# PREMIUM QUALITY TITANIUM ALLOY MELTING, CONVERSION: PROCESS QUALIFICATION REQUIREMENTS

**Specification Number: S-SPEC-44**
**aeDMS #: S-425**
**Issue Date: Jan 5, 2018**

*This specification is in addition to and in no way limiting, superseding, or abrogating any contractual obligation as required by the applicable procurement document.*

## 1. PURPOSE

1.1 This specification establishes minimum requirements for qualification of new or revised Premium Quality titanium alloy melting or conversion practices, including request for approval and documentation of results. Qualification requires verification that the new or revised process will produce material meeting all the requirements of applicable P1TFxx and C50TFxx Premium Quality process and material specifications without creating undesired effects.

1.2 Conformance to this specification is required for suppliers requesting approval to GE Aviation (GE-A) Data For Ordering (DFO) sheets and for process changes by DFO-approved suppliers.

## 2. APPLICABILITY

2.1 This specification is in addition to and in no way limiting, superseding, or abrogating any contractual obligation as required by the applicable procurement documents. GE-A reserves the right to revise this specification.

2.2 This specification may be imposed by GE-A in response to requests for a new melting or conversion supplier, a new melting or conversion practice, a significant change in melting or conversion practice or through a purchase order. Requirements for melting quantities of material, other than under a GE-A purchase order, in no way implies that GE-A will

compensate the supplier for material, processing, or evaluation costs. Approvals required herein usually precede issuance of procurement documents.

2.3 This specification applies when referenced on a Process Change Request (PCR) submitted for the change.

2.4 Applicable Documents: The following documents are referenced by this Quality Specification and are necessary for its implementation.

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| P1TF28 | PREMIUM QUALITY MULTIPLE VAR TITANIUM BASE ALLOYS |
| P1TF73 | PREMIUM QUALITY HEARTH MELT PLUS VAR TITANIUM BASE ALLOYS |
| P3TF34 | ULTRASONIC INSPECTION OF METALLIC BAR STOCK |
| P3TF35 | ULTRASONIC INSPECTION |
| P1TF95 | CONTROL OF MATERIALS USED IN THE MELTING OF PQ TITANIUM |
| P3TF5 | RADIOGRAPHIC INSPECTION |
| P3TF15 | ULTRASONIC INSPECTION OF BILLET - IMMERSION |
| S-210 | TRANSMITTAL OF BILLET DEFECT DATA ON PREMIUM TITANIUM BASE ALLOYS |

## 3. ADMINISTRATION AND APPROVALS

3.1 GE-A Administration: GE-A Quality Representative, Materials Value Stream will represent GE-A in the administration of this document, and will be responsible for approval of all new DFO listings.

Overseas Administration: The administration and audit of process change requests for European melting and conversion sources should be directed to GE-A Quality for requirements, review and final approval. Requests may be submitted simultaneously to SAFRAN Quality.

3.2 "Data for Ordering" (DFO) Approval Requirement: DFO approval of the supplier is required when the applicable GE-A Premium Quality forged part specification (series C50TFxx) requires procurement of forging stock only from suppliers approved by the purchaser (GE-A).

3.3 Request for DFO Qualification: Raw material, melting, or conversion suppliers will be qualified to GE-A DFOs only when a need for their product is established. Generally, request for qualification will be made through a material supplier, i.e., a supplier with existing or potential orders for forged parts or material requiring forged parts.

3.3.1 Quality (Melter) Agreement: Prior to qualification, suppliers are required to have a Quality Agreement with GE-A which covers basic quality disciplines and establishes coordination of necessary approvals. When adding new suppliers to a DFO, specific provisions of the agreement may be negotiated during the qualification effort.

3.3.2 Maintenance of Qualification: Raw material, melting, or conversion suppliers are subject to audit by GE-A and by the user of their product, i.e. suppliers with existing or potential orders for forged parts or material requiring forged parts. Approved fixed practices are subject to re-qualification, defined by GE-A, if the supplier does not produce material conforming to the approved fixed practice for a period greater than eighteen (18) months.

3.3.3 Refusal or Removal of Qualification: DFO qualification may be refused or removed from a supplier for any or all alloys and processes if there is no need for their product for an extended time; when nonconformances or insufficient controls are found which indicate basic process problems; for certifying results known to be in error; for failure to report nonconformances or approval of changes before introduction; or for failure to provide acceptable corrective action to identified problems in a timely manner.

3.4 Request for a new process or process change shall be submitted to GE-A using the PCR in accordance with the GE-A-Supplier Quality Agreement. The Supplier Quality Agreement establishes basic requirements but the supplier should consult with GE-A regarding the significance of a process change before implementation.

3.4.1 The PCR shall also be submitted to each customer for the product, either before or after GE-A requirements for qualification have been received.

3.4.2 The supplier shall assign an identification number to each PCR.

3.4.3 Approval from GE-A and from each applicable customer is required before shipping product represented by the new/revised process.

