FULL-SCALE CRASH TESTS

OF

MOTORIST AID CALL BOX SYSTEM

Prepared for

Delaware Department of Transportation
DDOT Contract No. IR-95-2(67)C
Dover, Delaware

by

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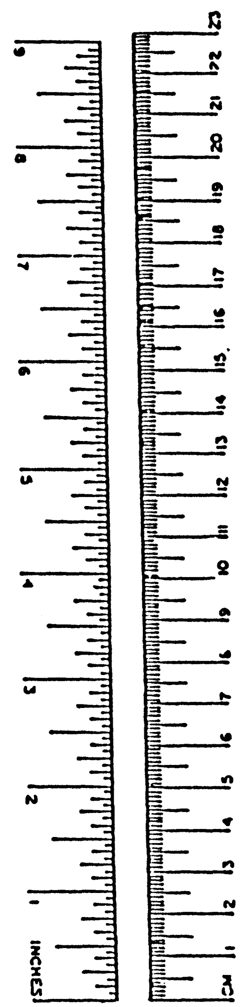
METRIC CONVERSION FACTORS

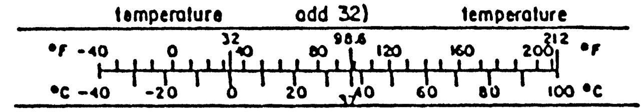
APPROXIMATE CONVERSIONS FROM METRIC MEASURES

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.6	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



APPROXIMATE CONVERSIONS FROM METRIC MEASURES

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	8.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

The Delaware Department of Transportation has proposed the lowering of motorist aid call boxes along the Delaware Interstate System to a height of 54 in (137 cm) in order to make the call boxes accessible to wheelchair, handicapped individuals. Before beginning the necessary modifications the Delaware DOT recognized the need to evaluate the safety performance of the proposed call box installations. In order to meet this objective, four full-scale vehicle crash tests were performed at the Texas Transportation Institute Proving Grounds. Procedures and standards set forth in the National Cooperative Highway Research Program Report 230[1] were used for conducting, evaluating and reporting these four tests. Reported herein are the findings of the tests.

TEST ARTICLE AND MATRIX

The test article consisted of a motorist aid call box installation. The installation included a Signal Communications user powered call box, an aluminum sign, a 5 in (13 cm) O.D. aluminum pole, an antenna, four Transpo Pole-Safe breakaway couplings, shown in figure 1, four 1 in (2.5 cm) by 40 in (102 cm) anchor bolts, and a 24 in (61 cm) diameter by 48 in (122 cm) deep concrete base, shown in figure 2. The call box and sign were mounted on the aluminum pole. The top-of-call box mounting height was 54 in (137 cm) above ground level. The pole was connected to the concrete anchor bolts through the breakaway couplings.

In the first and second tests, 0335-1 and 0335-2 respectfully, the call boxes were oriented to face 90 degrees to the direction of traffic. Figure 3 shows details of the installations.

In the third test, 0335-3, the call box was oriented to face 90 degrees to the direction of traffic, as shown in figure 3, and the installation was located behind a metal post W-beam guardrail. The guardrail, shown in figure 4, included 12 ga. W-beam rail elements, W6 × 9 steel posts and W6 × 9 steel offset blocks. The rail elements were bolted to the offset blocks which were bolted to the posts. The top-of-rail mounting height was 27 in (686 cm). The post spacing was 6.25 ft (1.9 m). The length of the guardrail including terminals was 125 ft (38 m). The concrete base was placed midway between posts 8 and 9 such that the centerline of the aluminum pole was 25 in (63.5 cm) from the face of the rail. The lateral positioning of the call box with respect to the guardrail is shown in figure 5.

To more closely represent the call box installations in use in Delaware which are not located behind guardrails, a fourth test, 0335-4, was performed with the call box oriented to face 180 degrees to the direction of vehicle travel. Figure 6 shows details of the installation for test 4.

Tests 1, 2, and 4 followed guidelines for breakaway and yielding supports described in Tests 62 and 63 of NCHRP Report 230[1]. Test 3 followed guidelines for longitudinal barriers described in Test 10 of NCHRP Report 230[1]. Test 1 was performed to evaluate the test article by observing the breakaway mechanism of the test article, the risk to an

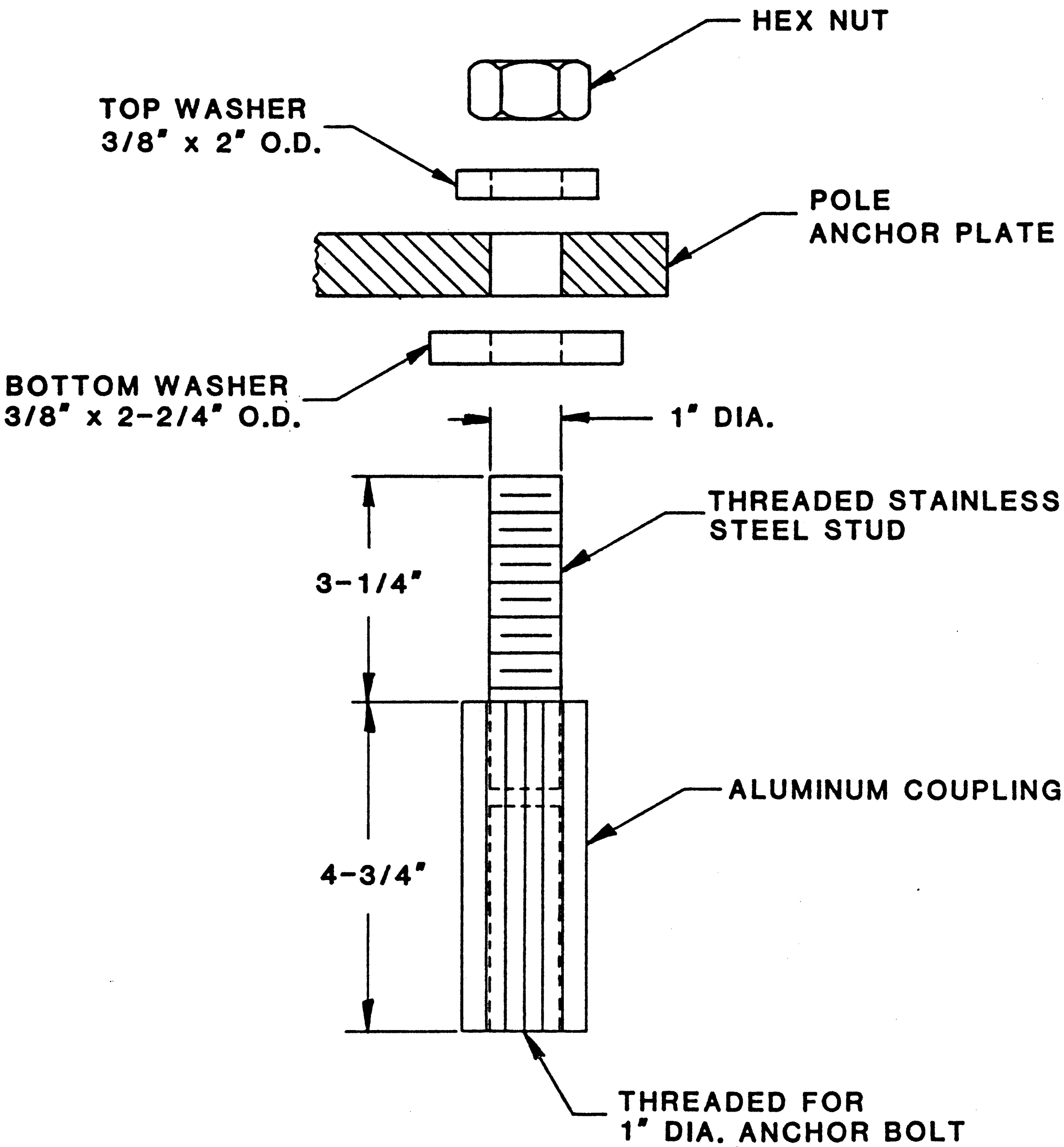


Figure 1. Transpo Pole-Safe breakaway coupling.

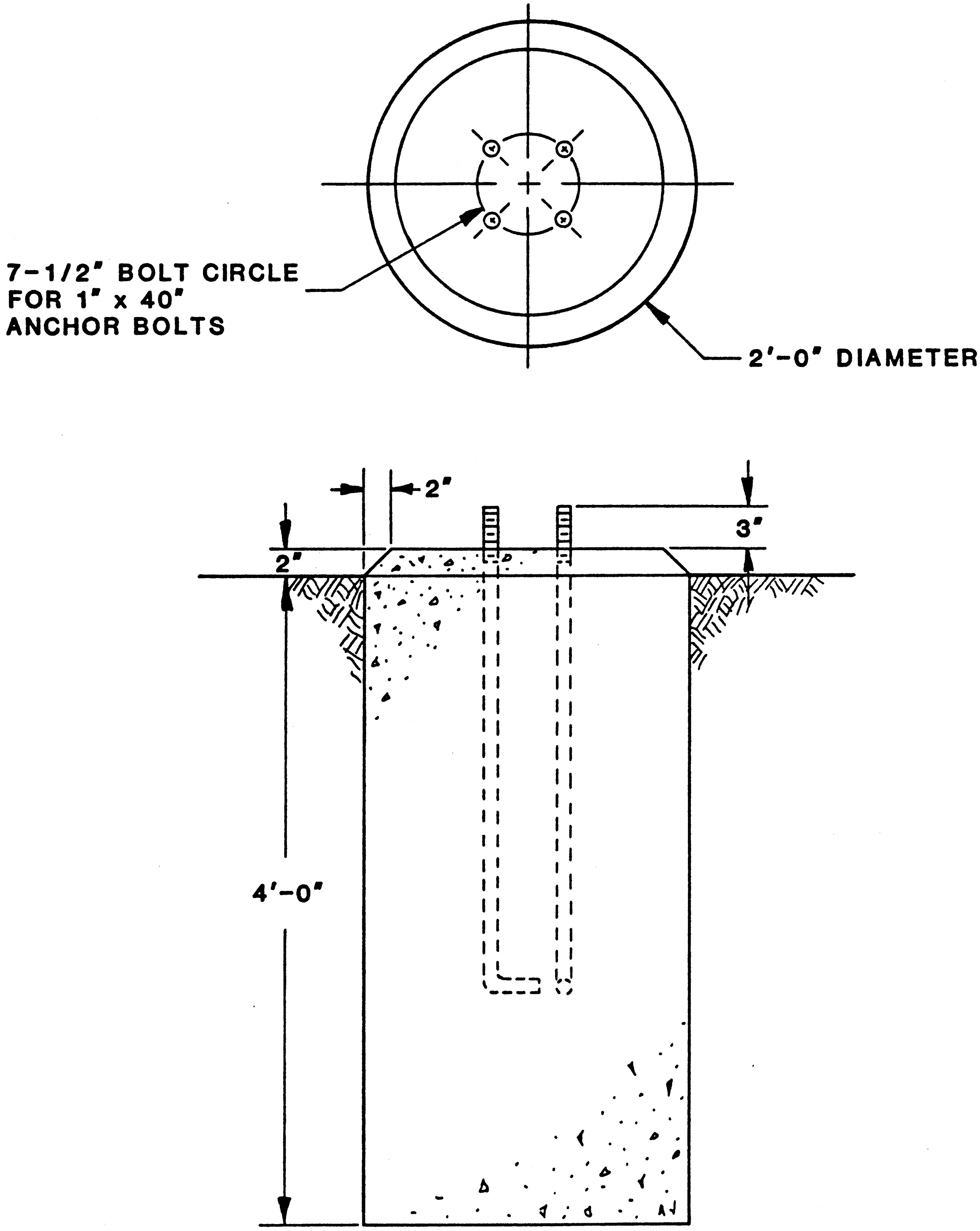


Figure 2. Delaware DOT Type 5 pole base.

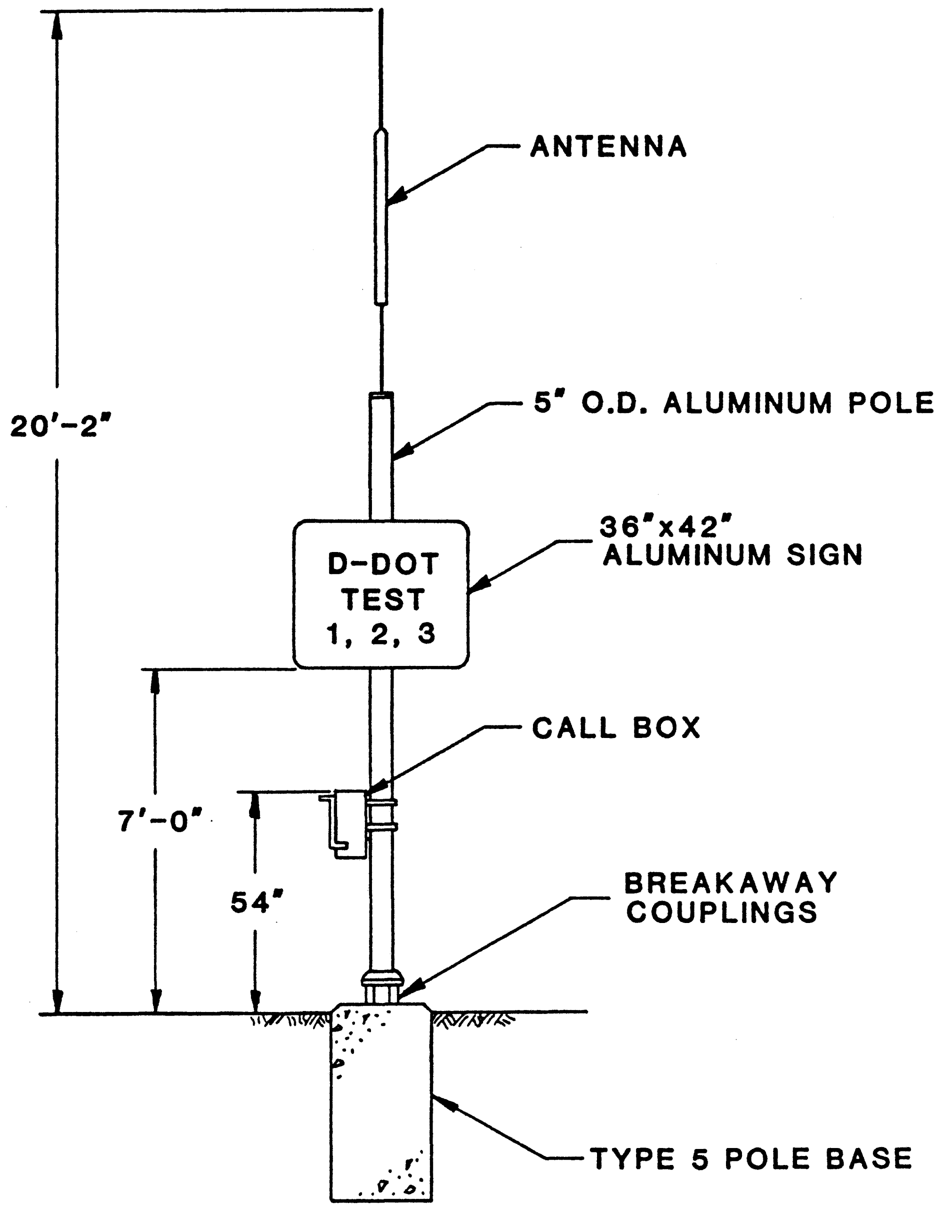


Figure 3. Details of call box installation for tests 0335-1, 0335-2 and 0335-3.

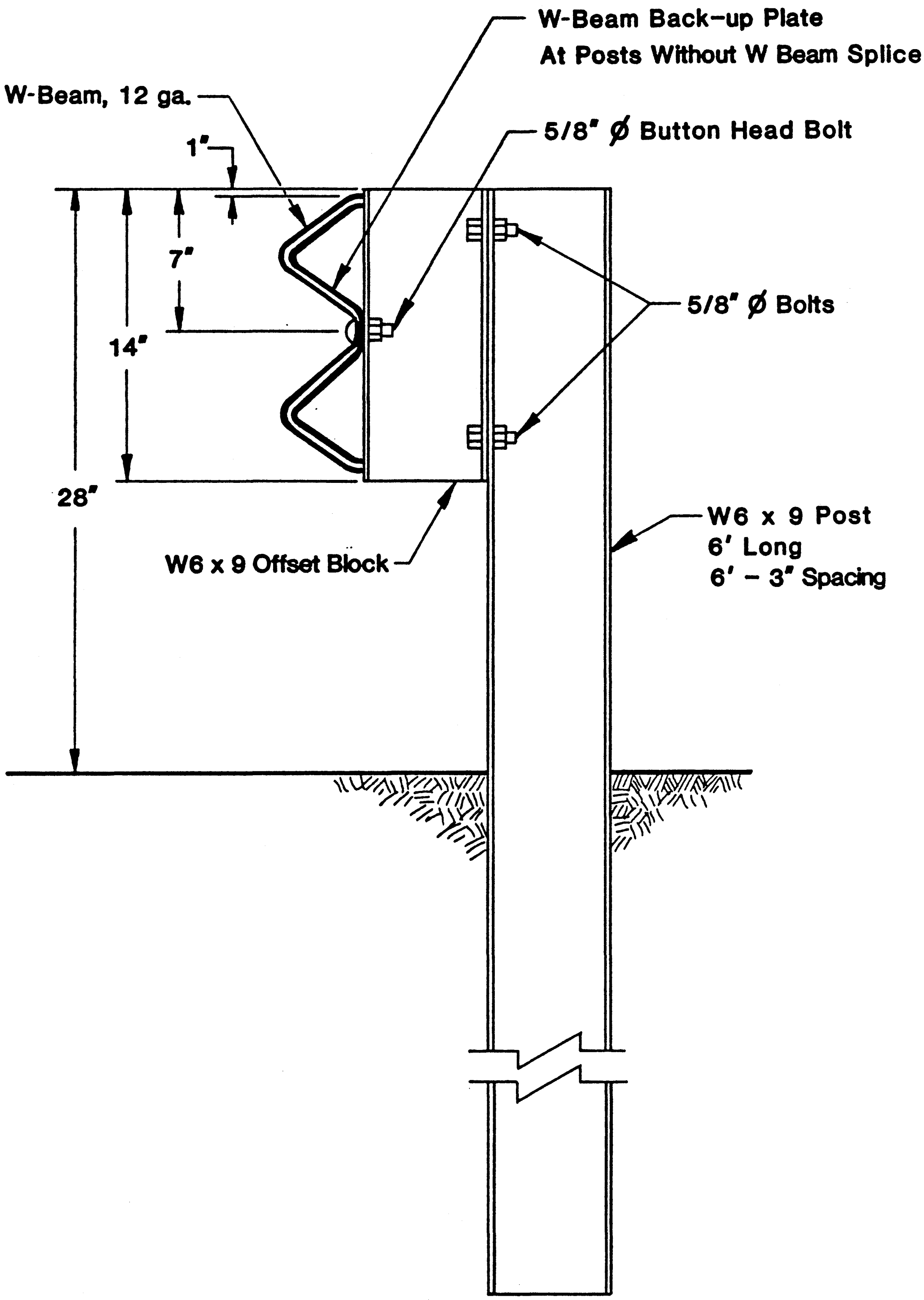


Figure 4. Details of W-beam guardrail.

