TO: DISTRIBUTION
FROM: C NEUMEYER
SUBJECT: TF INNER LEG ASSEMBLY GROUND INSULATION CRITERIA

References:

[1] 71-000128-CLN-01, " NSTX Voltage Isolation"
[2] 13-970430-JHC, "Center Stack R&D Final Report"
[3] "ITER Magnet Electrical Design Criteria", C. Neumeyer, May 1996

This memo addresses issues related to the TF ground insulation.

The TF power supply voltage is Vtf =1kV no load. However, since the TF inner leg column faces the OH tension tube which is at CHI potential, and since the TF flags face the hub assembly which is also at CHI potential, the TF ground insulation on the inner legs and flags can be exposed to a potential difference equal to Vtf – Vchi under worst case conditions.

Original plans for NSTX allowed for Vchi = 2kV. However, after deciding to connect the center stack structures to the CHI potential, CHI operation was restricted to Vchi = 1kV (ref. [1]). Even with this reduced CHI level, the TF ground insulation, originally anticipating 1kV maximum, was being operated at, in effect, 2kV. The hipot was held at 2E+1=3kV, where E=1kV, however, for fear of damaging the TF insulation by the hipot. In principle the hipot should have been 2E+1=5kV, where E=1+1=2kV.

Now that we are fabricating a new TF Inner Leg Assembly it is appropriate to revisit this situation and determine if the 2kV CHI capability can be achieved without major design impact. This would imply a DC hipot of 2E+1=7kV, where E=1+2=3kV.

TF Inner Leg Insulation

Insulation between copper and ground consists of CTD-112P turn insulation in series with Scotchply groundwall. Assessment of safety factors for the Vchi=1kV and Vchi=2kV cases is given in the following table.

Scotchply Groundwall Thickness	0.054	in	
Scotchply Groundwall Dielectric Strength	400	VPM @ 0.125" (Assume same as G10 (http://www.acculam.com/s2.htm))	
Scotchply Insulation Strength	21.6	kV	
CTD-112P Turn Insulation Thickness	0.032	in	
CTD-112P Dielectric Strength	341	VPM @ 0.038" (NSTX R&D Table 3-8, min value=13kV))	
CTD-112P Insulation Strength	10.92	kV	
Total Insulation Strength	32.52	kV	
Vchi	1	2	kV
Max Operating	2	3	kV
Hipot	5	7	kV
Safety Margin over Operating	16.3	10.8	
Safety Margin over Test	6.5	4.6	

TF Flag Insulation

Insulation between flag and flag boxes will consist of 2 half-lapped layers of 0.002” Kapton tape, along with Hysol potted glass wrap, nominally 0.125” but 0.1” minimum depending on tolerance build-up. Assessment of safety factors for the Vchi=1kV and Vchi=2kV cases is given in the following table.

Kapton Flag Insulation Thickness	0.008	in	
Kapton Dielectric Strength	3000	VPM @ 5 mil (http://www.pleo.com/dupont/kap_thick.htm)	
Kapton Insulation Strength	24	kV	
Potting Thickness (min)	0.1	in	
Potting Dielectric Strength	400	VPM @ 0.125" (Assume same as G10 (http://www.acculam.com/s2.htm))	
Potting Insulation Strength	40	kV	
Total Insulation Strength	64		kV
Vchi	1	2	kV
Max Operating	2	3	kV
Hipot	5	7	kV
Safety Margin over Operating	32.0	21.3	
Safety Margin over Test	12.8	9.1	

Creepage Paths

There are two creepage path situations associated with the flags as depicted in figures 1 and 2 below. There will be others associated with the water tubes in the bulkhead. Creepage paths #1 and #2 shown in the figure below exist between the flag conductor and the flag box.

