13-980720-CLN-01

TO: DISTRIBUTION
FROM: C NEUMEYER
SUBJECT: OH GROUND PLANE REWORK AND GROUNDING CONNECTIONS

Reference:

1) 13-980704-CLN-01, "OH Ground Plane Behavior"
2) 13-980714-CLN-01, "OH Ground Plane Rework And Grounding Connections"

Reference [1] provided an analysis of the OH ground plane behavior based on the ground plane provided by the coil manufacturer, which was judged therein to be too resistive.

Reference [2] described a rework scheme involving the application of a low resistance paint over the high resistance paint originally applied by the manufacturer, and suggested a means for making a grounding connection.

This memo provides revised instructions for reworking the ground plane and providing connections to ground, and therefore supercedes reference [2].

Revised Ground Plane Scheme

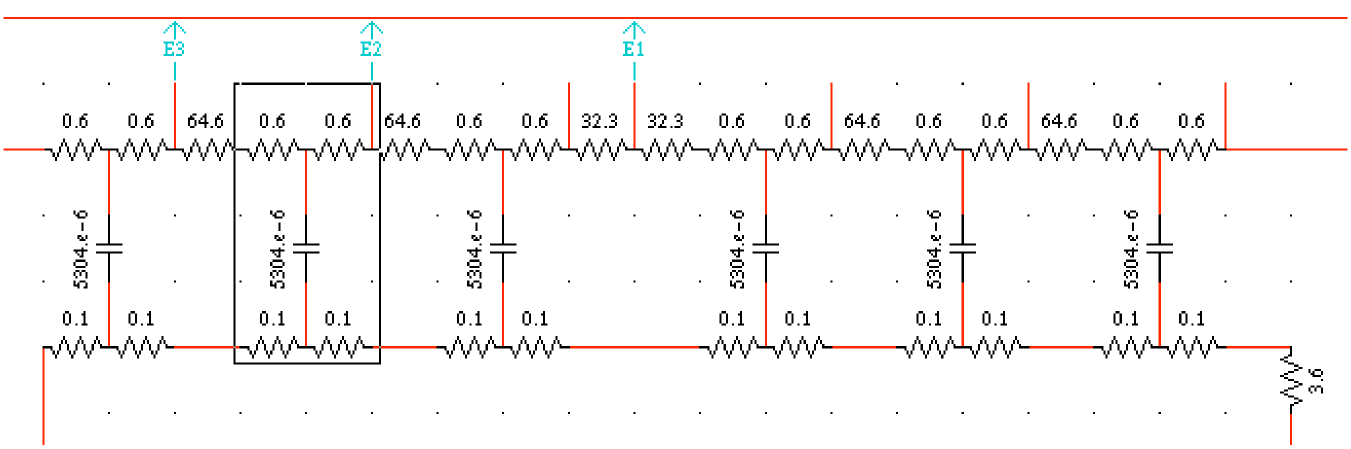
In recognition of the fact that voltage is induced in the poloidal, as well as toroidal, direction, and considering that, with the prior design, faults could occur which could lead to unacceptably large ground currents in the poloidal direction, it has been decided to mask off additional toroidally oriented stripes along the axis of the OH coil. The prior design called for only one such stripe. The following spreadsheet indicates the effective resistance and maximum current flow in the toroidal direction, and poloidal direction, with the proposed scheme consisting of two stripes opposite one another along the axis of the OH coil and five circumferential stripes equidistant from one another along the axis of the OH coil. The "Low Tol" column corresponds to the case where the high resistivity paint exhibits resistance on the low end of the manufacturer's (Ranbar) data sheet range, and "Hi Tol" the high end of the range. The "Assumed" column corresponds to the most likely value of resistivity, based on measurements made by T. Meighan. It is noted that, with the proposed design, using 50Ω resistors in the ground connections, the resulting ground/ground plane resistance is quite similar to that which would have been obtained using the originally specified (Von Roll/Osola #8003) 100Ω/square paint. Induced currents and energy loss in the conductive paint layers will be limited to acceptable levels.

