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SPECIFICATION

CONTROL OF MATERIALS USED IN THE MELTING OF PREMIUM QUALITY TITANIUM BASE ALLOYS

1. SCOPE

1.1 Scope. This in-process specification defines the minimum process control and evaluation requirements for preventing introduction of inclusions and other deleterious anomalies in raw materials used to produce double or triple VAR (vacuum arc remelt) or HM (hearth melt) plus VAR titanium alloy ingots.

1.1.1 Classification. This specification contains the following class(es). Unless otherwise specified, the requirements herein apply to all classes.

- CLASS A: Input material for P1TF73 applications
- CLASS B: Input material for P1TF28 applications
- CLASS C: Input material for P1TF103 applications

1.2 Definitions. The terminology used herein is in accordance with AS 1814. For purposes of this specification, the following definitions shall apply:

Billet - Converted material having a cross section greater than 103 cm² (16 square inches), and a width less than five (5) times the thickness.

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Capability - The words "shall be capable of" or "capability test" indicate characteristics or properties required in the product but for which testing of each lot or location is not required. However, if such testing is performed by the Purchaser, material not conforming to the requirements shall be subject to rejection.

Controlled Document - A document with an unique identification and controlled approval and distribution.

Established Procedure - A procedure that is subject to Purchaser approval and is contained in a controlled document. It may include limits, controls and applicable standards.

Established Standard - A standard that is subject to Melt Supplier approval and is referenced or defined in a controlled document.

Heat - The ingot produced from the final VAR of a single consumable electrode.

Hearth melt furnace - Furnace that has been approved for P1TF73 applications

Inclusions - Particles of impurities or foreign materials that are present or introduced during any stage of alloy processing. Examples include a Type I Hard Alpha inclusion formed by high interstitial element content, and a high density inclusion (HDI) formed by refractory metals such as tungsten or molybdenum.

Platter - The electrode or electrode stub material remaining on the electrode holder after completion of VAR. It is also known as a wafer.

Premium Quality - Material produced under special process and quality control requirements and used primarily for critical rotating parts.

Recycle Material-Premium Quality Sheet - Sheet, maximum thickness 0.075 inch (1.91 mm) and having no visible discontinuities, laps, folds, cracks or surfaces incapable of being 100 percent inspected

Recycle Material-Premium Quality Bar - Bar product, maximum diameter 51mm (2 inches) that has been ultrasonic inspected to P3TF34 and is not from a heat suspected or known to contain rejectable inclusions. The material shall not have flame cut surfaces or contain folds, cracks, split or rough ends or surfaces incapable of being 100 percent inspected.

Purchaser - The procuring activity of GE Aircraft Engines that issued the procurement document invoking this specification. When this specification is invoked by a U.S. Government purchasing activity (or such activity's designee), the Purchaser shall mean such activity or designee as the case may be.

Sponge Batch - The metal product of a single titanium or zirconium sponge reactor process.

Sponge Lot - The mixed or blended sponge product containing portions of one or more sponge batches.

Sponge Fire - Burning of sponge particles. Instantaneous sparking is not considered burning

Supplier - Source other than GE Aircraft Engines (GEAE) who provides material, parts or services, for incorporation into GEAE products.

Type I Hard Alpha Inclusion - An interstitially stabilized alpha-rich region of significantly higher hardness than the surrounding material. It arises from a high and out of specification concentration of one or more of the elements: nitrogen, oxygen, or carbon.

VAR - The vacuum arc melting or remelting process used for producing ingots to this specification.

X Ray - A non destructive inspection performed using suitable radiological or radioscopy techniques to identify contaminants having a significant density difference to the base material being inspected.

1.3 Regulated Materials. The requirements of P2TF1, CL-A, shall be complied with. The material(s) shown below were referenced in this specification and P2TF1, CL-A, as of the date of this specification issue. The list below does not include all materials which are referenced in sub-tier documents.

(a) Chromium and Compounds

2. APPLICABLE DOCUMENTS

2.1 Issues Of Documents. The following documents form a part of this specification to the extent identified herein. Unless otherwise indicated, the latest issue shall apply.

