TO: DISTRIBUTION
FROM: C NEUMEYER
SUBJECT: TF FLAG CONNECTIONS

References:

[1] 13-970213-JMS-01, " Summary Description of TF, OH and PF Connection Schemes"

This memo serves to clarify the requirements set forth in the reference memo for the angular twist of the TF inner leg bundle to minimize field errors. It also points out a non-ideal situation in the installation of the original NSTX TF bundle. The project needs to decide if it is important to correct this defect, which would require TBD rework and/or re-fabrication of some of the flag-to-outer leg connector pieces.

Ideal Configuration

The winding pattern at the top of the machine, viewed from above, is shown in figure 1.

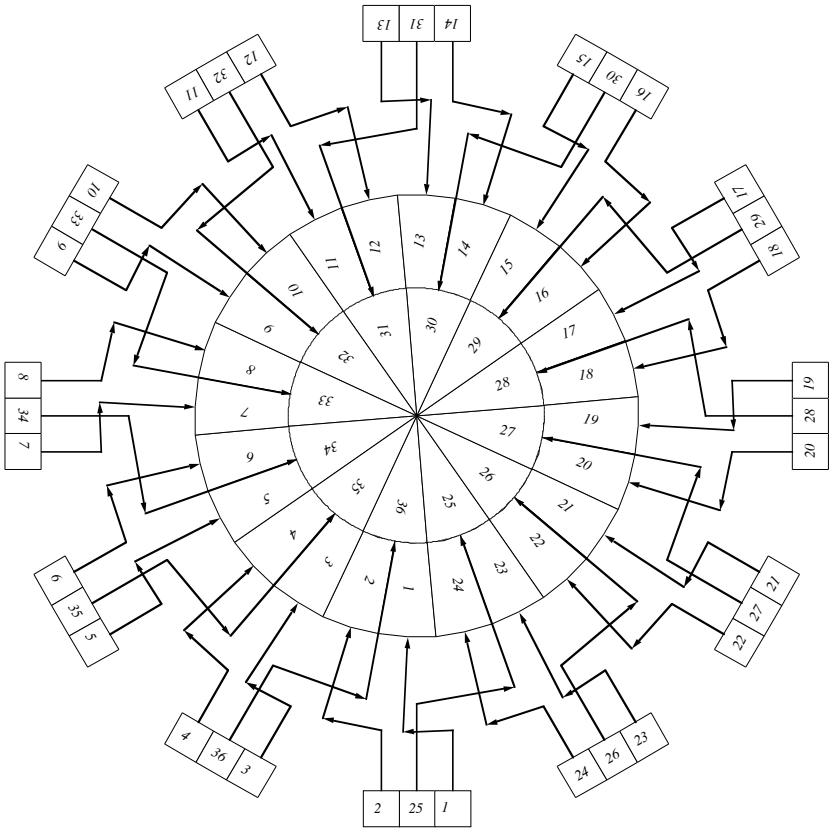

Figure 1: TF Connections at Top of Machine, Viewed from Above

It is noted that the connections proceed in the (CW) clockwise direction for the 24 outer layer turns and counter-clockwise (CCW) for the 12 inner layer turns. Positive current proceeds up the outer legs and down the inner legs, making a CW toroidal field, per the engineering convention.

The turn to turn connections result in a toroidal progression of the current. Each connection corresponds to a particular angle of toroidal progression. The criteria for field error minimization is to balance the CW toroidal progressions with the CCW toroidal progressions.

In order to accomplish this cancellation, a particular "clocking angle" is required, meaning that the inner leg bundle has to be rotated in the CCW direction, viewed from above, until the 12 CCW inner leg progressions equal the sum of the 24 CW outer leg progressions. The angles are identified in figure 2.