3.4.4 Suppliers who do not perform all melting and/or conversion require cooperative agreements with other sources in order to produce the material and data required.

3.4.5 The supplier requesting qualification is responsible for coordinating the Qualification program and providing the required reports and exhibits to GE-A. The GE-A Raw Material Quality Representative reserves the right to reject process change requests for insufficient data.

## 4. REQUIREMENTS

4.1 Qualification Plan: GE-A written requirements for qualification will be documented in the PCR. Appendix A outlines standard qualification requirements; GE-A will adapt these to specific applications depending on the change and the supplier's experience. Appendix B establishes requirements for producing seeded heats. "Heats" refers to typical production size heats. Appendix C describes the requirements for determining residence time during the melting process. Appendix D is describes the pinpointing method for location of sonic indications
To summarize:

Appendix A: Standard Plan for Qualification of New or Changed Processes
Appendix B: Requirements for Seeded Heats
Appendix C: Requirements for Resident Time Heats
Appendix D: Pinpointing Indications
Figure 1: Process Change Request/Nonconformance Report Form

4.1.1 Program Sequence, Hearth Melt Qualifications: Qualification shall be carried out in consecutive phases as noted below unless otherwise authorized by GE-A.

Development of fixed Hearth melt practices
Demonstration of Hearth process on commercial grade material
Melting and evaluation of residence time heats
Melting, conversion, and evaluation of seeded heats
Melting, conversion, and evaluation of bar heats
Melting, conversion, and evaluation of billet heats

4.1.2 Program Scope (Initial Process and Process Changes): The number of heats required to be produced and evaluated for qualification will be stated in the PCR or as a supplement to the PCR. The number of heats required will be determined by GE-A. Additional requirements may be added to the qualification requirements when deemed necessary by GE-A; lesser requirements may be authorized by GE-A based on experience and results from similar applications.

4.1.3 Written Procedures: Prior to initiating melting or conversion programs for qualification of a new process or process change for material intended for GE-A applications or the implementation of new equipment, or construction of new facilities, the supplier shall submit written procedures as required by the applicable appendix. Use of prior data obtained during melting or conversion of material not intended for GE-A applications may be acceptable for satisfying some requirements of this specification. Material may not be shipped to a GE-A product specification in

any form until all qualification requirements have been met and approved by GE-A, unless specifically approved in writing by GE-A Sourcing Quality.

4.1.4 Supplier shall perform all work required by the PCR and submit the results for final approval in the format outlined in Section 5 to GE-A and (for Process Changes) to other customers for the product.

4.1.5 To facilitate approval of Process Change Requests, suppliers may perform, at their own risk, work required by the appropriate standard qualification prior to requesting initial qualification or submitting the PCR. However, the supplier is responsible for any and all additional requirements imposed by GE-A. As such, GE-A recommends notification at the onset of new programs to facilitate the process.

4.2 Fixed Practices: Sufficient Hearth melt, VAR, and conversion experience is required to establish a recommended fixed practice or the total process proposed for Qualification. For qualification of the initial Hearth melt furnace type, melting of a minimum of 15 heats for commercial grade applications is required. The fixed practice shall include all tolerances which are accommodated during process operation without producing detectable differences in the product. GE-A approval shall be obtained for the fixed practice prior to initiating bar stock or billet production for qualification modifications required to the fixed process or planned qualification requirements during production of material shall be referred immediately to GE-A for approval. Process Change Requests (PCR) shall be issued if variations outside defined tolerances are desired or required to correct process problems. The PCR shall compare the approved practice with the proposed practice. Fixed practices must recognize that different chemical composition, macrostructure, or process control requirements could be imposed on Hearth melters by different VAR customers, or on VAR and conversion suppliers by different billet/bar customers, to ensure conformance to GE-A requirements of the final material provided. Therefore, coordination and approval of Process Change Requests must involve GE-A and all other customers. Any changes that affect the quality of the material should be discussed and approved by the GE-A Raw Material Quality Representative.

4.2.1 Quality Plan: Written quality plans must be in place for each product / process family (routine plan applicable to material after Qualification). The quality plan shall show which parameters and control points are monitored, where process control charts are being used, and what evaluations are used to accept material during and after processing.

4.2.2 Charge Material, Initial Melt, Compaction: Written procedures for material forms (i.e., sponge, turnings, solids; consolidation melted ingots), chemical composition percent ranges, material preparation, compaction and inspection must be in place and approved by GE-A for each type of charge material. For Hearth melting, these may recognize differences imposed by individual VAR customers. Initial charge input material types, sources, and inspection plans shall be approved by GE-A. Changes to the approved charge input material forms, size distributions, percent ranges, compaction method, and inspections shall not be made without prior approval by GE-A. Each raw material lot shall be inspected per P1TF95 for inclusion forming materials; this may include white and fluorescent light visual inspection and X-Ray inspection. Sampling procedures require GE-A approval; up to 100% inspection may be required.

