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A highly portable, positive construction zone barrier is described. The barrier is suitable for use at sites where duration of work is as short as several hours. It is constructed from used cars and thrie-beam guardrail. Two full-scale vehicular crash tests of the portable barrier are described that demonstrate its adequacy in terms of impact performance. The barrier can be used in construction zones where conventional positive barriers have been impractical.

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A PORTABLE TRAFFIC BARRIER FOR WORK ZONES

by

Dean L. Sicking
H. E. Ross, Jr.
D. L. Ivey
T. J. Hirsch

Research Report 262-3
on
Research Study No. 2-18-79-262
Safety Devices for Highway Work Zones

Sponsored by

Texas State Department of Highways and Public Transportation

in cooperation with

The U. S. Department of Transportation
Federal Highway Administration

October 1982

Texas Transportation Institute
Texas A&M University
College Station, Texas

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

Portable Barrier, Crash Test(s), Construction, Work Zone(s), Temporary, Safety

ACKNOWLEDGMENTS

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A PORTABLE TRAFFIC BARRIER FOR WORK ZONES

ABSTRACT

A highly portable, positive construction zone barrier is described. The barrier is suitable for use at sites where duration of work is as short as several hours. It is constructed from used cars and thrie-beam guardrail. Two full-scale vehicular crash tests of the portable barrier are described that demonstrate its adequacy in terms of impact performance. The barrier can be used in construction zones where conventional positive barriers have been impractical.

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A PORTABLE TRAFFIC BARRIER FOR WORK ZONES

INTRODUCTION

The number of injuries and fatalities among Texas highway construction and maintenance personnel has increased greatly over the past several years. In one Texas highway maintenance district, traffic accidents have caused 39 injuries and 12 fatalities among highway construction and maintenance personnel during the past two years. Examination of these accidents has revealed that most of the injury and fatality producing accidents have occurred at construction sites or routine maintenance sites where all blocked travel lanes were to be cleared at the end of each work period. Normal traffic control for this type operation includes arrow boards and cones for traffic channelization. Often most of the cones are knocked down during the course of a single work period. After cones have been knocked down, drivers can become confused and return to the blocked lane. Errant motorists also enter work zones as a result of collisions with other motorists or roadside objects.

Initial efforts to reduce the number of accidents in these work areas included increased law enforcement personnel, increased efforts to replace cones that have been knocked down, reducing the length of the work zones, and conducting the work only during periods of very light traffic. However, none of these alternatives have proven very effective. Therefore it was concluded that an effort should be made to develop a highly portable, positive barrier for use in certain critical work zones.

Conventional construction zone positive barriers include portable precast concrete barriers and W-beam on barrels. These barriers cannot be erected and removed quickly enough to allow their use in construction and maintenance zones where all blocked lanes are to be cleared at the end of each work period. Therefore this research was undertaken to develop a truly portable positive work zone barrier that would be 1) portable enough for use in maintenance zones that are to be in place only a few hours; 2) crashworthy for use in construction zones; and 3) be relatively inexpensive to construct and maintain.

PORTABLE CONSTRUCTION ZONE BARRIER

A truly portable construction zone barrier should be brought to the work site and set up in a matter of only a few minutes. No heavy machinery or specialized equipment should be necessary since these may not be available at the site. Further, the barrier must be capable of redirecting an errant vehicle without deflecting excessively and thereby endangering workers standing behind it. Finally, the barrier should be relatively inexpensive to build and maintain.

After examining many portable construction zone barrier concepts, researchers concluded that the used car barrier was the most promising design considered. This barrier consists of a line of cars connected together with tow bars. The barrier is extremely portable since it can actually be driven to the work site. No special equipment is required for its setup, and the barrier is relatively inexpensive when compared to other barriers considered.

The used car barrier is shown in Figure 1 and described in Figures 2 and 3. The vehicles used in the barrier were 1973 and 1974 Plymouth Suburban station wagons. These vehicles have torsion bar front suspension which allows the height of the front bumper to be easily adjusted for towing purposes. Standard thrie-beam guardrail is attached to each of the vehicles as shown in Figure 3. The thrie beam provides a continuous, smooth surface to prevent impacting vehicles from snagging on the used cars. A hinged thrie beam gate is used to prevent snagging on the joints between barrier vehicles. The thrie beam is blocked out 3.5 in. (8.9 cm) from the vehicles to reduce the possibility of wheel snag on the barrier and to allow the front wheels of the barrier vehicles to turn. The guardrail element is terminated at the rear of the last vehicle with a rounded end section as shown in Figure 4.

Three telescoping tube members, shown in Figures 5 and 6, constructed from standard schedule 40 steel pipe are employed to develop moment and shear

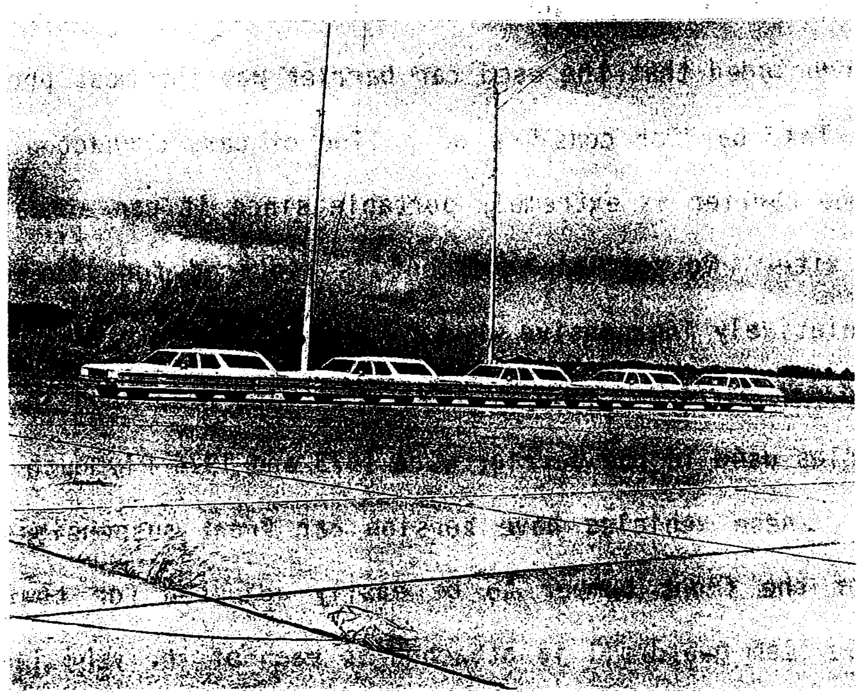


Figure 1. Used Car Barrier.

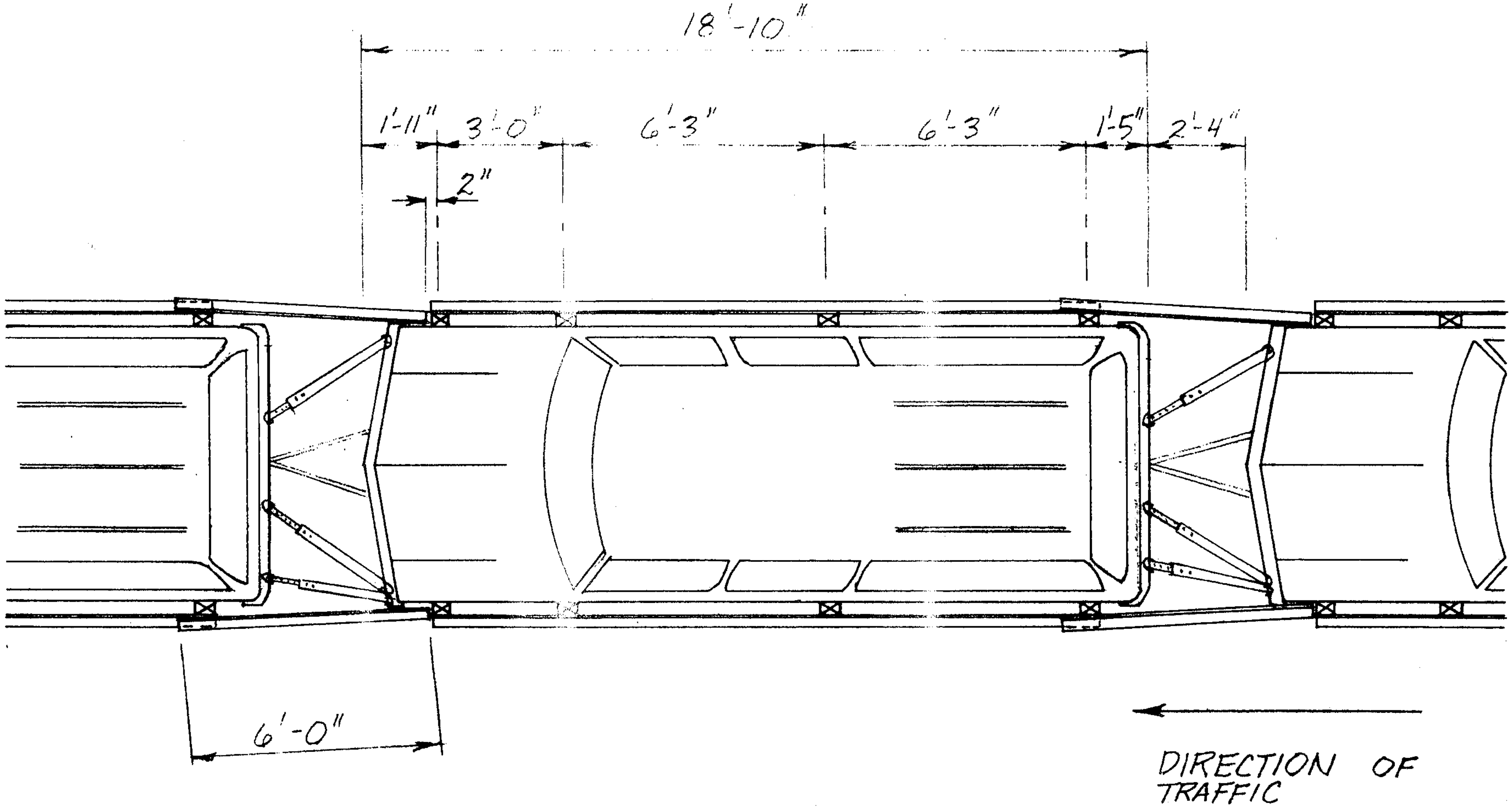


FIGURE 2. CONSTRUCTION DRAWING OF USED CAR BARRIER.

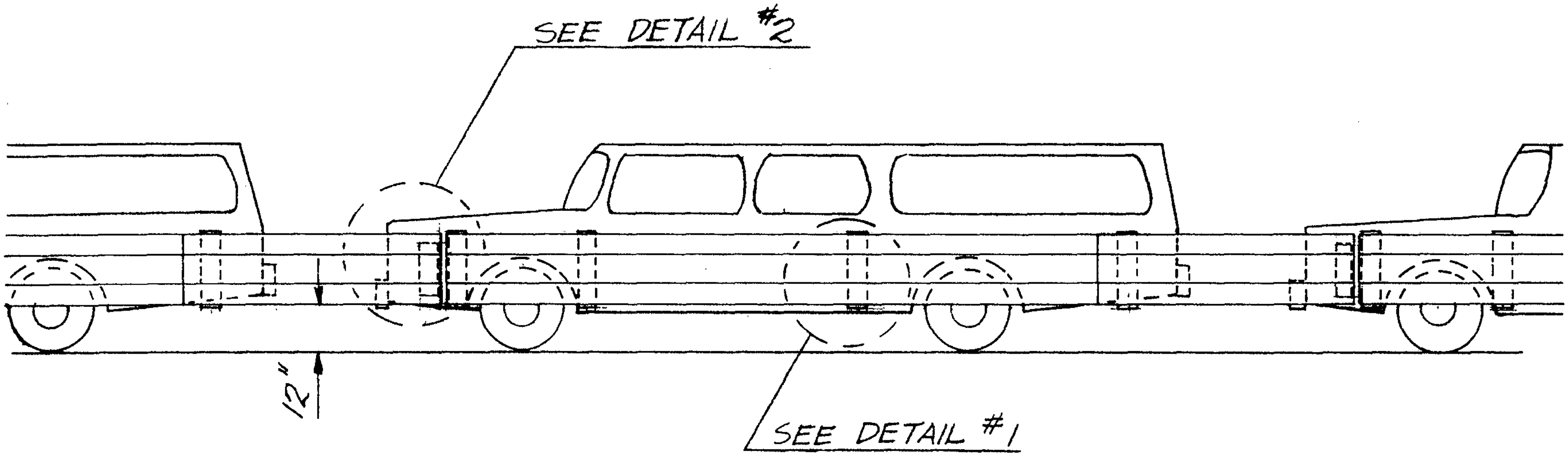


FIGURE 2. CONSTRUCTION DRAWING OF USED CAR BARRIER (continued).

