EVALUATION OF THE KELLY BALL AND MODIFIED BALL PENETRATION DEVICES AS A MEASURE OF CONCRETE CONSISTENCY

by

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3-01-68-013
March 1973

ABSTRACT

The investigation and evaluation of the Kelly Ball and Modified Ball penetration devices, using a modified procedure requiring single readings for comparisons with the standard slump cone procedure for measuring the consistency of plastic portland cement concrete. The purpose was to seek out a possible simplified procedure which could be an effective project control tool. The end result of the investigation was that no such statistical comparison existed over a wide range of test conditions and that the present procedure is not only more valid but also the least expensive and time consuming.

SUMMARY

Previously determined requirements on the need for closer control of plastic concrete prior to its placement led to the evaluation of methods which might yield satisfactory job control information and correlate to standard test procedures. The use of the Ball Penetration device and a simple modification of that device were logical targets of such an investigation. An evaluation program was set up with the assistance of two State Highway Districts and their project Engineers and a number of Materials and Tests Division Field Offices in various prestress plants to perform comparative tests by the three methods, standard slump cone, Kelly Ball and the Modified Ball. Results were then evaluated statistically and plotted to yield graphic as well as mathematical evaluations. The results of the investigation were completely negative as far as the use of single readings with the Penetration Devices and gave further support to the use of the standard slump cone.

CONTENTS

I. SUBJECT

The Evaluation of the Kelly Ball and Modified Ball Penetration Devices in making Rapid Field Measurements of Concrete Consistency.

II. PURPOSE

The need to closely control all facets of concrete to be placed in bridge deck concrete was emphasized by the survey and study of Texas bridge decks completed in 1967. As a result of that study, specifications were rewritten to require the testing of each load of concrete delivered to the project for certain physical requirements which included consistency measured by the slump test.

The Kelly Ball Penetration Device has long been an accepted alternate to the standard slump cone method of measuring the consistency of plastic concrete. The procedure adopted by ASTM as a standard for the Kelly Ball, Designation C 360, is a laborious procedure requiring the handling of a large amount of concrete.

This investigation was not undertaken to prove or disprove the validity of the Kelly Ball method, but was to be an evaluation of a modified version which would be more rapid and within acceptable limits for project control.

III. CONCLUSIONS AND RECOMMENDATIONS

Based on the information developed in this study the following conclusions are reached:

1.) The point to check for the proper consistency of plastic portland cement concrete is prior to placement. Any other procedure would be of no benefit in obtaining proper consistency and would require considerable time and expense to remove unsatisfactory material.

2.) Statistical analysis of the data in each test condition shows the standard slump cone test to be more reliable when compared to single ball penetration readings.

3.) The Ball Penetration Device as outlined by ASTM Designation C 360, requires a large amount of concrete and several readings to yield the required accuracy. This results in either waste or extra handling of the concrete and more time than required by the procedure using the slump cone.

4.) It would be of no benefit to the State and, in fact, would be detrimental to change present procedures to allow use of the Ball Penetration Device.

It is therefore recommended that no further action be taken regarding the use of the Ball Penetration device.

IV. MATERIALS

All tests were performed on plastic portland cement concrete produced for use on Texas Highway Department projects with normal departmental inspection.

V. EQUIPMENT FOR EVALUATION

1.) Kelly Ball device as specified in ASTM Designation C 360-63, "Ball penetration in fresh portland cement concrete."(1) (See Appendix 3)

2.) Modified Ball. A modification of the Kelly Ball device designed by A. C. Frankson, Resident Engineer, Texas Highway Department and constructed from a 10-inch length of 4-inch solid cylindrical drill shaft. The nose end is machined to a 4-inch hemispherical shape and a 3-inch handle is welded to the opposite (top) end. The shaft is calibrated and marked into seven 1-inch divisions with the zero mark located two inches from the nose end of the device. Total weight of the modified device is 30 pounds. (See Fig. 1)

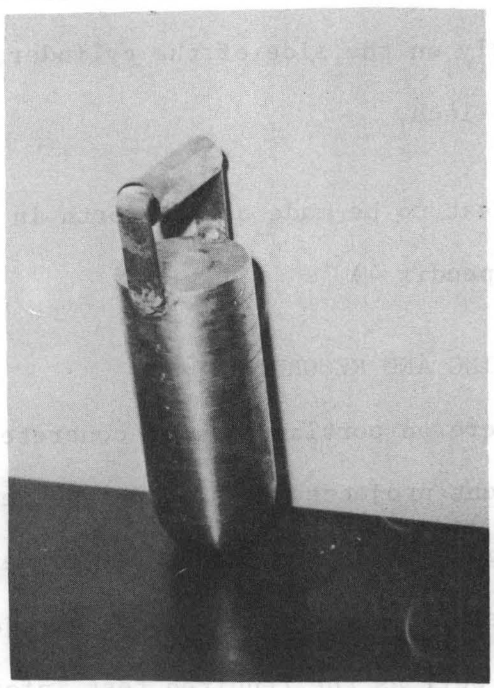


Figure 1.

3.) Standard slump cone as specified in Texas Test Method Tex-415A and ASTM Designation C 143, "Slump of Portland Cement Concrete."(1)(2)

VI. TEST PROCEDURES AND METHODS

1.) The Kelly Ball Test was used as specified in ASTM C 360 with the exception that single readings were to be recorded.

2.) Modified Ball Test was performed as follows:

a.) Device to be held vertical to the surface of the concrete with the nose of the device resting lightly on the surface. A minimum depth of 12 inches and a minimum clearance of 9 inches from the nearest confining wall of the sample shall be maintained.

b.) Release the device smoothly and read the depth of penetration directly on the side of the cylinder, estimated to the nearest 1/4-inch.

3.) Standard Slump Test to be made as set forth in Texas Test Method Tex-415A.(2) (See Appendix 4)

VII. PROCEDURES FOR ACQUIRING AND RECORDING DATA

All tests performed were on portland cement concrete furnished on Texas Highway Department projects which were required to meet all specifications. Design and mix conditions varied between projects and required the proper grouping of test data. Project materials and design information as well as the required test information were recorded on the data sheet shown in Appendix 5.

The Kelly Ball test had previously been determined by Kelly and Polivka(3) to yield a reading which was roughly one-half that of the Slump Cone. Similarly, Frankson had experimentally determined that the Modified Ball reading was approximately twice the value obtained with the slump cone. Therefore, for the purpose of this investigation, all readings taken with the two ball devices were adjusted by either dividing or multiplying by a factor of two, depending upon the device used.

On all but one project, concrete consistency was measured using the three devices each time a measurement of slump was required by the specifications. In the case of the exception, a number of measurements were made with the Slump Cone and the Kelly Ball over a period of several days and then the modified ball and the Slump Cone values were measured during a subsequent number of days. In addition for the same exception, the values reported were all averages of three readings instead of individual readings. Information developed on this project was extensive and is utilized in so far as possible in this report, however, some of the value was negated because of the inability to compare directly with the other projects data.

VIII. DISCUSSION

The Ball Penetration Test for the consistency of plastic portland cement concrete was developed a number of years ago and adopted as a tentative method C 360 by ASTM in 1955. It became a standard in 1963 and reapproved without change in 1968. AASHO adopted the method as a standard with the assigned number AASHO No. T 183.

A statistical analysis of the Ball Penetration test was made by the California Division of Highways and reported in 1966.[4] In addition, California has adopted a modification of the test as a standard test method. Similar adoption has been made by a few other State Highway organizations.

With this background of data and experience there was no need to further prove the validity of the test when performed as set forth in ASTM C 360. Instead, this study was directed toward evaluating a modification of the test procedure and a further proposed modification of the ball device itself to determine if an abreviated version could satisfactorily assist the project inspector in speeding up the pre-placement testing of concrete delivered to the project.

Two State Highway Districts, Lufkin and Yoakum, had previously indicated a desire to participate in an evaluation of the Kelly Ball test. One of the Districts, Yoakum, had already made a limited study with a modified ball device developed by Mr. A. C. Frankson, a Resident Engineer at Victoria, and requested that the modified ball be included in this evaluation study. Additional field studies were scheduled to be performed at prestress concrete plants located at Victoria by permanently assigned Materials and Tests Division inspection personnel. Information gathered by these organizations on plastic portland cement concrete delivered to State Highway projects forms the data for this investigation. District project data is indicated by "F" and prestress plant data by "P" in the figures referred to in this report.

Since neither the standard slump cone test nor the standard ball penetration test were being questioned as to allowable statistical accuracy, any proposed change in existing procedures, to be beneficial to project control, had to provide some tangible reason to support it. This could be in accuracy, ease of testing, time required for testing or in cost of testing. The decision had previously been made based on State-wide studies of existing conditions in concrete bridge decks that the testing itself was desirable and was reflected in changes in project specifications.

The standard method of performing the Ball Penetration Test is given in its entirety in the Appendix. Pertinent points of this method are:

1.) Sufficient concrete and area must be available to provide a minimum depth of 8 in. and a minimum horizontal distance of 9 in. from the center line of the handle to the nearest edge of the level surface on which the test is to be made.

2.) A minimum of 3 readings will be made with the foot of the stirrup moved at least 6 in. from the location for the preceding reading.

3.) If the maximum and minimum readings are more than 1 in. apart, additional readings shall be obtained until three <u>successive</u> readings agree within 1 in.

The State of California modified the test method to require that the minimum horizontal distance will be 9 in. between centers on readings.

With the need to use only acceptable concrete, the emphasis is on testing the concrete prior to placing in the forms and it is readily seen that a rather large amount of concrete must be dumped into an area suitable for test. This concrete must then be wasted or handled economically in such a manner that it can be used if approved.

It was readily apparent that performing the test by the standard methods would increase testing time and cost without yielding a corresponding benefit of accuracy, consistency or ease of testing, i.e., the change would hinder rather than help.

The decision was then made to evaluate single readings against values obtained with the standard slump cone test. Admittedly, the results obtained would not be as statistically sound but if a relationship could be established without excessively broadening the limits set by the specifications, then it might be possible to use the penetration test for project control by periodically correlating the test with the standard slump cone test. A precedent for this type of control had previously been established for another physical test of plastic concrete with the successful adoption of the Chace Air Meter for determining the amount of entrained air.

Data was then accumulated over a two year period as projects specifying portland cement concrete were placed under active construction. This data has been sorted by project, design and materials and examined on an individual basis.

Linear regression analysis comparing values obtained using the Kelly Ball and modified ball devices with those obtained by the standard slump cone were calculated and plotted graphically for each project. (See Appendix 1) In addition, the normal distribution curves of slump, Kelly Ball penetration and Modified Ball Penetration were plotted to show degree of uniformity and comparative values. (Appendix 2)

It is readily apparent upon reviewing the normal distribution curves that when making an analysis based upon single readings, only the routine slump test consistently has a desired pattern. In statistically comparing the three methods of measurements by use of the coefficient of variation (c.v.), in thirteen of the 16 test conditions which have sufficient data for comparison, the c.v. is considerably lower for the slump cone test than for the corresponding c.v. for either ball penetration test.

A careful look at the graphs of the linear regression analysis indicates there is little direct relation between either ball penetration test and the slump cone test when based on single readings.

Table I is a summary of the statistical analyses developed through the linear regression procedure to show the widespread and disjointed values which make a general correlation impossible. The columns headed MB/SL and KB/SL are individual comparisons of the ratios of the average values ($\bar{x}$) for each of the ball penetration tests to the standard slump cone test.

The total result of this study can be simply stated that the standard slump cone test, as specified presently by the Texas Highway Department for measuring the consistency of plastic portland cement concrete, is the only reliable and is the most accurate method of the three studied. To attempt to extend either ball penetration test to obtain greater accuracy would not make either method more reliable than the slump cone test and would so extend the time and material required to make them undesirable in comparison with present procedures.

ACKNOWLEDGEMENTS

Personnel from both the Yoakum and Lufkin Districts along with the Structural Section of the Materials and Tests Division were directly responsible for the accumulation of data from active project control which formed the basis for this report.

In addition, Mr. A. C. Frankson of the Yoakum District contributed much through his efforts to design and manufacture a simplified device which had the potential to enable the Department to properly perform its function at a reduced expense.

Table I

Summary of Statistical Determinations

Project #	$\bar{x}$			s.d.			c.v.				
	M.B.	K.B.	S.L.	S.B.	K.B.	S.L.	M.B.	K.B.	S.L.	MB/SL	KB/SL
P-68-1	0.611	2.944	2.833	0.220	0.464	0.559	36.078	15.758	19.730	0.216	1.039
P-68-2	0.806	3.850	3.088	0.767	0.975	0.508	95.105	25.316	16.464	0.261	1.247
P-68-3	Insufficient Data										
P-68-4	0.396	3.500	2.750	0.559	0.640	0.384	141.118	18.274	13.976	0.144	1.273
P-68-5	1.109	4.125	3.480	0.582	0.871	0.402	52.441	21.107	11.543	0.319	1.185
P-68-6	0.875	3.778	2.944	0.656	0.712	0.512	74.915	18.847	17.389	0.297	1.283
P-68-7	1.292	4.688	2.833	0.504	0.762	0.537	39.002	16.261	18.937	0.456	1.655
F-69-8	2.500	5.100	4.000	0.791	0.652	0.468	31.623	12.783	11.693	0.625	1.275
F-69-9	2.500	4.167	3.500	0.652	0.606	0.224	26.077	14.533	6.389	0.714	1.191
*F-69-10	2.539	8.575	2.832	0.558	2.408	0.741	21.984	28.080	26.151	0.897	3.028
P-70-11	1.209	4.336	2.938	0.660	1.058	0.589	54.588	24.402	20.065	0.412	1.476
P-70-12	1.234	4.500	2.500	0.628	0.926	0.327	50.903	20.574	13.093	0.494	1.800
P-70-13	0.977	3.545	2.000	0.834	1.150	0.403	85.386	32.439	20.156	0.489	1.773
P-70-14	1.291	4.333	3.042	0.881	1.260	0.708	68.188	29.083	23.290	0.424	1.424
P-70-15	0.650	2.400	2.000	0.445	1.294	0.500	68.533	53.926	25.000	0.325	1.200
P-70-16	1.175	4.550	3.375	0.933	1.739	0.738	79.483	38.225	21.877	0.348	1.348
P-70-17	1.326	5.000	3.514	0.780	1.534	0.793	58.821	30.679	22.561	0.377	1.423

Where $\bar{x}$ = Average reading w/device
s.d. = Standard deviation
c.v. = Coefficient of variation

M.B. = Modified Ball
K.B. = Kelly Ball
S.L. = Standard Slump Cone

BIBLIOGRAPHY

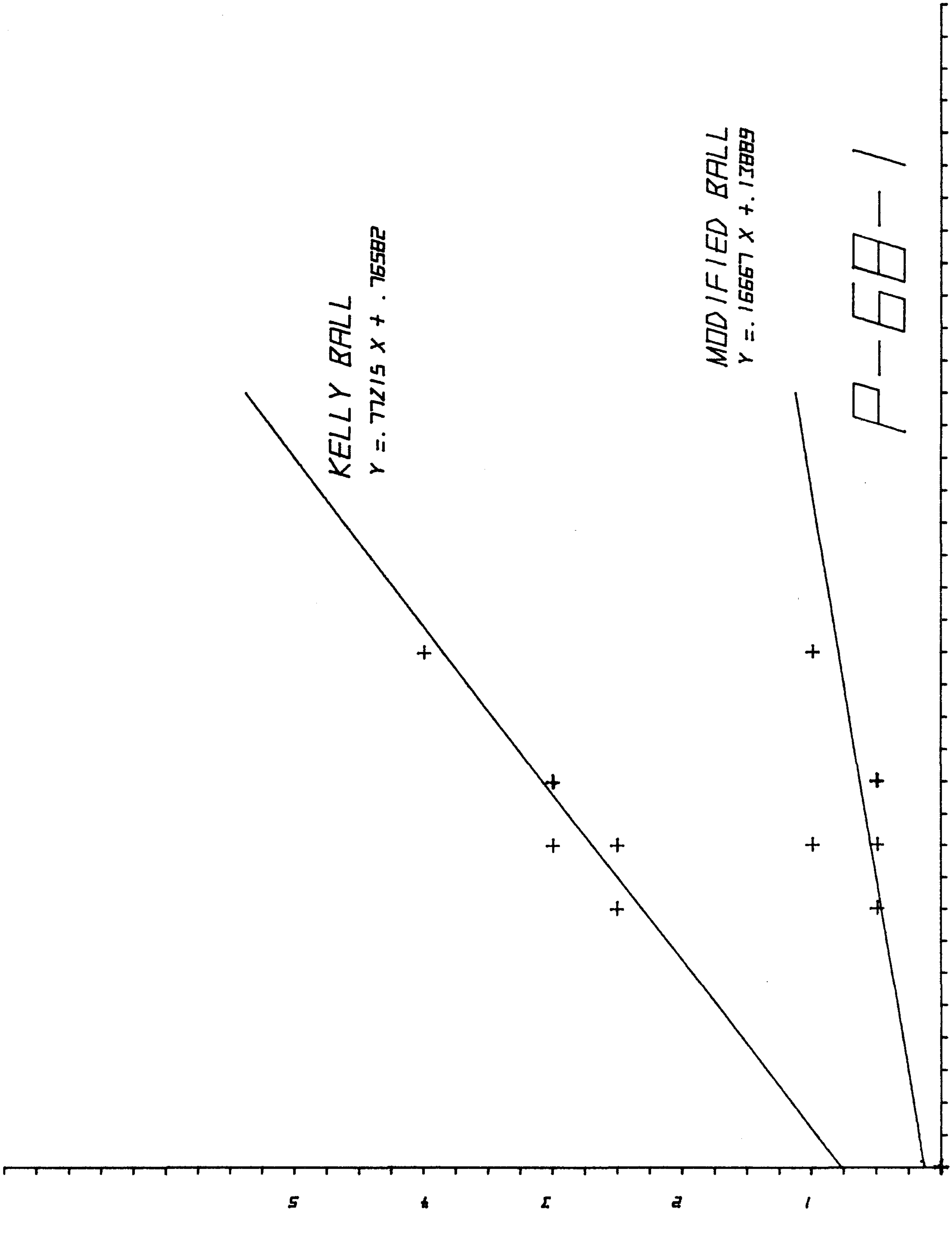
1.) ASTM Standards, Part 10.

