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

Q12 Progress Report and Status of Milestones

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Preparation of Pancake Coils for 1.7 MJ SMES Assembly

One of the most significant tasks during this period was to prepare inner and outer double pancake coils for 1.7 MJ SMES device. This required removing the large number of voltage taps (see Fig. 1) from all 46 single pancake coils (28 inner and 18 outer) that were used in doing the detailed post-fabrication testing at 77 K. These wires tend to break under large Lorentz forces present at high fields and are not required for the final test. In addition, the 12 pancakes that were used in meeting Q6 milestone, will be used in the full SMES. Therefore, the Q6 coil has been taken apart and all pancakes are recovered. We noted some marks on the copper discs. Also, the Mylar insulating sheets used between double pancakes, have been penetrated. Nonetheless, the key components – the pancake coils - appear to be in good form. New Mylar sheets and copper discs will be used for the final 1.7 MJ coil. The coil surfaces are cleaned and prepared for the final assembly which will have copper disks (as shown in Fig. 2) on either side of each double pancake.

Since the thickness of superconductor tape varied significantly, the o.d. of the inner and outer pancake coils also varied significantly. All coils must have the same o.d., which is determined by the smallest coil. Therefore we had to remove turns from the pancake coils, as needed. We prepared all (28) inner pancake coils and all (18) outer pancake in the form that they can be used in the full SMES. This required putting new voltage taps at the inner radius of each pancakes.

We also assembled all the inner coils onto the inner support tube and ten of eighteen pancakes (five of nine double pancakes) of the outer coils on the outer support tube. Assembly includes machining of the parts, structure to coil insulation, coil-to-coil insulation, copper disks (see Fig. 2) to increase the uniformity of coil cool-down and voltage taps. Assembly (e.g., arranging voltage tap wires so that they are not dislodged by the coils) required great care.

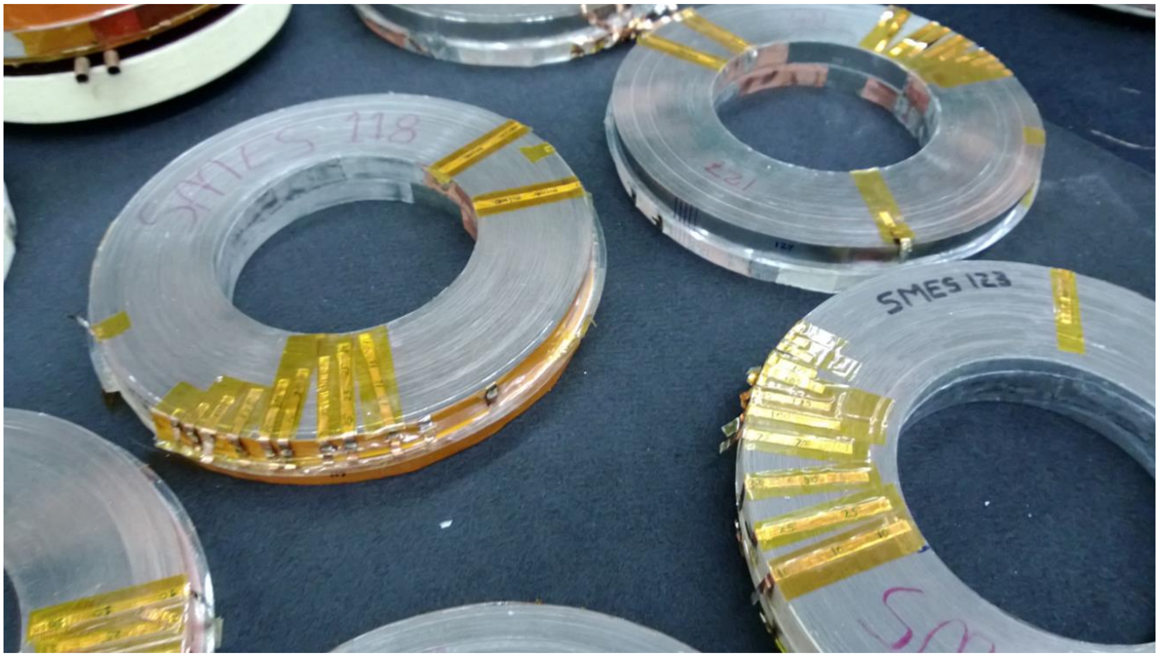

Fig. 1: HTS double pancakes with number of voltage taps foe QA testing. These v-taps are removed for final assembly.

