New Path Forward for the Hall D Solenoid

1. Perform 15A tests with power supply connected to the magnet as outlined in commissioning plan D00000-04-02-P002 Rev B

2. Update commissioning plan to rev C for 140A testing

3. Continue to work on the refrigerator to get the magnet to 4.5K

4. Perform 140A testing when plan is approved and magnet cold

In the mean time, the following will be done in parallel to prepare for high current testing;

- Calculate if a momentary turn-to-turn short could have caused a quench.

  - We know of actual instances where a shorted turn has caused a quench. There are several instances in the Tevatron where this has happened and also one in Hall A. It is certainly a possibility.
  - But one doubts if it caused the Hall D magnet to quench for the following reasons:
    - During ramp down the shorted turn would increase in current, and just a small increase at 1460A might cause a quench.
    - The magnet was ramping up and the shorted turn would actually experience a decrease in current.
    - If it was a "hard" short from the start of ramping, then the shorted turn could actually develop a very large current in the reverse direction. But one rather doubts such a persistent low resistance short occurred.
  - It is also possible that the heat from the resistive short itself could have triggered the quench. Perhaps this can't be ruled out.
  - In any case the committee is glad that Eugene is looking into this in a comprehensive way.

  - Determine whether a quench can be captured and the consequences to the magnet if only 1 coil quenches and whether or not changes in dump resistors would be helpful. This would take into consideration the maximum safe voltage for the magnet.

  - Determine a safe current to run the magnet at that will also satisfy physics requirements and DOE milestones. 1350A appears to satisfy the physics and DOE requirements. We need to come up with the determination of whether or not this gives us a safe operating margin. A 1000-liter Dewar is needed at all times during the high current run.

- Modify the power supply to tune for a 25H magnet. Danfysik is to supply the hardware and instructions on how to do so.

- Prepare a procedure to manually adjust the hardware quench detector as the current is increased. The PLC quench detector will be programmed with the changes.

- Prepare a final write up on the quench and its probable or speculated causes.

We concur that taking into consideration all the problems with the refrigerator and the overall Hall D schedule (and re-baseline schedule), it would be prudent to move forward on all testing and magnetic field mapping as soon as possible in a safe manner for the magnet. In order to do this, all of the low current testing would have to show that the magnet is still viable, and the items listed above for high current testing are to be completed. If we warm the refrigerator and do repairs, it will take us into August to begin the high current testing. This will cause delays in the re-baseline schedule as much as 2-4 months.

1. Complete 15A testing (complete by June 5)

    - It is very important to utilize the 15A magnet testing to test the use of the "total inductance relative detection" algorithm. Ve = Vtot * Lcoil / Ltot
    - It is an excellent opportunity to shift the primary quench detection from analog to digital for two reasons:
      There is zero risk of any damage at this current.
      There is no saturation at this current so this issue can be deferred to later.
    - The <u>software execution thread</u> must be securely linked directly to the <u>dump controller</u> in a fail-safe manner as mentioned in an earlier memo, "Quench Detection Improvements".
    - This important step can be prototyped, implemented, tested and verified with no risk at 15A.
    - Details of the algorithm can be improved and parameters (integration time?) adjusted with no risk.

2. Cool the magnet to 4.5K (complete by June 8)
3. Test to 140A (complete by June 14)

- At 140A the above software protection can be rechecked, verified, and certified as the primary high sensitivity quench protection system.
- The analog protection system sensitivity parameters, voltage threshold and integration time, can be opened up to avoid false trips. The analog system will still provide secure, robust, fail-safe backup protection, but just at a reduced sensitivity.
- This current level will start to provide some indication of hysteresis effects. Hopefully we will find that because this algorithm is a comparative one, it is inherently immune to hysteresis effects. (All channels produce the same hysteresis effect in direct proportion to their inductance, hence cancel out.)
- Again, there is very little saturation at this current, so that issue can still be deferred until high current.

4. Ramp to 1400A and hold for 30 min (with Dewar attached and all steps above documented) (complete by June 20)

- High current 1400A testing will need functional current dependent inductances to account for differential saturation.
- The archived data from the 1500A run can be used to find the inductance functions from 0 to 1500A.
- Preferably, simple polynomial fits can be used going up and down.
  Or lookup tables could be used.
- If the archived data is insufficient, a bootstrap technique could be used going up in steps and extrapolating to the next step in real time. Because the primary quench detection will be software, the current dependent inductance, and any other unexpected subtle problems that may arise, can be addressed effectively, comprehensively, and swiftly. (This last point is very important.)

5. Ramp down to 1350A and map the magnetic field. (With Dewar attached) (Complete by June 23)
6. Ramp down and back up to 1350A (with Dewar attached) (complete by June 24)
7. Commissioning complete - warm magnet and make scheduled repairs to the magnet and refrigerator.

Bob Flora would be very happy to consult with whoever is doing the actual software implementation. During his phone access to the Hall D meeting, he could hear Probir very clearly and really appreciated his presentation (even when he talks really fast), but it was a little hard for him to follow all the details of the general discussion.

Original Path Forward for the Hall D Solenoid

The magnet will be cooled and tested again. The path forward has been coordinated between the 12 GeV and Physics Divisions. There will be 3 steps:

1) Refill the magnet with helium (by May 16). The cryoplant needs to be warmed up and cleaned before.

2) Power the magnet at a relatively low current and do various tests (May 16-24).

The prerequisites:

a) An initial analysis of the event (done)
b) Determine where the 16 ohm short to ground is located (done)
c) Fill with liquid helium (in Process)
d) Write a test plan (TOSP) outlining the sub set of checks needed to ensure the magnet is still viable (done)
e) Modify the quench detector/power supply (that the transients at the ramp changes do not trigger the dump) Smooth out the transients created by the power supply while ramping up (below 150mA) (in Process)
f) Over the next week(s) develop a plan to go to some higher current which will include; modifying the quench detection system to account for changing inductances as the current increases. (see New Path Forward)
g) This portion of the testing will be limited to 141A, which is about 25% of the energy released into the helium from the quench. We have reviewed George's current calculation and presentation.

3) If 2) does not detect serious problems - prepare for the full power test.

The prerequisites include

a) Diagnostics and analysis of the problem to have a plausible scenario of what went wrong
b) Quantification on how to prevent or handle such a quench in the future
c) Analysis and new procedures approved by external reviewers
The timing is TBD. The earliest would be 2-3 months from now.

We are thinking to have someone from outside the lab to help to accomplish that plan, mainly to modify the quench detector/power supply, make the diagnostics and analysis of the problem and to prevent quenches in the future.