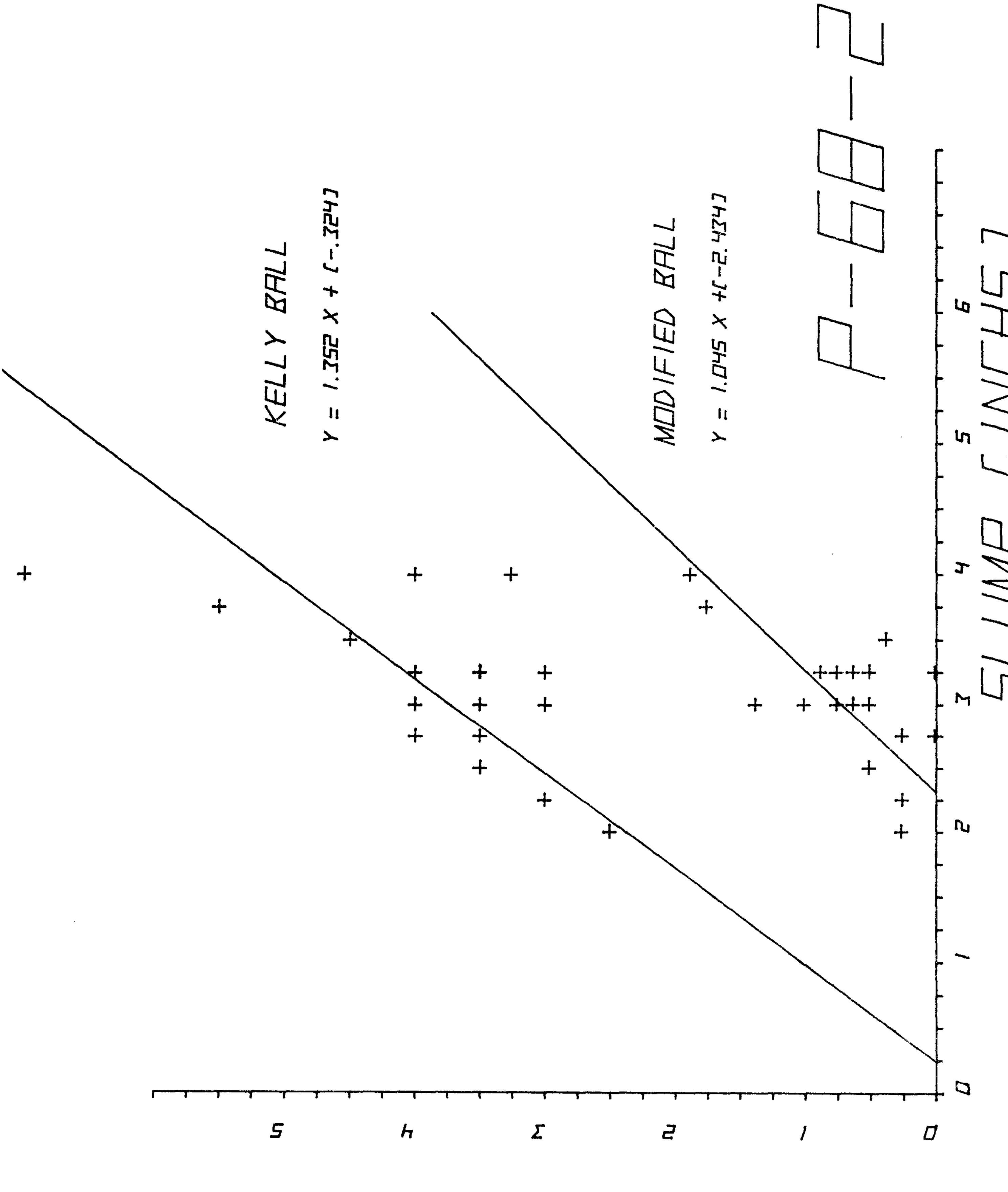
2.) Texas Highway Department Standard Testing Procedures, Vol. 2.

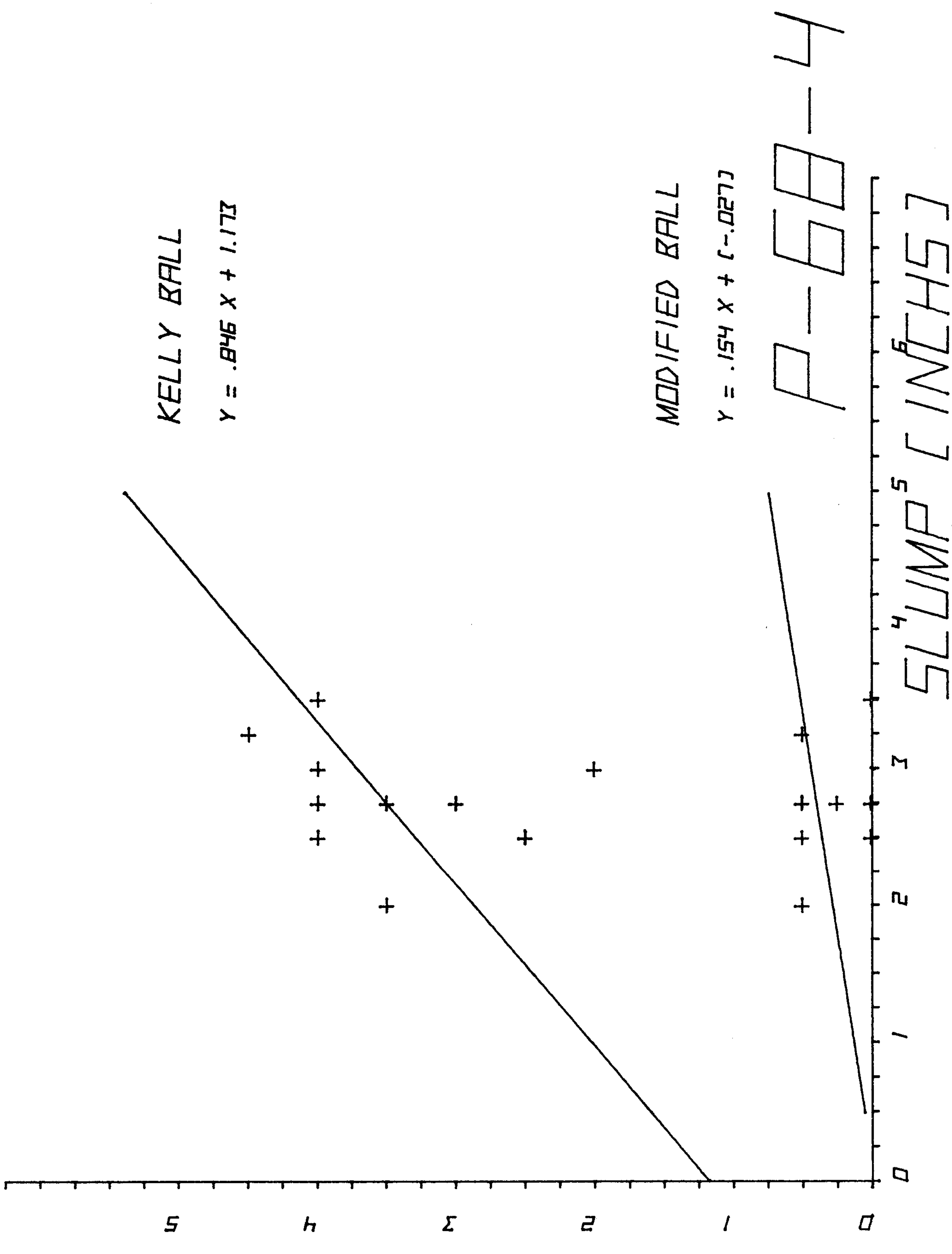
3.) "Ball Test for Field Control of Concrete Consistency" by Kelly and Polivka; Journal of the American Concrete Institute, May 1955.

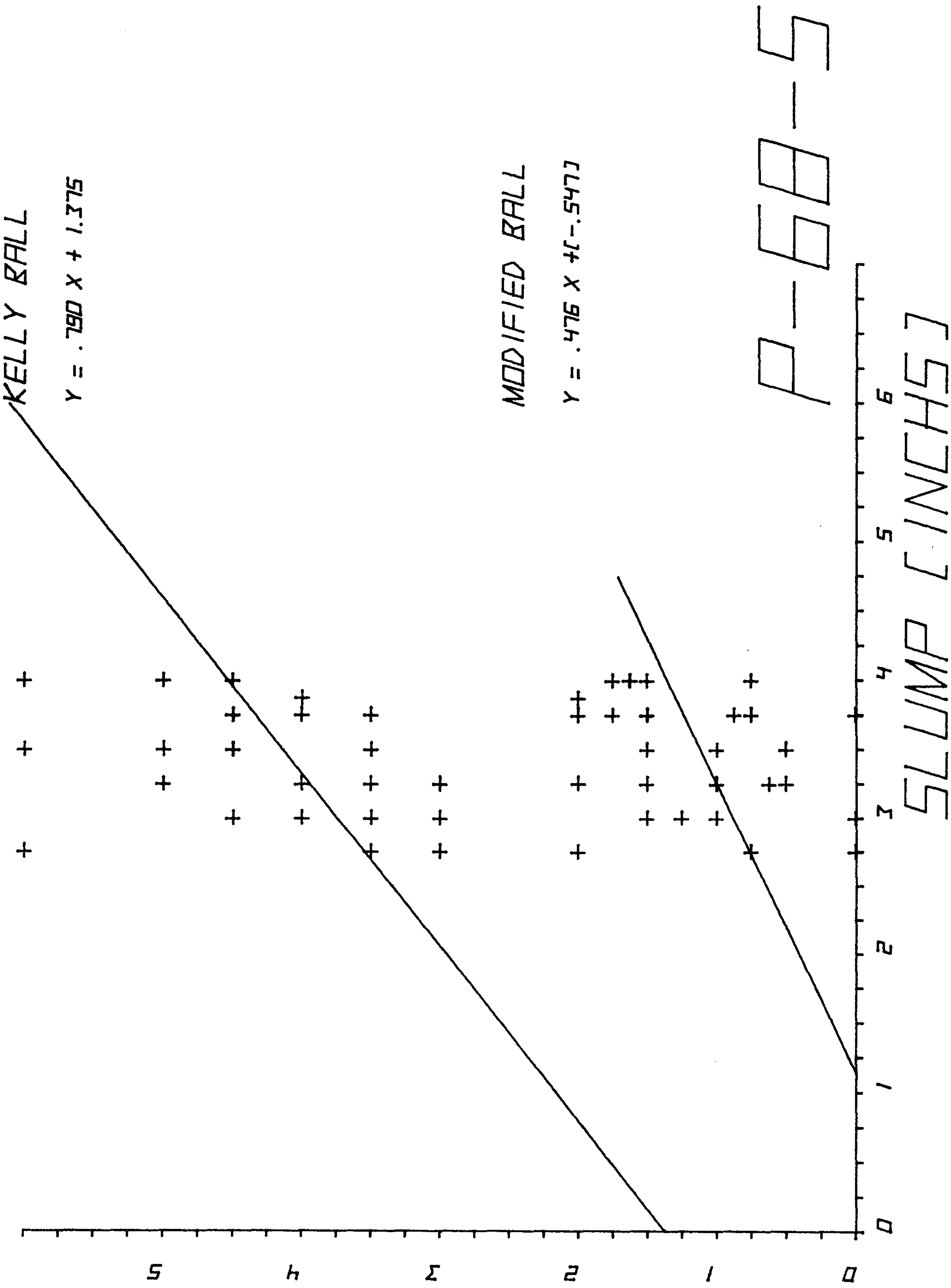
4.) "A Statistical Analysis of the Kelly Ball Test" by the General Services Section, Materials and Research Department, Department of Public Works, Division of Highways, State of California, Oct. 1966.

