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16. Abstract
TxDOT plans and specifications currently do not allow use of furnace butt welded pipe for sign supports. Use of this type pipe, if it is suitable and demonstrates acceptable performance for small sign supports, would result in significant cost savings.

Samples of furnace butt welded and electrical resistance welded, 51 mm I.D. schedule 40 pipe were subjected to static bending tests. Selected samples of furnace butt welded pipe were also used in pendulum and full-scale vehicle crash tests.

Researchers found that furnace butt welded pipe meeting ASTM A53 and having a yield strength of at least 240 Mpa demonstrates acceptable performance for small sign supports.

17. Key Words
Sign Supports, Slip Base, Furnace Butt Welded Pipe, Load Testing, Crash Testing, Roadside Safety

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IMPLEMENTATION RECOMMENDATIONS

Work performed under this project indicates that the impact performance of ASTM A53, Type F (furnace butt welded) pipe with a minimum yield strength of 240 Mpa is acceptable for small sign supports.

It is recommended that TxDOT change their plans and specifications to allow the use of ASTM A53, Type F pipe with a minimum yield strength of 240 Mpa for small sign supports.

DISCLAIMER

The contents of this report reflect the views of the authors who are solely responsible for the facts and accuracy of the data, and the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation, The Texas A&M University System, or Texas Transportation Institute. This report does not constitute a standard, specification, or regulation, and its contents are not intended for construction, bidding, or permit purposes. In addition, the above listed agencies assume no liability for its contents or use thereof. The names of specific products or manufacturers listed herein do not imply endorsement of those products or manufacturers. The engineer in charge of the project was Mr. C. Eugene Buth, P.E.#27579.

ACKNOWLEDGMENT

The TxDOT project director for this research was Ms. Elaine Campbell, Purchaser from the General Services Division. Ms. Campbell's assistance is acknowledged and appreciated.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

NOTE: Volumes greater than 1000 l shall be shown in m^3.

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE		
°C	Celcius temperature	1.8C+32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

SUMMARY

TxDOT's standard plans for small roadside signs include the requirement "...standard weight pipe conforming to ASTM Specification A53 Grade B, A501 or other standard weight steel pipe. Pipe may be of either electric resistance welded or seamless type, with a minimum yield strength of 35,000 psi [241 Mpa] and a minimum elongation of 15 percent in 2 inches [51 mm]."

Plans and specifications do not allow use of furnace butt welded pipe for sign supports. Use of this type pipe, if it is suitable and demonstrates acceptable performance for small sign supports, would result in significant cost savings.

ASTM A53, "Standard Specifications for Pipe, Steel, Black Hot-Dipped, Zinc-Coated, Welded and Seamless," covers Types E, S, and F pipe. It allows use of Grade A material for Type F pipe and Grades A and B material for both Types E and S pipe.

Samples of 51 mm I.D., schedule 40 pipe were subjected to static load tests in cantilevered beam configuration and selected samples of furnace butt welded pipe were used in dynamic pendulum and full-scale vehicle impact tests. The furnace butt welded pipe samples had yield strengths of 262 Mpa and 270 Mpa. The purpose of the tests was to determine whether the furnace butt welded pipe is suitable for use in small sign supports.

In the static bending tests, the furnace butt welded samples behaved the same as the electric resistance welded samples. No shortcomings were observed.

In dynamic impact tests with a pendulum and in full-scale vehicle crash tests, samples of furnace butt welded pipe sign supports behaved acceptably.

Furnace butt welded pipe of sufficient yield strength and ductility should be considered acceptable for use as small sign supports.

I. INTRODUCTION

TxDOT's standard plans for small roadside signs include the requirement "...standard weight pipe conforming to ASTM Specification A53 Grade B, A501 or other standard weight steel pipe. Pipe may be of either electric resistance welded or seamless type, with a minimum yield strength of 35,000 psi [241 Mpa] and a minimum elongation of 15 percent in 2 inches [51 mm]."

Plans and specifications do not allow use of furnace butt welded pipe for sign supports. Use of this type pipe, if it is suitable and demonstrates acceptable performance for small sign supports, would result in significant cost savings.

ASTM A53, "Standard Specifications for Pipe, Steel, Black Hot-Dipped, Zinc-Coated, Welded and Seamless," covers Types E, S,and F pipe. It allows use of Grade A material for Type F pipe and Grades A and B material for both Types E and S pipe. Definitions of these Types and grades are:

Type F - Furnace butt welded, continuous Grade A. Pipe produced in continuous lengths from coiled skelp and subsequently cut into individual lengths, having its longitudinal butt splice forge welded by the mechanical pressure developed in rolling the hot-formed skelp through a set of round pass welding rolls.

Type E - Electric resistance welded, Grades A and B. Pipe produced in individual lengths or in continuous lengths from coiled skelp and subsequently cut into individual lengths, having a longitudinal butt joint wherein coalescence is produced by the heat obtained from resistance of the pipe to the flow of electric current in a circuit of which the pipe is a part, and by application of pressure.

Type S - Seamless, Grade A and B. Wrought steel seamless pipe is a tubular product made without a welded seam. It is manufactured by hot working steel and, if necessary, by subsequently cold finishing the hot-worked tubular product to produce the desired shape, dimensions, and properties.

**Grade A* - Tensile strength 330 Mpa, yield strength 205 Mpa, elongation in 50.8 mm will be determined by the following equation:

$$e = 625\,000\,A^{0.2} \div U^{0.9}$$

where:

e = minimum elongation in 50.8 mm in percent rounded to the nearest 0.5%.

A = cross-sectional area of the tension test specimen in square inches, based on specified outside diameter or nominal specimen width and specified wall thickness to the nearest 0.01 inches squared. If the area thus calculated is greater that 0.75 inches squared, then the value of 0.75 will be used, and

U = specified tensile strength in psi.

**Grade B* - Tensile strength is 415 Mpa, yield strength is 240 Mpa, and elongation in 50.8 mm will be determined by the equation given above.

The objectives of this research study were to:

1. determine the number of steel pipe types currently manufactured to meet ASTM A53,

2. evaluate the dynamic response and plastic failure mode of different types of pipe, and

3. assess the applicability of the different pipe types meeting the ASTM A53 standard (i.e., type E, S, F, etc.) for use as breakaway sign supports.

II. STUDY APPROACH

As part of information gathering at the beginning of the project, TxDOT personnel identified current major pipe suppliers for TxDOT. The following list shows major suppliers:

Table 1. Major Pipe Suppliers.

Supplier Name	Address
N. Merfish Supply	P.O. Box 1937 Houston, TX 77251
Petro Amigos Supply Inc.	2620 Fountainview, Suite 225 Houston, TX 77057
All-Tex Plumbing Supply	P.O. Box 542885 Dallas, TX 75354-2885
NAFTA Steel & Pipe Inc.	5225 Katy Freeway #240 Houston, TX 77007
All States Steel Corp.	P.O. Box 9818 Houston, TX 77213

Samples of 51 mm I.D. pipe, schedule 40 were obtained from four sources as indicated in Table 2. It is noted that the Type F pipe samples have yield strengths of 262 Mpa and 269 Mpa. ASTM A53 requires that Type F pipe made from Grade A material have a yield strength of 205 Mpa minimum. It is argued that ASTM A53 Type F pipe with a minimum yield strength of 240 Mpa should perform adequately for small sign supports.

Objectives of the study were addressed through static bending tests, pendulum tests and full-scale vehicle crash tests. The pendulum and full-scale crash tests were a part of the testing program for TxDOT Contract 7-2996. Samples of pipe for the study reported herein were used in selected tests performed under contract 7-3911,making the tests multi-purpose and providing data for both studies.

Table 2. Types and Sources of Pipe Samples.

Source	Pipe Spec.	Grade	Type Weld	Yield (kPa)	% Elong.
A Domestic	A501	--	F Furnace Butt Weld	262 000	40
B Imported	A53	A	ERW Electrical Resistance Weld	381 300	28.9
C Domestic	A53	A	F Furnace Butt Weld	270 300	53
D Domestic	A53	B	ERW Electrical Resistance Weld	351 600	50

III. STATIC LOAD TESTS

Figure 1 shows the configuration used for static load tests. In all tests, the pipe was oriented such that the longitudinal weld joint was at the bending neutral axis and therefore subjected to maximum shear stress. A vertical upward load was applied to the end of the cantilevered pipe with a lifting crane. Rate of travel of the lifting hook was constant at 0.61 m per minute. Vertical direction of the lifting force was maintained throughout the test by visual reference and adjustment of the horizontal location of the crane.

Researchers computed displacements of the end of the cantilevered pipe (at the point of load application) usin elapsed time and travel rate of the crane lifting hook. They continuously recorded applied load versus time on a desktop computer. Table 3 summarizes results of the static load tests.

Photographs of pipe samples after testing are shown in Figures 2 through 5. In all tests, the pipes were subjected to large deformations and plastic hinges occurred adjacent to the fixed support. Collapse of the pipe cross section occurred when the deflections became very large. Neither the base metal nor the weld metal ruptured in any of the tests even with the large deflections that were imposed.

