D R A F T



**FERMILAB**

**Technical Division**

**LARP MQXFPM1 (Mirror)**

**Magnet Description**

|  |  |
| --- | --- |
| Author: G. Chlachidze  | Date: 12/15/2015 |
| Reviewed by:  | Date: 12/15/2015 |

Test Support

|  |  |
| --- | --- |
| Magnet Test Facility | VMTF at BNL |
| Magnet Power System |  |
| Top Plate Design |  |
| Warm Bore  | NO |

Magnet Type

|  |  |
| --- | --- |
| Accelerator / Project  | LARP  |
| Magnet Builder | FNAL |
| Magnet Type (# of poles)  | Quadrupole mirror (1) |
| Coil design | two layer cos 2 |
| Magnet Coil Volume – volume of superconductor + stabilizer | 12.45 mm2 Cu, 7.56 mm2 Nb3Sn, 3.75 mm2 Bronze and 9.71 mm2 G10 per cable cross-section (33.469 mm2) Total cable length is 403.5 m |
| Magnet Coil Weight | 80 lbs (estimate) |
| Magnet Aperture (inner coil radius) | 75 mm |
| Magnet Coil Length  | 4200 mm |
| Magnet outer structure diameter | 450 mm |
| Magnet Weight | 10400 lbs  |
| Cryostatted/not  | Not cryostatted |

Magnet Parameters

|  |  |
| --- | --- |
| Superconductor strand | Nb3Sn 0.853-mm RRP 108/127  |
| Cable design | 40-strand cable with a SS core (12x0.025 mm2) |
| Magnet Inductance @ 10kA (20Hz) |  |
| Magnet Inductance at 300 K, 20 Hz | 15.087 mH, Q=2.43 |
| Magnet Resistance (300K) | 0.589 Ohms |
| Maximum Voltage (Hipot) | 1000 Volts, I<0.02 µA |
| Spot Heater Hipot Voltage | N/A |
| Maximum current at 300 K | 10 A |
| Predicted Quench Current @ 4.5 K | 18.734 kA |
| Predicted Quench Current @ 1.9 K | 21.065 kA |
| Maximum Coil MIITs | 37 |
| Peak Field Gradient (on axis)@1.9K | 172 T/m |
| Peak Field Strength (on coil) @1.9K | 14.49 T |

Non-Typical Test/Safety Concerns

|  |  |
| --- | --- |
| 1 | Open voltage taps: N/A |
| 2 | Open SG: SG047 SLK\_30\_RE\_T, SG034 SKU\_30\_MIDLE\_T |
| 3 | Open PH: N/A |
|  |  |

Magnet Components

|  |  |
| --- | --- |
| Eighth Coil Segments | N/A |
| Quarter Coil Segments | N/A |
| Half Coil Segments | Yes |
| Correction Coils | No |
| Protection Strip Heaters Number of Protection Heaters Protection Heater Resistance | Yes 6 (4 OL and 2 IL) 3.96 Ω (A01), 4.01 Ω (A02), 2.29 Ω (B1), 2.26 Ω (B2, B3) and 2.28 Ω (B04)  |
| Spot Heaters Number of Spot Heaters Spot Heater Resistance | No -  - |
|  |  |

Magnet Instrumentation

|  |  |
| --- | --- |
| Configurable Voltage Taps (CVTs) Number of CVTs | Yes 16 (8 OL and 8 IL) |
| Voltage Spike Detection Taps Number of VSDS Taps | Yes  4 (2 Half coils)  |
| Quench Antenna Q.Antenna Version | Yes Printed circuit boards (PCB)12 segments |
| Strain Gauges (SGs) Number of 4-Wire Res. SGs Number of capacitive SGs Number of Bridge SGs  | Yes 64  N/A 4  |
| Resistive Thermal Devices (RTDs) Number of RTDs | Yes, To be installed at BNL  4  |