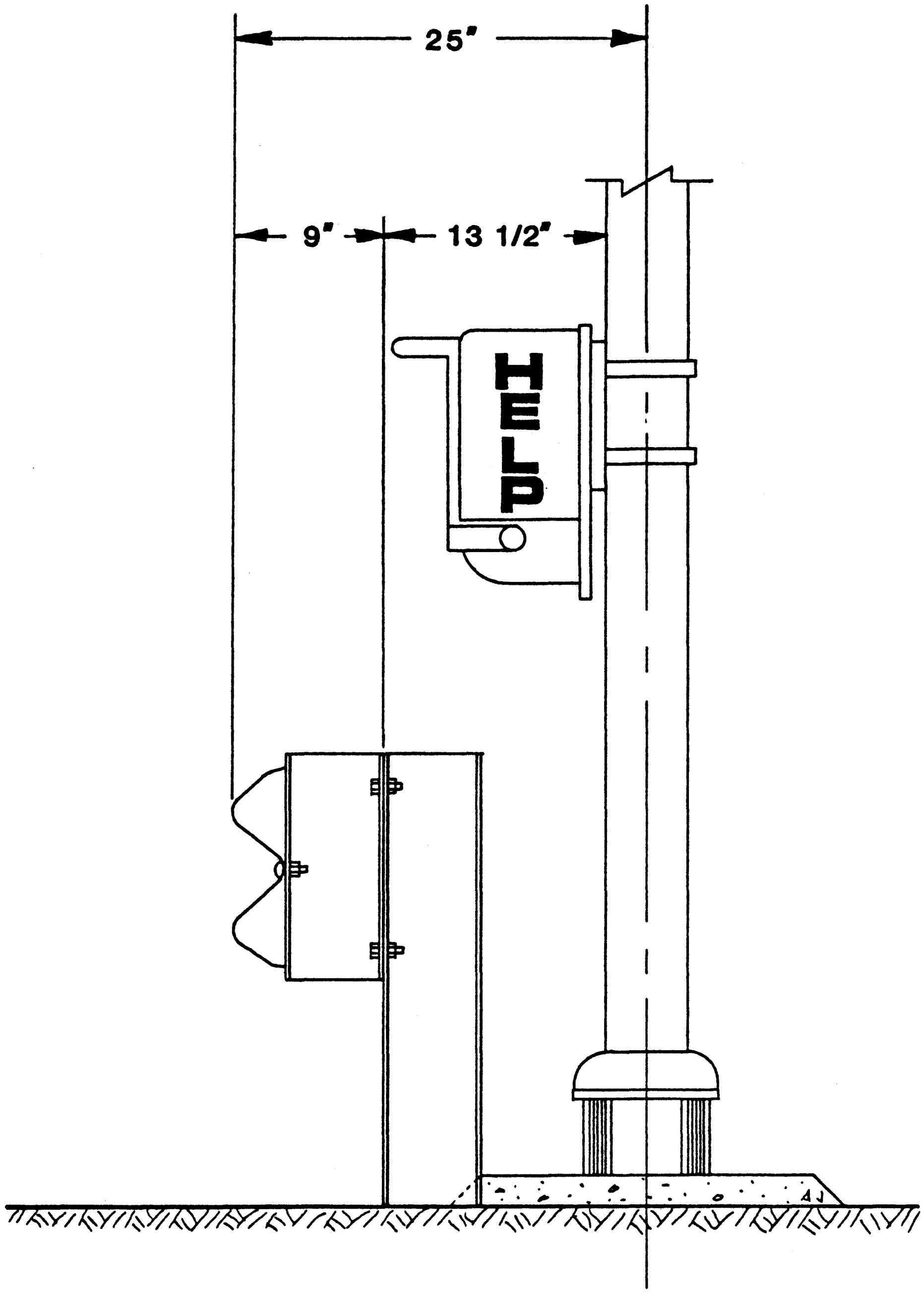


Figure 5. Lateral position of call box and guardrail.

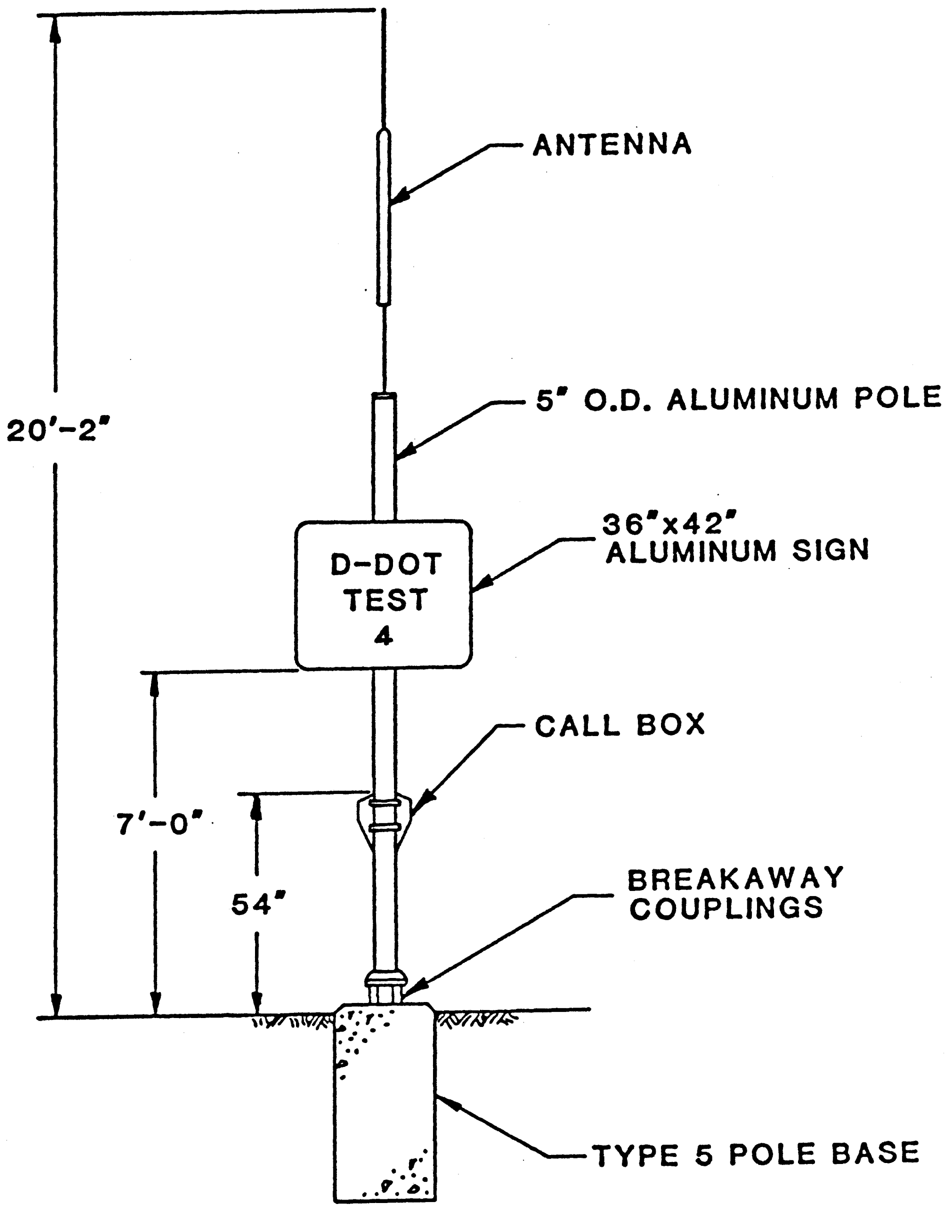


Figure 6. Details of call box installation for test 0335-4.

occupant and any penetration into the occupant compartment by detached test article debris. Tests 2 and 4 were performed to evaluate the test article by observing vehicle stability and trajectory, the risk to an occupant, and any penetration into the occupant compartment by detached test article debris. Test 3 was performed to evaluate the test article as installed behind a guardrail by observing vehicle stability and trajectory, and any penetration into the occupant compartment by detached test article debris. Table 1 shows the crash test matrix.

Table 1. Crash test matrix.

TEST DESIGNATION	NCHRP[1] TEST NO.	VEHICLE WEIGHT (lb)	IMPACT SPEED (mi/h)	IMPACT ANGLE (degree)	IMPACT POINT
0335-1	62	1800	20	0	Center of bumper
0335-2	63	1800	60	0	Right quarter of bumper
0335-3	10	4500	60	25	Midway between posts
0335-4	63	1800	60	0	Right quarter of bumper

INSTRUMENTATION AND DATA ANALYSES

Electronic Instrumentation

The vehicles in tests 1, 2, and 4 were equipped with biaxial accelerometers mounted near the center-of-gravity to measure longitudinal and lateral accelerations. The vehicle in test 3 was equipped with triaxial accelerometers mounted near the center-of-gravity to measure longitudinal, lateral, and vertical accelerations. In addition yaw, pitch, and roll rates were measured by on-board rate gyros in all tests. The electronic signals were telemetered to a base station for recording on magnetic tape and for display on a real-time strip chart. Provisions were made for transmission of calibration signals before and after the tests. Accurate time reference signals were simultaneously recorded with the data.

Contact switches on the bumpers were actuated just prior to impact by wooden dowels to indicate the elapsed time over a known distance to provide a measurement of impact velocities. The initial contacts also produced "event" marks on the data records to establish the instant of impact.

In accordance with NCHRP Report 230[1], an unrestrained, uninstrumented special purpose 50th percentile anthropomorphic test dummy was positioned in the driver seat of the test vehicle in tests 1, 2 and 4. This dummy was used to evaluate typical asymmetrical vehicle mass distribution and its effect on vehicle stability during impact.

Photographic Instrumentation

Still photography, real-time cine, and video were used to record conditions of the test vehicle and installation before and after each test. Real-time and high speed cine and video were used to document the tests. In tests 1, 2, and 4 one high speed camera was placed to have a field of view perpendicular to the direction of vehicle travel. Another high speed camera was placed to have a field of view 45 degrees to the direction of vehicle travel. In test 1 the perpendicular camera did not perform properly. In test 3 one high speed camera was placed to have a field of view perpendicular to the direction of vehicle travel. Another high speed camera was placed to have a field of view parallel to and aligned with the guardrail at the downstream end. A third high speed camera was placed over the call box installation to have a field of view perpendicular to the ground. These developed films from each test were used to observe phenomena occurring during collision and obtain time-event, displacement and angular data.

Computer Data Analyses

Analog data obtained from the electronic transducers for each test were digitized using a microcomputer for analyses by three computer programs: CRASHE, VEHICLE and PLOTANGLE.

The CRASHE program uses digitized data from one or two vehicle-mounted linear accelerometers to compute occupant/compartment impact velocities, times at occupant/compartment impacts after vehicle impact, final occupant displacements, highest 0.010-second averages of vehicle accelerations after occupant/compartment impacts, and times of highest 0.010-second averages. These results are based on 2 ft (0.6 m) longitudinal and 1 ft (0.5 m) lateral impact displacements, and are given for the longitudinal and/or vertical directions. The CRASHE program also calculates a vehicle impact velocity and the change in vehicle velocity at the end of a given impulse period.

The VEHICLE program also uses digitized data from up to three vehicle-mounted linear accelerometers to compute vehicle accelerations, areas enclosed by acceleration-time curves, changes in velocity, changes in momentum, instantaneous forces, average forces, and maximum average accelerations over 0.050-second intervals in each of the directions. The VEHICLE program also plots acceleration versus time curves for the longitudinal, lateral, and vertical directions.

The PLOTANGLE program uses the digitized data from the yaw, pitch, and roll rate charts to compute angular displacement in degrees at 0.001-second intervals and then instructs a plotter to draw a reproducible plot: yaw, pitch, and roll versus time. It should be noted that these angular displacements are sequence dependent with the sequence being yaw-pitch-roll for the data presented herein. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation of the vehicle-fixed coordinate system being that which existed at initial impact.

TEST 0335-1

Test Description

Test 0335-1, performed on February 11, 1986, followed guidelines for breakaway and yielding supports described in Test 62 of NCHRP Report 230[1]. The test installation is shown in figure 7. The 1979 Honda shown in figure 8 was directed into the call box installation using a cable reverse tow and guidance system. The Test Inertia Mass of the vehicle was 1,783 lb (809 kg) and its Gross Static Mass was 1,953 lb (887 kg). Vehicle mass properties and geometry are shown in figure 9. The point of impact was such that the center of the vehicle bumper contacted the call box support pole. The vehicle bumper height was 17.6 in (44.8 cm). The test vehicle was released from the tow and guidance system just prior to impact, thus it was free-wheeling and unrestrained at impact. The velocity of the vehicle at impact was 18.2 mi/h (29.3 km/h).

Test Results

As the center of the vehicle bumper impacted the call box pole, the pole pushed the bumper inward. The vehicle hood and grill then contacted the pole. As the hood and grill crushed inward, the breakaway couplings began leaning away from the vehicle. The pole flange began to break out at the coupling connections. As the flange broke out, the anchor bolts on three couplings sheared. The pole then began to rotate about a lateral axis with the lower end of the pole moving forward in the direction of vehicle travel. The couplings, with attached flange pieces, began tumbling forward. As the pole assembly moved forward, the call box housing began to separate from the mount, falling open while remaining attached by its hinge. The pole then parted from the vehicle as both the pole assembly and the vehicle continued to move forward. The pole dropped as it rotated about a lateral axis and somewhat about a vertical axis. The pole again contacted the hood at a point on the pole above the call box. The sign, still attached to the pole, then slapped the upper half of the vehicle windshield and the front of the roof. The assembly slowly slid forward and down the vehicle until the lower end of the pole contacted the ground. The vehicle brakes were applied. Table 2 presents the significant events of this test by time.

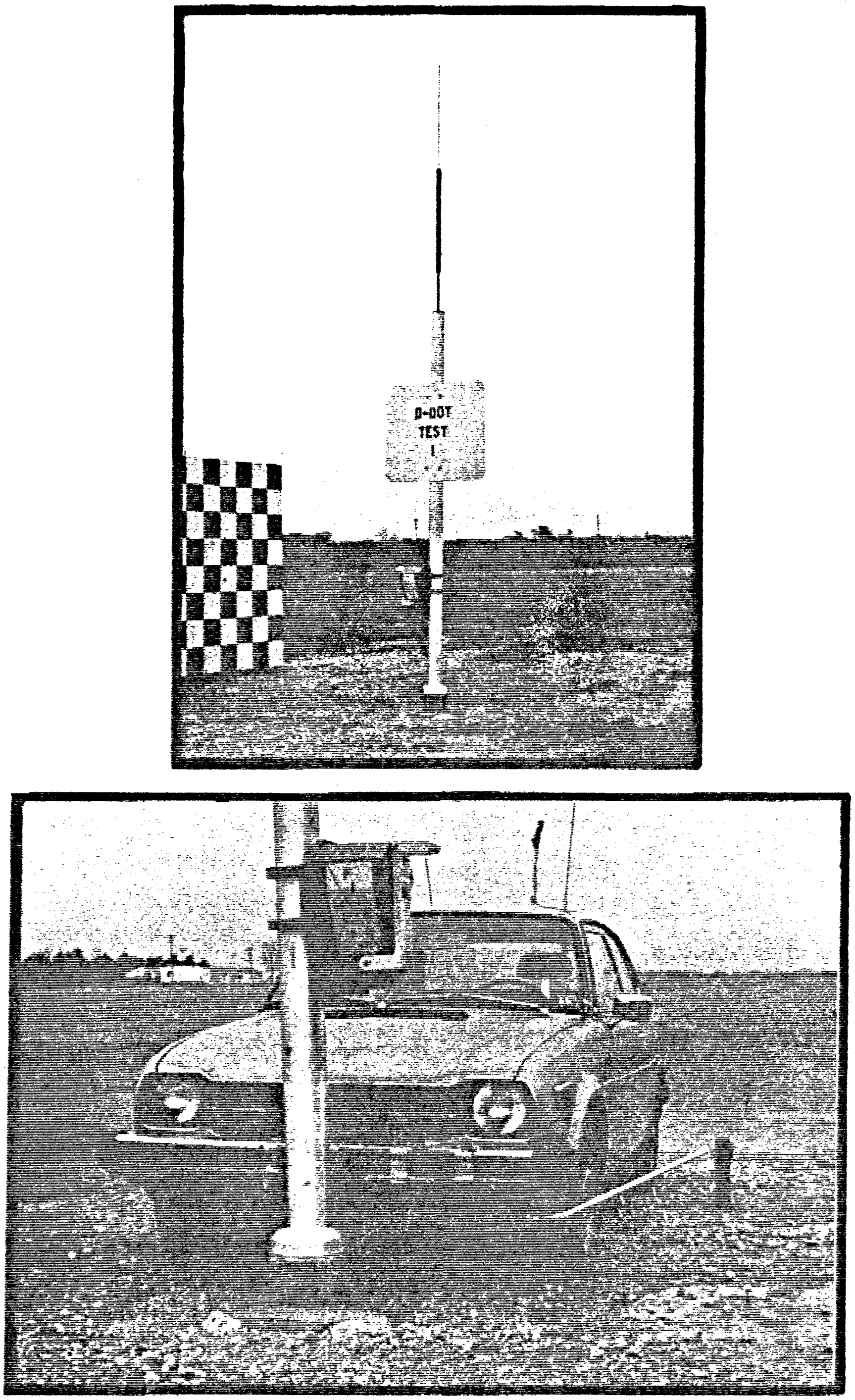


Figure 7. Call box installation before test 0335-1.

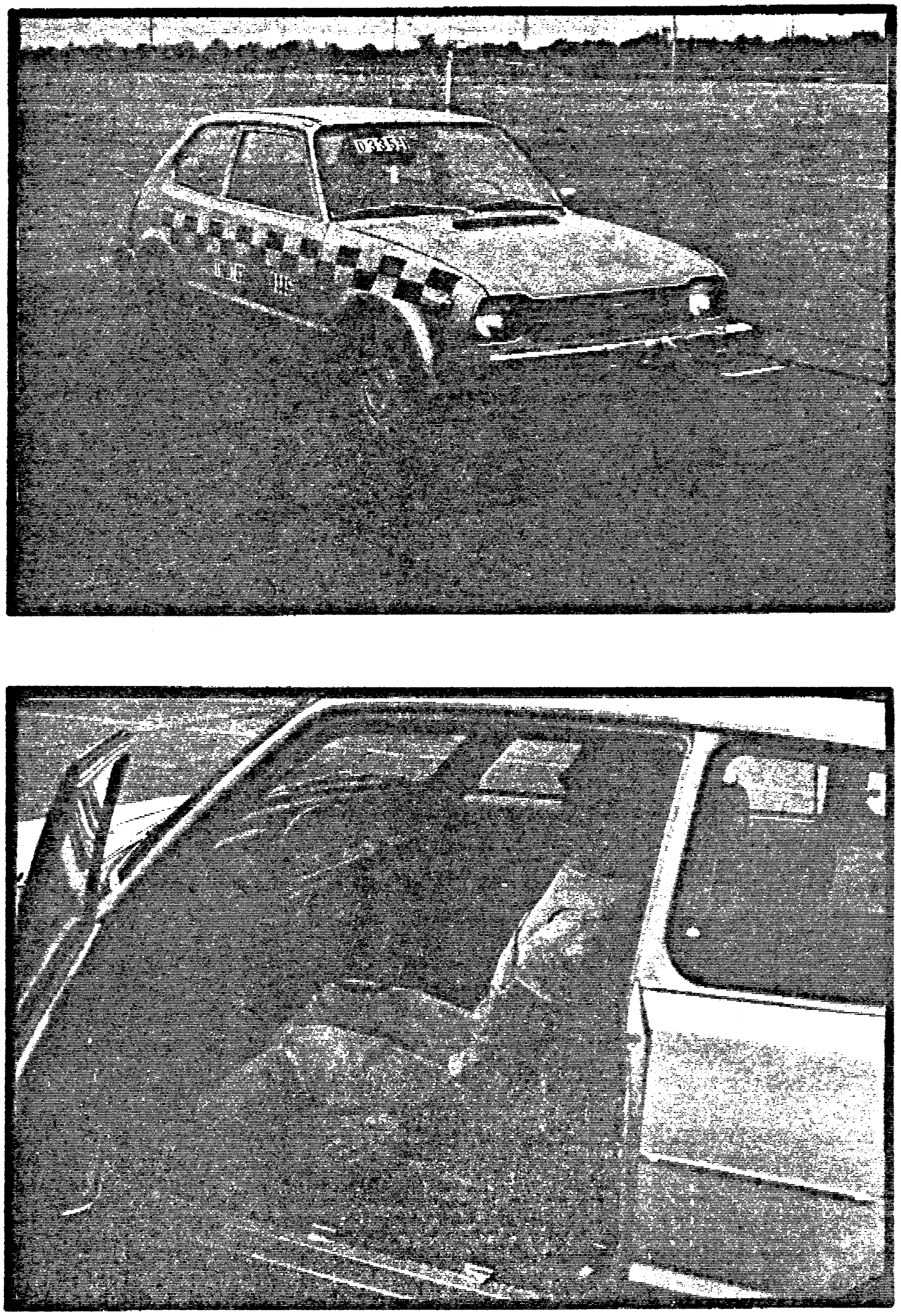
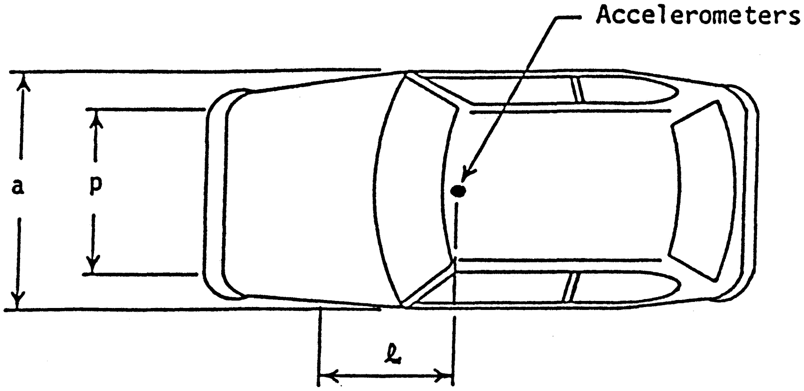


Figure 8. Test vehicle before test 0335-1.

