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SPECIFICATION

PREMIUM QUALITY HEARTH MELT PLUS VAR TITANIUM BASE ALLOYS

1. SCOPE

*1.1 Scope. This specification is an in-process specification that defines the minimum process control and evaluation requirements for assurance that titanium base billet, bar and plate produced from hearth melt plus vacuum arc remelt ingot and used to produce forgings to GE Aviation specifications are free from segregation, inclusions, and other deleterious anomalies.

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

CLASS A

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

Bar - Converted material having a cross section less than or equal to 16 square inches (406.4 mm^2), and a width less than five times the thickness.

Beta Fleck - A localized beta stabilizer enriched segregation that has a beta transus measurably lower than the surrounding normal matrix. An example of a rejectable beta flecks is displayed in GE photograph 8510040.

Beta Transus - The minimum metal temperature that alpha-beta processed material can be heated to transform it completely to the beta phase.

Billet - Converted material having a cross section greater than 16 square inches (406.4 mm^2), and a width less than five times the thickness.

Bottom Charge - The material placed in the VAR crucible to protect the crucible during arc initiation.

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.

EBM - The electron beam cold hearth melting process that may be used for melting to this specification.

Electrode - The product of a melt step that becomes the consumable electrode in the subsequent melt

Electrode Holder - The material that is joined to the top of the electrode or electrode stub to provide the connection between the electrode and the VAR furnace electrical equipment.

Electrode Marker - A titanium rod or other shape affixed to the consumable electrode, electrode stub, or electrode holder for VAR. The purpose of this marker is to provide visual reference for the electrode height position.

Electrode Stub - The material that may be joined to the top of electrode to provide the connection between the electrode and the electrode holder.
Established Procedure - A procedure that is subject to Purchaser approval and is contained in a controlled document. It includes limits, controls, and applicable standards.

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Glow Discharge - A condition occurring in VAR when the arc becomes diffuse and is transferred to the crucible wall, and the heat input to the melt is greatly reduced.

Heat - The ingot and ingot product produced from one VAR of a single EBM or PAM consumable electrode.

High Density Inclusion (HDI)- A region with a concentration of elements, usually tungsten, columbium or molybdenum, having a higher density than the matrix.

Hot Topping - Adjustments of process parameters during the latter stages of a melt process to minimize pipe, shrinkage porosity, and segregation.

Inclusions - Particles of impurities or foreign materials that are present or introduced during any stage of alloy processing which results in a non-conforming microstructure and an out of specification chemistry.

In Process Specification - A specification that defines in process controls and evaluation requirements that will result in a finished part that meets Engineering requirements.

In Process Deviation - Deviations to the requirements of an In Process Specification that are dispositioned as defined in a GE/Supplier controlled document. These deviations cannot result in non compliance to Engineering requirements defined in the appropriate C50TFXX specification or Engineering drawing.

Macroetch - Chemical treatment of a metal surface to accentuate structural details and anomalies for visual observation.

PAM - The plasma arc cold hearth melting process that may be used for melting to this specification.

Partitioning - The normal solidification enrichment, or depletion, of an element resulting from non-equilibrium solidification. The partition coefficients for oxygen, nitrogen and carbon are respectively, 1.6, 1.58 and 0.50. The oxygen coefficient would predict the maximum possible level for oxygen in an alloy with nominal oxygen content of 0.10% to be 0.16% as a result of partitioning.

Plate - Flat rolled converted material having a thickness greater than 0.1875 inches (4.76 mm), and a width greater than or equal to five times the thickness.

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

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

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Purchaser - The procuring activity of GE Aviation 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.

Segregation - Regions in the alloy product containing an out of specification content of alloying elements which result in an out of specification microstructure. These segregated regions appear as zones of microstructural variation where the morphology or volume fractions of the alpha and beta phases are discernibly different from the matrix.

Supplier - Source other than GE Aviation who provides material, parts or services, for incorporation into GE Aviation 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, which is not explained by partitioning.

