Calculation No: NSTXU-CALC-11-031-00 **Revision No: 0**

Tile shaping of the IBDH HHF Tiles

Purpose of Calculation: (Define why the calculation is being performed.)

Calculate the tile to tile and castellation to castellation gaps of the Inboard Divertor Horizontal tiles.

Codes and versions: (List all codes, if any, used)

Hand Calculations

References (List any source of design information including computer program titles and revision levels.)

1) NSTX-U Disruption Analysis Requirements NSTX-U-RQMT-RD-003-02 7/23/18
2) RECOMMENDED MODIFICATION TO PFC SYSTEM REQUIREMENT DOCUMENT ON SURFACE SHAPING PFC-180706-MAJ-01

Assumptions (Identify all assumptions made as part of this calculation.)

Axisymmetric heat fluxes (specified in SRD), 0.004" surface profile tolerance on tiles, 0.015" profile tolerance of the baseplate tiles.

Calculation (Calculation is either documented here or attached)

See attached work sheets.

Conclusion (Specify whether or not the purpose of the calculation was accomplished.)

Tile to tile gap of 0.030" and castellation to castellation gap of 0.010" is sufficient to eliminate direct heating of the tile edge heating in forward helicity case.

Cognizant Individual (or designee) printed name, signature, and date

Andrei Khodak

Andrei Khodak

Digitally signed by Andrei Khodak
Date: 2018.09.28 15:36:17 -04'00'

Preparer's printed name, signature and date

Andrei Khodak

I have reviewed this calculation and, to my professional satisfaction, it is properly performed and correct.

Checker's printed name, signature, and date

Michael Jaworski

Michael Jaworski

Digitally signed by Michael Jaworski
Date: 2018.09.28 13:48:02 -04'00'

Calculation

IBDH tile parameters are summarized in the table

				e-ed1434
Castellation gap	g_c	0.02	inch	Sht 1, B-11
Cast. Gap tol.	dg_c	0.005	inch	Sht 1, B-11
Tile gap	g_t	0.04	inch	Calc. assump
Tile gap tol.	dg_t	0.01	inch	Calc. assump
Grafoil Height	h_g	0.03	inch	
Grafoil Height tol.	dh_g	0.002	inch	
Cooling Plate Height	h_c	0	inch	
Cooling Plate Flatness tol.	dh_cf	0.015	inch	
Tile Height	h_1	2.125	inch	Sht 1, D-6
Tile Height tol.	dh_1	0.004	inch	
Surface Profile tol	ds	0.004	inch	
Erosion "tolerance"	d_e	0.003	inch	
Tile Length (IBDH)	L_2	4.462	inch	Sht 1, G-5

Castellation jump can be calculated as follows:

$$h_c = (h_c + dh_c)\tan(\alpha) + d_e + d_s$$

Tile to tile jump can be calculated as follows:

$$h_t = (g_t + dg_t)\tan(\alpha) + d_e + 2\left(\frac{dh_1}{2} + dh_g + d_s\right) + dh_c$$

Cooling plate tolerance dh_c is defined is the maximum tile to tile step height. For the tiles located on the same 180º cooling plate this value is limited by surface roughness height and is much less than 0.001". At the gap between two halves of the cooling plate assembly the step theoretically can be as high as cooling plate assembly tolerance of 0.015". To limit tile to tile jump, special requirement on the cooling plate assembly must be imposed: 0.005" maximum distance between edges of the cooling plates after assembly.

With this additional requirement maximum tile to tile step on cooling plate dh_c is 0.005". For $\alpha = 5°$ the following values can be obtained:

$$h_c = 0.009187"$$

$$h_t = 0.028374"$$

The following rounded up values were used in the IBDH design:

$$h_c = 0.010"$$

$$h_t = 0.030"$$

Checks for Calculation No: NSTXU-CALC-11-31-00
Revision No: 00

Tile shaping of the IBDH HHF Tiles

Component was checked against latest design

Yes. E-ED1434 is the referenced drawing.

All required load cases are included and current

Analysis primarily examines geometry which is current.

Discuss method used in the calculation

Hand calculations are made to determine the required step heights between castellations and across inter-tile gaps.

Discuss how the calculation was checked (*)

Checker's own spreadsheet tool in Excel was used for independent checks. Current drawing details were compared with the SRD specification for direction.

List issue identified and how they were resolved

For the current tile geometry, the castellation shaping profile is sufficient provided the HTP can be brought to an equivalent profile of 0.0035". This value is slightly less than the 0.005" value reported in the calculation.

The direction of the castellation is correct as per the SRD.

