Report of the External Oversight Committee for the HTS Cable Test Facility

ZOOM Meeting January 7, 2021

External Oversight Committee Members

- Joseph V. Minervini (MIT Massachusetts Institute of Technology) (Chair)
- Steve Gourlay (LBNL Lawrence Berkeley National Lab) (Co-chair)
- Luca Bottura (CERN)
- Luisa Chiesa (Tufts University)
- Danko van der Laan (ACT Advanced Conductor Technologies LLC)
- Ruben Carcagno (FNAL Fermi National Accelerator Laboratory)
- Nicolai Martovetsky (ORNL Oak Ridge National Laboratory)

Program

Thursday 07 January 2021

Presentations: Presentations (08:00-09:30)

time	[id] title	presenter
08:00	[1] Overview of the project	PRESTEMON, Soren (LBNL)
08:20	[2] Test facility preparation	VELEV, George (Fermilab)
08:50	[3] Magnet status	SABBI, GianLuca
09:20	[4] Summary and discussion points	PRESTEMON, Soren (LBNL)

Discussion: Discussion (09:30-11:00)

time	[id] title	presenter
09:30	[5] Discussion	
10:30	[6] Feedback from EOC	MINERVINI, Joseph (Massachusetts Institute of Technology)

General Comments

1. This first introductory meeting was very useful, especially since the majority of the EOC members have had no prior detailed knowledge of this project. But the EOC is overall very supportive of the initiative, because this is a mandatory test capability for the development of next step cables, especially in HTS.

2. Since there was no specific charge to the committee for this review it is not easy to formulate comments. We thus give here a mixture of impressions and specific comments on some details. Nevertheless, the committee welcomes the rather informal but effective way that this project has been set-up, profiting from the coalition of DOE and two major national labs with very well defined tasks.

3. There was some discussion of prior and existing test capabilities and stations, but a detailed overview summary of these facilities, both defunct and still in operation, could be very useful. The project should then profit from the history with the previous experiments, but also determine which capabilities might be redundant if included in the HFVMTF (High Field Vertical Magnet Test Facility). Besides the U.S. facilities, the summary should include operating facilities in both Europe and Asia. There are substantial operating facilities either under design or operational in China, Japan, and South Korea.

4. We agree with comments from the FES HEP program managers that the design be presented to stakeholders and potential users as the baseline. It should satisfy first the needs of the U.S. HEP and FES magnet research programs and then determine if any further modifications are deemed appropriate, or where else the test can be done. For example, the emphasis should be on testing HTS, but there was discussion about testing small HTS insert coils. It is clear that testing small HTS coils is not useful for fusion as their magnets are dominated by large characteristic dimensions. HEP does have interest in testing small HTS coils, but the importance of this as a requirement needs to be clarified before final parameters and facility requirements are fixed. This is particularly important for the CERN/EU side if one more such magnet needs to be built for inserts because it is crucial for them to do R&D in the range of high field with small coils.

Detailed Comments

The comments are collected under topical areas: Project Structure and Management, 15T Magnet Design, Facility Design, Facility Usage, and Budget and Schedule.

Project Structure and Management

1. The management structure is quite vague. There is a lot more to the project than calling meetings and reviews. Someone needs to be assigned primary responsibility for the day-to-day management of the project. For the next EOC meeting, a clear organization chart should

be created with well-defined Roles, Responsibilities, Authorities, and Accountabilities. It could also be helpful to have at least one member of the management group come from the fusion community who would be in a better position to recognize requirements for fusion conductors and magnets. This person could come from either a national laboratory or university.

2. It might also be useful to add one additional member to the EOC from the NHMFL because of their long experience operating magnet user facilities and could bring a good idea of best practices.

3. The project approach to tailor DOE Order 413.3b guidance for the management of this project, although not required, is a good practice. High overhead elements of this order that bring little value to the nature of this project should be avoided.

4. The project might benefit from a more rigorous approach to the Risk Management process, for example documenting identified risks in a Risk Register along with mitigation strategies. The project is already including substantial mitigation actions in their plan (e.g., planning for a long magnet iteration after the first test), so it would be helpful for future reviews if the thinking behind these actions is documented. Careful attention should be paid to the risk associated with magnetic forces on the structure and potential motion, including adequate materials QC to verify lack of unwanted magnetic behavior and instrumentation such as gravity sensors to verify lack of motion during commissioning (this is a recent lesson learned from the AUP (Accelerator Upgrade Project) vertical test stand at BNL, where after some investigation it was determined that a puzzling motion of the magnetic axis measurement was due to traces of magnetic material in the warm bore causing some bending of the tubes while energizing the magnet).

15 T Magnet Design

1. In general, the committee believes the conceptual design for the 15 T magnet is feasible. But beware, this is an R&D magnet, hopefully achieving 15 T operational. This part of the project should still be recognized as R&D and not just a series production magnet. The wire purchased by CERN (162/169) was in small quantities, from standard sub-elements, adapting the stacks and RRP cans. In some lots OST made them even better than expected, but in others not quite as good. So this is not yet a stable series production material. Cabling, however, is with LBNL and there they are well experienced.

