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The results of four vehicle impact tests into metal beam guardrail using three types of posts and blocks are reported. The then current (1971) California Standard Plans for metal beam guardrail required 8" x 8" (203 x 203 mm) (nominal) D.F. posts and blocks. It was desired to determine whether (1) smaller sized wood posts and blocks could be used and (2) whether steel posts and blocks could be used in place of
8x8's in order to reduce guardrail costs and to obtain another permissible post material beside wood. It was concluded that 6" x 8" (152 x 203 mm) (nominal) D.F. wood posts and blocks were an acceptable substitute. Also W 6 x 8.5 (152 mm x 12.65 kgf/m) steel posts and blocks could be used provided W-section backup plates were used at alternate posts where no beam splice occurred and a positive connection was used at the end anchor cable in place of cable clips. All four tests were conducted using 4960 lb. (2260 kgf) passenger vehicles with nominal impact speeds and angles of 65 mph (105 km/hr) and 25 degrees respectively.

The California Standard Plans and Specifications have been revised to incorporate all the findings of this study.

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HIGHWAY RESEARCH REPORT

DYNAMIC TESTS OF METAL BEAM GUARDRAIL SERIES XXVII

INTERIM REPORT

74-14

STATE OF CALIFORNIA

BUSINESS AND TRANSPORTATION AGENCY

DEPARTMENT OF TRANSPORTATION

DIVISION OF HIGHWAYS

TRANSPORTATION LABORATORY

RESEARCH REPORT

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DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
TRANSPORTATION LABORATORY
5900 FOLSOM BLVD., SACRAMENTO 95819

April, 1974
Trans Lab 636392-5
Item D-4-37

Mr. R. J. Datel
State Highway Engineer

Dear Sir:

Submitted herewith is an interim research report titled:

DYNAMIC TESTS

OF

METAL BEAM GUARDRAIL

SERIES XXVII

Principal Investigators
J. R. Stoker, P. E. and R. L. Stoughton, P. E.

Under the Supervision Of
Eric F. Nordlin, P.E.

Very truly yours,

JOHN L. BEATON
Chief, Transportation Laboratory

Attachment

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This work was accomplished in cooperation with the United States Department of Transportation, Federal Highway Administration, as Item D-4-37 of Work Program HPR-PR-1(10) Part 2, Research, and was titled, "Dynamic Full Scale Impact Tests on Rails and Barriers". The contents of this report reflect the views of the Transportation Laboratory which is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation. It should also be recognized that the opinions, findings, and conclusions expressed in this publication are not necessarily those of the Federal Highway Administration.

Appreciation is due the following staff members of the Transportation Laboratory who were instrumental in the successful completion of the tests reported herein:

Lee Staus Orvis Box	In charge of: barrier construction, preparation and operation of the test vehicle and other test equipment, and maintenance of test records and project paperwork.
Vince Martin James Keesling Bill Crozier Doug Parks Roger Pelkey	Assistance with: tests and barrier construction, data reduction, and preparation of report.
Robert Mortensen Lewis Green	Data and documentary photography
Richard Johnson Stanley Law Delmar Gans	Instrumentation of test barrier, vehicle and dummies.

Special appreciation is also due W. R. Juergens and E. J. Tye of the California Division of Highways Traffic Branch who served as consultants on this project.

I. INTRODUCTION

In 1964 the California Division of Highways performed a series of full-scale impact tests on Metal Beam Guardrail. Those tests[1]* resulted in the adoption of the current standard design which features a 12 ga. (2.66 mm) W-section steel beam mounted on 8" x 8" (203 x 203 mm) D.F. wood posts and blockout blocks that are spaced 6'-3" (1.9 m) on center. Top of rail height is 27 inches (685 mm). Later tests between 1965 and 1968 on short sections of guardrail[2] established the need for a positive anchor at the ends of guardrail installations. These anchors are now also part of the current standard guardrail design. Operational experience has proven this barrier effective in California. Tests conducted in 1968 and 1969 by the Southwest Research Institute[3] corroborated our test results. California's Metal Beam Guardrail design might be considered a national standard by virtue of its inclusion in NCHRP Report 118[4] which contains a group of recommended highway safety barrier designs. The standard design using 8" x 8" (203 x 203 mm) wood posts and blocks is shown in Figure 1.

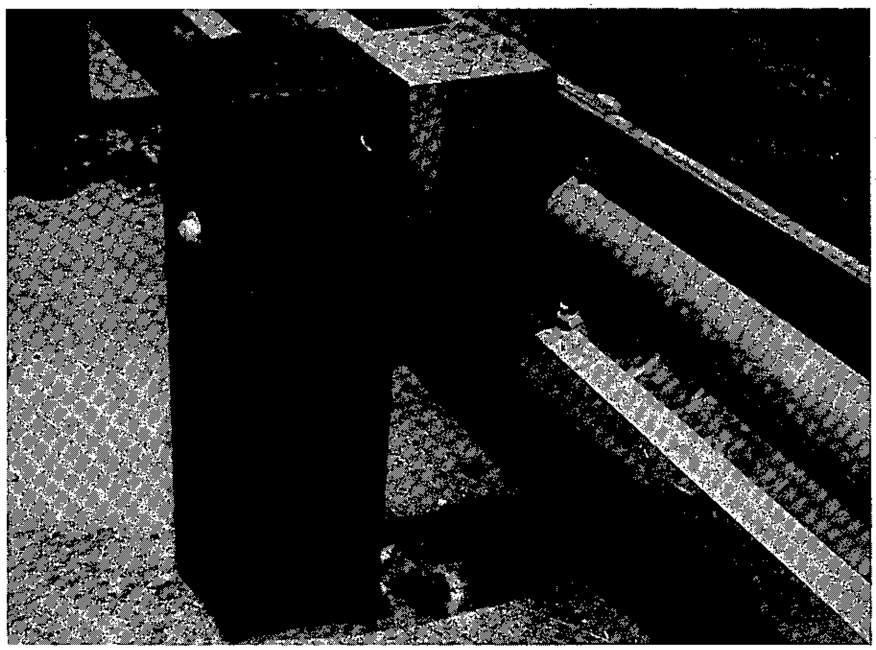

Figure 1, Standard Metal Beam Guardrail With 8" x 8" D.F. Wood Posts and Blocks

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*Numbers in brackets refer to a Reference list at the end of this report.

In 1971 consideration was given to changes in California's standard guardrail design which would decrease costs without impairing the effectiveness of the barrier. There was interest in the substitution of 6" x 8" (152 x 203 mm) D.F. wood posts and blocks due to their successful use by several other states and the substantial savings possible. It was also felt that a guardrail design using steel posts should be tested as this design is being used by other states. Previous studies had indicated that steel posts might not be economically competitive. It was felt, however, that if they proved successful, they should be permitted as an alternative to wood posts as a possible stimulus to competitive bidding. These designs are shown in Figures 2, 3 and 4.

Figure 2, Metal Beam Guardrail with 6" x 8" D.F. Wood Posts and Blocks

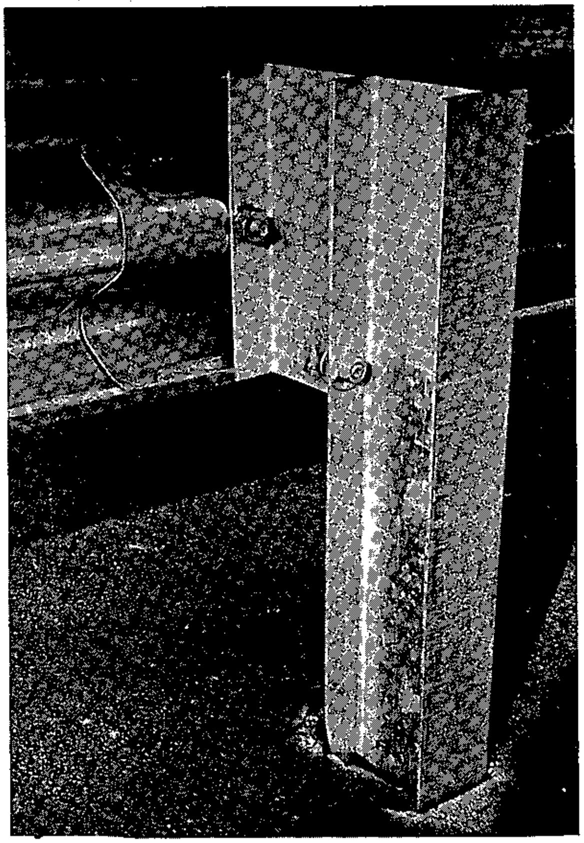


Figure 3

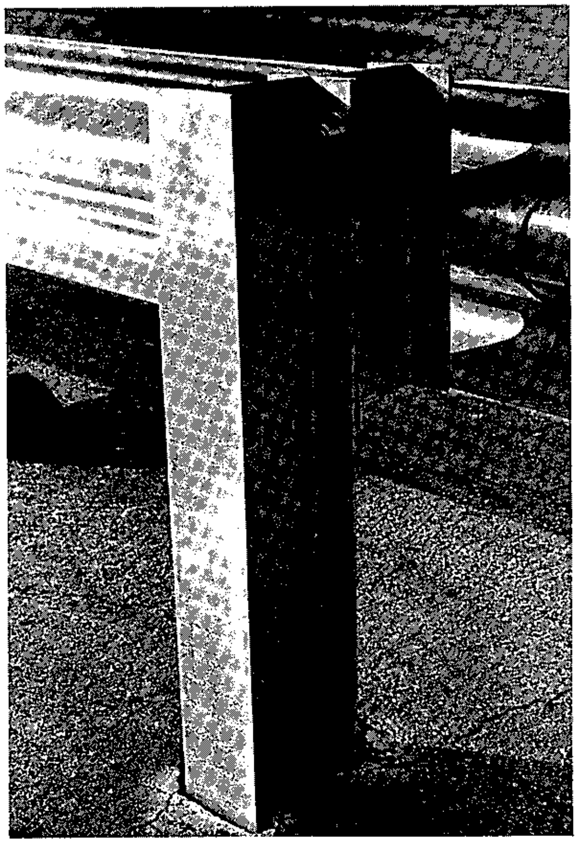


Figure 4

Metal Beam Guardrail with W6x8.5 Steel
Posts and Blocks

Tests conducted by the Southwest Research Institute on a guardrail design using W6 x 8.5 (152 mm x 12.65 kgf/m* steel posts [3] had been successful. Surprisingly, the long time economic advantage enjoyed by producers of wood posts evaporated during 1972 after the test series had begun. Costs of the wood posts increased by as much as 50%, and wood of satisfactory quality to make the posts became increasingly scarce. This turn of events made the test series most timely.

This report describes the results of four full scale dynamic impact tests on guardrail test barriers which incorporated either 8" x 8" (203 x 203 mm) and 6" x 8" (152 x 203 mm) wood posts and blocks or W6 x 8.5 (152 mm x 12.65 kgf/m) steel posts and blocks. Although tests by other agencies and operational experience by others indicated that all three types of posts would perform satisfactorily,

---

*kgf = kilogram-force; 1 kgf = 2.2 lbs.

these additional comparative tests were deemed necessary for three main reasons: 1) Barriers with either 6" x 8" (152 x 203 mm) wood posts and blocks or W6 x 8.5 (152 mm x 12.65 kgf/m) steel posts had never been tested under the more severe conditions considered representative of California freeways and thus typically used in California barrier tests: 4900± lb (2230 kgf) vehicle, 65 mph (105 km/hr) impact velocity, and 25° angle of impact. 2) The barriers with the three types of posts had never been compared under identical conditions. 3) In addition, good accelerometer data had not been obtained in previous California guardrail tests. The reliable instrumentation package developed in recent years thus could be used as another means to compare guardrail test barriers using the three types of post.

II. CONCLUSIONS AND IMPLEMENTATION

A. Conclusions

1. Metal beam guardrail using 6" x 8" (152 x 203 mm) D.F. wood posts and blocks, in place of the 8" x 8" (203 x 203 mm) D.F. wood posts and blocks specified in the 1971 California Standard Plans and Specifications, effectively redirected a 4960 lb (2260 kgf) vehicle impacting at a speed of 68 mph (109 km/hr) and an angle with the barrier of 24°.

2. Metal beam guardrail using W6 x 8.5 (152 mm x 12.65 kgf/m) steel posts and blocks, in place of the 8" x 8" (203 x 203 mm) D.F. wood posts and blocks specified in the 1971 California Standard Plans and Specifications, effectively redirected a 4960 lb (2260 kgf) vehicle impacting at a speed of 66 mph (106 km/hr) and an angle with the barrier of 25°. However, the following two modifications of the standard wood post design were necessary:

    a. A 1'-0" (0.305 m) long 12 ga. (2.66 mm) W-section "backup" plate was placed between the beam and block at alternate posts where beam splices did not occur.

    b. The cable clips at the standard end anchor connection were replaced with a swaged fitting and clevis resulting in a positive cable connection.

3. The barriers using either the 6" x 8" (152 x 203 mm) wood posts and blocks or the W6 x 8.5 (152 mm x 12.65 kgf/m) steel posts and blocks (as modified in Test 276) were as effective as the 1971 standard design using 8" x 8" (203 x 203 mm) D. F. wood posts and blocks which was also tested using a 4960 lb (2260 kgf) vehicle impacting at 66 mph (106 km/hr) and an angle with the barrier of 26°.

B. Implementation

The California Standard Plans and Specifications have been revised to permit the use of either 6" x 8" (152 x 203 mm) D.F. wood posts and blocks or W6 x 8.5 (152 mm x 12.65 kgf/m) steel posts and blocks, with the barrier modifications mentioned in conclusions 2a and 2b, in place of 8" x 8" (203 x 203 mm) D.F. wood posts and blocks for metal beam guardrail. Revised Standard Plans are shown in the Appendix as Figures 21A-24A.

III. TECHNICAL DISCUSSION

A. Test Conditions

1. Barrier Design and Construction

The basic objective of this series of tests was to compare the performance of guardrail test barriers which were identical except for the type of post and block-out block used. Test 272 was a control test on a guardrail design and end anchor identical to those detailed in the 1971 edition of the California Standard Plans, shown in Figure 5.

In Test 273, 6" x 8" (152 x 203 mm) wood posts and blocks were used in place of the standard 8" x 8" (203 x 203 mm) wood posts and blocks. There were no other changes in the barrier details.

In Test 274, W6 x 8.5 (152 mm x 12.65 kgf/m) steel blocks 1'-2" (0.356m) in length were used in place of the standard 8" x 8" (203 x 203 mm) wood posts and blocks. Barrier details were the same as those shown for the G4S system in NCHRP Report 118[4] Figure 6. Cable anchorage details were identical to those used in Test 272, Figure 5.

The test barrier for Test 276 was the same as that for 274 except that 1) 1'-0" long (0.305m) 12 ga (2.66 mm) steel W-section backup plates were placed between the beam and block at alternate posts where no beam splice occurred and 2) the end of the anchor cable detail was changed from five cable clips to a swaged fitting. These changes were made to strengthen the resistance of the barrier to penetration by an impacting vehicle.

Each test barrier was built approximately one and a half feet (0.457m) in front of the previous barrier tested with posts staggered midway between the post location of the previous barrier. This procedure ensured that 1) soil conditions would be nearly identical for all test barriers, 2) posts for each barrier would be placed in undisturbed soil, 3) post resistance in the soil would not be affected by post holes from previous barriers which were staggered out of the way, 4) the test vehicle was able to use the same approach guide line for all tests, and 5) only one camera tower location was needed for this series of tests.

Wood posts were installed in accordance with common practice in California. The 8" x 8" (203 x 203 mm) posts were driven into nine inch (228 mm) diameter predrilled holes. Figures 7, 8, and 9 show the machine which performed both operations. The auger could be swiveled out of the way while the post was being driven. The operator's remote truck controls along with versatile equipment controls permitted him to obtain good post alignment, quickly

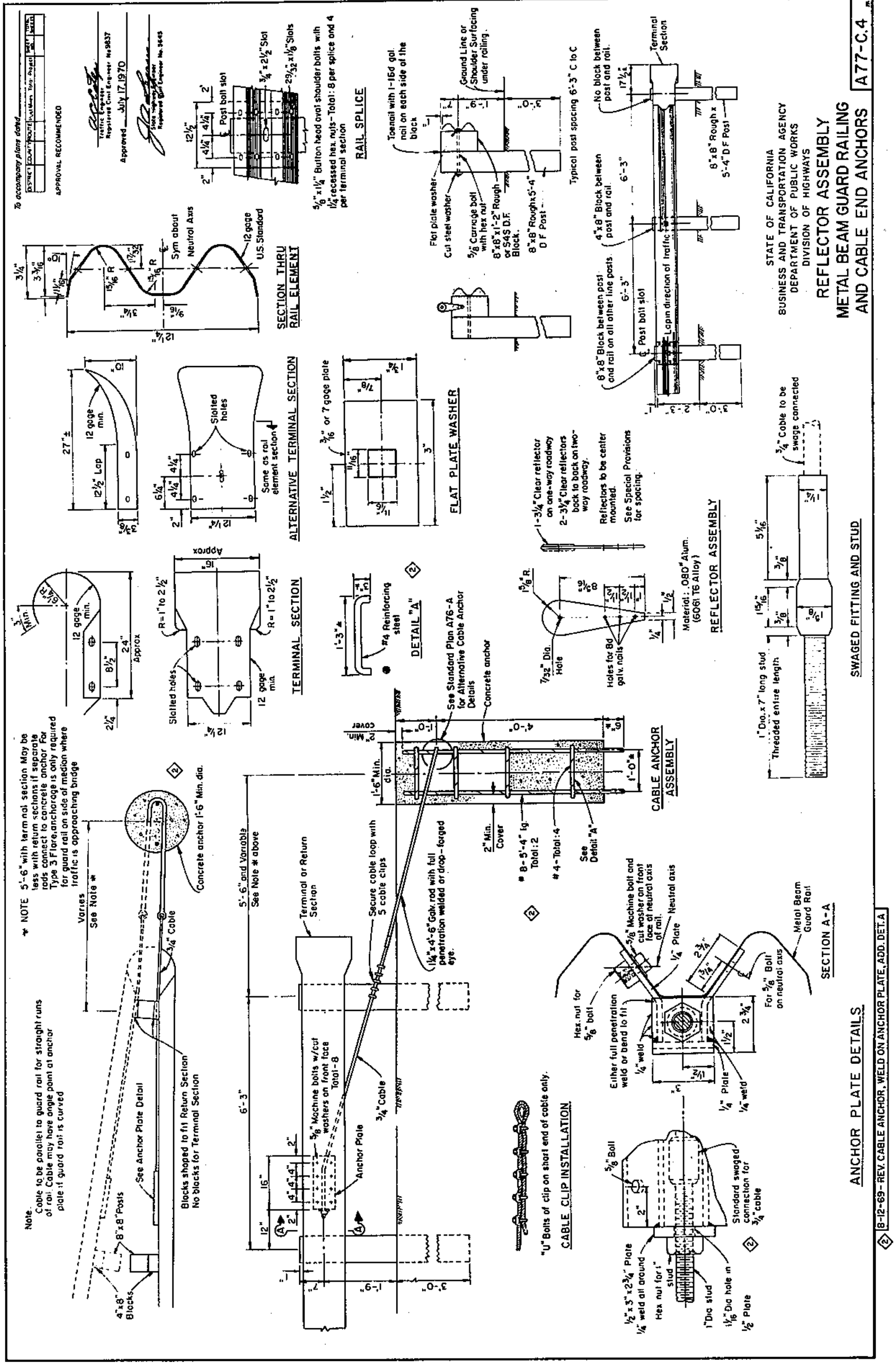
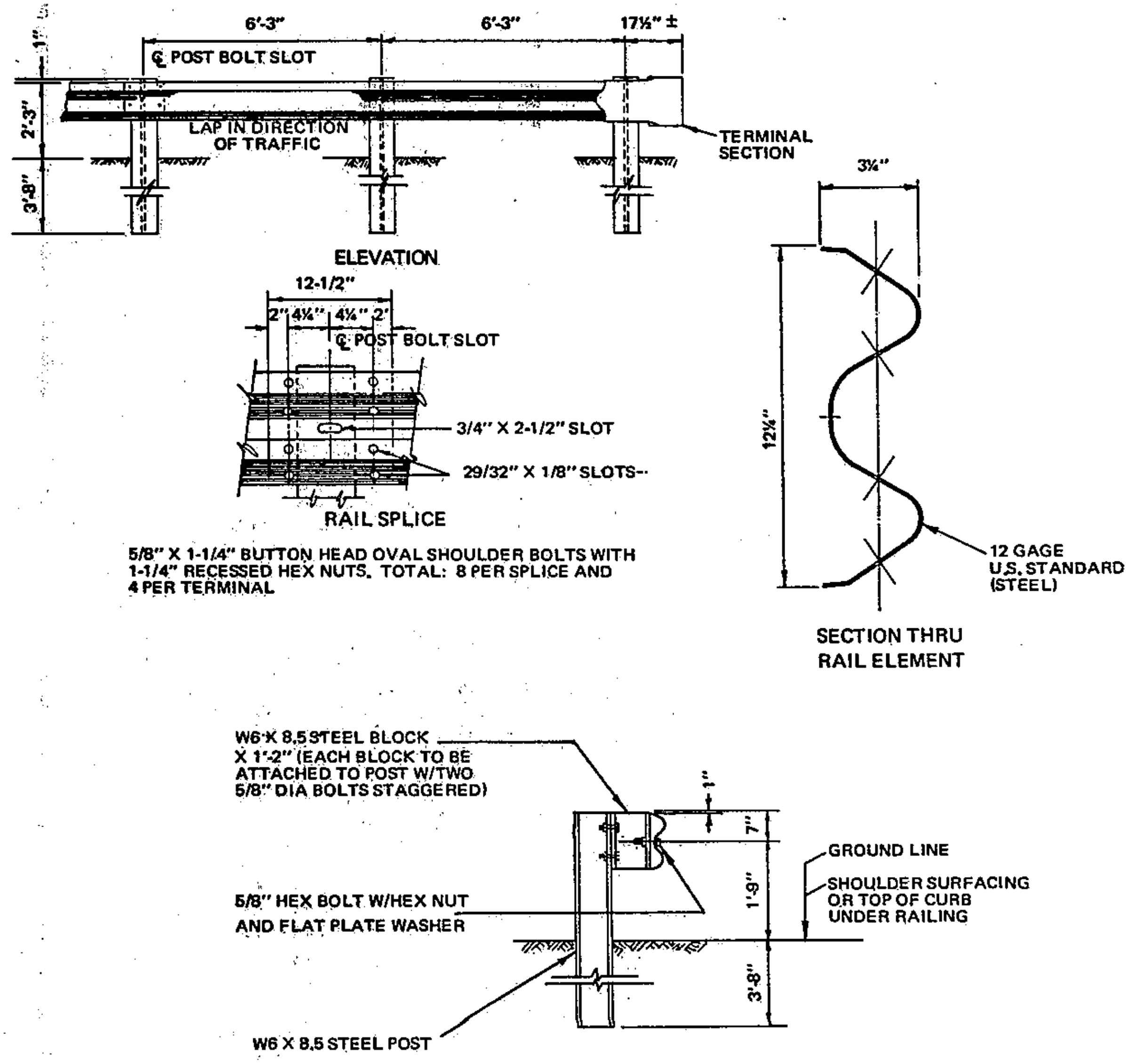

STATE OF CALIFORNIA
BUSINESS AND TRANSPORTATION AGENCY
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
REFLECTOR ASSEMBLY
METAL BEAM GUARD RAILING
AND CABLE END ANCHORS
A77-C.4
To accompany plans dated
APPROVAL RECOMMENDED
Approved July 17, 1970
RAIL SPLICE
SECTION THRU RAIL ELEMENT
ALTERNATIVE TERMINAL SECTION
TERMINAL SECTION
FLAT PLATE WASHER
DETAIL "A"
REFLECTOR ASSEMBLY
SWAGED FITTING AND STUD
CABLE ANCHOR ASSEMBLY
CABLE CLIP INSTALLATION
SECTION A-A
ANCHOR PLATE DETAILS
Typical post spacing 6'-3" C to C
8-12-69-REV. CABLE ANCHOR, WELD ON ANCHOR PLATE, ADD. DET. A

FIGURE 5



GENERAL NOTES

1. See Sheet 2 for Anchorage Details.

GUARDRAIL
SYSTEM G 4 S
BLOCKED OUT "W" BEAM
STEEL POST
DATE 1971 REV. ______

FIGURE 6

and easily. In order to simulate the same soil condition, the 6" x 8" (152 x 203 mm) wood posts were driven into eight inch (203 mm) diameter pilot holes. Steel W6 x 8.5 (152 mm x 12.65 kgf/m) posts were driven into the ground rather than into pre-drilled holes in order to achieve maximum lateral bearing resistance. The steel posts were driven with a Laboratory drill rig since the other machine was not available at that time.