AMERICAN SOCIETY FOR TESTING AND MATERIALS

ASTM E 11 Wire Cloth & Sieves For Testing Purposes

SOCIETY OF AUTOMOTIVE ENGINEERING

AEROSPACE STANDARDS

AS 1814 Terminology for Titanium Microstructure

GE AIRCRAFT ENGINES SPECIFICATIONS

C50TF39 Premium Quality Alpha-Beta Forged 6Al-2Sn-4Zr-2Mo Titanium Base Alloy Parts

C50TF93 Premium Quality Beta Forged 6Al-2Sn-4Zr-2Mo Titanium Base Alloy Parts

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P1TF28	Premium Quality Multiple VAR Titanium Base Alloys
P1TF73	Premium Quality Hearth Melt Plus VAR Titanium Base Alloys
P1TF103	Premium Quality Small Hearth Melt + VAR Titanium base Alloys
P2TF1	Regulated Materials
P3TF15	Ultrasonic Inspection of Billet - Immersion
P3TF34	Ultrasonic Inspection of Metallic Bar Stock

3. REQUIREMENTS

3.1 Raw Material. Raw materials for ingot charge shall be limited to sponge, master alloys, elemental additions, titanium dioxide, and recycle material. Melt Suppliers shall maintain specifications and procedures for the procurement, storage, processing, inspection and approval of these raw materials for control of their physical condition and chemistry. Procedures will be established to prevent contamination and the spread of contaminants throughout the processing or storage of raw materials. Melt Suppliers shall reference in a controlled document their raw material suppliers and to the extent possible sub tiers to these suppliers and raw material inspection suppliers. Changes to raw material suppliers require purchaser approval. Inspection procedures will be in place for raw materials to assure freedom from contaminants. To assist in identifying opportunities for introducing contaminants a material process flow diagram should be prepared for each raw material. The processing of raw materials should be performed to minimize the introduction of inclusions. Class A materials do not require the inspections defined in this document to identify high density inclusions (HDI's).

3.1.1 Sponge

*3.1.1.1 Titanium Sponge. Melt Suppliers shall only use titanium sponge suppliers approved by GEAE. Sponge finished by leaching or inert gas sweep is prohibited for heats to be converted into billet. Sponge used in the formulation of heats that are to be converted into billet shall be finished by a vacuum distillation process (VDP). Sponge Suppliers shall establish procedures and limits for sponge production. Each sponge lot shall be visually inspected to established standards representing potential types of contaminated sponge to identify and remove particles suspected of containing high nitrogen content and other contaminants known to cause Type I Hard Alpha inclusions. An entire titanium sponge lot shall be disqualified when any contaminated particle, or any group of contaminated particles combined for analysis, exceeds a nitrogen content of 0.20 weight percent. A titanium sponge batch or lot involved in a fire at any stage of processing shall be disqualified. Melt Suppliers are required to have the maximum sponge sieve size and size distribution for titanium sponge approved by the Purchaser. The maximum size for titanium sponge to be melted into product to be converted into Premium Quality billet shall be limited to sponge able to pass

through a 0.5" (12.7 mm) or finer mesh sieve. For C50TF39 and C50TF93 applications, a maximum of 10% of sponge may exceed the 0.5" (12.7 mm) size but will be able to pass through a 0.75" (19 mm) mesh sieve. Sieving will be in accordance with ASTM E11.

*3.1.1.2 Zirconium Sponge. Melt Suppliers shall only use zirconium sponge suppliers approved by GEAE. Sponge Suppliers shall establish procedures and limits for sponge production. Each sponge lot shall be visually inspected to established standards representing potential types of contaminated sponge to identify and remove particles suspected of containing high nitrogen content and other contaminants known to cause Type I Hard Alpha inclusions. Zirconium sponge lots involved or suspected of being involved in a fire at any stage of processing shall be segregated and the entire sponge lot shall be 100% sorted and inspected and all particles suspected of being burnt particles removed. Melt suppliers are required to have the maximum sponge sieve size and size distribution for zirconium sponge approved by the Purchaser.

