# Present Order of Magnets in the AGS Ring, with B.dl Offsets 

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Accelerator Division
Technical Note

No. 254

Present Order of Magnets in the AGS Ring, with B.d1 Offsets
R.E. Thern

June 5, 1986

TECHIICAL NOTE
Fresent Order of Megnete in the AGS Fing, with E.dl Offeets
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## i. IETRODUCTION

When the AGS magnets were originally put in the ring: results from the magnetic measurements were used to determine the "stacking order" in the wing and the radial offeete for each magnet. Now that we are doing a radial aurvey (ref 1) and may do a radial realignment, it i三 important that this data be taken into account again. over the years, magnet replacements heve shuffled the magnets from their ariginel order and brought in the magnets that used to be the spares. Thus the old publications of this data (ref $2-3$ ) have to be brought up to date.

The present order of the magnets in the ring -- which "magnet name" is in which "ring location" -- wes checked by walking around the ring and reading the numbers stamped in the backleg of each magnet.

The description of the magnetic measurement data and the rationale for how it isused is given below. The data are listed in Table 1 , ordered by magnet name, and in Table 2 , ordered by location in the rirg. Table 3 summazizes the changes that heve been made to the original magnet order.

## 2. E.DL AT 5000 GAUSS

At $\exists$ eet current, the integrated E.dl along the equilibrium orbit chould be the same for all members of each class ( $A_{9} E_{5}$ or $C$ ) of magnet. The line determined from the socket holes on the top of the magnet does not setisty this requirement, due to varigtions in the gap, the etees; the length of the magnet; and the placement of the socket holes relative to the gap. Since the megnets are gradient magnets, the Eudl at a given current can be changed by moving the magnet sideways. The data in reference 2 are the radial offaets of the magnet sockets from the design positions in the ring such that the E.dl values along the equilibrium orbit are uniforms within each clases at a fised current corresponding to about 5000 gauss. The sign convention used is that poeitive offsets mean that the socket is to be moved away from the center of the ring. These offsets also effect a slight rotation so the orbit is parallel to the front face of the magnet.

The definition of the offsets is as shown in Figure 1 . Note that helf the magnets in each superperiod have their gaps facing outward, and half inwards so the offeets for the surveyors to use - "upstream and downstrean" "in and out" - will depend on position in the ring.

Wote that magnet Ei, which was originally a spare but now is in usen seens to have no magnetic measurement data. (In compendia of mechenical detes it is refered to as E-1A, but I have not found anyone who remembers why. Hagnet E1 was used as the reference magnet for the rest of the B seriest the reference magnets for the A and C seriss were themselves measured by using another megnet for the reference.

## 3. FEMANENT FIELD

Since the variations in remanent field are larger (percentagewise) than the veriations at higher fields, the original stacking order of the magnets in the ring was designed to reduce the low order harmonics introduced by the remanent sield at injection. With the preent lou field dipolecorrection systen (and higher energy injection) this is no longer as important: the remanent field date is nevertheless included here for the sake of completeness.

The remanent field numbers are the offsets, in mils from the 5000 gauss centerline defined above, which give a uniform E.dl for the remanent field. The sign of the effect is, as best I can determine, such that a positive number means thet the remanent field is higher than the etandard. The remanent field gredient is about 1.5 gauss/inch ( $2.1 \mathrm{~g} / \mathrm{in}$ ) for clasees $A$ and $B$ (cleme C , with a central field of about 10 gauss.

The remanent field for the class A magnets but not clasees $B$ and $C$ were found in reference $\mathrm{S}_{\text {s }}$ the clese E and C numbers were found compiled on sheets in the data booke. They are, apparently not exactly the same as were ueed in figuring the stacking order in references becuse several magnets are interchanged in rank from that implied by the reference 3 order: The differences are only a few miles howevers much lese than the variation in multiple measurements:

## FEFEFENCES

1. R. E: Thern, "The 1905 Horizontel Surveys Fart II. Magnets", AGS Accelerator Division Technical Note No. 253, Mey $30,1980$.
2. J. Fu Falmer and F. H. Phillips: "Summary of Magnetic Measurements of Classes $A_{5} B_{s}$ and $C$ Hagnets Reduced to Equivalent Radial Offeet Corrections on the Ags Ring", Accelerator Development Depertment Internal Feport JPF/FHP-2, July 17 , 1959. This report covers the magnets that were originally placed in the ring. Over the years the magnete have been shuffled and the spares brought ing the offsets for the spares were found in the deta books with the help of J. Weisentloom.
3. E. D. Courant, "Stacking Order for Class A and Class E Magnets in the AES": Accelerator Development Department Internal Fepori EDC-2g: March 6 , 1957, and "Stacking Drder of Clase 0 Magnets in the AGS", Report EDC-30, May 25. 1959.


