National Spherical Torus eXperiment Upgrade

NSTX-U Plasma Facing Components Requirements Document: NSTXU-RQMT-RD-002-00

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Record of Revisions

Revision	Date	Description of Changes
0	7/25/17	First release

Distribution

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Note: Draft of Rev. 0 sent to TSG leaders on 5/4/17.

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0.0 References

[1] NSTX-SRD-11-031: System Requirements Document, Plasma Facing Components, Rev. 1, May 11, 1998
[2] NSTX-U-SRD-111-013: System Requirements Document, Plasma Facing Components, Rev. 0, June 20, 2011
[3] NSTX-CRIT-0001-02: NSTX Structural Design Criteria, January 2016
[4] NSTX-U CS-Upgrade GRD, Rev. 6
[5] Halo current requirements: https://drive.google.com/open?id=0B1NuAWPON9ODMElvaElNckpaT2M
[6] Carbon Blooms and CFCs PFCR-MEMO-003-00
[7] Design Point Spreadsheet, file NSTX_CS_Upgrade_120409.xls or http://w3.pppl.gov/~neumeyer/NSTX_CSU/Design_Point.html
[8] Heat Fluxes on the CSAS and Far OBD Region: PFCR-MEMO-008-00
[9] Heat Fluxes on the Vertical Target: PFCR-MEMO-009-00
[10] Heat Fluxes on the IBDH and Near OBD Regions: PFCR-MEMO-010-00
[11] NSTXU-CALC-11-05-00: Thermal Analysis of Neutral Beam Armor Array
[12] NSTXU-CALC-24-02-00 Armor Plate Backing Plate (Neutral Beam Armor E/M)

1.0 Requirements

The plasma facing components are designed with two complementary goals. First, they must protect the metallic structures of the vessel (the vessel wall, passive plates, etc.) from damaging heat fluxes from the vessel. Second, they must protect the plasma from influx of medium- and high-Z impurities that can contaminate it.

This document provides requirements for plasma facing components on NSTX-U. All statements in this document superseded the requirements in [1] and [2] in the event of conflict.

2.0 General requirements

2.1: Materials and Structural Requirements

All PFCs in NSTX-Upgrade shall be made from either fine grain isotropic graphite, or from other carbon based materials, for instance carbon-carbon composites, here referred to as CFCs. The exception to this is the outboard limiter which can be made from boron nitride if integrated/combined with the RF antenna limiter. The RF limiter shall not be regarded as a surface on which it is acceptable to limit the plasma.

For isotropic graphite, the brittle materials qualification shall be used, as per the structural design criterion [3], where PFCs are defined as critical components. The same criterion shall be applied to other carbon based materials for now; this requirement can be relaxed in a future revision based on test or additional data.

The PFCs themselves and any related materials should be compatible with a high vacuum environment. They should accommodate the following:

- Application of boron thin films as deposited by the dTMB system.
- Application of lithium thin films as deposited, for instance, by the LITER probes.
- Glow discharge cleaning with hydrogen, deuterium, helium, neon, and argon.

Non-ferritic materials should be used for all fasteners. SS316, A286, or Inconel are preferred. Magnetic permeability requirements shall be adhered to as per reference [4].

The design shall accommodate the following EM and thermal displacements:

- Attractive and repulsive forces, and displacements, of the inner-PF coils.

- Thermal growth during both high-power plasma operations and bakeout
    - EM loads shall be added to the plasma operations thermal displacements as one load & displacement case.
- Lateral displacements at the top of the CS due to toroidally asymmetric halo currents.

Here, design accommodation includes both providing sufficient clearance to avoid tile collisions, while also avoiding damage to tiles from flexure of their backing structures.

These displacements will be articulated in a future revision to this document.

2.2: Disruptions and Halo Currents

Accommodation for halo currents as per memo by S. Gerhardt [5]. Tile designs should have a well defined current path for halo currents entering the tile front surface to flow to backing structures. The design of the IBDH and OBD tiles (top and bottom) should accommodate halo currents bridging that gap during disruptions, with currents levels as per the memo.

Eddy current requirements as per the GRD [4].

The following disruption heat loads should be considered independently, coming after one of the heat loads from Section 3.1-3.6 have been applied from the ~5 second plasma.

