11-971215-CLN-01

TO: DISTRIBUTION
FROM: C NEUMEYER
SUBJECT: FORCES ON PASSIVE PLATES

References:

[1] 13-970217-AWB-02, "Loads on CS Due to Plasma Disruption"
[2] 11-971117-CLN-01, "PFC Geometry"

This memo provides an estimate of the forces on the passive plates during a stationary plasma disruption.

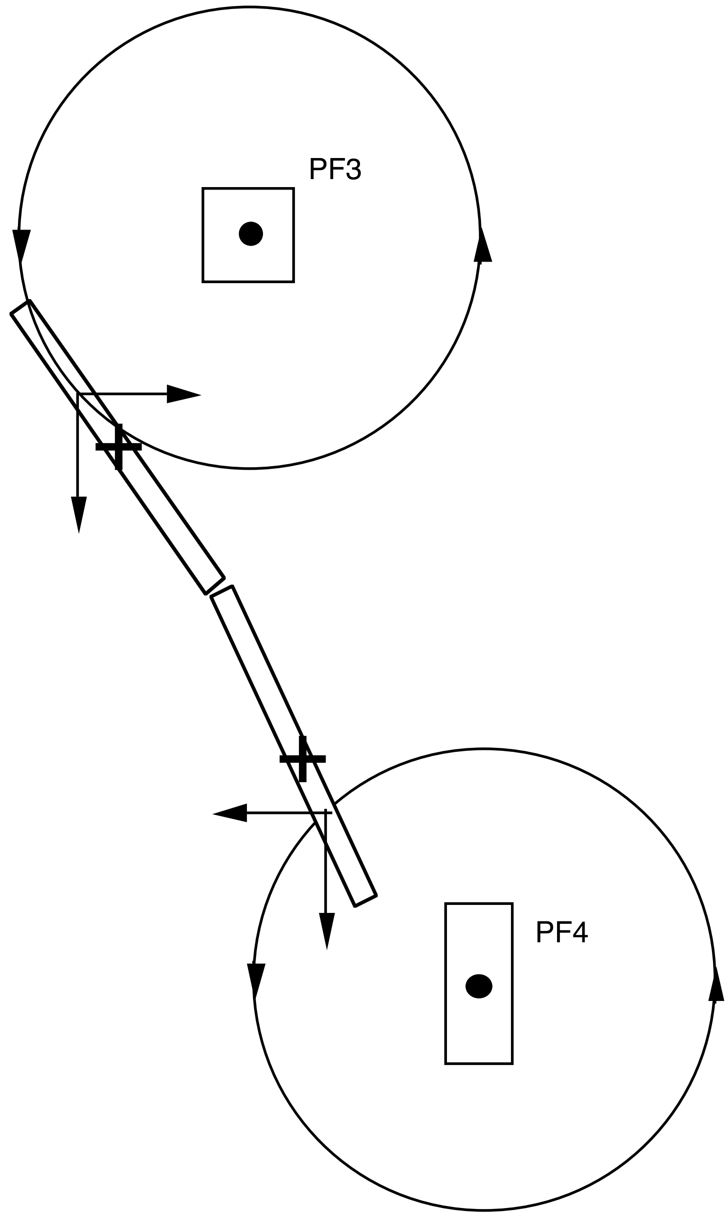
Plasma current decay rate is taken as 0.166MA/mS (6 mS disruption) [1]. At the time that the disruption induced eddy currents reach their peak, Ip has reached zero. The background field in the vicinity of the plates will be due mainly to the currents in the passive plates and in PF3 and PF4 (assume at peak rated current). From [1] the net peak plate current (above and below midplane summed together) is ≈ 300kA, and the currents in the passive plate (the primary and secondary plates each represented by two filaments) are as follows:

$$I_{s1} = 17.6\text{kA}$$
$$I_{s2} = 26.5\text{kA}$$
$$I_{p1} = 35.2\text{kA}$$
$$I_{p2} = 70.5\text{kA}$$

The following figure depicts the sense of the currents and fields produced by the plates and PF coils in the region of interest, following a disruption. The initial plasma current polarity is into the page. The post disruption plate currents are into the page, consisting with the conservation of flux. The PF currents are out of the page, consistent with a radial equilibrium prior to disruption.

It is noted that the maximum vertical field in the upper half plane as depicted would result from the sum of the contributions from the PF3 and PF4 currents.