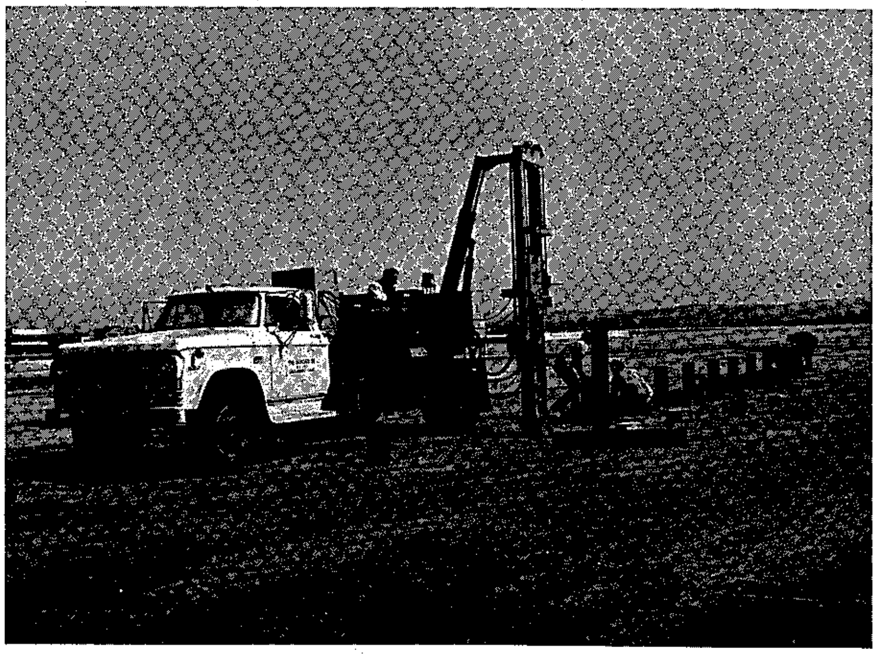


Figure 7

Machine that Augers Holes and Drives
Guard Rail Posts

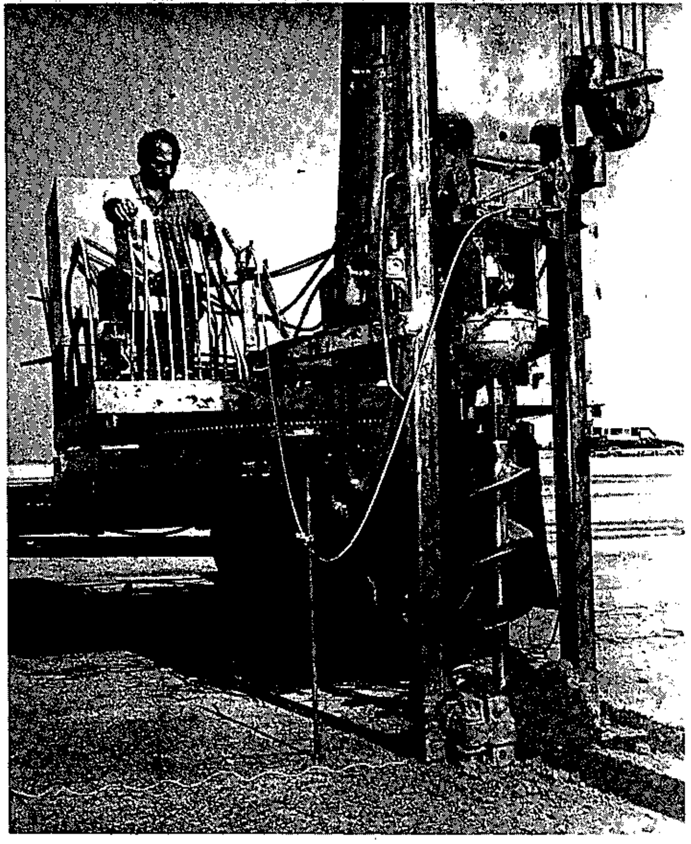


Figure 8

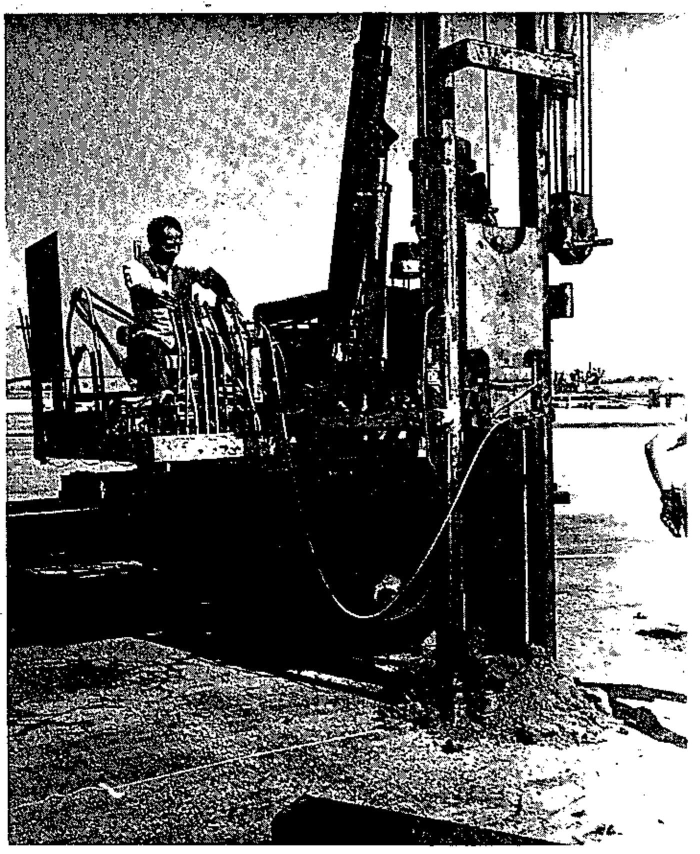


Figure 9

Machine that Augers Holes and Drives
Guard Rail Posts

Figure 10 shows the standard cable end anchor used at each end of the test barriers in Tests 272, 273 and 274. Figure 11 shows the cable end anchor with a swaged fitting (replacing the cable clips) which was used in Test 276. Note the strain gages that were used on the anchor for Test 276.

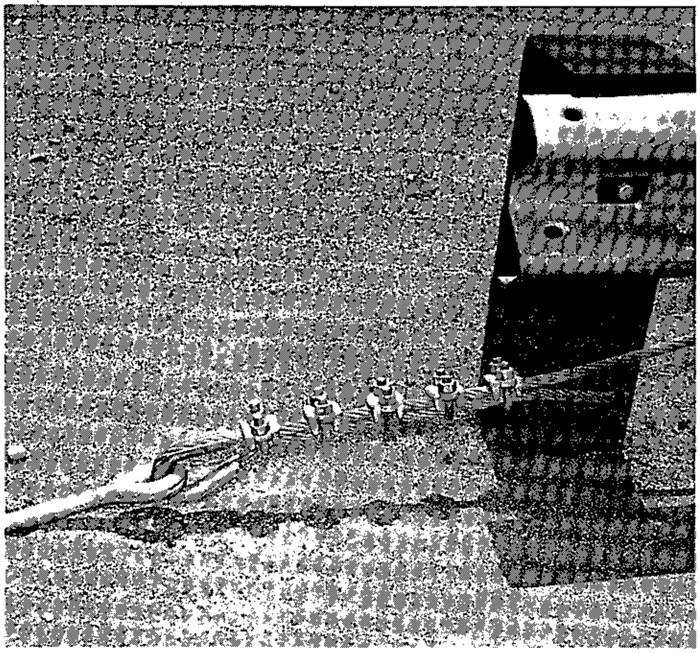


Figure 10
Cable End Anchor Used on Barriers for Tests 272, 273 and 274

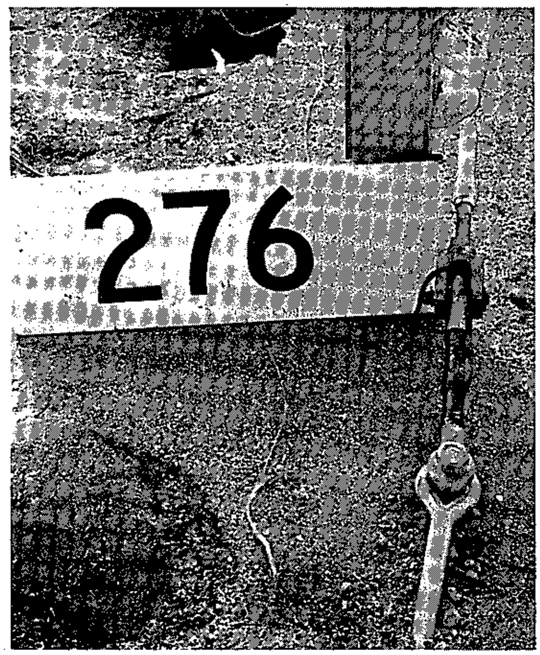


Figure 11
Cable End Anchor Used on Barrier for Test 276

2. Test Parameters

Since the primary purpose of this test series was to compare the effectiveness of metal beam guardrail when varying types of posts and block-out blocks were used, all other test parameters were kept constant as much as possible. Table 1 summarizes the parameters:

Table 1

TEST PARAMETERS

Test No.	Post and Block	Impact Speed mph (km/hr)	Angle of Impact (Degrees)	Test Vehicle	Vehicle Weight lbs. (kgf)
272	8" x 8" D.F. (203 x 203mm)	66 (106)	26	1970 Mercury	4960 (2260)
273	6" x 8" D.F. (152 x 203mm)	68 (109)	24	1970 Mercury	4960 (2260)
274	Stl. W6 x 8.5 (152mm x 12.65 kgf/m)	63 (101)	24	1970 Mercury	4960 (2260)
276	Stl. W6 x 8.5 (152mm x 12.65 kgf/m)	66 (106)	25	1970 Mercury	4960 (2260)

The vehicle weight, impact speed and angle of impact were selected as being representative of the most severe conditions that would normally be encountered by passenger vehicles on California highways. Consequently, these conditions are more severe than those recommended in HRB Circular 482[5].

3. Test Equipment and Procedure

Retired California Highway Patrol sedans modified for test purposes were used for all tests. The vehicle weight of 4960 lbs (2260 kgf) includes the on-board instrumentation, a dummy, and a gas tank filled with water. Control of the vehicle during impact was accomplished by remote radio control from a command car following approximately 100 feet (30.5m) behind the test vehicle in Tests 272, 273 and 274.

In Test 276 the vehicle was controlled by a cable guidance system attached to the left front wheel spindle of the test vehicle.

High speed and normal speed movie cameras and still cameras were used to record the impact event and the condition of the vehicle and the barrier before and after impact.

To obtain data on the motions and deceleration forces a human would be subjected to during these impacts, an anthropometric dummy was placed in the driver's seat of the crash vehicle for all tests. The dummy, Sierra Stan (Model P/N 292-850), manufactured by Sierra Engineering Company, is a 50th percentile male weighing 165 lbs (75 kgf). It was restrained during the tests by a standard lap belt.

Accelerometers were mounted on the vehicle and in the dummy to obtain deceleration data for use in judging the severity of injuries to passengers. A mechanical Impactograph mounted on the floorboard behind the front seat served as a backup for the accelerometers.

The appendix contains a detailed description of: the test vehicle mechanical instrumentation; photographic equipment and data collection techniques; electronic instrumentation and data reduction methods; and accelerometer and impactograph records.

B. Test Results

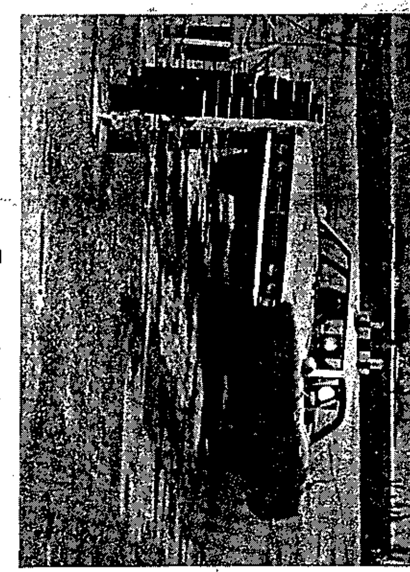
1. Introduction - Data Summary Sheets

Figures 12 through 15 summarize the results of the four tests. The exit angle represents the direction the center of gravity of the vehicle was moving immediately following final contact with the barrier. This angle is estimated using high speed movies from cameras mounted over the impact area. It is not necessarily the heading of the longitudinal axis of the vehicle. The values of vehicle rise shown in these figures represent the maximum rise of the vehicle with respect to the ground surface measured from targets on the right front fender.

Maximum permanent lateral rail deflection was measured at the top edge of the rail. The average deceleration values are either the results of one accelerometer, or in some cases, the average of the results from two accelerometers located close together. Other test observations are contained in the written descriptions of each test that follow. Pictures of vehicle and barrier damage and complete instrumentation results are included in C. Discussion of Test Results where the results of all tests are compared.

2. Test 272

The first test, Test 272, was a control test on the standard California metal beam guardrail using 8" x 8" (203 x 203 mm) wood posts and blocks. A 1970 Mercury sedan weighing 4960 lbs. (2260 kgf) impacted the barrier between posts #5 and #6 at a speed of 66 mph (106 km/hr) and an angle of impact of 26°. Figure 16



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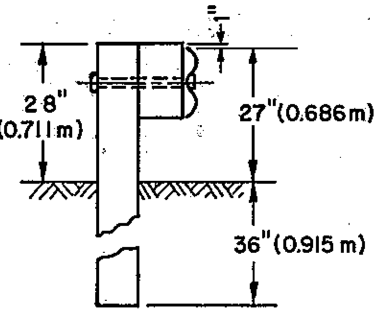


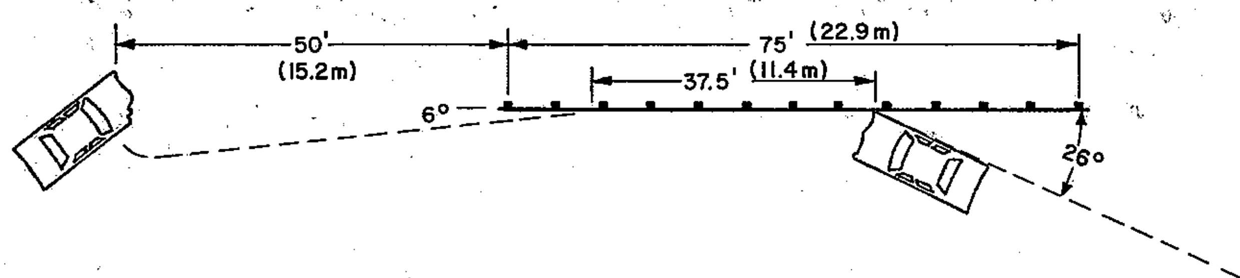
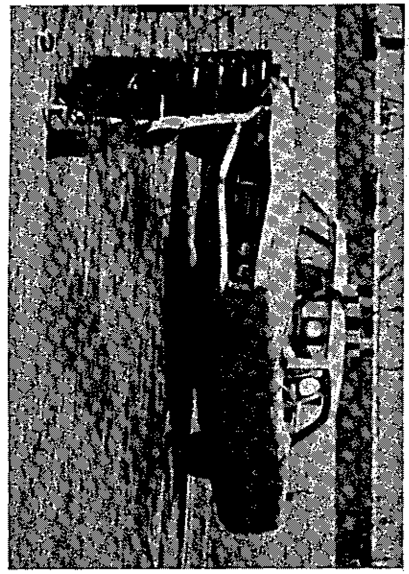


FIGURE 12, TEST 272

Beam Rail	(2.68 mm) 12 ga. Galv. Steel
Post	(203x203mmx1.62m) 8"x8" Rough D.F.x5'-4"
Post Embedment	(0.915 m) 3'-0"
Post Spacing	(1.90 m) 6'-3"
Length of Installation	(22.9 m) 75'-0"
Max. Perm. Rail Deflec. (lateral)	(0.677 m) 2.22'
End Anchorage	Cable, 5 cable clips
Max. 50msec. avg. vehicular deceleration - Lateral	5.45G's
Longitudinal	5.55G's

Test No.	272
Date	5/23/72
Vehicle	1970 Mercury
Vehicle Weight (w/dummy & instrumentation)	(2260 kgf) 4960#
Impact Speed	(106 km/hr) 66 mph
Impact Angle	26°
Exit Angle	6°
Vehicle Rise	(0.274 m) 0.9'
Dummy Restraint	Lap Belt



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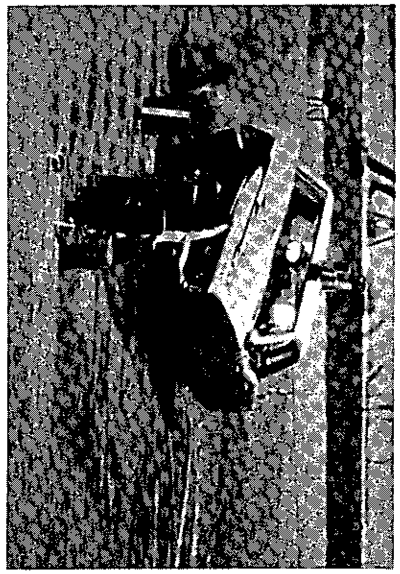

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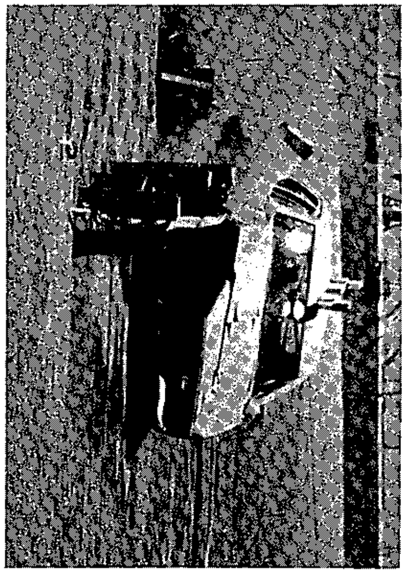

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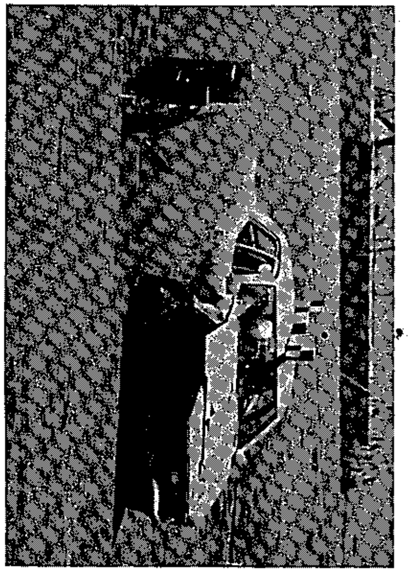


Impact + 0.776 Sec.

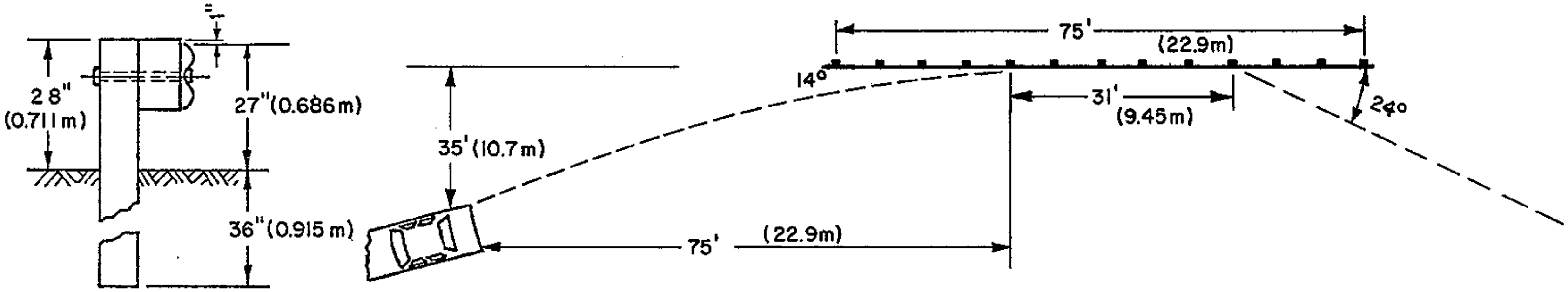
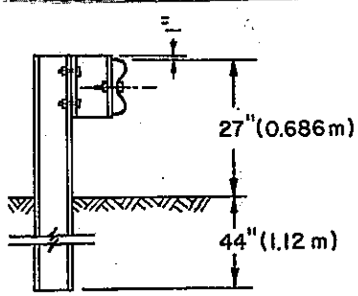


FIGURE 13, TEST 273

Beam Rail	(2.68 mm) 12 ga. Galv. Steel
Post	(152x203mmx1.63m) 6"x8" Rough D.F.x5'-4"
Post Embedment	(0.915 m) 3'-0"
Post Spacing	(1.90 m) 6'-3"
Length of Installation	(22.9 m) 75'-0"
Max. Perm. Rail Deflec. (lateral)	(0.710 m) 2.33'
End Anchorage	Cable, 5 cable clips
Max. 50msec. avg. vehicular deceleration - Lateral	6.95G's
Longitudinal	6.75G's

Test No.	273
Date	7/14/72
Vehicle	1970 Mercury
Vehicle Weight (w/dummy & instrumentation)	(2260 kgf) 4960#
Impact Speed	(109 km/hr) 68 mph
Impact Angle	24°
Exit Angle	14°
Vehicle Rise	(0.244 m) 0.8'
Dummy Restraint	Lap Belt



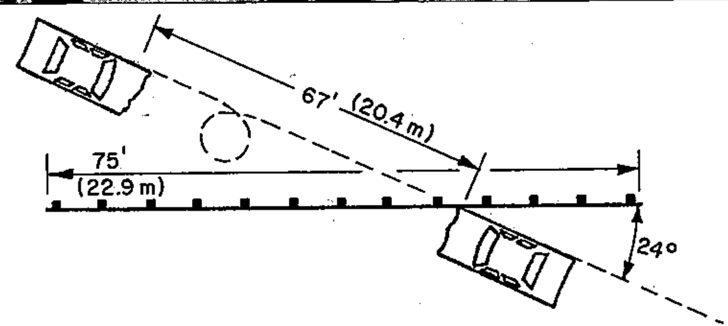
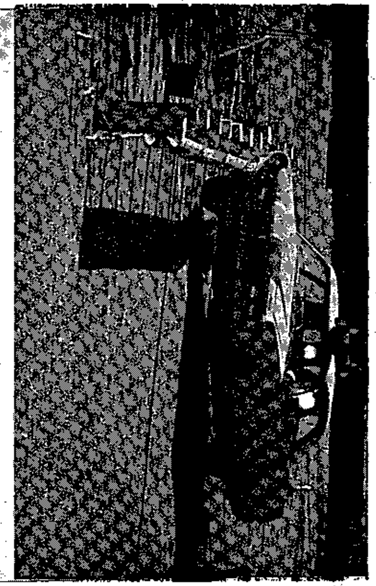


FIGURE 14, TEST 274

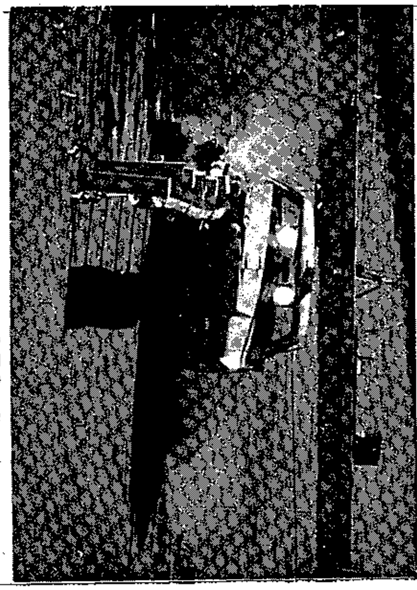
Beam Rail	(2.68 mm) 12 ga. Galv. Steel
Post	(152mmx12.65kgf/m) W6x8.5 Steel
Post Embedment	(1.12 m) 3'-8"
Post Spacing	(1.90 m) 6'-3"
Length of Installation	(22.9 m) 75'-0"
Max. Perm. Rail Deflec. (lateral)	Penetration
End Anchorage	Cable, 5 cable clips
Max. 50msec. avg. vehicular deceleration - Lateral	4.75G's
Longitudinal	5.80G's

Test No.	274
Date	8/22/72
Vehicle	1970 Mercury
Vehicle Weight (w/dummy & instrumentation)	(2260 kgf) 4960#
Impact Speed	(101 km/hr) 63 mph
Impact Angle	24°
Exit Angle	Penetration
Vehicle Rise	None
Dummy Restraint	Lap Belt

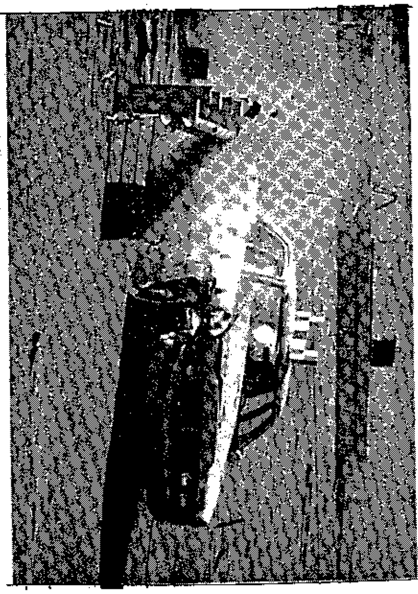


Impact + 0.025 Sec.

Impact + 0.174 Sec.



Impact + 0.273 Sec.



Impact + 0.673 Sec.

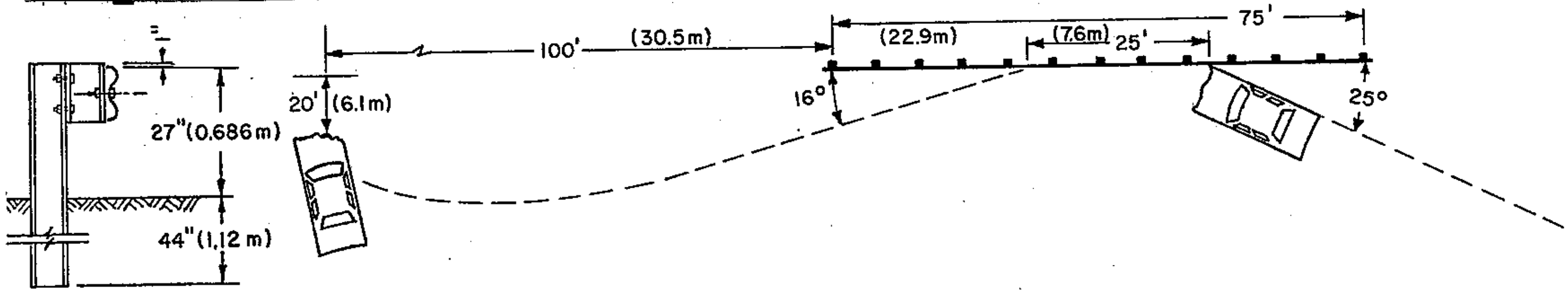


FIGURE 15, TEST 276

Beam Rail	(2.68 mm) 12 ga. Galv. Steel
Post	(152 mmx12.65 kgf/m) W6x8.5 Steel
Post Embedment	(1.12m) 3'-8"
Post Spacing	(1.90m) 6'-3"
Length of Installation	(22.9m) 75'-0"
Max. Perm. Rail Deflec. (lateral)	(0.536m) 1.76'
End Anchorage Cable, Swaged fittings both ends	
Max. 50msec. avg. vehicular deceleration - Lateral	6.85G's
Longitudinal	3,78G's

Test No.	276
Date	12/05/72
Vehicle	1970 Mercury
Vehicle Weight (w/dummy & instrumentation)	(2260 kgf) 4960#
Impact Speed	(106 km/hr) 66 mph
Impact Angle	25°
Exit Angle	16°
Vehicle Rise	None
Dummy Restraint	Lap Belt

shows the test barrier. Figure 17 shows the vehicle positioned at a 25° angle with the guardrail.

There was little rise or roll imparted to the vehicle during impact until it was nearly parallel to the barrier. Then the vehicle rolled away from the barrier about 15° and the right front end rose about 0.9 ft (0.274 m). The vehicle traveled smoothly through impact and had an exit angle of the vehicle c.g. of about 6° and an exit heading angle of 0° so that it stayed close to the barrier and almost parallel to it. Figure 12 shows sequential photographs of the impact event.

Principal damage to the vehicle included: a severely crushed right front bumper and fender, severe damage to the right front wheel, cracked windshield, crushed and jammed right front door, right door post torn loose at roof, and crimps in the roof on the right side. The car could not be driven away. There was no intrusion of vehicle parts or barrier components into the passenger compartment. Vehicle damage is shown in Figure 31 in Discussion of Test Results.

Two guardrail posts, #8 and #9, near the point of impact were destroyed and pieces of the posts and their blocks were splintered and broken and thrown behind the barrier. Two other posts, #4 and #7 and their blocks were split. The metal beam was partially flattened and raised near the area of impact. Maximum displacement of the posts at ground level was one foot. Table 5 in the Discussion of Test Results shows the post movement at ground level. Figure 22 in Discussion of Test Results shows the barrier damage.

