Chit Resolution Report for the PFC Diagnostics

Chit resolution report: NSTXU_1-4-1_CRR_chit_100

REVISION 1

October 9, 2019

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PFC Diagnostics Chit Resolution Report

Chit resolution report: NSTXU_1_4_1_CRR_chit_059

REVISION 0

May 29, 2019

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National Spherical Torus eXperiment Upgrade

Chit Resolution Report for *PFC Diagnostics*

NSTX-U-REC-173-01

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Record of Changes

Rev.	Date	Description of Changes
0	3/28/2018	Initial Release
1	5/3/2019	FDR Chits Updated

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PFC Diagnostics FDR

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CR-*DIAG*-01 – *Ip Rogowski*

Review	ID	Chit
Diagnostics DVVR	DIAGMAG01	Consider if new Ip Rogowskis need to be fabricated. Note that i) these have a strong space constraint, so cannot let them grow if fabricated again, and ii) the loss of Rogowskis would have a profound impact, so we cannot reinstall the old ones if we have any nervousness.
Diagnostics DVVR	DIAGMAG12	Try to determine how much of the damage was due to initial, poor fit. How much was due to fit after Microtherm was removed.
Diagnostics DVVR	DIAGMAG15	Rogowski coils are critical but may fail as evidenced by damage that occurred during installation. Should an alternative Ip measurement be considered as a back-up? A poloidal array of Mirnov coils like JET?
Diagnostics DVVR	DIAGMAG17	Is the plasma current Rogowski segmented? If not consider segmenting it so that if it fails, a workaround for the faulty section can be implemented
Diagnostics DVVR	DIAGMAG18	Consider use of fiber-optic measurement of Ip, to supplement the Rogowski measurements.
Diagnostics DVVR	DIAGMAG19	Consider adding FRP guard rails adjacent to centerstack Rogowski coils to protect Rogowskis during assembly

The damage to Ip Rogowskis was due to inadequate clearance between the CS bundle and CSC. Relocation, toroidally, of these coils, along with the new CS casing design, has solved this problem. We decided to make new Rogowskis rather than re-use the old, damaged ones.

CR-*DIAG*-02 – *Ip Rogowski Coil Design*

Review	ID	Chit
PFC Diagnostic PDR	PFCDIAG011	Regarding rogowski coil design: the use of the copper electrostatic sheath is reminiscent of the copper cooling line and may have exacerbated the EM motion thought to cause damage. The design of the rogowski should be reviewed as to whether the copper can be changed to a different material to improve reliability.

This chit pertains to the center stack halo current Rogowski coils. We have changed the copper electrostatic shield to stainless steel. Additionally, the stainless steel shield has slits which will further reduce the electromagnetic forces.

CR-*DIAG*-03 – *HALO Rogowski*

Review	ID	Chit
Diagnostics DVVR	DIAGMAG07	Five out of six of the center stack casing (CSC) rogowskis for halo current measurements failed during installation before the FY16 campaign. Design issue with the leads?

Inspection of the center stack halo current Rogowski coils revealed that the failure was in the coils themselves. Redesign of the coils has eliminated the causes of failure that we identified.

CR-*DIAG*-04 - *Design*

Review	ID	Chit
Diagnostics DVVR	DIAGGen15	It is likely that significant changes will be made to the vacuum vessel, tiles, CSC, etc. as a result of the corrective action plan. The impact of these changes need to be assessed, with appropriate design review for diagnostics that are affected and/or redesigned -- magnetics obviously having a high priority. SDDs must be written/upgraded to reflect these changes. Changes made to diagnostics to accommodate the corrective action plan should be summarized in a separate document -- and presented as part of the corrective action plan.

The PFC diagnostics portion of this chit is covered at the PFC diagnostics FDR. Designs have been updated to accommodate changed PFCs.

CR-*DIAG*-05 – *Stainless Steel*

Review	ID	Chit
Diagnostics DVVR	DIAGGen 25	The standards for S/S 304 have drifted w/r to permeability, and components should be progressively replaced by 316 components, especially shutters which may fail.

We will use 316 instead of 304. Note that this chit applies much more to components such as shutters, and while the portion that pertains to the PFC diagnostics will be satisfied by the design, the chit should remain open until the shutters and other items are addressed.

CR-*DIAG*-06 – *High Temperature Testing*

Review	ID	Chit
Project PDR	PROJPDR29	In vessel rogowskies cables should be tested at high temperatures

The in-vessel Rogowski coils were inspected. The problems were identified, redesigned and corrected; therefore, testing is not required.

CR-*DIAG*-07 – *Potential Sensor Replacement*

Review	ID	Chit
Diagnostics DVVR	DIAGMAG16	The rate of failure for magnetic sensors needs to assessed to determine if sensors should be replaced and/or additional spares should be installed during this outage. Many of these sensors are not accessible without a significant teardown of in vessel components. Therefore, the sensor set must project into the future with sufficient reliability to allow for (potentially) years of operation without hands-on maintenance.

We are implementing what is specified in the requirements document.