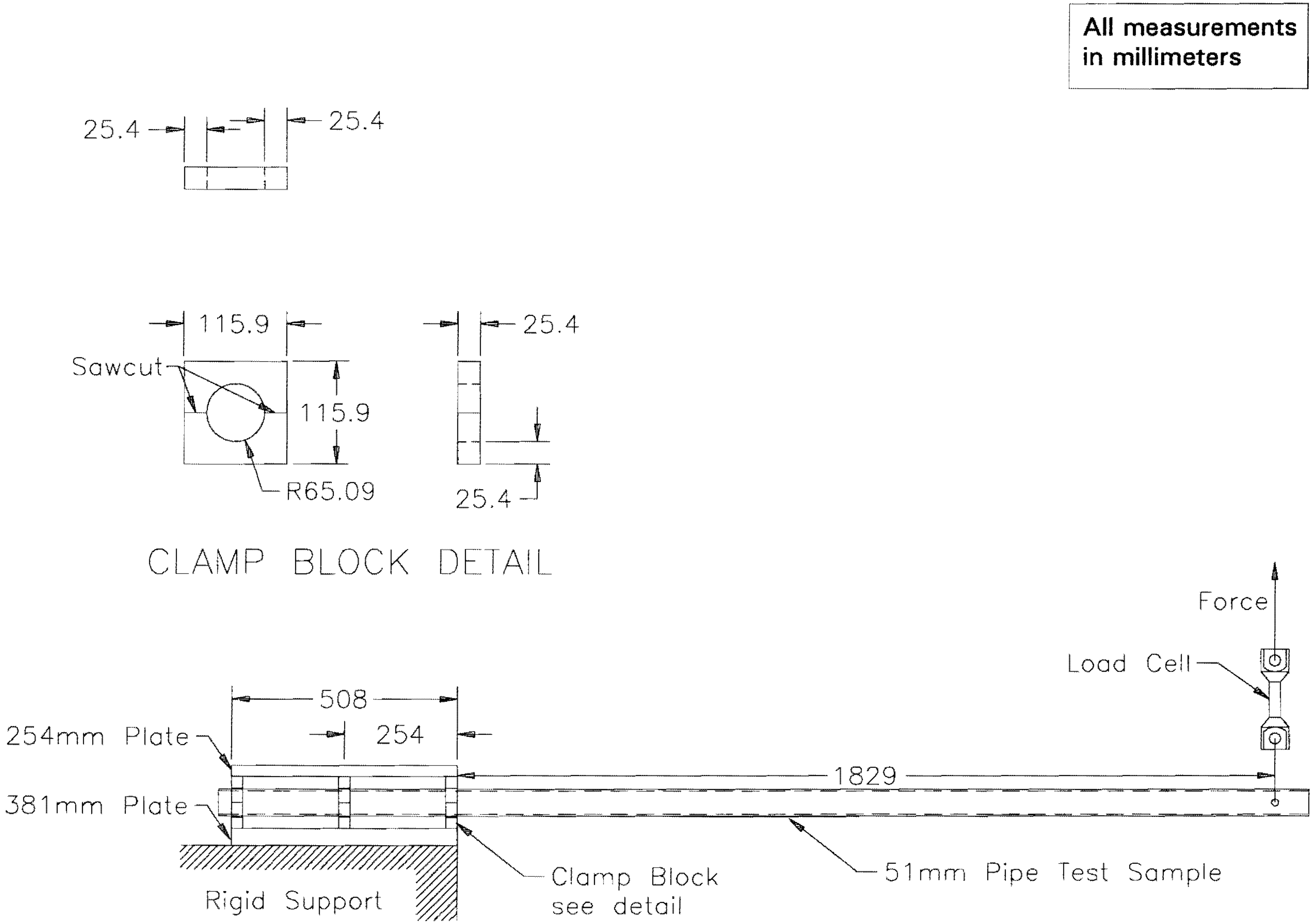
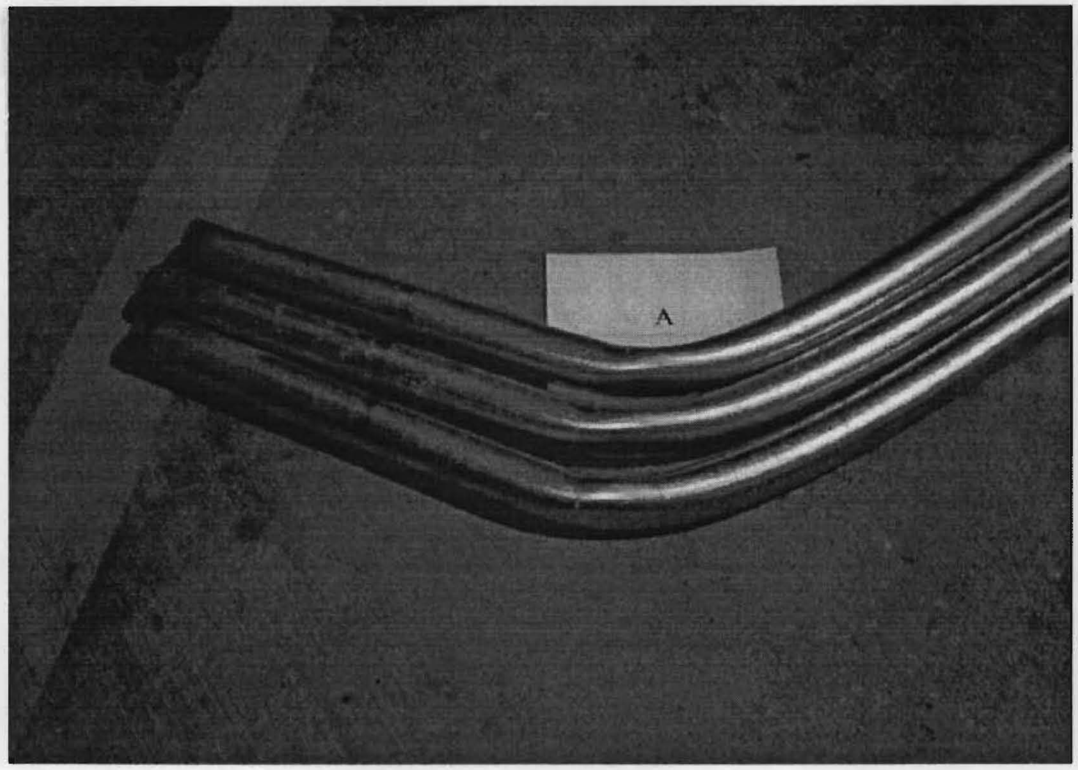


Figure 1. Physical Configuration for Static Load Tests.

Table 3. Summary of Results for Static Load Tests.

Product Code	Test Designation	Load at Yielding	Deflection at Yielding	Yield Stress
		(N)	(mm)	(kPa)
A	1	1831	83	364 500
	2	1824	89	363 000
	3	1769	81	352 200
Average		**1808**	**85**	**359 900**
B	1	2361.6	124.0	470 100
	2	2375.8	126.0	472 900
	3	1816.8	119.9	361 700
Average		**2184.7**	**123.3**	**434 900**
C	1	2056.0	99.6	409 300
	2	2141.3	99.6	426 300
	3	1726.8	89.4	343 700
Average		**1974.7**	**96.2**	**393 100**
D	1	1788.4	79.2	356 000
	2	2335.6	109.7	464 900
	3	2321.3	126.0	462 100
Average		**2148.4**	**105.0**	**427 700**



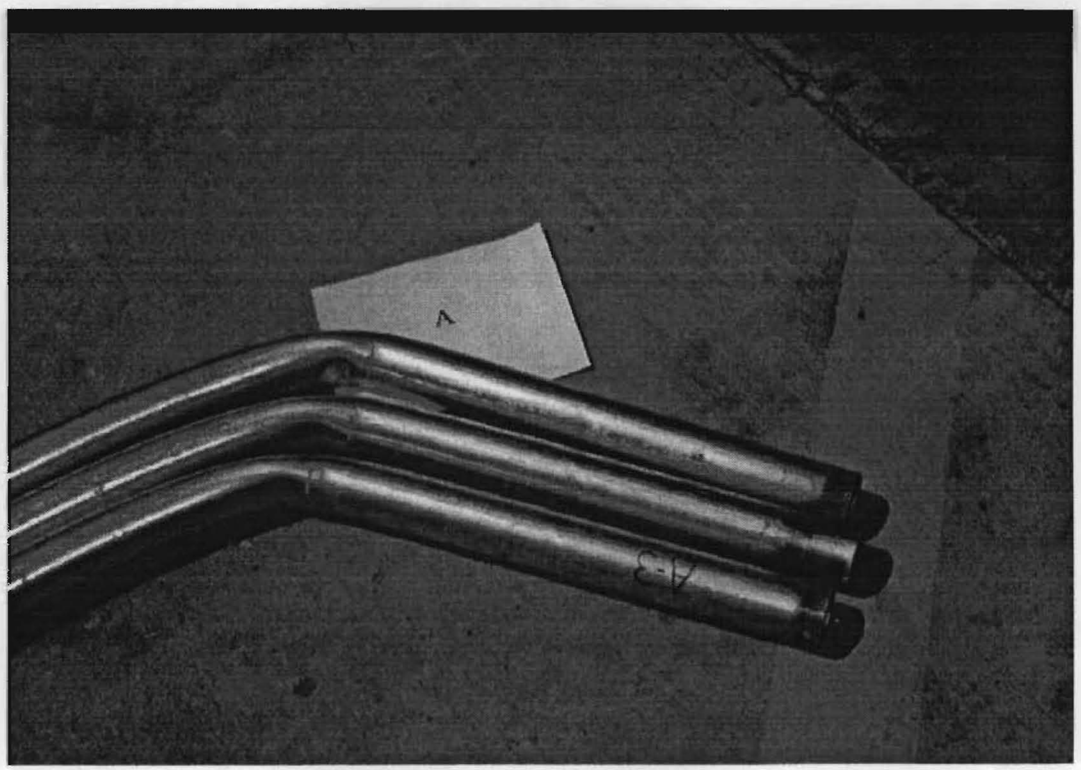


Figure 2. Samples from Source A After Static Tests.

