# NATIONAL BUREAU OF STANDARDS REPORT

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on

Interlaboratory Intercomparisons

of

400-Watt Mercury Vapor Lamps

by

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Photometry and Colorimetry Section
Metrology Division


U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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# NATIONAL BUREAU OF STANDARDS REPORT

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# Interlaboratory Intercomparisons of 400-Watt Mercury Vapor Lamps


## Abstract

Two groups of six 400-watt mercury vapor lamps were measured by each of seven laboratories. One group consists of six HILS clear bulb lamps; the other group consists of six HILB/W phosphor-coated lamps. The lamps were operated on a commercial ballast GE #89G164. Five of the laboratories, in addition, operated the lamps on an ASA reference ballast and two of the laboratories reported values for operation on their regular laboratory ballast. Measurements of lumens, lamp current, lamp volts, lamp watts, and lumens per watt were reported for operation of each lamp at 118 line volts and at 400 watts on ballast GE #89G164, and at 240 line volts on the ASA reference ballast. Similar measurements on their regular laboratory ballast were made by two laboratories. The results of the measurements made by the individual laboratories and an analysis of the results are given in this report.


## I. Measurements

This intercomparison was undertaken to determine the uniformity of measurements on 400-watt mercury vapor lamps made at the participating laboratories. The laboratories participating and the order of reading are as follows:

I. General Electric
II. National Bureau of Standards
III. Electrical Testing Laboratories
IV. Westinghouse
V. Duro Test
VI. Sylvania
VII. Champion.

The order in which the laboratories made their measurements was chosen to reduce shipment of the lamps as much as possible. Each laboratory made measurements on both groups of lamps using GE ballast #89G164 while holding the line voltage constant at 118 volts. A second set of measurements was made while holding the lamp watts constant at 400 watts. Five of the laboratories then used an ASA reference ballast (53.4 ohms impedance at 3.2 amperes, and 7-8% power factor) at 240 line volts. Two of the laboratories made additional measurements using their regular ballast. For each method of operation the following quantities were measured: lumens, lamp volts, lamp current, and lamp watts. Each laboratory followed its own customary procedure in making the measurements. The results of all the reported measurements are given in the tables which follow.

Table 1.

Lumens
HILS Mercury Lamps
GE Ballast #89G164, 118 line volts

| Lamp No. | GE | NBS | ETL | West. | Duro T. | Syl. | Champ. | Ave. |
|---|---|---|---|---|---|---|---|---|
| A-1 | 19290 | 19100 | 20400 | 19690 | 19310 | 19800 | 19800 | 19627 |
| A-2 | 19030 | 18800 | 20100 | 19650 | 19180 | 19680 | 19510 | 19421 |
| A-3 | 19120 | 18800 | 20000 | 19370 | 19140 | 19500 | 19450 | 19340 |
| A-4 | 19075 | 18900 | 20100 | 19653 | 19340 | 19580 | 19390 | 19434 |
| A-5 | 18950 | 18700 | 19900 | 19443 | 19130 | 19420 | 19370 | 19273 |
| A-6 | 19763 | 19700 | 20800 | 20400 | 19920 | 20420 | 20350 | 20193 |
| ave. | 19205 | 19000 | 20200 | 19701 | 19337 | 19733 | 19645 | 19546 |
| Δ | -341 | -546 | +654 | +155 | -209 | +187 | + 99 | |
| % Δ | -1.7% | -2.8% | +3.3% | + .8% | -1.1% | +1.0% | + .5% | |

Table 2.

Lumens
HILB/W Mercury Lamps
GE Ballast #89G164, 118 line volts

| Lamp No. | GE | NBS | ETL | West. | Duro T. | Syl. | Champ. | Ave. |
|---|---|---|---|---|---|---|---|---|
| B-1 | 19830 | 19600 | 20300 | 20617 | 20210 | 20480 | 20200 | 20177 |
| B-2 | 20120 | 19800 | 20400 | 20750 | 20320 | 20500 | 20450 | 20334 |
| B-3 | 19770 | 19400 | 20000 | 20190 | 19715 | 19720 | 19750 | 19792 |
| B-4 | 19445 | 19000 | 19700 | 19683 | 19370 | 19520 | 19800 | 19503 |
| B-5 | 20895 | 20700 | 21400 | 21590 | 20995 | 21360 | 21700 | 21234 |
| B-6 | 20333 | 20200 | 20500 | 20780 | 20210 | 20460 | 20550 | 20433 |
| ave. | 20066 | 19783 | 20383 | 20602 | 20137 | 20340 | 20408 | 20246 |
| Δ | -180 | -463 | +137 | +356 | -109 | + 94 | +162 | |
| % Δ | - .9% | -2.3% | + .7% | +1.8% | - .5% | + .5% | + .8% | |

Table 3.

Lumens
HILS Mercury Lamps
GE Ballast #89G164, 400 watts

| Lamp No. | GE | NBS | ETL | West. | Duro T. | Syl. | Champ. | Ave. |
|---|---|---|---|---|---|---|---|---|
| A-1 | 19125 | 19100 | 19400 | 19683 | 19070 | 19700 | 19620 | 19385 |
| A-2 | 19000 | 19100 | 19300 | 19767 | 19000 | 19660 | 19510 | 19334 |
| A-3 | 18995 | 18800 | 19200 | 19400 | 19100 | 19340 | 19050 | 19126 |
| A-4 | 18975 | 18900 | 19200 | 19700 | 19010 | 19580 | 19180 | 19221 |
| A-5 | 18935 | 18800 | 19100 | 19533 | 18800 | 19540 | 19110 | 19117 |
| A-6 | 19880 | 19800 | 20200 | 20483 | 18810 | 20600 | 20200 | 19996 |
| ave. | 19152 | 19083 | 19400 | 19761 | 18965 | 19737 | 19445 | 19363 |
| Δ | -211 | -280 | + 37 | +398 | -398 | +374 | + 82 | |
| % Δ | -1.1% | -1.4% | + .2% | +2.1% | -2.1% | +1.9% | + .4% | |

Table 4.

Lumens
HILB/W Mercury Lamps
GE Ballast #89G164, 400 watts

| Lamp No. | GE | NBS | ETL | West. | Duro T. | Syl. | Champ. | Ave. |
|---|---|---|---|---|---|---|---|---|
| B-1 | 19940 | 19700 | 20000 | 20633 | 20220 | 20260 | 20010 | 20109 |
| B-2 | 20240 | 19900 | 20200 | 20783 | 20500 | 20340 | 20150 | 20302 |
| B-3 | 20000 | 19700 | 20100 | 20252 | 20100 | 19900 | 19600 | 19950 |
| B-4 | 19620 | 19300 | 19500 | 19800 | 19570 | 19640 | 19440 | 19553 |
| B-5 | 20995 | 20800 | 21100 | 21600 | 21140 | 21360 | 21420 | 21202 |
| B-6 | 20553 | 20300 | 20400 | 20833 | 20600 | 20620 | 20300 | 20515 |
| ave. | 20225 | 19950 | 20217 | 20650 | 20355 | 20353 | 20153 | 20272 |
| Δ | - 47 | -322 | - 55 | +388 | + 83 | + 81 | -119 | |
| % Δ | - .2% | -1.6% | - .3% | +1.9% | + .4% | + .4% | - .6% | |

Table 5.

Lamp Volts
HILS Mercury Lamps
GE Ballast #89G164, 118 line volts

| Lamp No. | GE | NBS | ETL | West. | Duro T. | Syl. | Champ. | Ave. |
|---|---|---|---|---|---|---|---|---|
| A-1 | 135.1 | 133 | 136.3 | 134 | 135.4 | 135.5 | 133.5 | 134.7 |
| A-2 | 130.8 | 129 | 131.8 | 132 | 130.5 | 131.0 | 132.1 | 131.0 |
| A-3 | 136.8 | 136 | 137.9 | 137 | 136.7 | 137.0 | 136.9 | 136.9 |
| A-4 | 138.3 | 138 | 139.3 | 138 | 138.1 | 138.0 | 138.2 | 138.3 |
| A-5 | 134.9 | 134 | 136.1 | 134 | 135.2 | 134.5 | 134.9 | 134.8 |
| A-6 | 127.9 | 127 | 129.0 | 129 | 127.8 | 128.0 | 128.0 | 128.1 |
| ave. | 134.0 | 132.8 | 135.1 | 134.0 | 134.0 | 134.0 | 133.9 | 134.0 |
| △ | 0 | - 1.2 | + 1.1 | 0 | 0 | 0 | - .1 | |
| %△ | 0 | - .9% | + .8% | 0 | 0 | 0 | - .1% | |

Table 6.

Lamp Volts
HILB/W Mercury Lamps
GE Ballast #89G164, 118 line volts

| Lamp No. | GE | NBS | ETL | West. | Duro T. | Syl. | Champ. | Ave. |
|---|---|---|---|---|---|---|---|---|
| B-1 | 134.6 | 134 | 136.0 | 134 | 134.7 | 135.0 | 134.0 | 134.6 |
| B-2 | 133.9 | 133 | 135.2 | 134 | 133.8 | 134.5 | 133.8 | 134.0 |
| B-3 | 127.1 | 126 | 128.2 | 126 | 125.5 | 127.0 | 127.2 | 126.7 |
| B-4 | 130.0 | 129 | 131.3 | 130 | 130.7 | 130.0 | 130.0 | 130.1 |
| B-5 | 131.6 | 130 | 132.7 | 131 | 131.7 | 131.5 | 131.7 | 131.5 |
| B-6 | 128.3 | 126 | 129.3 | 128 | 128.6 | 128.5 | 129.9 | 128.4 |
| ave. | 130.9 | 129.7 | 132.1 | 130.5 | 130.8 | 131.1 | 131.1 | 130.9 |
| △ | 0 | - 1.2 | + 1.2 | - .4 | - .1 | + .2 | + .2 | |
| %△ | 0 | - .9% | + .9% | - .3% | - .1% | + .2% | + .2% | |

Table 7.

Lamp Volts
HILS Mercury Lamps
GE Ballast #89G164, 400 watts

| Lamp No. | GE | NBS | ETL | West. | Duro T. | Syl. | Champ. | Ave. |
|---|---|---|---|---|---|---|---|---|
| A-1 | 135.0 | 134 | 136.3 | 135 | 135.2 | 135.5 | 133.5 | 134.9 |
| A-2 | 130.7 | 130 | 131.6 | 132 | 130.2 | 131.0 | 132.2 | 131.1 |
| A-3 | 136.8 | 136 | 137.7 | 136 | 136.5 | 137.0 | 136.9 | 136.7 |
| A-4 | 138.2 | 137 | 139.1 | 138 | 137.8 | 138.0 | 138.2 | 138.0 |
| A-5 | 134.9 | 134 | 136.0 | 134 | 134.7 | 134.5 | 134.8 | 134.7 |
| A-6 | 127.9 | 127 | 128.9 | 129 | 127.7 | 128.0 | 128.0 | 128.1 |
| ave. | 133.9 | 133.0 | 134.9 | 134.0 | 133.7 | 134.0 | 133.9 | 133.9 |
| △ | 0 | -.9 | +1.0 | + .1 | - .2 | +.1 | 0 | |
| % △ | 0 | -.7% | + .7% | +.1% | -.1% | +.1% | 0 | |

Table 8.

Lamp Volts
HILB/W Mercury Lamps
GE Ballast #89G164, 400 Watts

| Lamp No. | GE | NBS | ETL | West. | Duro T. | Syl. | Champ. | Ave. |
|---|---|---|---|---|---|---|---|---|
| B-1 | 134.6 | 134 | 135.9 | 134 | 134.7 | 134.5 | 133.9 | 134.5 |
| B-2 | 133.9 | 133 | 135.1 | 134 | 133.7 | 134.5 | 133.8 | 134.0 |
| B-3 | 127.4 | 126 | 128.0 | 126 | 127.4 | 127.0 | 127.3 | 127.0 |
| B-4 | 130.0 | 128 | 131.2 | 130 | 130.2 | 130.0 | 130.0 | 129.9 |
| B-5 | 131.7 | 130 | 132.4 | 131 | 131.7 | 131.5 | 131.8 | 131.4 |
| B-6 | 128.5 | 127 | 129.2 | 128 | 128.2 | 128.5 | 129.9 | 128.5 |
| ave. | 131.0 | 129.7 | 132.0 | 130.5 | 131.0 | 131.0 | 131.1 | 130.9 |
| △ | +.1 | -1.2 | +1.1 | -.4 | + .1 | + .1 | +.2 | |
| % △ | +.1% | - .9% | +.8% | -.3% | +.1% | + .1% | +.2% | |

Table 9.
Lamp Current (amperes)
HILS Mercury Lamps
GE Ballast #89G164, 118 line volts

| Lamp No. | GE | NBS | ETL | West. | Duro T. | Syl. | Champ. | Ave. |
|---|---|---|---|---|---|---|---|---|
| A-1 | 3.19 | 3.18 | 3.10 | 3.20 | 3.17 | 3.19 | 3.28 | 3.187 |
| A-2 | 3.28 | 3.28 | 3.23 | 3.24 | 3.28 | 3.28 | 3.30 | 3.270 |
| A-3 | 3.15 | 3.14 | 3.11 | 3.14 | 3.15 | 3.17 | 3.20 | 3.151 |
| A-4 | 3.11 | 3.12 | 3.08 | 3.11 | 3.14 | 3.12 | 3.17 | 3.121 |
| A-5 | 3.18 | 3.18 | 3.14 | 3.20 | 3.19 | 3.18 | 3.23 | 3.186 |
| A-6 | 3.34 | 3.36 | 3.30 | 3.30 | 3.35 | 3.33 | 3.38 | 3.337 |
| ave. | 3.21 | 3.21 | 3.16 | 3.20 | 3.21 | 3.21 | 3.26 | 3.209 |
| △ | +.001 | +.001 | -.049 | -.009 | +.001 | +.001 | +.051 | |
| % △ | +.03% | +.03% | -1.5% | -.3% | +.03% | +.03% | +1.6% | |

Table 10.
Lamp Current (amperes)
HILB/W Mercury Lamps
GE Ballast #89G164, 118 line volts

| Lamp No. | GE | NBS | ETL | West. | Duro T. | Syl. | Champ. | Ave. |
|---|---|---|---|---|---|---|---|---|
| B-1 | 3.18 | 3.18 | 3.14 | 3.20 | 3.16 | 3.22 | 3.25 | 3.190 |
| B-2 | 3.20 | 3.21 | 3.17 | 3.20 | 3.17 | 3.22 | 3.25 | 3.203 |
| B-3 | 3.34 | 3.34 | 3.30 | 3.37 | 3.35 | 3.36 | 3.39 | 3.350 |
| B-4 | 3.28 | 3.27 | 3.24 | 3.28 | 3.24 | 3.28 | 3.36 | 3.279 |
| B-5 | 3.24 | 3.26 | 3.21 | 3.28 | 3.21 | 3.27 | 3.32 | 3.256 |
| B-6 | 3.31 | 3.34 | 3.27 | 3.30 | 3.27 | 3.32 | 3.35 | 3.309 |
| ave. | 3.26 | 3.27 | 3.22 | 3.27 | 3.23 | 3.28 | 3.32 | 3.264 |
| △ | -.004 | +.006 | -.044 | +.006 | -.034 | +.016 | +.056 | |
| % △ | -.1% | + .2% | -1.3% | + .2% | -1.0% | + .5% | +1.7% | |

Table 11.

Lamp Current (Amperes)
HILS Mercury Lamps
GE Ballast #89G164, 400 watts

| Lamp No. | GE | NBS | ETL | West. | Duro T. | Syl. | Champ. | Ave. |
|---|---|---|---|---|---|---|---|---|
| A-1 | 3.18 | 3.18 | 3.10 | 3.20 | 3.16 | 3.18 | 3.26 | 3.180 |
| A-2 | 3.29 | 3.31 | 3.21 | 3.25 | 3.26 | 3.29 | 3.28 | 3.270 |
| A-3 | 3.14 | 3.14 | 3.07 | 3.15 | 3.13 | 3.14 | 3.16 | 3.133 |
| A-4 | 3.10 | 3.12 | 3.03 | 3.12 | 3.08 | 3.12 | 3.13 | 3.100 |
| A-5 | 3.19 | 3.20 | 3.09 | 3.20 | 3.16 | 3.21 | 3.21 | 3.180 |
| A-6 | 3.36 | 3.40 | 3.27 | 3.32 | 3.34 | 3.35 | 3.35 | 3.341 |
| ave. | 3.21 | 3.22 | 3.13 | 3.21 | 3.19 | 3.22 | 3.23 | 3.201 |
| △ | +.009 | +.019 | -.071 | +.009 | -.011 | +.019 | +.029 | |
| % △ | +.3% | +.6% | -2.2% | +.3% | -.3% | +.6% | +.9% | |

Table 12.

Lamp Current (Amperes)
HILB/W Mercury Lamps
GE Ballast #89G164, 400 watts

| Lamp No. | GE | NBS | ETL | West. | Duro T. | Syl. | Champ. | Ave. |
|---|---|---|---|---|---|---|---|---|
| B-1 | 3.19 | 3.22 | 3.12 | 3.20 | 3.18 | 3.20 | 3.24 | 3.193 |
| B-2 | 3.21 | 3.24 | 3.13 | 3.20 | 3.19 | 3.21 | 3.23 | 3.201 |
| B-3 | 3.37 | 3.38 | 3.32 | 3.37 | 3.36 | 3.38 | 3.38 | 3.366 |
| B-4 | 3.29 | 3.33 | 3.22 | 3.29 | 3.26 | 3.30 | 3.32 | 3.287 |
| B-5 | 3.26 | 3.27 | 3.18 | 3.27 | 3.23 | 3.27 | 3.29 | 3.253 |
| B-6 | 3.34 | 3.35 | 3.25 | 3.31 | 3.32 | 3.33 | 3.32 | 3.317 |
| ave. | 3.28 | 3.30 | 3.20 | 3.27 | 3.26 | 3.28 | 3.30 | 3.270 |
| △ | +.01 | +.03 | -.07 | 0 | -.01 | +.01 | +.03 | |
| % △ | +.3% | +.9% | -2.1% | 0% | -.3% | +.3% | +.9% | |

Table 13.

Lamp Watts
HILS Mercury Lamps
GE Ballast #89G164, 118 line volts

| Lamp No. | GE | NBS | ETL | West. | Duro T. | Syl. | Champ. | Ave. |
|---|---|---|---|---|---|---|---|---|
| A-1 | 402 | 400 | 409 | 399 | 401 | 401 | 400.4 | 401.8 |
| A-2 | 399 | 397 | 404 | 399 | 401 | 399 | 401.2 | 400.0 |
| A-3 | 401 | 399 | 407 | 399 | 403 | 403 | 401.8 | 402.0 |
| A-4 | 401 | 401 | 404 | 399 | 403 | 400 | 405.2 | 401.9 |
| A-5 | 399 | 398 | 401 | 399 | 402 | 399 | 400.2 | 400.2 |
| A-6 | 396 | 398 | 401 | 399 | 401 | 396 | 399.2 | 398.6 |
| ave. | 399.7 | 398.8 | 404.8 | 399.0 | 402 | 399.7 | 401.3 | 400.8 |
| △ | -1.1 | -2.0 | +4.0 | -1.8 | +1.2 | -1.1 | +.5 | |
| % △ | -.3% | -.5% | +1.0% | -.4% | +.3% | -.3% | +.1% | |

Table 14.

Lamp Watts
HILB/W Mercury Lamps
GE Ballast #89G164, 118 line volts

| Lamp No. | GE | NBS | ETL | West. | Duro T. | Syl. | Champ. | Ave. |
|---|---|---|---|---|---|---|---|---|
| B-1 | 398 | 398 | 403 | 400 | 399 | 403 | 399.8 | 400.1 |
| B-2 | 397 | 398 | 401 | 399 | 398 | 401 | 401.6 | 399.4 |
| B-3 | 394 | 395 | 398 | 399 | 393 | 398 | 399.4 | 396.6 |
| B-4 | 396 | 396 | 401 | 399 | 394 | 398 | 401.8 | 398.0 |
| B-5 | 397 | 398 | 402 | 399 | 397 | 400 | 402.4 | 399.3 |
| B-6 | 395 | 399 | 401 | 399 | 394 | 397 | 399.6 | 397.8 |
| ave. | 396.2 | 397.3 | 401.0 | 399.2 | 395.8 | 399.5 | 400.8 | 398.5 |
| △ | -2.3 | -1.2 | +2.5 | +.7 | -2.7 | +1.0 | +2.3 | |
| % △ | -.6% | -.3% | +.6% | +.2% | -.7% | +.3% | +.6% | |

Table 15.

