# NATIONAL BUREAU OF STANDARDS REPORT

6965

on

Interlaboratory Intercomparisons

of

40-Watt T 12 Colored Fluorescent Lamps

by

Velma I. Burns

Photometry and Colorimetry Section

Metrology Division


U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

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# Interlaboratory Intercomparisons

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# 40-Watt T 12 Colored Fluorescent Lamps


## Abstract

Four groups of colored 40-watt T 12 fluorescent lamps were measured. Each group consists of six lamps of the same color; the colors are: pink, gold, blue, and green. Five laboratories made measurements of luminous flux, lamp current, lamp voltage, and lamp watts. The line voltage was held constant at 236 volts across the lamp in series with a reactor having an impedance of 439 ohms and a power factor of 7-8%. The luminous flux measurements were made at each laboratory in an integrating sphere photoelectrically and two laboratories made additional measurements by using a spectroradiometer. The results of the measurements made by the individual laboratories and an analysis of the results are given in this report.


## I Introduction

This intercomparison was undertaken to determine the uniformity of measurements on 40-watt fluorescent lamps of pink, gold, blue, and green colors made at the participating laboratories. The laboratories participating and the order of reading the lamps are as follows:

I. Sylvania
II. Westinghouse
III. Interlectric
IV. Duro Test
V. General Electric

Each laboratory followed its own customary procedure in making the measurements. Measurements in each laboratory were obtained by holding the line voltage at 236 volts. A reference ballast adjusted to 439 ohms impedance and 7-8% power factor was used. The supply was connected to the marked pins. Each laboratory measured the luminous flux in an integrating sphere photoelectrically, and in addition two of the laboratories measured the lamps by means of a spectroradiometer.

## II Results of Measurements

The results reported are given in tables 1 through 16. For each color the averages of the reported values for each lamp and for each laboratory are given. The difference between the average for each laboratory and the average of all laboratories for all lamps of each color is also given in the tables.

Table 1.

F40T12 Pink
Lumens

| Lamp No. | Photoelectric Measurements | | | | | | Spectro-radiometric Measurements | |
|---|---|---|---|---|---|---|---|---|
| | Syl. | West. | Interl | Duro T | G.E. | Ave. | Syl. | Duro T |
| 1 | 943 | 1098 | 1097 | 1115 | 964 | 1043.4 | 971 | 991 |
| 2 | 1042 | 1199 | 1197 | 1223 | 1053 | 1142.8 | 1026 | 1017 |
| 3 | 915 | 1035 | 1023 | 1060 | 883 | 983.2 | 988 | 960 |
| 4 | 1112 | 1284 | 1292 | 1310 | 1153 | 1230.2 | 1161 | 1146 |
| 5 | 1141 | 1324 | 1327 | 1345 | 1179 | 1263.2 | 1239 | 1245 |
| 6 | 1097 | 1281 | 1282 | 1303 | 1123 | 1217.2 | 1172 | 1158 |
| ave. | 1041.7 | 1203.5 | 1203.0 | 1226.0 | 1059.2 | 1146.7 | 1093 | 1086 |
| Δ | -105.0 | + 56.8 | + 56.3 | + 79.3 | - 87.5 | | | |
| %Δ | - 9.2% | + 5.0% | + 4.9% | + 6.9% | - 7.6% | | | |

Table 2.

F40T12 Gold
Lumens

| Lamp No. | Photoelectric Measurements | | | | | | Spectro-radiometric Measurements | |
|---|---|---|---|---|---|---|---|---|
| | Syl. | West. | Interl | Duro T | G.E. | Ave | Syl | Duro T |
| 7 | 1720 | 1860 | 1807 | 1904 | 1786 | 1815.4 | 1628 | 1832 |
| 8 | 1746 | 1887 | 1847 | 1913 | 1789 | 1836.4 | 1660 | 1813 |
| 9 | 1698 | 1819 | 1782 | 1858 | 1754 | 1782.2 | 1622 | 1790 |
| 10 | 1710 | 1875 | 1828 | 1905 | 1774 | 1818.4 | 1597 | 2188 |
| 11 | 1702 | 1869 | 1830 | 1905 | 1779 | 1817.0 | 1630 | 1808 |
| 12 | 1702 | 1854 | 1835 | 1901 | 1774 | 1813.2 | 1656 | 1855 |
| ave. | 1713.0 | 1860.7 | 1821.5 | 1897.7 | 1776.0 | 1813.8 | 1632 | 1881 |
| Δ | - 100.8 | + 46.9 | + 7.7 | + 83.9 | - 37.8 | | | |
| %Δ | - 5.6% | + 2.6% | + 0.4% | + 4.6% | - 2.1% | | | |

Table 3.

F40T12 - Blue
Lumens

| Lamp No. | Photoelectric Measurements | | | | | | Spectro-radiometric Measurements | |
|---|---|---|---|---|---|---|---|---|
| | Syl | West | Interl | Duro T | G.E. | Ave | Syl. | Duro T |
| 13 | 1099 | 1038 | 1000 | 1010 | 1058 | 1041.0 | 963 | 1094 |
| 14 | 1081 | 1027 | 995 | 995 | 1056 | 1030.8 | 1153 | 1152 |
| 15 | 1091 | 1036 | | | | | 922 | 1141 |
| 16 | 1109 | 1056 | 1020 | 1023 | 1064 | 1054.4 | 1000 | 984 |
| 17 | 1117 | 1058 | 1025 | 1022 | 1073 | 1059.0 | 1060 | 1140 |
| 18 | 1101 | 1054 | 1017 | 1022 | 1063 | 1051.4 | 1029 | 1211 |
| ave of 6 | 1100 | 1045 | | | | | 1021 | 1120 |
| ave of 5 | 1101.4 | 1046.6 | 1011.4 | 1014.4 | 1062.8 | 1047.3 | 1041 | 1116 |
| Δ | + 54.1 | - 0.7 | - 35.9 | - 32.9 | + 15.5 | | | |
| %Δ | + 5.2% | - 0.1% | - 3.4% | - 3.1% | + 1.5% | | | |

Table 4.

F40T12-Green
Lumens

| Lamp No. | Photoelectric Measurements | | | | | | Spectro-radiometric Measurements | |
|---|---|---|---|---|---|---|---|---|
| | Syl | West | Interl | Duro T | G.E. | Ave | Syl | Duro T |
| 19 | 3568 | 3531 | 3422 | 3435 | 3463 | 3483.8 | | 3464 |
| 20 | 3664 | 3595 | 3435 | 3506 | 3530 | 3546.0 | 3405 | 3804 |
| 21 | 3644 | 3592 | 3447 | 3465 | 3527 | 3535.0 | 3518 | 3610 |
| 22 | 3600 | 3487 | 3362 | 3380 | 3404 | 3446.6 | | 3214 |
| 23 | 3544 | 3570 | 3392 | 3465 | 3496 | 3493.4 | | 3654 |
| 24 | 3628 | 3569 | 3420 | 3446 | 3478 | 3508.2 | 3421 | 3514 |
| ave | 3608.0 | 3557.3 | 3413.0 | 3449.5 | 3483.0 | 3502.2 | | 3543 |
| Δ | + 105.8 | + 55.1 | - 89.2 | - 52.7 | - 19.2 | | | |
| %Δ | + 3.0% | + 1.6% | - 2.5% | - 1.5% | - 0.5% | | | |

Table 5.

F40T12 - Pink
Current

| Lamp No. | Syl | West | Interl | Duro T | GE | Ave |
|---|---|---|---|---|---|---|
| 1 | .429 | .433 | .437 | .429 | .434 | .4324 |
| 2 | .426 | .430 | .435 | .429 | .434 | .4308 |
| 3 | .427 | .431 | .430 | .427 | .434 | .4298 |
| 4 | .428 | .430 | .430 | .428 | .433 | .4298 |
| 5 | .426 | .430 | .430 | .428 | .430 | .4288 |
| 6 | .429 | .431 | .430 | .431 | .434 | .4310 |
| ave | .4275 | .4308 | .4320 | .4287 | .4332 | .4304 |
| Δ | -.0029 | +.0004 | +.0016 | -.0017 | +.0028 | |
| %Δ | - .67% | + .09% | + .37% | - .39% | + .65% | |

Table 6.

F40T12 - Gold
Current

| Lamp No. | Syl | West. | Interl | Duro T | GE | Ave |
|---|---|---|---|---|---|---|
| 7 | .429 | .432 | .434 | .429 | .433 | .4314 |
| 8 | .429 | .431 | .437 | .431 | .434 | .4324 |
| 9 | .430 | .430 | .431 | .426 | .432 | .4298 |
| 10 | .430 | .432 | .434 | .430 | .434 | .4320 |
| 11 | .432 | .436 | .438 | .432 | .436 | .4348 |
| 12 | .431 | .431 | .433 | .430 | .434 | .4318 |
| ave | .4302 | .4320 | .4345 | .4297 | .4338 | .4320 |
| Δ | -.0018 | .0000 | +.0025 | -.0023 | +.0018 | |
| %Δ | - .42% | 0% | + .58% | - .53% | + .42% | |

Table 7.

F40T12 - Blue
Current

| Lamp No. | Syl. | West | Interl | Duro T | GE | Ave |
|---|---|---|---|---|---|---|
| 13 | .427 | .425 | .430 | .425 | .430 | .4274 |
| 14 | .427 | .430 | .431 | .428 | .432 | .4296 |
| 15 | .421 | .425 | | | | |
| 16 | .427 | .429 | .431 | .428 | .432 | .4294 |
| 17 | .423 | .429 | .430 | .425 | .429 | .4272 |
| 18 | .423 | .428 | .430 | .425 | .428 | .4268 |
| ave of 6 | .425 | .428 | | | | |
| ave of 5 | .4254 | .4282 | .4304 | .4262 | .4302 | .4281 |
| Δ | -.0027 | +.0001 | +.0023 | -.0019 | +.0021 | |
| % Δ | - .63% | + .02% | + .54% | - .44% | + .49% | |

Table 8.

F40T12 - Green
Current

| Lamp No. | Syl. | West. | Interl | Duro T | GE | Ave |
|---|---|---|---|---|---|---|
| 19 | .425 | .429 | .430 | .428 | .433 | .4290 |
| 20 | .426 | .425 | .430 | .422 | .433 | .4272 |
| 21 | .424 | .427 | .430 | .422 | .430 | .4266 |
| 22 | .425 | .432 | .431 | .425 | .435 | .4296 |
| 23 | .431 | .429 | .432 | .426 | .431 | .4298 |
| 24 | .424 | .429 | .430 | .424 | .431 | .4276 |
| ave | .4258 | .4285 | .4305 | .4245 | .4322 | .4283 |
| Δ | -.0025 | +.0002 | +.0022 | -.0038 | +.0039 | |
| % Δ | - .58% | + .05% | + .51% | - .89% | + .91% | |

Table 9.

F40T12 - Pink
Volts

| Lamp No. | Syl. | West. | Interl | GE | Ave |
|---|---|---|---|---|---|
| 1 | 100.5 | 100.6 | 99.4 | 100.5 | 100.25 |
| 2 | 102.0 | 100.9 | 99.6 | 100.2 | 100.68 |
| 3 | 100.5 | 100.9 | 100.4 | 99.5 | 100.32 |
| 4 | 100.5 | 102.0 | 101.5 | 99.8 | 100.95 |
| 5 | 101.5 | 102.0 | 100.9 | 102.0 | 101.60 |
| 6 | 100.0 | 100.9 | 100.8 | 100.5 | 100.55 |
| ave | 100.83 | 101.22 | 100.43 | 100.42 | 100.72 |
| Δ | + .11 | + .50 | - .29 | - .30 | |
| %Δ | + .11% | + .50% | - .29% | - .30% | |

Table 10.

F40T12 - Gold
Volts

| Lamp No. | Syl. | West. | Interl | GE | Ave |
|---|---|---|---|---|---|
| 7 | 100.0 | 100.0 | 98.9 | 101.0 | 99.98 |
| 8 | 99.0 | 99.8 | 97.3 | 99.8 | 98.98 |
| 9 | 99.5 | 101.5 | 100.8 | 100.6 | 100.60 |
| 10 | 98.5 | 100.0 | 98.8 | 99.9 | 99.30 |
| 11 | 98.5 | 98.1 | 97.7 | 99.5 | 98.45 |
| 12 | 97.5 | 100.3 | 100.1 | 100.1 | 99.50 |
| ave | 98.83 | 99.95 | 98.93 | 100.15 | 99.47 |
| Δ | - .64 | + .48 | - .54 | + .68 | |
| %Δ | - .64% | + .48% | - .54% | + .68% | |

Table 11.

