially critical and, unless approved otherwise, must be qualified by the procedures for first article qualification as specified in paragraph 7.1.2. Damage due to excessive stripping chemical penetration can result in both stress risers and a significant reduction in base metal mechanical properties.

6.1.12. Each blade shall be examined for complete coating removal by heat tinting or etching.

6.1.13 F.P.I. all blades 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 using the 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 blade defects on one set of damage assessment forms.

6.1.14 Thoroughly clean components using an approved solvent cleaner or by other approved means such as steam cleaning or pressure spraying.

6.1.15 Inspect and record wall (ligament) thickness between airfoil surfaces and internal cooling passages on all blades per the instructions in 5.4.4 and Appendix I, Forms I-C, D and E.

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

- obtain written approval from the purchaser for any proposed changes to this specification, and

- obtain written or verbal authorization from the purchaser to proceed with the repairs.

6.2 Blade Repair Procedures

6.2.1 Unless approved otherwise, all process procedures applied during the repair of the blades 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.

6.2.2 Heat treat the blades in a vacuum of 1 micron ($1.3x10^{-3}$ millibar) or better at a temperature of 1190°C +/- 14°C (2175°F +/- 25°F) for 4 hours and Inert Gas Quench.. Fixture parts using only approved (7.1.2) fixture materials with the parts supported uniformly to prevent distortion. Avoid supporting the parts by any thin sections.

6.2.3 F.P.I. all blades following procedures outlined in paragraph 6.1.13. Document the location and extent of any defects not identified in paragraph 6.1.13 on the forms attached as Appendix II.

6.2.4 Prepare the areas of the blades to be repaired by removing the existing cracks / defects by abrasive grinding and F.P.I. to ensure the cracks are completely removed. Areas with defects outside the repair limits specified in Figure 3 can be blended to remove them within the manufacturer's blending limits. Grinding tools and procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.5 When requested, the purchaser shall be informed and allowed to inspect the components following weld preparation.

6.2.6 Weld repair the components using gas tungsten arc or plasma transferred arc welding methods and the filler metals identified in 5.2. Areas to be welded must be free of oxide, grease, dirt and penetrant chemicals. All welds must be performed using full penetration welds in the region being repaired. Unless specifically approved otherwise, weld repairs beyond the limits defined in Figure 3 are not allowed. 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. Grinding tools and procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.8 Restore to original dimensions any cooling holes plugged during repair. Check the restored passages to ensure they meet the requirements of paragraph 5.4.3.

6.2.9 F.P.I. the blades following procedures outlined in paragraph 6.1.13 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.

6.2.10 Parts that fail to meet the criteria of paragraph 5.3 may be recycled to repair any defects beginning at paragraph 6.2.4.

6.2.11 Vacuum heat treat the components to stress relieve the weldments using the cycle used in the original process qualification (7.1.2). Unless otherwise specified / approved by the purchaser, the following parameters shall be employed:

Post-weld stress relief/solution heat treat: 1190°C +/- 14°C (2175°F +/- 25°F) / 2 hours/ Inert Gas Quench.

6.2.12 Following the post-weld stress relief heat treatment, perform the following NDE procedures:

6.2.12.1 F.P.I. the entire blade using procedures outlined in paragraph 6.1.13 and the acceptance limits defined in 5.3. Record the results (pass/fail) by serial number.

6.2.12.2 Radiograph any welds made in the blade airfoil that extend below the squealer tip cover plate 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.

6.2.13 Parts that fail to meet the criteria of paragraph 5.3 may be recycled to repair any defects beginning at paragraph 6.2.4.

6.2.14 Thoroughly clean components using an approved solvent cleaner or by other approved means such as steam cleaning or pressure spraying.

6.2.15 Dimensionally check all blades to ensure conformance with paragraph 5.4. Record the results on the forms attached as Appendix I. Tip height dimensions may be checked with a Fixture provided the fixture allows actual dimensions to be recorded (i.e., pass / fail type results are not acceptable).

6.2.16 Apply the TBC bond coat using only processes and coating compositions that have been specified or approved by the purchaser. Unless specified / approved otherwise, coatings shall be in accordance with paragraph 5.7. Component surfaces that are not to be coated shall be protected during the coating process using an appropriate mechanical mask or a suitable stop-off compound. The method used shall completely prevent coating build-up on the prohibited areas and shall be easily removed after coating. The base alloy shall be unaffected by the masking procedure, as demonstrated on a test coupon prior to process qualification. Procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.17 Vacuum heat treat to diffuse the bond coat / internal coating (if required) and to restore the IN738 mechanical properties using the cycle used in the original process qualification (7.1.2). Unless otherwise specified / approved by the purchaser, the heat treatment shall be as follows:

1120°C + / - 14°C (2050°F + / - 25°F) / 2 hours / Inert Gas Quench;

843°C + / - 14°C (1550°F + / - 25°F) / 24 hours / Fan cool to room temperature.

6.2.18 Inspect bond coat to ensure it meets the requirements of the approved coating specification and that parts are acceptable for application of the ceramic topcoat.

6.2.19 Prepare bond coat surfaces as required for application of ceramic topcoat. Roughing of the bond coat surface to improve ceramic layer adhesion is permitted if it was a part of the original process qualification (7.1.2).

6.2.20 Apply TBC ceramic top coat using only processes and coating compositions that have been specified or approved by the purchaser. Unless specified / approved otherwise, coatings shall be in accordance with paragraph 5.7. Component surfaces that are not to be coated shall be protected during the coating process using an appropriate mechanical mask or a suitable stop-off compound. The method used shall completely prevent coating build-up on the prohibited areas and shall be easily removed after coating. The base alloy shall be unaffected by the masking procedure, as demonstrated on a test coupon prior to process qualification. Procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.21 Remove all residue and coating masking compounds remaining from the coating process.

6.2.22 Perform final blade cooling passage flow testing per Appendix IV. Record results by serial number. Inform purchaser and obtain disposition for any blades that exhibit cooling passage / exit hole blockage or that do not meet the criteria for post coating flow rate. (See Appendix IV)

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 Shot peen all dovetail serrations surfaces per AMS 2430 to Almen .008/.011A.

6.2.25 Production Control Tests. Metallographic samples of control material (see 6.1.8) from each lot of blades shall be prepared after all processing and examined for compliance with paragraphs 5.5 and 5.6. Failure of the metallographic specimens to meet the minimum requirements shall subject the entire lot to rejection.

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

6.2.27 Arrange a pre-shipment inspection with the purchaser to:

- review vendor's documentation including heat treat charts and Quality Control Test reports.
- visual inspection

6.2.28 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.

6.2.29 Advise purchaser of the shipping date, route and carrier, etc.

6.2.30 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 non-destructive 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 & 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 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) 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 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 five 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 which shall contain:

a) a mapping of all defects identified at paragraph 6.1.4, 6.1.13, 6.2.3 and 6.2.9. (Use form attached as Appendix II)

b) a copy of all incoming, in-process and final dimensional inspection forms (Use forms attached as Appendix I)

c) a copy of the final F.P.I.

a copy of all cooling passage flow test reports (Use forms attached as Appendix IV)

e) a copy of the moment weight/computer sequence report

f) a copy of the certificate of compliance

g) a copy of all production control test results (include photocopies of microstructural / metallographic specimen photographs)

7.3 Acceptance and Disposition.

7.3.1 All deviant parts shall be plainly labeled in a non-destructive manner, isolated from the batch and held for purchaser disposition.

7.3.2 Blades not meeting the requirements of this specification, the purchase order, and referenced drawings, shall be rejected and held for purchaser disposition.

7.4 Access

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

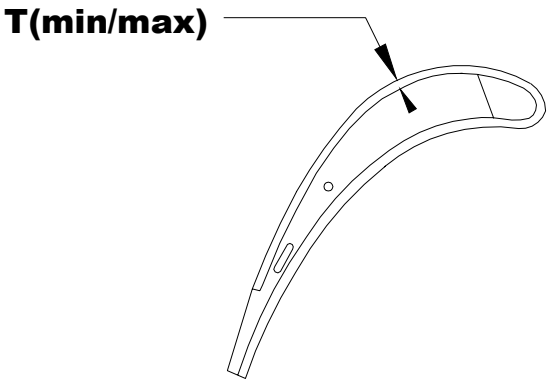
APPENDIX I - DIMENSIONAL INSPECTION FORMS

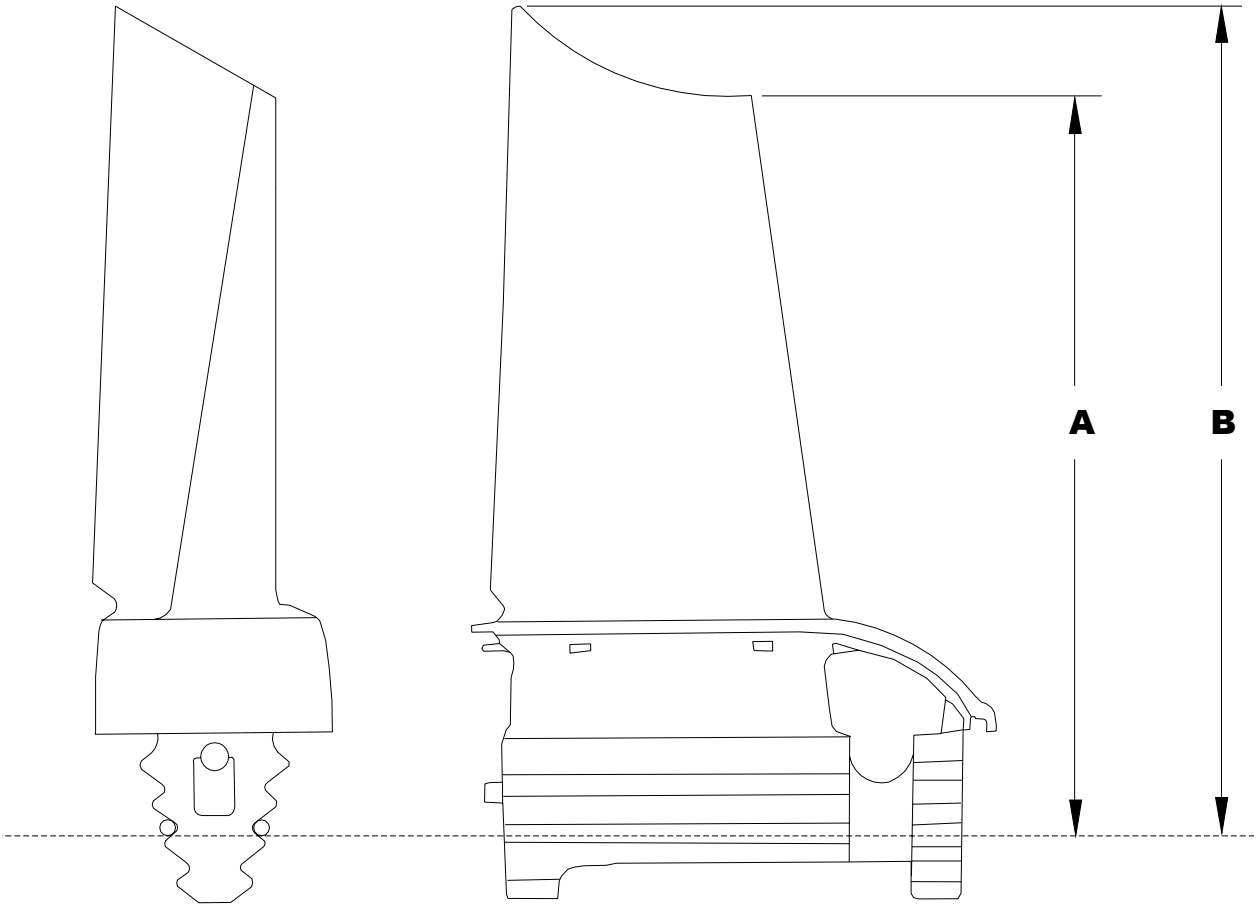
FORM I-A

ALSTOM GT11N2 FIRST STAGE BLADE

DIMENSIONAL INSPECTION FORM – EXTERNAL DIMENSIONS

RECORD MEASUREMENTS ON FORM I-B





FORM I-B

ALSTOM MODEL GT11N2 FIRST STAGE BLADE

DIMENSION SHEET – EXTERNAL DIMENSIONS

BLADE SERIAL NO.	**DIMENSIONS**		**SQUEALER WALL THICKNESS**	
	A	**B**	**T**	
			MIN.	**MAX.**
MINIMUM				
MAXIMUM				

PIN DIAMETER USED: _____

RECORDED DIMENSIONS ARE IN (Check one): ☐ INCHES ☐ MM

NOTES: 1. Measure T (Min. / Max.) on 10% of blades at incoming inspection.

2. Measure A and B on all blades at incoming and final inspections.

3. At final inspection, measure "T" (Min. / Max.) on all blades having tip repairs.

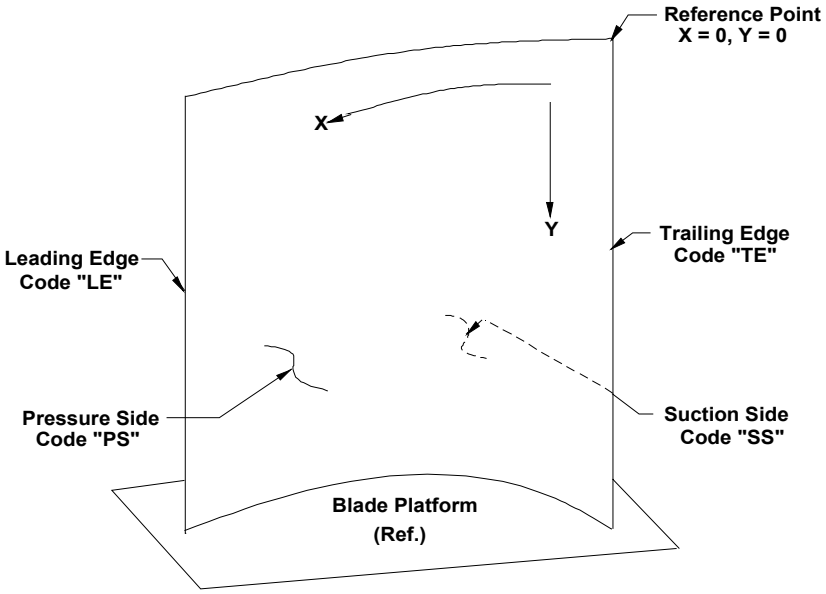
4. Checking Fixtures may be used, however, fixtures must allow recording of actual dimensions (not “Pass” or “Fail”).

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

FORM I-C

ALSTOM MODEL GT11N2 FIRST STAGE BLADE

DIMENSIONAL INSPECTION FORM – INSTRUCTIONS FOR RECORDING AIRFOIL WALL THICKNESS



Unless specified otherwise, airfoil wall thickness to be recorded on Form I-E using the method described here. Space (rows) is included on Form I-E for recording twelve (12) measurements on each blade. If additional measurements are made, continue in the spaces provided for the next blade and use a remark such as “ditto” or “same” in the blade Serial Number (S/N) column. In general, several measurements should be made near the leading and trailing edges and on both the pressure and suction sides of the airfoil; the goal is to record minimums. Measurements must be made in all areas where significant oxidation, corrosion, erosion or foreign object damage has occurred.

When recording wall thickness at or very near the leading or trailing edges, use the applicable code (LE or TE) and a “Y” dimension only (i.e., no X required). A tolerance of + / - 3mm (0.125”) is allowed on both X and Y. The X dimension is the distance measured along the contour (curvature) of the airfoil, as shown; i.e., not a straight line (chordal) distance.

For measurements made at airfoil locations other than the LE or TE, use location code PS or SS to indicate the pressure and suction sides of the airfoil and include both X and Y dimensions. Two examples are shown below for reference and the “Comments” shown are for defining the method. In practice, the “Comments” column should be used for descriptive information such as type of damage noted in the area (oxidation, foreign object, etc.) or other descriptive information that would be useful in understanding why the area was selected.

BLADE S/N	LOCATION CODE PS, SS, LE OR TE	X (in.)	Y (in.)	MEASURED WALL THICKNESS (in)	COMMENTS
12345 (Example)	LE	-	1.25	0.100	A wall thickness of 0.100 inches was measured at or very near the leading edge at a vertical location 1.25 inches below the blade tip.
	PS	2	3	0.070	A wall thickness of 0.070 inches was measured on the pressure side at a location 2 inches from the trailing edge and 3 inches below the tip.

FORM I-D
ALSTOM MODEL GT11N2 FIRST STAGE BLADE
DIMENSIONAL INSPECTION FORM – AIRFOIL WALL THICKNESS RECORD SHEET

BLADE S/N	**LOCATION CODE PS, SS, LE OR TE**	**X (in.)**	**Y (in.)**	**MEASURED WALL THICKNESS (in.)**	**COMMENTS**

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

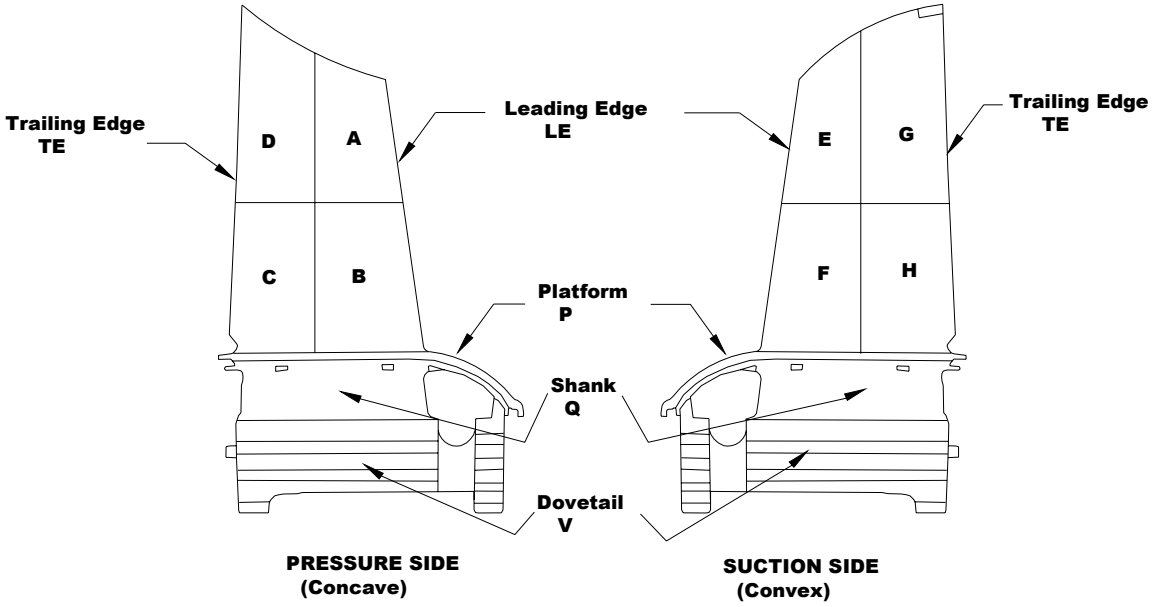
APPENDIX II - DAMAGE ASSESSMENT FORMS

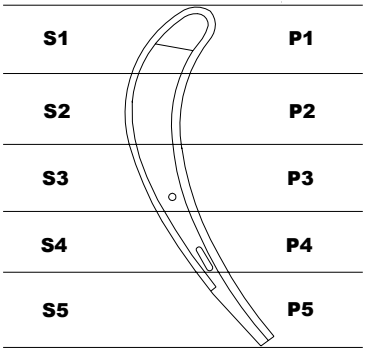
FORM II-A

ALSTOM MODEL GT11N2 FIRST STAGE BLADE

DAMAGE ASSESSMENT FORM – BLADE DAMAGE & LOCATION CODES

RECORD DEFECTS USING THE DAMAGE AND LOCATION CODES (ZONES) SHOWN
DAMAGE CODES: CR = CRACK IN RADIAL DIRECTION; CA = CRACK IN AXIAL DIRECTION;
D = DENT; T = TORN; PT = PUNCTURED; MM = MISSING MATERIAL;
OX = OXIDATION; C = CORROSION; E = EROSION; W = WEAR (RUBS) CL = COATING LOSS
SEE FORM II-B FOR NOTES / RECORD DATA ON FORM II-C





SQUEALER TIP DAMAGE LOCATION ZONES

FORM II-B
ALSTOM MODEL GT11N2 FIRST STAGE BLADE
DAMAGE ASSESSMENT FORM – NOTES FOR RECORDING BLADE DAMAGE

Record all damage information on Form II-C. Duplicate the form as required to record all damage information for the blade set being inspected.

