DESIGN REVIEW DOCUMENTATION – RESULTS – No: 3019

Title: Center Stack Casing Modifications

CAT: ☒ **A1** ☐ **A2** ☐ **A3**

Type of Review: ☐ **Peer** ☐ **CDR** ☒ **PDR** ☐ **FDR**

Cognizant Individual: Mark Smith (Mike Viola) **Date of Review: 16 October 2018**

Review Board Members:	**Review Board:**	**Review Board:**
Chairperson R. Ellis*	S. Gerhardt, Systems Integration	J. Klabacha, RE PFCs
RE A. Brooks**	P. Dugan, Systems Engineer	W. Blanchard, RE HTT/HTP
TA (*Mechanical*) Ellis	C. Neumeyer, Chief Engineer	J. Mitchell, CAD
TA (____)	M. Kalish, RE Magnets	M. Safabakhsh, Manufact. SME
TA (____)	S. Raftopoulos, RE Magnets	T. Stevenson, Ops (late)
	I. Zatz, Project Engineer	
QA F. Malinowski	Y. Zhai, Project Engineer	
ESH J. Levine (remote)		
Regulatory Compliance		

*also RE Diagnostics and Mechanical TA **Representing Doug Loesser, RE Tokamak Core

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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	☒	☐	
Cost objectives	☒	☐	
Other review objectives addressed	☒	☐	Objectives from charge letter

SUMMARY OF RESULTS:

Please see following pages.

Disposition: [check one]

_______ **Acceptable**

Xxxxxx **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 Robert Ellis Digitally signed by Robert Ellis Date: 2018.10.29 14:11:10 -04'00' Date: ____________

Cognizant Individual Acceptance Mark Smith Digitally signed by Mark Smith Date: 2018.10.29 14:16:43 -04'00' 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

Center Stack Casing Modifications

Preliminary Design Review

16 October, 2018

Attendees

R. Ellis, J. Menard, M. Smith, M. Viola, S. Horst, Y. Zhai, M. Sabfakhsh, C. Roman, C. Pagano, I. Kunsch, T. Ronge, P. Titus, D. Bishop, S. Raftopoulos, J. Klabacha, A. Brooks, S. Gerhardt, I. Zatz, W. Blanchard, C. Neumeyer, P. Dugan, D. Kai, F. Malinowski, H. Zhang, J. DeVoe, G. Swider, T. Stevenson, M. Kalish, J. Mitchell

Introduction

The center stack casing must be modified in order to meet the requirements of the NSTX-U Recovery Project. Threaded studs must be removed and repositioned. Welds between the inboard divertor vertical cylinder and the angled section, as well as between the CSFW and angled section, must be upgraded. Addition of the heat transfer plate requires modifications to the inboard divertor horizontal flange. And the bellows will be replaced.

Mark Smith and Mike Viola have organized a team that will expedite the design and implementation of the necessary modifications. Status of the design was presented at this review.

Scope

The scope of this review is defined in the charge letter. It includes the proposed modifications to the CSC, which includes regions and components between the upper and lower center stack bellows flanges. Interfaces to affected systems are also in the scope of this PDR. Fabrication planning is addressed.

Overview

Mark Smith presented an overview of the review, defining the scope, and noting that the design of the halo current side load restraints and alignment shims is outside the scope of this review.

Interfaces

Peter Dugan presented the design interfaces, beginning from Systems Requirements Documents and Requirements Documents. He noted that templates for interface control documents have been created, and that he will be working with the responsible engineers associated with those interfaces to complete the documents.

Chit Resolution

Chris Pagano presented a summary of the chit resolution report. The entire chit registry has been reviewed, with chits relevant to the polar region addressed at this review. Out of 173 chits, 58 are still open. These chits, plus the output from this review, must be closed by the final design review.

Polar Region Interfaces

Ian Kunsch described the interfaces between the center stack casing and the polar region. These include assembly tolerances and clearances for the inner PF coils, the design of the halo force restraints, the interfaces with organ pipes and coil flanges. A concern related to the organ pipes was whether Viton o-rings can withstand the temperatures reached during bakeout. Additionally, a concern about the temperature of coil ground wrap needing to be kept below its glass transition temperature was raised, and documented in a chit.

