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PRINCETON PLASMA PHYSICS LABORATORY

ENG-033 - CRR - CHIT RESOLUTION REPORT

BAKEOUT CHIT RESOLUTION REPORT

NSTXU_1-3-3_CRR_100

Rev. 1

Work Planning #:	
Effective Date:	**03/06/2020**
Prepared By:	**Peter Dugan**

Reviewed By	Joseph Petrella, Cognizant Individual	03/04/2020 11:40:50 AM
Reviewed By	Yuhu Zhai, Project Engineer	03/06/2020 08:12:22 AM
Approved By	Robert A. Ellis, Chief Engineer	03/06/2020 08:23:26 AM

National Spherical Torus eXperiment Upgrade

Chit Resolution Report for Bakeout Systems

NSTXU_1-3-3_CRR_101

Prepared By: P. Dugan, Cognizant Engineer

Reviewed By: J. Petrella, Responsible Engineer

Reviewed By: Y. Zhai, NSTX-U Project Engineer

Approved By: Tim Stevenson, Design Review Chair

Record of Changes

Rev.	Date	Description of Changes
0	January 10, 2020	Initial Release
1	January 28, 2020	FDR Chits Addition

Review	Chit Number	Status
Bakeout System FDR	BAKESYSFDR01	Closed
Bakeout System FDR	BAKESYSFDR02	Closed
Bakeout System FDR	BAKESYSFDR03	Closed
Bakeout System FDR	BAKESYSFDR04	Closed
Bakeout System FDR	BAKESYSFDR05	Closed
Bakeout System FDR	BAKESYSFDR06	Closed
Bakeout System FDR	BAKESYSFDR07	Closed
Bakeout System FDR	BAKESYSFDR08	Closed

Bakeout FDR Chits 01-10-2020

Review	ID	Chit
Bakeout System FDR	BAKESYSFDR02	Please look at trying to keep the bakeout thermocouples all going into the category 4 racks. This would apply to some of the cases where there TCs going into the same crate as the PF-1a TCs.

Closed: Based on the FDR there was a mixture of category 3 and category 4 grounding systems as spare slots were used. A new approach was developed to use only category 4 grounding systems. A field walkdown was conducted to ensure that all new thermocouples coming from the HTHS will be terminated using category 4 racks, category 4 cable trays & junction boxes. The HTHS thermocouples will be fed through the X4-U JB TC01 junction box. As part of the design, cross connects will be added to spare mounting locations. Using the cable tray N411 Cat. 4, they will then be terminated at a new cross connect within CTC-EE-418. From there, they will be fed to rack CTC-EE-429 where they will be connected to new cards in the CAMAC. These additional IO cards will be added by CI&C. Drawings are being developed to document this flow.

Review	ID	Chit
Bakeout System FDR	BAKESYSFDR03	Consider using the new insulation system on the piping through the test cell floor penetration to mitigate the need to remove the fire seal from the penetration every bakeout.

Closed: The approach was considered and will be implemented. New insulation on the piping through the test cell floor penetration was considered. Although the initial insulation locations were sufficient to satisfy the requirements, insulation will be added to the work planning package to reduce the transitioning time between bakeout and running the machine.

Review	ID	Chit
Bakeout System FDR	BAKESYSFDR04	Please add the ceramic breaks for the HTP and HTT feeds to the P&ID (EB1025) for the HTHS NTC distribution. This is important because it tells you which ground class these TCs are applied too.

Closed: Drawing EB1025 was updated to include the ceramic breaks for HTP. The HTT has cooling water provided to the tubes is not pertinent to the bakeout system.

Review	ID	Chit

Bakeout System FDR	BAKESYSF DR05	Consider adding/replacing expansion tank pressure sensors with level switches for high/low expansion tank measurements.

Closed: Upon consideration, a liquid level sight glass assembly (23-450 24" made to order or equivalent) will be installed parallel to the expansion tank and combined with a Optical Level Sensor (E2KL26MC1 or equivalent) to detect and signal high/low liquid level alarms for the expansion tank.

Review	ID	Chit
Bakeout System FDR	BAKESYSF DR01	Please add to the FMECA the consideration of what happens if more than one valve on the HTHS manifolds is closed. Consider both pressure issues, and thermal stresses due to the potentially colder area.
Bakeout System FDR	BAKESYSF DR06	Would like to see FMECA for PLC system. Its obvious great care has been taken in the design for safety, redundancy, etc. What are the cost and schedule implications of failures and how do those affect the categorization of the PLC system and its software (SQA). This should be fairly simple to determine and address as it is a legacy system.
Bakeout System FDR	BAKESYSF DR07	We discussed how the check valves in the instrument air prevent a loss of pressure. Please add this to the FMECA so that it is in the documentation

Closed: Added failure mode to the Recovery FEMECA for the case that more than one valve on the HTHS manifolds is closed. The Recovery FEMECA includes many Bakeout failure modes. Within each bakout capability i.e., HHTS, Ohmic Heating , & MTWS PLC FMECAS are included and identified as SBS 1.3.3.4 Bakeout PLC and Control. Added "Check Valve Failure" to the MTWS section of the Recovery FEMECA. FMECA Link

Review	ID	Chit
Bakeout System FDR	BAKESYSF DR08	Investigate using a different/additional method rather than rope tying the eighteen, 777 kcmil cables while in the vertically oriented storage portion of the tray. The tray appears to be solid covered, so it is not obvious how the cables would be effectively supported such that the weight of the cables are not pressing against the tray cover.

