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PRINCETON PLASMA PHYSICS LABORATORY

CRR_CHITID - CHIT RESOLUTION REPORT

CHIT RESOLUTION REPORT FOR THE CENTER STACK CASING FABRICATION

NSTXU_1-1-3-3-6_CRR_100

Rev. 3

Work Planning #:	
Effective Date:	**02/19/2020**
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Approved By	Kathleen Lukazik, Preparer	02/19/2020 09:12:45 AM

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NSTX-U-REC-111

CHIT CODE	§ OF REPORT	STATUS	CHIT CODE	§ OF REPORT	STATUS
ALLIGNPEER03	CR-VVIH-1041	CLOSED	CSCMODSPDR14	CR-VVIH-1004	CLOSED
ALLIGNPEER05	CR-VVIH-1031	CLOSED	CSCMODSPDR15	CR-VVIH-1011	CLOSED
ALLIGNPEER06	CR-VVIH-1042	CLOSED	CSCMODSPDR16	CR-VVIH-1012	CLOSED
ALLIGNPEER07	CR-VVIH-1043	CLOSED	CSCMODSPDR17	CR-VVIH-1013	CLOSED
ALLIGNPEER08	CR-VVIH-1044	CLOSED	CSCMODSPDR18	CR-VVIH-1014	CLOSED
ALLIGNPEER09	CR-VVIH-1032	CLOSED	CSCMODSPDR19	CR-VVIH-1015	CLOSED
ALLIGNPEER10	CR-VVIH-1045	CLOSED	CSCMODSPDR20	CR-VVIH-1016	CLOSED
ALLIGNPEER12	CR-VVIH-1030	CLOSED	CSCMODSPDR21	CR-VVIH-1017	CLOSED
CASFABPR02	CR-VVIH-1019	CLOSED	CSCMODSPDR22	CR-VVIH-1018	CLOSED
CASFABPR03	CR-VVIH-1020	CLOSED	CSMUPEER03	CR-VVIH-1029	CLOSED
CASFABPR04	CR-VVIH-1021	CLOSED	POLARPEER03	CR-VVIH-1047	CLOSED
CASFABPR05	CR-VVIH-1022	CLOSED	POLARPEER19	CR-VVIH-1049	CLOSED
CASFABPR06	CR-VVIH-1023	CLOSED	POLARPEER21	CR-VVIH-1050	CLOSED
CSCFDR04	CR-VVIH-1066	CLOSED	PRFORINSUPDR03	CR-VVIH-1053	CLOSED
CSCFDR06	CR-VVIH-1067	CLOSED	PRFORINSUPDR04	CR-VVIH-1054	CLOSED
CSCFDR07	CR-VVIH-1068	CLOSED	PRFORINSUPDR07	CR-VVIH-1055	CLOSED
CSCFDR08	CR-VVIH-1067	CLOSED	PRFORINSUPDR08	CR-VVIH-1056	CLOSED
CSCFDR09	CR-VVIH-1069	CLOSED	PRFORINSUPDR12	CR-VVIH-1057	CLOSED
CSCFDR10	CR-VVIH-1070	CLOSED	PRFORINSUPDR14	CR-VVIH-1058	CLOSED
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CSCFDR14	CR-VVIH-1072	OPEN	PRFORINSUPDR19	CR-VVIH-1061	CLOSED
CSCFDR16	CR-VVIH-1073	OPEN	PRFORINSUPDR26	CR-VVIH-1062	CLOSED
CSCFDR17	CR-VVIH-1074	CLOSED	PRFORINSUPDR29	CR-VVIH-1063	CLOSED
CSCFDR19	CR-VVIH-1075	CLOSED	PRFORINSUPDR34	CR-VVIH-1064	CLOSED
CSCFDR20	CR-VVIH-1076	CLOSED	PROJPDR11	CR-VVIH-1046	CLOSED
CSCFDR22	CR-VVIH-1077	CLOSED	PROJPDR13	CR-VVIH-1033	CLOSED
CSCFDR23	CR-VVIH-1077	CLOSED	PROJPDR28	CR-VVIH-1028	CLOSED
CSCFDR24	CR-VVIH-1078	CLOSED	REASSEMPDR05	CR-VVIH-1040	CLOSED
CSCFDR25	CR-VVIH-1079	CLOSED	REASSEMPDR14	CR-VVIH-1027	CLOSED
CSCFDR26	CR-VVIH-1080	CLOSED	RPCDR021	CR-VVIH-1036	CLOSED
CSCFDR27	CR-VVIH-1081	CLOSED	RPCDR022	CR-VVIH-1036	CLOSED
CSCFDR28	CR-VVIH-1082	CLOSED	RPCDR023	CR-VVIH-1037	CLOSED
CSCMODSPDR01	CR-VVIH-1000	CLOSED	RPCDR025	CR-VVIH-1038	CLOSED
CSCMODSPDR02	CR-VVIH-1001	CLOSED	RPCDR026	CR-VVIH-1028	CLOSED
CSCMODSPDR03	CR-VVIH-1002	CLOSED	RPCDR032	CR-VVIH-1026	CLOSED
CSCMODSPDR04	CR-VVIH-1066	CLOSED	RPCDR035	CR-VVIH-1039	CLOSED
CSCMODSPDR06	CR-VVIH-1003	CLOSED	VVIHA08	CR-VVIH-1051	CLOSED
CSCMODSPDR07	CR-VVIH-1004	CLOSED	VVIHBI01	CR-VVIH-1052	CLOSED
CSCMODSPDR08	CR-VVIH-1005	CLOSED	VVIHCP02	CR-VVIH-1034	CLOSED
CSCMODSPDR09	CR-VVIH-1006	CLOSED	VVIHCP06	CR-VVIH-1048	CLOSED
CSCMODSPDR10	CR-VVIH-1007	CLOSED	VVIHVV10	CR-VVIH-1035	CLOSED
CSCMODSPDR11	CR-VVIH-1008	CLOSED	VVIHCP13	CR-VVIH-1025	CLOSED
CSCMODSPDR12	CR-VVIH-1009	CLOSED	VVIHPF1CCB07	CR-VVIH-1024	CLOSED
CSCMODSPDR13	CR-VVIH-1010	CLOSED	VVIHPF1CCB21	CR-VVIH-1065	CLOSED

Cognizant Individual: ______________________ (sign and date)
M. Smith, Cognizant Individual

Approver (*): ______________________ 6/21/19 (sign and date)
C. Neumeyer, Chief Engineer

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National Spherical Torus eXperiment Upgrade

CHIT RESOLUTION REPORT
FOR
CENTER STACK CASING FABRICATION

NSTXU_1-1-3-3-6_CRR_100
PREVIOUSLY NSTX-U-REC-111

Reviewed By: ______________________
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Y. Zhai, Project Engineer

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RECORD OF CHANGES

Rev.	Date	Description of Changes
0	01/24/2019	Initial Release
1	02/19/2019	Added Authors for the Resolution each Closed Chit Added Chits and Resolutions generated during FDR on 12/28/2018 Updated Numbering Convention per Chief Engineer Recommendations
2	04/15/2019	Updated report to document closure of chits CSCFDR 11 & 20. Transferred CSCFDR chit 16 to MCS FDR scope.
3	06/18/2019	Dispositioned CSCFDR 67, 71, 73 and 76.

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Disposition Key:

A	=	Actionable
NA	=	Not Actionable
NB	=	Not Actionable due to budget constraints
O	=	Out of Scope
R	=	Redundant

CR-VVIH-1000 – Halo Current Strike Point Definition

Disposition	Review	ID	Chit
A	CSC Mods PDR	CSC MODS PDR01	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.

Resolution – *S. Gerhardt*

The document NSTX-U-RQMT-RD-003-02 specifies the exact positions of the halo current entrance and exit locations. It does not specify the toroidal phasing, because it remains the case that the toroidal phase between the entrance and exit points is determined by the edge magnetic "safety factor" of the disrupting plasma. This edge safety factor cannot be predicted in advance, and therefore the toroidal phase must be scanned to determine the worst case. Analysis "scanning" was performed to determine the worst loading conditions used for CSC design verification, see PPPL document NSTXU-CALC-12-20.