VAR - The vacuum arc remelting process used for final melting to this specification

*1.3 EHS 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) Copper and Compounds

2. APPLICABLE DOCUMENTS

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

MILITARY SPECIFICATIONS

MIL-H-81200	Heat Treatment of Titanium and Titanium Alloys

AEROSPACE MATERIAL SPECIFICATIONS

AMS 2380	Approval and Control of Premium Quality Titanium Alloys

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INTERNATIONAL ORGANIZATION FOR STANDARDS (ISO)

ISO 10012-1	Quality Assurance Requirements Measuring Equipment

AEROSPACE STANDARDS

AS 1814	Terminology for Titanium Microstructures

GE AVIATION SPECIFICATIONS

P1TF95	Control of Materials Used in the Melting of Premium Quality Titanium Based Alloys
P2TF1	Regulated Materials, Environmental, Health and Safety
P3TF15	Ultrasonic Inspection of Billet - Immersion
P3TF34	Ultrasonic Inspection of Metallic Bar Stock Using Pulse Echo Immersion Techniques
P3TF35	Ultrasonic Inspection

GE AVIATION PHOTOGRAPHS

8510040	Rejectable Beta fleck
S21607	Acceptable beta segregation in beta processed Ti17
S21608 & S26526-1 & S26526-2	Acceptable beta segregation in alpha beta processed Ti17
S26596	BEA indication requiring evaluation

*2.2 Order of Precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Material Processing. Material supplied to this specification shall be billet, bar, or plate, melted and converted only by Suppliers approved by the Purchaser. Melting shall be by an established procedure that includes an EBM or PAM melting step.

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3.1.1 Process Control. Suppliers shall maintain a controlled document with effective controls for each step of the processing sequence. Significant process parameters shall be identified along with their corresponding control points and control limits. Process parameter measurements shall be made at the control points. Frequency of control point monitoring also shall be identified. Statistical process control methods shall be employed to the extent they are applicable.

3.1.1.1 Process Parameter Control. The controlled document shall be subject to approval by the Purchaser and, once established, no changes to the significant process parameters shall be made without obtaining written approval from the Purchaser. When any of the significant process parameters exceed the defined control limits, the Purchaser shall be notified, and Purchaser approval shall be obtained as described in the controlled document before shipment of material.

3.1.1.2 Process Control Emphasis. The controlled document shall detail the methods for control, monitoring, and detection used during all stages of the processing sequence that inclusions could be formed or entrained, or segregation generated.

3.1.2 Data Review. Process parameter data, inspection results, and data plotted on statistical quality charts for trend analysis and corrective action shall be available for review by the Purchaser.

3.1.3 Inspection Suppliers. Inspections specified herein shall be performed only by Suppliers approved by the Purchaser.

3.1.4 Gas Tungsten-Arc Welding. The use of gas tungsten arc (TIG) welding for the manufacture or repair of equipment used in the storage or processing of product requires prior Purchaser approval. Welding, cleaning and inspection shall be performed to established procedures before installation to preclude introduction of potential HDI sources. The use of TIG welding is prohibited on condensate screens used in EBM which are located in an area where contamination of the liquid alloy could occur.

3.2 Hearth Melting. The hearth melt process shall be either EBM or PAM.

3.2.1 Melting Control. Melt Suppliers shall maintain effective controls for consistently producing electrodes free from Type I Hard Alpha and other deleterious inclusions (e.g. HDI). As a minimum, raw material procurement and preparation procedures, melting procedures, and acceptance standards shall be established. The configuration of the hearth shall be contained in a controlled document.

3.2.2 Raw Material. Raw material shall be controlled and evaluated in accordance with P1TF95. Titanium sponge, zirconium sponge and master alloys shall be procured only from Suppliers established by the Purchaser.

3.2.2.1 Charge Composition. The charge materials shall be composed of only sponge, master alloys, elemental additions, titanium oxide, and recycle material. The weight percent and chemical composition of each type of raw

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material used in the charge materials shall be recorded. The maximum size of sponge, master alloys, elemental additions and titanium oxide shall be recorded.

3.2.3 Raw Material Storage. Sponge, master alloy, elemental additions, titanium dioxide and blended recycle material shall be stored in covered containers or packaged to preclude the unintentional addition of foreign or uninspected material.

3.2.4 Raw Material Blending. Procedures shall be established for blending all raw material and for maintaining homogeneity of the blended material during storage and during charging of the furnace.

3.2.5 Compacting Raw Materials. All raw materials except bulk solid revert shall be processed by pressing to form a compact or briquette. The compacting process shall be performed to established procedures. Control points shall be established and monitored for the compaction process.

