11-971029-CLN-01

TO: DISTRIBUTION
FROM: C NEUMEYER
SUBJECT: PASSIVE PLATE CONNECTIONS

The purpose of this memo is to clarify the requirements and design considerations related the electrical connections between the segmented passive plate sections.

Passive plates consist of 12 toroidal x 4 poloidal segments. In each half plane, the segments closest to the midplane are called the "primary" segments and those furthest away the "secondary" segments.

Present Status

The existing design developed by ORNL includes jumpers between segments in the toroidal direction, except for one gap location. At this location saddle jumpers on each side of the gap connect the primary and secondary segments in the upper half plane to those in the lower half plane, such that there is no continuous toroidal connection, but a closed loop for the eddy currents flowing in opposite directions in the upper and lower half planes which stabilize the vertical instability. The present design does not include poloidal jumpers between the primary and secondary plates, except at the toroidal gap location.

The present design does not specify the toroidal position of the saddle jumpers (i.e. the "clocking" has not yet been fixed).

Meeting to Discuss Poloidal Connections

A meeting was held on 10/24 (S. Kaye, M. Ono, G. H. Neilson, M. Okabayashi, R. Hatcher, C. Neumeyer) to discuss the physics needs for poloidal connections the plate segments.

Whereas the existing configuration satisfies the main objective of slowing the growth rate of the plasma vertical instability, the plates are less effective in mitigating other MHD instabilities than they would be with additional poloidal connections between segments. From this point of view the more continuous copper area which faces the plasma, the better. Two means were identified to improve the situation. First, poloidal jumpers between each pair of primary and secondary segments, and second, poloidal jumpers between the primary segments in each half plane.

It was agree that the primary to secondary jumpers can be added with relative ease and should be included in the baseline, and that the jumpers which cross the midplane are more complex to implement and are perhaps not so important as the former, so they can be deferred into an upgrade category.

For design purposes it was recommended that the jumpers be designed to carry 10kA for 100 mS. Furthermore it was noted that this level current is expected during disruptions and that the background current should be a few hundred amps or so.

Toroidal Location of Saddle Jumper

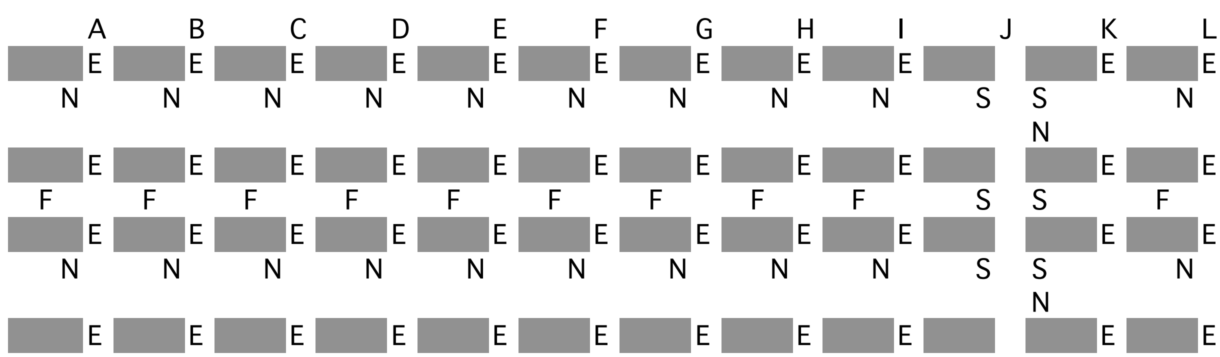
To allow diagnostic view of the plasma from the dome ports, the toroidal gaps in the plate segments need to be aligned with the dome ports. In addition, in order that the diagnostic views of the plasma from the dome ports (vertical view) and cylindrical section ports (radial view) be coplanar, the toroidal gaps need to be aligned also with the ports in the cylindrical section.

The saddle jumper will not obstruct radial view of the plasma from a port on the cylindrical section because the vertical limb of the jumper is offset toroidally approx. 15 degrees from the toroidal gap where it connects. This offset also results in a structure which has some degree of mechanical compliance with respect to the vertical growth of the vessel during bakeout.

Due to the utilization plan of the ports for NBI ducts (A & K), RF antenna (C, D & E), and NBI armor (F, G, H &I), and due to the need for the offset limb of the saddle connection, the only feasible locations for the saddle jumper are at bays I or J. The plan for a small port between bays I & J on the midplane for tangential view of the plasma (in the clockwise (CW) direction, viewed from above) favors the location of the saddle jumper at bay J, with the offset of the limb in the CCW direction.