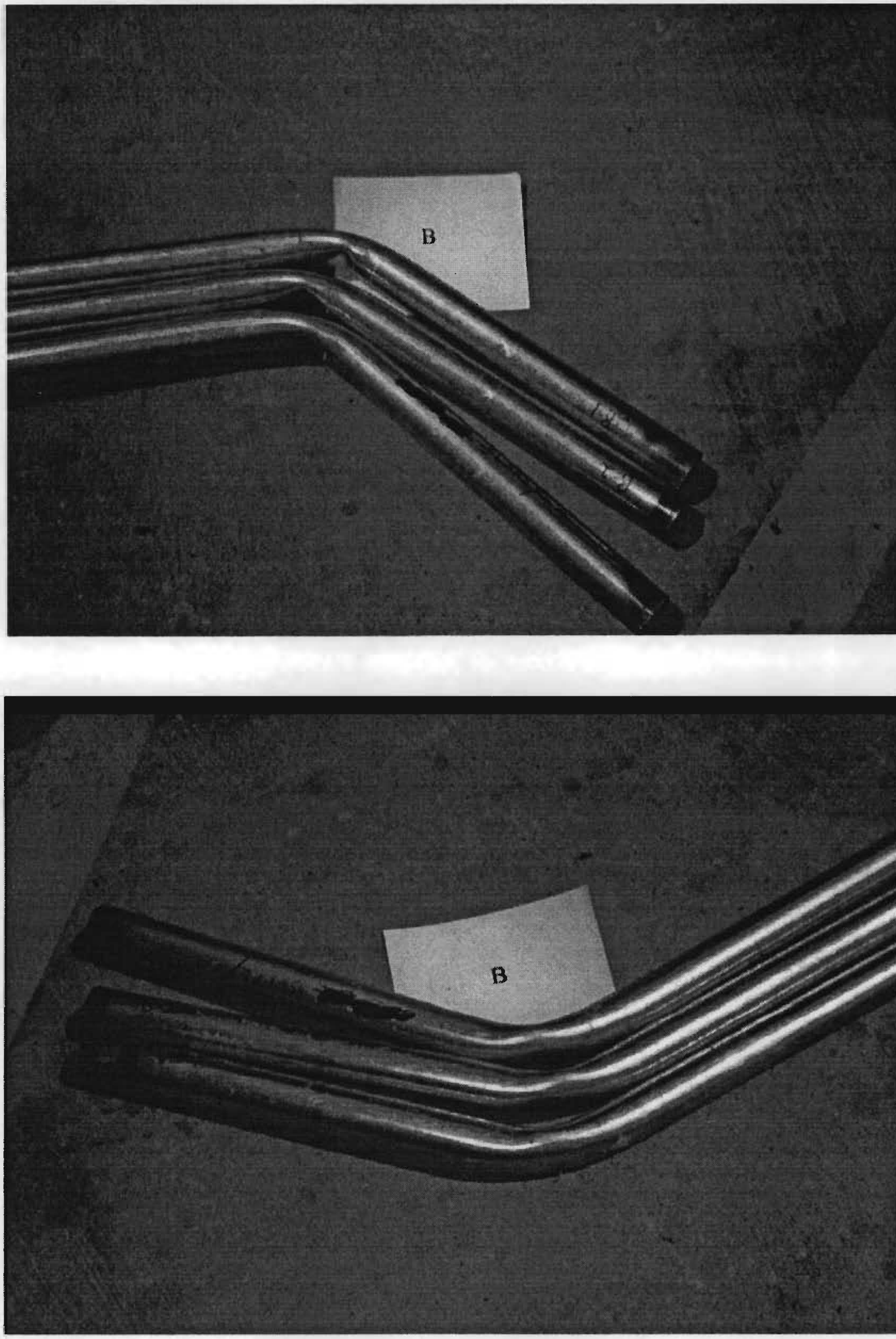


Figure 3. Samples from Source B After Static Tests.

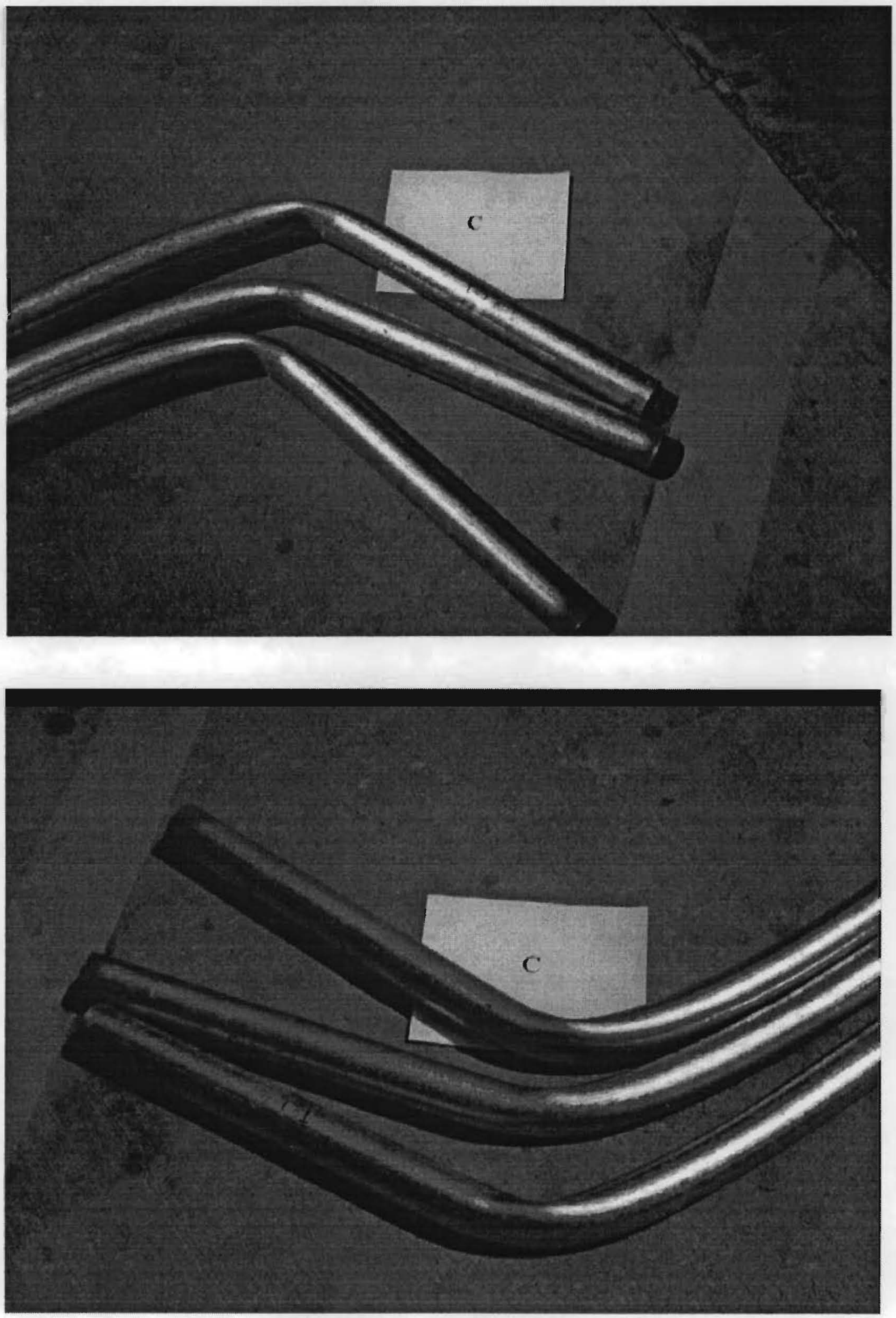


Figure 4. Samples from Source C After Static Tests.