Lumens per Watt
HILS Mercury Lamps
GE Ballast #89G164, 118 line volts

| Lamp No. | GE | NBS | ETL | West. | Duro T. | Syl. | Champ. | Ave. |
|---|---|---|---|---|---|---|---|---|
| A-1 | 48.0 | 47.8 | 49.9 | 49.3 | 48.2 | 49.4 | 49.5 | 48.87 |
| A-2 | 47.7 | 47.4 | 49.8 | 49.3 | 47.8 | 49.3 | 48.7 | 48.57 |
| A-3 | 47.7 | 47.1 | 49.1 | 48.7 | 47.5 | 48.4 | 48.4 | 48.13 |
| A-4 | 47.6 | 47.1 | 49.8 | 49.2 | 48.0 | 49.0 | 47.8 | 48.36 |
| A-5 | 47.5 | 47.0 | 49.3 | 48.7 | 47.6 | 48.7 | 48.4 | 48.17 |
| A-6 | 49.9 | 49.5 | 51.9 | 51.0 | 49.7 | 51.6 | 51.6 | 50.74 |
| ave. | 48.1 | 47.6 | 50.0 | 49.4 | 48.1 | 49.4 | 49.1 | 48.81 |
| △ | - .71 | -1.21 | +1.19 | + .59 | - .71 | + .59 | + .29 | |
| % △ | -1.5% | -2.5% | +2.4% | +1.2% | -1.5% | +1.2% | + .6% | |

Table 16.

Lumens per Watt
HILB/W Mercury Lamps
GE Ballast #89G164 118 line volts

| Lamp No. | GE | NBS | ETL | West. | Duro T. | Syl. | Champ. | Ave. |
|---|---|---|---|---|---|---|---|---|
| B-1 | 49.8 | 49.2 | 50.4 | 51.6 | 50.7 | 50.8 | 50.6 | 50.44 |
| B-2 | 50.7 | 49.7 | 50.9 | 52.0 | 51.1 | 51.1 | 51.0 | 50.93 |
| B-3 | 50.2 | 49.1 | 50.3 | 50.7 | 50.2 | 49.5 | 49.5 | 49.93 |
| B-4 | 49.1 | 48.0 | 49.1 | 49.3 | 49.2 | 49.0 | 49.3 | 49.00 |
| B-5 | 52.6 | 52.0 | 53.2 | 54.0 | 52.9 | 53.4 | 54.0 | 53.16 |
| B-6 | 51.5 | 50.6 | 51.1 | 52.0 | 51.3 | 51.5 | 51.4 | 51.31 |
| ave. | 50.7 | 49.8 | 50.8 | 51.6 | 50.9 | 50.9 | 51.0 | 50.80 |
| △ | - .1 | -1.0 | 0 | + .8 | + .1 | + .1 | + .2 | |
| % △ | - .2% | -2.0% | 0% | +1.6% | + .2% | + .2% | + .4% | |

Table 17.

Lumens per Watt
HILS Mercury Lamps
GE Ballast #89G164, 400 watts

| Lamp No. | GE | NBS | ETL | West. | Duro T. | Syl. | Champ. | Ave. |
|---|---|---|---|---|---|---|---|---|
| A-1 | 47.8 | 47.8 | 48.5 | 49.2 | 47.7 | 49.3 | 49.1 | 48.49 |
| A-2 | 47.5 | 47.8 | 48.2 | 49.4 | 47.5 | 49.2 | 48.8 | 48.34 |
| A-3 | 47.5 | 47.0 | 48.0 | 48.5 | 47.8 | 48.4 | 47.6 | 47.83 |
| A-4 | 47.4 | 47.2 | 48.0 | 49.4 | 47.5 | 49.0 | 47.9 | 48.06 |
| A-5 | 47.3 | 47.0 | 47.8 | 48.8 | 47.0 | 48.9 | 47.8 | 47.80 |
| A-6 | 49.7 | 49.5 | 50.5 | 51.2 | 47.0 | 51.5 | 50.5 | 49.99 |
| ave. | 47.9 | 47.7 | 48.5 | 49.4 | 47.4 | 49.4 | 48.6 | 48.42 |
| △ | - .52 | - .72 | + .08 | + .98 | -1.02 | + .98 | + .18 | |
| % △ | -1.1% | -1.5% | + .2% | +2.0% | -2.1% | +2.0% | + .4% | |

Table 18.

Lumens per Watt
HILB/W Mercury Lamps
GE Ballast #89G164, 400 watts

| Lamp No. | GE | NBS | ETL | West. | Duro T. | Syl. | Champ. | Ave. |
|---|---|---|---|---|---|---|---|---|
| B-1 | 49.8 | 49.2 | 50.0 | 51.6 | 50.6 | 50.7 | 50.0 | 50.27 |
| B-2 | 50.6 | 49.8 | 50.5 | 52.0 | 51.2 | 50.9 | 50.2 | 50.74 |
| B-3 | 50.0 | 49.2 | 50.2 | 50.6 | 50.2 | 49.8 | 49.0 | 49.86 |
| B-4 | 49.0 | 48.2 | 48.8 | 49.5 | 48.9 | 49.1 | 48.6 | 48.87 |
| B-5 | 52.5 | 52.0 | 52.8 | 54.0 | 52.8 | 53.4 | 53.5 | 53.00 |
| B-6 | 51.4 | 50.8 | 51.0 | 52.1 | 51.5 | 51.6 | 50.8 | 51.31 |
| ave. | 50.6 | 49.9 | 50.5 | 51.6 | 50.9 | 50.9 | 50.3 | 50.68 |
| △ | - .08 | - .78 | - .18 | + .92 | + .22 | + .22 | - .38 | |
| % △ | - .2% | -1.5% | - .4% | +1.8% | + .4% | + .4% | - .7% | |

Table 19.

Lumens
HILS Mercury Lamps
ASA Reference Ballast, 240 line volts

| Lamp No. | GE | ETL | West. | Duro T. | Syl. | Ave. |
|---|---|---|---|---|---|---|
| A-1 | 19228 | 19400 | 19190 | 19450 | 19400 | 19334 |
| A-2 | 18853 | 19000 | 18900 | 19110 | 18980 | 18969 |
| A-3 | 19285 | 19300 | 18920 | 19400 | 18940 | 19169 |
| A-4 | 19128 | 19400 | 19160 | 19480 | 19200 | 19274 |
| A-5 | 18997 | 19100 | 18880 | 19200 | 18760 | 18987 |
| A-6 | 19593 | 19800 | 19590 | 19600 | 19620 | 19641 |
| ave. | 19181 | 19333 | 19107 | 19373 | 19150 | 19229 |
| △ | - 48 | + 104 | - 122 | + 144 | - 79 | |
| % △ | - .2% | + .5% | - .6% | + .7% | - .4% | |

Table 20.

Lumens
HILB/W Mercury Lamps
ASA Reference Ballast, 240 line volts

| Lamp No. | GE | ETL | West. | Duro T. | Syl. | Ave. |
|---|---|---|---|---|---|---|
| B-1 | 19953 | 20300 | 19975 | 20460 | 19680 | 20074 |
| B-2 | 20140 | 20400 | 20065 | 20600 | 19800 | 20201 |
| B-3 | 19697 | 19600 | 19490 | 19860 | 19180 | 19565 |
| B-4 | 19587 | 19400 | 19180 | 19620 | 18960 | 19349 |
| B-5 | 20813 | 21100 | 20980 | 21340 | 20720 | 20991 |
| B-6 | 20153 | 20200 | 20085 | 20290 | 19780 | 20102 |
| ave. | 20057 | 20167 | 19963 | 20362 | 19687 | 20047 |
| △ | + 10 | + 120 | - 84 | + 315 | - 360 | |
| % △ | + .05% | + .6% | - .4% | +1.6% | -1.8% | |

Table 21.

Lamp Volts
HILS Mercury Lamps
ASA Reference Ballast, 240 line volts

| Lamp No. | GE | ETL | West. | Duro T. | Syl. | Ave. |
|---|---|---|---|---|---|---|
| A-1 | 135.0 | 136.2 | 136 | 135.1 | 135 | 135.5 |
| A-2 | 130.5 | 131.3 | 130 | 129.8 | 130 | 130.3 |
| A-3 | 136.8 | 138.0 | 136 | 136.9 | 137 | 136.9 |
| A-4 | 138.3 | 139.3 | 138 | 137.8 | 138 | 138.3 |
| A-5 | 134.7 | 136.3 | 134 | 132.2 | 135 | 134.4 |
| A-6 | 127.6 | 128.7 | 128 | 126.7 | 127 | 127.6 |
| ave. | 133.8 | 135.0 | 133.7 | 133.1 | 133.7 | 133.8 |
| △ | 0 | + 1.2 | - .1 | - .7 | - .1 | |
| % △ | 0 | + .9% | - .1% | - .5% | - .1% | |

Table 22.

Lamp Volts
HILB/W Mercury Lamps
ASA Reference Ballast, 240 line volts

| Lamp No. | GE | ETL | West. | Duro T. | Syl. | Ave. |
|---|---|---|---|---|---|---|
| B-1 | 134.2 | 135.8 | 134 | 133.9 | 134 | 134.4 |
| B-2 | 133.8 | 135.2 | 134 | 133.7 | 134 | 134.1 |
| B-3 | 127.0 | 128.3 | 126 | 126.2 | 126 | 126.7 |
| B-4 | 129.5 | 131.2 | 130 | 129.7 | 130 | 130.1 |
| B-5 | 131.3 | 132.7 | 131 | 131.2 | 131 | 131.4 |
| B-6 | 128.0 | 129.3 | 128 | 127.7 | 128 | 128.2 |
| ave. | 130.6 | 132.1 | 130.5 | 130.4 | 130.5 | 130.8 |
| △ | - .2 | + 1.3 | - .3 | - .4 | - .3 | |
| % △ | - .2% | + 1.0% | - .2% | - .3% | - .2% | |

Table 23.

Lamp Current (Amperes)
HILS Mercury Lamps
ASA Reference Ballast, 240 line volts

| Lamp No. | GE | ETL | West. | Duro T. | Syl. | Ave. |
|---|---|---|---|---|---|---|
| A-1 | 3.18 | 3.13 | 3.14 | 3.20 | 3.12 | 3.154 |
| A-2 | 3.26 | 3.21 | 3.22 | 3.27 | 3.20 | 3.232 |
| A-3 | 3.14 | 3.12 | 3.11 | 3.17 | 3.09 | 3.126 |
| A-4 | 3.11 | 3.09 | 3.09 | 3.14 | 3.07 | 3.100 |
| A-5 | 3.18 | 3.15 | 3.15 | 3.20 | 3.11 | 3.158 |
| A-6 | 3.31 | 3.27 | 3.29 | 3.33 | 3.23 | 3.286 |
| ave. | 3.20 | 3.16 | 3.17 | 3.22 | 3.14 | 3.176 |
| △ | +.024 | -.016 | -.006 | +.044 | -.036 | |
| % △ | + .8% | - .5% | - .2% | +1.4% | -1.1% | |

Table 24.

Lamp Current (Amperes)
HILB/W Mercury Lamps
ASA Reference Ballast, 240 line volts

| Lamp No. | GE | ETL | West. | Duro T. | Syl. | Ave. |
|---|---|---|---|---|---|---|
| B-1 | 3.19 | 3.13 | 3.17 | 3.22 | 3.12 | 3.166 |
| B-2 | 3.19 | 3.17 | 3.17 | 3.22 | 3.14 | 3.178 |
| B-3 | 3.32 | 3.28 | 3.29 | 3.34 | 3.29 | 3.304 |
| B-4 | 3.27 | 3.23 | 3.22 | 3.28 | 3.22 | 3.244 |
| B-5 | 3.24 | 3.21 | 3.21 | 3.26 | 3.20 | 3.224 |
| B-6 | 3.29 | 3.27 | 3.28 | 3.31 | 3.24 | 3.274 |
| ave. | 3.25 | 3.21 | 3.22 | 3.27 | 3.20 | 3.232 |
| △ | +.018 | -.022 | -.012 | +.038 | -.032 | |
| % △ | + .6% | - .7% | - .4% | +1.2% | -1.0% | |

Table 25.

Lamp Watts
HILS Mercury Lamps
ASA Reference Ballast, 240 line volts

| Lamp No. | GE | ETL | West. | Duro T. | Syl. | Ave. |
|---|---|---|---|---|---|---|
| A-1 | 402 | 406 | 391 | 402 | 393 | 398.8 |
| A-2 | 399 | 400 | 389 | 399 | 387 | 394.8 |
| A-3 | 402 | 408 | 395 | 403 | 394 | 400.4 |
| A-4 | 403 | 410 | 393 | 403 | 394 | 400.6 |
| A-5 | 400 | 406 | 391 | 399 | 390 | 397.2 |
| A-6 | 395 | 399 | 388 | 393 | 384 | 391.8 |
| ave. | 400 | 405 | 391 | 400 | 390 | 397.3 |
| △ | +2.7 | +7.7 | -6.3 | +2.7 | -7.3 | |
| % △ | + .7% | +1.9% | -1.6% | + .7% | -1.8% | |

Table 26.

Lamps Watts
HILB/W Mercury Lamps
ASA Reference Ballast, 240 line volts

| Lamp No. | GE | ETL | West. | Duro T. | Syl. | Ave. |
|---|---|---|---|---|---|---|
| B-1 | 401 | 405 | 391 | 401 | 391 | 397.8 |
| B-2 | 399 | 405 | 390 | 399 | 390 | 396.6 |
| B-3 | 394 | 399 | 388 | 392 | 389 | 392.4 |
| B-4 | 396 | 401 | 389 | 396 | 389 | 394.2 |
| B-5 | 398 | 404 | 391 | 399 | 391 | 396.6 |
| B-6 | 394 | 401 | 389 | 395 | 386 | 393.0 |
| ave. | 397 | 402 | 390 | 397 | 389 | 395.1 |
| △ | +1.9 | +6.9 | -5.1 | +1.9 | -6.1 | |
| % △ | + .5% | +1.7% | -1.3% | + .5% | -1.5% | |

Table 27.

Lumens per Watt
HILS Mercury Lamps
ASA Reference Ballast, 240 line volts

| Lamp No. | GE | ETL | West. | Duro T. | Syl. | Ave. |
|---|---|---|---|---|---|---|
| A-1 | 47.8 | 47.8 | 49.1 | 48.4 | 49.4 | 48.50 |
| A-2 | 47.3 | 47.5 | 48.6 | 47.9 | 49.0 | 48.06 |
| A-3 | 48.0 | 47.3 | 48.0 | 48.1 | 48.1 | 47.90 |
| A-4 | 47.5 | 47.3 | 48.8 | 48.3 | 48.8 | 48.14 |
| A-5 | 47.5 | 47.0 | 48.3 | 48.1 | 48.1 | 47.80 |
| A-6 | 49.6 | 49.6 | 50.5 | 49.9 | 51.1 | 50.14 |
| ave. | 47.95 | 47.75 | 48.9 | 48.4 | 49.1 | 48.42 |
| △ | - .47 | - .67 | + .48 | - .02 | + .68 | |
| % △ | -1.0% | -1.4% | +1.0% | - .04% | +1.4% | |

Table 28.

Lumens per Watt
HILB/W Mercury Lamps
ASA Reference Ballast 240 line volts

| Lamp No. | GE | ETL | West. | Duro T. | Syl. | Ave. |
|---|---|---|---|---|---|---|
| B-1 | 49.8 | 50.1 | 51.1 | 51.0 | 50.3 | 50.46 |
| B-2 | 50.5 | 50.4 | 51.5 | 51.6 | 50.8 | 50.96 |
| B-3 | 50.0 | 49.1 | 50.3 | 50.7 | 49.3 | 49.88 |
| B-4 | 49.5 | 48.4 | 49.0 | 49.5 | 48.9 | 49.06 |
| B-5 | 52.3 | 52.2 | 53.7 | 53.5 | 53.1 | 52.96 |
| B-6 | 51.1 | 50.4 | 51.7 | 51.4 | 51.3 | 51.18 |
| ave. | 50.5 | 50.1 | 51.2 | 51.3 | 50.6 | 50.75 |
| △ | - .25 | - .65 | + .45 | + .55 | - .15 | |
| % △ | - .5% | -1.3% | + .9% | +1.1% | - .3% | |

Table 29.

Lumens
Regular Laboratory Ballast, 400 Watts

| HILS Mercury Lamps | | | | HILB/W Mercury Lamps | | | |
|---|---|---|---|---|---|---|---|
| Lamp No. | NBS | GE | | Lamp No. | NBS | GE | |
| A-1 | 19100 | 19380 | | B-1 | 19700 | 20257 | |
| A-2 | 18800 | 19103 | | B-2 | 20000 | 20497 | |
| A-3 | 18800 | 19505 | | B-3 | 19800 | 20367 | |
| A-4 | 18800 | 19210 | | B-4 | 19400 | 20267 | |
| A-5 | 18900 | 19320 | | B-5 | 20800 | 21135 | |
| A-6 | 19800 | 19960 | | B-6 | 20300 | 20923 | |
| ave. | 19033 | 19413 | 19223 | | 20000 | 20574 | 20287 |

Table 30.

Lamp Volts
Regular Laboratory Ballast, 400 Watts

| HILS Mercury Lamps | | | | HILB/W Mercury Lamps | | | |
|---|---|---|---|---|---|---|---|
| Lamp No. | NBS | GE | | Lamp No. | NBS | GE | |
| A-1 | 134 | 134.7 | | B-1 | 134 | 134.2 | |
| A-2 | 128 | 130.6 | | B-2 | 133 | 134.0 | |
| A-3 | 136 | 136.5 | | B-3 | 126 | 127.3 | |
| A-4 | 136 | 138.5 | | B-4 | 129 | 130.0 | |
| A-5 | 134 | 134.6 | | B-5 | 130 | 131.4 | |
| A-6 | 127 | 128.0 | | B-6 | 127 | 128.0 | |
| ave. | 132.5 | 133.8 | 133.2 | | 129.8 | 130.8 | 130.3 |

Table 31.

Lamp Current (Amperes)
Regular Laboratory Ballast, 400 Watts

| HILS Mercury Lamps | | | | HILB/W Mercury Lamps | | | |
|---|---|---|---|---|---|---|---|
| Lamp No. | NBS | GE | | Lamp No. | NBS | GE | |
| A-1 | 3.18 | 3.18 | | B-1 | 3.20 | 3.19 | |
| A-2 | 3.32 | 3.29 | | B-2 | 3.24 | 3.21 | |
| A-3 | 3.15 | 3.14 | | B-3 | 3.40 | 3.37 | |
| A-4 | 3.13 | 3.09 | | B-4 | 3.32 | 3.30 | |
| A-5 | 3.22 | 3.19 | | B-5 | 3.28 | 3.26 | |
| A-6 | 3.38 | 3.35 | | B-6 | 3.36 | 3.35 | |
| ave. | 3.23 | 3.21 | 3.22 | | 3.30 | 3.28 | 3.29 |

Table 32.

GE Measurements Using Regular Laboratory Ballast at 208 Line Volts

| Lamp No. | Lamp Volts | Lamp Amperes | Lamp Watts | Lumens |
|---|---|---|---|---|
| A-1 | 135.1 | 3.27 | 412 | 20210 |
| A-2 | 131.0 | 3.37 | 413 | 19957 |
| A-3 | 136.9 | 3.22 | 410 | 20175 |
| A-4 | 139.0 | 3.16 | 408 | 19760 |
| A-5 | 135.0 | 3.27 | 410 | 20030 |
| A-6 | 128.5 | 3.45 | 415 | 20950 |
| ave. | 134.3 | 3.29 | 411 | 20180 |
| | | | | |
| B-1 | 134.8 | 3.28 | 411 | 20953 |
| B-2 | 134.0 | 3.29 | 410 | 21125 |
| B-3 | 127.8 | 3.47 | 413 | 21193 |
| B-4 | 130.3 | 3.38 | 412 | 20987 |
| B-5 | 132.0 | 3.35 | 412 | 21980 |
| B-6 | 128.7 | 3.43 | 414 | 21777 |
| ave. | 131.3 | 3.37 | 412 | 21336 |

## III Analysis of the Results

An analysis of the results of the measurements has been made following a modification of the method described by W. J. Youden (1), (2), (3). This modified method is described in National Bureau of Standards Reports No. 6605 "Interlaboratory Intercomparisons of 32-Watt T10 Cool-White Circline Lamps" and No. 6698 Interlaboratory Intercomparisons of 40-Watt T12 Cool White Fluorescent Lamps".

(1) Graphical Diagnosis of Interlaboratory Test Results, Industrial Quality Control. Vol. XV No. 11, May 1959.

(2) Product Specifications and Test Procedures, Industrial and Engineering Chemistry. Vol. 50, page 91A, October 1958.

(3) Circumstances Alter the Cases, Industrial and Engineering Chemistry. Vol. 50, page 77A, December 1958.