Pattern of Electrical Connections

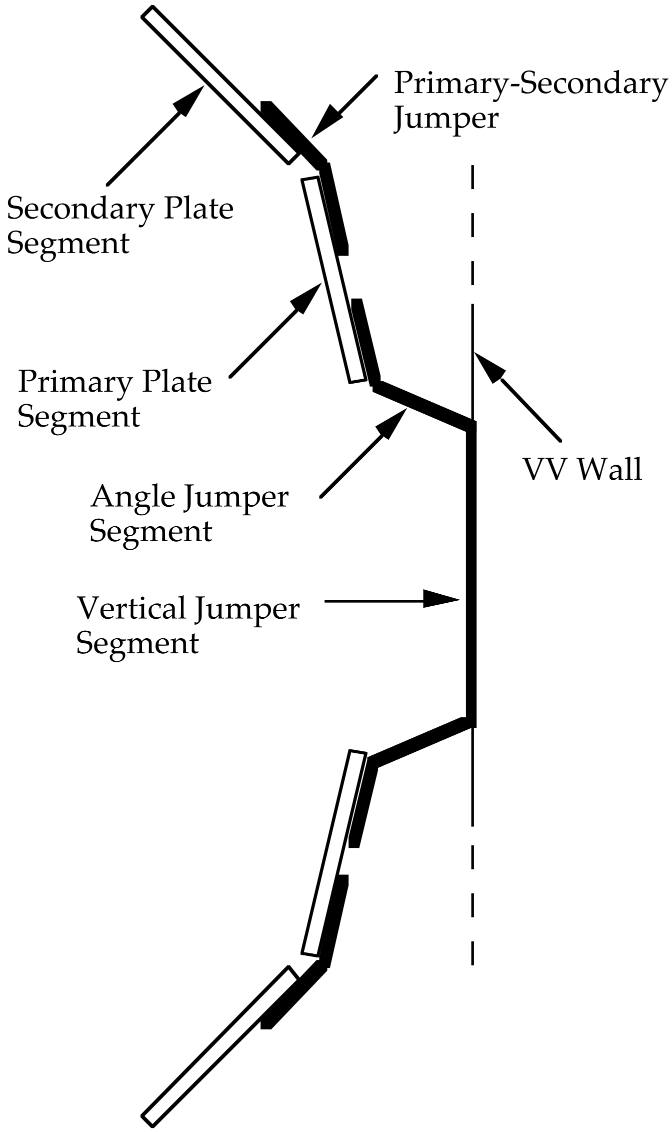
The following figure gives a map of the existing toroidal connections, new primary to secondary poloidal connections, saddle connections, and future primary to primary poloidal connections across the midplane.

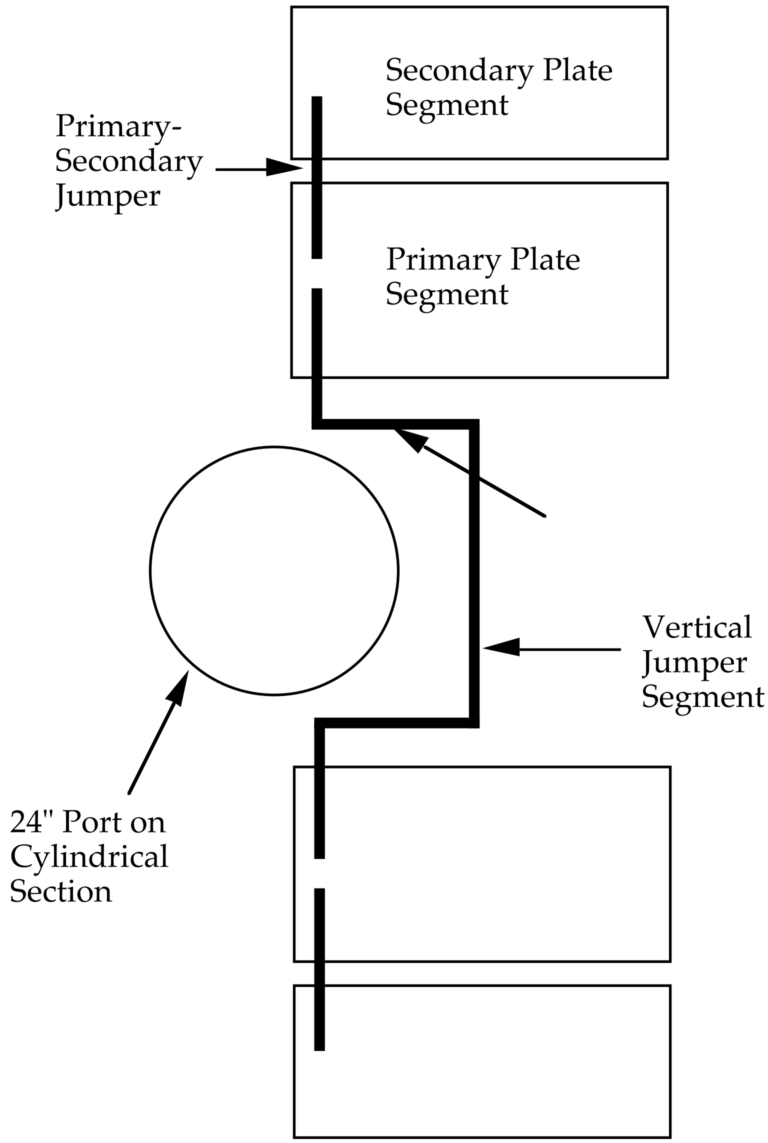


	=passive plate
E	=existing jumper
N	=new jumper
F	=future jumper
S	=saddle connection