CR-VVIH-1001 – Update NSTXU-CALC-33-01-00 Geometry

Disposition	Review	ID	Chit
A	CSC Mods PDR	CSC MODS PDR02	(i) Calculation NSTXU-CALC-33-01-00 to establish current needed to provide Ohmic heating of CSC during bake-out seems to be obsolete (targets wrong power level, has wrong current, etc.). It needs to be updated to match the latest CSC geometry and heating requirements. (ii) Also, Zhang is cited on the calculation webpage as the author, but actual download calculation document is authored by Dudek. Is there a new calculation that has not been properly uploaded?

Resolution – *H. Zhang*

(i) The latest CS Casing geometry and heating requirements are used in the global thermal analysis, see NSTXU document NSTXU-CALC-10-06.

(ii) L. Dudek, instead of H. Zhang, is now listed as the author of NSTXU-CALC-33-01 on the new calculation log page.

CR-VVIH-1002 – Organ Pipe Temperature and Permeation Requirements

Disposition	Review	ID	Chit
NA	CSC Mods PDR	CSC MODS PDR03	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

Resolution – *M. Smith*

The rubber seal allows for the sealing adjustment needed for proper installation and meets the design requirements including compatibility with the operating environment. Therefore, the incorporation of a bellows is not necessary.

CR-VVIH-1003 – Mocking Up HTP to Divertor Flange Positional Tolerances

Disposition	Review	ID	Chit
NA	CSC Mods PDR	CSC MODS PDR06	The achievable position tolerance after the Divertor flange is machined and welded onto the casing is likely larger than the specified HTP feature's positional tolerance. This should be mocked up to determine the achievable accuracy.

Resolution – *M. Smith*

The outer rings of holes that mate with the HTPs are to be machined on the divertor flange after welding the divertor to the IBDVs to avoid any further distortion and provide tight tolerances. The inner ring is to be machined prior to welding due to limited clearing for a machine tool head.

CR-VVIH-1004 – Metrology of Casing throughout Fabrication Process

Disposition	Review	ID	Chit
A	CSC Mods PDR	CSC MODS PDR07	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.
R	CSC Mods PDR	CSC MODS PDR14	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.

Resolution – *M. Viola*

Metrology measurements are planned throughout the CS Casing fabrication flow plan to verify dimensional tolerances are met at key assembly steps. The fabrication team shall ensure that these measurements are included by the vendors in their MIT plan. This is included as part of the technical specification, see PPPL document NSTX-U-SPEC-VVIH-002.

CR-VVIH-1005 – Leak Test Sequence for Bellows' Welds

Disposition	Review	ID	Chit
A	CSC Mods PDR	CSC MODS PDR08	Should leak test bellows to ring weld because you will not be able to fix weld later if it leaks.

Resolution – *M. Viola*

The bellows' weld skirt shall be leak tested prior to installation on the divertor flange per the test plan, see PPPL document NSTX-U-PLAN-021.

CR-VVIH-1006 – Tolerance Documentation

Disposition	Review	ID	Chit
	CSC Mods PDR	CSC MODS PDR09	Stefan to complete the Tolerance document...ICD, RD, or Memo defining tolerances required at interfaces. Ref. HTP and Divertor flange interface

Resolution – *S. Gerhardt*

Tolerances are outlined in PPPL document NSTX-U-CALC-133-37. The Tolerance analyses do not specify all tolerances for all interfaces; rather it defines important interface tolerances applicable to overall CSC alignment and/or assembly.

CR-VVIH-1007 – Component 'On-Demand' Availability Assumptions

Disposition	Review	ID	Chit
A	CSC Mods PDR	CSC MODS PDR10	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? Be sure to reference HTP availability.

Resolution – *M. Viola*

The HTP installation is included as part of the WAF (1160 VVIH 6035) but the manufacturing remains part of the HTT/HTP WAF. The CS Casing WAF adds the assumption that the HTT and HTP are available when needed and this assumption was added to the risk registry.

CR-VVIH-1008 – Proper Clocking of CS Casing for Installation over TFOH

Disposition	Review	ID	Chit
NA	CSC Mods PDR	CSC MODS PDR11	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.

Resolution – *M. Viola*

This concern is obsolete due to the project decision to fabricate a new CS Casing. There is no longer a requirement to maintain the same orientation used during the trial fit. A North marking is still incorporated into the design for providing a clocking reference during assembly.

CR-VVIH-1009 – Assembly Sequence for Flux Loops Installation

Disposition	Review	ID	Chit
A	CSC Mods PDR	CSC MODS PDR12	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...

Resolution – *M. Viola*

Per consultation with G. Smalley, it would be difficult to install the flux loops once the bellows are installed as the gap between the organ pipes and bellows is only approximately 1/2". The flux loops shall be installed as part of the vendor assembly process. It is included in the Technical Specification, See PPPL Doc NSTX-U-SPEC-VVIH-002.

CR-VVIH-1010 – Vendor Capability for Parallel Fabrication Sequencing

Disposition	Review	ID	Chit
A	CSC Mods PDR	CSC MODS PDR13	Added assumption and risk that Supplier can perform many tasks at both ends in parallel and within planned schedule time.

Resolution – *M. Viola*

The parallelism of tasks is accounted for in the CS Casing WAF (1160 VVHW 6035) through appropriate predecessor/successor assignment. This is also included in the risk registry.

CR-VVIH-1011 – WAF Manufacturing and Installation Costs for HTT/HTP

Disposition	Review	ID	Chit
A	CSC Mods PDR	CSC MODS PDR15	The manufacturing cost of HTT/HTP should be included in 1150VVIH6005. The installation cost should be included in the CSC WAF

Resolution – *M. Smith*

The manufacturing cost of the HTT/HTP and associated components have been included in the HTT/HTP WAF 1160 VVHW 6005. Only the component installation cost is included in the CS Casing WAF 1160 VVHW 6035.

CR-VVIH-1012 – Global Thermal Analysis and/or Sensitivity Study

Disposition	Review	ID	Chit
A	CSC Mods PDR	CSC MODS PDR16	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 axisymmetric 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.

Resolution – *H. Zhang*

The 2015 thermal model, which was used as a basis for the current model, was benchmarked to the 2015 mini-bake, see PPPL document NSTXU-CALC-10-04. The 2015 model was also validated by the full bake later in 2015. The current model shall be compared with temperature measurements in the next bake-out.

CR-VVIH-1013 – Grafoil Clearance Requirements for the Tiles and PFCs

Disposition	Review	ID	Chit
A	CSC Mods PDR	CSC MODS PDR17	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.

Resolution – *M. Smith*

The model under the IBDV low heat flux tiles has been updated to include the Grafoil and this updated model has been used in all analyses.

CR-VVIH-1014 – Weld Qualification Assumptions for CS Casing Analysis

Disposition	Review	ID	Chit
NA	CSC Mods PDR	CSC MODS PDR18	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 (.707×leg) 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.

Resolution – *D. Bishop*

Due to the project decision to make a new CSC, this is no longer required. The new design allows for full penetration welds that can be inspected so no reduction factor is added.

CR-VVIH-1015 – Weld Prototyping and Testing for Fatigue Strength

Disposition	Review	ID	Chit
NA	CSC Mods PDR	CSC MODS PDR19	We had weld issues with the tiny welds on the ribs and PF2/3 supports and we tested the small welds and found they were much stronger than we expected. - We have the test results for static loading. The same could be done for the specialized weld configurations for fatigue

Resolution – *I. Kunsch*

The project decision to fabricate a new CSC eliminates this concern. Larger welds can be included on the drawings and additional thickness can be incorporated to allow for post-weld machining to remove any potential distortion. At the same time, the welds can be appropriately design to be full-penetration reducing the knock-down factor used for the analysis. Together, these design changes should provide sufficient design margin to remove the need to physically demonstrate additional load capacity with testing.

CR-VVIH-1016 – Divertor Flange Rotation for Bake-Out Analysis

Disposition	Review	ID	Chit
A	CSC Mods PDR	CSC MODS PDR20	I am still not seeing the divertor flange rotation that I expect for bake-out with 350°C at the flange and 60°C at the collar base - Please check - maybe a sub model

Resolution – *H. Zhang*

The current integrated structural model shows this result. Deflection during bake-out will depend on the temperature distribution and the overall stiffness of the components, including welds, connections, contacts, and supports. The model includes most of these structure details. Additionally, deflection during normal operation also need to consider the combination with other loads (disruption, halo, pre-load, seismic, etc.), which is also included in the model. The results can be viewed in PPPL documents NSTXU-CALC-12-23-00 and NSTXU-CALC-12-32-00.

