BNL Quarterly Report on Superconducting Magnetic Energy Storage Prepared for ARPA-E Through CRADA No. BNL-C-11-01 With ABB Inc.

Q14 Progress Report and Status of Milestones

Superconducting Magnet Division
Ramesh Gupta, Piyush Joshi, S. Lakshmi Lalitha and P. Wanderer

BNL Project Manager, James Higgins

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Ramesh Gupta, Piyush Joshi, S. Lakshmi Lalitha, J. Schmalzle and P. Wanderer

1.7 MJ SMES Coil Assembly

During the previous quarter all (28) inner pancakes and all (18) outer pancakes on their respective steel support tubes were assembled. This quarter we completed full assembly of both inner and outer coils inside their support tube including installing and terminating necessary instrumentation.

The outer diameter of all inner pancake coils and similarly of all outer pancake coils should be the same to a very close tolerance. Also, both must have the conductor on the last turn lined-up so that the superconductor coating side faces outward to make a splice. This job has been completed for both inner and outer layers (28 pancakes for inner and 18 for outer). In addition, all leads and voltage taps have been brought out for all the inner pancakes. Leads from all pancakes have been internally connected so that finally only two leads go to the power supply for each inner and outer layer (coil).We have also applied nomex and kapton buffer layers, which is the last step before the fiberglass epoxy is applied. In addition, a few test runs were made to evaluate details of putting on the fiberglass epoxy.

We continue to perform the high-pot test at various stages of the assembly of both inner and outer coils. During this test a high voltage is applied across the whole set of outer coils to ensure that the integrity of the insulation and other components of the coils is not compromised by the high voltage generated during the energy extraction process after a quench.

The steps required for the items above are explained with a series of photographs taken throughout the process. Figures 1 through 7 are for the inner coil and figures 8 through 18 are for the outer coil.

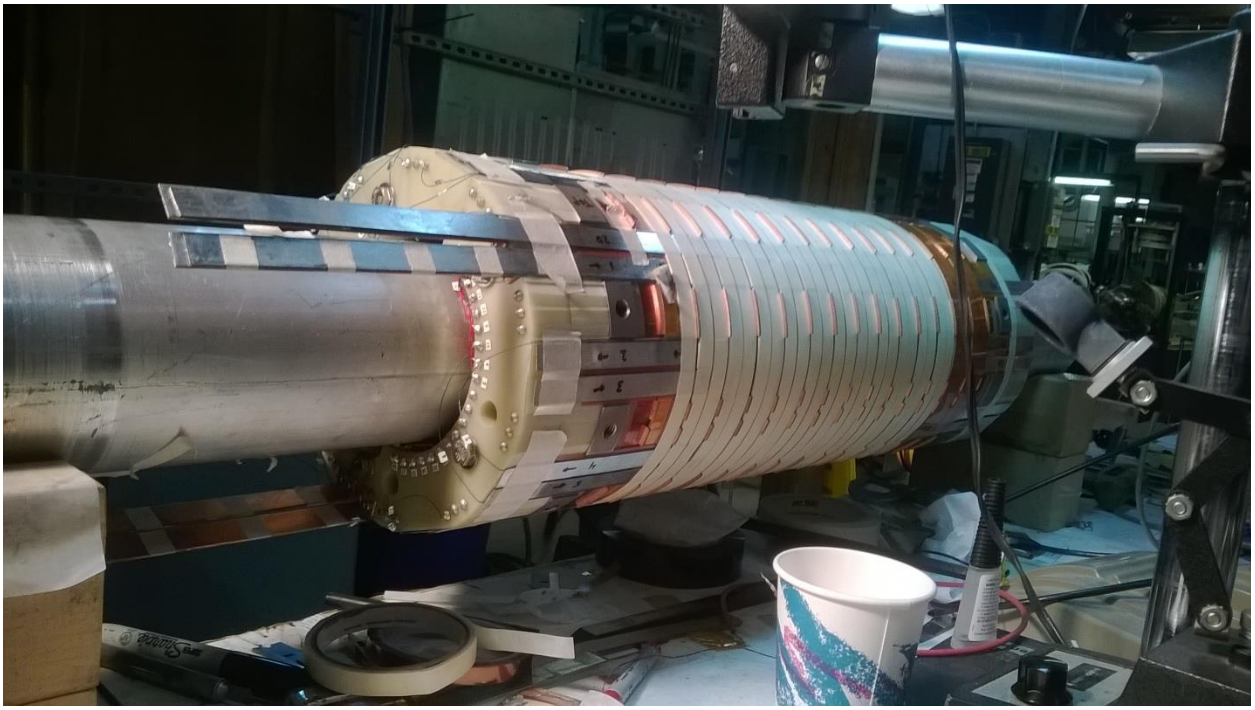

Figure 1: All leads installed, v-taps wires taken out and Nomex filler pieces placed in between and around the leads of the inner layer.

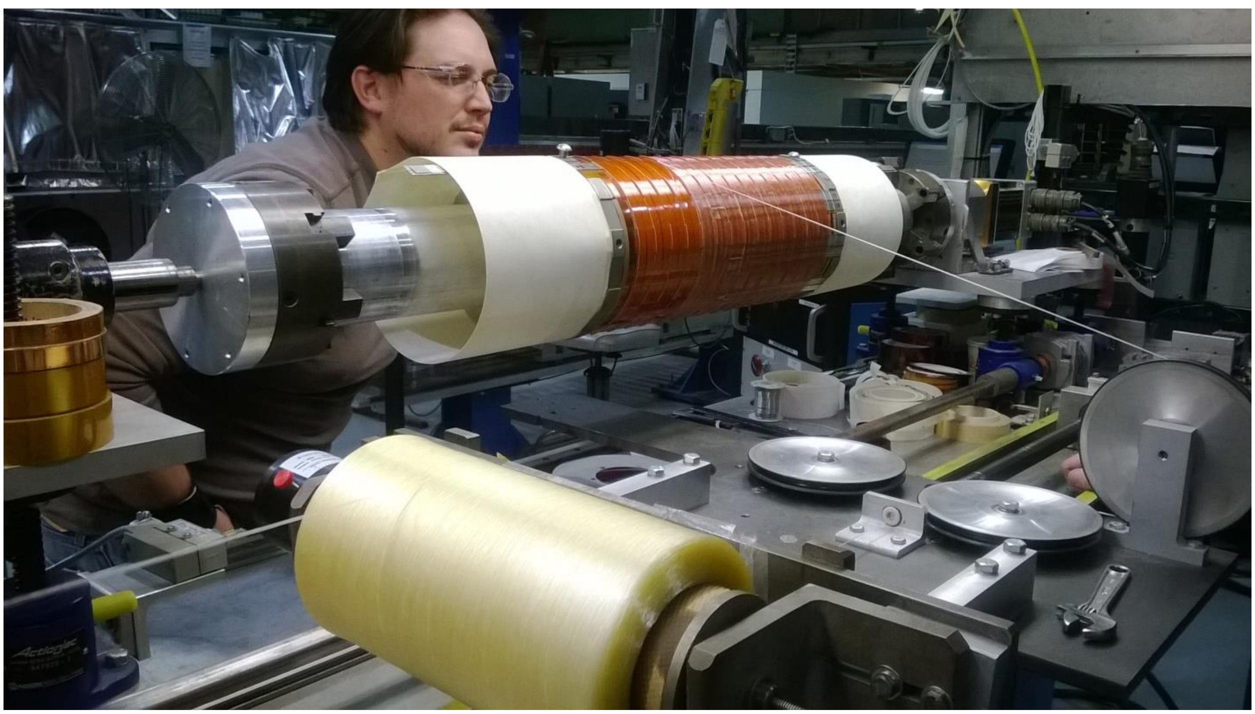

Figure 2: Kevlar string being put over the kapton which covers the inner pancake coil assembly.