Layout of Connections

Cross section view and radial view of a possible jumper scheme are given in the following figures.





The jumpers between primary and secondary plates are short and simple.

The jumpers across the midplane gap may consist of an angled segments, toroidal segments, and a vertical segment as shown. If the jumper across the midplane gap is not made at the edges of the plate segments as shown but rather at the middle of the plate segments, then the toroidal segments would not be needed.

Design Considerations

The jumpers must be able to carry the current without excess dissipation and must be able to withstand the J x B forces.

Concerning the dissipation, assuming adiabatic conditions, a 0.125 in^2 cross section results in < 10C rise with 10kA-100mS current pulse per the following calculation using the "G function" for copper[1] starting at 50C.

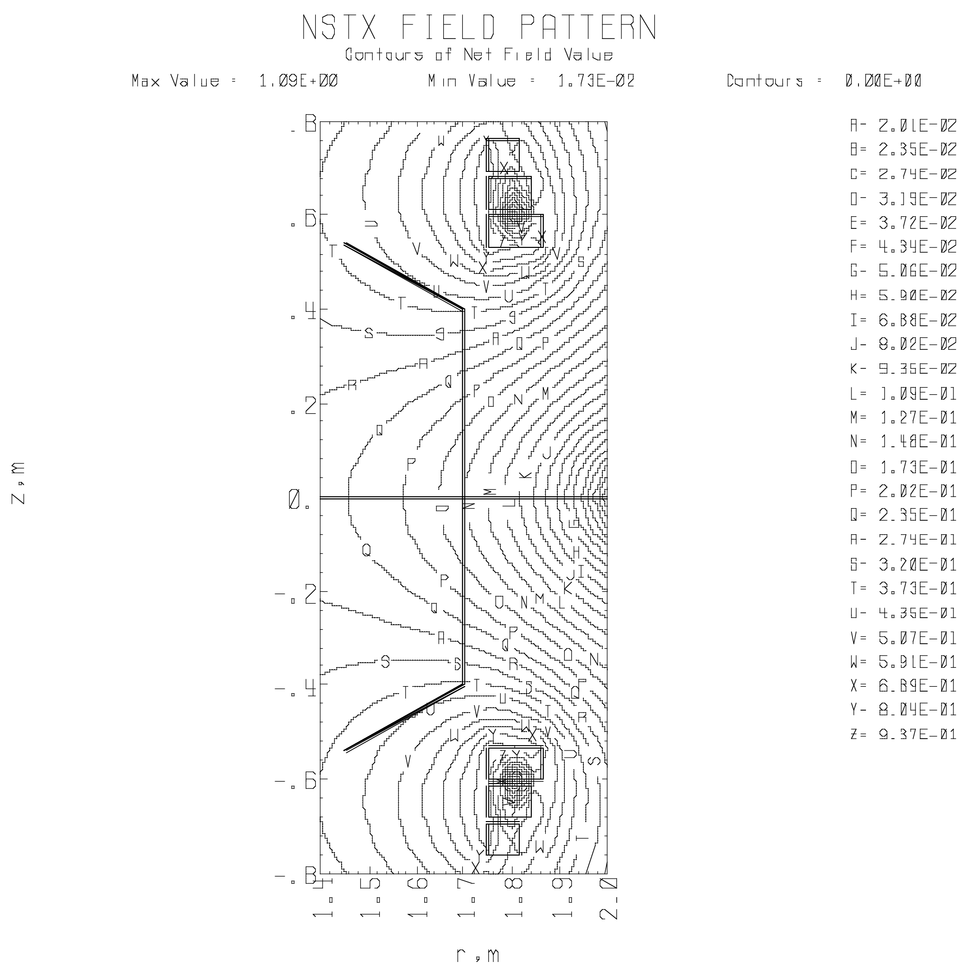
Initial Temp To	50.0	deg C
G(To)	9.81E+15	(A/m^2)^2-sec
Width	1.000	
Height	0.125	
CSA	0.125	in^2
	8.06E-05	m^2
Ipulse	10000.0	amp
Tpulse	0.100	sec
∫j^2dt	1.54E+15	(A/m^2)^2-sec
Final Temp	58.6	deg C

Cooling between pulses should be ample because the passive plates to which the jumpers connect are actively cooled (50C during operations), and the vacuum vessel to which the jumpers across the midplate would be affixed is a large heat sink.

