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PIN CONNECTED PLATES

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w/Research Report

Subject: 1) Connections
2) ~~Pin-connected~~ Plate Connections
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STRUCTURAL TESTS OF LARGE PIN-CONNECTED LINKS

FINAL REPORT

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Monroeville, PA

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STRUCTURAL TESTS OF LARGE PIN-CONNECTED LINKS

Abstract

Pin-connected plate links, such as those used to lift heavy beams, are dimensioned by using design equations that are based on limited test data developed more than 40 years ago. Therefore, the American Institute of Steel Construction (AISC) sponsored additional tension tests of pin-connected plate links with thicknesses ranging from 1/4 inch to 2 inches and with pin diameters between 2 and 3-1/2 inches. These tests were conducted by U. S. Steel Research.

All specimens failed in a ductile manner after extensive elongation of the pinhole. Of the 23 specimens tested, 18 failed in a single rupture line through the section behind the pin, 2 failed in a double rupture line through the section behind the pin, 2 failed through the net section beside the pin, and 1 failed by dishing. The data obtained can be used by AISC to refine the present design equations.

Introduction

Pin-connected plates and links are used in various types of erection equipment to lift heavy beams. The design specifications for these connections were developed experimentally and theoretically by B. G. Johnston,[1)*] who investigated a range of plate thicknesses varying between 0.125 and 0.75 inch (3 and 20 mm) by using 3-inch-diameter (76 mm) pins. Design equations based on the results of Johnston's work were extrapolated for thickness and pin diameters beyond the scope of the original study. This report describes the results of tests sponsored by the American Institute of Steel Construction (AISC) and conducted at the U. S. Steel Research Laboratory to obtain data for refining the current design equations.

Test Specimens

Plate-link specimens were fabricated by the American Bridge Division of U. S. Steel Corporation, in thicknesses from 1/4 inch to 2 inches (6 to 51 mm) as shown in Figures 1A through 1F. Carbon steel with a yield point from about 30 to 45 ksi (205 to 308 MPa), which was available in stock, was used for the specimens. The specimens were designed according to current AISC design criteria.[2)] To facilitate test observations, one end of each plate-link specimen (the bottom end in Figures 1A through 1F) was designed to fail before the opposite end. Various pin sizes ranging from 2 to 3-1/2 inches (51 to 89 mm) were used to determine pin-size effects. Each pinhole was 1/8 inch (3 mm) larger than the corresponding pin diameter. The mechanical properties of each plate are given in Table I. The as-fabricated dimensions at the location of the critical pinhole are given in Table II.

Testing Procedures for Thick-Link Plates

Tests of pin-connected plate links with thicknesses of 1-1/4, 1-3/4, and 2 inches (32, 44, and 51 mm) were conducted in the 4-million-pound (17.8 MN) tension-testing machine located at the National plant of U. S. Steel's National-Duquesne Works, Figure 2. Special clevises were designed to accomodate the plate-link specimens in this machine. The specimens were tested

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* See References.

horizontally in the test frame, with one end pinned to the moveable crosshead assembly. The loads were applied hydraulically through the moveable crosshead. Strain gages were applied to the center of both sides of the first test specimen to verify uniaxial loading and uniform loading of the specimen cross-section.

The applied forces were determined by reading a calibrated Heise pressure gage with a least reading of 20 psi (183 kN/m^2), which is equivalent to 20,000 pounds (88.98 kN) force. Displacements were measured using displacement transducers with a ±3-inch-maximum (76 mm) travel. Because of the large displacements of the yielding pin holes in the thick plates, autographic plotting of load versus displacement was not practical. Instead, loads were applied incrementally and the forces and displacements were recorded for each increment. The ultimate load was determined as the highest load reached prior to specimen failure.

Testing Procedures for Thin Link Plates

The pin-connected link-plate specimens, from 1/4 through 3/4 inch (6 through 19 mm) were tested at Research in a Baldwin Lima-Hamilton universal-testing-machine with a capacity of 440,000-pound force (1957 kN), Figure 3. Special clevises with spacers were fabricated to accomodate the different plate thicknesses. The spacers were used to keep the specimens centered and within an axial alignment of 1/16 inch (2 mm). Strain gages were applied to the center of both sides of the first specimen to verify uniaxial loading and uniform loading of the specimen cross section. Calculated loads from the strain-gage measurements agreed with the machine loads within 3 percent. (A slight camber in the test specimen induced some bending, which resulted in an apparent higher load.) One end of each specimen was pinned in a clevis that was bolted to the upper, moveable crosshead. The other end of the specimen was pinned to a clevis bolted to the lower stationary crosshead. Loads were applied hydraulically through the moveable-crosshead assembly until the highest load was reached prior to failure.

Test loads were indicated on a readout dial (part of the calibrated testing machine) and autographically recorded with the applied loads.

Results

The results of the pin-connected-plate-link tests are summarized in Table III. Load-displacement curves for each test are shown in Figures 4 through 27. The original plots and recorded data have been replotted for clarity and reporting convenience. Photographs for each of the failed specimen ends are shown in Figures 28 through 40. All specimens failed in a ductile manner. Extensive elongation of the pinholes of all specimens is evident in the figures.

All failures occurred at the ends designed to fail except for Specimen 2-B. In this case, a loose packing of spacers allowed the 2-inch-diameter pin to cause localized dishing around the pinhole. This resulted in a tearing of the pinhole before the larger 3-inch-diameter pinhole began to yield, Figure 30 (yielded end). The failures in all but five specimens resulted in a single rupture through the section behind the pins parallel to the direction of the applied load. Specimens 1-A and 2-A had tensile failures in the net section of one side of the pins as shown in Figures 28 and 29, respectively. Specimens 1-B and 2-D had double rupture lines through the section behind the pinhole, as shown in Figures 28 and 29, respectively.

Summary

Pin-connected plate links, such as those used to lift heavy beams, are dimensioned by using design equations that are based on limited test data developed more than 40 years ago. Therefore, the American Institute of Steel Construction (AISC) sponsored additional tension tests of pin-connected plate links with thicknesses ranging from 1/4 inch to 2 inches (6 to 51 mm) and with pin diameters between 2 and 3-1/2 inches (51 and 89 mm). These tests were conducted by U. S. Steel Research. The data obtained can be used by AISC to refine the present design equations.

Acknowledgments

N. W. Young of the American Bridge Division designed the test specimens and arranged for the fabrication. D. A. Morris, G. Peterson, and J. T. Thoma of the National plant of National-Duquesne Works provided assistance during tests on the 4-million-pound tensile-testing machine. R. M. Carratura, W. J. Jankovic, and R. E. Droske of the Research Laboratory conducted the tests. The assistance of each of these persons is gratefully acknowledged.

References

1. B. G. Johnston, "Pin-Connected Plate Links, "Transactions ASCE, 104, 1939.

2. American Institute of Steel Construction, "Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings," 1978.

Table I

Mechanical Properties of Pin-Link Plates*

Nominal Thickness, inches	Measured Thickness, inches	Yield Stress,** ksi	Tensile Strength, ksi	Percent Elongation in 8 Inches
0.250	0.256	45.4	74.4	24.0
0.375	0.388	37.3	62.4	27.8
0.500	0.488	37.5	68.1	27.0
0.750	0.722	38.0	69.4	28.0
1.250	1.256	33.3	67.6	32.0
1.750	1.766	40.9	72.0	31.3
2.000	2.018	30.8	60.8	32.2

* Average of two tests of strap-type tensile specimens for each plate thickness.

** 0.2% offset method.

Conversion Factors:
1 in. = 25.4 mm
1 ksi = 6.845 MPa

Table II

As-Fabricated Dimensions at the Critical Pinhole

Specimen No.	Nominal Hole Diameter, inches	Clear Edge Distance, be, inches	Clear End Distance, a, inches
1-A	3-1/8	1-5/8, 1-1/4	1-9/16
1-B	3-1/8	2-3/16, 2-3/16	1-3/8
1-C	2-1/8	1-1/2, 1-3/8	1-5/16
1-D	2-1/8	2-3/16, 2-3/16	1-3/8
2-A	3-1/8	1-15/16, 1-11/16	1-7/8
2-B	3/1-8	2-3/4, 2-13/16	2-1/16
2-C	2-1/8	1-3/4, 1-7/8	1-3/4
2-D	2-1/8	2-13/16, 2-13/16	1-7/8
3-A	3-1/8	2-3/16, 2-3/16	2-1/4
3-B	3-1/8	3-5/16, 3-5/16	2-1/4
3-C	2-1/8	2-3/16, 2-3/16	2-1/4
3-D	2-1/8	3-5/16, 3-5/16	2-1/4
4-A	3-1/8	2-15/16, 2-7/8	2-15/16
4-B	3-1/8	4-3/8, 4-7/16	2-13/16
4-C	2-1/8	3, 2-15/16	2-15/16
4-D	2-1/8	4-7/16, 4-9/16	2-7/8
4-E	3-5/8	3-1/8, 2-15/16	3
4-F	3-5/8	4-1/2, 4-1/2	3
5-C	3-5/8	4-9/16, 4-1/4	4-1/4
5-D	3-5/8	6-5/8, 6-11/16	4-7/16
6-C	3-5/8	5-7/8, 5-7/8	6
6-D	3-5/8	8-7/8, 8-7/8	5-7/8
7-C	3-5/8	6-11/16, 6-11/16	6-5/8
7-D	3-5/8	10, 10-1/8	6-3/4

1 in. = 25.4 mm

Table III

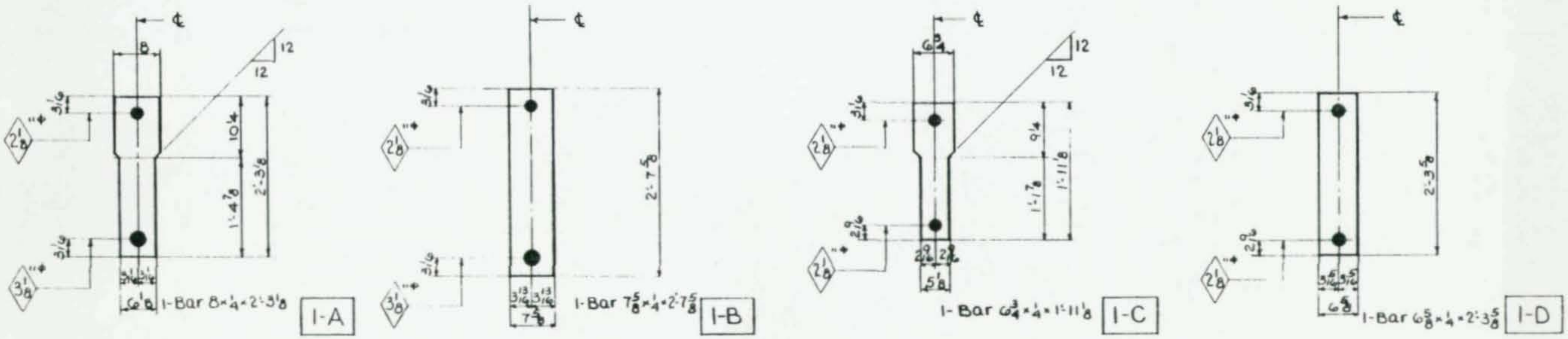
Pin-Link Test Results

Specimen Number	Nominal Plate Thickness, inches	Pin Diameter at Test End, inches	Ultimate Test Load, kips	Mode of Failure
1-A	0.250	3.00	53.1	Side Tension
1-B	0.250	3.00	57.9	Double Pull Through
1-C	0.250	2.00	47.5	Single Pull Through
1-D	0.250	2.00	50.1	Single Pull Through
2-A	0.375	3.00	79.8	Side Tension
2-B	0.375	3.00	85.7	Dishing at Wrong End
2-C	0.375	2.00	71.5	Single Pull Through
2-D	0.375	2.00	75.8	Double Pull Through
3-A	0.500	3.00	150	Single Pull Through
3-B	0.500	3.00	147	Single Pull Through
3-D	0.500	2.00	121	Single Pull Through
4-A	0.750	3.00	245	Single Pull Through
4-B	0.750	3.00	240	Single Pull Through
4-C	0.750	2.00	216	Single Pull Through
4-D	0.750	2.00	220	Single Pull Through
4-E	0.750	3.50	255	Single Pull Through
4-F	0.750	3.50	242	Single Pull Through
5-C	1.250	3.50	510	Single Pull Through
5-D	1.250	3.50	550	Single Pull Through
6-C	1.750	3.50	950	Single Pull Through
6-D	1.750	3.50	990	Single Pull Through
7-C	2.000	3.50	1100	Single Pull Through
7-D	2.000	3.50	1185	Single Pull Through

Conversion Factors:

1 in. = 25.4 mm

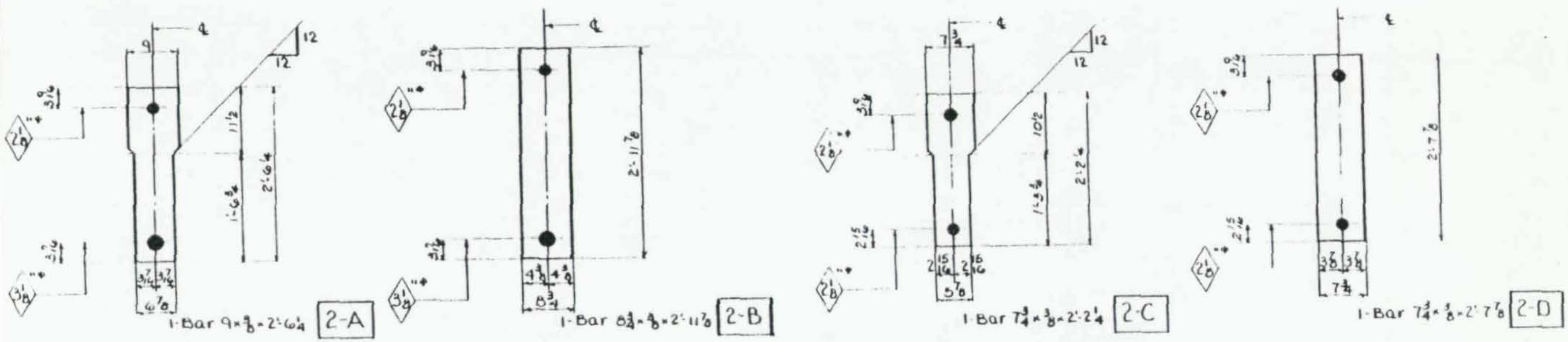
1 kip = 4.45 kN



PIN-CONNECTED PLATE SPECIMENS

RL-18-4748

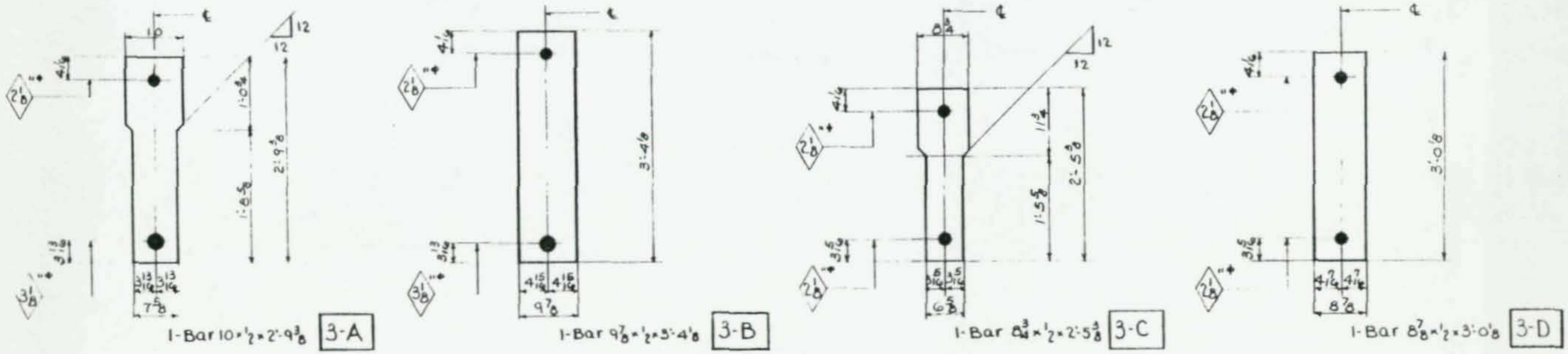
Figure 1-A



PIN-CONNECTED PLATE SPECIMENS

RL-18-4749

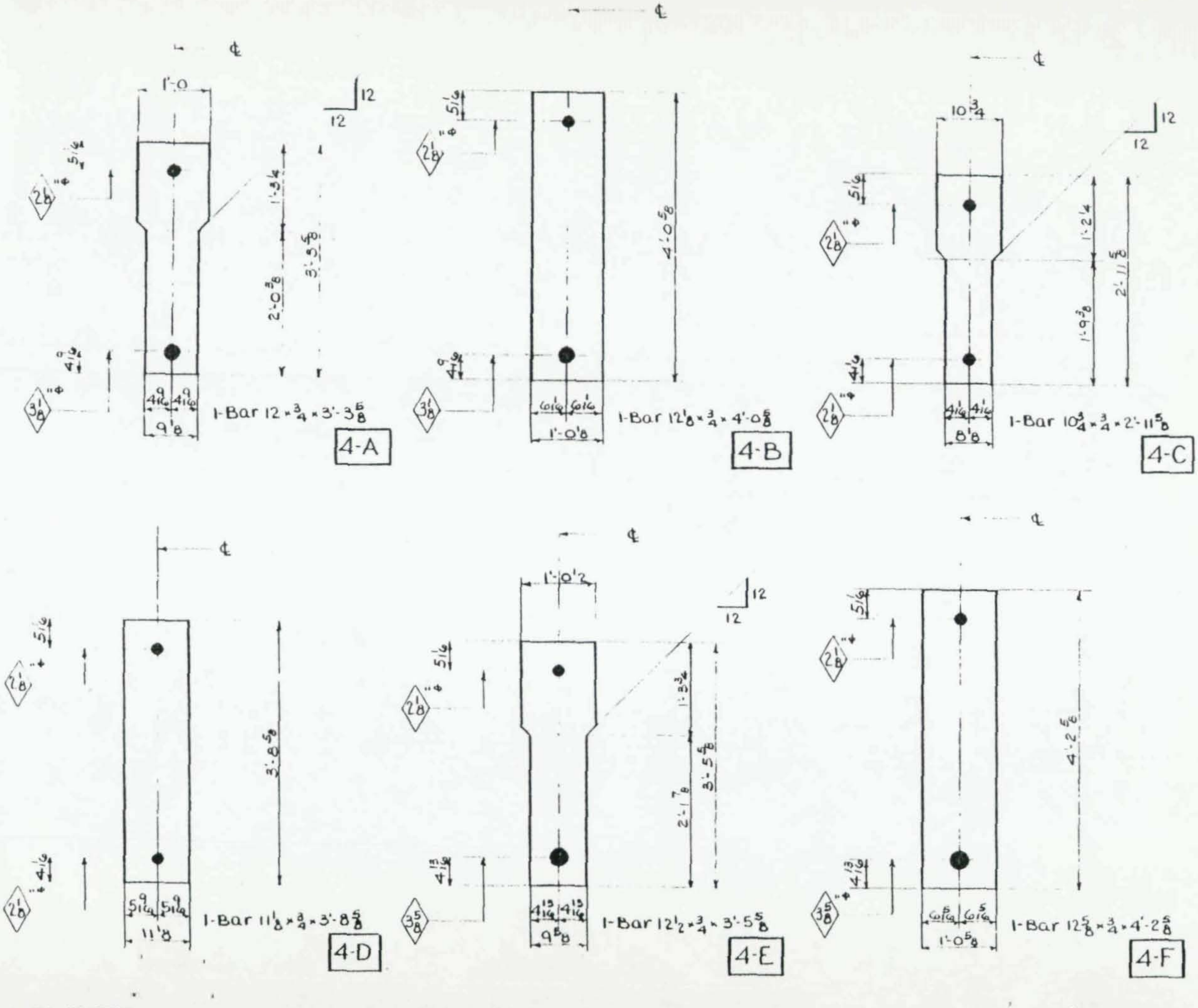
Figure 1-B



PIN-CONNECTED PLATE SPECIMENS

RL-18-4750

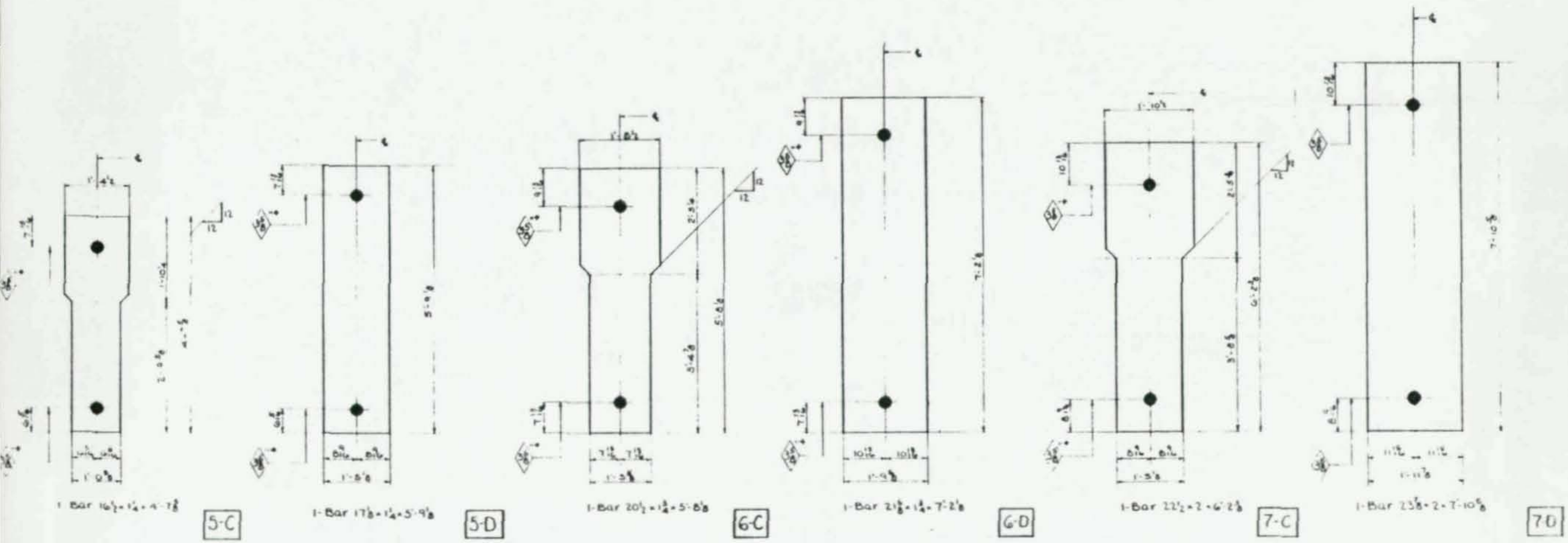
Figure 1-C



RL-18-4751

PIN-CONNECTED PLATE SPECIMENS

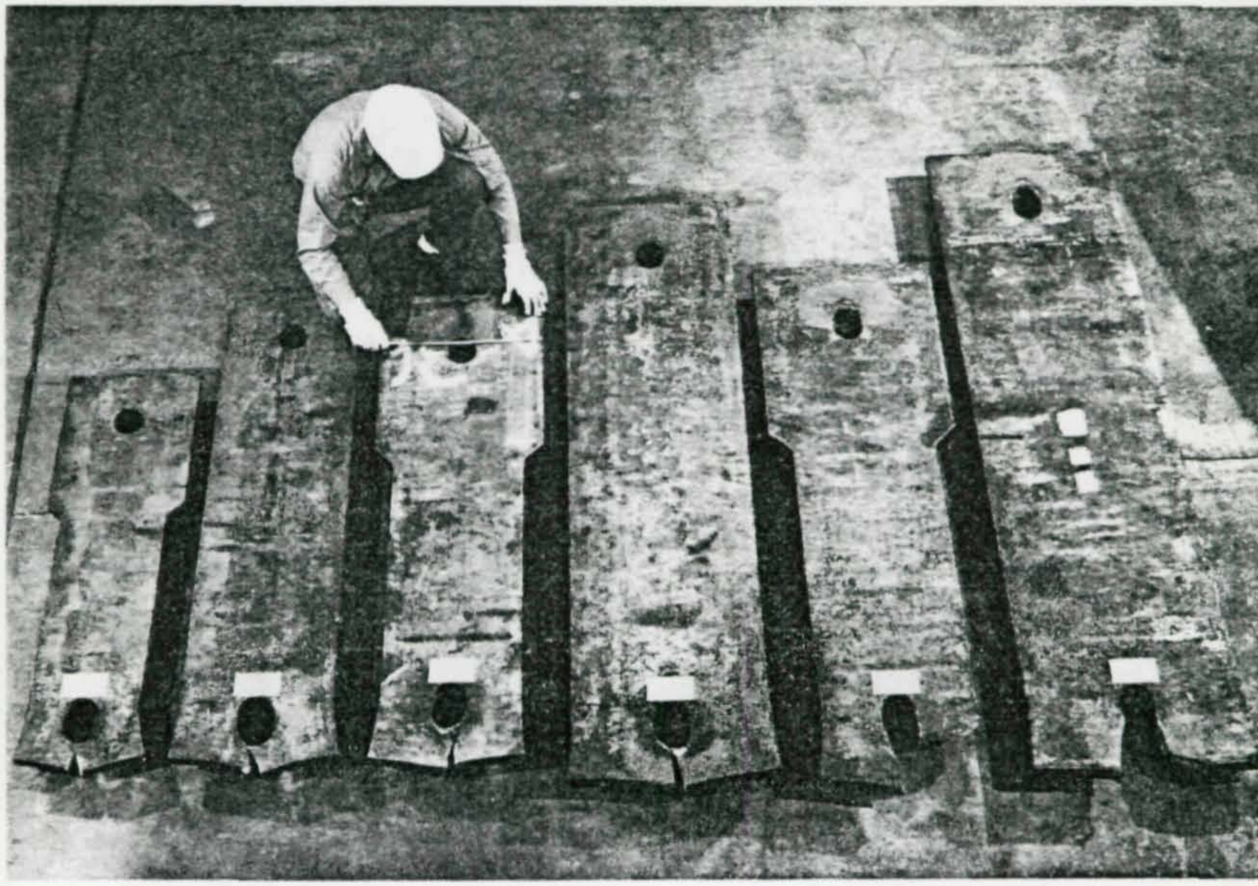
Figure 1-D



PIN-CONNECTED PLATE SPECIMENS

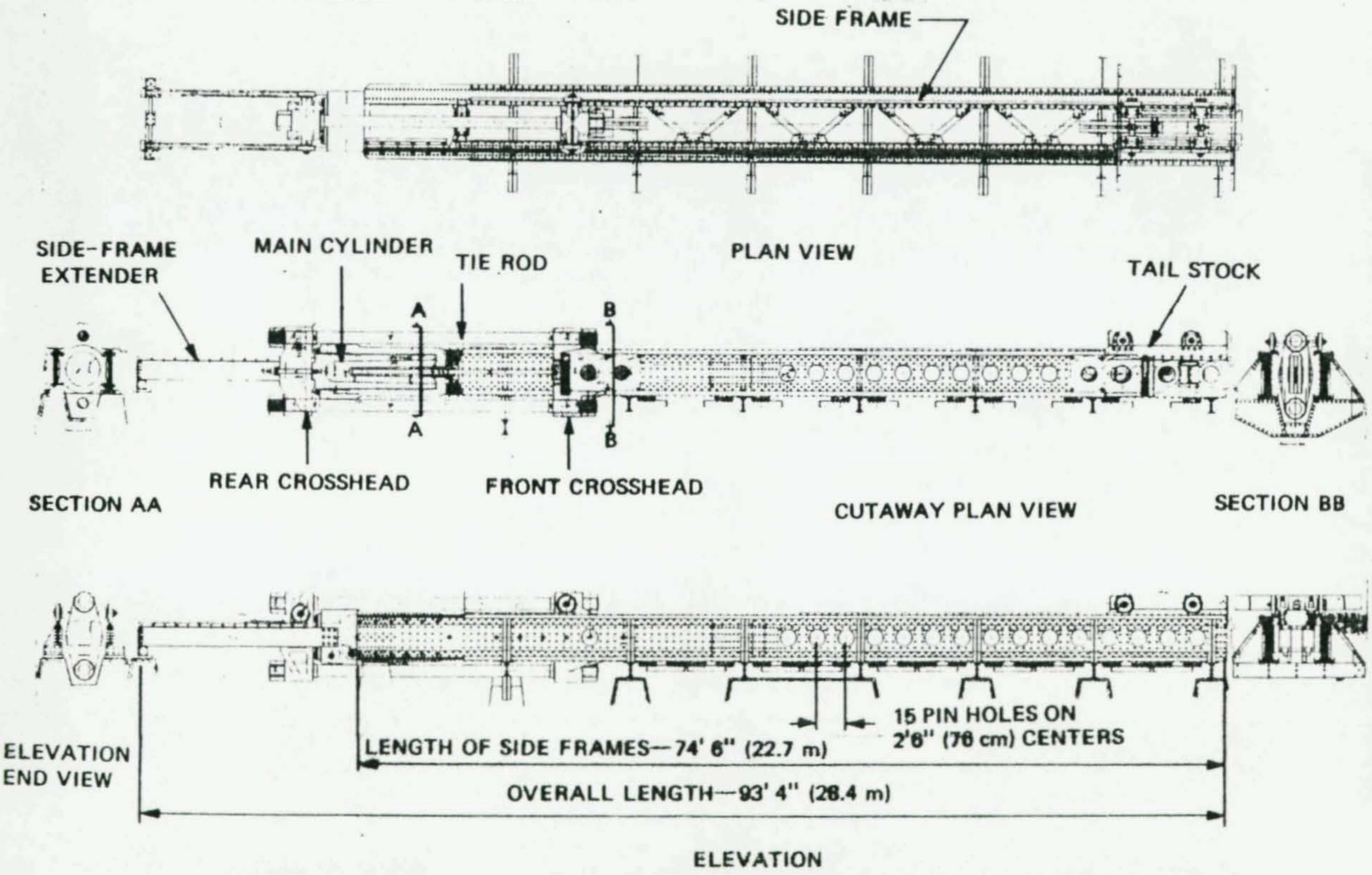
RL-18-4752

Figure 1-E



1-1/4-, 1-3/4-, AND 2-INCH PLATE-LINK SPECIMENS

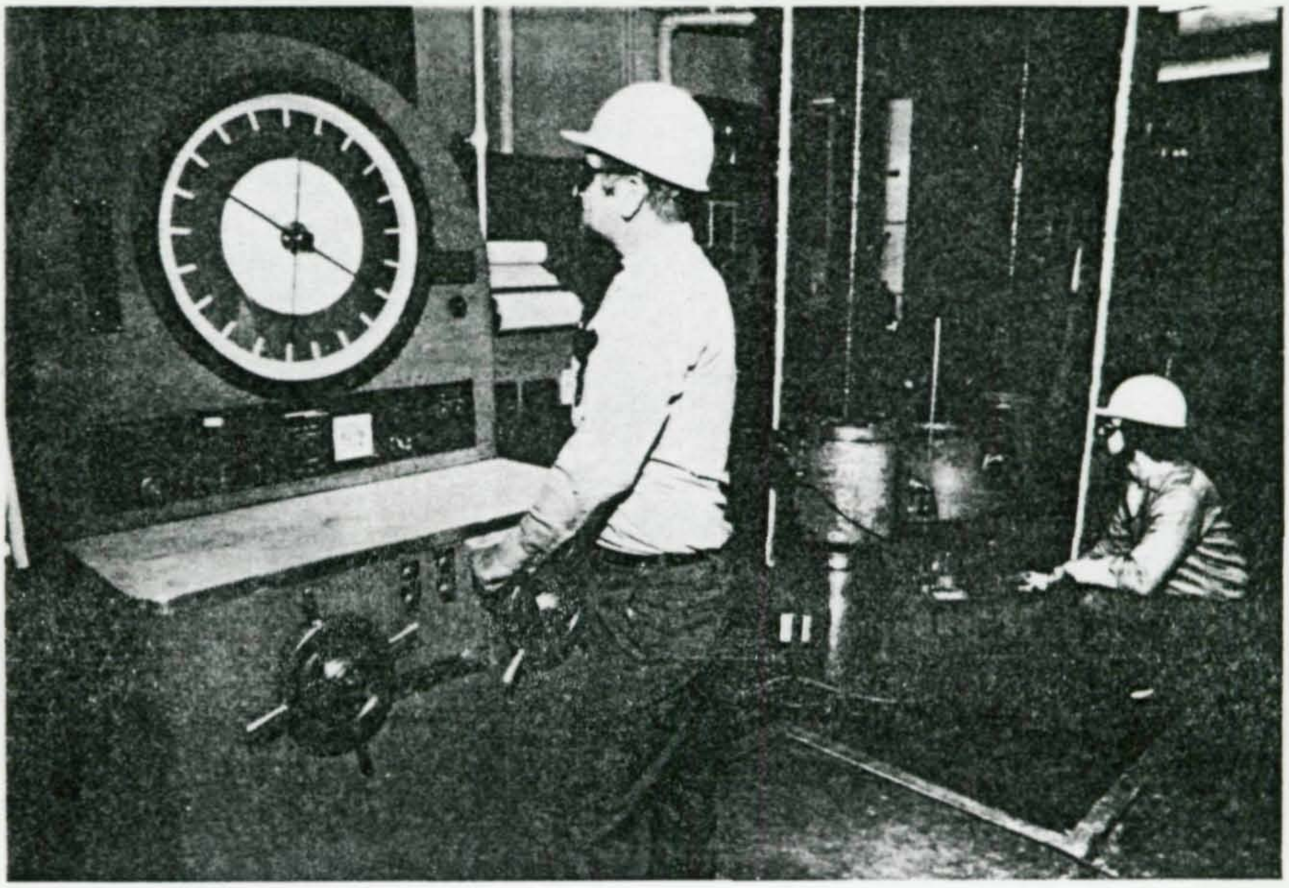
Figure 1-F



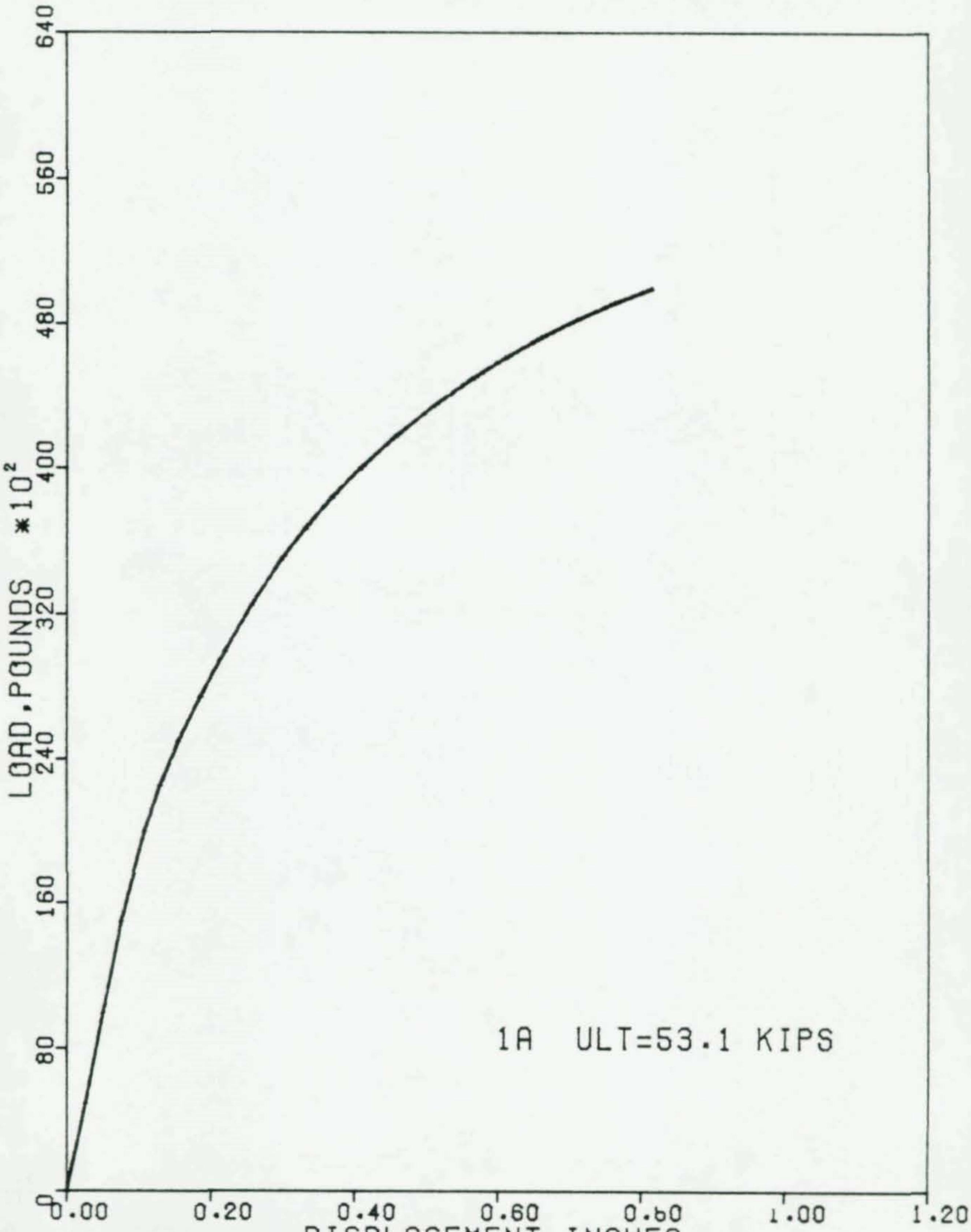
PLAN AND ELEVATION VIEWS OF 4-MILLION-POUND-CAPACITY (17.8 MN) TESTING MACHINE (FROM ABD DRAWING 3540)