Upon impact the dummy restrained in the driver's position by a lap belt was thrown sideways and downward toward the right passenger's seat. There were no apparent "abrasions" incurred by the dummy or damage to the interior of the vehicle caused by the dummy.

Figure 16, Barrier Used in Test 272 with 8" x 8" D.F. Wood Posts and Blocks

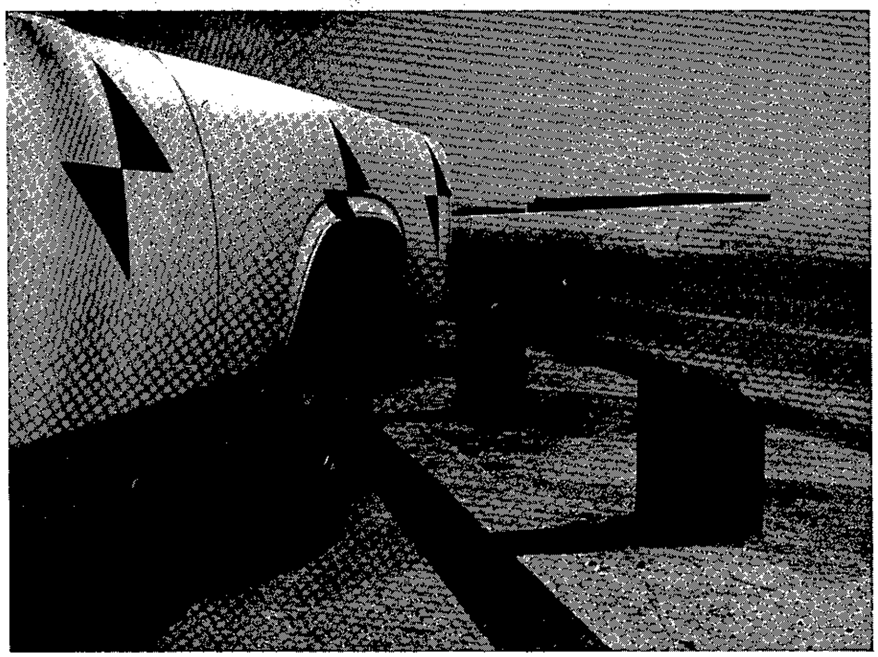


Figure 17, Test Vehicle Positioned at a 25° Angle With Barrier, Test 272

3. Test 273

Test 273 was on a barrier identical to the standard California metal beam guardrail except that 6" x 8" (152 x 203 mm) wood posts and blocks were used in place of 8" x 8" (203 x 203 mm) wood posts and blocks. A 1970 Mercury sedan weighing 4960 lbs (2260 kgf) impacted the barrier slightly downstream of post #4 at a speed of 68 mph (109 km/hr) and an angle of impact of 24°. Figure 18 shows the test barrier.

Vehicle behavior was very similar to that in Test 272. There was little rise or roll imparted to the vehicle during impact until it was nearly parallel to the barrier. Then the vehicle rolled away from the barrier about 15° and the right front end rose about 0.8 ft. (0.244 m). The vehicle traveled smoothly through impact. The exit angle of the vehicle c.g. was 14° which was the same as the exit heading angle of the vehicle. This angle gradually increased as the vehicle moved away from the barrier. Figure 13 shows sequential photographs of the impact event.

Principal damage to the vehicle included: severely crushed right front bumper and fender, severe damage to the right front wheel, cracked windshield, crushed and jammed right front door, and the right door post torn loose at the roof. The car could not be driven away. There was no intrusion of vehicle parts or barrier components into the passenger compartment. Vehicle damage is shown in Figure 32 in Discussion of Test Results.

Two guardrail posts, #6 and #7, near the point of impact were destroyed. A third adjacent post, #8, was splintered and one post near each end of the barrier was split. Three blocks were broken and thrown behind the barrier along with some of the splintered post debris. The beam was partially flattened and raised near the area of impact. Maximum displacement of the posts at ground level was 1.65 ft (0.503 m) perpendicular to the barrier at post #5. Table 5 in the Discussion of Test Results shows the post movement at ground level. Barrier damage is shown in Figure 23 in Discussion of Test Results.

Upon impact the dummy, restrained in the driver's position by a lap belt, was thrown sideways and downward toward the right passenger's seat. There were no apparent "abrasions" on the dummy or damage to the interior of the vehicle showing impact by the dummy.

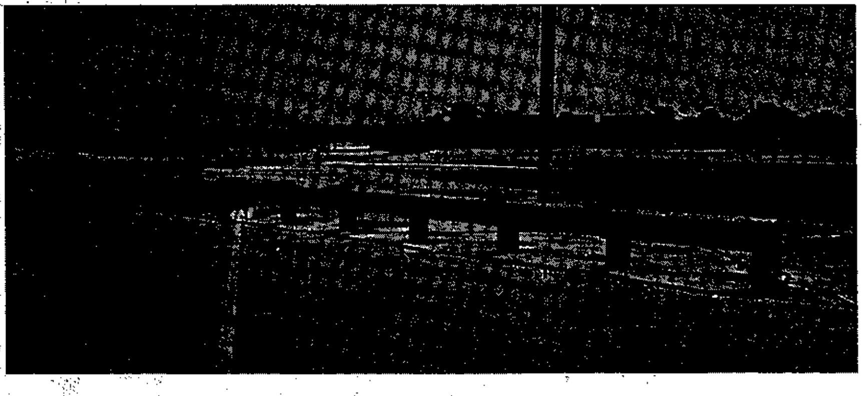


Figure 18, Barrier Used in Test 273, 6" x 8" D.F. Wood Posts and Blocks

4. Test 274

Steel W6 x 8.5 (152 mm x 12.65 kgf/m) posts and blocks were used in place of 8" x 8" (203 x 203 mm) wood posts and blocks in the barrier for Test 274. A 1970 Mercury sedan weighing 4960 lbs (2260 kgf) impacted the barrier between posts #4 and #5 at a speed of 63 mph (101 km/hr) and an angle of impact of 24°. Figures 19 and 20 show the test barrier.

The vehicle penetrated the barrier with little change in direction and spun around 180° as it slid to a stop. There was no rise and very little roll imparted to the vehicle during impact. Figure 14 shows sequential photographs of the impact event.

Principal damage to the vehicle included: severely crushed left and right front fenders and bumper, broken headlights, crushed hood, the engine moved upward about 12 inches (0.305m), the left front door jammed, and the left and right front tire movement were restricted. The car could not be driven away. There was no intrusion of vehicle parts or barrier components into the passenger compartment. No marks were apparent on the dummy or vehicle interior that would indicate a dummy to vehicle impact except for a five inch (127 mm) deformation of the steering wheel away from its original plane. The dummy was found lying on its right side on the car seat. The driver's seat back was broken. Vehicle damage is shown in Figure 33 in Discussion of Test Results.

Shearing of the "W" section beam occurred at the downstream edge of post #6 (posts numbered from upstream end). The beam was detached from post #6 and bent back around post #5. Two major bends occurred in the downstream segment: the first where post #7 had been attached and the second at the upstream edge of post #8. All 13 posts were twisted and displaced; post #1 was displaced 18 inches (0.457 m) downstream, and post #13 was displaced 15 inches (0.381 m) downstream. Posts #5, #6 and #7 were twisted and bent down near the ground about their minor axes with virtually no displacement of the posts in the ground. Slippage of the cable through five cable clips occurred at the upstream anchorage. These clips had been torqued to 50 ft-lbs (6.92 m-kgf) twice, including once on the day before the test. The bolt between the beam and block was sheared at posts #2, #3, and #12, and this bolt pulled through the beam at posts #5 #6, #7 and #8. At post #7 one bolt connecting the block to the post pulled through the flange of the block. The block at post #6 was buckled flat, and local buckling of block flanges occurred at several posts near impact. Barrier damage is shown in Figure 24 in Discussion of Test Results.

Figure 19, Barrier Used in Test 274 With W6 x 8.5 Steel Posts and Blocks

Figure 20, Test Vehicle Positioned At a 25° Angle With Barrier, Test 274

5. Test #276

The barrier for Test 276 also incorporated steel W6 x 8.5 (152 mm x 12.65 kgf/m) posts and blocks and was the same as that for Test 274 with two exceptions: 1) 1'-0" (0.305 m) long steel "W" section backup plates were placed behind the continuous guardrail beam at alternate steel posts where there were no beam splices and 2) the cable clips at the cable end anchors were replaced by a swaged fitting and clevis that connected to the standard eyerod which is embedded in the concrete footing at the ends of the barrier.

A 1970 Mercury sedan weighing 4960 lbs (2260 kgf) impacted the barrier between posts #4 and #5 at a speed of 66 mph (106 km/hr) and an angle of impact of 25°. Figure 21 shows the test barrier.

Vehicle behavior was very stable during impact; there was virtually no vehicular roll or rise as redirection occurred. The exit angle of the vehicle c.g. was about 16° and was the same as the exit heading angle of the vehicle. This angle decreased as the car skidded clockwise to a stop, coming back towards the barrier. Figure 15 shows sequential photographs of the impact event.

Principal damage to the vehicle included: severe crushing of the right front fender and bumper, jamming of the left and right front doors, damage to the right front wheel structure, and moderate crushing of the right rear fender. Vehicle damage is shown in Figure 34 in Discussion of Test Results.

Barrier damage consisted mainly of moderate twisting and bending of posts #5, #6 and #7 although none of the posts were bent to the ground. Separation of the metal beam guardrail from the steel post block occurred only at post #6. Severe buckling of the blocks occurred at posts #5, #6, and #7. A maximum of 3/8" (9.5 mm) slippage of a beam splice occurred at post #5. Minor twisting of the posts and blocks occurred at posts #4 and #8. Barrier damage is shown in Figures 25 through 30 in Discussion of Test Results.

During impact the dummy was thrown to the right and downward into the right passenger's seat, apparently without striking the dashboard. The dummy immediately bounced back into an upright position, struck the back of its head on the left door post, and came to rest against the left door with its head against the bottom of the window opening.

Figure 21, Barrier Used in Test 276 With W6 x 8.5 Steel Posts and Blocks

C. Discussion of Test Results

1. General

In this section the test results will be weighed against the service requirements and performance criteria for longitudinal barriers which are well covered in Reference 4. "The order of emphasis for service requirements is first to safety, second to economics, and third to aesthetics[4]." The key elements to safety are spelled out under performance criteria. "Traffic barrier dynamic performance criteria are formulated for full-scale vehicular crash testing of candidate barrier systems whereby both strength and safety are simultaneously evaluated. These criteria are composed of (1) vehicle impact characteristics and (2) barrier response requirements presented in the form of vehicle deceleration and trajectory. If the barrier system contains the moving vehicle (i.e. structural strength), the vehicle decelerations are judged to be within human tolerance levels, and the vehicle post impact trajectory is acceptable, the candidate barrier is considered acceptable for in-service experimental use. After the system has been carefully monitored and evaluated in service and its effectiveness has been established, the system is judged to be operational[4]."

2. Dynamic Performance Criteria - Safety

a. Structural Integrity of Barrier

"For the longitudinal barrier, the first dynamic performance requirement is to restrain the selected vehicle; otherwise, it cannot effectively shield the warranting roadside feature (i.e., lateral drop-off, fixed object, etc.). A longitudinal barrier that does not prevent vehicle penetration (i.e., by vaulting, breaking through, or wedging under the rail) can be a greater hazard due to its relative length than the roadside feature being shielded. Hence, only longitudinal barrier systems that successfully restrain the selected vehicle are acceptable for operational use.

In redirecting or stopping the vehicle, the longitudinal barrier must deform or function in such a manner as to minimize the hazard of the passenger compartment being invaded by parts or elements of the system. For example, the installation design should minimize the chance of a beam rail spearing the vehicle, or the system fragmenting into lethal projectiles[4]."

The barriers impacted in Tests 272, 273 and 276 all met the above requirements. There were no indications that the barriers were on the brink of failure. The barrier impacted in Test 274 was penetrated which was unacceptable. An analysis of that failure is described in a later section. Figures 22 through 25 show barrier damage for all four tests. Figures 26 through 30 show closeup views of posts near the impact area for Test 276. The backup plates at posts #4 and #8 clearly resisted excessive bending of the W-section beams at the posts. Samples of soil from the barrier test site were tested. A copy of the soil report is contained in the Appendix in Section D. This report indicates the soil was quite strong. It consisted of a layer of stiff, overconsolidated clay in the top 1.5 feet (.457 m) of soil and a layer of sandy clay with gravel and clayey sand with gravel (commonly called "hardpan") from 1.5 to 4.5 feet (0.457 - 1.37 m) of depth. This stiff soil probably gave the barrier added apparent stiffness and forced the wood posts near impact to shear and the steel posts to bend rather than yielding in the soil. However, the major restraining force in the barrier appears to come from the W-section beam as evidenced by Test 274 where the cable anchor slipped and the W-section tensile strength could not be developed.

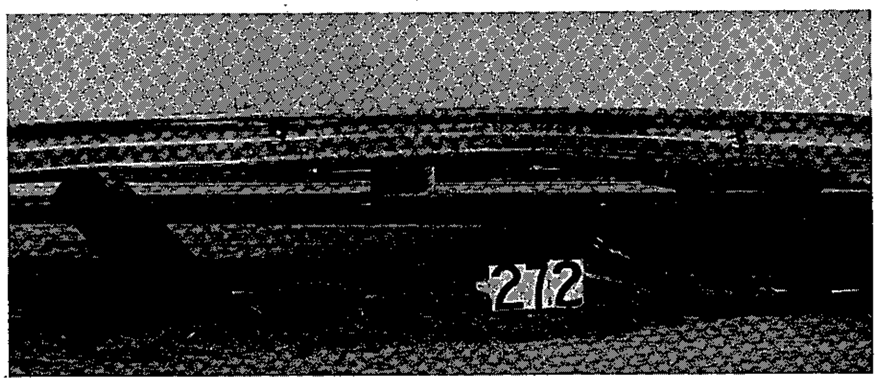


Figure 22, Test 272 Barrier Damage

Figure 23, Test 273 Barrier Damage

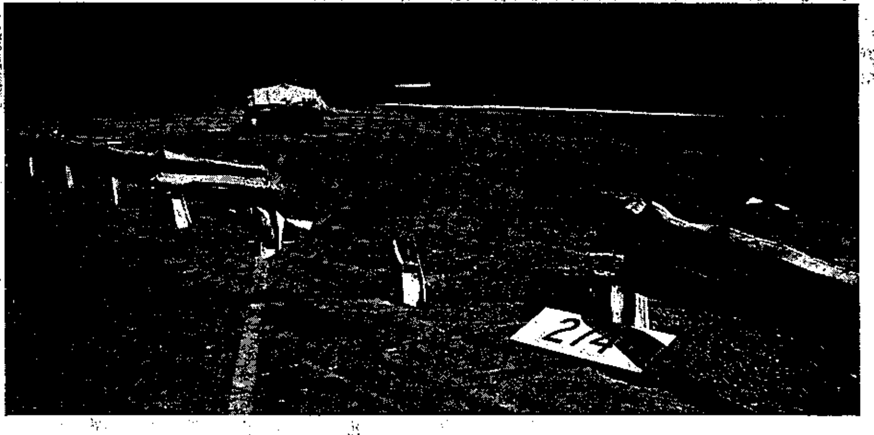


Figure 24, Test 274 Barrier Damage

Figure 25, Test 276 Barrier Damage

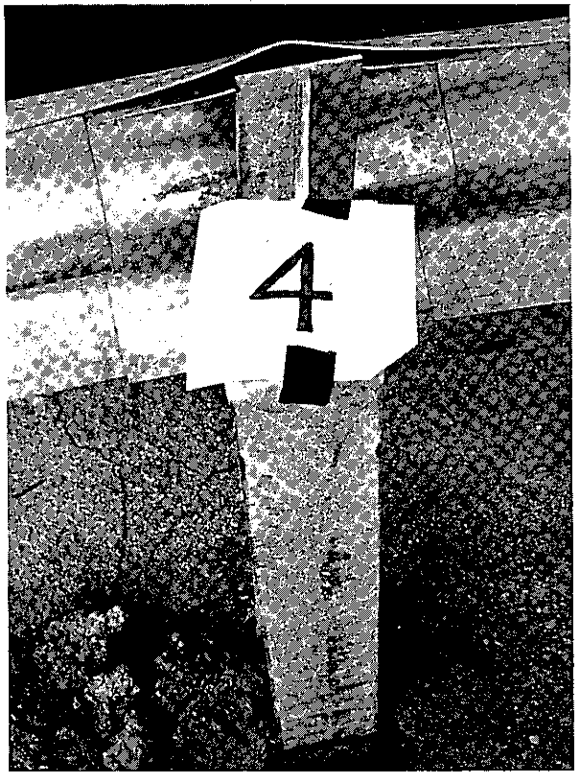


Figure 26, Test 276
Post #4

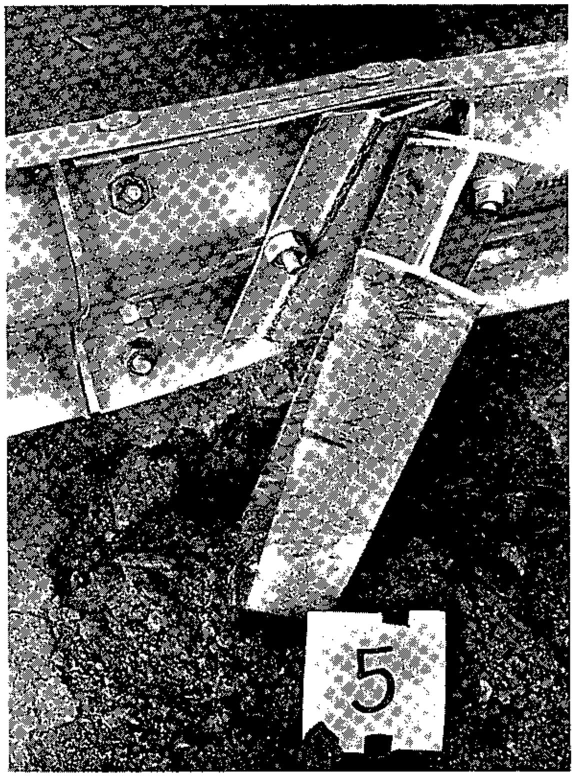


Figure 27, Test 276
Post #5

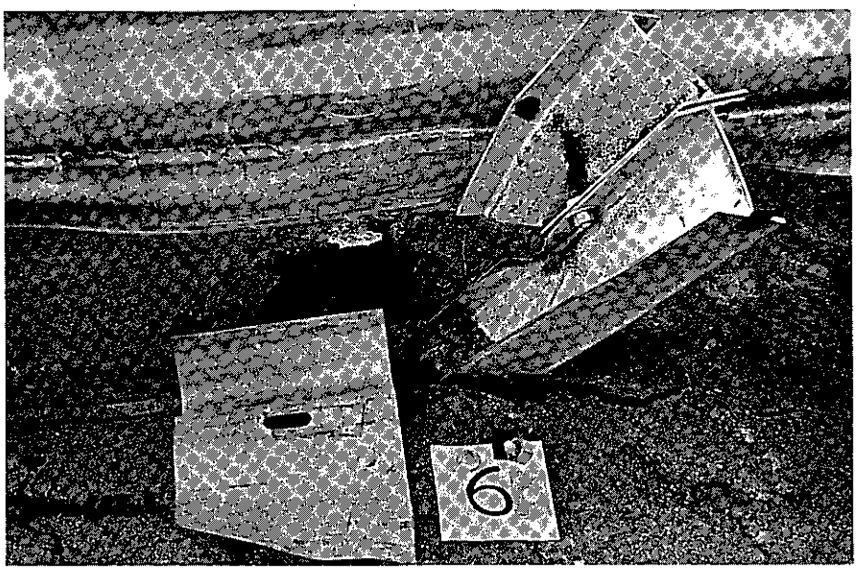


Figure 28, Test 276 Post #6

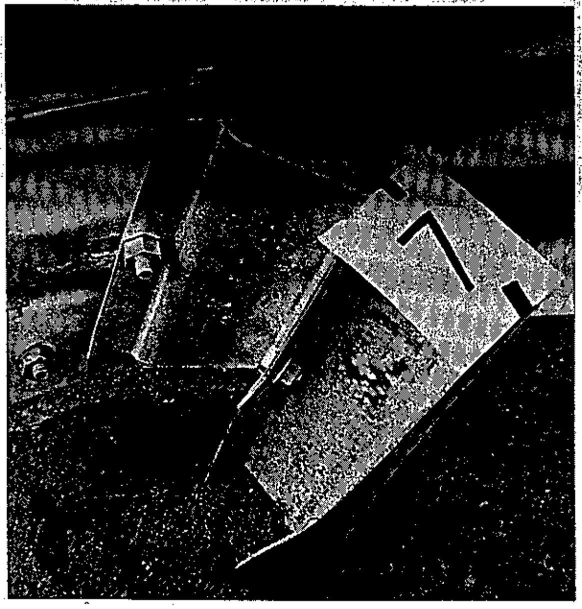


Figure 29, Test 276
Post #7

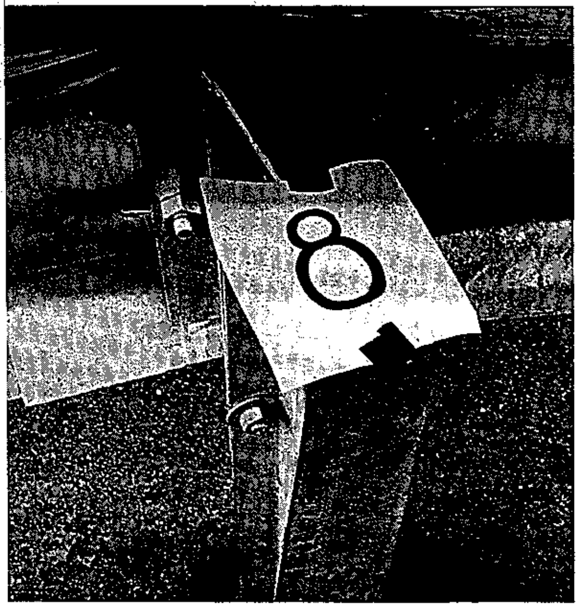


Figure 30, Test 276
Post #8

b. Vehicle Decleration.

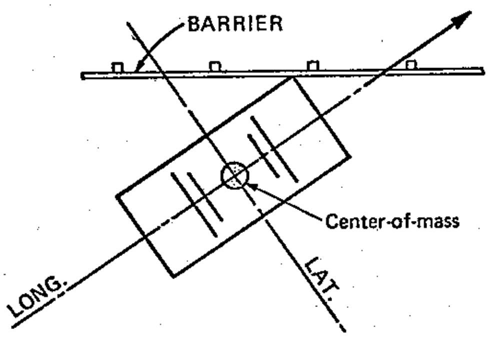
"The objective of a highway traffic barrier is to reduce the number of fatalities and the severity of occupant injuries in ran-off-the-road-type accidents. Occupant injury and fatality are usually related to (1) accident severity (i.e., vehicle deceleration intensity and duration), (2) precrash physiological condition of passengers, (3) the passengers' degree of restraint, and (4) the crashworthiness of the vehicle. However, of these factors only accident severity is significantly affected by the dynamic performance of a traffic barrier. Accordingly, primary traffic barrier performance is evaluated on deceleration induced in the vehicle during a collision. In comparing performance of two or more traffic barrier systems, the one that induces the lowest level of deceleration to the colliding vehicle is generally preferred.

"Guideline values for maximum vehicle decelerations (at center of mass) are presented in Table 2[6] according to vehicle reference axes and three performance ratings. The procedure used to establish deceleration values given in Table 2 is not precisely described in the original reference. However, subsequent researchers [1,26] have suggested the use of the highest 50-msec (milli-second) average deceleration occurring near the vehicle's center of mass during impact. The limits of deceleration given here are not nominal limits for "no injury", but rather are maximum limits beyond which disabling injury or fatality may be expected. The order of preference is Ratings A, B, and C. Barriers with full-scale crash test deceleration values within the limits of Table 2 are considered to have satisfied the deceleration requirements[4]."

Reference 7 explains in detail some reasons for using the 50 msec time interval.

MAXIMUM VEHICLE DECELERATIONS

Barrier Performance Rating†	Maximum Vehicle Decelerations (g's)*			
	Lateral	Longitudinal	Total	Remarks
A	3	5	6	Preferred Range
B	5	10	12	
C	15	25	25	



*Vehicle rigid body decelerations; maximum 500 g/sec onset rate; highest 50 msec average.
†A - limits for unrestrained passenger.
B - limits for passenger restrained by lap belt.
C - limits for passenger restrained by lap and shoulder belts.

Table 2 - Maximum Vehicle Decelerations

Table 3 indicates, in accordance with the values shown in Table 2, that for all tests, values of vehicle decleration in the longitudinal direction were well below the 10G recommended limit for lap belted passengers and slightly over the 5G recommended limit for unrestrained passengers.

The values of vehicle deceleration in the lateral direction, which are more critical for impacts into guardrail, slightly exceeded the recommended limit of 5G's for lap belted passengers but were well below the 15G limit for passengers wearing shoulder and lap belts.

Although the deceleration values shown are calculated from accelerometer data to one hundreth of a G, they should not be considered to have that accuracy. The values are in a range similar to that calculated for other tests of metal beam guardrail. Table 4 gives the results of other test series involving similar vehicle weights, impact speeds and angles of impact[4].

Values of deceleration for other barrier systems are included for comparative purposes. The number of tests for which 50 millisecond values of deceleration have been reported in the literature are rather limited.

Southwest Research Institute will soon be reporting results of tests on guardrail and median barrier terminals. Eight side angle tests into these barriers have yielded 50 millisecond values of longitudinal deceleration ranging from 4.6 to 8.5 G's and values of lateral deceleration ranging from 2.5 to 7.6 G's given test parameters similar to those in Table 3.

It is apparent that although the barrier in Tests 272, 273 and 276 may not have yielded ideal values of vehicle deceleration, the values for those tests indicate that the barriers performed equally as well as currently accepted barrier systems.

Values of the Gadd Severity Index were computed as detailed in the Appendix. In Test 273 only, the index slightly exceeded the threshold value of 1000 above which serious injury or death might be expected due to concussion. This value is not reliable as a sole indicator of the chance of passenger injuries for the following reasons:

(1) The dummy used was not sophisticated enough to completely simulate a live driver.

(2) The index is based on blows to the forehead. It could not be determined exactly what area of the dummy's head impacted the interior of the vehicle.

(3) Many variables such as portions of vehicle struck, original dummy position, seat position, seat belt tautness, etc. have an affect on dummy motions during impact.

(4) The dummy represents only a 50th percentile American male.

