PRINCETON PLASMA PHYSICS LABORATORY

ENG-033 - CRR - CHIT RESOLUTION REPORT

CHIT RESOLUTION REPORT FOR PF 4/5 REALIGNMENT

NSTXU_1-1-3-1_CRR_100

Rev. 6

Work Planning #:
Effective Date: **03/06/2020**
Prepared By: **Chris Pagano**

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NSTX-U Document #: NSTXU_1-1-3-1_CRR_100

CHIT CODE	§ OF REPORT	STATUS	CHIT CODE	§ OF REPORT	STATUS
PF4-5RealignCDR01	4000	CLOSED	PF4-5RealignFDR06	4035	CLOSED
PF4-5RealignCDR02	4001	CLOSED	PF4-5RealignFDR07	4036	CLOSED
PF4-5RealignPR01	4002	CLOSED	PF4-5RealignFDR08	4037	CLOSED
PF4-5RealignPR02	4003	CLOSED	PF4-5RealignFDR09	4038	CLOSED
PF4-5RealignPR03	4004	CLOSED	PF4-5RealignFDR10	4039	CLOSED
PF4-5RealignPR04	4005	CLOSED	PF4-5RealignFDR11	4040	CLOSED
PF4-5RealignPR05	4006	CLOSED	PF4-5RealignFDR12	4041	CLOSED
PF4-5RealignPR06	4007	CLOSED	PF4-5RealignFDR13	4030	CLOSED
PF4-5RealignPR07	4006	CLOSED	PF4-5RealignFDR14	4042	CLOSED
PF4-5RealignPR08	4008	CLOSED	PF4-5RealignFDR15	4043	CLOSED
PF4-5RealignPR09	4009	CLOSED	PF4-5RealignFDR18	4036	CLOSED
PF4-5RealignPR10	4010	CLOSED	PF4-5RealignFDR19	4044	CLOSED
PF4-5RealignPR11	4011	CLOSED	PF4-5RealignFDR20	4045	CLOSED
PF4-5RealignPR12	4012	CLOSED	COILBKBUSPDRII14	4046	CLOSED
PF4-5RealignPDR02	4013	CLOSED	PF4CSRPFDR01	4047	CLOSED
PF4-5RealignPDR03	4014	CLOSED	PF4CSRPFDR02	4048	CLOSED
PF4-5RealignPDR04	4015	CLOSED	PF45CoilRealPRII01	4049	CLOSED
PF4-5RealignPDR05	4016	CLOSED	PF45CoilRealPRII02	4050	CLOSED
PF4-5RealignPDR06	4017	CLOSED	PF45CoilRealPRII03	4051	CLOSED
PF4-5RealignPDR07	4018	CLOSED	PF45CoilRealPRII04	4052	CLOSED
PF4-5RealignPDR08	4019	CLOSED	PF45CoilRealPRII05	4053	CLOSED
PF4-5RealignPDR09	4015	CLOSED			
PF4-5RealignPDR10	4020	CLOSED			
PF4-5RealignPDR11	4021	CLOSED			
PF4-5RealignPDR13	4022	CLOSED			
PF4-5RealignPDR14	4023	CLOSED			
PF4-5RealignPDR15	4024	CLOSED			
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PF4-5RealignFDR04	4033	CLOSED			
PF4-5RealignFDR05	4034	CLOSED			

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National Spherical Torus eXperiment Upgrade

Chit Resolution Report for PF-4/5 Realignment

NSTXU_1-1-3-1_CRR_100

Prepared By: C. Pagano, Cognizant Individual

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Record of Changes

Rev.	Date	Description of Changes
0	08/09/2019	Initial Release
1	09/30/2019	Closed chits from PF-4/5 Realignment FDR on 08/09/2019
2	01/16/2020	Added and closed chit COILBKBUSPDRII14 from Coil-Bakeout Bus Support PDR on 10/14/2019
3	01/16/2020	Added and closed chits generated at the PF-4 Radial Pin FDR on 01/16/2020
4	02/05/2020	Closed all remaining chits prior to Peer Review II on 02/05/2020
5	03/03/2020	Added and closed all chits generated at Peer Review II on 02/05/2020

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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-4000 – PF-4/5 coil clamping system redesign

Disposition	Review	ID	Chit
A	PF4-5 Realignment CDR	PF4-5 Realign CDR01	Consider adding a risk related to redesign of PF-4/5 coil clamping system in a Risk Registry either this WBS.

This risk was considered but not implemented into the Risk Registry. Only minor redesign of the floating PF-4/5 coil clamps is required to provide enough clearance between the coil IDs and the OD of the VV to move the coils to meet the RD-011 position requirements.

