"K" VALUE CORRELATION STUDY

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ABSTRACT

One objective of this study was to determine what correlation existed between the modulus of subgrade reaction as determined by the Plate Bearing Test and the deflection determined by the first sensor of the Lane Wells "Dynaflect." The Research and Development Section of the Louisiana Department of Highways has used the Lane Wells "Dynaflect" and is satisfied with its ability to rapidly and accurately take readings of deflections of a section.

The second objective of this study was to determine the field value of the modulus of subgrade reaction "K" by the use of the Plate Bearing Test. "K" value is used in designing the thickness of concrete pavement for highways and has been assumed to be a constant. Therefore, a more valid and conclusive value of "K' was deemed necessary.

Plate Bearing Tests were conducted on three 6 inch soil-cement bases and on one 4 inch hot mix asphaltic concrete base overlying six inches of lime stablilized soil. Undisturbed subgrade cores were taken on which modified consolidation tests were run. Comparison was made of the corrected "K" value and "K" value used by the Design Section to ascertain if the design value of "K" is reasonable.

Ten Dynaflect readings and ten Plate Bearing determinations were obtained on each of the four separate projects.

A satisfactory correlation was found to exist between the Plate Bearing values and the first sensor reading of the Dynaflect. This provides our Department with a rapid, economical and valid method of determining the modulus of subgrade reaction.

The present range of "K" values obtained on these construction projects was also determined.

IMPLEMENTATION

The value of "K," the modulus of subgrade reaction, can be obtained more rapidly and economically in the field by using the Lane Wells "Dynaflect" to obtain first sensor readings and correlating them to "K" values. The "K" values obtained will be modified by the results of a consolidation test that is run on subgrade cores taken at the test site. The modified results will be compared to the present design "K," and recommendations can be made as to the quality of an as constructed base.

Further recommendations can be made as to any future change to be made in design "K" value after more values are obtained by field measurements.

SCOPE

Plate Bearing Tests were conducted on three 6 inch soil-cement bases and on one 4 inch hot mix asphaltic base. Undisturbed cores of the subgrade were taken, and modified consolidation tests were run on these cores. Comparison was then made of the corrected "K" values and the "K" value used by the Design Section to ascertain if the design value of "K" is reasonable, based on this and one other study.

The study was extended to include limited sampling and testing as follows: Dynaflect measurements were made on the bases. Modified consolidation tests were run on undisturbed cores taken from the subgrades. Moisture content and mechanical and physical analyses were made on the subgrades. Replicates of "K" value and Dynaflect readings were made at each test site. Dynaflect readings were plotted versus "K" value for correlation purposes.

INTRODUCTION

The Department uses a Lane Wells "Dynaflect" to determine the magnitude of induced deflections of subgrade, bases and pavements. The Dynaflect is capable of obtaining more readings at a much lower cost than the Plate Bearing Test.

This study was initiated to determine if a correlation exists between Dynaflect readings and Plate Bearing, "K," test values.

The Louisiana Department of Highways Design Section uses a number of parameters in designing the thickness of concrete pavement. Most of the parameters, such as projected daily traffic, vary somewhat with the particular road being constructed. However, the modulus of subgrade reaction, "K," is one design value for which the constant of 120 pci is now assumed for all roadways. This modulus reflects the ability of the subgrade to support loads placed upon the concrete slabs. The unit of measurement for "K" in pounds per cubic inch (pci) reveals that this value is the mathematical stress required to cause the subgrade to deflect one inch.

METHOD OF PROCEDURE

No study design was attempted because construction projects were utilized as they became available. If any factorial design had been introduced, the life of the study would have been excessive.

The projects selected were as follows:

Highway	Location	Lane	Parish	Type
La. 1	Natchitoches ByPass	Left	Natchitoches	6" soil-cement
Parish Road	Livonia	Right	Point Coupee	6" soil-cement
I-10	Ramah-Gross Tete	Right	Iberville	6" soil-cement
I-10	Lenora-Lafayette	Left	Lafayette	4" asphalt cement

The test sites on all projects were selected by using the "Dynaflect" to obtain the general range of deflection values on each project. This was done by generally obtaining twenty deflections throughout the project. Based on these deflections five test locations were selected representative of the highest, lowest and three of the mean deflections. Duplicate tests of deflections were run after two Plate Bearing Tests were conducted at each station. Undisturbed cores were taken of the subgrade at each test site, and consolidation tests at natural and saturated moisture contents were run on these cores in the laboratory. The core samples were then tested for gradation and Atterberg limits.

Field Testing

1. Dynaflect measurements were run at each test site.

2. Plate Bearing Tests were in accordance with the Student Reference, Section I, Soils Engineering, Volume I, Chapter I-X, U.S. Engineer School-Fort Belvoir, Virginia, (1967).

3. Undisturbed cores were taken with a thin walled sampling tube by using the hydraulic ram of a heavy core drill.

Laboratory Testing

1. Consolidation tests were run in accordance with the reference mentioned in Item Number 2 above, with the samples being soaked 72 hours to ensure saturation.

2. Physical and mechanical analyses of the subgrade material were run in accordance with LDH Designation: TR 428-67 and TR 407-69.

3. Moisture content determinations were run on the in-place subgrade material in accordance with LDH Designation: TR 418-67 (Method A).

The following pieces of equipment were used:

1. "K" value reaction plates consisting of one inch thick plates of 30, 24, 18 and 12 inch diameters. See Figure 2.

2. Three deflection gages sensitive to the nearest ten thousandth of an inch. See Figure 2.

3. A 30 ton hydraulic jack with pressure gage, previously calibrated for load. See Figure 3.

4. A five inch I-beam 20 feet long to serve as a gage reference beam. See Figure 4.

5. A Dynaflect device with towing vehicle. See Figure 5.

6. Two single axle dump trucks loaded to the legal rear axle load of 18,000 pounds to be used for reaction beam dead weights.

7. A twelve inch wide flange beam 30 feet long for use as a load transfer device or "Reaction Beam."

8. One vehicle (low boy type) to transport the reaction beam and trucks.

9. An A-frame or motorized crane to move the wide flange reaction beam.

10. A core drill to obtain undisturbed cores of the subgrade.

TEST RESULTS

K-Value Computation

Five loading points are plotted versus penetration as noted on Figure 9. The data points that will create a straight line are connected with a solid line. This forms the loading line. A broken straight line is drawn parallel to the loading line so that it intercepts the origin. This is the line used to determine "K" value as tested.

A line is drawn vertically from a known penetration to the parallel line and horizontally to the load. "K" value is the load determined divided by the known penetration. In this case the penetration used is 0.10 inches and the load determined to be 29.2 p.s.i. Dividing 29.2 p.s.i. by .10 inch equals 292 pci. This pci is corrected for bending of the plates as shown on Figure 8 by entering 292 pci on the ordinate and drawing a line horizontally to the curve. A vertical line is drawn from this point to the abscissa. This is "K" value corrected for bending.

"K" value is further reduced by a correction factor to reflect the worst moisture condition possible at saturation. This correction factor to be applied to "K" bending is the ratio of the deformations which the subgrade sample experiences during laboratory modified consolidation tests at natural moisture content to those deformations the sample experiences at saturation.

Statistical Relationship between Deflection and "K" Value

The data shown in Table 2 were used in determining the statistical relationship between the "K" values and Dynaflect deflections. The deflection values represent the first sensor readings of the Dynaflect. The "K" values are those obtained after correcting for plate bending.

For statistical analysis the deflection variable was chosen as the independent variable since the primary aim was to determine a predictive equation for "K" value. Plot of the data indicated that the relationship could be defined by the following equation:

$$\log Y = \log A + X \log B$$

where Y = K values

X = deflection, d

and A, B = constants that were determined from the analysis

The constants A and B were determined through standard statistical procedures. This gave the estimating equation.

$$\log Y = 2.8998 - 0.2007X$$

or in terms of the original data

$$K = \frac{794.3}{1.5875^d}$$

The measure of the amount of relationship between the two variables can be explained by means of R^2. When there is no correlation R^2 equals zero. On the otherside of the scale, R^2 equals 1.0 for perfect relationship. The R^2 of .88 for the above relationship indicates that about 88 percent of the variability in "K" value is removed by the linear correlation with deflection.

Figure 7 shows the fitted line along with scatter.

CONCLUSIONS

1. The deflection determined by the first sensor of the Lane Wells "Dynaflect" correlates to the Plate Bearing Tests corrected for bending as determined by the Corps of Engineer Method. The correlation equation is log "K" value equals 2.8998-0.2007 Dynaflect deflection with a confidence of 88.3 percent.

2. In-place "K" can be determined using the Lane Wells "Dynaflect" in conjunction with modified consolidation tests run on undisturbed cores of the subgrade.

3. The present design "K" value used by the Louisiana Department of Highways as based on this data is realistic.

RECOMMENDATIONS

1. Whenever "K" values need to be determined in the field, the Lane Wells "Dynaflect" should be used to determine "K" values in conjunction with taking undisturbed cores for a modified consolidation test.

2. The Department should continue to use its present value of "K" for design purposes until conditions should warrant a reevaluation.

APPENDIX

TABLE 1
DYNAFLECT AND "K" VALUE

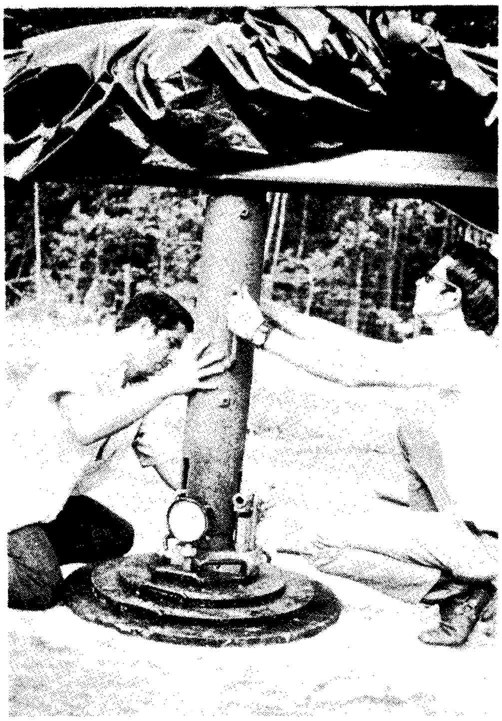
Station	Dynaflect 1st.	Dynaflect 2nd.	Dynaflect Ave.	"K" Value (Bending) 1st.	"K" Value (Bending) 2nd.	"K" Value (Bending) Ave.
Natchitoches Highway 1						
298+00	1.62	1.50	1.56	340	350	345
314+88	1.92	1.86	1.89	330	355	342
324+50	1.08	1.53	1.30	385	420	402
333+93	1.23	1.32	1.27	350	425	388
335+00	1.44	1.38	1.41	-	385	385
Livonia Parish Road						
26+00	2.34	2.40	2.37	220	260	240
36+40	3.00	2.64	2.82	154	176	165
38+00	3.90	3.80	3.85	123	111	117
39+00	4.40	4.40	4.40	116	130	123
43+00	4.80	4.10	4.45	144	119	132
Grosse Tete I-10 Ramp						
75+50	2.28	2.46	2.37	260	270	265
77+00	1.65	1.68	1.66	270	320	295
77+50	1.26	1.32	1.29	475	480	477
78+50	2.10	2.22	2.16	230	285	257
79+50	3.00	3.10	3.05	165	200	182
Lafayette I-10						
1375+00	0.99	1.02	1.00	810	840	825
1381+00	0.74	0.78	0.76	585	870	728
1403+00	1.23	1.26	1.24	380	430	403
1417+00	1.11	1.11	1.11	440	520	480

TABLE 2
MODIFIED CONSOLIDATION TEST RESULTS

Station	Deformation at Natural Moisture Content DN	Deformation at Saturated Conditions DS	DN/DS
Natchitoches			
298+46	.0065	.0132	0.49
314+88	.0287	.0247	Use 1.0
324+50	No Core	No Core	No Core
333+93	.0420	.0617	0.68
335+00	No Core	No Core	No Core
Livonia			
26+00	.0498	.0431	Use 1.0
36+40	.0464	.0491	0.95
38+00	.0461	.0575	0.80
39+00	.0327	.0430	0.76
43+00	.0343	.0640	0.54
Grosse Tete			
75+50	.0556	.0342	Use 1.0
77+00	.0181	.0538	0.34
77+50	.0158	.0311	0.51
78+50	.0097	.0231	0.42
79+50	.0317	.0374	0.85
Lafayette			
1375+00	No Core	No Core	No Core
1381+00	.017	.0191	0.89
1403+00	.0113	.0251	0.45
1417+00	.0230	.0339	0.68

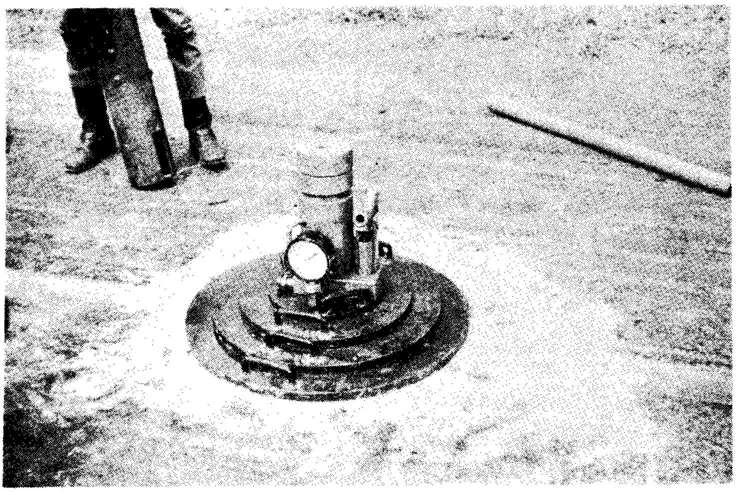
TABLE 3
"K" VALUE

Station	"K" Value As Tested		"K" Value Corrected for Plate Bending		"K" Value Corrected for Plate Bending and Consolidation		Ave.
	1st. Rd.	2nd. Rd.	1st. Rd.	2nd. Rd.	1st. Rd.	2nd. Rd.	KBC
Natchitoches La. 1							
298+46	424	436	340	350	167	172	170
314+88	406	446	330	355	330	355	342
324+50	494	534	385	420	No Core	No Core	No Core
333+93	438	564	350	425	238	289	264
335+00	No Core	492	+ Gage Beam Settled	385	No Core	No Core	No Core
Livonia (Parish Road)							
26+00	247	304	220	260	220	260	240
36+40	162	185	154	176	146	167	156
38+00	127	112	123	111	98	89	93
39+00	117	132	116	130	88	99	93
43+00	148	121	144	119	78	64	71
Grosse Tete I-10 Ramp							
75+50	292	317	260	270	260	270	265
77+00	318	380	270	320	91	109	100
77+50]	640	650	475	480	242	245	243
78+50	258	341	230	285	97	120	108
79+50	173	217	165	200	140	170	155
Lafayette I-10							
1375+00	1340	1470	810	840	No Core	No Core	No Core
1381+00	860	1510	585	870	520	774	647
1403+00	480	570	380	430	171	193	182
1417+00	580	720	440	520	299	354	327

