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A clinical analysis of the keystone astigmatism dial card

Abstract

A clinical analysis of the keystone astigmatism dial card

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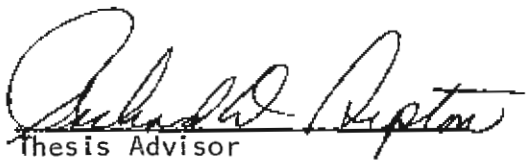
A CLINICAL ANALYSIS OF THE KEYSTONE ASTIGMATISM DIAL CARD

BY
Thomas G. Brookes
W. Earl Buchanan
Larry G. Rutledge

Submitted to the Faculty of the College of Optometry, Pacific University, in partial fulfillment of the requirements for the degree, Doctor of Optometry

May, 1976

Accepted by the Faculty of the College of Optometry, Pacific University, as partial fulfillment of the Doctor of Optometry Degree.



Thesis Advisor

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We would like to acknowledge with gratitude the help and guidance of Dr. Richard Septon, associate professor of Optometry, the Keystone View Company for their cards used in the study, to Mr. Fred Norton for his help in defining our thesis project, and the many subjects who cooperated with us.

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PURPOSE

The measurement of the cylinder axis and power has presented a problem to the optometrist in the past because of patient variability. Some patients do not respond to the most common tests presently in use; namely, the Jackson Cross Cylinder test and the Pratt Near Cylinder test. Therefore, the purpose of this study is to compare the Jackson Cross Cylinder technique, the Pratt Near Cylinder technique and the Keystone Lancaster-Regan type astigmatic dial technique. The validity of the Keystone test in defining the far point sphere, cylinder axis and power will also be determined. In the process we will answer the question as to whether or not the Keystone astigmatic card can be substituted reliably for the Jackson Cross Cylinder test and/or the Pratt Near Cylinder test.

REVIEW OF LITERATURE

Many tests and procedures have been devised for the determination of cylinder axis and power corrections. As many theories have been advanced for the interpretations and prescription from these findings. Of statistical concern is the correlation among these various tests.

Ong, Shanks, and McConnell have shown an "almost perfect correlation between the Jackson Cross Cylinder test and the polarized clock dial, regular clock dial and parabolic chart for astigmatisms."[6]

Adams, Kadet, and White have shown an excellent correlation between the Jackson Cross Cylinder test, the Four Ball test and the Pratt Near Cylinder test.[1]

Of further concern were the positive correlations between the Jackson Cross Cylinder test and the Autocross method by Ekman, Platt, and Siblerud;[3] and the Jackson Cross Cylinder test and Lebensohn's arrow head chart by Kimball and Lohr.[5]

To the extent of this survey-Pacific University thesis library, General Reference Library, the Visual Science Information Center at Berkeley, California, and the Keystone View Company, no comparisons or correlations have been drawn between the Jackson Cross Cylinder test, Pratt Near Cylinder test and the Keystone astigmatism dial card. This lack of correlation data and the potential use of the Keystone card provide the necessity for this study. Since the Keystone card also purports to measure the spherical component of the lens to best

visual acuity, the study will further compare this determination to the far point bichrome finding and the monocular 40 cm negative relative accommodation projection to the farpoint.

EXPERIMENTAL PROCEDURE

To minimize the number of variables in this study, the same examining room, equipment, test sequence, and instructions were kept constant. The examining room equipment consisted of a Bausch and Lomb Greens I Refractor with a $\pm$ .37 D cross cylinder, AO acuity projecter, distance projection chart at 13 feet, and a Keystone Telebinocular.

The following is the order in which the testing was performed:

I. Eye dominance test

Lens Control: patients habitual far point Rx

Lighting: standard room illumination (7fc)

Target: Single letter, about 20/60 size, projected on screen

Distance: 13 feet

Patient Instructed: "Take this card (standard #5 card) in both hands, hold it at arm's length. Raise it slowly to eye level and sight the projected letter through the hole in the card". (Used occluder to determine which eye is looking at letter)

II. Pratt's near cylinder

Targets:

1) Reduced Snellen Card
2) Vertical and horizontal near point cross cylinder card (on reverse side of reduced Snellen card)

3) Obliquely crossed cylinder near point card (cross cylinder oriented at 45 and 135 degrees)

Illuminations

1) Standard near point testing illumination was used throughout the entire test.

Control lens

1) Monocular negative relative accommodation recovery lens (21 monocular recovery lens). The near cylinder test was performed with this control lens so that the patients accommodative posture was placed as close to the far point posture as possible.

Procedure

1) The patient was comfortably seated behind the phoropter, the reduced Snellen card placed in the reading rod holder and the holder set at the 16 inch distance. The phoropter was set at the patient's near point P.D.
2) The left eye was occluded and a standard 21 monocular blur out and recovery was run on the right eye. (The 21 monocular test was run with no cylinder correction in the lens bank).
3) The above procedure was repeated for the left eye, again leaving the recovery lens in place.
4) Again the left eye was occluded and the right eye unoccluded.

5) The reduced Snellen card was flipped around so that the vertical-horizontal grid faced the patient. The oblique cross cylinder card in the reading rod holder was placed back to back with the vertical card. (The cards were placed back to back so that by flipping the holder around the patient could see either the vertical or oblique card.)

6) With the vertical card facing the patient, the patient was asked which set of lines appeared darker, the vertical or horizontal.

7) If the patient reported that the vertical lines appeared darker, the cylinder axis was rotated on the phoropter to 180 degrees.

8) If the patient reported that the horizontal lines appeared darker, the cylinder axis was rotated to 90 degrees.

9) Minus cylinder lenses were added until the patient reported reversal (i.e. the dark appearing set of lines switched from one set to the other). The patient was asked to report which set of lines was darker after each 0.25 diopter of power was added (spherical equivalent kept).

10) After reversal had been obtained, the card holder was flipped so that the oblique cross now faced the patient.

11) Again the patient was asked which set of lines was darker, those going up and to the right or those going up and to the left.

12) If the patient reported that the darker set of lines was up and to the right, the cylinder axis was rotated toward 45 degrees until reversal was reported. The axis was rotated slowly, and the patient asked to report which set of lines appeared darker after each 15 degrees of rotation.

13) If the patient originally reported that the set of lines going up and to the left appeared darker, the cylinder axis was rotated toward 135 degrees until reversal was obtained. (135 degrees was 90° away from the up and to left call).

14) Once reversal had been obtained, the cylinder axis was rotated back toward its original position, and the patient instructed to say "now" when both sets of lines appeared equal. (equally dark).

15) When the equality point was reached rotation of the axis was stopped. This was the axis of the correcting cylinder lens.

16) After the axis correcting cylinder had been determined, the reading rod holder was flipped around once more so that the vertical cross once again faced the patient.

17) Again the patient was asked which set of lines appeared darker, vertical or horizontal.

18) If the patient reported that both sets of lines were equally dark, the test was complete, and the lens in the bank was the correcting cylinder lens.

19) Since this part of the test was originally run to reversal, the patient usually reported the same set of lines appearing darker as he did at the end of step #8. (The set of lines which most closely parallels the cylinder axis usually appeared darker.)

20) The cylinder power was reduced in 0.25 D steps, asking the patient after each reduction to report which set of lines appeared darker. When the patient reported that both sets of lines were equally dark, the test was complete and the lens in the bank was the correcting cylinder lens. (Spherical equivalent was maintained)

21) If, at the end of step 17, the patient reported the opposite set of lines appeared darker than reported at the end of step 8, minus cylinder lens power was added until reversal was obtained and steps 10 through 20 repeated.

22) The above procedure, steps 6 through 21 were repeated for the left eye.

Red-Green test

Target: 20/40 letters on projecter, red-green filter in place

Illumination: All room lights turned down, test was done in 2 fc of illumination

Control Lens: Sphere and cylinder of Pratt's near cylinder in place at starting point. (One eye occluded)

Procedure: Patient was asked to compare "blackness" of letters on both sides of chart. With Pratt near cylinder lenses in place, the letters on the red side would appear darker when the test was started. Plus was reduced until the letters on the green side were blacker.

VA

Target: Standard distance acuity chart

Illumination: Standard room illumination (7fc)

Control lens: red-green sphere and cylinder

Procedure: Patient was asked to call out smallest letters readable monocularly

III. Jackson Cross Cylinder

Target: Single line of 20/40 letter at 13 feet

Illumination: Standard room illumination (7fc)

Control lens: red-green sphere and cylinder

Procedure: done monocularly

1) Preliminary phase -- The red dot was placed parallel to the cylinder axis and the patient asked in which position the letters appeared better. If the red dot was better; cylinder power was added. If the white dot was better, testing was stopped at that point and proceded to the next phase.

2) Axis phase -- The Handle Axis of the cross cylinder was placed parallel to the axis of cylinder in phoroptor.

The red dot was "chased" with cylinder axis until patient could see no difference between the two flipper positions (they both looked equally bad).

3) Power phase -- The cross cylinder was rotated until the principle meridians coincided with the principle meridians of the phoroptor cylinder. (Either red or white dots paralleled axis of cylinder) Patient was asked in which position the letters appeared better. If red dot better; cylinder power was added, if white dot better; cylinder power was reduced. Stopping point; reversal. If in doubt, lower cylinder power was chosen. (No further Red-Green sphere was taken)

VA

Target: Standard distance acuity chart

Illumination: Standard room illumination (7fc)

Control lens: Jackson cross cylinder sphere and cylinder

Procedure: Patient asked to call out smallest readable letters monocularly

IV. Procedure Used for the Telebinocular Refraction

Preliminary Steps

1) If the patient was emmotropic, hyperopic or mixed astigmatic, as determined by the prior refracting procedures, a +2.00 lens was placed in the telebinocular auxillary lens wells. High hyperopes required a more plus lens in the lens well.

