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16. Abstract

One of the objectives of this research study was to improve the design details of breakaway roadside signs in order to reduce their maintenance cost. During the past few years district maintenance engineers have reported large numbers of breakaway signs flopping or falling over in windstorms or just after a long period of service. In most cases the bolted, slotted friction fuse plate became loose and gave way.

The friction fuse plate was modified to make it a perforated tension fuse plate. The new tension fuse plate does not rely on bolt pretension and friction to resist wind loads. The critical section of the fuse plate is perforated with four drilled holes to weaken it to break in tension when an errant vehicle impacts the sign. Laboratory static tests were conducted to develop the design, and a full-scale vehicle crash test was conducted to verify it.

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PERFORATED TENSION FUSE PLATE FOR BREAKAWAY ROADSIDE SIGNS

by

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Research Report No. 343-3F
on
Improved Design of Lightpoles, Guardrails,
and Other Appurtenances
Research Study No. 2-18-83-343

Sponsored by
State Department of Highways and Public Transportation
in cooperation with the
U.S. Department of Transportation
Federal Highway Administration

October 22, 1984

Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843

ABSTRACT

One of the objectives of this research study was to improve the design details of breakaway roadside signs in order to reduce their maintenance cost. During the past few years district maintenance engineers have reported large numbers of breakaway signs flopping or falling over in windstorms or just after a long period of service. In most cases the bolded, slotted friction fuse plate became loose and gave way.

The friction fuse plate was modified to make it a perforated tension fuse plate. The new tension fuse plate does not rely on bolt pretension and friction to resist wind loads. The critical section of the fuse plate is perforated with four drilled holes to weaken it to break in tension when an errant vehicle impacts the sign. Laboratory static tests were conducted to develop the design, and a full-scale vehicle crash test was conducted to verify it.

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

KEY WORDS

Signs, Safety, Highways, Roadside, Tests

ACKNOWLEDGMENTS

This research study was conducted under a cooperative program between the Texas Transportation Institute (TTI), the State Department of Highways and Public Transportation (SDHPT) and the Federal Highway Administration (FHWA). Mr. Ralph K. Banks (Supervising Field Engineer, SDHPT) and Mr. John J. Panak (Supervising Designing Engineer, SDHPT) were closely involved in all phases of this study.

IMPLEMENTATION STATEMENT

The modified perforated tension fuse plate designs shown by Figure 3 are ready for use on all appropriate breakaway roadside signs in Texas.

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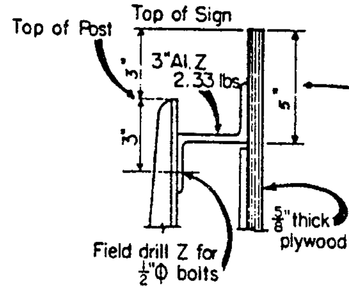
INTRODUCTION OF PROBLEM

During the past few years, district maintenance engineers in Texas and several other states have reported large numbers of breakaway signs flopping or falling over in windstorms or just after long periods of service. In most cases the friction fuse plate at the post hinge (see Figures 1 and 2) became loose, resulting in small-to-zero moment capacity. This hinge detail depends on bolt pretension to develop friction and thus moment capacity. After long periods of service the pretensioned bolts apparently lose their pretensioning force. This has created a continuous and expensive maintenance problem with these signs.

RECOMMENDED FUSE PLATE

To minimize or eliminate this problem, it is recommended that the current friction fuse plate (Figure 2) be replaced with a modified perforated tension fuse plate, as shown in Figure 3. This modified perforated tension fuse plate is interchangeable with the friction fuse plate.

The slotted holes in the friction fuse plate were removed, and four holes were drilled in a line across the plate to form a critical tension section (perforated section). The net area of the critical tension section was determined so that the ultimate tensile strength of the fuse plate would be approximately two thirds of the ultimate shear strength of the connecting bolts (two bolts, in this case). It is desired that the fuse plate fail in tension before the bolts shear. Some of the early tension



GENERAL NOTES:

DESIGN CONFORMS WITH A.A.S.H.T.O. SPECIFICATIONS FOR THE DESIGN AND CONSTRUCTION OF STRUCTURAL SUPPORTS FOR HIGHWAY SIGNS.

MATERIALS AND FABRICATION SHALL CONFORM TO THE REQUIREMENTS OF THE SPECIFICATIONS.

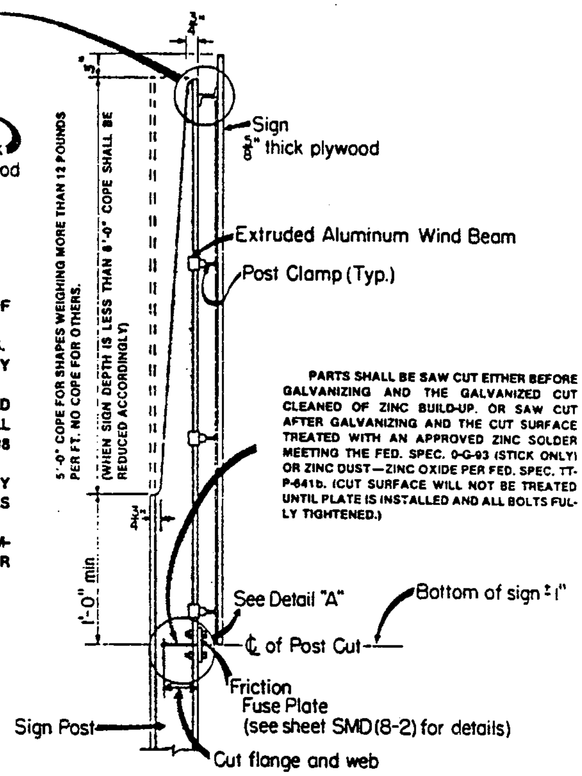
ALL STRUCTURAL STEEL SHALL CONFORM TO ASTM-A441 (ASTM-A572 GRADE 50, OR ASTM-A588 MAY BE SUBSTITUTED FOR A441 AT THE OPTION OF THE FABRICATOR).

ALL SHEET AND PLATE ALUMINUM SHALL CONFORM TO ASTM-B209 ALLOY 6061-T6. ALL EXTRUDED ALUMINUM SHALL CONFORM TO ASTM-B221 ALLOY 6061-T6. CAST ALUMINUM POST CLAMPS SHALL CONFORM TO ASTM-B26 ALLOY 356.0, ASTM-B108 ALLOY 356.0, ASTM-B26 ALLOY 713.0, OR ASTM-B108 ALLOY 713.0

ALL HIGH STRENGTH BOLTS, NUTS, AND WASHERS SHALL CONFORM TO ASTM-A325 (ASTM-A449 MAY BE SUBSTITUTED FOR ASTM-A325 PROVIDED PROPER BOLT HEAD, NUT AND/OR WASHER CLEARANCES ARE MAINTAINED).

ALL BOLTS OTHER THAN HIGH STRENGTH BOLTS SHALL CONFORM TO ASTM-307 CLASS A (ASTM-A394, A325 OR A449 MAY BE SUBSTITUTED FOR ASTM-A307 PROVIDED PROPER BOLT HEAD, NUT AND/OR WASHER CLEARANCES ARE MAINTAINED).

ALL STRUCTURAL STEEL, SHALL BE GALVANIZED ASTM A123 OR A153 CLASS A. STRUCTURAL STEEL TO BE GALVANIZED AFTER FABRICATION EXCEPT AS NOTED.



PARTS SHALL BE SAW CUT EITHER BEFORE GALVANIZING AND THE GALVANIZED CUT CLEANED OF ZINC BUILD-UP, OR SAW CUT AFTER GALVANIZING AND THE CUT SURFACE TREATED WITH AN APPROVED ZINC SOLDER MEETING THE FED. SPEC. O-G-93 (STICK ONLY) OR ZINC DUST—ZINC OXIDE PER FED. SPEC. TT-P-641b. (CUT SURFACE WILL NOT BE TREATED UNTIL PLATE IS INSTALLED AND ALL BOLTS FULLY TIGHTENED.)

SIDE VIEW

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

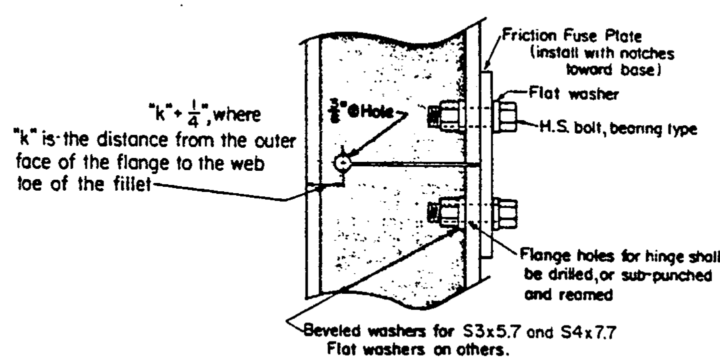
STRUCTURAL

MOUNTING DETAILS

FOR ROADSIDE GUIDE SIGNS

SMD(8-1)

DRAWING DATE: 4-78		STATE DISTRICT	FEDERAL REGION	FEDERAL AID PROJECT	SHEET
DN.-	REVISIONS		6		
CK.-	1-82			COUNTY / CONTROL / SECTION / JOB / HIGHWAY	
DW.-					
CK.-					16



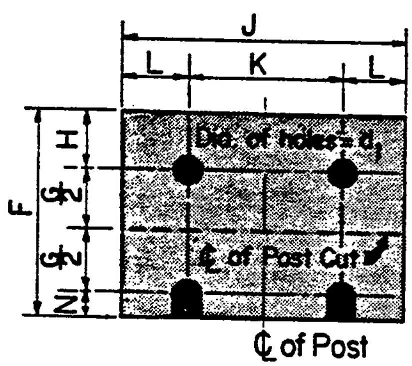
DETAIL "A"-HINGE

FABRICATOR NOTE: IMPORTANT - ALL FRICTION FUSE BOLTS SHALL BE TIGHTENED IN THE SHOP FOLLOWING A METHOD APPROVED BY THE ENGINEER. TIGHTENING SHALL BE TO SUCH A DEGREE AS TO OBTAIN THE FOLLOWING MINIMUM RESIDUAL TENSION IN EACH BOLT.

BOLT SIZE	MIN. RESIDUAL BOLT TENSION
1/2"Φ	12050 LBS.
5/8"Φ	19200 LBS.
3/4"Φ	28400 LBS.

Figure 1. Current Roadside Guide Sign Post with Hinge and Friction Fuse Plate

Dimensions / Post Size	Friction Fuse Plate Data Table										
	F	G	H	J	K	L	N	d_1	t_3	Bolt Dia.	Wt. of Each Fuse Plate
W6x9 W6x12	$3\frac{5}{8}$"	2"	$1\frac{1}{8}$"	4"	$2\frac{1}{4}$"	$\frac{7}{8}$"	$\frac{1}{2}$"	$\frac{9}{16}$"	$\frac{1}{4}$"	$\frac{1}{2}$"Φ	.94 lbs.
W6x15	$4\frac{3}{8}$"	$2\frac{1}{2}$"	$1\frac{1}{4}$"	6"	$3\frac{1}{2}$"	$1\frac{1}{4}$"	$\frac{5}{8}$"	$\frac{11}{16}$"	$\frac{3}{8}$"	$\frac{5}{8}$"Φ	2.58 lbs.
W8x18	$4\frac{3}{8}$"	$2\frac{1}{2}$"	$1\frac{1}{4}$"	$5\frac{1}{4}$"	$2\frac{3}{4}$"	$1\frac{1}{4}$"	$\frac{5}{8}$"	$\frac{11}{16}$"	$\frac{3}{8}$"	$\frac{5}{8}$"Φ	2.24 lbs.
W8x21	$4\frac{3}{4}$"	$2\frac{1}{2}$"	$1\frac{1}{2}$"	$5\frac{1}{4}$"	$2\frac{3}{4}$"	$1\frac{1}{4}$"	$\frac{3}{4}$"	$\frac{13}{16}$"	$\frac{1}{2}$"	$\frac{3}{4}$"Φ	2.95 lbs.
W10x22 W10x26	$5\frac{1}{4}$"	3"	$1\frac{1}{2}$"	$5\frac{3}{4}$"	$2\frac{3}{4}$"	$1\frac{1}{2}$"	$\frac{3}{4}$"	$\frac{13}{16}$"	$\frac{1}{2}$"	$\frac{3}{4}$"Φ	3.88 lbs
W12x26	$5\frac{1}{4}$"	3"	$1\frac{1}{2}$"	$6\frac{1}{2}$"	$3\frac{1}{2}$"	$1\frac{1}{2}$"	$\frac{3}{4}$"	$\frac{13}{16}$"	$\frac{1}{2}$"	$\frac{3}{4}$"Φ	4.14 lbs.
S3x5.7 S4x7.7	$3\frac{1}{8}$"	$1\frac{1}{2}$"	$1\frac{1}{8}$"	$2\frac{5}{8}$"	$1\frac{1}{2}$"	$\frac{9}{16}$"	$\frac{1}{2}$"	$\frac{9}{16}$"	$\frac{1}{4}$"	$\frac{1}{2}$"Φ	0.49 lbs.



Use H.S. hex. head bolts, hex. head nut and bevel or flat washer (where req'd.) under nut.
Plate thickness = t_3

FRICTION FUSE PLATE DETAIL

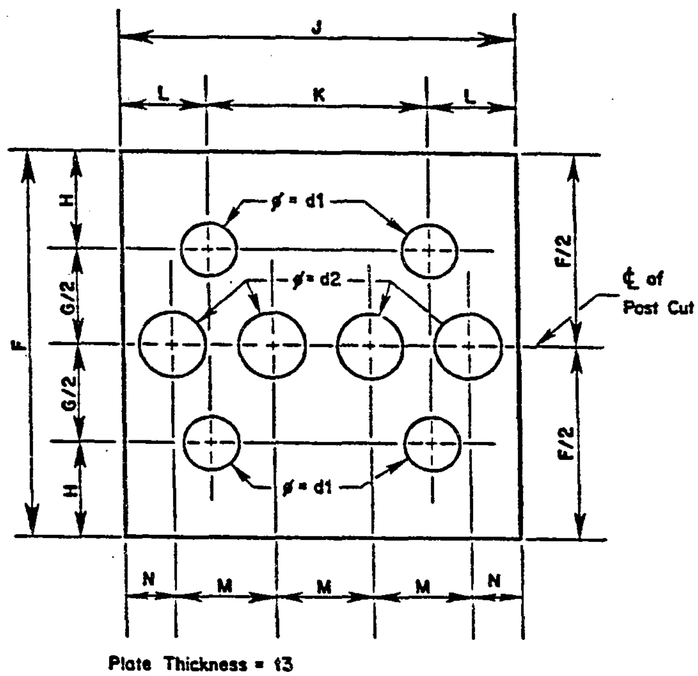
(See Table for Dimensions & Weight)

NOTCHED STEEL FRICTION FUSE PLATES SHALL CONFORM TO THE REQUIREMENTS OF ASTM-A441 (ASTM-A572 GRADE 50 OR ASTM-A588 MAY BE SUBSTITUTED FOR A441 AT THE OPTION OF THE FABRICATOR). ALL HOLES SHALL BE DRILLED. ALL PLATE CUTS SHALL PREFERABLY BE SAW CUTS. HOWEVER: FLAME CUTTING WILL BE PERMITTED PROVIDED ALL EDGES ARE GROUND. METAL PROJECTING BEYOND THE PLANE OF THE PLATE FACE WILL NOT BE PERMITTED.

Figure 2. Current Friction Fuse Plate Details

Post Size	F (in.)	G (in.)	H (in.)	J (in.)	K (in.)	L (in.)	M (in.)	N (in.)	d1 (in.)	d2 (in.)	t3 (in.)	Bolt Dia. (in.)	Wt. (ea.) (lbs.)	Bolt Length (in.)
W 6X9 W 6X12	4 1/4	2	1 1/8	4	2 1/4	7/8	1	1/2	9/16	3/4	1/4	1/2	1.01	1 1/2
W 6X16	5	2 1/2	1 1/4	6	3 1/2	1 1/4	1 1/2	3/4	11/16	1 1/4	3/8	5/8	2.51	2 1/4
W 8X18	5	2 1/2	1 1/4	5 1/4	2 3/4	1 1/4	1 1/4	3/4	11/16	1 1/16	3/8	5/8	2.26	2 1/4
W 8X21	5 1/2	2 1/2	1 1/2	5 1/4	2 3/4	1 1/4	1 1/4	3/4	13/16	1	1/2	3/4	3.35	2 1/4
W 10X22 W 10X26	6	3	1 1/2	5 3/4	2 3/4	1 1/2	1 3/8	13/16	13/16	1 1/8	1/2	3/4	4.03	2 1/4
W 12X26	6	3	1 1/2	6 1/2	3 1/2	1 1/2	1 5/8	13/16	13/16	1 5/16	1/2	3/4	4.47	2 1/4
S3X5.7 S4X7.7	3 3/4	1 1/2	1 1/8	2 5/8	1 1/2	9/16	5/8	3/8	9/16	3/8	1/4	1/2	0.60	1 1/2

Dimension F and the Wght. have changed. Dimensions M, N, and d2 are new. All other dimensions have remained unchanged from the Friction Fuse Plate Data Table on SDHPT Detail Sheet labeled STRUCTURAL MOUNTING DETAILS FOR ROADSIDE GUIDE SIGNS SMD(8-2). The Fuse Plate detailed here may be substituted for the Friction Fuse Plate detailed on the abovementioned SDHPT Detail Sheet.



NOTE:
USE H.S. HEX HEAD BOLTS, HEX HEAD NUT AND BEVEL OR FLAT WASHER(WHERE REQ'D) UNDER NUT.

FUSE PLATE DETAIL

(See Table For Dims. & Wghts.)

STEEL FUSE PLATES SHALL CONFORM TO THE REQUIREMENTS OF ASTM-A36 (ASTM-A441, ASTM-A572 GRADE 50, OR ASTM-A588 MAY BE SUBSTITUTED FOR A36 AT THE OPTION OF THE FABRICATOR). ALL HOLES SHALL BE DRILLED. ALL PLATE CUTS SHALL PREFERABLY BE SAW CUTS, HOWEVER; FLAME CUTTING WILL BE PERMITTED PROVIDED ALL EDGES ARE GROUND. METAL PROJECTING BEYOND THE PLANE OF THE PLATE FACE WILL NOT BE PERMITTED.

Figure 3. Modified Perforated Tension Fuse Plate Details

specimens (see Appendix A) produced failure by bolt shear. Pieces of bolts and nuts could potentially penetrate the windshield of an impacting vehicle, and this is not desirable.

These perforated tension fuse plates can be made from ASTM A36, A441, A572 Grade 50, or A588 steel plate since all have an ultimate tensile strength of about 70 ksi.

BRIEF DESCRIPTION OF STATIC LOAD TESTS ON FUSE PLATES

Table 1 shows a summary of the static load test results on various perforated tension fuse plate designs. Detailed test results are presented in Appendices A and B. Test Series 1 used A441 steel, while Test Series 2 used A36 steel. In addition to the actual test load on the fuse plate designs, Table 1 presents the theoretical ultimate load in tension, shear, and bearing for comparison. For both A441 and A36 steel, a minimum ultimate tensile strength of 70 ksi was assumed. For the A325 bolts, a minimum ultimate tensile strength of 120 ksi was used. The AISC allowable bearing stress of 1.5 F_u was increased by 1.7 to obtain a minimum ultimate bearing stress.

In Test Series 1 some of the theoretical tensile strengths exceeded the shear strength of the bolts. When the bolt sheared in tests 1 and 3 it was decided that this was not a desirable failure mode since pieces of bolt or nut could potentially penetrate the windshield of an impacting vehicle. Consequently, in Test Series 2 the fuse plates were designed so that their tensile strength was only about 2/3 of the bolt shear strength.

TABLE 1. SUMMARY OF STATIC LOAD TEST RESULTS ON PERFORATED TENSION FUSE PLATE DESIGNS
Detailed Test Results in Appendix A and B

Test Ser #		Beam Size	Fuse Plate Size	ASTM Desig.	Hole Dia. (in.)	Tension Cap. (kips)	ASTM-A325 Bolt Size	Shear 2-Bolt (kips)	Bearing Beam Flng. (kips)	Actual Failure Test Load (kips)	Actual Failure Mode
1	1	W 10X26	5 3/4" X 6" X 1/2"	A441	15/16	70.0	3/4" X 2 1/4"	61.2	117.8	72.5	Tension in Plate
1	2	W 6X9	4" X 4" X 1/4"	A441	13/16	13.1	1/2" X 1 1/2"	27.2	38.4	14.4	Tension in Plate
1	3	W 8X18	5 1/4" X 5" X 3/8"	A441	1	32.8	5/8" X 2"	42.5	73.6	39.0	Bolt Shear
1	4	W 10X26	5 3/4" X 6" X 1/2"	A441	1	61.3	3/4" X 2 1/4"	61.2	117.8	68.0	Tension in Plate
2	1	W 6X9	4" X 4" X 1/4"	A36	3/4	17.5	1/2" X 1 1/2"	27.2	38.4	19.2	Tension in Plate
2	2	W 10X26	5 3/4" X 6" X 1/2"	A36	1 1/8	43.8	3/4" X 2 1/4"	61.2	117.8	47.2	Tension in Plate
2	3	W 6X9	4" X 4" X 1/4"	A36	3/4	17.5	1/2" X 1 1/2"	27.2	38.4	19.5	Tension in Plate
2	4	W 8X18	5 1/4" X 5" X 3/8"	A36	1 1/16	26.3	5/8" X 2 1/2"	42.5	73.6	24.0	Tension in Plate
2	5	W 8X18	5 1/4" X 5" X 3/8"	A36	1 1/16	26.3	5/8" X 2 1/2"	42.5	73.6	22.4	Tension in Plate

Tension = $F_u * A_{net}$; Shear(2-Bolt) = $2 * A_{bolt} * 0.577 * F_u$; Bearing(Flng,2-Bolt) = $2 * d * t * 1.7 * 1.5 * F_u$

F_u = 70 ksi (min.) for ASTM-A36 and ASTM-A441; F_u = 120 ksi for ASTM-A325 bolts

In test 3 of Test Series 1, the 5/8 in. diameter x 2 in. long bolt failed by shearing through the threaded portion of the bolt. In Test Series 2 and the proposed designs of Table 3 the 5/8 in. diameter bolts were increased in length to 2-1/2 in. This removed the threaded portion of the bolt from the shear plane to further minimize the possibility of the bolts shearing.