Date: 2/11/86 Test No.: 0335-1 VIN: SBC-7013238

Make: Honda Model: Civic 1200 Year: 1979 Odometer: 79457.1

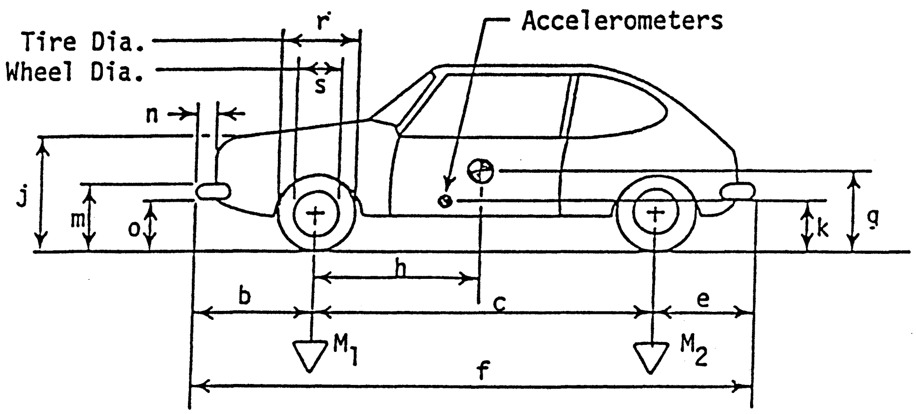
Tire Size: R155/12 Ply Rating: 4 Bias Ply: ___ Belted: x Radial: ___



Tire Condition: good x
fair ___
badly worn ___

Vehicle Geometry - inches

a	59	b	27.8
c	86.5	d*	52.3
e	27.3	f	141.5
g	-----	h	34.3
i	----	j	31.5
k	14.5	ℓ	34.3
m	20	n	5.3
o	15.3	p	51.3
r	22.5	s	13.3



Engine Type: 4 cyl

Engine CID: 76

Transmission Type:

Automatic or Manual

FWD or RWD or 4WD

Body Type: 3 Dr Hatch Back

Steering Column Collapse Mechanism:

- ___ Behind wheel units
- x Convoluted tube
- ___ Cylindrical mesh units
- ___ Embedded ball
- ___ NOT collapsible
- ___ Other energy absorption
- ___ Unknown

Brakes:

Front: disc x drum ___

Rear: disc ___ drum x

4-wheel weight for c.g. det. ℓf 560 rf 517 ℓr 370 rr 336

Mass - pounds	Curb	Test Inertial	Gross Static
M_1		1077	1159
M_2		706	794
M_T		1783	1953

Note any damage to vehicle prior to test:

No prior damage.

*d = overall height of vehicle

Figure 9. Test vehicle properties before test 0335-1.

Table 2. Times of events for test 0335-1.

Time (sec)	Event
0.000	Vehicle bumper impacted pole
0.017	Aluminum bolt cover over pole flange began to rise
0.022	Vehicle hood and grill contacted pole
0.027	Breakaway couplings began to lean
0.032	Pole flange began to break out, pole began to rotate
0.042	Couplings with broken flange pieces separated from pole
0.062	Couplings began to tumble
0.084	Vehicle lost contact with pole
0.448	Vehicle hood again contacted pole
0.475	Sign slapped against vehicle windshield and roof
0.972	Lower end of pole hit ground
2.34	Vehicle brakes were applied

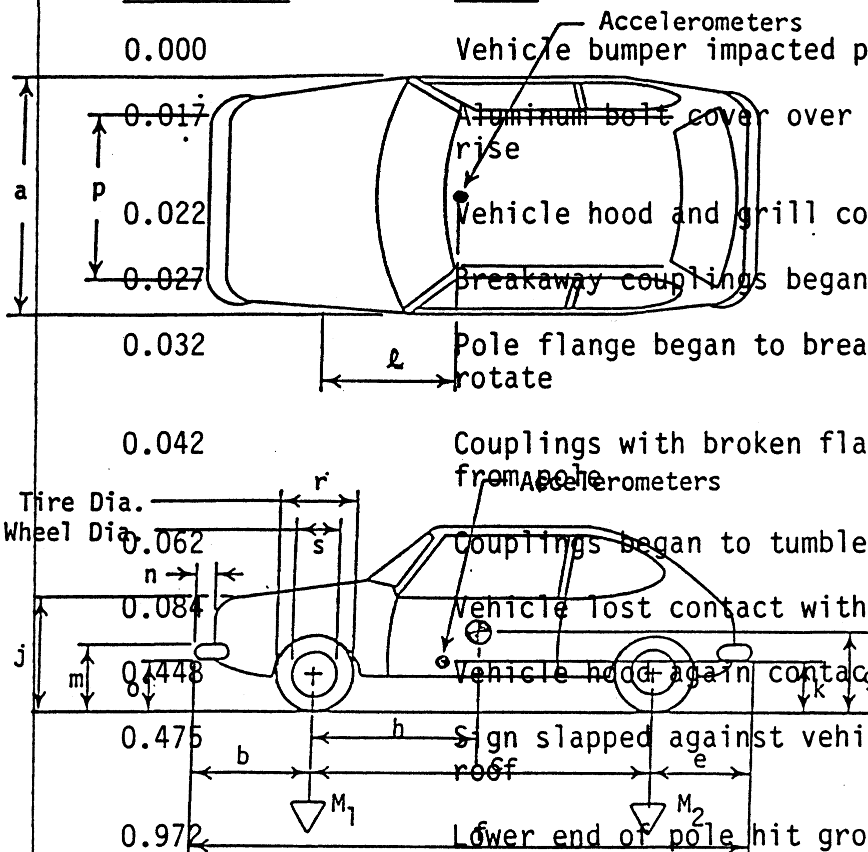
The vehicle and assembly came to rest with the sign resting against the hood of the vehicle. The vehicle's center of gravity at final rest was approximately 30 ft (9.2 m) from the pole base. The three breakaway couplings that separated from the base by the shearing of the anchor bolts came to rest approximately 7 ft (2.1 m) from the base. The other coupling broke into two major pieces. The lower portion of the coupling remained on the anchor bolt. The upper part traveled with the pole attached to the remaining pole flange. Sequential photographs of the test are shown in figure 10. Figure 11 shows the installation after test 0335-1.

Date: 2/11/86 Test No.: 0335-1 VIN: SBC-7013238

Make: Honda Model: Civic 1200 Year: 1979 Odometer: 79457.1

Tire Size: P155/12 Ply Rating: 4 Bias Ply: ___ Belted: x Radial: ___

Tire Condition: good x fair ___ badly worn ___



Vehicle Geometry - inches

a	59	b	27.8
c	86.5	d*	52.3
e	27.3	f	141.5
g	-----	h	34.3
i	----	j	31.5
k	14.5	ℓ	34.3
m	20	n	5.3
o	15.3	p	51.3
r	22.5	s	13.3

Engine Type: 4 cyl

Engine CID: 76

Transmission Type:

Automatic or Manual

FWD or RWD or 4WD

Body Type: 3 Dr Hatch Back

Steering Column Collapse Mechanism:

___ Behind wheel units
x Convoluted tube
___ Cylindrical mesh units
___ Embedded ball
___ NOT collapsible
___ Other energy absorption
___ Unknown

Brakes:

Front: disc x drum ___

Rear: disc ___ drum x

4-wheel weight for c.g. det. ℓf 560 rf 517 ℓr 370 rr 336

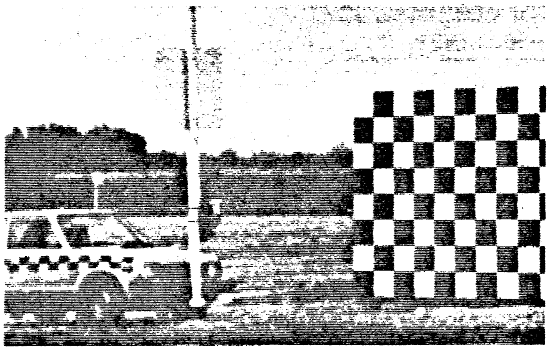
Mass - pounds	Curb	Test Inertial	Gross Static
M_1		1077	1159
M_2		706	794
M_T		1783	1953

Note any damage to vehicle prior to test:

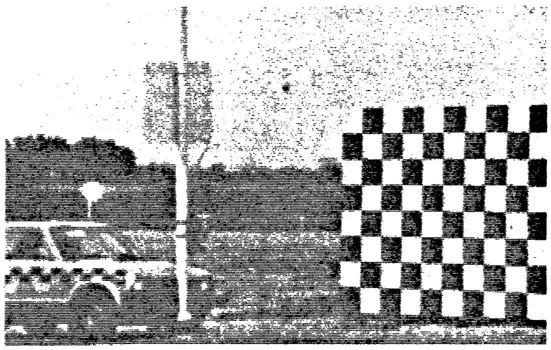
No prior damage

*d = overall height of vehicle

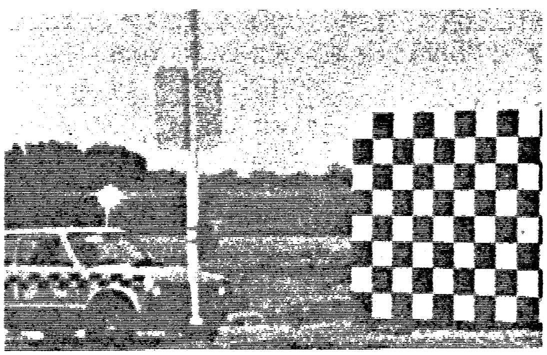
Figure 9. Test vehicle properties before test 0335-1.



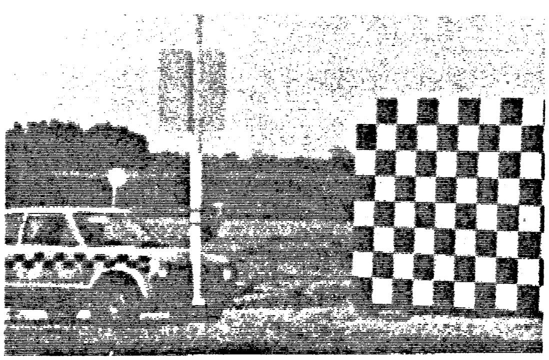
0.000 s



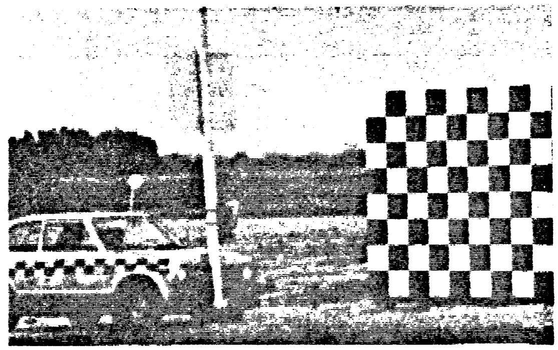
0.012 s



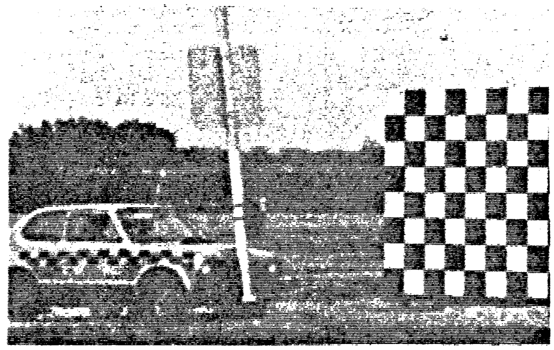
0.025 s



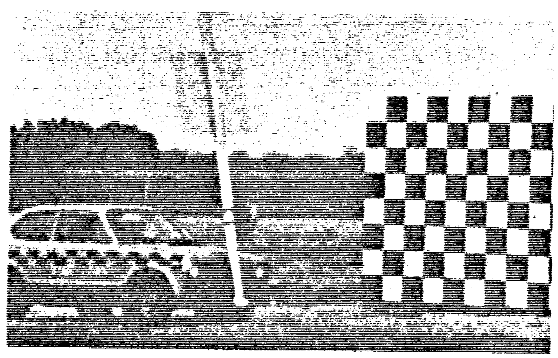
0.037 s



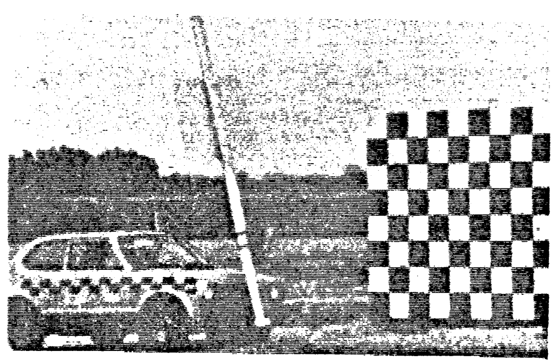
0.049 s



0.074 s



0.099 s



0.124 s

Figure 10. Sequential photographs for test 0335-1.

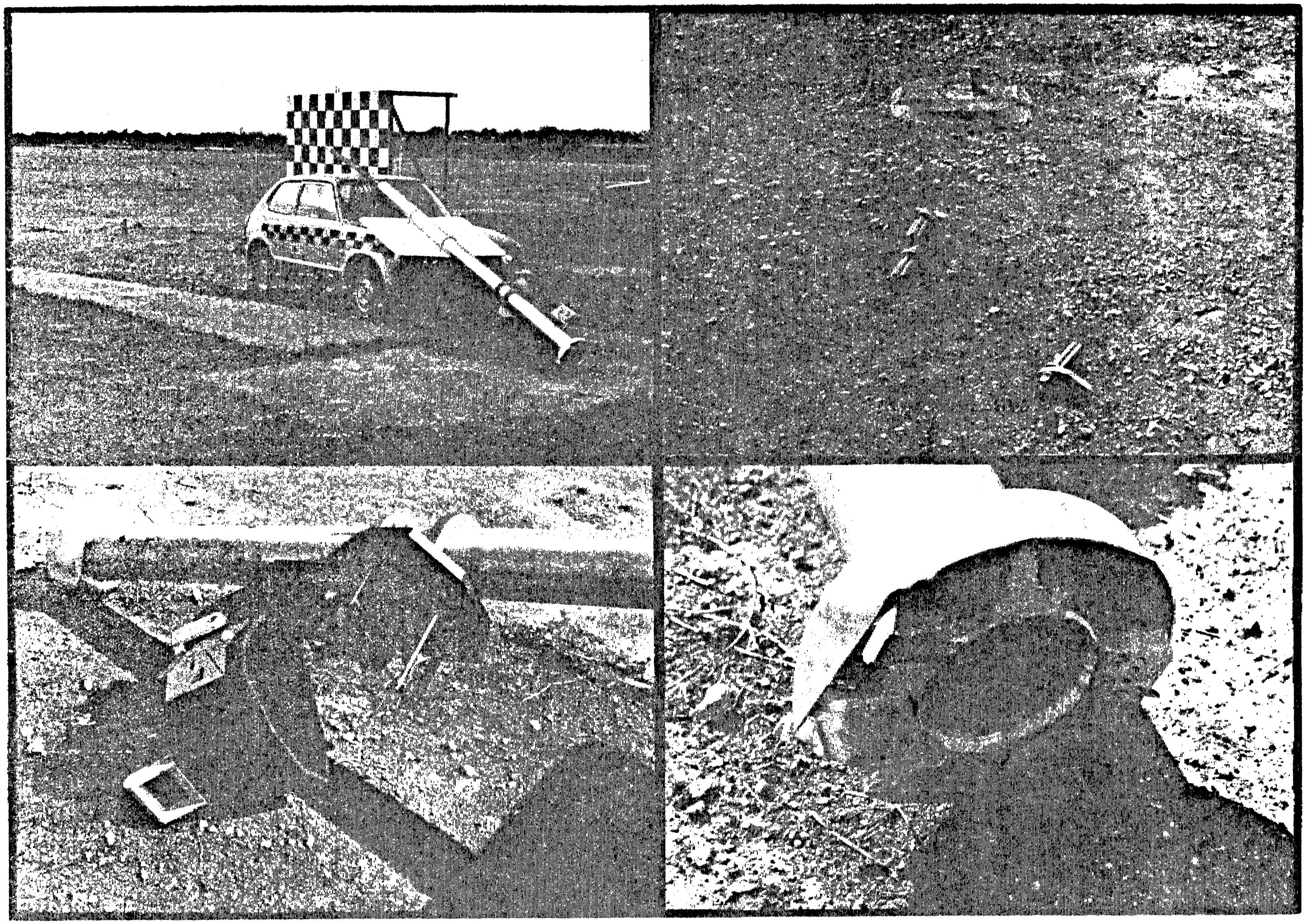


Figure 11. Call box installation after test 0335-1.

The test vehicle sustained minor damages to the front end as shown in figure 12. Maximum crush to the frontal plane of the vehicle at bumper height was 9.3 in (23.6 cm). The hood was crushed inward about 3 in (7.6 cm). The grill was broken into two pieces. The front valance panel was also bent. The front windshield was undamaged. After the test, the anthropomorphic dummy was observed to be in the driver seat in approximately its original position.

The change in velocity at the end of significant vehicle response, 0.500-second, was 6.1 mi/h (9.8 km/h). This yields a change in momentum of 496 lb-s (225 kg-s). The calculated occupant longitudinal impact velocity was 8.1 ft/s (2.5 m/s) and the absolute value of the measured maximum 0.010-second average longitudinal occupant ridedown acceleration was 0.73 g. The calculated occupant lateral impact velocity was 5.4 ft/s (1.6 m/s) and the absolute value of the measured maximum 0.010-second average lateral occupant ridedown acceleration was 0.75 g. Figures showing accelerometer traces for the test vehicle with locations of the highest 0.050-second averages and vehicle angular displacements are given in the Appendix. Results are summarized in figure 13.

