

Title: PF1A &1B Lower Bus, Bakeout Bus Final Design ReviewCAT: ☒ A1 ☐ A2 ☐ A3Type of Review: ☐ Peer ☐ CDR ☐ PDR ☒ FDRCognizant Individual: D. CaiDate of Review: 19 February 2020

Review Board Members: See

attached report

Chairperson _____

RE _____

TA (Subject) Name _____

TA (____) _____

QA _____

ESH _____

Regulatory Compliance _____

Invited Attendees:

Other Attendees:

Items Reviewed:

Sat.

Unsat.

Comments or n/a if not applicable

Appropriate requirements identified



Development plans and schedules



Reg. compliance incl. USI/USID and NEPA



Disposition of CHITS from previous reviews



Calculations (all listed are signed and filed)



Cost objectives



Other review objectives addressed

**SUMMARY OF RESULTS:** Please see attached report

Disposition: [check one].

Acceptable☒ **Acceptable pending resolution of concerns**- CHITS identified above must be resolved prior to installation.☐ **Incomplete** - Additional design work is required prior to another design review.☐ **Unsuccessful** – Corrective actions must be taken and another review process must be initiated.

Design Review Chair Person _____ Date: _____

Cognizant Individual Acceptance _____ Date: _____

Distribution: Review Board Members, Operations Center, Responsible Engineer (RE), Cognizant Individuals, Project Manager, Project Director, relevant Technical Authorities (TAs), Chief Engineer (CE), Fire Protection Engineer, Attendees, QA, ES&H, Security, Requesting & Performing Dept. Head

FDR Report for PF1A/B Lower, Bakeout Bus

February 19, 2020

Attendance: R. Ellis (Chair, CE, Mechanical TA), D. Cai, Y. Zhai, R. Hawryluk, S. Gerhardt (Systems Integration and Research Operations), P. Titus (Analysis TA), Neil Gerrish (ES&H), G. Swider, S. Sheckman, K. Cortes, A. Indelicato, J. Mitchell (CAD), J. Winkelman, P. Dugan, M. Safabakhsh (Manufacturing TA), T. Stevenson, W. Que A. Khodak, C. Rana, J. Fang, S. Raftopoulos, J. Dellas (Power Systems TA), D. Niemenski (DoE), M. Smith (MCS, remote connection)

Executive Summary

This final design review of the PF1A and B lower buses is the second in a series on the inner PF bus bars, following the PF1C bus bar FDR on February 7, 2020. The remaining buswork will be reviewed during the week of February 24-28, 2020. The goal of the review is to show that the bus bars satisfy their defined interfaces and requirements, have adequate stresses, and adequate contact at the coil connections.

Discussion

D. Cai presented an overview of the design of the PF1A and B lower buses and the bakeout bus. The terminals on the bakeout bus are made from CuCrZr for strength. A question, and chit, asked whether we were using the same ultra-strong grade of the material that cracked some years ago during the manufacture of the TF lead extensions. The connecting bracket between the vacuum vessel and bus bar has been changed from stainless steel to CuCrZr in order to reduce temperatures.

The full set of upper level assembly drawings is not complete, because they are dependent on progress in other areas of the project.

Yuhu Zhai presented the load specifications and boundary conditions for the PF1A and 1B lower bus bars. Loads are normal electromagnetic and thermal, plasma disruptions and post-disruption (over-currents). Loads for off-normal events were also presented. Suppress/bypass blip. We have sufficient margin for these off-normal events.

Normal EM loads are from Scenario 51 for PF1AL and Scenario 33 for PF1B lower. The 15% current overshoot for the Suppress/Bypass off-normal event is acceptable due to the higher K-factor in the structural design criteria for this unlikely event.

Loads from cloud data were mapped onto the structural models.