BRIEF DESCRIPTION OF CRASH TEST ON ROADSIDE SIGN

A full-scale vehicle crash test was conducted on a standard SDHPT 8 ft high by 16 ft wide roadside sign supported by two W8 x 18 steel posts using the modified tension fuse plate recommended by Figure 3. Details of the test are presented in Appendix C.

A 1975 Honda Civic weighing 1750 lb impacted one leg of the sign support at 20.4 mph. The slip base at the ground activated, and the W8 x 18 post rotated away from the vehicle, which was slowed to 16.7 mph. The new tension fuse plate did not break (but it almost did); instead the lower wind beam clamp was pulled through the lower extruded wind beam. Figure C5 (Appendix C) shows the tension fuse plate, which was on the verge of breaking. This behavior is very satisfactory from the safety standpoint and, incidentally, has been observed numerous times with the present friction fuse plate.

At different impact speeds the new perforated tension fuse plate will activate, and the potential wind beam clamp failure mode is merely a backup safety feature. The only requirement is that the hinge mechanism or upper wind beam-post connection hold on to the breakaway lower post to prevent it from becoming a flying missile.

SUMMARY AND CONCLUSIONS

The new proposed perforated tension fuse plates should minimize or eliminate the occurrence of flopping or falling overhead sign panels, which occurs when the pretensioned bolts in the friction fuse plates become loose. This should reduce maintenance costs on breakaway roadside signs.

The most important safety feature of a breakaway roadside sign is the slip base at the ground. The hinge, or fuse plate, is a secondary feature to control the trajectory of the breakaway post and reduce damage to the sign panel. As was seen in the crash test, the wind beam-sign panel clamp connection is a backup safety feature for the fuse plate (or hinge).

REFERENCES

1. "Structural Mounting Details for Roadside Guide Signs, SMD(8-2)," Texas State Department of Highways and Public Transportation, Traffic Control Standard Sheets, revised 2-82, sheets 16 and 17.

2. Samson, C. H., Jr., Rowan, N. J., Olson, R. M., and Tidwell, D. R., "Impact Behavior of Sign Supports," Research Report 68-1, Texas Transportation Institute, Texas A&M University, College Station, Texas, 1965.

3. Rowan, N. J., Olson, R. M., and White, M. C., "Development of Breakaway Sign Supports and Slotted Steel Plate Mechanical Fuses," Research Report 68-4 (Final), Texas Transportation Institute, Texas A&M University, College Station, Texas, 1968.

4. Rowan, N. J., Olson, R. M., Edwards, T. C., Hawkins, D. L., Gaddis, A. M., and Williams, T. G., "Impact Behavior of Sign Supports - II," Texas Transportation Institute, Texas A&M University, College Station, Texas, 1965.

METRIC CONVERSION FACTORS

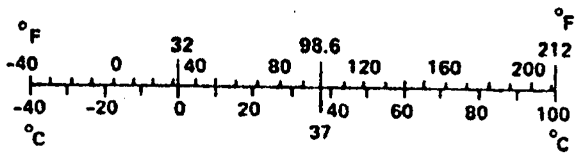
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



Appendix A

Table A1

TEST SERIES 1

Material Capacity From Test Specimen

Material : Steel

Designation : ASTM - A441

Minimum Yield Strength : 50 ksi

Minimum Ultimate Tensile Strength : 70 ksi

	Yield	Ultimate	Elongation
Test 1	55.5 ksi	83.2 ksi	----
Test 2	61.6 ksi	83.5 ksi	0.176 in./in.

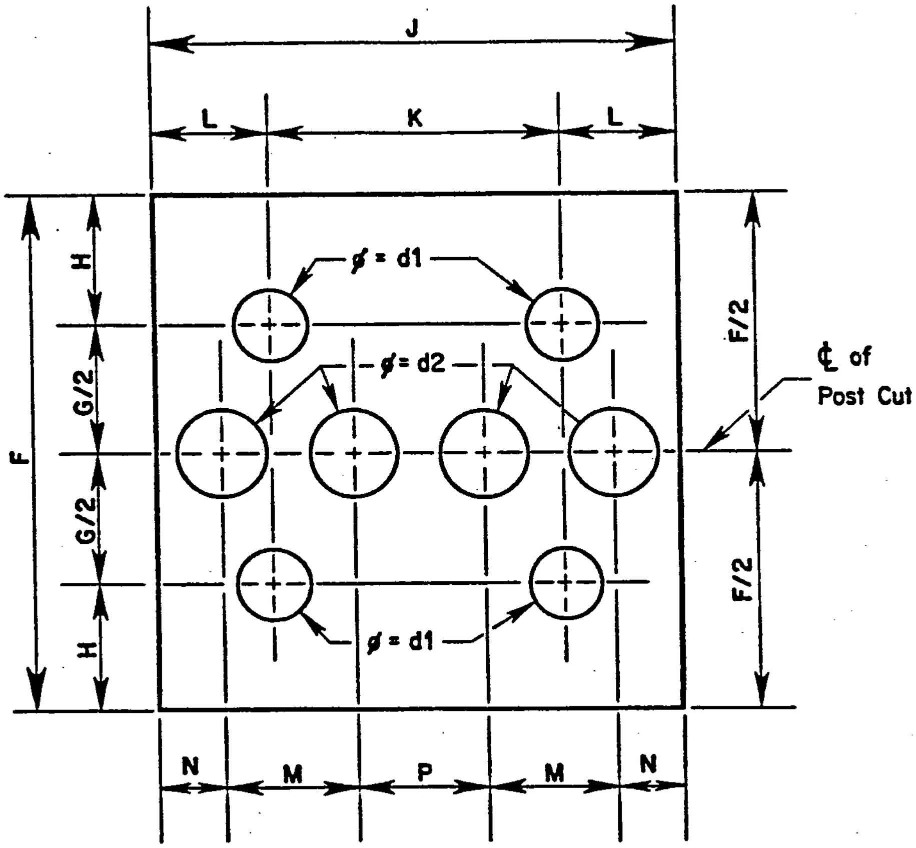
Description of Tests

TEST SERIES 1

Test 1

Test 1 was performed on a 5 3/4" x 6" x 1/2" Plate made of A441 steel. The cross-section was weakened by drilling four 15/16" holes leaving an effective cross-sectional area of 1.0 in.^{2}. The plate was fastened to the T-beam by means of two 3/4" A325 bolts on either side. These bolts were tightened by turn-of-the-nut method as per AISC recommendations.

When a load of 65 kips was achieved two bolts holding the T-beam to the testing machine broke. These were replaced and testing resumed. At a load of 72.5 kips the plate failed along the weakened section. The specimen elongated 0.52 inches. There was a bearing failure in the 7/16" flange (1/8" deformation) of the T-beam the 3/4" bolts were fastened through.



FUSE PLATE DETAIL
(See Table For Dims. & Wghts.)

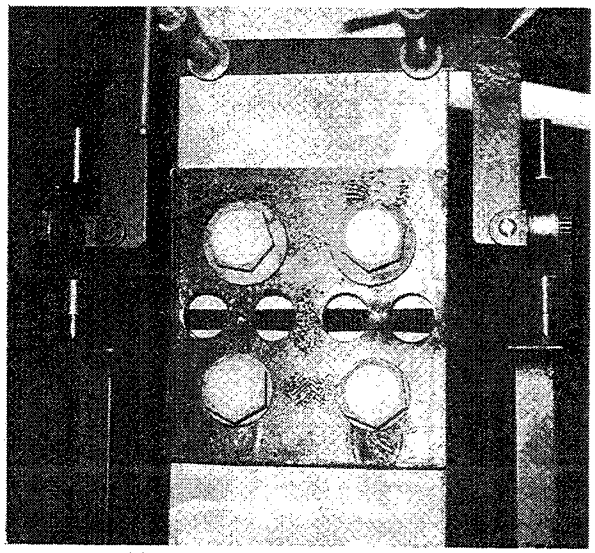
SERIES 1 TEST 1

Material : Steel   Designation : ASTM - A441

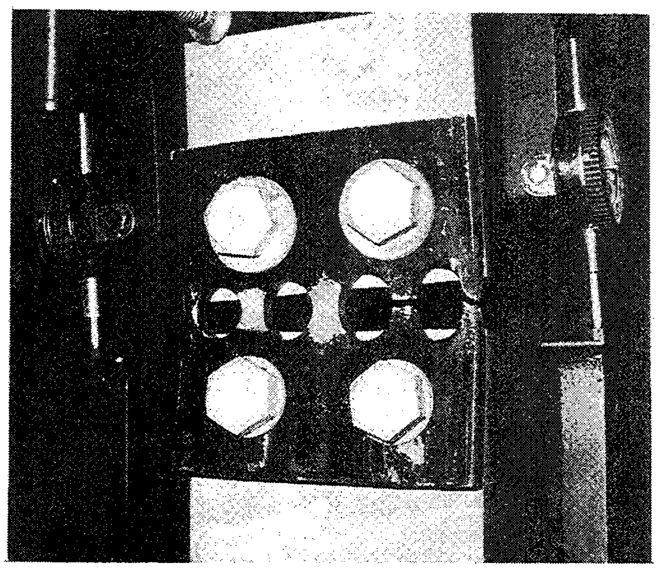
Post size(s) - W 10X22 or W 10X26	Wght. (lbs.) - 4.21
F (in.) - 6	M (in.) - 1 3/8
G (in.) - 3	N (in.) - 3/4
H (in.) - 1 1/2	P (in.) - 1 1/2
J (in.) - 5 3/4	d1 (in.) - 13/16
K (in.) - 2 3/4	d2 (in.) - 15/16
L (in.) - 1 1/2	t3 (in.) - 1/2

Bolt dia. (in.) - 3/4

Figure A1. 1/2" Fuse Plate Detail for Series 1, Test 1.



Before



After

Figure A2. 1/2" Plate Before and After Test 1.

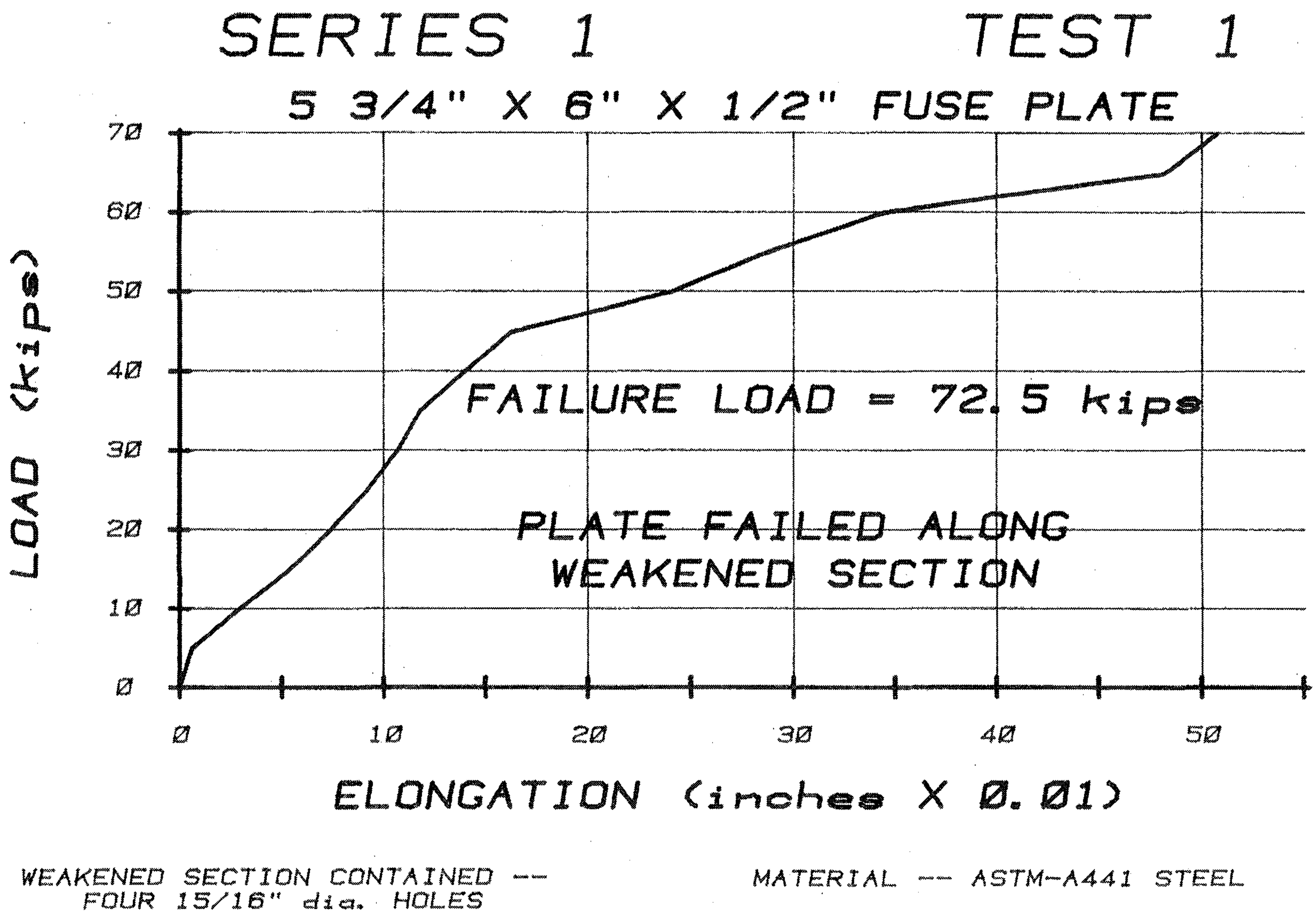


Figure A3. Load Versus Elongation Curve for Series 1, Test 1.

Test 2

Test 2 was performed on a 4" x 4" x 1/4" plate made of A441 steel. The cross-section was weakened by drilling four 13/16" holes leaving an effective cross-sectional area of 0.188 in². The plate was fastened to the T-beam by means of two 1/2" A325 bolts on either side. These bolts were tightened by turn-of-the-nut method as per AISC recommendation.

The 1/4" plate failed along the weakened section at an ultimate load of 13.0 kips. The maximum load reached during testing was 14.4 kips. Maximum elongation was 0.22 inches. There was a bearing failure in the 3/16" flange of 1/32".

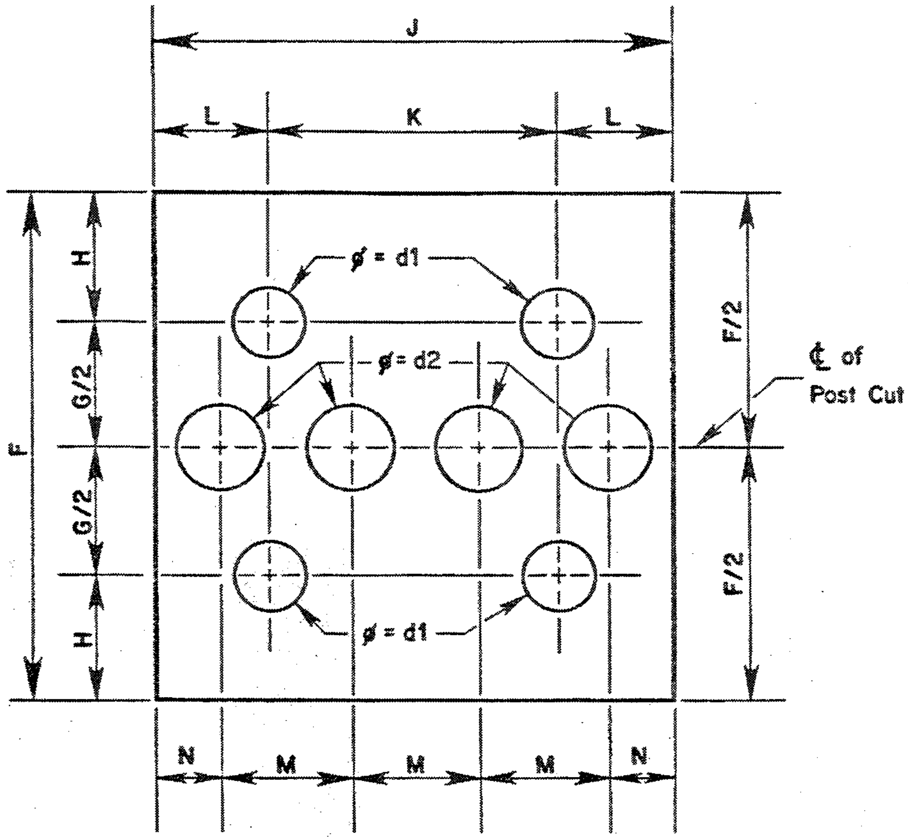


Plate Thickness = t3

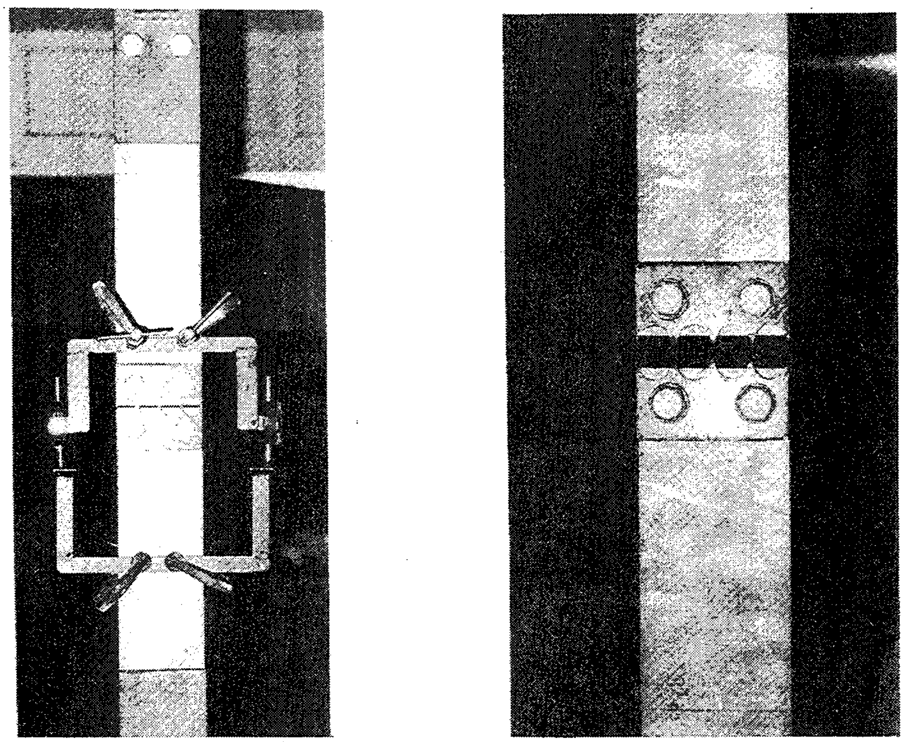
FUSE PLATE DETAIL
(See Table For Dims. & Wghts.)

SERIES 1 TEST 2

Material : Steel Designation : ASTM - A441

Post size(s) - W 6X9 or W 6X12	Wght. (lbs.) - 0.92
F (in.) - 4	M (in.) - 1
G (in.) - 2	N (in.) - 1/2
H (in.) - 1	d1 (in.) - 9/16
J (in.) - 4	d2 (in.) - 13/16
K (in.) - 2 1/4	t3 (in.) - 1/4
L (in.) - 7/8	Bolt dia. (in.) - 1/2

Figure A4. 1/4" Fuse Plate Detail for Series 1, Test 2.



Before After

Figure A5. 1/4" Plate Before and After Test 2.