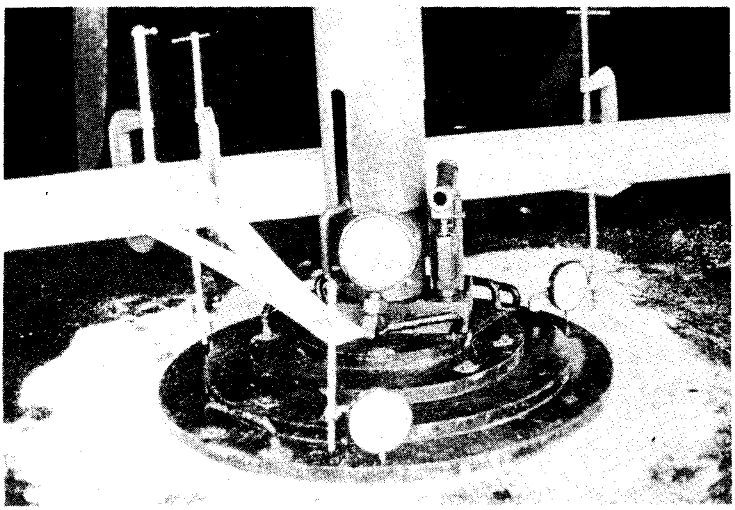


Setting Spacer Block
FIGURE 1

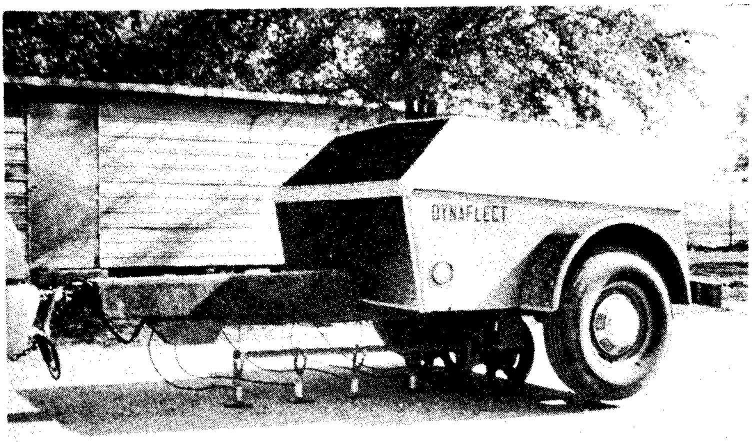
Nesting Plates
FIGURE 2



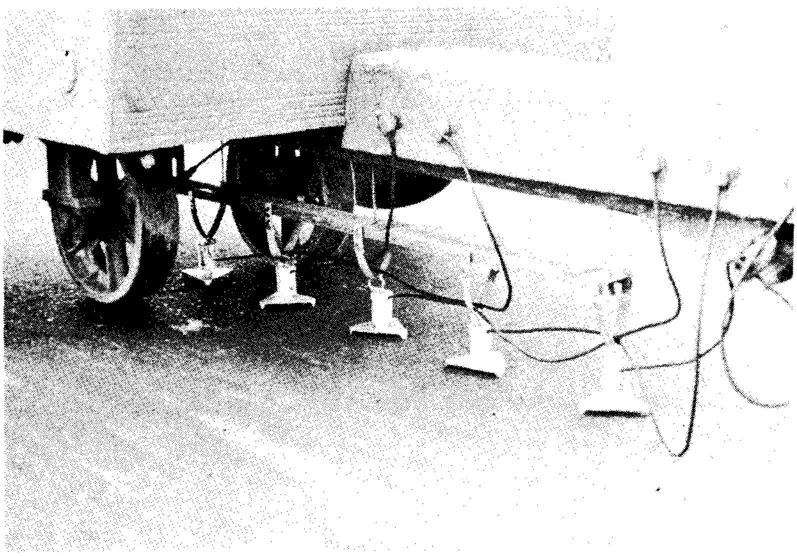
Plates and Jack
FIGURE 3



Plates with Gage Beam and Gages
FIGURE 4



Lane Wells "Dynaflect"
FIGURE 5



Dynaflect Sensors
FIGURE 6

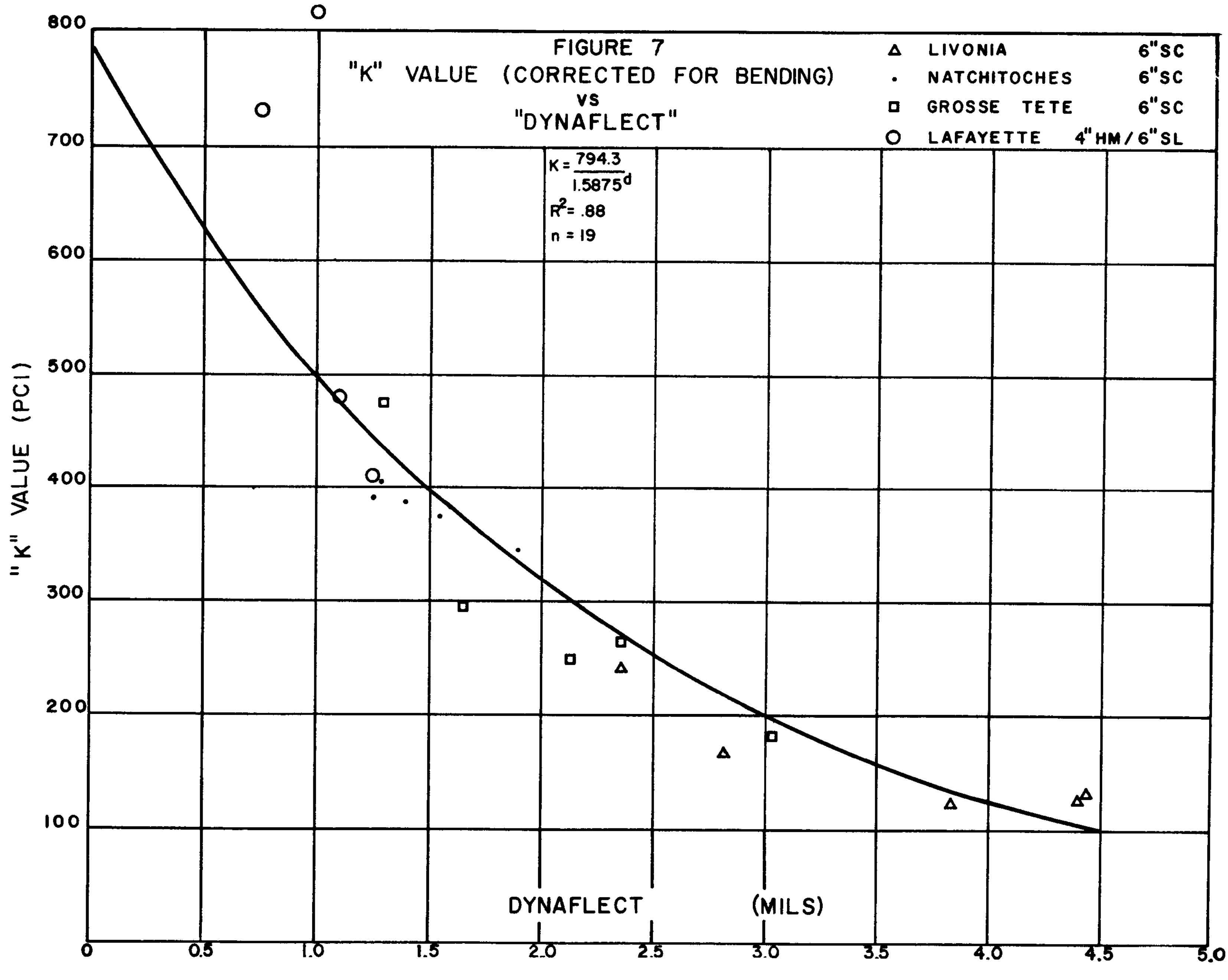
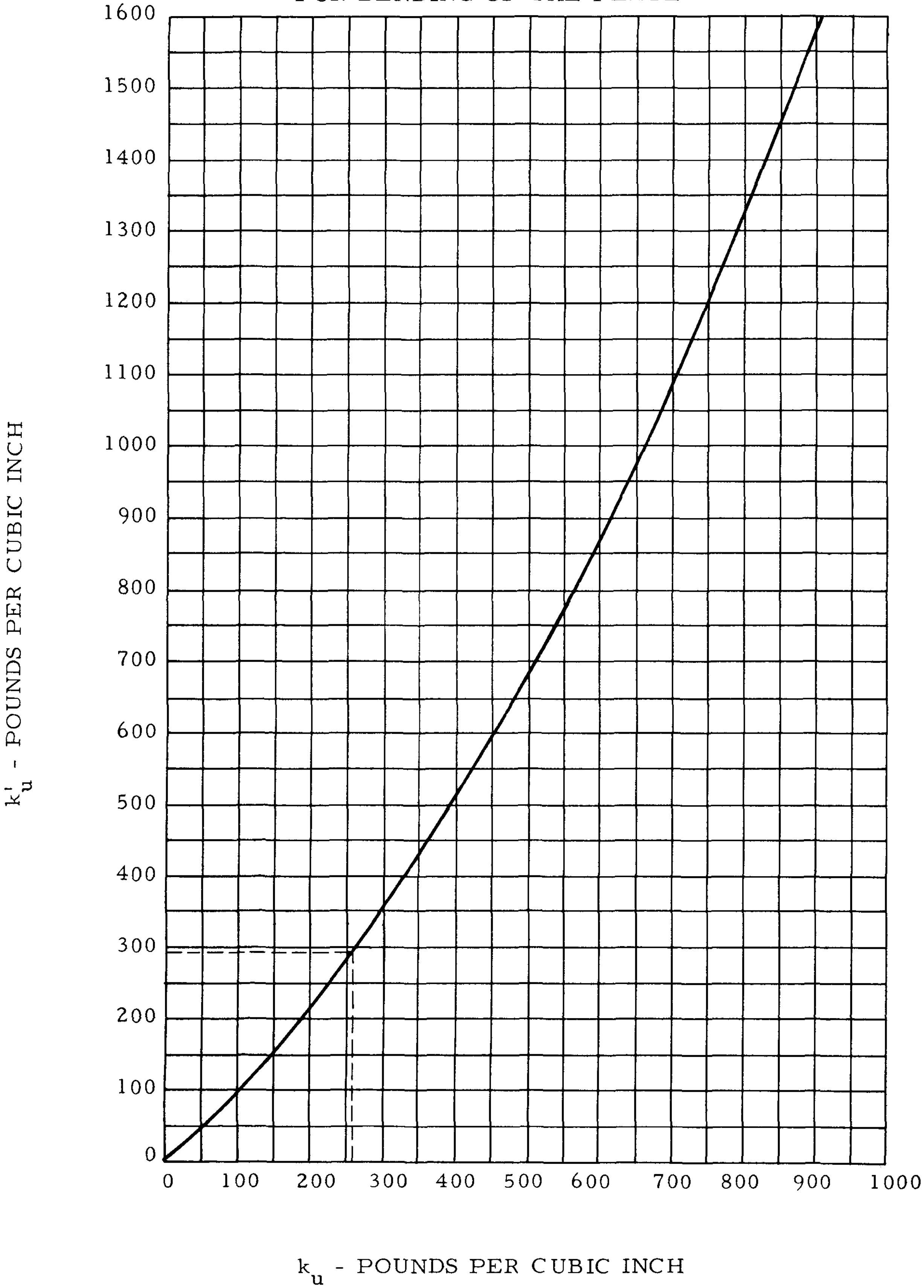


FIGURE 7
"K" VALUE (CORRECTED FOR BENDING)
VS
"DYNAFLECT"
LIVONIA 6"SC
NATCHITOCHES 6"SC
GROSSE TETE 6"SC
LAFAYETTE 4"HM/6"SL
K = 794.3 / 1.5875^d
R² = .88
n = 19
"K" VALUE (PCI)
DYNAFLECT (MILS)
800
700
600
500
400
300
200
100
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0

FIGURE 8

CHART FOR CORRECTION OF k_u

FOR BENDING OF THE PLATE



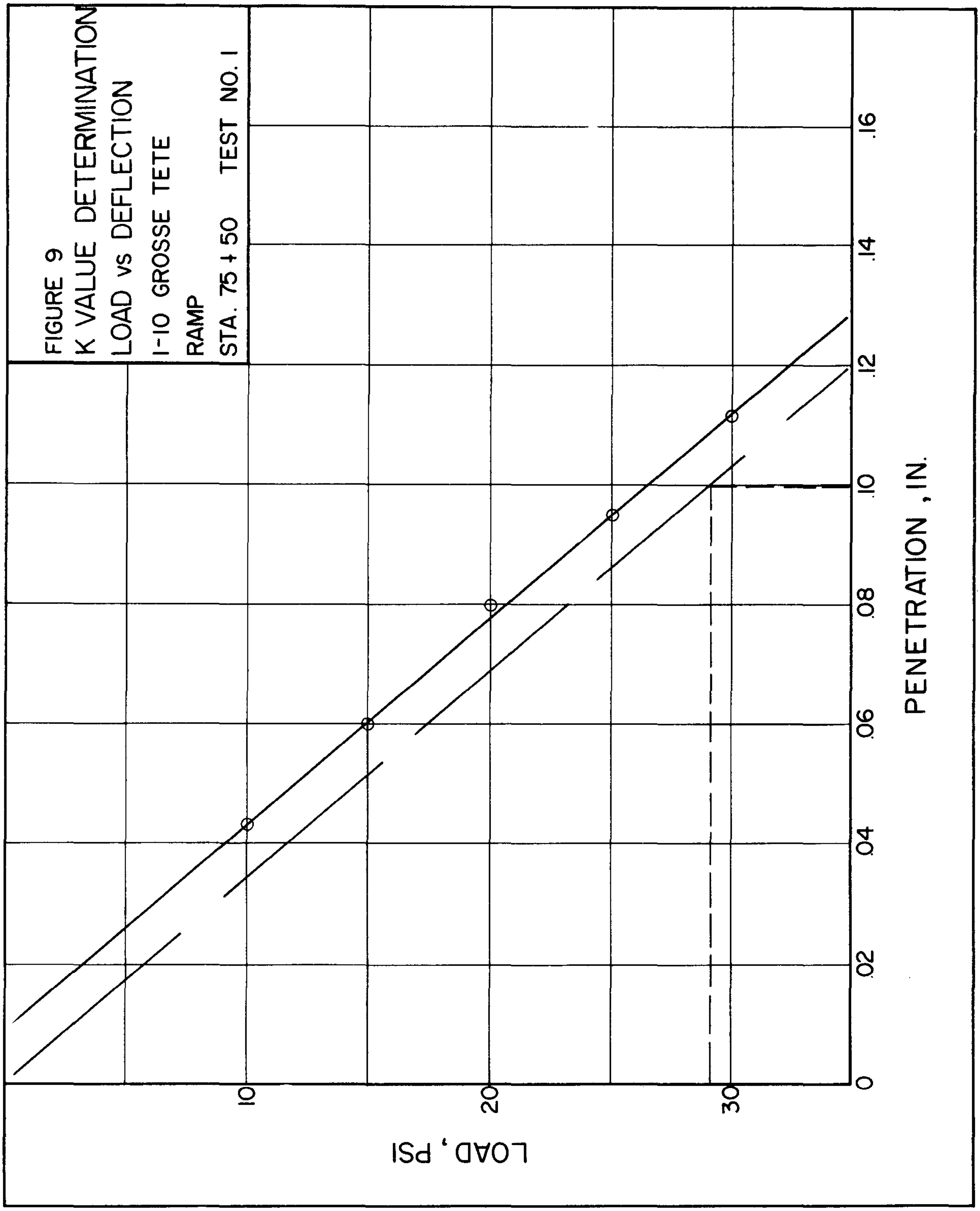


FIGURE 9
K VALUE DETERMINATION
LOAD vs DEFLECTION
I-10 GROSSE TETE
RAMP
STA. 75 + 50   TEST NO. 1
LOAD, PSI
10
20
30
PENETRATION, IN.
0
.02
.04
.06
.08
.10
.12
.14
.16

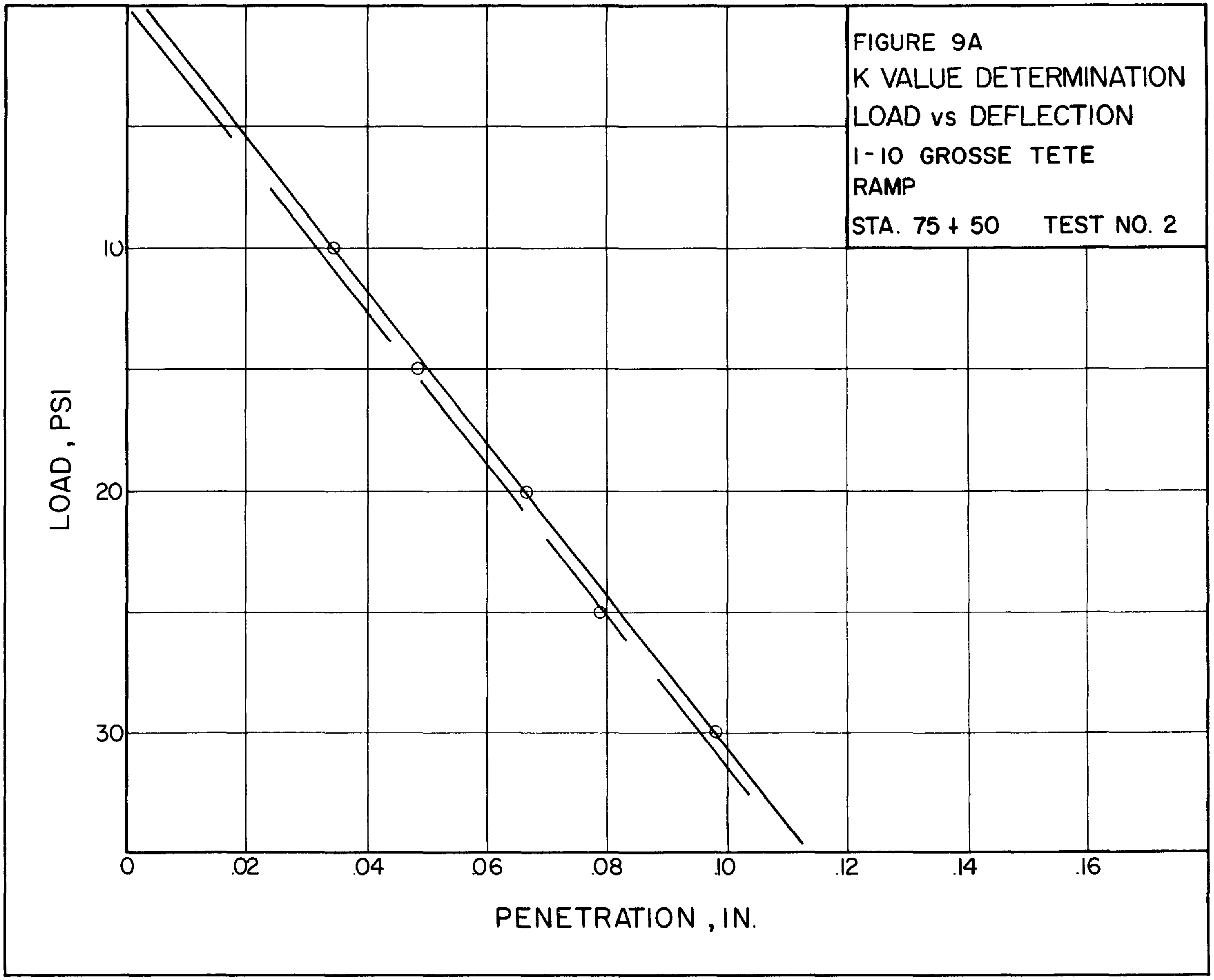


FIGURE 9A
K VALUE DETERMINATION
LOAD vs DEFLECTION
I-10 GROSSE TETE
RAMP
STA. 75 + 50 TEST NO. 2
LOAD, PSI
10
20
30
0
.02
.04
.06
.08
.10
.12
.14
.16
PENETRATION, IN.