Closed: An investigation was done on the cable trays and confirmed that rungs were included on the cable tray. Other methods were considered (eg. unistrut, pipe clamp, rachet, cable tray cover), however it was determined that using the cable tray rungs meets the requirements and is the most cost effective and simplistic method. Ropes will continue to be used as identified during the FDR.

Appendix A Previously Closed Chits

1.03.01.01 HTHS Bakeout System (B100)

HTHS-01 – Flow/Pressure

Review	ID	Chit
NSTX-U Recovery Project – CDR	RPCDR067	Balancing hot-helium gas flows: I think it would be more appropriate to balance the outlet temperatures rather than the flow rates in the different paths. Joe told us that the intended flow meter also measures temperature, so make sure they are in the outlets of the branches, not the inlets (or else both, if you can afford it).

Closed: There are thermocouples as indicated in the P&ID Drawing D-EB1025 added to the solution to more accurately maintain proper bakeout temperature. The supply/return branches will be monitored for flow and each feedthrough will have thermocouples monitoring the supply and return pipe temperatures. These feedthrough pipe thermocouples provide an augmentation to adjust flow measurement.

Review	ID	Chit
NSTX-U Recovery Project – CDR	RPCDR068	When looking at flow rates, or designing the # of throttling valves and flow measurements, please incorporate the need to feed He to the horizontal target heating/cooling features. This will change flow, and may be a degree of freedom for optimization???

Closed: There are currently 6 He feed-throughs to support Bakeout, and two in support of Neutral Beam armor. In support of the HTP interconnections an addition 2 supply and return lines will be added to the overall Helium lines. The flow rates will be adjusted to ensure proper heating and compensated by making field adjustments.

Review	ID	Chit
Bakeout System DVVR	BOHTHS17	It was stated that the pressure drop is predominantly from the in-vessel part of the system and that the 2.5" longer run to the upper diverter against the 3" shorter run to the lower divertor shouldn't affect this flow split. However, the NB helium is also taken from the upper. Please could we investigate this, particularly with respect to the historically lower temperatures on the upper divertor during baking (see early slides). Thanks

Closed: Requirements state only that there be a capability to throttle helium flow to allow for balancing thus flow analysis results were qualitative in nature. The addition of the thermocouples on the supply and return lines and the input from the PFC thermocouples provides localized input on the various thermal parameters across the feedthroughs and PFCs. Based on this input data the throttling valves across the

HTP, Internal helium lines and NB armor allows for individual tuning of the valves to adjust the flow. The HTHS P&ID Drawing EB1025 provides the locations of the thermocouples and valves.

Review	ID	Chit
Bakeout System DVVR	BOHTHS21	From the data record of the He skid outlet and inlet temperatures, it would seem that parts of the tokamak are seeing temperatures up to ~420° C, far above the SAD safety limit (?) and much worse for possible differentials than the range of temperatures seen by the thermocouples in/on the tokamak.

Closed: The maximum bakeout temperatures are identified in the requirements documents. The bakeout design meets these requirements. In addition, Configuration Managed Safeguards are provided to ensure that personnel are not exposed to any thermal hazards.

HTHS-02 - Piping

Review	ID	Chit
Gas Piping PDR	GASPIPING PDR01	Recommend renewing flex connections You can't really inspect the bellows inside the woven cover.

Closed: Flex connections at each helium feedthrough will be replaced during valve installation.

Review	ID	Chit
Gas Piping PDR	GASPIPING PDR02	Copper to pipe should have a contact resistance. It needs to be well fitted to avoid line contact – Maybe use grafoil or fully annealed copper shim interface. Analysis group can provide contact resistance vs pressure.

Closed: Thermocouples are mounted on the pipes with COTS pipe clamps. In order to improve the accuracy of the implementation and maintain contact with the pipes, thermocouples will be installed with thermal paste on the air-side of the helium feedthroughs to decrease contact resistance. Installation is very similar to existing ex-vv thermocouples.

Review	ID	Chit
Gas Piping PDR	GASPIPING PDR03	A recent revision to 10CFR851 requires use of ANSI/ASME B31.3 – 2014, issued 2/27/15. This design must use this revision of the code (compliance is required for all DOE labs by Jan 2019) Engineering Standard MECH-015 will need to ensure compliance

Bakeout System DVVR	BOG10	These two systems include a reasonable amount of custom pipework. Can the team please confirm if these were designed and constructed in accordance with the requirements of a recognised pipework code (particularly for flexibility requirements) e.g. ASME B31.3. If not is there an agreed methodology used at PPPL

Closed: ES-MECH-015 and ASME standards are required to be followed as part of the design. Historical components were designed in accordance with ASME standards at the time of design circa 2001. The new features of the design follows relevant standards through the use of appropriately rated COTS components and, as such, meets these requirements.