Record the serial number and the blade disk position (if known) for each blade.

Attach any photographs taken or lab analysis of corrosion to the set of forms.

Blade damage is to be documented in three (3) columns on Form II-C: “Cracks”, “Oxidation, Corrosion, Erosion or Wear”, and “Foreign Object Damage”. If additional space is required to complete damage information for a specific blade, continue with the information in the space provided for the next blade and show that it is a continuation using terms such as “ditto” or “same” in the Serial Number column.

Record the damage code first followed by the location code followed by the size or other description of the damage. Include descriptive information to further clarify locations, etc. Separate the codes and descriptions by slash marks. Several representative examples are given below.

Typical Crack Recording: For an axial crack approximately 0.25 inches in length located on the pressure side in squealer tip zone P5, record the damage as follows: CA / ST - P5 / 0.25”. For a 0.5 inch radial crack located on the pressure side airfoil in zone A near the axial center of the airfoil, record the damage as follows: CR / A, near mid-span / 0.5”. For a 0.25 inch long axial crack at the fifteenth (15th) trailing edge cooling slot below the tip, record the damage as follows: CA / TE at cooling slot 15 / 0.25”. For cracks in the leading edge, use the CA or CR code (as applicable), the location code “LE” and record the crack length and distance below the tip. State if the LE crack penetrates / starts at LE cooling holes.

Typical Oxidation, Corrosion, Erosion, Wear and Coating Loss Recording: Indicate the approximate dimension of the damage from the tip of the blade and use the applicable zone letters. Enter the radial height, axial width and approximate maximum depth of the damage. For an oxidized area approximately 1.5” below the tip that is 1 inch high by 2” wide by 0.010 “ deep on the pressure side airfoil in Zone A, record the damage as follows: OX / A-1.5” / 1”H X 2”W X 0.010” deep. Add additional comments as needed to further describe the damage such as “begins near LE”, etc.

Typical Foreign Object Damage Recording: Foreign object damage is recorded using the letter codes for Dents (D), Torn (T), Punctured (P, i.e., where the foreign object damage has penetrated into a cooling passage), or Missing Material (MM). Use the method for recording the locations and descriptive information similar to that used for Erosion / Corrosion. For a 0.5” diameter dent approximately 0.1 inches deep, near the leading edge on the pressure side at Zone C that is approximately 4” from the blade tip, record the damage as follows: D / C – 4”, near LE / 0.5” dia X 0.1” deep.

Blade Decision Codes: The last column on Form II-C (“DEC”) is reserved to record the decision made for each blade. Use the following codes:

WR = Repaired by welding

BR = Repaired by brazing (requires purchaser approval)

RN = Replaced with a new blade

N = No repair or replacement required

Use only lead free markers to mark blades.

FORM II-C

ALSTOM MODEL GT11N2 FIRST STAGE BLADE DAMAGE ASSESSMENT RECORD SHEET

BLADE S/N	**BLADE POSITION**	**CRACKS**	**OXIDATION, CORROSION, EROSION OR WEAR**	**FOREIGN OBJECT DAMAGE**	**DEC**

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

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 (i.e., 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 which appear visually to have surface damage. Internal surfaces of cooling passages should be examined in addition to the external surfaces.

The total depth of environmental attack should be measured. This should include:

i) remaining coating thickness

ii) the depth of any oxide layer,

ii) the depth of internal (cooling passage) oxidation,

iii) the depth of the alloy depleted zone,

iv) the depth of intergranular attack, and

v) an indication of the amount of metal lost due to oxidation/corrosion/erosion.

3. 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.

C. Microstructural Evaluation

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

Any deviations from normal microstructure should be noted.

APPENDIX IV - PROCEDURE FOR PERFORMING BLADE COOLING PASSAGE FLOW TESTING

Introduction

This appendix provides procedures to be used by blade repair vendors for testing cooling passage flows prior to and after repair of air cooled gas turbine blades. Two (2) types of procedures are required. These are summarized as follows:

Procedure 1: Qualitative pressurized water tests. This is a qualitative test procedure in that specific cooling passage flow rates are not measured / recorded. The purpose of this test is to determine by visual inspection that all blade cooling passages and exit holes / slots are unobstructed. It is conducted by connecting a pressurized water supply at the blade root plenum and visually inspecting to ensure that each cooling air exit hole / slot is passing water. Results for each blade tested are recorded as “Pass” or “Fail” on Form IV-A herein.

Procedure 2: Quantitative pressurized air flow tests. This is a quantitative test procedure in that cooling flow rates (lb/sec, kg/sec, cubic feet per minute, cubic meters per minute, etc.) or test stand pressures that are directly proportional to flow are measured and recorded. The purpose of this test is to determine if the blade cooling system has been affected by the repair and recoating processes. It is conducted by connecting a pressurized air supply at the blade root plenum and measuring the total air flow through each blade. Results for each blade are recorded on Form IV-B herein.

NOTE: There are numerous air flow test stand configurations that are acceptable for use in conducting this testing. Some test stands measure and display flow directly in engineering units (lb/sec, kg/sec, SCFM, etc.). Others, such as those that use a critical flow nozzle, measure and display system pressures which, as long as the nozzle is maintained at choke flow, are directly proportional to flow. The method used should be reviewed and approved by the purchaser prior to testing. Any test system used must meet the accuracy requirement listed in Section D below.

B. Test Sequence Requirements

Procedure 1 (qualitative water test) is a precursor to Procedure 2 (quantitative air flow test); i.e., successful completion of Procedure 1 is a prerequisite for proceeding to conduct Procedure 2. Both procedures are to be performed at (a) incoming inspection and (b) after completion of blade repair and re-coating.

C. Instructions for Conducting Qualitative Water Flow Tests (Procedure 1)

Water Supply. In most cases, tap water from the local water supply source may be used, however, it is strongly recommended that the water be pre-filtered and that piping downstream of the pre-filter be of non-corrosive material. The supply system should be thoroughly flushed prior to connecting blades for testing. Cooling air exit holes in GT11N2 blades are small in size and can potentially be clogged by particles entrained in the water source itself. Typical water supply pressures of 40 to 60 psig are satisfactory, however, a maximum water supply pressure of 100 psig should not be exceeded during the tests.

Water Connection / Manifolding. The water supply connection at the blade root plenum must be leak-free. Any connection design geometry that provides a leak free system is acceptable,

provided that the connection itself (a) does not prohibit complete visual inspection of the blade airfoil during the tests and (b) does not result in damage (scratches, dents, etc.) to the blade root plenum or dovetail serrations. Manifolding to permit simultaneous testing of multiple blades is permitted. Manifolds must be designed so that blades are either oriented or separated by a sufficient distance to ensure that the flow exiting each blade can be viewed independently; i.e., without mixing with or interference from flows exiting adjacent blades.

Blade Testing. Connect blades to water supply source and open supply line. Ensure that no leaks are occurring at the root plenum connection and supply piping. Carefully inspect and verify that each cooling air exit hole / slot is flowing freely. Record results (Pass / Fail) on Form IV-A. Note location of holes that are blocked or partially blocked in the Comments section of the form.

Failures. Blades that exhibit blocked are partially blocked cooling holes shall be considered as failures. The repair vendor may attempt to open cooling holes by one or more of the following steps: (a) back-flushing with a cleaning medium such as water or steam; (b) soaking using petroleum-based solvents (or other approved solvents) followed by back-flushing; (c) probing of individual exit holes / slots using appropriately sized wires; (d) other method approved by purchaser. All clogged or partially clogged blades must be re-tested following any attempt to clear passages and results recorded on Form IV-A. All blades that cannot be cleared shall be separated from the remaining lot and held for purchaser disposition.

Instructions for Conducting Quantitative Air Flow Tests (Procedure 2)

Air Supply. Testing shall be performed using clean (pre-filtered) air at a regulated pressure. The regulator must be capable of maintaining constant inlet pressure to the orifice / flow nozzle within + / - 0.2 psi (+ / - 0.0141 kg/cm^2).

Air Connection / Manifolding. The air supply system downstream of the flow orifice / nozzle (see item 3 below) must be leak-free. Any connection design geometry that provides a leak free system is acceptable, provided that the connection itself (a) does not impede air flow through the blade cooling system and (b) does not result in damage (scratches, dents, etc.) to the blade root plenum or dovetail serrations. Manifolding to permit simultaneous testing of multiple blades is permitted; however, the manifold system must have suitable provisions to ensure that the measured air flow is associated with only one blade. This may be accomplished by providing a separate flow orifice / nozzle in each branch line or by providing a single flow orifice / nozzle in the system header and including a positive shutoff valve in each branch line so that flow may be routed to only one blade at a time.

Flow Measurements. Unless approved otherwise, the total air flow rate shall be measured by an orifice flow meter or flow nozzle designed and installed to produce an accuracy of + / - 1 percent. In order to obtain the required test accuracy, flow straighteners and compensation for test air temperature and pressure are required. Airflow may be recorded in engineering units (lb/sec, kg/sec, SCFM, etc.) or as a system pressure that is directly proportional to airflow. Vendor shall obtain purchaser approval for the test stand configuration used and, for systems that do not display directly in engineering units, provide test system parameters that allow conversion of flow to engineering units.

Flow Criteria. Unless approved otherwise, the flow rate measured for each individual blade during the incoming air flow tests shall be used as a benchmark for the post coating flow tests. Both Incoming and Post Coating flow rates shall be recorded by blade serial number on Form

IV-B. The post coating flow rate for each blade shall be equal to the flow rate measured for that blade during the incoming air flow test within a tolerance of + / - 5 percent.

It is recognized that minimum to maximum flow rates measured across a full set of blades typically vary by as much as + / - 10 percent from the nominal flow rate for the set. The central purpose of this testing is to determine if the repair and recoating process has resulted in blockages that lower flow for individual blades by more that 5 percent from the values recorded during incoming inspection. It is reiterated that in the testing specified here, the flow recorded for each specific blade serial number at final inspection is compared to that recorded for the same serial number during incoming inspection.

It is also recognized that the incoming flow tests may reveal that some blades exhibit abnormally low flow rates (i.e., more than 10 percent lower than the nominal for the set). When this occurs, efforts should be made to find and clear blockages, etc., that may have caused flow restrictions and the blades retested. If the blockage cannot be cleared, the blades should be set aside and held until a disposition can be obtained from the purchaser.

Blade Testing. Connect blade to air supply source and open supply line. Ensure no air leaks are occurring in the system by conducting a soap/water solution “bubble” test at all connections downstream of the flow orifice/nozzle. Record the measured flow rate (or applicable system pressure for critical flow nozzle-based systems) on Form IV-B. Use the Comments section on the form to record any abnormal situations encountered or re-work / re-testing required.

Failures. Blades that exhibit flow rates outside the criteria in item 4 above shall be considered as failures. The repair vendor may attempt to open any cooling holes that appear to be blocked / partially blocked by one or more of the following steps: (a) back-flushing with a cleaning medium such as water or steam; (b) soaking using petroleum-based solvents (or other approved solvents) followed by back-flushing; (c) probing of individual exit holes using appropriately sized wires; (d) other method approved by purchaser. Any blade in which cleaning / back-flushing was attempted must be re-tested and results recorded on Form IV-B.

FORM IV-A

ALSTOM MODEL GT11N2 FIRST STAGE BLADE

WATER FLOW TEST RECORD SHEET

(PROCEDURE 1)

BLADE SERIAL NUMBER	**TEST RESULTS (PASS / FAIL)**	**COMMENTS**

Each blade must pass this water flow test before proceeding to the air flow tests (Procedure 2).

DATE:	INSPECTED BY:
OWNER:	PLANT:
UNIT DESIGNATION:	TURBINE S/N:
CHECK TYPE OF INSPECTION: ☐ INCOMING;	☐ AFTER REPAIR / COATING

FORM IV-B

ALSTOM MODEL GT11N2 FIRST STAGE BLADE

AIR FLOW TEST RECORD SHEET

(PROCEDURE 2)

BLADE SERIAL NUMBER	**INCOMING TESTS**	**POST COATING TESTS**		COMMENTS
	MEASURED FLOW (Or Pressure/ Flow Parameter)	**MEASURED FLOW (Or Pressure/ Flow Parameter)**	**RESULTS* (PASS OR FAIL)**	

*The post coating flow rate must match the incoming flow rate within + / - 5 percent.

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

6
REPAIR SPECIFICATION FOR ALSTOM MODEL GT11N2 SECOND STAGE TURBINE BLADES

1 SCOPE

1.1 Purpose.

This specification covers the minimum requirements for the repair and heat treatment of ALSTOM Model GT11N2 Second Stage Turbine Blades manufactured from Inconel 738LC alloy (Ni -16Cr – 8.5Co - 3.5Al – 3.5Ti – 2.6W – 1.8Mo – 1.75Ta – 0.9Cb - 0.11C – 0.055Zr – 0.0095B). An MCrAlY overlay coating, is applied to the blade airfoil and platform following repair to protect the substrate from oxidation and hot corrosion, as described in section 1.3. Blades repaired to these requirements should provide service life approaching that of new components. Sixty blades comprise a full set of second stage turbine blades.

1.2 Application.

Weld repair and blending of turbine blades is performed to repair physical damage such as rubbing, cracking and impact damage. Heat treatments are required prior to welding to improve ductility and after welding to stress relieve weldments and to restore the appropriate microstructure. Heat treatments associated with protective coatings are typically performed in conjunction with the blade postweld heat treatment. It should be noted that weld repair of IN738LC has proven difficult. For this reason, consideration should first be given to blending minor defects according to OEM blend limits or the blend limits in Table 1, reserving weld repairs for larger defects that cannot be blended. Straightening of deformed turbine blades is prohibited.

1.3 Blade Coating.

The OEM standard for external coatings has been an MCrAlY overlay on the blade airfoil and platform surfaces. This metallic overlay is reportedly applied by the vacuum plasma spray (VPS) process and is a NiCrAlY overlay designated as SV20.

As part of the blade refurbishment process, careful consideration must be made with regard to alternative coating systems to be applied. Industry experience has shown the High Velocity Oxy-Fuel (HVOF) process to be a viable and acceptable alternative to VPS for the application of overlay coatings. Alternative overlay coating chemistries may also be acceptable; however, careful consideration of comparative oxidation resistance and strain tolerance in cyclic service must be made (5.7).

2 DEFINITIONS & BLADE ILLUSTRATIONS

2.1 ALSTOM Model GT11N2 Second Stage Blade

Figures 1 and 2 are photographs of the blade pressure side and suction side respectively. Figure 3 shows a leading edge view of the blade. Figure 4 is a picture of the bottom of the blade root, showing the cooling air entrance point and the brazed-in closure plate (see note below). Figure 5 is a picture of the tip of the blade, showing one cooling air exit point. The GT11N2 second stage blade is a hollow, air-cooled blade. Cooling air enters the bottom of the blade, flows through a serpentine pathway, and exits through a hole in the tip and through a cut-back area on the pressure side of the airfoil, near the trailing edge tip. Internal turbulators are cast in to enhance heat transfer.

NOTE: The bottom of the root of this blade has a plate which is brazed in place to close off one of the original cast-in core penetrations. In order to preclude re-melt of the braze material, the heat treatments specified to be performed during refurbishment of these blades will be limited to below the full solution heat treatment temperature for IN738 (1190°C /2175°F). If the testing prescribed in paragraph 6.7 reveals significant microstructural deterioration of the material, it may be prudent to develop an alternate repair process which allows full solution heat treat temperatures, in order to restore proper microstructural properties in the base material. This alternate repair process would need to address the potential for braze re-melt, and would be subject to the first article inspection requirements outlined in section 7.1 of this document.

2.2 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 sub-groups for heat treatment, each sub-group shall constitute a lot.

2.3 E.D.M.

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

2.4 Linear Indications.

Non-destructive testing indications with a length of three times the width or greater. It is generally agreed that linear defects less than 0.38mm (0.015 inches) in length cannot be confirmed using conventional non-destructive testing techniques.

2.5 Non-linear Indications.

Non-destructive testing indications with a length of less than three times the width.

2.6 Through-Going Indications.

Non-destructive testing indications appearing directly opposite each other and apparently extending through the thickness of the section.

2.7 F.P.I.

Fluorescent Penetrant Inspection



Figure 6-1
OVERALL VIEW OF GT11N2 2nd STAGE BLADE, PRESSURE SIDE, SHOWING COOLING AIR EXIT AREA



Figure 6-2
OVERALL VIEW OF GT11N2 2nd STAGE BLADE, SUCTION SIDE



Figure 6-3
LEADING EDGE VIEW OF GT11N2 2nd STAGE BLADE



Figure 6-4
View of GT11N2 2nd Blade Root Showing Cooling Air Entry Point And Brazed-in Core Closure Plate



Figure 6-5
View of GT11N2 2nd Blade Tip Showing Cooling Air Exit Point

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.

ASTM 1417

"Inspection, Liquid Penetrant"

ASTM 1742

"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 Specifications 5837C

"Wire, Welding, Alloy- 62Ni 21.5Cr 9.0Mo 3.7(Cb +Ta)"

ASNT Recommended Practice No. SNT-TC-1A

"Personnel Qualification and Certification in Nondestructive Testing"

ANSI B46.1

"Surface Texture"

Aerospace Material Specifications 2430

"Shot Peening, Automatic"

Purchaser document BUCKMCrAlY_HVOF

"Specification for Application of MCrAlY Coatings on Industrial Gas Turbine Blades/Buckets Using the HVOF Thermal Spray Process".