The maximum radial field in the upper half plane will result from full current in PF3, due to the fact that the PF3 ampere-turns are somewhat higher than PF4, plus the fact that the currents in the primary passive plate, which are higher than those in the secondary passive plate, result in a radial field which is additive to that from PF3.



The currents, locations, and flux and field contours for the two worst cases are given in the following.

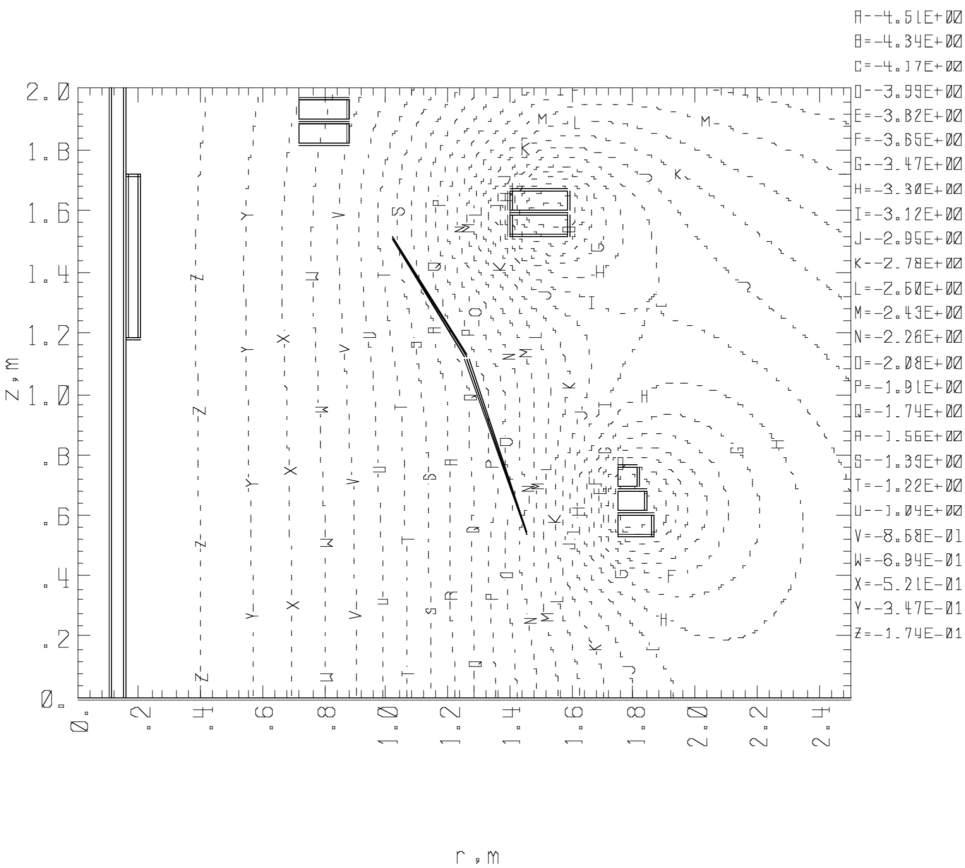
B_V Case....