3.1.2 Master Alloys. Melt Suppliers shall only use master alloy suppliers approved by the Purchaser. Melt Suppliers shall approve the manufacturing process, inspection method, inspection frequency and inspection limits for master alloy production. Any detrimental foreign materials, oxides, nitrides or other contaminants known to cause Type I Hard Alpha or high density inclusions (HDI's) which are identified during the inspection will be removed and melt suppliers shall be notified of these finds in a timely manner. Master alloys which pass through a 20 mesh sieve do not require 100 percent inspection. The Boron content of the master alloys shall not exceed 50 parts per million by weight.

3.1.3 Elemental Additions. Melt Suppliers shall approve the manufacturing process, inspection method, inspection limits and inspection frequency for elements used as additions. Processes having a high potential to introduce HDI's shall not be approved or shall be consolidation melted through an approved hearth melt furnace. Any detrimental foreign materials, oxides, nitrides or other contaminants know to cause Type I Hard Alpha or high density inclusions (HDI's) which are identified during the inspection shall be removed and melt suppliers shall be notified of these finds in a timely manner.

3.1.4 Titanium Dioxide. Titanium dioxide shall be in powder form. 100 percent of the titanium powder shall pass through a 50 mesh Tyler or ASTM sieve. Melt Suppliers wishing to use titanium dioxide powder larger than a 50 mesh sieve require Purchaser approval of the proposed maximum powder size, size distribution and compaction method. The Melt Supplier shall approve the size and chemistry limits for the titanium oxide.

3.1.5 Recycle Material. Previously melted titanium or titanium alloys may be recycled provided the material has been multiple vacuum arc melted, or cold hearth melted. Recycle material shall be clean and free of heavy scale and slag and is not from a heat suspected or known to contain rejectable inclusions except as allowed by paragraph 3.1.5.2. Recycle material is not permitted to be stored or mixed with recycle material from a different alloy prior to blending.

3.1.5.1 Standard Recycle Material. The melt Supplier shall define preparation and cleaning procedures for each form of recycle material. For Class-B input material, all recycle materials except turnings, Premium Quality bar and sheet and internally generated scrap from hearth melted Premium Quality material, shall be consolidation melt processed using an established hearth melt procedure. Recycle material that at any time was involved in a fire, or that experienced an air leak that violated approved process procedures during VAR or Hearth melting, shall be disqualified unless it is capable of receiving appropriate Purchaser approved cleaning and inspection processes.

3.1.5.1.1 Turnings. Cleaning and inspection procedures are subject to approval by the Purchaser. Class-B turnings shall be X ray inspected. The X ray inspection shall be capable of identifying a 0.4 mm (0.015 inch) maximum diameter tungsten alloy wire or an equivalent standard approved by the Purchaser. Suspect particles greater than 0.4 mm (0.015 inch) identified during the X ray inspection shall be removed.

3.1.5.1.2 Material Form. Material forms with enfoliations or other features which prevent complete visual inspection shall not be recycled unless approved by the Purchaser. Purchaser approval shall be based on cleaning and subsequent melting processes that have demonstrated elimination of any contaminants from these features in the final melted product. Surface cold shuts from hearth melting and sponge ends on primary electrodes are acceptable recycle materials. Recycling of casting revert, grinding products, dust, and sludge is prohibited.

3.1.5.1.3 Flame Cut Surfaces. Surfaces that have been flame cut shall be disqualified unless they have been prepared by blasting, etching and inspected to approved procedures. Surfaces adjacent to flame cut surfaces or surfaces capable of being impacted with flame cut spatter shall be cleaned and inspected to approved procedures.

*3.1.5.2 Revert of Previously Disqualified Material. Purchaser approval shall be obtained before recycling any material that previously has been disqualified for containing or suspected of containing melt related inclusions.

