EXPERIMENTAL INVESTIGATION OF TRUSS TYPE RIGID FRAMES INCLUDING CONNECTION STUDIES -BOTTOM CHORD STRUT CONNECTIONS- VOLUME I KN TEST RESULTS

by

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CHAPTER I

INTRODUCTION

1.1 General

Two tests of the knee area of truss type rigid frames were conducted at the Fears Structural Engineering Laboratory, University of Oklahoma as part of a continuing study of such frames under the sponsorship of VULCRAFT, a division of NUCOR Corporation, hereafter referred to as VULCRAFT. The tests are designated KN-1-2 and KN-6-2. The objective of the tests was to study the behavior of the knee portion of typical truss-type rigid frames when subjected to gravity loads and to verify the adequacy of a new column/rafter connection detail. The configuration of the test specimen and location of the line of action of the applied force was determined for each specimen so that the moment, shear, and thrust at the connection were identical to the internal forces of an actual frame subjected to combined dead plus full live loads. The testing procedure was similar to that reported in Volume I, Chapter IV of Report No. FSEL/VULCRAFT 84-02.

1.2 Overview

Each specimen consisted of a portion of a column and a rafter from a truss-type rigid frame, Figure 1.1(a). The sections were connected as shown in Figure 1.1(b). The

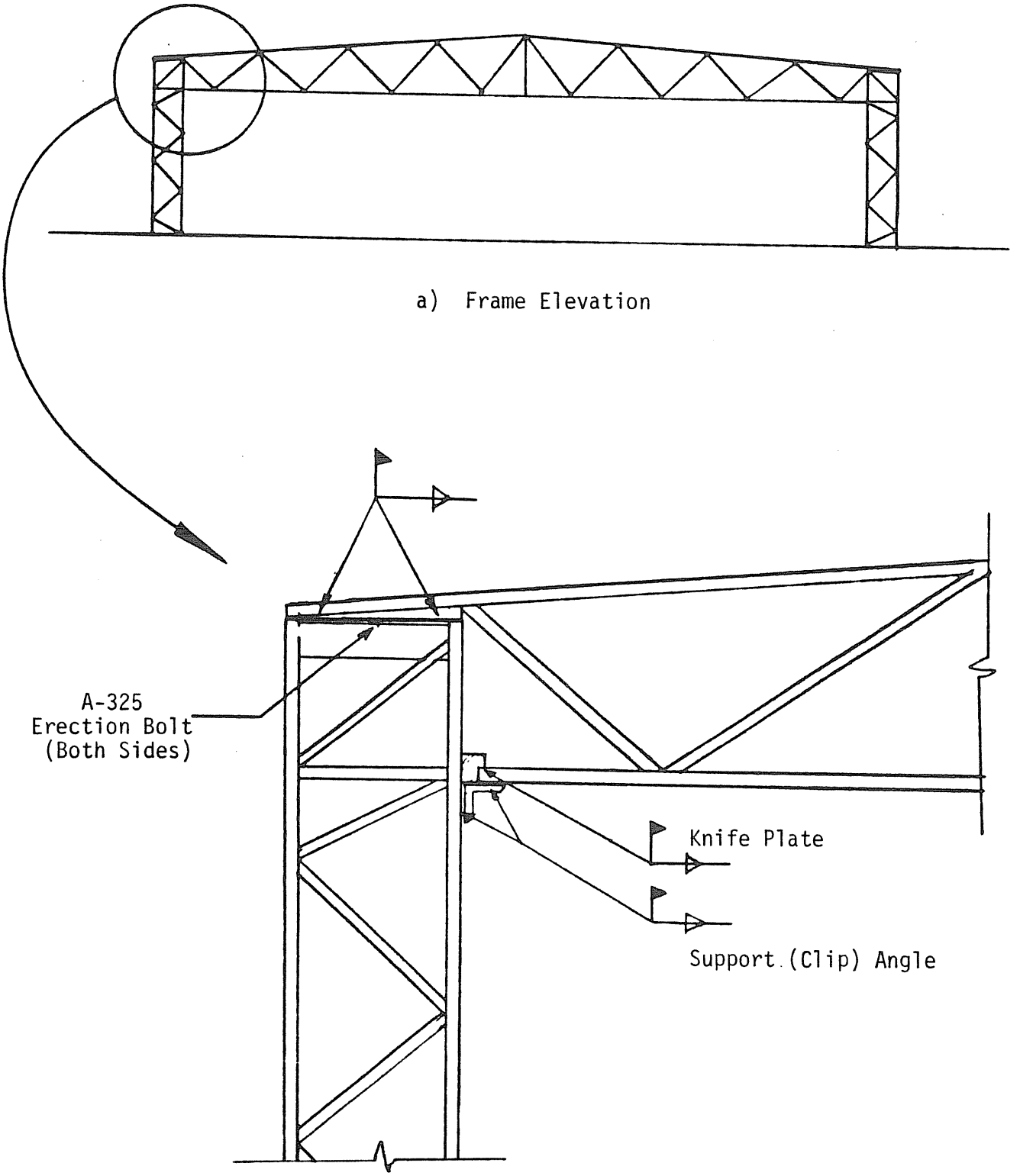


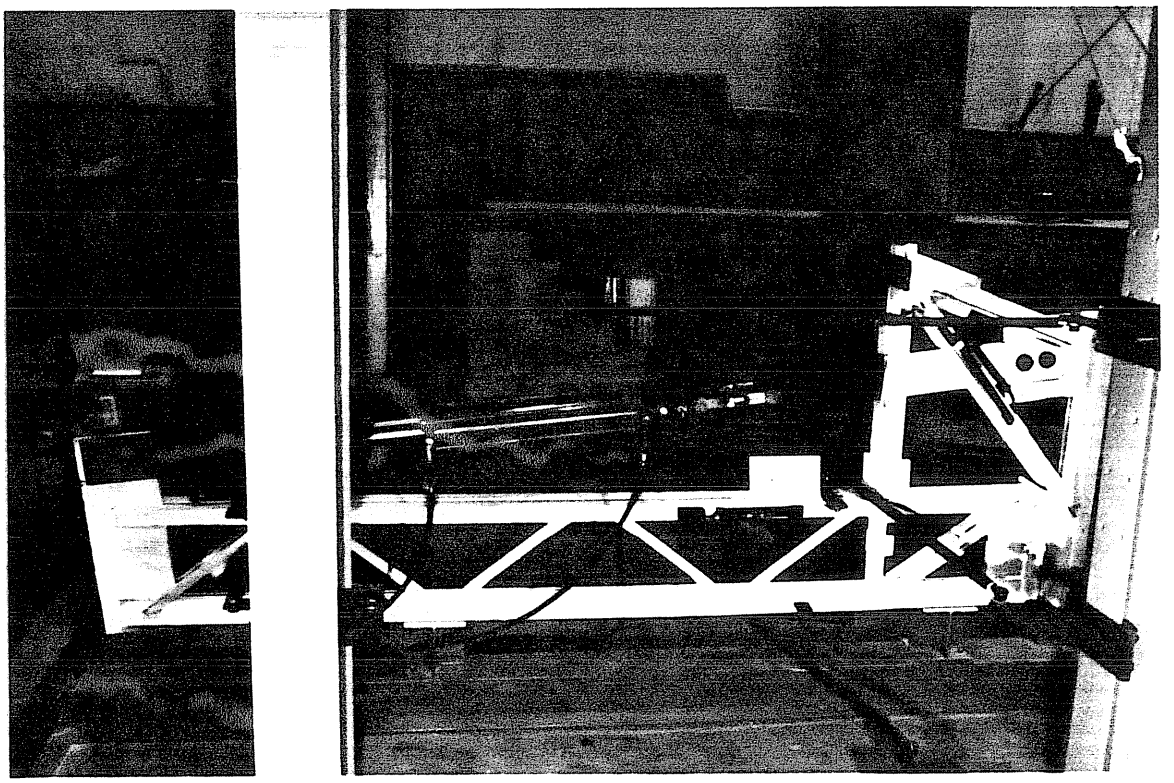
FIGURE 1.1 ELEVATION VIEW OF A TYPICAL TRUSS-TYPE RIGID FRAME WITH EXPERIMENTAL CONNECTION DETAIL

specimens were tested with the column section placed in a horizontal position and with the rafter section extending vertically as shown in Figures 1.2 and 1.3. A single test load was applied such that the only external reaction necessary was the support of the self-weight of the specimen.

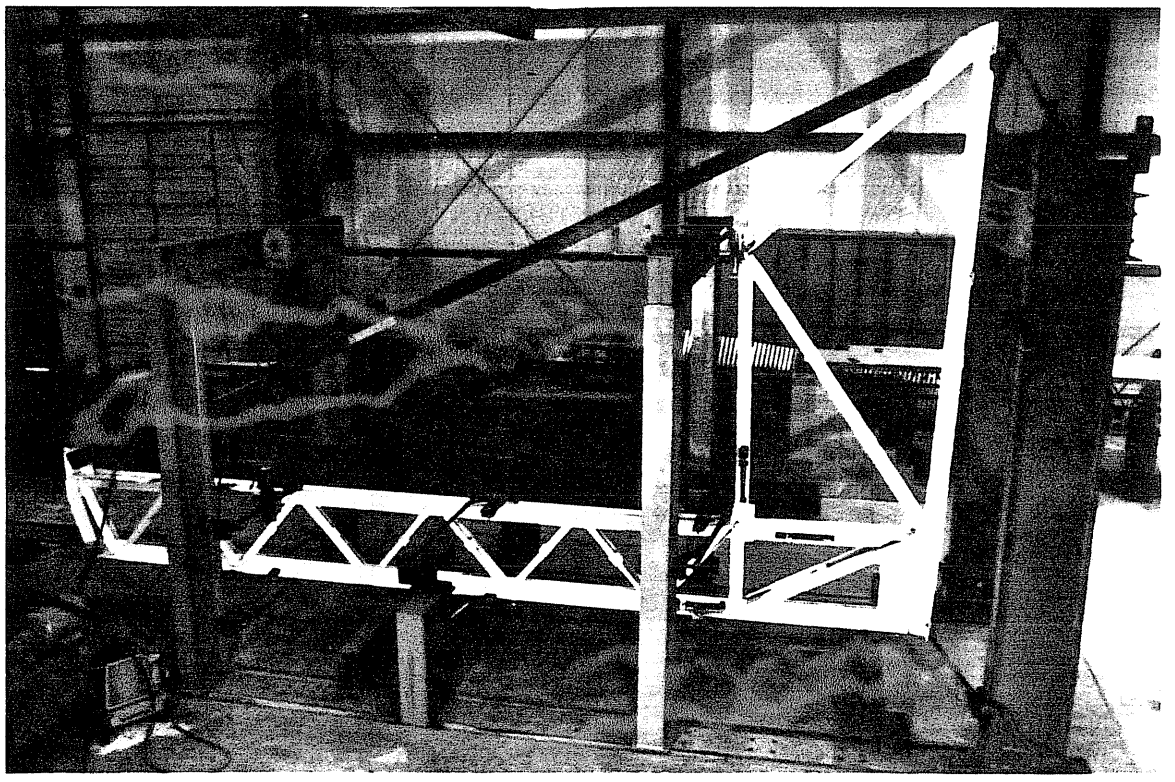
Tests were conducted on two specimens designated as KN-1-2 and KN-6-2. Specimen details and test data may be found in the Appendices A and B, respectively, of this report.

1.3 Analysis of Specimens

Analysis of each specimen was performed by Vulcraft. The specimens were analyzed using a computerized elastic stiffness analysis with all members considered to be pin connected at the joints. The results of the computer analysis included member forces and specimen deflections which were used as theoretical predictions to which test results were compared. Failure loads were calculated from individual member strengths which, in turn, were calculated using appropriate specification provisions. Calculations were based on an assumed yield stress of 55 ksi.



(a) KN-1-2



(b) Test KN-6-2

FIGURE 1.2 PHOTOGRAPHS OF THE TEST SET-UPS

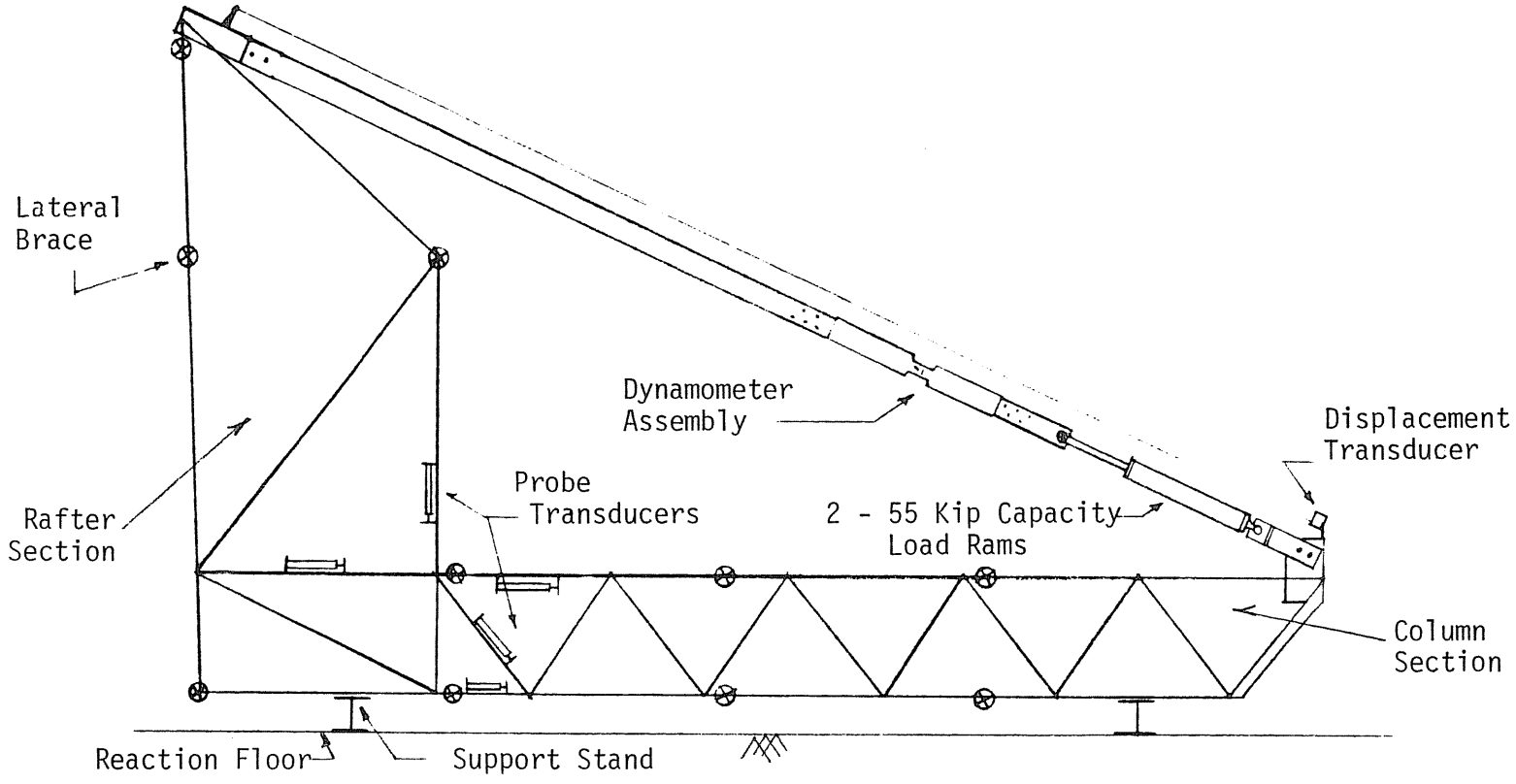


FIGURE 1.3 TYPICAL KNEE TEST SETUP AND INSTRUMENTATION

CHAPTER II

TESTING DETAILS

2.1 Test Setup

The test setup consisted of the knee area specimen which rested on support stands, a pair of hydraulic rams connected to the load points thru a dynamometer assembly, and lateral brace mechanisms which only prevent transverse movement of a brace point. The lateral brace mechanisms were attached to support frames which were bolted to the reaction floor.