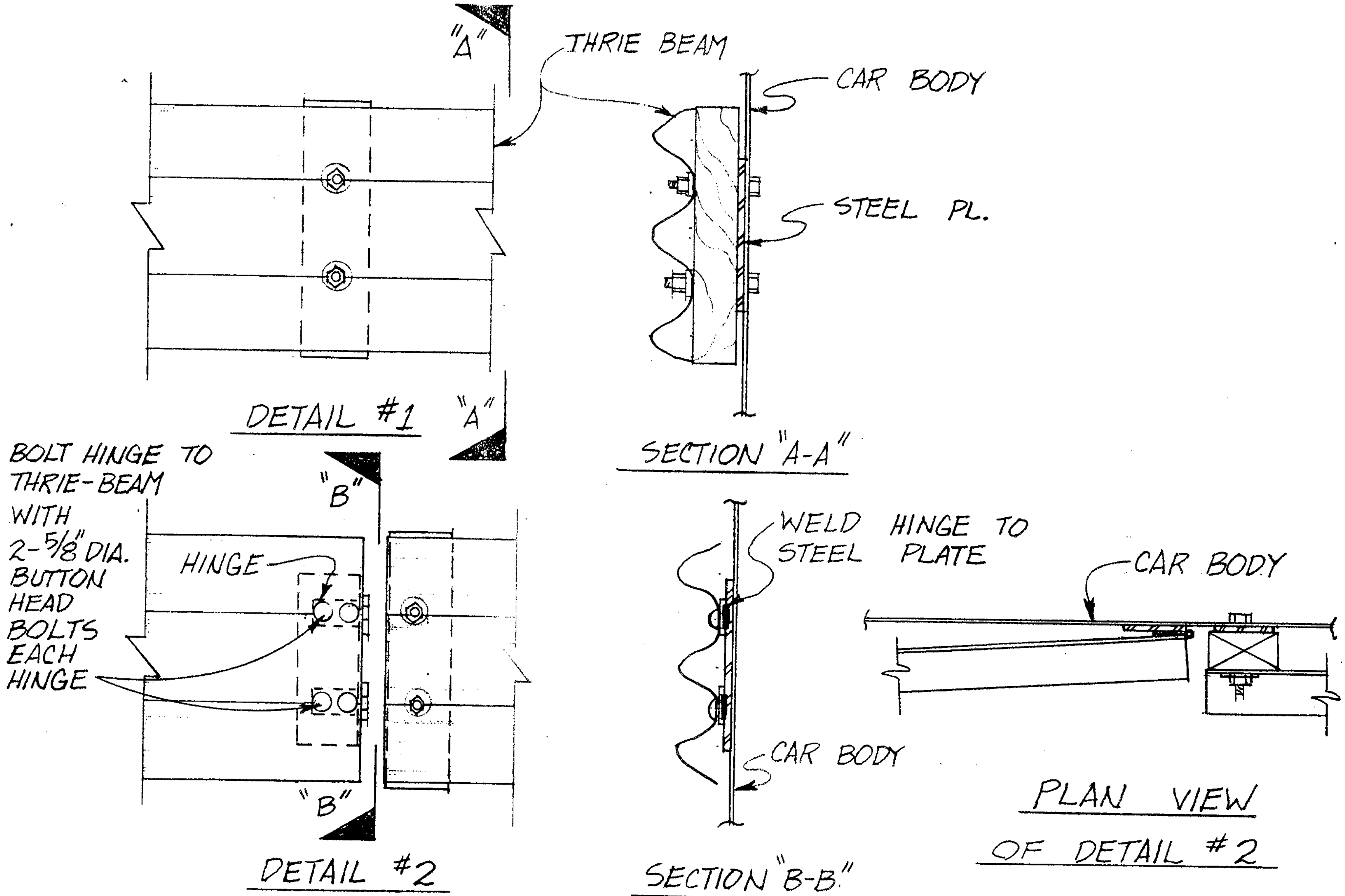
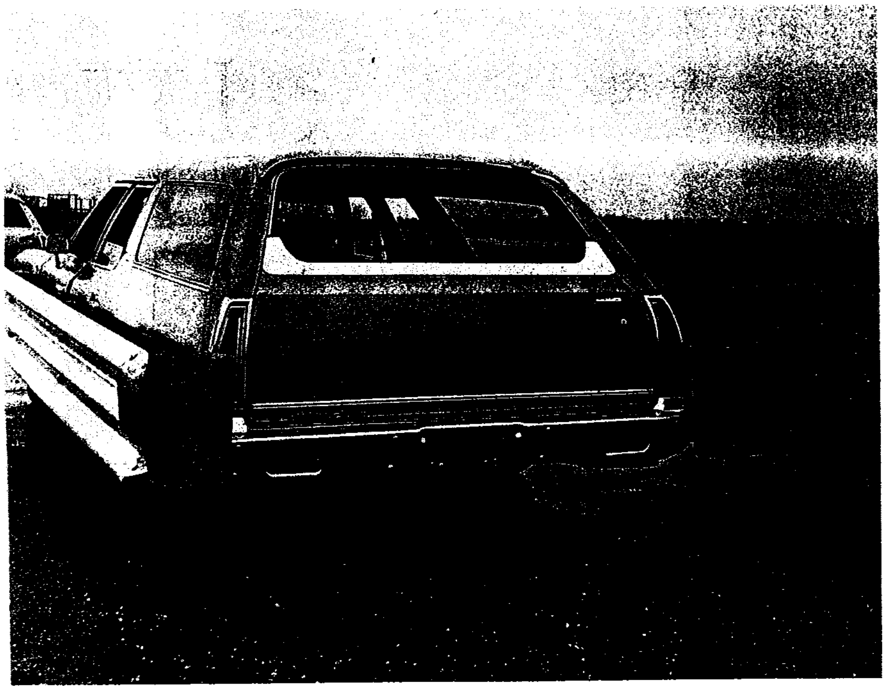


FIGURE 3. DETAILS OF THRIE-BEAM ATTACHMENT TO BARRIER.



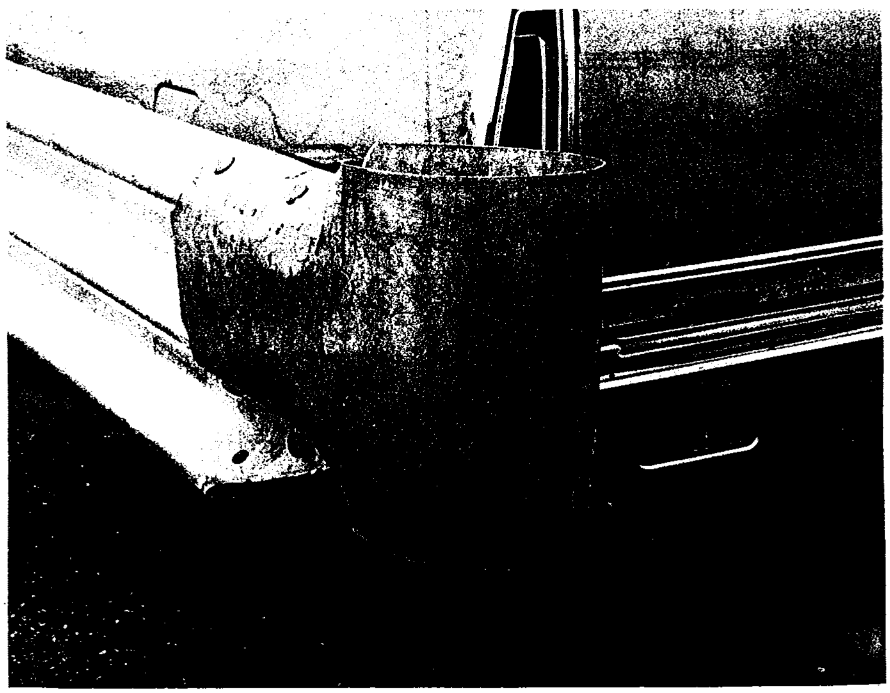


Figure 4. Rear View of Used Car Barrier.

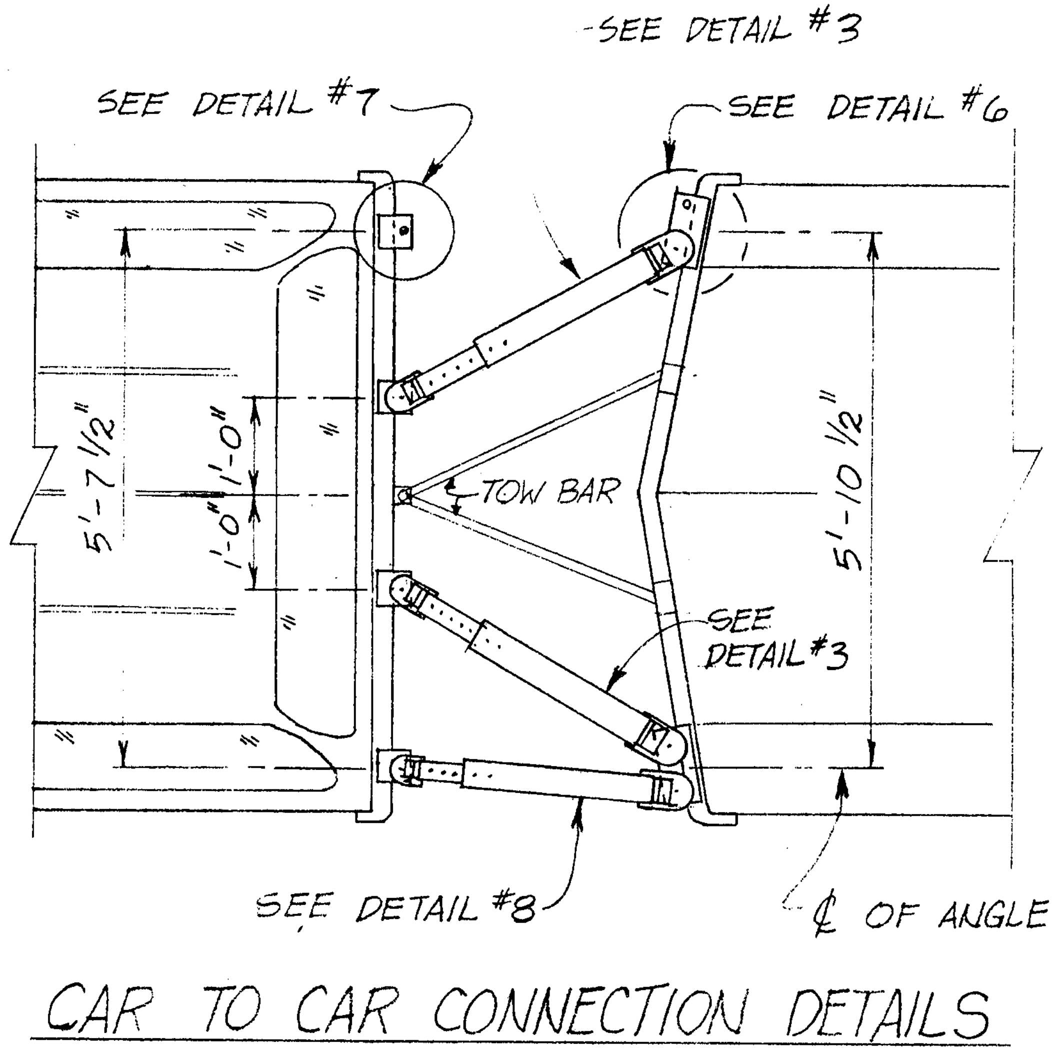


Figure 6. Details of Barrier Vehicle Joints.

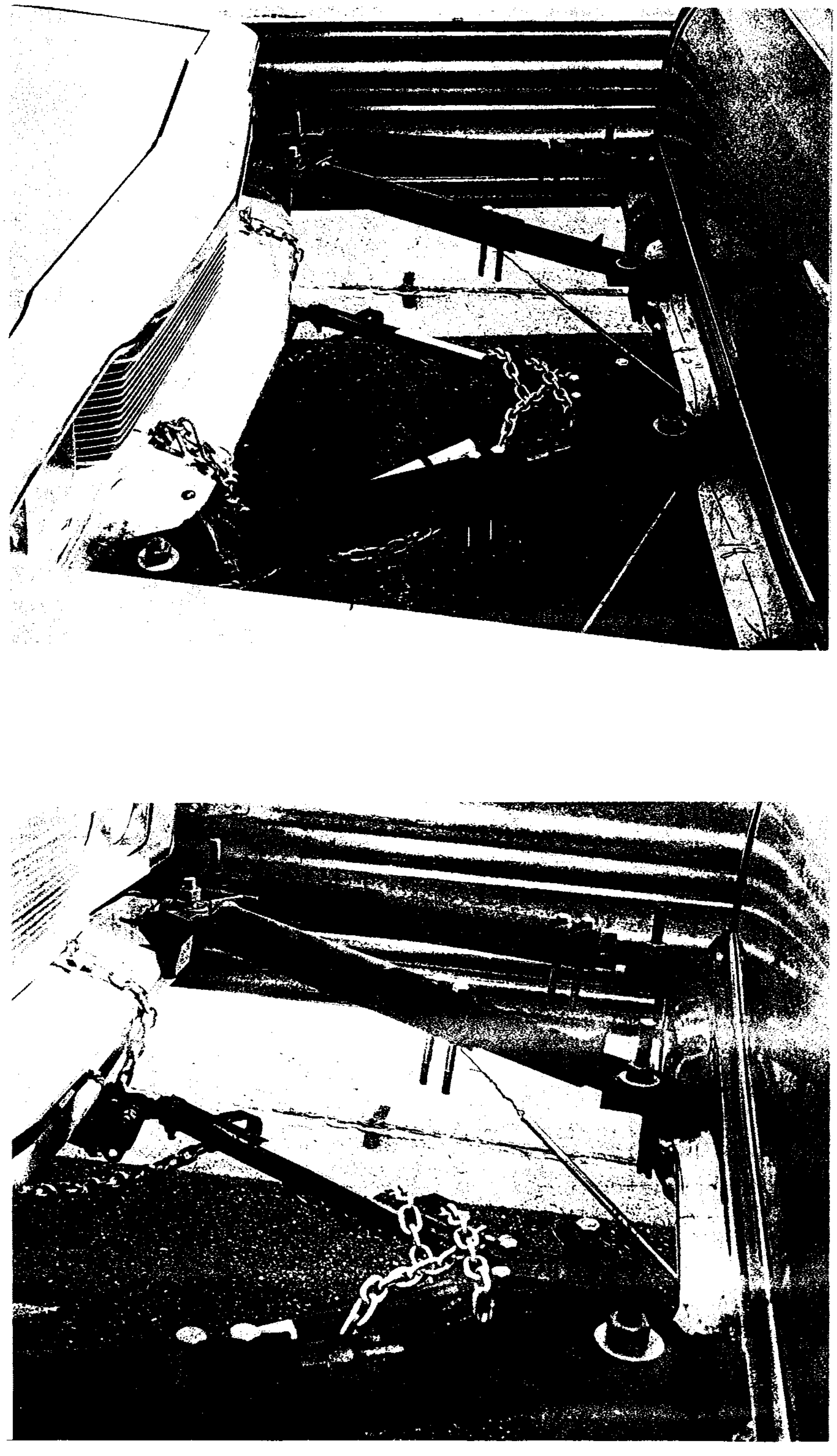


Figure 5. Barrier Segment Connection Details.