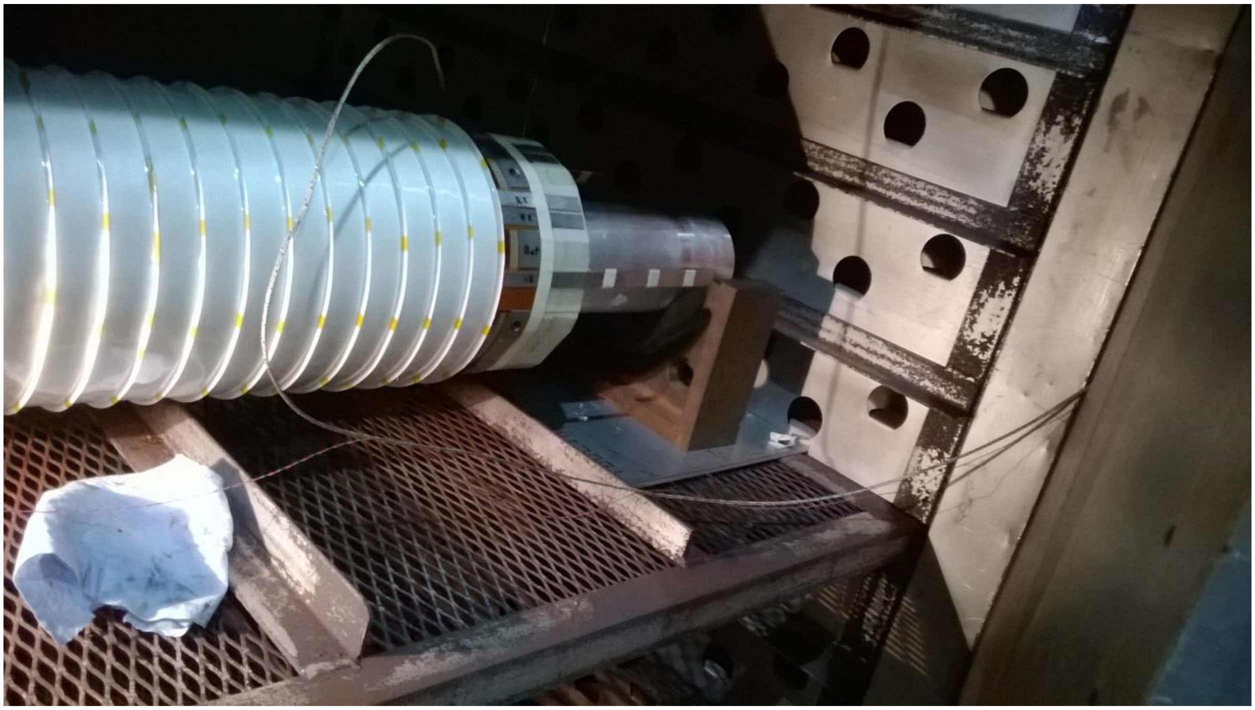

Figure 3: Inner pancake coil assembly inside the oven for curing after fiberglass epoxy tape was wrapped around it.

Figure 4: Completely cured inner pancake coil assembly.

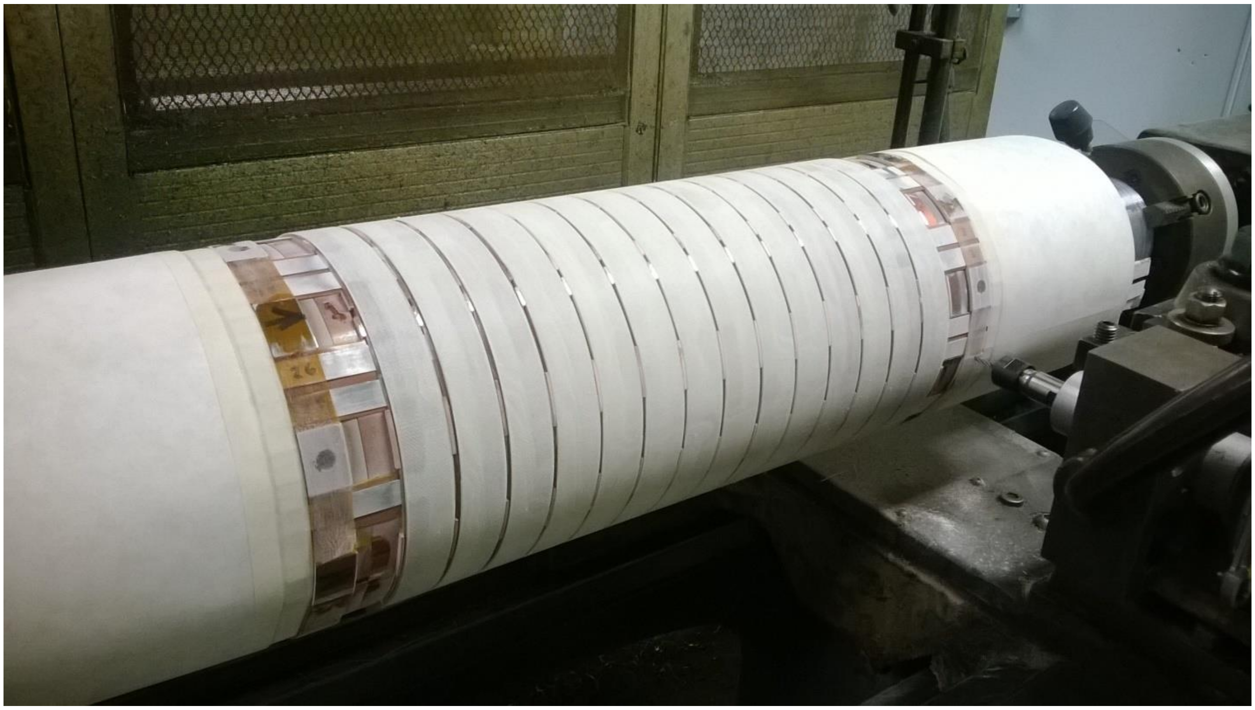

Figure 5: Inner pancake coil assembly after outer surface machined to required diameter.