Peter Titus presented the allowable material properties, and the loads on the bakeout bus, which keeps excessive currents out of the bellows during the bakeout and disruptions. Allowable stresses in heat affected braze areas are reduced compared to cold worked copper – the 76MPa

yield strength of fully annealed copper is assumed. A fatigue limit of 90MPa was used in these areas.

J. Fang presented the analysis of the PF1A and PF1B lower bus bars. His work included the coil leads, bus bars, and flex cable connections. Coil displacements from the Machine Core Structures model of PF1A and PF1B were applied to the models presented here. There was a question as to whether the brittle material allowable, based on $1/3$ of ultimate tensile strength of G-10, was more appropriate than the $2/3$ of yield strength or $1/2$ of ultimate strength. A chit was submitted asking for a check of the individual stress components at critical areas. Stresses in bus bars and bolts were acceptable. A calculation of contact resistance at the coil connection showed ~ 0.6 microhms. J. Dellas (Power systems TA) mentioned that we are typically content with 5 microhms at these types of contacts. Comparison of the assumed bolt preloads at this location to what we have used in previous bus connections lends confidence to the prediction shown here.

C. Rana presented the stress analysis of the bakeout bus. The contact resistance is ~ 1.1 microhms, based on the same integration of pressure, area and local resistance as was presented for the PF1A and PF1B bus bars. Stresses in the bus bars and supports, and contact resistances were acceptable.

D. Cai presented the manufacturing, cost and schedule for the bakeout bus and PF1A upper and lower bus.

There were 13 chits, of which 5 were rejected. None of the chits will prevent this design from being brought to a conclusion.

Conclusion

The review was considered successful pending resolution of concerns.

TO: D. CAI

FROM: Y. ZHAI

SUBJECT: CHARGE FOR PF1A&1B UPPER & LOWER BUS, BAKEOUT BUS FINAL DESIGN REVIEW – Rev. 1

1 Introduction

The NSTX-U Recovery Project completed a final design review (FDR) for the inner PF replacement coils on March 30, 2018 that included significant design improvement to the coil terminal supports. The project also completed two preliminary design reviews (PDR-I & PDR-II) on the inner PF Bus on February 28, 2019, on bakeout Bus, the PF4 Bus support and remaining Bus scope on October 14 2019 respectively. The FDR I held on February 7, 2020 covered the BUS work scope including

- Inner PF 1C coil bus bars and bus support structures
- The PF4 hard and flex bus and supports
- PF1B water cooled power cable connection from vessel to PCTS
- The TF extension connection field fit-up
- The OH coax hard bus field fit-up

This FDR II shall present the final design of remaining BUS work scope including

- Inner PF1A and 1B upper coil bus bars and bus support structures
- Inner PF1A and 1B lower coil bus bars and bus support structures
- The bake out bus and bus supports

The flex cable support at the far end of the coil bus bars will also be evaluated to ensure sufficient structural integrity for the inner PF Bus bar system. The design review methodology will conform to the latest version of ENG-033 (Rev. 8), based on A1 risk classification.

2 Purpose

The purpose of this final design review (FDR) is to review final design of the PF1A and 1B coil terminal support structure, PF1A&1B bus bars, and the bus support structures, including both upper and lower regions, as well as bakeout Bus listed above.

3 Requirements

- General Requirements Document, NSTX-U-RQMT-GRD-001-03.
- System Requirements Document for Magnet Systems, NSTX-U-RQMT-SRD-002-02.
- NSTX Structural Design Criteria, NSTX-CRIT-0001-02.

4 Scope

The scope of this FDR includes PF1A & 1B coil terminal supports, PF1A & 1B coil bus bar and bus support, the bakeout bus and bus support. Cost and schedule will be covered, and review of the manufacturing and installation of the bus, power cable, and supports will also be included.

5 Methodology

The FDR shall be conducted in accordance with existing PPPL procedure ENG-033 "Design Verification," supplemented by the participation of the NSTX-U Project Engineer.