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 for the repair / re-coating of gas turbine components are typically supplied in the Request for Proposal or Purchase Order, as applicable.

5 TECHNICAL REQUIREMENTS

5.1 Repair Materials

Unless qualified by the vendor and approved by the purchaser, repairs at the blade tip shall be performed by gas tungsten arc welding or plasma transferred arc welding using AMS 5837C (Alternate designations: Inconel 625, Alloy 625, UNS N06625), Waspaloy or Haynes 230 filler materials. Weld procedures and filler materials for repairs at the blade platform periphery require

specific purchaser approval (see Note below). Repairs in structural areas (e.g. airfoil below the tip) using advanced processes (such as laser powder fusion welding or micro plasma arc welding) and that employ filler materials that match (or more closely match) the blade alloy, when pre-qualified by vendor and approved by the purchaser, are allowed. Braze repair is not addressed in this specification and it may not be used without specific purchaser approval.

NOTE: Experience is still being gained with respect to the level of damage and the damage mechanisms at the blade platform periphery. The experience gained to date indicates that little to no platform damage is typical in this stage; however, guidance is offered in this document to address platform repairs if they are required on a specific set of blades. The solid solution weld fillers listed for repairs at the tip should be acceptable for minor nicks and dents along the platform edges that are within the allowable areas shown in Figure 6. Selecting the appropriate filler material for more serious damage, such as through wall cracking along the platform edges, should be accompanied by an analysis to determine the stress / temperature distribution and damage mechanism.

5.2 Blade Blend/Weld Repair Limits.

5.2.1 Unless approved otherwise between purchaser and supplier, minor defects may be blended (blend repaired) within the limits stated in Table 1. The blends must have a depth to length ratio of 1:8 minimum, and be smooth and gradual with no sharp edges remaining.

5.2.2 Surface oxidation/corrosion/alloy depletion on the airfoil surface may be blended out to the maximum depths outlined in Table 1. All surfaces to be coated must be metallurgically clean and free of all oxide and residual coating.

Blend repaired areas shall be fluorescent penetrant inspected to the requirements of 5.3.Unless approved otherwise between purchaser and supplier, weld repair limits shall be per Figure 6. All defects to be weld repaired must be fully removed prior to welding.

5.3 Non-Destructive Testing Acceptance Limits.

Linear indications of less than 1mm (0.040 inch) in length within ± 30 degrees of the radial direction and 0.76mm (0.030 inch) in all other directions are permitted within the weld repair limits identified in Table 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. Non-linear indications up to 0.76mm (0.030 inch) diameter or up to a diameter equal to 25% of the local section thickness, whichever is less, are permitted.

5.4 Dimensional Requirements

5.0.1 Tip height and squealer tip thickness dimensions shall be within the range identified on the forms attached as Appendix I.

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.

5.4.2 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 Cooling air exit and bleed hole sizes. Upon receipt the repair vendor shall check cooling air exit and bleed holes / slots on a typical blade in good condition and record the sizes for use as targets for others in the set. (If the nominal cooling / bleed hole sizes per OEM drawing requirement are known, these values shall be used instead of the measured target values.) Any cooling / bleed holes blocked during repair shall be restored to original dimensions and shall be checked for conformance with the target.

5.4.4 The minimum wall thickness (ligaments) between airfoil surfaces and internal cooling passages are critical dimensions that can govern repair / replacement decisions. The OEM typically provides some guidance on minimum acceptable ligaments for each blade design in the turbine instruction manuals. As specified in the forms in Appendix I, these ligaments are to be checked, recorded and compared to the minimum values recommended by the OEM. If recorded values closely approach the minimum values recommended by the OEM, vendor shall notify purchaser and obtain a repair / replace decision. Because more than one second stage blade design / cooling passage geometry may be operating in the GT11N2 fleet, specific minimum values are not included in the Appendix I forms. Ligament thickness shall be recorded at all airfoil locations where significant corrosion, erosion or foreign object damage has occurred.

NOTE: At this juncture, a generic method for recording blade wall thickness is specified in Appendix I, Form I-D. Specific locations on the blade airfoil for recording wall thickness are not currently specified. However, vendor and purchaser may agree on specific airfoil locations where wall thickness must be recorded. If no OEM wall thickness criteria are available, the values measured may be compared with those of a new blade and a judgment made on the severity of wall thinning and whether repairs are practical.

5.5 Mechanical Properties.

It is typically recommended that stress rupture bars be removed from the airfoil of a blade from the set being repaired and tested according to ASTM E-139. However, due to the limited wall (ligament) thickness available in the airfoil of the GT11N2 second stage blade, removal of specimens of a size to accommodate stress rupture testing is not practical. With this being the case, a thorough metallurgical analysis should be performed on a blade sacrificed from the set to be repaired. The metallurgical analysis should include electron microscopy (SEM or TEM) of the microstructural morphology of airfoil sample material that has been processed through the entire repair and heat treating processes. The size and morphology of the gamma prime phase as well as that of carbides should be determined and compared to that of new (un-serviced) IN738 material in the fully heat treated condition. A specimen extracted from the root of a blade may be used for this purpose. This metallurgical evaluation is recommended in lieu of stress rupture testing for this blade design. The assumption here is that, if heat treatments applied during the repair process result in a blade microstructure that is essentially equivalent to that of new IN738 material, then the blade mechanical properties should closely approach that of new IN738 material. Some guidance on metallurgical review of sample material is provided in Appendix III. Microstructural requirements are listed in paragraph 5.6.

5.6 Microstructural Requirements

5.6.1 The hold times and temperatures employed during thermal processing shall be held to minimum levels in order to minimize grain growth.

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

5.6.3 The re-cast layer on any E.D.M. surface shall not exceed 0.025mm (0.001 inch).

5.6.4 The microstructure shall be comparable to new material. The root section of an un-repaired blade may be used for comparison. Specifically, no continuous carbide films or needle phases shall be present after processing.

5.7 Coating Requirements.

The blade external protective coating shall be an MCrAlY overlay coating on the airfoils and platforms. Figure 6 outlines the extent of coating coverage. The OEM utilizes the Low Pressure Plasma Spray (LPPS) process to apply the MCrAlY, however, it is anticipated that some repair vendors will request approval to apply the MCrAlY using the High Velocity Oxy-Fuel (HVOF) process. If the HVOF process is to be used, the coating shall be performed according to purchaser specification BUCKMCrAlY_HVOF “Specification for Application of MCrAlY Coatings on Industrial Gas Turbine Blades / Buckets Using HVOF Thermal Spray Process”. If the coating is applied by LPPS, the coating process procedures and quality control requirements for the MCrAlY shall be defined by the vendor and approved by the purchaser. All coating process procedures and quality control requirements, including those used for the stripping of existing coatings, shall be qualified per the first article qualification procedures specified in paragraph 7.1.2. Materials used to deposit the overlay coating shall be approved by the Purchaser. Selection of the overlay coating shall be based on the level of contaminants contained in both the fuels and the ambient air. The level of aluminum in the overlay coating is an important consideration. Nominal compositions typically range from 8 to 12 weight percent. In

general, coatings with greater aluminum content offer better oxidation resistance, but also tend to be more brittle; therefore, the duty cycle of the engine (cycling duty or continuous operation) should be considered when specifying aluminum content. It should also be recognized that the level of elements in coating powders delivered from the manufacturers can typically vary by one to two percent from nominal values specified. Certificates of analysis for each lot of material used to coat components shall be maintained on file for a period of five years.

5.8 Cooling Passage Flow Test Requirements.

Unless otherwise specified or approved, the cooling passage flow testing procedure / requirements specified in Appendix IV shall be followed / met.

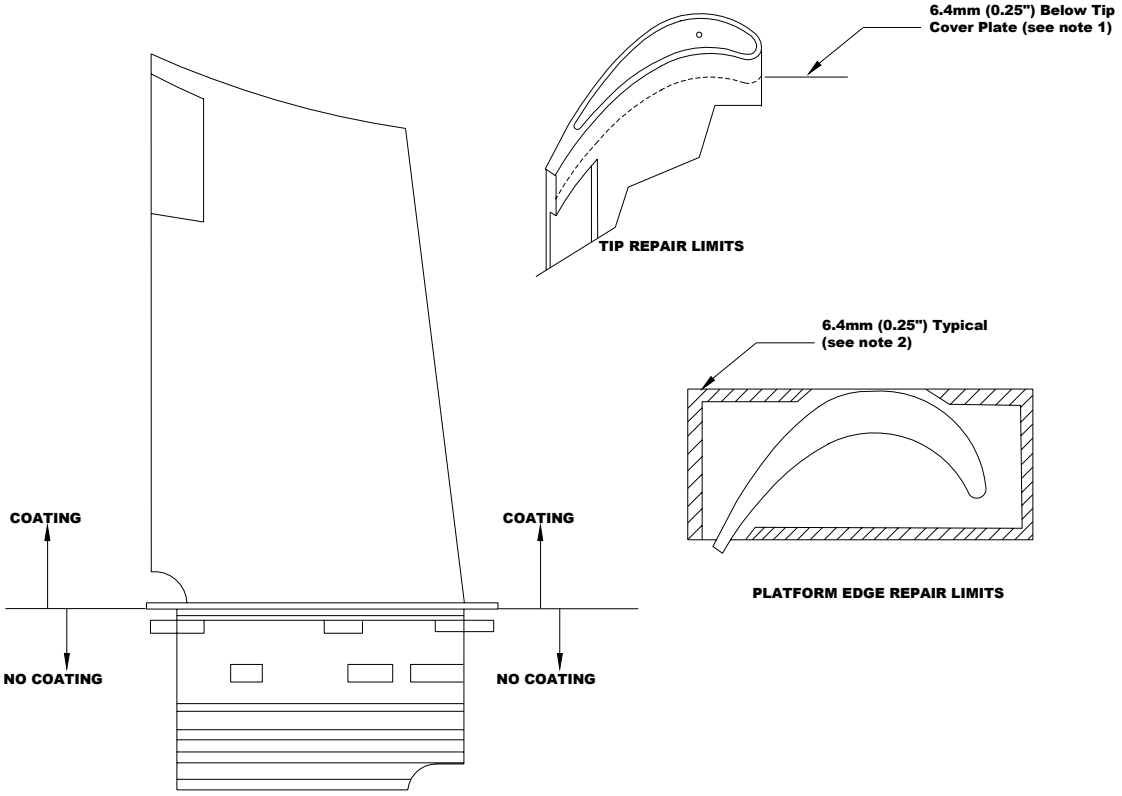
NOTE: Proper functioning of the blade cooling system is of critical importance in advanced technology turbine blades. For this reason, flow testing as described in Appendix IV is to be performed at (a) incoming inspection and (b) after all processing (i.e., following coating application).

Table 6-1
GT11N2 Row 2 Blade Blend Limits

DISCRIPTION	MAXIMUM BLENDING LIMITS
AREA: Upper 1/3 of Airfoil	
1. Tip Blend	max depth to top of tip cap X 25.4mm (1.0") maximum length.
2. Surface Blend	0.76mm (0.030") deep or 25% of design wall thickness, whichever is less
3. Trailing Edge Blend	4.1mm (0.170") maximum depth x 25.4mm (1.0") maximum length.
AREA: Lower 2/3 of Airfoil	
1. Surface Blend	0.5mm (0.020") deep or 10% of design wall thickness, whichever is less.
2. Trailing Edge Blend	1.5mm (0.06") maximum depth x 25.4mm (1.0") maximum length.
AREA: Blade Shank and Root	
1. Surface Blend	0.25mm (0.010") deep on shank and root end faces.
2. Root Blend	0.12mm (0.005") deep maximum. None on load bearing surfaces or fillet radii.

Note: All blends must have a depth to length ratio of 1:8 minimum, and shall be smooth and gradual with no sharp edges remaining.

Table 6-2
ALSTOM MODEL GT11N2
2nd STAGE BLADE WELD REPAIR LIMITS & COATING COVERAGE
NOTES FOR THIS FIGURE BEGIN BELOW AND CONTINUE ON THE NEXT PAGE



NOTES

1. In the tip area, the entire squealer tip wall may be repaired / rebuilt. From a structural standpoint, repair of radial cracks may extend into the airfoil down to 6.4mm (0.25 inches) below the tip cover plate. However, the following is offered as guidance when attempting to weld in the airfoil below the tip cover plate:

Welding a through wall crack from one side will require argon backing. Any welding process used should be qualified before production repairs are attempted and all welds in the airfoil below the tip cover plate should be radiographed after the post weld heat treatment (see 6.2.12).

Attempting to repair damage below the tip cover plate is expected to be problematic. Repairs of this nature should be reviewed on a case-by-case basis with the purchaser and would only be attempted in an effort to prevent retirement of blades that would otherwise be acceptable for extended service.

The crosshatched areas in Section A – A show the locations where platform repairs are allowed, however, the welding procedures and filler materials used for platform repairs require specific purchaser approval (SEE 5.1). In general, repairs along the edges may extend into the platform to

a depth of 6.4mm (0.25 inches); however, in no case should the repairs encroach into the airfoil to platform fillet areas. This will limit repairs to less than 6.4mm (0.25") in areas where fillets are near the edges (as shown at mid-chord on suction side and at the trailing edge).

Blade coating shall be an approved MCrAlY overlay coating on the airfoil and platform. See paragraphs 1.3 and 5.7.

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. Record blade serial numbers.

6.1.2 Advise purchaser immediately of any shipping damage.

6.1.3 Dimensionally inspect blades for:

- tip height (inspect all blades)
- squealer wall thickness (inspect 10% of lot)

Record the results using the forms attached as Appendix I. Tip height dimensions may be checked with a fixture provided the fixture allows actual dimensions to be recorded (i.e., pass / fail type results are not acceptable).

6.1.4 Visually inspect each blade for the following:

- tip rubs
- foreign object damage
- cracks
- surface oxidation, corrosion, erosion and coating loss

Record the results using the forms attached as Appendix II.

6.1.5 Non-destructively identify the alloy from which each blade is manufactured. If any alloy other than IN738 is identified, inform purchaser immediately.

6.1.6 Perform incoming blade cooling passage flow testing per Appendix IV. Record results by serial number. Inform purchaser and obtain disposition for any blades that exhibit cooling passage / exit hole blockage.

6.1.7 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 one which is damaged beyond repair limits. 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. Based on this evaluation, Recommendations / Decisions should be made for the blade set concerning repair/replace decisions. The balance of the material from this blade shall be saved for use as control material, as specified in 6.1.8.

6.1.8 Control material from the destructively examined blade or other IN738 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 5.5, 6.1.11 and 6.2.22. The control material for testing of paragraph 6.2.22 shall be processed through all thermal processing cycles (preweld heat treatment, postweld heat treatment, coating diffusion heat treatments and aging heat treatments).

6.1.9 Clean blades using grit blasting with 220 grit aluminum oxide. Avoid excessive blasting, particularly on the root, and ensure that the cooling passages are not plugged.

NOTE: Cooling passages can become filled with media during abrasive cleaning. It is imperative that the media be removed prior to any heat treatment since the passages 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.

Mask all internal surfaces and uncoated external surfaces to prevent base metal attack from stripping solutions.

Remove the coating by physical and chemical means, while ensuring no excessive base metal attack. Control samples of IN738 alloy shall be processed through any chemical stripping procedure (each stripping lot) and examined metallographically for surface attack, which shall not exceed the limits defined in 5.6.2. The use of coated IN738 material from a scrap blade from the set being repaired is strongly preferred for stripping control samples.

NOTE: The stripping procedures used to remove coatings on thin wall, serpentine cooled turbine blades is especially critical and, unless approved otherwise, must be qualified by the procedures for first article qualification as specified in paragraph 7.1.2. Damage due to excessive stripping chemical penetration can result in both stress risers and a significant reduction in base metal mechanical properties.

6.1.12. Each blade shall be examined for complete coating removal by heat tinting or etching.

6.1.13 F.P.I. all blades 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 using the 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 blade defects on one set of damage assessment forms.

6.1.14 Thoroughly clean components using an approved solvent cleaner or by other approved means such as steam cleaning or pressure spraying.

6.1.15 Inspect and record wall (ligament) thickness between airfoil surfaces and internal cooling passages on all blades per the instructions in 5.4.4 and Appendix I, Forms I-C, D and E.

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

- obtain written approval from the purchaser for any proposed changes to this specification, and

- obtain written or verbal authorization from the purchaser to proceed with the repairs.

6.2 Blade Repair Procedures

6.2.1 Unless approved otherwise, all process procedures applied during the repair of the blades 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.

6.2.2 Heat treat the blades in a vacuum of 1 micron ($1.3x10^{-3}$ millibar) or better at a temperature of 1120°C +/- 14°C (2050°F +/- 25°F) for 4 hours and Inert Gas Quench.. Fixture parts using only approved (7.1.2) fixture materials with the parts supported uniformly to prevent distortion. Avoid supporting the parts by any thin sections.

6.2.3 F.P.I. all blades following procedures outlined in paragraph 6.1.13. Document the location and extent of any defects not identified in paragraph 6.1.13 on the forms attached as Appendix II.

6.2.4 Prepare the areas of the blades to be repaired by removing the existing cracks / defects by abrasive grinding and F.P.I. to ensure the cracks are completely removed. Areas with defects outside the repair limits specified in Figure 6 can be blended to remove them within the manufacturer's blending limits. Grinding tools and procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.5 When requested, the purchaser shall be informed and allowed to inspect the components following weld preparation.

6.2.6 Weld repair the components using gas tungsten arc or plasma transferred arc welding methods and the filler metals identified in 5.1. Areas to be welded must be free of oxide, grease, dirt and penetrant chemicals. All welds must be performed using full penetration welds in the region being repaired. Unless specifically approved otherwise, weld repairs beyond the limits defined in Figure 6 are not allowed. 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. Grinding tools and procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.8 Restore to original dimensions any cooling holes plugged during repair. Check the restored passages to ensure they meet the requirements of paragraph 5.4.3.

6.2.9 F.P.I. the blades following procedures outlined in paragraph 6.1.13 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.

6.2.10 Parts that fail to meet the criteria of paragraph 5.3 may be recycled to repair any defects beginning at paragraph 6.2.4.

6.2.11 Vacuum heat treat the components to stress relieve the weldments using the cycle used in the original process qualification (7.1.2). Unless otherwise specified / approved by the purchaser, the following parameters shall be employed:

Post-weld stress relief/solution heat treat: 1120°C +/- 14°C (2050°F +/- 25°F) / 2 hours/ Inert Gas Quench.

6.2.12 Following the post-weld stress relief heat treatment, perform the following NDE procedures:

6.2.12.1 F.P.I. the entire blade using procedures outlined in paragraph 6.1.13 and the acceptance limits defined in 5.3. Record the results (pass/fail) by serial number.