4.2.3 Ingot Melting and Preparation: Written procedures and quality plans must be in place for each specific alloy, melt practice, and ingot size. For melters who perform only initial or intermediate melting, these may recognize differences imposed by individual VAR customers. Practice must identify all processing steps and critical parameters to be monitored. The quality plan must identify all areas in the process where hard alpha (Type I) can be formed, inclusions entrained, or segregation generated; and detail the methods for control, monitoring, and detection of the above listed problems. Crucible and hearth fabrication, repair and inspection methods must be documented and approved by GE-A. Ingot surface preparation procedures and method for achieving stub joint for VAR melting shall be documented and approved by GE-A. Material which is supplied in the beta processed condition will have slices from each billet evaluated for beta fleck capability per applicable material specification. This evaluation will be required on 5 consecutive heats.

4.2.4 Conversion: Written conversion practice(s) must be in place for each specific size billet or bar. Practice must identify all processing steps including all reheats, temperatures, reduction schedule and equipment. Sufficient data will be required to verify the practice yields billet product that meets a minimum percent reduction, which will be established by GE. Process change requests for conversion practices must demonstrate equivalent or higher percent reduction to the initial process for approval. Alternatively, process change requests for conversion practices may be approved on the basis of equivalent or higher degree of grain randomization, measured by a method approved by GE-A.

4.3 Evaluation Requirements: Evaluations are to be performed as required by the PCR qualification requirements and as follows:

4.3.1 Ultrasonic Inspection: All billets/bars shall be immersion ultrasonically inspected per P1TF28 or P1TF73 (as applicable), and P3TF15 CL-B (billet) or P3TF34 (bar), to a plan which includes inspection limits and is approved by GE-A (billet or bar). All rejectable ultrasonic indications, and all repeatable indications which are more than 10% FSH above the noise level of adjacent material, shall be removed and characterized to determine cause. Other repeatable indications which are above the alarm threshold but below the rejectable limits shall be recorded and reviewed with GE-A, and shall be subject to characterization. Ultrasonically inspected billets or bars shall be mapped as applicable per the material specification and S-210, with noise level comparisons, all removals noted and all repeatable, non-rejectable signals indicated.

4.3.2 Radiographic Inspection of Bars: All the bar product representing seeded heats shall be inspected per P3TF5 CL-A for the presence of inclusions. Ten (10) percent of the bars shall be reinspected at 90 degrees; to the original exposure direction. All indications shall be marked and removed for characterization.

4.3.3 Characterization of Indications: Characterization shall be performed after all x-ray and ultrasonic inspection is completed, and shall also include any indications which might be revealed during macro/micro survey. Characterization shall be per a plan approved by GE-A, pin pointing of the defect using C-Scan or acoustic microscopy is required before step polishing into the defect. See Appendix D for pinpointing method. Characterization shall include microstructural analysis, microhardness, and chemical analysis as required to determine the nature of the defect. Characterization shall be performed per a plan approved by GE-A. Results shall include photos of the defect or artifact at suitable magnification. Microphotographs or equivalent at 100X and 500X will be included in the report.

4.3.4 Chemical Composition Survey (Bar/Billet): Chemical composition per the material specification shall be surveyed to represent five equally spaced longitudinal locations in the cropped ingot, except that seeded heats require analysis only of top and bottom ingot positions. Evaluation shall be made at an intermediate re-roll billet size for bar, and final billet size for billet product. Each of the five locations shall be evaluated at five equally spaced locations across the diameter of the billet slice. Data shall be presented in statistical form so as to illustrate composition uniformity throughout the heat. Requirements for evaluating fewer or alternate locations may be established by the PCR Generally, if a heat contains less than 4 billets, chemistry shall be evaluated at five equally spaced locations across the

diameter of the billet slice from the top of each billet and the bottom of the bottom billet. In this case, top and bottom ingot barrel chemistry is required in addition to the chemical composition survey.

4.3.5 Macro/Micro Survey of Bar and Billet: Samples shall be taken after conversion to the final diameter and prior to any subsequent thermal treatment. Cross-section slabs at least 3/4 inch (19 mm) thick shall be taken to represent top, middle, bottom, and at two intermediate ingot locations. Slabs shall be taken after standard crops have been taken; specific locations may be coordinated with evaluation of indications or suspect areas found by nondestructive testing. Micro specimens are generally taken from the macro slabs. Macro slab segments (at least half the slab) and micro specimens shall be retained for GE-A review until PCR has been approved.

4.3.6 Macrostructure: Surface preparation and macroetching procedures shall be per P1TF28 or P1TF73, as applicable. Etch-anodize per P3TF25 is required for Ti17 billets used to satisfy qualification requirements of this specification. Etching procedures shall produce an etched surface that clearly defines light or dark areas. Etching procedures shall be capable of clearly defining tree rings, Type I or Type II segregation, and beta flecks. Macrostructure shall be evaluated for segregation and uniformity of structure against standard AMS 2380, ETTC-3, and/or controlled standards of the supplier. Photographs of all slices will be taken and reported to GE-A. Beta fleck examination, when required by the applicable material specification, shall be carried out per P1TF28 or P1TF73 (as applicable).