CR-VVIH-4001 – PF-4/5 insulation resistance measurements

Disposition	Review	ID	Chit
A	PF4-5 Realignment CDR	PF4-5 Realign CDR02	As a minimum, perform the basic set of insulation resistance measurements of the PF-4/5 repair plan (M9-1 Inspect Outer PF Coils/Repair) under room temperature conditions BEFORE this realignment activity is performed, then perform the full repair plan including thermal cycling AFTER the realignment. Also consider the cost versus benefit of including the thermal cycling both BEFORE and AFTER to reduce the risk that a problem may be missed and discovered only after realignment.

Insulation resistance measurements of the PF-4/5 are being performed by Weiguo Que and Antonio Falcon as document in Procedure D-NSTX-PTP-CL-068. The PF-4/5 Alignment team shall coordinate the realignment schedule to perform the work while not negatively affecting the insulation testing. The initial test shall be performed after the installation of the permanent clamps on the coils. This is to remove the possibility of the thermal growth of the coils during the insulation tests shifting the relative position of each pancake. A second set of measurements shall be performed after the coils are realigned to verify that the coils are not damaged during the shift. During both tests, dial indicators shall also be used to measure the shift of the coil along the T-slots to check if the coils return back to their initial position.

CR-VVIH-4002 – Alignment requirements calculation check

Disposition	Review	ID	Chit
A	PF4-5 Realignment Peer Review	PF4-5 Realign PR01	Please check Stefan's calculations for alignment requirements

The alignment requirement calculation and check has been documented in PPPL Calculation Report NSTXU_1-1-2-3-2_CALC_100.

CR-VVIH-4003 – Refinement of PF-4/5 and TFIL alignment requirements

Disposition	Review	ID	Chit
A	PF4-5 Realignment Peer Review	PF4-5 Realign PR02	TFIL alignment goals are tight. What PF-4/5 alignment parameters can be used to reduce the difficulty in aligning the TFIL? Recommend, investigate / target better alignment of PF-4/5 where this improvement reduces the alignment burden for the inner bundle.

Requirements Document, NSTX-U-RQMT-RD-011-01, explains that the TFIL alignment requirement (<.8mm) is limited by side load limitations of the Center Stack Bellows not by the alignment of the PF coils. Therefore, tightening the tolerance zone of the PF coil alignment currently adds no benefit. Both the PF coils and the TFIL shall be independently aligned with respect to the VV global axis. PF-4/5 clamps' effect on peripheral components.

CR-VVIH-4004 – PF-4/5 clamps' effect on peripheral components

Disposition	Review	ID	Chit
A	PF4-5 Realignment Peer Review	PF4-5 Realign PR03	Installing permanent clamps to the PF-4/5 could be an issue with respects to the peripheral structures and diagnostics, etc. Recommend the survey of the available space include accounting for "all the other stuff" not in the model that was or will be installed on the machine in these regions.

A survey has been performed to ensure that the clamps can easily installed and shall not interfere with any existing diagnostics and peripheral structures. Per the COG for diagnostics, no additional equipment/peripherals are expected that would interfere with the permanent pancake clamp locations. One new diagnostic that is to be installed shall be placed on the existing threaded rods atop the fixed coil supports. No interference is expected between the new clamps and the diagnostic supports as the new clamps are thinner than the existing clamps and so if the supports fit over the existing clamps they fit over the new pancake clamps. Additionally, a fit-up test has been performed to confirm the proposed clamp locations are accessible, see the prototype results form NSTXU_1-1-3-1_REC_101 for more details.

CR-VVIH-4005 – PF-4/5 clamps' effect on coil stress under thermal loads

Disposition	Review	ID	Chit
A	PF4-5 Realignment Peer Review	PF4-5 Realign PR04	How will the permanent pancake clamps impact the coil stress under thermal loads? Note: Adding the permanent clamps changes locally the radial expansion "modulus" of the coil packs. The clamp geometry provides stress concentration, local change in cross section, which affects the coil radial growth/stress. Recommend evaluating the impact to the coil stress for these additional clamps under operational conditions.

Coil stress analysis was performed under the expected operational conditions of NSTX-U. The results of this analysis can be found in PPPL Calculation Report NSTXU_1-1-3-1_CALC_100. The results show the stresses are well within the allowable for both the new permanent clamps and the coil copper and insulation. This removes any potential risk of damaging the coil. A megger test of

the coil is also included at the end of the clamp installation procedure to confirm no damage has been done.

CR-VVIH-4006 – Re-center dovetail during alignment

Disposition	Review	ID	Chit
A	PF4-5 Realignment Peer Review	PF4-5 Realign PR05	During realignment, re-center the dovetail travel as necessary after each translation.
R	PF4-5 Realignment Peer Review	PF4-5 Realign PR07	Ensure sufficient travel for the dove tail joints after the coils have been aligned. If needed, reset dovetails for sufficient travel under operational and bake-out conditions.