Heat Transfer Tube (HTT) and Heat Transfer Plate (HTP) Interfaces

Dang Cai discussed the interfaces between the center stack casing and the HTT/HTP. The HTP interfaces are the flat surface on the horizontal inboard divertor flange, and the holes in the inboard divertor for mounting holes.

Plasma Facing Component (PFC) Interfaces

Jonathan Klabacha discussed the interfaces between the center stack casing and PFCs. There are stud alignment requirements, and surface flatness and profile requirements, that are critical too the PFC design. The surface deformation in the area of the weld between the center stack first wall and angled section was discussed extensively because of its potential impact on the PFC design.

Diagnostic Interfaces

Catalin Roman described the interfaces between diagnostics and the center stack casing. Air side diagnostics are installed on the center stack bundle. A trial fit verified that there is adequate clearance between the bundle and the inside of the center stack casing. The polar region team is providing wire passages for the plasma current Rogowski coils and other air side diagnostics. The new design and positioning of the center stack halo current Rogowski coils was discussed. This information has been integrated in to the CAD model of the center stack case. Details of the PFC diagnostics will be discussed at a separate review.

Fabrication Planning

Chris Pagano presented the plan for fabrication/modification of the center stack. The plan assumes that all drawings and documents required by PPPL's QAPD are complete at the start of fabrication, and also assumes that all of the components arrive when dictated by the schedule. This last point is of particular interest to the group working on the HTP. There was discussion on whether flux loops can all be installed at PPPL, or if some will need to be installed at the center stack fabrication vendor. Assembly tolerances were discussed; they are tightly defined within each target region, with somewhat larger allowances between the upper and lower targets.

Load Specifications

Mark Smith discussed the load specifications, design considerations, and an analysis flow chart. Of the disruption scenarios P0 through P6, P2 and P6 are the worst cases for this design. The halo current side loads have increased, from 25 kips to somewhere between 40 and 70 kips. An improved specification for these loads is desired. A 2-D global thermal model (please see next section) defined the worst case thermal scenarios.

Global Thermal Analysis

Han Zhang presented the results of thermal analysis using a global 2-D model that included the vacuum vessel, plasma facing components, center stack casing components, and important structural components. Thermal ratcheting is addressed by simulating a complete run day. Five operational and two bakeout scenarios were evaluated, and the worst cases selected for input into detailed stress analyses.

Electromagnetic Global Analysis

Peter Titus presented the results of electromagnetic analyses to date. Global electromagnetic loads have been calculated based on the worst disruption scenarios. He added some slides on heating of the bellows during bakeout.

For bakeout and halo currents, roughly 10 per cent of the current passes through the bellows. Forces in the bellows from eddy currents are small, as they flow predominantly in the toroidal direction.

The loads, in a nearly final form, have been passed to the analysis.

Bellows

Thomas Ronge presented the analysis of the bellows – a continuation of the work done for the polar region PDR earlier this year. Not all of the stresses are within the allowable range, and the allowable stresses claimed here did not utilize the efficiency factors shown elsewhere in this review. The proposed path to obtaining allowable weld stresses was to use Miner's Rule and a Goodman diagram to refine the fatigue loads, claim fully cold worked material properties in the weld zone, and count on material tests for additional margin. This chairman is skeptical of this approach, particularly the latter two proposals.

Detailed Analysis

Doug Bishop presented the results of his extensive analyses of the center stack casing, in particular the polar regions. His models used linear materials, with nonlinear and linear contact elements as needed. Disruption scenario P2a was analyzed. The most critical stresses were at the welds between the angled section and the center stack first wall and the inboard divertor vertical target. Most of these weld stresses were within the static allowable range; some failed the fatigue criteria. More substantial welds will be required.

Cost and Schedule

Cost and schedule estimates were presented. The budget at completion (BAC) is $5.5M. Expected completion is April 2020.

SAD/ASE

Stefan Gerhardt discussed SAD/ASE implications. The SAD will need an update to its narrative for this configuration, but this work does not otherwise affect the SAD. NSTX-U does not yet have a DoE-approved Accelerator Safety Envelope. No impact on potential credited controls is expected.

Chit Resolution

Twenty two chits were generated at this review. The board rejected one and classified another as out of scope for this review. None of the chits would point to a major change to the design. See chit summary at the end of this report.

Conclusion

The review board considered the design review to be "Acceptable pending resolution of concerns." We also noted that, in order to get to this review, a large amount of work was completed and coordinated in a very short time, and this reflects an excellent job on the part of the team. The biggest concerns emerging from the review are the resolution of concerns with the bellows design, and the strengthening of the welds on each end of the angled section.