	Low Tol	Assumed	Hi Tol	
Coil OD	12.3			in
Coil Circumference	38.7			in
Coil Length	210.0			in
Length of End Sections	6.0			in
Ground Plane Length	198.0			in
Hi R Resistivity	2000.0	2500.0	5500.0	Ω/square
Lo R Resistivity	1.0	1.5	2.0	Ω/square
Layer Thickness	0.002			in
TOROIDAL				
#Hi R Stripes	2			
Hi R Stripe Width	1.00			in
R/Hi R Stripe	2000.0			Ω-in
	10.1			Ω
∑R(Hi R)	4000.0			Ω-in
	20.2			Ω
#Lo R Stripes	2			
Lo R Stripe Width	18.4			in
R/Lo R Stripe	18.4			Ω-in
	0.1			Ω
∑R(Lo R)	36.7			Ω-in
	0.2			Ω
∑R	4036.7			Ω-in
	20.4			Ω
Voltage	10			volt
Current	0.002			amp/in
	0.490			amp
Power	6.137			watt/in^3
Time	0.005			sec
Energy	0.031			joule/in^3

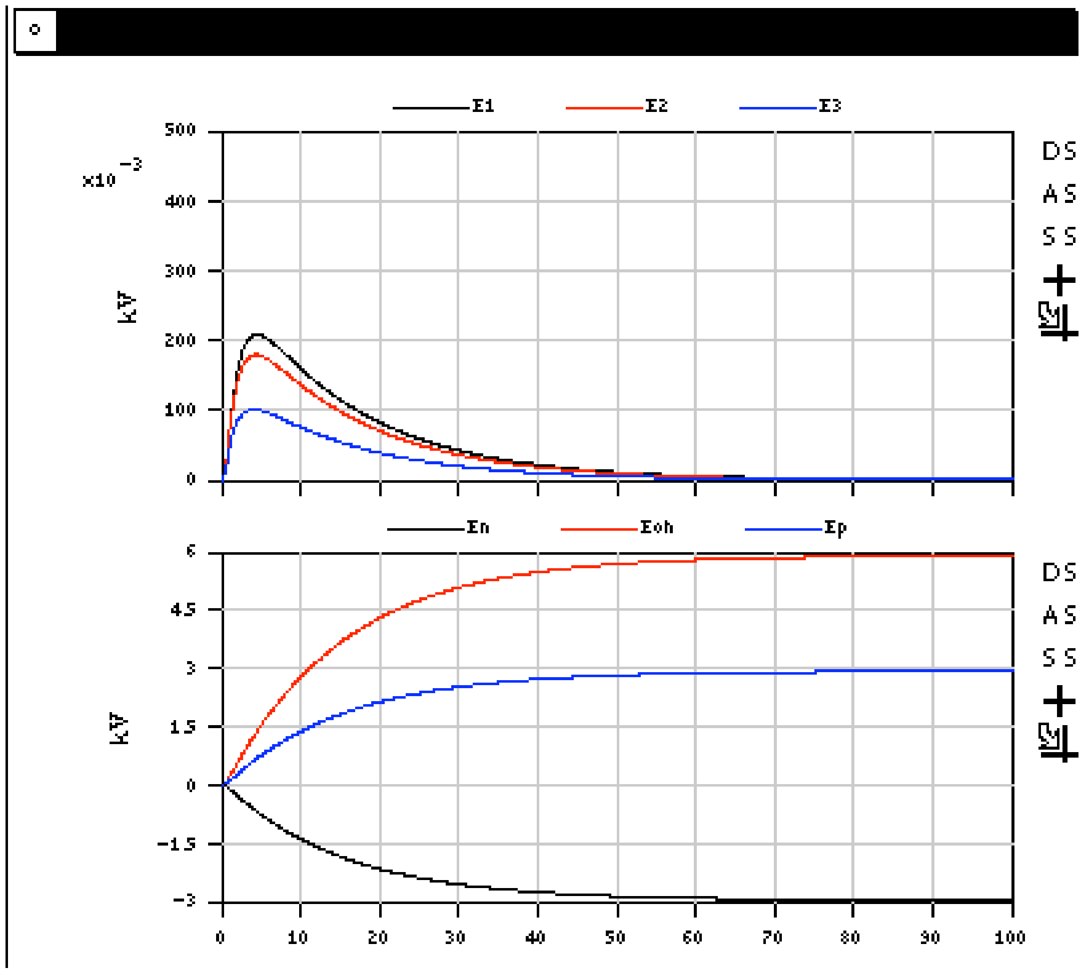
POLOIDAL				
#Hi R Stripes	5			
Hi R Stripe Width	1.00			in
R/Hi R Stripe	2000.0			Ω-in
	51.7	64.6	142.1	Ω
∑R(Hi R)	10000.0			Ω-in
	258.3			Ω
#Lo R Stripes	6			
Lo R Stripe Width	32.2			in
R/Lo R Stripe	32.2			Ω-in
	0.8	1.2	1.7	Ω
∑R(Lo R)	193.0			Ω-in
	5.0			Ω
∑R	10193.0			Ω-in
R/ground resistor	50.0			Ω
Rnet	363.3			Ω
Voltage	27.8			volt
Current	0.002			amp/in
	0.076			amp
Power	3.901			watt/in^3
Time	1.000			sec
Energy	3.901			joule/in^3