F4OT12 - Blue
Volts

| Lamp No. | Syl. | West | Interl | GE | Ave |
|---|---|---|---|---|---|
| 13 | 101.0 | 104.0 | 101.0 | 100.8 | 101.70 |
| 14 | 100.5 | 102.4 | 100.8 | 100.3 | 101.00 |
| 15 | 103.0 | 104.9 | | | |
| 16 | 100.0 | 103.1 | 100.6 | 100.3 | 101.00 |
| 17 | 102.0 | 102.9 | 101.4 | 102.0 | 102.08 |
| 18 | 101.0 | 102.8 | 101.9 | 102.6 | 102.08 |
| ave of 6 | 101.2 | 103.4 | | | |
| ave of 5 | 100.90 | 103.04 | 101.14 | 101.20 | 101.57 |
| Δ | - .67 | + 1.47 | - .43 | - .37 | |
| %Δ | - .66% | + 1.45% | - .42% | - .36% | |

Table 12.

F4OT12 - Green
Volts

| Lamp No. | Syl. | West. | Interl | Duro T | GE | Ave |
|---|---|---|---|---|---|---|
| 19 | 101.0 | 102.6 | 101.8 | | 100.9 | 101.58 |
| 20 | 101.5 | 104.3 | 102.4 | | 100.0 | 102.05 |
| 21 | 103.0 | 104.0 | 102.7 | | 101.7 | 102.85 |
| 22 | 101.5 | 101.6 | 100.3 | | 99.4 | 100.70 |
| 23 | 99.0 | 101.8 | 100.8 | | 101.9 | 100.88 |
| 24 | 102.0 | 103.5 | 102.7 | | 101.2 | 102.35 |
| ave | 101.33 | 102.97 | 101.78 | | 100.85 | 101.73 |
| Δ | - .40 | + 1.24 | + .05 | | - .88 | |
| %Δ | - .39% | + 1.22% | + .05% | | - .87% | |

Table 13.

F4OT12 - Pink
Watts

| Lamp No. | Syl. | West | Interl | Duro T | GE | Ave |
|---|---|---|---|---|---|---|
| 1 | 39.1 | 39.5 | | 39.2 | 40.0 | 39.45 |
| 2 | 40.0 | 39.3 | | 39.1 | 40.1 | 39.62 |
| 3 | 39.4 | 39.2 | | 39.1 | 39.7 | 39.35 |
| 4 | 39.2 | 39.8 | | 39.0 | 39.4 | 39.35 |
| 5 | 39.6 | 39.9 | | 39.3 | 40.4 | 39.80 |
| 6 | 39.2 | 39.2 | | 39.0 | 39.9 | 39.32 |
| ave | 39.42 | 39.48 | | 39.12 | 39.92 | 39.48 |
| Δ | - .06 | .00 | | - .36 | + .44 | |
| %Δ | - .15% | 0% | | - .91% | + 1.1% | |

Table 14.

F4OT12 - Gold
Watts

| Lamp No. | Syl. | West | Interl | Duro T | GE | Ave |
|---|---|---|---|---|---|---|
| 7 | 39.3 | 39.0 | | 39.2 | 39.9 | 39.35 |
| 8 | 38.9 | 38.9 | | 38.6 | 39.8 | 39.05 |
| 9 | 39.1 | 39.4 | | 39.6 | 39.9 | 39.50 |
| 10 | 38.8 | 38.9 | | 38.8 | 39.8 | 39.08 |
| 11 | 39.1 | 38.4 | | 38.7 | 39.7 | 38.98 |
| 12 | 38.4 | 39.0 | | 38.7 | 39.7 | 38.95 |
| ave | 38.93 | 38.93 | | 38.93 | 39.80 | 39.15 |
| Δ | - .22 | - .22 | | - .22 | + .65 | |
| %Δ | - .56% | - .56% | | - .56% | + 1.66% | |

Table 15.

F4OT12 - Blue
Watts

| Lamp No. | Syl. | West | Interl | Duro T | GE | Ave |
|---|---|---|---|---|---|---|
| 13 | 39.5 | 40.2 | | 39.3 | 39.7 | 39.68 |
| 14 | 39.3 | 39.8 | | 39.2 | 39.5 | 39.45 |
| 15 | 39.7 | 40.2 | | | | |
| 16 | 39.2 | 40.0 | | 39.1 | 39.5 | 39.45 |
| 17 | 39.5 | 39.7 | | 39.4 | 40.0 | 39.65 |
| 18 | 39.1 | 39.4 | | 39.4 | 40.0 | 39.48 |
| ave 6 | 39.4 | 39.9 | | | | |
| ave of 5 | 39.32 | 39.82 | | 39.28 | 39.74 | 39.54 |
| Δ | - .22 | + .28 | | - .26 | + .20 | |
| %Δ | - .56% | + .71% | | - .66% | + .51% | |

Table 16.

F4OT12 - Green
Watts

| Lamp No. | Syl. | West | Interl | Duro T | GE | Ave |
|---|---|---|---|---|---|---|
| 19 | 39.3 | 39.8 | | 39.7 | 40.1 | 39.72 |
| 20 | 39.8 | 40.3 | | 40.4 | 39.7 | 40.05 |
| 21 | 40.0 | 40.0 | | 40.3 | 40.1 | 40.10 |
| 22 | 39.7 | 39.4 | | 40.2 | 39.6 | 39.72 |
| 23 | 39.1 | 39.5 | | 40.0 | 40.3 | 39.72 |
| 24 | 39.6 | 40.1 | | 40.4 | 40.1 | 40.05 |
| ave | 39.58 | 39.85 | | 40.17 | 39.98 | 39.89 |
| Δ | - .31 | - .04 | | + .28 | + .09 | |
| %Δ | - .78% | - .10% | | + .70% | + .23% | |

## 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 Report 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". The analysis is shown on the following graphs. The point representing measurements by each individual laboratory is designated by the first letter in the name of the laboratory. The point representing the average of all laboratories is designated by the letter A.

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 914, October 1958.