2) If the patient was myopic, a -1.00 lens was placed initially in the lens wells. If it was apparent that the amount of myopia would be more than -2.50, a -2.00 lens or more was used in the lens wells.

3) These above mentioned lenses provided for measurements to plus 2.75 and minus 5.00 when combined with readings on the calibrated shaft. If the refractive error was known to be higher, an addition of more plus or minus was made in the lens wells.

4) Room Illumination - standard (7fc) with telebinocular light on.

Refraction Procedures

1) One eye occluded. The auxillary lenses as indicated were placed in the lens wells.

2) The Refraction Test Card was placed in the holder and moved as far out on the shaft as it would go. The axis lines of the card were set at 90 degrees and 180 degrees.

3) The patient was asked if one set of lines was darker, (clearer) than the other. (Since the card holder was set out in plus, myopes and those with low plus findings reported the lines very blurred out.

4) The holder was moved in, asking the patient to state as soon as one set of meridian determining lines became clear. (Clear meant that the three lines could be seen

clearly.) If the lines in both sets of axis lines became clear at the same time, the dial was rotated to 45 degrees and 135 degrees and the subject asked if the lines remained equally clear. If they did the absence of astigmatism was confirmed.

5) If one set of axis lines was clearer as the card was rotated to 45 degrees and 135 degrees, the holder was moved out into plus; Then moved inward until one of the axis became clear.

6) When one of the axis was clearer, the examiner pointed to the red and blue panels on that axis and asked "Are the thin lines clearer in the red or in the blue panel?" If the patient responded that the lines in the blue panel were clearer, or that they were equally clear in the two panels, the holder was moved out into plus until the lines in the red panel first became clearer. The axis arm would appear somewhat blurred at this point. This gave the proper plus fog for refining the axis.

Procedure when no Astigmatism was present.

1) If no astigmatism was found in steps 4,5, and 6, the subject's attention was directed to either set of the axis arms. The holder was moved inward and the patient stated when the lines were clear. The examiner pointed to the red and blue panels and asked, "Are the lines equally clear in the red and blue panels?"

a) If the lines were clearer in the red, more minus was needed, therefore the holder was moved inward.

b) If the lines were clearer in the blue panel, the holder was moved out until they became clearer in the red panel and moved in until the lines in the two panels became equally clear. Since no astigmatism had been shown, the reading on the shaft plus any lens power in the lens wells became the spherical lens finding.

Procedure in locating the Astigmatic Axis.

1) With the card set at the proper fogging distance point to the axial guide lines on the axis that is clearer, he was asked "Are the two sets of axial guide lines equally clear?" If one set was clear, the dial was rotated in the direction of the clearer pair until the two sets of axial guide lines were equally clear or equally blurred. The position denoted the axis.

Finding the lens values when Astigmatism was present.

1) Spherical Power

a) Again attention was directed to the lines in the red and blue panels on the axis used previously. The lines in the red panel normally were darker if the fogging in plus had been done correctly.

b) Examiner: "Tell me when the lines become equally clear in the red and blue panels." The card

holder was moved in until equalization was obtained. When equalization was noted, the position on the shaft was read and the procedure repeated for verification of the finding.

c) The reading on the shaft, plus the power of the auxillary lens in the lens wells was recorded.

2) Cylinder Power

a) The Examiner pointed to the red and blue panels on the opposite axis and asked, "Are the lines equally black in the red and blue panels?" In small amounts of astigmatism the patient would have difficulty in seeing any difference. To recheck, the holder was moved out into plus until the lines became clearer in the red panel and inward again to equalization. The reading on the shaft was then taken and added to the amount of lens power in the lens wells.

3) The Keystone lens finding

The first finding was the sphere power setting.

The second finding was the cylinder power setting.

The cylinder axis was the axis used to determine the cylinder power or the axis 90 degrees from the sphere axis.

Example:

1st finding - +1.00 axis 125 (sphere)

2nd finding - + .50 axis 35

Prescription - +1.00 - .50 x 35

Visual Acuity

1) The lens formula was placed in the phoroptor.

2) One eye occluded and acuities taken using the standard Snellen chart at the far room setting.

Comments

1) Any difficulty in responding that the patient may have was recorded.

2) Any miscellaneous comments the patient made during the test were recorded.

Table 1

Red-Green Sphere versus Keystone Sphere

Subject	Red-Green	Keystone sphere	Change in sphere
MR	+.25	+.25	0
	+.25	-.37	-.62
LR	+1.50	+1.00	-.50
	+1.75	+1.37	-.37
EB	+1.50	+1.37	-.12
	+1.25	+1.25	0
TB	-1.00	-1.50	-.50
	-2.00	-2.37	-.37
KB	-3.25	-3.75	-.50
	-3.50	-3.62	-.12
CJ	-0.25	- .75	-.50
	plano	-.25	-.25
JC	-4.00	-4.37	-.37
	-5.00	-5.62	-.62
RR	plano	-.75	-.75
	plano	-.25	-.25
JC	+.25	plano	-.25
	+.25	-.25	-.50
CB	-1.00	-1.00	0
	-1.25	-.87	+.37
BW	-.50	-1.37	-.87
	+1.00	-1.00	-2.00
JE	-2.50	-3.25	-.75
	-3.00	-4.12	-1.12
RM	-.25	-1.37	-1.12
	-.25	-1.12	-.87
LF	+.50	+.25	-.25
	+.50	+.25	-.25
GW	+4.25	+3.25	-1.00
	+3.00	+3.25	+.25
DG	-2.00	-2.87	-.87
	-1.75	-2.50	-.75
BK	-4.25	-5.75	-1.50
	-4.25	-4.87	-.62
BV	-2.50	-3.12	-.62
	-1.75	-2.37	-.62
DL	-3.25	-4.62	-1.37
	-2.75	-3.12	-.37
TC	plano	-.25	-.25
	plano	-.62	-.62
JD	+.25	+.25	plano
	+.25	-.12	-.12
RH	-4.50	-5.00	-.50
	-4.75	-5.25	-.50
DS	-4.00	-4.62	-.62
	-3.75	-4.50	-.75
BB	-.50	-.62	-.12
	-.75	-.12	+.62
RR	+.50	-1.00	-1.50
	+.50	-.37	-.87

N=50 M= ¯a523 S=0.484276 V=0.234523

Table 2 Jackson Cross Cylinder axis versus Keystone axis for Right Eye

Subject	JCC axis	Keystone axis	Change in axis
MR	98	105	+7
LR	177	175	-2
EB	72	50	-18
TB	75	72	-3
KB	4	5	+1
CJ	*	90	*
JC	70	67	-3
RR	76	90	+14
JC	160	170	+10
CB	90	85	-5
BW	94	180	-86
JE	15	15	-10
RM	4	90	+86
LF	177	175	-2
GW	163	30	+47
DG	72	90	+18
BK	22	18	-4
BV	165	155	-10
DL	135	100	-35
TL	*	80	*
JD	*	*	*
RK	119	118	-1
DS	174	172	-2
BB	*	90	*
RR	160	180	+20

Sign convention + indicates an extorsion; - indicates an intorsion

* Denotes no cylinder found N=19 M= 1.73684 S=16.5658 V=274.427

Table 3 Jackson Cross Cylinder axis versus Keystone axis for Left Eye

Subject	JCC axis	Keystone axis	Change in axis
MR	105	95	-10
LR	175	176	-1
EB	163	140	+23
TB	122	115	+7
KB	177	176	+1
CJ	164	158	+6
JC	115	106	+9
RR	102	90	+12
JC	30	5	+25
CB	80	103	-23
BW	2	180	+2
JE	5	15	-10
RM	25	90	-65
LF	30	2	+28
GW	76	98	-22
DG	168	165	+3
BK	155	160	-5
BV	2	180	+2
DL	167	160	+7
TC	90	90	0
JD	180	105	+75
RH	95	71	+24
DS	10	15	-5
BB	X	90	X
RR	X	66	X

X denotes no axis found
Sign convetnion + indicates an extorsion
- indicates an intorsion

N=21 M+3.47619 S=13.9665 V=195.062

Table 4 Pratt axis vs. Keystone axis for Right Eye.

Subject	Pratt axis	Keystone axis	Change in axis
MR	97	105	+8
LR	2	175	-7
EB	72	50	-22
TB	72	72	0
KB	2	5	+3
CJ	X	90	X
JC	71	67	-$
RR	180	90	-90
JC	180	170	-10
CB	90	85	-5
BW	X	180	X
JE	15	15	0
RM	5	90	+85
LF	177	175	-2
GW	20	30	+10
DG	15	90	+75
BK	15	18	+3
BV	166	155	-11
DL	105	100	-5
TC	71	80	-9
JD	175	X	X
RH	102	118	-16
DS	172	172	0
BB	83	90	-7
RR	172	180	+8

X denotes no axis found

Sign convention + indicates an extortion
- indicates an intortion

N = 19 M=-3.47368 S = 8.25542 V=68.152

Table 5 Pratt axis versus Keyston axis for Left Eye

Subject	Pratt axis	Keystone axis	Change in axis
MR	97	95	+2
LR	173	176	-3
EB	165	140	+25
TB	125	115	+10
KB	2	176	+6
CJ	170	158	+12
JC	108	106	+2
RR	106	90	+16
JC	4	5	-1
CB	80	103	-23
BW	2	180	+2
JE	5	15	-10
RM	5	90	-85
LF	17	2	+15
GW	77	98	-22
DG	170	165	+5
BK	162	160	+2
BV	175	180	-5
DL	166	160	+6
TC	102	90	+12
JD	180	15	-15
RH	87	71	+16
DS	10	15	-5
BB	83	90	-7
RR	7	66	-59