The assembly of the test setup consisted of bolting and welding the rafter to the column as shown in Figure 1.1(b), coating the specimen with "white wash", placing the specimen on the support stands, and connecting the lateral brace mechanisms. The load rams and dynamometer assembly were then attached to the specimen and the specimen was instrumented.

2.2 Test Specimens

All specimens were fabricated by VULCRAFT at their Brigham City Plant from angles and plates having a nominal yield stress of 50 ksi. Shop drawings of each specimen may be found in the appendices. (Specimen KN-1-2 is similar to

specimen KN-1 and KN-6-2 is similar to specimen KN-2 of the previously cited report).

2.3 Instrumentation

Instrumentation as shown in Figure 1.3 consisted of a displacement transducer mounted so that the relative displacement of the load points along the line of action of the load could be measured, probe transducers attached to critical members so that member strain (and elastic member force) could be calculated, and a dynamometer so that applied load could be monitored. Instrumentation varied between tests only in the locations of the probe transducers. All instrumentation was connected to a micro-computer based data acquisition system which was used to process and plot data as the testing progressed.

2.4 Testing Procedure

In each test, the specimen was incrementally loaded to approximately 10% of the predicted failure load. This was done so that the instrumentation and test setup could be checked. The specimen was then unloaded and the actual test began.

After the initial loading, the ram load was applied in increments of 5-10% of the predicted failure load until failure was achieved. At each load increment, instrumentation readings were recorded and plots were made of load versus displacement along the line of action of the load, and load versus member force for a critical member. These plots were compared to predicted curves obtained from the stiffness analysis. Also, at each load increment the

specimen was studied for signs of yielding and member failure. Failure was defined as loss of stiffness of the specimen marked by a leveling of the load versus displacement curve.

2.5 Supplementary Tests

Upon completion of all testing, sections of undamaged members were out of the specimens. The sections were then sent to the VULCRAFT, Norfolk, Nebraska facility where both angles from each member were tested using a specially designed angle test device mounted in a universal testing machine. The location of the tested members, yield stresses, tensile strengths and percent elongations at failure are found in Section 3.4. The coupons conformed to ASTM A370 requirements.

CHAPTER III

TEST RESULTS AND COMPARISONS

3.1 General

Test results consist of a test summary sheet, load versus displacement along the line of action of applied load, and load versus member force for critical members in the knee area. Comparisons to predicted displacements and member forces are made using the results of the stiffness analysis for the specimen. The prediction curves are based on the assumption of a linear relationship between the applied load and the quantity plotted.

The predicted ultimate load was obtained by multiplying the working load by 1.67. Working load levels were supplied by VULCRAFT.

Detailed results for each test are found in the Appendices A and B of this report. Each appendix contains a test summary sheet, a test setup and instrumentation sketch, a sketch of the connection detail, a member number and lateral brace location sketch, specimen shop drawings, theoretical analyses, and the aforementioned plots. Appendix C is a steel inventory for correlating the section codes on the shop drawings to the physical properties of the individual members used in the specimens. A discussion

of each test follows.

3.2 TEST KN-1-2

The results of this test are outlined in the test summary, page A.1 of Appendix A. The capacity of the load rams (70.0 kips) was reached prior to failure of the specimen. The maximum applied load was 2.12 times the working load (33.0 kips); the required safety factor of 1.67 was exceeded by nearly 27%. Figure 3.1 shows the specimen under maximum applied load.

Figure A.6 shows the theoretical and experimental curves for load versus displacement in the load direction. The stiffness of the specimen was close to that predicted to approximately 60 kips (1.8 times the working load) at which load the specimen began to loose stiffness

Figures A.7 to A.9 are plots of predicted and experimental member force versus applied load for members #4, #11, and #21 (see Figure A.2 for location). At working load, the measured force in member #4 was approximately 67% less than predicted; the measured force in member #11 was approximately 37% less than predicted; and the measured force in member #21 was approximately 41% less than predicted. The member force plots do not continue to the maximum applied load because the probe transducers were removed at an earlier load to prevent damage due to a possible sudden failure of a member.

3.3 TEST KN-6-2

The results of this test are outlined in the test

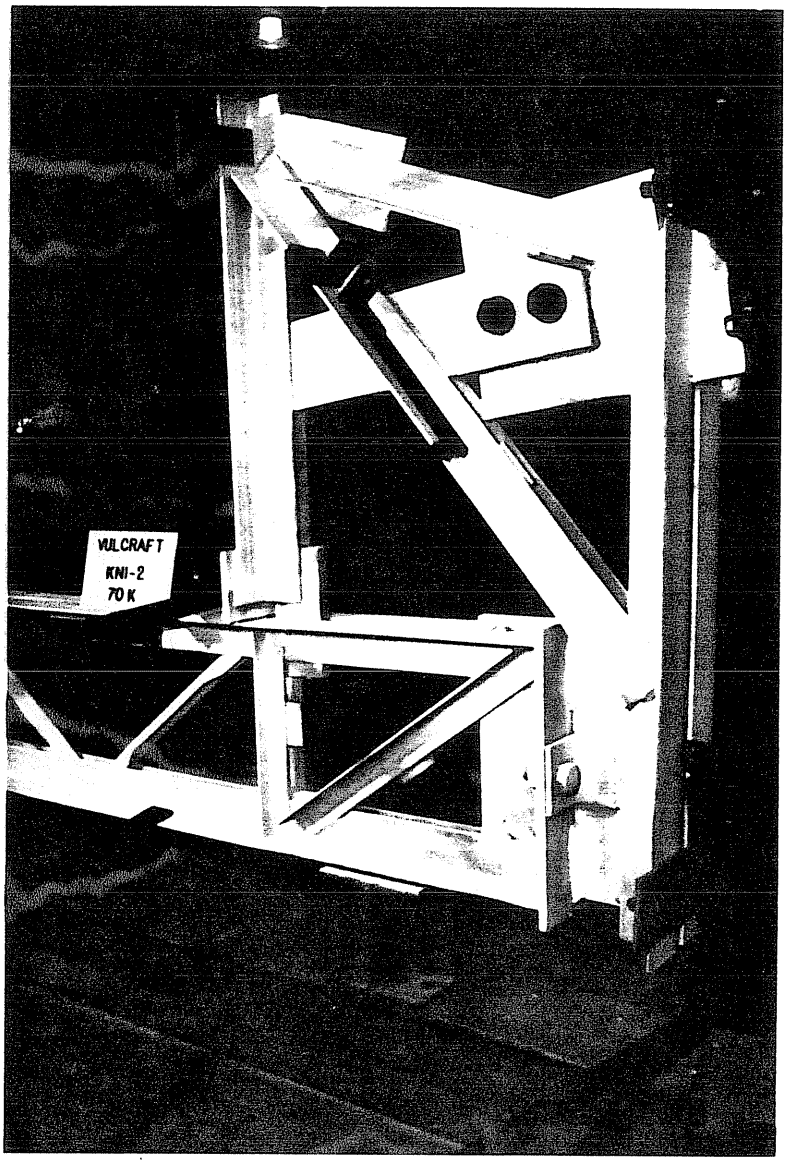


FIGURE 3.1 PHOTOGRAPH OF SPECIMEN KN-1-2 UNDER MAXIMUM LOAD

summary on page B.1 of Appendix B. Failure of this specimen occurred at 97.0 kips, which was 1.68 times the working load (57.8 kips). Figure 3.2 shows the specimen under maximum applied load. Figure B.6 shows the theoretical and experimental curves for load versus displacement in the load direction. The stiffness of the specimen was relatively close to that predicted up to working load. The specimen then softened at an increasing rate until failure was reached.

The failure mode of this specimen was buckling of member #29, the inside vertical member of the knee area. An attempt to increase the load past 97.0 kips resulted in the failure of the stitch angle which was welded at midspan of member #10 causing, in turn, the angles of the member to buckle about their respective Z-axes. The instability of member #29 is not apparant in the plots of member force versus applied load, Figure B.11, because the probe transducers were removed at an earlier load to prevent damage.

Figure B.7 is a plot of predicted and experimental member force versus applied load for member #6. The plot shows that with an increase in applied load, the member force increased at a decreasing rate. At an applied load of 70.0 kips, the member force curve becomes nearly vertical but this does not indicate complete yielding of the member cross section since the measured quantity was strain which became constant. At working load, the measured member force was 36% less than predicted.

Figure B.8 is a plot of member force versus applied load for member #15. The plot shows that with an increase

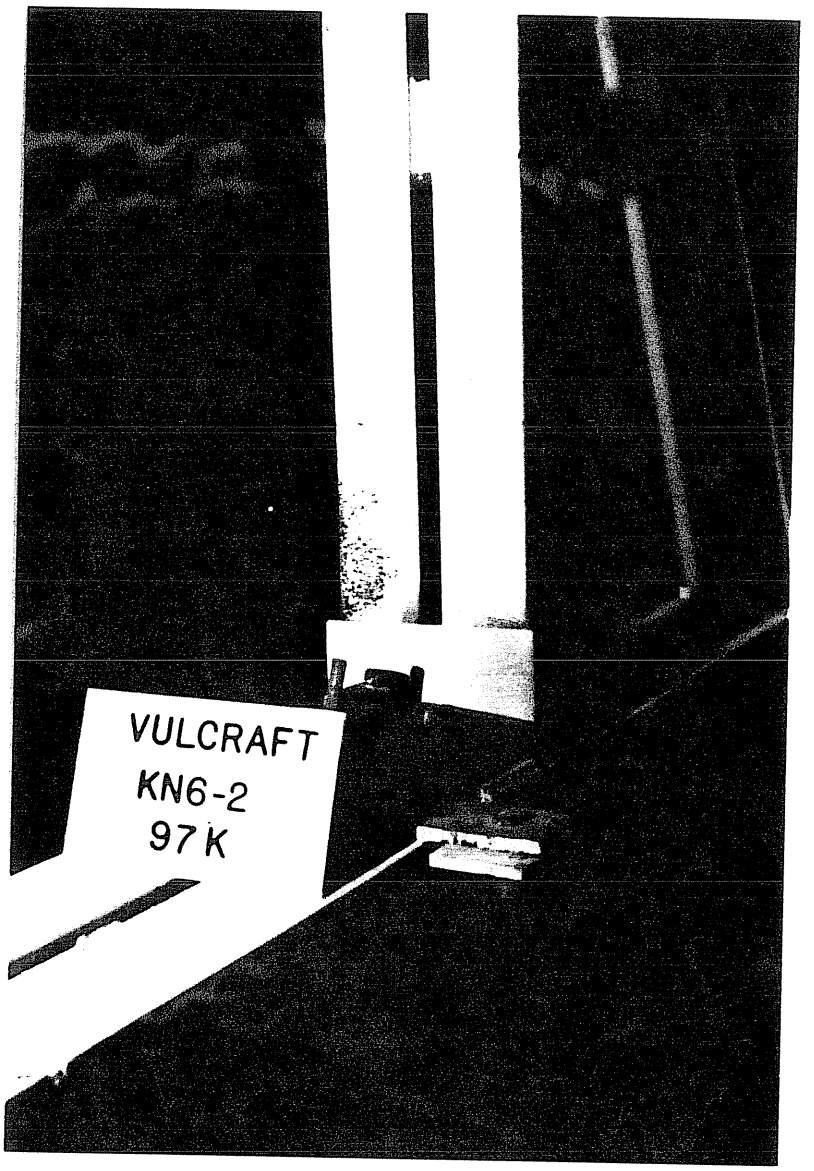


FIGURE 3.2 PHOTOGRAPH OF SPECIMEN KN-6-2 UNDER MAXIMUM LOAD

in applied load, the member force increased at a relatively constant rate; and at working load, the member force was 32% less than predicted.

Figure B.9 is a plot of member force versus applied load for member #16. The plot shows that with an increase in applied load, the member force increased at nearly the same rate; and at working load, the member force was 2% less than predicted.

Figure B.10 is a plot of member force versus applied load for member #26. The plot shows that the force in this member was nearly identical to the predicted force.

Figure B.11 is a plot of member force versus applied load for member #29. The plot shows that the member force was close to that predicted to about 50 kips applied load, at which point the rate of increase in member force slightly exceeded that predicted. It was observed during the test that when the applied load passed 60 kips, member #29 assumed a double curvature which would have added to its stiffness.

3.4 Supplementary Test Results

Results of the tensile coupon tests are given in Table 3.1. The average yield stress for the samples cut from specimen KN-1-2 is 54.3 ksi and for specimen KN-6-2, 54.5 ksi.

Table 3.1

Tensile Coupon Test Results

Specimen	Description	Location On Test Specimen	Yield Stress (ksi)	Tensile Strength (ksi)	Elongation (%)
KN-1-2	Angles				
	3x3x0.287	Member 3	54.7	81.7	26.7
	3x3x0.293	Member 3	53.8	80.4	26.8
KN-6-2	Coupons				
	1 1/2"x0.445"	Member 9	55.4	85.2	25.1
	1 1/2"x0.450"	Member 9	55.3	86.5	24.9
	1 1/2"x0.500"	Member 2	52.7	82.7	26.1

CHAPTER IV

CONCLUSIONS

The stiffnesses for both knee tests corresponded well to the predicted stiffnesses. The member forces measured in Test KN-1-2 were considerably less than predicted, but the member forces measured in Test KN-6-2 correspond well to the predicted values except for member #6 and #15. In all member measurements, the probe transducer readings may have been affected by changes in member curvature.

In both tests,the maximum applied loads exceeded the required load of 1.67 times the working load.

APPENDIX A

KNEE AREA TEST DATA

TEST KN-1-2

VULCRAFT KNEE CONNECTION TEST SUMMARY

Project: VULCRAFT

Test No.: KN-1-2

Test Date: March 14, 1985

Purpose: Study of Behavior of Knee Area

Knee Area Dimensions: 23.5 in. x 16.0 in.

Knee Diagonal Length: 23.0 in.

Size of Support (Clip) Angle: 5 x 5 x 1/2 x 9 in.

Knife Plate Detail: Not welded to bottom chord of rafter

Failure Load: Failure was not reached due to exceedence of ram capacity

Failure Mode:

Predicted Failure Load:

Method: VULCRAFT Analysis **Load:** $33^k \times 1.67 = 55.1^k$

Predicted Failure Mode: Instability of member 11

Maximum Displ. in Load Direction: 0.727 in. @ 70.0 kips

Discussion:

Observations:

- At 6 kips, some minor yielding at the ends of members 18 and 19 was noted.
- At 33 kips (working load), no important yielding had occurred.
- At 70.0 kips (2.12 x 33 kips), the test was stopped due to exceedence of load ram capacity, and no important yielding had occurred.