RL-18-3130

Figure 2

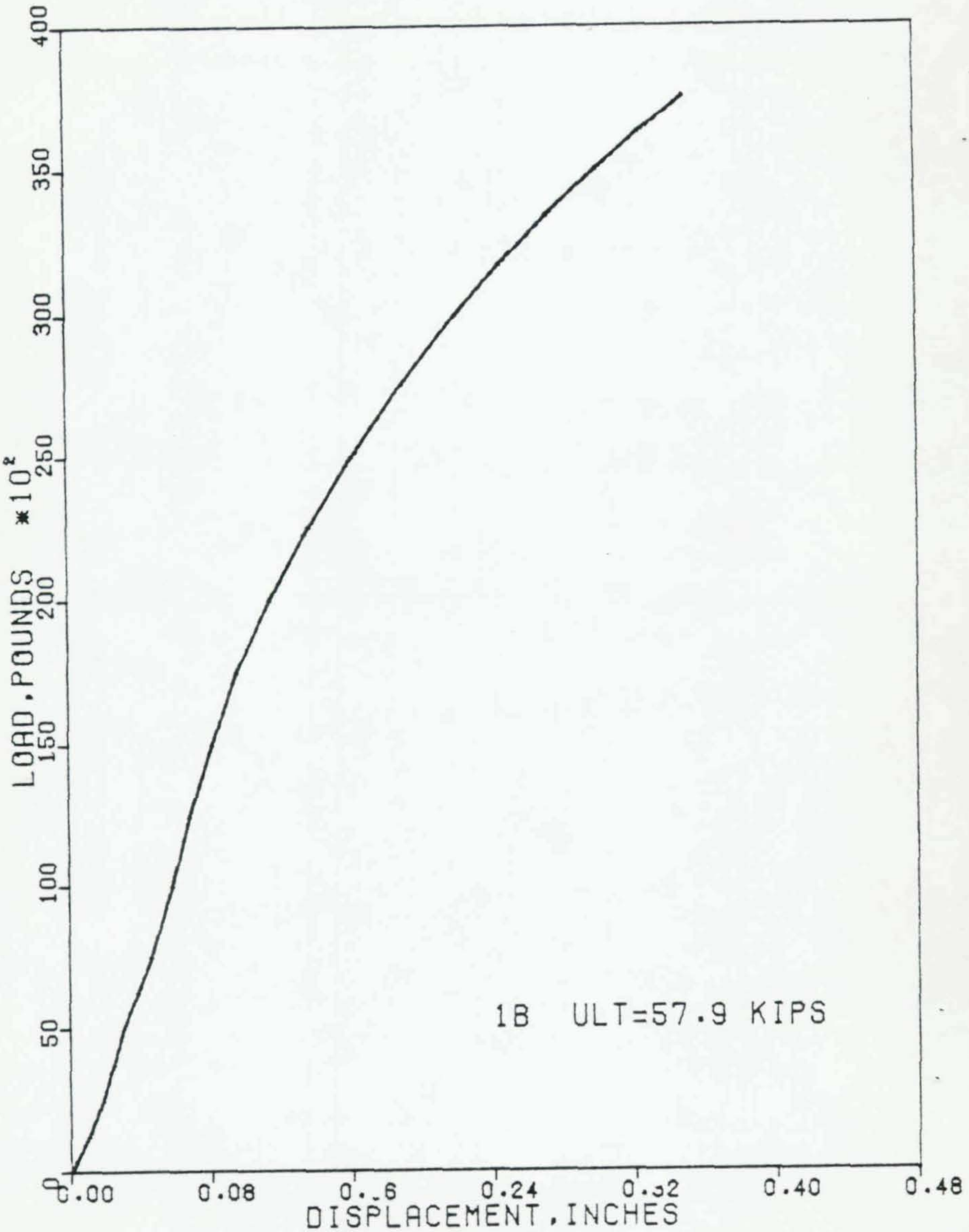


PIN-CONNECTED LINK PLATES BEING TESTED IN 440-KIP
(1957 kN) UNIVERSAL-TESTING MACHINE



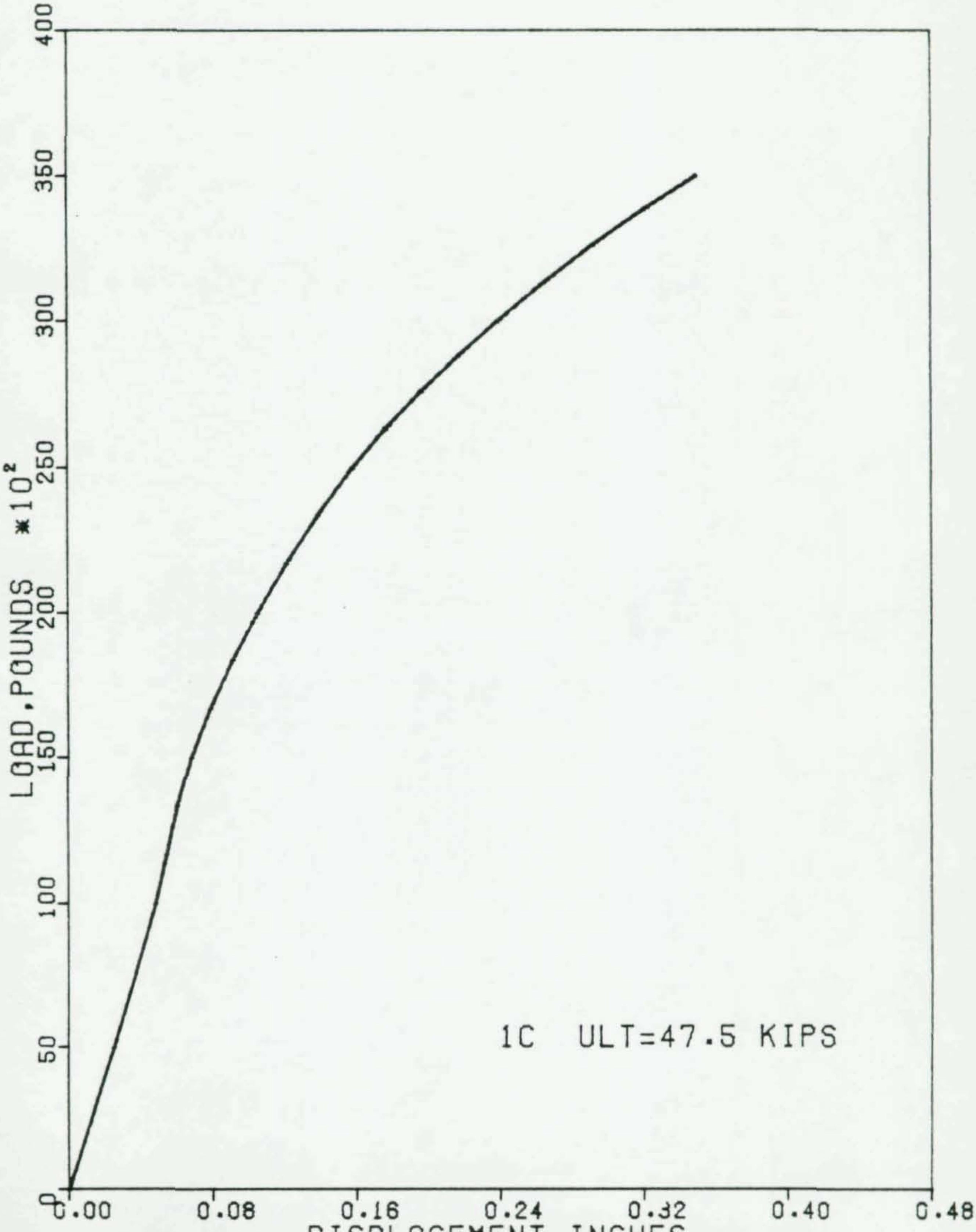
PIN-CONNECTED LINK TESTS

FIGURE 4



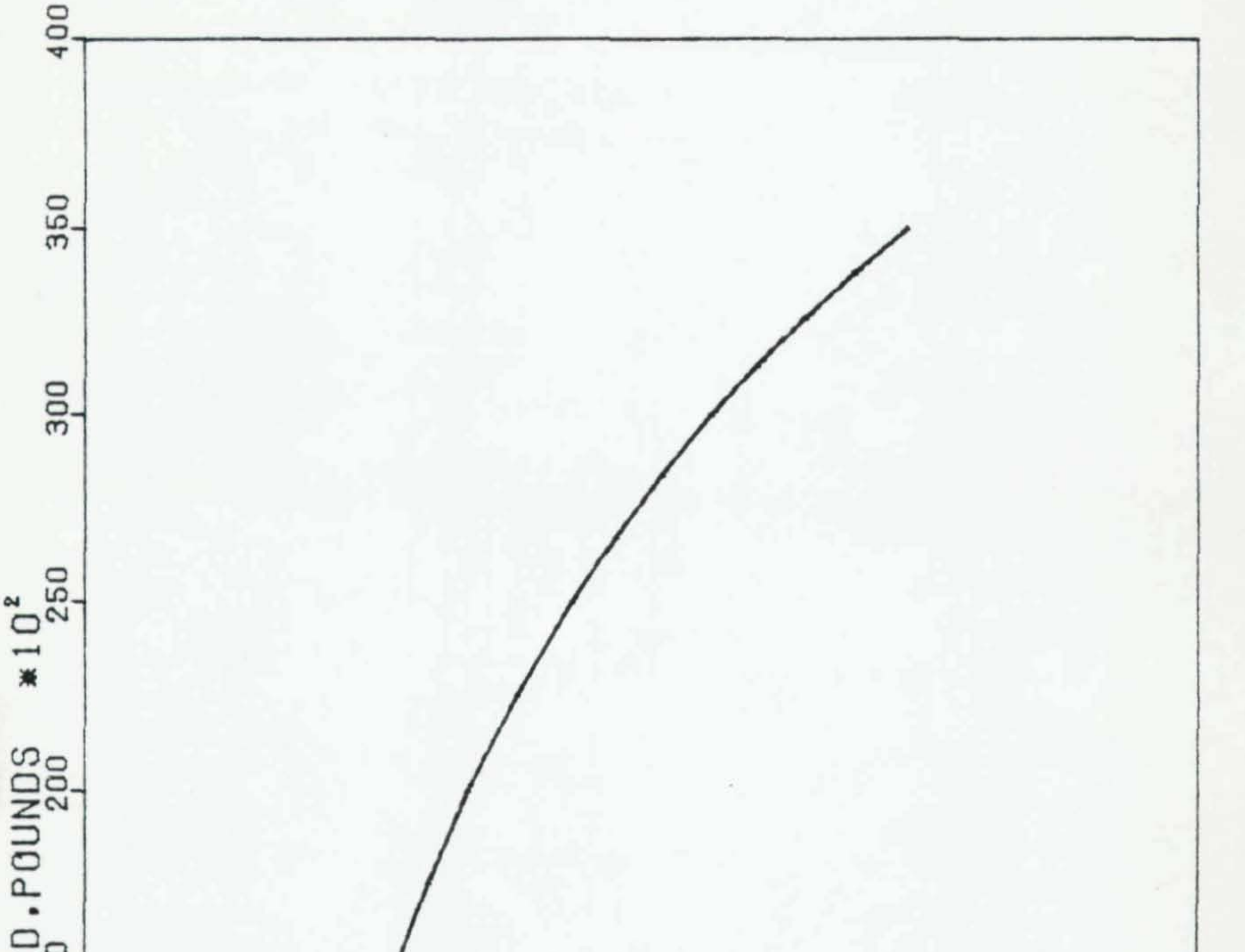
PIN-CONNECTED LINK TESTS

FIGURE 5



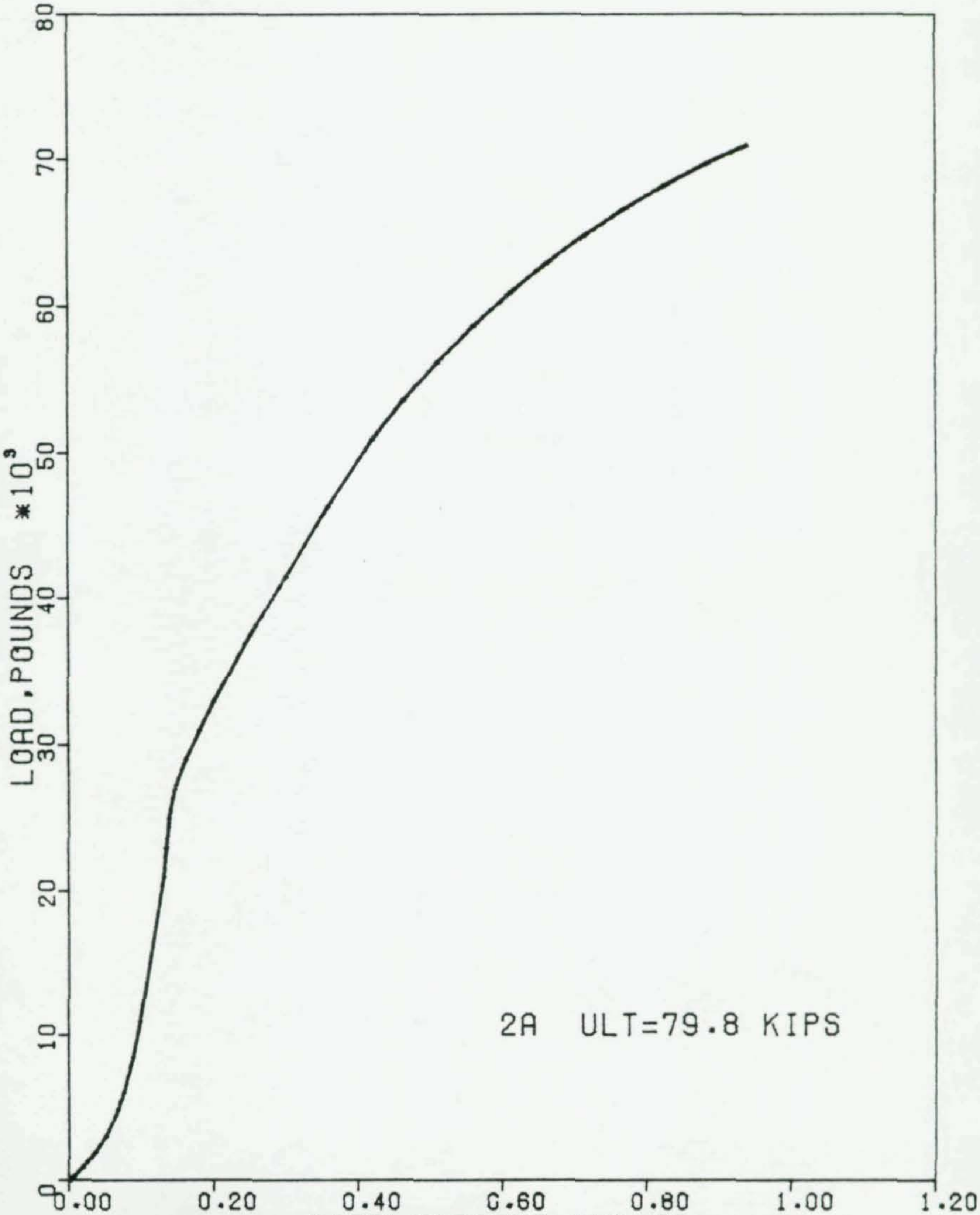
PIN-CONNECTED LINK TESTS

FIGURE 6



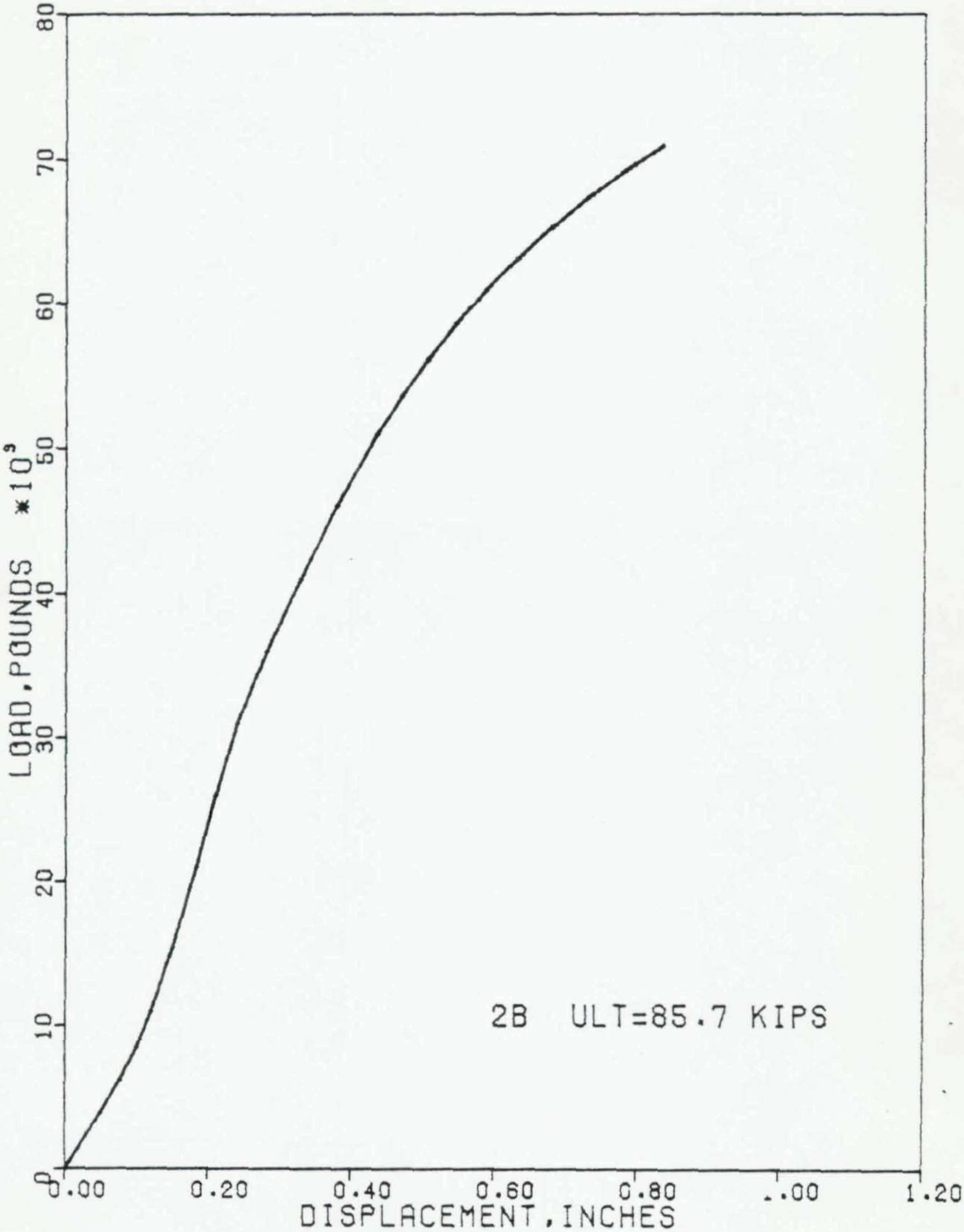
PIN-CONNECTED LINK TESTS

FIGURE 7



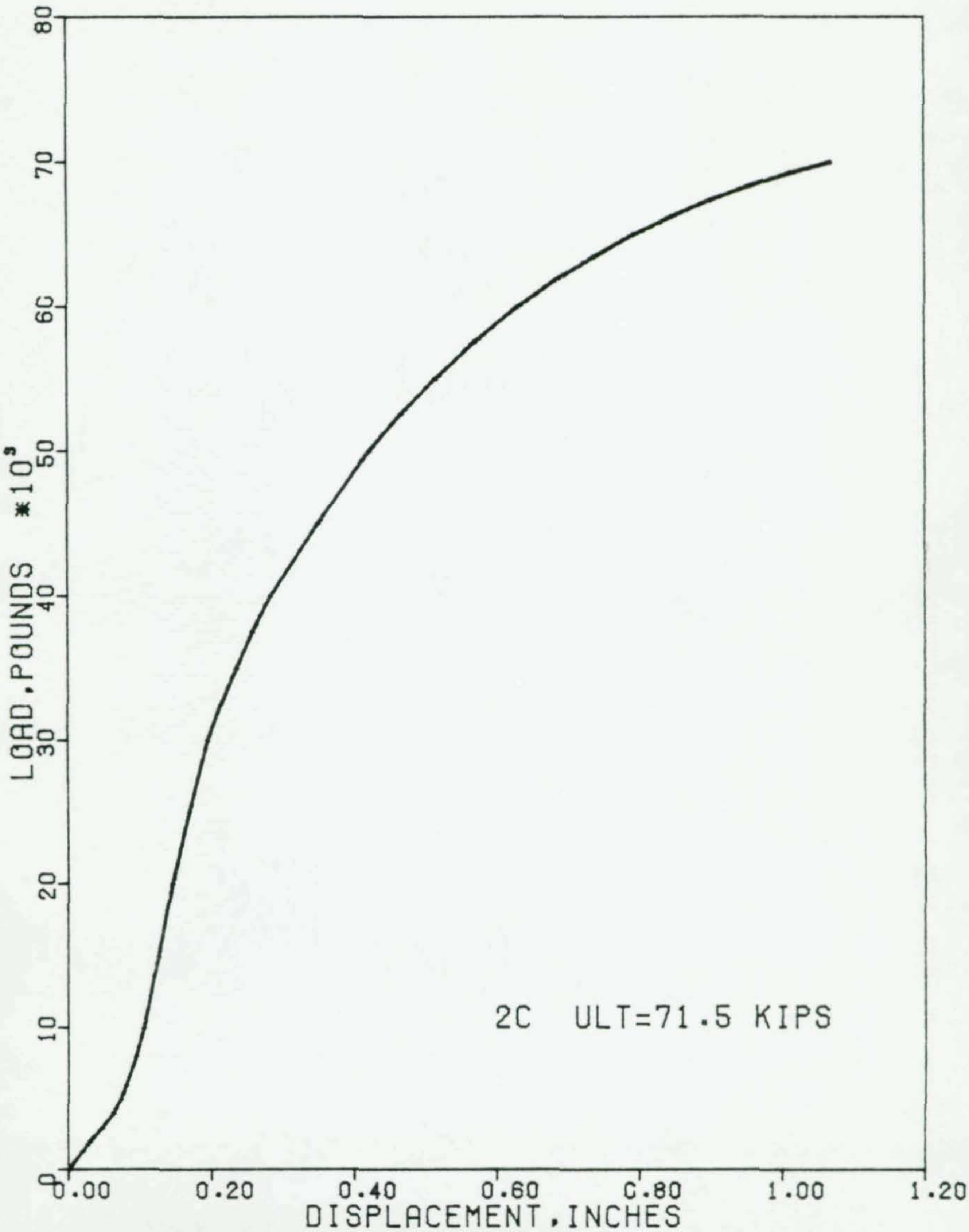
PIN-CONNECTED LINK TESTS

FIGURE 8



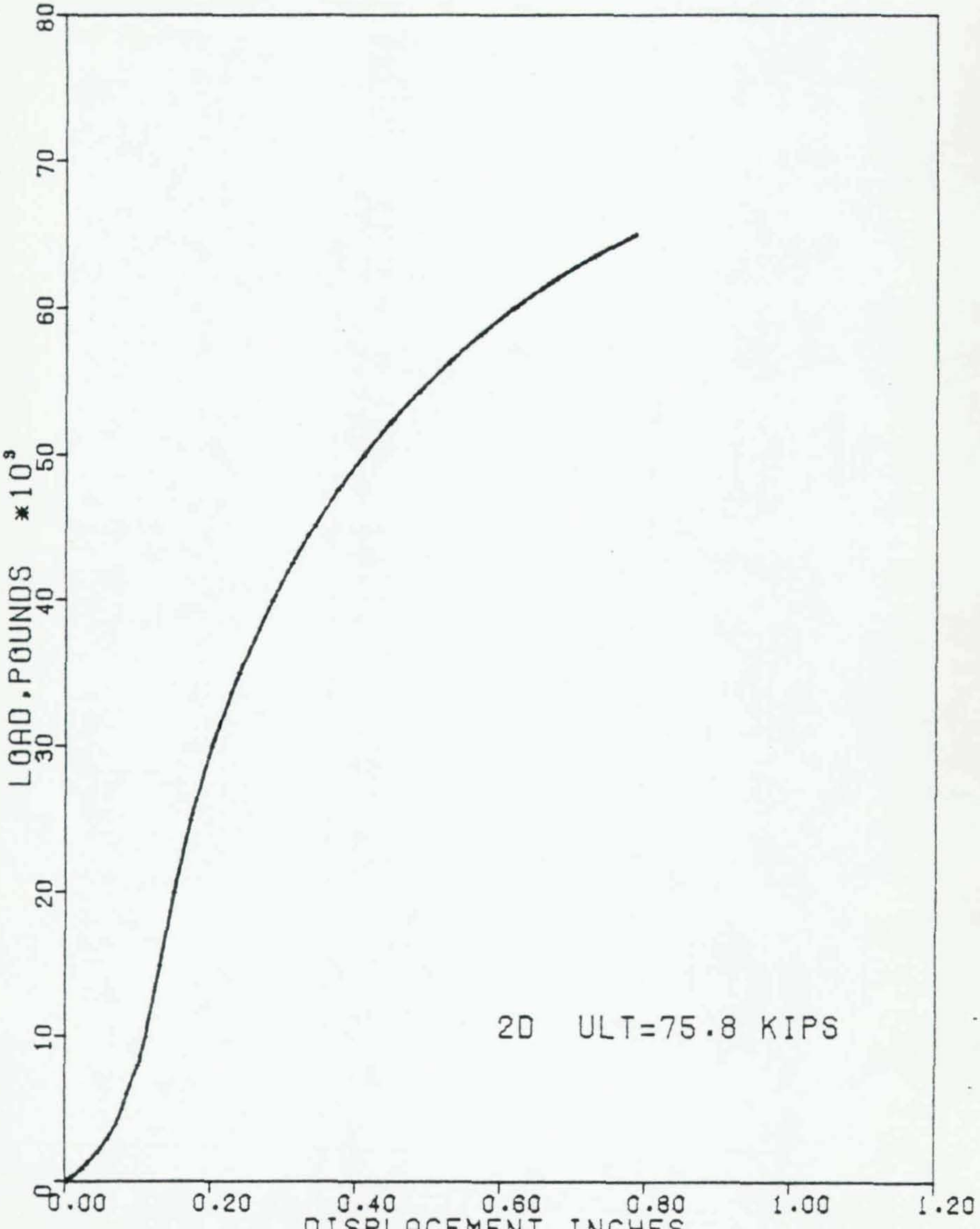
