PRINCETON PLASMA PHYSICS LABORATORY

ENG-033 - CRR - CHIT RESOLUTION REPORT

Chit Resolution Report for Coil & Bakeout Bus Bars

NSTXU_1-1-3-4_CRR_100

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Chit Resolution Report for Coil & Bakeout Bus Bars

NSTXU_1-1-3-4_CRR_100 R1

(also includes SBS 1.3.3.2.1)

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Record of Changes

Rev.	Date	Description of Changes
0	March 6, 2019	Initial release

Review	Chit Number	Status		Review	Chit Number	Status
Magnets DVVR	MDCB01	Open		PDR #2	COILBKBUSPDRII05	Closed
Magnets DVVR	MDCB03	Closed		PDR #2	COILBKBUSPDRII06	Closed
Magnets DVVR	MDCB04	Closed		PDR #2	COILBKBUSPDRII07	Closed
Magnets DVVR	MDCB05	Closed		PDR #2	COILBKBUSPDRII08	Open
Magnets DVVR	MDCB09	Closed		PDR #2	COILBKBUSPDRII09	Closed
Magnets DVVR	MDCB11	Closed		PDR #2	COILBKBUSPDRII10	Closed
Magnets DVVR	MDCB14	Closed		PDR #2	COILBKBUSPDRII11	Closed
Magnets DVVR	MDCB15	Closed		PDR #2	COILBKBUSPDRII12	Closed
Magnets DVVR	MDCB16	Closed		PDR #2	COILBKBUSPDRII13	Closed
Magnets DVVR	MDCB20	Closed		PDR #2	COILBKBUSPDRII14	Closed
M9.1 Outer PF Inspections PDR	M9.1OUTPFINSP02	Closed		PDR #2	COILBKBUSPDRII15	Closed
PDR#1	COILBKBUSPDRI01	Closed		PDR #2	COILBKBUSPDRII16	Closed
PDR#1	COILBKBUSPDRI02	Closed		PDR #2	COILBKBUSPDRII17	Closed
PDR#1	COILBKBUSPDRI03	Closed		PDR #2	COILBKBUSPDRII18	Closed
PDR#1	COILBKBUSPDRI04	Closed		PDR #2	COILBKBUSPDRII19	Closed

PDR#1	COILBK BUSPDR I05	Closed		PDR #2	COILBKBU SPDRII20	Closed
PDR#1	COILBK BUSPDR I06	Closed		PDR #2	COILBKBU SPDRII21	Closed
PDR#1	COILBK BUSPDR I07	Closed		PDR #2	COILBKBU SPDRII22	Closed
PDR#1	COILBK BUSPDR I08	Closed		PDR #2	COILBKBU SPDRII23	Closed
PDR#1	COILBK BUSPDR I09	Closed		PDR #2	COILBKBU SPDRII24	Closed
PDR#1	COILBK BUSPDR I10	Closed		PDR #2	COILBKBU SPDRII25	Closed
PDR#1	COILBK BUSPDR I11	Closed		PDR #2	COILBKBU SPDRII26	Closed
PDR#1	COILBK BUSPDR I12	Closed		PDR #2	COILBKBU SPDRII27	Closed
PDR#1	COILBK BUSPDR I13	Closed		PDR #2	COILBKBU SPDRII28	Closed
PDR#1	COILBK BUSPDR I14	Closed		PDR #2	COILBKBU SPDRII29	Closed
PDR#1	COILBK BUSPDR I15	Closed		PDR #2	COILBKBU SPDRII30	Closed
PDR #2	COILBK BUSPDR II01	Closed		PDR #2	COILBKBU SPDRII31	Open
PDR #2	COILBK BUSPDR II02	Closed		PDR #2	COILBKBU SPDRII32	Closed
PDR #2	COILBK BUSPDR II03	Closed		PF1A PDR	PF1APDR 05	Closed

PDR #2	COILBK BUSPDR II04	Closed				

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General

01 – Categorization

Review	ID	Chit
PDR#2	COILBKBU SPDRII01	Given QAPD table 1, Row 3, I am not convinced that the bakeout bus bars are A3. If they fail, for instance at the interface to the casing, it will take more than a month to repair. Please revisit.

