EuCARD-WP7-HFM
ESAC Review

Task 3 : High Field Magnet

27/02/2013

Responses to the recommendations of the second ESAC dipole review

Questions asked to the reviewers

- 1. Is the magnet construction process sufficiently studied to start coil construction?
- 2. Is the conductor technically ready for this magnet?
- 3. Are there risks which have not been covered?
- 4. Is the quench protection for the dipole sufficient?
- 5. Is the schedule credible?

General remarks :

***G1**: The deliverable within the EuCard time frame has changed to a single coil, to be tested in the Fresca2 structure. Nonetheless CERN and CEA have an informal agreement and remain committed for achieving the original goal (a complete Fresca2 magnet). The Committee agrees with this change, because it sets a more attainable goal and provides the Team with a more realistic plan.*

- To take into account the actual status of the project, EuCARD deliverables have been redefined:(due end of march)
  - Design report for the dipole magnet
  - Dipole magnet structure tested in LN2
  - Nb3Sn conductor procured for one dipole magnet
  - One double pancake copper test coil made
- discussions are underway to determine how collaboration can continue beyond 2013

General remarks :

***G2**: the Committee recommends focusing the analysis on the single coil test, and adding another milestone to review RMC and 1st coil test results before investing a significant amount of conductor in the fabrication of the other coils.*

- Realization of RMC coils is underway (will be treated in the talk by Juan Carlos Perez). Test is planned in summer 2013. No review is actually planned.
- Test of one single Nb3Sn coil with 3 copper coils has been cancelled:
  - Test facility not available before spring 2014
  - Mechanical risk during cold test (non-nominal distribution of efforts
  - it seems better to keep people trained and working
- Planning will be treated in the talk by Maria Durante

General remarks

***G3**: There were a few minor inconsistencies among the presentations (the material of the pole in analysis and in fabrication talks; the time of 1st coil test in schedule and test talks). The plan should be fine-tuned to resolve these inconsistencies.*

- This is true
- Material pole was still under discussion. It is now fixed since October 2012 : Tititanium (TA6V)
  - Thermal shrinkage close to that of iron (1.8 vs 2.)
  - Less loose of prestress
- Schedule has been revised : will be treated in the talk by Maria Durante

Is the magnet construction process sufficiently studied to start coil construction ?

***MC1**: the contraction of the coil after the heat treatment of Nb3Sn, causing stress and strain in the winding, and possibly peak stresses in the ramp regions and the coil ends. A clear analysis of this effect has not yet been done. This analysis is recommended in order to have a complete understanding of stress and strain in the coils*

- Extensive tests have been undertaken with Pit cable. Same study in course with RRP cable : will be treated in the talk by Maria Durante

Is the magnet construction process sufficiently studied to start coil construction ?

***MC2**: Nevertheless the design team has to make a clear choice about the strategy, which should be oriented to learn as much as possible through the achievements of intermediate objectives.*

- Our strategy:
  - Do things as soon as possible to find difficulties and overcome them
  - Maintain activities to keep people trained
  - ➔ this led to cancel the test of one Nb3Sn coil alone with 3 copper coils

Planning will be treated in the talk by Maria Durante

Is the magnet construction process sufficiently studied to start coil construction ?

***MC3**: the impregnation of the small gap between two double pancakes is a good point, but it could be a difficult and critical operation (risk of large voids inside). Some test shall be done using the copper dummy coils.*

- One copper coil 3-4 and one copper coil 1-2 will be fabricated.
- The assembly of these 2 coils is scheduled and will answer to this question

Is the conductor technically ready for this magnet ?

***C1**: Cabling studies using RRP® strands are yet to be performed.*

- RRP strand is now available
- Strand and cable status will be treated in the talk by Luc oberli
- Mechanical measurements and behavior during heat treatment are being studied : will be treated in the talk by Maria Durante

Is the conductor technically ready for this magnet ?

***C2**: consider acquiring additional strand for spare coils*

- No decision on that point for the moment.
- The production delay, about 1 year, has to be taken into account.
- Remember : We will have enough cable to build 1 Pit magnet and 1 RRP magnet

Is the conductor technically ready for this magnet ?

