VEHICULAR CRASH TESTS OF A NESTED THRIE BEAM TRANSITION BARRIER

FINAL REPORT # FHWA/CA/TL-2001/09

STATE OF CALIFORNIA

DEPARTMENT OF TRANSPORTATION

ENGINEERING SERVICES

MATERIALS ENGINEERING AND TESTING SERVICES

Supervised by ....Dan Speer, P.E.

Principal Investigator ....Rich Peter, P.E.

Report Prepared by...John Jewell, P.E., Natane Clark

Research Performed by ....Roadside Safety Technology Unit

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May, 2002

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This project was performed in cooperation with the US Department of Transportation, Federal Highway Administration, under the research project titled "F99TL28".

16. ABSTRACT

In order to comply with a federal mandate, the California Department of Transportation initiated a project to develop a bridge rail transition design that met NCHRP Report 350 test level 4 (TL-4) criteria. During the project a total of three transition designs were tested. The first design pocketed, causing excess floorboard deformation in the test vehicle. The second design deflected excessively, causing the test vehicle to roll over. Tests of the third design using 2000-kg vehicles impacting two different locations on the transition proved to be successful. The third design was also tested with an 8000-kg vehicle in order to establish a TL-4 rating. The tests on the third transition design showed that it can successfully withstand the impact of both 2000-kg and 8000-kg vehicles, satisfying the requirements for structural adequacy, occupant risk and vehicle trajectory of NCHRP 350.

The third design is recommended for operational use as a TL-4 transition.

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SI CONVERSION FACTORS

To Convert From	To	Multiply By
	ACCELERATION	
m/s^2	ft/s^2	3.281
	AREA	
m^2	ft^2	10.76
	ENERGY	
Joule (J)	$ft.lb_f$	0.7376
	FORCE	
Newton (N)	lb_f	0.2248
	LENGTH	
m	ft	3.281
m	in	39.37
cm	in	0.3937
mm	in	0.03937
	MASS	
kg	lb_m	2.205
	PRESSURE OR STRESS	
kPa	psi	0.1450
	VELOCITY	
km/h	mph	0.6214
m/s	ft/s	3.281
km/h	ft/s	0.9113

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Other persons from Caltrans also made important contribution. Robert C. Anderson and Nahed Abdin (Division of Engineering Services - Office of Structures), Ellis Hirst (Division of Traffic Operations - Safety), and Joy Pinne (Division of Construction) assisted as technical consultants. Don Tateishi, Herb Holman and Lynn Harrison, from the Headquarters Photo Section helped to ensure that our photographic record was complete.

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1. INTRODUCTION

1.1. Problem

The Federal Highway Administration has set forth a number of deadlines after which new roadside safety hardware installations will have to comply with criteria embodied in the National Highway Safety Research Program (NCHRP) Report 350[1]. The deadline for new bridge rail transitions to meet these criteria is October 1, 2002. At the start of this research project, neither Caltrans nor the FHWA had approved or accepted transition designs that would meet NCHRP Report 350 test level 3 or 4 criteria.

1.2. Objective

The objective of this project was to develop and crash test a bridge rail transition that will successfully contain 820- to 8000-kg vehicles impacting between 80 and 100 km/h and at angles of 15° to 25°.

The Report 350 test level 4 test matrix for longitudinal barrier transitions is shown in Table 1-1 below. Since the transition includes a W-beam to thrie beam connector ("Y-section"), one additional test was added (4-21) to assess the effect of impacting that section.

Table 1-1 - Transition Test Matrix

Test designation	Vehicle	Nominal speed (Km/h)	Nominal Angle, ø (deg)
4-20	820C	100	20
4-21	2000P	100	25
4-21 (Y-section)	2000P	100	25
4-22	8000S	80	15

1.3. Background

In a recent study administered by the Federal Highway Administration (FHWA), it was determined that the existing transition designs failed to meet applicable NCHRP Report 350 criteria. The old transition designs were too flexible to connect to concrete bridge rails. To solve this problem, the FHWA issued Technical Advisory T5040.26 addressing the concerns regarding the transitions. The deadline for states to begin installing NCHRP Report 350-compliant transitions was set for October 1, 2002. Since Caltrans and the FHWA did not have a transition that would meet the NCHRP Report 350 test level 3 or 4 criteria, it was necessary for Caltrans to design a transition that would meet these requirements.

1.4. Literature Search

A search for information about the transition barrier mainly consisted of information contained in reports of past transition designs. Information was also found in:

- Testing of New Bridge Rail and Transition Design , FHWA-RD-93-058[2]
- The Triple T: Truck, Thrie beam, Transition, No. 950925[3]
- Development and Testing of an Approach Guardrail Transition to a Single Slope Concrete Median Barrier, TRP-03-47-95[4]
- Vehicle Crash Tests of Steel Bridge Barrier Rail Systems for Use on Secondary Highways, FHWA-CA-TL-93-01[5]
- Evaluation of Bridge Approach Rails, FHWA-AZ92-329[6]
- Safety Performance Evaluations: Bridge Rails and Approach Guardrail Transitions, No. 910264[7]

The literature research led to understanding that there is one recurring problem: transitioning from a flexible barrier to a rigid barrier may create a pocketing problem. Any effort made to eliminate one pocketing problem may create another. The solution is in the gradual increase in rigidity of the transition.

1.5. Scope

A total of three tests were performed and evaluated in accordance with NCHRP Report 350. The testing matrix established for this project is shown in Table 1-2. Tests 516 and 517 were conducted on transition designs that were found to be unacceptable. Tests 514, 518, and 519 were conducted on design 3, which met the TL-4 criteria.

Table 1-2 - Target Impact Conditions

Test Number	Barrier Type	Mass of Test Vehicle (kg)	Speed (km/h)	Angle (deg)
514	Transition D3	8000	80	15
516	Transition D1	2000	100	25
517	Transition D2	2000	100	25
518	Transition D3	2000	100	25
519	Transition D3	2000	100	25

2. TECHNICAL DISCUSSION

2.1. Test Conditions

2.1.1. Test Facilities

Each of the crash tests was conducted at the Caltrans Dynamic Test Facility in West Sacramento, California. The test area is a large, flat, asphalt concrete surface. There were no obstructions nearby except for a 2-m high earth berm 40 meters downstream from the barrier.

2.1.2. Test Barrier

The design of the transition underwent three variations. The primary objectives for the design of the transition were: 1) Gradually increase the stiffness of the transition between the upstream W-beam guardrail and the concrete bridge rail, 2) Minimize pocketing potential for the 2000-kg pickup, and 3) Minimize the snagging potential for both the pickup and the small vehicle.

Design 1

The first design transitioned between a W-beam guardrail and the concrete bridge rail in increments (Figure 5-16). The W-beam connected to a W-beam to thrie beam Y-section. The Y-section then connected to a thrie beam barrier, which in turn connected to a California Type 732 bridge rail (a concrete rail with a single-slope face at 9.1 degrees from vertical). All of the metal rail was 12-gage galvanized steel. The thrie beam section was attached to the concrete bridge rail with a metal box spacer designed to match the 9.1° slope of the concrete face. In order to smoothly transition the stiffness of the barrier, the post spacing was decreased from 1905 mm to 953 mm for the last six posts. The three wood supports closest to the bridge rail were 250-mm X 250-mm X 1.83-m Douglas Fir posts with 200 mm X 200-mm X 560-mm blockouts. The soil used in the test was a native clay material except for the top 250 mm, which was a fine aggregate base.

Design 2

The second design also transitioned from a W-beam guardrail to the concrete through the use of a “Y”-section and thrie beam section (see Figure 5-17). However, in order to solve the snagging and pocketing problem several changes in the design were introduced:

1) The Y-section of the barrier was switched from 12-gage to 10-gage.

2) The thrie beam section included a nested thrie beam in the front of the barrier and a single thrie beam in the back.

3) At the connection point with the transition barrier, the 732 concrete bridge rail was converted to a vertical concrete parapet with a 125-mm chamfer on the leading edge.

4) The thrie beam was directly attached to the concrete rail with four 24-mm bolts and a terminal connector instead of a metal box spacer.

5) The three 250-mm X 250-mm posts were lengthened from 1.83 m to 2.13 m.

All of the beam members were 12-gage galvanized steel except for the 10-gage "Y"-section. The soil conditions were not modified for Design 2. The terminal connector was sandwiched between the two front thrie beam sections.

Design 3

The second design solved the snagging problem, but deflection was still excessive. The third design (Figure 5-18) was very similar to the second. However, in order to solve the deflection problem the following changes in the design were introduced:

1) One of the nested thrie beam elements and the W-beam connecting to the Y-section were switched from 12-gage to 10-gage. All other steel beam elements were 12-gage galvanized steel.

2) The five posts closest to the bridge rail were all converted to 250 mm X 250 mm and lengthened to 2.44 m. The sixth post was also converted to 250 mm X 250 mm, but was not lengthened.

2.1.3. Construction

Caltrans did all construction for this project, with the exception of the bridge rail construction. Douglas fir was used for all wood components.

The Caltrans District 3 Maintenance Crew constructed the first design. Augers were used to dig undersized postholes. Posts were set in place by hand and pushed down with power equipment to the appropriate depth. The rail elements were installed using the auger boom for adjustments to the appropriate height. The connection to the concrete bridge rail was made with four M24 galvanized bolts. The soil was allowed to settle for several months before the first test. All bolts were tightened up before the first test.

Construction on the second design was performed by members of the Roadside Safety Technology Branch (engineers and technicians). Work included the removal of some posts and rails as well as modification to the concrete bridge rail. Again, the postholes were augered using the appropriately-sized auger bits. All of the replaced posts were backfilled with class 2 aggregate base. All splices were lapped in the same direction. A filler block was used to take up the gap on the fourth post created by using a 150-mm X 200-mm post instead of a 250 mm X 250 mm post. All bolts were tightened up before the first test.

The Roadside Safety Technology Branch staff also constructed the third design. A backhoe was used to dig a trench 640-mm wide and 1630-mm deep from the bridge deck to 300 mm beyond the third post. The trench was then backfilled with Class 2 aggregate base and compacted. The base material was augered for the posts. For ease of construction, the nested thrie beam section was assembled on the ground before being hoisted into position. All bolts were tightened before the tests. Repairs to the transition were made consistent with the initial construction.

2.1.4. Test Vehicles

The test vehicles complied with NCHRP Report 350. For all tests, the vehicles were in good condition, free of major body damage and were not missing structural parts. All of the vehicles had standard equipment and front-mounted engines. The vehicle inertial masses were within recommended limits (see Table 2-1).

Table 2-1 - Test Vehicle Information

Test No.	Vehicle	Ballast (kg)	Test Inertial (kg)
514	1995 Ford F800	2556	8011
516	1993 GMC 2500	0	1963
517	1989 Chevrolet 2500	0	2000
518	1997 Chevrolet 2500	0	1996
519	1994 Chevrolet 2500	0	1974

The pickups and truck were self-powered; a speed-control device limited acceleration once the impact speed had been reached. Steering was accomplished by means of a guidance rail anchored to the ground. Remote braking was possible at any time during the test for the pickups through a tether line, and in the case of the 8000S, by radio control. A short distance before the point of impact, each vehicle was released from the guidance rail and the ignition was turned off (for the Geo, the tow cable was released from the undercarriage). A detailed description of the test vehicle equipment and guidance systems is contained in Sections 5.1 and 5.2 of the Appendix.

2.1.5. Data Acquisition System

Each test was documented through the use of still cameras, video cameras, high-speed film cameras, and transient data recorders.

The impact phase of each crash test was recorded with seven high-speed, 16-mm movie cameras, one normal-speed 16-mm movie camera, one Beta format video camera, one 35-mm still camera with an auto winder and one 35-mm sequence camera. The test vehicles and the barrier were photographed before and after impact with a normal-speed 16-mm movie camera, a Beta format video camera and a color 35-mm camera. A film report of this project was assembled using edited portions of the film coverage.

Two sets of orthogonal accelerometers were mounted at the centers of gravity for each of the test vehicles. Rate gyro transducers were also placed at the centers of gravity of the test vehicles to measure the roll, pitch and yaw. The data were used in calculating the occupant impact velocities, ridedown accelerations, and maximum vehicle rotation.

A digital transient data recorder (TDR), Pacific Instruments model 5600, was used to record electronic data during the tests. The digital data were analyzed using a desktop computer.

2.2. TEST 516

2.2.1. Impact Description and Results

The vehicle speed and angle were 100.0 km/h and 25.0 degrees, respectively. The centerline of the vehicle was pointed directly at the leading edge of the concrete bridge rail. The impact occurred between posts 13 and 14 (the second and third posts from the concrete bridge rail). The contact with the barrier was limited to the length of rail between the initial contact point and the end of the thrie beam (about 2.6 m). The rail pocketed severely at the upstream end of the concrete bridge rail.

Upon impact, the front right corner of the vehicle began to crush, allowing the hood to ride over the post and rail elements of the transition. When the leading edge of the vehicle reached post 15 (i.e. the post nearest the concrete bridge rail), the barrier had dynamically deflected over 330 mm at post 15. The front right tire snagged at both the concrete parapet and the metal spacer, pushing the tire back into the firewall. As the rear of the vehicle reached the concrete, the back wheel rim snagged, ripping the rear axle from the suspension. The vehicle remained relatively level with a maximum pitch of 20 degrees.

The vehicle exited the barrier at a speed and angle of 76 km/h and 3 degrees, respectively.

Figure 2-1 - Test 516 Pre-Impact Dynamic

Figure 2-2 - Test 516 Post-Impact Dynamic 1

Figure 2-3 - Test 516 Post-Impact Dynamic 2

Figure 2-4 - Test 516 Post-Impact Dynamic 3

Figure 2-5 - Test 516 Post-Impact Dynamic 4

2.2.2. Barrier Damage

Damage to the barrier consisted of a pocketed thrie beam section, posts that had been pushed back, and a deformed metal box spacer. The maximum, permanent post deflection was 270 mm which occurred at post 15. Posts 13 and 14 also move significantly with 90 and 180 mm of deflection, respectively.

Figure 2-6 - Test 516 Barrier Damage

2.2.3. Vehicle Damage

Damage to the vehicle was extensive. The right side of the engine compartment was pushed back into the firewall. The right front tire was pushed back and under the doorjamb. The right door was crumpled and jammed. The rear axle was completely separated from the frame. The drive shaft had severed near the transmission. The windshield was severely cracked, but not penetrated. The maximum floor deformation on the passenger side was 210 mm.

Figure 2-7 Test 516 - Post Impact Vehicle Damage

Figure 2-8 - Test 516 Post Impact Occupant Compartment Damage

Figure 2-9 - Test 516 Data Summary Sheet


t = 0.000


t = 0.143


t = 0.285

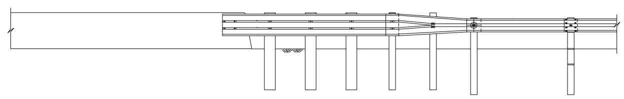

t = 0.428

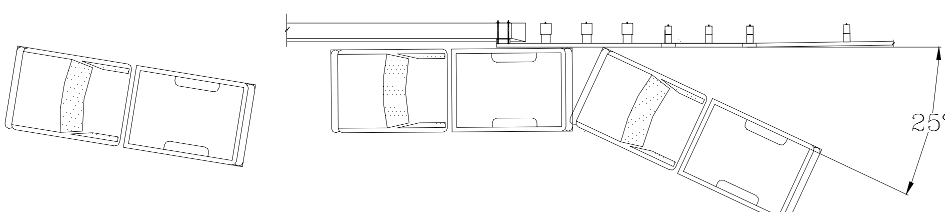

t = 0.571


t = 0.714


t = 0.857


t = 0.999





General Information:
- Test Agency ---------- California DOT
- Test Number --------- 516
- Test Date -------------- April 1, 1998

Test Article:
- Name ------------------- Transition Design 1
- Installation Length --- 5.715 m
- Description ------------

Test Vehicle:
- Model ------------------ 1993 GMC 2500 PU
- Inertial Mass --------- 1963 kg

Impact Conditions:
- Velocity --------------- 100.5 km/h
- Angle ------------------ 25°

Exit Conditions:
- Velocity --------------- 76 km/h
- Angle ------------------ 3°

Test Dummy:
- Type ---------------------- NA
- Weight / Restraint ---- NA
- Position ----------------- NA

Vehicle Interior:
- O.C.D.I. ---------------- RF1022000

Occupant Risk Values	*Longitudinal*	*Lateral*
Occupant Impact Velocity	10.62 m/s	7.39 m/s
Ridedown Acceleration	-8.11 g	-10.51 g

TEST 517

2.3.1. Impact Description and Results

The vehicle speed and angle were 100.5 km/h and 26 degrees, respectively. The centerline of the vehicle was pointed directly at the leading edge of the concrete bridge rail. The impact occurred at post 13 (the third post from the concrete bridge rail). The contact with the barrier was limited to the length of rail from the point of impact to the end of the thrie beam (about three meters). The pocketing from this test was substantially less than that of test 516.

The vehicle was smoothly redirected. Upon impact, the front right corner of the vehicle began to crush, allowing the hood to ride over the post and rail elements of the transition. The barrier had a maximum dynamic deflection of 190 mm at post 13. Posts 14 and 15 also deflected 145 and 180 mm respectively. The vehicle exited the barrier at a speed and angle of 85 km/h and 19.0 degrees, respectively.