6.2.12.2 Radiograph any welds made in the blade airfoil that extend below the squealer tip cover plate 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.

6.2.13 Parts that fail to meet the criteria of paragraph 5.3 may be recycled to repair any defects beginning at paragraph 6.2.4.

6.2.14 Thoroughly clean components using an approved solvent cleaner or by other approved means such as steam cleaning or pressure spraying.

6.2.15 Dimensionally check all blades to ensure conformance with paragraph 5.4. Record the results on the forms attached as Appendix I. Tip height dimensions may be checked with a Fixture provided the fixture allows actual dimensions to be recorded (i.e., pass / fail type results are not acceptable).

6.2.16 Apply the MCrAlY coating using only processes and coating compositions that have been specified or approved by the purchaser. Unless specified / approved otherwise, coatings shall be in accordance with paragraph 5.7. Component surfaces that are not to be coated shall be protected during the coating process using an appropriate mechanical mask or a suitable stop-off compound. The method used shall completely prevent coating build-up on the prohibited areas and shall be easily removed after coating. The base alloy shall be unaffected by the masking procedure, as demonstrated on a test coupon prior to process qualification. Procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.17 Vacuum heat treat to diffuse the overlay coating and to restore the IN738 mechanical properties using the cycle used in the original process qualification (7.1.2). Unless otherwise specified / approved by the purchaser, the heat treatment shall be as follows:

1120°C + / - 14°C (2050°F + / - 25°F) / 2 hours / Inert Gas Quench;

843°C + / - 14°C (1550°F + / - 25°F) / 24 hours / Fan cool to room temperature.

6.2.18 Inspect bond coat to ensure it meets the requirements of the approved coating specification and that parts are acceptable for application of the ceramic topcoat.

6.2.19 Perform final blade cooling passage flow testing per Appendix IV. Record results by serial number. Inform purchaser and obtain disposition for any blades that exhibit cooling passage / exit hole blockage or that do not meet the criteria for post coating flow rate. (See Appendix IV)

6.2.20 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.

6.2.21 Shot peen all dovetail serrations surfaces per AMS 2430 to Almen .008/.011A.

6.2.22 Production Control Tests. Metallographic samples of control material (see 6.1.8) from each lot of blades shall be prepared after all processing and examined for compliance with paragraphs 5.5 and 5.6. Failure of the metallographic specimens to meet the minimum requirements shall subject the entire lot to rejection.

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

6.2.24 Arrange a pre-shipment inspection with the purchaser to:

- review vendor's documentation including heat treat charts and Quality Control Test reports.

- visual inspection

6.2.25 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.

6.2.26 Advise purchaser of the shipping date, route and carrier, etc.

6.2.27 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 non-destructive 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 & 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 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) 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 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 five 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 which shall contain:

a) a mapping of all defects identified at paragraph 6.1.4, 6.1.13, 6.2.3 and 6.2.9. (Use form attached as Appendix II)

b) a copy of all incoming, in-process and final dimensional inspection forms (Use forms attached as Appendix I)

c) a copy of the final F.P.I. a copy of all cooling passage flow test reports (Use forms attached as Appendix IV)

e) a copy of the moment weight/computer sequence report

f) a copy of the certificate of compliance

g) a copy of all production control test results (include photocopies of microstructural / metallographic specimen photographs)

7.3 Acceptance and Disposition.

7.3.1 All deviant parts shall be plainly labeled in a non-destructive manner, isolated from the batch and held for purchaser disposition.

7.3.2 Blades not meeting the requirements of this specification, the purchase order, and referenced drawings, shall be rejected and held for purchaser disposition.

7.4 Access.

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

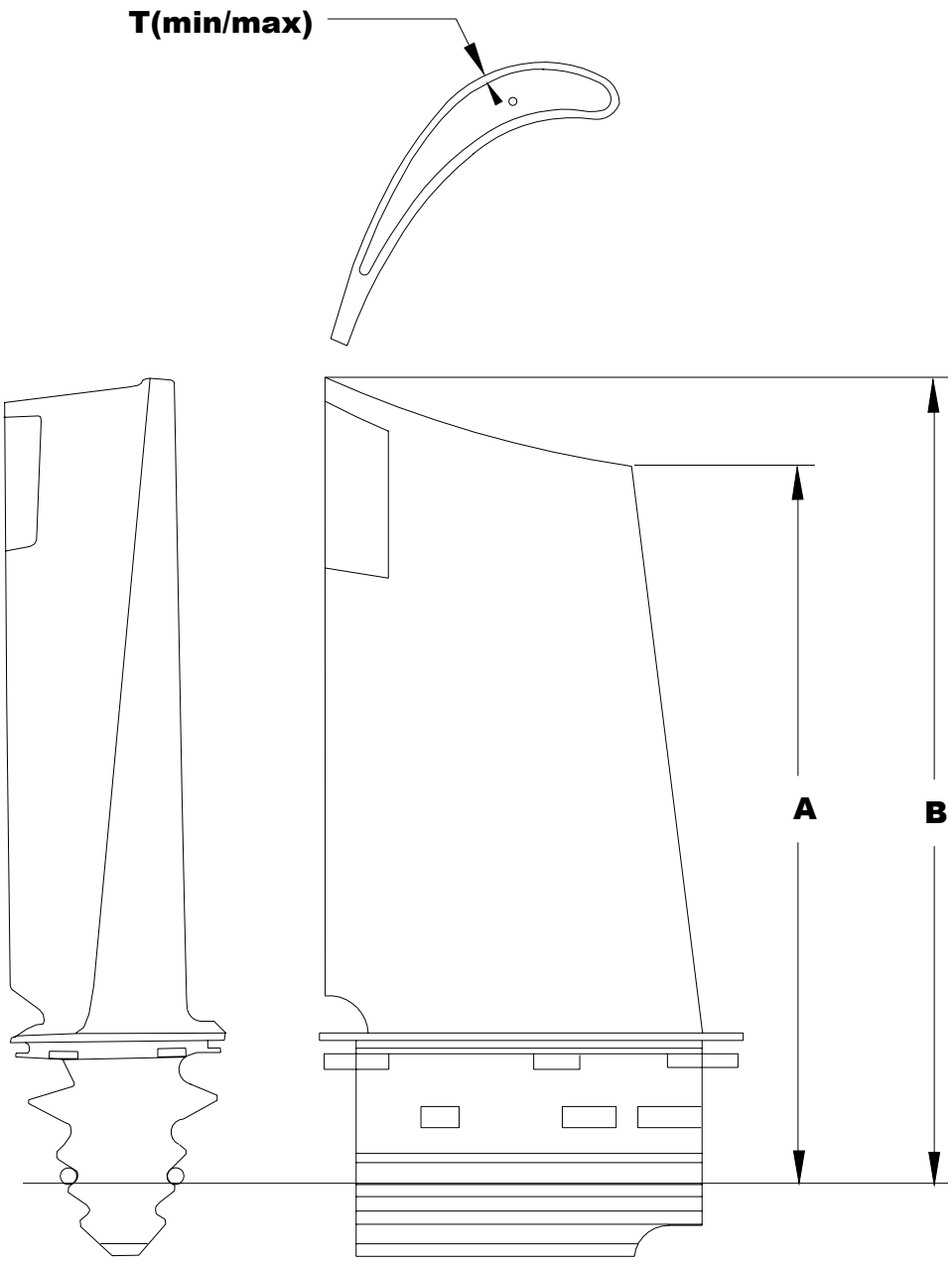
APPENDIX I - DIMENSIONAL INSPECTION FORMS

FORM I-A

ALSTOM GT11N2 SECOND STAGE BLADE

DIMENSIONAL INSPECTION FORM – EXTERNAL DIMENSIONS

RECORD MEASUREMENTS ON FORM I-B



FORM I-B

ALSTOM MODEL GT11N2 SECOND STAGE BLADE

DIMENSION SHEET – EXTERNAL DIMENSIONS

BLADE SERIAL NO.	**DIMENSIONS**		**SQUEALER WALL THICKNESS**	
	A	B	T	
			MIN.	MAX.
MINIMUM				
MAXIMUM				

PIN DIAMETER USED: _____

RECORDED DIMENSIONS ARE IN (Check one): ☐ INCHES ☐ MM

NOTES: 1. Measure T (Min. / Max.) on 10% of blades at incoming inspection.

2. Measure A and B on all blades at incoming and final inspections.

3. At final inspection, measure "T" (Min. / Max.) on all blades having tip repairs.

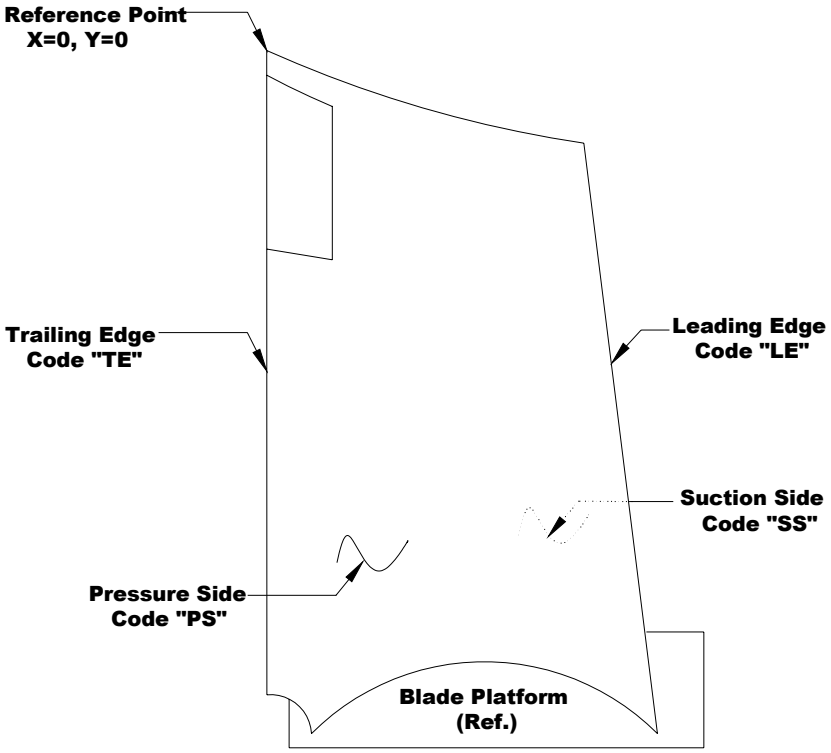
4. Checking Fixtures may be used, however, fixtures must allow recording of actual dimensions (not “Pass” or “Fail”).

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

FORM I-C

ALSTOM MODEL GT11N2 SECOND STAGE BLADE

DIMENSIONAL INSPECTION FORM – INSTRUCTIONS FOR RECORDING AIRFOIL WALL THICKNESS



Unless specified otherwise, airfoil wall thickness to be recorded on Form I-E using the method described here. Space (rows) is included on Form I-E for recording twelve (12) measurements on each blade. If additional measurements are made, continue in the spaces provided for the next blade and use a remark such as “ditto” or “same” in the blade Serial Number (S/N) column. In general, several measurements should be made near the leading and trailing edges and on both the pressure and suction sides of the airfoil; the goal is to record minimums. Measurements must be made in all areas where significant oxidation, corrosion, erosion or foreign object damage has occurred.

When recording wall thickness at or very near the leading or trailing edges, use the applicable code (LE or TE) and a “Y” dimension only (i.e., no X required). A tolerance of + / - 3mm (0.125”) is allowed on both X and Y. The X dimension is the distance measured along the contour (curvature) of the airfoil, as shown; i.e., not a straight line (chordal) distance.

For measurements made at airfoil locations other than the LE or TE, use location code PS or SS to indicate the pressure and suction sides of the airfoil and include both X and Y dimensions. Two examples are shown below for reference and the “Comments” shown are for defining the method. In practice, the “Comments” column should be used for descriptive information such as type of damage noted in the area (oxidation, foreign object, etc.) or other descriptive information that would be useful in understanding why the area was selected.

BLADE S/N	LOCATION CODE PS, SS, LE OR TE	X (in.)	Y (in.)	MEASURED WALL THICKNESS (in)	COMMENTS
12345 (Example)	LE	-	1.25	0.100	A wall thickness of 0.100 inches was measured at or very near the leading edge at a vertical location 1.25 inches below the blade tip.
	PS	2	3	0.070	A wall thickness of 0.070 inches was measured on the pressure side at a location 2 inches from the trailing edge and 3 inches below the tip.

FORM I-D
ALSTOM MODEL GT11N2 SECOND STAGE BLADE
DIMENSIONAL INSPECTION FORM – AIRFOIL WALL THICKNESS RECORD SHEET

BLADE S/N	LOCATION CODE PS, SS, LE OR TE	X (in.)	Y (in.)	MEASURED WALL THICKNESS (in.)	COMMENTS

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

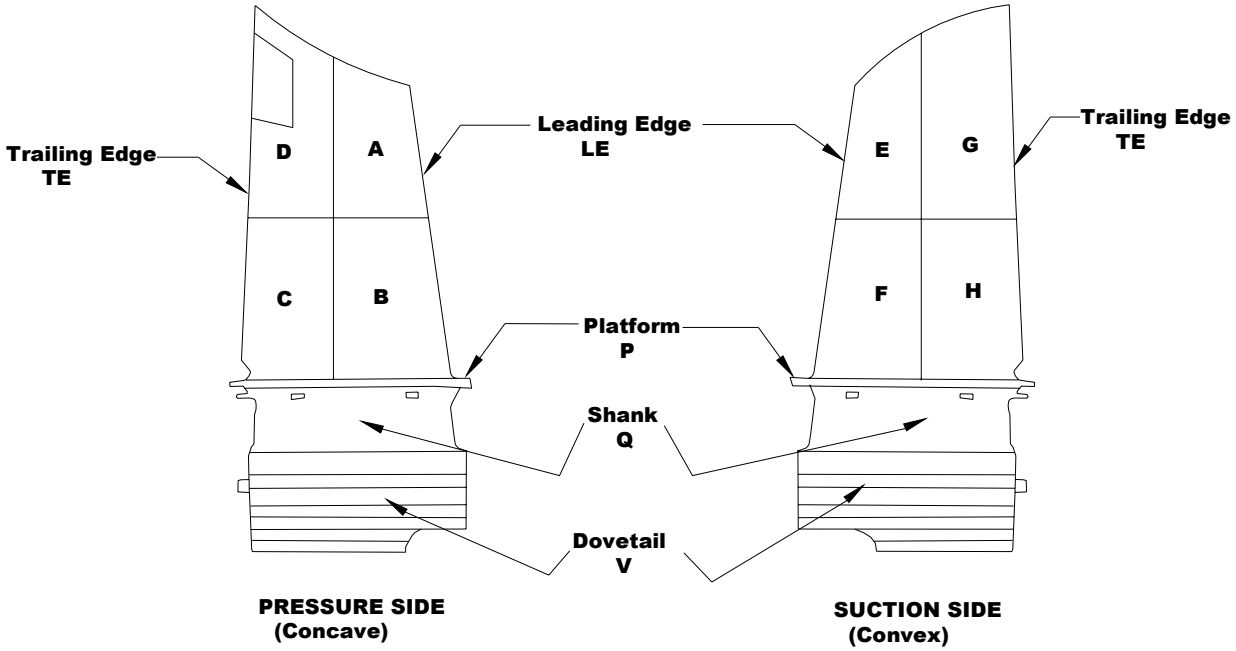
APPENDIX II - DAMAGE ASSESSMENT FORMS

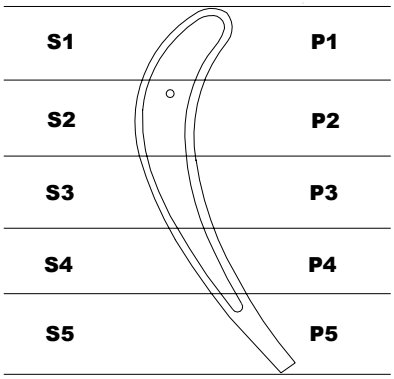
FORM II-A

ALSTOM MODEL GT11N2 SECOND STAGE BLADE

DAMAGE ASSESSMENT FORM – BLADE DAMAGE & LOCATION CODES

RECORD DEFECTS USING THE DAMAGE AND LOCATION CODES (ZONES) SHOWN
DAMAGE CODES: CR = CRACK IN RADIAL DIRECTION; CA = CRACK IN AXIAL DIRECTION;
D = DENT; T = TORN; PT = PUNCTURED; MM = MISSING MATERIAL;
OX = OXIDATION; C = CORROSION; E = EROSION; W = WEAR (RUBS) CL = COATING LOSS
SEE FORM II-B FOR NOTES / RECORD DATA ON FORM II-C





FORM II-B
ALSTOM MODEL GT11N2 SECOND STAGE BLADE
DAMAGE ASSESSMENT FORM – NOTES FOR RECORDING BLADE DAMAGE

Record all damage information on Form II-C. Duplicate the form as required to record all damage information for the blade set being inspected.

Record the serial number and the blade disk position (if known) for each blade.

Attach any photographs taken or lab analysis of corrosion to the set of forms.

Blade damage is to be documented in three (3) columns on Form II-C: “Cracks”, “Oxidation, Corrosion, Erosion or Wear”, and “Foreign Object Damage”. If additional space is required to complete damage information for a specific blade, continue with the information in the space provided for the next blade and show that it is a continuation using terms such as “ditto” or “same” in the Serial Number column.

Record the damage code first followed by the location code followed by the size or other description of the damage. Include descriptive information to further clarify locations, etc. Separate the codes and descriptions by slash marks. Several representative examples are given below.

Typical Crack Recording: For an axial crack approximately 0.25 inches in length located on the pressure side in squealer tip zone P5, record the damage as follows: CA / ST - P5 / 0.25”. For a 0.5 inch radial crack located on the pressure side airfoil in zone A near the axial center of the airfoil, record the damage as follows: CR / A, near mid-span / 0.5”. For a 0.25 inch long axial crack at the fifteenth (15th) trailing edge cooling slot below the tip, record the damage as follows: CA / TE at cooling slot 15 / 0.25”. For cracks in the leading edge, use the CA or CR code (as applicable), the location code “LE” and record the crack length and distance below the tip. State if the LE crack penetrates / starts at LE cooling holes.

Typical Oxidation, Corrosion, Erosion, Wear and Coating Loss Recording: Indicate the approximate dimension of the damage from the tip of the blade and use the applicable zone letters. Enter the radial height, axial width and approximate maximum depth of the damage. For an oxidized area approximately 1.5” below the tip that is 1 inch high by 2” wide by 0.010 “ deep on the pressure side airfoil in Zone A, record the damage as follows: OX / A-1.5” / 1”H X 2”W X 0.010” deep. Add additional comments as needed to further describe the damage such as “begins near LE”, etc.

