Design and Milestone Review Report

▪ The title of the item or system ▪ A description of the item ▪ WBS Number ▪ Type of design review ▪ Date of the review ▪ Names of the presenters ▪ Names, institutions and department of the reviewers ▪ Names of all the attendees (attach sign-in sheet) ▪ Completed Design Checklist (if utilized)	▪ Recommendations – these are items that require formal action and closure in writing for the review to be approved. See Document Review Guidelines PPUP-101-PC0001-R01 for Design Review Requirements and Guidelines ▪ Comments – these are comments that require action by the design/engineering team, but a response is not required to approve the review ▪ Findings/Observations – these are general comments and require no response

Type of Review:	Final Design Review (FDR)		
Title of the Review:	SNS Proton Power Upgrade (PPU) Cryomodule Final Design Review		
WBS:	1.02.03 Cryomodules		
Presented By:	JLab Design Team (agenda includes presenters)		
Report Prepared By:	Tom Nicol, Fermilab (Chair)		
Reviewers and observers:	Tom Nicol, Fermilab (Chair) and John Hogan, JLab SNS observers – Sang-Ho Kim, Matt Howell, Stephen Stewart, ORNL	**Date:**	Review Date: 10-11 Jun 2019 Report Date: 12 Jul 2019
Distribution:	E. Daly and Design Team, JLab, M. Howell, ORNL		

Attachments:	☐ Review Slides	☐ Design Checklist	☐ Calculations	☐ Other

Purpose and Goal of the Review

The purpose of the review is to evaluate whether the status of the SNS Proton Power Upgrade cryomodule design at Jefferson Lab meets the requirements for final design, i.e. greater than 90% complete, and will be ready to proceed to procurement by the end of fiscal year 2019.

Review Charge

In following the charge, the committee should respond to the following questions:

1. Is the baseline design of the PPU cryomodule sufficiently mature to meet the standard for a Final Design, >90% complete, and support readiness for CD-3B?
2. Have recommendations from previous reviews been addressed?
3. Does the cryomodule design support the project KPPs?
4. Are the drawings and design documentation complete and available?
5. Have SCL PPU risks been properly identified and are mitigation plans adequate?

Review Charge
6. Are there unresolved issues that may have significant safety, quality, cost, schedule or performance impacts?

Agenda

Monday, June 10, 2019

08:15	Introduction & Charge	Edward Daly
08:30	SNS PPU Overview	Matthew Howell
08:55	JLab CM Design Overview	Mark Wiseman
09:20	Helium Vessel	Katherine Wilson
09:45	Clean Room Assembly, Helium Vessel to Cavity, CR Assembly with Tooling	Katherine Wilson
10:15	BREAK	
10:30	Tuner	Mark Wiseman
10:50	Shipping	Edward Daly
11:10	Space Frame	Matt Marchlik
11:35	Thermal Shield and MLI	Matt Marchlik
12:10	LUNCH	
13:10	Magnetic Shields	Gary Cheng
13:35	Vacuum Vessel	Matt Marchlik
14:00	End Cans	Gary Cheng
14:40	Cryomodule Final Assembly	James Henry
15:05	BREAK	
15:20	Instrumentation	Peter Owen
15:35	CM Assembly Plan	Kurt Macha
16:15	JLab Cost & Schedule: Design, Procurement, Fabrication	Anthony Reilly
16:45	Discussion	
17:15	Adjourn	

Tuesday June 10, 2019

8:00	Reviewer Work Time
9:00	Questions/Discussion
10:00	Reviewer Work Time
11:30	Closing
12:00	Adjourn

Introduction and Outcome Summary of the Review

The committee would like to thank all the presenters for their work in preparing for this review. We know it's extra work on top of already busy schedules, but it showed in the quality of all the presentations. We were impressed by what has been accomplished since the PDR last February and

Introduction and Outcome Summary of the Review

especially since choosing Jefferson Lab as the partner lab early last year. We look forward to our continued association with the project.