Sign convention + indicates an extortion
- indicates an intortion

N=24 M=-0.791667 S-17.1641 V=294.607

Table 6 Jackson Cross Cylinder versus Keystone Cylinder

Subject	Jackson Cross Cylinder	Keystone Cylinder	Change
MR	-.50	-.75	-.25
	-.25	-.62	-.37
LR	-5.50	no response	no response
	-6.25	-7.00	-.75
EB	-.50	-.75	-.25
	-.25	-.25	0
TB	-2.25	-1.50	+.75
	-2.25	-2.37	-.12
KB	-.50	-1.75	-1.25
	-.25	-.62	-.37
CJ	plano	-.12	-.12
	-.25	-.87	-.62
JC	-2.00	-2.87	-.87
	-1.00	-2.37	-1.37
RR	-.12	-.25	-.12
	-.37	-.37	0
JC	-.25	-.62	-.37
	-.25	-.37	-.12
CB	-.75	-.25	+.50
	-1.00	-.50	+.50
BW	-.25	-.50	-.25
	-.25	-.50	-.25
JE	-.50	-.37	-.12
	-.75	-.25	+.50
RM	-.25	-.25	0
	-.25	-.37	-.12
LF	-.37	-1.25	-.87
	-.50	-.25	+.25
GW	-.25	-.12	-.12
	-.75	-.87	-.25
DG	-.12	-.37	-.25
	-.37	.62	-.25
BK	-.75	.87	-.12
	-1.25	-.62	+.62
BV	-1.25	-1.62	-.37
	-1.50	-1.00	+.50
DL	-.25	-.25	0
	-.75	-.75	0
TC	plano	-.62	-.62
	-.25	-.25	0
JD	plano	plano	0
	-.25	-.25	0
RH	-.25	-.37	-.12
	-1.00	-.25	+.75
DS	-1.00	-1.37	-.37
	-.75	-1.00	-.25
BB	plano	-.75	-.75
	plano	-.37	-.37
RR	-.50	-.12	+.37
	plano	-162	-.62

N=49 M= -0.138775 S = 0.493447 V = 0.24349

Table 7 Pratt Cylinder versus Keystone Cylinder

Subject	Pratt Cylinder	Keystone Cylinder	Change in Cylinder
MR	-.50	-.75	-.25
	-.50	-.62	-.12
LR	-5.75	No response	no response
	-6.50	-7.00	-.50
EB	-.75	-.75	0
	-.25	-.25	0
TB	-2.00	-1.25	+.75
	-2.25	-1.00	+1.26
KB	-.50	-1.75	-1.25
	-.25	-.62	-.37
CJ	X	-.12	-.12
	-.25	-.87	-.62
JC	-1.75	-2.87	-1.12
	-1.00	-2.37	-1.37
RR	-.25	-.25	0
	-.25	-.37	-.12
JC	+.50	-.62	-.12
	-.50	-.37	+.12
CB	-.75	-.25	+.50
	-.75	-.50	+.25
BW	X	-.50	-.50
	-.50	-.50	0
JE	-.50	-.37	+.12
	-.75	-.25	+.50
RM	-.25	-.25	0
	-.25	-.37	-.12
LF	-.50	-1.25	-.75
	-.50	-.25	+.25
GW	-.50	-.12	+.37
	-1.75	-.87	+.87
DG	-.25	-.37	-.12
	-.50	-.62	-.12
BK	-.75	-.87	-.12
	-1.00	-.62	+.37
BV	-1.50	-1.62	-.12
	-1.00	-1.00	0
DL	-.25	-.25	-.25
	-.50	-.75	-.37
TC	-.25	-.62	+.50
	-.75	-.25	+.25
JD	-.25	X	0
	-.25	-.25	+.12
RH	-.50	-.37	+.25
	-.50	-.25	-.37
DS	-1.00	-1.37	-.25
	-.75	-1.00	-.50
BB	-.25	-.75	-.12
	-.25	-.37	+.37
RR	-.50	-.12	-.37
	-.25	-.62	

N = 49 M = -0.065102 S = 0.48719 V = 0.237354

Table 8 Pratt Spherical Equivalent versus Keystone Spherical Equivalent

Subject	Pratt Spherical Equivalent	Keystone Spherical Equivalent	Change
MR	plano	-.12	-.12
	plano	-.68	-.68
LR	-1.37	no response	no response
	-1.50	-2.13	-.62
EB	+1.12	+1.00	-.12
	+1.12	+1.12	plano
TB	-2.00	-2.12	-.12
	-2.12	-2.87	-.75
KB	-3.50	-4.62	-1.12
	-3.62	-3.93	-.31
CJ	-.25	-.82	-.57
	-.12	-.62	-.50
JC	-4.87	-5.80	-193
	-5.50	-6.80	-1.30
RR	-.12	-.87	-.75
	-.12	-.44	-.32
JC	plano	-.37	-.37
	plano	-.43	-.43
CB	-1.37	-1.12	+.25
	-1.62	-1.12	-.50
BW	-.50	-1.62	-1.12
	+.75	-1.25	-2.00
JE	-.275	-3.44	-.69
	-3.37	-4.37	-1.00
RM	-.37	-1.50	-.62
	-.37	-1.31	-.96
LF	+.25	-.37	-.62
	+.25	+.12	-.12
GW	+4.00	+3.20	-.80
	+2.12	+2.82	+.70
DG	-2.12	-3.06	-.93
	-2.00	-2.87	-.87
BK	-4.62	-6.19	-1.57
	-4.75	-5.18	-.43
BV	-3.25	-3.93	-.68
	-2.25	-2.87	-.62
DL	-3.37	-4.75	-1.38
	-3.00	-3.50	-.50
TC	-.12	-.56	-.44
	-.12	-.75	-.62
JD	+.12	+.25	+.12
	+.12	-.25	-.37
RH	-4.75	-5.19	-.44
	-5.00	-5.37	-.37
DS	-4.50	-5.31	-.81
	-4.12	-5.00	-.87
BB	-.62	-1.00	-.37
	-.87	-.31	-.56
RR	+.25	-1.06	-1.31
	plano	-.68	-.68

N= 49 M= -0.593264 S = 0.49845 V = 0.248452

Table 9 Jackson Cross Cylinder Spherical Equivalent versus Keystone Spherical Equivalent

Subject	J.C.C. Spherical Equivalent	Keystone Spherical Equivalent	Change
MR	plano	-.12	-.12
	+.12	-.68	-.75
LR	-1.25	no response	no response
	-1.38	-2.13	-.75
EB	+1.25	+1.00	-.25
	+1.12	+1.12	0
TB	-2.12	-2.12	0
	-3.12	-2.87	+.25
KB	-3.50	-4.62	-1.12
	-3.62	-3.93	-.31
CJ	-.25	-.02	-.57
	-.12	-.62	-.50
JC	-5.00	-5.80	-.80
	-5.50	-6.80	-1.30
RR	-.06	-.87	-.81
	-.19	-.44	-.25
JC	+.12	-.37	-.50
	+.12	-.43	-.55
CB	-1.37	-1.12	+.25
	-1.75	-1.12	+.62
BW	-.62	-1.62	-1.00
	-.87	-1.25	-.37
JE	-2.75	-3.44	-.69
	-3.37	-4.37	-1.00
RM	-.37	-1.50	-1.12
	-.37	-1.31	-.94
LF	+.31	-.37	-.68
	+.25	+.12	-.12
GW	+4.12	+3.20	-1.08
	+2.87	+2.82	-.05
DG	-2.06	-3.06	-1.00
	-2.00	-2.87	-.87
BK	-4.62	-6.19	-1.57
	-4.87	-5.18	-.31
BV	-3.12	-3.93	-.81
	-2.50	-2.87	-.37
PL	-3.37	-4.75	-1.38
	-3.12	-3.50	-.37
TC	plano	-.56	-.56
	-.12	-.75	-.62
JD	+.25	+.25	0
	+.12	-.25	-.37
RH	-4.62	-5.19	-.57
	-5.25	-5.37	-.10
DS	-4.50	-5.31	-.81
	-4.12	-5.00	-.87
BB	-.50	-1.00	-.50
	-.75	-.31	+.44
RR	+.25	-1.06	-1.31
	+.50	-.68	-1.18

N = 49 M = -0.564285 S = 0.485357 V = 0.235571

Table 10 Pratt axis versus Keystone axis lesser than -.75

Subject	Power	Change
MR	-.50	+8
	-.50	+2
EB	-.25	+25
KB	-.50	+3
	-.25	+6
CJ	-.25	+12
RR	-.25	-90
	-.25	+16
JC	-.50	-10
	-.50	-1
BW	-.50	+2
JE	-.50	0
RM	-.25	+85
	-.25	-85
LF	-.50	-2
	-.50	+15
GW	-.50	+10
DG	-.25	+75
	-.50	+5
DL	-.25	-5
	-.50	+6
TC	-.25	-9
JD	-.25	0
	-.25	-15
RH	-.50	-16
	-.50	+16
BB	-.25	-7
	-.25	-7
RR	-.50	+8
	+.25	-59

Mean = -.4
Standard Deviation = 34.38
Variance = 1182.4
(+) indicates extortion
(-) indicates intortion

Table 11 Pratt axis versus Keystone axis greater than -.75

Subject	Power	Change
LR	-6.50	-3
EB	-.75	-22
TB	-2.00	0
	-2.25	+10
JC	-1.75	-4
	-1.00	+2
CB	-.75	+5
	-.75	-23
JE	-.75	-10
GW	-1.75	-22
BK	-.75	+3
	-1.00	+2
BV	-1.50	-11
	-1.00	-5
TC	-.75	-9
DS	-1.00	0

Mean = -6.06
Standard Deviation 9.67
Variance 93.5
t-test -11.18 to -.94 95% confidence interval
(+) indicates extortion
(-) indicates intortion

