"DFH DETAILED Design Review" Report

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(Editor: Michele Modena)

This document reports the outcome of the *"DFH DETAILED Design Review"* held on 16 June 2020

(https://indico.cern.ch/event/925877/)

This Report is structured in:

1. *Introduction*
2. *Findings, Comments and main Recommendations.*

1. Introduction

A Detailed Design Review for the DFH system (DFHX and DFHM) was organized in agreement with HL-LHC Project by TE-MSC on the 16 June 2020:

Scope: Review the detailed design of the DFHX and DFHM with the purpose of validating maturity and confirm readiness for starting production of the first unit DFHX.

(Note: review held via Vidyo).

Mandate of the Review Committee:

1) Review the functional, technical and interface documentation and confirm their completeness in terms of cryogenic, mechanical and electrical requirements;

2) Review the detailed design wrt cryogenic design and operational aspects, mechanical design and interfaces, electrical design and interfaces;

3) Review location of the DFH in the underground area and interfaces with the other systems;

4) Review requirements for safety aspects and compatibility of safety equipment with tunnel environment;

5) Review plan and schedule for DFH production;

6) Review strategy and plan for QA and QC, as well as plan for intermediate and final acceptance tests

Review Committee: M. Modena (chair), S. Atieh, K. Brodzinski and D. Tommasini.

Scientific secretary: M. Mendes

Presentations Plan:

- *Welcome (L. Bottura)*
1. *DFH in WP6a and Master Plan (A. Ballarino)*
2. *DFH Overview and detailed production schedule (P. Cruikshank)*
3. *Follow-up from CDR (P. Cruikshank)*
4. *Location of DFH in underground areas (M. Mendes)*
5. *DFH functional and technical requirements – including cryogenic cooling aspects (Y. Leclercq, V. Gahier)*
6. *DFH Cables, splices & instrumentation (J. Fleiter)*
7. *DFH Detailed mechanical design: helium & vacuum vessels, supports, interfaces (Y. Leclercq)*
8. *DFH Assembly sequence and tunnel transport aspects (R. Betemps)*
9. *Status of CAD drawings (R. Betemps)*
10. *DFH maintenance and repair in underground area (P. Cruikshank)*
11. *Design and integration of safety equipment and safety aspects in the LHC tunnel (N. Grada)*
12. *DFH acceptance tests and QA Plan (Y. Leclercq)*
13. *DFH in the QA plan of WP6a (S. Hopkins)*

Acknowledgement
The Review Panel would like to thank the Speakers for the clear and concise presentations provided.

The Review Panel would like also to thank the invited and joined participants at this "premiere" for a Vidyo review. Despite the very dense program of presentations, the review advanced in an efficient way permitting clarification of questions from all participants also through the "chat" channel provided by the Vidyo application.

2. Findings, Comments and main Recommendations:

This review follows a 1st review held on the 15 November 2019 (*DFH Conceptual Design review ref. https://indico.cern.ch/event/862994/ and https://indico.cern.ch/event/867075/*).

DFH systems (DFHX and DFHM) are key elements of the HL-LHC Cold powering system, with also a big impact on the global integration of the new UR galleries of the HL-LHC Project. The design and integration will concern a wide number of aspects (equipment and integration from: WP6b-PS equipment, WP9-Cryogenic system, WP17.2-powering cables system, WP15, EN-HE, EN-EL EN-CV, etc.).

Referring to the **six Review Mandate specifications**, the Review findings, comments and main recommendations are here reported:

1) "Review the functional, technical and interface documentation and confirm their completeness in terms of cryogenic, mechanical and electrical requirements":

- The functionality aspects, already presented in the DFH CDR, are not changed. They were mainly presented in the talk n.5, and seem clear and complete considering the expected interfaces.
- The main project documentation (specifications, supporting studies, safety documentation, etc.) is available. Some documents are still in draft version (e.g. the Functional Specification, some stress calculation reports, etc.).
  → ***RECOMMENDATION N.1*** *Finalize the whole project documentation (also necessary for a correct start-up of the activities with the Swedish collaboration).*

Some aspects must be correctly reported and handled (e.g. the inclusion at the right section of the Functional Specification of the most critical cases to be assumed for the thermo-mechanical design (the so-called "non-nominal events").

