



Fermi National Accelerator Laboratory

FERMILAB-TM-1758

A Compilation of the Data on the Low- β Spools

N. Gelfand

*Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510*

October 1991

A Compilation of the Data on the Low- β Spools

Norman M. Gelfand

October 10, 1991

Each of the high gradient correction quadrupoles associated with the new low- β lattice is built into a package which contains correction coils similar to the correction coils in the existing Tevatron spool packages. ¹ These coils have been measured in Lab. 5. The quench currents are measured in a vertical dewar. The only correction element which failed the quench test was TSL003. In that one case the skew dipole coil quenched at 90A, lower than the required current of 100A.

The strength ($\int B \cdot dl$) of the various coils (the magnetic field B is measured at a radius of 1" with 50A in the coil) and the harmonic composition of the magnetic field due to the various coils are measured with the coil warm using a 11Hz signal in the coils. ² The strength of a coil can be used to compute a transfer constant. The transfer constant is then used to compute the current needed to generate the value of the field in the coil needed for Tevatron operation. Currently, I believe, nominal values of the transfer constants are used, but it would be better if the actual values were available and used.

¹It should be noticed that the location of a given correction coil in these packages, relative to the adjacent quadrupole is different from that in a normal Tevatron spool. The high gradient quadrupole coil is in the location of the normal upstream coil package while the correction coils normally located in the upstream package are now downstream.

²A discussion of the procedure used to measure the coils in the original Tevatron spools can be found in the *Proceedings of the 12th International Conference on High Energy Accelerators.(1983) pg. 536*. The coils in the low- β spools were measured using a similar procedure.

Unfortunately, the fact that the coils were measured at 11Hz and not with a D.C. current, means that a correction needs to be made to the transfer constant obtained from the 11Hz data to get the correct transfer constant for operation in the Tevatron. The data presented here are *as reported* and have not been corrected. If we use the information found in the reference cited in footnote 2, we would estimate that the correction would increase the strength of the dipole coils by $\approx 15\%$, the strength of the quadrupole coils by $\approx 6\%$, and the strength of the sextupole coils by $\approx 2\%$. I must emphasize that I do not know of any measurements which would allow one to directly determine the correction factors for the strength of these coils. Until such measurements exist then an uncertainty of perhaps 1/2 of the correction factor exists in the value correction factor. This uncertainty is a limitation on our knowledge of the transfer constants.

The data available for these spools is reported on data sheets, the content of which has been stored in a data base. The data base is located on the ALMOND VAX cluster. The data base can be accessed either directly or from a FORTRAN program. Data sheets summarizing the information have been prepared and are also available.

The following tables and graphs summarize the data on the harmonics and the magnet strengths.

Table 1.1
Moments for Spool Type TSJ
DIPOLE Coil

Spool	001	002	003	Average	Sigma
b0	100.00	99.98	100.00	99.99	0.00
a0	0.61	2.25	1.37	1.41	0.67
b1	1.11	0.36	-0.52	0.32	0.67
a1	-0.76	-0.45	-0.19	-0.47	0.23
b2	-3.51	-1.75	-1.74	-2.33	0.83
a2	0.08	-0.01	-0.10	-0.01	0.07
b3	0.39	0.14	-0.21	0.11	0.25
a3	0.01	-0.16	-0.10	-0.08	0.07
Strength	140.80	141.90	140.90	141.20	0.50

Table 1.2
Moments for Spool Type TSJ
Quad. Coil

Spool	001	002	003	Average	Sigma
b0	-0.44	-0.49	0.01	-0.31	0.22
a0	3.87	0.81	1.85	2.18	1.27
b1	99.99	99.99	99.99	99.99	0.00
a1	1.28	1.36	1.08	1.24	0.12
b2	-0.27	-0.33	0.23	-0.12	0.25
a2	0.77	-0.15	0.28	0.30	0.38
b3	-0.11	0.10	-0.12	-0.04	0.10
a3	-0.05	-0.02	0.10	0.01	0.06
Strength	63.70	62.90	62.90	63.17	0.38

Table 1.3
Moments for Spool Type TSJ
Sext. Coil

Spool	001	002	003	Average	Sigma
b0	3.18	-1.81	-0.95	0.14	2.18
a0	0.50	-2.02	-1.20	-0.91	1.05
b1	-1.96	-0.95	-0.09	-1.00	0.76
a1	3.14	0.51	1.46	1.70	1.09
b2	100.00	99.98	99.93	99.97	0.04
a2	0.31	2.13	3.67	2.04	1.37
b3	0.72	-0.25	0.43	0.30	0.41
a3	-1.01	-0.51	0.05	-0.49	0.43
Strength	50.50	49.00	49.70	49.73	0.61

Table 2.1
Moments for Spool Type TSK
Quad. Coil

Spool	001	002	003	004	Average	Sigma
b0	-2.36	0.25	3.19	-0.47	0.15	2.00
a0	2.57	0.66	1.56	1.58	1.59	0.68
b1	99.98	99.99	99.99	99.99	99.99	0.04
a1	1.98	0.98	1.41	1.56	1.48	0.36
b2	0.01	-0.26	-0.08	-0.25	-0.14	0.11
a2	0.27	0.22	0.66	0.25	0.35	0.18
b3	-0.03	0.04	0.05	0.02	0.02	0.03
a3	-0.07	-0.06	0.01	-0.06	-0.04	0.03
Strength	62.80	63.30	63.00	63.50	63.15	0.27

Table 2.2
Moments for Spool Type TSK
Sext. Coil

Spool	001	002	003	004	Average	Sigma
b0	-1.35	-2.90	2.19	-0.29	-0.59	1.85
a0	0.64	0.90	-0.16	0.09	0.37	0.42
b1	-3.68	0.13	4.99	-0.12	0.33	3.08
a1	2.24	0.72	2.81	0.24	1.50	1.06
b2	100.00	99.99	100.00	99.98	99.99	0.00
a2	0.33	1.05	-0.87	1.90	0.60	1.02
b3	0.49	-0.34	0.30	-0.03	0.11	0.32
a3	-0.52	0.51	-0.12	0.04	-0.02	0.37
Strength	49.70	49.70	49.60	49.70	49.67	0.05

Table 2.3
Moments for Spool Type TSK
Sk. DIP. Coil

Spool	001	002	003	004	Average	Sigma
b0	1.69	0.33	0.74	0.68	0.86	0.50
a0	-99.99	-100.00	-100.00	-100.00	-100.00	0.00
b1	-0.20	0.00	-0.10	0.06	-0.06	0.10
a1	0.32	-0.62	-0.71	-0.55	-0.39	0.41
b2	0.09	0.02	0.15	0.03	0.07	0.05
a2	-1.89	-2.52	-1.88	-2.54	-2.21	0.32
b3	-0.10	-0.13	-0.08	-0.22	-0.13	0.05
a3	-0.06	-0.01	0.21	-0.07	0.02	0.11
Strength	140.20	140.70	140.40	140.90	140.55	0.27

Table 3.1
Moments for Spool Type TSL
DIPOLE Coil

Spool	001	002	003	004	005	006
b0	100.00	99.99	99.99	99.99	99.99	100.00
a0	-0.57	-1.45	-1.14	1.37	1.56	-0.20
b1	0.51	0.21	-0.72	0.06	-1.54	0.19
a1	0.22	-0.60	-0.48	-0.41	-0.13	0.28
b2	-1.40	-2.44	-1.96	-1.25	-2.89	-3.66
a2	-0.06	0.11	-0.01	0.04	0.27	0.00
b3	0.20	0.22	-0.04	0.02	-0.18	0.16
a3	0.05	0.20	-0.09	-0.13	-0.13	-0.12
Strength	228.30	240.00	254.90	221.10	241.44	210.40

Table 3.1
Moments for Spool Type TSL
DIPOLE Coil

Spool	Average	Sigma
b0	99.99	0.00
a0	-0.07	1.16
b1	-0.22	0.70
a1	-0.19	0.34
b2	-2.27	0.84
a2	0.06	0.11
b3	0.06	0.14
a3	-0.04	0.12
Strength	232.69	14.57

Table 3.2
Moments for Spool Type TSL
Sk. DIP. Coil

Spool	001	002	003	004	005	006
b0	0.04	-0.80	-1.91	0.92	1.40	-0.16
a0	-100.00	-100.00	-99.99	-100.00	-99.99	-100.00
b1	-0.39	1.43	0.18	0.23	-1.18	-0.61
a1	-0.61	0.36	0.06	0.55	1.22	-0.86
b2	0.03	-0.11	-0.11	-0.03	0.20	0.16
a2	-1.19	-3.22	-3.04	-0.80	2.53	-0.48
b3	0.05	-0.37	-0.22	-0.11	0.08	0.07
a3	-0.01	-0.03	-0.07	0.03	0.11	-0.01
Strength	205.50	216.70	226.00	202.60	220.60	198.50

Table 3.2
Moments for Spool Type TSL
Sk. DIP. Coil

Spool	Average	Sigma
b0	-0.09	1.09
a0	-100.00	0.00
b1	-0.06	0.82
a1	0.12	0.70
b2	0.02	0.12
a2	-1.03	1.91
b3	-0.08	0.17
a3	0.00	0.06
Strength	211.65	10.03

Table 4.1
Moments for Spool Type TSM
DIPOLE Coil

Spool	001	002	003	004	005	006
b0	100.00	99.99	100.00	99.99	100.00	100.00
a0	0.13	1.66	0.65	1.52	0.09	0.26
b1	-0.03	0.03	0.36	0.28	-0.73	0.58
a1	-0.29	-0.19	0.33	0.73	0.63	0.06
b2	-1.15	-1.78	-2.02	-2.97	-4.42	-1.35
a2	-0.07	-0.12	-0.11	-0.29	-0.11	-0.03
b3	-0.06	0.05	0.08	-0.04	-0.18	0.16
a3	-0.36	-0.03	-0.06	0.20	-0.21	-0.08
Strength	144.80	144.10	143.30	143.00	139.80	143.30

Table 4.1
Moments for Spool Type TSM
DIPOLE Coil

Spool	007	008	Average	Sigma
b0	99.99	100.00	100.00	0.00
a0	0.96	0.50	0.72	0.57
b1	0.17	0.95	0.20	0.46
a1	-0.47	0.24	0.13	0.40
b2	-0.81	-1.92	-2.05	1.08
a2	-0.07	0.00	-0.10	0.08
b3	0.00	0.27	0.04	0.13
a3	0.06	-0.23	-0.09	0.17
Strength	141.70	140.50	142.56	1.63

Table 4.2
Moments for Spool Type TSM
Quad. Coil

Spool	001	002	003	004	005	006
b0	-2.63	-0.32	-0.47	1.67	-1.84	-0.51
a0	4.44	1.36	-0.43	0.11	0.78	1.17
b1	99.96	99.98	99.99	99.99	99.99	99.99
a1	2.71	2.21	1.06	1.38	0.95	0.96
b2	-0.17	0.34	0.30	-0.32	0.66	-0.19
a2	0.37	0.11	-0.27	0.52	-0.26	0.00
b3	0.10	0.00	0.07	0.08	-0.06	-0.03
a3	-0.08	-0.05	0.00	-0.15	-0.11	0.01
Strength	65.00	63.90	63.60	64.20	63.70	63.50

Table 4.2
Moments for Spool Type TSM
Quad. Coil

Spool	007	008	Average	Sigma
b0	1.99	-0.72	-0.35	1.46
a0	1.69	1.51	1.33	1.36
b1	99.99	99.99	99.98	0.04
a1	1.69	1.18	1.52	0.60
b2	-0.58	-0.11	-0.01	0.38
a2	0.09	-0.34	0.03	0.29
b3	-0.08	0.14	0.03	0.08
a3	-0.20	-0.37	-0.12	0.12
Strength	63.80	63.20	63.86	0.51

Table 4.3
Moments for Spool Type TSM
Sext. Coil

Spool	001	002	003	004	005	006
b0	2.95	2.77	3.62	-0.68	1.13	-1.19
a0	1.87	0.65	0.32	-0.10	-1.28	-1.70
b1	-0.11	-0.39	0.60	1.67	-0.59	-1.78
a1	4.37	4.38	1.22	-2.66	2.33	2.59
b2	99.97	99.91	99.98	99.97	99.98	100.00
a2	2.49	4.30	2.17	2.49	1.97	-0.86
b3	-0.55	0.06	-0.52	-0.24	0.02	0.76
a3	-0.80	-0.23	-0.43	-0.08	-0.83	0.49
Strength	49.50	52.20	50.00	50.60	50.40	48.90

Table 4.3
Moments for Spool Type TSM
Sext. Coil

Spool	007	008	Average	Sigma
b0	-1.71	-1.95	0.62	2.13
a0	0.78	0.09	0.08	1.07
b1	3.60	0.24	0.41	1.52
a1	2.64	2.97	2.23	2.09
b2	99.98	99.98	99.97	0.03
a2	1.88	-1.95	1.56	1.87
b3	-0.09	0.36	-0.03	0.41
a3	0.67	-0.38	-0.20	0.51
Strength	49.60	49.60	50.10	0.94

Table 5.1
Moments for Spool Type TSN
Quad. Coil

Spool	001	002	003	004	005	006
b0	0.87	0.22	1.33	3.15	0.05	-1.13
a0	-1.15	4.24	0.44	-0.76	0.69	1.67
b1	99.96	99.98	100.00	100.00	100.00	100.00
a1	1.17	1.92	0.57	0.90	-0.17	0.13
b2	-0.55	-0.15	0.25	-0.23	-0.01	-0.06
a2	0.06	1.10	-0.29	0.06	-0.15	0.16
b3	0.01	0.02	-0.13	-0.07	-0.10	-0.07
a3	-0.08	0.19	0.27	0.16	0.06	0.17
Strength	64.00	64.10	65.30	63.80	64.00	64.10

Table 5.1
Moments for Spool Type TSN
Quad. Coil

Spool	007	008	Average	Sigma
b0	-4.02	1.78	0.28	2.01
a0	-0.64	1.04	0.69	1.62
b1	100.00	99.99	99.99	0.03
a1	0.12	1.52	0.77	0.69
b2	0.00	-0.90	-0.21	0.34
a2	-0.70	-0.28	0.00	0.49
b3	0.08	-0.05	-0.04	0.07
a3	-0.09	-0.21	0.06	0.16
Strength	62.90	63.70	63.99	0.62

Table 5.2
Moments for Spool Type TSN
Sext. Coil

Spool	001	002	003	004	005	006
b0	-2.05	-0.80	-2.91	0.15	0.12	-0.26
a0	-3.45	3.21	-1.16	-2.36	-0.01	-2.54
b1	0.34	2.25	3.00	5.23	-0.05	1.54
a1	-0.41	3.33	1.50	-2.20	0.04	3.40
b2	99.96	99.97	99.99	99.99	99.99	99.99
a2	2.78	2.49	-0.95	1.56	1.27	-1.11
b3	-0.49	0.55	0.03	-0.28	-0.05	-0.97
a3	0.54	-0.08	-0.41	-1.40	-0.09	0.17
Strength	50.70	49.70	52.00	51.60	51.10	51.10

Table 5.2
Moments for Spool Type TSN
Sext. Coil

Spool	007	008	Average	Sigma
b0	-0.49	-3.25	-1.19	1.27
a0	0.53	-0.23	-0.75	1.98
b1	-4.25	1.66	1.22	2.57
a1	0.43	6.90	1.62	2.66
b2	100.00	99.97	99.98	0.00
a2	0.06	2.42	1.07	1.45
b3	-0.68	-0.21	-0.26	0.44
a3	-0.15	0.98	-0.05	0.65
Strength	49.50	49.50	50.65	0.91

Table 5.3
Moments for Spool Type TSN
Sk. DIP. Coil

Spool	001	002	003	004	005	006
b0	1.94	1.56	-0.17	0.20	-0.43	0.77
a0	-99.98	-99.99	-100.00	-100.00	-100.00	-100.00
b1	0.19	0.31	0.50	0.16	0.08	0.75
a1	0.07	-0.50	-0.05	0.56	0.23	-0.67
b2	-0.01	0.16	0.21	0.14	0.06	0.08
a2	-1.98	-2.26	-2.36	-3.82	-2.26	-3.57
b3	0.00	-0.20	-0.32	0.02	-0.20	-0.33
a3	-0.04	0.02	0.21	0.43	0.04	-0.07
Strength	143.90	144.20	148.00	140.70	144.30	143.00

