Lumi Dipole Inspection and Test Plan

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Abstract

The Lumi Dipole system is located on the Lumi beamline and includes two identical dipole magnets, a Sweeper and an Analyzer, each producing 1 T-m integrated field. The dipoles will be oriented on the Lumi beamline near the Electron line magnets. The magnets will be independently powered by separate power supplies and internally cooled with LCW. Figure 1 shows the preliminary CAD model of a single dipole, and Figure 2 shows the preliminary system assembly on the beamline. To ensure that the magnets meet physics requirements, testing must be performed during manufacture and upon delivery. Dimensional checks, electrical tests, brazing and welding compliance, pressure system testing, lifting and fiducials, instrumentation and magnetic field testing must be validated prior to installation in the experiment.

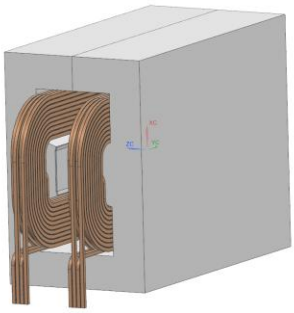

Figure 1. Preliminary CAD model of single Lumi Dipole

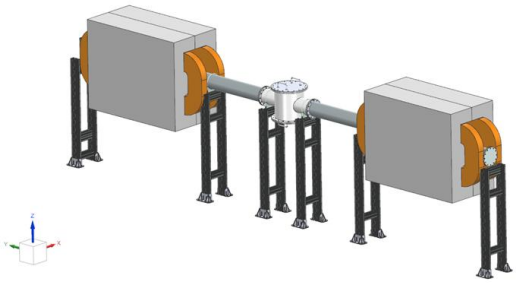

Figure 2. Preliminary CAD model of Lumi Dipole system assembly

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Figure 2. Preliminary CAD model of Lumi Dipole system assembly ..... *i*

1. LUMI DIPOLE PROPERTIES

The main components of the magnet system are:

- Coils with steel yoke
- Magnet lifting arrangement
- Connection points for alignment cartridges to support the magnet under normal operating conditions
- Fiducials for magnet alignment in the experimental hall
- Water cooling bus connections
- Electrical connections and lead connections
- Safety and magnet protection interlocks

The specifications of the individual magnets are given in Table 1

Parameter	**Value**
Coil Length (mm)	1670
Steel Length (mm)	1200
Pole Gap (mm)	170
Pole Width (mm)	190
Overall Width (mm)	614
Magnet Weight (kg)	3800
Integrated Field (T-m)	1.08
Stray field requirement at nearby magnets	<100 G @ x= -0.4 m
NI (Ampere-Turns)	5700
Maximum Current Draw (A)	1423
Voltage (V)	50.4
Current Density (A/mm^2)	9.64

The following are the key properties that will be evaluated by these tests and inspections.

1.1. Dimensional Checks

- Overall dimensions of the magnet system
- Length and coil pack dimensions of the wound coils
- Dimensions of the poles
- Dimensions of the steel yoke and mounting points

1.2. Electrical

- Electrical resistance measurement for all coils
- Insulation tests on coils and magnet
- High-potential testing to verify isolation from ground

1.3. Pressure System and Welding Compliance

- Pressure testing according to ASME B31.3
- Welding/Brazing compliant to ASME B31.3-328.2

1.4. Lifting and Alignment Fiducials

- Lifting arrangements
- Fiducials for alignment

1.5. Instrumentation

Verification of all sensors

- Klixon-type temperature interlocks
- Orifice plate flow interlock

1.6. Magnetic Field

- Full current testing
- Field mapping and validation against specification

2. PROCESSES AND PROCEDURES

2.1. Dimensional Checks

The overall dimensions of the magnet system are crucial for installation in the LUMI beamline. The magnets are located in a tight space between the electron line and the CRAB cavities. Additionally, the overall coil length (i) is critical to ensure fitment between other beamline components. Several other dimensional checks are important to the performance of the magnet, including dimensions of the poles and pole gap (ii), dimensions of the steel yoke (iii), dimensions of the coil with potting (iv) and locations and dimensions of the alignment points (v).

2.1.1. In-Process Testing

All these dimensional checks will be done while manufacturing. The vendors will provide dimensional inspection reports upon delivery.

2.1.2. Incoming Inspections or Acceptance Testing

Receipt inspections of all components will be performed upon delivery to confirm compliance with requirements.

2.1.3. Verification Testing

The dimensional checks will be verified either by the quality person from the vendor and/or technical representative.

2.1.4. Failures and Non-Conformances

If any of the dimensions is out of specification range, immediate corrective action will be taken by the vendor and approved by technical representative.