*3.2.6 Welding of Electrodes. All welding of compacts, holders or fixtures in preparation for consolidation melting shall be performed in a weld chamber to established procedures. Effective controls and limits for the weld process shall be maintained for consistently producing welded product free from contaminants known to cause Type I Hard Alpha or other deleterious inclusions. The controls shall include the method used for monitoring the weld chamber atmosphere.

3.2.6.1 Pusher Welding. Welding of pushers and the repair of pusher welds shall be to established procedures and shall be contained in a controlled document. Melting into welds (and weld affected zones) that were generated in an air atmosphere or air contaminated atmosphere is prohibited.

3.2.7 Conditioning of Electrodes. Grinding or dry abrasive cutting of electrodes or welds is prohibited. The actual conditioning method, subsequent inspection procedure and limits shall be contained in a controlled document.

3.2.8 Consolidation Melt. Some or all of the raw material may be prepared using an established consolidation melt procedure before charging of the hearth melt furnace. Effective controls and limits for the consolidation process shall be maintained for consistently producing material free from contamination known to cause Type I Hard Alpha or other deleterious inclusions. The consolidation melt process shall be performed in a vacuum or inert gas filled chamber. For non consumable electrode processes, the electrode shall be water-cooled copper; tungsten or graphite electrodes are not permitted.

3.2.9 Integral Electrode Stub. The electrode may be cast directly onto a prepared electrode stub in the hearth melt process. Melting into the electrode stub is acceptable during consolidation melting if the integral electrode stub has the same nominal composition and quality as the electrode or is hearth melted premium Quality commercially pure (CP) titanium. The integral stub shall be prepared using an established procedure. For

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consolidation melting, if the integral electrode stub is not the same nominal composition and Quality as the electrode or is hearth melted premium Quality commercially pure (CP) titanium, a platter of sufficient size to contain all the stub material shall remain on the electrode at completion of the melting process.

3.2.10 Hearth Melt Furnace Preparation. The hearth melt furnace shall be cleaned, prepared, and inspected using established procedures in accordance with an established schedule and after any fire in the furnace chamber or feeder system. The procedure shall include provisions for cleaning of the feeder system, hearth, hearth skull, electrode mold, chamber, and condensate grates. Condensate grates above the hearth and the electrode mold shall be changed at least between melting of different alloy grades. Inspection and maintenance records shall be maintained by the hearth melt Supplier.

3.2.11 Hearth Melt Parameter Controls. Molten pool area, molten pool temperature, casting rate and melt chamber pressure shall be continually measured and recorded during the melting cycle in accordance with an established procedure. As a minimum, limits shall be established at the designated control points for the following parameters:

(a) Leak rate and pressure for the melting chamber before melt start-up. Alternatively, the chamber may be tested for leaks using an established procedure.

(b) Molten pool area, molten pool temperature, casting rate and melt chamber pressure.

(c) Monitoring of chamber atmosphere for nitrogen content or for the partial pressure of nitrogen in the chamber is required.

(d) Maximum electrode top surface metal temperature before exposure of the electrode to air. The temperature limit shall not exceed 1800 °F (982 °C).

3.2.11.1 Additional EBM Parameter Controls. For EBM, beam power shall be continually measured and recorded during the melting cycle. Initial settings and all changes in beam deflection pattern and scanning frequency shall be within limits contained in an established procedure. Beam interruptions which exceed 60 seconds shall be recorded. Limits shall be established at the designated control points for the following parameters:

(a) Beam power, deflection pattern and scanning frequency during steady state melting.

(b) Duration of beam interruptions during melting.

3.2.11.2 Additional PAM Parameter Controls. For PAM, torch voltage, current, gas flow, and gas purity shall be continually measured and recorded during the melting cycle. Initial settings and all changes in torch motion pattern and velocity shall be within limits contained in an established

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procedure. Limits shall be established at the designated control points for the following parameters:

(a) Torch voltage, current, gas flow, gas purity and motion pattern during steady state melting.

(b) Duration of arc interruptions during melting.

(c) Torch voltage, current, gas flow, gas purity, motion pattern, during hot topping.

3.2.12 Electrode Composition. The electrode shall be capable of producing an ingot, after a single subsequent VAR involving no further intentional alloying additions, with a chemical composition in accordance with the appropriate alloy or part specification.