Magnet Quench Protection

|  |  |
| --- | --- |
| Maximum HFU Voltage |  420 V |
| Strip Heater Power Supply HFU\_1 HFU\_1 Capacitance HFU\_1 Voltage HFU\_1 Delay Strip Heater Configuration | Yes19.2 mF 100 V 0 msA01 and A02 |
| Strip Heater Power Supply HFU\_2 HFU\_1 Capacitance HFU\_1 Voltage HFU\_1 Delay Strip Heater Configuration  | Yes19.2 mF 100 V 0 msB01, B02, B03 and B04 |
| Energy Extraction (Dump) Resistor Dump Resistance Dump Delay | YES 30 mΩ  1 ms  |
|  |  |
|  |  |
|  |  |

Magnet Quench Detection

|  |  |
| --- | --- |
| Digital Quench Detection (DQD) Whole Coil – Ref (DQD\_1) Whole Coil – Idot (DQD\_2) +Half Coil - -Half Coil (DQD\_3) Copper leads – Current (DQD\_4) SC Leads – Whole Coil (DQD\_5)  | Yes 5.0 V 3.0 V  0.5 V  0.030 V  0.025 V  |
| Analog Quench Detection (AQD) Whole Coil – Ref (DQD\_1) Whole Coil – Idot (DQD\_2) +Half Coil - -Half Coil (DQD\_3) Copper leads – Current (DQD\_4) SC Leads – Whole Coil (DQD\_5) | Yes 5.0 V 3.0 V  See **Attachment I**  0.030 V  0.025 V  |

Comments:

See heater/VT traces in **Attachment II**.

See lead voltage taps in **Attachment III.**

See coil VT and magnet schematics in **Attachment IV**.

See the magnet interface document in **Attachment V**.

**Attachment I**

FPGA DQD settings:

1 0-400 A: 0.5 V

2 400-1500 A: 0.8 V

3 1500-3000 A: 1.5 V

4 3000-4000 A: 1.2 V

5 4000-5000 A: 0.8 V

6 5000-6000 A: 0.6 V

7 6000-20000 A: 0.5 V

VME AQD Hcoils settings:

0-500 A: 0.5 V

500-6000 A: 1.5 V

6000-15000 A: 0.5 V

**Attachment II**

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**Attachment III**



**Attachment IV**





**Attachment V**

MQXFPM1 (mirror) magnet Interface Document

**PURPOSE**

The purpose of this document is to provide information for assembling Hypertronic connectors on MQXFPM (mirror) magnets.

# INTRODUCTION

Magnet or coil instrumentation is connected to the test facility’s DAQ system through several Hypertronic connectors installed on the bottom surface of the lambda plate. All modules in a magnet connector are assumed to have the same sex, and all connectors on the magnet side are “Male” connectors.

Below magnet connectors are described.

5-pin “male” module, part # LAMSTH:

Configurable (coil) voltage taps (CVT)

 Fixed voltage taps (FVT)

 Spot heaters (SH), Voltage signals from protection heaters

17-pin “male” modules, part # **LDMSTH:**

Coil strain gauges (SG)

2-pin “male” modules, part # **LMMSTH**:

Protection heaters (PH)

In some connector assemblies described below the single unit-wide empty (blank) Hypertronic modules will be used, part # **LAHT**.

Wires and connectors are uniquely labeled according to supplied schematics. Pin diagrams and labels unambiguously describe the orientation of each module. Key modules on both ends of the connector unambiguously describe the orientation of “male” and “female” connectors.

Wire length of the magnet instrumentation cable should be enough to reach the “female” Hypertronic connectors on the header assembly (Lambda plate). Usually 4 feet long wires after the magnet lead end is sufficient (to be checked at the local test facility)

**The “male” Hypertronic connectors should be properly protected and wrapped in a protective material when magnet is shipped.**

**Important:**

*Currently pin orientations are not indicated in the key modules*

**CONFIGURABLE VOLTAGE TAP (CVT) CONNECTORS:**

There is ONE CVT connector with 15 “male” 5-pin modules (part # **LAMSTH**) and key modules on each side of the connector. The first and last modules in each connector are blank (empty module, part # **LAHT**). CVT connector diagram (**solder-cup view**) are shown below. Wire direction is also shown.

**The first voltage tap at the Positive power lead (A1) has to be wired to the module 2, pin 1 of the CVT connector.** Then wiring makes a serpentine form: consecutive voltage taps in two adjacent 5-pin modules will be wired in opposite direction. For example, wiring will go from pin 1 to 5 in the module #2 and then from pin 5 to 1 in the module #3 of CVT1 connector.