2. The rest of the engineering still needs much work, so the timeline is a bit optimistic.

Facility Design

1. Test pit construction may be advancing too fast. There has been no convergence on facility specifications. The project may become paralyzed by trying to accommodate all requested features. Some open issues include:

a. The design of the lambda plate seal on a large flange. CERN is found issues of sealing a very large flange on the FRESCA2 cryostat. They are still working on the most practical solution. FNAL, BNL, and CERN have a tradition of relatively small test inserts, compared to the HFVM. The project stated that it is evaluating two alternatives for the Lambda Plate sealing. We suggest investigating a third alternative provided by a novel Lambda Plate sealing method used by BNL in their AUP Vertical Test Stand, which seems to be working quite well.

b. The other item is the sample mechanical interface. FRESCA2 is designing for high torque (several kN m), resulting from the demand to test in cross-field conditions. It will also be crucial for HTS cable characterization to measure B_{perp}, hence large torque. Under these conditions the force retaining mechanism becomes difficult. For a bottom and top key, there are insertion tolerances, and the forces have to go through the sample test well and the cryostat back to the magnet. This could be the dominating mechanical effect (i.e. more critical than the centering of the magnet in the pit). Taking the SULTAN test well design into the TFD magnet installed in HFVMTF may not be a working solution. This needs to be considered early, as the sample needs to be integrated from the start.

2. Sample cooling and temperature control is an area that seems to require more attention, especially if a supercritical helium circuit is required. This scope seems to be missing from the plan. Cooling of the HTS CICC in SULTAN is done with forced flow liquid or gaseous helium. Supercritical helium may not be needed for HTS sample tests. An HTS interface between the superconducting transformer at 4.2 K and the sample needs to be developed to allow sample tests at temperatures of 10 – 50 K.

3. The test well dimensions are based on SULTAN well dimensions. Intuitively, the conductors of the future will have higher overall current densities, but also likely will not be much smaller, since evacuation of energy will require increase of the operating current. That is despite that Commonwealth Fusion Systems (CFS) chose half of the ITER size conductors (in diameter or side of the square) due to relatively small dimensions of the machine. Future tokamaks with higher field and stored energy will unlikely use smaller than ITER conductors. From these configurations, the size of the test well is reasonable.

4. The 100x150 mm well size is not feasible for any reasonably sized model coil for fusion. Only conductors for fusion are likely to be tested in this facility. A solenoid with a decent aperture ($\geq$~1 m) like the ITER CSMC or the Chinese Model Coil (under construction) is much more appropriate. But a test in such a facility is much more expensive - $6-8 M a campaign.

5. The uniform length of field of 1 m within 1% field quality is excellent. It is important to have the entire highest stage twist pitch in the high field region so that the current cannot be shorted by strands that never enter the high field.

6. The stray magnetic field line looks strange for a model containing just a dipole and two concentric shields. One would not expect the field lines to look so strange. Perhaps the mesh

is too coarse or there is some other model deficiency. Or it could be due to the presence of some ferromagnetic elements not clearly shown in the model (rebars or something?).

7. In the facility presentation it says:
   - For now, we are replicating the EDIPO sample holder with SC transformer
   - Needs input from the FES community and Oversight Committee.

   The committee would like to see this addressed in the design requirements and description documents. It is not clear if the project has taken into account that it is most likely that cables for fusion magnets will need to be cooled by flowing supercritical helium at variable temperature and pressure.

8. Forces on the sample were not addressed well and need to be analyzed before the Preliminary Design Review. What axial forces are acceptable, and what are the requirements for lateral forces due to misalignment? How is the test well insulated to accept 50 K temperatures in the well and reasonable support to a sample? The situation is different from SULTAN and that needs attention and careful analysis.

9. In regard to the power supply, there was discussion by committee members concerning the requirements and specifications for the power converter units, especially with regard to the specified voltage, stability, accuracy, and ac ripple requirements. The powering of magnet and sample for direct drive needs to be revisited. In general cable samples require higher currents than the background field magnet.

10. In the dipole field, the sample joints should not be sitting in the same field as the conductor, unless purposely placed there. That means there should be a minimum of 600 mm below the dipole to place the joints in a low field to obtain representative results of the conductor performance. The presentation shows that there is some space, but it was not presented specifically.

11. There was a discussion about the size of the test well and possibility of rounding the corners to provide structural support of the well. It is probably better that the test well not be made a big structural member, because users may need the corners for supporting of the sample.

12. No means for measuring AC loss were presented. This would possibly be a required, or at least desirable feature for this facility.

13. Is there a possibility of testing the joint after you test the conductor as is possible in SULTAN?

Facility Usage

1. There was quite a bit of discussion on the business model. After all was said and done, it was clear there is not one. They need to work with DOE to iron out the details. Ken Marken emphasized that the facility would be primarily used for MDP projects. It was not clear what FES's point of view was in that regard, although it seems that the facility would be open to use for all FES stakeholders, including labs, universities, and industry. A structure similar to

the INFUSE program, where FES has a certain annual budget available for testing, may be useful. Outside parties would submit proposals for testing. They would be responsible for paying for the samples, while DOE pays for the tests of the selected experiments.

2. DOE and the Project management should begin to determine the costs for supporting the maintenance and operation of the facility and the funding source or sources, as well as the cost to the users. The cost to the user for testing at SULTAN is at the level of $100K per two-weeks test with installation, cooldown, testing in different regimes, one Warm up and Cool Down (WUCD) and testing characteristics looking for changes after that. It costs about $100K for preparation of the sample, assembly into the specimen, instrumentation, etc.

Budget and Schedule

A very high-level cost estimate was shown. It is understood that there will be a Cost and Schedule review in the near future. As mentioned above, there are several risk contingencies built into the budget and schedule. The impact of these should be explicitly shown.

The schedules shown in the "Conceptual Cost and Schedule . . . " document and the one presented at the review need to be reconciled. It is not clear what the current status of the project is relative to the 2018 document.

The project schedule is based on some assumptions of the availability of resources and facilities that were not discussed in detail. How will this project be coordinated with ongoing program commitments such as AUP, MDP activities and other deliverables?

It is very important at this early stage that realistic expectations are made for both cost and schedule.