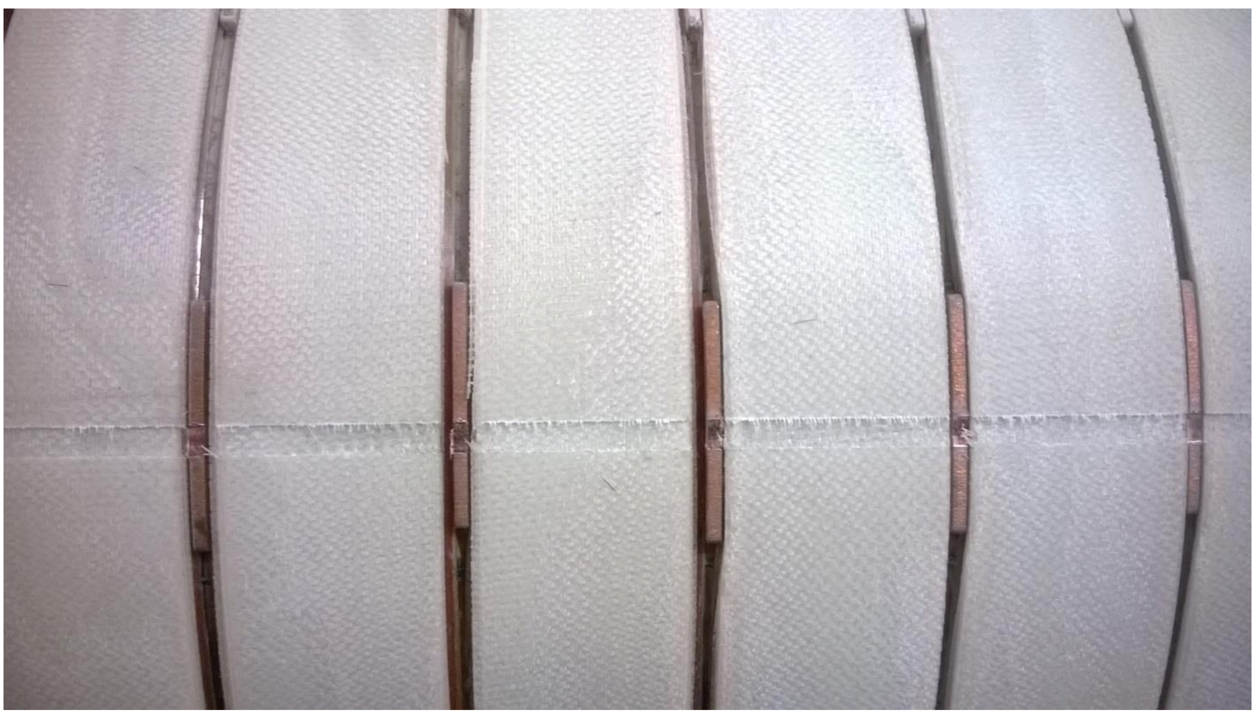

Figure 6: Inner pancake coil assembly with groves cut for helium flow for uniform cooling. One can also see copper discs between each pair of double pancakes to provide more uniform radial cooling

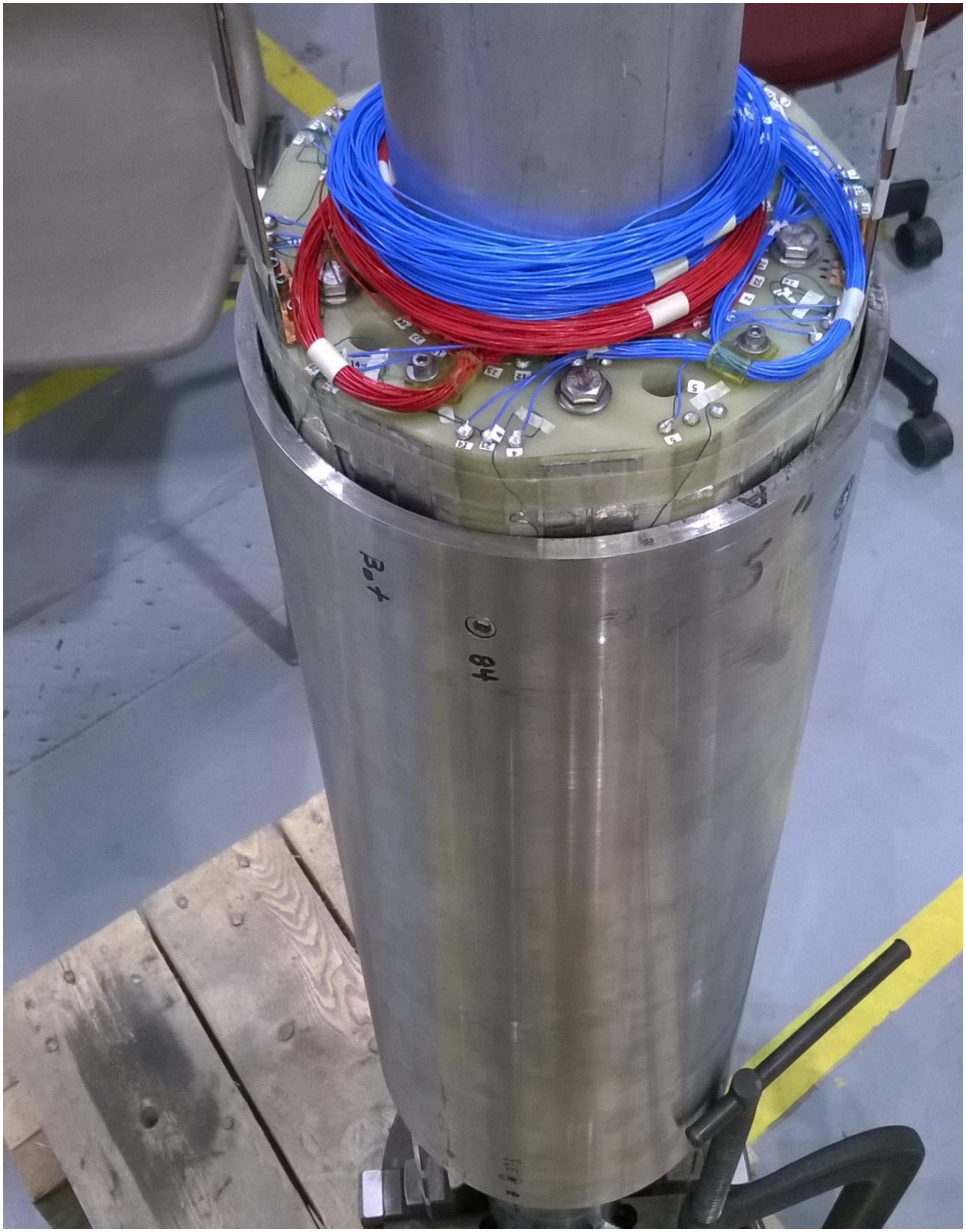

Figure 7: Complete inner pancake coil with outer stainless steel support tube structure installed over the coil. One can also see instrumentation wires (red connected to those coming from inside and blue from outside).

