



PRODUCT STANDARD GAS TURBINES

GT10117

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ACCEPTANCE REQUIREMENTS - COMPRESSOR WHEEL FORGINGS

1. SCOPE

- 1.1 This specification provides the Engineering Requirements for Gas Turbine Compressor Wheel Forgings. It supplements the general requirements for rotating forgings that are specified in process specification GT10047 and it must be used with GT10047 and the material specification called for on the respective forging drawing.
- 1.2 This specification is applicable to, and limited to, the following forgings identified by Part Identity and material specification as follows:

Identity		Material Specification
Type "A" Forgings		
MS-3002 - Stages 2 thru 15	}	HY19462
MS-5001 - Stages 1 thru 10		
MS-5002A - Stages 2 thru 10		
MS-5002B - Stages 1 thru 10		
MS-6001 - Stages 2 thru 11	}	HY19460
MS-7001A thru E - Stages 2 thru 11		
MS-9001A thru E - Stages 2 thru 11		
Type "B" Forgings		
MS-5001 - Stages 11 thru 15	}	HY19462
MS-5002A - Stages 11 thru 14		
MS-5002B - Stages 11 thru 14		
MS-6001 - Stages 12 thru 15	}	HY19460
MS-7001A thru E - Stages 12 thru 15		
MS-9001A thru E - Stages 12 thru 15		

- 1.3 Parts other than those specifically set forth above (Ref. Para. 1.2) which are ordered to the requirements of this specification should be referred promptly through BHEL GT Purchase and further to GT Engineering for clarification resolution.
- 1.4 Unless otherwise specified, the requirements of this specification are applicable to both materials (Ref. Para. 1.2).



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2. APPLICABLE DOCUMENTS

2.1 BHEL SPECIFICATIONS

HY19460	Ni-Cr-Mo-V Alloy Steel Forgings
HY19462	Nickel-Chromium-Molybdenum-Vanadium Allow Steel Forgings
GT10146	Magnetic Particle Test - General
GT10047	Rotor Forgings - General
GT10185	Acpt. Reqt.-Turbine Wheels
GT10184	Ultrasonic Testing - General
P14A-AL-0217	Forging Sonic & Machining Requirements for 100% Ultrasonic Inspection Coverage

2.2 American Society for Testing & Materials

ASTM E45	Standard Practice for Determining the Inclusion Content of Steel
ASTM E112	Standard Test Methods for Determining Average Grain Size

3. DEFINITIONS

- 3.1 The definitions contained in process specification GT10047 , Section 3 apply to this specification.
- 3.2 Type A Forgings - These forgings have the mechanical properties evaluated by a sample of two forgings per heat treatment batch. They are either less than 30 inches in diameter and/or they are relatively low stressed in the respective service applications.
- 3.3 Type B Forgings - These forgings have the mechanical properties tested for every piece.



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4. ENGINEERING REQUIREMENTS

4.1 Forging Supplier - Process Qualification

4.1.1 The Forging Supplier shall provide for each type of part the following information for purchaser review and approval:

- detailed processing plan
- dimensional drawing showing the configuration during heat treatment
- production test specimen locations and orientations in forging
- type of test at each location.

4.1.2 A first piece qualification (FPQ) forging shall be required of a new supplier, a new plant of a current supplier, or when there is a significant change in the shape, the composition or the processing of the forging. This FPQ generally requires the destructive sectioning and evaluation of the forging; however, when the forging's configuration permits the deep seated characteristics to be measured with prolongations or trepans, purchaser can select alternative evaluation methods. When the forging supplier has made similar parts for BHEL / internal departments that have similar requirements Materials & Processes Engineering, Design Engineering and Quality Assurance representatives will review the results. Purchaser will then decide whether or not a qualification forging is required and if a destructive cut-up qualification is needed.