Review	ID	Chit
Bakeout System DVVR	BOHTHS20	Add mass flow rates measurements for the lower/upper heating loops. Can the flow rate be actively controlled during the baking? If not perhaps throttle valves or other means should be considered.
Bakeout System DVVR	BOHTHS02	The HTHS gas distribution system is comprised of various sized pipes often run in parallel paths. There are no provisions in the parallel paths for balancing flow. The distribution of thermal energy can not be balanced between flow paths in the present embodiment of the design.

Closed: Manual throttling valves have been incorporated into the design.

Review	ID	Chit
Bakeout System DVVR	BOHTHS05	It was observed that the piping insulation evidenced breakdown of the insulation jacket where insulation is restrained and/or not exposed to ambient air. It is probable that the insulation jacket surface temperature is only under the rated 65° C if it is exposed to ambient air and when it is covered the temperature exceeds the rating of the material. The insulation temperature exposure and ratings should be re-examined.

Closed: Insulation thickness will be increased by 1-1.5 inches throughout the system. For instances where ASJ on adjacent pipes are touching the pipes will be bundled into one insulation assembly and covered with metal protective jacketing.

HTHS-03 – Cutting/Welding

Review	ID	Chit
Helium Feedthrough PDR	HTHSF08	Check NB Armor feedthrough for Helium bakeout stresses

Helium Feedthrough PDR	HTHSF04	Ensure / demonstrate that the weld type and inspection method match the weld strength reduction factor and that the stress evaluation has accounted for this.

Closed: A Helium Feed-Through Thermal Stress calculation was conducted NSTXU_1-3-3-1_CALC_100 that determines that the design of the welds and associated stress at the weld joints are adequate. Additionally, the calculation shows that the neutral beam armor is more robust than the PFC helium feedthrough design.

Review	ID	Chit
Helium Feedthrough PDR	HTHSF01	Consider using a conflat flange in-vessel for connecting to the in-vessel ring manifolds. This allow for the removal of the feed through without cutting/welding.
Helium Feedthrough PDR	HTHSF02	Consider developing a jig/fixture to assist in cutting the existing port flanges off of the machine. Ideally a small tool cutting wheel could be fixed in all DOF except axial rotation and translation so that the only cut could be at the back of the VV flange pipe. This would greatly reduce labor in removing the flange.
Helium Feedthrough PDR	HTHSF07	Please present the system for cutting the existing vessel flanges off at the FDR if possible, otherwise need a separate review on the tool and product
Helium Feedthrough PDR	HTHSF09	The cutting of the flange from the vessel should be tested using the actual equipment to verify the effectiveness, timing, safety, human interface, etc

Closed: These chits are no longer applicable as the current design does not require cutting of the flanges.

HTHS-04 – Materials/Performance

Review	ID	Chit
Helium Feedthrough PDR	HTHSF06	Should use 316 SS as the base assumption. If for some reason, 316 is prohibitive, then 304 can be used. But it should not be the basic assumption.

Closed: Agree with the Chit, SS 316 will be used on any new SS parts.

Review	ID	Chit
Bakeout System DVVR	BOHTHS14	The SDD states that although empirical data shows that the helium system imparts ~2x the heat anticipated by calculation (see S2.4 p 33 of SDD). Please could the design team examine the pipework insulation solution currently employed for 2 reasons; I)this could be a relatively large heat load on the He (particularly towards the end of the ramp when the PFCs are hot), this would be a relatively easy way IMO to improve system performance and possibly accounts for the difference between refs 9 and 10 of the SDD. Note the insulation paradox where in some cases insulation can increase the heat loss from a round pipe upto a certain

		thickness (see for example https://energyeverywhere.wordpress.com/2017/01/19/le-paradoxe-de-lisolation-thermique-thermal-insulation-paradox/ (English translation below each para); ii) as per the issue identified in Fig 19, consider a copper jacket in areas not exposed to ambient air with a fin-type heat transfer calculation to determine the maximum length which can move the heat to an adequate place.

Closed: The required insulation thickness was determined and documented in calculation NSTXU-1-3-3-1-1_CALC-100.

HTHS-05 – Loads/Stresses

Review	ID	Chit
Helium Feedthrough PDR	HTHSF05	The stress on the pipe (11.2 ksi) is close to the allowable (11.3 ksi). It is best to analyze the fatigue stress and determine the component's life.

Closed: This chit is no longer applicable as the design has changed and this concern is no longer part of the design.

Review	ID	Chit
Helium Feedthrough PDR	HTHSF03	Please look into possible EM load on the helium tube to be added to stress calculation

Closed: This chit was addressed as part of the plassive plate FDR. The stresses do indeed exceed yield as noted. We are now qualifying the tubes/pipes for a limited life based on strain levels from an elastic-plastic analysis. Based on the ITER fatigue design curve for 304 ss we can tolerate 0.6% strain for 1000 cycles or 0.32% strain for 10,000 cycles. See analysis report NSTX-U recovery project Structural analysis report for Helium line bracket and Weld Evaluation - NSTXU_1_1_1_2_1_CALC_054

Review	ID	Chit
Bakeout System DVVR	BOHTHS22	Check that B31.1 piping stress calculations are OK at 450C. Also check that stresses due to thermal expansion along pipe length are ok at 450C. Original qualification was for 420C

Closed: The pipe stresses were checked against the original calculation dated and reviewed 12/21/2000 developed by Mike Kalish. It was determined that the results were within the original safety factor.

