

1 Scope:

This specification covers the fabrication and delivery of the vacuum vessels to be used for the D1, D2, D3, and D4 LHC magnets built by BNL. The D1 vessels are nominally 24 inches in outside diameter. The D2, D3, and D4 vessels are nominally 36 inches in outside diameter.

2 Applicable Documents:

The following documents, of the issue in effect on the date of invitation to quote, shall be considered as an integral part of this specification.

BNL drawing 14060030	“Assembly, D1 Vacuum Vessel”
BNL drawing 14060010	“Assembly, D2 Vacuum Vessel”
BNL drawing 14060040	“Assembly, D3 Vacuum Vessel”
BNL drawing 14060050	“Assembly, D4 Vacuum Vessel”
BNL-QA-101	“Brookhaven National Laboratory Seller Quality Assurance Requirements”
RHIC-CR-E-4703-0041	“Leak Checking Specification: Magnets, Cryostats, and Associated Equipment”
LHC-MAG-M-1025	“Surface Preparation and Painting Requirements for LHC Vacuum Vessels”
ASTM E 23,	“Notched Bar Impact Testing of Metallic Materials”
ASTM A53	"Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless"
ASTM A530/530M,	"Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe"

3 Requirements:

All vacuum vessels shall be fabricated so as to comply with BNL drawing 14060030, BNL drawing 14060010, drawing 14060040, and/or BNL drawing 14060050, as applicable based on purchase order. Vessels must be manufactured, cleaned, and sealed using Viton O-rings such that they can sustain an absolute internal static pressure below 10^{-4} Pa (10^{-6} bar). The vessel must also exhibit an overall helium leak rate below 10^{-9} Pa-m³/sec (10^{-8} mbar-l/sec = 10^{-8} Atm-cc/sec) at 20° C.

Any and all conflicting requirements among the various applicable documents referenced within this specification, or the specification itself, shall be brought to the attention of BNL for resolution prior to commencement of work. The Seller is to take no other initiative prior to receiving written resolution.

3.1 Materials:

The cylindrical part of the vessel and its reinforcing rings shall be made from steel of type L485MB (EN 10208-2) or approved equivalent. All end flanges are to be made from AISI 304L stainless steel forgings. Filler wire materials used in welding shall conform to MIL-E-19933-309L for stainless to carbon steel welds; for steel to steel welds AWS-ER70S2 mild steel rod shall be used, or approved equivalent. Any vendor-desired deviations from the requirements above must be brought to the attention of BNL, must be submitted in writing, and must receive written approval from BNL prior to being incorporated.

The steel used for the cylindrical part of the vessel and its reinforcing rings must be capable of a minimum energy absorption of 21 J/cm² and an average value of 28 J/cm² at standard and sub-zero temperatures. Refer to paragraph 3.4.1 for complete impact testing requirements. Other steels may be proposed for BNL approval provided the impact data is submitted which substantiates that the toughness requirements are satisfied. The outer diameter of 914 mm [36 inches] with wall thickness of 12.7 mm [0.500 inches], and outer diameter of 610 mm [24 inches] with wall thickness of 6.4 mm [0.25 inches] for the vacuum vessels have been chosen to match commercially available pipe sizes to take advantage of existing tooling and manufacturing methods.

Only certified materials are to be used in the manufacture of these vessels. Materials conforming to the mechanical properties specified above shall also be fabricated in accordance with ASTM A53 and ASTM A530/530M.

Vacuum vessel cradle castings to be attached to the vessel shall be supplied to the vendor by BNL.

3.2 Welding:

All welds are to be made using the TIG or MIG method and shall conform to the specifications of Section IX of the ASME Code. Welds must not be finished by grinding or any other mechanical abrasion. Welders shall be Code-certified.

The drawings of the completed vessel reflect sound engineering judgment that recommends the sealing and related surfaces of the stainless steel flanges be

machined after they are welded to the tubular part of the vessel. This guarantees that the surfaces will not be distorted by the welding operation. Weld distortion of these large diameter surfaces would otherwise allow leaks that would inhibit maintaining the necessary static pressure below 10^{-4} Pa (10^{-6} bar). Each prospective seller shall explicitly address this requirement in the quotation by indicating compliance with this directive, or proposing a detailed alternate fabrication method that will be used to obtain the same results. In either case, the flatness, perpendicularity, circularity, and concentricity of the flanges with respect to the tubular part of the vessel shall conform to the applicable drawings.

3.3 Cleaning and Painting:

CAUTION!

It is imperative that all LEAK TESTS be conducted PRIOR to any interior or exterior cleaning and application of any surface protection.

All surfaces shall be cleaned and properly prepared for the application of the coatings as specified in LHC-MAG-M-1025, with the exception of those surfaces/parts noted below. The choice and use of the cleaning agents shall not compromise or degrade the ability of the vessel to maintain its required degree of vacuum, and the agents and methods used shall be compatible with the subsequent coatings such that optimum adhesion is assured.