We appreciate the design team taking advantage of the opportunity to learn from their and other previous design efforts to improve cavity performance, lower field emission, improve reliability and manufacturability and, in general, produce a better design in many areas.

The review provided a good forum for active and open discussion among reviewers, reviewees, and other members of the team. In addition to formal presentations there was good discussion throughout the course of the review from procurement strategy to acceptance criteria.

What follows is our collection of findings, comments, and recommendations plus input, where appropriate, from observers present at the review. There is no significance in the order of any of the content below. We are comfortable in our assessment that the design status is consistent with that of a final design and confident that the team will be ready for a procurement later this year.

The charge, agenda, presentations, and supporting material can be found at:
https://www.jlab.org/indico/event/326/

Responses to the Charge

In following the charge, the committee should respond to the following questions:

1. Is the baseline design of the PPU cryomodule sufficiently mature to meet the standard for a Final Design, >90% complete, and support readiness for CD-3B? Yes. The design is more than 90% complete in all major areas. Although only about half (172/404) of the final drawings are approved and ready for procurement, the remainder are expected to be approved by the end of July 2019. Attention should be paid to prioritizing procurement packages as needed and the schedule requires.
2. Have recommendations from previous reviews been addressed? Yes. All the technical recommendations from the preliminary design review in February of this year have been addressed in each of the respective subsystem presentations. One exception is the recommendation to complete all the procurement packages, but all major procurement packages are expected to be complete before funding is approved. All other recommendations are being tracked and are either in progress or closed.
3. Does the cryomodule design support the project KPPs? Yes. A study of the cavity processing recipe was reviewed and shown adequate to achieve the required average cavity gradient of 16 MV/m. The associated KPP's are achievable with this cavity performance.
4. Are the drawings and design documentation complete and available? Qualified yes. The design is more than 90% complete, the detail drawings are approximately 50% complete and the statements of work (SOW) are greater than 60% (8/12) complete. Statements of work and specifications have their basis in those from the original SNS cryomodule production and need only minor revisions to bring them up to date.
5. Have SCL PPU risks been properly identified and are mitigation plans adequate? Yes. The risk registry continues to be maintained on a regular basis. The risk registry was thoroughly evaluated in preparation for the DOE CD-3B review in early June 2019. As a result of that evaluation, after

Responses to the Charge

mitigation, the current risk registry for the PPU SCL will have no high risks and two medium risks. All identified risks associated with cost, schedule, and technical issues are appropriate based on lessons learned from previous production.

6. Are there unresolved issues that may have significant safety, quality, cost, schedule or performance impacts? No. From a cryomodule design standpoint, there are no significant unresolved issues relating to safety, quality, cost, schedule or performance. However, due diligence is required to take advantage of the opportunity to pull the schedule forward to minimize the known issues of vendor performance and to provide the project with additional contingency.

Findings and Observations

1. Priorities are always Safety, Quality, Schedule.
2. Partner laboratory contribution to cryomodules.
   Procure all major CM components from industry.
   Assemble and deliver seven high beta cryomodules.
   Cavities and couplers provided by SNS.
   Tuners provided by partner lab.
3. CD-3B was held June 4-6, 2019. All action items from CD-1 and CD-3A are closed.
4. Installation to take place over three shutdown periods.
5. Seven new cryomodules, nine available slots.
6. Three cavities in reserve to provide margin.
7. Beam energy will increase from 1 GeV to 1.3 GeV.
8. Average gradient today is 14.8 MV/m. The goal is 16 MV/m.
9. Beam power will increase from 1.4 MW to 2 MW with one target, 2.8 MW with two targets.
10. All cryomodules will be cold tested at JLab, cold and RF tested at SNS. Cooldown acceptance testing with high power RF will be done at SNS.
11. First PPU cryomodule delivery ~Dec 2021, last ~Feb 2023.
12. CD-3A status – cavities awarded to RI, inner conductors awarded to Sumitomo, outer conductors awarded to CPI.
13. Vacuum vessel and end cans to be code stamped to meet Oak Ridge requirements.
    a. Vacuum vessel MAWP is 25 psig.
    b. JLab requires “intent of the code”.
    c. The vacuum vessel is the pressure boundary defined by SNS.
    d. The vendor will code stamp both end cans.
14. Shipping loads:
    4 g vertical
    5 g longitudinal

Findings and Observations

1.5 g transverse.