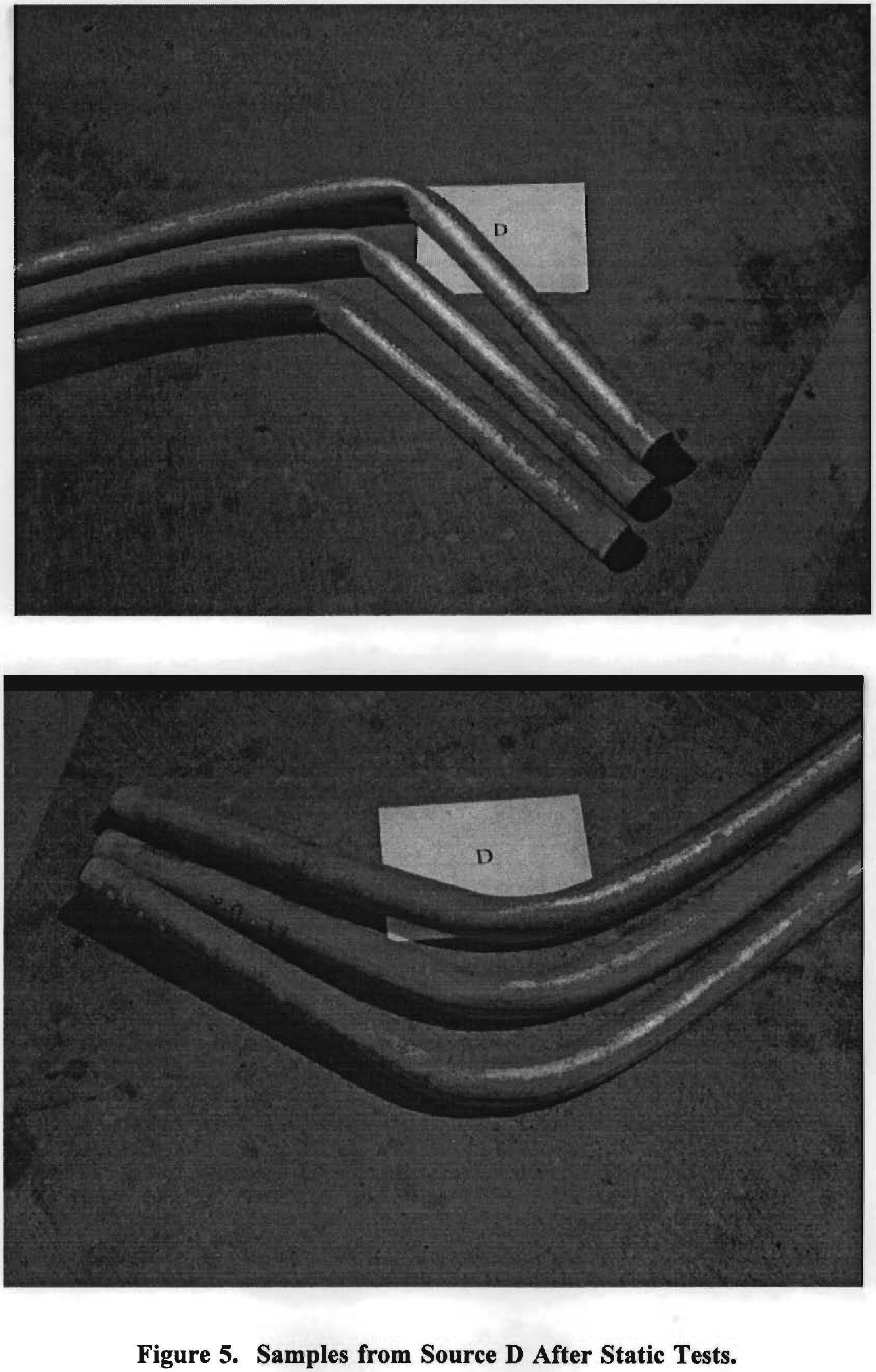


Figure 5. Samples from Source D After Static Tests.

IV. PENDULUM TESTS

Samples of ASTM A53 Type F, furnace butt welded pipe from source C (Table 1) were used for sign supports subjected in impact tests with a pendulum. The tests were performed as a part of the experimental program under contract 7-3911. That series of tests was performed to investigate the effect of keeper plate thickness on the breakaway performance of a triangular slip base.

Drawings of the test articles are shown in Figure 6. Photographs of a typical sign installation before testing and the crushable pendulum nose are shown in Figures 7 and 8, respectively.

A total of four pendulum tests (439117-P3 through P6) were performed in this series of tests. In all tests the slip base disengaged and performed acceptably. The pipe support did not show any distress and its performance was acceptable.

Photographs of the pipe supports for each of the four tests are shown in Figures 9 through 12. Reference number 1 contains additional details of these tests.

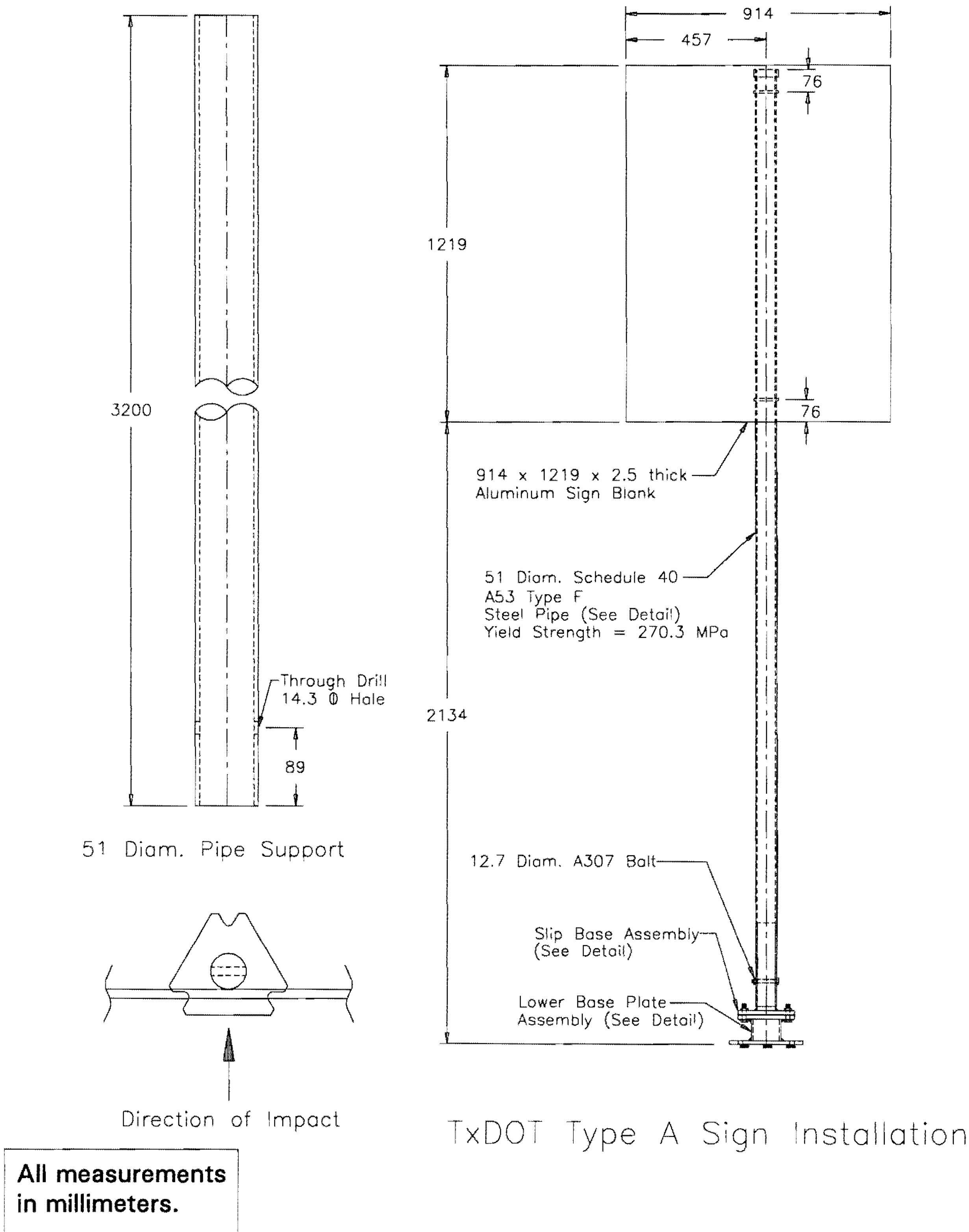


Figure 6. Details of Pipe Support Used in Pendulum Testing.

