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LHC-MAG-M-1010A

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1. Scope:

This specification establishes the requirements for the manufacture and identification of seamless tubing made from stainless steel to be used for the fabrication of LHC magnet beam tubes.

2. Applicable Documents:

The following documents, of the issue in effect on the date of invitation to quote, form a part of this specification to the extent specified herein:

2.1	ASTM A269-88a	Seamless and Welded Austenitic Stainless Steel Tubing for General Service
2.2	ASTM A511-88	Seamless Stainless Steel Mechanical Tubing
2.3	ASTM A450/A450M-88A	General Requirements for Carbon, Ferritic Alloy and Austenitic Alloy Steel Tubes
2.4	ASTM E426-88	Eddy Current Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Products
2.5	ASTM E498-73(1980)	Leak Testing by Mass Spectrometer Leak Detector
2.6	ASTM E112-88	Determining Average Grain Size
2.7	ASTM A342-84(1988)	Standard Test Methods for Permeability of Feebly Magnetic Materials
2.8	ASTM A213/213M-89a	Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes
2.9	RHIC-CR-E-4703-0041	Leak checking specificaiton
3.0	BNL QA-101	Quality Assurance Requirements

3. Requirements:

3.1 Tubing raw material - Raw material used in fabrication of LHC magnet beam tubes shall be 316LN, in accordance with the chemical composition requirements of ASTM A213/A213M. Material shall be inspected and tested by the tubing fabricator before commencing fabrication.

3.1.1 Non-conforming raw material - Material which is found to deviate from the requirements of this specification shall not be offered to the buyer.

3.1.2 Raw material identification - Each lot of raw material shall be identified so as to be traceable to seller inspection, manufacturing and testing records. These records shall be made available to the buyer upon request.

3.2 Beam tube manufacturing requirements - LHC magnet beam tubes shall be fabricated in accordance with the requirements of ASTM A511-88, and shall be seamless.

3.2.1 Tube Drawing - The seamless hollow shall be cut to the appropriate length to provide material suitable for drawing. The hollow shall be subjected to multiple draws, with each draw exceeding 30% permanent strain deformation.

3.2.2 Cleaning - After each drawing operation, and before annealing, the tube shall be thoroughly cleaned using a detergent solution and water rinse to remove all traces of drawing lubricants.

3.2.3 Annealing - The tube material shall be annealed at 1950⁰F and water quenched for rapid cooling after each draw. The duration of the anneal must be such as to reduce delta ferrite content to 0.1% or less

3.2.4 Overdraw and Straightening - The final anneal shall be followed by a final overdraw and roll straightening operation to achieve specified tolerances. The tube shall be cleaned and bright finished after overdraw. After completion of tube fabrication, magnetic permeability tests shall be performed to determine uniformity of permeability.

3.2.5 Length

Tubes shall be cut to final lengths as specified on the applicable engineering drawing. Cutting may be done after final cleaning, but shall not compromise the clean condition of the tube.

3.2.6 Final Cleaning - After all operations of 3.2.4 are completed, the tubes shall be cleaned by the following process:

1. Degrease, using only non-chlorinated solvents, to remove all remaining drawing lubricants. Rinse in cold running tap water for 1 minute.
2. Insert a power brush into the tube and scrub the entire inside surface using a hot (60-65 C) alkaline solution. Continue scrubbing for approximately 5 minutes. In lieu of power brushing, immersion of the tube into a bath of hot, agitated alkaline solution may be performed.
3. Rinse in cold running tap water for 2 minutes. If water forms beads on inside surface, repeat Step 2.
4. Pickle in acid (solution composed of 1 part hydrofluoric acid, 1 part nitric acid, 1 part distilled water) at room temperature for 5-10 minutes.
5. Rinse in hot deionized water for 2 minutes.
6. Dry using oil free hot dry air, nitrogen, or natural convection.
7. Install snug fitting plastic end caps on the O.D. These caps must be easily removable without the use of tools, and should be reusable. Caps must not leave any residue when removed.
8. Mark the tube, as indicated on the applicable engineering drawing, with the part number. The marking shall be performed using electro-chemical etching to avoid distortion of the tube.

3.3 Dimensions and Physical Requirements

3.3.1 Dimensions

Outside Diameter	73.0+/- .38mm [2.875+/- .015 in.]
Wall Thickness	1.96+/- .18mm [.077+/- .007 in.]
O.D./I.D. concentricity	.15mm [.006 in.]
Ovality	within O.D. max. tolerance
Straightness	.8mm per one meter length (4mm total, max) measured with no loading on a flat surface
Surface finish	better than 1.6 μ m[63 μ in] on both inner and outer surfaces.

3.3.2 Magnetic Permeability Requirements

The tubing shall possess axial and circumferential magnetic permeability of less than 1.005 at 300K and less than 1.02 at 4.5K, for 500 Oe magnetizing force.

3.3.3 Other Acceptance Criteria

- 3.3.3.1 Surface Condition - The surfaces of the tube, when finished, shall be smooth and free of scale, lubricants, inclusions, residues of all kinds, dirt, grease, burrs, circumferential or helical scratches greater than .05mm [.002 in.] deep, pits, cracks or surface porosities. Scratches shall be less than 300mm [12 in.] long, and surface pitting shall be less than .05mm [.002 in.] deep and shall not cover more than 0.5% of the tube surface. Pits or other surface imperfections shall be random and not align axially over a distance greater than .5m [20 in.]. "Corkscrew" or "S" shaped tubes shall not be considered acceptable.

4. Quality Assurance Provisions:

By making a shipment of tubes, the supplier automatically certifies that the tubes, and the processes used in manufacture of the tubes, comply with this specification and the requirements of the purchase order. The supplier agrees to retain objective evidence, including records of inspection and test during production, test and final inspection. These records shall be made available to representatives of BNL for review on request.