Performance of Ground Plane

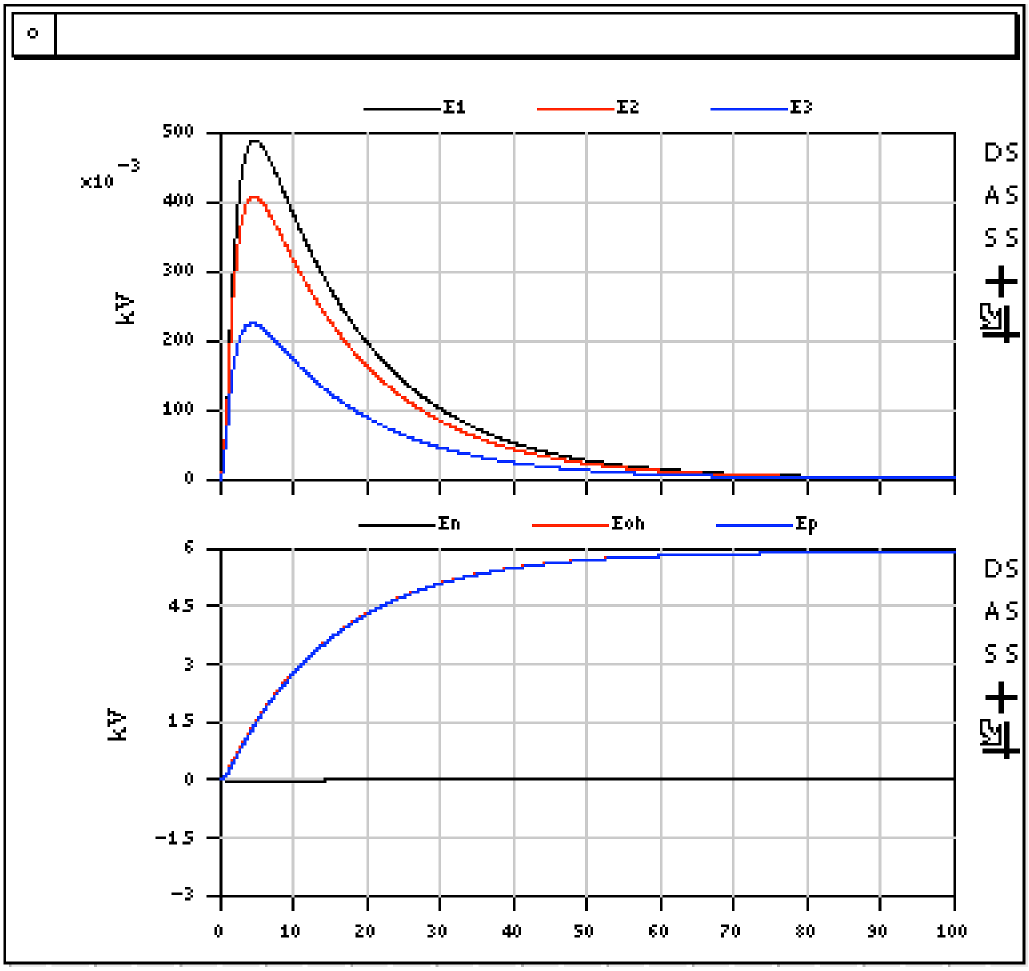
As described in [1] a model of the transient behavior of the ground plane was created using PSCAD. The simulation reported in [1] was repeated using the nominal expected value of ground plane resistance (64.6 Ω per high resistance stripe, 1.2 Ω per low resistance stripe) with the new proposed design. The results are given in the following figures.



Coil/Ground Plane Model



Voltages on Ground Plane for Normal Operations



Voltages on Ground Plane in Case of Ground Fault
on One Terminal of Coil/Power Supply

The peak voltages of 200V and 500V, respectivly, for the two cases, are considered acceptable.

