SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

SAE AMS2380 REV. F

Issued 1972-11
Revised 2008-06
Reaffirmed 2013-04

Superseding AMS2380E

Approval and Control of Premium-Quality Titanium Alloys

RATIONALE

AMS2380F has been reaffirmed to comply with the SAE five-year review policy.

1. SCOPE

1.1 Purpose

This specification covers the procedures for approval of products of premium-quality titanium alloys and the controls to be exercised in producing such products.

1.1.1 This specification requires approved sources (See 3.1 and 4.4).

1.2 Application

This specification has been used typically for parts fabricated from titanium alloys that require approval of the product and facets of its production to ensure that production lots are of the same metallurgical quality, are produced by the same basic procedures as the products originally qualified, and for parts subjected to rigid inspection standards throughout manufacture from ingot to finished part, but usage is not limited to such applications.

1.3 Classification

This specification covers four grades of premium-quality titanium alloy products based on the melting practice used in making the alloy, as follows:

Grade 1 - Double Consumable Electrode Vacuum Arc Melted
Grade 2 - Triple Consumable Electrode Vacuum Arc Melted
Grade 3 - Electron Beam Cold Hearth Refined (EBCHR) Followed by a Single Consumable Electrode Vacuum Arc Melt
Grade 4 - Plasma Arc Melted Cold Hearth Refined (PAMCHR) Followed by a Single Consumable Electrode Vacuum Arc Melt

1.3.1 Any grade may be supplied unless a specific grade is specified. The grade supplied shall be reported.

2. APPLICABLE DOCUMENTS

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
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2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

AMS2631	Ultrasonic Inspection, Titanium and Titanium Alloy Bar and Billet
AMS2642	Structural Examination of Titanium Alloys, Etch-Anodize Inspection Procedure
AMS2643	Structural Examination of Titanium Alloys, Chemical Etch Inspection Procedure

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM B 299	Titanium Sponge
ASTM E 539	X-Ray Emission Spectrometric Analysis of 6Al-4V Titanium Alloy
ASTM E 1409	Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique
ASTM E 1447	Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity/Infrared Detection Method
ASTM E 1941	Determination of Carbon in Refractory and Reactive Metals and Their Alloys
ASTM E 2371	Analysis of Titanium and Titanium Alloys by Atomic Emission Plasma Spectrometry

3. TECHNICAL REQUIREMENTS

3.1 Ingot

Shall be produced as specified herein under effective controls of all variables of the melting processes to produce consistently uniform ingots that will yield products meeting the requirements of this specification. Ingots shall be produced only by approved sources (See 1.1.1 and 4.4).

3.1.1 Raw Material Control

3.1.1.1 Sponge

Melt source shall either produce or procure sponge to a specification approved as in 4.4.2.1.1. Sponge shall be free of contaminants considered to cause high and/or low-density inclusions or of excess elements that might alter or influence the phase structure or content of the intended final product. Inspection frequency and methods shall be as agreed upon by purchaser and vendor. Composition shall be determined as follows: carbon in accordance with ASTM E 1941, hydrogen in accordance with ASTM E 1447, oxygen and nitrogen in accordance with ASTM E 1409, and other elements in accordance with ASTM E 539 or ASTM E 2371. Other analytical methods may be used if acceptable to the purchaser.

3.1.1.2 Master Alloy and Alloying Elements

Melt source shall procure master alloy and alloying elements to a specification approved as in 4.4.2.1.1. Master alloy and alloying elements shall be free of oxides, nitrides, and other detrimental foreign materials, including materials that would cause high and/or low-density inclusions. The boron content of the master alloy shall not exceed 0.005% by weight (50 ppm). Methods of analysis and inspection of master alloys and alloying elements shall be as agreed upon by the melter or supplier and purchaser. No elements shall be added except as shown as an element in the composition detailed in the applicable material specification. A residual element is defined as an element present in a metal or an alloy in small quantities inherent to the raw materials or manufacturing process but not added intentionally.

3.1.1.3 Recycling

3.1.1.3.1 Grade 1 and Grade 2

Previously melted alloy may be recycled provided such material is clean, free of heavy scale, refractories, high-density material, and carbides and is segregated as to alloy grade. Stubs may be used for remelt and shall be melted a minimum of two times as specified in 3.1.2. No flame-cut material "or split ends" shall be recycled unless all hard scale is removed, followed by acid pickling and rinsing or is processed by hydrogenation, crushing, and inspection. Turnings that have been cut with carbide tools may be recycled provided they are shown to be free of high-density material, determined by a procedure agreed upon by purchaser and vendor. Casting scrap shall not be recycled.

3.1.1.3.2 Grade 3 and Grade 4

The use of recycled material for Grade 3 and Grade 4 shall be in accordance with 3.1.1.3.1 or as agreed upon by purchaser and vendor.

3.1.2 Melting Practice

Grade 1 alloy shall be double melted under vacuum and Grade 2 alloy shall be triple melted under vacuum using consumable electrode practice. Grade 3 shall be electron beam cold hearth refined followed by a single vacuum arc remelt. Grade 4 shall be plasma arc melted, cold hearth refined, followed by a single consumable electrode vacuum arc melt. The critical variable of each melting cycle shall be continuously monitored and recorded. The bottom charge shall be of the same nominal composition as the material being melted and shall conform to 3.1.1.3.

3.1.2.1 First Melt

3.1.2.1.1 Grade 1 and Grade 2

A suitable vacuum during the steady state portion of the first melt is defined as a pressure not higher than 2000 microns (2 mm) of mercury with occasional momentary peaks not higher than 6000 microns (6 mm) of mercury. The pressure shall be maintained by continuous pumping.

3.1.2.1.2 Grade 3

A suitable vacuum during the steady state portion of the first melt is defined as a pressure not higher than 100 microns (0.1 mm) of mercury with occasional momentary peaks not higher than 300 microns (0.3 mm) of mercury. The pressure shall be maintained by continuous pumping.

3.1.2.1.3 Grade 4

Melting shall be performed under inert gas at a pressure no higher than 1000 mm of mercury. Momentary pressure rises up to 1500 mm of mercury are allowed up to 180 seconds.

3.1.2.1.4 A consolidation melt to provide electrodes for first stage melting may be made by consumable electrode, nonconsumable electrode, electron beam, or plasma arc melting practice.

3.1.2.2 Subsequent Vacuum Melt(s) of Grades 1, 2, 3, and 4

A suitable vacuum during the steady state portion of subsequent melts is defined as not higher than 750 microns (0.75 mm) with occasional momentary peaks to 2000 microns (2 mm) permitted.

3.1.2.3 A momentary peak is defined as a temporary surge of pressure that recovers to the maximum allowable pressure level in not more than 90 seconds in the second-stage of a double melt or third stage of a triple melt and 120 seconds in the first-stage melt and in the second stage of a triple melt.

3.1.2.4 Welding of primary melt electrodes for either Grade 1 or Grade 2 alloy and of second melt electrodes for Grade 2 alloy shall be performed in vacuum or in an inert gas (argon and/or helium) filled chamber or fixture, using plasma arc, electron beam, or gas metal arc (GMA) techniques only; use of gas tungsten arc (GTA) welding is not permitted. Electrodes shall not be welded outside of chamber unless agreed upon by purchaser and manufacturer. Welding of the holding fixture may be performed with an inert gas (argon and/or helium) shielded plasma or gas metal arc welding, but such welds shall not be used as recycle material and, if this weld joint is melted into the ingot, that portion of the ingot shall be removed.

3.1.2.5 Preliminary Melting Cycles

Any of the following discrepancies occurring during the first melting cycle for Grades 1, 3, and 4 alloy or during either the first or second cycles for Grade 2 alloy shall disqualify the heat for any application requiring this specification. Deviations from established limits may be referred to alloy purchaser for acceptance.

3.1.2.5.1 For Grades 1 and 2, any loss of vacuum exceeding the limits of 3.1.2.1.1 associated with an air leak.

3.1.2.5.2 For Grade 3, any loss of vacuum exceeding the limits of 3.1.2.1.2 associated with an air leak.

3.1.2.5.3 For Grade 4, any system leak detected by continuous analysis of the furnace atmosphere. Compositional limits shall be as agreed upon by purchaser and vendor.

3.1.2.5.4 Any water leak occurring during the melting cycle shall be confirmed by chemical analysis after grinding. Minor discoloration due to pinhole water leaks may be removed by machining or by grinding provided all traces of grinding media are subsequently removed.

3.1.2.5.5 Any unscheduled furnace disassemblies.

3.1.2.6 Final Melt Cycle

Any of the following melting discrepancies shall disqualify the heat for applications requiring this specification.

3.1.2.6.1 Any loss of vacuum exceeding the limits of 3.1.2.2.

3.1.2.6.2 Any water leak into the ingot chamber during the melting period. Minor discoloration due to pinhole water leaks may be removed by grinding. Ingot shall be considered acceptable only if chemical analysis of alloy removed from the leak area after grinding indicates absence of contamination.

3.1.2.6.3 Any power interruption lasting longer than 30 seconds during the melting cycle.

3.1.2.7 Hot Topping

During final melting, ingots shall be hot topped according to an established procedure with defined limits that shall be continuously monitored and recorded. The melting discrepancy restrictions of 3.1.2.6.2 and 3.1.2.6.3 shall apply during hot topping. If one or more of the defined limits are exceeded during the hot topping operation, the corresponding portion of the ingot shall be discarded and the balance shall be considered acceptable only if chemical analysis or other tests show the ingot to be free of contamination or other detrimental defects.

3.1.2.8 Furnace Cleaning

The furnace shall be inspected and cleaned in accordance with an established schedule and procedure.

3.2 Stock for Forging or Extruding

Billet, bar, and slabs for forging and extruding shall be manufactured from ingot produced as in 3.1. Limits shall be established for ingot conversion procedures that will produce stock conforming to the following requirements; these limits shall be continuously monitored and recorded. Deviations from established parameters for the control factors for ingot

conversion procedures of 4.4.2.1.2 shall be reported to purchaser of the stock and approval obtained before the stock may be considered acceptable.