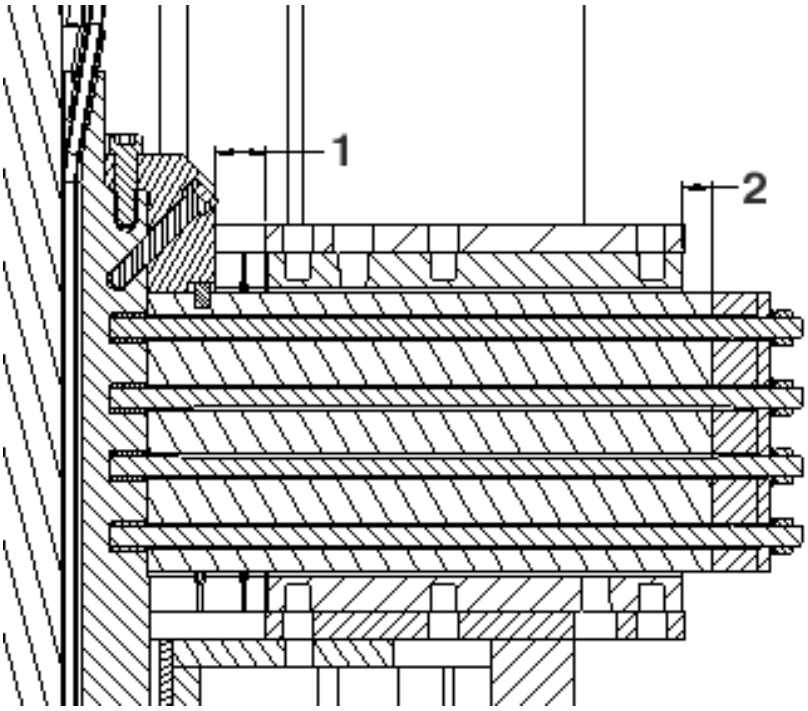

Fig. 1

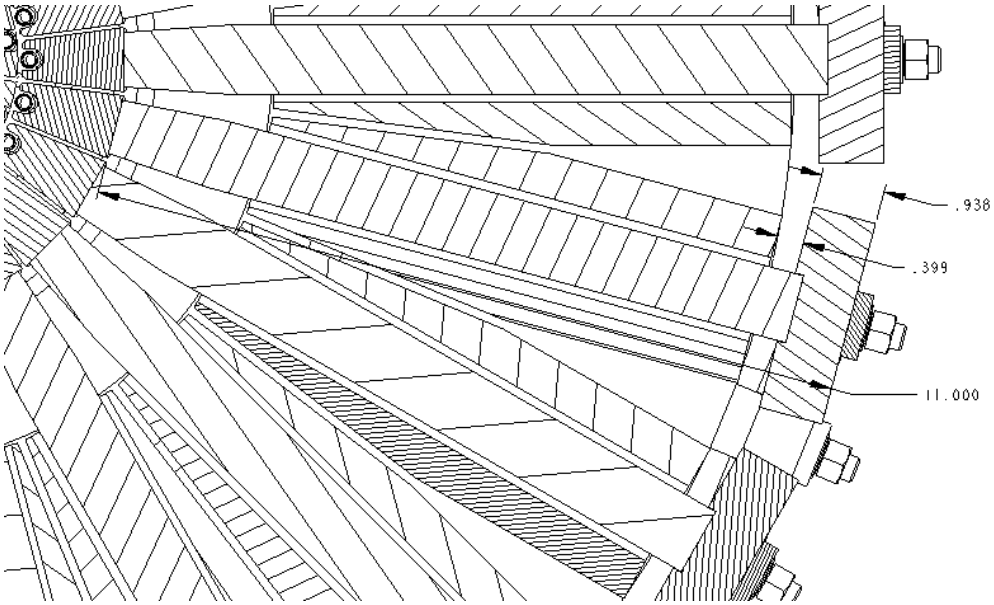

Fig. 2

The electric field configuration is similar to that of the ends of an insulated conductor with ground plane as shown in figure 3.