Figure 1. Definitions of the offsets, in the magnet coordinate system, and ir the ring coordinate system. The convention is that the two are the same for magnets with their wide gap llow-field side) facing outward, ines the defocussing magnets (class C in the first half of each euperperiod, classes A and E in the second). For the other magnets, the offsets are interchanged and the signs reversed.

Table la. Wagnet list ordered by magnet name for elass f magnete. The offeetsy in milsy are from the socket holes to a magnetic centerline which has the same E.dl for all members of a class (at a set current corresponding to about 5000 gausel. Xrem is the offeet, in mile from the above centerline, needed to make the remanent field the same as in the reference magnet. The asterisk (茧) denotes that the magnet is in a location different from its original location. $N A=$ data not available. "Spare" denotes magnets not in the ring, and "242" denotes the magnet under the Siemens power room.

| 1 Mag. <br> I name | Fing 10c: | Mag. offset offl offz |  |  |
| :---: | :---: | :---: | :---: | :---: |
| A0, | E-05 | -7 | 23 | 166 |
| A02 | K-16 | 3 | 37 | 29 |
| f0S | 1-15 | 5 | 8 | 96 |
| A04 | H-06 | -8 | 19 | 13 |
| A05 | D-06 | 0 | 22 | -6 |
| A06 | ]-15 | -3 | 31 | 96 |
| A07 | 3-16 | 22 | 22 | 30 |
| A00 | L-06 | 1 | 14 | -34 |
| A0\% | c-16 | 3 | 28 | 28 |
| A10 | E-16 | -13 | 32 | 22 |
| A11 | k-06 | -1t | 22 | -17 |
| A12 | J-06 | 6 | 7 | -15 |
| A13 | E-06 | -5 | 30 | -20 |
| A14 | E-06 | -11 | 21 | 14 |
| A15 | F-0t 䨐 | 6 | 34 | -118 |
| A16 | G-16 | 1 | 34 | 65 |
| A17 | spare* | -8 | 15 | 11 |
| A1B | $\mathrm{A}^{-6 \mathrm{~b}}$ | -23 | 23 | -58 |
| - A17 | A-16 | 11 | 17 | 15 |
| 1 A20 | 1-05 | 0 | 9 | 137 |
| A21 | F-16 | -11 | 28 | 46 |
| 1 A22 | $\mathrm{H}-16$ | 8 | 12 | 38 |
| 1 A23 | -15 ${ }^{\text {a }}$ | 0 | 20 | $-120$ |
| - A24 | I-06 | 10 | 39 | -5 |
| 1 A25 | F-15 | -9 | 24 | 70 |
| 1 A26 | L-15 | 0 | 10 | 102 |
| 1 A27 | C-06 | -12 | 12 | -16 |
| 1 A28 | L-16 | -15 | 8 | 20 |
| 1 A2? | D-15 | -1 | 40 | 88 |
| 1 A30 | E-15 | 2 | 13 | 80 |