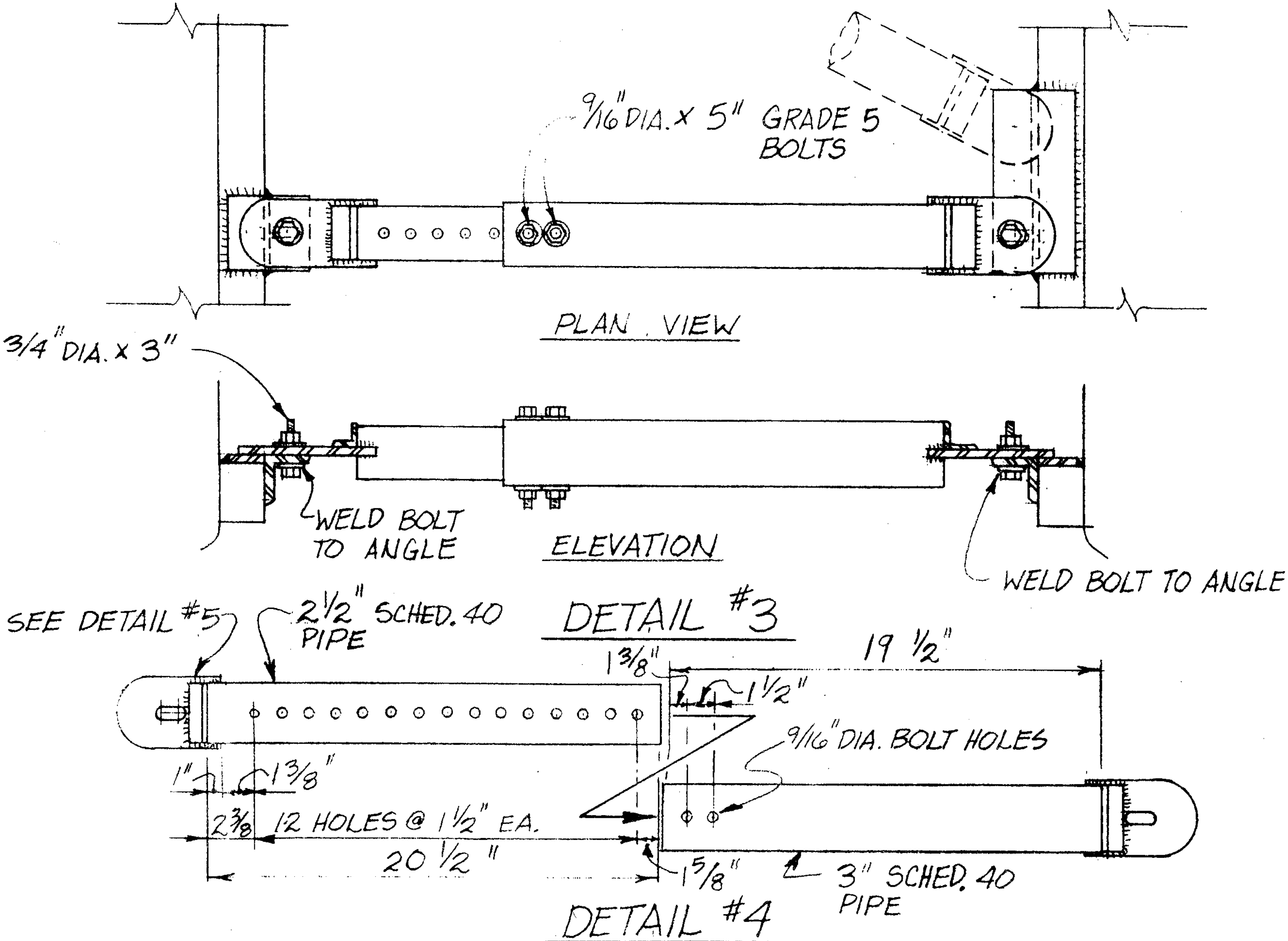


Figure 6. Details of Barrier Vehicle Joints (continued).

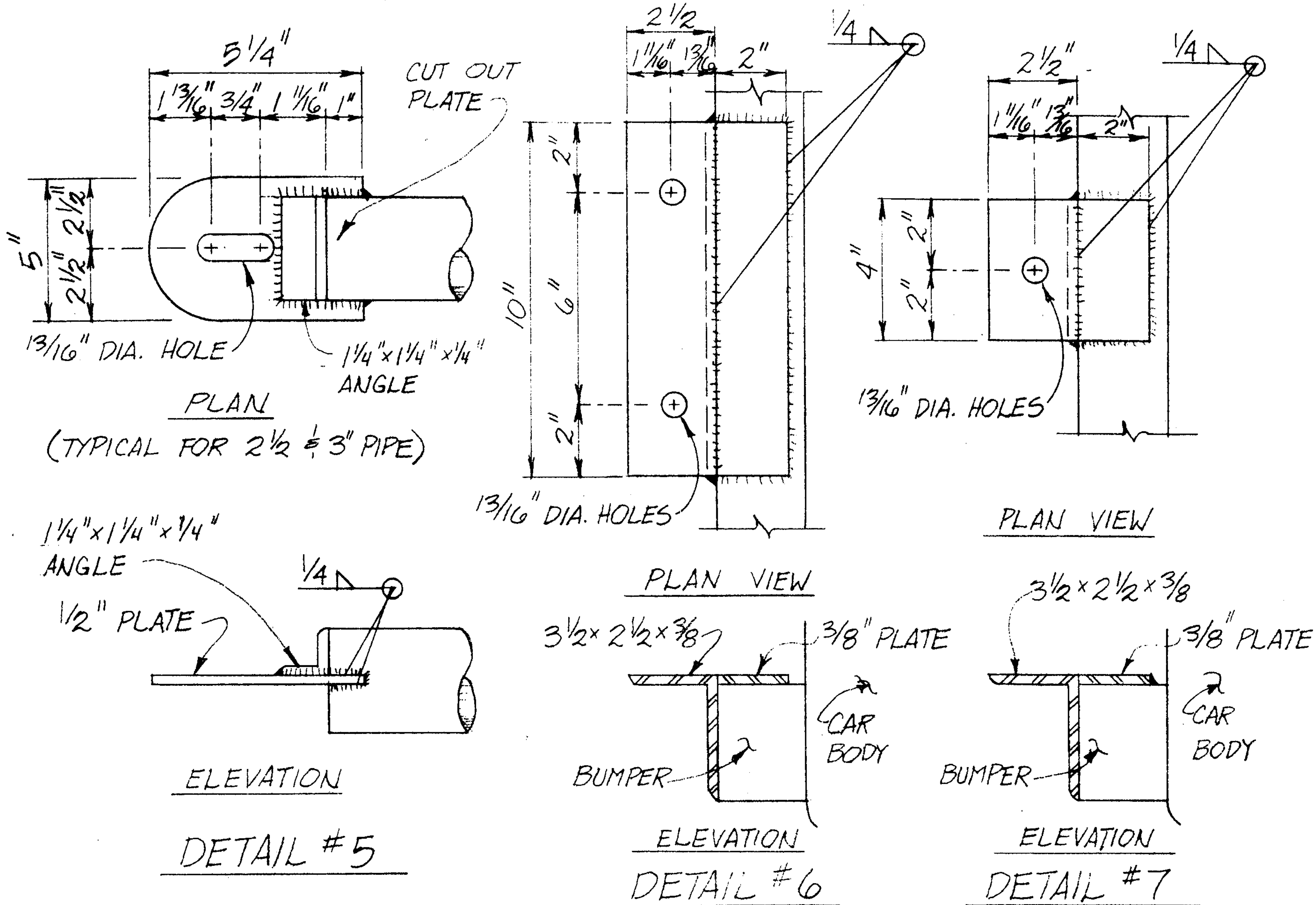
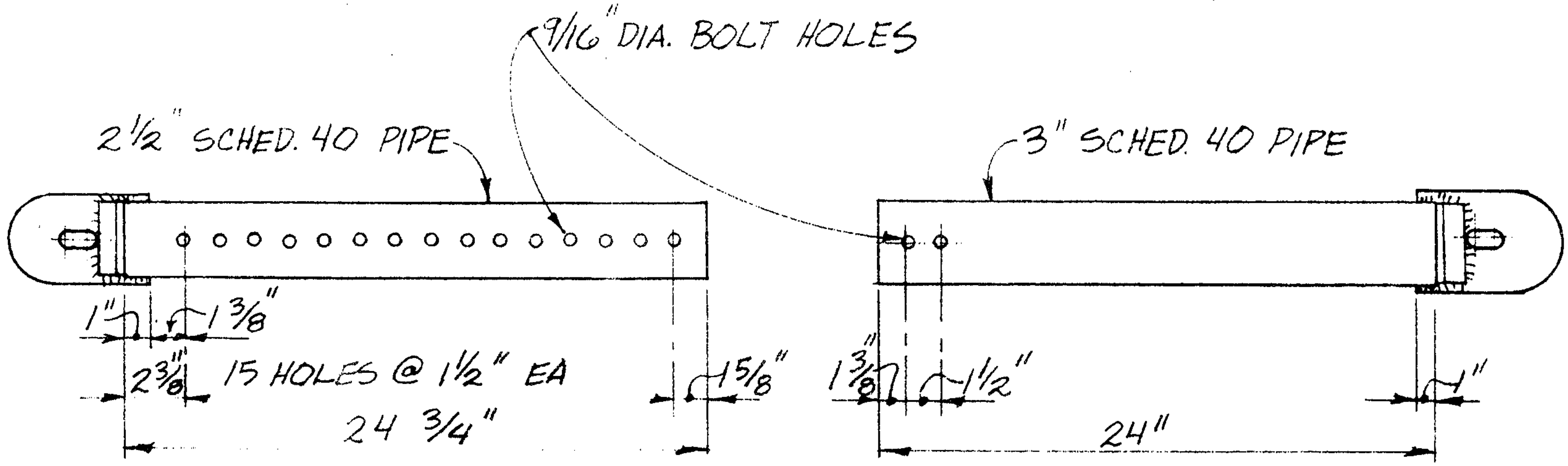


Figure 6. Details of Barrier Vehicle Joints (continued).

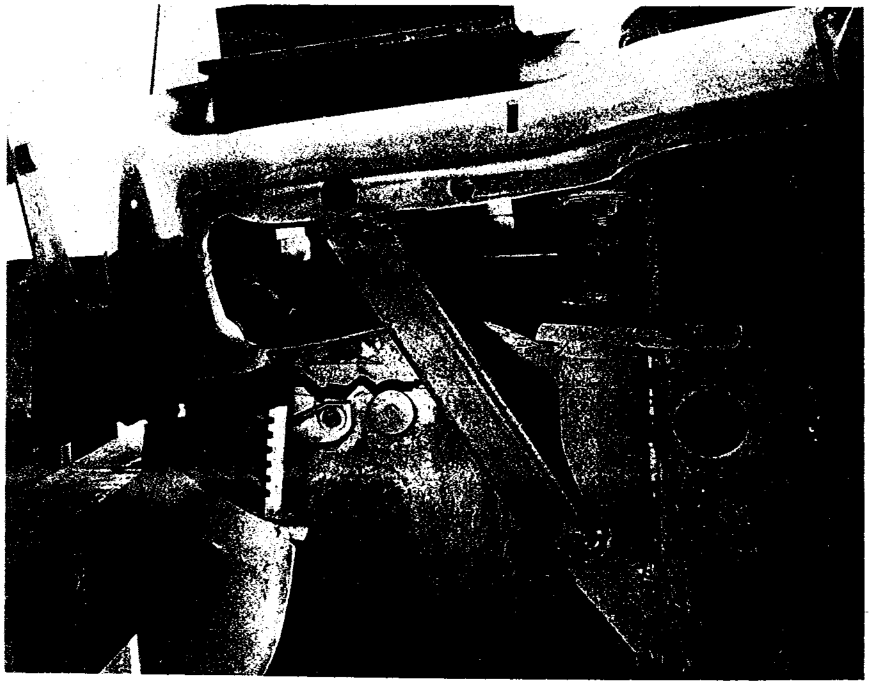


DETAIL #8

Figure 6. Details of Barrier Vehicle Joints (continued).

capacity between the barrier vehicles. When the barrier is to be moved, only one of the members must be removed from the joint and two steel pins must be removed from each of the other members. Telescoping members are designed to withstand an 18 kip (80.0 kN) axial load before yielding begins. The yield moment of the car-to-car joint is approximately 50 kips-ft (67.8 kN-m). The vehicle bumpers were reinforced, as shown in Figure 7, to develop the yield strength of the telescoping tube members. As shown in Figure 6, commercially available heavy-duty tow bars are employed to move the barrier. The tow bars remain in place when the barrier is put into service, thereby reducing set-up time.

The used car barrier constructed at the Texas Transportation Institute consisted of five vehicles. The leading car was maintained in operational condition and was used as a tow vehicle to move the barrier. The barrier was very maneuverable and had a turning radius of approximately twice that of a conventional automobile. Further, the time required to set up the barrier is very short since only one telescoping member and four pins must be placed in each joint at setup time. The barrier was 100 ft (30.5 m) long and cost approximately $7,000. At a cost of $70/ft the barrier is very inexpensive when compared to other alternatives.