Notwithstanding the above limitations it can be surmised that in the severe proof tests of the barriers, vehicle passengers had a fair chance of survival. Hence, in the large majority of actual

TABLE 3 - SUMMARY OF DECELERATION DATA

1.	Test Number	272	273	274	276
2.	Type of Post	8" x 8" DF	6" x 8" DF	W6" x 8.5# Stl.	W6" x 8.5# Stl.
3.	Impact Angle (Degrees)	26	24	24	25
4.	Impact Velocity (mph) (km/hr)	66 (106)	68 (109)	63 (101)	66 (106)
5.	Kinetic Energy (ft-kips) (m-kgf)	725 (100,000)	770 (107,000)	661 (91,800)	725 (100,000)
6.	Vehicle C. G. Deceleration (Max. 50 msec. average)				
	a. Lateral G's	5.45	6.95	4.75	6.85
	b. Longitudinal G's	5.55	6.75	5.80	3.78
7.	Dummy Chest Deceleration (Max. 50 msec. average)				
	a. Longitudinal G's	8.75	8.10	9.95	3.65
8.	Dummy Head Deceleration (Max. 50 msec. average)				
	a. Resultant G's*	43.30	49.76	25.05	33.70
9.	Gadd Severity Index (Max. 50 msec. interval)	883	1130	279	371
10.	Max. Lap Belt Load (lbs.) (kgf)	845 (384)	1012 (460)	500 (228)	925 (420)

*Vector resultant of longitudinal, lateral, and vertical accelerometer traces.

TABLE 4 - VEHICLE DECELERATIONS FROM MISCELLANEOUS BARRIER TESTS

System*	Vehicle Weight lbs (kgf)	Vehicle Speed mph (km/hr)	Kinetic Energy ft-kips (m-kgf)	Impact Angle Degrees	Vehicle Decelerations G's** Longitudinal	Lateral
Guardrail						
G4W	4042 (1830)	55.3 (89.0)	414 (57,300)	30.5	4.6	4.6
G4W	4123 (1870)	60.1 (96.7)	500 (69,200)	22.2	3.0	6.1
G4S	3813 (1730)	56.8 (91.4)	413 (57,100)	28.4	3.9	6.6
G2	4051 (1840)	59.2 (95.3)	476 (65,900)	27.8	2.9	3.8
G3	4031 (1820)	57.7 (92.8)	451 (62,400)	26	2.8	5.8
Bridgerail						
BR-2	4900 (2220)	66 (106)	716 (99,100	25	14.8	9.1
Crash Cushions						
C1	4760 (2160)	59.8 (96.2)	572 (79,100)	11	6.6	5.3
C2	4760 (2160)	57.0 (91.7)	520 (71,900)	9	8.4	5.2

*System designation in Reference 4

**Maximum deceleration averaged over a period of 50 milliseconds. Values for guardrail computed from high speed movie film; other values computed from accelerometer data. The G4W and G4S systems tested were very similar to the barriers used in Tests 272 and 276 respectively.

highway accidents involving these guardrail systems, it can be predicted that passengers would sustain something less than serious injuries.

The degree of injury would, of course, depend greatly on the type of passenger restraints.

c. Vehicle Post Impact Trajectory

(1) General

"To minimize the possibility of involving other traffic, the third performance criterion is for vehicles impacting longitudinal barriers or the sides of crash cushions to be redirected in a trajectory nearly parallel to the pavement edge. For normal or angle hits on the nose of crash cushions, vehicle post impact trajectory is judged satisfactory if the vehicle is not rebounded into the main traffic streams.

Accidents in which a vehicle is redirected into the traffic lane and becomes involved in a multicar collision seem to be few in number. Accordingly, post impact trajectory is a performance consideration that is reserved in making a selection among systems that are comparable with regard to structural strength characteristics and decelerations produced during vehicle redirection[4]."

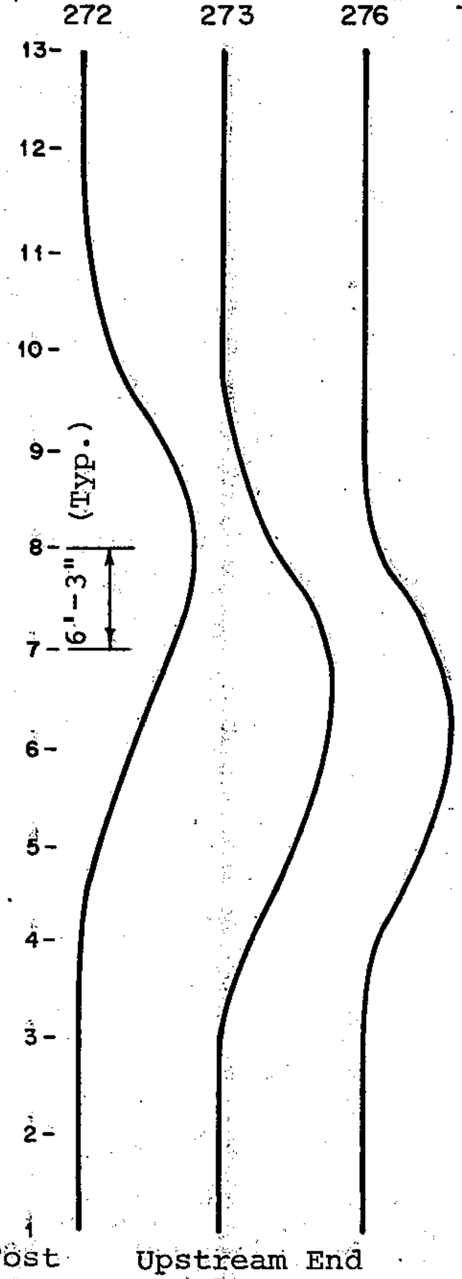
The following sections describe some elements of the impact event which have an influence on vehicle post impact trajectory.

(2) Barrier Deflection

Table 5 shows the barrier rail and post deflections for Tests 272, 273 and 276. The diagram on Table 5 and Figures 22 through 25 show that the rail deflected in a smooth curve as desired. The figures also show the damage to the barrier posts at the area of impact.

The deflection of the rail in Test 276 is less than that for Tests 272 and 273 and may account for the relatively low longitudinal vehicle deceleration. Table 6 compares the barrier rail deflections of these tests with other test series. This table clearly shows that the permanent barrier rail deflections were in the same range as those recorded for previous test series. It should be noted that the vehicle kinetic energy at impact for Tests 272, 273 and 276 was appreciably higher than that for other tests in the table. Barrier damage in Tests 272 and 273 was very

Plan of Lateral Rail Deflection



Post No.	Test 272 Post Defl. Ground Long. *	Test 272 Post Defl. Ground Perp. **	Test 272 Rail Defl. **	Test 273 Post Defl. Ground Long. *	Test 273 Post Defl. Ground Perp. **	Test 273 Rail Defl. **	Test 276 Post Defl. Ground Long. *	Test 276 Post Defl. Ground Perp. **	Test 276 Rail Defl. **
13	0	0	-	0	0	-			-.08
	-	-	.01	-	-	0			-.07
12	0	0	-	0	0	-			-.04
	-	-	.02	-	-	0			-.04
11	0	.02	-	0	0	-			-.04
	-	-	.38	-	-	0			-.04
10	.05	.32	-	0	0	-		0	-.04
	-	-	1.44	-	-	0			-.03
9	-	-	-	0	.01	-	0	.04	.03
	-	-	2.22	-	-	.64			.12
8	-	-	-	.05	.59	-	.04	.08	.39
	-	-	2.22 (0.677)	-	-	1.96			1.08
7	.60	1.0	-	.05	.75	-	.08	.12	1.53
	-	-	1.47	-	-	2.33 (0.711)			1.76 (0.536)
6	.07	.40	-	1.15	1.40	-	.17	.12	1.73
	-	-	.73	-	-	1.90			1.59
5	0	.18	-	.05	1.65	-	.17	.12	1.19
	-	-	.14	-	-	1.11			.84
4	0	.02	-	.01	.17	-	0	.12	.26
	-	-	.02	-	-	.21			.11
3	0	0	-	0	.06	-		0	.01
	-	-	.03	-	-	.02			.00
2	0	0	-	0	0	-			
	-	-	.03	-	-	.01			
1	0	0	-	0	0	-			

NOTE: All meas. in feet
Horiz. Scale: 1" = 4'
No vertical scale
Only maximum rail deflections are given in metric units (Meters)

* Measured longitudinal to the barrier

** Measured perpendicular to the barrier

TABLE 5 BARRIER DEFLECTION

TABLE 6 - COMPARISON OF GUARDRAIL DEFLECTION AND EXIT ANGLE VALUES FROM VARIOUS GUARDRAIL TESTS

Test No. (System)	Vehicle Weight lbs. (kgf)	Vehicle Speed mph (km/hr)	Kinetic Energy ft-kips (m-kgf)	Impact Angle Degrees	Max. Perm. Guardrail Deflection ft. (m)	Exit Angle Degrees
Southwest Research Institute [3]						
101 (G4W)	4042 (1830)	55.3 (89.0)	414 (57,300)	30.5	2.60 (0.793)	11.7
102 (G4W)	3856 (1740)	54.7 (88.0)	387 (53,500)	25.2	1.50 (0.457)	12.5
103 (G4W)	4123 (1870)	60.1 (96.7)	500 (69,200)	22.2	2.40 (0.732)	15.0
119 (G4S - No Blockout)	4169 (1890)	53.4 (85.9)	400 (55,300)	30.2	2.67 (0.814)	19.8
120 (G4S One Blockout)	3813 (1730)	56.8 (91.4)	413 (65,700)	28.4	2.90 (0.885)	8.0
122 (G4S Dbl. Blockout)	4570 (2070)	62.9 (101.)	607 (84,000)	25.3	2.90 (0.885)	9.0
California Division of Highways [1,2]						
107 (G4W)	4570 (2070)	60 (96.5)	552 (76,400)	25	1.5 (0.457)	17
108 (G4W - 24" beam ht.)	4570 (2070)	59 (94.9)	534 (73,900)	25	1.5 (0.457)	19
133 (G4W)	4540 (2060)	56 (90.1)	477 (66,200)	30	2.8 (0.855)	7
135 (G4W)	4540 (2060)	59 (94.9)	534 (74,100)	28	1.6 (0.488)	24
This Test Series						
272 (G4W)	4960 (2260)	66 (106)	725 (100,000)	26	2.22 (0.677)	6
273 (G4W 6" x 8" posts)	4960 (2260)	68 (109)	770 (107,000)	24	2.33 (0.710)	14
276 (G4S)	4960 (2260)	66 (106)	725 (100,000)	25	1.76 (0.537)	16

similar which indicates that the anchored metal beam was the critical restraining element, rather than the wood posts.

(3) Vehicle Crush

Figures 31 through 34 compare the vehicle damage incurred in the four tests. Comparing Tests 272, 273 and 276 the damage to the right front portion of the vehicle was quite severe and roughly similar for all tests. The right front wheel was disabled in all three tests.

Figure 31, Test 272 Vehicle Damage

Figure 32, Test 273 Vehicle Damage

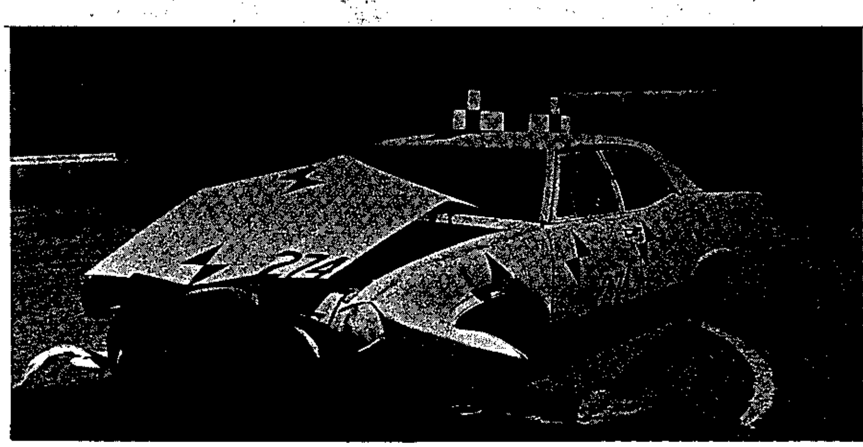


Figure 33, Test 274 Vehicle Damage

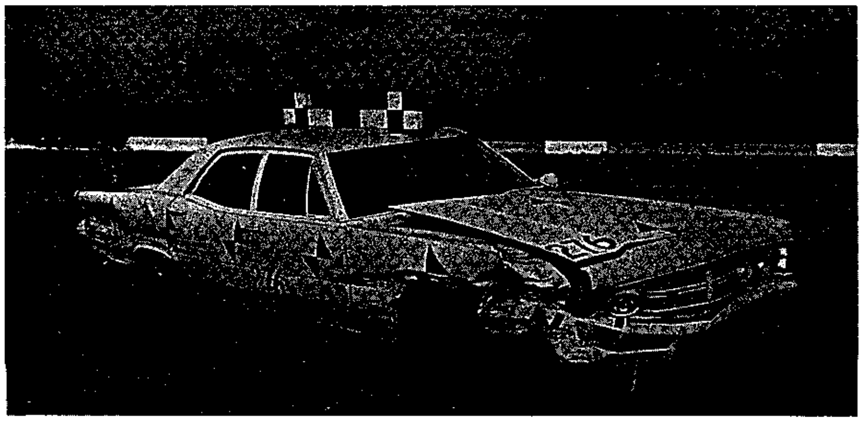


Figure 34, Test 276 Vehicle Damage

(4) Vehicle Rise and Roll

Analysis of the high speed movie film produced the following values of rise and roll:

TABLE 7

Vehicle Rise and Roll

Test No.	Rise* Ft. (m)	Roll** Degrees
272	0.9 (0.274)	Front 15° Rear 12°
273	0.8 (0.244)	Front 17° Rear 13°
276	- -	Front 0° Rear -1°

* Rise measured at target on right front fender

** Roll measured at top of front and rear windshields in degrees away from a horizontal plane.

These values and the movies demonstrate the stable condition of the test vehicles as they progressed through impact. The most stable condition occurred with the steel post guardrail.

(5) Final Vehicle Position

Figures 35 through 38 show the test vehicles in their final position after impacting the test barriers. There is no easy answer to explain the variance in post impact trajectories. Various factors may have an effect including barrier deflection, vehicle crush and damage to the wheel, time when brakes are actuated by remote control, amount of rise and roll, paving surface condition, etc.

Figure 35, Test 272 Final Vehicle Location

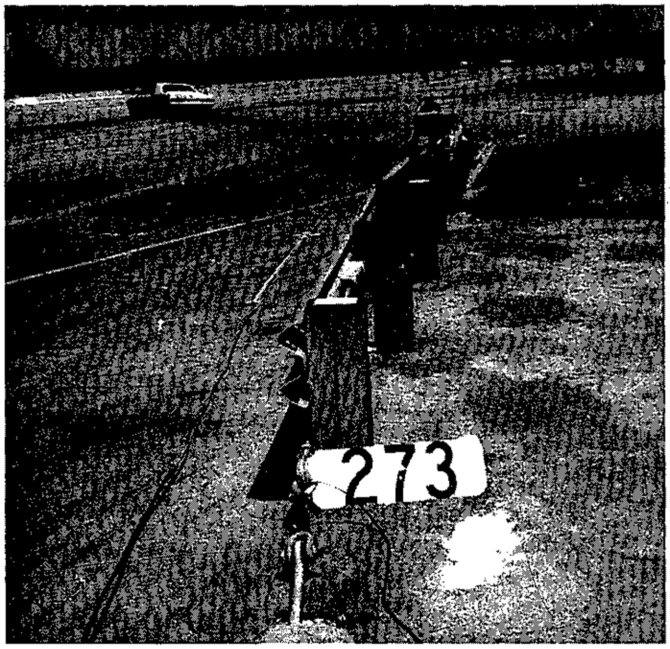


Figure 36, Test 273 Final Vehicle Location

Figure 37, Test 274 Final Vehicle Location

Figure 38, Test 276 Final Vehicle Location

(6) Barrier Debris

The steel post guardrail appears to have an advantage over wood post guardrail in that no barrier parts were dislodged in Test 276. In Tests 272 and 273 pieces of wood posts and blocks were thrown behind the barrier. Therefore, when guardrail is placed in median or gore areas it might be preferable to use the steel post type from the debris standpoint.

3. Cost

In the past only wood posts were approved for use in guardrail. The use of steel posts had not been seriously considered because they were not cost competitive, and the wood post type guardrail had proven fully effective in full scale tests and in operation. About the time this latest test series was conducted, the cost of wood posts and blocks was rising rapidly and there was an apparent shortage. These rapid changes in supply and cost have made it highly desirable to also approve as a standard the use of steel posts in guardrail. It appears that they may now be competitive. Fortunately the steel post guardrail was shown in Test 276 to be equally as effective as the wood post guardrail.

It does not appear that there would be any difference in maintenance and repair labor costs for the barrier types tested in Test 272, 273 and 276. Cost and availability of replacement components are not predictable based on current shortages of highway construction materials which may continue into the future.

4. Aesthetics

Guardrails with 6" x 8" (152 x 203 mm) wood posts and blocks and W6 x 8.5 (152 mm x 12.65 kgf/m) steel posts and blocks do not appear to offer any substantial improvement or down grading of the appearance of guardrail using 8" x 8" (203 x 203 mm) wood posts and blocks. The steel post guardrail is slightly more streamlined and has uniformity of materials (all steel); the wood post guardrail may have a blockier, more substantial appearance, and perhaps a more rustic appearance which may be desirable in rural areas or other selected locations. However, bare steel posts made of any of the weathering steels could also be used to provide a rustic appearance.

5. Analysis of Test 274

The barrier used in this test incorporated W6 x 8.5 (152 mm x 12.65 kgf/m) steel posts and blocks. Penetration of the rail resulted when the vehicle impacted the barrier. Figure 18A in the Appendix shows the rail which tore next to a post at the downstream edge. This section describes the analysis of that failure which led to the successfully revised barrier design used in Test 276.

a. The steel posts have about 90 times less torsional rigidity than wood posts, hence they absorbed very little of the tensile load developed in the rail. Instead, they twisted and transmitted a large load almost instantly to the cable end anchors.

b. Due to this large dynamic load ("jerk") the cable slipped through the five cable clips at the upstream anchor.

c. Slipping of the cable relaxed the tension in the steel W-section beam permitting severe pocketing, coldworking, and weakening of the metal beam.

To correct this condition, two changes were made to the barrier design for Test 276; (1) a swaged fitting and clevis were used to replace the five cable clips on the cable end anchorage to provide a positive anchorage and (2) twelve inch long backup sections of W-section beam were placed behind the beam at alternate posts where beam splices did not occur. These backup sections reduced the tendency of the rail to tear along the hard sharp edge of the steel blocks and posts. The results of Test 276 proved the effectiveness of these modifications.

The Southwest Research Institute (SWRI) also has conducted several successful tests on guardrail systems with W6 x 8.5 (152 mm x 12.65 kgf/m) steel posts and blocks. SWRI Test 141 seems to confirm the effectiveness of backup plates on a steel post guardrail system[8]. See the Appendix for a more detailed analysis of Test 274.

IV. REFERENCES

1. Nordlin, E. F., Field, R. N., and Prysock, R. H., "Dynamic Full Scale Impact Tests of Double Blocked-out Metal Beam Barriers and Metal Beam Guard Railing, Series X", California Division of Highways, February 1965.

2. Nordlin, E. F., Field, R. N., and Ames, W. H., "Dynamic Tests of Short Sections of Corrugated Metal Beam Guardrail, Series XIII", October 1968.

3. Michie, J. D., Calcote, L. R., and Bronstad, M. E., "Guardrail Performance and Design", NCHRP Final Report, January 1970.

4. Michie, J. D., and Bronstad, M. E., "Location Selection, and Maintenance of Highway Traffic Barriers", NCHRP Report 118, 1971.

5. Highway Research Board Committee on Guardrails and Guide Posts, "Proposed Full-Scale Testing Procedures for Guardrails", Circular 482, September 1962.

6. Shoemaker, N. E., and Radt, H. S., "Summary Report of Highway Barrier Analysis and Test Program", Report No. VJ-1472-V-3, Cornell Aeronautical Laboratory (July 1961).

7. Nordlin, E. F., Woodstrom, J. H., and Hackett, R. P., "Dynamic Tests of the California Type 20 Bridge Barrier Rail, Series XXIII", California Division of Highways, October 1970.

8. NCHRP Research Results Digest 43 - October 1972.

V. APPENDIX

A. Crash Car Equipment

Following is a description of the modifications made to crash cars prior to impact tests. The method of controlling the car remotely is also described. These procedures were used in Tests 272, 273 and 274.

1. The test vehicle gas tank was disconnected from the fuel supply line, drained and refilled with water. A one gallon safety gas tank was installed in the trunk compartment and connected to the fuel supply line.

2. Three wet-cell storage batteries (6, 8, and 12 volt) were mounted on the floor of the rear seat compartment. They supplied power for the remote control equipment.

3. A solenoid-valve actuated CO_2 system was connected to the brake line for remote braking. With 700 psi in the accumulator tank, the brakes could be locked in less than 100 milliseconds after activation.

4. The ignition system was connected to the brake relay in a failsafe interlock system. When the brake system was activated, the vehicle ignition was switched off. Also, any loss of steering control caused by a failure of either the radio transmitting or receiving systems would automatically energize the brake relay, thus cutting the vehicle ignition and braking the vehicle to a stop.

5. The accelerator pedal was linked to a small electric motor which, when activated, opened the throttle. The motor was activated by a manually thrown switch mounted on the top of the rear fender of the test vehicle.

6. Steering was mechanically accomplished with a 400 inch-ounce (0.288 m-kgf) stepping motor through a V-belt driven pully attached to the steering shaft. The stepping motor was mounted on a bracket secured to the floorboard of the front seat compartment and activated through the remote radio tuned relay system for right or left turns.

7. A radio control receiver, tone actuated relays, steering pulse and handi-talkie radio were mounted on a chassis bolted to the floorboard of the trunk compartment. Whip antennas for the radio receivers were mounted on the vehicle's rear fenders.

8. A micro switch was mounted below the front bumper and connected to the ignition system. A trip line installed

20 to 40 feet (6.1 to 12.2 m) from impact triggered the switch; thus opening the ignition circuit and cutting the vehicle motor prior to impact.

9. The right front and right rear tires were painted to delineate wheel contact and climb on the guardrail face (front-red, rear-yellow).

For Test 276 the above procedures were followed except that instead of remote steering a cable guidance system was used to direct the vehicle into the barrier. The follow vehicle was used for remote braking. The guidance cable, anchored at each end of the vehicle path, passed through a pipe attached to a bracket on the left front wheel spindle of the vehicle. A steel angle driven into the ground near the barrier projected high enough to knock the bracket off the vehicle just prior to impact so that the vehicle was free of the cable. Figure 1A shows the guidance bracket attached to the vehicle.

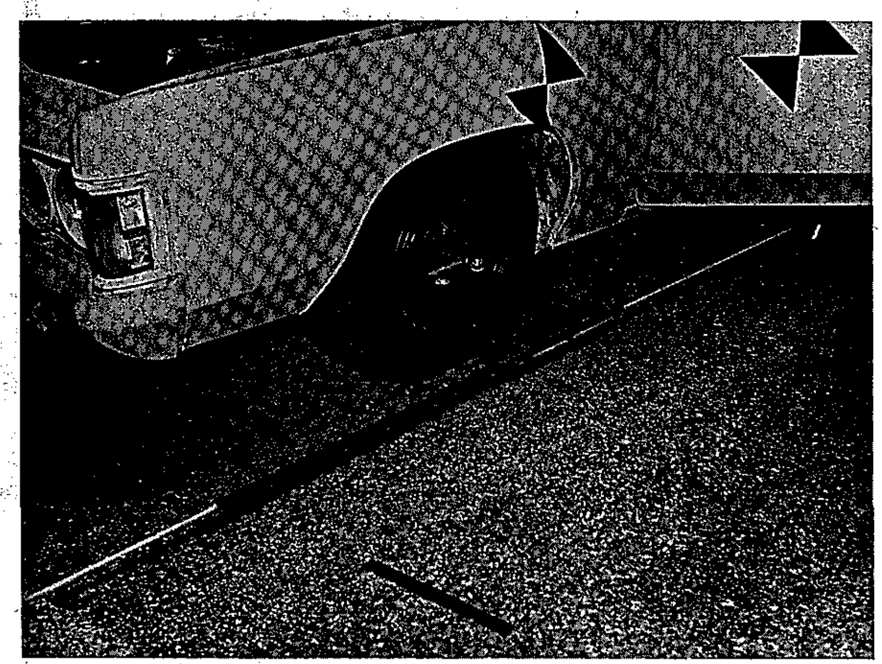


Figure 1A, Cable Guidance System Used in Test 276

B. Photo-Instrumentation

Data film was obtained by high speed cinematography through the use of seven Photosonic 16mm cameras (250-400 frames per second). These cameras were located on tripods to the front, rear, and sides of impact and on a tower 35 ft (10.7m) above impact. All cameras were electrically actuated from a central control console Figure 2A. An eighth Photosonic camera was located in the test vehicle to record the motions of the anthropometric dummy. This camera was triggered by a tether-line actuated switch mounted on the rear bumper of the test vehicle.

All cameras were equipped with timing light generators which exposed reddish timing pips on the film at a rate of 1000 per second. The pips were used to determine camera frame rates and to establish time-sequence relationships. Additional coverage of the impacts was obtained by a 70mm Hulcher operating at a rate of 20 frames per second, and a 35mm sequence camera operating at 20 frames per second. Documentary coverage of the tests consisted of normal speed movies and still photographs taken before, during, and after each impact. Data reduction from the high-speed movies was accomplished on a Vanguard Motion Analyzer. Procedures taken to instrument the crash vehicle and the test site to assist in the reduction of data are listed below:

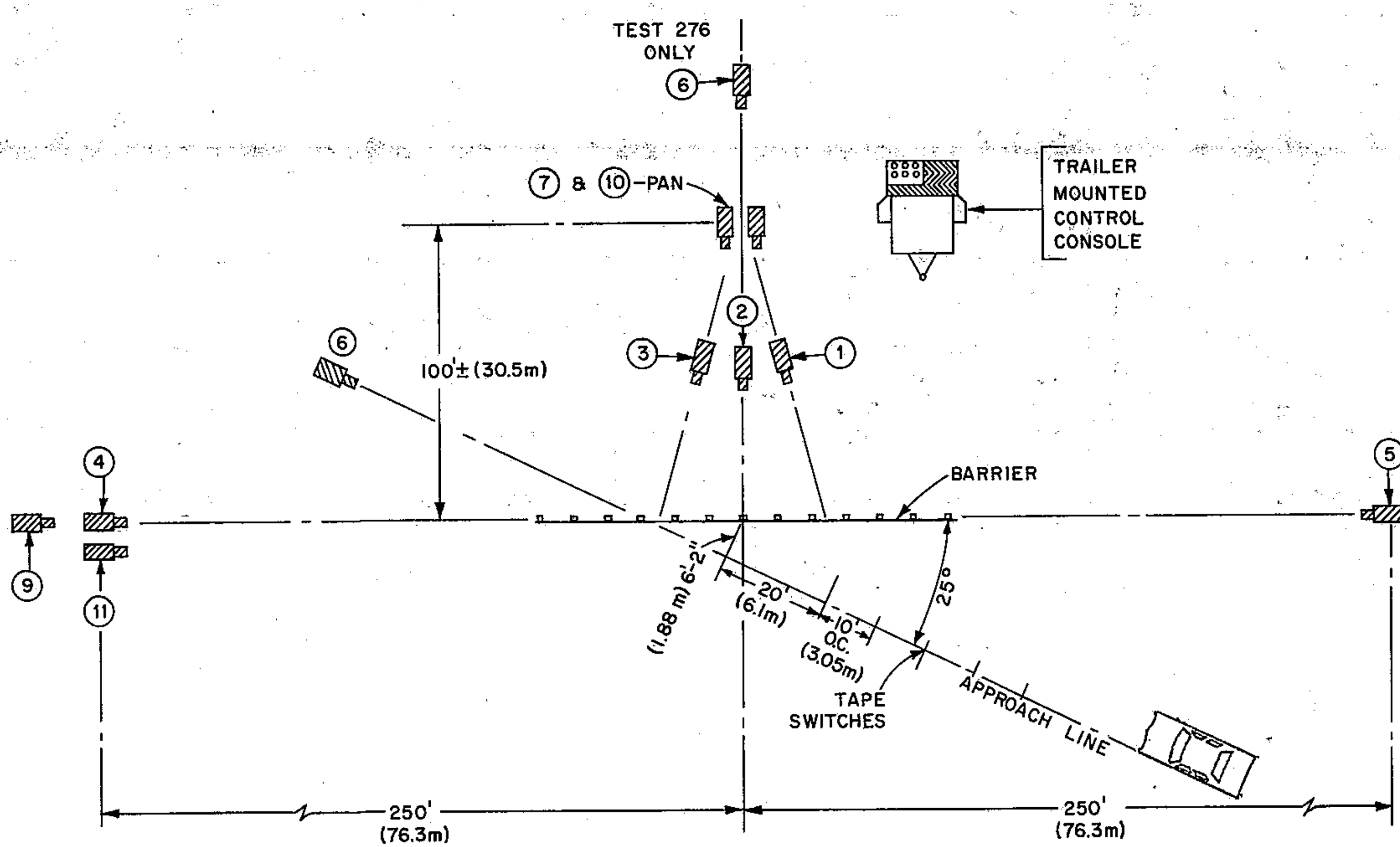
1. Targets were attached to the vehicle body and the face of the barrier, and placed at ground locations to the front and rear of the barrier.