Closed: The categorization for the bakeout bus-bar has been upgraded to an A-1 for the components that are within the umbrella. This is due to the time and expense of access to the components. There are also components that are ex-umbrella. that remains A-3 since accessibility is not an issue.

02 – Silver-Plating Bolt

Review	ID	Chit
Magnets DVVR	MDCB16	Deteriorated silver plating may cause degradation of resistance. Make sure that the thickness is bigger than 5 microns. Sounds like somebody from PPPL knows that, including procedure. Please, implement
PDR#2	COILBKBU SPDRII02	Consider silver plating 1/2"-13 inconel bolt used on the terminal foot to avoid/prevent assembly galling. Please also review other similar-material threaded interfaces to the same end.

Closed: Bolts will be silver plated to prevent seize. Manufacturing plan is updated and presented as part of the FDR package. In addition, the silver plating will be 0.2 mil (5.08 microns) via the Silver Coating Procedure D-NSTX-IP-2853.

03 – Current Cancellation Clamp

Review	ID	Chit
PDR#1	COILBKB USPDRI03	The locations of current cancellation clamp need verification that space for them is available in the field.

Closed: The location of the current cancellation clamp has been verified against the 3D CAD model and field pictures. The location aligned with the inspection and model alignment.

– FMEA/FMECA

Review	ID	Chit
PDR#2	COILBKBUS PDRII06	Please use the FMECA format in the FMECA Plan
PDR#1	COILBKBUS PDRI04	FMEA needs to include failure mode where a joint becomes loose, then overheats and melts and creates an open circuit.
PDR#1	COILBKBUS PDRI05	FMEA should include fault between (+) and (-) conductors due to movement of parts under load that closes the gap or water leak where water bridges the gap.

Closed: The FMECA has been updated to the NSTX-U template with all the other recovery failure modes. The summary of the formatted text is presented as part of the FDR presentation and includes all the indicated potential failure modes. (FMECA Link)

05 - Cooling

Review	ID	Chit
Magnets DVVR	MDCB03	Design/analysis of the water-cooled flex bus as it's supported in the coil bus tower. Has it been done?

Closed: The water cooled flex bus was initially addressed at the PDR and is specifically addressed in the FDR. Mechanical testing has been completed to qualify the water-cooled cables and distance between support brackets in NSTXU_1-1-3-4_TREP_100. Material properties of the cables were also collected during testing.

06 - Requirements & Acceptance Criteria

Review	ID	Chit
PDR#1	COILBKB USPDRI13	For each presentation, make very clear the requirements and acceptance criteria. This will help convey the acceptability of the design being presented.

Closed: The requirements are included in the FDR presentation and a summary of how the requirements are closed is included in the FDR presentations.

07 - Dielectric Strength Insulation

Review	ID	Chit
PDR#1	COILBKB USPDRI15	Should determine dielectric strength of bus bar insulation and confirm safety factor of at least 10x maximum operating voltage. Not accurate to multiply strength per layer x number of layers.

Closed: There are two layers of half-lap 2mil kapton tape (6.1 kV/mil) and one layer of half lap 0.005" thick fiber glass tape. The total insulation thickness is 9 mil. The dielectric strength can be expressed as V= kd^n. Here k is 8.8 kV/mil^0.5, n=0.5. So the dielectric strength is 8.8*sqrt(9)=26.4 kV. The maximum operation voltage is 2kV so the safety factor is 10x maximum operating voltage.