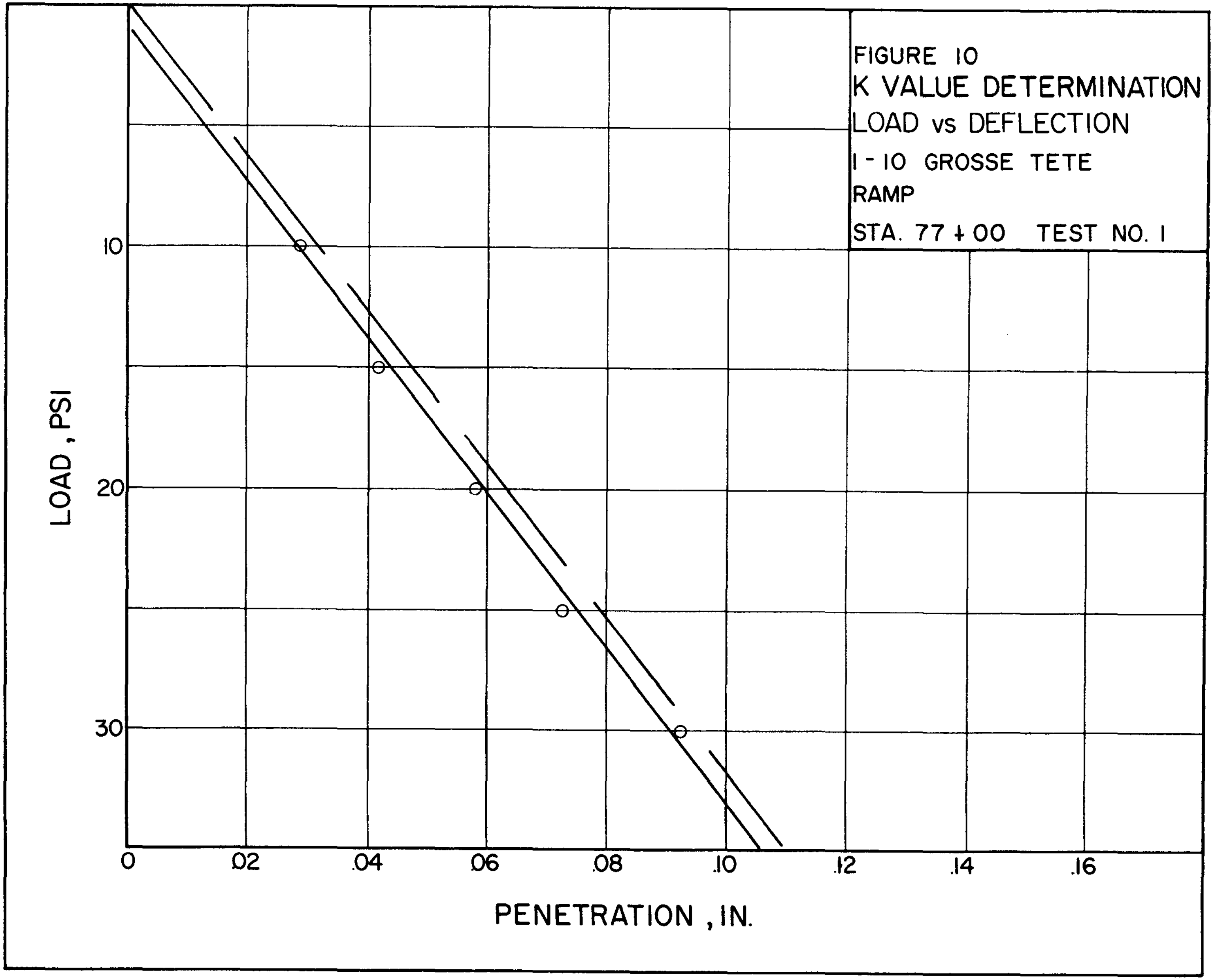


FIGURE 10
K VALUE DETERMINATION
LOAD vs DEFLECTION
I - 10 GROSSE TETE
RAMP
STA. 77 + 00 TEST NO. 1

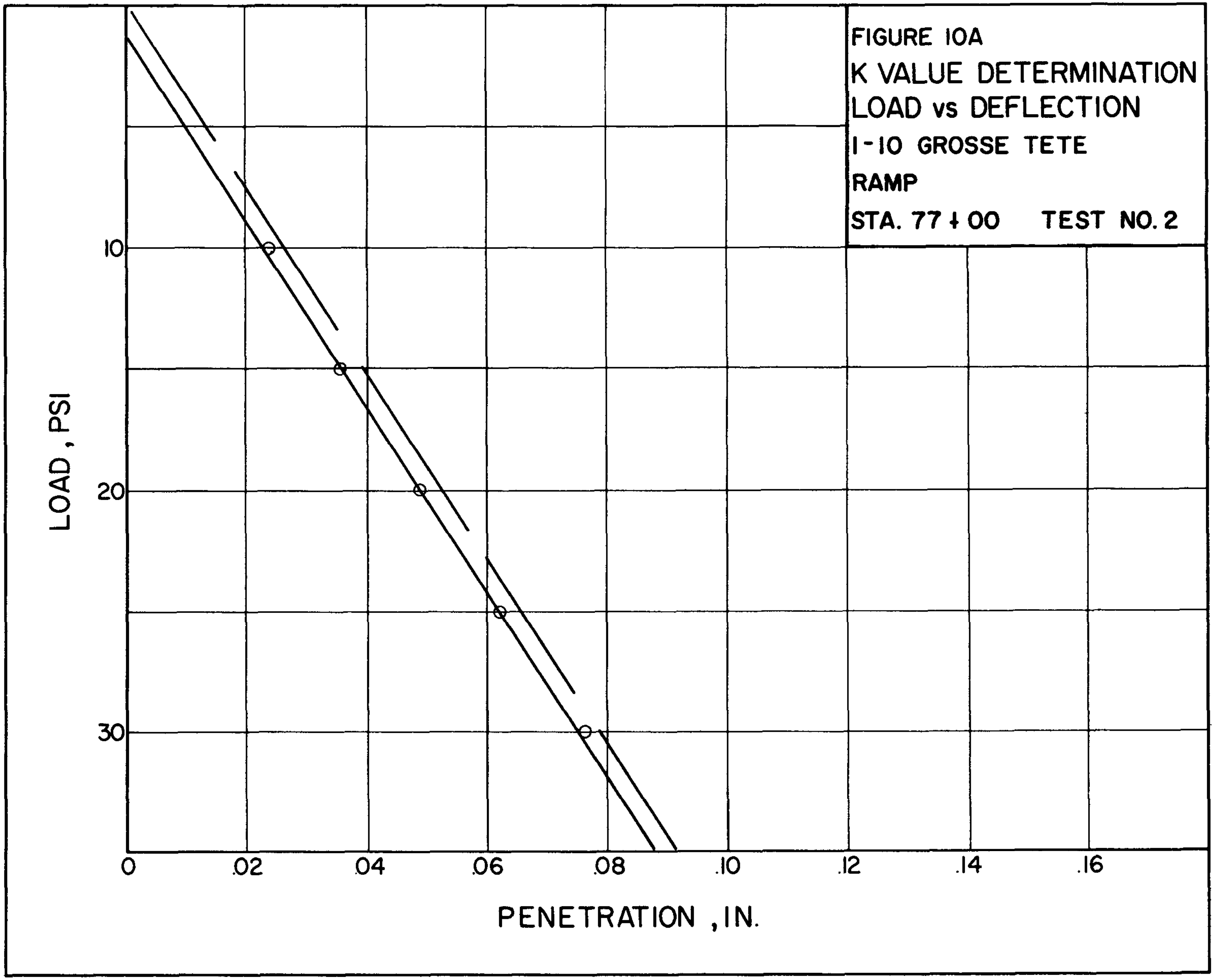


FIGURE 10A
K VALUE DETERMINATION
LOAD vs DEFLECTION
I-10 GROSSE TETE
RAMP
STA. 77 + 00 TEST NO. 2

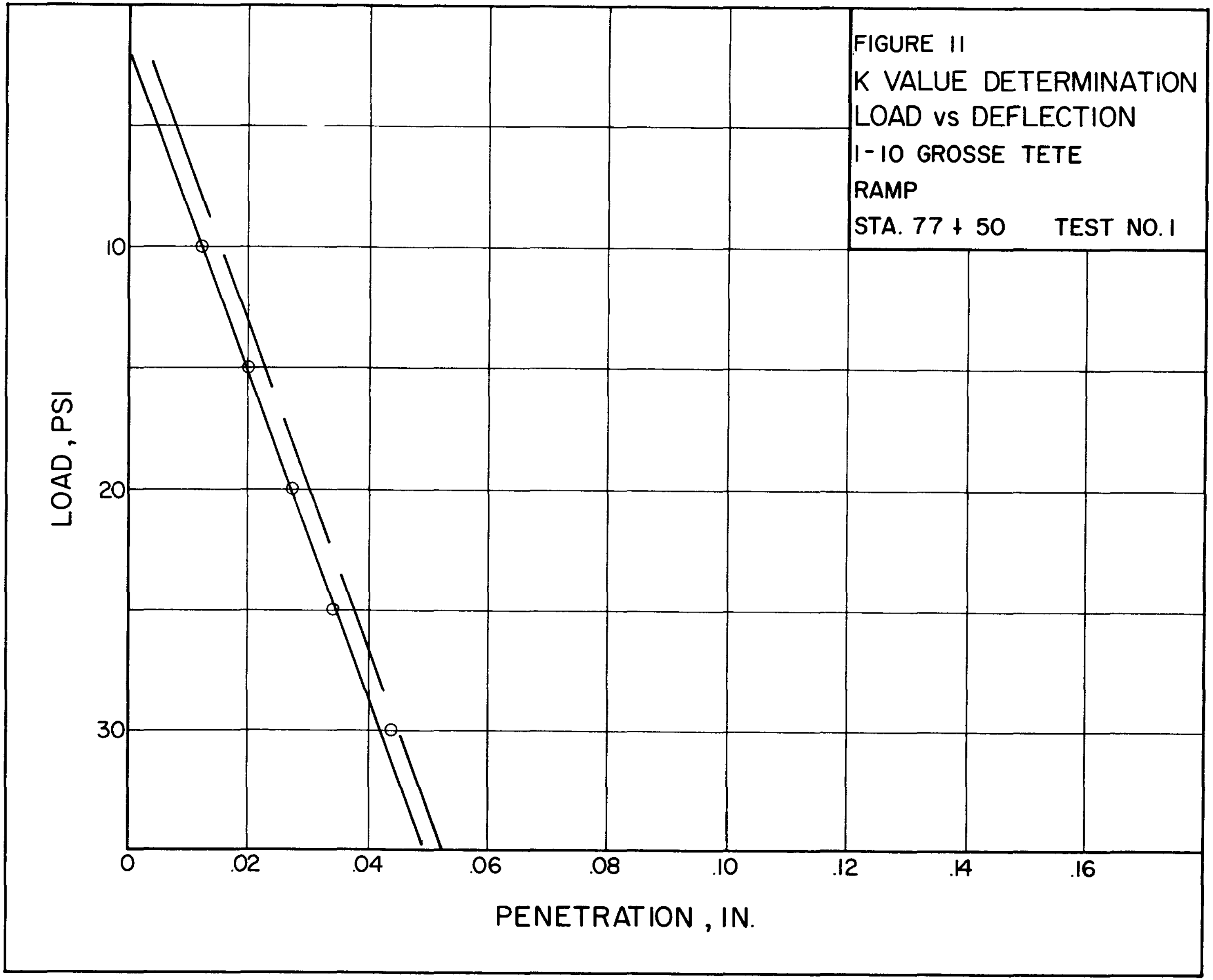


FIGURE 11
K VALUE DETERMINATION
LOAD vs DEFLECTION
I-10 GROSSE TETE
RAMP
STA. 77 + 50 TEST NO. 1

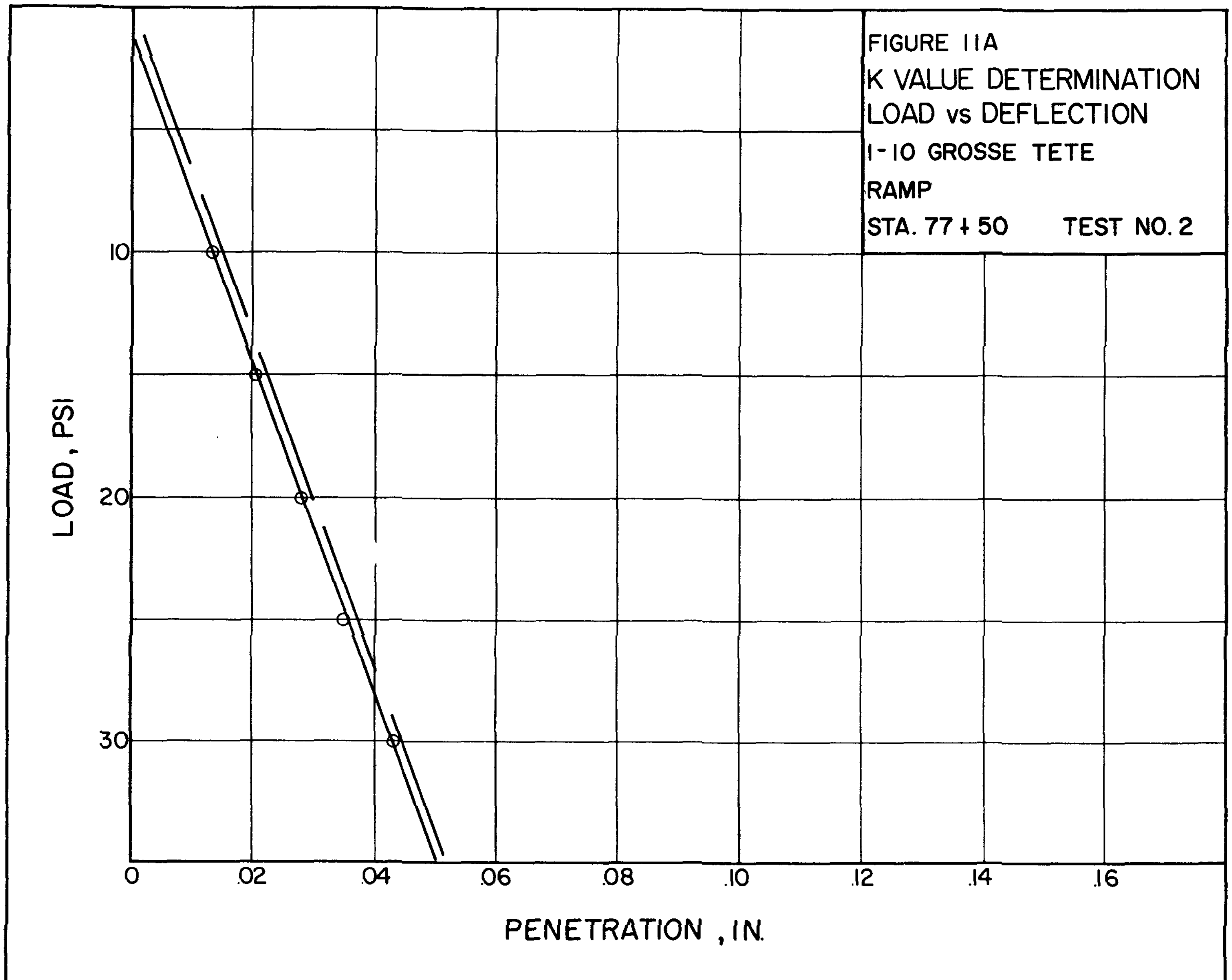


FIGURE 11A
K VALUE DETERMINATION
LOAD vs DEFLECTION
I-10 GROSSE TETE
RAMP
STA. 77 + 50 TEST NO. 2

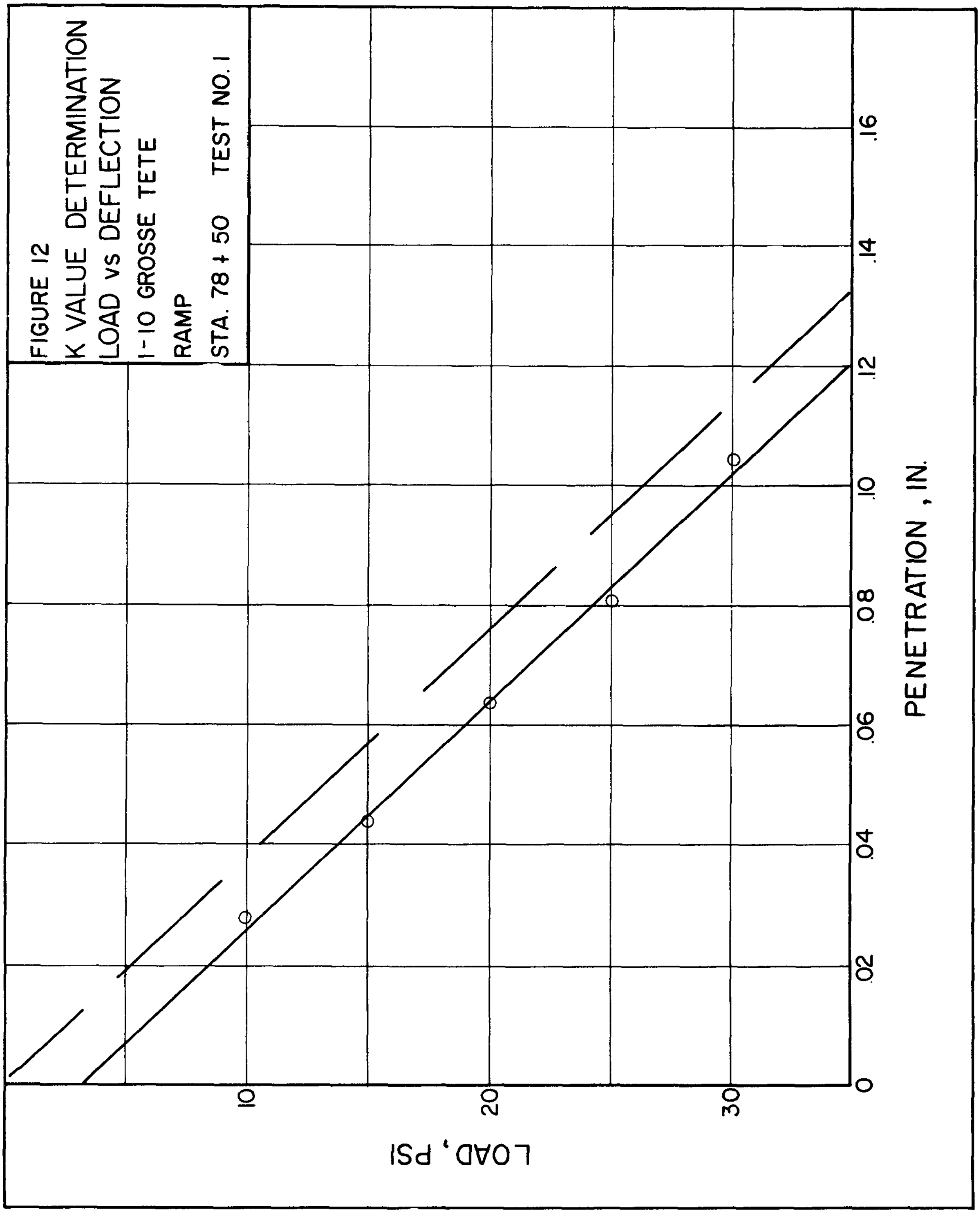


FIGURE 12
K VALUE DETERMINATION
LOAD vs DEFLECTION
I-10 GROSSE TETE
RAMP
STA. 78 + 50 TEST NO. 1
LOAD, PSI
10
20
30
PENETRATION , IN.
0
.02
.04
.06
.08
.10
.12
.14
.16

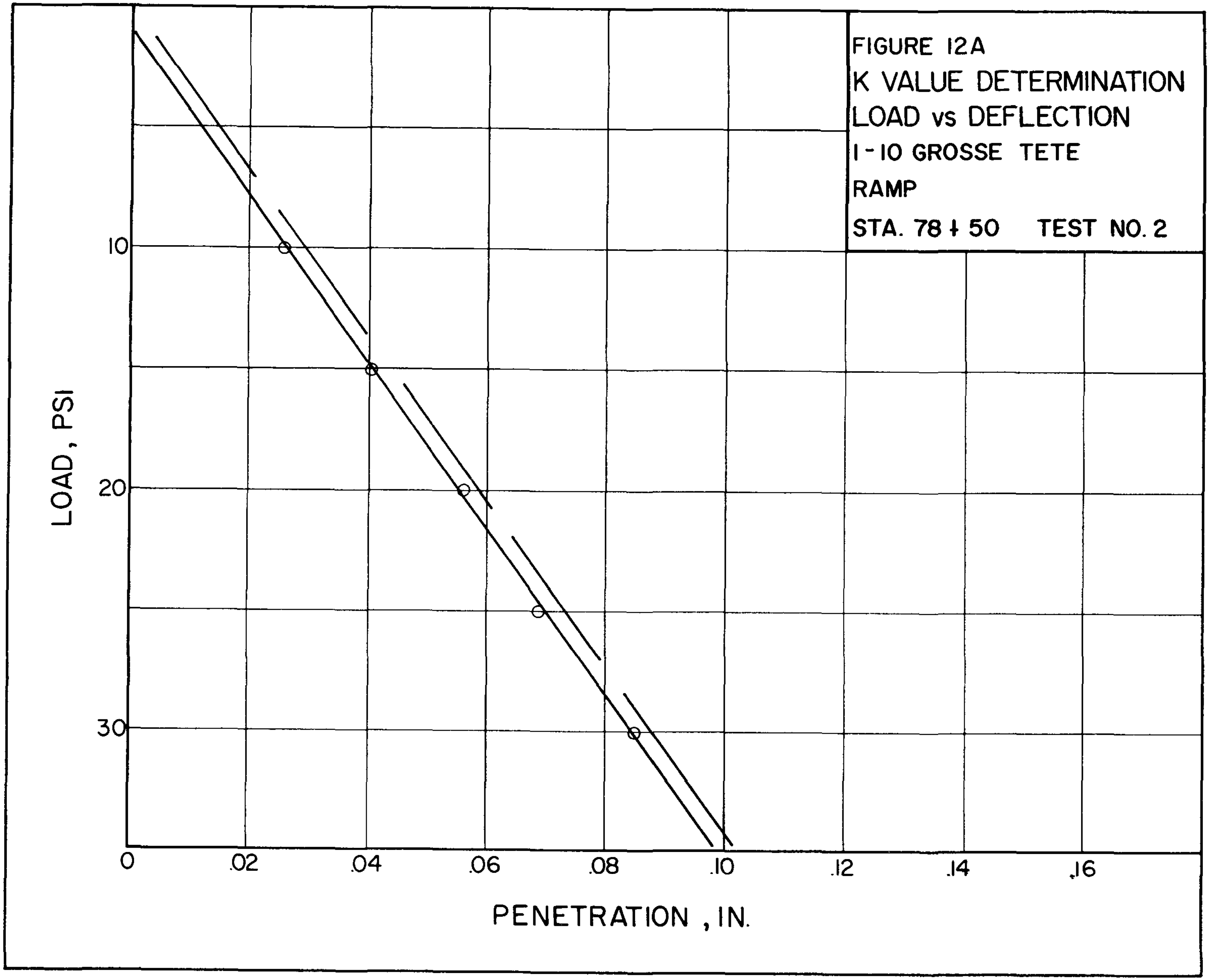


FIGURE 12A
K VALUE DETERMINATION
LOAD vs DEFLECTION
I-10 GROSSE TETE
RAMP
STA. 78 + 50 TEST NO. 2

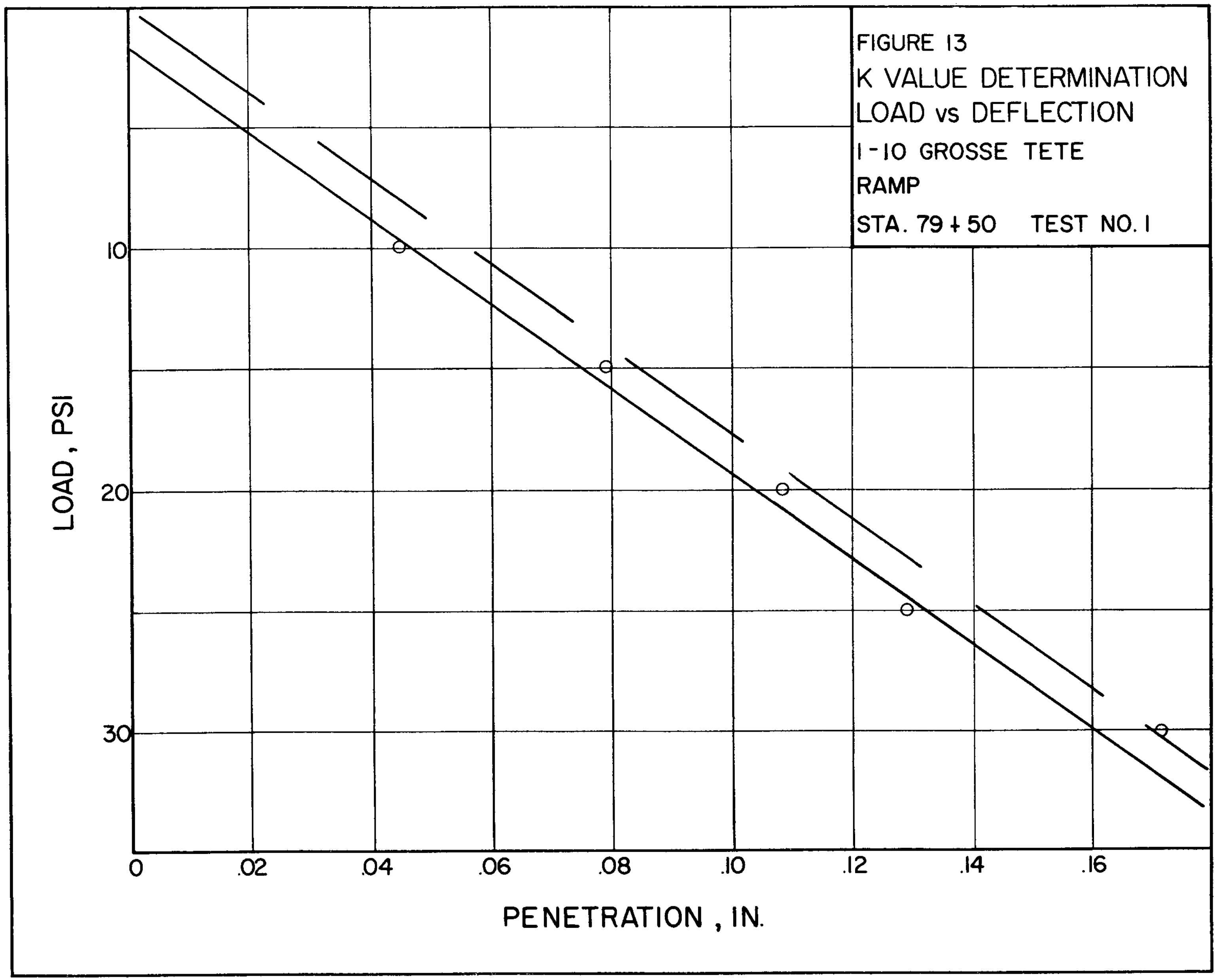


FIGURE 13
K VALUE DETERMINATION
LOAD vs DEFLECTION
I-10 GROSSE TETE
RAMP
STA. 79+50 TEST NO. I
LOAD, PSI
10
20
30
0
.02
.04
.06
.08
.10
.12
.14
.16
PENETRATION, IN.