Table ib．Magnet list ordered by magnet name for class B magnets．

|  | Mag． name | Fing 10． | Mag．offeet －ffl off2 |  |  | Xrem |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | B01 | E－01 | ＊ | NA | WA | WA |
| ｜ | B02 | J－09 |  | －3 | 4 | 151 |
| I | E0S | E－12 | ＊ | 4 | 16 | 64 |
| ＋ | B04 | k－12 |  | 18 | 18 | 11 |
| 1 | B05 | $\mathrm{k}-20$ |  | 8 | E | 2 |
| ｜ | B0e | L－01 |  | －22 | 20 | 185 |
| ｜ | E07 | L－11 |  | －10 | 21 | 105 |
| 1 | B08 | G－20 |  | －4 | 5 | 61 |
| 1 | E0\％ | K－09 |  | －1 | 9 | 180 |
| 1 | E10 | F－20 |  | 0 | 15 | 61 |
| 1 | B11 | E－01 |  | －2 | 0 | 123 |
| 1 | E12 | E－11 | ＊ | －11 | 19 | 71 |
| 1 | E1S | G－10 |  | 7 | －3 | －26 |
| 1 | B14 | $\mathrm{H}-01$ |  | 8 | 15 | 118 |
| 1 | E15 | 3－20 |  | 2 | －4 | 23 |
| 1 | E16 | F－0i | ＊ | 9 | 2 | 214 |
| 1 | E17 | $\mathrm{E}-09$ |  | －4 | 4 | 176 |
| 1 | B18 | E－19 |  | －4 | 5 | 102 |
| 1 | B19 | I－19 | ＊ | －3 | －10 | 80 |
| 1 | E20 | I－20 |  | －3 | －1 | 41 |
| 1 | E21 | H－11 |  | －8 | 0 | 73 |
| 1 | E22 | J－12 |  | －12 | －2 | 8 |
| 1 | E2S | L－12 |  | －7 | 3 | －6 |
| 1 | E24 | A－02 |  | 5 | $-19$ | －163 |
| － | E25 | J－11 |  | 10 | －6 | 86 |
| 1 | E26 | C－10 |  | －1 | 10 | －64 |
| 1 | E27 | D－20 |  | －12 | 5 | 41 |
| 1 | E28 | L－02 |  | 3 | 3 | －129 |
| 1 | B29 | I－01 |  | 3 | 0 | 125 |
| ， | E80 | k－02 | 其 | 2 | 1 | 160 |
|  | ES1 | E－11 | 真 | 4 | 13 | 51 |
| 1 | ES2 | k－19 |  | 6 | 16 | 103 |
|  | ESS | C－12 |  | $-15$ | 16 | 20 |
| ｜ | B34 | E－20 |  | －7 | 26 | 47 |
| ！ | ES 5 | I－02 |  | $-15$ | 16 | －47 |
| ， | BSE | A－09 |  | 4 | 3 | 206 |
| ， | ES7 | J－02 |  | 1 | 0 | －64 |
| 1 | ES8 | D－02 |  | －6 | 9 | －59 |
|  | E39 | F－10 |  | －2 | 17 | －26 |
| 1 | E40 | J－19 |  | －12 | 12 | 93 |
|  | E41 | E－01 |  | 3 | 8 | 113 |
|  | E42 | G－11 | ＊ | －12 | 7 | 104 |
| 1 | E43 | E－10 |  | 1 | 6 | －41 |
|  | E44 | J－10 |  | $-4$ | 12 | －74 |
|  | E45 | H－02 |  | 14 | 21 | －31 |
|  | E46 | L－20 |  | 10 | 4 | －15 |
|  | E47 | A－11 |  | 6 | 6 | 107 |
|  | E4E | E－02 |  | －13 | 6 | －47 |
|  | E4C | D－01 |  | －8 | 9 | 140 |
|  | E50 | L－09 |  | 2 | 10 | 207 |


| 1 Mag． ｜name | Fing 10c． | Meg．offeet oft1 off2 |  | Yrem |
| :---: | :---: | :---: | :---: | :---: |
| ； $\mathrm{ESL}_{1}$ | D－10 | 0 | 11 | －48 |
| E52 | E－20 | 6 | 2 | 6 |
| 1 ESS | I－11＊ | 10 | 2 | 76 |
| ｜B54 | C－01 | －16 | 11 | 152 |
| ｜E5S | D－12 | 3 | 5 | 34 |
| ｜E56 | 6－09 | －14 | 10 | 114 |
| － 157 | C－17 | －16 | 4 | 92 |
| ESE | C－09 | －13 | 12 | 148 |
| ESc | D－09 | 4 | 14 | 136 |
| －E60 | 6－19＊ | －2 | 8 | 62 |
| E61 | C－02 | $-5$ | 6 | －77 |
| E62 | $\mathrm{H}-10$ | －8 | 10 | －45 |
| B63 | D－19 | 2 | 日 | 81 |
| B64 | $\mathrm{B}-12$ | $-13$ | 11 | 1 |
| B65 | H－17 ${ }^{\text {\％}}$ | －6 | 4 | 82 |
| 1 B66 | A－10 | －6 | 15 | $-130$ |
| －E67 | H－20＊ | －6 | 16 | 43 |
| －E68 | A－20＊ | －6 | 12 | 72 |
| － 869 | I－10 | －21 | 17 | －48 |
| （ 870 | E－10 | －10 | $1 E$ | －85 |
| ｜B71 | K－01＊ | 10 | 5 | －78 |
| 1 872 | E－02 | －6 | 3 | －23 |
| －B73 | H－12 | －10 | 3 | 50 |
| 1874 | spare＊ | $-6$ | 5 | －13 |
| 1 875 | H－07 | $-10$ | 1 | 122 |
| 1 87\％ | D－11 | －12 | 20 | 84 |
| 1 877 | A－01＊ | $-4$ | 0 | 192 |
| 1 878 | c－20 | $-13$ | 6 | 30 |
| －879 | A－19 | 7 | 6 | 105 |
| －EPO | L－17 | －2 | 11 | 106 |
| ｜E81 | I－12＊ | $-4$ | 5 | 46 |
| －B82 | E－12 | 1 | 日 | 45 |
| ｜ESS | F－19 | －2 | 18 | 66 |
| ｜ 884 | F－09 | －10 | 12 | 113 |
| B85 | spare＊ | －-3 | 15 | 114 |
| B86 | E－19 | 5 | 4 | 75 |
| ｜E87 | I－09 | －3 | 8 | 139 |
| ｜E88 | k－11 | 0 | －11 | 101 |
| B89 | F－12＊ | －-2 | 12 | 79 |
| E90 | L－10 | －6 | 11 | $-131$ |
| 891 | F－11＊ | －-18 | 4 | －206 |
| 192 | J－01 | －13 | 9 | 141 |
| E93 | E－09 | －1 | 11 | 120 |
| 1894 | C－11 | －2 | 7 | 99 |
| E95 | E－02 | －11 | 21 | －110 |
| 1 896 | $k-10$ | －8 | 2 | －107 |
| 1897 | A－12 | 2 | 4 | －18 |
| E98 | F－02 | $-14$ | 11 | －28 |