PIN-CONNECTED LINK TESTS

FIGURE 9



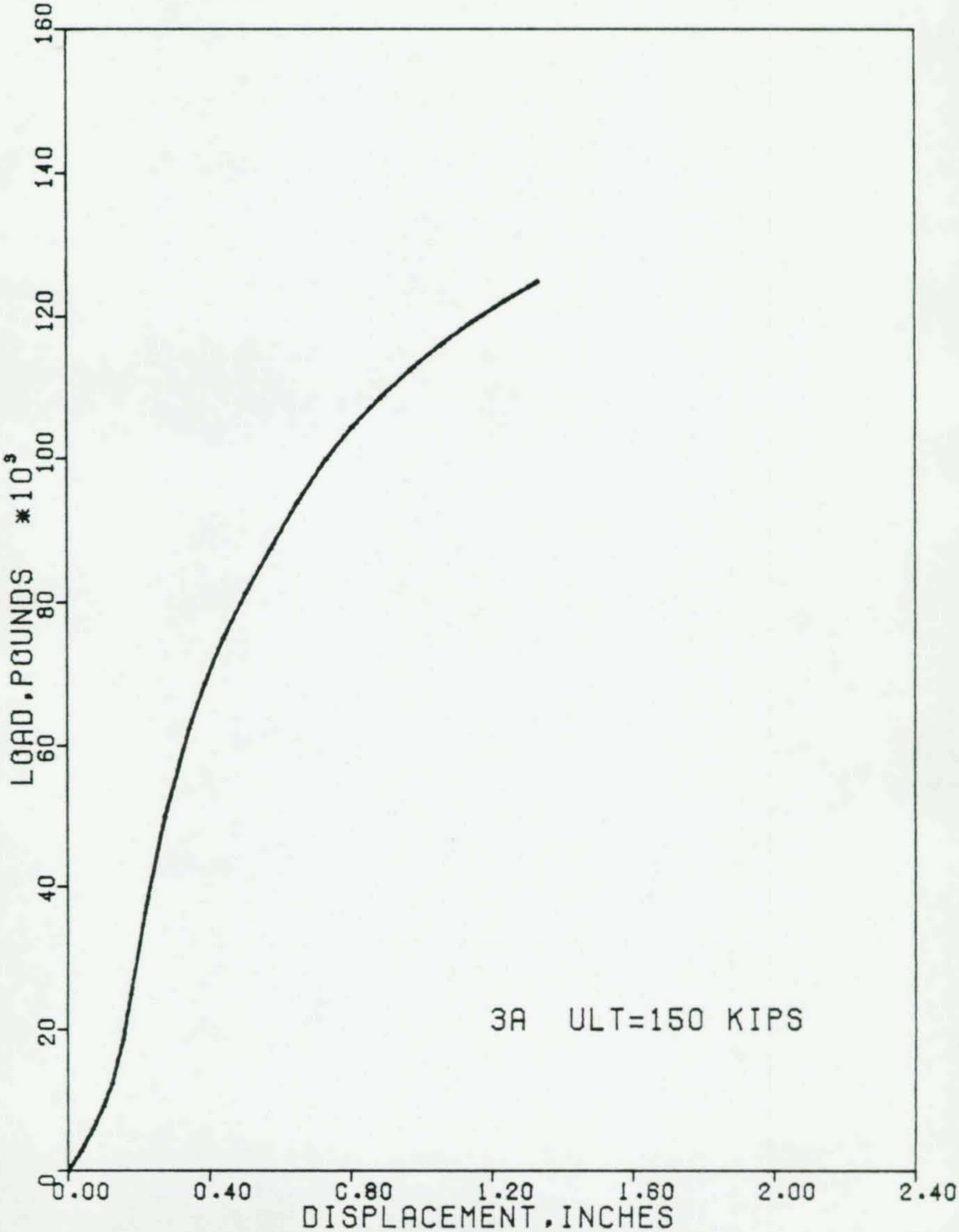
PIN-CONNECTED LINK TESTS

FIGURE 10



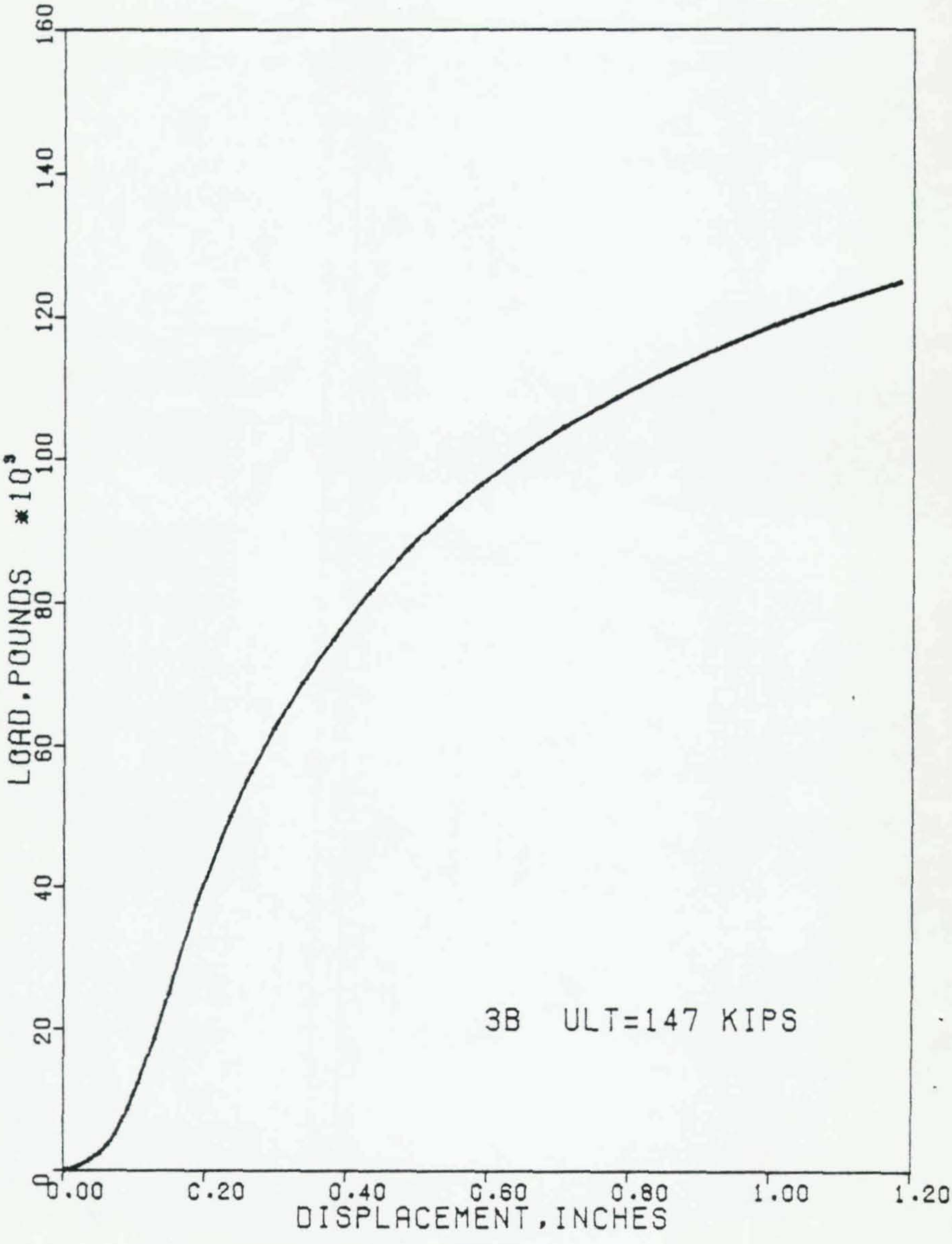
PIN-CONNECTED LINK TESTS

FIGURE 11



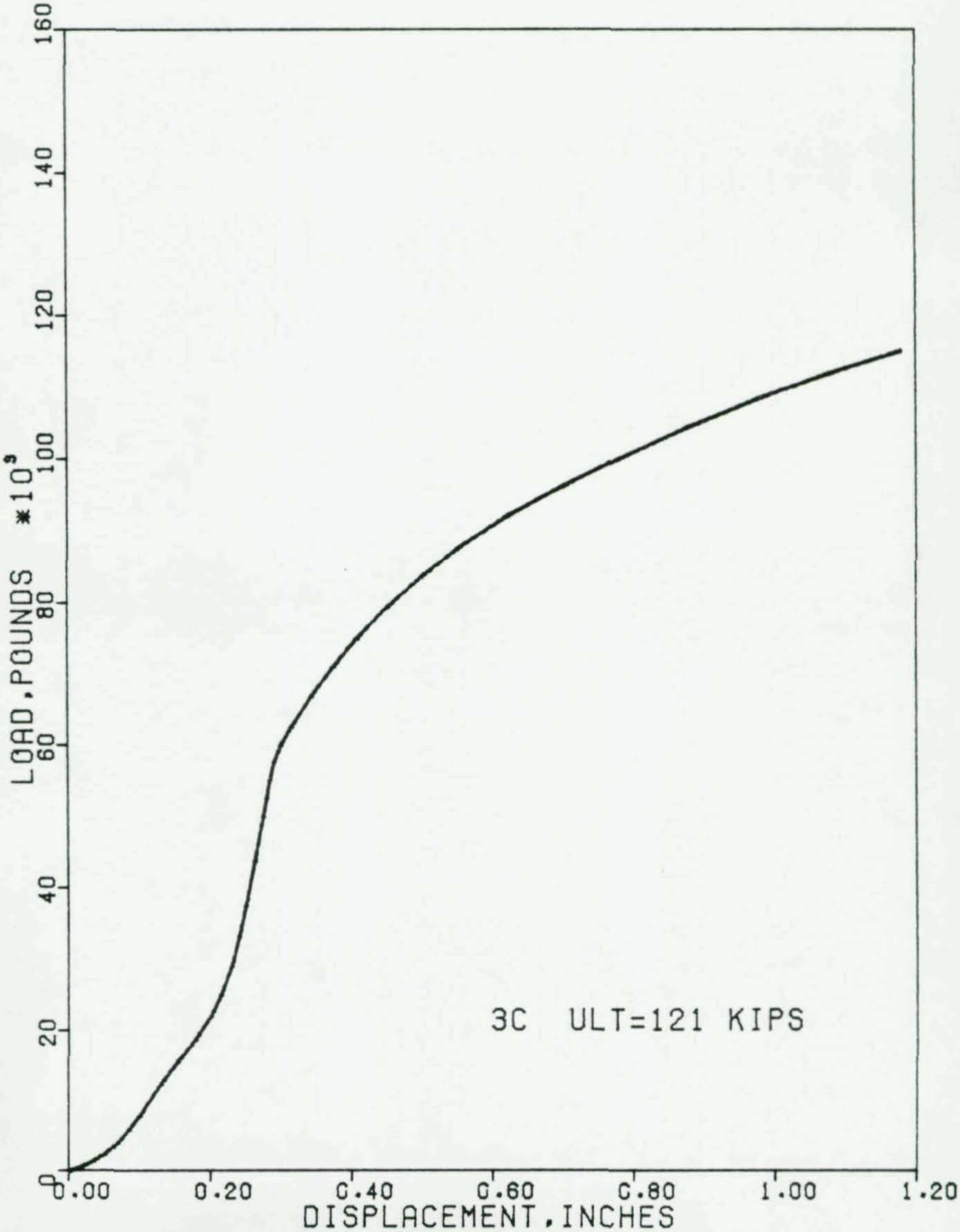
PIN-CONNECTED LINK TESTS

FIGURE 12



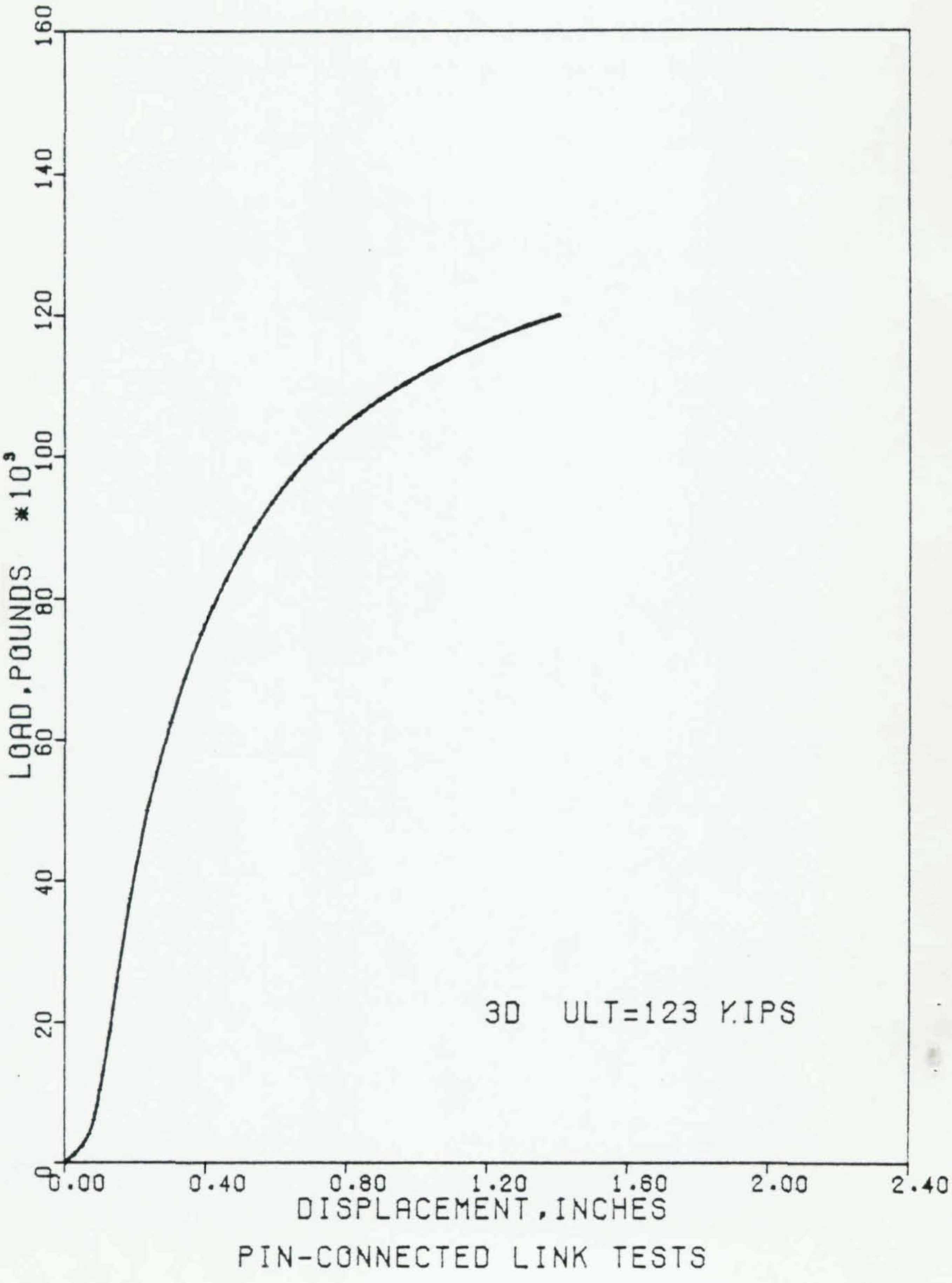
PIN-CONNECTED LINK TESTS

FIGURE 13



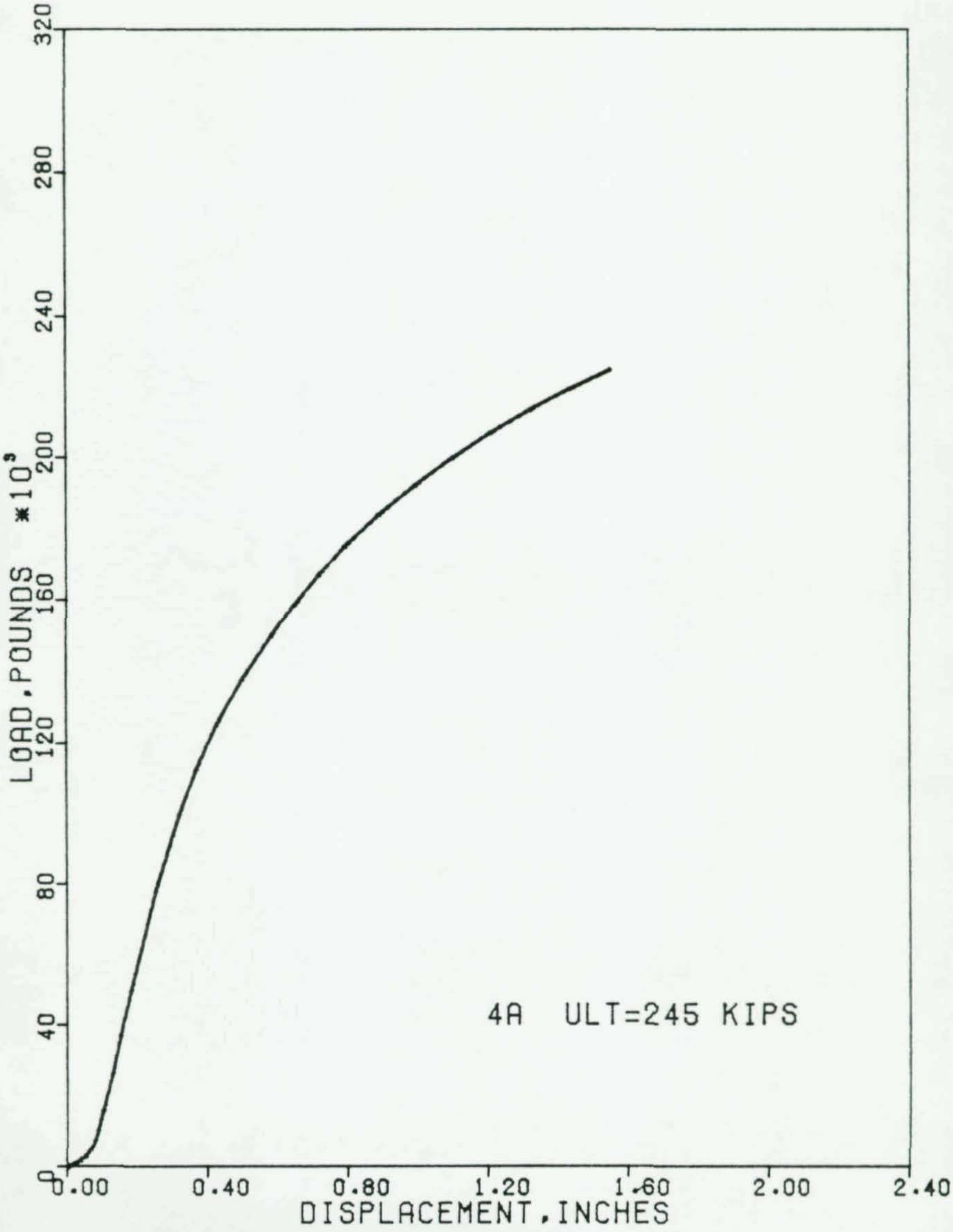
PIN-CONNECTED LINK TESTS

FIGURE 14



160
140
120
100
80
60
40
20
0
LOAD, POUNDS $*10^3$
0.00
0.40
0.80
1.20
1.60
2.00
2.40
DISPLACEMENT, INCHES
3D ULT=123 KIPS
PIN-CONNECTED LINK TESTS