These are allowable loads at extremes of the cryomodule after attenuation by the shipping frame.

15. Cavities arrive from the vendor ready for VTA testing. Any needed hardware provided by SNS.
16. Helium vessel procurement is “build to print”.
17. New tooling being designed for FPC installation to reduce field emission.
18. Magnetic shield material internal and external to the spaceframe is the same.
19. No plan for temperature control during shipping.
20. Spaceframe to vacuum vessel attachment concept in question – differential screw or conventional locking mechanism.
21. Explosion bonded joint design updated based on R&D by other national labs. Intermediate tantalum layer is used in the Ti/SS transitions and has improved success rate. Controlling heat during welding is very important.
22. Tuner operating frequency ~1-2 times/day. Life requirement is 29,000 cycles.
    a. Maximum tuner load 8900 N, maximum travel 1.8 mm, capable of 2 mm.
    b. Planning to run tuner life test in VTA.
    c. Piezos are not required in PPU.
23. There are not expected to be any internal shipping restraints required. Shipping tests should confirm this.
24. During the original SNS cryomodule production, twenty-four cryomodules were shipped from JLab to SNS, ~500 miles. Same shipping system to be employed for PPU.
25. Lessons learned from SNS and LCLS-II will be implemented whenever possible.
26. Questions remain about accommodating end can interference with existing shipping frame.
27. Alignment tolerances same as current SNS cavities and cryomodules.
28. Spaceframe material is 304 stainless. Extensions added for thermal and magnetic shield support.
29. MLI procured as blankets.
30. Slots in the vacuum vessel to cold mass flanges allow +/-5 degrees of rotational misalignment.
31. No new requirements on the magnetic shield design.
32. Heaters and liquid level probes are installed inside the helium vessels.
    a. Ceramic feedthrough-style pin connectors inside the cryomodule are mounted adjacent to access ports to accommodate maintenance and replacement if necessary.
33. Maximum piping design pressure is 200 psia.
34. Cryomodule to end can weld qualification by visual inspection, leak testing and pressure testing. None by radiography.

Findings and Observations

35. Tooling is at about the PDR level.
36. New end can assembly procedures and tooling required due to their new designs.
37. The bayonets need to be within ~3/8" laterally and ~3/16" vertically from their nominal positions. The goal is half that laterally.
38. The nominal gap between end cans on adjacent module assemblies is ~0.8".
39. Domestic vendors will be sought wherever possible.
40. Traveler system is Pansophy.
41. Labor peaks at 20 FTEs during FY22. LCLS-II averages 45 FTEs during production.
42. One cavity string at a time in the cleanroom across at least three projects. Management will determine priorities.
43. Each production line will have its own dedicated, experienced crew of technicians.

Comments

1. We realize tooling design is only at the PDR level, but encourage tracking that effort to ensure it meets the needs of cryomodule production.
2. The project recognizes several production area space conflicts, especially in the cleanroom, and should make every effort to minimize the potential for schedule delays.
3. Ensure adequate in-process inspection during installation of the supply and return can overall length to ensure positive clearances between installed cryomodules.
4. We appreciate the consistency in specification of allowed shipping loads and encourage expanding that specification to include lessons learned about frequency attenuation during dynamic modeling of the detailed cryomodule structure.
5. All areas of the project are encouraged to continue taking advantage of lessons learned by other similar projects to avoid duplicating problems encountered elsewhere.
6. Ensure acceptance and installation criteria at SNS are documented in advance of task.

Recommendations

1. Complete all procurement packages by the end of fiscal year 2019.
2. Identify opportunities to pull the schedule forward. Having this information will allow the project to increase schedule contingency and potentially avoid competition with other projects.
3. Finalize the installed cryomodule interface control drawing.