Table 1(e)

Expected values of integral harmonics in 80 mm Arc Quadrupoles
at 30 Amp (warm measurements) at 25 mm reference radius.

[<bn> = mean, d(bn) = uncertainty in mean, sig(bn) = sigma for bn]

n	<bn>	d(bn)	sig(bn)	<an>	d(an)	sig(an)
1	0	10	10	0	10	0
2	0	1.4	1.4	-1.8	0.5	2.2
3	-1.0	1	.6	0.0	0.1	.7
4	0	0.7	.6	0.0	0.7	.5
5	1.0	2	.5	-3.7	0.5	.15
6	0.0	0.1	.1	0.	0.2	.1
7	-0.6	.1	.1	0.	0.1	.1
8	0.0	0.1	.1	.0	0.1	.1
9	-1.3	0.2	.1	.3	0.1	.1

Expected integral harmonics at 660 A
(Same as above for all harmonics except for b5)

5	-2.6	2	.5

Expected integral harmonics at 1450 A
(Same as above for all harmonics except for b5)

5	0.0	2	.5

Expected integral harmonics at 5000 A
(Same as above except for b5 due to saturation)

5	4.7	2	.5

Expected values of "body" harmonics in 80 mm Arc Quadrupoles
at 30 Amp (Warm) at 25 mm reference radius :

[<bn> = mean, d(bn) = uncertainty in mean, sig(bn) = sigma for bn]

n	<bn>	d(bn)	sig(bn)	<an>	d(an)	sig(an)
1	0	0	10	0	0	0
2	0.0	-1.3	1.4	0.	0.7	2.2

3	-1.	1	.6	0.	0.4	.7
4	0.0	0.3	.6	0.	0.7	.5
5	-7.6	2	.5	0.0	1.	.15
6	0.0	.1	.1	.0	0.2	.1
7	-0.6	.1	.1	.0	0.1	.1
8	0.0	.1	.1	.0	0.1	.1
9	-1.8	0.2	.1	.0	0.1	.1

Expected harmonics at 660 A
(Same as above for all harmonics except for b5)

5	-11.2	2	.5

Expected harmonics at 1450 A
(Same as above for all harmonics except for b5)

5	-8.6	2	.5

Expected harmonics at 5000 A
(Same as above except for b5 due to saturation)

5	-3.9	2	.5

Expected values of harmonics in LEAD END at "ALL" currents (Unit-m)

n	<Bn>	d(Bn)	sig(Bn)	<An>	d(An)	sig(An)
1	0	0	0	0	0	0
2	-.3	0	.9	-2.2	0	1.5
3	0.1	0	.4	0.7	0	.5
4	0.2	0	.2	0.5	0	.2
5	9.5	1.	.3	-5.2	1.	.2
6	.01	0	.1	-0.05	0	.05
7	0.05	0	.05	-0.06	0	.04
8	0.04	0	.03	-0.02	0	.07
9	0.5	0.05	.05	0.35	0	.07

Expected values of harmonics in RETURN END at "ALL" currents (Unit-m)

n	<Bn>	d(Bn)	sig(Bn)	<An>	d(An)	sig(An)
1	0	0	0	0	0	0
2	0.3	0	.9	-.4	0	1.4

3	-.1	0	.2	-0.2	0	.6
4	.1	0	.2	-0.1	0	.2
5	1.7	0	.3	-0.05	0	.1
6	.02	0	.02	-0.03	0	.03
7	.01	0	.02	-0.03	0	.06
8	-.01	0	.02	-0.01	0	.02
9	0.25	0	.03	-0.02	0	.03

Notes:

0. X in 1st/2nd column of the following lines means that this argument is either not valid any more or not relevant any more. These lines are left here for historical reasons. Similarly, a question mark in the 1st/2nd column of a line would mean that it is under review.

X 1. Item in () means that it is either inserted after the 6/2/93 meeting or needs further examination. This number would be the same in table 1(b) if it was merely inserted and different if I have put my best guess. If item is still in () in table 1(b), that means that the item is being currently examined.