3.2.1 Macrostructure and Defects

3.2.1.1 Visual examination at 1X magnification of transverse sections of stock for forging or extrusions, etched in an ammonium bifluoride etch solution of 68 grams/gallon (18 g/L) of NH_4HF_2 at room temperature, or in accordance with AMS2643, or other etching procedure agreed upon by purchaser and vendor, for sufficient time to develop a well-defined macrostructure, shall show no imperfections, such as unhealed pipe, cracks, porosity, laps, folds, pitted areas, segregation, or inclusions, detrimental to usage of the stock. A processing tree ring structure is permitted provided there is no chemical segregation outside of the composition limits and microstructure of the tree ring pattern is acceptable. Additional etching procedures, such as AMS2642 etch anodize, may be used when agreed upon by purchaser and vendor.

3.2.1.2 Macro-Grain Structure

The macro-grain structure shall be equal to or better (lower number) than the levels shown in Tables 1 and 2. Visual standards for macro-grain structure are shown in Figures 1 through 10.

TABLE 1 - MACRO-GRAIN STRUCTURE STANDARDS, FORGING AND EXTRUDING STOCK, ROUNDS

Nominal Diameter Inches	Nominal Diameter Millimeters	Macro-Grain Structure Level Ti-6Al-4V, Ti-6Al-6V-2Sn Ti-6Al-2Sn-4Zr-2Mo	Macro-Grain Structure Level Other Alloys
Up to 2.0, incl	Up to 51, incl	20	20
Over 2.0 to 6.0, incl	Over 51 to 152, incl	30	30
Over 6.0 to 10.0, incl	Over 152 to 254, incl	40	50
Over 10.0 to 14.0, incl	Over 254 to 356, incl	50	60
Over 14.0 to 17.0, incl	Over 356 to 432, incl	60	70
Over 17.0	Over 432	70	70

TABLE 2 - MACRO-GRAIN STRUCTURE STANDARDS, FORGING AND FORGING STOCK, SQUARES, RECTANGLES, HEXAGONS, OCTAGONS

Nominal Cross Sectional Area Square Inches	Nominal Cross Sectional Area Square Centimeters	Macro-Grain Structure Level Ti-6Al-4V, Ti-6Al-6V-2Sn Ti-6Al-2Sn-4Zr-2Mo	Macro-Grain Structure Level Other Alloys
Up to 4, incl	Up to 26, incl	20	20
Over 4 to 28, incl	Over 26 to 181, incl	30	30
Over 28 to 79, incl	Over 281 to 510, incl	40	50
Over 79 to 154, incl	Over 510 to 994, incl	50	60
Over 154 to 226, incl	Over 994 to 1458, incl	60	70
Over 226	Over 1458	70	70

3.2.1.3 Any macrostructural defects, including unhealed pipe, internal cracks, porosity, folds, pitted areas, segregation, and inclusions, visible at 1X magnification with 20/20 standard vision at a light intensity of not less than 100 foot-candles (1076 lx) are not acceptable. Figures 11 through 13 are typical of the type, but not the minimum size, of such defects that are cause for rejection.

3.2.2 Microstructure

Shall be that structure resulting from processing within the alpha-beta phase field (See 8.3). Microstructure shall conform to 3.2.2.1 or 3.2.2.2.

3.2.2.1 Equiaxed or equiaxed and elongated primary alpha in a transformed beta matrix with no continuous network of alpha at prior beta grain boundaries.

3.2.2.2 Essentially complete field of equiaxed and/or elongated alpha with or without intergranular beta and with no continuous network of alpha at prior beta grain boundaries.

3.2.3 Ultrasonic Inspection

Unless otherwise agreed upon by purchaser and vendor, the product shall conform to the classification requirements of Tables 3, 4, or 5, determined in accordance with AMS2631, using longitudinal wave method. Product size and configuration at which the inspection is performed shall be as agreed upon by purchaser and vendor. Product 4.5 inches (114 mm) and over in nominal diameter or 16 square inches (103 cm^2) and over in cross-sectional area containing indications exceeding the limits of the applicable classification of Tables 3, 4, or 5 shall not be shipped until the indications have been investigated and verified as to type; areas containing ultrasonic indications exceeding the specified limits shall be removed. Sonic indications exceeding the specified limits shall be removed from product under 4.5 inches (114 mm) in nominal diameter or under 16 square inches (103 cm^2) in cross-sectional area prior to shipment; removed indications do not require investigation and classification. End faces of removed sections shall be free of defects; if end faces reveal defects, the product shall be further cropped as required. If only evidence of grain size variation is revealed after etching, additional cropping will not be required.

TABLE 3 - ULTRASONIC CLASSIFICATION FOR ROUNDS

Nominal Diameter Inches	Nominal Diameter Millimeters	Ultrasonic Classification
Up to 4.0, incl	Up to 102, incl	AA
Over 4.0 to 9.0, incl	Over 102 to 229, incl	A1
Over 9.0 to 14.0, incl	Over 229 to 356, incl	A
Over 14.0	Over 356	B

TABLE 4 - ULTRASONIC CLASSIFICATION FOR PRODUCT OTHER THAN ROUNDS AND PLATE

Nominal Dimension Between Parallel Sides Inches	Nominal Dimension Between Parallel Sides Millimeters	Ultrasonic Classification
Up to 3.0, incl	Up to 76, incl	AA
Over 3.0 to 9.0, incl	Over 76 to 229, incl	A1
Over 9.0 to 14.0, incl	Over 229 to 356, incl	A
Over 14.0 to 18.0, incl	Over 356 to 457, incl	B

TABLE 5 - ULTRASONIC CLASSIFICATION FOR PLATE

Nominal Thickness Inches	Nominal Thickness Millimeters	Ultrasonic Classification
0.5 to 4.0, incl	13 to 102, incl	A1

3.2.3.1 Product containing evidence of interstitially stabilized alpha structure (Type I), aluminum-rich stabilized alpha structure (Type II), voids, porosity, bursts, pipe, and inclusions found by ultrasonic inspection and identified by metallurgical investigation, by macroetching in accordance with AMS2643, or by other macroetching procedure agreed upon by purchaser and vendor may be used only if the requirements of 3.2.3 are met.

3.2.3.2 All areas containing surface defects such as laps, end concavity, and enfoliations shall be etched after removal of the defect to ensure complete removal.

3.3 Forgings

Shall be produced from forging stock conforming to 3.2.

3.3.1 Preproduction Forgings

3.3.1.1 The forging vendor shall produce preproduction forgings and shall heat treat these forgings as specified by purchaser. A representative forging or section thereof shall be tested to determine conformance to all applicable technical requirements of the forging specification and this specification and supplementary requirements of the drawing and/or purchase order. A second forging or the balance of the vendor-test forging shall be submitted to purchaser for confirmatory tests. The preproduction forgings may be produced as part of the initial production run.

3.3.1.2 One or more sections taken from designated areas of the test forgings shall be suitably prepared and etched to reveal the cross-sectional structure, including grain flow if discernible, developed in the forgings. The section or sections shall also be used for general macrostructure examination. Photographs of the section or sections shall be submitted to purchaser.

3.3.1.3 A report of the process control factors (See 4.4.2.1.3) used to produce preproduction forgings shall be submitted with the results of tests conducted on such forgings. Alternatively, the report need not be submitted with the test results but shall be prepared and kept on file for inspection by purchaser at any time.

3.3.2 Production Forgings

Shall be produced using the same basic operations and practices, and the same tolerances where applicable, as used on the approved (See 4.4) preproduction forgings.

3.3.2.1 Production forgings shall not be shipped prior to approval of the preproduction forgings by purchaser.

3.3.3 Forging Acceptance Standards

Preproduction forgings, when required by purchaser, and production forgings shall be in accordance with the following:

3.3.3.1 Macrostructure

Visual examination of representative sections from forgings, etched in accordance with AMS2643 or other etching procedure agreed upon by purchaser and forger, shall show a uniform structure of fine or medium grain size as defined in Figures 14 and 15 and shall show no imperfections, such as pipe, cracks, porosity, laps, folds, pitted areas, segregation, and inclusions, detrimental to usage of the forgings. Examples of defects are shown in Figures 11, 12, and 13. Figure 16 is defined as unacceptable coarse grains in section sizes under 5 inches (127 mm) and Figure 17 is defined as unacceptable coarse grains in section sizes 5 to 9 inches (127 to 229 mm) exclusive. If grain size is obscured by flow lines, as indicated in Figure 18, the structure shall be acceptable. These macrostructure standards shall not be applied to forged surface planes.

3.3.3.2 Microstructure

Shall be in accordance with requirements of the applicable product specification. Photomicrographs, Figures 19 through 22, are for information only and are not intended for use as acceptance standards.

3.3.3.3 Ultrasonic Inspection

Each forging shall be ultrasonically inspected at the stage of manufacture agreed upon by purchaser and vendor. If an inspection is to be performed by the vendor, that vendor shall submit a procedure to purchaser that includes the method to be used, standards for acceptance, and a scan plan.

3.3.3.4 Etch Inspection

Each forging shall be etched and inspected to reveal surface imperfections in accordance with AMS2642 or AMS2643 as agreed upon by purchaser and vendor, and, when specified by purchaser, shall be machined prior to etching to reveal segregation and inclusions. Examples of defects are shown in Figures 13 and 19.

3.3.3.5 Etch-Anodize Inspection

Specimens shall be cut from forgings and etch-anodized in accordance with AMS2642 to determine the nature and extent of segregation and defects if present.

3.4 Finished Mill Products

3.4.1 Bar and Plate

Shall be manufactured from ingot that meets the requirements of 3.1. The finished bar and plate shall meet the requirements of 3.2 and 3.3.3.3.

3.4.2 Extrusions

Shall be produced from extruding stock conforming to 3.2. Visual examination of a slice from the back end of each extrusion, etched in accordance with AMS2643, shall show a uniform structure and no imperfections, such as pipe, cracks, porosity, laps, folds, pitted areas, segregation, and inclusions, detrimental to usage of the product.

3.5 Quality Requirements

In the event that more than three distinct and separate confirmed areas of segregation, inclusions, voids, or combination thereof on an ingot are found, or more than one for each 1500 pounds (680 kg) of ingot product are found, whichever is less, the entire ingot product shall be rejected. Conformance to this requirement shall apply only to products over 4.5 inches (114 mm) in nominal thickness or diameter.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The vendor of the product shall supply all samples for vendor's tests and shall be responsible for the performance of all required tests. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to specified requirements.