Table 15: Magnet list ordered by magnet name for clase $C$ magnets.

| 1 Mag. <br> \| name | Ring loc. | Mag. offset offi off2 |  | grem |
| :---: | :---: | :---: | :---: | :---: |
| - COH | A-07 | -10 | -30 | 53 |
| co2 | L-0] | 1 | -3 | 54 |
| cos | E-04 | -4 | -12 | -13 |
| C04 | F-17 | -21 | -21 | 59 |
| cos | J-13 | 5 | -17 | 93 |
| C06 | J-08 | -15 | -7 | -2 |
| COF | I-03 | -14 | $-18$ | 36 |
| cog | F-18 | -27 | 1 | -23 |
| C0\% | G-08 | -21 | -11 | 15 |
| C10 | K-04 | -29 | 1 | -6 |
| C11 | F-14 | -8 | -6 | -28 |
| C12 | D-18 | -7 | -5 | -38 |
| C13 | I-18 | -1 | -17 | -40 |
| C14 | A-18 | -3 | -11 | -87 |
| C15 | L-14 | -21 | -7 | -86 |
| C16 | E-17 | -23 | 3 | 73 |
| C17 | D-04 | -8 | 14 | 6 |
| C18 | H-14 | -25 | -3 | -30 |
| C19 | A-14 | -6 | -14 | -128 |
| 020 | E-18 | -25 | -11 | -33 |
| C21 | spare | -11 | -9 | 19 |
| \| C22 | L-08 | -16 | -8 | -22 |
| C23 | F-07 * | -3 | -7 | -150 |
| C24 | J-03 | -17 | -21 | 41 |
| 1 C 25 | 5-04 | -23 | $-23$ | 17 |
| C26 | spare | -9 | 3 | -147 |
| C27 | D-14 | -4 | -28 | -42 |
| - C8g | I-04 | -14 | -24 | 10 |
| C29 | A-04 | -4 | -6 | -21 |
| 030 | k-14 | -5 | -19 | -62 |
| C31 | J-04 | -15 | 1 | 4 |
| - C32 | E-18 | -14 | -24 | -25 |
| 1 63 | H-04 | -11 | -1 | 7 |
| C34 | E-17 | -23 | -9 | 110 |
| CS5 | E-15 | -11 | - | 56 |
| CS6 | D-0S | -8 | -2 | 40 |
| 1 C87 | A-13 | -18 | $-20$ | 143 |
| \| CS8 | H-17 | -19 | -9 | 79 |
| 1 C87 | 6-07 | -16 | 0 | 25 |
| - C40 | $\mathrm{k}-07$ | -3 | $-19$ | 50 |
| 1 C41 | F-04 | -30 | 4 | 13 |
| $1 \mathrm{C42}$ | A-0S | -17 | -5 | 56 |
| 1 C4S | 6-14 | -8 | 2 | -21 |
| 1 C 44 | I-14 | -12 | -12 | -36 |
| 1 645 | [-03 | -18 | -6 | 47 |
| 1 C 46 | C-07 | -12 | -10 | 44 |
| - C47 | 1-08 | -24 | -6 | 5 |
| ; c4e | $\mathrm{E}-13$ | -12 | -8 | 111 |
| 1 C 49 | C-17 | -8 | -6 | 74 |
| - 650 | k-18 | $-15$ | $-13$ | -66 |