As the vehicle lost contact with the barrier, it was lifted into the air with both a light roll to the right and a yaw to the left. This aerial maneuver was catastrophic for the vehicle, which underwent a 990-degree rollover ending with the vehicle upside-down.

Figure 2-10 - Test 517 Pre-Impact Dynamic

Figure 2-11 - Test 517 Post-Impact Dynamic 1

Figure 2-12 - Test 517 Post-Impact Dynamic 2

2.3.2. Barrier Damage

The barrier damage consisted of two bent thrie beam members and some posts that needed to be straightened. The greatest dynamic deflection was at Post 14 with a lateral deflection of 180 mm. The maximum permanent deflection was 95 mm at post 13.

Figure 2-13 - Test 517 Barrier Damage

2.3.3. Vehicle Damage

Damage to the vehicle was extensive. The right front corner of the vehicle sustained some damage prior to the rollover. The right third of the bumper was pushed pack into the tire. The hood was crumpled. A crease from the thrie beam extended along the entire right side of the vehicle.

The remainder of the damage was due to the rolling of the vehicle, which included the crushing of the cab and the hood.

Figure 2-14 - Test 517 vehicle Damage

Figure 2-15 - Test 517 Data Summary Sheet


t = 0.000


t = 0.143


t = 0.286

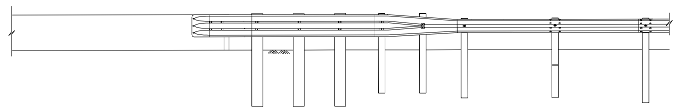

t = 0.429

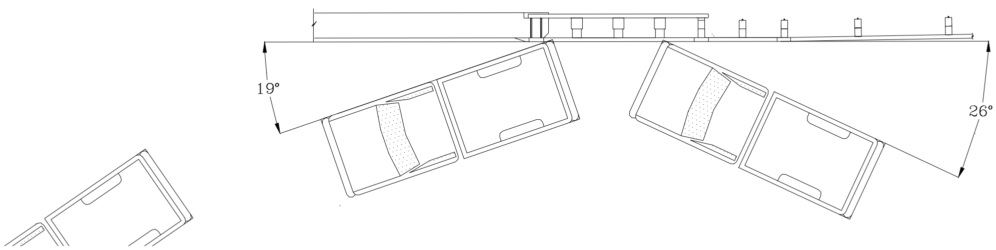

t = 0.572


t = 0.715


t = 0.858


t = 1.000





General Information:
- Test Agency ---------- California DOT
- Test Number --------- 517
- Test Date -------------- July 28, 1999

Test Article:
- Name ------------------- Transition Design 2
- Installation Length --- 5.715 m
- Description------------

Test Vehicle:
- Model ------------------ 1989 Chevy 2500 PU
- Inertial Mass --------- 2000 kg

Impact Conditions:
- Velocity---------------- 100.5 km/h
- Angle ------------------- 26°

Exit Conditions:
- Velocity --------------- 85 km/h
- Angle ------------------- 19°

Test Dummy:
- Type -------------------- NA
- Weight / Restraint ----- NA
- Position ----------------- NA

Vehicle Interior:
- O.C.D.I. ----------------- RF0301021

Occupant Risk Values	*Longitudinal*	*Lateral*
Occupant Impact Velocity	N/A m/s	N/A m/s
Ridedown Acceleration	N/A g	N/A g

2.4. TEST 519

2.4.1. Impact Description and Results

The vehicle speed and angle were 100.0 km/h and 25.5 degrees, respectively. The centerline of the vehicle was pointed directly at the leading edge of the concrete bridge rail. The impact occurred at post 13 (the third post back from the concrete bridge deck). The contact with the barrier was limited to the length of rail between the post 13 and the end of the thrie beam (about three meters). The vehicle was smoothly redirected with no tendency toward pocketing of the rail.

Upon impact, the front right corner of the vehicle began to crush, allowing the hood to ride over the post and rail elements of the transition. When the leading edge of the vehicle reached post 15 (i.e. the post nearest the concrete), the barrier had dynamically deflected 80 mm at post 14. Posts 13 and 15 also deflected 50 and 65 mm, respectively. The vehicle started a light roll to the right as the vehicle was redirected. The maximum roll was about 16 degrees. The maximum pitch of the vehicle was about 7 degrees and occurred as the vehicle lost contact with the barrier.

The vehicle exited the barrier at a speed and angle of 85 km/h and 10.4 degrees, respectively. The vehicle had all four wheels back on the ground 0.85 seconds after impact and tracked well after this point.

Figure 2-16 - Test 519 Impact

Figure 2-17 - Test 519 Post-Impact Dynamic 2

Figure 2-18 - Test 519 Post-Impact Dynamic 3

2.4.2. Barrier Damage

The barrier received minimal damage during impact. The posts exhibited small amounts of permanent lateral deflection. For posts 12, 13, 14, and 15 the deflections were 10, 19, 25, and 13 mm at the tops, respectively. The blockout for post 14 was damaged enough to require replacement. There was minor scraping and scuffing of the barrier.

Figure 2-19 - Test 519 Barrier Damage

2.4.3. Vehicle Damage

Most of the vehicle damage was limited to the front and right side. The right front corner was pushed in, exposing the battery and crumpling the corner panel. The steering linkage was still connected, but no longer functional. The front right wheel was pushed back and pressed up against the firewall. The right third of the bumper was pushed back into the vehicle. The right side of the vehicle was creased where contact had been made with the barrier rail.

Figure 2-20 - Test 519 Vehicle Damage

Figure 2-21 - Test 519 Data Summary Sheet


t = 0.000


t = 0.143


t = 0.286

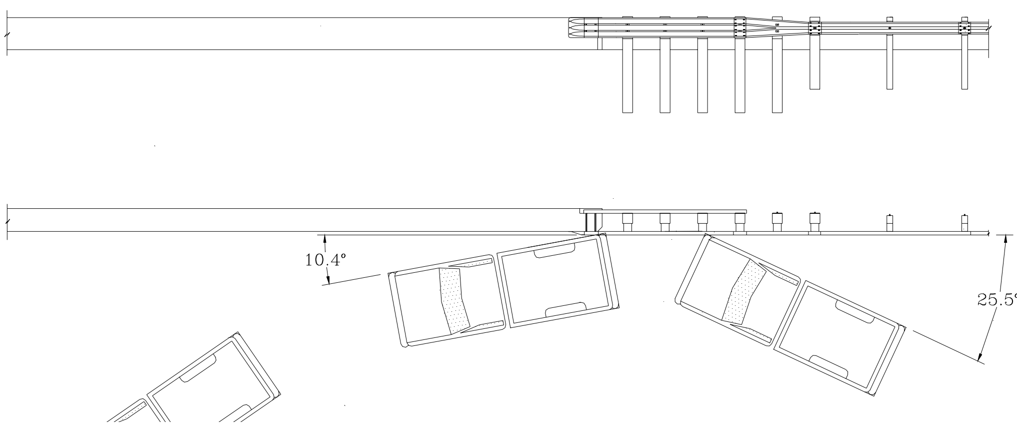

t = 0.428


t = 0.571


t = 0.714


t = 0.857


t = 0.999



General Information:
- Test Agency ---------- California DOT
- Test Number ---------- 519
- Test Date ---------- May 24, 2000

Test Article:
- Name ---------- Transition Design 3
- Installation Length --- 9.525 m
- Description ----------

Test Vehicle:
- Model ---------- 1994 Chevy 2500 PU
- Inertial Mass ---------- 1974 kg

Impact Conditions:
- Velocity ---------- 100.0 km/h
- Angle ---------- 25.5°

Exit Conditions:
- Velocity ---------- 84.9 km/h
- Angle ---------- 10.4°

Test Dummy:
- Type ---------- NA
- Weight / Restraint ----- NA
- Position ---------- NA

Vehicle Interior:
- O.C.D.I. ---------- RF0000000

Occupant Risk Values	*Longitudinal*	*Lateral*
Occupant Impact Velocity	7.96 m/s	7.66 m/s
Ridedown Acceleration	-4.26 g	-4.26 g

TEST 518

2.5.1. Impact Description and Results

The vehicle speed and angle were 99.9 km/h and 25.0 degrees, respectively. Impact with the barrier occurred 950 mm upstream from post 10 (the sixth post back from the concrete bridge deck.) Contact with the barrier was lost midway between posts 13 and 14. The vehicle was smoothly redirected with no tendency toward pocketing of the rail.

As in test 519, while the front right corner of the vehicle began to crush, allowing the hood to ride over the post and rail elements of the transition. The maximum dynamic deflection of the barrier was 240 mm at post 10. The posts on either side of post 10 also deflected. The vehicle started a light roll to the right as it was redirected. The maximum roll was about 8 degrees. The maximum pitch of the vehicle was about 12 degrees and occurred as the vehicle lost contact with the barrier.

The vehicle exited the barrier at a speed and angle of 82 km/h and 17 degrees, respectively. At 0.95 seconds after impact all four wheels of the vehicle were back on the ground. The vehicle tracked well after that point. The maximum floorboard deformation was 85 mm.

Figure 2-22 - Test 518 Pre-Impact Dynamic

Figure 2-23 - Test 518 Post-Impact Dynamic 1

Figure 2-24 - Test 518 Post-Impact Dynamic 2

2.5.2. Barrier Damage

The barrier received minimal damage during impact. The posts had moderate permanent lateral deflection. Posts 9, 10, 11, 13, 14, and 15 deflected 52, 164, 162, 80, 41, and 65 mm at the tops, respectively (post 12 also deflected, but the measuring target was destroyed during impact). The blockout for post 11 was damaged enough to require replacement. The Y-section and the 10-ga. W-beam section needed to be replaced. Several of the posts needed to be straightened, but were still useable.

Figure 2-25 - Test 518 Barrier Damage

2.5.3. Vehicle Damage

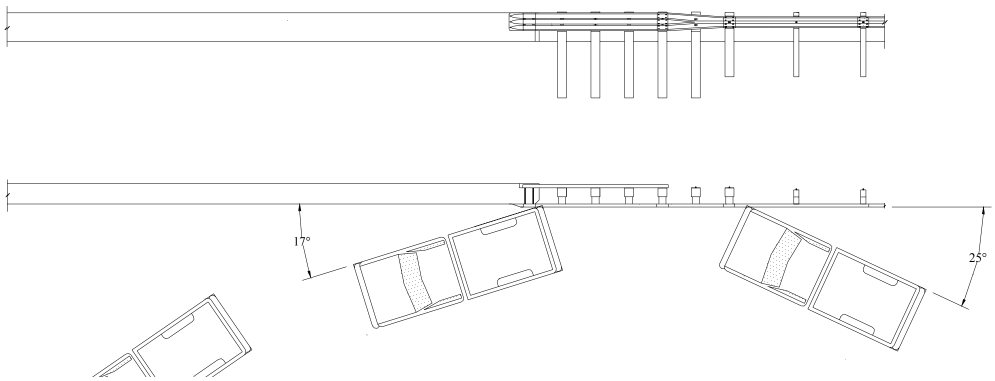
Most of the vehicle damage was limited to the front and right side. The right front corner was pushed in, exposing the battery and crumpling the corner panel. The steering linkage was no longer functional. The front right wheel was pushed back and pressed up against the firewall. The right third of the bumper was pushed back into the vehicle and the right side of the vehicle was creased where contact had been made with the barrier rail.

Figure 2-26 - Test 518 Vehicle Damage

Figure 2-27 - Test 518 Data Summary Sheet

t = 0.000 t = 0.143 t = 0.286 t = 0.428

t = 0.571 t = 0.714 t = 0.857 t = 0.999



General Information:
- Test Agency ---------- California DOT
- Test Number ---------- 518
- Test Date ---------- June 28, 2000

Test Article:
- Name ---------- Transition Design 3
- Installation Length --- 9.525 m
- Description ----------

Test Vehicle:
- Model ---------- 1997 Chevy 2500 PU
- Inertial Mass ---------- 1996 kg

Impact Conditions:
- Velocity ---------- 99.9 km/h
- Angle ---------- 25.0°

Exit Conditions:
- Velocity ---------- 82 km/h
- Angle ---------- 17°

Test Dummy:
- Type ---------- NA
- Weight / Restraint ----- NA
- Position ---------- NA

Vehicle Interior:
- OCDI ---------- RF0011000

Occupant Risk Values	*Longitudinal*	*Lateral*
Occupant Impact Velocity	8.85 m/s	6.78 m/s
Ridedown Acceleration	-5.61 g	-10.82_g

2.6. TEST 514

2.6.1. Impact Description and Results

The vehicle speed and angle were 75.5 km/h and 16.0 degrees, respectively. Impact with the barrier occurred midway between posts 13 and 14. Contact with the barrier continued past the end of the thrie beam and onto the concrete bridge rail. The vehicle was smoothly redirected with no tendency toward pocketing of the rail. The impact severity of 132.3 kJ was within the limits specified in NCHRP Report 350.

As in previous tests for this transition (i.e. tests 518 and 519), the front right corner of the vehicle began to crush as the vehicle made contact with the barrier. The barrier did move back during impact, however the vehicle obscured the posts from view, making it impossible to measure the dynamic deflections. The maximum permanent deflection was 48 mm. The maximum roll was about 26 degrees. The maximum pitch of the vehicle was less than 10 degrees and occurred 0.75 seconds after impact.

The vehicle exited the barrier at a speed and angle of 67 km/h and 0 degrees, respectively.

2.6.2. Barrier Damage

Damage to the barrier was limited to post deflections and the tearing of the outer thrie beam element. All posts were reusable (after realignment). The 10-ga. thrie beam element that was damaged would have been replaced in the field. In addition, the bridge rail displayed some minor scraping from the lug nuts on the truck wheels.

2.6.3. Vehicle Damage

Damage to the vehicle was mostly limited to the cargo box, the right wheels, the front suspension and steering linkage, and the right front portion of the cab. The engine could still run. The steering was not functional.

The right front of the vehicle sustained most of the damage as the front tire was pushed into the fuel tank. The steering linkage was severed on the right side, but the steering wheel was still connected to the left wheel. The steering wheel was sheared from the steering column.

The rim of the right rear wheel was damage as it made contact with the shredded thrie beam on the transition. The lift-gate on the rear of the vehicle was pushed to the left.

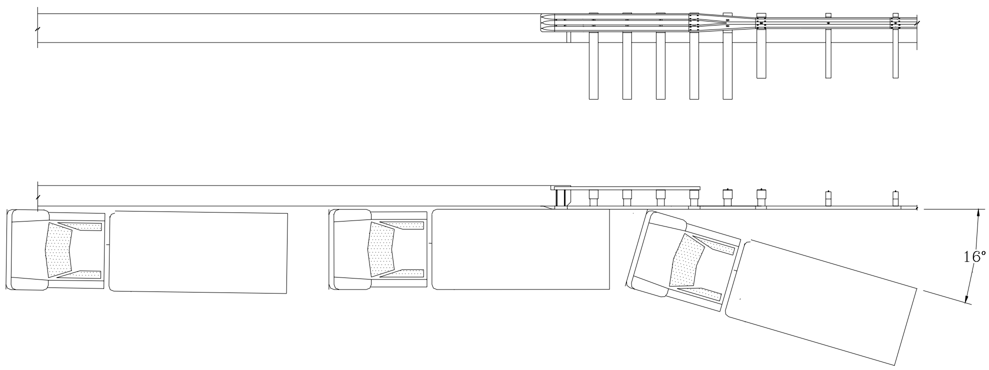
The cargo box shifted to the right during impact, but was not penetrated. The ballast also shifted to the right.

Figure 2-28 - Test 514 Cargo Shift

Figure 2-29 - Test 514 Data Summary Sheet

t = 0.000 t = 0.200 t = 0.400 t = 0.600

t = 0.800 t = 1.000 t = 1.200 t = 1.400



General Information:
- Test Agency ---------- California DOT
- Test Number ---------- 514
- Test Date ---------- November 8, 2000

Test Article:
- Name ---------- Transition Design 3
- Installation Length --- 9.525 m
- Description----------

Test Vehicle:
- Model ---------- 1995 Ford F800
- Inertial Mass ---------- 8011 kg

Impact Conditions:
- Velocity---------- 75.5 km/h
- Angle ---------- 16.0°

Exit Conditions:
- Velocity ---------- 67 km/h
- Angle ---------- 0°

Test Dummy:
- Type ---------- NA
- Weight / Restraint ----- NA
- Position ---------- NA

Vehicle Interior:
- OCDI ---------- RF0000000

2.7. Discussion of Test Results

2.7.1. General - Evaluation Methods

NCHRP Report 350 stipulates that crash test performance be assessed according to three evaluation factors: 1) Structural Adequacy, 2) Occupant Risk, and 3) Vehicle Trajectory.

The structural adequacy, occupant risk and vehicle trajectories associated with each of the three barrier designs were evaluated in comparison with Tables 3.1 and 5.1 of NCHRP Report 350.

2.7.2. Structural Adequacy

The structural adequacy of Transition Design 3 is acceptable. The movement of the rail during these tests was acceptable. During the time of contact between the test vehicles and the barriers there were minor amounts of scraping and spalling.