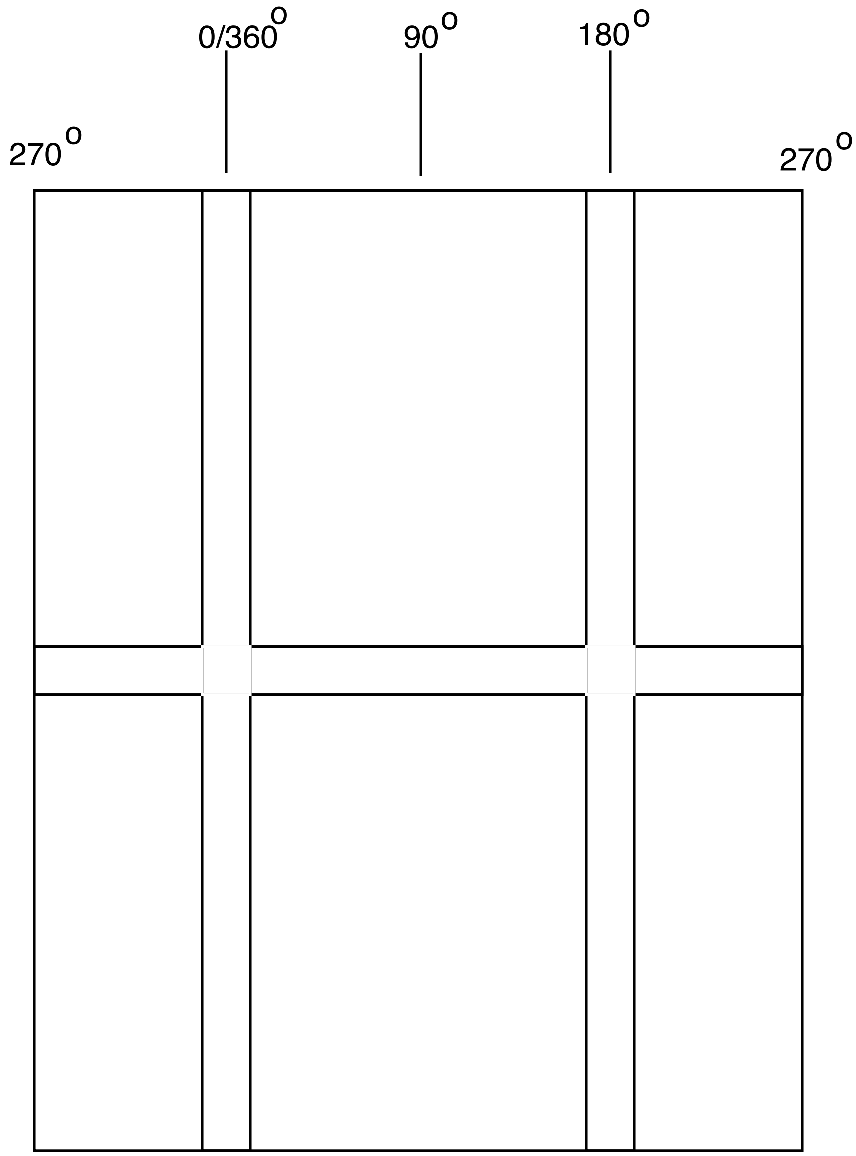
Rework and Grounding of Coil

Prior to the rework, the condition of the coil is assumed as follows based on the prior sequence of steps:

• Groundwall of coil covered by Ranbar B-2-135 type semi-conductive paint (2000-5500 ohms/square) by the manufacturer, Everson Electric;

• Semi-conductive paint covered by polycrylic sealer by PPPL;

• Three 1.25" wide stripes (two azimuthal, one circumferential) of semi-conductive paint and sealer were removed by PPPL, down to the original ground plane surface, as depicted in the following figure (developed view, outer surface of OH coil). Azimuthal stripes located at 0^o and 180^o positions.