Loading and deformations:

- At working load (33 kips), deflection was 0.314 inches.
- Maximum applied load was 70.0 kips with a deflection of 0.727 inches.
- At working load, axial micro strain in member 4 was 91.617 in/in (Tension)
- At working load axial micro strain in member 11 was 495.5 in/in (Compression)
- At working load axial micro strain in member 21 was 389.9 in/in (Tension)

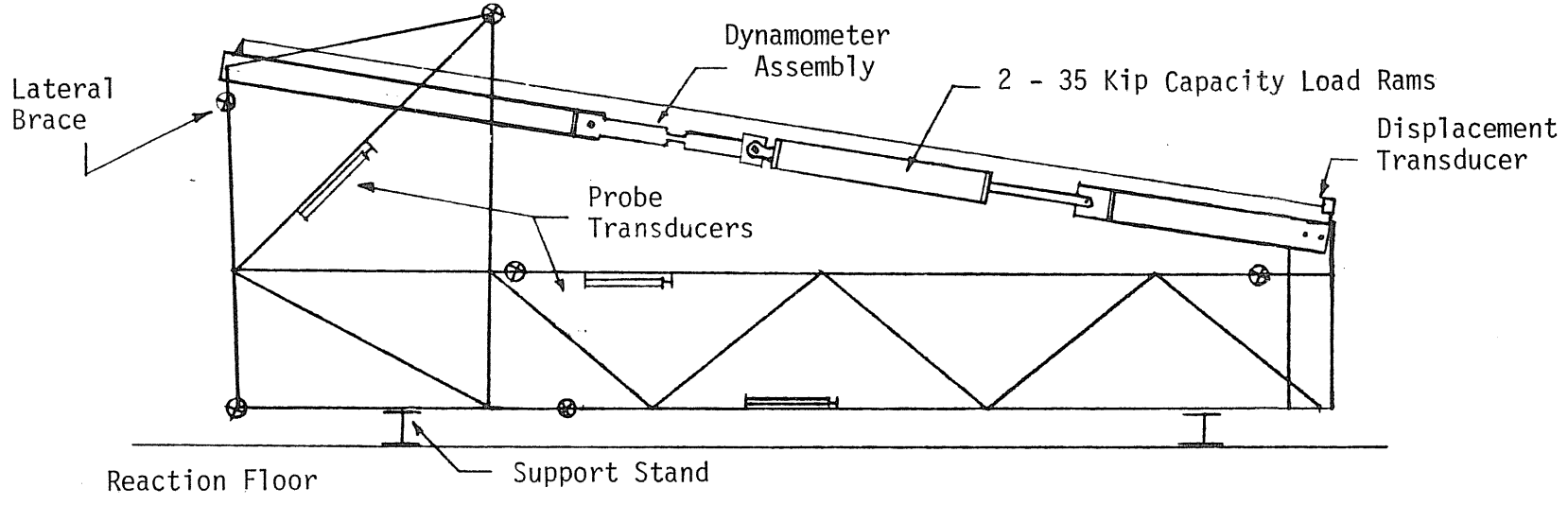


FIGURE A.1 KNEE TEST SETUP, TEST KN-1-2

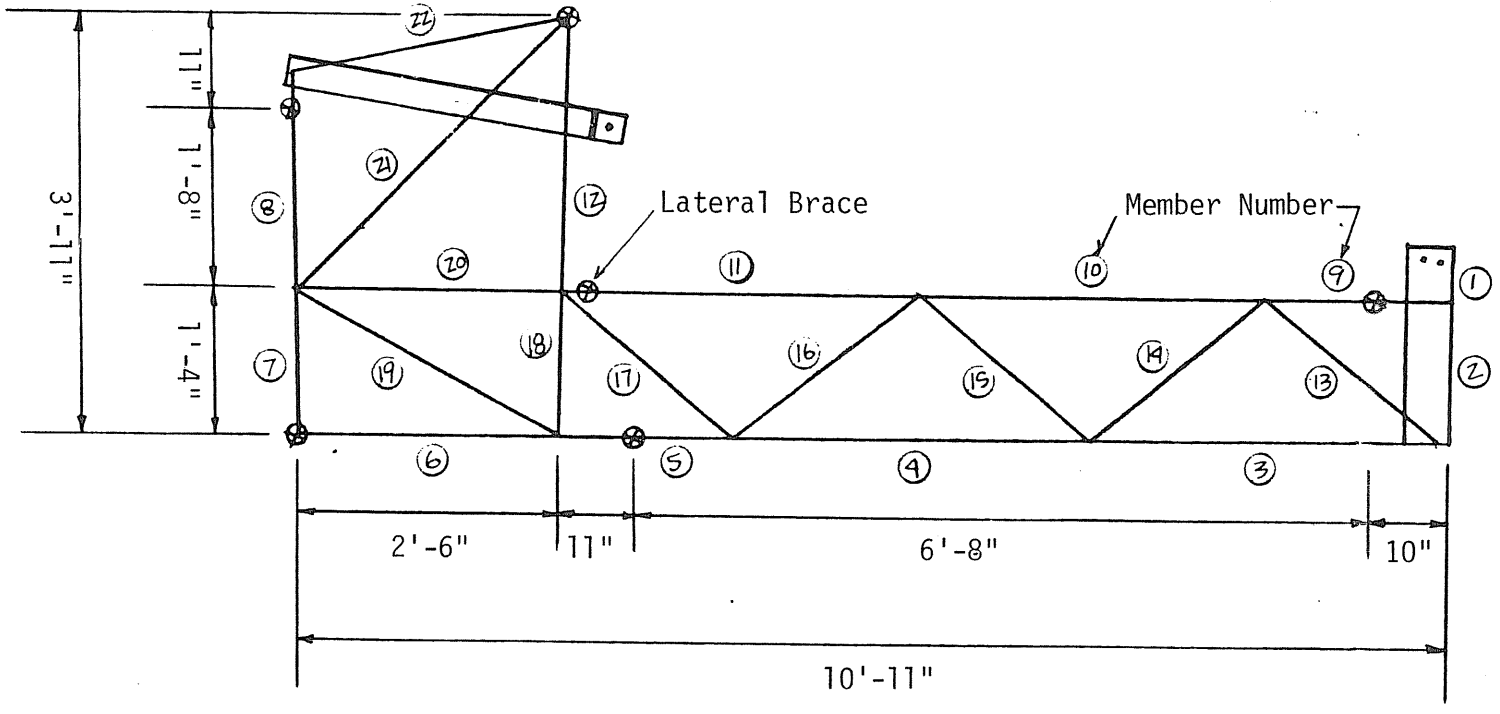


FIGURE A.2 SPECIMEN MEMBER NUMBERS AND LATERAL BRACE LOCATIONS, TEST KN-1-2

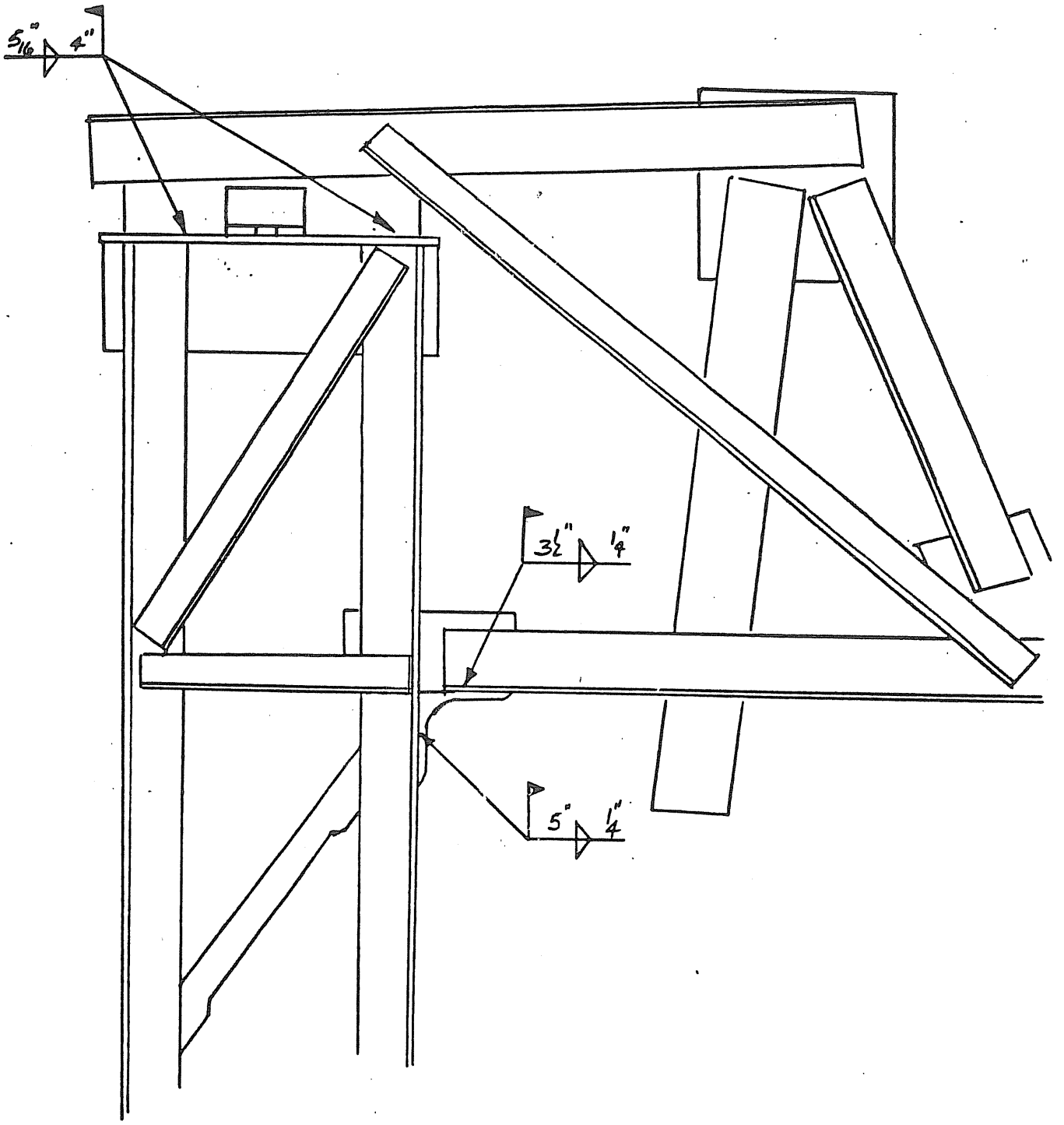
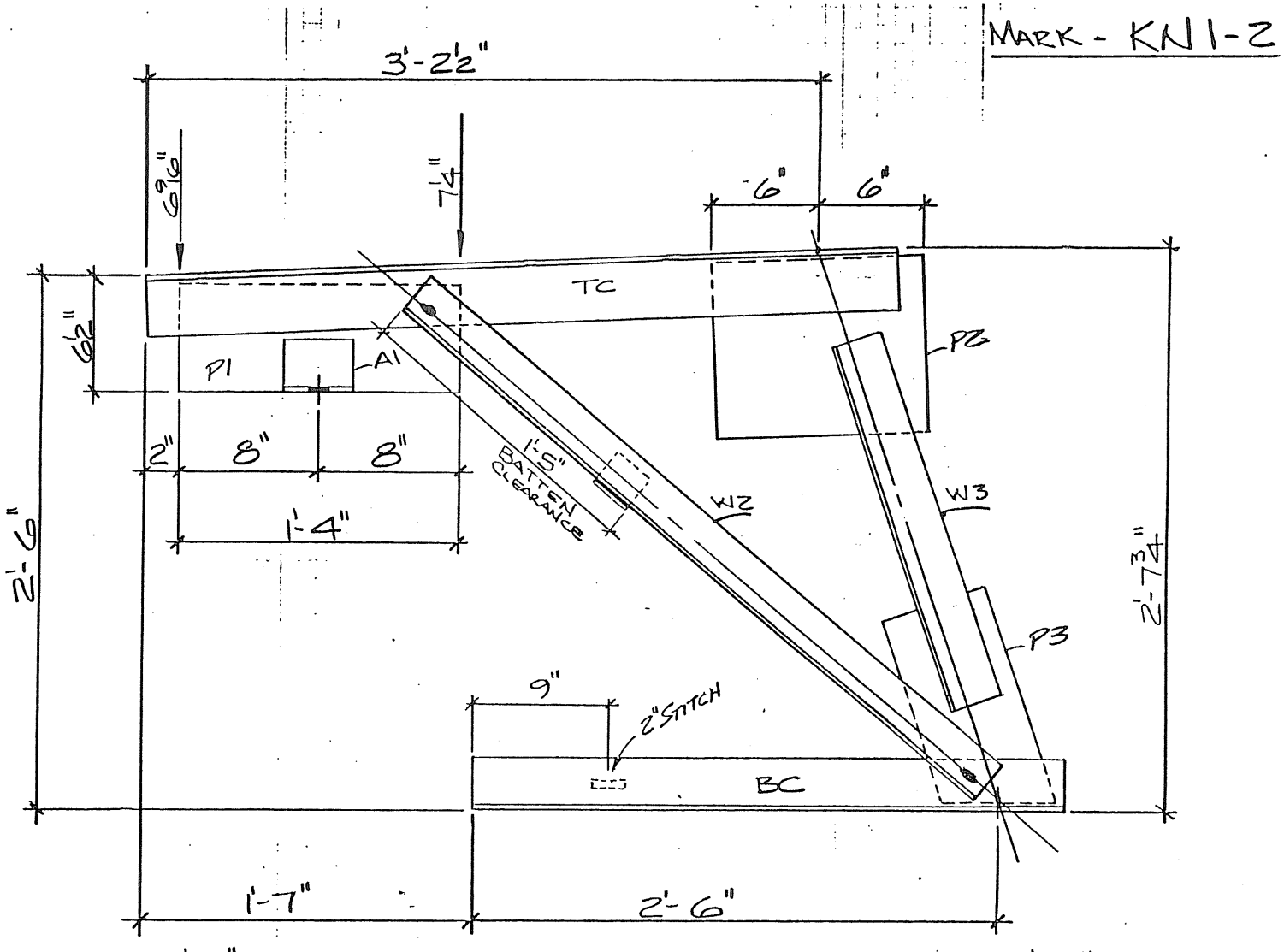


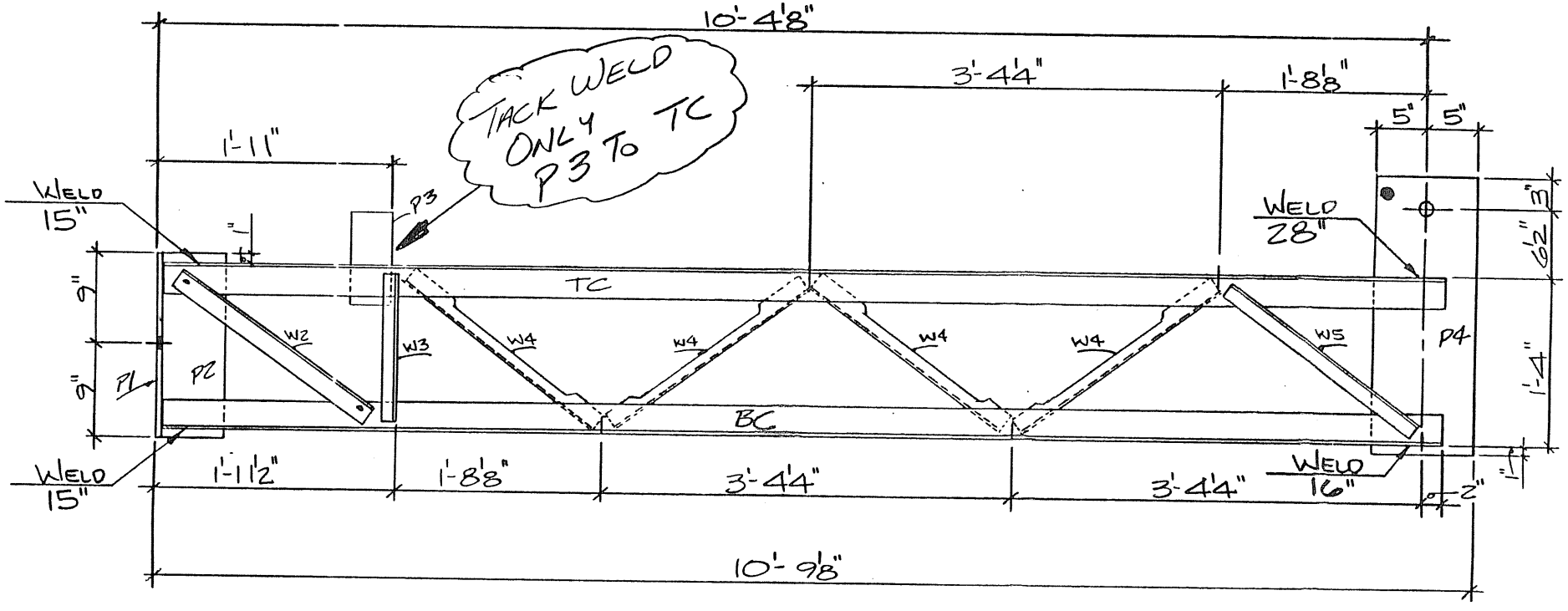
FIGURE A.3 KNEE CONNECTION DETAIL, TEST KN-1-2



2- TC - SEC. 54 - 3'-7"
2- BC - SEC. 48 - 2'-10"
2- W2 - SEC. 39 - 3'-7" WELD 16.4" BATTEN SLOT WELD
2- W3 - SEC. 43 - 1'-9½" WELD 24.4"
2- A1 - SEC. 57 - 4" WITH 1 1/16" Ø HOLES 5" GA.

