NSTX-U Document #: NSTX-U-REC-093-01

CHIT CODE	§ OF REPORT	STATUS	CHIT CODE	§ OF REPORT	STATUS
CASFABPR01	CR-VVIH-53	CLOSED	CSHCTPDR37	CR-VVIH-26	CLOSED
CSCMODSPDR05	CR-VVIH-24	CLOSED	CSHCTPDR38	CR-VVIH-28	CLOSED
CSHCTPDR01	CR-VVIH-04	CLOSED	HTTHTPFDR01	CR-VVIH-34	CLOSED
CSHCTPDR02	CR-VVIH-05	CLOSED	HTTHTPFDR02	CR-VVIH-35	CLOSED
CSHCTPDR03	CR-VVIH-06	CLOSED	HTTHTPFDR03	CR-VVIH-36	CLOSED
CSHCTPDR04	CR-VVIH-07	CLOSED	HTTHTPFDR04	CR-VVIH-37	CLOSED
CSHCTPDR05	CR-VVIH-04	CLOSED	HTTHTPFDR05	CR-VVIH-38	CLOSED
CSHCTPDR06	CR-VVIH-02	CLOSED	HTTHTPFDR06	CR-VVIH-39	CLOSED
CSHCTPDR07	CR-VVIH-24	CLOSED	HTTHTPFDR07	CR-VVIH-35	CLOSED
CSHCTPDR08	CR-VVIH-28	CLOSED	HTTHTPFDR08	CR-VVIH-40	CLOSED
CSHCTPDR09	CR-VVIH-08	CLOSED	HTTHTPFDR09	CR-VVIH-41	CLOSED
CSHCTPDR10	CR-VVIH-09	CLOSED	HTTHTPFDR10	CR-VVIH-42	CLOSED
CSHCTPDR11	CR-VVIH-10	CLOSED	HTTHTPFDR11	CR-VVIH-43	CLOSED
CSHCTPDR12	CR-VVIH-11	CLOSED	HTTHTPFDR12	CR-VVIH-44	CLOSED
CSHCTPDR13	CR-VVIH-11	CLOSED	HTTHTPFDR13	CR-VVIH-45	CLOSED
CSHCTPDR14	CR-VVIH-12	CLOSED	HTTHTPFDR14	CR-VVIH-46	CLOSED
CSHCTPDR15	CR-VVIH-13	CLOSED	HTTHTPFDR15	CR-VVIH-47	CLOSED
CSHCTPDR16	CR-VVIH-14	CLOSED	HTTHTPFDR16	CR-VVIH-48	CLOSED
CSHCTPDR17	CR-VVIH-14	CLOSED	HTTHTPFDR18	CR-VVIH-49	CLOSED
CSHCTPDR18	CR-VVIH-15	CLOSED	HTTHTPFDR19	CR-VVIH-50	CLOSED
CSHCTPDR19	CR-VVIH-16	CLOSED	HTTHTPFDR20	CR-VVIH-51	CLOSED
CSHCTPDR20	CR-VVIH-17	CLOSED	HTTHTPFDR21	CR-VVIH-39	CLOSED
CSHCTPDR21	CR-VVIH-19	CLOSED	HTTHTPFDR22	CR-VVIH-52	CLOSED
CSHCTPDR22	CR-VVIH-24	CLOSED	PF1CONDPEER03	CR-VVIH-4	CLOSED
CSHCTPDR23	CR-VVIH-24	CLOSED	POLARPEER43	CR-VVIH-30	CLOSED
CSHCTPDR24	CR-VVIH-20	CLOSED	POLARPEER44	CR-VVIH-32	CLOSED
CSHCTPDR25	CR-VVIH-27	CLOSED	POLARPEER45	CR-VVIH-41	CLOSED
CSHCTPDR26	CR-VVIH-21	CLOSED	POLARPEER46	CR-VVIH-33	CLOSED
CSHCTPDR27	CR-VVIH-22	CLOSED	POLARPEER47	CR-VVIH-33	CLOSED
CSHCTPDR28	CR-VVIH-24	CLOSED	POLARPEER48	CR-VVIH-41	CLOSED
CSHCTPDR29	CR-VVIH-14	CLOSED	POLARPEER50	CR-VVIH-41	CLOSED
CSHCTPDR30	CR-VVIH-23	CLOSED	RPCDR036	CR-VVIH-25	CLOSED
CSHCTPDR31	CR-VVIH-28	CLOSED	RPCDR039	CR-VVIH-01	CLOSED
CSHCTPDR32	CR-VVIH-04	CLOSED	RPCDR046	CR-VVIH-29	CLOSED
CSHCTPDR33	CR-VVIH-03	CLOSED	RPCDR062	CR-VVIH-02	CLOSED
CSHCTPDR34	CR-VVIH-18	CLOSED	VVIHPFC08	CR-VVIH-31	CLOSED
CSHCTPDR35	CR-VVIH-25	CLOSED			
CSHCTPDR36	CR-VVIH-28	CLOSED			