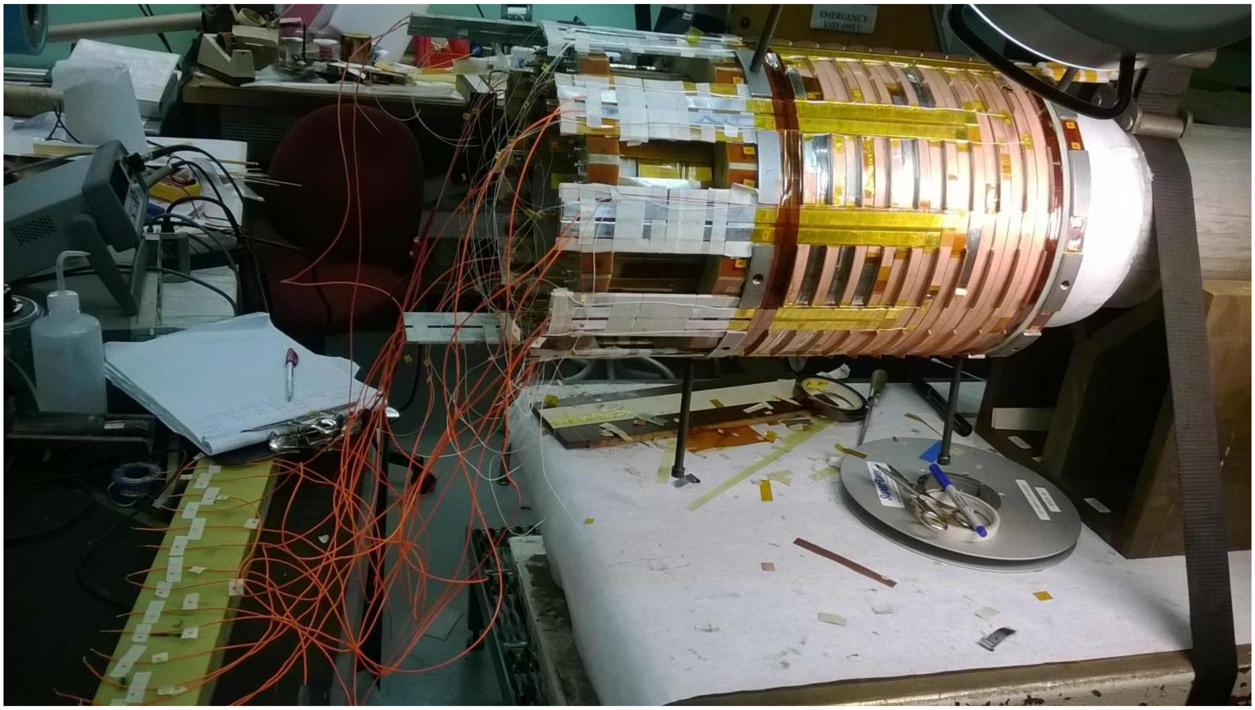

Figure 8: Preparation for high-pot test for outer pancake coil assembly.

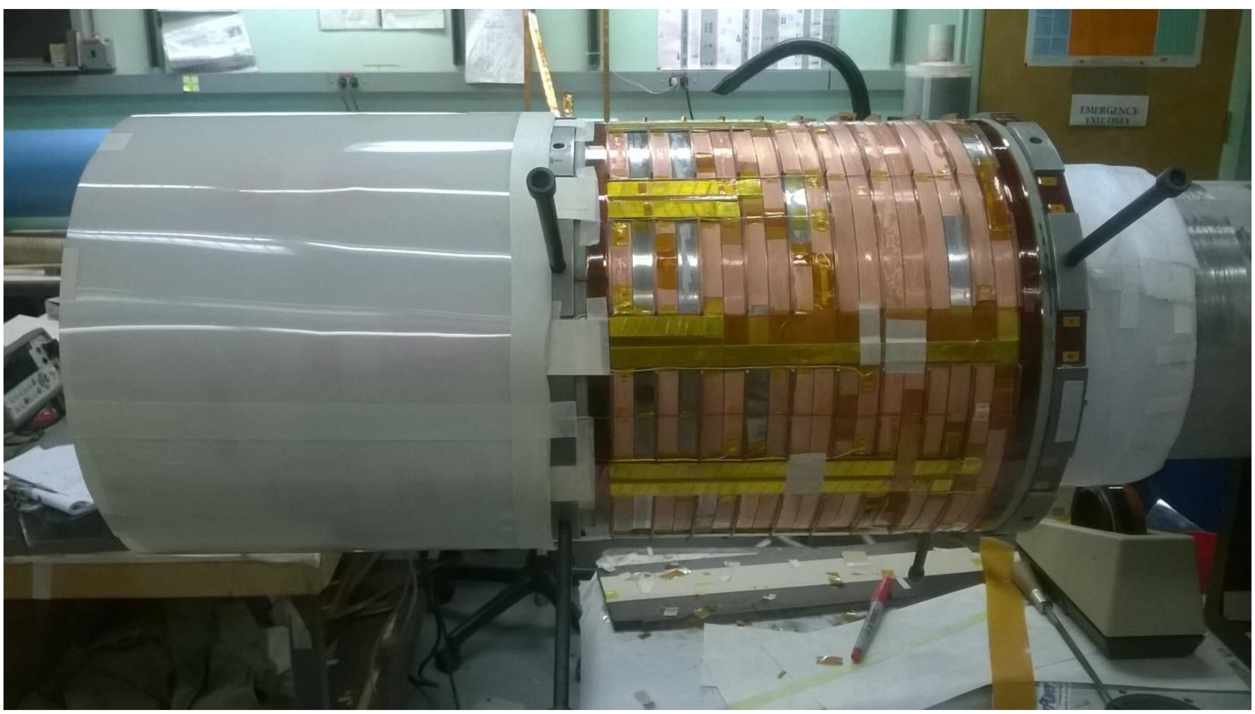

Figure 9: Leads installed (running across axially) for outer pancake coil assembly.

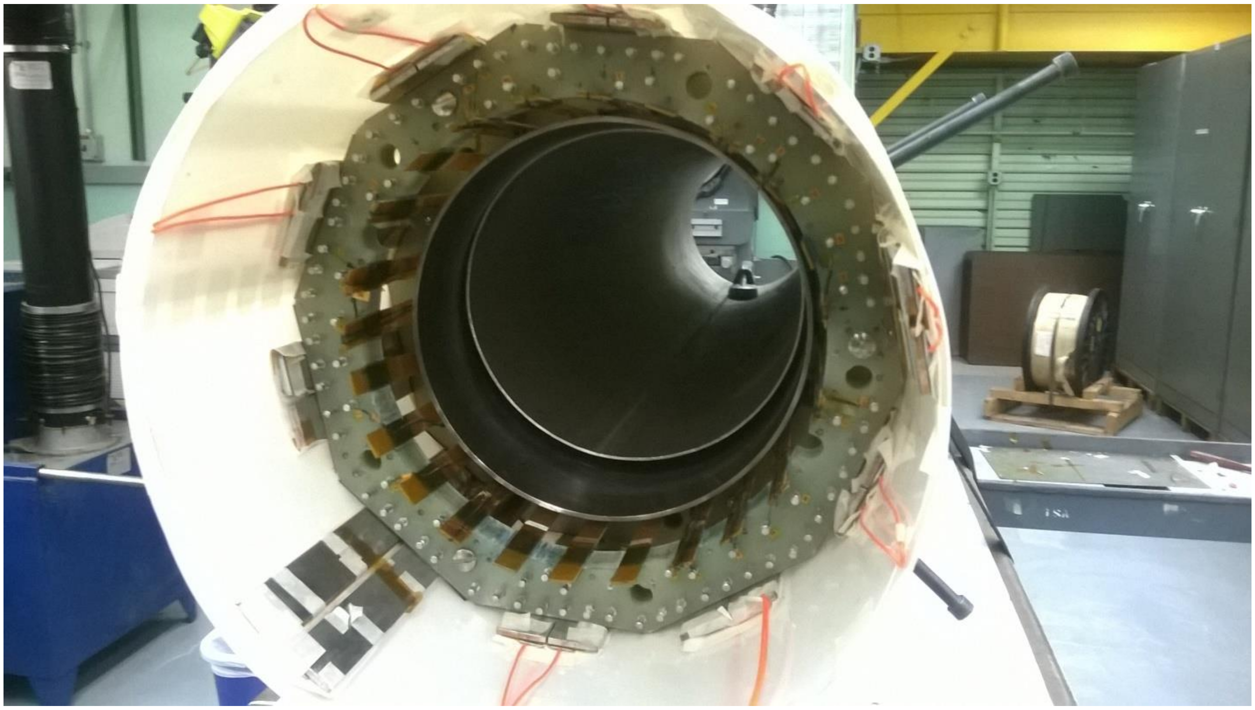

Figure 10: A view of leads, etc. from one side of outer coil during the construction.