- (a) Material generated from a production heat melted to approved procedures and identified as having HDI inclusions may be recycled for P1TF73 CL-A applications.
- (b) Material generated from a production heat melted to approved procedures and identified as having Type 1 Hard Alpha inclusions may be recycled for class A P1TF73 CL-A applications provided either of the following conditions are satisfied:
 - (1) The melted product has been converted to product having nominal diameter equal to or less than 10 inches (25.4 cm). If the diameter of the product is greater than 4.5 inches (11.43 cm), inspection shall be to P3TF15 CL-B. If the diameter of the product is equal to or less than 4.5" (11.43 cm), inspection shall be to the appropriate class of P3TF34. All rejectable

internal indications identified during the ultra sonic inspection are to be removed.

or,

(2) The melted product has been converted into turnings.

3.2 Process Equipment. Equipment used in the manufacturing or inspection process for raw or charge materials shall be evaluated prior to introduction for Premium Quality materials production, to assure the absence of any potentially detrimental materials or contaminants. When in use, the equipment shall be cleaned and inspected to established standards at a frequency to prevent cross contamination of processed raw or charge materials. Procedures and limits for the repair and subsequent inspection of the process equipment to prevent introduction of potential HDI sources shall be described in a controlled document.

3.2.1 Welding. MIG welding is the recommended method for repairing equipment used in the processing of raw materials. TIG welding is permitted provided the following conditions are met:

- (a) Materials or equipment used in titanium alloy production that have the potential to be contaminated by weld spatter, shall be removed or shielded during the welding operation.
- (b) When equipment used in the processing of materials is manufactured or repaired by TIG welding, cleaning and inspection procedures for the weld and adjacent surfaces shall be to standards approved by the Melt Supplier. Any TIG weld that will contact class-B raw materials is to be X rayed to ensure absence of tungsten. The standard used for the X ray inspection shall be 0.4 mm (0.015 inch) tungsten standard.

3.3 Raw Material Storage. All raw material shall be stored in covered containers to preclude the unintentional addition of foreign or uninspected material. Material handling procedures shall be established to control cleaning and identification of containers and their contents. Packaging procedures shall be established. Mixing of production lots by Raw material suppliers is prohibited. With the exception of revert, melt Suppliers are prohibited from mixing material of the same type from different suppliers. Melt suppliers are prohibited from mixing revert of different alloys.

3.4 Material Traceability And Accountability

3.4.1 Traceability. Raw material shall be documented and traceable to the supplier. Titanium sponge, zirconium sponge, elemental additions and master alloys shall also be traceable to the raw material Suppliers manufacturing lot number.

3.4.2 Documentation. Documenting traceability and disposition of material shall be available for review by the Purchaser and the melt supplier. The Supplier shall maintain traceability as described and provide accountability of all raw materials. The manufacturing and inspection processes conducted on all raw materials including identification of

equipment and processes conducted by subtier suppliers, shall be documented, to the extent possible, and be available for review by the Purchaser and the melt supplier. Suppliers of titanium sponge, zirconium sponge, master alloys or elemental additions shall document all finds of contamination particles that have the potential to form a hard alpha inclusion or high-density inclusion. This data shall be available for review by the Purchaser and the Melt Supplier.

4. QUALITY ASSURANCE PROVISIONS

4.1 Supplier Qualification. Titanium sponge, Zirconium sponge and Master alloys shall be procured only from suppliers approved by the Purchaser.

4.1.1 Titanium Sponge Suppliers. New titanium sponge suppliers to the Purchaser shall have at least 0.45 million Kgs (1 million pounds) of their sponge melted into ingots and converted into bar stock of maximum diameter 51 mm (2 inch). The bar stock shall be inspected in accordance with P3TF34 as determined by the Purchaser. There will be no more than one Type 1 hard alpha inclusion found (attributable to the sponge) in the 0.45 million Kgs (1 million pounds) for the titanium sponge supplier to be qualified.

4.1.2 Zirconium Sponge Suppliers. New zirconium sponge suppliers to the Purchaser shall have at least 4,545 Kg (10,000 lb) of their sponge melted into ingots and converted into bar stock of maximum diameter 51 mm (2 inch). The bar stock shall be inspected in accordance with P3TF34 as determined by the Purchaser. There shall be no Type 1 hard alpha inclusion attributable to zirconium found in any of the heats for the zirconium sponge supplier to be qualified.