- <u>Disruption thermal quench loading based on thermal and magnetic energy converted to radiated power flux.</u> Assume a radiative heat flux of 100 MW/m^2 is applied for 1 ms applied normal to the tile surface. This is based on an assumption of 1.5 MJ of energy in 1 ms, with 100% of the energy distributed into 15 square meters (~½ of the area). *This specification may be updated with more complete requirements in a future revision.*

or

- <u>Disruption loading based on the plasma making contact with the PFCs during a vertical disruption event.</u> *The energy flux, duration and attack angle specification will be included in a future revision, including guidance on how to resolve the impact of ablation. In general, requirements related to expected lifetime of small scale surface features like PFC shaping, including the impact of erosion will also be provided.*

2.3: General Thermal and Cycle Requirements

The PFCs shall meet the following general thermal requirements

- The design scenarios described in sections below shall be qualified for repetition rate of <= 1200 seconds.
- As a design constraint, the surface temperature of the wetted top face, away from local peaks at the edges, at the end of the pulse shall not exceed 1600 ^{o}C; disruption heating need not be included in this consideration. [6]
- As a design constraint, the edge temperature shall not exceed 2000 ^{o}C; disruption heating need not be included in this consideration.
- Unless otherwise stated, the duration of heat flux is to be taken as 5 seconds
- PFC surface/edge temperatures may exceed 1600/2000 ^{o}C following disruption loads given in Section 2.2, but bulk tile stress limits must not be exceeded.

The tiles and fasteners should be qualified for the full lifetime of NSTX-U as per the GRD shot spectrum [2]. In particular, the mechanical performance noted here shall be qualified for >5000 cycles.[1]

Specific requirements on a per-location basis are provided in Section 3.1-3.6.

Tile designs favoring one target helicity may be used if necessary. Specifics of the helicity direction are identified in Section 3.1-3.6 per each individual PFC area. Vertical gaps, front-surface holes, etc. are allowed provided that designs can meet stress and temperature requirements.

2.4: Bakeout Considerations

All graphite shall be capable of being baked to 350 C. Provision shall be made to ensure that the mounting structure for PFCs provides appropriate levels of heat transfer to underlying heated structures. *Interface heat fluxes shall be provided for each tile region specifying the thermal energy which can be provided by the Bake Out System.*

CS Bakeout will continue to use a DC supply, and it is assumed here that one insulator at the top of the machine will be retained. Therefore, the gap between the upper IBDH and OBD tiles should be designed to satisfy a 500 voltage differential w/o arcing at the

[1] As noted in Section 2.2, erosion of the tile surface from disruptions or normal operations may impact the tile surface rampings; this will be assessed in a future revision.

following pressure levels: atmospheric pressure, NSTX-U operational vacuum, and NSTX-U bake out.

2.5: PFC Locations

In general, PFCs should conform to the envelope stated in Figure 2.5.1 and Table 2.5.1, below. These numbers take precedence over previous envelope definitions. The table provides allowed radial or vertical expansion of the PFCs in order to meet new requirements.

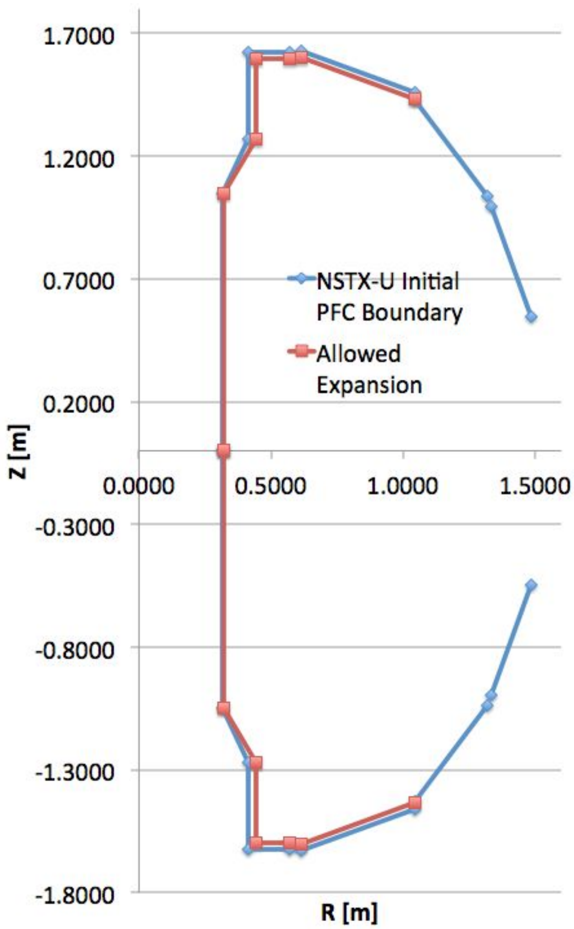

Figure 2.5.1: NSTX-U PFC boundary and allowed expansion of PFCs to accommodate new requirements