A detailed assessment summary of the structural adequacy of this and other designs is shown in Table 2-2 through Table 2-6.

2.7.3. Occupant Risk

The occupant risk of Transition Design 3 is also acceptable. In each of the tests of the third design there were no signs of snagging or pocketing with the rail. There were no signs of spalling concrete penetrating the occupant compartment of the vehicles. All of the calculated occupant ridedown accelerations and occupant velocities were within the “preferred” range.

Please refer to in Table 2-2 through Table 2-6 for a detailed assessment summary of occupant risk for all transition designs.

2.7.4. Vehicle Trajectory

The detailed assessment summaries of the vehicle trajectories for all transition designs may be seen in Table 2-2 through Table 2-6. Vehicle trajectories for Design 3 were acceptable.

Table 2-2 - Test 514 Assessment Summary

Test No. 514
Date November 8, 2000
Test agency California Dept. of Transportation

<table>
<tr><th>Evaluation Criteria</th><th>Test Results</th><th>Assessment</th></tr>
<tr><td>Structural Adequacy
A. Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the article is acceptable</td><td>The vehicle was contained and smoothly redirected.</td><td>pass</td></tr>
<tr><td>Occupant Risk
D. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.</td><td>Only moderate amounts of spalling were created during impact. There was no significant debris from the vehicle.</td><td>pass</td></tr>
<tr><td>F. The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable</td><td>The vehicle remained upright through out the test.</td><td>pass</td></tr>
<tr><td>H. Occupant impact velocities (see Appendix A, Section A5.3 for calculation procedure) should satisfy the following:</td><td>Occupant impact velocities were within acceptable range.</td><td>pass</td></tr>
<tr><td><table><tr><th colspan="3">Occupant Impact Velocity Limits (m/s)</th></tr><tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr><tr><td>Longitudinal and lateral</td><td>9</td><td>12</td></tr></table></td><td>N/A on 8000S</td><td>-</td></tr>
<tr><td>I. Occupant Ridedown Accelerations (see Appendix A, Section A5.3 for calculation procedure) should satisfy the following:
<table><tr><th colspan="3">Occupant Ridedown Acceleration Limits (g)</th></tr><tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr><tr><td>Longitudinal and lateral</td><td>15</td><td>20</td></tr></table></td><td>N/A on 8000S</td><td>-</td></tr>
<tr><td>Vehicle Trajectory
K. After collision it is preferable that the vehicle’s trajectory not intrude into adjacent traffic lanes</td><td>The vehicle maintained a relatively straight course after exiting the barrier.</td><td>pass</td></tr>
<tr><td>M. The exit angle from the test article preferably should be less that 60 percent of the test impact angle, measured at time of vehicle loss of contact with test device.”</td><td>Exit angle 0 degrees</td><td>pass</td></tr>
</table>

Table 2-3 - Test 516 Assessment Summary

Test No. 516
Date April 1, 1998
Test agency California Dept. of Transportation

<table>
<tr><th>Evaluation Criteria</th><th>Test Results</th><th>Assessment</th></tr>
<tr><td>Structural Adequacy
A. Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the article is acceptable</td><td>The vehicle was contained and redirected.</td><td>pass</td></tr>
<tr><td>Occupant Risk
D. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.</td><td>The floor deformation was 210 mm, which is considered excessive.</td><td>fail</td></tr>
<tr><td>F. The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable</td><td>The vehicle remained upright</td><td>pass</td></tr>
<tr><td>H. Occupant impact velocities (see Appendix A, Section A5.3 for calculation procedure) should satisfy the following:</td><td>Occupant impact velocities were within acceptable range.</td><td>pass</td></tr>
<tr><td><table><tr><th colspan="3">Occupant Impact Velocity Limits (m/s)</th></tr><tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr><tr><td>Longitudinal and lateral</td><td>9</td><td>12</td></tr></table></td><td>The lateral OIV was 7.39 and the longitudinal OIV was 10.62.</td><td>pass</td></tr>
<tr><td>I. Occupant Ridedown Accelerations (see Appendix A, Section A5.3 for calculation procedure) should satisfy the following:<table><tr><th colspan="3">Occupant Ridedown Acceleration Limits (g)</th></tr><tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr><tr><td>Longitudinal and lateral</td><td>15</td><td>20</td></tr></table></td><td>The lateral ridedown was –10.51 and the longitudinal ridedown was –8.11.</td><td>pass</td></tr>
<tr><td>Vehicle Trajectory
K. After collision it is preferable that the vehicle’s trajectory not intrude into adjacent traffic lanes</td><td>The vehicle remained fairly straight.</td><td>pass</td></tr>
<tr><td>M. The exit angle from the test article preferably should be less that 60 percent of the test impact angle, measured at time of vehicle loss of contact with test device.”</td><td>Exit angle 3 degrees or 12% of exit angle</td><td>pass</td></tr>
</table>

Table 2-4 - Test 517 Assessment Summary

Test No.	517
Date	July 28, 1999
Test agency	California Dept. of Transportation

<table>
<tr><th>Evaluation Criteria</th><th>Test Results</th><th>Assessment</th></tr>
<tr><td>Structural Adequacy</td><td></td><td></td></tr>
<tr><td>A. Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the article is acceptable</td><td>The vehicle was contained and redirected.</td><td>pass</td></tr>
<tr><td>Occupant Risk</td><td></td><td></td></tr>
<tr><td>D. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.</td><td>The occupant compartment was crushed during roll over.</td><td>fail</td></tr>
<tr><td>F. The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable</td><td>The vehicle failed to remain upright</td><td>fail</td></tr>
<tr><td>H. Occupant impact velocities (see Appendix A, Section A5.3 for calculation procedure) should satisfy the following:</td><td>Occupant impact velocities were within acceptable range.</td><td>pass</td></tr>
<tr><td><table>
<tr><th colspan="3">Occupant Impact Velocity Limits (m/s)</th></tr>
<tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr>
<tr><td>Longitudinal and lateral</td><td>9</td><td>12</td></tr>
</table></td><td>NA</td><td>N/A</td></tr>
<tr><td>I. Occupant Ridedown Accelerations (see Appendix A, Section A5.3 for calculation procedure) should satisfy the following:
<table>
<tr><th colspan="3">Occupant Ridedown Acceleration Limits (g)</th></tr>
<tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr>
<tr><td>Longitudinal and lateral</td><td>15</td><td>20</td></tr>
</table></td><td>NA g</td><td>N/A</td></tr>
<tr><td>Vehicle Trajectory</td><td></td><td></td></tr>
<tr><td>K. After collision it is preferable that the vehicle’s trajectory not intrude into adjacent traffic lanes</td><td>The vehicle did not remain straight after it began to roll.</td><td>fail</td></tr>
<tr><td>M. The exit angle from the test article preferably should be less that 60 percent of the test impact angle, measured at time of vehicle loss of contact with test device.”</td><td>Exit angle 19 degrees or 76% of exit angle</td><td>fail</td></tr>
</table>

Table 2-5 - Test 518 Assessment Summary

Test No. 518
Date May 24, 2000
Test agency California Dept. of Transportation

<table>
<tr><th>Evaluation Criteria</th><th>Test Results</th><th>Assessment</th></tr>
<tr><td>Structural Adequacy</td><td></td><td></td></tr>
<tr><td>A. Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the article is acceptable</td><td>The vehicle was contained and smoothly redirected.</td><td>pass</td></tr>
<tr><td>Occupant Risk</td><td></td><td></td></tr>
<tr><td>D. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.</td><td>Only moderate amounts of spalling were created during impact. There was no significant debris from the vehicle. The maximum floorboard deformation was 85 mm.</td><td>pass</td></tr>
<tr><td>F. The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable</td><td>The maximum roll, pitch and yaw were -11.59, 6.46, and –25.74°, respectively. These are all acceptable.</td><td>pass</td></tr>
<tr><td>H. Occupant impact velocities (see Appendix A, Section A5.3 for calculation procedure) should satisfy the following:</td><td>Occupant impact velocities were within acceptable range.</td><td>pass</td></tr>
<tr><td><table>
<tr><th colspan="3">Occupant Impact Velocity Limits (m/s)</th></tr>
<tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr>
<tr><td>Longitudinal and lateral</td><td>9</td><td>12</td></tr>
</table></td><td>Long. Occ. Impact Vel. = 3.94 m/s
Lat. Occ. Impact Vel. = 5.80 m/s</td><td>pass</td></tr>
<tr><td>I. Occupant Ridedown Accelerations (see Appendix A, Section A5.3 for calculation procedure) should satisfy the following:
<table>
<tr><th colspan="3">Occupant Ridedown Acceleration Limits (g)</th></tr>
<tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr>
<tr><td>Longitudinal and lateral</td><td>15</td><td>20</td></tr>
</table></td><td>Longitudinal Acceleration = -1.13 g
Lateral Acceleration = -17.62 g</td><td>pass</td></tr>
<tr><td>Vehicle Trajectory</td><td></td><td></td></tr>
<tr><td>K. After collision it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes</td><td>The vehicle maintained a relatively straight course after exiting the barrier.</td><td>pass</td></tr>
<tr><td>M. The exit angle from the test article preferably should be less that 60 percent of the test impact angle, measured at time of vehicle loss of contact with test device."</td><td>Exit angle 4 degrees, or 20% of impact angle</td><td>pass</td></tr>
</table>

Table 2-6 - Test 519 Assessment Summary

Test No. 519
Date May 24, 2000
Test agency California Dept. of Transportation

Evaluation Criteria	Test Results	Assessment
Structural Adequacy		
A. Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the article is acceptable	The vehicle was contained and smoothly redirected.	pass
Occupant Risk		
D. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.	Only moderate amounts of spalling were created during impact. There was no significant debris from the vehicle. The maximum floorboard deformation 20 mm.	pass
F. The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable	The maximum roll, pitch and yaw were -16, 7, and –7.64°, respectively. These are all acceptable.	pass
H. Occupant impact velocities (see Appendix A, Section A5.3 for calculation procedure) should satisfy the following: Occupant Impact Velocity Limits (m/s) Component / Preferred / Maximum Longitudinal and lateral / 9 / 12	Occupant impact velocities were within acceptable range. Long. Occ. Impact Vel. = 7.96 m/s Lat. Occ. Impact Vel. = 7.66 m/s	pass
I. Occupant Ridedown Accelerations (see Appendix A, Section A5.3 for calculation procedure) should satisfy the following: Occupant Ridedown Acceleration Limits (*g*) Component / Preferred / Maximum Longitudinal and lateral / 15 / 20	Longitudinal Acceleration = -4.26 *g* Lateral Acceleration = -12.56*g*	pass
Vehicle Trajectory		
K. After collision it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes	The vehicle maintained a relatively straight course after exiting the barrier.	pass
M. The exit angle from the test article preferably should be less that 60 percent of the test impact angle, measured at time of vehicle loss of contact with test device."	Exit angle 10.4 degrees, or 42% of impact angle	pass

Table 2-7 - Vehicle Trajectories and Speeds

Test Number	Impact Angle	60% of Impact Angle	Exit Angle	Impact Speed, V_i	Exit Speed, V_e	Speed Change V_i - V_e
	[deg]	[deg]	[deg]	[km/h]	[km/h]	[km/h]
514	16.0	9.0	0	75.5	67	8.5
516	25.0	15.0	3	100.5	76	24.5
517	26.0	15.6	19	100.5	85	15.5
518	25.0	15.0	17	99.9	82	17.9
519	25.5	15.3	10	100.0	89.9	10.1

3. CONCLUSION

Based on the performance of the three transitions involved in this project, the following conclusions can be drawn:

1) Design 1 produced major snagging during Test 516. This makes Design 1 unacceptable as either a TL-3 or TL-4 transition.

2) Design 2 was stiffer than Design 1, but still produced an unacceptable amount of deflection which induced rollover of the test vehicle (Test 517).

3) Design 3 solved the pocketing problems and deflection that plagued the first two designs, and successfully contained and redirected a 2000-kg pickup truck impacting at 25° and 100 km/h (Test 519). The occupant impact velocity and ridedown acceleration values were within acceptable limits of NCHRP Report 350. The maximum dynamic lateral deflection of the transition at the tops of the posts did not exceed 80 mm.

4) Design 3 did not shift the pocketing problem upstream of the concrete-thrie beam connection. The second pickup test (Test 518) on the third design, impacting just upstream of the Y-section, proved that the transition from a flexible barrier to a rigid barrier was done gradually enough to eliminate the pocketing danger. The maximum lateral post deflection was 240 mm (measured at the top of the post), demonstrating that the lateral flexibility decreases as the transition approaches the concrete bridge rail.

5) Transition Design 3 can smoothly and successfully redirect an 8000-kg van truck impacting at 15° and 80 km/h (Test 514).

4. RECOMMENDATION

Transition Design 3 is recommended as an NCHRP Report 350 TL-4 transition for concrete bridge rails.

5. APPENDIX

5.1. Test Vehicle Equipment

The test vehicles were modified as follows for the crash tests:

- The gas tanks on the test vehicles were disconnected from the fuel supply line and drained. For tests 516, 517, 518 and 519, a safety gas tank was installed in the truck bed and connected to the fuel supply line. The stock fuel tanks had gaseous CO_2 added in order to purge the gas vapors and eliminate oxygen. For test 514, a safety gas tank was installed in the cargo area.

- One pair of 12-volt, wet cell, motorcycle batteries was mounted in the vehicle. The batteries operated the solenoid-valve braking/accelerator system, rate gyros and the electronic control box. A second 12-volt, deep cycle, gel cell battery powered the transient data recorder.

- A 4800-kPa CO_2 system, actuated by a solenoid valve, controlled remote braking after impact and emergency braking if necessary. Part of this system include a pneumatic ram, which was attached to the brake pedal. The operating pressure for the ram was adjusted through a pressure regulator during a series of trial runs prior to the actual test. Adjustments were made to assure the shortest stopping distance without locking up the wheels. When activated, the brakes could be applied in less than 100 milliseconds.

- The remote brakes were controlled at a console trailer. A cable ran from the console trailer to an electronic instrumentation van. From there, the remote brake signal was carried on one channel of a multi-channel tether line that was connected to the test vehicle. Any loss of continuity in these cables would have activated the brakes automatically. Also, if the brakes were applied by remote control from the console trailer, removing power to the coil would automatically cut the ignition for the self-powered vehicle. For test 514 a radio controlled braking system was used.

- For tests 514, 516, 517, 518 and 519, an accelerator switch was located on the rear fender. Activating the switch opened an electric solenoid which, in turn, released compressed CO_2 from a reservoir into a pneumatic ram that had been attached to the accelerator pedal. The CO_2 pressure for the accelerator ram was regulated to the same pressure of the remote braking system with a valve to adjust CO_2 flow rate.

- For tests 514, 516, 517, 518 and 519, a speed control device, connected in-line with the ignition module signal to the coil, was used to regulate the speed of the test vehicle based on the signal from the vehicle transmission speed sensor. This device was calibrated prior to the test by conducting a series of trial runs through a speed trap comprised of two tape switches set a specified distance apart and a digital timer.

- For tests 514, 516, 517, 518 and 519, a microswitch was mounted below the front bumper and connected to the ignition system. A trip plate on the ground near the impact point triggered the switch when the truck passed over it. The switch opened the ignition circuit and shut off the vehicle's engine prior to impact.