Cognizant Individual: Dang Cai
Digitally signed by Dang Cai
DN: cn=Dang Cai, o=PPPL, ou=Engineering, email=dcai@pppl.gov, c=US
Date: 2019.02.19 14:58:59 -05'00'
(sign and date)

D. Cai, Cognizant Individual

Approver (*): Charles L. Neumeyer
Digitally signed by Charles L. Neumeyer
DN: cn=Charles L. Neumeyer, o=PPPL, ou, email=neumeyer@pppl.gov, c=US
Date: 2019.02.19 15:49:39 -05'00'
(sign and date)

C. Neumeyer, Chief Engineer

National Spherical Torus eXperiment Upgrade

Chit Resolution Report for Center Stack Heating/Cooling Transfer Tubes (HTT) & Plates (HTP)

NSTX-U-REC-093-01

Prepared By: Christopher Pagano Digitally signed by Christopher Pagano Date: 2019.02.19 14:52:47 -05'00'
C. Pagano, Engineer

Reviewed By: Dang Cai Digitally signed by Dang Cai DN: cn=Dang Cai, o=PPPL, ou=Engineering, email=dcai@pppl.gov, c=US Date: 2019.02.19 14:59:18 -05'00'
D. Cai, Cognizant Engineer

Approved By: G Douglas Loesser Digitally signed by G Douglas Loesser Date: 2019.02.19 15:39:14 -05'00'
D. Loesser, Responsible Engineer

Approved By: Yuhu Zhai Digitally signed by Yuhu Zhai Date: 2019.02.19 15:46:52 -05'00'
Y. Zhai, Project Engineer

Record of Changes

Rev.	Date	Description of Changes
0	10/30/2018	Initial Release
1	02/19/2019	(1) Added Chit Resolutions CR-VVIH-34 thru -52 for Chits issued and assigned to HTT/HTP group at the FDR (2) Added Additional Cover Sheet per ENG-033 R007-03 (3) Added reference to new naming convention per NSTX-U-SPEC-VVIH-002 (4) Resolved CSHCTPDR11 (CR-VVIH-10) , originally listed as "Out of Scope" (5) Added additional chits related to HTT/HTTP: CASFABPR01, PF1CONDPEER03 POLARPEER45, POLARPEER48, POLARPEER50, PRFORINSUPDR11, PRFORINSUPDR16 (6) Added updated PPPL Calculation Document Numbers

Table of Contents

Disposition Key:

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

CR-VVIH-0001 – Heat Transfer Plate Interface Assumptions

Disposition	Review	ID	Chit
A	NSTX-U Recovery Project - CDR	RP CDR039	For the heating plate design consider interfaces with and requirements for the Helium Heating/Cooling system a priority so that we can early on identify scope and cost for modifications to the system (or a new smaller system). Modifications necessary to use the Helium system during daily operations would also incur cost.

The bake-out system RE is involved with the heating/cooling requirement. The scope has been identified early on and integrated into the design.

CR-VVIH-0002 – Test Fit to Verify Clearance between Center Stack Casing and Bundle

Disposition	Review	ID	Chit
A	NSTX-U Recovery Project - CDR	RP CDR062	Cooling plate systems appear to have an OD that is too large given present allowed 1/4" growth for permanent components. Either the space allowance needs to grow, or the plate needs to shrink. This should be resolved for PDR.
R	Cooling Tube	CSHCT PDR06	Please demonstrate that this can be assembled (flange growth vs nozzle)

The assembly has undergone a mockup to test fit and verify clearance issues with expected growth of all permanent components. The test fit found no clearance issues.

CR-VVIH-0003 – SRD Completion

Disposition	Review	ID	Chit
A	Cooling Tube PDR	CSHCT PDR33	SRD completed

The SRD has been signed and published.

CR-VVIH-0004 – Heat Transfer Tube Clearance with TFOH & PF1A/B

Disposition	Review	ID	Chit
A	NSTXU Recovery CS Heating & Cooling	CSHCT PDR01	CS casing tubing must be sized (radially) to allow the TFOH bundle to fit and allow adjust-ability of TFOH & PF1A/B sub-assembly with respect to PFC's
R	NSTXU CS Casing Tubing	CSHCT PDR05	Please provide for adjustment capability (≈ 4 mm) of PF1A coil in IBDV section
R	CS Casing Coolant Loop	CSHCT PDR32	Investigate an oval-shaped return coolant line either by purchasing or rolling (and annealing)
R	PF1 Conductor Size Peer Review	PF1COND PEER03	Consider changing the CSC return coolant tube from a round profile to a oblong/rectangular profile of equivalent flow capacity to increase available clearance to the CS bundle.

