13-010111-CLN-01

TO: DISTRIBUTION
FROM: C NEUMEYER
SUBJECT: MEETING ON OH GROUND FAULT FINDINGS AND OPTIONS

The attached material (with some additions based on the latest information which became available just prior to the meeting) was presented at the subject meeting on 01/10/01.

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NSTX File

OH Coil Ground Fault

Summary of Findings

&

Options for Proceeding

C. Neumeyer

01/10/01

- OH coil failed hipot test at 9kV dc after holding for 15 seconds out of 60 seconds required (12/11/00)
    - full hipot rating is 13kV, but 9kV was adopted due to known difficulties with insulation strength of water tube/clamping
- Subsequent attempts failed at progressively lower voltages
- Insulation resistance to ground measured by a digital VOM indicated R ≈ 10MΩ or less (value deteriorated with time)
- Normal resistance ≈ 100's MΩ (e.g. 13kV/75μA = 175MΩ on 8/3/00)
- Voltage from hipotter could not be raised to 100V w/o trip

- Inspection of water tube areas and loosening of some of the tube clamps did not reveal any problems

- AC Injection via Techron amplifier and pickup sensing could not isolate current path

- Disconnection of ground plane leads did not change resistance measured to ground, but ungrounding CS casing did, indicating fault to CS casing

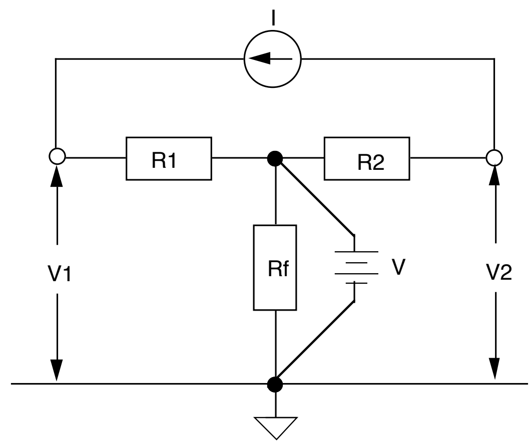
- Injection of DC through coil using bakeout PS indicated null near bottom of first layer

- Additional inspections did not reveal any problems at water tubes or leads or any accessible areas

- Injection of DC using floating auto battery and special ultra-low leakage voltage measuring devices now indicates fault within layer 4 (outer layer)

- Measurement of resistance between all equipotential surfaces involved (ground plane sectors, hub assembly, CS casing, etc.) indicates that these elements are not properly isolated from one another.