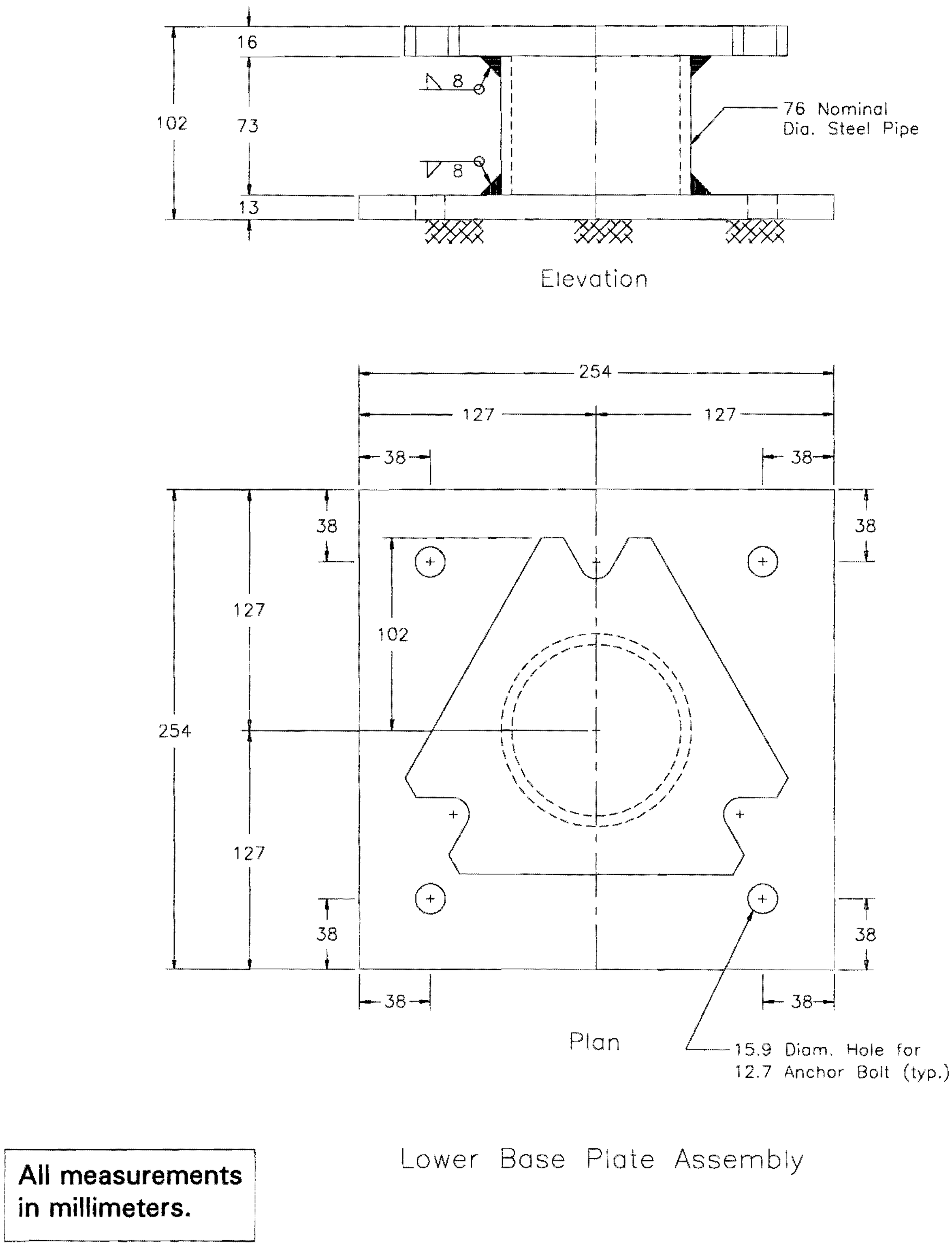
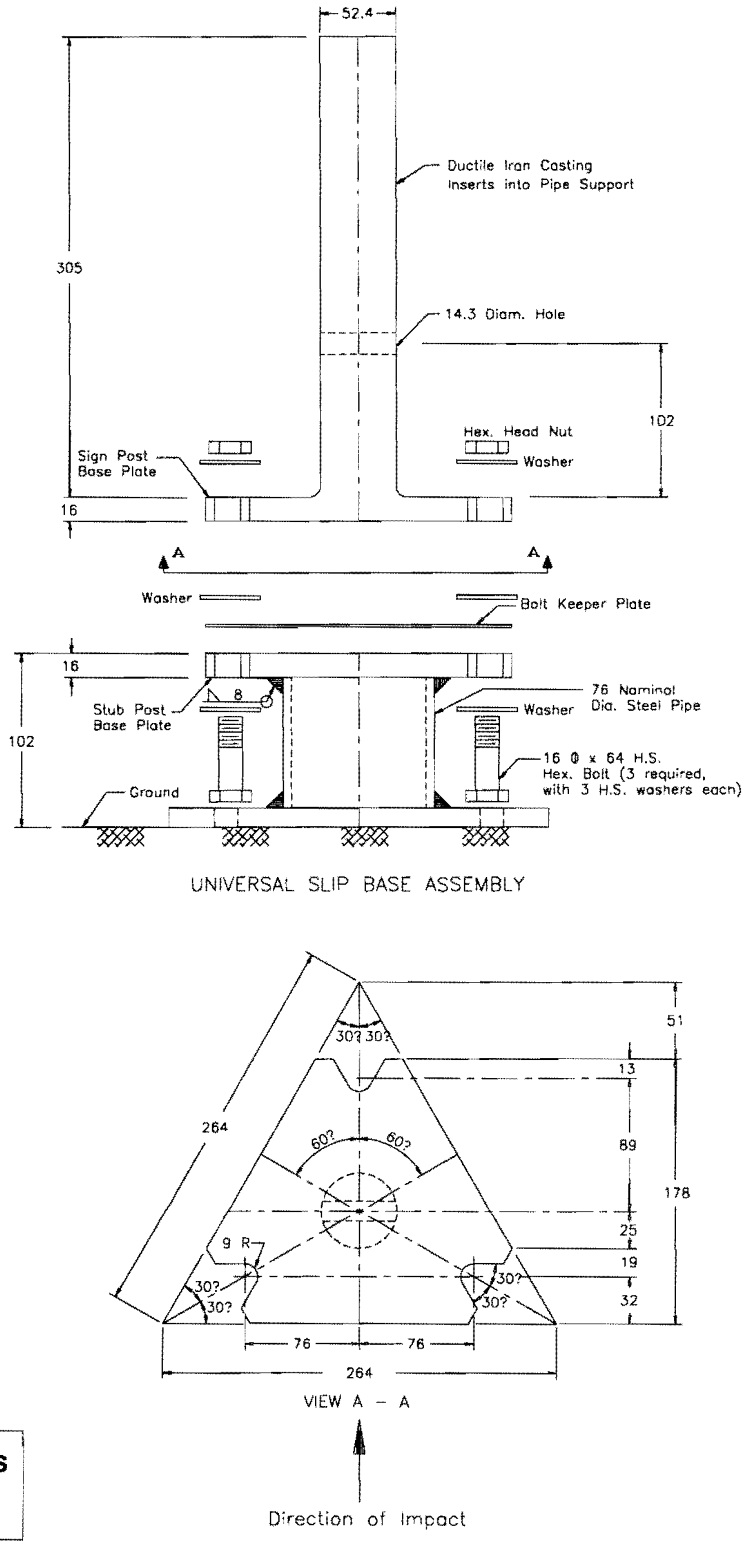


Figure 6. Details of Pipe Support Used in Pendulum Testing (continued).



All measurements in millimeters.

Figure 6. Details of Pipe Support Used in Pendulum Testing (continued).

Figure 7. Typical Sign Support Before Pendulum Testing.

Figure 8. Crushable Pendulum Nose.

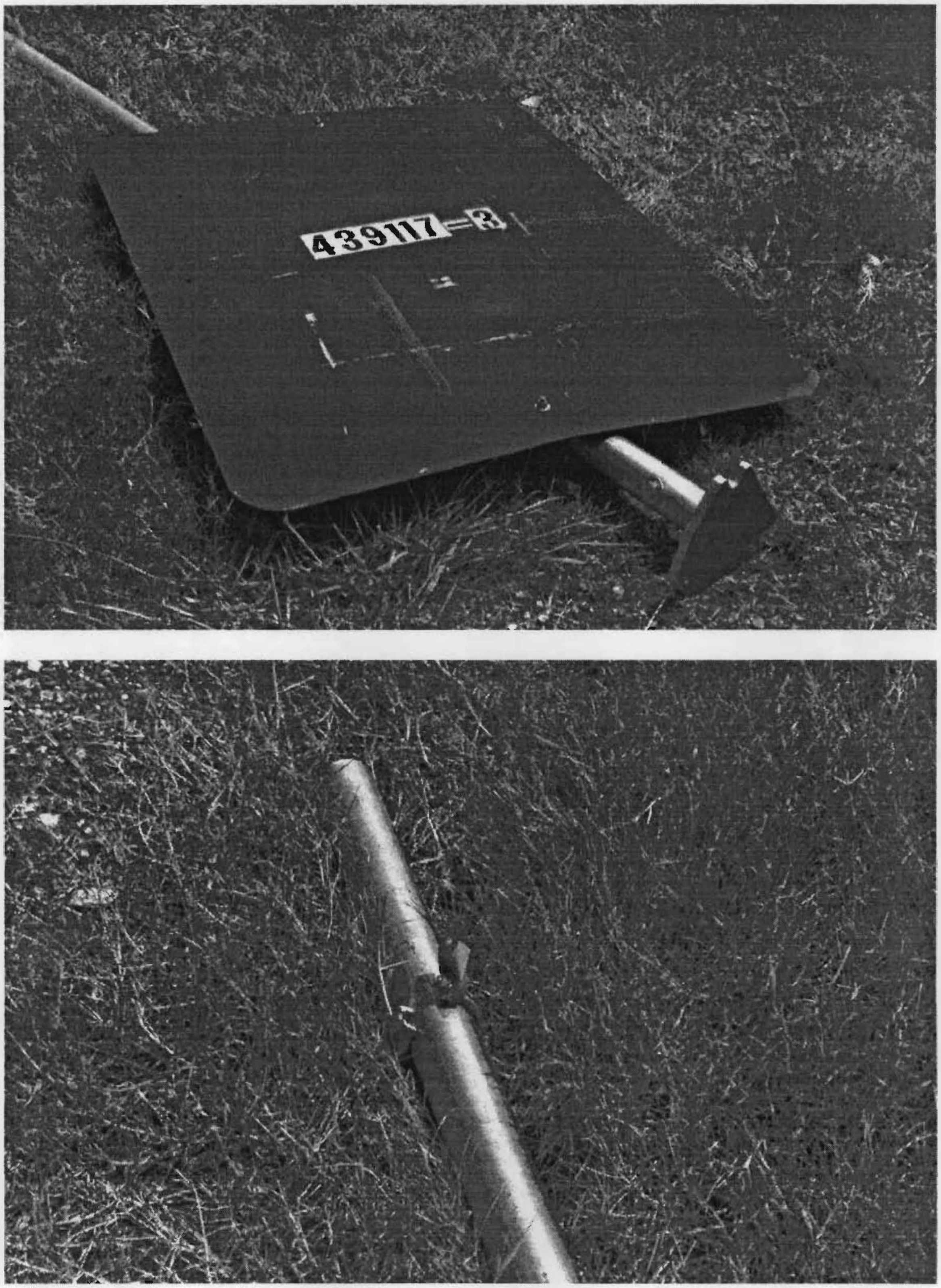


Figure 9. Pipe Support After Test 439117-P3.