FIGURE 15



PIN-CONNECTED LINK TESTS

FIGURE 16

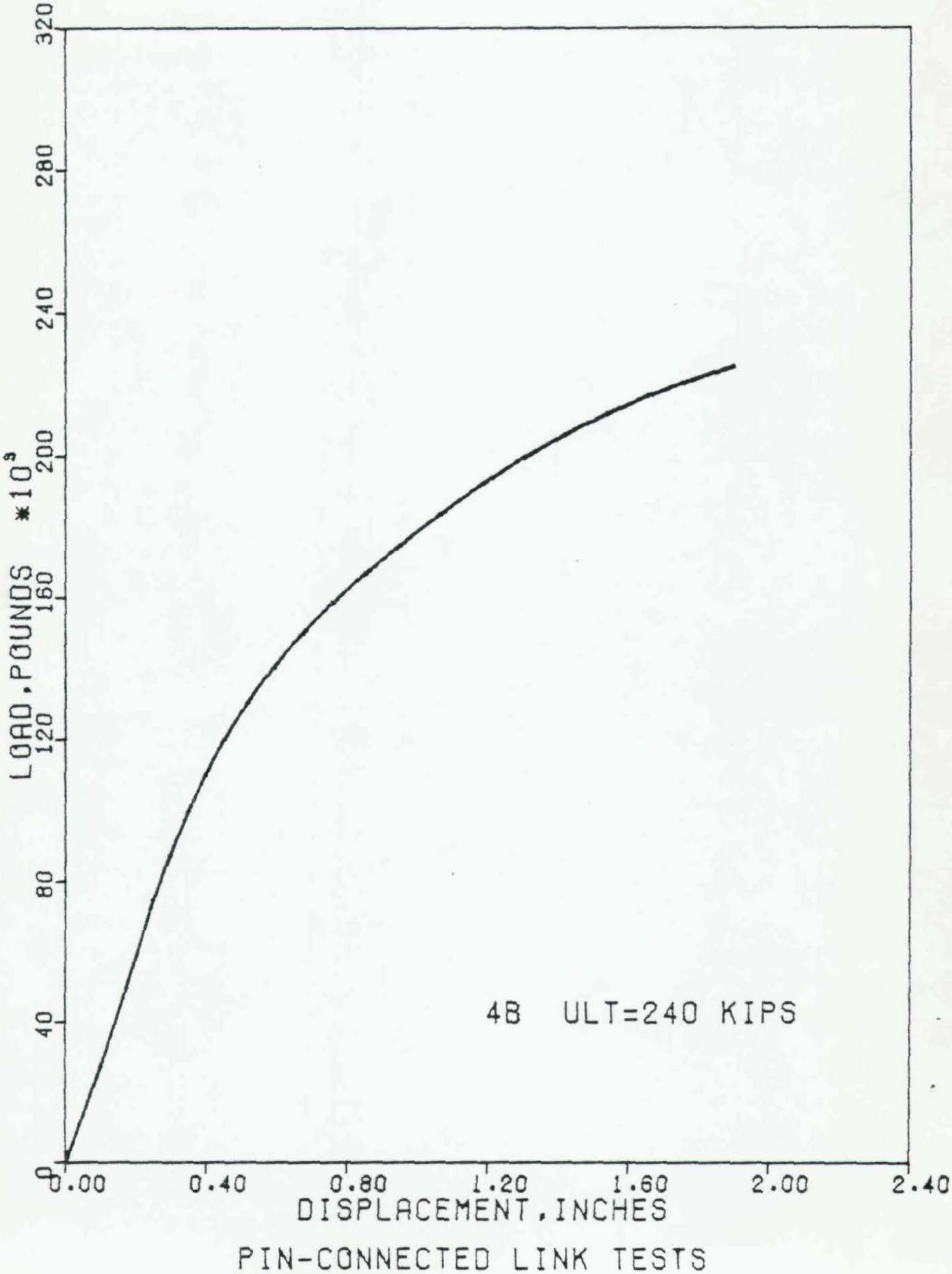
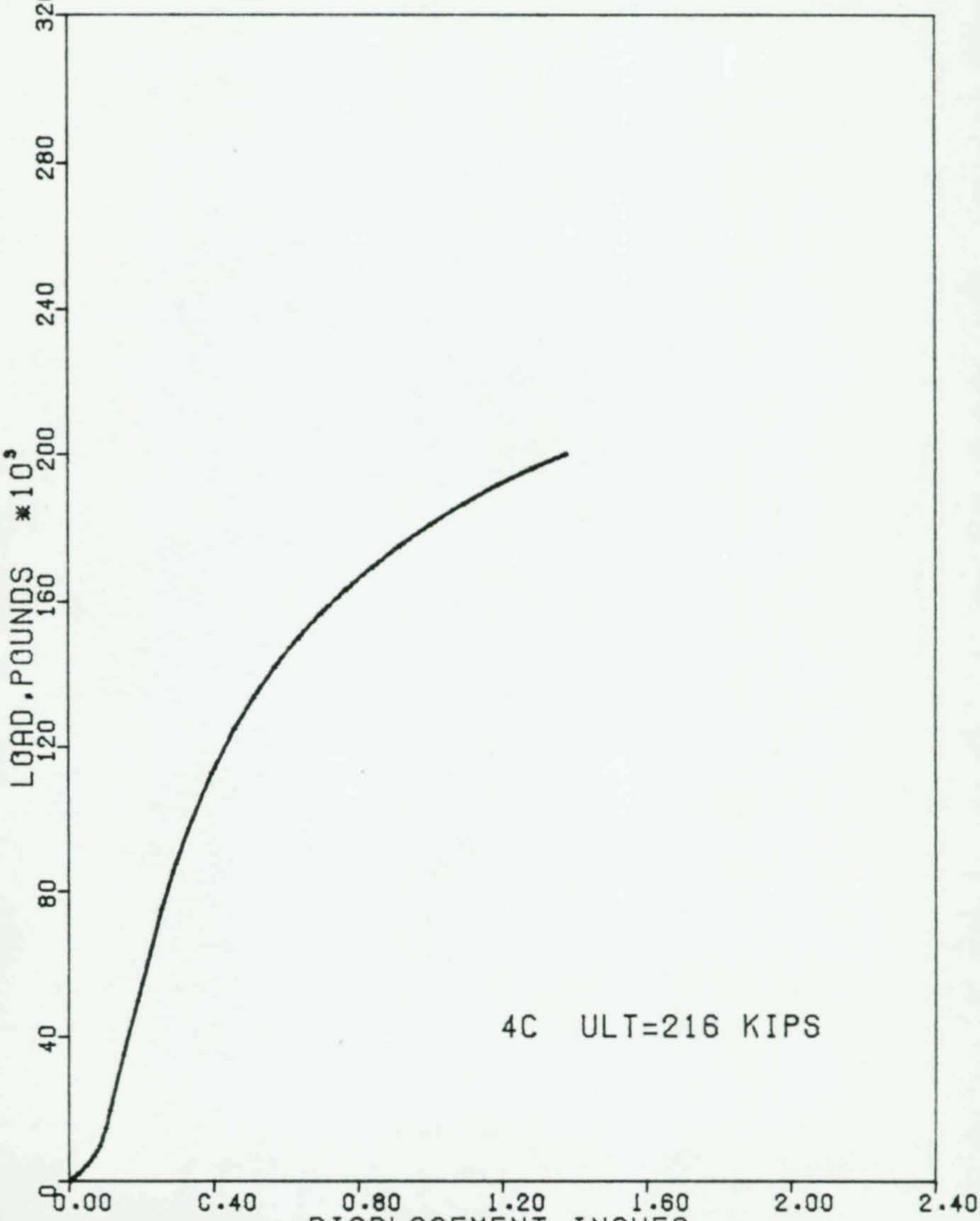

LOAD, POUNDS $*10^3$
0
40
80
120
160
200
240
280
320
0.00
0.40
0.80
1.20
1.60
2.00
2.40
DISPLACEMENT, INCHES
4B ULT=240 KIPS
PIN-CONNECTED LINK TESTS