4.3.7 Microstructure: Specimens shall be taken at center, mid radius, and near-surface locations of each billet/bar slab and examined in the longitudinal direction; transverse macrostructure shall be used as a guide in selecting specimen location. After polish and etching, microstructure shall be evaluated and rated against standard AMS 2380, ETTC-2, and/or controlled standards of the supplier; microstructure at each location shall be uniform with no pronounced segregation of alpha or beta regions. Photomicrographs or equivalent of typical microstructure shall be taken at 100X and reported. Any abnormal microstructures shall also be photographed and reported as to amount, type, and location.

4.3.8 Raw Material Evaluations: When the raw material is required to be evaluated as-is (not after melting), sampling and evaluation methods are usually described and controlled by the supplier's documentation rather than by GE-A specifications or other standard documents. Approvals are issued via the applicable Quality Agreement. Evaluations include: Chemical composition, visual inspection (white

light or fluorescent light), and X-ray inspection. Specific GE-A requirements are as follows:

(a) X-ray inspection of chips: The method shall be capable of detecting a tungsten carbide sphere 0.4 mm (0.015 inch) maximum diameter or equivalent density defect when it is processed with chips under production inspection conditions. (Note: X-Ray inspection is not required for raw material which will be cold Hearth melted.)

(b) Chemical composition inspection of sponge mass**:** The method used to determine the zones of a sponge mass are determined by chemical analysis of the different areas of the mass. Each unique area will be analyzed to determine the effect of a process change.

4.3.9 Ti-6242 and Creep Resistant Alloy Conversion: Conversion practices shall be reviewed for potential impact on forging dwell fatigue capability. This requirement applies to alpha-beta alloys with creep capability equal to or better than Ti-6242. New practices with potential for extensive aligned alpha colony structure or that are outside current industry experience may require dwell fatigue testing or crystallographic evaluation. Process change requests for conversion practices may be approved on the basis of equivalent or higher degree of grain randomization, measured by a method approved by GE-A.

## 5. QUALIFICATION REPORTS AND APPROVALS; RECORD RETENTION

5.1 Qualification Report: The qualification data shall be submitted to the purchaser. The qualification package shall include a cover sheet which defines the purpose (initial qualification or PCR number), material name and specification. The qualification data shall contain a set of original photographs or equivalent of all macrostructures and microstructures required by the PCR qualification requirements. The order of exhibits and data shall be as follows, and must include all items (or note "NOT APPLICABLE").

a. Copy of the applicable PCR, with qualification requirements from GE-A.
b. Outline of conversion process utilized.
c. Any nonconformance reports associated with the qualification heats.
d. Billet map(s) for the heat(s).
e. Evaluation reports for characterization of ultrasonic, radiographic, or other indications.
f. All test reports and material certifications for material (electrode, ingot, billet/bar).
g. Chemistry evaluations required by the PCR qualification requirements.
h. Macrostructure photographs and ratings.
i. Microstructure photographs and ratings.

5.2 All exhibits and data from qualification evaluations (not in report) shall be made available for GE-A on-site review. These include billet/bar slices, photomacrographs, photomicrographs, inspection records, chemical analysis and indication characterizations from seeded heats or qualification billet/bar heats, conversion, melting and inspection records and procedures.

5.3 Approval of Qualification, Release of Qualification Heats

5.3.1 Written approval of qualification will be indicated by unrestricted approval in the DFO, or (for process changes) approval of the PCR, will be based on the final results of the qualification package.

5.3.2 Release of Qualification Heats: Release of material prior to full approval of the qualification package (i.e., completing production and evaluation of the full number of heats required by the PCR may be permitted by GE Quality Representative in writing after coordination with the forging, billet, and ingot sources as applicable. When qualification requirements include routine acceptance evaluation of a large number of heats, GE Quality Representative may approve release of material prior to completion of the full program if all heats conform to GE-A specification requirements. For purchaser direct orders, shipment may be authorized by purchase order before qualification is approved.

5.4 Retention of Records and Exhibits: Minimum retention periods shall be as follows:

a. Permanently:
- Copies of reports required to be sent to GE-A
- Fixed Practices
- Material or photos identified by GE-A for such retention

b. Until use of a new process is approved and use of the process described has been discontinued for Premium Quality material:
- Representative macro slabs and micro samples identified by GE-A for such retention; e.g., for comparison of conversion practices must be retained.

## 6. DEFINITIONS

The following definitions apply for purposes of this specification. Additional terms are defined in P1TF28, P1TF73 and P1TF95.

**Conversion** - Forging the ingot (cast structure) by a controlled procedure to produce billet or bar (wrought structure).