The fit of the CS Casing around the coils and TFOH bundle are vital to the physics capabilities of the NSTX-U. To ensure a clean assembly, a minimum 4 mm gap was maintained between the heat transfer tubing assembly and the insulated PF1A coils in both the upper and lower IBDV (CSVS) regions. Switching from a round to oval cross section HTT was considered but deemed unnecessary during the design phase as the clearance was achieved without changing the existing geometry.

CR-VVIH-0005 – Radial Loads in Heat Transfer Plate

Disposition	Review	ID	Chit
A	HTP HTT PDR	CSHCT PDR02	Account for any vertical distribution of the eddy currents in the HTP. Vertical currents cross the TF field and produce radial loads not yet accounted.

The radial loads from the vertical current passing through the HTP were accounted for in subsequent iterations of the analysis performed since PDR, see NSTXU-CALC-12-26-01.

CR-VVIH-0006 – Halo Current Path with Grafoil Layers

Disposition	Review	ID	Chit
A	HTP HTT PDR	CSHCT PDR03	Concerned about the effect of Grafoil layers. Will the Grafoil layers between the tiles and HTP and HTP and flange cause Halo current to flow into bellows or some other path than assumed.

The halo current path at vessel bottom was believed to be affected by the inclusion of Grafoil layers between the PFC tiles & HTP and the HTP & Divertor Flange. Grafoil and bake-out bus were considered in the new 3D halo current distribution simulation, see NSTXU-CALC-12-26-01 which includes thermal, EM and structural analyses.

CR-VVIH-0007 – Helium Temperature and Pressure Requirements

Disposition	Review	ID	Chit
A	IBDH&V Cooling/ Heating PDR	CSHCT PDR04	The IBDH design uses helium at 20°C and 280 PSIG at inlet for cooling. Ensure that this requirement can be provided by the bake out system, which is also used to provide hot helium at 420°C and 280 PSIG.

The bakeout system is capable of providing Helium at 20°C and 280 PSIG as required for cooling as confirmed by J. Petrella.

CR-VVIH-0008 – Heat Transfer Plate Feedthrough

Disposition	Review	ID	Chit
A	Cooling Tubes	CSHCT PDR09	Where the feedthrough goes through the casing flange, it seems that having a minimum weld is desirable. Or better yet, some bellow convolution or similar compliant seal feature.

The original feedthrough puck design for the HTP showed a high stress level due to overall stiffness. As such it was proposed to minimize the weld or replace with a compliant sealing feature. Both of these designs were consider and a redesign was performed. The new puck design achieved reduced stiffness, and thus reduced stress, by making the puck hollow.

CR-VVIH-0009 – Maximum Operating Conditions for Heat Transfer Tube Helium & Water

Disposition	Review	ID	Chit
A	IBD Heating/ Cooling Tubes Design	CSHCT PDR10	Specify the MAWP, Maximum Operating Temperature and Allowable Test Pressure for both fluids (helium and water) to comply with MECH-015.

The following are the MAWP, operating temperature and test pressure:

For HTP (Helium Only): MAWP: 280 PSIG, Maximum Operating Temperature, 450°C, Allowable Testing Pressure, 420 PSIG.

For HTT (Water Only): MAWP: 120 PSIG, Maximum Operating Temperature, 60°C, Allowable Testing Pressure, 180 PSIG.

CR-VVIH-0010 – Heat Transfer Plate Weldment Proximity to Bellows and Leak Check

Disposition	Review	ID	Chit
A	NSTX-U Center Stack Heating/ Cooling Tube PDR	CSHCT PDR11	Concerned about proximity of the HTP component welding to CS bellows. Do we need to vacuum leak test the bellows after the welding activities? (perhaps this is already planned)

The HTP components that would be impacted with the bellows on the CS Casing are to be installed prior to the installation of the bellows. This includes the HTP feedthrus, and HTT/HTP Stub weldments. All welds are leak and pressure tested as required by the type of service. The bellows weld is also to be leak tested once installed. This sequencing and testing plan is outlined in the CS Casing fabrication technical specification PPPL Document NSTX-U-SPEC-VVIH-002-00.

CR-VVIH-0011 – Electrical and Thermal Insulation for Helium Tubing

Disposition	Review	ID	Chit
A	HTP HTT PDR	CSHCT PDR12	Ensure the feed / return of the heating / cooling line has electrical and thermal insulation from the adjacent bus bars. Need to prevent electrical shorts and heat transfer from tubing to bus bars. Need to remove interference. Need to account for space of insulation.
R	Center Stack H&C	CSHCT PDR13	Design thermal barriers as required for helium supply/return piping to protect surrounding structures and in particular bus bars.

The current design considered electrical and thermal insulation between the helium tubing and its environment in order to provide electrical and thermal insulation.