Checker's name: Michael Jaworski

Robert Ellis Digitally signed by Robert Ellis Date: 2018.09.28 16:01:07 -04'00'

Technical Authority:_____(sign and date)

(*) independent calculations can be appended

Calculation Check Report:

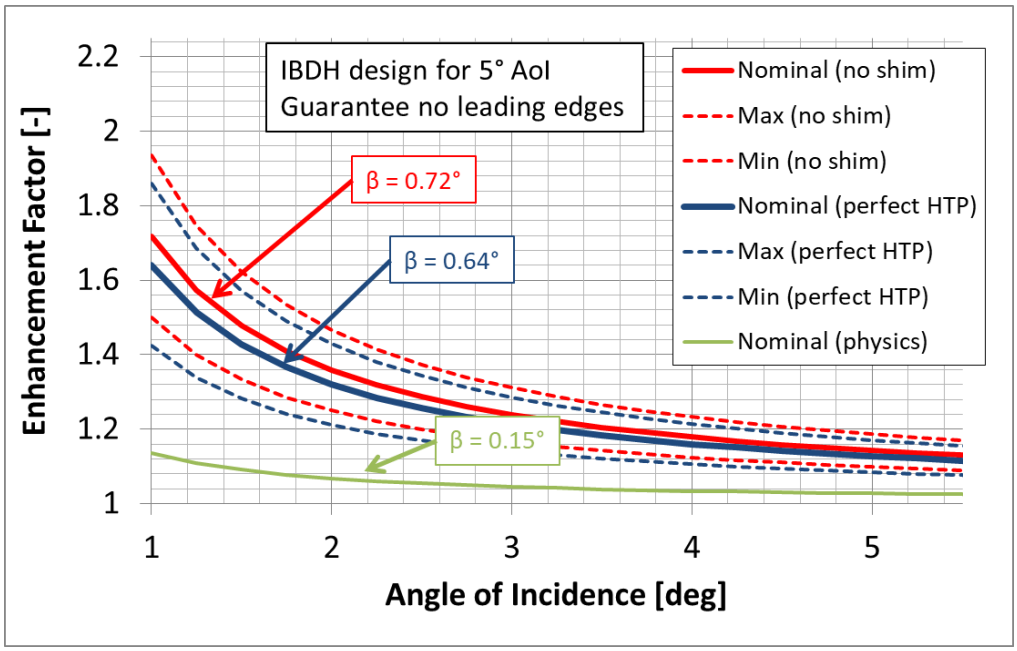
A table is constructed is used to verify dimensions:

Key geometric features, Drawing E-ED1434				
Name	Symbol	Value	unit	Drawing sht and quadrant
Castellation gap	g_c	0.02	inch	sht 1, B-11
Cast. Gap tol	dg_c	0.005	inch	sht 1, B-11
Tile gap	g_t	0.04	inch	Design Doc
tile gap tol.	dg_t	0.004	inch	grafoil comp
Grafoil height	h_g	0.03	inch	E-ED1466
grafoil height tol	dh_g	0.002	inch	grafoil comp
Base plate height	h_b	0	inch	assumpt.
base plate tol	dh_b	0.0035	inch	assumpt.
Tile height (typ)	h_1	2.125	inch	sht 1, D-5
tile height tol	dh_1	0.004	inch	sht 2, C-11
Surface profile tol	ds	0.004	inch	sht 2, C-11
Erosion "tolerance"	d_e	0.003	inch	SRD
Tile length (OBD12)	L_2	5.3511795	inch	sht 1, G-6
N_CAST GAPS L2	N_2	4		

In this case, the independently calculated h_c=0.009” which is less than the design value of 0.010”. The elimination of intertile steps is achieved with h_t=0.030”.