**Data for Ordering (DFO)** - A document issued by GE-A for each applicable Premium Quality Forged Part specification to show GE-A approvals: e.g., C50TF12 is supplemented by DFO-C50TF12. Items requiring approval include sponge, master alloys, revert material, melting (VAR and Hearth), and conversion.

**Dopant / Doping** - Material added to the melting hearth or ingot pool at predetermined times to determine the residence time associated with the hearth. The dopant shall be metals which are not part of the normal alloy chemistry and whose presence in the ingot can be determined by chemical analysis.

**ETTC Standards** - Photographic standards issued by the Technical Committee of European Titanium Producers. Includes microstructure (ETTC-2) and macrostructure (ETTC-3).

**Pour Stop** - A pour stop in Hearth melting is a complete departure of the fixed practice for steady state melting and which includes a complete cessation of material flow into the electrode mold.

**Premium Quality Material** - Material purchased, manufactured and inspected per the appropriate P1TFxx specification defined in the Quality Agreement.

**Process Change Request (PCR)** - A form used to notify GE-A of a proposed change to an approved melting or conversion procedure or a new melting or conversion procedure.

**Product Quality Representative** - The Sourcing Quality representative (or delegate) having supplier responsibility (either casting and/or machining) having authority to implement and approve items of this S-specification. Includes Product Value Engineer or Casting Engineer.

**Quality Agreement** - A document negotiated and agreed to by the supplier and GE-A which delineates supplier systems and controls which ensure conformance to GE-A requirements.

**Raw Material** - Material from which the primary melt is made to the applicable Premium Quality specification: e.g. sponge, master alloy, elements, compounds, revert, consolidation melts.

**Residence Time Heat** - A heat conducted with synchronized doping events which when evaluated can determine the minimum and distribution of residence times of the dopant through the hearth system.

**Seeded Heats** - A heat to which foreign materials of known tendency for forming Type I hard alpha or high density inclusions have been added prior to melting, in order to determine the capability of the melting process being qualified to eliminate them.

**Skull** - For Hearth melting, a layer of solidified titanium alloy formed on the hearth.

**VAR (Vacuum Arc Remelting)** - Consumable arc melting of an electrode.

**Appendix A:**

**STANDARD PLAN FOR QUALIFICATION OF NEW OR CHANGED PROCESSES**
**All Unseeded heats, lots, bars/billets will be normal production sizes.**
**Note: Purchaser reserves the right to add additional requirements**

# HEARTH

**Hearth, Initial Qualification: New Furnace Type**

Seeded heats:

1 per alloy with nominal diameter 2 inch maximum
One (1) residence time trial per hearth.
Ultrasonic, Radiographic, Characterization of indications
Chemical Composition (ingot top and bottom)
Note: Ti17 approves Ti-64 and Ti-6242, Ti-64 approves Ti-811 if processed the same. Any other alloy may require an additional seeded heat trial for approval.

Seeded heats must completely eliminate all defects before starting unseeded heats

Unseeded Heats:

10 Bar Heats (16 square inches maximum)
Ultrasonic (all heats, all alloys, all VAR sources) (characterization of indications)
Five (5) Chemical composition surveys (any VAR source)
Five (5) Macroetch and microetch survey (any VAR source)
Normal release testing (balance of heats)

50 Billet heats (10 inch diameter maximum)
Ultrasonic (all billets, all alloys, all VAR sources)
(characterization of indications)
Five (5) Chemical composition surveys (any VAR source)
Five (5) Macroetch and microetch survey (any VAR source)
Normal release testing (balance of heats)

**Hearth Melt : Additional Furnaces or Furnace Modifications**

Seeded heats:

1 per alloy with nominal diameter 2 inch maximum
One (1) residence time trial per hearth.
Ultrasonic, Radiographic, Characterization of indications
Chemical Composition (ingot top and bottom)
Note: Ti17 approves Ti-64 and Ti-6242, Ti-64 approves Ti-811 if processed the same. Any other alloy may require an additional seeded heat trial for approval.
Seeded heats must completely eliminate all defects before starting unseeded heats

Unseeded Heats:

5 Bar Heats (16 square inches maximum)
Ultrasonic (all bars total, all alloys, all VAR sources) (characterization of indications)
Five (5) Chemical composition surveys (per material, any VAR source)
Five (5) Macroetch and microetch surveys (any VAR source)
Normal release testing (balance of bars)

25 Billet heats (10 inch diameter maximum)
Ultrasonic (all billets, all alloys, all VAR sources) (characterization of indications)
Five (5) Chemical composition surveys (any VAR source)
Five (5) Macroetch/Microetch surveys (per material, any VAR source)
Normal release testing (balance of billets)

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**Change in Hearth Melt Rate or Hearth Design**

Seeded heats:

1 per alloy with nominal diameter 2 inch maximum
One (1) residence time trial per hearth.
Ultrasonic, Radiographic, Characterization of indications
Chemical Composition (ingot top and bottom)
Note: Ti17 approves Ti-64 and Ti-6242, Ti-64 approves Ti-811 if processed the same. Any other alloy may require an additional seeded heat trial for approval.