CR-VVIH-0012 – Shared Helium Cooling Gas Outlet Return Tubes

Disposition	Review	ID	Chit
A	NSTX-U Center Stack Heating/ Cooling Tube PDR	CSHCT PDR14	Consider having a shared Helium Cooling Gas Outlet return (in the region of the bellows) to reduce the number of net outlet tubes (near the PF1A coil) from 4 to 3 to reduce the interferences with the PF1A coil leads

The two Helium Cooling Gas inlets were combined to have a total of 3 lines interface with the PF1A leads.

CR-VVIH-0013 – USID Form for the Heat Transfer Plate

Disposition	Review	ID	Chit
A	Cooling Tube	CSHCT PDR15	You need to fill out the USID form for the HTP system. If we get to the point of the HTT using hot Helium, then an additional USID should be completed.

The USID form has been filled out for the HTP system.

CR-VVIH-0014 – Heat Transfer Tube Clamp Design and Installation

Disposition	Review	ID	Chit
A	HTP HTT PDR	CSHCT PDR16	Recommend prototyping of the IDBV (CSVS) clamp installation. How do you plan to preload the clamp? How do you ensure the min and max preload requirements are met?
R	Cooling Tube	CSHCT PDR29	Concerned that installing the coiled Inconel 625 "spring" (the HTT) will not be trivial. Should get concurrence on the method with technicians who will have to do the work, maybe via prototyping or other method.
NA	Center Stack H&C	CSHCT PDR17	Consider specifying welding pattern order on the angled section mounting plates to regulate pull-in.

A prototype HTT to be made to test the manufacturing and installation details designed and indicated in the drawing package. The angled section is now obsolete; therefore no welding pattern is required. Jigs were designed to assist fabrication and installation of HTT.

CR-VVIH-0015 – Helium Temperature Used in Analysis

Disposition	Review	ID	Chit
A	Center Stack H&C	CSHCT PDR18	The supply piping helium temperature used was noted as 400C. The helium system is capable of supplying up to 450°C. The 2016 campaign pushed the helium temperatures to 440°C. Consider performing calculations at 450°C as a conservative approach.

The helium temperature was set to 450°C for analysis as requested.

CR-VVIH-0016 – Rated Power Used in Analysis

Disposition	Review	ID	Chit
A	Cooling Tube	CSHCT PDR19	Please check and use the latest radiated power numbers from NSTX-U-RQMT-RD-13.

The latest power numbers from NSTX-U-RQMT-RD-13 were used for analysis.

CR-VVIH-0017 – Emissivity Used in Analysis

Disposition	Review	ID	Chit
A	Cooling Tube	CSHCT PDR20	Please use emissivity of 0.7 in calculations. Can of course do sensitivity studies w/ other values, but 0.7 should be the base value. See latest RD-013.

The emissivity of 0.7 was used for analysis as requested.

CR-VVIH-0018 – Determination of Thermal Contact Resistance

Disposition	Review	ID	Chit
A	Cooling tube PDR	CSHCT PDR34	Perform testing to find out the thermal contact resistance between Inconel 625 plates in air

The measured heat transfer coefficient between Inconel 625 plates in air was obtained from testing and used in analysis and the results are outlined in report NSTX-U-REC-094-00.

CR-VVIH-0019 – Effective Heat Transfer between Heat Transfer Tube & Water vs Casing

Disposition	Review	ID	Chit
A	Center Stack H&C	CSHCT PDR21	Ensure that the thermal conductivity to the water in the water cooling tubes is higher than the conductivity through the tiles to the water cooling tube sidewall. In other words, verify that there is no possibility that the ID surface of the cooling tube does not cause localized flashing of the cooling water resulting in a skin effect.

It has been confirmed that the effective heat transfer coefficient between water and the tube is much higher than the effective heat transfer between the tube and casing.

CR-VVIH-0020 – Lorentz 3D Force Density of the Heat Transfer Plate

Disposition	Review	ID	Chit
A	HTP HTT PDR	CSHCT PDR24	Demonstrate or evaluate that the Lorentz 3D force density of the HTP is trivial as compared to using smear Lorentz loads.

The Analysis group (P. Titus) has confirmed that the 3D effect of the Lorentz force density is trivial.

CR-VVIH-0021 – Heat Transfer Plate Cooling Channel Stress Mitigation

Disposition	Review	ID	Chit
NA	Center Stack H&C	CSHCT PDR26	Consider adding fillets to the cooling channel machined inner corners to reduce stress concentration corners.

Not Actionable Considered, however fillets are unnecessary as no high stress concentrations were found at gas channel corner in the analysis of the HTP.

CR-VVIH-0022 – Required Metrology & Drawing Updates for Heat Transfer Tube Installation

Disposition	Review	ID	Chit
A	CS casing cooling loop	CSHCT PDR27	Perform metrology on casing groove & update tubing model/ drawing prior to fabrication

Cooling groove width, depth and pitch were in-field verified. The dimensions are consistent with the drawing package.

