SLAC NATIONAL ACCELERATOR LABORATORY FACET

SLAC Magnetic Measurement Plan and Traveler for the FACET Quadrupole Magnet Q4E#3 Q202221T (style 1.625Q27.3)

Account Number to be charged: 9141204

This traveler covers the magnetic measurements plan for one of 6 water-cooled quadrupoles, of engineering type 1.625Q27.3, called Q4E#3, to be used as Q202221T in sector 20 in FACET. This quadrupole was made in 1986 at SLAC and previously ran in the SLC arcs here at SLAC. Consequently it may have a very little residual radioactivity, the levels are marked on radiation tags and Jim Allan (ext 4064) can provide you further information on the type of radiation and what precautions you should take when handling these magnets.

This magnet weighs about 1375 lb, and comes to you on its final T1 mount. It has yellow labels that indicate its beamline position in FACET: Q4E#3 (Q202221T). It will run in series with 5 other quads: Q4E#2; #3; #4; #5; and #6. A booster PS will provide extra current to #1 to #3 and an equivalent booster PS will provide extra current to #4 to #6. They provide up to 22 A each.

1. Receiving Information:

Received by (MM initials)	SDA
Date received : (dd-mm-yyyy):	10-11-2010
Checked Magnet Number(Q4E#3),Optics name(Q202221T)	SDA
Magnet Engineer (Cherrill Spencer or her substitute) verifies that this magnet is ready to be magnetically measured. The refurbishment is finished as much as it can be at this time.	
If quad does not have a barcode sticker then ask Magnet Engineer to add one and she will write the 6 digit barcode number here:	002592

Retrieve past measurements (from July 1986, when this magnet was called ~~54Q7~~ 54Q12 or 1.625Q27.3#1) Attach copy of old record (from David Jensen): CMS

~~54Q7~~ 54Q12, old measurements attached (check):	

Preparation:

2. Power and LCW Connections: Unipolar PS >=300A , 40 V required. Cosine-shaped ramp that mimics the ramps produced by an Ethernet-driven controller. You will not use a booster PS. High pressure LCW system will be needed to cool this magnet in your measurement lab.

3. Magnet Orientation:

A beam direction arrow, should be visible on the top or side of the core, .Notice: This magnet has coil interconnects, power terminals and water fittings **~~downstream~~.** UPSTREAM If there is no arrow, contact Cherrill Spencer, x3474.

CMSpencer 19 Jan 2011

Beam-direction arrow in place (initials):	SDA

4. Magnet Alignment:

This magnet has sockets for 4 old tooling balls (TBs), they were last fiducialized in 1986 and now it has new TB sockets. Alignment crew should do a translation from old to new TBs (as Cherrill previously discussed with them), could be done before magnet arrives at MMG.

Fiducialization of new TB complete (Alignment Initials :)	

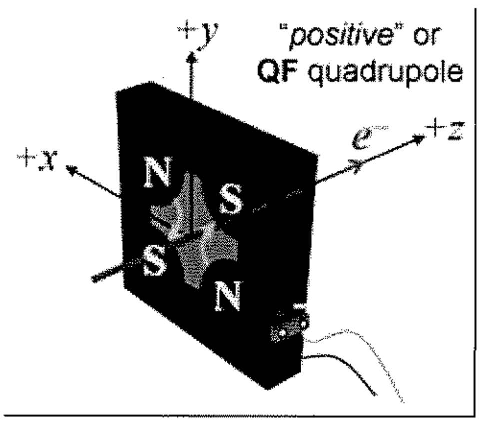
Alignment crew should do set up on measurement stand , and use the x,y,z axes of the whole magnet (as defined by TB measurements) such that the roll angle (angle of horizontal axis) is less than about 2.4 milliradian (or as small as possible), and pitch and yaw is also minimized. Fiducialization data on location of tooling balls with respect to geometric axis when poles are aligned perfectly horizontally should be saved.

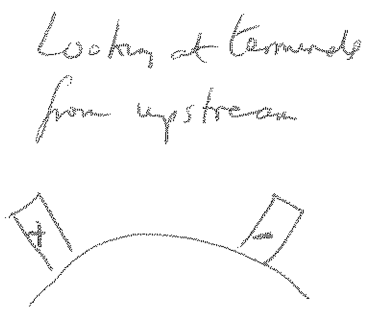
Alignment completed, Roll Angle = ________millirad (Alignment Initials :)	

The rotating coil should have its windings oriented that a 'zero' angle quoted for a pole is indeed zero relative to the horizontal axis defined by the alignment crew. (Angle of first south pole, and of higher multipoles is important). A stretched wire will be used before the rotating coil – see step 11.

