**Rotating coil measurement system design review**

**REPORT**

**v. 1.0**

The Fermilab/TD Rotating coil measurement system design review team conducted this review on June 8th, 2018. The team met in the IB1 conf. room. The review promptly started at 9:30 am and concluded at 2:30 pm on June 8th.

The AUP magnetic measurement team has previous experience in measuring superconducting magnets for several different projects and programs, example LARP, GARD and the original Fermilab-built Interaction region quadrupoles.

The Goals and Charge of this review are attached to this document. The main goal was formulated as: “… to assess the rotating coil system design, including the probe motion system and the cable spooler”.

The Review Committee would like to congratulate the team on the amount of design effort.

Below, we are summarizing the Committee comments and recommendations to the charge questions.

**Are the rotating coil measurement system requirements well defined and technically achievable?**

Fermilab/TD and the Magnet Sector has a lot of experience building rotating coil magnetic measurement systems (RCMMS). In the past 20 years, two measurement systems were built and they served the needs for field characterization.

The Committee found that the RCMMS requirements are well defined and documented in the project note (**US-HiLumi-doc-818)** and they are technically achievable.With more than one year before the measurement on the real size prototype, we suggest a magnetic measurement plan to be developed. During the process of planning, some optimization and deficiencies of the RCMMS can be revealed.

**Comment:** Develop a magnetic measurement plan**.**

**Recommendations:**

1. Discuss with CERN and agree on the definition of local for the local “waviness” deviation requirement (on 0.2 mm level ) from the magnet axes.

**Are the rotating coil system hardware and software components adequate for the proposed measurement system requirements?**

The committee was satisfied with the current level of the RCMMS development. In general, there is a clear plan how to build the system and which components to use. During the discussion, some concerns were raised: the encoder (integration) trigger is recorded with an FPGA card while the probe signals are recorded via DSA cards. It is not very clear how the synchronization between them will occur. Another concern is the synchronization, and stitching of the current measurement with the probe signals while still integrating over the power cycle. One possibility to resolve the synchronization problem is to select a specific DSA frequency which is proportional to the 60 Hz and record the current in one of the DSA channels. To check algorithms, we suggest to buy a minimalistic version of the system as soon as possible, e.g. one DSA card and one FPGA card, preferable this summer.

**Comments:**

1. Based on the previous experience, we suggest increasing the integration (startup) time of the RCMMS. In the current schedule the startup is only 3 months, we suggest doubling it.
2. Review an option to support the probe on the 3-point spring-loaded bearing blocks.
3. Check on the possibility of buying a DSA cards with truly differential inputs.

**Recommendations:**

1. Manufacture a second, identical, rotating coil probe to mitigate the risk of mechanical probe breakage and schedule delay.
2. The project should provide funds to purchase an additional DSA card. It will be needed to digitize additional channels for quality control of the magnetic measurements, e.g. like index pulse from the encoder, and have several spare channels.

**Are the probe motion and cable spooler hardware adequate for the horizontal magnetic measurements at stand 4?**

This is system contains two independent parts: a longitudinal probe motion system and the cable spooler. The committee believes that the latter is the riskiest component of the RCMMS.

In principle, the longitudinal probe motion system based on a stepper and DC motor, should work. Special attention should be given to the control of the stepper so that the probe is moved in a smooth way. An additional concern is that the information from the laser tracker is not fed to the motion system. Based on this observation, it is not clear how the probe will be positioned with accuracy of 0.1 mm.

The design of the spooler is innovative. There is a possibility that this device will need a long-time to fine tune and achieve smooth operation. Special attention should be paid to the component which inserts the cable and removes the cable from the warm bore. Additionally, there was no discussion on how the interlock with the motion system will be organized if the spooler fails.

**Comments:** Explore the possibility of substituting the laser tracker with a simpler measurement device. If this is not possible, explore the option to synchronize the laser tracker with the RCMMS DAQ.

**Recommendations:**

1. The committee is concerned about the laser trackers ability to follow the probe inside the ~ 12 m-long warm bore and measure the probe position with accuracy of 0.1 mm. We suggest performing, as early as possible, a test using the long warm bore.
2. Attach the cable moving the probe to the radial probe center, minimizing the effect of possible probe bending.
3. Assemble a model of the cable spooler to show a “proof of principle” check and perform a test of the Cable Capture Device

**Are there any significant risks associated with the rotating coil system development?**

Yes, the committed agrees with the presented risks.

**Comments:**

None

**Recommendations:**

1. Promptly start to discuss with the project and department management the need of resources to finish the RCMMS.

2. Start the purchase of the required DAQ electronics as soon as possible to mitigate any risk of purchase delays.

Review Team:

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| --- | --- |
| Name | Company/Position |
| K. Badgley | FNAL/TD Physicist |
| S. Krave | FNAL/TD Engineer  |
| Velev, George (Chair) | FNAL/TD Physicist  |

**Goals and Charge**

In preparation for Q1/Q3 cryo-assemblies horizontal test we are building new rotating coil based magnetic measurement system. Measurements of a 36ft long cryo-assembly with two MQXFA magnets inside is a challenging task. Dedicated probe motion system is developed for harmonics measurements along the magnetic length of the magnet. Long signal and probe drive cables for the rotating coil system also require a dedicated support system – the cable spooler.

The goal of this internal review is to assess the rotating coil system design, including the probe motion system and the cable spooler.

The reviewers are requested to answer the following questions:

* Are the rotating coil measurement system requirements well defined and technically achievable?
* Are the rotating coil system hardware and software components adequate for the proposed measurement system requirements?
* Are the probe motion and cable spooler hardware adequate for the horizontal magnetic measurements at stand 4?
* Are there any significant risks associated with the rotating coil system development?

Brief close-out presentation is expected after the review meeting, while a written report is expected within one week.

**Committee**

K. Badgley, G. Velev (chair) and S. Krave

**Date and Time**

June 8th, 2018 starting 9:30 am

**Location/Connection**

IB1 conference room

**Link to talks and agenda:**

<https://indico.fnal.gov/event/17234/>