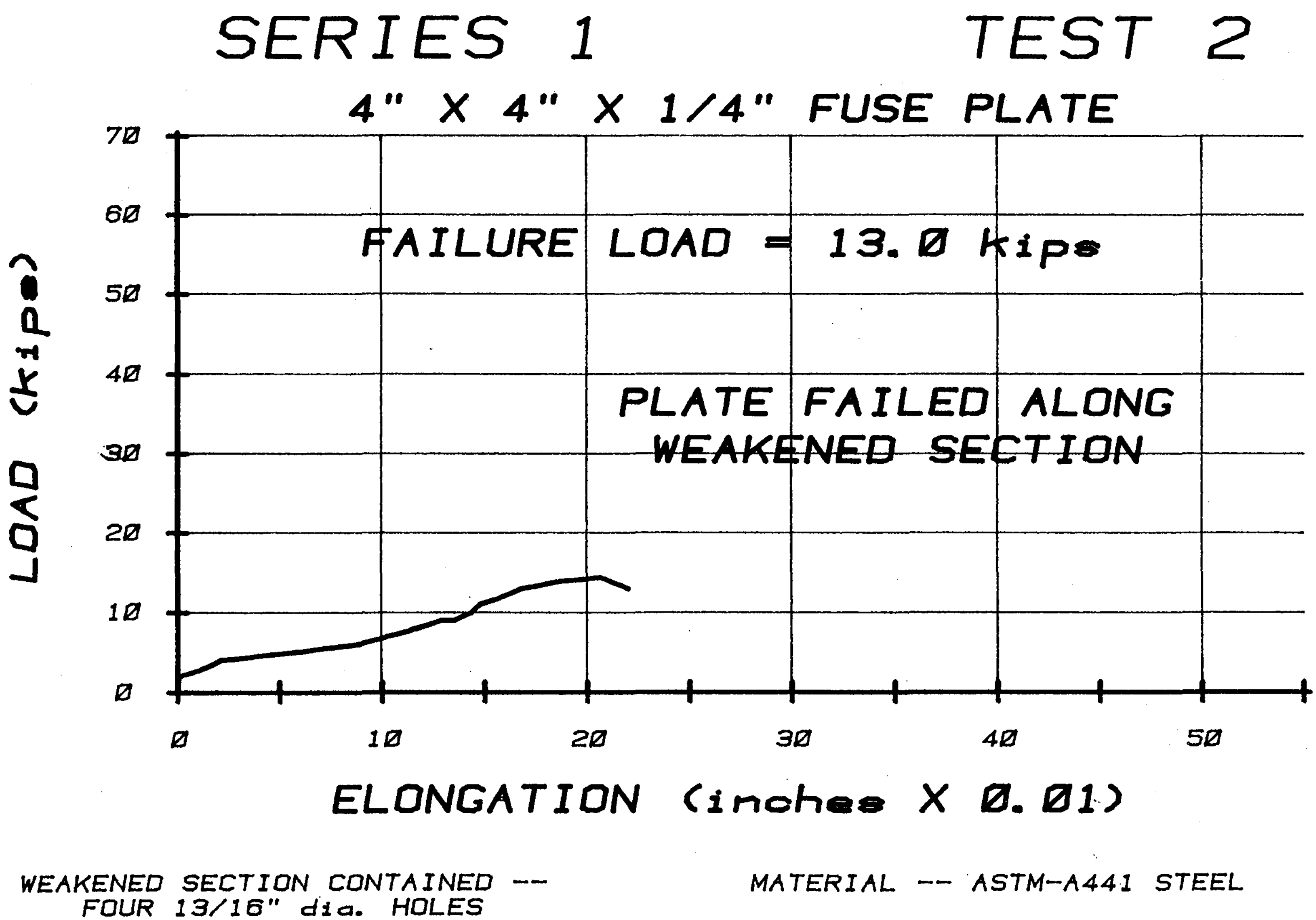
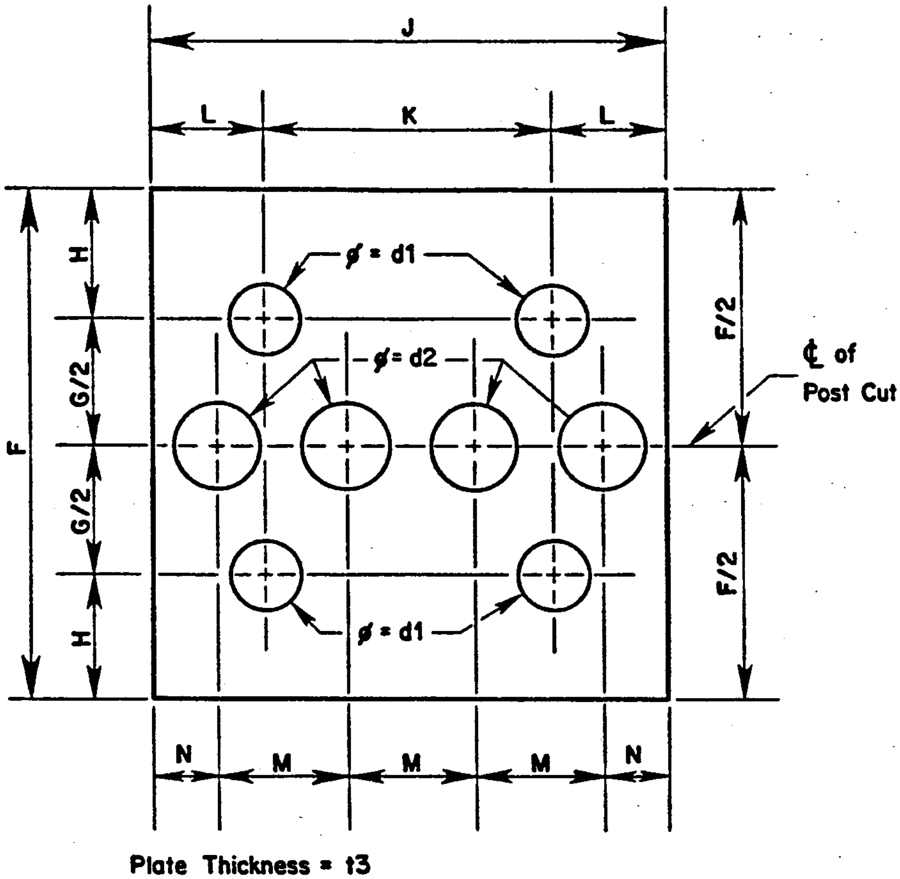


Figure A6. Load Versus Elongation Curve for Series 1, Test 2.

Test 3

Test 3 was performed on a 5 1/4" x 5" x 3/8" plate made of A441 steel. The cross-section was weakened by drilling four 1" holes leaving an effective cross-sectional area of 0.469 in^2. The plate was fastened to the T-beam by means of two 5/8" A325 bolts on either side. These bolts were tightened by turn-of-the-nut method as per AISC recommendation.

At a load of 39 kips one of the 5/8" bolts broke. The specimen had elongated 0.20 in. at time of failure. Yielding occurred through the weakened section. There was a bearing failure in the 5/16" flange of 1/32".



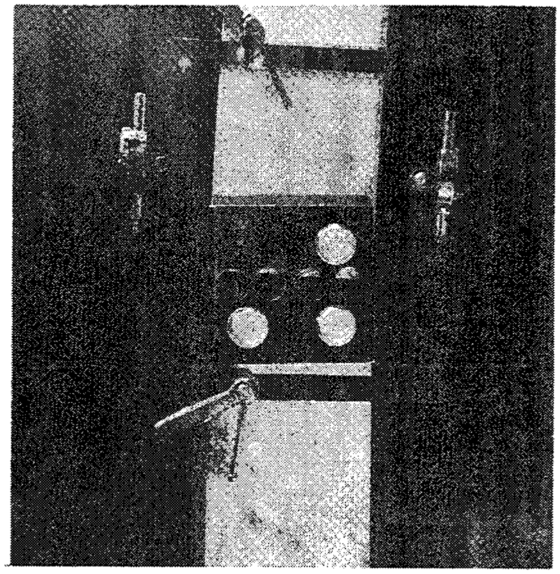
FUSE PLATE DETAIL
(See Table For Dims. & Wghts.)

SERIES 1 TEST 3

Material : Steel   Designation : ASTM - A441

Post size(s) - W 8X18	Wght. (lbs.) - 2.30
F (in.) - 5	M (in.) - 1 1/4
G (in.) - 2 1/2	N (in.) - 3/4
H (in.) - 1 1/4	d1 (in.) - 11/16
J (in.) - 5 1/4	d2 (in.) - 1
K (in.) - 2 3/4	t3 (in.) - 3/8
L (in.) - 1 1/4	Bolt dia. (in.) - 5/8

Figure A7. 3/8" Fuse Plate Detail for Series 1, Test 3.



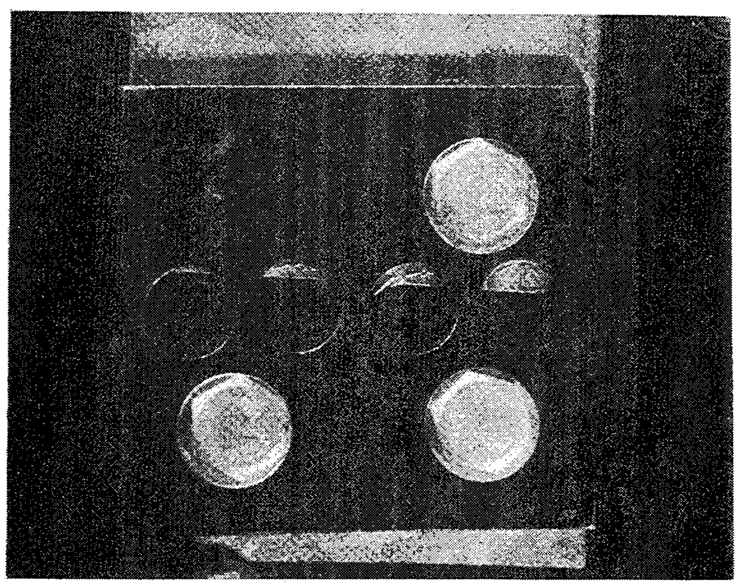
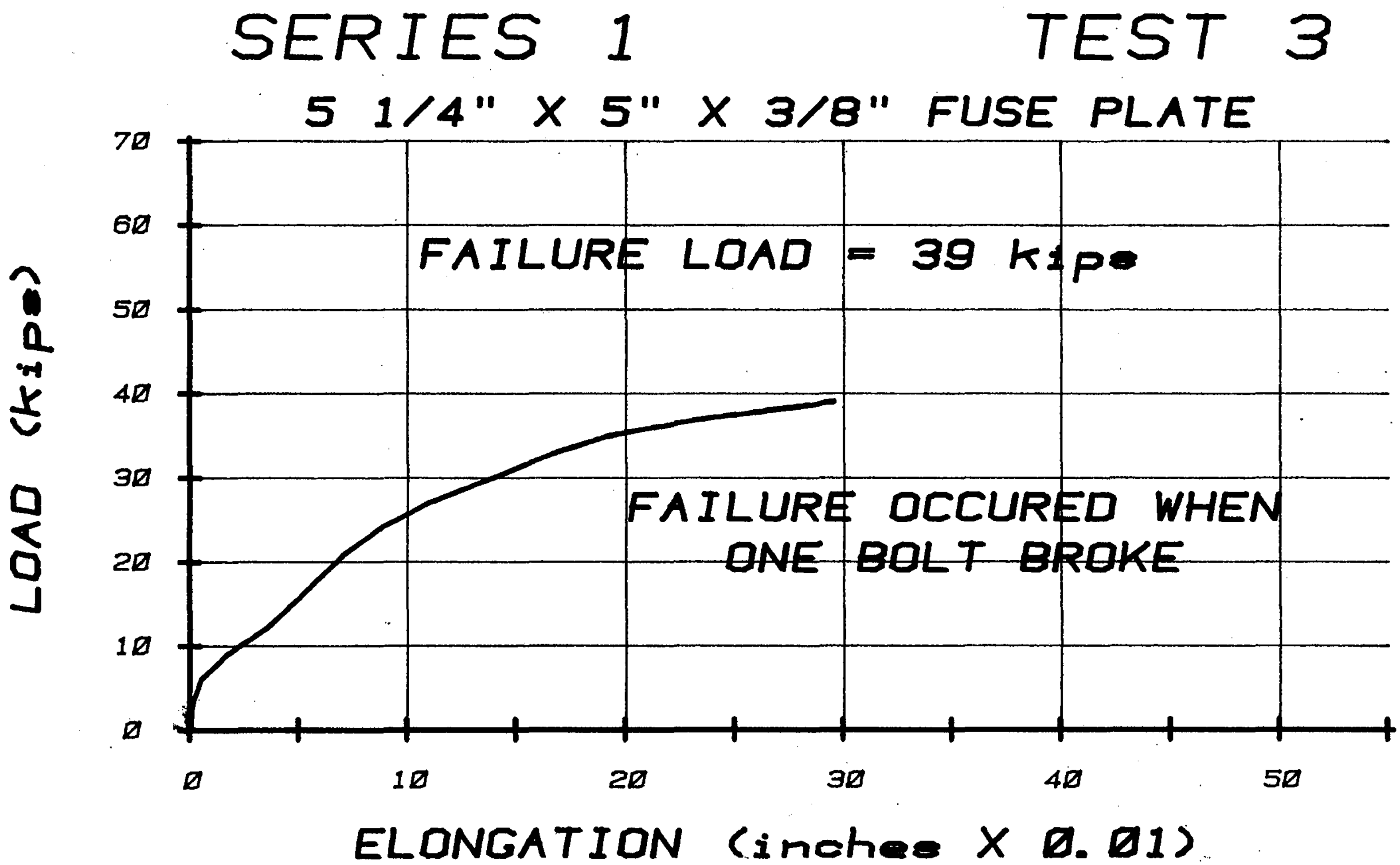


Figure A8. 3/8" Plate After Test 3.



WEAKENED SECTION CONTAINED -- FOUR 1" dia. HOLES

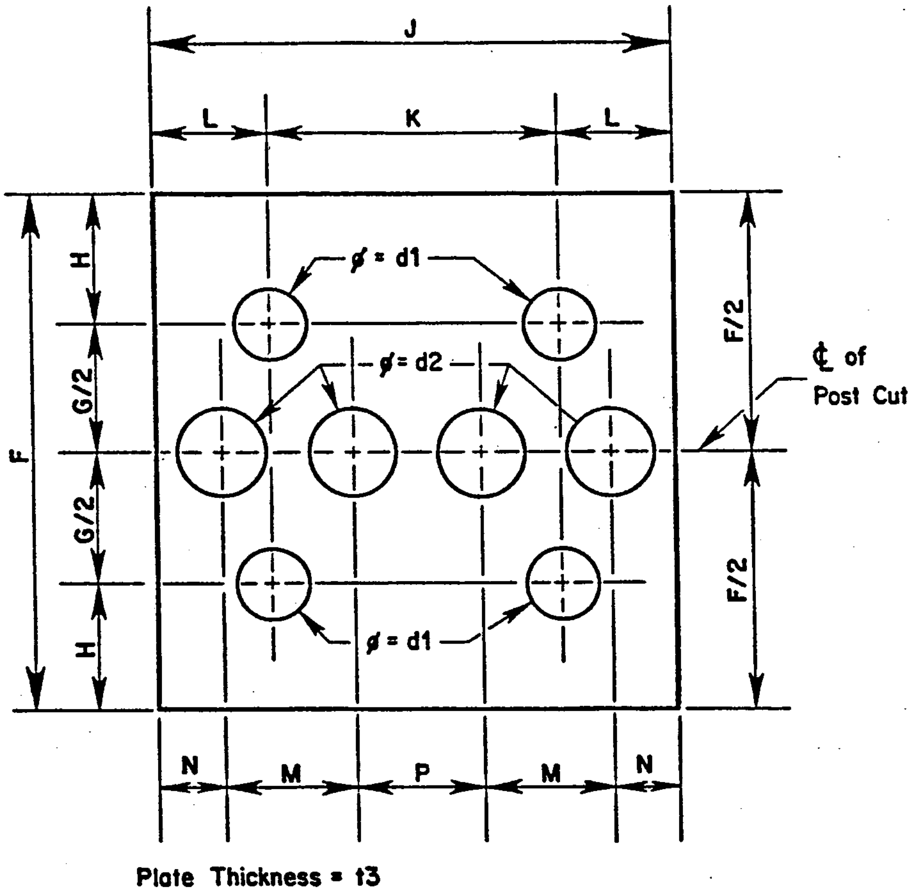
MATERIAL -- ASTM-A441 STEEL

Figure A9. Load Versus Elongation Curve for Series 1, Test 3.

Test 4

Test 4 was a repeat of Test 1 (5 3/4" x 6"x 1/2" plate) except the weakened section contained holes 1 in. in diameter. This leaves an effective area of 0.875 in^2. The plate was fastened with two 3/4" A325 bolts that were tightened by the turn-of-the-nut method.

The plate failed along the weakened section at an ulimate load of 68 kips. The specimen had elongated 0.54 in. just before failure. There was a bearing failure in the 7/16" flange of 1/16 ".



FUSE PLATE DETAIL

(See Table For Dims. & Wghts.)

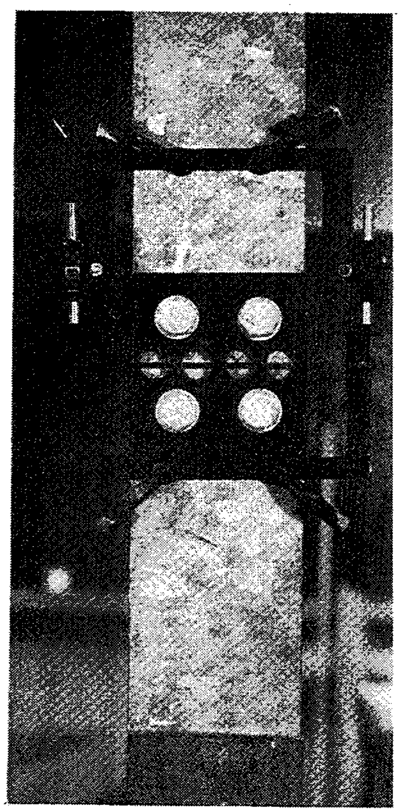
SERIES 1   TEST 4

Material : Steel   Designation : ASTM - A441

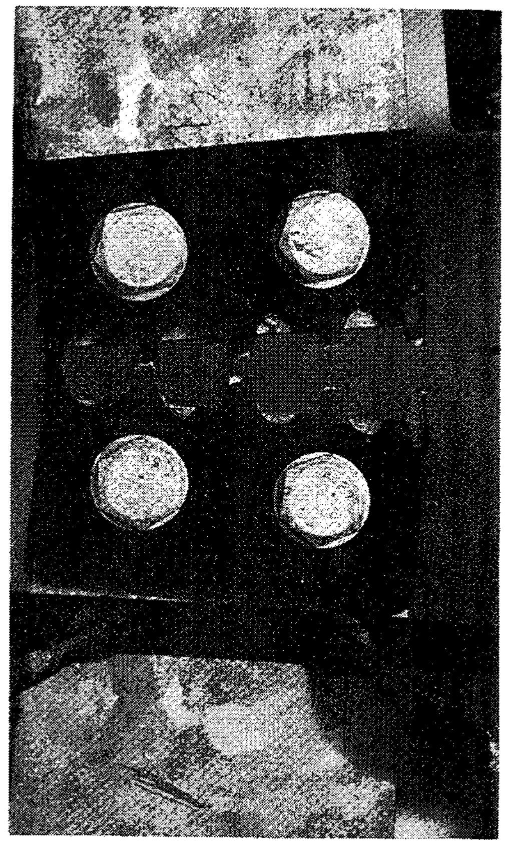
Post size(s) - W 10X22 or W 10X26	Wght. (lbs.) - 4.15
F (in.) - 6	M (in.) - 1 3/8
G (in.) - 3	N (in.) - 3/4
H (in.) - 1 1/2	P (in.) - 1 1/2
J (in.) - 5 3/4	d1 (in.) - 13/16
K (in.) - 2 3/4	d2 (in.) - 1
L (in.) - 1 1/2	t3 (in.) - 1/2

Bolt dia. (in.) - 3/4

Figure A10. 1/2" Fuse Plate Detail for Series 1, Test 4.



Before



After

Figure A11. 1/2" Plate Before and After Test 4.

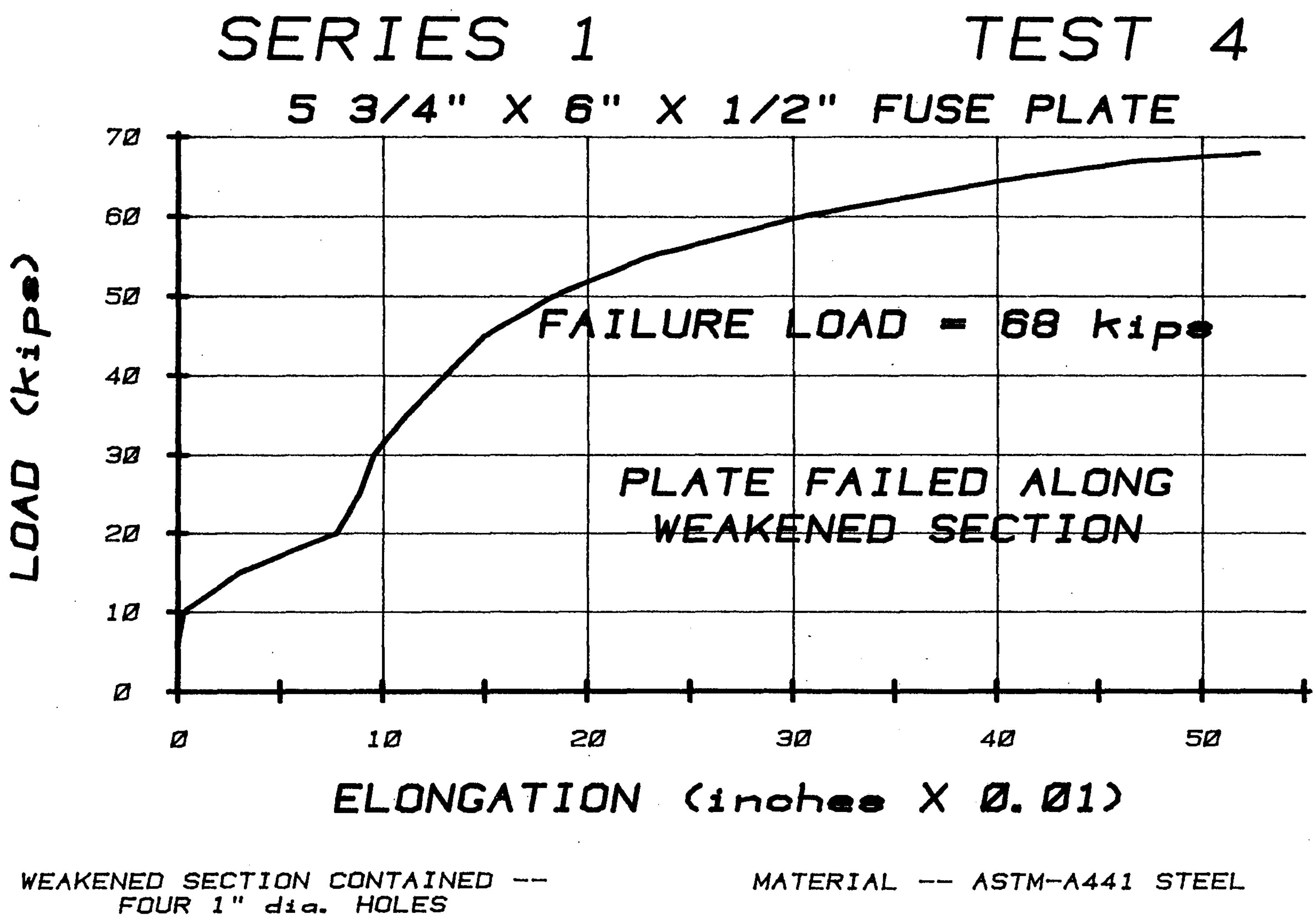


Figure A12. Load Versus Elongation Curve for Series 1, Test 4.