5. Power leads and polarity:

The required polarity for Q4E#3 is *focussing.* Looking downstream the upper-left pole should be a NORTH pole as shown in this figure:





Determine the electrical connection polarity (with supply outputting positive current) which produces the required magnetic field polarities.

Place + and - labels on or near the main power flags for the required polarity.

Polarity established, power +/- labels applied	SR

6. Cooling Water Flow Check:

Each quadrupole has 8 water circuits, 2 per coil, with 4 input and 5 output hoses with appropriate Ys. There is no water manifold coming with the quad, please use your own manifold.

Adjust the differential pressure across each water circuit (deltaP) to be about 150 psi.

Total water flow should be about 2.55 gpm. If you cannot adjust deltaP to 150 psi, first use 200 psi (or max), measure the flow, then make total flow 2.6+/-0.2 gpm by adjusting the valve).

	Water flow [gpm]	Check
Maximum delta P ________		
Adjusted to produce 2.6gpm	2.6 or	

7. Thermocouple placement and Thermal Test: (thermal test to be done on Q3E#3 only)
Place 5 thermocouples at these locations:
- any one of the coils – on the incoming LCW – on the outgoing LCW -elsewhere on bench for ambient temperature measurement – on the steel core near any pole tip.

Arrange for temperatures to be read at least once every 3 minutes for the following thermal test: After water flow has been checked on each circuit, run JUST the FIRST quad to 250 A for three hours, reading the thermocouples, magnet current and voltage.

Confirm total LCW flow is 2.6 +/- 0.2 gpm	Flow is 2.9 gpm
Name of thermal test file and date of test	[illegible] [illegible]
URL of webpage where datafile stored	
Final LCW temp (in) – Final LCW temp (out)	= °C

If the rise in the LCW temperature is more than 12 deg C, something is wrong; stop, call Cherrill Spencer at x3474 or substitute.

8. Initialization:

To be done only once per quad, after successful completion of the water flow check and Thermal Test above. Use the cosine ramp with an equivalent linear rate of 15 A per second; minimum current of 5 A, maximum current of 300 A and pause time of 120 seconds at the minimum and maximum currents. Take the quad from 5 A to 300 A and back 7 times, ending up at 5 A

Initialization completed: date , MMG initials:	10 / 14 /2010 SDA

9. (a) Standardisation parameters and detail: (For use in measurements below)

Ramp type: cosine shape
Minimum standardisation current: 5 amps
Maximum standardisation current : 250 amps
Pause time at minimum or maximum standardization current: 30 seconds
Equivalent linear ramp rate for standardization process: 15 amps/second (increasing or decreasing)
Start at 5 A and ramp up to 250 A and down to 5 A FIVE times, finishing at 5 amps. A standardization procedure always involves FIVE up and down ramps; the up ramp followed by the down current ramp is called a *cycle* [this five is an increase in number of cycles since you started measuring Q3E#3]

Setting to desired current (BDES) : ramp UP to BDES at 5 amps/second

All operating currents should be approached from below; except when I request a series of decreasing currents – these will be approached from a higher current. When moving from one current to another for the strength or harmonics measurements use 5 amps/second and wait at least 30 seconds after the operating current has been reached before making any magnetic measurements. Put basic standardization details in all datafile comments.

Confirm that magnet will ramp at 15 A/s (initials:)	SDA

9 (b) Multiple standardization cycles to be carried out BEFORE any measurements are made. NEW instruction to be carried out on all the Q4E#n quads.

Based on observations of the behavior of the very first 1.625Q27.3 quad to be measured it is necessary to carry out many standardization cycles on this style quad before any measurements are made on it. This will "train" the magnet into a state to produce a repeatable integrated strength when it is powered up in the beamline. The large number of cycles compensates for the low maximum standardization current; the size of the FACET power cables and the maximum voltage of the string's power supply limit the current.

Take the quad through 75 standardization cycles (equivalent to 15 standardization procedures)

Quad has undergone 75 standardization cycles	Date: 10/19/2010 Start time: 3:00 PM

10. Poletip Field Measurements

When it is convenient, maybe when the rotating coil is not in the quad's aperture, please use a Hall probe to measure the poletip field at 193.5 amps (after a regular standardization procedure). Please make a correction in the field value for the thickness of the Hall probe.

