



**PRODUCT STANDARD**  
**HYDERABAD**  
**GT ENGINEERING**

Prod. Std. No. : GT10649

Rev. No. 01

Page 1 of 14

**ACCEPTANCE REQUIREMENTS - LOW ALLOY STEEL GAS TURBINE  
COMPRESSOR WHEELS AND LAST STAGE COMPRESSOR WHEEL SHAFTS  
FOR OPERATIONS OVER 343.3°C**

**1. SCOPE**

1.1. This process specification defines specific process and quality requirements for Gas Turbine Compressor Wheels and Aft Compressor Shaft Forgings.

1.2. This specification is applicable to, and but not limited to, the following forgings identified by Part Identity and Material Specification as follows:

1.2.1.

Forging Category	Frame Size	Forging
A	MS6001	16th Stg. Wheel
F	MS6001FA	15, 16th Stg. Wheel
A	MS7001	16th Stg. Wheel
F	MS7001EC	16th Stg. Wheel
F	MS7001F/FA	13, 14, 15, 16th Stg. Wheel
F	MS7001G&H	12 to 16th Stg. Wheel
A	MS9001	16th Stg. Wheel
F	MS9001EC	16th Stg. Wheel
F	MS9001F/FA	13, 14, 15, 16th Stg. Wheel
F	MS9001G&H	12 to 17th Stg. Wheel
A	MS6001	17th Stg. Wheel Shaft
F	MS6001FA	17th Stg. Wheel Shaft
A	MS7001	17th Stg. Wheel Shaft
F	MS7001EC	17th Stg. Wheel Shaft
F	MS7001F/FA	17th Stg. Wheel Shaft
F	MS7001G&H	18th Stg. CDP Seal
A	MS9001	17th Stg. Wheel Shaft
F	MS9001EC	17th Stg. Wheel Shaft
F	MS9001F/FA	17th Stg. Wheel Shaft
F	MS9001G&H	18th Stg. CDP Seal

1.3. **NOTE:** 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 to BHEL for confirmation.

1.4. **NOTE:** Unless otherwise specified, the requirements of this specification are applicable to all materials (Ref. Para. 1.2).

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Revisions :  
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Prepared :


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Approved :

*[Signature]*  
(SSR)


Date :


