TO: T. LOOBY
FROM: M.L. REINKE
SUBJECT: INITIAL HEAT FLUX PROFILES AND CONSTRAINTS FOR MODEL VALIDATION SIMULATIONS FOR R18-1/3-G3

For Milestone R18-1/3, GOAL-3 described in PFCR-MEMO-014, the objective is to evaluate whether sub-surface temperature measurements can be used to derive scaling parameters of a heat flux model with a modest number of plasma discharges. This initial step will use a sub-section of a single IBDH castellated tile as show in Figure 1. This is the center of the 5 castellations, with no fish-scaling or chamfering of the surface. To specify the heat flux profile in a simple manner a triangular shaped profile will be applied to the surface as shown in Figure 2, with private flux and common flux features. This simply shape allows it to be specified over the surface without plasma simulation.

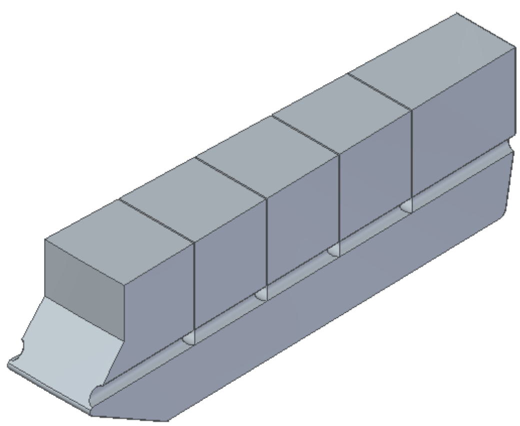

Figure 1: Sub-section of the IBDH tile. Generated from in-progress design as of 1/18/18.

The basic heat flux model is one connected to the Eich parameterization with the dependencies identified in single or multi-machine scalings.

$$\frac{S}{\lambda_q} = C_1$$

$$\lambda_q[mm] = C_2 P_{heat}^{C_3} B_p^{C_4}$$

The constants can be selected over the following ranges, with the added constraint that $\lambda_q > 1$ $[mm]$, to avoid unrealistically narrow heat flux profiles.

$$0.1 < C_1 < 0.3$$
$$1.0 < C_2 < 2.5$$
$$-0.1 < C_3 < 0.25$$
$$-1.2 < C_4 < -0.5$$

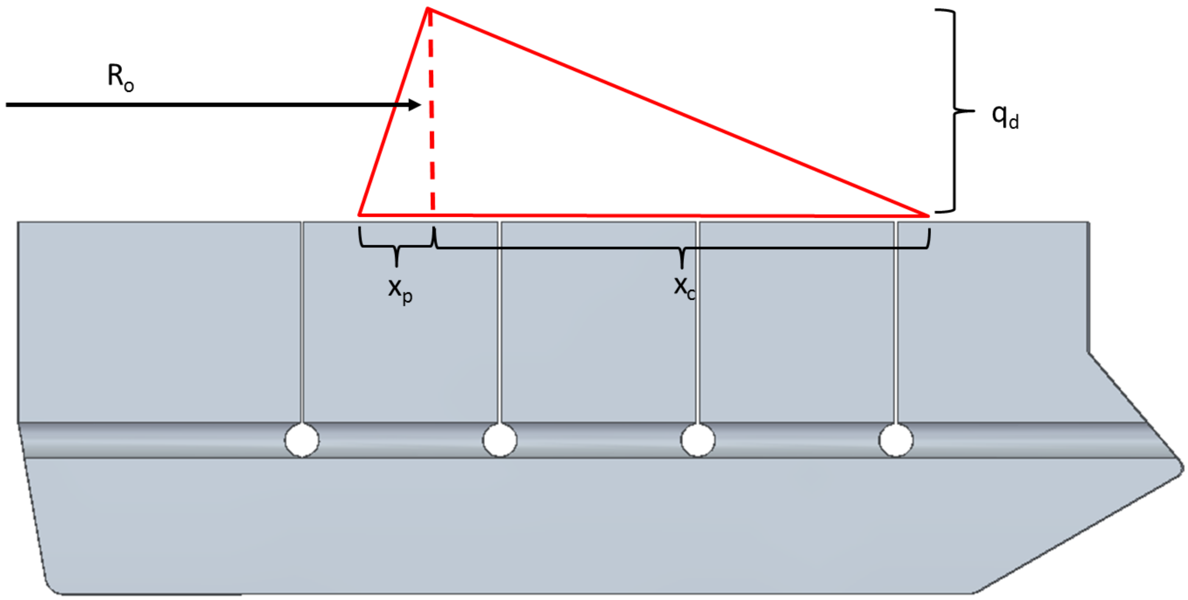

Figure 2: Heat flux model to be applied to the PFC surface.

These are then connected to the target heat flux parameters shown in Figure 2

$$x_P = Sf_x$$
$$x_C = \lambda_q f_x$$
$$P_{heat} = \int_{R_O - x_p}^{R_O + x_c} q(R) 2\pi R dR$$

Where f_x accounts for the poloidal flux expansion, assumed to be controllable, and the integral relation defines q_d.

The 'model' consists of selection of values for C_1-C_4 and then a series of 'experiments' which define the heat load to the surface by selecting values of the engineering parameters within the following ranges.

$$0.2 < B_p[T] < 0.6$$
$$0.5 < P_{heat}[MW] < 4.9$$
$$4 < f_x < 30$$
$$46.0 < R_o[cm] < 57.5$$
$$1 < \Delta t \ [sec] < 5$$

While R_o can be assumed to vary over the duration of heating pulse, Δt, within the given range, all other parameters should assumed to be fixed. Note, the tile starts at $R = 43.80$ [cm] as specified by the coordinate system in the STP file. For combinations of R_o and x_c that would put heat flux off the PFC surface, assume that there is another horizontal surface that accommodates this heat flux, for the purposes of calculating the integral to derive q_d, but only load the IBDH tile.

An 'experiment' is allowed if it does not violate the temperature limit. Assume $T_{LIM} = 1600$ degC and use the temperature-dependent properties of Sigrafine 6710 from the XML provided by the PFC team. Future studies will include demonstration that stress limits are not violated as well, but for now we expect PFCs to be temperature limited. Assume a starting temperature of 22 degC and constrain the model so that the bottom surface of the PFC remains at a fixed temperature of 22 degC.

The 'measurement' of each 'experiment' will be the time history of a sub-surface temperature measurement for $t > \Delta t$, i.e. after plasma discharge has ended. Assume that the temperature measurement is taken 1.9 cm below the surface of the PFC in the center of each castellation. For simplicity, holes for the thermocouples do not need to be included.

The goal of the study is use the 'measurements' to derive the 'model' parameters from a limited series of 'experiments', essentially deriving the transfer matrix. The desire is to increase confidence that a limited number of NSTX-U plasmas can be run well within the PFC temperature limits to derive model parameters from thermocouples for future use in model-based control of PFC temperature. Subsequent modeling will add more realistic plasma scenario and thermocouple measurement limitations.

Record of Changes

Rev.	Date	Description of Changes
0	3/12/18	Initial release for examination and review for errors.