
MQXFA1 assembly readiness Review

Close-out

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Outline

- General comments
- Answers to review charges
- Some findings/comments/recommendations

Overview and general comments

- **Review goals**
 - assess assembly readiness of MQXFA1
- **Charges**
 - Are MQXFA requirements clear and complete for the scope of this review?
 - Are the measurements performed on the MQXFA1 yoke-shells subassembly satisfactory to assure that MQXFA1 will meet requirements?
 - Are the measurements performed on the MQXFA1M assembly with dummy coils satisfactory?
 - Are the following procedures and targets adequate to meet requirements and reasonably based on experience and performance of short models?
 - MQXFA1 coils-pads sub-assembly procedure
 - MQXFA1 assembly procedure
 - MQXFA1 loading procedure and targets
 - Are all procedures sufficiently documented?
 - Are QA and QC adequate?
 - Is there any other comment or recommendation to assure MQXFA1 will meet requirements?

Overview and general comments

- The committee congratulates the LARP team for the amount and quality of the work. The committee acknowledges the extra effort done by the technical team to perform the MQXFA1M on time for this review.
- The committee thanks Giorgio Vallone (CERN) for his contribution on the FEA analysis and mechanical measurements analysis of the short models

Overview and general comments

- The committee is concerned by the limited resources attributed to the project at LBNL both on the technical and scientific level.
- The committee noticed:
 - an excellent engineering work
 - that a closer senior scientific oversight would :
 - reduce the present risks
 - Reduce the project risks as the complexity of the process will grow.

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- **Answers to review charges**
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Answers to review charges

- Are MQXFA requirements clear and complete for the scope of this review?
 - **Yes**, the requirements on quench performance are clear and they seem adequate:
 - Reach **ultimate** gradient of 143.2 T/m, 17.89 kA, 108% of the nominal (no requirement on the number of quenches)
 - Memory after thermal cycle: reach **nominal** gradient after 1 quench
 - **However**, although not required, performing some field quality and alignment measurements could support the assembly effort

Answers to review charges

- Are the measurements performed on the MQXFA1 yoke-shells subassembly satisfactory to assure that MQXFA1 will meet requirements?
 - **YES**, the measurements were showing an excellent assembly process with uniform dimensions

Answers to review charges

- Are the measurements performed on the MQXFA1M assembly with dummy coils satisfactory?
 - Yes, the SG data are in very good agreement with expectation. The pressure sensitive film results validate the assembly process in terms of overall uniformity.

Answers to review charges

- Are the following procedures and targets adequate to meet requirements and reasonably based on experience and performance of short models?
 - MQXFA1 coils-pack sub-assembly procedure
 - **Partially yes.** The coil pack sub-assembly procedure including coil position was not presented in detail. The radial/midplane shim plan was missing and the step-by-step assembly process for MQXFA1 was not presented.

Answers to review charges

- Are the following procedures and targets adequate to meet requirements and reasonably based on experience and performance of short models?
 - MQXFA1 assembly procedure
 - **YES**. The experience from MQXFA1M has been clearly stated and the various issues encountered are clearly addressed. **However** the step-by-step assembly process for MQXFA1 was not presented.

Answers to review charges

- Are the following procedures and targets adequate to meet requirements and reasonably based on experience and performance of short models?
 - MQXFA1 loading procedure and targets
 - **Partially.** The targets came out following a discussion with the review committee.

Answers to review charges

- Are all procedures sufficiently documented?
 - **Partially YES.** The committee was pleased on the ongoing progress made on the documentation preparation

Answers to review charges

- Are QA and QC adequate?
 - **Partially Yes**. The committee was pleased on the ongoing progress made on the QA QC.

Answers to review charges

- Is there any other comment or recommendation to assure MQXFA1 will meet requirements?
 - See next slides

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Requirements Findings

- 2 successful prototypes are required by DOE before starting production in the US (CD3b)
 - 1st prototype main goal is quench performance:
 - Reach 143.2 T/m, 108% of the nominal (no requirement on the number of quenches)
 - Memory: nominal in 2 quenches
 - No requirement on ultimate after thermal cycle
 - 2nd prototype must address additional features such as field quality and alignment

Requirements

Comments

- Feedback from magnetic measurements is also beneficial to QC of the assembly and loading procedures.