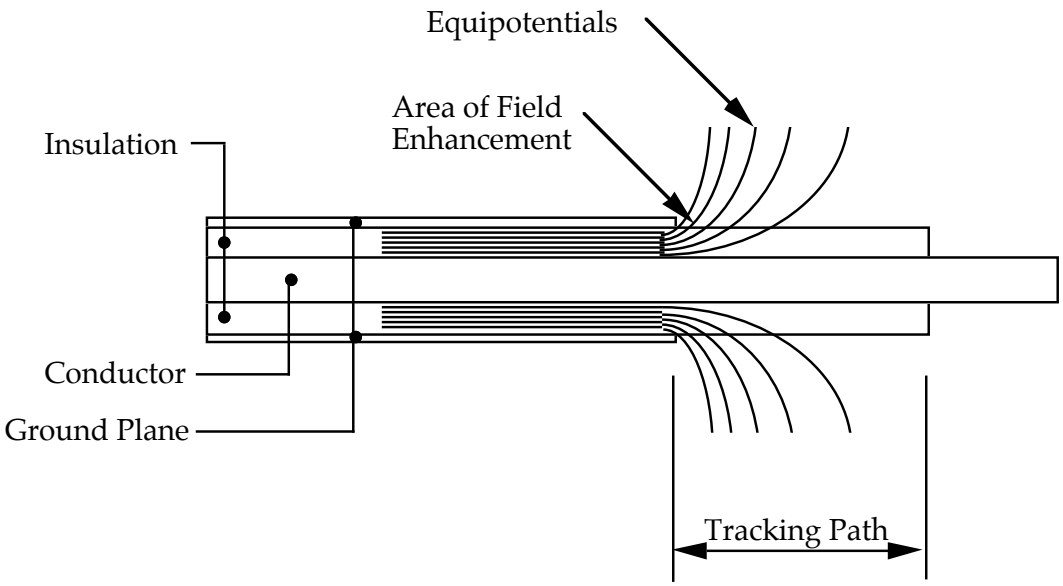

Fig. 3

In ref. [3] a method is derived for approximation of breakdown in air under worst case electrode geometry conditions (Vbreakdown = 8.485*(d*2.54)^0.823), V in kV, d in inches). This can be applied, for purposes of rough approximation, to the creepage situation under clean (uncontaminated) conditions. The following table summarizes the result for the two creepage paths.

Path	#1		#2		
Path Length	0.90		0.40		in
Breakdown Voltage	16.8		8.6		kV
Vchi	1.0	2.0	1.0	2.0	
Max Operating	2.0	3.0	2	3.0	kV
Hipot	5	7	5	7	kV
Safety Margin over Operating	8.4	5.6	4.3	2.9	
Safety Margin over Hipot	3.4	2.4	1.7	1.2	

Conclusions and Recommendations

1) The TF inner leg ground insulation and the flag insulation appear to have sufficient margin to accommodate the Vchi=2kV operation, 7kV hipot.
2) Creepage path #1 (0.9") also seems adequate.
3) Creepage path #2 is not, by itself, adequate at 0.4". It is recommended that insulation be applied over the entire end of the flag (tee) so as to extend the path to > 1". This was done on the original TF flags, which were insulated with Fusa-fab. In order to accomplish the same thing with the kapton wrap on the main body of the flag, some sort of insulating boot is needed over the end of the tee.

4) The methodology used in the above is very rough, and does not account properly for electric field enhancement and composite dielectrics in series. Prototype tests should therefore be performed to confirm these findings, even though the safety factor appears to be quite adequate in the case of the groundwall and flag insulation. The following are recommended:

    a. Perform breakdown tests (sample set of at least four) from copper to (temporary paint or foil) ground on the original TF inner leg assembly, either before or after dissection, whichever is more convenient. (ACTION: T. Meighan)
    b. Perform a breakdown test on the prototype flag potted in the box. More samples would be better, but we plan only one prototype. (ACTION: T. Meighan)
    c. Perform mock-up creepage breakdown tests of the configuration shown in figure 4 for gaps of d = 0.2 to 1.0 inch, in 0.1 inch increments. (ACTION: E. Baker)
    d. Repeat c. with configuration shown in figure 5 (ACTION: E. Baker)