Table 5-1 - Test 516 Vehicle Dimensions

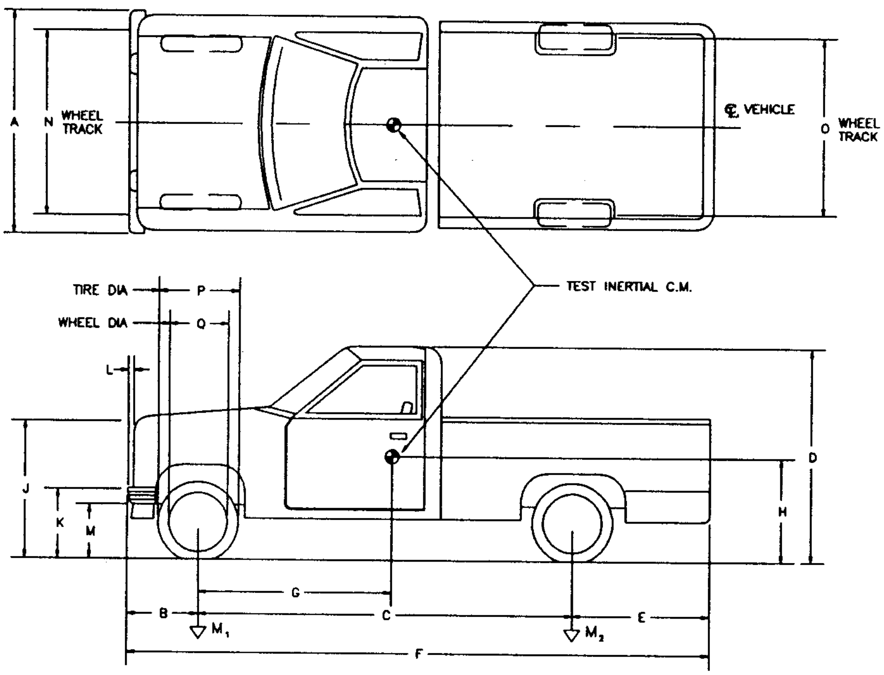
DATE: 6/8/99 **TEST NO:** 516 **VIN NO:** 1GTFC24K7PE543979 **MAKE:** GMC

MODEL: 2500 Pick-Up **YEAR:** 1993 **ODOMETER:** 85257 (MI) **TIRE SIZE:** LT235/85R16

TIRE INFLATION PRESSURE: 80 (PSI)

MASS DISTRIBUTION (kg) **LF** 532 **RF** 543.5 **LR** 459 **RR** 428

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST: NONE



ENGINE TYPE: V8

ENGINE CID: 350

TRANSMISSION TYPE :

X AUTO

___ MANUAL

OPTIONAL EQUIPMENT:

A/C

DUMMY DATA:

TYPE: NA

MASS: NA

SEAT POSITION: NA

GEOMETRY (cm)

A 183	**D** 183	**G** 150	**K** 64	**N** 158	**Q** 44
B 86	**E** 134	**H**	**L** 8	**O** 162	
C 336	**F** 557	**J** 101	**M** 43	**P** 80	

MASS - (kg)	CURB	TEST INERTIAL	GROSS STATIC
M1	1087.0	1075.5	1075.5
M2	821.5	887	887
MT	1908.5	1963	1963

Table 5-2 - Test 517 Vehicle Dimensions

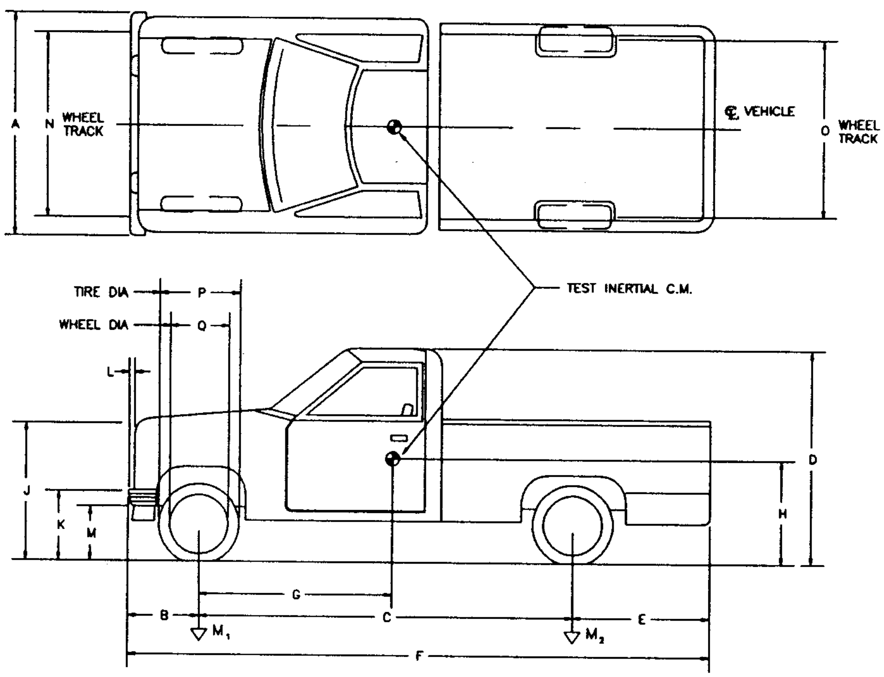
DATE: 5/28/99 **TEST NO:** 517 **VIN NO:** 1GCFC24HXKE147025 **MAKE:** CHEVY

MODEL: 2500 Pick-Up **YEAR:** 1989 **ODOMETER:** 1450387 (MI) **TIRE SIZE:** LT235/85R16

TIRE INFLATION PRESSURE: 45 (PSI)

MASS DISTRIBUTION (kg) **LF** 536.5 **RF** 555.5 **LR** 401.0 **RR** 372.0

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST: NONE



ENGINE TYPE: V8

ENGINE CID: 350

TRANSMISSION TYPE :

X **AUTO**

___ **MANUAL**

OPTIONAL EQUIPMENT:

A/C

DUMMY DATA:

TYPE: NA

MASS: NA

SEAT POSITION: NA

GEOMETRY (cm)

A 197.5	**D** 183	**G** 149.1	**K** 65	**N** 156.5	**Q** 44.4
B 90	**E** 115.5	**H**	**L** 8.5	**O** 161.5	
C 335	**F** 539	**J** 105.3	**M** 37.7	**P** 78.5	

MASS - (kg)	CURB	TEST INERTIAL	GROSS STATIC
M1	1092.5	1109.9	1109.9
M2	773.0	890.1	890.1
MT	1865.0	2000	2000

Table 5-3 - Test 519 Vehicle Dimensions

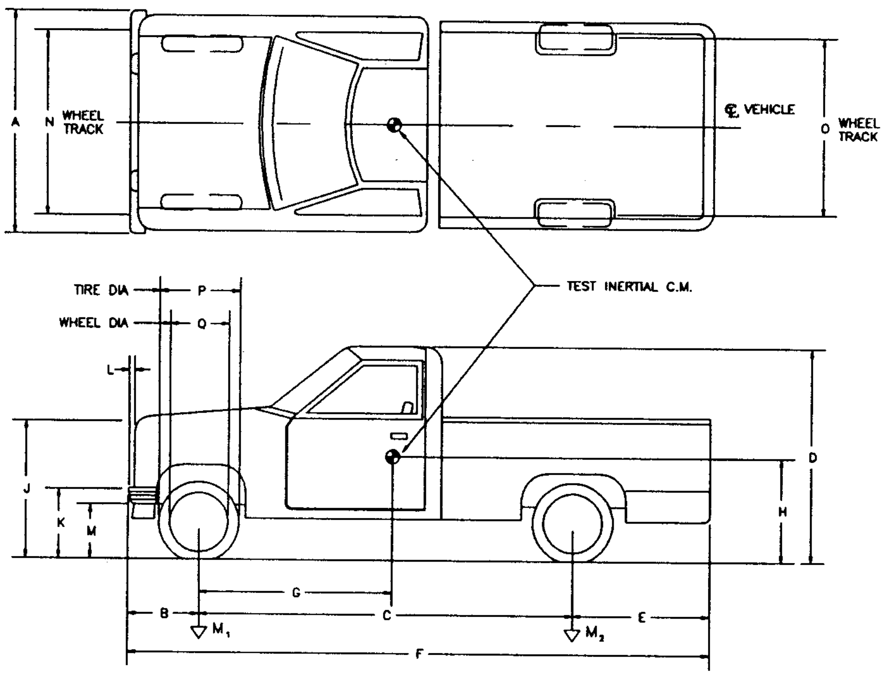
DATE: 5/10/00 **TEST NO:** 519 **VIN NO:** 1GCFC24H8RE182043 **MAKE:** CHEVY

MODEL: 2500 Pick-Up **YEAR:** 1994 **ODOMETER:** 143905 (MI) **TIRE SIZE:** LT225/75R16

TIRE INFLATION PRESSURE: 60 (PSI)

MASS DISTRIBUTION (kg) **LF** 537.5 **RF** 535.5 **LR** 379.0 **RR** 382.0

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST: NONE



ENGINE TYPE: V8

ENGINE CID: 350

TRANSMISSION TYPE :

X **AUTO**

MANUAL

OPTIONAL EQUIPMENT:

NONE

DUMMY DATA:

TYPE: NA

MASS: NA

SEAT POSITION: NA

GEOMETRY (cm)

A	195	**D**	177.5	**G**	147.8	**K**	59.4	**N**	157.5	**Q**	44.5
B	91	**E**	130	**H**		**L**	8.2	**O**	161.5		
C	334	**F**	555	**J**	102.1	**M**	37.6	**P**	72.5		

MASS - (kg)	CURB	TEST INERTIAL	GROSS STATIC
M1	1073.0	1100.5	1100.5
M2	761.0	873.5	873.5
MT	1834.0	1974.0	1974.0

Table 5-4 - Test 518 Vehicle Dimensions

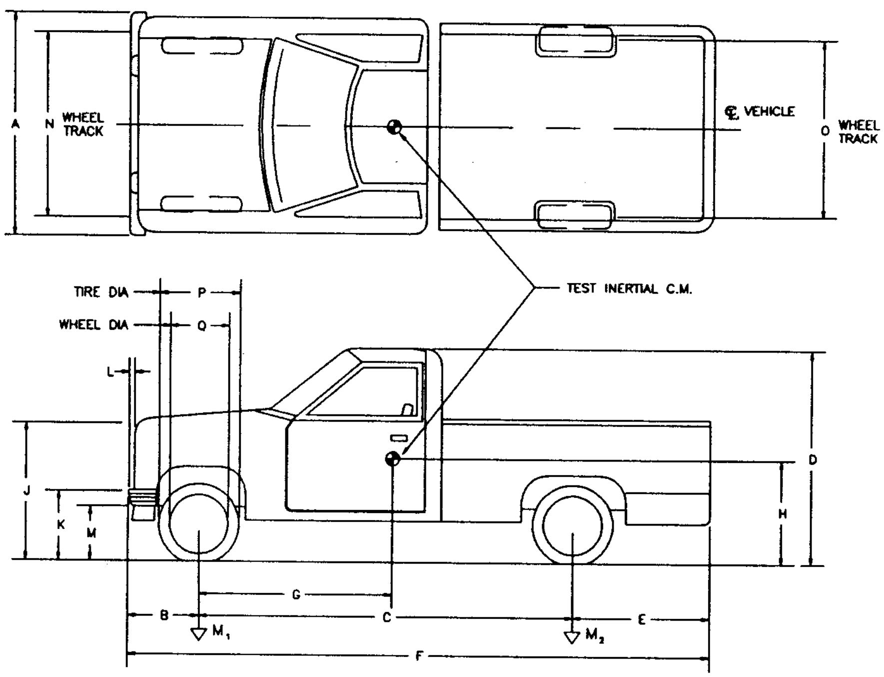
DATE: 6/9/00 **TEST NO:** 518 **VIN NO:** 1GCFC24M2VE178173 **MAKE:** CHEVROLET

MODEL: 2500 Pick-Up **YEAR:** 1997 **ODOMETER:** 95669 (MI) **TIRE SIZE:** LT225/75R16

TIRE INFLATION PRESSURE: 45 (PSI)

MASS DISTRIBUTION (kg) **LF** 554.0 **RF** 567.0 **LR** 414.5 **RR** 389.5

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST: NONE



ENGINE TYPE: V8

ENGINE CID: 350

TRANSMISSION TYPE :

X AUTO

___ MANUAL

OPTIONAL EQUIPMENT:

A/C

DUEL AIRBAGS

DUMMY DATA:

TYPE: NA

MASS: NA

SEAT POSITION: NA

GEOMETRY (cm)

A 197	D 178	G 146.1	K 59.6	N 157.5	Q 44.3
B 93	E 135	H	L 7.2	O 163	
C 334	F 553.5	J 104	M 38	P 71.5	

MASS - (kg)	CURB	TEST INERTIAL	GROSS STATIC
M1	1121.0	1123.5	1123.5
M2	804.0	872.5	872.5
MT	1925.0	1996.0	1996.0

Table 5-5 - Test 514 Vehicle Dimensions

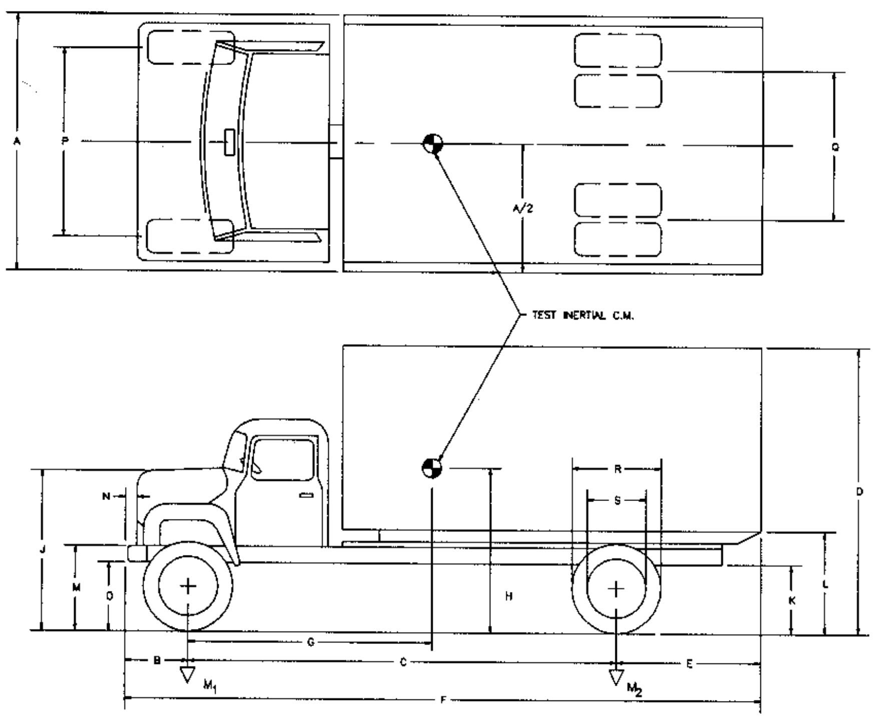
DATE: 10/26/00 **TEST NO:** 514 **VIN NO:** **MAKE:** FORD

MODEL: F800 **YEAR:** 1995 **ODOMETER:** 102563 (MI) **TIRE SIZE:** 11R22.5

TIRE INFLATION PRESSURE: 80 (PSI)

MASS DISTRIBUTION (kg) **LF** 1073 **RF** 1086 **LR** 1622 **RR** 1674

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST: DENT IN ROOF



ENGINE TYPE: V8

ENGINE CID: XX

TRANSMISSION TYPE :

X AUTO

____ MANUAL

OPTIONAL EQUIPMENT:

NONE

DUMMY DATA:

TYPE: NA

MASS: NA

SEAT POSITION: NA

GEOMETRY (mm)

A 2430	**D** 3665	**G** 3173	**K** 700	**N** 30	**Q** 1870
B 885	**E** 2450	**H**	**L** 1190	**O** 455	**R** 1010
C 5250	**F** 6600	**J** 1610	**M** 775	**P** 2010	**S** 595

MASS - (kg)	**CURB**	**TEST INERTIAL**	**GROSS STATIC**
M1	2159	2541	2541
M2	3296	5470	5470
MT	5455	8011	8011

5.2. Test Vehicle Guidance System

A rail guidance system directed the vehicle into the barrier. The guidance rail, anchored at 3.8-m intervals along its length, was used to guide a mechanical arm, which was attached to the front left wheel of each of the test vehicles. A plate and lever were used to trigger the release mechanism on the guidance arm, thereby releasing the vehicle from the guidance system before impact.

5.3. Photo - Instrumentation

Several high-speed movie cameras recorded the impact during the crash tests. The types of cameras and their locations are shown in Table 5-6 and Figure 5-1.

All of these cameras were mounted on tripods except the three that were mounted on a 10.7 m-high tower directly over the impact point on the test barrier.

A video camera and a 16-mm film camera were turned on by hand and used for panning during the test. Switches on a console trailer near the impact area remotely triggered all other cameras. Both the vehicle and barrier were photographed before and after impact with a normal-speed movie camera, a beta video camera and a color still camera. A film report of this project has been assembled using edited portions of the crash testing coverage.

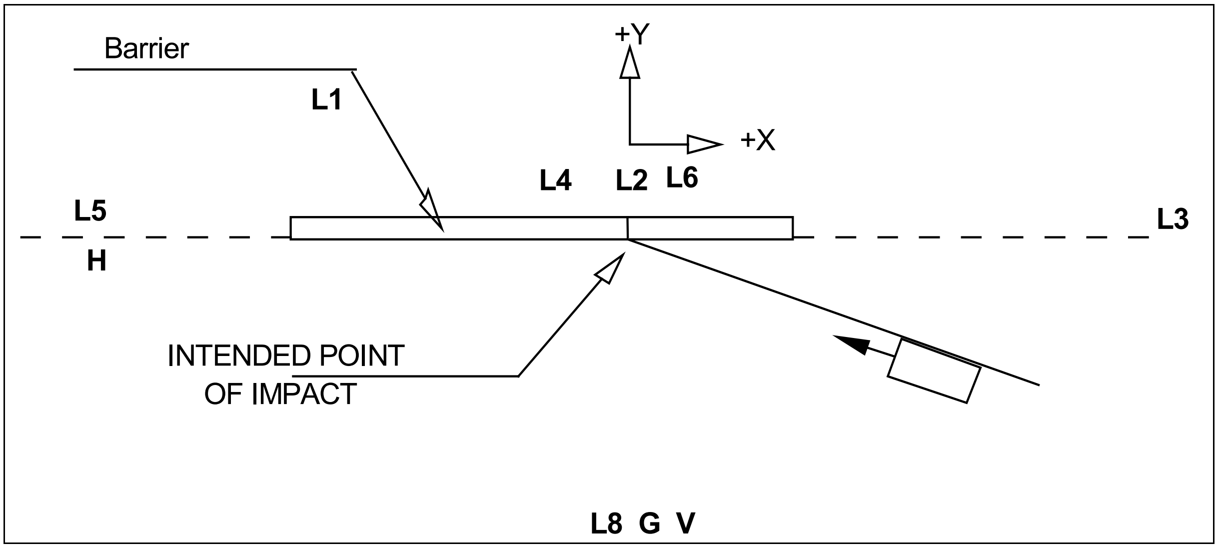


Figure 5-1 - Camera Locations

Typical Coordinates, m						
Camera Label	Film Size (mm)	Camera Type	Rate: (fr./sec.)	Test 517		
				X*	Y*	Z*
L1	16	LOCAM 1	400	-22.7 m	9.5 m	1.2 m
L2	16	LOCAM 2	400	0.0 m	0.0 m	9.1 m
L3	16	LOCAM 3	400	29.2 m	0.0 m	1.2 m
L4	16	LOCAM 4	400	-0.5 m	0.0 m	9.1 m
L5	16	LOCAM 5	400	-84.3 m	0.0 m	2.4 m
L6	16	LOCAM 6	400	0.5 m	0.0 m	9.1 m
L8	16	LOCAM 8	400	0.9 m	-23.9 m	1.7 m
V	1.27	SONY BETACAM	30	-3.0 m	-21.2 m	1.7 m
H	35	HULCHER	40	-84.0 m	-2.0 m	2.4 m
Note: Camera location measurements were surveyed after each test. For each test in this series the cameras were placed in nearly identical locations allowing the average location to be recorded in this table. *X, Y and Z distances are relative to the impact point.						