- Basis for Voltage Drop Measurement



$$V1 = V + IR1$$

$$V2 = V - IR2$$

$$\overline{V1} = V + \overline{I}R1$$

$$\overline{V2} = V - \overline{I}R2$$

$$V1 - \overline{V1} = R1\ (I - \overline{I}) = R1\ (I-(-I)) = 2IR1$$

$$V2 - \overline{V2} = R2\ (I - \overline{I}) = R2\ (I-(-I)) = 2IR2$$

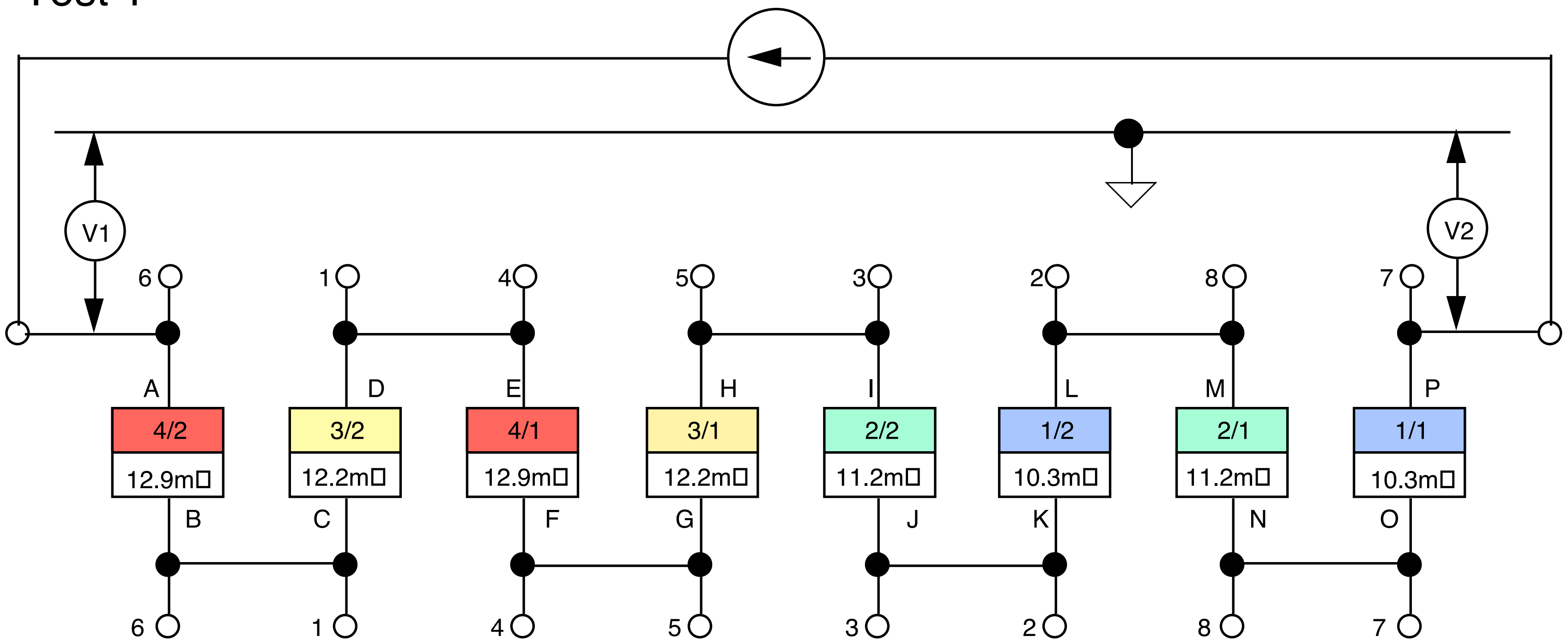
$$V1 - V2 = I\ (R1+R2)$$

$$\overline{V1} - \overline{V2} = \overline{I}\ (R1+R2) = -I\ (R1+R2)$$

$$(V1 - V2) - (\overline{V1} - \overline{V2}) = 2I(R1+R2)$$

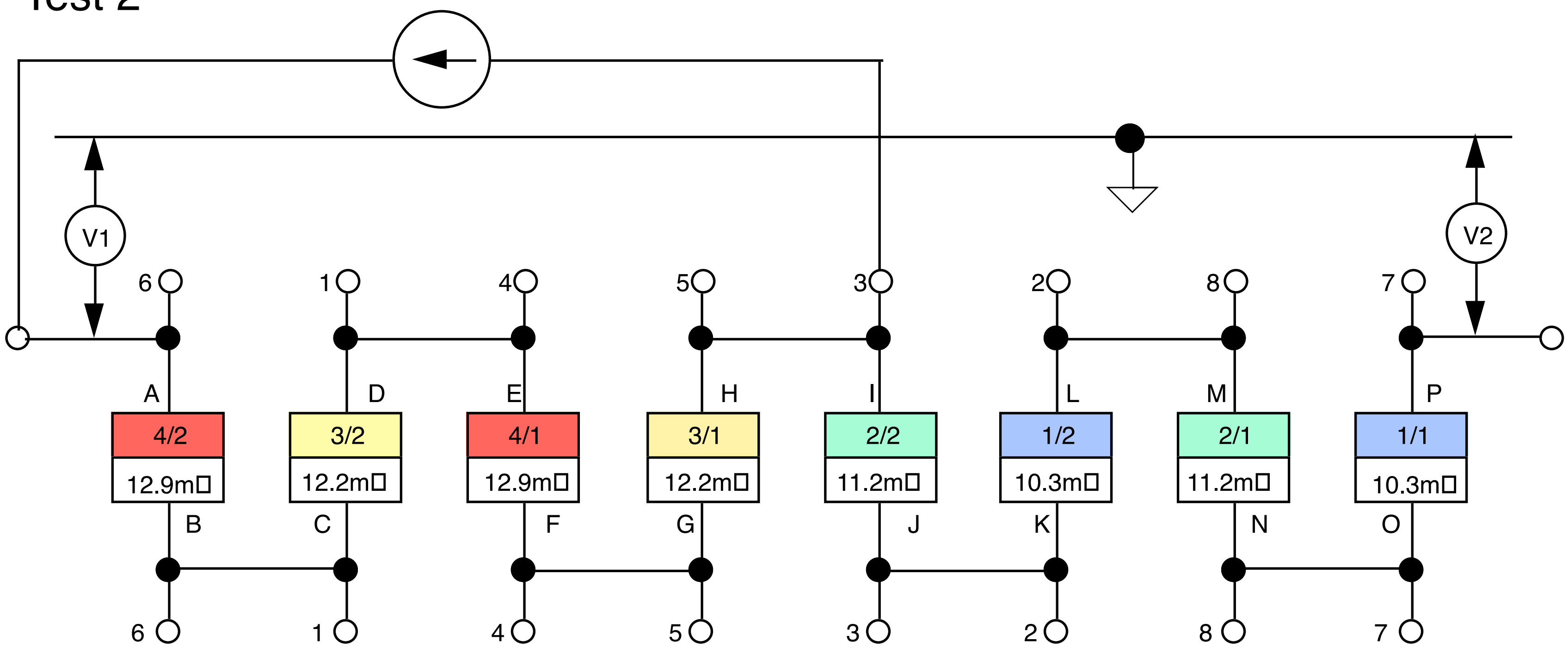
$$\frac{(V1 - \overline{V1})}{(V1 - V2) - (\overline{V1} - \overline{V2})} = \frac{2IR1}{2I(R1 + R2)} = \frac{R1}{(R1 + R2)}$$