Front

Rear

Figure 7. Bumper Reinforcement Details

IMPACT PERFORMANCE CRITERIA

Present test standards contained in NCHRP Report 230 (3) recommend that temporary barriers be designed for impact conditions equal to those for permanent barriers. However, NCHRP Report 230 does not specifically address the type of barrier discussed herein, i.e., a highly portable, relatively short, longitudinal barrier system. Preliminary analysis indicated it would be extremely difficult and impractical to design such a system to meet permanent barrier standards. Selection of crash test conditions (vehicle size, impact speed, impact angle) was therefore made jointly by TTI and SDHPT engineers. Factors considered in the subjective selection process included exposure time, traffic speeds in work zones, costs, and the state-of-the-art regarding temporary barriers. As a result of this process, the test conditions described in the following section were chosen.

ANALYSIS

When impacted by an errant vehicle the used car barrier should behave similarly to the portable precast concrete traffic barrier. Both barriers are a series of large rigid beams with moment resisting joints. The used car barrier was therefore analyzed with a computer program developed to model portable precast concrete barriers (2). For a description of the computer model the reader should refer to the referenced report.

The algorithm employed to examine impact with the barrier is a two dimensional model designed to predict barrier deflections and the forces transmitted by the barrier joints. Therefore only impacts with a large, 4500 lb (2043 kg) vehicle were investigated since impacts with smaller vehicles would produce lower deflections and joint loadings. Predicted barrier deflections for the impact conditions investigated and barrier deflections for the crash tests conducted are shown in Table 1. As shown in the table, predicted barrier deflections compare well with test results. Further, the computer model predicted a barrier deflection of only 26 in. (66 cm) for an impact at 60 mph (96.6 km/h) and 25 deg. which is a small deflection for a test of this severity. Therefore the barrier may be acceptable for use in place of conventional construction zone barriers.

TABLE 1. BARRIER DEFLECTIONS

Impact Velocity mph (km/h)	Impact Angle (deg.)	Maximum Barrier Deflection in. (cm) Predicted	Actual
50 (81)	7	0.5 (1.3)	2.0 (5.1)
50 (81)	15	10. (25.4)	7.2 (18.3)
60 (97)	15	15. (38.1)	*
60 (97)	25	26. (66.0)	*

TEST RESULTS

Two full-scale crash tests were conducted on the used car barrier as shown in Figure 1. The tests conducted were designed to evaluate the limits of performance of the barrier. Impact with small vehicles was not investigated since barrier performance is very similar to that of the thrie beam guardrail for small vehicle and low angle impacts. The impact point for both tests was upstream from the last joint between the barrier vehicles. This point of impact should cause maximum barrier deflection and give the greatest possibility of joint failure and vehicle snag on the barrier. The tests are summarized in Table 2. Sequential photos of the tests are given in Appendix A. Appendix B shows accelerometer traces and plots of roll, pitch, and yaw angles.

<u>Test 7*</u>

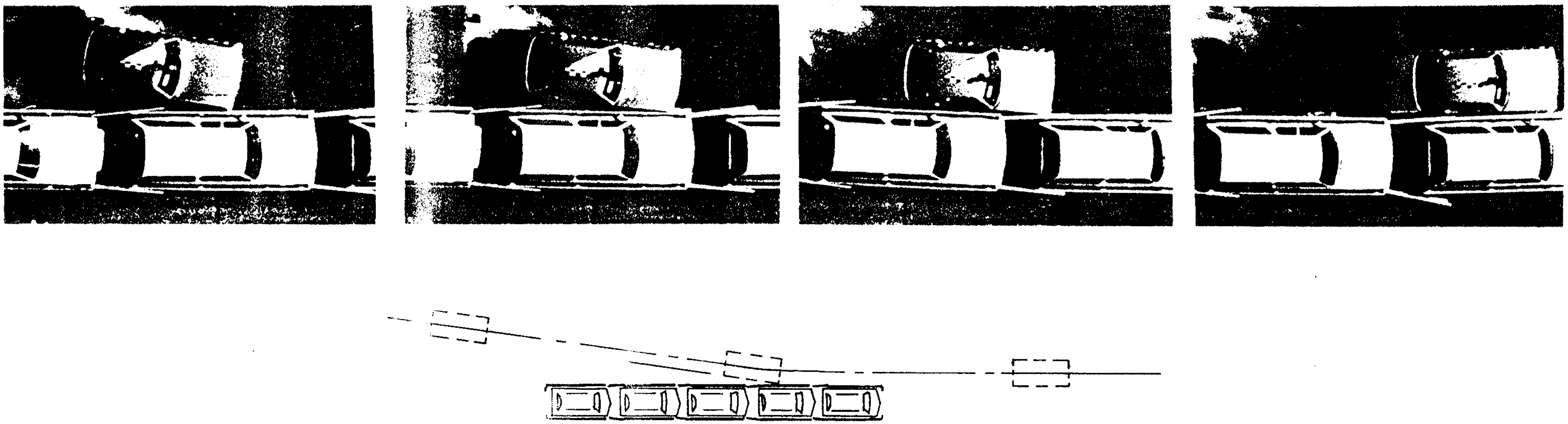
In the first test a 4500 lb (2043 kg) vehicle impacted at 51.7 mph (83.2 km/h) and 7 deg. Figure 8 contains a summary of this test. The test vehicle was smoothly redirected and exhibited no tendency to pocket or snag on the end treatment. As shown in Table 2, all occupant risk values and the vehicle trajectory hazard were well below recommended values (<u>2</u>).

Figures 9 and 10 show the test vehicle and barrier before and after test 7, respectively. As shown in Figure 10, test vehicle damage was limited to sheet metal deformations. The barrier sustained no visible damage and was driven from the test site. Barrier displacement was limited to 2 in. Test 1 was considered very successful due to the light test vehicle damage and negligible barrier damage.

*Tests 1 through 6 were conducted during previous research (see Research Reports 2262-1 and 2262-2) and were unrelated to the work reported herein.

TABLE 2. SUMMARY OF CRASH TESTS

Test	7	8
Impact Speed, mph (km/h)	51.7 (83.2)	48.3 (77.7)
Impact Angle, deg.	7	15
Exit Angle, deg.	2	2
Barrier Displacement, in. (cm)	2 (5.1)	8.4 (21.0)
Occupant Impact Velocity f/s (m/s)		
Longitudinal	10.9 (3.3)	12.1 (3.7)
Lateral	0	0
Occupant Ridedown Acceleration, g's		
Longitudinal	2.8	8.66
Lateral	0	0
Vehicle Damage Classification		
TAD	10RFQ1	10RFQ3
VDI	10RFMW1	10RFMW3



Test No.	2262-7
Date	11/25/82
Installation	
Drawing Nos.	2262-([illegible]1-6)
Length-ft(m)	1075 ([illegible]2.8)
Beam Rail	
Member	12 ga. thrie beam
Length of Segment ft(m)	21.5 (6.6)
Maximum Deflections	
Dynamic-in(cm)	7.2 ([illegible]8.0)
Permanent-in(cm)	2.0 (5.0)
Vehicle	
Model	1974 Plymouth Fury I
Mass-lb(kg)	4500 (2045)

Speed-mph (kph)	
Impact	51.7 (83.2)
Exit	49.3 (79.3)
Angle - deg	
Impact	7.0
Exit	0.0
Occupant Impact Velocity - fps(m/s)	
Forward	10.86 (3.3)
Lateral	N/A
Occupant Ridedown Accelerations - g's	
Forward	2.80
Lateral	N/A
Vehicle Damage	
TAD	10-RFQ-1
VDI	10RFMW1

Figure 8. Summary of Test 7.

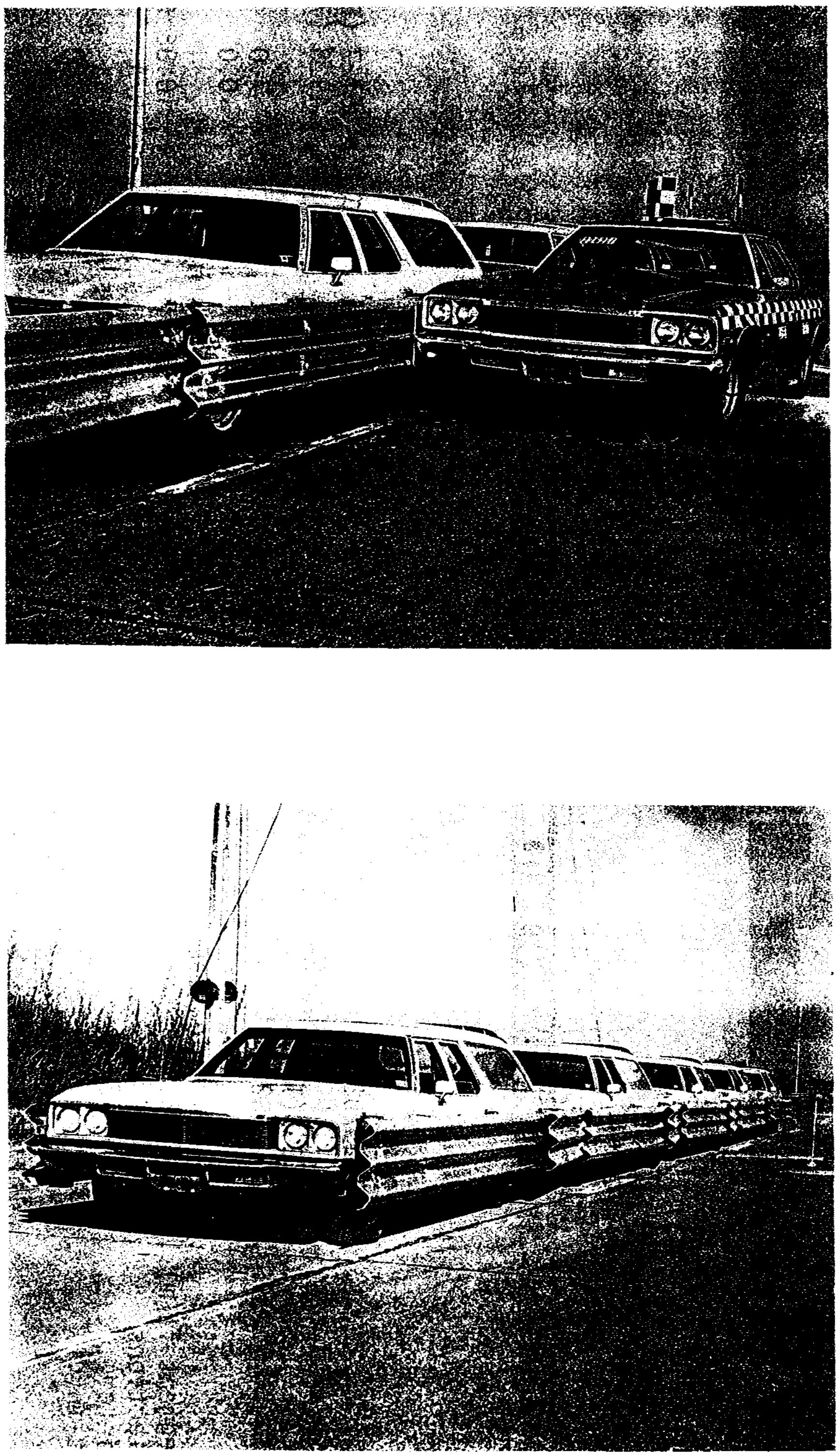


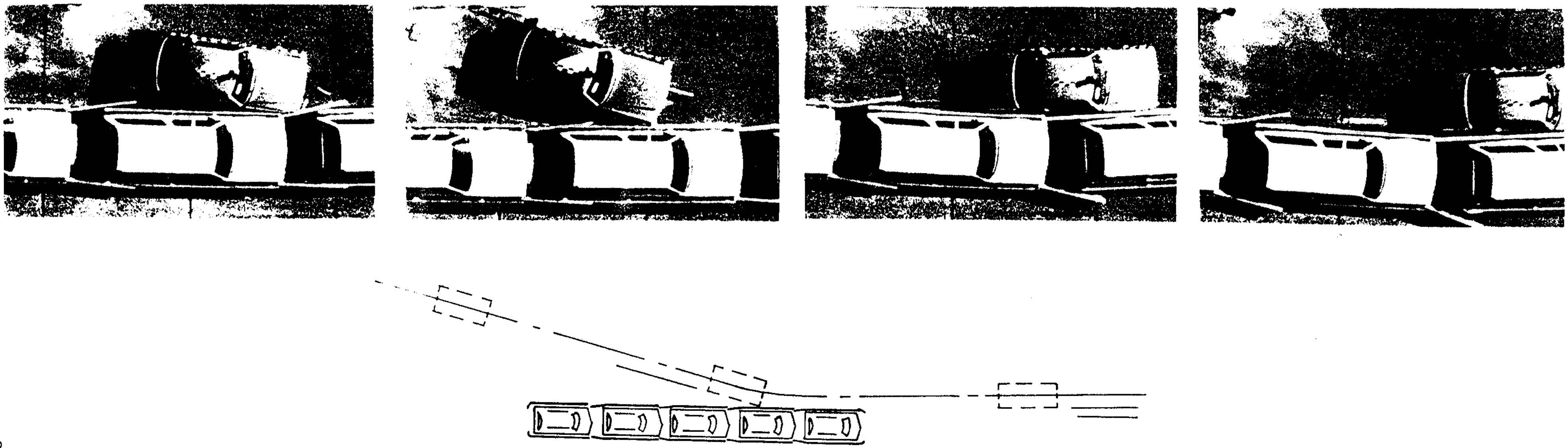
Figure 9. Test Vehicle and Barrier Before Test 7.

Figure 10. Test Vehicle and Barrier After Test 7.

Test 8

Test 8 involved impacting the barrier at 48.3 mph (77.7 km/h) and 15 deg. with a 4500 lb (2043 kg) vehicle. A summary of this test is shown in Figure 11. Since the vehicle damage from test 1 was very light, the same vehicle was used in test 2. The test vehicle was smoothly redirected and, as shown in Table 2, occupant risk values and the vehicle trajectory hazard were below recommended limits (2). Maximum barrier deflection was limited to 8.4 in.