3. Circumstances alter the cases, Industrial and Engineering Chemistry, Vol. 50, page 77A, December 1958.

Figure 1

Lumens

F40T12 Pink

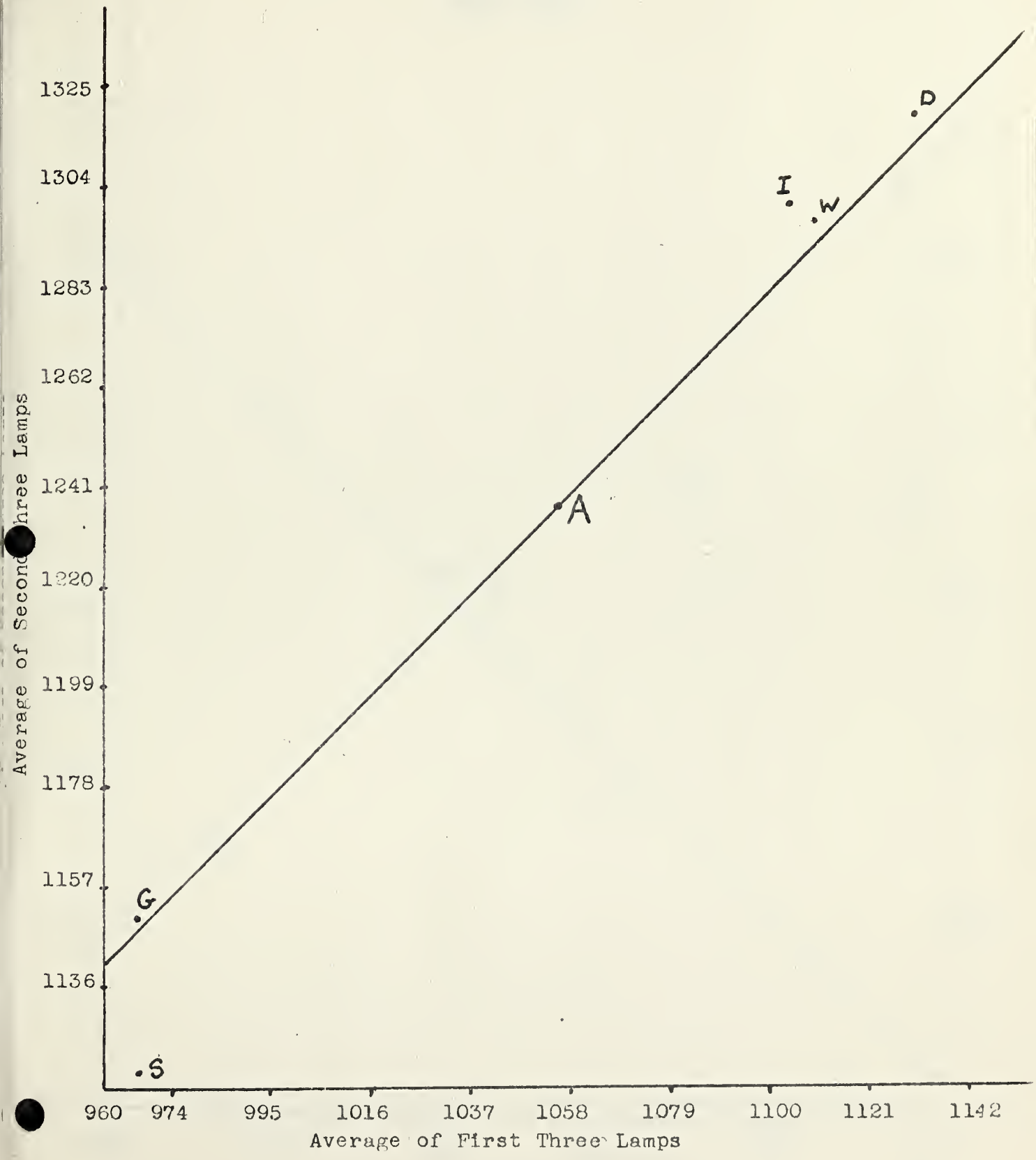


Figure 2

Lumens

F40T12 Cold

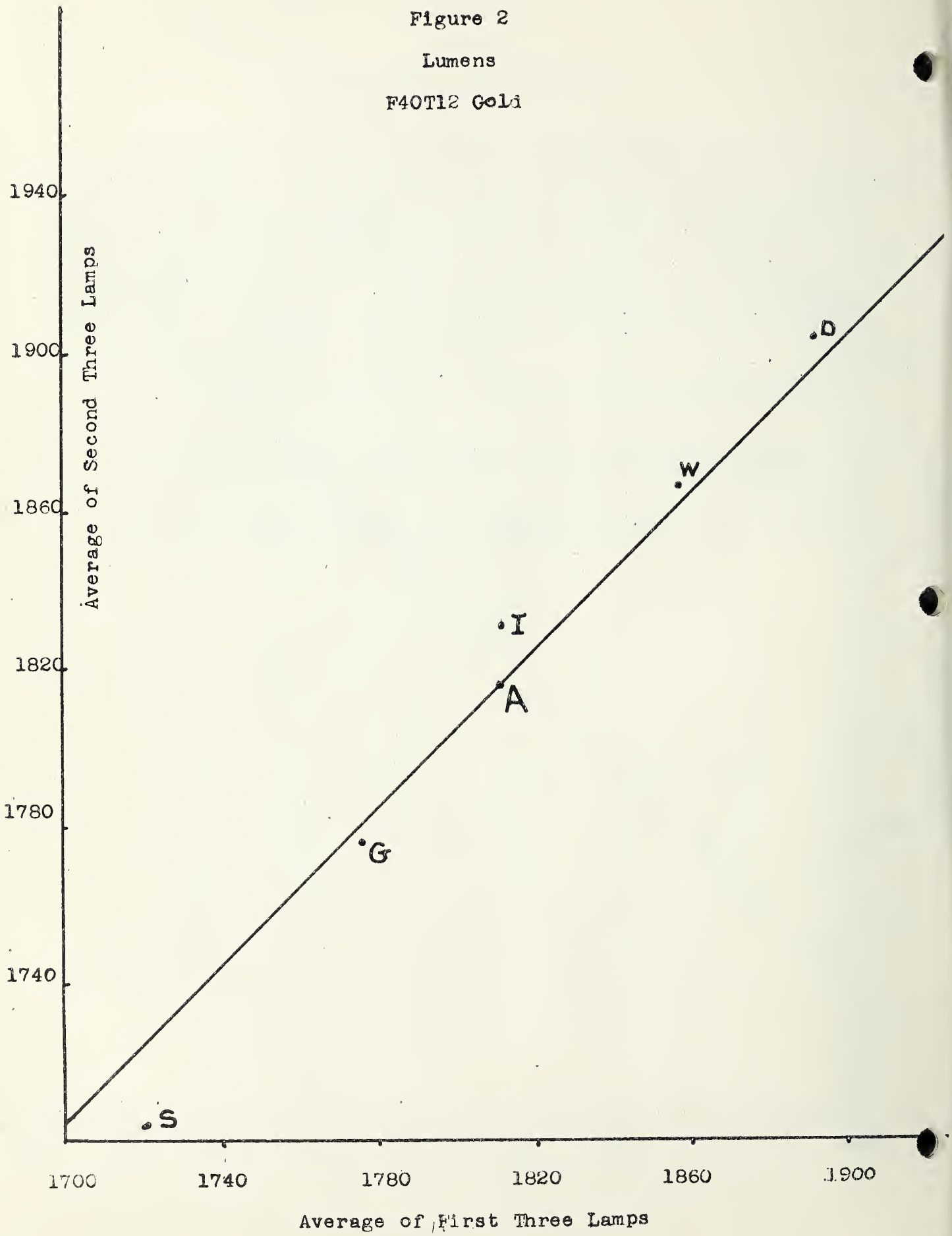


Figure 3

Lumens

F40T12 Blue