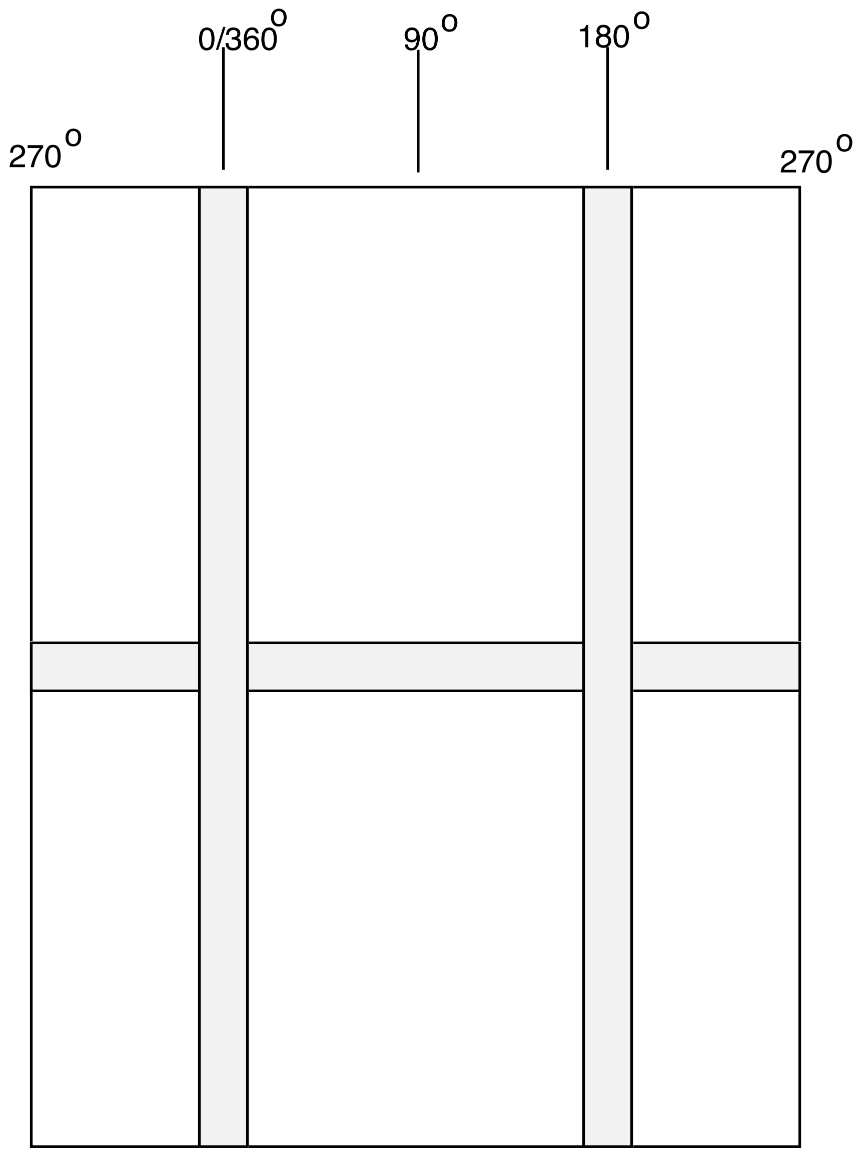


• Three 1.25" wide stripes of Glyptal insulating paint applied by PPPL over the stripes made in the previous step.