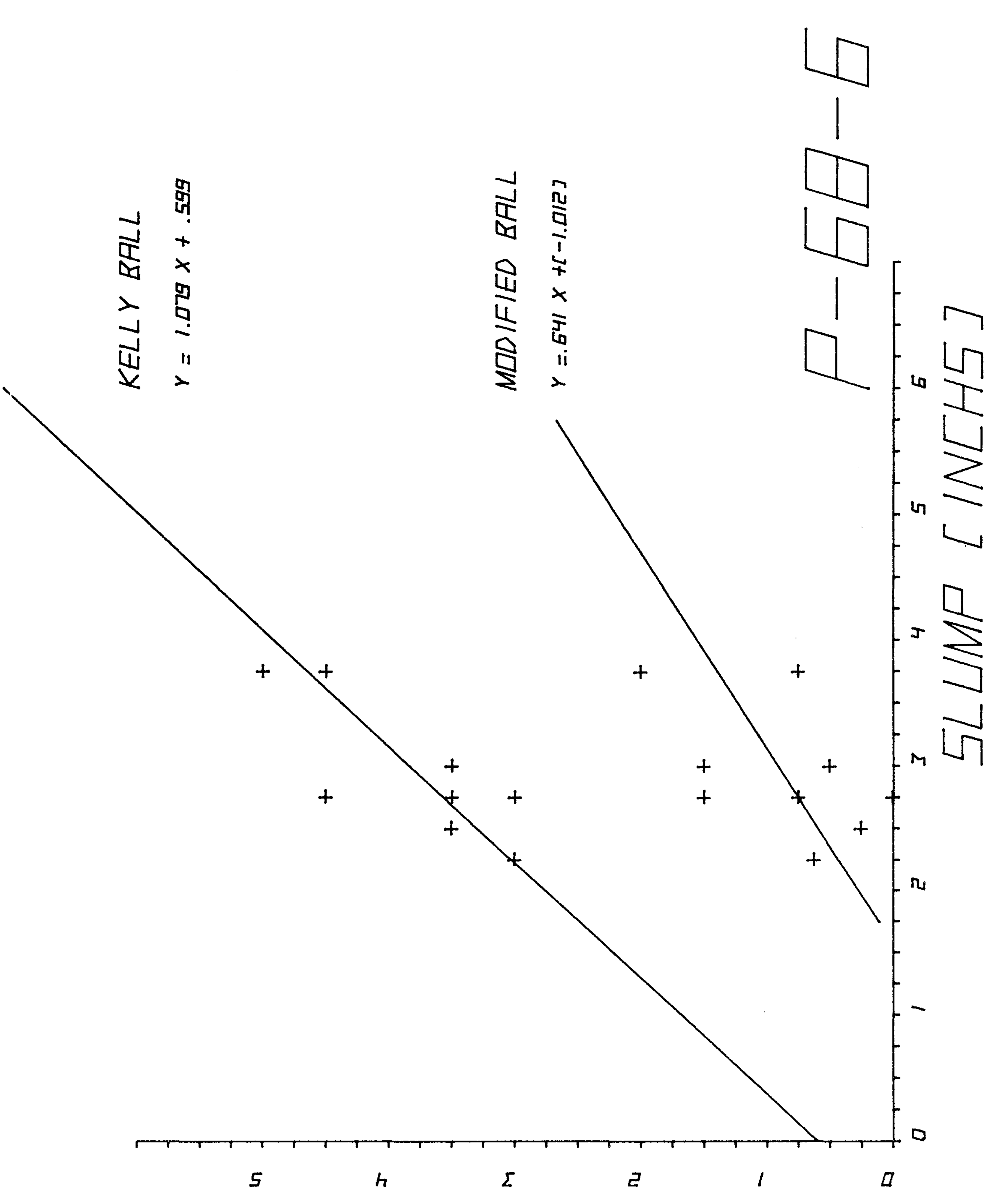
APPENDIX 1

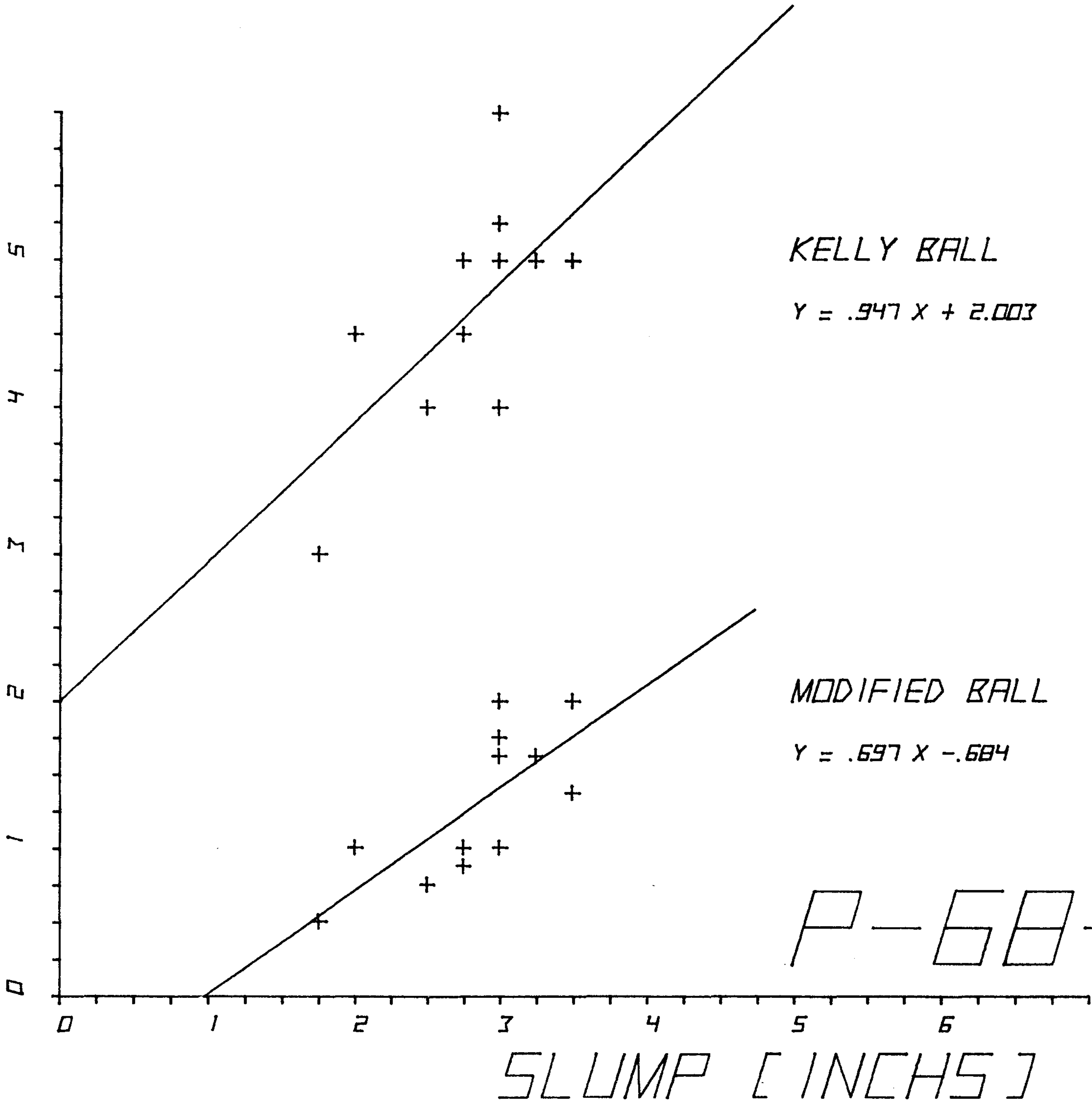

KELLY BALL
Y =.77215 X + .76582
MODIFIED BALL
Y =.16667 X +.13889
P-68-1
SLUMP (INCHS)
0
1
2
3
4
5
6
1
2
3
4
5


P-68-2
SLUMP (INCHS)
KELLY BALL
Y = 1.352 X + (-.324)
MODIFIED BALL
Y = 1.045 X +(-2.434)
0
1
2
3
4
5
6
0
1
2
3
4
5

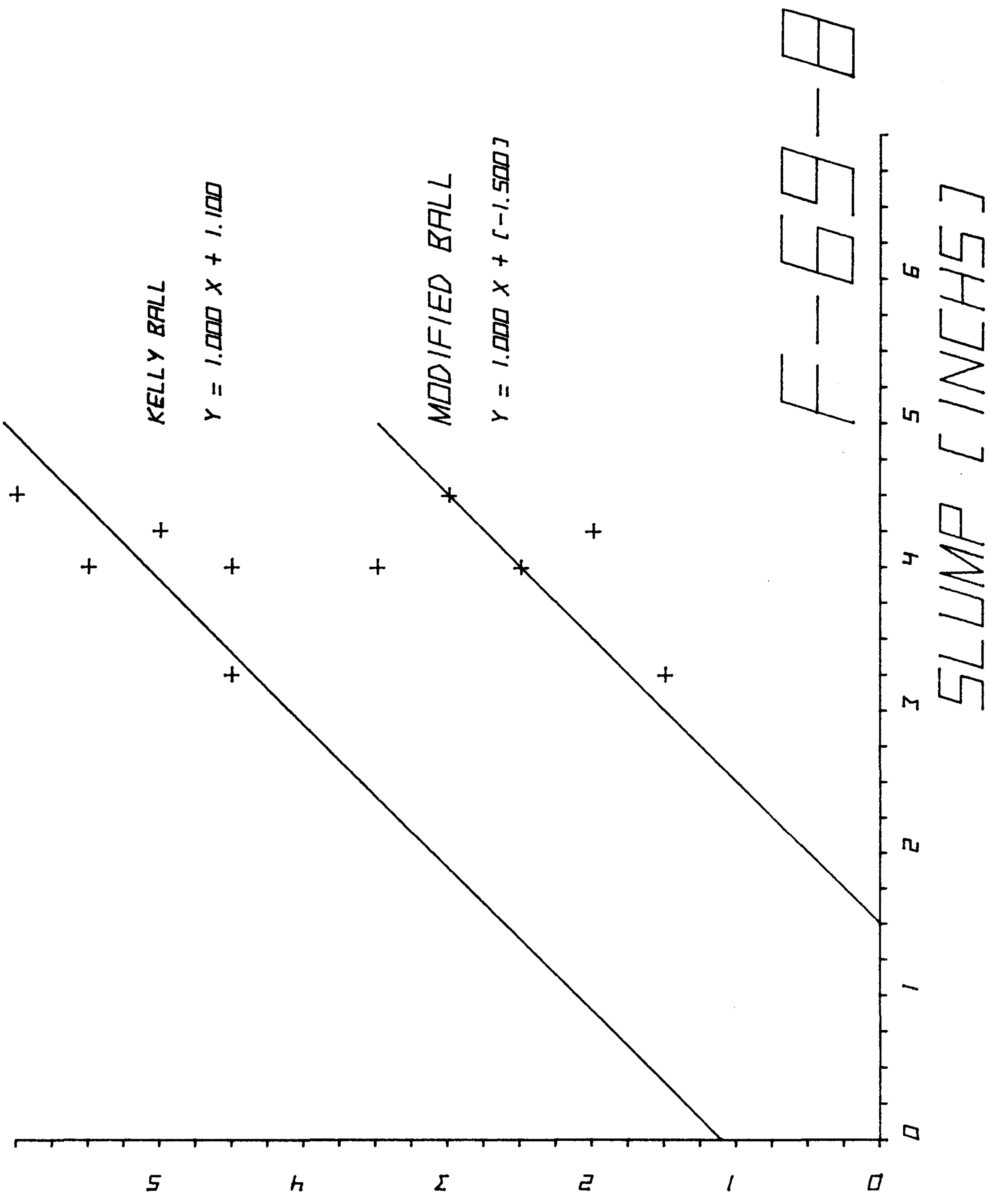

KELLY BALL
Y = .846 X + 1.173
MODIFIED BALL
Y = .154 X + (-.027)
P-68-4
SLUMP (INCHS)
0
1
2
3
4
5
6

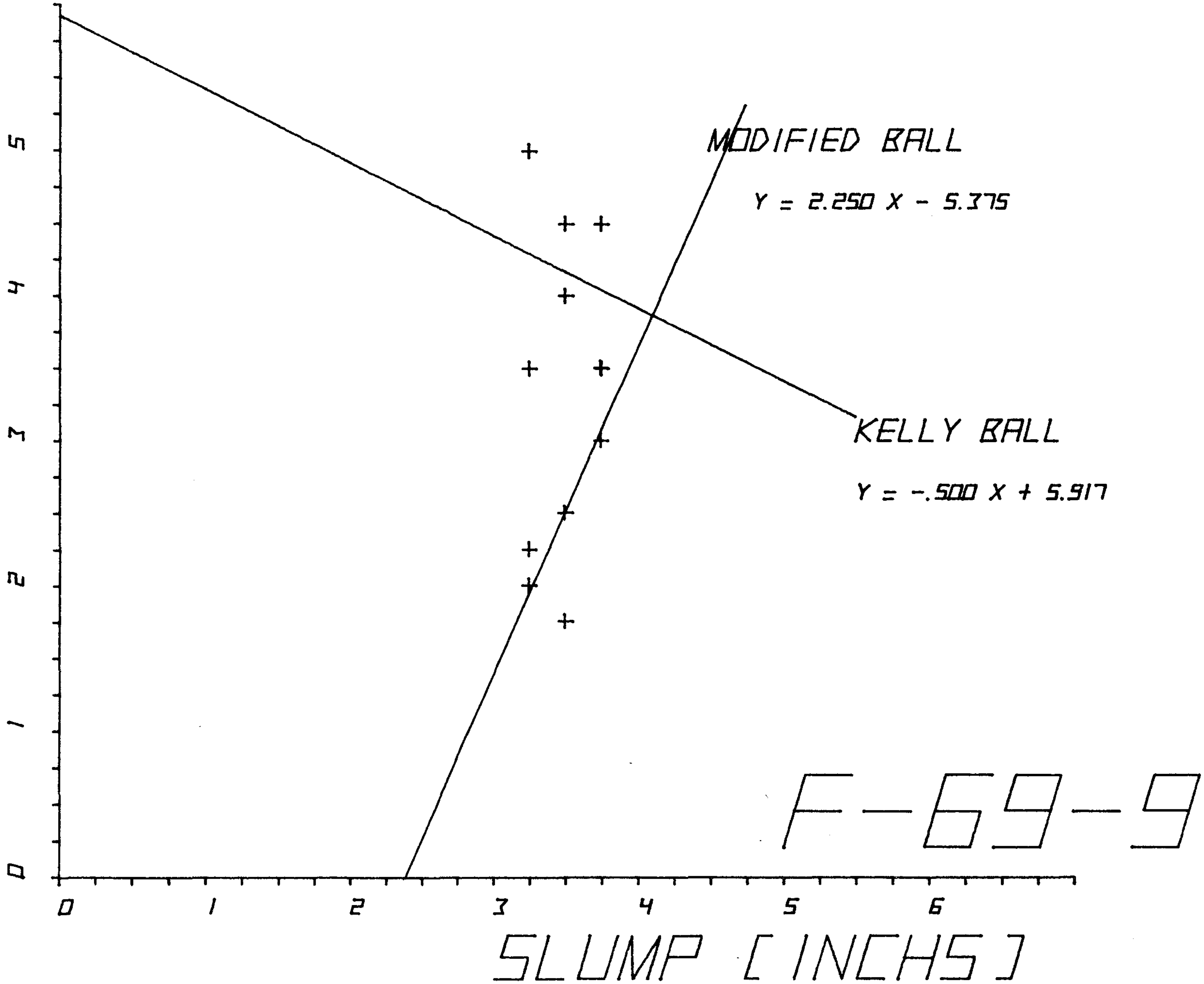

P-68-5
KELLY BALL
Y = .790 X + 1.375
MODIFIED BALL
Y = .476 X +(-.547)
SLUMP (INCHS)
0
1
2
3
4
5
6
0
1
2
3
4
5

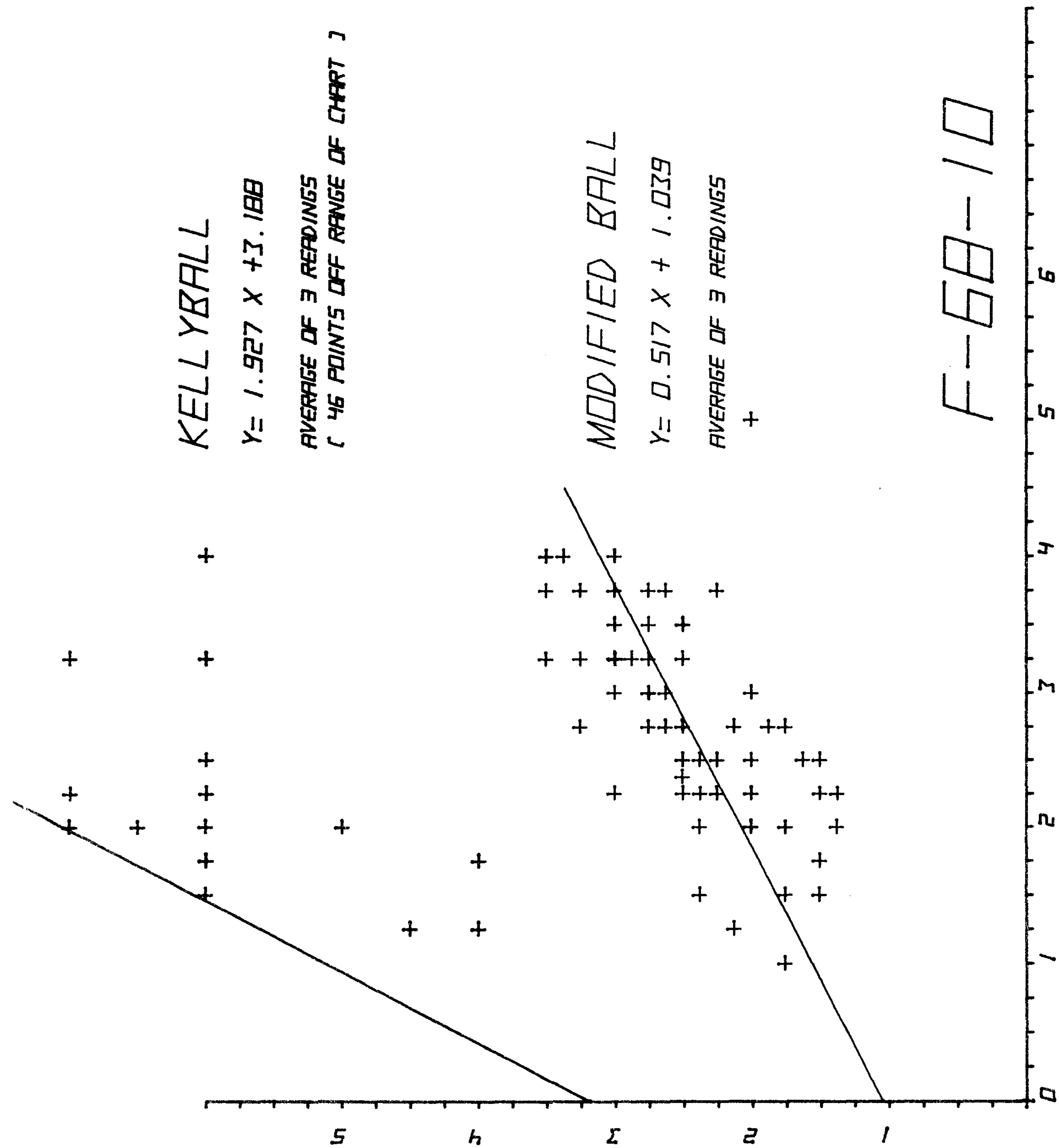

P-68-6
SLUMP [INCHS]
KELLY BALL
Y = 1.079 X + .599
MODIFIED BALL
Y =.641 X +[-1.012]

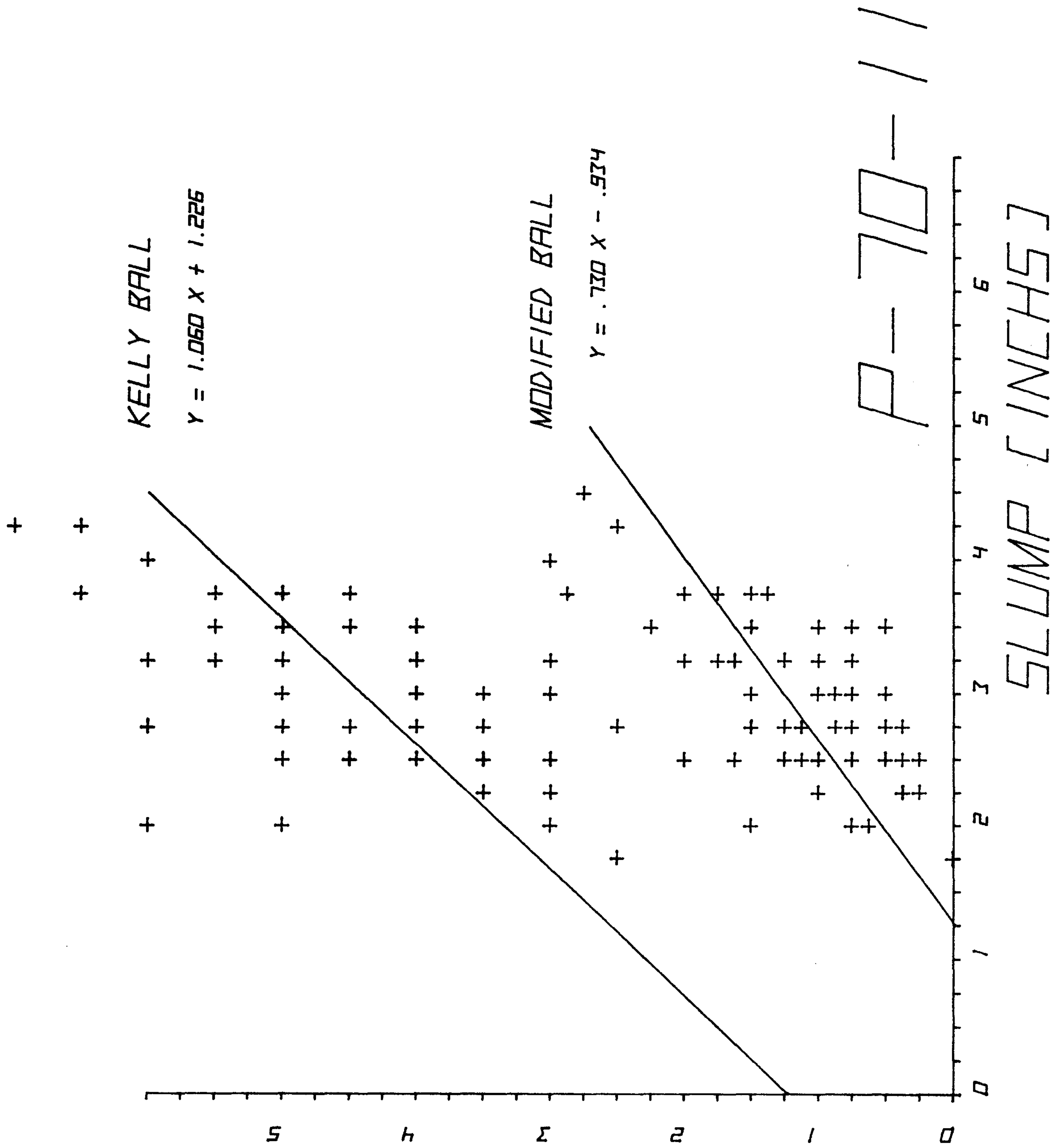

KELLY BALL
Y = .947 X + 2.003
MODIFIED BALL
Y = .697 X -.684
0
1
2
3
4
5
6
SLUMP [INCHS]