Appendix B

Table B1

TEST SERIES 2

Material Capacity From Test Specimen

Material : Steel

Designation : ASTM - A36

Minimum Yield Strength : 36 ksi

Ultimate Tensile Strength : 58-80 ksi

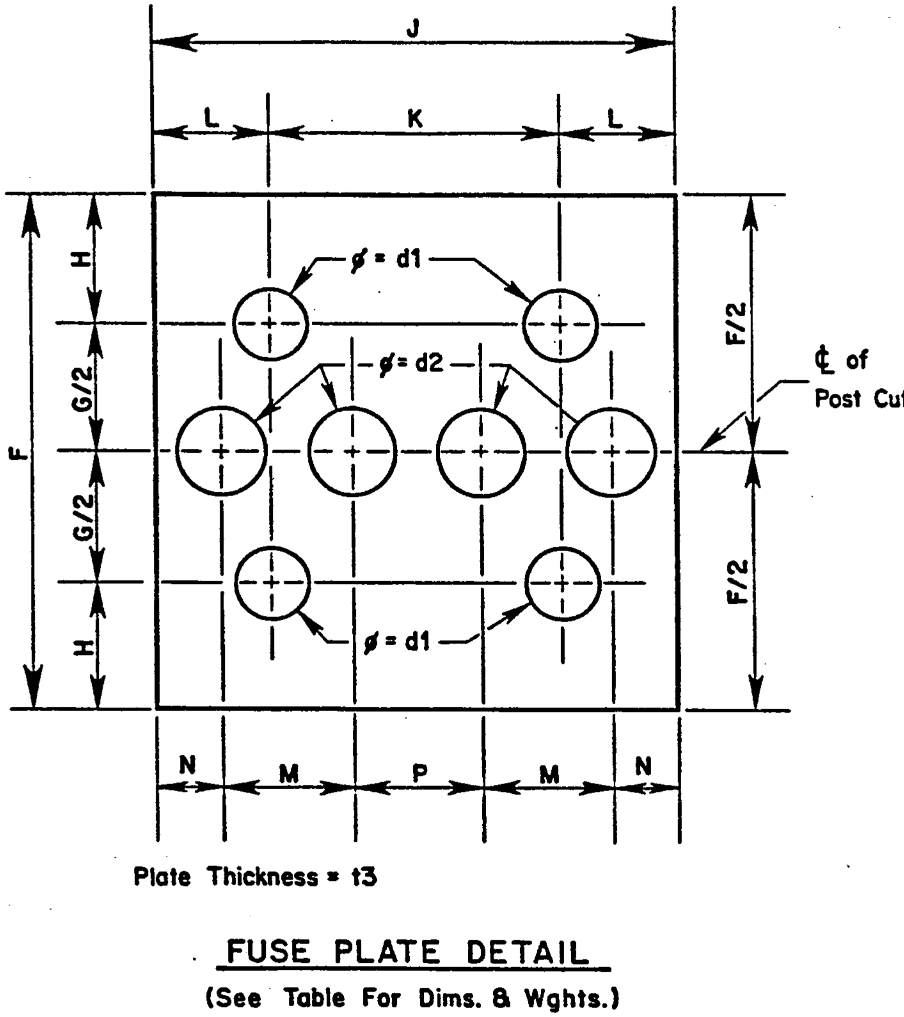
	Yield	Ultimate	Elongation
Test 1	43.9 ksi	64.9 ksi	0.290 in./in.
Test 2	41.7 ksi	63.9 ksi	0.290 in./in.

TEST SERIES 2

Test 1

Test 1 was performed on a 4" x 4" x 1/4" plate made of A36 Steel. The cross-section was weakened by drilling four 3/4" dia. holes, leaving an effective cross-sectional area of 0.25 sq. inches. The plate was fastened to the T-beam by means of two 1/2" A325 bolts on each side. These bolts were tightened by the turn-of-the-nut method as per AISC recommendations.

When a load of 19.2 kips was achieved the plate failed along the weakened section. The specimen elongated 0.19 inches.



SERIES 2 TEST 1

Material : Steel

Designation : ASTM - A36

Post size(s) - W 6X9 or W 6X12

Wght. (lbs.) - 1.01

F (in.) - 4

G (in.) - 2

H (in.) - 1

J (in.) - 4

K (in.) - 2 1/4

L (in.) - 7/8

M (in.) - 15/16

N (in.) - 9/16

P (in.) - 1

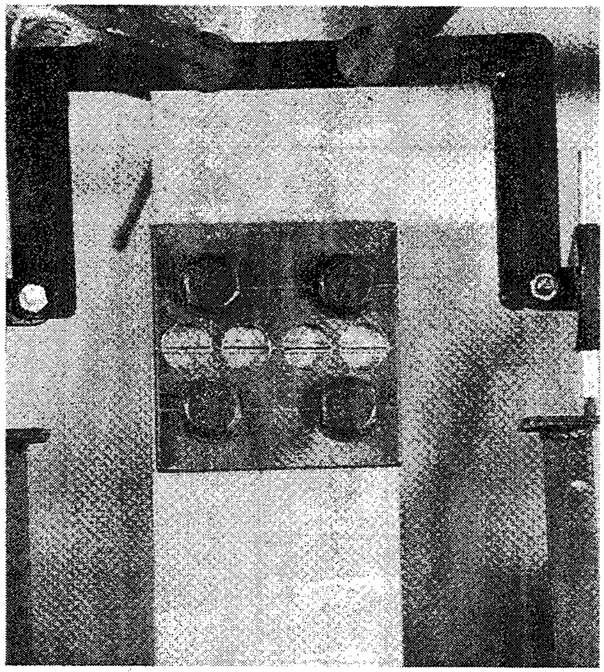
d1 (in.) - 9/16

d2 (in.) - 3/4

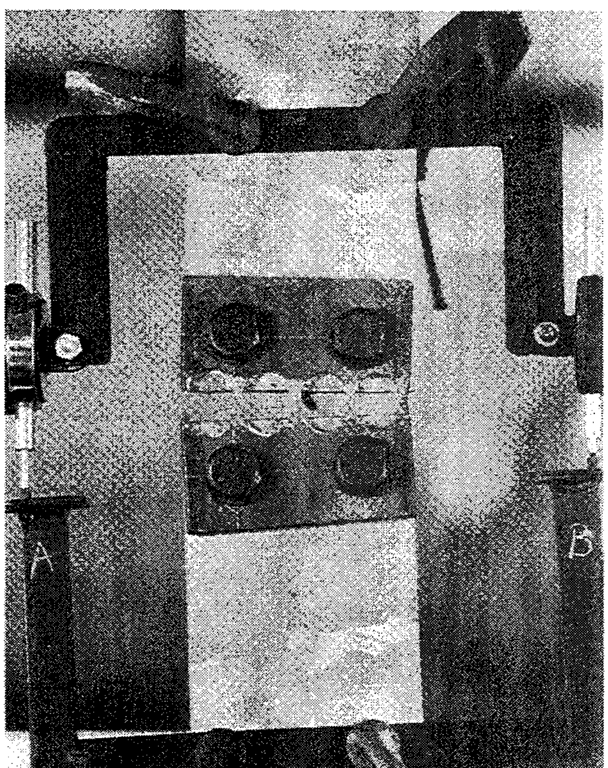
t3 (in.) - 1/4

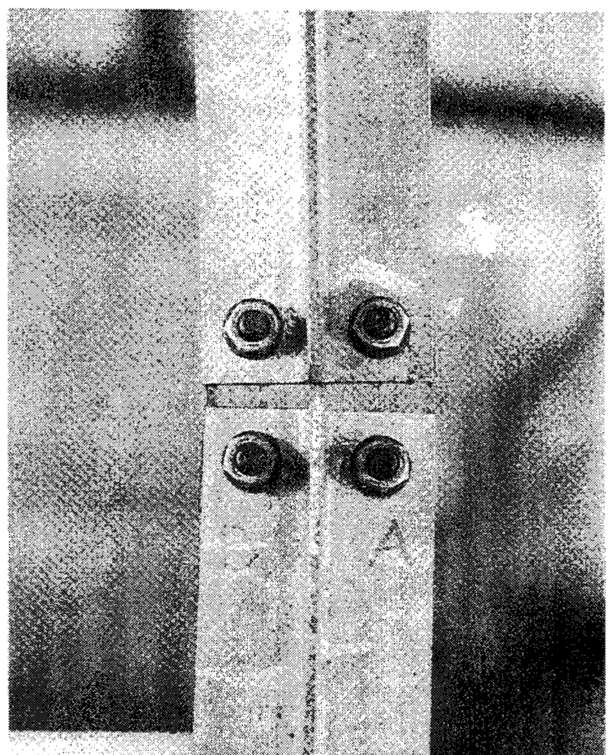
Bolt dia. (in.) - 1/2

Figure B1. 1/4" Fuse Plate Detail for Series 2, Test 1.



Before





After

Figure B2. 1/4" Plate Before and After Series 2, Test 1

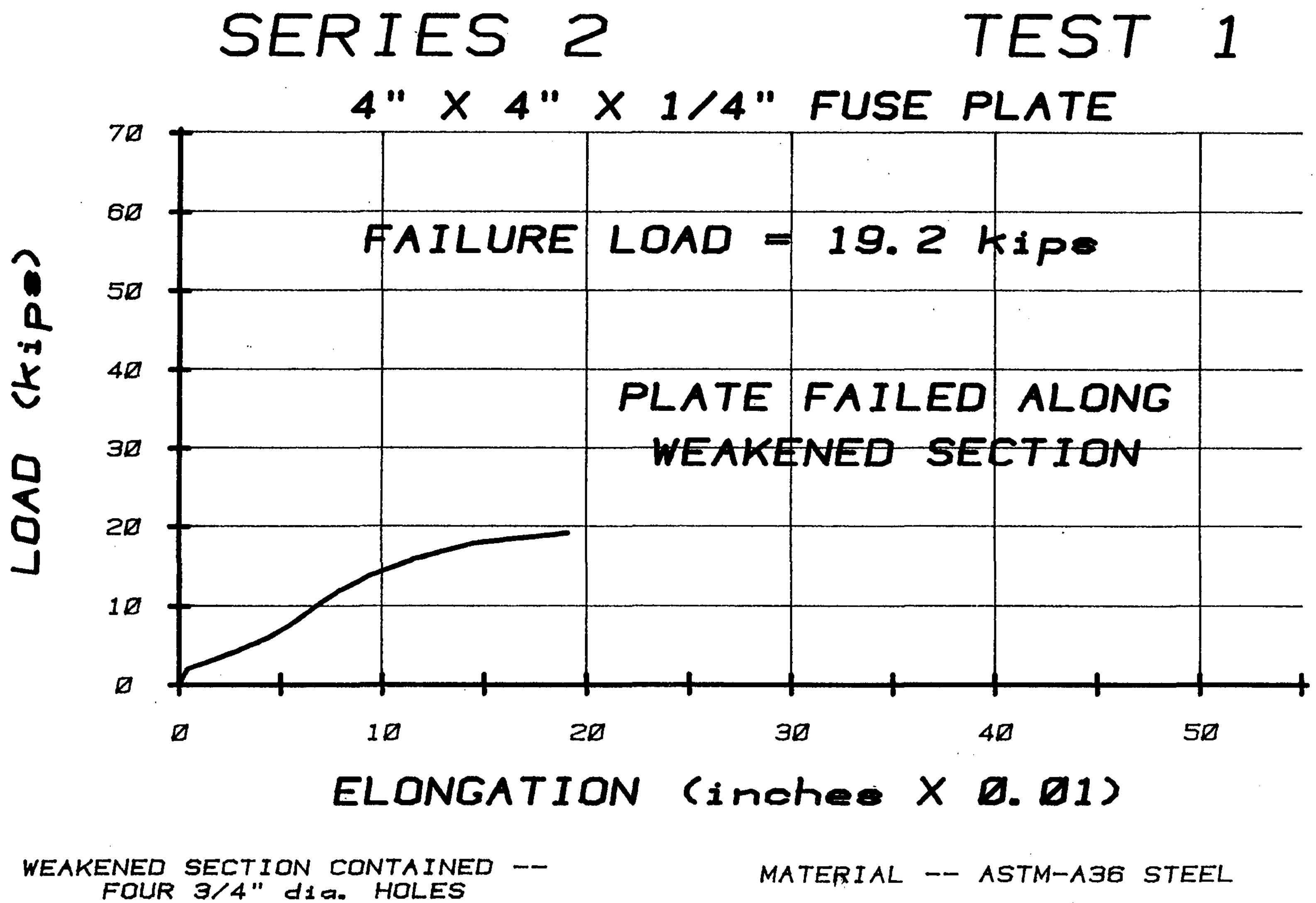


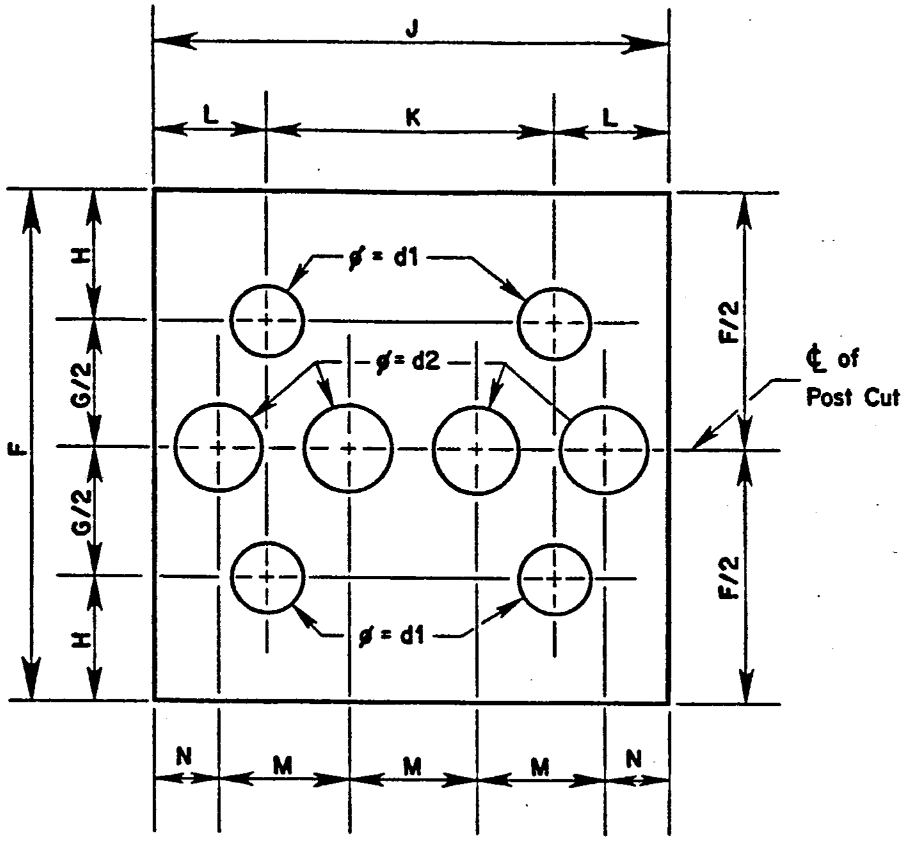
Figure B3. Load Versus Elongation Curve for Series 2, Test 1.

TEST SERIES 2

Test 2

Test 2 was performed on a 5 3/4" x 6" x 1/2" plate made of A36 Steel. The cross-section was weakened by drilling four 1 1/8" dia. holes, leaving an effective cross-sectional area of 0.625 sq. inches. The plate was fastened to the T-beam by means of two 3/4" A325 bolts on each side. These bolts were tightened by the turn-of-the-nut method as per AISC recommendations.

When a load of 47.2 kips was achieved the plate failed along the weakened section. The specimen elongated 0.38 inches.



FUSE PLATE DETAIL

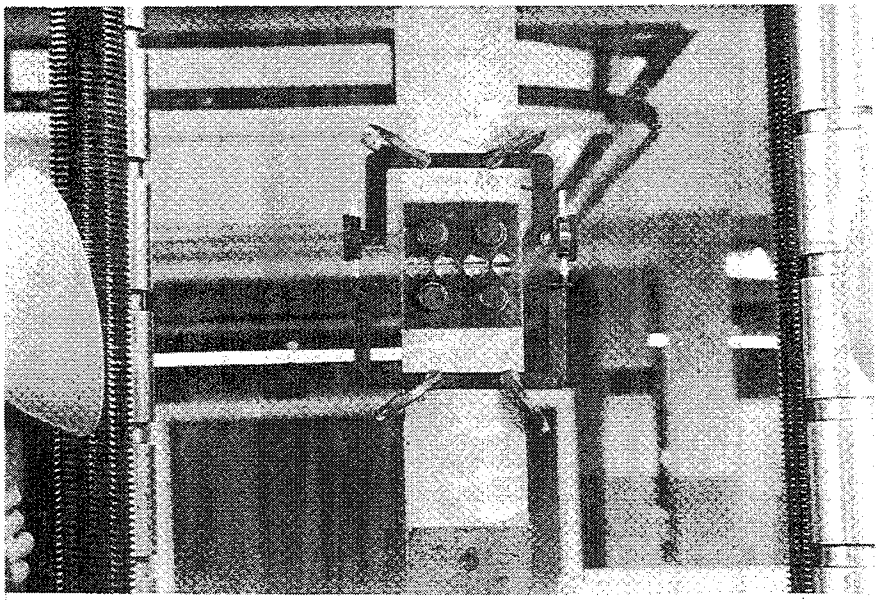
(See Table For Dims. & Wghts.)

SERIES 2 TEST 2

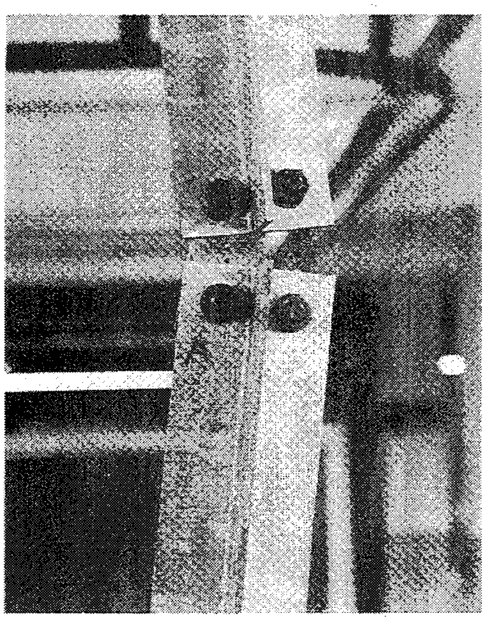
Material : Steel Designation : ASTM - A36

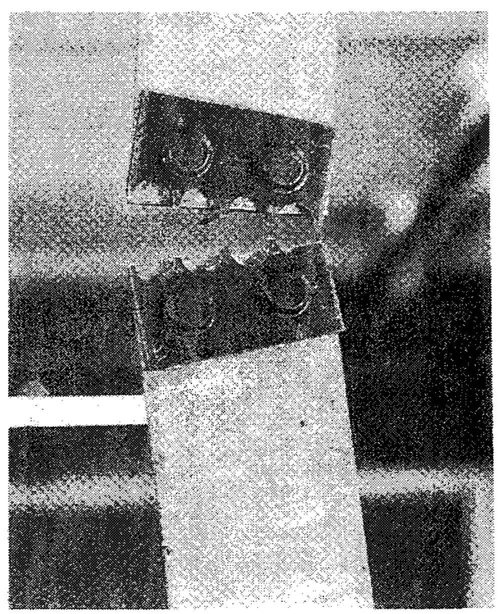
Post size(s) - W 10X22 or W 10X26	Wght. (lbs.) - 4.03
F (in.) - 6	M (in.) - 1 3/8
G (in.) - 3	N (in.) - 13/16
H (in.) - 1 1/2	d1 (in.) - 13/16
J (in.) - 5 3/4	d2 (in.) - 1 1/8
K (in.) - 2 3/4	t3 (in.) - 1/2
L (in.) - 1 1/2	Bolt dia. (in.) - 3/4

Figure B4. 1/2" Fuse Plate Detail for Series 2, Test 2.