2) *"Review the detailed design wrt cryogenic design and operational aspects, mechanical design and interfaces, electrical design and interfaces":*

- One of the main open question from the CDR was successfully clarified: the design pressure for all the elements of the cold powering cryogenic system (DFH, DSHX, DFHX) is now standardised to 3.5 bara. This will bring major advantages in term of cryogenic operation and control and on safety considerations for the full system.

- We have understood that a revision of the instrumentation (e.g. on the n. of TT and on redundancy of some other signals) will be done at the completion of the DEMO2 test campaign. This could explicitly regard the number of thermometers. If proven by DEMO2 that splices are working at constant and correct temperature, the presence of thermometers on splices for series production must be revised (reduction). These splices will be anyway instrumented with voltage taps.
  → ***RECOMMENDATION N.2:*** *This instrumentation review is a very important step for the design completion and should also be done in the aegis of the Magnet Circuit Forum to be aligned with general instrumentation policy. The Review Panel recommends to reduce the n. of TT on the splices to the minimum necessary for the cryogenic control.*

- The validation of the DFH design is also based on the (very good!) results of the DEMO2 prototype now under testing.
  Nevertheless, the layout of the DEMO2 is not exactly the same of the DFHX and DFHM. The design of some components is different as well as the layout of some components utilized in both DEMO2 and DFH (e.g. current leads orientation and related risk of external condensation).
  → ***RECOMMENDATION N.3:*** *carefully analyse the main differences existing between the DEMO2 and DFHX/M designs and attentively check that these differences could not bring later to unexpected problems (also considering that there will be no possibility to intensively test the DFHX proto since it is then needed to operate the String program and then be kept as spare).*

- Mechanical design is quite advanced but it is not fully completed. Some aspects (e.g. final forces computation with consequent dimensioning of vessel supports; agreement of HSE on performed calculation following Safety Codes; check of possible impact of vibrations due to cryogenic operation; etc.) are not yet finalized. The completion of these design aspects and the consequent finalization of the drawings folders is now urgent, also considering that the validation with other parties (e.g. HSE) can require certain time. The procurement of some key elements for the DFHX prototype (e.g. cylinders for the different vessels) could probably be launched before the release of the technical documentation for the complete DFHX/M.
  COMMENT: *The implementation in the design of solutions and dimensions standardization (e.g. tubes diameter) developed for LHC (e.g. on welding, cutting machines & procedures, clam shell testing) could be extremely proficient and simplify the performance of the intermediate assembly tests)*

COMMENT: *We understood the specificity of this procurement and that the priority is with the design of the components that will be subject of the Swedish contribution. Other components (mainly internal elements) will be procured by CERN and needed only for the 1st complete assembly in 2021.*

→ ***RECOMMENDATION N.4:*** *complete the detailed mechanical study of the structure, in particular with respect to the vacuum vessel supports design assuming the different operational (and failure) modes.*
Where possible implement in the design the developed technologies, procedures and custom made tooling established for LHC.

→ ***RECOMMENDATION N.5:*** *consolidate a detailed plan for the release of the technical documentation needed for the procurement of the critical components (specifications, safety requirements, drawings folders fully approved, etc.). This plan should follow and be consistent with the general WP6a plan but updated to the latest CERN and HL Project evolutions.*

3) *"Review location of the DFH in the underground area and interfaces with the other systems"*

- The full integration of the DFHX and DFHM in the UR galleries was a study done recently with a joined and very efficient effort from all concerned parties. The result is very positive and we think that the validation of the whole cold powering system integration is very close. There was no need to modify the DFH design due to the integration constraints also considering the integration of the new CDB and all ancillary equipment.

