PRINCETON PLASMA PHYSICS LABORATORY

ENG-033 - CRR - CHIT RESOLUTION REPORT

NSTX-U Project Chit Resolution Report

NSTXU_1_CRR_101

Work Planning #:
Effective Date: **03/06/2020**
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Chit Resolution Report for Project Level Chits

NSTXU_1_CRR_101 R0

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Record of Changes

Rev.	Date	Description of Changes
0	2/10/2020	Initial release
1	3/2/2020	FDR Chits

Review	Chit Number	Status		Review	Chit Number	Status
Project PDR	PROJPDR05	Closed		Project CDR	RPCDR041	Closed
Project PDR	PROJPDR10	Closed		Project CDR	RPCDR051	Closed
Project PDR	PROJPDR24	Closed		Project CDR	RPCDR064	Closed
Project PDR	PROJPDR27	Closed		Project CDR	RPCDR066	Closed
Project PDR	PROJPDR31	Closed		Project CDR	RPCDR072	Closed
Project PDR	PROJPDR32	Closed		Project CDR	RPCDR080	Closed
Project CDR	RPCDR034	Closed		Project CDR	RPCDR083	Closed
Project CDR	RPCDR038	Closed		Project CDR	RPCDR088	Closed

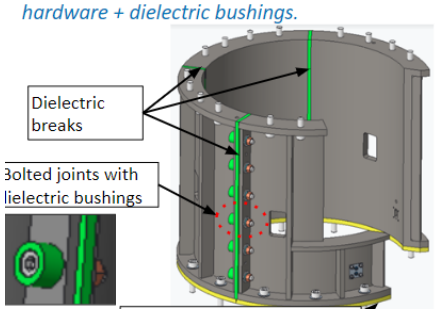
ject PDR

Review	ID	Chit
Project PDR	PROJPDR05	A brief discussion of the gravity support skirt immediately underneath PF1AL suggested that the four (?) sections it comprises do not include any insulating shims and insulating bolts to prevent this component from carrying toroidal current. If true, please analyse the effect on the poloidal fields, required PF1BL current, EM loads etc.. Or just insulate it, as I think the new system design requirements "require"!

Closed: The new outer skirt has insulating shims. These can be seen in the slides for the MCS FDR.

See presentation “MCS Design 08052019.pptx” located here: https://drive.google.com/drive/folders/1qtawZHvqWGovp4zVSvaatfZPon4R_kht

The Outer Skirt is a 4 part weldment made from In625 with G7 dielectric breaks between each section. The sections are bolted together with hardware + dielectric bushings.



Review	ID	Chit
Project PDR	PROJPDR10	TF debonding on inner surfaces: Consider using cohesive zone modeling (CZM) in ANSYS to show propagation or stoppage of delamination/ failing elements over cycles.

Closed: Cohesive Zone Modeling (CZM) was studied but not selected for the final calculations of record. The virtual crack closure technique (VCCT) was used instead with Paris constants measured in PPPL's material test Lab. The simulations may be found in:

"TF Insulation Delamination Growth Rate" NSTXU-CALC-132-19-00 by A. Brooks

The relation of fracture simulation to the global delamination simulation is discussed in the EKILL Calculation No: NSTXU_1-1-3-3-1_CALC-102

This method/conclusion was reviewed and accepted at the inner-TF review in August 2019.

Review	ID	Chit
Project PDR	PROJPDR24	It appears that currently there is no intention to systematically incorporate the results of metrology into revisions of the CAD configuration model, because it is not considered to be within the scope of the present project. This thinking dogged JET for many years and resulted in many examples of new equipment being impossible to fit without significant reworking after planned installation jobs failed. I recommend that the configuration files are updated in the light of metrology "as soon as resources permit" and definitely before any new equipment has to be fabricated which has mechanical interfaces with the tokamak load assembly or anything in the hot cell area.

Closed: The Project lacks the resources for an abstract activity of making the CAD model match metrology; this is an open-ended task. However, engineers and CAD work to understand the as-built condition through the following steps: incorporation of metrology in the design as needed (for instance, on the vacuum vessel main flange hole drilling), and fabrication of mockup components (for instance, mock-ups of the PF-⅘ clamps, mockups of the passive plate brackets, etc).

Review	ID	Chit
Project PDR	PROJPDR27	Consider developing and using a mega-traveller for machine assembly to assure that steps are not missed

Closed: The concept of a mega-traveller was used in the fabrication of the PF-1A Prototype coil. Although burdensome, that concept showed merit, ensuring that components were ready for integration into the coil. In order to minimize the impact across the program, a mega-traveller pilot will be implemented across a small portion of upcoming project work. Feedback from the pilot, will be considered into the final decision and format that may be implemented across the re-assembly process.