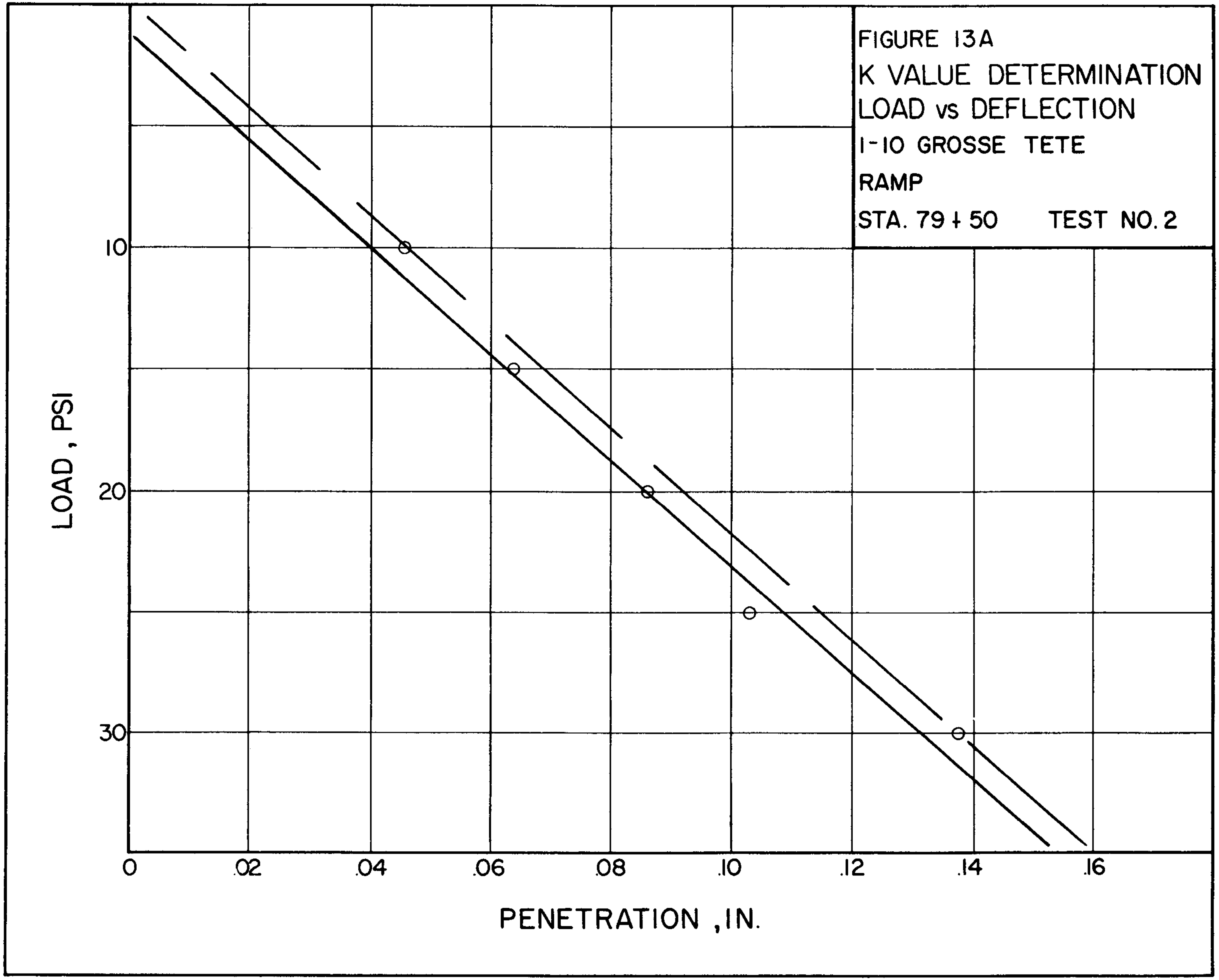


FIGURE 13A
K VALUE DETERMINATION
LOAD vs DEFLECTION
I-10 GROSSE TETE
RAMP
STA. 79 + 50 TEST NO. 2

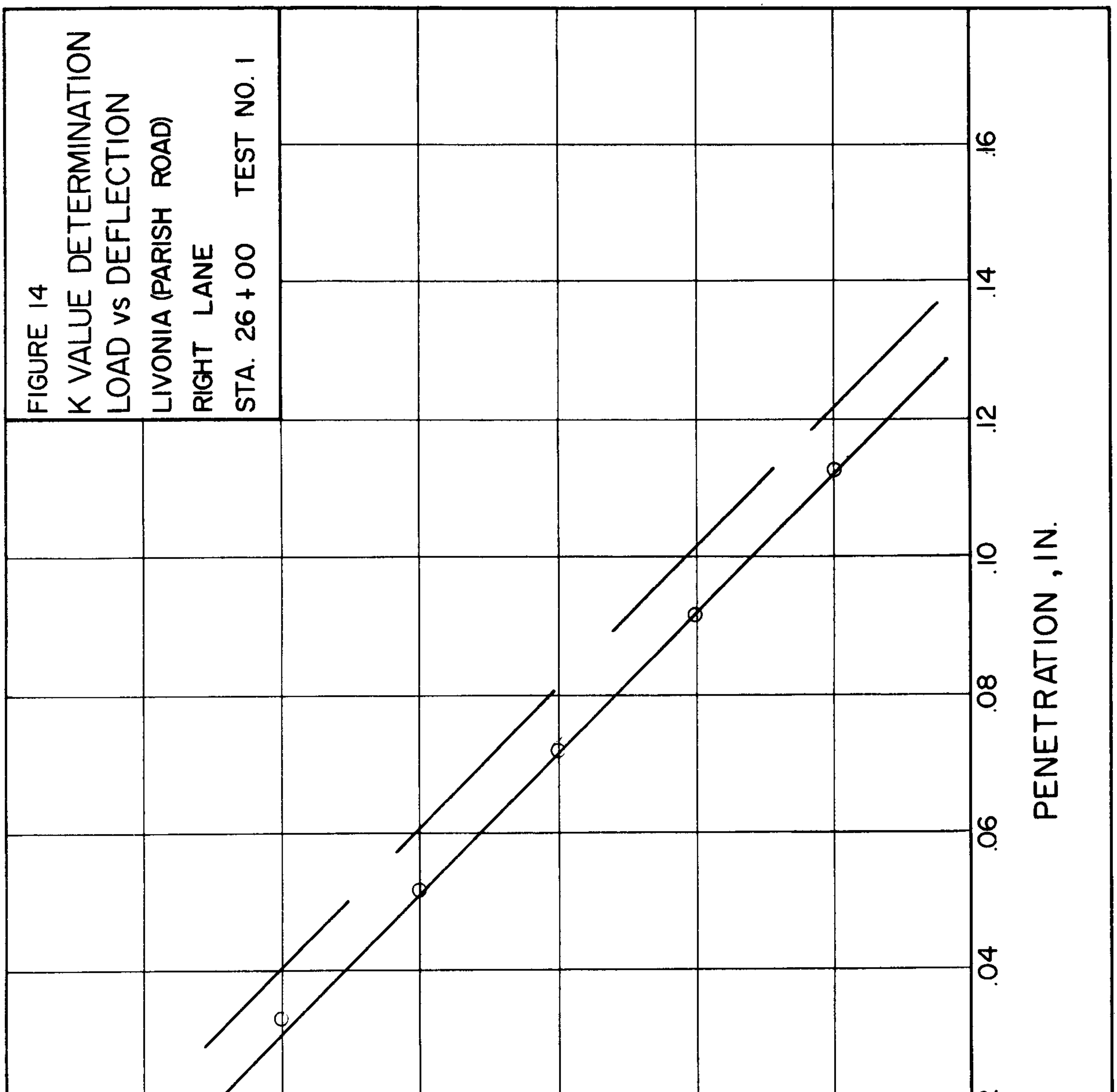


FIGURE 14
K VALUE DETERMINATION
LOAD vs DEFLECTION
LIVONIA (PARISH ROAD)
RIGHT LANE
STA. 26 + 00 TEST NO. 1
PENETRATION , IN.
LOAD , PSI
0
.02
.04
.06
.08
.10
.12
.14
.16
10
20
30