CR-VVIH-0023 – Heat Transfer Plate Weldment Stress Mitigation

Disposition	Review	ID	Chit
A	NSTX-U Center Stack Heating/ Cooling Tube PDR	CSHCT PDR30	Concerned about stresses from thermal transients and disruptions on the IBDH (Divertor Flange) HTP vacuum weldments. Is there need or utility in having keys/locks near the He inlets/outlets to reduce or eliminate any differential motion between the CS Casing horizontal flange and the heating plate to reduce stresses on the welds? Definitely don't want to spring a leak in this region since it is so difficult to get to.

The differential motion between the CS Divertor (IBDH) flange and the HTP is restricted by the introduction of shear pins and bolts in the HTP design thus reducing weld stresses. The new hollow puck design further reduced stress to be lower than the allowable one.

CR-VVIH-0024 – Manufacturing & Installation of Heat Transfer Plate

Disposition	Review	ID	Chit
A	HTP HTT PDR	CSHCT PDR07	Need to detail the features, method, and process for installing the HTP, aligned, per PFC requirements.
R	HTP HTT PDR	CSHCT PDR22	If HTP bolting preload is critical to maintain, what design feature ensures this preload?
R	HTP HTT PDR	CSHCT PDR28	Ensure metrology features/fiducials are included in the HTP design in order to align HTP to PFC requirements.
R	CS Casing cooling	CSHCT PDR23	Consider manufacturing method & tolerances needed to add pins (matched) between cooling plate & flange
NA R	CSC Mods PDR	CSCMODS PDR05	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.

Detailed steps for the manufacturing and installation of the HTP are shown in the FDR slide deck. Additional features were introduced including beveled washers for bolt preload, metrology features for alignment/positioning, and reaming feature for shear pins. A step is to be added to the surface of the divertor flange to act as a guideline to match HTP concentricity to CSC.

1 Not Actionable Change considered but rejected by COG

CR-VVIH-0025 – Mitigation of Warping from Heat Transfer Plate Weld

Disposition	Review	ID	Chit
A	CS Cooling Tube	CSHCT PDR35	We have had problems with welding causing distortions in large plates. It was mentioned that the proposed welding method would reduce this problem. Do you have experience with this?
R	NSTX-U Recovery Project - CDR	RP CDR036	IBDH HTP plate welds all on one side will tend to distort the plate, consider a vacuum oven braze. Best solution, as mentioned, would be to 3D print the plate.

Post machining will be performed to achieve the specified/desired flatness. This flatness is designed with enough tolerance to guarantee that the buildup between the HTP and the divertor flange will be within required system limits.

CR-VVIH-0026 – VCR Fitting Installation Requirements

Disposition	Review	ID	Chit
A	CS Cooling Tube	CSHCT PDR37	There have been issues with VCR fitting being loosened after being bumped/jostled. Do you have similar experiences? Do you ever provide a means to better secure the fittings?

The VCR male and female nuts will be welded and covered by thermal insulation.

CR-VVIH-0027 – Strength Reduction for Welds

Disposition	Review	ID	Chit
A	HTP HTT PDR	CSHCT PDR25	Ensure that all welds analyzed account for weld strength reduction factors due to weld type, quality, and level of inspection.

Analysis was performed using a 10% strength reduction. HTP E-beam welds will be inspected through x-ray and sonogram methodologies to guarantee that the actual weld quality on the production part meets/exceeds this assumed reduction factor.

CR-VVIH-0028 – Additional Cost & Schedule for Weld Inspections/Testing

Disposition	Review	ID	Chit
A	CS casing cooling	CSHCT PDR31	If E-Beam welding coolant channel cover, cost & schedule should be adjusted to allow vendor to perform test/setup welds
R	Cooling Tubes	CSHCT PDR08	Please document the steps of fabrication & assembly where leak checking is required
R	CS cooling tube	CSHCT PDR36	How do you check vendor welds, i.e. that full penetrations weld are 100% down the entire length of the weld?
R	CS Cooling Tube	CSHCT PDR38	How you already developed a plan to leak check all the welds? After the fact can prove challenging.

All E-beam welds to be performed as part of this scope are to be inspected per AMS 2680C and leak tested under vacuum and high pressure.

Detailed steps for leak testing during manufacturing and installation of the HTP are outlined in the HTT/HTP He Cooling Tubes FDR slide deck. This includes but is not limited to the leak testing of the following: pass-through tubes to HTP, HTP cover to HTP base, pass-through puck to divertor flange, and pass-through tube to pass through puck. Where necessary a tool or fixture may be required in order to obtain a vacuum for the leak test.

CR-VVIH-0029 – Disruption Load Assumptions

Disposition	Review	ID	Chit
A	NSTX-U Recovery Project - CDR	RP CDR046	IBDH (Divertor Flange) - there is a lot of additional metal between the original flange and the plasma: the heating/cooling plate and the carrier plate. At the end the fixings on the original flange (or a variation of these) will have to take a much larger EM load during disruption.