Unseeded Heats:

Three (3) heats (Bar or Billet) per alloy
Chemical composition survey
Macroetch, Microetch and Beta Fleck test

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**Changes in: Input Material, Form or Source, Blending method, Compaction Method**
**Beam/Torch Pattern, Pour Lip Design, or Ingot Size**

Unseeded Heats:

1 heat per alloy per VAR source
Chemical composition Survey on each heat
NOTE: If initial process was qualified with compaction, changes to the compaction process may require a seeded heat. Changes to input material should be discussed with purchaser.

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## VAR

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**Use of New (GE Qualified) Hearth Melter, New VAR Furnace, New Ingot Size, or New Alloy**

Unseeded Heats:

Five (5) ingots per alloy (Bars are OK if only bars are produced)
Chemical composition survey
Ultrasonic (characterization of indications)
Macroetch, Microetch and Beta Fleck test

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**Changes in: Melting Parameters, Blending Method, Weld fabrication of electrode, or welding of electrode to holder/stub**

Unseeded Heats:

Three (3) ingots per alloy (Bars are OK if only bars are produced)
- Chemical composition survey
- Ultrasonic (characterization of indications)
- Macroetch, Microetch and Beta Fleck test

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**Changes in: Input material, Material sources, or Consolidation practices**

Unseeded Heats:

- One (1) ingot per alloy (Bar are OK if only bars are produced)
- Chemical composition survey
- Ultrasonic (characterization of indications)
- Macroetch, Microetch and Beta Fleck test

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## CONVERSION

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**New conversion source or changes in Equipment used, New ingot source, New ingot alloy, New ingot melt method, Change conversion process**

Five (5) heats
- Macroetch and Microetch Evaluations
- Ultrasonic (characterization of indications)

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**Ingot, Billet or Bar diameter decrease > 10%**
**Ingot, Billet or Bar diameter increase > 20%**

Five (5) heats
- Macroetch and Microetch Evaluations
- Ultrasonic (characterization of indications)

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**Increase in conversion parameters or sequence diameters 20% to 10%**
**Decrease in conversion parameters or sequence diameters 10% to 5%**

Three (3) heats
- Macroetch and Microetch Evaluations
- Ultrasonic (characterization of indications)

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**Increase in conversion parameters or sequence diameters >5%**
**Decrease in conversion parameters or sequence diameters >10%**

One (1) heat
- Macroetch and Microetch Evaluations
- Ultrasonic (characterization of indications)

# RAW MATERIAL

**All Raw Material Inspection Standards**
30 lots of material (specific inspection will be specified on the PCR based on the alloy system to be produced)
Visual Inspection, Visual (fluorescent light) and X-Ray

**Cleaning Method for Revert Material**
5 lots of revert
Chemical Composition

**Processing Chips: Change in Inspection Method, Equipment or Defect removal process**
**5 lots of revert**
X-Ray inspection

**Processing Solids: Change in revert form**
5 lots of revert
Chemical Composition
Visual Inspection

**Processing Solids: Change in cleaning method**
5 lots of revert
Chemical Composition
Visual (White Light)

**Processing Solids: Change in inspection method or equipment**
5 lots of revert
Visual Inspection

# SPONGE PRODUCTION

**New Production Process**
5 lots of sponge
Chemical Composition of Zones
Visual Inspection

5 Billet/Bar heats
Chemical Composition
Ultrasonic Inspection

**New or changes to Equipment or Controls**
5 lots of sponge
Chemical Composition of Zones
Visual Inspection

**New Reactor (> 5% increase in size)**
3 lots of sponge
Chemical Composition of Zones
Visual Inspection

**New Leaching or Sizing Line, New Sponge Raw Material Source**
1 lot of sponge
Chemical Composition of Zones
Visual Inspection

## MASTER ALLOY AND ELEMENTAL ADDITIONS

**New Production Process**
5 lots of master alloy
Chemical Composition (On Quality Plan, based on material type)
Visual (White Light)
Fluorescent Light
X-Ray

5 Billet or Bar Heats (unseeded only)
Chemical Composition
Ultrasonic Inspection

**New Master Alloy. New ship shape, size or weight.**
5 lots of master alloy
Chemical Composition (On Quality Plan, based on material type)
Visual (White Light)
Fluorescent Light
X-Ray

5 Billet or Bar Heats (unseeded only)
Chemical Composition
Ultrasonic Inspection

**Change Inspection Method or Equipment**

The number of lots will be specified on the Quality Plan
- Visual (White Light)
- Fluorescent Light
- X-Ray

**Change in Production Process**

3 lots of master alloy
- Chemical Composition (On Quality Plan, based on material type)
- Visual (White Light)
- Fluorescent Light
- X-Ray

**Change in Raw Material Source**

1 lot of master alloy
- Chemical Composition (On Quality Plan, based on material type)
- Visual (White Light)
- Fluorescent Light
- X-Ray

## Appendix B:

## REQUIREMENTS FOR SEEDED HEATS

B1. **Quantity of Material:** A minimum of 2000 lb. (900 kg) shall be melted to the fixed practice and evaluated for the presence of surviving seeds. Melting and evaluation of seeded heat(s) are required for each alloy to be qualified, except that successful completion of melting and evaluation for Ti-17 alloy seeded heat(s) satisfies this requirement for Ti-64 and Ti-6242.