Test 1



$$\frac{(V1-\overline{V1})}{(V1-V2)-(\overline{V1}-\overline{V2})} = \frac{R1}{(R1+R2)} =$$ 4.66% (1st test), 4.0% (2nd test) Galvanic voltage @ I=0 □280mV prior to tests

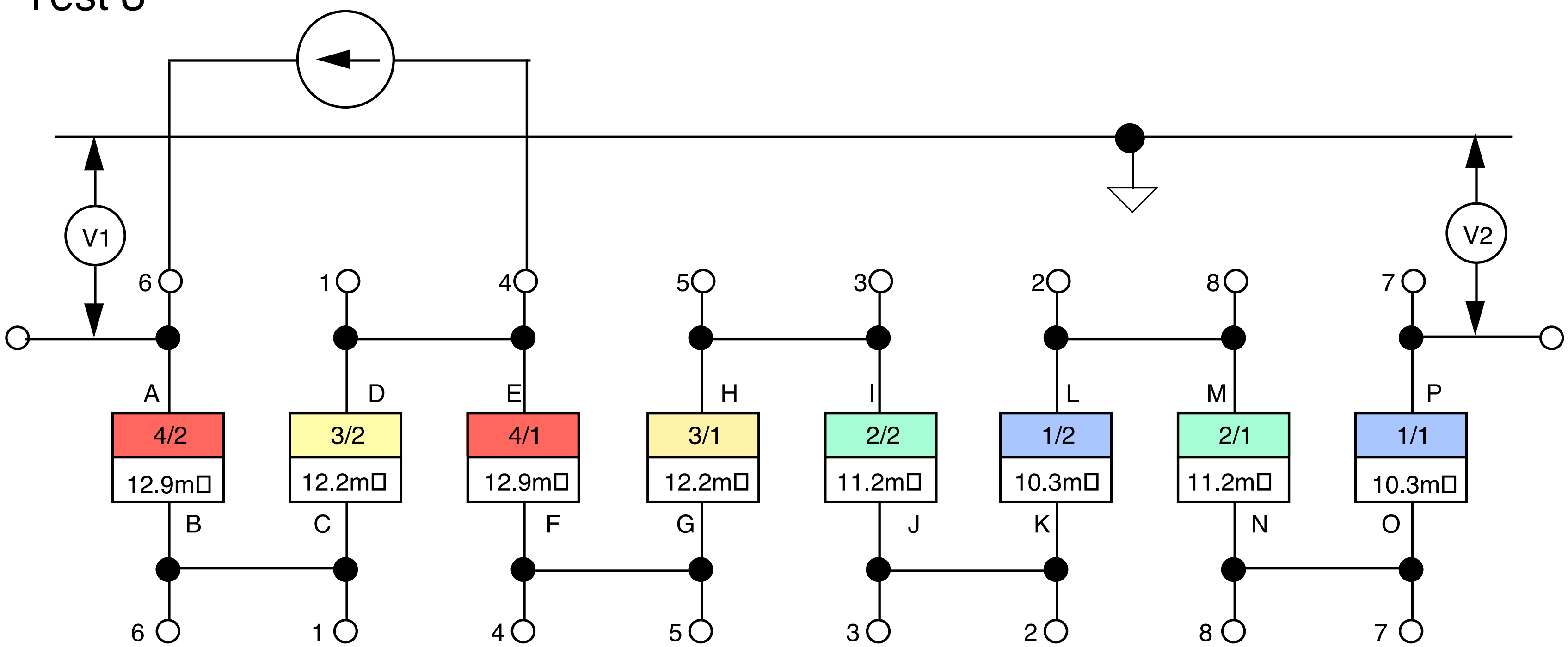
Test 2



$$\frac{(V1-\overline{V1})}{(V1-V2)-(\overline{V1}-\overline{V2})} = \frac{R1}{(R1+R2)} = 6.6\%$$