Lumens
Differences from the Averages
HILS Mercury Vapor Lamps
GE Ballast #89G164 at 118 Line Volts

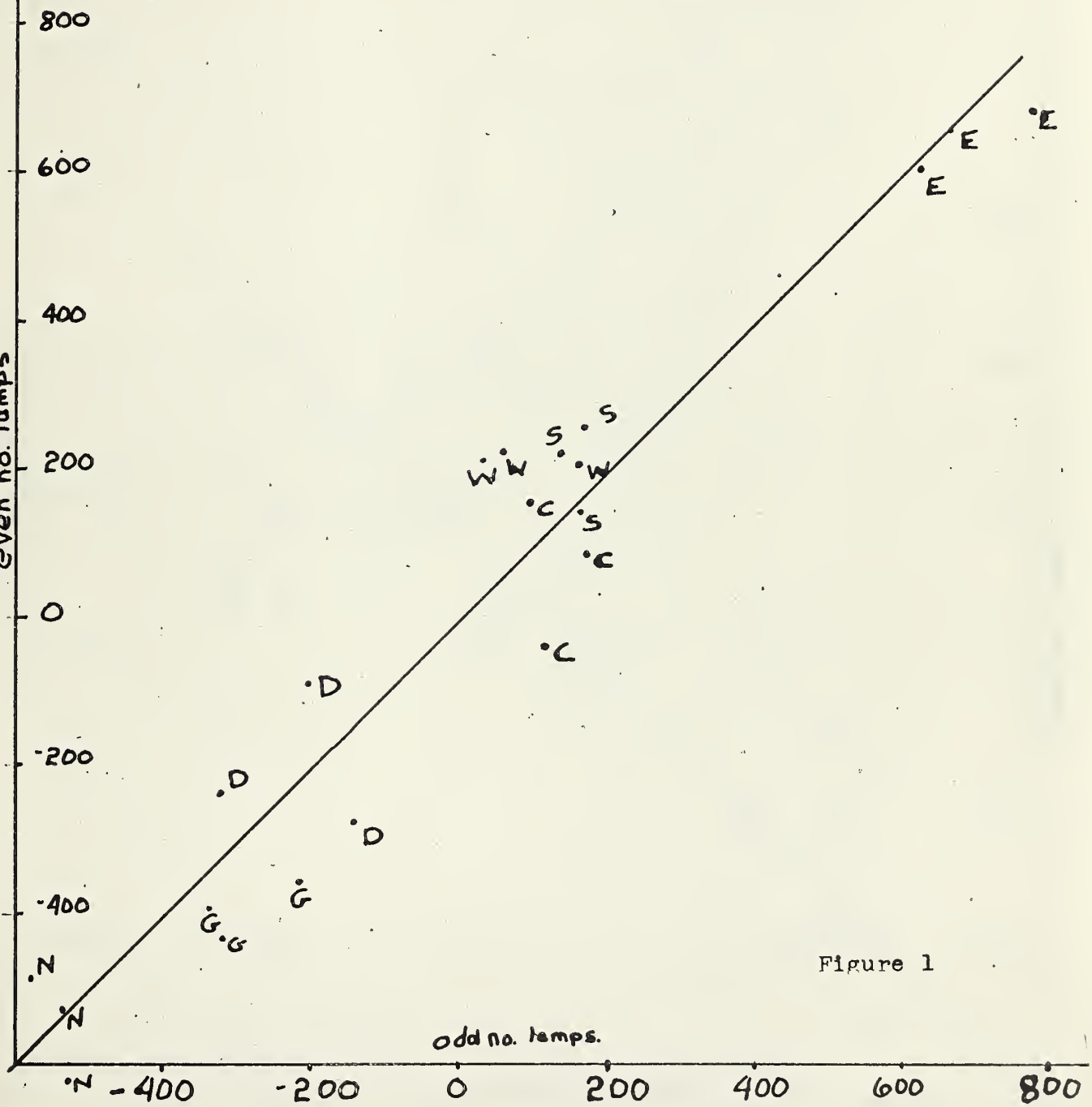


Figure 1

Lumens
Differences from the Averages
HILB/W Mercury Vapor Lamps
GE Ballast #89G164 at 118 Line Volts

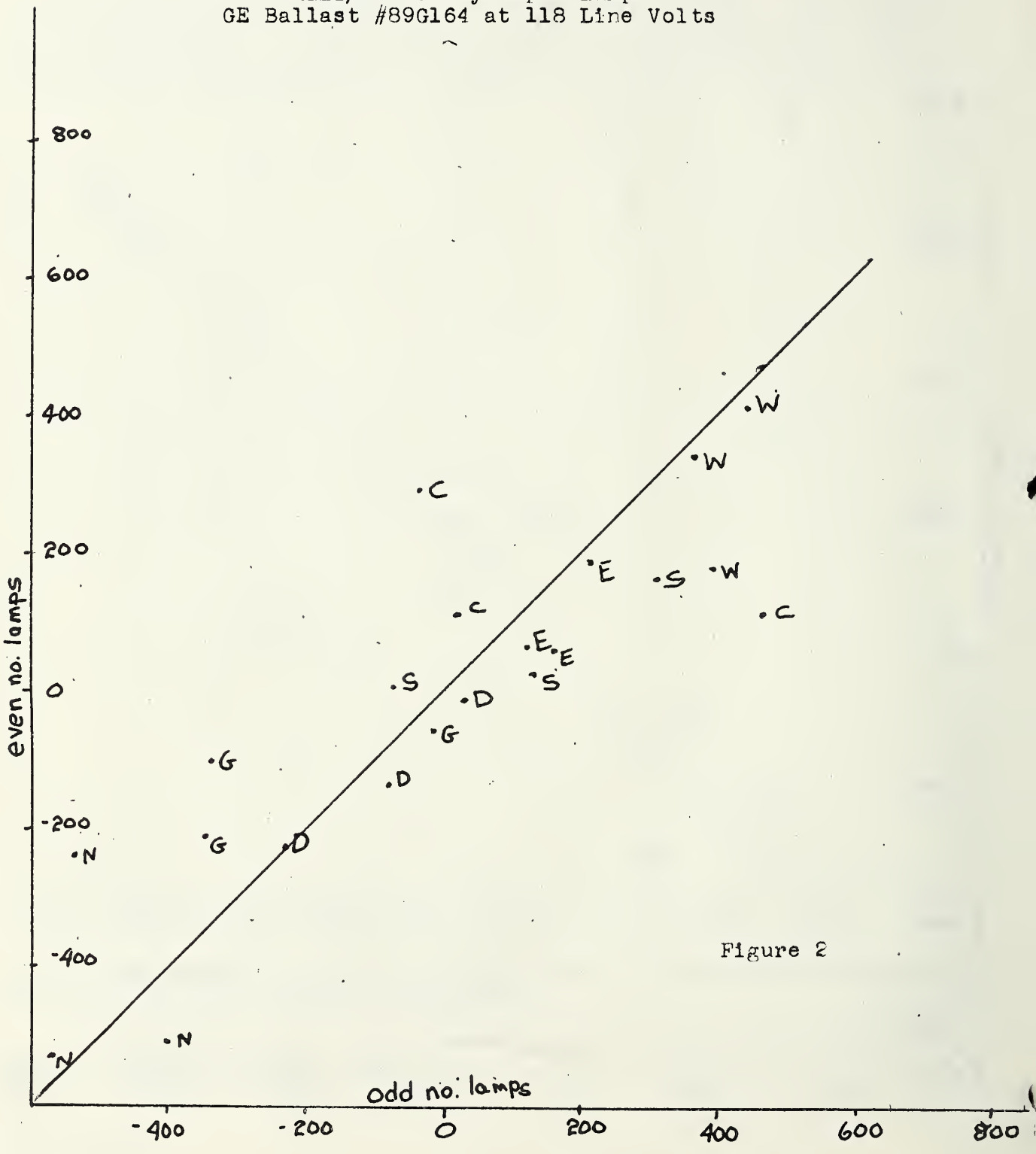


Figure 2

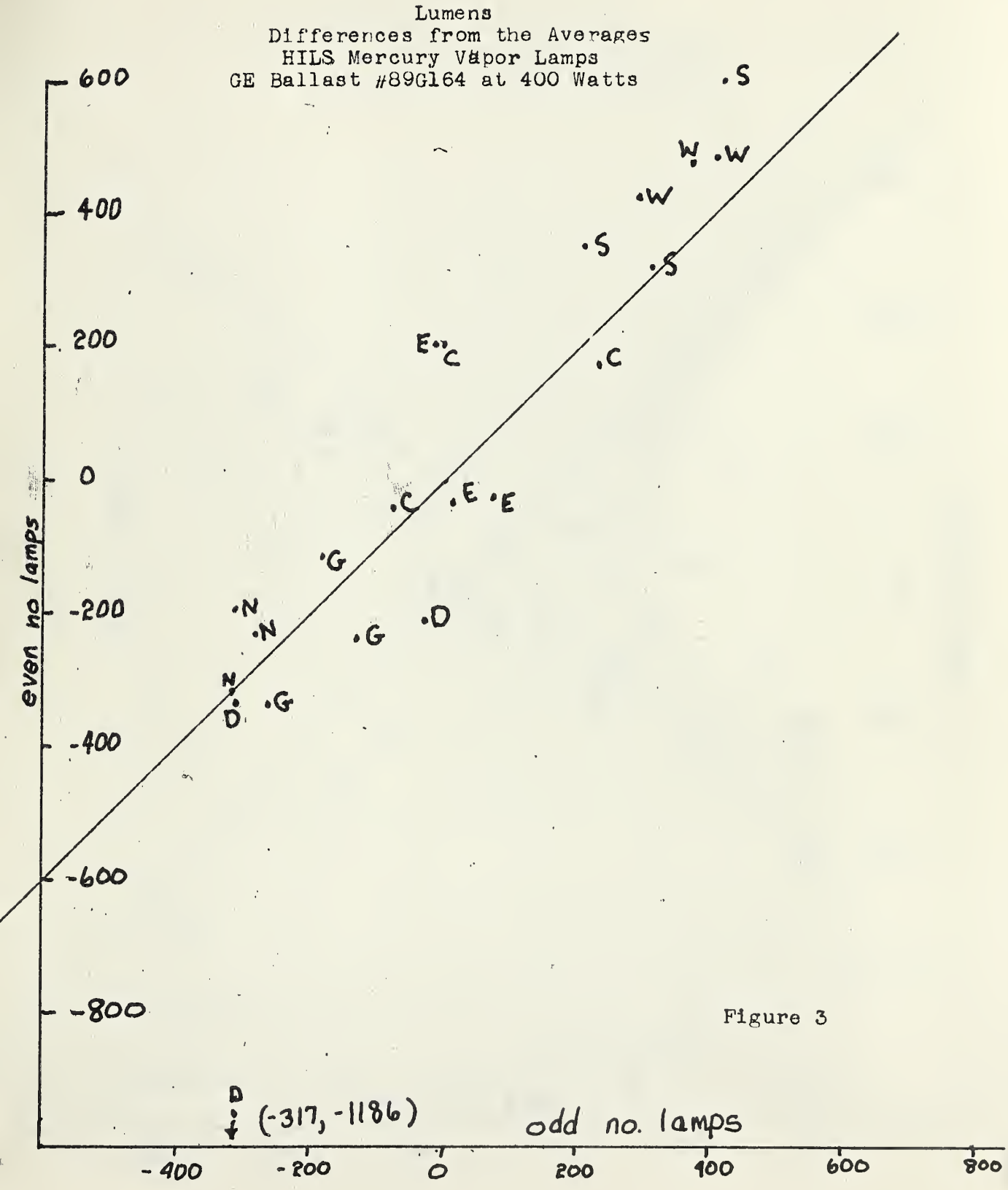
Lumens
Differences from the Averages
HILS Mercury Vapor Lamps
GE Ballast #89G164 at 400 Watts
600
400
200
0
-200
-400
-600
-800
even no lamps
odd no. lamps
(-317, -1186)
-400
-200
0
200
400
600
800

Figure 3

Lumens
Differences from the Averages
HILB/W Mercury Vapor Lamps
GE Ballast #89G164 at 400 Watts

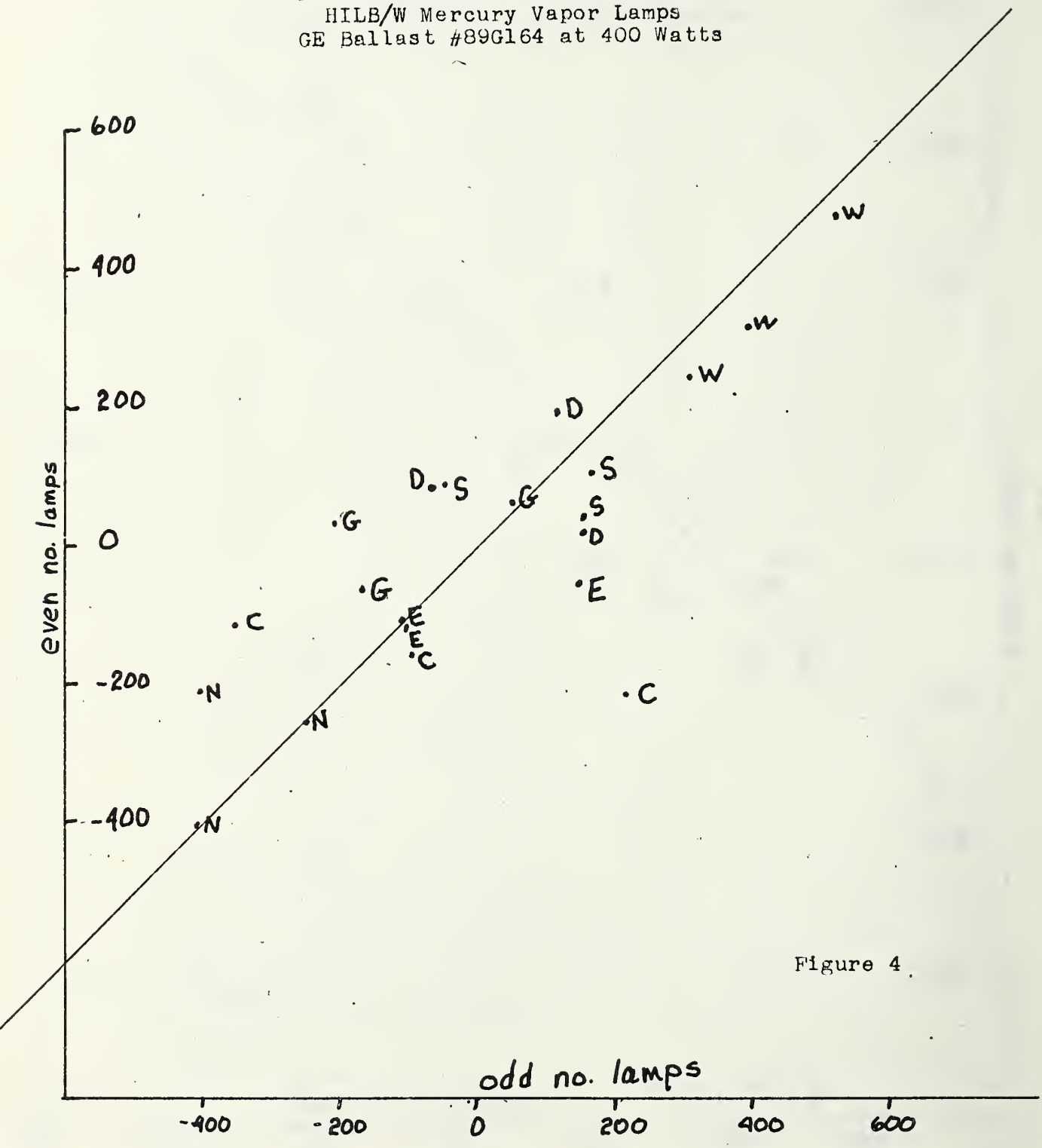


Figure 4

Lamp Volts
Differences from the Averages
HILS Mercury Vapor Lamp
GE Ballast #89G164 at 118 Line Volts

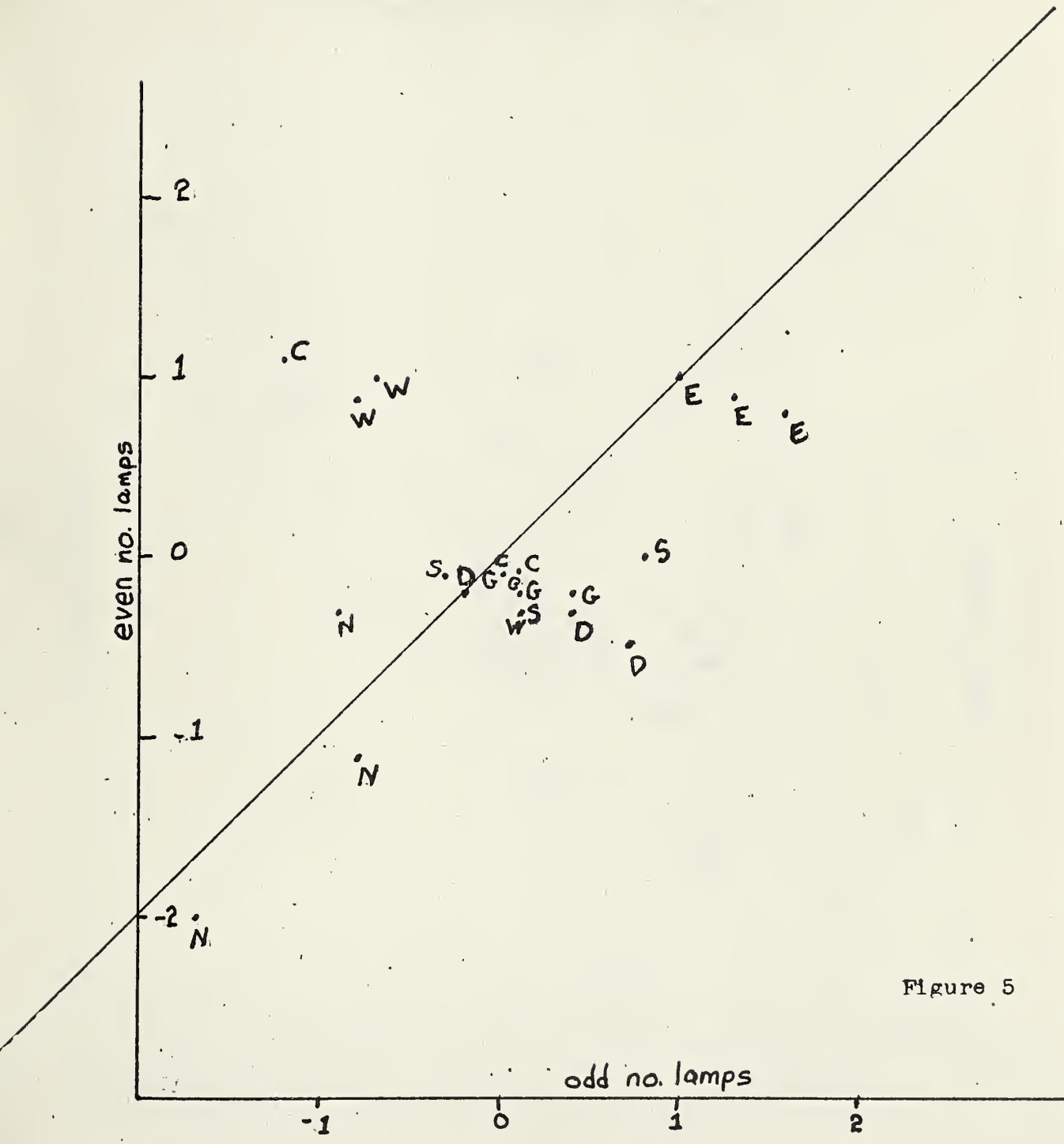


Figure 5

Lamp Volts
Differences from the Averages
HIL B/W Mercury Vapor Lamps
GE Ballast #89G164 at 118 Line Volts

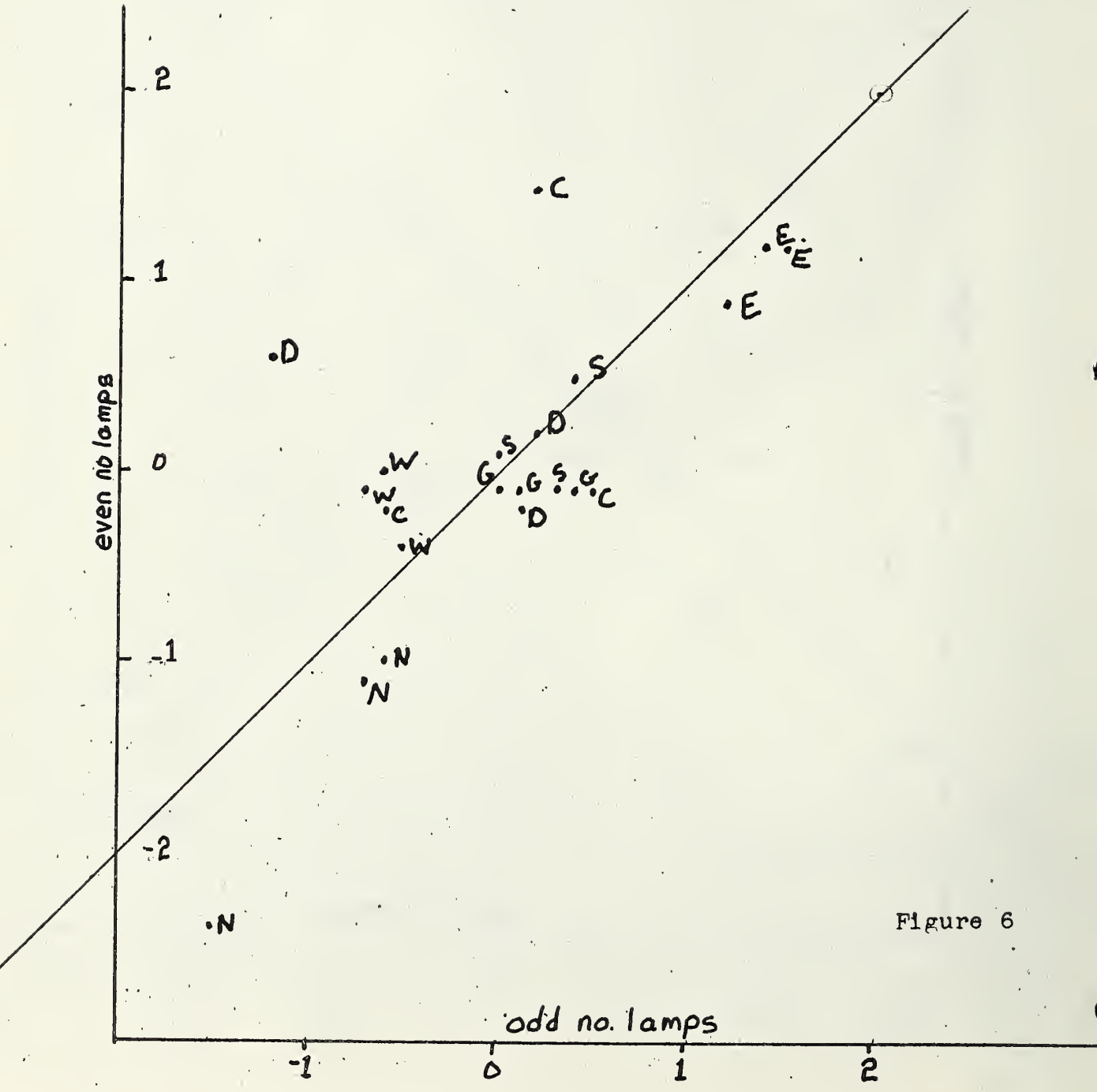


Figure 6

Lamp Volts
Differences from the Averages
HILS Mercury Vapor Lamps
GE Ballast #89G164 at 400 Watts