Table 5.3
Moments for Spool Type TSN
Sk. DIP. Coil

Spool	007	008	Average	Sigma
b0	-0.30	2.28	0.73	1.00
a0	-100.00	-99.97	-99.99	0.00
b1	0.02	0.82	0.35	0.28
a1	-0.08	1.11	0.08	0.53
b2	0.11	0.16	0.11	0.06
a2	-1.53	-2.42	-2.53	0.73
b3	-0.14	-0.39	-0.19	0.14
a3	-0.32	-0.05	0.03	0.21
Strength	141.60	142.10	143.48	2.10

Table 6.1
Moments for Spool Type TSP
DIPOLE Coil

Spool	001	002	003	004	005
b0	99.99	99.99	99.99	100.00	100.00
a0	-1.10	1.00	-1.31	0.65	-0.09
b1	0.05	0.24	-0.85	-0.21	-0.45
a1	-0.04	1.14	-0.17	0.57	-0.05
b2	-1.29	-4.13	-1.95	-3.88	-5.77
a2	-0.03	-0.30	-0.23	0.09	-0.16
b3	-0.18	0.13	-0.43	0.05	0.04
a3	-0.16	-0.12	-0.11	0.11	-0.26
Strength	150.80	150.20	151.90	145.10	137.10

Table 6.1
Moments for Spool Type TSP
DIPOLE Coil

Spool	Average	Sigma
b0	99.99	0.00
a0	-0.17	0.92
b1	-0.24	0.38
a1	0.29	0.50
b2	-3.40	1.61
a2	-0.13	0.14
b3	-0.08	0.20
a3	-0.11	0.12
Strength	147.02	5.48

Table 6.2
Moments for Spool Type TSP
Sk. DIP. Coil

Spool	001	002	003	004	005
b0	-0.69	1.80	0.48	2.46	1.17
a0	-100.00	-99.98	-100.00	-99.97	-99.99
b1	-0.39	0.53	-0.22	-1.36	0.50
a1	-0.80	0.92	-0.72	1.44	0.66
b2	0.10	0.20	0.09	0.27	0.17
a2	-1.18	-2.52	-1.34	-2.64	-2.54
b3	0.03	-0.13	-0.09	0.23	-0.20
a3	0.05	0.00	-0.04	-0.01	-0.02
Strength	150.40	150.80	152.40	143.90	139.60

Table 6.2
Moments for Spool Type TSP
Sk. DIP. Coil

Spool	Average	Sigma
b0	1.04	1.09
a0	-99.99	0.03
b1	-0.19	0.69
a1	0.30	0.90
b2	0.17	0.07
a2	-2.04	0.64
b3	-0.03	0.15
a3	0.00	0.03
Strength	147.42	4.87

Table 6.3
Moments for Spool Type TSP
Sk. QUAD Coil

Spool	001	002	003	004	005
b0	1.13	2.39	3.50	0.56	1.10
a0	-1.55	3.06	0.40	0.57	-1.29
b1	-1.96	3.41	-0.29	2.96	2.14
a1	-99.98	-99.94	-100.00	-99.96	-99.98
b2	0.20	-1.02	-0.28	-0.36	0.19
a2	-0.45	-0.88	-0.36	0.49	0.59
b3	-0.03	-0.12	-0.01	0.01	-0.03
a3	-0.09	-0.44	-0.14	-0.11	-0.13
Strength	65.20	63.70	65.00	65.20	63.50

Table 6.3
Moments for Spool Type TSP
Sk. QUAD Coil

Spool	Average	Sigma
b0	1.74	1.07
a0	0.24	1.65
b1	1.25	2.05
a1	-99.97	0.03
b2	-0.25	0.45
a2	-0.12	0.57
b3	-0.04	0.04
a3	-0.18	0.13
Strength	64.52	0.76

Coil Strengths TSJ Magnets

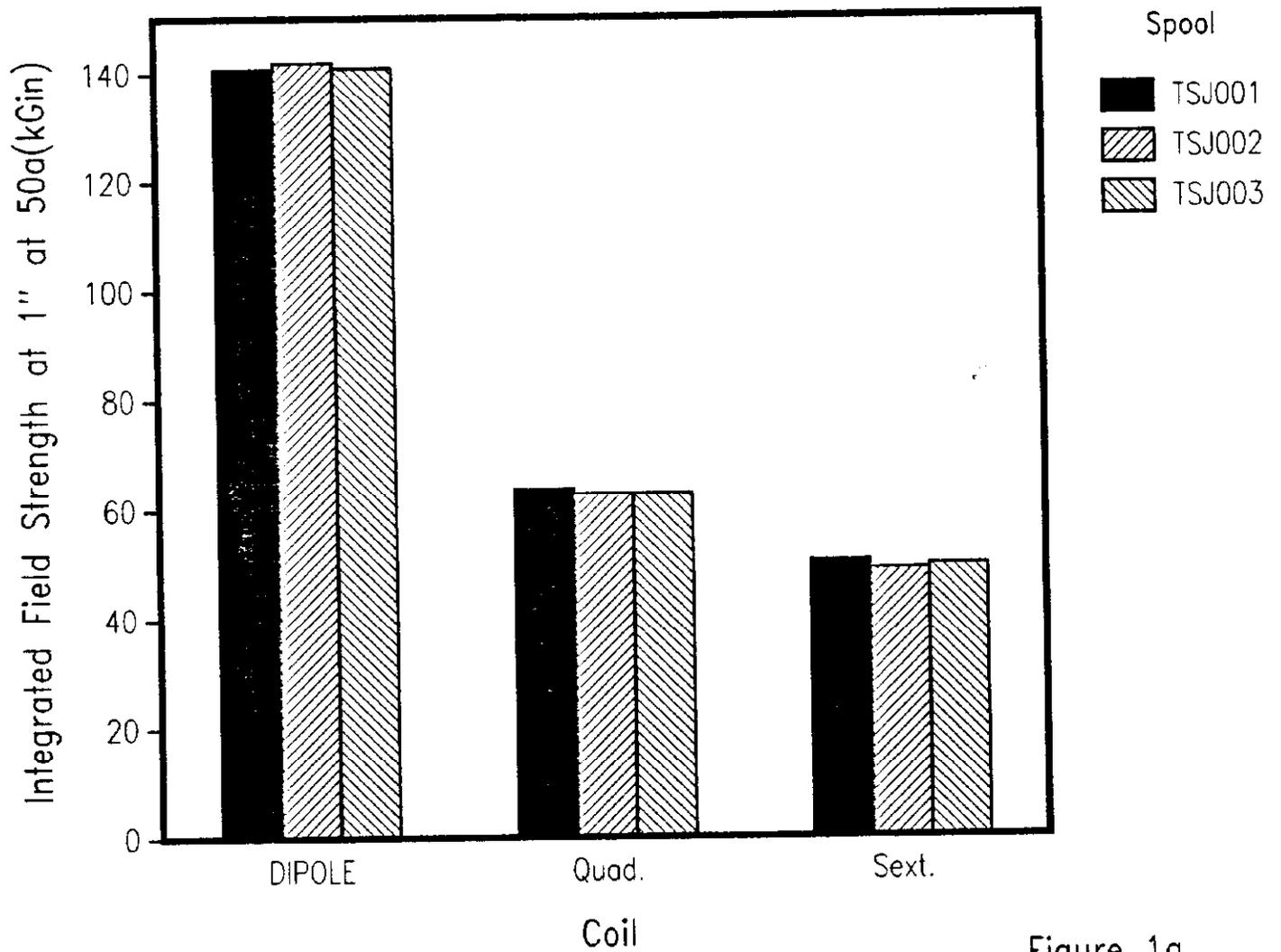


Figure 1a

Diff. Coil Strengths TSJ Magnets

Average DIPOLE = 141.20 +/- 0.50

Average Quad. = 63.17 +/- 0.38

Average Sext. = 49.73 +/- 0.61

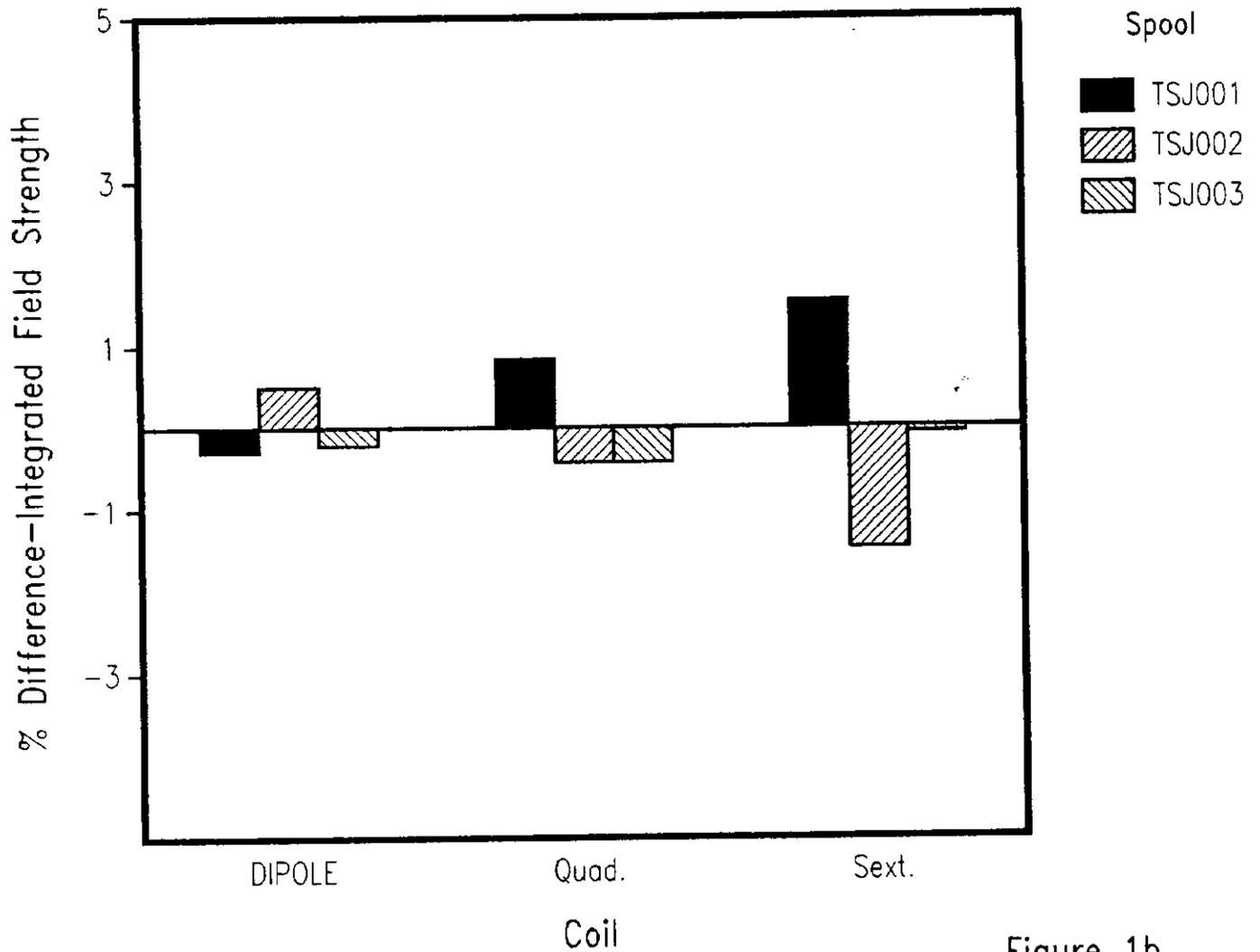


Figure 1b

Harmonics for the DIPOLE Coil TSJ Magnets

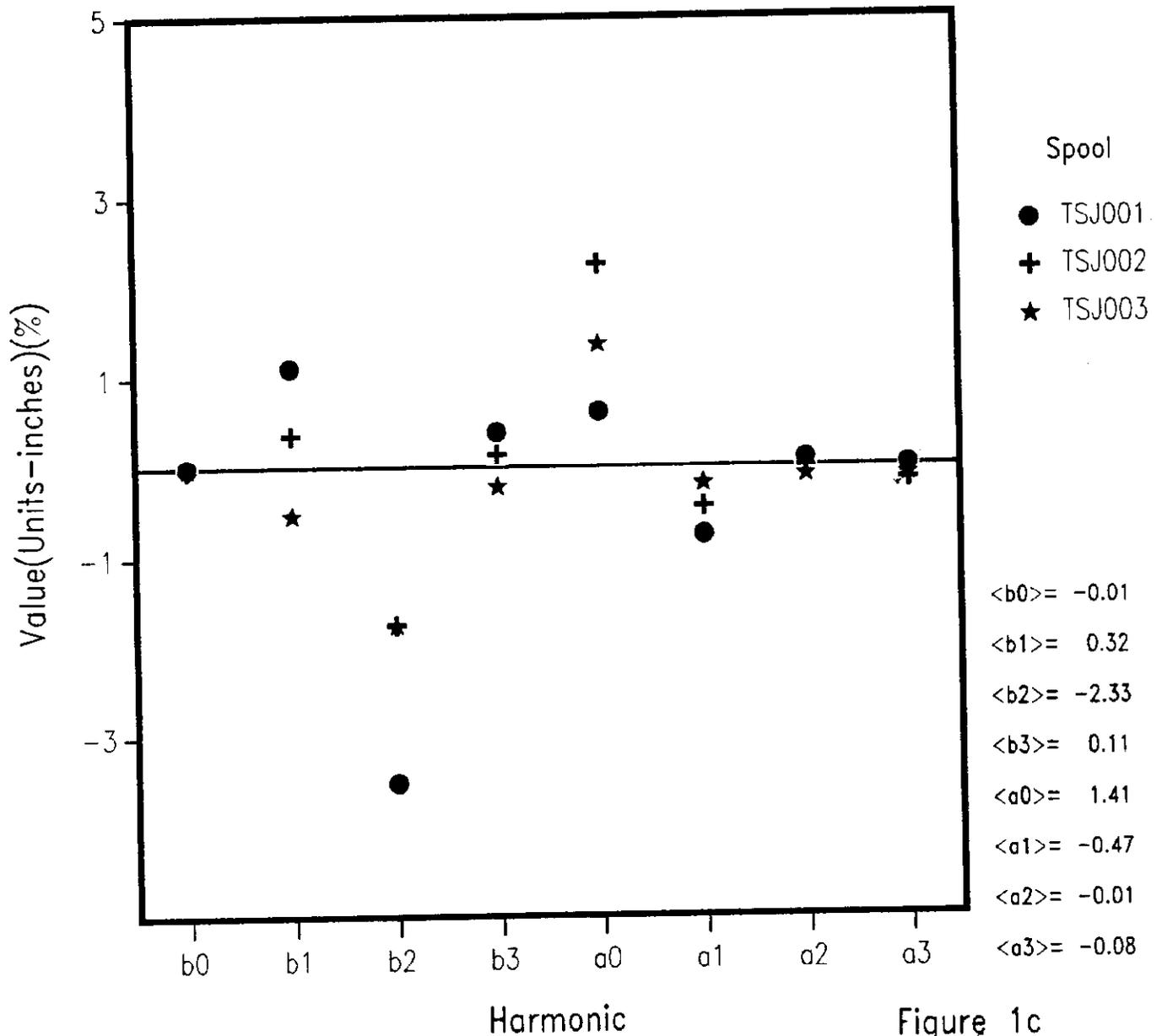


Figure 1c

Harmonics for the Quad.