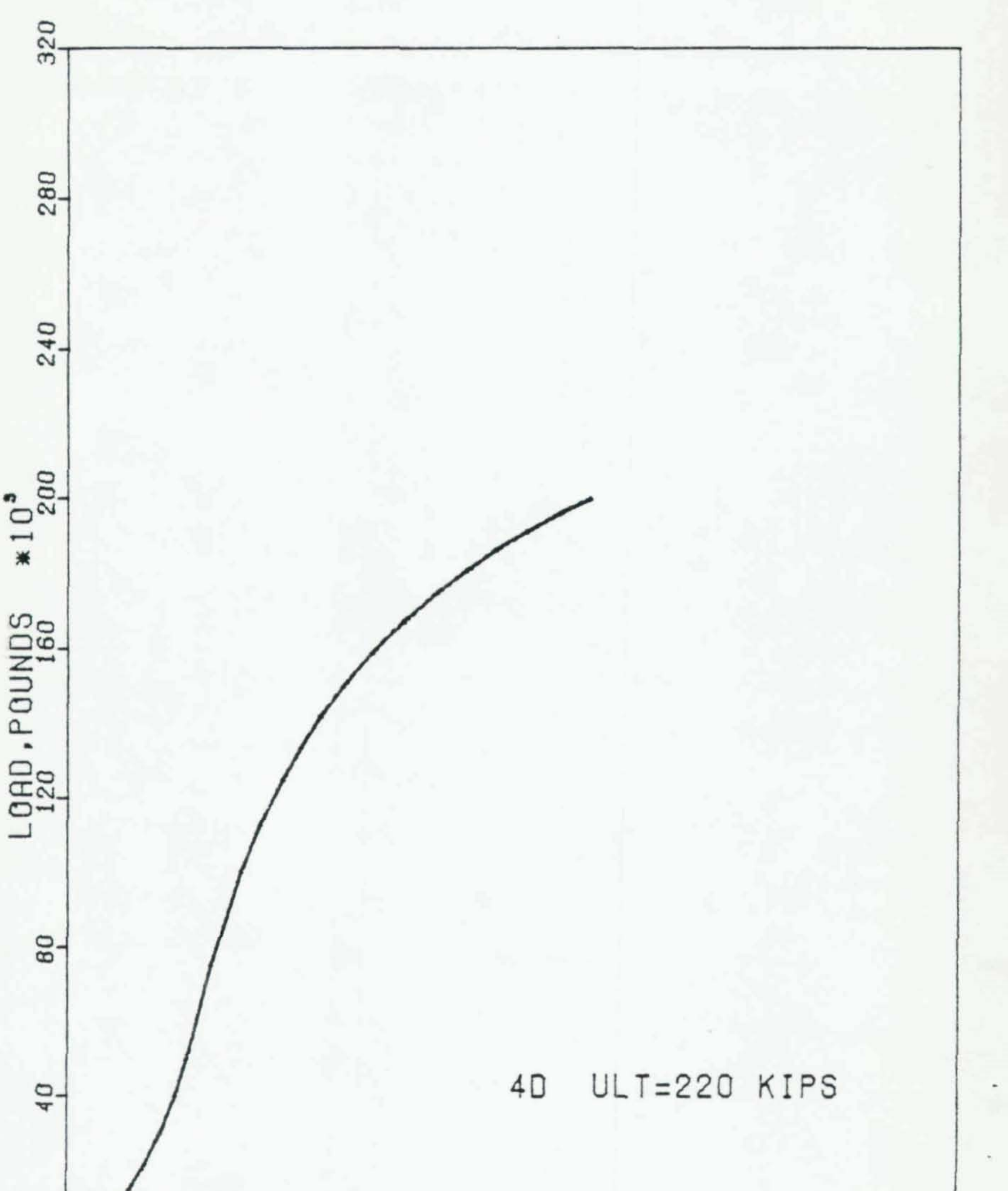
FIGURE 17

010054



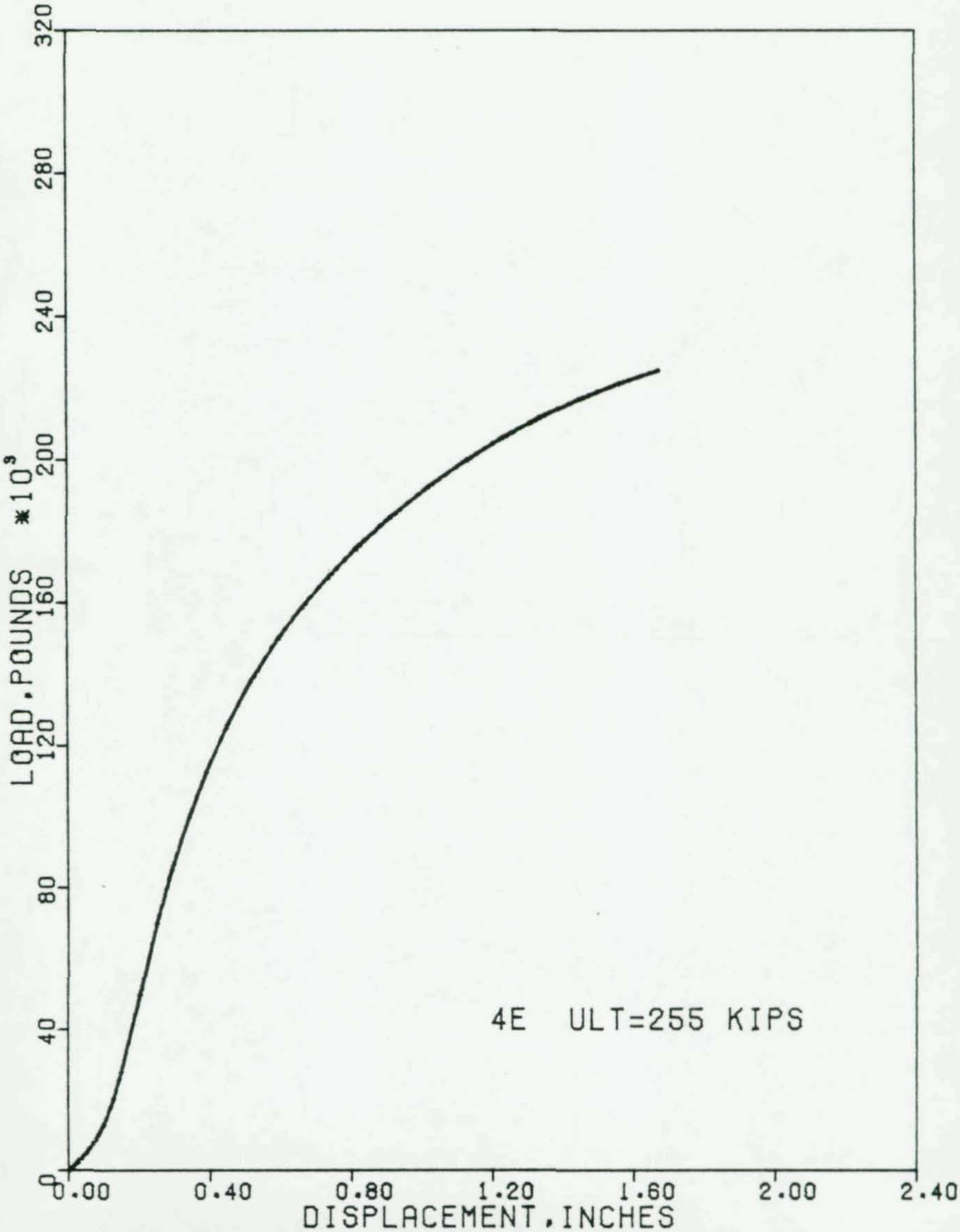
PIN-CONNECTED LINK TESTS

FIGURE 18



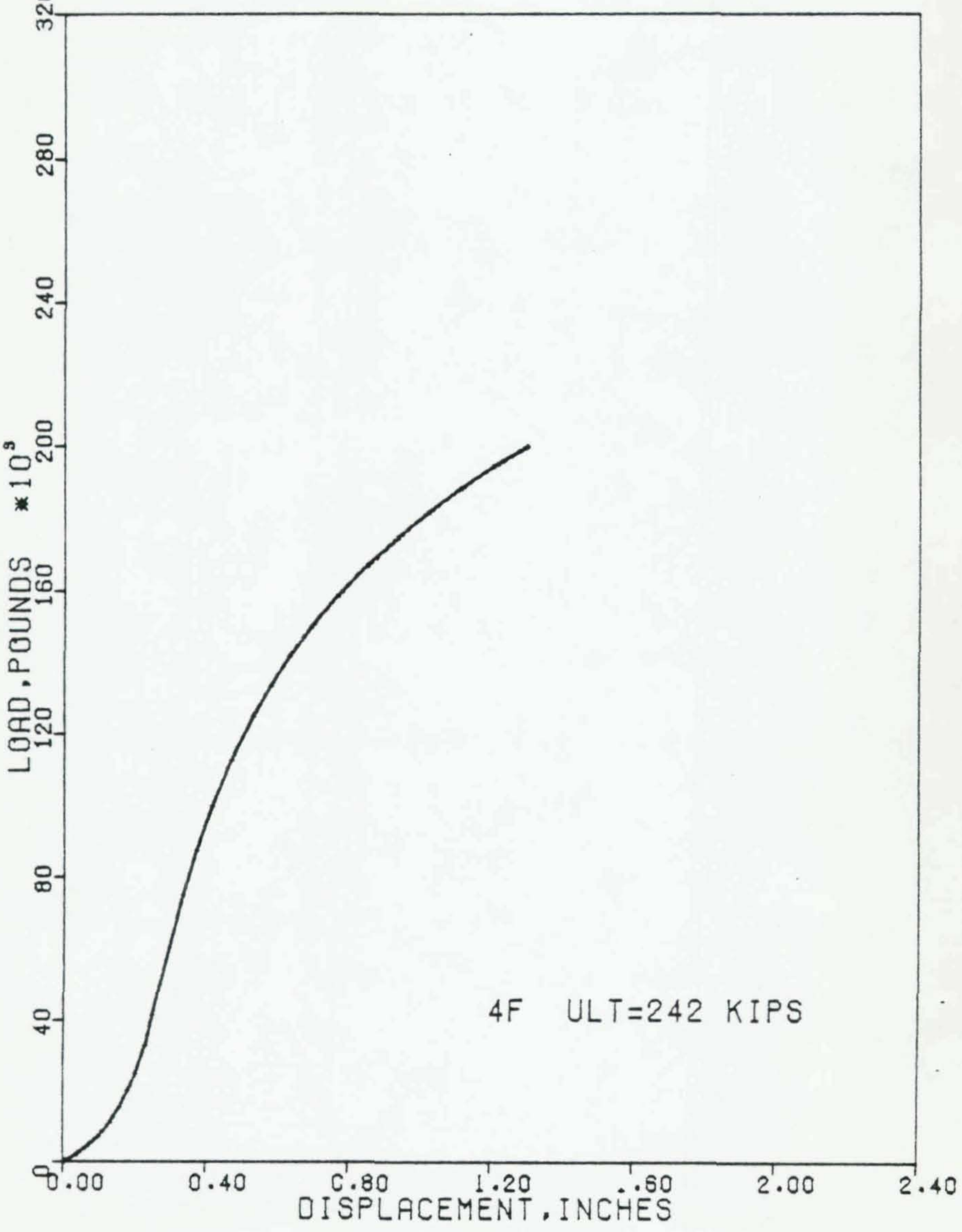
PIN-CONNECTED LINK TESTS

FIGURE 19



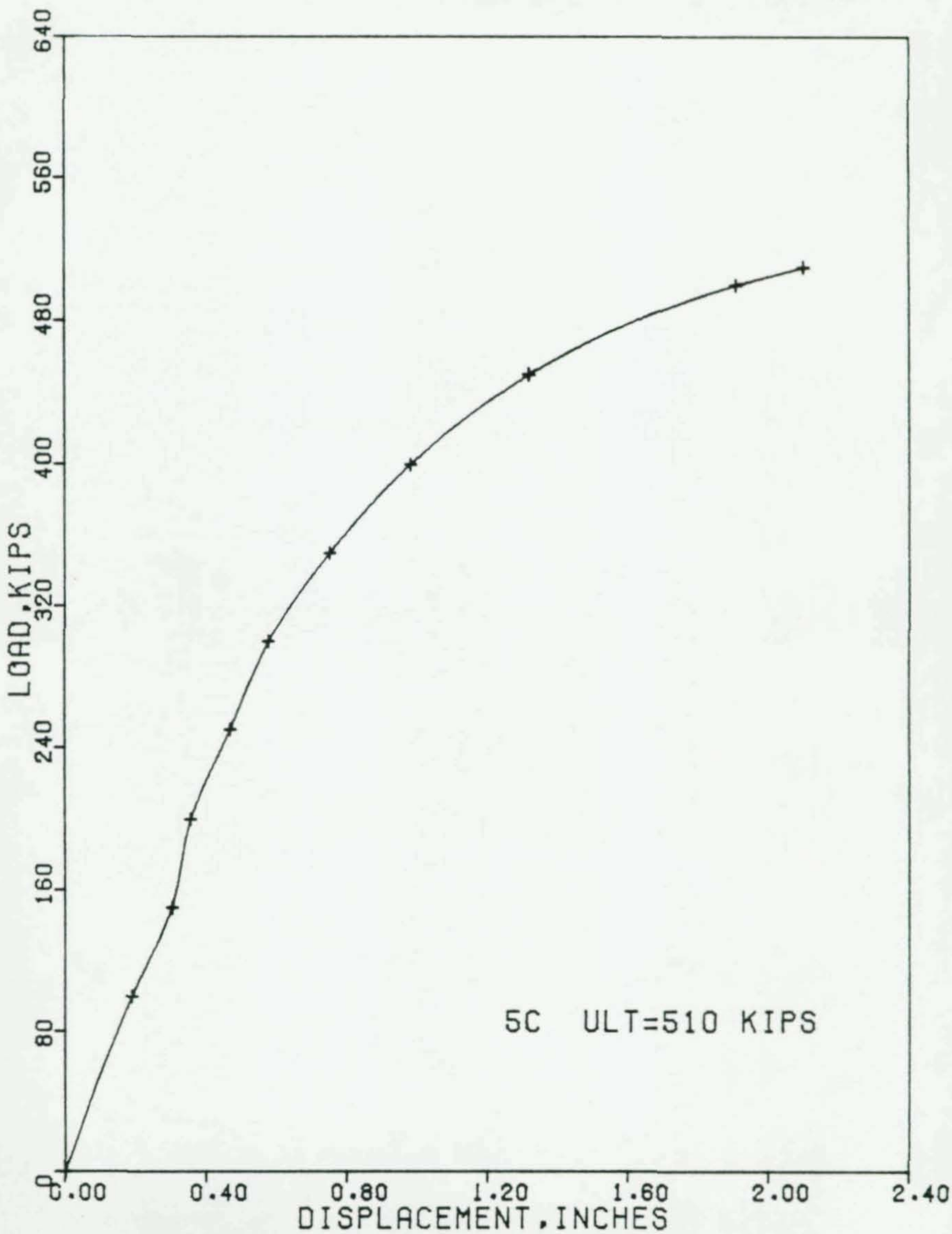
PIN-CONNECTED LINK TESTS

FIGURE 20



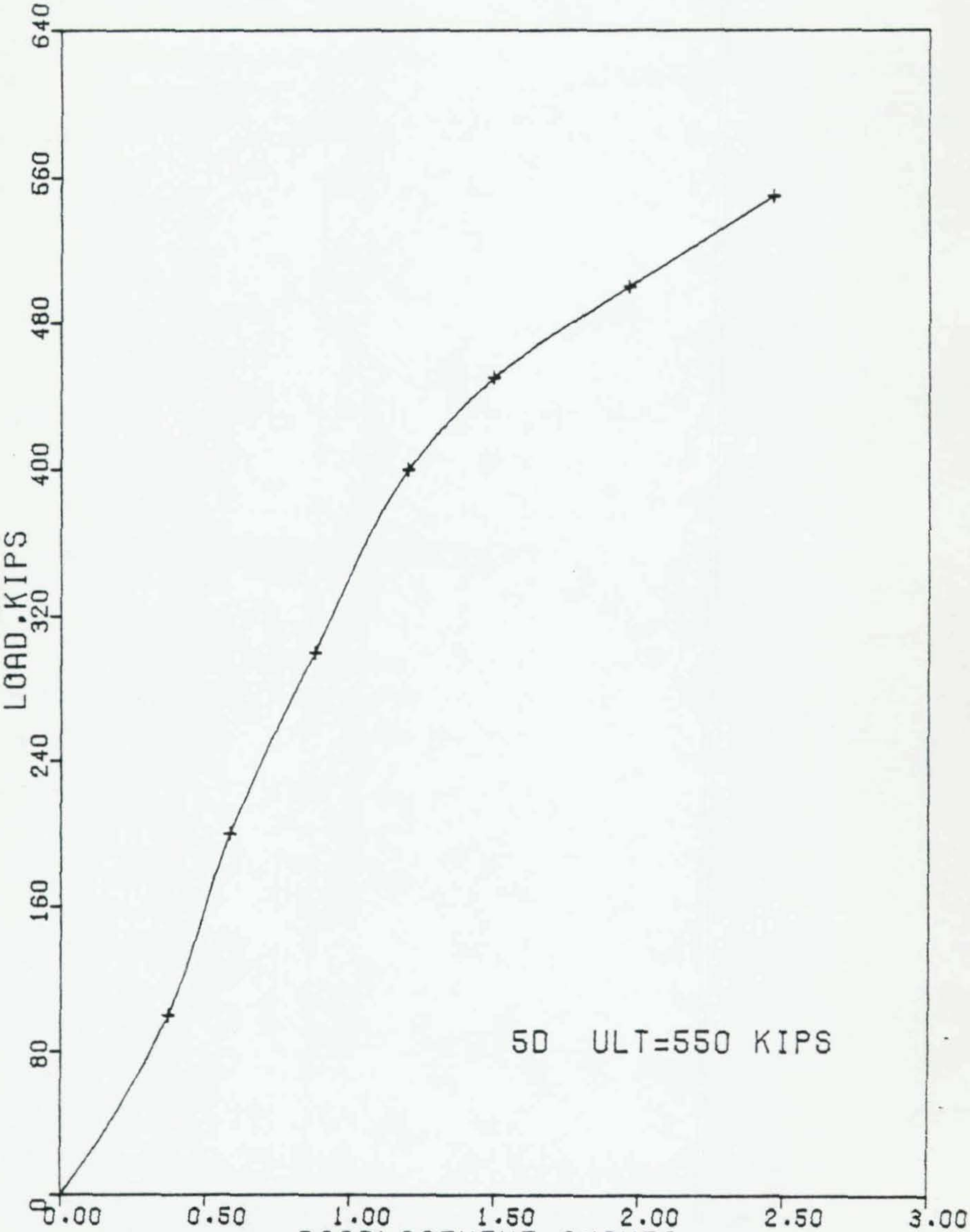
PIN-CONNECTED LINK TESTS

FIGURE 21



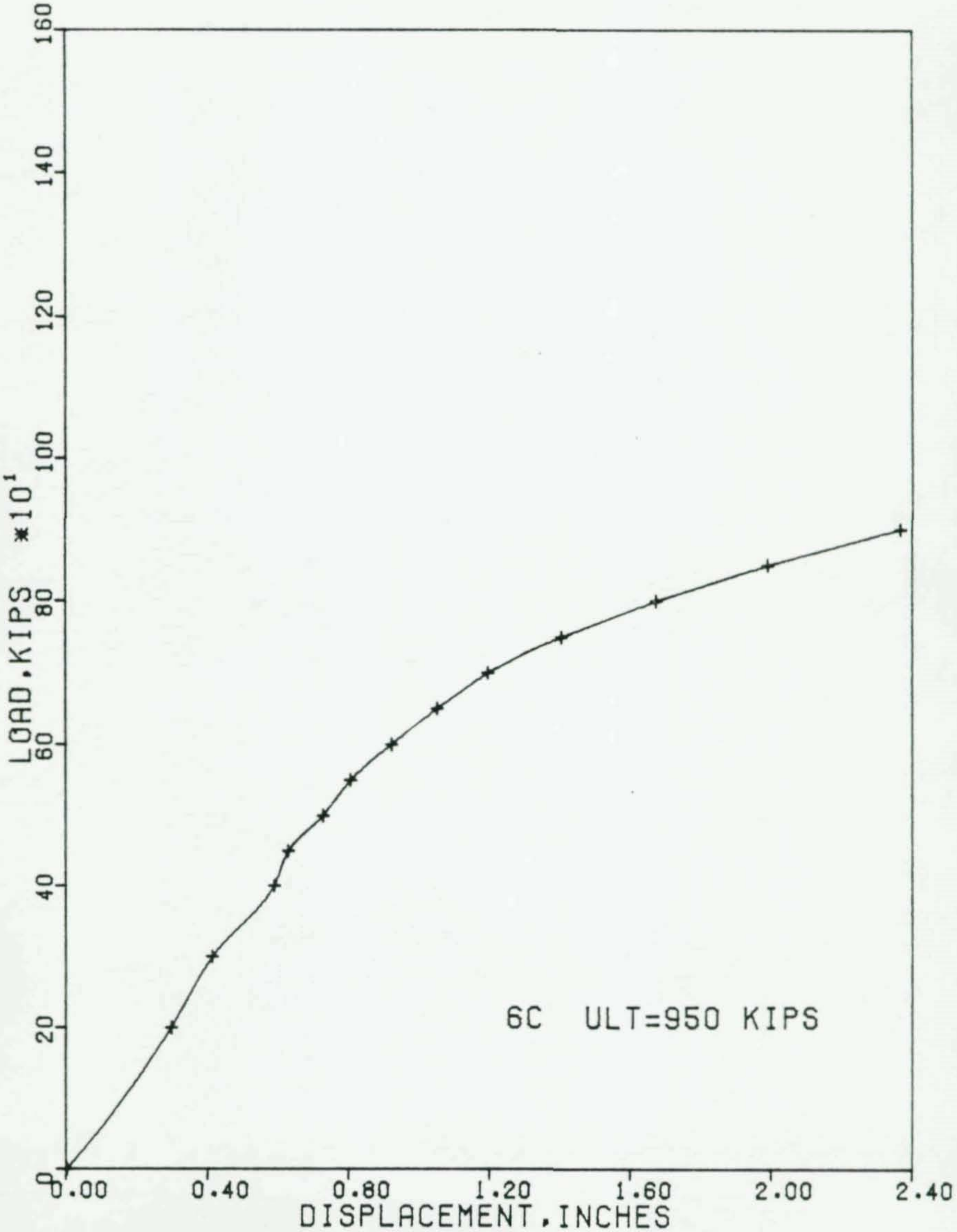
PIN-CONNECTED LINK TESTS

FIGURE 22



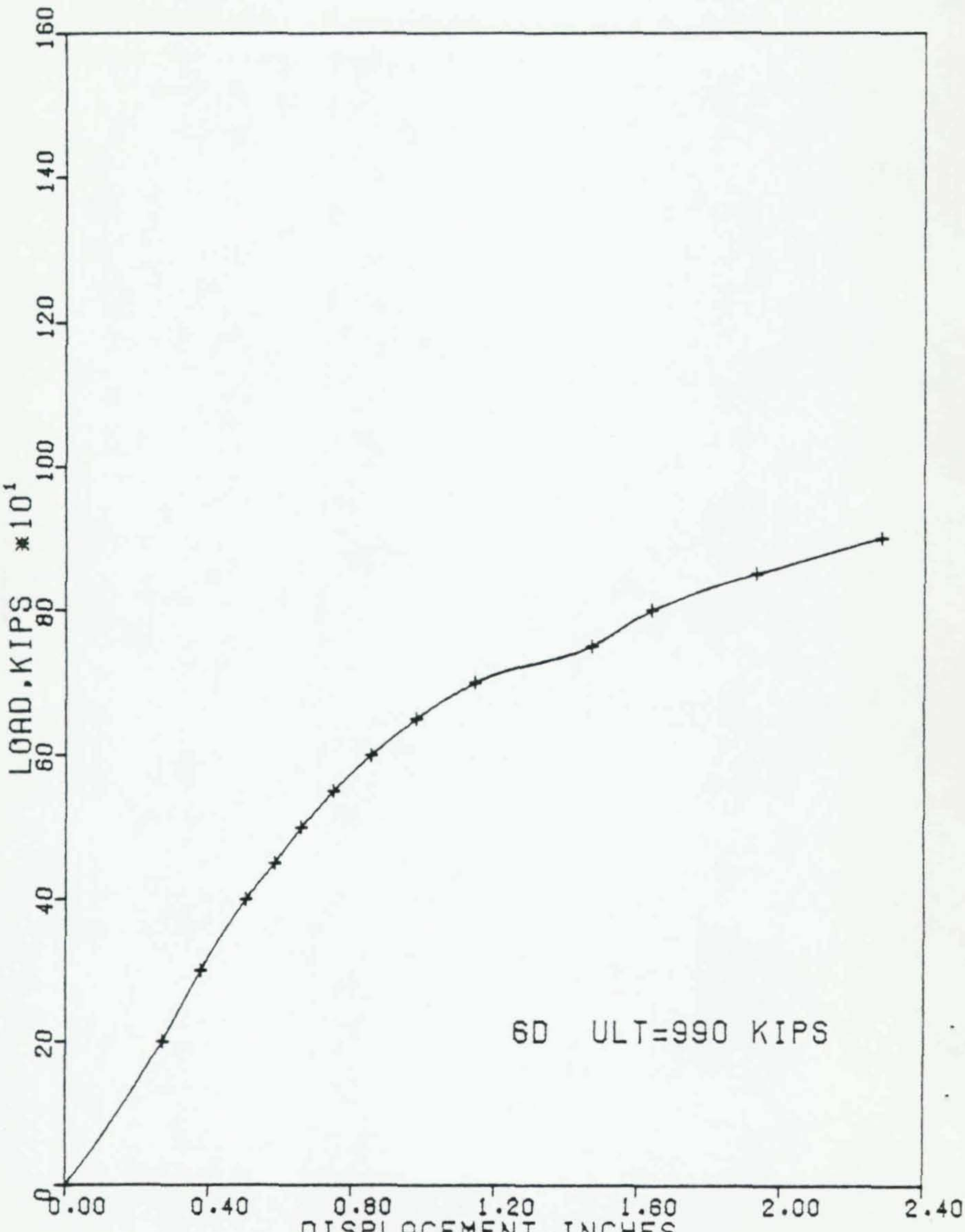
PIN-CONNECTED LINK TESTS

FIGURE 23



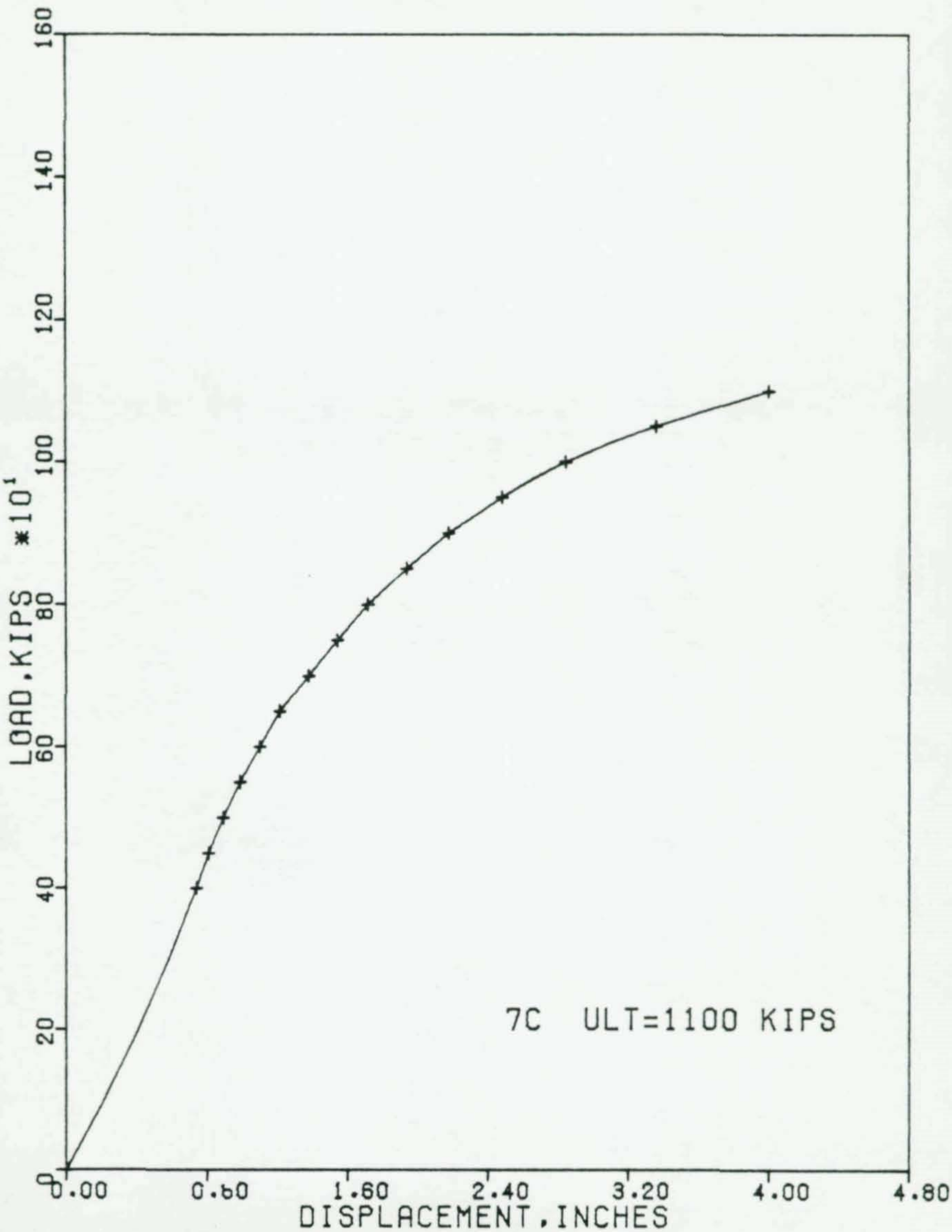
PIN-CONNECTED LINK TESTS