Table 5-6 - Camera Type and Locations

The following are the pretest procedures that were required to enable film data reduction to be performed using a film motion analyzer:

1) Butterfly targets were attached to the top and sides of each test vehicle. The targets were located on the vehicle at intervals of 305, 610 and 1219 mm (1, 2 and 4 feet.). The targets established scale factors and horizontal and vertical alignment. The test barrier segments were targeted with stenciled numbers on each.

2) Flashbulbs, mounted on the test vehicle, were electronically triggered to establish 1) initial vehicle-to-barrier contact, and 2) the time of the application of the vehicle brakes. The impact flashbulbs begin to glow immediately upon activation, but have a delay of several milliseconds before lighting up to full intensity.

3) Five tape switches, placed at 4-m intervals, were attached to the ground near the barrier and were perpendicular to the path of the test vehicle. Flash bulbs were activated sequentially when the tires of the test vehicle rolled over the tape switches. The flashbulb stand was placed in view of most of the cameras. The flashing bulbs were used to correlate the cameras with the impact events and to calculate the impact speed independent of the electronic speed trap. The tape switch layout is shown in Figure 5-2.

4) High-speed cameras had timing light generators which exposed red timing pips on the film at a rate of 100 per second. The pips were used to determine camera frame rates.

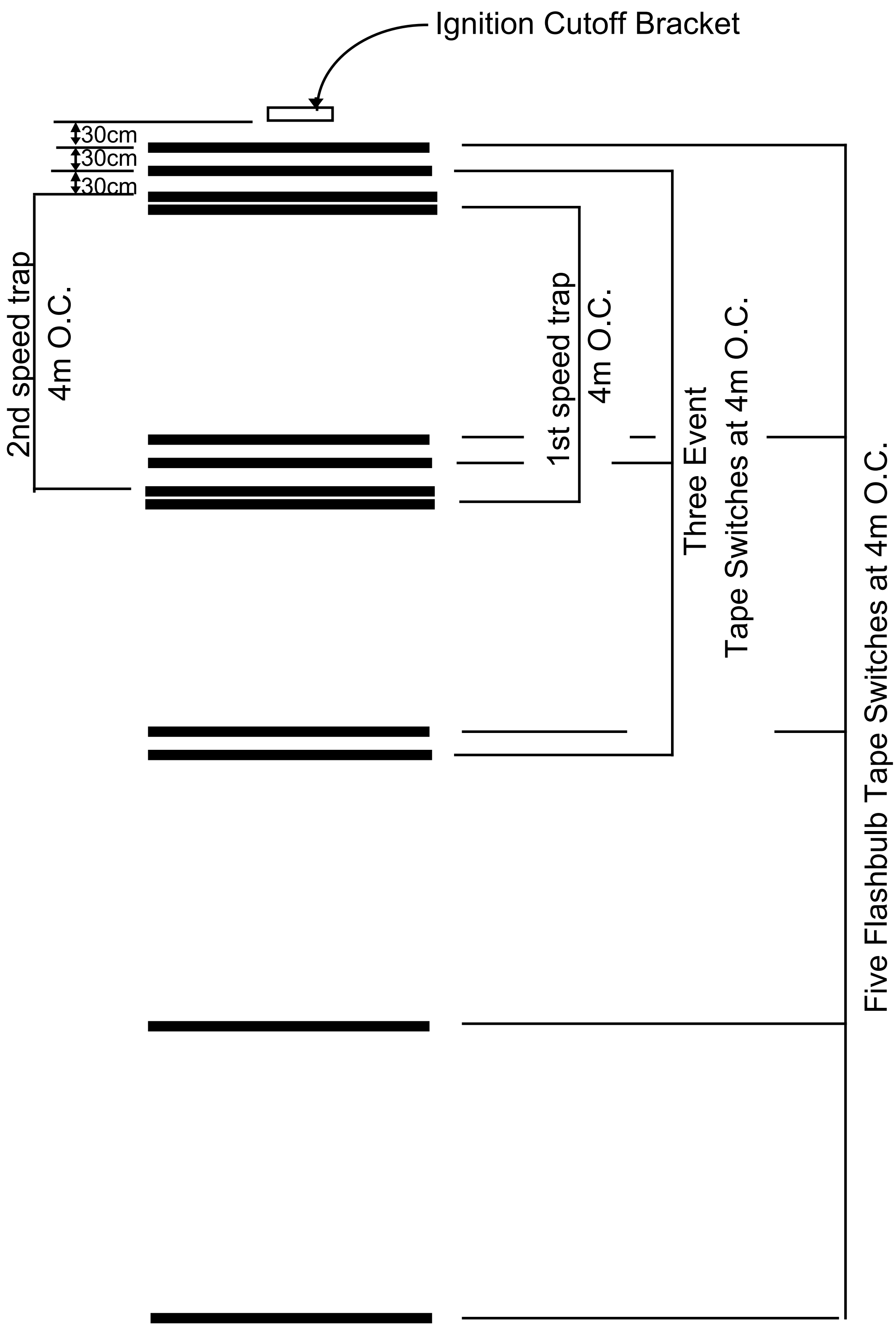


Figure 5-2 - Tape Switch Layout

5.4. *Electronic Instrumentation and Data*

Transducer data were recorded on a Pacific Instruments digital transient data recorder (TDR) model 5600, which was mounted in the vehicle. The transducers mounted on the two vehicles included two sets of accelerometers and one set of rate gyros at the center of gravity. The TDR data were reduced using a desktop computer.

Three pressure-activated tape switches were placed on the ground in front of the test barrier. They were spaced at carefully measured intervals of 4 m. When the test vehicle tires passed over them, the switches produced sequential impulses or "event blips" which were recorded concurrently with the accelerometer signals on the TDR, serving as "event markers". A tape switch on the front bumper of the vehicle closed at the instant of impact and triggered two events: 1) an "event marker" was added to the recorded data, and 2) a flash bulb mounted on the top of the vehicle was activated. The impact velocity of the vehicle could be determined from the tape switch impulses and timing cycles. Two other tape switches, connected to a speed trap, were placed 4 m apart just upstream of the test barrier specifically to establish the impact speed of the test vehicle.

The data curves are shown in figures Figure 5-4 through Figure 5-15 and include the accelerometer and rate gyro records from the test vehicles. They also show the longitudinal velocity and displacement versus time. These plots were needed to calculate the occupant impact velocity defined in NCHRP Report 350. All data were analyzed using software written by DADiSP and modified by Caltrans.

Table 5-7 - Accelerometer Specifications

TYPE	LOCATION	RANGE	ORIENTATION	TEST NUMBER
ENDEVCO	VEHICLE C.G.	100 G	LONGITUDINAL	ALL
ENDEVCO	VEHICLE C.G.	100 G	LATERAL	ALL
ENDEVCO	VEHICLE C.G.	100 G	VERTICAL	ALL
HUMPHREY	VEHICLE C.G.	180 DEG/SEC	ROLL	ALL
HUMPHREY	VEHICLE C.G.	90 DEG/SEC	PITCH	ALL
HUMPHREY	VEHICLE C.G.	180 DEG/SEC	YAW	ALL
ENDEVCO	VEHICLE C.G.	100 G	LONGITUDINAL	ALL
ENDEVCO	VEHICLE C.G.	100 G	LATERAL	ALL
ENDEVCO	VEHICLE C.G.	100 G	VERTICAL	ALL

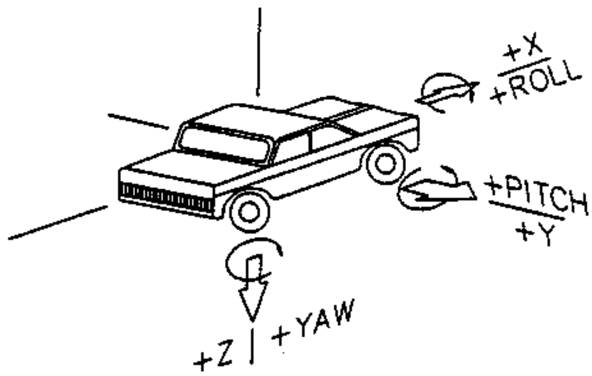


Figure 5-3 - Vehicle Accelerometer Sign Convention

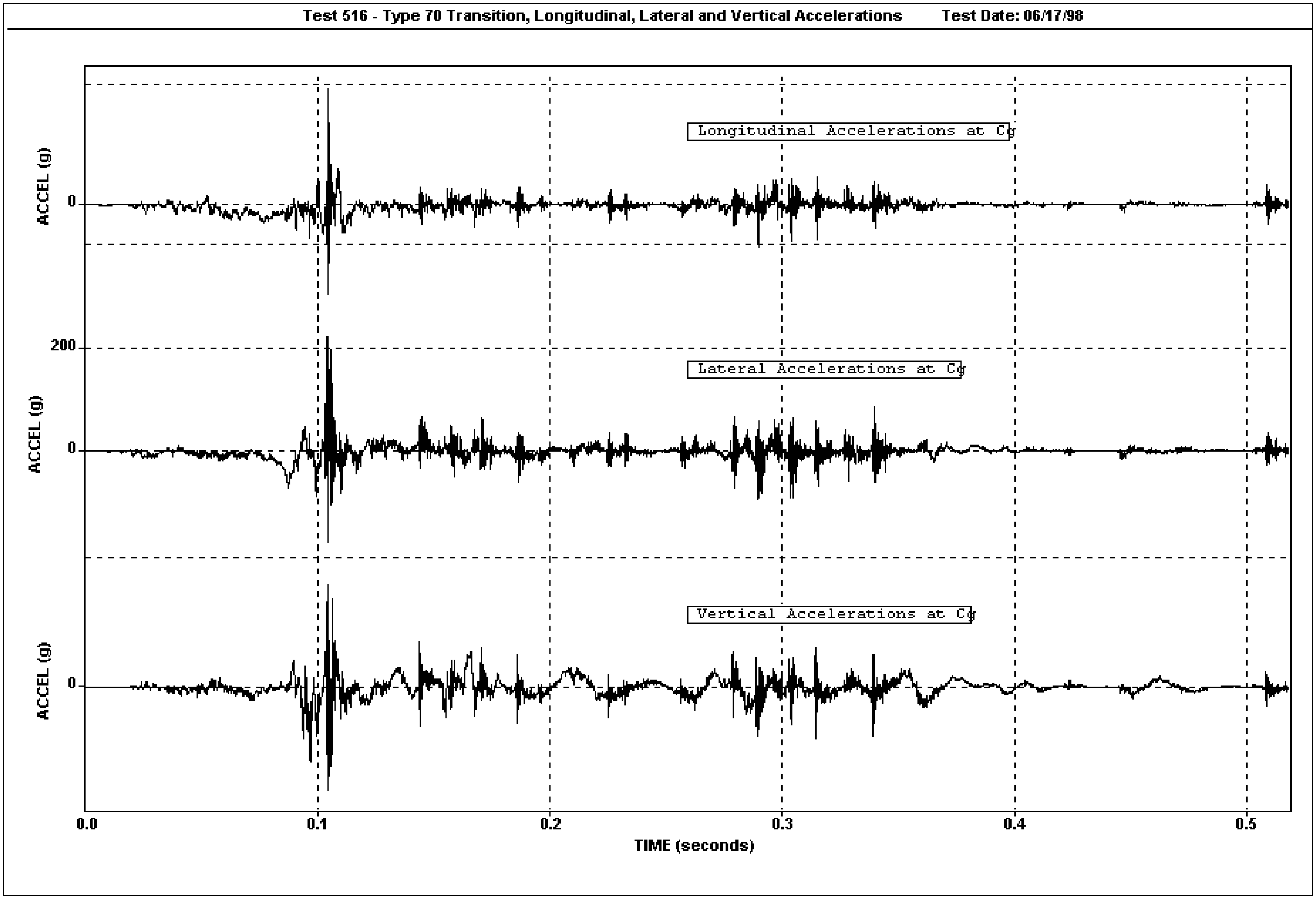


Figure 5-4 - Test 516 Vehicle Accelerations -Vs- Time

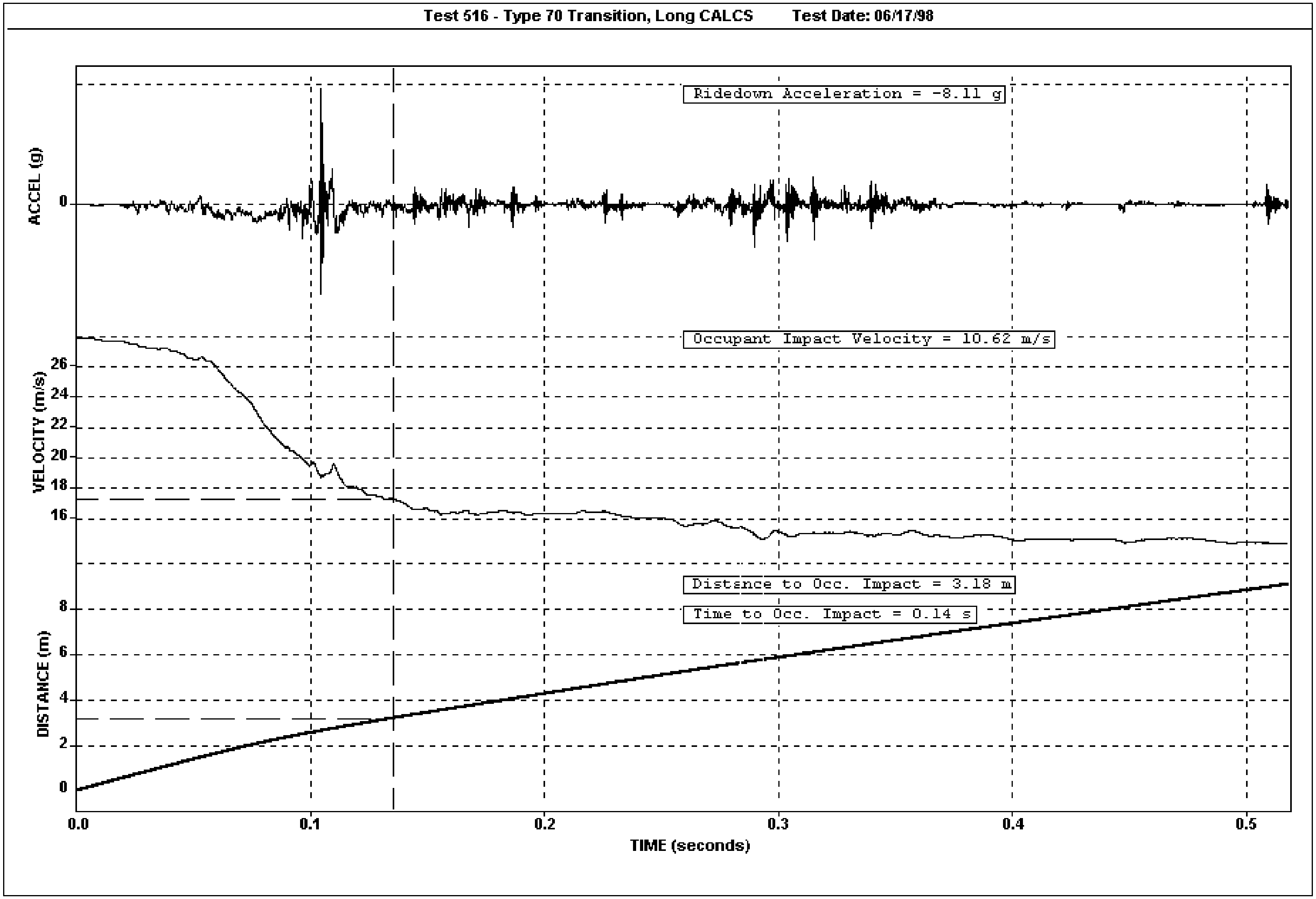


Figure 5-5 - Test 516 Vehicle Longitudinal Acceleration, Velocity and Distance -Vs- Time