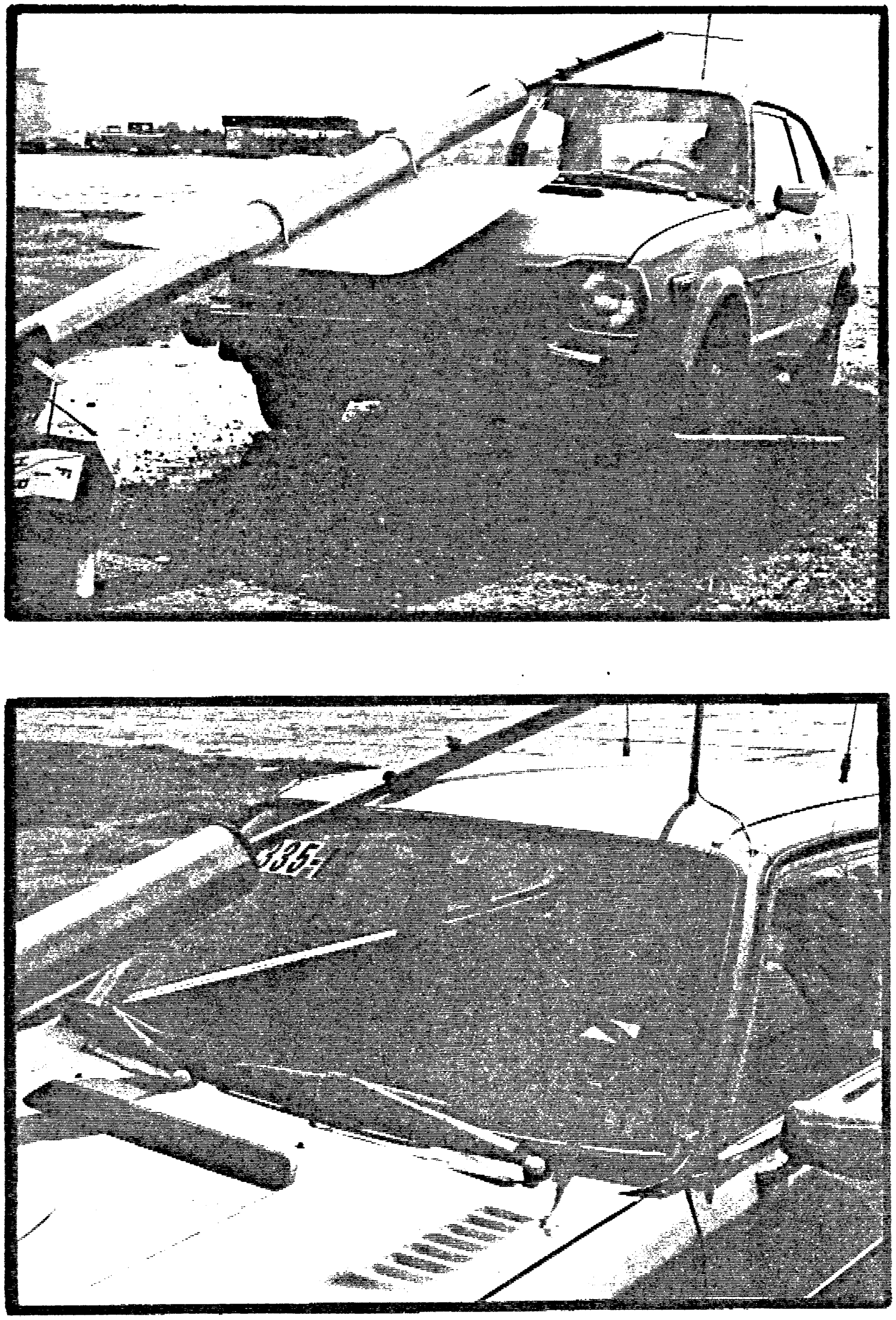
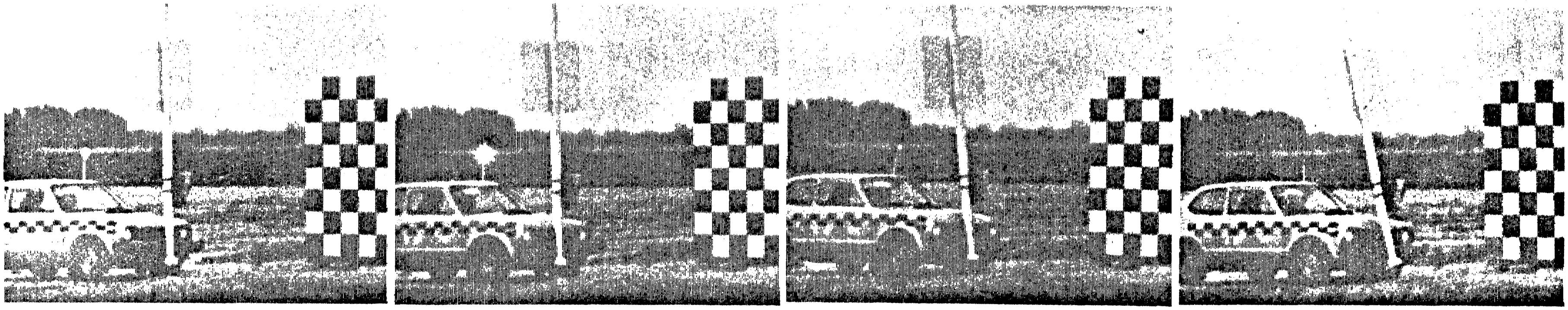
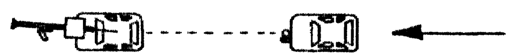


Figure 12. Vehicle after test 0335-1.



0.000 s   0.025 s   0.074 s   0.124 s



Test No.	0335-1
NCHRP Report 230 Test No .	62
Date	2/11/86
Test Article	Motorist aid call box installation with 54 in (137 cm) mounting height
Vehicle.	1979 Honda Civic
Vehicle Weight	
Test Inertia	1,783 lb (809 kg)
Gross Static	1,953 lb (887 kg)
Vehicle Damage Classification	
TAD.	12-FC-2
SAE.	12FCEN1

Impact Speed.	18.2 mi/h (29.3 km/h)
Change in Velocity. . .	6.1 mi/h (9.8 km/h)
Change in Momentum. . .	496 lb-s (225 kg-s)
Vehicle Accelerations .	(Max. 0.050-sec Avg)
Longitudinal	-4.7 g
Lateral	0.9 g
Occupant Impact Velocity	
Longitudinal.	8.1 ft/s (2.5 m/s)
Lateral	5.4 ft/s (1.6 m/s)
Occupant Ridedown Accelerations	
Longitudinal.	-0.73 g
Lateral	0.75 g
Maximum Vehicle Crush at	
Bumper Height	9.3 in (23.6 cm)

Figure 13. Summary of results for test 0335-1.

Performance Evaluation

This call box installation met the evaluation criteria recommended in NCHRP Report 230[1] for Test 62 for structural adequacy, occupant risk and vehicle trajectory.

The installation readily activated by breaking away. The manner of activation was not completely expected, however, due to the nature of breakaway devices. The flange and anchor bolts at three of the four supports fractured rather than the breakaway couplings. A similar activation would be predicted in a duplicate test. The detached elements from the test article did not penetrate nor show potential for penetrating the passenger compartment, nor presented undue hazard to other traffic due to the off-road location of the elements. The vehicle remained upright during and after the collision. The calculated longitudinal occupant impact velocity against the vehicle interior was below the limit of 15 ft/s (4.6 m/s). The absolute value of the measured maximum 0.010-second average longitudinal occupant ridedown acceleration was below the limit of 15 g. After collision, the vehicle trajectory and final stopping position was such that the vehicle did not intrude into adjacent traffic lanes. The vehicle trajectory behind this test article was acceptable.

TEST 0335-2

Test Description

Test 0335-2, performed on February 12, 1986, followed guidelines for breakaway and yielding supports described in Test 63 of NCHRP Report 230[1]. The test installation is shown in figure 14. The 1979 Honda shown in figure 15 was directed into the call box installation using a cable reverse tow and guidance system. The Test Inertia Mass of the vehicle was 1,750 lb (795 kg) and its Gross Static Mass was 1,917 lb (870 kg). Vehicle mass properties and geometry are shown in figure 16. The point of impact was such that the right quarter point of the vehicle bumper contacted the call box support pole. The vehicle bumper height was 17.6 in (44.8) cm). The test vehicle was released from the tow and guidance system just prior to impact, thus it was free-wheeling and unrestrained at impact. The velocity of the vehicle at impact was 64.6 mi/h (103.9 km/h).

Test Results

As the right quarter point of the vehicle bumper impacted the call box pole, the pole pushed the bumper inward. The vehicle hood and grill then contacted the pole. As the hood, grill and bumper crushed inward, the breakaway couplings began leaning away from the vehicle, and the pole flange began to break out at the coupling connections. As the flange broke out, the anchor bolts on the couplings sheared. The pole then began to rotate about a lateral axis with the lower end of the pole moving forward in the direction of vehicle travel. The couplings, with attached flange pieces, began tumbling forward. The pole also began to rotate counterclockwise about a vertical axis and rise upward. As the pole assembly moved forward, the call box housing separated from the mount. The vehicle then lost contact with the pole as both the pole assembly and the vehicle continued to move forward. The handle on the detached call box housing contacted the lower portion of the vehicle windshield just as the housing struck the middle of the windshield. The housing partially penetrated the windshield. The call box generator came out of the housing and began to rise upward. One of the couplings and a flange fragment were propelled forward ahead of the vehicle. Another coupling rose upward about 2 ft (0.6 m) as it came out from

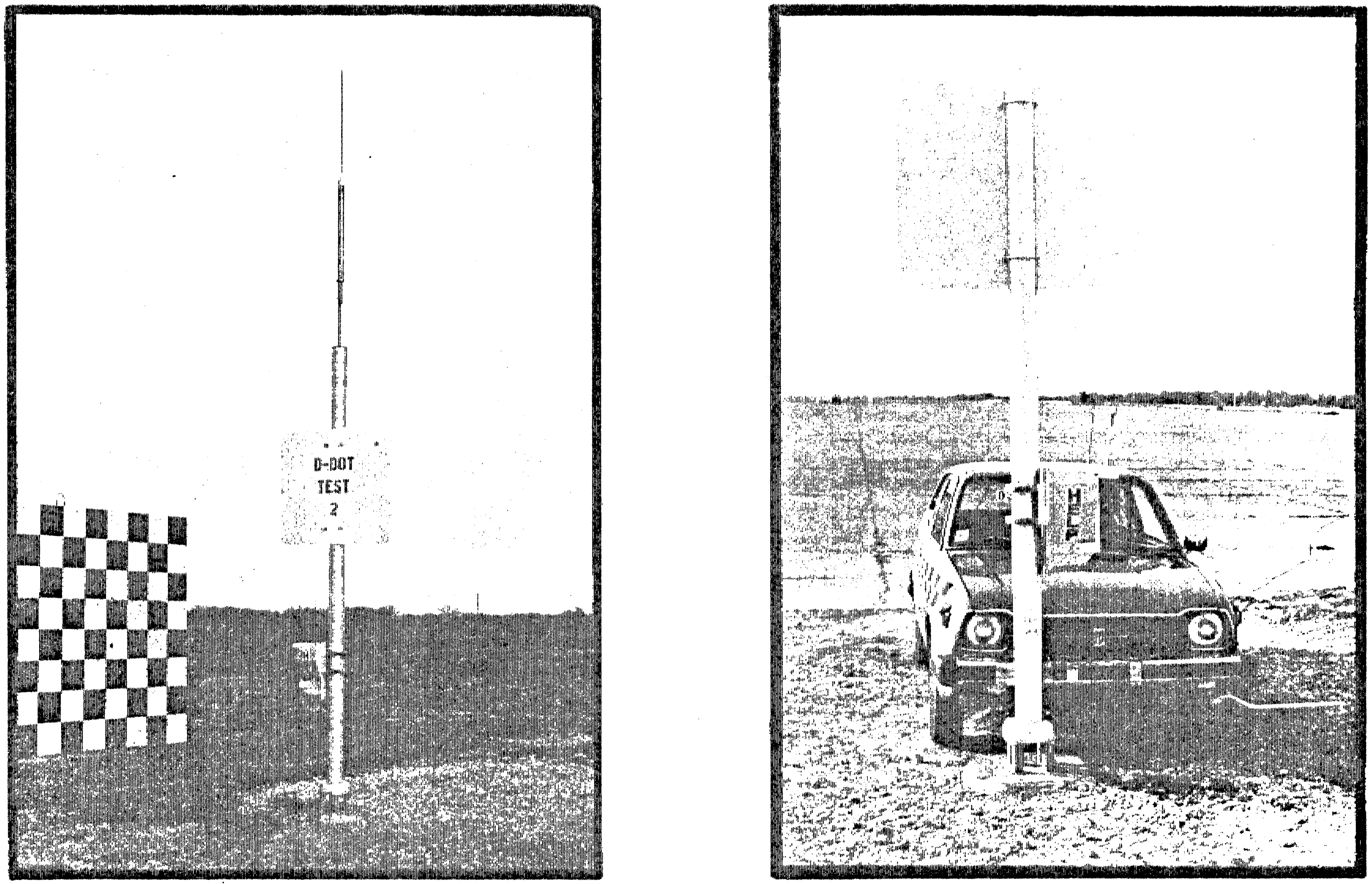


Figure 14. Call box installation before test 0335-2.

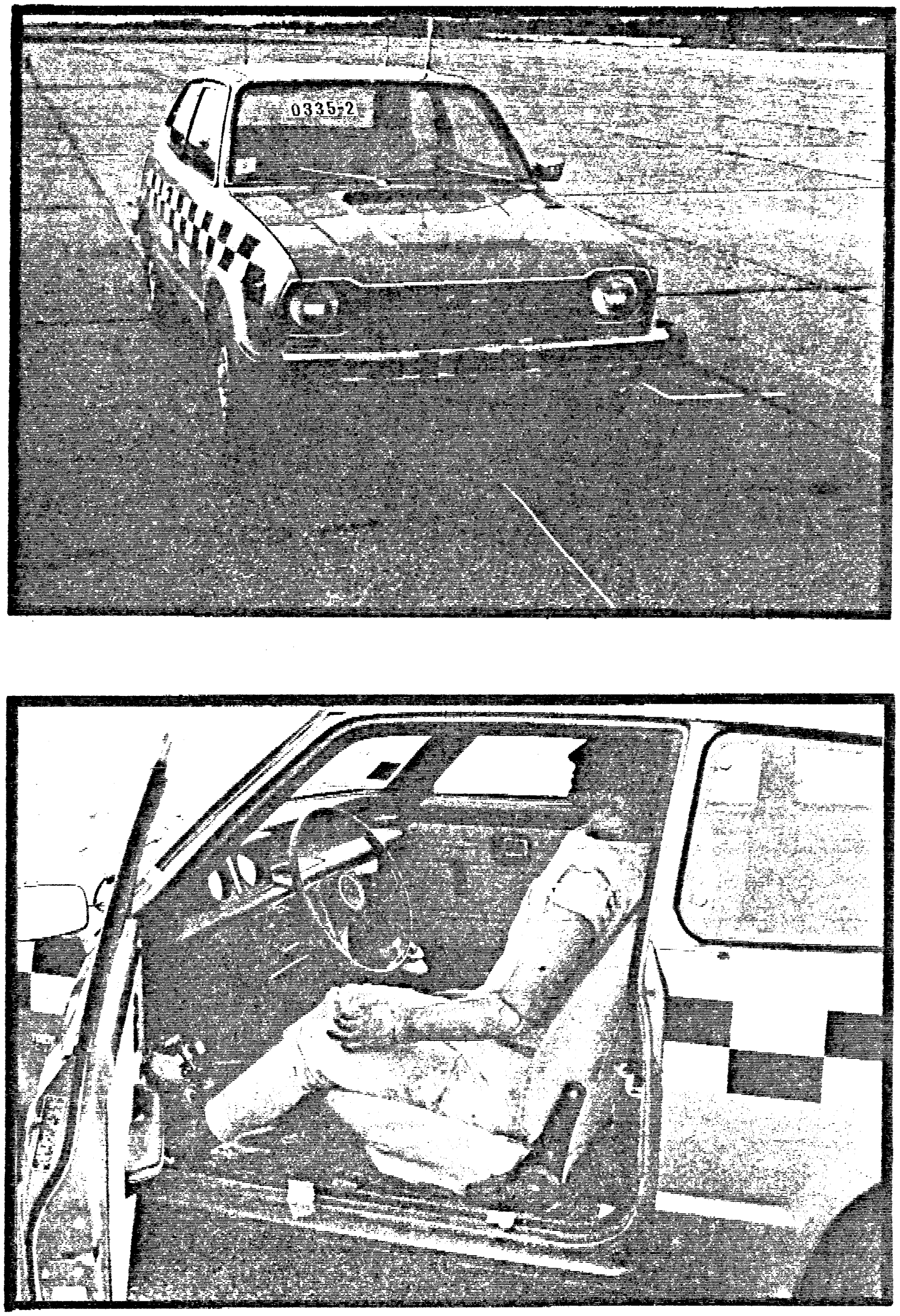


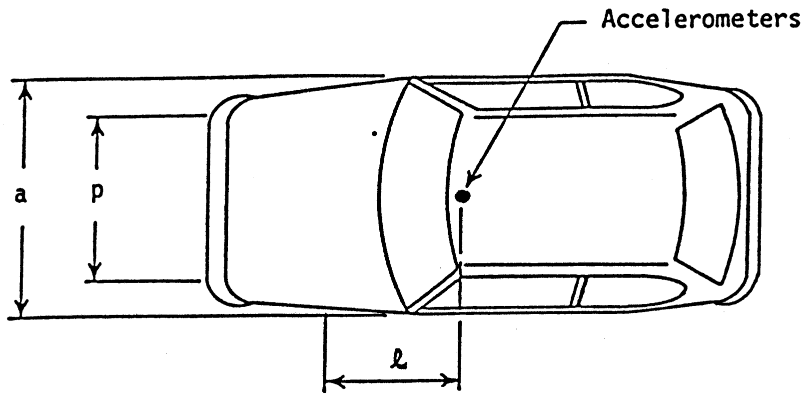
Figure 15. Test vehicle before test 0335-2.

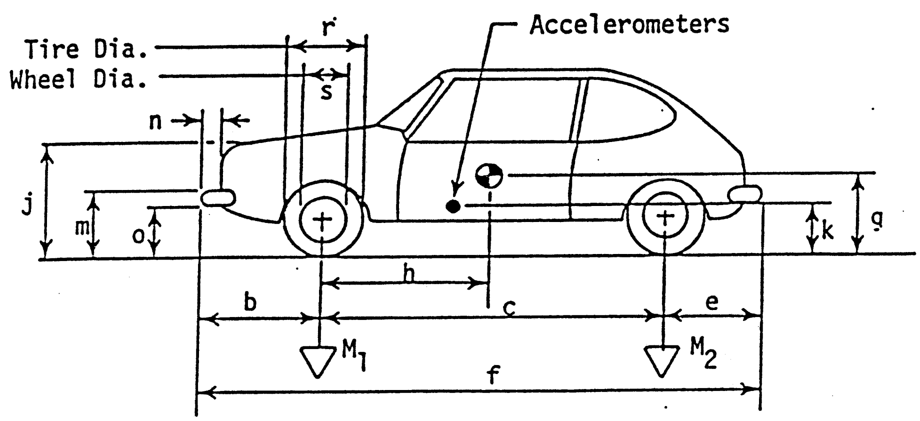
Date: 2/12/86 Test No.: 0335-2 VIN: SBC-7025804

Make: Honda Model: Civic 1200 Year: 1979 Odometer: 95998.2

Tire Size: 600/12 Ply Rating: 4 Bias Ply: ___ Belted: x Radial: ___

Tire Condition: good x
fair ___
badly worn ___





Vehicle Geometry - inches

a	59	b	27.8
c	86.5	d*	52.3
e	27.3	f	141.5
g	----	h	35.3
i	----	j	31.5
k	14.5	ℓ	34.3
m	20	n	5.3
o	15.3	p	51.3
r	22.5	s	13.3

Engine Type: 4 cyl

Engine CID: 76

Transmission Type:

Automatic or Manual

FWD or RWD or 4WD

Body Type: 3 Dr Hatch Back

Steering Column Collapse Mechanism:

- ___ Behind wheel units
- x Convoluted tube
- ___ Cylindrical mesh units
- ___ Embedded ball
- ___ NOT collapsible
- ___ Other energy absorption
- ___ Unknown

Brakes:

Front: disc x drum ___

Rear: disc ___ drum x

4-wheel weight for c.g. det. ℓf 525 rf 512 ℓr 351 rr 362

Mass - pounds	Curb	Test Inertial	Gross Static
M_1		1037	1117
M_2		713	800
M_T		1750	1917

Note any damage to vehicle prior to test:

No prior damage.

*d = overall height of vehicle

Figure 16. Test vehicle properties before test 0335-2.

under the right side of the vehicle. The vehicle then passed under the pole assembly and the generator. The pole had reached a height of approximately 6 ft (1.8 m) while positioned parallel to the ground. The antenna separated from the pole as the pole continued to rotate about lateral and vertical axes. The call box housing rose upward, losing contact with the vehicle. After approximately 360 degrees of lateral rotation and 180 degrees of vertical rotation, the lower end of the pole contacted the ground. The vehicle brakes were applied. Table 3 presents the significant events of this test by time.

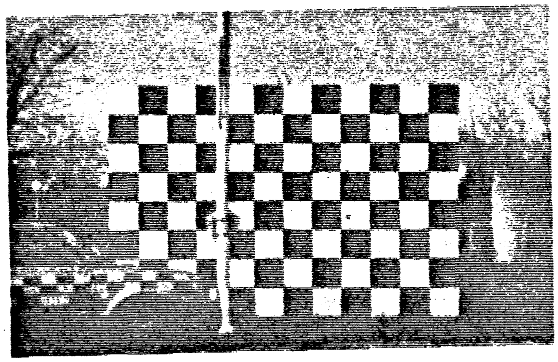
Table 3. Times of events for test 0335-2.

