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Two parallel and complimentary aspects of the program:

1. Design and build a 12.5 Tesla, "React & Wind" Common Coil Magnet.

2. Design and operate a "mini magnet R&D program" that allows new ideas, designs and technologies to be tested in a time and cost effective manner.

Life of 10-turn Coil Program

While you optimize the 12.5 T design for cost, performance and large scale production, the 10-turn coil program continues in parallel.

The 12.5 T magnet becomes a part of "magnet R&D factory!"

The 12.5 T magnet provides a significant background field facility for testing coil modules with large Lorentz forces on them and to simulate high field magnet situations.

Can test insert/auxiliary coil for field quality configuration also.

Good approach for HTS magnet development as well.

An Experimental Program with a Modular Approach

A few examples of systematic studies in a modular approach:

- Different technologies:
  - Wind & React Vs. React & Wind
  - Different conductors:
  - Nb3Sn, HTS, etc.
  - Different insulation
  - Different geometry:
  - Tape, cable
  - Stress management/High stress configuration
  - Coiling, winding and Splicing
  - and a variety of other things that are not included (especially those that are not included)

* A Dynamic Program with fast turn-around time for exploring new frontiers/ideas *
The Team for Phase II Program

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And the experienced designers and technicians.

**Nb\textsubscript{2}Sn Cable Short Sample Test at BNL (Arup Ghosh)**

- **Question:**
  - Do we have a good superconductor handling recipe Nb\textsubscript{2}Sn cable?

- **Observation:**
  - ITER cable (obtained from LBL) was tested at BNL. Good results were obtained but some issues remain.

**Nb\textsubscript{2}Sn Cable Coming Out of Spool**

- The coil is wound like a regular NbTi coil, of course with proper care (e.g., lower tension). This should help avoid problems, as consistent handling is crucial for Nb\textsubscript{2}Sn magnets.

**Coil Tensioner with 10-turn coil on the Winding Table**
10-turn Coil Being Prepared for Vacuum Impregnation

Side Plate for Vacuum Impregnation

Drawing of One Coil Module (ready for vacuum impregnation)

Vacuum Impregnation Setup

Vacuum Impregnated Coil

Vacuum impregnated coil made after “react and wind” technique

Non-end view of the vacuum impregnated coil
**Vacuum Impregnated Coil**

- with large bend radius (no 3-d ind)
- Conductor friendly (suitable for brittle tapes and HTS)
- Compact (compared to single aperture LBL's D20 magnet, half the size for 1 turn coil)
- Block design (for large Lorentz forces at high fields)
- It is cost to design
- R&D due to simple design
- Minimum requirements on big expensive tooling and labor
- Lower cost magnets expected

**Field Quality in a Common Coil Design**

- From other speakers/experts:
  - One of the challenges in the common coil design is to demonstrate good field quality
  - Demonstrated here:
    - Common coil design can produce as good field quality as cosine theta design with similar amount of conductor
    - Significant progress since last meeting!

**Common Coil Design in Handling Large Lorentz Forces in High Field Magnets**

- In common coil design, geometry and forces are such that the impregnated solid volume can move as a block without gap instability or damage. Ref. in BBL's common coil test configuration.
- Inside the coils, the geometry is such that coil module remains move as a block. These forces are sufficient to cause movement, damage, or loss of field quality.
- We must check how far we can go in allowing such movement in the body and ends of the magnet. This may involve removing some elements of the current structure. Field quality optimization should include it as was done in HBC and HTBC magnet designs.
Mixing two technologies may create complications. Also, a larger required volume of NbTi conductor makes the support structure and magnet bigger.

- \( J_1 \) of NbTi at 8 T (field in outer coil) is over 4 times that of Nb3Sn.

- Compare the cost of the same size (0.8 mm) wire per meter (remember much more NbTi is needed):
  - NbTi: $0.65/m
  - Nb3Sn: $3.50-4.00/m (W/G Goal $1/m)

- Copper, by weight, is about an order of magnitude cheaper. The effective cost of Nb3Sn can be significantly reduced by mixing it.
A multi-pronged approach:

- Likely a magnet system evolved from a simple geometry.
- Possibility of applying new construction techniques in reducing magnet costs.
- Possibility of reducing magnet costs due to more favorable magnet parameters in the proposed common coil magnet system design.
- Opportunity to reduce high energy losses (thermal, magnetic) in the proposed system.
- Possibility of using high temperature superconductors (HTS) that may reduce overall cost in the proposed common coil magnet system design.

Need to examine the viability of these proposals further; need to continue the process of exploring new ideas and re-examine old ones (they may be attractive now due to advances in technology, etc.). Need to keep focus on the bigger picture...

VLHC cost reduction may also come from other advances: cheaper tunnel development, superconducting technology, etc.

Summary

- Set on a path for carrying out dynamic and innovative magnet R&D.
- This is expected to significantly reduce the cost of building VLHC.