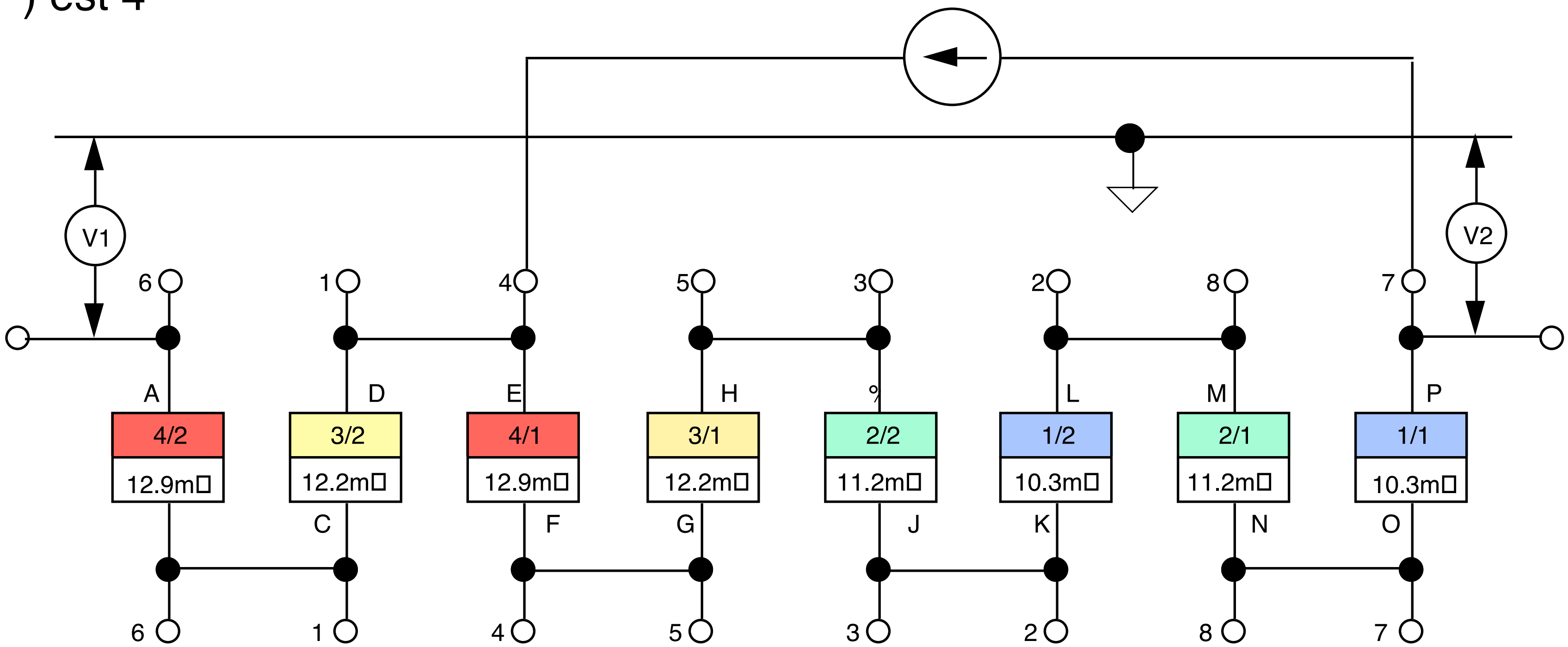
G%lv%nic volt%ge @ I=0 □160mV p(io(to tests

Test 3



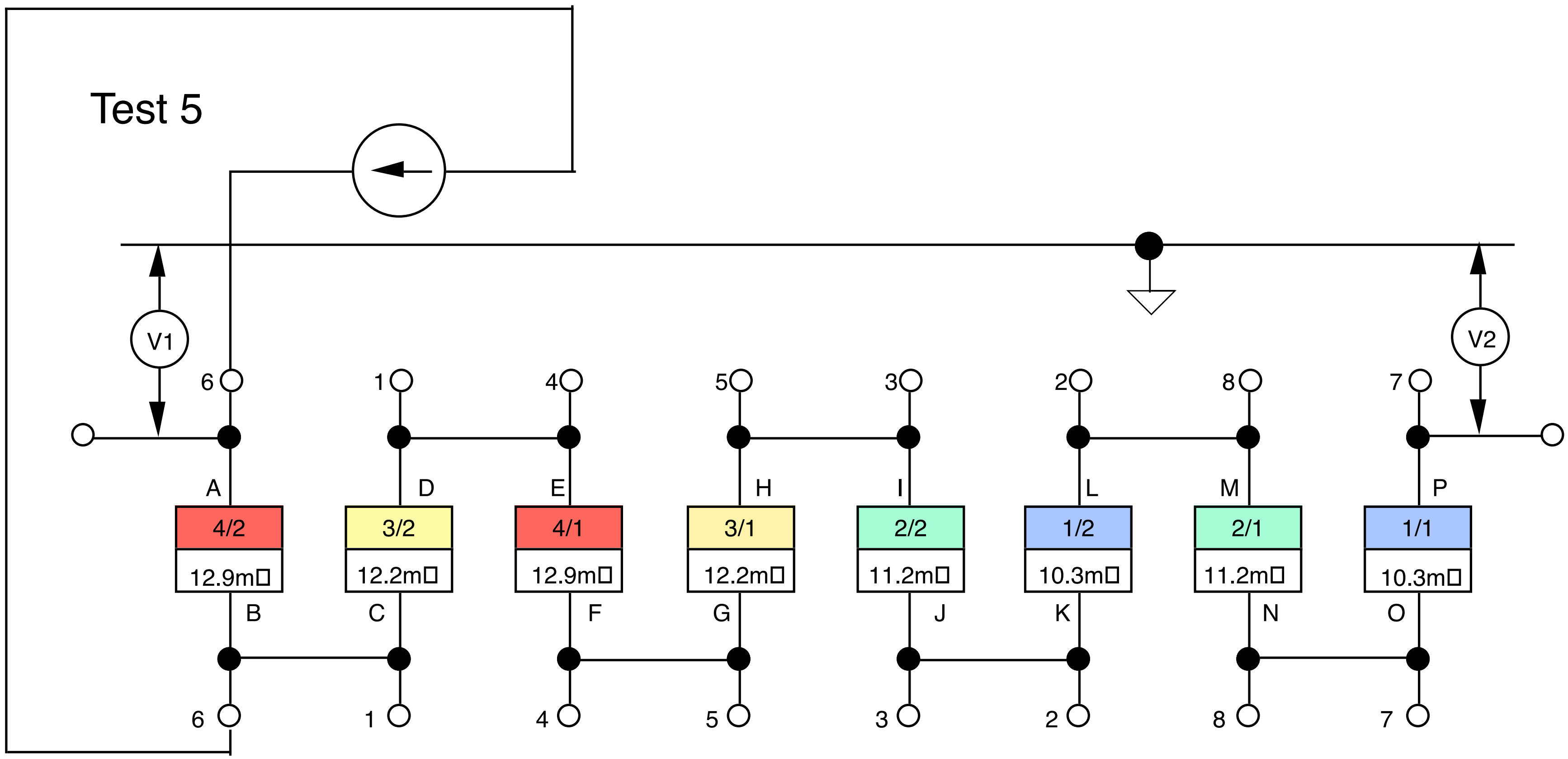
$$\frac{(V1-\overline{V1})}{(V1-V2)-(\overline{V1}-\overline{V2})} = \frac{R1}{(R1+R2)} =$$ 11.74% (1st test), 13.1% (2nd test) Galvanic voltage @ I=0 □200mV prior to test