B2. **Seed Type, Size, and Composition:** The seeds used in seeded heats shall conform with the following requirements. All chemical percents, dimensions, and weights given in these Appendixes are approximate (typical) values; e.g. "2000 lb. melted, 1/4 inch sponge particle, 8% nitrogen, 5 pounds seed per 250 pounds ingot". GE-A will furnish upon request the name(s) of sources for "seed" material. Alternate seeding densities and types may be authorized for process changes.

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**Low Density Inclusions (Type I Hard Alpha)**

1. Nitrided sponge particles
   - o 15% nitrogen
   - o 1/4 to 1/2 inch (6 to 13 mm) long
   - o Nominally 1 seed per 5 pounds (2.3 kg) of ingot

2. Nitrided sponge particles
   - o 2-8% nitrogen
   - o 1/4 inch (6 mm) long
   - o Nominally 2 seeds per 5 pounds (2.3 kg) of ingot

3. Burned Sponge Particles
   - o 1/8 to 1/2 inch (3 to 13 mm) long
   - o 5 seeds per 250 pounds (115 kg) of ingot
   - o Seeding is required for only one third of the ingot; seeded portion shall be identified

3a. Torch-cut sheet stock
   - o 2 inch or less length
   - o Cross section shall approximate torch-cut revert used as charge material
   - o Ti 6-2-4-2 or Ti 6-2-4-6 alloy shall be used
   - o 1 seed per 250 pounds (115 kg) of ingot

3b. Air-Contaminated Weldment-Simulation Particles
   - o Nitrogen/oxygen % as produced by welding without backup shielding
   - o 1/4 inch (6 mm) long
   - o 1 seed per 250 pounds of ingot

Use either torch cut sheet or contaminated weldment seeds (3a. or 3b.). The type of seeds used shall be reported.

## Appendix B: REQUIREMENTS FOR SEEDED HEATS (cont'd)

**High Density Inclusions (HDI)**

Note: For process changes, modification of the seeding plan to omit the HDI seeds will be considered by GE-A, based on the type of change in the Hearth melting process being proposed on the PCR. The actual seeding requirements will be defined by GE-A on the PCR.

1. Crushed tungsten carbide tool bits:
   One pound (.5 kg) of tool bits per heat blended with the ingot charge.

| Particle | | Amount |
|---|---|---|
| -3/8 inch to +1/4 inch | (9.51-6.35 mm) | 37% |
| -1/4 inch to +8 mesh | (6.35-2.38 mm) | 25% |
| -8 to +14 mesh | (2.38-1.68 mm) | 15% |
| -14 to +20 mesh | (1.68-0.841 mm) | 10% |
| -20 to +40 mesh | (0.841-0.420 mm) | 8% |
| -40 to +60 mesh | (0.420-0.250 mm) | 5% |

2. Whole tungsten carbide tool bit (one per heat):
   Introduced at the midpoint of the melt

3. 0.04 inch (1 mm) diameter Molybdenum wire
   - o 1/4 to 1/2 inch (6 to 13 mm) long
   - o 2 pieces per 250 lb. (113 kg) of ingot

4. Angular piece of Molybdenum
   - o 1/4 inch (6mm) diameter
   - o 1 piece per 250 lb. (113 kg) of ingot

5. Angular piece of Tantalum
   - o 1/4 inch (6mm) diameter
   - o 1 piece per 250 lb. (113 kg) of ingot

6. Angular piece of Tungsten
   - o 1/4 inch (6mm) diameter
   - o 1 piece per 250 lb. (113 kg) of ingot

7. 0.03 inch (0.8 mm) diameter Tungsten wire
   - o 1/4 to 1/2 inch (6 to 13 mm) long
   - o 1 piece per 250 lb. (113 kg) of ingot

B3. **Blending and Compacting:** Seeds shall be blended, compacted, and introduced with other input materials in accordance with established procedures approved by GE-A. Blending and compaction to be performed in production equipment, with seeds introduced during blending. Alternative methods (e.g. wrapping seeds in foil and adding to compact) or processing through non-production equipment is not permitted.

## Appendix B: REQUIREMENTS FOR SEEDED HEATS (cont'd)

B4. **Feeding and Melting Method:** When the production practice to be used for Premium Quality material utilizes an initial hearth melt of blended and compacted input material, feeding and melting of the seeded heat shall be in accordance with the production practice. Solid revert or electrode feed are not permitted during seeded heats.

B5. **Skull:** Seeded portion of heat shall be preceded by standard new skull building procedure using unseeded material of same grade and alloy. Use of pre-existing (inventory) same grade and alloy skull is permissible.