FIGURE 24



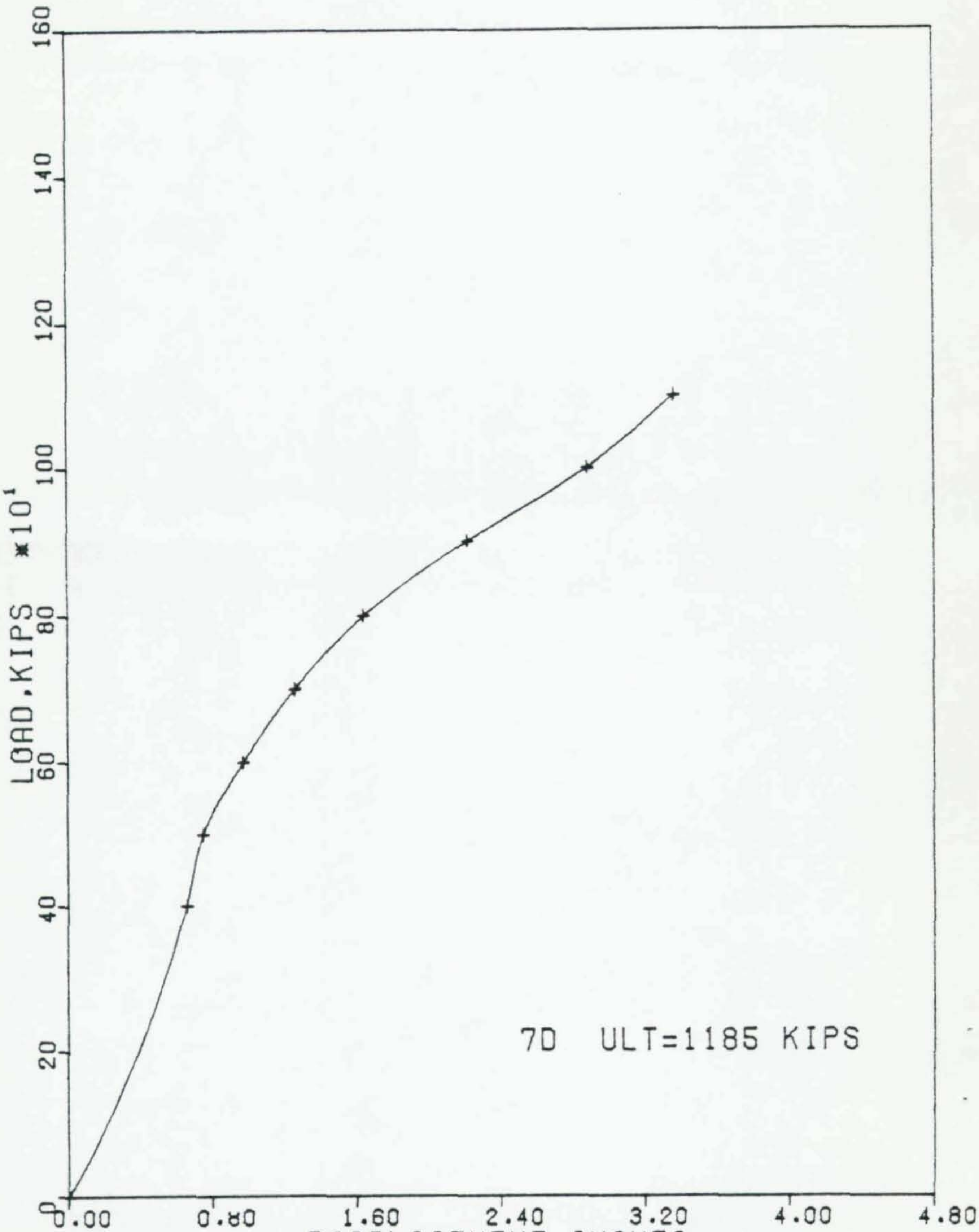
PIN-CONNECTED LINK TESTS

FIGURE 25



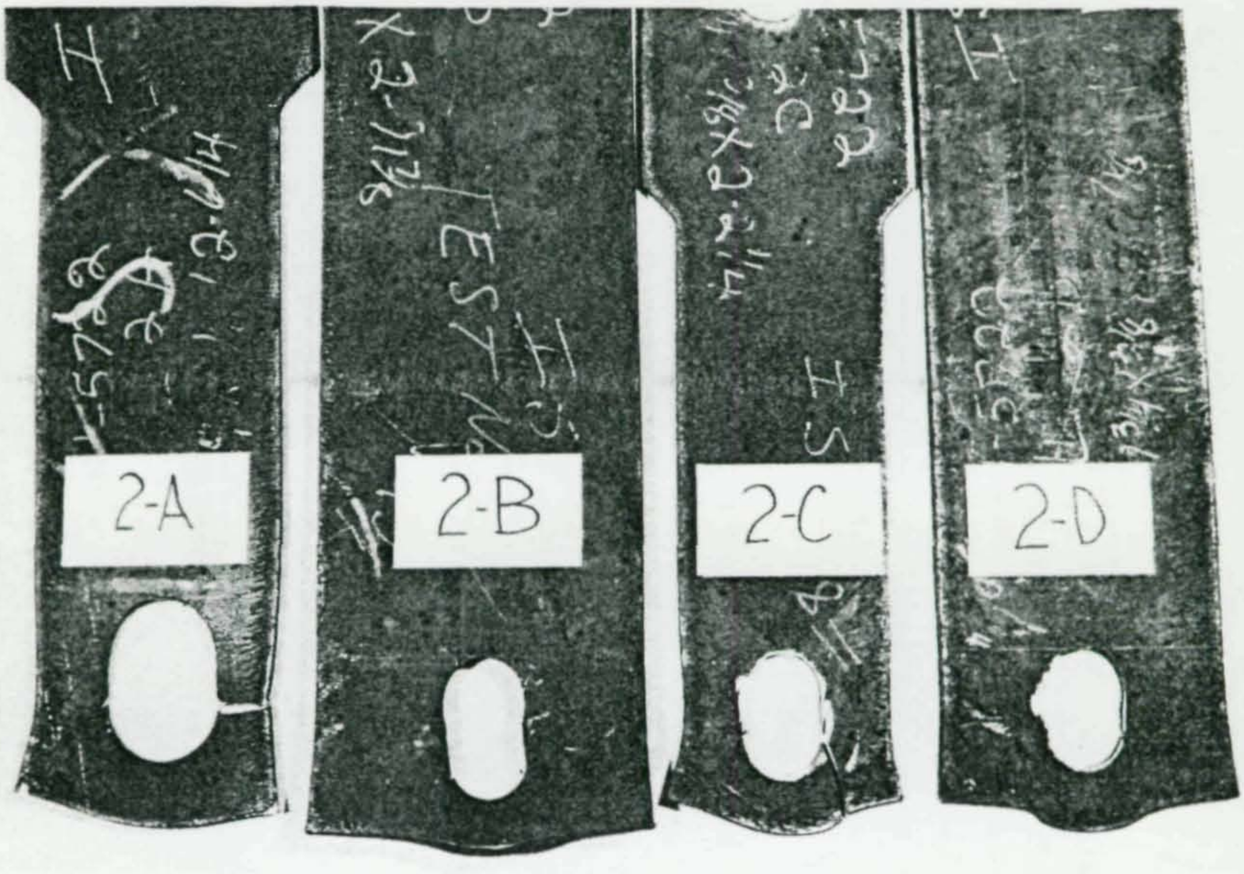
PIN-CONNECTED LINK TESTS

FIGURE 26

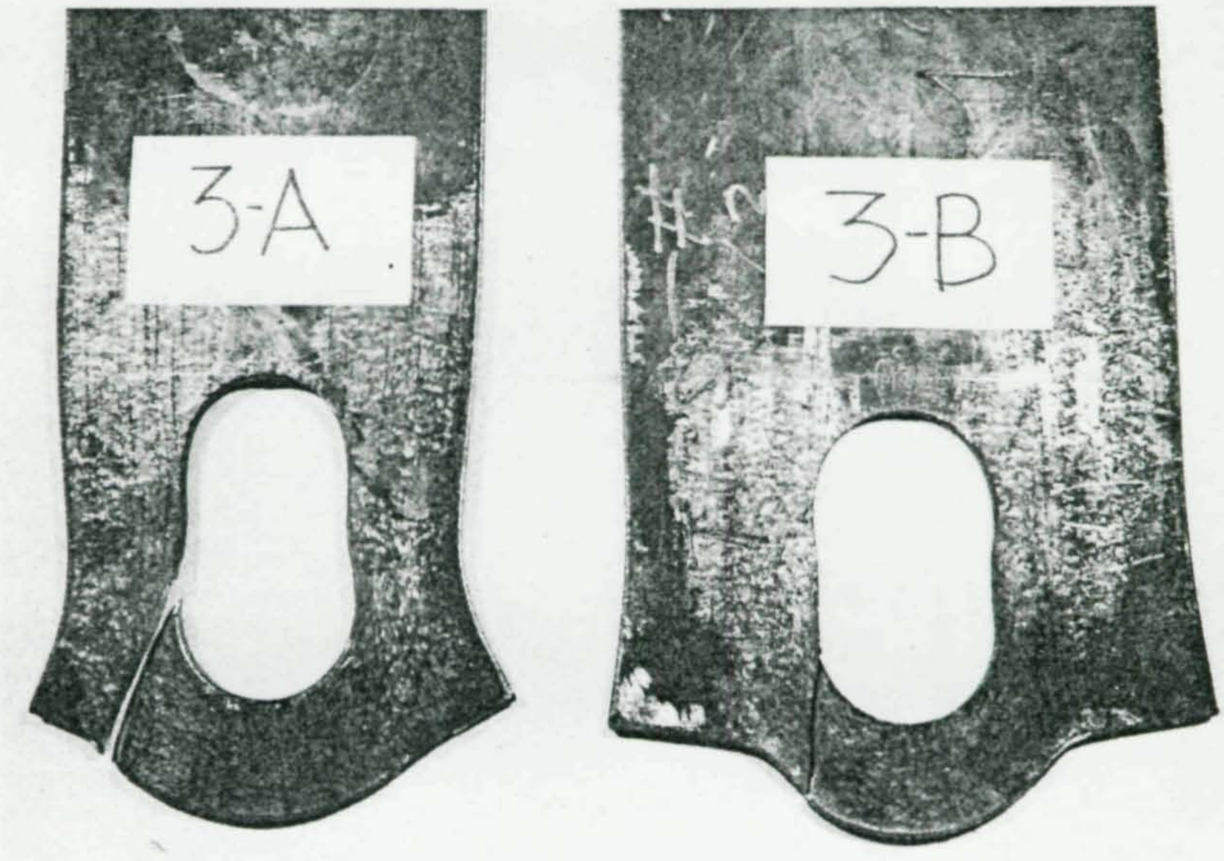


PIN-CONNECTED LINK TESTS

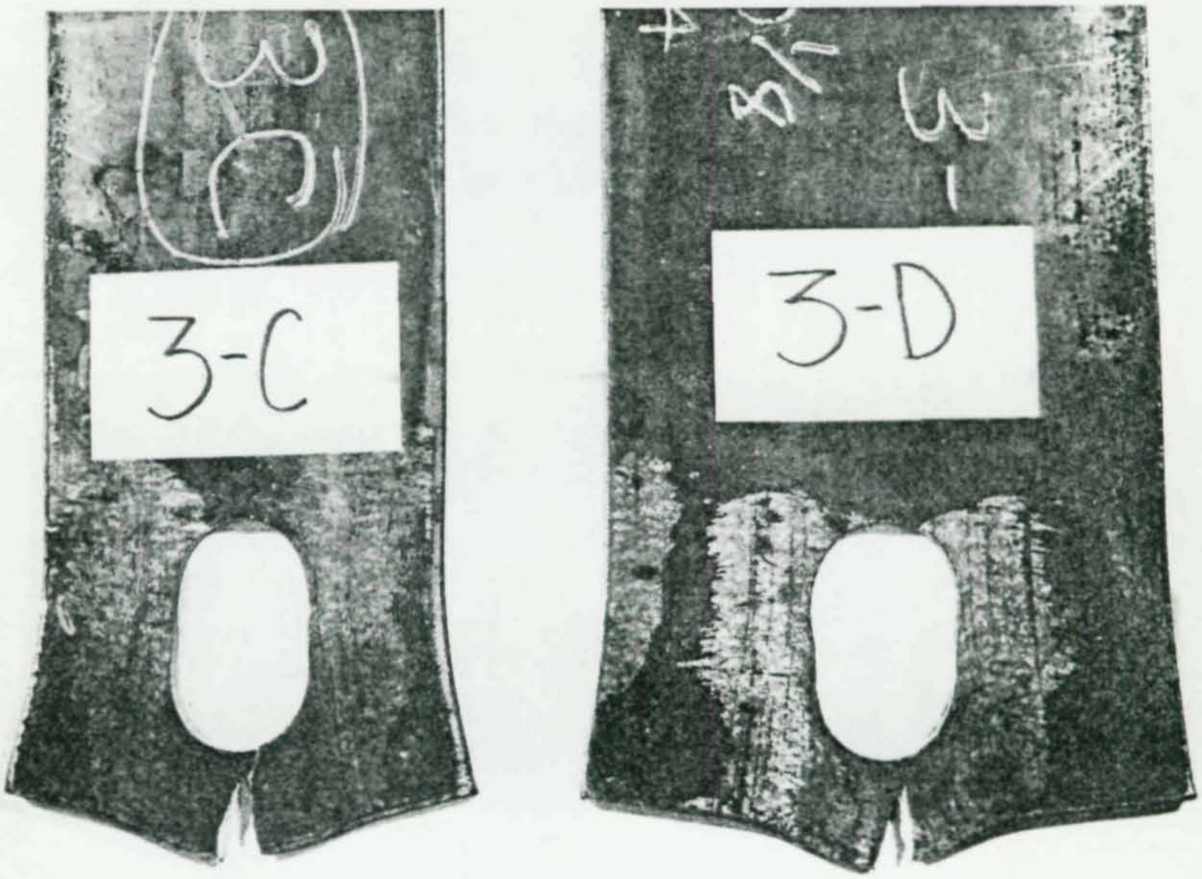
FIGURE 27



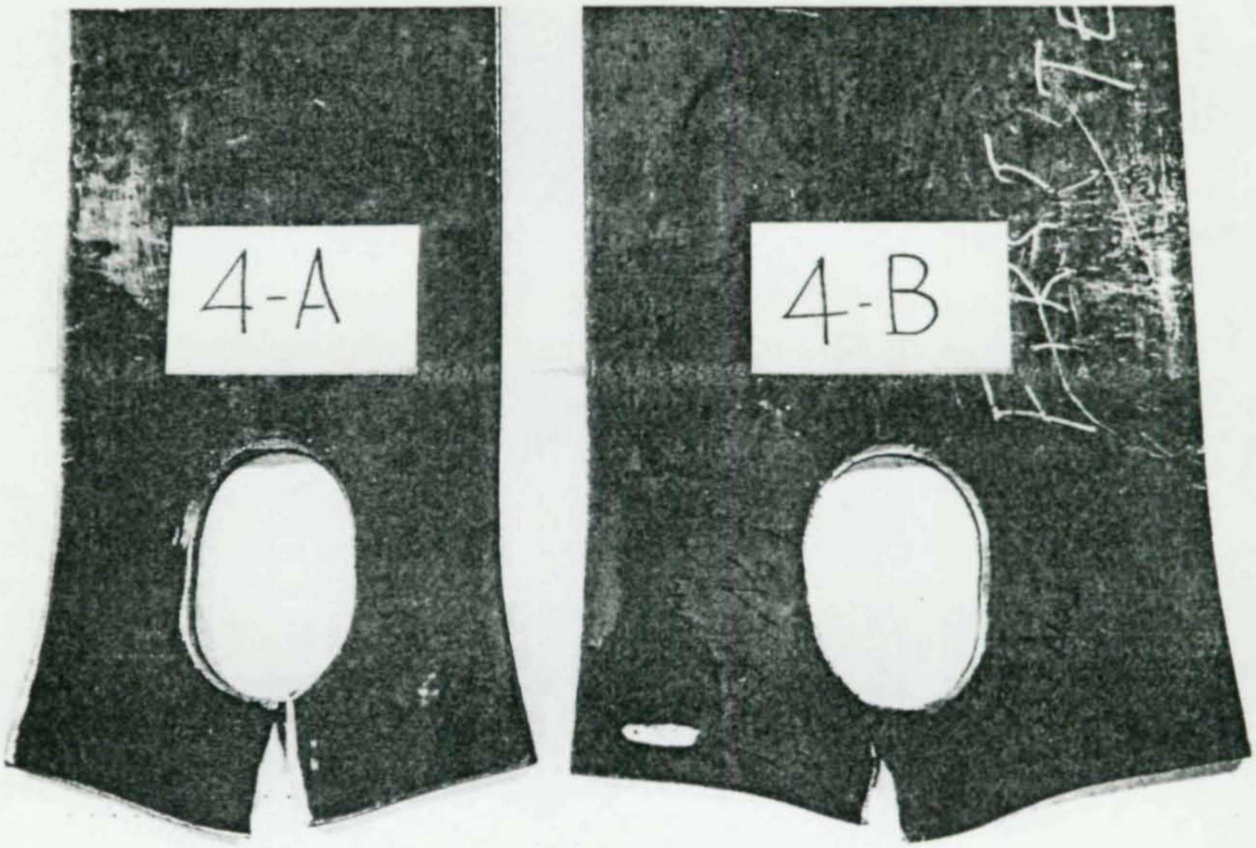
3/4-INCH (10 mm) PLATE-LINK SPECIMENS



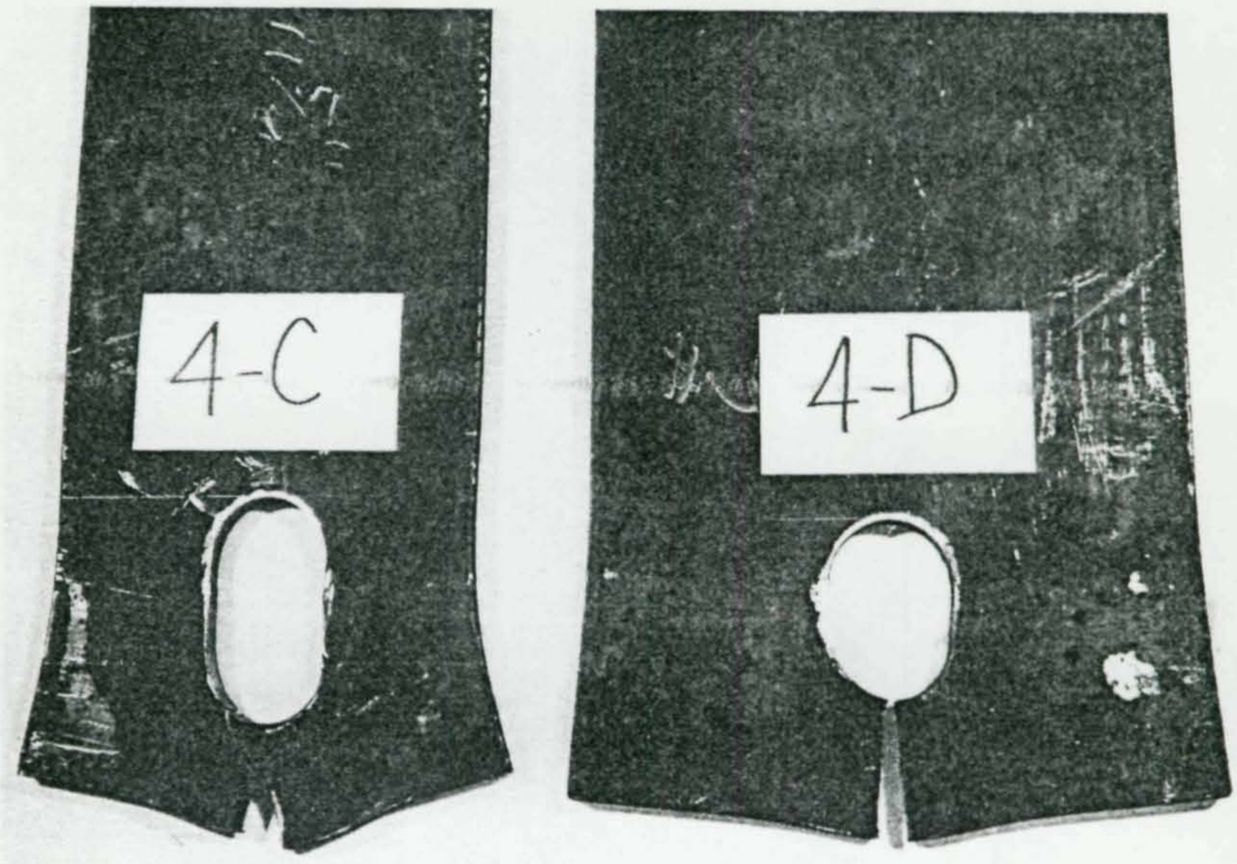
1/2-INCH (13 mm) PLATE-LINK SPECIMENS



1/2-INCH (13 mm) PLATE-LINK SPECIMENS



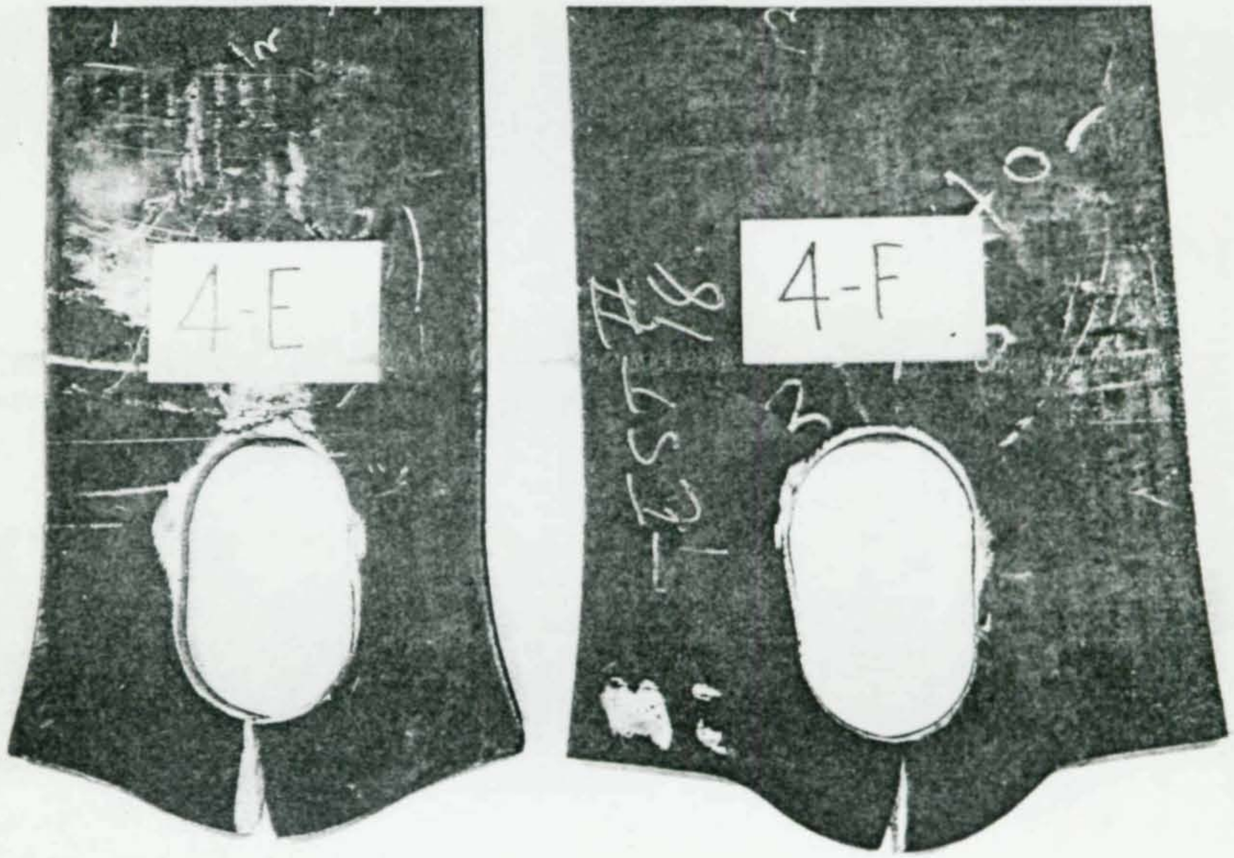
3/4-INCH (19 mm) PLATE-LINK SPECIMENS