The FPQ shall, as a minimum, include the following:

- 4.1.2.1 Figure 1 is a sketch showing the qualification mechanical properties test locations for a typical part.
- 4.1.2.2 The precise location of each test specimen in relation to the heat treat envelope shall be recorded and reported by the Supplier in the Manufacturing Process Plan.
- 4.1.2.3 Ultrasonic Examination - The interior quality of the forging must be evaluated after the forging supplier has machined forging to Sonic Shape per P14A-AL-0217 requirements. Axial and radial ultrasonic inspections must be performed on all accessible surfaces per Specification GT10184 and GT10047



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- 4.1.2.4 Macro Cross-Section - When a complete cut-up destructive qualification procedure is specified, an axial-radial cross-section of the qualification forgings shall be etched and photographs shall be taken to reveal grain flow and chemical segregation (Figure 1). Etch in accordance to Process Specification GT10185
- 4.1.2.5 Hardness Survey - When a complete cut-up destructive qualification procedure is specified, a hardness survey shall be made on the face of the axial-radial cross-section cut, and there must be a sufficient number of test positions to accurately reflect hardness; therefore tensile strength uniformity. In addition, a circumferential hardness survey must be performed per Para. 4.2.2.4.
- 4.1.2.6 The microstructure and the grain size shall be determined for a sample obtained from all of the specified Qualification Forging testing locations, Table I and Figure 1. The grain size shall be determined per specification ASTM E112 and the cleanliness rating per specification ASTM E45. The microphotographs shall be at 100X after etching with a 2 percent Nital solution. All metallographic examination results must meet the requirements of the appropriate material specification and they shall be contained in the Qualification Program Report.
- 4.1.2.7 Production/Part Chemical Composition - The chemical composition must be determined for the bore location and carbon check analyses for all of the other testing locations. All results shall be contained in the Qualification Program Report.
- 4.1.2.8 Magnetic Particle Inspection - All accessible surfaces of the forging shall be magnetic particle inspected in two directions in the finish machined state. If the wheel is spin tested, it shall be magnetic particle inspected after spin testing. The magnetic particle inspection shall be per process specification GT10146

4.1.3 In order for the Forging Supplier to achieve qualification status for a specific forging, capability must be demonstrated for the consistent development of all required mechanical properties and material qualities. Important for the proof of capability is the production of a forging that exhibits the properties and qualities that are expected with the applied processing operations. A part of this expectation is the development of characteristics that are similar to those that are developed in the same or similar forgings produced by other current forging suppliers. It follows that simply producing a



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forging that just meets the minimum requirements does not earn a supplier qualification status.

After a forging supplier achieves qualification status, this status might be extended to apply to other forgings that present the same or lesser degrees of difficulty during manufacture. Decisions regarding the expansion of qualification status to forgings will be made by Purchaser in consultation with Engineering.

Production status, i.e. the authority to proceed with production forgings, shall be given by Purchaser.

- 4.1.4 After Purchaser has given process qualification to the Forging Supplier the manufacturing process will be considered "FROZEN" and deviations from it will be allowed only if written permission from Materials & Processes Engineering has been obtained.

4.2 Forging Supplier Production Wheels

- 4.2.1 Manufacture - The maximum number of forgings in a furnace heat treatment batch will depend on the Supplier's austenitizing and/or tempering furnaces. This information and the typical positioning of the compressor wheel forgings in the different furnaces must be submitted in the appropriate Supplier Manufacturing Process Plan (MPP), or must be documented in a Supplier's standard manufacturing practices instruction.

Additional information to be reported in the MPP or contained in the standard Manufacturing Practices Instruction is the method of positioning each forging or a number of forgings in the water tank during the quenching operation.

4.2.2 Testing and Evaluation

- 4.2.2.1 Type A Compressor Wheel Forgings - Two forgings per melt heat and per heat treatment (temper operation) batch must be tested at the bore location as shown in Figure 1 and Table II. The forgings to be tested are to be placed in the furnace in the following way: One of the forgings must be located in the back of the furnace and the other, second forging, must be near the front/ door of the furnace.

