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Electron-Ion Collider, Brookhaven National Laboratory			
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TECHNICAL SPECIFICATION
for the
Forward Hadronic Calorimeter Absorber Structure

Quality Classification: A-3

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REVISION HISTORY

Revision #	Effective Date	Summary of Change
00	12/4/2024	Initial Release
01	1/15/2025	Revised requirements for magnetic permeability
02	7/15/2025	Removed testing of pre-production type 4M units from Section 4.1.1, revised Sections 4.1.1 and 4.1.2.2 to state that testing will occur at ORNL
03	3/09/2026	Updated requirements for magnetic permeability, identified locations of samples along each heat of steel
04	6/18/2026	Updated requirements for laser welding, nickel-plating, and GD&T for pre-production modules

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LIST OF ACRONYMS

AISI	American Iron and Steel Institute
ASTM	American Society for Testing and Materials
ATP	Acceptance Test Procedure
BNL	Brookhaven National Laboratory
BSA	Brookhaven Science Associates
EIC	Electron-Ion Collider
Fe/Sc	Iron-Scintillator
GD&T	Geometric Dimensioning and Tolerancing
IP-6	Experimental Hall of the EIC Detector
LFHCal	Longitudinally segmented Forward Hadronic Calorimeter
ORNL	Oak Ridge National Laboratory
PCB	Printed Circuit Board

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Technical Specification for the Forward Hadronic Calorimeter Absorber Structure

1 SCOPE

This specification defines the technical requirements for the Absorber Structure for the Longitudinally segmented Forward Hadronic Calorimeter (LFHCal) of the Electron-Ion Collider (EIC) at Brookhaven National Laboratory (BNL) managed by Brookhaven Science Associates (BSA).

1.1 Background

The EIC Project will design, build, and install the accelerator hardware for a new electron storage ring, an electron injector, and modifications to the hadron ring required to produce an electron-ion collider and its infrastructure. It will include one interaction region, with an allowance for a second, and one detector. The facility is designed to meet requirements to ensure high reliability and availability for the user program.

The detector in IP-6 (Experimental Hall of the EIC Detector) will provide an almost 4π coverage in tracking, particle identification, electromagnetic and hadronic calorimetry. The hadronic calorimeter in the forward (hadron-going) endcap is of particular importance, to measure highly energetic particle jets with a sufficient energy resolution, isolate the jet neutral components (neutrons and K_L particles), complement the tracking and electromagnetic calorimetry in particle flow algorithms, and be an integral part of the detector solenoid magnetic field flux return.

The LFHCal is an Iron Scintillator (Fe/Sc) sampling sandwich calorimeter, where 16 mm thick steel plates are alternated with 4 mm thick scintillator plates (for a total of 60 layers each) with a depth of around 1.32 meters. All absorber layers will be made of a magnetic carbon steel because they are part of the EIC detector solenoid magnetic flux return. The full LFHCal is comprised of 1138 modules; 1066 are of the 8M layout and 72 are of the 4M layout. The 8M modules have a transverse size of about 200 mm (width) by 100 mm (height) and the 4M modules are one half of an 8M module in transverse size (100 mm x 100 mm). In addition, there are two insert modules (insert left and insert right) which have a combined transverse size of 600 mm x 600 mm with a conical opening to allow for the beampipe to pass through. The steel pieces are laser beam welded to one module. Nickel-plating of each full weldment to prevent corrosion shall be included as an option to this contract.

Each of the LFHCal modules consists of 55 regular absorber plates, 5 tapped absorber plates, and a case (top, bottom, front, back plates) made from magnetic carbon steel (AISI 1020). In addition, each module will include two Printed Circuit Board (PCB) side covers and tower brackets made of AISI 304 stainless steel and 34 screws of various sizes. The total number of pieces for the two different types of modules are listed in the tables below. Dimensions and tolerances are specified

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in the engineering drawings EPC-FWD-HCL-DET-ASM-100 and EPC-FWD-HCL-DET-ASM-200.

The absorber plates are laser beam welded to the top and bottom plates of an LFHCal module. The PCB side-covers are mounted to the assembly with screws prior to packaging and shipping.