The test vehicle, shown in Figure 12, was only lightly damaged. Barrier damage, shown in Figure 13, was limited to minor deformations in the thrie beam rail and the barrier vehicle sheet metal. The barrier was again driven from the test site, and no barrier repair was required. This test was also considered to be very successful.



Test No.	2262-8
Date	
Installation	
Drawing No.	2262-3(1-6)
Length-ft (m)	107.5 (32.8)
Beam Rail	
Member	12 ga. thrie beam
Length of Segment ft (m)	21.5 (6.6)
Maximum Deflections	
Dynamic-in(cm)	17.3 (43.3)
Permanent-in(cm)	8.4 (21.0)
Vehicle	
Model	1974 Plymouth Fury I
Mass-lb(kg)	4500 (2045)

Speed - mph (kph)	
Impact	48.3 (77.7)
Exit	43.5 (70.0)
Angle-deg.	
Impact	15.0
Exit	1.0
Occupant Impact Velocity - fps (m/s)	
Forward	12.05 (3.7)
Lateral	N/A
Occupant Ridedown Acceleration - g's	
Forward	8.66
Lateral	N/A
Vehicle Damage	
TAD	10-RFQ-3
VDI	10RFMW3

Figure 11. Summary of Test 8.

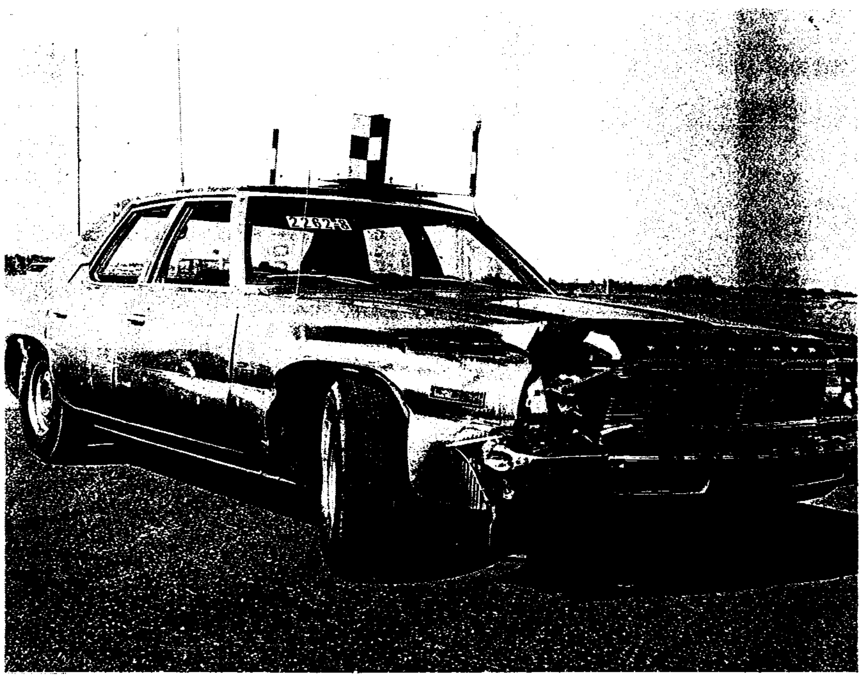


Figure 12. Test Vehicle After Test 8.

Figure 13. Used Car Barrier After Test 8.

SUMMARY AND CONCLUSIONS

The number of injuries and fatalities among Texas highway construction and maintenance personnel has increased significantly in recent years. Investigation of the problem revealed that much of this increase resulted from accidents at very short duration construction and maintenance zones and that the only practical solution was to employ positive barriers at these sites. There are currently no construction zone barriers which can be installed and removed quickly enough for use at very short duration construction sites. Therefore a truly portable positive construction zone barrier has been developed that is 1) portable enough for use in maintenance zones that are to be in place only a few hours; 2) crashworthy for use in construction zones; and 3) relatively inexpensive to construct and maintain.

The used car barrier consists of a line of used cars with thrie beam guardrail attached to each side. Telescoping tube members provide moment capacity in the joints and hinged thrie beam gates provide a smooth redirecting surface between barrier vehicles. The leading vehicle is maintained operational and can be used to tow the barrier.

The barrier was successfully crash tested with a 4500 lb (2043 kg) vehicle at an impact speed of 48.3 mph (77.7 km/h) at an angle of 15 deg. Barrier deflection for this test was 8.4 in. (21 cm). Computer simulation of an impact at 60 mph (96.6 km/h) and 25 deg. with a 4500 lb (2043 km/h) vehicle predicted only 26 in. of barrier deflection.

The used car barrier was constructed for testing at a cost of approximately $70 per foot of barrier. No barrier repairs were required subsequent to the two crash tests conducted. Therefore the barrier should be both inexpensive to construct and maintain. The barrier can be placed on either a tangent or in a transition zone as shown in Figures 14 and 15. Note that Figure 14 contains photos of the barrier in use on Houston freeways. The barrier was test deployed upon completion of the study and has performed well according to Texas SDHPT engineers. However, a minor difficulty with the hinged thrie beam gates has arisen. During transport and impact of the barrier, the hinged gates swing open and endanger traffic or workers standing behind the barrier. This problem can easily be solved with thin steel rods bent into a U-shape which could be slipped over the gate and the thrie beam rail on the forward car, thereby restraining the gate from moving laterally.

The used car barrier can be used to protect highway construction and maintenance personnel at work sites where conventional positive construction zone barriers are impractical. This barrier can be set up and removed quickly enough to allow its use when maintenance is to be started and completed within a few hours. The used car barrier should therefore reduce injury and fatality rates among highway construction and maintenance personnel.

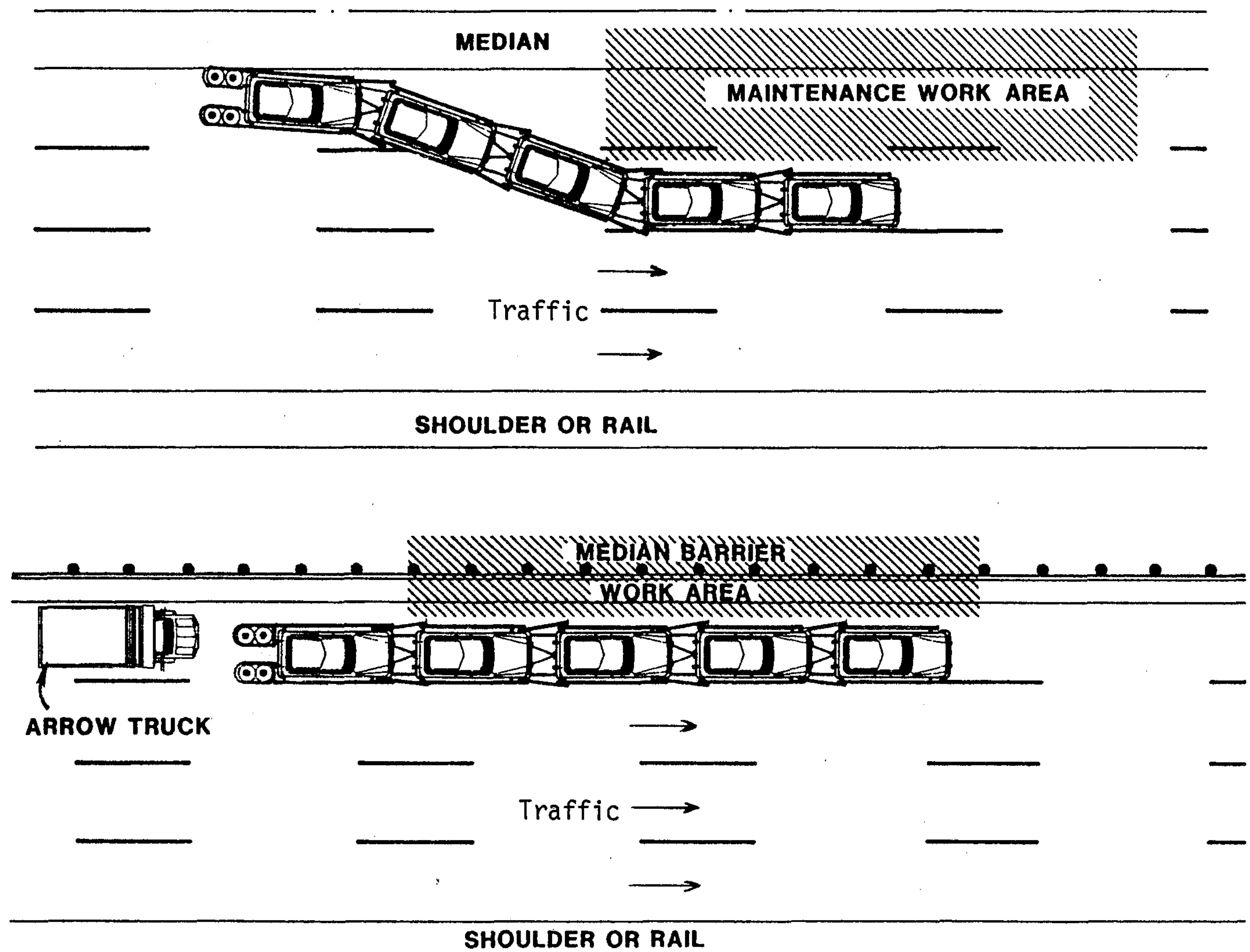
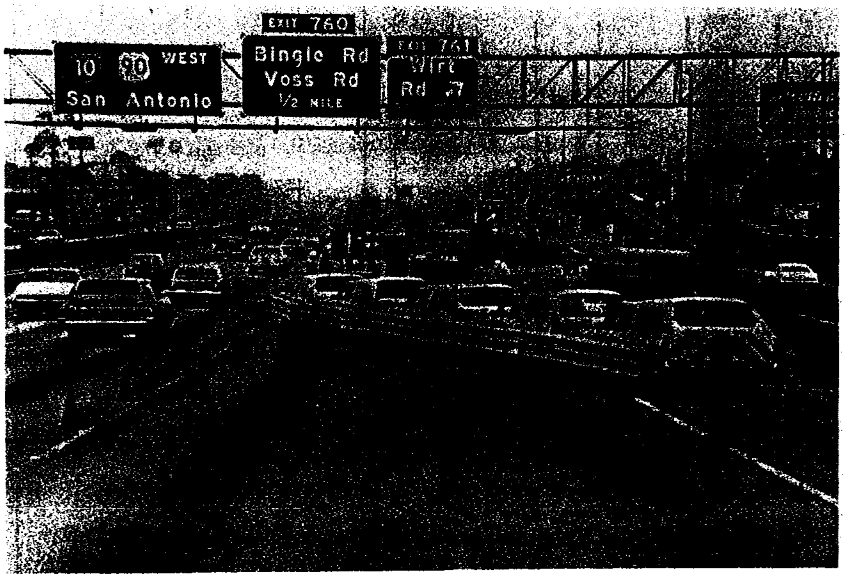


Figure 15. Applications of Used Car Barrier.



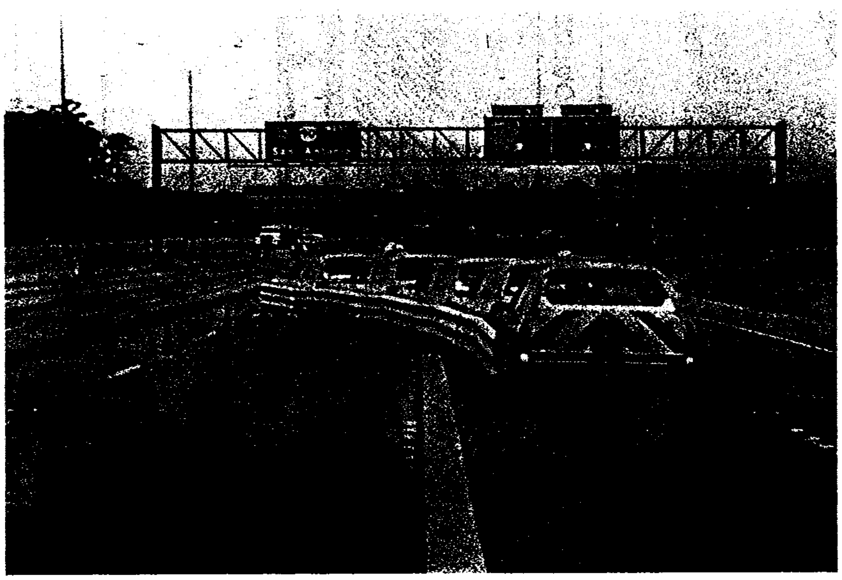


Figure 14. Used Car Barrier in Use at Maintenance Site.

APPENDIX A.