Fig. 2: Copper disks for inner and outer coils. These copper disks will be placed on either side of each double pancake during the final assembly.

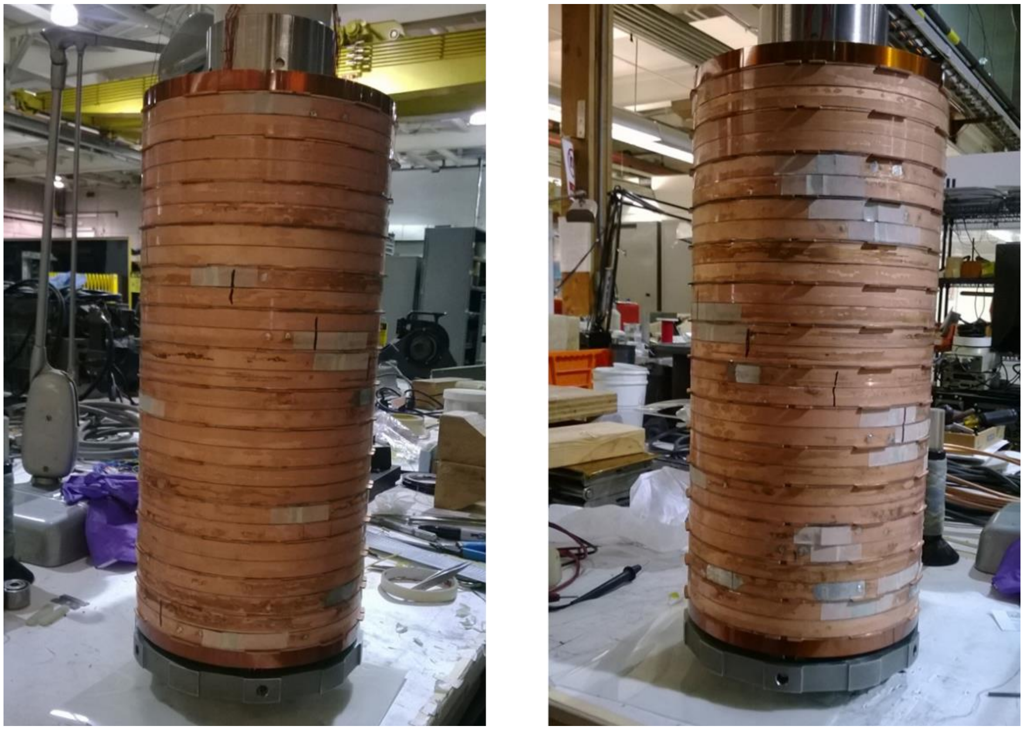

Fig. 3: Inner coil consisting of all (28) HTS pancakes assembled on the inner tube.