Coil TSJ Magnets

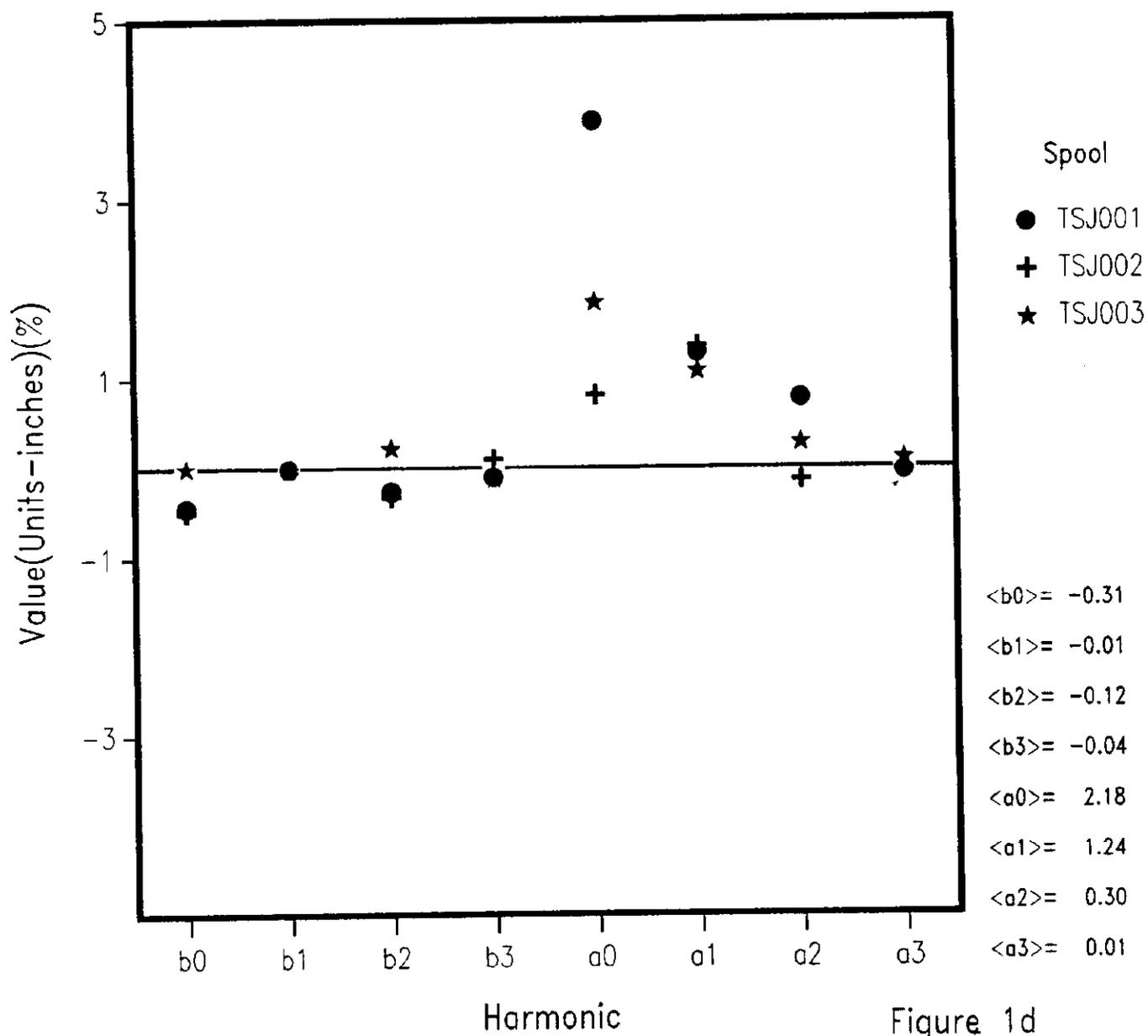


Figure 1d

Harmonics for the Sext.

Coil TSJ Magnets

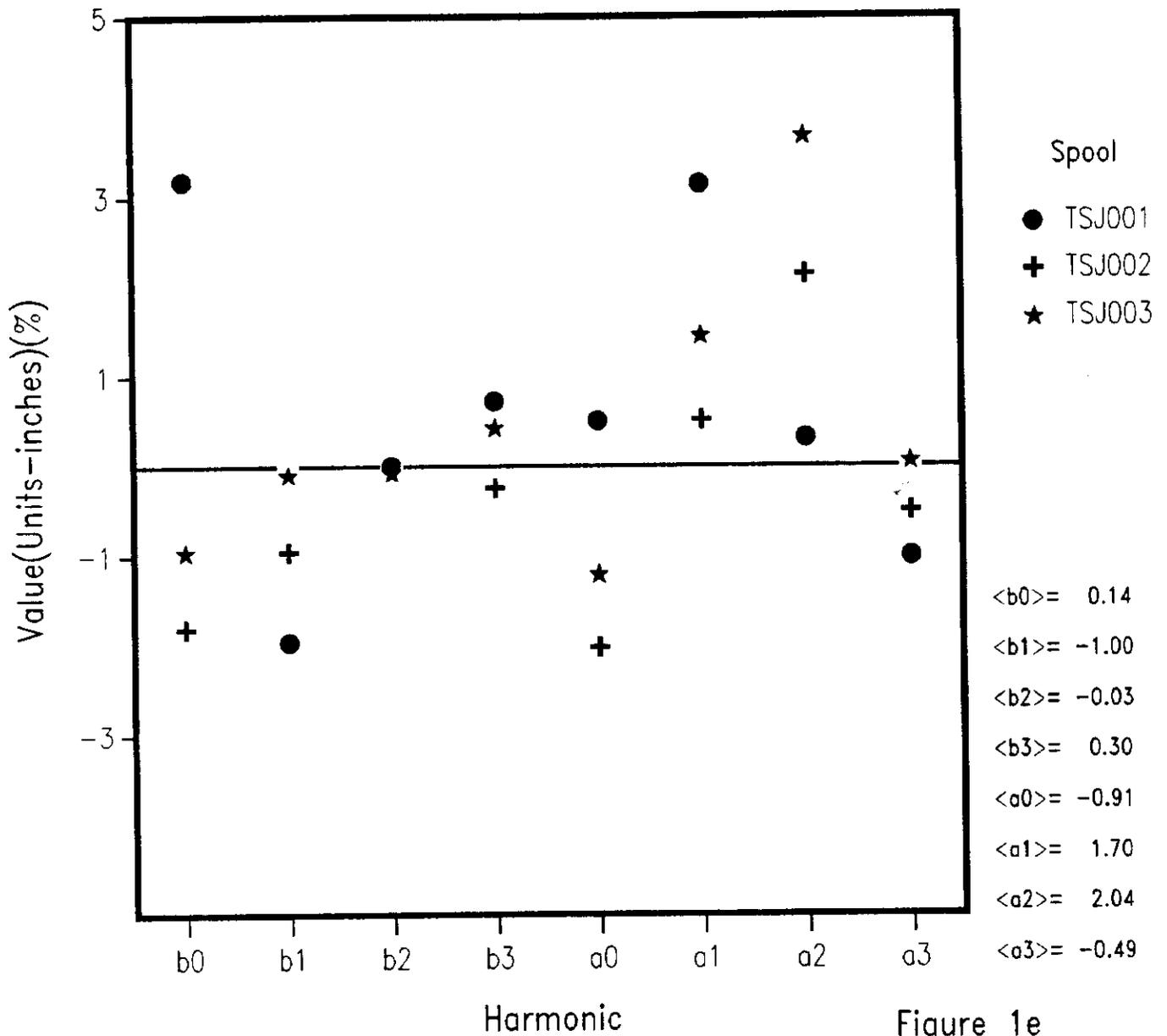


Figure 1e

Coil Strengths TSK Magnets

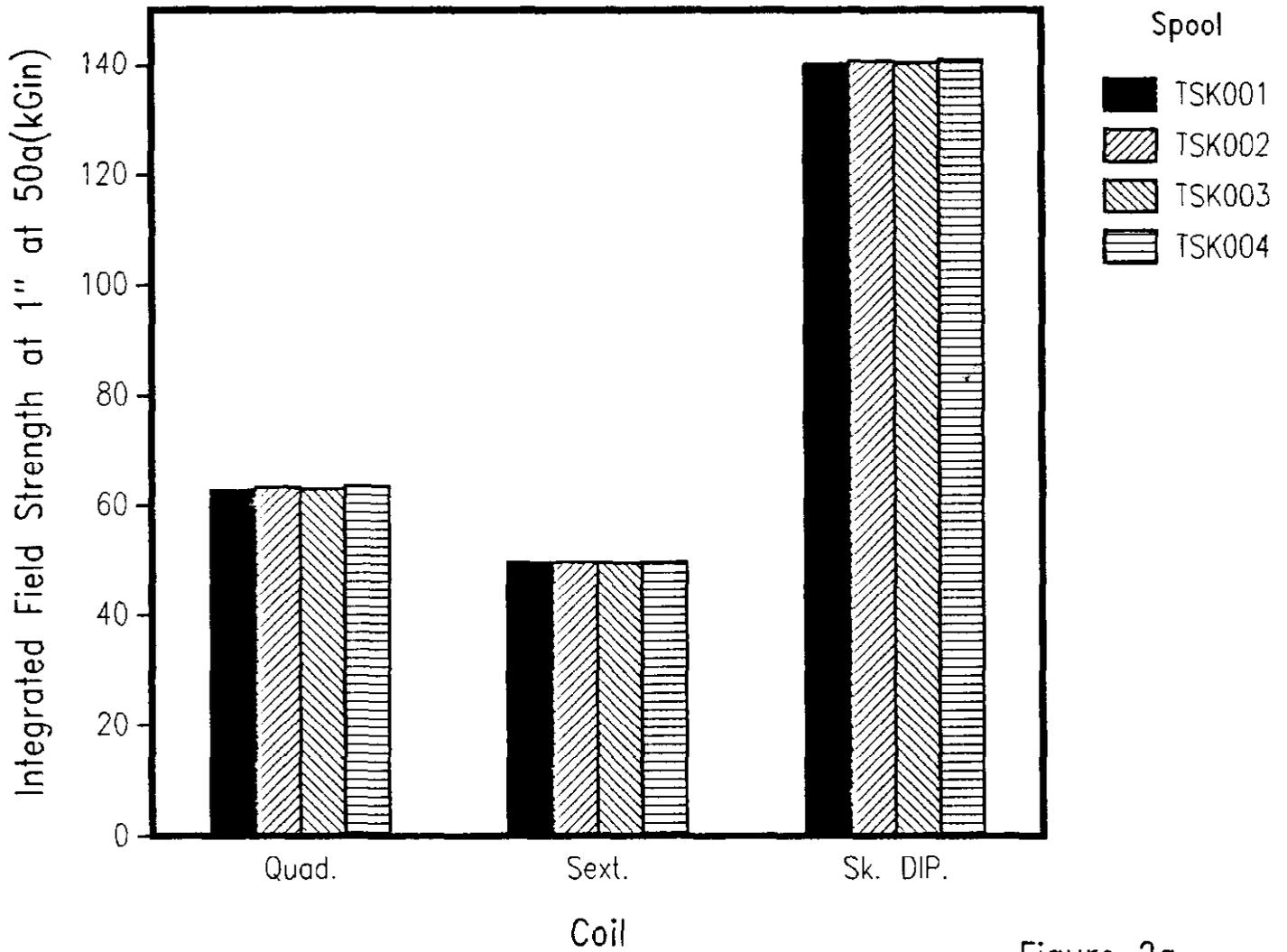


Figure 2a

Diff. Coil Strengths TSK Magnets

Average Quad. = 63.15+/- 0.27

Average Sext. = 49.67+/- 0.05

Average Sk. DIP. = 140.55+/- 0.27

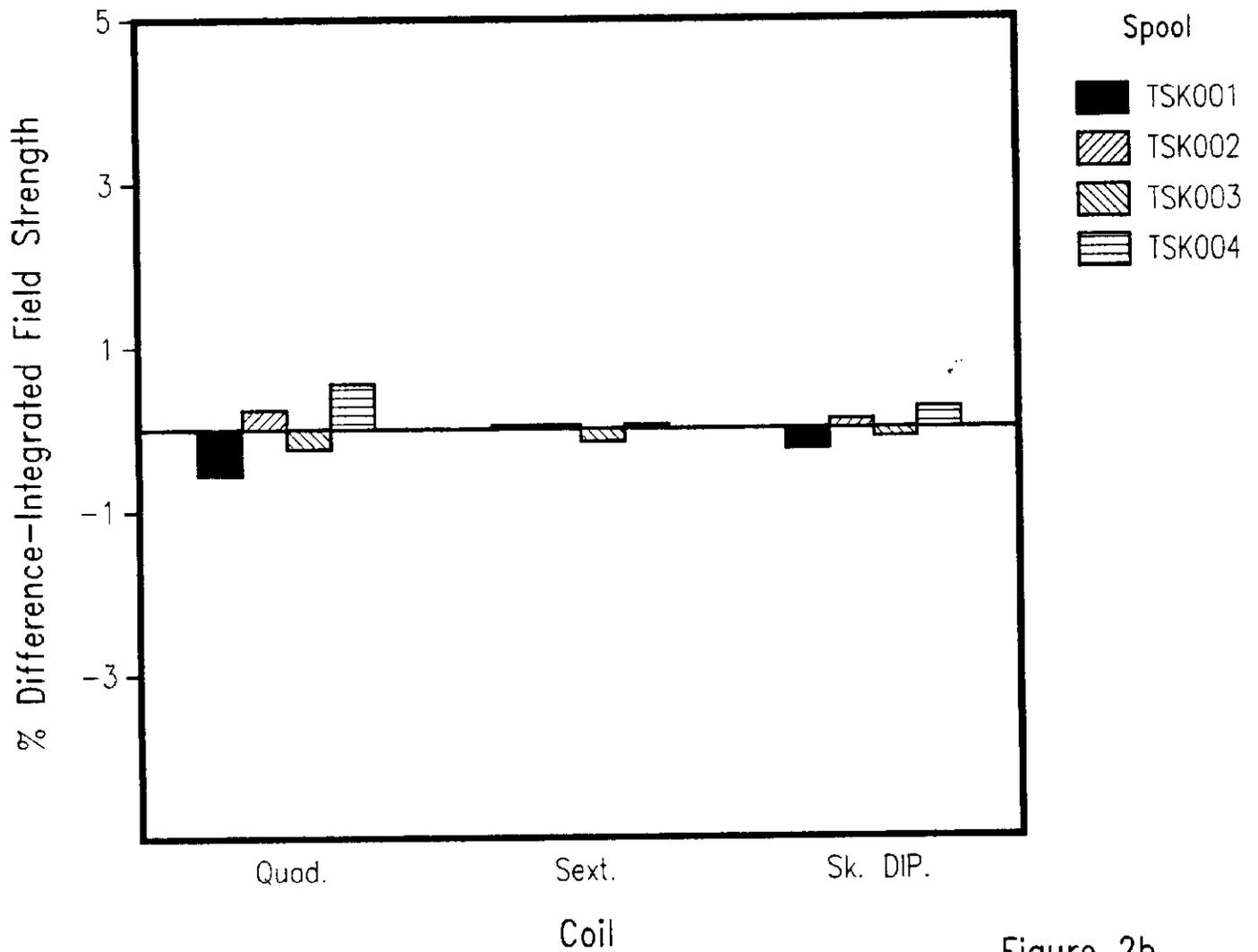


Figure 2b

Harmonics for the Quad.