A copy of a reviewed calculation from 2001 can be found at this link: https://drive.google.com/open?id=1jRq6rdHAy3Q_zzbxfpNcR12iwpmYSCTR

THS-06 – Design

Review	ID	Chit
Bakeout System DVVR	BOHTHS11	The IBD tie-in to the Ex-Vessel helium manifolds is not present in the as-built condition. Drawings for this tie-in also do not exist.

Closed:The helium lines are being included as part of the HTP interconnection scope of work. This involves adding connections to support the upper and lower supply and return lines. This involves conducting standard welding techniques to add these helium connections.

Review	ID	Chit
Bakeout System DVVR	BOHTHS03	Examine and vet blower oil coalescing filter blow-through as part of the FMEA. Specifically examine the blower oil flash point and its relationship to the helium gas temperature.

Closed: This failure mode was added to the Recovery FMECA table.

Review	ID	Chit
Bakeout System DVVR	BOHTHS18	May need insulated breaks in the He tubing to eliminate disruption currents. At least analyze the induced currents, and loads

Closed: As part of the in-vessel design (not in bakeout scope), He Tubing components will be flame sprayed to establish insulted breaks. The effects of including the insulated breaks is included in calculation NSTXU_1_1_1_2_1_CALC_054.

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1.03.01.02 Ex-Vessel Heating System (B105)

EVHS-01 – Pressure/Flow

Review	ID	Chit
Ex-VV Heating System PDR	EXVVHEATP DR01	Recommend installing flow meters on working fluid return path.

Closed: The skid contains flow meters on each return line in order to properly measure the water flow as shown in Drawing D-EB1098.

Review	ID	Chit
Ex-VV Heating System PDR	EXVVHEATP DR04	Add FMEA pressure loss due to failed pipe or appurtenance

Closed:This failure mode and a myriad of others related to MWTS was added to the NSTXU Recover FMECA Table.

Review	ID	Chit
Bakeout System DVVR	BOVVHS02	The as-built design does not conform to critical aspects of the recommended ASHRAE design features such as independent system pressurization and system pressure interlocking. System pressure becomes a critical control and safety element and if it were to drop below the saturated steam pressure the superheated water would rapidly flash to steam and can cause significant water hammer and other energetic phenomenon. The lack of reviewed design revision to the Budzar skid for use as a MTWS system has been identified as a gap.

Closed: The revised MTWS system design meets the pressurization requirements as identified by ASHRAE. In addition, interlocks and configuration managed safeguards have been added to multiple parts of the system protecting the machine and personnel.

EVHS-02 – Failure Modes

Review	ID	Chit

Ex-VV Heating System PDR	EXVVHEATPDR02	With regard to air blow down in the event of a power outage, please consider the ballast of the existing air system and evaluate if a dedicated ballast tank is required.

Closed: Based On an inspection of the as-is environment, the current air system has about +600 gallons of air in ballast tanks. Ex-VVHS requires approximately 30.5 gallons; therefore the revised design will only use a fraction of the reserved air during a power outage.

EVHS-03 – Measuring Temperature

Review	ID	Chit
Bakeout System DVVR	BOVVHS09	If the low temperature water skid is largely retained in its present form, then measurements of the water temperatures at the manifolds should be considered in order to better understand the behavior of the system

Closed: New thermocouples are being added to the MTWS vessel manifolds to capture temperature as part of the system design as shown in Drawing D-EB1098.

EVHS-04 - Safety

Review	ID	Chit
NSTX-U Recovery Project – CDR	RPCDR066	Review the 150C maximum temperature listed as part of the Safety Certificate. Why is 150 C chosen and is it really an operational goal and not safety related? It was stated that the 150C is an average temperature and not a local maximum. If so, this should be stated. If there are concerns about local vessel temperatures above 150C, then this should be stated separately and it should be determined if it is safety or operational.
Bakeout System DVVR	BOR08	The procedure NSTX-OP-G-156 Rev 4 temperature limits conflict with the present Safety Certificate and SAD. The Safety Certificate and SAD have absolute temperature limits of 150° C for the vacuum vessel and 350° C for the PFCs. The procedure lists higher temperature limits up to 190° C for the VV and 360° C for the CSC. The procedure/safety certificate inconsistency is identified as a gap.
Bakeout System DVVR	BOOHS02	The CSC PFCs evidenced temperatures in excess of the 350° C safety certificate limit in the October 2015 bakeout.
NSTX-U Recovery Project – CDR	RPCDR064	Need to assess why there is a 150 limit in the Safety Certificate. What safety issues are we addressing? Having it be a limit is fine, but safety?