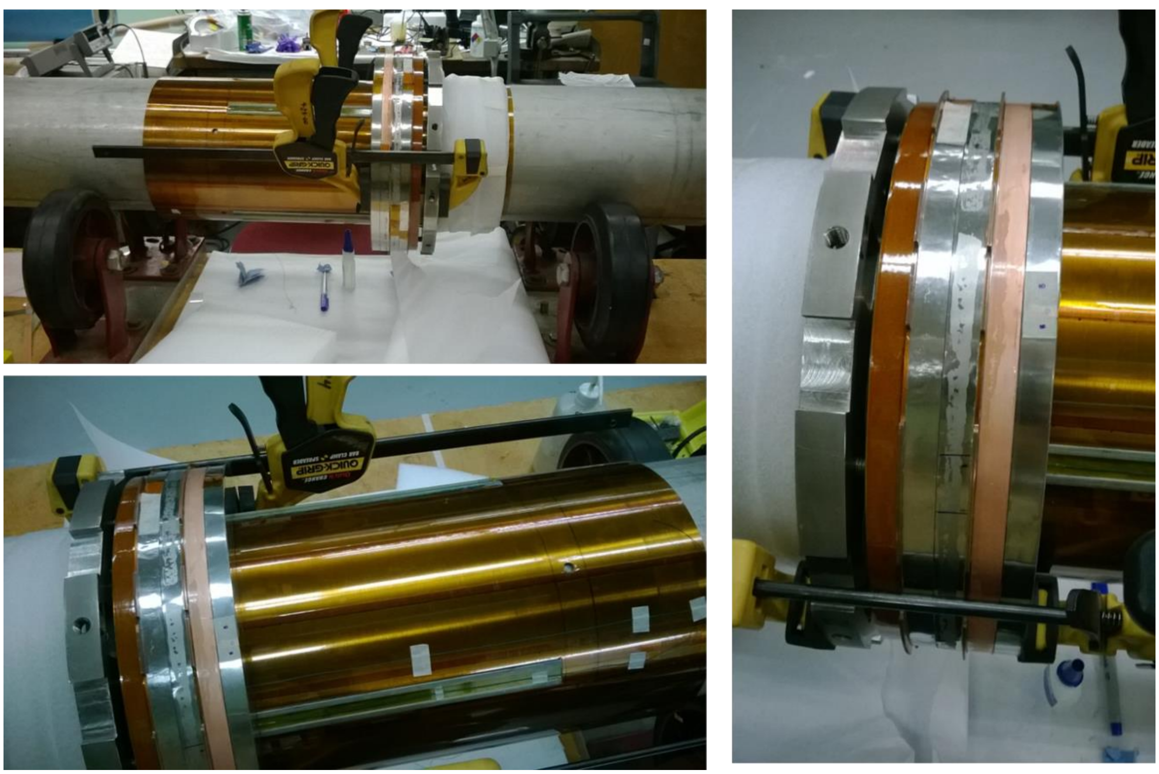

Fig. 4: Outer coil being assembled with the HTS pancakes on the inner tube of outer assembly.

Construction and Machining of Components of 1.7 MJ Support Structure

The SMES design being developed under this proposal is based on very high field magnet (24 T) that requires a robust support structure. Some of the components of SMES are shown in Fig. 5. A selected set of components are shown in more detail in Fig. 6. Several components of the support structure are manufactured on site but many had to be procured from outside. Additional machining work was required on a number of parts of support structure to ensure that they all fit well and in addition secure the coils and leads well. This is consistent with the experience with the other projects.

Once the coils are assembled, leads will be installed and fiberglass tape will be wrapped. Finally, all coils will be machined to a constant outer diameter so that there is minimum gap between the coil and support structure. A simulation of this important process was carried out on a dummy coil and the results are shown in Fig. 7.