Coil TSK Magnets

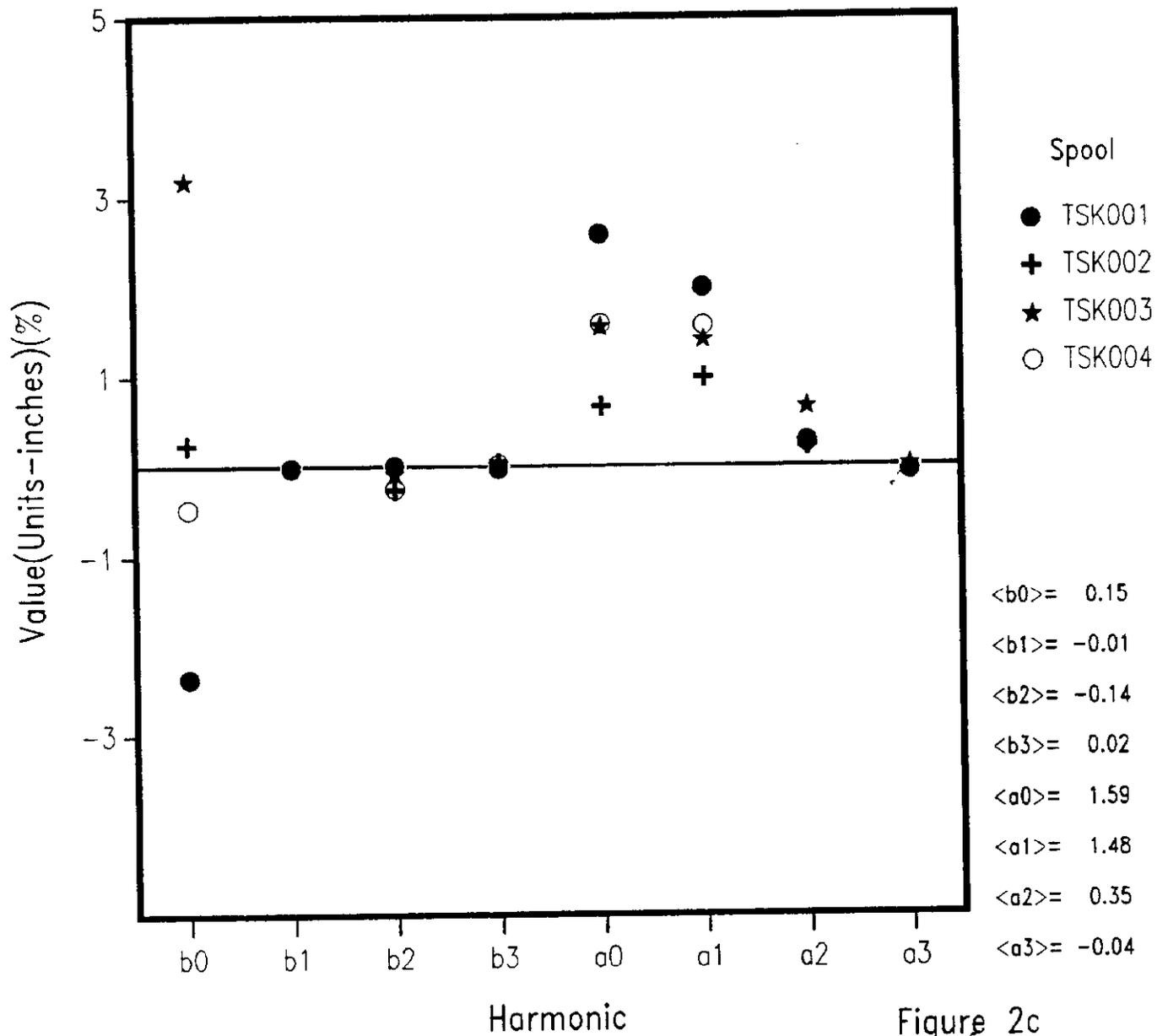
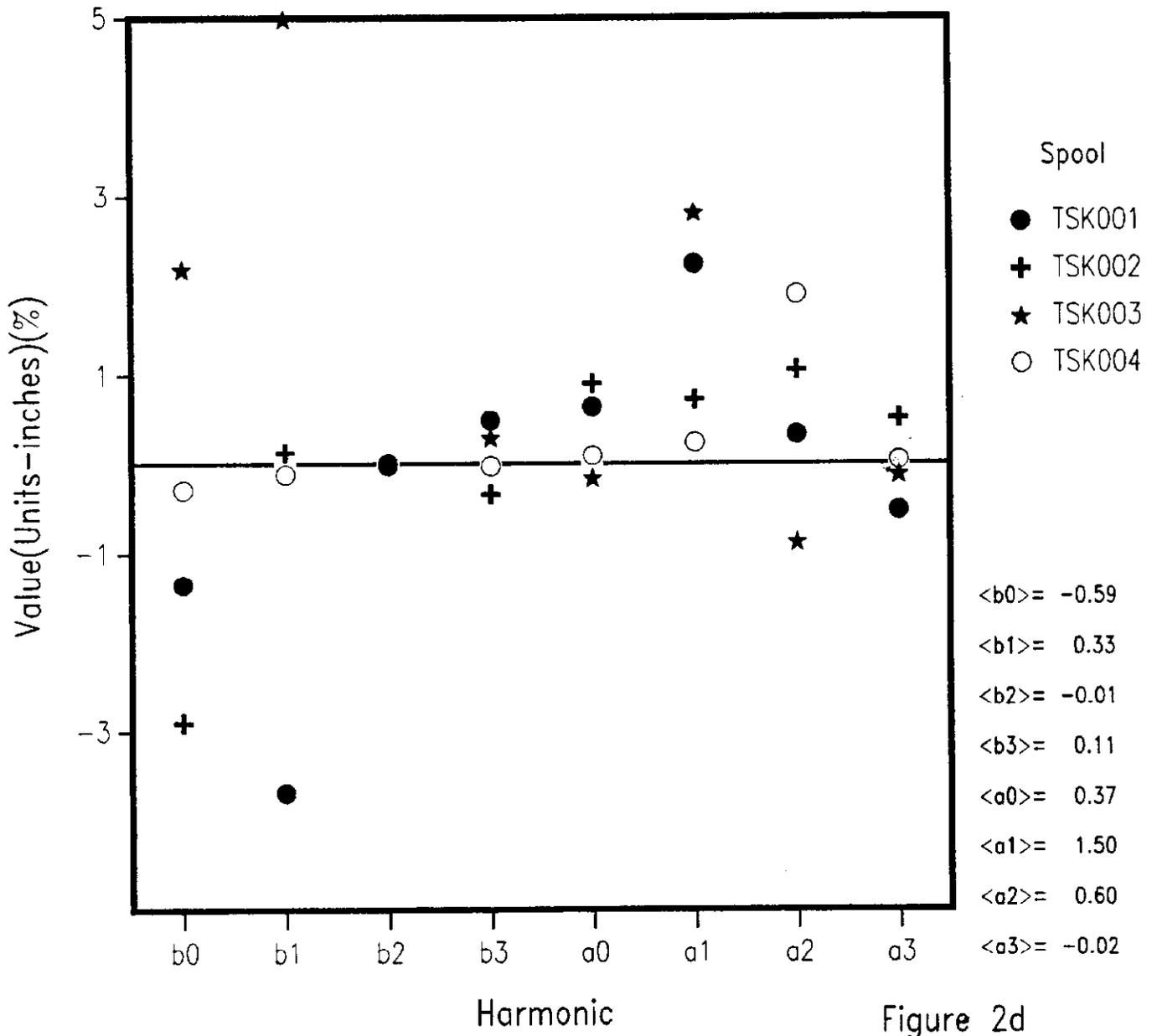


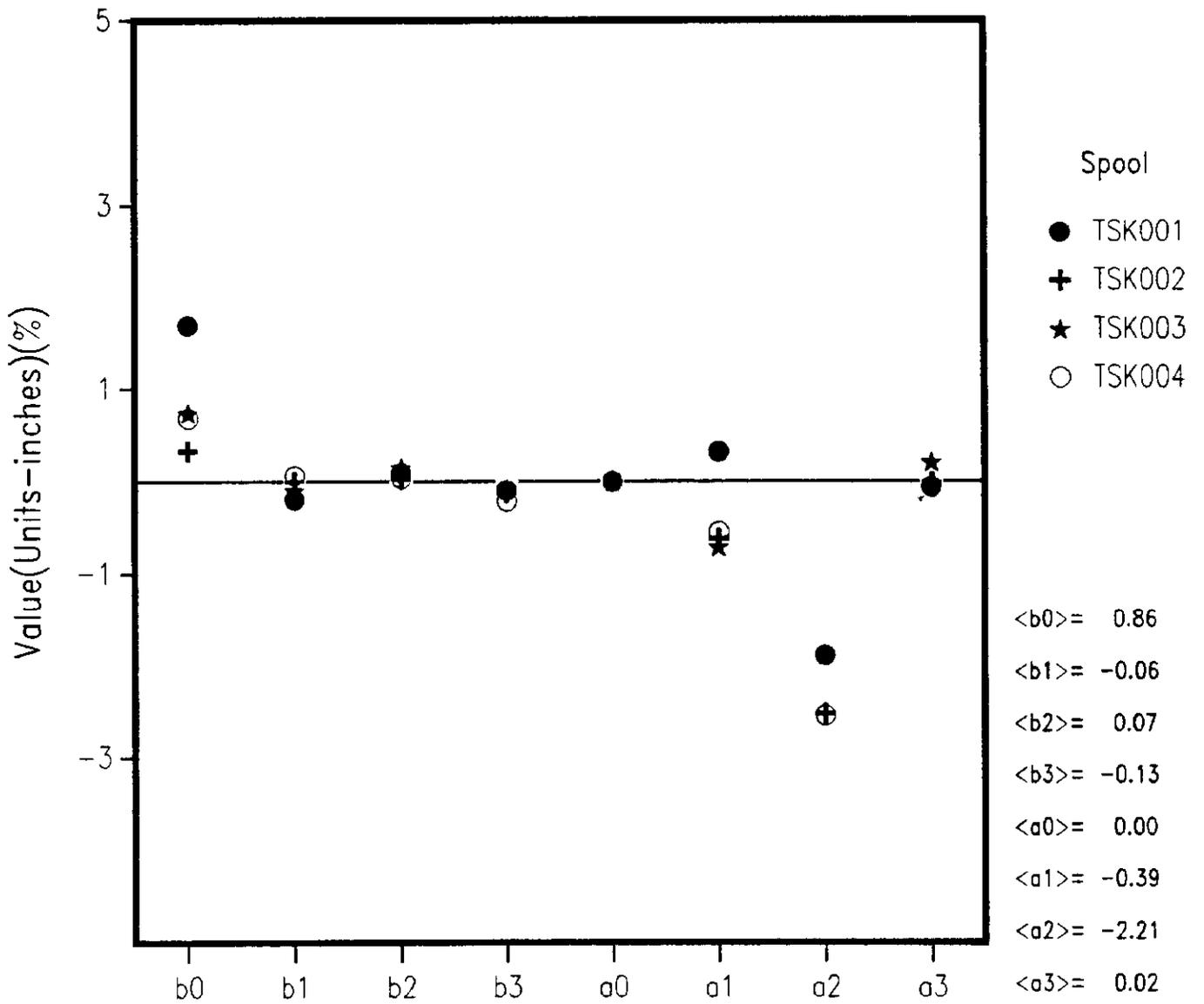
Figure 2c

Harmonics for the Sext.

Coil TSK Magnets



Harmonics for the Sk. DIP. Coil TSK Magnets



Harmonic

Figure 2e

Coil Strengths TSL Magnets

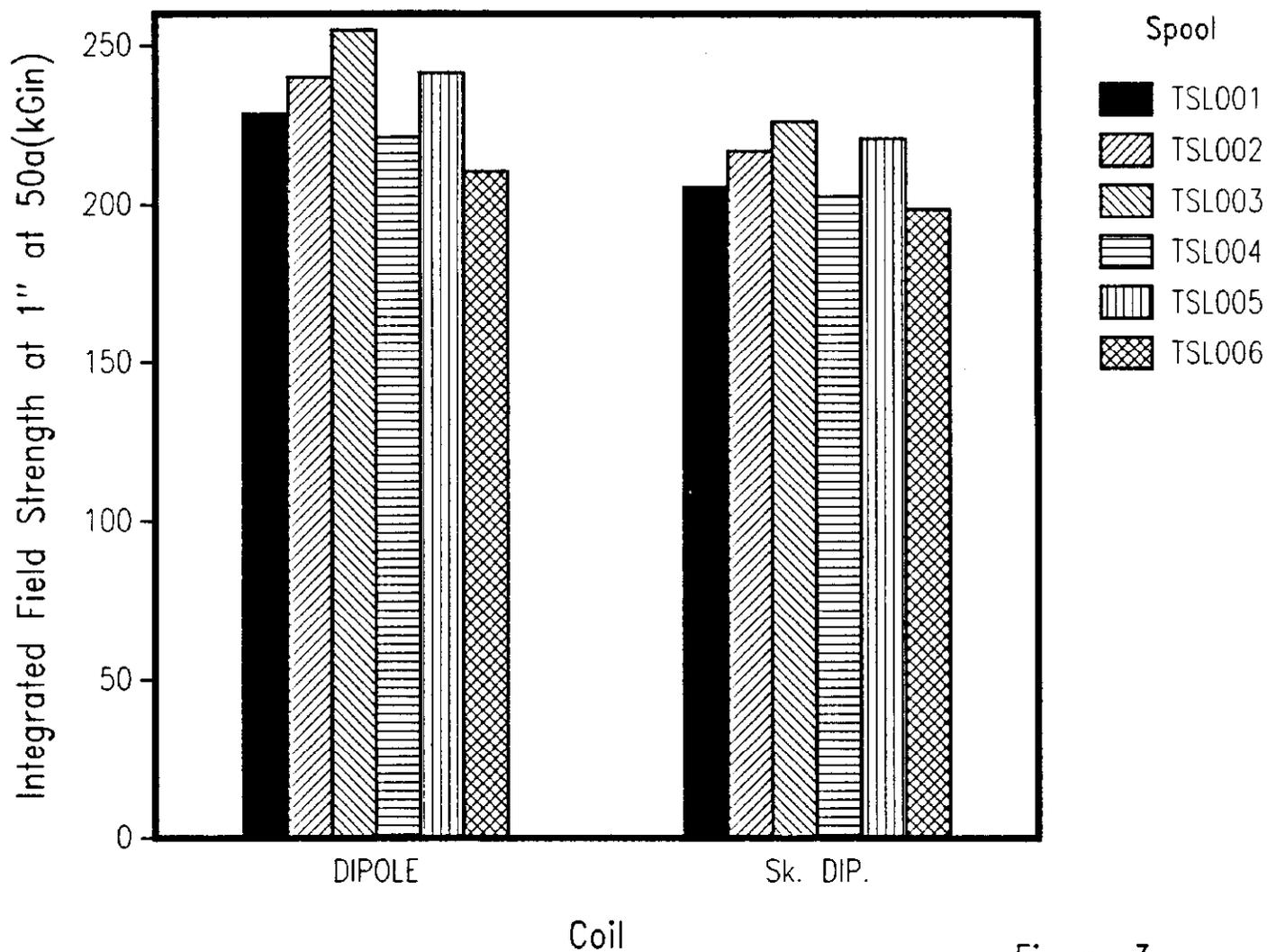
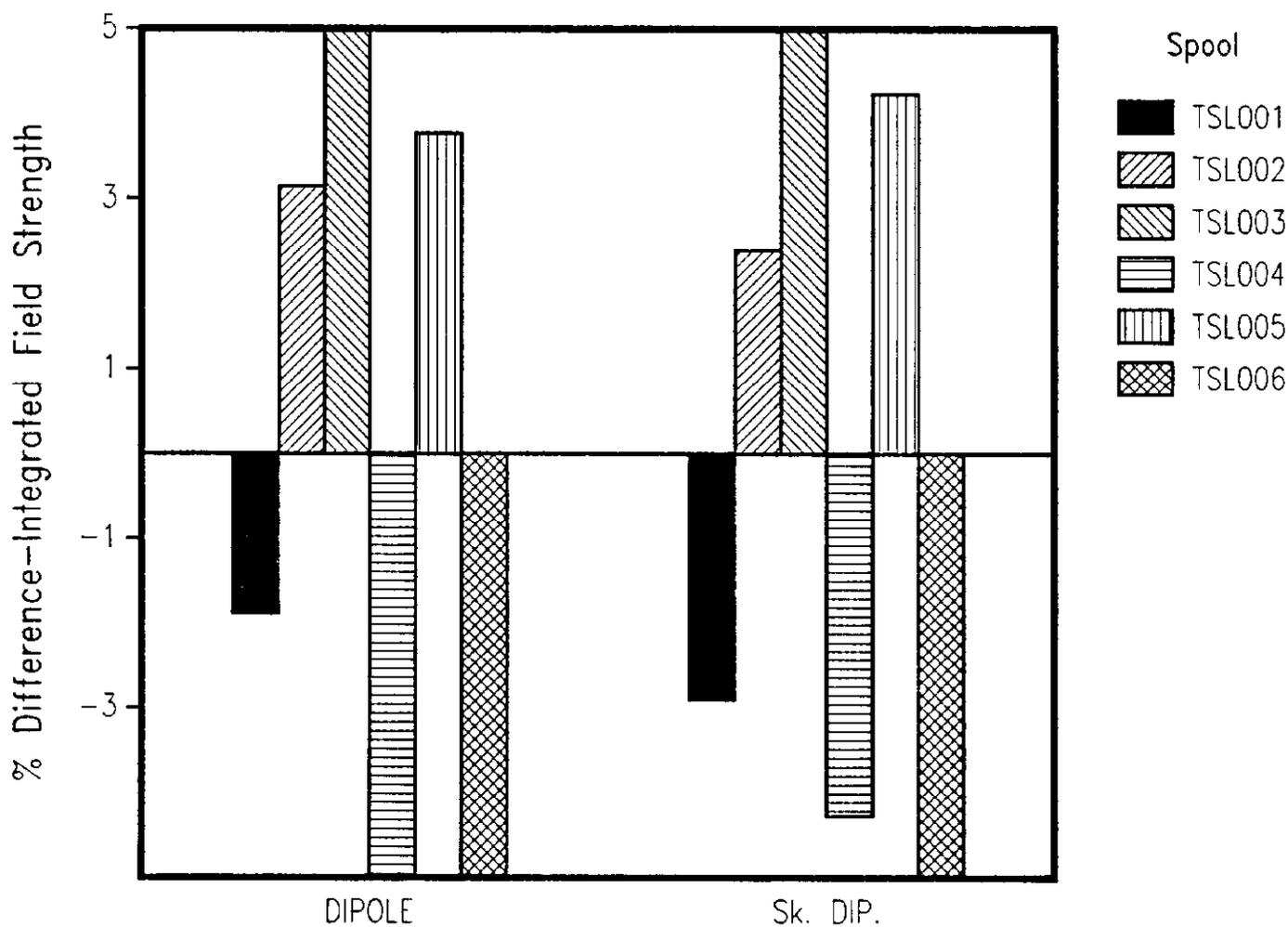