PFCs design should ensure that there is no large line-of sight from the plasma to the centerstack casing, centerstack bellows, outer vacuum vessel in the “polar regions”, or PF-1c reentrant housing; included in this is the requirement that graphite armor be present in continuous form from the outboard divertor to the secondary passive plates as per Fig. 2.5.1. Here, “large gaps” do not preclude nominally small tile-to-tile gaps. Regions on the casing and divertors not protected from direct lines of sight shall be minimized.The intra-tile heat loads should be calculated assuming a power flux of 1 MW/m^2 normal to the PFC surface. The value at the bottom of any gaps will depend on the depth and width of any gap.

	R	Z	Allowed ΔR	Allowed ΔZ
	m	m	m	m
Upper CS	0.3148	0.0000	0.0050	0.0000
	0.3148	1.0500	0.0050	0.0000
	0.4150	1.2700	0.0300	0.0000
	0.4150	1.6234	0.0300	-0.0254
	0.5715	1.6234	0.0000	-0.0254
Upper OBD	0.6171	1.6280	0.0000	-0.0254
	1.0433	1.4603	0.0000	-0.0254
Upper SPP	1.0433	1.4300		
	1.3192	1.0397		
Upper PPP	1.3358	0.9976		
	1.4851	0.5450		
Lower PPP	1.4851	-0.5450		
	1.3358	-0.9976		
Lower SPP	1.3192	-1.0397		
	1.0433	-1.4300		
Lower OBD	1.0433	-1.4603	0.0000	0.0254
	0.6171	-1.6280	0.0000	0.0254
Lower CS	0.5715	-1.6234	0.0000	0.0254
	0.4150	-1.6234	0.0300	0.0254
	0.4150	-1.2700	0.0300	0.0000
	0.3148	-1.0500	0.0050	0.0000
	0.3148	0.0000	0.0050	0.0000

Table 2.5.1: NSTX-U PFC boundary and allowed expansion of PFCs to accommodate new requirements

2.6: Diagnostic Requirements

Requirements for diagnostics for specific locations are provided in the individual sections below. Detailed requirements will be provided in a later revision. Use of existing designs is encouraged but not required.

General requirements include:

- Tiles should provide for sufficient wire ways to enable all wires to reach their feedthroughs at the bottom of the organ pipers.
- Use of the existing Mirnov coil design is encouraged but not required. Any new designs for Mirnov coils should attempt to match the effective loop area * turns of the existing sensors at those locations as best possible. Mirnov may be mounted in tiles themselves as in the present design, or in structure immediately behind/beneath the tiles.
- If the present copper/omega-bond scheme is utilized for Mirnov coils, then the temperature of the Mirnov coils shall not exceed 500 C at any time during the plasma pulse or subsequent between-shot cooling period.
- Thermocouples should be placed in tiles as specified in Sections 3.1-3.6 such that the energy deposited in the tiles can be quantified.
- Langmuir probes should be integrated in the CS, IBDH, IBDV and OBD tiles or between tile submodules.

Future versions of this document, or new documents, will specify more detailed requirements for diagnostic designs.

Diagnostics and procedures to monitor PFCs between discharges to help ensure operational temperature limits are within these requirements will be covered in a seperate, to be written document.

2.7: Installation and Maintenance Requirements

In order to ensure that the PFCs can be installed in a safe and efficient manner, the following requirements hold:

- No module or single component installed by a single person shall weigh more than 50 lbs, unless lifting and handling equipment and procedures are specially developed.
- Any module and component must fit through the Bay A duct w/o the use of an overhead crane.
- Tiles of the base design should be able to bear the weight and typical movement of technicians working in vessel. For design purposes, this can be assumed to be 300 lbf distributed over an area of 4 in^2. Langmuir probe tips or other specific fine features are an exception to this rule, and may require protection.

The design shall be such that removal replacement of any tile shall not mandate the removal of the center-stack or outboard divertor copper/stainless structure.

