Measurements of Probe 14 Shaft
(25 cm Tangential Probe)

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This memo summarizes measurements made on the unwired G11 shaft of Probe 14[1], a tangential harmonic probe intended for use in Lab 2[2].

Specified Dimensions: Table 1 shows the names and specified azimuthal angles, depths, widths, and lengths of the longitudinal grooves cut into the surface of the Probe 14 shaft. The specified tolerances on the groove angles are ±5 minutes of arc (~±1.5 mrad, or ±.75 mils), with no cumulative tolerance. Groove depths and widths have tolerance bands specified as shown in the Table 1. Groove lengths have ±.005 inches tolerance specified. The probe shaft has diameter 1.000±.005".

Groove Name	Azimuthal Angle (deg.min.sec)	Depth (inches)	Width (inches)	Length (inches)
T+	11.32.13	.0285 - 0290	.0355 - .0360	9.566
T-	348.27.47	"	"	"
A+	174.15.39	.0285 - .0290	.0355 - .0360	9.390
A-	185.44.21	"	"	"
BB+	90.0.0	.0245 - .0250	.0280 - .0285	9.574
BB-	270.0.0	"	"	"
D1+	45. 0.0	.0160 - .0165	.0105 - .0110	9.832
D1-	225.0.0	"	"	"
D2+	135.0.0	.0160 - .0165	.0105 - .0110	9.718
D2-	315.0.0	"	"	"

Table 1. Specified Dimensions of Probe 14 Tangential Probe

[1]Drawing 0102-ME-263941, two sheets.
[2]See TS-SSC 91-066 for the inspection specifications for this shaft, and TS-SSC 91-088 for a list of the numerical designations of new harmonic probes being made for Lab 2 at this time.

Description of Grooves and Wires: The T+ and T- grooves form the primary tangential winding. A+ and A- form an auxilliary tangential winding with 1/2 the sensitive area of the primary tangential winding. A 20-conductor Litz wire[3] with mean diameter .035" will be used for these two windings. All 20 conductors will be put in series in these windings.

BB+ and BB- are used for dipole windings which buck the primary and auxilliary tangential windings. The wire used will be a 7-conductor Litz wire. Four of the conductors will be wired in series to buck the T+- winding. Two of the remaining three conductors will be wired in series to buck the A+- winding.

The D1+, D1-, and D2+, D2- grooves are used for two dipole windings at right angles used for further bucking to remove effects due to manufacturing errors in the T, A, and BB windings. The wire used will be 10-mil diameter wire available from stock.

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[3]See TS-SSC 91-090 for detailed information on the Litz wires used in this probe.

Measured Dimensions: The measurements made on the groove cut in the Probe 14 shaft were done in the Lab D quality assurance lab by Tom Van Raes on April 14, 1991. His work (Appendix 1) was done in accordance with the specifications given in TS-SSC 91-066. Further measurements of groove lengths were made at Lab 2 by C. Hess and A Russe (Appendix 2).

i. Azimuthal Positions: Measurements were made of the azimuthal positions of each longitudinal groove at three positions (1 1/2", 5 1/2", and 9 1/2") along the ~11" shaft. Two sets of independently set up measurements were made at each of the three positions. Table 2 gives the numerical values of the measured deviations.

Groove Name	Azimuthal Deviation at 1 1/2" Position (mrad)	Azimuthal Deviation at 5 1/2" Position (mrad)	Azimuthal Deviation at 9 1/2" Position (mrad)
T+	-0.2, -0.4	-0.5, -0.7	0.3, 0.2
T-	0.3, 0.1	0.7, 0.1	-0.2, -0.3
A+	0.3, 0.3	-0.7, -1.5	0.8, 0.8
A-	0.2, 0.9	0.2, **-2.1**	-0.9, -0.6
BB+	-1.4, -1.3	**-3.4, -3.9**	-1.4, -1.7
BB-	**2.4, 2.3**	**3.0, 2.4**	**1.9, 1.6**
D1+	**-4.1, -3.9**	**-4.7, -5.3**	**-3.4, -3.3**
D1-	-1.1, **-0.9**	-1.0, **-1.8**	**-1.7, -1.8**
D2+	**-5.0, -5.3**	**-7.1, -7.9**	**-4.5, -4.4**
D2-	**-1.6, -1.6**	-0.3, -1.0	**-2.4, -2.5**

Table 2. Measured Azimuthal Deviations of Longitudinal Grooves

The measurements of the groove angles were recorded in degrees, minutes, seconds notation, and have been converted in the table and figures into milliradians. At 0.5 inch radius, .1 mrad corresponds to .05 inches. The ±5 minutes tolerance is equivalent to ±1.5 mrad. Out of tolerance measurements are shown in bold print.