| 1 Mag. \| name | Ring <br> 10c. | Mag. offeet off1 off2 |  | Yrem |
| :---: | :---: | :---: | :---: | :---: |
| ( C5i | L-18 | -6 | -6 | -91 |
| - cse | F-0s | -2 | -4 | 24 |
| \| CES | J-14 | 3 | -13 | -46 |
| - $\mathrm{C5} 4$ | K-03 | -5 | $-23$ | 47 |
| \| 055 | D-08 | -15 | 7 | 6 |
| - C56 | H-18 | -13 | -27 | -32 |
| 1 $\mathrm{CS7}$ | E-18 | -5 | -5 | -64 |
| ; $\mathrm{C5}$ | [-14 | -15 | -3 | -60 |
| C59 | D-13 | -28 | -12 | 70 |
| - 660 | $\mathrm{B}-07$ | -11 | -17 | 48 |
| - C61 | $\mathrm{H}-\mathrm{OS}$ | $-22$ | -14 | 27 |
| 1 c62 | J-17 | -17 | -25 | 75 |
| 1 C0s | E-17 | -23 | -13 | 63 |
| 1 C64 | D-17 | -10 | -8 | 85 |
| 1 665 | k-13 | -23 | 5 | 105 |
| - C6S | 1-13 | -21 | -27 | 83 |
| 1 C67 | C-18 | -22 | -16 | -48 |
| - C68 | D-07 | -19 | $-27$ | 36 |
| C69 | C-13 | -20 | 0 | 104 |
| 1070 | J-07 | -10 | -4 | 46 |
| 071 | I-07 | -35 | -11 | 3E |
| C72 | L-13 | -12 | -36 | 120 |
| c73 | $\mathrm{E}-13$ | -26 | -20 | 82 |
| 1574 | F-13 | -19 | -15 | 67 |
| 1 675 | H-13 | -29 | -13 | 69 |
| c7e | $\mathrm{H}-07$ | -25 | -23 | 29 |
| 1 C 77 | L-17 | -17 | -7 | 136 |
| 1 678 | $\mathrm{k}-17$ | -10 | -24 | 109 |
| 1079 | L-07 | -27 | -1 | 57 |
| 1 CBO | A-17 | -6 | -22 | 131 |
| C81 | E-04 | $-26$ | -2 | 9 |
| 1 CE2 | J-18 | -12 | -14 | $-56$ |
| C83 | L-04 | $-6$ | -4 | -12 |
| C84 | C-04 | -1 | -15 | -5 |
| \| C85 | B-08 | -2 | -6 | -6 |
| C86 | C-08 | -10 | -10 | 3 |
| C87 | [-03 | 10 | $-12$ | 18 |
| Cg8 | E-14 | -24 | 2 | -78 |
| C89 | F-08 | 6 | -8 | 15 |
| C90 | 1-17 | -15 | 11 | 90 |
| 1891 | A-00 | 0 | 4 | -18 |
| - C 92 | k-08 | $-27$ | -5 | -9 |
| C95. | E-03 | 1. | -11 | 32 |
| 094 | H-08 | $-29$ | 21 | 10 |
| C95 | E-08 | 1 | -5 | 9 |
| 096 | B-0S | -30 | 0 | 52 |
| 1897 | $\mathrm{E}-07$ | 6 | -4 | 28 |
| 098 | E-14 | -7 | 25 | -33 |

Table 2. Magnet names and offeets, ordered by location in ring. The asterisk (*) denotes that a location has a magnet different from the original stacking order: $N A=$ data not available.

| $1$ | Ring loc. | mag name |  | Fing offeet听fA offB |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | A-01 | 877 | * | 0 | 4 |  |
| 1 | A-02 | E24 |  | 19 | -5 |  |
| 1 | A-03 | $\mathrm{C42}$ |  | -17 | -5 |  |
| \| | A-04 | C29 |  | -4 | -6 |  |
| 1 | A-05 | A42 |  | -27 | 10 |  |
| 1 | A-06 | A18 |  | -23 | 23 |  |
| ! | A-07 | COL |  | -10 | -30 |  |
| 1 | A-08 | C91 |  | 0 | 4 |  |
| + | A-0¢ | Ese |  | - | -4. |  |
| I | A-10 | B66 |  | -15 | 6 |  |
| 1 | A-11 | 847 |  | 6 | 6 |  |
| ! | A-12 | 897 |  | 2 | 4 |  |
| I | A-13 | CS7 |  | 20 | 18 |  |
|  | A-14 | [19 |  | 14 | 6 |  |
| I | A-15 | A45 |  | 4 | 12 |  |
| , | A-16 | A19 |  | 11 | 17 |  |
|  | A-17 | ceo |  | 22 | 6 |  |
|  | A-18 | C14 |  | 11 | 3 |  |
|  | A-19 | B77 |  | 7 | 6 |  |
|  | A-20 | 868 | * | $-6$ | 12 |  |
| \| | E-01 | B01 | * | WA | NA |  |
| 1 | E-02 | E95 |  | -21 | 11 |  |
|  | $\mathrm{B}-03$ | C96 |  | -38 | 0 |  |
| + | $\mathrm{B}-04$ | cos |  | -4 | -12 |  |
|  | $\mathrm{E}-05$ | AO1 |  | -23 | 7 |  |
|  | $\mathrm{E}-06$ | A13 |  | -30 | 5 |  |
| 1 | E-07 | C60 |  | -11 | -17 |  |
|  | E-08 | CES |  | -2 | -6 |  |
| ! | E-09 | 817 |  | -4 | 4 |  |
| ! | E-10 | E70 |  | -18 | 18 |  |
|  | E-11 | B12 | * | -11 | 19 |  |
| ' | E-12 | E64 |  | -13 | 11 |  |
|  | E-13 | C48 |  | 8 | 12 |  |
|  | E-14 | C88 |  | -2 | 24. |  |
| 1 | E-15 | A39 |  | 14 | 24 |  |
|  | E-16 | A10 |  | $-13$ | 32 |  |
|  | E-17 | [34 |  | 9 | 23 |  |
|  | E-19 | [57 |  | 5 | 5 |  |
|  | E-19 | B18 |  | -4 | 5 |  |
|  | E-20 | ES2 |  | 6 | 2 |  |