SEQUENTIAL PHOTOGRAPHS

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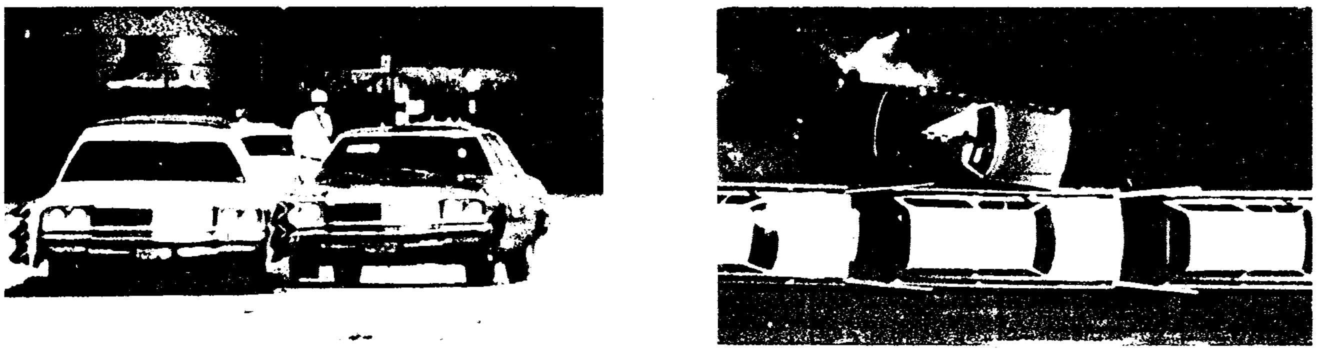

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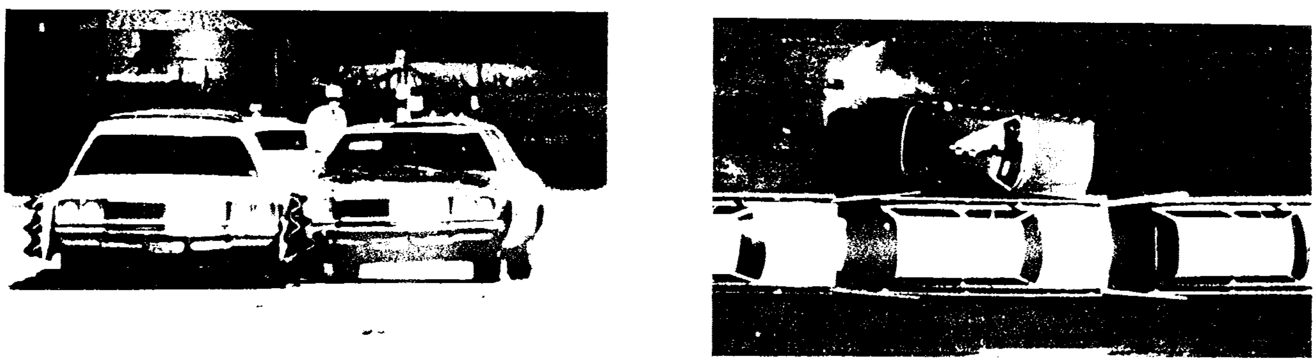

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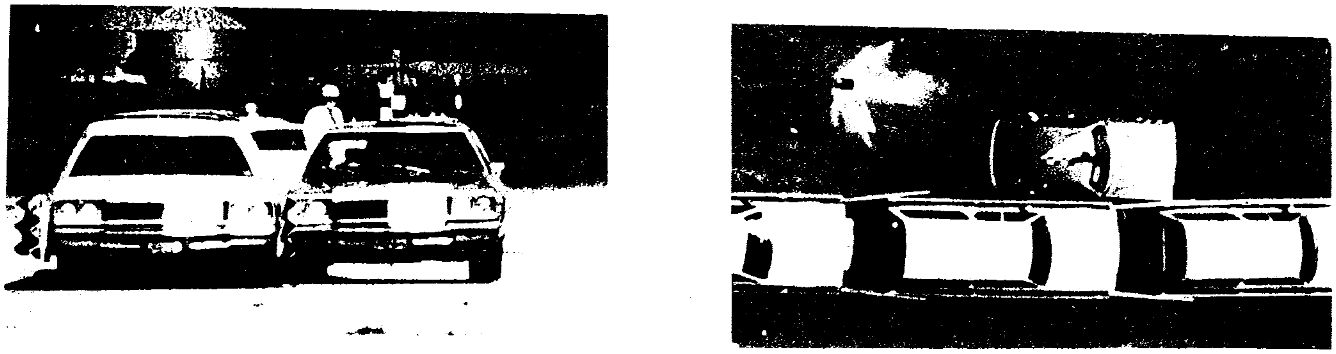
Figure 16. Sequential Photographs for Test 7.



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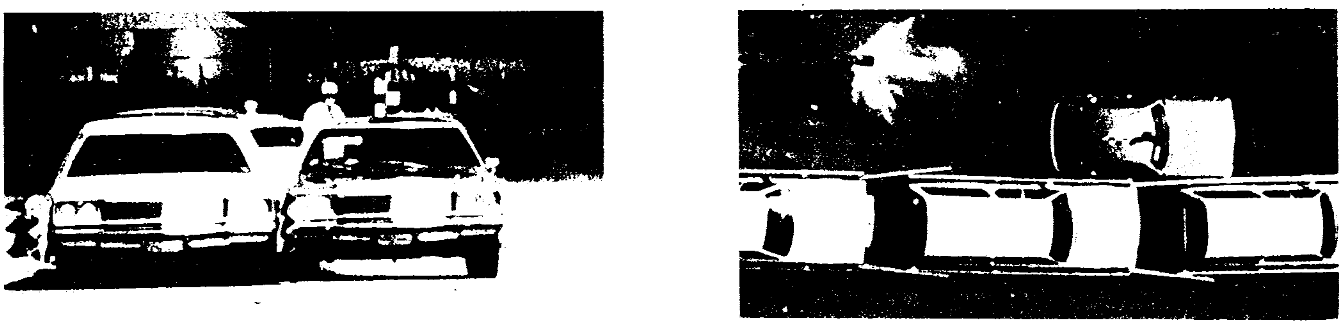

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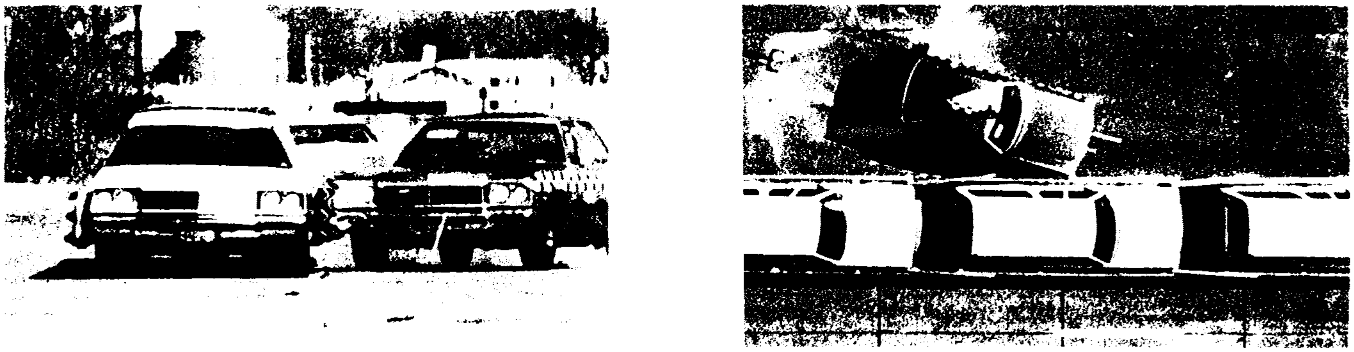
Figure 16. Sequential Photographs for Test 7 (continued).



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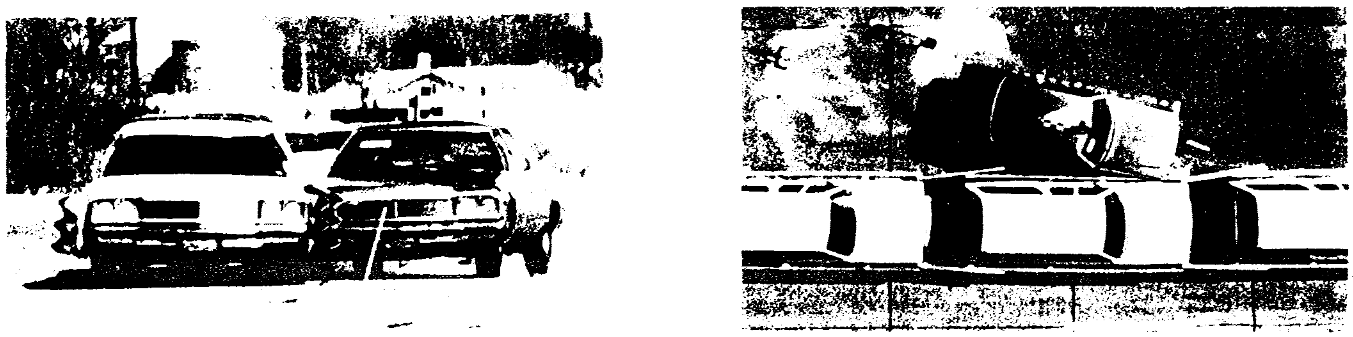

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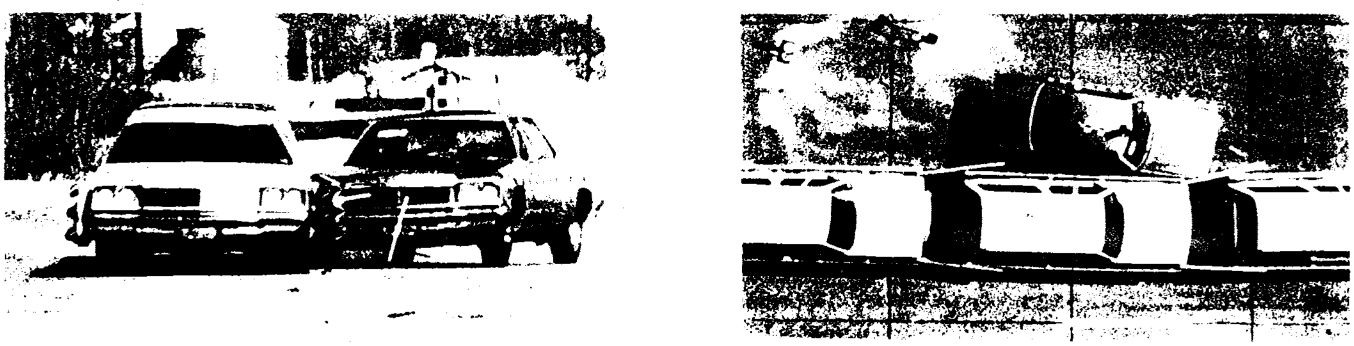

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Figure 17. Sequential Photographs for Test 8.

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Figure 17. Sequential Photographs for Test 8 (continued).

APPENDIX B.

ACCELEROMETER TRACES
AND
PLOTS OF ROLL, PITCH, AND YAW RATES

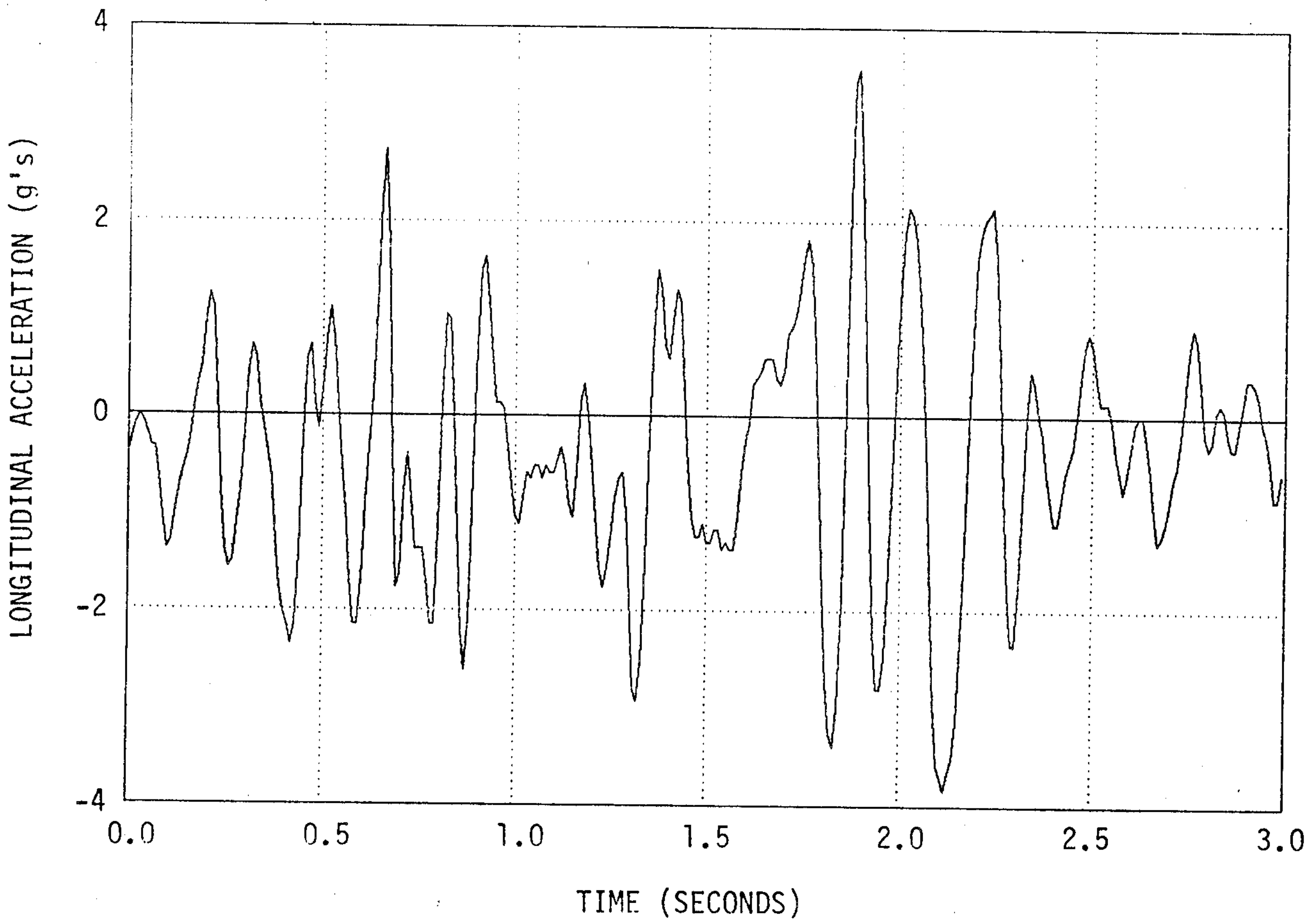

Figure 18. Vehicle Longitudinal Acceleration for Test 7.