An assembly sequence shall be provided with the design that takes account of machine assembly (including CS insertion to the machine), wire management, and any industrial hygiene and health physics concerns.

2.8: In-Vessel Requirements for Gas Delivery:

The PFCs must accommodate and integrate methods of gas delivery, which fall into three categories.

2.8.1: CS Gas Fuelling

The CS Gas Fuelling in the initial NSTX-U design is indicated by the drawings E-ED1324, E-DC1605 and further drawings indicated therein. There are four fueling lines, with associated puff injectors. These fuelling lines exhaust their gas as per Table 2.9.1

Vertical Location of Outlet	**Toroidal Location of Organ Pipe**	**Gas Line**	Drawing
Shoulder	105 degrees	0.25 ”OD x 0.02 wall	E-DC1607
Shoulder	285 degrees	0.125” OD x 0.016” wall	E-DC1752
~11” Above Midplane[2]	255 degrees	0.25” OD x 0.02” wall	E-DC1606
Midplane	75 degrees	0.125” OD x 0.016” wall	E-DC1608

Table 2.9.1*: Centerstack Fuelling Injectors*

The diameters of the gas lines listed in Table 2.9.1 should be preserved, and it is likely appropriate the retain the allocation of organ pipes for this usage. The outlet locations should also stay at approximately the previous locations, though small (1”-3”) changes in the location can likely be tolerated with the exception of a movement of the 255 degree injector toward the midplane. The routing behind the PFCs should have the

[2] Note that the 255 degree midplane injector outlet location is located ~11 inches above the midplane, so that the light cloud produced by the puff does not interfere with the MPTS measurement.

minimum reasonable number of bends, though there is no mandate to retain the previous routing.

2.8.2: OBD Fuelling

Divertor gas injectors were installed in the NSTX-U lower outer divertor, at Bays C & I. These systems are described in drawings E-EA3009 & E-EA3010. These fueling lines should be maintained as the PFCs evolve. Provision in the Row-1-equivalent tiles should be made for allowing this gas to enter the plasma volume at approximately the same location as the initial implementation.

If the Row-1-equivalent design has a mechanism to hide/avoid front-surface mounting holes, then this gas inlet need not be accomplished via addition top-surface orifice. For instance, gas could be allowed to flow through one of the existing mounting holes, or potentially via a horizontal orifice directing gas through the remnant of the CHI gap.

2.8.3: Private Flux Region Fueling

To assist in mitigating large heat fluxes in the IBDV [9] in addition to the IBDH [10], it is desirable to have an additional gas fueling method in the private flux region (PFR) (i.e. the region between the inner and outer strike-points). This is generally within the region defined as R<0.48 and |Z|>1.5.

Requirements include:

- Systems should be implemented at both the top and bottom; these gas orifices need not be at the same toroidal locations
- Piezo-electric valve with PCS control shall be used to control the fuelling.
- 5000 Torr rating on the system

As a minimum requirement, a single gas delivery orifice, at a single toroidal location each of top and bottom, shall be implemented. It is desirable, but not required, to generate designs that lead to a more toroidally uniform distribution of gas.

To illustrate potential solutions for this requirement, the following solutions would satisfy the requirement:

Option 1: Gas is puffed into an organ pipe, through which it propagates to the backing structure for the PFCs. The inter-tile/module/block spacing is used to leak gas into the

PFR at locations above the organ pipe locations. Mounting plates and PFCs that cover these regions should be perforated resulting in a total area of ~ 0.5 cm^2.

Option 2: A ~½" OD pipe is run up the organ pipe and to an orifice location at the corner of the IBDH/IBDV. A hole is placed in the PFC surface at that location, allowing gas to enter the PFR.

3.0 Requirements By Location

This section defines the heat load requirements by location. The mechanical pre-loads and thermal loads so-derived should be added to those from halo currents and eddy currents. *Future revisions to this section will discuss diagnostic requirements by region in more detail*.

The heat fluxes in the tables below are based on the Ref [8-10]. All justification for these requirements can be found in those memos. Heat fluxes should applied uniformly over the PFC surface, at the given angles of incidence for the listed duration. If PFC designs are shown to not meet these requirements, relaxation may be granted. First, more accurate profiles of field directions and heat flux magnitudes along the divertor surface can be made available, by contacting the Head of the PFC Requirements Working Group and/or the Head of NSTX-U Research Operations. If necessary, reduction of the ultimate parameters may be feasible, but the impact on NSTX-U operational space must be taken into consideration, and modifications to these requirements be done in coordination with the Head of NSTX-U Research Operations and the NSTX-U Research Director.