2.2. Electrical Testing

There are multiple electrical tests to be performed during magnet manufacturing and installation. Electrical resistance will be measured for each coil; this value will be compared with the theoretical value. Any discrepancy or deviation from theoretical values should be notified to JLab and winding will be paused till a cause and solution is found. After making the joints, the resistance checks will be made after every joint. These values will be compared with theoretical values. The inductance of the magnet will be measured in the frequency range of 50 Hz to 1kHz. A difference greater than 5% between the measured and the computed inductance will be considered as an indication of a short circuit.

In order to verify the quality of turn-to-turn insulation and to prove the dielectric strength of the insulation winding should be tested with an impulse voltage. All the conductive parts should be connected to the ground to the ground or to the high potential terminal of the coil under test. The potential of the conductive parts should be selected in accordance to the operating conditions of these parts. The detailed design of the test circuit is the responsibility of the vendor. The test circuit must be designed to produce an oscillatory test voltage with the following electrical characteristics:

- Frequency: less than 1000 Hz
- The impulse voltage test must be initially applied at reduced voltage. After that, the voltage of the impulse will be progressively increased up to the maximum value indicated in the test program.

The absence of phenomena that can be interpreted as an indication of voltage breakdown will be the acceptance criterion.

All the coils and joints should be tested to qualify the ground insulation. All the conductive parts should be connected to the ground or to the high potential terminal of the coil under test. The potential of the conductive parts should be selected in accordance to the operating conditions of these parts. The insulation to ground must be tested at atmospheric pressure and voltage in both polarities. The test voltage should be twice the operating voltage.

2.2.1. In-Process Testing

All the above electrical tests will be performed several times during the manufacturing process.

2.2.2. Incoming Inspections or Acceptance Testing

Some of these tests will be part of the final acceptance test.

2.2.3. Verification Testing

The electrical tests will be done by the magnet vendor and be witnessed by the JLab technical representative.

2.2.4. Failures and Non-Conformances

Corrective actions will be taken by the vendor for any discrepancy or failure of the electrical tests and will be approved by JLab technical representation.

2.3. Pressure System and Welding Compliance

All piping in the system is governed by ASME B31.3. All the pressure and vacuum vessels are designed using the ASME code. All the design calculations should be verified by the JLab pressure vessel authority and/or should be ASME stamped.

As JLab considers all the brazing critical to the success of the project, vendors are requested to provide ASME BPVC, Section IX-qualified Brazing Procedure Specification (BPS), supporting Procedure Qualification Record (PQR), Brazing Performance Qualifications (BPQ) of brazers and brazing operators in accordance with Subsection 328.2. Requirements in B31.3 Section 333 that are applicable to brazing must be followed.

2.3.1. In-Process Testing

The pressure system design calculation and weld qualifications will be approved by JLab prior to start of work.

2.3.2. Incoming Inspections or Acceptance Testing

All the pressure system design calculations and required qualification documents will be reviewed and approved by the JLab technical representative.

2.3.3. Verification Testing

All the pressure system design calculations and required qualification documents will be reviewed and approved by the JLab technical representative. The system will be vacuum leak checked with a helium sniffer and pressure tested to ASME B31.3 standards to verify system integrity.

2.3.4. Failures and Non-Conformances

Any failure to provide the required documentation and analysis work will be paused by JLab until these are provided.

2.4. Lifting and Alignment Fiducials

Each magnet assembly weighs approximately 4.2 tons. Proper lifting arrangements should be planned for lifting the magnet at the vendor site and at time of arrival at BNL. The magnet assembly will be installed on the Lumi beamline. Fiducials are required to align the magnet during installation.

2.4.1. In-Process Testing

The lifting lugs will be designed for magnet lifting. The magnet vendor will design the lifting arrangement and share their design report with JLab technical representative. The fiducials details will be shared with JLab and BNL technical team.

2.4.2. Incoming Inspections or Acceptance Testing

The lifting lugs design and calculations along with the required qualification documents will be approved by JLab technical representative.

2.4.3. Verification Testing

Before shipping from the vendor, the lifting lugs and fiducials details shall be approved by JLab. The lifting lugs should be stamped for the approved weight.

2.4.4. Failures and Non-Conformances

Magnet shipping to BNL will be paused if lugs or fiducials are not approved by the JLab technical team.

2.5. Instrumentation Checks

In order to operate and monitor the Lumi dipoles, an instrumentation plan has been defined. Klixon-type thermal interlocks will be applied to the magnet coils to monitor the temperature and protect the magnet from overheating. An orifice-plate flow interlock will be installed to trip if water flow is interrupted.