X 2. The table 1.0 (made for Accelerator Physicists) will have only two columns. The 2nd column will be absorbed in the 1st. In most cases the magnitude of the second column would be added to the magnitude of the first column of this table to make the first column of the new table 1.0. The exception will be the systematic allowed harmonics at 660 A where the value will not exceed its 1450 A value, if d(bn) > |bn(660A)-bn(1450A)|. This general exception is given because of the way coil will be iterated. In 80 mm quad, though the coil will actually be not iterated but the actual pole position is not fixed(?) since the first 10 quads will use shim and the rest will not. Therefore, in principle one can change the pole by 1-2 mil which changes b5 by 1-2 unit. The difference in b5 for [b5(660A)-b5(1450A)] is -2.6 unit. This data is provided by Animesh and is inserted in the table 1(b). Since this is greater than the 2 unit of uncertainty for d(b5) in column 2 of the above table, we may use this as the value in Table 1.0.

3. A value of d(b9) = 0.2 is inserted in this table to represent the uncertainty in b9. This is consistent with the way d(b5) = 2.0 unit is arrived. Recall 1 mil pole error gives b5 of ~1 unit, 1 mil wedge error gives b5 ~ 0.5 and level of iteration error in b5 is ~ 1 unit.

4. A value of d(b7) = 0.1 unit is inserted so that it is consistent

with the way d(b3) = 1.0 is obtained.

X 5. The value of <a4> = 2.7 unit (obtained from the measurements with
X the integral coil) is not resolved yet. It is not consistent with
X adding several 9" coil measurements. In QRB003, QRB004 and QRB009,
X one obtains an average <a4> = 0.3 by adding 9" coil measurements
X with a maximum of 0.7 unit in magnet QRB003. For <b4> the 9" coil
X measurements in these three magnet gives an average of 0.3 unit
X and a maximum of 0.4 unit in the magnet QRB009.

Careful warm measurements on the best aligned integral coil in magnet QRB005 gives a value of ~1 unit for a4 in magnet QRB005.

<a4> = 0.7 is the accepted value from the meeting on 6/10/93.

6. Values for a1 are not given here. It is presumed that misalignment errors will predominate this harmonic. In any case this was not a measured harmonics in the magnets tested so far.

7. d(b1) = 10 was arrived from the estimated errors in coil length and similar parameters.

8. d(b7) = 0.1 unit and d(b9) of 0.2 unit are suggested values.

9. RMS in a5 is changed from 0.1 to 0.15, which is more closer to the measurements.

10. d(b1) and sig(b1) values are inter-changed.

11. All "-"'s in d(bn) and d(an) columns are replaced by 0.0.

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12. Table 1(d) includes the measurements from QRB005 and QRB006 also. Table 1(c) was based on QRB007-QRB012 magnets. The only change in the table for integral harmonic is in the sigma for a2. It goes up to 2.2 unit from the previous value of 1.2 unit. No other harmonic was changed since the change in the value would not have been significant.

13. In addition to the integral values, we now also give the body and end harmonics separately. These are derived from the of z-scan using the procedure described by Animesh. However, z-scan was only done in 2 magnets -- QRB006 and QRB009. To improve the statistics we include the z-scans from the magnets QRB003 and QRB004. The ends in these magnets were the same as in the 8 magnets QRB005-QRB012. The only

difference was in the value of pole shims. The pole angle in QRB003 and QRB004 was 11 mil smaller than in QRB005-QRB012.

14. First, the expected harmonics in the lead and return ends are obtained from the 4 magnets QRB003,4,6,9. The integral harmonics are obtained from the magnet QRB005-012. The end harmonics are subtracted from the integral harmonics to obtain the mean <an> and <bn> in the body. d(bn) and sig(bn) in the integral are used for the d(bn) and sig(bn) in the body.

15. As before for obtaining b3, b5, b7 and b9 the arguments based on the factors other than the measured harmonics in magnets QRB005-012 are used for estimating the integral harmonics and for the body harmonics.

16. <b3> in the body is changed from an idealised value of 0.0 to a more realistic value of 0.5. Note that no tuning will be done in this harmonic to bring it to zero, and in any case the resolution in the midplane shim is not there to bring it to zero. The same value is used for the integral <b3>. For the body <b4> and <a4>, see item No. 5.

Nov 17, 1994

17. The table is now updated to include expected warm harmonics as requested by RAP (Peggs, et.al.).

18. The non-allowed harmonics have now a zero expected value, unless there is some geometric reason to expect otherwise. The uncertainty in the average go to d(bn) column. This would now be consistent with what is being done in the tables of other magnets.