Open:The procedure/safety certificate inconsistency has been identified as a gap and a new safety certificate will be issued by the project as part of the commissioning process.

EVHS-05 - Inspection

Review	ID	Chit
NSTX-U Recovery Project – CDR	RPCDR075	When inspecting the inside of the water pipe and / or replacing sections need to consider required corrosion allowances for water. The original Dowtherm skid was designed and built for oil and may not have wall thicknesses required for water.
NSTX-U Recovery Project – CDR	RPCDR082	Should inspect the SS portions of the cooling water system on the VV. There may be sediment from corrosion products in the CS sections that can cause flow restrictions.

Closed: The pipe was inspected and documented in D-NSTX-IP-3946 "Bakeout Hot Water System Corrosion Inspection". The inspection indicated that there is no internal corrosion. Since the water continuously flows during bakeout and is blown out after operations there is limited opportunity for sediment build up. In addition, the inspection indicated no sediment build up.

Bakeout System DVVR	BOG09	Part (b) of section 6.15 of operating procedure asks operators to set the pressure to a minimum of 35psi(g) (2.41bar(g)-3.4bar(a)), this gives a saturation pressure of ~147C, I believe. Please review this instruction in light of the system operating temperature of 150C as I understand 2-phase operation is not desired. There appears to be adequate operating margin to simply review the operating procedure.

Closed: The operating procedure will be updated to reflect new operating points. The new one will have a set point of 150C. Also, "gives a saturation pressure of ~147C" … that's not a pressure value.

Review	ID	Chit
Bakeout System DVVR	BOVVHS11	Regulatory requirements for high pressure gas systems apply presumably to the NSTX-U high temperature pressurized water loop. Such requirements should be identified to ensure compliance with regulations.

Closed: The requirements document RD-15 Bakeout Upgrades contains the following requirements: The system pressure shall be maintained at a minimum of 125% of the vapor pressure of the water at the peak system temperature in accordance with ASHRAE Systems and Equipment Handbook Section 14.1 (2000). The revised design meets this requirement.

Review	ID	Chit
Ex-VV Heating System PDR	EXVVHEA TPDR03	Ensure safety-related valves meet MECH-015 and ASME pressure and flow requirements.

Closed: Valves and hardware are verified to have the appropriate ASME ratings. The revised design meets the requirements.

1.03.01.03 Bake Requirements/Limits (B110)

Bake-01 – Performance/Feedback

Review	ID	Chit
Bakeout System DVVR	BOG02	In-vessel PFC TC's are limited and located in one toroidal area. This limited sampling is not a representative sample of the in-vessel PFC bulk temperature. Determining the quality of the bakeout and adjusting bakeout parameters is compromised by a lack of feedback data.

Closed: This chit is beyond the scope of the bakout system and is relevant to PFC Diagnostics. That being said, the PFC diagnostics have included a myriad of thermocouple locations identified in Drawing 9D11556 for the center stack structures and Drawing ED-1471 for the OBD and by extension passive plates.

Review	ID	Chit
NSTX-U Recovery Project – CDR	RPCDR069	Analyze how the added radiation shield for helping baking will affect heat removal during operation

Closed: This feature was eliminated from the revised design.

Review	ID	Chit
Bakeout System DVVR	BOHTHS09	Operational experience has evidenced that the blower oil reservoir and oil level sensor does not function properly during operation. A false low-oil signal is activated shortly after turning the blower on. This false signal blinds the system to a real low-oil condition and as such needs correction. The blower oil reservoir size and oil level sensing design has been identified as a gap.

Closed: The existing blower will be replaced as part of M&RP (out of scope for bakeout systems recovery scope) and the oil sensor will require re-fitment as part of this work. The re-fitment of the oil sensor is anticipated to resolve this issue.

Bake - Design/Maintenance

Review	ID	Chit
Bakeout System DVVR	BOHTHS13	Perform known needed repairs on system components such as the helium/HVAC chiller water heat exchanger leak and blower replacement.

Closed: The FDR addresses modification based on gaps identified in the current design to include flow meters, remote control, and additional accuracy in temperature measurement. Routine maintenance and repair will be addressed under M&RP work scope and is out of scope for bakeout systems recovery.

Review	ID	Chit
Bakeout System DVVR	BOR04	A design specifying the holistic bakeout system cooling method/capacity/process for NSTX-U has not been performed to date.

Closed: A global heat balance calculation NSTX U-CALC-10-06-00 was performed to holistically assess bakeout performance.

Bake-03 - Temperature

Review	ID	Chit
NSTX-U Recovery Project – CDR	RPCDR065	Consider using average and local peak temperature limits for external vacuum vessel during bakeout

Closed: The requirements documents have been updated and provided a method of using average temperatures per region. In addition, the requirements define localized maximum temperatures.

