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Prism contact lens effectivity as related to vertical phoria and duction testing

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Abstract
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PRISM CONTACT LENS EFFECTIVITY AS RELATED TO VERTICAL PHORIA AND DUCTION TESTING

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M.L.O.

J.E.P.

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INTRODUCTION

To date very little research has been done on the relationship of vertical prism in contact lenses to the measured effect on vertical phoria and duction testing. Although several authors state an opinion as to the vertical effectivity of a prism contact lens, there has been little systematic study to support their position.

It is the purpose of this study to investigate the effect of vertical prism in contact lenses on vertical phorias and ductions, both near and far.

REVIEW OF THE LITERATURE

Mandell states in his text that "a phoria of sufficient magnitude to cause subjective symptoms with spectacle lenses will probably cause the same difficulty with contact lenses. Vertical phorias up to 3 prism diopters can be corrected with prism corneal contact lenses."[1] Grosvenor and several other authors have also stated that 3 prism diopters seem to be the maximum amount of prism which can be used in a corneal contact lens for correcting a vertical imbalance.

Girard further states:

> "The use of these lenses to secure a prismatic effect optically has met with little success. First, a thin ophthalmic prism with a given power in air has only about one fourth of the original deviating power when placed in contact with a medium having an index of refraction equal to that of tears.
>
> Consequently, a corneal contact lens that has six diopters of deviation power as measured with a lensometer in air would theoretically have approximately one and one half diopters of potential deviating power when in contact with the eye.
>
> Second, when the lens is in contact with the eye, a new optical condition is established for lens-eye combination. When the prism is combined with the eye in order for a constant prismatic deviating effect to result, not only is it necessary for these separate optical units to have their optic axis decentered by a constant amount, but also the prism must maintain a constant angular orientation about its axis. Since these conditions are not feasible with corneal contact lenses, there will be a highly variable optical prismatic effect ranging from a fraction of the indicated power in air to two or three times this value, depending upon the orientation of this prism on the eye."[2]

In a very limited study, Filderman tested two subjects to determine the effects of surrounding media on prismatic contact lenses.

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1 Mandell, Robert B. Contact Lens Practice: Basic and Advanced, p. 67.

2 Girard, Louis J. Corneal Contact Lenses, p. 290-291.

From this study he concluded that:

> "...the prismatic effect of a contact lens is affected by the indices of the surrounding media. A contact lens when bordered on each side by precorneal fluid has about 25% of the prismatic effect of the same lens when bordered on each side by air. A contact lens bordered on the front surface by air and the rear surface by precorneal fluid has about 63% of the prismatic value of the same lens bordered on each side by air. Considering only indical factors, the effective power on the eye of a given prism is always less than the effective power in air."[3]

A clinic year thesis at the Pacific University College of Optometry, A Study of the Effect of Vertical Prism in Contact Lenses as Related to Changes in Vertical Testing, was submitted to the faculty by Gregory, Hehn, and Milton in January, 1965. The experimenters concluded that with distance Von Graefe and Maddox Rod phorias "all responses of the two tests were less than the prism worn and only the mean responses of the Von Graefe method indicated a possible proportional progression."[4]

---

3 Filderman, Irving P. "The Effect of Surrounding Media on Prismatic Contact Lenses," Optometric Weekly, (July 1, 1965) p. 19.

4 Gregory, R., Hehn, R., Milton, D. A Study of the Effect of Vertical Prism in Contact Lenses as Related to Changes in Vertical Testing, unpublished clinic year thesis, Pacific University College of Optometry, January, 1965.

PROCEDURE

Twenty-six habitual contact lens wearers were tested in this study. The majority of the subjects selected were Pacific University students, while a small number were young adults living in the Forest Grove community.

The lenses used were plano prism contact lenses with base curves ranging from 42.00 to 45.50 diopters in one half diopter steps. Prism values in each of these base curves were approximately three, four, and five prism diopters.

A bite-board was used in the testing in order to minimize the induced prismatic effect from a subject changing head posture relative to the measuring prisms and lenses. The bite-board consisted of two disposable wooden tongue depressors clamped to an adjustable metal stand.

For the phoria measurements a Stevens Phorometer was selected. This phorometer is calibrated in 0.2 prism diopter steps, providing finer graduations than the Risley prism.

The phorometer also enabled the examiners to observe the centering and possible rotation of the contact lenses during the testing sequence. The base-apex line on the three prism diopter lenses was dotted with red ink, insoluble in water and easily seen by the examiner. In no cases was there observed more than a five degree base rotation as compared to the cylinder axis indicator. With the four and five prism diopter lenses, the weight of the base kept rotation to a negligible amount.

In an effort to minimize the effect of lateral heterophoria on the vertical measurements, a fused vertical component was used for the near test targets. For the vertical ductions, the subject fused one vertical line and reported when the horizontal line doubled and then become one again. (See figure 1) The vertical phorias were taken by first breaking the two vertical lines into four by the introduction of large amounts of base-in prism. (See figure 2) This prism was gradually reduced until the two inner vertical lines became fused. Vertical phorias were then measured by aligning the two horizontal lines. (See figure 3)

Prior to any testing sequence, the dominant eye of the subject was determined. At this time the subject was instructed to remove the lens from the dominant eye and a keratometer reading was taken. While one experimenter was taking the keratometer reading, the other neutralized the subject's contact lens. Three, four, and five prism diopter lenses with base curves paralleling the flattest keratometer finding were selected from the trial lens set.

Each subject inserted his habitual lens and was seated in the refracting chair. The bite-board was positioned and the subject instructed to bite down on it. The phorometer was then moved into position and adjusted for the subject's interpupillary distance. The subject was centered relative to the optical centers of the lenses with a pin hole disc.

First a series of Von Graefe phorias were taken at eighteen feet with the subject fixating a 20/40 line of letters. Ten measurements were taken: five with the left eye fixating and five with the right eye fixating. The first two measurements in each series were used to familiarize the subject with the procedure and only the last three were recorded.

The same procedure was repeated for the Maddox Rod phorias, OD measuring and OS measuring, with the subject fixating a spot of light on the wall.

Next, both supra and infra ductions for right and left eye were measured using the standard Risley prisms.

Following the far testing, the interpupillary distance was adjusted for near and the near target swung into place.

A series of Von Graefe phorias were taken at sixteen inches with the subject fixating the horizontal line. As in the previous tests, a series of ten measurements were taken: five with left eye fixating and five with right eye fixating. Only the last three measurements of each series were recorded.

Near duction testing was done by using the standard Risley prisms. Both supra and infra ductions were measured for right and left eye.

This completed the testing through the habitual contact lens. The phorometer was moved away and the subject removed the habitual lens from the dominant eye, and placed the three prism diopter lens on this eye. The testing procedure was repeated for the three, four, and five prism diopter lenses.

In nearly every case, when the subject's wearing four and five prism diopter lenses were tested, the measured hyperphoria was equal to, or above, the limits of the measuring capability of the Stevens phorometer. In such a situation, a loose prism base down was added in the lens well before the non-dominant eye. Since the lens well was four centimeters closer to the center of rotation of the eye than was the measuring prism, the effective prism power at the measuring plane was calculated. Using the formula $E = \frac{d - T'}{d}$ (Prism); where E is effective prism; prism is the prismatic effect measured in a lensometer; d is the target distance from the center of rotation of the eye; and T' is the distance of the measuring prism from the center of rotation. The difference in effective prism at the measuring plane was negligible when testing at eighteen feet, but was considered at the sixteen inch testing distance. This difference in effective prism was considered negligible for the near ductions since the planes of the Risley prism and the loose prism were nearly coincident.

The experimenters were aware of the tendency for some subjects to readily adapt to vertical prism. To minimize this adaption, the testing was started as soon as excessive lacrimation subsided. Since the subjects were habitual contact lens wearers, this delay in testing was generally under one minute.

On a small minority of the subjects, monocular diplopia was caused by the poor centering of the prism contact lens. Due to the presence of these images during the phoria testing, two subjects became confused as to which images to align. These two cases were excluded from the final population considered in the statistical analysis.

The third subject excluded from the population was troubled with an alternate suppression, especially during the near testing.