Figure 3a

Diff. Coil Strengths TSL Magnets

Average DIPOLE = 232.69 +/- 14.57

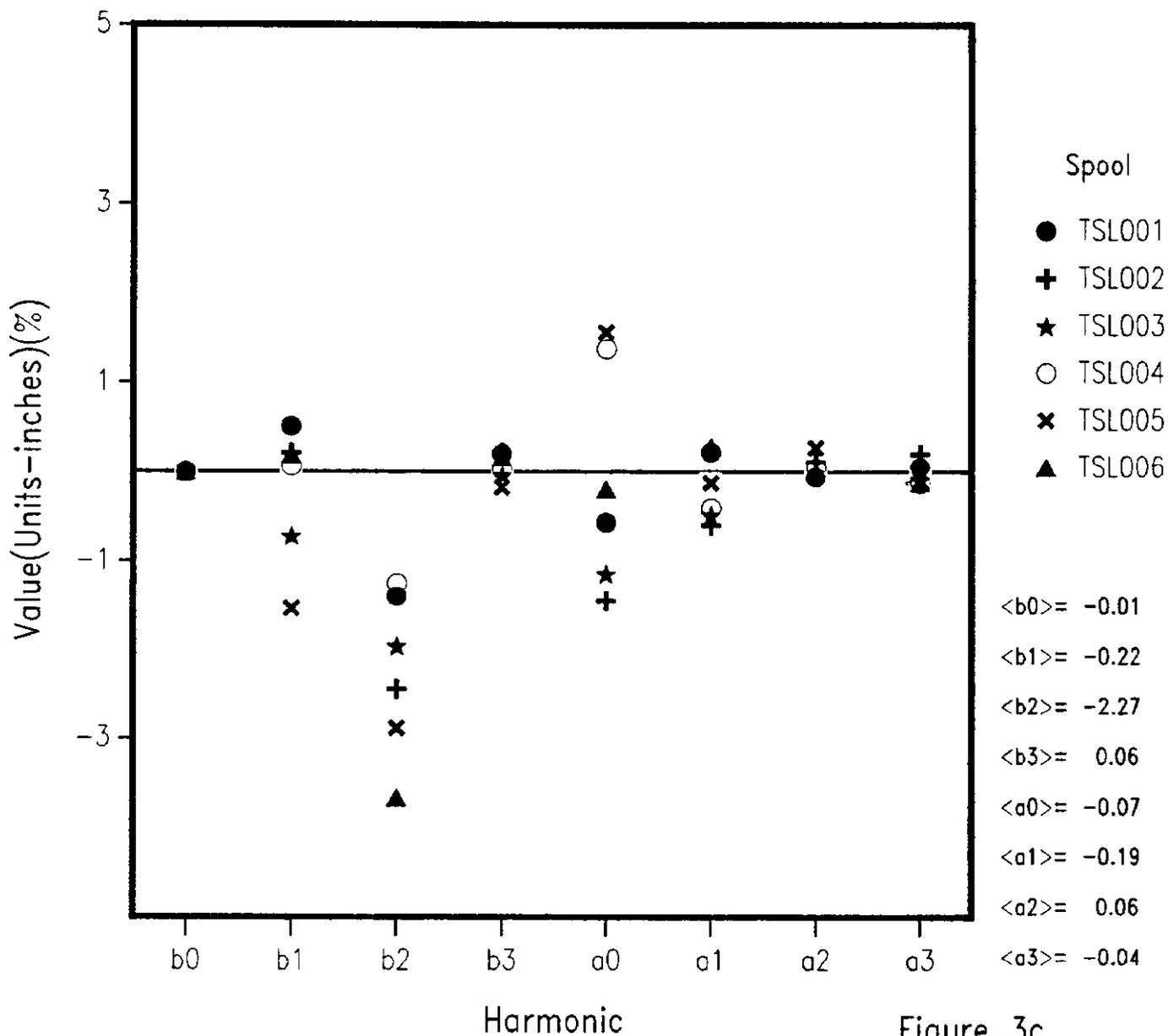
Average Sk. DIP. = 211.65 +/- 10.03



Coil

Figure 3b

Harmonics for the DIPOLE Coil TSL Magnets



Harmonics for the Sk. DIP. Coil TSL Magnets

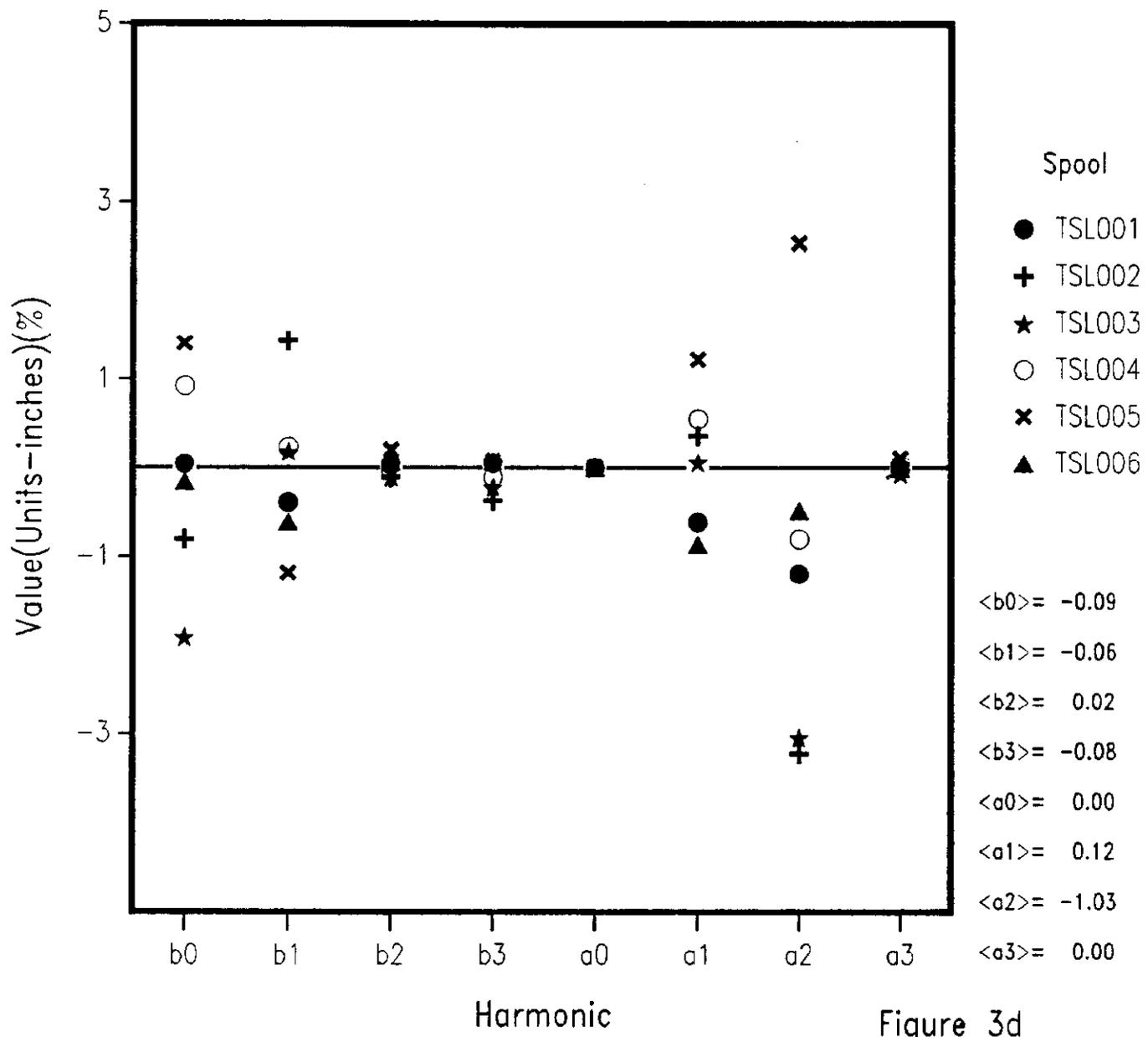


Figure 3d

Coil Strengths TSM Magnets

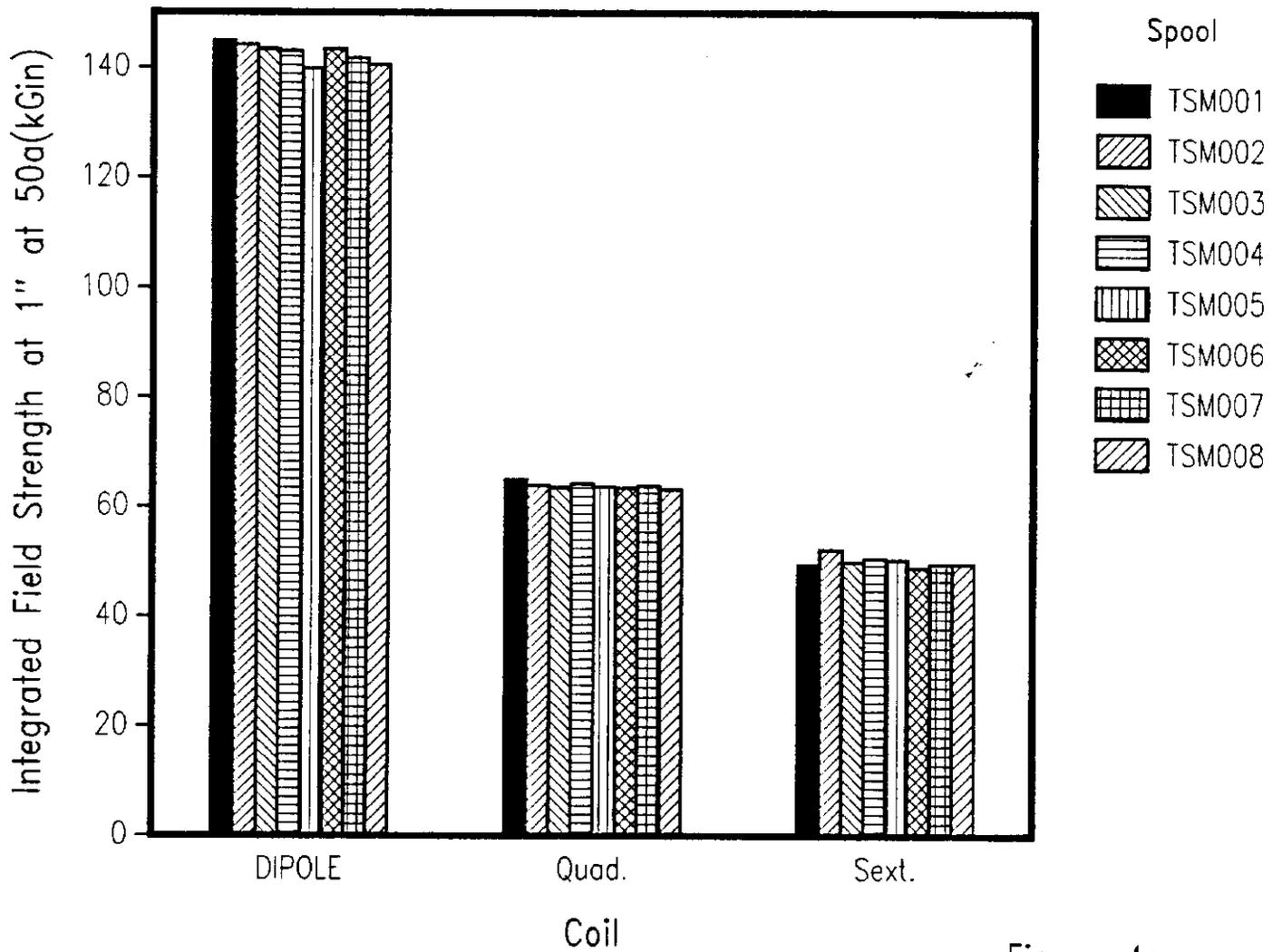


Figure 4a

Diff. Coil Strengths TSM Magnets

Average DIPOLE = 142.56 +/- 1.63

Average Quad. = 63.86 +/- 0.51

Average Sext. = 50.10 +/- 0.94

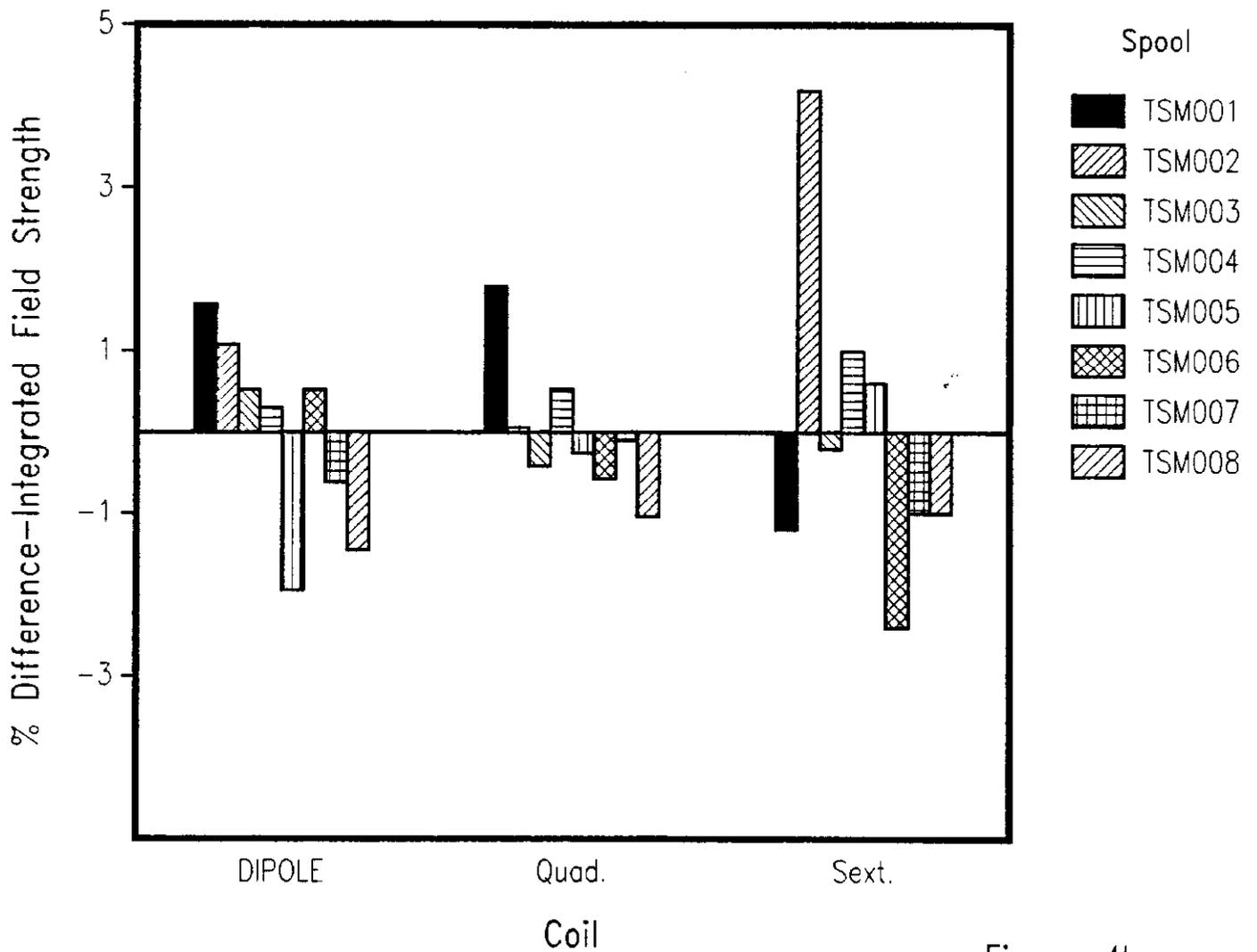