Before





After

Figure B5. 1/2" Plate Before and After Series 2, Test 2

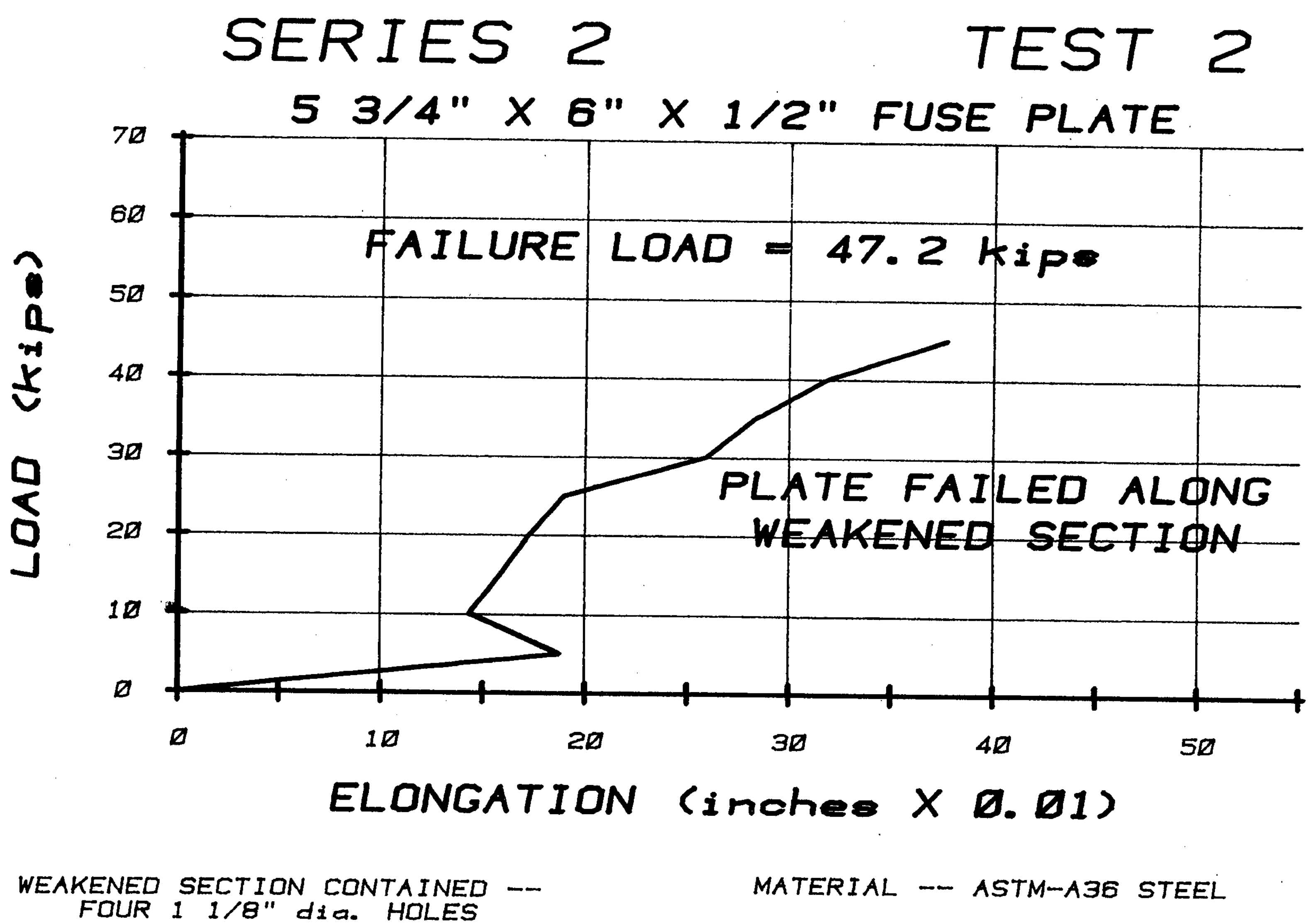


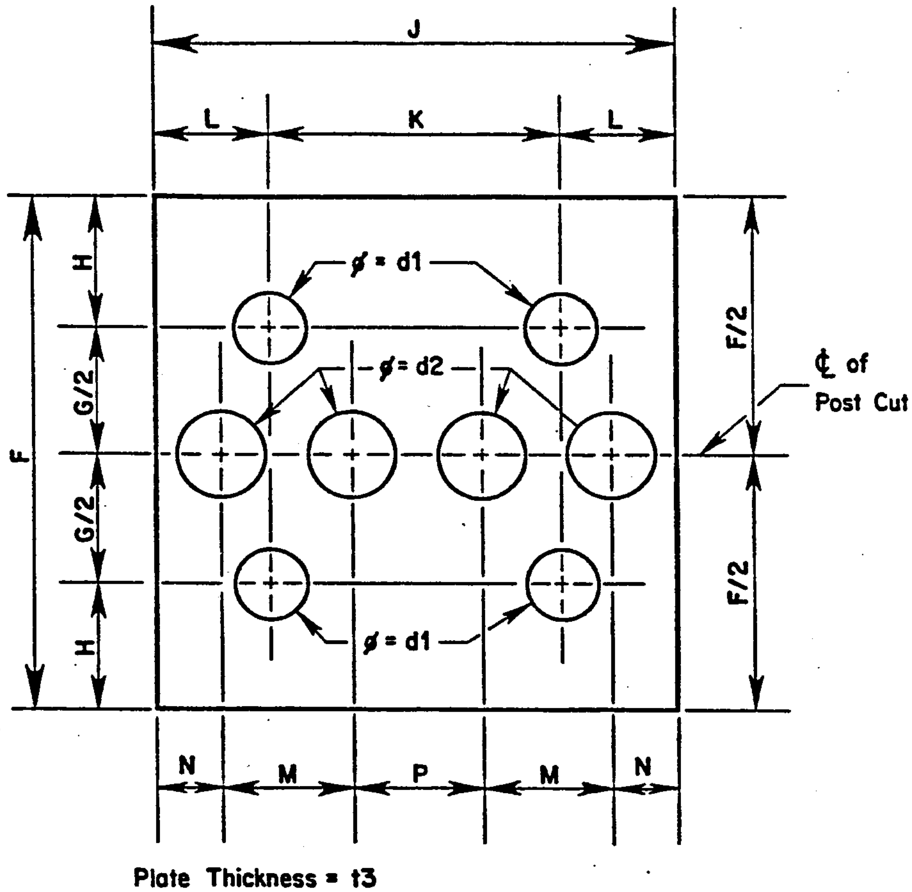
Figure B6. Load Versus Elongation Curve for Series 2, Test 2.

TEST SERIES 2

Test 3

Test 3 was performed on a 4" x 4" x 1/4" plate made of A36 Steel. The cross-section was weakened by drilling four 3/4" dia. holes, leaving an effective cross-sectional area of 0.25 sq. inches. The plate was fastened to the T-beam by means of two 1/2" A325 bolts on each side. These bolts were tightened by the turn-of-the-nut method as per AISC recommendations.

When a load of 19.5 kips was achieved the plate failed along the weakened section. The specimen elongated 0.32 inches.



FUSE PLATE DETAIL

(See Table For Dims. & Wghts.)

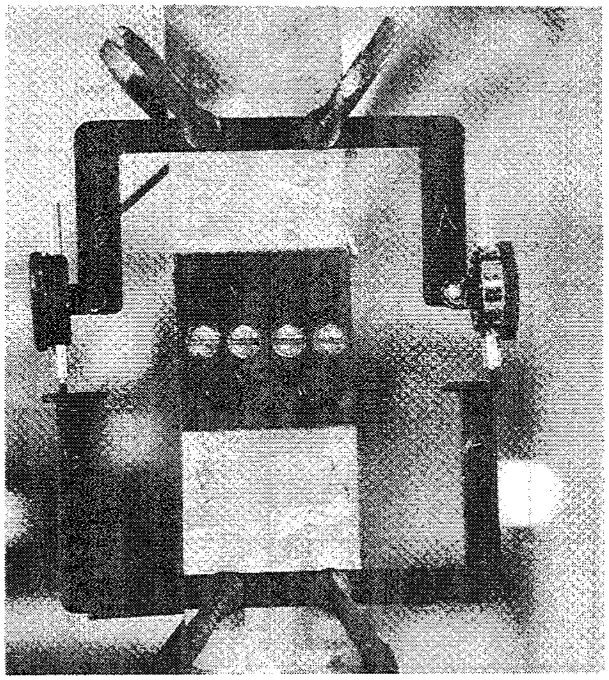
SERIES 2 TEST 3

Material : Steel Designation : ASTM - A36

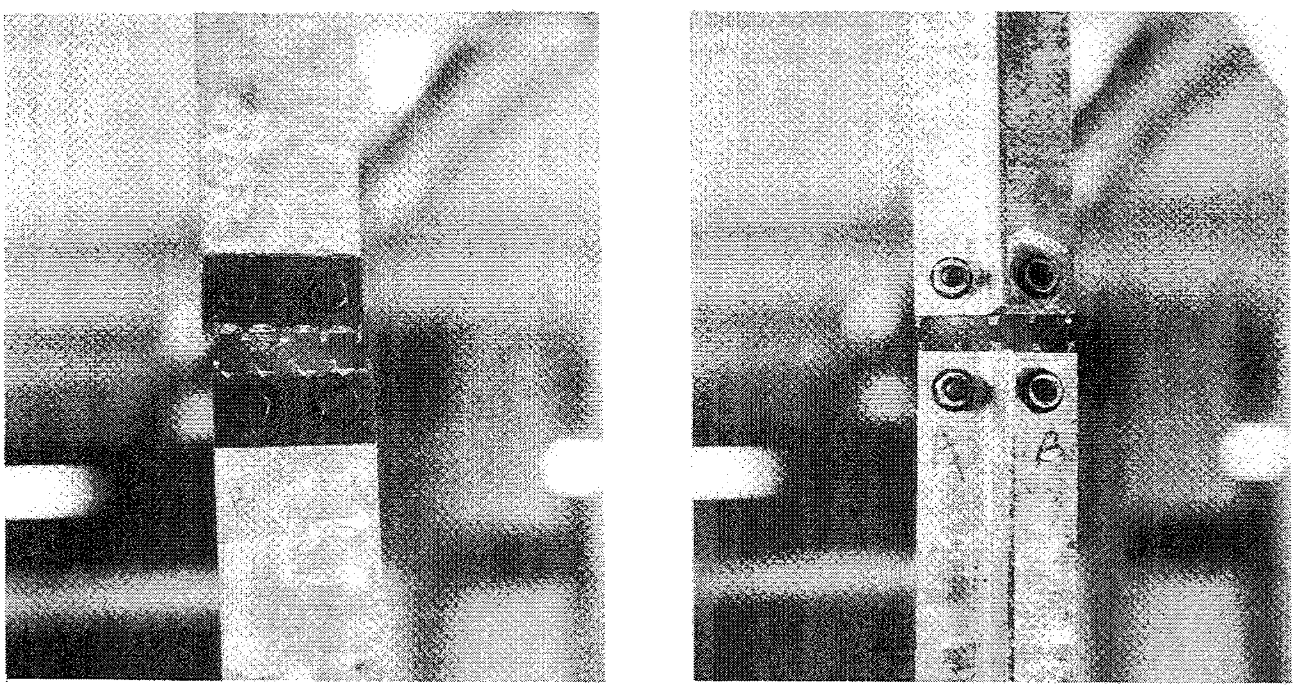
Post size(s) - W 6X9 or W 6X12	Wght. (lbs.) - 0.94
F (in.) - 4	M (in.) - 15/16
G (in.) - 2	N (in.) - 9/16
H (in.) - 1	P (in.) - 1
J (in.) - 4	d1 (in.) - 9/16
K (in.) - 2 1/4	d2 (in.) - 3/4
L (in.) - 7/8	t3 (in.) - 1/4

Bolt dia. (in.) - 1/2

Figure B7. 1/4" Fuse Plate Detail for Series 2, Test 3.



Before



After

Figure B8. 1/4" Plate Before and After Series 2, Test 3

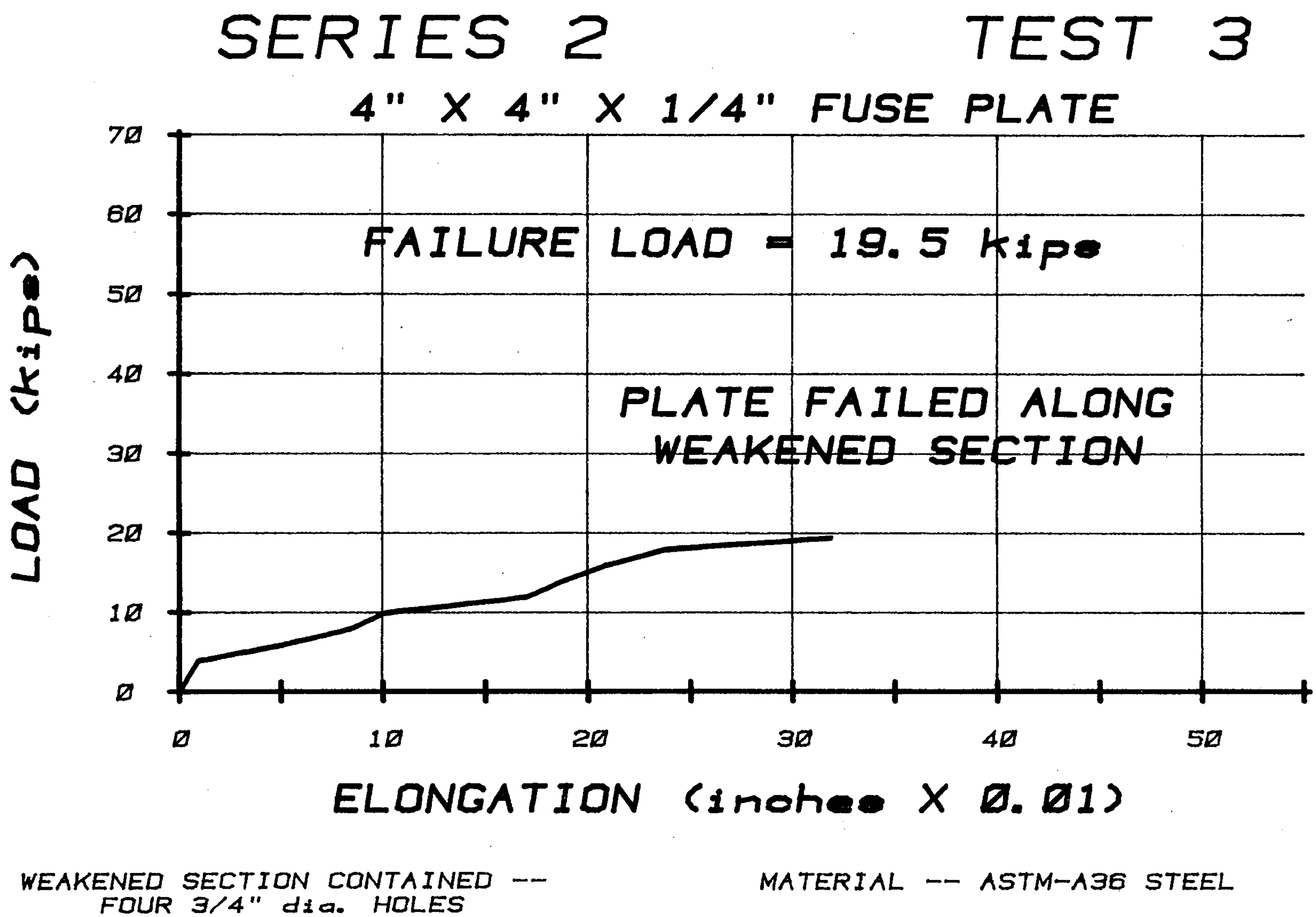


Figure B9. Load Versus Elongation Curve for Series 2, Test 3.

Test 4

Test 4 was performed on a 5 1/4" x 5" x 3/8" plate made of A36 Steel. The cross-section was weakened by drilling four 1 1/16" dia. holes, leaving an effective cross-sectional area of 0.375 sq. inches. The plate was fastened to the T-beam by means of two 5/8" A325 bolts on each side. These bolts were tightened by the turn-of-the-nut method as per AISC recommendations.

When a load of 24 kips was achieved the plate failed along the weakened section. The specimen elongated approximately 0.12 inches.

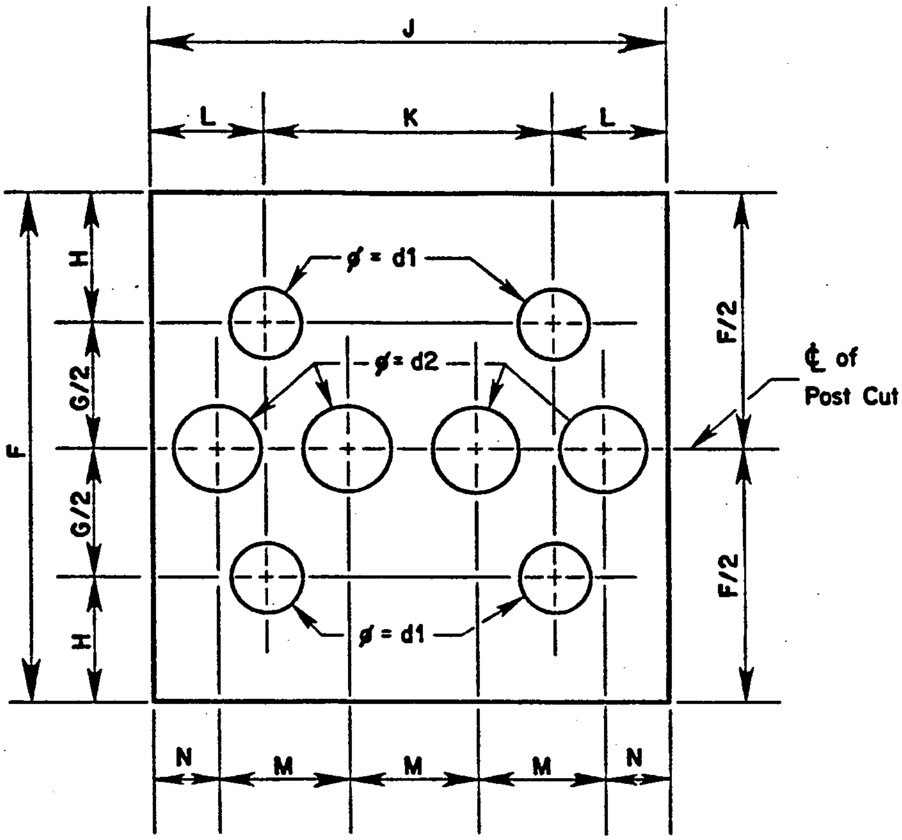


Plate Thickness = t3

FUSE PLATE DETAIL

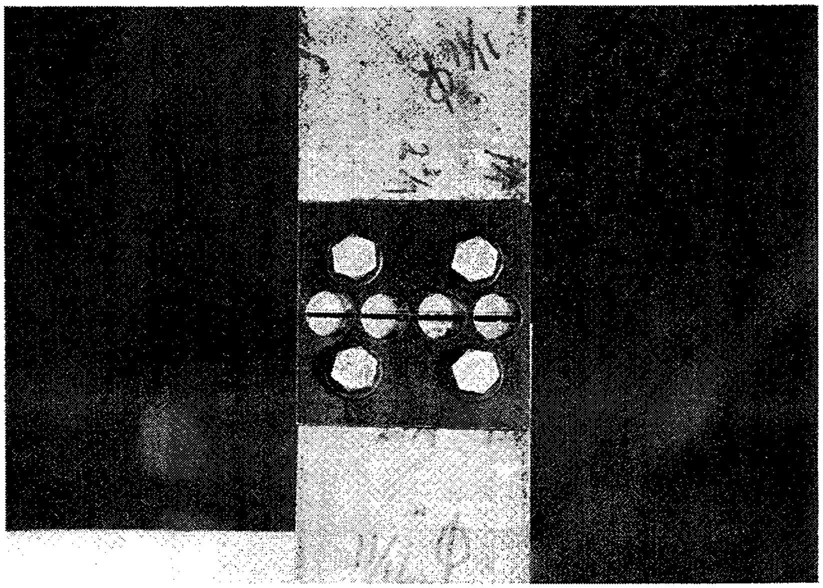
(See Table For Dims. & Wghts.)

SERIES 2 TEST 4

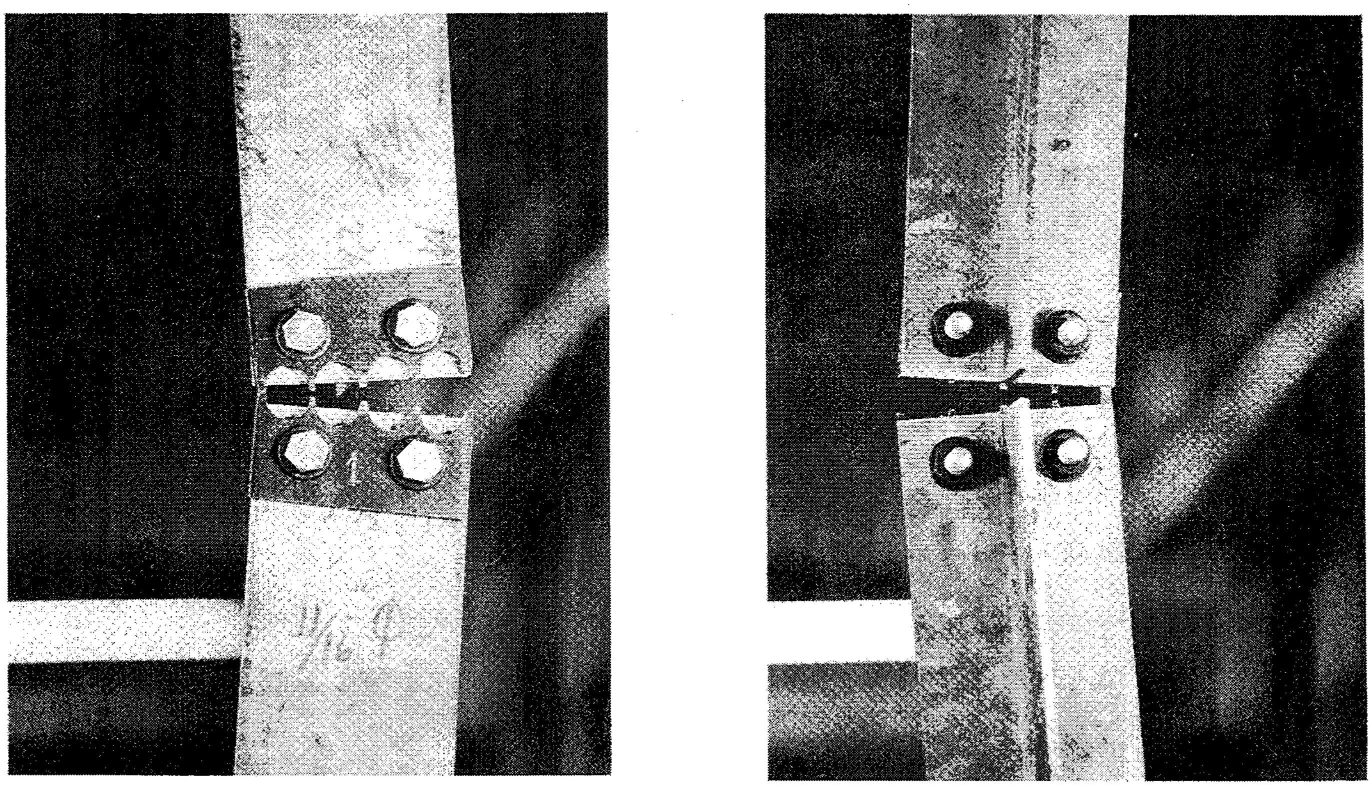
Material : Steel Designation : ASTM - A36

Post size(s) - W 8X18	Wght. (lbs.) - 2.26
F (in.) - 5	M (in.) - 1 1/4
G (in.) - 2 1/2	N (in.) - 3/4
H (in.) - 1 1/4	d1 (in.) - 11/16
J (in.) - 5 1/4	d2 (in.) - 1 1/16
K (in.) - 2 3/4	t3 (in.) - 3/8
L (in.) - 1 1/4	Bolt dia. (in.) - 5/8

Figure B10. 3/8" Fuse Plate Detail for Series 2, Test 4.