The PF coil sliding support locations along the T-slot shall be inspected after the move to allow sufficient travel for both operations and bake-out. Assuming a maximum vessel temperature of 190°C the vessel can grow outward by up to 0.194". During operations the PF-4 and PF-5 coils can grow 0.037" and 0.195" respectively. These expected expansions require that the slide allow for the following minimum translations:

- PF-4 sliding support to Vessel: 0.319"
- PF-4 sliding support to PF-5 sliding support: 0.037"
- PF-5 sliding support to T-slot support fixed gusset: 0.194"
- PF-5 sliding support to PF-5 radial straining pin: 0.195"

If insufficient space is available, the sliding supports shall be adjusted along the T-slot to meet these requirements. This step shall be included as part of the alignment procedure, document D-NSTXU-IP-CL-4083.

CR-VVIH-4007 – Provide lifting system component specifications

Disposition	Review	ID	Chit
A	PF4-5 Realignment Peer Review	PF4-5 Realign PR06	Please provide specification of lifting system to me

The pneumatic lifting bag information presented during the review (PARATECH KPI-I) was provided to the Critical Lift Engineer for review. Only an approved lifting bag shall be used in any of alignment procedure. If the selected bag is changed, a new specification shall be provided.

CR-VVIH-4008 – Refine coil stress analysis

Disposition	Review	ID	Chit
A	PF4-5 Realignment Peer Review	PF4-5 Realign PR08	Please redo the coil stress analysis with credible numbers (Design factor of 2) and include shear stresses

The coil stress analysis presented at the CDR on 9/25/18 has been redone with a design factor of 2 including shear stresses. The results of this analysis are outlined in PPPL Calculation Report NSTXU_1-1-3-1_CALC_102, R0.

CR-VVIH-4009 – Metrology requirements during realignment

Disposition	Review	ID	Chit
A	PF4-5 Realignment Peer Review	PF4-5 Realign PR09	Provide local metrology to provide real time feedback also metrology method to provide verification and maintain coil position.

Dial indicators, in conjunction with laser trackers in 'build mode' will be used to track movement of the coils at two locations. In addition, monument location can be captured before and after movement. Should data taken at these two locations conclude that there was negligible coil deformation, trackers can be used to check additional locations along the coils. To maintain coil position, additional radial restraining pins and shims shall be added to the existing supports.

CR-VVIH-4010 – Close all chits

Disposition	Review	ID	Chit
A	PF4-5 Realignment Peer Review	PF4-5 Realign PR10	Close chits from previous review

The Chit Resolutions have been collected in this Chit Resolution Report.

CR-VVIH-4011 – Coil center reference for realignment to VV

Disposition	Review	ID	Chit
NA	PF4-5 Realignment Peer Review	PF4-5 Realign PR11	Are you checking if magnetic center of the coil corresponds to geometrical center?

This methodology was considered, but the project decision has been made to assume the geometric center of the coil directly corresponds to the magnetic center.

CR-VVIH-4012 – Produce formal calculations for all analyses

Disposition	Review	ID	Chit
A	PF4-5 Realignment Peer Review	PF4-5 Realign PR12	Document analyses as formal calculations

All analyses performed as part of this scope of work have been documented as formal Calculation Reports see:

- NSTXU_1-1-2-3-2_CALC_100 for alignment requirements
- NSTXU_1-1-3-1_CALC_100 for coil, coil insulation and permanent clamp stresses

CR-VVIH-4013 – Megger test of coils after clamp installation

Disposition	Review	ID	Chit
A	PF4-5 Realignment PDR	PF4-5 Realign PDR02	Perform a megger of outer PF coils (immediately after the clamps are installed) as part of the installation procedure.

A megger test shall be performed on each coil after the installation of the clamps and is included as part of the installation procedure D-NSTXU-IP-4048. This shall be done following the exiting D-Site procedure PTP-CL-NSTX-026 §5.8 for PF-5 and §5.9 for PF-4.

CR-VVIH-4014 – Incorporate EM loads in PF-4/5 coil analysis

Disposition	Review	ID	Chit
A	PF4-5 Realignment PDR	PF4-5 Realign PDR03	The calculation states that the EM loads are out of scope. This inappropriate for qualifying a component of a coil

The analysis and calculation reports have been updated to include EM loads. The results show all stresses are within the allowable limits. More details can be found in PPPL Calculation Report # NSTXU_1-1-3-1_CALC_100.

CR-VVIH-4015 – Analysis performed assuming coil is un-bonded conductors

Disposition	Review	ID	Chit
A	PF4-5 Realignment PDR	PF4-5 Realign PDR04	Phil Heitzenroeder's S-1 paper quotes the insulation system for our PF2, 3, and 4 as four half laps of Mylar and then Fusifab. No primer is used. This is also true of PF-5. There is no shear strength in the winding pack. The winding pack should be analyzed as an un-bonded assemblage of copper conductors
R	PF4-5 Realignment PDR	PF4-5 Realign PDR09	The assumption of bonded insulation/conductors over estimates the efficacy of the four clamps to hold the full perimeter of the coil aligned. Re analyze with the coil modeled as an un-bonded assemblage of conductors

The analysis and calculation reports have been performed assuming the coil is an un-bonded assemblage of copper conductors. The results show that the stress are all within acceptable limits, see PPPL Calculation Report # NSTXU_1-1-3-1_CALC_100.