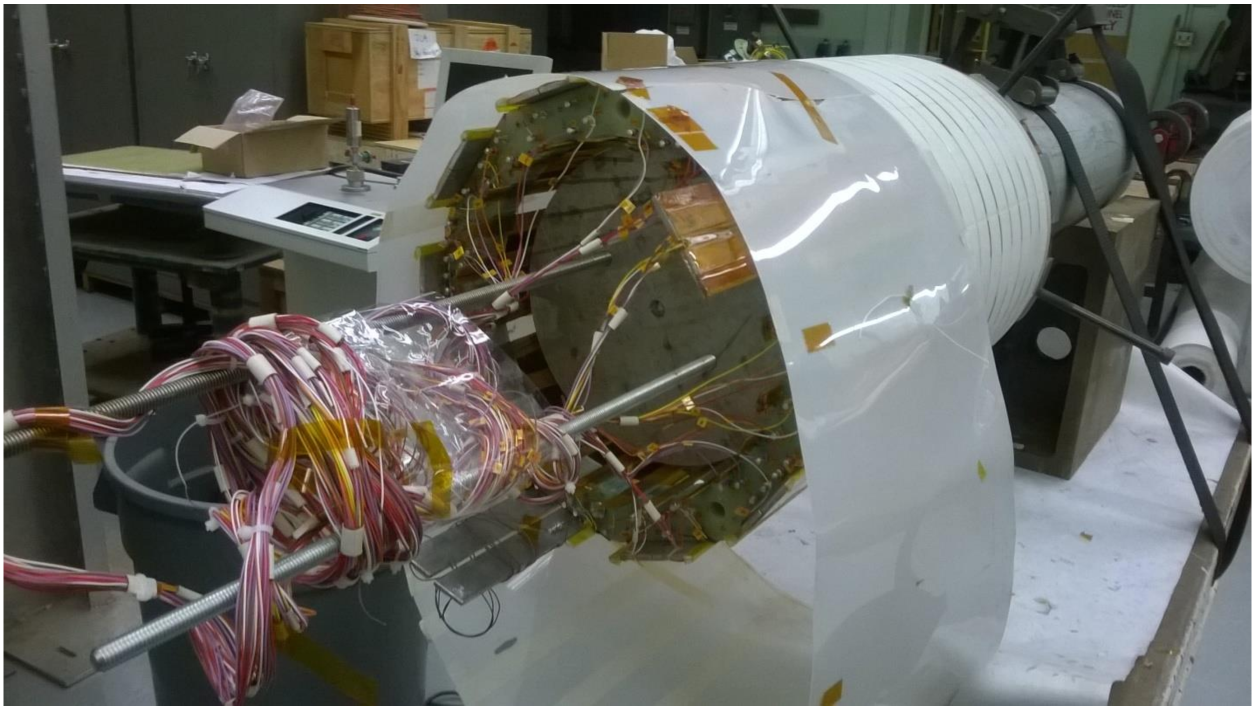

Figure 11: A large number of instrumentation wires installed on the outer coil assembly to monitor onset of any resistive voltage across any pancake or joint during the test. The complete set of instrumentation also includes a number of temperature sensors.

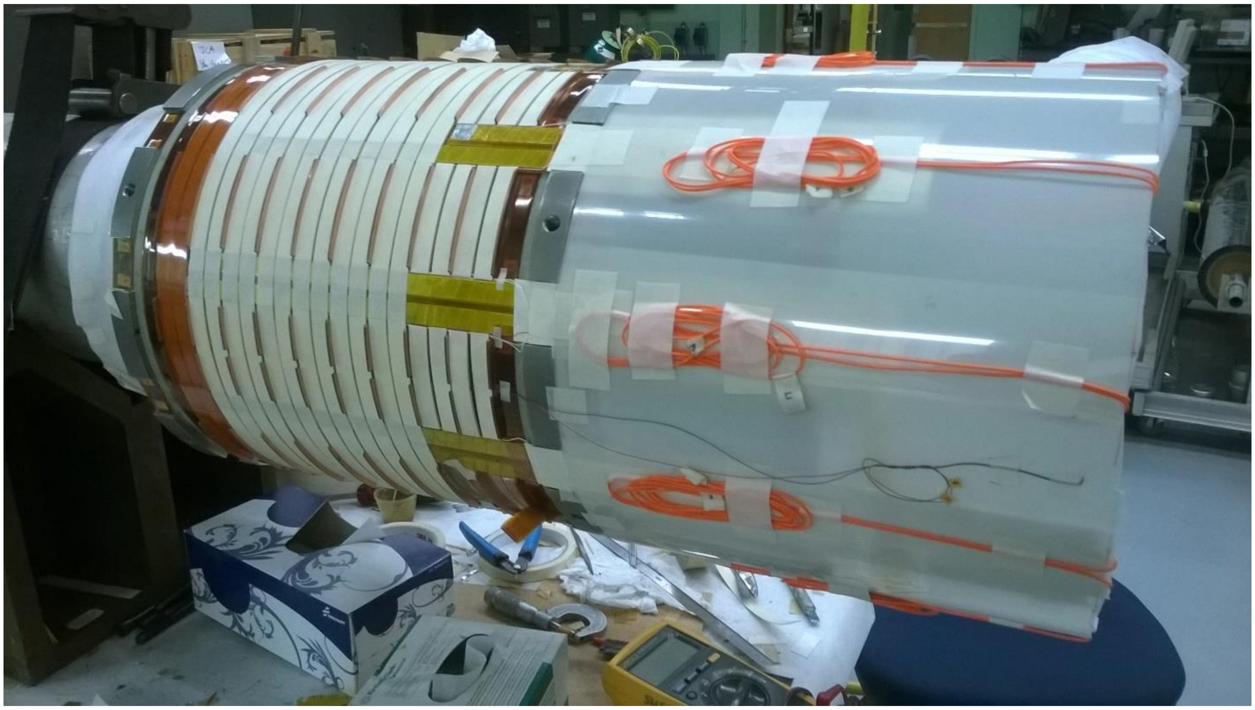

Figure 12: Nomex filler pieces placed in between all leads and around several pancakes of outer layer.

Figure 13: Preparation is being made to put Kevlar string over the outer layer.