Figure 4b

Harmonics for the DIPOLE Coil TSM Magnets

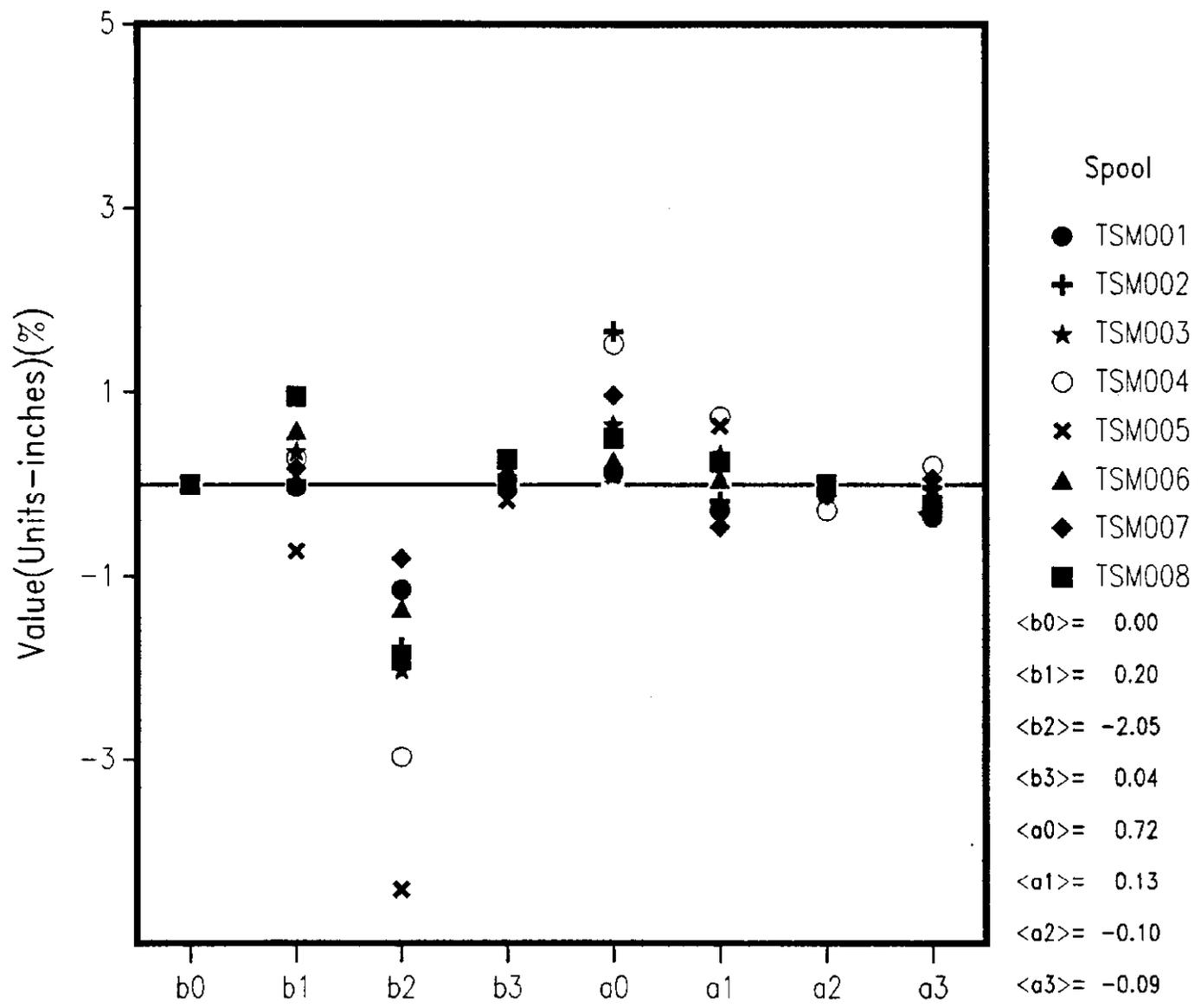
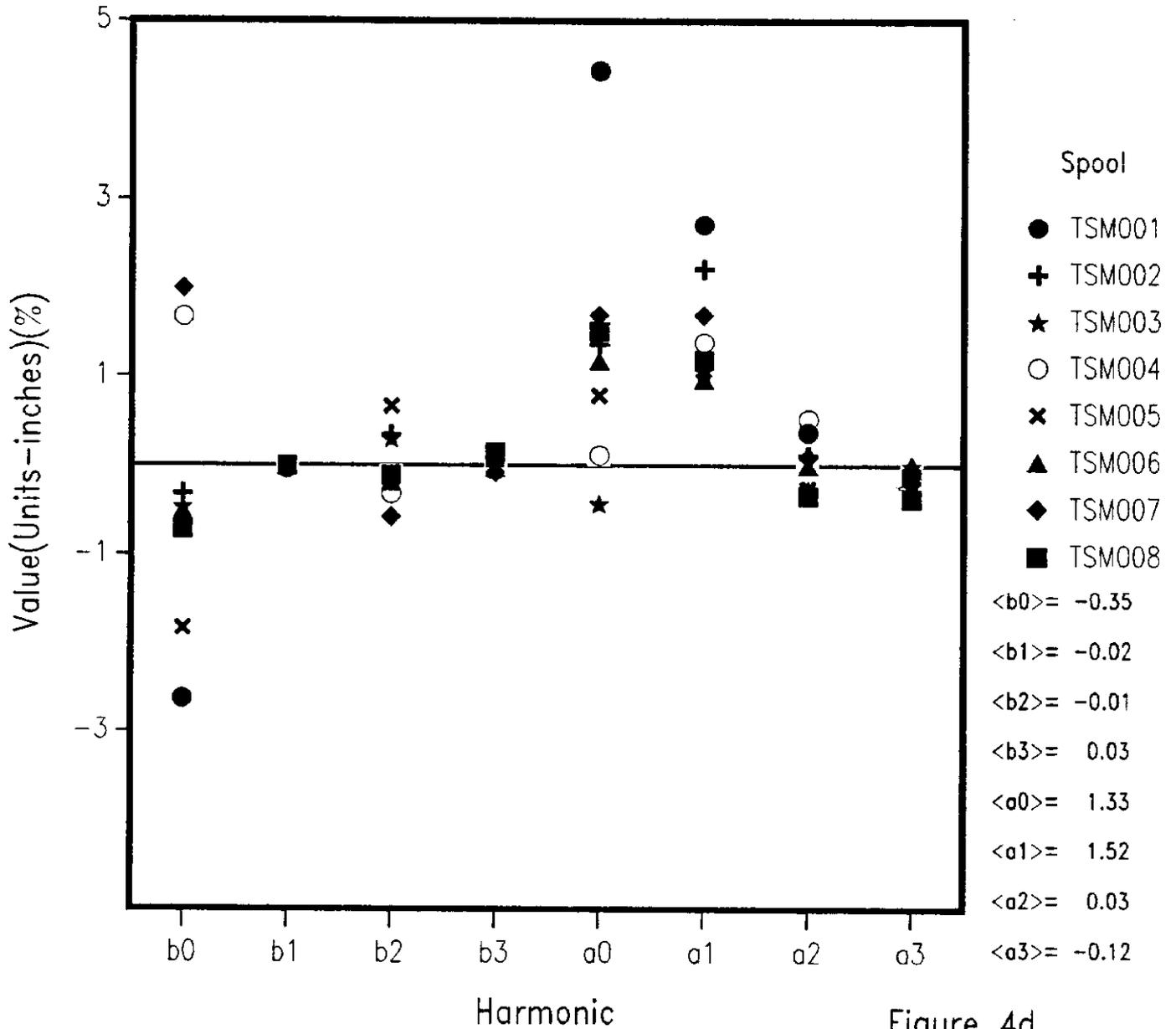


Figure 4c

Harmonics for the Quad. Coil TSM Magnets



Harmonics for the Sext.

Coil TSM Magnets

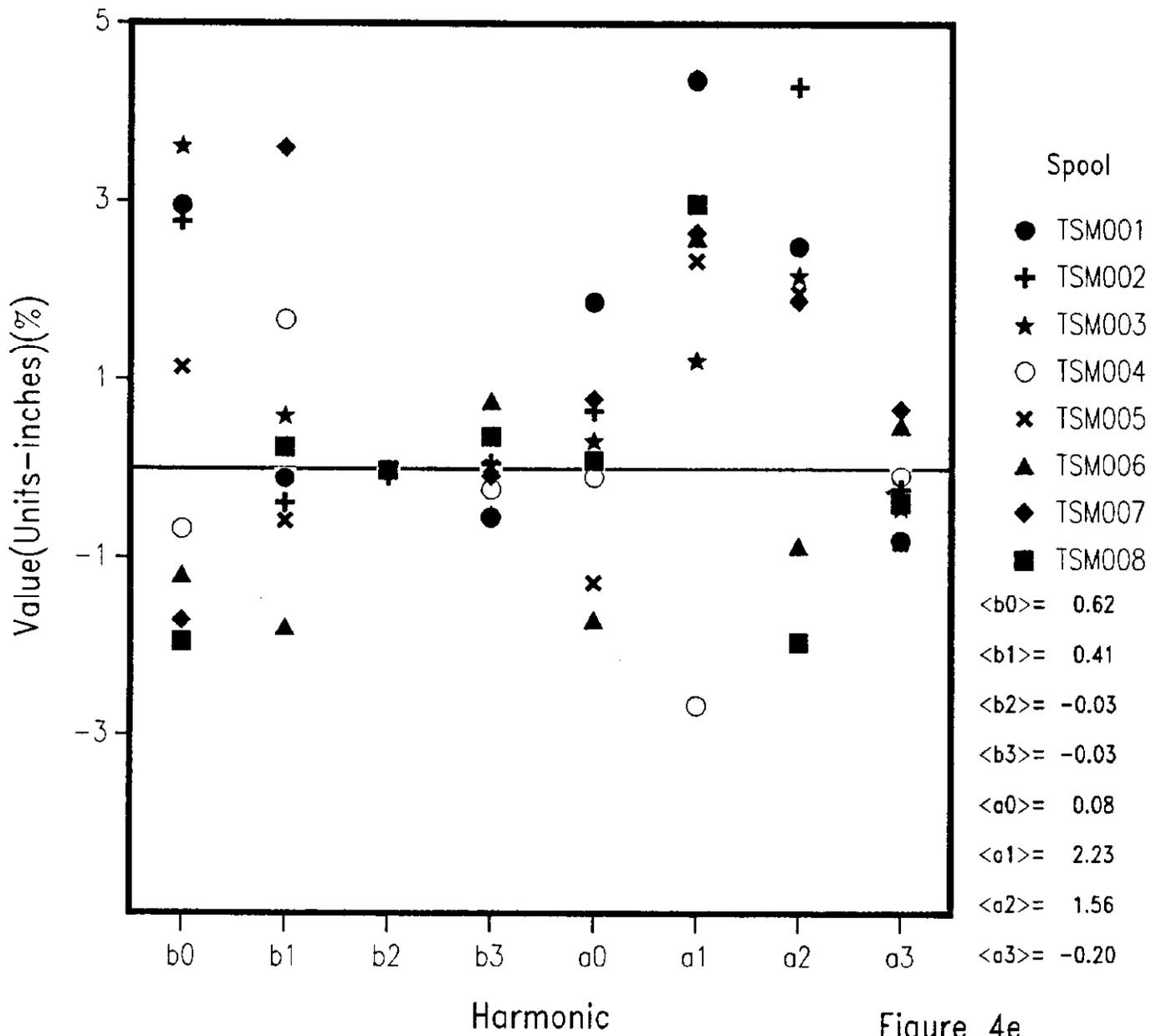


Figure 4e

Coil Strengths TSN Magnets

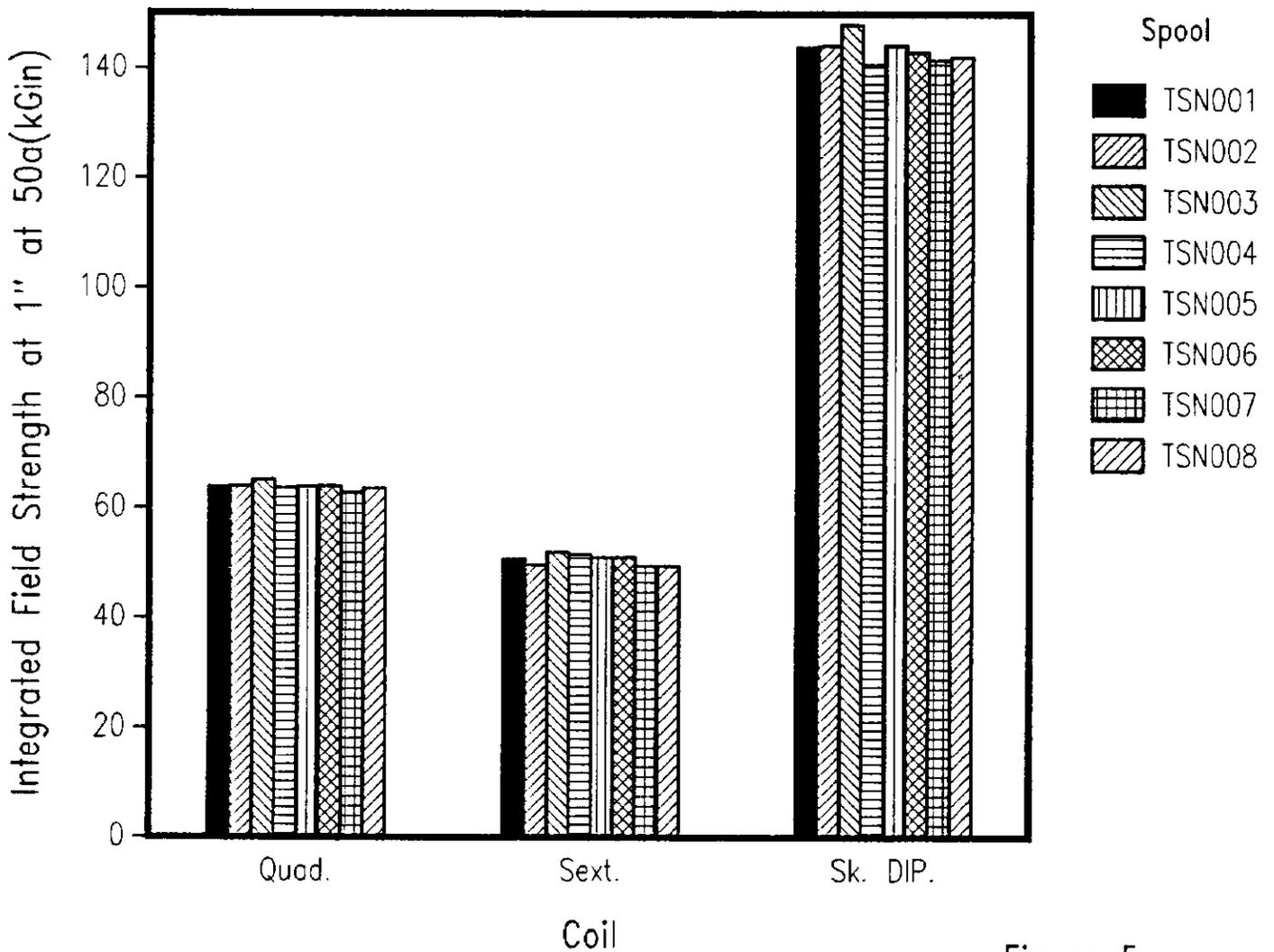


Figure 5a

Diff. Coil Strengths TSN Magnets

Average Quad. = 63.99 +/- 0.62

Average Sext. = 50.65 +/- 0.91

Average Sk. DIP. = 143.48 +/- 2.10

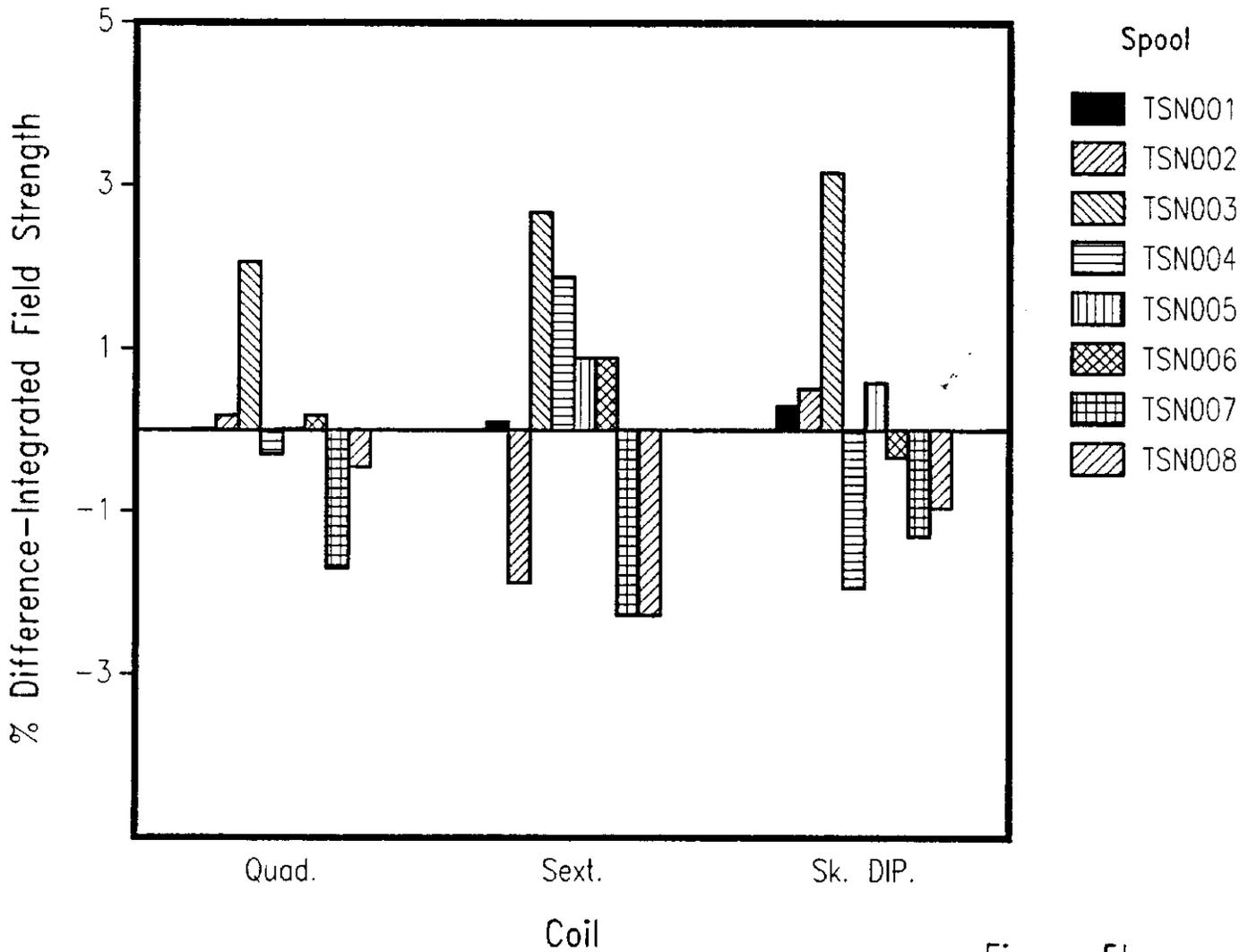


Figure 5b

Harmonics for the Quad.