***C3**: Using "inexpensive" bronze wire for qualifying coil winding/reaction/impregnation is not advisable*

- This possibility is not envisaged.
- Although copper doesn't behave like Nb3Sn, each process is tested with that material before first nb3Sn operation

Are there risks which have not been covered ?

***R1**: Before proceeding with the final construction with additional coils, test results will have to be analyzed and followed by an external review*

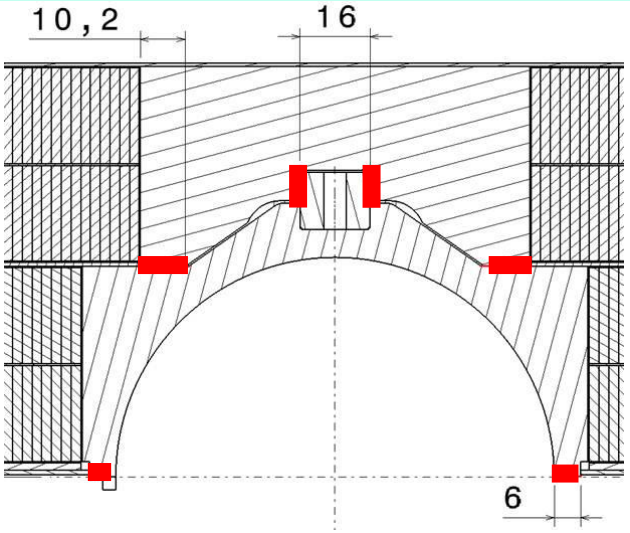
- This relates to the “miror configuration”, which is cancelled.
- However, RMC fabrication and tests will be analyzed

Are there risks which have not been covered ?

***R2**: The contribution of the proposed alignment to the inner structural rigidity should be calculated and compared*

***R3**: The interaction (displacements) between the inner layer pole and the outer layer island should be looked at*

- Contacts and centering are shown in the figure beside
- Contact are taken into account in FE calculations



Are there risks which have not been covered ?

***R4**: Unexpected results may impact expectations and raise doubts of the final FRESCA2 coil performance. Additional tests may therefore be required and time need be allocated for such an unforeseen situation*

- This relates to RMC magnet, whose cold test is planned in summer 2013. It is clear that, if some problem occur during this test, work on FRESCA2 coils should be stopped until the difficulty is understood and remedies implemented

Are there risks which have not been covered ?

***R5**: Continue R&D work on insulation and supplemental coating to reduce potential risk of shorts.*

- In addition to Al_2O_3 coating, glass fiber tissue will be inserted (and impregnated) between post and conductors

Are there risks which have not been covered ?

***R6**: All tooling and coil fabrication procedures should be designed and engineered in order to allow for longitudinal gaps, in case the experimental tests show they are needed.*

- Experimental tests will be treated in the talk by Maria Durante
- A study has already started for the winding, reaction and impregnation tooling to be modified if necessary. This will be discussed in the talk by Maria Durante

Are there risks which have not been covered ?

***R7**: FEM analysis of strain in the coil during and after cool-down depending on pole material*

- Pole material chosen (see G3) for relative thermal shrinkage reasons
  - this is taken into account in FE calculation
  - The comparison in no longer necessary

Are there risks which have not been covered ?

***R8**: Study of conductor behavior during heat treatment including tests with gaps in the pole for both RRP and PIT conductor*

- This study has been performed for PIT cable and is in underway for RRP cable
- Will be treated in the talk by Maria Durante

Is the quench protection for the dipole sufficient ?

***Q1**: it would be quite beneficial, if time and resources are available, to have this 2D simulation result validated with one of the RMC coils*

- The RMC coil will incorporate traces and an insulation scheme similar to the FRESCA2 coil,
  - ➢ the first test of RMC, to be expected in the summer of 2013, will provide a full validation of the assumptions considered for the thermal delay of FRESCA2

Is the quench protection for the dipole sufficient ?

***Q2**: Within the system, e.g., between the vapor-cooled current leads, across the coil terminals, a voltage of 1000 V appears. The system should be prepared accordingly*

- The requirement will be given to the current leads designer
- Re-use of LHC design : voltage at terminals : 3000 V

Is the quench protection for the dipole sufficient ?