Review	ID	Chit
Project PDR	PROJPDR31	Consider adding a formal "issues expediter" to the WCC...somebody with a technical background to help Frank and Steve run things to ground through the full engineering system.

Closed: There is a major activity of the Project Team to identify all individuals required for the construction phase of the Project. The project has already hired a work planning and control expert, and an individual with experience in outage-planning for nuclear power plant outages. It has also hired a number of procedure writers. Additional schedulers are being interviewed. Overall, the

project is responding to issues of efficiency on a front much broader than simply hiring an expediter.

Review	ID	Chit
Project PDR	PROJPDR32	There is a general high level plan that engineers doing detail design will transition into assembly related tasks, such as installation oversight, procedure writing, field metrology measurements, tooling and lifting fixtures, etc. However, there is a risk that these design oriented tasks continue longer than expected, and the design engineers will not be available in time. (Design engineers may become involved in procurement oversight, Title III, etc.). Consider developing more detailed staffing requirements for tasks like tooling design, metrology engineers, etc, which can be integrated into the project level resource loaded schedule. This will identify a "drop dead date" by which these assembly support tasks need to start before becoming the critical path.

Closed: The project is presently making a major effort to identify Title-III design support. This includes analysts and CAD resources to address ECNs, QC people for incoming parts inspection and control, and on-the-floor safety professionals. PPPL has a Basic Ordering Agreement (BOA) with a metrology subcontractor who can provide a variety of modern metrology services (CMMs, laser scanner, photogrammetry, etc). These are all being folded into the Title-III staffing plan, as suggested by the chit.

Review	ID	Chit
Project CDR	RPCDR38	There are reliability concerns about using the helium bakeout system during normal operations to provide "room temperature" helium for cooling purposes. A stand alone system has been proposed for the IBD-H cooling helium, but if additional cooling power circulating through the Passive Plates or Outboard Divertor is necessary, it could be problematic. The IBD-H helium and IBD-V (air side) water cooling removes approximately 70% of the heat content per shot. Need to assess, as an integrated system, whether additional cooling is necessary, or passive mechanisms like convection to the test cell air are sufficient to avoid unacceptable thermal ratcheting of the entire machine throughout the day. If additional cooling is necessary, assess the pros/cons of using the helium bakeout system vs some alternative like water through the air side tubes welded on the outside of the vessel.

Closed: The thermal simulations done for the full-power all-day operations assume that there is water on the vertical divertor targets (the heat transfer tube, or HTT), and gaseous helium cooling on the inner horizontal targets. There is no helium used for cooling the passive plates or outboard divertor. The vessel and outboard divertors are cooled by radiation (and convection in the case of the vessel). These simulation show acceptable machine performance, and are used as the thermal inputs to various structural qualifications (bus work, bellows, etc); see NSTXU_1-3-3_CALC, which was formerly NSTXU-CALC-10-6-02.

This mode of operations, with full power on every shot, would be uncommon, and so would not present a large additional burden on the existing He system. Additionally, with the limited He cooling assumed, the blower may not need to operate at full parameters.

Hence, the project position is to NOT invest in an additional He cooling system at the present time.

Review	ID	Chit
Project CDR	RPCDR83	The PFC Halo current force needs to be calculated and verified by the worst case of 96 scenarios in the background magnetic fields of global model.

Closed: The PFC Halo Current for es have been calculated (in NSTXU-CALC-11-08-00, "PFC Tiles Eddy and Halo Forces") using the worse case background fields calculated in NSTXU-CALC-55-03-00, "PFCs Fields and dBdts". That calculation scanned all 96 scenarios for the highest field components at each PFC location. The halo currents used were specified in NSTX-U-RQMT-RD-003-01, "NSTX-U Disruption Analysis Requirements", Stefan, Gerhardt, 2018.

Review	ID	Chit
Project CDR	RPCDR88	For the TF coil outer leg, a strain measurement on the surface is intended to monitor the possible risk of internal de-bonding. But how large is actually the effect of complete internal de-bonding on the bending stiffness? Corresponding to a 10%, 50% or 80% stiffness reduction? Is the measurement capable of detecting critical damage in an early stage? Proposal: Modelling of as-built vs. (not yet critically) degraded coil under operational load and verify resulting surface strain at sensor location is well in a range detectable by envisaged hardware.