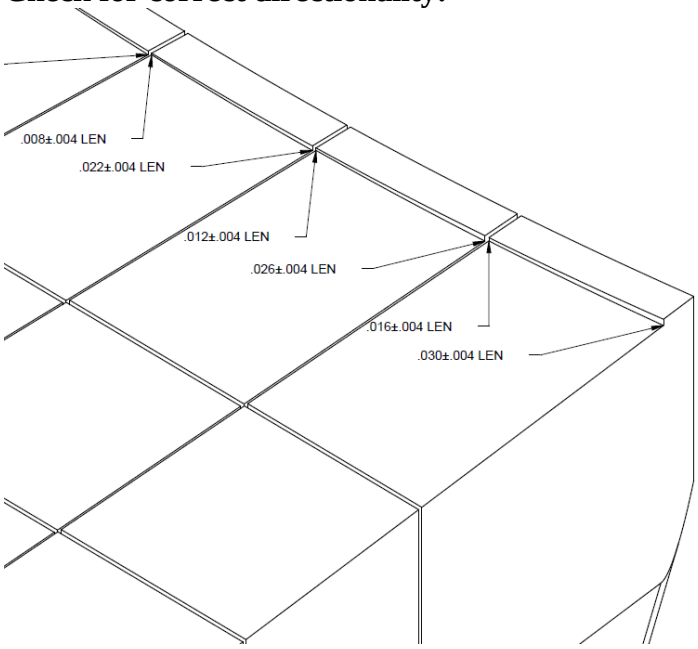
This calculation report assumes that steps within the heat transfer plate can be eliminated or reduced. Effectively, the base plate tolerance must be brought to within 0.0035” as indicated in the table above. With a base plate surface profile tolerance of 0.010”, the value of h_t=0.043”.

Either the IP for these tiles will have to reflect this requirement or a surface finish waviness will have to be defined for the Heat Transfer Plate.



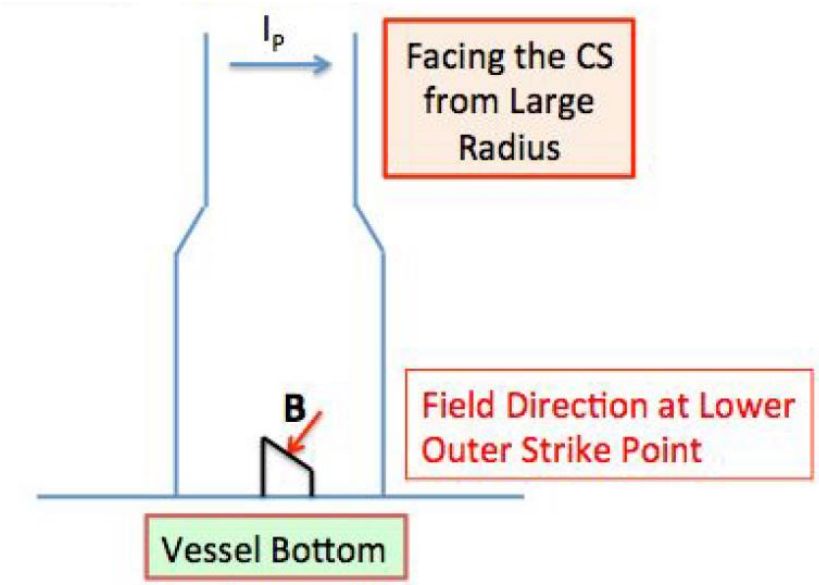
The calculated enhancement factors on these assumptions are shown above.

Check for correct directionality:



A detail from drawing E-ED1434 sht. 2 is shown above. The high side is on the left edge of each castellation when viewed from further outboard.

The comparison SRD image is shown below:



The SRD image shows that the high-point of the castellations is on the left edge when viewed from outboard. This matches the current drawing.

Minimum Requirements for Checking Calculations

1. Assure that inputs were correctly selected and incorporated into the design.

2. Calculation considers, as appropriate:

   - Performance Requirements (capacity, rating, system output)
   - Design Conditions (pressure, temperature, voltage, etc.)
   - Load Conditions (Electromagnetic (Lorentz Force), seismic, wind, thermal, dynamic)
   - Environmental Conditions (radiation zone, hazardous material, etc.)
   - Material Requirements
   - Structural Requirements (foundations, pipe supports, etc.)
   - Hydraulic Requirements (NPSH, pressure drops, etc.)
   - Chemistry Requirements
   - Electrical Requirements (power source, volts, raceway, and insulation)
   - Equipment Reliability (FMEA)
   - Failure Effects on Surrounding Equipment
   - Tolerance Buildup

3. Assumptions necessary to perform the design activity are adequately described and reasonable.

4. An appropriate calculation method was used.

5. The results are reasonable compared to the inputs.

6. Error bars (range) for inputs used, results / conclusions, assumptions, have been considered and are acceptable.

NOTE: IT IS THE RESPONSIBILITY OF THE CHECKER TO USE METHODS THAT WILL SUBSTANTIATE TO HIS/HER PROFESSIONAL SATISFACTION THAT THE CALCULATION IS CORRECT.

BY SIGNING CALCULATION, CHECKER ACKNOWLEDGES THAT THE CALCULATION HAS BEEN APPROPRIATELY CHECKED AND THAT THE APPLICABLE ITEMS LISTED ABOVE HAVE BEEN INCLUDED AS PART OF THE CHECK.