Current Actual current 193.64	Poletip field : 0.722 T
193.5 A nominal	
Date and initials:	10 / 19 /2010 SOA

11 (a) Stretched Wire Measurement to calibrate the rotating coil:
If a stretched wire is used to calibrate the rotating coil then record the datafile name and URL:

http://www-group.slac.stanford.edu/met/MagMeas/MAGDATA/FACET_Sector_20/ Q4E#3/Coil Calibration

11 (b) Stretched Wire Measurement to Estimate Harmonics- NEW instruction
Please do this stretched wire measurement on Q4E#3 as well.
Based on observations of the behavior of the rotating coil DC55 we need to make some stretched wire measurements to estimate the sizes of the multipoles, especially the sextupole.
Set up a stretched wire along the x=0, y=0 magnetic center of the quad's aperture, have an Alignment Crew help set it up as well as they can.

Ramp up to 193.5 amps at 5 amps/second. Pause for 30 seconds before taking any data.
Measure integral G.dl at the following x positions (and y=0) with the stretched wire:
-1.8,-1.5,-1.2,-0.9,-0.6,-0.3, 0.0, 0.3, 0.6, 0.9, 1.2, 1.5, 1.8 cm
Go back across the aperture at the same x in reverse order and measure integral G.dl at 193.5 amps. Put all the data in the same data file.
Tell the Magnet Engineer when this data is available and don't remove the stretched wire until the Magnet Engineer says it's OK to proceed.

Filename of Wire-Harmonics Measurement	Wirevsx .ru 1
Date of measurement, initials	10 / 20 /2010

12. Rotating Coil Magnetic Measurements: ∫G.dl and harmonics at various currents.
Purpose of these measurements is to find the transfer functions (Current required to reach a certain integrated gradient strength) especially for certain desired integrated gradients, and to check that the multipole harmonics do not exceed FACET requirements. We have agreed to use rotating coil DC55 on the remaining 1.625Q27.3 style quads.

For Q4E#3, the desired ∫Gdl is 255.7932 kGauss (will need about 193.5 A)

Rotating Coil Designation (Name)	DC55
Rotating Coil Radius	0.016349

13. Integrated Strength Measurements: The data in steps. 13, 14, 18 + 19 will become the reverse polarity data.
Measure the integrated gradient ∫Gdl at these currents:
25, 75, 100, 125, 150, 175, 193.5, 210, 220, 230, 240, 250 amps
Then back to 25 amps from 250 amps, measure the ∫Gdl at the same set of currents in reverse order. Remember to ramp at 5 A/second and wait for 30 seconds after reaching the new current before starting a measurement. In the beamline will use both main and booster PS to reach 250 amps, not enough voltage capacity in the main PS for it to provide 250 amps to 6 quads in string.

Filename of Int. Strength Measurement	strdat .ru3
Date of measurement, initials	10 / 21 /2010

14. Harmonics Measurements (with rotating coil, still do this, because we will take the 12-pole value from the rotating coil measurements)
Measure the strength and angle of each multipole component at 193.5 amps.
(or at the operating current provided after analysis of integrated strength measurement).
Multipole values should be given as a percentage of the quadrupole moment calculated at a 1cm, PLEASE. Also provide the magnetic center X and Y coordinates measured during the harmonics measurements at the above current.

Filename of Harmonics Measurement	hardat .ru3
Date of measurement, initials	10 / 21 /2010

15. Polarity Reversal Test: I need to do this test on Q4E#3. I am not happy with polarity reversal behavior of some Q3E quads and we may have to switch one of the Q4E quads into a Q3E quad. Purpose of this test is to check the multiple standardizations in step 9(b) are sufficient to train this 1.625Q27.3 style quad.
REVERSE THE POLARITY OF Q4E#3 and redo the integrated strength and harmonics measurements (16, 17 below).
Swap the power cables on Q4E#3 when you have done its nominal polarity data-taking and do one standardization procedure [5 cycles] in the new polarity and redo the measurements of integrated strength and harmonics, as indicated below, no need to measure the reversed polarity with the stretched wire.

The magnet engineer will do a comparison of the polynomials in the two polarities and decide if the single standardization is sufficient to maintain the behavior of the quad within tolerances. Then swap back to the original polarity and standardize JUST ONCE and do the strength and harmonics measurements again (18,19 below) and the magnet engineer will do a comparison analysis and tell you of she needs any further measurements on Q4E#3.

