DS0313 TEST PLAN

TS-SSC 90-095
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12/4/90

Test Objectives

Test objectives for magnet 313 are to make the standard quench, strain gage and harmonics measurements through two thermal cycles. Heater strip tests will also be made at the end of the first thermal cycle. Some of the field measurements will be made both with the standard magnetometer and with the partially completed HAL2 system. All standard magnetometer tests will be made with probe #11.

The instrumentation on magnet 313 is identical to that of magnet 311, except for a) the absence of the two return end can external deflectometers*, b) the addition of two more active strain gages on the return end can of 313 and c) the addition of heater strips to quadrants 1, 2, and 4 of 313.

The quadrant 1 and 2 heater strips are to be instrumented with voltage taps at both ends to facilitate testing. The quadrant 4 heater strip is not to be connected. The quadrant 1 heater strip is a BNL copper strip with resistance .8 Ohms. The quadrant 2 heater strip is an SSC Lab steel strip with resistance 2.1 Ohms.

The lead end voltage taps from the upper and lower outer coils of 313 (upper and lower coil tap 20A) were both lost during end can installation. The lower ramp splice 21A and 22A taps were both lost also. The upper ramp splice 21A and 22A taps are intact, however.

This plan follows the DS0311 plan documented in TS-SSC 90-073 quite closely.

* The holes for the deflectometers were drilled in the wrong positions in the magnet shell.

THERMAL CYCLE I

1) **Cool to 4.2 K** monitoring all thermometers and strain gages at 10 minute logging intervals.

2) Protect magnet with a 30 mohm dump resistor. Delay dump firing 50 msec after quench detection, but phase back power supply promptly. Evacuate the warm bore tube.

3) Check safety circuit balances:

a) sawtooth ramps between 100 A and 200 A at 50 A/sec.

b) manual trip from 1000 A.

4) Set data logger sampling frequencies and pre-quench windows:

a) data loggers 1 and 2: 2 kHz and 25% pre-quench.

b) data loggers 3 and 4: 5 kHz and 50% pre-quench.

STRAIN GAGE AND QUENCH TESTING

5) **Bring magnet to 4.35 K (850 Torr or 16.5 psia.)** Ramp rate = 16 A /sec.

a) Take strain gage runs, one file per current loop, using the sequences of currents below. Take data at all currents on the way up, and for the currents marked "*" on the way down.

Run 1: 0*, 2200, 3100*, 3800, 4400*, 4900 A

Run 2: 0*, 2200, 3100*, 3800, 4400*, 4900, 5400*, 5800 A

Run 3: 0*, 2200, 3100*, 3800, 4400*, 4900, 5400*, 5800, 6200 A

Run 4: 0*, 2000, 3100*, 3800, 4400*, 4900, 5400*, 5800, 6200*, 6600 A

Run 5: 0*, 2000, 3100*, 3800, 4400*, 4900, 5400*, 5800, 6200*, 6600, 7000 A

Note: Runs 4 and 5 are really ramps to quench in some cases.

6) With ramp rate = 16 A/sec, train the magnet until 4 plateau quenches have occurred. Do not do more than 15 quenches. The predicted short sample limit currents (inner coil) as a function of temperature are:

3.6 K	7383 A
3.8 K	7190 A
4.0 K	6978 A
4.2 K	6749 A
4.35 K	6567 A

7) Take a strain gage run to $I_{plateau}$ - 100 A.

HARMONICS MEASUREMENTS

8)

a) **Bring the magnet to 4.2K.** Establish I_{quench} under these conditions. (Note: At this point the warm bore tube is still evacuated.)

b) Bring the warm bore tube to room temperature, insert probe #11, and establish the flow of room temperature purge gas. Quench the magnet twice to establish I_{quench} under these conditions.

9) Measure harmonics at 4.2 K.

a) Power the magnet with 200 A. Locate the ends of the magnet relative to the tape measure on the probe mounting fixture by moving the probe vertically and identifying the points at which the dipole field is 1/2 its central value. Define the magnet center to be half way between the two end points.

b) Ramp the magnet to quench at 16 A/sec.

c) Position the probe at the center of the magnet and measure the harmonics as a function of current: Do one sawtooth cycle at 16 A/sec from 0 to 6500 A or I_{quench} - 200 A, whichever is lower. Record data every 6 seconds (approximately every 100 A) starting from 0 A.

d) Ramp the magnet to quench at 16 A/sec.

e) Ramp the magnet at 12 A/sec to 6500 A or I_{quench} - 200 A, whichever is lower, hold a flattop for 2 minutes, ramp down at -12 A/sec to 110 A, hold for 2 minutes, ramp at 6 A/sec to 5000 A. (If I_{quench} < 5500 A, the final ramp should be to I_{quench} - 500 A.)