Typical Foreign Object Damage Recording: Foreign object damage is recorded using the letter codes for Dents (D), Torn (T), Punctured (P, i.e., where the foreign object damage has penetrated into a cooling passage), or Missing Material (MM). Use the method for recording the locations and descriptive information similar to that used for Erosion / Corrosion. For a 0.5” diameter dent approximately 0.1 inches deep, near the leading edge on the pressure side at Zone C that is approximately 4” from the blade tip, record the damage as follows: D / C – 4”, near LE / 0.5” dia X 0.1” deep.

Blade Decision Codes: The last column on Form II-C (“DEC”) is reserved to record the decision made for each blade. Use the following codes:

WR = Repaired by welding

BR = Repaired by brazing (requires purchaser approval)

RN = Replaced with a new blade

N = No repair or replacement required

Use only lead free markers to mark blades.

FORM II-C

ALSTOM MODEL GT11N2 SECOND STAGE BLADE DAMAGE ASSESSMENT RECORD SHEET

BLADE S/N	BLADE POSITION	CRACKS	OXIDATION, CORROSION, EROSION OR WEAR	FOREIGN OBJECT DAMAGE	DEC

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

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 (i.e., 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 which appear visually to have surface damage. Internal surfaces of cooling passages should be examined in addition to the external surfaces.

The total depth of environmental attack should be measured. This should include:

i) remaining coating thickness

ii) the depth of any oxide layer,

ii) the depth of internal (cooling passage) oxidation,

iii) the depth of the alloy depleted zone,

iv) the depth of intergranular attack, and

v) an indication of the amount of metal lost due to oxidation/corrosion/erosion.

3. 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.

C. Microstructural Evaluation

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

Any deviations from normal microstructure should be noted.

APPENDIX IV - PROCEDURE FOR PERFORMING BLADE COOLING PASSAGE FLOW TESTING

Introduction

This appendix provides procedures to be used by blade repair vendors for testing cooling passage flows prior to and after repair of air cooled gas turbine blades. Two (2) types of procedures are required. These are summarized as follows:

Procedure 1: Qualitative pressurized water tests. This is a qualitative test procedure in that specific cooling passage flow rates are not measured / recorded. The purpose of this test is to determine by visual inspection that all blade cooling passages and exit holes / slots are unobstructed. It is conducted by connecting a pressurized water supply at the blade root plenum and visually inspecting to ensure that each cooling air exit hole / slot is passing water. Results for each blade tested are recorded as “Pass” or “Fail” on Form IV-A herein.

Procedure 2: Quantitative pressurized air flow tests. This is a quantitative test procedure in that cooling flow rates (lb/sec, kg/sec, cubic feet per minute, cubic meters per minute, etc.) or test stand pressures that are directly proportional to flow are measured and recorded. The purpose of this test is to determine if the blade cooling system has been affected by the repair and recoating processes. It is conducted by connecting a pressurized air supply at the blade root plenum and measuring the total air flow through each blade. Results for each blade are recorded on Form IV-B herein.

NOTE: There are numerous air flow test stand configurations that are acceptable for use in conducting this testing. Some test stands measure and display flow directly in engineering units (lb/sec, kg/sec, SCFM, etc.). Others, such as those that use a critical flow nozzle, measure and display system pressures which, as long as the nozzle is maintained at choke flow, are directly proportional to flow. The method used should be reviewed and approved by the purchaser prior to testing. Any test system used must meet the accuracy requirement listed in Section D below.

B. Test Sequence Requirements

Procedure 1 (qualitative water test) is a precursor to Procedure 2 (quantitative air flow test); i.e., successful completion of Procedure 1 is a prerequisite for proceeding to conduct Procedure 2. Both procedures are to be performed at (a) incoming inspection and (b) after completion of blade repair and re-coating.

C. Instructions for Conducting Qualitative Water Flow Tests (Procedure 1)

Water Supply. In most cases, tap water from the local water supply source may be used, however, it is strongly recommended that the water be pre-filtered and that piping downstream of the pre-filter be of non-corrosive material. The supply system should be thoroughly flushed prior to connecting blades for testing. Cooling air exit holes in GT11N2 blades are small in size and can potentially be clogged by particles entrained in the water source itself. Typical water supply pressures of 40 to 60 psig are satisfactory, however, a maximum water supply pressure of 100 psig should not be exceeded during the tests.

Water Connection / Manifolding. The water supply connection at the blade root plenum must be leak-free. Any connection design geometry that provides a leak free system is acceptable,

provided that the connection itself (a) does not prohibit complete visual inspection of the blade airfoil during the tests and (b) does not result in damage (scratches, dents, etc.) to the blade root plenum or dovetail serrations. Manifolding to permit simultaneous testing of multiple blades is permitted. Manifolds must be designed so that blades are either oriented or separated by a sufficient distance to ensure that the flow exiting each blade can be viewed independently; i.e., without mixing with or interference from flows exiting adjacent blades.

Blade Testing. Connect blades to water supply source and open supply line. Ensure that no leaks are occurring at the root plenum connection and supply piping. Carefully inspect and verify that each cooling air exit hole / slot is flowing freely. Record results (Pass / Fail) on Form IV-A. Note location of holes that are blocked or partially blocked in the Comments section of the form.

Failures. Blades that exhibit blocked are partially blocked cooling holes shall be considered as failures. The repair vendor may attempt to open cooling holes by one or more of the following steps: (a) back-flushing with a cleaning medium such as water or steam; (b) soaking using petroleum-based solvents (or other approved solvents) followed by back-flushing; (c) probing of individual exit holes / slots using appropriately sized wires; (d) other method approved by purchaser. All clogged or partially clogged blades must be re-tested following any attempt to clear passages and results recorded on Form IV-A. All blades that cannot be cleared shall be separated from the remaining lot and held for purchaser disposition.

Instructions for Conducting Quantitative Air Flow Tests (Procedure 2)

Air Supply. Testing shall be performed using clean (pre-filtered) air at a regulated pressure. The regulator must be capable of maintaining constant inlet pressure to the orifice / flow nozzle within + / - 0.2 psi (+ / - 0.0141 kg/cm^2).

Air Connection / Manifolding. The air supply system downstream of the flow orifice / nozzle (see item 3 below) must be leak-free. Any connection design geometry that provides a leak free system is acceptable, provided that the connection itself (a) does not impede air flow through the blade cooling system and (b) does not result in damage (scratches, dents, etc.) to the blade root plenum or dovetail serrations. Manifolding to permit simultaneous testing of multiple blades is permitted; however, the manifold system must have suitable provisions to ensure that the measured air flow is associated with only one blade. This may be accomplished by providing a separate flow orifice / nozzle in each branch line or by providing a single flow orifice / nozzle in the system header and including a positive shutoff valve in each branch line so that flow may be routed to only one blade at a time.

Flow Measurements. Unless approved otherwise, the total air flow rate shall be measured by an orifice flow meter or flow nozzle designed and installed to produce an accuracy of + / - 1 percent. In order to obtain the required test accuracy, flow straighteners and compensation for test air temperature and pressure are required. Airflow may be recorded in engineering units (lb/sec, kg/sec, SCFM, etc.) or as a system pressure that is directly proportional to airflow. Vendor shall obtain purchaser approval for the test stand configuration used and, for systems that do not display directly in engineering units, provide test system parameters that allow conversion of flow to engineering units.

Flow Criteria. Unless approved otherwise, the flow rate measured for each individual blade during the incoming air flow tests shall be used as a benchmark for the post coating flow tests. Both Incoming and Post Coating flow rates shall be recorded by blade serial number on Form

IV-B. The post coating flow rate for each blade shall be equal to the flow rate measured for that blade during the incoming air flow test within a tolerance of + / - 5 percent.

It is recognized that minimum to maximum flow rates measured across a full set of blades typically vary by as much as + / - 10 percent from the nominal flow rate for the set. The central purpose of this testing is to determine if the repair and recoating process has resulted in blockages that lower flow for individual blades by more that 5 percent from the values recorded during incoming inspection. It is reiterated that in the testing specified here, the flow recorded for each specific blade serial number at final inspection is compared to that recorded for the same serial number during incoming inspection.

It is also recognized that the incoming flow tests may reveal that some blades exhibit abnormally low flow rates (i.e., more than 10 percent lower than the nominal for the set). When this occurs, efforts should be made to find and clear blockages, etc., that may have caused flow restrictions and the blades retested. If the blockage cannot be cleared, the blades should be set aside and held until a disposition can be obtained from the purchaser.

Blade Testing. Connect blade to air supply source and open supply line. Ensure no air leaks are occurring in the system by conducting a soap/water solution “bubble” test at all connections downstream of the flow orifice/nozzle. Record the measured flow rate (or applicable system pressure for critical flow nozzle-based systems) on Form IV-B. Use the Comments section on the form to record any abnormal situations encountered or re-work / re-testing required.

Failures. Blades that exhibit flow rates outside the criteria in item 4 above shall be considered as failures. The repair vendor may attempt to open any cooling holes that appear to be blocked / partially blocked by one or more of the following steps: (a) back-flushing with a cleaning medium such as water or steam; (b) soaking using petroleum-based solvents (or other approved solvents) followed by back-flushing; (c) probing of individual exit holes using appropriately sized wires; (d) other method approved by purchaser. Any blade in which cleaning / back-flushing was attempted must be re-tested and results recorded on Form IV-B.

FORM IV-A

ALSTOM MODEL GT11N2 SECOND STAGE BLADE

WATER FLOW TEST RECORD SHEET

(PROCEDURE 1)

BLADE SERIAL NUMBER	**TEST RESULTS (PASS / FAIL)**	**COMMENTS**

Each blade must pass this water flow test before proceeding to the air flow tests (Procedure 2).

DATE:	INSPECTED BY:
OWNER:	PLANT:
UNIT DESIGNATION:	TURBINE S/N:
CHECK TYPE OF INSPECTION: ☐ INCOMING;	☐ AFTER REPAIR / COATING

FORM IV-B

ALSTOM MODEL GT11N2 SECOND STAGE BLADE

AIR FLOW TEST RECORD SHEET

(PROCEDURE 2)

BLADE SERIAL NUMBER	INCOMING TESTS	POST COATING TESTS		COMMENTS
	MEASURED FLOW (Or Pressure/ Flow Parameter)	MEASURED FLOW (Or Pressure/ Flow Parameter)	RESULTS* (PASS OR FAIL)	

*The post coating flow rate must match the incoming flow rate within + / - 5 percent.

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

7
REPAIR SPECIFICATION FOR ALSTOM MODEL GT11N2 THIRD STAGE TURBINE BLADES

1 SCOPE

1.1 Purpose

This specification covers the minimum requirements for the repair and heat treatment of ALSTOM Model GT11N2 Third Stage Turbine Blades manufactured from Inconel 738LC alloy (Ni -16Cr – 8.5Co - 3.5Al – 3.5Ti – 2.6W – 1.8Mo – 1.75Ta – 0.9Cb - 0.11C – 0.055Zr – 0.0095B). No coatings are utilized on this blade. Blades repaired to these requirements should provide service life approaching that of new components. Sixty blades comprise a full set of Third stage turbine blades.

1.2 Application.

Weld repair and blending of turbine blades is performed to repair physical damage such as rubbing, cracking and impact damage. Heat treatments are required prior to welding to improve ductility and after welding to stress relieve weldments and to restore the appropriate microstructure. It should be noted that weld repair of IN738LC has proven difficult. For this reason, consideration should first be given to blending minor defects according to OEM blend limits or the blend limits in Table 1, reserving weld repairs for larger defects that cannot be blended. Straightening of deformed turbine blades is prohibited.

2 DEFINITIONS & BLADE ILLUSTRATIONS

2.1 ALSTOM Model GT11N2 Third Stage Blade.

Figures 1 and 2 are photographs of the blade pressure side and suction side respectively. Figure 3 shows a leading edge view of the blade. Figure 4 is a picture of the tip of the blade. The GT11N2 Third stage blade is a solid, un-cooled blade.

2.2 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 sub-groups for heat treatment, each sub-group shall constitute a lot.

2.3 E.D.M.

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

2.4 Linear Indications.

Non-destructive testing indications with a length of three times the width or greater. It is generally agreed that linear defects less than 0.38mm (0.015 inches) in length cannot be confirmed using conventional non-destructive testing techniques.

2.5 Non-linear Indications.

Non-destructive testing indications with a length of less than three times the width.

2.6 Through-Going Indications.

Non-destructive testing indications appearing directly opposite each other and apparently extending through the thickness of the section.

2.7 F.P.I.

Fluorescent Penetrant Inspection



Figure 7-1
OVERALL VIEW OF GT11N2 3rd STAGE BLADE, PRESSURE SIDE



Figure 7-2
OVERALL VIEW OF GT11N2 3rd STAGE BLADE, SUCTION SIDE



Figure 7-3
LEADING EDGE VIEW OF GT11N2 3rd STAGE BLADE

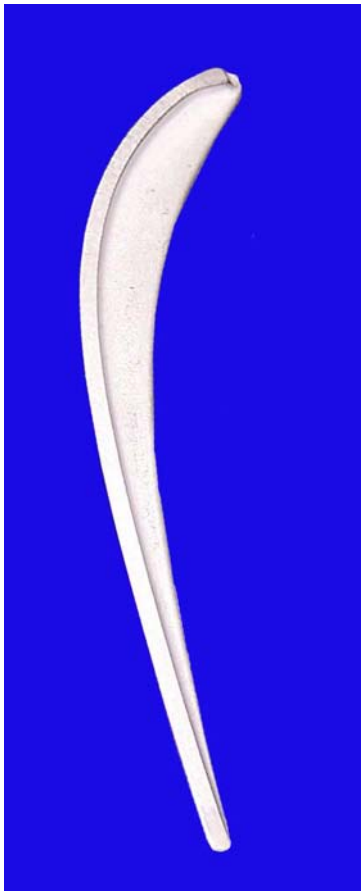


Figure 7-4
VIEW OF GT11N2 3rd STAGE BLADE TIP

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.

ASTM 1417

"Inspection, Liquid Penetrant"

ASTM 1742

"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 Specifications 5837C

"Wire, Welding, Alloy- 62Ni 21.5Cr 9.0Mo 3.7(Cb +Ta)”

ASNT Recommended Practice No. SNT-TC-1A

"Personnel Qualification and Certification in Nondestructive Testing"

ANSI B46.1

"Surface Texture"

Aerospace Material Specifications 2430

“Shot Peening, Automatic”

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 for the repair / re-coating of gas turbine components are typically supplied in the Request for Proposal or Purchase Order, as applicable.

5 TECHNICAL REQUIREMENTS

5.1 Repair Materials

Unless qualified by the vendor and approved by the purchaser, repairs at the blade tip shall be performed by gas tungsten arc welding or plasma transferred arc welding using AMS 5837C (Alternate designations: Inconel 625, Alloy 625, UNS N06625), Waspaloy or Haynes 230 filler materials. Weld procedures and filler materials for repairs at the blade platform periphery require specific purchaser approval (see Note below). Repairs in structural areas (e.g. airfoil below the tip) using advanced processes (such as laser powder fusion welding or micro plasma arc welding) and that employ filler materials that match (or more closely match) the blade alloy, when pre-qualified by vendor and approved by the purchaser, are allowed. Braze repair is not addressed in this specification and it may not be used without specific purchaser approval.

NOTE: Experience is still being gained with respect to the level of damage and the damage mechanisms at the blade platform periphery. The experience gained to date indicates that little to no platform damage is typical in this stage; however, guidance is offered in this document to address platform repairs if they are required on a specific set of blades. The solid solution weld fillers listed for repairs at the tip should be acceptable for minor nicks and dents along the platform edges that are within the allowable areas shown in Figure 5. Selecting the appropriate filler material for more serious damage, such as through wall cracking along the platform edges, should be accompanied by an analysis to determine the stress / temperature distribution and damage mechanism.

5.2 Blade Blend/Weld Repair Limits.

5.2.1 Unless approved otherwise between purchaser and supplier, minor defects may be blended (blend repaired) within the limits stated in Table 1. The blends must have a depth to length ratio of 1:8 minimum, and be smooth and gradual with no sharp edges remaining.

5.2.2 Surface oxidation/corrosion/alloy depletion on the airfoil surface may be blended out to the maximum depths outlined in Table 1. All surfaces must be metallurgically clean and free of all oxide and scale.

Blend repaired areas shall be fluorescent penetrant inspected to the requirements of 5.3.

Unless approved otherwise between purchaser and supplier, weld repair limits shall be per

Figure 5. All defects to be weld repaired must be fully removed prior to welding.

5.3 Non-Destructive Testing Acceptance Limits.

Linear indications of less than 1mm (0.040 inch) in length within ± 30 degrees of the radial direction and 0.76mm (0.030 inch) in all other directions are permitted within the weld repair limits identified in Table 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. Non-linear indications up to 0.76mm (0.030 inch) diameter or up to a diameter equal to 25% of the local section thickness, whichever is less, are permitted.

5.4 Dimensional Requirements

5.0.1 Tip height and squealer tip thickness dimensions shall be within the range identified on the forms attached as Appendix I.

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.

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

5.5 Mechanical Properties

It is typically recommended that stress rupture bars be removed from the airfoil of a blade from the set being repaired and tested according to ASTM E-139. Alternatively, a thorough metallurgical analysis should be performed on a blade sacrificed from the set to be repaired. The metallurgical analysis should include electron microscopy (SEM or TEM) of the microstructural morphology of airfoil sample material that has been processed through the entire repair and heat treating processes. The size and morphology of the gamma prime phase as well as that of carbides should be determined and compared to that of new (un-serviced) IN738 material in the fully heat treated condition. A specimen extracted from the root of a blade may be used for this purpose. This metallurgical evaluation is acceptable in lieu of stress rupture testing for this blade design. The assumption here is that, if heat treatments applied during the repair process result in a blade microstructure that is essentially equivalent to that of new IN738 material, then the blade mechanical properties should closely approach that of new IN738 material. Some guidance on metallurgical review of sample material is provided in Appendix III. Microstructural requirements are listed in paragraph 5.6.

5.6 Microstructural Requirements

5.6.1 The hold times and temperatures employed during thermal processing shall be held to minimum levels in order to minimize grain growth.