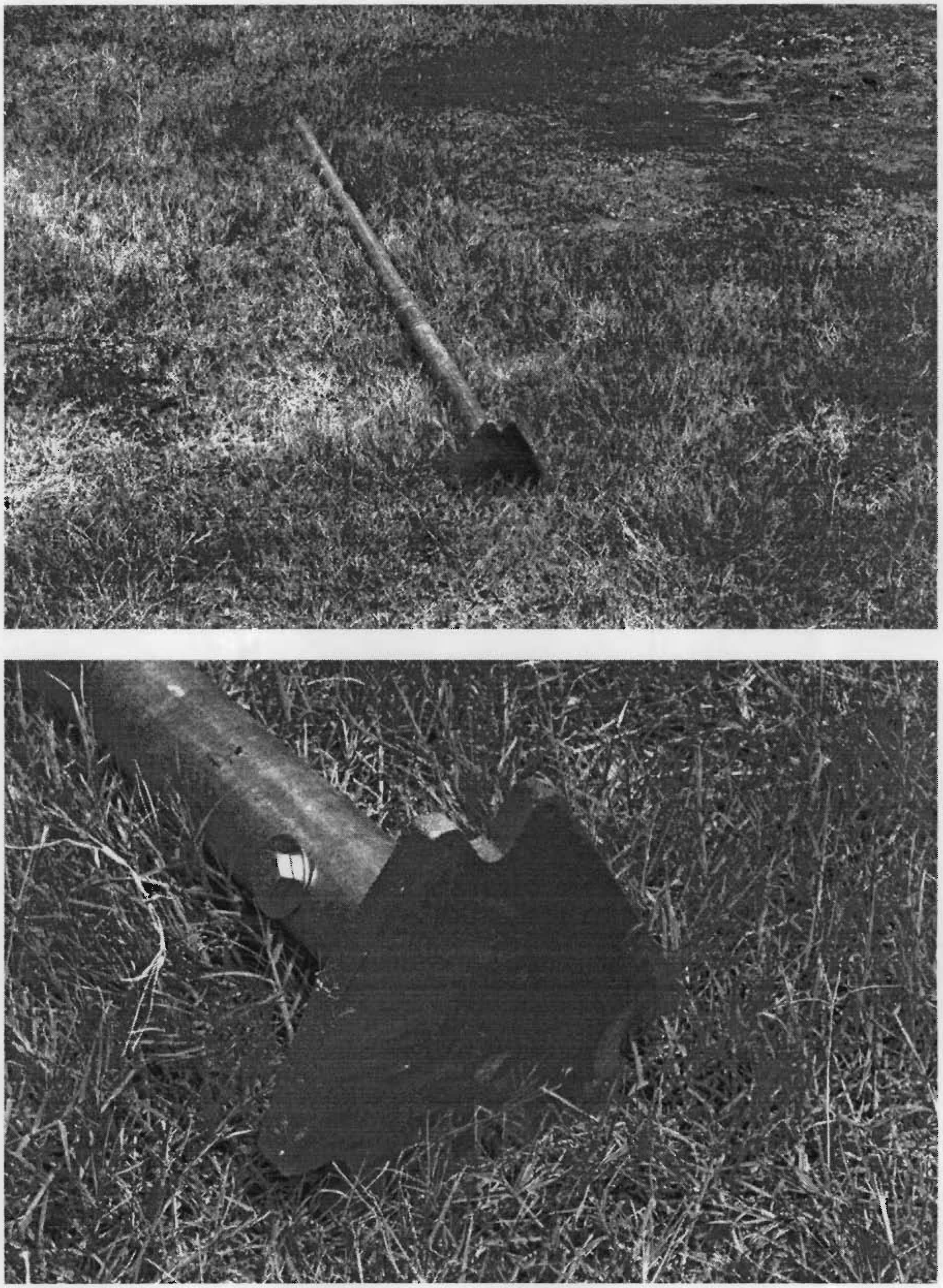


Figure 10. Pipe Support After Test 439117-P4.

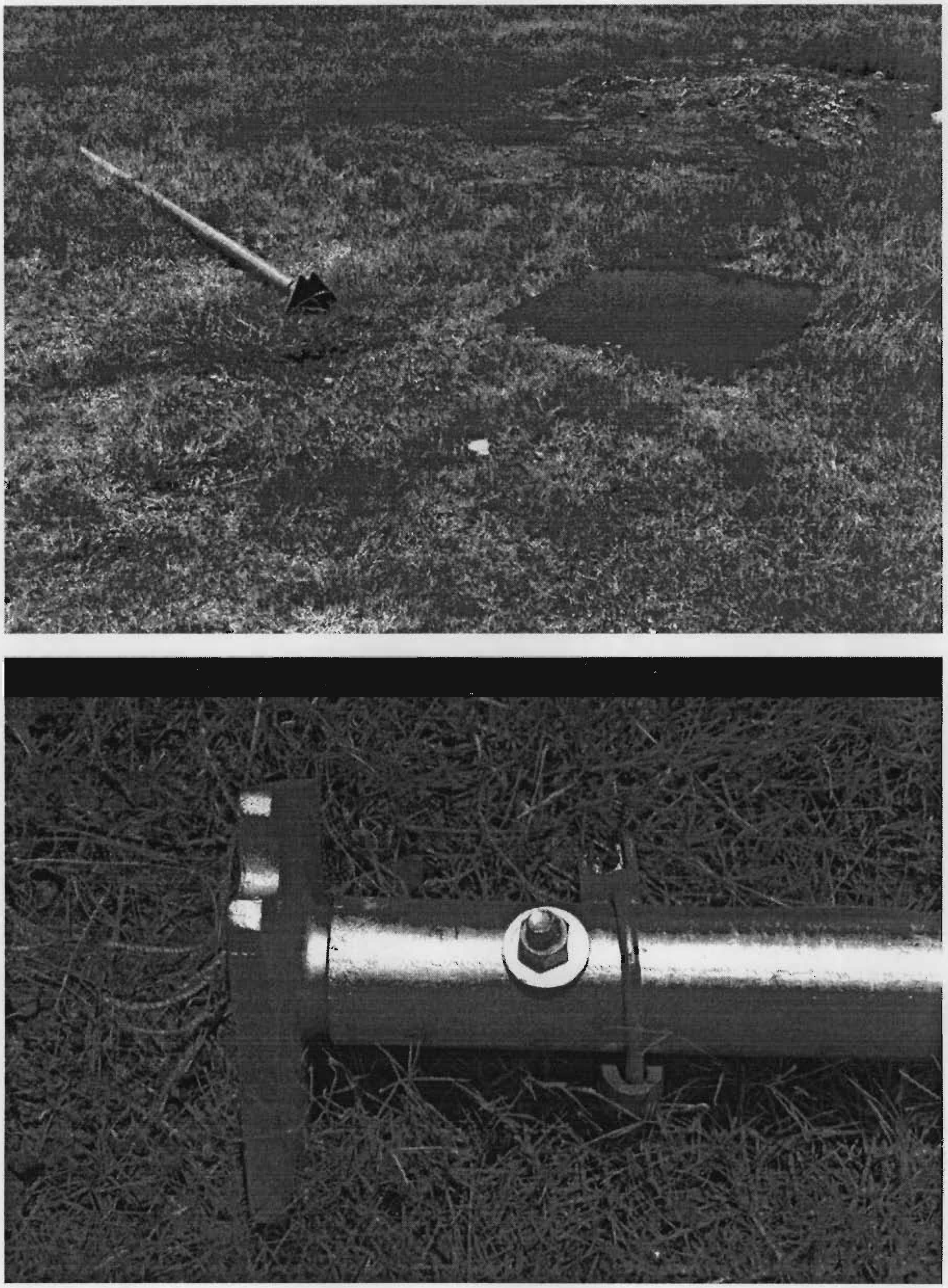


Figure 11. Pipe Support After Test 439117-P5.