Time (sec)	Event
0.000	Vehicle bumper impacted pole
0.005	Vehicle hood and grill contacted pole, breakaway couplings began to lean, flange began to break out
0.010	Couplings with broken flange pieces began to separate from pole, pole began to rotate about a lateral axis
0.017	Couplings began to tumble
0.025	Pole began to rotate about its vertical axis
0.035	Call box housing began to open
0.052	Vehicle lost contact with pole
0.054	Handle on call box housing contacted vehicle windshield
0.072	Call box housing contacted windshield
0.168	Antenna separated from pole
0.193	Call box housing lost contact with windshield
0.594	Lower end of pole hit ground
3.0 +	Vehicle brakes were applied

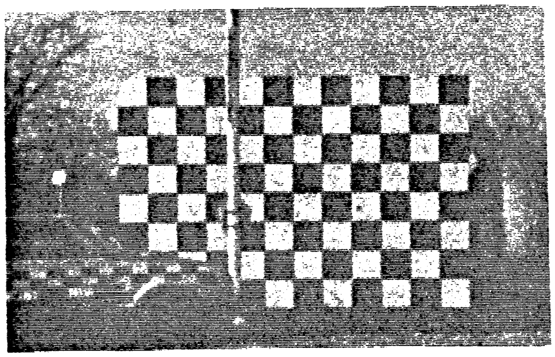
The center of gravity of the vehicle at final rest was approximately 225 ft (68.6 m) in the longitudinal direction and 43 ft (13.1 m) to the right of the pole base. The pole landed approximately 21 ft (6.4 m) from the base. Two of the four breakaway couplings that separated from the base by the shearing of the anchor bolts came to rest approximately 60 ft (18.3 m) from the base. These two couplings were connected by one piece of the broken flange. Another coupling came to rest about 35 ft (10.7 m) from the base. The fourth coupling was not located. The call box housing was found 125 ft (38.1 m) from the base. The call box generator was located 65 ft (19.8 m) from the base. The antenna landed 3 ft (0.9 m) from the base. Sequential photographs of the test are shown in figure 17. Figure 18 shows the installation after test 0335-2.

The test vehicle sustained major damages to the front end and windshield as shown in figure 19. Maximum crush to the frontal plane of the vehicle at bumper height was 15.3 in (38.7 cm). The hood was crushed inward about 10 in (25 cm). The grill was broken into two pieces. The front valance panel was crushed inward. The right half of the front windshield was shattered and torn. The radiator was punctured and leaked fluid. After the test, the anthropomorphic dummy was observed to be in the driver seat leaning toward the door. The dummy had contacted the sun visor.

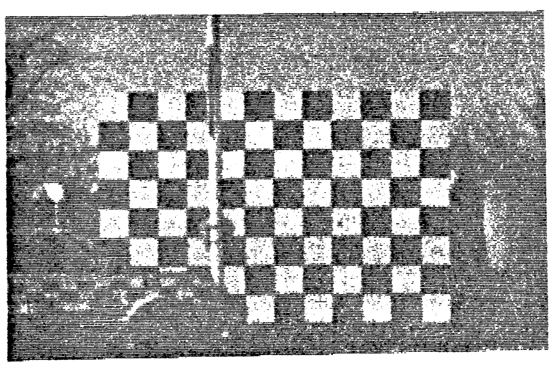
The change in velocity at the end of significant vehicle response, 0.500-second, was 7.1 mi/h (11.4 km/h). This yields a change in momentum of 566 lb-s (257 kg-s). The calculated occupant longitudinal impact velocity was 8.5 ft/s (2.6 m/s) and the absolute value of the measured maximum 0.010-second average longitudinal occupant ridedown acceleration was 1.03 g. The calculated occupant lateral displacement was 0.33 ft (0.1 m) showing no lateral impact. Figures showing accelerometer traces for the test vehicle with locations of the highest 0.050-second averages and vehicle angular displacements are given in the Appendix. Results are summarized in figure 20.



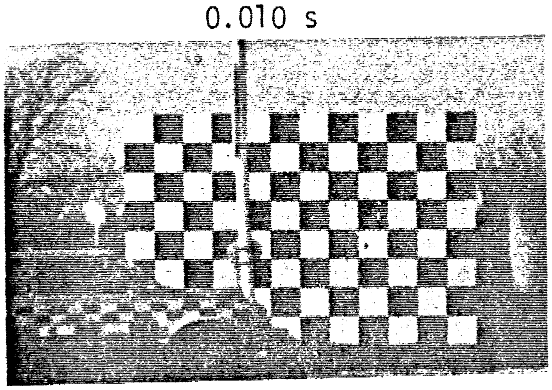
0.000 s



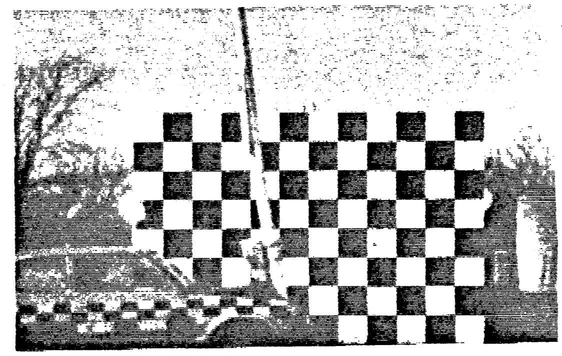
0.005 s



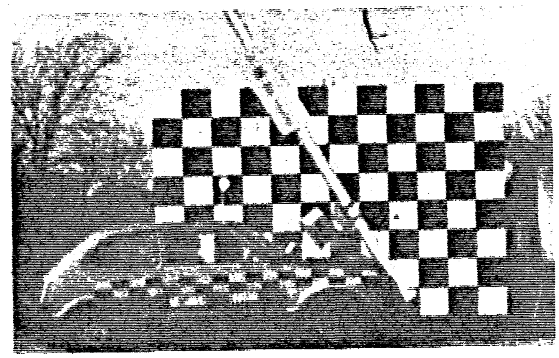
0.010 s



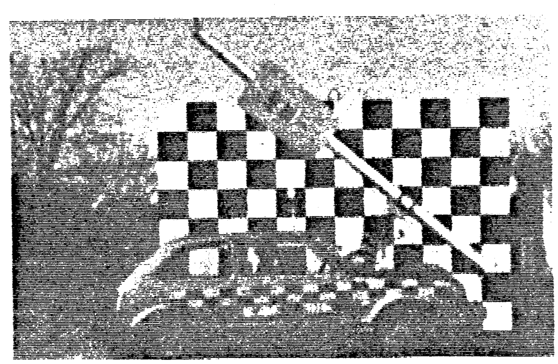
0.015 s



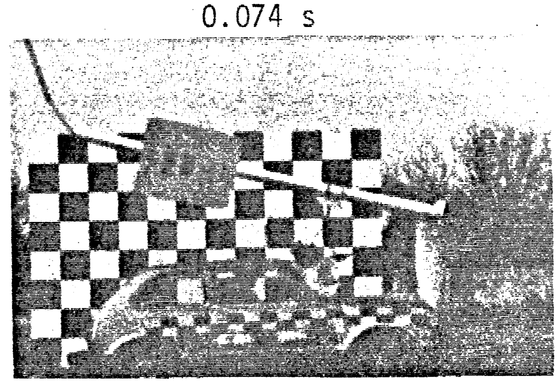
0.025 s



0.050 s



0.074 s



0.111 s

Figure 17. Sequential photographs for test 0335-2.

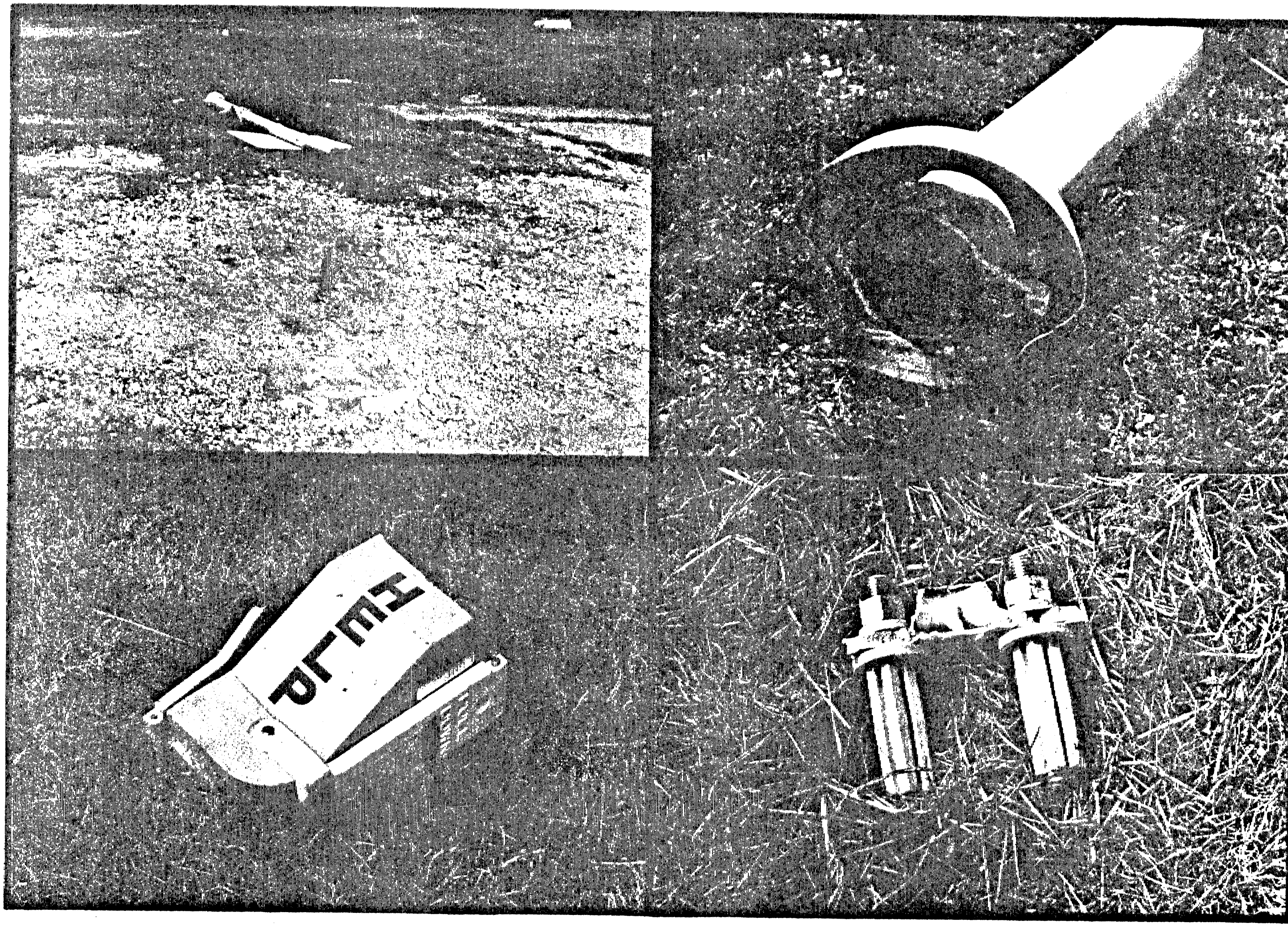
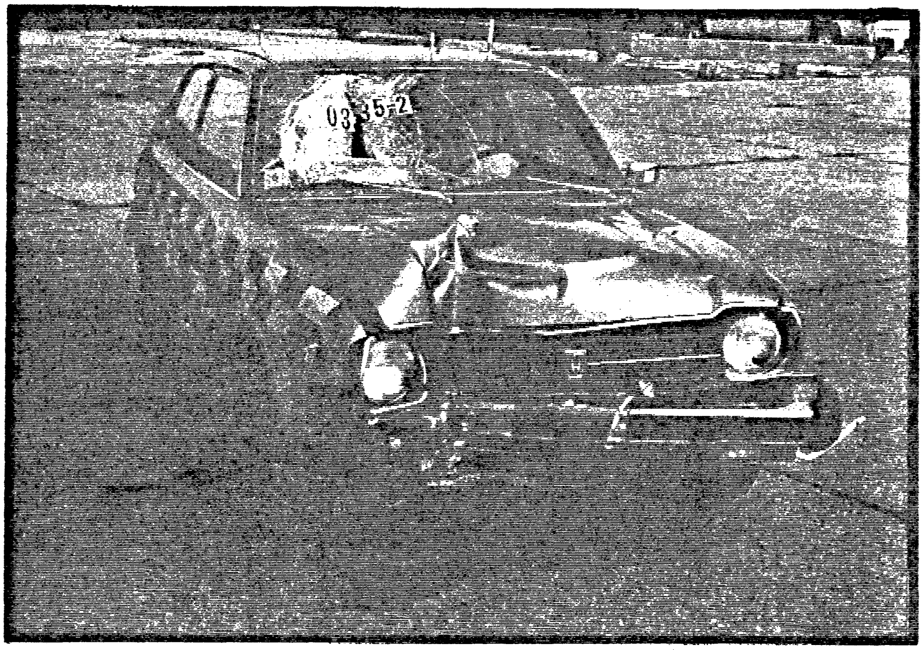


Figure 18. Call box installation after test 0335-2.



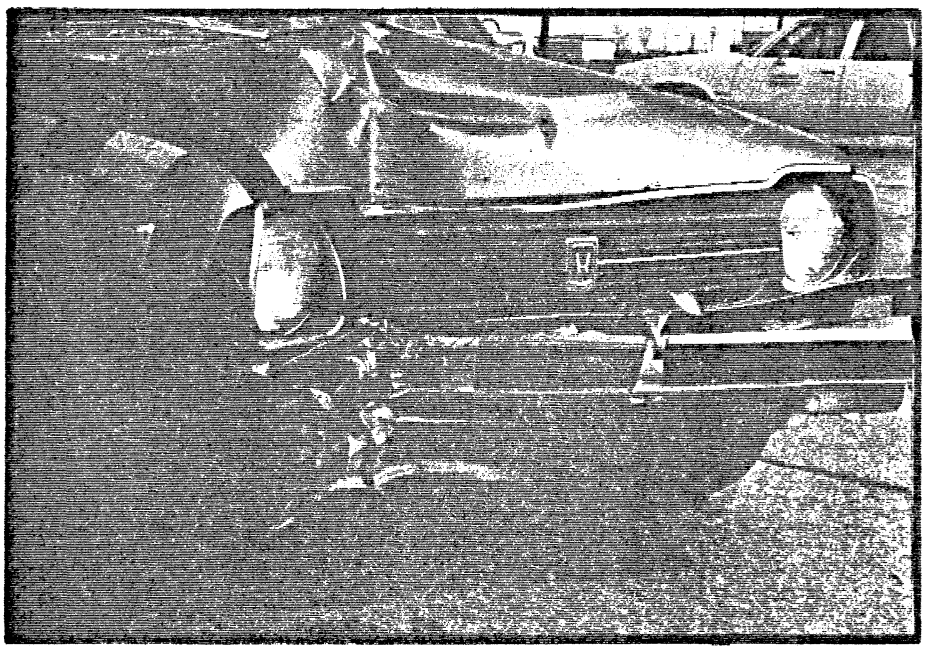
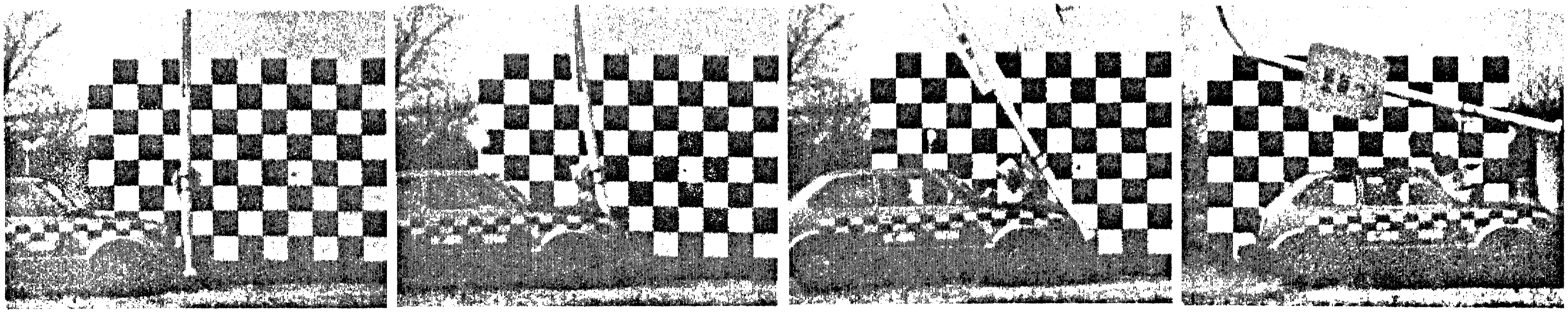
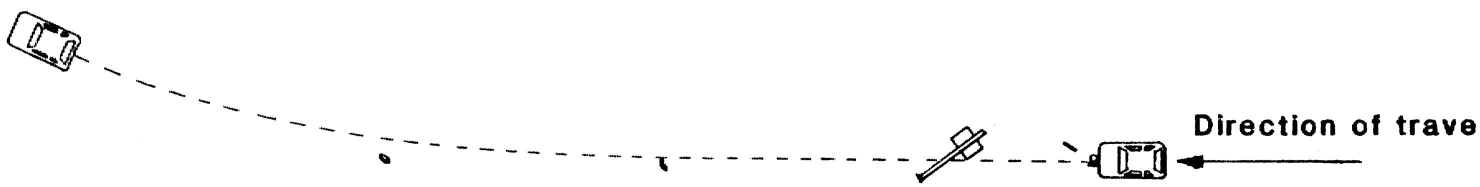
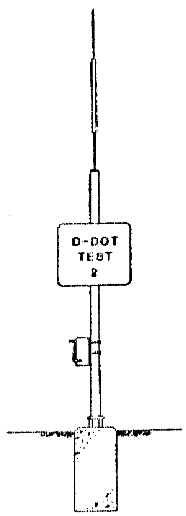


Figure 19. Vehicle after test 0335-2.



0.000 s | 0.025 s | 0.050 s | 0.111 s





Test No.	0335-2
NCHRP Report 230 Test No .	63
Date	2/12/86
Test Article	Motorist aid call box installation with 54 in (137 cm) mounting height
Vehicle.	1979 Honda Civic
Vehicle Weight	
Test Inertia	1,750 lb (795 kg)
Gross Static	1,917 lb (870 kg)
Vehicle Damage Classification	
TAD.	12-FR-4
SAE.	12FRAN6

Impact Speed.	64.6 mi/h (103.9 km/h)
Change in Velocity. . .	7.1 mi/h (11.4 km/h)
Change in Momentum. . .	566 lb-s (257 kg-s)
Vehicle Accelerations .	(Max. 0.050-sec Avg)
Longitudinal	-3.8 g
Lateral	0.8 g
Occupant Impact Velocity	
Longitudinal.	8.5 ft/s (2.6 m/s)
Lateral	No Occupant Impact
Occupant Ridedown Accelerations	
Longitudinal.	-1.03 g
Lateral	No Occupant Impact
Maximum Vehicle Crush at	
Bumper Height	15.3 in (38.7 cm)

Figure 20. Summary of results for test 0335-2.

Performance Evaluation

This call box installation did not meet the evaluation criteria recommended in NCHRP Report 230[1] for Test 63 for structural adequacy. The installation met the criteria for occupant risk and vehicle trajectory.

The installation readily activated by breaking away. The manner of activation was not completely expected, however, due to the nature of breakaway devices. The flange and anchor bolts at the four supports fractured rather than the breakaway couplings. A similar activation would be predicted in a duplicate test. The test article displayed structural inadequacy as detached call box housing penetrated the occupant compartment. The detached elements did not show potential for presenting undue hazard to other traffic due to the off-road location of the elements. The vehicle remained upright during and after the collision. The calculated longitudinal occupant impact velocity against the vehicle interior was below the limit of 15 ft/s (4.6 m/s). The absolute value of the measured maximum 0.010-second average longitudinal occupant ridedown acceleration was below the limit of 15 g. After collision, the vehicle trajectory and final stopping position was such that the vehicle did not intrude into adjacent traffic lanes. The vehicle trajectory behind this test article was acceptable.

TEST 0335-3

Test Description

Test 0335-3, performed on February 25, 1986, followed guidelines for longitudinal barriers described in Test 10 of NCHRP Report 230[1]. The test installation is shown in figure 21. The 1979 Ford LTD II shown in figure 22 was directed into the guardrail using a cable reverse tow and guidance system. The Test Inertia Mass and Gross Static Mass of the vehicle was 4500 lb (2043 kg). Vehicle mass properties and geometry are shown in figure 23. The point of impact was such that the right corner of the vehicle contacted the guardrail midway between posts 6 and 7, 40.6 ft (12.4 m) downstream from the upstream terminal at a 25.1 degree angle to the rail. The vehicle bumper height was 15.4 in (39.1 cm). The test vehicle was released from the tow and guidance system just prior to impact, thus it was free-wheeling and unrestrained at impact. The velocity of the vehicle at impact was 62.9 mi/h (101.2 km/h).

