Using Lunar Superconducting Magnetic Energy Storage (LSMES) for NASA Artemis Program

M. E. Evans[1], A. Ignatiev[2,3], [1]NASA-JSC, Astromaterials Research and Exploration Science (ARES), Houston, TX 77058 (Michael.E.Evans@nasa.gov); [2]Metal Oxide Technologies, Inc., 8807 Emmott Rd, #100, Houston, TX 77040; [3]Depatment of Physics, University of Houston, Houston, TX 77204 (Ignatiev@uh.edu)

Introduction: The development of High Temperature Superconductors (HTS) with transition temperatures >91K allows for their application in the Permanently Shadowed Regions (PSRs) on the Moon, where temperatures range from ~40K-60K. These are well below the critical temperature, Tc for the $YBa_2Cu_3O_{7-x}$ HTS material. An HTS coil installed in a PSR would not require cooling to remain below Tc. The coil can be energized with solar panels during daylight and maintain a magnetic field during night. The coil can be loaded and unloaded in millisecond time scales. The long lifetime with minimal losses is an attractive option for NASA's Artemis program to consider for energy management on the Moon.

Experiment: Innovation funding from NASA in 2019 provided an opportunity to fabricate and test a LSMES coil. A 40cm double pancake coil was fabricated with a stainless steel bobbin structure that was wound with 350 m of HTS wire tape segments joined together. A fabricated persistent switch built from HTS wire loads the coil with energy when the switch is heated, then isolates the coil when the switch is cooled to Tc (See Figure 1). METOX encountered numerous problems generating the HTS wire causing a delay in testing until 2021. Joints connecting the wire segments create resistance which dissipate the coil energy over time.

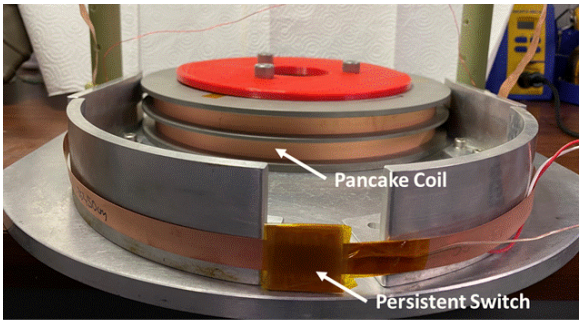

Figure 1: NASA LSMES Coil Prototype

Results: The coil was tested in liquid nitrogen at 77K. The fabricated coil created a magnetic field of 0.17T with 70A loading, but a field of 3T could be tested in a future cryocooler with the system at 40K. Energy decay in the system is shown in Figure 2:

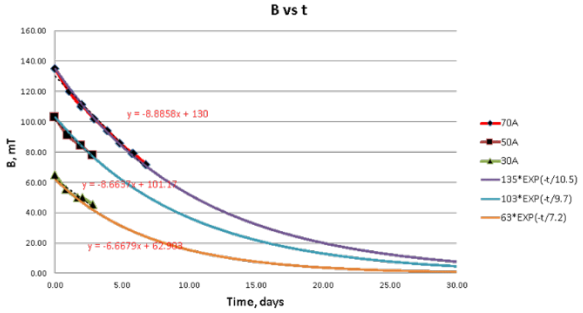

Figure 2: NASA LSMES Coil Results

The goal of this experiment was to store energy for 14 days in the LSMES coil. The fabricated coil contained only 350m of HTS wire (originally planned for 500m). The maximum current for this coil to maintain superconductivity at 77K is 90A. The coil, loaded at a 70A current, created a magnetic field of .14 mT and dissipated energy over 7 days from resistance in the wire joints.

Future: The HTS wire is coated in copper on both sides for terrestrial uses. The copper provides stability on both sides of the HTS core, and makes joining segments easy with solder (See Figure 3). This is impractical for spaceflight that requires a less massive fabrication.

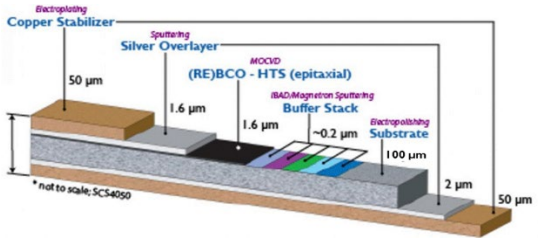

Figure 3: HTS wire fabrication components

Longer segments of fabricated wire with less joints reduce the dissipation from internal coil resistance. Lastly, use of a cryocooler to test the coil at temperatures <77K is necessary to demonstrate increased energy density efficiency at anticipated lunar PSR temperatures.