01.02.2000


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<p align="center"><b>COPYRIGHT AND CONFIDENTIAL</b></p> <p>The information on this document is the property of BHARAT HEAVY ELECTRICALS LIMITED. It must not be used directly or indirectly in any way detrimental to the interest of the company.</p>	<p><b>2. APPLICABLE DOCUMENTS</b></p> <p>2.1. The following documents shall form an integral part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue shall apply.</p> <p>2.1.1. <u>BHEL</u></p> <table border="0"> <tr> <td>HY19467</td> <td>Chromium-Molybdenum-Vanadium Alloy Steel Forgings</td> </tr> <tr> <td>HY19460</td> <td>Nickel-Chromium-Molybdenum-Vanadium Alloy Steel Forgings</td> </tr> <tr> <td>GT10146</td> <td>Magnetic Particle Test - General</td> </tr> <tr> <td>GT10047</td> <td>Rotor Forgings - General</td> </tr> <tr> <td>GT10185</td> <td>Turbine Wheels &amp; Spacers, Etching</td> </tr> <tr> <td>GT10186</td> <td>Spin Testing - Gas Turbine Rotor Components</td> </tr> <tr> <td>GT10184</td> <td>Ultrasonic Testing - General</td> </tr> <tr> <td>P14A-AL-0217</td> <td>Forging Sonic &amp; Machining Requirements for 100% Ultrasonic Inspection Coverage</td> </tr> </table> <p>2.1.2. American Society for Testing and Materials</p> <table border="0"> <tr> <td>ASTM E21</td> <td>Standard Recommended Practice for Elevated Temperature Tension Testing of Metallic Materials</td> </tr> <tr> <td>ASTM E45</td> <td>Practice for Determining the Inclusion Content of Steel</td> </tr> <tr> <td>ASTM E112</td> <td>Methods for Determining Average Grain Size</td> </tr> </table> <p><b>3. DEFINITIONS</b></p> <p>3.1. The definitions contained in process specification GT10047 - Section 3, apply to this specification.</p> <p>3.2. <u>Type "A" Forgings</u> - These forgings are applied to the older non "F", "FA", "G" and "H" technology applications and do not require the measurement of the rupture strength.</p> <p>3.3. Type "F" Forgings - These forgings are applied to "F", "FA", "G" and "H" technology applications and require the measurement of the rupture strength due to their generally higher gas turbine operating temperatures and stresses.</p>			HY19467	Chromium-Molybdenum-Vanadium Alloy Steel Forgings	HY19460	Nickel-Chromium-Molybdenum-Vanadium Alloy Steel Forgings	GT10146	Magnetic Particle Test - General	GT10047	Rotor Forgings - General	GT10185	Turbine Wheels & Spacers, Etching	GT10186	Spin Testing - Gas Turbine Rotor Components	GT10184	Ultrasonic Testing - General	P14A-AL-0217	Forging Sonic & Machining Requirements for 100% Ultrasonic Inspection Coverage	ASTM E21	Standard Recommended Practice for Elevated Temperature Tension Testing of Metallic Materials	ASTM E45	Practice for Determining the Inclusion Content of Steel	ASTM E112	Methods for Determining Average Grain Size
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<p style="writing-mode: vertical-rl; transform: rotate(180deg);"> <b>COPYRIGHT AND CONFIDENTIAL</b>          The information on this document is the property of BHARAT HEAVY ELECTRICALS LIMITED.          It must not be used directly or indirectly in any way detrimental to the interest of the company.       </p>	<p><b>4. ENGINEERING REQUIREMENTS</b></p> <p><b>4.1. <u>Forging Supplier-Process Qualification</u></b></p> <p>4.1.1. The <u>first step</u> for a Supplier to achieve the status of Qualified Supplier for a given class/type of gas turbine rotor forgings is the successful production and evaluation of a First Piece Qualification forging. The 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, BHEL can select alternative evaluation methods.</p> <p>When the forging supplier has made similar parts for BHEL that have similar requirements, then Materials &amp; Processes Engineering will review the results and will decide whether or not a qualification forging is required and if a destructive cut-up qualification is needed.</p> <p>4.1.2. The <u>second step</u> for achieving qualified Supplier status is the successful production and evaluation of a set of "pilot lot" forgings. These pilot lot forgings will generally have tests and examinations that are in addition to those required for the production forgings manufactured by a Supplier, after qualified forging Supplier status has been obtained. The pilot lot forging requirements might include the additional destructive evaluation of forgings, but most likely it will specify additional tests on special core sections and prolongations, plus nondestructive examinations. The exact details of the pilot lot program, including the number of forgings, and the nature of the tests and examinations will be determined by Materials &amp; Processes Engineering after the review of the results of the First Piece Qualification forging with the forging supplier.</p> <p>4.1.3. The Supplier must first submit for approval by Materials &amp; Processes Engineering, a "FPQ" Manufacturing Processes Plan. Second, the Supplier seeking the status of qualified Supplier, must submit for approval by Materials and Processes Engineering, a "pilot lot" Manufacturing Process Plan. Release to manufacture production forgings shall require the submittal and approval of a Production MPP. Reference GT10047 for MPP requirements.</p> <p>4.1.4. A "verification of qualification status" forging will be required by BHEL after a Supplier has made a particular forging for five years or longer, after a Supplier has not made a particular forging or similar forgings for two years or longer, or after the Supplier's production forgings exhibit unusual mechanical properties and/or quality trends.</p>		
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TD-106. - 2 Rev. No. : 00 Form No. :		<b>PRODUCT STANDARD</b>  <b>HYDERABAD</b>  <b>GT ENGINEERING</b>	Prod. Std. No. : GT10649 Rev. No. 01 Page 4 of 14