CR-VVIH-1017 – Applying a Dynamic Load Factor to the Eddy Current Load

Disposition	Review	ID	Chit
A	CSC Mods PDR	CSC MODS PDR21	The buckling analysis is good, but to be complete apply a DLF to the eddy current load.

Resolution – *D. Bishop*

A Dynamic Load Factor (DLF) has been applied to the eddy current load for the buckling analysis, see PPPL document NSTXU-CALC-12-23.

CR-VVIH-1018 – Disruption and Halo Current Requirements

Disposition	Review	ID	Chit
A	CSC Mods PDR	CSC MODS PDR22	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.

Resolution – *D. Bishop*

The updated disruption and halo current requirements are detailed in the document DIS-181120-SPG-01. All CS casing analyses use these updated requirements.

CR-VVIH-1019 – Change to Divertor Flange to Accept a Short IBOU Casing

Disposition	Review	ID	Chit
NA	Casing Fabrication Peer Review	CASFAB PR02	Please make sure the shortened 1/8" of the IBOU Casing will be compensated by increasing flange thickness so casing flange sealing surface is not moved.

Resolution – *M. Smith*

With the project decision to fabricate a new CS Casing, this issue no longer exists. The Divertor Flange and CS Casing are properly design to be welded and meet the existing dimensional requirements.

CR-VVIH-1020 – Removal of Studs prior to Transporting Old CS Casing

Disposition	Review	ID	Chit
NA	Casing Fabrication Peer Review	CASFAB PR03	The vertical Section studs need to be removed (the 4 rows closest to the CSA section, last 2 rows closest to the IBDH section will remain) this should be done before the CS is shipped out to alleviate shipping and handling difficulties

Resolution – *M. Viola*

This concern is obsolete due to the project decision to fabricate a new CS Casing. The vendor shall make the new casing sleeves and install all new studs at the vendor's facility.

CR-VVIH-1021 – Use the Strength as a Secondary Seal

Disposition	Review	ID	Chit
NA	Casing Fabrication Peer Review	CASFAB PR04	Use strength weld as secondary seal weld. Add temporary port feature pump interface, leak check, remove port and weld over.

Resolution – *M. Smith*

The trapped volume pumping was considered but rejected by Vacuum Engineer as the volume is considered trivial in size. However, due to the project decision to fabricate a new CS Casing, the trapped volume no longer exists. The CS Casing is now designed for single full penetration welds.

CR-VVIH-1022 – Final Metrology of the CS Casing for Proper PFC Mounting

Disposition	Review	ID	Chit
A	Casing Fabrication Peer Review	CASFAB PR05	Once all the welding and other CS work is complete, we will need to know the final geometry of the CS for PFC mounting. Metrology or other measurements should be done to get final CS geometry.

Resolution – *M. Viola*

The final geometry of the new CS Casing assembly shall be measured by and at the vendor prior to shipment to PPPL. This is included as part of the technical specification, see PPPL document NSTX-U-SPEC-VVIH-002.

CR-VVIH-1023 – Temperature Gradient Simulation on the CS Casing

Disposition	Review	ID	Chit
NA	Casing Fabrication Peer Review	CASFAB PR06	Plan a mini bake to stress the casing welds thermally before the final bake so that if bake-out thermal gradients cause a vacuum leak there would be time to fix it.

Resolution – *M. Viola*

The thermal temperature gradient request was considered but rejected based on the new CS Casing bake out FEA results. The vacuum leak due to the temperature gradient is unlikely with the new full penetration welds.

CR-VVIH-1024 – Bellow's O-ring Seal Design Change

Disposition	Review	ID	Chit
A	Vacuum Vessel & Internal Hardware DVVR	VVIHPF1C CB07	The O-rings on the formed bellows on the casing often leaked. There should be some design change or mitigating strategy.

Resolution – *F. Cai*

The bellow's single O-ring design has been replaced with a double O-ring appropriately sized for the proper compression ratio and with a guard vacuum. This new design will meet the allowable system leak rate.

CR-VVIH-1025 – Reduction Factor for CS Casing Sleeve Welds

Disposition	Review	ID	Chit
NA	Vacuum Vessel & Internal Hardware DVVR	VVIHCP13	CS Casing top level weldment assembly is has a complicated welding design. There are many small fillets or partial penetration welds; sometimes where welds are opposing sides of the casing are not co-located. Ensure that the analysis sufficiently qualifies these welds. (This was probably done, but it wasn't clear from the presentation, because some of the screenshots show monolithic solids.)

Resolution – *D. Bishop*

Due to the project decisions to make a new CSC, this is no longer a concern. The welds are now full penetration. The qualification is performed as part of the CS Casing Integrated structural analysis detailed in PPPL document NSTXU-CALC-12-23.

CR-VVIH-1026 – Helium Leak Check Grooves for Bellows/Flange Weld Joint

Disposition	Review	ID	Chit
A	NSTX-U Recovery Project - CDR	RP CDR032	Regarding weld on a flange with double O-ring onto the flange welded to casing bellow, consider add four narrow grooves 90 degree apart from air side on the added part to allow helium reachable to the welds from air side in case there is a break on the welds and one tries to do helium leak check

Resolution – *F. Cai*

The O-ring grooves are on PF flanges, the mating components to the bellows flanges, but the CHIT still applies. The design engineer for the O-rings has provided the CAD group with the dimensions and locations for the appropriate O-ring grooves for integration into the model.

CR-VVIH-1027 – O-ring Seal Fit-up for PF1C to OH/TF

Disposition	Review	ID	Chit
A	NSTX-U Alignment Peer Review	REASSEM PDR14	PF1C and O-ring fit up: In 2014 OH/TF was positioned to seal O-rings. Pedestal was moved to fit OH/TF. In 2018 OH/TF positioned per alignment requirements. How to fit up O-ring seal?

Resolution – *F. Cai*

The Polar Region and CSC flange Design engineers are implementing the appropriate tolerances on the contact surface on the CSC to properly fit up the O-ring seal with new alignment procedure. A tolerance stack analyses was used to determine appropriate clearances (e.g. oversized holes) which allow the bellows to be installed with minimal distortion. Therefore, the bolted O-ring joint is subjected to minimal distortion as well. The CSC tolerance stack can be viewed in PPPL document NSTXU-CALC-133-37.

CR-VVIH-1028 – O-ring Retention on Bottom CS Casing Assembly

Disposition	Review	ID	Chit
A	Project PDR	PROJ PDR28	The assembly of the center stack onto the TF center core has two O-rings facing down where they engage the flange on the bottom of the vacuum vessel. Gravity encourage the O-rings to fall out of their slots, has mitigation steps been identified to keep the O-rings in place during assembly
R	NSTX-U Recovery Project CDR	RP CDR026	Consider having half dovetail O-ring groove when O-rings are at top part of the sealing for easy installation.

Resolution – *F. Cai*

To prevent O-ring slippage during assembly, the new flanges to the vacuum vessel implement half dovetail grooves. The grooves are appropriately sized to the proper compression ratio needed for engagement with the rest of the vacuum vessel.

CR-VVIH-1029 – Tilt and Handling Lift Fixture Design for the CS Casing

Disposition	Review	ID	Chit
NA	CS Mock-Up Peer Review	CSMU PEER03	Design lift fixture to accommodate required tilting and handling to insert center stack into vacuum vessel then prove with mockup

Resolution – *S. Raftopoulos*

This recommendation was considered but is not required. The existing CS Casing lift fixture successfully handled tilting during the original installation in 2014.

CR-VVIH-1030 – Temporary Installation Sleeve for OH Microtherm

Disposition	Review	ID	Chit
NA	NSTX-U Alignment Peer Review II	ALLIGN PEER12	Consider the use of a thin low-friction temporary sleeve to hold the OH Microtherm in place (and avoid snagging) during insertion of the OH bundle in the casing. Analogy: a piston ring compression sleeve tool used for installing pistons in an engine block.

Resolution – *S. Raftopoulos*

This recommendation was considered but is not required. The Microtherm is wrapped in a half-lap layer of fiberglass tape. This installation configuration was successful during the CS Casing trial fit-up.