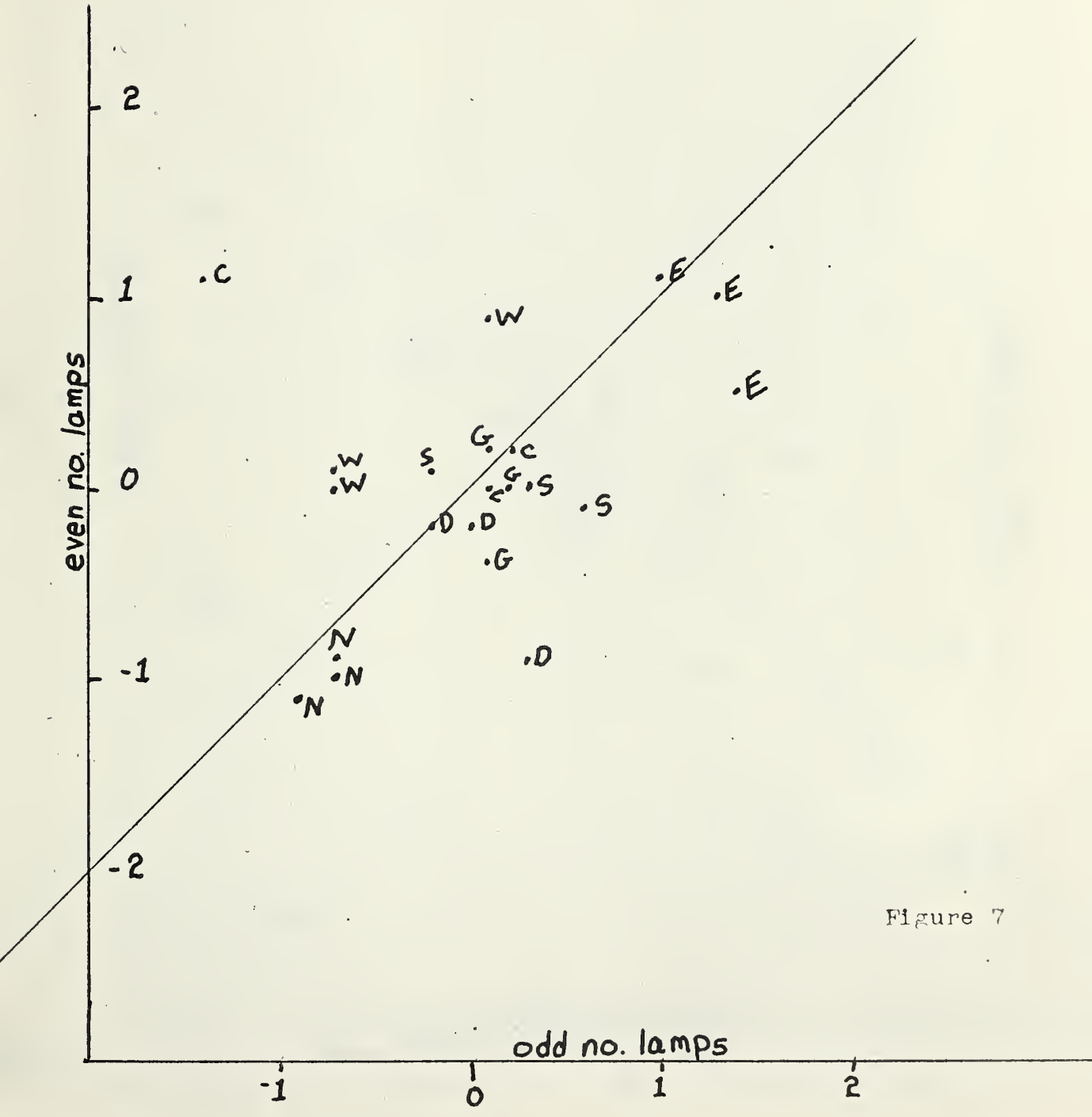


Figure 7

Lamp Volts
Differences from the Averages
HILB/W Mercury Vapor Lamps
GE Ballast #89G164 at 400 Watts

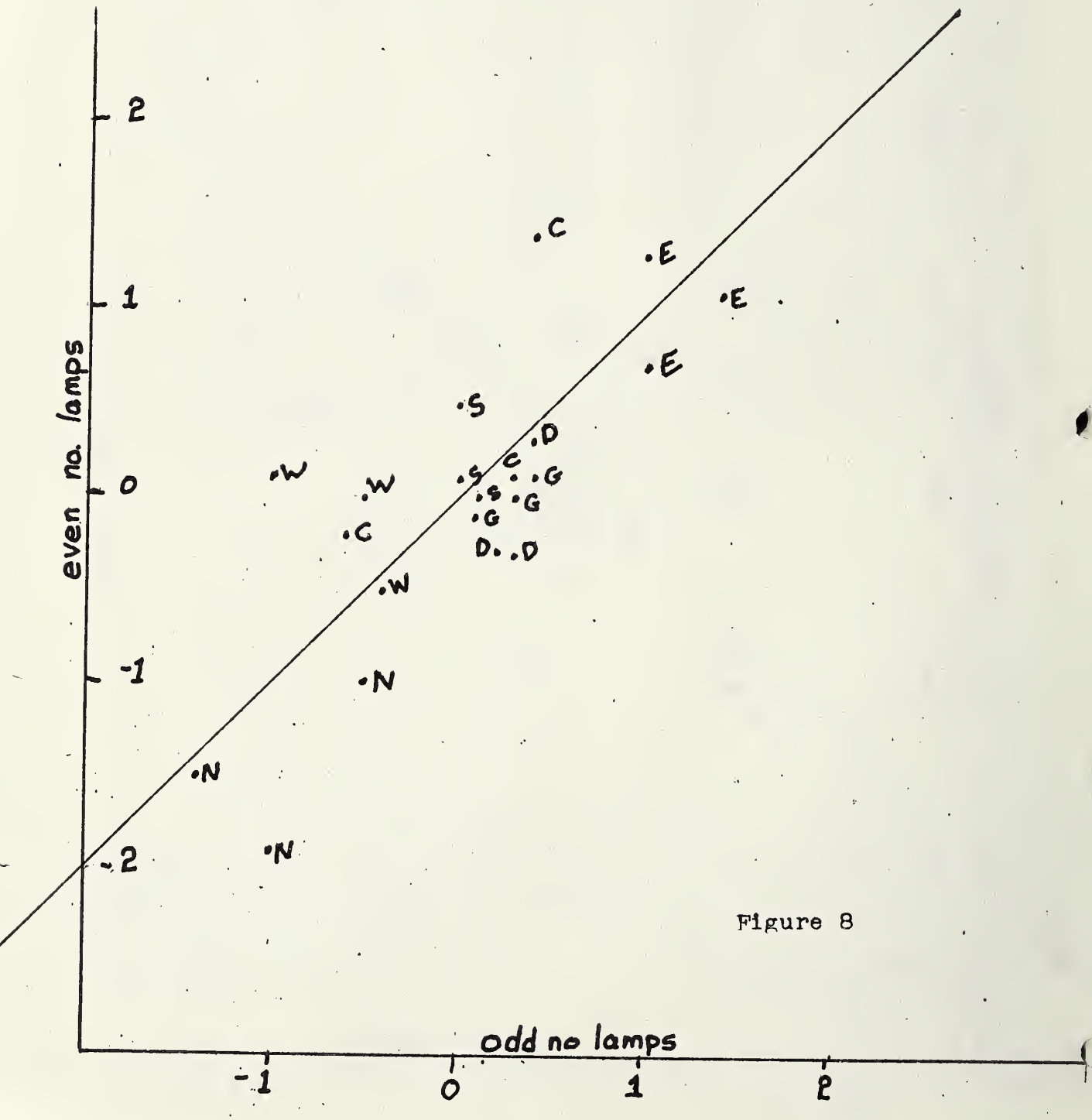


Figure 8

Amperes

Differences from the Averages
HILS Mercury Vapor Lamps
GE Ballast #89G164 at 118 Line Volts

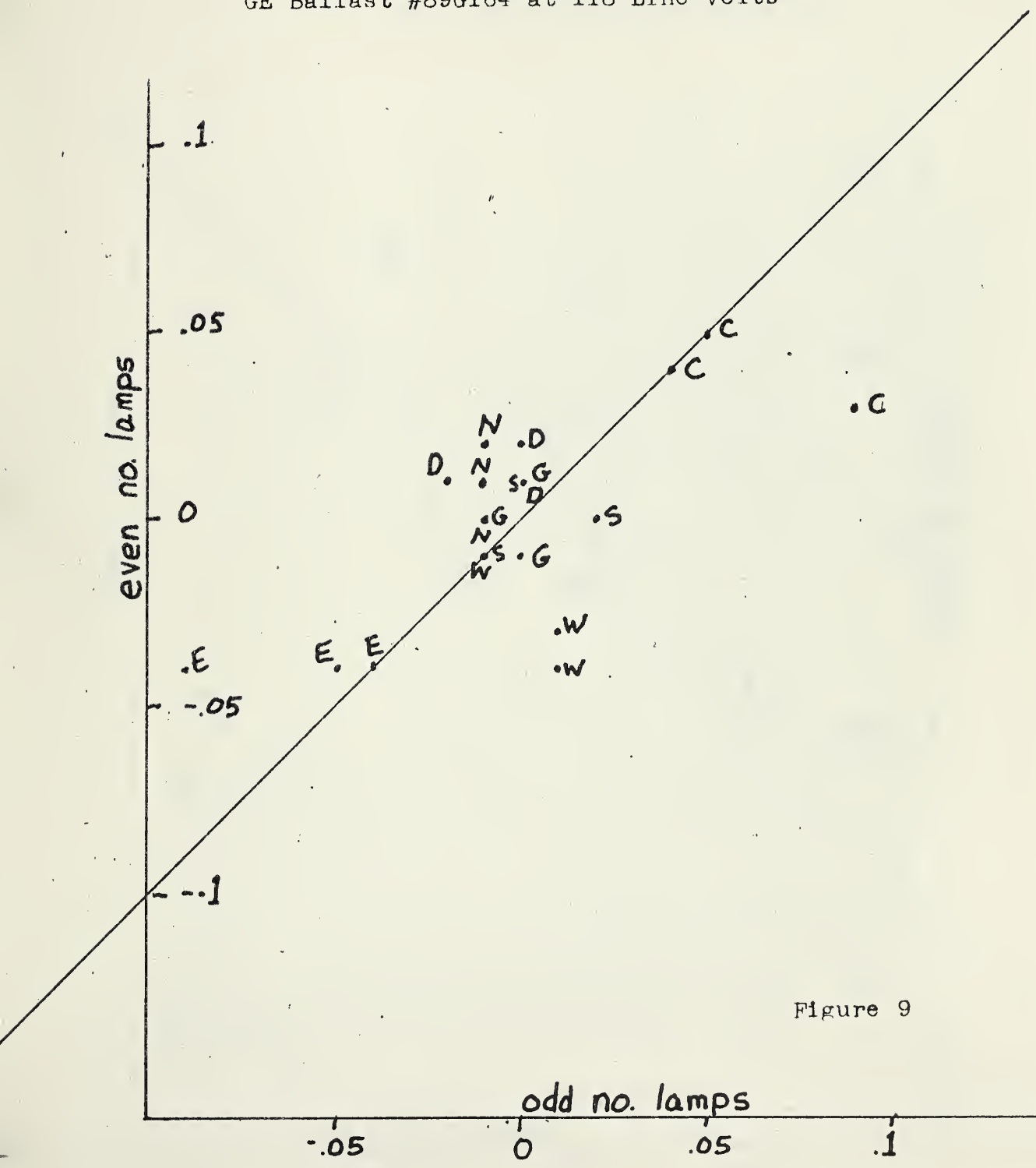


Figure 9

Amperes

Differences from the Averages
HILB/W Mercury Vapor Lamps
GE Ballast #89G164 at 118 Line Volts

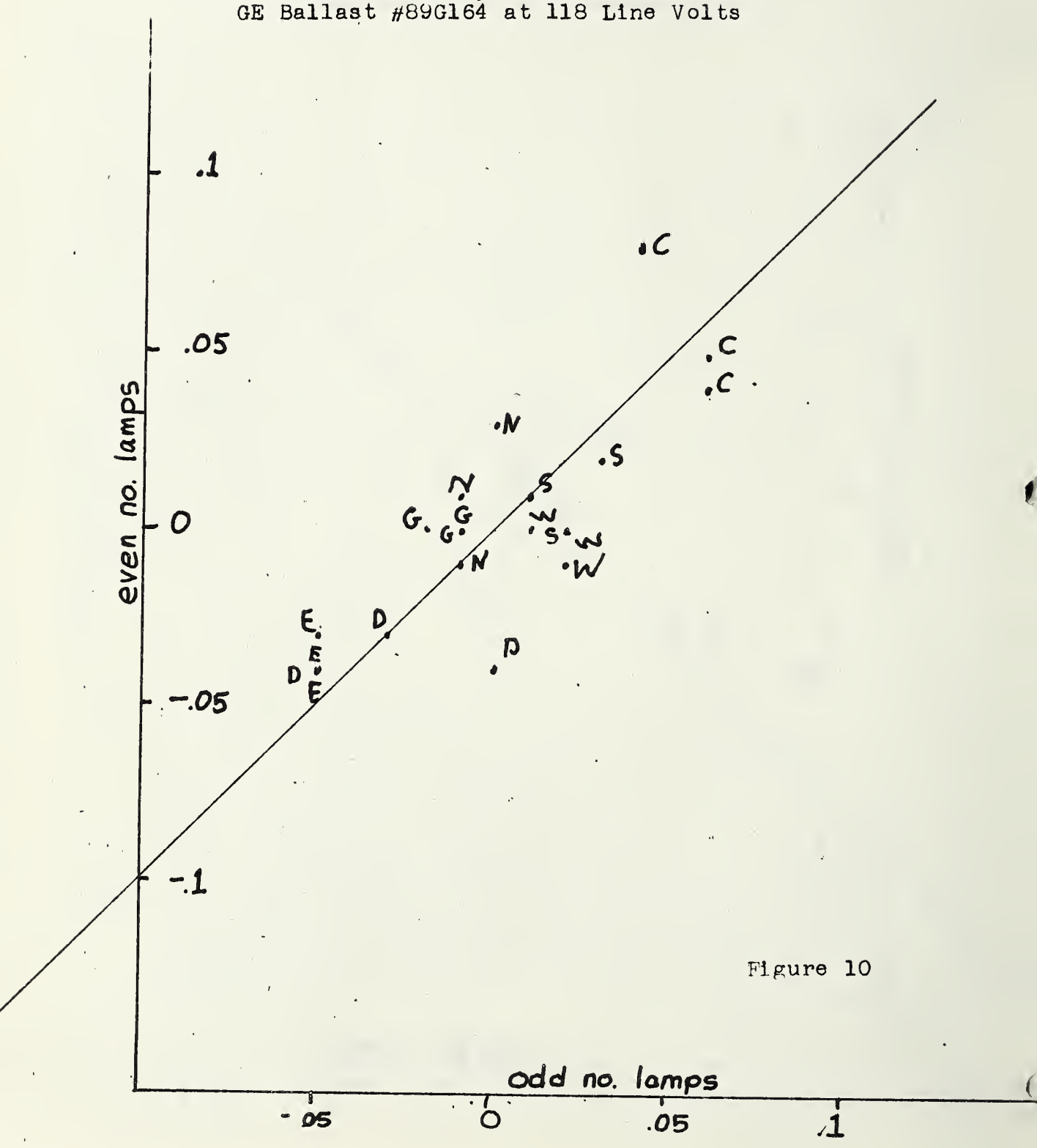


Figure 10

Amperes
Differences from the Averages
HILS Mercury Vapor Lamps
GE Ballast #89G164 at 400 Watts

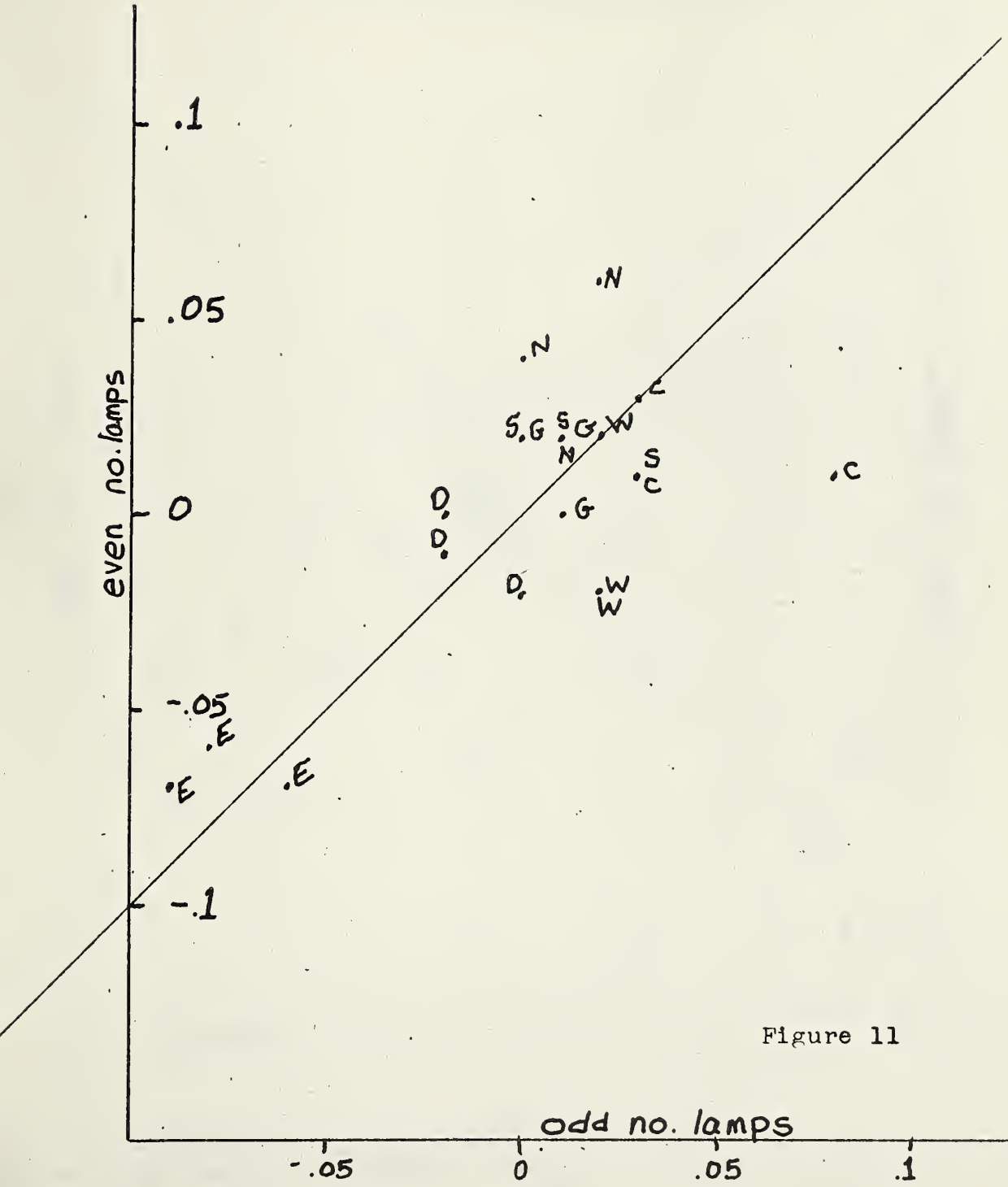


Figure 11

Amperes

Differences from the Averages
HILB/W Mercury Vapor Lamps
GE Ballast #89G164 at 400 Watts