Before



After

Figure B11. 3/8" Plate Before and After Series 2, Test 4

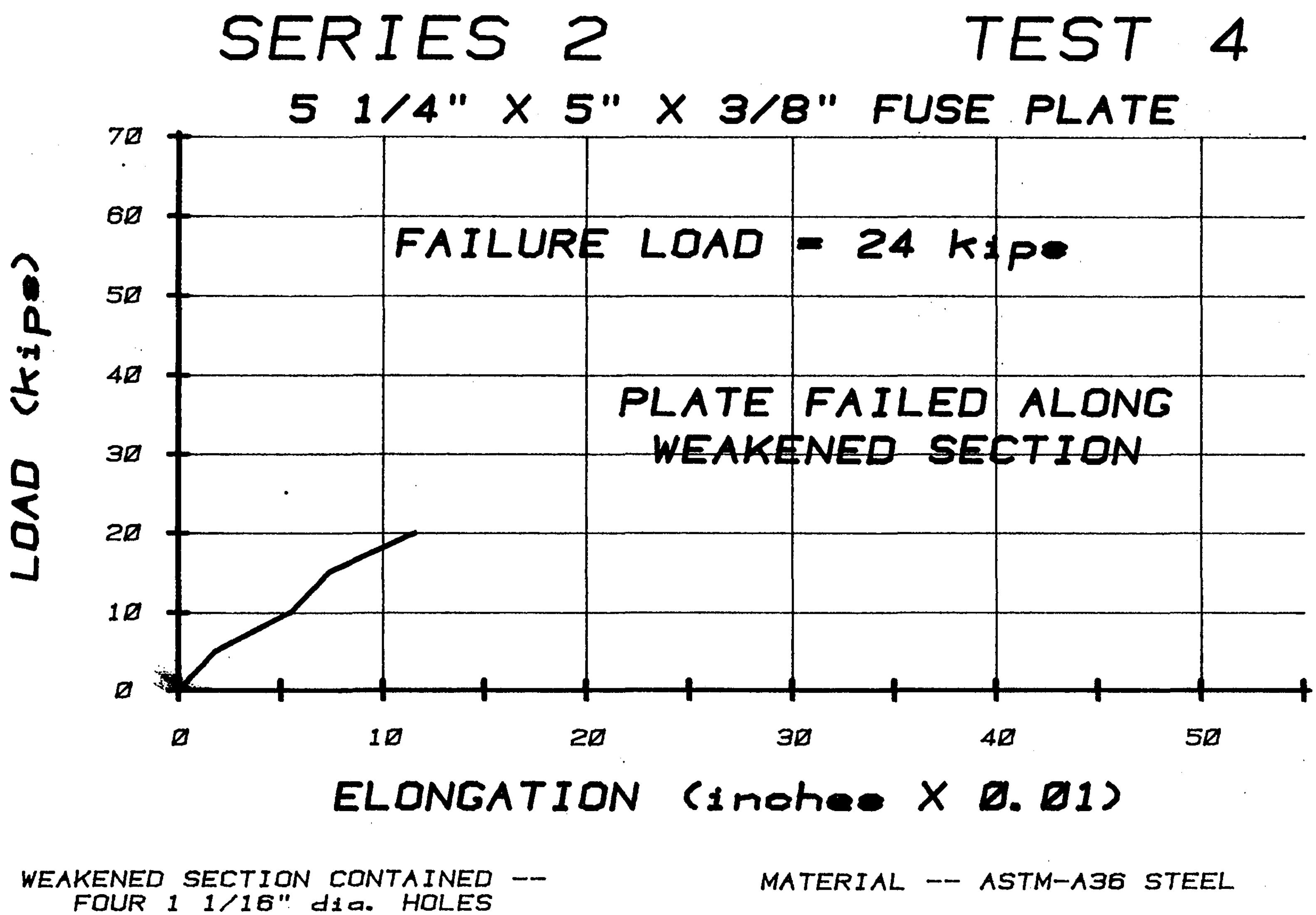


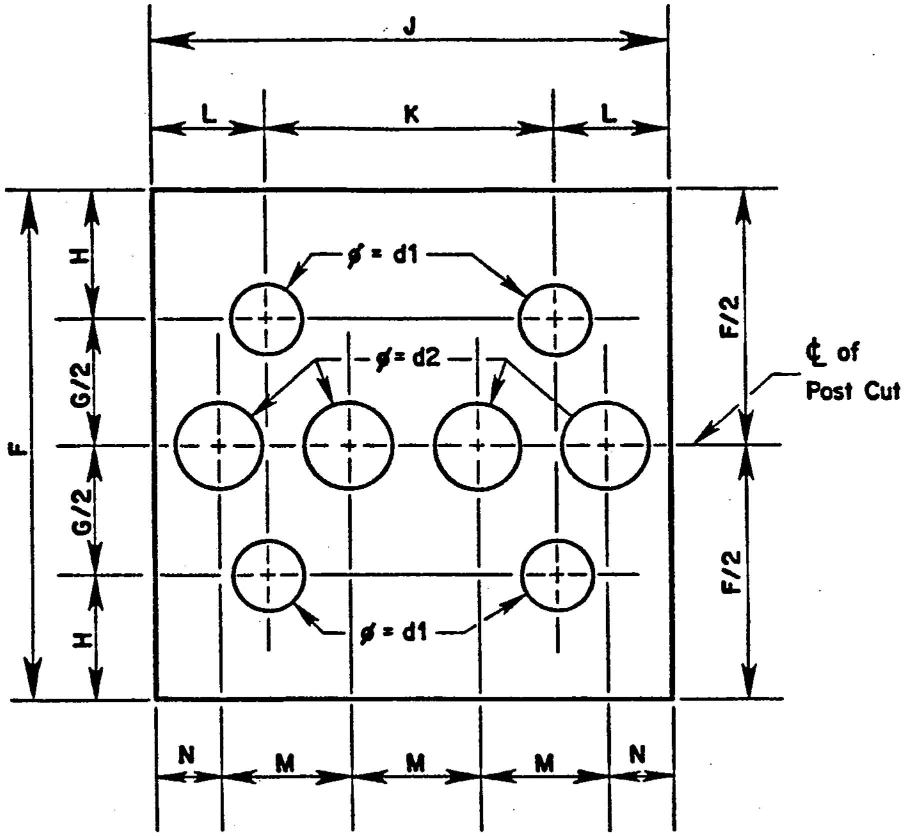
Figure B12. Load Versus Elongation Curve for Series 2, Test 4.

TEST SERIES 2

Test 5

Test 5 was performed on a 5 1/4" x 5" x 3/8" plate made of A36 Steel. The cross-section was weakened by drilling four 1 1/16" dia. holes, leaving an effective cross-sectional area of 0.375 sq. inches. The plate was fastened to the T-beam by means of two 5/8" A325 bolts on each side. These bolts were tightened by the turn-of-the-nut method as per AISC recommendations.

When a load of 22.4 kips was achieved the plate failed along the weakened section. The specimen elongated 0.19 inches.



FUSE PLATE DETAIL

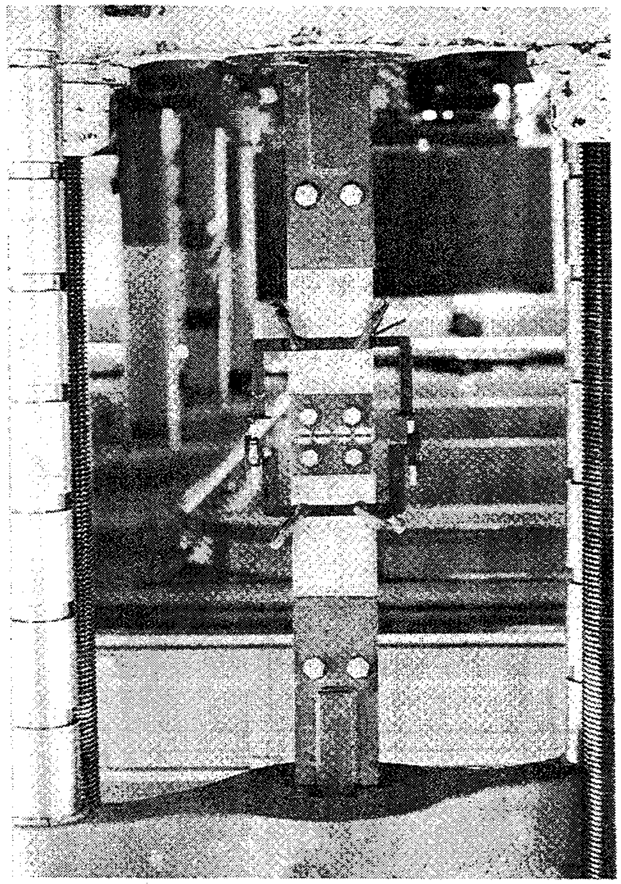
(See Table For Dims. & Wghts.)

SERIES 2 TEST 5

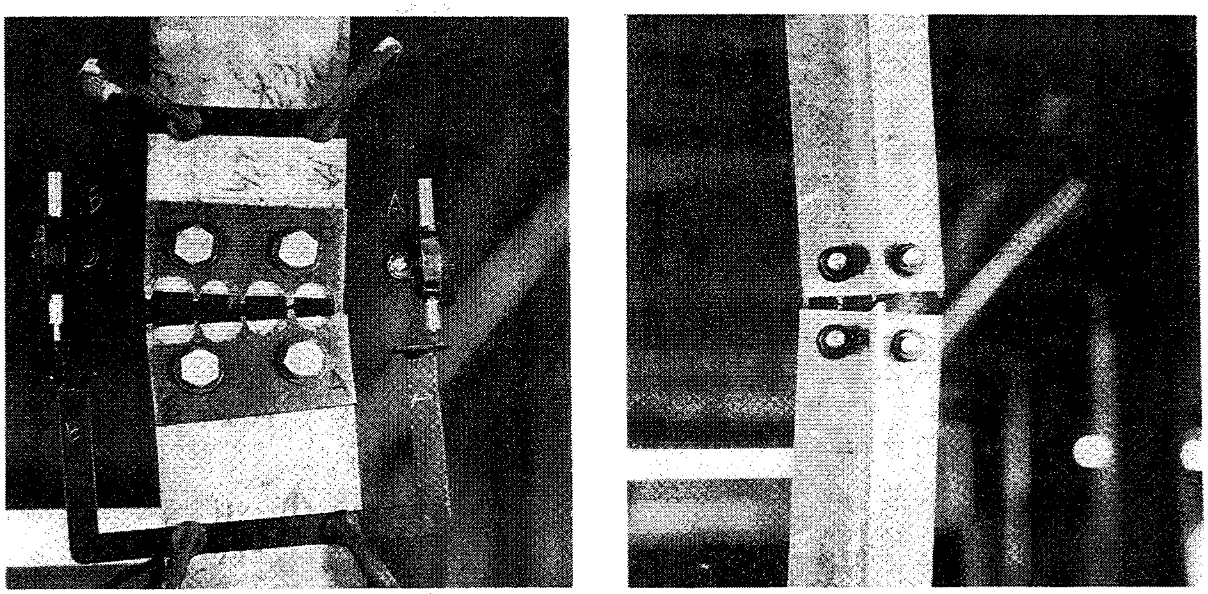
Material : Steel Designation : ASTM - A36

Post size(s) - W 8X18	Wght. (lbs.) - 2.26
F (in.) - 5	M (in.) - 1 1/4
G (in.) - 2 1/2	N (in.) - 3/4
H (in.) - 1 1/4	d1 (in.) - 11/16
J (in.) - 5 1/4	d2 (in.) - 1 1/16
K (in.) - 2 3/4	t3 (in.) - 3/8
L (in.) - 1 1/4	Bolt dia. (in.) - 5/8

Figure B13. 3/8" Fuse Plate Detail for Series 2, Test 5.



Before



After

Figure B14. 3/8" Plate Before and After Series 2, Test 5

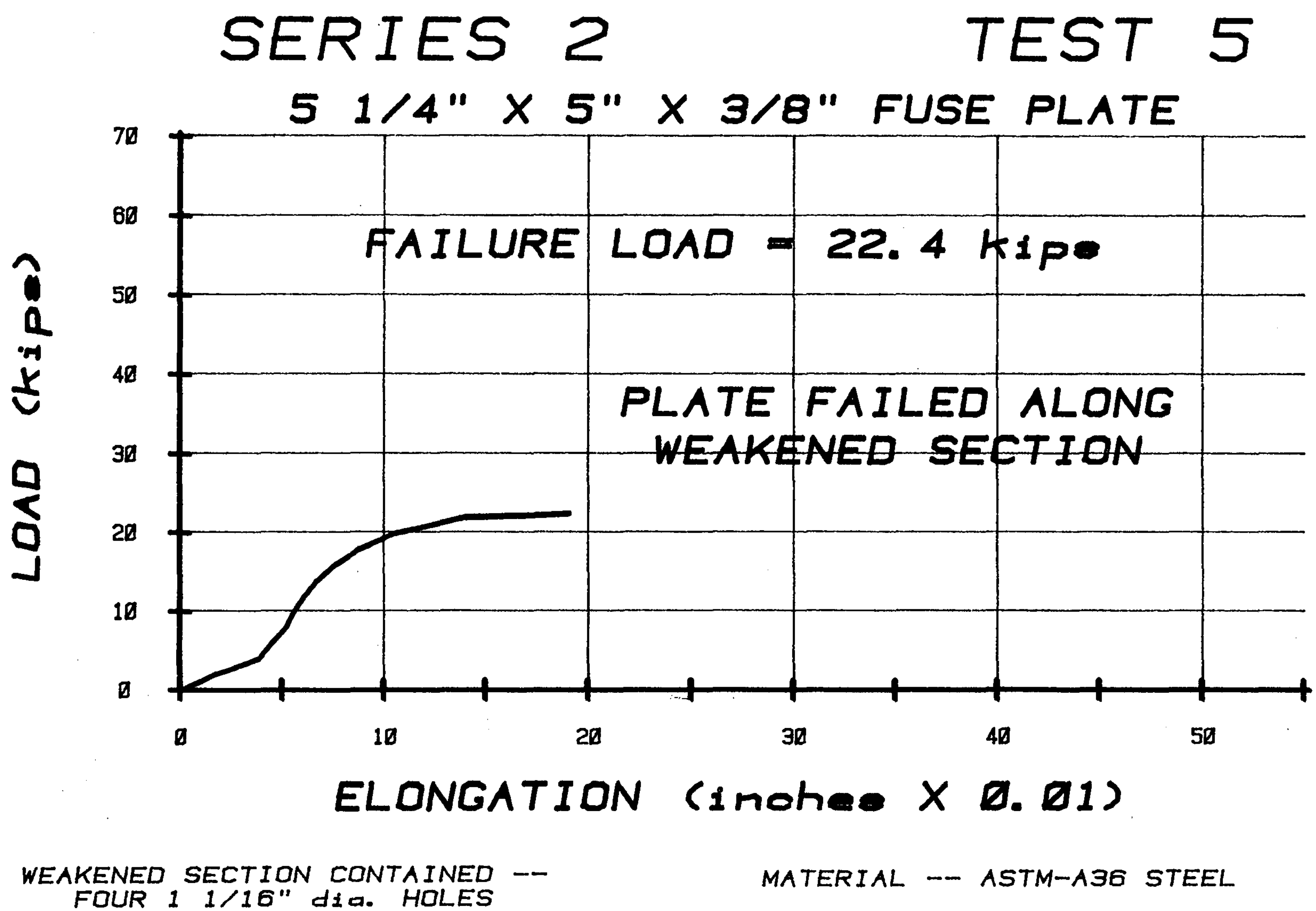


Figure B15. Load Versus Elongation Curve for Series 2, Test 5.

Appendix C

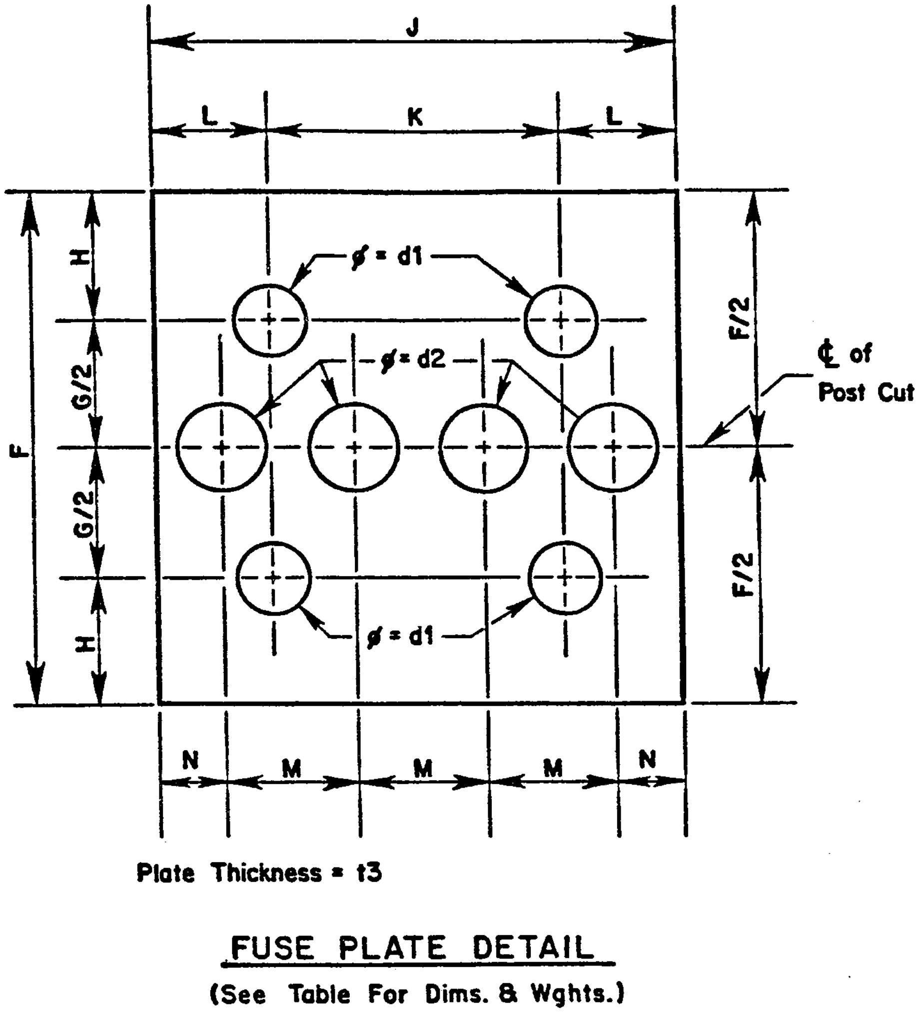
Test Installation

A standard SDHPT 8' X 16' roadside guide sign was fabricated at the District 17 sign shop for Test 2343-2. The 5/8" thick plywood sign was installed according to typical field installation procedures by a District 17 sign maintenance crew. The sign was supported by two W 8X18 structural steel posts. The sign configuration and construction was as called for on SDHPT Detail Sheets STRUCTURAL MOUNTING DETAILS FOR ROADSIDE GUIDE SIGNS SMD(8-1,2,3) except that a weakened section fuse plate was substituted for the standard friction fuse plate. The 5" X 5 1/4" X 3/8" fuse plate was made of ASTM-A36 steel and was fastened to the support post by four 5/8" diameter ASTM-A325 bolts. A detail of the weakened section fuse plate is shown in Figure C1. Photographs of the test installation before testing are presented in Figures C2 and C3.

Instrumentation and Data Analysis

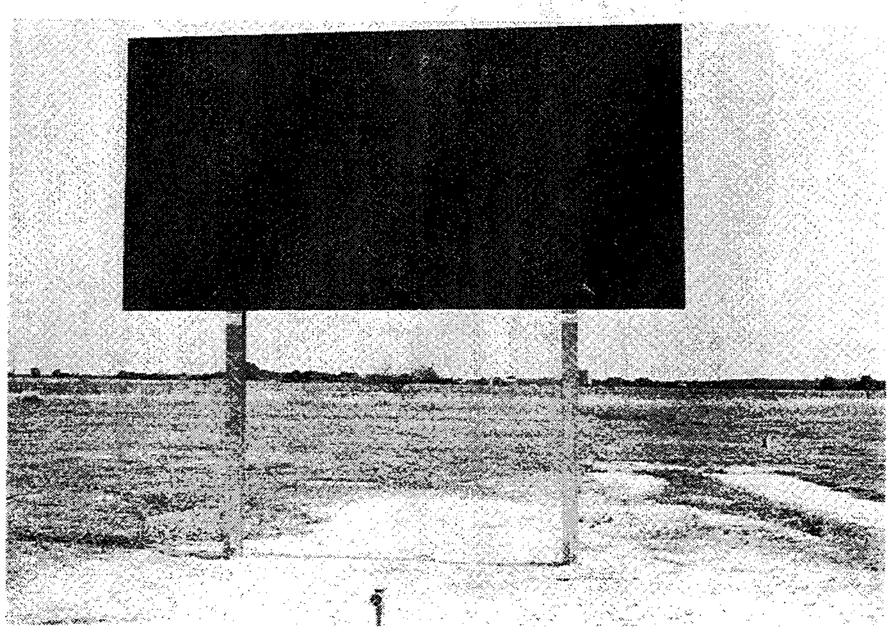
The vehicle was equipped with triaxial accelerometers mounted near the center of gravity. Yaw, pitch, and roll were sensed by on-board gyroscopic instruments. The electronic signals were telemetered to a base station for recording on magnetic tape and for display on a real-time strip chart. Provision was made for transmission of calibration signals before and after the test, and an accurate time reference signal was simultaneously recorded with the data.