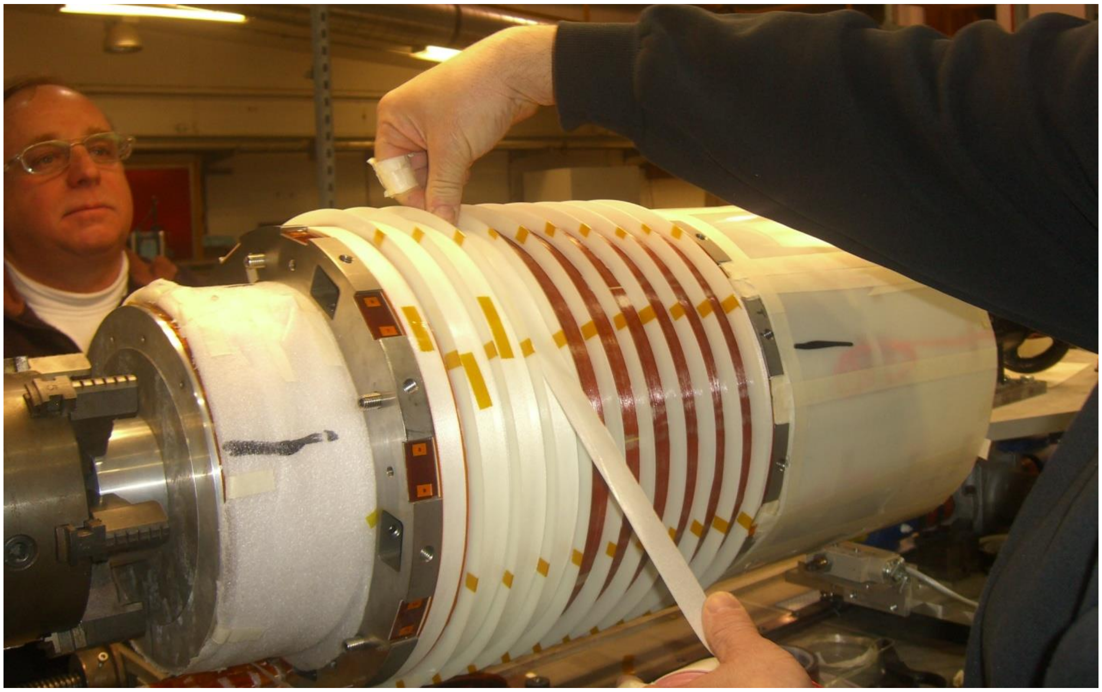

Figure 14: Fiberglass tape is being wrapped over the double pancake of the outer layer before curing.

Figure 15: Outer pancake after curing. The coil is put on the fixture so that the outer diameter of it can be machined to required dimensions.

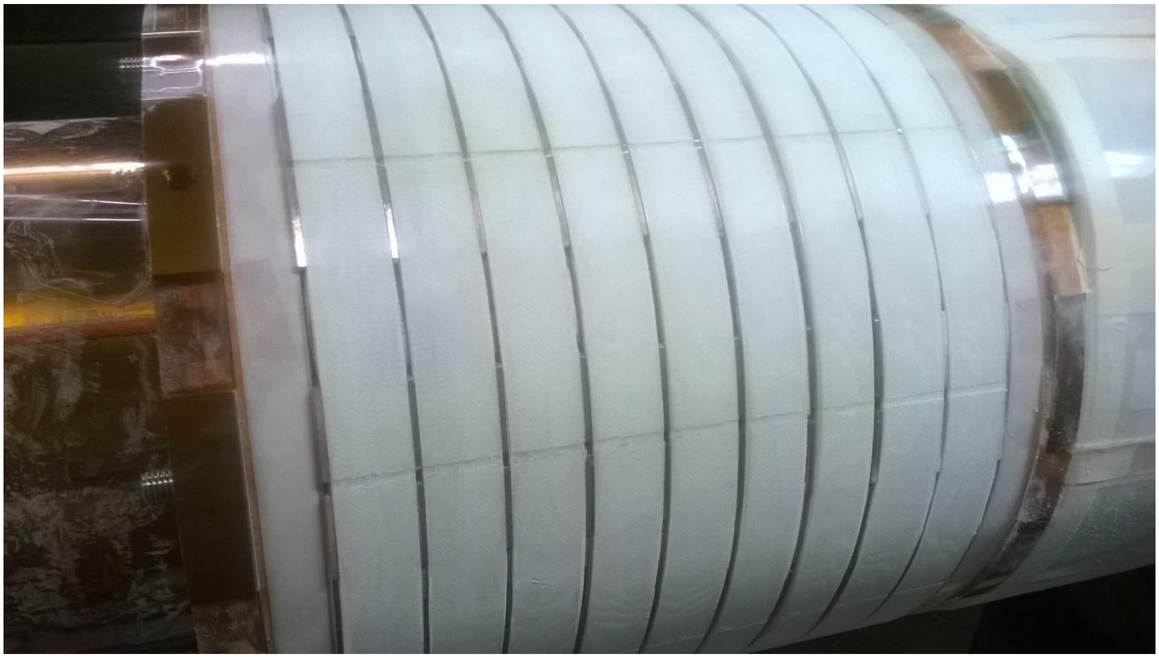

Figure 16: Outer pancake after outer diameter machined to the required dimensions and axial groves for helium cut.

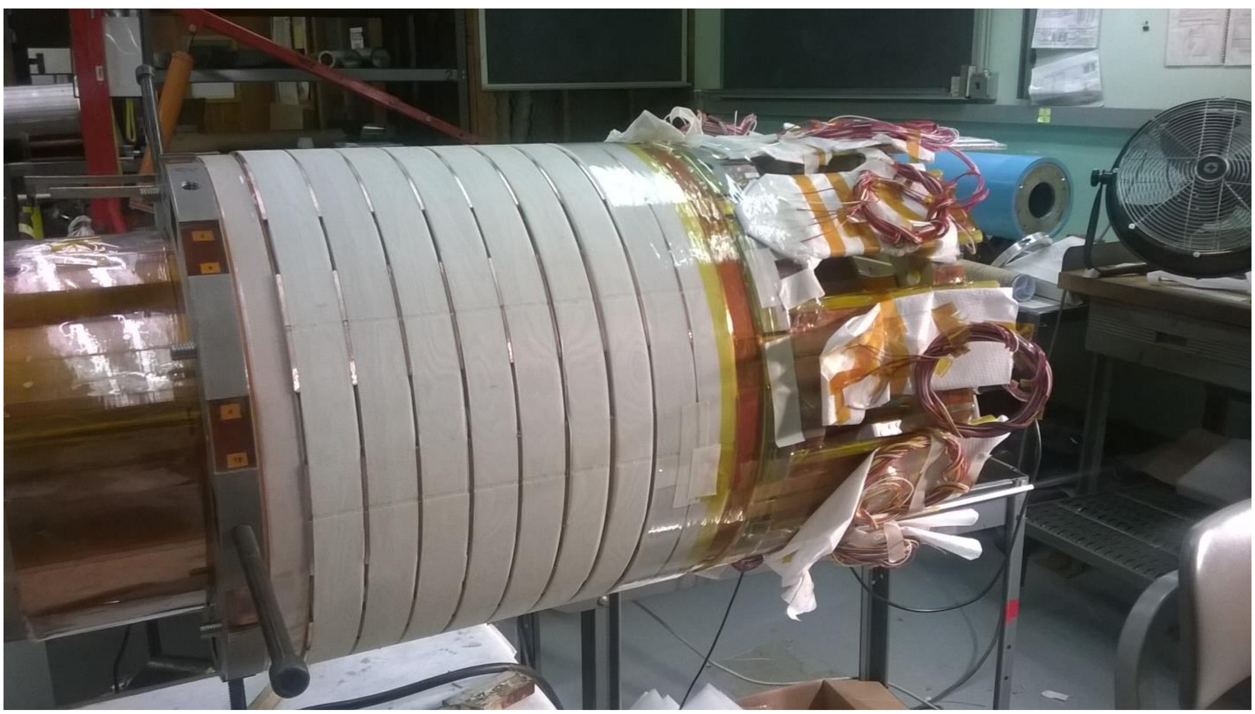

Figure 17: Full view of the outer coil after machining with instrumentation wires.