Review	ID	Chit
Bakeout System DVVR	BOG17	EITHER (1) Analyze the heat flows well enough that the heating and cooling capability matches the components well enough that thermal gradients are minimized OR (2) Provide a way to balance the heating and cooling capability to match the components heat flows well enough that thermal gradients are minimized

Closed: Currently, Bakeout only considers heating and protection from the heat sensitive components.i.e, magnets via insulation and active cooling. A global heat balance calculation NSTX U-CALC-10-06-00 was performed to ensure the proper heating of the tiles. To allow more accuracy, additional thermocouples have been added as part of PFC diagnostics and Bakeout systems to better regulate the temperature in various areas.

Bake--04 – Scope/Requirements

Review	ID	Chit
Bakeout System DVVR	BOR09	Neutral Beam armor is not listed in the NSTX-CSU-RQMT-GRD as requiring bakeout.

Closed: The requirement is in paragraph 6.1.1.2.3.2.c for the GRD.

Review	ID	Chit
Bakeout System DVVR	BOR01	The requirements document prescribes a bakeout target temperature of 350C and 150C for the PFCs and VV respectively. There is no tolerance/bandwidth expressed or implied. The SAD/Safety certificate state a maximum of 350C and 150C for the PFCs and VV respectively. Empirical data, operational experience, and theoretical heat transfer dynamics indicate that the PFCs and VV cannot be temperature regulated en-mass at the same exact temperature. The GRD and SAD/Safety certificate requirements are mutually exclusive in practice. The GRD and SAD/Safety certificate temperature values should be numerically different and conditionally described with a practical bandwidth.
Bakeout System DVVR	BOHTHS06	The HTHS (coupled with the other two bakeout subsystems) does not presently meet the 1998 GRD requirements of achieving 350°C PFC bulk temperature in 48hrs. The previous statement presumes that the GRD's intention is that all PFCs reach 350°C with an undefined measure of uniformity.
Bakeout System DVVR	BOOHS01	The October 2015 NSTX-U bakeout evidenced that monitored OHS-heated PFC temperatures ranged from 296° C to 383° C after 13 days of heating (IBD flange omitted). It is presumed that the GRD's intention is for all PFCs to reach 350°C with an undefined measure of uniformity. Correspondingly, the OHS (coupled with the other two bakeout subsystems) does not meet the 1998 GRD thermal requirements of achieving 350°C PFC surface temperature.

Closed: The PFC SRD-003 recognizes that some tiles will be greater than 350 by ten's of degrees to allow for a range versus an exact number. The Bakeout SRD-005 for the vessel provides a range of >115 deg C and < 160 deg C. Similarly, the new requirements for the PFC talk to an average temperature per region shall not exceed 350 deg C.

Review	ID	Chit
Bakeout System DVVR	BOR03	The 2012 GRD does not specify a cooling requirement for the bakeout system. Earlier NSTX requirements specify a cooling requirement but this has not been updated for NSTX-U.
Bakeout System DVVR	BOR10	Consider either i) upgrading the GRD or ii) issuing a revision to the legacy SRD, to bring the requirements up to date with the present situation.

Closed: The GRD and SRD have been updated and aligned to the Bakeout requirements. In addition, there is a specific Bakeout RD to provide the appropriate level of requirement detail.

Bake-05 - Analysis

Review	ID	Chit
Bakeout System DVVR	BOR02	A holistic bakeout system thermal analysis defining the overall heating and cooling requirements of the bakeout system has not been performed for NSTX-U.
Bakeout System DVVR	BOR07	To date there have been no additional documents or calculations discovered that explicitly defines the heating/cooling energy requirements of the VV wall during bakeout or plasma operations. Operational experience and data has shown that bakeout requires heating of the VV wall to maintain the GRD requirement of 150° C VV wall temperature which conflicts with the original design conclusions. Updating the design basis calculations for the NSTX-U exVVHS has been identified as a gap.

Closed: Bake out has a Thermal Analysis Requirements that defines the Bakeout scenarios to model. This led to a global heat balance calculation NSTX U-CALC-10-06-00 which identifies the heat distribution across the vessel and center stack for 7MA and 8MA scenarios.

Review	ID	Chit
Bakeout System DVVR	BOHTHS07	Observed performance in the 2015 NSTX-U bakeout data indicates that there is inadequate system mass flow for the HTHS to bring all the PFCs simultaneously to the design point temperature of 350° C in 48 hours, and/or over an extended period.

Closed: Flow Meters and the ability to control the HTHS throttling valves allows for manual adjustment of the helium flow into the manifolds.

Bake-06 - Thermocouples

Review	ID	Chit
Bakeout System DVVR	BOG14	Thermocouples have historically been unreliable for various reasons. We should analyze the failures and make systematic improvements to the system so that we have high confidence in our temperature measurements during bakeout.

Closed: More sensors are being added so data that is inconsistent can be detected and after a test run the components inspected, troubleshot and replaced, if necessary.

Review	ID	Chit
Bakeout System DVVR	BOG15	Make a plan to test, calibrate, and possibly replace the thermocouples during the installation process. (e.g. have a second calibrated thermocouple temporarily installed next to the installed thermocouple and use a heat gun to check that the responses track adequately well)

Closed: As part of the pre-operational test procedures, the thermocouples will be measured and calibrated to ensure proper operation based on known temperatures. In addition prior to the PTP thermocouples will be acceptance tested to ensure that they are operation prior to installation.