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TD-106. - 2 Rev. No. : 00 Form No. :		<b>PRODUCT STANDARD</b> <b>HYDERABAD</b> <b>GT ENGINEERING</b>	Prod. Std. No. : GT10649 Rev. No. 01 Page 5 of 14
<b>COPYRIGHT AND CONFIDENTIAL</b> The information on this document is the property of BHARAT HEAVY ELECTRICALS LIMITED. It must not be used directly or indirectly in any way detrimental to the interest of the company.	<p><b>4.3. <u>Production Requirements</u></b></p> <p>4.3.1. Hardness Survey - A hardness survey shall be made by BHEL approved procedure on each forging as follows:</p> <p>4.3.1.1. Compressor Wheel Forgings</p> <p>4.3.1.1.1. Bore Area - Hardness measurements must be made on one surface and adjacent to the bore. One measurement at 0 degrees and one measurement at 180 degrees for a total of two bore tests</p> <p>4.3.1.1.2. Rim Area - Hardness measurements must be made on any of the rim surfaces and every 60 degrees for a total of six rim tests.</p> <p>4.3.1.2. Aft Compressor Wheel Shafts and CDP Seals</p> <p>4.3.1.2.1. <u>Large Diameter End</u> - Hardness measurements must be made adjacent to the bore. One measurement at 0 degrees and one measurement at 180 degrees for a total of two bore tests.</p> <p>4.3.1.2.2. <u>Small Diameter and Large Diameter End</u> - Hardness measurements must be made on any rim surface and every 90 degrees for a total of four rim tests at each end of the forging.</p> <p>4.3.2. <u>Mechanical Tests</u> - Test quantities and locations shall be determined by BHEL based on individual supplier process and results from FPQ/PLQ process. Unless otherwise approved by BHEL and documented in MPP, the testing requirements shall be as follows:</p> <p>4.3.2.1. <u>Tensile/CVN Toughness</u> - Required in accordance with the quantities and locations as set forth in Table 1 and Figure 1 or 2 (as applicable). The testing shall be in accordance with GT10047 to the requirements of the applicable Material Specification.</p> <p>4.3.2.2. <u>Stress Rupture (HY19467 Material Only)</u> - Required in accordance with the quantity and location set forth in Table 1 and Figure 1 or Figure 2 (as applicable). The testing shall be in accordance with the requirements set forth in GT10047 and the HY19467 material specification.</p> <p>4.3.3. <u>Ultrasonic Examination</u> - The interior quality of the forging must be evaluated after the forging supplier has machined forging to drawing or to an mutually agreed configuration meeting UT requirements. Axial and radial ultrasonic inspections must be performed on all accessible surfaces per Specification GT10184 and GT10047.</p> <p>4.3.4. <u>Magnetic Particle Inspection</u> - Unless otherwise approved by BHEL and documented in MPP, all accessible surfaces of compressor wheel forgings shall have all surface magnetic particle examined per specification GT10146 or by</p>		
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<p align="center"><b>COPYRIGHT AND CONFIDENTIAL</b></p> <p align="center">The information on this document is the property of BHARAT HEAVY ELECTRICALS LIMITED. It must not be used directly or indirectly in any way detrimental to the interest of the company.</p>	<p>another equivalent and approved examination procedure. This examination shall be made after machining the forging to the specific forging drawing configuration.</p> <p>4.3.5. <u>Metallography</u> - Required in accordance with GT10047 on specimens that represent both the rim (periphery) and bore locations. The grain size must be reported on the Certificate of Test. Photomicrograph (100X) must be included with the Certificate of Test when either the grain size does not meet the requirements of the applicable material specification or when unusual microstructural characteristics are observed. The microstructure, cleanliness and grain size shall conform to the requirements of the applicable Material Specification.</p> <p>4.3.6. <u>BHEL Test Material</u> - The test material shall be retained by the Supplier in accordance with GT10047.</p> <p>4.3.7. <u>Certificate of Test (CT)</u> - A Certificate of Test is required in accordance with GT10047 and the applicable Material Specification.</p> <p><b>5. PURCHASER QUALITY ASSURANCE TESTING</b></p> <p>5.1. <u>Ultrasonic Examination</u> - Each forging shall be ultrasonically inspected from the radial (outer diameter) and axial surfaces. These examination surfaces are defined on the forging drawing. BHEL examinations can be performed at the Manufacturing Plant or at another location by examiners selected and approved by Purchaser. After the spin test, the finished part shall have the bore UT inspected per applicable specification (i.e. GT10184.)</p> <p>5.2. Parts that require spin testing shall be tested in accordance with GT10186.</p> <p>5.3. Magnetic Particle Inspection - All accessible surfaces of the part shall be magnetic particle inspected in the finish machined state. If the part is spin tested, the magnetic particle inspection shall be after the spin test. The magnetic particle inspection shall be per Specification GT10146.</p> <p>5.3.1. Indications found by magnetic particle inspection greater than 1/16 inch shall be documented using QCRs and referred to Design and Materials Engineering for disposition. Special care will be taken to inspect high stress concentration areas including dovetail, bolt hole and fillet radii regions for axial-circumferential and axial-radial defects.</p>		
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		Rev. No. 01
		Page 7 of 14
<b>COPYRIGHT AND CONFIDENTIAL</b> The information on this document is the property of BHARAT HEAVY ELECTRICALS LIMITED. It must not be used directly or indirectly in any way detrimental to the interest of the company.	<p>6. <b>NOTES</b></p> <p>6.1. The forging supplier is responsible for conducting all tests under Section 4 of this specification.</p> <p>6.2. BHEL is responsible for conducting all tests under Section 5 of this specification.</p>	Ref. Doc P29A- AG214, P