Requirements Recommendations

- Given the limited number of prototypes:
 - consider evaluating the impact on schedule of performing warm magnetic measurements and alignment measurements on MQXFA1.

Experience on MQXFA1M measurements

Findings

- Excellent measurements results were found on the yoke-shell sub-assembly
- The SG data and pressure sensitive film data from MQXFA1M are meeting expectations

Experience on MQXFAM1 measurements

Recommendations

- Bolting all the load-pads during the coil-pack Fuji paper assembly is required for a better understanding of the coil/collar contact condition
- Check the spread and the distribution along the length for comparison with the short models

Procedures and targets

Findings (2)

- The objectives of MQXFA1M were to
 - Verify tooling scale up from MQXFS to MQXFA
 - Refine processes for assembly operations
 - Define documentation templates for the capture of manufacturing data that will eventually need to be transferred during the project
 - Initially, evaluate the magnet fiducialization process. This last objective has been given up due to time constraint.
- The cooling holes bladders have been used successfully to perform the yoke shell sub assembly
- The cross tooling is used as an anti seismic fixture
- Tooling for the coil pack subassembly was used successfully

Procedures and targets

Findings (2)

- Non conformities in yoke and load pad stack length have been identified and corrected and fed back into the next prototype structure procurement
- The process flow has been shown but not every steps will be applied to MQXFA1 due to the tight schedule and lack of time
- The plan for load keys is to use double keys shimmed in the middle proposed and then abandoned by CERN. The cost associated to the individual keys is considered excessively high for LARP and AUP.

Procedures and targets

Comments

- The committee understands the necessity to minimize bladder pressure but encourages the team to go beyond 6500 psi if needed

Procedures and targets

Recommendations

- The updated (not generic) MQXFA1 assembly flow chart describing Fuji steps and mechanical measurements should be provided before starting the assembly
- The coil radial shimming plan should be reviewed before starting the assembly.

Procedure and targets

Findings

- 3 short models have been assembled. 2 have seen several loading conditions
 - Different Axial and Azimuthal preloads were explored in short models which provides guidance for target definition
 - MQXFS1 results indicate that the modulus of the coils is lower than the 44 GPa used historically within LARP.
 - Values of 20 GPa in Young modulus and of 3.88 mm/m in CTE were chosen to match the experimental SG data of MQXFS1
 - MQXFS3 results indicate over shimming of the pole key and point out the critical impact of the pole key shims on the coil preload.
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Procedure and targets

Findings

- The mechanical limits of the shell and yoke are a concern. Reducing the shimming of the pole key is considered to increase the preload on the coils while preserving the shell peak stress
 - The fracture study indicates that the minimum crack fracture limit is set at 2 mm defect for the shell
 - Upon request from the committee a set of targets was presented: MQXFS1b cold preload target was proposed as the reference
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Procedure and targets

Comments

- The value of the coil modulus remains uncertain and it is of primary interest to the project to settle on a value
- Clear assembly targets were presented upon request from the committee.

Procedure and targets

Recommendations

- The stress limit of 120 MPa for Magnetil appears to be very low and should be verified
- The issue of sagging of long rods should be quantified and addressed.
- Prepare a summary of the final target decided with the committee along with a justification
- Prepare a reference 3D computation corresponding to the chosen targets
- The axial preload foreseen for MQXFA1 seems appropriate but the committee recommends to move to larger diameter axial rods for future assemblies.
- If possible, feedback the MQXFS1c test results into the axial preload target of MQXFA1

Procedure and targets

Recommendations

- Pay particular attention not to overshim the pole key and consider the possibility to leave gaps between the collars and the key
 - No field quality nor alignment requirements in MQXFA1
 - Better control of the preload
- Ensure an accurate measurement of the pole keys to collar gaps

To conclude

- *The committee proposes to have a short term follow-up meeting on target summary and radial shimming scheme*