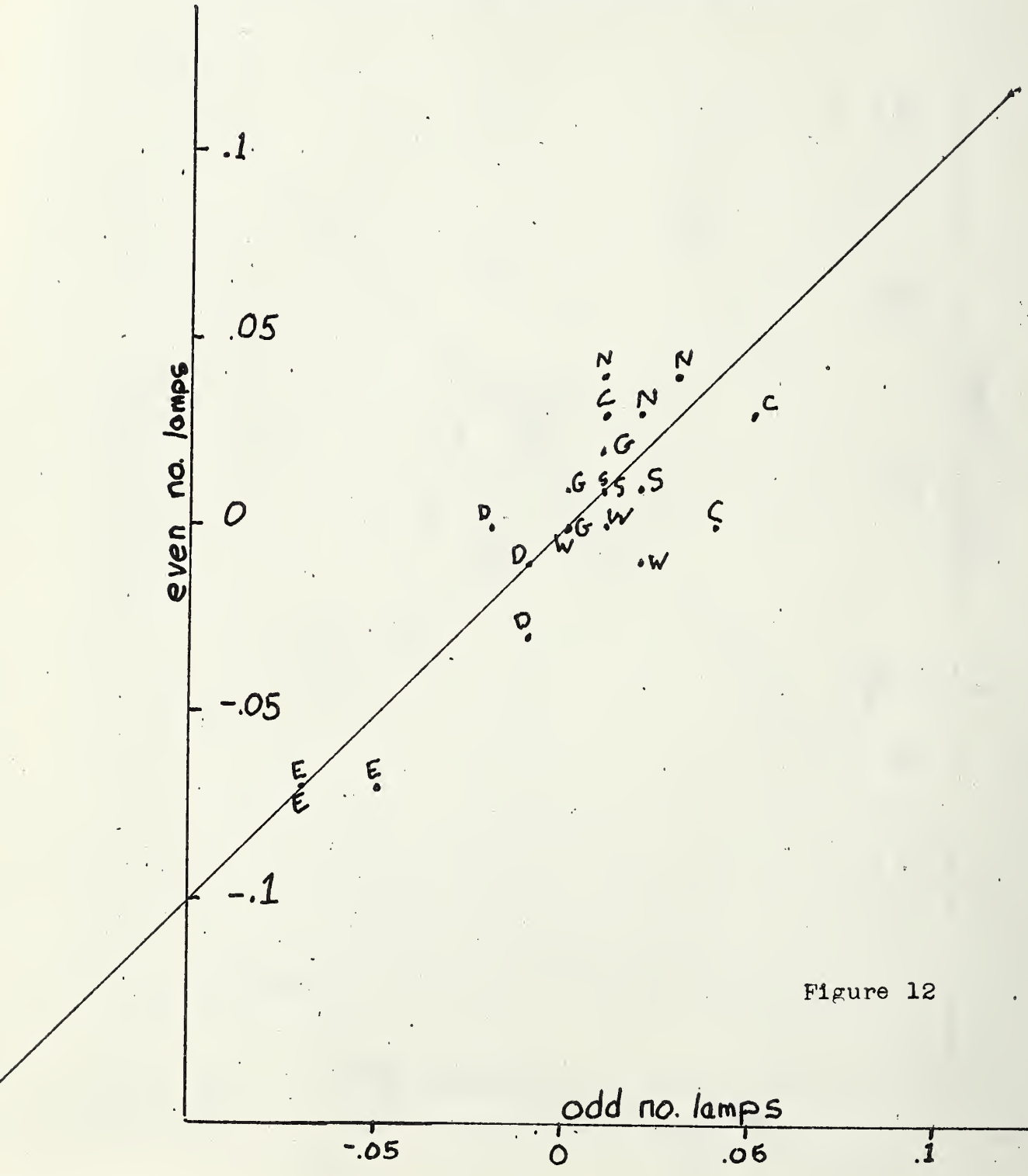


Figure 12

Watts
Differences from the Averages
HILS Mercury Vapor Lamps
GE Ballast #89G164 at 118 Line Volts

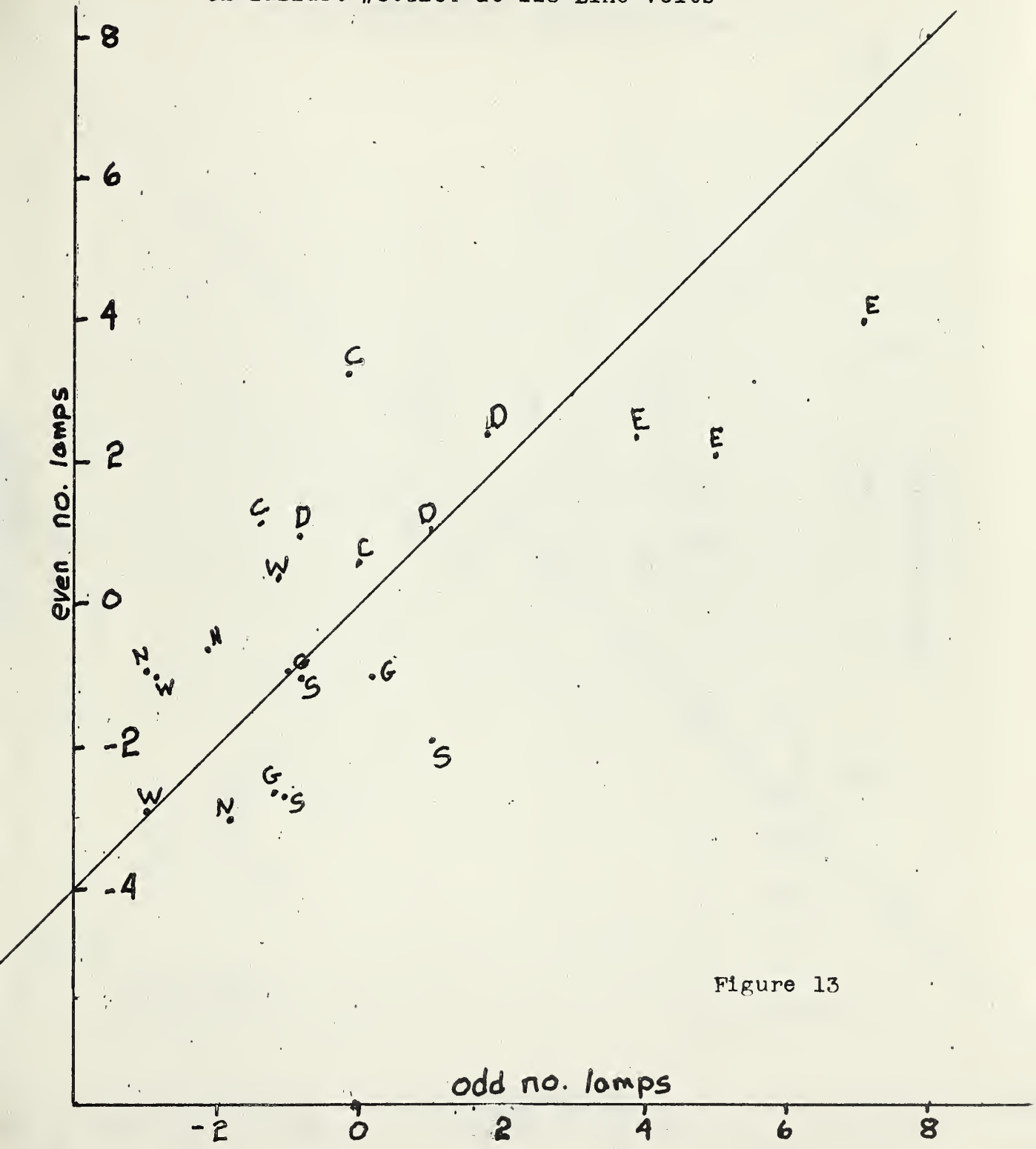


Figure 13

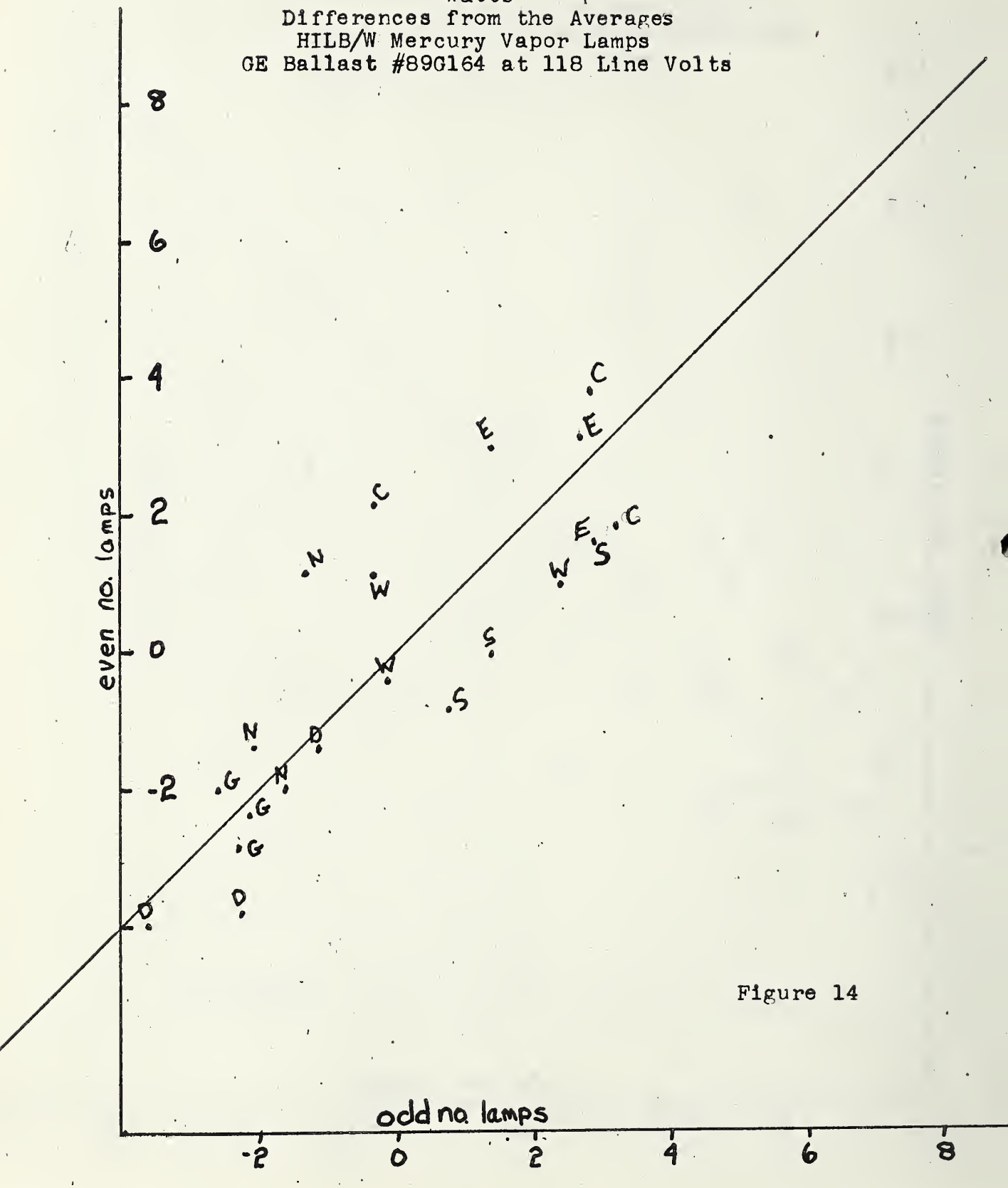
Watts
Differences from the Averages
HILB/W Mercury Vapor Lamps
GE Ballast #89G164 at 118 Line Volts
even no. lamps
odd no lamps
8
6
4
2
0
-2
-2
0
2
4
6
8

Figure 14

Lumens per Watt
Differences from the Averages
HILS Mercury Vapor Lamps
GE Ballast #89G164 at 118 Line Volts

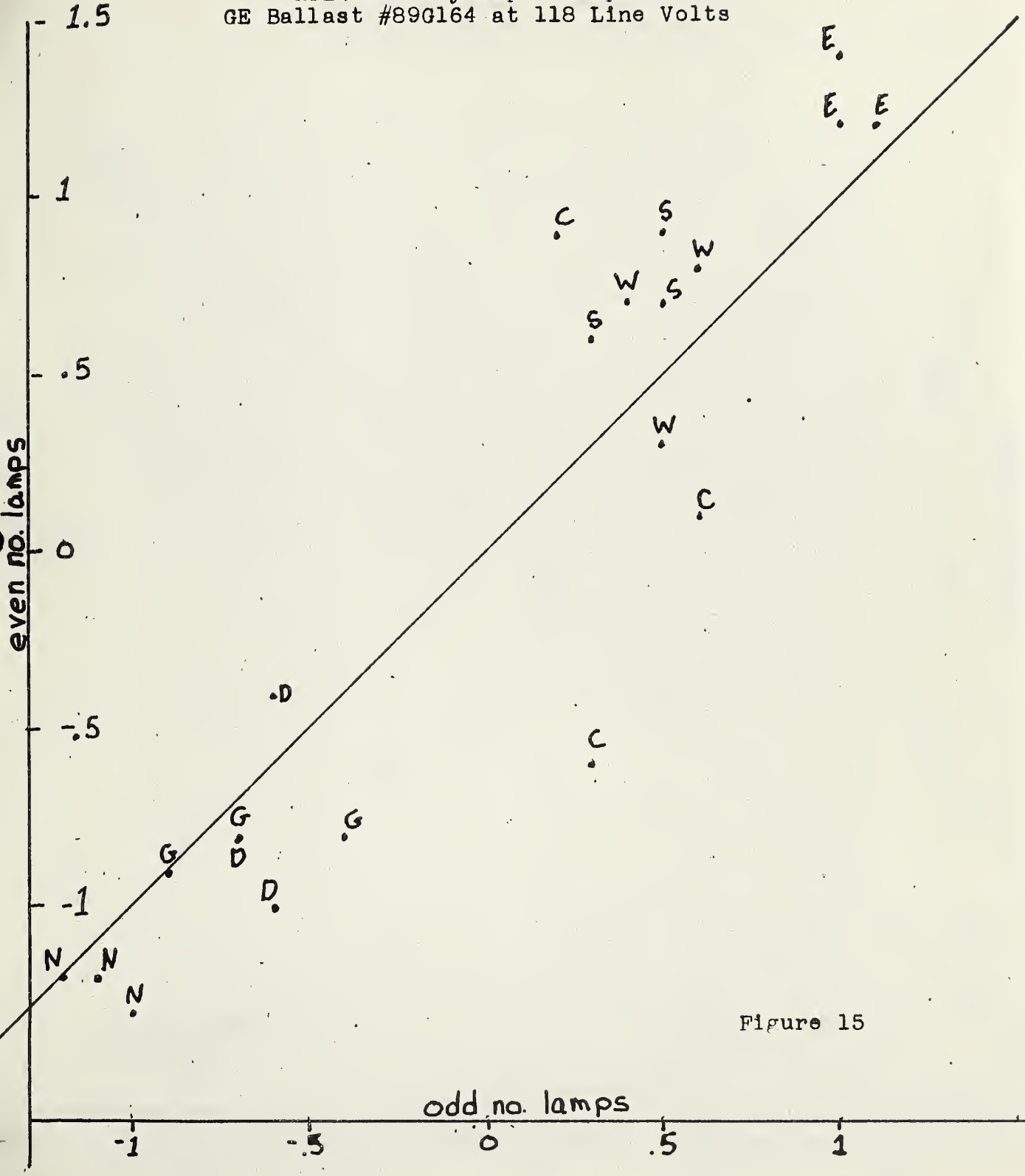


Figure 15

Lumens per Watt
Differences from the Averages
HILB/W Mercury Vapor Lamps
GE Ballast #89G164 at 118 Line Volts

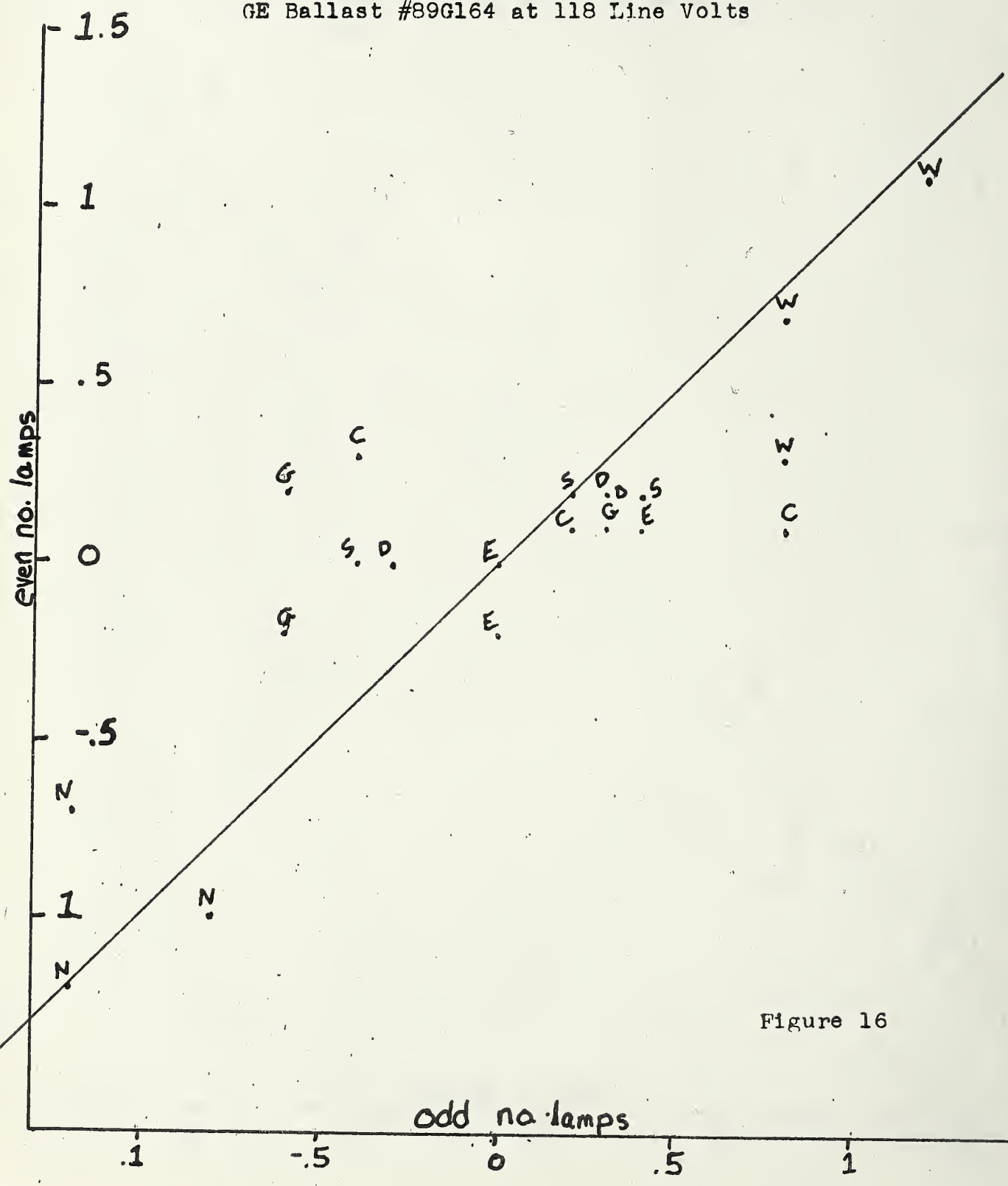


Figure 16

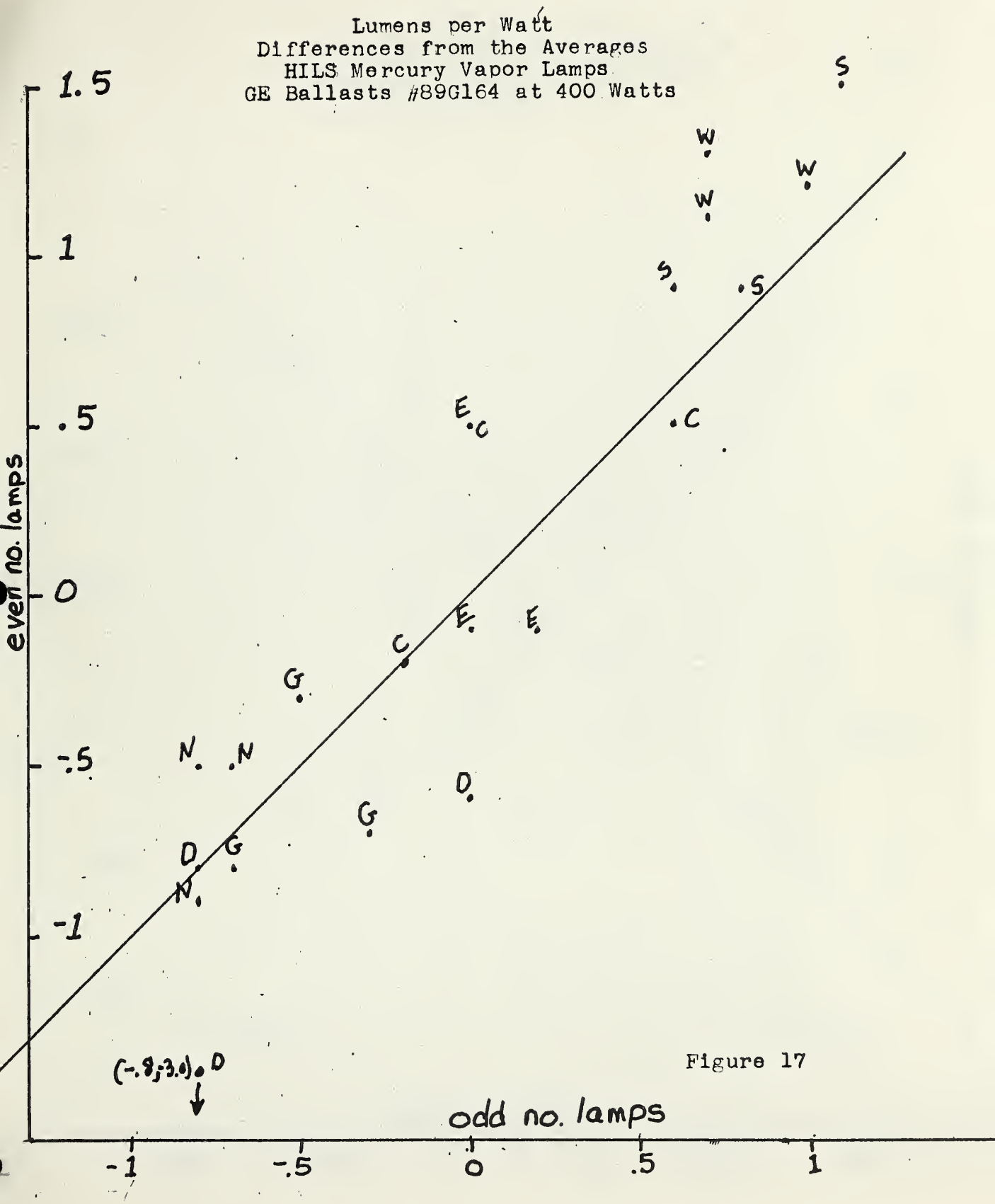
Lumens per Watt
Differences from the Averages
HILS Mercury Vapor Lamps
GE Ballasts #89G164 at 400 Watts
1.5
1
.5
0
-.5
-1
even no. lamps
odd no. lamps
-1
-.5
0
.5
1
(-.8,-3.0)
W
S
E
C
G
N
D