CR-VVIH-4016 – Low friction contact between pusher plate and coil

Disposition	Review	ID	Chit
A	PF4-5 Realignment PDR	PF4-5 Realign PDR05	The G-10 pusher plate should have a low friction layer that is less than the Mylar layers in the interior of the winding pack to preclude causing vertical shear and shearing motion to occur in the winding pack.

The contact surface between the PF coils and the G-10 pusher plate shall host a thin sheet of Mylar to minimize friction and prevent shear stresses between the conductors and insulation. Refer to the updated clamp design in the Design Report NSTXU_1-1-3-1_REC_100 and the installation drawing D-DC11279.

CR-VVIH-4017 – Wet lay-up detail on drawings

Disposition	Review	ID	Chit
A	PF4-5 Realignment PDR	PF4-5 Realign PDR06	The configuration of the G-11 & wet lay-up should be reflected on the drawings. The drawings can and should indicate the field fitting allowances.

The way lay-up procedure presented at the PDR has been replaced with local resin pads bonded to each coil pancake. The installation process for these pads is outlined in the Design Report NSTXU_1-1-3-1_REC_100 and installation procedure D-NSTXU-IP-4048, and detailed on the installation drawing D-DC11279.

CR-VVIH-4018 – Prototype the clamp assembly

Disposition	Review	ID	Chit
A	PF4-5 Realignment PDR	PF4-5 Realign PDR07	Prototype of the clamp assembly is desirable to check wet-wrap molding procedure.

Prototype clamp housings for both PF-4 and 5 have been 3D printed and test fit at the proposed locations around the vacuum vessel utilizing procedure D-NSTXU-IP-4039-00-MCP1. The results of these test fits can be viewed in the Prototype result form, NSTXU_1-1-3-1_REC_101. Since the wet-wrap design has been removed, the epoxy pads have been prototyped separate to ensure proper curing at the proposed pad thickness, and verify the ability to easily release the bonded pad from the mold.

CR-VVIH-4019 – Remove all sharp corners on clamp

Disposition	Review	ID	Chit
A	PF4-5 Realignment PDR	PF4-5 Realign PDR08	Please remove sharp corners on the clamp.

All corners on the PF-4/5 clamps that are in close contact with the coils have been filleted; see the clamp housing drawings D-DC11274 and D-DC11275. All other edges shall be broken.

CR-VVIH-4020 – Avoid obstructions near the Neutral Beam Port Cover

Disposition	Review	ID	Chit
A	PF4-5 Realignment PDR	PF4-5 Realign PDR10	Clamp at PF-5 Bay A needs to accommodate (or be removable) so that the Neutral Beam port cover removal/installation is not impacted.

As part of the fit-up test, the installation location for the PF-5 clamps around bay A (TF-B) has been verified to ensure clearance for installation, see the Prototype result form, NSTXU_1-1-3-1_REC_101, for details about clearance and fit-up. At the same time, the clamp design has been modified since the PDR to allow the clamp to be removable. The only non-removable feature of the clamps is the cast epoxy pads on the OD and ID surfaces of the pancakes.

CR-VVIH-4021 – Reconcile assumed temperature gradients for PF-4/5

Disposition	Review	ID	Chit
A	PF4-5 Realignment PDR	PF4-5 Realign PDR11	Reconcile the calculation temperature gradients with the analysis of the cooldown by Art Brooks for both PF-4/5 - This is a filed calculation.

The temperature gradient has been updated to match that of Art Brooks' prior analyses and integrated into the PF-4/5 coil and clamp analysis. The temperature gradient is detailed in PPPL Calculation Report # NSTXU_1-1-3-1_CALC_100.

CR-VVIH-4022 – Verify existing supports still prevent n = 1 distortion

Disposition	Review	ID	Chit
A	PF4-5 Realignment PDR	PF4-5 Realign PDR13	The two opposed "fixed" positions are fixed at the slide. The new clamps may cause a shift at this location. Another feature is needed to maintain pancake registration at the fixed location otherwise the n = 1 distortion can occur

Analysis has shown that there is a potential for displacement at the fixed slides due to the introduction of the pancake clamps, see PPPL Calculation Report # NSTXU_1-1-3-1_CALC_100. In order to prevent this movement after the realignment is performed, rubber pads shall be placed between the fixed clamps and the coil. This step shall be added to the alignment procedure. The same calculation report shows that the inclusion of these rubber pads is sufficient to prevent this movement.

CR-VVIH-4023 – Perform analysis using final clamp positions

Disposition	Review	ID	Chit
A	PF4-5 Realignment PDR	PF4-5 Realign PDR14	Clamp forces shown may change if clamp locations are adjusted to avoid obstructions. Re-evaluate after the final positions are established.