Review	ID	Chit
Bakeout System DVVR	BOG12	Reconsider both quantity and distribution of VV thermocouples in keeping with desired readings, hot spots, temperature differentials, and accuracy of taking a bulk average reading during operations.
Bakeout System DVVR	BOHTHS19	Consider installing temperature measurements on the individual manifolds inputs and outputs in the test cell.

Closed: Thermocouples have been added to each of the Helium Supply and Return lines and the Water Heating system.

1.03.01.05 DC Bakeout to NSTX-U Top (B120)

DCBake-01 – Cabling/Accessibility

Review	ID	Chit
Bakeout DC Connection PDR	BAKEDCCONPDR05	Verify spacing of cables in permanent trays. If less than one diameter spacing between cables will have to derate cables to 75% as per Article 392 of the NEC.

Closed: Cables are spaced with an air gap as shown in Drawing EB1092.

Review	ID	Chit
Bakeout DC Connection PDR	BAKEDCCONPDR04	lease assess how the situation would be handled if people needed to stand or lay on the trays on the 118' platform, for some rare maintenance activity. Can a temporary platform be easily installed, or does some provision need to be made at this time to facilitate this.

Closed: The new design to store cables is specifically designed to allow access to the trays without needing to step on them. Any other requirement to perform maintenance or access trays is beyond the scope of the bakeout bus bar interconnection.

DCBake-02 - Grounding

Review	ID	Chit
Bakeout DC Connection PDR	BAKEDCCONPDR07	Need to understand the circuit behavior of the ground paths introduced by the bakeout connections and factor this into the grounding scheme.
Bakeout DC Connection PDR	BAKEDCCONPDR01	The DVVR chit BOOHS5 (Issue BO3-7) concerning the purpose of the 500MCM ground cable on the outer VV needs further investigation. If the cable is retained, since it will not carry significant current under normal conditions, a current sensor should be used to trip the power supply under abnormal conditions rather than increasing the ampacity.

Closed: The recovery design bonds the center stack casing to the vacuum vessel via the lower Bakeout Bus Bar. This removes the need for separate and distinct Ground category 3 and Ground category 4 during bakeout and negates the potential for unusual ground paths such as through the 500MCM ground cable.

Review	ID	Chit
Bakeout System DVVR	BOOHS05	Multiple ground paths are evidenced in the present design. A 500 MCM ground cable is connected to the VV ahead of the DC (−) terminal of the IPS-FEST power supplies (Figure 27). This connects category 4 ground to category 1 ground, as well as establishes the zero potential location away from the IPS-FEST power supplies. In addition, the exVVHS piping is not electrically isolated during bakeout, providing another category 4 to category 1 ground bond. The ramifications of multiple ground loops during bakeout should be studied further even with the low voltages present due to the significant current available in the current flow path

Closed: The design and depiction of ground paths are identified in Figure 1. The DC Power Supply Floats in reference to building steel (center of the earth). As the results of Figure 2, show that VV Equipment Ground is has 2 Orders of magnitude less resistance than connected pipes in the event of a catastrophic fault.