CR-*DIAG*-08 – *Sensor Failure*

Review	ID	Chit
Diagnostics DVVR	DIAGMAG16	The rate of failure for magnetic sensors needs to assessed to determine if sensors should be replaced and/or additional spares should be installed during this outage. Many of these sensors are not accessible without a significant teardown of in vessel components. Therefore, the sensor set must project into the future with sufficient reliability to allow for (potentially) years of operation without hands-on maintenance.
Diagnostics DVVR	DIAGMag14	The recent bakeout temperature was not as high as for future operation. Try to determine the cause of failure of the wiring of failed sensors during the shutdown to determine the failure mode to provide an expectation for survival in future.
PFC Diagnostic PDR	PFCDIAG003	Consider failure testing PFC embedded diagnostics in an autoclave to confirm max safe temperature. (Especially mirnovs).

Failure of the sensors was primarily due to failures in the wiring. Minimizing the number of in-vessel splices, smoothing sharp corners and burrs on the wire passages, and laying the wires into the passages rather than pulling them will minimize the failure rate.

CR-*DIAG*-09 - *Design*

Review	ID	Chit
Diagnostics DVVR	DIAGGen1 5	It is likely that significant changes will be made to the vacuum vessel, tiles, CSC, etc. as a result of the corrective action plan. The impact of these changes need to be assessed, with appropriate design review for diagnostics that are affected and/or redesigned -- magnetics obviously having a high priority. SDDs must be written/upgraded to reflect these changes. Changes made to diagnostics to accommodate the corrective action plan should be summarized in a separate document -- and presented as part of the corrective action plan.

The PFC diagnostics portion of this chit is covered at the PFC diagnostics FDR. Designs have been updated to accommodate changed PFCs.

CR-*DIAG*-10 – Wiring Installation and Routing

Review	ID	Chit
PFC Diagnostic PDR	PFCDIAG013	Installation/wire routing on the CS Casing may require new or different techniques than those used during the 2014 assembly, e.g., splicing Q Glass insulated twisted pairs. Identify if new techniques are necessary, and prototype as needed.

No new techniques are required.

CR-*DIAG*-11 – RF-Cable probes Special Cabling

Review	ID	Chit
PFC Diagnostic PDR	PFCDIAG005	RF-capable probes may require special cabling (e.g. coaxial, either flex or hard) which impacts required cutouts for tile/structural routing. The Requirements Document (physics) should be refined to indicate if special cabling is required.

Updates to in-vessel cabling made necessary by new plasma facing components and the new requirements document are addressed in this design. The center stack and outboard divertor cabling have been revised as part of the PFC diagnostics design effort.

CR-*DIAG*-12 – *Thermocouple Calibration*

Review	ID	Chit
PFC Diagnostic PDR	PFCDIAG012	Slide 12/d (first presentation) – Are the thermocouples calibrated to ensure they are giving accurate numbers? Will they be checked periodically to ensure there is no degradation? Calibration should cover the full range of temperatures needed to be measured. (operating temperature through bakeout temperatures if they are used to measure bakeout)

We rely on the manufacturer to calibrate the thermocouples because they can do it more accurately than we can. We can check the thermocouple assemblies in the tiles with a heated plate applied to the front surface before installation and possibly during a machine outage. I do not see gradual deterioration of the thermocouples as an issue given the non-corrosive environment. During operation and bakeout, the thermocouples can be cross checked with IR diagnostics.

CR-*DIAG*-13 – *Thermocouples Grounding Plan*

Review	ID	Chit
PFC Diagnostic PDR	PFCDIAG008	Need to develop the grounding plan for the TCs to be compatible with the requirements of Diagnostics Ops and Bakeout.

We have developed a new thermocouple assembly that can maintain electrical isolation up to 500V as per the requirements document, and verified by megger and hi-pot tests on prototypes.

CR-*DIAG*-14 – *Thermocouples Design Down Select*

Review	ID	Chit
PFC Diagnostic PDR	PFCDIAG007	Will need Peer review to down-select thermocouple design.

The (new) requirement for additional voltage standoff of the thermocouples ruled out all but one of our design options. No down-selection was required.

CR-*DIAG*-15 – *Thermocouple Installation*

Review	ID	Chit
Project PDR	PROJPDR25	We discussed the possibility of making the ends of the thermocouple accommodation drillings smoothly rounded so as to allow them to be drilled nearer to the heated surface of the castellation without introducing too much stress concentration in the graphite. Bob said he wanted to have good thermal contact by pushing a flat-ended BN sheath against a conical end of the drilling, but I'd go with better time response and a different shape or material (Grafoil?) for the sheath end to recover decent thermal contact (without raising stresses in the graphite significantly!). Stefan noted that deeper drillings would also separate the heat loads on the individual castellations better for local dynamic calorimetry. (Grafoil inside the BN sheath tip as well?)

The geometry of the thermocouple assemblies and tiles [particularly the high heat flux tiles referred to in this chit] was addressed at the PFC FDR. The diameter and distance from the plasma face of the thermocouple hole in the tile was defined, and finite element analyses were used to optimize the design, and define the permissible distance of the thermocouple from the plasma face of the tile. A 5/32" diameter hole, flat bottomed, with a rounded edge was selected. These features are incorporated into the PFC drawings.