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

5.6.3 The re-cast layer on any E.D.M. surface shall not exceed 0.025mm (0.001 inch).

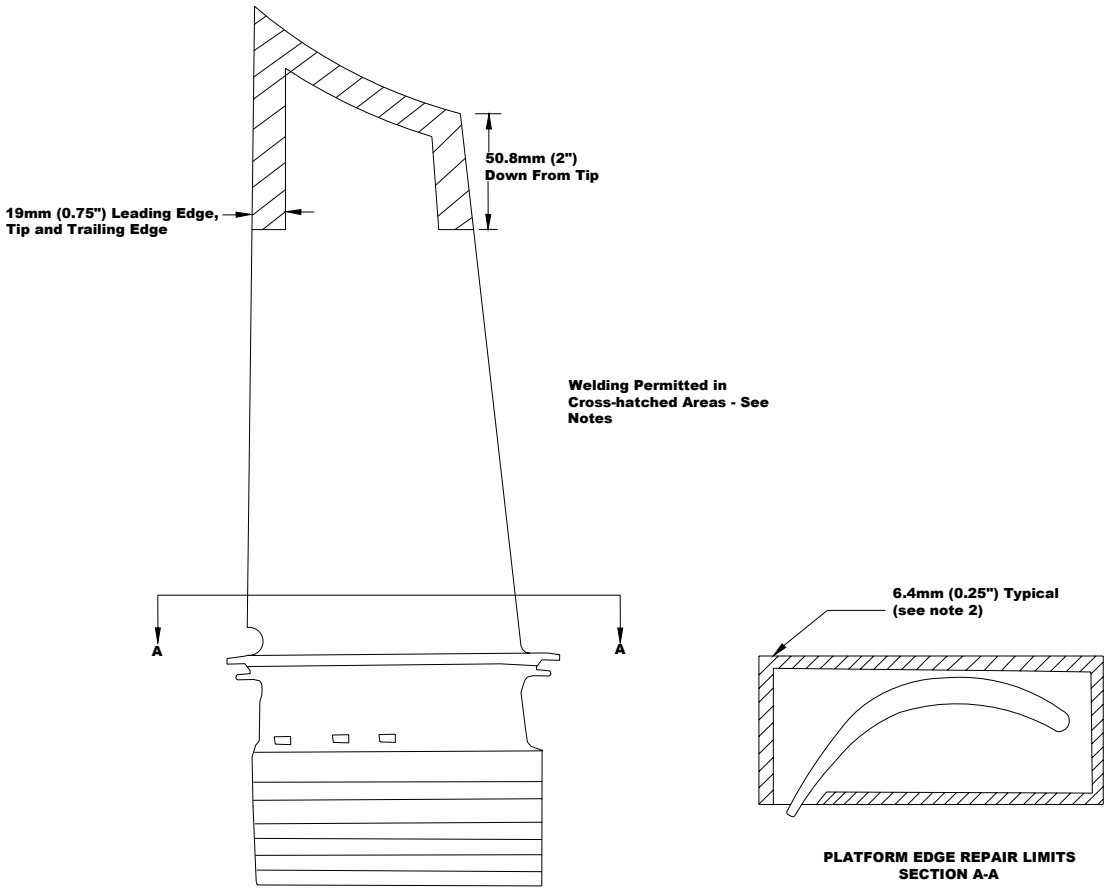
5.6.4 The microstructure shall be comparable to new material. The root section of an un-repaired blade may be used for comparison. Specifically, no continuous carbide films or needle phases shall be present after processing.

Table 7-1
GT11N2 Row 3 Blade Blend Limits

DESCRIPTION	MAXIMUM BLENDING LIMITS
AREA: Upper 1/3 of Airfoil	
1. Tip Blend	6.4 mm (0.250”) maximum depth x 50 mm (2.0") maximum length
2. Surface Blend	0.76 mm (0.030") deep or 25% of design wall thickness, whichever is less
3. Trailing Edge Blend	6.4 mm (0.250”) maximum depth x 50 mm (2.0") maximum length.
AREA: Lower 2/3 of Airfoil	
1. Surface Blend	0.5 mm (0.020") deep or 10% of design wall thickness, whichever is less
2. Trailing Edge Blend	2.3 mm (0.090") maximum depth x 25 mm (1.0") maximum length.
AREA: Blade Shank and Root	
1. Surface Blend	0.25mm (0.010") deep on shank and root end faces.
2. Root Blend	0.013 mm (0.005" deep maximum. None on load bearing surfaces or fillet radii.

Note: All blends must have a depth to length ratio of 1:8 minimum, and shall be smooth and gradual with no sharp edges remaining.

Figure 7-5
ALSTOM MODEL GT11N2
3rd STAGE BLADE WELD REPAIR LIMITS
NOTES FOR THIS FIGURE BEGIN BELOW AND CONTINUE ON THE NEXT PAGE



NOTES

1. In the tip area, the entire squealer tip wall may be repaired / rebuilt. From a structural standpoint, repair of radial cracks may extend into the airfoil down to 2 inches (50.8 mm) below the squealer tip. Any welding process used should be qualified before production repairs are attempted and all welds in the airfoil should be radiographed after the post weld heat treatment (see 6.2.11).

2. The crosshatched areas in Section A – A show the locations where platform repairs are allowed, however, the welding procedures and filler materials used for platform repairs require specific purchaser approval (See 5.1). In general, repairs along the edges may extend into the platform to a depth of 0.25 inches (6.4 mm); however, in no case should the repairs encroach into the airfoil to platform fillet areas. This will limit repairs to less than 0.25 inches in areas where fillets are near the edges (as shown at mid-chord on suction side and at the trailing edge).

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. Record blade serial numbers.

6.1.2 Advise purchaser immediately of any shipping damage.

6.1.3 Dimensionally inspect blades for tip height (inspect all blades).

Record the results using the forms attached as Appendix I. Tip height dimensions may be checked with a Fixture provided the fixture allows actual dimensions to be recorded (i.e., pass / fail type results are not acceptable).

6.1.4 Visually inspect each blade for the following:

- tip rubs
- foreign object damage
- cracks
- surface oxidation, corrosion, and erosion

Record the results using the forms attached as Appendix II.

6.1.5 Non-destructively identify the alloy from which each blade is manufactured. If any alloy other than IN-738 is identified, inform purchaser immediately.

6.1.6 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 one which is damaged beyond repair limits. 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. Based on this evaluation, Recommendations / Decisions should be made for the blade set concerning repair/replace decisions. The balance of the material from this blade shall be saved for use as control material, as specified in 6.1.7.

6.1.7 Control material from the destructively examined blade or other IN-738 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 5.5, 5.6 and 6.2.17. The control material for testing of paragraph 6.2.17 shall be processed through all thermal processing cycles (preweld heat treatment, postweld heat treatment, and aging heat treatments).

6.1.8 Clean blades using grit blasting with 220 grit aluminum oxide. Avoid excessive blasting, particularly on the root.

6.1.9 F.P.I. all blades 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 using the 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 blade defects on one set of damage assessment forms.

6.1.10 Thoroughly clean components using an approved solvent cleaner or by other approved means such as steam cleaning or pressure spraying.

6.1.11 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 specification,

- obtain written or verbal authorization from the purchaser to proceed with the repairs.

6.2 Blade Repair Procedures

6.2.1 Unless approved otherwise, all process procedures applied during the repair of the blades 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.

6.2.2 Heat treat the blades in a vacuum of 1 micron ($1.3x10^{-3}$ millibar) or better at a temperature of 1190°C + / - 14°C (2175°F + / - 25°F) for 4 hours and Inert Gas Quench.. Fixture parts using only approved (7.1.2) fixture materials with the parts supported uniformly to prevent distortion. Avoid supporting the parts by any thin sections.

6.2.3 F.P.I. all blades following procedures outlined in paragraph 6.1.9. Document the location and extent of any defects not identified in paragraph 6.1.9 on the forms attached as Appendix II.

6.2.4 Prepare the areas of the blades to be repaired by removing the existing cracks / defects by abrasive grinding and F.P.I. to ensure the cracks are completely removed. Areas with defects outside the repair limits specified in Figure 5 can be blended to remove them within the blending limits specified in Table 1. Grinding tools and procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.5 When requested, the purchaser shall be informed and allowed to inspect the components following weld preparation.

6.2.6 Weld repair the components using gas tungsten arc or plasma transferred arc welding methods and the filler metals identified in 5.1. Areas to be welded must be free of oxide, grease, dirt and penetrant chemicals. All welds must be performed using full penetration welds in the region being repaired. Unless specifically approved otherwise, weld repairs beyond the limits defined in Figure 5 are not allowed. 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. Grinding tools and procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.8 F.P.I. the blades following procedures outlined in paragraph 6.1.9 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.

6.2.9 Parts that fail to meet the criteria of paragraph 5.3 may be recycled to repair any defects beginning at paragraph 6.2.4.

6.2.10 Thoroughly degrease components using approved solvent cleaner or other approved methods such as steam cleaning or pressure washing.

6.2.11 Vacuum heat treat to stress relieve the weldments /solution anneal the microstructure using the cycle used in the original process qualification (7.1.2). Unless otherwise specified / approved by the purchaser, the heat treatment shall be as follows:

1190°C + / - 14°C (2175°F + / - 25°F) / 2 hours / Inert Gas Quench;

NOTE: This heat treatment step is not required if no welding was performed, and the full solution heat treatment step was previously performed at step 6.2.2.

6.2.12 Immediately following heat treatment (if performed) and before any surface cleaning or blasting, liquid penetrant inspect the blades using the method outlined in paragraph 6.1.9 and acceptance criteria outlined in paragraph 5.3. Record the results on the forms attached as Appendix II.

6.2.13 Vacuum heat treat to restore the base material mechanical properties using the cycle used in the original process qualification (7.1.2). Unless otherwise specified / approved by the purchaser, the heat treatment shall be as follows:

1120°C + / - 14°C (2050°F + / - 25°F) / 2 hours / Inert Gas Quench;

843°C + / - 14°C (1550°F + / - 25°F) / 24 hours / Fan cool to room temperature.

6.2.14 Immediately following heat treatment and prior to any surface cleaning or blasting, perform the following NDE procedures:

6.2.14.1 F.P.I. the entire blade using procedures outlined in paragraph 6.1.9 and the acceptance limits defined in 5.3. Record the results (pass/fail) by serial number.

6.2.14.2 Radiograph any welds made in the blade airfoil that extend below the squealer tip 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.

6.2.15 Parts that fail to meet the criteria of paragraph 5.3 may be recycled to repair any defects beginning at paragraph 6.2.4.

6.2.16 Thoroughly clean components using an approved solvent cleaner or by other approved means such as steam cleaning or pressure spraying.

6.2.17 Dimensionally check all blades to ensure conformance with paragraph 5.4. Record the results on the forms attached as Appendix I. Tip height dimensions may be checked with a Fixture provided the fixture allows actual dimensions to be recorded (i.e., pass / fail type results are not acceptable).

6.2.18 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.

6.2.19 Shot peen all dovetail serrations surfaces per AMS 2430 to Almen .008/.011A.

6.2.20 Production Control Tests. Metallographic samples of control material (see 6.1.7) from each lot of blades shall be prepared after all processing and examined for compliance with paragraphs 5.5 and 5.6. Failure of the metallographic specimens to meet the minimum requirements shall subject the entire lot to rejection.

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

6.2.22 Arrange a pre-shipment inspection with the purchaser to:

- review vendor's documentation including heat treat charts and Quality Control Test reports.

- visual inspection

6.2.23 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.

6.2.24 Advise purchaser of the shipping date, route and carrier, etc.

6.2.25 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 non-destructive 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 & 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 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) 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 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 five 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 which shall contain:

a) a mapping of all defects identified at paragraphs 6.1.4, 6.1.9, 6.2.3 and 6.2.8. (Use form attached as Appendix II)

b) a copy of all incoming, in-process and final dimensional inspection forms (Use forms attached as Appendix I)

c) a copy of the final F.P.I.

d) a copy of the moment weight/computer sequence report

e) a copy of the certificate of compliance

f) a copy of all production control test results (include photocopies of microstructural / metallographic specimen photographs)

7.3 Acceptance and Disposition.

7.3.1 All deviant parts shall be plainly labeled in a non-destructive manner, isolated from the batch and held for purchaser disposition.

7.3.2 Blades not meeting the requirements of this specification, the purchase order, and referenced drawings, shall be rejected and held for purchaser disposition.

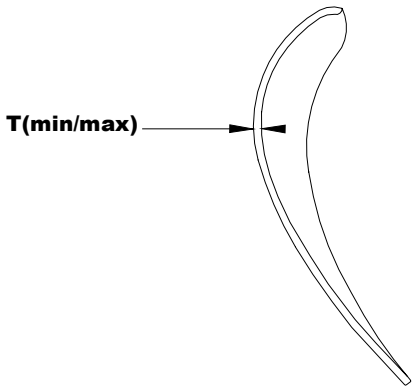
7.4 Access.

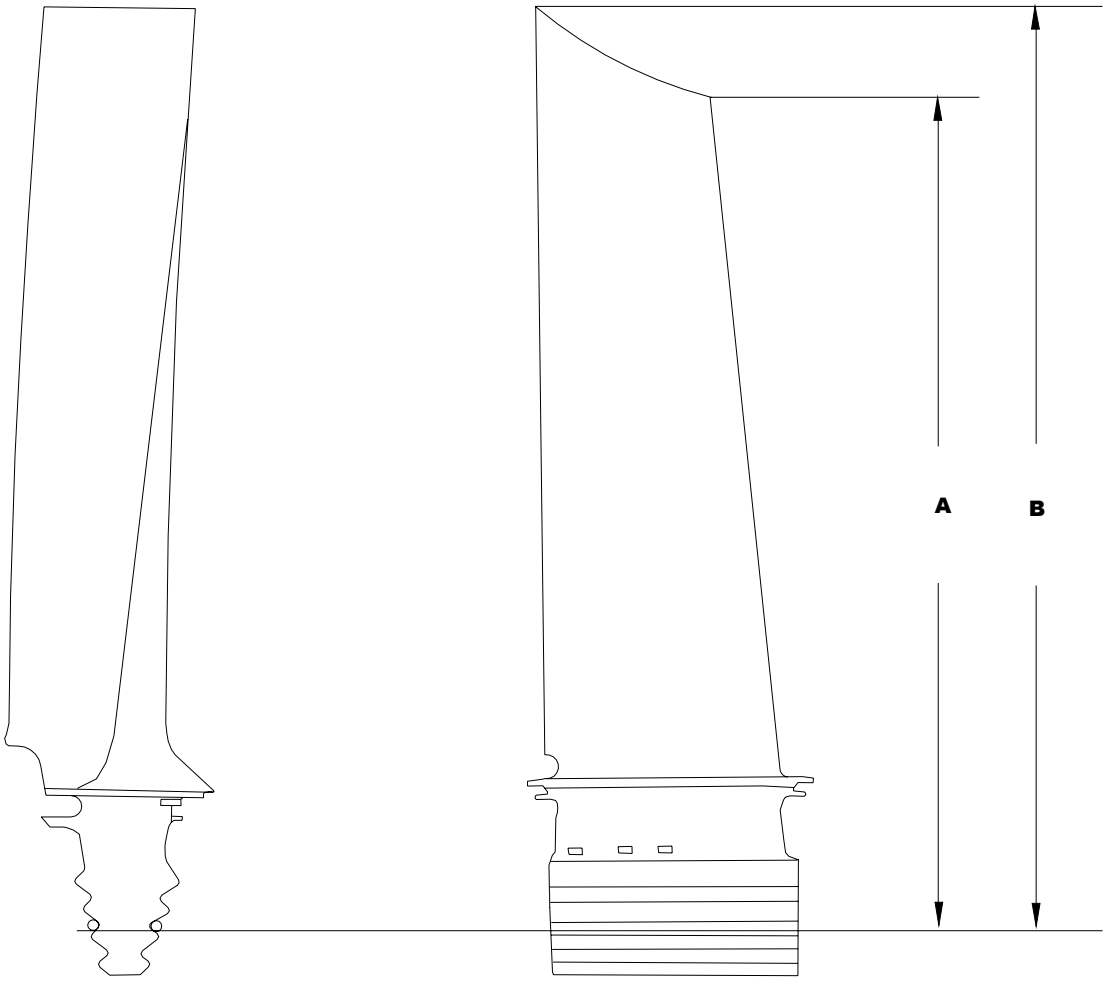
The purchaser shall be allowed reasonable access to inspect components at all times during the repair process.

APPENDIX I - DIMENSIONAL INSPECTION FORMS

FORM I-A

ALSTOM GT11N2 THIRD STAGE BLADE
DIMENSIONAL INSPECTION FORM – EXTERNAL DIMENSIONS
RECORD MEASUREMENTS ON FORM I-B





FORM I-B

ALSTOM MODEL GT11N2 THIRD STAGE BLADE

DIMENSION SHEET – EXTERNAL DIMENSIONS

BLADE SERIAL NO.	**DIMENSIONS**		**SQUEALER WALL THICKNESS**	
	A	B	T	
			MIN.	MAX.
MINIMUM				
MAXIMUM				

PIN DIAMETER USED: _____

RECORDED DIMENSIONS ARE IN (Check one): ☐ INCHES ☐ MM

NOTES: 1. Measure T (Min. / Max.) on 10% of blades at incoming inspection.

2. Measure A and B on all blades at incoming and final inspections.

3. At final inspection, measure "T" (Min. / Max.) on all blades having tip repairs.

4. Checking Fixtures may be used, however, fixtures must allow recording of actual dimensions (not “Pass” or “Fail”).

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

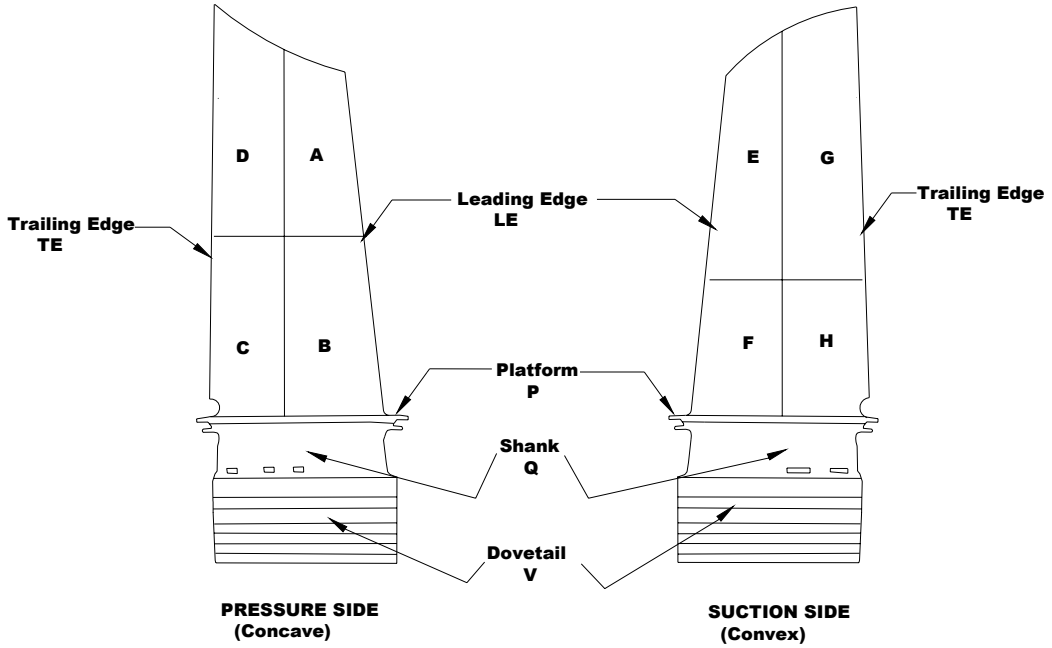
APPENDIX II - DAMAGE ASSESSMENT FORMS

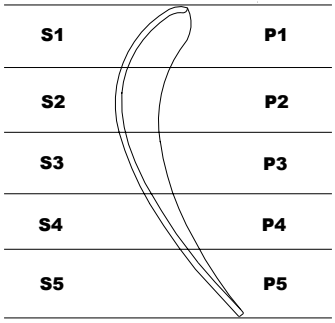
FORM II-A

ALSTOM MODEL GT11N2 THIRD STAGE BLADE

DAMAGE ASSESSMENT FORM – BLADE DAMAGE & LOCATION CODES

RECORD DEFECTS USING THE DAMAGE AND LOCATION CODES (ZONES) SHOWN
DAMAGE CODES: CR = CRACK IN RADIAL DIRECTION; CA = CRACK IN AXIAL DIRECTION;
D = DENT; T = TORN; PT = PUNCTURED; MM = MISSING MATERIAL;
OX = OXIDATION; C = CORROSION; E = EROSION; W = WEAR (RUBS) CL = COATING LOSS
SEE FORM II-B FOR NOTES / RECORD DATA ON FORM II-C





SQUEALER TIP DAMAGE LOCATION ZONES

FORM II-B
ALSTOM MODEL GT11N2 THIRD STAGE BLADE
DAMAGE ASSESSMENT FORM – NOTES FOR RECORDING BLADE DAMAGE

Record all damage information on Form II-C. Duplicate the form as required to record all damage information for the blade set being inspected.