Table 12 JCC axis versus Keystone axis for cylinder power lesser than .75

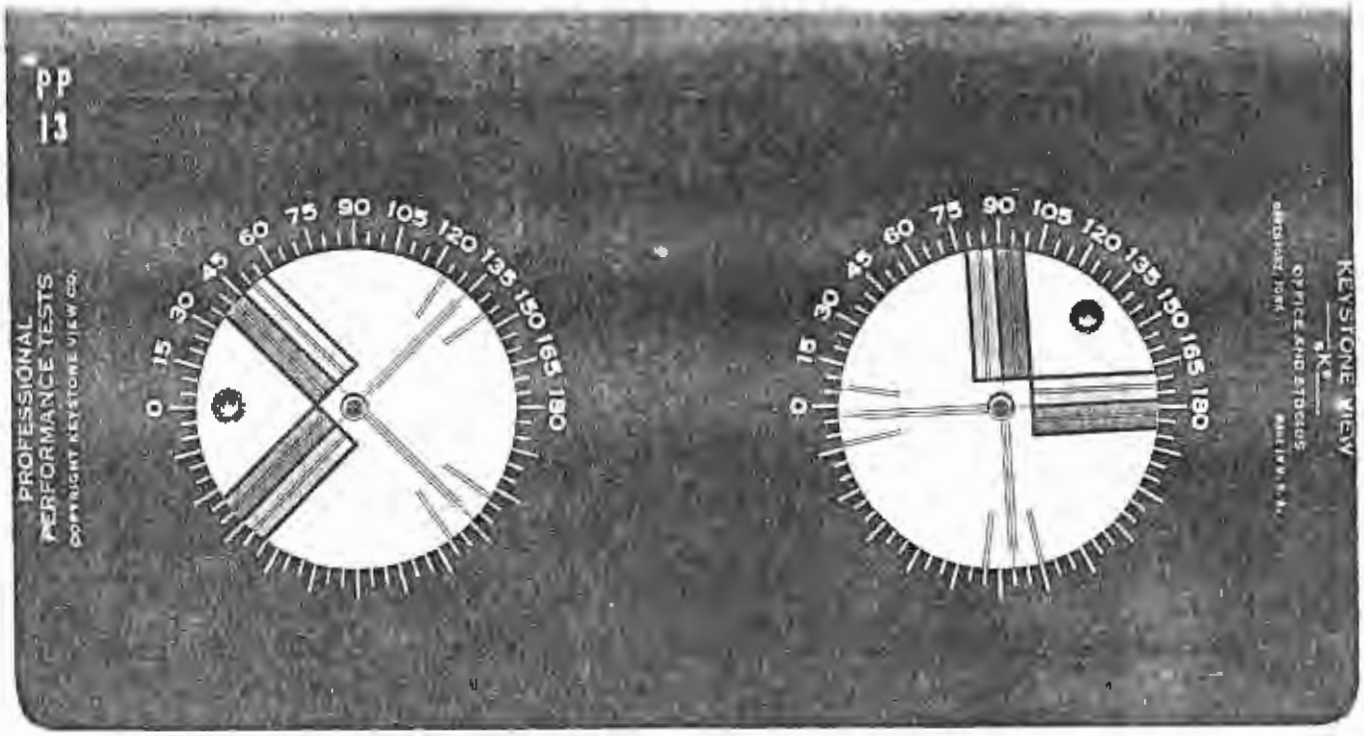
Subject	Power	Change
MR	-.50	+7
	-.25	-10
EB	-.50	-18
	-.25	+23
KB	-.50	+1
	-.25	+1
CJ	-.25	0
RR	-.12	+14
	-.37	+12
JC	-.25	-3
	-.25	+9
BW	-.25	-86
	-.25	+2
JE	-.50	-10
RM	-.25	-65
	-.25	+86
LF	-.37	-2
	-.50	+28
GW	-.25	+47
DG	-.12	+18
	-.37	+3
DL	-.25	-35
TC	-.25	0
JD	-.25	+75
RH	-.25	-1
RR	-.50	+20

Mean 4.46
Standard Deviation 35.0
Variance = 1224.7
(+) indicates extortion
(-) indicates intortion

Table 13 J.C.C. axis versus Keystone axis for cylinder greater than .75

Subject	Power	Change
LR	-6.25	-1
TB	-2.25	-3
	-2.25	+7
JC	-2.00	-3
	-1.00	+9
CB	-.75	-5
	-1.00	-23
JE	-.75	-10
GW	-.75	-22
KB	-.75	-4
	-1.25	-5
BV	-1.25	-10
	-1.50	+2
DL	-.75	+7
RH	-1.00	+24
DS	-1.00	-2
	-.75	-5

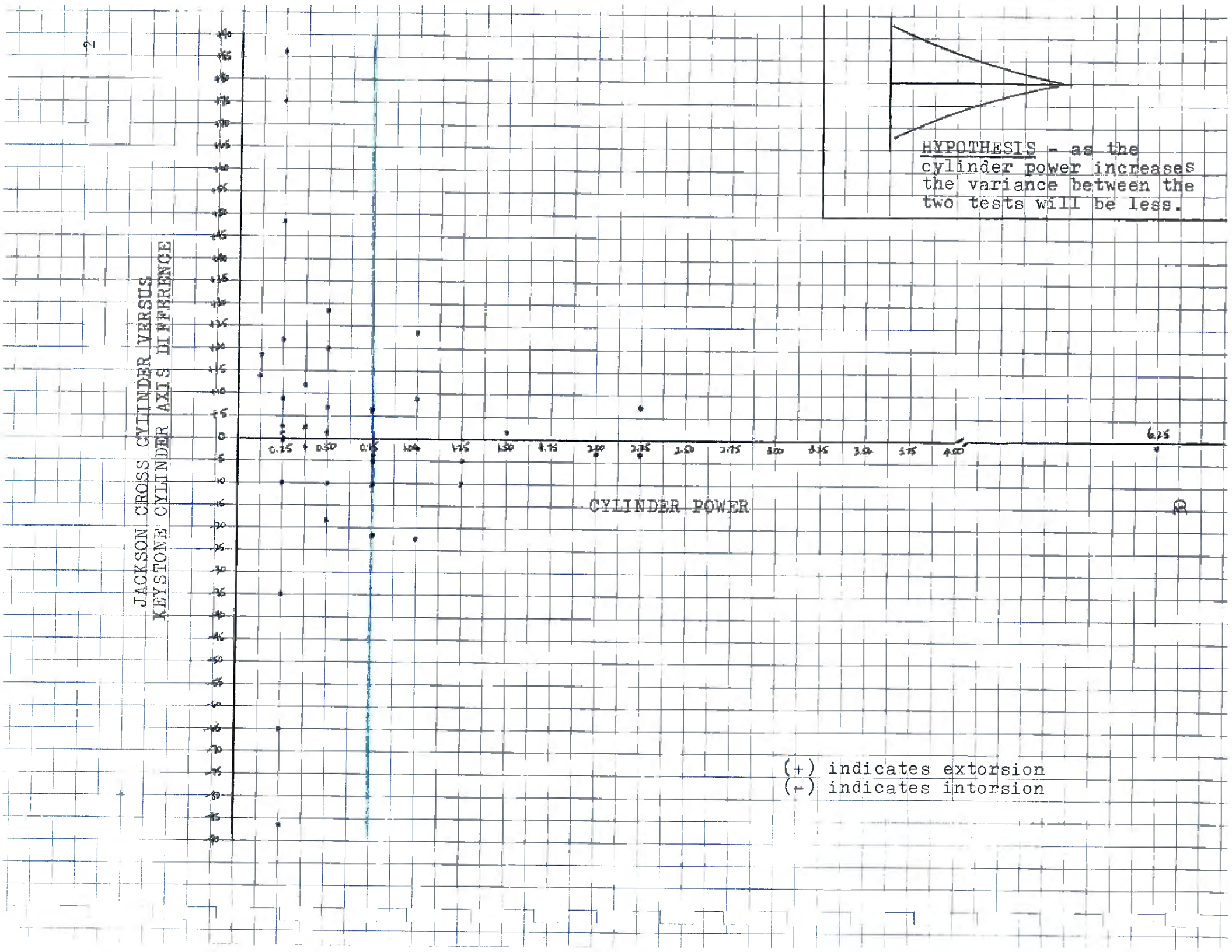
Mean -2.59
Standard Deviation 11.1
Variance 123.3
t-test -8.27 to 5.60 95% confidence interval
(+) indicates extortion
(-) indicates intortion



KEYSTONE-REGAN CARD (PP-13)