08 - Testing/Inspection

Review	ID	Chit
PDR#2	COILBKBU SPDRII07	Verify by testing that a brazed copper joint has the 11 ksi strength that is assumed in analysis

Closed: The braze allowable was developed from two sources one was a calculation for the CHI Bus Bar analysis NSTXU-CALC-54-01-1 Rev 0 in addition a Report for ITER, EWI Final Report Project No. 52690GTH, was developed Joining of Stainless Steel Jacketed, Magnesium Oxide Insulated Conductors for ITER In-Vessel Coils, that addressed the testing of the brazed joints in developing test specimens and conduction testing.

09 - *Plate Contact*

Review	ID	Chit
PDR#2	COILBKBU SPDRII03	Consider performing the analysis of the SS vessel lugs with only weld contact not with full plate contact to bracket the performance/capability.
PDR#1	COILBKBU SPDRI16	Details of joints (bolting hardware, contact pressure) need to be included and presented at FDR.
PDR#1	COILBKBU SPDRI12	Check a few of the bolted connections. Bonded connections are not physical

Closed: A field walkdown of lug connection was performed. A visual inspection of a lower connector was conducted. The inspection found two parallel welds lengthwise on the lower connections. This was accomplished on one of the legs.

Based on the results of the inspection, an analysis was conducted using only the contacts of the side welds. The results show that these contacts were adequate. This is documented in NSTXU_1-3-3-2-1_CALC_101.

Review	ID	Chit
PDR#2	COILBKBU SPDRII18	Consider the merit of shaping the base of the casing/leg interface to counteract the reduction in contact pressure between the bolts during events.

Closed: The concept of shaping was considered but rejected as the results of the analysis captured in the calculations determined that there was adequate contact pressure between the bolts.

10 – *Drawings vs As-Built*

Review	ID	Chit
Magnets DVVR	MDCB15	Confirm that all field changes have been processed by ECNs and drawing revisions. Electrical/electromagnetic specialist to review all ECNs to determine if revised calculation is needed.

Closed: Based on the FDR, the drawings have been updated to reflect the "as is" condition of the Bus Bars being implemented. These drawings provide some latitude for field adjustments, but if there is a field change as a result of the installation procedure, a red-line and associated ECN will be processed in accordance with the QAPD process.

Review	ID	Chit
PDR#2	COILBKBU SPDRII09	Slide 10 of Danny's presentation and slide 14 of P. Titus' presentation appear visually to show a slightly different toroidal spacing of the CHI flags. Please check that all the analysis has the same geometric assumptions

Closed:The models have been verified and the models are consistent to each other.

11 – *Conductivity on Bolted Bus Joints*

Review	ID	Chit

Magnets DVVR	MDCB20	Please, consider using a conductive grease on the bolted bus joints, like NOOXID or similar. That significantly reduces the resistance and degradation of resistance in time.

Closed: The need for conductive grease was considered, but the design determined that it was not necessary. The design is adequate based on the silver plating to improve joint resistance.The silver plating ensures that the joint resistance is consistent with the requirement

12 – *Thermal*

Review	ID	Chit
PDR#1	COILBKB USPDRI10	Please make sure the thermal analysis inputs for the Design Review (5 seconds) shall be consistent with the Requirements defined in GRD and SRD etc.

Closed: Thermal inputs are included as part of all calculations. These thermal values are consistent with the requirements in the GRD and SRD.

13 – *Stresses*

Review	ID	Chit
PDR#2	COILBKBU SPDRII22	Need to demonstrate for FDR that all high stress areas where fillets are needed do have lower stresses and strains that meet the structural design criteria

Closed: There were features added to the design to accomodate the stresses. These new design features show that the high stress areas have been removed and are included in calculations NSTXU_1-1-3-4_CALC_100-104.

14 – Field Fit-able parts

Review	ID	Chit
PDR#2	COILBKBU SPDRII28	From the presentation it is not clear that all the field-fit-able part to connect TF Inner legs to outer leg flag was presented. Review and present any remaining "bits" at the FDR.

Closed: Field fit components have been identified and will be reviewed during FDR. Field fitting of components has been annotated on drawing C-DC1894.