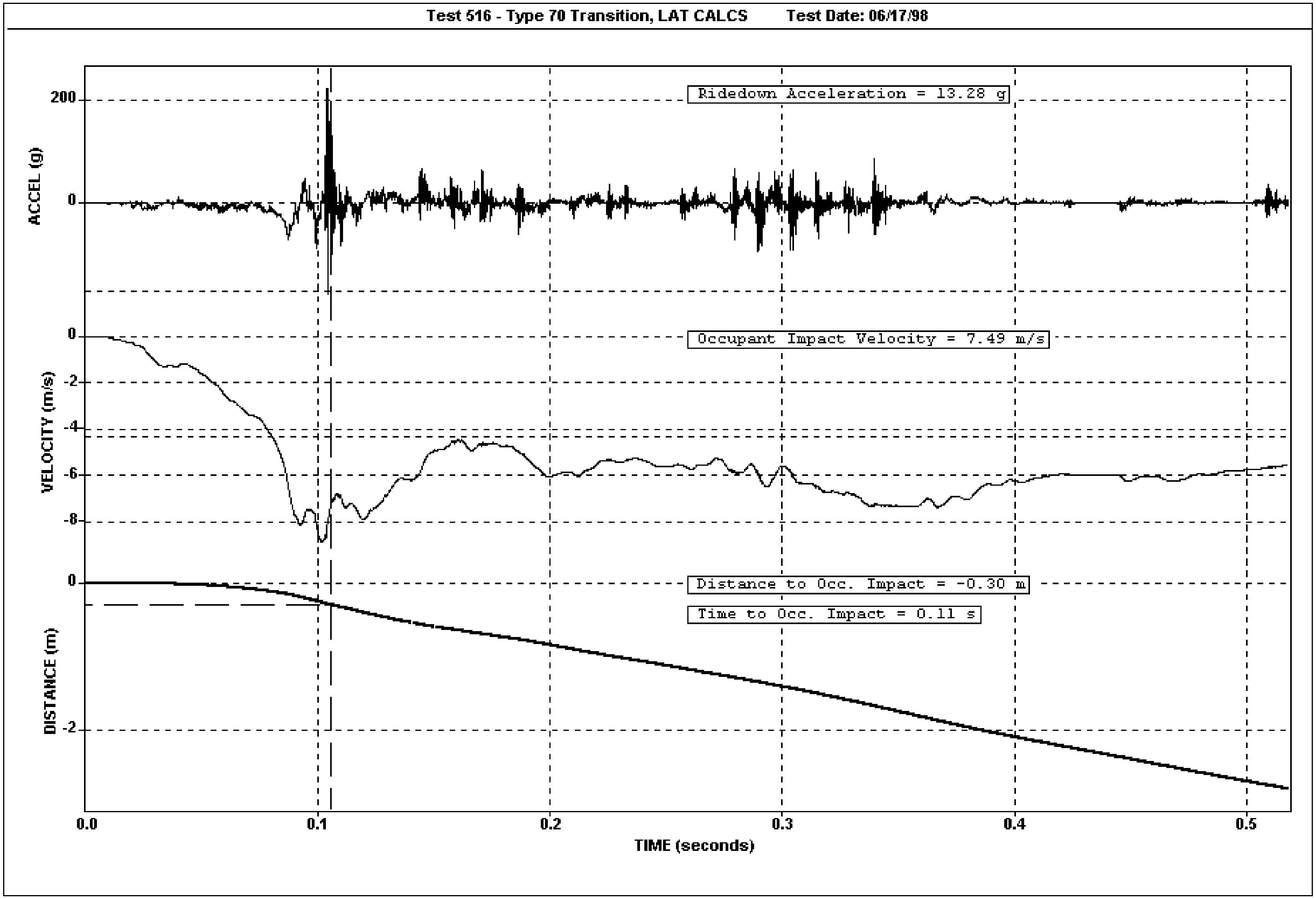


Figure 5-6 - Test 516 Vehicle Lateral Acceleration, Velocity and Distance -Vs- Time

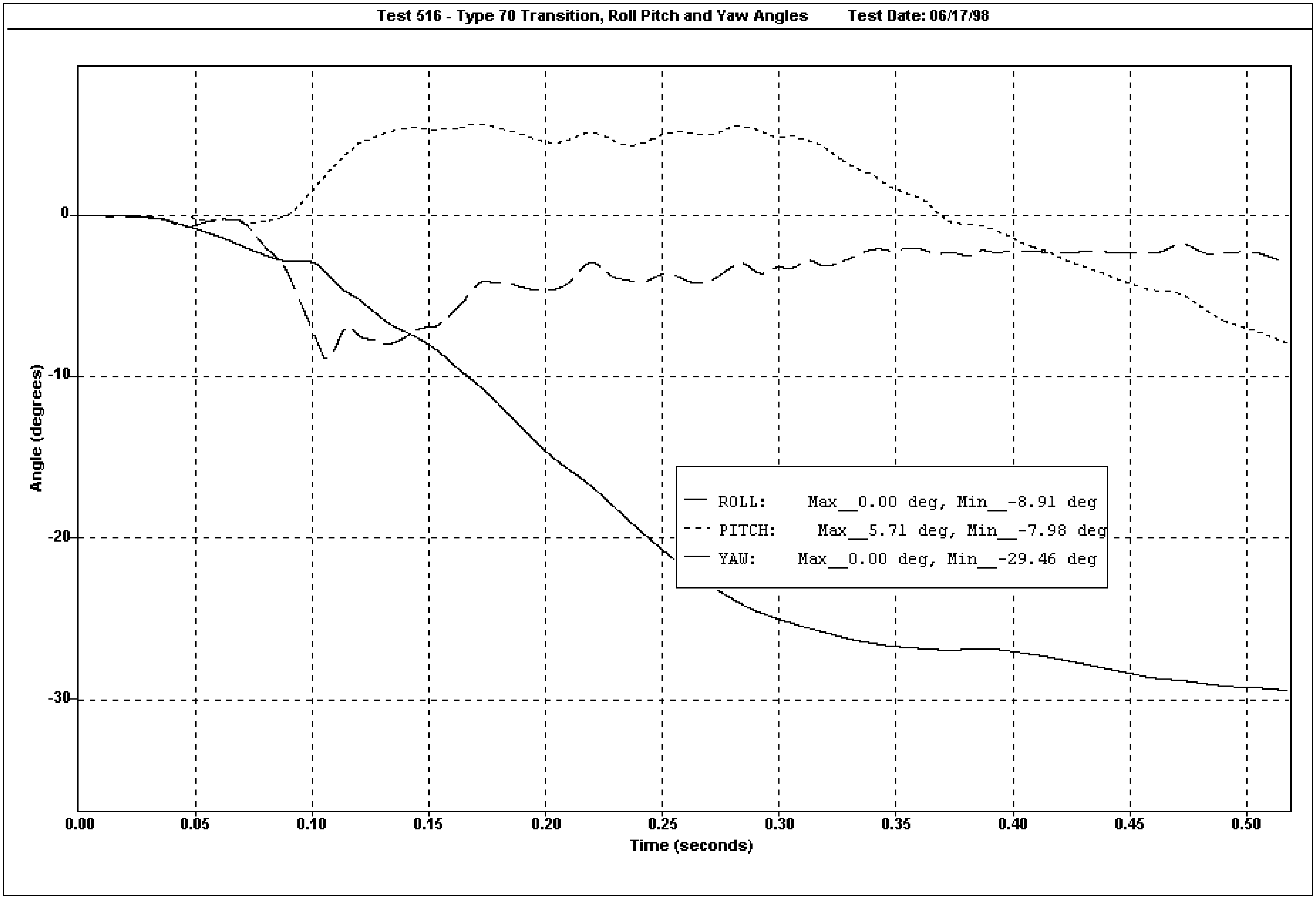


Figure 5-7 - Test 516 Vehicle Roll, Pitch and Yaw -Vs- Time

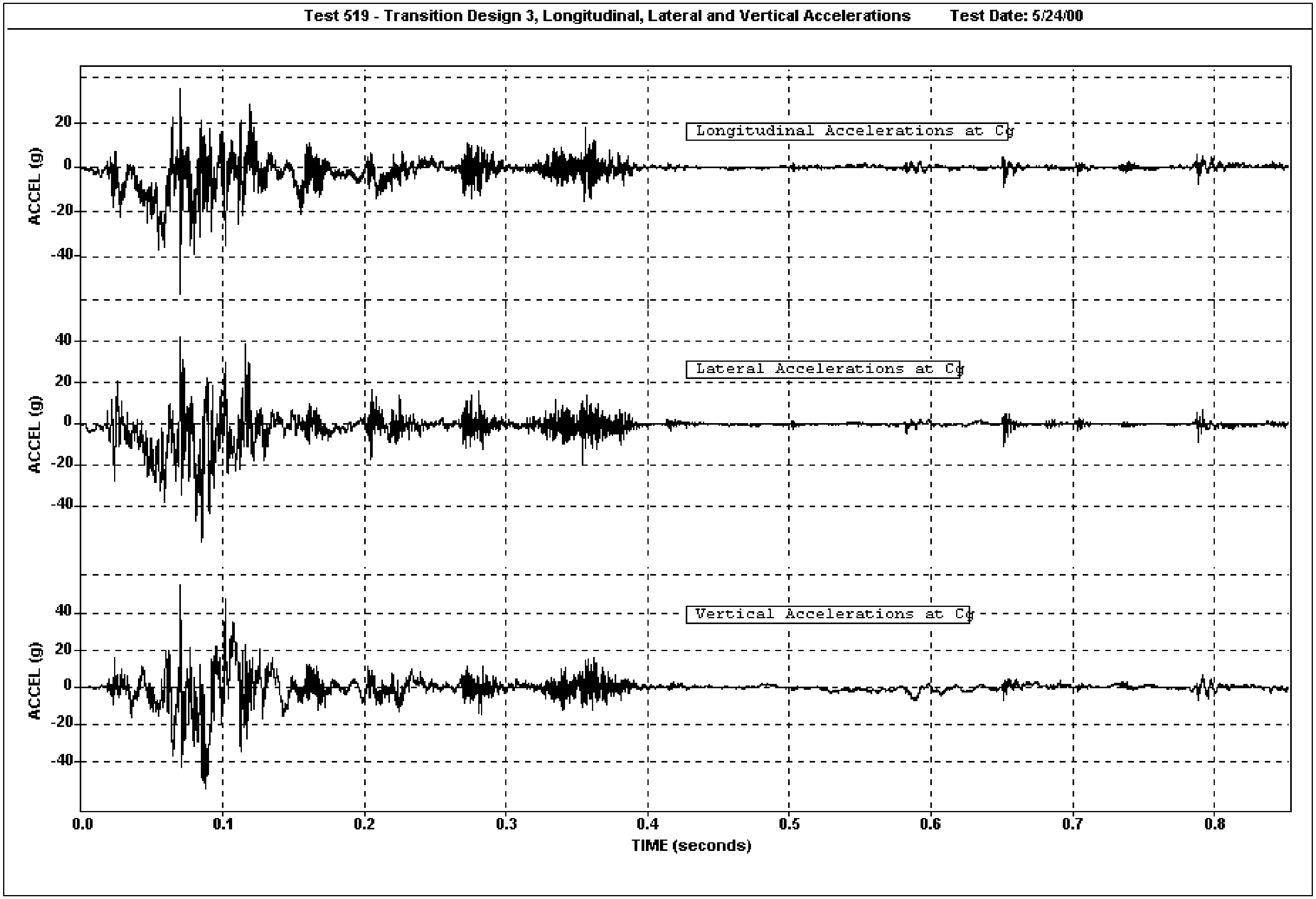


Figure 5-8 - Test 519 Vehicle Accelerations -Vs- Time

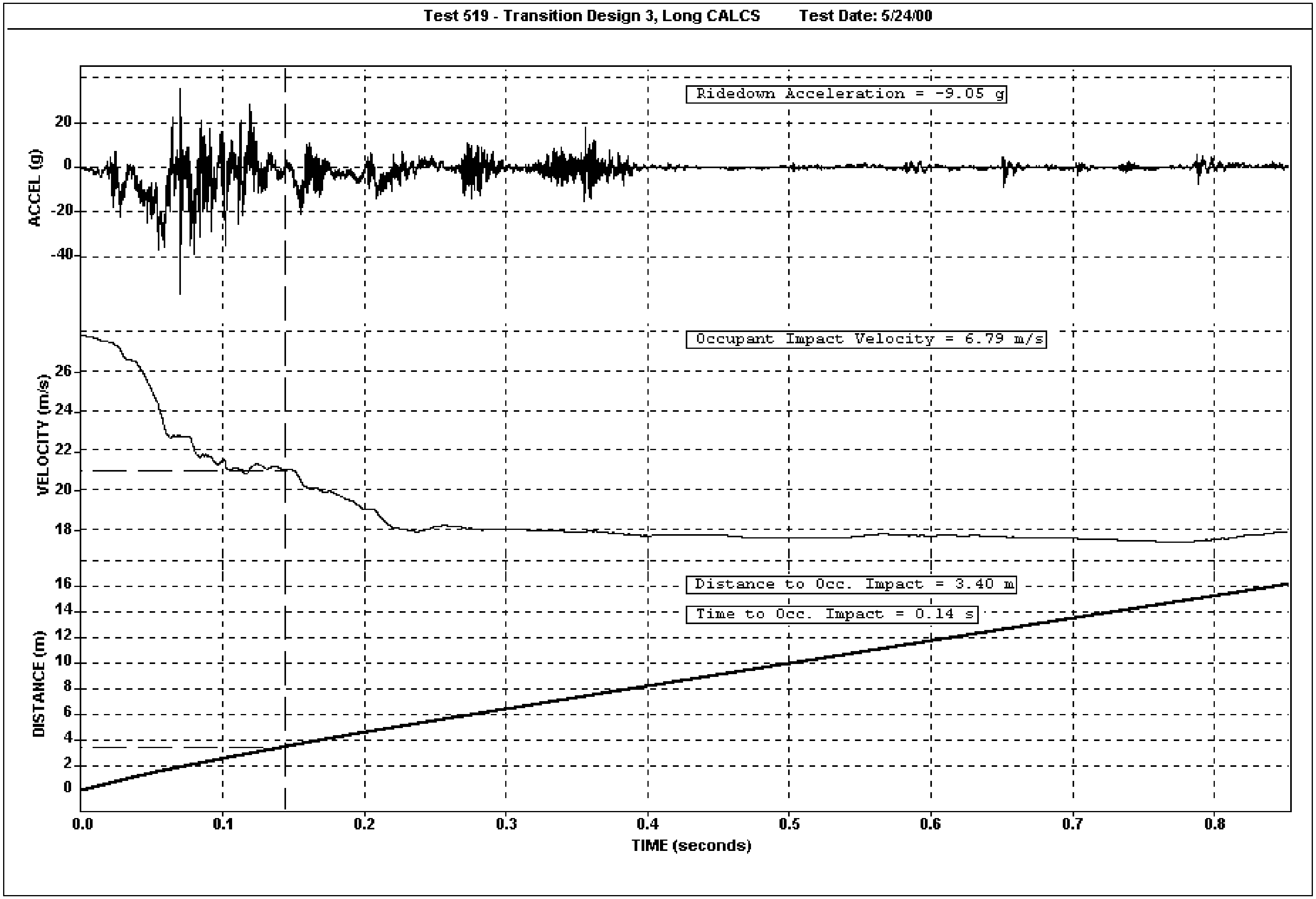


Figure 5-9 - Test 519 Vehicle Longitudinal Acceleration, Velocity and Distance -Vs- Time

