Relativistic Heavy Ion Collider
Magnet Division Specification

Proc. No.: RHIC-MAG-M-4000

Issue Date: 4/18/90

Rev. No.: B

Rev. Date: 7/12/91

Class: Ancillary Specifications
Title: Niobium-Titanium Alloy Bars and Rods

- Cognizant Engineer: Signature on File
- Approved by: Signature on File
- BNL Q. A. Category: Signature on File
  Major

REVISION RECORD

Rev. No.	Date	Page	Subject	Approved	QA
A	6/27/91	Numerous	Miscellaneous Changes. Production RFQ Release.	On File	On File
B	7/12/91	1,2,5,10	Lot Definition; Straightness; Grain Size	On File	On File

1. Scope:

This specification establishes the requirements for the finished product of niobium alloy bar and rod containing 47 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 and processed with the same parameters.

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:

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

* MIL-I-45208; Inspection System Requirements

2.2 Industry and Society Documents:

* ANSI B46-1; Surface Texture

* ASTM E1001-84; Standard Practice for Detection and Evaluation of Discontinuities by the Immersed Pulse - Echo Ultrasonic Method Using Longitudinal Waves

* 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.

* ASTM E165 - Standard Practice for Penetrant Inspection Method

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:

	Permissible Variations from Nominal Diameter, Inch	
Nominal Diameter, Inch	Plus	Minus
1/8 to 3/8, exclusive	0.002	0.002
3/8 to 1/2, exclusive	0.004	0.004
1/2 to 2	0.006	0.006
2 to 8	0.015	0.015

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 bar stock shall be 0.045 inch per foot of length.

3.1.2 Chemical Composition

3.1.2.1 Melt: The chemical composition shall be as follows:

Ti	47 wt%, ± 1 wt%	
Nb	53 wt%, ± 1 wt%	
O	1000	ppm maximum
H	35	ppm maximum
C	200	ppm maximum
Fe	200	ppm maximum

Ta	2500	ppm maximum (Grade 2)
N	150	ppm maximum
Ni	100	ppm maximum
Si	100	ppm maximum
Cu	100	ppm maximum
Al	100	ppm maximum
Cr	60	ppm maximum

Niobium or Titanium may be analyzed, with the other element reported as balance by difference.

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

O	1000	ppm maximum
H	20	ppm maximum (vacuum annealed);
	35	ppm (air annealed, water quenched)
C	200	ppm maximum
N	150	ppm maximum

3.1.2.3 Analytical Chemistry Procedures: The procedures for analyzing 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.

3.1.2.4 Grade Certification:Product shall be high homogeneity grade or BNL-approved equivalent. High homogeneity grade material shall be analyzed by means of a high resolution radiograph taken from a section of the ingot that has been processed to a 5-8 in. diameter. High homogeneity shall be verified by comparison of the radiograph with a series of standard radiographs which have been mutually agreed upon by the Buyer and the vendor to define high homogeneity. A photograph of the product radiograph shall be supplied as part of the material certification documentation (see para. 4.4).

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 and reported to the Buyer.

3.1.3.2 Hardness Properties: The average hardness for each annealed 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 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, and from discontinuities unacceptable to the specified nondestructive examination and tolerance requirements. Any defects of this nature in excess of those permitted by ultrasonic examination acceptance criteria of paragraph 4.5.1.1 shall be cause for rejection.

3.1.4.2 Surface Texture: The surface texture shall be 125 micro-inch (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. The surface texture on the ends of the specified finished product shall be 500 microinch (arithmetical average) or better.

3.1.5 Internal Structure

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

Finished Product Size	Inclusion Size Limit
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	No inclusions in excess of 3% but less than 2 inch diameter of the product diameter as determined by 100% ultrasonic inspection.
2 inch to 4 inch diameter	No inclusions in excess of 0.062 inch (equivalent diameter) as determined by 100% ultrasonic inspection.

Greater than 4 inch diameter	No inclusions greater than 0.096 inch (equivalent diameter) as determined by 100% ultrasonic inspection.