2. Flashbulbs, mounted on the test vehicle, were electronically flashed to establish (a) initial vehicle/barrier contact and (b) the application of the vehicle's brakes.

3. Five tape switches were laid on the ground perpendicular to the vehicle path leading into the point of impact. Placed at 10-foot (3.05 m) intervals, the switches were actuated sequentially by the tires of the test vehicle, thus triggering a series of flashbulbs. The flashbulbs were in the field of view of all the data cameras and were used to correlate cameras to collision events and to determine the impact velocity.

C. Electronic Instrumentation and Data

A total of eight Statham accelerometers, of the unbonded strain gage type, were used for deceleration measurement. Of these, four were mounted, one in the chest and three in the head cavity, in the anthropometric dummy, and four were mounted on the floorboard of the test vehicle. In addition one seat belt transducer was installed on the dummy's lap belt. The nine transducers



CAMERA DATA

(1)(2)(3) PHOTO-SONICS, 13.0 MM LENS, 380 FPS,* MOUNTED ON 35' TOWER AND ORIENTED TO COVER THE AREAS INDICATED ABOVE.

(4)(5) PHOTO-SONICS, 4" LENS, 380 FPS.

(6) PHOTO-SONIC, 2" LENS, 380 FPS.

(7) PHOTO-SONIC, 2" LENS, 380 FPS.

(8) PHOTO-SONIC, 5.3 MM WIDE ANGLE LENS, 200 FPS, INSIDE TEST CAR.

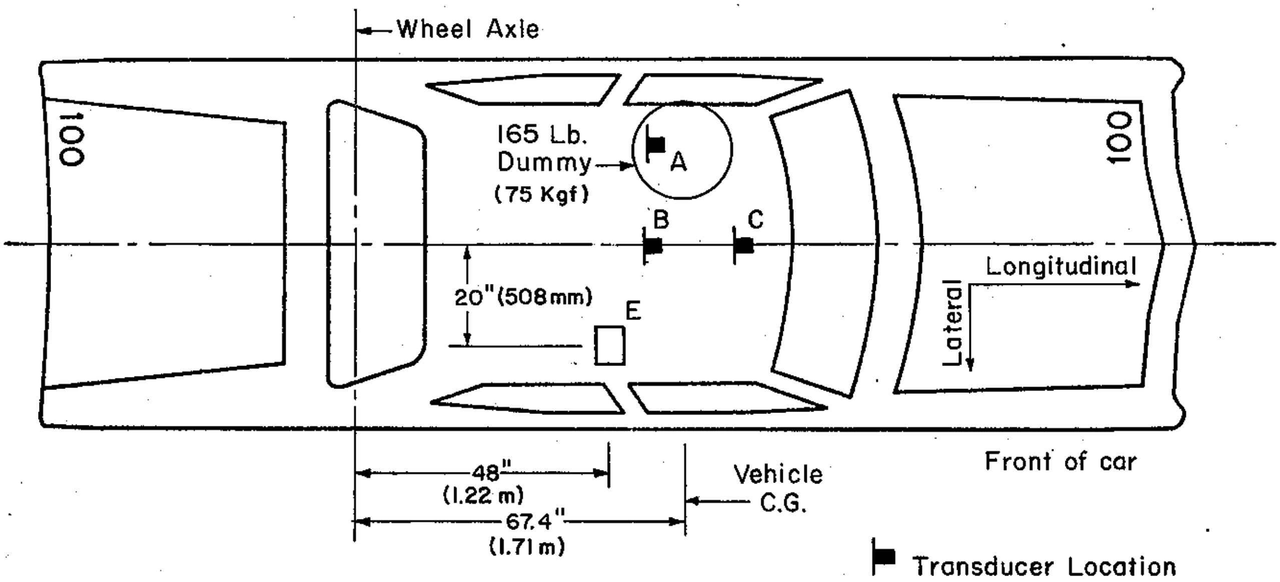
(9) HULCHER, 70MM SEQUENCE CAMERA, 12" LENS, MOUNTED ABOUT 12' HIGH ON SCAFFOLD.

(10) BOLEX, 1" LENS, 24 FPS.

(11) HULCHER, 35 MM SEQUENCE CAMERA.

*FRAMES PER SECOND

FIGURE 2A, CAMERA LAYOUT



DATA CHANNEL NO.	TEST		LOCATIONS
1	All	A	Longitudinal - Accelerometer in dummy's head.
2	All	A	Vertical - - - Accelerometer in dummy's head.
3	All	A	Lateral - - - Accelerometer in dummy's head.
4	All	A	Longitudinal - Accelerometer in dummy's chest.
5	273 & 274	C	Longitudinal - Accelerometer enclosed with foam in steel box mounted on car floor.
5	272 & 276	B	Longitudinal - Accelerometer mounted on C.G. of car floor.
6	273 & 274	C	Longitudinal - Side of steel box mounted on car floor.
6	272 & 276	B	Longitudinal - Accelerometer mounted on C.G. of car floor.
7	All	B	Lateral - - - Accelerometer mounted on C.G. of car floor.
8	All	B	Longitudinal - Accelerometer mounted on C.G. of car floor.
9	All	A	Seat belt transducer across dummy's lap.

Impact-O-Graph

All tests - Location E - Vehicle Floor.

NOTE: Location A (for accelerometers) is on the back of the head or in the chest cavity of the dummy; Location B is on a steel angle bracket welded to the floor at the vehicle center of gravity. Location C is on the longitudinal axis 30" forward of Location B.

FIGURE 3A - VEHICLE INSTRUMENTATION

transmitted data through a 1000 ft. (305m) Belden #8776 umbilical cable that ran from a rear mounting on the test vehicle to a 14 channel Hewlett Packard 3924C magnetic tape recording system. This recording system was mounted in an instrumentation trailer located in the test control area. Figure 3A shows the location of the transducers in the test vehicle. Three pressure activated tape switches were mounted on the pavement at fixed intervals in the vehicle approach path. When activated by the test vehicle's tires, these switches produced sequential impulses which were recorded with the transducer signals on the tape recorder. Concurrently a 100 millisecond time cycle signal was impressed on the tape. All of the tape recorder data were subsequently played back through a Visicorder which produced an oscillographic trace (line) on paper. Each paper record contained a curve of data from one of the nine transducers, the signals from the three tape switches, and the 100 millisecond time cycle marking. Some of the records of accelerometer data had high frequency spikes which made analysis difficult. Therefore, the original test data was filtered at 100 Hertz with a Krohn-Hite filter. The smoother resultant curves gave a good representation of the overall vehicle deceleration without significantly altering the amplitude and time values of the deceleration pulse. Transducer records from all tests are presented in Figures 5A through 13A.

A mechanical Impactograph was bolted to the test vehicle floorboards behind the right front seat. The mechanical styli of this device record lateral, longitudinal, and vertical impact forces. The records produced are not as accurate as those from the transducers because the Impactograph is insensitive to higher frequencies. However, it does provide a comparison of impact severity and serves as a back-up system in case the electronic system fails. The traces from the Impactograph are presented in Figures 14A and 15A.

A strain gaged clevis was used on the upstream end anchor, Figure 4A, to measure loads in the cable for all four tests and in the downstream anchor for Tests 273, 274 and 276. Records from these strain gages are shown in Figures 16A and 17A.

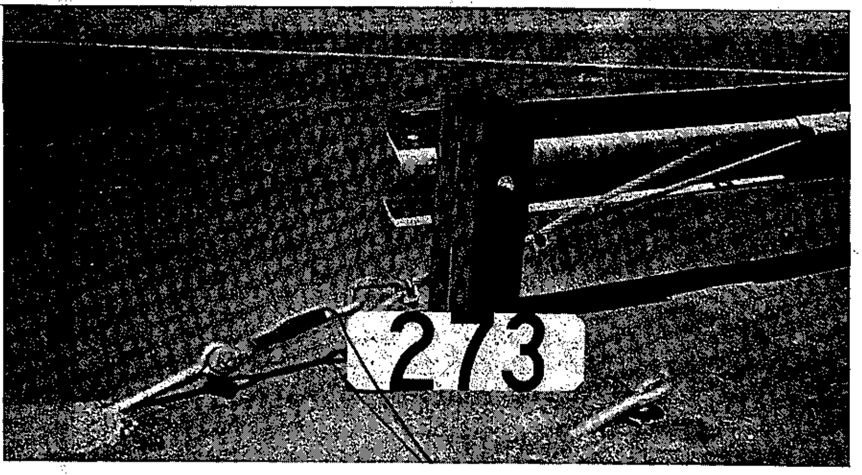


Figure 4A, Strain Gaged Clevis on Cable End

Figure 5A VEHICLE ACCELERATION VS TIME

TEST 272, 66 MPH, 26° DEGREES, LAP BELT

DATA FILTERED AT 100 HERTZ

8"x 8" WOOD POSTS

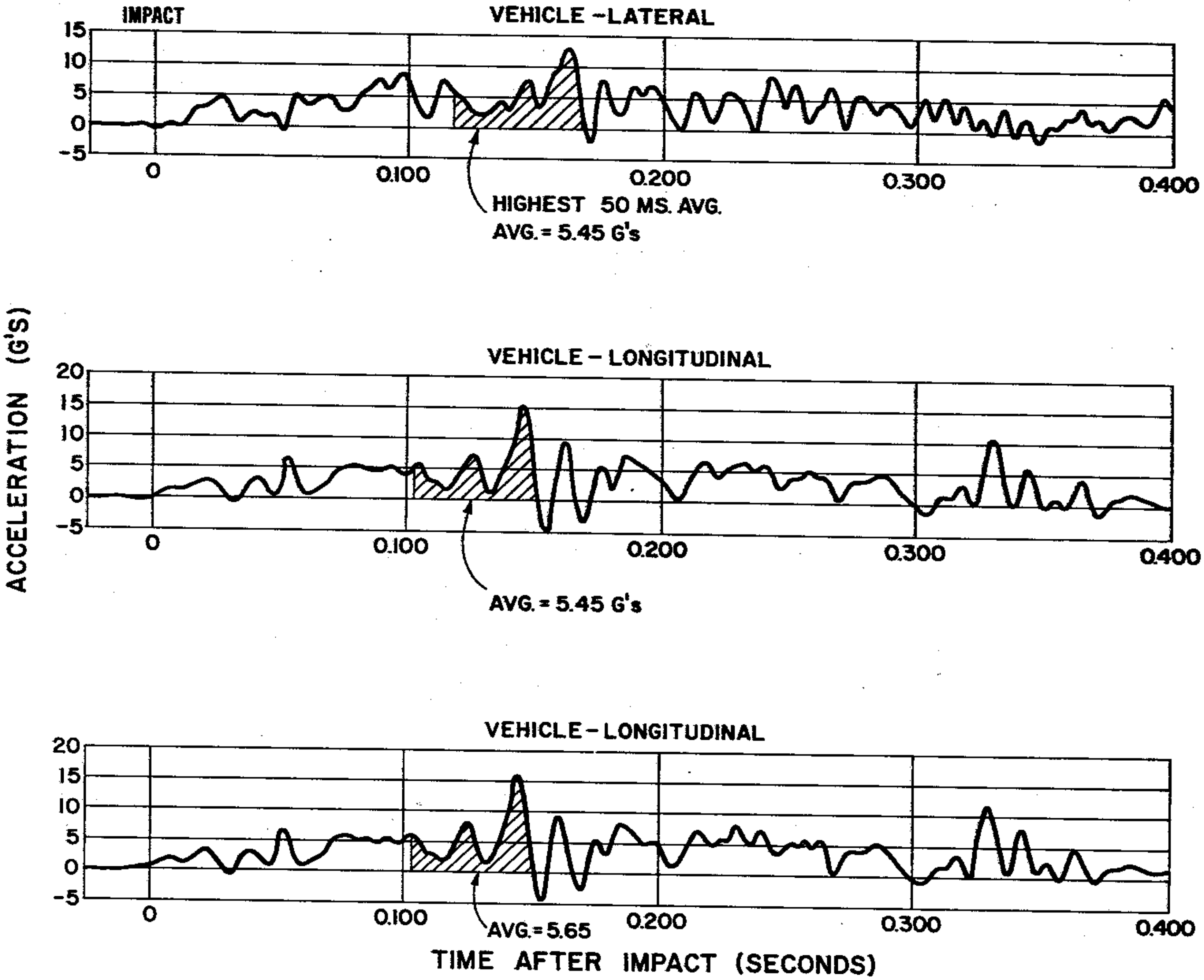


Figure 6A VEHICLE ACCELERATION VS TIME

TEST 273, 68 MPH, 24 DEGREES, LAP BELT

DATA FILTERED AT 100 HERTZ

6" x 8" WOOD POSTS

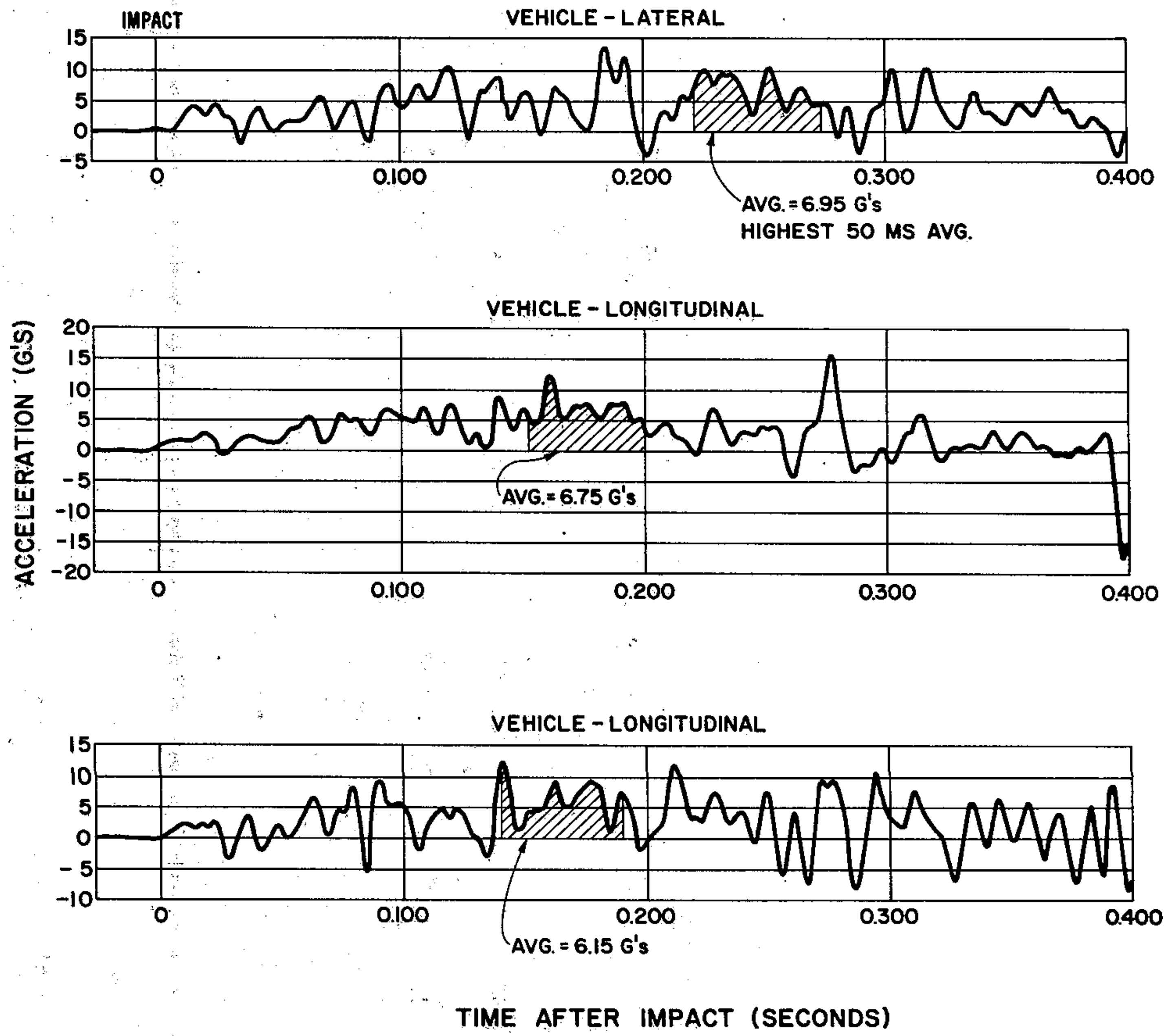


Figure 7A VEHICLE ACCELERATION VS TIME
TEST 274, 63 MPH, 24 DEGREES, LAP BELT
DATA FILTERED AT 100 HERTZ
W6 x 8.5 STEEL POSTS