| $1$ | Fing <br> loc. | $\operatorname{Mag}$ name | Fing offset off $A$ ff $B$ |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | C-01 | E54 | -11 | 16 |  |
| 1 | $\mathrm{C}-02$ | B61 | -6 | 5 |  |
| 1 | C-03 | C45 | -18 | -6 |  |
| \| | [-04 | C84 | -1 | -15 |  |
| 1 | C-05 | A47 | -15 | 1 |  |
| , | C-06 | A27 | -12 | 12 |  |
| , | C-07 | [46 | -12 | $-10$ |  |
|  | C-08 | c8b | -10 | -10 |  |
| 1 | C-09 | ESE | -12 | 13 |  |
| 1 | C-10 | E2b | -10 | 1 |  |
|  | C-11 | 894 | -2 | 7 |  |
| I | C-12 | ESS | $-13$ | 16 |  |
| 1 | C-13 | C69 | 0 | 28 |  |
| , | C-14 | C59 | 3 | 15 |  |
| 1 | C-15 | ASE | -6 | 16 |  |
| 1 | c-16 | A09 | 3 | 28 |  |
| 1 | C-17 | C49 | 6 | 8 |  |
| 1 | C-18 | C67 | 16 | 22 |  |
| 1 | C-19 | 857 | $-16$ | 4 |  |
| 1 | C-20 | E76 | $-13$ | 6 |  |
| 1 | D-01 | 849 | $-9$ | 8 |  |
| 1 | D-02 | ESE | -9 | 8 |  |
| 1 | D-03 | CSb | -9 | -2 |  |
| 1 | D-04 | C17 | -8 | 14 |  |
| 1 | D-05 | A48 | -23 | 19 |  |
| ! | D-06 | A0S | -22 | 0 |  |
| 1 | D-07 | c68 | -19 | $-27$ |  |
| 1 | D-68 | CES | -15 | 7 |  |
| 1 | D-09 | E59 | -14 | -4 |  |
| 1 | D-10 | E51 | -11 | 0 |  |
| 1 | D-11 | B76 | -12 | 20 |  |
| 1 | D-12 | E55 | 3 | 5 |  |
| 1 | D-13 | C59 | 12 | 28 |  |
| 1 | D-14 | $\mathrm{C27}$ | 20 | 4 |  |
| 1 | D-15 | A29 | -1 | 40 |  |
| , | D-16 | A 38 | 1 | 21 |  |
| 1 | D-17 | C64 | 8 | 10 |  |
| 1 | D-18 | $\mathrm{Cl2}$ | 5 | 7 |  |
| 1 | D-17 | B6.3 | 2 | 8 |  |
| 1 | D-20 | E27 | $-12$ | 5 |  |

Table 2 (continued).


