NSTX

TF INNER LEG COOLING USING FCOOL

NSTX-CALC-132-10-00

October 20, 2010

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PPPL Calculation Form

Calculation # **132-10-00**_____ Revision # **00** WP #, if any **1672** (ENG-032)

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

To estimate the cooling time and temperature of the TF inner leg during the cooling period between discharges. The analysis was performed to provide input to the coupled EM and thermal analysis as reported in calculation: NSTXU-CALC_132-05-00.

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

[1]The FCOOL code by Fred Dahlgren
[2] NSTX Design Point June 2010
http://www.pppl.gov/~neumeyer/NSTX_CSU/Design_Point.html

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

The flow velocity is 3.3 m/s which equates to approximately 2.5 gallons per minute (GPM). An 8.5 second equivalent square wave (ESW) pulse of 135,000 Amperes is assumed to pass through each conductor during a shot.

Calculation (Calculation is either documented here or attached)

Attached

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

Calculation shows that for 135,000A flowing in each TF inner leg conductor for a pulse width (equivalent square wave) of 8.5 seconds, the cooling takes 600-700 seconds.

Cognizant Engineer's printed name, signature, and date

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

Checker's printed name, signature, and date: *Note: MATHCAD check attached at end of calc.*

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Executive Summary

The objective of this analysis was to estimate the cooling time and temperature of the TF inner leg during the cooling period between discharges. The TF inner legs are cooled by water flowing in the coolant channels in each of the 36 TF conductors. 1D Finite-section transient simulations of flow and cooling parameters were performed using the Fcool code developed by Fred Dhalgren and the PPPL team. Fcool uses input including the current flow and pulse length, coolant flow length, pressure drop, coolant channel size, and conductor size to model the flow and heat transfer in the coil and calculate the cooling time. We have calculated that for 135,000A flowing in each TF inner leg conductor for a pulse width (equivalent square wave) of 8.5 seconds, the cooling takes 600-700 seconds.

Modeling:

Figure 1 is a cross section of the TF inner bundle. The length of the TF conductor is 17.68 ft, the inner diameter of the cooling channel is 0.305 inches. The copper cross sectional area of the conductor is 4.97 square inches. The flow velocity is 3.3 m/s which equates to approximately 2.5 gallons per minute (GPM). An 8.5 second equivalent square wave (ESW) pulse of 135,000 Amperes is assumed to pass through each conductor during a shot.

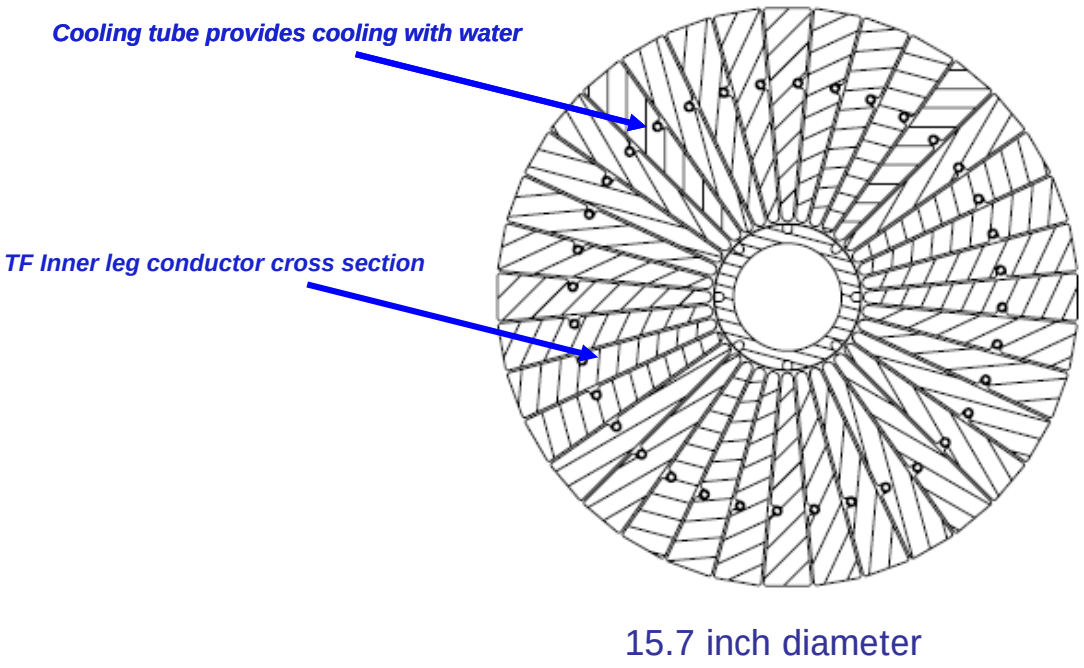

Figure 1: TF inner leg bundle cross section

Fcool program, developed by Fred Dhalgren and the PPPL team, was used for this analysis. Fcool uses input including the current flow and pulse length, coolant flow length, pressure drop, coolant channel size, and conductor size to calculate the heating due to the current pulse and model the flow and heat transfer in the coil in order to calculate the cooling time. It does this by dividing the coil into small finite length sections and sequentially solving the cooling and hydraulic parameters in the length sections using closed form equations.