CR-VVIH-1031 – Costs and Risks for New CS Casing versus Rework

Disposition	Review	ID	Chit
A	NSTX-U Alignment Peer Review II	ALLIGN PEER05	If proceeding with Casing modification, assess: 1. The incremental cost of building a new Casing instead of modifying the old one. 2. The risk reduction due to building a new Casing instead of an old one

Resolution – *S. Gerhardt*

As wisely suggested by the chit, extensive discussions and studies have been held along these lines. Various manufacturing paths were assessed, balancing the risks associated with repairs (design complexity, ability to do the repairs with high quality, etc.) against the risks of a new casing (mostly schedule and follow on programmatic implications). The outcome of this study was a decision to make a new casing, and this path is presented in the FDR package.

CR-VVIH-1032 – Uniformity of CS Casing Thickness

Disposition	Review	ID	Chit
NA	NSTX-U-Alignment Peer Review II	ALLIGN PEER09	Would be worthwhile checking the consistency of the CS internal measurements with spot checks of the external dimensions from calipers. The thickness of the casing should be uniform except at and near the welded seam.

Resolution – *M. Viola*

This concern is obsolete due to the project decision to fabricate a new CS Casing. The new casing shall be post-weld machined to achieve the tolerances required by the PFCs.

CR-VVIH-1033 – Connecting Feature between the Flange and CS Casing

Disposition	Review	ID	Chit
NAL NA	Project PDR	PROJ PDR13	For welding of flanges for CS case: recommend welding trials to determine proper technique to reduce distortion. Consider using not only a bolted connection, but a bolted and match drilled pin connection for further strength/reinforcement. Using fasteners to tackle the same loading of a weld is usually problematic because of the fatigue thread factor. Pins can handle the shear forces and the bolts provide pure axial clamping (no bend on the first thread).

Resolution – *M. Viola*

This concern is obsolete due to the project decision to fabricate a new CS Casing. All welded flanges are now sequenced to allow for post-weld machining to achieve the flatness requirements. No bolted or pin connections are required.

CR-VVIH-1034 – Engagement Bolts for PF1B and PF1C

Disposition	Review	ID	Chit
A	Vacuum Vessel & Internal Hardware DVVR	VVIHCP02	The 1/2 diameter thread-engagement bolts under/over PF1b and PF1c are a bit worrisome -- could they have been replaced by studs?

Resolution – *S. Gerhardt*

The new design robustly addressed these issues; the collar is welded to the casing, and this design has been shown to pass a stringent set of load cases including the so-called "VDE-Load" [add reference here to some slide or calculation]. The PF-1a and -1b are robustly mounted to the collar via the common flange assembly; this design also passes the all required load cases. All threaded fasteners from the legacy design of the "polar region" have been removed; these include the bolts on the OD of the PF-1b coil that attach to the casing flange, and those that mounted the -1a coil to the -1b.

CR-VVIH-1035 – Single O-ring Sealing Weaknesses

Disposition	Review	ID	Chit
A	Vacuum Vessel & Internal Hardware DVVR	VVIHVV10	Use of single-O-rings (i.e. not double O-rings with a pumped interspace) is non-ideal, especially in a machine with significant temperature cycling (i.e. thermally induced differential movements). What is the history of the base pressure achieved in NSTX and NSTX-U (running on TMPs, i.e. with no cryo-pump), compared to "a few times 10^{-8} torr" that we heard was a design target (and which I accept as satisfactory for tokamak operation)?

Resolution – *M. Smith*

The design has been updated to double O-ring with a guard vacuum to minimize the leak risks due to temperature cycling.

CR-VVIH-1036 – Blind Tapped Holes, Air Side CS Casing Flange

Disposition	Review	ID	Chit
NA	NSTX-U Recovery Project CDR	RP CDR021	I may be misunderstanding, but it appears that there are blind tapped holes on the air side of the CS-Casing Flange which are intended to interface with highly preloaded Inconel studs. Is there sufficient depth to allow a proper number of threads to engage? (Typically, blind tapped holes do not have fully formed threads all the way down....)
NA	NSTX-U Recovery Project CDR	RP CDR022	Further to my chit about the stresses in the blind tapped holes in the divertor support flange, it was said that an archaic centering step of that mechanical joint could be welded if desired. So why not make this a structural weld good for the launching load (etc.) and then the bolts become very short and only secure the other end of the box-like sections to the big flange, where the flange on the box-like section can be arbitrarily thick? 22mm SS bolts instead of 20mm Inconel, maybe?

Resolution – *M. Smith*

The design has been changed. This issue no longer exists.

CR-VVIH-1037 – Operational Temperature Limits for Viton O-rings

Disposition	Review	ID	Chit
A	NSTX-U Recovery Project CDR	RP CDR023	Consider limit the highest temperature Viton O-rings will see to 170°C to prevent compression set of O-rings at elevated temperature

Resolution – *M. Smith*

The highest temperature limit of the Viton O-rings was accounted for in the current design to prevent compression set at high temperatures.

CR-VVIH-1038 – Abandoned O-ring Groove Space

Disposition	Review	ID	Chit
NA	NSTX-U Recovery Project CDR	RP CDR025	The design concept for implementing double O-rings on the CS bellows by welding on an adapter plate leaves a large, abandoned in place, entrapped volume from the obsolete o ring groove. Consider pumping this space along with the interspace between the O-rings.

Resolution – *M. Smith*

The design has been changed. This issue no longer exists.

CR-VVIH-1039 – Continuous Weld Reinforcements to Minimize Leakage

Disposition	Review	ID	Chit
A	NSTX-U Recovery Project CDR	RP CDR035	Using a continuous welded reinforcement between the CS Vertical Section and the CS Flange seems to introduce a large vertical leak. Even if this space was vented, the continuous structural ring would preclude access to the vacuum seal weld if there was an issue. Consider accepting welding starts and stops, which should be allowable under the NSTX-U structural criteria for thermally driven peak stresses, in order to design a reinforcing scheme which allows better access.

Resolution – *M. Smith*

The CS Casing flange has been redesigned with continuous weld reinforcements that are now integrated into the flange as a machined feature. As such, the weld is available for repair if needed.

CR-VVIH-1040 – Trial Fit of Existing CS Casing

Disposition	Review	ID	Chit
NA	NSTX-U Alignment Peer Review	REASSEM PDR05	Slide 11 Add cost and schedule for Trial Fit of CS casing

Resolution – *M. Smith*

A trial fit-up cost and schedule was created and the fit-up has been performed, see associated document VVIH-180731-MHM-00. However, since a new CS Casing is being fabricated, this issue is obsolete.

CR-VVIH-1041 – Routing Rogowski Coils to Increase Effective Clearance

Disposition	Review	ID	Chit
A	NSTX-U Alignment Peer Review II	ALLIGN PEER03	I Believe the Rogowski can be routed toroidally around pinch points like the flux loop leads. Would this allow a routing path that would increase effective clearance?

Resolution – *M. Smith*

With the project decision to fabricate a new CS Casing, no special locations are required for the Rogowski loops. The casing shall be design and made with sufficient clearance to avoid the pinch points determined through the Casing Trial Fit-up, see PPPL document VVIH-180731-MHM_CasingTrialAsm-signed.

CR-VVIH-1042 – Center Bundle Analysis with Rogowski and Flux Cabling

Disposition	Review	ID	Chit
NA	NSTX-U Alignment Peer Review II	ALLIGN PEER06	Would like to see analysis of ability to assemble center bundle inside existing casing with Rogowski coils and flux loop cabling located in biggest gap according to latest metrology. Only need to take bundle from top to final position.

Resolution – *M. Smith*

A trial fit-up was completed with no interference issues found, see associated document VVIH-180731-MHM-00. However, since a new CS Casing is being fabricated, this issue is obsolete.

CR-VVIH-1043 – Increasing the Case Center Section Size

Disposition	Review	ID	Chit
NA	NSTX-U Alignment Peer Review II	ALLIGN PEER07	Re-opening the Casing design for modifications not directly related to alignment may introduce opportunities for other systems (cooling plate etc.), but it may also introduce new schedule risks. Consider that increasing the size of the center section nay be done with or without ancillary changes to benefit interfacing systems.

Resolution – *M. Smith*

A trial fit-up was completed with no interference issues found, see associated document VVIH-180731-MHM-00. However, since a new CS Casing is being fabricated, this issue is obsolete.