3.3 Vacuum Arc Remelting. The hearth melt electrode shall be subsequently VAR processed to produce a heat of material.

3.3.1 VAR Control. The VAR Suppliers shall maintain effective controls for consistently producing uniform ingots free from Type I Hard Alpha and other deleterious inclusions, and unacceptable segregation and voids. As a minimum, the electrode procurement and preparation, VAR crucible condition immediately prior to melting, melting procedures, and acceptance standards shall be established by the VAR Supplier and shall be subject to Purchaser approval.

3.3.2 VAR Charge Materials. VAR Suppliers shall maintain effective specifications and procedures for the procurement and conditioning of the hearth melt electrode. Other than the bottom charge, intentional additions of titanium or alloying elements after the hearth melt process are prohibited.

3.3.2.1 VAR Bottom Charge. If a bottom charge is used, the composition, form, and preparation procedures shall be established. Sponge shall not be used as a bottom charge.

3.3.3 Conditioning of Hearth Melt Electrodes. Grinding or dry abrasive cutting of hearth melt electrodes is prohibited. The conditioning method, subsequent inspection procedure and established limits shall be as approved by the Purchaser and shall be contained in a controlled document.

*3.3.4 Electrode Welding. Unless otherwise specified herein, all welding involving the hearth melt electrode, electrode stub, or electrode holder shall be performed in a weld chamber using established inert gas welding procedures. In addition, the stub may be welded to the electrode using established plunge arc welding procedures. Effective controls and limits for the weld process shall be maintained for consistently producing welded product free from contaminants known to cause Type I Hard Alpha or other deleterious inclusions. The controls shall include the method used for monitoring the weld chamber atmosphere.

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3.3.4.1 Inert Gas Welding. Inert gas welding shall be performed using plasma-arc or gas metal-arc welding practices in an inert gas filled chamber. For plasma-arc welding, the welding torch electrode shall be water-cooled copper. Gas tungsten-arc welding is not permitted. Limits and procedures for continually measuring weld chamber and torch gas purities shall be established.

3.3.4.2 Plunge Arc Welding. Plunge arc welding shall be performed in a vacuum chamber. Limits and procedures for weld chamber leak detection and for continually measuring and recording chamber pressure shall be established.

3.3.4.3 Weld Inspection. All welds shall be visually inspected to established standards. Melt Suppliers shall establish procedures for the removal and rewelding of welds.

*3.3.5 Electrode Stub and Holder. The electrode stub and electrode holder shall be prepared and inspected using established procedures. The stub and holder shall be clean and visually free from tool bits and other foreign materials, and from features that may indicate contamination. The electrode stub shall have the same nominal composition as the ingot being produced or shall be commercially pure (CP) titanium or other titanium alloy. Melting into a stub or holder during VAR operation is prohibited.

3.3.5.1 Electrode Holder Joining. The electrode holder shall be joined to the electrode stub, or directly to the electrode without the use of a stub, using an established procedure. Before the stub is joined to the electrode, the holder may be welded to the stub without the use of an inert gas filled chamber. If welding is performed without the use of an inert gas filled chamber, the weld spatter shall be removed from the stub and the stub shall be inspected before the stub is joined to the electrode.

3.3.5.2 Electrode Stub Joining. If used, the electrode stub shall be joined to the electrode using an established procedure. Alternatively, the electrode may be cast directly onto the stub during the hearth melt process. Grinding of the electrode, electrode run downs, or electrode stub is prohibited.

3.3.6 Electrode Markers. If used, electrode markers shall be prepared and fastened to the electrode, stub, or holder using established procedures. The markers shall have the same nominal composition and quality as the electrode.

3.3.7 VAR Furnace Preparation. The VAR furnace shall be cleaned, prepared, and inspected in accordance with an established schedule and procedure. The procedure shall include provisions for cleaning of all furnace vacuum chamber internal surfaces. The furnace shall be inspected to an established standard after cleaning, and before melting each electrode. Inspection and maintenance records shall be maintained by the VAR Supplier.

3.3.8 VAR Parameter Controls. Arc voltage, arc current, stirring parameters and melt chamber pressure shall be continually measured and

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recorded during the melting cycle. A procedure for identifying and recording glow discharge events shall be established. As a minimum, limits shall be established at the designated control points for the following parameters: (see 6.2)

(a) Leak rate and pressure for the melting chamber before arc initiation.

(b) Melt chamber pressure during steady state melting. If an established method for continually monitoring the presence of oxygen and nitrogen is used during the melt process, limits shall be established for nitrogen and oxygen levels during steady state melting and for momentary peaks. A momentary peak is a pressure surge event that temporarily exceeds the maximum melt chamber pressure limit.