3.1: CS First Wall Section (CSFW)

3.1.1 CS Tile Alignment Tolerance

The nominal alignment target of .010" between adjacent tiles shall be used as per [2]. There is not an expectation that eccentricities in the casing itself will be compensated out by this tile installation.

3.1.2 CS Tile Diagnostics and Gas Interface

The CS tiles shall have as an initial goal diagnostics as indicated in drawing E-D1324. Provision shall be made for diagnostic wireways as appropriate.

Provision shall be made for the midplane fueling injectors as per Section 2.9.

3.1.3 CS Tile Heat Flux

The CS tile heat flux is assumed to be dominated by radiation. For the present design activity, a uniform normal heat flux of 1 MW/m^2 for 5 seconds should be used.

3.2 Inner Horizontal Target

The horizontal target is the one plasma facing surface that may have heat from either the inner or outer strikepoint deposited on it. For the purpose of this document, “standard target helicity” refers to the field line direction when the Outer Strike Point (OSP) is located on the IBDH tiles, for clockwise toroidal field and counter-clockwise plasma current (when viewing the tokamak from the above). Reversed target helicity refers to cases where the Inner Strike Point (ISP) falls on the horizontal target tiles. The field directions at the outer strike point are indicated in the figure below, along with severely exaggerated ramped tiles. Field lines approach the surfaces at very shallow angles, and those given in Table 3.2.1 are referenced such that 90^o would make the field line normal to the IBDH surface.

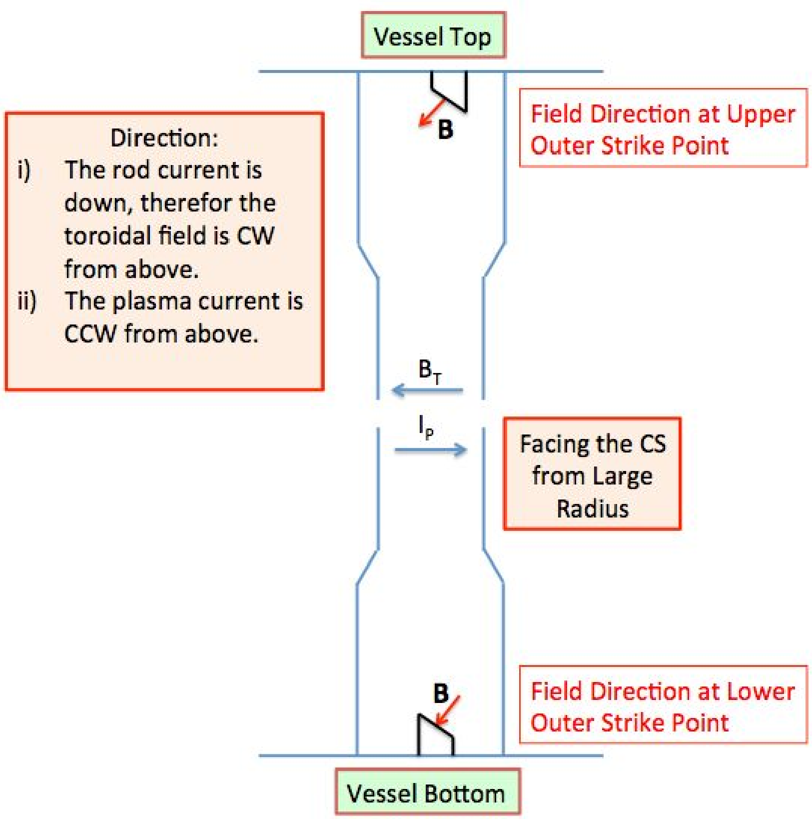

Fig: 3.2.1: *Field line direction on the horizontal target for “Standard Helicity”*

