

SUPERCONDUCTING
SUPER
COLLIDER

MATERIAL SPECIFICATION

NO. SSC-MAG-M-400

TITLE: NIOBIUM TITANIUM ALLOY
BARS AND RODS

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REVISION RECORD

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1. Scope:

This specification establishes the requirements for niobium alloy bar and rod containing 45 - 55 wt% titanium for use in manufacturing wire for superconducting magnets.

1.1 Definitions

Lot - A lot is defined as all material of a single size, process and casting, heat treated in a single charge in a batch-type furnace.

2. Applicable Documents

The following documents of the issue in effect on the date of invitation for bids form a part of this specification to the extent specified herein.

2.1 Government Documents

2.1.1 Military Specification - MIL-I-6866; Liquid Penetrant Inspection

2.1.2 AEC-Reactor Development Technology (RDT) Standard - RDT F2-4T (December, 1974); Quality Verification Program Requirements.

2.1.3 National Bureau of Standards (NBS) - NBS Handbook 91; Experimental Statistics.

2.2 Industry and Society Documents

2.2.1 American National Standards Institute (ANSI) - ANSI B46.1; Surface Texture.

2.2.2 American Society for testing and Materials (ASTM)
- ASTM A388; Ultrasonic Testing and Inspection of Heavy Steel Forgings.
- ASTM E8; Tension Testing of Metallic Materials
- ASTM E29; Recommended Practices for Indicating Which Places of Figures are to be Considered Significant in Specified Limiting Values.
- ASTM E92; Test for Vickers Hardness of Metallic Materials.
- ASTM E112; Standard Methods for Estimating the Average Grain Size of Metals.

2.3 Conflicts - Where any of the above standards or specifications conflict with the requirements of the purchase order or this specification, such conflict shall be brought to the attention of the buyer.

3. Requirements

3.1 Material Properties - For purposes of determining conformance with these specifications, all specified limits in this specification are absolute limits, as defined in ASTM Recommended Practice E29.

3.1.1 Shape

3.1.1.1 Size - Final dimensions will be specified by purchase order.

3.1.1.2 Tolerances - The tolerances on the finished round product shall be as follows:

<u>Nominal Diameter, Inch</u>	<u>Permissible Variations from Nominal Diameter, Inch</u>	
	<u>Plus</u>	<u>Minus</u>
1/8 to 3/8, exclusive	.002	.002
3/8 to 1/2, exclusive	.004	.004
1/2 and greater	.006	.006

The finished product shall not be out-of-round by more than one-half the total permissible variations in diameter specified above. Permissible deviations from straightness of finished products shall be .045 inch per foot of length. Straightness shall be determined on a calibrated flatness table using standard techniques. No kinks are allowed.

3.1.2 Chemical Composition

3.1.2.1 Melt - The chemical composition shall be as follows:

Ti	45, 46.5, 48, 55 wt% ±1.5 wt%*
O	1000 ppm maximum
H	35 ppm maximum
C	200 ppm maximum
Fe	200 ppm maximum
Ta	1000 or 2500 ppm maximum*
N	150 ppm maximum
Ni	100 ppm maximum
Si	100 ppm maximum
Cu	100 ppm maximum
Al	100 ppm maximum
Cr	60 ppm maximum
Nb	Balance

*As specified by purchase order.

Niobium or Titanium may be analysed, with the other elements reported as balance by difference.

3.1.2.2 Finished Product - Chemical analysis of the finished vacuum annealed product shall be performed for the interstitial elements and shall conform to the following limits:

O	1000 ppm maximum
H	20 ppm maximum
C	200 ppm maximum
N	150 ppm maximum

3.1.2.3 Analytical Chemistry Procedures - The procedures for analysing to the chemistry requirements of this specification shall be in accordance with standards considered industrially acceptable for the specified alloys and shall be submitted to the buyer for information.

3.1.3 Mechanical Properties

3.1.3.1 Tensile Properties - The tensile properties for each lot shall be provided to the buyer for information, and shall include the ultimate tensile strength, the yield strength, percent elongation, and the percent reduction in area. Tensile testing shall be in accordance with the applicable provisions of ASTM E8.

3.1.3.2 Hardness - The average recrystallized hardness for each lot shall be less than 170 DPH. Hardness testing shall be in accordance with applicable provisions of ASTM E92, with the magnitude of the test load stated in the test report to the buyer.

3.1.4 Surface Requirements

3.1.4.1 Surface Conditions - The finished materials shall be free from visually detectable cracks, seams, slivers, blisters, laps, gouges, and other injurious imperfections, and from discontinuities unacceptable to the specified nondestructive examination and tolerance requirements.

3.1.4.2 Surface Texture - The surface texture shall be 125 micro-inch finish (arithmetical average) or better for specified finished product. In process (or intermediate) material may be supplied in accordance with standard supplier practices. Surface texture measurements shall be in accordance with ANSI B46.1.