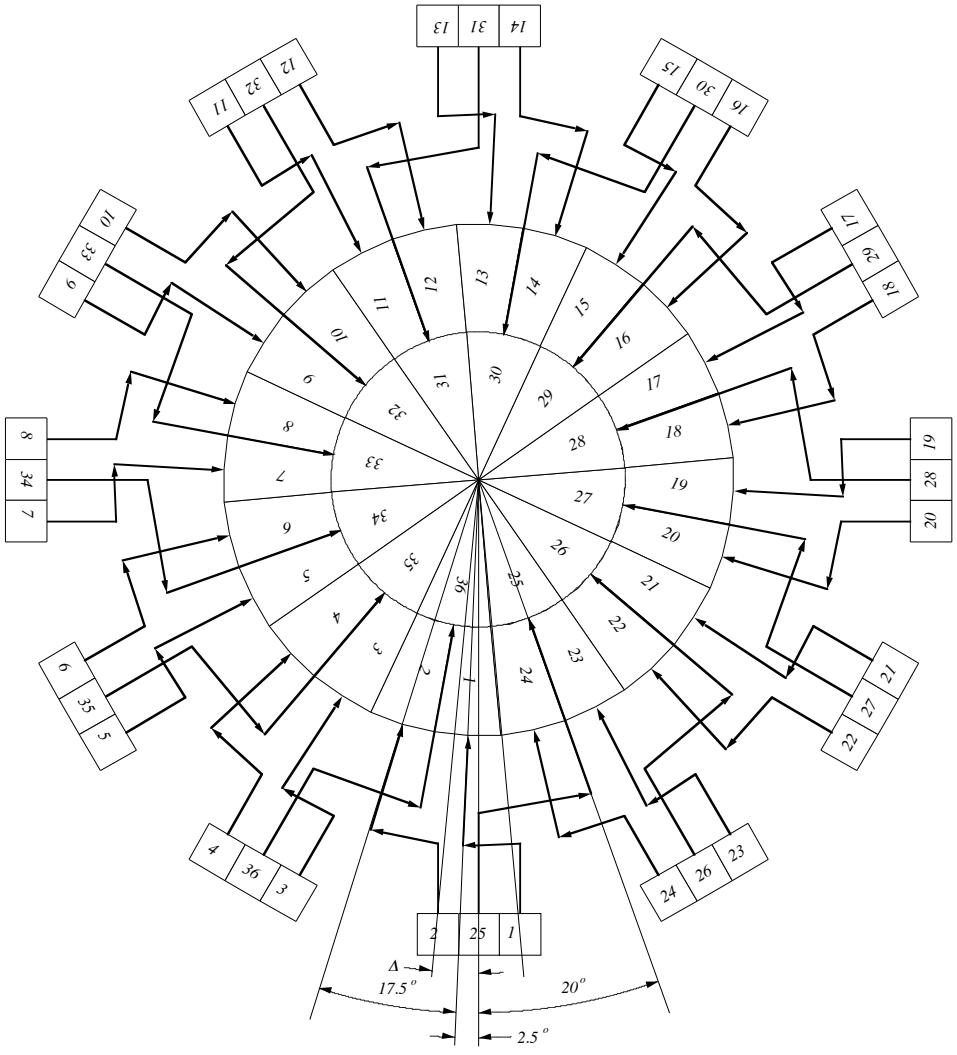

Figure 2: TF Connections at Top of Machine, Viewed from Above, Showing Angles

Note that the inner leg bundle is positioned such that the centerline of turn 25 is 20º CCW from vertical. Therefore the connection from the outer leg to inner layer turn 25 has a 20º CCW toroidal progression. Next, note that the centerlines of turns 1 and 2 are located 30º /2+15º /2=22.5º CW and 30º /2+15º +15º /2=37.5º CW respectively, from the centerline of turn 25, which translates to 22.5º - 20º = 2.5º CW and 37.5º- 20º =17.5º CW, respectively, from vertical as shown. The sum of these progressions is 2.5º + 17.5º = 20º which offsets the 20º CCW from the outer leg to turn 25. In actuality, the outer leg location of turn 2 is offset by a CW angle Δ from vertical, and turn 1 by a CCW angle Δ from vertical. In terms of the net summation of toroidal progressions, these angles cancel out.

The 20º clocking of the inner leg bundle also serves to cancel the field errors on the bottom of the machine as shown in figure 3.