4.2 Classification of Tests

4.2.1 Acceptance Tests

The following requirements are acceptance tests and shall be performed on each heat or lot (See 8.2) as applicable:

4.2.1.1 Elemental Additions

Composition requirements of the respective procurement specifications.

4.2.1.2 Sponge, Master Alloy, Alloying Elements, and Recycle Material

Visual and x-ray inspections or other equivalent nondestructive inspections and composition requirements of the respective procurement specifications.

4.2.1.3 Stock for Forging or Extruding

Composition, macrostructure, microstructure, beta transus temperature, and ultrasonic inspection.

4.2.1.4 Forgings, Bar, and Plate

Ultrasonic, microstructural, etch inspections, and the acceptance tests of the material specification.

4.2.1.5 Extrusions

Macrostructure examination and the acceptance tests of the material specification.

4.2.2 Periodic Tests

The following requirements are periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser:

4.2.2.1 Sponge, Master Alloy, and Elemental Additions

Trace element determination.

4.2.2.2 Forgings, Bar, and Plate

Macrostructure.

4.3 Sampling and Testing

Shall be in accordance with the following; when sampling is on a lot basis, a lot shall be as defined in 8.2 for each product.

4.3.1 Composition

4.3.1.1 Sponge

Each lot shall be sampled in accordance with ASTM B 299.

4.3.1.2 Master Alloy and Alloying Elements

Each lot shall be sampled at a frequency sufficient to ensure compliance with the procurement specification.

4.3.1.3 Ingot

One sample at or near the top and bottom of each ingot. Results shall be reported separately by location.

4.3.1.4 Stock for Forging or Extruding, Forgings, Extrusions, Bars, and Plate

When chemical analysis is not performed on an ingot, two samples shall be selected from the product of the ingot, one each from the top portion and the bottom portion of the ingot. If the location in the ingot cannot be determined, three random samples shall be selected or, if a lot represents less than one-quarter of an ingot, a single sample shall be selected. Samples for determination of hydrogen content of forgings, extrusions, bars, and plates shall be taken from each lot after all processing has been completed.

4.3.2 Macrostructure and Microstructure

4.3.2.1 Forging Stock

One transverse slice shall be taken from the top of each billet and from the bottom of the bottom billet. If only a portion of a billet or a heat is used, one slice shall be taken from each end of the portion; however, the testing frequency shall be not less than that for a full heat. For bar stock, when traceability relative to ingot position cannot be maintained, one transverse slice shall be taken from each end of each bar for macrostructure. Sampling for microstructure will be as agreed upon by purchaser and vendor.

4.3.2.2 Forgings

At least one preproduction forging shall be sectioned to reveal grain flow, microstructure, and general macrostructure. The specific areas to be examined shall be as agreed upon by purchaser and vendor. Production forgings shall be sectioned in the same manner at a frequency agreed upon by purchaser and vendor.

4.3.2.3 Extrusions

Transverse slice from the back end of each extrusion.

4.3.2.4 Bar and Plate

As agreed upon by purchaser and vendor.

4.3.3 Etch Inspection

Each forging shall be etched to reveal surface defects and, when specified by purchaser, the forging shall be machined and etched to reveal subsurface defects and segregation.

4.3.4 Ultrasonic Inspection

4.3.4.1 Stock for Forging or Extruding, Bar, and Plate

Each billet, bar, and plate.

4.3.4.2 Forgings and Extrusions

As specified by purchaser.

4.4 Approval

4.4.1 Preproduction forgings and the forging procedure shall be approved by purchaser before forgings for production use are supplied. Approval of preproduction forgings shall in no way relieve the forging vendor of responsibility for continued conformance to all purchase order requirements.

4.4.2 The respective vendors shall establish for ingot, forging stock, extruding stock, bar, plate, and forgings and extrusions of each part number or configuration, parameters for the process control factors that will yield products meeting the respective requirements of this specification and the material specification. These parameters shall constitute the approved manufacturing procedures for each product and shall be used for subsequent production of the product. If necessary to make any significant change in parameters for process control factors, vendor shall submit for reapproval a statement of the revised operations and, when requested, sample product. Production products incorporating the revised operations shall not be shipped prior to receipt of reapproval.

4.4.2.1 Control factors for producing the product include, but are not limited to, the following for the respective product forms:

4.4.2.1.1 Ingot

Sources and methods of producing sponge, master alloy, elemental addition, and recycle material
Specifications and inspection procedures for sponge and master alloy
Procedures for use of recycle alloy
Nonconsumable, EBCHR, or PAMCHR melting practice
Electrode fabrication procedure
Preparation of ingot for remelting after preliminary melting cycle
Arc voltage and current
Parameters for arc stirring of melt, if used
Melting chamber pressure
Ingot cooling procedure
Hot topping practice
Ingot quality analysis procedure

4.4.2.1.2 Stock for Forging and Extrusion

Conversion source if not the ingot source
Preparation of ingot for conversion
Ingot heating procedure
Cogging and rolling procedures
Inspection procedures

4.4.2.1.3 Forgings

Source of stock
Nominal size (cross-sectional area) and shape of forging stock
Type of processing equipment (e.g., press, hammer, ring roll, mill, etc.)
Sequence or number of operation changes that would result in a different cross-sectional structure or different working of the metal
Protective atmosphere and/or coatings, if used
Thermal cycling, including heating for working and specified heat treatment of the product
Cleaning operations (e.g., chemical descaling, blasting, etc.)
Inspection procedures

4.4.2.1.4 Any of the above process control factors that parameters are considered proprietary by the vendor may be assigned a code designation. Each variation in such parameters shall be assigned a modified code designation.

4.5 Records

4.5.1 Maintenance of Facilities

Each vendor shall keep records demonstrating that the facilities used to produce, control, measure, and test the respective products during manufacture and inspection are properly maintained and are checked at stated intervals against acceptable standards for accuracy.

4.5.2 Process Sheets

Each vendor shall prepare and maintain documented instructions defining the processing methods and routing in the manufacturing cycle for producing the respective products.

4.5.3 Traceability

The ingot producer shall maintain records to provide traceability of each ingot to raw material including recycle alloy. The vendor shall maintain records to provide traceability of each billet or slab that exceeds 16 square inches (103 cm^2) as to its location and orientation in the final remelt ingot. If forgings are made from billets or slabs exceeding 16 square inches (103 cm^2), the forging vendor shall maintain records to provide traceability to a particular billet or slab and its orientation. Records of the disposition of all stock shall be maintained by the vendor (e.g., scrapped for cause, shipped, still in ingot form, etc). A similar degree of traceability may be requested by the purchaser for other product forms. Records shall be maintained for not less than ten years.

4.6 Reports

The vendor shall furnish with each shipment a report showing the grade supplied (See 1.3) and the results of tests to determine conformance to the technical requirements and stating that the product conforms to the other technical requirements. These data shall be included in the report required by the material specification.

4.7 Resampling and Retesting

If any specimen of any product used in the above tests fails to meet specified requirements, disposition of the product may be based on the results of additional testing as specified below. Except where retesting results in discard of nonconforming material, failure of any retest specimen to meet specified requirements shall be cause for rejection of the product represented. Resampling and retesting of bars, plate, and extrusions shall be in accordance with requirements of the applicable material specification.

4.7.1 If segregation, laps, folds, cracks, pitted areas, inclusions, or voids are found in macrostructural examination of stock for forging or extruding, two adjacent slices, one adjacent to each face of the original slice, shall be cut and examined. This procedure may be repeated until the defective area has been removed.

4.7.2 If acceptable limits of macrostructure are exceeded, further working of forging stock and extruding stock to produce a smaller size with acceptable macrostructure is permitted.

4.7.3 If ultrasonic indications greater than the limits permitted for the respective class are found, the areas containing such indications shall be removed and examined. The defect characterization procedures shall include, as a minimum, analyses by metallography and microhardness testing. Wavelength or energy dispersive X-ray analysis in a scanning electron microscope shall also be used when metallography and hardness evaluation are insufficient to identify the indication or when the indication is identified as a Type I hard alpha defect. Type I hard alpha defects shall be analyzed as required to characterize the defect. The product faces adjacent to the indications shall be macro-etched and examined. If the ultrasonic indications are determined to be isolated and caused by, or associated with, segregation, voids, or inclusions, the remainder of the affected billet, bar, or slab may be used. However, if etching of the adjacent cut faces of the product reveals additional evidence of segregation, voids, or inclusions, further cutting, etching, and examination as in 4.7.1 shall be conducted until it is ensured that the defective area has been removed.

5. PREPARATION FOR DELIVERY

5.1 Identification

All product forms ordered to and meeting this specification shall be identified with AMS2380 and the following:

5.1.1 Ingot and Extruding Stock

Shall be identified as agreed upon by purchaser and vendor.

5.1.2 Forging Stock, Forgings, Extrusions, Bar, Plate, and Slab

Shall be identified in accordance with requirements of the applicable material specification.

5.2 Packaging

The product shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the product to ensure carrier acceptance and safe delivery.

6. ACKNOWLEDGMENT

A vendor shall mention this specification number and its revision letter in all quotations and when acknowledging purchase orders.

7. REJECTIONS

Product not conforming to this specification, or to modifications authorized by purchaser, will be subject to rejection.

8. NOTES

8.1 A change bar (|) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of a specification. An (R) symbol to the left of the document title indicates a complete revision of the specification, including technical revision. Change bars and (R) are not used in original publications, nor in specifications that contain editorial changes only.

8.2 Terms used in AMS are clarified in ARP1917 and as follows:

8.2.1 Sponge, Master Alloy, and Alloying Elements

A lot shall be all material produced in one time period by a single source as defined by the producer's specification and maintained, sampled, tested, and inspected as a common unit.

8.2.2 Forging Stock and Extruding Stock

A lot shall be all material of the same nominal size from the same heat processed in accordance with the same approved manufacturing procedures.

8.2.3 Forgings, Extrusions, Bar, and Plate

A lot shall be all product of the same part number or configuration from the same heat and processed in accordance with the same approved manufacturing and heat treatment procedures.

8.2.4 Electrode Stub

The material that may be joined to the top of an electrode to provide the connection between the electrode and the electrode holder.

8.2.5 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.

8.3 Terminology for titanium microstructures is presented in AS1814.

8.4 Dimensions and properties in inch/pound units and the Fahrenheit temperatures are primary; dimensions and properties in SI units and the Celsius temperatures are shown as the approximate equivalents of the primary units and are presented only for information.