*4.1.3 Revert Qualification. Material forms with enfoliations or other features which prevent a complete visual inspection shall only be considered as acceptable recycle material when the material has been cleaned and then multiple vacuum arc melted or cleaned and hearth melted to establish procedures and following conversion into 2" (51 mm) diameter or less bar.

CLASSES B and C: Ultrasonic inspection of the bar shall be in accordance with P3TF34.

4.2 Qualification Retention. To maintain qualification, Suppliers qualified to this specification shall adhere to the requirements of this specification and deliver product of acceptable quality.

4.3 Qualification And Re-Qualification. Melt Suppliers are responsible for qualification and/or requalification of Suppliers of raw material to this specification and for verifying material suppliers have a material process flow diagram for each raw material which includes significant operations. Changes to significant operations will require melters approval prior to introduction. The qualification program will include, if appropriate, review and approval of a training program for operators and inspectors responsible for processing or inspecting raw materials. The Melt Supplier shall define and implement an effective audit program at raw material sources to assure adherence to approved procedures. The frequency of contaminated particles

shown to be HDI's or following chemical analysis having a high potential to form a Type 1 Hard Alpha shall be monitored by Melt Suppliers for each raw material source. Significant increases in such inclusions will require notification to the Purchaser and the raw material supplier(s) manufacturing process to be re-evaluated and possibly requalified.

4.4 Raw Material Inspection. The Melt Supplier shall inspect procured raw material from every raw material supplier at least once a year.

*4.4.1 Titanium Sponge Inspection. Qualified sponge suppliers shall inspect sponge from each sponge lot. The inspection method and the amount to be inspected shall be defined in an established procedure. A minimum of 10 percent of each sponge lot shall be inspected for burnt particles. Suspect particles from the visual inspection shall be removed and characterized. Particles suspected of being high in nitrogen content shall be analyzed for chemistry. Smaller suspect particles may be combined into groups of approximately 0.1 gram for this analysis.

*4.4.2 Zirconium Sponge Inspection. Qualified sponge suppliers shall inspect sponge from each sponge lot. The inspection method and the amount to be inspected shall be defined in an established procedure. A minimum of 10 percent of each sponge lot shall be inspected for burnt particles. Particles suspected of being high in nitrogen content shall be analyzed for chemistry. Smaller suspect particles may be combined into groups of approximately 0.1 gram for this analysis.

*4.4.3 Master Alloy Inspection. Master alloy Suppliers shall visually and if appropriate X-Ray inspect 100 percent of each lot. Prior to approval of the X-ray inspection process on production material, the sensitivity of the X-ray inspection process shall be demonstrated to be capable of detecting a 0.40mm (0.015 inch) tungsten wire. Periodic verification of the inspection capability will be to a frequency approved by the melt supplier with the use of parallel line pair gages or similar encapsulated low hazard material e.g. tin or lead of an appropriate size to ensure the initial demonstrated detectability has not deteriorated. Contaminants suspected of having the potential to form Type 1 Hard Alpha or HDI's shall be analyzed for chemistry.

*4.4.4 Elemental Additions Inspection. Elemental addition alloy suppliers shall visually inspect each lot. Contaminants suspected of having the potential to form Type 1 Hard Alpha or HDI's shall be analyzed for chemistry.

*4.4.5 Recycle Material Inspection. Recycle material shall be 100% visually inspected. Turnings do not require visual inspection.

4.5 Documentation. Melt Suppliers evaluations and audit findings will be subject to Purchaser review.

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REVISION HISTORY

P1TF95-S1	INITIAL ISSUE	04-25-95
Amend 1	CID 078348	02-12-96
-S2	CID 078807	11-19-98
-S3	CID 078910	08-05-99
-S4	CID 079266	09-26-02
S5	Reincorporation 079266	10-15-02
-S6	Reincorporation 079266	11-14-02
-S7	CID 079635	02-10-06

* Denotes latest change