The EM load on the HTP was analyzed to ensure the stress in the plate and carrier plate was within allowable limits.

CR-VVIH-0030 – Methods to Enhance Heat Transfer in Heat Transfer Tube

Disposition	Review	ID	Chit
NA	Polar Region Design Integration Peer Review	POLAR PEER43	Investigate thermal paste products for enhancing heat transfer between CS cooling tubes (HTT) and CS Casing. (Tack welding can be used for mechanical fixation locally, but welding/brazing may be undesirable over large surface areas due to practical considerations or to avoid thermal distortion).

Not Actionable Thermal paste is not allowed as it can create dust over time.

CR-VVIH-0031 – Required Heat Transfer from Center Stack Casing Flange

Disposition	Review	ID	Chit
NA	Vacuum Vessel & Internal Hardware DVVR	VVIH PFC08	Define a requirement for the amount of heat transfer required across the cooling tubes in the CS Casing so they can be sized appropriately.

Not Actionable - Requirement is no longer necessary; the Heat Transfer Plate will be used to cool/heat the IBDH (Divertor Flange) tiles instead of tubing. The total amount of heat that needs to be removed under different plasma thermal scenarios has been defined in NSTX-U-RQMT-RD-013-00-00.

CR-VVIH-0032 – Fatigue Analysis of Heat Transfer Tube

Disposition	Review	ID	Chit
A	Polar Region Design Integration Peer Review	POLAR PEER44	Do transient thermal calculation to determine if tubing fatigue is an issue with helium cooling of divertor

The Heat transfer plate will be used to cool/heat the IBDH (Center Stack Casing Divertor Flange) tiles instead of the tubing. Fatigue has been analyzed and is within the allowable, see NSTXU-CALC-12-23-00.

CR-VVIH-0033 – Proposed Modifications to Heat Transfer Tube Design

Disposition	Review	ID	Chit
A	Polar Region Design Integration Peer Review	POLAR PEER46	IBD cooling tubes (HTT). Why not use more than one start in the tube meander, e.g. two or three in parallel? And why not just squash the 3/8" tube to fit over the main tube winding for the return path, rather than making a transition to 1/4" tube as was said to be the previous solution? (Indeed the main winding tube could be similarly squashed at the cross-over points.)
R	Polar Region Design Integration Peer Review	POLAR PEER47	Consider dividing cooling tube circuit on CS Casing flange to two parallel circuits to increase mass flow and minimize thermal gradients

Each divertor flange will have two HTPs running helium in parallel. Squashing the 3/8" tubing is not needed as the required 4 mm gap between HTT and PF1A OD is satisfied.

CR-VVIH-0034 – Heat Transfer Tube Plate Calculation Reports

Disposition	Review	ID	Chit
A	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR01	Checked and signed calculations have not been posted on the FDR website.

Resolution — *D. Cai*

All signed calculations have now been uploaded to HTT/HTP FDR dashboard.

CR-VVIH-0035 – Technical Specifications and Test Plan

Disposition	Review	ID	Chit
A	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR02	Technical specifications are not posted on FDR website.
NA	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR07	Test plans, e.g. pressure testing of the helium tubes, are missing in the posted material. Features might have to be adjusted to allow some of the tests to be performed.

Resolution — *D. Cai*

Three technical specifications have been developed for this scope, see the following documents

- *NSTX-U-SPEC-VVIH-003*: Technical Specification for Fabrication of the Heat Transfer Tube Inlet and Outlet Lines
- *NSTX-U-SPEC-VVIH-004*: Technical Specification for Fabrication of the Heat Transfer Tube and Heat Transfer Plate Assemblies and Associated Components
- *NSTX-U-SPEC-VVIH-005*: Technical Specification for Fabrication of the Heat Transfer Plate Helium Interconnection Lines

Per a recommendation from the Chief Engineer, the test plans are included within the Technical Specification.

CR-VVIH-0036 – Material Selection for Heat Transfer Tube Elbow Fittings

Disposition	Review	ID	Chit
A	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR03	Regarding the 90-degree transition piece on the HTT that is currently stainless steel, suggest make it from Inconel 625 in order to achieve a better weld and reduce thermal stresses during operations. Also make the transition to stainless steel tubing further away from the vacuum vessel.

Resolution — *D. Cai*

The material of the 90-degree transition piece has been changed to Inconel 625. Additionally, Inconel 625 is now used up to the VCR gland connection.

CR-VVIH-0037 – Heat Transfer Tube Clamp Weld Prototype

Disposition	Review	ID	Chit
A	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR04	There is no report for the weld prototypes of the HTT clamps posted on the FDR website.

Resolution — *D. Cai*

The welding prototype report for the HTT clamp has been signed and recorded, see NSTX-U-REC-125-00.