Figure 17

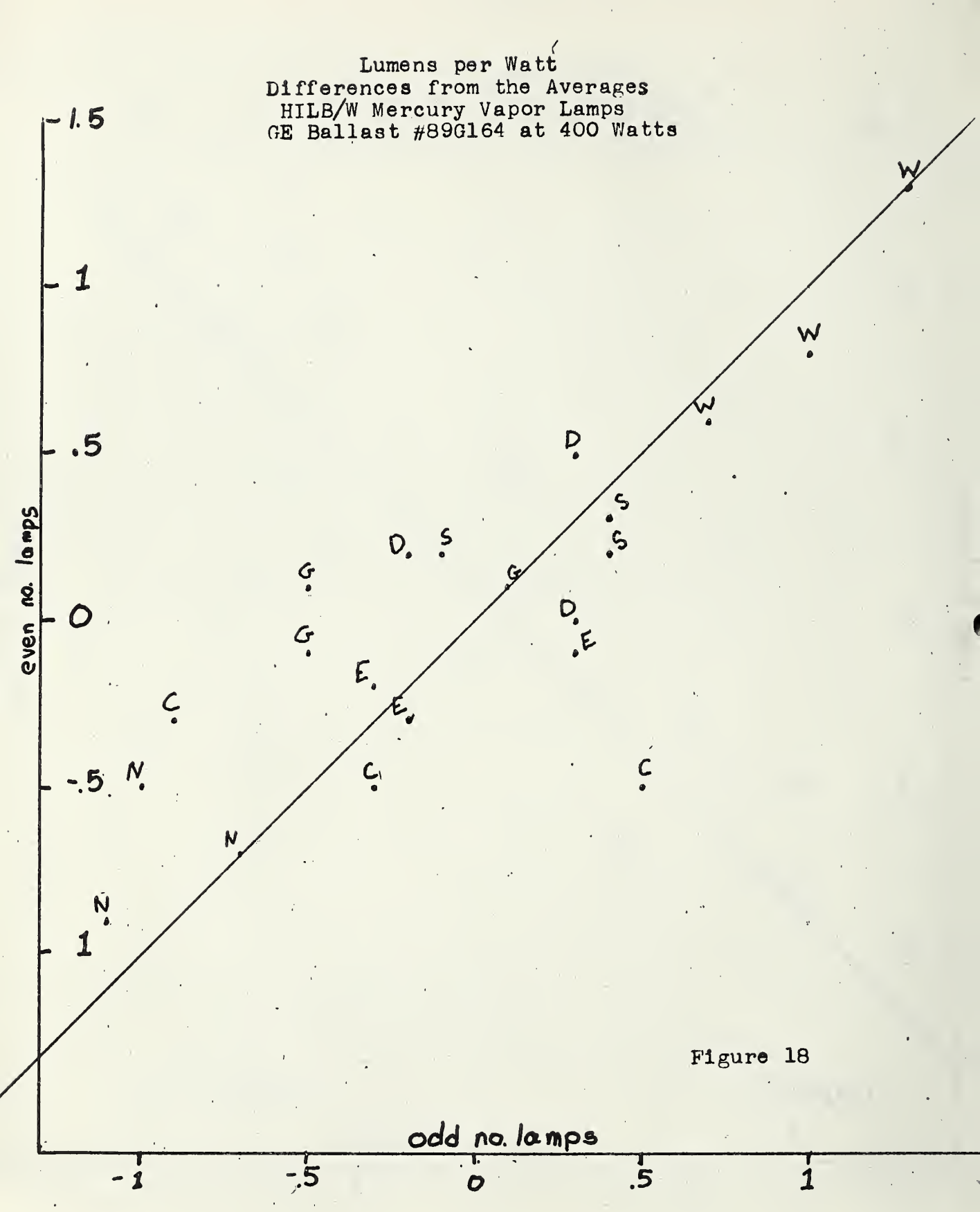
Lumens per Watt
Differences from the Averages
HILB/W Mercury Vapor Lamps
GE Ballast #89G164 at 400 Watts
1.5
1
.5
0
-.5
-1
even no. lamps
odd no. lamps
-1
-.5
0
.5
1
W
W
W
D
D
D
S
S
S
G
G
G
E
E
E
C
C
C
N
N
N

Figure 18

Lumens
Differences from the Averages
HIlS Mercury Vapor Lamps
Reference Ballast

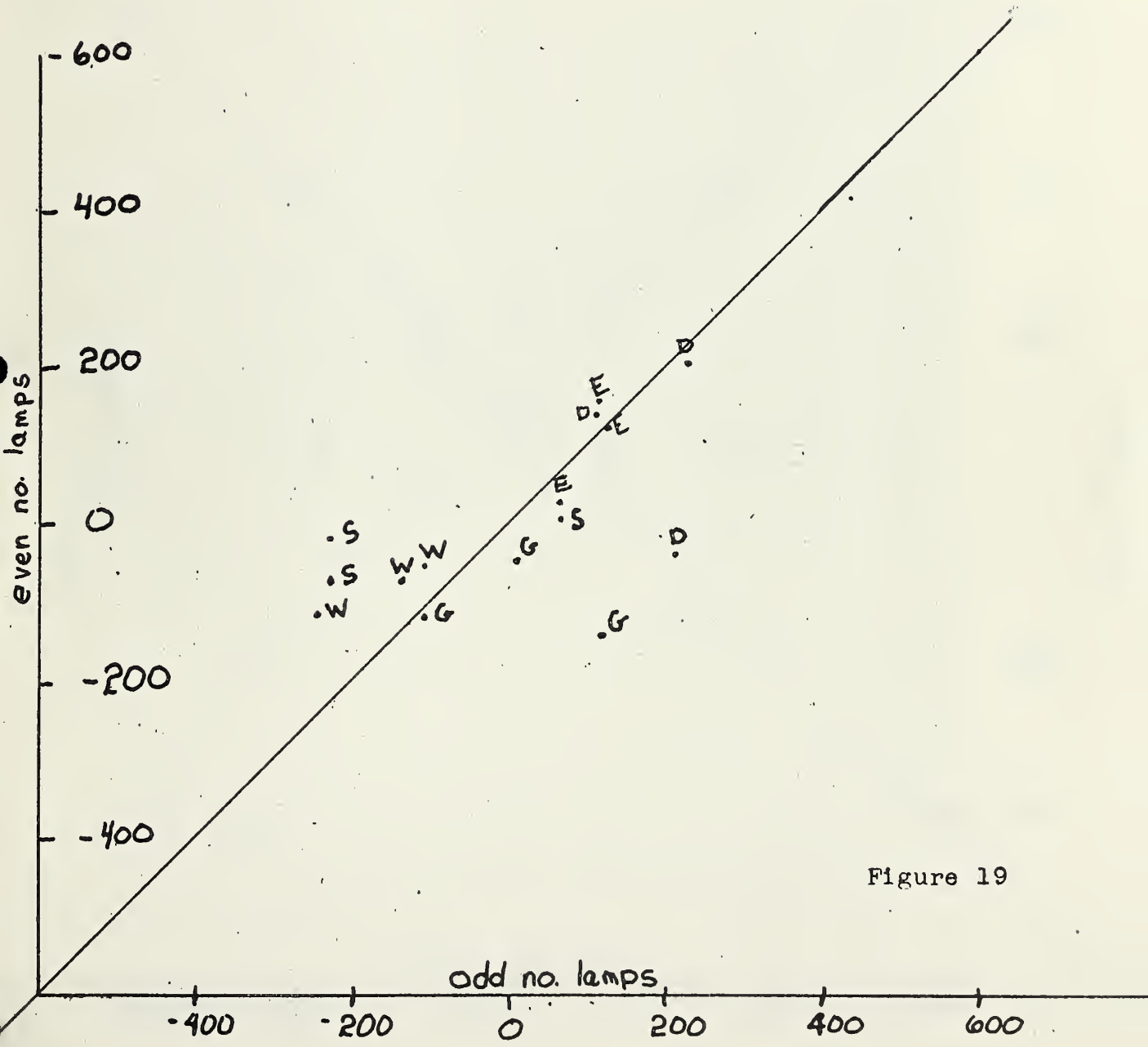


Figure 19

Lumens
Differences from the Averages
HILB/W Mercury Vapor Lamps
Reference Ballast

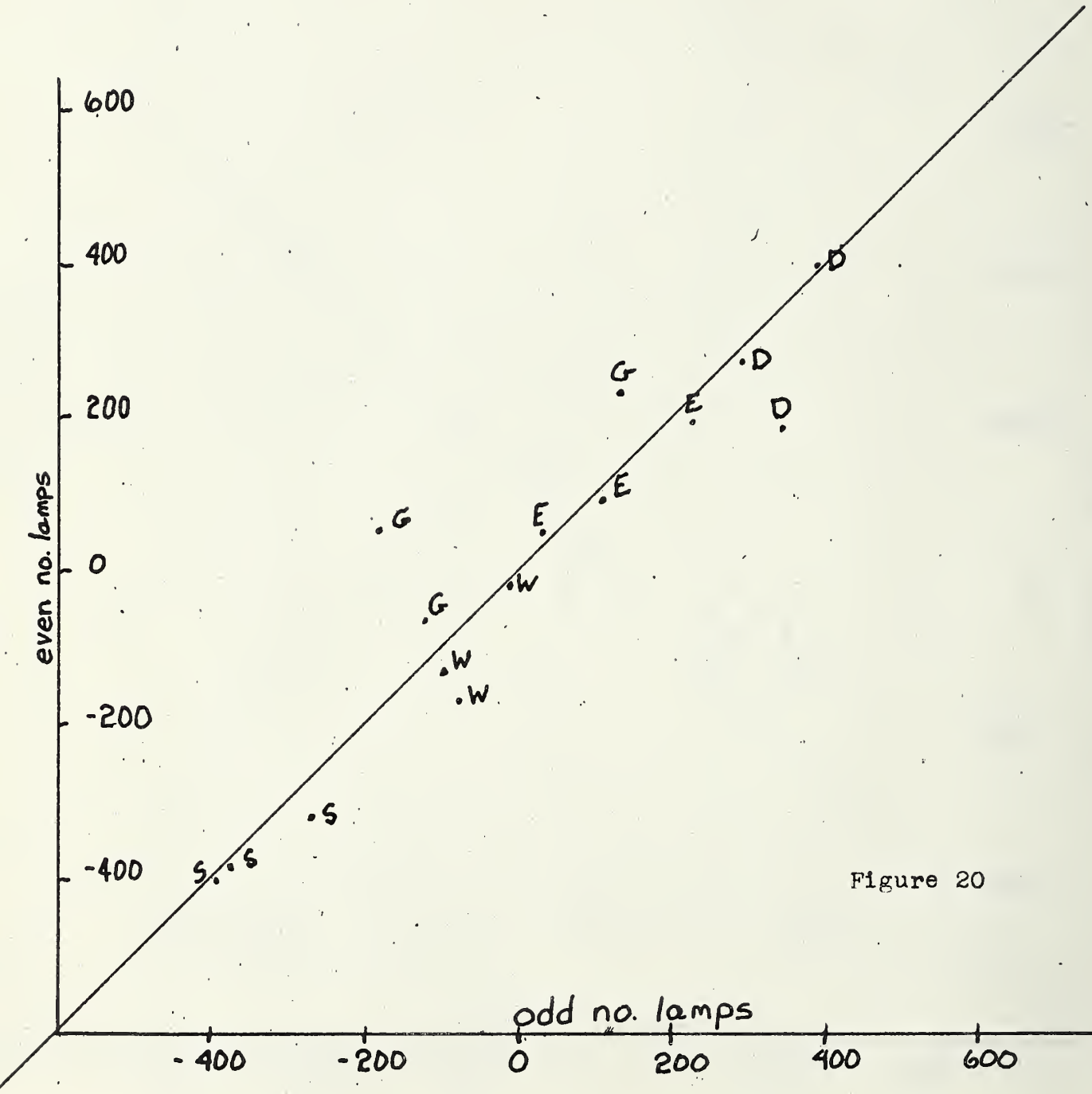


Figure 20

Lamp Volts
Difference from the Averages
HILS Mercury Vapor Lamps
Reference Ballast

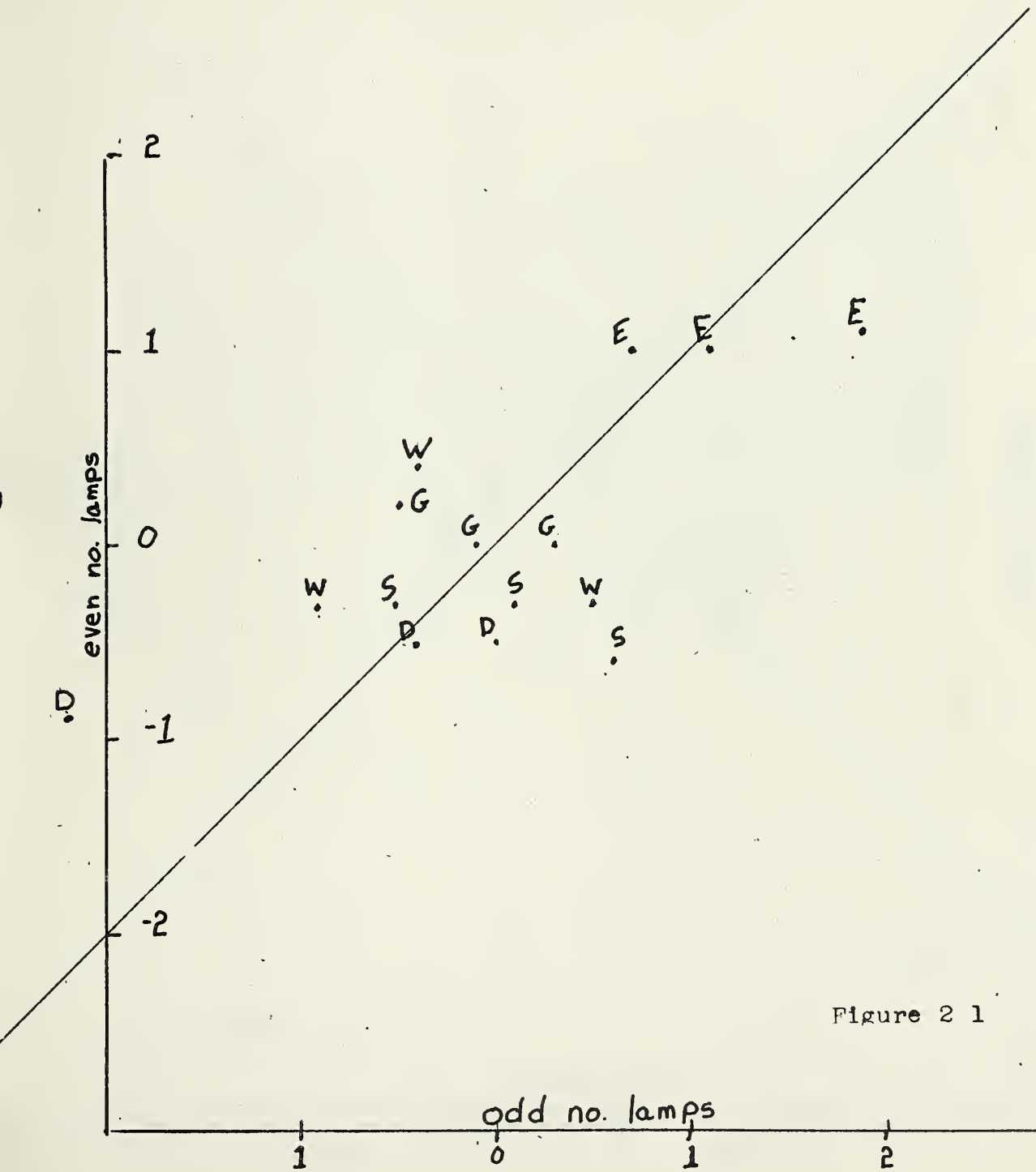


Figure 2 1

Lamp Volts/
Differences from the Averages
HILB/W Mercury Vapor Lamps
Reference Ballast