Unless otherwise specified, responsibility for performance of the listed tests and inspections rests with the supplier.

For all quality assurance and test conditions listed in this specification, a lot of tubes is a maximum of 10 tubes of one part number and from one material heat number.

Sample size - The sample size for each tube lot shall be one tube.

- 4.1 Tubing Acceptance - With the exception of the leak test of 4.1.3, samples of each lot of tubing shall be inspected by the seller and shall be subjected to the inspections and tests listed below. In the event of the failure of a sample, the lot shall be considered as rejected. The supplier may elect, at his option, to subject each tube of the lot to the listed inspections. The seller shall record that accepted tubes were sorted from a rejected lot, and the buyer shall be notified.

- 4.1.1 Hydrostatic Burst Pressure - A hydrostatic burst pressure test shall be performed in accordance with ASTM A450/A450M-88A to determine tube wall pressure integrity. Tube leaks or fractures at hydrostatic pressure less than 11.0MPa [1600 psi] shall be cause for rejection.
- 4.1.2 Ultrasonic and Eddy Current Test - An ultrasonic test shall be performed to detect internal voids or inclusions. Eddy current testing in accordance with ASTM E426-88 shall verify the results of the ultrasonic test. Flaws greater than 10% of nominal wall thickness shall be cause for rejection.
- 4.1.3 Leak Test - A leak test shall be performed in accordance with ASTM E498-73, Method B or C, using a Helium mass spectrometer leak detector. Leak rates in excess of 1×10^{-11} std Atm. cc He/sec., with the tube at 250⁰C, shall be cause for rejection. Tubes shall be clean and dry before being tested. Every tube shall be subjected to this test. (This test to be performed at BNL in accordance with RHIC-CR-E-4703-0041).
- 4.1.4 Grain Size - Grain size shall be measured in accordance with ASTM E112-88. A grain size of 6 or finer is acceptable.
- 4.1.5 Mechanical Strength - Tensile tests shall be performed in accordance with ASTM A511-88,S2. Ultimate strength, yield strength and elongation shall conform to the published data of ASTM A213/213M.
- 4.1.6 Chemical Analysis - Chemical analysis shall be performed on each heat in accordance with the requirements of ASTM A269-88a or A213/213M and a certificate of compliance shall be submitted with each lot of tubing. Analysis shall comply with the published chemical composition for the alloy, per ASTM A213/213M or A269.
- 4.2 Final Inspection - Each tube shall be inspected to determine conformance to the criteria of Section 3.3 above. Test methods are defined in Appendix A.
- 4.3 Quality Data - Each lot of tubes shall be accompanied by a written statement certifying compliance with the requirements of this specification. Complete mechanical property and chemical analysis data shall be included with the certificate of compliance.

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5. Preparation for Delivery:

- 5.1 Tube handling and preparation - Tube lengths shall be handled with structural supports (strongbacks) to preclude bending and surface damage.
- 5.2 Packing - Tubes shall be packed in crates designed to contain not more than 900kg [2000 pounds]. Internal supports shall be provided such that tube center distances are not less than 10cm[3.75 inches], and tubes are supported at intervals not exceeding 1.5m[60 inches].
- 5.3 Packaging - The tube crates shall be weather-proof, and shall be designed so that tubes may be removed from the crate from the top or end. The crates shall be constructed such that outdoor storage shall not result in dirt, water or other contaminants reaching the stored tubes. The ends of the crate shall contain shock absorbing material such that axial shifting of the tubes, in transit or handling, shall not result in damage to the tubes.
- 5.4 Marking and Identification - Each crate shall be identified with the following information:

LHC Magnet Beam Tube (P/N_____Rev____)
Specification LHC-MAG-M-1010
Manufacturer_____
P.O. Number_____
Tube Length_____
No. of Tubes_____
Date of Manufacture_____

APPENDIX A

Beam Tube Test Methods

1. All inspections called out in the statement of work shall be after final cleaning. The cleanliness of the tube shall not be compromised by these tests.
2. Visual Inspection - All tubes shall be examined for obvious damage and imperfections, and for pits, scratches, cracks, dents and foreign matter. Surface finish shall be evaluated by use of a finish comparator.
3. Dimensions
 - 3.1 Straightness - The tube shall be placed on a suitable surface plate with no pressure other than the weight of the tube. Using feeler gauges, determine that the straightness is within the limits specified.
 - 3.2 Outside Diameter - Mount the tube in a measuring fixture which permits essentially continuous measurement of the diameter. Complete one lengthwise pass, then rotate the tube 90 deg. about its axis and repeat the measurements. Record the tube diameter and roundness data.
 - 3.3 Inside Diameter - A hard chrome plated plug 68.325 \pm .025mm [2.690 \pm .001 in.] diameter, 50mm [2.0 in.] long, must pass freely through the tube without binding at any point along the tube. The plug shall be fabricated from steel and hardened to Rc 40-45. All edges of the plug shall be radiused to prevent damage to the tube inner surface.
 - 3.4 Wall Thickness and Concentricity - Inspect the tube with appropriate ultrasonic or eddy current instruments to determine the wall thickness at at least six points around the tube. The points shall lie in one plane perpendicular to the axis of the tube. The measurements shall be repeated at points located approximately at the quarter, half and three-quarter length points of the tube.
 - 3.5 Length - Inspect the tube with a calibrated steel measuring tape to verify length is as required by the engineering drawing.
4. Permeability - Test the tube material in accordance with the procedures of ASTM A342-84(1988), as applicable. A short sample of each tube lot shall be tested at 300K (and at 4.5K upon receipt of sample at BNL).