1- P1 - 6x1 PL x 1'-4"
1- P2 - 10x1 PL x 1'-0"
1- P3 - 6x1 PL x 1'-1" W/ 2" SKEW

FIGURE A.4 SHOP DRAWINGS, TEST KN-1-2



2- TC - SEC. 46 - 10'-5⅝"
2- BC - SEC. 46 - 10'-5⅝"
2- W2 - SEC. 31 BS - 1'-11" WELD 16.8"
2- W3 - SEC. 19 B - 1'-2½" WELD 7.9"
4- W4 - SEC. 16 - 1'-11¼" WELD 3.4"
2- W5 - SEC. 16 B - 1'-11" WELD 6.0"
1- P1 - 8x½" R x 1'-5" WITH 2- 1/16" Ø HOLES 5" GA.
1- P2 - 6x1" R x 1'-5"
1- P3 - 4x1 R x 9"
1- P4 - 10x1" R x 2'-2½" WITH 1 5/16" Ø HOLE (DRILLED)

KN1-2

FIGURE A.4 SHOP DRAWINGS, TEST KN-1-2, CONTINUED

SID FRAME TEST #2 KN1-2 FINAL RUN 1-29-85

STIFFNESS METHOD OF RIGID FRAME AND TRUSS ANALYSIS

NO OF NP = 26 NO OF MEMBERS = 22 NO OF LOAD CONDIT = 1
NO NLC TO WIND NLC = 0 NO NON-ZERO P = 2 METRIC (1 =METRIC)
NO ISTIFF ZEROED = 286 MOD ELASTICITY = 29000.0 IWRITX = 1 IW

NLC FOR D + L = 0 NLC FOR WIND ON BEAM = 0

MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
1	1	2	3	4	5	0	-6.42	0.00	6.42	10.00	83.30
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
2	4	5	6	7	8	9	-16.00	0.00	16.00	10.00	83.30
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
3	8	9	12	13	0	0	0.00	40.25	40.25	3.21	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
4	12	13	16	17	0	0	0.00	40.25	40.25	3.21	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
5	16	17	20	21	0	0	0.00	20.13	20.13	3.21	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
6	20	21	22	23	0	0	0.00	30.00	30.00	3.21	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
7	22	23	24	25	0	0	16.00	0.67	16.01	4.58	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
8	24	25	27	27	0	0	20.49	0.85	20.50	4.58	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
9	5	6	10	11	0	0	0.00	20.13	20.13	3.21	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
10	10	11	14	15	0	0	0.00	40.25	40.25	3.21	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
11	14	15	18	19	0	0	0.00	40.25	40.25	3.21	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
12	18	19	26	27	0	0	31.00	0.00	31.00	3.56	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
13	8	9	10	11	0	0	16.00	20.13	25.71	0.74	1.00
EMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
14	12	13	10	11	0	0	16.00	-20.13	25.71	0.37	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
15	12	13	14	15	0	0	16.00	20.13	25.71	0.37	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
16	16	17	14	15	0	0	16.00	-20.13	25.71	0.37	1.00

FIGURE A.5 STIFFNESS ANALYSIS, TEST KN-1-2

EMBER	NP1	NP2	NP3	NP4	NP5	NPo	H	V	L	A	I
17	16	17	18	19	0	0	16.00	20.13	25.71	0.37	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NPo	H	V	L	A	I
18	20	21	18	19	0	0	16.00	0.00	16.00	0.89	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
19	20	21	24	25	0	0	16.00	30.67	34.59	1.75	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
20	18	19	24	25	0	0	0.00	30.67	30.67	3.21	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
21	24	25	26	27	0	0	31.00	-30.67	43.61	2.37	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
22	27	27	26	27	0	0	10.52	-31.52	33.23	2.62	1.00

NO. STIFI(I) ENTRIES = 280, BAND WIDTH = 11

THE P-MATRIX, K AND 'K

NP=	1	0.00
NP=	2	3.49
NP=	3	32.80
NP=	4	0.00
NP=	5	0.00
NP=	6	0.00
NP=	7	0.00
NP=	8	0.00
NP=	9	0.00
NP=	10	0.00
NP=	11	0.00
NP=	12	0.00
NP=	13	0.00
NP=	14	0.00
NP=	15	0.00
NP=	16	0.00
NP=	17	0.00
NP=	18	0.00
NP=	19	0.00
NP=	20	0.00
NP=	21	0.00
NP=	22	0.00
NP=	23	0.00
NP=	24	0.00
NP=	25	0.00
NP=	26	0.00

THE X-MATRIX IN OR RADIANS

NX =	1	-0.01
NX =	2	0.60
NX =	3	0.23
NX =	4	-0.01
NX =	5	0.60
NX =	6	0.17

FIGURE A.5 STIFFNESS ANALYSIS, TEST KN-1-2, CONTINUED

NX =	7	-0.01
NX =	8	0.60
NX =	9	0.04
NX =	10	0.44
NX =	11	0.16
NX =	12	0.28
NX =	13	0.05
NX =	14	0.15
NX =	15	0.14
NX =	16	0.04
NX =	17	0.06
NX =	18	-0.04
NX =	19	0.11
NX =	20	-0.03
NX =	21	0.07
NX =	22	-0.00
NX =	23	0.07
NX =	24	-0.00
NX =	25	0.09
NX =	26	-0.05

LOADING CONDITION NO = 1

MEMBER	AXIAL FORCE - K	DESIGN END MOMENTS CORRECTED FOR FEM AND WIND (NEAR END FIRST), FT-K	
1	3.49	-0.00	17.56
2	3.49	-17.56	0.00
3	17.56	----	----
4	26.34	----	----
5	35.12	----	----
6	-0.00	----	----
7	0.00	----	----
8	-14.25	----	----
9	-45.97	----	----
10	-54.75	----	----
11	-63.53	----	----
12	-21.82	----	----
13	-5.61	----	----
14	5.61	----	----
15	-5.61	----	----
16	5.61	----	----
17	-5.61	----	----
18	-18.32	----	----
19	39.62	----	----
20	-67.92	----	----
21	45.80	----	----
22	-33.95	----	----