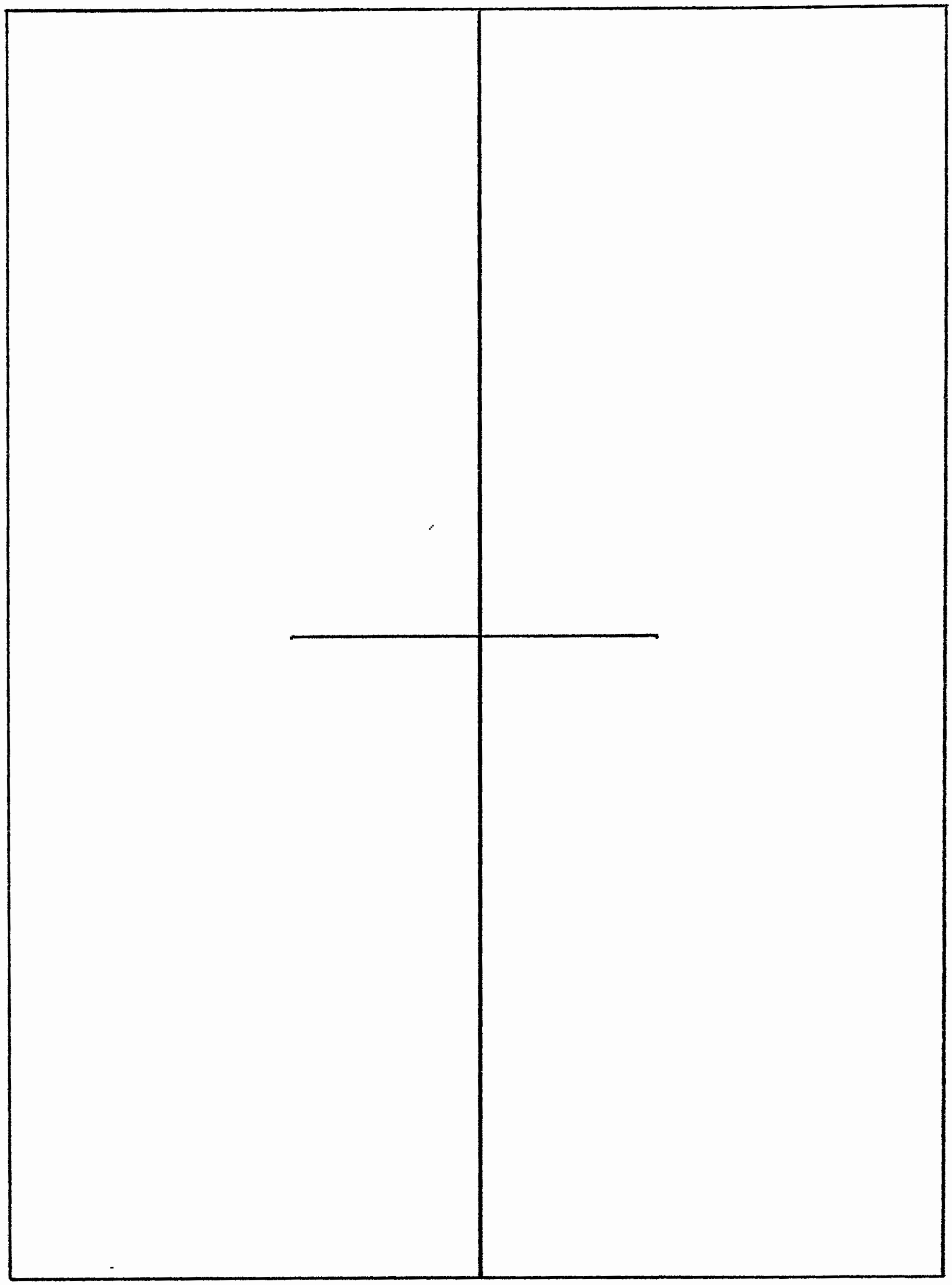


Figure I

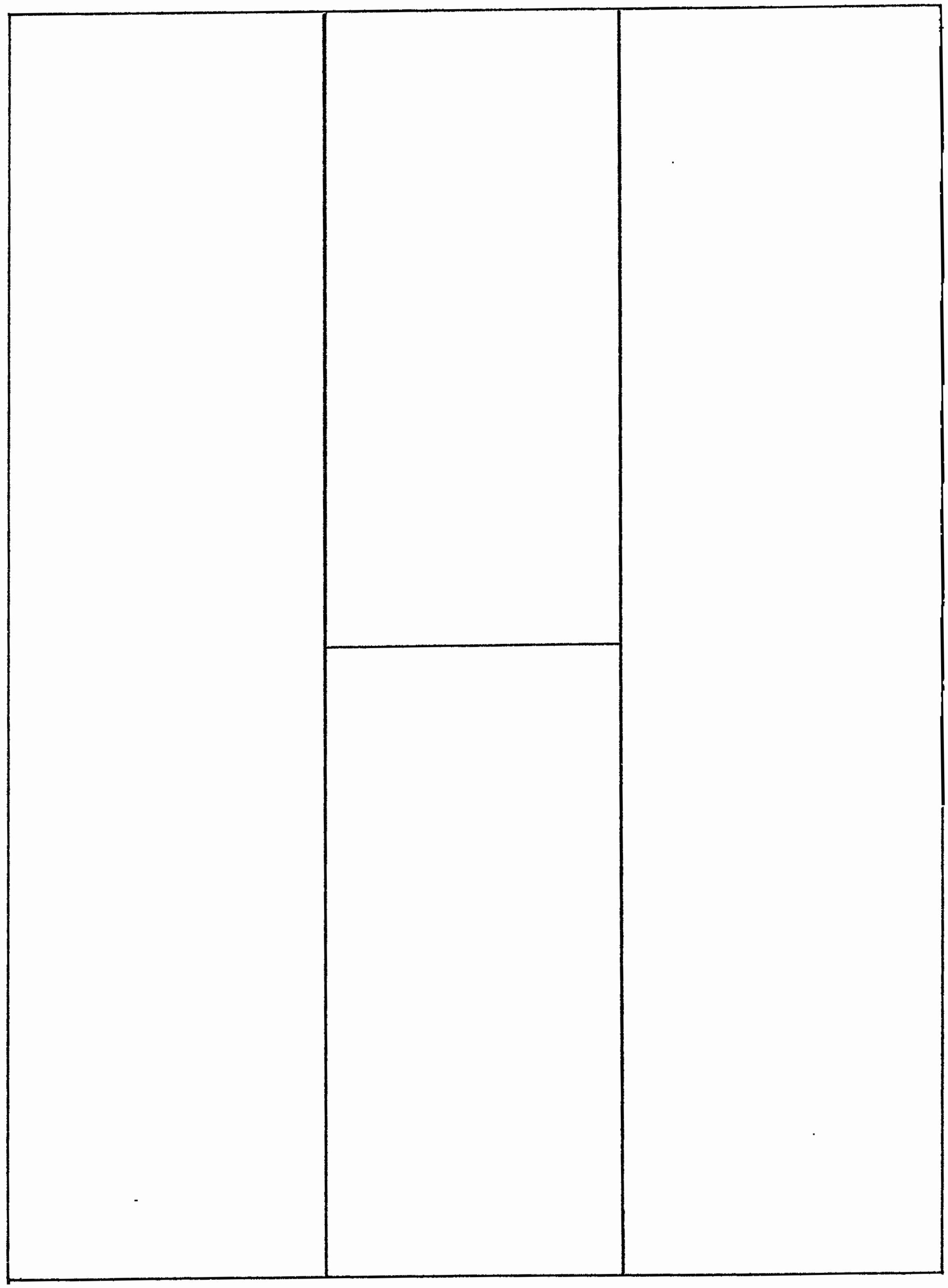


Figure 2

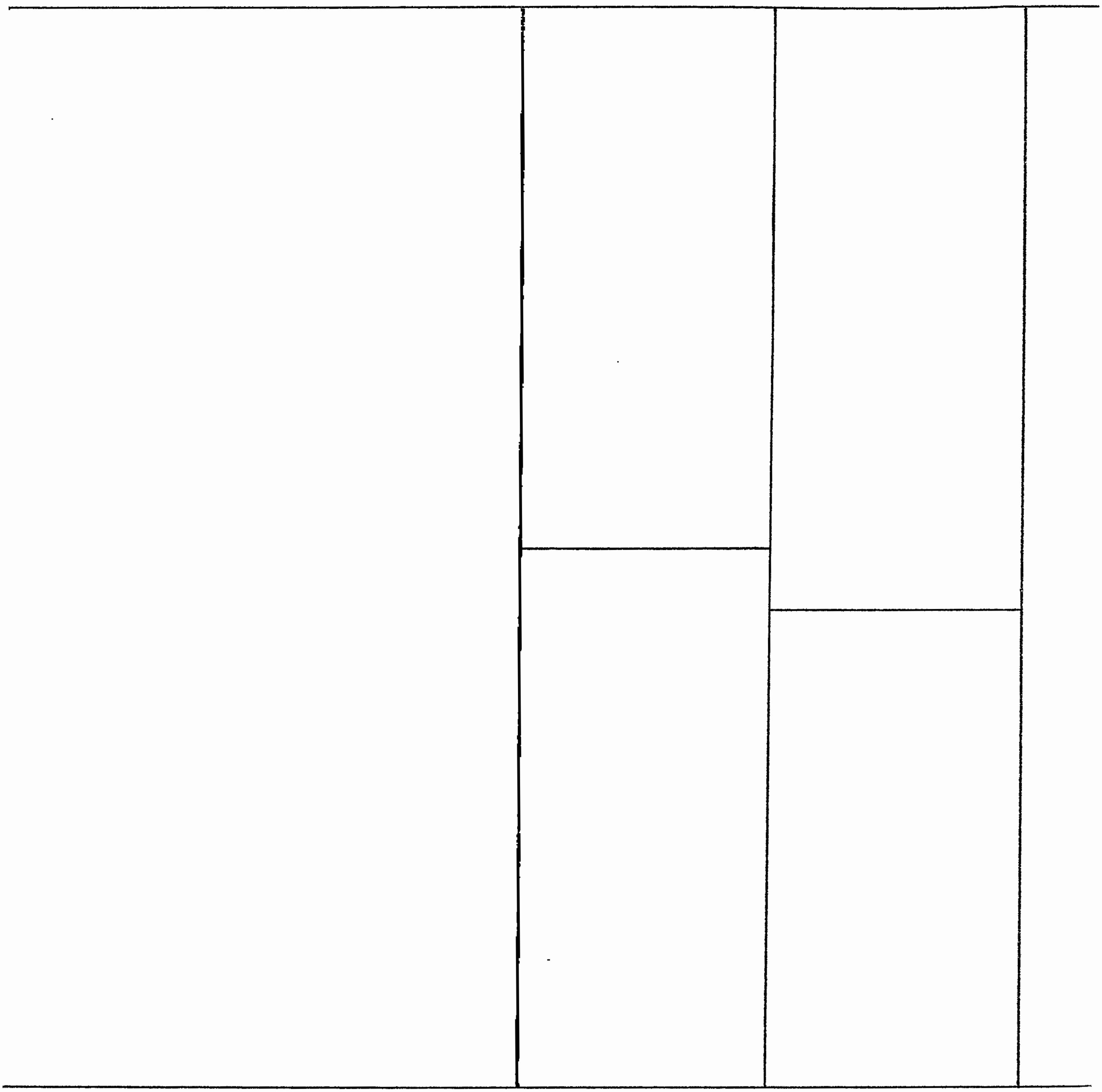


Figure 3

Formulae Utilized

1) Mean

$\bar{X} = X/n$

2) Variance

$S^2 = \Sigma y^2/n$

3) Standard Deviation

$S = \sqrt{\Sigma y^2/n}$

4) $\Sigma x^2 = \Sigma X^2 - (\Sigma X)^2/n$

$\Sigma y^2 = \Sigma Y^2 - (\Sigma Y)^2/n$

$\Sigma xy = \Sigma XY - (\Sigma X)(\Sigma Y)/n$

5) Correlation Coefficient

$$r = \frac{\Sigma xy}{\sqrt{\Sigma x^2 \Sigma y^2}}$$

6) Standard Error of Estimate

$$\Sigma(y - \tilde{y})^2 = \Sigma y^2 - (\Sigma xy)^2/\Sigma x^2$$

$$s_{y.x} = \sqrt{\frac{(y - \tilde{y})^2}{n - 2}}$$

7) Regression Line

$b_{x.y} = \Sigma xy/\Sigma y^2$

TABULATED STATISTICS

Measure	$\bar{Y}$	$\bar{X}$	S	$b_{y.x}$	$b_{x.y}$	$s_{y.x}$	$r_{3^\Delta - 5^\Delta}$
3^Δ $VG_{20'}$	2.393	2.771	1.136	-	-	-	.335
4^Δ $VG_{20'}$	4.021	3.741	1.403	-	-	-	-
5^Δ $VG_{20'}$	5.185	4.988	1.690	.498	.225	.756	
3^Δ $MR_{20'}$	2.326	2.771	1.218	-	-	-	.01
4^Δ $MR_{20'}$	4.197	3.714	0.990	-	-	-	-
5^Δ $MR_{20'}$	5.290	4.988	1.240	.011	.01	1.30	-
3^Δ $VG_{16''}$	2.325	2.771	1.510	-	-	-	.184
4^Δ $VG_{16''}$	4.049	3.741	1.480	-	-	-	-
5^Δ $VG_{16''}$	5.561	4.988	1.850	.224	.150	1.62	-
Duction Balance @ 20 feet							
3^Δ	2.290	2.771	0.796	-	-	-	.525
4^Δ	3.926	3.741	1.118	-	-	-	-
5^Δ	5.063	4.988	0.840	.555	.498	0.74	-
Duction Balance @ 16 inches							
3^Δ	3.092	2.771	0.935	-	-	-	.133
4^Δ	4.613	3.741	1.00	-	-	-	-
5^Δ	5.611	4.988	1.485	.211	.084	1.510	-