P-68-7

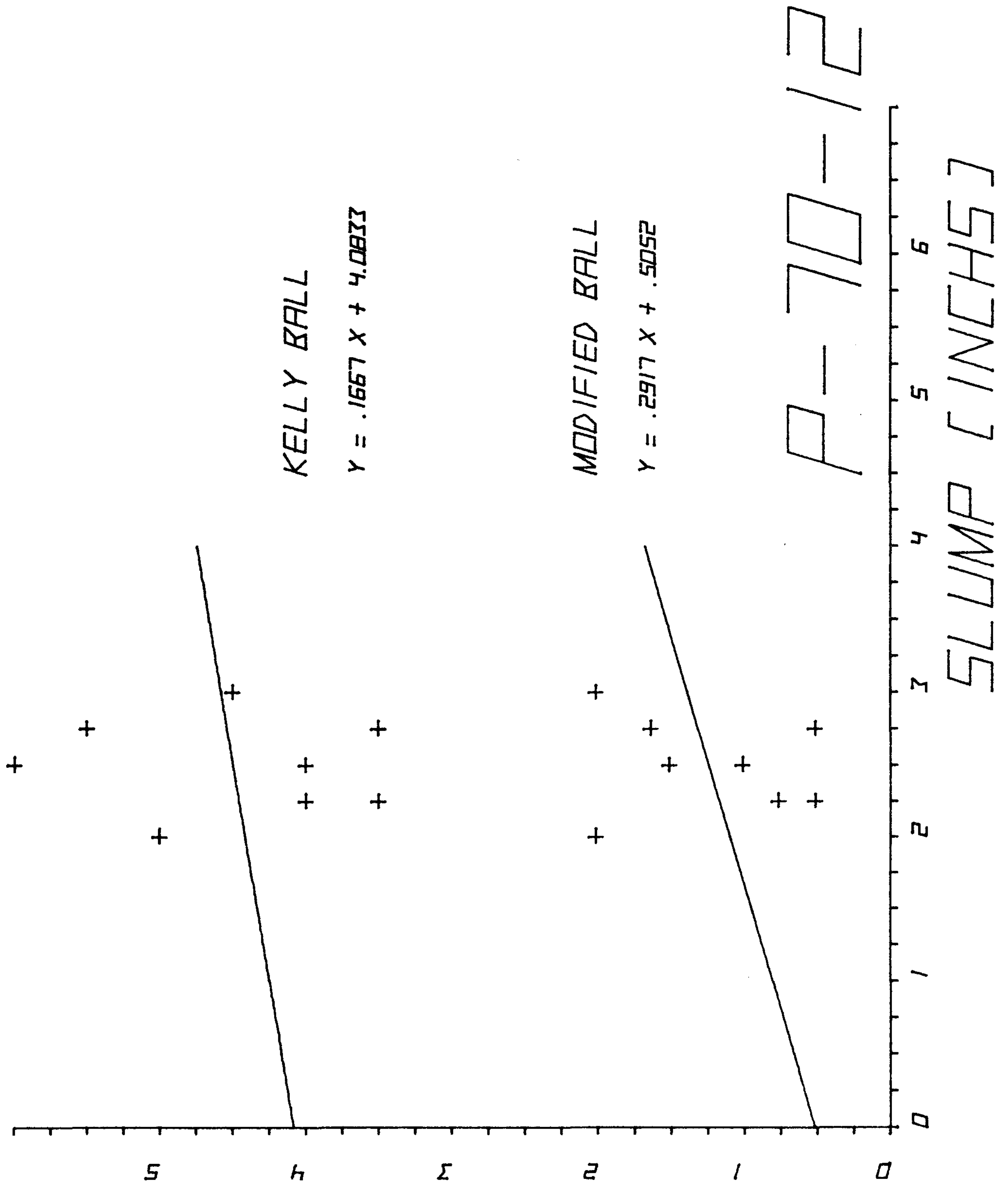

F-69-B
KELLY BALL
Y = 1.000 X + 1.100
MODIFIED BALL
Y = 1.000 X + (-1.500)
SLUMP (INCHS)
0
1
2
3
4
5
6
0
1
2
3
4
5

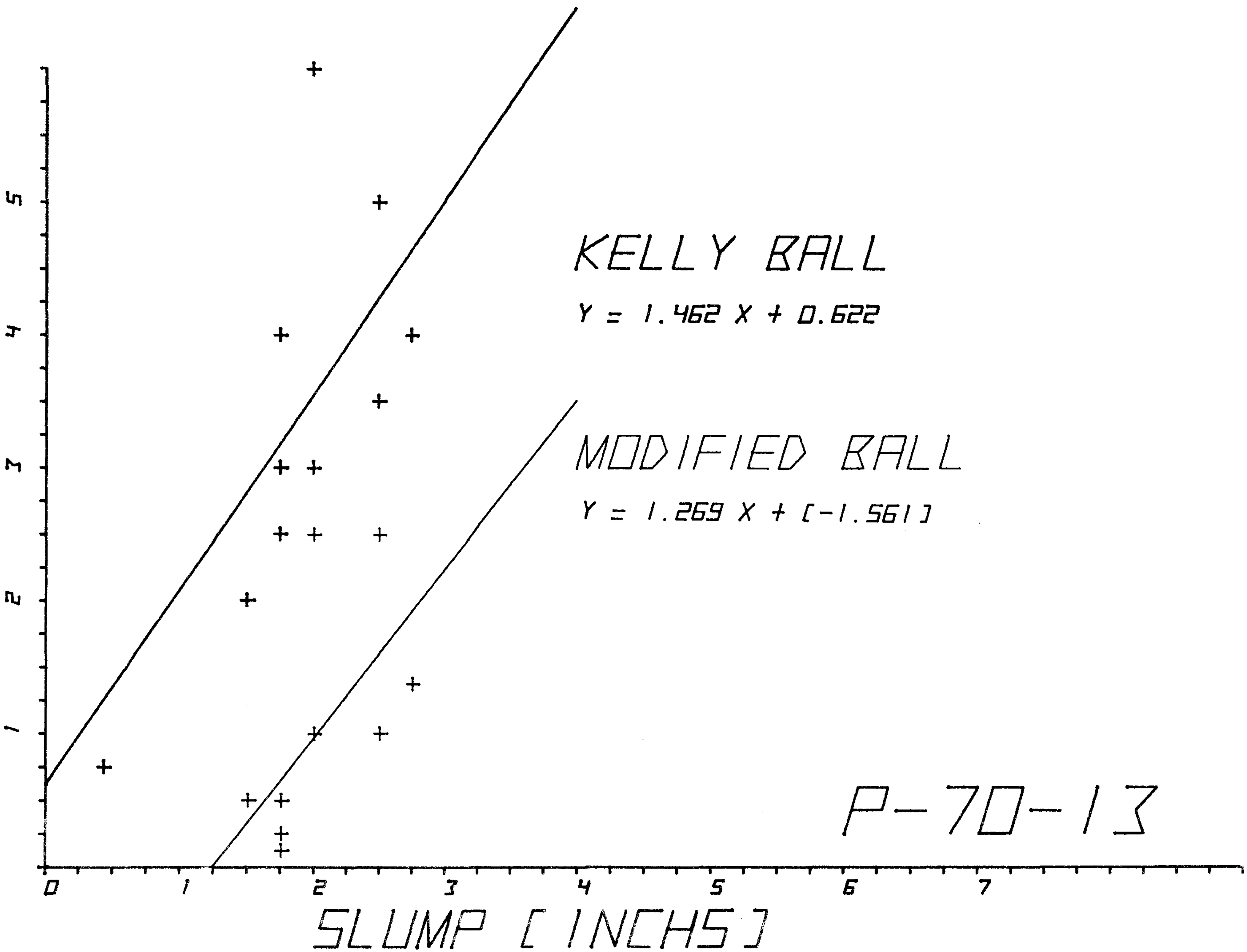

MODIFIED BALL
Y = 2.250 X - 5.375
KELLY BALL
Y = -.500 X + 5.917
F-69-9
0
1
2
3
4
5
6
SLUMP [INCHS]

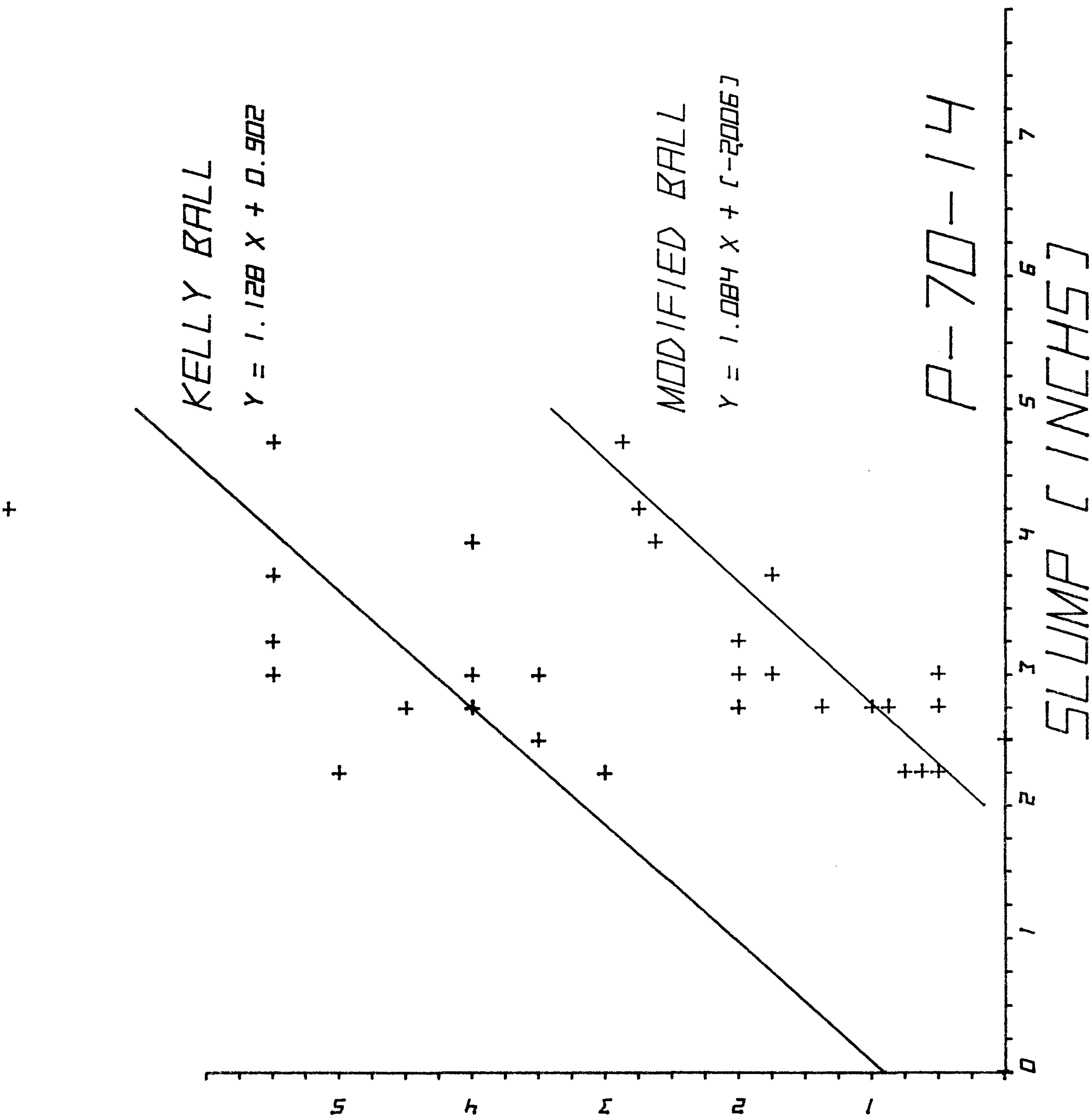

KELLYBALL
Y= 1.927 X +3.188
AVERAGE OF 3 READINGS
(46 POINTS OFF RANGE OF CHART)
MODIFIED BALL
Y= 0.517 X + 1.039
AVERAGE OF 3 READINGS
F-68-10
SLUMP (INCHS)
0
1
2
3
4
5
6
1
2
3
4
5



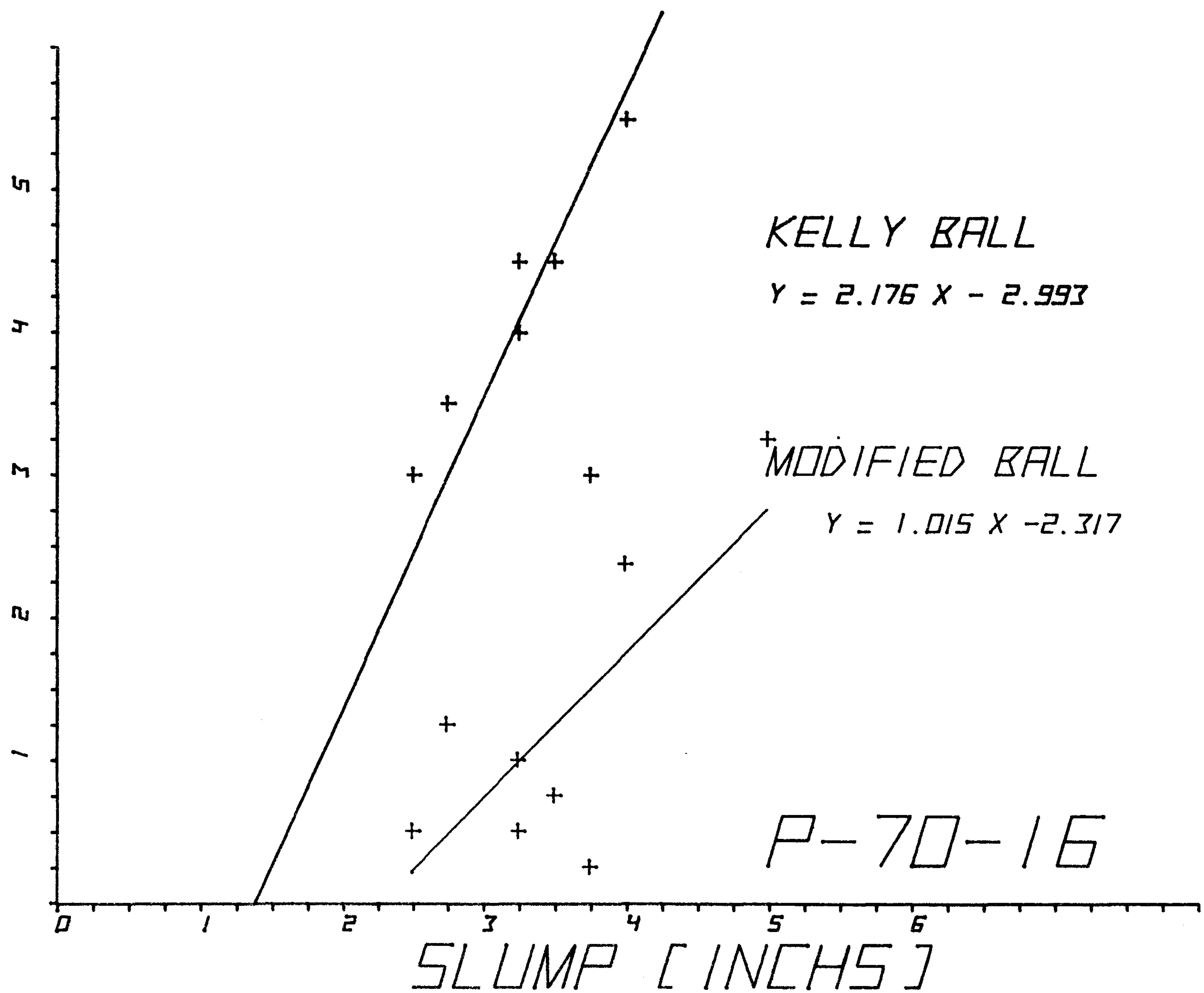
P-70-11
SLUMP [INCHS]
KELLY BALL
Y = 1.060 X + 1.226
MODIFIED BALL
Y = .730 X - .934
0
1
2
3
4
5
6
0
1
2
3
4
5