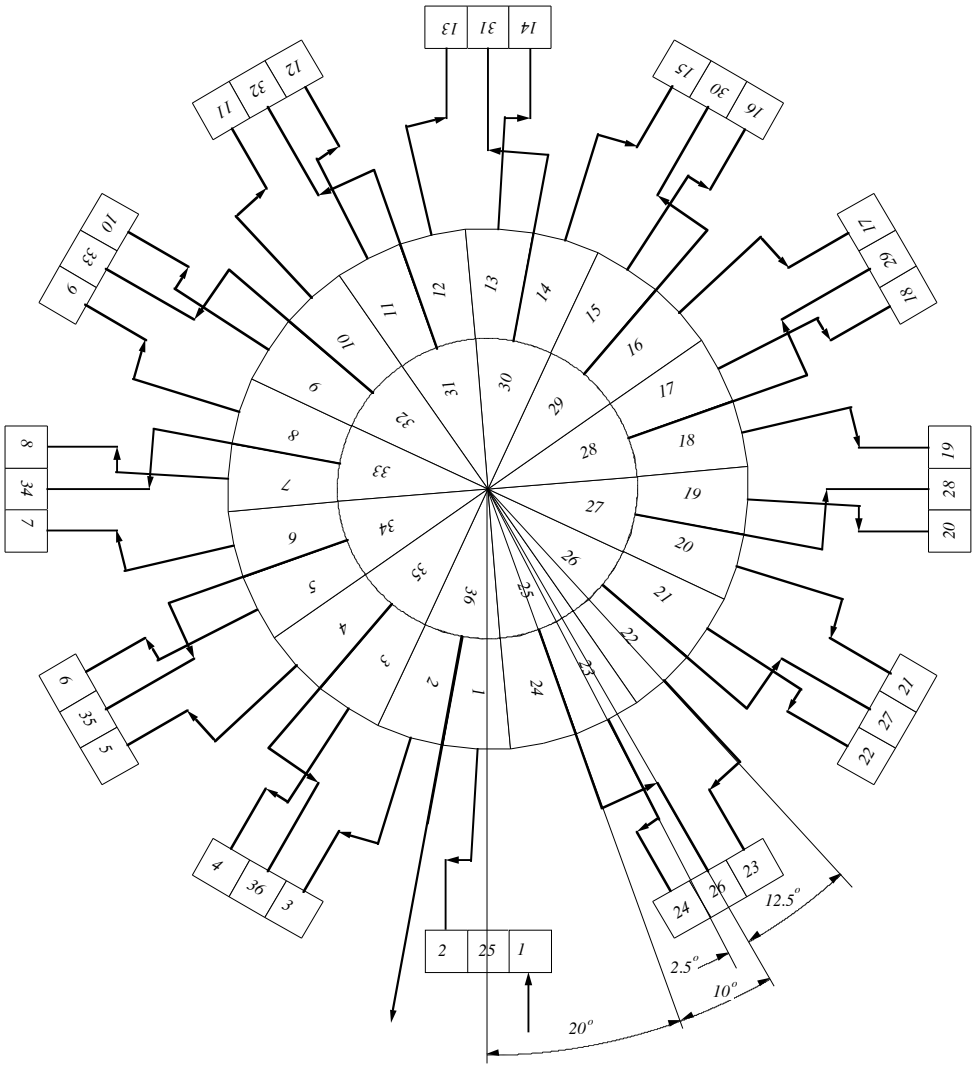

Figure 3: TF Connections at Bottom of Machine, Viewed from Above, Showing Angles

On the bottom current enters from the external circuit on turn 1 and exits from turn 36. The connection from the inner layer turn 25 to the outer leg is noted to have a toroidal progression of 10º CCW. The connections from outer layer turns 22 and 23 have progressions of 12.5º CW and –2.5º CW, respectively, which has a net of 10º CW, offsetting the connection from turn 25.

Original NSTX TF Bundle Installation

Examination of the drawings of the connector arrangement of the original NSTX TF bundle installation indicates that the centerlines of the outer layer conductors are aligned with the centerlines of the outer legs. This means that the aforementioned clocking angle is 22.5º instead of the intended 20º.

Therefore, on the top of the machine, the connections to the inner layer amount to a total toroidal progression of 12*22.5º =270º in the CCW direction. The connections to the inner layer turns consist of 12 with zero toroidal progression (they line up with the centerline of the outer leg) and another 12 with a 15º progression (one turn away) which amounts to a total toroidal progression of 12*15º =180º in the CW direction. The net equivalent would consist of 12 CCW current vectors each of 22.5º - 15º = 7.5º extent.

On the bottom of the machine, the connections to the inner layer amount to a total toroidal progression of 12*12.5º=150º in the CCW direction. The connections to the inner layer turns consist of 12 with zero toroidal progression (they line up with the centerline of the outer leg) and another 12 with a 15º progression (one turn away) which amounts to a total toroidal progression of 12*15º =180º in the CW direction. The net equivalent would consist of 12 CW current vectors each of 15º – 12.5º = 2.5º extent.

To guide in the evaluation of the field errors, the elevations of the centerlines of these connections are as follows…

Original TF Bundle:

Outer layer z = +/- 2.461m
Inner layer z = +/- 2.718m

New TF Bundle:

Outer layer z = +/- 2.461m
Inner layer z = +/- 2.769m

The radius midway between the end of the flag and the outer leg connector is 0.561m.

cc:	M Bell	J Chrzanowski	T Egebo	J Menard
	M Ono	B Paul	A VonHalle	M Williams