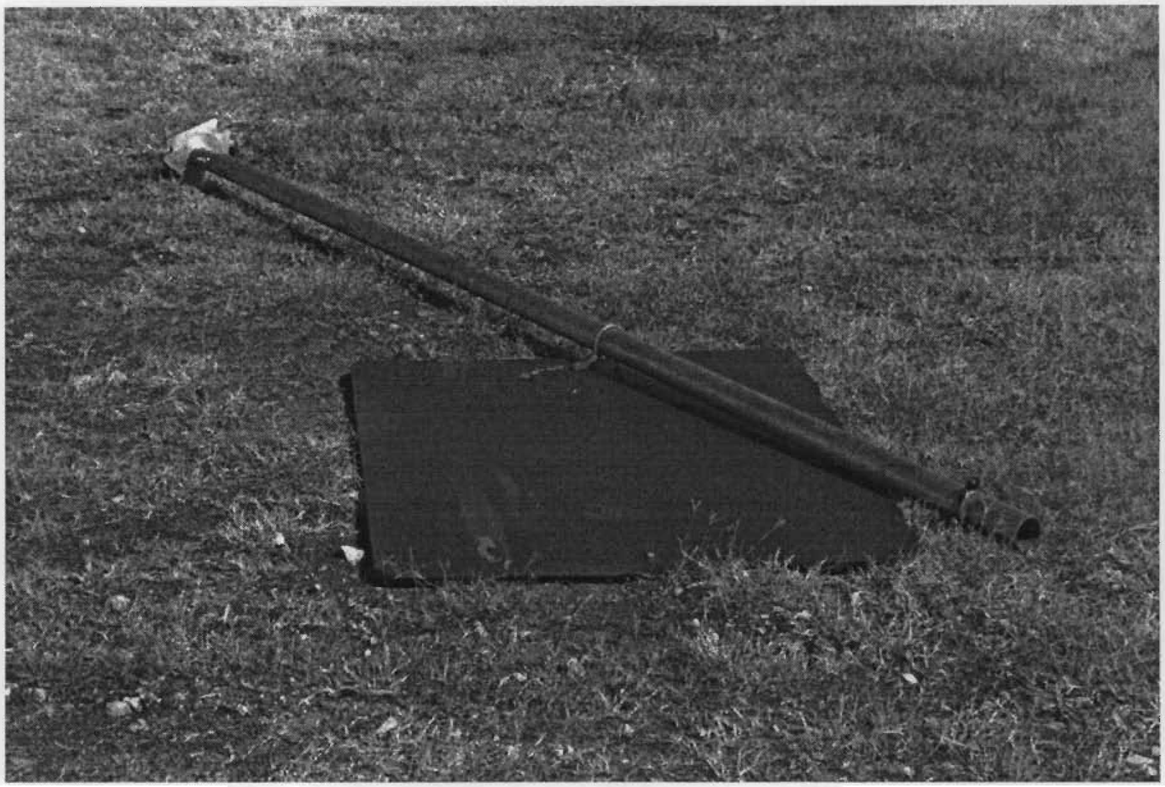


Figure 12. Pipe Support After Test 439117-P6.

V. FULL-SCALE CRASH TESTS

A sample of pipe from source C (Table 1) was used in a low-speed full-scale vehicle crash test. Details of this test (test 439117-3) are contained in reference 1.

Drawings of the sign support are shown in Figure 13. Photographs of the sign support after the test are shown in Figure 14.

Behavior of the pipe sign support in this test was considered acceptable.

A sample of pipe from source A (Table 1) was used in a high-speed full-scale vehicle crash test. Details of this test (test 439117-4) are also contained in reference 1. Other than the source of pipe the test installation was the same as that used in test 439117-3 and shown in drawings in Figure 13.

During the collision the pipe support bent into a smooth long-radius curve as shown in Figure 15. The pipe did not exhibit any fracture or brittle behavior. It functioned acceptably in this test.

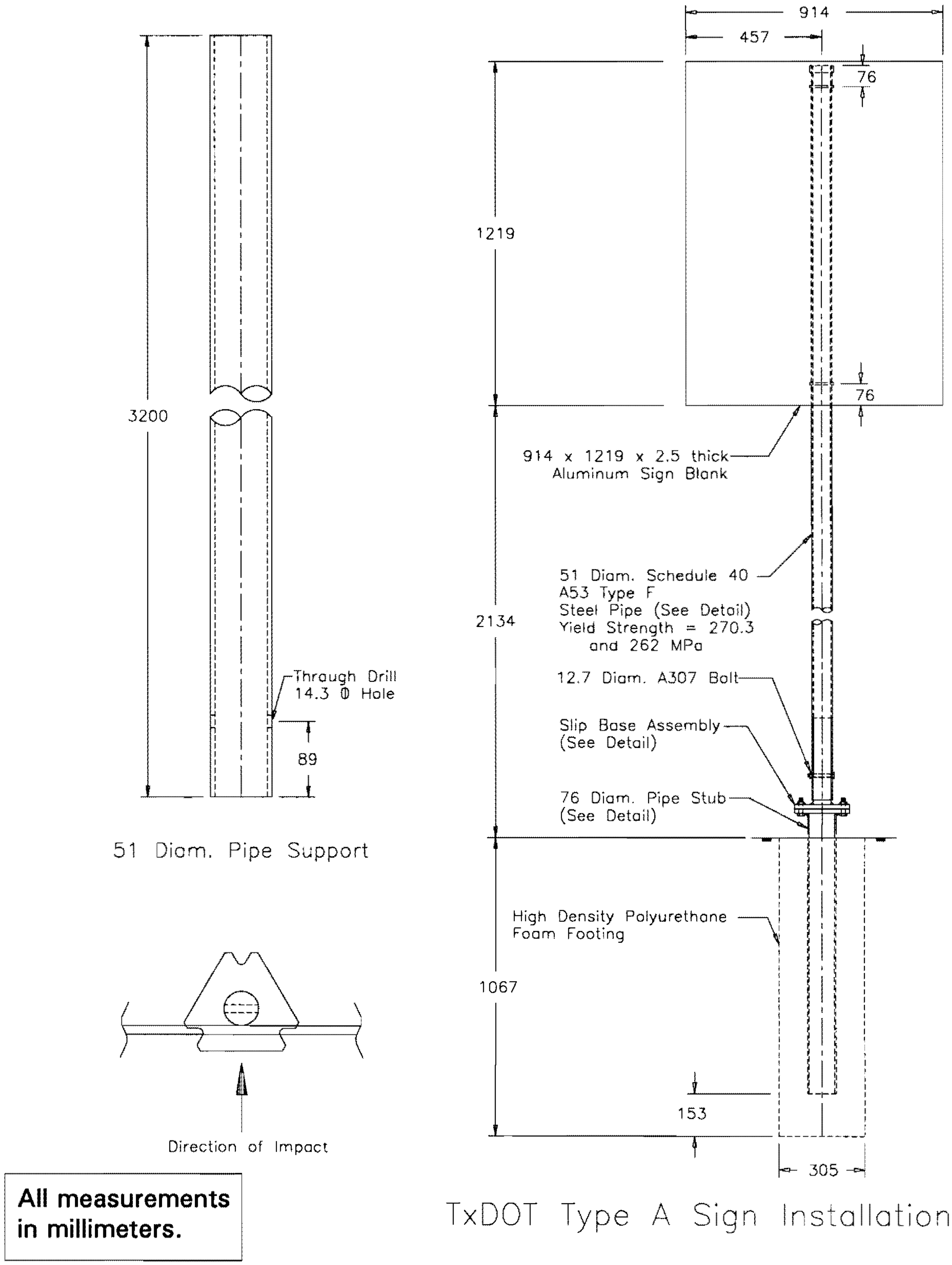


Figure 13. Details of Pipe Support Used in Vehicle Crash Tests.

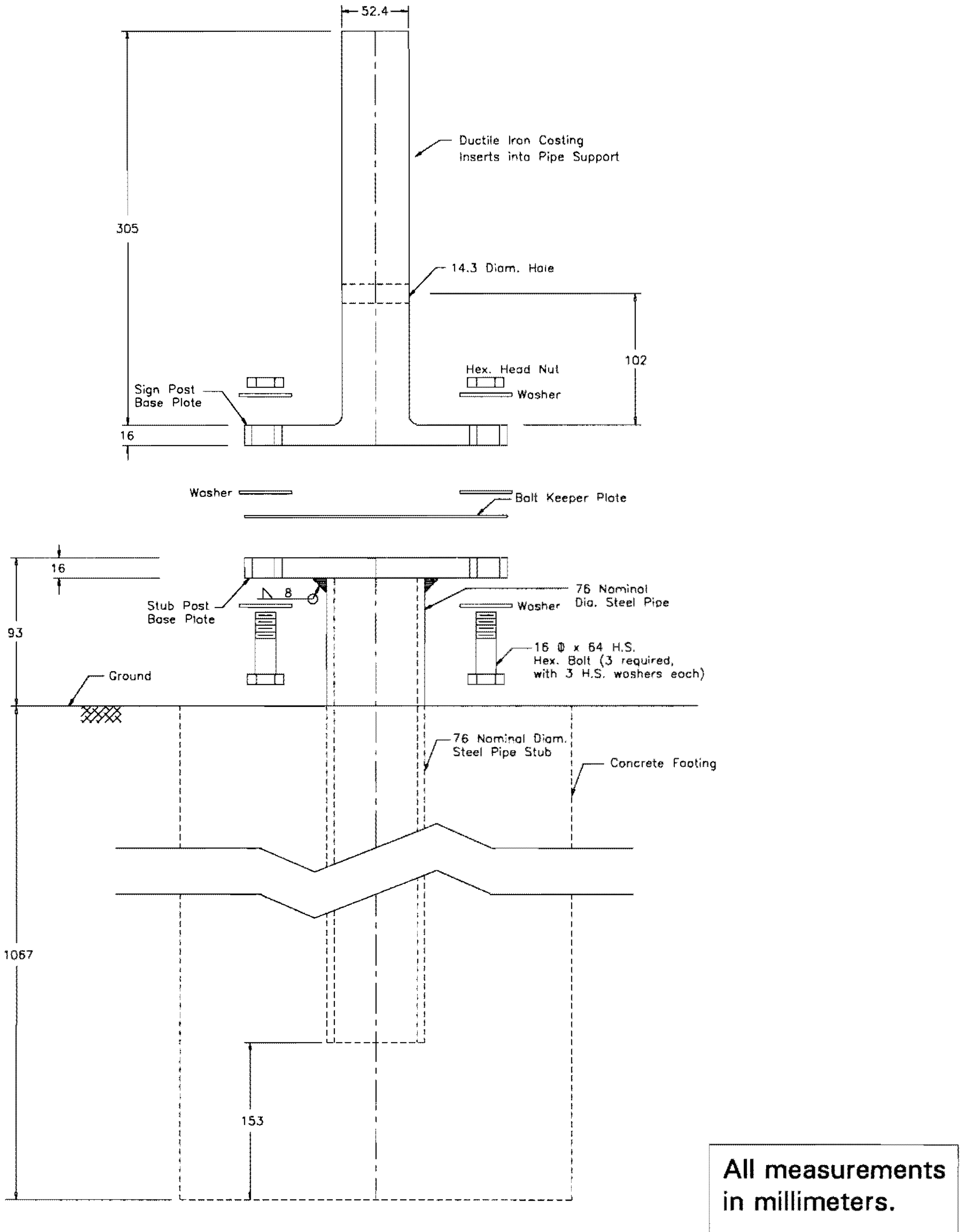


Figure 13. Details of Pipe Support Used in Vehicle Crash Tests (continued).