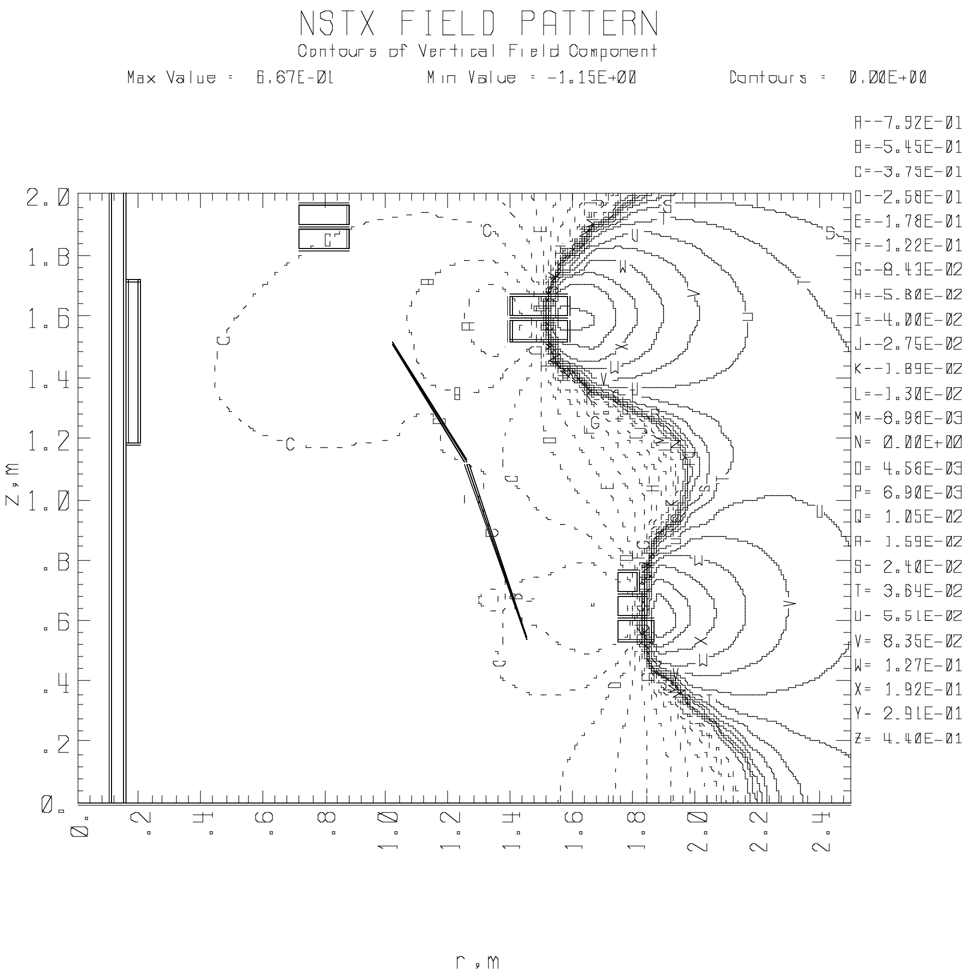
Element	R(m)	Z(m)	ΔZ(m)	ΔR(m)	A-turns
Secondary Plate Filament 1 Upper	1.100	1.400	0.034	0.034	17600.0
Secondary Plate Filament 2 Upper	1.190	1.240	0.034	0.034	26500.0
Primary Plate Filament 1 Upper	1.310	0.998	0.033	0.033	35200.0
Primary Plate Filament 2 Upper	1.420	0.665	0.033	0.033	70500.0
Secondary Plate Filament 1 Lower	1.100	-1.400	0.034	0.034	17600.0
Secondary Plate Filament 2 Lower	1.190	-1.240	0.034	0.034	26500.0
Primary Plate Filament 1 Lower	1.310	-0.998	0.033	0.033	35200.0
Primary Plate Filament 2 Lower	1.420	-0.665	0.033	0.033	70500.0
PF3a Upper	1.495	1.634	0.068	0.186	-300000.0
PF3b Upper	1.495	1.553	0.068	0.186	-300000.0
PF3a Lower	1.495	-1.634	0.068	0.186	-300000.0
PF3b Lower	1.495	-1.553	0.068	0.186	-300000.0
PF4a Upper	1.783	0.728	0.068	0.068	-100000.0
PF4b Upper	1.795	0.647	0.068	0.092	-160000.0
PF4c Upper	1.807	0.566	0.068	0.115	-180000.0
PF4a Lower	1.783	-0.728	0.068	0.068	-100000.0
PF4b Lower	1.795	-0.647	0.068	0.092	-160000.0
PF4c Lower	1.807	-0.566	0.068	0.115	-180000.0