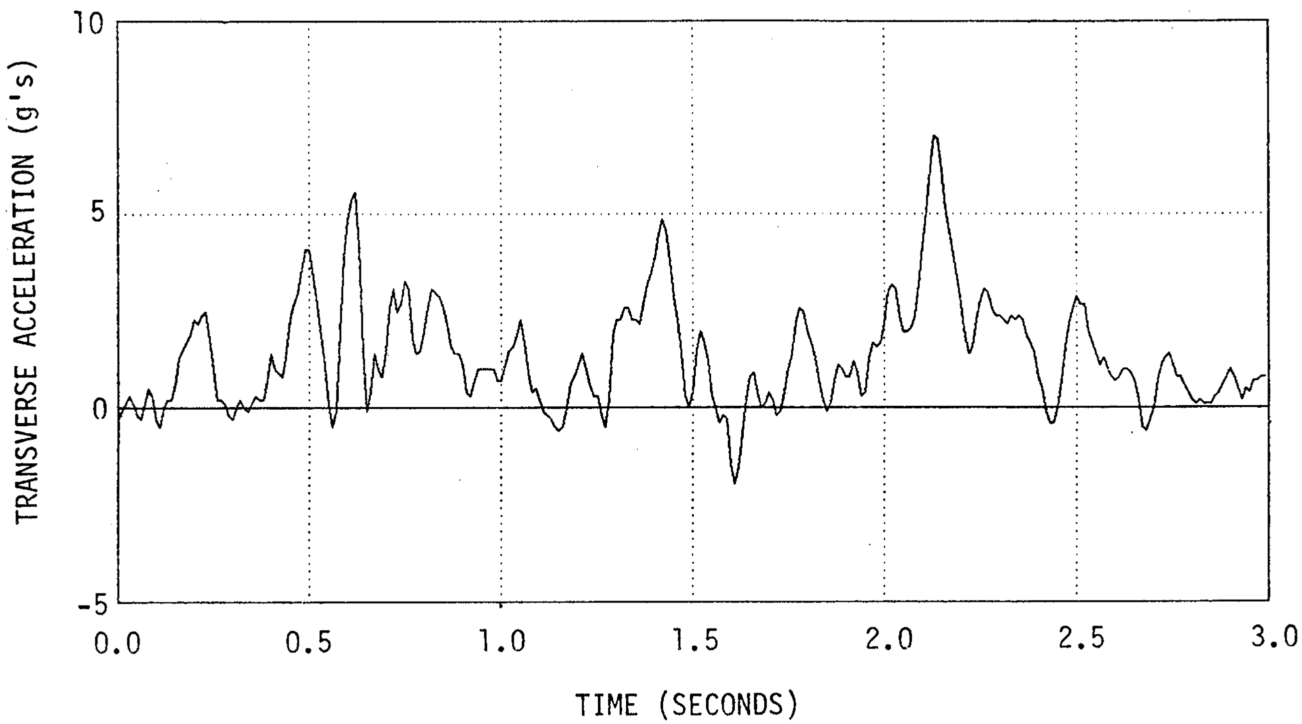

Figure 19. Vehicle Transverse Acceleration for Test 7.

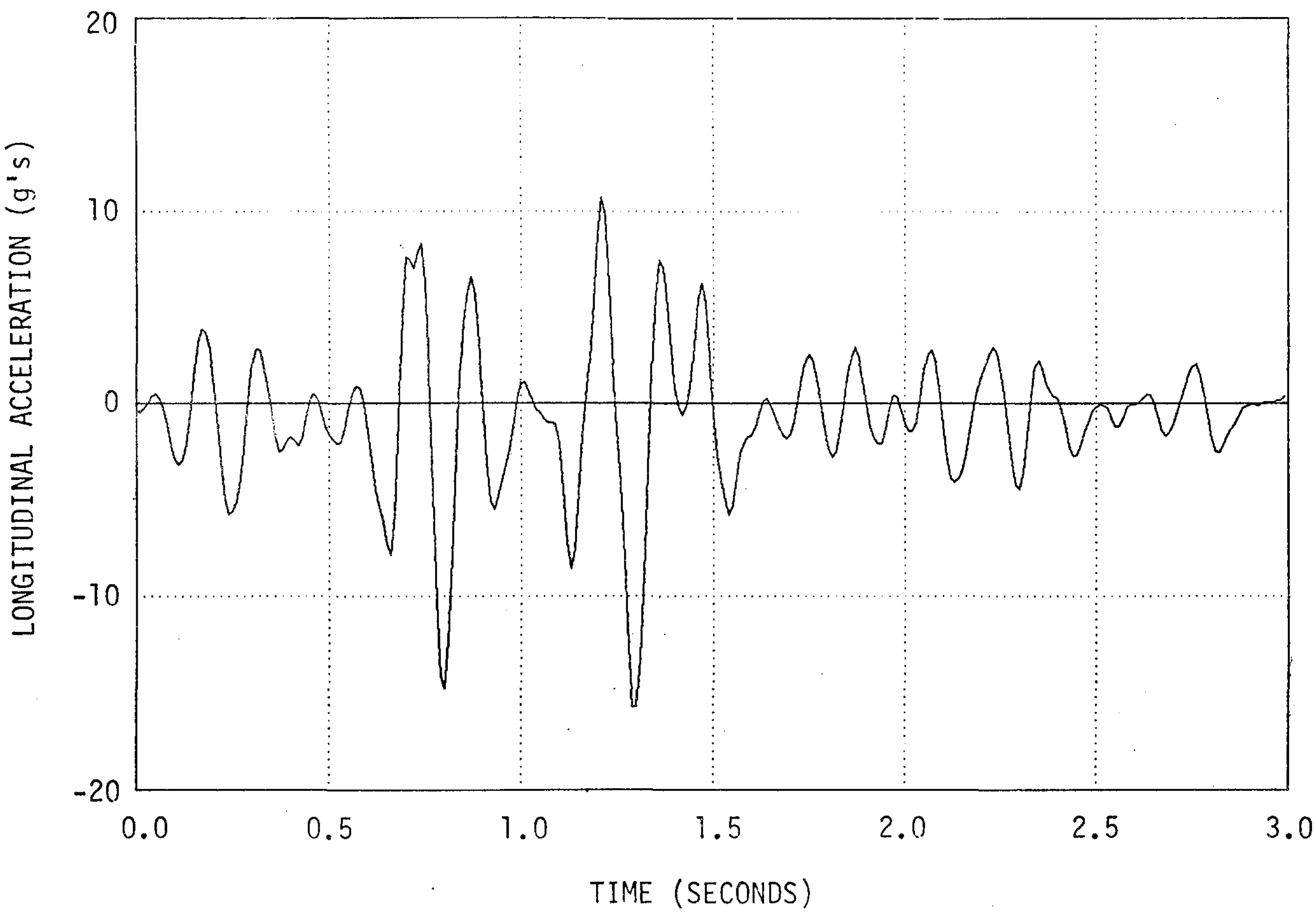

Figure 20. Vehicle Longitudinal Acceleration for Test 8.

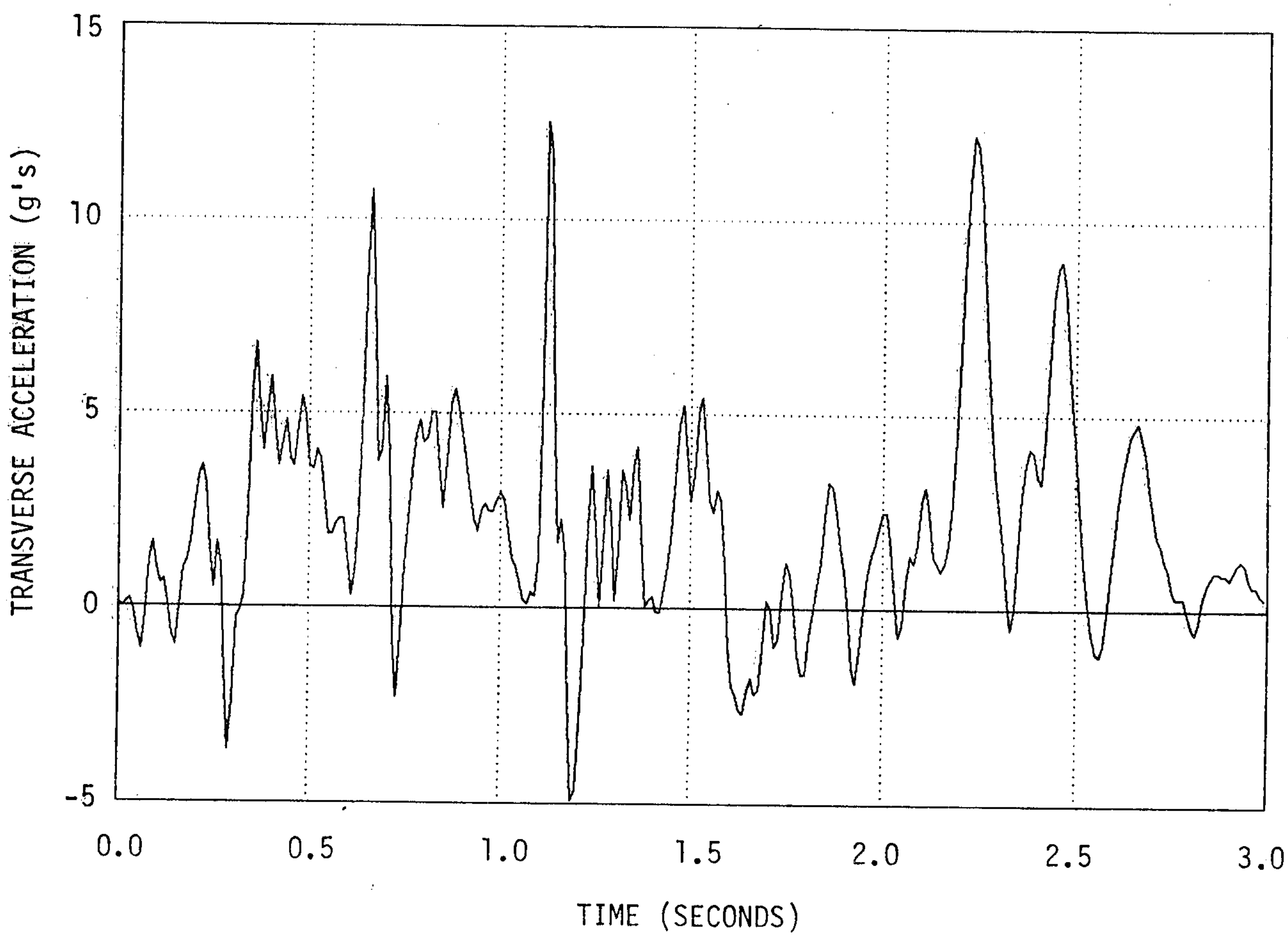

Figure 21. Vehicle Transverse Acceleration for Test 8.

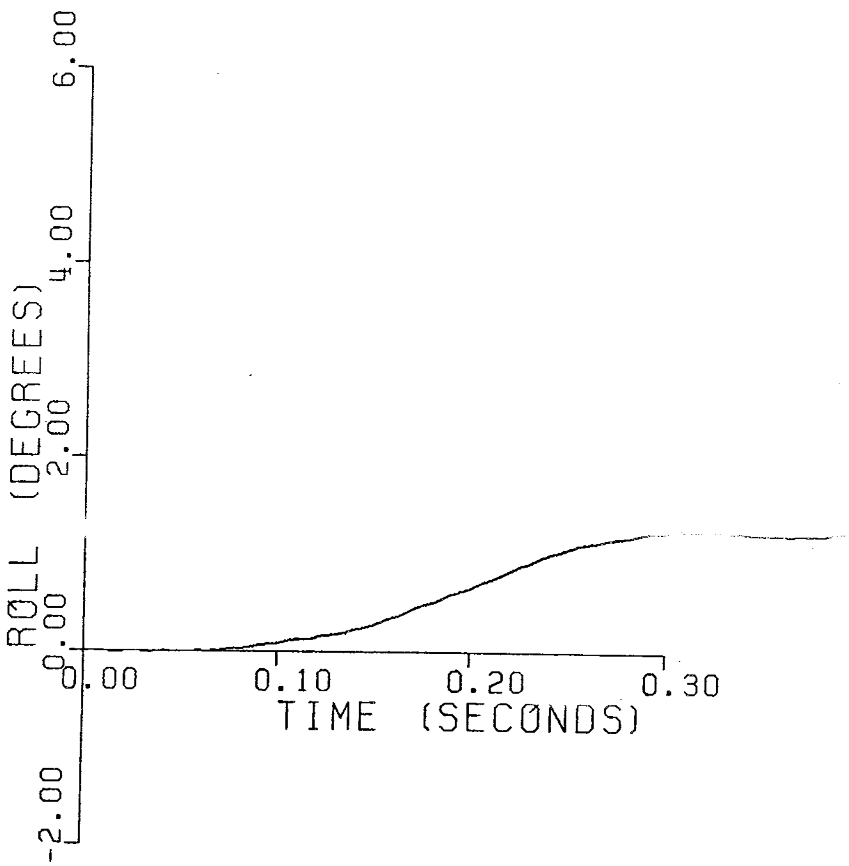

Figure 22. Vehicle Roll Angle For Test 7.