15 – Tolerance Stack Up

Review	ID	Chit
PDR#1	COILBKB USPDRI14	Design of support blocks in the lead supports should accommodate the possibility that the coils fail to meet the flag location tolerances. Every effort will be made to meet this requirement but there is a risk that vendors or PPPL will have difficulty maintaining the required dimensions. I recommend that the design allows for some field fit capability to shave or modify blocks to fit the as built condition.

Closed: The drawings make reference to an ability to field fit components to a reasonable limit based on the expected tolerances. If the tolerances in the drawings are exceeded, ECNs will be generated and drawings will be updated.

Review	ID	Chit
PDR#2	COILBKBU SPDRII16	Consider performing a sensitivity analysis on the tolerance stack and assembly capability of the inconel reinforcement plate boss connection.

Closed: Inconel reinforcement plate will be pre-fit to the boss connection before installation to ensure a tight fit. Sufficient tolerances are allocated as part of the drawings to consider sensitivity to variation of the design.

16 – Static Criteria

Review	ID	Chit
PDR#1	COILBKB USPDRI11	Static criteria primary membrane, and membrane plus bending, must be checked and satisfied for all cases.

Closed: Static criteria primary membrane, and membrane plus bending are using a worst case that is included in the models and analyses. These are defined in all the calculations and presented at the FDR.

17 – Dielectric Standoff

Review	ID	Chit

PDR#1	COILBKBUSPDRI01	Before the FDR if not already done examine carefully all of the gaps and tracking distance to verify that there is adequate dielectric standoff between the coil leads. Keep in mind that surfaces that are difficult to reach and exposed to dust or contamination may be particularly vulnerable to tracking and may require an extra barrier or greater distance than the general rules of thumb for dielectric standoff.

Closed: The drawings and field fit contain the appropriate gaps. Every effort was made to inspect and measure the as-built tolerances and ensure they are accurately represented in the drawings. The distances indicated on the drawings provide an adequate dielectric standoff which allows for 10kV/in as provided in IPC-2221A.

18 – Manufacturability

Review	ID	Chit
PDR#2	COILBKBUSPDRII29	If it was assumed that most of the bus bar can be made ahead of time, please revisit this assumption. Last time the pre-made bus was thrown out remade as a field fit process. This will not affect the design/analysis however the in house resources and the duration need to be accounted for.

Closed: The Bus Bar will not be assembled a priori. Rather, it will be field fit based on the lessons learned and input from the field technicians. The bus bar will be measured in the test cell prior to manufacture, and assembly will occur at PPPL and required resources have been accounted for.

19 – Rogowski Coils

Review	ID	Chit
PDR#2	COILBKBUSPDRII25	The present lower CHI bus has a set of Rogowskis used to assess halo currents. Given the discussion today, it appears that these should be retained.

Closed. The assumption that the Rogowskis is correct and will be retained to assist in measuring the HALO currents.

20 – Grounding

Review	ID	Chit
PDR#2	COILBKBUSPDRII26	The small double-pull single throw NTC grounding switches should be included in the design discussion.

Closed: The PF-1B that the ground switch is included as part of the PF-1B FDR power supply. The ground switches are documented in drawings 4D256 and 4D090.

21 – CU Cu Joint Resistance

Review	ID	Chit
PDR#2	COILBKBUS PDRII19	Rana, slide 27: I believe that Hans Schneider once made measurements of Cu-Cu joint resistance as a function of contact pressure. Assess if that PPPL data is confirmatory of the data in the slide from the literature.

Closed: Art Brooks provided measured data presentation regarding Cu-Cu joint resistance from Hans Schneider. The reference data was correlated and found to be consistent and is documented in NSTXU_1-3-3-2-1_101.