A heat treat batch can contain two or more "B" type forgings, therefore eliminating the need to test any of the "A" type forgings in the heat treat batch.



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- When the heat treatment batch has forgings from two different heats a wheel from each heat must have the mechanical properties tested; i.e. one forging from heat "x" in the front and one forging from heat "y" in the back. If three or more heats are in the heat treat batch then three or more wheel forgings must have the mechanical properties tested.
- 4.2.2.2 Type "B" Compressor Wheel Forgings - Each forging must be tested at the bore location as shown in Figure 1 and Table II.
- 4.2.2.3 Purchaser Test Material - The test rings shall be retained by the Supplier in accordance with GT10047 .
- 4.2.2.4 A Brinell hardness test survey must be made on each forging and the results reported in the Forging Supplier Certificate of Test. All forgings must be tested near the bore surface at locations 180 degrees apart (total of two tests) and also near the rim at locations 60 degrees apart (total of six tests).
- 4.2.2.5 Ultrasonic Examination - The interior quality of compressor wheel forgings must be evaluated after the Forging Supplier has machined the forging to sonic shape per P14A-AL-0217 requirements. Axial and radial ultrasonic examinations must be performed on all accessible surfaces per specification GT10184 and GT10047.
- The following higher stressed compressor wheel forgings must be produced with sufficient material stock to have flat and parallel AFT and FWD surfaces for the ultrasonic examinations:
- MS5001 15th Stage
 - MS5002 14th Stage
 - MS7001E 12th & 14th Stages
 - MS9001E 12th & 14th Stages
- 4.2.2.6 The microstructure and the grain size shall be determined from a specimen from the bore test location, and they shall meet the requirements of the appropriate material specification. The grain size as determined per ASTM E112 shall be reported. Photomicrographs shall be contained in the Certificate of Test to document any unusual features that are observed during the metallographic examination.



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4.2.2.7 Carbon Product Analysis - The carbon content must be measured on a sample from the bore test ring and reported on the Supplier Certificate of Test for the bottom most compressor wheel forging from all ingots that have bottom discards of 10 percent or less. This value must be within the material specification's maximum and minimum values for the heat carbon analysis.

4.2.2.8 The mechanical properties, hardness values and all other quality attributes measured must meet the requirements of the applicable material specification.

5. PURCHASER QUALITY ASSURANCE TESTING

5.1 Magnetic Particle Inspection - All accessible surfaces of the forging shall be magnetic particle inspected in two directions in the finish machined state. If the wheel is spin tested, it shall be magnetic particle inspected after spin testing. The magnetic particle inspection shall be per process specification GT10146.

5.2 Hardness Testing - An approved audit program will be used to Brinell Hardness test wheel forgings (periphery - 4 places - 90 degrees apart on one surface), but in any case shall not be less than 1 per every 5 forgings of the same material made by a single supplier .

5.3 Supplemental Material Acceptance Testing - Purchaser has the right to make any additional non-destructive tests, chemical analyses or mechanical properties tests that are considered necessary to demonstrate that the forging meets the requirements of this specification and the needs of the intended turbine wheel application. Forgings failing these tests will be the responsibility of the forging supplier.

6. NOTES

6.1 The Forging Supplier is responsible for conducting all tests under Section 4.

6.2 Purchaser is responsible for conducting all tests under Section 5.



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TABLE I - QUALIFICATION FORGING MECHANICAL PROPERTIES TESTING

Test Location	RT Tensile	FATT (°F) (2)	Charpy V-Notch Fibrosity at Temperature (3)	
			of -50°F (%)	of -100°F (%)
R	2 (0 & 180)	1X	2X	2X
MR	1X	1X		
B	1X	1X	2X	2X
MB	1X	1X		
BB	1X	1X	2X	2X