Documentation

Documentation for this review can be found on the 10181016 CSC Mods PDR Dashboard.

Originator (First & Last Name):	Organizational Breakdown Structure (OBS)	Subject: (Check as Applicable)	Comment/Concern/Recommendation:	Review Board Comment	Review Board Recommendation
Art Brooks	VV & Internal Hardware	Requirements	In addition to specifying the distance between halo current strike points on the CSC, a limited combination of strike point locations, both height and toroidal phasing should be specified. At present the requirement is silent requiring full scanning of parameters.	Action: Stefan	Concur
Charles Neumeyer	VV & Internal Hardware, Bakeout System	Requirements, Analysis, I	Calculation NSTXU-CALC-33-01-00 to establish current needed to provide ohmic heating of CSC during bakeout seems to be obsolete (targets wrong power level, has wrong current, etc.). Needs to be updated to match latest CSC geometry and heating requirements. Also, Zhang is cited on the calc webpage as the author, but actual download calc document is authored by Dudek. Is there a new calculation that has not been properly uploaded?	Fix calcualtion documentation	Concur
Danny Cai	VV & Internal Hardware	Performance	If it is hard to meet temperature and permeation requirement at the same time using rubber seal for organ pipe, consider use a bellow so that a copper gasket can be used to meet both temperature and permeation requirement		Do not concur
Michael Kalish	VV & Internal Hardware	Requirements	Requirement as stated in the review is that the coil ground wrap shall not exceed the glass transition	Review criteria and margin and provide temperature.	Concur
Moji Safabakhsh	VV & Internal Hardware	Reliability/Maintainability,	1- HTT and HTP and fittings through the diverter flange have too many joints. See if welded joints/fittings can be eliminated/reduced. 2- 1/4"-20 bolts need not that tight tolerance as long as dowel pins accurately secure the plates.	Consider. Action: D. Cai	Concur
Mike Viola	VV & Internal Hardware	Requirements, Hardware,	The achievable position tolerance after the Divertor flange is machined and welded onto the casing is likely larger than the specified HTP feature positional tolerance. This should be mocked up to determine the achievable accuracy.	Consider if resources permit	Consider
Jon Menard	VV & Internal Hardware	Requirements, Hardware	Reminder - need to perform metrology during additional welding of ID/OD of casing to ensure top/bottom casing cylinders retain common centerline and alignment (within tolerance) with central casing cylinder to ensure overall alignment of PF1 coils with TF/OH bundle.	Planned	Concur
Bill Blanchard (fmalinowsk	VV & Internal Hardware	Hardware, Configuration	Should leak test bellows to ring weld because you will not be able to fix weld later if it leaks.	Planned - 2 leak checks	Concur
Mark Smith	VV & Internal Hardware	Requirements	Stefan to complete the Tolerance document...ICD, RD, or Memo defining tolerances required at interfaces. Ref..HTP and Divertor flange interface	Action: Stefan	Concur
Mark Smith	VV & Internal Hardware	Cost/Schedule	CSC Fabrication plan assumes All components are available at the start of the CSC contract. Is this reflected in all the individual WAF/schedules and the Master schedule. Reference HTP availability.	out of scope for this PDR but required consideration at project P6 level review to determine if schedule matters	Concur - project