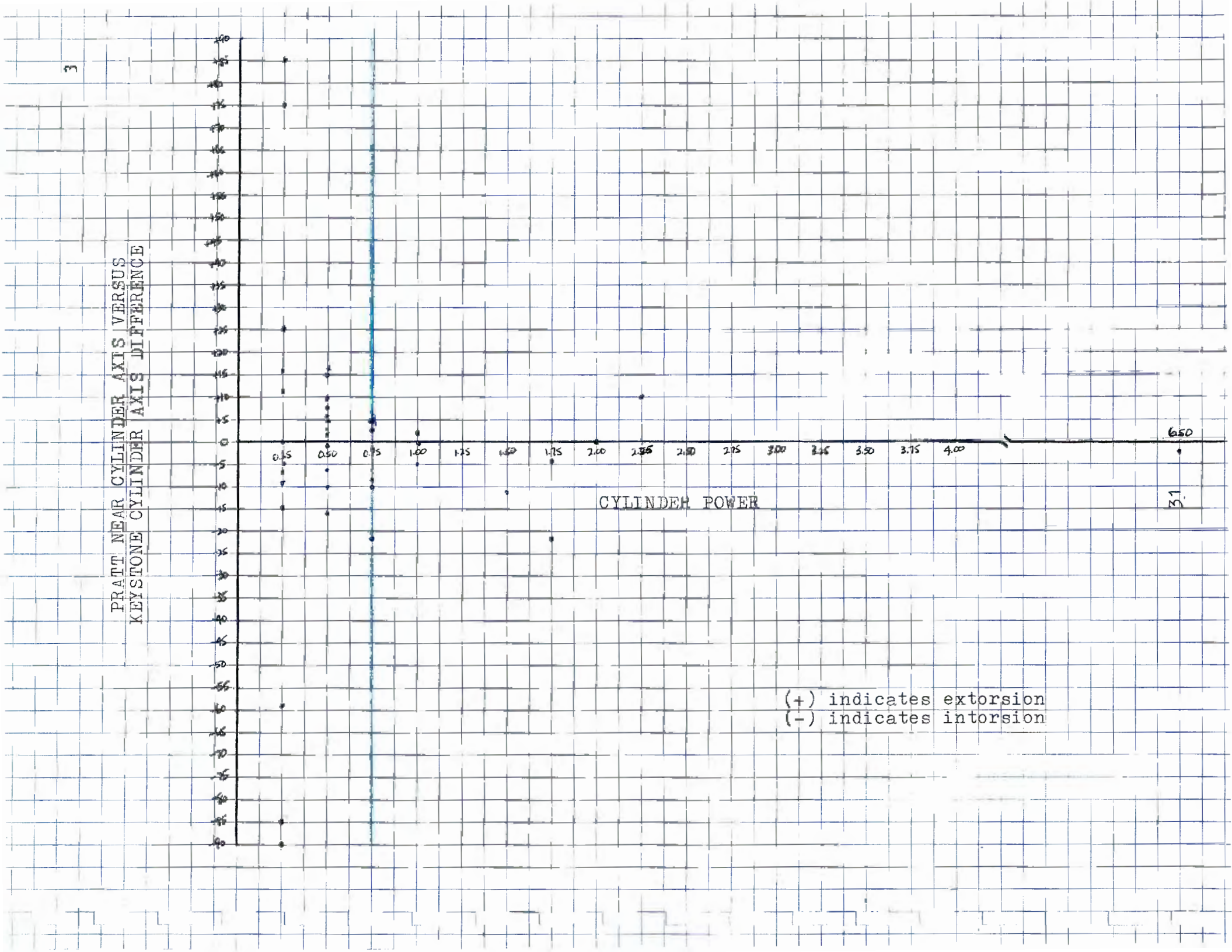
Contains two Lancaster-Regan type astigmatic dials, one mounted so as to be seen only by the right eye, the other by the left eye. The dials are movable so that they may be rotated to any axis. The axis lines are the three long lines (oriented at 135 and 225 on the left dial), the lines 10 degrees to either side of the axis lines are the axial guide lines. Oriented 90 degrees from each axis line is the duochrome test with two thin black lines on a red background and two thin black lines on a blue background.