(c) Arc voltage, arc current, stirring parameters and melt rate during steady state melting.

(d) Arc current interruptions during steady state melting.

(e) Glow discharge events during steady state melting.

(f) Electrode weight or length at the start of hot topping.

(g) Arc voltage, arc current, stirring parameters, melt chamber pressure, and melt rate during hot topping.

(h) The length of the platter remaining after VAR. A statistically determined minimum platter length or weight shall be established so that no electrode holder material, no inert gas weld affected metal and none of the electrode top surface is melted into the ingot.

3.3.9 Furnace Water Leaks. The ingot surface shall be visually inspected for discoloration characteristic of a water leak. If a water leak is suspected, the VAR Supplier shall identify the source of the water leak. The ingot shall be subject to disqualification unless chemical analysis of all suspected leak areas on the ingot, after removal of the water stain, indicates the absence of contamination.

3.3.10 Ingot Composition. The ingot shall have a chemical composition in accordance with the appropriate alloy or part specification.

3.4 Ingot Conversion. The VAR ingot shall be converted to produce billet, bar, or plate.

3.4.1 Conversion Control. The conversion Suppliers shall maintain effective controls for consistently producing uniform converted material free from Type I Hard Alpha and other deleterious inclusions, segregation, and voids. As a minimum, the ingot procurement and preparation, conversion procedures, and acceptance standards shall be established by the conversion Supplier.

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3.4.2 Ingot Preparation. Conversion Suppliers shall maintain effective specifications and procedures for the procurement and conditioning of the ingot. The beta transus of the ingot material may be calculated from the ingot composition using an established procedure, to aid determination of appropriate temperature parameters for the conversion process.

3.4.3 Conversion Parameter Controls. Furnace temperature shall be continually measured and recorded during the homogenization and processing heat treatments and metal temperature shall be measured and recorded before and after each selected reduction step. As a minimum, limits shall be established at the designated control points for the following parameters:

(a) Nominal material size before conversion.

(b) Furnace temperature and duration for the homogenization and processing heat treatments.

(c) On-die metal temperature before each reduction step.

(d) The area reduction (in percent) for each reduction step.

(e) Off-die metal temperature after each reduction step.

(f) Furnace temperature and duration for heat treatments between reduction steps.

(g) Nominal finished size of the material after conversion.

3.4.4 Standard Crop. Limits for crop length from the ends of converted material shall be established. Actual crop length within these limits shall be based on the results of ultrasonic, macroetch and beta fleck inspection.

3.4.5 Beta Transus Temperature. The conversion Supplier shall determine the beta transus temperature and the minimum temperature when uncontrolled grain growth is observed for each heat after conversion.

3.5 Acceptance Criteria

3.5.1 Material Quality. Material supplied to this specification shall be uniform in quality, meet applicable chemistry requirements, and be free from surface cracks, foreign materials, segregation, and discontinuities detrimental to forging, machining, or performance of the parts produced.

3.5.2 Ultrasonic Inspection. Ultrasonic inspection shall be performed on converted material at finished size to limits as follows:

(a) Billet in accordance with P3TF15, CL-B.

(b) Bar in accordance with P3TF34.

(c) Plate in accordance with P3TF35, CL-A.

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3.5.2.2 Billet to Bar Processing. Billet which has been produced in accordance to the requirements of this specification and have declared acceptable following inspection in accordance with P3TF15, Cl-B may be converted in accordance to an established procedure to a smaller diameter product. The inspection of the smaller size product shall be in accordance with an established procedure.

*3.5.3 Macroetch Inspection. Slices of the converted material that are macroetched and inspected shall be free of indications resulting from inclusions, voids or segregation. Macroetch indications resembling GE Photo Standard S26596 require evaluation. Limits for acceptable beta segregation in beta processed alloys are shown in GE Photo Standards S21607, S26526-1 and S26526-2. The limit for acceptable beta segregation in alpha beta processed alloys is shown in GE Photo Standards S21608. Limits for macrostructure and segregation as measured in transverse sections shall be in accordance with AMS 2380, except the limits for bar shall be Level 20 or better. Samples from all billet macro slices representing the worst macro condition or if no worst condition the predominant macro condition, shall be retained for a minimum of two years after certification of the heat.