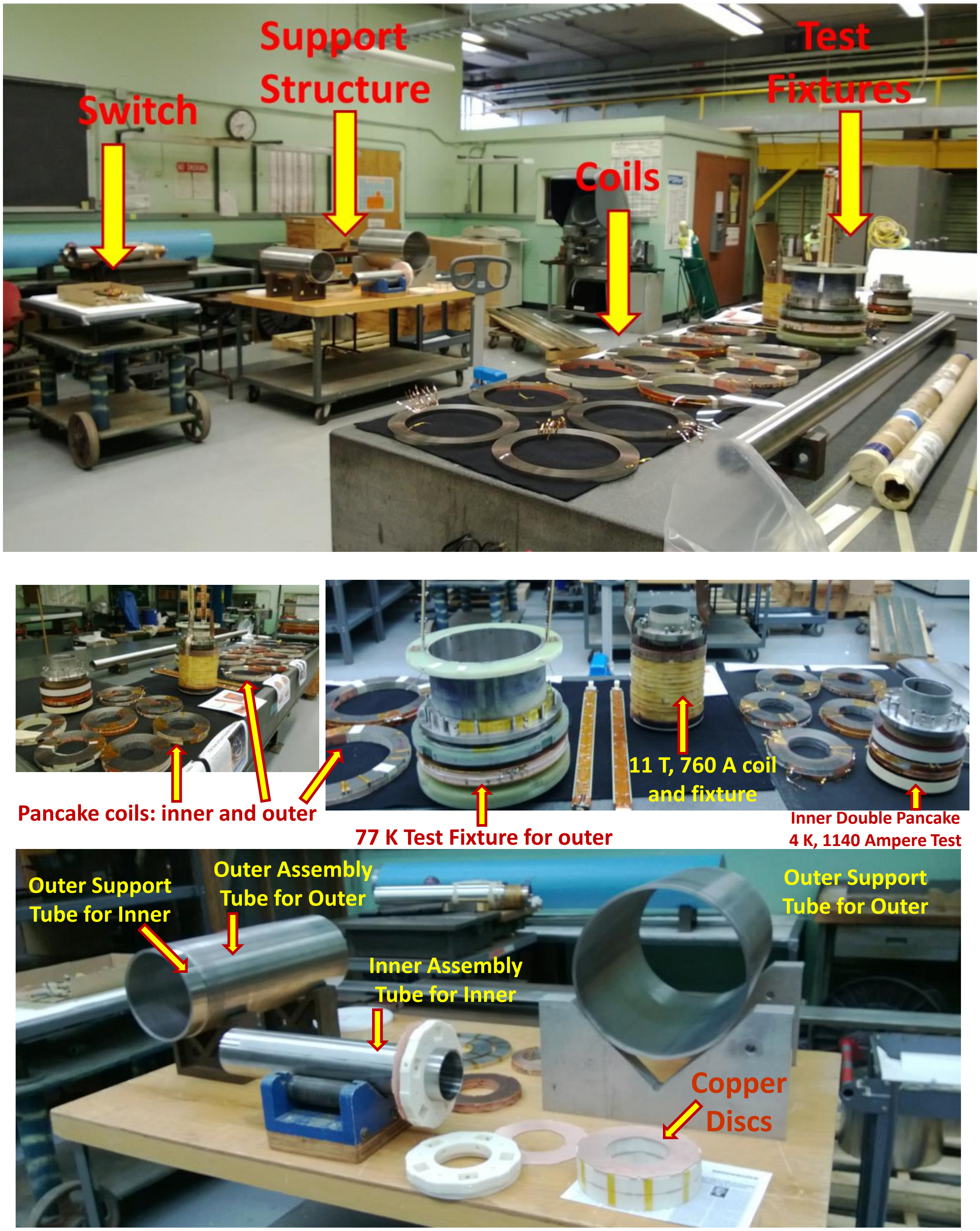

Fig. 5: Various components of high field SMES (coil and support structure).

Fig. 6: A select components of high field SMES support structure shown in more details.