3.1.5.2 Grain Size: The grain size of the finished product shall be determined at two locations 90^0 apart using the applicable provisions of ASTM E112. The grain size shall be determined in the outer 25% of the radial dimension and shall be as follows:

Nominal Diameter, Inch	Maximum Grain Size
0.50 to 2.0	No. 4.5 or finer
2.1 to 4.5	No. 2.5 or finer
4.6 to 5.5	No. 1.5 or finer
greater than 5.5	No. 1.0 or finer

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 of paragraph 3.1.2, and that will ensure each item of the lot has nominally 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 Buyer. This will be supplied by the Buyer with the final dimensional requirements.

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 Products: 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. The presence of contamination (i.e., grease, oil, dirt, lubricants) is cause for rejection.

3.2.6 Manufacturing Plan

A manufacturing plan, except for proprietary processes, shall be established by the vendor, defined by flow chart, diagram, or narrative; and shall be available to the Buyer for information upon request.

3.2.7 Control of Manufacturing Machines and Methods

The machine and equipment used to process all material made to this specification shall be identified for the Buyer and documented. No changes to machines methods or processes shall be permitted without prior written approval of the Buyer.

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 MIL-I-45208, and any additional quality assurance requirements of the contract or purchase order.

4.2 Quality Assurance Plan

A Quality Assurance Plan shall be established by the vendor and submitted to the Buyer for approval, 30 days prior to use. The Plan shall be considered acceptable unless disapproved in writing by the Buyer.

4.3 Responsibility

The vendor shall be responsible for the performance of all tests and inspections, at his facility or an approved outside facility, 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 vendor 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 bars 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 shall be performed in accordance with the applicable requirements of ASTM E1001-84 or Buyer-approved procedure.

c) Each finished rod or bar shall be examined using the angle beam

technique, with the sound beam directed circumferentially. A notch parallel to the longitudinal axis of the rod or bar with a depth no greater than 0.125 inch shall be used as the reference notch. Any indication of an amplitude equal to or greater than the notch signal amplitude shall be rejected.

d) Additionally, the reference standard shall contain a hole drilled into the end of the standard parallel to the axis and a distance of 1/4 of the diameter from the axis. This hole shall be drilled 1/2 inch deep, with diameters as follows:

Rod Diameter, Inch	Hole Diameter, Inch
5/8 and less	0.013
Greater than 5/8	3% of product diameter, or 0.32, whichever is smaller.

Any indication produced which has an amplitude greater than the hole signal shall be rejected.

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 ASTM E-165. 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 4 times the piece thickness or 1/2 inch.

4.5.1.3 Procedures: All nondestructive examination procedures shall be established by the vendor 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 vendor to the Buyer 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 of each casting or 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 if the rod diameter is less than 1/2-in.

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% confidence level in accordance with the provisions of NBS Handbook 91, Experimental Statistics.

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% confidence level in accordance with the provisions of the NBS Handbook 91, Experimental Statistics.

4.6 Documentation

The vendor shall submit to the Buyer the following documentation in accordance with this specification:

4.6.1 Analytical Chemistry Procedures (paragraph 3.1.2.3)

4.6.2 Tensile Properties (paragraph 3.1.3.1)

4.6.3 Hardness Properties (paragraph 3.1.3.2)

4.6.4 Quality Assurance Plan (paragraph 4.2)

4.6.5 Certifications (paragraph 4.4)

4.6.6 Nondestructive Examination Procedures (paragraph 4.5.1.3)

4.6.7 Destructive Testing (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, for purchases made directly by BNL, each package shall include the information described in paragraph 5.2.

5.2 Marking for Shipment

If the purchase is made directly by BNL, each bundle or packing box shall be legibly and conspicuously marked with the following information:

"Niobium-Titanium Alloy Bars and Rods"
Specification No. RHIC-MAG-M-4000, Rev. No. B
BNL P.O. Number _____
Name of Material _____
Heat or Casting Number _____
Log Number _____
Size _____
Weight _____
Date of Manufacture _____
Name of Manufacturer _____