The analysis has been performed using the clamp locations selected during the fit-up tests. The results show the clamp and coil stresses are within the allowable. For more details refer to PPPL Calculation Report # NSTXU_1-1-3-1_CALC_100.

CR-VVIH-4024 – Perform analysis showing non-symmetry of existing coil

Disposition	Review	ID	Chit
A	PF4-5 Realignment PDR	PF4-5 Realign PDR15	Symmetry of clamp/coil model should reflect non symmetry of the existing coil

The analysis has been redone with a model that includes the entire coil and all existing fixed and floating support structures, see PPPL Calculation Report # NSTXU_1-1-3-1_CALC_100. Symmetry is no longer assumed.

CR-VVIH-4025 – No-separation contact between the clamp and wet-wrap

Disposition	Review	ID	Chit
A	PF4-5 Realignment PDR	PF4-5 Realign PDR16	The wet wrap is not bonded to the clamp and can slip. This affects the analysis and may give concern to grinding from the point load of the pusher bolts.
R	PF4-5 Realignment PDR	PF4-5 Realign PDR19	The no-separation condition was assumed on the internal side between clamp and the wet wrap. This assumes Mylar insert which should be reflected in the design, or design should assume bonded connection.

The wet-wrap has been replaced with cast epoxy pads that are bonded to the coil but not bonded to the clamp. A Mylar slip plane has been added between the spacer block/pusher plate and the coil; see design report NSTXU_1-1-3-1_REC_100. This matches the analysis assumption of a non-bonded connection to the coil.

CR-VVIH-4026 – Verify PF-5 peak temperature to use in the analysis

Disposition	Review	ID	Chit
A	PF4-5 Realignment PDR	PF4-5 Realign PDR17	Consult the latest design point spreadsheet for PF-5 peak temperature. I think it is lower than 100°C

The design point spreadsheet indicates that the PF-5 peak temperature is 100°C.

CR-VVIH-4027 – Run insulation analysis with bounding parameters

Disposition	Review	ID	Chit
A	PF4-5 Realignment PDR	PF4-5 Realign PDR18	The compressive modulus of the insulation system will be much lower than for G-10. We see this in the 425/Kapton system used for OH and Inner PF and we expect that to be true for the Mylar/Fusifab Run analyses with variations and bounded properties

The analysis has been updated to include the material and boundary conditions based on recommendations from Pete Titus, the author of this chit. The results of this updated analysis can be seen in PPPL Calculation Report # NSTXU_1-1-3-1_CALC_100.

CR-VVIH-4028 – Consider use of existing jack screws

Disposition	Review	ID	Chit
A	PF4-5 Realignment PDR	PF4-5 Realign PDR21	Consider using the existing jack screws to maintain pancake registration

The use of the jack screws to maintain pancake registration was considered but rejected as the currently alignment procedure shall loosen or even completely remove these clamps. Therefore the clamp for maintaining the relative position between pancakes needs to be independent from the existing fixed and floating supports.

CR-VVIH-4029 – Verify clamps can withstand assumed temperature delta

Disposition	Review	ID	Chit
A	PF4-5 Realignment PDR	PF4-5 Realign PDR22	Analysis presentation does not show that the clamp can withstand the 10°C difference between pancakes

To validate the clamps can survive a 10°C temperature gradient, the required forces the clamp requires to maintain pancake positions were extracted from a conservative coil stress analysis and the forces were then directly applied to the clamp. The evaluated stresses are still within the allowable limits. For more details see PPPL Calculation Report # NSTXU_1-1-3-1_CALC_100.

CR-VVIH-4030 – Pancake clamp hardware material

Disposition	Review	ID	Chit
A	PF4-5 Realignment FDR	PF4-5 Realign FDR01	Consider, as applicable, using cold worked 316SST hardware, ASTM A193 B8 Class 2. Refer to: https://www.portlandbolt.com/technical/specifications/astm-a193/
R	PF4-5 Realignment FDR	PF4-5 Realign FDR13	Consider different grade or materials selected (SST vs Inconel 718) for bolts used in the new clamp supports

After extracting the bolt force and moment from the pancake clamp analysis models, a stress calculation was performed proving that using 316SST 1/2"-13 fasteners were indeed strong enough. All shoulder fasteners have been changed to 316SST. This calculation is captured in NSTXU_1-1-3-1_CALC_100 Rev 01.

CR-VVIH-4031 – Verify fasteners can handle pull-out stresses

Disposition	Review	ID	Chit
A	PF4-5 Realignment FDR	PF4-5 Realign FDR02	Confirm that pull-out stresses in the female threads for the clamp box bolts are acceptable. Inconel 718 bolts, 316SST box.

Per the resolution of chits PF4-5RealignFDR-01 and 13, the hardware has been changed from Inconel 718 to 316SST. A calculation was performed showing that using a 1/2"-13 bolt made of 316SST with the applied 2000lbs of preload will not overstress either the male or female threads. This calculation is captured in NSTXU_1-1-3-1_CALC_100 Rev 01.