) est 4



$$\frac{(V1-\overline{V1})}{(V1-V2)-(\overline{V1}-\overline{V2})} = \frac{(\ 1}{((\ 1+(\ 2)} = 0.362\%$$

Ga-vani+ vo-tage @ %0 □0mV . rior to test

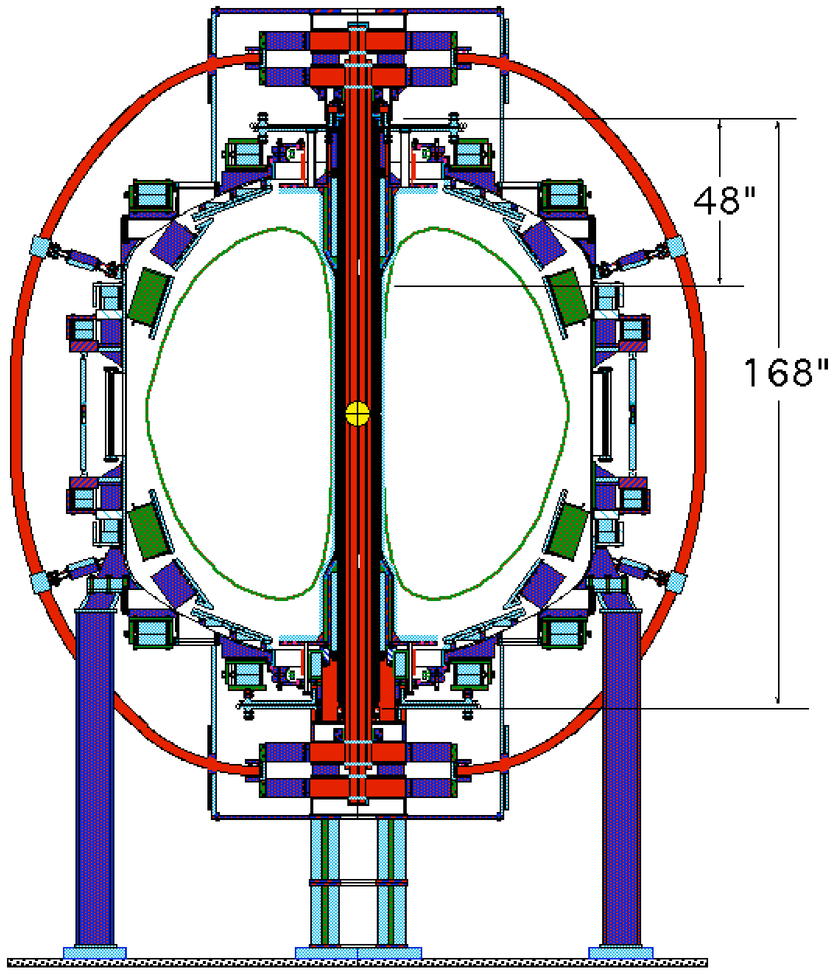


$$\frac{(V1-\overline{V1})}{(V1-V2)-(\overline{V1}-\overline{V2})} = \frac{R1}{(R1+R2)} = 29\%$$