PREPARED BY AMS COMMITTEE “G”

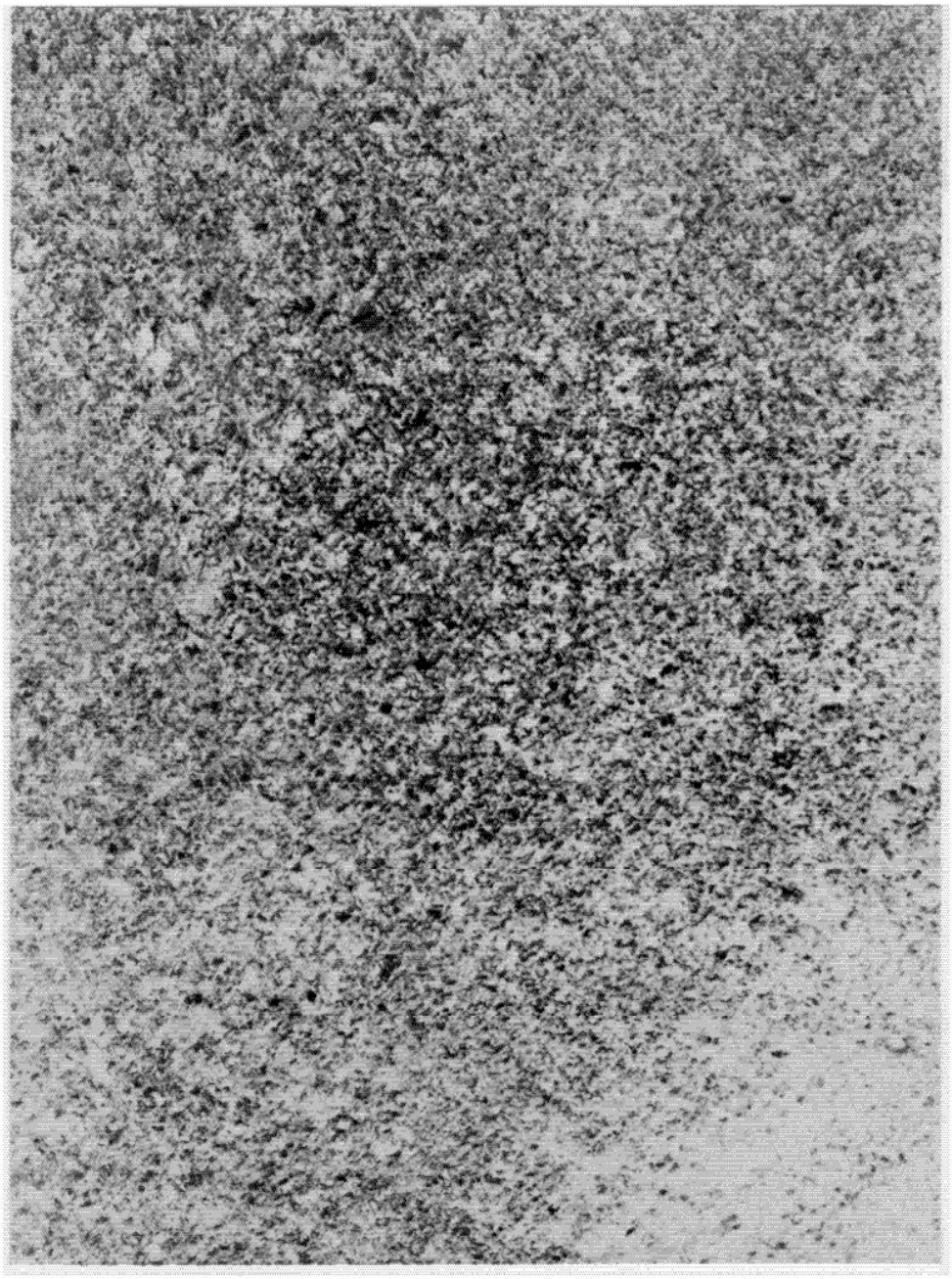


FIGURE 1 - LEVEL 10 TITANIUM BILLET MACROSTRUCTURE AT 1X MAGNIFICATION

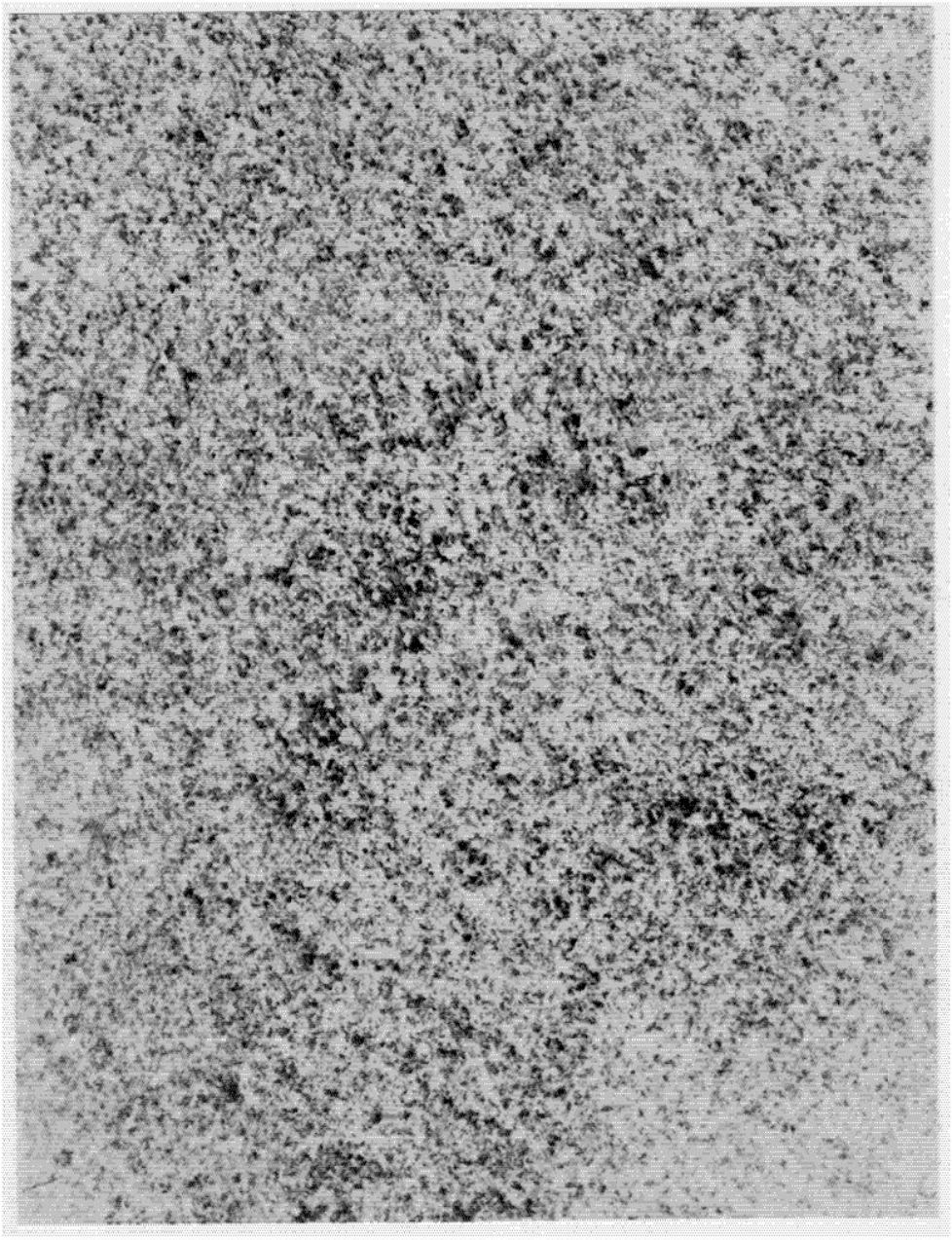


FIGURE 2 - LEVEL 20 TITANIUM BILLET MACROSTRUCTURE AT 1X MAGNIFICATION

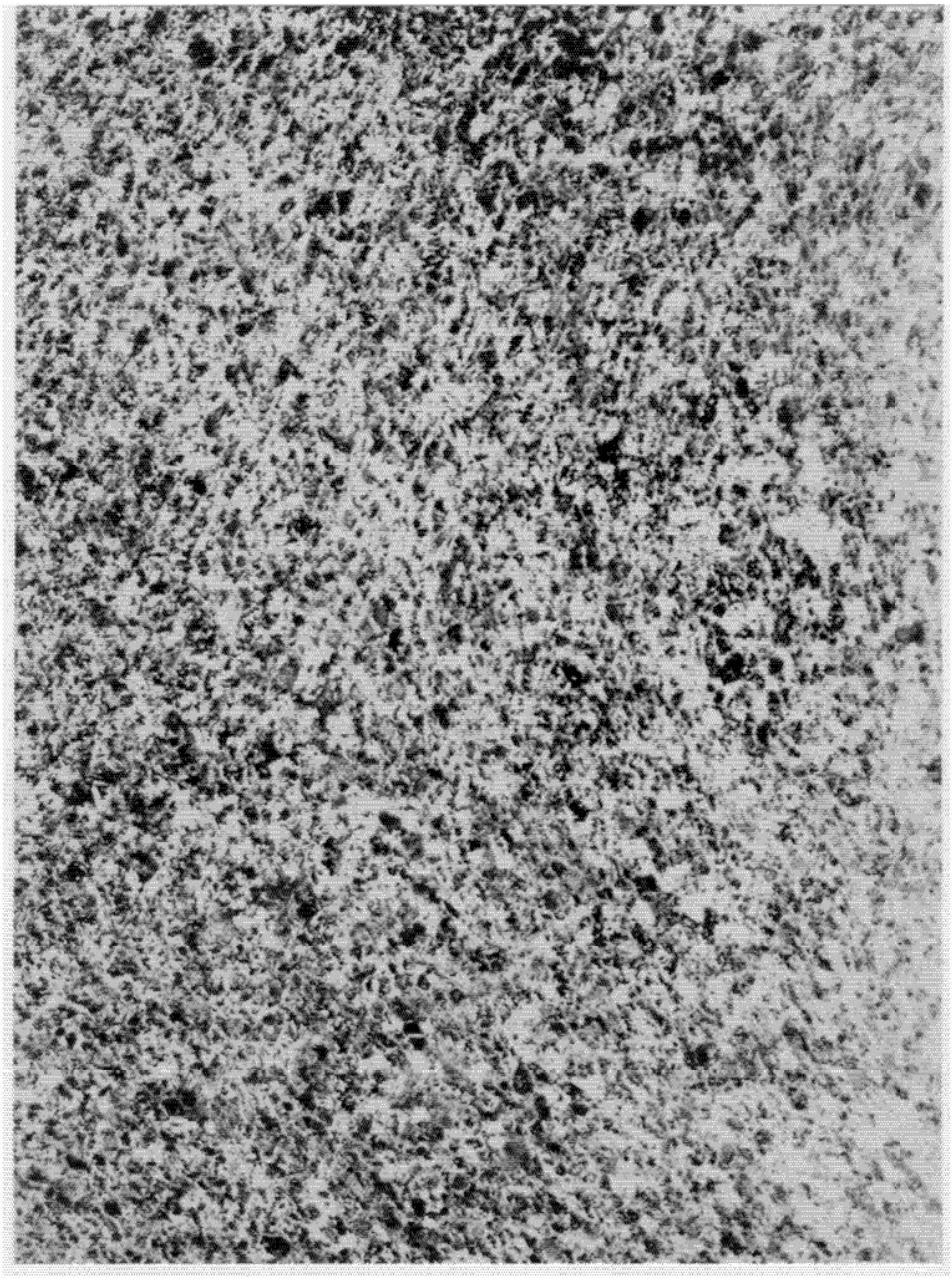


FIGURE 3 - LEVEL 30 TITANIUM BILLET MACROSTRUCTURE AT 1X MAGNIFICATION

FIGURE 4 - LEVEL 40 TITANIUM BILLET MACROSTRUCTURE AT 1X MAGNIFICATION

FIGURE 5 - LEVEL 50 TITANIUM BILLET MACROSTRUCTURE AT 1X MAGNIFICATION

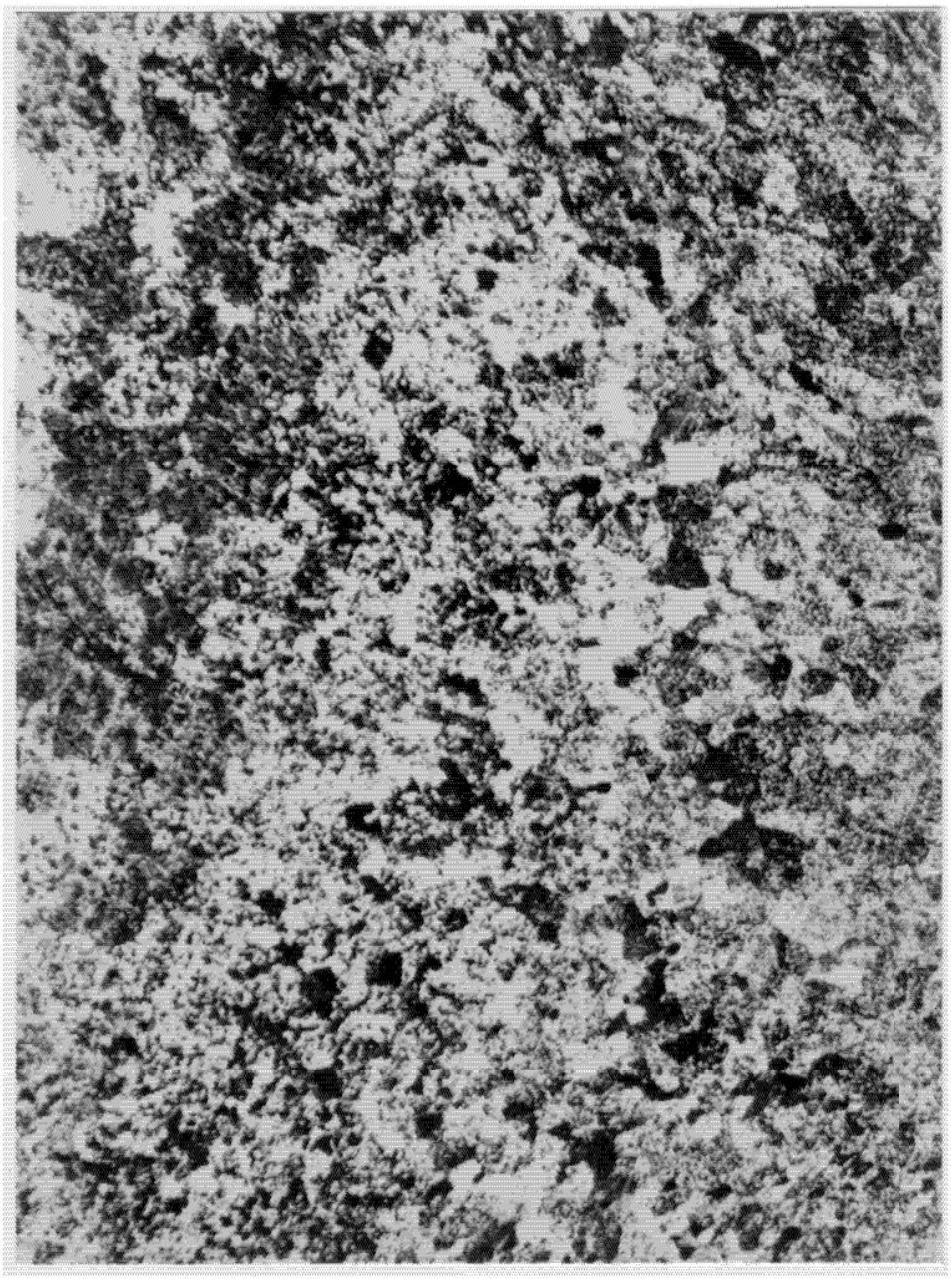