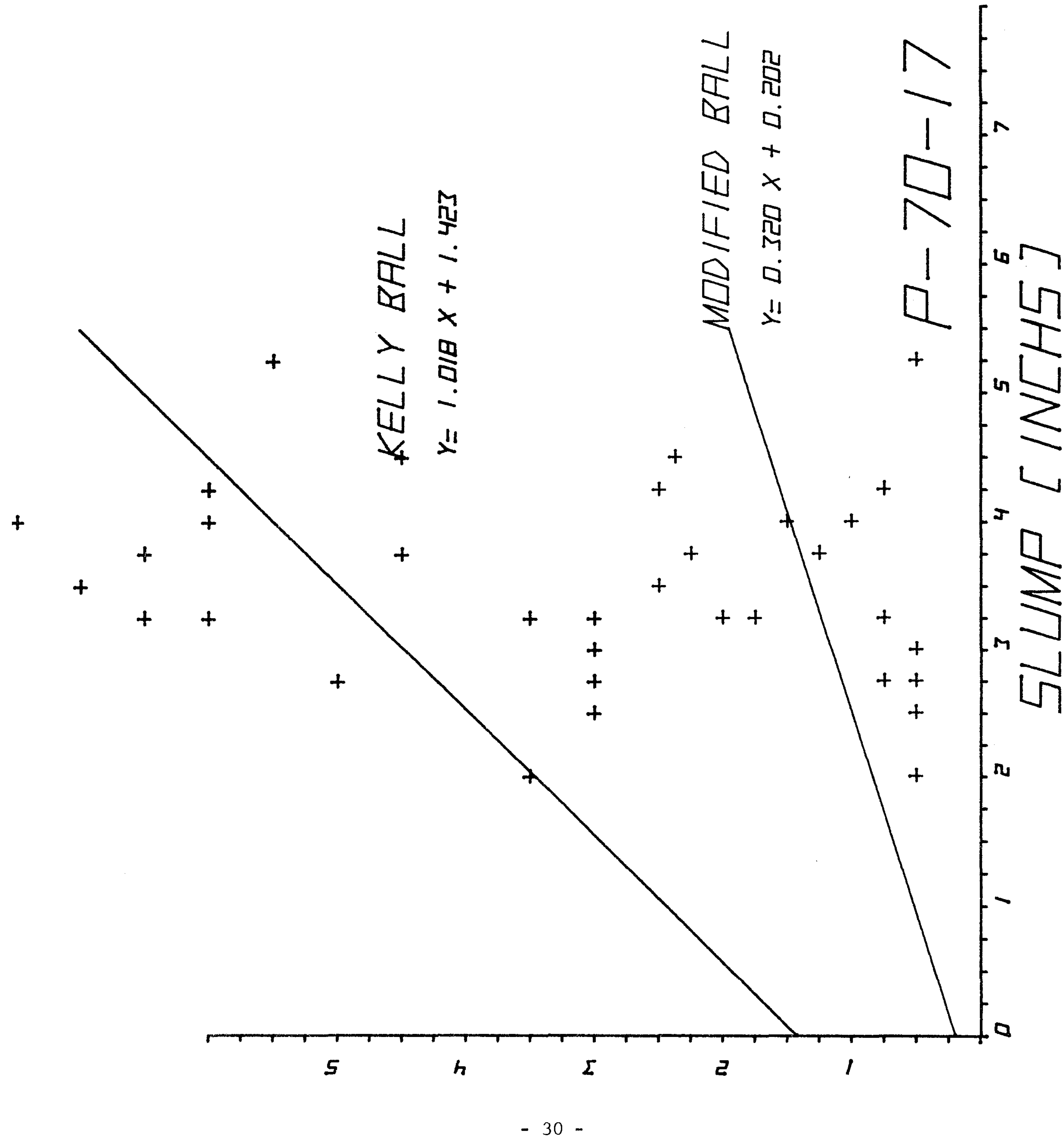

P-70-12
SLUMP (INCHS)
KELLY BALL
Y = .1667 X + 4.0833
MODIFIED BALL
Y = .2917 X + .5052
0
1
2
3
4
5
6
0
1
2
3
4
5


KELLY BALL
Y = 1.462 X + 0.622
MODIFIED BALL
Y = 1.269 X + [-1.561]
P-70-13
SLUMP [INCHS]
0
1
2
3
4
5
6
7


KELLY BALL
Y = 1.128 X + 0.902
MODIFIED BALL
Y = 1.084 X + (-.2006)
P-70-14
SLUMP (INCHS)
0
1
2
3
4
5
6
7
1
2
3
4
5

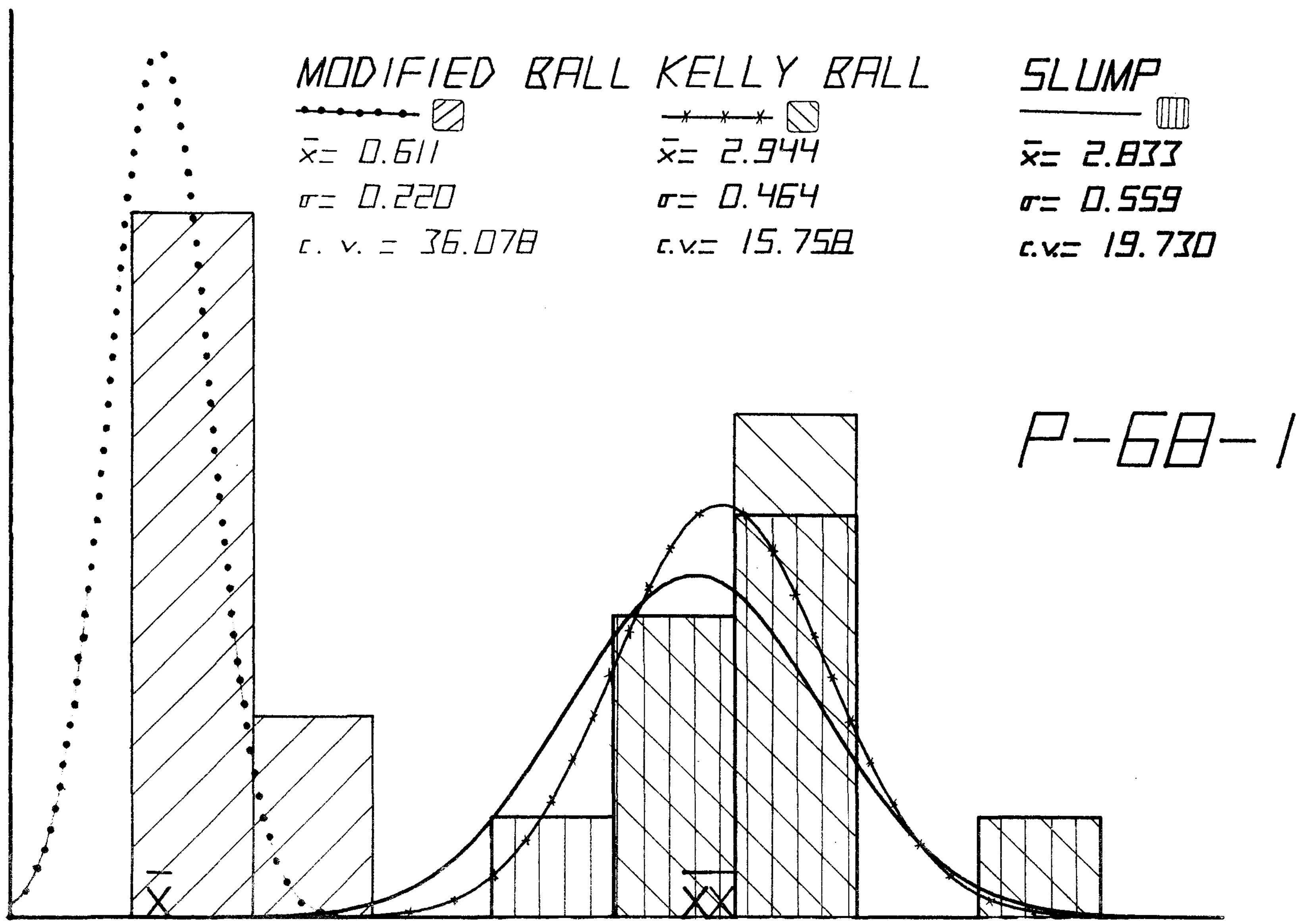

KELLY BALL
Y = 0.250 X + 1.900
MODIFIED BALL
Y = 0.250 X + (-0.850)
P-70-15
SLUMP (INCHS)
0
1
2
3
4
5
6
1
2
3
4
5


KELLY BALL
Y = 2.176 X - 2.993
MODIFIED BALL
Y = 1.015 X -2.317
P-70-16
SLUMP [INCHS]
0
1
2
3
4
5
6

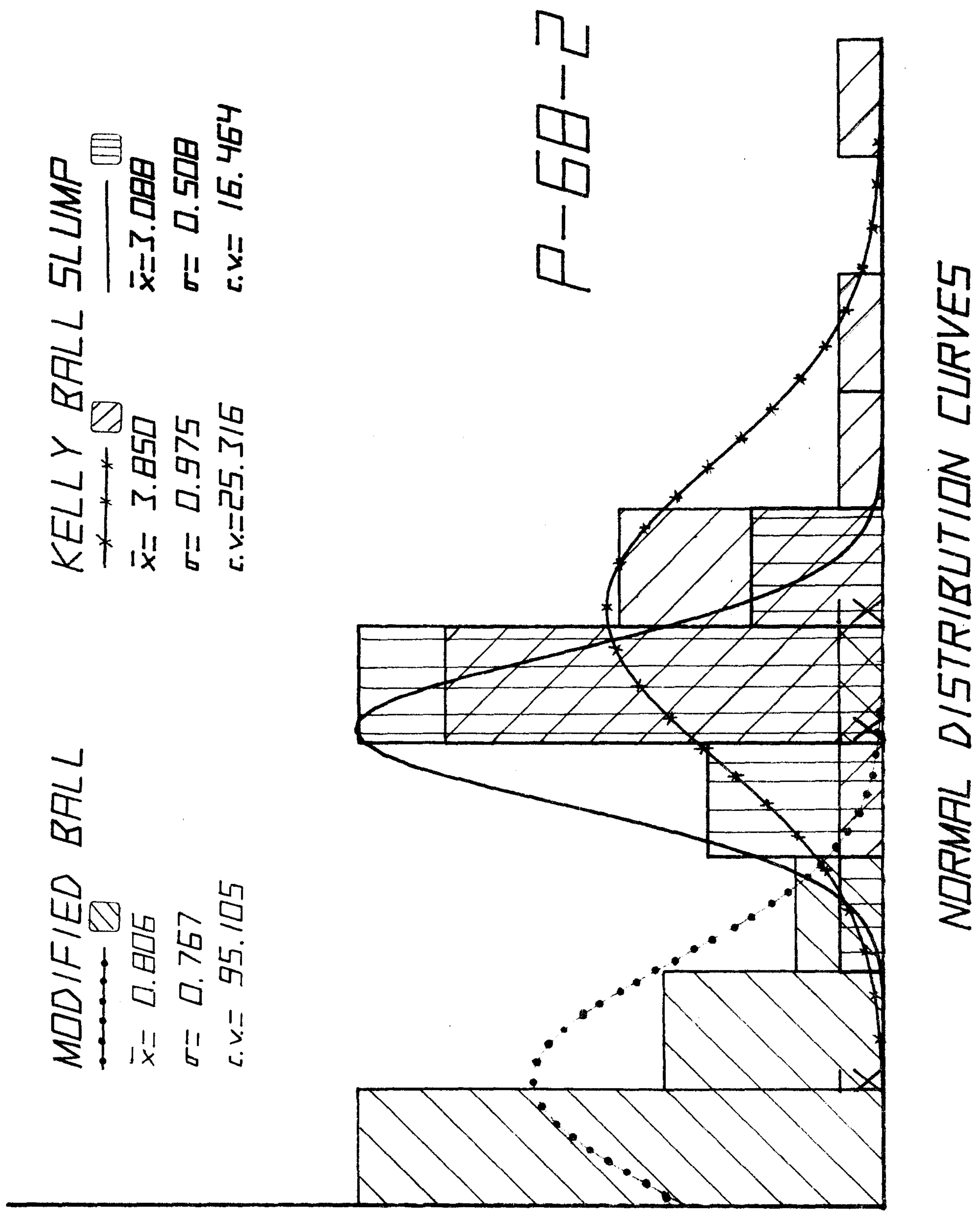


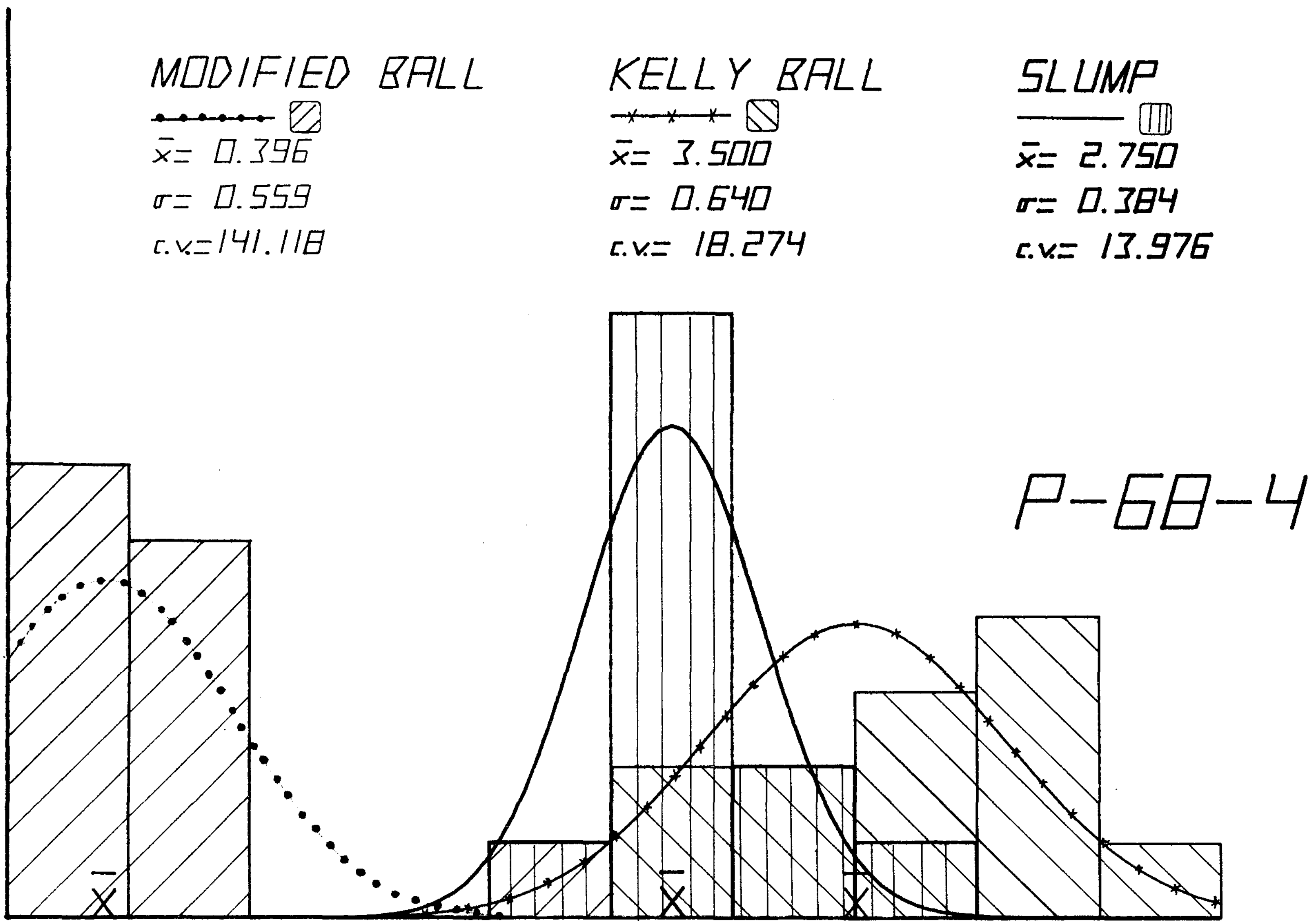
KELLY BALL
Y= 1.018 X + 1.423
MODIFIED BALL
Y= 0.320 X + 0.202
P-70-17
SLUMP (INCHS)
0
1
2
3
4
5
6
7
1
2
3
4
5

APPENDIX 2



NORMAL DISTRIBUTION CURVES


MODIFIED BALL
x̄= 0.806
σ= 0.767
c.v.= 95.105
KELLY BALL
x̄= 3.850
σ= 0.975
c.v.=25.316
SLUMP
x̄=3.088
σ= 0.508
c.v.= 16.464
P-68-2
NORMAL DISTRIBUTION CURVES



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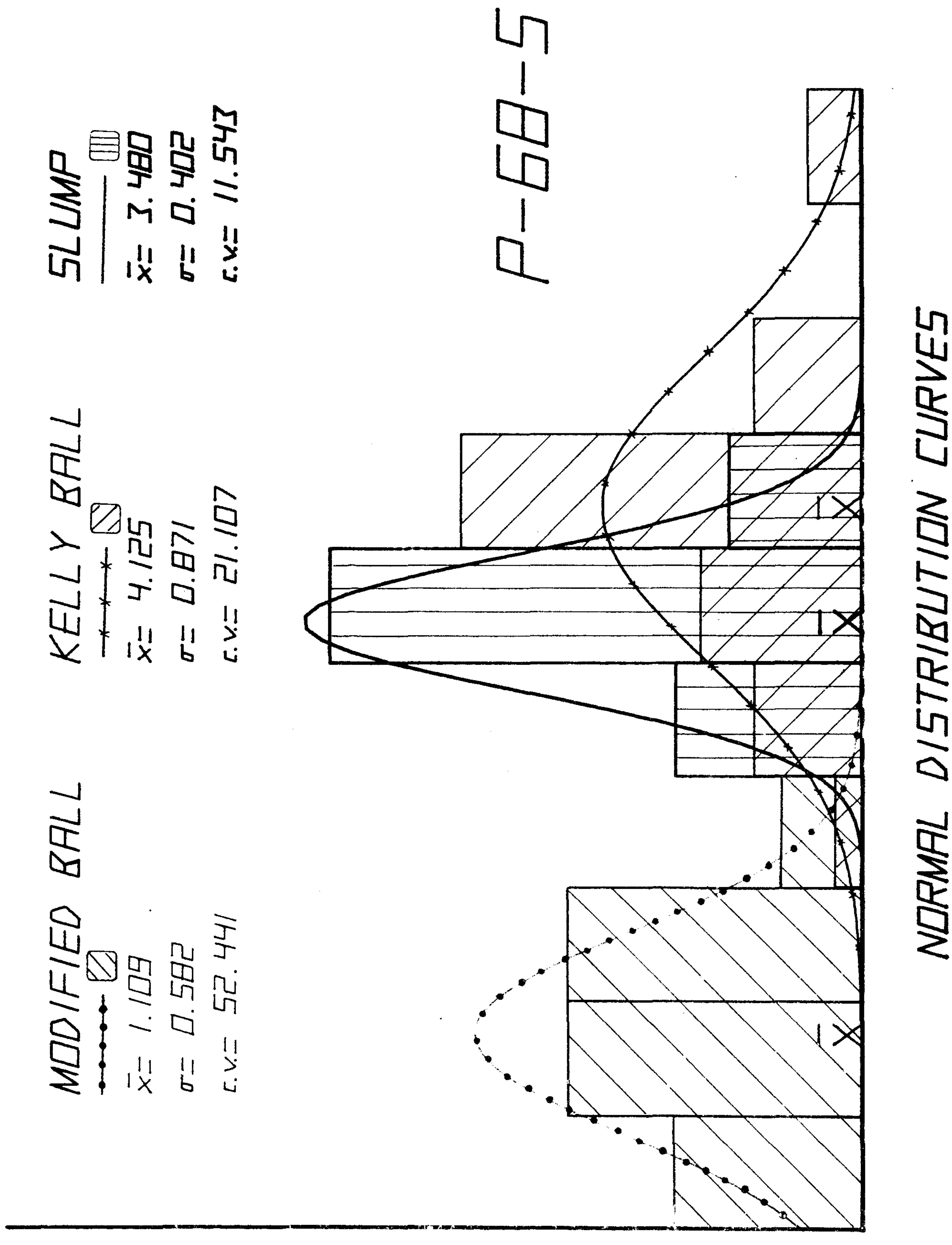
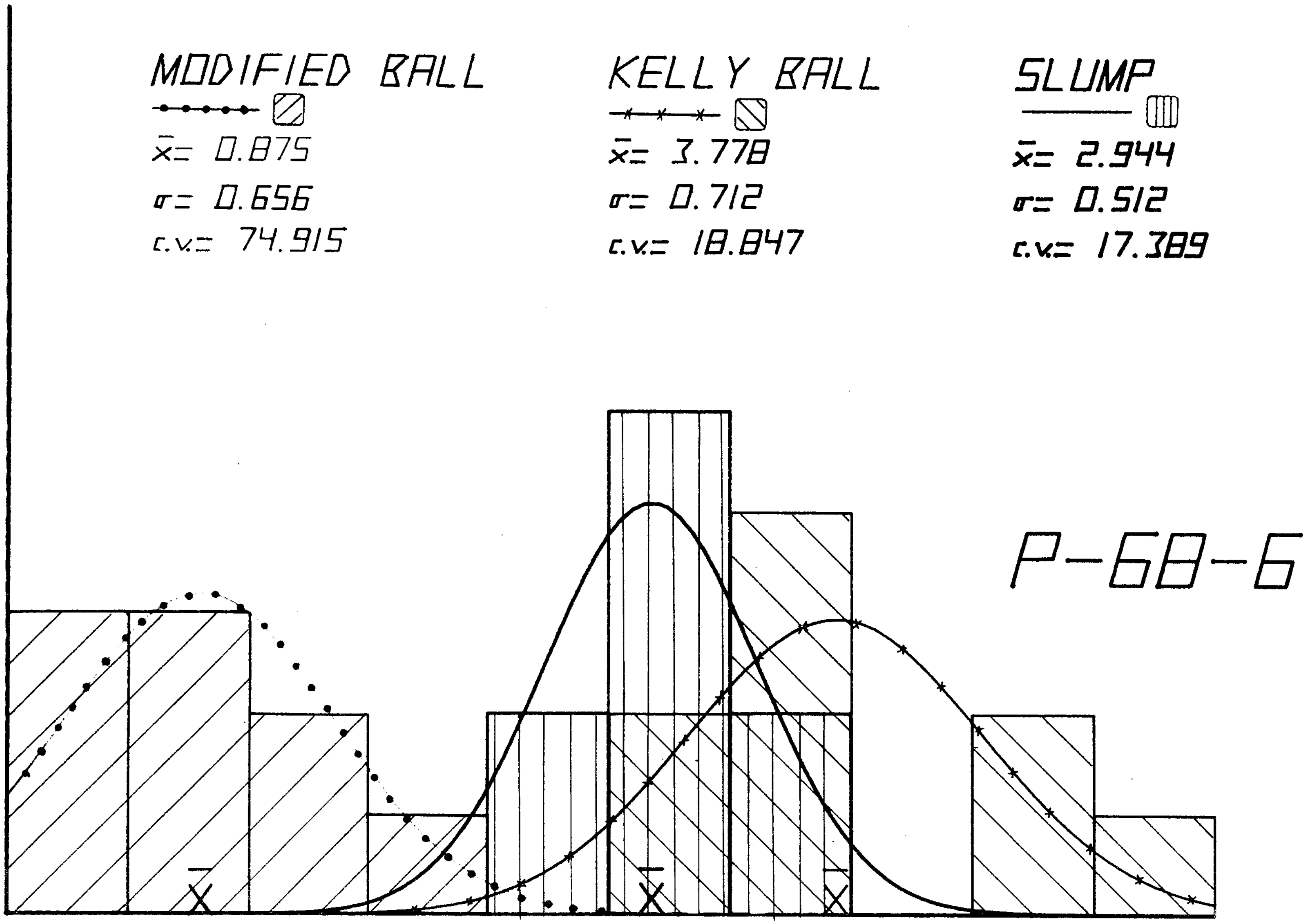
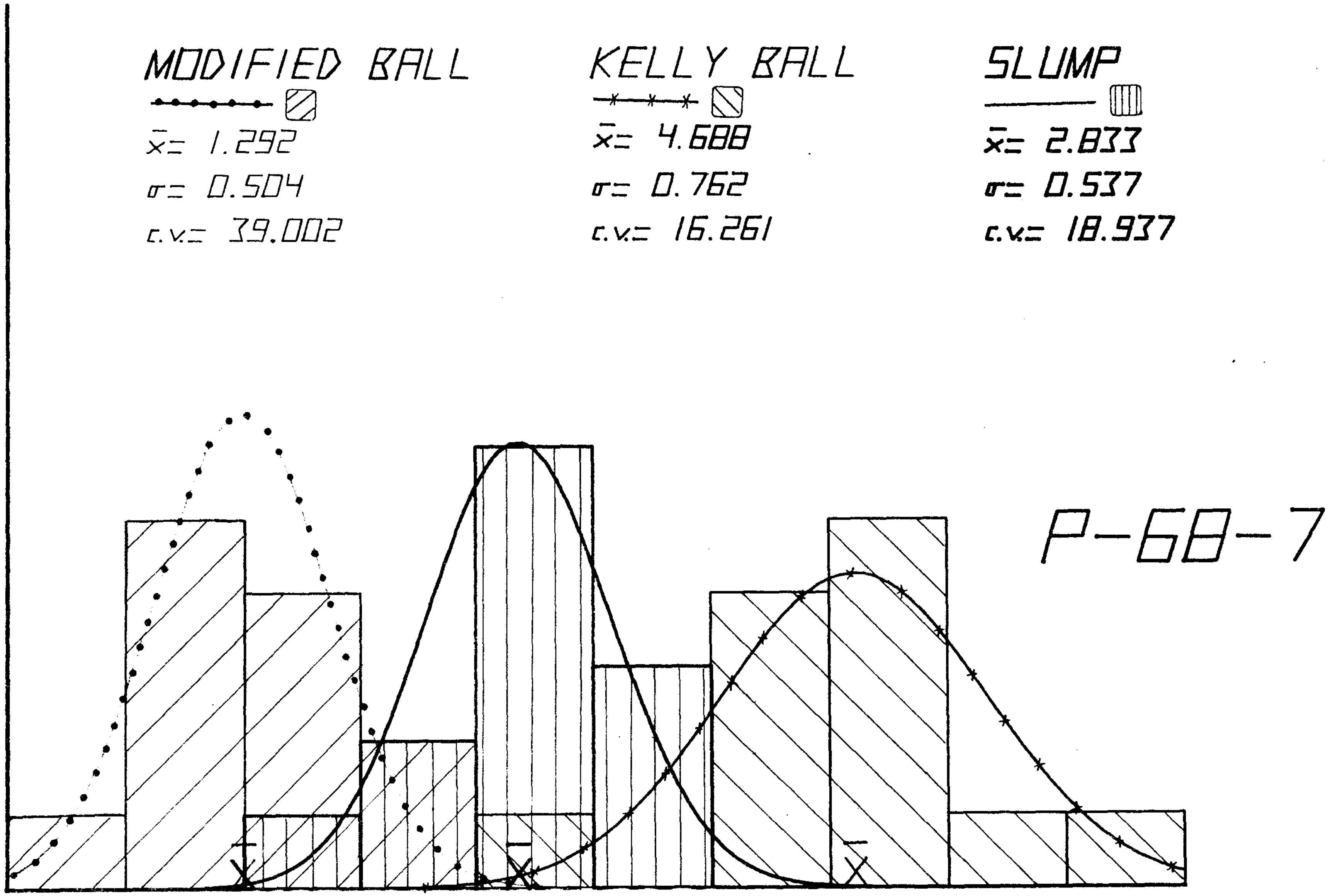
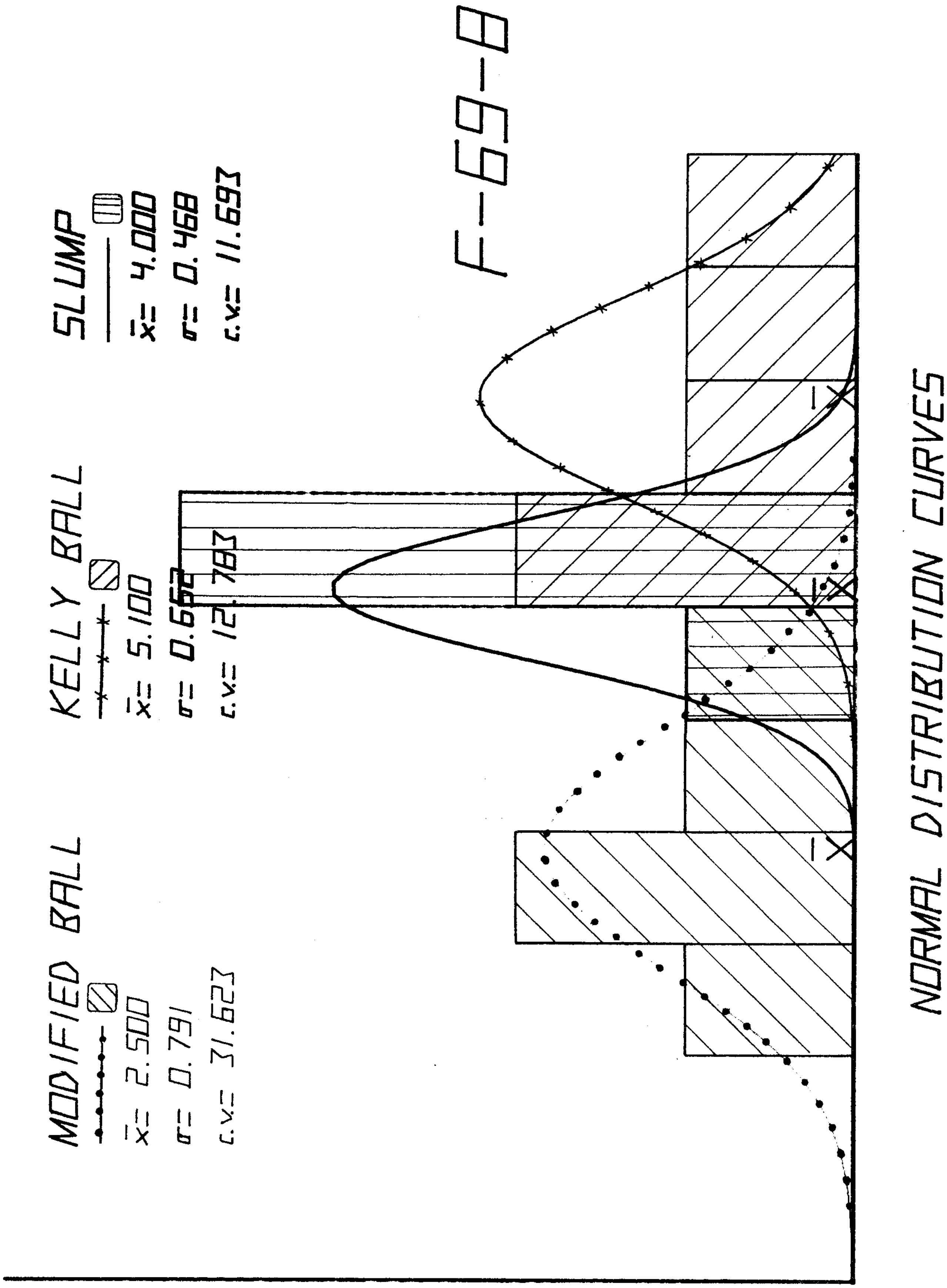