CR-VVIH-1044 – Importing Metrology Data to CAD to Verify Clearances

Disposition	Review	ID	Chit
NA	NSTX-U Alignment Peer Review II	ALLIGN PEER08	Import latest metrology data into CAD model so that clearances can be calculated as locations for Rogowski and flux loop cabling are designed.

Resolution – *M. Smith*

The latest metrology data was imported into CAD model and used to determine the best locations for the wires. These locations were implemented in the design and were proven through a trial fit-up. A new CS Casing is being fabricated with similar geometry with the exception of the weld joints, and thus these selected locations shall still be used.

CR-VVIH-1045 – Minimum Gap Analysis for Center Bundle Insertion

Disposition	Review	ID	Chit
NA	NSTX-U Alignment Peer Review II	ALLIGN PEER10	Recommend performing the minimum gap analysis for insertion of the center bundle into the casing only as far as it needs to go to its final position. Present analysis is effectively for passing the bundle all the way through the casing. This may be unduly restrictive.

Resolution – *M. Smith*

A trial fit-up was completed with no interference issues found, see associated document VVIH-180731-MHM-00. However, since a new CS Casing is being fabricated, this issue is obsolete.

CR-VVIH-1046 – Residual Stress Reduction in CS Casing Welds

Disposition	Review	ID	Chit
NA	Project PDR	PROJ PDR11	Stitch welding of CS casing: Peak stresses show ~550MPa peak stress vs ~350MPa for the complete weld. In both plots the extreme edge elements show highly localized stress. Re-mesh and or smoothening of the stress should be done. Unclear if stitch welding should be discounted. Consider using peening (conventional or ultrasonic hammer) around the edges to knock down the weld residual stress. This impacts the mean stress correction factors used to calculate S_{eq} for an S-N assessment.

Resolution – *M. Smith*

Upon refined analysis and with the new CS Casing welds, the stresses are much lower and within the allowable values removing the need for shot peening.

CR-VVIH-1047 – Low Inductive Jumpers to Provide Halo Current Paths

Disposition	Review	ID	Chit
A	Polar Region Design Integration Peer Review	POLAR PEER03	Evaluate potential advantage of low inductance jumpers across insulating breaks during operations to provide definitive, mid-plane symmetric halo current paths

Resolution – *S. Gerhardt*

This wise chit was considered and, in a sense, was adopted. For the lower polar region, where there is no ceramic insulator, the tile gap between the IDBH and OBDR1 presents a conducting path in parallel with the path through the bellows. This presented the possibility of substantial current flowing directly through the bellows. To protect against this, bake-out bus work will be left in place, and qualified for the EM loads that occur on the bus bar during disruptions. This bake-out bus work is in a sense a set of "low inductance jumpers" as suggested in the chit. See -RD-003-02 for additional information on how this current sharing should be computed. For the upper polar region, the insulator means that there is no simple path for current to flow from the IBDH to the OBDR1 through the bellows. However, it is possible that a small plasma "arc" between the -1cU can and the outer vessel, in parallel with the inevitable arc between the OBDR1 and IBDH tiles, will result in some current in the upper bellows. This method to compute this current is specified in -RD-003-02. No low-inductance jumpers are deemed necessary in this case. These various cases are described in NSTX-CALC-NSTXU -10-08 Center Stack Casing Bellows Recovery Project Loads, Halo, and Bake-out. See that calculation for more details.

CR-VVIH-1048 – High Z Tiles for the Center Stack

Disposition	Review	ID	Chit
NA	Vacuum Vessel & Internal Hardware DVVR	VVIHCP06	Does the original design basis for the Center Stack include any specification for high-Z tiles? This is being described in physics presentations, but is the added mass a problem? Is the conductive pathway a disruption load problem? Probably outside scope...

Resolution – *S. Gerhardt*

This is beyond the scope of the NSTX-U Recovery redesign for the casing. There are currently no requirements for upgrades to high-Z tiles. The CSFW tiles may be high-Z coated graphite, as their power loading is relatively low and this would likely eliminate any dead-weight or disruption issues. However, the vertical and horizontal targets may require a significant redesign as part of a high-Z upgrade.

CR-VVIH-1049 – Verify Thermal Expansion Stresses in Bellows with CMTR

Disposition	Review	ID	Chit
A	Polar Region Design Integration Peer Review	POLAR PEER19	Bellows Stress: Slide 25 of P. Titus' presentation shows high stresses in the bellow do to differential thermal expansion. Check the CMTRs for actual mechanical properties to allow a better assessment.

Resolution – *P. Titus*

New CS Casing bellows will be made of Inconel 625. The material data from the manufacturer have been used all thermal and structural analyses (data from the paper: Scott Stelmar, Cyclic Fatigue in Metal Bellows, Proceedings of the ASME 2013 Pressure Vessels and Piping Conference, July 14-18, 2013, Paris, France).

CR-VVIH-1050 – Divertor Flange Temperature Needed to Heat Tiles

Disposition	Review	ID	Chit
A	Polar Region Design Integration Peer Review	POLAR PEER21	Bake-out analysis assumed CS Casing Flange held at 350°C. In actuality the flange (and other metal parts) will need to be hotter than 350°C to get the tiles this hot.

Resolution – *P. Titus*

The global thermal analysis, see document NSTXU-CALC-10-06, addresses the thermal gradient of the tiles and the divertor plate. The new heat transfer plate reaches temperatures >350°C and provides the necessary thermal transfer to heat the tiles to 350°C.

CR-VVIH-1051 – Dynamic Load Factors for Structural Integrity Checks

Disposition	Review	ID	Chit
A	Vacuum Vessel & Internal Hardware DVVR	VVIHA08	Some analysis shown was transient. Other stress analysis shown was static. When performing the static FEA and using the results for structural integrity check, were dynamic load factors used? If so, what was the DLF and how was it derived?

Resolution – *P. Titus*

Dynamic Load Factors were used for the static FEA. The DLF for the eddy loads ca be found in document NSTXU-CALC-10-07-02 and for the bellows in document NSTXU-CALC-10-08.

CR-VVIH-1052 – Tile Heating/Cooling as an Integrated System

Disposition	Review	ID	Chit
A	Vacuum Vessel & Internal Hardware DVVR	VVIHBI01	Evaluate the heating and cooling of the tiles as an integrated design system including the performance of the O-ring system in the region of the machine

Resolution – *P. Titus*

The evaluation of the heating/cooling of the tiles and performance of the O-ring system– Bolt vs Weld for Collar Installation are discussed in document NSTXU-CALC-10-08.

CR-VVIH-1053 – Divertor Flange Collar Mounting Design Considerations

Disposition	Review	ID	Chit
A	Polar Region - Flanges/O-rings/Insulators/Supports - PDR	PRFOR INSU PDR03	Consider eliminating welding of bottom of collar. Allows for easier fabrication and removes weld distortion risk.
	Polar Region - Flanges/O-rings/Insulators/Supports - PDR	PRFOR INSU PDR17	Consider change the collar installation from bolt/weld to bolt only. The new casing flange might allow this to happen. Bolting the collar can save 6 weeks of casing fabrication time and also decouple the work for HTT/HTP and bake-out bus bar from casing rework.

Resolution – *M. Smith*

A new CS Casing is being fabricated, this issue no longer exists. Any distortion caused by the welding of the collar to the divertor flange can be compensated by post-weld machining. The collar is also stiffer due to it being made out of a single forging rather than a tube section and flange. The HTT/HTP installation is no longer required prior to the collar installation through the introduction of windows along the bottom.

CR-VVIH-1054 – Organ Pipe O-ring Survival at High Temperatures

Disposition	Review	ID	Chit
A	Polar Region - Flanges/O-Rings/Insulators/Supports - PDR	PRFORINS UPDR04	Need to analyze peak temperature of O-rings on the organ pipes to ensure O-rings will not be damaged during bake-out and/or high-power operations.

Resolution – *W. Wang*

A detailed thermal analysis for organ pipes was developed to show that the O-ring's maximum continuous working temperature is not exceeded during bake-out and operation. The detailed results are shown in PPPL document NSTXU-CALC-12-30.