<u>IBDH</u>	Case # ->	1	2	3	4	5
Range of Application	m	0.48 < R < 0.6			R < 0.6	R < 0.48
Max Angle	degrees	1.0	5.0	3.6	-1	4.0
Min Angle	degrees	1.0	1.5	3.6	-5	1.0
Heat Flux	MW/m^2	7.0	5.5	14	1	3.5
Duration	sec	5	5	1	1	5
Reference Scenario	---	Stationary High Ip/Bt w/ large poloidal flux expansion (Table 5.1)	High Ip/Bt Long Pulse Swept Case (Table 6.1)	Stationary High Power Short Pulse (Table 4.1.1)	Reversed Helicity Requirement (Section 7)	Spill Over From HHF Regions (Section 8)

***Table 3.2.1**: Required heat flux parameters for the IBDH (0.48 < R < 0.6). Cases 1 through 3 have the "normal" helicity.*

Uniform heat flux requirements for 0.48 < R < 0.6 [m] on this surface are given in Table 3.2.1. Note that there is a region for R<0.48 where basic good engineering practice should be applied (chamfer choice, no too-large pre-load), but high thermal performance is not required.

3.2.4: PFC Dimensions

See Table 2.5.1 for PFC boundaries and regions for expansion. If the thickness of the IBDH tiles changes compared to the initial NSTX-U design, then the OBD tiles should be adjusted so that leading edges are minimized are made if the outer divertor heat flux is spread across the IBDH/OBD gap. The gap between the IBDH and OBD tiles should be the smallest gap consistent with the lateral/vertical displacements on Section 2.1 and the electrical standoff requirement of Section 2.4.

3.2.5: Diagnostic Requirements for the Horizontal Target

As a base assumption, the diagnostic layout should remain as manifest in E-D1324.

However, new designs may lead to revised constraints on diagnostics. Should that be the case, the following prioritization should apply:

- Thermocouples assessing the temperature of the bulk tile material should be integrated into the baseline design of any new tiles. *Number and layout in the device in order to provide redundancy and assess potential non-axisymmetries to be defined in future revisions.*
- Two axis magnetic field sensors ("2D Mirnovs") should be installed at at least 2 toroidal angles in each of the upper and lower targets. As per E-D1324, Bays B and H are the ideal locations. Having multiple radial positions at each angle, as at Bay H in the initial NSTX-U design, is desirable but not required. Mirnov coils need not be embedded in graphite if other constraints render that inconvenient.
- Langmuir probes shall be developed consistent with high-level mechanical requirements. This may include locating sensors on the corners or edges of tiles. *Number and layout to be defined in future revisions.*
- Holes centered around the organ pipes as per E-DC1324 shall be included. The holes should be of dimension matching the PFC holes in the initial NSTX-U design (see E-ED1298), with the critical caveat that they should not extend radially beyond R=48 cm.

3.3: Vertical Target

3.3.1: Heat fluxes

Heat flux requirements are as per Table 3.1.1. These refer to "standard" helicity, which is illustrated in Fig. 3.3.1.

IBDV	Case# ->	1	2	3	4
Range of Application	m	1.27< |Z| < 1.5	1.27< |Z| < 1.5	|Z|>1.5	|Z| > 1.27
Max Angle	degrees	5.5	6.0	4.0	-1
Min Angle	degrees	2.0	2.0	1.0	-5
Heat Flux	MW/m^2	5.0	10	3.5	1
Duration	s	5	1	5	1
Reference		High I_p and B_T DN w/ Sweeping (Table 5.6)	LSN Sweeping (Table 5.5)	Spill Over from Scans in HHF region	Reversed Helicity Requirement (Section 6)