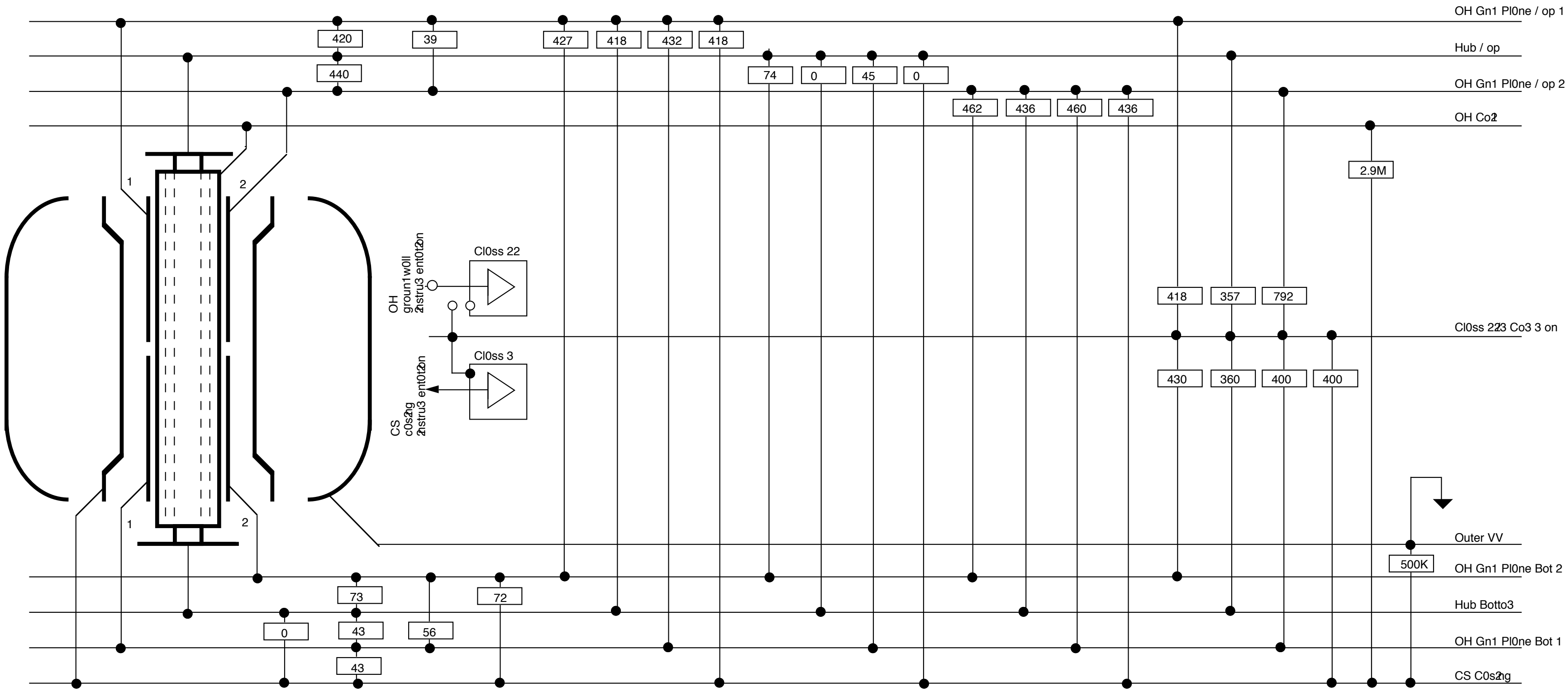
Galvanic voltage @ I=0 □200 mV prior to test (jumpy)

Roh Layer 1	10.3	mΩ			OH Ztop	84	in
Roh Layer 2	11.2	mΩ			PF1A Ztop	67.5	in
Roh Layer 3	12.2	mΩ			PF1A Zbottom	46.5	in
Roh Layer 4	12.9	mΩ					
∑Roh	93.2	mΩ					
OH ΔZ	168	in					
Test #	R1+R2	R1/(R1+R2)	R1	R1/Roh	R1/RL4	ΔZ	Z
	(mΩ)	(%)	(mΩ)	(%)	(%)	(inch)	(inch)
1 (1st)	93.20	4.663	4.3	4.7	33.7	56.6	27.4
1 (2nd)	93.20	4.023	3.7	4.0	29.1	48.8	35.2
2	50.20	6.642	3.3	3.6	25.8	43.4	40.6
3 (1st)	38.00	11.741	4.5	4.8	34.6	58.1	25.9
3 (2nd)	38.00	13.102	5.0	5.3	38.6	64.8	19.2
5	12.90	29.000	3.7	4.0	29.0	48.7	35.3

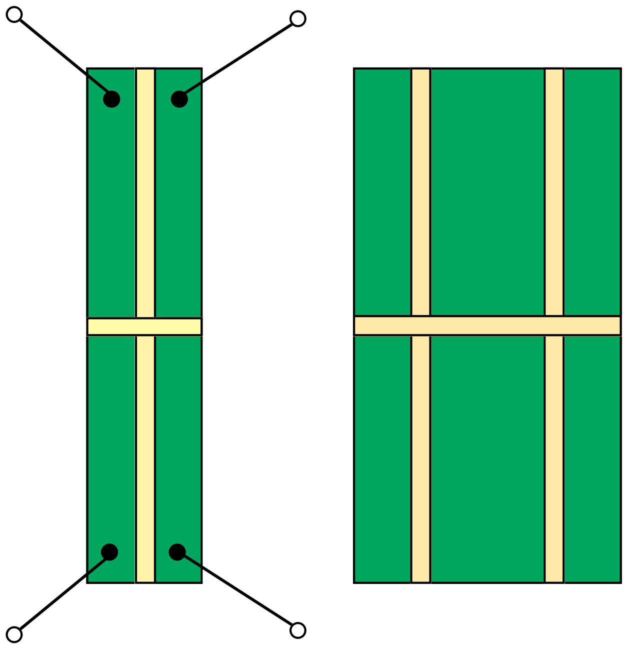
- Ground Fault Location 48” down from Top of OH Coil