TD-106. - 2 Rev. No. : 00 Form No. :		<b>PRODUCT STANDARD</b> <b>HYDERABAD</b> <b>GT ENGINEERING</b>	Prod. Std. No. : GT10649 Rev. No. 01 Page 8 of 14
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**TABLE I**  
**REQUIRED MECHANICAL PROPERTIES TESTING<sup>(1)</sup>**  
**(REFER TO FIGURES #1, 2 AND 3)**

**A. First Piece Qualification-Mechanical Properties Requirements**  
**A1. Figures #1 and #2**

Test Ring Location	R.T.	CVN Energy		CVN <sup>(2)</sup>	Stress Rupture <sup>(3)(5)</sup>
	(Tensile)	RT	@0° F	(FATT )	(1100°F & 35 KSI)
M Ring <sup>(6)</sup>	2X <sup>(4)</sup>	1X	1X	1X	--
R Ring	2X <sup>(4)</sup>	1X	1X	1X	2X <sup>(4)</sup>
B Ring	2X <sup>(4)</sup>	1X	1X	1X	1X
2	1X	1X	1X	1X	--
3	1X	1X	1X	--	--
4	1X	1X	1X	1X	--
5	1X	1X	1X	1X	--
8	1X	1X	1X	--	--

**A2. Figure #3**

Test Ring Location	R.T.	CVN Energy		CVN <sup>(2)</sup>	Stress Rupture <sup>(3)(5)</sup>
	(Tensile)	RT	at 0° F	(FATT )	(1100°F & 35 KSI)
M Ring	2X <sup>(4)</sup>	1X	1X	1X	--
R1 Ring	2X <sup>(4)</sup>	1X	1X	1X	1X
R2 or R2A Ring	2X <sup>(4)</sup>	1X	1X	1X	1X
4	1X	1X	1X	1X	--
5	1X	1X	1X	1X	--
6	1X	1X	1X	1X	--
7	1X	1X	1X	1X	--

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 P29A-  
 AG214, P

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**PRODUCT STANDARD**  
**HYDERABAD**  
**GT ENGINEERING**

Prod. Std. No. : GT10649

Rev. No. 01

Page 9 of 14

**B. Production - Mechanical Properties Requirements for "A" Category Forgings - 16th Stage Compressor Wheels**

**B1.**

Test Ring Location	R.T. Tensile	CVN Ft. Lbs. & % FIB	
	(KSI)	@ 0°F	@ R.T.
B - Bore	1X @ 0°	2X	2X

**B2. Production - Mechanical Properties Requirements for "F" Category Forgings - Compressor Wheels**

Test Ring Location	R.T. Tensile	CVN Ft. Lbs. & % FIB		Stress Rupture <sup>(3)(5)</sup>
	(KSI)	0°F	@ R.T.	(1100°F & 35 KSI)
B - Bore	1X @ 0°	2X	2X	1X

**B3. Production - Mechanical Properties for "A" Category Forgings - Aft Compressor Wheel Shafts**

Test Ring Location	R.T. Tensile	CVN Ft. Lbs. & % FIB		
	(KSI)	@ 0°F	@ R.T.	@ -100°F <sup>(7)</sup>
R- Rim	1X @ 0°	2X	2X	2X
M	1X @ 0°	2X	2X	2X