FIGURE 6 - LEVEL 60 TITANIUM BILLET MACROSTRUCTURE AT 1X MAGNIFICATION

FIGURE 7 - LEVEL 70 TITANIUM BILLET MACROSTRUCTURE AT 1X MAGNIFICATION

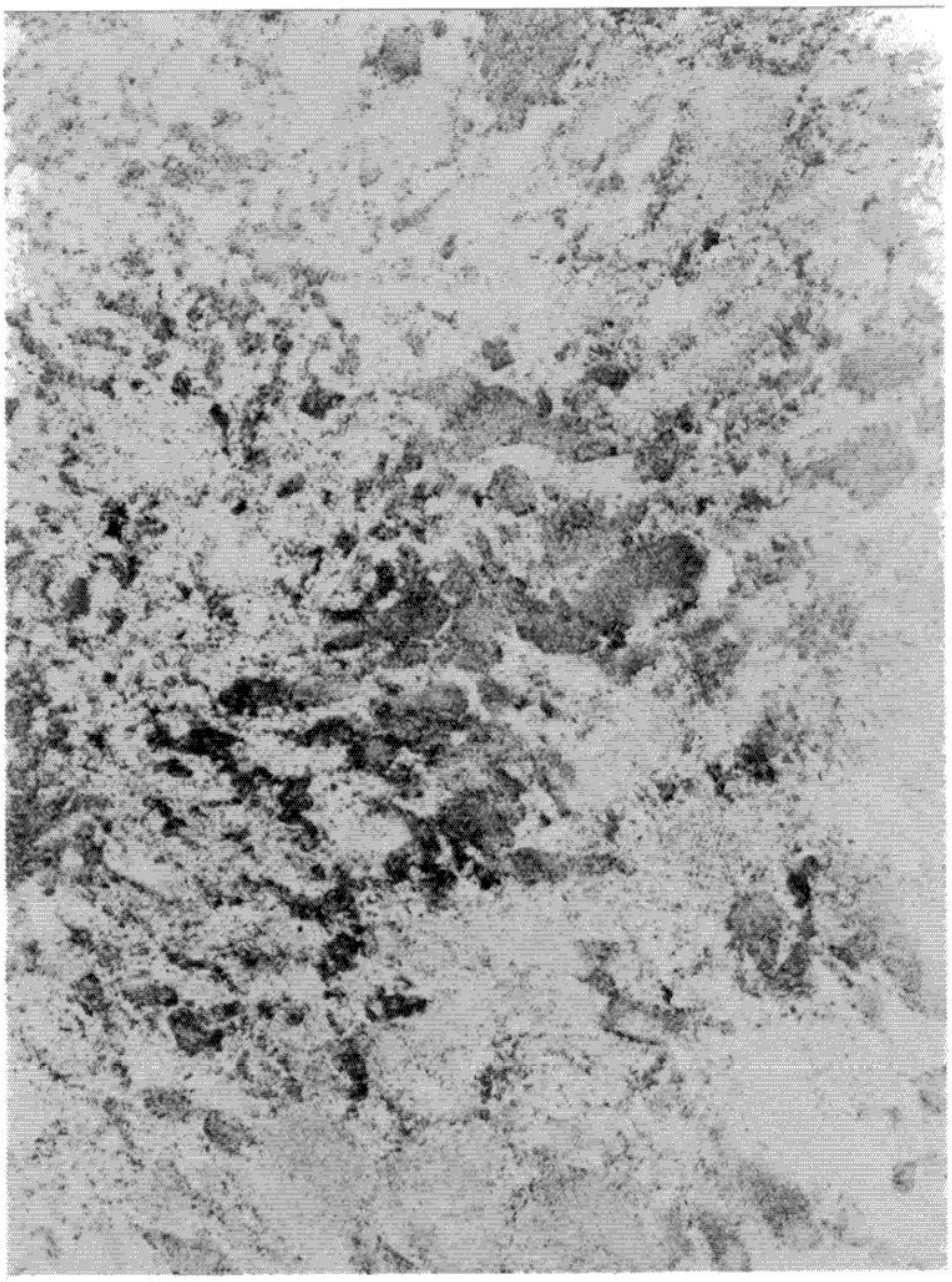


FIGURE 8 - LEVEL 80 TITANIUM BILLET MACROSTRUCTURE AT 1X MAGNIFICATION

FIGURE 9 - LEVEL 90 TITANIUM BILLET MACROSTRUCTURE AT 1X MAGNIFICATION

FIGURE 10 - LEVEL 100 TITANIUM BILLET MACROSTRUCTURE AT 1X MAGNIFICATION

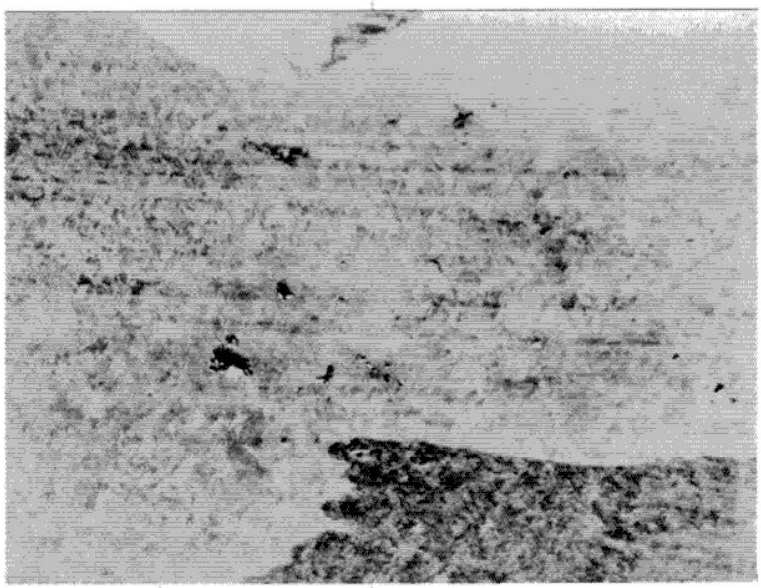


FIGURE 11 - UNACCEPTABLE SECONDARY PIPE (TYPICAL TYPES OF MACROSTRUCTURAL DEFECTS)

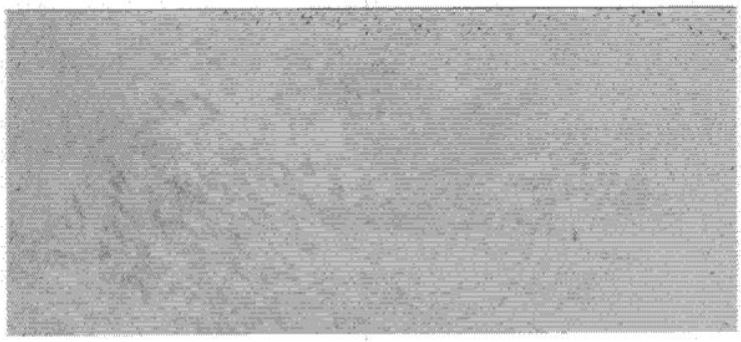


FIGURE 12 - UNACCEPTABLE POROSITY (TYPICAL TYPES OF MACROSTRUCTURAL DEFECTS)