Test Results

As the vehicle impacted the W-beam rail, the bumper began to shift toward the left, the rail and post 7 began to displace to the right, and the vehicle began to rotate counterclockwise. The front corner of the vehicle crushed inward, popping out the grill and causing the hood to raise. The grill swept upward striking the call box. The rail contacted the call box pole. The breakaway couplings began to lean just before the couplings and the pole flange broke away. The call box housing began to open as the pole began to rotate about longitudinal and lateral axes with the bottom end of the pole moving forward and to the right. The partially raised hood contacted the call box housing. The pole then began to rotate about its vertical axis. The hood began buckling as the housing separated from the mount. The hood lost contact with the housing, projecting the housing forward and to the right. The call box generator separated from the housing. As the vehicle redirected to an exit angle of 14.7 degrees to the rail, the vehicle lost contact with the rail. The upper end of the pole contacted the ground after approximately 45 degrees of longitudinal, 110 degrees of lateral and 90 degrees of vertical rotation. The vehicle brakes were applied. Table 4 presents the significant events of this test by time.

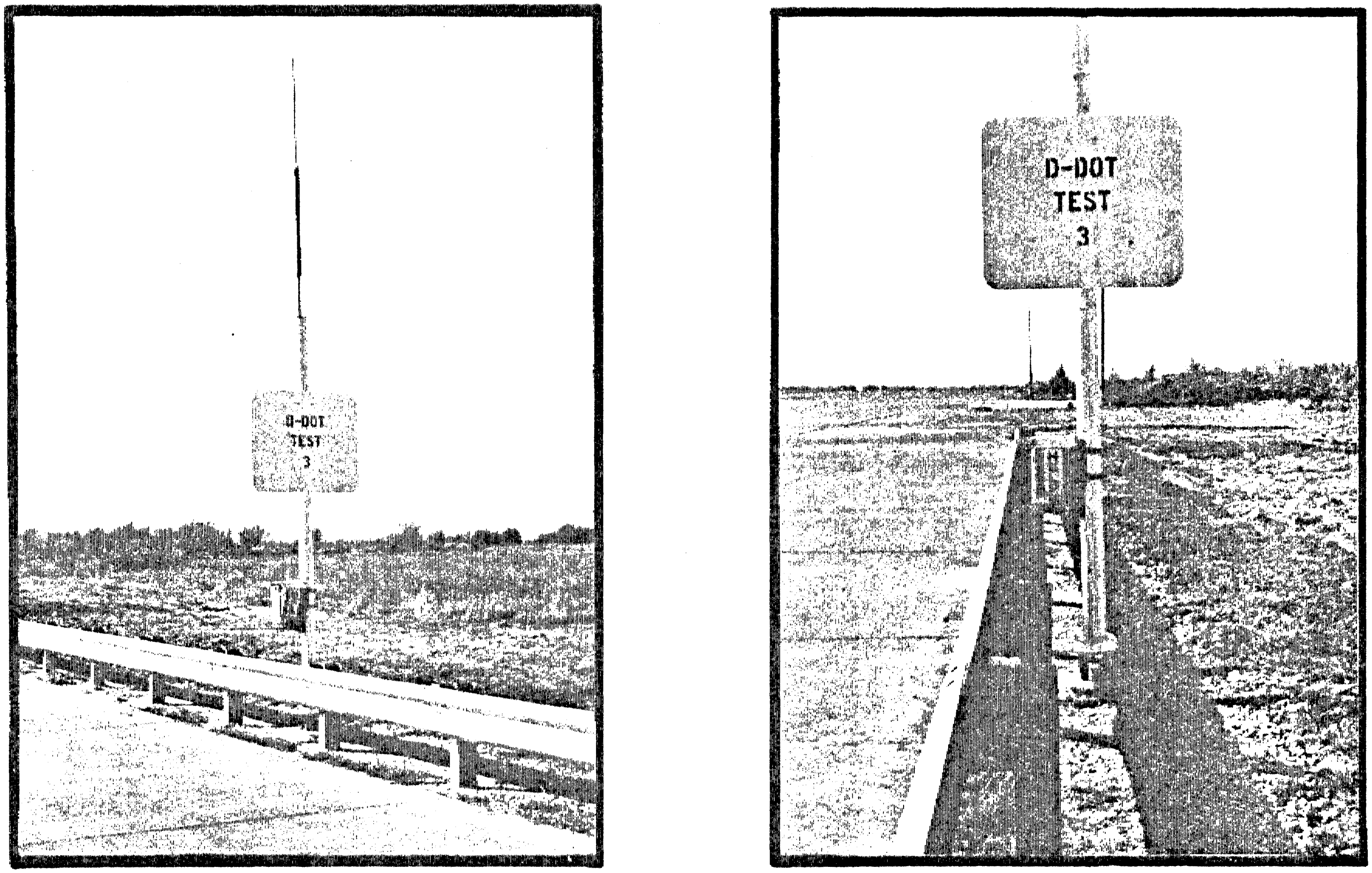


Figure 21. Call box installation before test 0335-3.

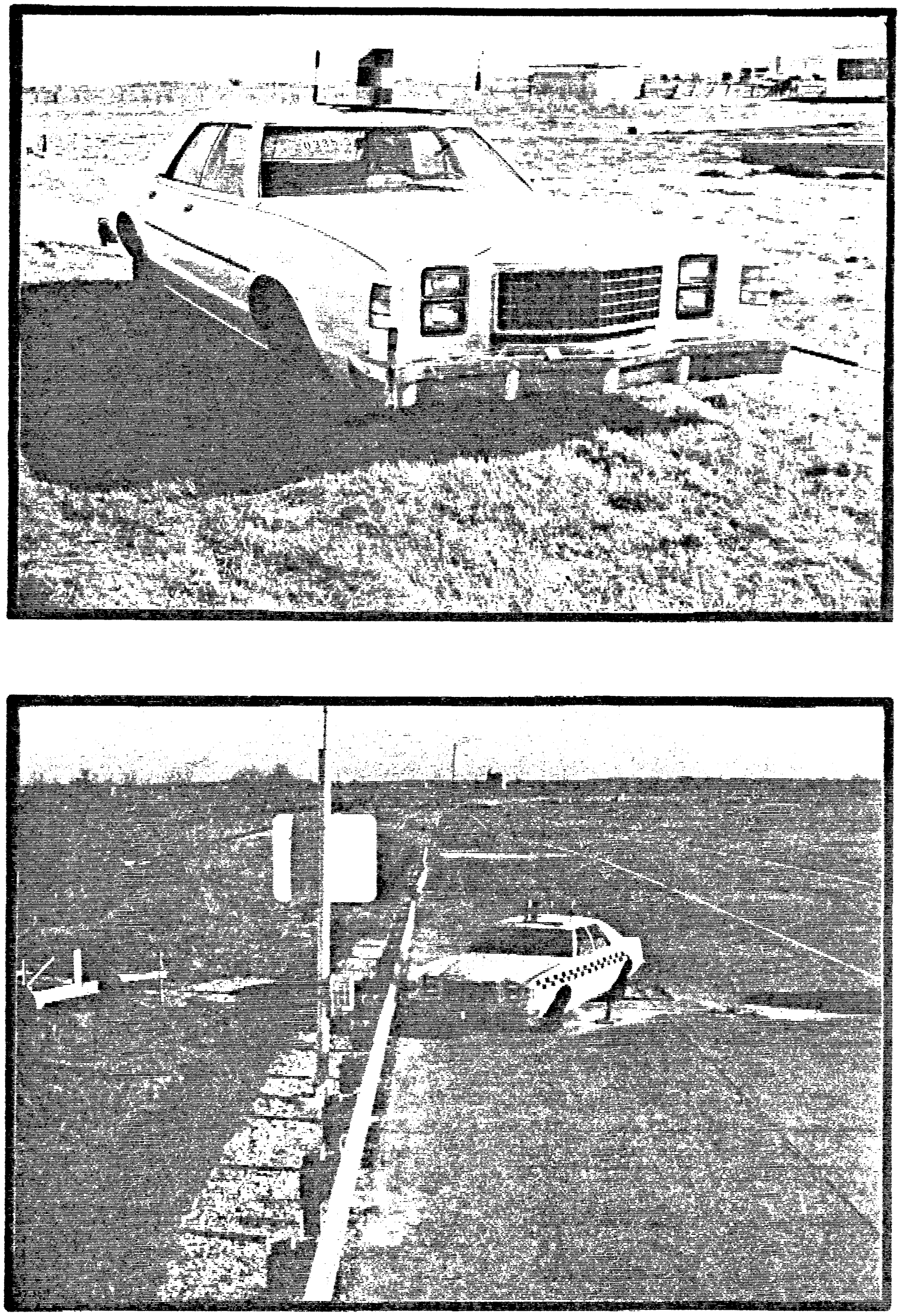


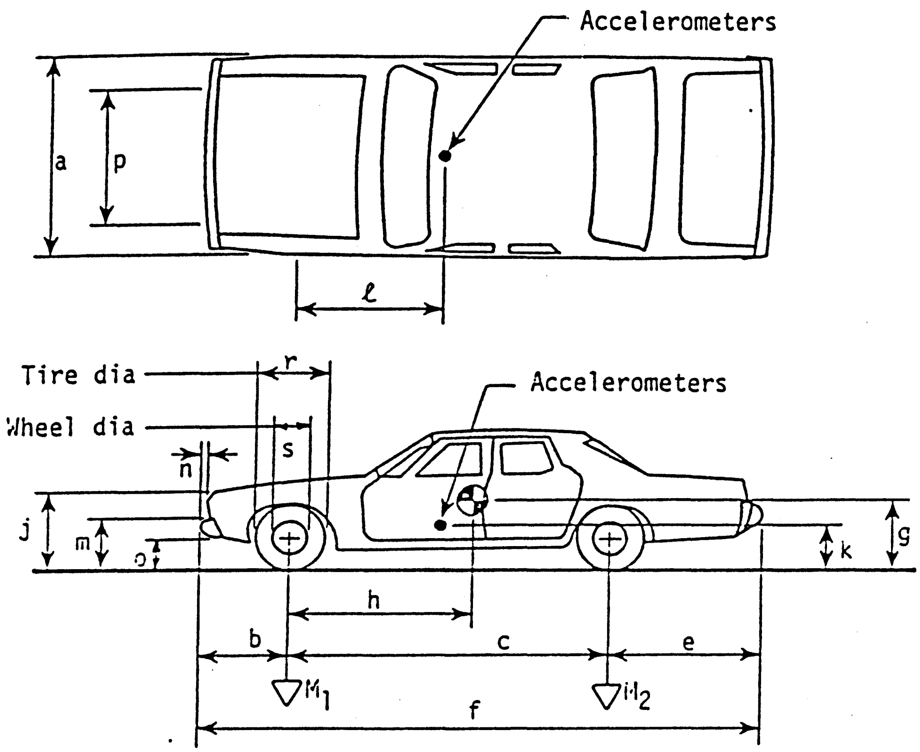
Figure 22. Test vehicle before test 0335-3.

Date: 2/25/86 Test No.: 0335-3 VIN: 9H31H130405

Make: Ford Model: LTD II Year: 1979 Odometer: 89010.8

Tire Size: P205/75R14 Ply Rating: 4 Bias Ply: ___ Belted: ___ Radial: x

Tire Condition: good ___
fair x
badly worn ___



Vehicle Geometry - inches

a	78.5	b	48.8
c	117.5	d*	55.0
e	53.0	f	219.3
g	----	h	50.9
i	----	j	34.0
k	17.5	ℓ	41.0
m	19.0	n	5.0
o	11.8	p	63.5
r	26.0	s	15.2

Engine Type: 8 cyl

Engine CID: 351

Transmission Type:

Automatic or Manual

FWD or RWD or 4WD

Body Type: 4 Dr

Steering Column Collapse Mechanism:

___ Behind wheel units
x Convoluted tube
___ Cylindrical mesh units
___ Embedded ball
___ NOT collapsible
___ Other energy absorption
___ Unknown

Brakes:

Front: disc x drum ___

Rear: disc ___ drum x

4-wheel weight for c.g. det. ℓf 1296 rf 1254 ℓr 984 rr 966

Mass - pounds	Curb	Test Inertial	Gross Static
M_1		2550	2550
M_2		1950	1950
M_T		4500	4500

Note any damage to vehicle prior to test:

No prior damage.

*d = overall height of vehicle

Figure 23. Test vehicle properties before test 0335-3.

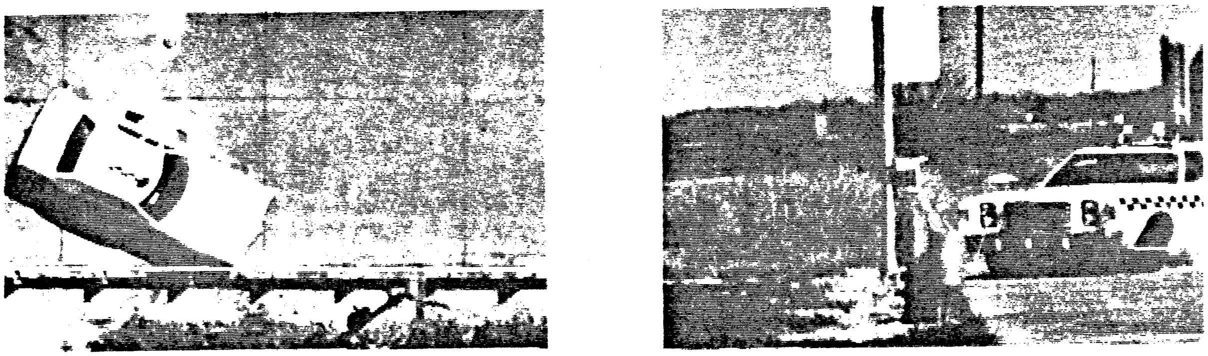
Table 4. Times of events for test 0335-3.

Time (sec)	Event
0.000	Vehicle bumper impacted rail
0.013	Pole 7 began to displace
0.028	Right front corner of vehicle began crushing inward
0.035	Post 8 began to displace, vehicle grill popped out, vehicle hood began to raise
0.078	Left end of bumper contacted ground
0.090	Post 9 began to displace
0.121	Grill struck call box
0.136	Rail contacted pole, post 10 began to displace
0.146	Coupling began to lean
0.150	Couplings and flange broke, pole began to rotate about longitudinal and lateral axes, call box housing began to open
0.171	Hood contacted call box housing, hood began to buckle, housing separated from mount, pole began to rotate about a vertical axis
0.235	Hood lost contact with housing, post 11 began to displace
0.251	Call box generator separated from housing
0.284	Vehicle and guardrail became parallel to each other
0.540	Vehicle lost contact with rail
0.600	Upper end of pole contacted ground
1.5+	Vehicle brakes were applied

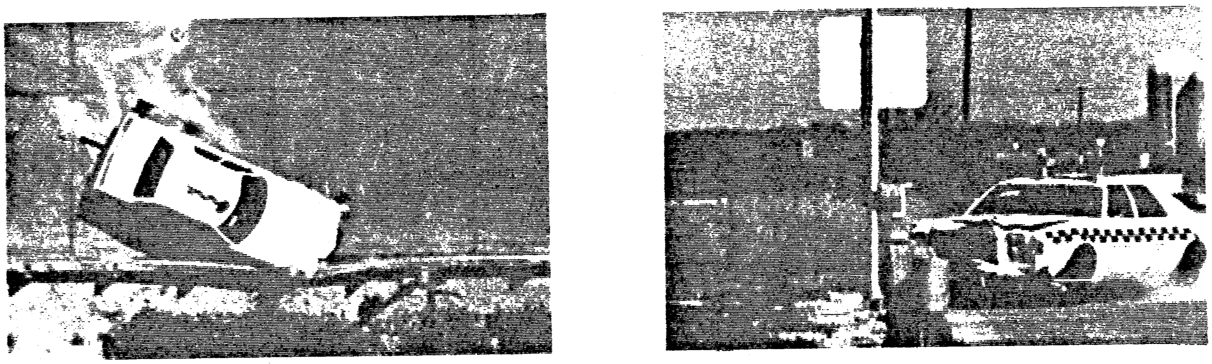
The center of gravity of the vehicle at final rest was approximately 140 ft (42.7 m) in the longitudinal direction and 25 ft (7.6 m) to the left of the pole base. The pole came to rest 9 ft (2.7 m) to the right of the rail with the upper end of the pole aligned with post 11 and the lower end of the pole aligned with post 12. All four breakaway couplings separated from the base by the shearing of the anchor bolts. Two of the couplings also sheared with the upper portions remaining fastened to the pole flange. One of the lower portions landed 14 ft (4.3 m) from the base and the other portion landed 21 ft (6.4 m) from the base. The third coupling with attached flange piece came to rest 35 ft (10.7 m) from the base. The fourth coupling landed with the call box housing and generator approximately 83 ft (25 m) from the base. Sequential photographs of the test are shown in figure 24. Figure 25 shows the call box installation after test 0335-3.

A maximum permanent rail deflection of 22.3 in (56.5 cm) was measured midway between posts 8 and 9. The dynamic rail deflection obtained from the overhead high speed film was 38.5 in (97.8 cm). The rail remained deformed over a 44 ft (13.4 m) length between posts 5 and 12. Posts 8 and 9 showed evidence of vehicle snagging. Posts 8, 9 and 10 showed tire rubbing marks. The bolt head and washer that fastened the rail to the offset block at post 8 had torn through the rail. Figure 26 shows the guardrail after test 0335-3.

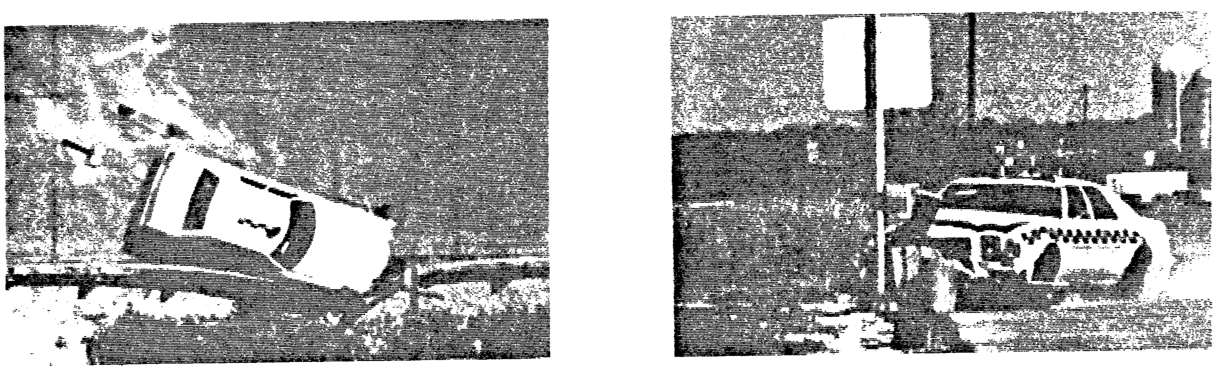
The test vehicle sustained extensive damage to the front end and right side as shown in figure 27. Maximum crush to the frontal plane of the vehicle at bumper height was 26.5 in (67.3 cm). Vehicle exterior items that were damaged were the hood and latch, front end panel, grill, front bumper, right head lights and turn signal, right and left front fenders, right front and rear doors, right rear quarter panel, rear bumper, rear tail light, and windshield. The frame was slightly bent. The right upper ball joint was separated. The radiator and support, fan and front bumper shocks were all damaged. The right front and rear tires were punctured and the rims were bent.