Originator (First & Last Name):	Organizational Breakdown Structure (OBS)	Subject: (Check as Applicable)	Comment/Concern/Recommendation:	Review Board Comment	Review Board Recommendation
Steve Raftopoulos	VV & Internal Hardware	Configuration	As discussed, clearly mark "North" on a section of the CS case that it not removed. Also, ensure that the current North is maintained as the CS test fit over the TF/OH is based on the current definition of North of the CS FW tube.	Add fiducial datum to maintain alignment in trail fit but not "true North"	Concur
Stefan	VV & Internal Hardware	assembly	The slide in C. Pagano showed the casing flux loop being installed before the bellows are welded in place. While I understand the rational, it is worth inquiring with Gus Smalley whether he can install those loops after the casing is returned to PPPL. If not, then will need a significant verbiage in the SOW/RFQ about how to do this installation, or will be sending Gus to vendors...	Evaluate with Gus Smalley.	Concur
Mike Viola	VV & Internal Hardware	Cost/Schedule	Added assumption and risk that Supplier can perform many tasks at both ends in parallel and within planned schedule time.	Check Tab A of WAF and risk registry; assess SOW	Consider
Jonathan Klabacha	VV & Internal Hardware	Requirements	Alignment of the CS Main sleeve to the CS sleeve adapter to the CS transition sleeve is very important to the PFCs to be concentric. With the welding of the CS, the sleeves might become misaligned. During the welding of the CS, methods should be used to measure concentricity.	See chit 8	Concur
Danny Cai	VV & Internal Hardware	Cost/Schedule	The manufacturing cost of HTT/HTP should be included in 1150VVIH6005. The installation cost should be included in the CSC WAF	Evaluate with S. Langish	Consider
Michael Kalish	VV & Internal Hardware	Analysis	With respect to the global thermal analysis consider further bench-marking of calculations after operation to confirm assumptions and that as built conditions matches the 2d axi-symmetric model (emissivity? insulation as built insulation installation? hot spots due to local brackets welded to inside wall of vacuum vessel?) Or alternatively perform a sensitivity study varying assumptions with uncertainty to verify analysis is conservative.	Out of scope for this review. Operations scope.	Out of scope
Jonathan Klabacha	VV & Internal Hardware	Analysis	In the integrated analysis from Han, the IBDV low heat flux tiles are stated not to have grafoil underneath the tiles, yet in the PFC design there is grafoil. Please confirm with the PFC team on the proper geometries.		Concur
Peter Titus	VV & Internal Hardware	Analysis	An accepted approach for fillet welds is to take the line load on the weld - as long as moments are secondary, calculate the stress by dividing by the fillet leg*.707 and then multiplying by 4 to enter the ASMS SN curve. The ASME SN has the 2 and 20 built into it - this might be less limiting.		Concur

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Peter Titus	VV & Internal Hardware	Analysis	I am still not seeing the divertor flange rotation that I expect for bake-out with 350 C at the flange and 60C at the collar base - Please check - maybe a sub model		Concur
Peter Titus	VV & Internal Hardware	Analysis	The buckling analysis is good - but to be complete, apply a DLF to the eddy current load		Concur
Yuhu Zhai	VV & Internal Hardware	Requirements	Please check with Stefan to clarify the disruption and halo current requirements. 1) correct error in drift time in Table 2.1 of Disruption Requirement documents for P0 and P1 central plasma disruptions 2) halo current span (0.5 m or 1 m?) on the CS casing		Concur

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National Spherical Torus eXperiment Upgrade

VVIH-181010-IJZ-01

TO: M. SMITH
FROM: I. ZATZ
SUBJECT: CHARGE FOR CENTER STACK CASING MODIFICATIONS PRELIMINARY DESIGN REVIEW – Rev. 1

1 Introduction

The NSTX-U Recovery Project is reviewing a variety of potential modifications to the center stack casing (CSC) assembly, which was originally fabricated in 2012. These modifications include the incorporation of additional features/components as well as updating the interfaces with adjacent systems. This PDR presents the design modifications proposed for the CSC leading to convergence on the final design to be presented at an FDR in December 2018.

The General Requirements Document, NSTX-U-RQMT-GRD-001-01, defines the overall engineering requirements as well as those specific to each major element of Vacuum Vessel and associated structures. More detailed requirements and interfaces related between the CSC regions are defined in the System Requirement Documents, NSTX-U-RQMT-SRD-004-00 and NSTX-U-RQMT-SRD-005-00 plus applicable interfacing system requirement documents.

Design review methodology will conform to the latest version of ENG-033 (Rev. 7) based on A1 risk classification.

2 Purpose

The purpose of the PDR is to review the development of the NSTX-U Center Stack Casing design modifications and the impact to all related system interfaces. Once they are resolved, final details will lead to an FDR in December 2018.

3 Requirements

- NSTX-U General Requirements Document, NSTX-U-RQMT-GRD-001-01
- NSTX-U System Requirements Document for Vacuum Vessel and Torus Support Structure, NSTX-SRD-004-00
- NSTX-U System Requirements Document for Auxiliary Systems, NSTX-SRD-005-00
- NSTX Structural Design Criteria, NSTX-CRIT-0001-02

4 Scope

The PDR shall cover the proposed modifications to the CSC. The CSC includes those regions and components between the center stack bellows flanges and includes those flanges as well as the divertor flanges, bellows, organ pipes, and collars, in addition to the main body of the casing (main sleeve, sleeve adapter flanges and transition sleeves). Interfaces to impacted systems, including the Polar Regions, HTT/HTP, PFCs, and Diagnostics, are also within the scope of the PDR. Fabrication planning is also part of this PDR scope.