2.5.1. In-Process Testing

All the interlock systems will be calibrated and their calibration will be shared with JLab, all the wiring will have enough redundancy. The type of sensor and level of required redundancy will be approved by JLab technical representative.

2.5.2. Incoming Inspections or Acceptance Testing

All the interlock setpoint values will be checked during magnet acceptance testing.

2.5.3. Verification Testing

The interlock calibration will be done by the vendor, and the calibration data will be shared with JLab. All the interlocks will be checked at the arrival check.

2.5.4. Failures and Non-Conformances

If interlock type or calibration does not meet specifications, the manufacturer will replace the sensor. Changes will be approved by JLab technical representation.

2.6. Magnetic Field Testing

The magnets will be connected to LCW and power supplies and tested prior to delivery. The magnet vendor will be responsible for testing the magnet at 110% of full current.

2.6.1. In-Process Testing

During manufacturing, all coil connections, joints, etc. will be checked for leaks, insulation and continuity checks.

2.6.2. Incoming Inspections or Acceptance Testing

All electrical checks will be repeated at the receipt inspection.

2.6.3. Verification Testing

The magnet will be cooled and energized to the full field. The magnet will be mapped in the bore prior to installation to verify that the magnetic field meets physics requirements.

2.6.4. Failures and Non-Conformances

Corrective actions will be taken by the vendor for any discrepancy or failure in the magnet test. The corrective actions will be approved by the JLab technical representative.

3. EXPERIMENTAL/TEST SETUPS

3.1. Dimensional Checks

All the dimensional checks will need measurement tools. Vendor to provide a method for measuring all the dimensions.

3.1.1. Resource Requirements

No special resources required.

3.1.2. Test Conditions

These tests are to be done at controlled room temperature ~27 degrees C.

3.1.3. Equipment

Dimensional analysis tools may include:

- Calipers
- Dial indicators
- Feeler gauges
- CMM

3.2. Electrical Testing

Special test equipment is required to complete all electrical tests. The vendor will provide their test methodology to JLab for approval.

3.2.1. Resource Requirements

A trained test technician and test engineer are required to perform these tests.

3.2.2. Test Conditions

Electrical tests will be performed at room temperature ~27 degrees C.

3.2.3. Equipment

Electrical test equipment may include:

- High-potential Tester
- Impulse Voltage Surge Tester/Surge Generator
- Digital Storage Oscilloscope

3.3. Instrumentation Checks

3.3.1. Resource Requirements

A trained test technician and test engineer are required to perform these tests.

3.3.2. Test Conditions

Electrical tests will be performed at room temperature ~27 degrees C.

Temperature Interlocks:

- Interlocks will be mounted to a controlled heat source and cross-checked with a calibrated sensor to check switching temperature

Flow Interlock:

- Interlock will be checked against a calibrated flowmeter to verify setpoint

3.3.3. Equipment

Test equipment may include:

- Calibrated temperature sensor
- Dry-block calibrator
- LCW supply source

- Calibrated flow meter

3.4. Magnetic Field Testing

3.4.1. Resource Requirements

A trained test technician and test engineer are required to perform these tests.

3.4.2. Test Conditions

Electrical tests will be performed at room temperature ~27 degrees C.

3.4.3. Equipment

Test equipment may include:

- Hall probe

4. ENVIRONMENT, SAFETY & HEALTH CONSIDERATIONS

The procedures will be implemented in a way consistent with the environment, safety, and health policies of the relevant work areas. Within Jefferson Lab the process is described in the ES&H manual Chapter 3200, Work Planning and Control Program and at BNL within the SBMS: "Work Planning & Control for Experiments and Operations".

5. RECORDS AND DOCUMENTATION

This section details all of the documentation that will be generated and exchanged during the manufacturing lifecycle. In all likelihood there will be many transient documents that are created that will not be collected or maintained as part of the project. This transient documentation need only be listed if it is pertinent to a specific experiment or test.

5.1. Manufacturer/Producer Records

For every item that is manufactured, the manufacturer will be responsible for maintaining records (travelers) of all raw material that are used in the fabrication process and document the processes and procedures that were used for production. The resultant documentation will be compiled into a report and will be provided to the project as part of the deliverable, which will be reviewed, validated, and then placed in the central data repository.

5.2. Deliverable Documentation and Records

This includes test results, tables of measurements, parameter lists or other records that must be provided to the project. All testing and inspection data that is collected as part of the validation, verification and testing plan will be provided to the project as part of the final report.

- Manufacturer test procedure & results
- All testing and calibration data
- Magnet operating manual

6. REFERENCES

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