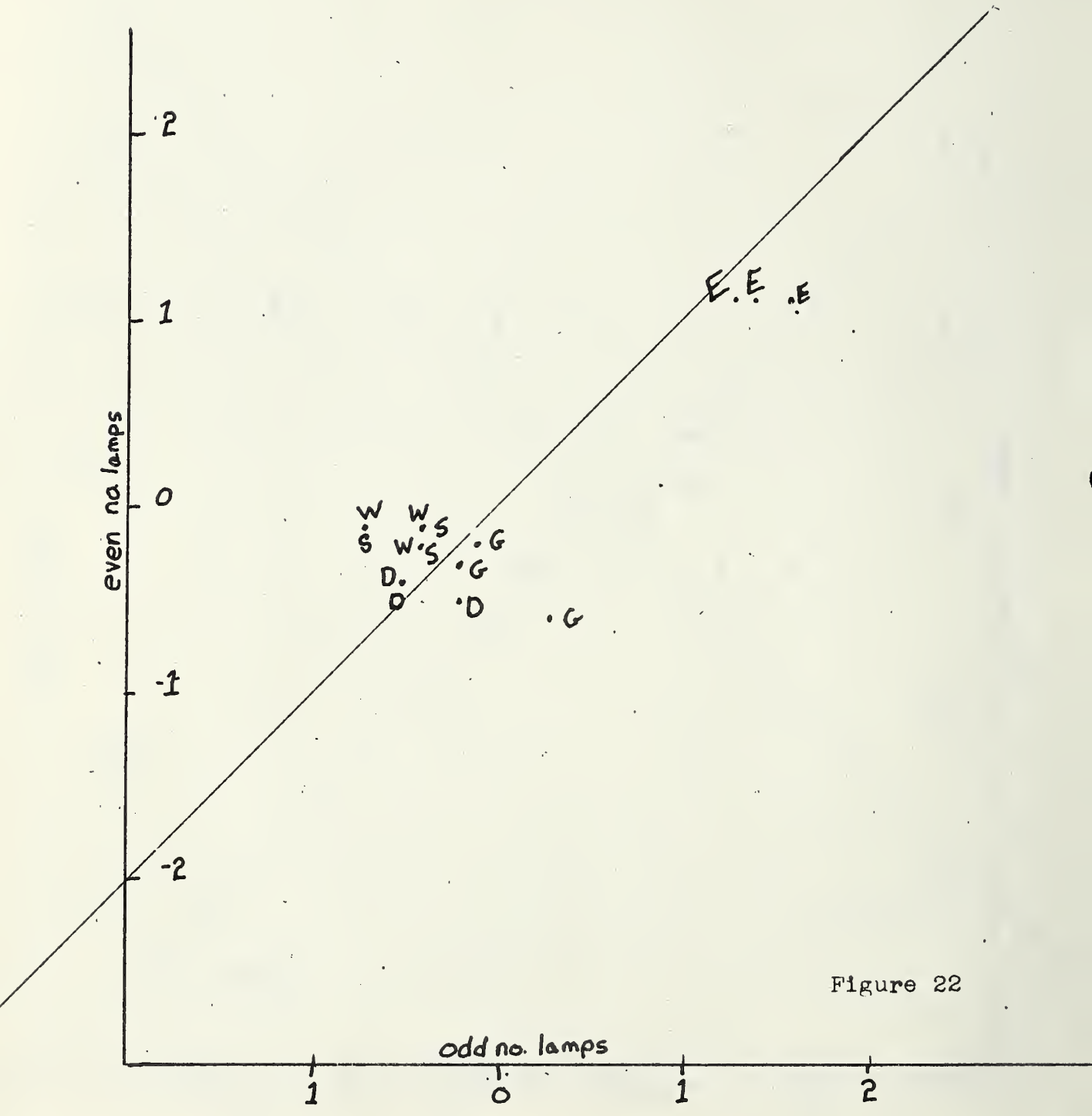


Figure 22

Amperes
Differences from the Averages
HILS Mercury Vapor Lamps
Reference Ballast

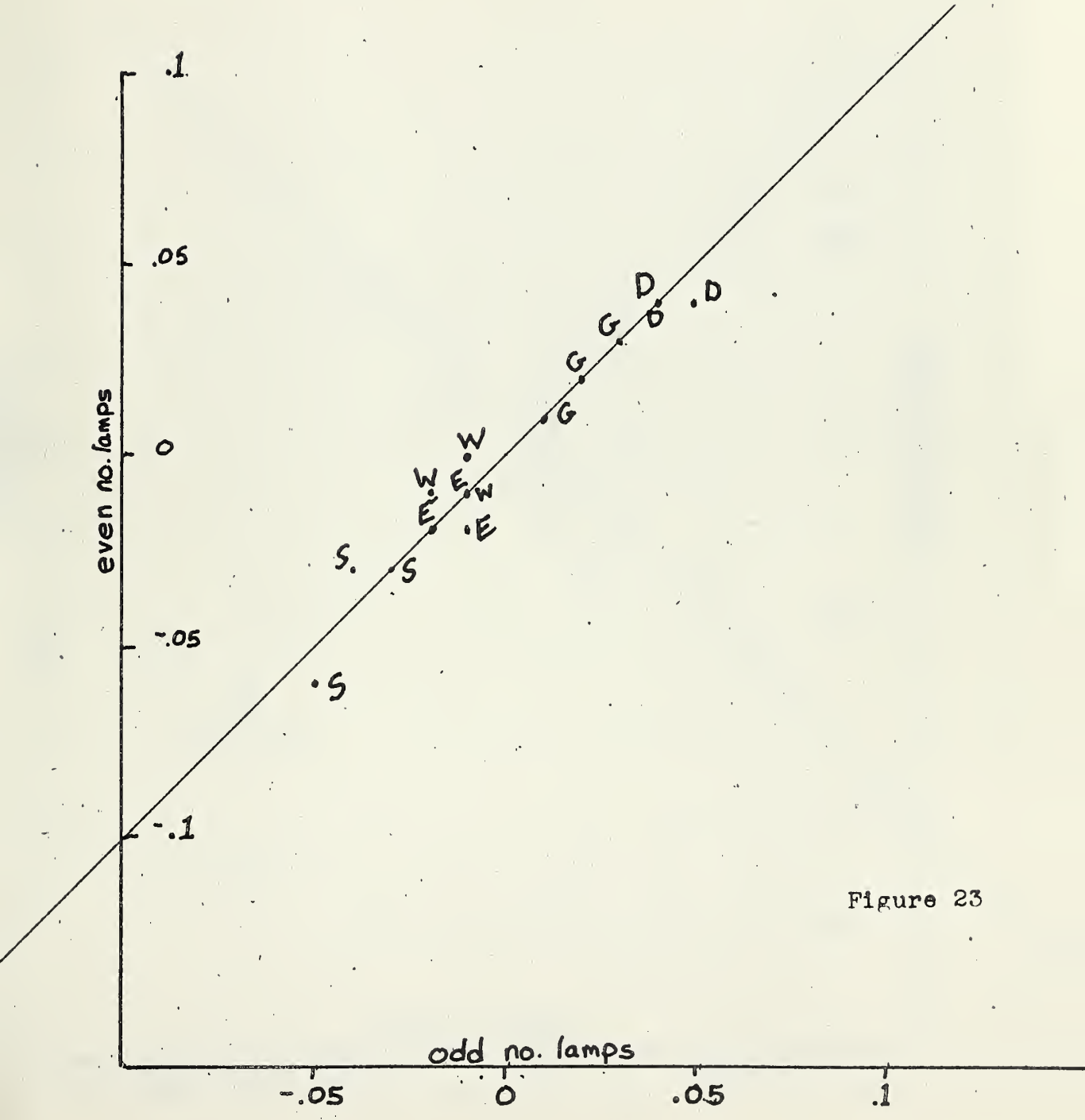


Figure 23

Amperes
Differences from the Averages
HILB/W Mercury Vapor Lamps
Reference Ballast

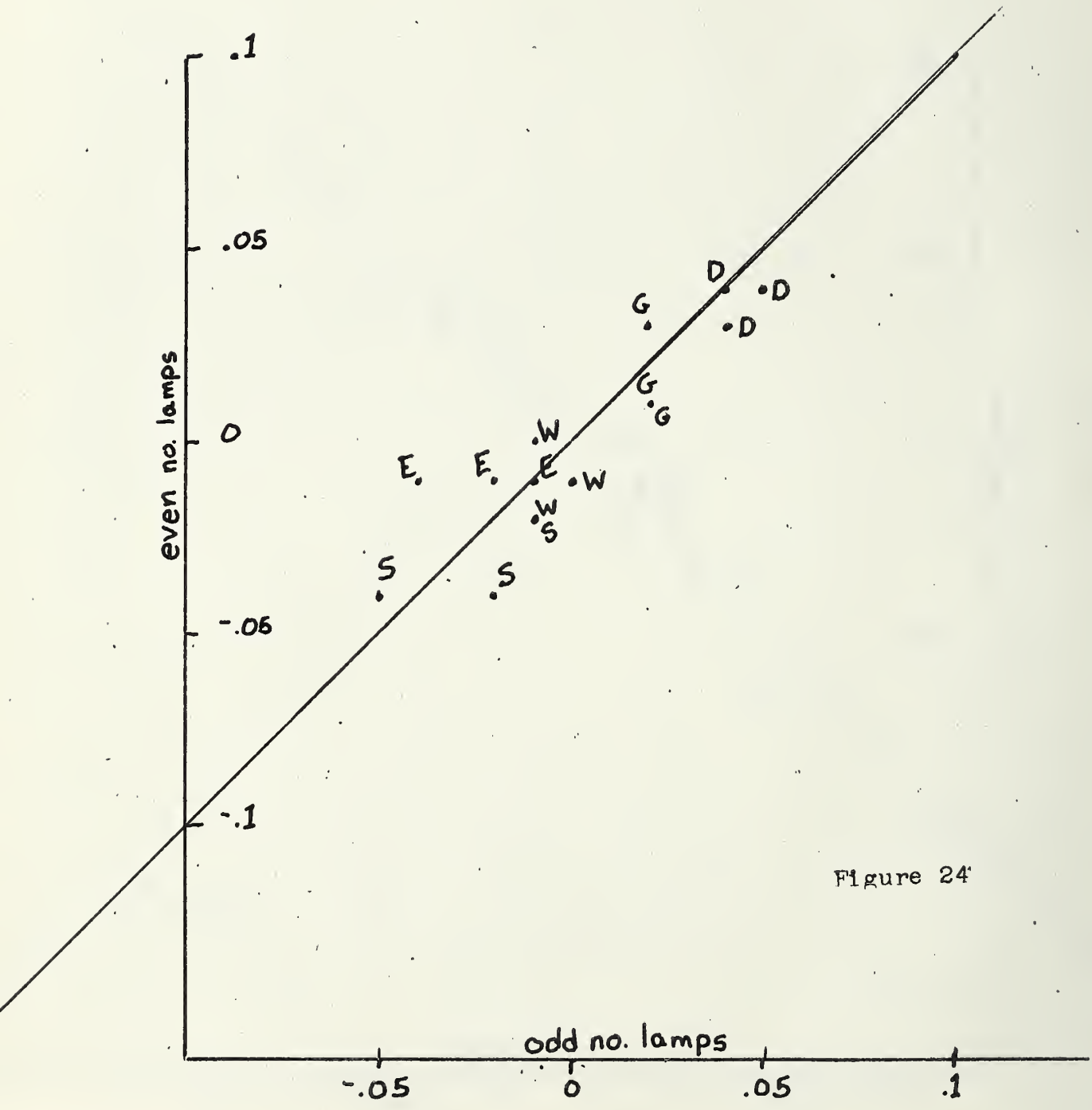


Figure 24

Watts
Differences from the Averages
HILS Mercury Vapor Lamps
Reference Ballast

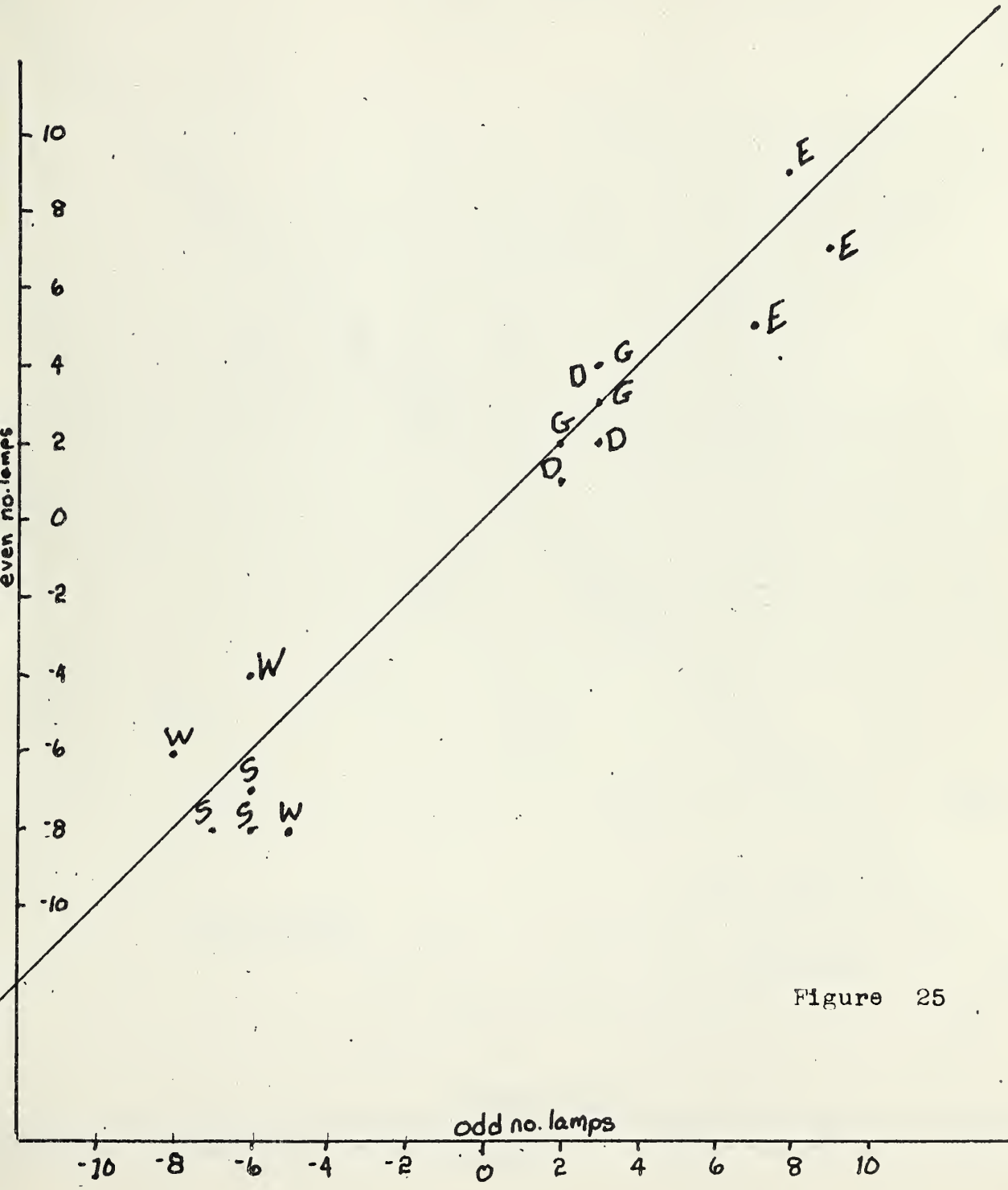


Figure 25

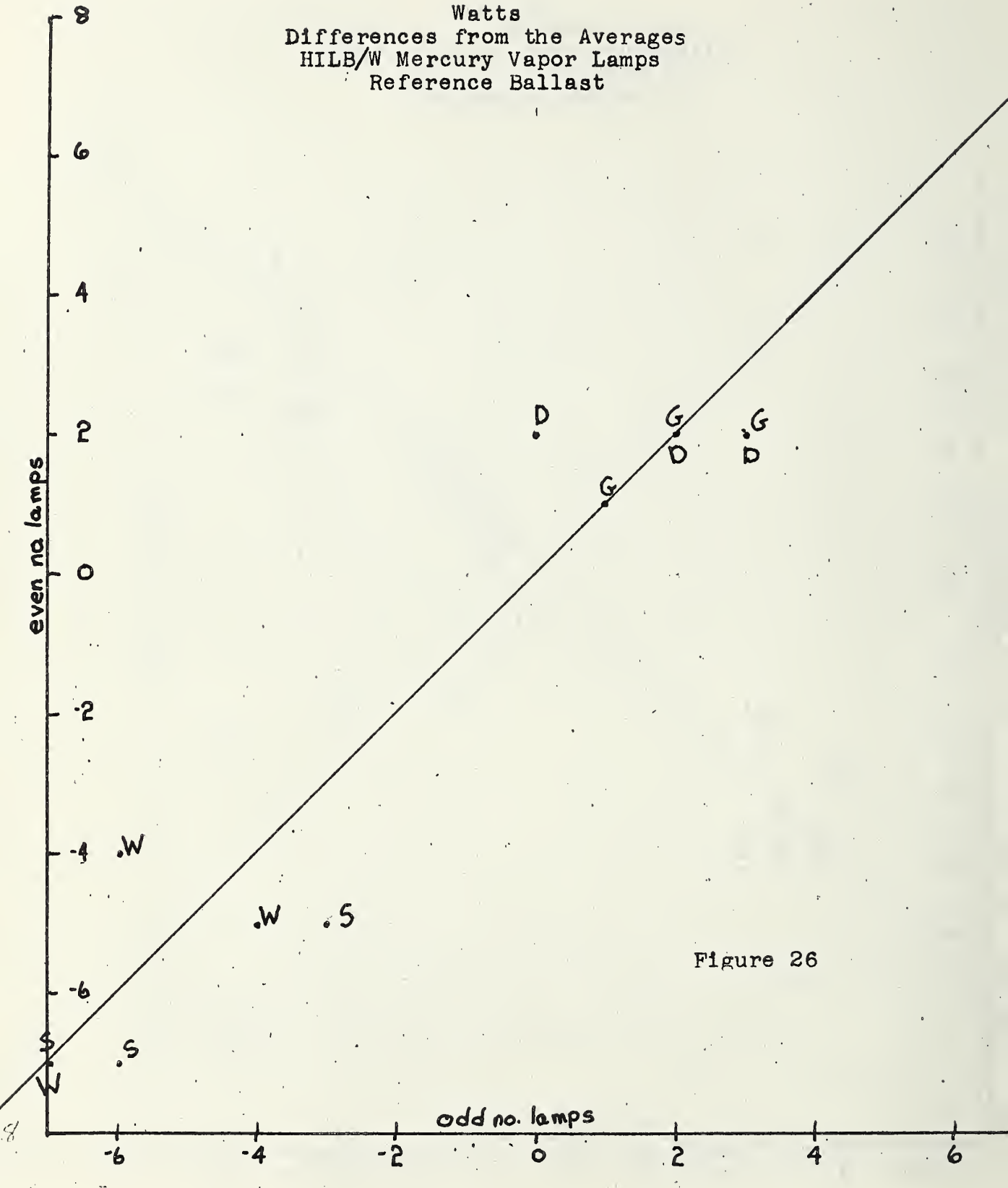
Watts
Differences from the Averages
HILB/W Mercury Vapor Lamps
Reference Ballast
8
6
4
2
0
-2
-4
-6
even no lamps
odd no. lamps
-6
-4
-2
0
2
4
6
D
G
D
G
D
G
W
W
S
S
S

Figure 26

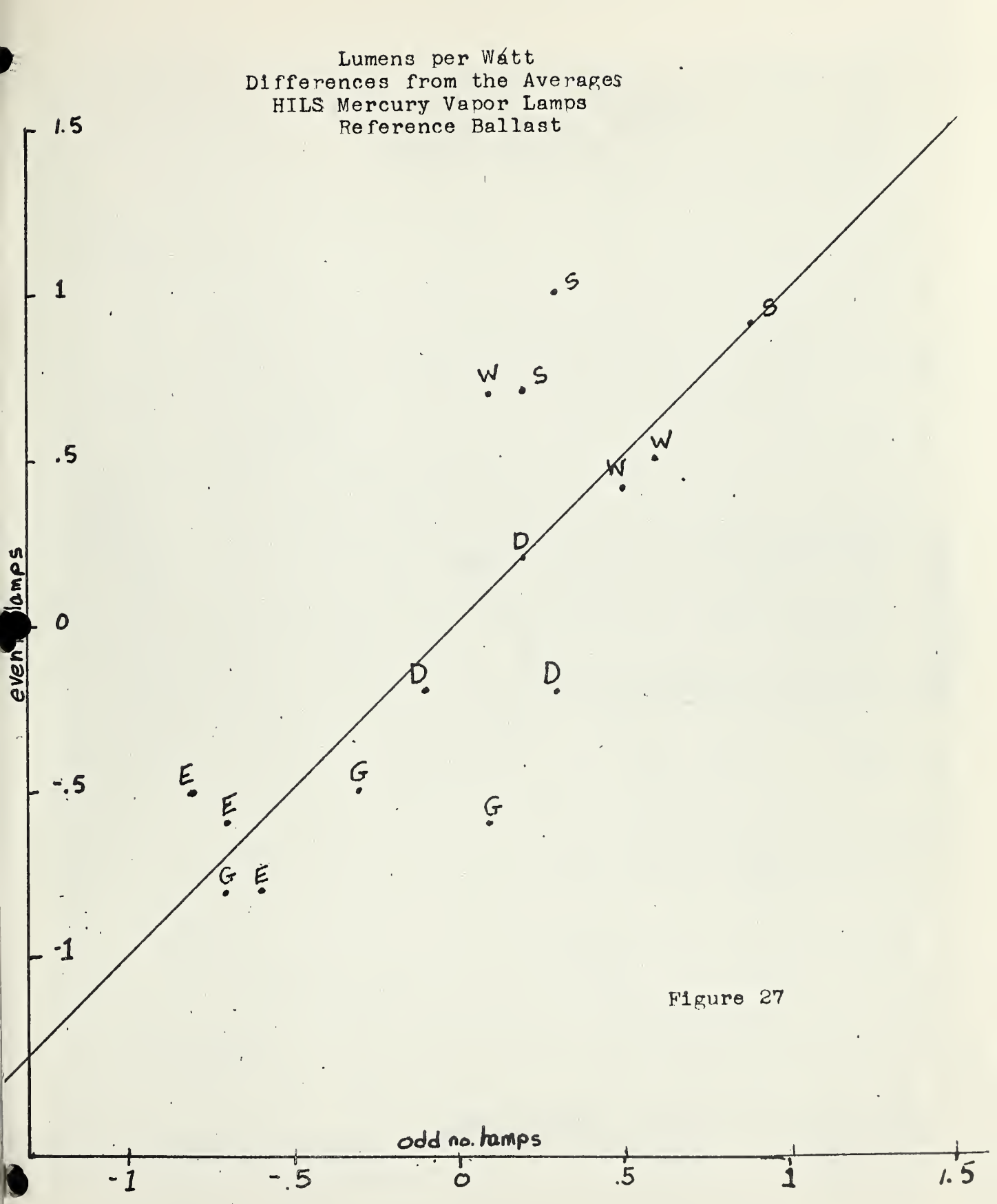
Lumens per Watt
Differences from the Averages
HILS Mercury Vapor Lamps
Reference Ballast
1.5
1
.5
0
-.5
-1
even no. lamps
odd no. lamps
-1
-.5
0
.5
1
1.5
S
S
W
S
W
W
D
D
D
E
E
G
G
G
E

Figure 27

Lumens per Watt
Differences from the Average
HILB/W Mercury Vapor Lamps
Reference Ballast