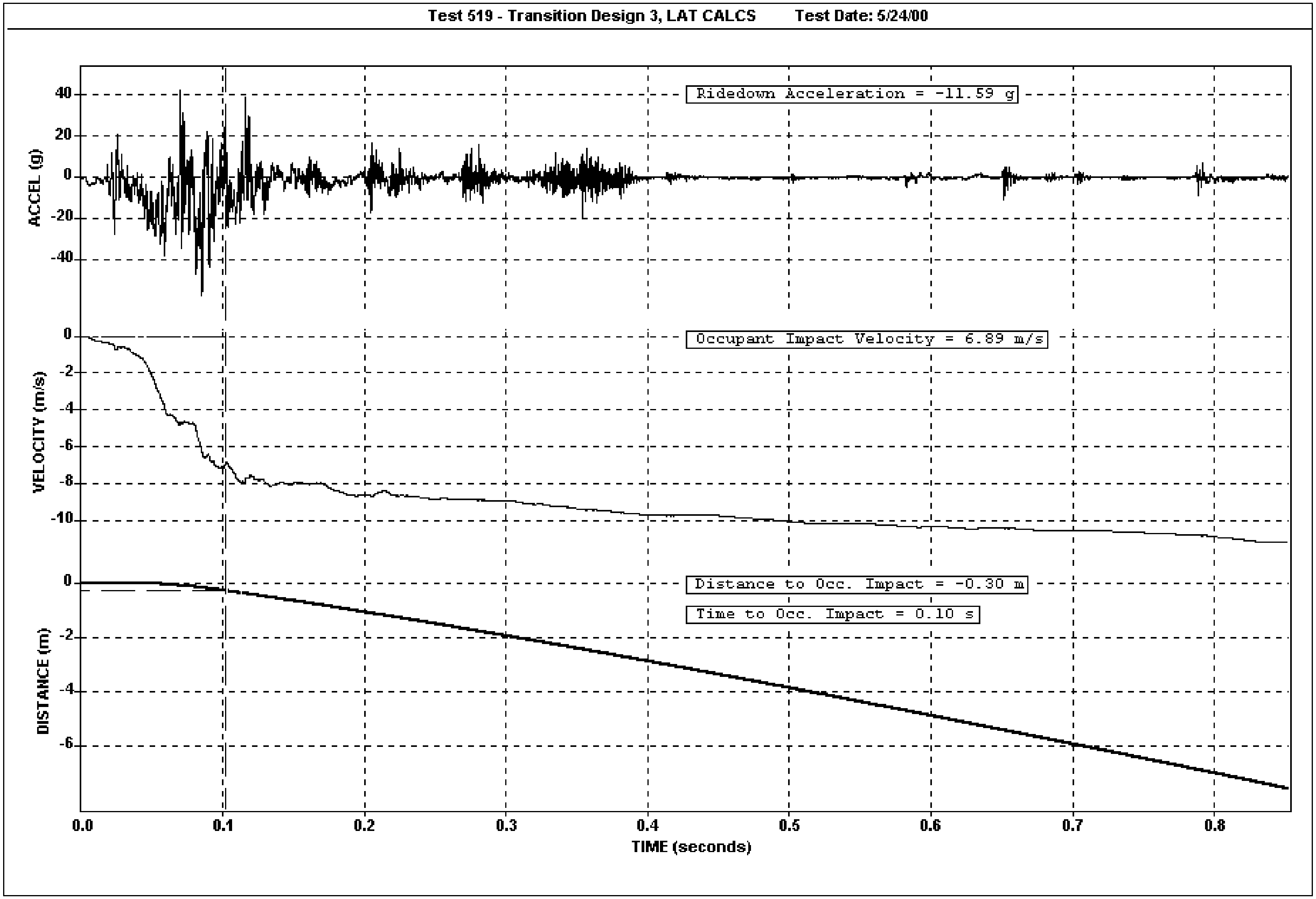


Figure 5-10 - Test 519 Vehicle Lateral Acceleration, Velocity and Distance -Vs- Time

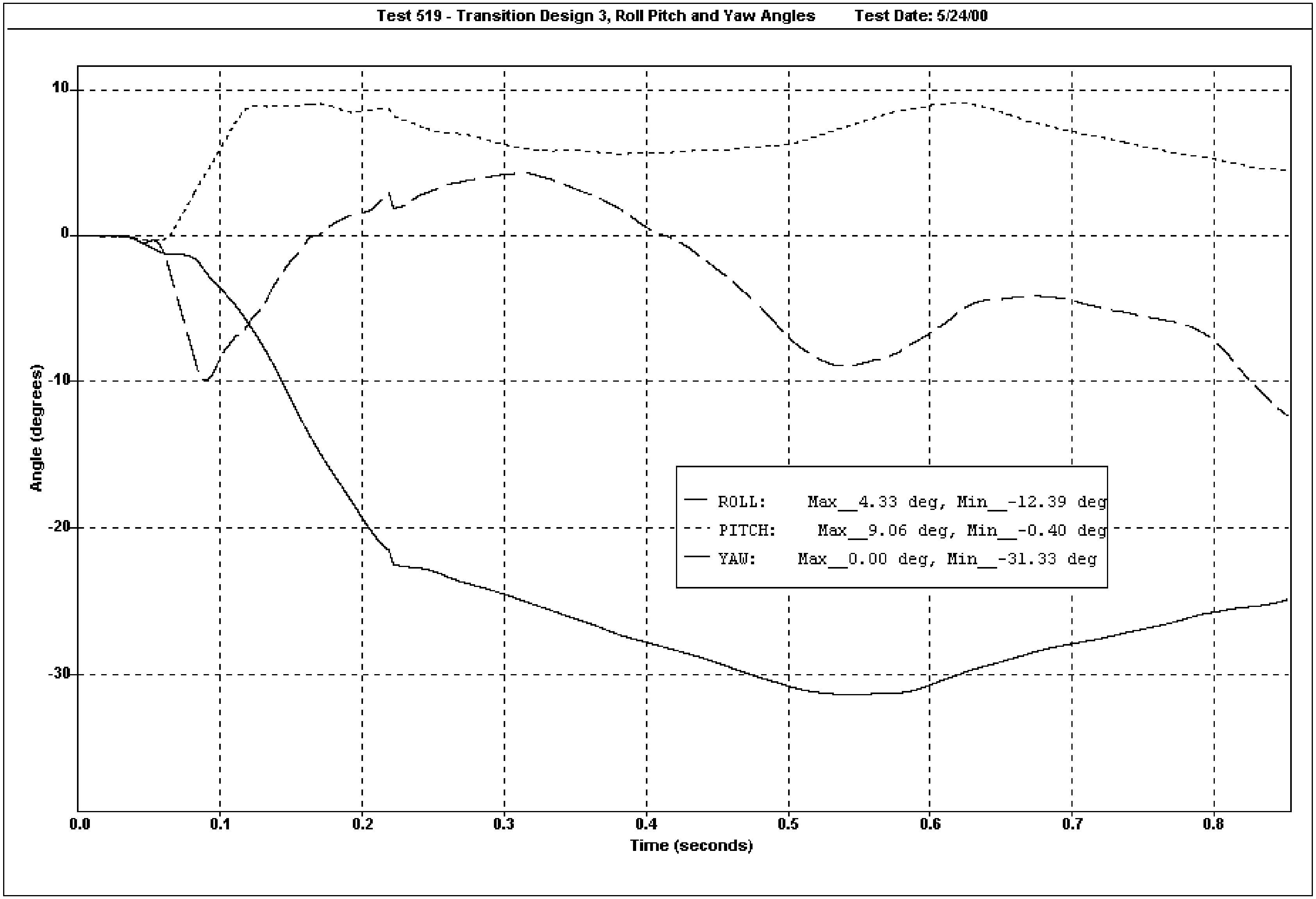


Figure 5-11 - Test 519 Vehicle Roll, Pitch and Yaw -Vs- Time

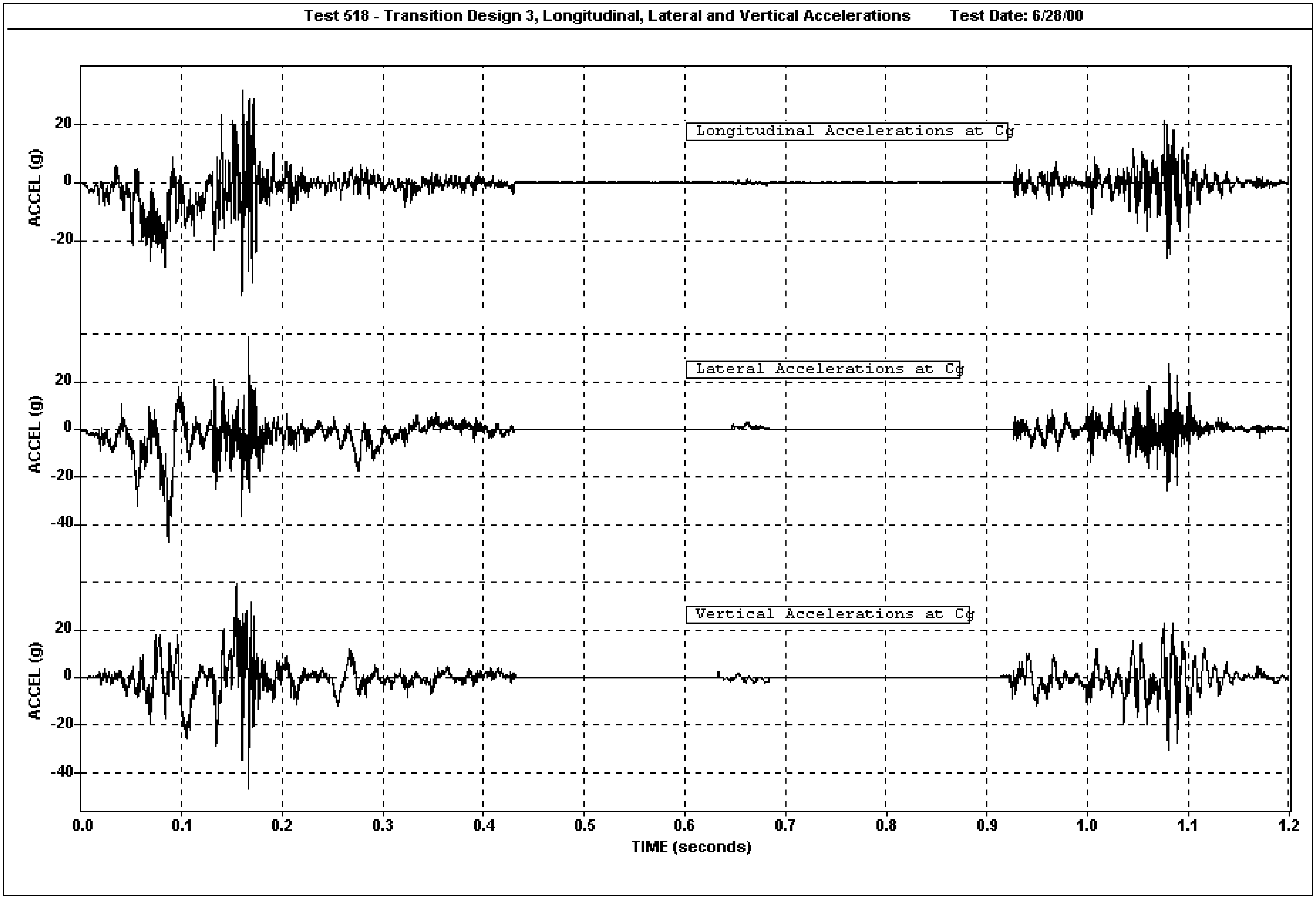


Figure 5-12 - Test 518 Vehicle Accelerations -Vs- Time

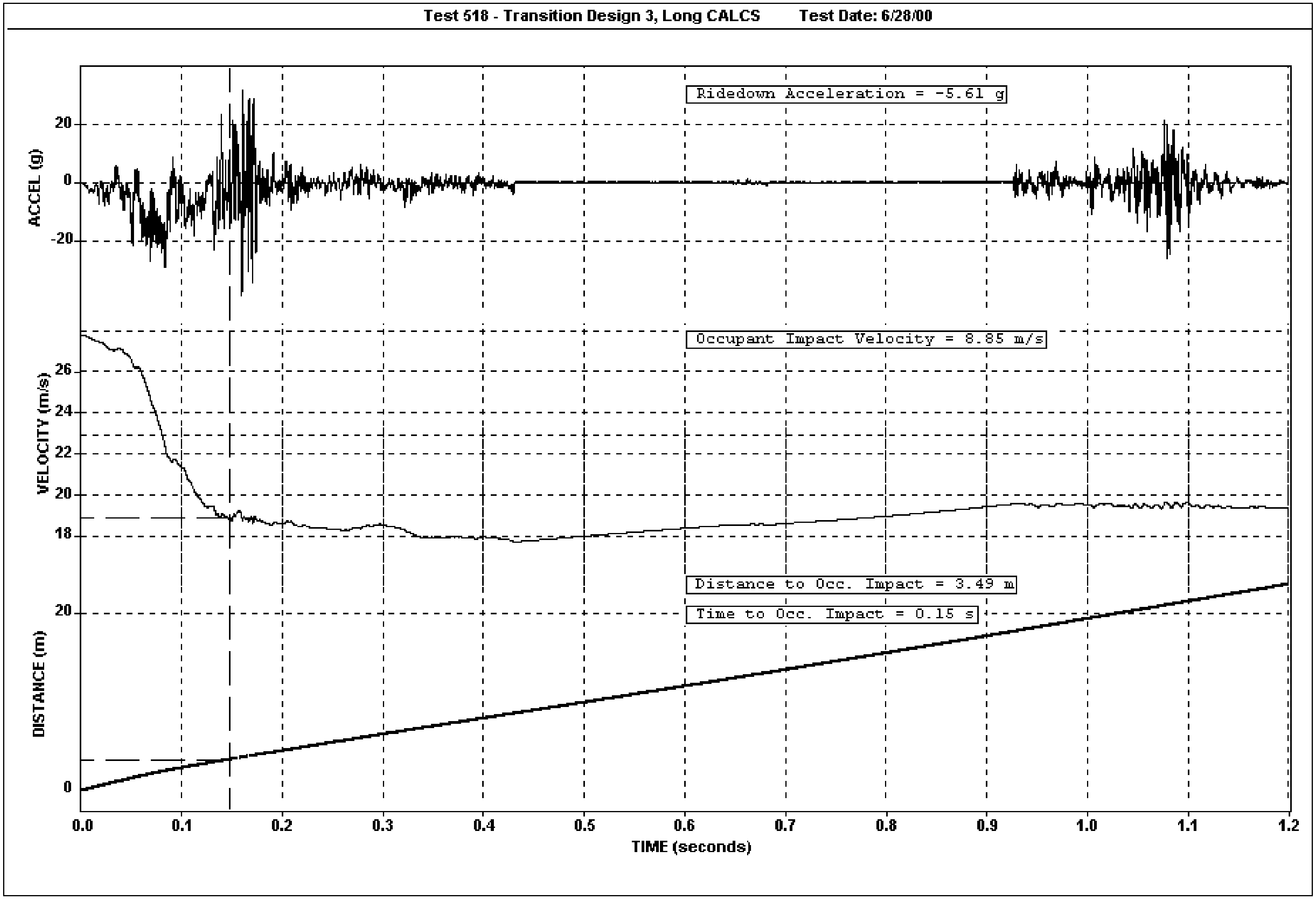


Figure 5-13 - Test 518 Vehicle Longitudinal Acceleration, Velocity and Distance -Vs- Time

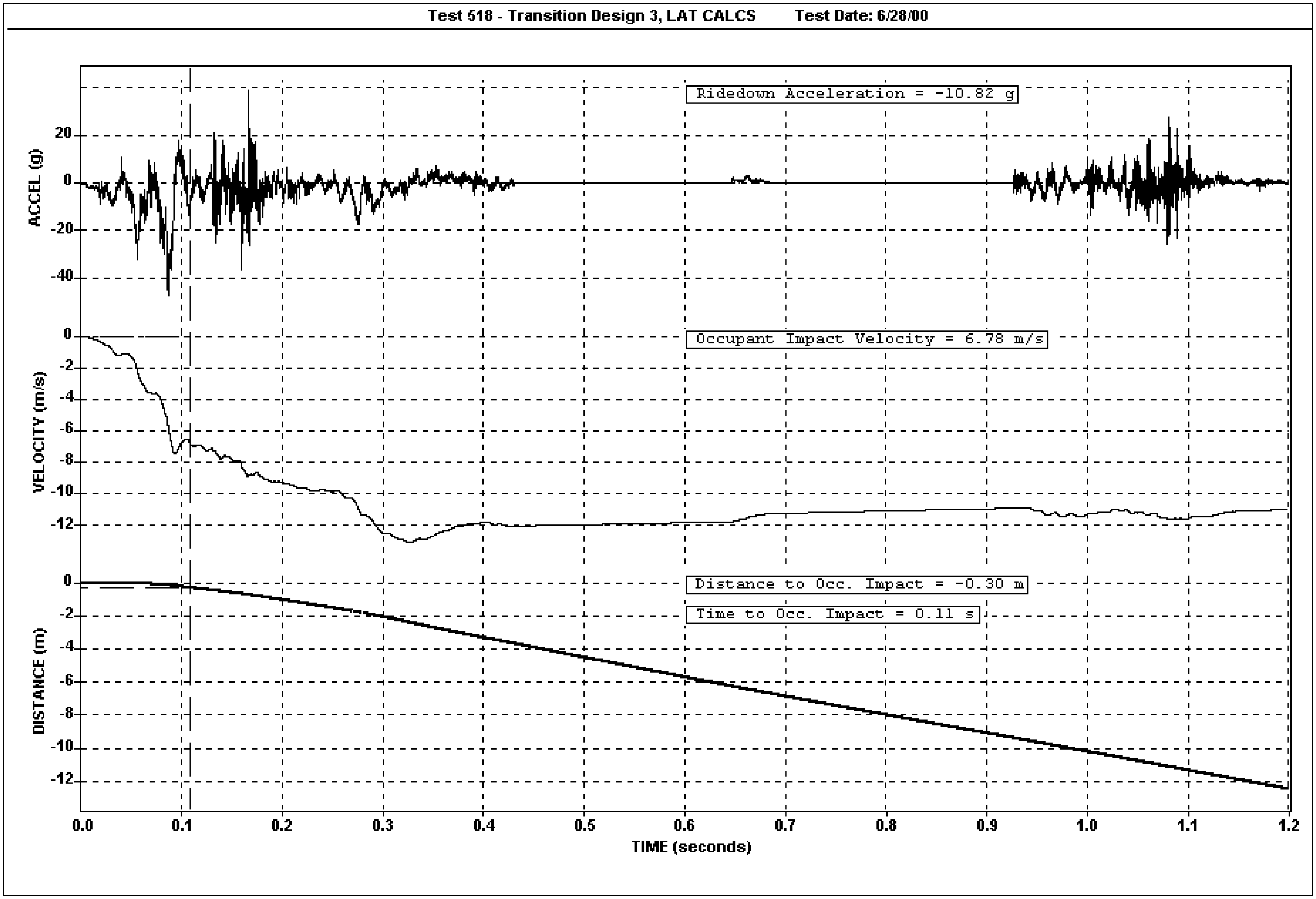


Figure 5-14 - Test 518 Vehicle Lateral Acceleration, Velocity and Distance -Vs- Time