22 – Thermal Expansion

Review	ID	Chit
PDR#2	COILBKBU SPDRII21	Please evaluate Impact of Difference in coefficient of thermal expansion due to Bracket material change from SS316 to Inconel 625 for qualifying the vertical bar support design

Closed: The material properties were assigned and placed into the analysis for the operational and bakeout cases. The thermal stresses associated with bakeout are the worst case. The findings address the the proper materials as indicated in CALC 1.3.3.2.1.101

23 – *PF-4 Current Limits*

Review	ID	Chit
PDR#2	COILBKBUS PDRII05	I strongly suspect that the cables for PF-4 do not meet the ESW/rep rate requirements in P. Dugan's talk. Please document that ESW/rep rate constraints (RMS current?) of the design

Closed: PF4 ESW/rep rate requirements were currently reviewed by John Dellas. Current specifications for the PF4 cables do not allow an excess of 10kA, the requirement requires 16kA at a 6 sec ESW. This is addressed in memo: MAG-191118-SPG-01.

Review	ID	Chit
M9.1 Outer PF Inspections PDR	M9.1OUTPFINSP02	With regard to the PF-4 flex bus: i) the support for the flex-bus appears to be debated, and ii) maintenance of operations within the RMS current limit is not assured.

Closed: The design of the PF-4 is addressed in the design for the flex-bus and presented in the FDR..

24 – PF-4 Pinning

Review	ID	Chit
PDR#2	COILBKBUSPDRII14	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.

Closed: As a result of this review it was determined that there was no one responsible for pinning the PF-4 coil. As a result, a separate activity was established to pin the Coil under the PF4/5 Realignment scope. This chit will be closed at that design review. Link is here PF4 Radial Constrain Peer Review.

25 – Cooling

Review	ID	Chit

PDR#2	COILBKBUSPDRII12	PF4 Analysis did not consider Water Cooling however the current Hardbus contains water cooling. Design & analysis needs to include a consistent Hardbus Cooling design.
PDR#2	COILBKBUSPDRII32	If water cooling is removed for PF4 hard bus, please re-calculate the air-cooled scenario with the reduced CSA due to the cooling path (if the existing bus is re-used).

Closed: The analysis presented at the FDR was modified to consider using water cooling. as identified in calculations NSTXU_1-1-3-4_CALC_104.

26 – Model Versus As-Built

Review	ID	Chit
PDR#2	COILBKBUSPDRII13	Check the as-built condition of the PF-4 hard bus; model should match the as-built for those components not being modified.
PDR#1	COILBKBUSPDRI02	The coil terminal supports show a closely coupled (I'm assuming bonded from analysis POV) G10/11 piece surrounding the coil terminals and flags. The as built terminals will deviate from the CAD model. At FDR please show the process that will achieve the support requirements.

Closed: The existing hard bus was measured to capture the as-is condition and included in both the models and calculations. In the event changes were required to the as-built condition due to design changes, the models and drawings were updated accordingly via the ECN process.

27 – Stresses

Review	ID	Chit
PDR#2	COILBKBUSPDRII15	Slide 21 of J. Fang presentation; it looks like there are high stresses at the interface of the leads to the coil proper. I understand that these are due to the simplifications of the model employed (very rigid model for the coil). However, it leaves open the question about whether the clamps are fully protecting the coil, i.e. protecting the locations where the leads break out of the back. Please assess.

Closed: The models were assessed and modified as appropriate to ensure that the data represented in the model was accurate. The results were included in the calculations addressed in the FDR.

28 – Salisbury Overwrap

Review	ID	Chit
PDR#2	COILBKBU SPDRII27	Consider adding Salisbury overwrap on the bus link connections (on top of Kapton) and note on the drawings.

Closed: The use of Salisbury overwrap was considered, accepted, and implemented in the design and the documentation and drawings have been modified accordingly.