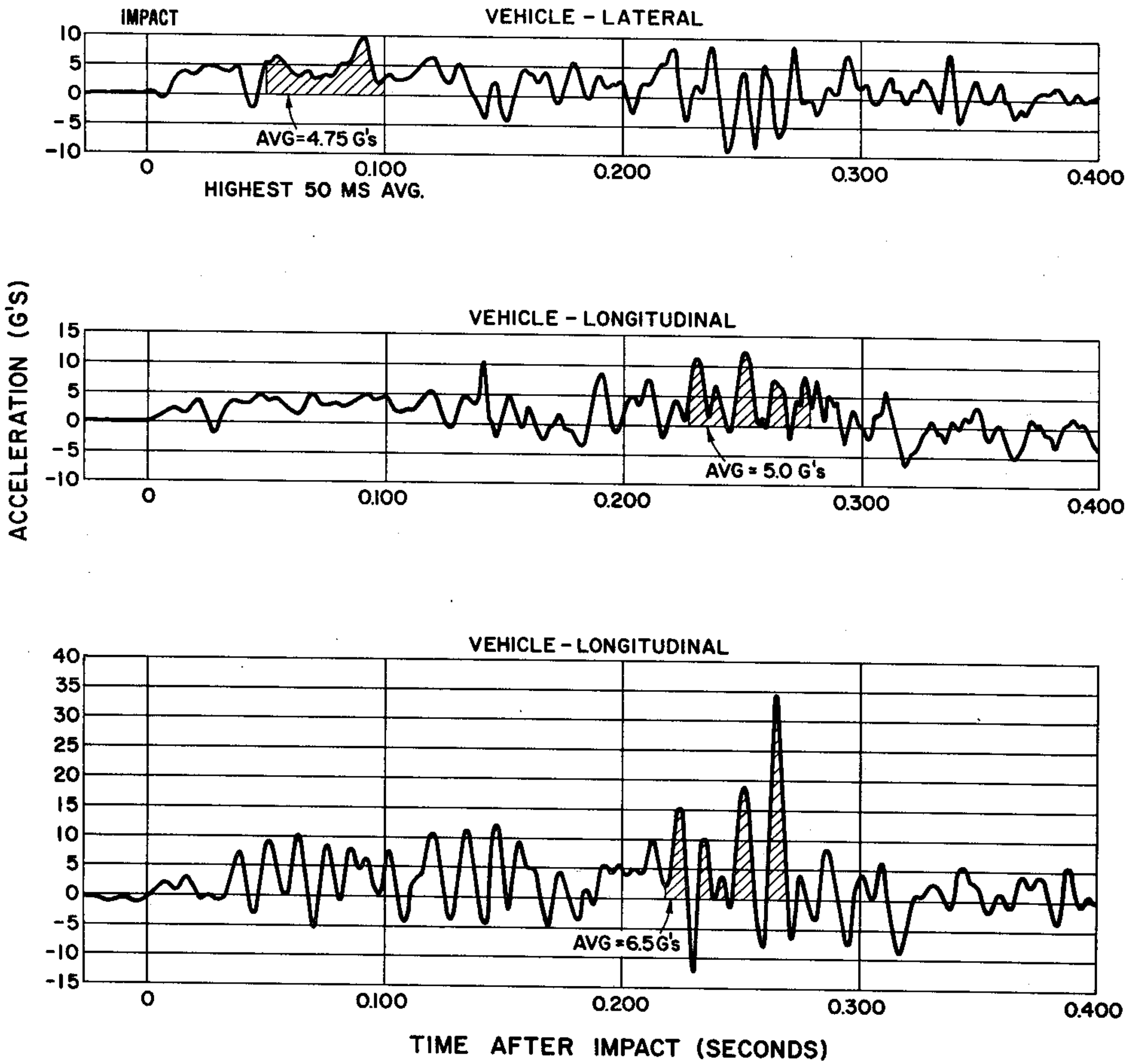


Figure 8A VEHICLE ACCELERATION VS TIME

TEST 276, 66 MPH 25 DEGREES, LAP BELT

DATA FILTERED AT 100 HERTZ

W6 x 8.5 STEEL POSTS

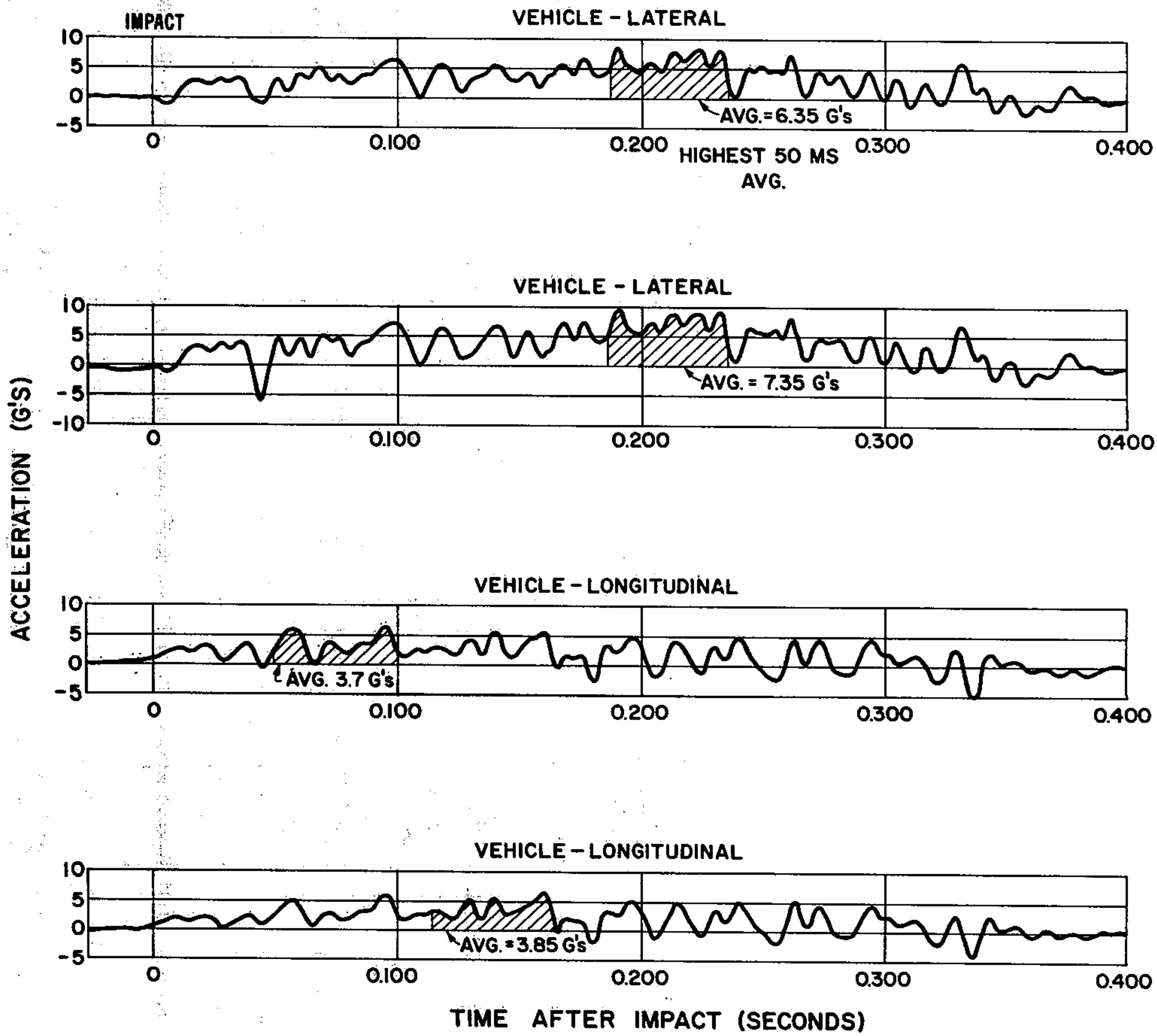


Figure 9A DUMMY ACCELERATION VS TIME
TEST 272, 66 MPH, 26 DEGREES LAP BELT
8"x 8" WOOD POSTS

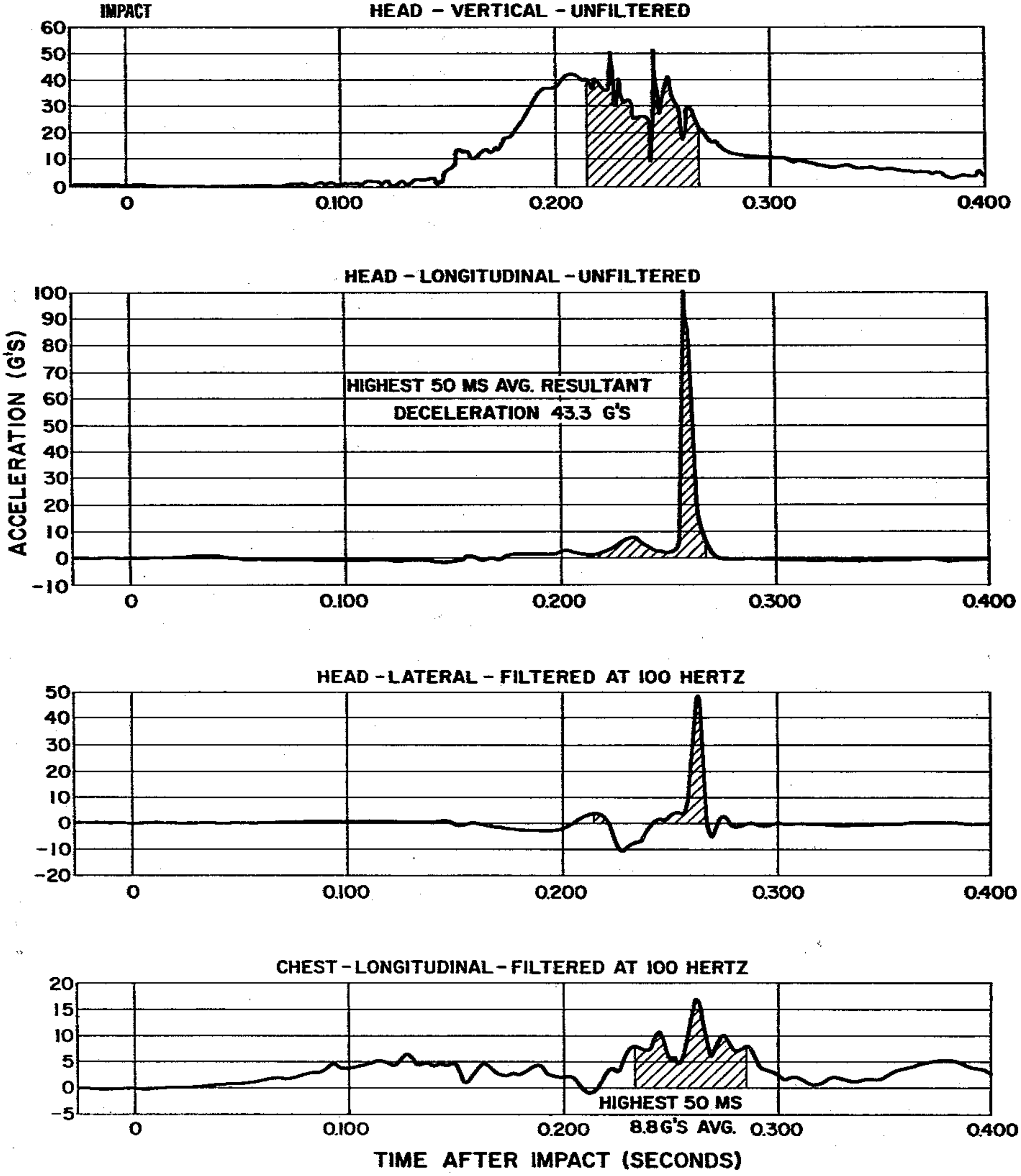


Figure 10A DUMMY ACCELERATION VS TIME
TEST 273, 68 MPH, 24 DEGREES LAP BELT
6"x 8" WOOD POSTS

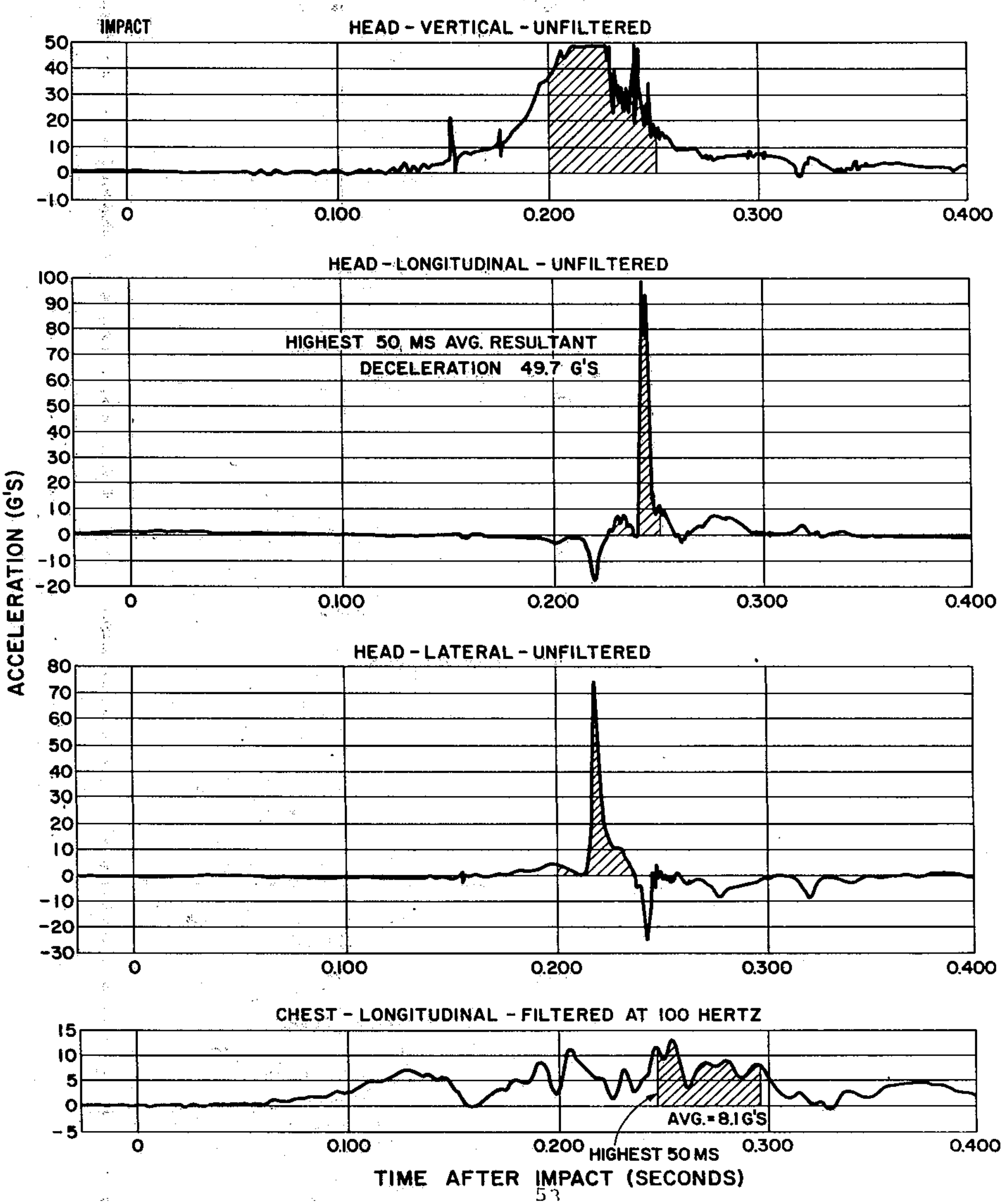


Figure 11A DUMMY ACCELERATION VS TIME
TEST 274, 63 MPH, 24 DEGREES LAP BELT
W6 x 8.5 STEEL POSTS

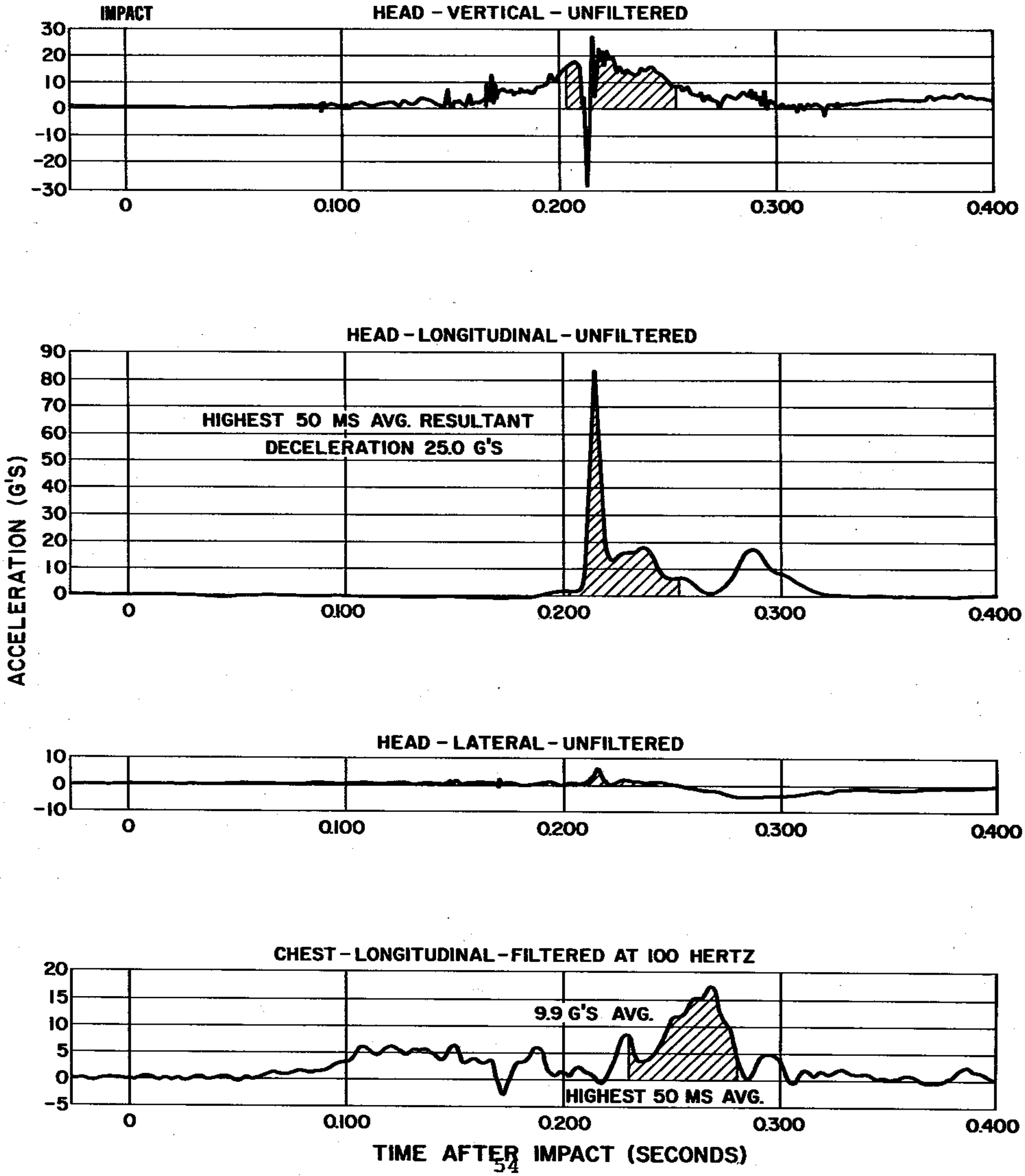


Figure 12A DUMMY ACCELERATION VS TIME
TEST 276, 66 MPH, 25 DEGREES LAP BELT
W6 x 8.5 STEEL POSTS

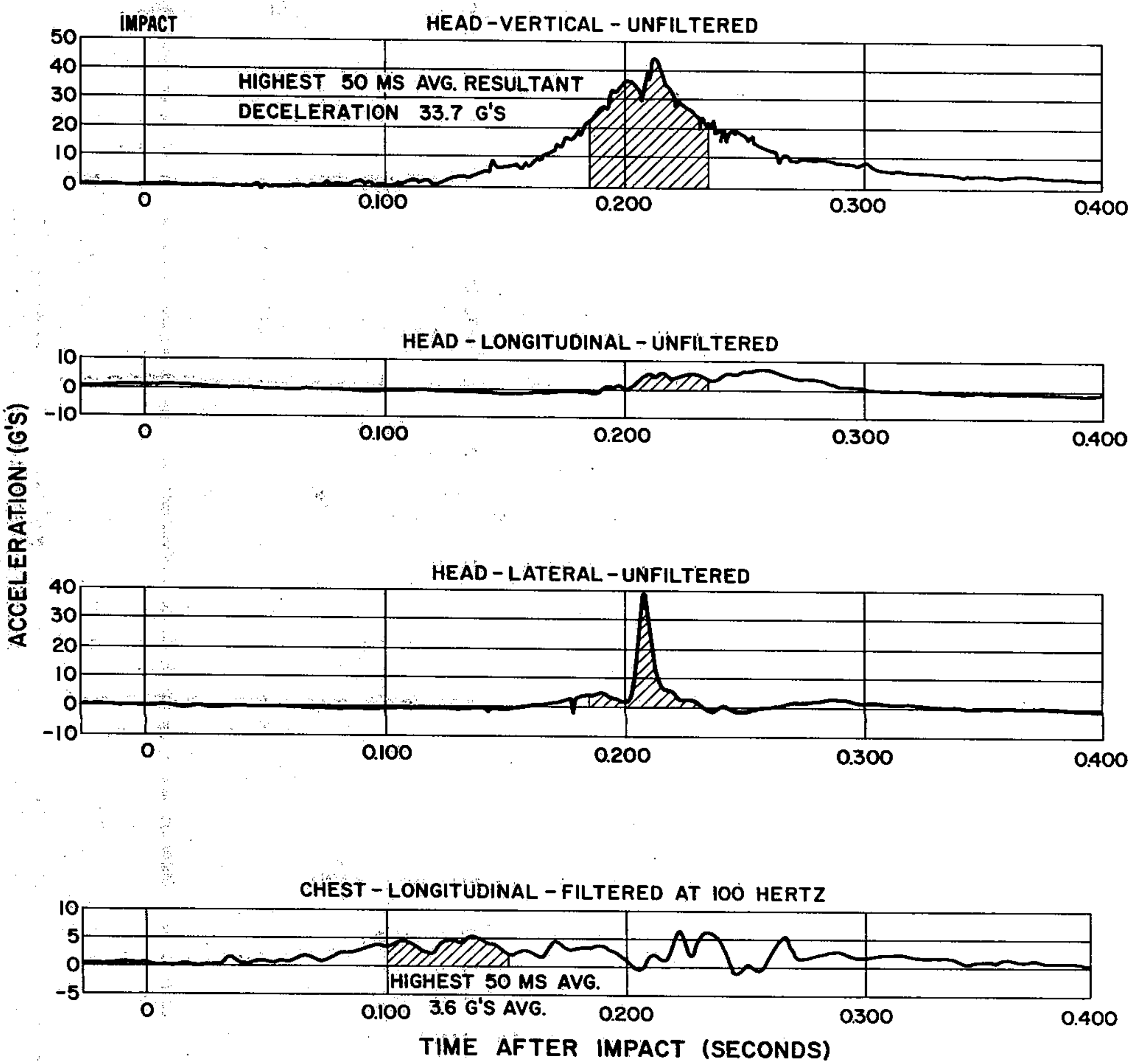
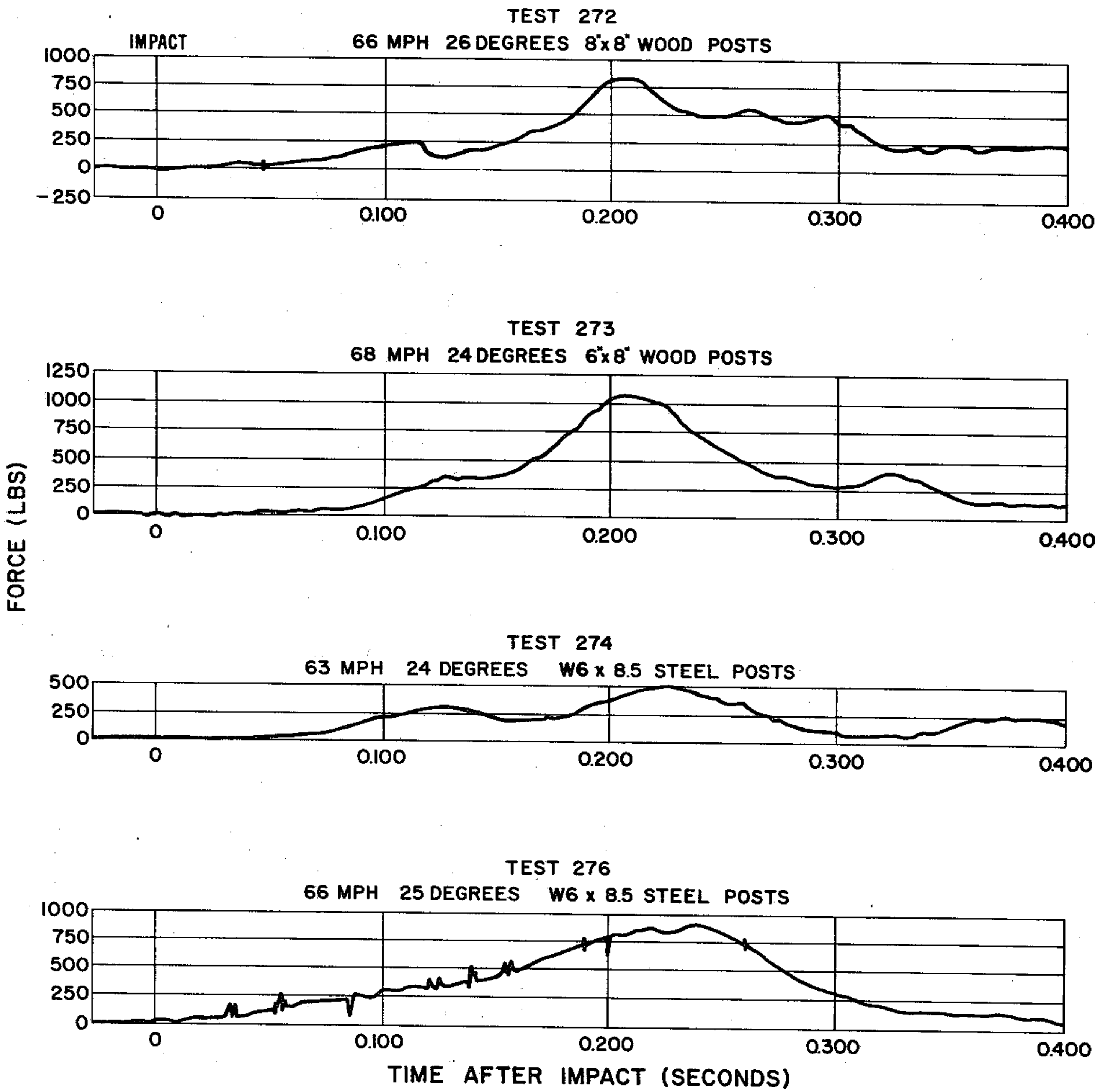
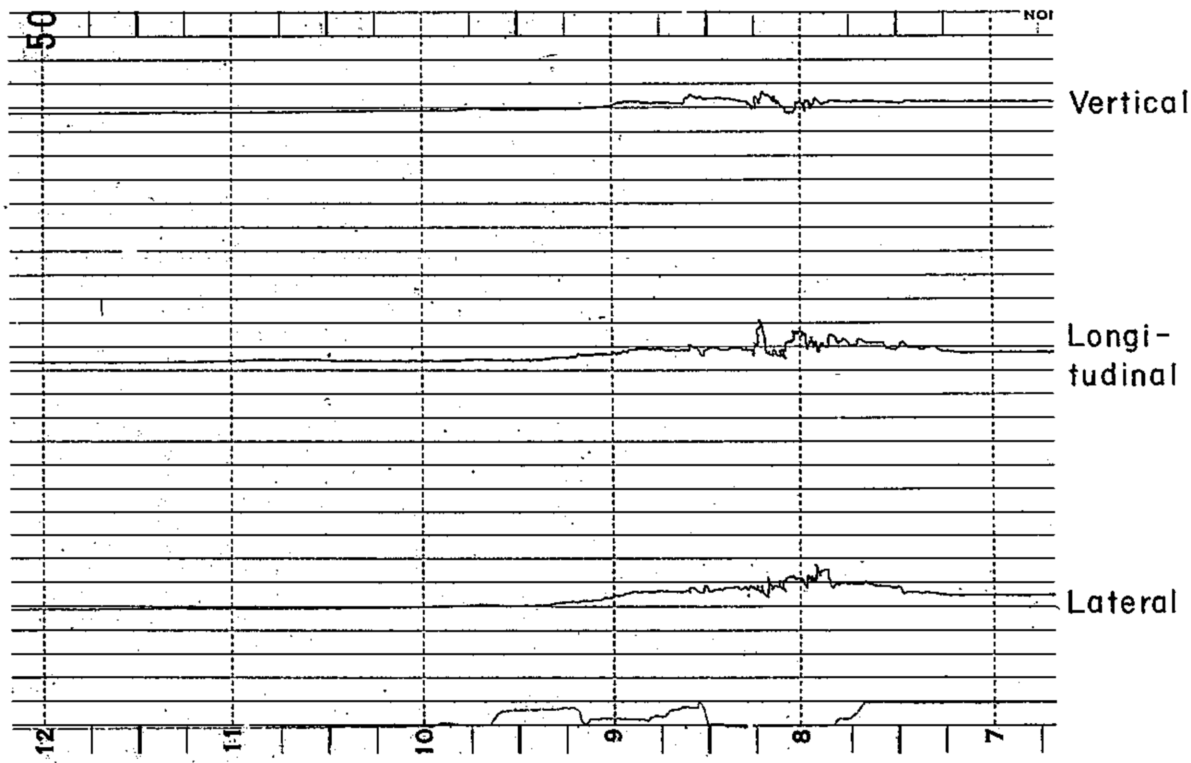


Figure 13A LAP BELT LOAD VS TIME

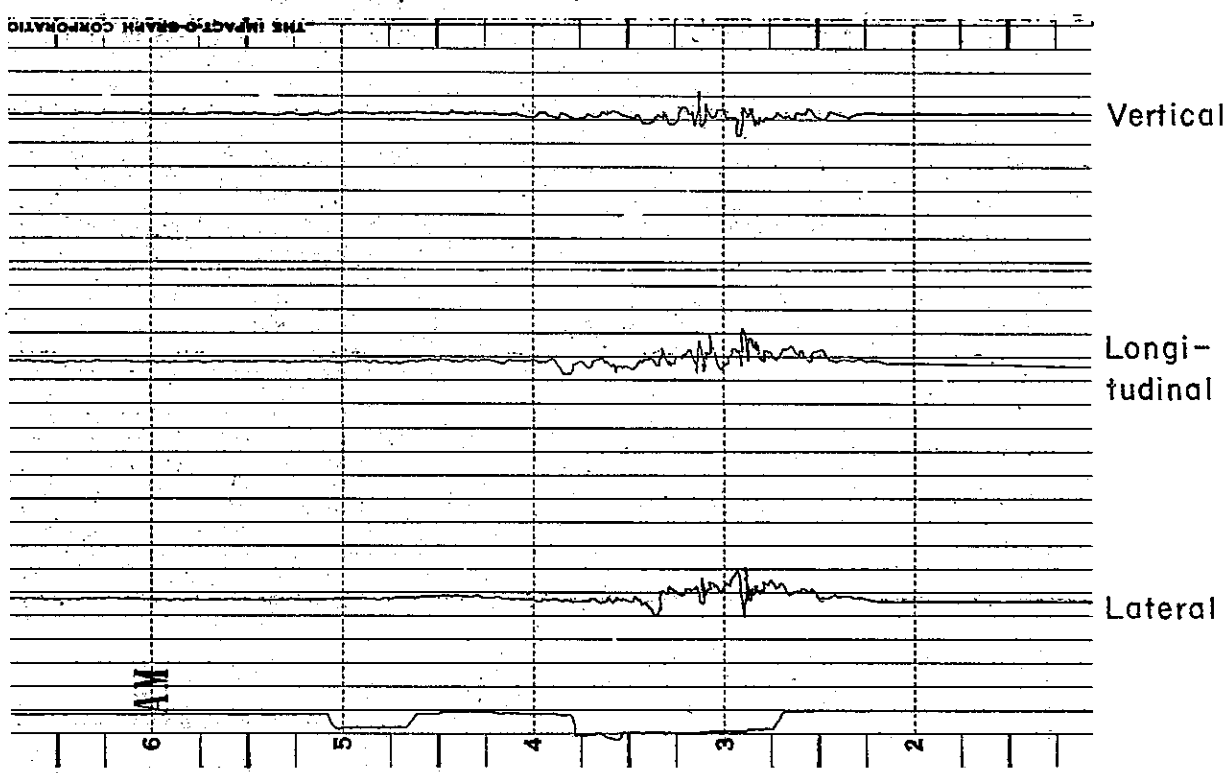
DATA UNFILTERED



TEST 272, 66 MPH, 26 DEGREES



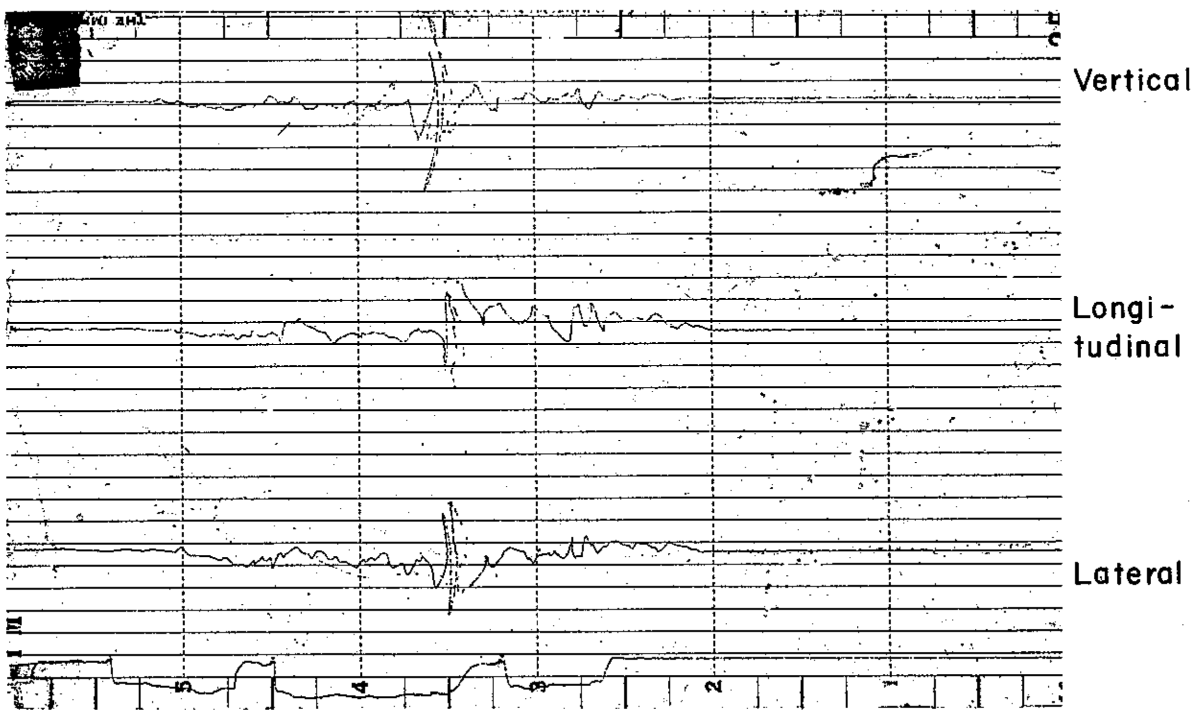
TEST 273, 68 MPH, 24 DEGREES



(Post-impact) TIME (6"/SEC ±) (Pre-impact)