CR-VVIH-4032 – Commonality of PF-4 clamps

Disposition	Review	ID	Chit
A	PF4-5 Realignment FDR	PF4-5 Realign FDR03	On behalf of Scott Gifford, consider using everywhere the clamp design that fits everywhere. This would result in greater commonality.

The clamp installation drawing, D-DC11279, has been updated to utilize only two versions of the pancake clamps. The PF-4 Variant (thin walled) clamp, D-DC11285-01, shall be used for all PF-4 locations. The PF-5 clamp, D-DC11275-01, has not been changed since the FDR, and remains to be used for all PF-5 locations.

CR-VVIH-4033 – Anvil plate supports

Disposition	Review	ID	Chit
A	PF4-5 Realignment FDR	PF4-5 Realign FDR04	The anvil [plates] are shown as floating in the air. By design the anvils do not drag on the bottom or top clamp plates. Analyses was performed assuming preload is fully into the coil without frictional losses. The design needs to ensure no friction sliding of the anvil plates and even the plunger pins through the clamps.

All coil clamp designs have been updated to include a 1/4" nylon 66 spacer to prevent the clamp plates from dragging on the clamp floor due to gravity. The design also includes a thin layer of 5mil thick Kapton tape with PSA that will eliminate any friction between the sides of clamp front plate and the anvil plate.

CR-VVIH-4034 – Belleville washer housing design and sizing

Disposition	Review	ID	Chit
A	PF4-5 Realignment FDR	PF4-5 Realign FDR05	Does the Belleville washer design, including the housing and tolerances follow washer vendor design guidelines, clearances, tolerances, washer deflection, etc.?

The Belleville washer design and installation procedure incorporates the guidelines the manufacturer provides as outlined in the Key Belleville, Inc. Engineering Handbook dated 05/17/2013. A few of the engineering parameters the handbook provides are incorporated into the design:

- Company software used to determine preload force and deflection, final load and deflection for static loading
- Engineering guidance on how to predict hysteresis in a multi stack of series and parallel configurations
- Preferred orientation of the Belleville washers for a series/parallel stack configuration to ensure the stack performs as predicted. This guidance also helps ensure the Belleville washes stay aligned vertically to provide repeatable and consistent load force.
- Material selection guidance of the spring and faying surfaces to minimize the possibility of galling and pitting of the materials under load
- Lubrication of spring and faying surfaces to help minimize any friction between contact surfaces.
- Application procedure that the PPPL installation procedure includes a “break-in” step to exercise the series/parallel stack one to two times prior to the actual clamp preload step. This procedure will help minimize any hysteresis as outlined in the second bullet.

The design considers the recommended tolerances and thickness to ensure correct clearances between the washers and housing. The tolerance also ensures that there will be no interference assuming the worst case stack-up. All drawing design incorporate best practices and GTO tolerances per ASME Y14.5 requirements

CR-VVIH-4035 – Break all corners of PF clamps

Disposition	Review	ID	Chit
A	PF4-5 Realignment FDR	PF4-5 Realign FDR06	On behalf of Scott Gifford...add fillets on outside sharp corners where needed.

The drawings have been updated to include a .125-.25" radius on all outside corners in close contact with the coil based on the analysis outlined in calculation report NSTXU_1-1-3-1_CALC_100 Rev 01.

CR-VVIH-4036 – QA oversight during clamp fabrication and installation

Disposition	Review	ID	Chit
A	PF4-5 Realignment FDR	PF4-5 Realign FDR07	[Project] will need to have a complete Q&A oversight plan to ensure implementing steps proposed in the procedure will not damage the coils. The oversight plan shall not only cover the external fabricated parts but also the detailed steps to install the clamp supports.
R	PF4-5 Realignment FDR	PF4-5 Realign FDR18	Review ENG-030 for required reviews and approval for the draft installation procedure (IP-4048). QA review is Mandatory per ENG-030 and is important for ensuring incorporation of proper oversight.

A QA oversight plan shall be generated to support both external fabrication, as well as internal fabrication and installation procedures. The QA department shall be included as a reviewer and approver of the oversight and installation plans.

CR-VVIH-4037 – Post signed calculation report

Disposition	Review	ID	Chit
A	PF4-5 Realignment FDR	PF4-5 Realign FDR08	The posted calculation is in draft form. This calculation must be finalized (checked, signed, and filed). Also, the posted draft calculation is listed as Rev 0, but is actually a revision to the calculation posted during the PDR. The new one should be Rev 1.

NSTXU-1-1-3-1 CALC 100 Rev 01 is fully signed off and filed in the DMS system.

CR-VVIH-4038 – PF-4/5 coil shapes during operations

Disposition	Review	ID	Chit
A	PF4-5 Realignment FDR	PF4-5 Realign FDR09	Get physics (Stefan) agreement to the new PF-4/5 coil shapes with the new clamps. There is a requirement to meet a specific shape during the pulse with the 2 fixed supports.