Issues specific to the interfaced systems themselves (Polar Regions, HTT/HTP, PFCs, and Diagnostics) are considered out-of-scope for this review.

5 Methodology

The PDR 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 PDR objectives/deliverables (as applicable):

- Review updated design.
- Verify that all requirements are being addressed. Identify requirements or design conflicts and potential "show-stoppers".
- Verify that interfaces are identified and defined.
- Ensure consideration of chits from previous reviews.
- Review the results of analyses, calculations, and tests performed to justify the design.
- Review the ability to implement the design taking into consideration capabilities, tolerances, costs, quality, reliability, human factors, ES&H and security.
- Review manufacturability.
- Review plans, costs and schedules.
- Review procurement issues, e.g. build vs. buy.
- Review test requirements and plans.
- Review SAD/ASE considerations.

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 as follows:

R. Ellis	Chairperson / RE Diagnostics / ME TA
A. Brooks	Tokamak Core Engineering
S. Gerhardt	System Integration
P. Dugan	Systems Engineer
T. Stevenson	Operations
C. Neumeyer	Chief Engineer
M. Kalish	RE Magnets
S. Ratfopoulos	SME
I. Zatz / Y. Zhai	Project Engineer
J. Klabacha / M. Jaworski	RE PFCs
B. Blanchard	RE HTT/HTP
J. Mitchell	CAD
M. Safabakhsh	Manufacturing SME
QA Representative	F. Malinowski, B. Jedic, A. Amaya, or A. Castaneda
ES&H Representative	Safety / SAD Considerations

7 Agenda

The review shall be accomplished over a full day, scheduled for October 16, 2018, with the following preliminary agenda.

Start	Duration	Topic	Presenter
9:15 AM	0:10	Chairman's Introduction	R. Ellis
9:25 AM	0:10	Introduction and Overview of Scope	M. Smith
9:35 AM	0:30	Requirements	P. Dugan
10:05 AM	0:30	CHITs Review	C. Pagano
10:35 AM	0:15	**Break**	
10:35 AM	0:15	Interfaces - Polar Region	Ian Kunsch
10:50 AM	0:15	Interfaces - HTT/HTP	Danny Cai
11:05 AM	0:15	Interfaces - PFCs	J. Klabacha
11:20 AM	0:15	Interfaces - Diagnostics	Catalin Roman
11:35 AM	1:00	**Lunch**	
11:35 AM	0:45	Fabrication planning and logistics	C. Pagano / M. Viola
12:20 PM	0:30	Analysis - Load Spec, Design Criteria, C&S	M. Smith
12:50 PM	0:20	Thermal Global	H. Zhang
12:50 PM	0:20	EM Global	P. Titus
12:50 PM	0:20	Analysis - Bellows	T. Ronge
1:10 PM	0:15	**Break**	
1:25 PM	0:45	Analysis - Collar, Diverter Flange and CSC Structures	D. Bishop
2:10 PM	0:45	Analysis - Circumferential Weld Design	D. Bishop
2:55 PM	0:30	Recovery Project Planning, Cost and Schedule	R. Feder
3:25 PM	0:05	SAD	S. Gerherdt
3:30 PM	0:30	New CHIT Review and Consolidation, Meeting Closeout	R. Ellis
4:00 PM	-	Meeting End	

cc:

D. Bishop
W. Blanchard
A. Brooks
D. Cai
P. Dugan
T. Egebo
R. Ellis
R. Feder
S. Gerhardt
S. Gifford
M. Jaworski
P. Johnson - PSO
M. Kalish
J. King – DOE
J. Klabacha
I. Kunsch
S. Langish
J. Levine
D. Loesser
J. Menard
J. Mitchell
C. Neumeyer
C. Pagano
S. Raftopoulos
V. Riccardo
C. Roman
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W. Slavin
M. Smith
T. Stevenson
P. Titus
M. Viola
S. Weidner – PU
J. Winston
I. Zatz
Y. Zhai
H. Zhang

PPPL QA
NSTX-U File