16. Reversed Polarity Integrated Strength Measurements:
Measure the integrated gradient ∫G.dl at these currents:
25, 75, 100, 125, 150, 175, 193.5, 210, 220, 230, 240, 250 amps
Then back to 25 amps from 250 amps, measure the ∫G.dl at the same set of currents in reverse order. Remember to ramp at 5 amps/second and wait for 30 seconds after reaching the new current before starting a measurement.

The data in steps 16 + 17 will become the standard polarity data

Filename of Int. Strength Measurement	strdat .ru3
Date of measurement, initials	10/22/2010

17. Reversed Polarity Harmonics Measurements:
Measure the strength and angle of each multipole component at 193.5 amps.
(or at operating current provided after analysis of integrated strength measurement).
Multipole values should be given as a percentage of the quadrupole moment calculated at a 1cm radius. Also provide the magnetic center X and Y coordinates measured during the harmonics measurements at the above current.

Filename of Harmonics Measurement	hardat .ru3
Date of measurement, initials	10/22/2010

18. Original Polarity Integrated Strength Measurements:
Measure the integrated gradient ∫G.dl at these currents:
25, 75, 100, 125, 150, 175, 193.5, 210, 220, 230, 240, 250 amps
Then back to 25 amps from 250 amps, measure the ∫G.dl at the same set of currents in reverse order. Remember to ramp at 5 amps/second and wait for 30 seconds after reaching the new current before starting a measurement.

Filename of Int. Strength Measurement	strdat .ru4
Date of measurement, initials	10/25/2010

19. Original Polarity Harmonics Measurement:
Measure the strength and angle of each multipole component at 193.5 amps.
(or at operating current provided after analysis of integrated strength measurement).
Multipole values should be given as a percentage of the quadrupole moment calculated at a 1cm radius. Also provide the magnetic center X and Y coordinates measured during the harmonics measurements at the above current.

Filename of Harmonics Measurement	hardat .ru4
Date of measurement, initials	10/28/2010

The magnet engineer will do a comparison of the polynomials in the two polarities and decide if the single standardization procedure is sufficient to maintain the behavior of the quad. Check with her/him before removal of Q4E#3 from bench.

Magnet Engineer Approval obtained	CMSpencer 30 / Oct /2010

20. Saving and Distributing the Magnetic measurement data

Please post all data at

http://www-group.slac.stanford.edu/met/MagMeas/MAGDATA/FACET_Sector_20/quad/
Q4E#3

in a subdirectory with the magnet name.
Please inform Magnet Engineer (Cherrill Spencer at cherrill@slac.stanford.edu (ext 3474). and /or achim@SLAC.Stanford.EDU, wittmer@SLAC.Stanford.EDU of FACET) when the strength and harmonic measurement data are available for inspection and analysis, and for final approval .

21. This section is to be completed by FACET Magnet Engineer.

Data been inspected & analyzed by Magnet Engineer	CMSpencer 13 Nov 2010
Based on Magnet Engineer analysis of data can confirm the pre-assigned beamline location (optics-deck name):	Optics beamline location: Q4E#3, Q202221T
Quadrupole is released from Magnetics Group, signed and dated by FACET Magnet Engineer:	CMSpencer 19 Jan 2011
Remove the LCW from the coils and take the magnet to the designated storage area. Signed & dated by MMG personnel:	Done in October 2010

22. This section is to be completed by FACET Beam Physicist (Walter Wittmer).

Checked that integrated strength data is satisfactory and have generated the polynomial function for the controlling database to set the magnet. Nominal operating current is 191.2 ① amps. Checked that this is within the capability of the assigned power supply max 223 A + Max Std = 250 A	Signature and date: [signature] 01/20/11
Checked that the multipole values at r=10mm are below the Physics Requirements tolerances (initial):	[signature]
Magnet accepted for FACET (signed):	[signature]

① current set point differs within string. Shunt resistor may be required!

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Date accepted (Month-Day-Year):	01/20/11

When this traveler is completed, attach it to the refurbishment traveler of this magnet and send these hardcopies to the designated person in Kathleen Ratcliffe's group at MS 18 to be scanned into a pdf file. Then that electronic file will be stored in a place TBD and the hardcopies will be returned to sit with the magnet until it is installed in the beamline.

Two travelers for this magnet been scanned into a pdf file; by Catherine Creech	Name of pdf file Magnet Q4E#3 Q202221T
Two travelers been returned to sit with magnet in its "waiting for installation" place.	Signed & dated: [signature] 1.28.11

Further Tasks to be done on this magnet will be recorded on its Refurbishment Traveler.

END OF FACET Q4E#3 (Q202221T) MAGNET MAGNETIC MEASUREMENT PLAN AND TRAVELER