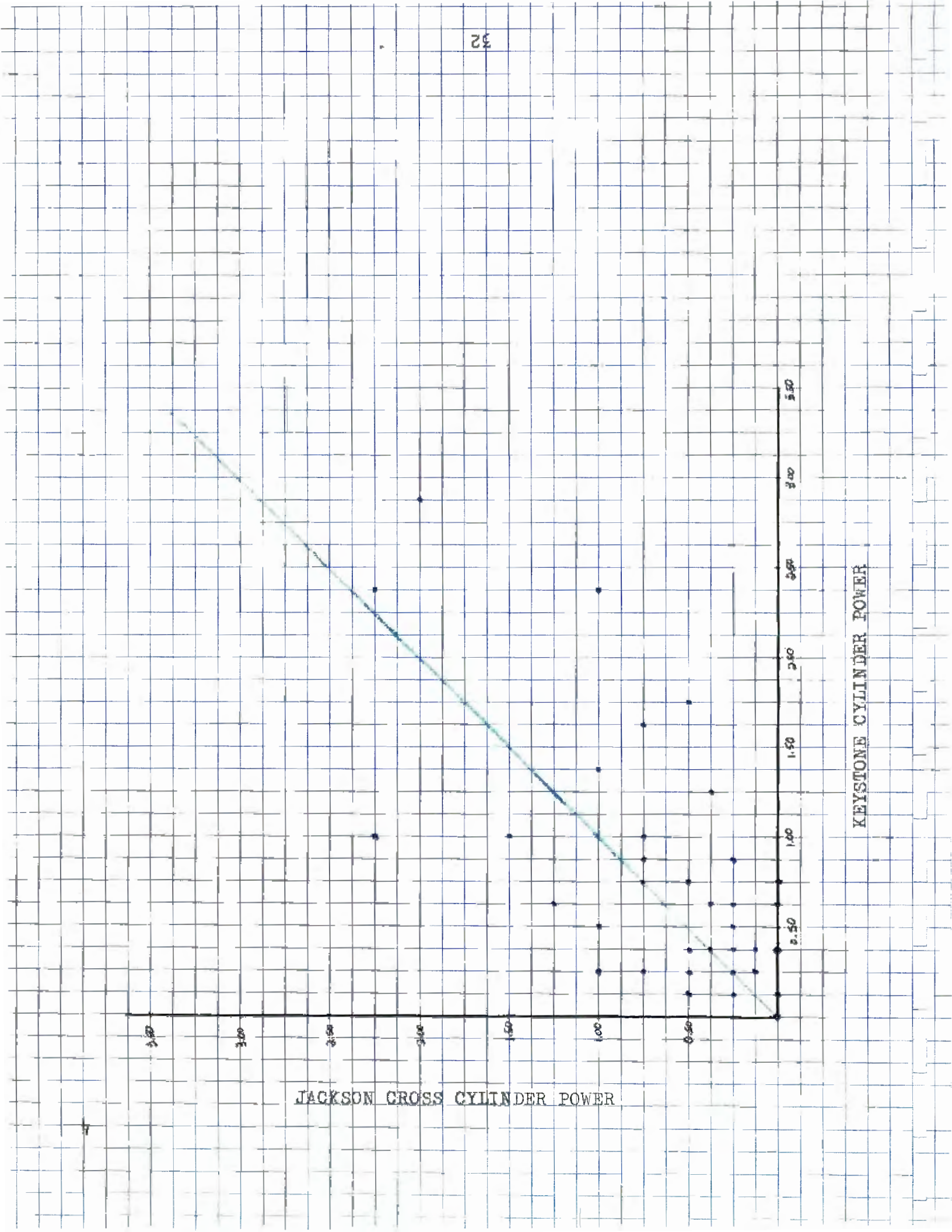
JACKSON CROSS CYLINDER VERSUS
KEYSTONE CYLINDER AXIS DIFFERENCE

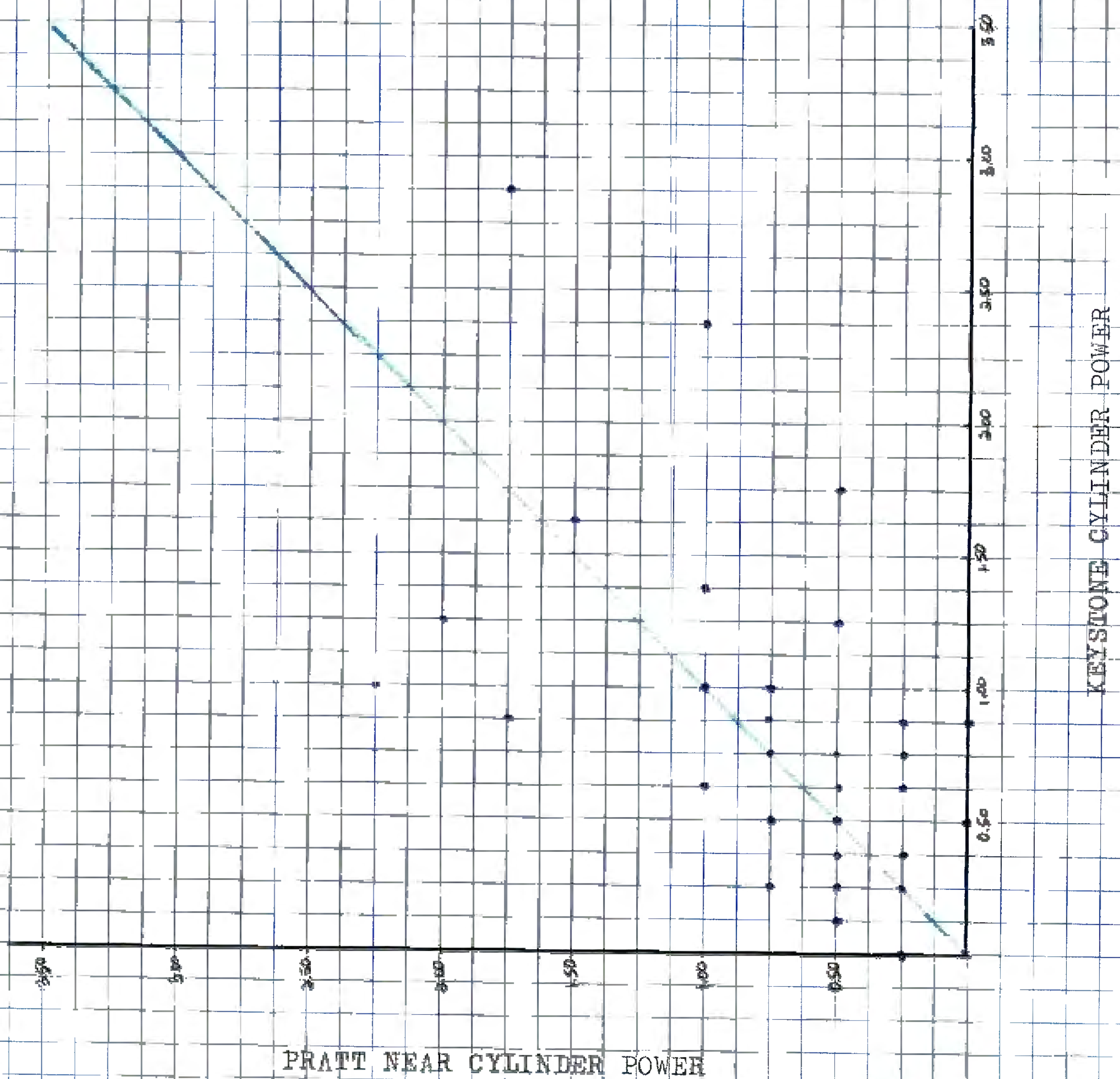


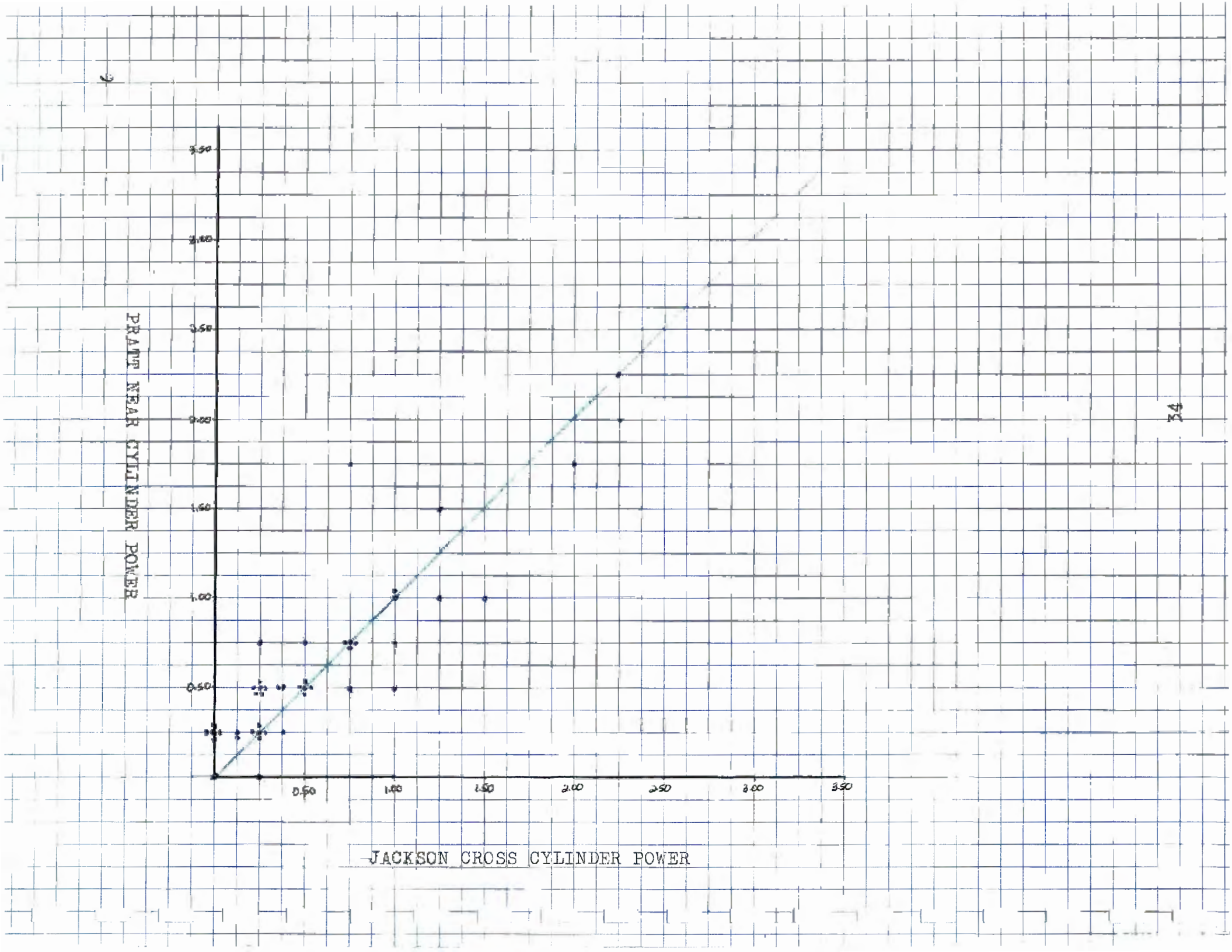
HYPOTHESIS - as the cylinder power increases the variance between the two tests will be less.

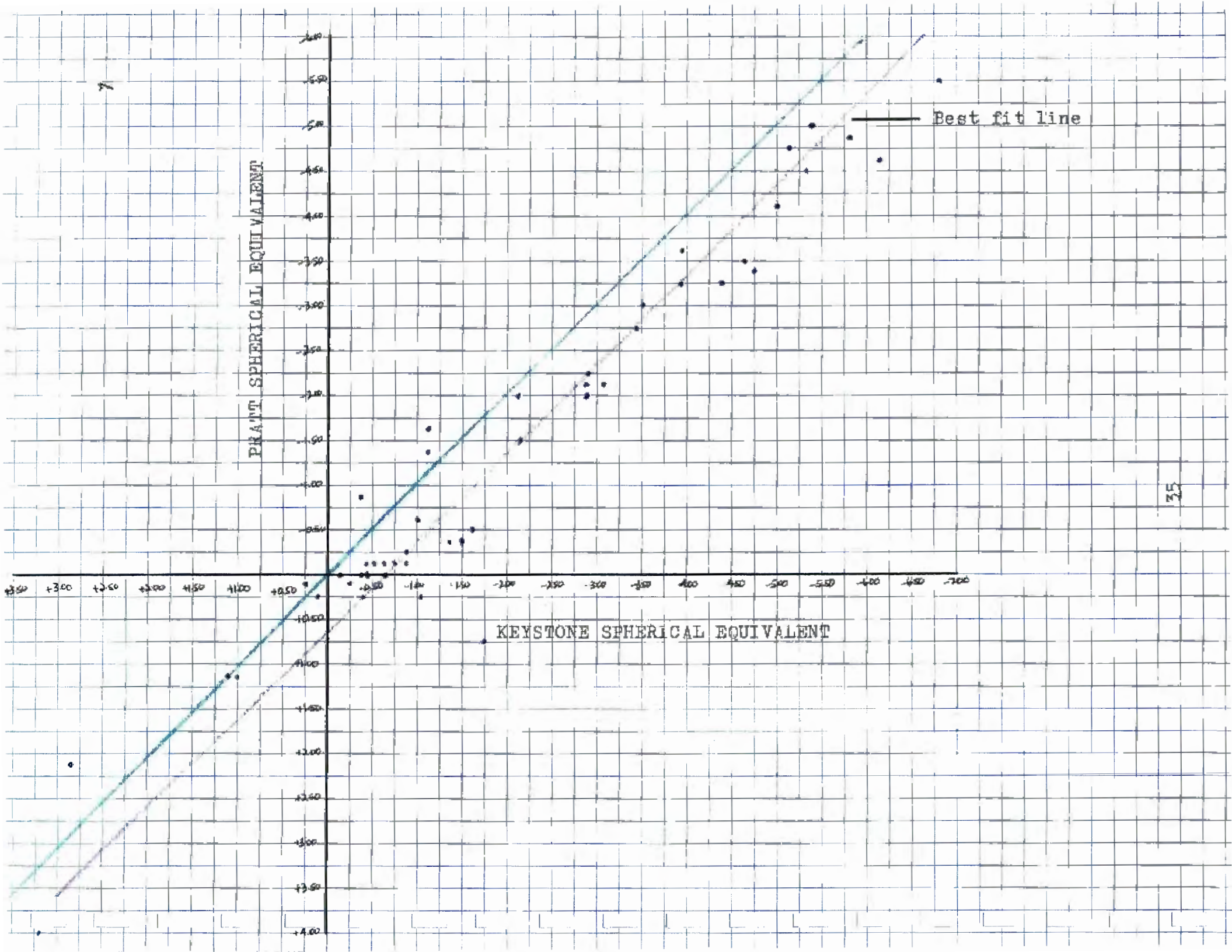
(+) indicates extorsion
(−) indicates intorsion