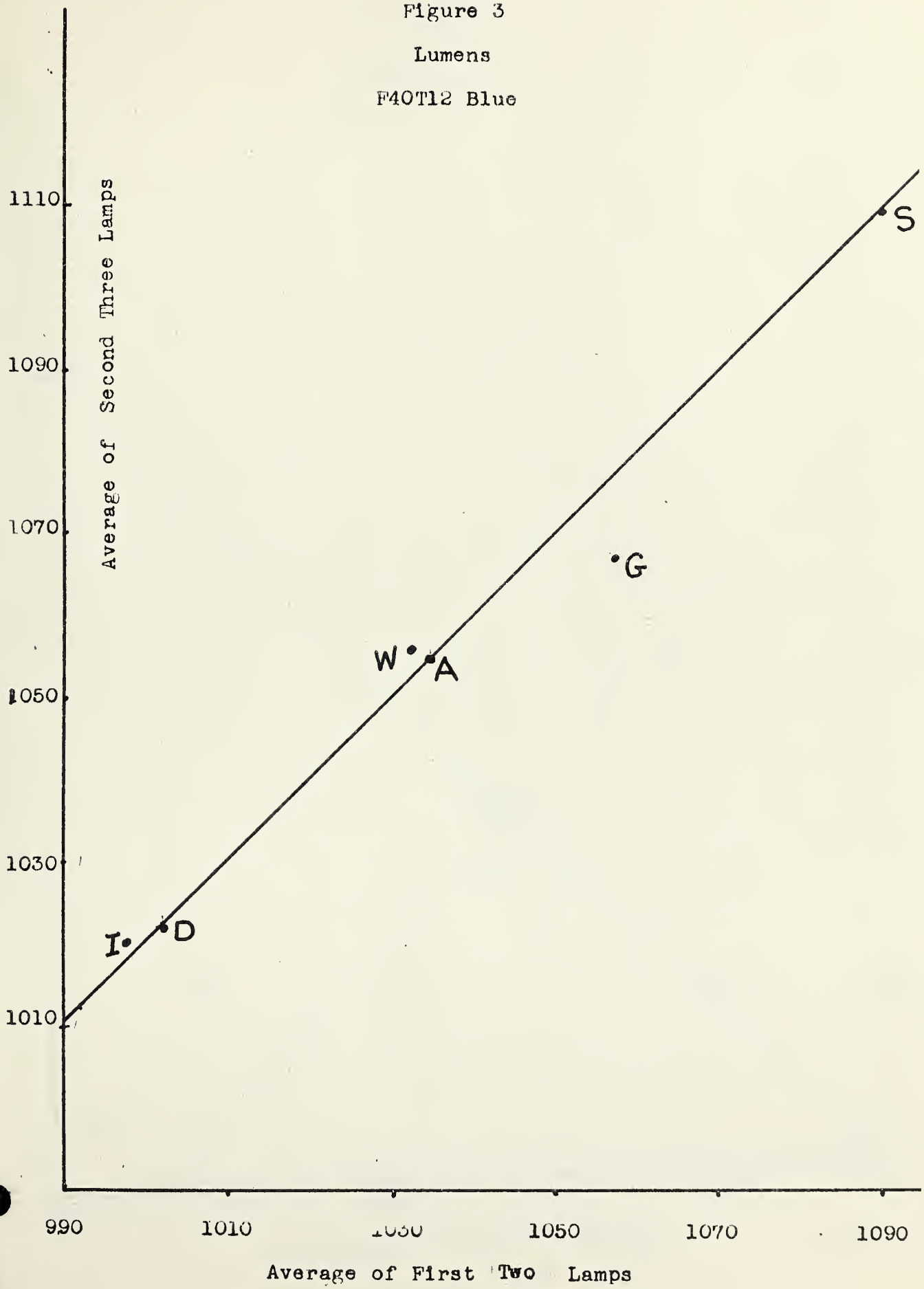


Figure 4

Lumens
F40T12 Green

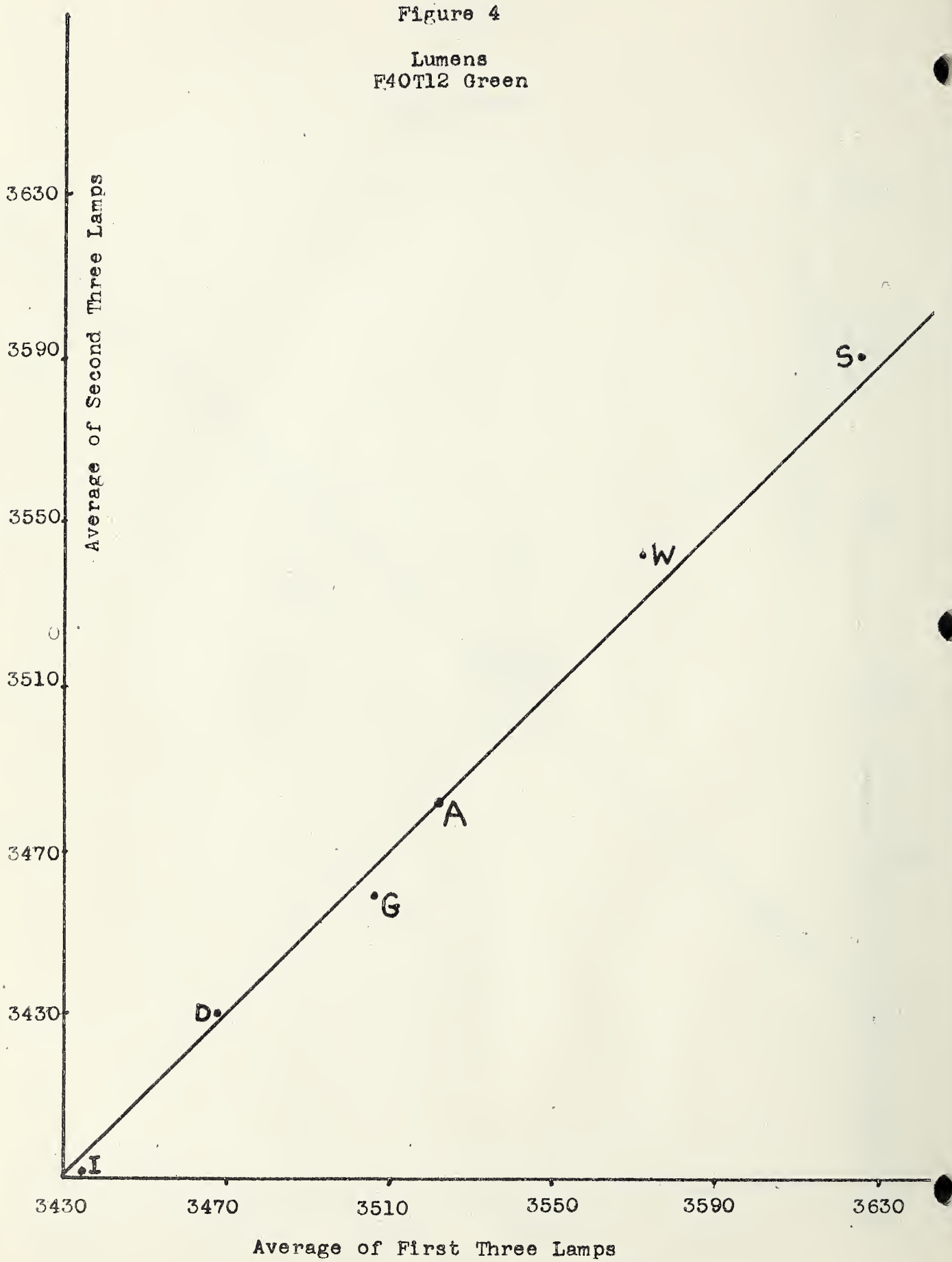


Figure 5

Amperes

F40T12 Pink

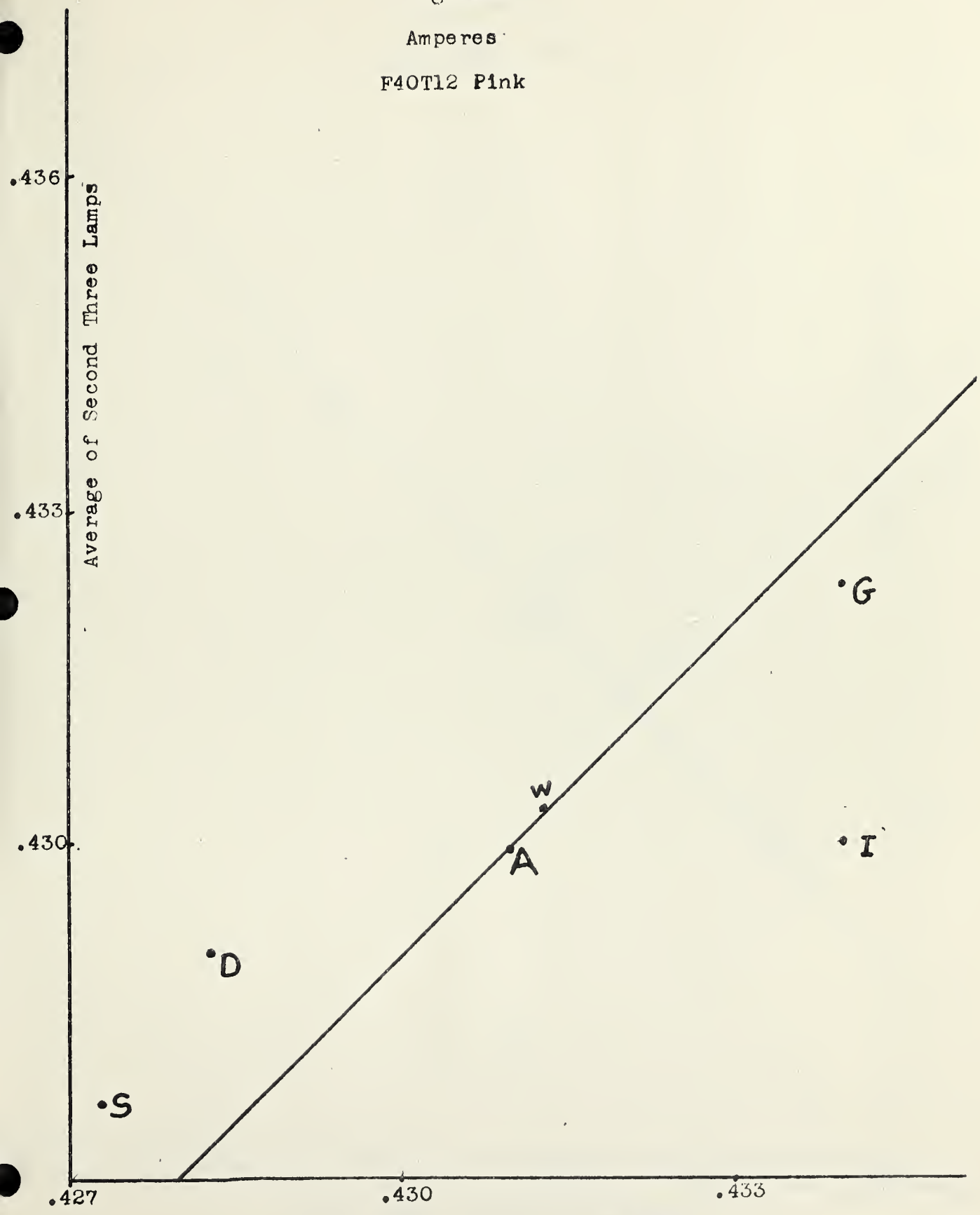


Figure 6

Amperes

F40T12 Gold

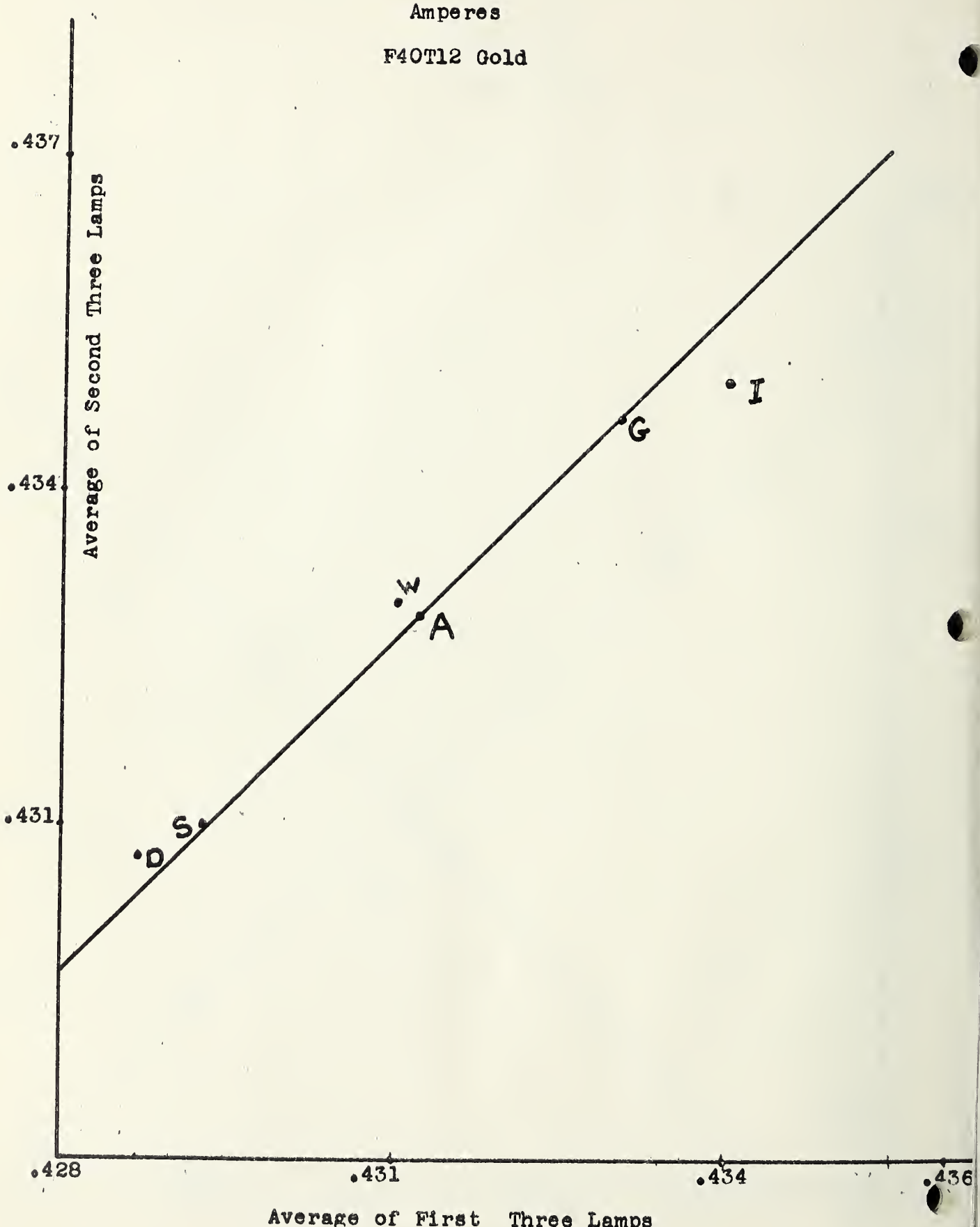


Figure 7.