Results:

Table 1 is a list of important parameters of the flow and cooling analysis. Figure 2 is a plot of coil temperature vs. time.

PARAMETERS:		
PRESSURE DROP:	15.50	PSI
VELOCITY:	11.25	FT./SEC.
FLOW RATE:	2.58	GPM
MDOT:	0.36	LBS/SEC
PATH LENGTH:	17.68	FT.
REYNOLDS NO.:	21349.44	
h-film:	0.60	BTU/SQ.FT.-SEC.-DEG.F
CUR. DENSITY:	27184.95	AMPS/SQ.IN
TIME INCR.:	0.01572	SEC
ESW:	8.50	SEC.
REP. RATE:	1800.00	SEC.
INLET TEMP.:	53.00	DEG. F
CMASS:	0.00	LBS
HTL:	0.24530	FT.
NODE INTERVAL:	0.17680	FT.

Table 1: Analysis parameters

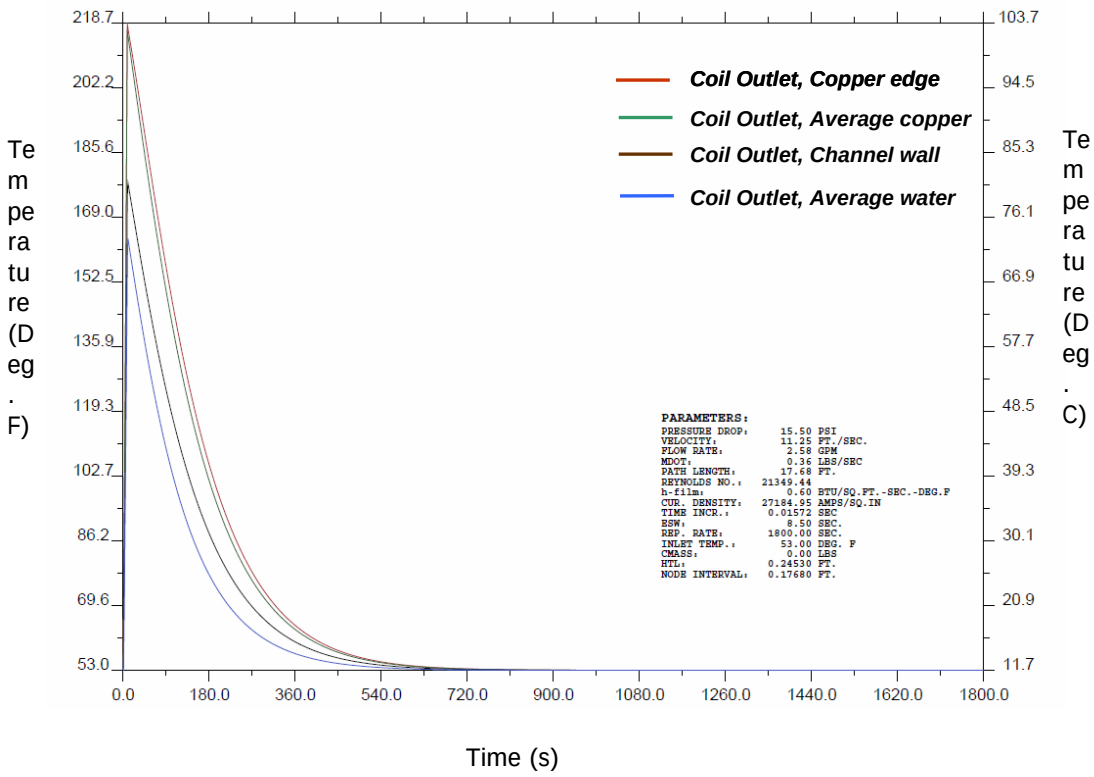

Figure 2: Temperature vs. time at the coil outlet

Figure 2 shows that the TF inner leg conductor is cooled in 600-700 seconds.