FIGURE A.5 STIFFNESS ANALYSIS, TEST KN-1-2, CONTINUED

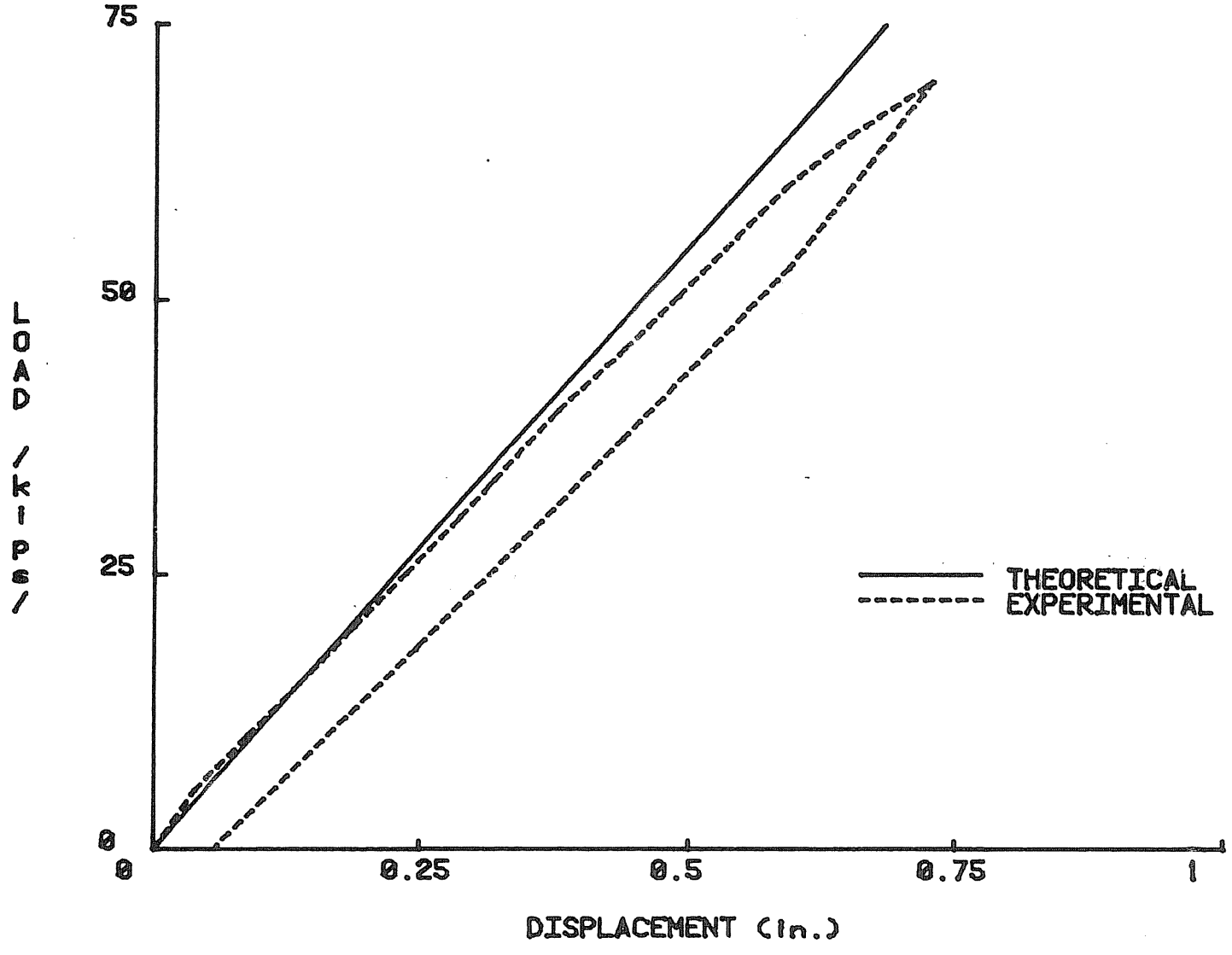


FIGURE A.6 LOAD VS. DISPL. IN LOAD DIRECTION, KN-1-2

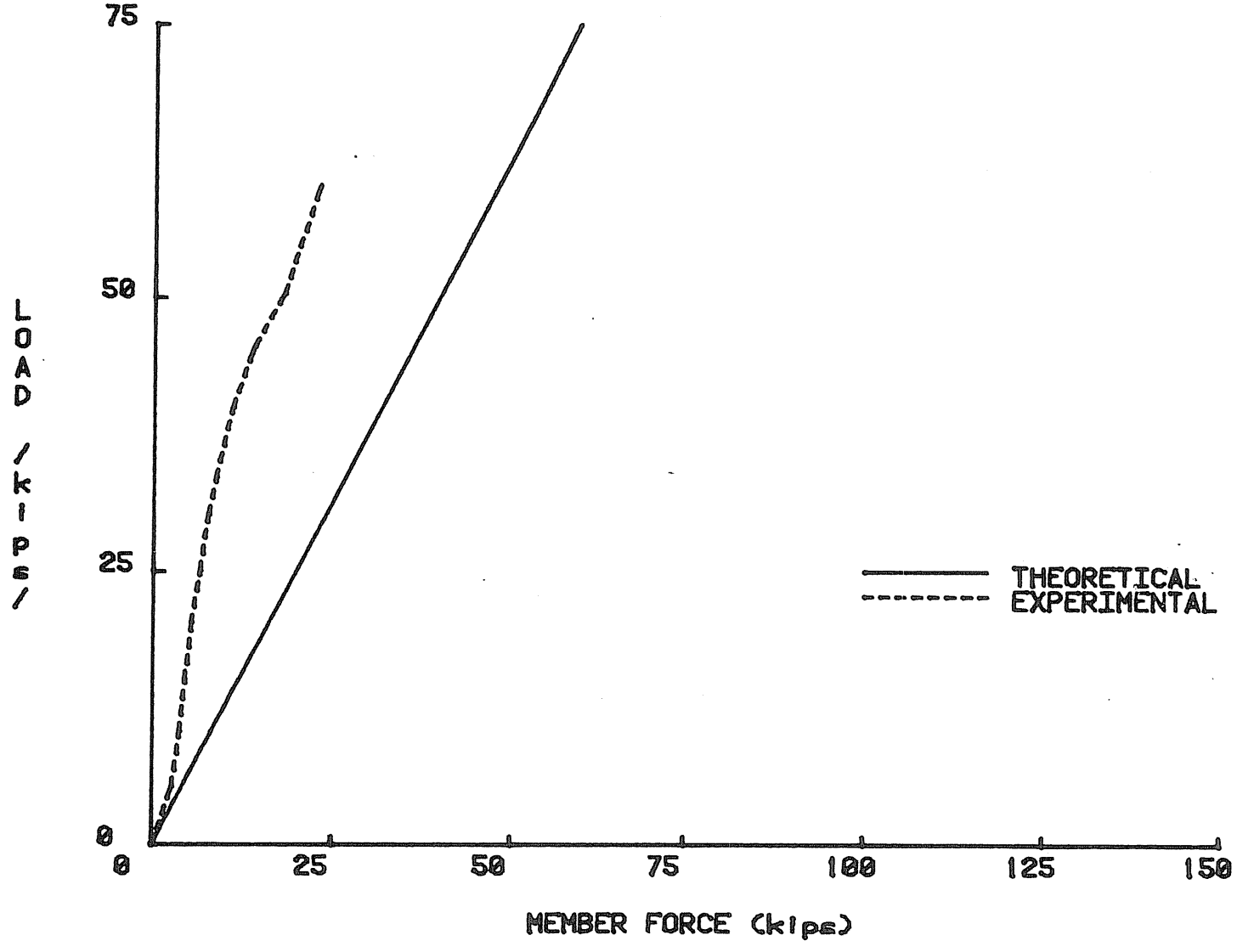


FIGURE A.7 LOAD VS. MEMBER (#4) FORCE, KN-1-2

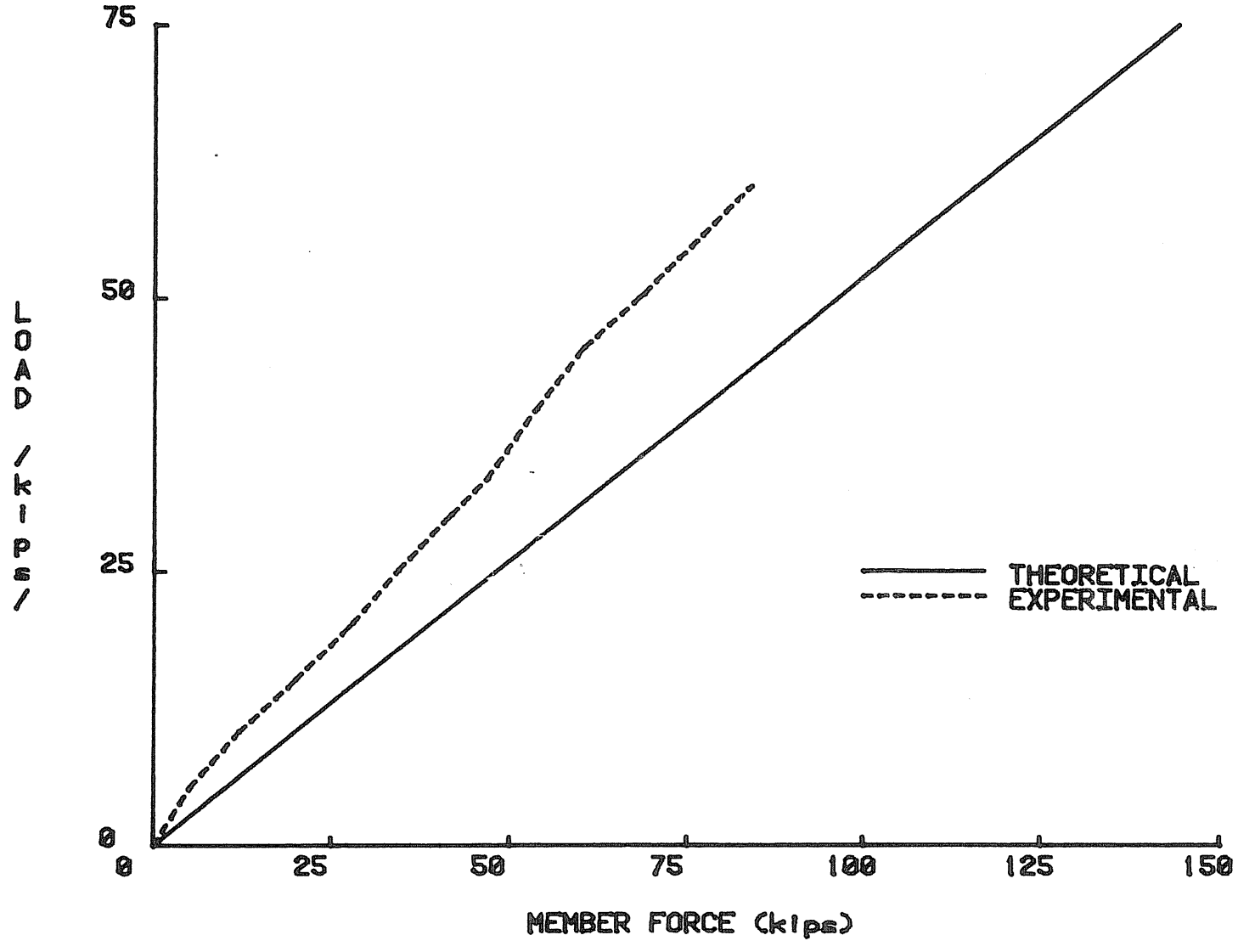


FIGURE A.8 LOAD VS. MEMBER (#11) FORCE, KN-1-2

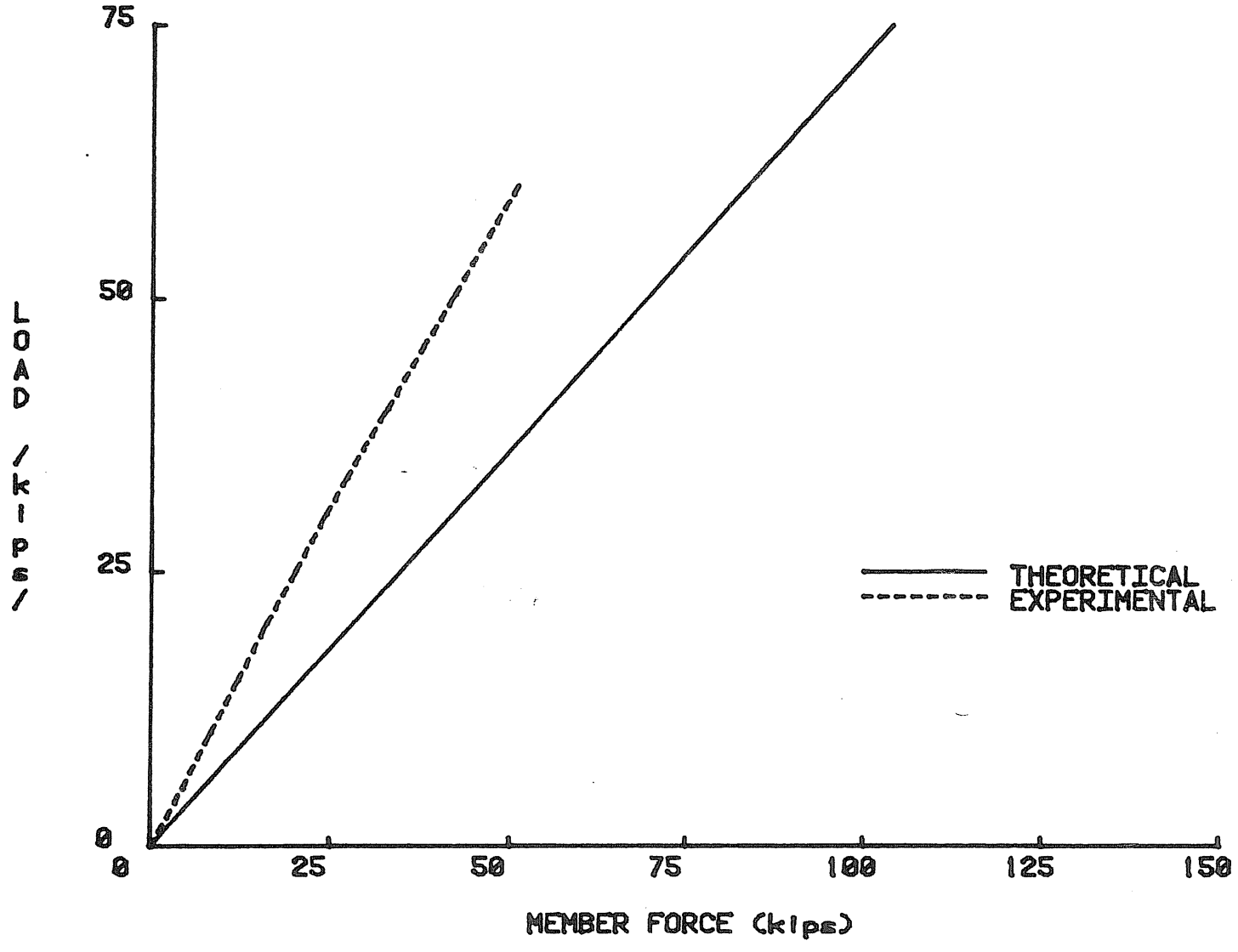


FIGURE A.9 LOAD VS. MEMBER (#21) FORCE, KN-1-2

APPENDIX B

KNEE AREA TEST DATA

TEST KN-6-2

VULCRAFT KNEE CONNECTION TEST SUMMARY

Project: VULCRAFT

Test No.: KN-6-2

Test Date: April 9, 1985

Purpose: Study of Behavior of Knee Area

Knee Area Dimensions: 53.13 in. x 30.0 in.

Knee Diagonal Length: 52.25 in.

Size of Support (Clip) Angle: 6 x 6 x 1/2 x 10 in.

Knife Plate Detail: Welded to bottom chord of rafter

Failure Load: 97.0^{k}

Failure Mode: Instability of member 29 resulting in specimen loss of stiffness.

Predicted Failure Load:

Method: VULCRAFT Analysis **Load:** 57.8 x 1.67 = 96.6 kips

Predicted Failure Mode: Instability of member 29

Maximum Displ. in Load Direction: 3.72 in. @ 97.0 kips

Discussion:

Observations:

- At 60 kips, some yielding at the ends of member 29 was noted.
- At 70 kips, yielding at the ends of member 28 was noted.
- At 71 kips, member 29 assumed a slightly bent configuration.
- At 80 kips, yielding at midspan of member 29 was noted.
- At 97 kips, loss of stiffness of specimen occurred. With further increase in load, the stitch weld at midspan of member 10 fractured and member 10 immediately buckled about the Z-axis, causing loss of load.

Loading and deformations:

- At working load (57.8 kips), deflection was 1.69 inches.
- Maximum applied load was 97.0 kips with a deflection of 3.72 inches.
- At working load, axial microstrain in member 6 was 336.3 in/in (Tension).
- At working load, axial microstrain in member 15 was 557.3 in/in (Compression).
- At working load, axial microstrain in member 16 was 706.5 in/in (Compression).
- At working load, axial microstrain in member 26 was 767.8 in/in (Compression).
- At working load, axial microstrain in member 29 was 926.2 in/in (Compression).