**B4. Production - Mechanical Properties Requirements for "F" Category Forgings - Aft Compressor Wheel Shafts**

Test Ring Location	R.T. Tensile	CVN Ft. Lbs. & % FIB		Stress <sup>(3)(5)</sup> Rupture
	(KSI)	@ 0°F	@ R.T.	(1100°F & 35 KSI)
R - Rim	1X @ 0°	2X	2X	1X
	1X @ 180°			
B - Bore <sup>(8)</sup>	1X @ 0°	2X	2X	--
M	1X @ 0°	2X	2X	--
	1X @ 180°			

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P29A-  
AG214, P



**PRODUCT STANDARD**  
**HYDERABAD**  
**GT ENGINEERING**

Prod. Std. No. : GT10649

Rev. No. 01

Page 10 of 14

**B5. Production - Mechanical Properties Required for MS7 and MS9 G&H CDP Seal Forgings**

	R.T.	CVN		Stress <sup>(3)(5)</sup>
Test Ring	Tensile	Ft. Lbs. & % FIB		<u>Rupture</u>
<u>Location</u>	<u>(KSI)</u>	<u>@ 0°F</u>	<u>@ R.T.</u>	<u>(1100°F &amp; 35 KSI)</u>
M Ring	1X	2X	2X	--
R1 Ring	1X @ 0°	2X	2X	--
	1X @ 180°			
R2 or R2A Ring	1X @ 0°	2X	2X	1X
	1X @ 180°			

**NOTES FOR TABLE 1:**

(1) All specimens must be in the tangential or circumferential direction. 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. Two of these test temperatures must be 0°F and room temperature (RT) for HY19467 material forgings. The only specified test temperature for HY19460 material forgings is 0°F. The test temperatures must be selected in 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) Combination smooth-notch tangential rupture test specimen.

(4) Test specimens are to be located 180 degrees apart.

(5) Stress rupture tests are required only for HY19467 forgings that are for MS7001F, FA G&H and MS9001F, FA, G&H designs.

(6) The measurement of mechanical properties at an "M" test ring location is required for 17th stage aft compressor wheel forgings for MS7001F, MS7001FA, MS9001F and MS9001FA designs, and the CDP seal for the MS9001G and H designs.

(7) Required for HY19460 alloy steel forgings

(8) These tests may be waived if approved by BHEL and documented in MPP.

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AG214, P

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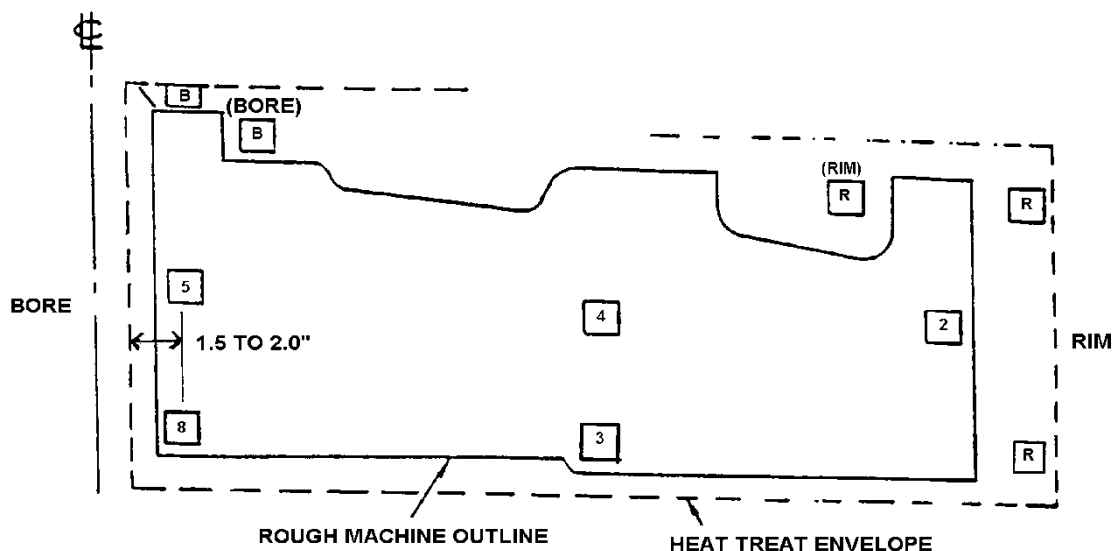
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**HYDERABAD**  
**GT ENGINEERING**

Prod. Std. No. : GT10649

Rev. No. 01

Page 11 of 14

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**Figure (1)**  
**TEST SPECIMEN LAYOUT FOR MECHANICAL PROPERTIES**  
**TESTING COMPRESSOR WHEELS**

**NOTES FOR FIGURE 1:**

(1) Specimen R - (19.1mm x 19.1mm Nominal Cross Section Ring) - The center of the test ring must be 31.75mm to 38.1 below both heat treated surfaces - the forging's radial circumferential surface, and the rim's inner or outer diameter depending on the position selected by the forging supplier.