MODIFIED BALL
x̄= 1.109
σ= 0.582
c.v.= 52.441
KELLY BALL
x̄= 4.125
σ= 0.871
c.v.= 21.107
SLUMP
x̄= 3.480
σ= 0.402
c.v.= 11.543
P-68-S
NORMAL DISTRIBUTION CURVES



NORMAL DISTRIBUTION CURVES



NORMAL DISTRIBUTION CURVES


F-69-8
MODIFIED BALL
x̄ = 2.500
σ = 0.791
c.v. = 31.623
KELLY BALL
x̄ = 5.100
σ = 0.662
c.v. = 12.783
SLUMP
x̄ = 4.000
σ = 0.468
c.v. = 11.693
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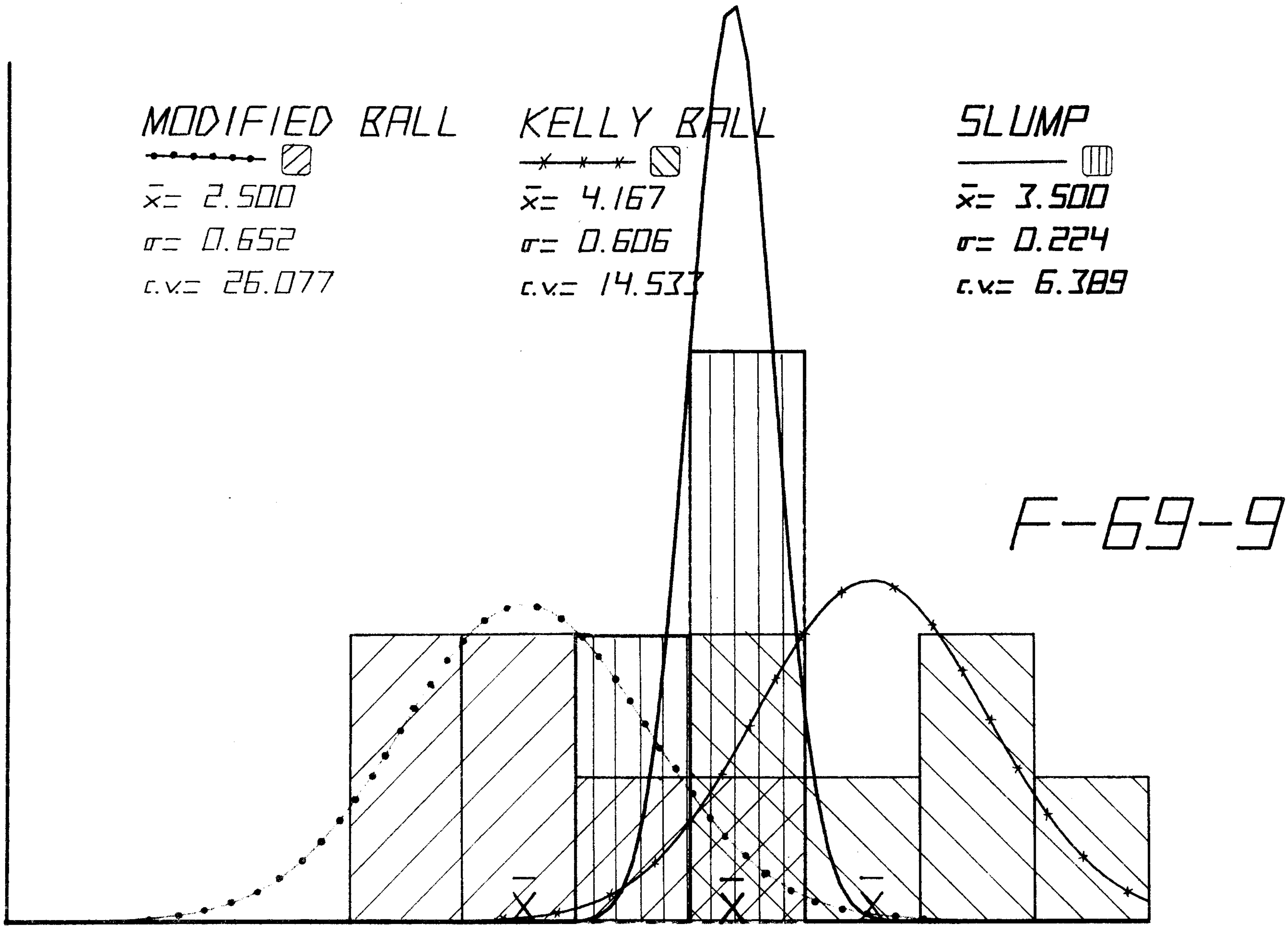

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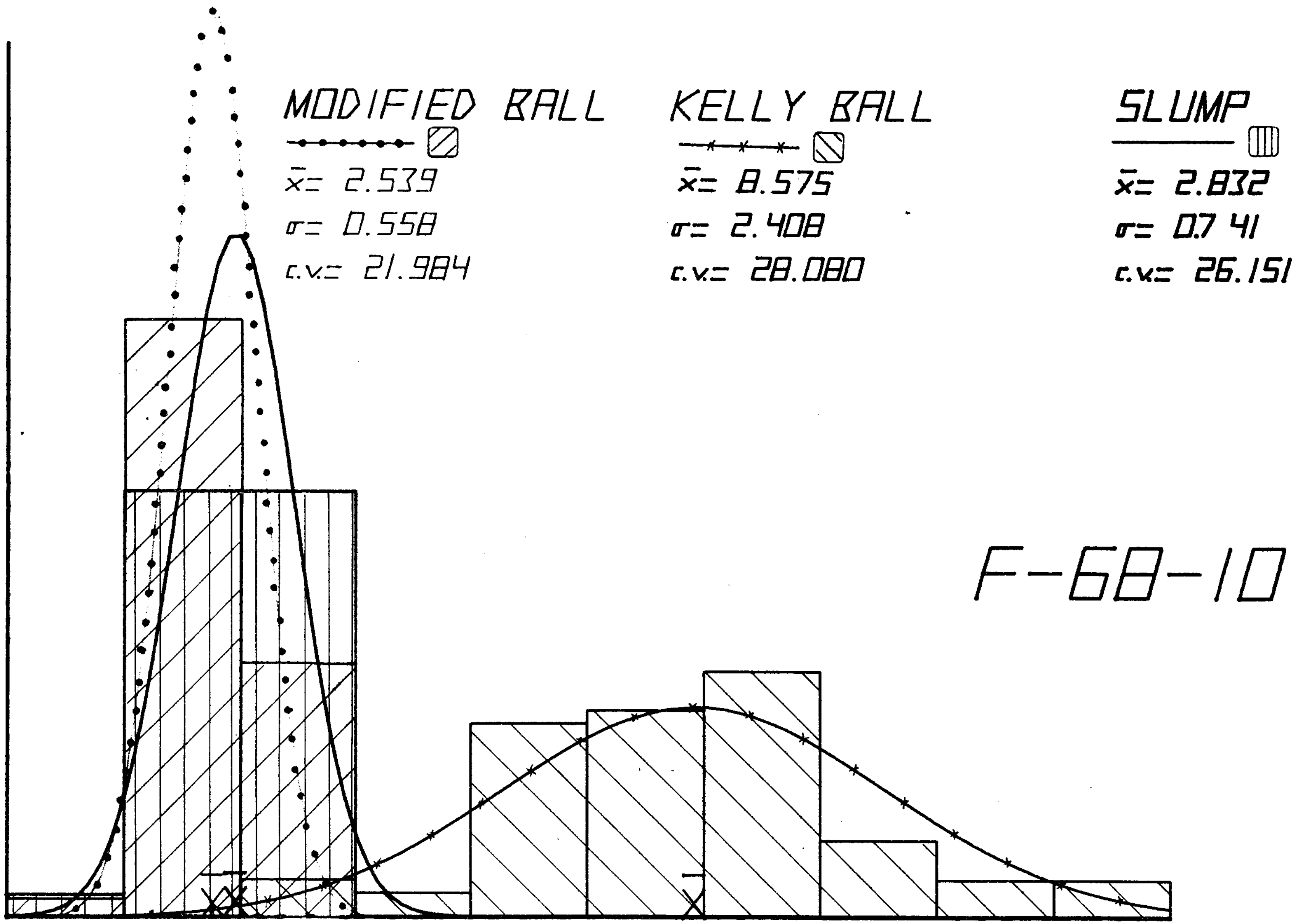

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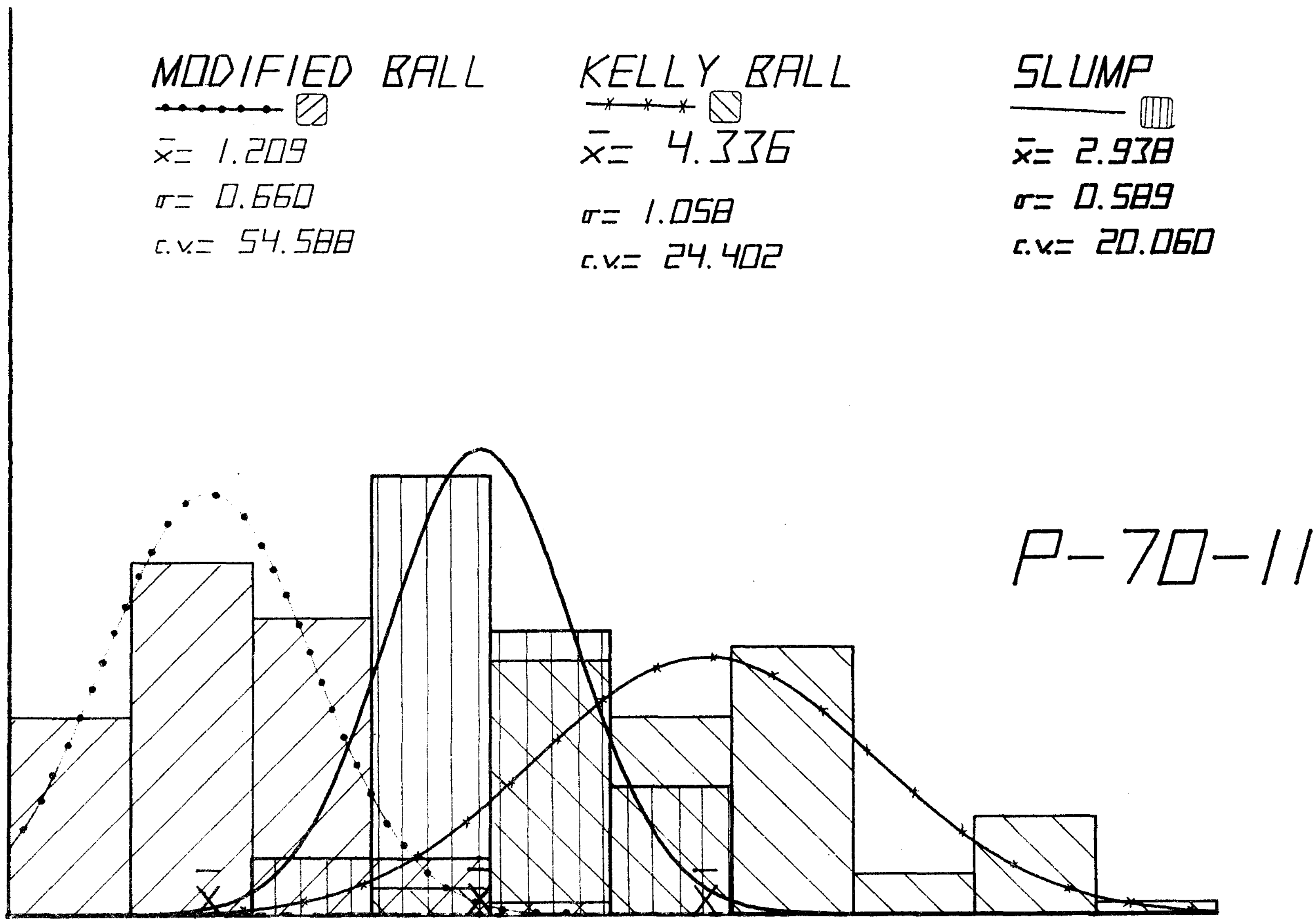