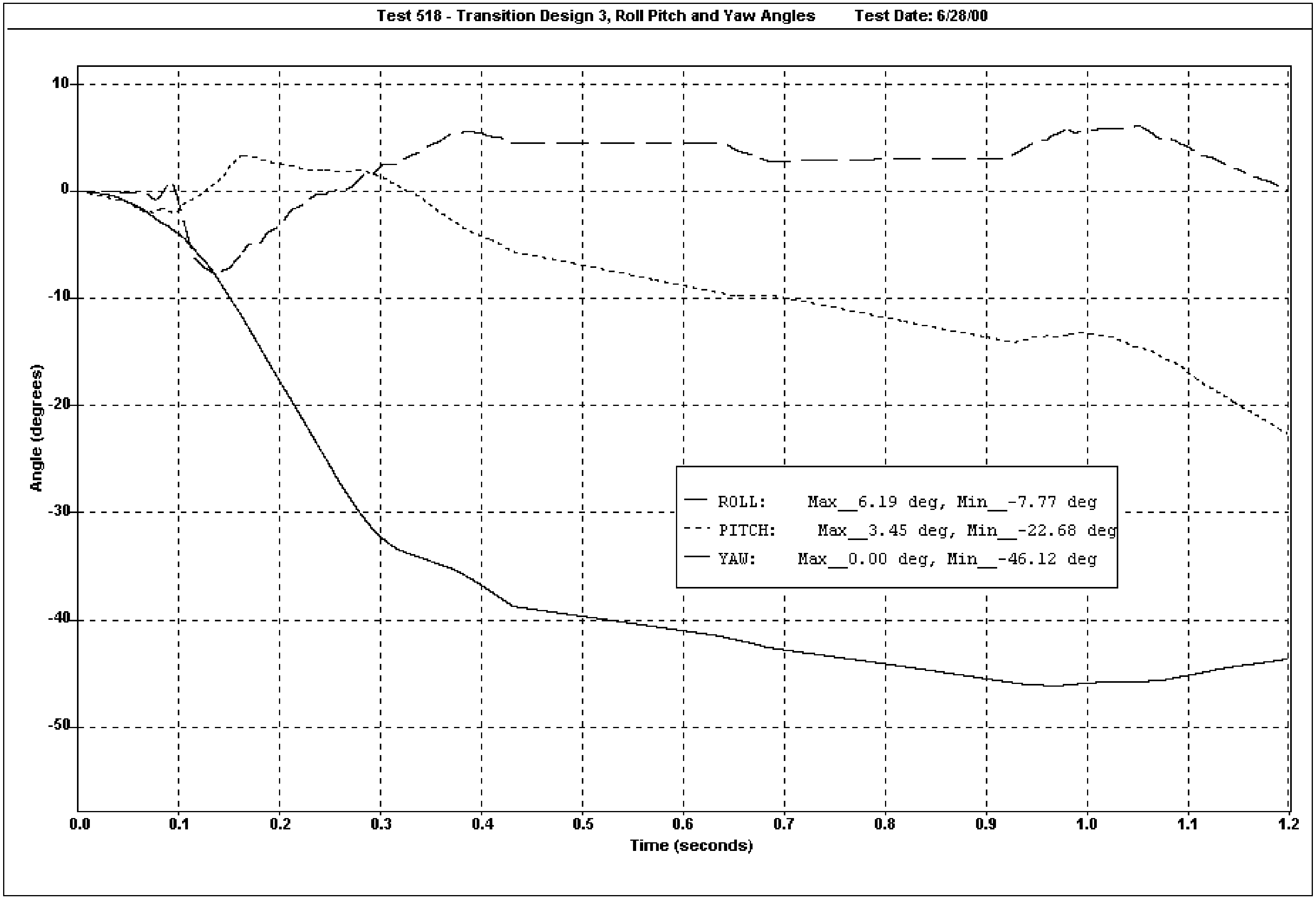


Figure 5-15 - Test 518 Vehicle Roll, Pitch and Yaw -Vs- Time

5.5. Detailed Drawing

There are three designs depicted below:

- Transition Design 1
- Transition Design 2
- Transition Design 3

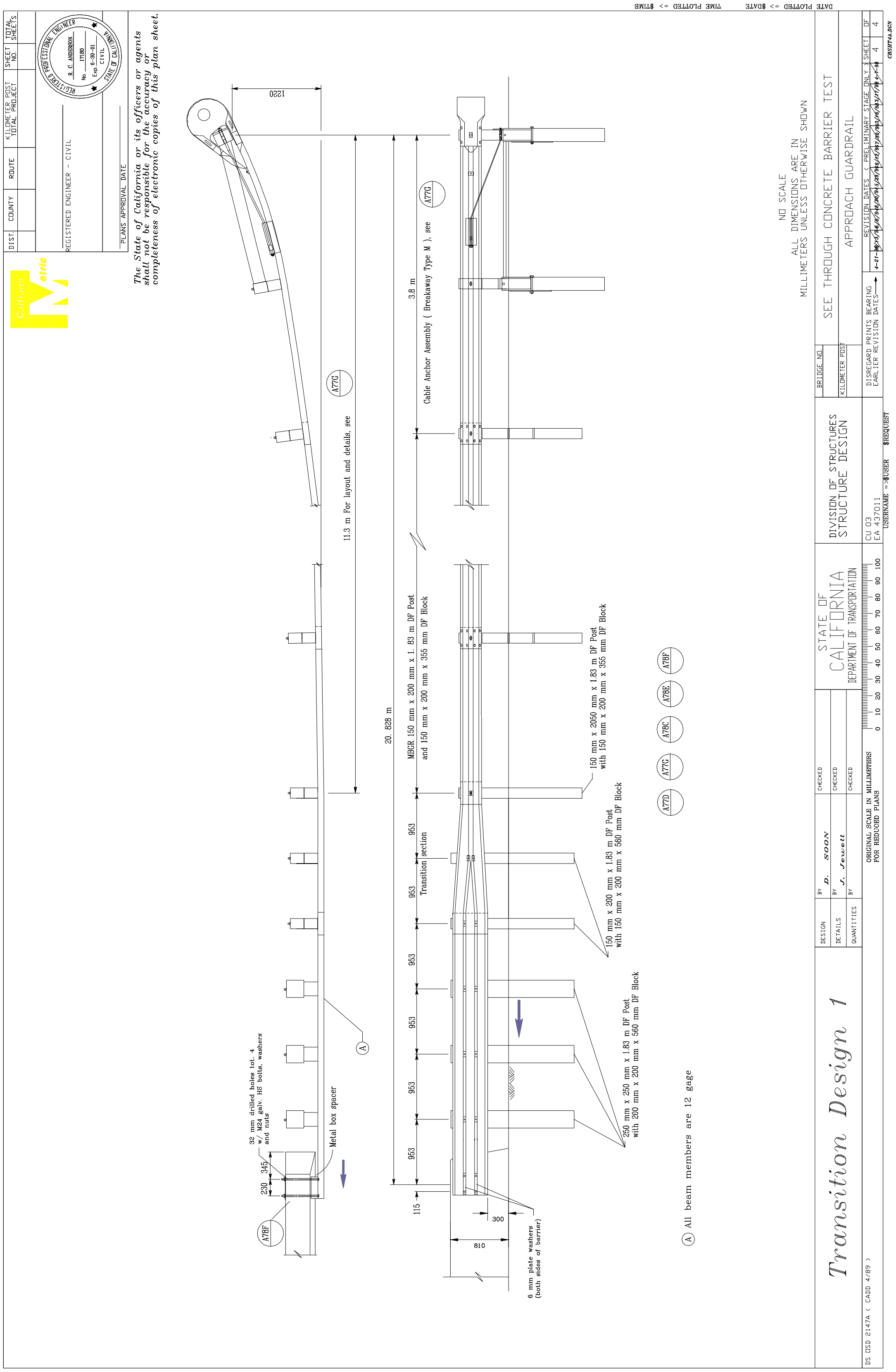


Figure 5-16 - Transition Design 1

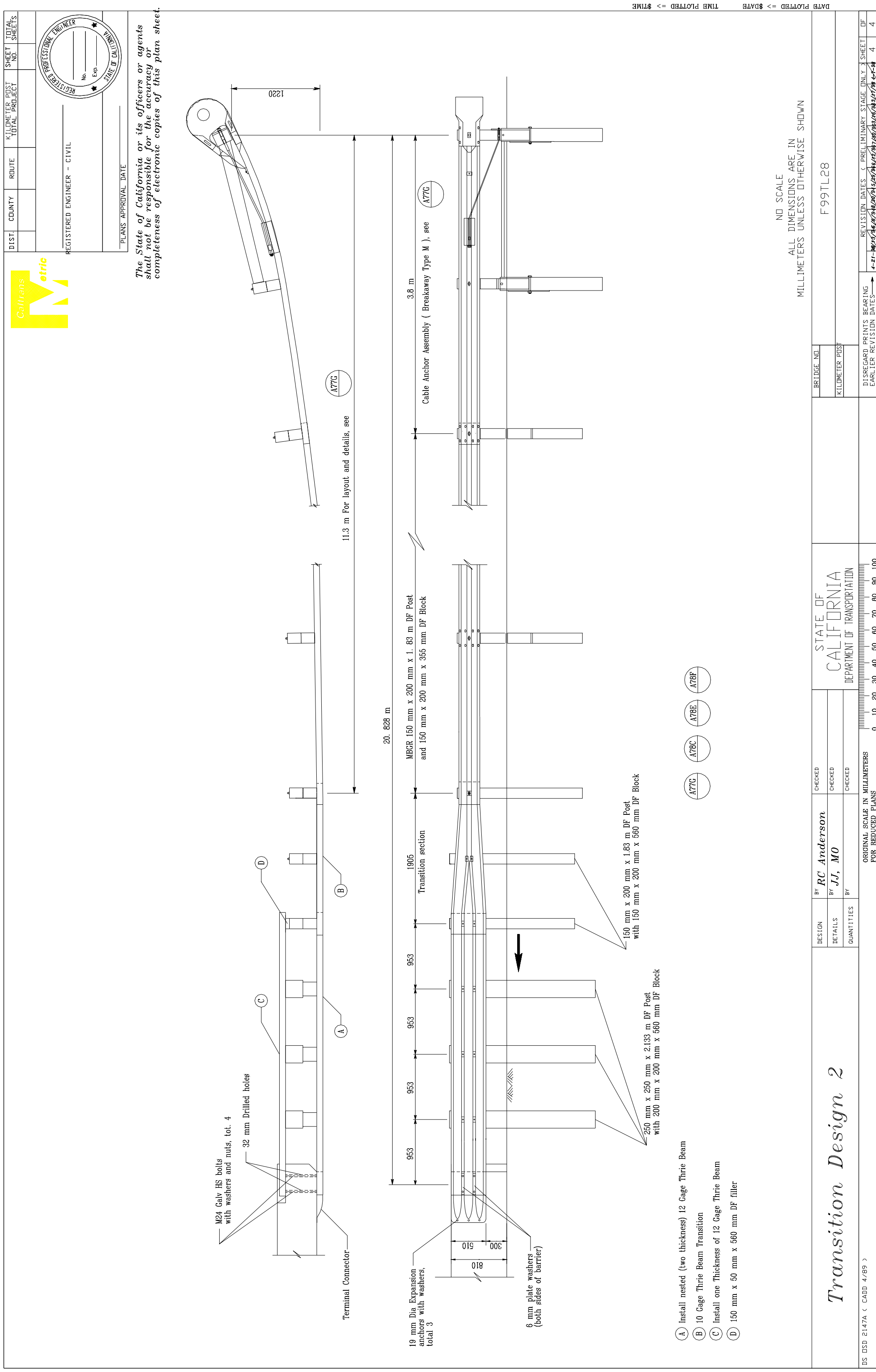


Figure 5-17 - Transition Design 2

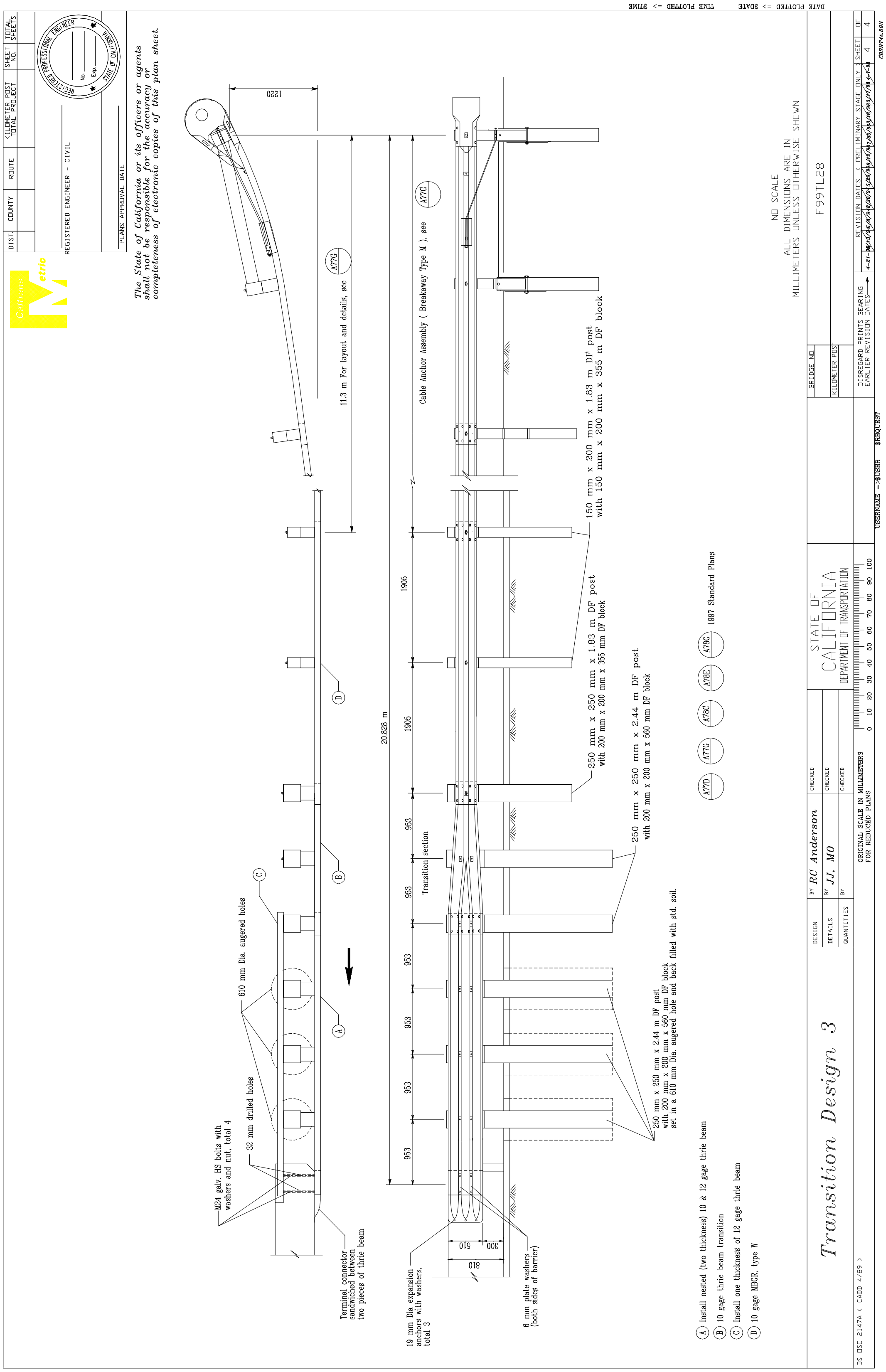


Figure 5-18 - Transition Design 3

6. REFERENCES

[1] "Recommended Procedures for the Safety Performance Evaluation of Highway Features", Transportation Research Board, National Cooperative Highway Research Program Report 350, 1993.

[2] Buth, C. Eugene, et al., "Testing Of New Bridge Rail And Transition Designs", V.1 Technical Report, JAN-97, FHWA, Mc Lean, VA

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[4] "Development and Testing of an Approach Guardrail Transition to a Single Slope Concrete Median Barrier", TRP-03-47-95

[5] Jewell, John, et al, "Vehicle Crash Tests of Type 115 Barrier Rail Systems for Use on Secondary Highways", Oct-93, Transportation Research Board, National Research Council

[6] Bligh, Roger P., et al, "Evaluation of Bridge Approach Rails", May-92, Arizona DOT, Phoenix, AZ

[7] Faller, R.K., Holloway, J.C., Pfeifer, B.G., Ataullah, S., Post, E.R., and Lundquist, W.A., "Safety Performance Evaluations: Bridge Rails and an Approach Guardrail Transition", Jan-91, Iowa Department of Transportation, Ames, Iowa.