NSTX

13-010226-CLN-01

TO: DISTRIBUTION
FROM: C NEUMEYER
SUBJECT: MINUTES OF MEETING ON OH HIPOT LEVEL

Subject meeting was held 2/23/01. In attendance were Al VonHalle, M Williams, M Bell, T Meighan, S Ramakrishnan, and P Heitzenroeder.

The attached information was presented by C. Neumeyer. In addition, S. Ramakrishnan presented an excerpt from a G.E. Instruction Booklet for hipot testing of AC generator windings which indicated the use of a formula 1.2E+0.5 to establish the test voltage "to demonstrate suitability for continued service".

After much discussion, it was decided that the OH coil hipot test voltage should be reduced from 13kV to 9kV for the upcoming tests, as well as for future routine tests after the OH coil is reinstalled.

Following is a summary of the main points:

1) It was agreed that the choice of test voltage is a judgement call which trades off the risk that the coil might fail during the test vs. the risk that the coil might fail in service. Furthermore, for the NSTX OH coil insulation, lacking any breakdown or corona inception voltage data on the specific formulation/configuration/thickness we are using, it is difficult to make the judgement.

2) The factory acceptance test voltage was based on 2E+1, where E is taken to be 6kV, which is the power supply voltage line to line. This is consistent with past practice here at PPPL (e.g. TFTR). There was much discussion about whether E should be taken to be 3kV instead, because the coil is center point grounded. However, since transients and other mis-operations (such as technican error in restoration of the grounding network) can in principle lead to 6kV to ground, it seemed prudent to continue to use this as the basis for now. Still it was decided to analyze in detail the voltage to ground measurements durign actual operations so that we can determine to what extent such transients are occurring on a regular basis.

ACTION: C Neumeyer to examine OH voltage transients via MDS data.

3) Tests at PPPL have been conducted at both the 13kV level and at 9kV, which is 75% of 13kV. The reduction to 9kV came about mainly due to difficulties in avoiding flashover on external bare copper tubes, etc. Since the low aspect ratio NSTX design drove the insulation to a thickness which does not have a large margin, and is therefore vulnerable to manufacturing defects, it was the general consensus of the group that testing at such a

reduced level is desirable from a standpoint of not putting the coil at undue risk of failure during test. The possibility of further reduction to something like 1.2*6+0.4=7.6kV was also considered, but is was decided to remain at 9kV for now.

4) The tradeoff between finding weaknesses during test vs. finding weaknesses during operation was discussed. If a ground fault occurs during operation, it will be detected by the ground fault detection system and the power supply will be shut down, after a delay. With 10kΩ grounding resistors, the maximum energy would be deposited into a fault where $R_{fault} = R_{ground} = 10k\Omega$ fault. At 6kV, if the ground fault detection, fault communication, and power supply shutdown takes 100mS, the deposited energy would be 6e3^2/1e4*0.100=360 Joules, which is not much. If the fault is not near the turn-turn region, it would not likely propagate. So, the consequence of a single fault occurring during operation is likely not to be severe. However, it is critical that the detection be fast acting and reliable. In any case, from this perspective, high test voltages are an unnecessary risk.

ACTION: S. Ramakrishnan shall proceed with the installation of a fast "instantaneous" ground fault detector on the OH system.

5) In connection with 4), the configuration of the existing surge arrestors which are connected from each line to ground was discussed. It is important that the V-I characteristic of these arresters be coordinated such that minimal current flows through them at 6kV. Otherwise, if a ground fault occurs near one terminal of the OH coil, then the arrester on the opposite terminal will begin conducting and the amount of current let through will be determined by the arrester in parallel with the 10kΩ resistor, i.e. the grounding resistor will not be current limiting. This could result in large current flow and energy dissipation in the fault. *ACTION: S Ramakrishnan to investigate and provide an alternate arrester, if ncessary.*

6) It was noted that, with the present grounding configuration, the OH coil terminals are symmetrically connected to ground via 10kΩ resistors which is an effective way of limiting the voltage on the ground insulation of the coil but only when the ground plane is at ground. Since the ground plane is connected to the CS casing, then when CHI operation is underway the ground plane is at CHI potential which will contribute 1kV to the voltage to be withstood by the groundwall insulation. Thus, when OH and CHI operations are combined, instead of a balanced +/-3kV across the groundwall, it would shift to +4/-2kV, e.g. In order to avoid this situation, it is probably more desirable to connect the OH grounding resistors to CS casing potential which will serve, under all conditions, to minimize the voltage across the OH groundwall insulation.