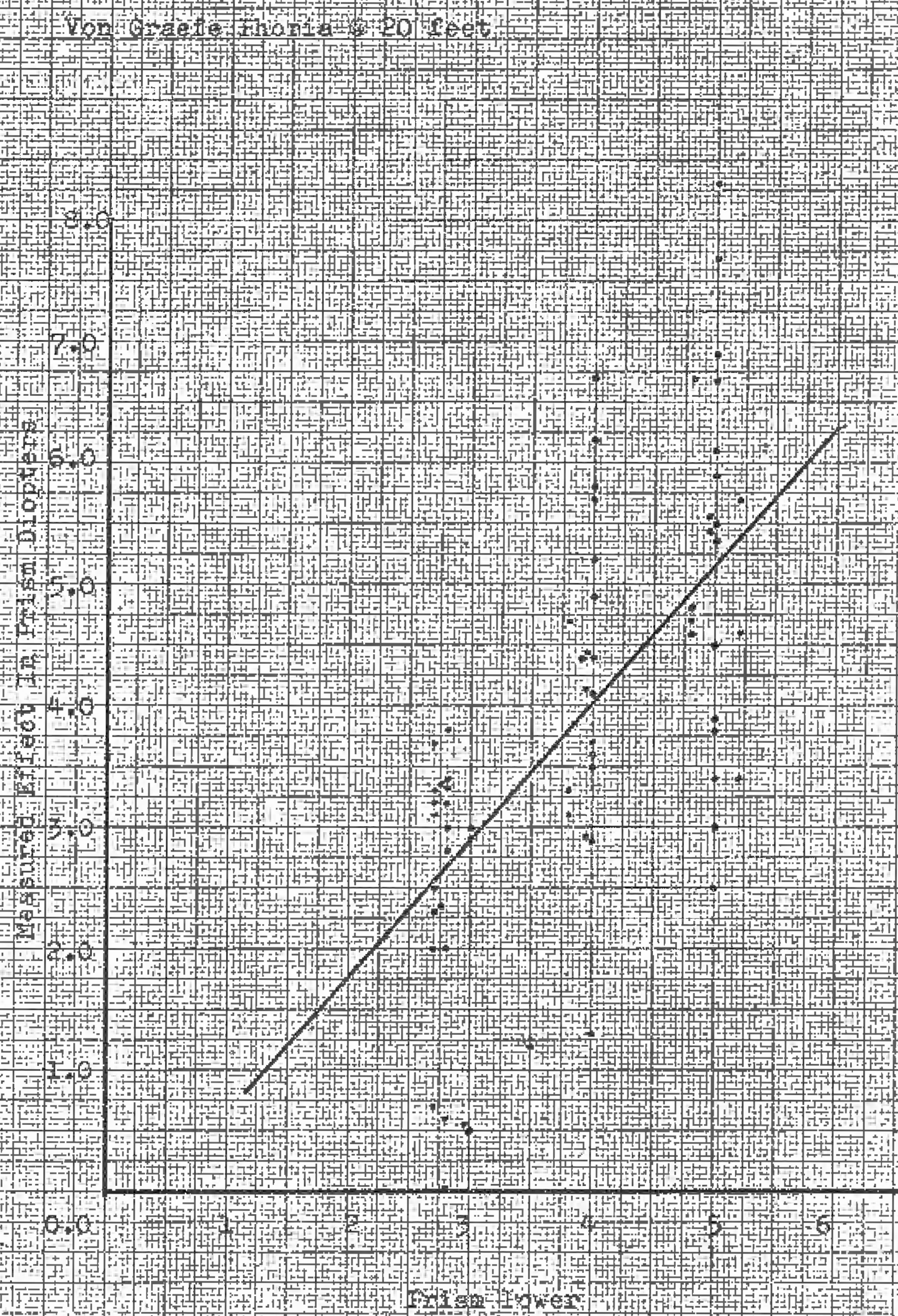

Von Graefe Phoria @ 20 feet
Measured Effect In Prism Diopters
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1
2
3
4
5
6
Prism Power

Figure 4

Von Graefe Phoria @ 20 feet

1) Line of Best Fit

$\tilde{Y} = a + bX$

$\tilde{Y} = -.464 + (1.126)X$

2) Regression Line

a) $b_{x.y}$

$Y_3 = b(Y_5 - \bar{Y}_5) + \bar{Y}_3$

$Y_3 = 2.25(Y_5 - 5.19) + 2.39$

b) $b_{y.x}$

$Y_5 = b(Y_3 - \bar{Y}_3) + \bar{Y}_5$

$Y_5 = .498(Y_3 - 2.39) + 5.19$

Von Graefe Phoria @ 20 feet – 3^{Δ} effect plotted against 5^{Δ} effect.