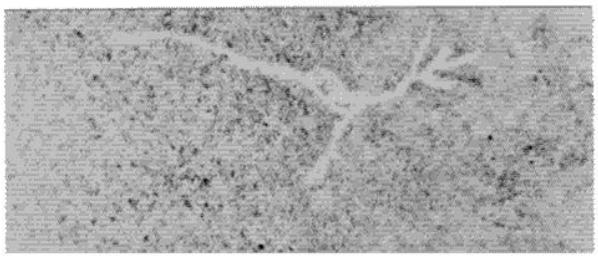


FIGURE 13 - CONDITIONALLY UNACCEPTABLE ALPHA SEGREGATION
(FINAL ACCEPTANCE BASED UPON ACCEPTABLE MICROSTRUCTURE)
TYPICAL TYPES OF MACROSTRUCTURAL DEFECTS

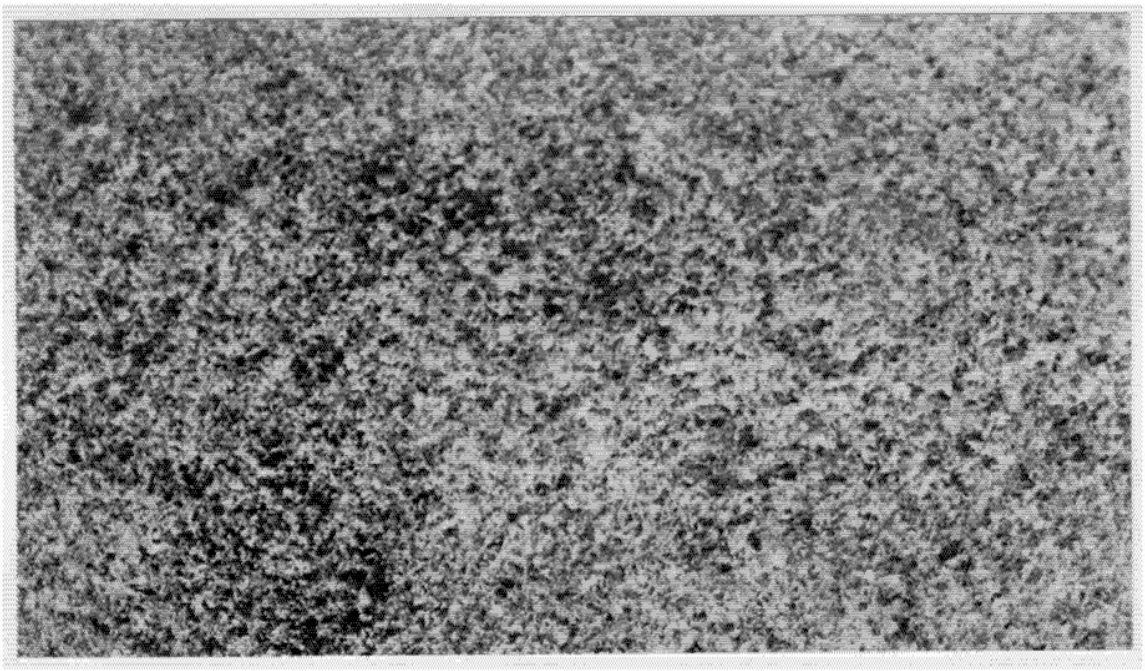


FIGURE 14 - ACCEPTABLE, FINE MACRO-GRAIN, UNIFORM MACROSTRUCTURE
MACROSTRUCTURE ACCEPTANCE STANDARDS FOR FORGINGS
AT 1X MAGNIFICATION

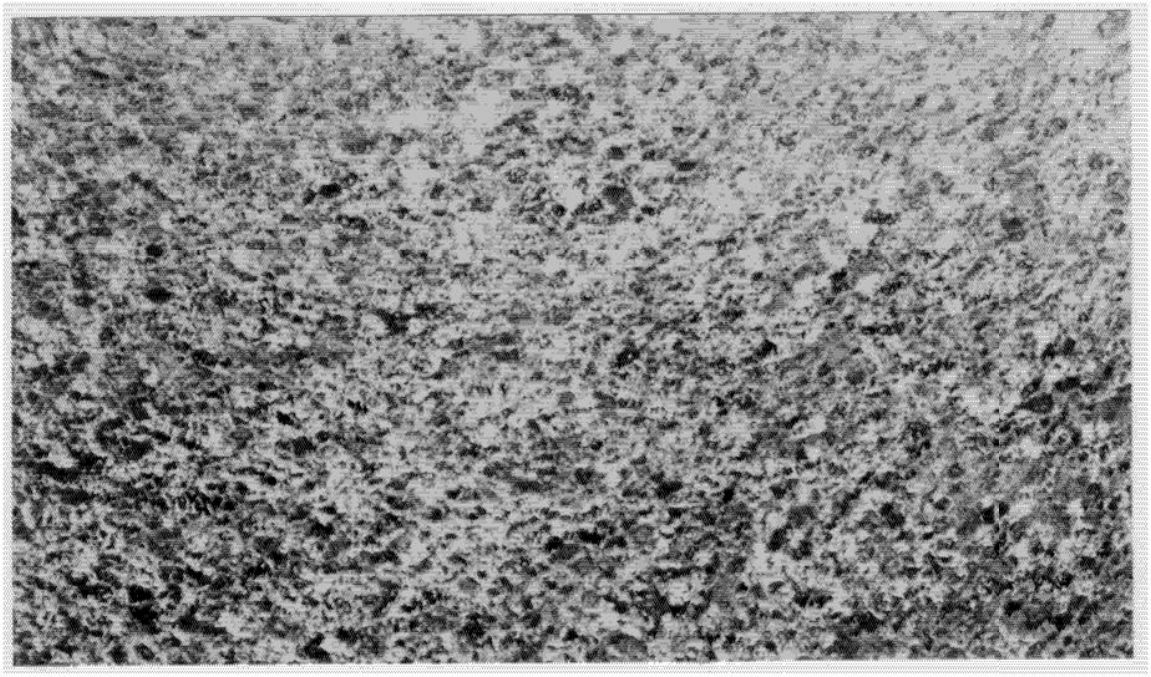


FIGURE 15 - ACCEPTABLE, MEDIUM MACRO-GRAIN, UNIFORM MACROSTRUCTURE
MACROSTRUCTURE ACCEPTANCE STANDARDS FOR
FORGINGS AT 1X MAGNIFICATION