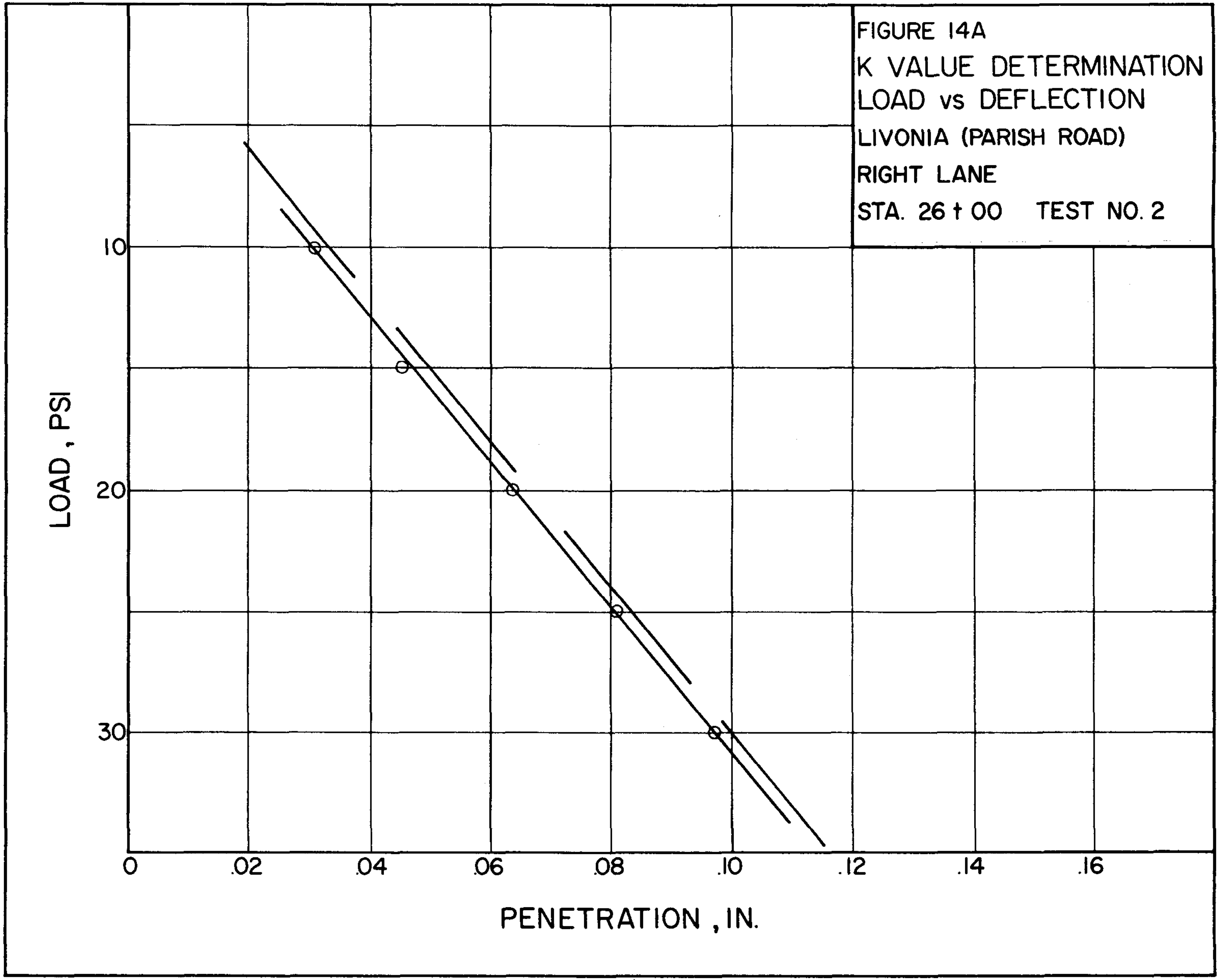


FIGURE 14A
K VALUE DETERMINATION
LOAD vs DEFLECTION
LIVONIA (PARISH ROAD)
RIGHT LANE
STA. 26 + 00 TEST NO. 2

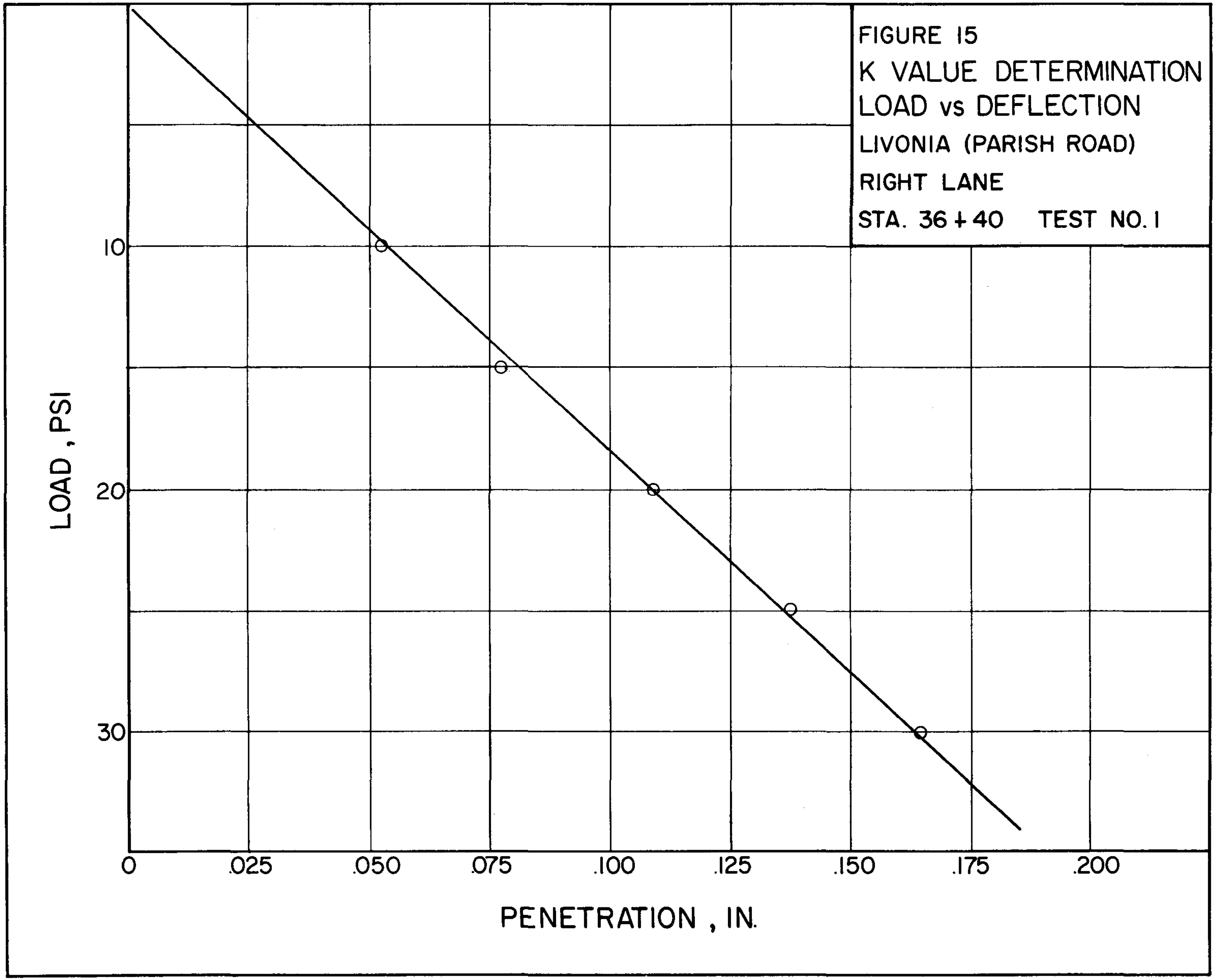


FIGURE 15
K VALUE DETERMINATION
LOAD vs DEFLECTION
LIVONIA (PARISH ROAD)
RIGHT LANE
STA. 36 + 40 TEST NO. 1

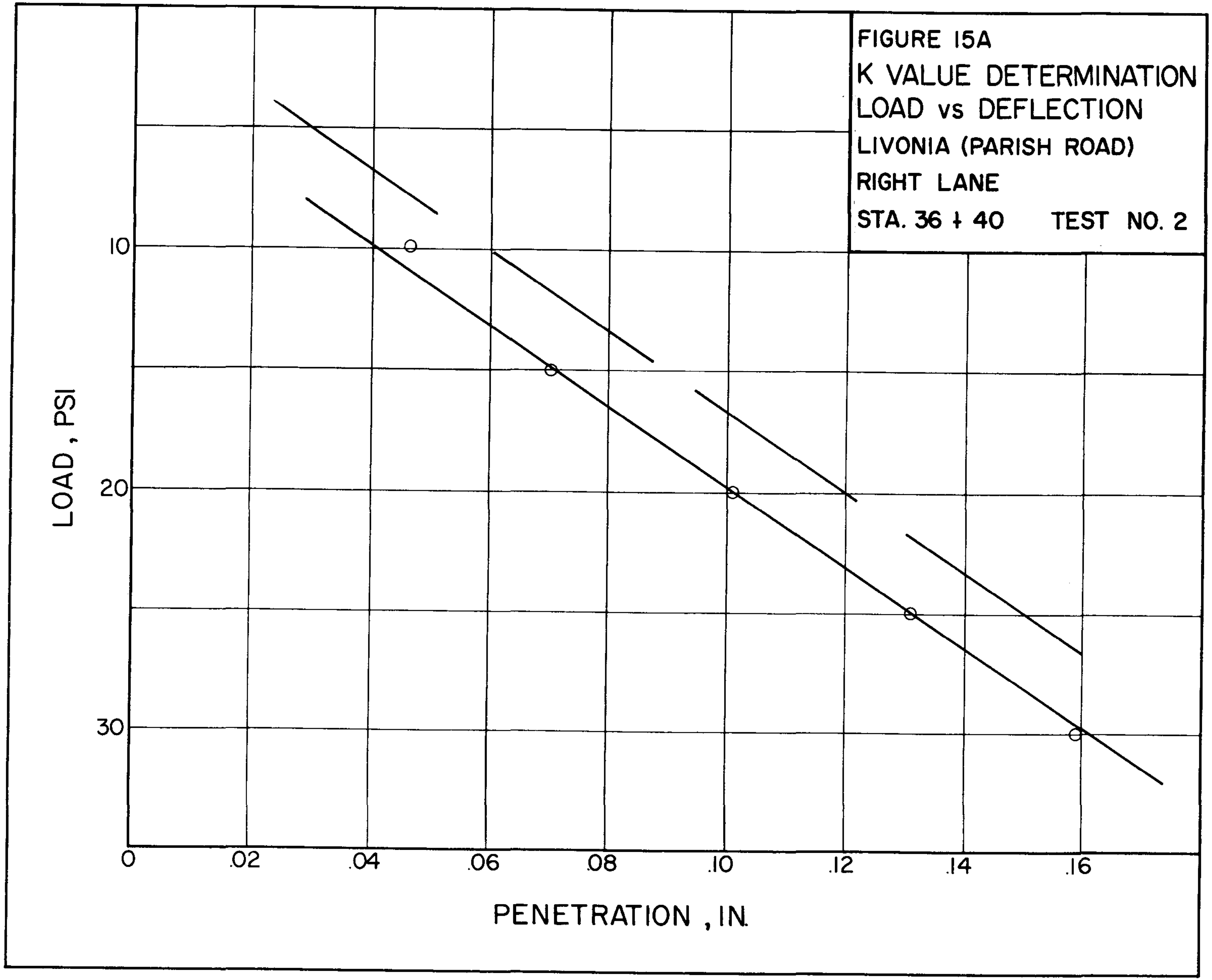


FIGURE 15A
K VALUE DETERMINATION
LOAD vs DEFLECTION
LIVONIA (PARISH ROAD)
RIGHT LANE
STA. 36 + 40 TEST NO. 2

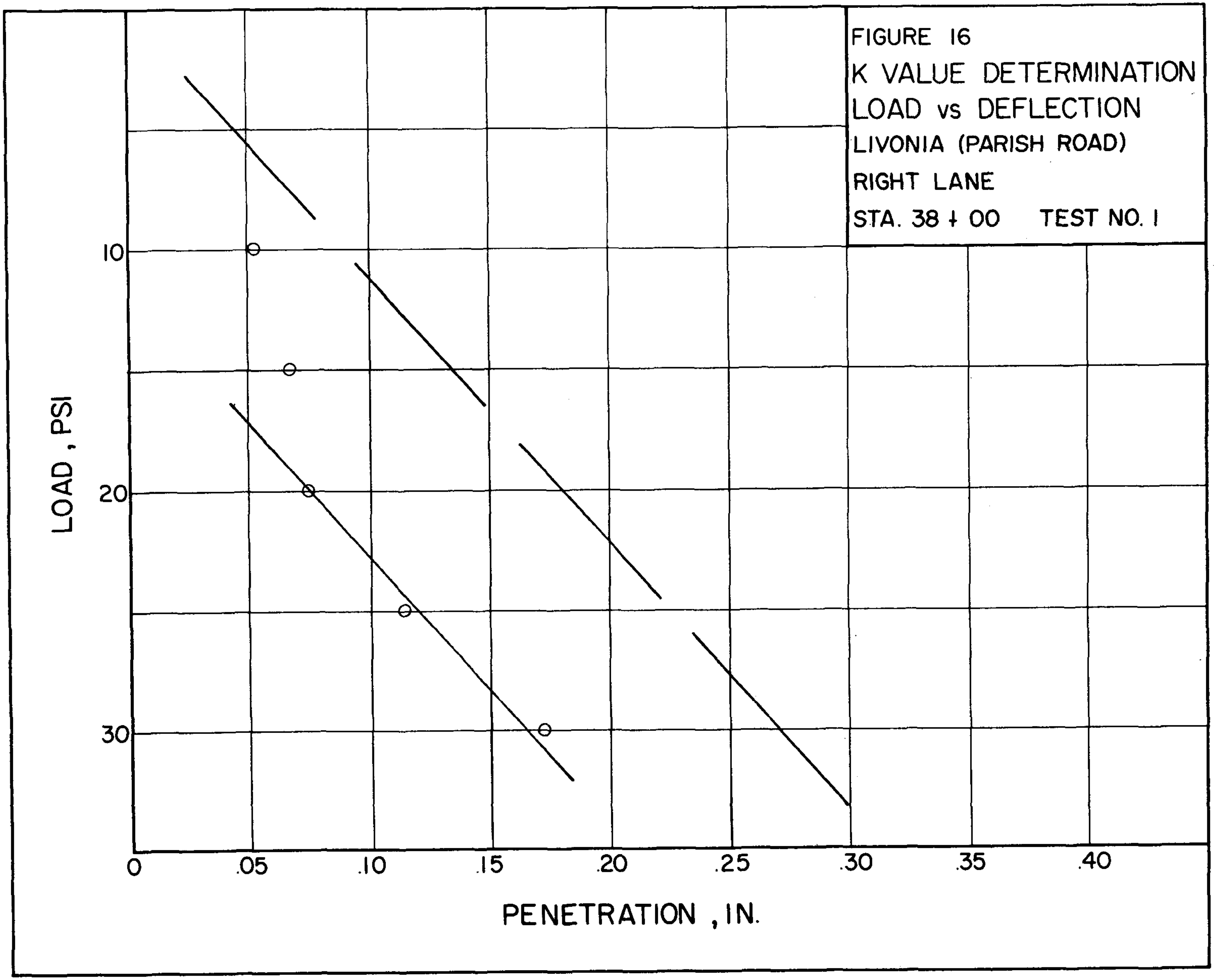


FIGURE 16
K VALUE DETERMINATION
LOAD vs DEFLECTION
LIVONIA (PARISH ROAD)
RIGHT LANE
STA. 38 + 00 TEST NO. 1

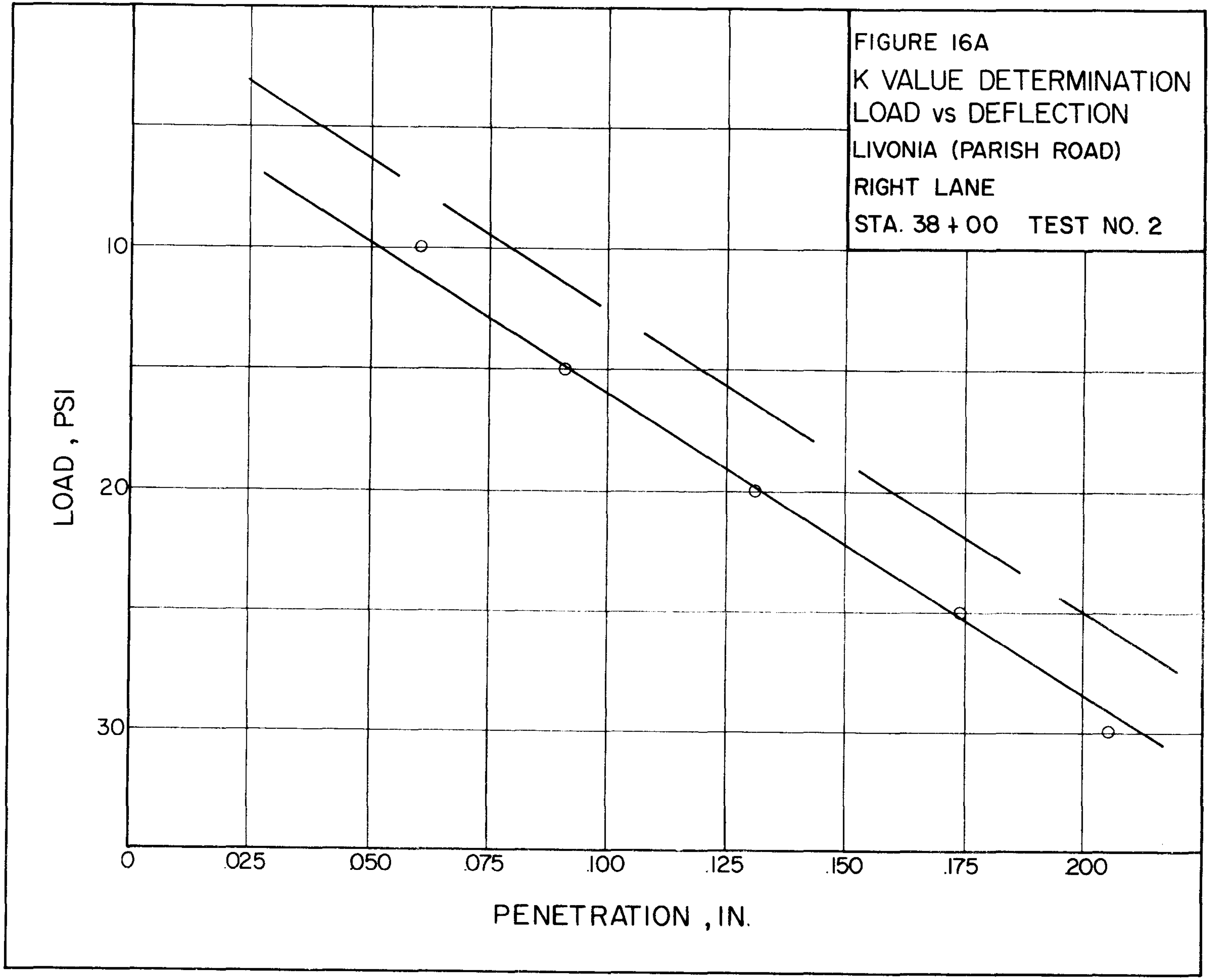


FIGURE 16A
K VALUE DETERMINATION
LOAD vs DEFLECTION
LIVONIA (PARISH ROAD)
RIGHT LANE
STA. 38 + 00 TEST NO. 2

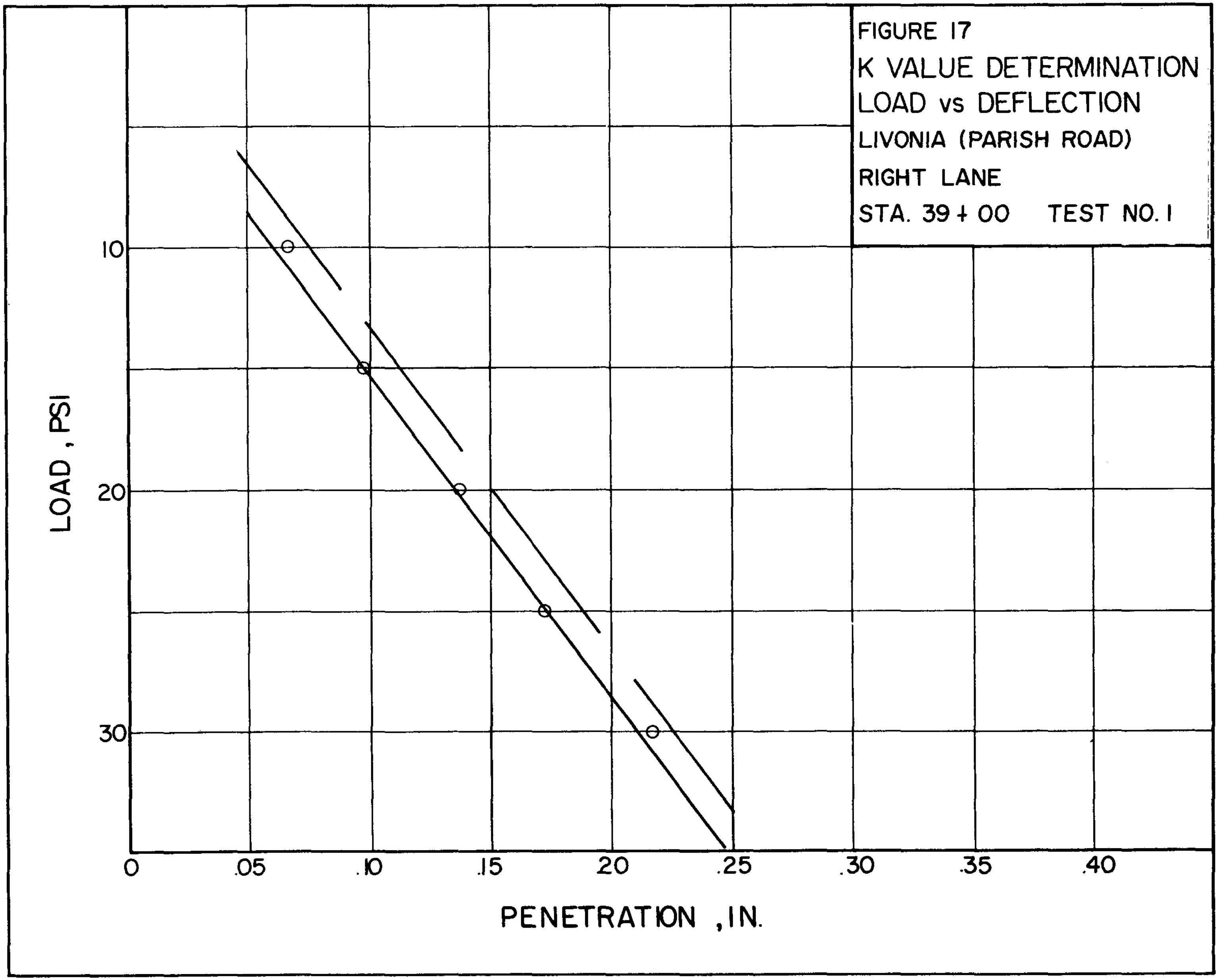


FIGURE 17
K VALUE DETERMINATION
LOAD vs DEFLECTION
LIVONIA (PARISH ROAD)
RIGHT LANE
STA. 39 + 00 TEST NO. 1
LOAD, PSI
10
20
30
0
.05
.10
.15
.20
.25
.30
.35
.40
PENETRATION, IN.