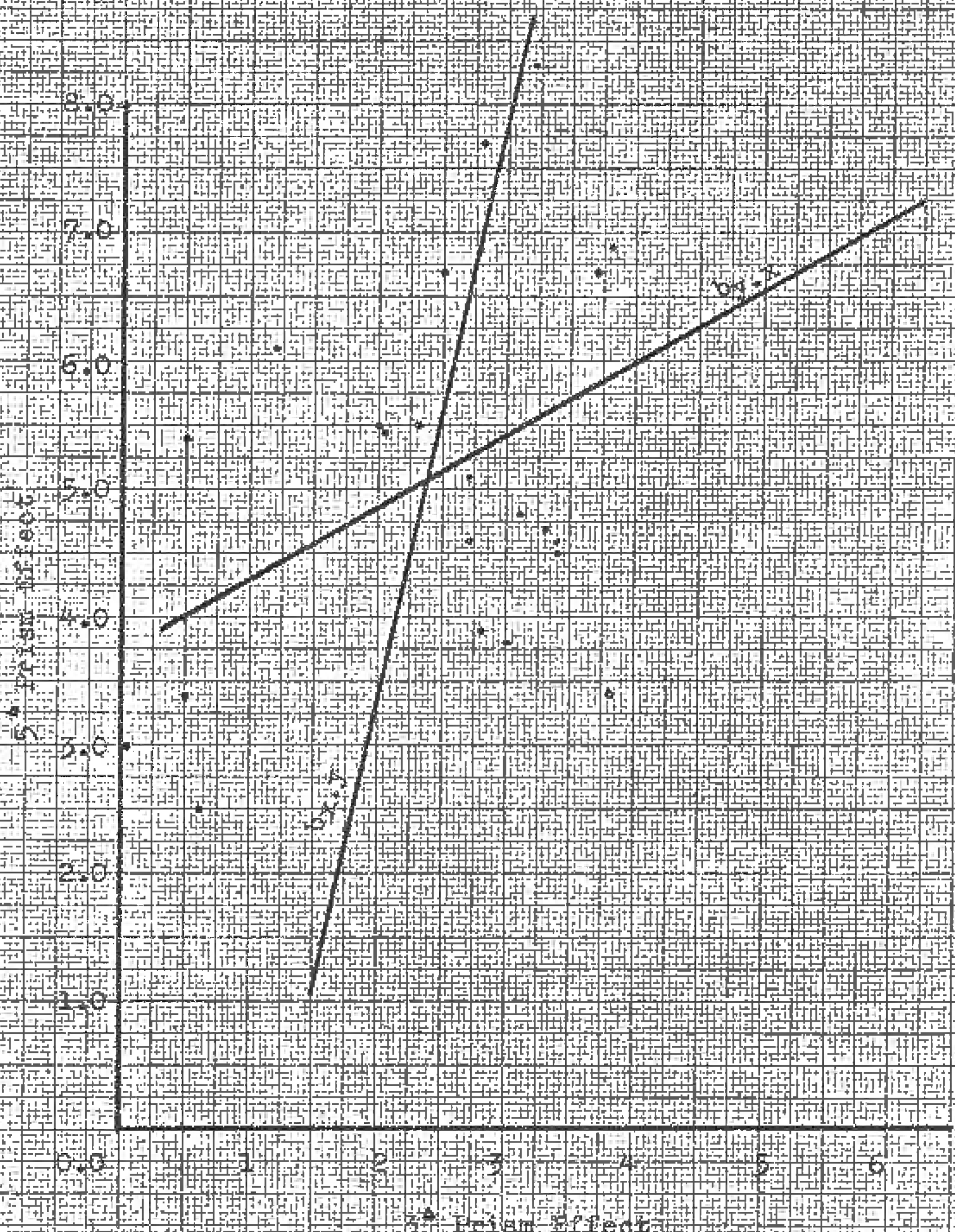


Figure 5

12-188

Von Greefe Phoria @ 20 feet - Percent Effectivity

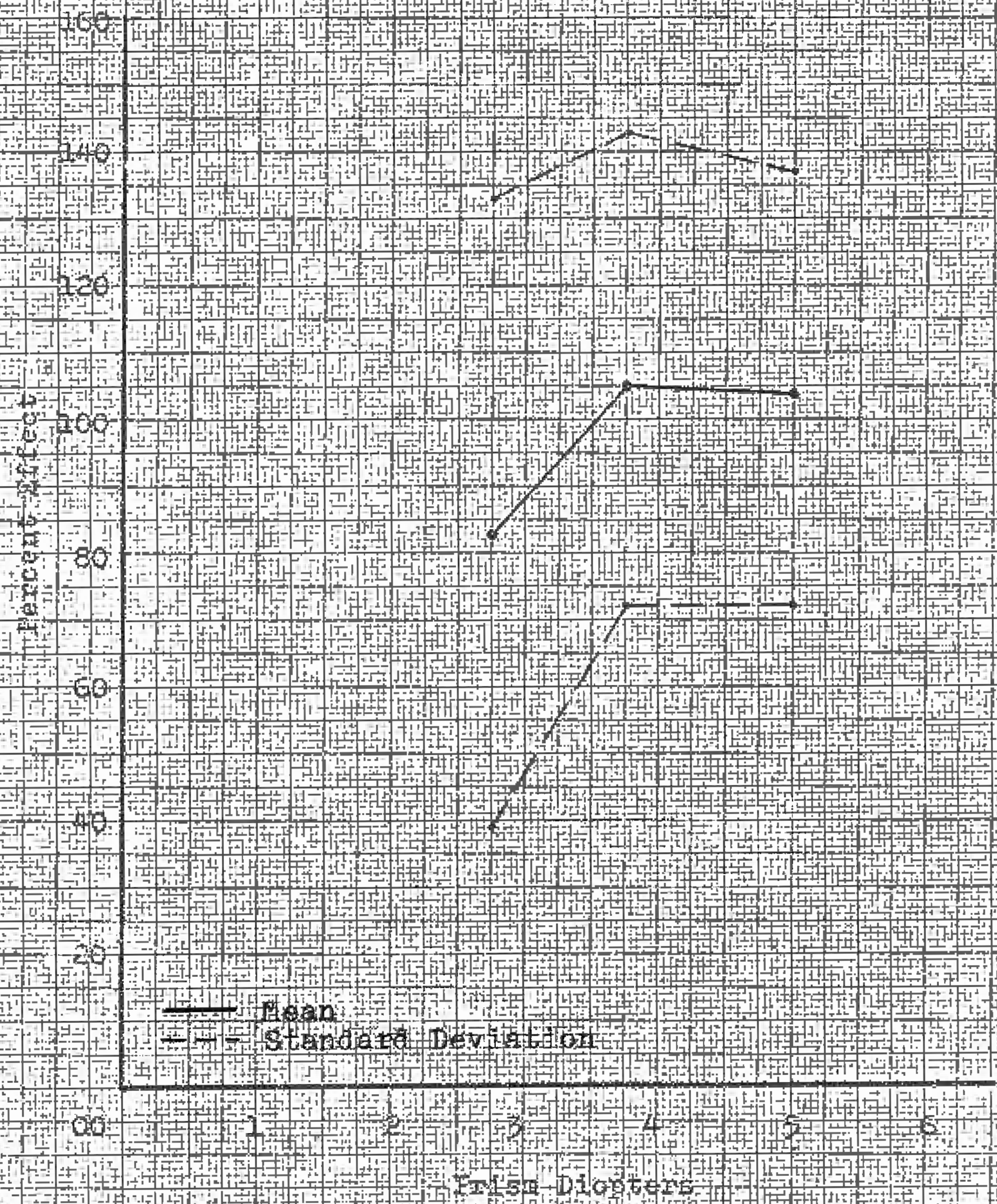


Figure 6

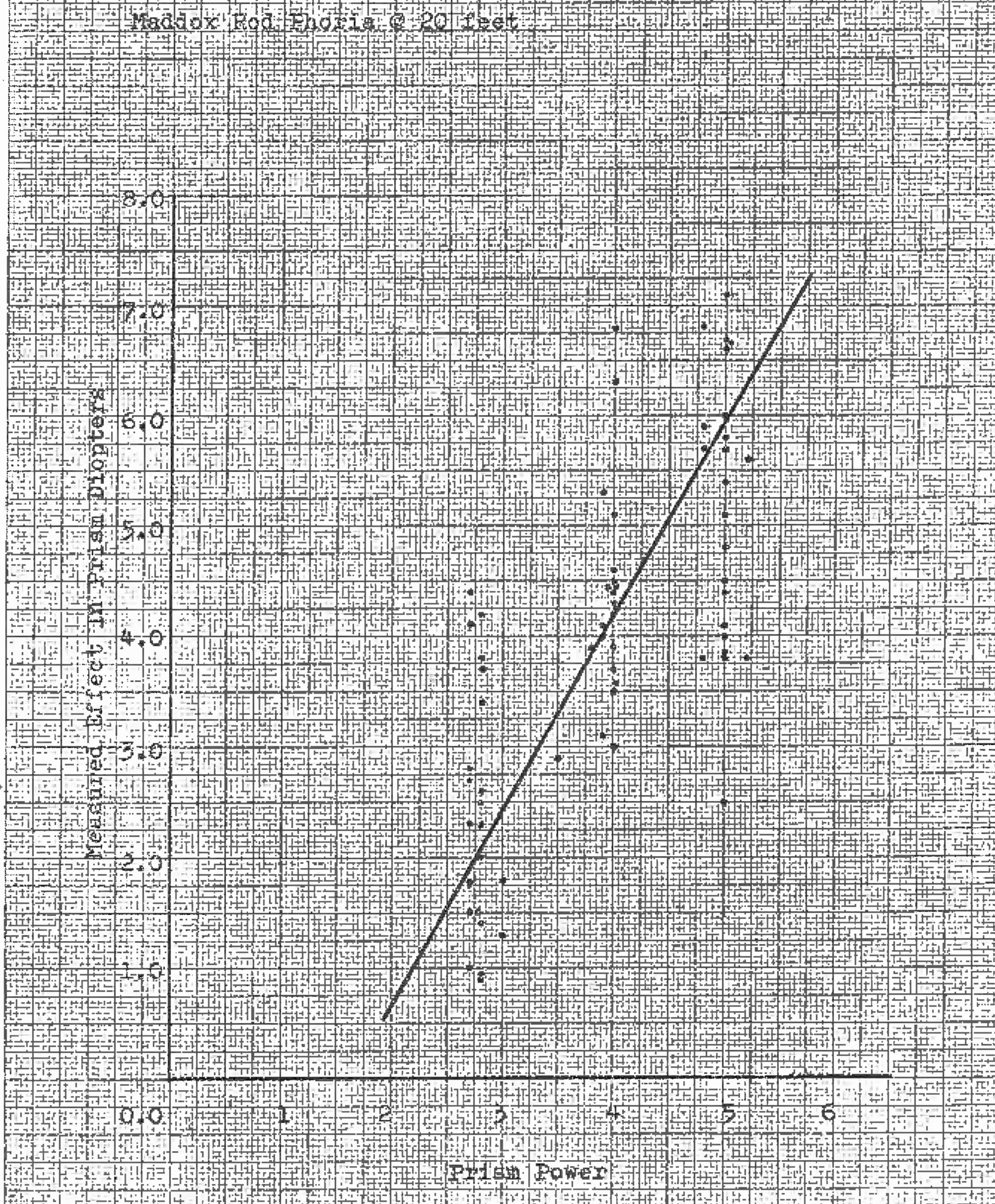

Maddox Rod Phoria @ 20 feet
Measured Effect in Prism Diopters
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1
2
3
4
5
6
Prism Power

Figure 7

Maddox Rod Phoria @ 20 feet

1) Line of Best Fit

$$\tilde{Y} = a + bX$$

$$\tilde{Y} = -2.91 + (1.78)X$$

2) Regression Line

a) $b_{x.y}$

$$Y_3 = b(Y_5 - \bar{Y}_5) + \bar{Y}_3$$

$$Y_3 = .01(Y_5 - 5.29) + 2.33$$

b) $b_{y.x}$

$$Y_5 = b(Y_3 - \bar{Y}_3) + \bar{Y}_5$$

$$Y_5 = .01(Y_3 - 2.33) + 5.29$$

Maddox Rod Phoria @ 20 feet - 3^{Δ} effect plotted against 5^{Δ} effect.

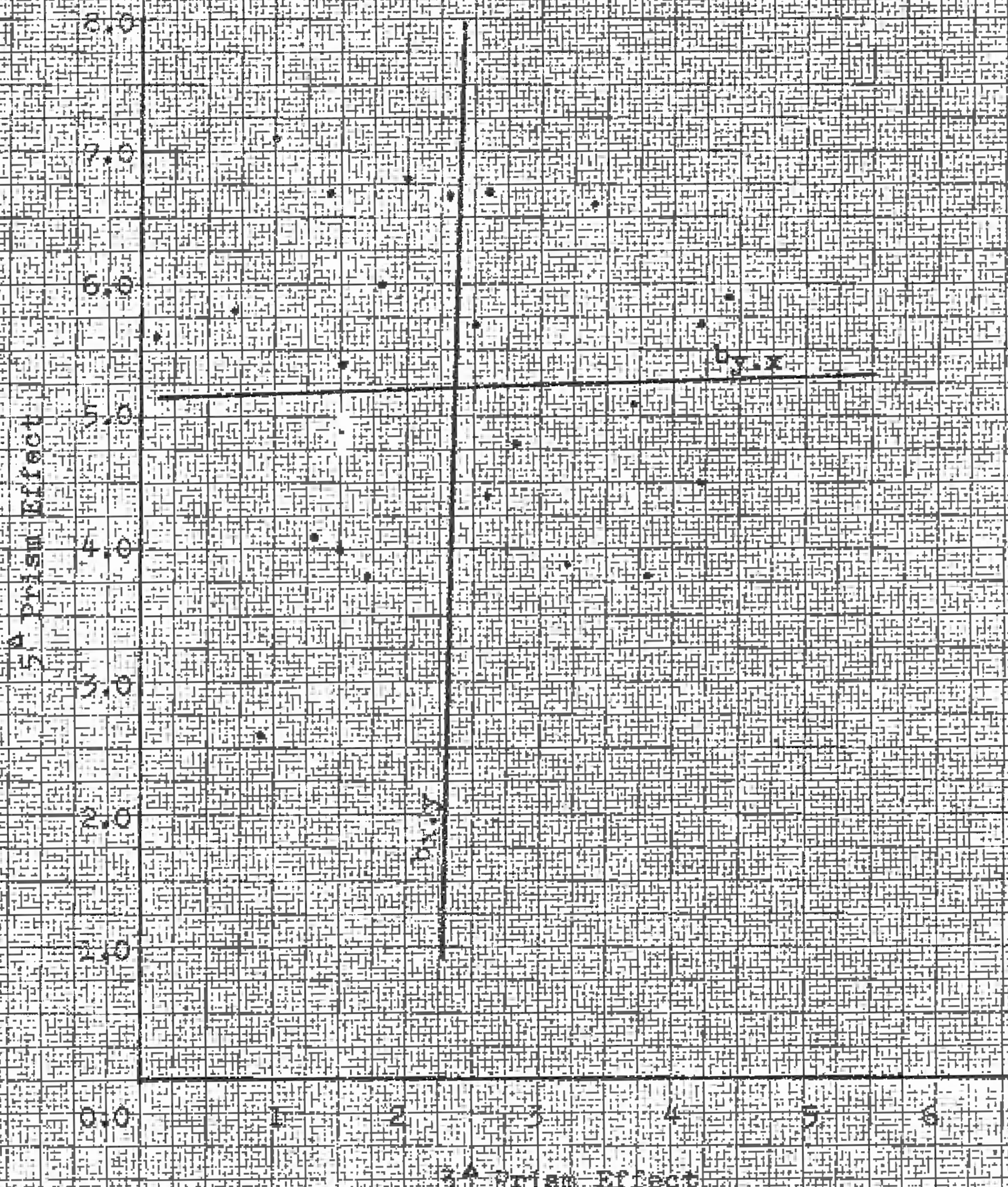


Figure 8

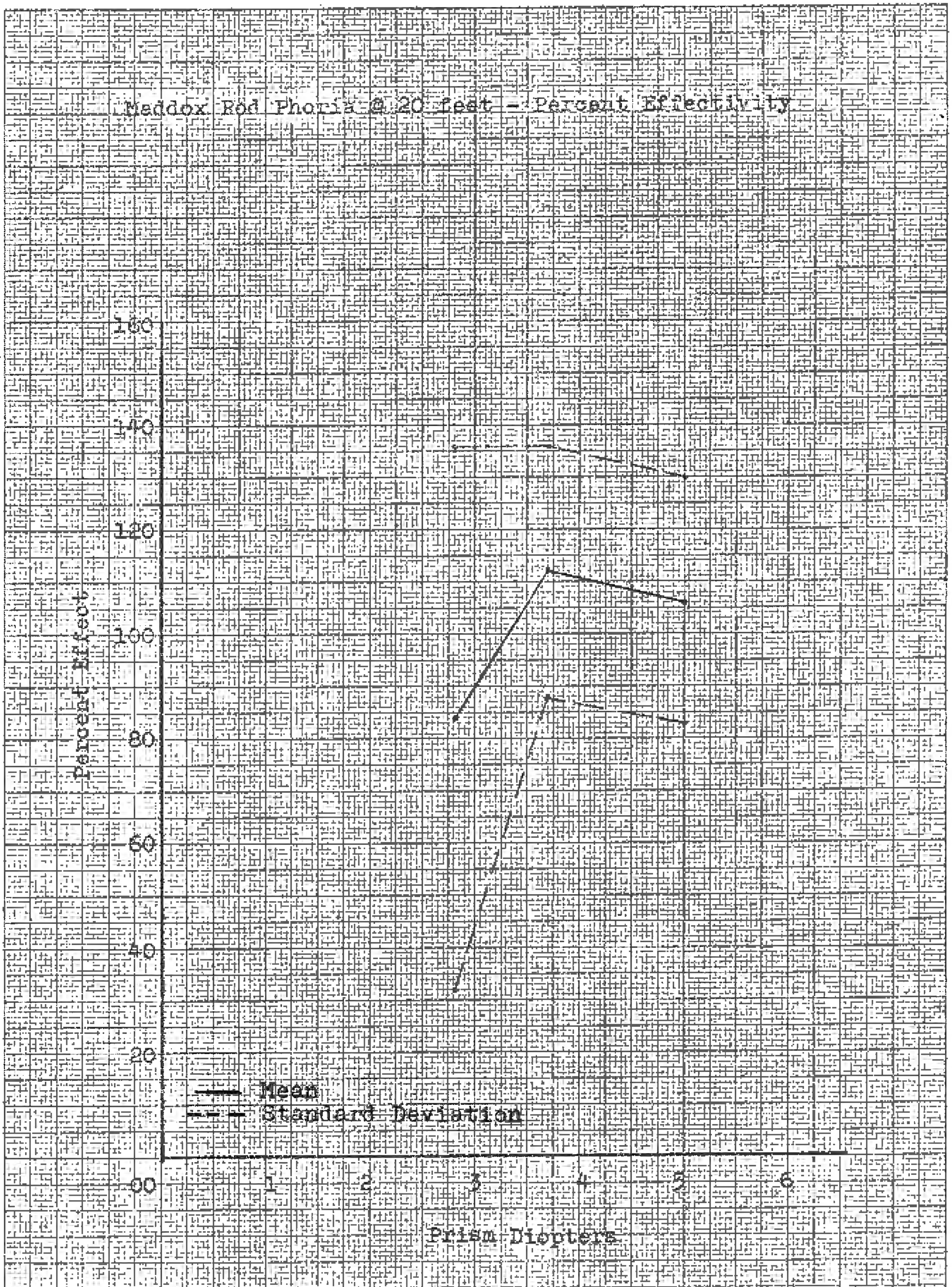

Maddox Rod Phoria @ 20 feet - Percent Effectivity
160
140
120
100
80
60
40
20
00
Percent Effect
1
2
3
4
5
6
Prism Diopters
Mean
Standard Deviation