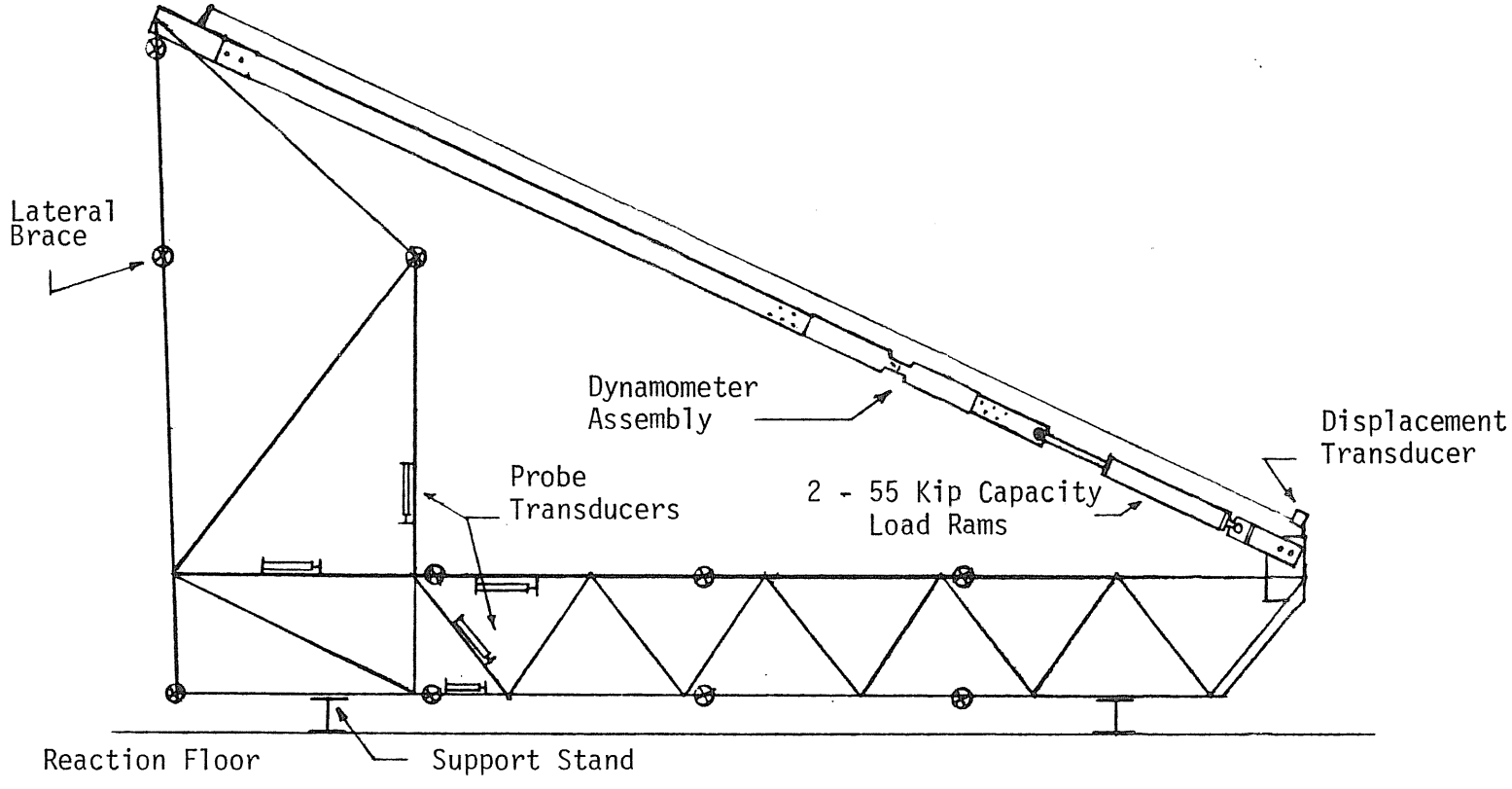


FIGURE B.1 KNEE TEST SETUP, TEST KN-6-2

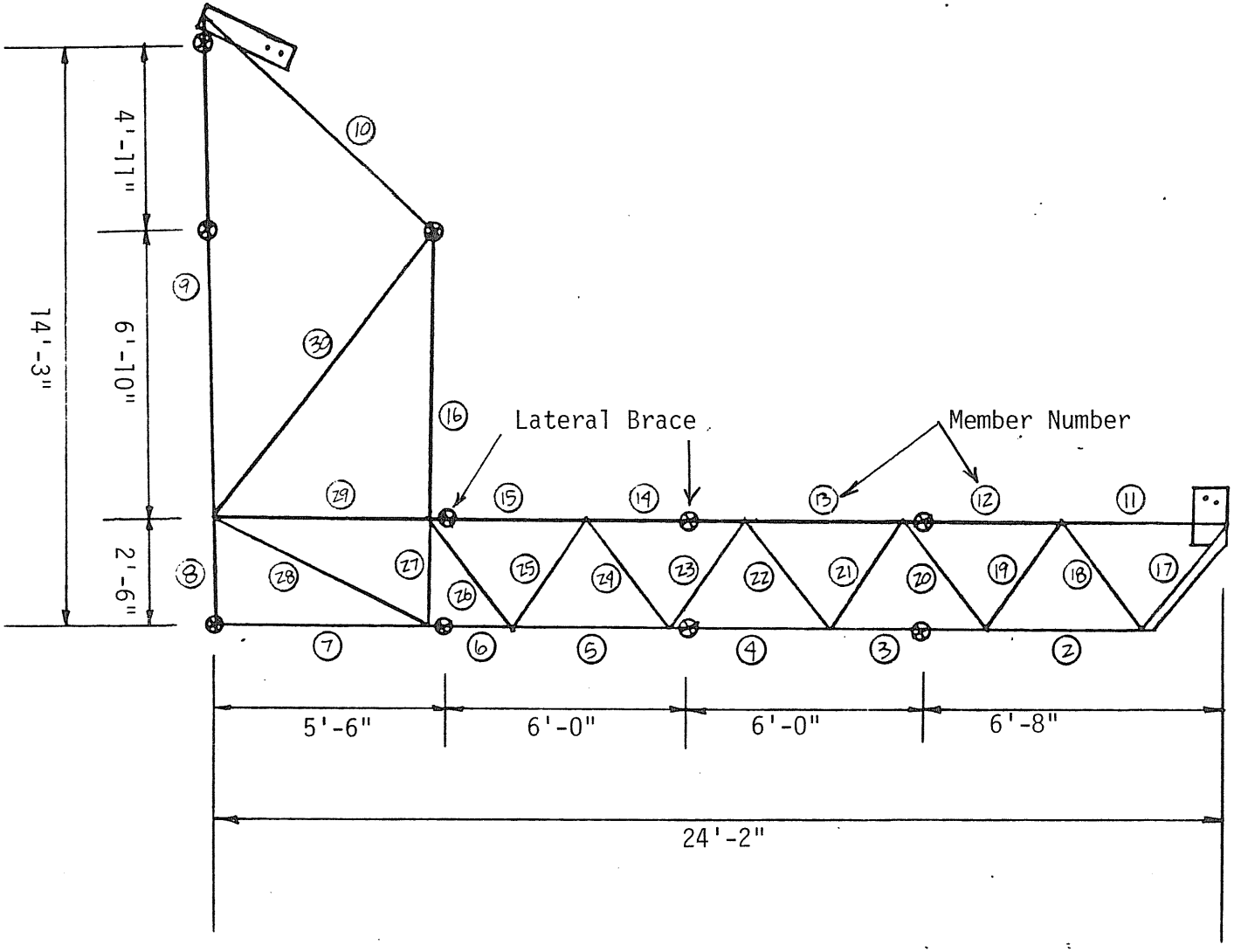


FIGURE B.2 SPECIMEN MEMBER NUMBERS AND LATERAL BRACE LOCATIONS, TEST KN-6-2

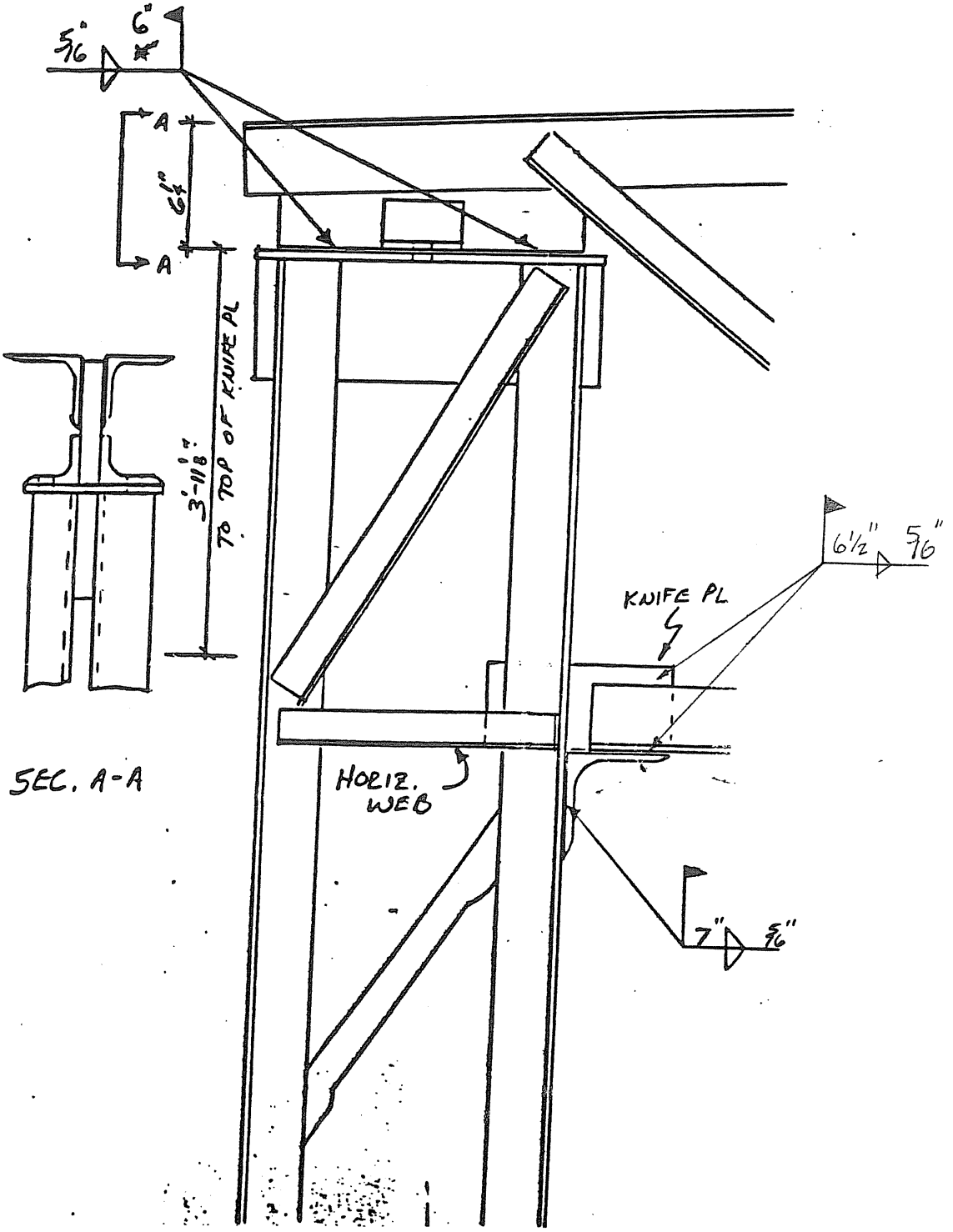
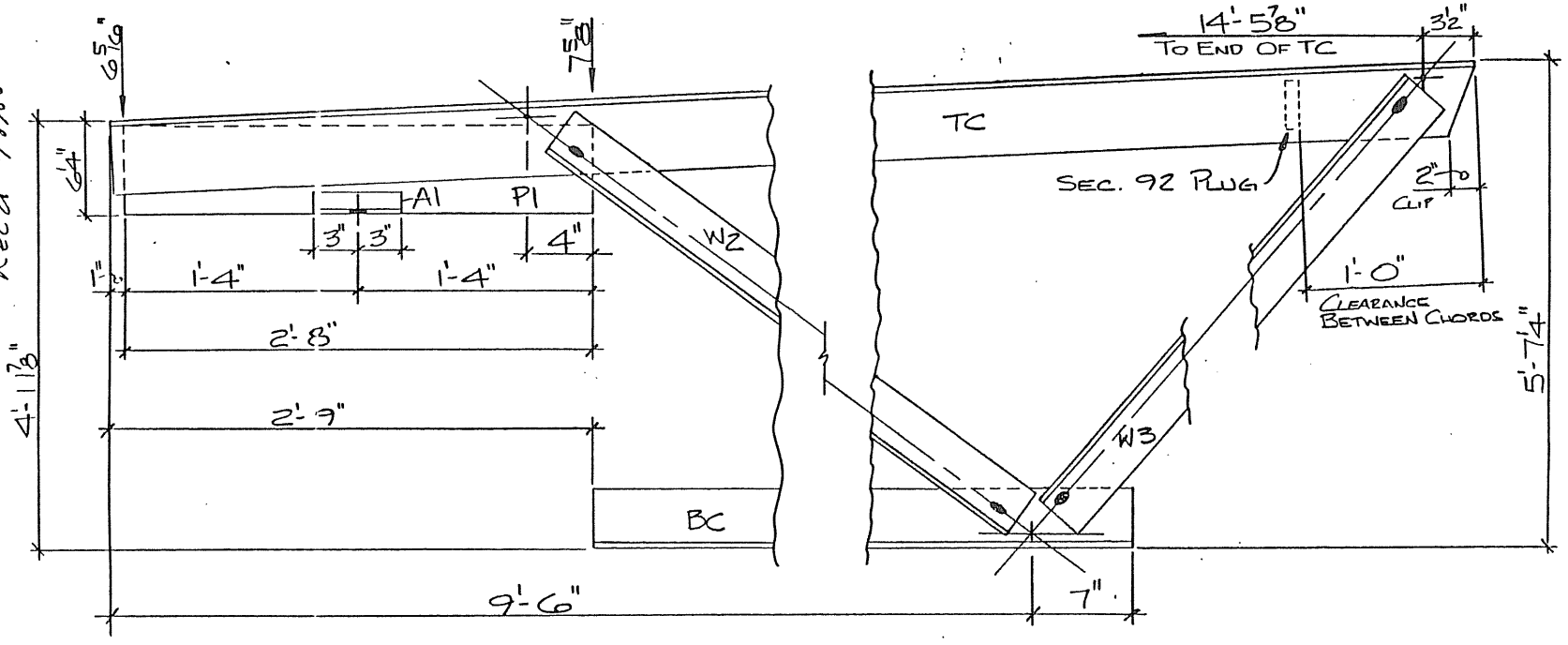


FIGURE B.3 KNIFE CONNECTION DETAIL, TEST KN-6-2

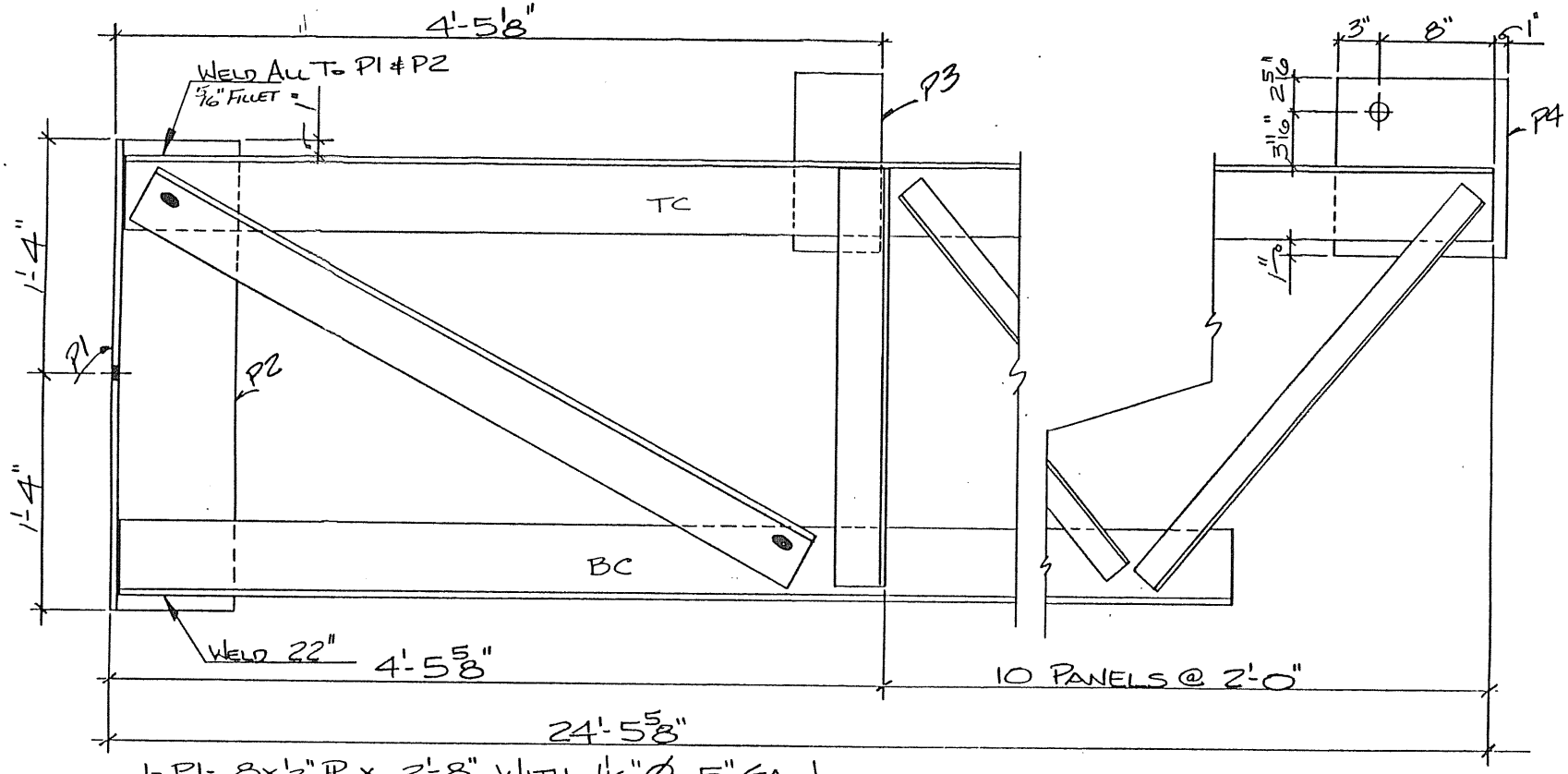


2 - TC - Sec. 64 - 14'-9½"
2 - BC - Sec. 59 - 7'-4"
2 - W2 - Sec. 54 - - Weld 21.4" Batten Slot
2 - W3 - Sec. 52 - - Weld 19.3" Batten Slot

1 - P1 - 6 x 1 PL x 2'-8" Weld All To TC
2 - A1 - Sec. 57 x 6" Long With 1 1/16" Ø 5" GA
Clip One Leg Down To 1½" Weld All To P1

KN6-2

FIGURE B.4 SHOP DRAWINGS, TEST KN-6-2



1- P1- 8x1/2" PL x 2'-8" WITH 1/16" Ø 5" GA } -5/16" WELD ALL
1- P2- 8x1" PL x 2'-8"
1- P3- 6x1 PL x 1'-0" WELD ALL AVAIL 5/16" FILLET
1- P4- 12x1 PL x 1'-0" WITH 1 5/16" Ø DRILLED WELD ALL 5/16" FILLET

FIGURE B.4 SHOP DRAWINGS, TEST KN-6-2, CONTINUED

STIFFNESS METHOD OF RIGID FRAME AND TRUSS ANALYSIS

NO OF NP = 36 NO OF MEMBERS = 32 NO OF LOAD CONDIT = 1
NO NLC TO WIND NLC = 0 NO NON-ZERO P = 2 METRIC (1 = METRIC)
NO ISTIFF ZEROED = 468 MOD ELASTICITY = 29000.0 IWRITX = -1 IW

NLC FOR D + L = 0 NLC FOR WIND ON BEAM = 0

MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
1	8	9	10	11	0	0	0.00	14.00	14.00	9.50	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
2	10	11	14	15	0	0	0.00	48.00	48.00	9.50	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
3	14	15	18	19	0	0	0.00	48.00	48.00	9.50	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
4	18	19	22	23	0	0	0.00	48.00	48.00	9.50	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
5	22	23	26	27	0	0	0.00	48.00	48.00	9.50	1.00
EMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
6	26	27	30	31	0	0	0.00	24.00	24.00	9.50	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
7	30	31	32	33	0	0	0.00	59.88	59.88	9.50	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
8	32	33	34	35	0	0	30.00	1.25	30.03	8.36	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
9	34	35	37	37	0	0	141.87	5.91	142.00	8.26	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
10	36	37	37	37	0	0	59.88	67.04	89.88	4.18	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
11	5	6	12	13	0	0	0.00	38.00	38.00	9.50	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
12	12	13	16	17	0	0	0.00	48.00	48.00	9.50	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
13	16	17	20	21	0	0	0.00	48.00	48.00	9.50	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
14	20	21	24	25	0	0	0.00	48.00	48.00	9.50	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
15	24	25	28	29	0	0	0.00	48.00	48.00	9.50	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
16	28	29	36	37	0	0	82.00	0.00	82.00	5.72	1.00

FIGURE B.5 STIFFNESS ANALYSIS, TEST KN-6-2

EMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
17	10	11	5	6	0	0	30.00	-14.00	33.11	1.89	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
18	10	11	12	13	0	0	30.00	24.00	38.42	1.43	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
19	14	15	12	13	0	0	30.00	-24.00	38.42	1.06	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
20	14	15	16	17	0	0	30.00	24.00	38.42	1.43	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
21	18	19	16	17	0	0	30.00	-24.00	38.42	1.06	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
22	18	19	20	21	0	0	30.00	24.00	38.42	1.43	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
23	22	23	20	21	0	0	30.00	-24.00	38.42	1.06	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
24	22	23	24	25	0	0	30.00	24.00	38.42	1.43	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
25	26	27	24	25	0	0	30.00	-24.00	38.42	1.06	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
26	26	27	28	29	0	0	30.00	24.00	38.42	1.43	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
27	30	31	28	29	0	0	30.00	0.00	30.00	4.58	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
28	30	31	34	35	0	0	30.00	61.13	68.09	7.50	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
29	28	29	34	35	0	0	0.00	61.13	61.13	9.50	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
30	34	35	36	37	0	0	82.00	-61.13	102.28	4.58	1.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
31	7	8	9	4	5	6	30.00	0.00	30.00	12.00	36.00
MEMBER	NP1	NP2	NP3	NP4	NP5	NP6	H	V	L	A	I
32	4	5	6	1	2	3	4.62	0.00	4.62	12.00	144.00