Part ID	Description	Material	Units per module	Total units
EPC-FWD-HCL-DET-ASM-100	**LFHCal 8M module**			**1,066**
EPC-FWD-HCL-DET-PRT-101	Front plate	AISI 1020 Carbon steel	1	1,066
EPC-FWD-HCL-DET-PRT-102	Back plate	AISI 1020 Carbon steel	1	1,066
EPC-FWD-HCL-DET-PRT-103	Top plate	AISI 1020 Carbon steel	1	1,066
EPC-FWD-HCL-DET-PRT-104	Bottom plate	AISI 1020 Carbon steel	1	1,066
EPC-FWD-HCL-DET-PRT-105	PCB side cover	AISI 304 Stainless steel	2	2,132
EPC-FWD-HCL-DET-PRT-106	Absorber plate	AISI 1020 Carbon steel	55	58,630
EPC-FWD-HCL-DET-PRT-107	Absorber plate, tapped	AISI 1020 Carbon steel	5	5,330
EPC-FWD-HCL-DET-PRT-108	Tower bracket	AISI 304 Stainless steel	1	1,066

Part ID	Description	Material	Units per module	Total units
EPC-FWD-HCL-DET-ASM-200	**LFHCal 4M module**			**72**
EPC-FWD-HCL-DET-PRT-201	Front plate	AISI 1020 Carbon steel	1	72
EPC-FWD-HCL-DET-PRT-202	Back plate	AISI 1020 Carbon steel	1	72
EPC-FWD-HCL-DET-PRT-203	Top plate	AISI 1020 Carbon steel	1	72
EPC-FWD-HCL-DET-PRT-204	Bottom plate	AISI 1020 Carbon steel	1	72
EPC-FWD-HCL-DET-PRT-205	PCB side cover	AISI 304 Stainless steel	2	144
EPC-FWD-HCL-DET-PRT-206	Absorber plate	AISI 1020 Carbon steel	55	3,960
EPC-FWD-HCL-DET-PRT-207	Absorber plate, tapped	AISI 1020 Carbon steel	5	360
EPC-FWD-HCL-DET-PRT-208	Tower bracket	AISI 304 Stainless steel	1	72

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2 APPLICABLE DOCUMENTS

The following specifications, standards and drawings form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of these documents shall be that in effect on the date of the solicitation or Contract. Exceptions must be approved in writing by BSA.

In the event of a conflict between the applicable documents and this specification, the Contractor shall immediately notify the BSA Contractual Representative who will in each instance determine which document takes precedence and advise the Contractor accordingly. Failure to notify BSA of a document conflict shall not relieve the Contractor's responsibility to ensure full compliance to all requirements.

Document Number	Document Title
EPC-FWD-HCL-DET-ASM-100	A full set of engineering drawings for 8M modules
EPC-FWD-HCL-DET-ASM-200	A full set of engineering drawings for 4M modules

3 REQUIREMENTS

3.1 Technical/Performance Characteristics

Refer to the drawing(s) listed in Section 2 for component orientations, dimensions, tolerances, and other required technical/performance characteristics.

3.2 Materials

As specified in the drawing package(s) and the tables above, all raw components except the PCB side covers and tower brackets will be AISI 1020 carbon steel, while the PCB covers and tower brackets will be made from AISI 304 stainless steel. All parts shall have broken edges and be thoroughly cleaned and free of grease and oils.

All materials used in this fabrication shall have mill certification from the manufacturer as Certified Material Test Reports. A heat analysis shall be performed in accordance with ASTM A751 to verify the chemical composition of each individual heat, including residual elements. The Contractor shall submit a certified report of each heat analysis to BSA. Magnetic permeability shall be documented in compliance with ASTM A773 for each pour. All dimensions of the components shall be inspected with respect to the specifications and tolerances, including the nickel-plating if option is exercised. The carbon steel components shall be assembled using laser beam welding. If approved by BSA, the fully welded modules shall be coated using electroless nickel-plating for corrosion protection (0.001" minimum thickness, 0.002" maximum thickness).

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3.3 Code/Standard Compliance

All Standards to be followed as listed or equivalent to be approved by BSA.