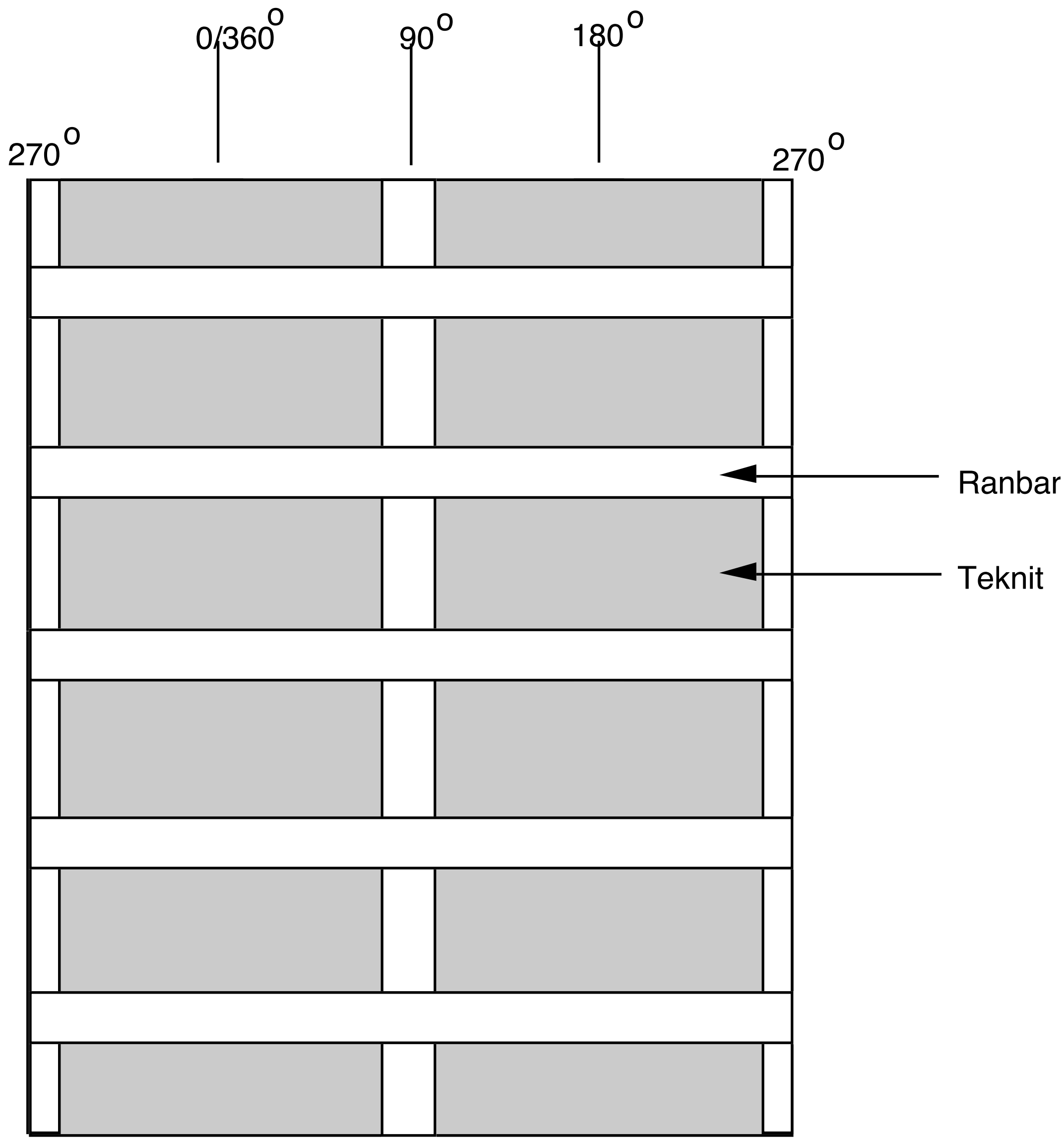
Rework Instructions

• Prepare the regions of the coil surface still covered by sealer to accept additional coats of paint by very light sanding.

• Apply Ranbar B-2-135 type semi-conductive paint (2000-5500 ohms/square) over the previously applied stripes of Glyptal insulating paint as depicted in the following figure.