NSTX FIELD PATTERN

Contours of Flux

Max Value = 0.00E+00 Min Value = -4.69E+00 Contours = 1.74E-01

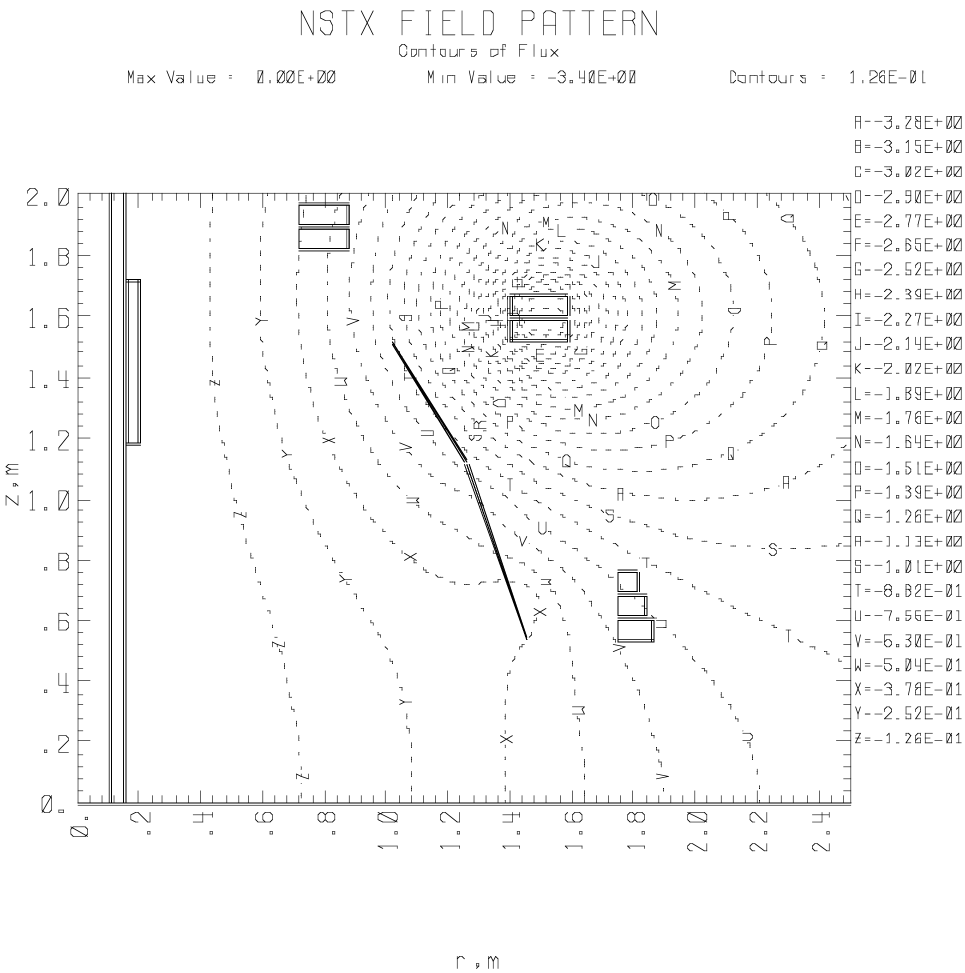


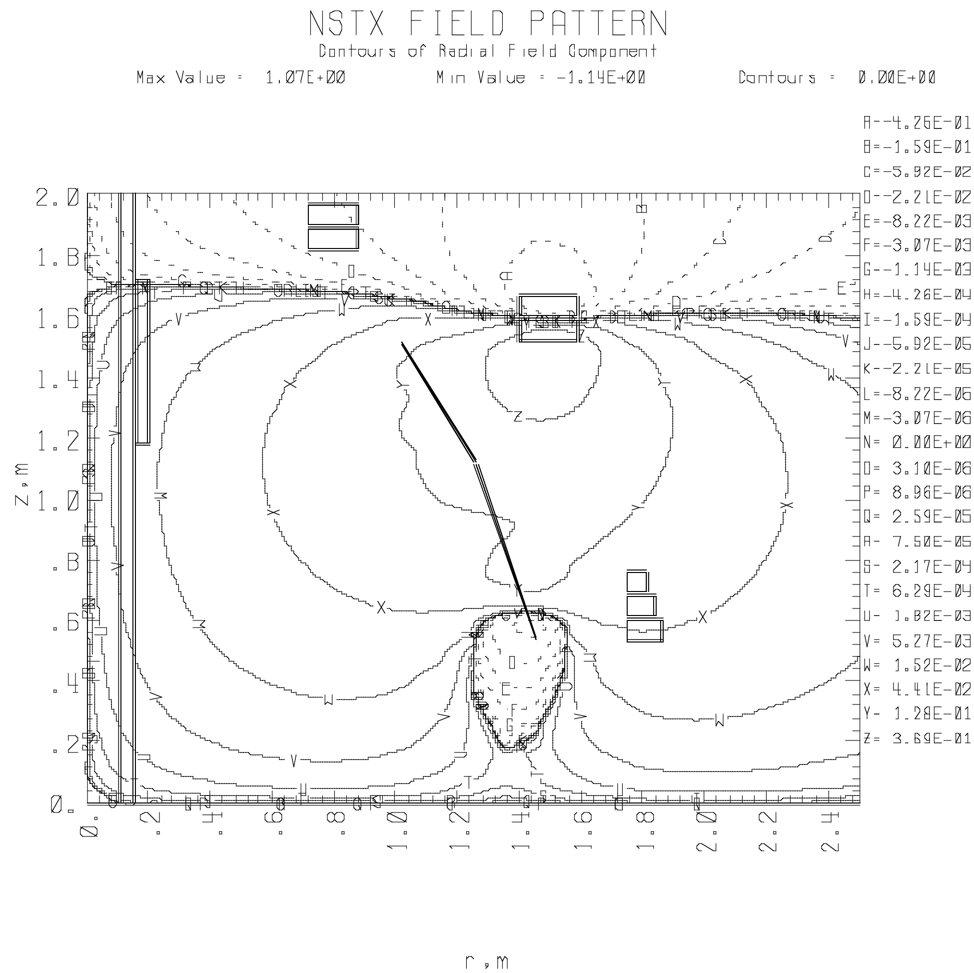


In the region of interest the B_v contours are B=-0.545T and C=-0.375T.

B_r Case....

Currents for the B_r case are the same as above except that I_{pf4} is set to zero.


NSTX FIELD PATTERN
Contours of Flux
Max Value = 0.00E+00
Min Value = -3.40E+00
Contours = 1.26E-01
A=-3.28E+00
B=-3.15E+00
C=-3.02E+00
D=-2.90E+00
E=-2.77E+00
F=-2.65E+00
G=-2.52E+00
H=-2.39E+00
I=-2.27E+00
J=-2.14E+00
K=-2.02E+00
L=-1.89E+00
M=-1.76E+00
N=-1.64E+00
O=-1.51E+00
P=-1.39E+00
Q=-1.26E+00
R=-1.13E+00
S=-1.01E+00
T=-8.82E-01
U=-7.56E-01
V=-6.30E-01
W=-5.04E-01
X=-3.78E-01
Y=-2.52E-01
Z=-1.26E-01
z, m
r, m



In the region of interest the B_r contours are Y=0.128T, and Z=0.389T.

Forces (on each of the 12 segments, upper half plane) are summarized in the following table.

	Secondary			Primary			
	1	2	∑	1	2	∑	
Current	17600.000	26500.000	44100.0	35200.000	70500.000	105700.0	Amp
Radius	1.100	1.190		1.310	1.420		m
Segments	12.000	12.000		12.000	12.000		
Length/Seg	0.576	0.623		0.686	0.744		m
Bv	-0.545	-0.545		-0.545	-0.545		Tesla
Fr	-5524.6	-8998.9	-14523.5	-13158.6	-28567.5	-41726.1	N