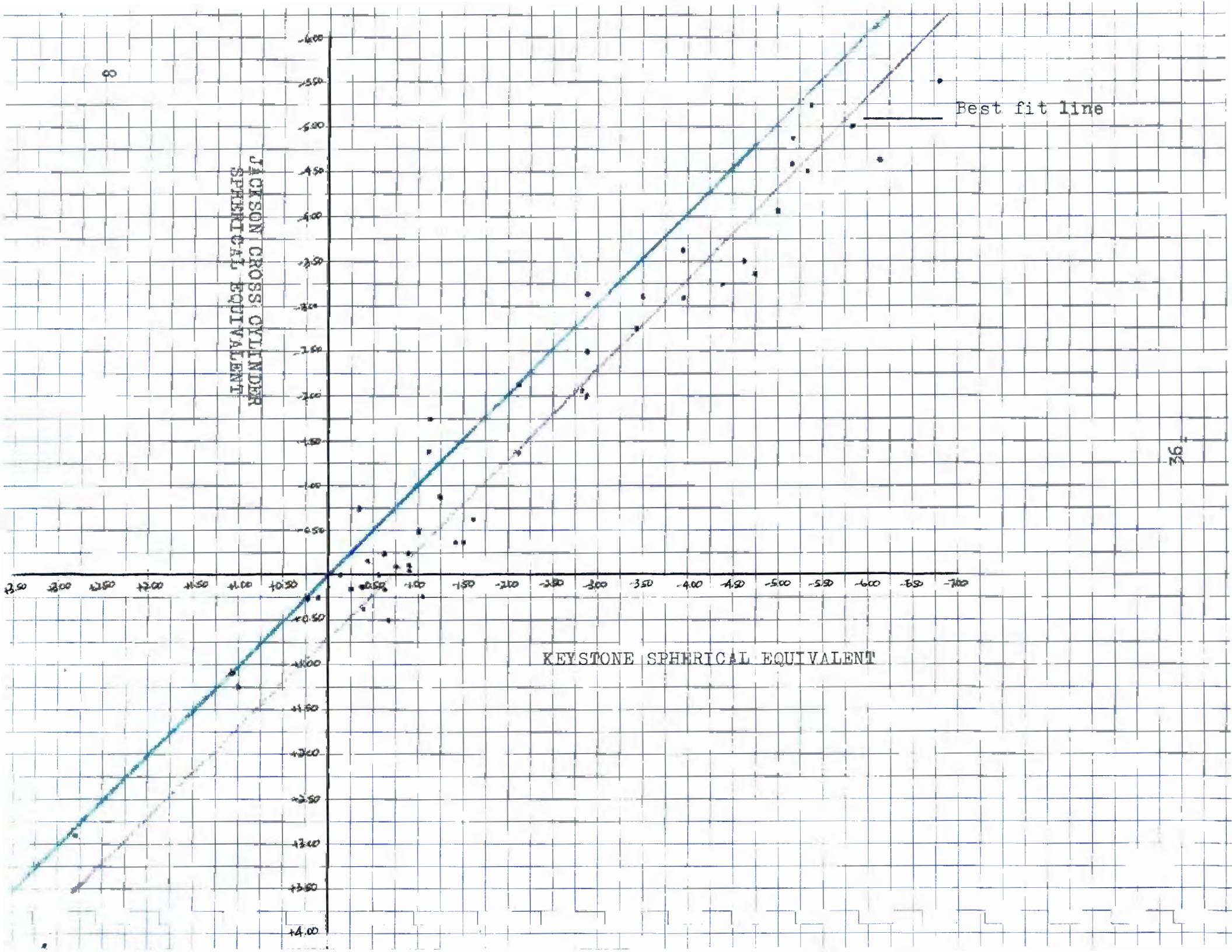

PRATT NEAR CYLINDER AXIS VERSUS
KEYSTONE CYLINDER AXIS DIFFERENCE
CYLINDER POWER
(+) indicates extorsion
(-) indicates intorsion


KEYSTONE CYLINDER POWER
JACKSON CROSS CYLINDER POWER


KEYSTONE CYLINDER POWER
0.50
1.00
1.50
2.00
2.50
3.00
3.50
PRATT NEAR CYLINDER POWER


PRATT NEAR CYLINDER POWER
JACKSON CROSS CYLINDER POWER
0.50
1.00
1.50
2.00
2.50
3.00
3.50
1.00
1.50
2.00
2.50
3.00
3.50


PRATT SPHERICAL EQUIVALENT
KEYSTONE SPHERICAL EQUIVALENT
Best fit line


Best fit line
JACKSON CROSS CYLINDER SPHERICAL EQUIVALENT
KEYSTONE SPHERICAL EQUIVALENT

DISCUSSION

The mean, standard deviation, variance and t-test were calculated for the various categories using the following equations:

$$\text{Mean} = \frac{\Sigma x}{n}$$

$$\text{Standard deviation} = s = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$$

$$\text{Variance} = s^2 = \frac{\Sigma(x-\bar{x})^2}{n-1}$$

$$\text{T-test} \quad \bar{X} - t_{\alpha/2}\frac{s}{\sqrt{n}} < \mu < \bar{x} + t_{\alpha/2}\frac{s}{\sqrt{n}}$$

The red-green versus the Keystone sphere mean difference was -.523D with a standard deviation of .484D, a variance of .234D and a t-test at the 95% confidence level of $-.657 < -.523 < -.389$.

The Jackson Cross Cylinder axis versus the Keystone axis for the right eye had a mean difference of 1.73°, a standard deviation of 16.56°, with a variance of 274.4°. The right eye extorted. The t-test at the 95% confidence level was $-6.23 < 1.736 < 9.708$. The Jackson Cross Cylinder axis versus the Keystone axis for the left eye had a mean difference of 3.47°, standard deviation of 13.96°, and a variance of 195.1°. The t-test, 95%, was $-2.86 < 3.476 < 9.82$. The scattergram (Fig. 2) shows a wide range of axis differences on small cylinder powers. A cut off at .75 D shows lesser range with powers over .75D, but fewer points in this area prevent a best fit line from being constructed.

The Pratt near cylinder axis versus the Keystone axis for the right eye mean difference was -3.47°, standard deviation of 8.25°, and a variance of 68.15°. The right eye intorted. The t-test was $-7.54 < -3.473 < -.5$.

The Pratt near cylinder axis versus the Keystone axis for the left eye mean difference was .79°, standard deviation of 17.16°, and a variance of 294.6°. The t-test was $-8.02 < -0.792 < +6.44$. As with the JCC, the Pratt had a wide distribution in lower powers but too few points above .75 D to construct a best fit line. (Fig. 3).

The Jackson Cross Cylinder versus Keystone cylinder mean difference was -.14D, standard deviation of .49D with a variance of .24D. T-test results were $-2.76 < -1.39 < 0$. A scattergram (Fig. 4) of these points shows this wide variance of points no best fit line could be derived from these points.

The Pratt near cylinder versus the Keystone cylinder mean difference was -.06D, standard deviation of .48D with variance of .24D. The t-test was $-.20 < -.065 < +.07$. The scattergram (Fig. 5) also shows a wide disparity and no possible best fit line. A similar plot (Fig. 6) of the Pratt versus the Jackson Cross cylinder power has a much tighter cluster of points and a best fit line over a range of powers. This further illustrates the validity of the Jackson Cross Cylinder and the Pratt and illustrates the variability of the keystone method.

The Pratt near cylinder spherical equivalent versus the Keystone spherical equivalent mean difference was -.59D, standard deviation of .49D and a variance of .25D. The t-test was $-.733 < -.593 < -.45$. Points plotted for a scattergram (Fig. 7) basically fall on the more minus side of the normal line. A best fit line constructed shows the Keystone finding to be .50D more minus than the Pratt.

The Jackson Cross Cylinder spherical equivalent versus the Keystone spherical equivalent mean difference was -.56D, standard deviation of .48D and a variance of .23D. The t-test results were $-.7 < -.564 < -.428$. The similar scattergram (Fig. 8) for the JCC vs the Keystone also has a best fit line of .50D more minus for the Keystone.

CONCLUSIONS

It was found that the various axis findings ranged approximately 7^{o} on either side of the mean according to the t-test, using 95% confidence limits. This was found with both the keystone axis versus the Jackson Cross Cylinder axis and the Pratt axis. The majority of subjects had small amounts of cylinder causing a varied axis determination. The confidence interval may have been much smaller had a cut off on low cylinder values been incorporated in the sample selection. To estimate this factor, cylinder powers of .75D were grouped and compared for the JCC vs Keystone and the Pratt near cylinder vs the Keystone. As both right and left eyes were lumped for this determination, the standard deviation has more significance than the variance. For values less than .75D the standard deviation was 33.5^{o} or 3 times the standard deviation (11.1) of the values greater than .75D. Considering the Pratt vs the Keystone; the values less than .75D were again 3.5 times the standard deviation of the greater than .75D value. (34.4^{o} vs 9.7^{o}).

This offers a clear illustration that larger cylinder powers allow for more accuracy in axis determination. However a t-test for each comparison shows a range from -8.27 to 5.60^{o} for the JCC vs Keystone and -11.18 to -.94 for the Pratt vs Keystone. Thus a 14^{o} and 11^{o} range for a 95% confidence interval does not constitute an accurate evaluation of axis by the Keystone card.

This is shown graphically in Figures 2 and 3.

By using the Red-green versus the Keystone sphere, it was found that the Keystone was .523D more minus. The t-test found a range of -.657 to -.389D for a 95% confidence limit.

Lastly, the equivalent sphere for the Pratt bichrom sphere was compared to the sphere equivalent of the Keystone. This also showed a .59D more minus value for the Keystone and a 95% confidence limit of -.73 to -.45D. Correspondingly, a confidence limit at 95% of -.70 to -.43D was found for the Keystone equivalent sphere versus the Jackson Cross cylinder equivalent sphere. The mean value was .56D more minus for the Keystone finding. Not calculated in these findings was the effect of the 13 foot testing distance for the Red-Green Sphere determinations. Had this been considered the Keystone card would have shown a more minus variation from the Jackson Cross cylinder and the Pratt sphere findings.

In conclusion, it is found that the Keystone Astigmatism card could not be used effectively as a screening device for power, sphere, and cylinder determinations. As the data have shown, approximately .50D of plus must be added to the Keystone sphere finding to approximate the Red-green or 7a finding. A similar amount must be incorporated to approximate the Jackson Cross Cylinder and Pratt sphere equivalent finding. Further, axis determinations do not indicate adequate accuracy for any cylinder power range. In view of this, these authors suggest that while the Keystone card had some value in finding an adjusted sphere and sphere equivalent it could not produce reliability for axis and cylinder power determination. The Keystone card does not possess sufficient accuracy or saving of time to replace any of the conventional methods of sphere, cylinder, and axis determinations.