| 1 | Ring loc. | Mag | Fing offeet offa offB |  |  | 1 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ' | E-01 | E41 |  | -8 | -3 | ! |
| \| | E-02 | E72 |  | -3 | 6 | 1 |
| 1 | G-03 | C87 |  | 10 | -12 | ; |
| 1 | E-04 | $\mathrm{C25}$ |  | $-23$ | -23 | 1 |
| 1 | E-05 | ASS |  | -26 | 9 | 1 |
| 1 | E-06 | A14 |  | -21 | 11 | ! |
| 1 | E-07 | csg |  | -16 | 0 | ! |
| 1 | G-08 | C09 |  | -21 | -11 | 1 |
| 1 | 6-09 | E56 |  | -10 | 14 | 1 |
| 1 | 6-10 | E13 |  | 3 | -7 | ! |
| 1 | G-11 | E42 | * | -12 | 7 | ; |
|  | 6-12 | B03 | * | 4 | 16 | 1 |
| 1 | G-13 | CSS |  | 3 | 11 | ! |
|  | G-14 | [43 |  | -2 | 8 | 1 |
|  | G-15 | A2S | * | 0 | 20 | ; |
|  | G-16 | A16 |  | 1 | 34 | 1 |
|  | G-17 | C6S |  | 13 | 23 | 1 |
|  | E-18 | C32 |  | 24 | 14 | 1 |
| , | G-17 | E60 | * | -2 | 8 | ! |
| 1 | 6-20 | E08 |  | -4 | 5 | 1 |
|  | H-01 | 814 |  | $-15$ | -8 | 1 |
| 1 | $\mathrm{H}-02$ | E45 |  | $-21$ | -14 | ; |
|  | H-03 | C61 |  | -22 | -14 | ! |
| 1 | H-04 | CS3 |  | -11 | -1 | ! |
| 1 | H-05 | A43 |  | -17 | 8 | ; |
|  | H-06 | A04 | * | -19 | 8 | 1 |
| 1 | H-07 | c76 |  | -23 | -23 | ; |
| 1 | H-08 | 094 |  | -29 | 21 | 1 |
|  | H-09 | 675 |  | -1 | 10 | ; |
|  | H-10 | B62 |  | $-10$ | 8 | 1 |
|  | H-11 | E21 |  | -8 | 0 | 1 |
|  | H-12 | E7S |  | $-10$ | 3 | ! |
| 1 | H-13 | 075 |  | 13 | 27 | ! |
|  | H-14 | c18 |  | 3 | 25 | 1 |
|  | H-15 | A 37 |  | -6 | 33 | ; |
|  | H-16 | A22 |  | 8 | 12 | 1 |
| ; | H-17 | CS8 |  | 9 | 19 | ; |
|  | H-18 | C56 |  | 27 | 13 | ! |
|  | H-19 | B65 | * | -6 | 4 | ! |
|  | H-20 | 867 | 客 | -6 | 16 | ; |

Table 2 (continued).

| $:$ | $\begin{aligned} & \text { Fing } \\ & \text { loc. } \end{aligned}$ | $\mathrm{Nag}$ name |  | Fing o offA | ff:et of $f \mathrm{~B}$ | 1 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| : | I-01 | E29 |  | 0 | -3 | ! |
| 1 | 1-02 | ES 5 |  | $-16$ | 15 | \| |
| 1 | I-0S | $\mathrm{CO7}$ |  | -14 | -18 | I |
| 1 | I-04 | c28 |  | -14 | -24 | ! |
| 1 | I-05 | A20 |  | -7 | 0 | ! |
| 1 | 1-06 | A24 |  | -39 | -10 | ! |
| 1 | 1-07 | C71 |  | -35 | -11 | ! |
| 1 | I-08 | C47 |  | -24 | $-6$ | 1 |
| 1 | I-09 | 887 |  | -9 | 3 | 1 |
| 1 | I-10 | 869 |  | -17 | 21 | 1 |
| 1 | I-11 | E5S | * | 10 | 2 | ! |
| 1 | I-12 | B81 | * | -4 | 5 | 1 |
| 1 | I-13 | C66 |  | 29 | 21 | ! |
| 1 | I-14 | C44 |  | 12 | 12 | I |
| 1 | I-15 | A0S |  | 5 | 8 | ! |
| 1 | I-16 | A 4 |  | B | 3 | 1 |
| , | I-17 | c90 |  | -11 | 15 | I |
|  | I-18 | C13 |  | 17 | 1 | \% |
| , | I-17 | 819 | * | -3 | -10 | ; |
| 1 | I-20 | 820 |  | -3 | -1 | ; |
|  | J-01 | B92 |  | -9 | 13 | ; |
|  | J-02 | BS7 |  | 0 | -1 | ; |
|  | J-03 | C24 |  | -17 | -21 |  |
|  | J-04 | CSI |  | -15 | 1 | ; |
|  | J-05 | ASI |  | $-3$ | 14 | , |
|  | J-06 | Al2 |  | -9 | -6 |  |
|  | J-07 | c70 |  | $-10$ | -4 |  |
|  | J-08 | cob |  | -15 | -7 | ! |
|  | J-09 | B02 |  | -4 | 3 | ! |
|  | J-10 | E4.4 |  | -12 | 4 | , |
|  | J-11 | B25 |  | 10 | -b |  |
|  | J-12 | E22 |  | -12 | -2 |  |
|  | J-13 | cos |  | 17 | -5 | ; |
|  | J-14 | C5S |  | 13 | -3 |  |
|  | J-15 | A06 |  | -3 | 31 |  |
|  | J-16 | A07 |  | 22 | 22 | ! |
|  | J-17 | c62 |  | 25 | 17 |  |
|  | J-19 | C82 |  | 14 | 12 |  |
|  | J-19 | E40 |  | -12 | 12 | ; |
|  | J-20 | E15 |  | 2 | -4 | 1 |