Table 3.3.1: *Heat flux requirements on the vertical target*

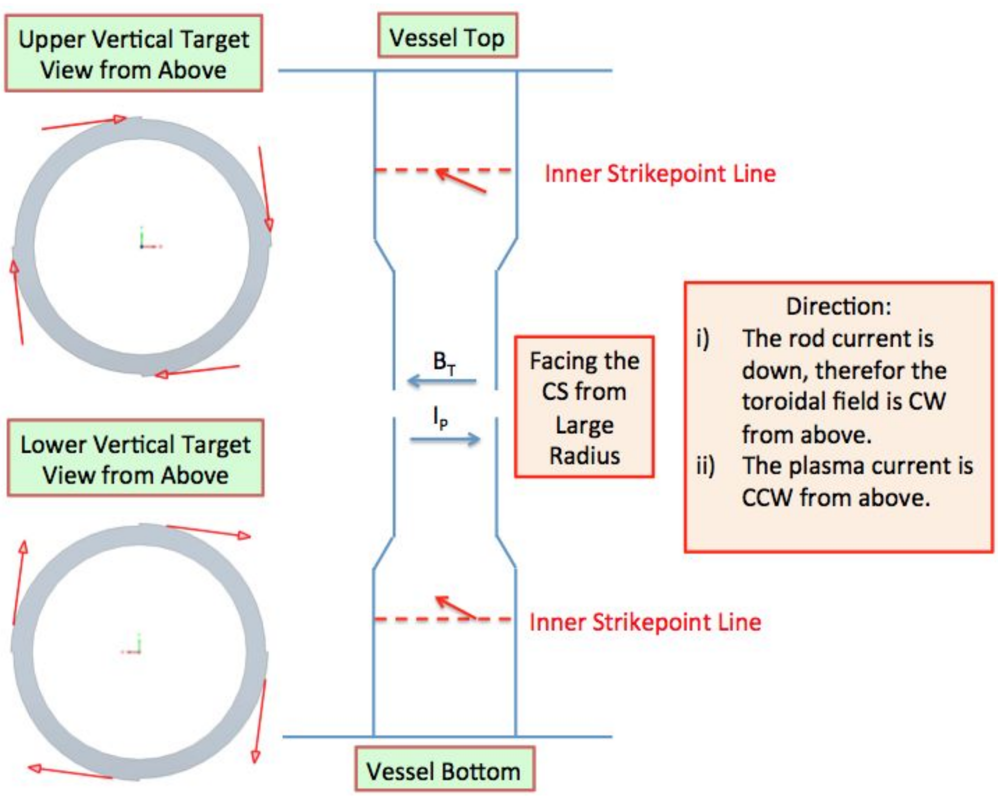

Fig: 3.3.1: *Field line direction on the vertical target for "Standard Helicity"*

3.3.2: Inboard Vertical Target Diagnostics

In general, the diagnostics on the inboard vertical target should mimic those on the initial NSTX-U IBDV, as per E-D1324. This includes the Mirnov coils, thermocouples, langmuir probes, and CSC rogowski sensors.

The details of these diagnostic designs will be determined as the base design is further evolved, but will be similar to those outlined in 3.2.5 for the IBDH.

3.4: Outboard Divertor

Only the outer strike-point can reach the outer target. Therefore reversed target helicities are not required; the helicity is as indicated in Fig. 3.2.1

3.4.1: Heat Flux Requirements

The heat fluxes in this region are as per Ref. [8] & [10]. The requirements so derived are shown in Tables 3.4.1 through 3.4.3

Near OBD (aka R1,R2)	**Case # ->**	**1**	**2**	**3**	**4**
Max Angle	degrees	1.0	5.0	4.4	6.0
Min Angle	degrees	1.0	1.5	2.6	6.0
Heat Flux	MW/m^2	6.0	5.5	3.0	11
Duration	sec	5	5	5	1
Reference Scenario	---	'Spillover' for stationary large poloidal flux expansion (Table 5.2.2)	'Spillover' for High Ip/Bt Long Pulse Swept Case (Table 6.1)	Swept Case on OBD (Table 6.2)	High Power Short Pulse (Table 6.2, 4.2.2-4.2.4)

***Table 3.4.1**: Heat fluxes on the OBD Row 1 & 2 tiles*

OBD-R3	Case # ->	1	2
Max Angle	degrees	7.9	10
Min Angle	degrees	2.2	8.5
Heat Flux	MW/m^2	10.5	3.0
Duration	sec	1.0	5.0
Reference Scenario		short duration high power (DivSol 8-07)	MPFC Far-OBD MAPP Scan

Table 3.4.2: *Heat fluxes on the OBD Row 3 tiles*

Note the large cut-outs in the Row 4 tiles in the vicinity of Bays L (P-CHERS) and Bay D (Vertical Viewing Spectrometer), as well as the smaller cut-outs at each vertical-viewing dome port. The impact of these cut-outs should be assessed, to ensure that direct field line impingement on metal is not possible. Protective tiles may need to be designed if direct field line impingement on metal is possible.