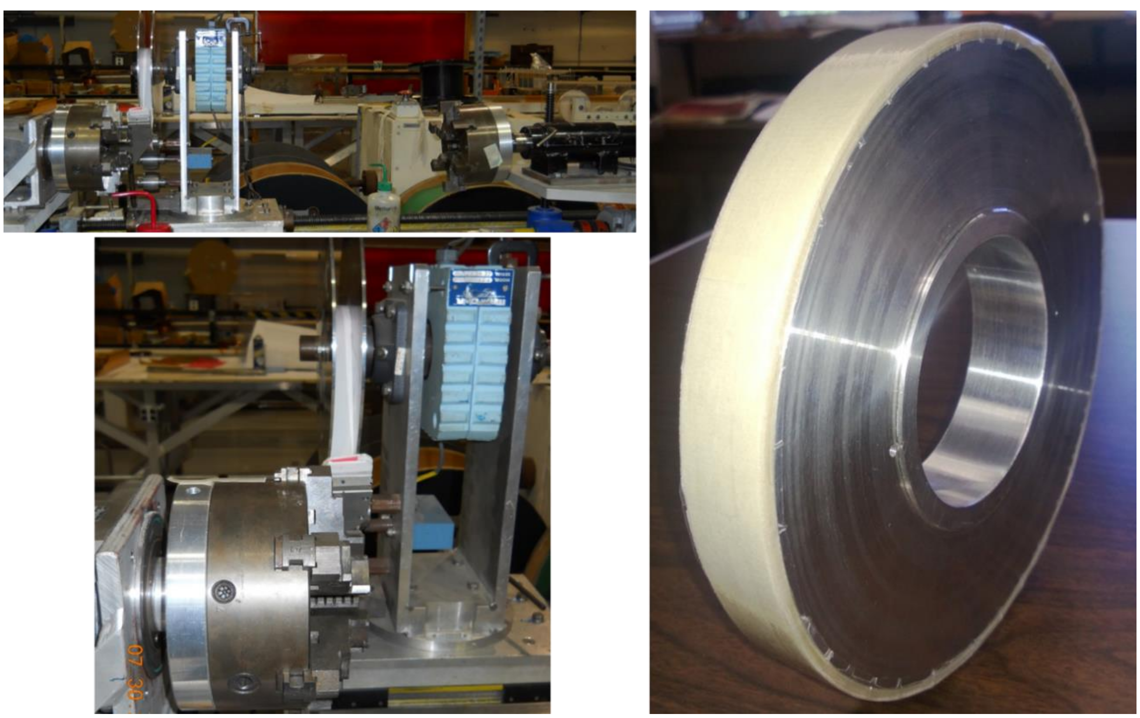

Fig.7: Simulation of wrapping and machining of fiberglass-epoxy wrap on the coil.

Advanced Quench Protection and Energy Extraction Systems

The quench detection and quench protection system has been primarily fabricated (Fig. 8). One significant remaining task is installing the high voltage isolators with +/-500mv input and +/-10V output with isolation in range of 2KV to 3KV. After evaluating isolators from Knick and Verivolt, we placed purchase orders from the special funds made available by the laboratory management. All components have been received.

We continue to test the quench detection and quench protection system. We recently debugged and field tested this system with two magnets built for other projects. The first test was with a superconducting solenoid for RHIC e-lens system that has similar inductance as the SMES coil. The second test was with an HTS magnet for Facility for Rare Isotope Beams (FRIB) built with the similar conductors as SMES (Fig. 8). A significant amount of instrumentation related to quench detection and quench protection system that was used in this HTS magnet test will be used in SMES also. The quench detection system successfully detected a small quench threshold voltage and quench protection system was able to extract significant amount of energy to protect the coil made with 12 mm wide HTS from SuperPower.

Fig.7: Quench detection and quench protection hardware ready for test.

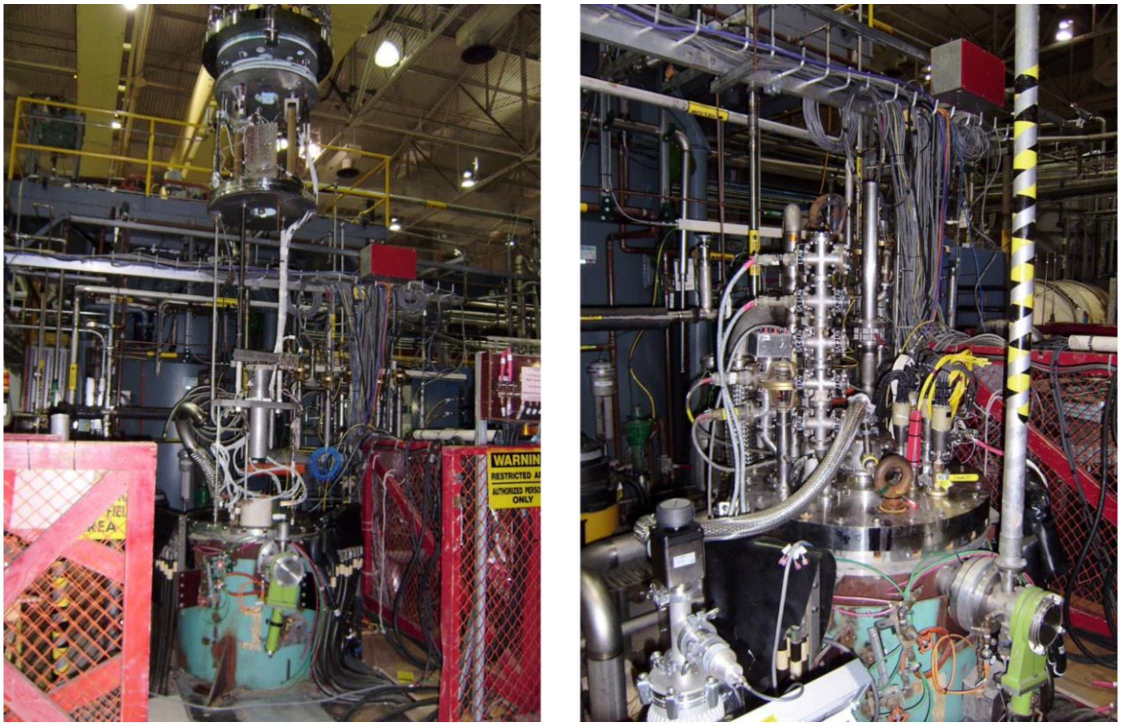

Fig.8: An HTS magnet in the vertical test Dewar with installed instrumentation. The same test Dewar and a large amount of the same instrumentation will be used during the SMES testing.