ACTION: S Ramakrishnan to investigate and develop suitable modification.

7) The idea of an R&D program to develop corona inception and breakdown voltage data on the OH coil insulation was discussed. Although we have published literature on this information for the basic constituents (CTD-112P, Kapton tape, Scotchply) we do not have any data on our specific configuration, namely one half lapped layer of CTD-112P without Kapton, one half lapped layer CTD-112P with Kapton, with Scotchply overwrap. NSTX did perform such tests on the TF coil insulation formulation (three half lapped layers CTD-112P without Kapton). While this information would lead to a better understanding of what margins exist over the test voltage, it would not necessarily tell us anything about

weaknesses in our OH coil which may have arisen due to QA problems during manufacture.

ACTION: J Chrzanowski to develop an estimate for preparing and testing 10 samples of the OH insulation system over copper.

cc:

M Bell
J Chrzanowski
L Dudek
T Egebo
P Heitzenroeder
F Malinowski
T Meighan
M Ono
G Pearson
M Peng
S Ramakrishnan
A VonHalle
M Williams

NSTX File

- Meeting Purpose:

Decide on the upcoming OH hipot test voltage:
Should it be reduced from 13kV to a lower value (e.g. 9kV)?

- Operating Voltage:

OH coil operates with nominal +/-3kV to ground with transients to 6kV

- Normal Rule of Thumb:

2E+1 = 2*6+1 = 13kV

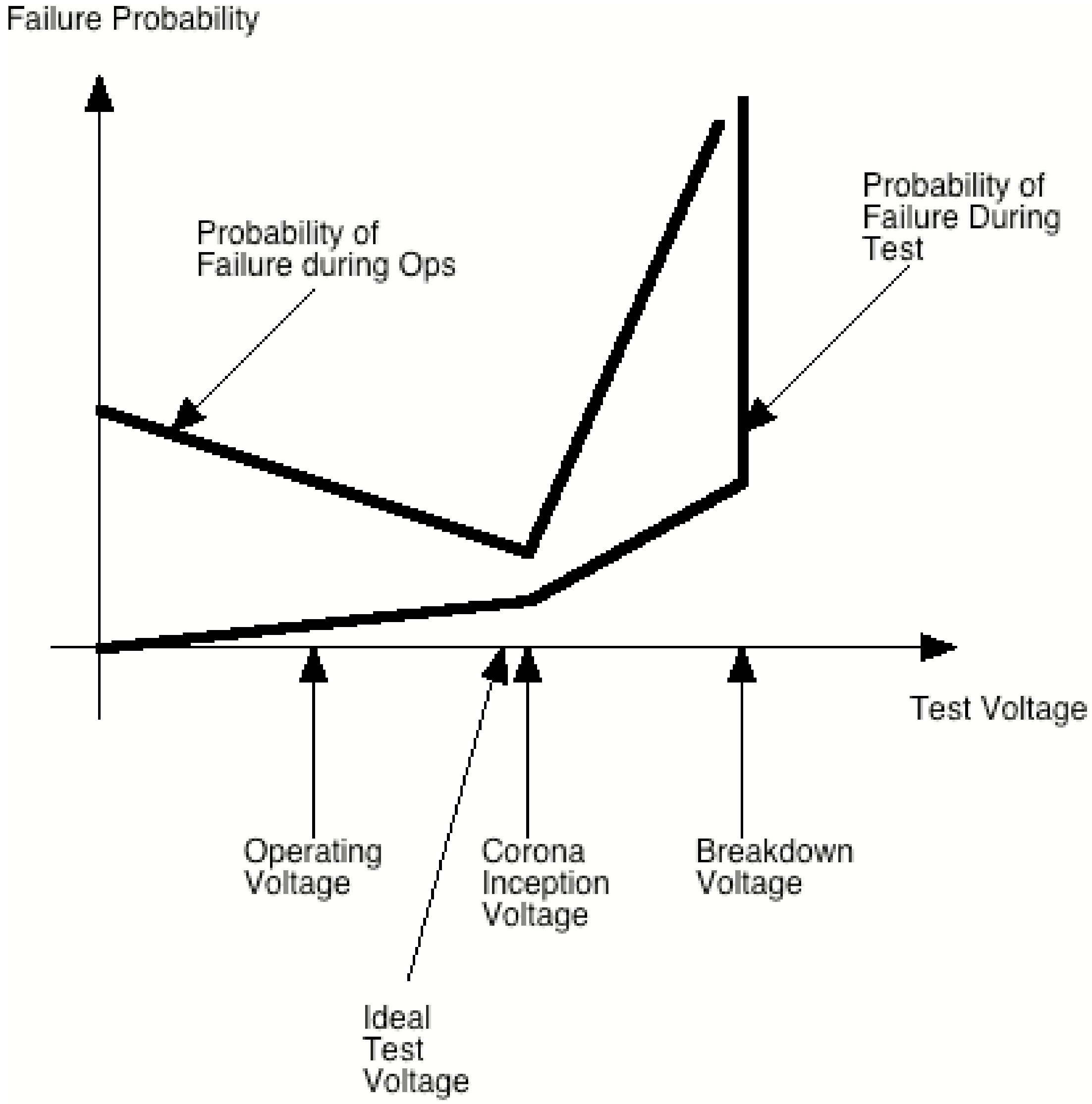
- Past Practice:

13kV tests for acceptance from factory, and during center stack assembly. Since then:

Date	kilo volts	mico amps
2/3/99	9	31
8/30/99	9	36
11/3/99	9	21
12/8/99	13	26
6/29/00	9	110
8/3/00	13	74
12/11/00	9	Failure

Back off to 9kV was primarily due to problems with external flashover.

- Criteria for Setting Test Voltage


Failure Probability
Probability of Failure during Ops
Probability of Failure During Test
Test Voltage
Operating Voltage
Corona Inception Voltage
Breakdown Voltage
Ideal Test Voltage

- R&D Tests did not test OH insulation system (2 half lapped layers of CTD-112P, one with, and one without, Kapton, with Scotchply overwrap)

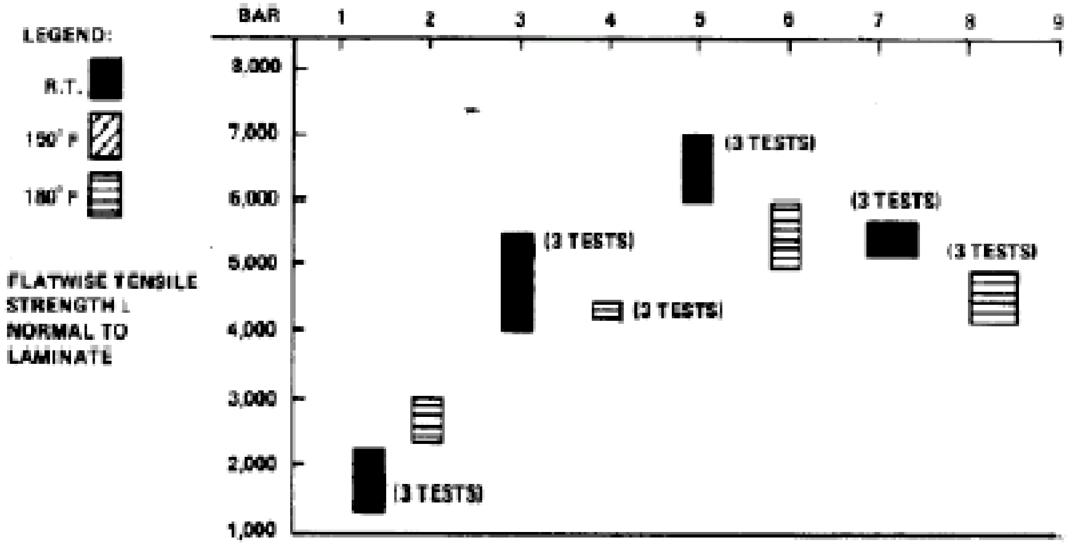
- Published literature would indicate voltage stresses are OK, at least under ideal conditions