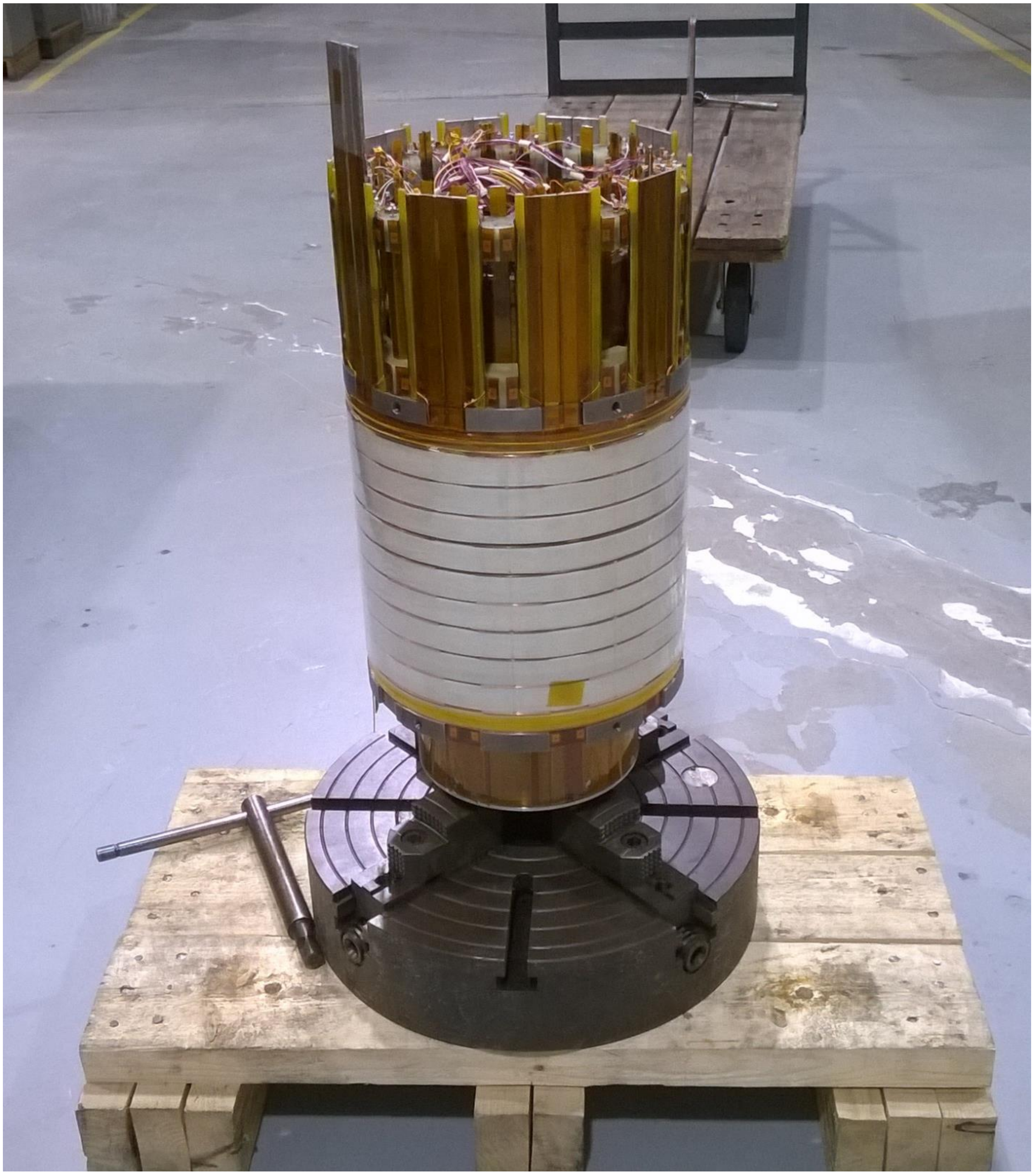

Figure 18: Outer coil being prepared for installation of outer support tube.

Figure 19: Outer coil with stainless steel support tube installed.

Figure 20: Outer coil with support structure being inserted over the inner coil with support structure.

Power Supplies, Advanced Quench Protection and Energy Extraction Systems

Significant work has been performed on the power supplies, quench detection and quench protection system (including energy extraction). There are two power supplies – one for all inner layer and one for the outer as shown in Figure 21. The quench detection and protection system is integrated with the high voltage isolators, as required for 1.7 MJ SMES for fast energy extraction. The system has been assembled in a new larger cabinet, as shown in Figure 22, to accommodate all high voltage isolators and many other components as there was not sufficient space in the previous setup.

After the power supply is shut down following a quench, the energy will be dumped to an external dump resistor. Part of the dump resistor system to deal with 1.7 MJ energy is shown in Figure 23.

The basic quench detection (QD) hardware and software was earlier tested with the coils made for another HTS magnet project, namely HTS quadrupole for Facility for Rare Isotope Beams (FRIB). The QD system was able to protect the HTS coils against the quench when there was an increase in temperature caused by a vacuum leak. The system was recently expanded to allow significantly more channels as needed for the SMES. The expanded quench detection and protection system was also tested with the FRIB quadrupole in the month of March. The test of FRIB quadrupole used the same two BNL power supplies that will be used in the initial testing of SMES. These two power supplies will be replaced by a single ABB power supply (convertor) during the final test.

The test of the FRIB quadrupole also allowed the test of the significant SMES instrumentation package and provides good insights into the test plan to be followed in the SMES test. Figure 24 shows the instrumentation package used during the quadrupole test. A similar package will be used for SMES. Figure 25 shows the test console used to monitor the test run power supplies and debug and optimize the quench detection and quench protection system. A similar system will be used for SMES.

Figure 21: Power supplies for inner and outer coils.