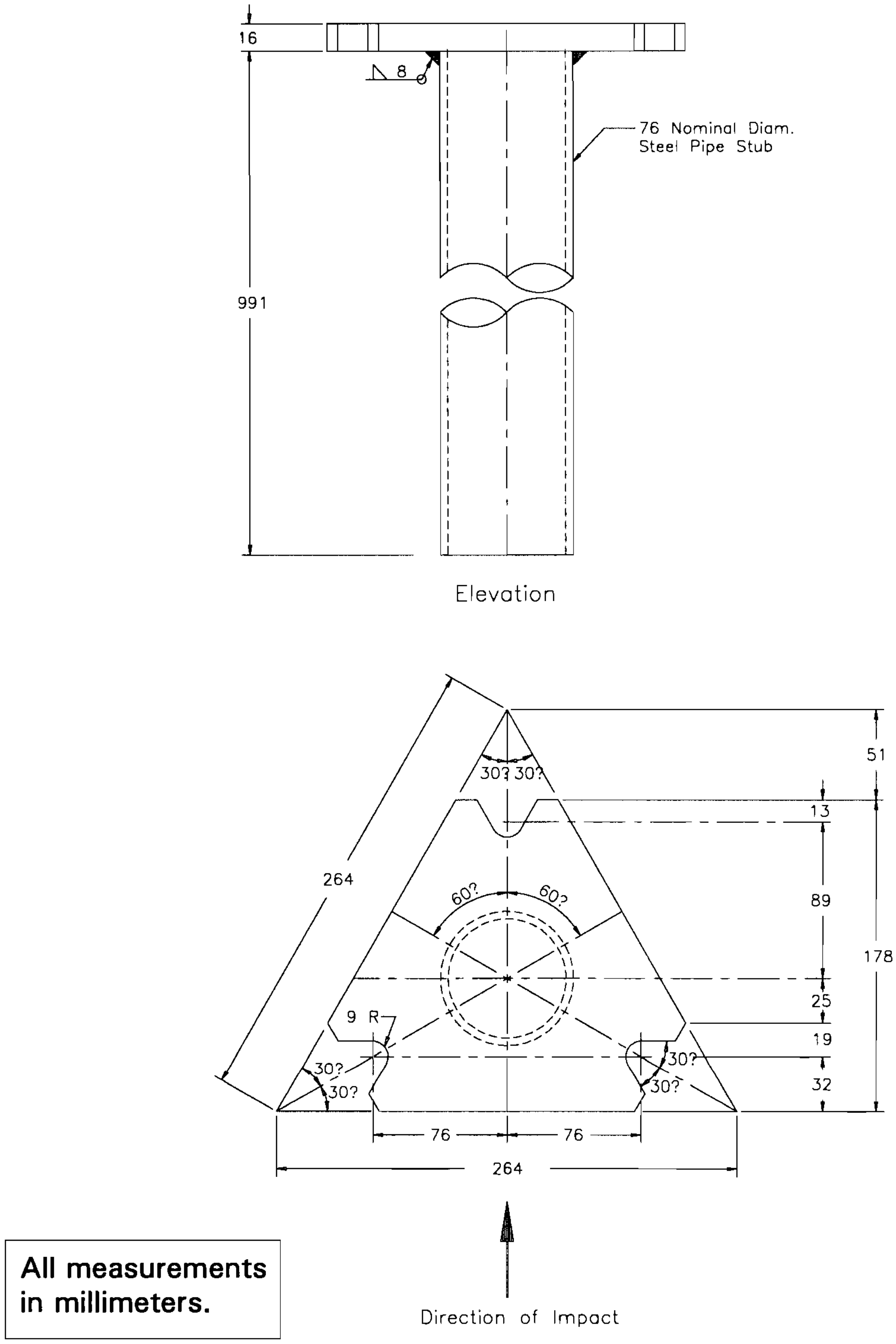


Figure 13. Details of Pipe Support Used in Vehicle Crash Tests (continued).

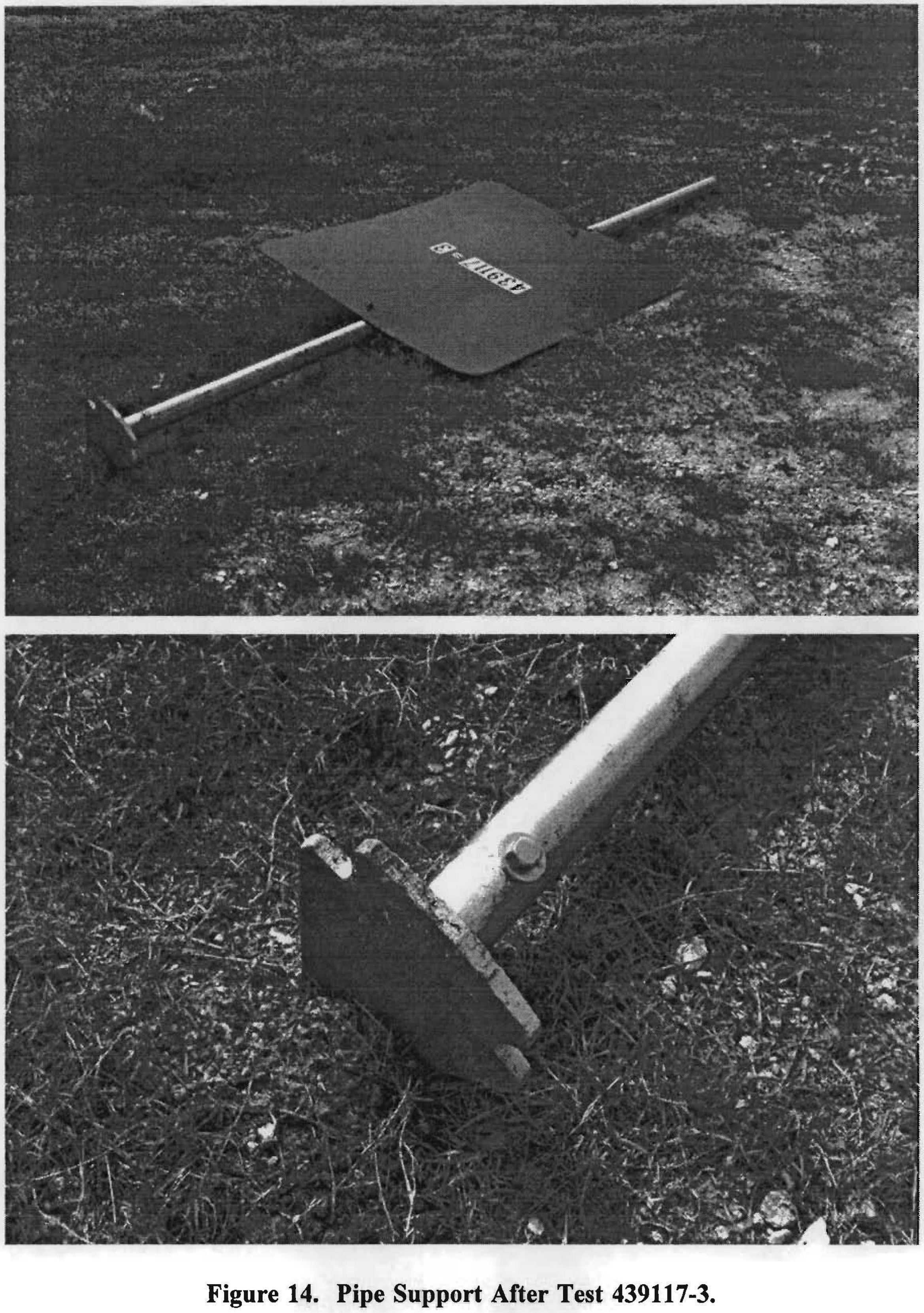


Figure 14. Pipe Support After Test 439117-3.

Figure 15. Pipe Support After Test 439117-4.

VI. CONCLUSIONS

Samples of 51 mm I.D., schedule 40 pipe were subjected to static load tests in cantilevered beam configuration and selected samples of furnace butt welded pipe were used in dynamic pendulum and full-scale vehicle impact tests. The furnace butt welded pipe samples had yield strengths of 262 Mpa and 270 Mpa. The purpose of the tests was to determine whether the furnace butt welded pipe is suitable for use in small sign supports.

In the static bending tests, the furnace butt welded samples behaved the same as the electric resistance welded samples. No shortcomings were observed.

In dynamic impact tests with a pendulum and in full-scale vehicle crash tests, samples of furnace butt welded pipe sign supports behaved acceptably.

Researchers recommend that TxDOT consider furnace butt welded pipe of sufficient yield strength and ductility acceptable for use as small sign supports.

REFERENCES

1. Roger P. Bligh, C. Eugene Buth, Wanda L. Menges, and Barbara G. Butler, "Design and Testing of New Support Systems -- Lubbock District," TxDOT Study No. 7-3911, November 1997.