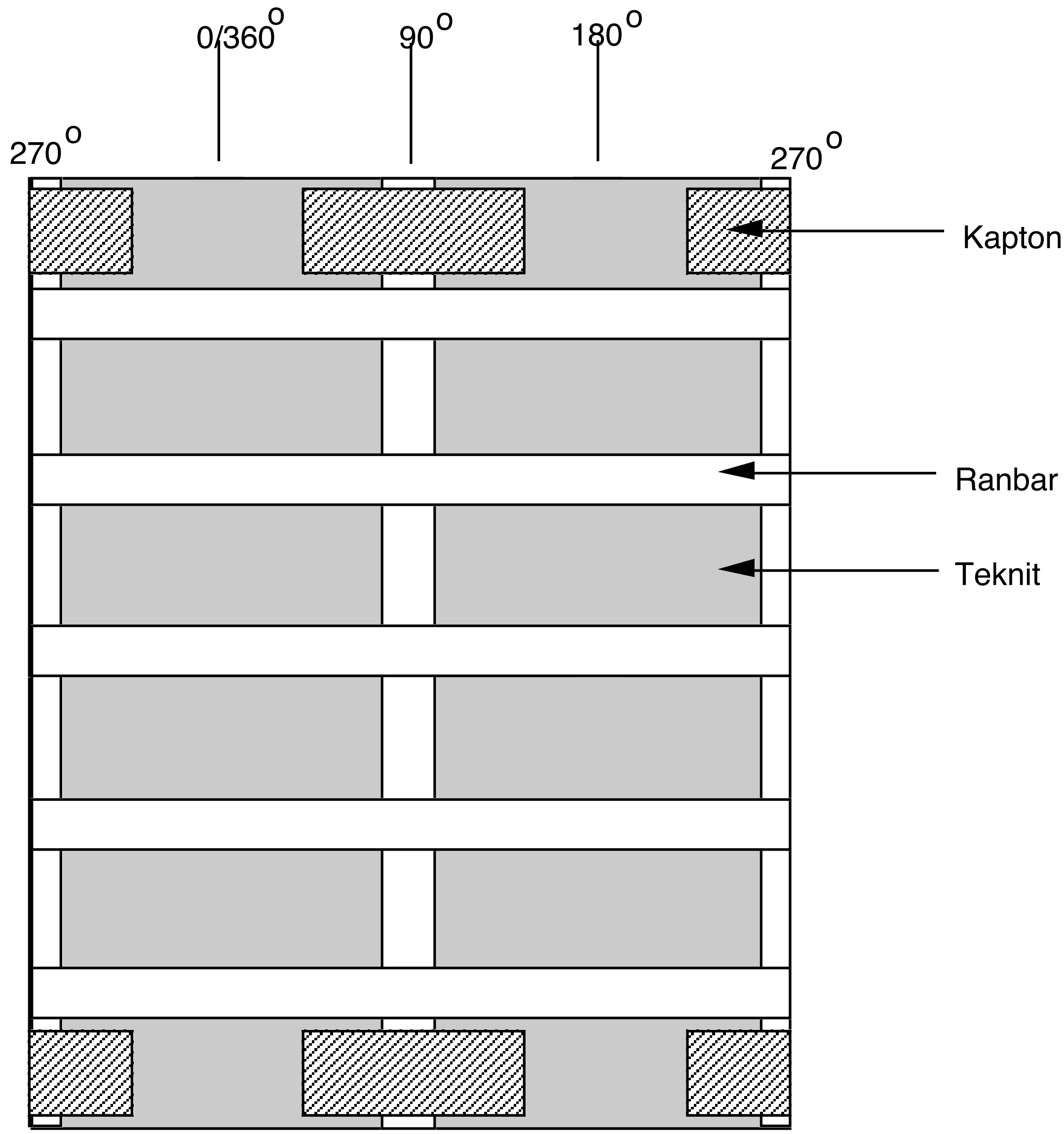


• Mask off seven 1" wide stripes, two azimuthal and five circumferential, with azimuthal stripes located at 90º and 270º positions (180º apart). Five circumferential stripes shall be evenly spaced in the azimuthal direction. Then overcoat the entire unmasked area with Tecknit type 73-0025 conducting paint (1 Ω/square) as depicted in the following figure.