f) Measure harmonics as a funciton of position at 5000 A (or I_{quench} -500 A.) Take data at the following positions relative to the center of the magnet (positive is towards the lead end, i.e. up.) z = -20", -18", -16", -14", -12", -10", -8", -6", -4", -2", 0", 2", 4", 6", 8", 10", 12", 14", 16", 18", 20".

g) Ramp the magnet to 5500 A (or I_{quench} -200 A), then back to 5000 A (or I_{quench} -500 A.) Measure harmonics as a function of position at z = -20", -18", -16", -14", -12", -10", -8", -6", -4", -2", 0", 2", 4", 6", 8", 10", 12", 14", 16", 18", 20".

h) Position the harmonic probe at the center of the magnet and measure the harmonics as a function of current: Ramp the magnet from 5000 A down to 110 A, then to I_{quench} - 200 A, back to 110 A, then to 1000 A, all at 16 A/sec. Record data every 6 seconds (approximately every 100 A) starting from 500 A on the first down ramp until 1000 A on the second up ramp.

i) **HAL2 Harmonics:** Ramp the magnet to quench at 16 A/sec. Repeat steps e) and f) with the HAL2 System instead of the magnetometer.

10) Remove the harmonic probe and evacuate the warm bore. **Take the magnet to 4.35 K (850 Torr or 16.5 psia.)**

RAMP RATE AND FURTHER STRAIN GAGE STUDIES

11) Ramp value studies (with chart recorder on power supply):

a) Ramp to quench at 16, 25, 50, 75, 100, 125, 150, 200 A/sec.

b) Ramp to 6500 A at 16 A/sec, then ramp down from 6500 A to 4000 A at 100, 200, 300, and 400 A/sec.

12) **Take the magnet to 3.8 K.** Using 16 A/sec ramp rate, quench the magnet at 3.8 K until 3 quenches have occurred on plateau or a total of 10 quenches have been taken, whichever comes first.

13) Take a strain gage run at 3.8K to I_{quench} - 100 A.

HEATER STRIP STUDIES

These studies are described in detail in the Appendix to this plan, which is taken from Chris Haddock's mail message from SSC Lab, also attached. Chris will try to be here during these tests.

THERMAL CYCLE II

14) **Warm the magnet to within 10 K of the pretest temperature** (the dewar temperature before it was cooled down the first time.) Record the strain gages and thermometers at 10 minute intervals during the thermal cycle.

15)

a) Repeat steps 2 - 8 and steps 9 e-i from the first thermal cycle, except in steps 9 f and 9 g record data only at the center of the magnet.

b) If time permits, go to step 16), the optional test.

OPTIONAL TEST (If time permits)

16) Optional test: **Bring the magnet to 4.35K (850 Torr or 16.5 psia.)**

a) From the ramp rate study (step 11), choose a ramp rate well above the "knee" for which the quench current is at least 300 A below the low ramp rate value. Ramp the magnet to quench at this ramp rate, and verify the quench current.

b) Perform a series of ramp cycles between 100 A and progressively higher peak currents. Each ramp cycle consists of an up ramp, at the rate chosen in step 16 a, from 100 A to the peak current, a 20 second flattop at that current, a down ramp to 100 A at the chosen ramp rate and a 10 second dwell at 100 A. Five successive ramp cycles should be performed to the same peak current before increasing the peak current. The first 5 ramps should be to 200 A below the quench current found in step 16 a, the next five should be to 175 A below the quench current, and so on. Continue this sequence until the magnet quenches. (This procedure will require the use of the table-driven ramp function.)

c) Perform 50 ramp cycles to the last current at which all 5 cycles were completed without quenching. (25 A below the quench current in step 16 b.)

17) **Tests of EI / EO?**

18) **Warm to room temperature.** Monitor all strain gages and thermometers at 10 minute logging intervals until T > 100 K, then at 30 minute intervals. Continue to monitor until the magnet is within 5 K of its pretest temperature.

Appendix. Strip Heater Tests

A- BNL Heater

1) Determine firing C and V0 for BNL heaters such that discharge time is the same as for long magnet tests, and energy deposited into heater is appropriate for a short magnet. (See Appendix to Chris Haddock's mail message.)

2) Measure warm and cold resistance of BNL heaters.

3) Record voltage across strip heater as a function of time after heater is fired.

4) Record voltage across taps to determine at which time, after the heater is fired, the magnet coil becomes normally resistive.

5) Fire BNL heater at .5*V0, .75*V0, ... until a quench occurs withing 200 msec when the magnet current is 2000 A. Determine the time between heater firing and coil becoming normally resistive (T_fn) for the BNL heater.

6) Record magnet current as a function of time and determine Integral(i**2 dt) (MIITS) for the quench.

B - SSC Heater

Repeat steps 1 - 6 for the SSC1 heater.