Amperes

F40T12 Blue

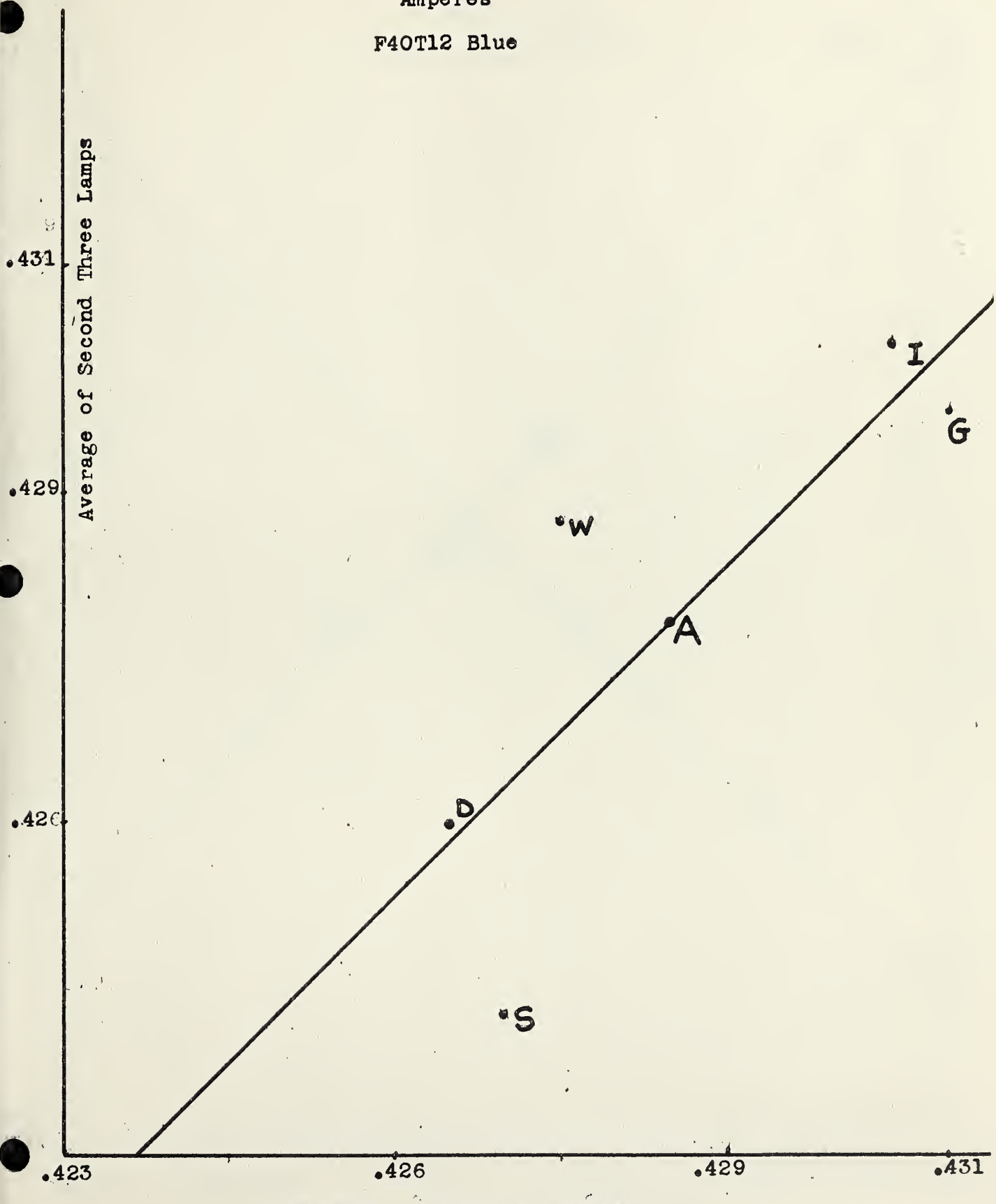


Figure 8

Amperes

F40T12 Green

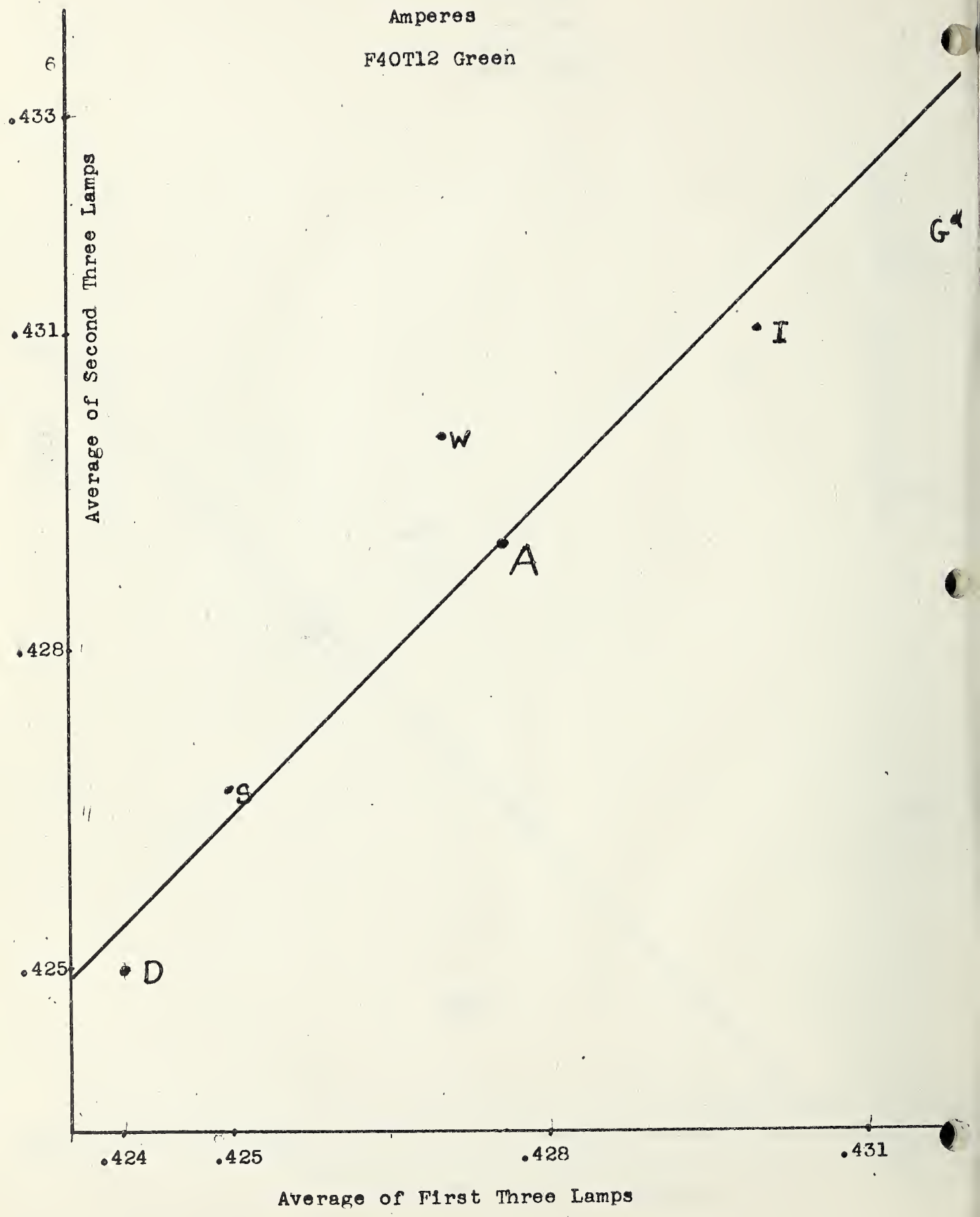


Figure 9

Volts

F40T12 Pink

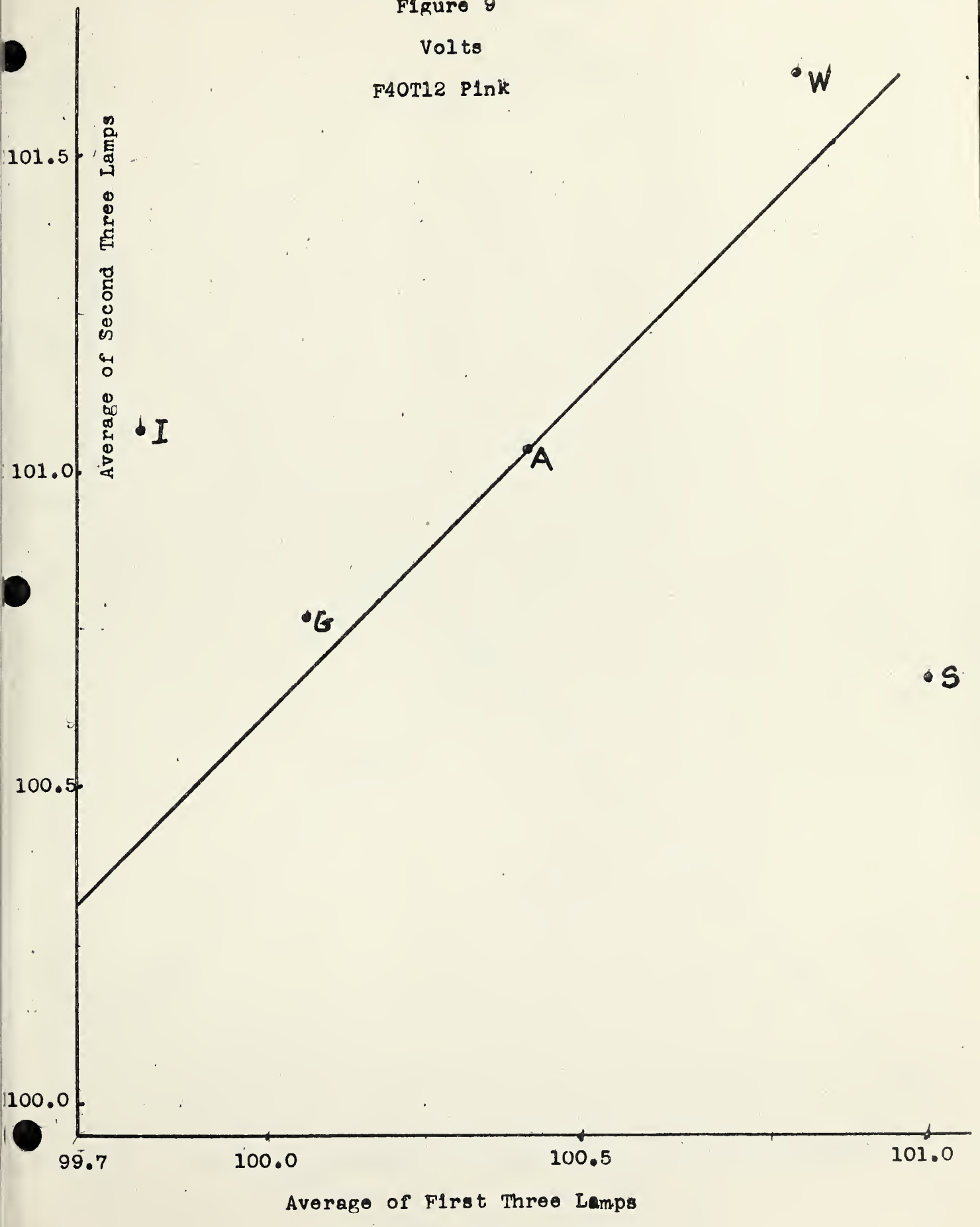


Figure 10

Volts

F40T12 Gold

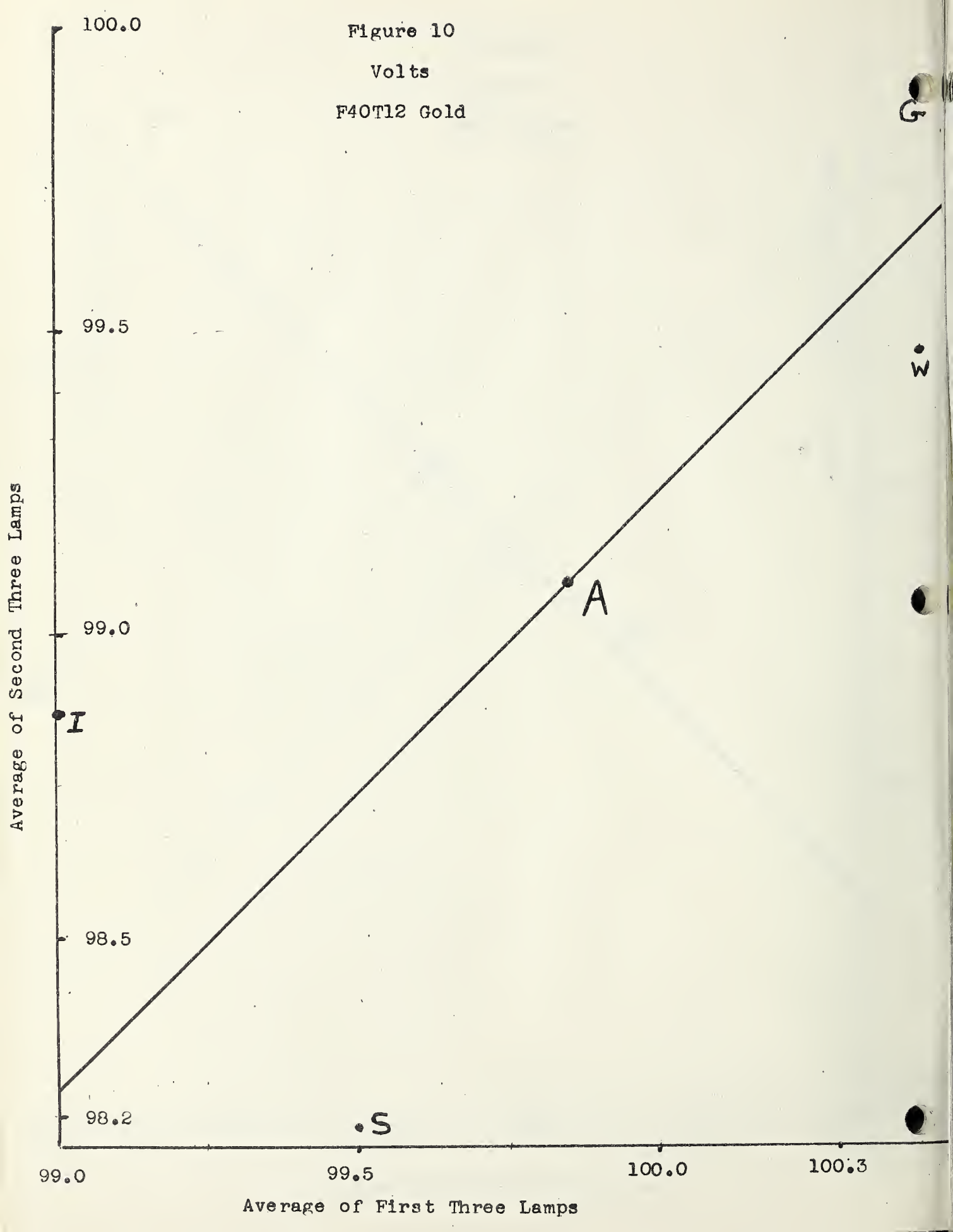


Figure 11

Volts