- AISI 1020: Low Carbon Steel
- AISI 304: Stainless Steel
- ASTM A240: "Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications" (if option is exercised)
- ASTM A1008: "Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability" ASTM A370: "Standard Test Methods and Definitions for Mechanical Testing of Steel Products"
- ASTM A751: "Standard Test Methods and Practices for Chemical Analysis of Steel Products"
- ASTM A773: "Standard Test Method for Direct Current Magnetic Properties of Low Coercivity Magnetic Materials Using Hysteresigraphs"
- ASTM B733: "Standard Specification for Autocatalytic (Electroless) Nickel-Phosphorus Coatings on Metal"
- ASTM A830: "Standard Specification for Plates, Carbon Steel, Structural Quality, Furnished to Chemical Composition Requirements"
- AWS C7.4: "Process Specification and Operator Qualification for Laser Beam Welding"

3.4 Environment, Safety and Health

Identification of hazards, and their mitigation, during all stages of the life of the Equipment including: installation, commissioning, operation, maintenance, and repair. Identification of means to eliminate or manage each hazard shall be provided based on the following hierarchy:

- Substitute with something less hazardous, or
- Engineer – mitigate the severity of the hazard, or
- User Personal Protective Equipment (least desirable).

3.5 Packaging/Shipping

LFHCal modules shall be crated and packaged on pallets, suitable for forklift handling. The corresponding crate structure will be agreed upon prior to shipping to allow easy access to the various sites of the module, without removing the crate. The number of LFHCal modules per pallet is to be defined in a communication with the Contractor. During shipment, LFHCal modules shall be protected from extreme humidity or water. If nickel-plating is not applied, Silica Gel packs shall be added to the modules appropriate for the volume of the packaging

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3.6 Storage

Storage at the manufacturing facility after the production shall be done in a dry area, to avoid any adverse effects mentioned in Section 3.5.

4 VERIFICATION

Appropriate inspection/tests shall be performed to ensure Absorber Structures conform to all requirements in Section 3 of this specification.

4.1 Classification of Inspections

Items covered by this specification shall be subjected to the following tests to determine compliance with all applicable requirements:

4.1.1. Pre-Production Tests (First Article)

Compliance with the specification shall be verified using the Acceptance Test Procedure (ATP) generated by the Contractor and approved by BSA in writing. Testing and inspection of pre-production units shall be conducted at Oak Ridge National Laboratory (ORNL). The Contractor shall not commence fabrication of the production units until receiving notification of pre-production unit acceptance and authorization in writing from BSA. Five LFHCal modules of 8M size are required for pre-production tests at ORNL.

- Formal Geometric Dimensioning and Tolerancing (GD&T) document: Report all measured inspection dimensions on formal GD&T document for each pre-production assembly with reference to each assembly's serial number.

4.1.2. Acceptance Tests

4.1.2.1. Acceptance Tests Performed at Contractor - The Contractor shall submit ATPs for BSA written approval that are in accordance with this specification and all reference documents noted herein. Material composition of the AISI 1020 steel components shall be documented for each production run and magnetic permeability shall be measured for four samples of each heat of steel (randomly selected absorber plates from each heat). The number of steel heats shall be limited and preferably the same heat shall be used for all modules. The LFHCal modules shall be tested at the Contractor's facility, Contractor's subcontractor facility, or pre-approved BSA collaborator to demonstrate compliance with this specification. This includes tests of parts of the assembly prior to the laser beam welding of absorber plates and after the nickel-plating (if it is applied). All data shall be documented and delivered to BNL for review prior to acceptance. In addition, the following tests shall be conducted on Absorber Structures by the Contractor in accordance with the ATP, prior to shipping:

- Dimensional Measurement – Dimensions of the individual components, prior to assembly shall be measured for conformance to the technical requirements. Additionally, report maximum overall length, width, and height for each production

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unit with reference to assembly serial number in the BSA-approved ATP. The slot widths between all absorber plates shall be certified with a BSA-approved go/no-go gauge in the ATP.

- Weld inspections: All welds shall receive a visual inspection and be certified in the BSA-approved ATP.

4.1.2.2. Acceptance Tests Performed at ORNL – Acceptance tests are to be performed at ORNL. All received LFHCal modules will be tested regarding their dimensions. The acceptance of the shipment will depend upon these results and their compliance with the specifications listed in Section 3.1.

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