| I | Fing <br> loc. | Mag name |  | Fing offeet offA offB |  | 1 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | $\mathrm{k}-01$ | E71 | * | -5 | -10 |  |
| 1 | K-02 | B80 | * | -1 | -2 |  |
| 1 | k-03 | C54 |  | -5 | -23 |  |
| 1 | K-04 | c10 |  | -29 | 1 |  |
| 1 | $\mathrm{k}-05$ | AS2 |  | -12 | 4 |  |
| 1 | $\mathrm{k}-06$ | Alı |  | -22 | 16 |  |
| 1 | 1-07 | c40 |  | -3 | -19 |  |
| 1 | $\mathrm{k}-08$ | c92 |  | -27 | -5 |  |
| 1 | k-09 | E09 |  | -9 | 1 |  |
| 1 | $\mathrm{k}-10$ | 896 |  | -2 | 日 |  |
| 1 | k-11 | E88 |  | 0 | -11 |  |
| 1 | $\mathrm{k}-12$ | E04 |  | 18 | 18 |  |
| 1 | k-13 | 665 |  | -5 | 23 |  |
| 1 | K-14 | C30 |  | 19 | 5 |  |
|  | $k-15$ | A41 |  | $-13$ | 32 |  |
|  | $k-16$ | A02 |  | 3 | 37 |  |
| 1 | $\mathrm{k}-17$ | c78 |  | 24 | 10 |  |
|  | K-19 | C50 |  | 13 | 15 |  |
|  | k-19 | ES2 |  | 6 | 16 |  |
|  | k-20 | E0S |  | 8 | 8 |  |
|  | L-01 | B06 |  | $-20$ | 22 |  |
|  | L-02 | E28 |  | -3 | -3 |  |
|  | L-03 | C02 |  | 1 | -3 |  |
|  | L-04 | ces |  | $-6$ | -4 |  |
|  | L-05 | A40 |  | $-14$ | 0 |  |
|  | L-06 | A08 |  | -14 | -1 |  |
|  | L-07 | c79 |  | $-27$ | -1 |  |
| \| | L-08 | $\mathrm{C22}$ |  | -16 | -8 |  |
|  | L-09 | E50 |  | $-10$ | -2 |  |
|  | L-10 | EFO |  | -11 | 6 |  |
|  | L-11 | E07 |  | -10 | 21 |  |
|  | L-12 | E23 |  | -7 | 3 |  |
|  | L-13 | c72 |  | 36 | 12 |  |
|  | L-14 | C15 |  | 7 | 21 |  |
|  | L-15 | A26 |  | 0 | 10 |  |
|  | L-15 | A28 |  | -15 | $\square$ |  |
|  | L-17 | C77 |  | 7 | 17 |  |
|  | L-18 | C51 |  | 8 | 6 |  |
|  | L-17 | B80 |  | -2 | 11 |  |
|  | L-20 | B46 |  | 10 | 4 |  |
|  | spare | A17 | * |  |  |  |
| I | "242" | A49 | * |  |  |  |
|  | spare | B74 | * |  |  |  |
| 1 | spare | Bg5 | * |  |  |  |
|  | spare | C21 | * |  |  |  |
|  | spare | C26 |  |  |  |  |

Table S. Summary of magnet changes.

| i | $\begin{aligned} & \text { Ring } \\ & \text { loc. } \end{aligned}$ | Original magnet | Fresent magnet |
| :---: | :---: | :---: | :---: |
| 1 | A-0. | E16 | B77 |
| 1 | A-20 | B74 | E68 |
| 1 | E-01 | E77 | B01 |
| + | E-11 | E42 | E12 |
| 1 | E-11 | 889 | ES1 |
| 1 | F-01 | E85 | E16 |
| ! | F-06 | A04 | A15 |
| 1 | F-07 | C21 | c23 |
| 1 | F-11 | E68 | E91 |
| 1 | F-12 | ES 1 | B99 |
| 1 | G-11 | BOS | B42 |
| 1 | G-12 | E60 | BOS |
| 1 | 6-15 | A49 | A23 |
| 1 | 6-19 | B 12 | B60 |
| + | H-06 | A17 | A04 |
| 1 | H-19 | ESS | E65 |
| 1 | H-20 | BE1 | 867 |
| 1 | I-11 | B17 | B53 |
| 1 | I-12 | E67 | ER1 |
| 1 | I-17 | B65 | B19 |
| 1 | k-01 | ESO | E71 |
| 1 | K-02 | E71 | ESO |
| ! | spares: | A15 | A17 |
| 1 |  | A23 | A49 |
| I |  | B01 | B74 |
| 1 |  | 891 | E8S |
| ; |  | C23 | C21 |
| 1 |  | c26 | C26 |


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