Coil TSN Magnets

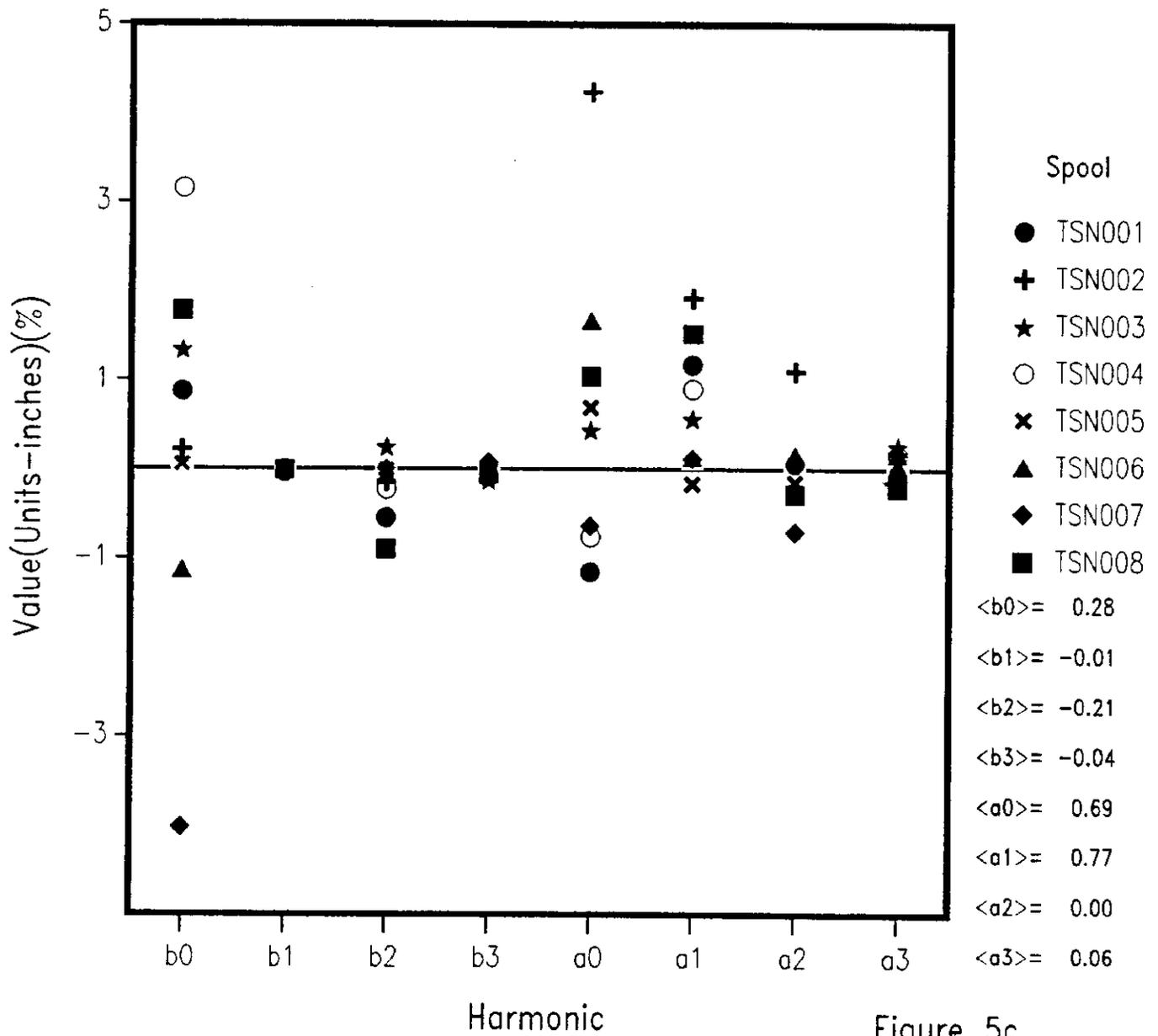


Figure 5c

Harmonics for the Sext. Coil TSN Magnets

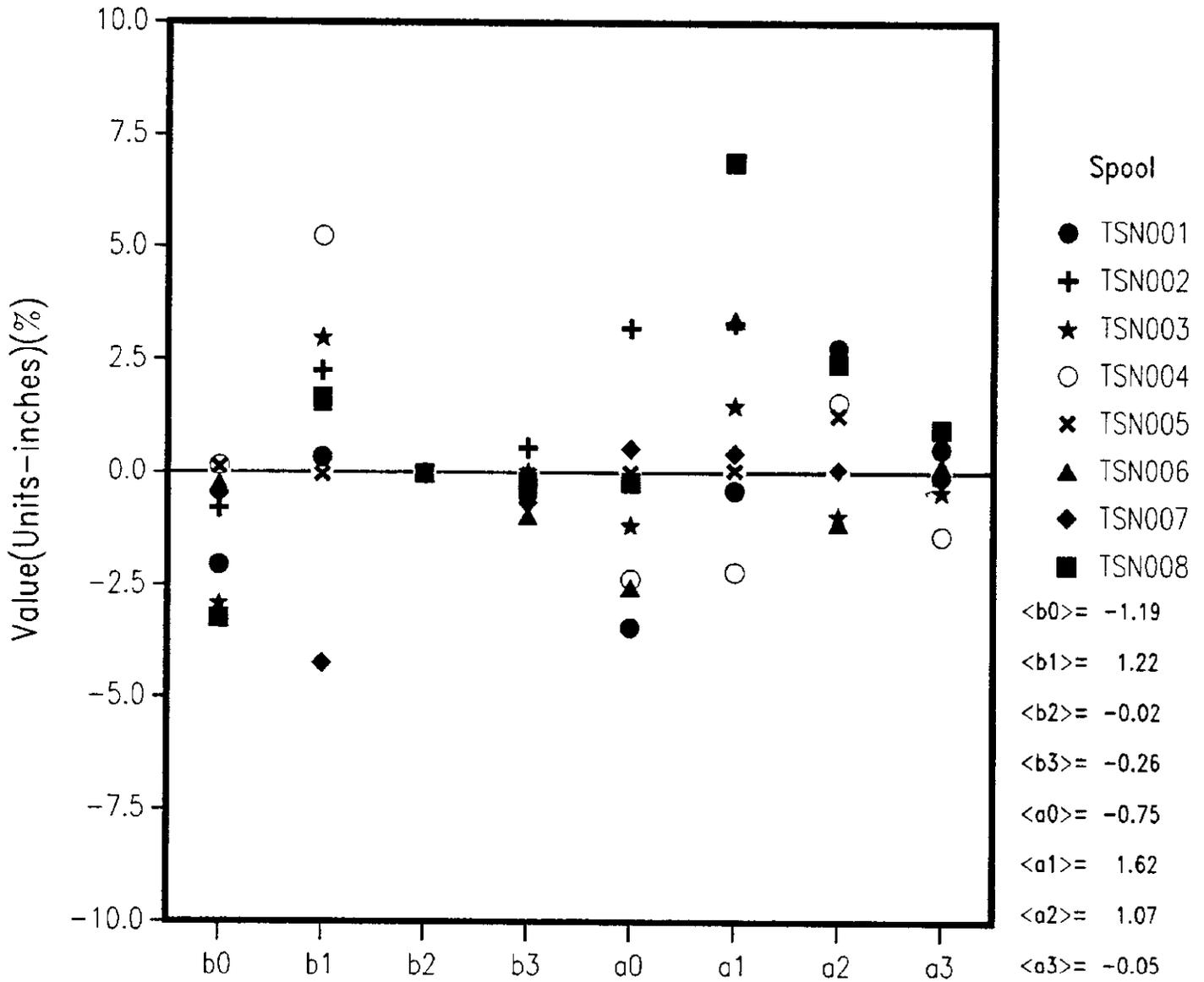


Figure 5d

Harmonics for the Sk. DIP. Coil TSN Magnets

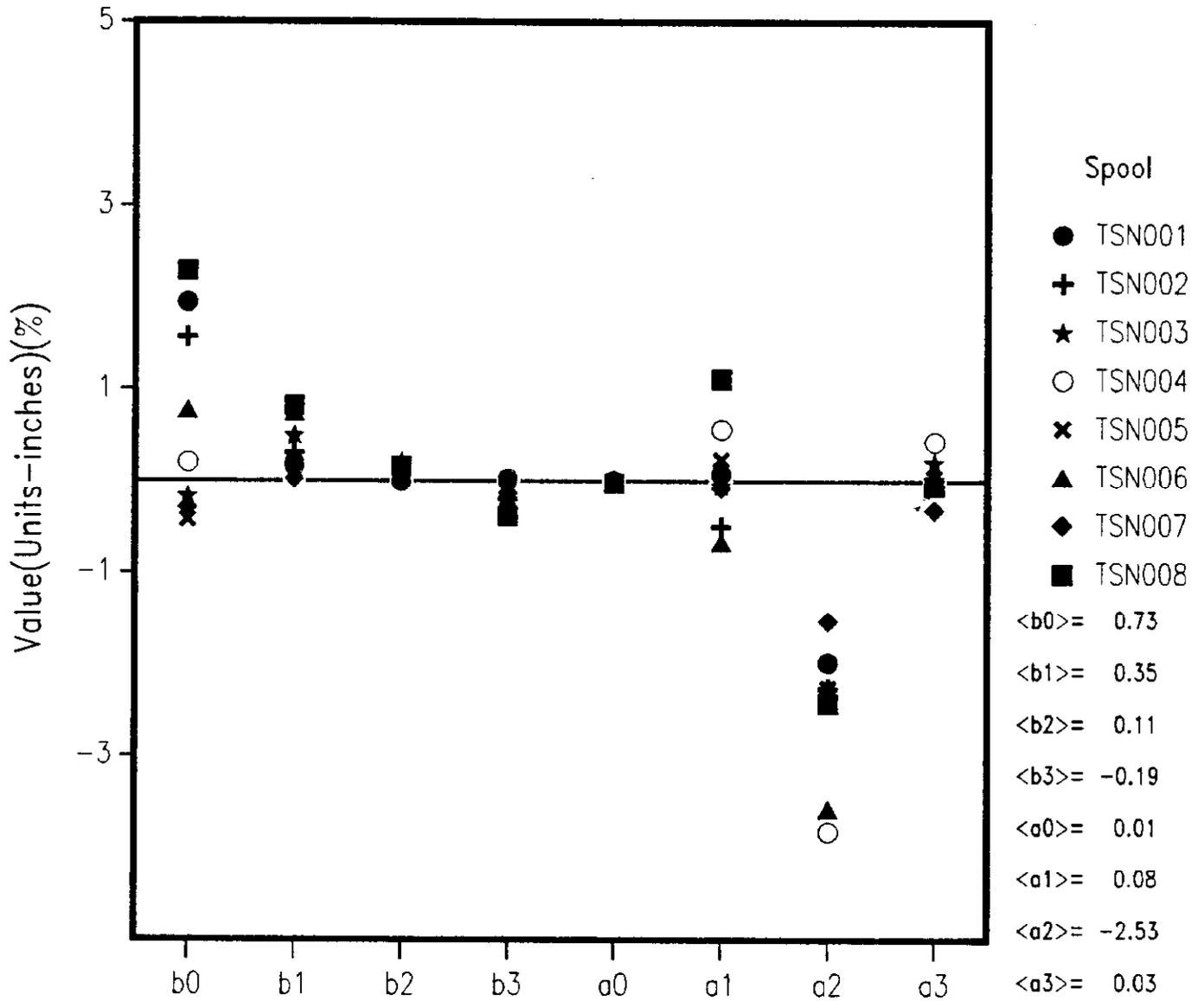


Figure 5e

Coil Strengths TSP Magnets

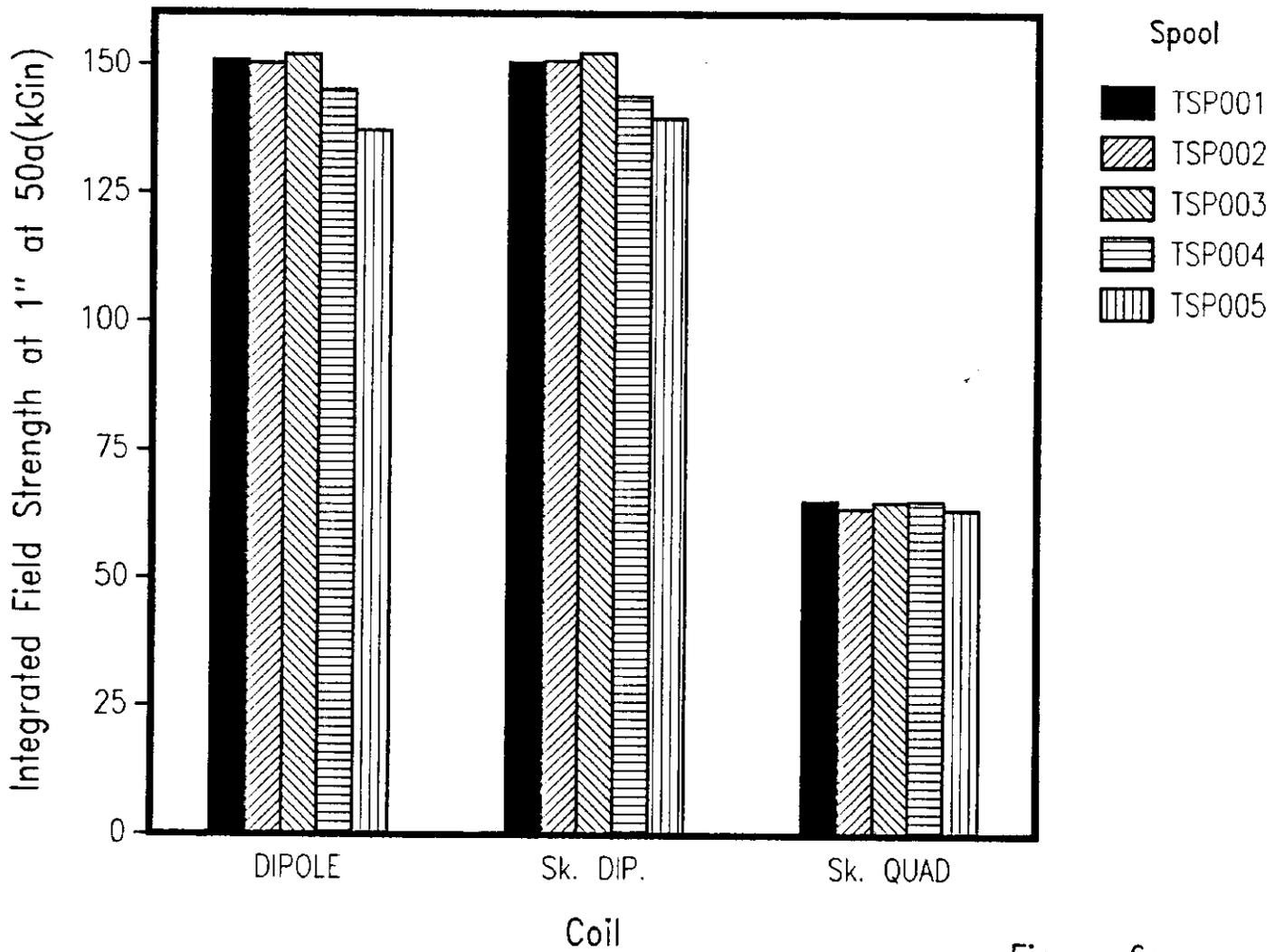


Figure 6a

Diff. Coil Strengths TSP Magnets

Average DIPOLE = 147.02 +/- 5.48

