1.0 SCOPE

This specification covers Titanium Alloy 6Al-4V in the form of flat products and formed in annealed condition, i.e. for sheets, strips, plates and plate-formed domes etc. for aerospace components.

2.0 APPLICABLE DOCUMENTS

The following standards form a part of this specification to the extent specified herein. The latest issue of these documents in effect on the date of material purchase shall be applicable.

2.1 ASTM Standards

- ASTM E8: Tension Testing of Metallic Materials
- ASTM E120: Chemical Analysis of Titanium and Titanium Alloys
- ASTM E165: Standard Method for Liquid Penetrant Testing
- ASTM E399: Plane Strain Fracture Toughness Testing of Metallic Metallic Materials
- ASTM E539: X-ray emission spectrometric Analysis of 6Al-4V Titanium alloy
- ASTM B600: Guide for Cleaning and Descaling Titanium and Titanium alloy surfaces
- ASTM E1409: Determination of Oxygen and Nitrogen in Titanium by Inert Gas Fusion Technique
- ASTM E1447: Determination of Hydrogen in Titanium and Titanium alloys by Inert Gas Fusion Thermal conductivity/infra-red detection Method
- ASTM E1941: Determination of Carbon in Refractory and Reactive Metals and their Alloys
- ASTM E2371: Analysis of Titanium and Titanium alloys by Atomic Emission Plasma Spectrometry

2.2 AMS Standards

- AMS 2380: Approval and Control of Premium Quality Titanium Alloys
- AMS 2630: Inspection, Ultrasonic Product over 0.5 inch (12.7 mm) thick
- AMS 2631: Ultrasonic Inspection of Titanium & Titanium Alloys
- AMS 2632: Inspection, Ultrasonic, of thin materials 12.7mm and under in cross sectional thickness
- AMS 2642: Structural Examination of Titanium Alloys, Etched Anodized Procedure
- AMS 2643: Structural examination of Titanium alloys, Chemical Etch Inspection Procedure
- AMS 2750: Pyrometry
- AMS 4911: Titanium Alloy, Sheet, Strip, and Plate, Ti-6Al - 4V Annealed
- AMS-H-81200: Heat Treatment of Titanium and Titanium Alloys
3.0 MELTING PRACTICE

Melting shall be carried out as per the standard procedure specified in AMS 2380 under effective control of all the variables of melting process to produce consistently uniform ingots so as to meet the quality requirements specified in this plan. The ingots shall be produced through at least double vacuum arc re-melting. First melt shall be made by consumable electrode, non-consumable electrode, electron beam cold hearth or plasma arc cold hearth melting practice. Subsequent melt or melts shall be made under vacuum using VAR practice with no alloy additions permitted.

4.0. CHEMICAL COMPOSITION

4.1 Composition shall conform to following percentage by weight, determined by wet chemical methods or any other method approved by purchaser

<table>
<thead>
<tr>
<th>ELEMENTS</th>
<th>% BY WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td>Aluminum (Al)</td>
<td>5.50</td>
</tr>
<tr>
<td>Vanadium (V)</td>
<td>3.50</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>-</td>
</tr>
<tr>
<td>Oxygen (O)</td>
<td>-</td>
</tr>
<tr>
<td>Carbon (C)</td>
<td>-</td>
</tr>
<tr>
<td>Nitrogen (N)</td>
<td>-</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>-</td>
</tr>
<tr>
<td>Residual Element (each)(^a,b)</td>
<td>-</td>
</tr>
<tr>
<td>Residual elements (Total)(^a,b)</td>
<td>-</td>
</tr>
<tr>
<td>Titanium</td>
<td>Balance</td>
</tr>
</tbody>
</table>

\(^a\) determination not required for routine purpose

\(^b\) residual elements like Zr, Hf, Mn, Cr, etc

4.2 Ingot Analysis

Chemical composition shall be checked on one sample each from top and bottom of each ingot after adequate removal to eliminate piping and other defects. The composition shall meet the requirements specified in 4.1

4.3 Lot definition

A lot shall be all sheets, strips, plates and formed domes of the same nominal cross section and configuration processed together from a single heat

4.4 Product Analysis

4.3.1 Product analysis shall be carried out from each lot as check analysis

4.3.2 If heat/lot traceability cannot be established, each product shall be checked for chemical conformity by taking sufficient number of samples to establish chemical conformity to 4.1.