	-1241.9	-2022.9	-3264.9	-2958.0	-6422.0	-9380.0	lb
Br	0.389	0.389		0.128	0.128		Tesla
Fv	-3943.2	-6423.0	-10366.3	-3090.5	-6709.4	-9799.9	N
	-886.4	-1443.9	-2330.3	-694.7	-1508.3	-2203.0	lb

In addition to the above there will be a force due to the cross product of the radial current at the toroidal gap with the toroidal field.

The maximum rated toroidal field at R_0 = 85.4m is 6kG. The maximum field in the region of interest can be computed from this case.

	Secondary	Primary	
Ro	0.854	0.854	m
Bt@Ro	0.600	0.600	Tesla
Rpp(avg)	1.150	1.360	m
Rvv(avg)	1.473	1.697	m
Ravg	1.312	1.529	m
Bt@Ravg	0.391	0.335	Tesla
Current	44100.0	105700.0	Amp
Length	0.323	0.337	m
Fv	5568.2	11956.4	N
	1251.7	2687.8	lb

Vertical disruption events could result in substantial asymmetry in the division of current between the upper and lower plates. The PF coil background fields would remain more or less as specified herein. To account for this, until such time that more refined information becomes available, it seems reasonable to assume that the maximum possible forces could be 150% of those given in the above tables.

	Secondary Plate	Primary Plate	
Fr	-4897	-14070	lbs
Fv	-3496	-3305	lbs
Fv @ Toroidal Gap	+/- 1878	+/- 4030	lbs

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NSTX File