Average Sk. DIP. = 147.42 +/- 4.87

Average Sk. QUAD = 64.52 +/- 0.76

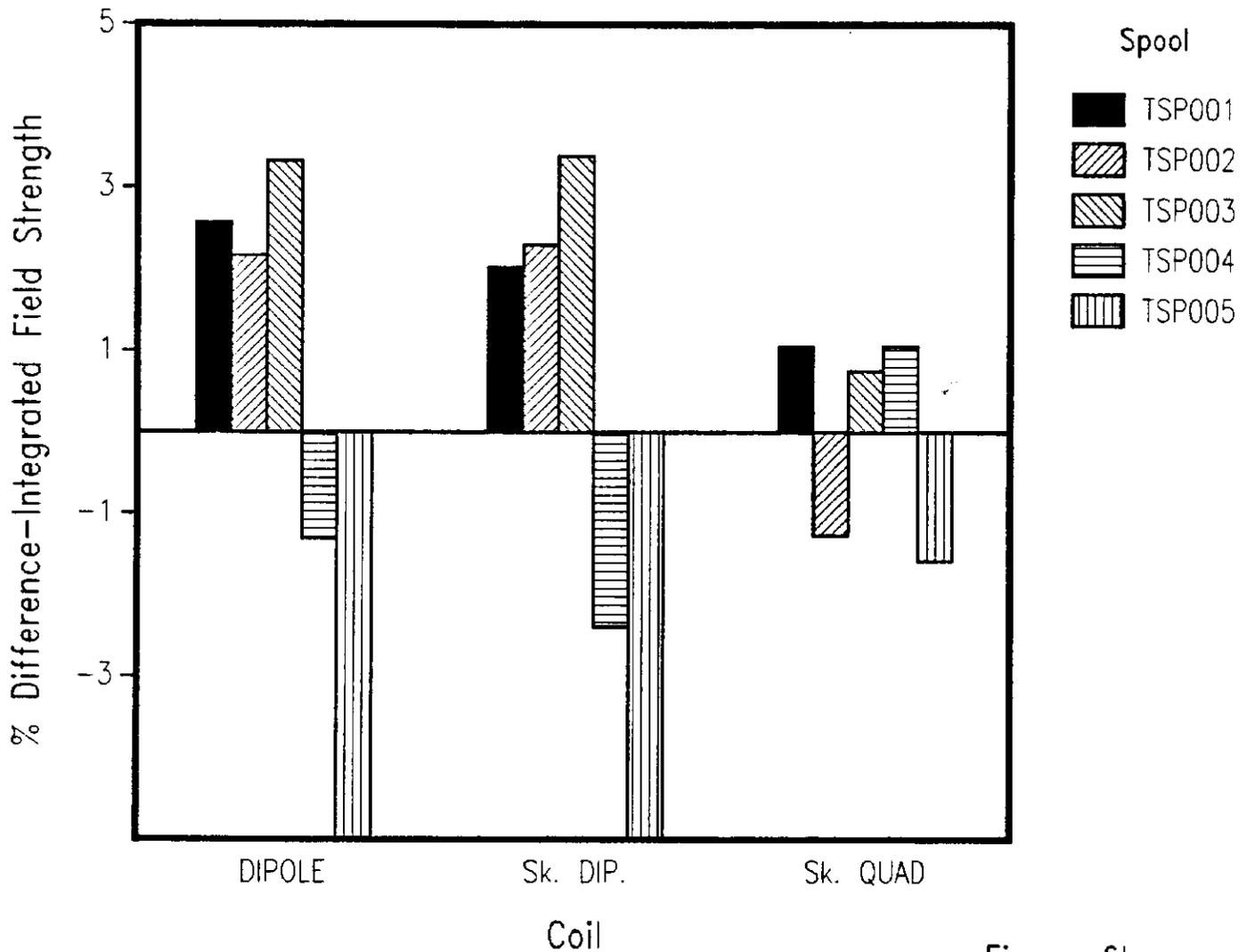


Figure 6b

Harmonics for the DIPOLE Coil TSP Magnets

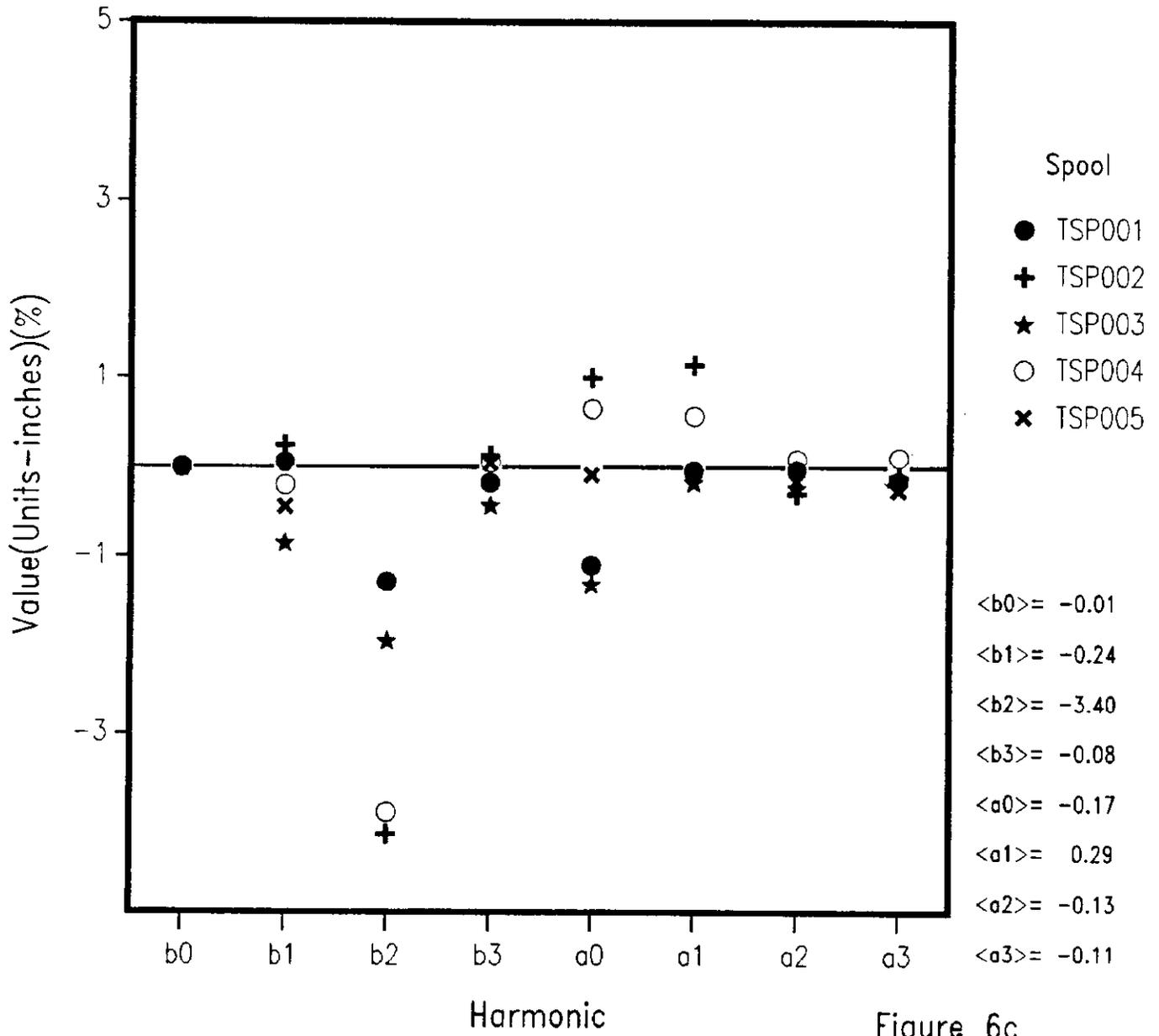


Figure 6c

Harmonics for the Sk. DIP. Coil TSP Magnets

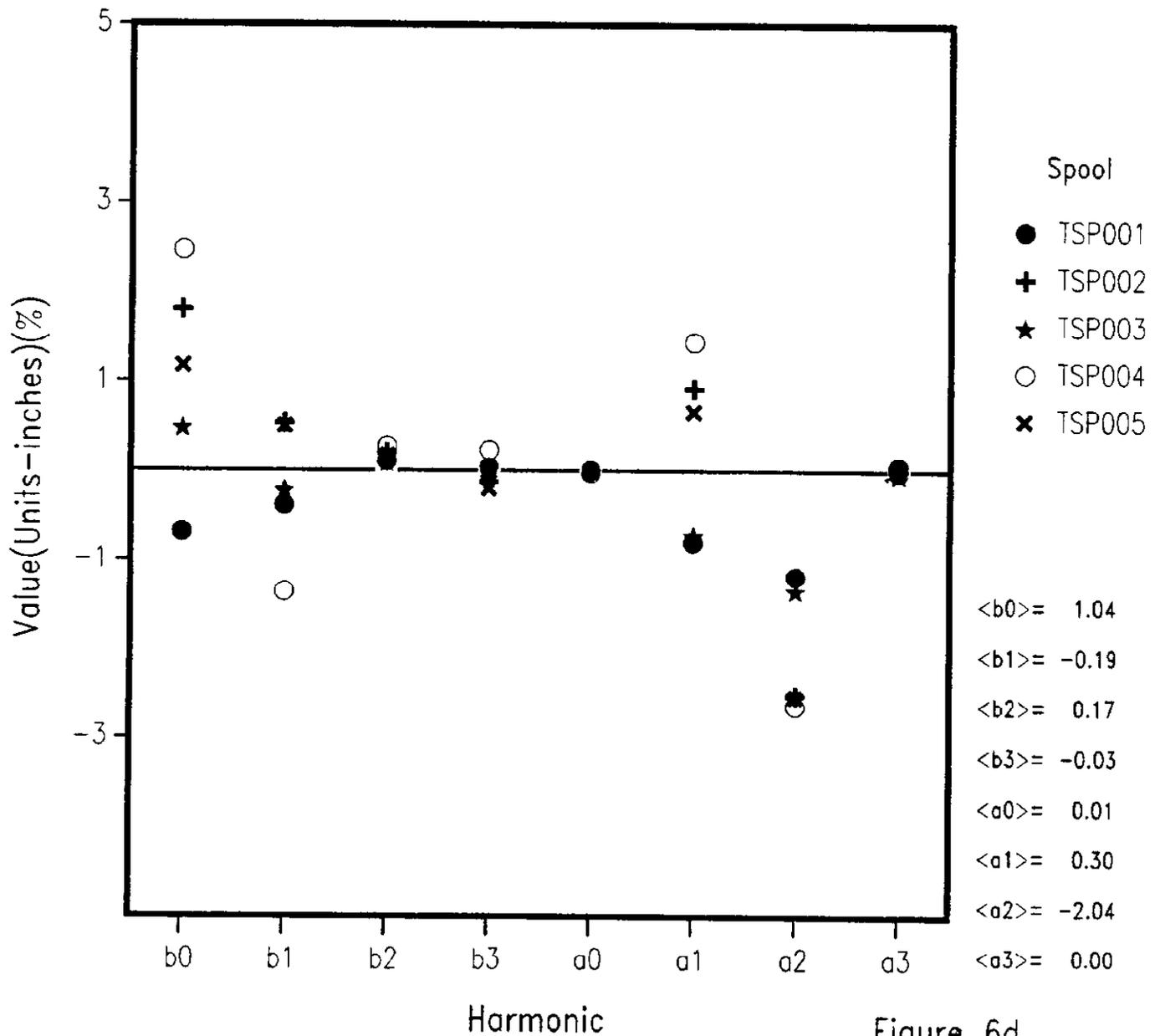


Figure 6d

Harmonics for the Sk. QUAD Coil TSP Magnets

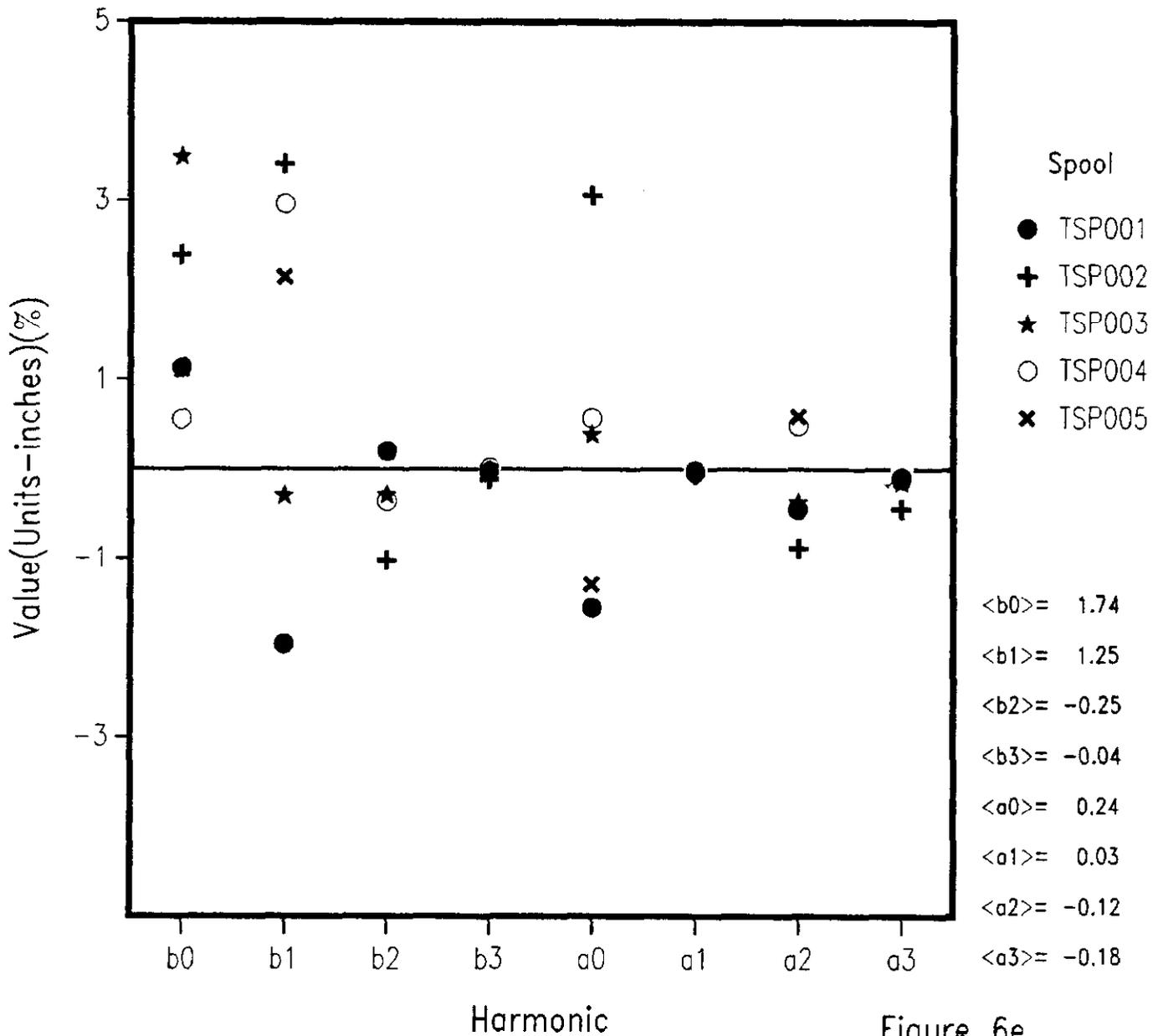


Figure 6e