3.1.5 Internal Structure

3.1.5.1 Inclusions - the finished product shall be free of inclusions as follows:

<u>Finished Product Size</u>	<u>Inclusion Size Limit</u>
5/8 inch diameter or less	No inclusions in excess of 0.013 inch (equivalent diameter) as determined by 100% ultrasonic inspection.
Greater than 5/8 inch diameter	No inclusions in excess of 3% of the product diameter or 0.032 inch (equivalent diameter), whichever is smaller.

3.1.5.2 Grain Size - The grain size of the finished product shall be as follows:

<u>Finished Product Size</u>	<u>Grain Size</u>
1/2 inch diameter or less	No 6 or finer as determined using the applicable provisions of ASTM E112.
Greater than 1/2 inch diameter	Specified by purchase order

3.1.5.3 Defects - Defects such as cracks, laminations, and other ruptures in excess of those permitted by ultrasonic examination acceptance criteria of paragraph 4.5.1.1 shall be cause for rejection.

3.2 Manufacture

3.2.1 Melting - The melting process shall be a process that has been established by the supplier for melting niobium alloy containing the required titanium for use in manufacturing wire for superconducting magnets.

3.2.2 Working - Each ingot shall be reduced during manufacturing by a process that has been established by the supplier for working niobium alloy containing the required titanium for use in manufacturing wire for superconducting magnets.

3.2.3 Heat Treatment - Heat treatment shall be accomplished in a manner that will preclude contamination causing a violation of the chemistry requirements, and that will ensure each item in the lot being heat treated has essentially the same heat treated properties.

3.2.4 Fabrication

- a. Manufacturing shall be in accordance with processes established and shall result in a minimum of 75% reduction from ingot to billet.
- b. Annealing specifications will be specified by the superconductor manufacturers. This will be supplied with the final dimensional requirements.
- c. After billet forming, material shall be cold reduced by further work, a minimum of 50%.

3.2.5 Cleanliness

- 3.2.5.1 In Process - Precautions shall be taken during manufacture to assure removal of substances that might be deleterious to use of the finished product for the intended application. Cleaning shall be performed subsequent to performance of all nondestructive examinations.
- 3.2.5.2 Finished Product - Materials shall be clean to the extent that no contamination is visible to the unaided eye, corrected for 20/20 vision, when viewed under an illumination of at least 100 foot-candles on the surface being inspected.
- 3.2.6 Manufacturing Plan - A manufacturing plan, except for proprietary processes, shall be established by the seller, defined by flow chart, diagram, or narrative; and shall be available to the buyer for information upon request.

4. Quality Assurance Provision

- 4.1 Quality Assurance Program Requirements - The seller shall plan, establish, implement and maintain a documented quality assurance program that fulfills all requirements of RDT F204T, and any additional quality assurance requirements of the contract or purchase order.
- 4.2 Quality Verification Plan - The Quality Verification Plan (QVP) provided by RDT F2-4T, Section 7b, shall be established by the seller and submitted to the purchaser for approval, 30 days prior to use. The QVP shall be considered acceptable unless disapproved in writing by the buyer.

- 4.3 Responsibility - In accordance with RDT F2-4T, Section 2, the seller shall be responsible for the performance of all tests and inspections required prior to submission to the buyer of any of the products for acceptance. The performance of such tests and inspections does not limit the right of the buyer to conduct tests and inspections to verify conformance to all requirements of this specification. Such buyer testing and inspection shall be confined to the scope of requirements defined in this specification or approved variations thereof.
- 4.4 Certifications - The seller's certified test reports shall be furnished to the buyer at the time the material is readied for storage or shipment. These reports shall include the actual results of all required analyses and tests; a report of all nondestructive examinations performed and all special heat treatments performed. The supplier shall certify that all requirements of this specification have been met. All test reports shall be identified to permit correlation with the material supplied.
- 4.5 Inspection and Test
- 4.5.1 Nondestructive Testing Requirements - All finished products shall be examined nondestructively in accordance with the following requirements and shall comply with the specified acceptance criteria.
- 4.5.1.1 Ultrasonic Examination - Each finished bar or rod shall be examined during processing as follows:
- a. All bar and rods 1/2 inch diameter or larger shall be examined with ultrasonic test equipment calibrated with a flat bottom hole standard. Discontinuities producing indications with an amplitude equal to or greater than that produced in the reference hole shall be cause for rejection.
 - b. Longitudinal wave examination: Longitudinal wave examination shall be performed in accordance with the applicable requirements of ASTM A388.

In addition, all bars and rods shall be examined with ultrasonic test equipment calibrated with a flat bottom hole standard in accordance with the provision of Table I. For bars one inch diameter to two inch diameter, the level 0 applies. For bars and rods less than one inch diameter, the flat bottom hole in the standard shall be .013 inch. Discontinuities producing indications with an amplitude equal to or greater than that produced in the reference hole shall be cause for rejection.