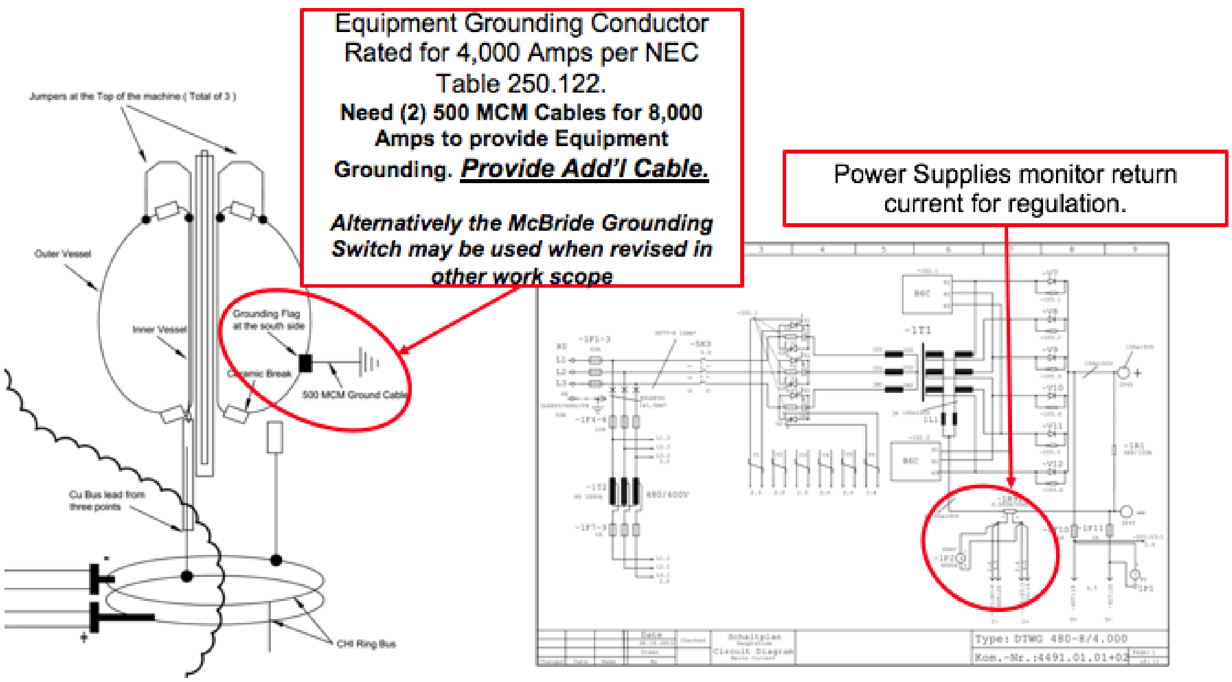

Figure 1. Grounding Cables and Power Supply Monitor

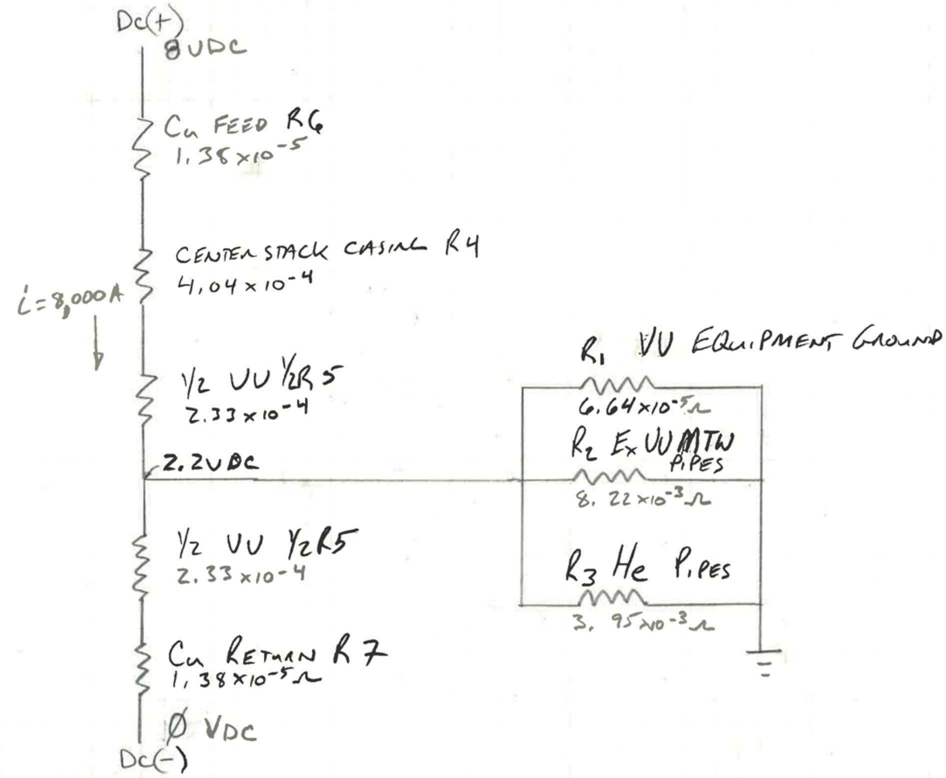

Figure 2. Resistance Hand Calculation

DCBake-03 – Water Leakage

Review	ID	Chit
Bakeout DC Connection PDR	BAKEDCCONPDR08	WRT water leak failure consider mitigation like a tray or other containment to avoid collateral damage and impacts including sensing and annunciation

Closed: Power Supplies will sit in a drip pan with a drain to a NTC sump pump as shown in Drawing EB1092.

DCBake-04 – Forces/Stresses

Review	ID	Chit
Bakeout DC Connection PDR	BAKEDCCONPDR02	Evaluate magnetic force on ferromagnetic material (transformer) in the power supply cabinet and confirm that it is not an issue for platform mounting.

Closed: The DC power supplies will be mounted on the wooden platform outside the 50 gauss field lines of the machine and will not be moved by the limited magnetic field in that area.

Review	ID	Chit
Bakeout DC Connection PDR	BAKEDCCO NPDR03	Evaluate the platform loads from the power supplies with regard to seismic requirements including bolting arrangements to supports.

Open: An initial analysis was produced in an unsigned calculation regarding the loading on the platform due to the addition of both DC power supplies. The analysis showed that the platform as currently design is inadequate as identified in NSTXU_1-8-1-1-1_CALC_100 for the dead load. NSTXU_1-8-1-1-1_CALC_102 covers the seismic analysis.

DCBake-05 - Performance

Review	ID	Chit
Bakeout DC Connection PDR	BAKEDCCO NPDR06	WRT FMEA consider risk to KPP and future ops where Bakeout delays the program and consider including responses to ensure minimal impact (e.g. spare PS, spare parts, etc.)

Closed: A recovery FMEA has been developed whereby the nearly all Bakeout hardware components Helium, and water in addition to DC power consider the loss of a component specifically the loss of one of the two power supplies. As part of the evaluation criteria schedule and cost are considered.