CR-VVIH-0038 – Heat Transfer Tube Clamp Weld Distortion of IBDV (CSVS)

Disposition	Review	ID	Chit
NA	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR05	Apply the measured distortion (shrinkage causing bending) of the HTT clamp weld test plate to the complete IBDV and verify that it does not distort the IBDV beyond acceptability. Otherwise a new IBDV will be required that allows for post machining of the OD.

Resolution — *D. Cai*

A project decision was made to fabricate a completely new Center Stack Casing assembly. The design now includes additional thickness on the OD of the IBDV (CSVS) to accommodate post weld machining after the installation of the HTT Vertical clamps. This process has also been integrated into the Center Stack Casing Fabrication Technical Specification, NSTX-U-SPEC-VVIH-002, and into the CSVS drawing E-DC11206. With these changes, the distortion is no longer a concern.

CR-VVIH-0039 – Clearance between Heat Transfer Tube Clamps and Coil Slings

Disposition	Review	ID	Chit
A	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR06	Please check with Polar Region team the maximum deflection of coil support slings with respect to the HTT support clamps to ensure sufficient clearance during plasma events (eddy current loads from disruptions combined with halo current loads)
R	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR21	Please add about 6 inches of the casing cylindrical section model, replacing the radial coupling so that the compliance of the shell will reduce the weld stress (but probably increase the 1.6 mm displacement

Resolution — *D. Cai*

The maximum deflection of the coil support slings with respect to the Heat Transfer Tube support clamps due to the eddy current load is 1.3 mm while the allowable gap is 5 mm. No interference is expected.

CR-VVIH-0040 – Pressure Testing of the Heat Transfer Tube and Plate

Disposition	Review	ID	Chit
A	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR08	1- Suggestion: Pressure test the lines at 2.5 times operating pressure to prevent possible leakage 2- To apply that level of pressure, what are the means of applying the pressure, such as power sources, connection point, measurement, and detection?

Resolution — *D. Cai*

1. Pressure tests shall be performed to 2 times of operation pressure, which is higher than the 1.5 times required by ASME B31.3.

2. Testing will be performed according to ASME B31.3.

These tests are implemented for both the bench assembly of the Heat Transfer Tubes and Stub Weldment assemblies, and the weldment as part of the Center Stack Casing assembly. For more details see the testing section, §6.0, of the CS Casing Fabrication Technical Specification, NSTX-U-SPEC-VVIH-002.

CR-VVIH-0041 – Thermal Conduction through Heat Transfer Tube

Disposition	Review	ID	Chit
A	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR09	The thermal conductivity coefficient assumes full contact of the tube and the CSC. It is highly likely that the tubes separate and will have contact only under the brackets. How much reserve capacity we have to crank up speed/pressure to reach that level of heat exchange?
R	Polar Region Design Integration Peer Review	POLAR PEER45	Consider using cryo- or shrink fitting to have a mechanical interference between cooling tubes and the CS Casing.
R	Polar Region Design Integration Peer Review	POLAR PEER48	Tube retention and thermal joint in groove. If you go the cryo-cooled way, so that recovery to room temperature (and above) grips the tube by differential expansion, check that there are no thermal or Lorentz stress conditions that subsequently bend the cooled/heated plate and release the tube...
R	Polar Region Design Integration Peer Review	POLAR PEER50	To install the SS tube in the groove in the CS cylinder consider hydroforming it in place to create a tight fit

Resolution — *D. Cai*

All analyses performed for the design of the HTT assume the worst case of only line contact in the areas in contact with the clamp, not full contact between the Heat Transfer Tube and groove in the IBDV (CSVS). Therefore, mechanical interference between the HTT and groove is not required removing the need for alternate installation procedures (e.g. cyro or shrink fitting).

CR-VVIH-0042 – Reliability of Heat Transfer Tube Welded Joints

Disposition	Review	ID	Chit
A	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR10	The ramifications of leak(s) in the HTT field joints are extremely undesirable - pulling the CS Casing assembly out and disassembling it to repair. Consider prototyping and testing the designs of, and then the actual field joints as rigorously as possible to ensure reliability.

Resolution — *D. Cai*

All of the joints shall be welded and inspected according ASME B31.3 with the severe cyclic conditions' acceptance criteria. All joints shall also be leak checked and pressure tested to 2 times of the maximum operation pressure. These testing requirements are captured in the HTT/HTP Fabrication Technical Specification, NSTX-U-SPEC-VVIH-004, as well as in the CS Casing Fabrication/Assembly Specification, NSTX-U-SPEC-VVIH-002.

CR-VVIH-0043 – Heat Transfer Plate Deflection's Effect on PFCs

Disposition	Review	ID	Chit
A	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR11	Under Han's presentation on the "Integrated Analysis" the results of the HTP deflections are shown. The PFC team should look into these results to make sure that the HTP deflections do not cause any problems with the PFCs.

Resolution — *D. Cai*

PFC RE has confirmed that there is no issue. The HTP deflections are within the allowed PFC limits.