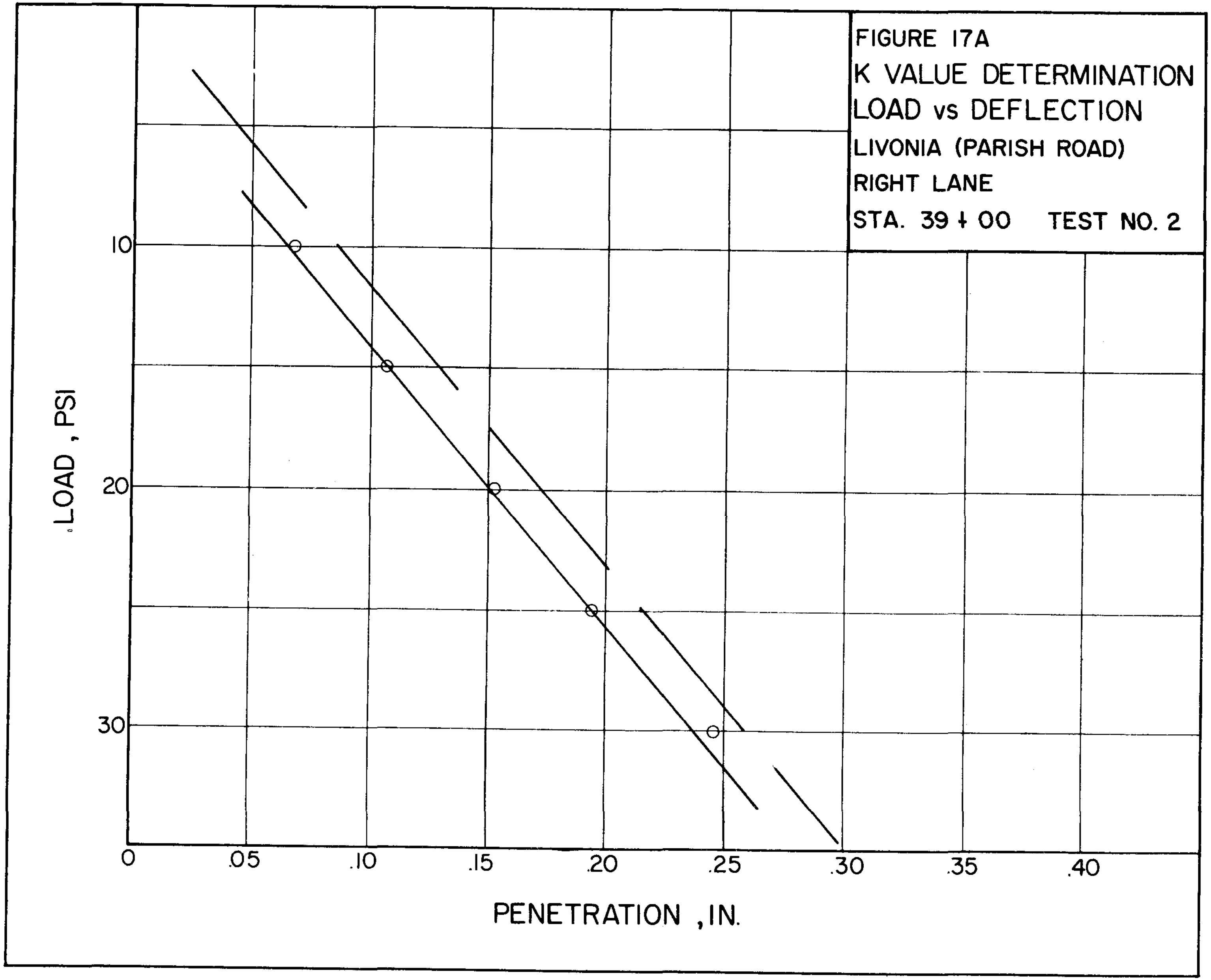


FIGURE 17A
K VALUE DETERMINATION
LOAD vs DEFLECTION
LIVONIA (PARISH ROAD)
RIGHT LANE
STA. 39 + 00 TEST NO. 2

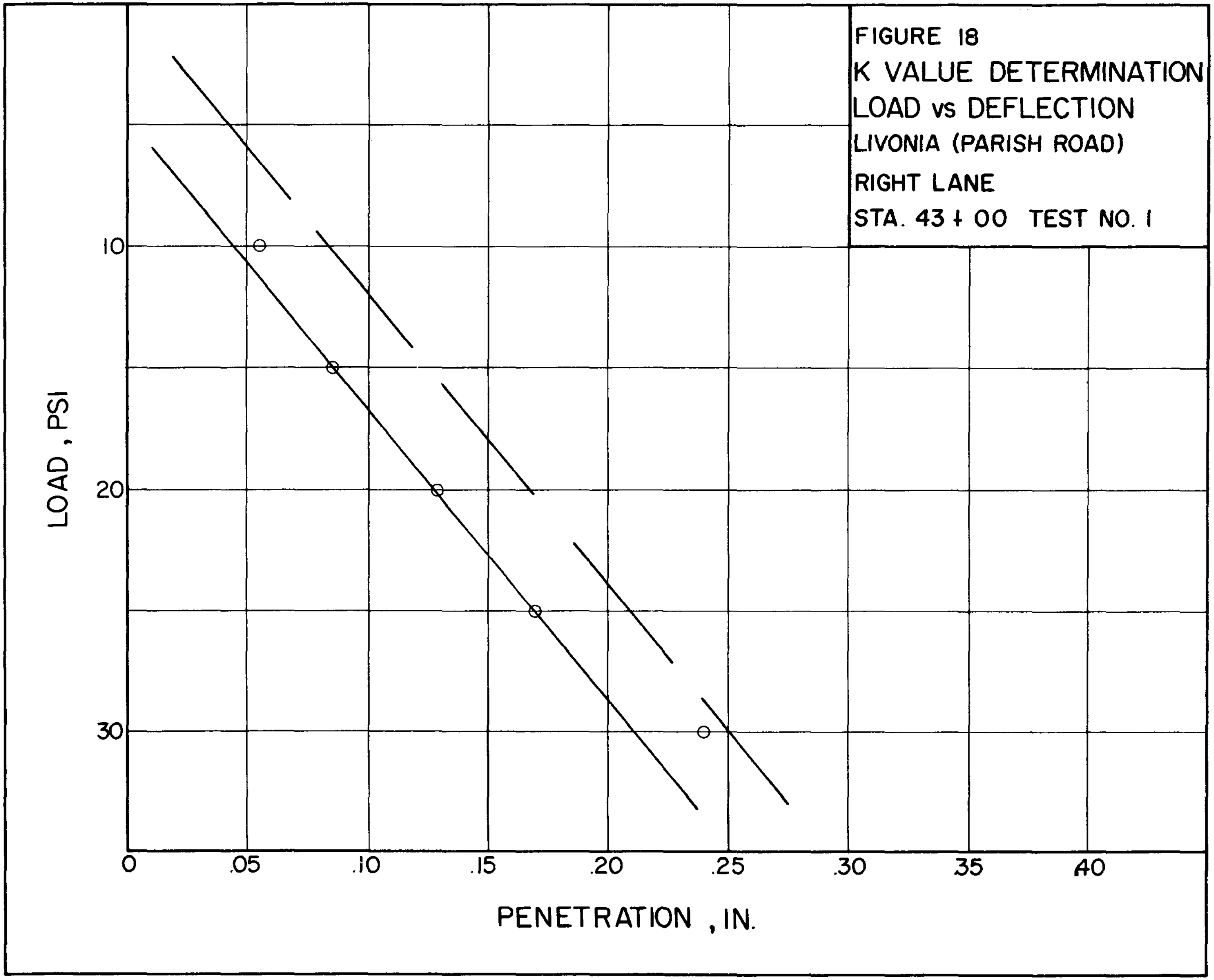


FIGURE 18
K VALUE DETERMINATION
LOAD vs DEFLECTION
LIVONIA (PARISH ROAD)
RIGHT LANE
STA. 43 + 00 TEST NO. 1

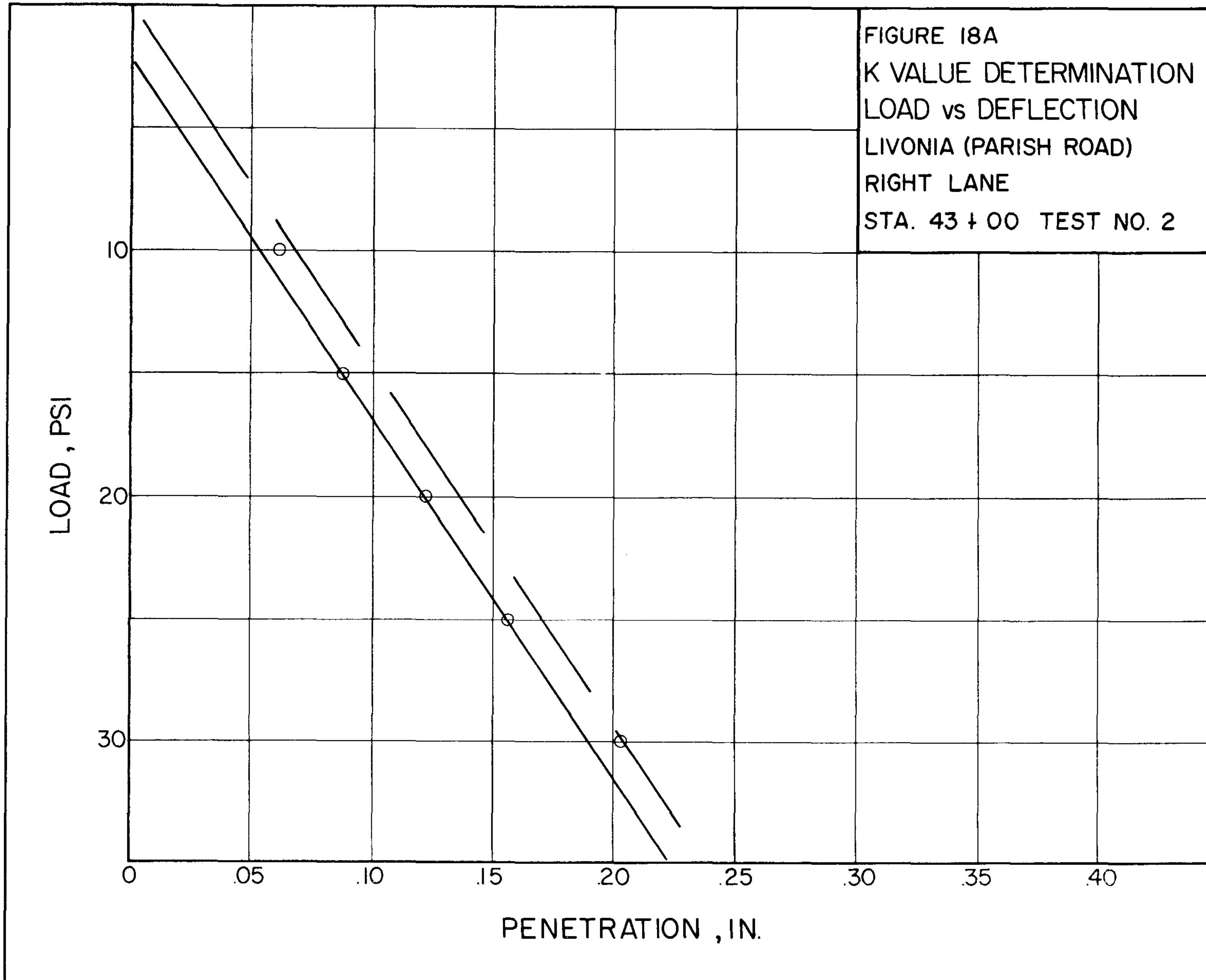


FIGURE 18A
K VALUE DETERMINATION
LOAD vs DEFLECTION
LIVONIA (PARISH ROAD)
RIGHT LANE
STA. 43 + 00 TEST NO. 2

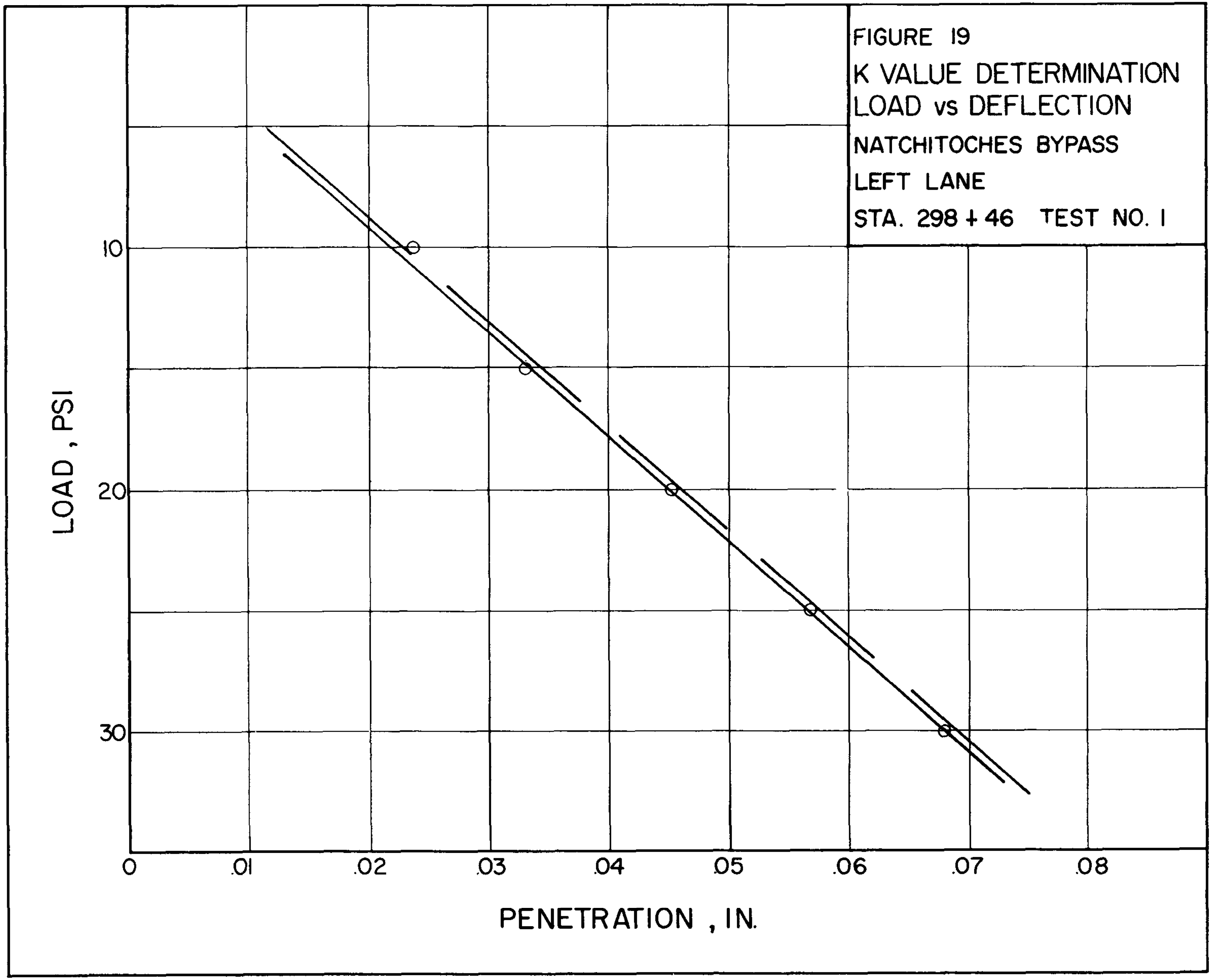


FIGURE 19
K VALUE DETERMINATION
LOAD vs DEFLECTION
NATCHITOCHES BYPASS
LEFT LANE
STA. 298 + 46 TEST NO. 1

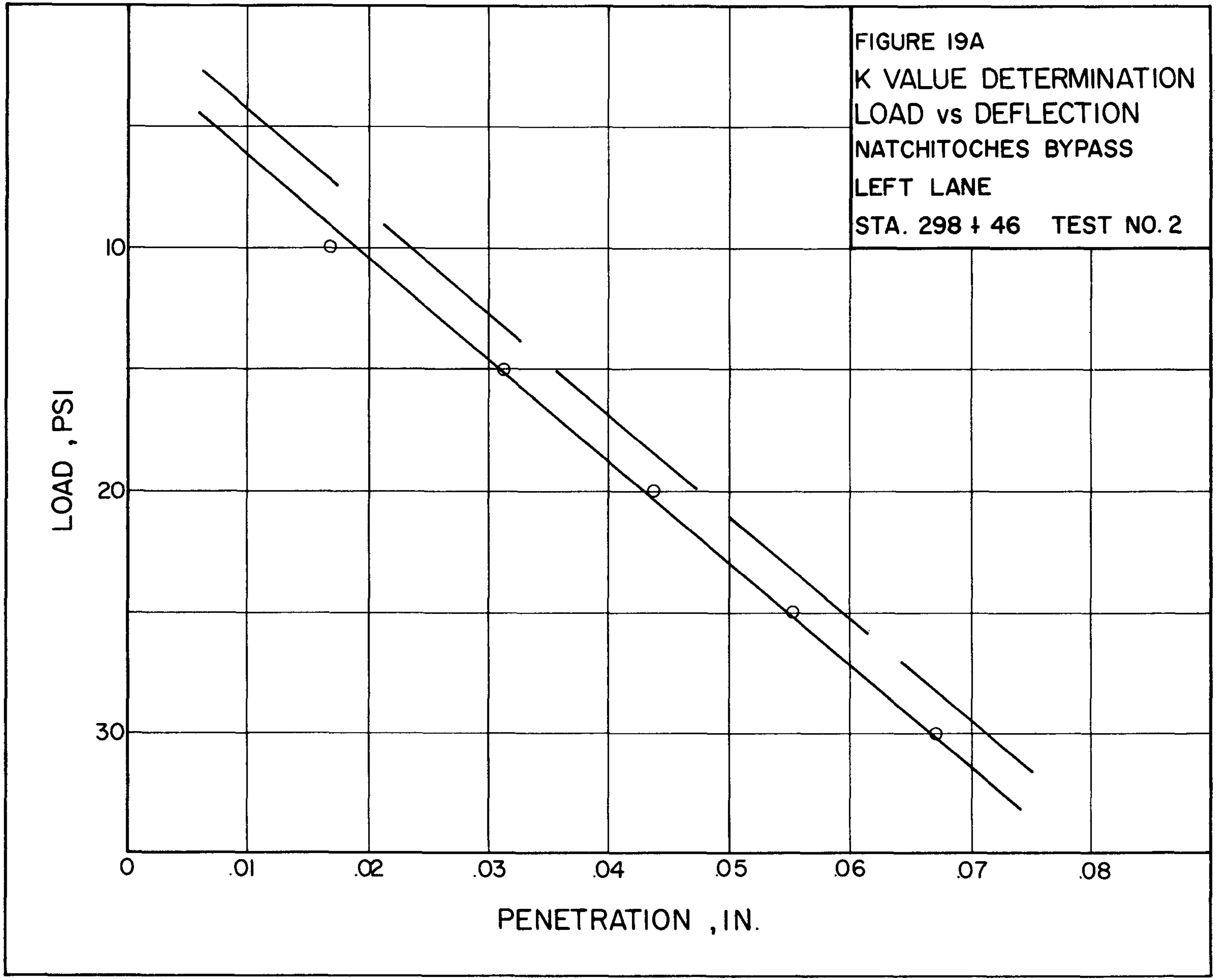


FIGURE 19A
K VALUE DETERMINATION
LOAD vs DEFLECTION
NATCHITOCHES BYPASS
LEFT LANE
STA. 298 + 46 TEST NO. 2

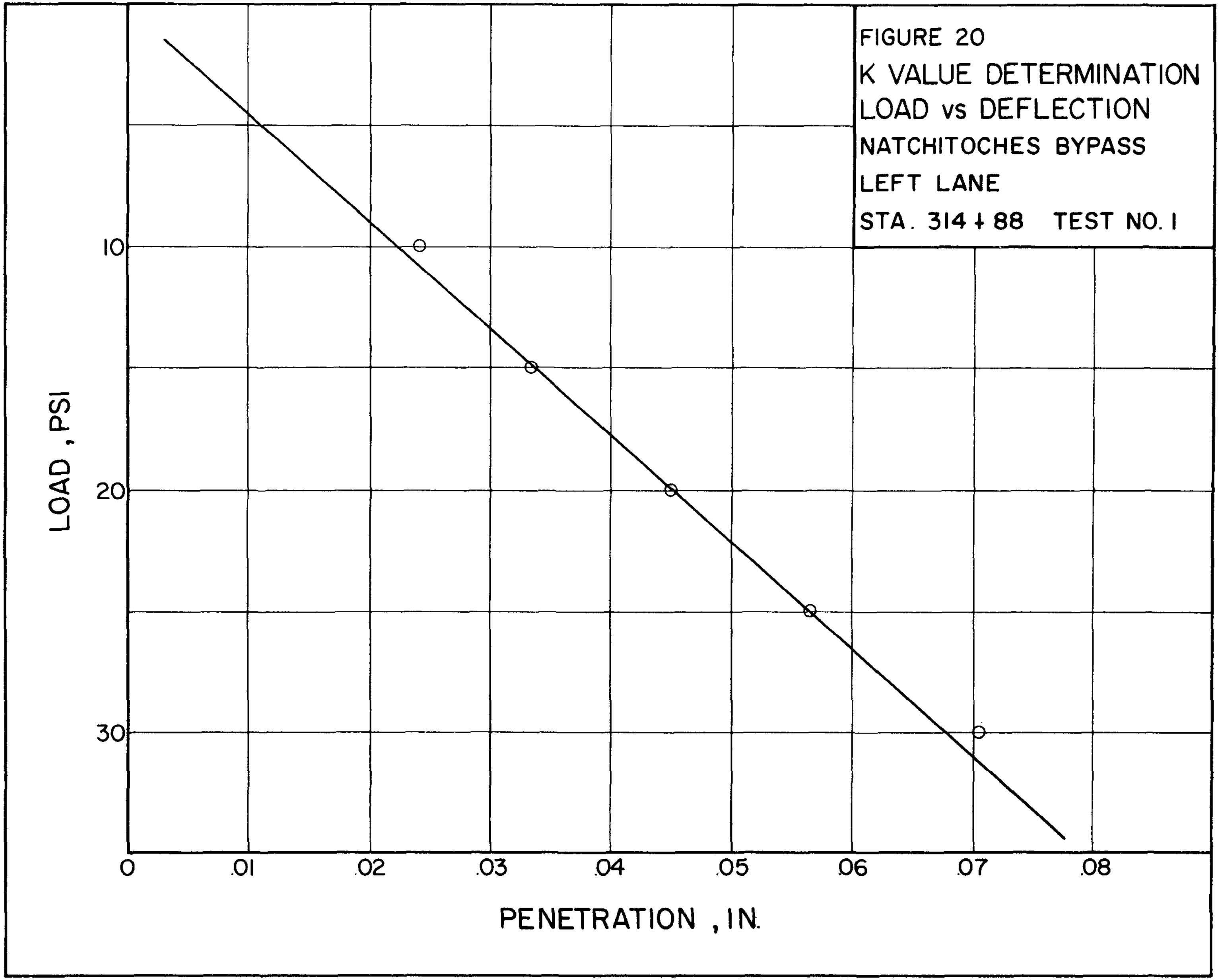


FIGURE 20
K VALUE DETERMINATION
LOAD vs DEFLECTION
NATCHITOCHES BYPASS
LEFT LANE
STA. 314 + 88 TEST NO. 1

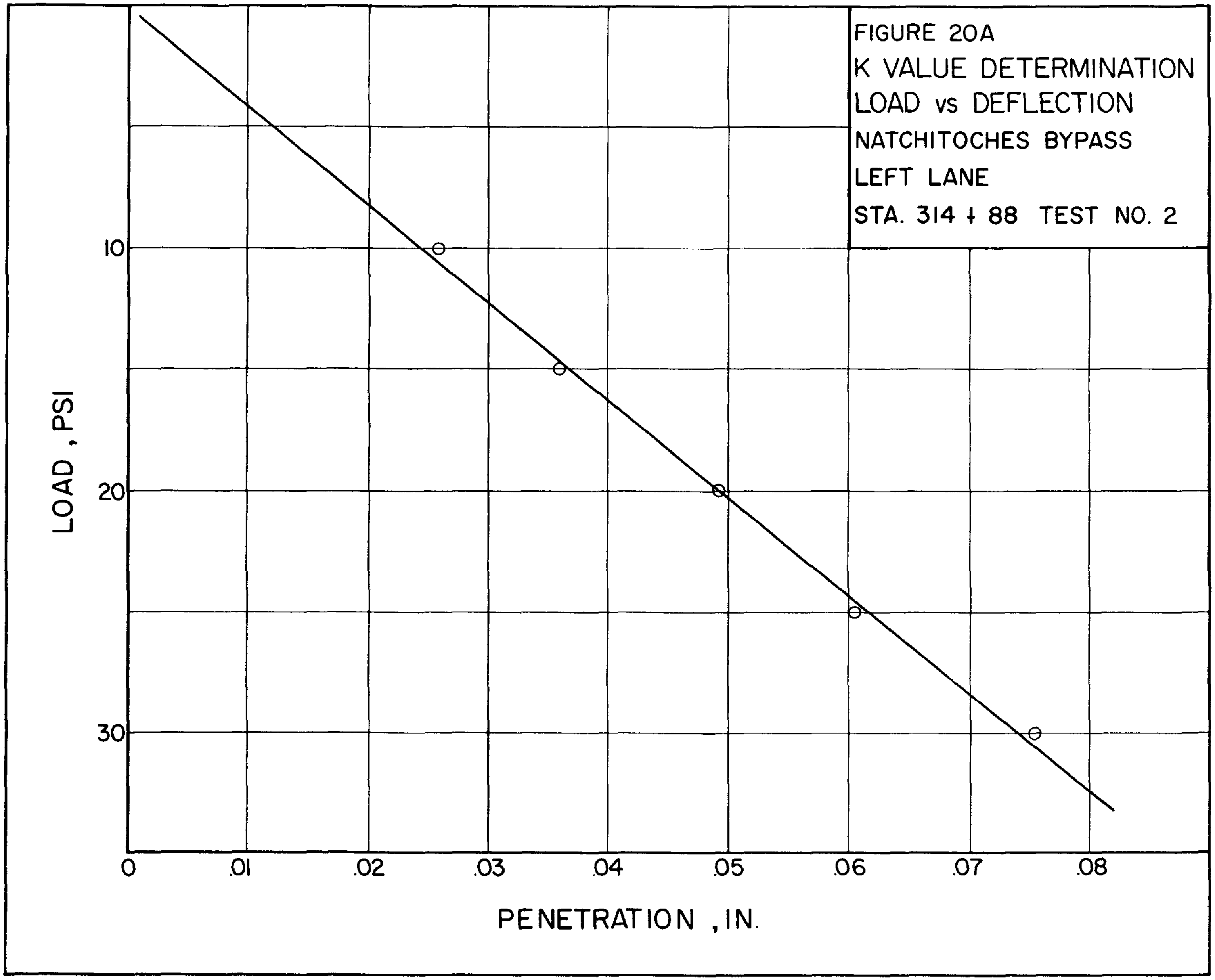


FIGURE 20A
K VALUE DETERMINATION
LOAD vs DEFLECTION
NATCHITOCHES BYPASS
LEFT LANE
STA. 314 + 88 TEST NO. 2
LOAD , PSI
10
20
30
0
.01
.02
.03
.04
.05
.06
.07
.08
PENETRATION , IN.

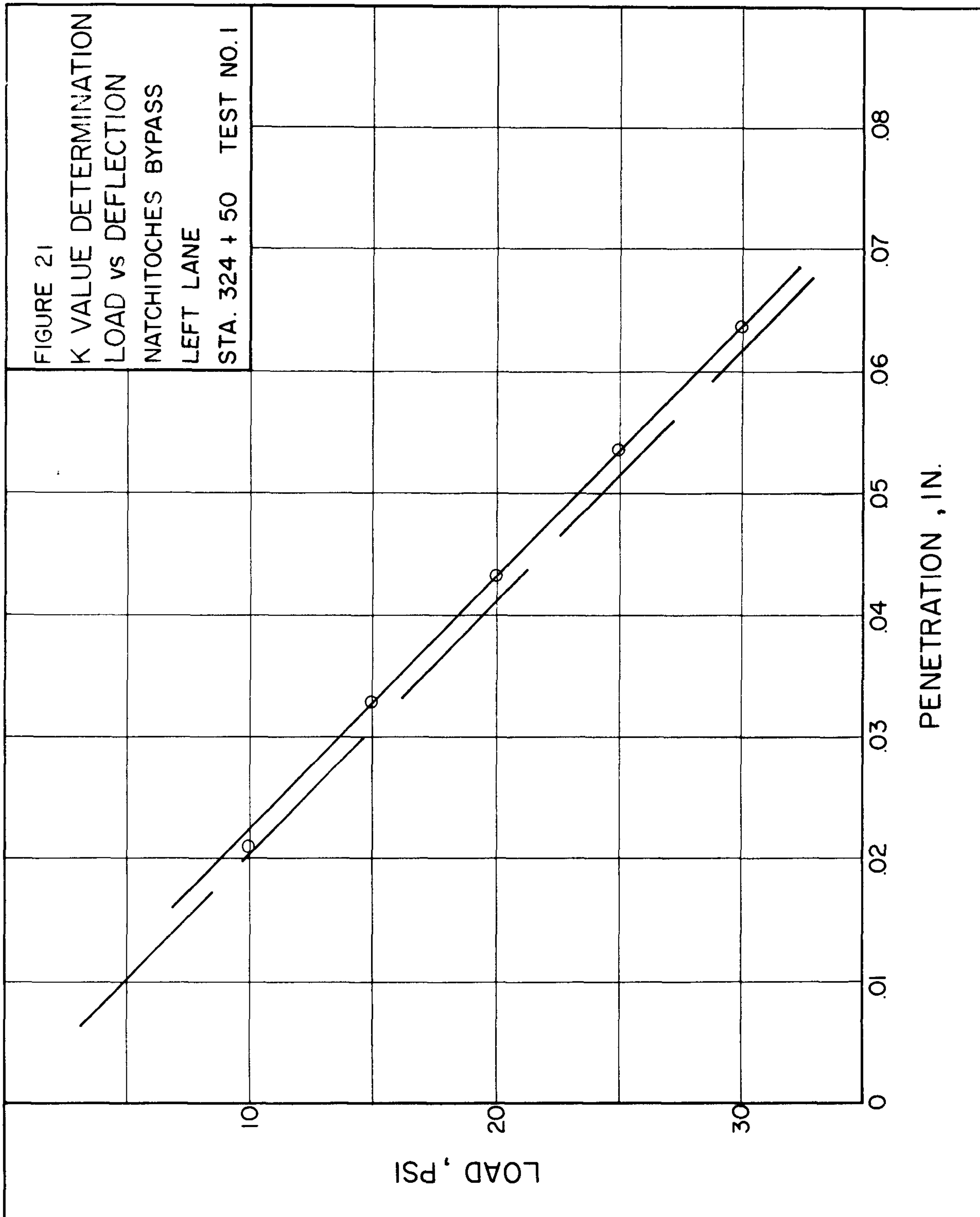


FIGURE 21
K VALUE DETERMINATION
LOAD vs DEFLECTION
NATCHITOCHES BYPASS
LEFT LANE
STA. 324 + 50 TEST NO. 1
0
.01
.02
.03
.04
.05
.06
.07
.08
PENETRATION , IN.
10
20
30
LOAD , PSI