S. Gerhardt has approved the coil shape after adding the pancake clamps and the rubber pads on the fixed clamps. He has approved calculation report NSTXU-1-1-3-1 CALC 100 Rev 01 as a secondary reviewer, considering only the coil shape.

CR-VVIH-4039 – Update analyses with bounded friction values

Disposition	Review	ID	Chit
A	PF4-5 Realignment FDR	PF4-5 Realign FDR10	Per NSTXU SDC, [you] need to bound the nominal friction values using higher and lower friction at all frictional interfaces.

The clamp analysis was repeated with a ±0.15 safety factor against the coefficient of friction. The low friction analysis always showed higher stresses than the high friction model. This is included in calculation report NSTXU_1-1-3-1_CALC_100 Rev 01.

CR-VVIH-4040 – Use of load sensing washers in PF clamps

Disposition	Review	ID	Chit
A	PF4-5 Realignment FDR	PF4-5 Realign FDR11	Consider the use of load sensing compression washers between the pusher bolt and the Belleville stack to measure/monitor clamp forces: https://assets.omega.com/pdf/test-and-measurement-equipment/load-and-force/load-cells/LCWD.pdf

The Belleville washer housing could be modified to accommodate the Omega load sensing compression washers, however due to their high cost their use on every clamp (16 total) has been rejected. Instead a few (1 or 2) shall be procured and used in a test fixture to confirm the load-to-displacement relationship for each Belleville stack prior to their installation in the clamp. This calibration step shall help ensure that each stack imparts an equal load between the coil pancakes and that each clamp is tuned equally rather than relying on the nominal values provided by the manufacturer.

CR-VVIH-4041 – Remove no-separation condition

Disposition	Review	ID	Chit
A	PF4-5 Realignment FDR	PF4-5 Realign FDR12	[In the] FEA settings, the no-separation contact is a simplification. But, this contact carries load that would transfer to other components, bolts, etc. Need to remove the no separation contact, for at least 1 FEA to ensure the full load is carried by the respective parts. Compare this FEA to the no separation results to ensure the no separation results are still conservative.

The no-separation conditions were removed from the pancake clamp analysis for 1 FEA model. This model had no effect on the peak stresses in the analysis. However, some lower stress regions did show a small change in how stresses were carried through the part, but were within approximately ±10% of the stresses with the no-separation condition. All other analyses were performed with the no separation condition.

CR-VVIH-4042 – Remove rubber pads on existing coil clamps

Disposition	Review	ID	Chit
A	PF4-5 Realignment FDR	PF4-5 Realign FDR14	There is no rubber pad installed on the machine existing coil support. Please make sure to include the silicon rubber pad on the existing fixed supports

The rubber pads were removed from all existing coil supports and the models were re-run. The conclusion of the analyses remained unchanged. See calculation report NSTXU_1-1-3-1_CALC_100 Rev 01 for details.

CR-VVIH-4043 – Update clamp bolt torque values

Disposition	Review	ID	Chit
A	PF4-5 Realignment FDR	PF4-5 Realign FDR15	Scott Gifford asserts that the floating clamp bolts are torqued to 45 ft·lbs rather than 20 ft·lbs as was used in the analysis. Double check the signed installation procedure to verify and assess the effect on the results. Also verify the integrity of other design inputs, especially those that would have significant effect on results in the event they are incorrect.

Procedure D-NSTX-IP-3340 r0 specifies 43 ft·lbs torque for all 1/2" hardware. The model was updated and re-run with this new torque value. The conclusion of the analysis remained unchanged. See calculation report NSTXU_1-1-3-1_CALC_100 Rev 01 for details.

CR-VVIH-4044 – Add Mylar for electrical isolation of clamps from coils

Disposition	Review	ID	Chit
A	PF4-5 Realignment FDR	PF4-5 Realign FDR19	Consider adding a Mylar sheet to the bottom of the clamp to account for an "off normal event". It's cheap easy insurance.

The current clearance between the coil surface and the bottom of the PF-4 and PF-5 clamp is approximately 1/2". The design is updated to include a 5mil thick piece of Kapton tape and secured by PSA to provide an extra level of assurance against an electrical short.

CR-VVIH-4045 – Provide range of loads of Belleville washers during operations

Disposition	Review	ID	Chit
A	PF4-5 Realignment FDR	PF4-5 Realign FDR20	Please indicate the range of force imposed on the coil by the Belleville washer stack on the coil, at all possible displacements of the stack during operation and bake-out.

The range of forces imposed on the coil by the Belleville washer stack on the coil was added to calculation report NSTXU_1-1-3-1_CALC_100 Rev 01. The washer stack for PF-5 will provide between 2,875lbs and 3230lbs force and the PF-4 washer stack will provide an approximately constant force of 1507lbs.