Figure 9

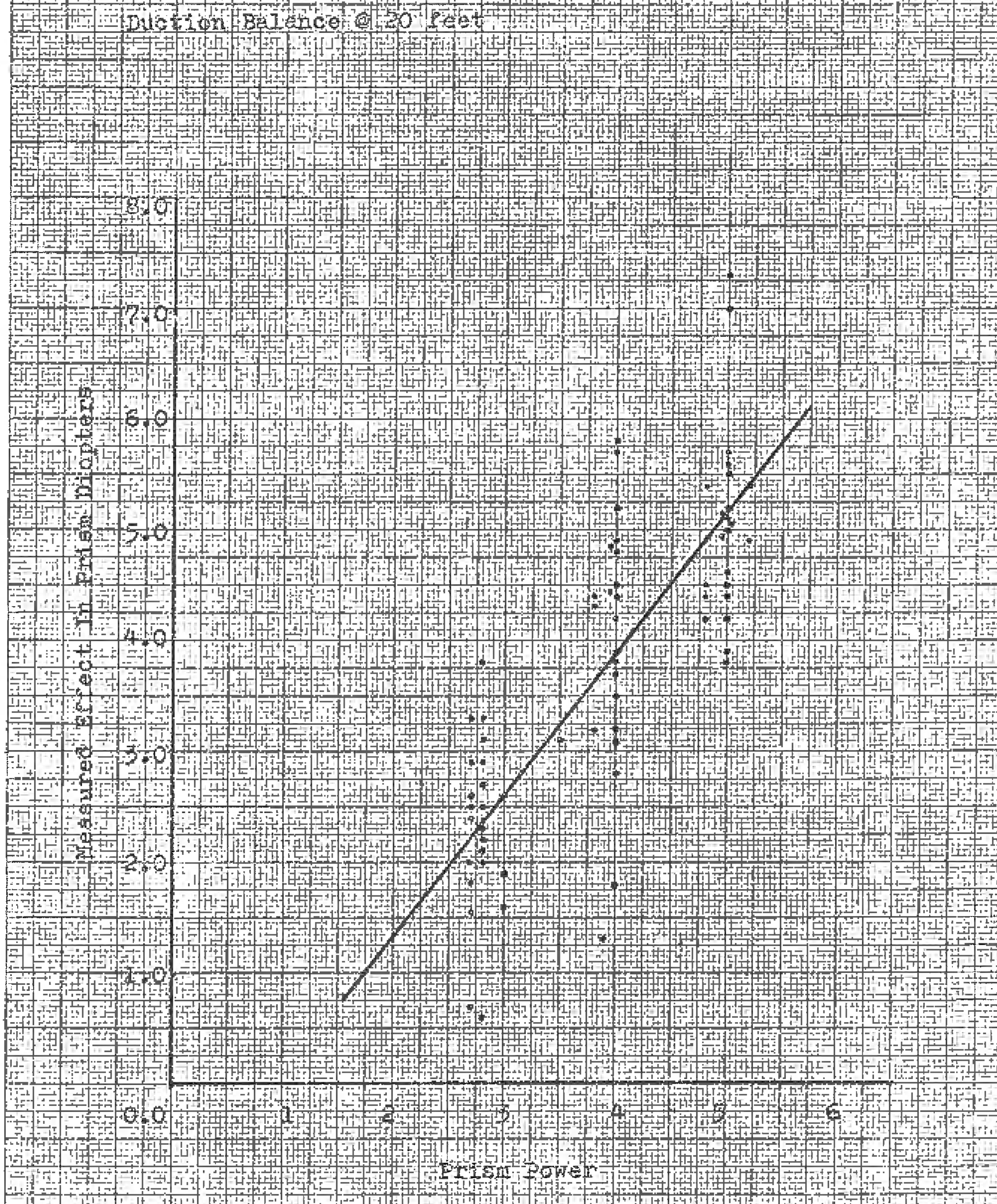

Duction Balance @ 20 feet
Measured Effect In Prism Diopters
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1
2
3
4
5
6
Prism Power

Figure 10

Duction Balance @ 20 feet

1) Line of Best Fit

$\tilde{Y} = a + bX$

$\tilde{Y} = -1.1 + (1.26)X$

2) Regression Line

a) $b_{x.y}$

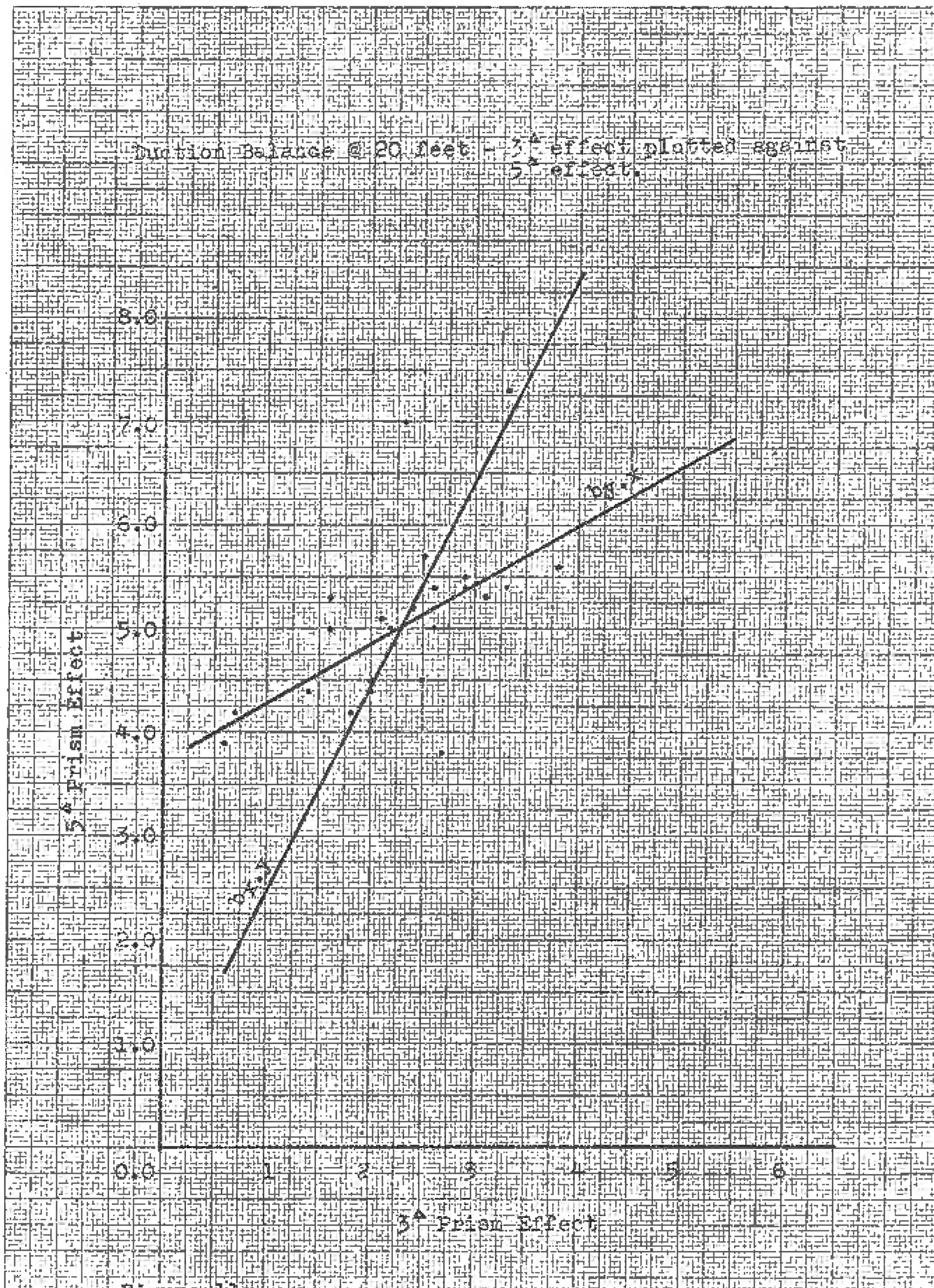
$Y_3 = b(Y_5 - \bar{Y}_5) + \bar{Y}_3$

$Y_3 = .498(Y_5 - 5.06) + 2.29$

b) $b_{y.x}$

$Y_5 = b(Y_3 - \bar{Y}_3) + \bar{Y}_5$

$Y_5 = .555(Y_3 - 2.29) + 5.05$



Duction Balance @ 20 feet - 3^ effect plotted against 5^ effect.
5^ Prism Effect
3^ Prism Effect
bx.y
by.x
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
1
2
3
4
5
6