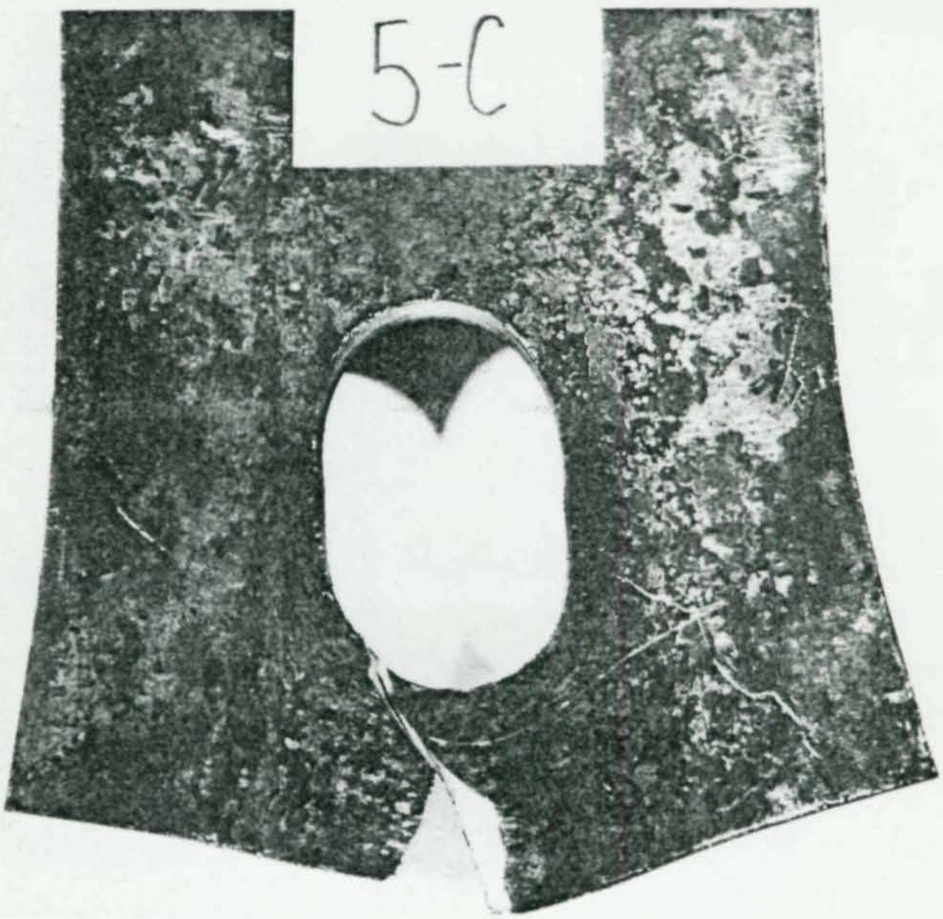
3/4-INCH (19 mm) PLATE-LINK SPECIMENS

P8553B-13

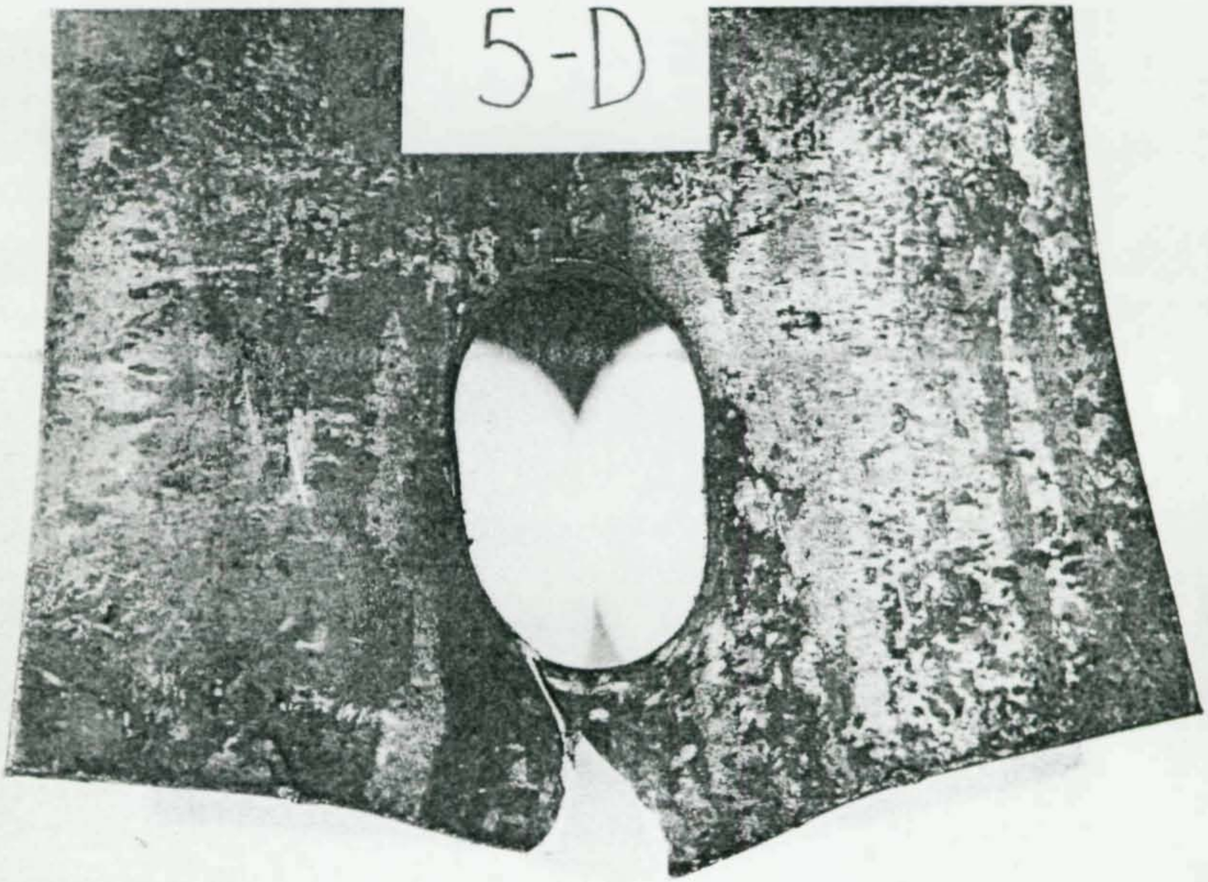
Figure 33



3/4-INCH (19 mm) PLATE-LINK SPECIMENS



1-1/4-INCH (32 mm) PLATE-LINK SPECIMEN



1-1/4-INCH (32 mm) PLATE-LINK SPECIMEN

1-3/4-INCH (44 mm) PLATE-LINK SPECIMEN

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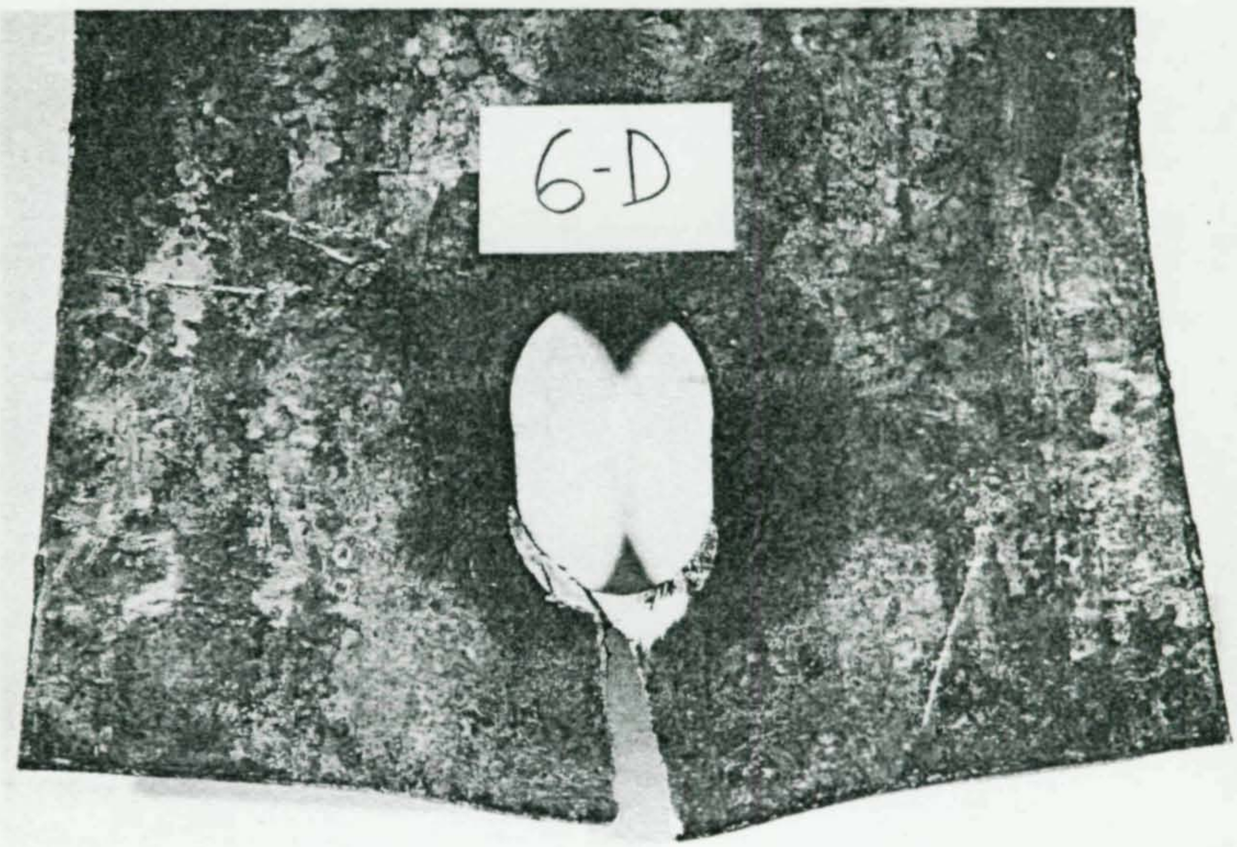
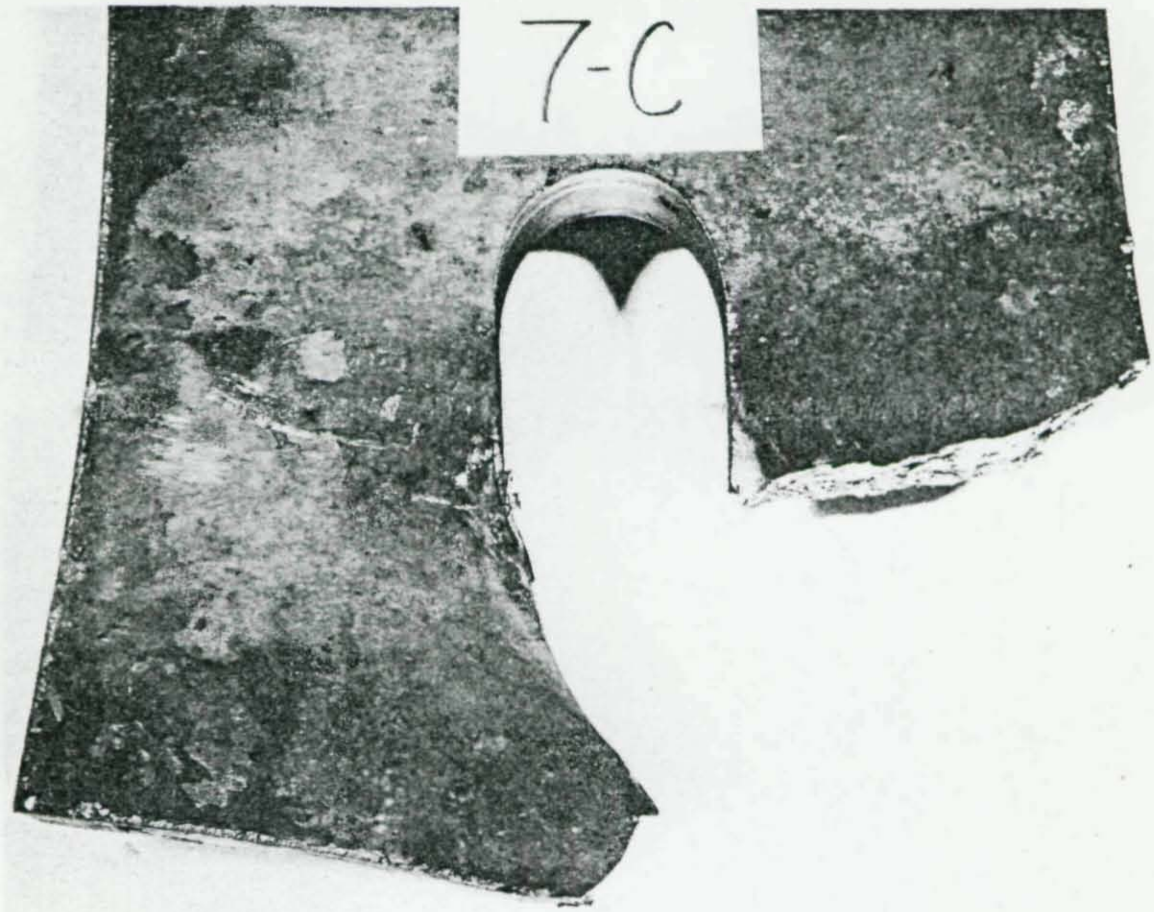
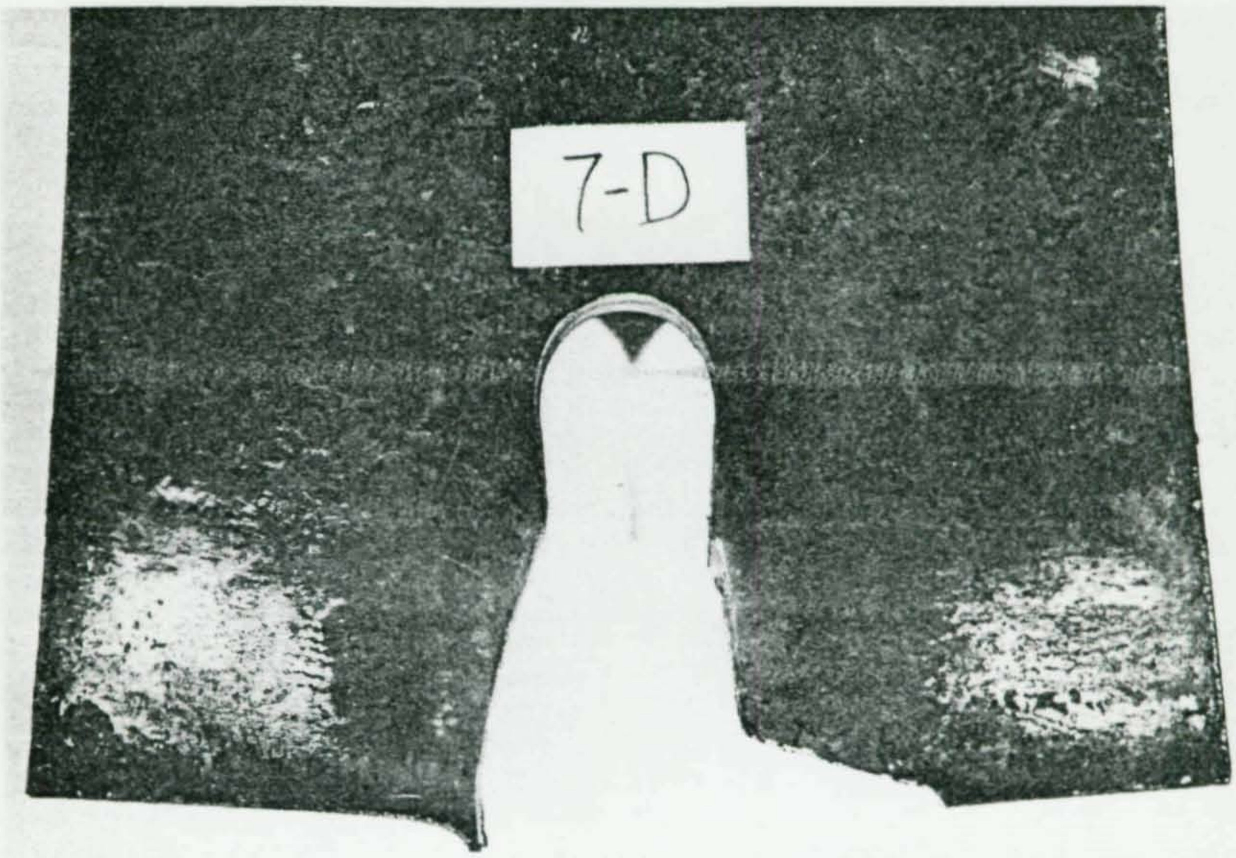
Figure 37



1-3/4-INCH (44 mm) PLATE-LINK SPECIMEN



2-INCH (50.8 mm) PLATE-LINK SPECIMEN



2-INCH (50.8 mm) PLATE-LINK SPECIMEN