B6. **Pour Stop**: A pour stop during the middle of the steady state seeded section of the seeded heat must occur. The pour stop should allow enough time for a portion of the hearth to solidify. Resuming melting following the pour stop should be conducted according to an established procedure. This procedure must be demonstrated to be monitored and under appropriate controls. An intentional casting rate spike (surge) should not be created, or should be minimized if it occurs. The casting rate during significant casting rate spikes upon restart will be excluded from melt rate limit calculations so as not to artificially increase the melt rate limit(s). Casting rates for production heats shall be established based on the results of the seeded heat.

B7. **Conversion:** The seeded heat shall be converted following Hearth melting without any further melting (i.e. no final VAR), with the final 65% (minimum) work performed in the alpha-beta range in order to promote cracking at any retained inclusion or embrittled material. Converted bar nominal diameter shall be 2.0 inch (51 mm) maximum. Resulting bar shall be inspected in accordance with P3TF34 to a #2 flat-bottom hole (FBH). The conversion practice shall result in ultrasonic noise levels equal to or lower than the supplier's current product produced by the conversion source for that alloy and diameter.

B8. **Reporting Requirements:** For all seeded heats required for Qualification, the seeding plan and all evaluation results shall be included in the Qualification package to GE-A, regardless of whether indications were found or verified. This includes all inspection results, chemical analysis, and any indication characterization results.

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## Appendix C:

## REQUIREMENTS FOR THE RESIDENCE TIME HEATS

C1. **Quantity of Material:** A minimum of two heats shall be melted. One melted using fixed practice casting rate and one at a casting rate above the fixed practice casting rate. Casting rate above fixed practice will be established based on hearth type. Both heats shall be large enough to conduct two full doping experiments during the heat. Melting and evaluation of the residence time heat is required to be qualified for any premium quality Ti alloy production.

C2. **Residence Time Experiment Plan:** The melter shall provide an experimental plan containing: the process dopants, the doping schedule, the proposed doping locations, and evaluation plan. A written plan shall be submitted to GE-A for approval prior to performing the test. A sample experiment plan may be requested from GE-A.

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## Appendix D:

## PINPOINTING INDICATIONS

The supplier's procedures for the evaluation of rejectable indications identified during ultrasonic inspection of bar or billet shall be approved by the purchaser. Refer to the current revision of JETQC-001 for more details. The basic format for the evaluation procedure requires:

D1. A slice (minimum axial length 3") to be taken from the billet/bar. The indication is to be axially located approximately in the center of the slice.

D2. A cube is machined from the slice. The dimensions of the cube are typically 3" (axial) x 2" x 2". Cube faces are identified and correlated to original billet surface and ultrasonic signal.

D3. The source of the rejectable ultrasonic indication is pinpointed ultrasonically and remarked to maintain orientation.

D4. The cube is remachined to provide a cube having sides approximately 1.0" with the indication approximately in the center of the cube.

D5. Pinpointing of the indication is repeated ultrasonically.

D6. Consider performing 3D Computer Aided Tomography (CAT) scanning or other NDT technique to determine the 3D shape and size of the defect.

D7. A cube is then machined for metallography. The orientation of the indication in the cube is used to select the face to be step polished. The location of the indication is tracked based on the ultrasonic response.

D8. Step polishing/ machining is in accordance with approved removal limits, based on the location of the indication from the face being polished.
Polish in steps from 50 to 500 microns
Macroetching and metallographic evaluation is required after each step polish.
Consider performing 3D CAT scanning or other NDT technique to assist in determination of the 3D shape and size of the defect.

D9. Step polishing is continued until either the source of the rejectable signal is identified or the face being viewed is 0.10" past the predicted location of the indication.

D10. Procedures are required for the evaluation of indications which violate applicable controlling specifications.

**FIGURE 1: PROCESS CHANGE REQUEST/NONCONFORMANCE REPORT FORM**

**☐ Process Change Request** **☐ Nonconformance Report**

| | | | |
|---|---|---|---|
| **Number (rev):** | | **Date:** | |
| **GE Addressee(s):** | | **Material Identification:** | |
| **Alloy:** | | **Size:** | |
| **Spec(s):** | | **Plant Location:** | |
| **Associated PCR (as applicable)** | | **Customer: (as applicable)** | |

1. **CURRENT PROCESS:**

2. **NATURE OF CHANGE/DEVIATION:**

3. **REASON:**

4. **SUPPORTING DATA/RATIONALE:**

5. **CORRECTIVE/FUTURE ACTIONS:**

_____

(Supplier Representative) Date

Contact information: _____

| | Action Required (see below) | | Final Approval | | Rejected/Withdrawn | |
|---|---|---|---|---|---|---|
| Signature | | | | | | |
| Organization | Quality | MAE | Quality | MAE | Quality | MAE |
| Date | | | | | | |

Comments/Action Required

CC: PROPRIETARY