(2) Specimens #2 and #3 - The centers of the test specimens must be located 31.75mm to 38.1mm below the as-heat treated forging's outer diameter. In addition, the center of Specimen #3 must be 31.75mm to 38.1mm below the radial circumferential surface.

(3) Specimens #2, #4 and #5 - The test specimen centers must be located at the forgings mid height or thickness. In addition, Specimen #4 must also be located at the forging's mid radius.

(4) Specimen B - The test ring must have a 19.1mm nominal height and the radial dimension should be that needed to provide all of the mechanical property test specimens. The test specimen center must be located 12.7mm to 19.1mm below the as-heat treated radial-circumferential surface.

(5) Specimens #5 and #8 - The test specimen's centers must be located 38.1mm to 50.8mm below the as-heat treated bore surface.

(6) All test specimen locations and orientations within the as-heat treated forging envelope must be accurately defined and documented in the part manufacturing process instructions, MPI, and when applicable also in the supplier's qualification report.

Ref. Doc  
P29A-  
AG214, P



**PRODUCT STANDARD**  
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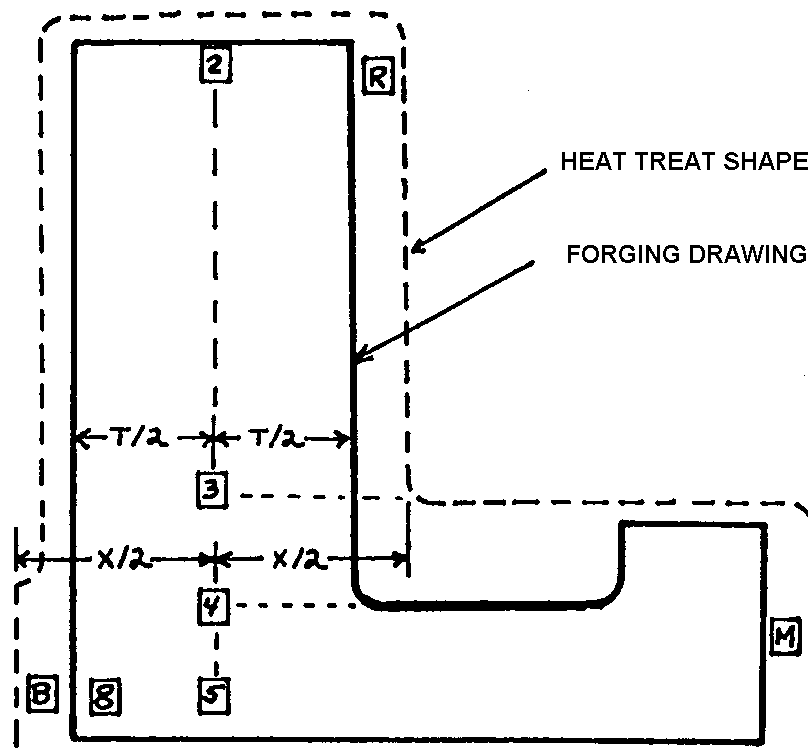
Prod. Std. No. : GT10649

Rev. No. 01

Page 12 of 14

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**Figure (2)**  
**TEST SPECIMEN LAYOUT FOR MECHANICAL PROPERTIES TESTING**  
**17TH STG. COMPRESSOR SHAFT**



**NOTES FOR FIGURE 2:**

(1) Specimen R - (19.1mm x 19.1mm Nominal Cross Section Ring) - The center of the test ring must be 31.75mm to 38.1mm below the radial-circumferential as-heat treated surface.

(2) Specimen #2 - The test specimen centers must be 31.75mm to 38mm below the outer diameter of the as-heat treated forging envelope.