Table I

Flat Bottom Hole Size for Longitudinal Wave Calibration

<u>Section Thickness</u> (Inches)	<u>Hole Diameters for Each Examination Level and Section Thickness (Notes 1&2) (Inches)</u>					
1 to 2 inclusive	L-0	L-1	L-2	L-3	L-4	L-5
Over 2 to 8 inclusive	1/16	1/8	3/16	1/4	3/8	1/2
Over 8 to 24	3/16	1/4	3/8	1/2	1/2	1/2
Over 24	1/4	3/8	1/2	1/2	1/2	1/2

Note 1: The examination level L-0, L-1, etc., shall be specified in the referencing standard or other procurement documents.

Note 2: Depth of holes shall be as follows: (a) 25% of the material thickness for 2 inch thickness or less, (b) the greater of 1/2 inch or 10% of the material thickness for material thickness greater than 2 inches.

Note 3: Section thickness is defined as the thickness of the material in the direction of propagation of the ultrasonic wave.

- c. Circumferential angle-beam examination: Each finished bar or rod shall be examined by circumferential angle-beam examination. This examination shall be performed by relating the angle-beam ultrasonic inspection procedures described in ASTM A388 to solid bars or rods. For bars and rods, the ultrasonic equipment shall be calibrated using a standard containing the following diameter hole drilled to a depth of 1/2 inch into the end of the standard parallel to the axis and a distance one-fourth of the diameter from the axis:

<u>Rod Diameter, Inch</u>	<u>Hole Diameter in Standard, Inch</u>
5/8 and less	0.013
greater than 5/8 to 2	3% of product diameter or 0.32 inch, whichever is smaller.

The ultrasonic equipment shall also be calibrated for all bars using standards containing a notch which has the following depth and is no longer than 1/4 inch cut parallel to the longitudinal axis:

<u>Rod Diameter, Inch</u>	<u>Notch Depth, Inch</u>
1/2 to 2	1% of produce diameter

Ultrasonic examination can be performed on finished product less than 1/2 inch diameter.

Discontinuities producing indications with an amplitude equal to or greater than that produced in the reference or notch shall be cause for rejection.

- 4.5.1.2 Liquid Penetrant Examination - Liquid penetrant examination of the surfaces of all finished bars or rods shall be performed in accordance with Military Specification MIL-I-6866. The following indications are unacceptable:
- a. Any cracks.
 - b. Any linear indications.
 - c. Rounded indications with dimensions exceeding 1/32 inch (rounded indications separated by 1/16 inch or less edge to edge shall be evaluated as a single indication).
 - d. Rounded indications separated by less than the larger of 4T or 1/2 inch.
 - e. Ten or more indications in any size square inches of surface with the major dimension of this area not to exceed six inches with the area taken in the most unfavorable locations relative to the indications being evaluated.
- 4.5.1.3 Procedures - All nondestructive examination procedures shall be established by the seller and submitted to the buyer for approval, 30 days prior to use. These procedures shall be considered acceptable unless disapproved in writing by the buyer.
- 4.5.2 Destructive Testing - Destructive sampling plans to verify the applicable requirements of this specification shall be submitted by the supplier to the purchaser for approval, 30 days prior to use, and shall be considered acceptable unless disapproved in writing by the buyer.
- 4.5.2.1 Chemical Composition - The chemical composition for each lot shall be established by representative sampling.
- 4.5.2.2 Tensile Properties - A minimum of one tension test shall be made for each lot of finished product.

- 4.5.2.3 Hardness - The hardness requirements of this specification shall be demonstrated by a sampling plan which verifies the requirements to a 90-90 confidence level in accordance with the provisions of NBS Handbook 91, Experimental Statistics. Previously submitted and experimentally verified plans are acceptable.
- 4.5.2.4 Grain Size - The grain size requirements of this specification shall be established by a sampling plan which verifies the requirements to a 90-90 confidence level in accordance with the provisions of the NBS Handbook 91, Experimental Statistics. Previously submitted and experimentally verified plans are acceptable.

4.6 Documentation

The seller shall submit the following documentation in accordance with this specification:

- 4.6.1 Analytical Chemistry Procedure (paragraph 3.1.2.3)
- 4.6.2 Tensile Properties (paragraph 3.1.3.1)
- 4.6.3 Hardness Test Report (paragraph 3.1.3.2)
- 4.6.4 Quality Verification Plan (paragraph 4.2)
- 4.6.5 Certified Test Reports (paragraph 4.4)
- 4.6.6 Nondestructive Examination Procedures (paragraph 4.5.1.3)
- 4.6.7 Destructive Testing Plans (paragraph 4.5.2)

5. Preparation for Storage or Delivery

- 5.1 Packaging - In preparation for either storage or delivery, the finished bars or rods shall be packaged in such a manner as to maintain cleanliness and prevent damage during ordinary handling during storage or shipment. Bars or rods shall be segregated as to lot number, and each package shall include the following information in identification: Name of material; heat or casting number; lot number; and size.
- 5.2 Marking for Shipment - Each bundle or packing box shall be legibly and conspicuously marked with the information furnished by the buyer.