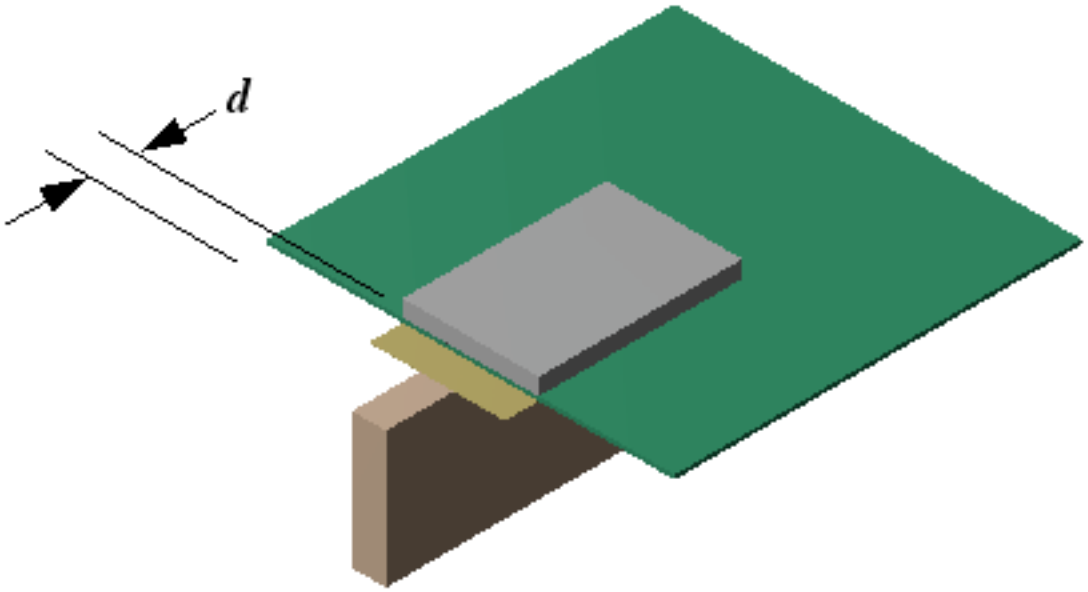

Fig. 4 – Mock-up of creepage
(1”x4”x6” Cu (or steel) block) simulating flag, 12”x12”x0.125” G10 sheet simulating potting, 4” x 6” x 0.008” Kapton sheet, 0.5”x4”x6” steel block simulating flag box)

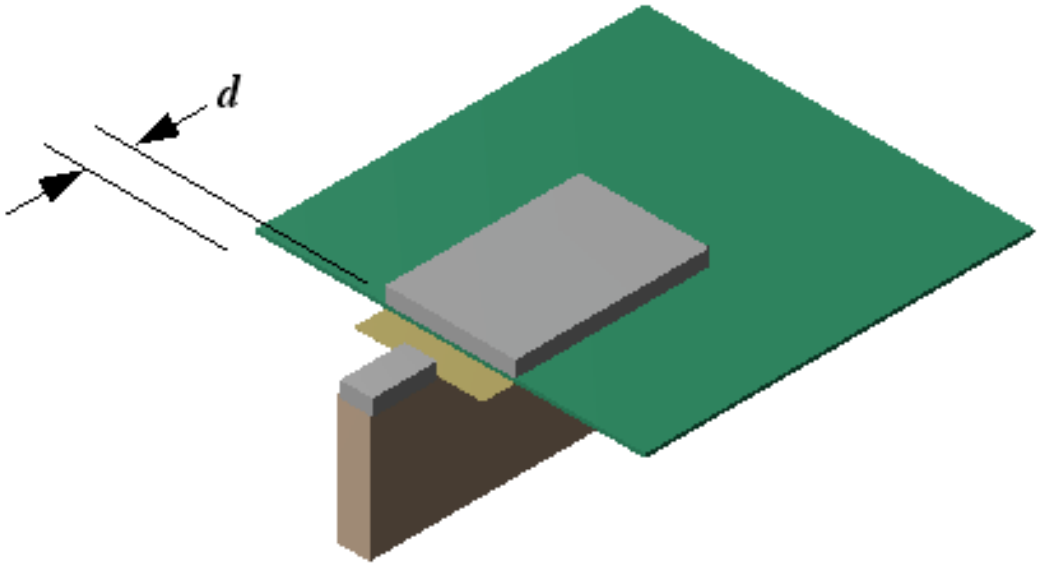

Fig. 5 – Same as figure 4 except add 1/2" x 1" x 2" block on top of simulated flag

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