Concerning the J x B forces, the force due to the toroidal field (B_{Tmax} = 6kG @ r = 85.4 cm) can be approximated using the value of B_T at the maximum radius of the passive plates (r = 1.45 m), and the force due to the poloidal field can be approximated by considering the effect of PF4 @ 20kA. The plasma can be ignored (if present it would reduce the field), as well as the other PF coils (they are rather far away).

The field contours due to PF4 at 20kA are given in the following figure[2], along with line segments representing a possible path for the midplane jumper running from the end of the primary passive plate, to the vacuum vessel wall (r = 1.7 m), down to the other primary passive plate. The field (contour U) is on the order of 5 kG.

[1]NSTX-CALC-13-1-0, "PF Coil Parameters"
[2]From program "contpf2.x"


NSTX FIELD PATTERN
Contours of Net Field Value
Max Value = 1.09E+00
Min Value = 1.73E-02
Contours = 0.00E+00
A= 2.01E-02
B= 2.35E-02
C= 2.74E-02
D= 3.19E-02
E= 3.72E-02
F= 4.34E-02
G= 5.06E-02
H= 5.90E-02
I= 6.88E-02
J= 8.02E-02
K= 9.35E-02
L= 1.09E-01
M= 1.27E-01
N= 1.48E-01
O= 1.73E-01
P= 2.02E-01
Q= 2.35E-01
R= 2.74E-01
S= 3.20E-01
T= 3.73E-01
U= 4.35E-01
V= 5.07E-01
W= 5.91E-01
X= 6.89E-01
Y= 8.04E-01
Z= 9.37E-01
.8
.6
.4
.2
0.
-.2
-.4
-.6
-.8
Z, m
1.4
1.5
1.6
1.7
1.8
1.9
2.0
r, m

Calculations of the forces on the midplane jumpers is given in the following table, based on 10kA. Forces on the primary to secondary jumpers are trivial, due to the short length (about an inch).

Length Angled Seg	11.3	in
Length Vertical Seg	31.5	in
Length Toroidal Seg	12.0	in
Bt Max @ Ro	0.6	
Background Bt @ plate	0.2	Tesla
Fp/length	2482.8	N/m
	14.2	lbs/in
Fp Angled Seg	159.9	lbs
Fp Vertical Seg	446.5	lbs
Background Bp	0.5	Tesla
Ft/length	5000.0	N/m
	28.5	lbs/in
Ft Angled Seg	322.1	lbs
Ft Vertical Seg	899.2	lbs
Fp Toroidal Seg	342.6	lbs

The background toroidal field causes forces in the poloidal plane on the angled and vertical jumper segments as indicated. Assuming that the toroidal jumper is aligned with the toroidal field, there is no cross product. The background poloidal field causes forces in the toroidal direction on the angled and vertical segments, and a force in the poloidal plane on the toroidal segments.

Recommended Design

Per discussions with B. Nelson of ORNL, the primary to secondary jumpers can be implemented using four 1/32" x 3.5" copper sheets which are sandwiched between the jumpers which connect the plates toroidally (the jumpers already in the existing design) and the stainless steel support brackets which attach to the vacuum vessel. In order to maintain the same radial dimension on all of the supports, while a jumper will be sandwiched only with every other support, 1/8" thick blanks can be sandwiched on the supports which have no jumpers.

There are several design options for the midplane jumpers, which may be added as an upgrade. One option would use a sandwich connection at the location of the blank mentioned in the preceding paragraph but, since this is located at the edge of the plates, a toroidal offset feature would be required such that the jumper does not cut across the 24" port. Another option would connect the jumper at the middle of the plate segments, in which case the toroidal offset is not needed. In this case the availability of a bolting feature at the middle of the primary plates would be desirable in the baseline configuration so that the plates would not have to be removed at the time that the jumpers are added.

Issues

An excerpt from the SRD for WBS 11 is given below. Although it could perhaps be more explicit in language, it does imply a poloidal connection between the plates. So, the subject work (at least the primary to secondary jumpers) is considered to be within the existing scope.

"2.2 Passive Stabilizers

b. Each stabilizer shall be made up of a series of conically shaped copper plates which are electrically connected in the toroidal and poloidal directions. Each stabilizer shall have a minimum of one toroidal electrical break"

Following the meeting the issue of the possible flow of halo currents through the connections across the midplane was raised. S. Kaye indicated that indeed this could occur but that it would not all be concentrated in one jumper, it would be shared. In any case this issue will need to be addressed at the time that jumpers across the midplane are considered.

cc:

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NSTX File