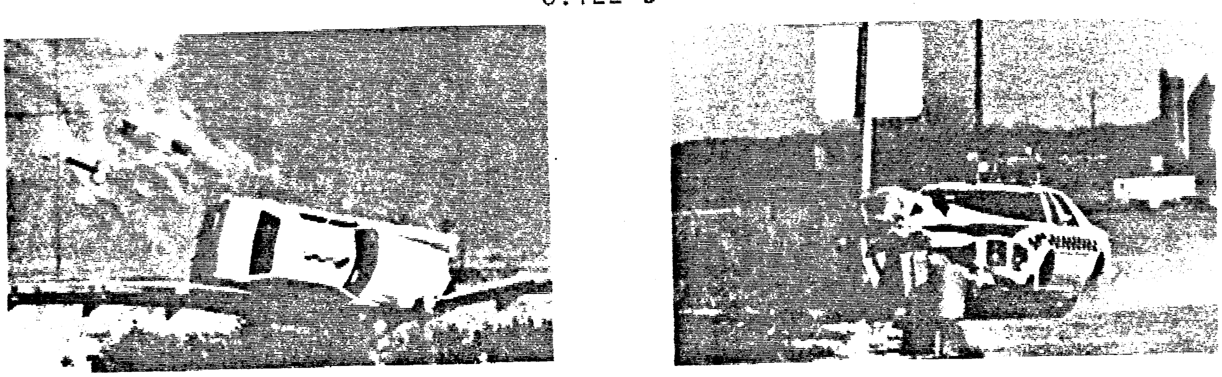
0.000 s



0.061 s

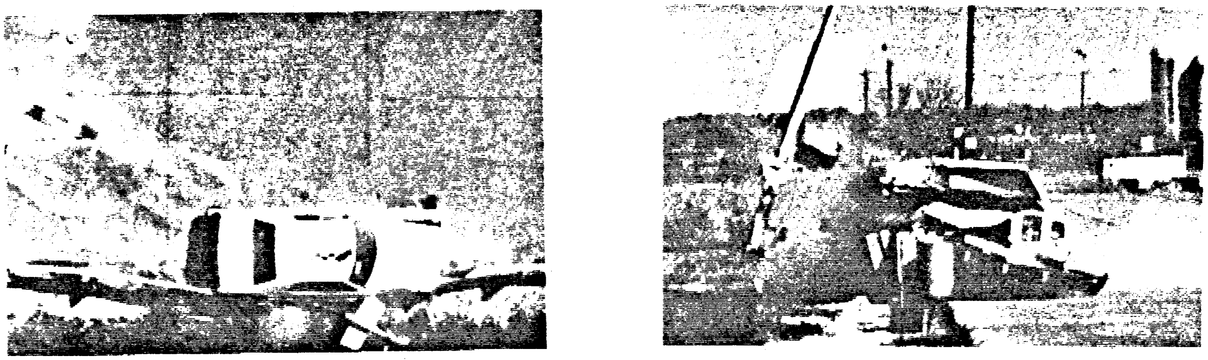


0.122 s

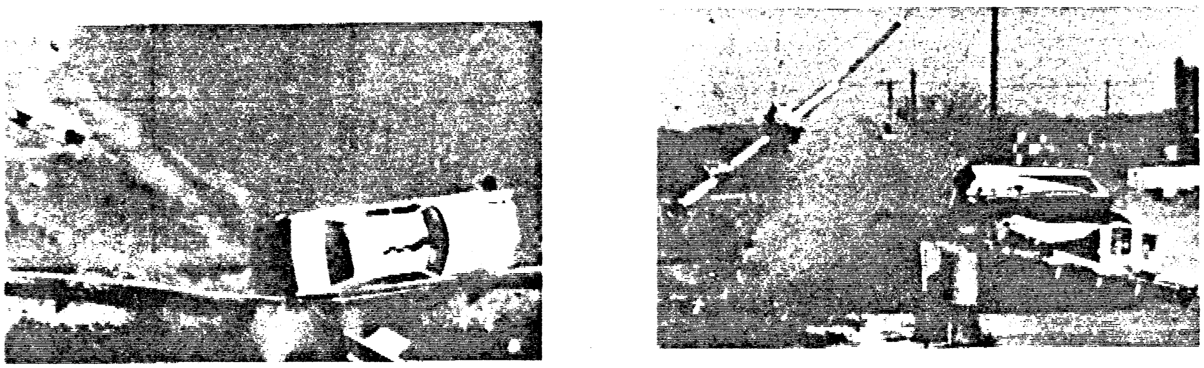


0.183 s

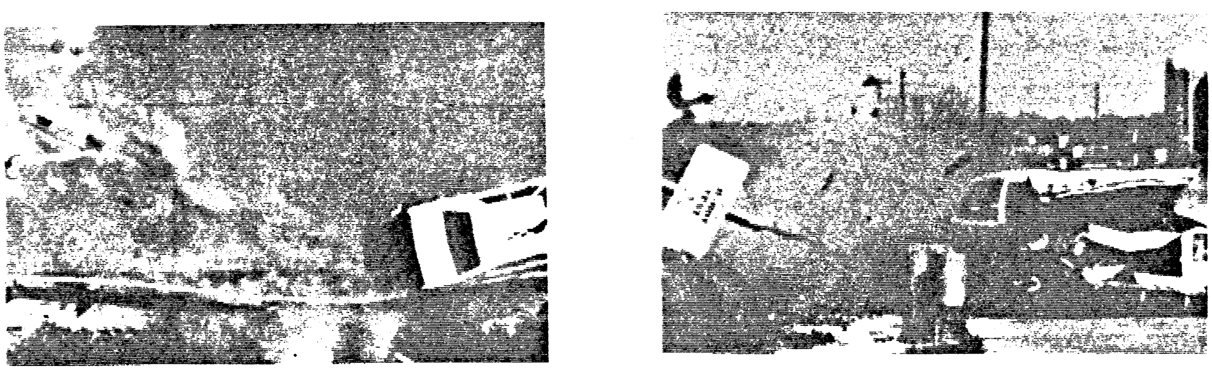
Figure 24. Sequential photographs for test 0335-3.



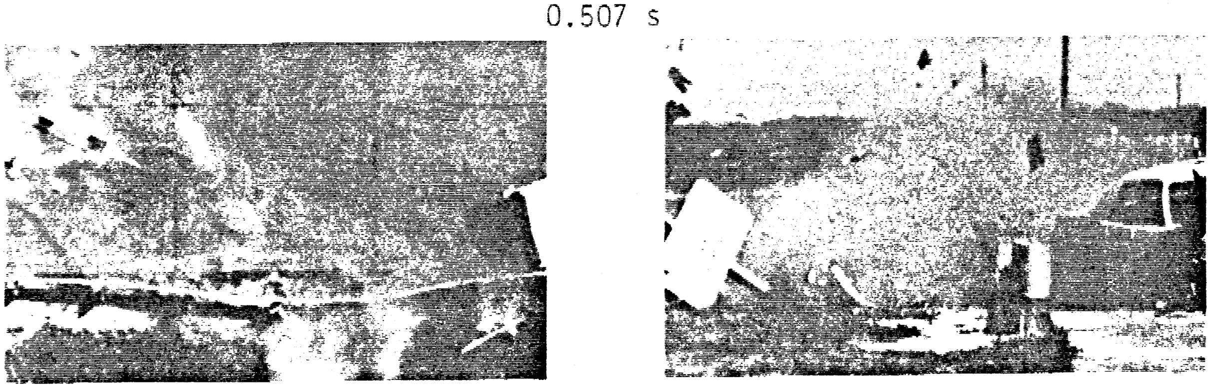
0.284 s



0.385 s



0.507 s



0.649 s

Figure 24. Sequential photographs for test 0335-3 (continued).

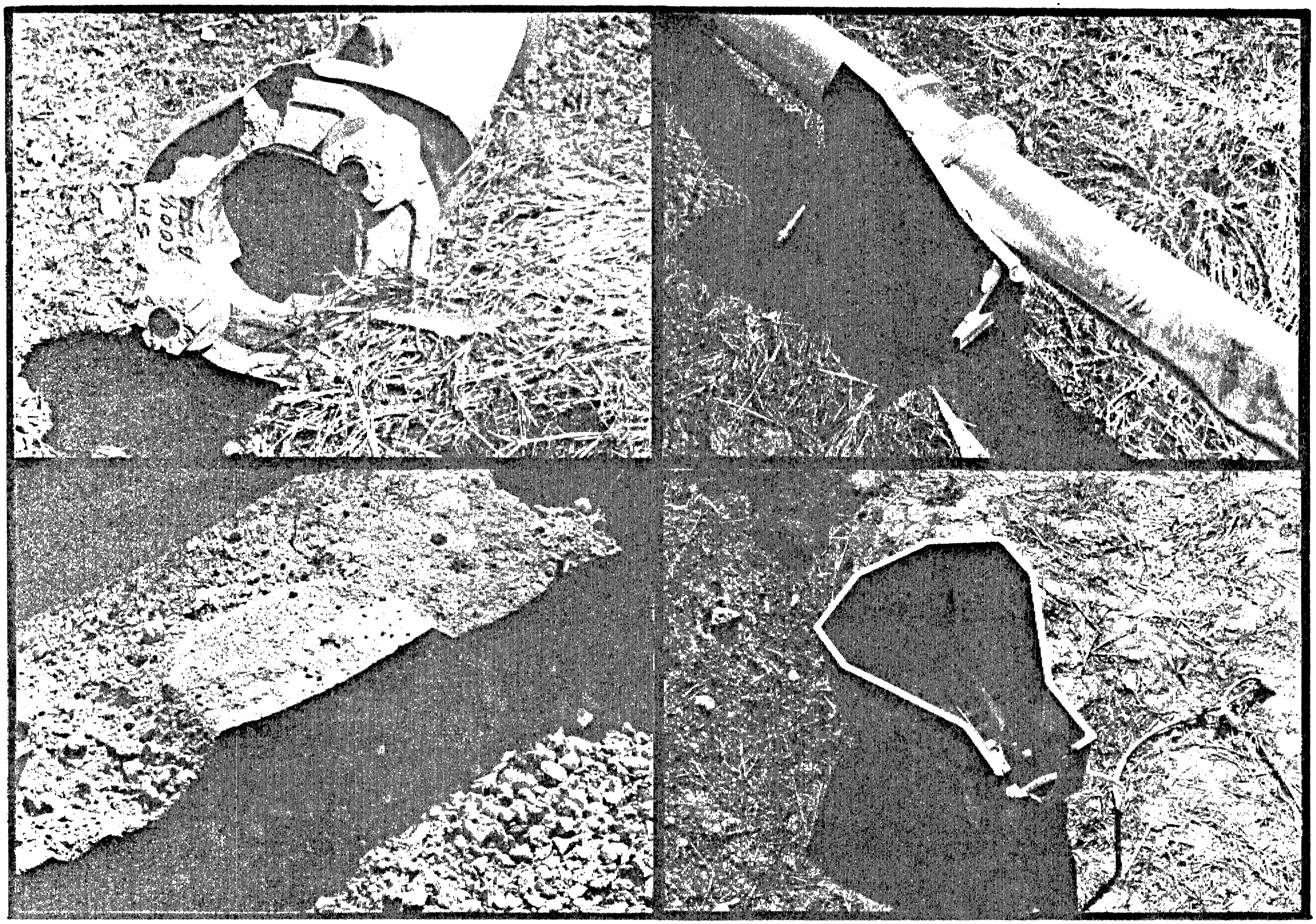


Figure 25. Call box installation after test 0335-3.

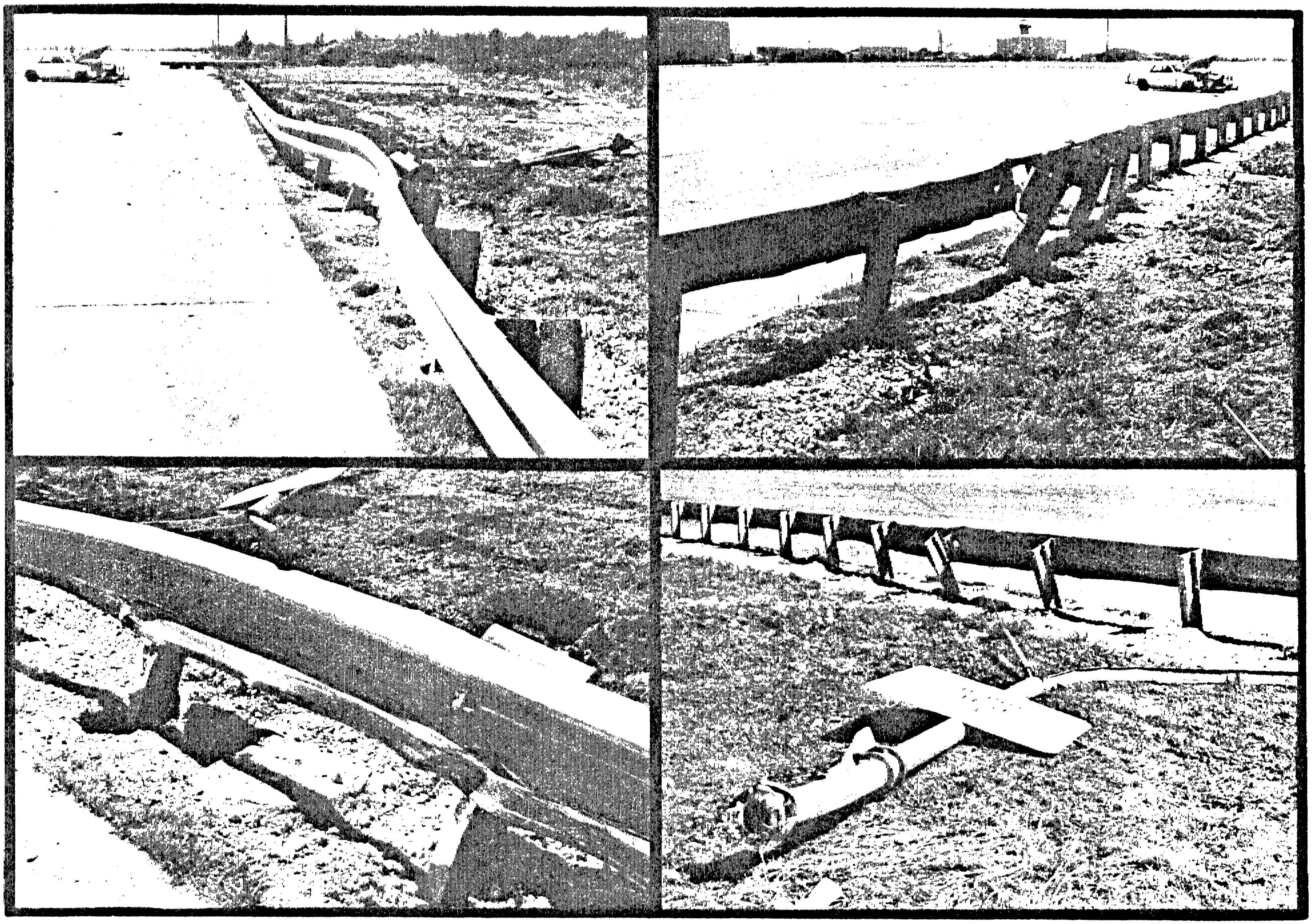


Figure 26. Guardrail after test 0335-3.

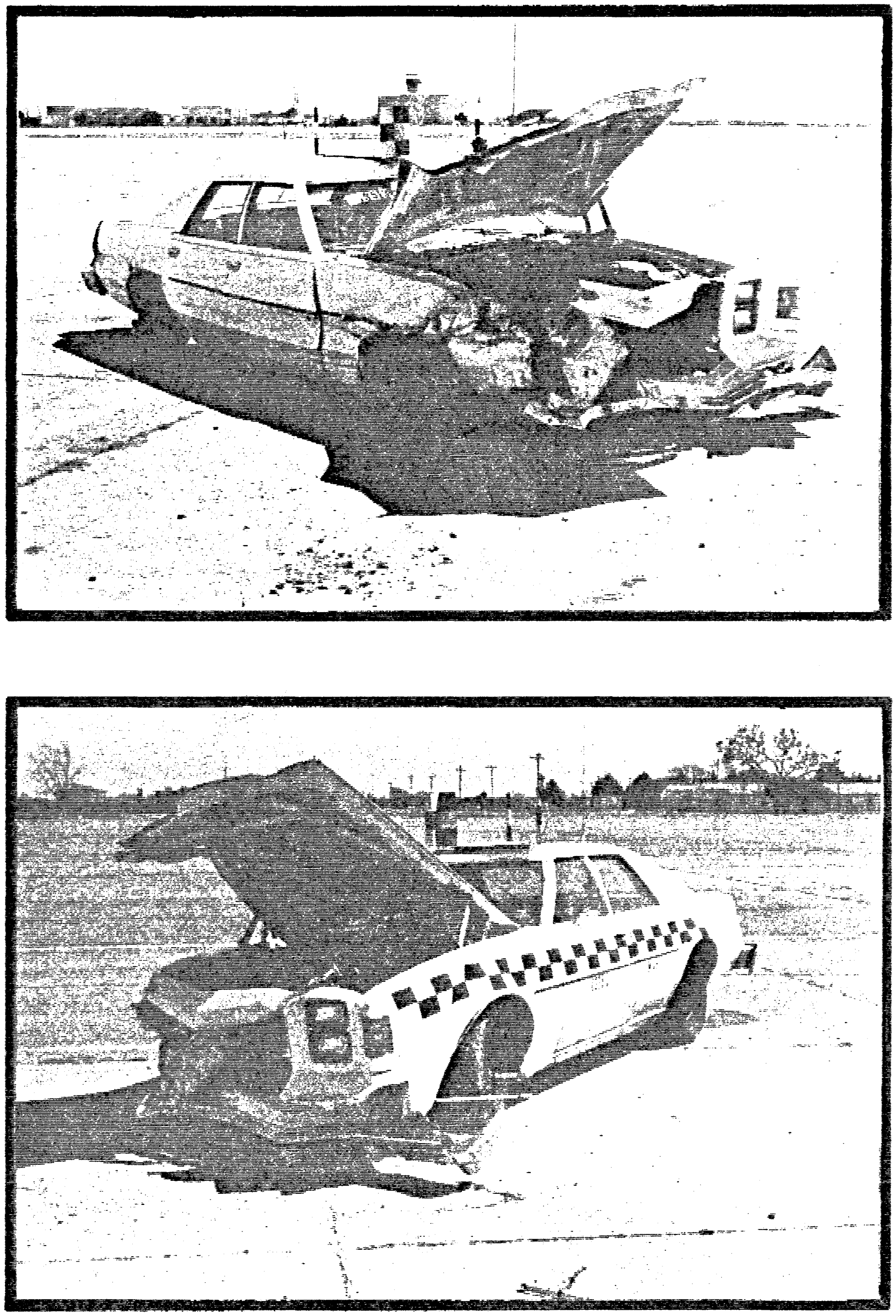
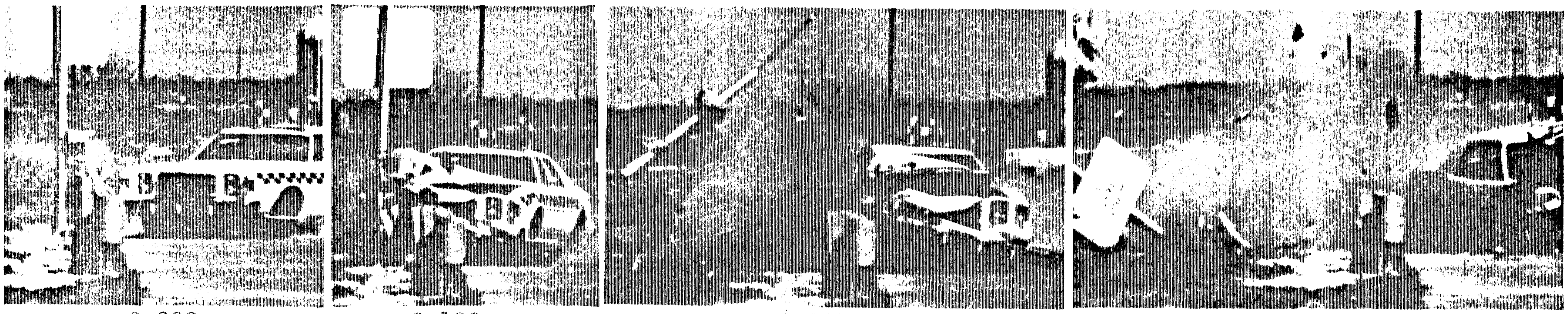
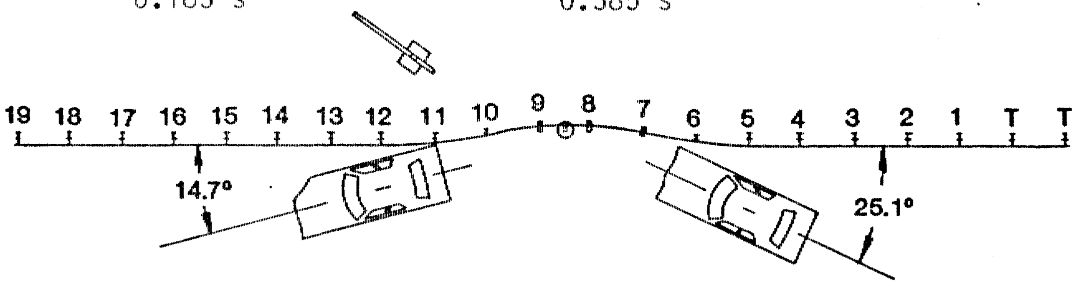


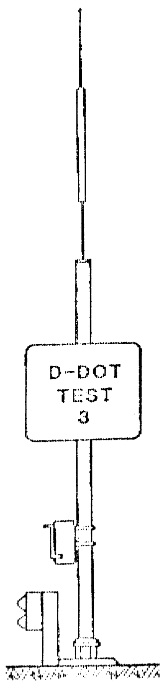
Figure 27. Vehicle after test 0335-3.