Closed: The TF coil outer leg is made up of three turns bonded together. Each is 2 by 3 inches in cross section.
Fully bonded the leg acts as a beam with a section modulus of 3*6^2/6. =18 in^3 If the three turns debond then the leg acts like 3 separate beams, each with section moduli of 3*2^2/6=2

When the leg debonds, the stress will increase by a factor of 18/3/2 = 3. Partial debonding will produce smaller changes but these will easily be detected by the planned fiber bragg grating strain gauges which can discriminate small percentages in the trending data. A "standard" combination PF and TF shot without plasma will be used to assess all the instrumentation measuring out-of-plane behavior including the TF inner leg strain rosette and laser twist measurement. The repeatability of test shots will ensure small changes in the measured OOP response can be detected

Review	ID	Chit
Project CDR	RPCDR34	Assess if the frictional restraints in the vicinity of the ceramic break are acceptable under the present design, considering the required decrement of the friction coefficient from the design criteria and the observed loss of preload. Use high friction coatings on the flanges that mate to G7 parts?

Closed: The frictional characteristics of the ceramic break assembly were found to be acceptable in the the calculation *Calculation of Machine Core Structure Ceramic Break Structural Analysis* (NSTXU_1-1-3-3_CALC_109), available here:
https://drive.google.com/open?id=15hzNQYBGAeZ0NqLNWt_IhANzprSetA9X

Review	ID	Chit
Project CDR	RPCDR051	The EoC2 report states: "The Digital Coil Protection System should be complemented with a system ensuring that an impending coil fault (in any magnet) can be detected well before more severe damage is inflicted on other parts of the machine by a major coil failure. This may require some additional sensors, or perhaps just a real-time or inter-shot

		implementation of the same type of magnetic diagnostics analysis as was made after the recent major coil failure to determine when it had really begun. This action is considered by the Panel as necessary for start-up." Progress on this topic has not been covered in the CDR. Implementation plans should be presented.

Closed: The Project has adopted a “Shorted Turn Protection System” as WBS element 1.10.1.1. The design of this system can be understood by looking at the FDR web page:
https://sites.google.com/pppl.gov/20200116-shorted-turn-protecti/home

Review	ID	Chit
Project CDR	RPCDR080	In regard to the TF torsional Twist, if there is a big twist, then its upper lateral retainers should subject the force at not only the radius direction but also circumference direction. The design of the CS stability should consider both directions. I am thinking of a modification of a triangle structure for the existing design of the stabilizer.

Closed: The halo load shims and load cells are mainly loaded by lateral halo loads and coil error field loads. The global twist of the tokamak is transmitted through the bellows from the outer vessel side to the inner casing, and also through the spoked lid to the inner leg This twist is small and included in the bellows qualification. This twist will also appear at the shims. The twist angle can change due to the TF delamination, but the twist we predict for the delaminated case , from the TF bundle analyses as shown in this report NSTXU-1-1-3-3-1_DOC-102, is so small that it will not alter the shim radial load or the bellows torsion significantly.

Review	ID	Chit
Project CDR	RPCDR041	Consider using a co-axial or bi-axial feed on the cooling plates so that two can be fed independently using the presently assigned feedthroughs.

Closed: The HTP uses a bi-axial feed. See drawing 0EDC11174.

Review	ID	Chit
Project CDR	RPCDR064	Need to assess why there is a 150 limit in the Safety Certificate. What safety issue are we addressing? Having it be a limit is fine, but safety?

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.

Closed: First of all, the 150 C value was always in reality a design point, not a limiting condition for safety under any analysis done at the time the safety certificate was created; it should not have been in the safety certificate!.

We have since learned of the safety issue related to the BLEVE risk, and made modifications to the MTWS to eliminate that risk as a matter of first principles. Hence, the outer vessel temperature remains a matter of the operating point and machine protection, but not personal safety.

Secondly, now that we are under the ASO, the Safety Certificate will be eliminated, to be replaced by the Accelerator Safety Envelope (ASE). The ASE will almost certainly not have the 150 C limit, as it is not related to any "Accelerator Specific Hazard" (or actually any specific hazard threshold: 60 C is the ANSI touch-safe threshold, so we are far beyond that).

The 150 C limit, or something similar to it, may appear in the operations envelope, though this is something still being discussed.

Review	ID	Chit
Project CDR	RPCDR072	RE: Radiation Shields on the Passive Plates. The passive plates have significant mechanical loads. Structural improvements, including Inconel bolts and Inconel shear bushings were required for the NSTX-U Upgrade Project. The proposed standoffs to reduce thermal conduction could be problematic....

Closed: We have analysed these effects of heat shields and found them to be not profoundly effective. We have also looked at heat leaks out the brackets and found that term to be small relative to the radiation losses. Overall, we are not confident in reaching the bakeout KPP and Project goals without these heat shields.