3.5.4 Beta Fleck Inspection. Beta fleck testing is required on beta processed alloys when macro etching of billet or bar slices displays beta segregation in excess of GE Photo Standards S21607, S26526-1 or S26526-2. Beta fleck testing is required on alpha beta processed alloys when macroetching of billet or bar slices displays beta segregation in excess of GE Photo Standards S21608. When testing is required, slice(s) of the converted material shall be prepared and evaluated for beta flecks. Material will be considered rejectable if there are any beta flecked areas exceeding 0.0008 sq inches (0.5 mm^2) devoid of spheroidized or acicular primary alpha. An isolated nodule of primary alpha in the depleted area shall not be taken into account or be sufficient to accept the flecked area.

3.5.5 Converted Material Acceptability Limits

*3.5.5.1 Heats with Inclusions or Internal Ultrasonic Test (UT) Indications. The entire heat shall be subject to disqualification, and the Purchaser shall be notified immediately, if one or more of the following acceptability limits is exceeded:

(a) The heat contains one or more Type I Hard Alpha or other rejectable inclusion(s)

(b) The total weight of material removed for all rejectable subsurface ultrasonic test indications combined with material removed for all rejectable macroetch indications is greater than ten percent of the net ingot weight remaining after standard cropping. Material removed within the standard crop limits, material removed for characterization of non-rejectable indications and material removed due to mechanical damage on the surface of billet which prevented ultrasonic inspection of the material, are not included in the reject criteria.

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3.5.5.2 Billet Heats Displaying Segregation. Heats displaying segregation shall have the segregated material rejected. The supplier shall determine by statistical methods the average and 2σ amount of material cropped, following conversion into billet, from the top and bottom of the ingots of the same alloy as the heat displaying the segregation. The Purchaser shall be notified immediately and prior to shipping a heat, of all occurrences of segregation that are not associated with the top 2σ crop or bottom 2σ crop of a heat and when material cropped from a heat exceeds the 2σ crop weight due to segregation.

3.5.5.3 Bar Heats Displaying Segregation. Bars displaying segregation shall be rejected. If each bar is traceable to its position within the ingot the reporting requirements in 3.5.5.2 applies. If bars are only traceable to a segment of the ingot, then any segregation found in more than one bar per segment shall be reported to the Purchaser prior to shipment of any bar from that segment.

3.6 Material Traceability And Accountability

3.6.1 Ingot Traceability. The VAR ingot shall be traceable to the hearth melt electrode and location in the electrode. Raw material used in each heat shall be documented and traceable to the source. The record shall include disposition of all material from the ingot.

3.6.2 Ingot Product Traceability. Billet shall be traceable to the VAR ingot and location in the ingot. Bar and plate shall be traceable to the VAR ingot and at least the top, middle, or bottom third of the cropped ingot. The record shall include disposition of all material from the converted material.

3.6.3 Record Submittal. Records describing traceability and disposition of material shall be available for review by the Purchaser. The Supplier shall maintain traceability as described and provide accountability of all material beginning with raw material through shipment of converted material.

4. QUALITY ASSURANCE PROVISIONS

4.1 Supplier Qualification. Initial qualification or requalification of raw materials shall be in accordance with P1TF95. Qualification of materials or processes defined in this specification shall be on a per alloy basis. Initial qualification or requalification of melt, and conversion Suppliers for production of material to this specification shall consist of the following:

(a) Acceptable quality systems evaluation.

(b) Demonstrated fixed process for each alloy produced to this specification.

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(c) Demonstration of product and process capability for each alloy produced to this specification.

(d) Demonstration that product produced to this specification meets all chemistry requirements defined in appropriate specifications.

4.1.1 Hearth Melt Qualification. A hearth melt Supplier will be considered for qualification for an alloy after producing at least 500,000 lbs. of hearth melted product that has been melted and converted into bar per P1TF73 and following ultrasonic inspection per P3TF34 has been found to be free of inclusions. The process shall have a demonstrated capability for removal of Type I Hard Alpha and other deleterious inclusions.

4.1.2 VAR Qualification. A VAR Supplier will be considered for qualification for an alloy after producing at least five production size ingots by either EBM plus VAR, or PAM plus VAR, in accordance with this specification.

4.1.3 Conversion Qualification. A conversion Supplier will be considered for qualification for an alloy after producing at least five production size heats of material converted from the same nominal ingot size to the same nominal finished size in accordance with this specification. As a minimum, the Supplier shall send documentation for review by the Purchaser of the macroetch and metallographic inspection results for those five heats as required by the applicable specification or purchase order.