***Q3**: The dump resistor should always have enough mass for it to absorb the entire magnet energy, regardless the quench-inducing/quench-propagating heaters work or fail*

- Due to reaction time of detection system, not all energy will be dissipated in the dump resistor
  - 40 % of energy is assumed to be dissipated in cryostat
  - Cryostat designed for a pressure of 4 bars

Is the quench protection for the dipole sufficient ?

***Q4** : It is acceptable to allow a dump resistor to be heated up to 500-800 °C, provided it is well isolated and not readily accessible for safety*

- True → Installation and safety will be checked carefully

Is the quench protection for the dipole sufficient ?

Q5**: In addition to a threshold trigger voltage (1 mV, 10 mV, 100 mV, or whatever appropriate) as well as a dV/dt level, consistent with a time delay of 100 ms, a criterion based on an $\int V\,dt$ (where the integral time duration should be in the 10-50 ms) is recommended. The dump should be triggered only when there is a genuine **non-recovering quench

- The threshold voltage is adjustable from 10 to 100 mv
- Time window is adjustable from 10 to 50 ms
- The dump is triggered within a time made of:
  - Time to attain the threshold
  - Verification time, user dependent (can be 0)
  - Reaction time of switch (about 2 ms)
- It is possible to use the dump only or combined with heaters, with adjustable delay with respect to each other

Is the quench protection for the dipole sufficient ?

***Q6**: In order to have redundancy, the protection system should be based on 2 heaters per coil, 4 heaters should be used, and each pair connected to a separate capacitor bank*

- There are 4 heater strips per coil layer (8 coil layers for the whole magnet)
- the strips are connected outside of the coil, in or outside of the cryostat
- Final connection scheme to be fixed

Is the quench protection for the dipole sufficient ?

***Q7**: Two dump switches should be used, as planned, for the same reason*

- There are 2 switches:
  - One based on thyristor
  - The second one , mechanical , ensure safety and redundancy

Is the quench protection for the dipole sufficient ?

***Q8**: The protection system should be designed regardless the location of the quench start: high-field or low-field*

- We agree
- All regions of the coils are controlled with potential wires

Is the schedule credible ?

***S1**: The Committee strongly suggests the team to speed up the preparation of the testing cryostat so that the first test can be made by April 2013. It is worth to explore the possibility of testing in a simple horizontal cryostat, even at 4.2 K only; while the final vertical cryostat and facility are prepared*

- To speed up the realization, CERN will order components and will take care of installation (system)
- This is a heavy project. In addition resources have been dedicated to LN2 structure test ➔The cryostat should be available in spring 2014
- The option 4.2K and in horizontal requires the same persons to study the solution → parallel project not possible today.

Is the schedule credible ?

***S2**: The Committee suggests that the team should accelerate the cable study to thoroughly understand the performance and finalize the cable parameters for both PIT and RRP conductors as soon as possible*

- Since last year, cable studies have made significant progress:
  - Degradation is now under control, better than 5%. Will be treated in the talk By Luc Oberli
  - Cable behavior after heat treatment are measured for PIT cable and underway for RRP cable. Will be treated in the talk by Maria Durante

Is the schedule credible ?

***S3**: To avoid them (delays and overload), the Committee suggests the team to strengthen the human resources and appropriately to allocate them to the tasks*

- Unfortunately, resources are limited
- However
  - There is a common will to go ahead and to finish the project
  - discussions are underway to determine how collaboration can continue after EuCARD program and French contribution to LHC. FRESCA2 magnet is one topic of this collaboration

Is the schedule credible ?

***S4**: the Committee would like to ask the project leader to provide a concise project schedule showing all important milestones, including the RMC development, and underlining deadlines and target dates*

- Planning will be treated in the talk by Maria Durante
- Some key dates :
  - First copper coil (3-4) : April to July 2013
  - Test of RMC magnet : summer 2013
  - Second copper coil (1-2) : June to October 2013
  - First Nb3Sn coil : September to December 2013
  - Assembly of FRESCA2 magnet : May to July 2014
  - Test of FRESCA2 magnet : July to October 2014