Record the serial number and the blade disk position (if known) for each blade.

Attach any photographs taken or lab analysis of corrosion to the set of forms.

Blade damage is to be documented in three (3) columns on Form II-C: "Cracks", "Oxidation, Corrosion, Erosion or Wear", and "Foreign Object Damage". If additional space is required to complete damage information for a specific blade, continue with the information in the space provided for the next blade and show that it is a continuation using terms such as "ditto" or "same" in the Serial Number column.

Record the damage code first followed by the location code followed by the size or other description of the damage. Include descriptive information to further clarify locations, etc. Separate the codes and descriptions by slash marks. Several representative examples are given below.

Typical Crack Recording: For an axial crack approximately 0.25 inches in length located on the pressure side in squealer tip zone P5, record the damage as follows: CA / ST - P5 / 0.25". For a 0.5 inch radial crack located on the pressure side airfoil in zone A near the axial center of the airfoil, record the damage as follows: CR / A, near mid-span / 0.5". For a 0.25 inch long axial crack at the fifteenth (15th) trailing edge cooling slot below the tip, record the damage as follows: CA / TE at cooling slot 15 / 0.25". For cracks in the leading edge, use the CA or CR code (as applicable), the location code "LE" and record the crack length and distance below the tip. State if the LE crack penetrates / starts at LE cooling holes.

Typical Oxidation, Corrosion, Erosion, and Wear Recording: Indicate the approximate dimension of the damage from the tip of the blade and use the applicable zone letters. Enter the radial height, axial width and approximate maximum depth of the damage. For an oxidized area approximately 1.5" below the tip that is 1 inch high by 2" wide by 0.010 " deep on the pressure side airfoil in Zone A, record the damage as follows: OX / A-1.5" / 1"H X 2"W X 0.010" deep. Add additional comments as needed to further describe the damage such as "begins near LE", etc.

Typical Foreign Object Damage Recording: Foreign object damage is recorded using the letter codes for Dents (D), Torn (T), Punctured (P, i.e., where the foreign object damage has penetrated into a cooling passage), or Missing Material (MM). Use the method for recording the locations and descriptive information similar to that used for Erosion / Corrosion. For a 0.5" diameter dent approximately 0.1 inches deep, near the leading edge on the pressure side at Zone C that is approximately 4" from the blade tip, record the damage as follows: D / C – 4", near LE / 0.5" dia X 0.1" deep.

Blade Decision Codes: The last column on Form II-C ("DEC") is reserved to record the decision made for each blade. Use the following codes:

WR = Repaired by welding

BR = Repaired by brazing (requires purchaser approval)

RN = Replaced with a new blade

N = No repair or replacement required

Use only lead free markers to mark blades.

FORM II-C

ALSTOM MODEL GT11N2 THIRD STAGE BLADE DAMAGE ASSESSMENT RECORD SHEET

BLADE S/N	**BLADE POSITION**	**CRACKS**	**OXIDATION, CORROSION, EROSION OR WEAR**	**FOREIGN OBJECT DAMAGE**	**DEC**

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

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 (i.e., 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 which appear visually to have surface damage. Internal surfaces of cooling passages should be examined in addition to the external surfaces.

The total depth of environmental attack should be measured. This should include:

i) remaining coating thickness

ii) the depth of any oxide layer,

ii) the depth of internal (cooling passage) oxidation,

iii) the depth of the alloy depleted zone,

iv) the depth of intergranular attack, and

v) an indication of the amount of metal lost due to oxidation/corrosion/erosion.

3. 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.

C. Microstructural Evaluation

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

Any deviations from normal microstructure should be noted.

8
REPAIR SPECIFICATION FOR ALSTOM MODEL GT11N2 - FOURTH STAGE TURBINE BLADES

1 SCOPE

1.1 Purpose

This specification covers the minimum requirements for the repair and heat treatment of ALSTOM Model GT11N2 Fourth Stage Turbine Blades manufactured from Inconel 738LC alloy (Ni -16Cr – 8.5Co - 3.5Al – 3.5Ti – 2.6W – 1.8Mo – 1.75Ta – 0.9Cb - 0.11C – 0.055Zr – 0.0095B). No coatings are utilized on this blade. Blades repaired to these requirements should provide service life approaching that of new components. Sixty blades comprise a full set of Fourth stage turbine blades.

1.2 Application

Weld repair and blending of turbine blades is performed to repair physical damage such as rubbing, cracking and impact damage. Heat treatments are required prior to welding to improve ductility and after welding to stress relieve weldments and to restore the appropriate microstructure. It should be noted that weld repair of IN738LC has proven difficult. For this reason, consideration should first be given to blending minor defects according to OEM blend limits or the blend limits in Table 1, reserving weld repairs for larger defects that cannot be blended. Straightening of deformed turbine blades is prohibited.

2 DEFINITIONS & BLADE ILLUSTRATIONS

2.1 ALSTOM Model GT11N2 Fourth Stage Blade

Figures 1 and 2 are photographs of the blade pressure side and suction side respectively. Figure 3 is a picture of the tip of the blade. The GT11N2 Fourth stage blade is a solid, un-cooled blade. Each blade has two holes below the tip for blade-to-blade damping pins. Fretting wear in these holes is quite typical on service-run blades.

2.2 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 sub-groups for heat treatment, each sub-group shall constitute a lot.

2.3 E.D.M.

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

2.4 Linear Indications.

Non-destructive testing indications with a length of three times the width or greater. It is generally agreed that linear defects less than 0.38mm (0.015 inches) in length cannot be confirmed using conventional non-destructive testing techniques.

2.5 Non-linear Indications.

Non-destructive testing indications with a length of less than three times the width.

2.6 Through-Going Indications.

Non-destructive testing indications appearing directly opposite each other and apparently extending through the thickness of the section.

2.7 F.P.I.

Fluorescent Penetrant Inspection



Figure 8-1
OVERALL VIEW OF GT11N2 4th STAGE BLADE, PRESSURE SIDE



Figure 8-2
OVERALL VIEW OF GT11N2 4th STAGE BLADE, SUCTION SIDE



Figure 8-3
VIEW OF GT11N2 4th STAGE BLADE TIP

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.

ASTM 1417

"Inspection, Liquid Penetrant"

ASTM 1742

"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 Specifications 5837C

"Wire, Welding, Alloy- 62Ni 21.5Cr 9.0Mo 3.7(Cb +Ta)”

ASNT Recommended Practice No. SNT-TC-1A

"Personnel Qualification and Certification in Nondestructive Testing"

ANSI B46.1

"Surface Texture"

Aerospace Material Specifications 2430

“Shot Peening, Automatic”

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 for the repair / re-coating of gas turbine components are typically supplied in the Request for Proposal or Purchase Order, as applicable.

5 TECHNICAL REQUIREMENTS

5.1 Repair Materials

Unless qualified by the vendor and approved by the purchaser, repairs at the blade tip shall be performed by gas tungsten arc welding or plasma transferred arc welding using AMS 5837C (Alternate designations: Inconel 625, Alloy 625, UNS N06625), Waspaloy or Haynes 230 filler materials. Weld procedures and filler materials for repairs at the blade platform periphery require specific purchaser approval (see Note below). Repairs in structural areas (e.g. airfoil below the tip) using advanced processes (such as laser powder fusion welding or micro plasma arc welding) and that employ filler materials that match (or more closely match) the blade alloy, when pre-qualified by vendor and approved by the purchaser, are allowed. Braze repair is not addressed in this specification and it may not be used without specific purchaser approval.

NOTE: Experience is still being gained with respect to the level of damage and the damage mechanisms at the blade platform periphery. The experience gained to date indicates that little to no platform damage is typical in this stage; however, guidance is offered in this document to address platform repairs if they are required on a specific set of blades. The solid solution weld fillers listed for repairs at the tip should be acceptable for minor nicks and dents along the platform edges that are within the allowable areas shown in Figure 4. Selecting the appropriate filler material for more serious damage, such as through wall cracking along the platform edges, should be accompanied by an analysis to determine the stress / temperature distribution and damage mechanism.

5.2 Blade Blend/Weld Repair Limits.

5.2.1 Unless approved otherwise between purchaser and supplier, minor defects may be blended (blend repaired) within the limits stated in Table 1. The blends must have a depth to length ratio of 1:8 minimum, and be smooth and gradual with no sharp edges remaining.

5.2.2 Surface oxidation/corrosion/alloy depletion on the airfoil surface may be blended out to the maximum depths outlined in Table 1. All surfaces must be metallurgically clean and free of all oxide and scale.

Blend repaired areas shall be fluorescent penetrant inspected to the requirements of 5.3.

Unless approved otherwise between purchaser and supplier, weld repair limits shall be per

Figure 4. All defects to be weld repaired must be fully removed prior to welding.

5.3 Non-Destructive Testing Acceptance Limits.

Linear indications of less than 1mm (0.040 inch) in length within ± 30 degrees of the radial direction and 0.76mm (0.030 inch) in all other directions are permitted within the weld repair limits identified in Table 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. Non-linear indications up to 0.76mm (0.030 inch) diameter or up to a diameter equal to 25% of the local section thickness, whichever is less, are permitted.

5.4 Dimensional Requirements

5.0.1 Tip height and squealer tip thickness dimensions shall be within the range identified on the forms attached as Appendix I.

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.

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

5.5 Mechanical Properties

It is typically recommended that stress rupture bars be removed from the airfoil of a blade from the set being repaired and tested according to ASTM E-139. Alternatively, a thorough metallurgical analysis should be performed on a blade sacrificed from the set to be repaired. The metallurgical analysis should include electron microscopy (SEM or TEM) of the microstructural morphology of airfoil sample material that has been processed through the entire repair and heat treating processes. The size and morphology of the gamma prime phase as well as that of carbides should be determined and compared to that of new (un-serviced) IN738 material in the fully heat treated condition. A specimen extracted from the root of a blade may be used for this purpose. This metallurgical evaluation is acceptable in lieu of stress rupture testing for this blade design. The assumption here is that, if heat treatments applied during the repair process result in a blade microstructure that is essentially equivalent to that of new IN738 material, then the blade mechanical properties should closely approach that of new IN738 material. Some guidance on metallurgical review of sample material is provided in Appendix III. Microstructural requirements are listed in paragraph 5.6.

5.6 Microstructural Requirements

5.6.1 The hold times and temperatures employed during thermal processing shall be held to minimum levels in order to minimize grain growth.

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

5.6.3 The re-cast layer on any E.D.M. surface shall not exceed 0.025mm (0.001 inch).

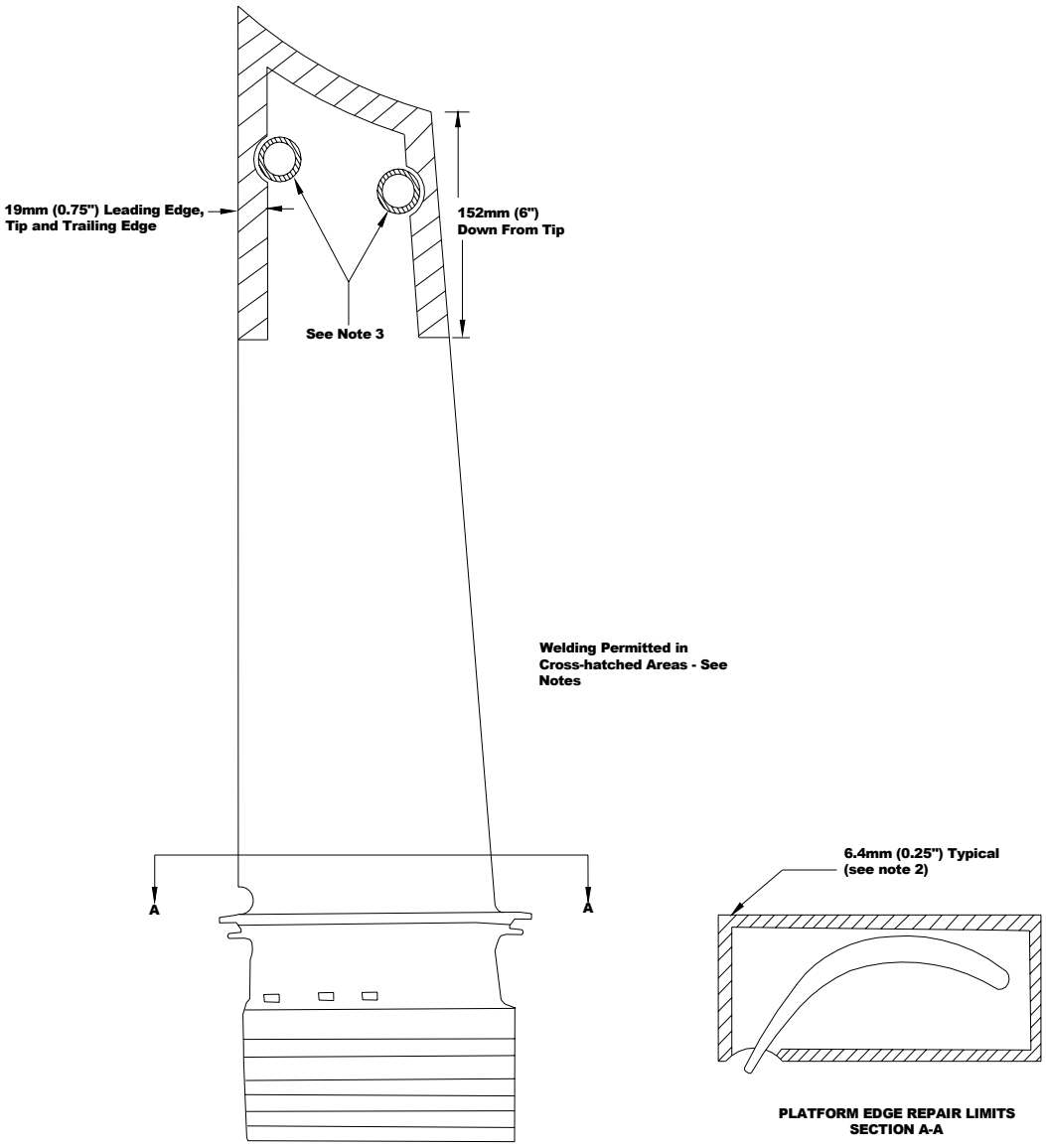
5.6.4 The microstructure shall be comparable to new material. The root section of an un-repaired blade may be used for comparison. Specifically, no continuous carbide films or needle phases shall be present after processing.

Table 8-1
GT11N2 Row 4 Blade Blend Limits

DETAILS	MAXIMUM BLENDING LIMITS
AREA: Upper 1/3 of Airfoil	
1. Tip Blend	6.4 mm (0.250”) maximum depth x 50 mm (2.0") maximum length.
2. Surface Blend	0.76 mm (0.030") deep or 25% of design wall thickness, whichever is less
3. Trailing Edge Blend	6.4 mm (0.250”) maximum depth x 50 mm (2.0") maximum length.
AREA: Lower 2/3 of Airfoil	
1. Surface Blend	0.5 mm (0.020") deep or 10% of design wall thickness, whichever is less
2. Trailing Edge Blend	2.3 mm (0.090") maximum depth x 25 mm (1.0") maximum length.
AREA: Blade Shank and Root	
1. Surface Blend	0.25mm (0.010") deep on shank and root end faces.
2. Root Blend	0.013 mm (0.005" deep maximum. None on load bearing surfaces or fillet radii.

Note: All blends must have a depth to length ratio of 1:8 minimum, and shall be smooth and gradual with no sharp edges remaining.

Figure 8-4
ALSTOM MODEL GT11N2
4th STAGE BLADE WELD REPAIR LIMITS
NOTES FOR THIS FIGURE BEGIN ON THE NEXT PAGE



NOTES

1. In the tip area, the entire squealer tip wall may be repaired / rebuilt. From a structural standpoint, repair of cracks may extend into the airfoil down to 152 millimeters (6") below the squealer tip. Any welding process used should be qualified before production repairs are attempted and all welds in the airfoil should be radiographed after the post weld heat treatment (see 6.2.11).

2. The crosshatched areas in Section A – A show the locations where platform repairs are allowed, however, the welding procedures and filler materials used for platform repairs require specific purchaser approval (See 5.1). In general, repairs along the edges may extend into the platform to a depth of 0.25 inches (6.4 mm); however, in no case should the repairs encroach into the airfoil to platform fillet areas. This will limit repairs to less than 0.25 inches in areas where fillets are near the edges (as shown at mid-chord on suction side and at the trailing edge).

3. Fretting wear and cracks in the damping pin holes may be weld repaired, provided cracks do not extend to within 12.7mm (0.5") of the leading or trailing edge. Following weld repair, holes shall be properly blended/drilled to correct diameter for damping pins.

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. Record blade serial numbers.

6.1.2 Advise purchaser immediately of any shipping damage.

6.1.3 Dimensionally inspect blades for tip height (inspect all blades).

Record the results using the forms attached as Appendix I. Tip height dimensions may be checked with a Fixture provided the fixture allows actual dimensions to be recorded (i.e., pass / fail type results are not acceptable).

6.1.4 Visually inspect each blade for the following:

- tip rubs
- foreign object damage
- cracks

surface oxidation, corrosion, and erosion

fretting/cracking in damping pin holes

Record the results using the forms attached as Appendix II.

6.1.5 Non-destructively identify the alloy from which each blade is manufactured. If any alloy other than IN-738 is identified, inform purchaser immediately.