- DFH transport in the UR: there was not a dedicated presentation on this critical aspect but the subject was briefly presented in the talk n. 8. The preference for the transport of the DFHX/M together with the rolled DSHX/M is confirmed.
  After the review, in private discussion with C. Bertone, we have understood that EN-HE is acquiring confidence in the feasibility of this extremely complex transport (a revised overall packed assembly dimensions and frame concept are now proposed). What seems will be even more critical and will need a very careful study, are the procedures for transport AND manipulation of the UNROLLED DSHX/M due to the fragility of the equipment and its impressive length. *(Note: this aspect is not directly link with the scope of this review and is not urgent to be solved, but seems quite important!).*

4) *"Review requirements for safety aspects and compatibility of safety equipment with tunnel environment":*

- A detailed presentation on safety aspects and study of possible failure modes was provided. One of the questions raised during the CDR was positively answered: the setting of the burst disks of the different elements of the cold powering system will be done as proposed at the review in order to maximise the safety aspects for the personnel eventually present in the UR galleries. Some aspects (e.g. how to highlight a zone of limited stay around the DFH) have still to be finalized, but those should not have impact on DFH design.
  COMMENT*: Concerning the safety of the equipment, the DFHX/M design should implement all possible means to guarantee the integrity of the DSHX/M in case of a major mechanical failure*

in the DFHX/M. In fact, the reparation (or even worst the replacement) of the DSHX/M will have an enormous impact in terms of logistic and planning.

5) *"Review plan and schedule for DFH production":*

- The presented planning seems challenging mainly for the DFHX prototype design completion and procurement. The best effort to limit the effect of recent events (Covid-19 crisis) was taken. The comfortable margin between DFHX prototype test and installation in the String presented at the CDR is now reduced.
- Due to the specificity of the procurement (DFHX prototype needed for system test, then needed for the String operation and finally stored as the unique spare), it will be not possible to perform an intense test program on the prototype (e.g. toward cycling and fatigue aspects) and this fact should bring an extra motivation to finalize and check a DFH design as much as possible sound and conservative concerning these aspects.
  ***COMMENT**: By private discussion with A. Ballarino, we understood that the details of the DFHX prototype procurement are not yet fully finalized but still under discussion inside the CERN/Uppsala Univ. collaboration. WP6a team seems very conscious of the priorities in the design completion and drawings folder release for the different subassemblies, anyway the maximum attention and tracking of potential sources of delay must be kept on these aspects (also because other parties, e.g. HSE, will play a role too).*

6) *Review strategy and plan for QA and QC, as well as plan for intermediate and final acceptance tests:*

- The basic structure of the QA and QC to be implemented for this procurement was presented together with the required fulfilment of design Codes and procedures. The QA and QC will follow the standards required by CERN and by HL-LHC Project. The proposed structure seems sound but is evidently not yet in place.
- The aspects link with MIP (Manufacturing Inspection Plan) and other expected intermediate and final acceptant tests were not presented at the review.
- Due to the particular DFH design and assembly, the intermediate assembly tests will be of a critical importance.
  → ***RECOMMENDATION N.6:** MIP (Manufacturing Inspection Plan) must be carefully established. It has to include the intermediate and final tests for the acceptance of the components (since supply from Swedish collaboration will be done in sets of components to be then assembled at CERN).*

***COMMENT:** concerning the important aspect collected as a main worry of EN-HE, on the risk in manipulation of the DSHX/M:*
It seems mandatory to develop a protocol of tests to check the integrity of this very delicate equipment during the different phases of transport and installation. As much as possible integrity aspects (electrical, vacuum, mechanic) should be possibly covered by these tests.

→ ***RECOMMENDATION N.7:** Seen the status not yet completed for the design and procurement documentations, we recommend that in due time, the DFH equipment is subject of a HL-LHC Production Readiness Review (PRR), as done for similar equipment (e.g. DFX).*