Tape switches near the impact area were actuated by the vehicle to indicate the elapsed time over a known distance to provide a quick check of impact speed. The initial contact also produced an "event" mark on the data record to establish the instant of impact.



Material : Steel	Designation : ASTM - A36
Post size(s) - W 8X18	Wght. (lbs.) - 2.26
F (in.) - 5	M (in.) - 1 1/4
G (in.) - 2 1/2	N (in.) - 3/4
H (in.) - 1 1/4	d1 (in.) - 11/16
J (in.) - 5 1/4	d2 (in.) - 1 1/16
K (in.) - 2 3/4	t3 (in.) - 3/8
L (in.) - 1 1/4	Bolt dia. (in.) - 5/8

Figure C1. Weakened Section Fuse Plate Detail



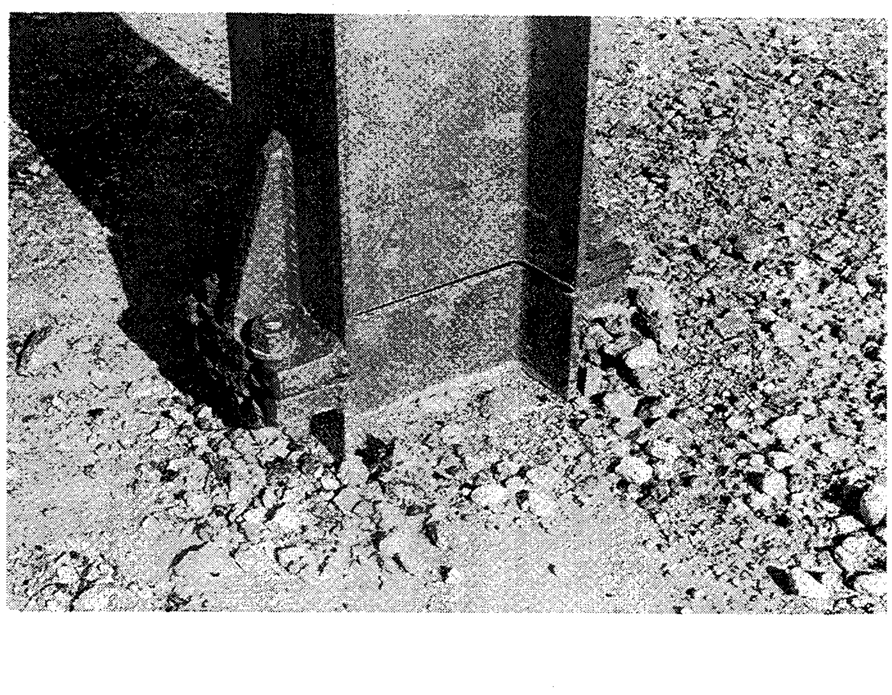
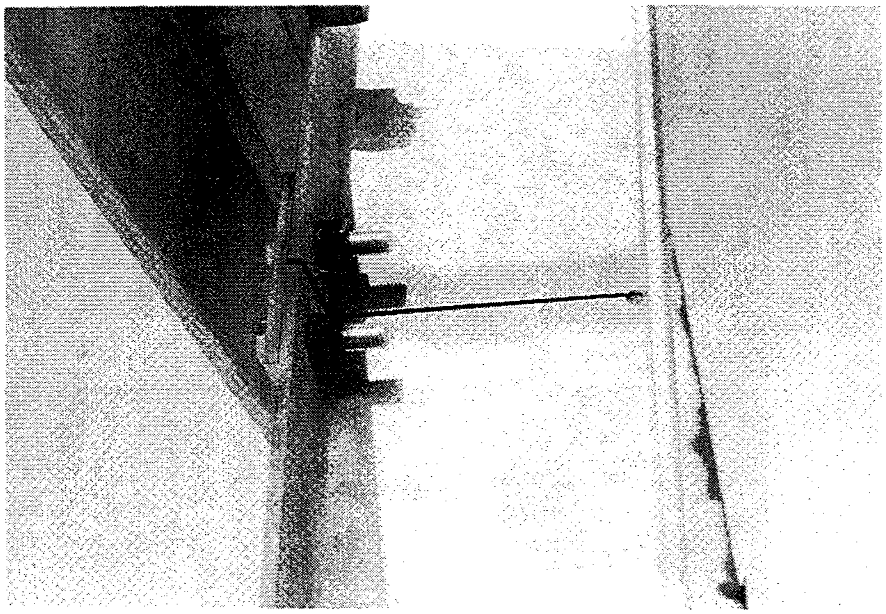


Figure C2. Test Installation Before Test 2343-2



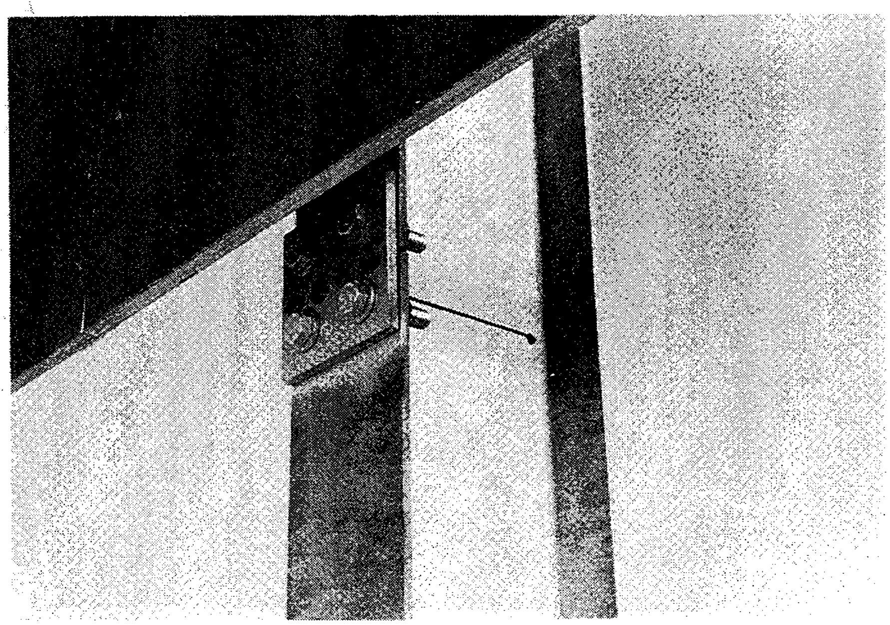


Figure C3. Weakened Section Fuse Plate

Data from the electronic transducers was digitized, using a Southwest Technical Products 6800 micro-computer, for analysis and evaluation of performance. Several computer programs were used to process various types of data from the test vehicle.

Still and motion photography were used to document the test, to obtain time-displacement data, and to observe phenomena occurring during the impact. Still photography was used to record conditions of the test vehicle and sign installation before and after the test. Motion photography was used to record the collision event.

Test Description

A 1975 Honda Civic was directed into the right support of the roadside guide sign at a speed of 20.4 mph (32.8 kph) and a zero degree angle of incidence. Test inertia mass and gross static mass of the vehicle was 1,750 lbs (794 kg). The vehicle was free-wheeling and unrestrained at impact. Impact point was 10 in. (25 cm) to the left of the vehicle centerline. Relative positions of the vehicle and sign are shown in Figure C4.

The slip base began to break away from the stub post at 0.038 sec after impact. The vehicle lost contact with the support post at 0.138 sec with a speed of 16.7 mph (26.9 kph). The slip base had been displaced a distance of 2.7 ft. (0.8 m) when the vehicle lost contact. The lower wind clamp pulled through the extruded aluminum wind beam at 0.325 sec after the slip base had displaced 7.0 ft. (2.1 m). The middle wind clamp pulled through at 0.388 sec following a slip base displacement of 7.9 ft. (2.4 m). The vehicle stopped 69 ft. (21 m) from the impact point.

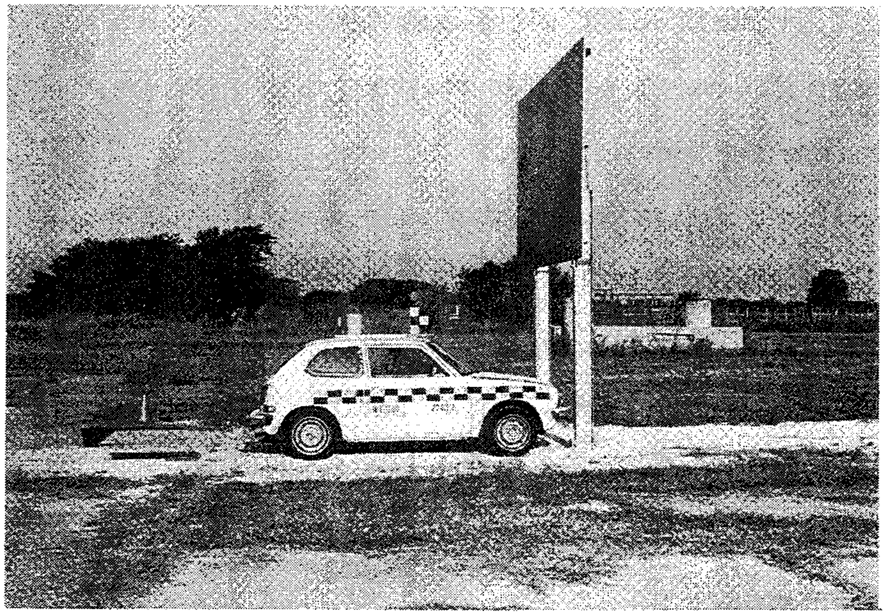
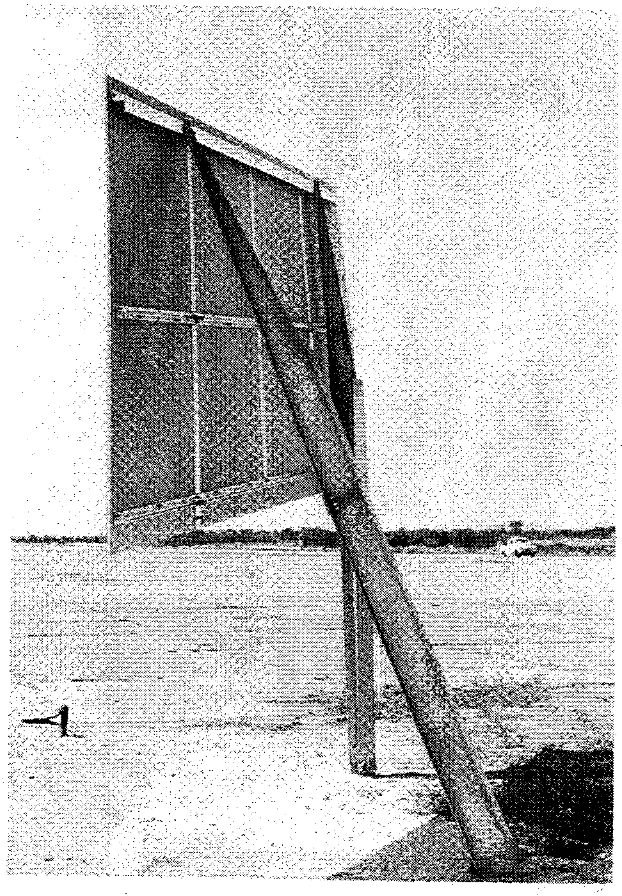


Figure C4. Relative Position of Vehicle and Sign



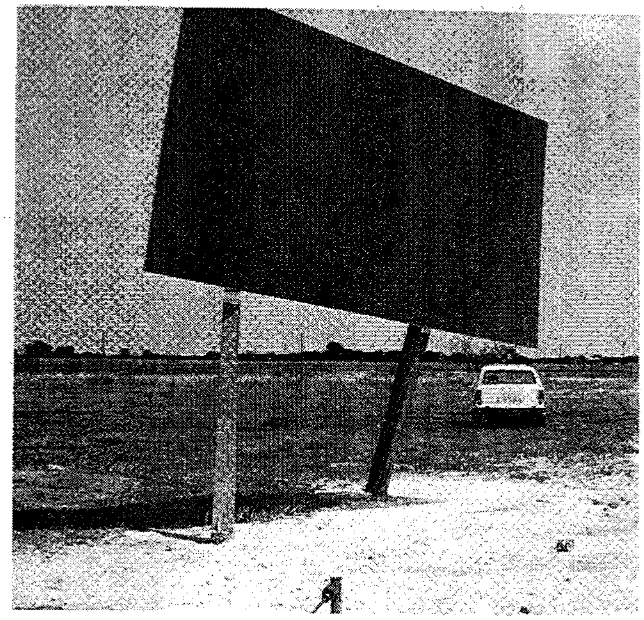
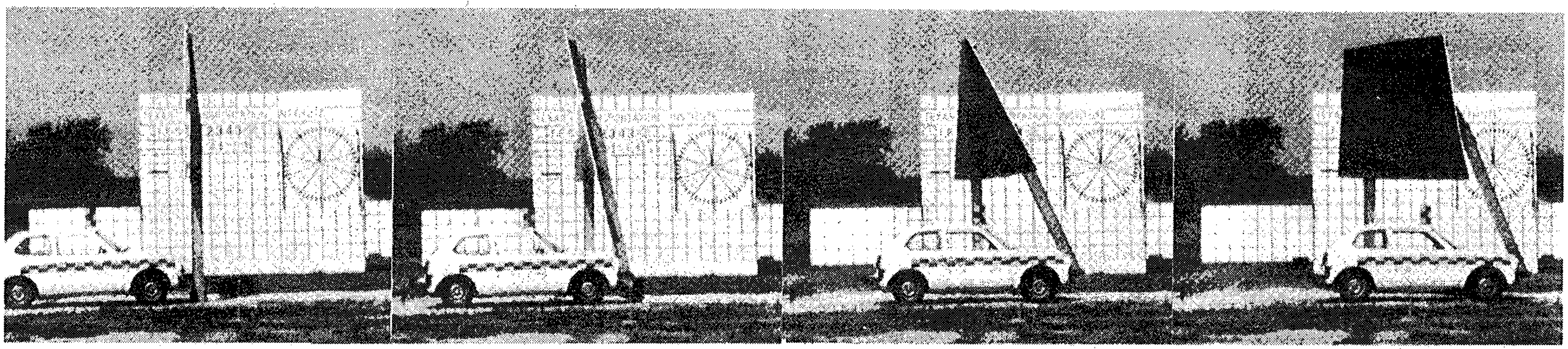


Figure C5. Test Site After Test 2343-2

Figure C6. Vehicle Before and After Test 2343-2

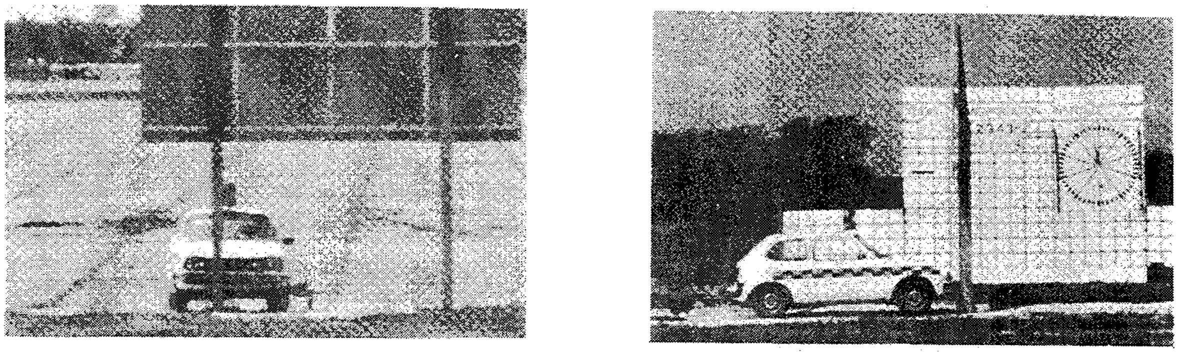


0.000 sec　　0.100 sec　　0.250 sec　　0.400 sec

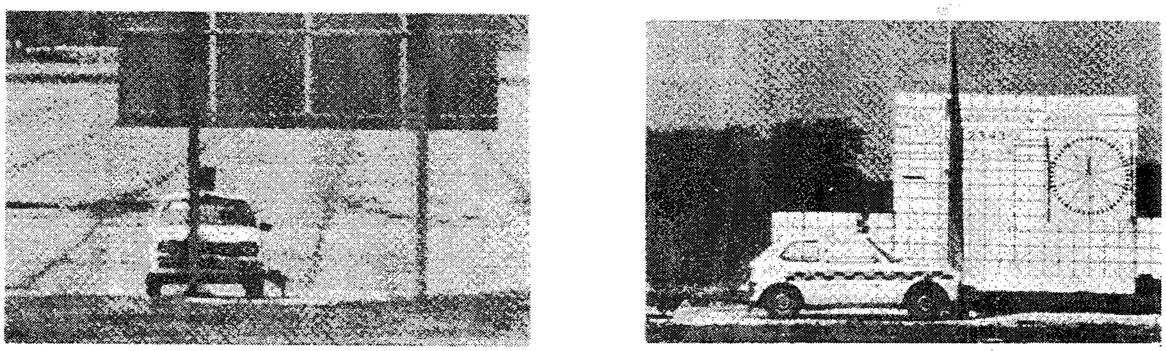
Test No.	2343-2
Date	8/21/84
Test Installation.	8' X 16' Roadside Guide Sign w/ weakened section fuse plate
Vehicle	1975 Honda Civic
Vehicle Weight	
Test Inertia.	1750 lbs (794 kg)
Vehicle Damage Classification	
TAD	12FC3
SAE	12FCEN2

Impact Speed.	20.4 mph (32.8 kph)
Exit Speed at loss of contact	16.7 mph (26.9 kph)
Change in Velocity.	3.7 mph (6.0 kph)
Change in Momentum.	296 lb-sec
Vehicle Accelerations (Max. 0.050 sec Avg)	
Longitudinal	-3.0 g's
Lateral.	0.2 g's
Occupant Impact Velocity	
Longitudinal	None
Lateral.	None
Occupant Ridedown Accelerations	
Longitudinal	No Contact
Lateral	No Contact

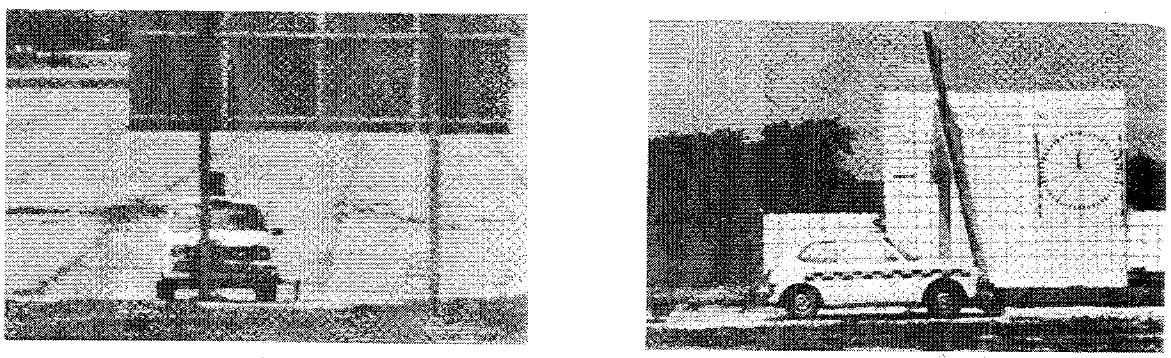
Figure C7. Data Summary.