29 – *Fields & Forces*

Review	ID	Chit
Magnets DVVR	MDCB05	If DC bus bar pairs are not built as an integrated assembly with +/- conductors over-wrapped with common epoxy-glass structure, the repulsive force between conductors will be transmitted to whatever leads or cables that the bus bars attach to. This is a bad design that can result in structural overloads. Adding an external wrap or clamping should be considered. Design must consider forces under short-circuit conditions, not just normal operating current.
Magnets DVVR	MDCB04	Have all bus bars and flexible cables been analyzed in terms of fields and forces considering as-built condition? Are all bus bars and flexible cable connections able to carry required current for full pulse duration at required repetition period? This needs to be confirmed.
Magnets DVVR	MDCB09	Verify that joint design for bus connections included calculations to size the correct Belleville washers. Washers must be chosen for available deflection and force that guarantees joint clamping load is adequate during thermal excursions.
Magnets DVVR	MDCB14	There were field changes to the bus bars, which generated ECNs. They should have a more detailed review due to the impact of failure. There is also a backlog of drawing changes.

Closed: The design presented at the PDRs and FDR addresses all the fields and forces and preloads required using the Belleville washers. All these designs are included in the design and are addressed in the FDR.

30 – PF-4 Coil Lead Shape

Review	ID	Chit

Magnets DVVR	MDCB11	We were shown a four-cable bus assembly which was drawn in two CAD pictures as an unnecessarily open and dipole assembly (++ against - -), I think for PF4. Never mind the coil tails (leads) formed in a non-optimum shape, since they can't easily be changed, but the cables should be brought together as close as possible to the tails, and brought into a quadrupole geometry (+ - against - +). This will lower the separation forces on the cables and considerably reduce the stray field. It was said that cable runs are not thought to be important for stray fields but as with choice of joggle locations inside coils, etc.this could be considered as not attending to basic good practice for tokamak design, even for the no-cost options.

Closed: The cables are run as close to one another as feasible to cancel the effects and minimize stray fields. All the effects of the design are considered in the FDR design.

31 – Test and Inspect

Review	ID	Chit
PDR#2	COILBKBU SPDRII31	Inspect PF5 Terminal supports to see if similar supports to PF4 are needed

Open: This Chit is out of scope for the Bus bar scope. This inspection and modification of the PF-5 is completely out of scope for this effort. The recovery scope determined that only the PF-4 Bus work needed to be addressed. The project engineer to check the analysis calculation on the potential need to add this scope.

Review	ID	Chit
PDR#2	COILBKBUS PDRII30	Electrical considerations on the PF-2/3/4/5 lead supports...please check that there are no floating metal parts, and have an assessment of creep distances. This chit came up in the context of PF-4, but it was recommended to make the same assessment on the other outer-PF coils.

Closed: The grounding design has been included in the design of all floating brackets.

32 – HALO Side Loads

Review	ID	Chit
PDR#1	COILBKBUSP DRI17	Include displacements from Shim Gap due to Halo Side Load

Closed: The 0.75mm Shim Gap displacement has been included in the analysis for the Upper PF-1A and 1B. It is included as part of the calculation NSTXU_1-3-3-1_CALC_100 & NSTXU_1-3-3-1_CALC_101 presented at the FDR.

33 – *Design/Analysis*

Review	ID	Chit
Magnets DVVR	MDCB01	Assess if there was any need to lash together the (+) and (-) PF-1a, -1b, -1c bus bars inside the umbrella. Were they lashed in the past? Did the analysis assume it?
Magnets: PF1A PDR	PF1APDR05	If the current per turn is increased to meet J. Menard's request to preserve the total kA-turns in the PF1 coils relative to the original DPSS/GRD, this will impact the heating and forces on the buswork. This needs to be analyzed for the PF1A coil ASAP. Also, there are PF1B and PF1C designs around where the # of turns is reduced (PF1C turns may be significantly reduced). The buswork implications should be considered ASAP.

Closed: The Inner PF Buswork design presented consists of all the loads that are anticipated and considers the current Magnet designs and is presented in the FDR.

34 – *Reverse Field Case Analysis*

Review	ID	Chit
PDR#1	COILBKBUSP DRI09	Please run additional calculation for the TF reverse field case for the PF1CL BUS analysis. The load and field distribution can be different between forward and reverse field cases.