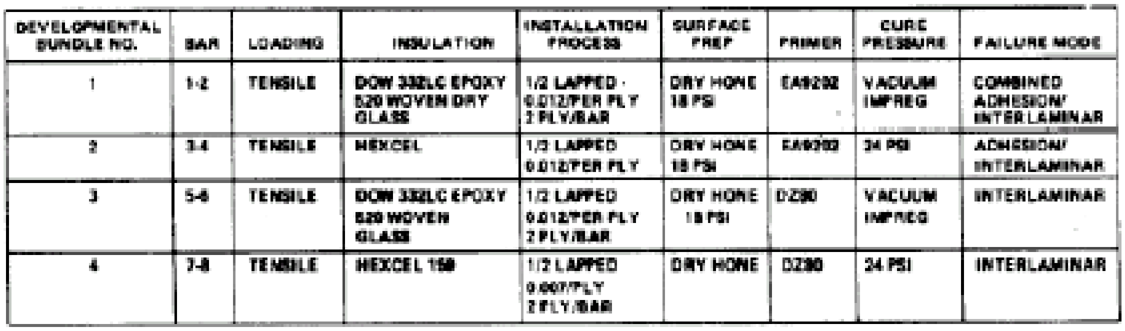
Operating @ 6kV E=75 volts/mil
Test @ 13kV = 163 volts/mil

ITER test samples exhibited failures at 1850 volts/mil

NSTX test samples exhibited failures at 420 volts/mil without Kapton

- No matter what voltage we select, it would be desirable to mock-up some samples and perform breakdown tests





DEVELOPMENTAL BUNDLE NO.	BAR	LOADING	INSULATION	INSTALLATION PROCESS	SURFACE PREP	PRIMER	CURE PRESSURE	FAILURE MODE
1	1-2	TENSILE	DOW 332LC EPOXY 520 WOVEN DRY GLASS	1/2 LAPPED - 0.012/PER PLY 2 PLY/BAR	DRY HONE 18 PSI	EA9202	VACUUM IMPREG	COMBINED ADHESION/ INTERLAMINAR
2	3-4	TENSILE	HEXCEL	1/3 LAPPED 0.012/PER PLY	DRY HONE 18 PSI	EA9202	24 PSI	ADHESION/ INTERLAMINAR
3	5-6	TENSILE	DOW 332LC EPOXY 520 WOVEN GLASS	1/2 LAPPED 0.012/PER PLY 2 PLY/BAR	DRY HONE 18 PSI	DZ80	VACUUM IMPREG	INTERLAMINAR
4	7-8	TENSILE	HEXCEL 150	1/2 LAPPED 0.007/PLY 2 PLY/BAR	DRY HONE	DZ80	24 PSI	INTERLAMINAR

Fig. 2-10 Flatwise Tensile Test Results of Turn-To-Turn Insulation

As we discussed. the 30 C adiabatic temp. rise should result in a max. dT of .7 x this, or 21 C, which is the dT Art and HM used in their calculations. The figure above is from the TFTR RDAC and shows the flatwise tensile strength in several glass/epoxies. I would expect the DOW DER-332 to be very similar (if not weaker) than the CTD-112 used in NSTX. This data is, fortunately, also based on the use of DZ-80 primer as in NSTX.. (The top axis shows the bar numbers; 5&6 are for the DER-332). This shows the flatwise tensile strength to be in the range of 4.5-7 ksi. HM's analysis (13-001208-HMF-01) indicates a maximum tensile stress of 1.9 ksi. and a maximum combined shear of 2.07 ksi. If we assume that the tensile load reduces the shear allowable by (tensile stress x 0.3) or 570 psi, the allowable would be 2.9-.57, or 2.33 ksi. Based on this, I conclude it is safe to proceed with the 30 C adiabatic temp. rise. As we are getting close to the shear allowable, I recommend that be considered the limit.