(3) Specimen B and M - The test ring must have a 19.1mm nominal axial dimension and the radial dimension should be that needed to provide all of the mechanical property test specimens. The test specimen centers must be located 12.7mm to 19.1mm below the as-heat treated radial- circumferential" surface. In addition, the inner diameter of test ring "B" must be within 25.4mm of the bore surface and the "M" test ring must be at the mid-radial location.

(4) Specimens #5 and #8 - The test specimen's centers must be located 12.7mm to 19.1mm below the as-heat treated bore surface.

(5) All test specimen locations and orientations within the as-heat treated forging envelope must be accurately defined and documented in the part manufacturing

Ref. Doc  
P29A-  
AG214, P



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Prod. Std. No. : GT10649

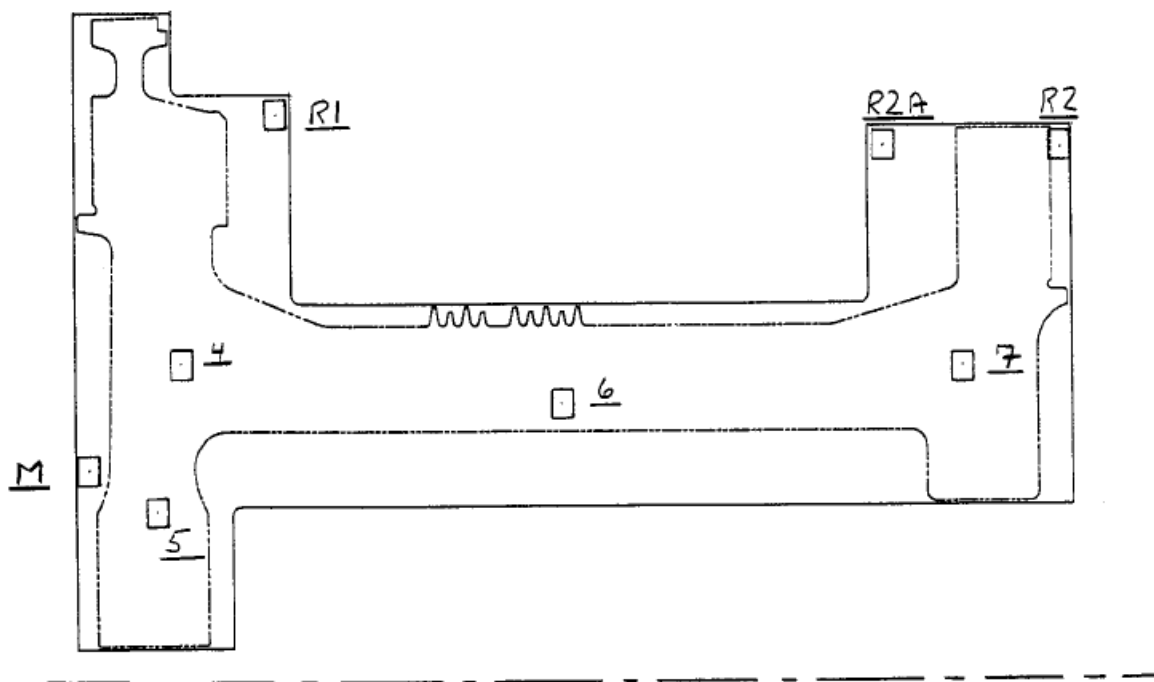
Rev. No. 01

Page 13 of 14

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**Figure (3)**  
**TEST SPECIMEN LAYOUT FOR MECHANICAL PROPERTIES TESTING**  
**17TH & 18TH STAGE CDP SEAL FORGINGS**



\* Alternate mechanical properties testing plans might be approved in the Supplier's Manufacturing Process Plan (MPP).

**NOTES FOR FIGURE 3:**

(1) Specimens M, R1, R2 and R2A - (19.1mm x 19.1mm Nominal Cross Section Ring). The center of the test rings must be 12.7mm to 19.1mm below the respective adjacent as-heat treated surfaces.

(2) Specimens #4, #5, #6 and #7 - The locations shall depend on the supplier's as-forged and as-heat treated configurations. They will be positioned in the approved suppliers "FPQ" MPP.

Ref. Doc  
P29A-  
AG214, P

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