The Tangential and Auxilliary grooves are all within tolerance. The Belly Band and Dipole windings are out of tolerance. The worst values, for the D2+ groove at the 5 1/2" position, correspond to a deviation of about 4 mils from the required position.

ii. Groove Widths, Depths, and Lengths:

Longitudinal groove widths were measured at the same three positions as the azimuthal positions. Groove depths were measured at five positions (1 1/2",3 1/2", 5 1/2", 7 1/2", and 9 1/2") along the shaft. The lengths of the longitudinal grooves were measured at Lab D, except for the D1 and D2 grooves, for which a small enough tool bit was unavailable. At Lab 2, a different technique (mounting the shaft on a lath bed with precision indexing head, and moving the bed past a microscope) was used to obtain values for groove lengths. Table 3 gives the measured average depths, widths, and lengths of the longitudinal grooves.

Groove Name	Average Depth (inches)	Average Width (inches)	Length (inches) (Lab 2 in bold print)
T+	.0284 (.0285 - .0290)	.0360 (.0355 - .0360)	9.5640, **9.561** (9.566)
T-	.0289 (.0285 - .0290)	.0362 (.0355 - .0360)	9.5638, **9.561** (9.566)
A+	.0310 (.0285 - .0290)	.0361 (.0355 - .0360)	9.3893, **9.3860** (9.390)
A-	.0305 (.0285 - .0290)	.0361 (.0355 - .0360)	9.3897, **9.3870** (9.390)
BB+	.0255 (.0245 - .0250)	.0291 (.0280 - .0285)	9.5733, **9.5665** (9.574)
BB-	.0251 (.0245 - .0250)	.0291 (.0280 - .0285)	9.5728, **9.5690** (9.574)
D1+	.0166 (.0160 - .0165)	.0114 (.0105 - .0110)	**9.840** (9.832)
D1-	.0184 (.0160 - .0165)	.0114 (.0105 - .0110)	**9.840** (9.832)
D2+	.0186 (.0160 - .0165)	.0115 (.0105 - .0110)	**9.714** (9.718)
D2-	.0162 (.0160 - .0165)	.0114 (.0105 - .0110)	**9.713** (9.718)

Table 3. Measured Groove Depths, Widths, and Lengths of Tangential Probe 14 (Specified Values in Parentheses)

The average values for groove depth look quite close to the specified depths. The Auxilliary + groove is 1.5 mils deeper than the maximum specified depth. The Dipole 2 + groove is 2.5 mils deeper than the maximum specified depth. The groove depths vary along the probe shaft by ~.5 mils, as shown in Figures 6 - 9.

The Belly Band grooves are ~.6 mils wider than specified, and the Dipole grooves are .4 - .5 mils wider than specified. The groove widths show no position dependence.

The longitudinal groove lengths are the most difficult to measure of the measurements specified in the inspection procedure. Nevertheless, they are all within 10 mils of the specified values from the drawing.

iii. "Spiralling" of Longitudinal Grooves: An attempt was made to measure "spiralling" of the longitudinal grooves around the shaft by measuring the vertical position of the T+ groove relative to a flat surface. If this is position is a constant, and if the angles of the other grooves relative to the T+ groove are constant, then there is no spiralling for any groove. The vertical position of the T+ groove was measured to be 2.1149 ± .0001".

Conclusions: The as-built values of Probe 14 dimensions are adequate to proceed with coil winding and testing. Measurements have now been made with Probe 14 at Lab 2 on several 50 mm model SSC dipole magnets, both with the Lab 2 Magnetometer system and the newer HAL2 ("harmonics at Lab 2") system. Values of the dipole field and the first allowed harmonics (sextupole and decapole) appear to be in good agreement with the Lab 2 standard Morgan coil probe, Probe 11[4].

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[4]M. Lamm, private communication.