TABLE II - PRODUCTION FORGING MECHANICAL PROPERTIES TESTING

Forging	Test Location	RT Tensile	Charpy V-Notch Fibrosity at Temperature (3)	
			of -50°F (%)	of -100°F (%)
Type "A"				
and	B	1X	2X	2X
Type "B"				

NOTES FOR TABLES I AND II:

- (1) All specimens must be in the tangent i al or circumferential direct ion. The Charpy V-notch specimens must have the root of the notch parallel with the centerline of the forging and the notch opening facing the bore.
- (2) The FATT must be estimated from a minimum of four specimens tested at different temperatures. The test temperatures must be selected i n a manner that will result in high probability that two test temperatures are above the FATT at 50 percent and two test temperatures are below.
- (3) The percent fibrous fracture must be equal or greater than 50 percent for HY19460-B10 forgings when tested at -100°F. HY19462-D10 forgings shall be tested at -500°F and the percent fibrous fracture must be equal or greater than 50 percent. This process specification requirement precedes any conflicting material specification requirements.
- (4) Hardness testing is required for all qualification and production wheel forgings and it must respectively be performed per Paras. 4.1.2.5 and/or 4.2.2.4.



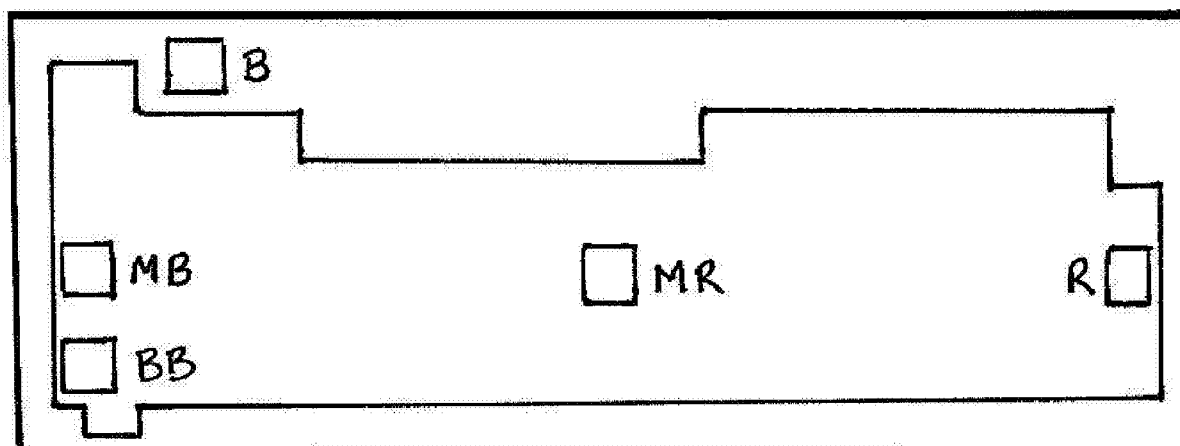
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FIGURE 1 - MECHANICAL PROPERTY TESTING LOCATIONS



NOTES FOR FIGURE 1:

- (1) Specimens MB and BB - The test specimen centers must be 0.50" to 0.75" from the bore surface. In addition, Specimen BB must be 0.50" to 0.75" below the as-heat treated radial-circumferential surface.
- (2) Specimens R, MR and MB - The test specimen centers must be located at the forging's mid height or mid thickness. In addition, Specimen MR must be located at the forging's mid radius and specimen R must be 0.50" to 0.75" from the as-heat treated outer diameter.
- (3) Specimen B - (0.75" x 0.75" Nominal Cross Section Ring) - The center of the bore ring must be 0.50" to 0.75" below the as-heat treated radial circumferential surface. In addition, the surfaces of the ring must be located as close as possible to the forging's surface, i.e. 0.50" or less.
- (4) All test specimen locations and orientations within the as-heated forging envelope must be accurately defined and documented in the qualification report.



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