CR-VVIH-1055 – Reanalyze Current through CS Bellows with New Bus Bar

Disposition	Review	ID	Chit
A	Polar Region - Flanges/O-rings/Insulators/Supports - PDR	PRFOR INSU PDR07	The analysis of the current/temperature through/on casing bellows during bake-out needs to be updated according to the new design of the bus bar. The cross section of bus bar in between bellow and collar is reduced due to the new polar region design

Resolution – *H. Zhang*

In the 2D global model, during bake-out 8KA, 555A of current passed through bellow. The latest analysis using the new detailed CHI bus design shows 591A of current passing through bellows and 7409A through CHI bus. The results are not significantly different. The results of the bellows analyses can be seen in PPPL document numbers NSTXU-CALC-12-19 and NSTXU-CALC-12-31.

CR-VVIH-1056 – Verification of Convection for Organ Pipe and Bellows

Disposition	Review	ID	Chit
A	Polar Region - Flanges/O-rings/Insulators/Supports - PDR	PRFOR INSU PDR08	Assure that convection assumptions for Organ pipe and bellows cooling is correct for both the top and bottom of the machine to protect the O-rings

Resolution – *H. Zhang*

A conservative convective heat transfer coefficient (5 W/m^{2}K) has been used for pipe 22and bellow cooling analysis, see PPPL document number NSTXU-CALC-12-31.

CR-VVIH-1057 – Bus Bars in Bake-Out Thermal Analysis

Disposition	Review	ID	Chit
A	Polar Region - Flanges/O-rings/Insulators/Supports - PDR	PRFOR INSU PDR12	Bake-out bus bars at vessel bottom are not included in thermal model and most of the current is pushed through collar. This artificially increased collar temperature during baking

Resolution – *H. Zhang*

The bottom collar is about 90°C higher than top due to the artificial bake-out current going through it. However this thermal data for bottom collar was not used in integrated structural analysis. The temperature of the top collar was used instead, which is not affected by the artificial bake-out current, see PPPL document numbers NSTXU-CALC-10-06, NSTXU-CALC-12-26, NSTXU-CALC-12-31.

CR-VVIH-1058 – Bellow's Analysis Comparison using New or Existing

Disposition	Review	ID	Chit
NA	Polar Region - Flanges/O-rings/Insulators/Supports - PDR	PRFOR INSU PDR14	Consider trading analysis of existing bellows with analysis of a purchased new bellows. We will likely have to cut off existing bellows to replace diverter flange. Is all this work worth it?

Resolution – *M. Viola*

A new CS Casing is being fabricated, this issue no longer exists. The previous bellows design is considered acceptable.

CR-VVIH-1059 – Bound the Upper Bellows Halo Current

Disposition	Review	ID	Chit
A	Polar Region Flanges/O-rings/Insulators/Supports - PDR	PRFOR INSU PDR15	Requirements allow for non-zero halo current through bellows at top but bellows analysis assumed zero halo current in upper bellows. Agree current will likely be smaller than at bottom, but recommend quantifying/bounding the upper bellows halo current and include in analysis prior to FDR.

Resolution – *S. Gerhardt*

The requirements document NSTX-U-RQMT-RD-003-01 (and the recent revision -02) have clearly stated calculation assumptions for determining the current in the upper bellows. In particular, a cold plasma (0.1 eV) is assumed in the form of an arc between the PF-1cU reentrant flange and the outer vessel. This arc, whose current must flow through the bellows, is in series with a warmer (1 eV) arc across the IBDH/OBDR1 tile gap. The halo current is then computed based on the resistive/inductive division between these paths. This current is used to qualify the bellows in NSTXU-CALC-12-19.

CR-VVIH-1060 – Applying Upper Coil Loading into the Lower Coils

Disposition	Review	ID	Chit
A	Polar Region - Flanges/O-rings/Insulators/Supports - PDR	PRFOR INSU PDR18	Check if the correct boundary condition is applied to the lower model to account for the loads from the upper coils. In the CDR analyses the upper and lower coil loads were applied with a worst case centering and worst case bursting load

Resolution – *D. Bishop*

The correct boundary condition is applied. A complete model including the lower section with the appropriate boundary conditions has been built and loads from the upper coils have been implemented in the analysis.

CR-VVIH-1061 – Load Inventory of Upper Coils

Disposition	Review	ID	Chit
A	Polar Region - Flanges/O-rings/Insulators/Supports - PDR	PRFOR INSU PDR19	Check if the load inventory from the upper coils has properly been applied to the lower model. The CDR analysis included centering and bursting loads transmitted through the casing shell. These were important in assessing the bending of the divertor flange and the welds to the casing.

Resolution – *D. Bishop*

The load inventory from the upper coils has been properly applied to the lower model, see PPPL documents NSTXU-CALC-12-23 and NSTXU-CALC-12-32.

CR-VVIH-1062 – Complete Global Model for Center Stack

Disposition	Review	ID	Chit
A	Polar Region - Flanges/O-rings/Insulators/Supports - PDR	PRFOR INSU PDR26	Try to have a SIMPLE full up-down Center Stack global model that would allow application of a more complete inventory of loads. Maybe a cyclic symmetry model, for in-plane loads, and a 360° or 180° model for side-loads

Resolution – *M. Smith*

A complete inventory of loads has been accounted for in the CS Casing FEA, see PPPL document NSTXU-CALC-12-28.

CR-VVIH-1063 – Collar to Divertor Flange Weldment and HTT Installation

Disposition	Review	ID	Chit
A	Polar Region – Flanges/ O-rings/ Insulators/ Supports- PDR	PRFOR INSU PDR29	If welding is required for collar to Divertor flange, prototype welding a section of casing to section of divertor flange and then a section of collar to divertor to assess need to machine divertor to required flatness. CAUTION - Danny requires his tubing to be installed before collar is welded which prevents post welding machining.

Resolution – *M. Viola*

The new CS Casing collar and divertor flange shall be fabricated oversized to allow for post-weld machining to the required tolerances. A weld prototype is no longer necessary. To allow for the proper installation sequence for the HTT/HTP into the CS Casing, windows have been incorporated into the collar to accommodate assembly post-weld. This now allows post machining of the collar prior to the HTT installation to achieve the required dimensional tolerances.

CR-VVIH-1064 – Bake-Out Temps at PF/Coil Supports

Disposition	Review	ID	Chit
A	Polar Region - Flanges/O-rings/Insulators/Supports - PDR	PRFOR INSU PDR34	Bake out should be included - if the temperature files are not available from Han in a timely manner, the component temperatures can be constructed from the bake-out requirements i.e. 350°C at the divertor flange cold at the ends of the coil supports which are thermally connected to the coils. Intended Microtherm installations etc.

Resolution – *D. Bishop*

A bake-out analysis has been performed; see CSC integrated structural analysis in PPPL document NSTXU-CALC-12-23.

CR-VVIH-1065 – Bellows Hoop Stress

Disposition	Review	ID	Chit
A	Vacuum Vessel & Internal Hardware DVVR	VVIHPF1C CB21	A back of envelop estimate of the hoop stress in the bellows if it ever carries as much as 100kA of CHI current (using pure guesses for the bellows thickness, local TF strength, major radius etc.) suggests a "significantly higher" stress than the sub-MPa values reported. Maybe they need to be checked but the buckling/squirming limit of the bellows should be checked with the supplier's catalogue data for external pressure, as well as considering simple bursting.

Resolution – *P. Titus*

The bellows stress for all load conditions was analyzed. The Bellows is acceptable under the presently defined loads, see PPPL document NSTXU-CALC-12-19.

CR-VVIH-1066 – Allowable Ground Wall Temperature

Disposition	Review	ID	Chit
A	Center Stack Casing FDR	CSCFDR04	In the final content slide of the talk by C. Pagano, there was an assignment of the chit CSCMODSPDR04 to the magnet group. I think that this assignment should be revisited. It sounds like Han may have already done the appropriate calculation, and maybe it can be closed? In any case, this is not IMHO a matter for the magnet group.
R	Center Stack Casing PDR	CSCMODS PDR04	The requirement as stated in the review is that the coil ground wrap shall not exceed the glass transition temperature. I suggest that we provide more margin and choose a cooler temperature more like 100C. If we are required to go to a higher temperature we must carefully consider degradation in strength vs pre-load. Also we should consider the G11 filler material as it has a lower T_g than CTD 425.

Resolution – *M. Smith*

The requirements document, NSTX-U-RQMT-SRD-004, has been updated per PPPL Memo MAG-190205-SPG-01 setting the ground wall temperature (T_g) limit at 140°C. This limit provides a 10°C buffer below the temperature at which the storage modulus of the CTD-425 in the PF coils begins to degrade.