Figure 11

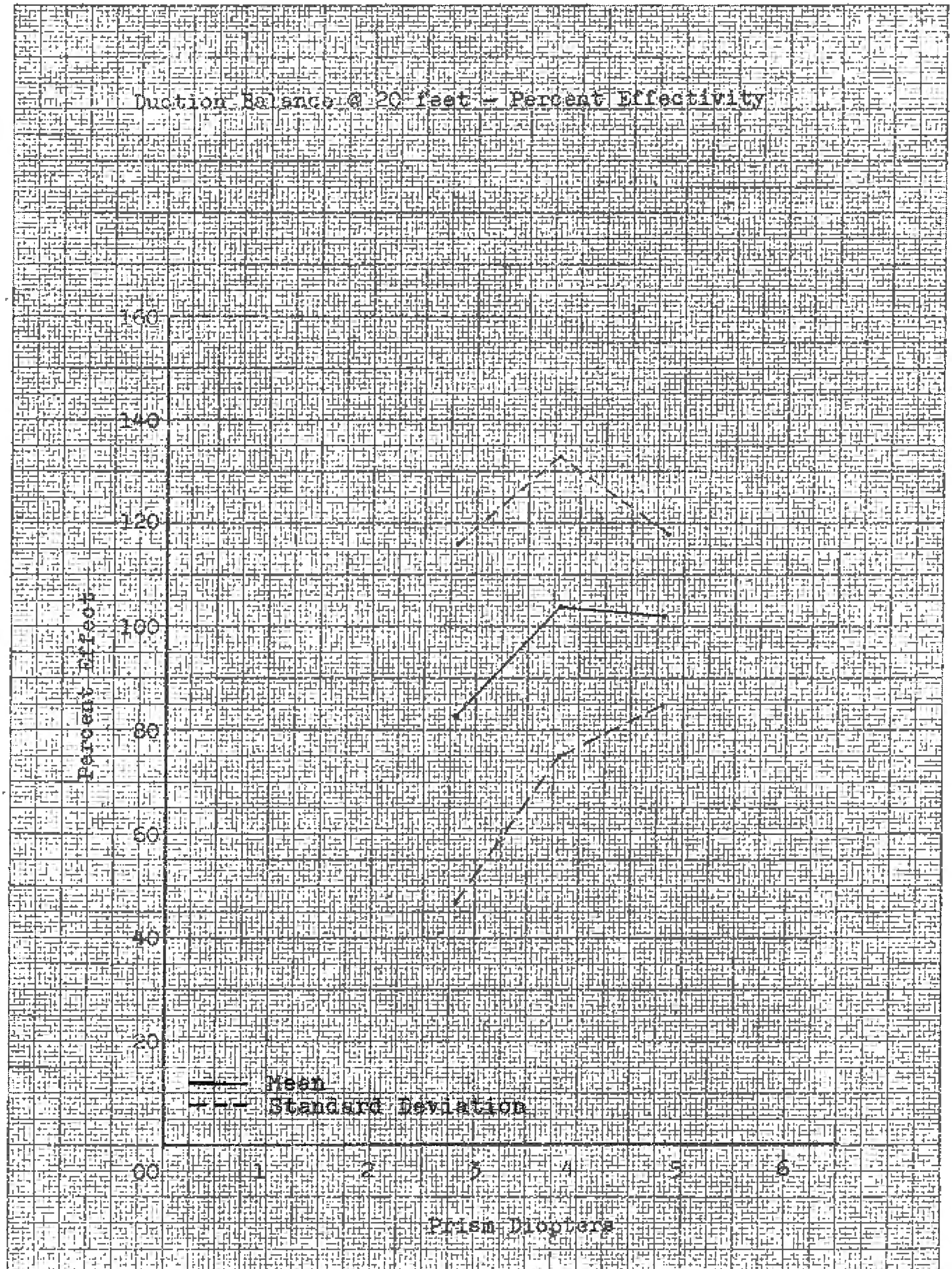
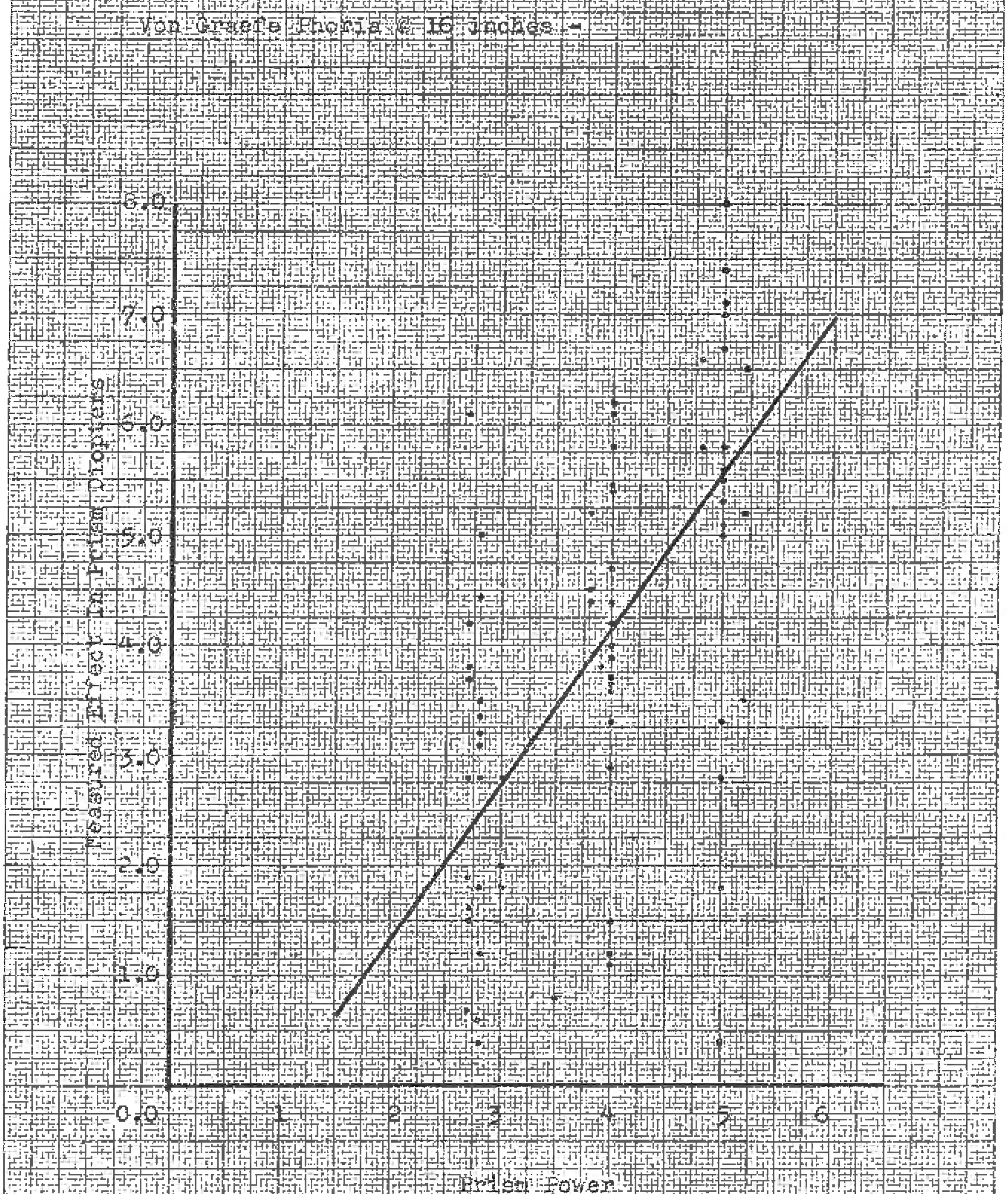

Duction Balance @ 20 feet - Percent Effectivity
160
140
120
100
80
60
40
20
00
Percent Effect
1
2
3
4
5
6
Prism Diopters
Mean
Standard Deviation

Figure 12



Von Graefe Phoria @ 16 Inches -
Measured Effect In Prism Diopters
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1
2
3
4
5
6
Prism Power

Figure 13

Von Graefe Phoria @ 16 inches

1) Line of Best Fit

$\tilde{Y} = a + bX$

$\tilde{Y} = -1.49 + (1.42)X$

2) Regression Line

a) $b_{x.y}$

$Y_3 = b(Y_5 - \bar{Y}_5) + \bar{Y}_3$

$Y_3 = .15(Y_5 - 5.56) + 2.35$

b) $b_{y.x}$

$Y_5 = b(Y_3 - \bar{Y}_3) + \bar{Y}_5$

$Y = 2.24(Y \quad - 2.35) + 5.56$

Von Graefe Phoria @ 16 inches - 3^{Δ} effect plotted against 5^{Δ} effect.