4.1.4 Disqualification. Suppliers may be disqualified for failure to maintain acceptable quality systems and fixed processes, for production of heats with Type I Hard Alpha or other rejectable inclusions, or for unacceptable quality of the delivered product.

4.2 Process Control Instrumentation. Except for conversion furnace temperature controllers and recorders, measuring devices used for monitoring or control of significant process parameters shall be calibrated in accordance with the requirements of ISO 10012-1.

4.3 Chemical Analysis. Chemical analyses shall be performed in accordance with ASTM standards or methods approved by the Purchaser.

4.4 Raw Material Inspection. The melt Supplier shall inspect procured raw material at a frequency sufficient to verify conformance to those procurement specifications. The inspections shall be performed in accordance with P1TF95 using established procedures.

4.5 Electrode Weld Inspection. The entire surface area of the weld and weld affected metal shall be visually inspected. If the weld fails to meet the acceptance standards, the VAR Supplier shall identify the cause for failure. If the cause is solely a lack of penetration, additional welding and inspection as specified herein may be required before melt processing. If the cause is a reason other than a lack of penetration, such as cracking or contamination, the electrode shall be disqualified unless the entire weld and weld affected metal are removed using an established procedure, and then

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additional welding and inspection is performed in accordance with the requirements herein. Grinding of weldments or weld affected metal is prohibited.

4.6 Conversion Furnace Control. Furnace temperature uniformity, furnace surveys, and calibration of temperature controllers and recorders for conversion preheat furnaces shall be in accordance with established procedures. Furnace temperature uniformity, furnace surveys, and calibration of temperature controllers and recorders for heat treatment furnaces shall be in accordance with MIL-H-81200.

4.7 Ultrasonic Inspection. Ultrasonic inspection shall be performed on converted material at the finished size using procedures as follows:

(a) Billet in accordance with P3TF15, CL-B.

(b) Bar in accordance with P3TF34.

(c) Plate in accordance with P3TF35, CL-A.

4.7.1 Ultrasonic Indications. Procedures shall be established for documenting, removing, preparing, and characterizing ultrasonic indications. All rejectable indications shall be documented, removed, prepared, and characterized. Indications found in material which is within the standard crop shall be removed and characterized, but need not be reported if confirmed to be Type 2 segregation and associated with ingot pipe.

4.7.1.1 Documentation. Each rejectable indication in bar and plate shall be recorded with the bar or plate identity, percentage of full screen height, and the results of characterization, if performed. Each rejectable indication in billet shall be recorded on the billet map with the billet identity, axial location with respect to a reference point, depth from the surface, percentage of full screen height, and the results of characterization, if performed.

4.7.1.2 Characterization. Characterization of rejectable indications shall be in accordance with an established procedure. Evaluation of melt related defects or inclusions shall include chemistry and microhardness measurements. A photomicrograph or "C Scan" (for false indications) of the indication shall be included with the characterization records. Type I Hard Alpha inclusions shall be analyzed for oxygen, nitrogen, carbon, silicon, zirconium and the alloying elements, and the results shall be recorded. Melting and conversion process records shall be evaluated for events which correlate with the location.

4.7.2 Remaining Material Disposition. The heat shall be disqualified unless characterization of each rejectable ultrasonic indication, and macroetch inspection of the slices adjacent to the removed sections, verify that the material is in accordance with the acceptability criteria herein.

4.8 Macroetch Inspection. Transverse cross section surfaces shall be macroetch inspected on slices from selected locations of the converted

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material. Slices shall be removed from converted material corresponding at least to the top, middle, and bottom locations in the ingot. For bar, additional transverse slices corresponding to each end of each bar converted from within the top 25 percent of the cropped final VAR ingot shall also be macroetched. Other slices shall be macroetch inspected as specified herein, such as in removal of ultrasonic indications.

4.8.1 Macroetch. The slices shall be prepared and macroetched using established procedures. Before being etched, the prepared surfaces shall have a surface finish of 70 microinches (1.8 mm) or better.

4.8.2 Examination. The macroetched surfaces shall be examined using established procedures at a minimum of 2.5X magnification for general macrostructure and for the presence of inclusions, segregation, and voids. The measured macrostructure level shall be recorded.