Eye	Initials	Age	Dom. eye	Skilled	Un-skilled	21 mono	Pratt near cyl	Red-Green	VA	Jackson Cross cyl	VA	Comp. Sphere	Sphere Shaft Setting	Cylinder Shaft Setting	Axis	Keystone finding	VA	Comments
OD	MR	26	x		x	+3.50	-0.50 x 97	+0.25	15+	-0.50 x 98	15	+2.00	-1.75	-2.50	105	+0.25 +0.75 x 105	15	Large pupils
OS	MR					+3.25	-0.50 x 97	+0.25	15+	-0.25 x 105	15	+2.00	-2.37	-3.00	95	-0.37 -0.62 x 95	15	
OD	LR	28	x	x		+5.00	-5.75 x 2	+1.50	15	-5.50 x 177	15	+1.00	Plano	no response thru -5.00				
OS	LR					+5.50	-6.50 x 173	+1.75	15	-6.25 x 175	15	+1.00	+0.37 thru +1.00	-2.00 thru -4.00	176	+1.37 -7.00 x 176	15	
OD	EB	27		x		+4.50	-0.75 x 72	+1.50	15	-0.50 x 72	15	+2.00	-0.62	-1.37	50	+1.37 -0.75 x 5	15	
OS	EB		x			+4.50	-0.25 x 165	+1.25	15	-0.25 x 163	15	+2.00	-0.75	-1.00	140	+1.25 -0.25 x 140	15	
OD	TB	26	x	x		+1.75	-2.00 x 72	-1.00	15	-2.25 x 75	15	-1.00	-0.50	-1.75	72	-1.50 -1.25 x 72	15-	
OS	TB					+1.25	-2.25 x 125	-2.00	15	-2.25 x 122	15	-1.00	-1.37	-2.37	115	-2.37 -1.00 x 115	30	Left eye acuity was better after JCC in place
OD	KB	27	x		x	Plano	-0.50 x 2	-3.25	15	-0.50 x 4	15	-2.00	-1.75	-3.50	5	-3.75 -1.75 x 5	20	
OS	KB					-0.25	-0.25 x 2	-3.50	15	-0.25 x 177	15	-2.00	-1.62	-2.25	176	-3.62 -0.62 x 176	15	
OD	CJ	31		x		+3.00	Plano	-0.25	15	Plano	15	+1.00	-1.75	-1.87	90	-0.75 -0.12 x 90	20+	
OS	CJ		x			+3.50	-0.25 x 170	Plano	15	-0.25 x 164	15	+1.00	-1.25	-2.12	158	-0.25 -0.87 x 158	15	
OD	JC	26		x		-3.25	-1.75 x 71	-4.00	15	-2.00 x 70	15	-5.00	+0.62	-2.25	67	-4.37 -2.87 x 67	20	
OS	JC		x			-2.00	-1.00 x 108	-5.00	15	-1.00 x 115	15	-5.00	-0.62	-3.00	106	-5.62 -2.37 x 106	25	Poor responder on Pratt OS and Keystone
OD																		

Eye	Initials	Age	Dom. eye	Skilled	Un-skilled	21 mono	Pratt near cyl	Red-Green	VA	Jackson Cross cyl	VA	Comp. Sphere	Sphere Shaft Setting	Cylinder Shaft Setting	Axis	Keystone finding	VA	Comments
OD	RR	29	X	X		+2.75	-0.25 x180	Plano	15	Plano -0.12 x 76	15	+1.00	-1.75	-2.00	90	-0.75 -0.25x90	15	Keystone V.A. not as clear as others
OS	RR					+3.00	-0.25 x106	Plano	15	Plano -0.37 x 102	15	+1.00	-1.25	-1.62	90	-0.25 -0.37x90	15	
OD	JC	24	X	X		+3.00	-0.50 x180	+0.25	15	-0.25 x 160	15	+1.00	-1.00	-1.62	170	Plano -0.62x170	15	
OS	JC					+3.25	-0.50 x 4	+0.25	15	-0.25 x 30	15	+1.00	-1.25	-1.62	5	-0.25 -0.37x 5	15	
OD	CB	25	X	X		+2.00	-0.75 x90	-1.00	15	-0.75 x 90	15	-1.00	Plano	-0.25	85	-1.00 -0.25x85	15	
OS	CB					+1.75	-0.75 x 80	-1.25	15	-1.00 x 80	15	-1.00	+0.12	-0.37	103	-0.87 -0.50x103	20	
OD	BW	25	X		X	+2.75	No cyl	-0.50	15	-0.25 x 94	15	+1.00	-2.37	-2.87	180	-1.37 -0.50x180	15	
OS	BW					+3.25	-0.50 x 2	+1.00	20	-0.25 x 2	25	+1.00	-2.00	-2.50	180	-1.00 -0.50x180	20	
OD	JE	23	X	X		+0.75	-0.50 x 15	-2.50	15	-0.50 x 15	15	-2.00	-1.25	-1.62	15	-3.25 -0.37x15	15	
OS	JE					Plano	-0.75 x 5	-3.00	15	-0.75 x 5	15	-2.00	-2.12	-2.37	15	-4.12 -0.25x15	15	
OD	RM	25	X	X		+3.00	-0.25 x 5	-0.25	15	-0.25 x 4	15	+1.00	-2.37	-2.62	90	-1.37 -0.25x90	20	
OS	RM					+3.50	-0.25 x 5	-0.25	15	-0.25 x 25	15	+1.00	-2.12	-2.50	90	-1.12 -0.37x90	20	
OD	LF	23		X		+3.75	-0.50 x177	+0.50	15	-0.37 x 177	15	+1.00	-0.87	-2.12	175	+0.25 -1.25x175	15	
OS	LF		X			+4.00	-0.50 x 17	+0.50	15	-0.50 x 30	15	+1.00	-0.75	-1.00	2	+0.25 -0.25x 2	15	
OD																		

Eye	Initials	Age	Dom. eye	Skilled	Un-skilled	21 mono	Pratt near cyl	Red-Green	VA	Jackson Cross cyl	VA	Comp. Sphere	Sphere Shaft Setting	Cylinder Shaft Setting	Axis	Keystone finding	VA	Comments
OD	GW	24	X	X		+7.00	-0.50 X 20	+4.25	15	-0.25 X 163	15	+3.00	+0.25	+0.12	30	+3.25 -0.12x30	15	
OS	GW					+5.75	-1.75 X 77	+3.00	40-	-0.75 X 76	30	+3.00	+0.25	-0.62	98	+3.25 -0.87x98	25-	History of amblyopia
OD	DG	23	X	X		+1.75	-0.25 X 15	-2.00	15	-0.12 X 72	15	-1.00	-1.87	-2.25	90	-2.87 -0.37x90	15	Could feel himself accommodating on
OS	DG					+1.75	-0.50 X 170	-1.75	15	-0.37 X 168	15	-1.00	-1.50	-2.12	165	-2.50 -0.62x165	15	Keystone V.A.
OD	BK	24		X		-1.00	-0.75 X 15	-4.25	15	-0.75 X 22	15	-3.00	-1.87	-2.75	18	-5.75 -0.87x18	15	Could feel himself accommodating on
OS	BK		X			-1.00	-1.00 X 162	-4.25	15	-1.25 X 155	15	-3.00	-1.87	-3.50	160	-4.87 -0.62x160	15	Keystone V.A.
OD	BV	25	X	X		+1.00	-1.50 X 166	-2.50	15	-1.25 X 165	15	-2.00	-1.12	-2.75	155	-3.12 -1.62x155	15	
OS	BV					+1.50	-1.00 X 175	-1.75	15	-1.50 X 2	15	-2.00	-0.37	-1.37	180	-2.37 -1.00x180	15	
OD	DL	24	X	X		-0.25	-0.25 X 105	-3.25	15	-0.25 X 135	15	-3.00	-1.62	-1.87	100	-4.62 -0.25x100	15	
OS	DL					+0.50	-0.50 X 166	-2.75	15	-0.75 X 167	15	-3.00	-0.12	-0.87	160	-3.12 -0.75x160	15	
OD	TC	26	X	X		+3.00	-0.25 X 71	Plano	15	Plano	15	+1.00	-1.25	-1.87	80	-0.25 -0.62x80	15	
OS	TC					+3.00	-0.25 X 102	Plano	15	-0.25 X 90	15	+1.00	-1.62	-1.87	90	-0.62 -0.25x90	15	
OD	JD	25	X	X		+3.00	-0.25 X175	+0.25	15	Plano	15	+1.00	+0.25	No cyl	15	+0.25	15	
OS	JD					+3.00	-0.25 X 180	+0.25	15	-0.25 X 180	15	+1.00	-1.12	-1.37	15	-0.12 -0.25x15	15	
OD																		

Eye	Initials	Age	Dom. eye	Skilled	Un-skilled	21 mono	Pratt near cyl	Red-Green	VA	Jackson Cross cyl	VA	Comp. Sphere	Sphere Shaft Setting	Cylinder Shaft Setting	Axis	Keystone finding	VA	Comments
OD	RH	23		X		+1.50	-0.50 X102	-4.50	15	-0.25 X119	15	-3.00	-2.00	-2.37	118	-5.00 S -0.37 C X 118	15	
OS	RH		X			+1.50	-0.50 X 87	-4.75	15	-1.00 X 95	15	-3.00	-2.25	-2.50	71	-5.25 S -0.25 C X 71	15	
OD	DS	23		X		-0.75	-1.00 X172	-4.00	15	-1.00 X174	15	-3.00	-1.62	-3.00	172	-4.62 S -1.37 C X 172	15	
OS	DS		X			-0.25	-0.75 X 10	-3.75	15	-0.75 X 10	15	-3.00	-1.50	-2.50	15	-4.50 S -1.00 C X 15	15	
OD	BB	23	X	X		+2.75	-0.25 X 83	-0.50	15	Plano	15	+1.00	-1.62	-2.37	90	-0.62 S -0.75 C X 90	15	
OS	BB					+2.50	-0.25 X 83	-0.75	15	Plano	15	+1.00	-1.12	-1.50	90	-0.12 S -0.37 C X 90	15	
OD	RR	24	X	X		+3.00	-0.50 X172	+0.50	15	-0.50 X160	15	+1.00	-2.00	-2.12	180	-1.00 S -0.12 C X 180	20	
OS	RR					+3.00	-0.25 X 7	+0.50	20	Plano	15	+1.00	-1.37	-2.00	66	-0.37 S -0.62 C X 66	20	Not immediately clear on Keystone visual acuity
OD																		
OS																		
OD																		
OS																		
OD																		
OS																		
OD																		

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