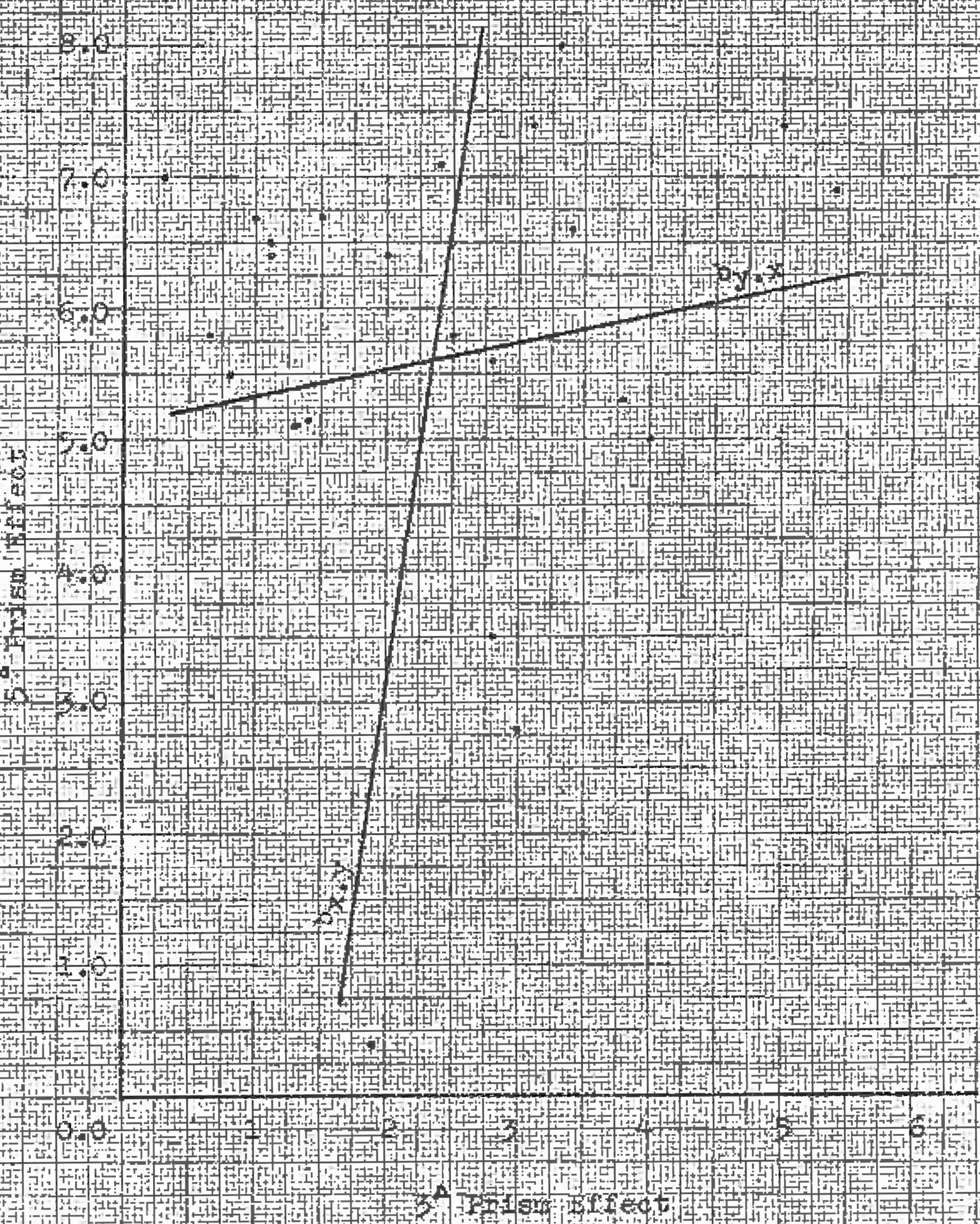
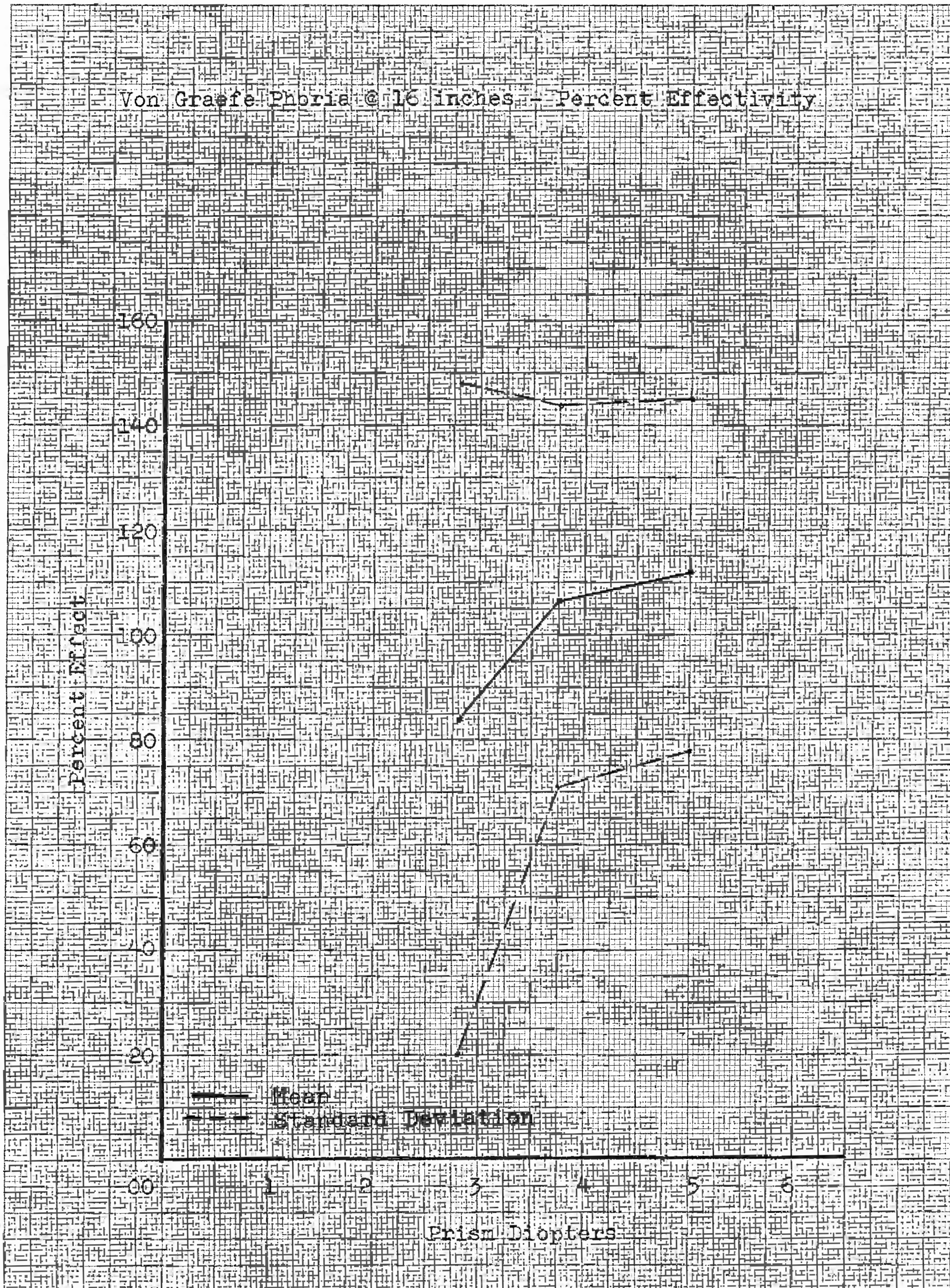


Figure 14



Von Graefe Phoria @ 16 inches - Percent Effectivity
Percent Effect
160
140
120
100
80
60
40
20
00
1
2
3
4
5
6
Prism Diopters
Mean
Standard Deviation

Figure 15

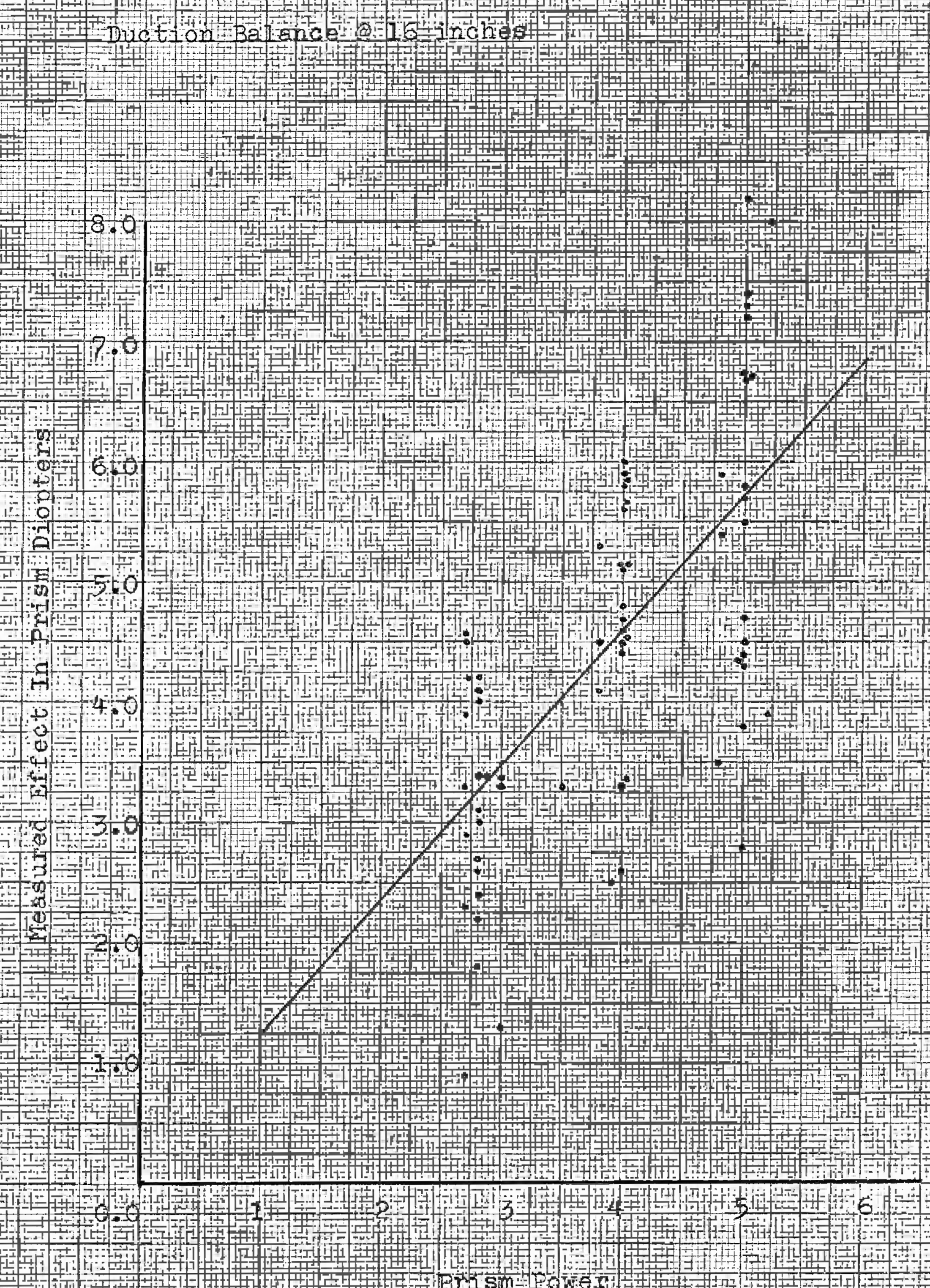

Duction Balance @ 15 inches
Measured Effect In Prism Diopters
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1
2
3
4
5
6
Prism Power

Figure 16

Duction Balance @ 16 inches

1) Line of Best Fit

$$\tilde{Y} = a + bX$$

$$\tilde{Y} = .173 + (1.109)X$$

2) Regression Line

a) $b_{x.y}$

$$Y_3 = b(Y_5 - \bar{Y}_5) + \bar{Y}_3$$

$$Y_3 = .084(Y_5 - 5.61) + 3.09$$

b) $b_{y.x}$

$$Y_5 = b(Y_3 - \bar{Y}_3) + \bar{Y}_5$$

$$Y_5 = .211(Y_3 - 3.09) + 5.61$$

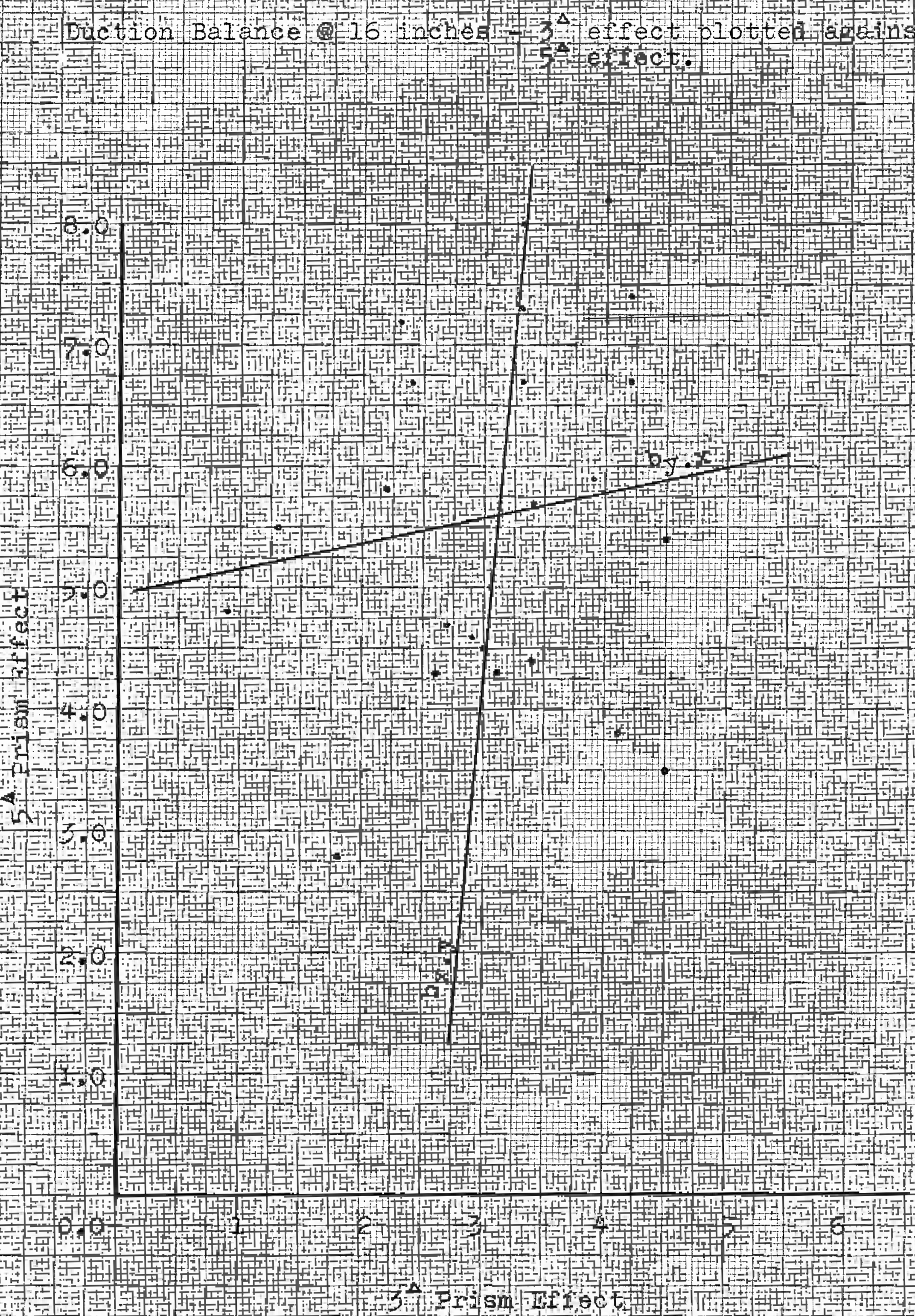

Duction Balance @ 16 inches - 3^ effect plotted against 5^ effect.
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1
2
3
4
5
6
5^ Prism Effect
3^ Prism Effect
by.x
bx.y