If T_fn (SSC) is less than T_fn(BNL), increase the SSC1 heater power and measure Integral(i**2 dt) (MIITS.)

From: SSCVX1::HADDOCK 3-DEC-1990 15:10:42.26
To: FNAL::DELCHTS
CC:
Subj: tests of qph's

PROPOSED TEST SCHEDULE FOR QUENCH PROTECTION HEATERS IN DSS313

The purpose of these tests is to study the effectiveness of a redesigned quench protection heater and compare it with a Brookhaven style heater, by performing tests on a single magnet which contains both types of heater. The tests will be done on a short magnet operating under pool boiling cryogenic conditions.
Supporting information is contained in the appendix.

THE SCHEDULE SHOULD INCLUDE THE FOLLOWING:
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1) Determine firing C and Vo for BNL heaters such that discharge time is the same as for long magnet tests, and energy deposited into heater is appropriate for a short magnet (see Appendix).
2) Measure warm and cold resistance of BNL heaters.
3) Record voltage across strip heater as a function of time after heater is fired.
4) Record voltage across taps to determine at which time, after the heater is fired, the magnet coil becomes normally resistive.
5) Fire BNL heater at 1/2Vo, 3/4Vo,.... until a quench occurs within 200 ms when the magnet current is 2000 Amperes. Determine the time between heater firing and coil becoming normally resistive (T_fn) for the BNL heater.
6) Record magnet current as a function of time and determine Integral i**2 dt (MIITS) for the quench.

7) Repeat the entire test sequence using one SSC1 heater.
8) If possible repeat using both SSC1 heaters in parallel or series or separately.
9) Compare T_fn (BNL) with T_fn (SSC1).
10) Compare MIITS (BNL) with MIITS (SSC1).
11) Assuming T_fn (SSC1) is less than T_fn (BNL), increase the SSC1 heater power and measure Integral i**2 dt (MIITS).

Appendix:

The Brookhaven design (BNL) consists of a steel strip containing heater "pads". Each pad is essentially 3 spot heaters in series, a quench is produced when the pad is energized by creating a large temperature gradient across the coil insulation.

The SSC design (SSC1) consists of continuous strip "pads" which produce a smaller temperature gradient, but do so over a much larger area.

The advantages of the SSC design are that (i) there is no risk of the insulation being damaged by high temperatures of the heater pads and (ii) the fabrication of the pad is much easier and the finished product will be much more robust.

(1) First Compare the performance of a BNL style heater under pool boiling conditions with that of a heater in a long magnet (from previous

tests e.g DD0017). (All the resistances below need to be measured before firing the heater power supply.)

(i) Time constant of circuit.
Need to match the energy deposition rate so that it is the same as for long magnets. This effectively sets the RC time constant for the circuit. The resistance of the BNL heater strip on a long magnet is approximately 1.5 ohms cold. The time constant observed for a discharge on a long magnet is 75 ms. For a short magnet there will be two heater pads instead of twelve. The expected cold resistance is therefore 1.5/12 * 2 = 0.25 ohms.
Assume the resistance of the leads which connects the heater strip to the heater firing unit (hfu) are 2 ohms each. The circuit resistance is therefore (2+2+0.25)=4.25 ohms. In order for the circuit discharge time to equal 75 ms the required capacitance is C = tau/R_total = 75e-3/4.25 = 17.6 mF to meet this 6 of the 3.2 mF capacitors will be wired in parallel.

(ii) Voltage required at HFU
From long magnet data one may determine the power deposited into a BNL style heater (e.g DD0017 at 2000 A). This power is approximately 200J per strip or 200/12 Joules per pad (note on DD0017 2 heater strips were fired together whereas DSS313 only has one installed). Let the ratio of energy deposited into a short versus a long magnet be the ratio of their collared lengths. Then energy deposited into a short magnet will be : 1.0/16.00 * 200 = 12.5 Joules. The energy deposited into the strip heater is given by:
P = 1/2 C Vo**2 [R_circuit_total / R_heater_strip]
This expression sets Vo, the voltage across the heater strip to be 9.1 volts. The required voltage from the hfu will therefore be:
V_hfu = 9.1/0.25 * 4.25 = 154.7 volts.
In practice, the value of the hfu voltage should be initially 50V, 100V and then in increments of 20 volts until a quench occurs. One should not expect the same T_fn (time between firing of hfu and entire coil becoming normally resistive) as long magnets since (i) only one quench heater strip is being used and (ii) The conditions are pool boiling as opposed to forced flow.

(2) Capacitance and Voltage for SSC1 strip heater.

The expected resistance of the SSC1 short heater strip is 0.524 ohms. If the lead resistance is approximately 2.0 ohms then the same capacitance and voltage values as for the BNL heater can be used.

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