OBD-R4/5	Case # ->	1	2	3	4
Max Angle	degrees	14	8.2	16.5	10
Min Angle	degrees	9.2	4.8	13.5	8.5
Heat Flux	MW/m^2	4.3	1.8	3.0	3.0
Duration	sec	2.0	2.0	2.0	5.0
Reference Scenario		High I_P/B_T LSN Swept L-Mode	Low I_P/B_T LSN Swept L-Mode	High I_P/B_T LSN Swept L-Mode	MPFC Far-OBD MAPP Scan

Table 3.4.2: *Heat fluxes on the OBD Row 4 & 5 tiles*

3.4.2 OBD Diagnostic Considerations

The outboard divertor diagnostics are described in drawing NSTX-345. The diagnostic layout should remain similar to the largest extent possible. *Modifications from that layout shall be determined in future documentation, in consultation with physics.*

3.5: CSAS

The CSAS tiles shall slightly shadow the IBDV tiles in the poloidal direction.

Heat fluxes for the CSAS are as per Ref. [9], and provided again in this table for reference.

CSAS	Case # ->	1	2	3
Max Angle	degrees	9.2	4.0	12
Min Angle	degrees	7.3	2.5	9.5
Heat Flux	MW/m^2	5.2	1.0	3.6
Duration	sec	2.0	2.0	2.0
Reference Scenario		High I_P/B_T LSN L-Mode, 3 MW	Low I_P/B_T LSN L-Mode, 1.5 MW	High I_P/B_T LSN L-Mode, 2 MW

Table 3.5.1*: Heat flux requirement for the CSAS.*

3.6: Passive Plates

The requirements enumerated in Section 2.2 of Ref. [3] shall continue to hold for the passive plate PFCs. No changes are anticipated for these PFCs, *but these values will be updated or confirmed and incorporated into a future revision of this document.*

3.7: Outboard Limiter

This section will be updated in a future revision to this document.

3.8 Neutral Beam Armor

The neutral beam armor shall tolerate radiative heat fluxes from the plasma of ~1 MW/m2. The armor must also tolerate neutral beam fluxes, as described in Ref. [11] & [12]. These need not be applied simultaneously.

3.9 Regions not otherwise specified

This section will be updated in a future revision to this document to specify requirements for other regions, e.g., minimum heat fluxes for components not protected by PFCs including expected fluxes during disruptions

4.0 Interfaces

4.1: Vessel Heating/Cooling Systems

The tiles must interface to the vessel heating and cooling systems in order to
i) bake out the tiles
ii) cool the tiles between discharges.

With regard to item i), the PFC engineers should work with the Bakeout Systems and VV & Internal Hardware engineers to develop the interface requirements, including conduction and radiative heat transfer from components directly heated by the hot He system. *This document will be updated once these requirements are more explicitly defined.*

With regard to item ii), the PFC engineers should work with VV & Internal Hardware engineers to develop cooling requirements for the in-vessel systems in order to maintain a 1200 s cycle time. *This document will be updated when more explicit requirements are available.*

4.2: Diagnostics

The PFC engineers should work with the Diagnostics RE and the individual cognizant physicists to ensure appropriate interface to diagnostics. Of particular concern are electrical connections to the vessel and in-vessel cabling. Key diagnostic contacts include:

Langmuir Probes: Robert Lunsford and Mike Jaworski
Magnetic Diagnostics: Clayton Myers and Stefan Gerhardt
Thermocouples: Joe Petrella, Matthew Reinke and Paul Sichta

4.3: Tile Region Interfaces

4.3.1: CSFW and CSAS

There are specific requirements for this interface beyond those stated in Section 2.

4.3.2: CSAS and IBDV

Requirements in Section 2 shall be met. Additionally, the CSAS tiles shall overhang the IBDV tiles.

4.3.3: IBDV and IBDH

There are no specific requirements for this tile region interface beyond those stated in Section 2. Note from Tables 3.2.1 and 3.3.1 that the region in the immediate vicinity of this interface is a relatively low heat flux region.

4.3.4: IBDH and OBD

There are no specific requirements for this tile region interface beyond those stated in Section 2

4.4: Gas injection

The interfaces to the gas injection system are defined in Section 2.9

4.5: IBDH Cooling Plate Interface

The IBDH tile assembly shall have a defined interface to the cooling plate, accommodating tile fixturing, heat conduction, wire ways, gas delivery tubing, and through access to the holes in specific IBDH tiles. This interface will be better defined in future revisions.

4.6: Structural Interfaces

Acceptable reaction loads and any displacements shall be determined and tabulated at the interface between each PFCs support element and the area of the machine structure which it is connected to.