5.0 MACRO-ETCH TEST

5.1 Macro-etch test shall be carried out after ingot breakdown operation on the forged stock, prior to rolling/forging of items into the final product. Macro-etch sample shall be taken from both and top and bottom end of the rolling stock after adequate
removal of metal to eliminate piping and other defects from the entire cross section of the stock.

5.2 Macro-etch test shall be carried out in accordance with AMS 2642/2643. Structure shall be free from pipe, cracks, porosities, laps, folds, pitting, segregation, inclusions etc. Acceptance shall be as per section 3.2.1 of AMS 2380.

6.0 SUPPLY CONDITION

The products shall be supplied in the following conditions.

6.1 Sheets, Strips and Plates

Sheets, Strips and Plates in rolled, annealed and descaled/pickled condition.

6.2 Formed domes

Supply shall be in annealed and proof machined condition.

7.0 HEAT TREATMENT

7.1 Heat treatment shall be performed using equipment and procedural controls in accordance with AMS–H–81200.

7.2 Annealing

<table>
<thead>
<tr>
<th>Ruling Thickness, mm</th>
<th>Temperature °C</th>
<th>Soaking time</th>
<th>Cooling Medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 30</td>
<td>730 ± 10</td>
<td>Sheets/Strips = 30 minutes Plates = 2 hours</td>
<td>Furnace cool up to 565°C followed by air cooling</td>
</tr>
<tr>
<td>&gt; 30</td>
<td>730 ± 10</td>
<td>2 Hours minimum and add 15 minutes for each 6 mm</td>
<td>Air cool</td>
</tr>
</tbody>
</table>

8.0 MECHANICAL PROPERTIES

8.1 The sheets, strips, plates and formed domes shall conform to the requirements for mechanical properties as specified in Table 1.

### TABLE 1: Room temperature mechanical property requirements

<table>
<thead>
<tr>
<th>Nominal Thickness during heat treatment, mm</th>
<th>UTS MPa, Min</th>
<th>0.2% P.S MPa. min</th>
<th>Elongation in 50 mm or 4d (%)</th>
<th>Reduction in area (%)</th>
<th>Fracture Toughness (MPa√m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Long Trans</td>
<td>Long Trans</td>
<td>Long Trans</td>
<td>Long Trans</td>
<td>Long Trans</td>
</tr>
<tr>
<td>Up to 100 incl.</td>
<td>895</td>
<td>825</td>
<td>10</td>
<td>25</td>
<td>50</td>
</tr>
</tbody>
</table>

8.2 Hardness shall be measured for all products and it shall be 290 to 330 BHN

8.3 Sampling for mechanical properties

8.3.1 Sheets & Strips

Three tensile specimens shall be taken from a sheet/strip representing each lot in both longitudinal and transverse directions.
8.3.2 Plates
Three tensile and three fracture toughness specimens shall be taken from a plate representing each lot in both longitudinal and transverse directions.

8.3.3 Formed Domes
8.3.3.1 Three tensile and three fracture toughness specimens shall be taken from a dome representing each forming campaign in both longitudinal and transverse directions.
8.3.3.2 For heat qualification, mechanical testing shall be carried out from the prolongation provided in the dome.
8.3.4 The tension test shall be made in accordance with ASTM E 8 and the fracture toughness test shall be made as per ASTM E 399.

9.0 ULTRASONIC INSPECTION
9.1.1 All the plates & domes shall be ultrasonically inspected for 100% of its volume by both normal beam and angle beam as per AMS 2630/AMS2632 and AMS 2631
9.1.2 For sheets, ultrasonic inspection shall be carried out in an intermediate stage (<50mm thickness) as per AMS 2631 and AMS 2630 and acceptance shall be as per clause 9.2.