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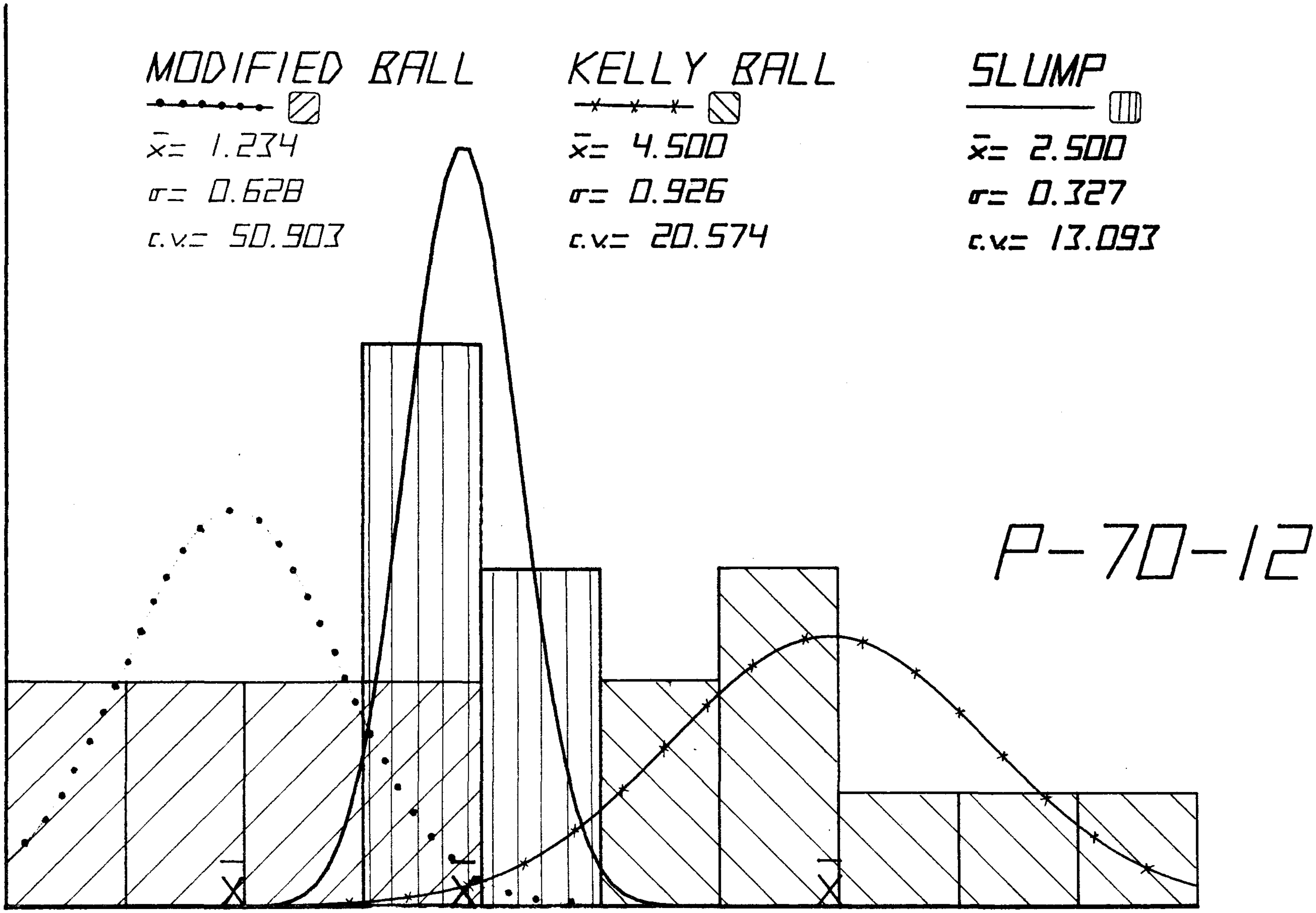

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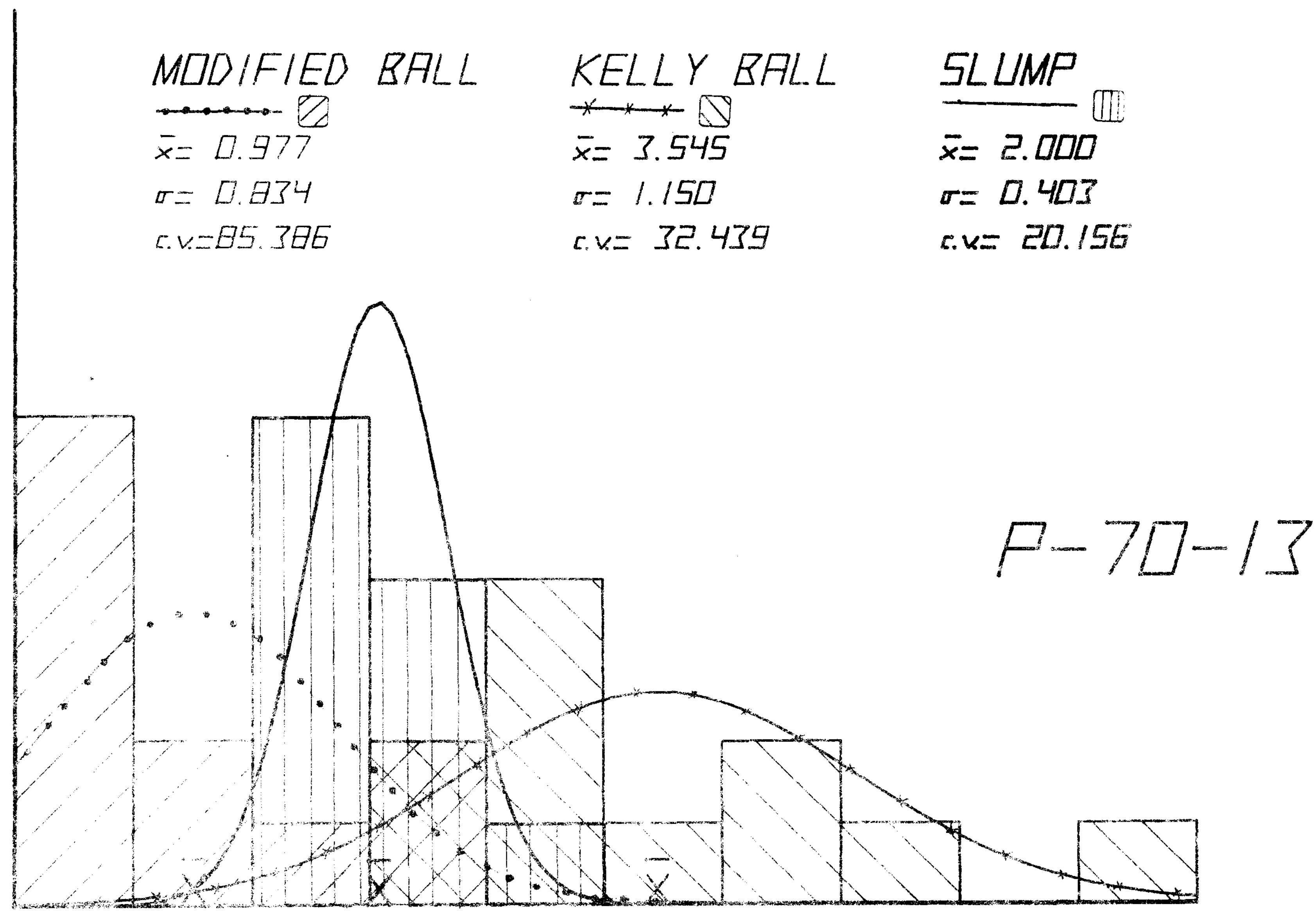

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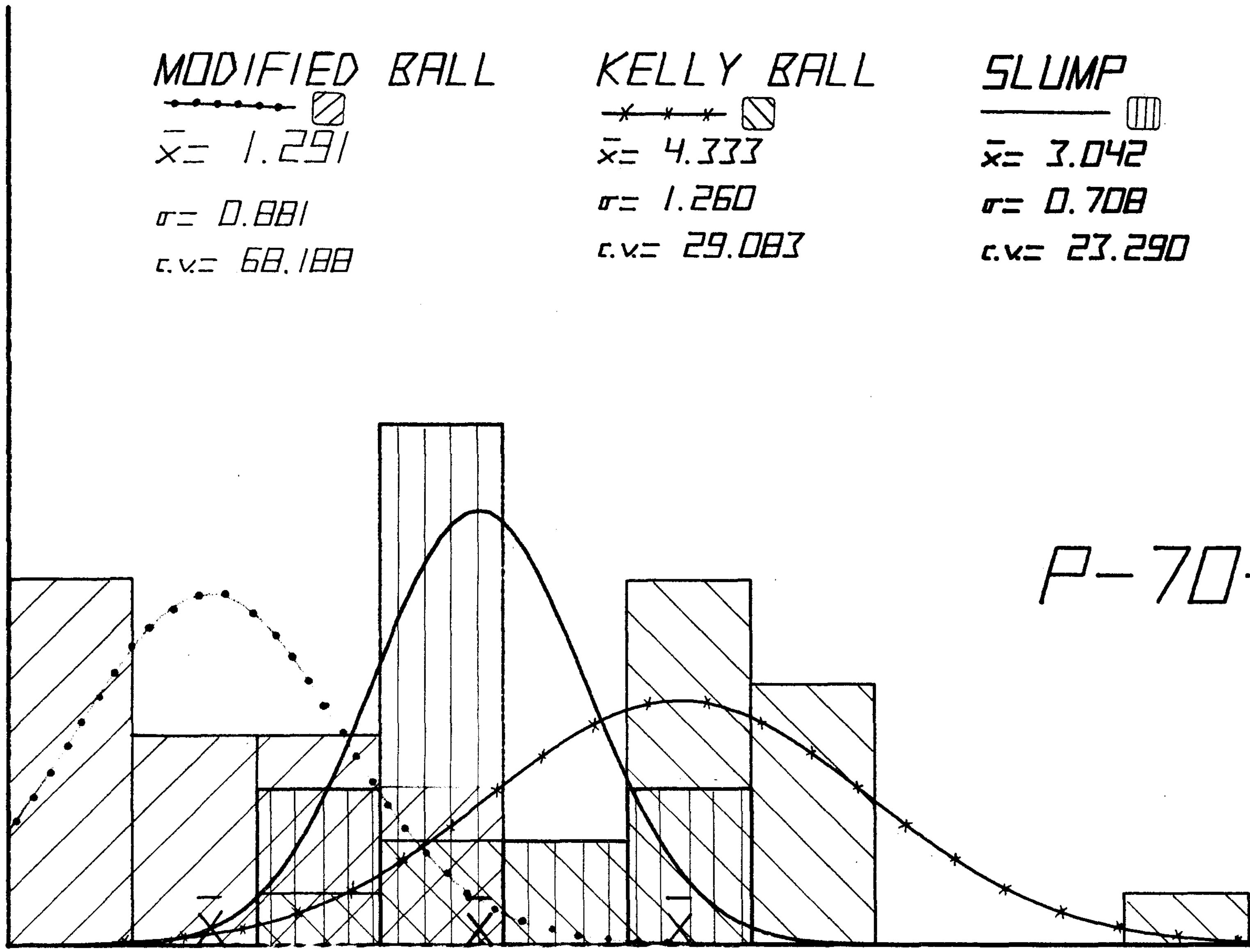
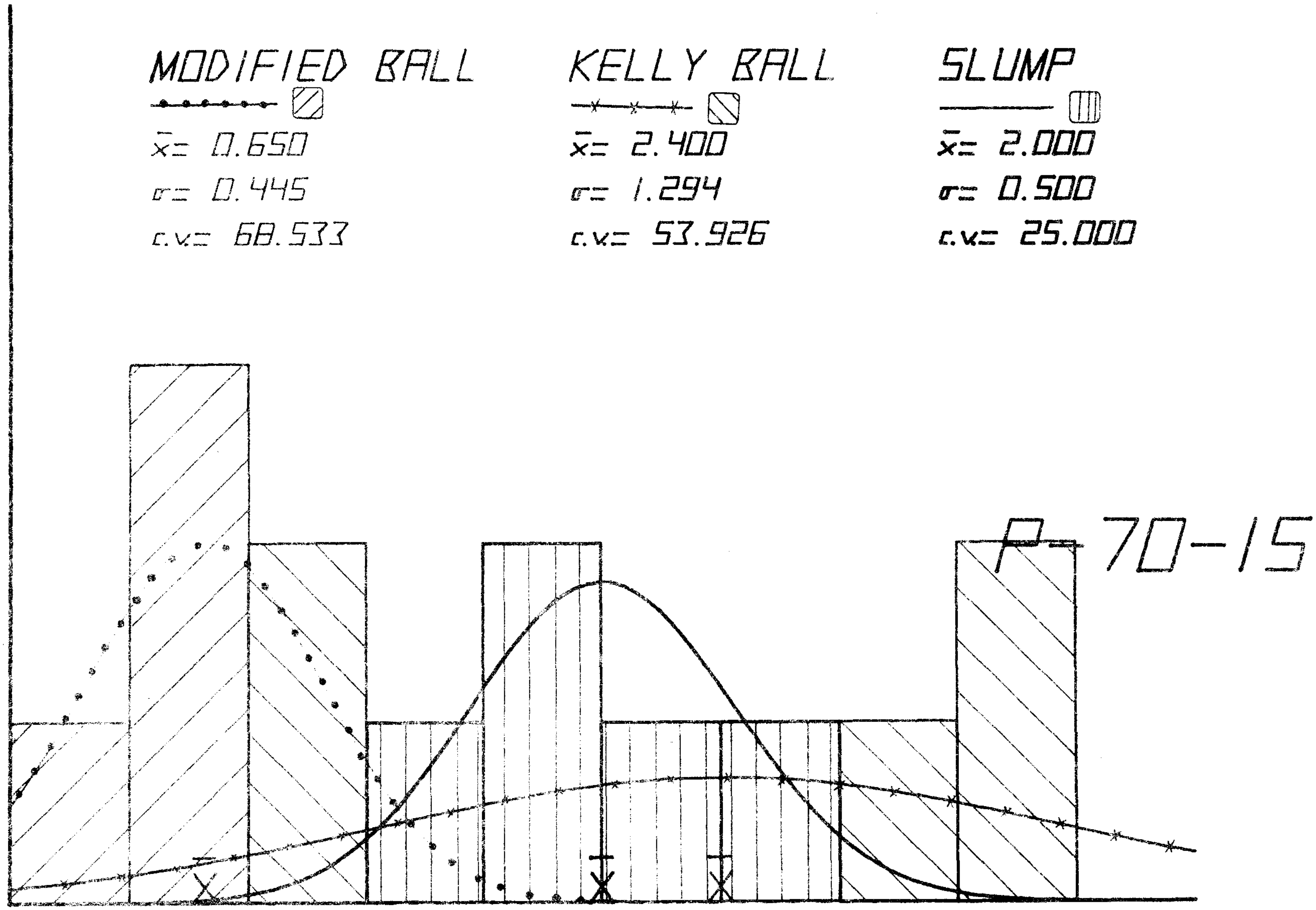
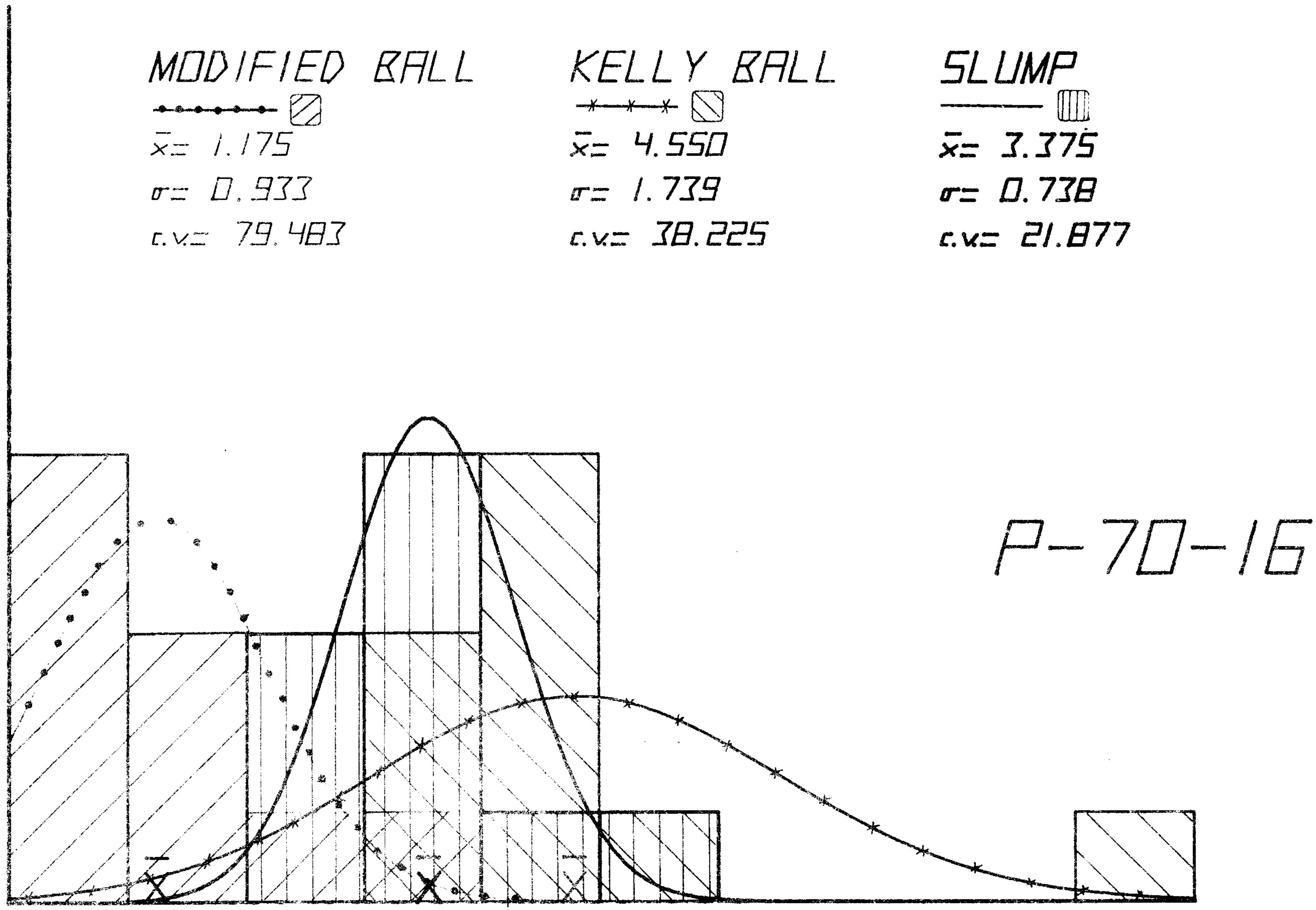