NO. STIFI(I) ENTRIES = 468, BAND WIDTH = 13

THE P-MATRIX, K AND 'K

NP=	1	0.00
NP=	2	24.25
NP=	3	52.49
NP=	4	0.00
NP=	5	0.00
NP=	6	0.00

FIGURE B.5 STIFFNESS ANALYSIS, TEST KN-6-2, CONTINUED

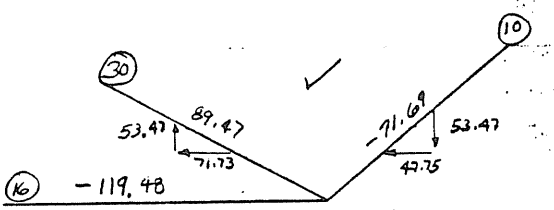
NP=	7	0.00
NP=	8	0.00
NP=	9	0.00
NP=	10	0.00
NP=	11	0.00
NP=	12	0.00
NP=	13	0.00
NP=	14	0.00
NP=	15	0.00
NP=	16	0.00
NP=	17	0.00
NP=	18	0.00
NP=	19	0.00
NP=	20	0.00
NP=	21	0.00
NP=	22	0.00
NP=	23	0.00
NP=	24	0.00
NP=	25	0.00
NP=	26	0.00
NP=	27	0.00
NP=	28	0.00
NP=	29	0.00
NP=	30	0.00
NP=	31	0.00
NP=	32	0.00
NP=	33	0.00
NP=	34	0.00
NP=	35	0.00
NP=	36	0.00

THE X-MATRIX IN OR RADIANS

NX =	1	-0.02
NX =	2	3.21
NX =	3	0.25
NX =	4	-0.02
NX =	5	3.21
NX =	6	0.17
NX =	7	-0.01
NX =	8	3.21
NX =	9	-0.26
NX =	10	2.99
NX =	11	-0.26
NX =	12	2.62
NX =	13	0.16
NX =	14	2.24
NX =	15	-0.25
NX =	16	1.89
NX =	17	0.14
NX =	18	1.54
NX =	19	-0.23
NX =	20	1.22
NX =	21	0.12
NX =	22	0.90
NX =	23	-0.21
NX =	24	0.63
NX =	25	0.08
NX =	26	0.36

FIGURE B.5 STIFFNESS ANALYSIS, TEST KN-6-2, CONTINUED

NX = 27	-0.19
NX = 28	0.14
NX = 29	0.04
NX = 30	0.16
NX = 31	-0.17
NX = 32	-0.01
NX = 33	-0.17
NX = 34	-0.01
NX = 35	-0.01
NX = 36	0.08



LOADING CONDITION NO = 1

MEMBER	AXIAL FORCE K	DESIGN END MOMENTS CORRECTED FOR FEM AND WIND (NEAR END FIRST), FT-K	
1	8.08	----	----
2	38.80	----	----
3	77.61	----	----
4	116.42	----	----
5	155.23	----	----
6	194.03	----	----
7	-0.00	----	----
8	-0.00	----	----
9	23.52	----	----
10	-71.69	----	----
11	-71.89	----	----
12	-110.70	----	----
13	-149.51	----	----
14	-188.31	----	----
15	-227.12	----	----
16	-119.48	----	----
17	26.77	----	----
18	-31.06	----	----
19	31.06	----	----
20	-31.06	----	----
21	31.06	----	----
22	-31.06	----	----
23	31.06	----	----
24	-31.06	----	----
25	31.06	----	----
26	-31.06	----	----
27	-95.23	----	----
28	216.14	----	----
29	-246.52	----	----
30	89.47	----	----
31	0.00	0.00	-20.21
32	24.27	20.21	0.00