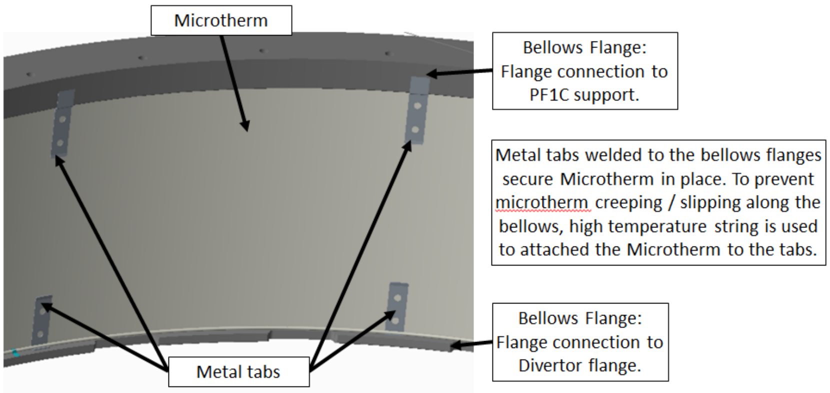
CR-VVIH-1067 – Microtherm Flexibility and Support in CSC Assembly

Disposition	Review	ID	Chit
A	Center Stack Casing FDR	CSCFDR06	How does the Microtherm on the bellows ID flex with the bellows? How is it supported?
R	Center Stack Casing FDR	CSCFDR08	Consider developing methods to keep the Microtherm insulation in place between the bellows and collar support.
R	Center Stack Casing FDR	CSCFDR12	There is a plan to cut the Microtherm that wraps around the collar, so that there are little "teeth" in the Microtherm that poke between the bolting features on the collar. I am concerned that cutting this material will result in it spilling the "powder" material within the pockets. This powder material could leak out onto high voltage connections of the TF on the bottom, and if it leaks out, it compromises the insulation quality anyway. So my question is it possible to cut those little features in the Microtherm, and if they are really needed.
R	Center Stack Casing FDR	CSCFDR13	Han shows the Microtherm on the ID of the bellows as a key part of the global thermal analysis. The design of how to mount and hold the Microtherm here needs to be designed. Probably need a sheet metal cylinder welded at one end to the lower or upper bellows flange ID but with a gap at the other end to allow for motion. Then attach the insulation to the inside of this sheet metal cylinder. Is there room for this? This design needs to be demonstrated to validate the thermal model assumptions.

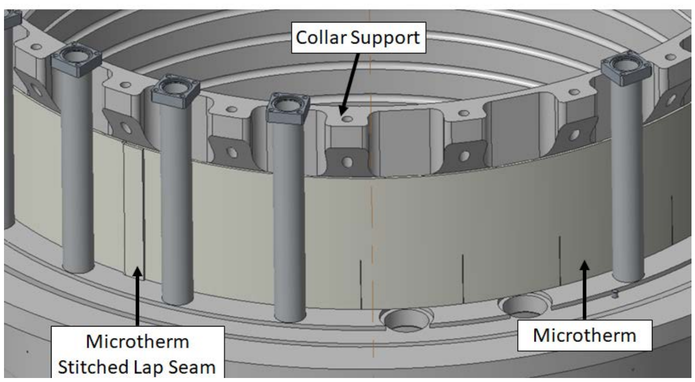
Resolution – *M. Smith*

Insulation support features have been integrated into the design to secure the Microtherm onto the bellows while still allowing bellows motion. The shape of Microtherm on the OD of the Collar has been changed to accommodate securing the Microtherm with stitching at the lap seam. See images below. Analyses has been performed which shows that not having the toothed shaped Microtherm on the Collar support is acceptable. Therefore, the tooth features which provided the Microtherm between the Collar-Common flange bolting features are not required. The supporting documentation for this analysis can be found in the next revision to the NSTXU Global Thermal calculation: NSTXU-CALC-10-06-XX.

Microtherm on the Bellows ID



Microtherm around the Collar Support



CR-VVIH-1068 – Chit Resolution Procedures

Disposition	Review	ID	Chit
A	Center Stack Casing FDR	CSCFDR07	Concerning the “Chit Resolution Report for Center Stack Casing Fabrication” NSTX-U-REC-111, per the NSTX-U Chit Tracking and Closure Plan NSTX-U-PLAN-003, the OBS Manager (or RE under the current ENG-057 definitions) and Project Engineer have to sign off. Then the document needs to be uploaded to the final FDR documentation package.

Resolution – *M. Smith*

The Project Engineer reviewed and agreed to the selection of Chits used at the CS Casing FDR. The initial release of Chit Resolution Report NSTX-U-REC-111-00 has been signed and uploaded onto the CS Casing FDR dashboard.

CR-VVIH-1069 – Plating Specification for Buswork Pads

Disposition	Review	ID	Chit
A	Center Stack Casing FDR	CSCFDR09	Add copper electroplating of pad to CSC fabrication sequence, drawings and technical specification

Resolution – *Y. Zhai*

The copper and silver plating specifications for the bus connecting pads on the CS Casing have been added the divertor flange drawing, E-DC11210, and the CS Casing Technical Specification, NSTX-U-SPEC-VVIH-002. The specification is based upon memo MAG-190116-YZ-01.

CR-VVIH-1070 – Bolt Torque Requires for CS Casing Assembly

Disposition	Review	ID	Chit
A	Center Stack Casing FDR	CSCFDR10	Add HTP and bellows bolt torque requirements to the drawing and/or technical specification.

Resolution – *D. Cai*

The Heat Transfer Plate (HTP) torque requirements have been added to the HTP installation drawing, E-DC11211, as well as the CS Casing Fabrication Technical Specification, NSTX-U-SPEC-VVIH-002.

Resolution – *M. Smith*

The bellows' flange bolts have been removed as they are no longer required per the updated analyses, see calculation NSTXU-CALC-12-19-01.

CR-VVIH-1071 – Bellows’ Connection with Bolts versus Welds

Disposition	Review	ID	Chit
A	Center Stack Casing FDR	CSCFDR11	Please assess whether the bellows’ bolts will survive welding and operation and/or assess that they will perform satisfactorily if tightened after welding. Also provide a torque value for the bolts.

Resolution – *A. Khodak*

Bolts have been removed and the FEA updated accordingly. New simulations were performed without the bolt. Weld analyses was performed and determined to be acceptable. Refer to the updated bellows calculation: *Upper and Lower Bellows Analysis Calculations. NSTX-U-CALC-12-19-01*.

CR-VVIH-1072 – PFC Bake-Out Temperature Requirements

Disposition	Review	ID	Chit
A	Center Stack Casing FDR	CSCFDR14	Under the requirements document, the PFCs "shall be capable of being baked to at least 350°C." (NSTX-U-RQMT-SRD-003-03 Section 3.2.a). Under the "Thermal result for CSC and bellows" Presentation done by Han Zhang, there is a bullet point that the states the PFC bake-out temperature is >260°C (slide 5). Confirm that the analysis matches the PFC requirement.

Resolution – *H. Zhang*

The PowerPoint presentation has been corrected to match the 350°C PFC requirements. Additional analysis of PFCs and bake-out to be performed as part of the Machine Core Structures FDR assigned to the MCS Cognizant Engineer.

CR-VVIH-1073 – Thermal Isolation Requirements for VVIH

Disposition	Review	ID	Chit
A	Center Stack Casing FDR	CSCFDR16	This is in the VV&IH SRD: "10.4.3 Coil Thermal Isolation a: Structures should be designed so that coil ground insulation shall not exceed the glass transition temperature of the resin system or any glass reinforced plastic/laminate material under any possible thermal scenario (operations, bake out, etc.). b. The insulation protecting the OH and PF-1A/B coils from the heated casing surface must provide at least 1 hour response time following a coil loss of cooling condition during bake-out. Somebody can argue with me about whether 100°C or T_{glass} is the right limit, but in any case the final documentation associated with the review should show that these are accomplished. If they are not satisfied, then there may need to be changes to the cooling water systems or some other operating procedure.

Resolution – *M. Smith*

This chit has been assigned to the Machine Core Structure team and will be dispositioned and closed at the MCS FDR.