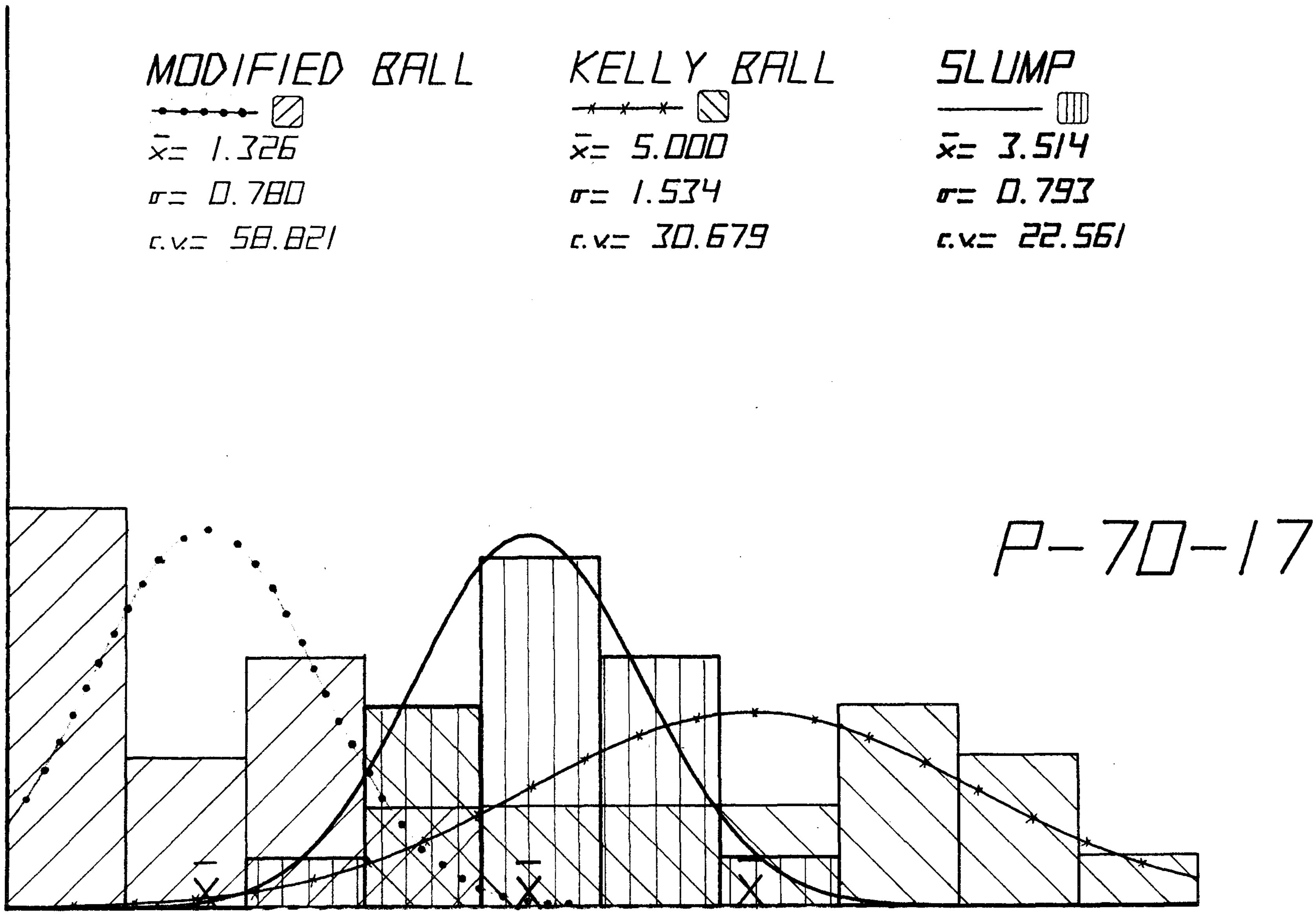
NORMAL DISTRIBUTION CURVES



NORMAL DISTRIBUTION CURVES



NORMAL DISTRIBUTION CURVES



NORMAL DISTRIBUTION CURVES

APPENDIX 3

Designation: C 360 – 63 (Reapproved 1968) American National Standard A37.92-1964 (R 1969)
American National Standards Institute
American Association State
Highway Officials Standard
AASHO No.: T 183

Standard Method of Test for
BALL PENETRATION IN FRESH PORTLAND CEMENT CONCRETE[1]

This Standard is issued under the fixed designation C 360; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

1. Scope

1.1 This method covers determination of the depth of penetration of a metal weight into plastic concrete.

2. Apparatus

2.1 The ball-penetration apparatus shall consist of a cylinder with a hemispherically shaped bottom and handle weighing 30 ± 0.1 lb (14 ± 0.05 kg), and a stirrup or frame to guide the handle and serve as a reference for measuring the depth of penetration (Fig. 1).

2.1.1 *Weight*—The cylindrical weight shall be approximately 6 in. (152 mm) in diameter and 4⅝ in. (117 mm) in height, with the top surface at right angles to the axis and the bottom in the form of a hemisphere of 3-in. (76-mm) radius. The cylindrical weight may be machined from metal stock or cast or spun provided the dimensions and weight with the handle meet requirements, and the finish is smooth.

2.1.2 *Handle*—The handle shall be a metal rod, ½ in. (13 mm) in diameter and graduated in increments of ¼ in. (6.4 mm), with each inch numbered from the zero point at the stirrup. The handle may be T-shaped or a closed rectangle at the top to permit grasping by the hand.

2.1.3 *Stirrup*—The stirrup shall be at least 1½ in. (38 mm) in width and each foot shall have a minimum bearing area of 9 in.^{2} (57 cm^2). The clear distance between feet shall be at least 9 in. (228 mm). The top edge of the stirrup shall coincide with the zero mark on the graduated handle when the apparatus is rested upon a plane solid surface.

3. Sample

3.1 The concrete may be tested either as placed in the forms prior to any manipulation, or in a suitable container such as a can, pan, hopper, or wheelbarrow. In any case the minimum depth of the concrete shall be at least three times the maximum size aggregate, but in no case less than 8 in. (203 mm). The minimum horizontal distance from the center line of the handle to the nearest edge of the level surface on which the test is to be made shall be 9 in. (228 mm).

4. Procedure

4.1 Bring the surface of the concrete to a smooth and level condition by the use of a small wood float or screed, working the surface as little as possible to avoid formation of mortar layers. During the test, the adjoining concrete should not be subjected to vibration, jarring, or agitation. Set the base of the apparatus on the levelled concrete surface, with the handle in a vertical position and free to slide through the frame. Lower the weight to the surface of the concrete and release slowly. After the weight has been released and has come to rest, read the penetration to the

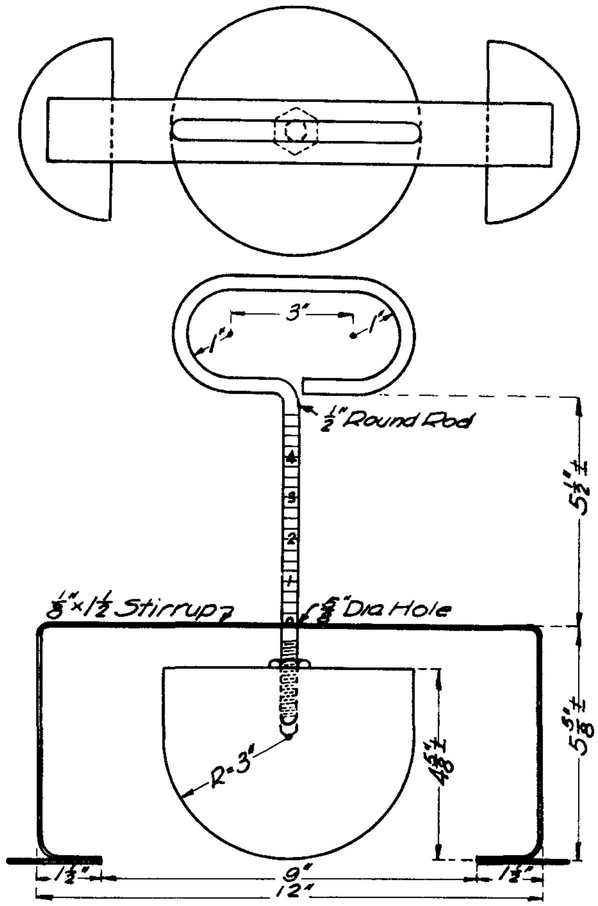
[1] This method is under the jurisdiction of ASTM Committee C-9 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.03.03 on Methods of Testing Fresh Concrete.

Current edition effective Sept. 20, 1963. Originally issued 1955. Replaces C 360 – 55 T.

nearest ¼ in. (6.4 mm). Take a minimum of three readings from a batch or location. These readings shall not be taken with the foot of the stirrup within 6 in. (152 mm) of a point where the foot rested in a previous test. If the difference between the maximum and minimum readings is more than 1 in. (25 mm), make additional measurements until three successive readings have been obtained which agree within 1 in. Make no correction for any slight settlement of the feet of the stirrup.

5. Report

5.1 The penetration shall be recorded in terms of inches (or millimeters) or penetration. The values reported shall be the average of the three or more readings, which agree within 1 in. (25 mm), taken on the sample of concrete. They shall be reported to the nearest ¼ in. (6.4 mm).



Metric Equivalents

in.	mm	in.	mm
⅛	3.2	4⅝	117
½	13	5½	140
⅝	16	5⅝	143
1	25	9	228
1½	38	12	304
3	76		

FIG. 1 Ball Penetration Apparatus.

APPENDIX 4

Texas Highway Department

Materials and Tests Division

SLUMP OF PORTLAND CEMENT CONCRETE

Scope

This test method, which is a slight modification of A.S.T.M. Designation: C 143, describes a procedure for determining the slump of freshly mixed concrete by means of a slump cone both in the laboratory and in the field.

Apparatus

1. Mold: A slump cone made of metal not readily attacked by the cement paste and in the form of a truncated cone with the base 8 inches in diameter, the top 4 inches in diameter and 12 inches in height. The base and the top shall be open and parallel to each other and at right angles to the axis of the cone. The cone is provided with foot pieces and handles as shown in Figure 1.

2. Tamping rod: A straight steel rod 5/8 inch in diameter and approximately 24 inches in length, having one end rounded to a hemispherical tip, the diameter of which is 5/8 inch.

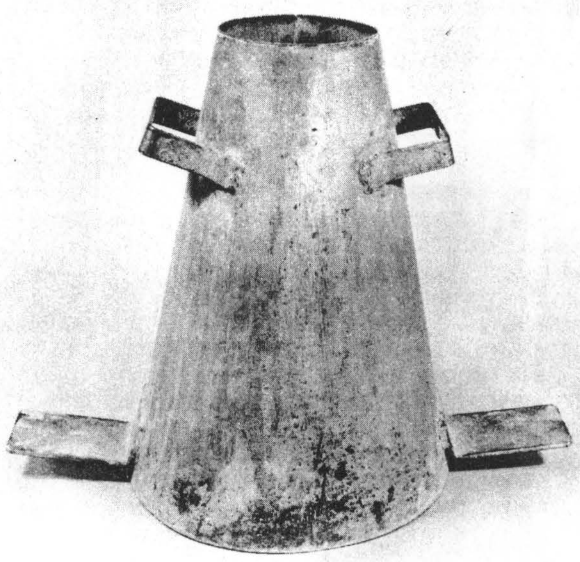


Figure 1

3. Small hand-scoop

4. A rule graduated in 1/8-inch increments

Sample

The sample of concrete from which the test specimens are made shall be representative of the entire batch and secured immediately after mixing operations have been completed. The sample may be obtained at the mixer or after the concrete has been placed on the roadway.

Procedure

1. Dampen the slump cone and place it on a level, rigid surface. Hold the slump cone down firmly while placing, rodding and finishing the concrete.

2. Use the small hand-scoop to place the concrete into the mold. Immediately after mixing, carefully fill the slump cone in three layers, each layer occupying approximately one-third the volume of the mold, in such a manner as to secure a uniform distribution of the concrete. (Figure 2)

3. Rod each layer with 25 strokes of the tamping rod distributing the strokes uniformly over the cross-section of each layer. For the bottom layer rod the material throughout the full depth. Rod the second layer and top layer each throughout its depth so that the rod just penetrates into the underlying layer.

4. After the top layer has been rodded, use the tamping rod as a straight edge and strike off the surface of the concrete level with the top of the mold. Remove the slump cone immediately from the concrete by raising it carefully in a vertical direction. Do not jerk the mold or vibrate the test specimen. (Figure 3)

5. Measure the slump of the concrete by determining the difference between the height of the mold and the height over the original center of the base of the specimen. Place the mold on a level with the base of the specimen and lay the rod horizontally across the top of the mold so that it extends over the center of the specimen. Measure the distance from the bottom of the rod to the top of the specimen to the nearest 1/4-inch. Record this measurement as the slump of the concrete. (Figure 4)

Notes

When there is a considerable amount of coarse aggregate over 2 in. in size in concrete, remove the oversize particles before making the test for slump.

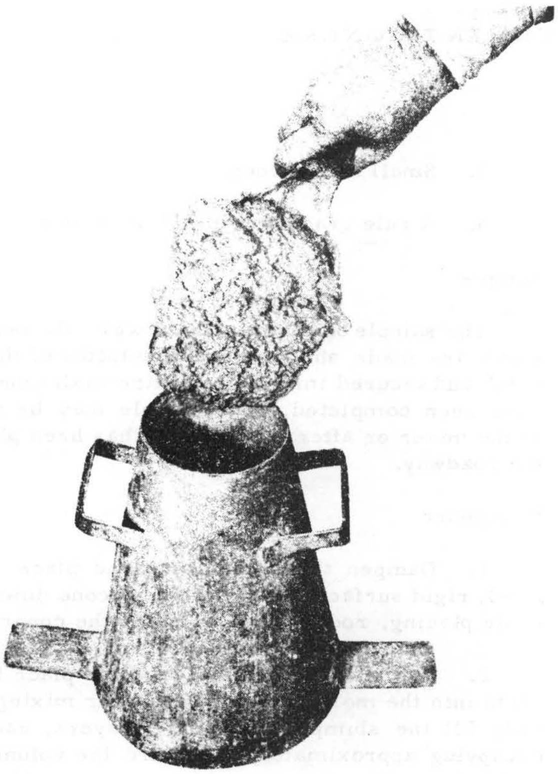


Figure 2

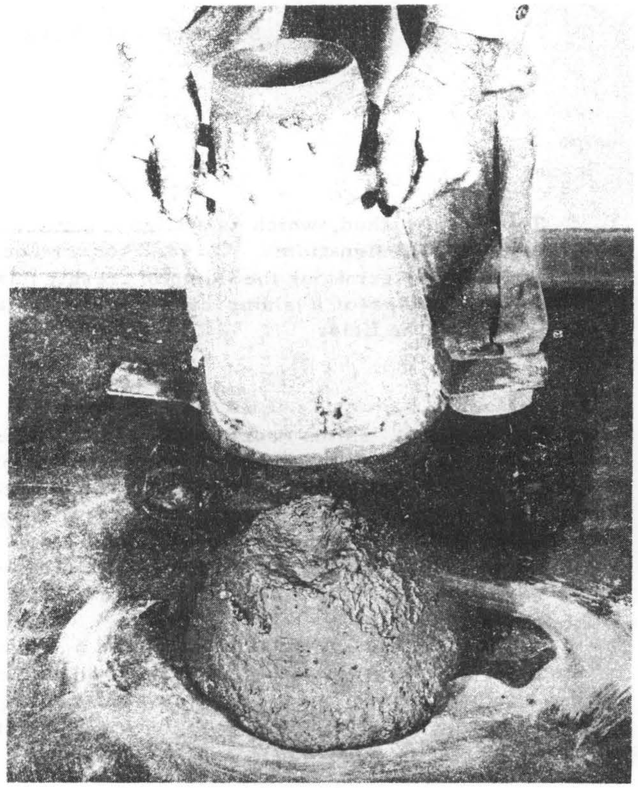


Figure 3

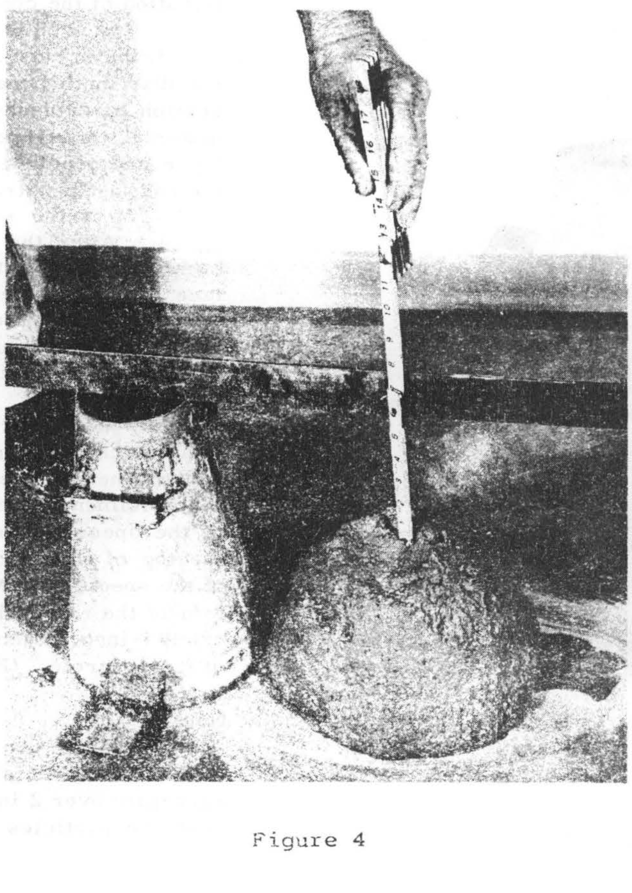


Figure 4

APPENDIX 5

DATA SHEET
KELLY BALL AND MODIFIED BALL TEST EVALUATION

District No.: ____________ Tests Performed by: ____________
County: ____________ Project: ____________ Highway: ____________

(Cr./Uncr.)
C.A.: ____________ Type ____________ Source ____________
F.A.: ____________ Type ____________ Source ____________
Admixtures: Type ____________ Source ____________
Cement: Type ____________ Source ____________
Class Concrete: ____________ Design Strength:(psi) ____________
Design: (1-Sack) (c.f.)
C.A.: ____________ CAF ____________ Sp.Gr. ________ Unit Wt. ________ % Solids ________
F.A.: ____________ FAF ____________ Sp.Gr. ________ Unit Wt. ________ % Solids ________
Cement ____________ C/F ____________
Water ____________ W/C ____________
Air ____________ % Air ____________
Retarder ____________ % Water Reduction ____________
Transit Mix: ________ (Yes, No) Length of Haul: ____________ Mixing Time: ____________

Test No.	Date	Moisture (%) F.A.	Moisture (%) C.A.	Ent. Air (%)	Kelly Ball Value (in.)	KBV x 2 (in.)	Mod. Ball Value (in.)	MBV ÷ 2 (in.)	Slump Cone Value (in.)