FIGURE B.5 STIFFNESS ANALYSIS, TEST KN-6-2, CONTINUED

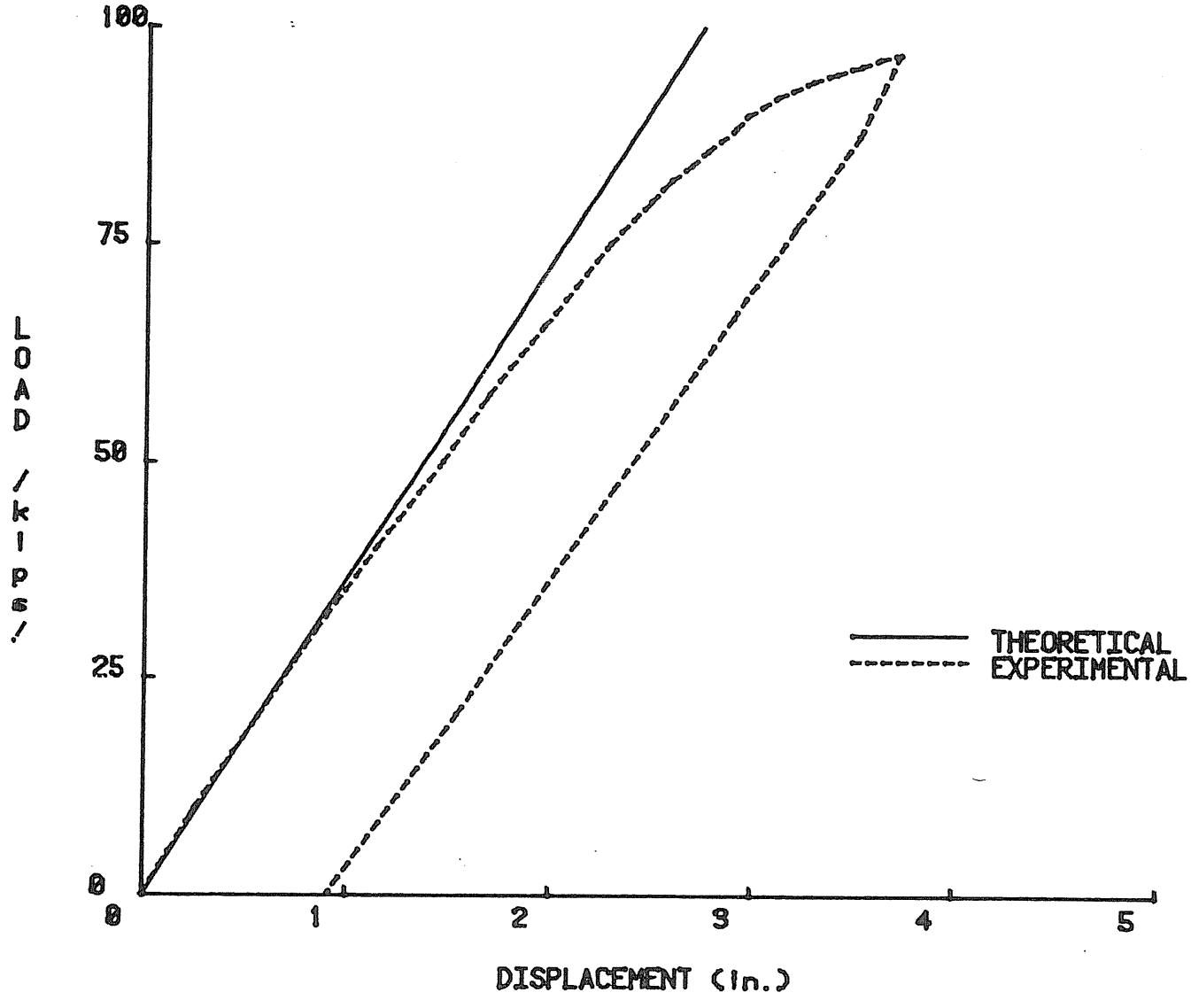


FIGURE B.6 LOAD VS. DISPL. IN LOAD DIRECTION, KN-6-2

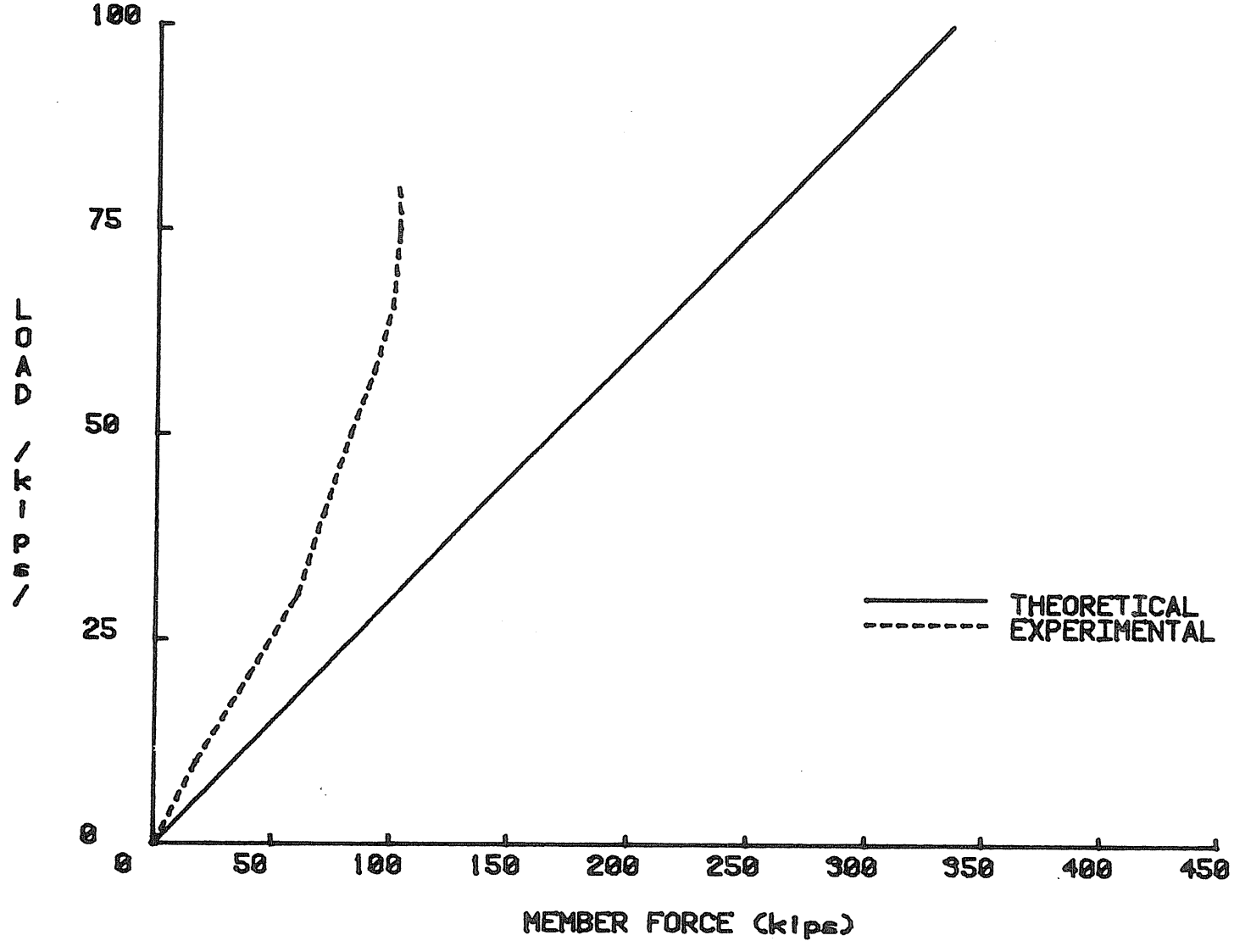


FIGURE B.7 LOAD VS. MEMBER (#6) FORCE, KN-6-2

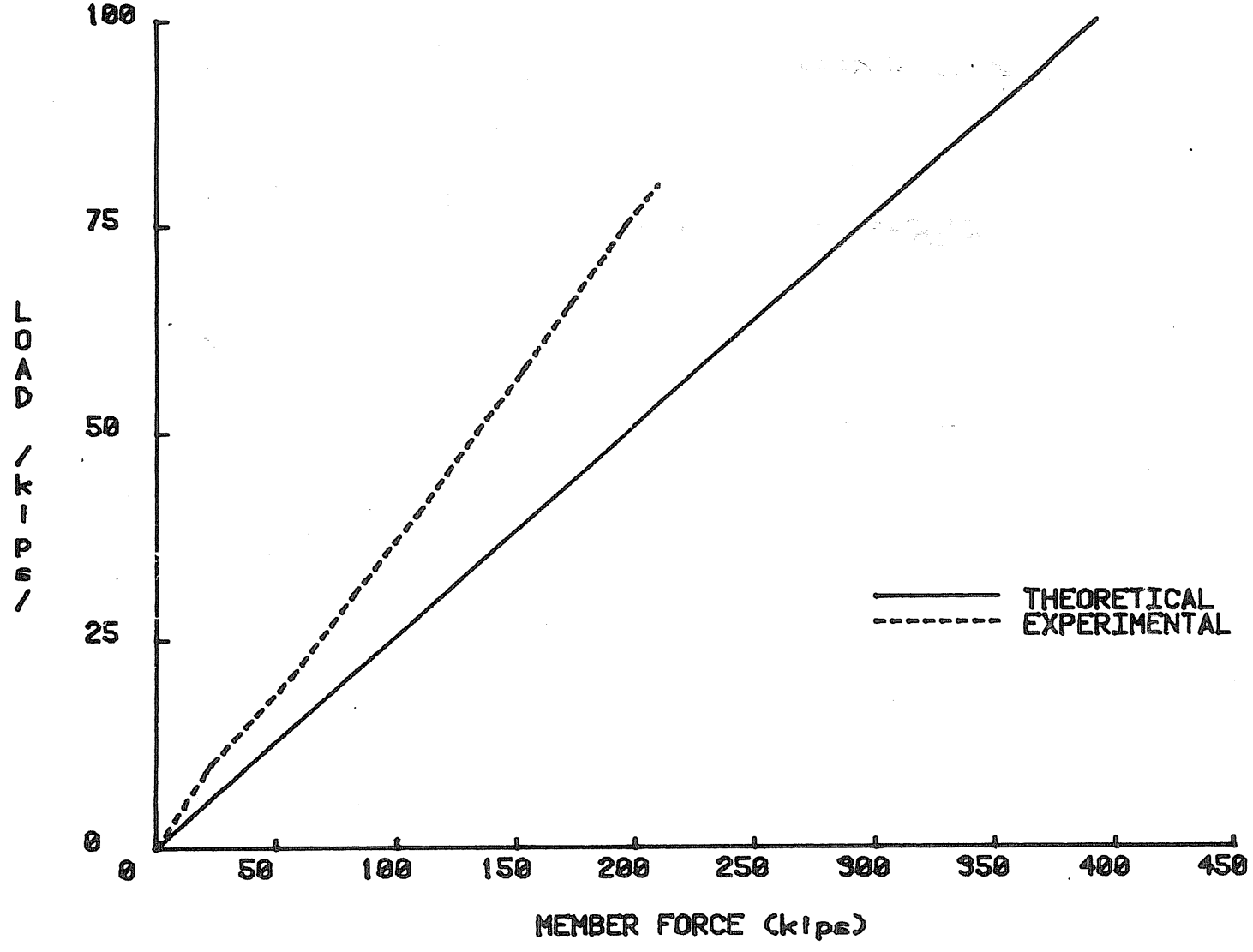


FIGURE B.8 LOAD VS. MEMBER (#15) FORCE, KN-6-2

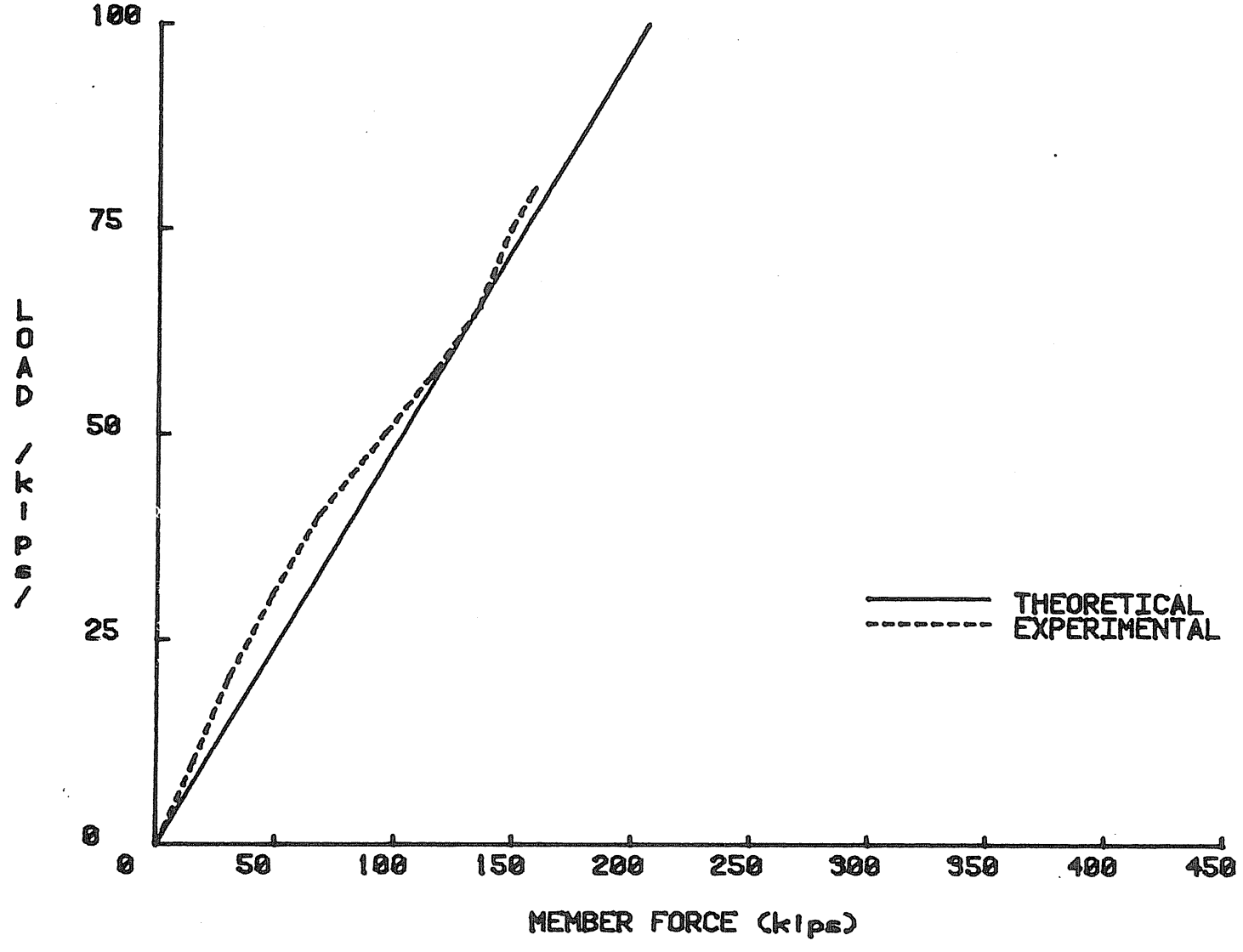


FIGURE B.9 LOAD VS. MEMBER (#16) FORCE, KN-6-2

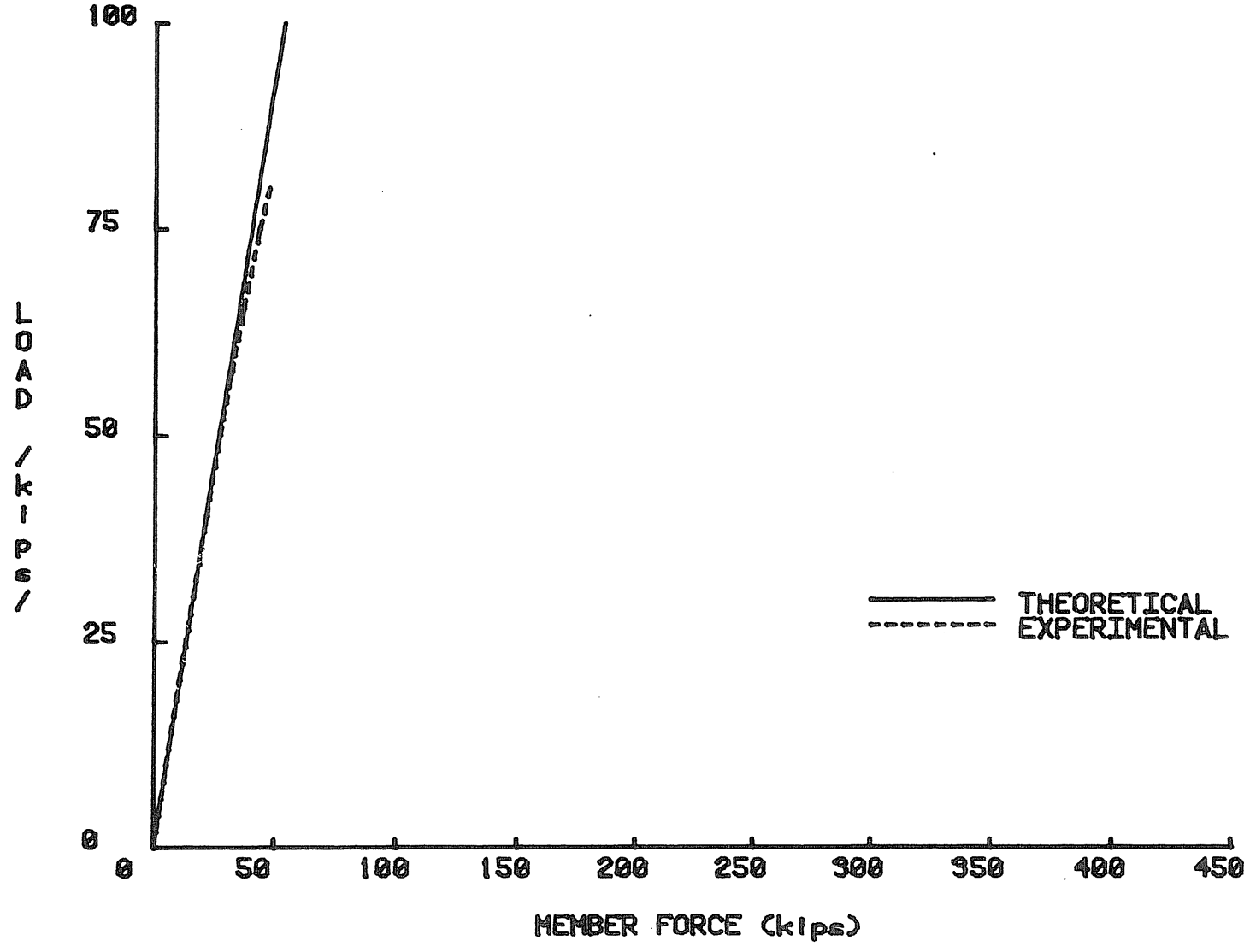


FIGURE B.10 LOAD VS. MEMBER (#26) FORCE, KN-6-2

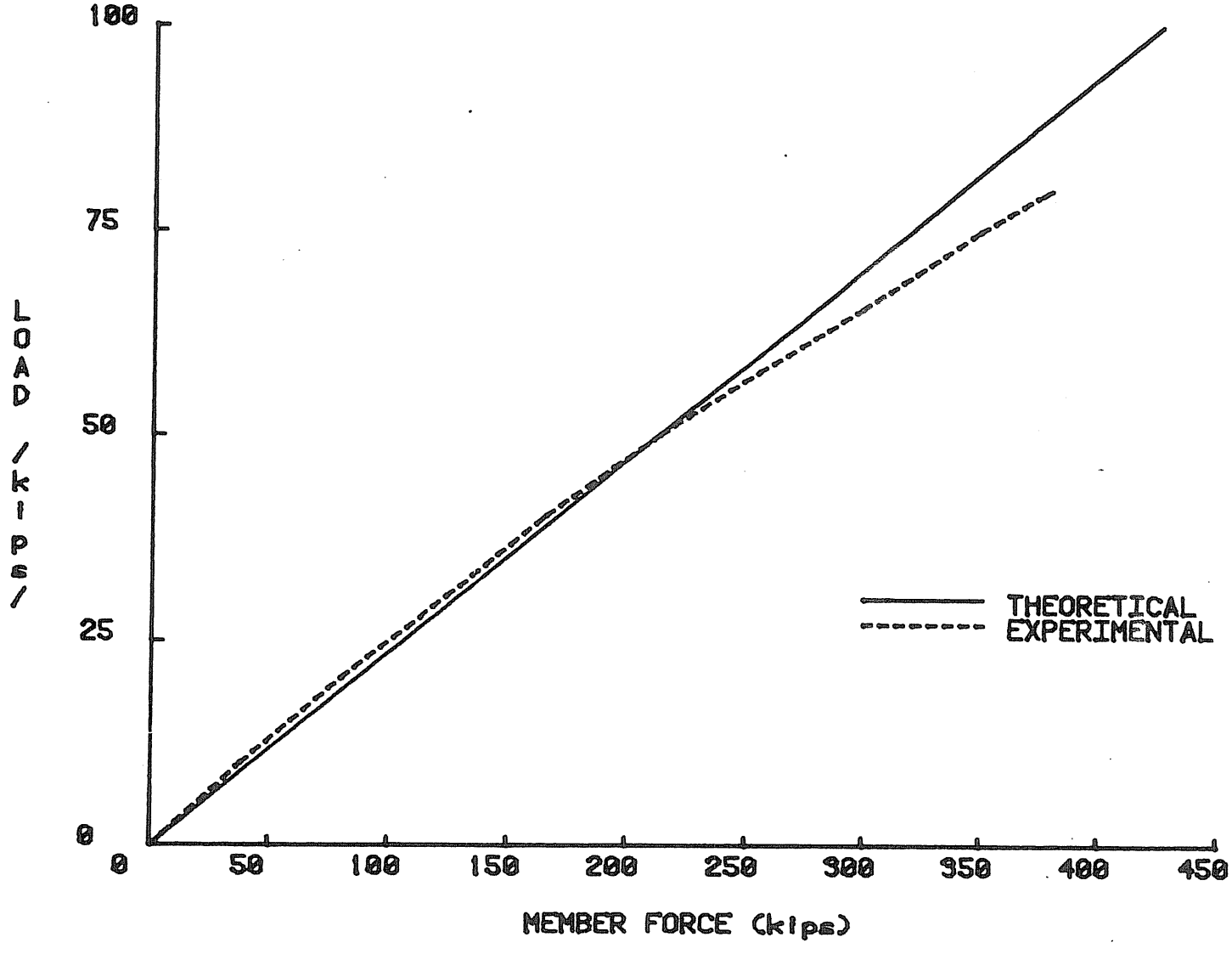


FIGURE B.11 LOAD VS. MEMBER (#29) FORCE, KN-6-2

APPENDIX C

VULCRAFT STEEL INVENTORY
(Brigham City)

SEC	ANGLE	AREA	RX	RZ	RY-1	SL	SS	V	Θ	IXX	MELD
3	1.00X.109	0.206	0.3066	0.1962	0.8464	0.067	0.027	0.290	1.0000	0.019	1619
6	1.25X.111	0.265	0.3880	0.2500	0.9373	0.113	0.044	0.353	0.9841	0.040	1668
12	1.50X.139	0.315	0.4675	0.2972	1.0278	0.166	0.063	0.415	0.9050	0.069	1619
14	1.50X.115	0.332	0.4670	0.2990	1.0296	0.174	0.067	0.418	0.9277	0.072	1708
16	1.50X.130	0.373	0.4660	0.2980	1.0336	0.191	0.075	0.424	0.9753	0.080	1856
17	1.50X.138	0.395	0.4660	0.2970	1.0357	0.200	0.079	0.426	0.9964	0.085	1856
18	1.50X.143	0.416	0.4660	0.2970	1.0383	0.207	0.083	0.429	1.0000	0.089	1856
19	1.50X.156	0.444	0.4610	0.2950	1.0403	0.217	0.089	0.433	1.0000	0.094	1856
20	1.50X.170	0.481	0.4590	0.2960	1.0430	0.232	0.095	0.437	1.0000	0.101	2060
22	2.00X.137	0.529	0.6265	0.3997	1.2223	0.375	0.142	0.551	0.8756	0.206	1856
23	2.00X.148	0.570	0.6229	0.3960	1.2250	0.399	0.153	0.555	0.9129	0.221	1856
25	2.00X.163	0.625	0.6208	0.3951	1.2295	0.430	0.167	0.560	0.9522	0.241	1956
26	2.00X.175	0.669	0.6191	0.3944	1.2322	0.454	0.179	0.565	0.9788	0.257	2136
27	2.00X.186	0.717	0.6170	0.3940	1.2337	0.478	0.190	0.569	1.0000	0.272	2320
28	2.00X.200	0.760	0.6156	0.3932	1.2379	0.502	0.202	0.574	1.0000	0.288	2320
9	2.00X.213	0.807	0.6140	0.3930	1.2405	0.526	0.214	0.579	1.0000	0.304	2320
..	2.00X.232	0.876	0.6113	0.3918	1.2455	0.558	0.231	0.585	1.0000	0.327	2517
33	2.50X.197	0.946	0.7769	0.4943	1.4279	0.819	0.317	0.693	0.9339	0.571	2320
36	2.50X.212	1.015	0.7740	0.4930	1.4308	0.866	0.339	0.703	0.9673	0.609	2320
38	2.50X.230	1.097	0.7720	0.4920	1.4356	0.921	0.365	0.710	0.9964	0.654	2487
39	2.50X.250	1.187	0.7690	0.4910	1.4399	0.980	0.394	0.717	1.0000	0.703	2784
42	3.00X.227	1.310	0.9330	0.5930	1.6293	1.369	0.527	0.834	0.9223	1.142	2442
43	3.00X.250	1.437	0.9300	0.5920	1.6321	1.473	0.577	0.842	0.9607	1.240	2736
44	3.00X.281	1.607	0.9260	0.5907	1.6404	1.614	0.642	0.854	1.0000	1.378	3246
45	3.00X.313	1.780	0.9220	0.5890	1.6503	1.758	0.707	0.869	1.0000	1.510	3712
51	3.50X.287	1.927	1.0860	0.6910	1.8365	2.315	0.902	0.981	0.9543	2.273	3333
52	3.50X.313	2.093	1.0800	0.6900	1.8414	2.475	0.976	0.990	0.9866	2.430	3712
54	3.50X.344	2.290	1.0781	0.6893	1.8489	2.657	1.065	1.002	1.0000	2.661	4179
57	3.50X.375	2.484	1.0700	0.6870	1.8535	2.842	1.150	1.010	1.0000	2.870	4643
59	4.00X.375	2.859	1.2300	0.7880	2.0530	3.825	1.520	1.160	1.0000	4.360	4643
61	4.00X.438	3.312	1.2300	0.7850	2.0631	4.284	1.750	1.163	1.0000	4.970	5568
63	4.00X.500	3.750	1.2200	0.7820	2.0749	4.712	1.975	1.180	1.0000	5.560	5568
66	5.00X.438	4.188	1.5500	0.9850	2.4563	7.092	2.790	1.413	0.9792	10.000	5568
66	5.00X.500	4.750	1.5490	0.9830	2.4706	7.902	3.160	1.430	1.0000	11.300	5568
67	5.00X.563	5.313	1.5310	0.9801	2.4845	8.562	3.512	1.457	1.0000	12.465	5568
	6.00X.500	5.750	1.8500	1.1800	2.8659	11.345	4.610	1.680	0.9607	19.900	5568
69	6.00X.563	6.439	1.8530	1.1900	2.8838	12.923	5.140	1.719	1.0000	22.100	5568
70	6.00X.625	7.139	1.8400	1.1900	2.8963	13.938	5.560	1.733	1.0000	24.200	5568
71	6.00X.688	7.772	1.8430	1.1800	2.9041	14.930	6.160	1.750	1.0000	26.200	5568
72	6.00X.750	8.438	1.8300	1.1700	2.9224	15.843	6.660	1.780	1.0000	28.250	5568