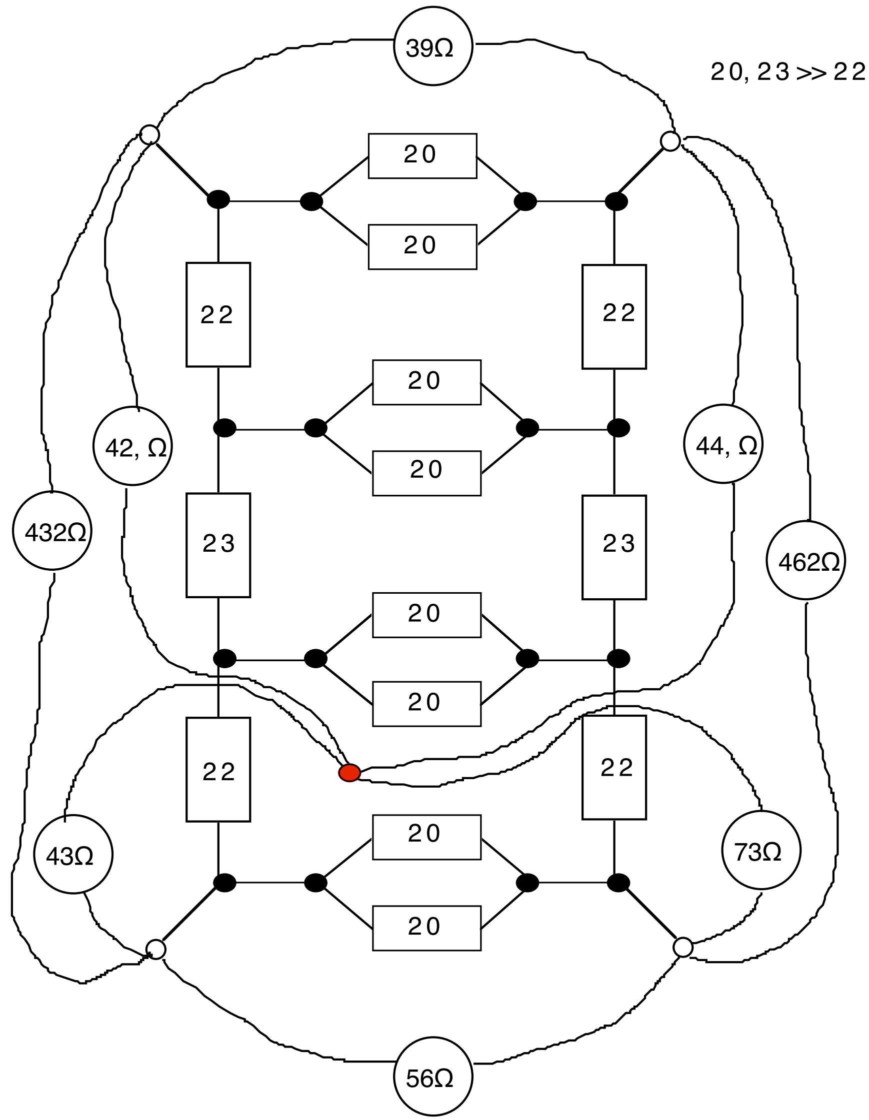


• Resistances Measured Between All Elements



• Anomalous Connection Exists between Ground Plane Segments and Hub/CS Casing Near Bottom of OH Coil





Conclusions

- Evidence points to:

  - fault through OH groundwall on outer layer approx. 30% down from the top, below the PF1A area