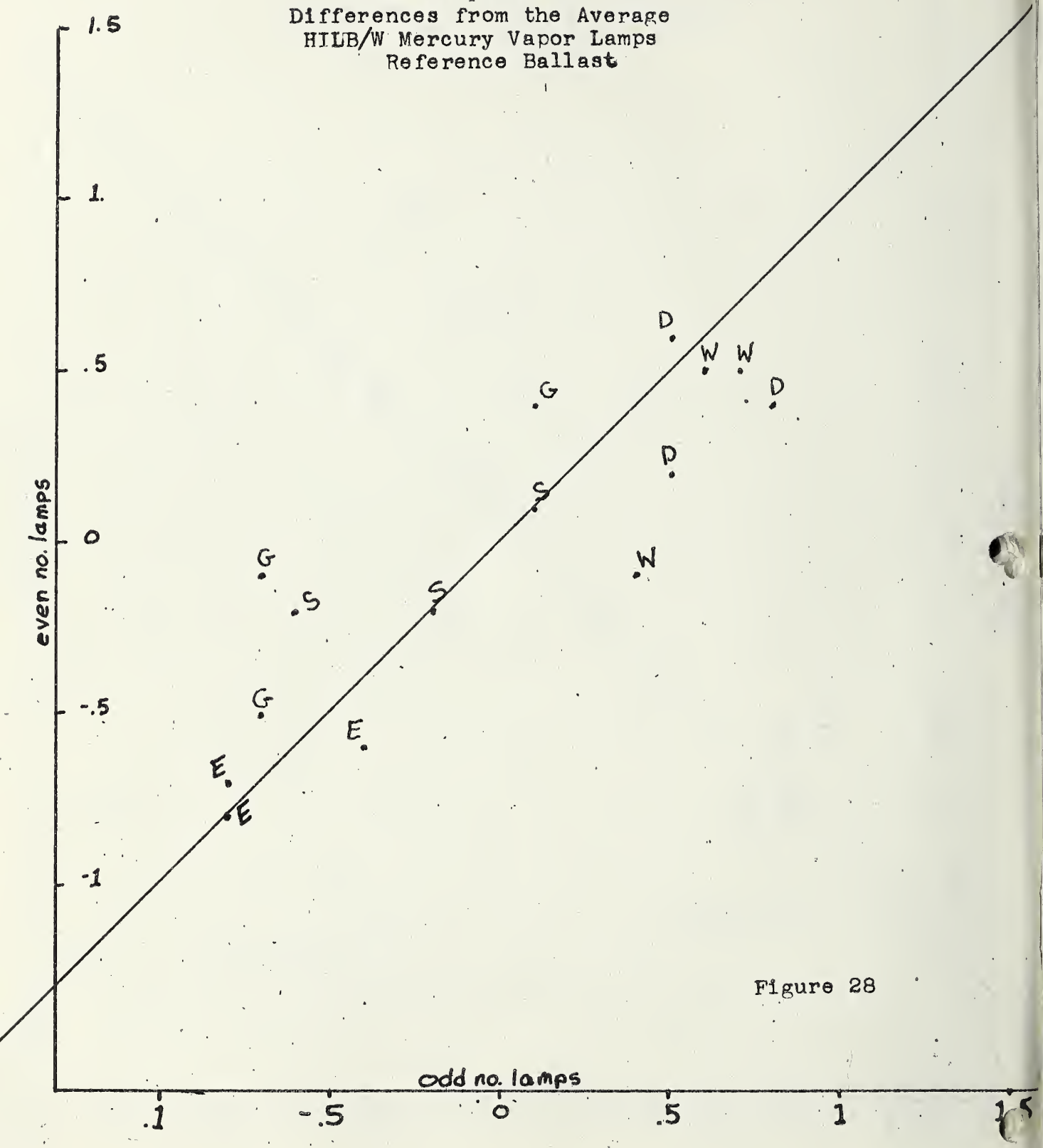


Figure 28

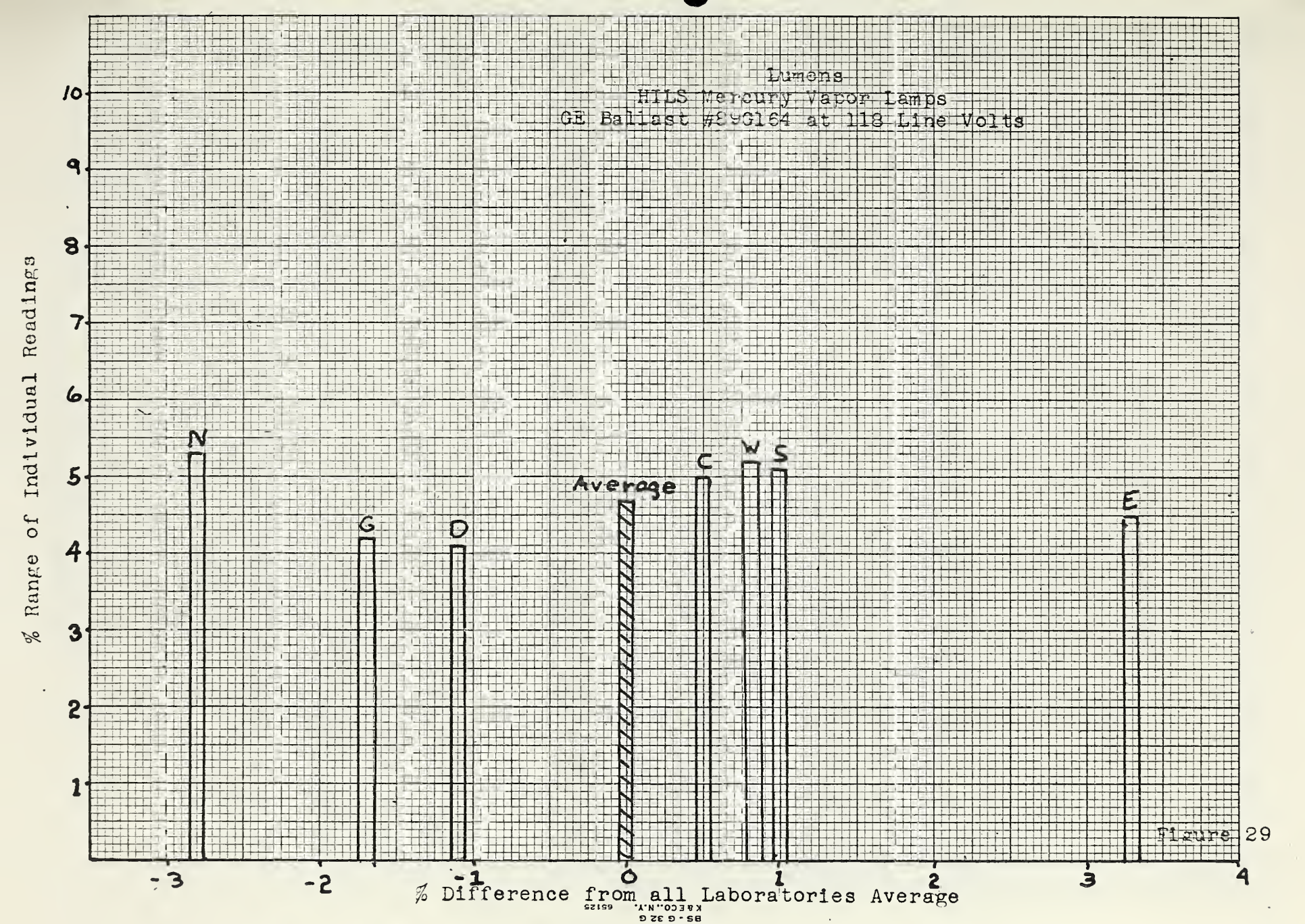
Lumens
HILS Mercury Vapor Lamps
GE Ballast #E96164 at 118 Line Volts
% Range of Individual Readings
10
9
8
7
6
5
4
3
2
1
N
G
D
Average
C
W
S
E
-3
-2
-1
0
1
2
3
4
% Difference from all Laboratories Average

Figure 29

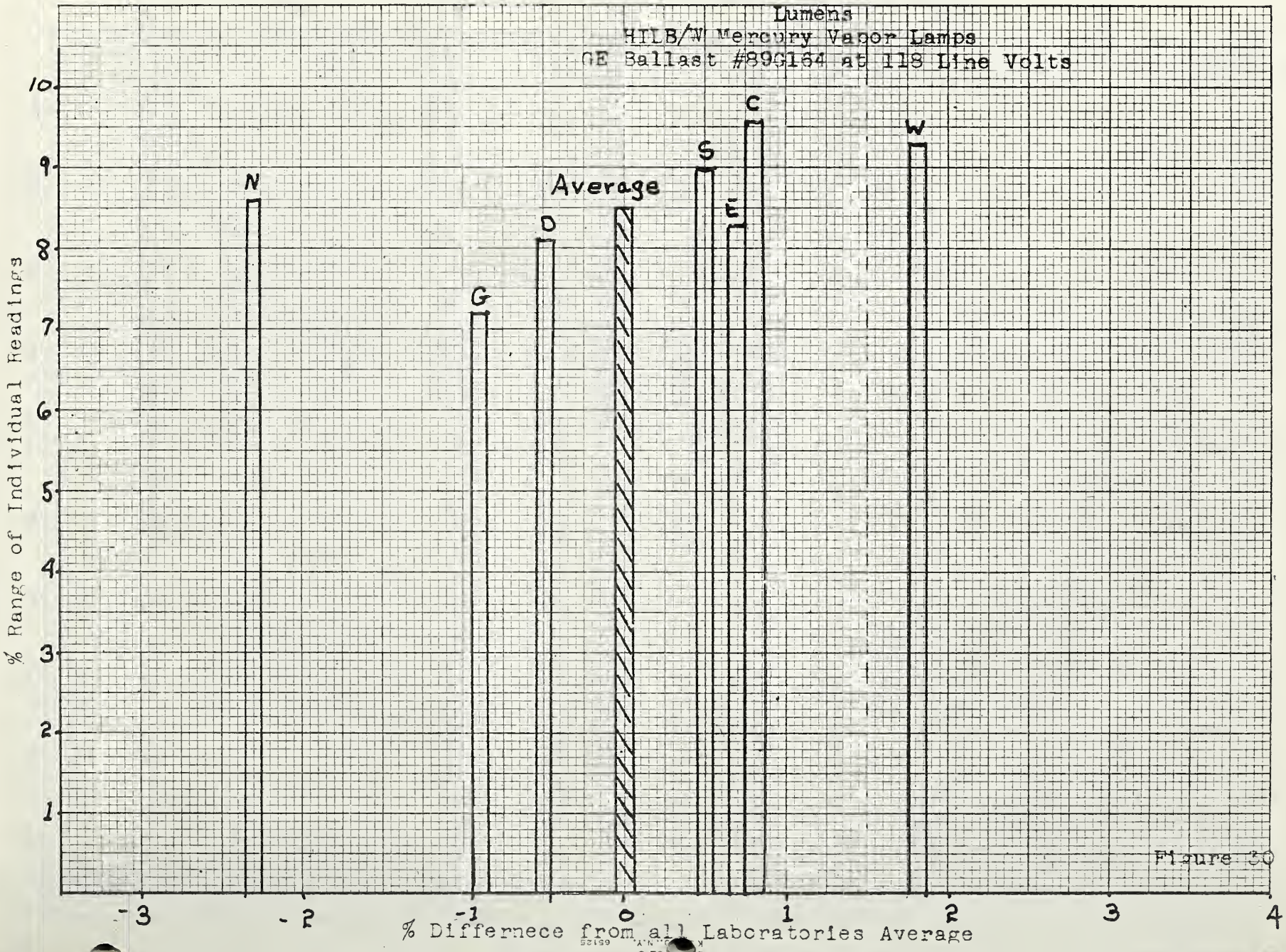
Lumens
HILB/W Mercury Vapor Lamps
GE Ballast #899164 at 118 Line Volts
% Range of Individual Readings
% Differnece from all Laboratories Average
N
G
D
Average
S
E
C
W
10
9
8
7
6
5
4
3
2
1
-3
-2
-1
0
1
2
3
4

Figure 30

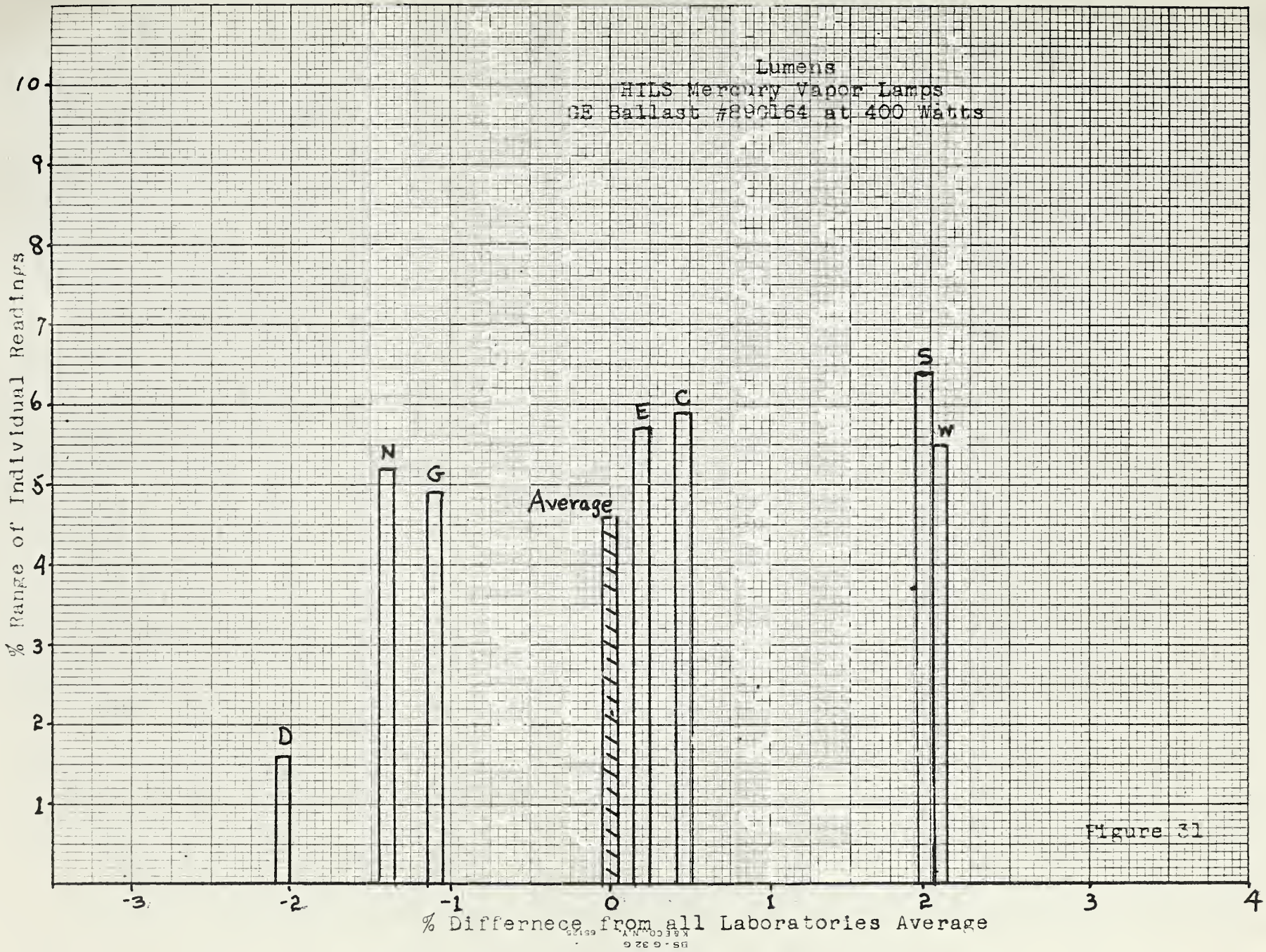
Lumens
HILS Mercury Vapor Lamps
GE Ballast #800164 at 400 Watts
% Range of Individual Readings
10
9
8
7
6
5
4
3
2
1
D
N
G
Average
E
C
S
W
-3
-2
-1
0
1
2
3
4
% Differnece from all Laboratories Average

Figure 31

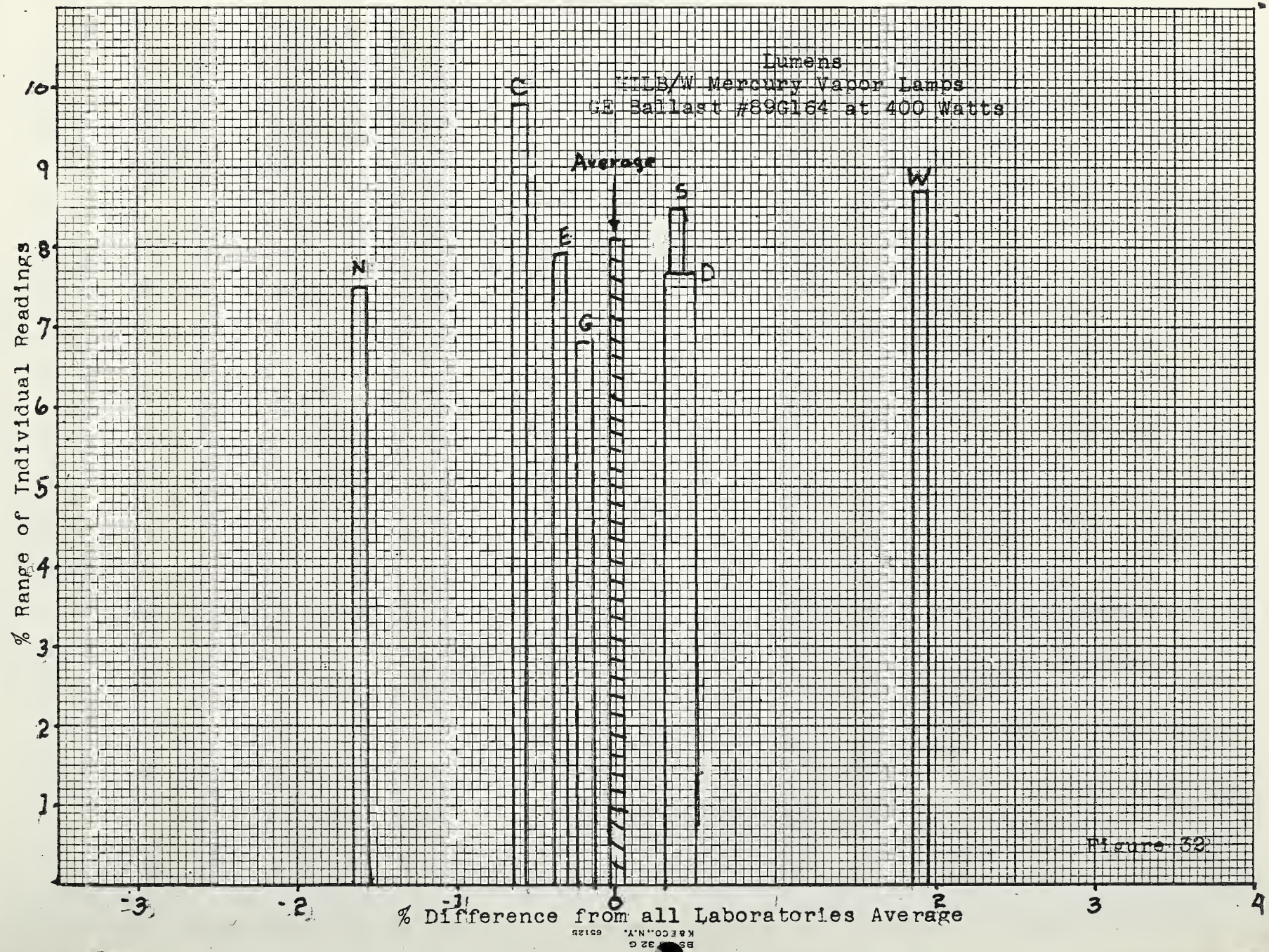
Lumens
WLB/W Mercury Vapor Lamps
GE Ballast #89G164 at 400 Watts
Average
C
E
G
N
S
D
W
% Range of Individual Readings
% Difference from all Laboratories Average
10
9
8
7
6
5
4
3
2
1
-3
-2
-1
0
2
3
4

Figure 32

U.S. DEPARTMENT OF COMMERCE
Frederick H. Mueller, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

# THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

## WASHINGTON, D.C.

**Electricity and Electronics.** Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

**Optics and Metrology.** Photometry and Colorimetry. Photographic Technology. Length. Engineering Metrology.

**Heat.** Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Molecular Kinetics. Free Radicals Research.

**Atomic and Radiation Physics.** Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Radiation Theory. Radioactivity. X-rays. High Energy Radiation. Nucleonic Instrumentation. Radiological Equipment.

**Chemistry.** Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

**Mechanics.** Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

**Organic and Fibrous Materials.** Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

**Metallurgy.** Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

**Mineral Products.** Engineering Ceramics. Glass. Refractories. Enameled Metals. Constitution and Microstructure.

**Building Technology.** Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer. Concreting Materials.

**Applied Mathematics.** Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

**Data Processing Systems.** SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Application Engineering.

• Office of Basic Instrumentation.

• Office of Weights and Measures.

## BOULDER, COLORADO

**Cryogenic Engineering.** Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

**Radio Propagation Physics.** Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships. VHF Research. Radio Warning Services. Airglow and Aurora. Radio Astronomy and Arctic Propagation.

**Radio Propagation Engineering.** Data Reduction Instrumentation. Modulation Research. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation Obstacles Engineering. Radio-Meteorology. Lower Atmosphere Physics.

**Radio Standards.** High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Electronic Calibration Center. Microwave Physics. Microwave Circuit Standards.

**Radio Communication and Systems.** Low Frequency and Very Low Frequency Research. High Frequency and Very High Frequency Research. Ultra High Frequency and Super High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Systems Analysis. Field Operations.


NBS