CR-VVIH-0044 – Restraint for Heat Transfer Plate Stub Weldments

Disposition	Review	ID	Chit
A	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR12	HTP tubing near the common flange needs some sort of restraint to prevent over-stressing the weld connection down below (What Steve Raftopoulos brought up)

Resolution — *D. Cai*

The calculation report NSTXU-CALC-12-26-01 included the calculation for deformation and stress of the HTP tubing near the common flange and all the way to vessel umbrella. The results of the analysis show that the current design satisfied the deformation and stress requirements.

CR-VVIH-0045 – Connecting Feature for Heat Transfer Tube and Plate Joints

Disposition	Review	ID	Chit
A	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR13	Consider welding the HTP/HTT joints instead of using VCR fittings. This method would be more reliable.

Resolution — *D. Cai*

VCR fittings shall be used for easy assembly, installation and service. VCR fittings are currently used for NSTX-U bake-out system with no issues. A VCR fitting with 316SST gasket is rated to 537°C according to ASME B31.3 pressure, process and power piping code, which is higher than the maximum bake-out temperature of 450°C.

CR-VVIH-0046 – Hoop Stress in Heat Transfer Tube during Installation

Disposition	Review	ID	Chit
NA	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR14	Hand calculations performed at FDR indicate that the hoop stress in the tube to install is too large to be possible. Review that the coil insertion jig/plan is possible.

Resolution **—** *D. Cai*

The HTT installation plan has been changed from utilizing a plastic tube jig to several plastic plates (see drawing E-DC11126). With this design change, the hoop stress issue is eliminated.

CR-VVIH-0047 – Strain Relief in Heat Transfer Tube and Plate Connections

Disposition	Review	ID	Chit
A	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR15	Consider adding strain relief on the tubes so that the VCR fittings are not loaded by CS Casing motion.

Resolution **—** *D. Cai*

The calculation report NSTXU-CALC-12-26-01 included the calculation of deformation and stress for HTP tubing near common flange all the way to vessel umbrella. The analysis shows that the Center Stack motion does not affect VCR fitting connection due to the flexibility of the 5/8” tubing.

CR-VVIH-0048 – Pressure Zone and Relief

Disposition	Review	ID	Chit
A	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR16	Additional scope is needed for CWS to design and install HTT reduced pressure zone with accompanying pressure relief device. Adjust the WAF to include this scope.

Resolution **—** *D. Cai*

The additional scope has been included; see the WAF for WBS 1.01.02.04 (6005).

CR-VVIH-0049 – Current Loop Loads in Heat Transfer Plate Stud Weldments

Disposition	Review	ID	Chit
A	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR18	Check the current loop formed in supply/return HTP tubing where they are tee-d together.

Resolution — *D. Cai*

A calculation was performed indicating the force induced on the loop is about 3lbs, with a corresponding stress level much lower than the allowable. This result can be reviewed in PPPL document NSTXU-CALC-12-26-01. Therefore, the current HTP tube stub weldments design is acceptable as is.

CR-VVIH-0050 – Heat Transfer Plate Stub Weldment Installation

Disposition	Review	ID	Chit
A	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR19	Comment/document the anticipated process of adjusting HTP supply/return tubing manifold dimensions to field conditions or capture this as an assembly risk. Alternatively consider a welded-in bellows to accommodate minor misalignment.

Resolution — *D. Cai*

The 1" HTP supply and return lines will be fit in-situ.

CR-VVIH-0051 – Boiling Potential of Heat Transfer Tube Cooling Water

Disposition	Review	ID	Chit
A	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR20	Consider reviewing/performing calculations that examine the potential for localized boiling of the cooling water in the case that the tube contact thermal resistance is as low as it can be (and not the conservative assumption used).

Resolution — *D. Cai*

An additional calculation was performed to examine the potential for localized boiling. Per the result of this analysis outlined in report NSTXU-CALC-12-26-01, no boiling issue is expected.

CR-VVIH-0052 – Lifting Points for the Heat Transfer Plate Assembly Jig

Disposition	Review	ID	Chit
A	HTT-HTP He Cooling Tubes FDR	HTTHTP FDR22	Consider adding lift attachment points to the HTT assembly jig(s).

Resolution — *D. Cai*

Lift attachment points have been design and integrated into the for HTT jig assembly, see PPPL drawing E-DC11198 for details.

CR-VVIH-0053 – Removal of Final Turn of the Heat Transfer Tube

Disposition	Review	ID	Chit
A	Casing Fabrication Peer Review	CASFAB PR01	May not need final coolant tube revolution near ends of vertical sections of casing. This may simplify design to get tubing outside of casing without substantial machining of casing or removal of material from casing.

Resolution — *D. Cai*

The final heat transfer tube revolution nearest the divertor flange has been shown to be unnecessary through stress (see NSTXU-CALC-12-23-00) and thermal (see NSTXU-CALC-12-26-01) analyses. As such, the turn has been removed from the heat transfer tube design.