6.1.6 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 one which is damaged beyond repair limits. 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. Based on this evaluation, Recommendations / Decisions should be made for the blade set concerning repair/replace decisions. The balance of the material from this blade shall be saved for use as control material, as specified in 6.1.7.

6.1.7 Control material from the destructively examined blade or other IN-738 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 5.5, 5.6 and 6.2.20. The control material for testing of paragraph 6.2.20 shall be processed through all thermal processing cycles (preweld heat treatment, postweld heat treatment, and aging heat treatments).

6.1.8 Clean blades using grit blasting with 220 grit aluminum oxide. Avoid excessive blasting, particularly on the root.

6.1.9 F.P.I. all blades 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 using the 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 blade defects on one set of damage assessment forms.

6.1.10 Thoroughly clean components using an approved solvent cleaner or by other approved means such as steam cleaning or pressure spraying.

6.1.11 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 specification,

- obtain written or verbal authorization from the purchaser to proceed with the repairs.

6.2 Blade Repair Procedures

6.2.1 Unless approved otherwise, all process procedures applied during the repair of the blades 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.

6.2.2 Heat treat the blades in a vacuum of 1 micron ($1.3x10^{-3}$ millibar) or better at a temperature of 1190°C + / - 14°C (2175°F + / - 25°F) for 4 hours and Inert Gas Quench.. Fixture parts using only approved (7.1.2) fixture materials with the parts supported uniformly to prevent distortion. Avoid supporting the parts by any thin sections.

6.2.3 F.P.I. all blades following procedures outlined in paragraph 6.1.9. Document the location and extent of any defects not identified in paragraph 6.1.9 on the forms attached as Appendix II.

6.2.4 Prepare the areas of the blades to be repaired by removing the existing cracks / defects by abrasive grinding and F.P.I. to ensure the cracks are completely removed. Areas with defects outside the repair limits specified in Figure 4 can be blended to remove them within the blending limits specified in Table 1. Grinding tools and procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.5 When requested, the purchaser shall be informed and allowed to inspect the components following weld preparation.

6.2.6 Weld repair the components using gas tungsten arc or plasma transferred arc welding methods and the filler metals identified in 5.1. Areas to be welded must be free of oxide, grease, dirt and penetrant chemicals. All welds must be performed using full penetration welds in the region being repaired. Unless specifically approved otherwise, weld repairs beyond the limits defined in Figure 4 are not allowed. 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. Machine/drill repaired damping pin holes to proper dimension and location. Tools and procedures used shall be identical to those used in the original process qualification (7.1.2).

6.2.8 F.P.I. the blades following procedures outlined in paragraph 6.1.9 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.

6.2.9 Parts that fail to meet the criteria of paragraph 5.3 may be recycled to repair any defects beginning at paragraph 6.2.4.

6.2.10 Thoroughly degrease components using approved solvent cleaner or other approved methods such as steam cleaning or pressure washing.

6.2.11 Vacuum heat treat to stress relieve the weldments /solution anneal the microstructure using the cycle used in the original process qualification (7.1.2). Unless otherwise specified / approved by the purchaser, the heat treatment shall be as follows:

1190°C + / - 14°C (2175°F + / - 25°F) / 2 hours / Inert Gas Quench;

NOTE: This heat treatment step is not required if no welding was performed, and the full solution heat treatment step was previously performed at step 6.2.2.

6.2.12 Immediately following heat treatment (if performed) and before any surface cleaning or blasting, liquid penetrant inspect the blades using the method outlined in paragraph 6.1.9 and acceptance criteria outlined in paragraph 5.3. Record the results on the forms attached as Appendix II.

6.2.13 Vacuum heat treat to restore the base material mechanical properties using the cycle used in the original process qualification (7.1.2). Unless otherwise specified / approved by the purchaser, the heat treatment shall be as follows:

1120°C + / - 14°C (2050°F + / - 25°F) / 2 hours / Inert Gas Quench;

843°C + / - 14°C (1550°F + / - 25°F) / 24 hours / Fan cool to room temperature.

6.2.14 Immediately following heat treatment and prior to any surface cleaning or blasting, perform the following NDE procedures:

6.2.14.1 F.P.I. the entire blade using procedures outlined in paragraph 6.1.9 and the acceptance limits defined in 5.3. Record the results (pass/fail) by serial number.

6.2.14.2 Radiograph any welds made in the blade airfoil that extend below the squealer tip 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.

6.2.15 Parts that fail to meet the criteria of paragraph 5.3 may be recycled to repair any defects beginning at paragraph 6.2.4.

6.2.16 Thoroughly clean components using an approved solvent cleaner or by other approved means such as steam cleaning or pressure spraying.

6.2.17 Dimensionally check all blades to ensure conformance with paragraph 5.4. Record the results on the forms attached as Appendix I. Tip height dimensions may be checked with a Fixture provided the fixture allows actual dimensions to be recorded (i.e., pass / fail type results are not acceptable).

6.2.18 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.

6.2.19 Shot peen all dovetail serrations surfaces per AMS 2430 to Almen .008/.011A.

6.2.20 Production Control Tests. Metallographic samples of control material (see 6.1.7) from each lot of blades shall be prepared after all processing and examined for compliance with paragraphs 5.5 and 5.6. Failure of the metallographic specimens to meet the minimum requirements shall subject the entire lot to rejection.

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

6.2.22 Arrange a pre-shipment inspection with the purchaser to:

- review vendor's documentation including heat treat charts and Quality Control Test reports.
- visual inspection

6.2.23 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.

6.2.24 Advise purchaser of the shipping date, route and carrier, etc.

6.2.25 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 non-destructive 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 & 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 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) 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 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 five 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 which shall contain:

a) a mapping of all defects identified at paragraphs 6.1.4, 6.1.9, 6.2.3 and 6.2.8. (Use form attached as Appendix II)

b) a copy of all incoming, in-process and final dimensional inspection forms (Use forms attached as Appendix I)

c) a copy of the final F.P.I.

d) a copy of the moment weight/computer sequence report

e) a copy of the certificate of compliance

f) a copy of all production control test results (include photocopies of microstructural / metallographic specimen photographs)

7.3 Acceptance and Disposition.

7.3.1 All deviant parts shall be plainly labeled in a non-destructive manner, isolated from the batch and held for purchaser disposition.

7.3.2 Blades not meeting the requirements of this specification, the purchase order, and referenced drawings, shall be rejected and held for purchaser disposition.

7.4 Access

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

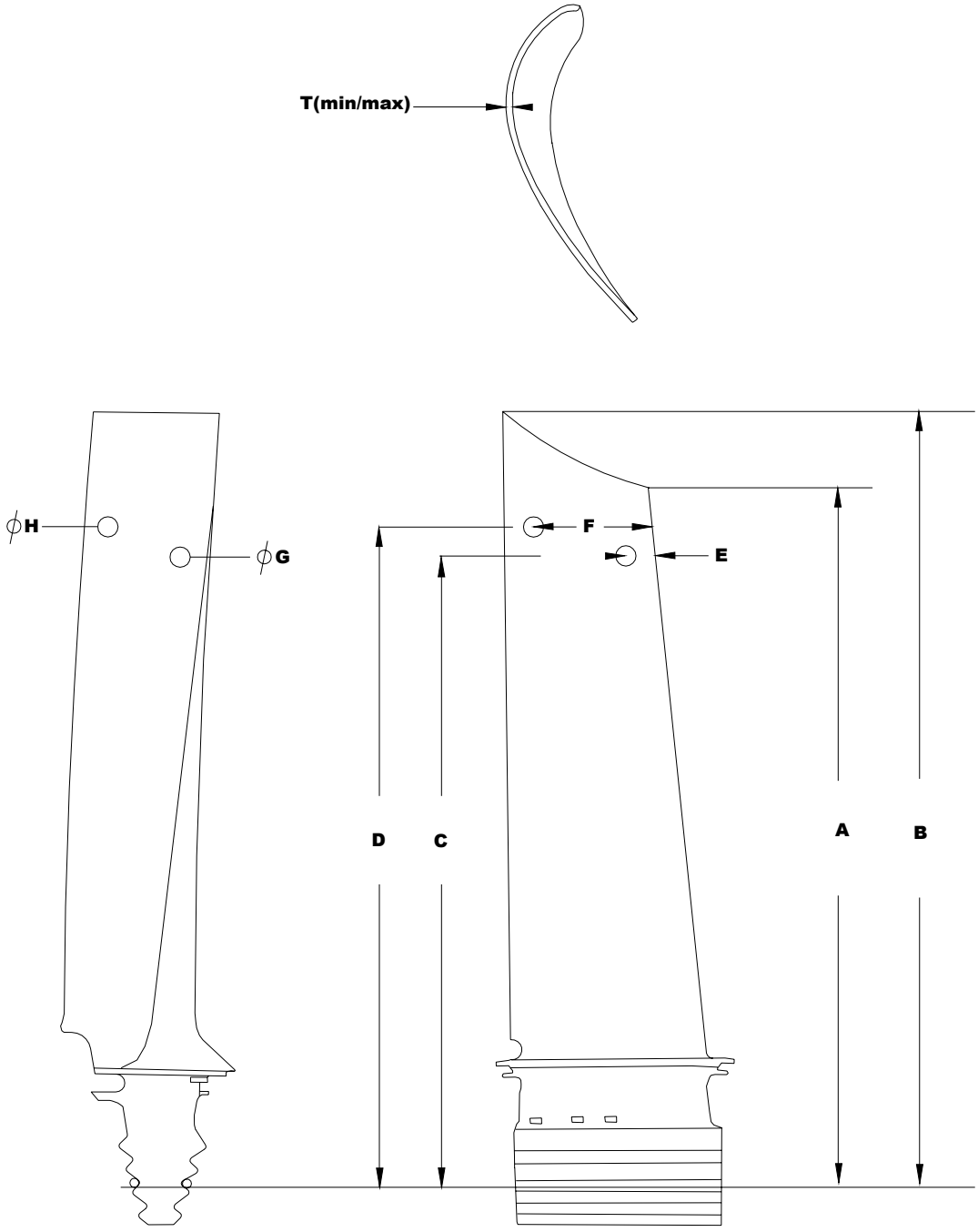
APPENDIX I - DIMENSIONAL INSPECTION FORMS

FORM I-A

ALSTOM GT11N2 FOURTH STAGE BLADE

DIMENSIONAL INSPECTION FORM – EXTERNAL DIMENSIONS

RECORD MEASUREMENTS ON FORM I-B



FORM I-B

ALSTOM MODEL GT11N2 FOURTH STAGE BLADE

DIMENSION SHEET – EXTERNAL DIMENSIONS

BLADE SERIAL NUMBER	DIM. "A"	DIM. "B"	DIM. "C"	DIM. "D"	DIM "E"	DIM. "F"	DIM "G"	DIM "H"	DIM "T" Min/Max

PIN DIAMETER USED: _____

RECORDED DIMENSIONS ARE IN (Check one): ☐ INCHES ☐ MM

NOTES: 1. Measure T (Min. / Max.) on 10% of blades at incoming inspection.

2. Measure A and B on all blades at incoming and final inspections.

3. At final inspection, measure "T" (Min. / Max.) on all blades having tip repairs.

4. Checking Fixtures may be used, however, fixtures must allow recording of actual dimensions (not "Pass" or "Fail").

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

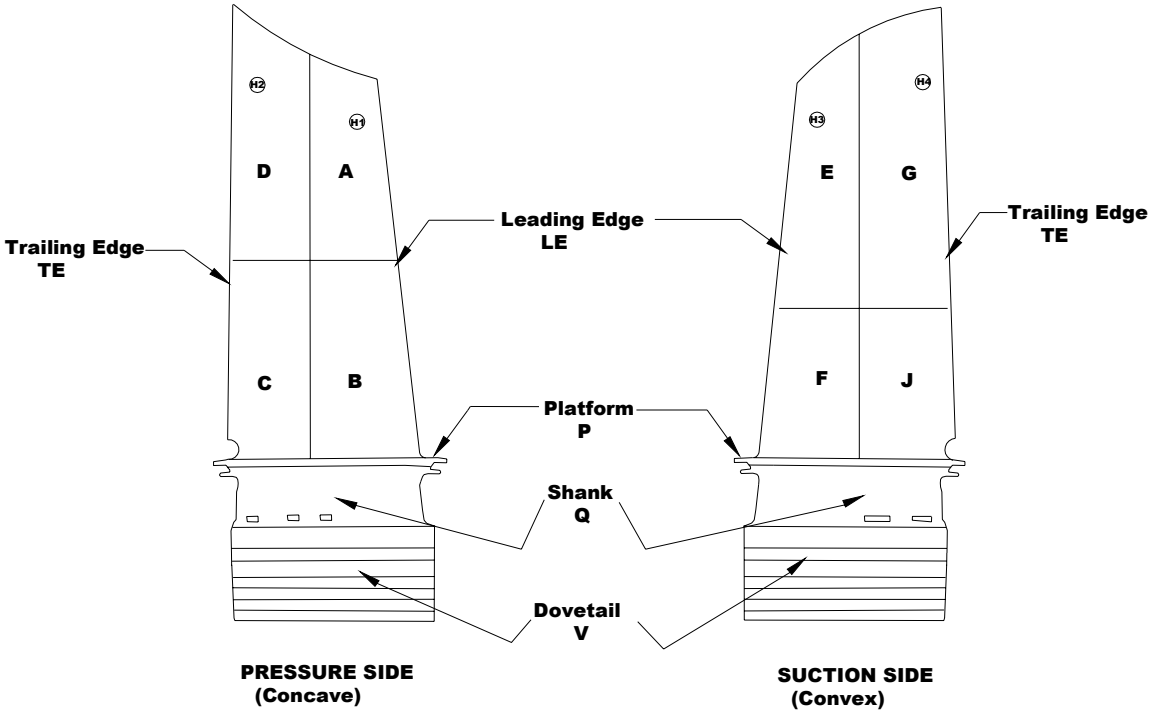
APPENDIX II - DAMAGE ASSESSMENT FORMS

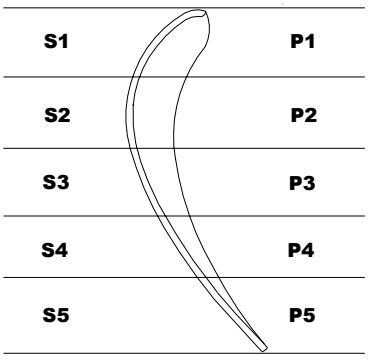
FORM II-A

ALSTOM MODEL GT11N2 FOURTH STAGE BLADE

DAMAGE ASSESSMENT FORM – BLADE DAMAGE & LOCATION CODES

RECORD DEFECTS USING THE DAMAGE AND LOCATION CODES (ZONES) SHOWN
DAMAGE CODES: CR = CRACK IN RADIAL DIRECTION; CA = CRACK IN AXIAL DIRECTION;
D = DENT; T = TORN; PT = PUNCTURED; MM = MISSING MATERIAL;
OX = OXIDATION; C = CORROSION; E = EROSION; W = WEAR (RUBS) CL = COATING LOSS
SEE FORM II-B FOR NOTES / RECORD DATA ON FORM II-C





SQUEALER TIP DAMAGE LOCATION ZONES

FORM II-B
ALSTOM MODEL GT11N2 FOURTH STAGE BLADE
DAMAGE ASSESSMENT FORM – NOTES FOR RECORDING BLADE DAMAGE

Record all damage information on Form II-C. Duplicate the form as required to record all damage information for the blade set being inspected.

Record the serial number and the blade disk position (if known) for each blade.

Attach any photographs taken or lab analysis of corrosion to the set of forms.

Blade damage is to be documented in three (3) columns on Form II-C: "Cracks", "Oxidation, Corrosion, Erosion or Wear", and "Foreign Object Damage". If additional space is required to complete damage information for a specific blade, continue with the information in the space provided for the next blade and show that it is a continuation using terms such as "ditto" or "same" in the Serial Number column.

Record the damage code first followed by the location code followed by the size or other description of the damage. Include descriptive information to further clarify locations, etc. Separate the codes and descriptions by slash marks. Several representative examples are given below.

Typical Crack Recording: For an axial crack approximately 0.25 inches in length located on the pressure side in squealer tip zone P5, record the damage as follows: CA / ST - P5 / 0.25". For a 0.5 inch radial crack located on the pressure side airfoil in zone A near the axial center of the airfoil, record the damage as follows: CR / A, near mid-span / 0.5". For a 0.25 inch long axial crack at the fifteenth (15th) trailing edge cooling slot below the tip, record the damage as follows: CA / TE at cooling slot 15 / 0.25". For cracks in the leading edge, use the CA or CR code (as applicable), the location code "LE" and record the crack length and distance below the tip. State if the LE crack penetrates / starts at LE cooling holes.

Typical Oxidation, Corrosion, Erosion, and Wear Recording: Indicate the approximate dimension of the damage from the tip of the blade and use the applicable zone letters. Enter the radial height, axial width and approximate maximum depth of the damage. For an oxidized area approximately 1.5" below the tip that is 1 inch high by 2" wide by 0.010 " deep on the pressure side airfoil in Zone A, record the damage as follows: OX / A-1.5" / 1"H X 2"W X 0.010" deep. Add additional comments as needed to further describe the damage such as "begins near LE", etc.

Typical Foreign Object Damage Recording: Foreign object damage is recorded using the letter codes for Dents (D), Torn (T), Punctured (P, i.e., where the foreign object damage has penetrated into a cooling passage), or Missing Material (MM). Use the method for recording the locations and descriptive information similar to that used for Erosion / Corrosion. For a 0.5" diameter dent approximately 0.1 inches deep, near the leading edge on the pressure side at Zone C that is approximately 4" from the blade tip, record the damage as follows: D / C – 4", near LE / 0.5" dia X 0.1" deep.

Blade Decision Codes: The last column on Form II-C ("DEC") is reserved to record the decision made for each blade. Use the following codes:

WR = Repaired by welding

BR = Repaired by brazing (requires purchaser approval)

RN = Replaced with a new blade

N = No repair or replacement required

Use only lead free markers to mark blades.

FORM II-C

ALSTOM MODEL GT11N2 FOURTH STAGE BLADE DAMAGE ASSESSMENT RECORD SHEET

BLADE S/N	BLADE POSITION	CRACKS	OXIDATION, CORROSION, EROSION OR WEAR	FOREIGN OBJECT DAMAGE	DEC

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

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 (i.e., 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 which appear visually to have surface damage. Internal surfaces of cooling passages should be examined in addition to the external surfaces.

The total depth of environmental attack should be measured. This should include:

i) remaining coating thickness

ii) the depth of any oxide layer,

ii) the depth of internal (cooling passage) oxidation,

iii) the depth of the alloy depleted zone,

iv) the depth of intergranular attack, and

v) an indication of the amount of metal lost due to oxidation/corrosion/erosion.

3. 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.

C. Microstructural Evaluation

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

Any deviations from normal microstructure should be noted.

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