F40T12 Blue

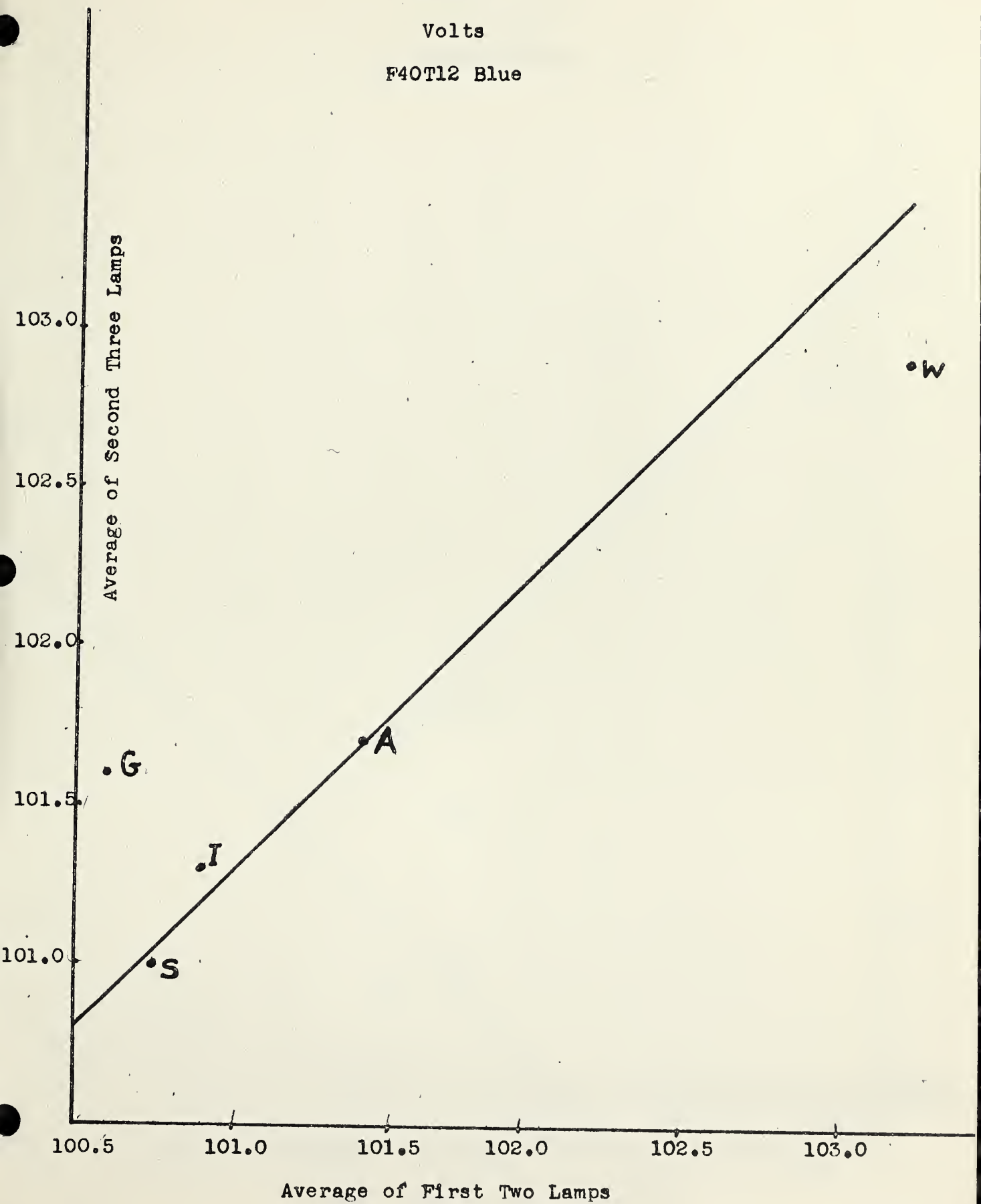


Figure 12
Volts
F40T12 Green

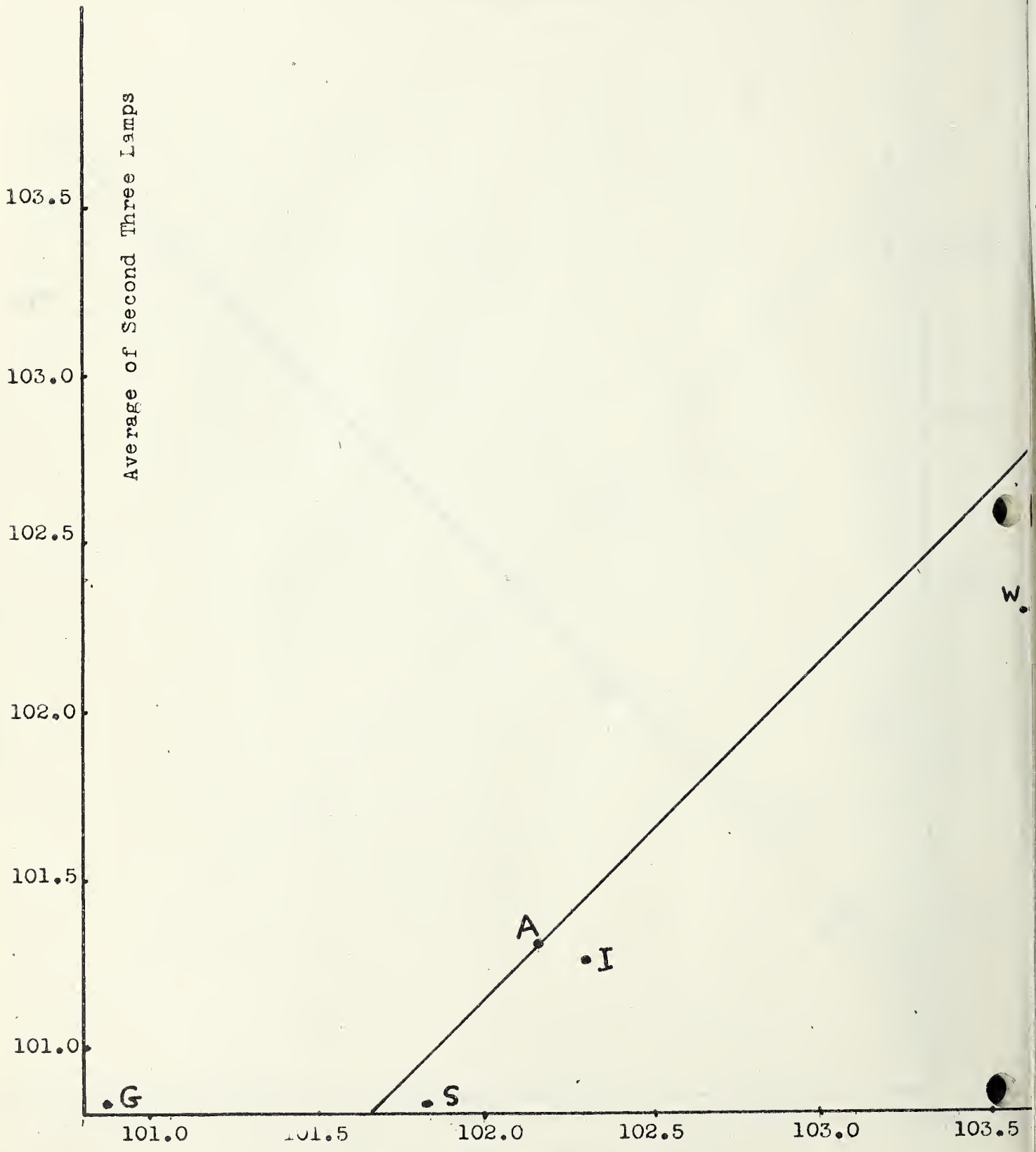


Figure 13

Watts

F40T12 Pink

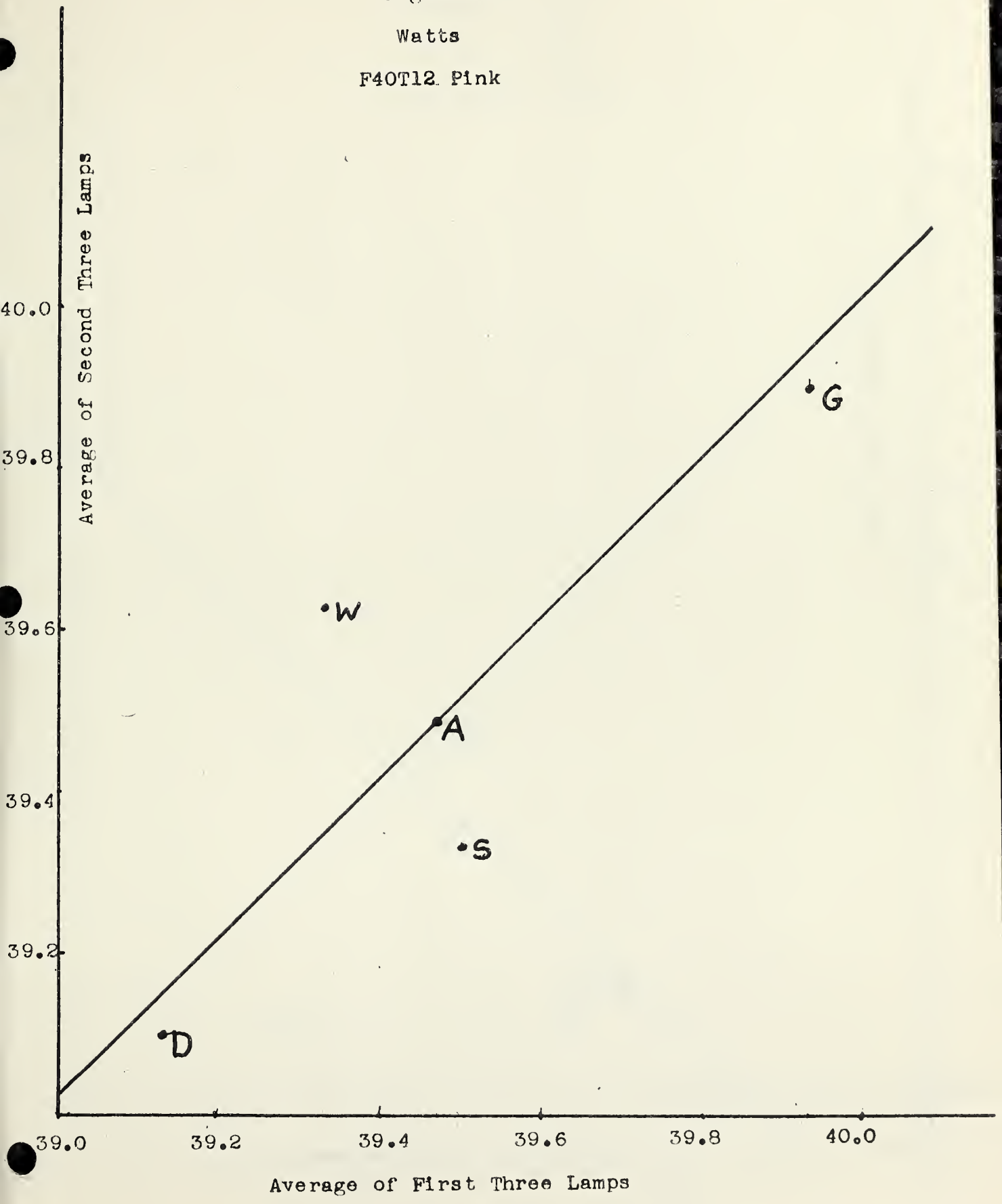


Figure 14

Watts

F40T12 Gold

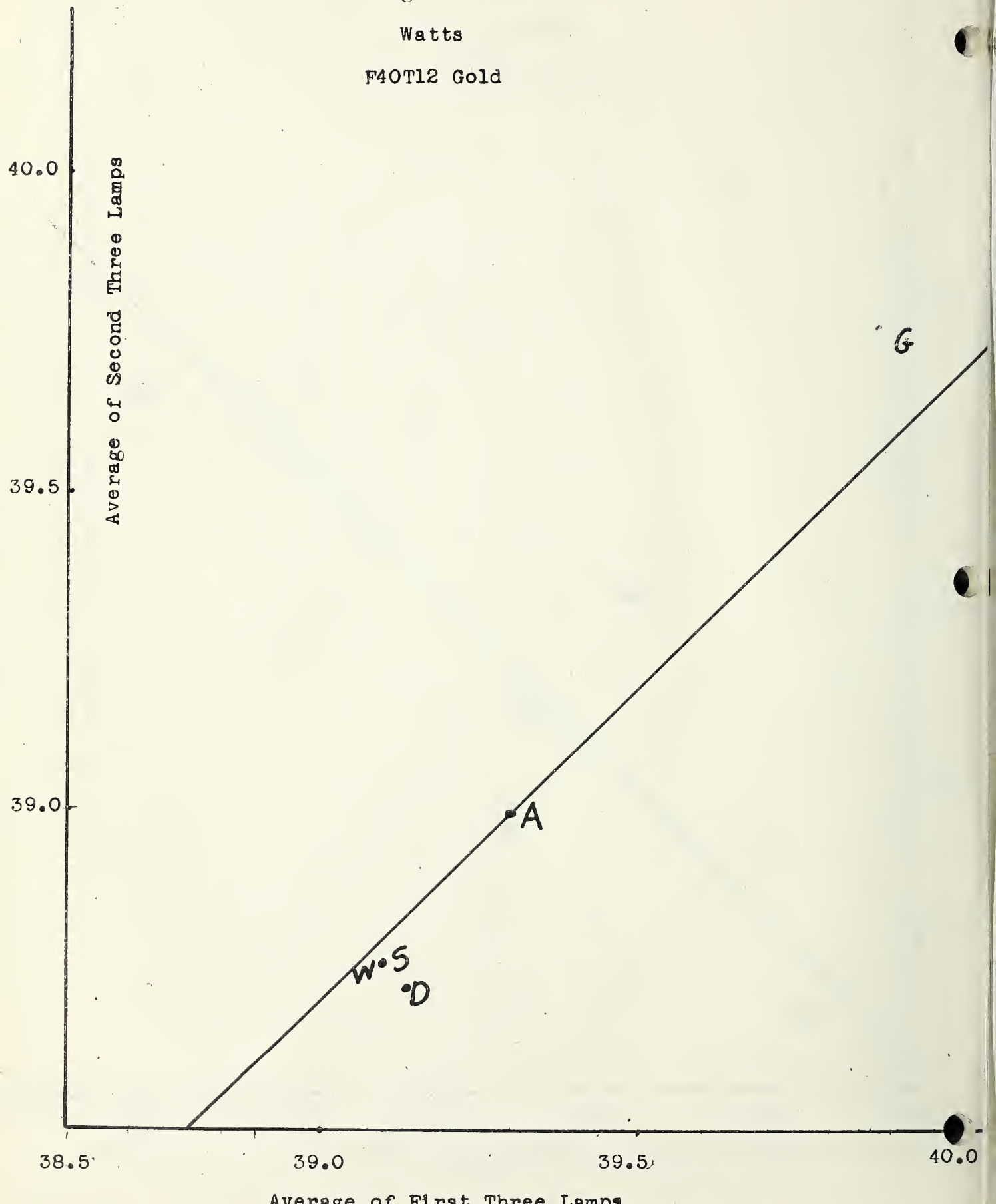


Figure 15

Watts

F40T12 Blue