CR-VVIH-4046 – Radial Constraining Pin on PF-4 Upper and Lower

Disposition	Review	ID	Chit
A	Coil-Bake Bus Support PDR	COIL BKBUS PDRII14	PF-4 analysis assumes a fixed point whereby the nearest support is pinned to prevent radial expansion due to thermal and EM loads. What is the effect if the PF-4 support is not pinned

Additional scope has been added to the recovery project to introduce locking pin features to the existing support structure of the PF-4 coils at Bay locations B and H. The design is similar to the existing PF-5 locking pins at the same toroidal locations. The inclusion of these additional locking pins removes the need to determine the effect of the unpinned condition as the analysis shall not line up with in-field conditions.

CR-VVIH-4047 – Corrections for the Design Review Waiver

Disposition	Review	ID	Chit
A	PF-4 Coil Support Radial Pin FDR	PF4CSRP FDR01	NSTXU_1-1-2-3-2_WVR_100 Requires Chief Engineer Approval (A-2). Please work with Kathleen for the most appropriate way to rectify.

The initial revision of the waiver was approved in the DMS prior to the FDR and as such the approvers could not be modified. Instead, a revision has been submitted through the DMS with the corrected reviewers and approvers per this chit and ENG-033.

CR-VVIH-4048 – Corrections for the Design Review Plan

Disposition	Review	ID	Chit
A	PF-4 Coil Support Radial Pin FDR	PF4CSRP FDR02	NSTXU_1-1-2-3-2_DRP_100 lists NSTXU_1-1-2-3-2_CALC_100 as the checked calculation to be prepared for FDR. However, this calc was done in July, and is actually input to this DR, rather than generated to support this design. NSTXU_1-1-3-1_CALC_101 is the appropriate calculation to reference in the DRP. Please update DRP (and correct typo of the inclusion of "chit" in the Filing # of the CRR).

The Calculation report number included on the DRP per this chit and the FDR documentation has been corrected. The naming convention of the CRR has also been corrected. The DRP has been resubmitted and signed through the DMS.

CR-VVIH-4049 – Relocation of Optics Box movement work scope

Disposition	Review	ID	Chit
A	PF-4/5 Realignment Peer Review II	PF45 CoilReal PRII01	The present plan has this -3A scope contingent upon a -3B scope task (moving the optics box). It is fully legitimate to BCP the optics box relocation task to authorized WBS 1.1.2.8, since that task is required to complete the authorized work. Recommendation: implement the BCP.

The work scope/activities associated with the removal of the MTPS optics box (Activity IDs SEAL-20001, SEAL-20011, SEAL-20141) shall be transferred to CA6030 through BCP132.

CR-VVIH-4050 – Define maximum applied torque for fasteners in-field

Disposition	Review	ID	Chit
A	PF-4/5 Realignment Peer Review II	PF45 CoilReal PRII02	On the alignment fixtures, should determine a "likely" and "hold point" torque for use in the field (or something similar that allows a quick identification of if there is a problem).

The hold point torque values that should not be exceeded during the realignment process have been calculated and documented in Calculation Report NSTXU_1-1-3-1_CALC_102.

CR-VVIH-4051 – Metrology method selection

Disposition	Review	ID	Chit
A	PF-4/5 Realignment Peer Review II	PF45 CoilReal PRII03	Consider and evaluate photogrammetry to provide the pre and post movement characterization of the coil location and shape. The time to obtain characterization of the coil shape & location, including verifying that the pancake pairs did not shift could be considerably shorted with photogrammetry. Additionally, once the reflective targets are applied, a single individual can make photogrammetry measurements as opposed to the crews required to operate multiple laser tracker locations.

The metrology approach presented at PRII is adequate to measure the position of the coils during and after alignment to meet the requirements with respect to the global coordinate system. Should discussions with vendors indicate improvements in cost and schedule by switching to photogrammetry, it can be implemented in lieu of laser trackers.

CR-VVIH-4052 – Sliding support shim installation field conditions

Disposition	Review	ID	Chit
A	PF-4/5 Realignment Peer Review II	PF45 CoilReal PRII04	For the slider side spacers, ask the welders to assess the feasibility of welding the back spacers. If infeasible, see if the use of front spacers only is good enough.

An in-field visit was performed with the PPPL welders to determine the feasibility of installing the shim design presented at the PRII at both the ID and OD locations. It was determined that the existing shim design was unusable at all ID locations due to space limitations, and furthermore no welding can be performed on the right-hand side locations at Bay H. To accommodate these limitations, a new shim design has been developed which relies on the welded tab of the shim attaching to the bottom surface of the sliding support rather than the front and back faces. At the same time, since no shims can be installed on the right side of Bay H, shims shall only be installed on one side of the support at both the Bay B and H locations. This change is documented in memo MAG-200303-KC-01.

CR-VVIH-4053 – PF-4 Lift Fixture analysis closure

Disposition	Review	ID	Chit
A	PF-4/5 Realignment Peer Review II	PF45 CoilReal PRII05	Check and sign calculations for PF4 Lift Fixture Analysis.

Calculation Report NSTXU_1-1-3-1_CALC_102 has been checked and signed.