9.2 Acceptance Criteria

<table>
<thead>
<tr>
<th>Size, mm</th>
<th>Class</th>
<th>Single Discontinuity</th>
<th>Multiple/Linear Discontinuity</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 50</td>
<td>A1</td>
<td>1.2mm FBH or equivalent</td>
<td>0.8mm FBH or equivalent</td>
</tr>
<tr>
<td>&gt;50</td>
<td></td>
<td>Mutually agreed between supplier and purchaser</td>
<td></td>
</tr>
</tbody>
</table>

9.2.1 All acceptable indications between 50% and 100% of DAC shall be reported.

10 DYE PENETRANT TEST
10.1 Dye penetrant test shall be carried out on sheets, strips, plates and domes as per ASTM E165 or other equivalent standard. All the products shall be free from any kind of surface defects.

11 METALLURGICAL ANALYSIS
11.1 Metallographic examination per lot shall be carried out as per AMS 2642/2643. The material shall be free from micro-porosity, stringers, segregation etc.
11.2 Microstructure shall essentially contain equiaxed primary α in the transformed β matrix resulting from α – β processing.
11.3 Occasional elongated primary α in the transformed β matrix resulting from α – β processing is acceptable.
11.4 Microstructure with continuous grain boundary α at prior beta grain boundary is not acceptable.
11.5 Product shall be free of any oxygen rich layer/ α case or other surface contamination determined by microscopic examination, at not lower than 100 x magnification.
12 DIMENSIONAL TOLERANCES

12.1 All products shall conform to the shape and dimensions specified in the contract or order within such dimensional tolerances as may be specified in the contract order or referenced drawings.

13.0 IDENTIFICATION MARKING

13.1 Each item shall be steel impression stamped or ink marked with the information required below.

- Manufacturer’s name
- Specification & Grade number
- Part Number
- Heat Number
- Ingot Number and Serial Number
- Size / Weight
- Condition
- Purchase Order Number
- Inspector’s stamp for clearance
- VSSC RMC No.

13.1.1 The character shall be of such size as to be legible, shall be applied using a suitable marking fluid and shall be sufficiently stable to withstand normal handling. The marking shall have no deleterious effect on the product or its performance.

13.2 Identification of forgings shall be in accordance with AMS 2809

14 PACKING

14.1 The product shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules & regulations pertaining to the handling, packing and transportation of the product as per MIL-STD-163 level applicable to aerospace material.

14.2 The package shall be done in such a way that they are not supported on identification marks and the package shall be water proof.

14.3 Net weight and total weight shall be marked on the package.

14.4 The package shall be checked by manufacturer as per approved check list and certified on the package.

15 RESAMPLING AND RETESTING

15.1 If any specimen used in the mechanical tests as per 8.0 fails to meet the specified requirements, the supplier shall go for retest on two additional specimens for each original nonconforming specimen. Retest specimen shall be taken as close as possible to the same location in the same forging or from a second forging from the same lot as was the original unacceptable specimen. Failure of any retest specimen to meet the specified requirements shall be cause for rejection of the forgings represented and no additional testing shall be permitted. Results of all tests shall be reported.
16 INSPECTION

16.1 The manufacturer shall afford the purchaser’s Inspector all reasonable facilities necessary to satisfy him that the material is being produced and furnished with this specification. All tests and inspection shall be made at the place of manufacturer unless otherwise agreed to.

17 CERTIFICATES AND REPORTS

17.1 Manufacturer shall furnish the following certificates and test reports.
   17.1.1 Chemical analysis of heat
   17.1.2 Heat treatment report
   17.1.3 Metallurgical analysis report
   17.1.4 Mechanical property report
   17.1.5 Ultrasonic inspection report
   17.1.6 Dimensional inspection report
   17.1.7 DP Report

18 REJECTION

18.1 Material that has any non-conformances to the above specified requirements prior to or subsequent to acceptance by the purchaser shall be subjected to rejection and the manufacturer shall be notified.