Closed: The TF reverse field case was included in the analysis at PDR and FDR is addressed in Calculation NSTXU_1-1-3-4_CALC_103.

35 – *Thermal*

Review	ID	Chit
PDR#1	COILBKBUSP DRI08	PF1CL transient thermal calculation for 1/2 day of pulsing is still ratcheting. Also, unclear where the actual peak is occurring along the length of the bus bar and what is the value (to be checked to ensure compatibility with insulation). Final calculation result should account for full ratcheting and maximum peak along the length of the bus.
PDR#1	COILBKBUSP DRI07	Please review and check the input thermal data used and thermal calculation assumptions used in the PF1CL thermal calculation to make sure the thermal calculation is conservative and correct.

Closed: The analysis includes the thermal data extracted from Global Thermal Analysis NSTXU_CALC_10-06 and incorporates this analysis in the calculations. The results of this overarching analysis is provided in all the calculations and the design presented at the FDR.

36 – PF1BL Stress

Review	ID	Chit
PDR#1	COILBKBUSP DRI06	Please present more detailed evaluation of PF1BL BUS local maximum stress and local peak stress location to make sure the stress meets the BUS bar and terminal flag fatigue allowable

Closed: The stresses were analyzed, included in the design, and included in calculation NSTXU_1-1-3-4_CALC_101 and is presented during the FDR.

37 – *Coil - Flag displacement*

Review	ID	Chit
Polar Region - Flanges/O-Rings/Insulators/Supports - PDR	PRFORINSUP DR20	What is the relative displacement between the end of the coil and the flag fixed at the tower? This was an important source of cyclic bending stress of the break-out region of the coil. The compliance of the preload system has to be checked to make sure it isn't violating the assumptions in the inner coil analysis

Closed:The PF 1 analyses, NSTXU_1-1-3-4_CALC_ 101-104 address the displacement and is presented during the FDR.

38 - *Cooling*

Review	ID	Chit
PDR#2	COILBKBUSP DRII24	Evaluate whether the power requirements of the PF1B necessitates water-cooled flex cables. If it does not, consider air-cooled cables (less opportunities for water leaks, etc).

Closed: Power requirements for the PF1B cable were evaluated and discussed, requirements below 1000 kcmil require multiple cables in parallel. Flexible air-cooled cable insulation is thinner than water-cooled cables. The Lorentz loads experienced by the PF1B cable (worst case) is 952lb/ft. Water-cooled cables have been mechanically tested per test report NSTXU_1-1-3-4_TREP_100..

39 – Cable Voltages

Review	ID	Chit
PDR#2	COILBKBUSP DRII23	Sam's Talk, slide 12: it is likely a minor point, but the operating voltage is 2 kV, the fault case voltage is 4 kv, and the hipot voltage is 2*4+1=9 kV. So make sure the manufacturer is clear on what they are being asked to provide.

Closed: The vendors have been supplied to vendor and they understand these requirements. The vendor has committed to ensuring that the cables provided meet these requirements.

Bakeout

40 – *CHI BUS*

Review	ID	Chit
Magnets DVVR	MDCB06	NSTXU-CALC-54-01-00 shows the three pairs of vertical bus bars for the CHI connections, with each pair tightly coupled. In the implementation, two of the pairs are tightly coupled, but one pair is not. So this appears to be an inconsistency that should be assessed. It may or may not be an issue.

Closed: The CHI Bus Bar has been replaced with a new design for the Bakeout Bus Bar. The major delta is that the one line requires a longer run due to interference. The calculations for Bakeout Bus Bar Calculation NSTXU_1.3.3.2.1_CALC_101 considered resistance of these runs.

41 – *Bellows*

Review	ID	Chit
PDR#2	COILBKBUSP DRII08	If bakeout current asymmetries through the lower bus work can put the bellows at risk, consider adding current measurement capabilities to each bus link with adequate resolution to detect/prevent bellows damage.