4.8.3 Macroetch Indications. Macroetch indications suspected of being inclusions shall be reported. Other rejectable indications found after standard cropping also shall be reported. Reportable indications shall be documented and characterized using the procedures herein for ultrasonic indications. Analysis techniques shall be the same as those used for certification of Premium Quality titanium alloys. The type, extent, and suspected cause for reportable indications shall be recorded with the documentation.

4.8.4 Remaining Material Disposition. Sections of converted material adjacent to each rejectable macroetch indication shall be removed. Slices adjacent to the removed sections shall be macroetch inspected to verify that the remaining material is in accordance with the acceptability criteria herein.

4.9 Beta Fleck Inspection. Center to edge specimens shall be cut from the macroetch slice(s) that display beta segregation in excess of GE Photo Standards S21607, S26526-1, S26526-2, and S21608 respectively. The specimens shall be prepared and evaluated using established procedures.

4.9.1 Beta transus Temperature (Bt). The conversion supplier shall determine the beta transus temperature and the minimum temperature when uncontrolled grain growth is observed on each heat after conversion in accordance to an established procedure. Determinations will be conducted on specimens representing the top and bottom of the heat.

4.9.2 Preparation. The specimens shall be heat treated for one hour at a selected temperature below the beta transus as defined in an established procedure and then water quenched. The specimens may then be given an aging heat treatment to enhance the contrast between the alpha and beta phases. The heat treated specimens shall be prepared using standard titanium alloy polishing and macroetched using established procedures.

4.9.3 Evaluation. The size of the beta flecks on the etched surface shall be determined at 10X to 100X magnification. The quantity of alpha phase present in beta flecks shall be evaluated at 100X magnification.

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4.9.4 Beta Fleck Indications. Rejectable beta fleck indications shall be documented and characterized using the procedures herein for ultrasonic indications.

4.9.5 Remaining Material Disposition. Sections of converted material adjacent to each rejectable beta fleck indication shall be removed. Slices adjacent to the removed sections shall be macroetch and beta fleck inspected to verify that the remaining material is in accordance with the acceptability criteria herein.

4.10 Disqualified Ingot Product. If a Supplier ascertains that an ingot product shipped to the requirements herein has been disqualified, the Purchaser shall be notified immediately.

4.11 In Process Deviations. A system shall be described in a controlled document in accordance with 3.1 for disposition of material and corrective actions when in process parameters vary from the limits defined in the established procedure or this specification.

5. PACKAGING

This section is not applicable.

6. NOTES

*6.1 Purpose. This section contains information of a general nature, which may be helpful, but is not mandatory. It does not contain any requirements.

*6.2 Future Requirement. It is the intention of GE Aviation to require the welding of pushers and the repair of pusher welds (3.2.6.1) to be conducted in either a vacuum or weld chamber. Air welding of pushers and the repair of pusher welds will then be prohibited.

*6.3 VAR Parameter Controls

*6.3.1 Melt Chamber Pressure During Steady State Melting.

(a) The maximum chamber pressure limit should not exceed 0.2 mm (200 microns) of mercury, except during momentary peaks which should not exceed 0.4 mm (400 microns) of mercury, a duration of 90 seconds each and a total of three events.

(b) If an established method for continually monitoring the presence of oxygen and nitrogen is not used during the melt process, the maximum limit for chamber pressure should not exceed 0.2 mm (200 microns) of mercury, except during momentary peaks. The maximum limit for chamber pressure during a momentary peak should

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not exceed 0.4 mm (400 microns) of mercury, a duration 90 seconds each or total three events.

*6.3.2 Arc Current Interruptions. Maximum duration of arc current interruptions during steady state melting should not exceed 30 seconds.

*6.3.3 Glow Discharge Events. Maximum duration of glow discharge events during steady state melting should not exceed 90 seconds.

*6.4 Classified as Significant. In the definition of a Type I inclusion, the requirement is for the hardness of the inclusion to be significantly higher than the surrounding material. To be classified as significant, hardness values of the inclusion are expected to be >10% higher than the adjacent matrix.

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P1TF73-S12

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-S4	CID 076679	04-12-90
-S5	CID 077781	09-16-93
-S6	CID 077825	11-11-93
-S7	CID 077825-1	02-03-94
-S8	CID 077968	04-15-94
-S9	CID 078452	08-19-96
-S10	CID 078911	07-15-99
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* Denotes latest revision

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