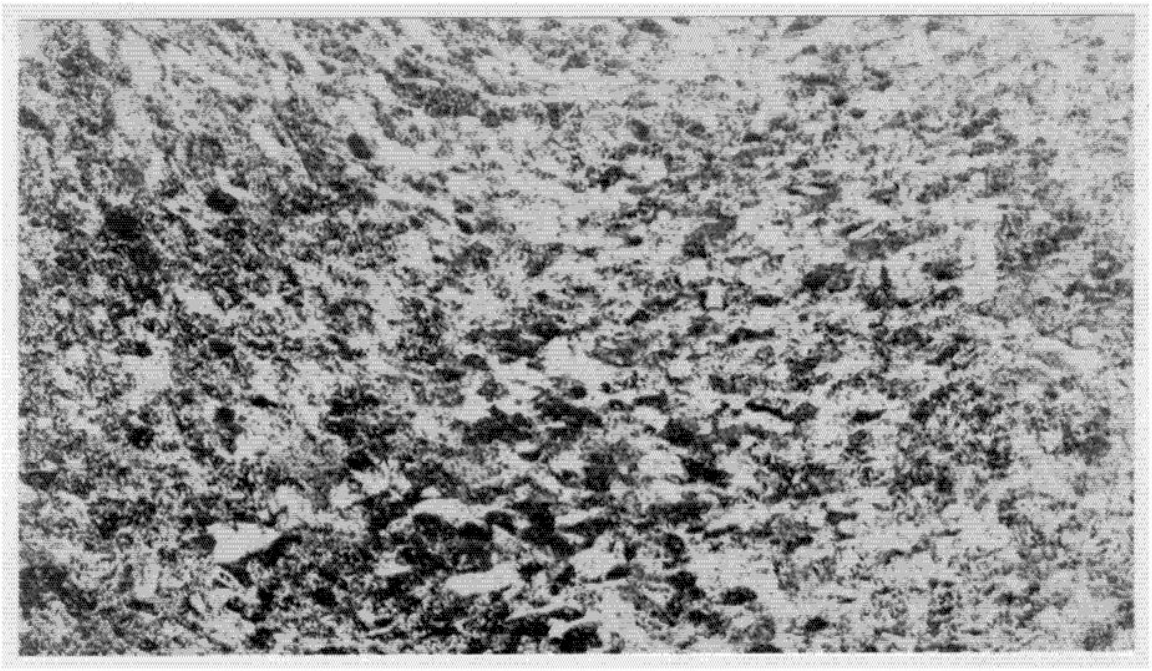


FIGURE 16 - UNACCEPTABLE COARSE MACROSTRUCTURE FOR SECTION SIZES UNDER 5 INCHES (127 MM)
MACROSTRUCTURE ACCEPTANCE STANDARDS FOR
FORGINGS AT 1X MAGNIFICATION

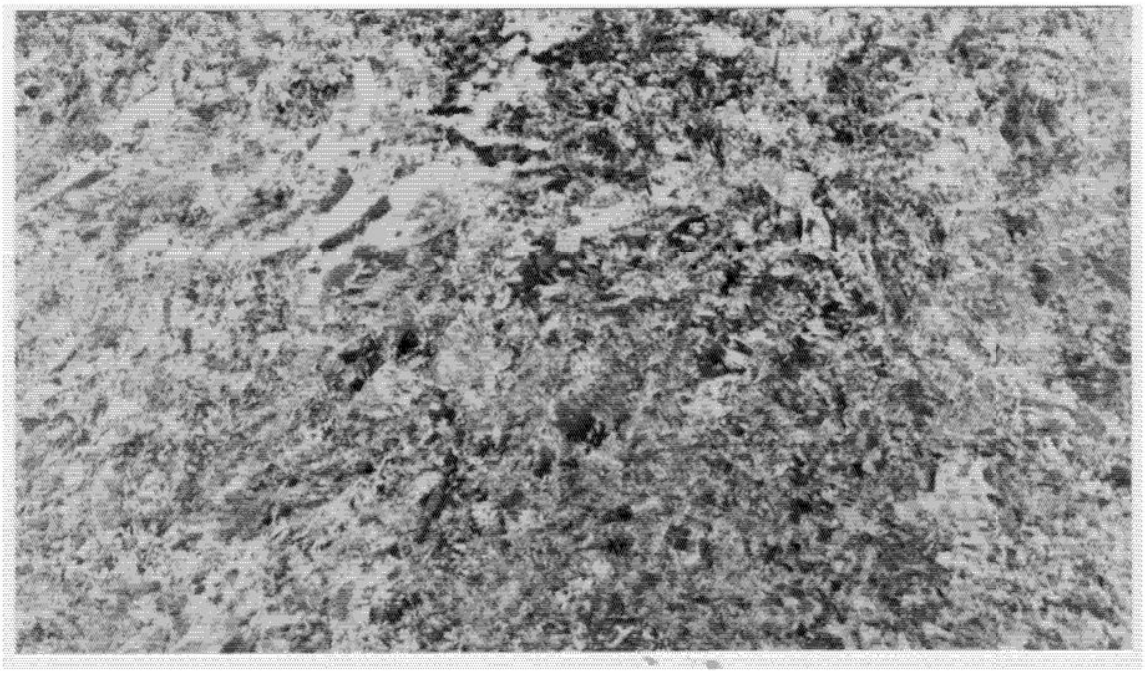


FIGURE 17 - UNACCEPTABLE COARSE MACROSTRUCTURE FOR SECTION SIZES
5 TO 9 INCHES (127 TO 229 MM), EXCLUSIVE
MACROSTRUCTURE ACCEPTANCE STANDARDS FOR
FORGINGS AT 1X MAGNIFICATION