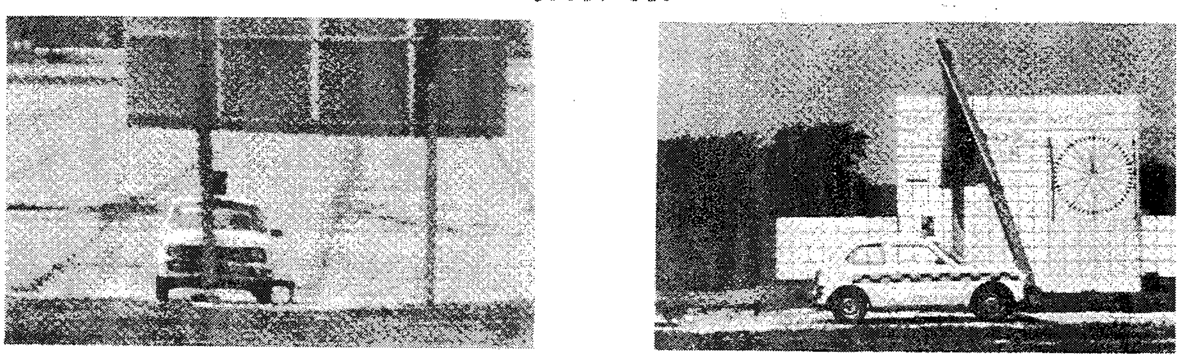
0.000 sec



0.044 sec

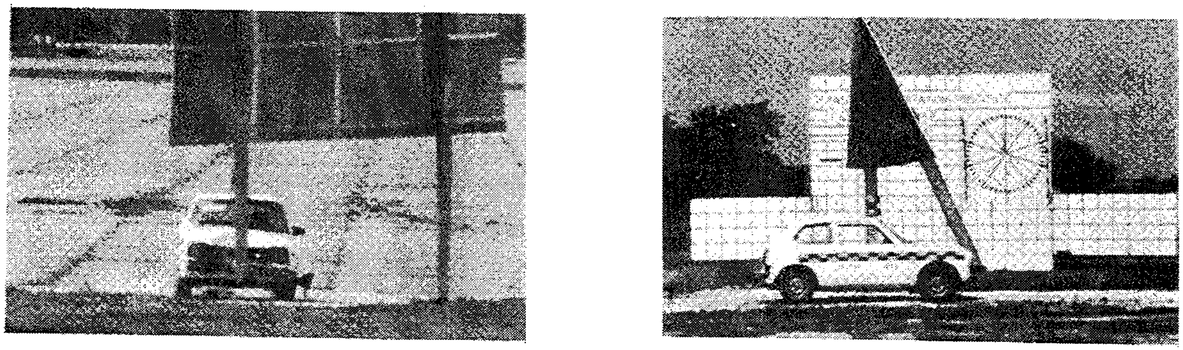


0.101 sec

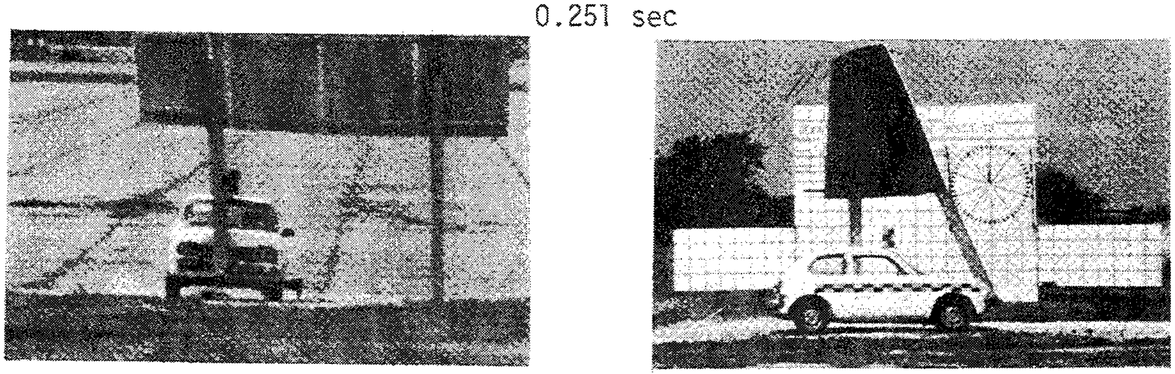


0.175 sec

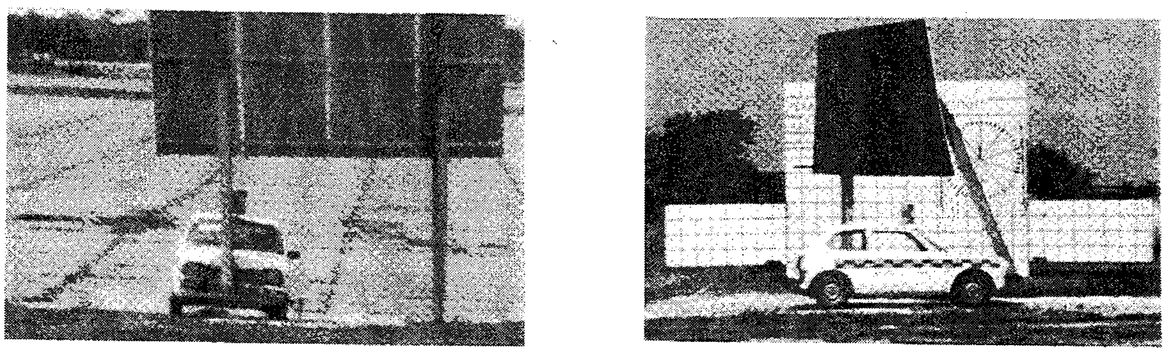
Figure C8. Sequential Photographs for Test 2343-2.



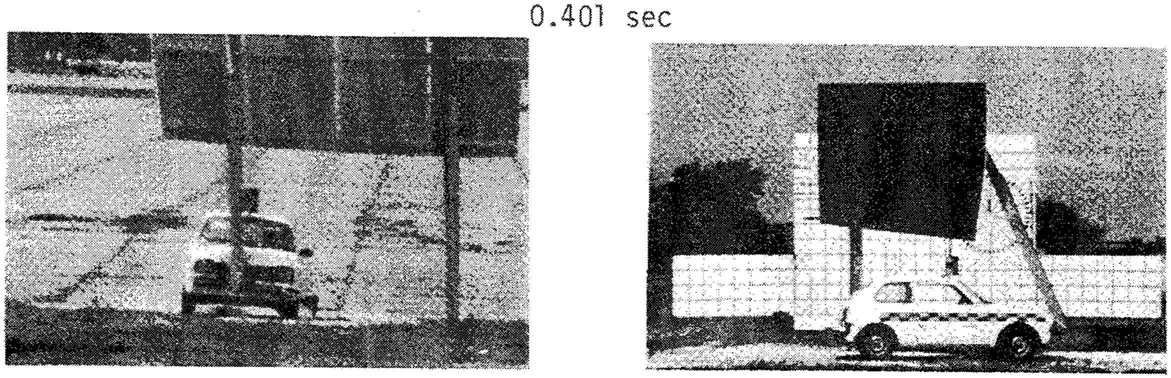
0.251 sec



0.325 sec



0.401 sec



0.500 sec

Figure C8. Sequential Photographs for Test 2342-2. (Continued)

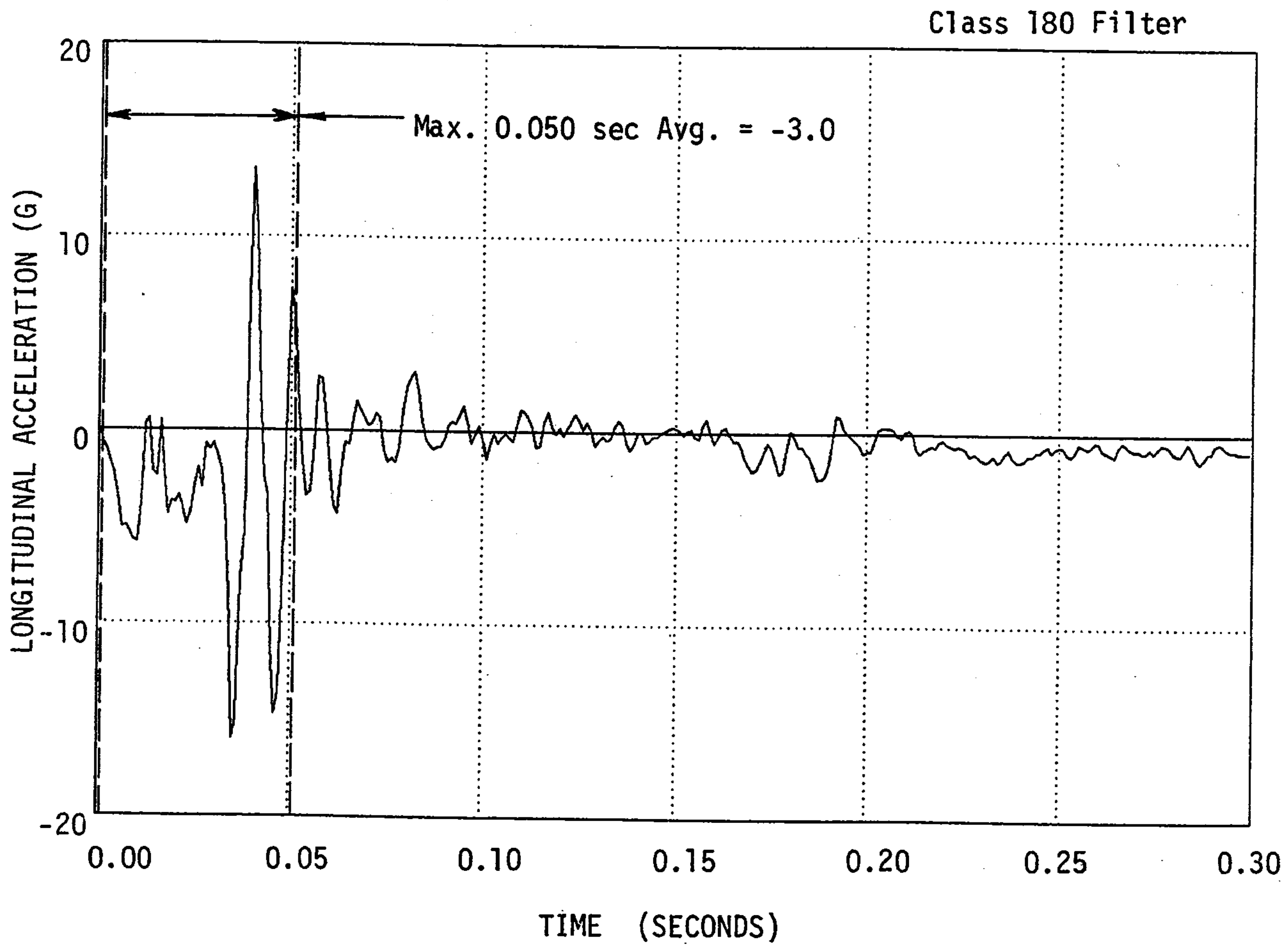


Figure C9. Vehicle Longitudinal Accelerometer Trace for Test 2343-2.

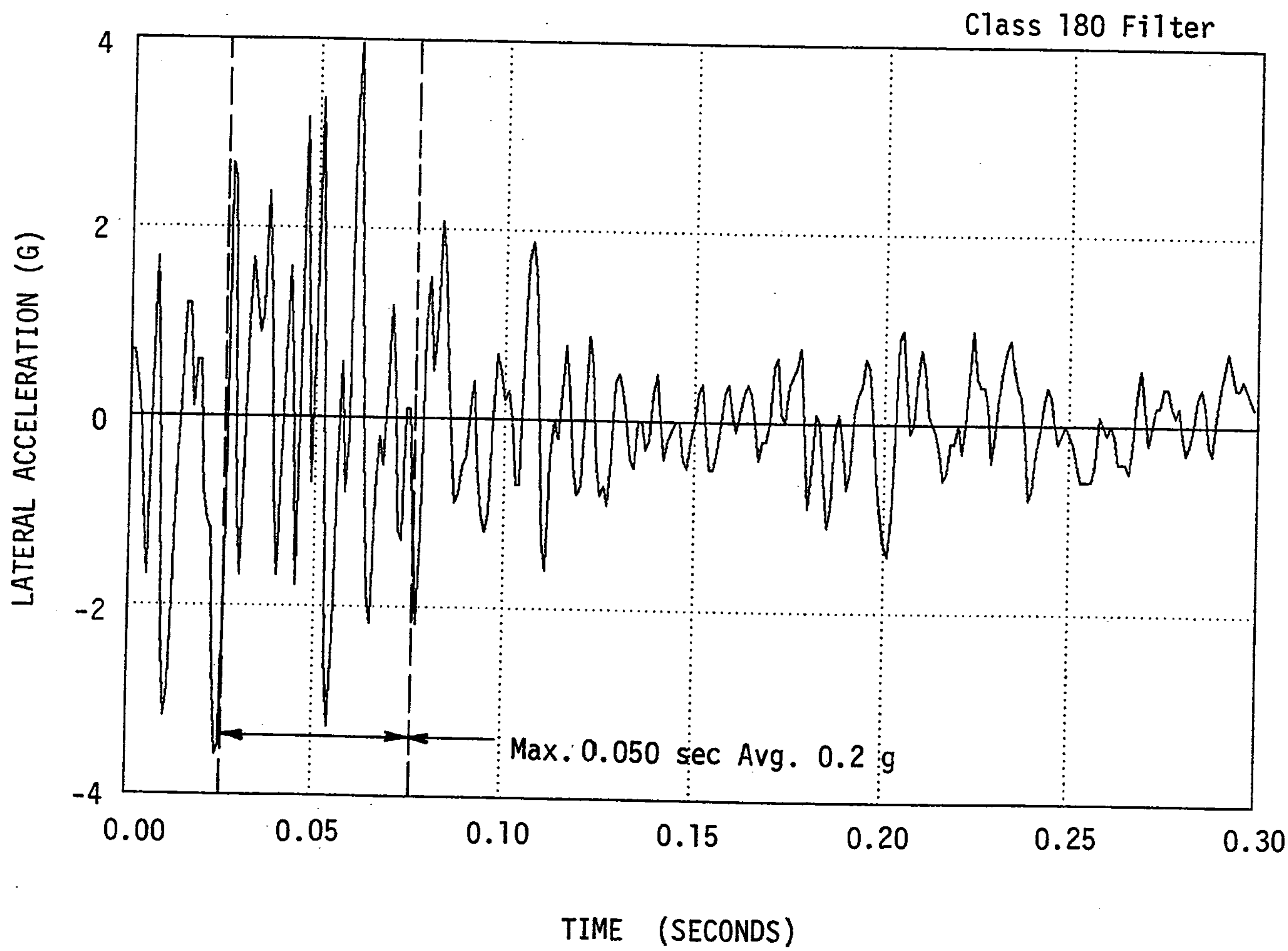


Figure C10. Vehicle Lateral Accelerometer Trace for Test 2343-2.

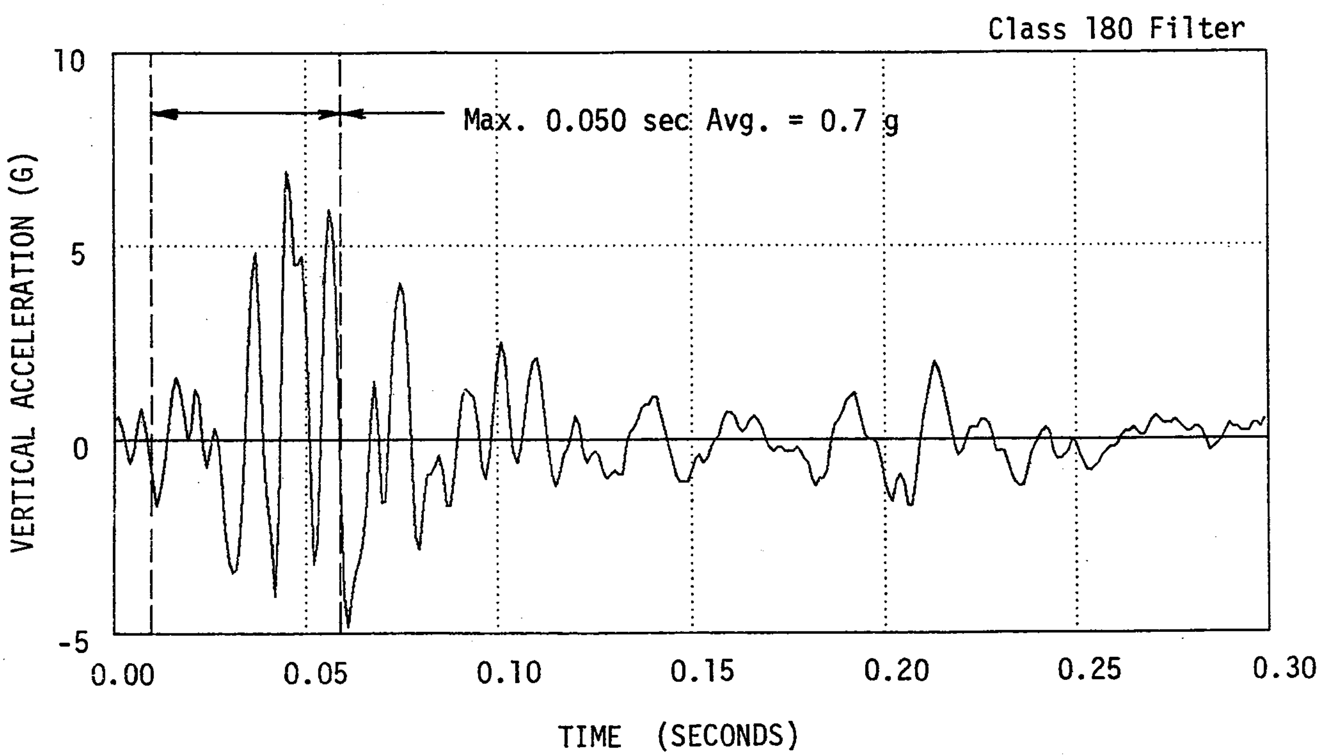
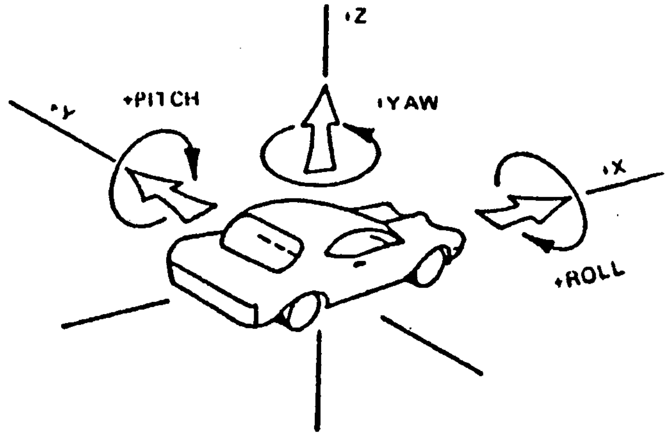


Figure C11. Vehicle Vertical Accelerometer Trace for Test 2343-2.



Axes are vehicle fixed.
Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

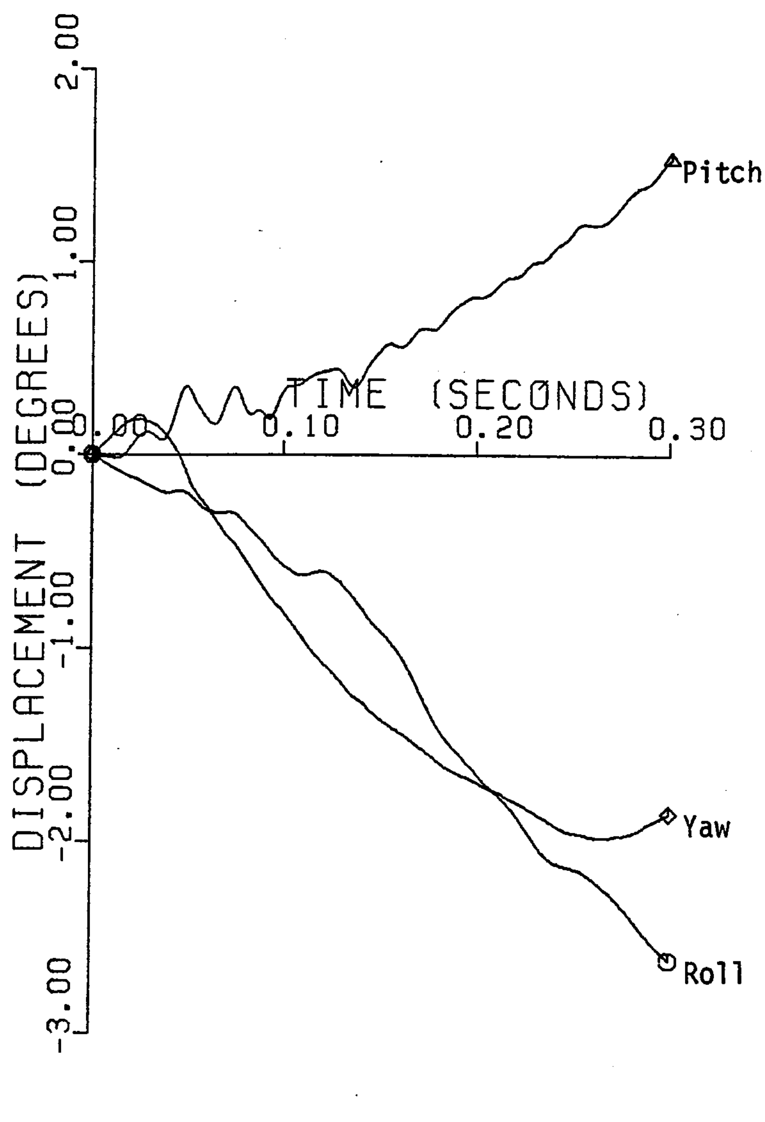


Figure C12. Vehicle Angular Displacements for Test 2343-2.

Yielding occurred through the weakened section of the fuse plate but separation did not take place. The sign and support posts remained intact as shown in Figure C5. Damage to the vehicle was minor as depicted in Figure C6.

Results and Evaluation

A summary of test data is provided in Figure C7. Sequential photographs are presented in Figure C8. Longitudinal, lateral, and vertical vehicle accelerations are shown in Figures C9, C10 and C11. Yaw, pitch and roll displacements are shown in Figure C12.

The maximum 50 msec longitudinal acceleration was -3.0 g's. Change in vehicle velocity at 0.138 sec (loss of contact) was 3.71 mph (6.0 kph) and change in vehicle momentum was 296 lb-sec.

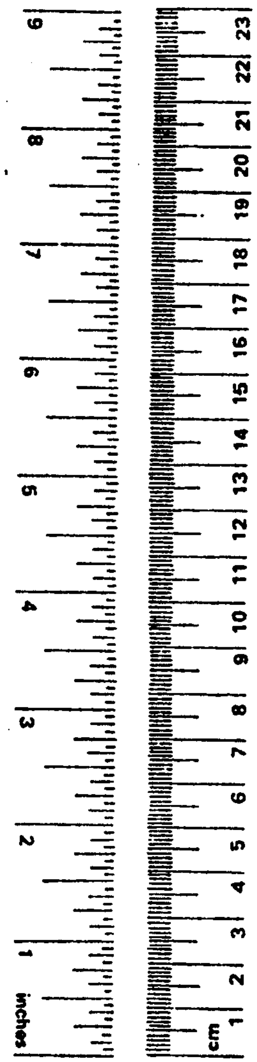
NCHRP Report 230 (1) contains recommended evaluation criteria for the impact performance of sign supports and places limits on these criteria for acceptable performance. The support post yielded to the vehicle and no detached elements penetrated the vehicle compartment. This performance meets the applicable evaluation criteria for structural adequacy. There was no occupant impact in the longitudinal or lateral direction during the test. The vehicle remained upright and stable with no deformation or intrusion of the passenger compartment. This performance satisfied the criteria for occupant risk. The test also met the requirements for vehicle trajectory.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F