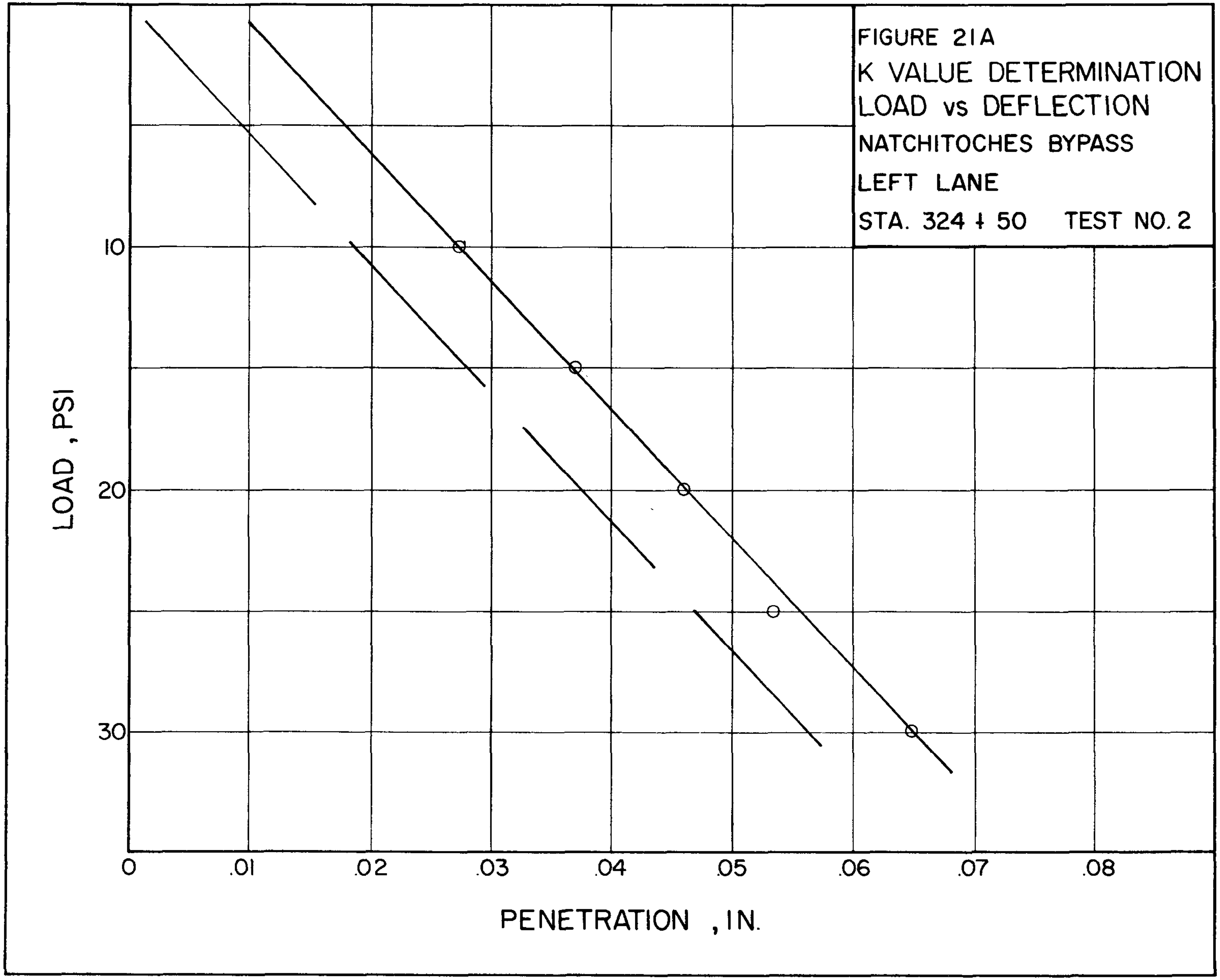


FIGURE 21A
K VALUE DETERMINATION
LOAD vs DEFLECTION
NATCHITOCHES BYPASS
LEFT LANE
STA. 324 + 50 TEST NO. 2

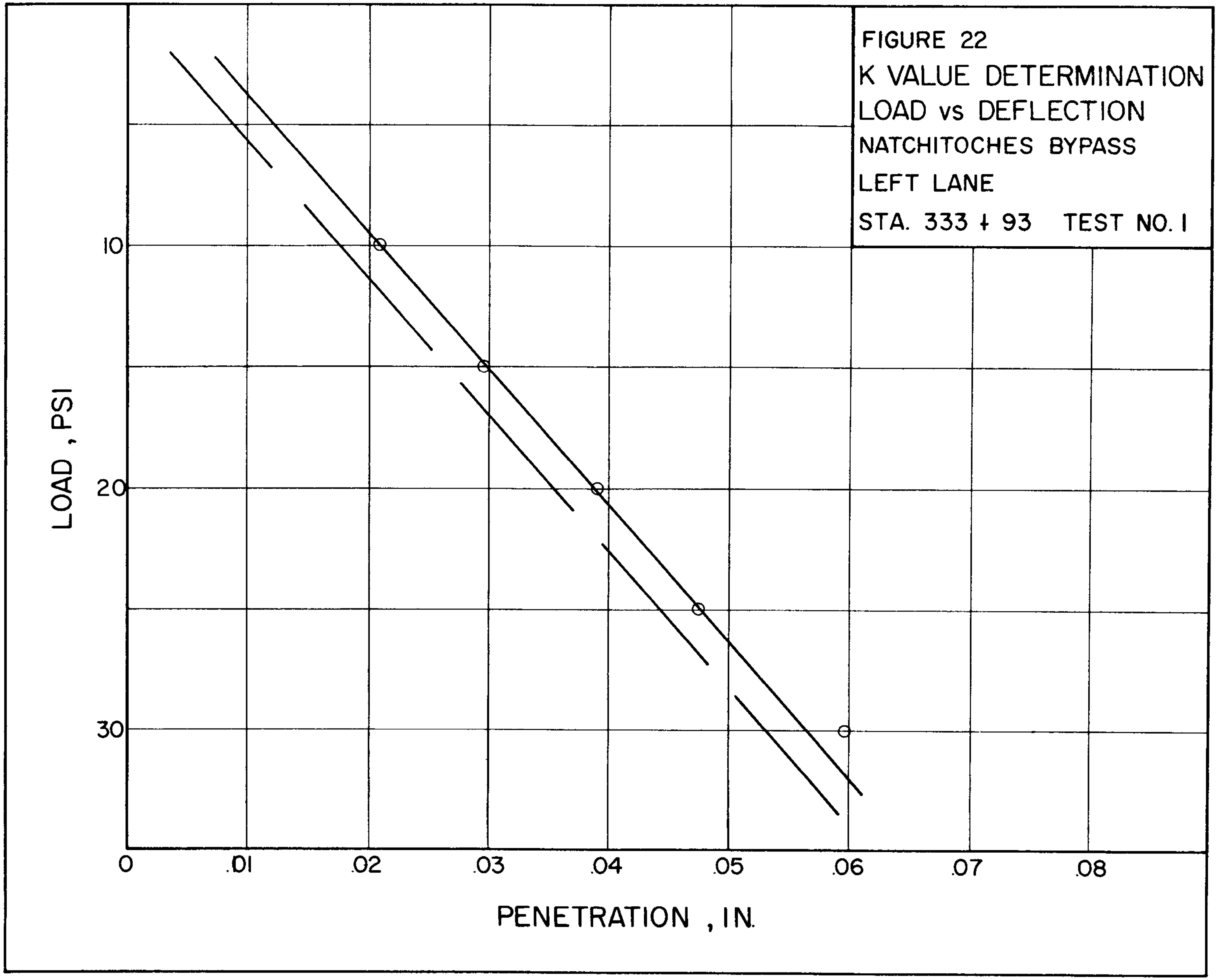


FIGURE 22
K VALUE DETERMINATION
LOAD vs DEFLECTION
NATCHITOCHES BYPASS
LEFT LANE
STA. 333 + 93 TEST NO. 1

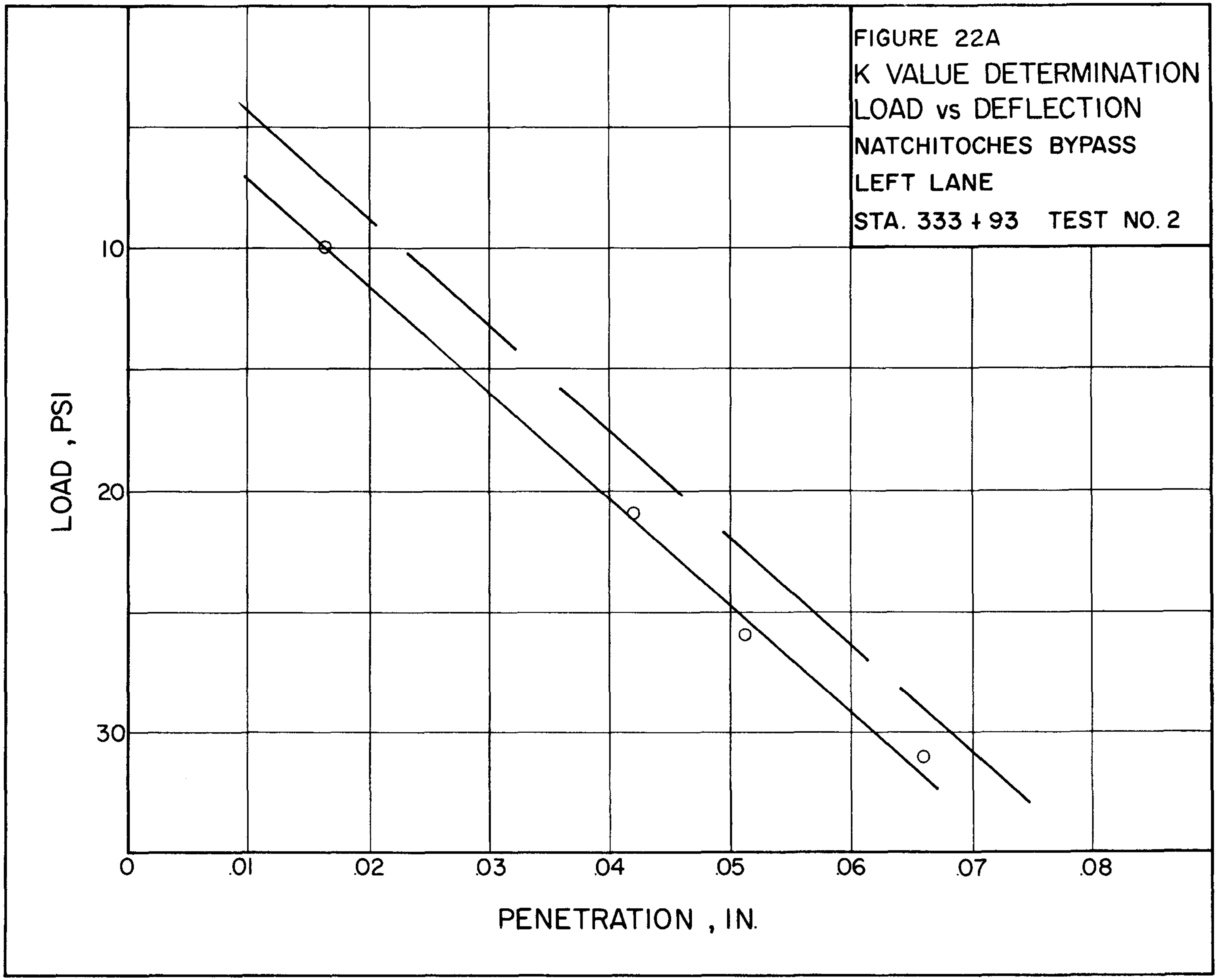


FIGURE 22A
K VALUE DETERMINATION
LOAD vs DEFLECTION
NATCHITOCHES BYPASS
LEFT LANE
STA. 333 + 93 TEST NO. 2

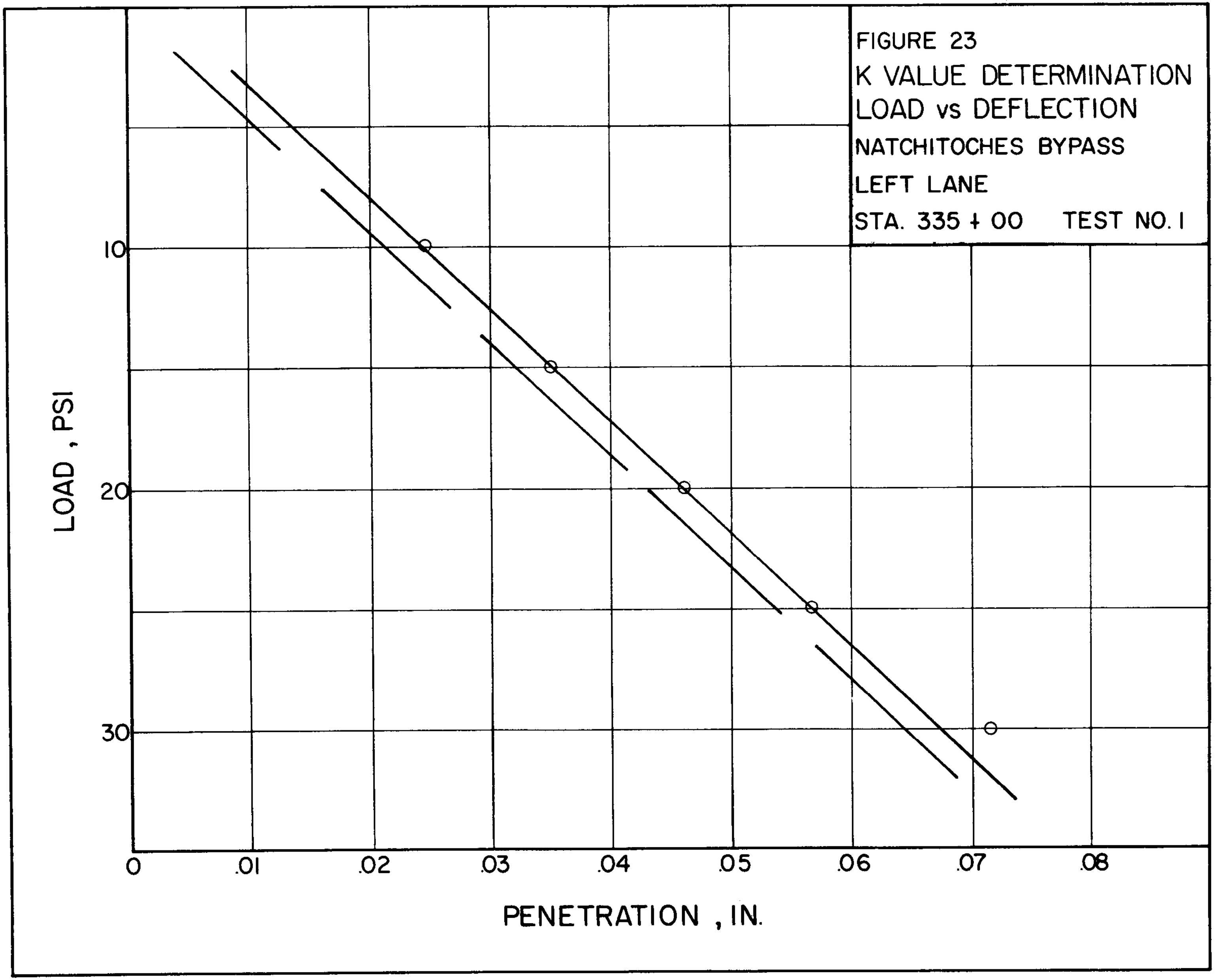


FIGURE 23
K VALUE DETERMINATION
LOAD vs DEFLECTION
NATCHITOCHES BYPASS
LEFT LANE
STA. 335 + 00 TEST NO. 1

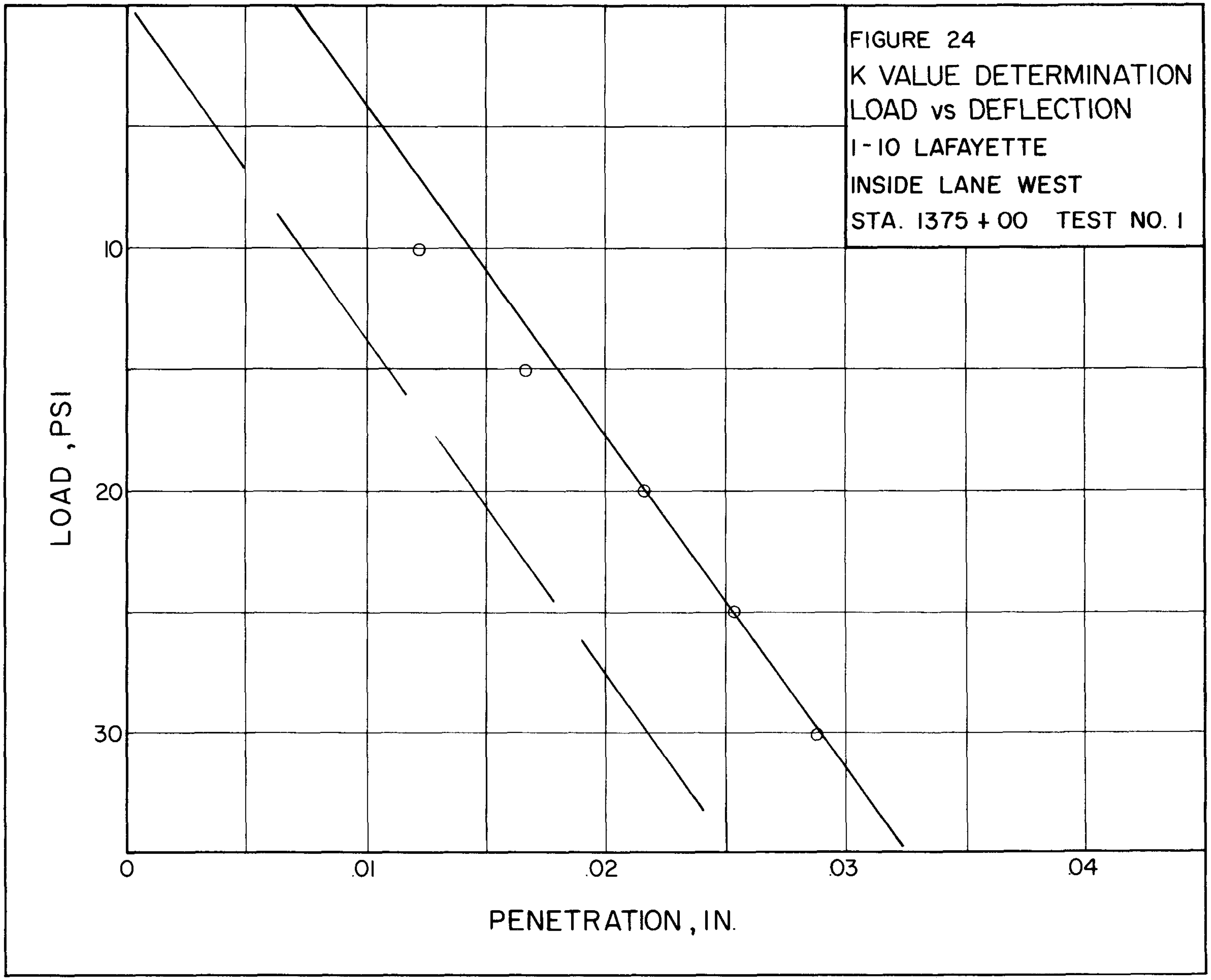


FIGURE 24
K VALUE DETERMINATION
LOAD vs DEFLECTION
I-10 LAFAYETTE
INSIDE LANE WEST
STA. 1375 + 00 TEST NO. 1
LOAD, PSI
10
20
30
0
.01
.02
.03
.04
PENETRATION, IN.

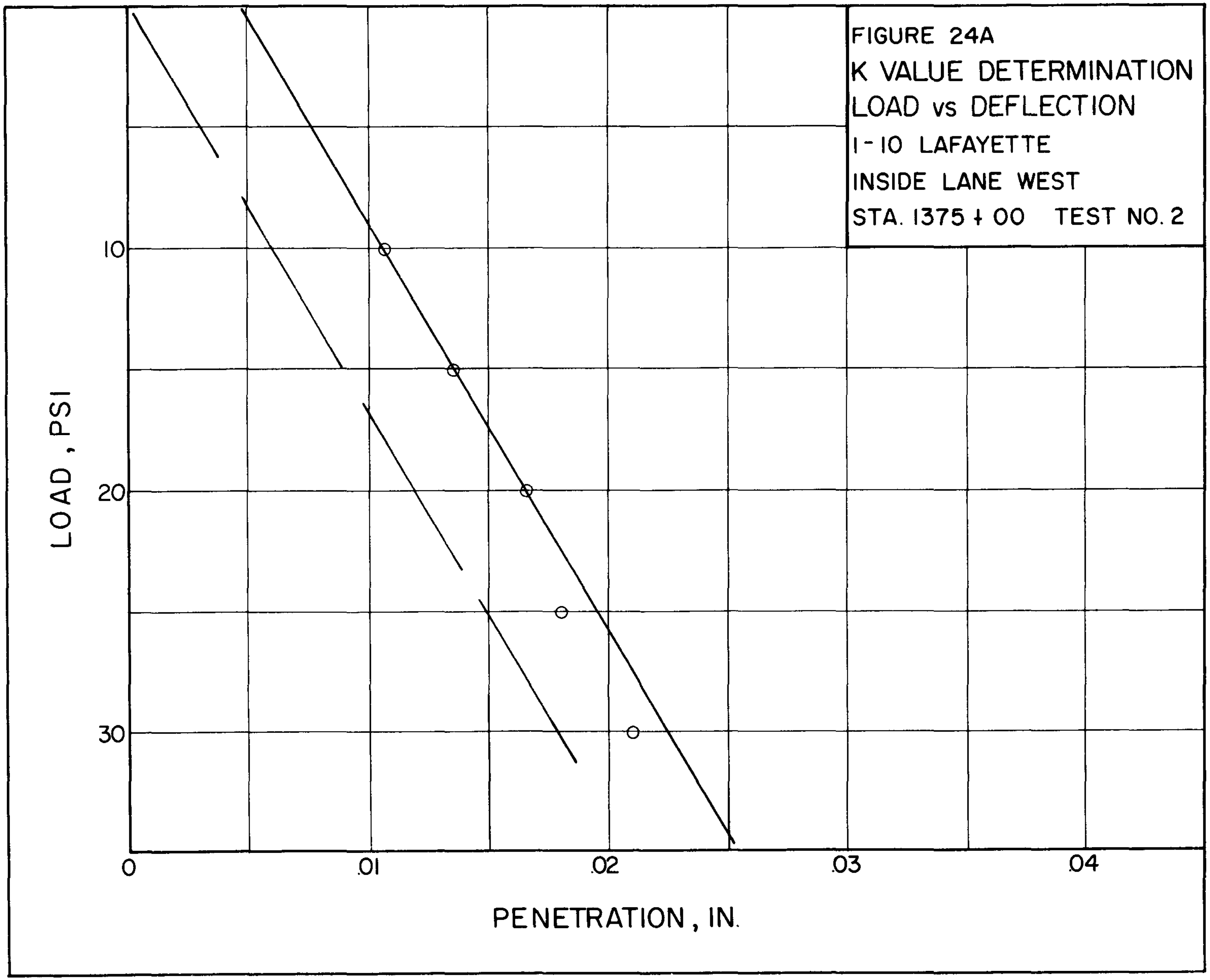


FIGURE 24A
K VALUE DETERMINATION
LOAD vs DEFLECTION
I-10 LAFAYETTE
INSIDE LANE WEST
STA. 1375 + 00 TEST NO. 2
LOAD, PSI
10
20
30
0
.01
.02
.03
.04
PENETRATION, IN.