FIGURE 14A VEHICLE IMPACTOGRAPH DATA

TEST 274, 63 MPH, 24 DEGREES



TEST 276, 66 MPH, 25 DEGREES

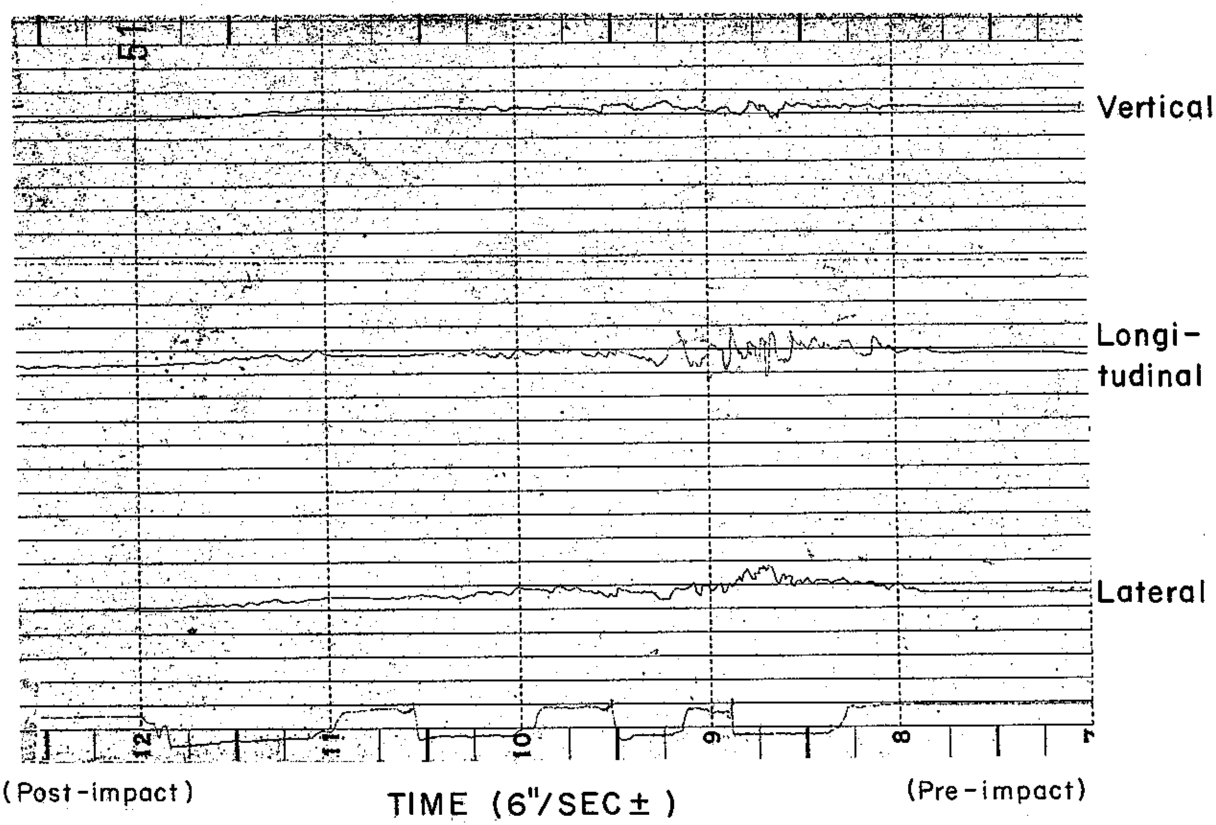


FIGURE 15A VEHICLE IMPACTOGRAPH DATA

Figure 16A UPSTREAM ANCHORAGE
LOAD VS TIME

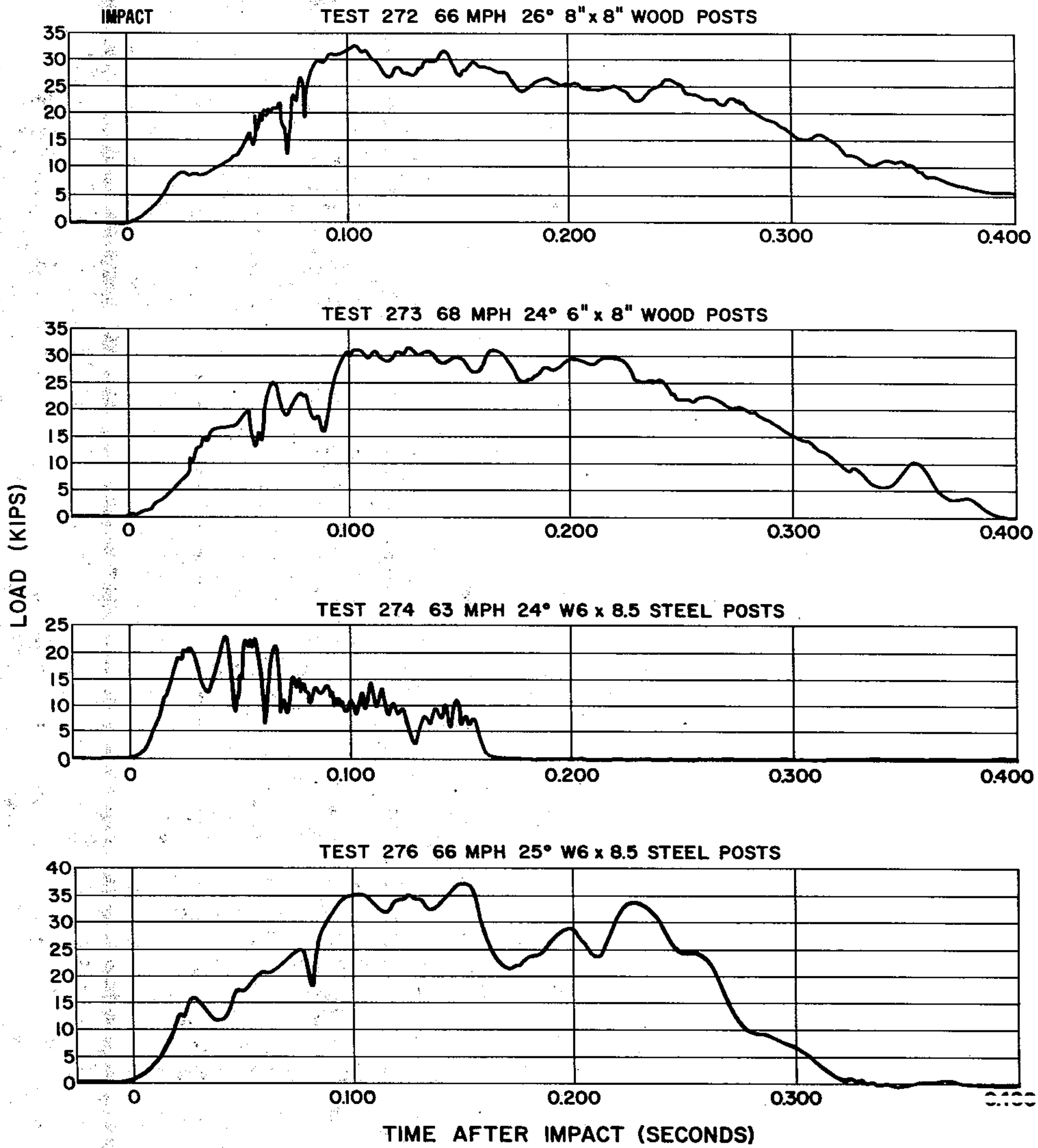
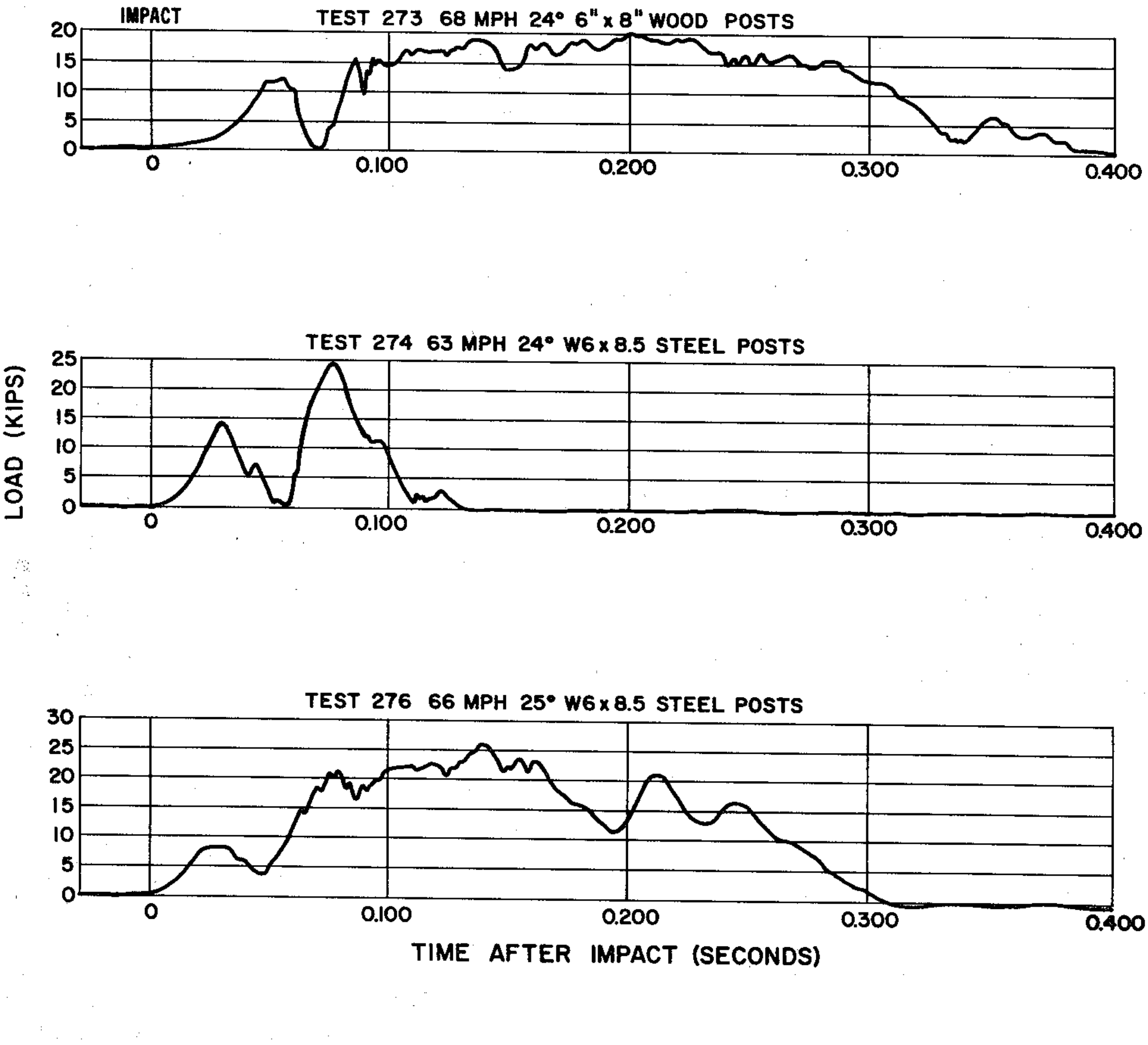


Figure 17A DOWNSTREAM ANCHORAGE
LOAD VS TIME



D. Material Test Report Summary

1. W-Section Rail Strength:

Test	Sample	Yield psi (kgf/mm^2)	Ultimate psi (kgf/mm^2)	Elongation %
273	1A	56,195 (39.5)	72,076 (50.7)	23
	1B	54,655 (38.4)	71,207 (50.1)	28
	2A	56,363 (39.6)	75,636 (53.2)	29
	2B	56,852 (40.0)	76,666 (53.9)	26
274	1	55,000 (38.7)	75,185 (52.9)	29
	2*	58,868 (41.4)	77,925 (54.8)	27
	3	57,547 (40.5)	76,038 (53.5)	29
	4	56,111 (39.4)	75,370 (53.0)	28

276 Rail specimens complied with AASHTO M-180 specifications.

Above specimens met the minimum requirements: 50,000 psi (35.2 kgf/mm^2) yield strength, 70,000 psi (49.2 kgf/mm^2) ultimate strength and 12% minimum elongation in 2 inches (50.8 mm) as specified in AASHTO M-180.

*This specimen taken from rail next to tear.

2. Wood Post cross-sectional dimensions - Test 273

(Measured after impact) These posts were ripped from 8" x 8" (203 x 203 mm) D.F. guardrail posts.

Post No.	Size (ft.)	Size (meters)
1	.660 x .495	.201 x .151
2	.650 x .490	.198 x .149
3	.650 x .495	.198 x .151
4	.670 x .490	.204 x .149
5	.660 x .485	.201 x .148
6	Destroyed	
7	Destroyed	
8	.650 x .490	.198 x .149
9	.660 x .490	.201 x .149
10	.650 x .500	.198 x .153
11	.650 x .500	.198 x .153
12	.650 x .490	.198 x .149
13	.650 x .470	.198 x .143

3. Soil Report.

Following is the report on tests of soil samples from the test site by the Foundation Section of the Transportation Laboratory:

July 18, 1972

Mr. E. F. Nordlin

Research
Lab Auth 636392

Attention Mr. J. R. Stoker

Materials and Research Department

In April 1972 undisturbed soil samples were taken at the site of impact test research at the Lincoln Airport. The samples represent the material in which posts have been embedded when guard rail barriers are tested to evaluate the barriers' protective effect in accident situations. The purpose of the sampling was to determine the strength characteristics of the soil which tends to maintain the posts in their upright positions when hit by a moving vehicle. Five holes were drilled at each of three locations for a total of fifteen holes. The relative positions of the borings are shown on attached Figure 2.

Sampling was done using a Joy-22 drill rig and all test holes were made 4.5 feet deep. Each hole was uniformly sampled. The sampler was advanced three times per hole: from the surface to the 1.5-foot depth, from 1.5 feet to 3.0 feet, and from 3.0 feet to 4.5 feet. The samples were recovered in brass liners 2 inches in diameter by 4 inches in height and strength determinations were made using unconsolidated undrained (UU) triaxial testing.

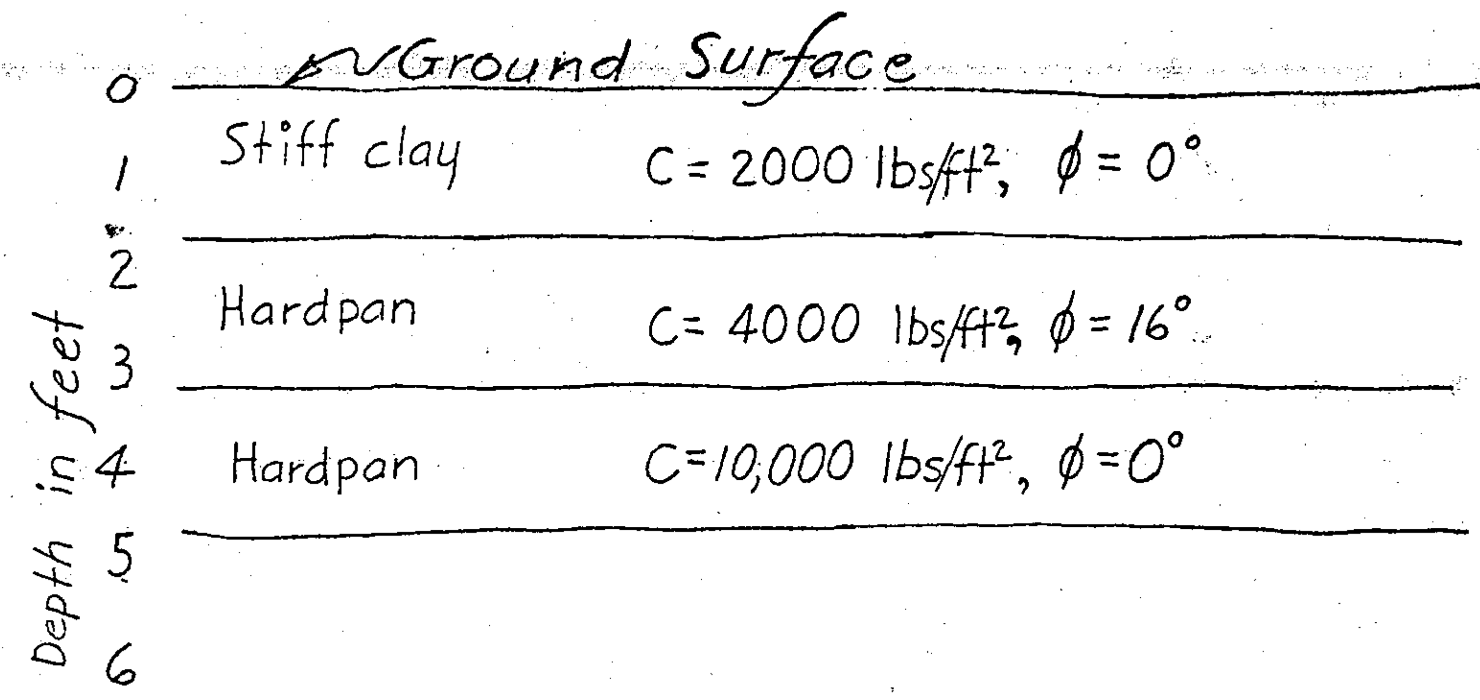
The top 1.5 feet of soil in the subject area is stiff, over-consolidated clay with UU strength parameters of 2,000 lb/ft^2 cohesion and 0° angle of internal friction. The soil between depths of 1.5 feet and 4.5 feet is particularly strong. In texture, it can be classified as sandy clay with gravel to clayey sand with gravel, and it is commonly referred to as "hardpan" due to extensive subsoil cementing. UU test parameters varied from 0° friction and 7,000 lb/ft^2 cohesion to 35° friction and 2800 lb/ft^2 cohesion for this material.

UU testing yields strength parameters "as sampled." These in-place parameters can vary with time due to changes in moisture content and/or overburden pressure. We are confident, however, that, in this situation, the parameters quoted above fairly represent the soils' strength over the entire period of impact testing. This confidence is due to the asphaltic cement pavement over the area which tends to reduce the escape of moisture to the air. Additionally, the clayey texture of the soil, with its low permeability, limits possible changes in soil water content due to internal migration of moisture.

A composite soil profile showing typical strength parameters for each sampling range is attached as Figure 1. Also accompanying this letter are all test sheets and boring logs accumulated in our work on the project. Reserve samples are available for additional testing, if necessary.

Raymond A. Forsyth
Assistant Materials and
Research Engineer - Foundation

BTS:ml
Attachments



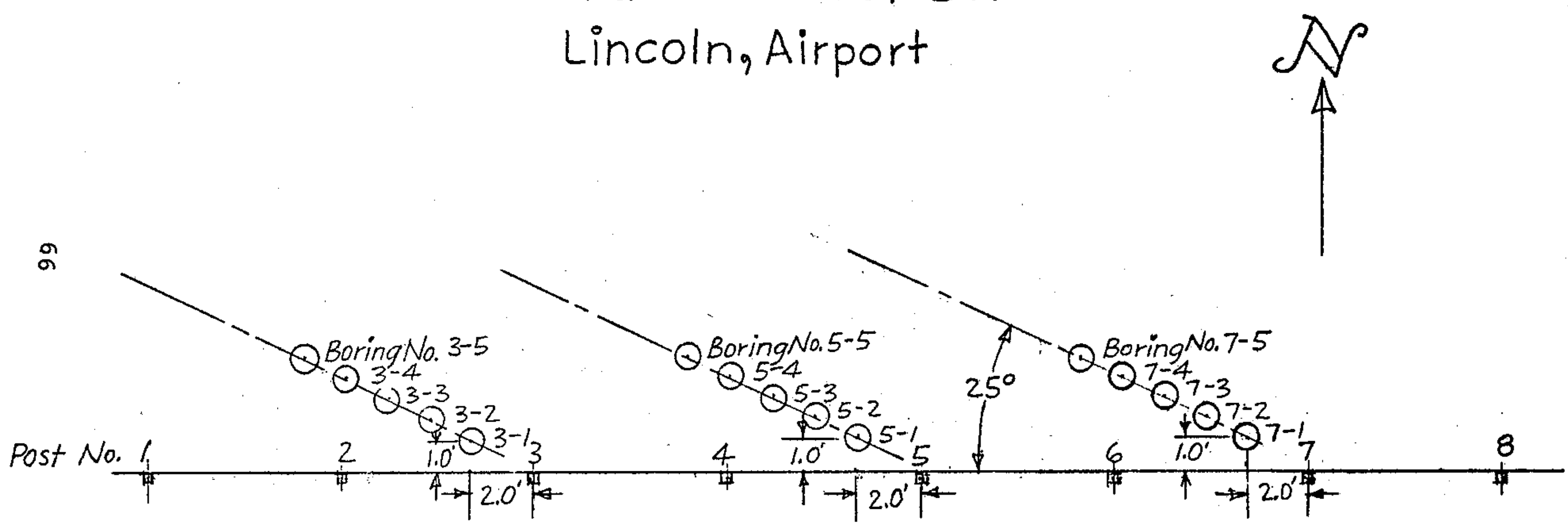
Composite Soil Profile
Lincoln, Airport

Fig. 1

Plan

Guard Rail Test Site

Lincoln, Airport



Scale: 1in = 5 ft.

Fig. 2

E. Detailed Analysis of Test 274

The following analysis is made with reference to Figure 19A which shows load vs. time of the end anchor cables during impact and events observed on the data movies at the specified times. Figure 20A also relates to this analysis.

Time After Impact	Event (Reference Figure 19A)
I (Impact) + 0 to I+25 (milliseconds)	The rate of onset of load in the upstream cable is much higher for steel posts than wood posts. (Figure 16A). The wood posts, possessing much higher torsional rigidity, help the cable anchor carry the load.
I + 25 to I + 50	Upstream cable slips slightly, say 1"± (2.5 cm), due to the high rate of onset. The loss of tension in the W-section decreases its beam strength - the compressive bending stresses exceed the tensile cable stresses allowing the beam to buckle at post #5. Because of this hinge, post #5 is not moved (perpendicular to rail) prior to being impacted by the car.
I + 50 to I + 60	Post #5 is solidly hit by the car. The upstream cable slips drastically.
I + 60 to I + 80	The upstream posts are bent severely as they attempt to carry the tension in the upstream beam. The downstream anchor carries tension in accordance with the tension carried by the upstream posts.
I + 80 to I + 120	Rail has pocketed so far that car is tending to push rail downstream. Upstream anchor continues to slip.
I + 120 to I + 150	Post #6 is solidly hit by car. At upstream end, the bolts connecting the W-section to the blockouts are sheared off (or torn through rail).
I + 150	Rail is under engine compartment of car when it tears at the downstream face of post #6 (Figure 18A).
I + 205	Car hits post #7 which pushes the remaining portion of the downstream rail downstream.

The following are additional observations about this test:

1. Buckling of the blockouts did not occur prior to failure.

2. The steel posts did not move prior to being impacted. The wood post in our Tests 272 and 273 and the steel posts in Southwest Research Test #120 did move prior to impact[3]. (Figure 20A)

Test	Post	Post Embedment Length
Tests 272, 273	8" x 8" and 6" x 8": (203 x 203 mm and 152 x 203 mm)	36" (0.915 m)
Test 274	W6 x 8.5 (4" wide) (152 mm x 12.65 kgf/m) (102 mm wide)	Calif: 44" (1.12m)
Test 120		SWRI: 41 1/2" (1.05m)

3. Five cable clips were torqued to 50 ft.-lbs (6.92 m-kgf.) about 5 days prior to the test. The day before the test, they were checked and found to be between 35 ft.-lbs (4.84 m-kgf and 40 ft.-lbs. (5.53 m-kgf). They were retorqued to 50 ft.-lbs (6.92 m-kgf) at this time. Two or three days after the test, the downstream cable clips were checked again and found to be between 35 ft.-lbs (4.84 m-kgf) and 40 ft.-lbs (5.53 m-kgf).

   This is consistent with our recent cable clip study which showed torque relaxing from 50 ft.-lbs (6.92 m-kgf) to 32-38 ft.-lbs (4.42-5.26 m-kgf) in 4 to 5 days. The full strength of the cable was developed under static load conditions when the cable clip torque relaxed.

4. Calif. Test 132[2] exhibited failure characteristics similar to Test 274. The 62.5 ft (19.1 m) unanchored section on 8" x 8" (203 x 203 mm) wood post and blocks:

   a. Allowed a hinge to form at the post because of low tension in the rail;

   b. The post was therefore not pushed back far enough;

   c. The car hit the post directly;

   d. The entire upstream rail tore from its posts;

   e. The rail did not tear because the upstream end was completely loose.

Following are the test conditions compared for Test 274 and the SWRI Test #120.

	Vehicle Weight-Lbs kgf	Impact Speed-mph (km/hr)	Angle
SWRI #120	3813 (1730)	56.8 (91.5)	28.4°
Calif. #274	4960 (2260)	62.5 (101)	25°

(Impact point almost identical for these two tests.)

Anchorage: SWRI - Sloping beam end anchor (Texas Twist).
Calif - Cable end anchor with cable clips

Beam/Blockout Connection: SWRI - No washers.
Calif. - Plate washers

In the SWRI test, two posts, #13 and #14, were knocked loose from the rail - bolt heads pulled through rail.

Post Embedment: SWRI - 41 1/2" (1.12m)
Calif. - 44" (1.05m)

Soil Conditions: The SWRI posts moved considerably through the soil while the California posts did not move at all until "they were hit by the car." The California posts were driven into undisturbed soil with no predrilled hole. The SWRI posts were set in drilled holes which were backfilled and tamped.