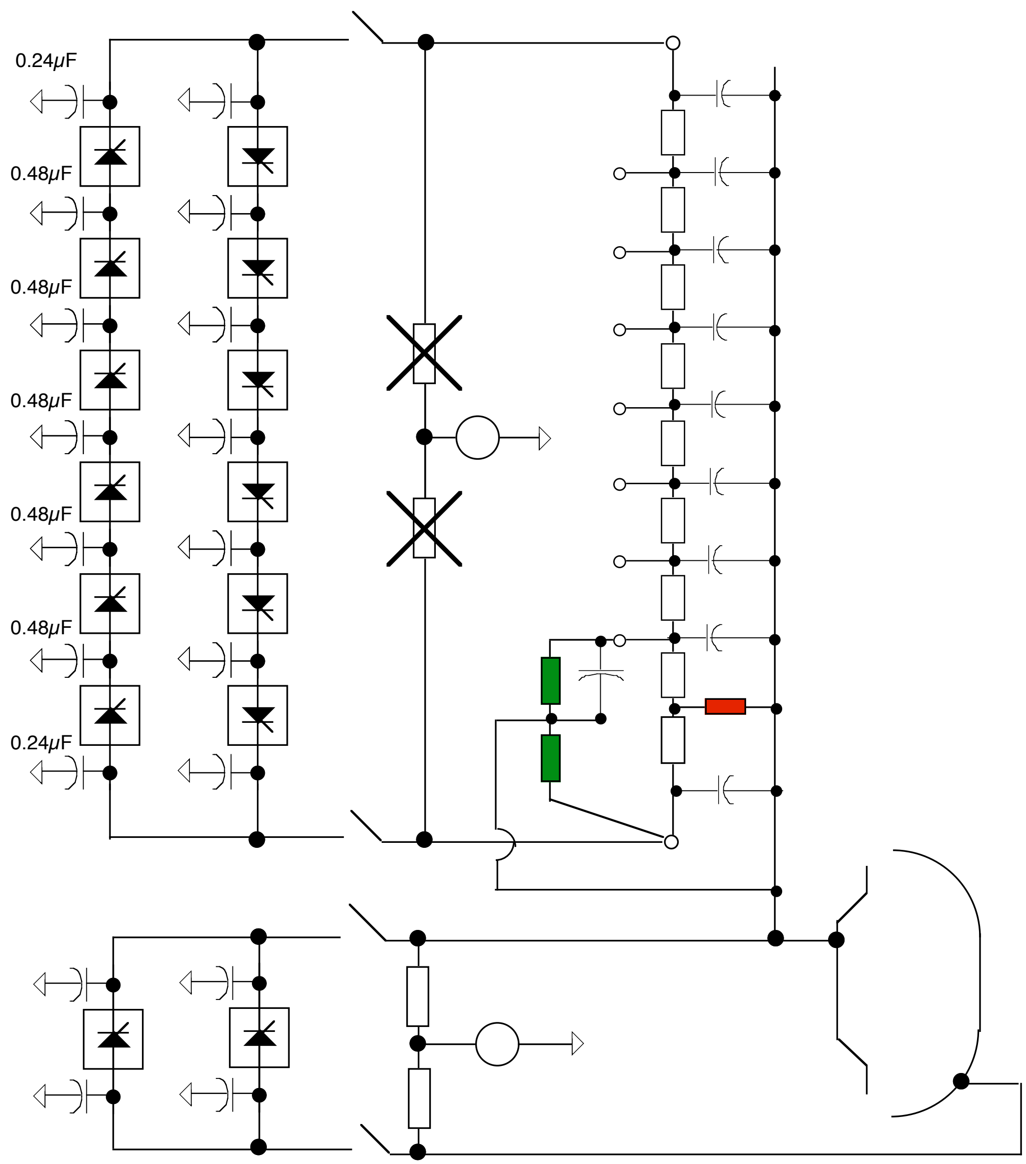
  - evidence seems solid but only if the fault is limited to a single location

  - turn-turn fault is ruled out because adjacent conductors in layer 4 do not exhibit any influence on null location (due to the two-in-hand winding they are electrically far away)

- there appears to be a spurious connection from the lower OH ground plane to the hub assembly, which carries the ground fault leakage current (othewise the lifting of the ground plane ground wire(s) would isolate the fault)

- there appears to be a spurious connection from the hub assembly to the CS casing (otherwise the lifting of the hub assembly ground wires would isolate the fault)

- Can we continue to run?
  - a scheme could be adapted to aim a null voltage at the perceived fault location w.r.t. the CS casing using a combination of resistors and capacitors



0.24μF
0.48μF
0.48μF
0.48μF
0.48μF
0.48μF
0.24μF

- this will be imperfect for a variety of reasons, there will be finite energy dissipation in the fault each pulse

- resistors alone are not sufficient, capacitors are needed

- if OH and CHI operations are mutually exclusive, then one set of R's and C's will work

- if OH is to be run with CHI then a second set of R's and C's will be needed

- if the fault propogates, either due to energy dissipation or other mechanism then a turn-turn fault could easily develop which would embrace a large fraction of the coil (due to the two-in-hand winding adjacent turns are electrically far away)

- the consequences of the fault would most likely be severe, including arcing and melting of OH conductor, probable damage to microtherm, magnetic diagnostics on OH groundwall, and CS casing

• Can we make a repair?

  - if the OH coil is removed then the fault should be repairable since it is on the outer layer

  - problems with ground plane and hub isolation, as well as water tube insulation could also be addressed

  - duration of required outage is TBD

- it has been confirmed that CS can be lifted over south wall
- probably necessary to completely pull off the CS casing to reveal problem areas which exist on both the top and bottom

- Conclusion
  - several problems exist which are repairable but not without a schedule hit
  - an option exists to continue to run but there is significant risk that the fault may degrade
  - if we continue to run and the fault degrades to a turn-turn fault then the consequences would be severe including schedule hit >> that associated with a repair of the present problems
  - a hard management decision must be taken!!