Open: This is a diagnostics task and is out of scope for the Bus work. However, the bellows can have a thermocouple added as part of an extension of the PFC diagnostics effort. This is a minor modification to the existing design and adds an ex-vessel thermocouple.

42 – *Brazed Copper Allowable*

Review	ID	Chit
PDR#2	COILBKBUSP DRII17	on the analysis for bakeout bus (page 16) has the allowable for brazed copper been used (11ksi or whatever we determine via test)

Closed: The calculations for Bakeout Bus Bar Calculation NSTXU_1.3.3.2.1_CALC_101 used the proper allowable for brazed copper.

43 –Bakeout Flag Socket Head Cap

Review	ID	Chit
PDR#2	COILBKBUSP DRII04	For the socket head cap screw that retains the bakeout flag to the CS divertor flange, make sure to use a standard depth head. Socket head cap screws are vulnerable to fail in tension if the socket goes too deep into the bolt head.

Closed: The depth head was considered and the depth was considered as part of the design and presented as part of the design presented at FDR.

44 – Bakeout Thermal Growth

Review	ID	Chit
PDR#2	COILBKBUSP DRII10	Assess collision between upper IBDH flange and PF-1cU coil case under the CS-only bakeout. Is this configuration no longer allowed?

PDR#2	COILBKBUSPDRII11	Assess the potential between the PF-1cU can and the upper IBDH flange under any of the various scenarios where the bakeout heating is abruptly removed. This abrupt removal of heating can occur in various scenarios (D-site power loss, E-stop, various local breaker trips, etc.)

Closed: While this is an MCS task and is out of scope for the Bus work. However, there is a notch being removed from the flange to accommodate the the ⅜" clearance to ensure that the flange does not interfere with the PF-1C can as discussed and addressed in the memo Upper Diverter Flange Modification VVIH_200122_TJR_2

45 – *Bakeout DC Testing & Inspection*

Review	ID	Chit
Magnets DVVR	MDCB13	Confirm that 2 micro–ohm is proper pass/fail criteria for joint resistance

Closed: The 2 micro–ohm or less joint resistance is quite low and comprises a very small percentage of the total resistance of the coil loop.

Review	ID	Chit
Magnets DVVR	MDCB18	Due to thermal and EM induced motions, it is good practice to check high current bus–bar joints periodically, either on a time cycle (of say 6 months or a year) or just before each operational campaign after long shut–downs. If the first few complete tests of all joints reveal no problems, then the frequency of checking could be reduced and/or spot–sample checking could be used instead of checking all the joints. In JET and Compass, "interesting" problems arose due to the failure of ~100kA joints that had not been maintained because they were very difficult to access.

Closed: The standard system testing and inspection method will be addressed using standard PPPL testing and inspection procedures.

46 – *Overwrapping conductors*

Review	ID	Chit
Magnets DVVR	MDCB12	Confirm by inspection that the plus and minus leads are tied together as appropriate.

Closed: The cables are run as close to one another as feasible to cancel the effects and minimize stray fields.The design addresses the appropriate level of lead connection and are addressed as part of the FDR design.

47 – *Cooling*

Review	ID	Chit
PDR#2	COILBKBUSPDRII20	Rana, slide 29: The mass flow rate of 36 g/sec is not explicitly connected to the properties of the cooling water system. Please check that as plumbed in the field (series I believe) and with 120 PSI, the flow matches this assumption.

Closed: The flow rates were checked and included in the analysis and design included in calculation NSTXU_1-3-3-2-1_CALC_101.

48 – *Dipole error fields*

Review	ID	Chit
Project PDR	PROJPDR23	Some of the busswork used to connect the magnets to the power supplies appear to generate dipole error fields. Have these error fields been evaluated for their effect on the plasma rotation?

Closed: The error fields were determined to be small and did not have an impact. These error fields have been calculated and are included in the calculations for the high heat flux Plasma facing components.