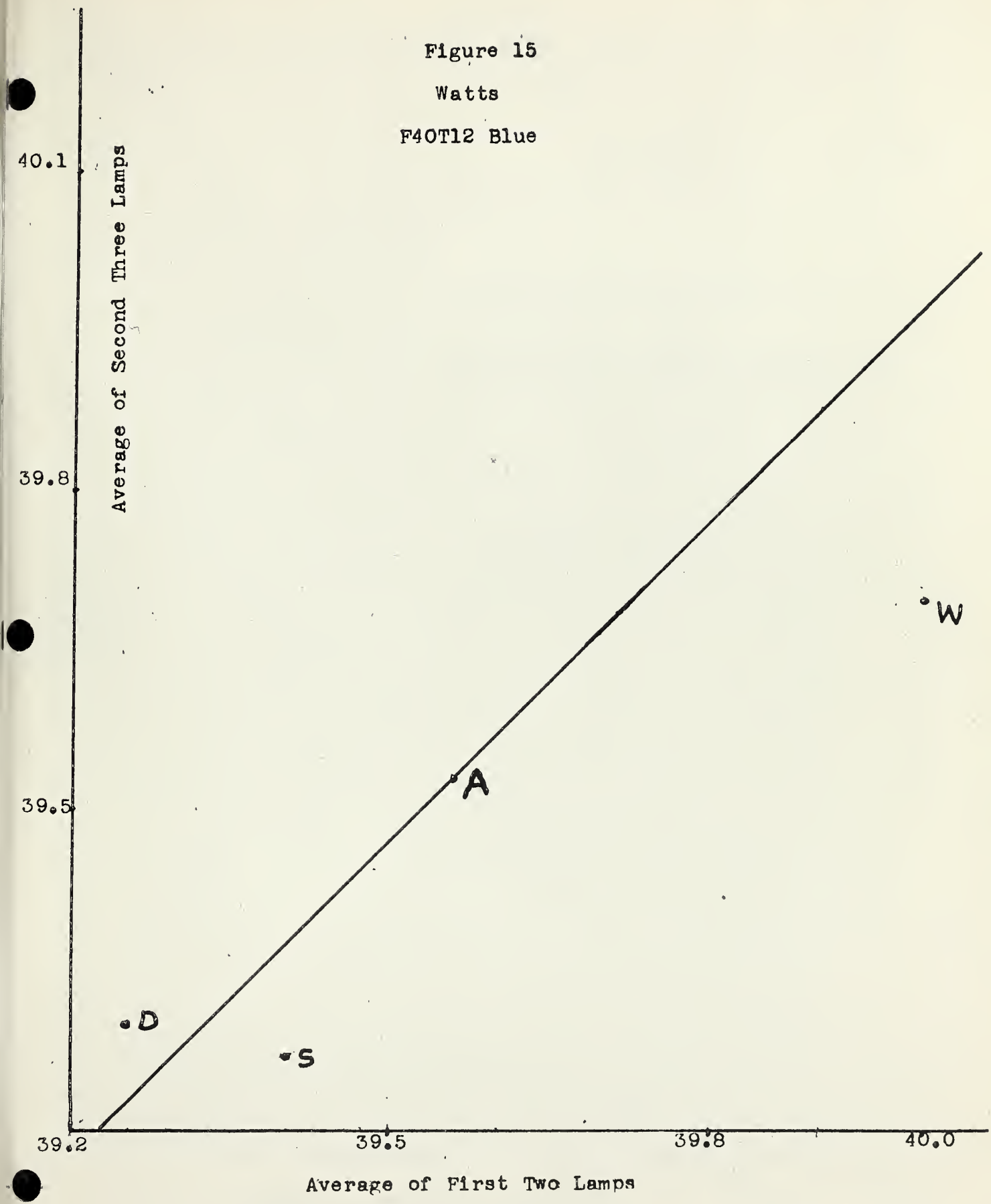


Figure 16

Watts

F40T12 Green

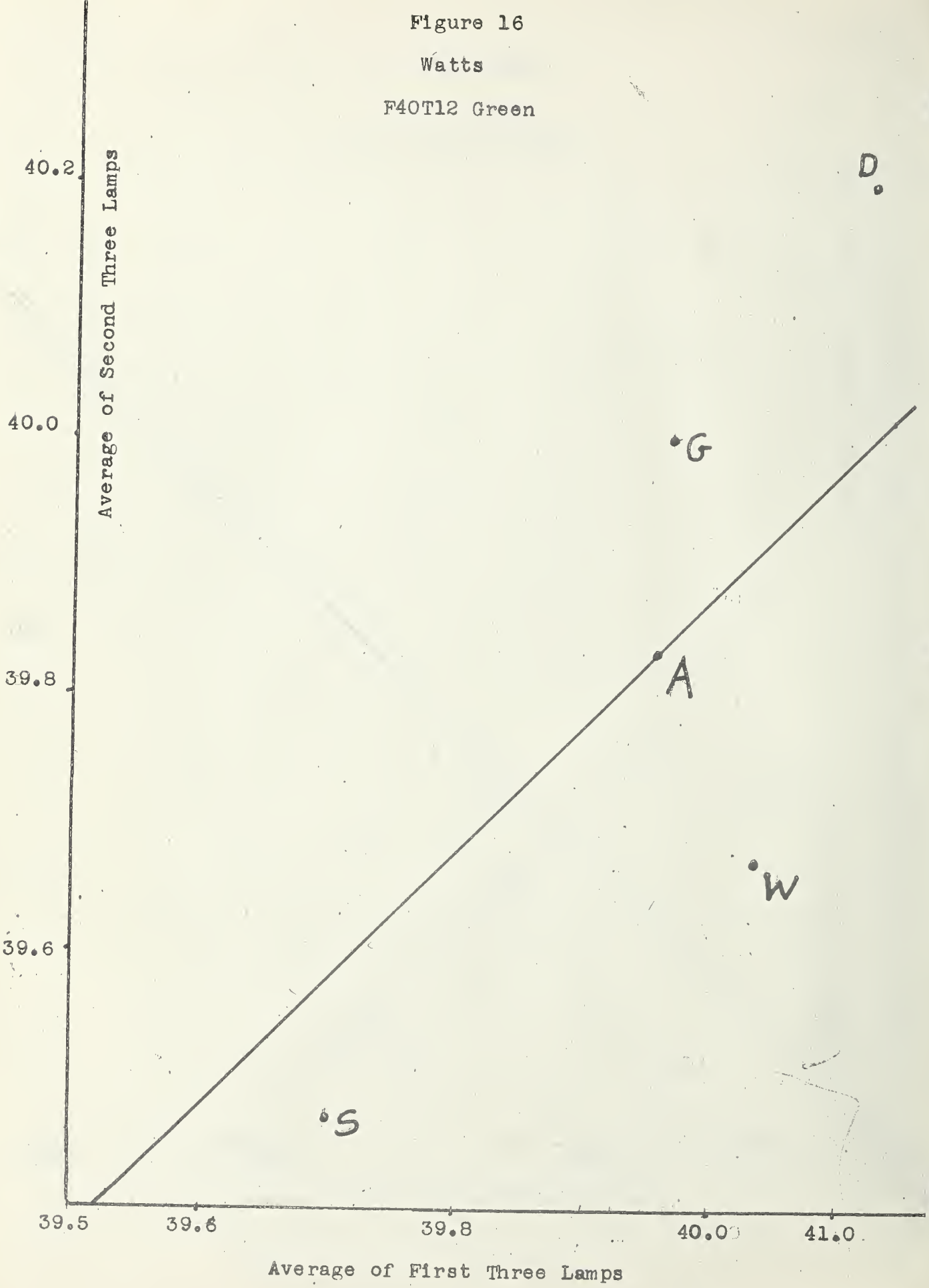


Figure 17

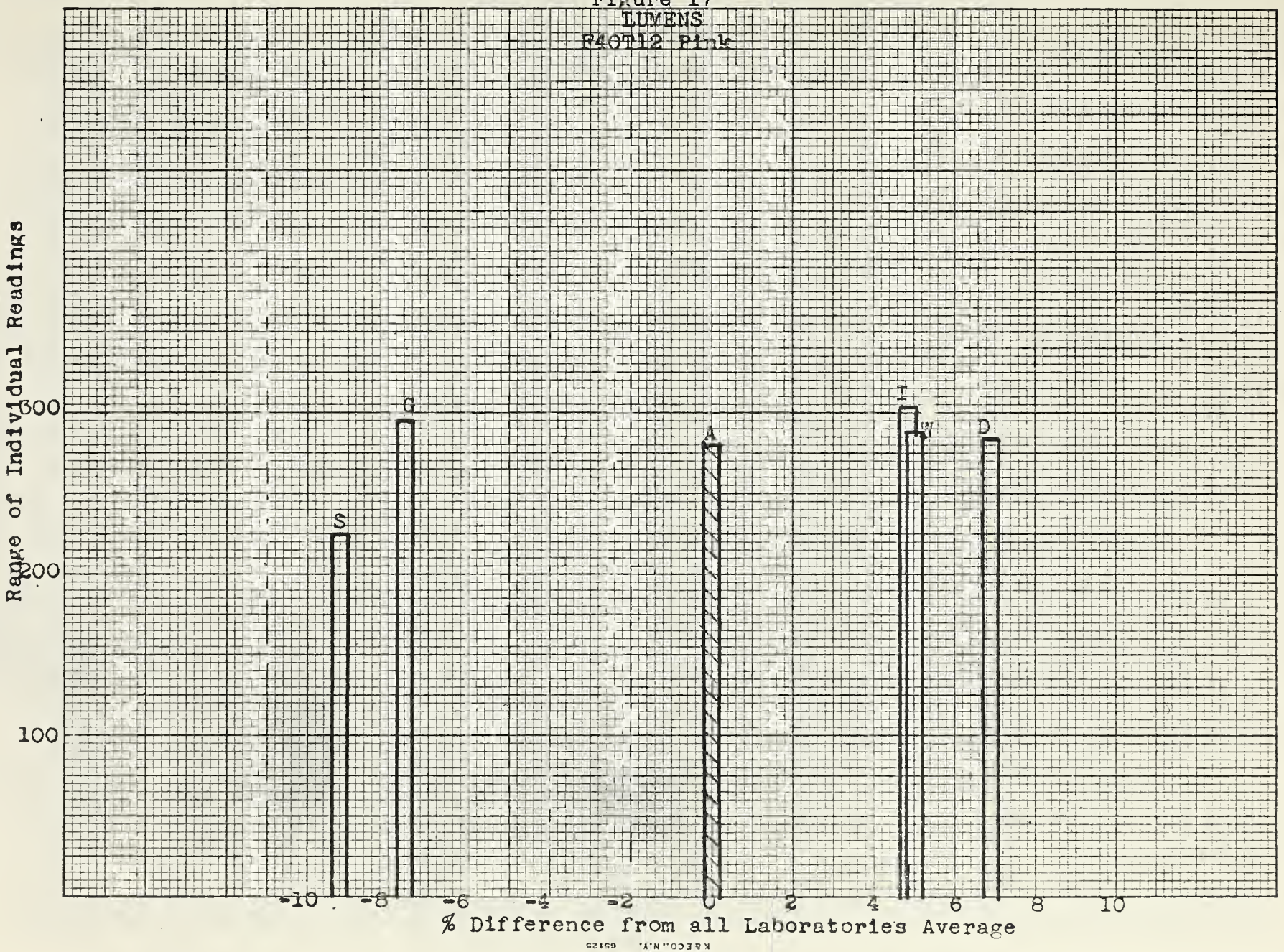

LUMENS
F40T12 Pink
Range of Individual Readings
300
200
100
S
G
A
T
T
D
-10
-8
-6
-4
-2
0
2
4
6
8
10
% Difference from all Laboratories Average