Tasks for Plus-up Work

We made significant progress on several tasks of “Plus-up” work. It was necessary to do them earlier to maintain our overall schedule. Specifically we have partially completed subtasks (a) divide coil in two sections so that the energy from coils can be extracted in separate sections, and (b) make enhancement in two power supply/electronics systems. In addition, we have completed subtasks (c) make four copper leads, modify cryo-test station for leads and instrumentation.

Moreover, we recently tested the high current leads, mentioned in the subtask (c) above, in a magnet built with conductors similar to those in SMES. That test demonstrated that each lead can carry 375 A; since two of them will be used in SMES, the test verified the ability of these leads to carry 700 Amps with some margin.

We continue to work on the system integration. A sketch of the proposed integrated system is shown in Fig. 10.

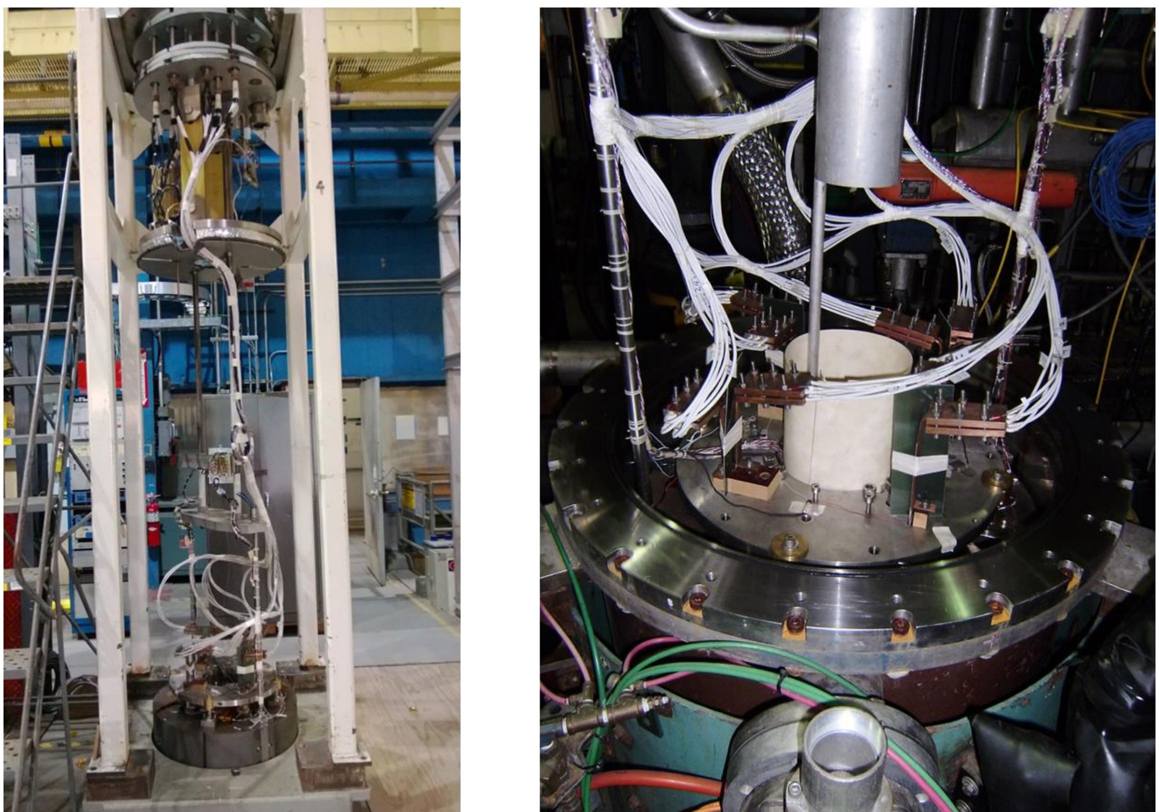

Fig. 9: High current (7000 A) copper leads (white) that will be used in SMES testing was recently proven to work.