The outer surfaces of the vessel wall shall be protected by applying two coats of anti-rust primer and two coats of epoxy paint in accordance with the specification referenced in Section 2.

All sealing surfaces shall be protected from damage during blasting and when not in use, and are to remain free of paint. There shall be no coatings applied to the stainless steel parts, nor to the inside surfaces of the vessels.

3.4 Acceptance Tests:

3.4.1 Impact Testing

The material for the cylindrical part of the vessel and its reinforcing rings shall be impact tested in accordance with ASTM E 23, "Notched Bar Impact Testing of Metallic Materials", employing Type A specimens for the tests. Alternatively, ISO 82-1974 (E) may be followed.

Test samples shall be fabricated to represent the base material, the weld material, and the heat-affected zone adjacent to these two. Groups of three samples shall be tested from each of these three material areas. A complete set of tests shall be done at 20° C, and another set at -50° C. The minimum energy absorption for any single test shall be 21 J/cm², and the average value of the three specimens from any group shall be at least 28 J/cm². This will constitute a total of 18 samples being tested.

3.4.2 Dimensional Inspections

Vessels shall be 100% inspected for compliance with all drawing dimensions. A detailed inspection report shall be compiled which clearly shows each nominal dimension, the tolerance range, and the actual measured dimensional data for each feature. Any out-of-tolerance conditions on any vessel shall be resolved with BNL prior to shipment of that vessel from the Seller's site.

3.4.3 Leak Test

The ability of the vessel to maintain the specified vacuum level must be demonstrated. Perform a vacuum leak test in accordance with BNL specification RHIC-CR-E-4703-0041. Attach the leak detector to the most convenient opening in the vessel. Seal the remaining openings using suitable end caps and flange covers. All welds shall be checked with the helium probe defined in the leak check specification. Using a helium mass spectrometer of sensitivity equal to or greater than 5×10^{-10} Pa-m³/sec, verify that the vessel exhibits a leak rate below 10-9 Pa-m³/sec (10^{-8} mbar-l/sec) at 20° C. (Note: it is granted by the Buyer that this leak rate is an order of magnitude less stringent than that given in specification RHIC-CR-E-4703-0041; this is not to be considered a conflicting requirement)

All equipment and fixturing necessary to carry out these tests is to be provided by the Seller.

Leak test records for the vacuum vessels shall be included as part of the end item documentation package accompanying the completed vessels, in accordance with the Quality Assurance requirements.

4 Quality Assurance:

The following paragraphs from the "Brookhaven National Laboratory Seller Quality Assurance Requirements" document, BNL-QA-101, apply to the procurement of these vacuum vessels and shall be strictly adhered to. Non-

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LHC-MAG-M-1027B

Page 5 of 5

conformance to any of these requirements shall be just cause for rejection and non-shipment of vessels to BNL.

Applicable paragraphs are: 3.1.2, 4.2, 4.3, 4.4 (including all sub-paragraphs), 4.5, 4.7, 4.7.1(all except leak checking), 4.7.2 (leak checking only), 4.8, 4.9, 4.10, 4.10.1, 4.10.2, 4.11, 4.14, 4.16, 4.18, 4.18.1, 4.18.4, 4.19, 4.21, 4.23, 4.30, and 4.31

BNL withholds from the Seller the authority to accept in “as is” condition items which do not conform to the requirements of this specification and the applicable drawings, or items to be repaired to a still non-conforming condition.

5 Preparation for Delivery:

The vacuum vessels shall be packaged to preclude physical, structural, and cosmetic damage to any of the vessel surfaces during land and ocean transport. All O-ring seal surfaces shall have protective covers installed to avoid degradation of the fine surface finish due to impact, chafing, and dirt, moisture, salt, or other environmental elements. All openings in the vessel itself shall be capped to preclude the entrance of these same elements during transport.

Each vessel shall have a nameplate attached to it at the location indicated on the drawing. The nameplate shall contain the following information:

LHC Dipole Vacuum Vessel
Purchase Order No. _____
BNL Part No. _____
Serial No.* _____
Manufactured by _____
Date of Manufacture: _____

*Note: serial numbers begin at 001

The nameplate shall be made from aluminum or stainless steel of maximum dimensions 100 mm x 70 mm x 0.5 mm thick. It shall be attached using screws or blind rivets at the location shown on the drawing. Nameplates made from other materials or affixed using adhesives are not permitted. The blind holes for the mounting hardware MUST be drilled PRIOR to leak checking.

Only vessels that are in full compliance with the Quality Assurance requirements stated in Section 4 of this specification shall be shipped to Brookhaven National Laboratory after manufacture.