Figure 17

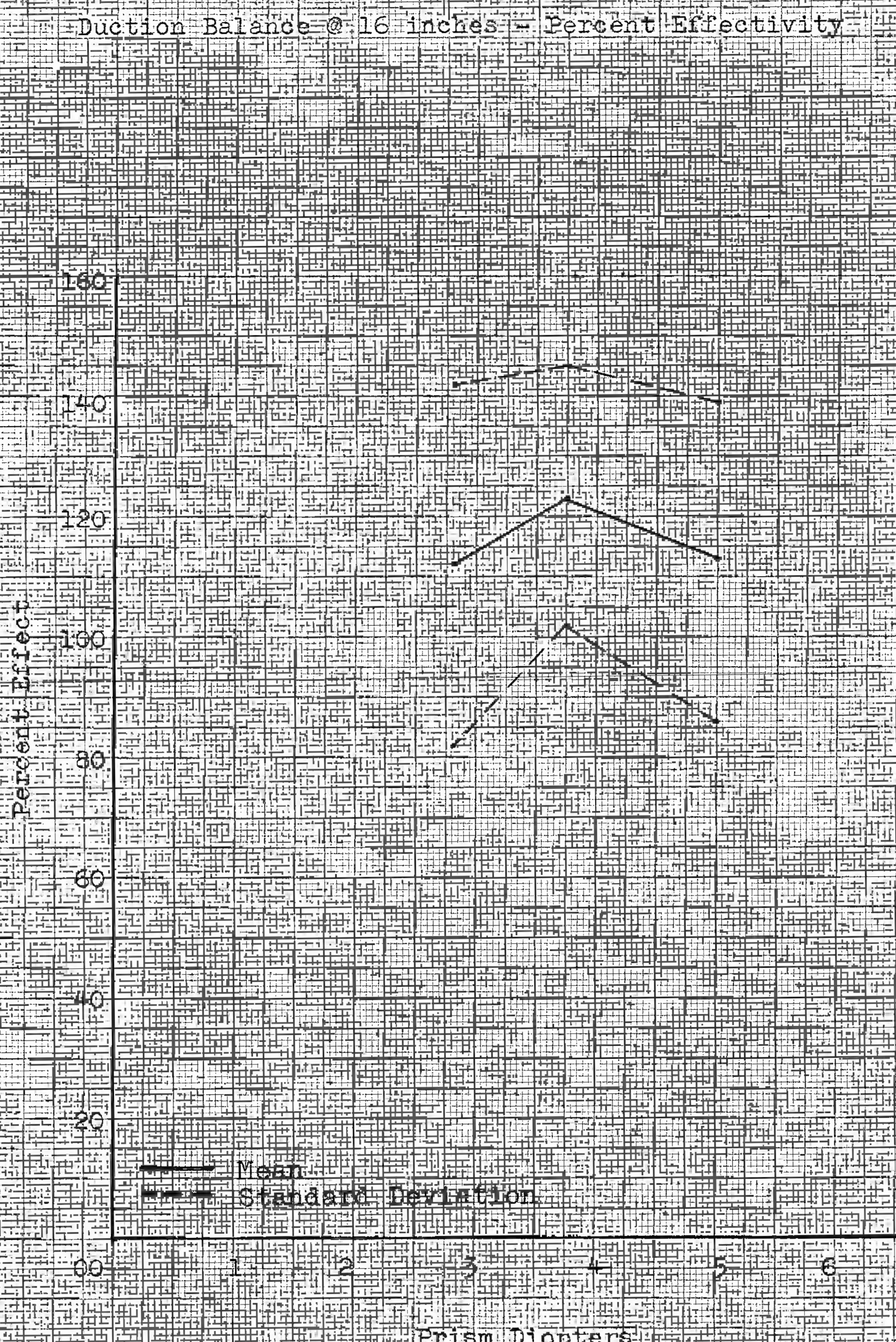

Duction Balance @ 16 inches - Percent Effectivity
Percent Effect
160
140
120
100
80
60
40
20
00
1
2
3
4
5
6
Mean
Standard Deviation
Prism Diopters

Figure 18

POSSIBLE SOURCES OF ERROR

A source of error could have been the inferior centering of lenses. It is possible that on occasion a subject aligned undeviated images due to the decentering of the lenses; giving a reading of little or no effect from the prism. All patients should have been definately instructed to immediately report if they experienced monocular diplopia. The phorometer, with its lack of lens banks, enabled the examiner to objectively check lens position by looking at the lens over the measuring prisms.

Although an effort was made to keep the binocular exposure to a minimum during the testing, a certain amount of adaption to the vertical prism may have taken place.

In a future study, the examiners should consider pre-testing the subjects for adaption to vertical prism with vertical prism in the spectacle plane.

SUMMARY

There has been little written in the literature about the effect of prism in contact lenses on vertical testing. This study was conducted to determine if there is a consistent relationship between the amount of vertical prism worn in a contact lens and the amount of change in the subject's vertical phorias and ductions. Dominant eyes of twenty-six habitual contact lens wearers were fitted with three, four, and five prism diopter contact lenses. Vertical phorias were run at eighteen feet using the Von Graefe and Maddox Rod techniques and at sixteen inches using the Von Graefe technique. Vertical ductions were taken at both eighteen feet and sixteen inches.

For the three, four, and five prism diopter contact lens, there was a relation between the amount of prism worn and the measured effect. In three of the five tests, the mean effect of the three prism diopter lens was slightly less than the amount worn. The mean effect of the four and five prism diopter lenses was slightly in excess of the amount worn. On the duction balance at eighteen feet, in which the standard deviation was under 1.10 prism diopters, the amount of prism worn very closely approximated the effect measured. The near duction balance and near Von Graefe phoria measured considerably more effect than the prism in the contact lens.

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APPENDIX

APPENDIX A

Index Number	Verified Base Curve	Verified Prism Power	OZD	PCW/PCR	ICW/ICR	Diameter	Blends	Back Vertex Power
17	7.43	-3	7.7	.4/10.0	—	9.0	B/	+.25
18	7.50	3	7.7	.4/10.33	—	9.0	B/	+.12
19	7.58	2.75	7.7	.4/10.33	—	9.0	B/	+.12
20	7.67	2.7	7.7	.4/10.4	—	9.0	B/	+.25
21	7.76	2.7	7.7	.4/10.4	—	9.0	B/	+.37
22	7.84	2.75	7.7	.4/10.6	—	9.0	B/	+.37
23	7.94	2.7	7.7	.4/10.7	—	9.0	B/	-.12
24	8.04	2.75	7.7	.4/10.75	—	9.0	B/	+.37
14	7.38	3.5	6.5	.4/9.75	.4/8.50	8.7	B/8.5 B/9.5	+.50
7	7.56	4.0	6.5	.4/9.75	.4/8.50	8.7	B/8.0 B/9.0	pl
2	7.63	4.0	6.5	.4/9.75	.4/8.50	8.7	B/8.0 B/9.0	pl
13	7.65	3.9	7.0	.4/10.0	.4/8.75	9.2	B/8.25 B/9.25	+.62
4	7.73	3.75	7.0	.4/10.0	.4/8.75	9.2	B/8.25 B/9.25	pl
3	7.89	4.0	7.0	.4/9.0	.4/10.25	9.2	B/8.50 B/9.50	+.25
6	7.94	4.0	7.0	.4/9.0	.4/10.25	9.2	B/8.50 B/9.50	pl
16	8.01	4.0	7.5	.4/9.0	.4/10.25	9.7	B/8.50 B/9.50	+.75
5	7.40	5.0	6.5	.4/9.75	.4/8.50	8.7	B/8.0 B/9.0	+.25
15	7.44	5.2	6.5	.4/9.75	.4/8.50	8.7	B/8.0 B/9.0	+1.00
11	7.61	4.8	7.0	.4/10.0	.4/8.75	9.2	B/8.25 B/9.25	+.50
1	7.64	4.8	6.5	.4/10.0	.4/8.75	8.7	B/8.25 B/9.25	pl
8	7.73	4.75	7.0	.4/10.0	.4/8.75	9.2	B/8.25 B/9.25	+.12
10	7.83	5.0	7.0	.4/10.25	.4/9.0	9.2	B/8.50 B/9.50	+.50
9	7.89	5.0	7.0	.4/10.25	.4/9.0	9.2	B/8.50 B/9.50	+1.00
12	8.03	5.0	7.5	.4/10.25	.4/9.0	9.7	B/8.50 B/9.50	+.62

Figure 19

APPENDIX B

SUMMARY OF COMPUTATIONS

Measure	ΣX	ΣY	ΣX^2	ΣY^2	ΣXY	ΣY_3Y_5
3^{Δ} $VG_{20'}$	63.75	55.05	176.904	160.234	152.569	-
4^{Δ} $VG_{20'}$	90.80	96.54	358.02	413.929	366.330	-
5^{Δ} $VG_{20'}$	114.70	119.26	572.32	667.415	594.315	298.10
3^{Δ} $MR_{20'}$	63.75	53.50	176.904	157.133	144.299	-
4^{Δ} $MR_{20'}$	90.80	96.54	358.02	426.691	381.226	-
5^{Δ} $MR_{20'}$	114.70	121.69	572.32	677.677	606.107	281.73
3^{Δ} $VG_{16''}$	63.75	53.49	176.904	175.193	147.552	-
4^{Δ} $VG_{16''}$	90.80	93.14	358.02	416.03	361.644	-
5^{Δ} $VG_{16''}$	114.70	127.92	572.32	787.154	639.466	308.968
Duction Balance @ 20 feet						
3^{Δ}	63.75	52.69	176.904	134.561	145.849	-
4^{Δ}	90.80	90.32	358.02	381.980	354.532	-
5^{Δ}	114.70	116.45	572.32	605.137	581.744	273.47
Duction Balance @ 16 inches						
3^{Δ}	63.75	71.12	176.904	241.241	196.919	-
4^{Δ}	90.80	106.12	358.02	513.216	420.04	-
5^{Δ}	114.70	129.07	572.32	761.186	629.893	402.80