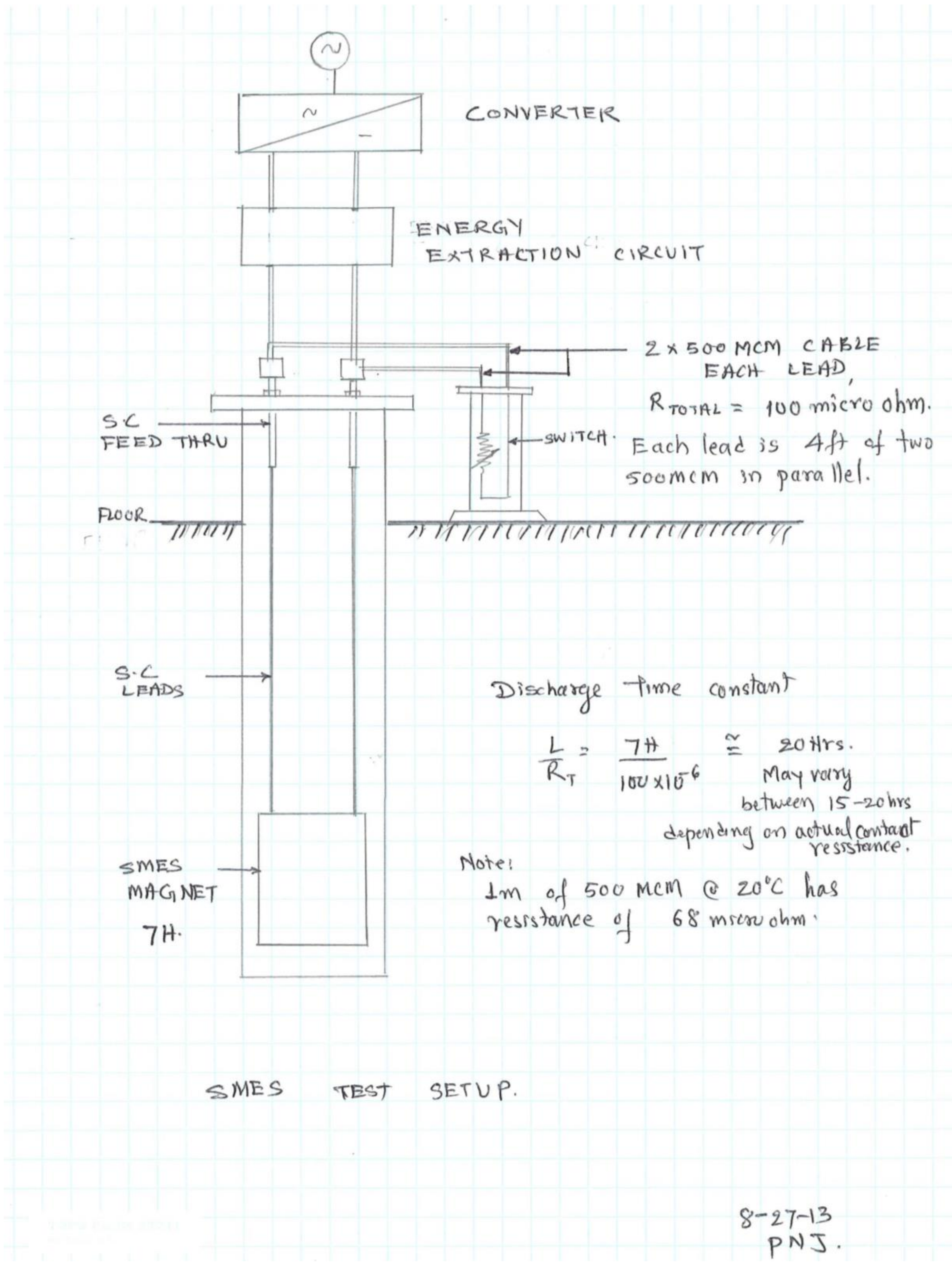

Fig.10: A proposed SMES test setup.