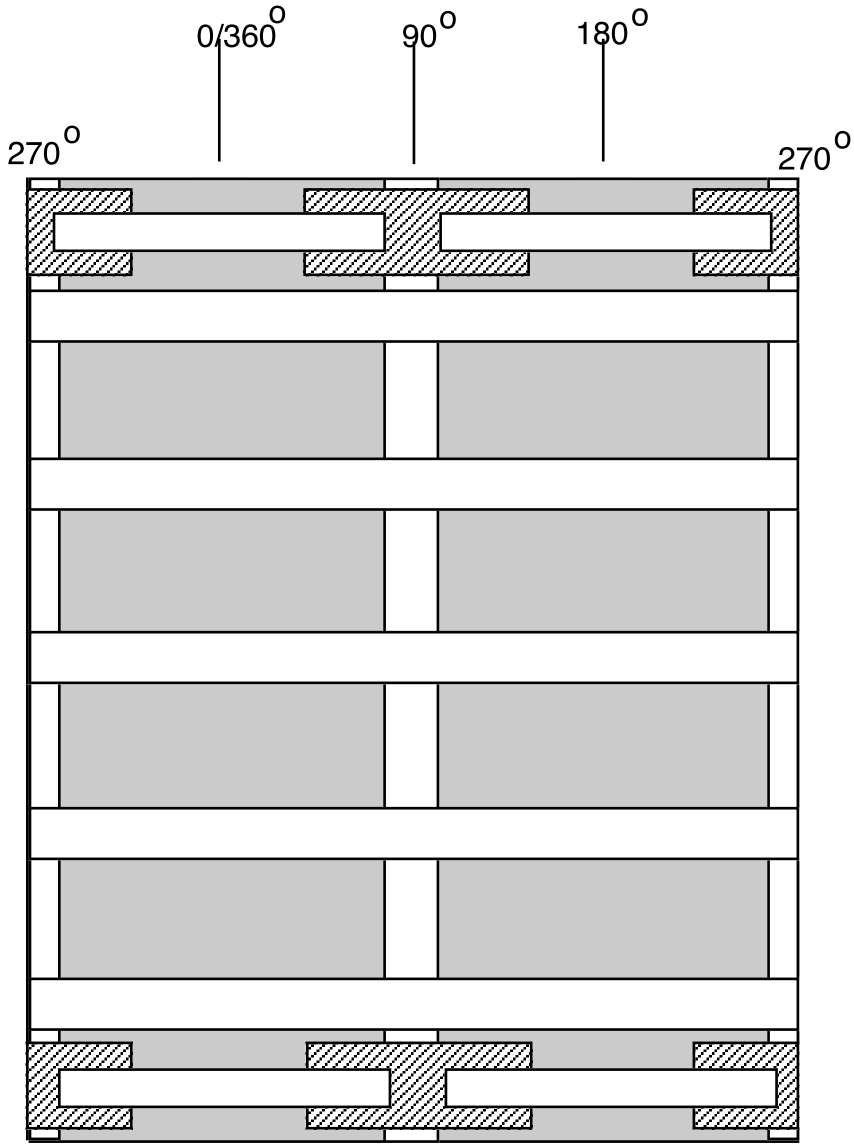


Grounding

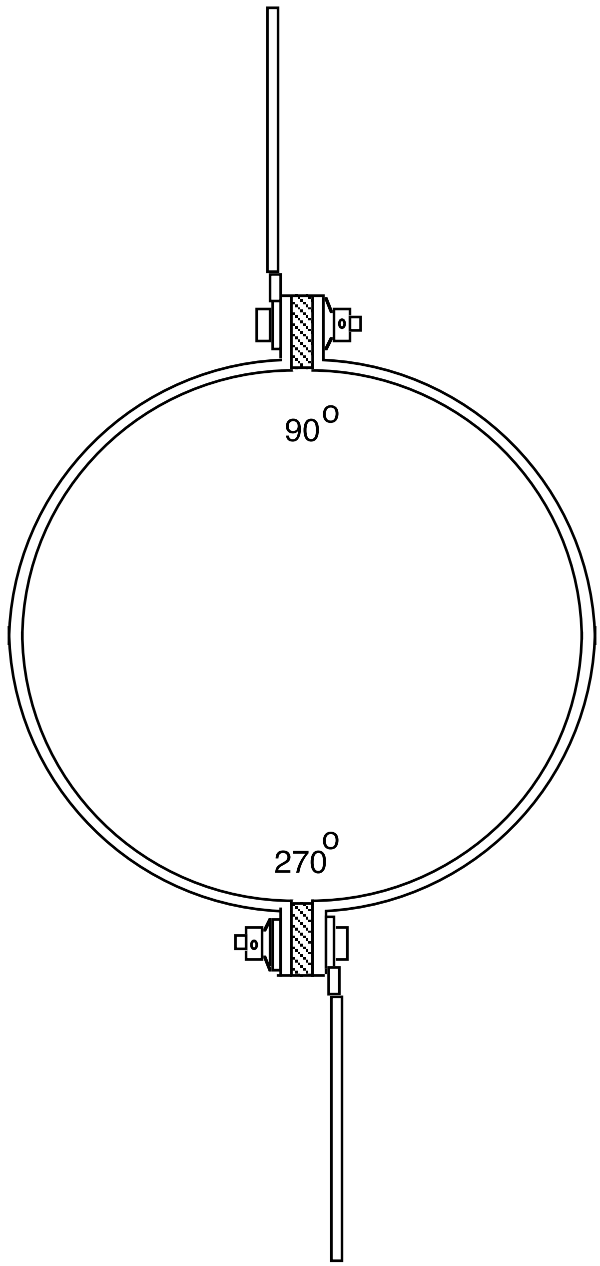
• Apply 2" wide Kapton tape, approximately 4" from the two opposite ends of the ground plane region, in the circumferential direction, overlapping the regions masked in the prior step (Ranbar B-2-135 type semi-conductive paint exposed) by 2" on either side as shown in the following figure (Kapton pieces 2+1+2 = 5" long).



• Affix, using clamps with dielectric breaks, at each end of the coil, 1" wide braided copper conductors with soldered ends, such that a 1" gap exists at the 90º and 270º positions, per the following figure.



• Suggested clamp design is shown in the following figure. Clamp is made from 2 pieces of thin (e.g. 1/16") non-magnetic stainless steel, 1" wide to cover copper braid. At joints, G-10 spacer block, and G-10 nut/bolt provide dielectric break in toroidal direction. Spring washer under nut provides for thermal expansion/contraction. Set screw through nut/bolt provides locking. Wire lug under bolt head at 90 and 270^o postions connect to 10' long #10 (600V insulated, stranded) conductor. Subsequent routing of the pair of wires should keep them nested together (e.g. twisted). Final point of connection of ground wires will be determined later. Series resistor (e.g. 50Ω) will be introduced in each path. Prior design, which included "anti-turn" of ground wire around coil, was judged not to be beneficial.



- After installation, measure resistance between all four ground leads:

1-2
1-3
1-4
2-3
2-4
3-4

cc:

J Chrzanowski
P Heitzenroeder
T Meighan
M Ono
S Ramakrishnan
M Williams

NSTX File