The following are the FDR objectives/deliverables (as applicable):

- Review and verify that the final design satisfies all requirements and is ready for implementation.
- Verify resolution of chits from previous reviews.
- Verify that detailed analyses, calculations, and tests are complete and documented including calculation checking.
- Review and verify that the final product can be manufactured, inspected, assembled, stored, delivered, and installed reliably, safely, and cost effectively.
- Review and verify that appropriate documentation is available for producing the final product (e.g. drawings, installation procedures).
- Review and verify that procurement issues have been identified and resolved.
- Review and verify that appropriate test plans for the final product have been established.
- Review and verify that identification and control of items has been addressed.
- Review and verify any SAD/ASE considerations have been resolved.
- Review and verify that human factors are appropriately addressed in the design.
- Formally convey the design output for approval via the Design Approval Form (ENG-033 - Attachment 6).

Review materials shall be presented to the Design Review Committee and Project Engineer for acceptance, and then distributed to the review committee one week in advance of the review.

6 Review Committee

The Design Review Committee shall be constituted as follows. In case any persons are absent, the review may proceed at the discretion of the Design Review Chair (DRC) and NSTX-U Project Engineer (PE).

Robert Ellis	Design Review Chair and Chief Engineer
John Dellas	Power System TA
Stefan Gerhardt	Systems Integration and Research Operation
Michael Kalish	COG, Magnets
ES&H	N. Gerrish or H. Wetzel
Doug Loesser	VV+IH RE & ME TA
QA Representative	F. Malinowski or A. Castaneda
Mark Smith	VV+IH, SME
Steve Raftopolous	RE, Magnets
Mojtaba Safabakhsh	Manufacturing TA
Peter Titus	Analysis TA
John Mitchell	CAD Design

7 Agenda

The review shall be accomplished over one half day, scheduled for February 19, 2020, with the following preliminary agenda:

19-Feb-20	NSTX-U INNER PF BUS WORK PDR		
	Agenda		
Start	Duration	Topic	Presenter
12:00	5	Introduction & Requirements	S. Raftopoulos
12:05	20	Bakeout and PF1A&B BUS Design	D.Cai
12:25	10	PF1 Bus Load and Boundary Conditions	Y. Zhai
12:35	20	PF1A&1B Upper BUS Analysis	A. Brooks
12:55	20	PF1A&1B Lower BUS Analysis	J. Fang
13:15	10	Bakeout BUS Load and Boundary Conditions	P. Titus
13:25	25	Bakeout BUS Analysis	C. Rana
13:50	10	Manufacturing & Installation Plan	D.Cai
14:00	15	Chit Disposition	DRC
14:15	Adjourn		

cc:

L. Hill	J. Mitchell
D. Loesser	R. Ellis
D. Cai	Y. Zhai
G. Swider	A. Brooks
A. Castaneda	W. Que
J. Dellas	S. Raftopolous
P. Dugan	C. Rana
J. Fang	M. Safabakhsh
R. Hawryluk	P. Titus
S. Gerhardt	S. Weidner - PU
M. Kalish	J. Winkelman
J. King – DOE	B. Sullivan – DOE
A. Indelicato – DOE	P. Johnson – DOE
S. Rogan – DOE	D. Niemenski - DOE
F. Malinowski	
N. Gerrish	J. Mitchell
H. Wetzel	
S. Sheckman	PPPL QA
M. Smith	NSTX-U File

PF BUS WORK FDR-2

Feb 19, 2020

Yuhui Zhai
Bob Ellis

Di Cai

PETER TITUS

Stefan Gerhardt

Rich Hawryluk

TIM STEVENSON

Weiguo Que

Andrei Kholodak

John Dellar

Chirag Rana

Steve Raptopoulos

Jiangy Fang

JOAN GALAYDO

KEVIN CORTES

Sam Sheckman

Gary Swider

Neil Gerrish ESH

Mojib SAFARZADEHSH TI Group

Peter Dugan

John Winkelman

John Mitchell

Anthony Indelicato

Deborah Niemenski