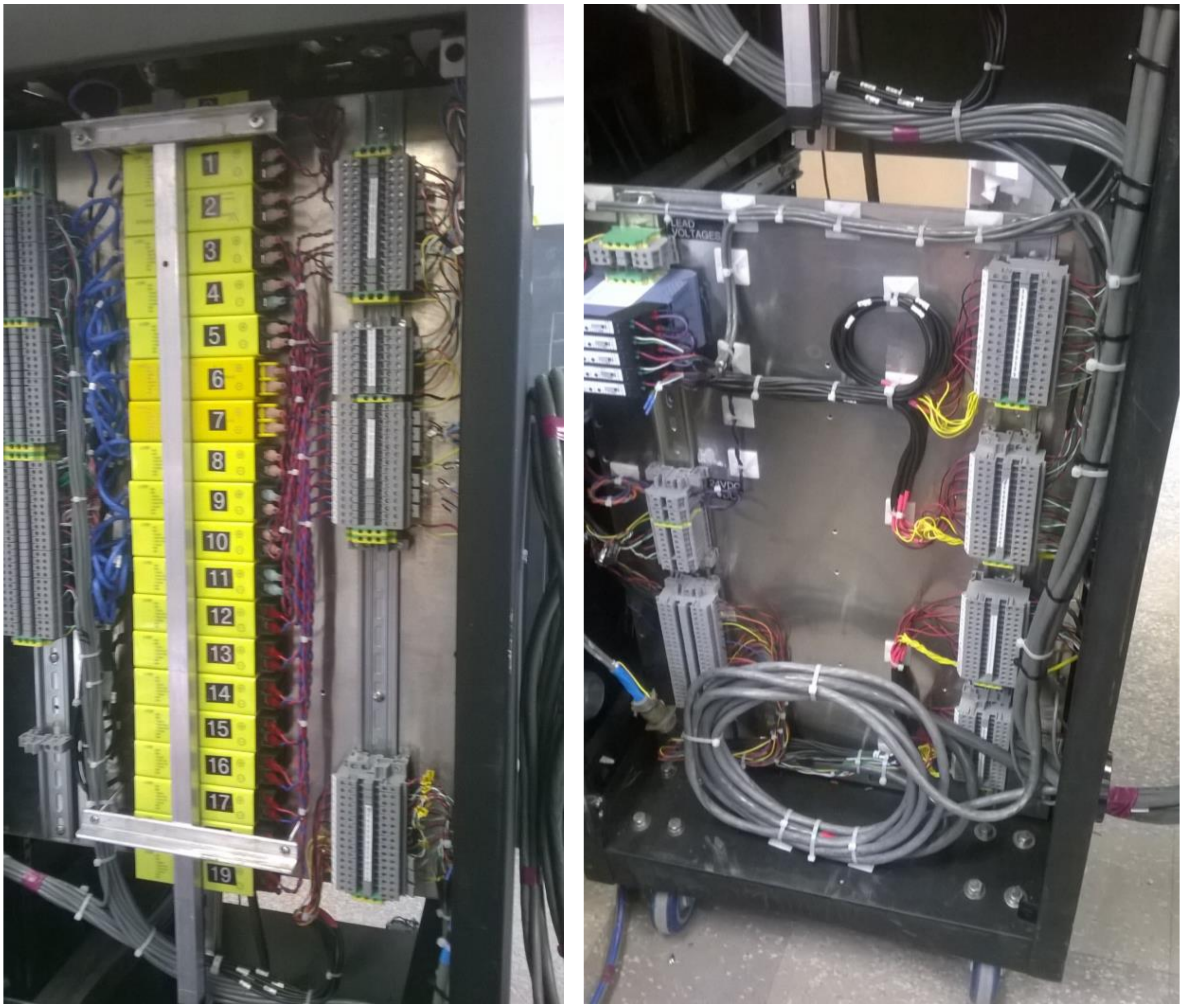

Figure 22: Expanded quench detection and protection system with high voltage isolators.

Figure 23: Part of the external dump resistor system for extracting 1.7 MJ of energy.

Figure 24: Instrumentation package used during the test of the HTS FRIB quadrupole. A similar package will be used for SMES.

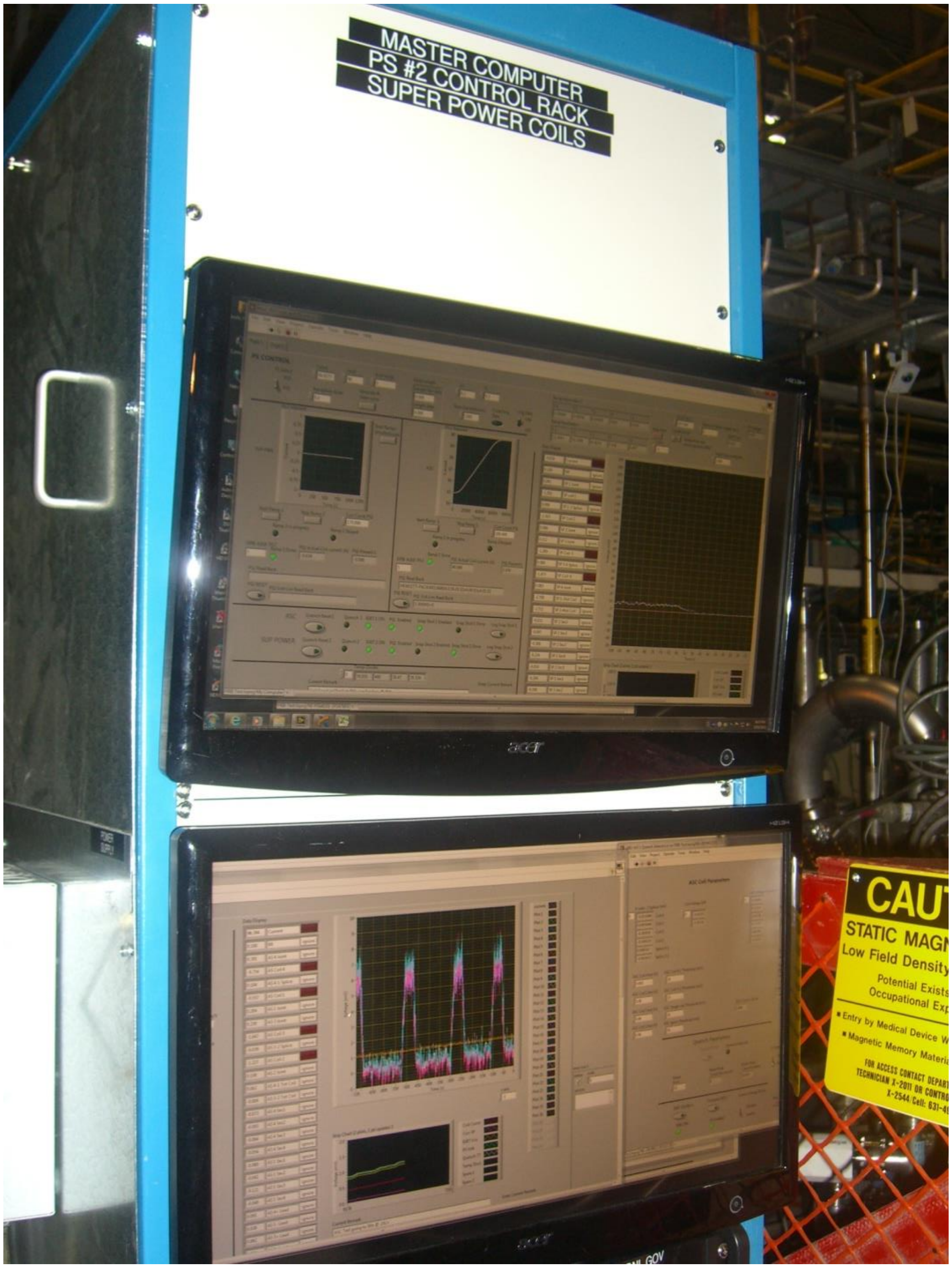

Figure 25: Test console used to monitor the test, run power supplies and debug and optimize the quench detection and quench protection system. A similar system will be used for SMES.

System Integration

Work continued on the Integrated Control System (ICS) and its interfaces with the Superconducting Switch, the Magnet, and the ABB Power Converter. The ICS consists of the quench detection and quench protection (QD&QP) system, real time data logging, energy metering, Converter and Superconducting Switch interface control signals, temperature, field, faults, and other supervisory signal monitoring. Our work included efforts to finalize the hardware and software for the ICS, including the addition of signals for interface between the ICS and both the superconducting switch and the converter. The system has been expanded to allow more channels as compared to those present in the earlier setup. Several modules of the integration software were recently tested on the FRIB superconducting Magnet. We have also worked on plans to ensure the test facilities are properly configured and will be ready for the integrated test.

Software is being further developed for system integration of the quench detection and protection system with the switch and the power convertor.