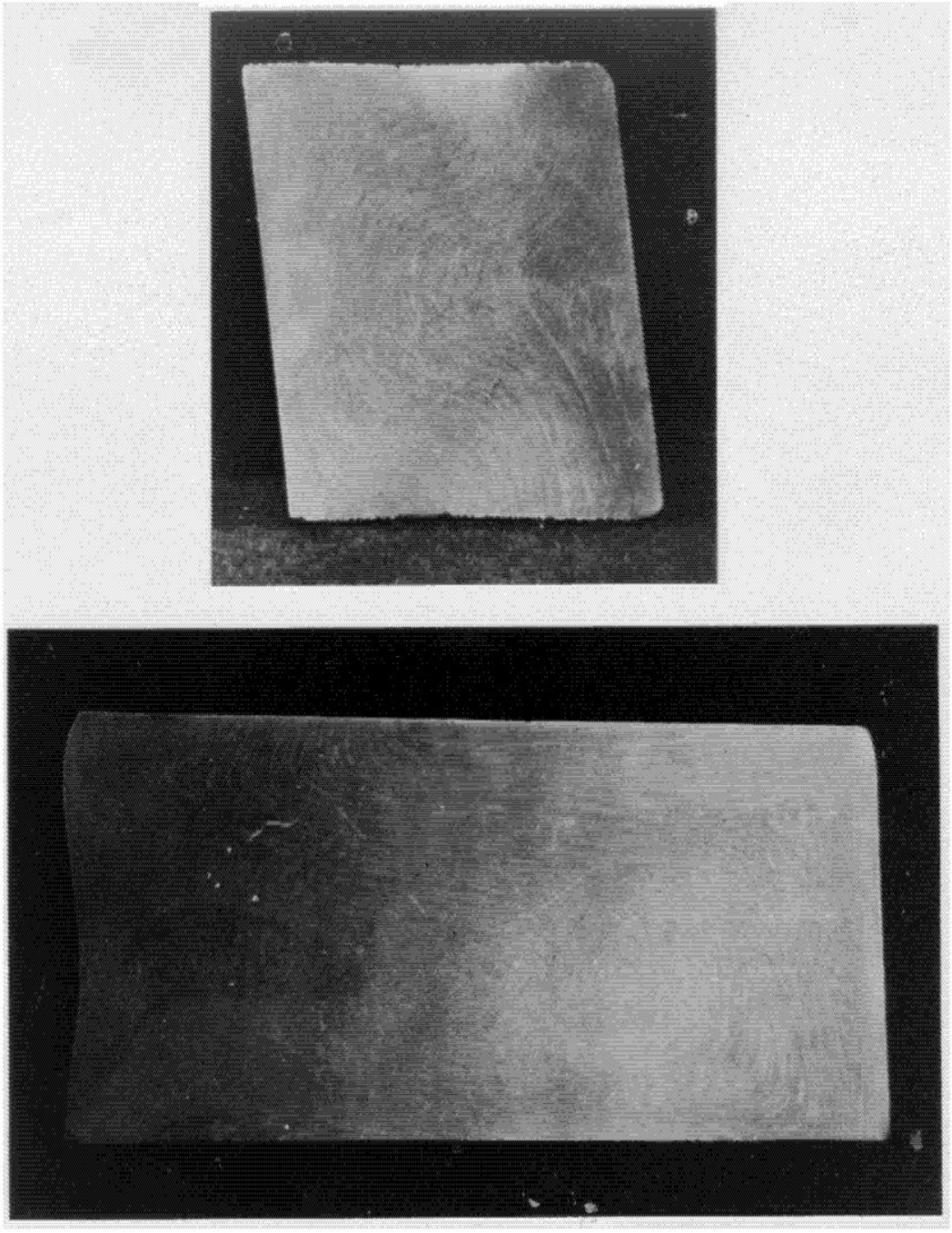


FIGURE 18 - EXAMPLES OF MACROSTRUCTURE WHERE GRAIN SIZE IS OBSCURED BY FLOW LINES
1X MAGNIFICATION

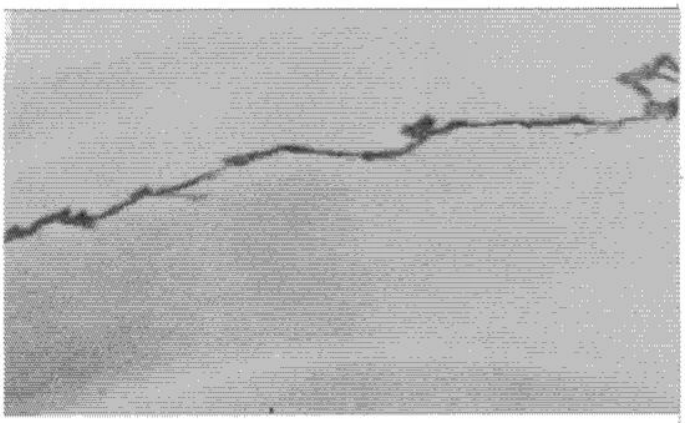


Illustration of Alpha Segregation

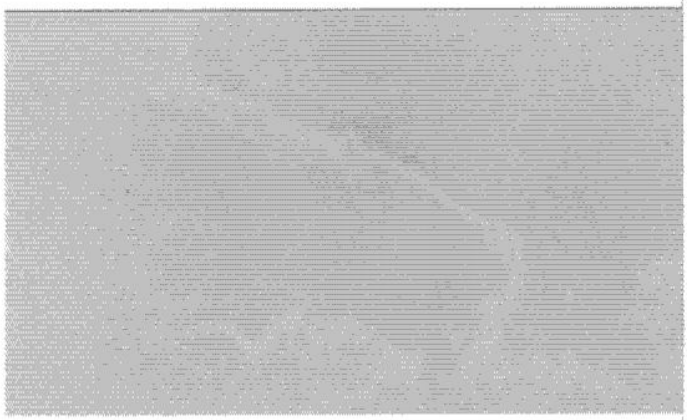


Illustration of Beta Segregation

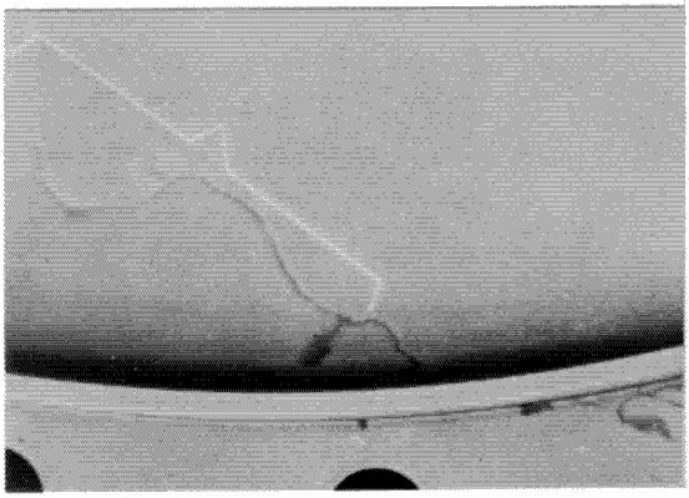
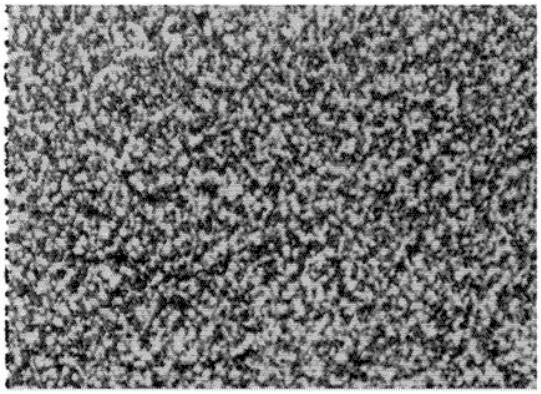
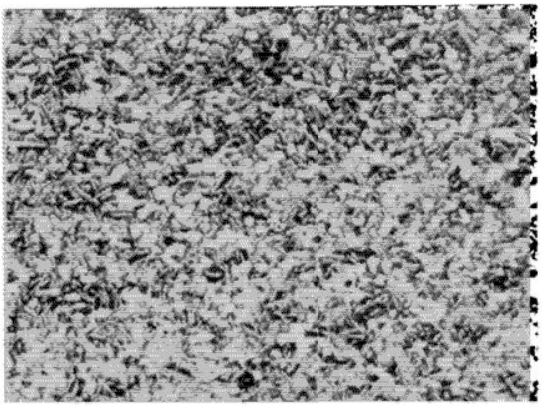


Illustration of Beta Segregation Adjacent to Aluminum-Stabilized Alpha Segregation (Bracket)

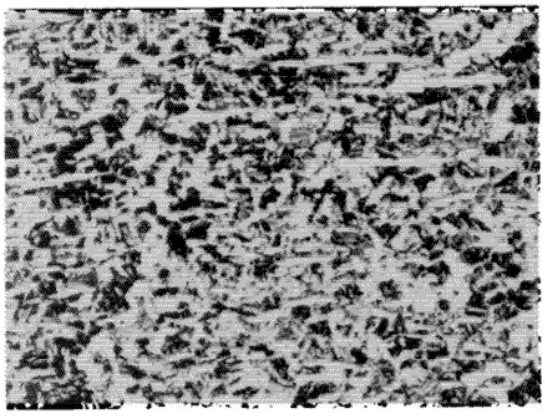
FIGURE 19 - AREAS OF SEGREGATION REVEALED BY ETCH-ANODIZE INSPECTION PROCEDURE (ACCEPTANCE BASED UPON ACCEPTABLE MICROSTRUCTURE)



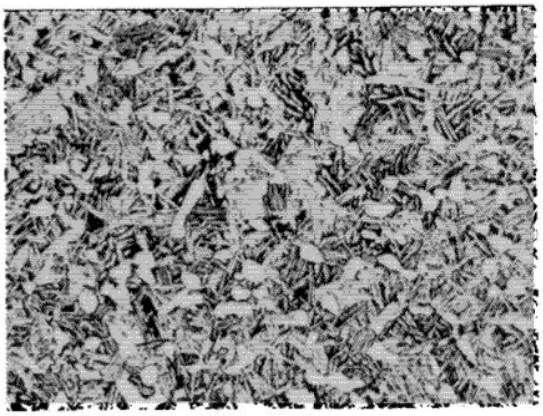
(a) Fine Primary Alpha in Transformed Beta Matrix



(b) Medium Equiaxed Primary Alpha in Transformed Beta Matrix



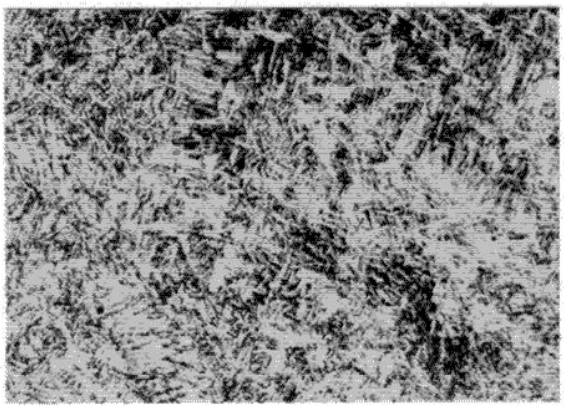
(c) Elongated Primary Alpha in Transformed Beta Matrix



(d) Medium Equiaxed Primary Alpha in Transformed Beta Matrix

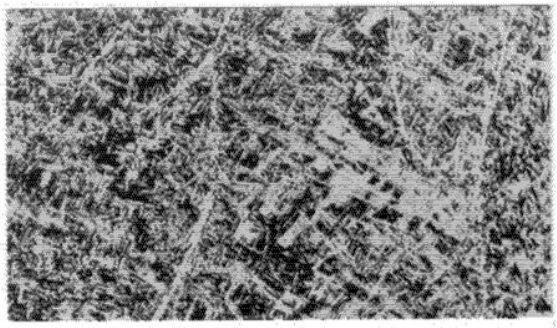
FIGURE 20 - EXAMPLES OF MICROSTRUCTURE AT 100X MAGNIFICATION

(a) Deformed Beta Grains Not Outlined by Primary Alpha

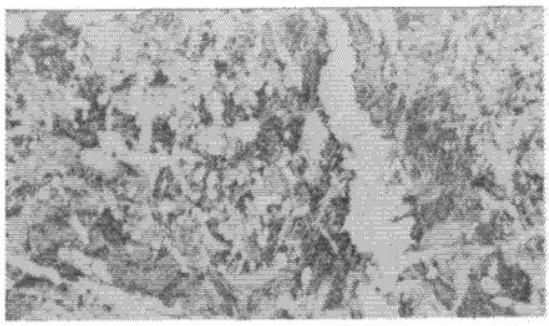


(b) Undeformed Beta Grains Not Outlined by Primary Alpha

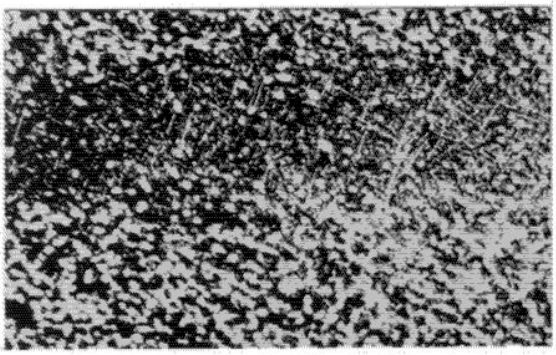
FIGURE 21 - EXAMPLES OF MICROSTRUCTURE AT 100X MAGNIFICATION



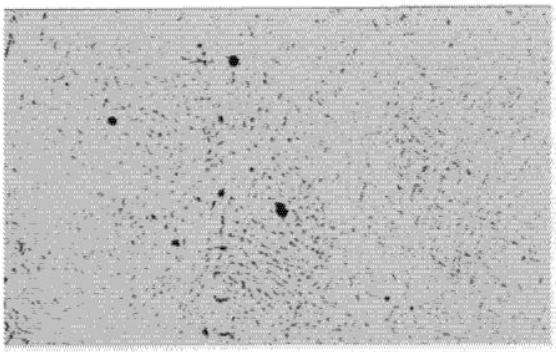
(a) Undeformed Beta Grains Outlined by Primary Alpha at 100X



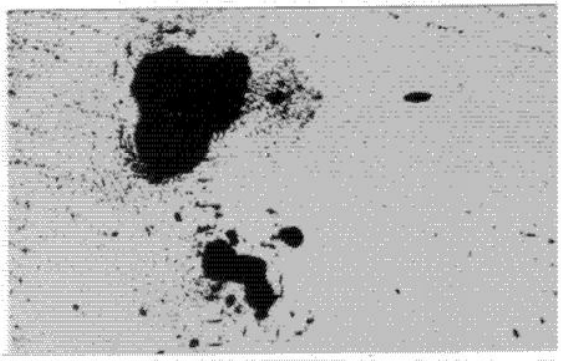
(b) Blocky Primary Alpha and Alpha Stringers at 100X



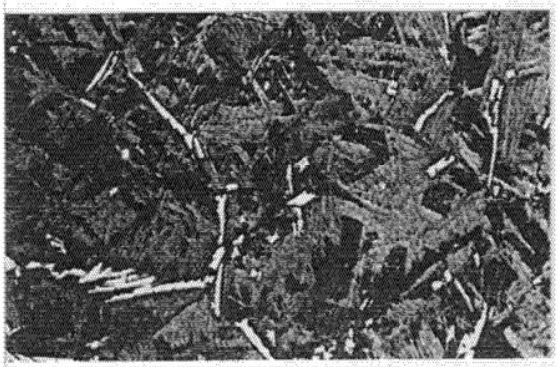
(c) Alpha Lean at 100X



(d) Alpha Type I Segregation Surrounding Small Voids at 35X



(e) Alpha Type I Segregation Surrounding Large Voids at 35X



(f) Typical Microstructure of Overheated Material at 100X

FIGURE 22 - EXAMPLES OF MICROSTRUCTURE