CR-VVIH-1074 – Center Stack Deformation

Disposition	Review	ID	Chit
A	Center Stack Casing FDR	CSCFDR17	Suggest assessment of center stack first wall under worst deformation cases and making sure internal and external (PFC) components are not damaged, or stressed more than expected.

Resolution – M. Smith

The Center Stack First Wall Section was analyzed under the worst case deformation, see the CSC Integrated Structural Analysis Report NSTXU-CALC-12-23-01, Based upon the results, including a the tolerance stack assessment and Monte Carlo simulations, all internal components have a very low probability of contacting adjacent components during operations. Therefore, all internal components are expected to be neither damaged nor stressed above the allowable limits. The effect of deformation on external (PFC) components shall be analyzed separated through Chit CSCFDR29, assigned to the PFC Cognizant Engineer.

CR-VVIH-1075 – Fillets on CS Casing Sleeve Joints

Disposition	Review	ID	Chit
A	Center Stack Casing FDR	CSCFDR19	In the analysis model there is a 0.1" radius fillet on the OD between angled section and a center section of the CSC. This fillet is not in the design model currently, and should be included. In addition fillet can be included on the ID in the transition between angled section and vertical divertor section of the CSC. Both these fillets will eliminate sharp inside angles, which create high stresses.

Resolution – *J. Hennessy*

The fillet radius has been added to the joint between the CSVS and CSFWS in the CAD model.

CR-VVIH-1076 – Lower Bellows' Thermal Stress

Disposition	Review	ID	Chit
A	Center Stack Casing FDR	CSCFDR20	Assessment of thermal stress in lower bellows needs to consider non-axisymmetric current injection, by changing the model or applying an appropriate peaking factor.

Resolution – Tom Ronge

Updated FEA was performed with these thermal conditions. The results were within acceptable limits. Note, the thermal loads and results were barely different / discernable as compared to as the prior FEA without these conditions. Refer to the updated Bellows calculation, document: NSTX-U-CALC-12-19-01.

CR-VVIH-1077 – PFC Stud Welding Quality

Disposition	Review	ID	Chit
A	Center Stack Casing FDR	CSCFDR22	Evaluate stud welding technique and quality with testing and inspection cuts to verify that intended welds on CSC are adequately filling the dimple
R	Center Stack Casing FDR	CSCFDR23	Analyze the dimple/HTT groove wall thickness for adequacy against crack propagation

Resolution – *M. Viola*

Per the updated Technical Specification, NSTX-U-SPEC-VVIH-002, prior to installing any studs on the CSC the Subcontractor shall perform stud shooting tests on a scrap plate to demonstrate the quality and repeatability of the stud welds. All test results and photos shall be submitted to PPPL for approval and approved in writing prior to proceeding with actual stud welding to the CSC. When starting the installation process and at each shift change during installation, the Subcontractor shall perform an additional pull and bend test on a test plate to re-verify the quality and repeatability of the stud welds. All weld fillets shall complete 360° around the perimeter of the stud and fill the dimple. With a full dimple, there is no wall thickness concern. Test stud welds were created and cross sectioned to evaluate the weld filling of the stud locating dimples. All dimples were filled with weld, see Figure 1 below. Note, a void was found in one weld, see Figure 2. This concern was passed along to the PFC design team and was added to the NSTX-U Chit Registry.

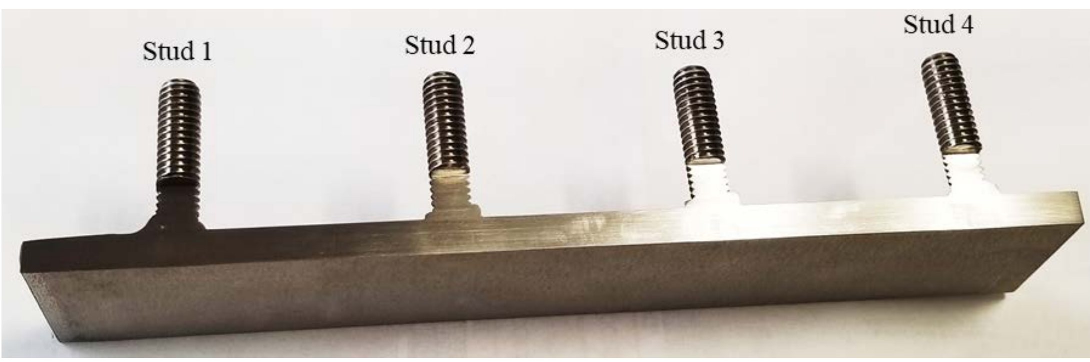


Figure 1. Stud weld test specimen with four sectioned studs.

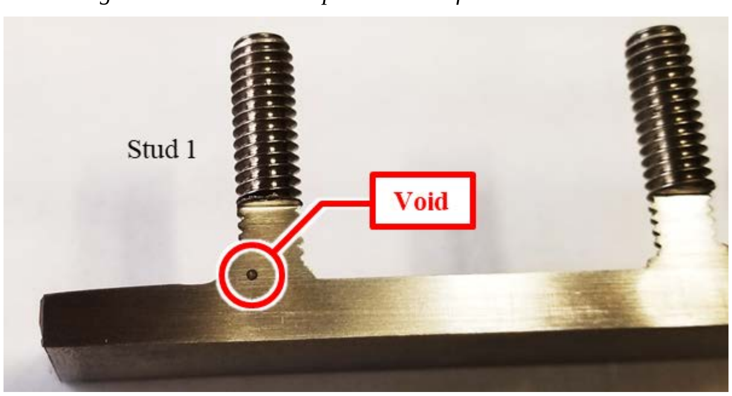


Figure 2. Sectioned Stud #1 with void

CR-VVIH-1078 – Weld Oversight throughout CS Casing Fabrication

Disposition	Review	ID	Chit
A	Center Stack Casing FDR	CSCFDR24	Weld oversight is a worthwhile investment. The slide and the Oversight Plan do not explicitly address it. I recommend that the weld prep be verified, sometimes in person, maybe sometimes using video or photos, and that weld inspection be witnessed, preferably by one of our CWI's, when possible.

Resolution – *M. Viola*

The Technical Specification, NSTX-U-SPEC-VVIH-002, now requires test coupons and weld qualification prior to performing welds on the production parts. The subcontractor is also required to provide 1 weeks' notice to PPPL prior to performing tests on all welded joints in order to coordinate providing a witness if desired. The Oversight Plan, NSTX-U-OP-VVIH-001, includes verification of weld joint records, inspection and testing.

CR-VVIH-1079 – Heat Transfer Plate Mounting Hole Tolerance Stack

Disposition	Review	ID	Chit
A	Center Stack Casing FDR	CSCFDR25	Coordinate/check the HTP inner diameter bolt holes tolerances compared to the mating holes in the divertor flange.

Resolution – *D. Cai*

The interface between the Heat Transfer Plate and CS Casing Divertor Flange has been dimensioned to ensure proper installation. This includes providing sufficient tolerance to allow positional adjustment to achieve the required flatness and concentricity. Refer to drawings E-DC11210, E-DC11124 and E-DC11125 for specific tolerance callouts.

CR-VVIH-1080 – CS Casing Toroidal Clocking

Disposition	Review	ID	Chit
A	Center Stack Casing FDR	CSCFDR26	Check if / define tolerances needed between upper and lower ends of the CSC Assembly WRT toroidal clocking

Resolution – *M. Smith*

The toroidal clocking tolerances between the upper and lower ends of the CS Casing assembly have been investigated and defined in an ICD, see PPPL Document 20191111-VVIH-PFD-01.

CR-VVIH-1081 – Oversize Bellows' Flanges for Post-Machining

Disposition	Review	ID	Chit
A	Center Stack Casing FDR	CSCFDR27	Fabrication team to include additional material - make it fat - the bellows flanges for machining out sloppy bellows.

Resolution – *M. Smith*

The bellows' flanges CAD models and drawings have been updated to include additional material to allow post-weld machining, see drawing E-DC11167.

CR-VVIH-1082 – GD&T on Drawings

Disposition	Review	ID	Chit
A	Center Stack Casing FDR	CSCFDR28	Investigate the feasibility of putting all GDT and critical tolerances onto a minimum set of drawing sheets.

Resolution – *J. Mitchell*

The merging of all critical GD&T tolerances onto a minimum set of drawing sheets was investigated and implemented as much as possible across all drawings that are part of the CS Casing Fabrication.