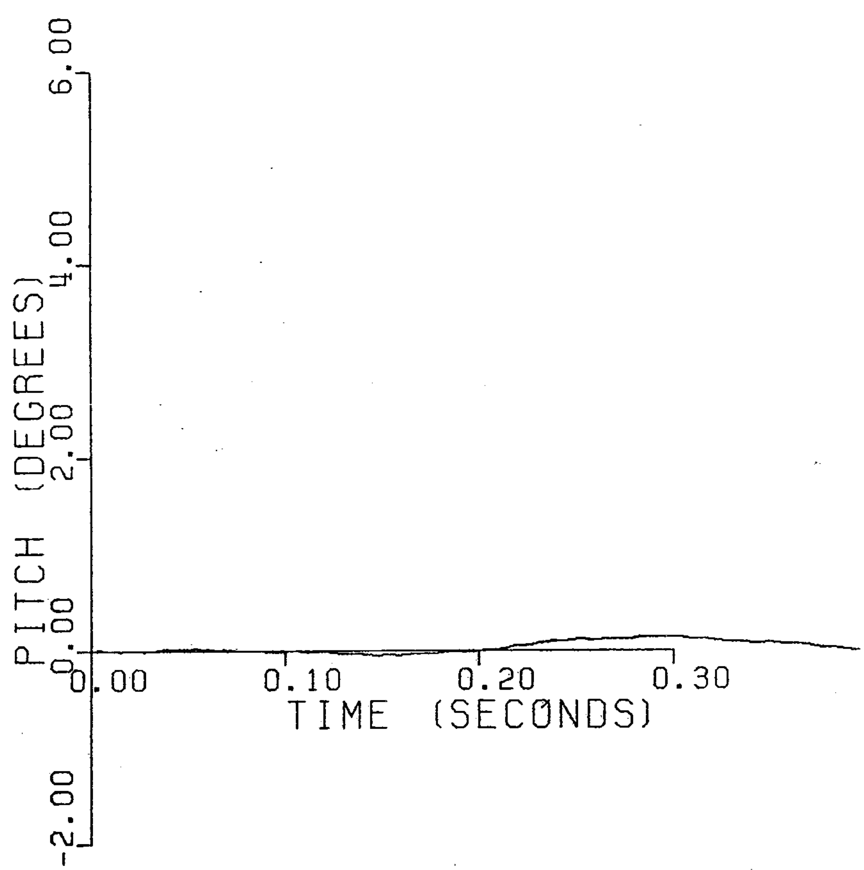

Figure 23. Vehicle Pitch Angle For Test 7.

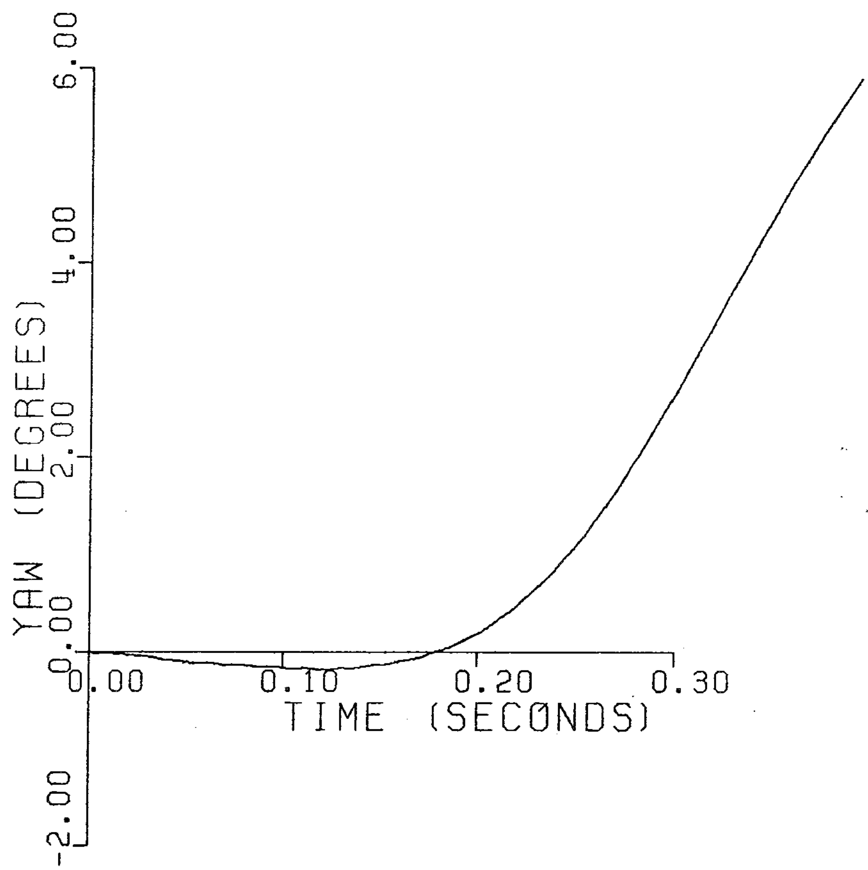

Figure 24. Vehicle Yaw Angle For Test 7.

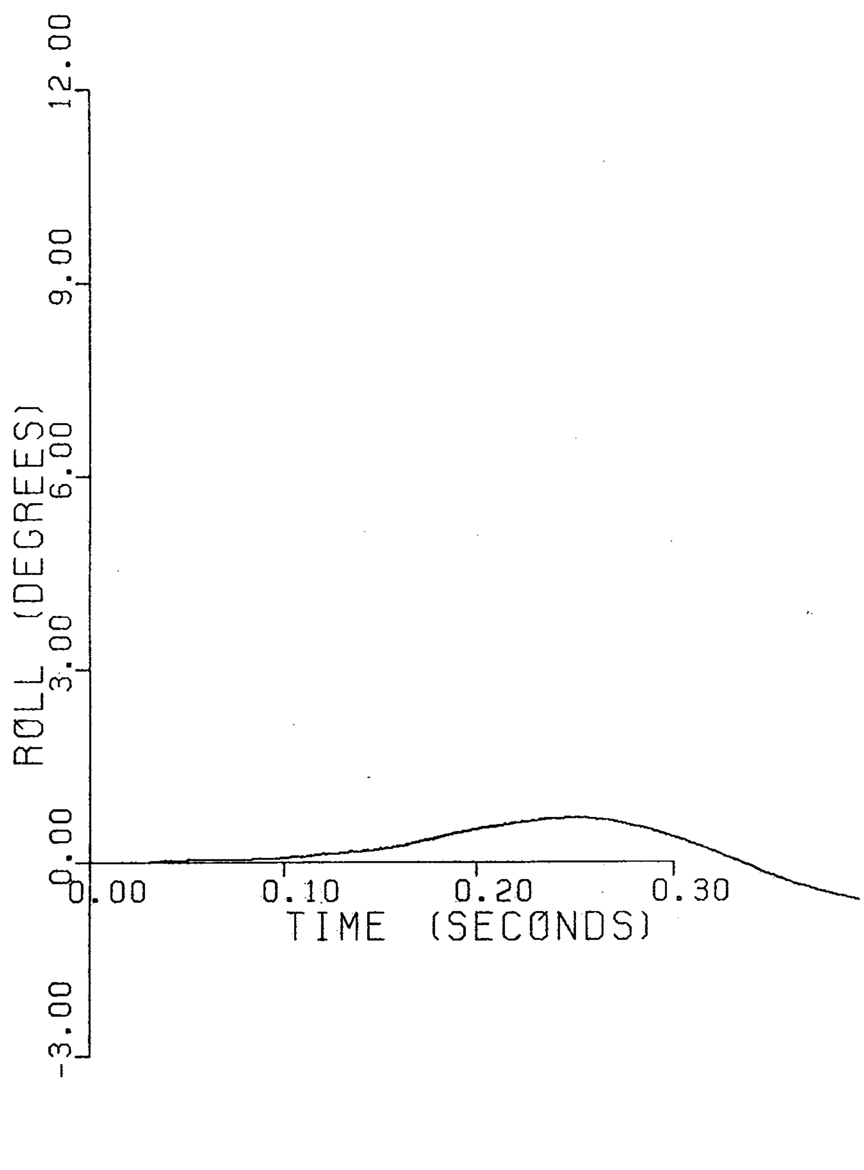

Figure 25. Vehicle Roll Angle For Test 8.

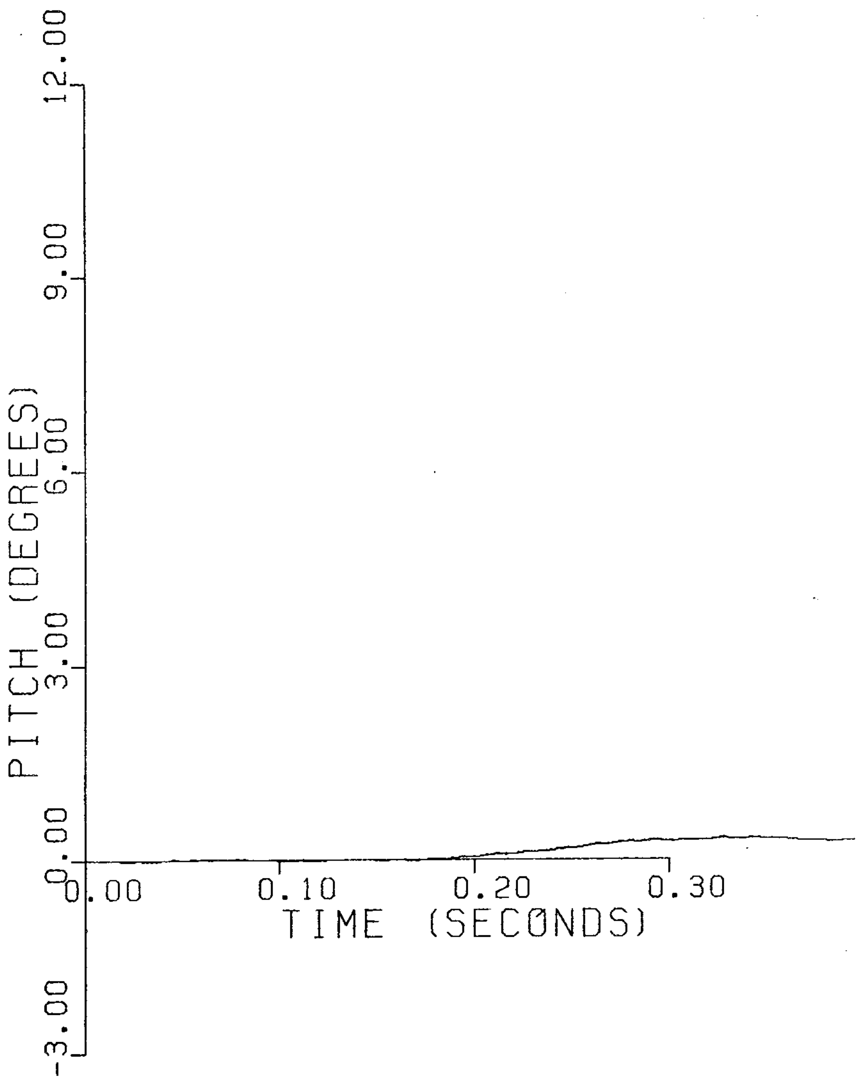

Figure 26. Vehicle Pitch Angle For Test 8.

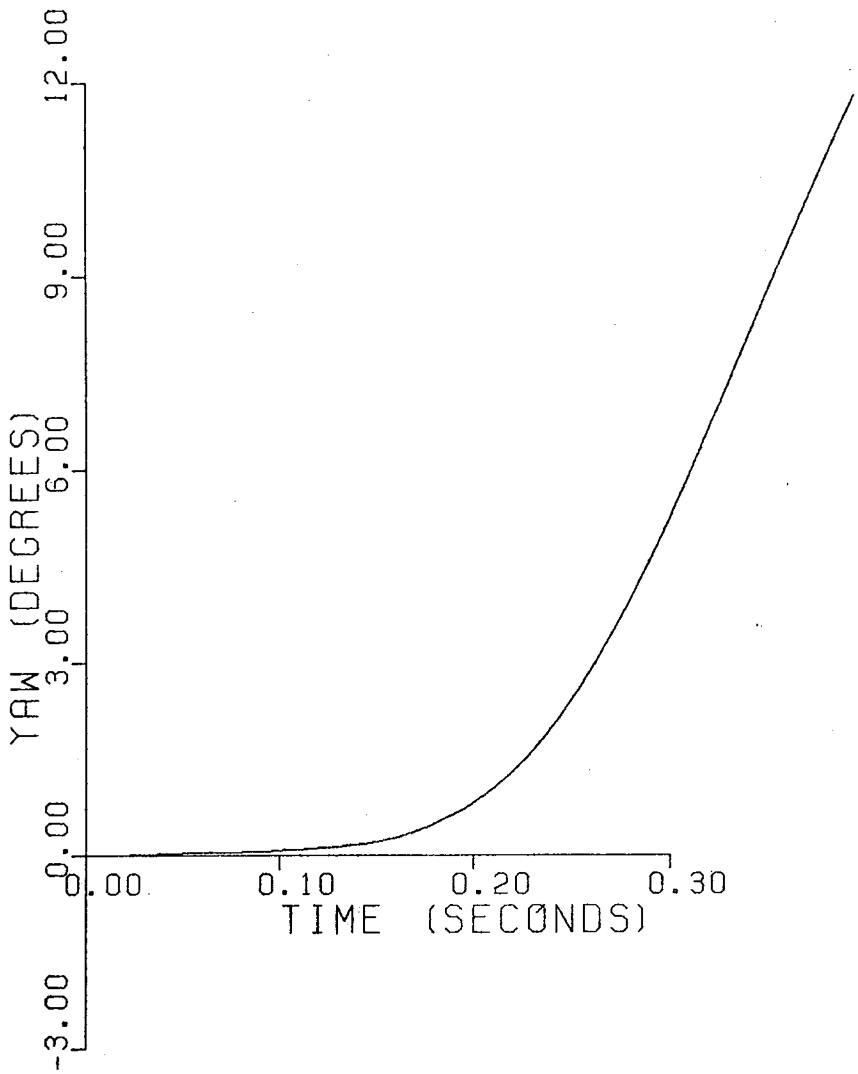

Figure 27. Vehicle Yaw Angle For Test 8.

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