Figure 18

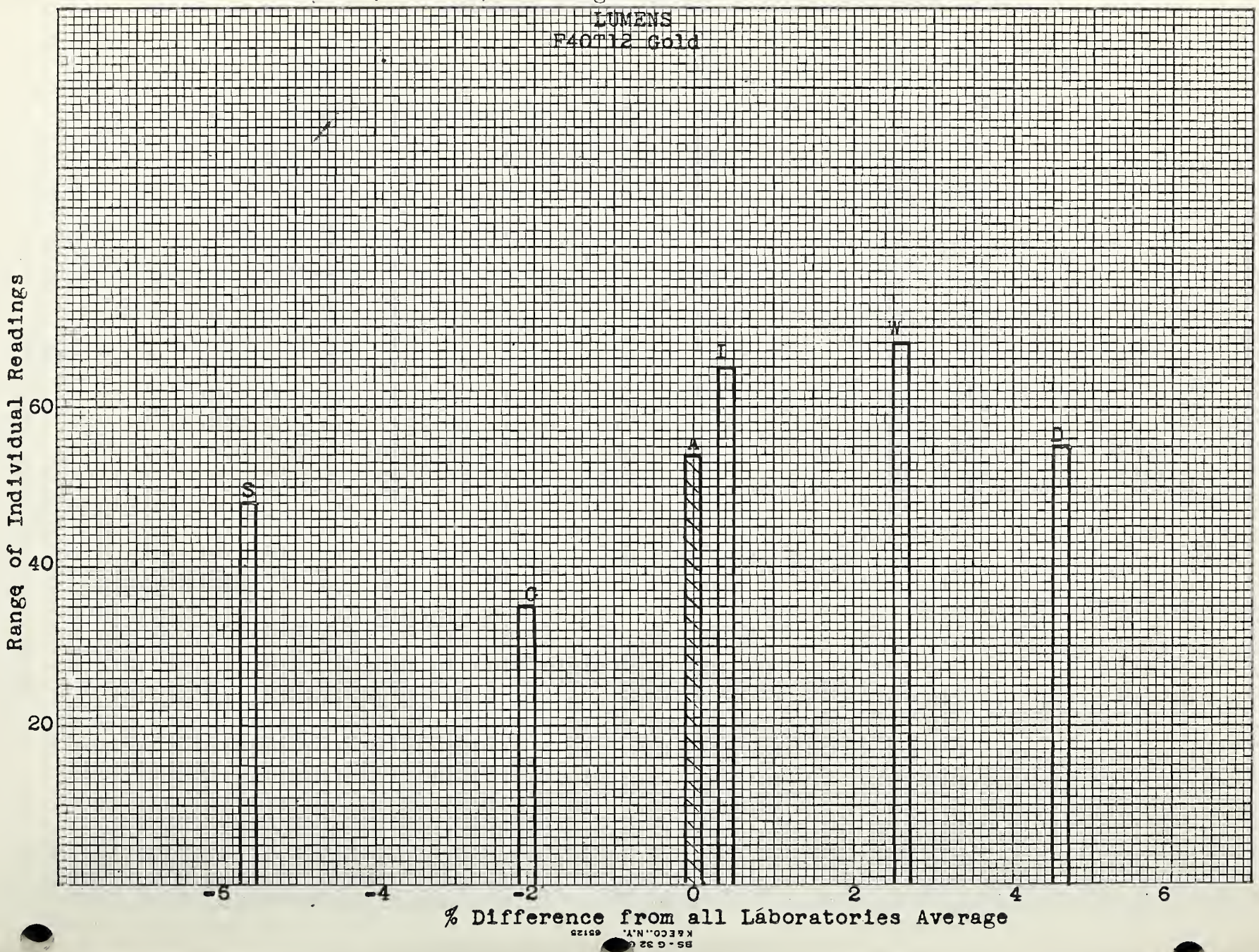

LUMENS
F40T12 Gold
Range of Individual Readings
60
40
20
S
C
A
I
W
D
-5
-4
-2
0
2
4
6
% Difference from all Laboratories Average

Figure 19

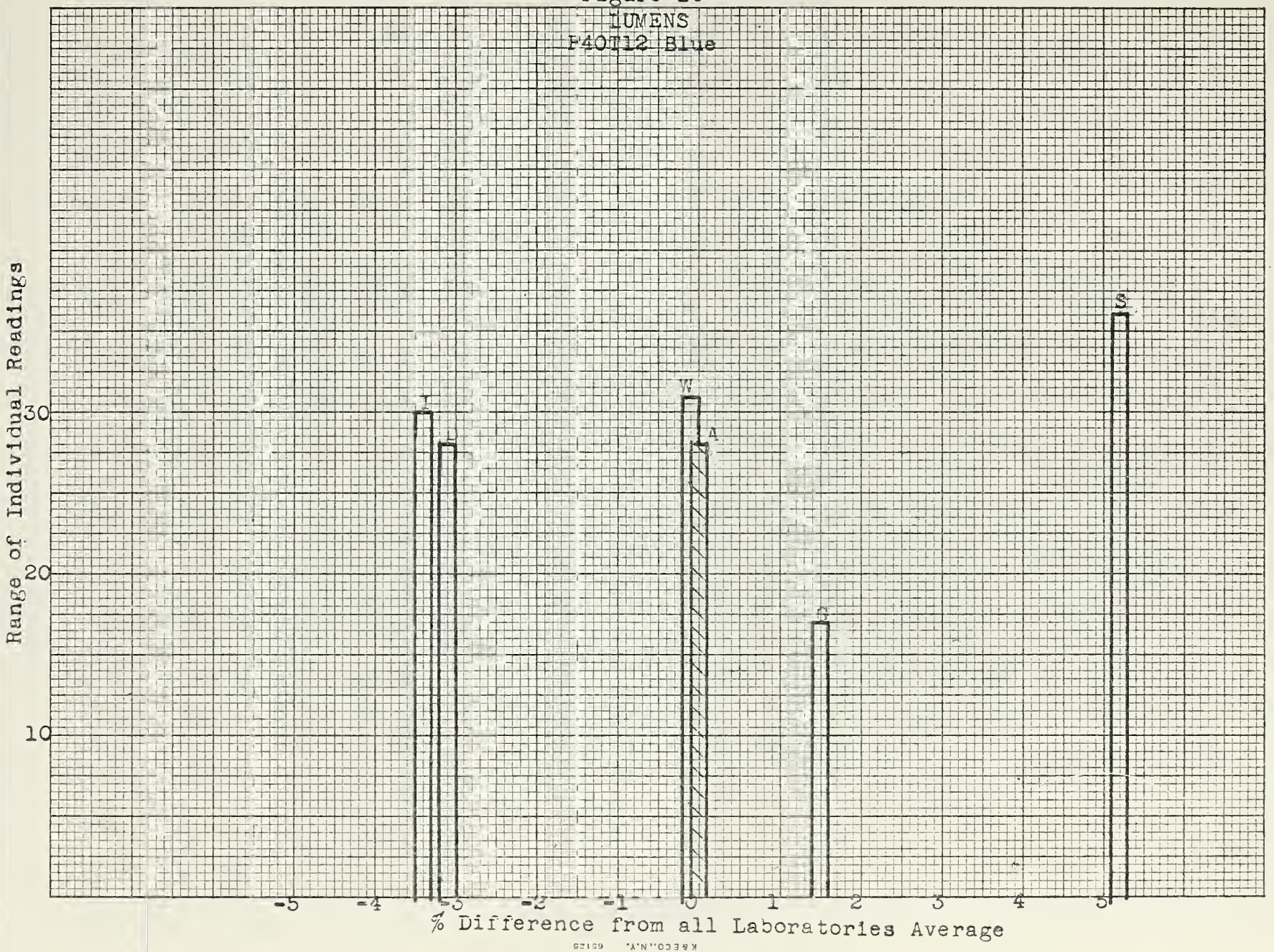
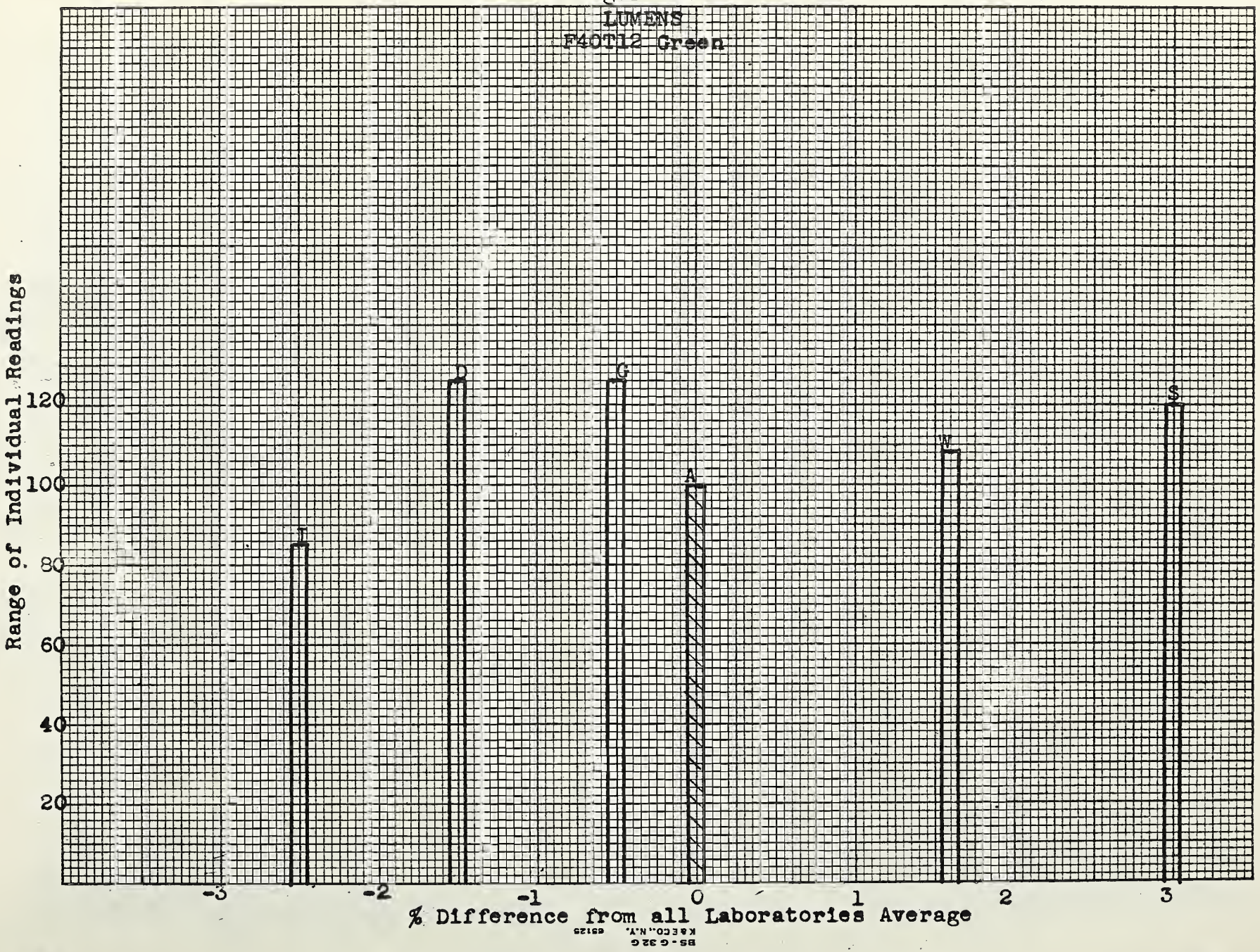

LUMENS
F40T12 Blue
Range of Individual Readings
30
20
10
-5
-4
-3
-2
-1
0
1
2
3
4
5
% Difference from all Laboratories Average
L
E
W
A
D
S

Figure 20


LUMENS
F40T12 Green
Range of Individual Readings
120
100
80
60
40
20
-3
-2
-1
0
1
2
3
% Difference from all Laboratories Average
T
D
G
A
W
$

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, Colo., 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. Resistance and Reactance. Electrochemistry. Electrical Instruments. Magnetic Measurements. Dielectrics.

METROLOGY. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

HEAT. Temperature Physics. Heat Measurements. Cryogenic Physics. Rheology. Molecular Kinetics. Free Radicals Research. Equation of State. Statistical Physics. Molecular Spectroscopy.

RADIATION PHYSICS. X-Ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

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

MECHANICS. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. 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 RESEARCH. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials.

APPLIED MATHEMATICS. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

DATA PROCESSING SYSTEMS. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Applications Engineering.

ATOMIC PHYSICS. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics.

INSTRUMENTATION. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Office of Weights and Measures.

BOULDER, COLO.

CRYOGENIC ENGINEERING. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

IONOSPHERE RESEARCH AND PROPAGATION. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services.

RADIO PROPAGATION ENGINEERING. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

RADIO STANDARDS. High frequency Electrical Standards. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time Standards. Electronic Calibration Center. Millimeter-Wave Research. Microwave Circuit Standards.

RADIO SYSTEMS. High Frequency and Very High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Space Telecommunications.

UPPER ATMOSPHERE AND SPACE PHYSICS. Upper Atmosphere and Plasma Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.


NBS