**Total number of wired CVT channels in MQXFPM1 is 20: 16 regular and 4 redundant (A01b, A02b, B01b, B02b) VTs**

**QA signals (12) also could be wired to the CVT connector**

CVT “male” connector (solder cup view)

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CVT connector pin asignment

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **V-Tap** | **Conn.** | **Module** | **Pin** | **V-Tap** | **Conn.** | **Module** | **Pin** |
| VT01 | CVT | 2 | 1 | VT06 | CVT | 3 | 5 |
| VT02 | CVT | 2 | 2 | VT07 | CVT | 3 | 4 |
| VT03 | CVT | 2 | 3 | VT08 | CVT | 3 | 3 |
| VT04 | CVT | 2 | 4 | VT09 | CVT | 3 | 2 |
| VT05 | CVT | 2 | 5 | VT10 | CVT | 3 | 1 |

**HEATER CONNECTORS:**

There is ONE 11-module Strip Heater connector STRIP HTR. The connector consists of 7 2-pin modules (part **#LMMSTH**) used for the strip heaters and 4 5-pin (part **#LAMSTH**) modules for the voltage signals from the strip heaters.

There are also key modules on each side of the connectors. Heater connector diagrams (**solder-cup view**) are shown below. Wire direction is also shown.

**There are 6 protection strip heaters in MQXFPM1 magnet.**

**Comments:** 5-pin modules 1-4 in connectors are NOT wired. Corresponding pins for the PH voltage signals are wired in the connector on the Lambda plate.

STRIP HTR connector (solder cup view)



**STRAIN GAUGE CONNECTORS:**

There are TWO 9-module strain gauge (SG) connectors SG1 and SG2. Each 17-pin Hypertronic module (part # **LDMSTH)** can accommodate 4 strain gauges. There are key modules on each side of the connector.

**There are 64 SG in MQXFPM1 magnet.**

SG1 connector diagram (**solder-cup view**) is shown below. Wire direction is also shown.



SG2



Example of SG1 Connector Pin Assignment in one 17-pin module is shown below:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Coil** | **SG** | **Conn.** | **Mod.** | **Pin** | **WIRE COLOR** |
| 1 | SG1 | SG1 | 1 | 12/13/14/15 | R/B/G/W (I+/I-/V+/V-) |
| 1 | SG2 | SG1 | 1 | 16/17/11/10 | R/B/G/W (I+/I-/V+/V-) |
| 1 | SG3 | SG1 | 1 | 9/8/7/1 | R/B/G/W (I+/I-/V+/V-) |
| 1 | SG4 | SG1 | 1 | 2/3/4/5 | R/B/G/W (I+/I-/V+/V-) |

# FIXED VOLTAGE TAP (FVT) CONNECTORS:

There is one 15-module connector for the Fixed Voltage Taps (FVT). These 5-pin modules (part **# LAMSTH**) are used for the whole- and half-coil signals, which will participate in the quench detection and protection systems. The half-coil signals for the voltage spike detection system also will be wired in this connector. FVT connector diagram (**solder-cup view**) is shown below. Wire direction is also shown.

**Important:** FVT segments will see the largest voltage drop in the magnet, therefore the FVT modules are alternated with the blank modules in the connector. In addition, individual pins are also alternated with the empty pin-space (see below)

**Important:**

Modules 1, 2, 4, 12 & 14 are not used in MQXFPM1

FVT connector (solder cup view)



FVT Connector Pin assignment for the magnet

|  |  |  |
| --- | --- | --- |
| **FVT** | **Mod.** | **Pin** |
| WC+ (FVT) | 14 | 5 |
|  |  |  |
|  |  |  |
| ½ C (FVT) | 10 | 5 |
|  |  |  |
|  |  |  |
|  |  |  |
| WC- (FVT) | 10 | 1 |
| **Spikes** | **Mod.** | **Pin** |
| WC+ (Spikes) | 8 | 2 |
| ½+C (Spikes) | 8 | 4 |
| ½-C (Spikes) | 6 | 5 |
| WC- (Spikes) | 6 | 3 |

FVT twisted pairs: **(WC+, 1/2, WC-),**

Spike twisted pairs **(WC+,1/2,WC-)**