CR-*DIAG*-16 – Vacuum

Review	ID	Chit
PFC Diagnostic PDR	PFCDIAG010	Review all in vessel materials against vacuum material list or get approval from Bill Blanchard/ Vacuum Materials committee.

With the exception of the new core for the center stack halo current Rogowski coils, all materials to be used have been approved previously. The material proposed for the halo current Rogowski coils has undergone a successful outgassing test at PPPL.

CR-*DIAG*-17 – *Langmuir Probes*

Review	ID	Chit
PFC Diagnostic PDR	PFCDIAG009	Requirements Document indicates 4 Langmuir probes in IBDH length (1 per castellation cut). Current model indicates only 3. Please investigate feasibility of 4th probe tip to meet requirements.

We now have 4. The requirements document and the tile drawings agree.

CR-*DIAG*-18 - *Drawings*

Review	ID	Chit
Diagnostics DVVR	DIAGGen21	Multiple diagnostics have missing drawings – some trivial, some not. Suggest a policy, with sign-off at appropriate gateways, that all new installations into test cell (other areas too?) must have full set of drawings in the central CAD database.

The PFC diagnostics portion of this is covered by this FDR. Drawings of PFC diagnostic assemblies will be available at FDR. The last sentence of this chit is presumably answered by some parts of our QAPD.

CR-*DIAG*-19 – *Additional Passive Plate Thermocouples*

Review	ID	Chit
PFCs Diagnostics FDR	PFCDIAGFDR01	Please consider including review of additional / new thermal couples added onto the passive plate into the passive plate FDR

This chit is beyond the scope of the PFC diagnostics. The addition of thermocouples into the existing is entirely feasible using the current thermocouple design once the scope is added. A suitable forum to address the scope is the passive plate FDR.

CR-*DIAG*-20 – *Mirnov Coil Tabs*

Review	ID	Chit
PFCs Diagnostics FDR	PFCDIAGFDR02	On the Mirnov coils, The tabs on the stainless steel? shield that look like they are supposed to wrap around the corner look too short and look like they could cut into the winding

The prototype presented at the FDR were hand cut and not completely representative of the final design. The drawings and final design address this concern.

CR-*DIAG*-21 – *Mirnov Shielding Material*

Review	ID	Chit
PFCs Diagnostics FDR	PFCDIAGFDR03	Early NSTX Mirnovs without Cu e-shields were susceptible to both noise spikes (probably "electrostatic") and premature sensor failure caused by disruptions. The copper e-shields on the Mirnovs alleviated both problems. I am concerned that the change from Cu to SS e-shield will reduce impulse shielding during disruptions and make it more likely sensors will fail - especially since the disruption currents into tiles will increase at higher Ip. Recommend retaining Cu shields that are shown to work or using thicker SS to match the skin-depth of the Cu sheeting used in the past.

The design has been updated to use a copper alloy.

CR-*DIAG*-22 – *Drawing Cross Reference*

Review	ID	Chit
PFCs Diagnostics FDR	PFCDIAGFDR04	The wire diagram will be the configuration control for all diagnostic locations and counts. There are other documents that also show tile variants and quantities (outboard divertor assemblies, CS assemblies). If there is a disconnect between any documents with tile variants and quantities, the wire diagram is the trumping drawing and all others should be updated to match. There should also be a process in place that will make sure, if the wire diagram is changed, all other documents are changed also.

Cross references have been provided from the Center Stack Wiring Diagram (9D11996) to the assembly drawing (ED1445), Additionally, the OBD Wiring Diagram (9D1471) provides cross references to the OBD Assembly (ED1384)

CR-*DIAG*-23 – *Phantom Model*

Review	ID	Chit
PFCs Diagnostics FDR	PFCDIAGFDR05	Is there a phantom assembly that includes all the PFC diagnostics. The schematic offered for wire routing needs to be translated into a phantom model and the BOM generated from that.

The cost of changing the design to include addition the diagnostic and associated wiring added as a phantom model was considered. However, the cost associated with addition this level of fidelity at this time was considered too great.

CR-*DIAG*-24 – *Sensor vs Private Flux Region Gas Injector*

Review	ID	Chit
PFCs Diagnostics FDR	PFCDIAGFDR06	Please resolve the inconsistency of the 15 degree toroidal interval or 155 degree (lower part) for the private flux region injector on the Wire Routing Diagram. This should be resolved before the final design approval and the Private flux loop Design Review.

The inconsistency has been resolved in a modification to RD-014 NSTX-U Gas Delivery and Injection System Parameters. The correct location was used in the Private Flux Region Preliminary Design Review.

CR-*DIAG*-25 – *Calculation Signatures*

Review	ID	Chit
PFCs Diagnostics FDR	PFCDIAGFDR07	Ensure that Calculation with updated calc number, is finalized - signed using both Calc & Check form (ENG-033 Attachments 2 & 3), and is filed in the NSTX-U Calculation Log.

The calculation has been signed and added to the document management system.