Figure 18A, Test 274 Torn W-Section Beam

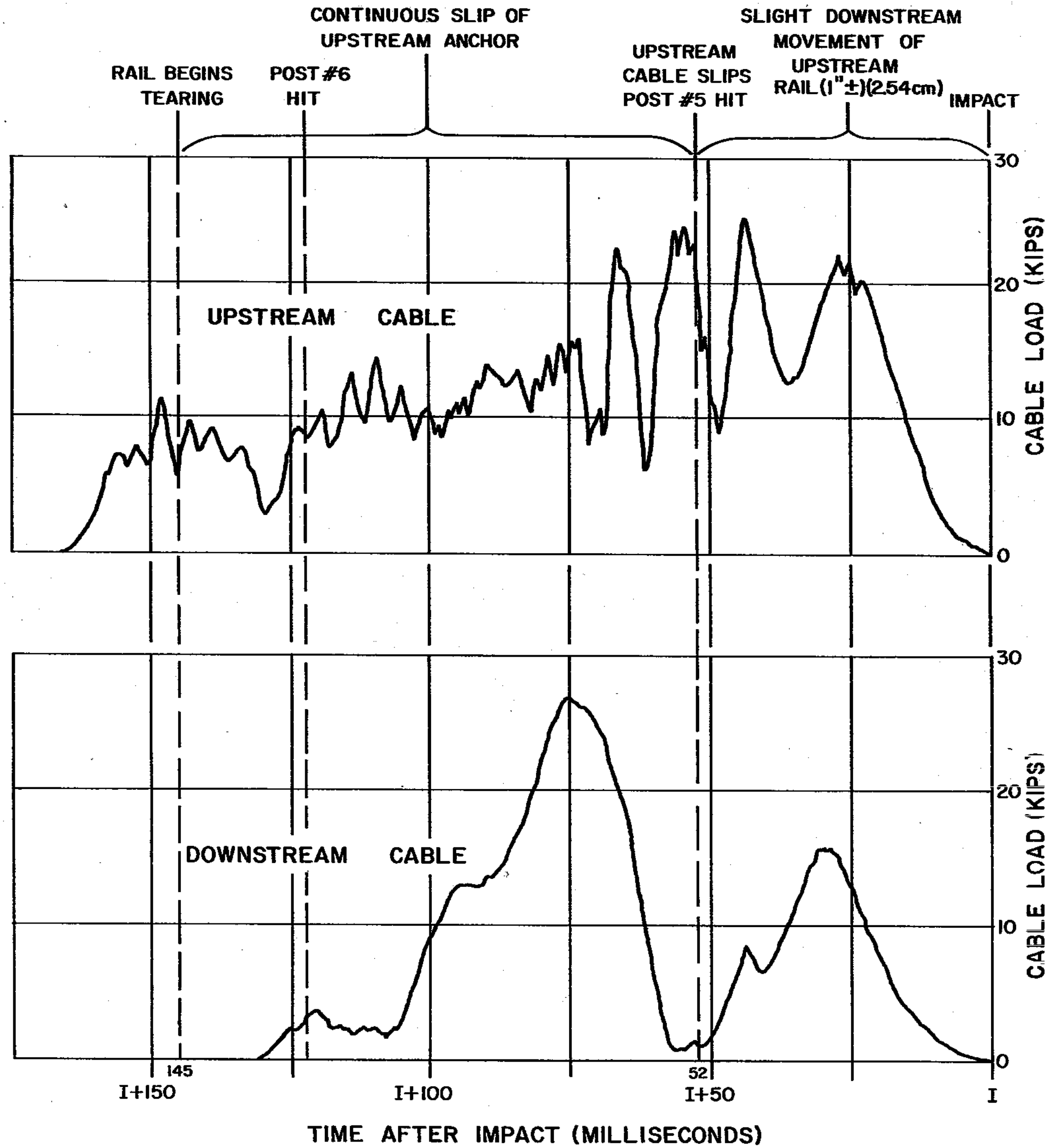
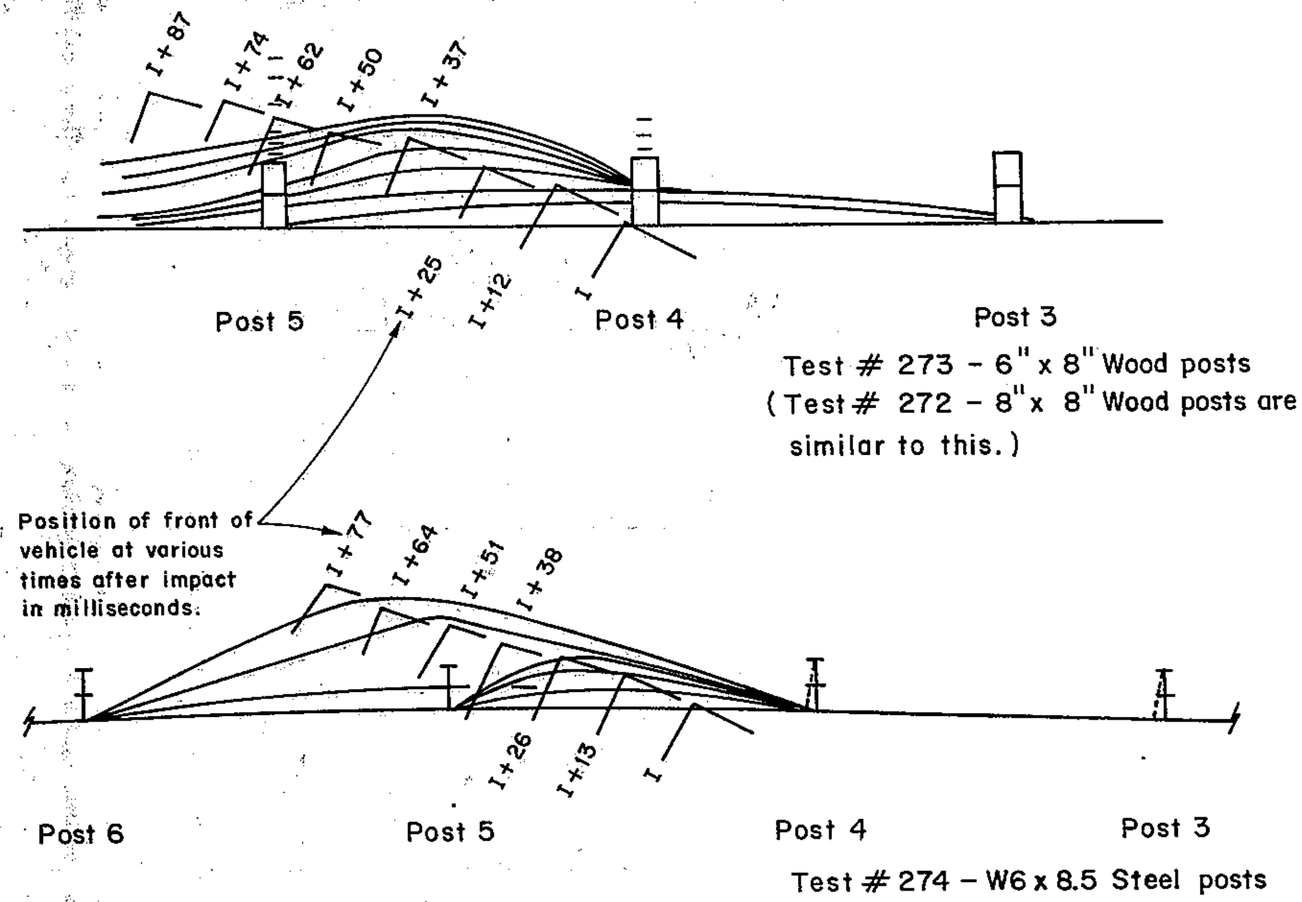


FIGURE 19A, TEST 274



These are tracings from overhead camera #2, as viewed on the Vanguard Motion Analyzer. Note that the steel posts do not move prior to being impacted by the car.

FIGURE 20 A

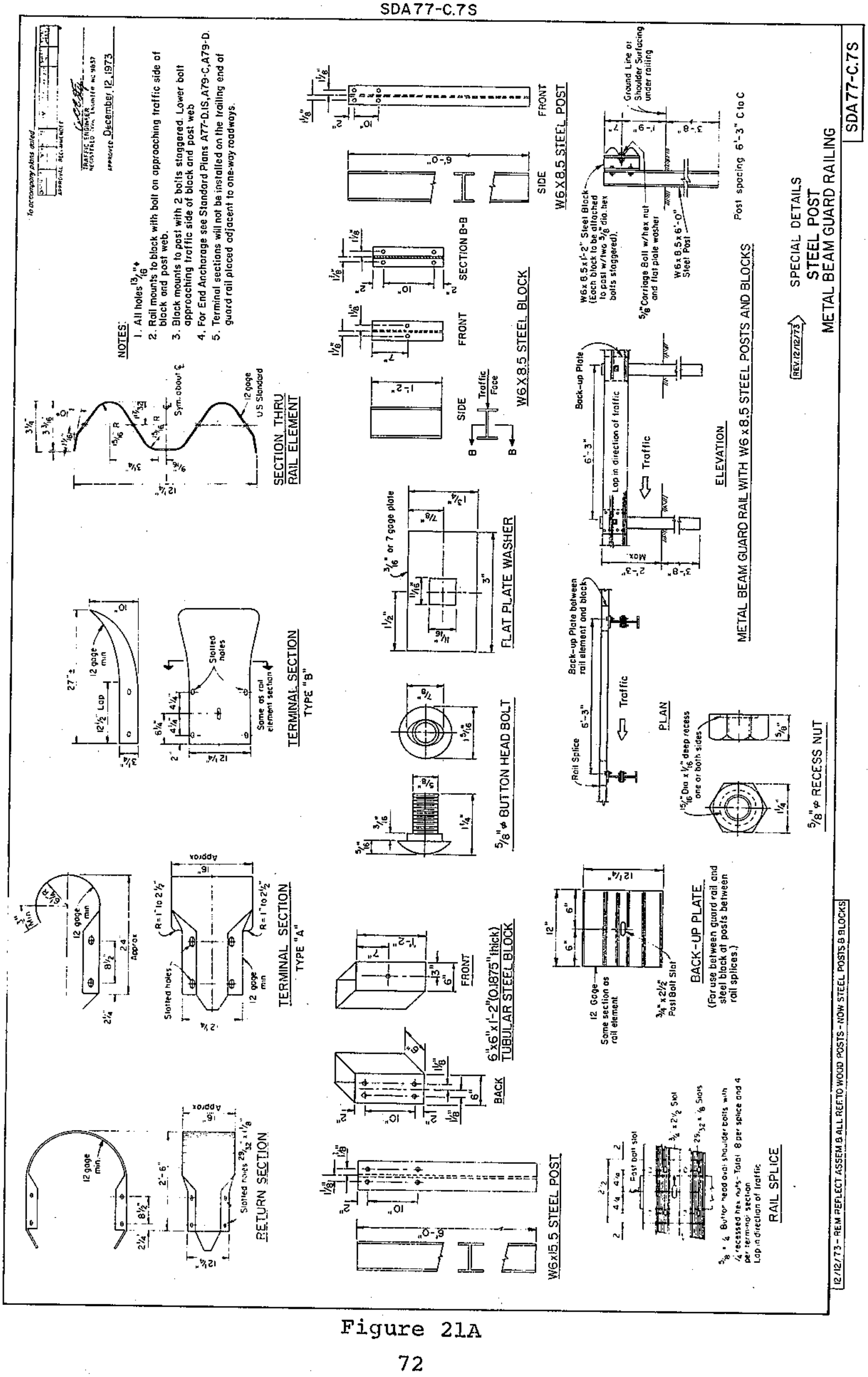

NOTES:
1. All holes 13/16"φ
2. Rail mounts to block with bolt on approaching traffic side of block and post web.
3. Block mounts to post with 2 bolts staggered. Lower bolt approaching traffic side of block and post web
4. For End Anchorage see Standard Plans A77-D.1S, A79-C, A79-D.
5. Terminal sections will not be installed on the trailing end of guard rail placed adjacent to one-way roadways.
Approved December 12, 1973
SECTION THRU RAIL ELEMENT
TERMINAL SECTION TYPE "B"
TERMINAL SECTION TYPE "A"
RETURN SECTION
W6X8.5 STEEL BLOCK
SECTION B-B
FLAT PLATE WASHER
5/8"φ BUTTON HEAD BOLT
6"x6"x1'-2"(0.1875" thick) TUBULAR STEEL BLOCK
W6x15.5 STEEL POST
W6X8.5 STEEL POST
ELEVATION
PLAN
METAL BEAM GUARD RAIL WITH W6x8.5 STEEL POSTS AND BLOCKS
5/8"φ RECESS NUT
BACK-UP PLATE
RAIL SPLICE
REV. 12/12/73
SPECIAL DETAILS
STEEL POST
METAL BEAM GUARD RAILING
SDA77-C.7S
12/12/73 - REM REFLECT ASSEM & ALL REF TO WOOD POSTS - NOW STEEL POSTS & BLOCKS

Figure 21A

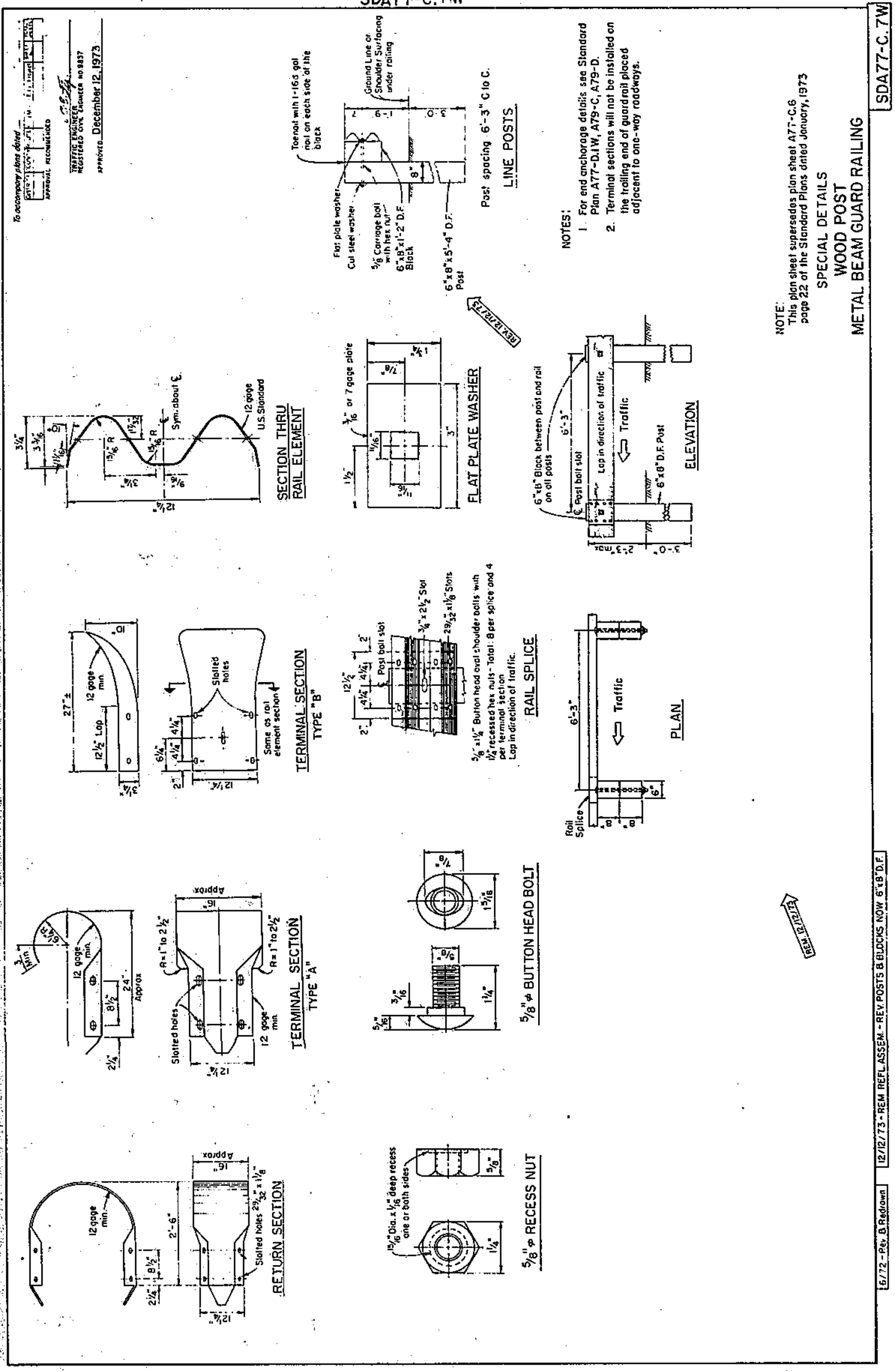

SDA77-C.7W
SPECIAL DETAILS
WOOD POST
METAL BEAM GUARD RAILING
NOTE:
This plan sheet supersedes plan sheet A77-C.6 page 22 of the Standard Plans dated January, 1973
NOTES:
1. For end anchorage details see Standard Plan A77-D.1W, A79-C, A79-D.
2. Terminal sections will not be installed on the trailing end of guardrail placed adjacent to one-way roadways.
LINE POSTS
Post spacing 6'-3" C to C.
ELEVATION
PLAN
SECTION THRU RAIL ELEMENT
FLAT PLATE WASHER
RAIL SPLICE
TERMINAL SECTION TYPE "B"
TERMINAL SECTION TYPE "A"
RETURN SECTION
5/8" ⌀ BUTTON HEAD BOLT
5/8" ⌀ RECESS NUT
APPROVED December 12, 1973
12/12/73 - REM REFL ASSEM. - REV. POSTS & BLOCKS NOW 6"x8" D.F.
6/72 - Rev. & Redrawn

Figure 22A

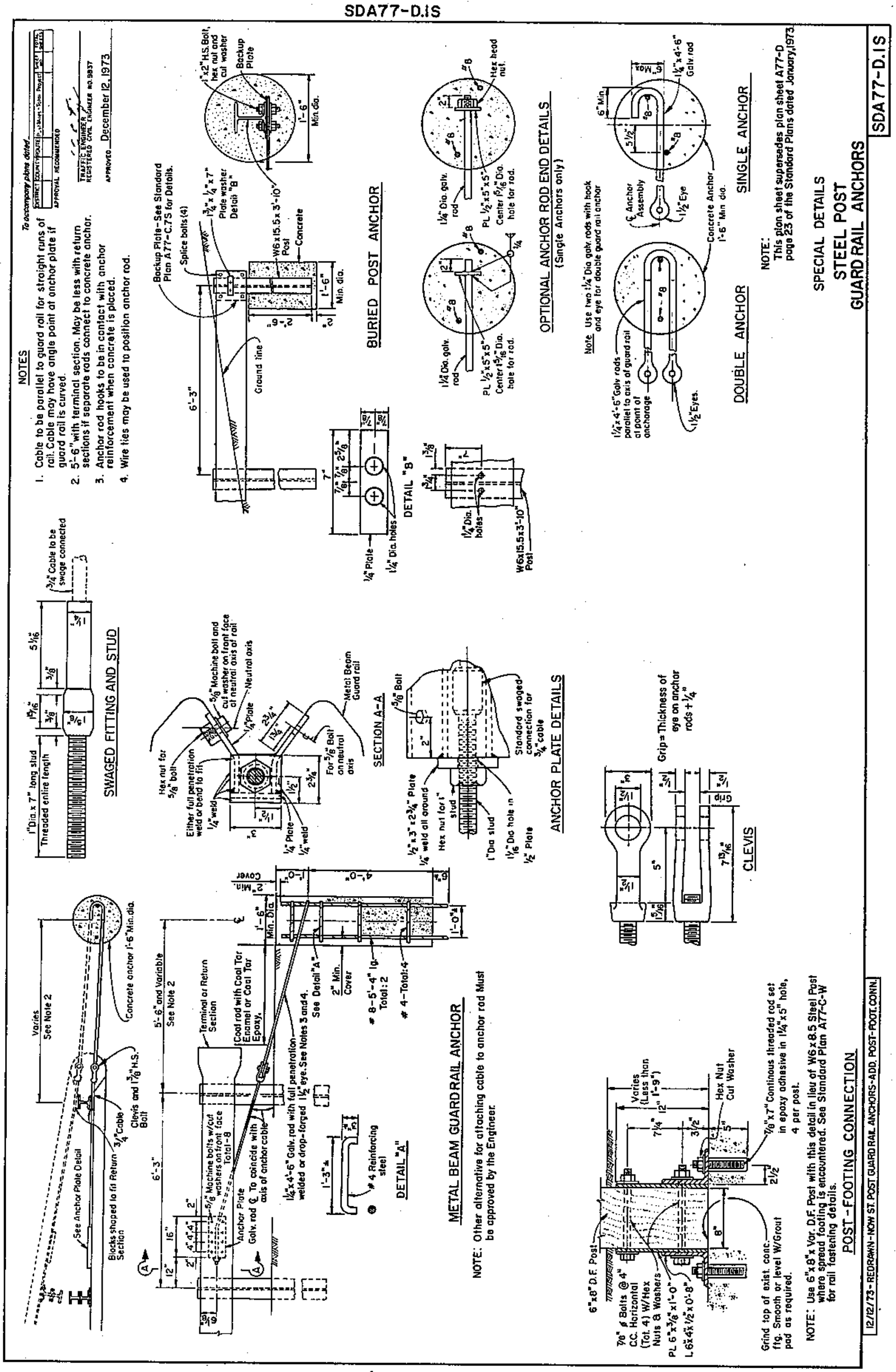

NOTES
1. Cable to be parallel to guard rail for straight runs of rail. Cable may have angle point at anchor plate if guard rail is curved.
2. 5'-6" with terminal section. May be less with return sections if separate rods connect to concrete anchor.
3. Anchor rod hooks to be in contact with anchor reinforcement when concrete is placed.
4. Wire ties may be used to position anchor rod.
BURIED POST ANCHOR
DETAIL "B"
OPTIONAL ANCHOR ROD END DETAILS
(Single Anchors only)
DOUBLE ANCHOR
SINGLE ANCHOR
NOTE: This plan sheet supersedes plan sheet A77-D page 23 of the Standard Plans dated January, 1973.
SPECIAL DETAILS
STEEL POST
GUARDRAIL ANCHORS
SDA77-D.IS
SWAGED FITTING AND STUD
SECTION A-A
ANCHOR PLATE DETAILS
CLEVIS
METAL BEAM GUARDRAIL ANCHOR
NOTE: Other alternative for attaching cable to anchor rod Must be approved by the Engineer.
DETAIL "A"
POST-FOOTING CONNECTION
APPROVED December 12, 1973
12/12/73-REDRAWN-NOW ST. POST GUARD RAIL ANCHORS-ADD. POST-FOOT. CONN.

Figure 23A

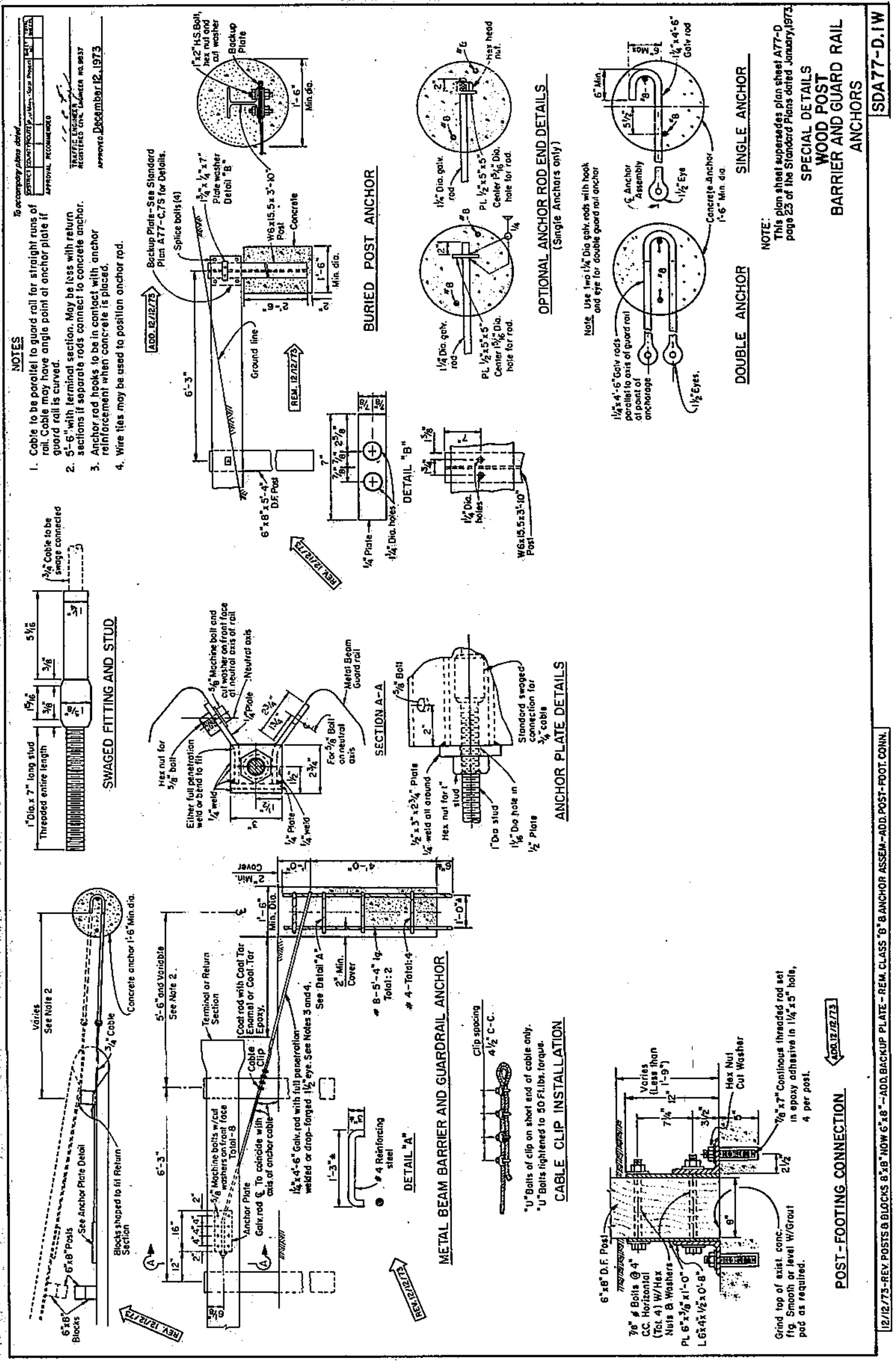

NOTES
1. Cable to be parallel to guard rail for straight runs of rail. Cable may have angle point at anchor plate if guard rail is curved.
2. 5'-6" with terminal section. May be less with return sections if separate rods connect to concrete anchor.
3. Anchor rod hooks to be in contact with anchor reinforcement when concrete is placed.
4. Wire ties may be used to position anchor rod.
BURIED POST ANCHOR
DETAIL "B"
OPTIONAL ANCHOR ROD END DETAILS
(Single Anchors only)
DOUBLE ANCHOR
SINGLE ANCHOR
NOTE:
This plan sheet supersedes plan sheet A77-D page 23 of the Standard Plans dated January, 1973.
SPECIAL DETAILS
WOOD POST
BARRIER AND GUARD RAIL
ANCHORS
SDA77-D.IW
SWAGED FITTING AND STUD
SECTION A-A
ANCHOR PLATE DETAILS
METAL BEAM BARRIER AND GUARDRAIL ANCHOR
DETAIL "A"
CABLE CLIP INSTALLATION
POST-FOOTING CONNECTION
APPROVED December 12, 1973
12/12/73-REV. POSTS & BLOCKS 8"x8" NOW 6"x8"-ADD. BACKUP PLATE-REM. CLASS "B" & ANCHOR ASSEM.-ADD. POST-FOOT. CONN.

Figure 24A