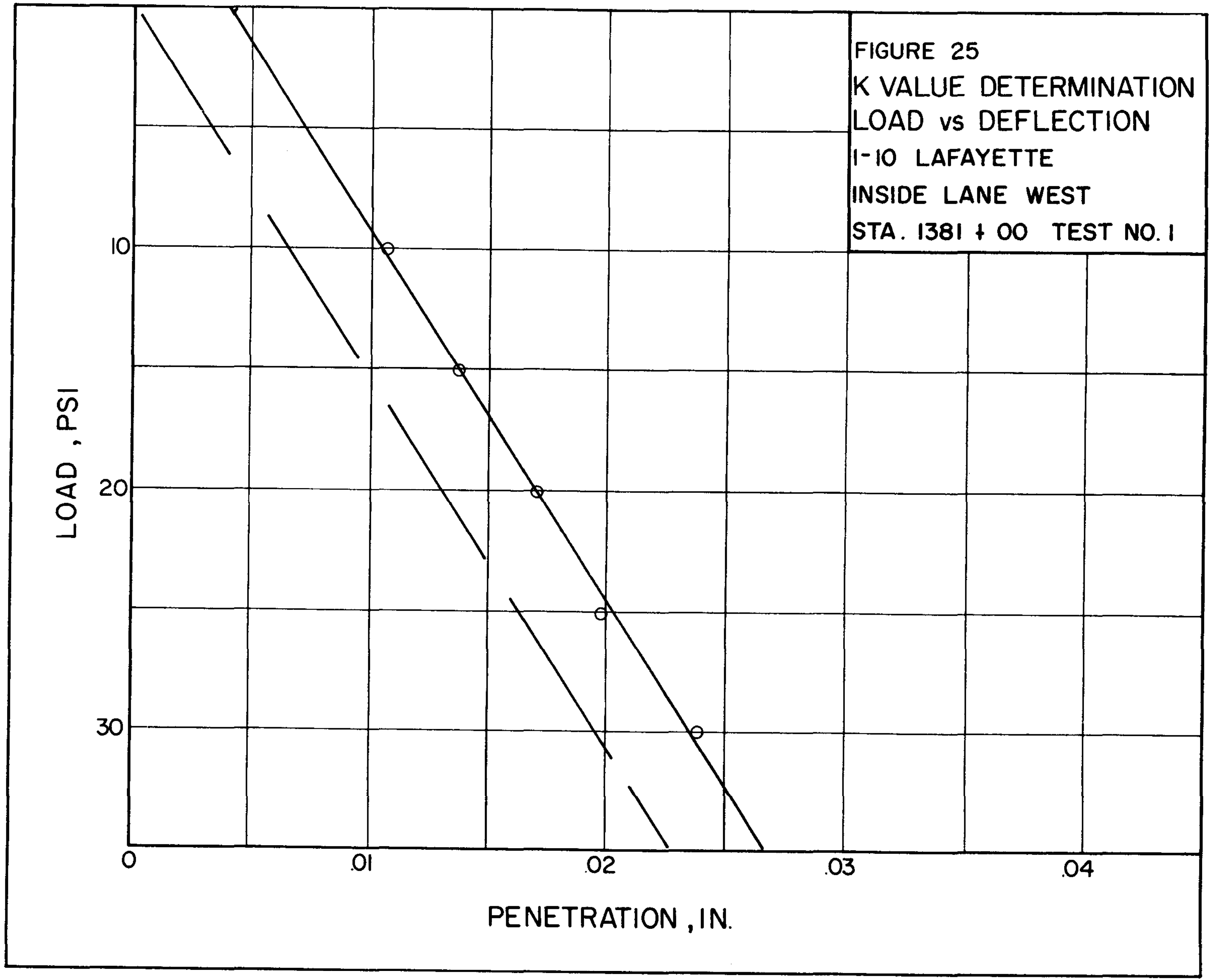


FIGURE 25
K VALUE DETERMINATION
LOAD vs DEFLECTION
I-10 LAFAYETTE
INSIDE LANE WEST
STA. 1381 + 00 TEST NO. 1

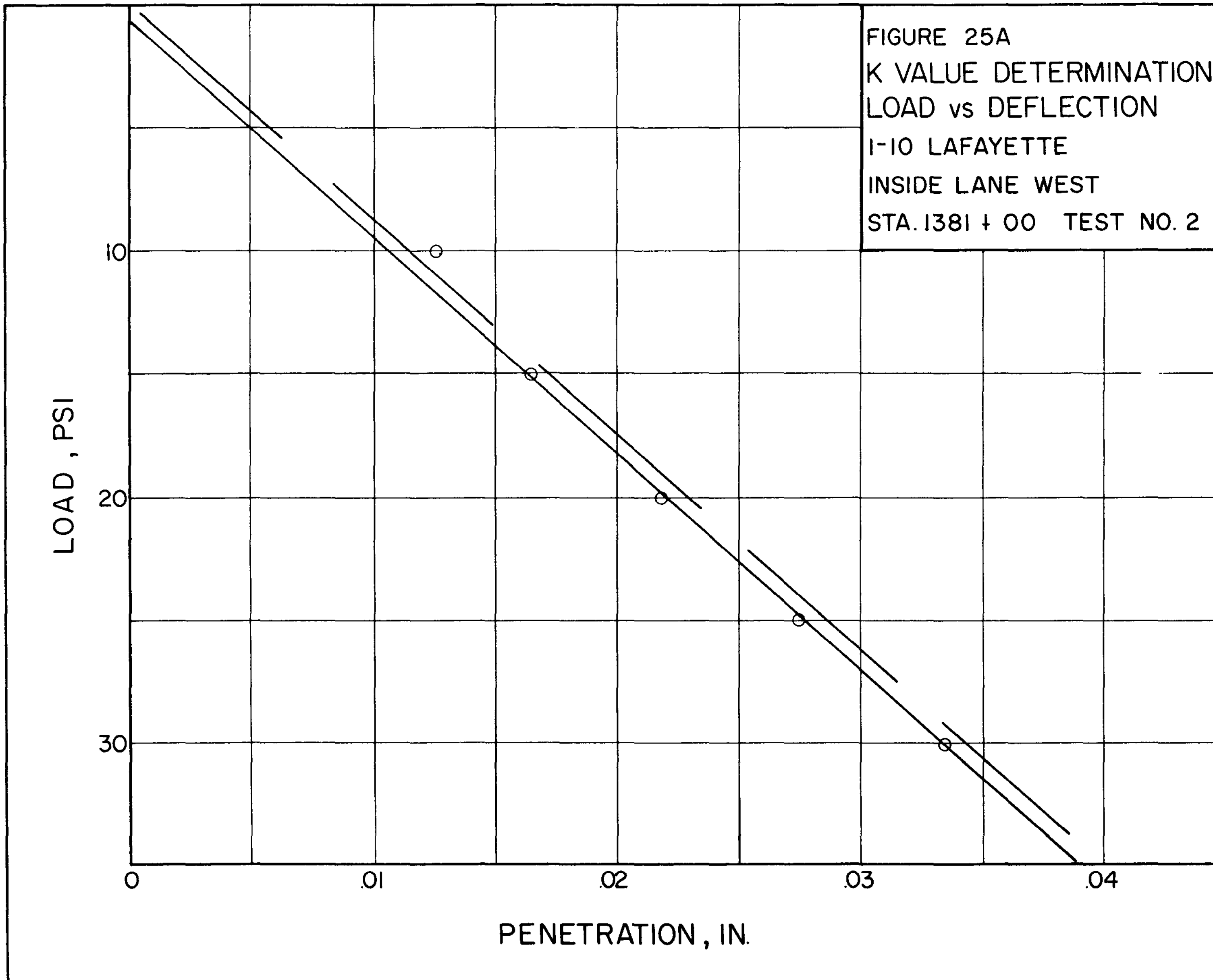


FIGURE 25A
K VALUE DETERMINATION
LOAD vs DEFLECTION
I-10 LAFAYETTE
INSIDE LANE WEST
STA. 1381 + 00 TEST NO. 2

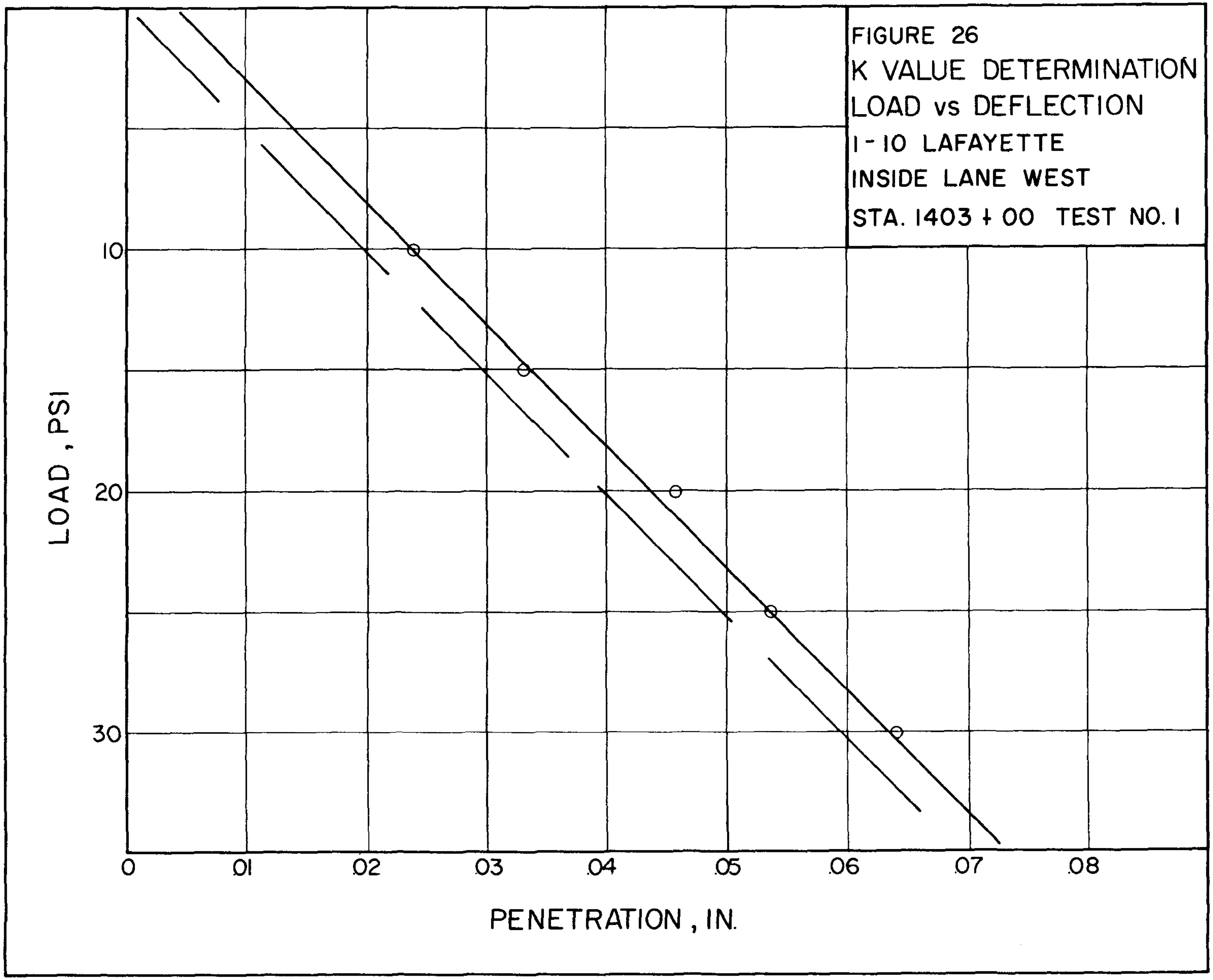


FIGURE 26
K VALUE DETERMINATION
LOAD vs DEFLECTION
I-10 LAFAYETTE
INSIDE LANE WEST
STA. 1403 + 00 TEST NO. 1

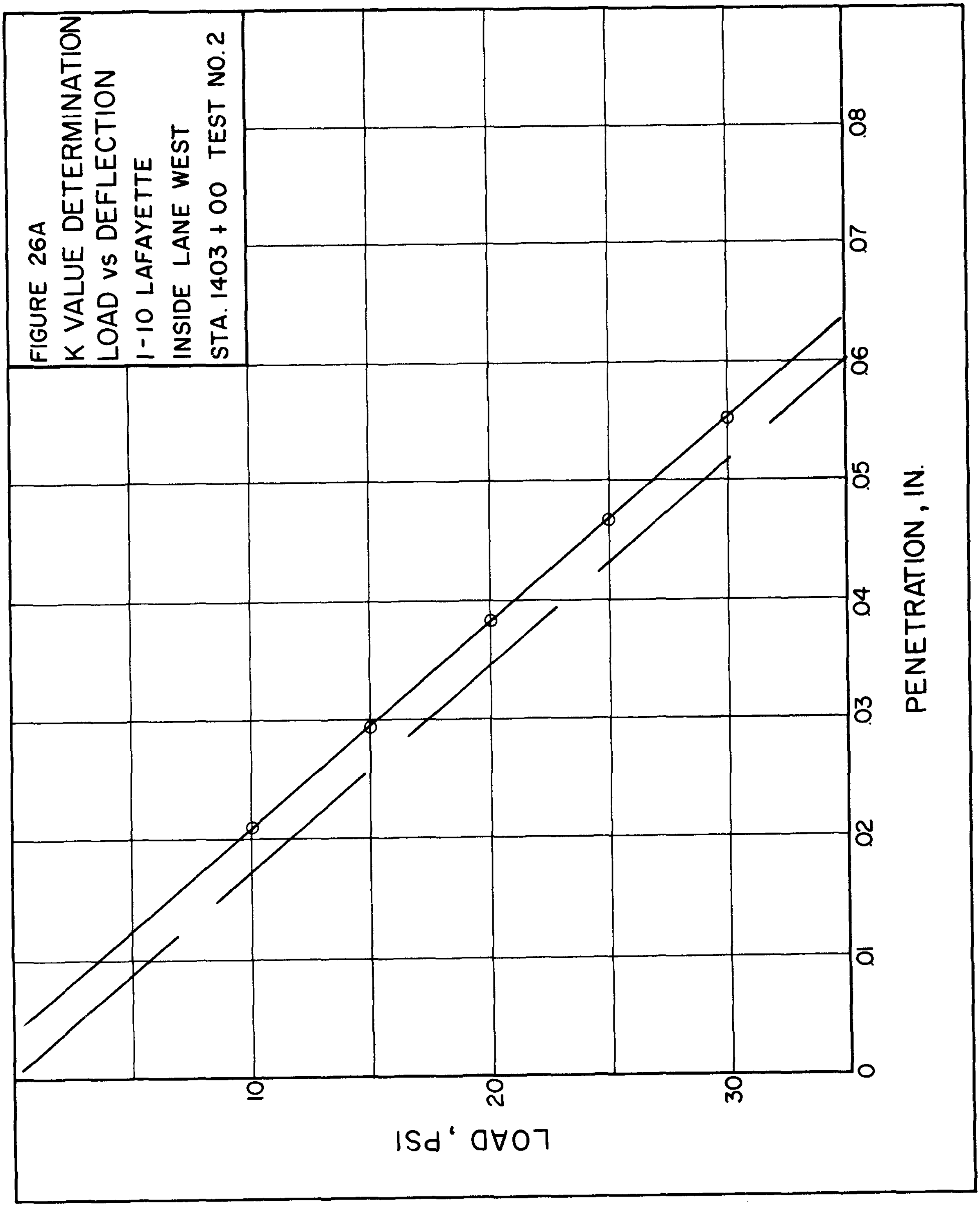


FIGURE 26A
K VALUE DETERMINATION
LOAD vs DEFLECTION
I-10 LAFAYETTE
INSIDE LANE WEST
STA. 1403 + 00 TEST NO. 2
LOAD, PSI
10
20
30
PENETRATION, IN.
0
.01
.02
.03
.04
.05
.06
.07
.08

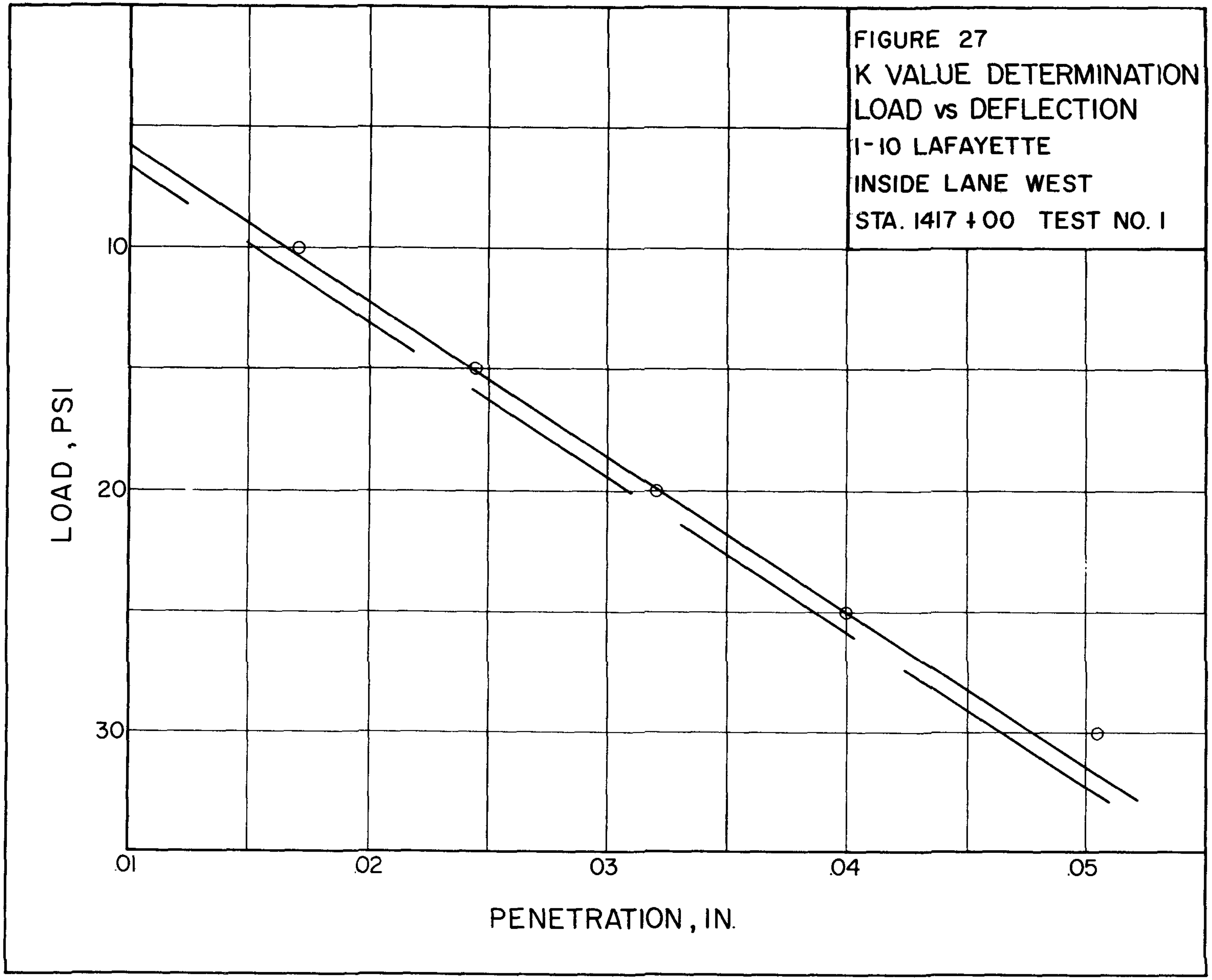


FIGURE 27
K VALUE DETERMINATION
LOAD vs DEFLECTION
I-10 LAFAYETTE
INSIDE LANE WEST
STA. 1417 + 00 TEST NO. 1

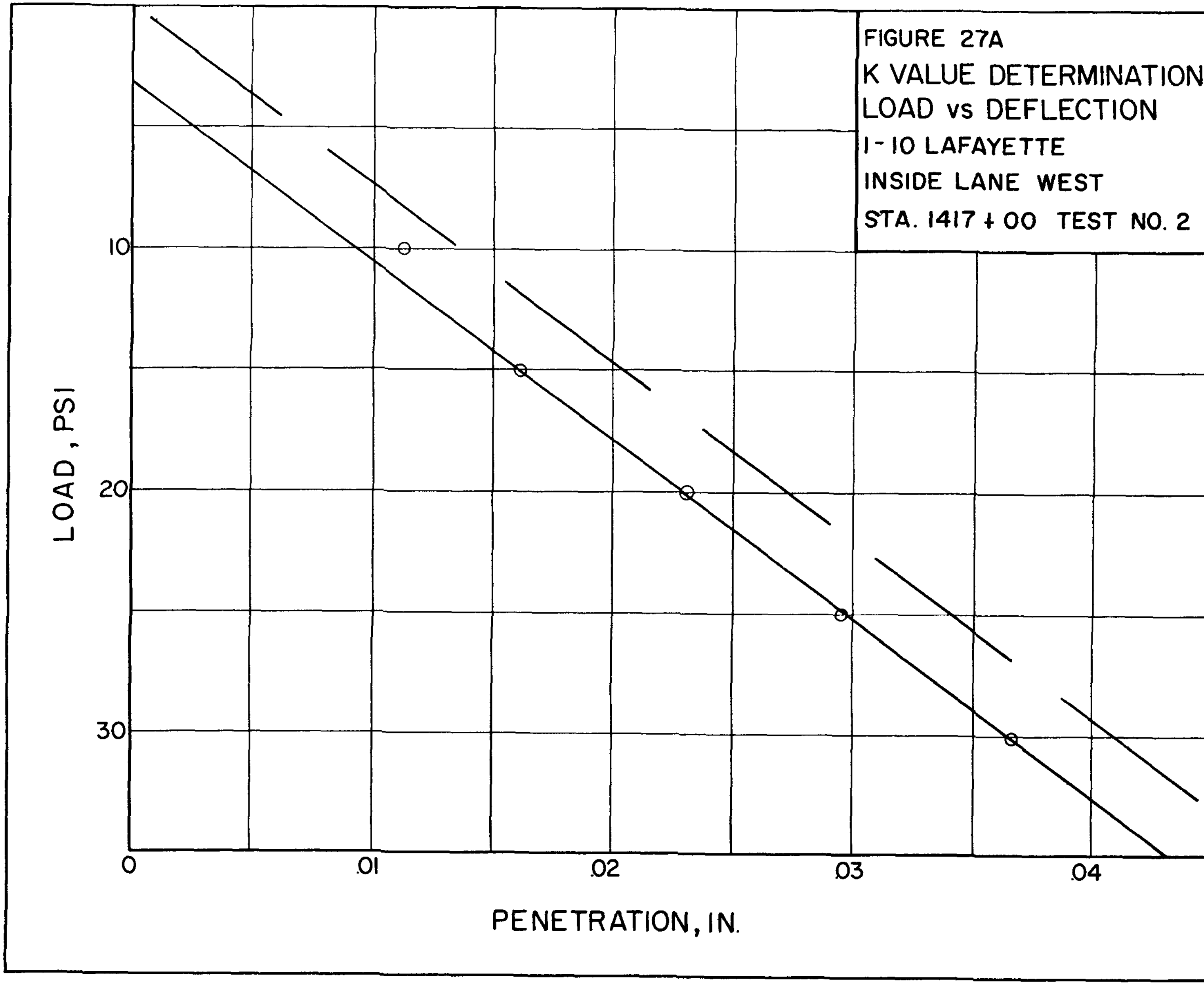


FIGURE 27A
K VALUE DETERMINATION
LOAD vs DEFLECTION
I-10 LAFAYETTE
INSIDE LANE WEST
STA. 1417 + 00 TEST NO. 2