The change in velocity at the end of significant vehicle response, 0.500-second, was 22.2 mi/h (35.7 km/h). This yields a change in momentum of 4551 lb-s (2066 kg-s). The calculated occupant longitudinal impact velocity was 23.7 ft/s (7.2 m/s) and the absolute value of the measured maximum 0.010-second average longitudinal occupant ridedown acceleration was 5.7 g. The calculated occupant lateral impact velocity was 19.4 ft/s (5.9 m/s) and the absolute value of the measured maximum 0.010-second average lateral occupant ridedown acceleration was 11.2 g. Figures showing accelerometer traces for the test vehicle with locations of the highest 0.050-second averages and vehicle angular displacements are given in the Appendix. Results are summarized in figure 28.



0.000 s   0.183 s   0.385 s   0.649 s





Test No.	0335-3
NCHRP Report 230 Test No .	10
Date	2/25/86
Test Article	Motorist call box with 54 in (137 cm) height behind "W" section guardrail
Length of Guardrail. . . .	125 ft (38 m)
Rail Deflection	
Permanent.	22.3 in (56.5 cm)
Dynamic.	38.5 in (97.8 cm)
Vehicle.	1979 Ford LTD II
Vehicle Weight	
Test Inertia	4,500 lb (2,043 kg)
Gross Static	4,500 lb (2,043 kg)
Vehicle Damage Classification	
TAD.	1-FR-5 & 1-RD-4
SAE.	01FREK1 & 01RDES2

Impact Speed.	62.9 mi/h (101.2 km/h)
Impact Angle.	25.1 degrees
Exit Angle.	14.7 degrees
Change in Velocity. . .	22.2 mi/h (35.7 km/h)
Change in Momentum. . .	4551 lb-s (2066 kg-s)
Vehicle Accelerations .	(Max. 0.050-sec Avg)
Longitudinal.	-6.1 g
Lateral	8.0 g
Vertical.	2.4 g
Occupant Impact Velocity	
Longitudinal.	23.7 ft/s (7.2 m/s)
Lateral	19.4 ft/s (5.9 m/s)
Occupant Ridedown Accelerations	
Longitudinal.	-5.7 g
Lateral	11.2 g
Maximum Vehicle Crush at	
Bumper Height	26.5 in (67.3 cm)

Figure 28. Summary of results for test 0335-3.

Performance Evaluation

This guardrail and call box installation met the evaluation criteria recommended in NCHRP Report 230[1] for Test 10 for structural adequacy, occupant risk and vehicle trajectory.

The guardrail smoothly redirected the test vehicle without allowing the vehicle to penetrate the guardrail. The detached elements from the guardrail and call box installation did not penetrate nor show potential for penetrating the passenger compartment, nor presented undue hazard to other traffic. The vehicle remained upright during and after the collision. After collision, the vehicle trajectory and final stopping position were such that the vehicle intruded a minimum distance into the adjacent traffic lane.

TEST 0335-4

Test Description

Test 0335-4, performed on May 7, 1986, followed guidelines for breakaway and yielding supports described in Test 63 of NCHRP Report 230[1]. The test installation is shown in figure 29. The 1979 Honda shown in figure 30 was directed into the call box installation using a cable reverse tow and guidance system. The Test Inertia Mass of the vehicle was 1783 kg lb (809 kg) and its Gross Static Mass was 1953 lb (887 kg). Vehicle mass properties and geometry are shown in figure 31. The point of impact was such that the right quarter point of the vehicle bumper contacted the call box support pole. The vehicle bumper height was 17.6 in (44.8 cm). The test vehicle was released from the tow and guidance system just prior to impact, thus it was free-wheeling and unrestrained at impact. The velocity of the vehicle at impact was 60.9 mi/h (98.0 km/h).

Test Results

As the right quarter point of the vehicle bumper impacted the call box pole, the pole pushed the bumper inward. The vehicle hood and grill then contacted the pole. As the hood, grill and bumper crushed inward, the breakaway couplings began leaning away from the vehicle, the front two couplings sheared, and the pole flange began to break out at the back two coupling connections. As the flange broke out, the anchor bolts on the back two couplings sheared. The pole then began to rotate about a lateral axis with the lower end of the pole moving forward in the direction of vehicle travel. The two couplings, with attached flange piece, began tumbling forward. The vehicle then lost contact with the pole as both the pole assembly and the vehicle continued to move forward. The vehicle then passed under the pole assembly. The pole had reached a height of approximately 6 ft (1.8 m) while positioned parallel to the ground. The antenna separated from the pole.

After approximately 490 degrees of lateral rotation, the lower end of the pole contacted the ground. The vehicle brakes were applied. Table 5 presents the significant events of this test by time.

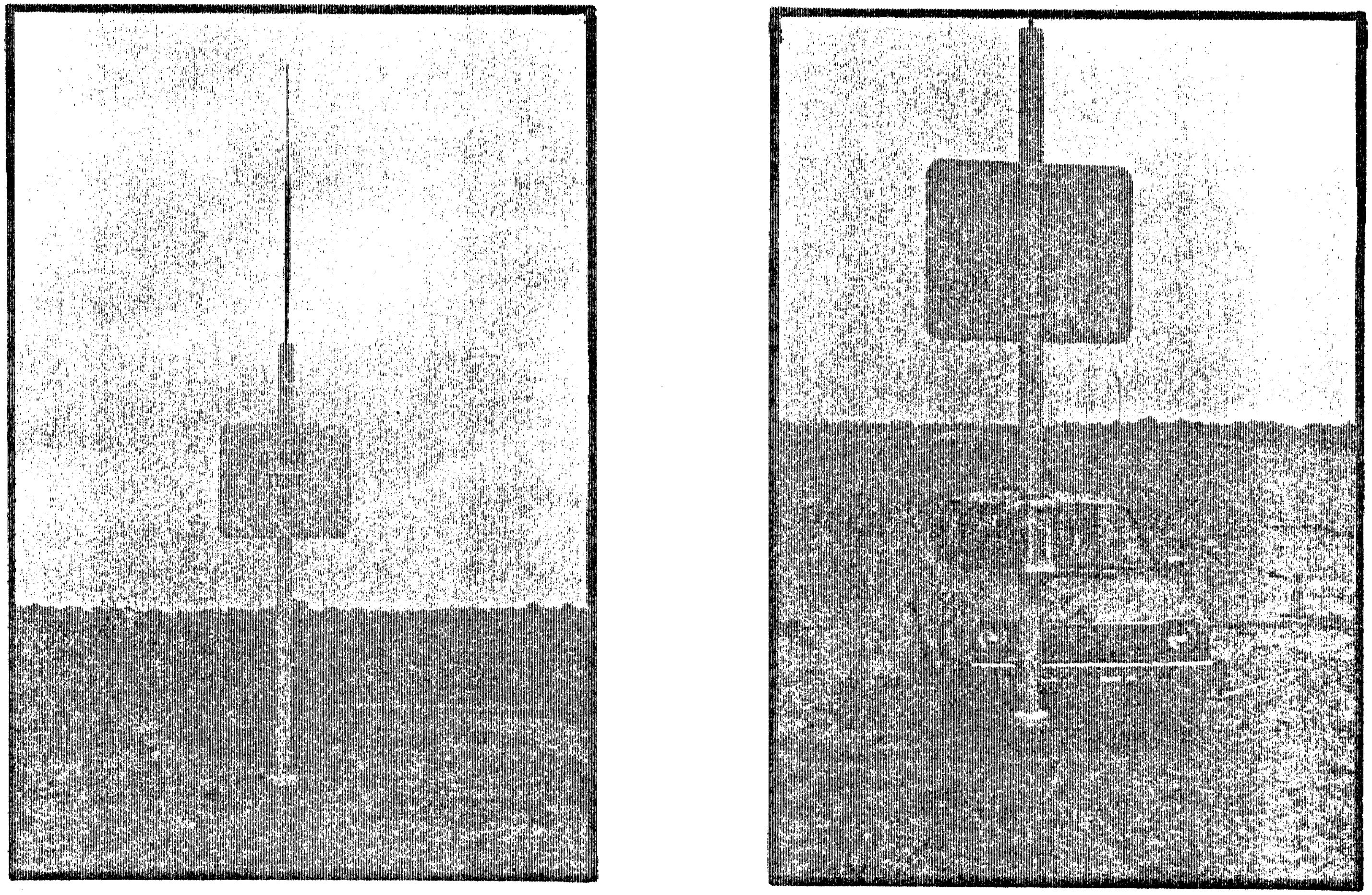


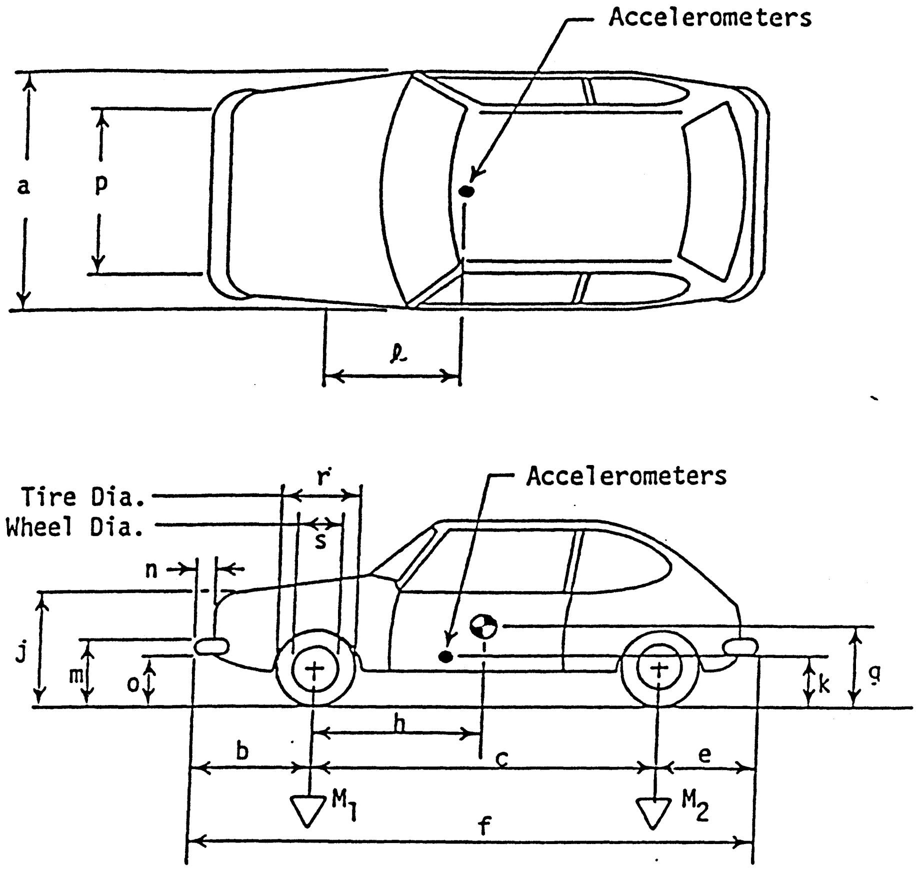
Figure 29. Call box installation before test 0335-4.

Figure 30. Test vehicle before test 0335-4.

Date: May 7, 1986 Test No.: 0335-4 VIN: SBC-7013238

Make: Honda Model: Civic 1200 Year: 1979 Odometer: 79458.3

Tire Size: P155/12 Ply Rating: 4 Bias Ply: ___ Belted: x Radial: ___



Tire Condition: good x fair ___ badly worn ___

Vehicle Geometry - inches

a	59.0	b	27.8
c	86.5	d*	52.3
e	27.3	f	141.5
g	----	h	34.7
i	----	j	31.5
k	14.5	ℓ	34.3
m	20.0	n	5.3
o	15.3	p	51.3
r	22.5	s	13.3

4-wheel weight for c.g. det. ℓf 535 rf 532 ℓr 354 rr 362

Mass - pounds	Curb	Test Inertial	Gross Static
M_1		1067	1149
M_2		716	804
M_T		1783	1953

Note any damage to vehicle prior to test:

Slight denting in center of hood.

*d = overall height of vehicle

Engine Type: 4 cyl

Engine CID: 76

Transmission Type:

Automatic or Manual

FWD or RWD or 4WD

Body Type: 3 Dr HatchBack

Steering Column Collapse Mechanism:

___ Behind wheel units
x Convoluted tube
___ Cylindrical mesh units
___ Embedded ball
___ NOT collapsible
___ Other energy absorption
___ Unknown

Brakes:

Front: disc x drum ___

Rear: disc ___ drum x

Figure 31. Test vehicle properties before test 0335-4.

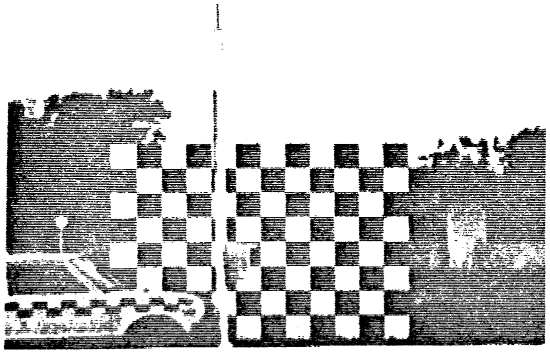
Table 5. Times of events for test 0335-4.

Time (sec)	Event
0.000	Vehicle bumper impacted pole
0.005	Vehicle hood and grill contacted pole, breakaway couplings began to lean, couplings shear, flange began to break out
0.013	Couplings with broken flange piece began to separate from pole, pole began to rotate about a lateral axis
0.020	Couplings began to tumble
0.045	Vehicle lost contact with pole
0.169	Sign contacted back of vehicle roof
0.189	Antenna separated from pole
0.785	Lower end of pole hit ground
3.0+	Vehicle brakes were applied

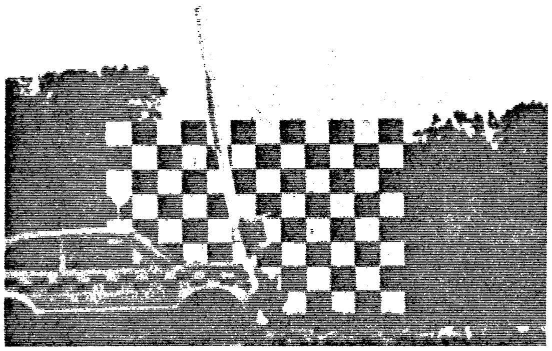
The center of gravity of the vehicle at final rest was approximately 230 ft (70 m) in the longitudinal direction. The pole landed approximately 43 ft (13 m) from the base. Two of the four breakaway couplings that separated from the base by the shearing of the anchor bolts came to rest approximately 235 ft (72 m) from the base. These two couplings were connected by one piece of the broken flange. The antenna landed 15 ft (4.6 m) from the base. Sequential photographs of the test are shown in figure 32. Figure 33 shows the installation after test 0335-4.

The test vehicle sustained major damages to the front end as shown in figure 34. Maximum crush to the frontal plane of the vehicle at bumper height was 13.7 in (34.8 cm). The hood was crushed inward about 8 in (20.3 cm). The grill was broken into two pieces. The front valance panel was crushed inward. The radiator was punctured and leaked fluid. After the test, the anthropomorphic dummy was observed to be in the driver seat laying toward the passenger seat. Dummy movement was mainly due to after test vehicle braking.

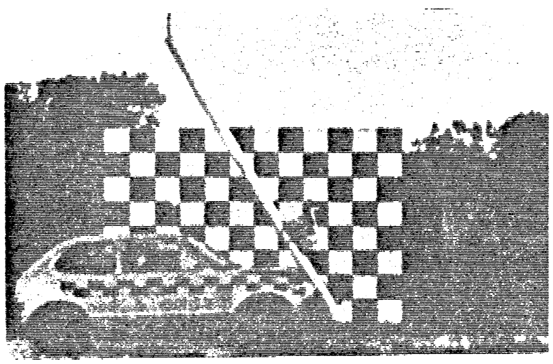
The change in velocity at the end of significant vehicle response, 0.500-second, was 6.6 mi/h (10.6 km/h). This yields a change in momentum of 536 lb-s (243 kg-s). The calculated occupant longitudinal impact velocity was 7.9 ft/s (2.4 m/s) and the absolute value of the measured maximum 0.010-second average longitudinal occupant ridedown acceleration was 0.86 g. The calculated occupant lateral impact velocity was 5.1 ft/s (1.6 m/s) and the absolute value of the measured maximum 0.010-second average lateral occupant ridedown acceleration was 0.85 g. Figures showing accelerometer traces for the test vehicle with locations of the highest 0.050-second averages are given in the Appendix. Results are summarized in figure 35.



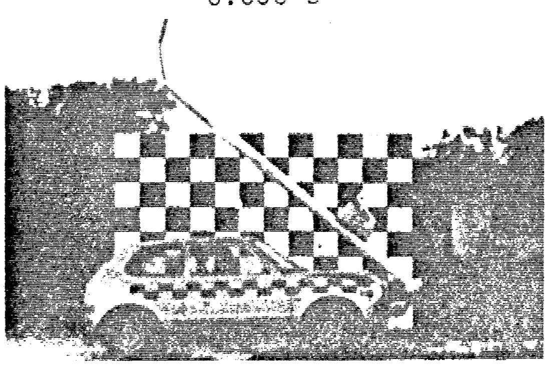
0.000 s



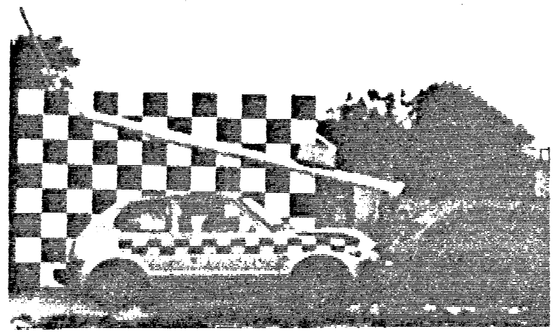
0.025 s



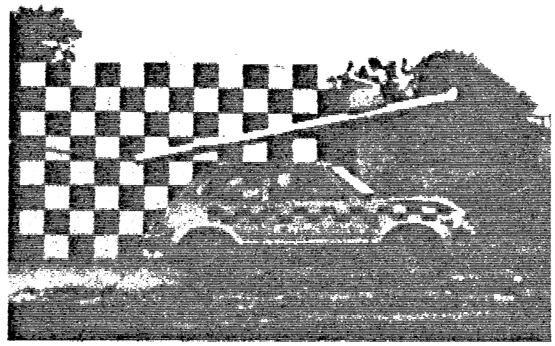
0.050 s



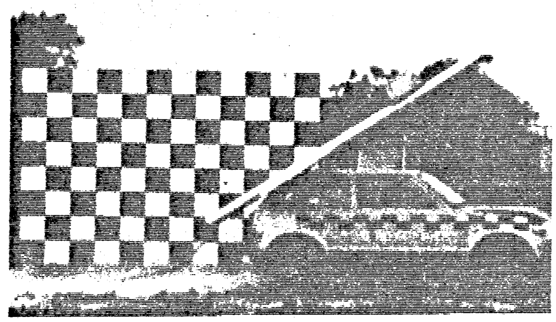
0.075 s



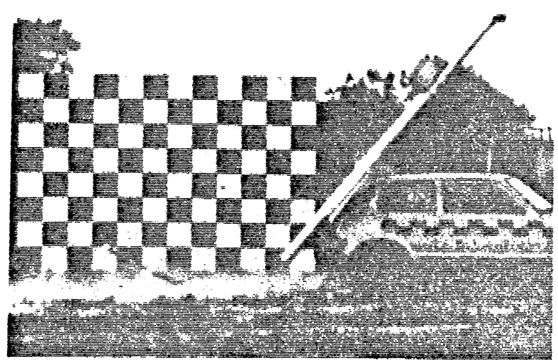
0.113 s



0.151 s



0.189 s



0.226 s

Figure 32. Sequential photographs for test 0335-4.

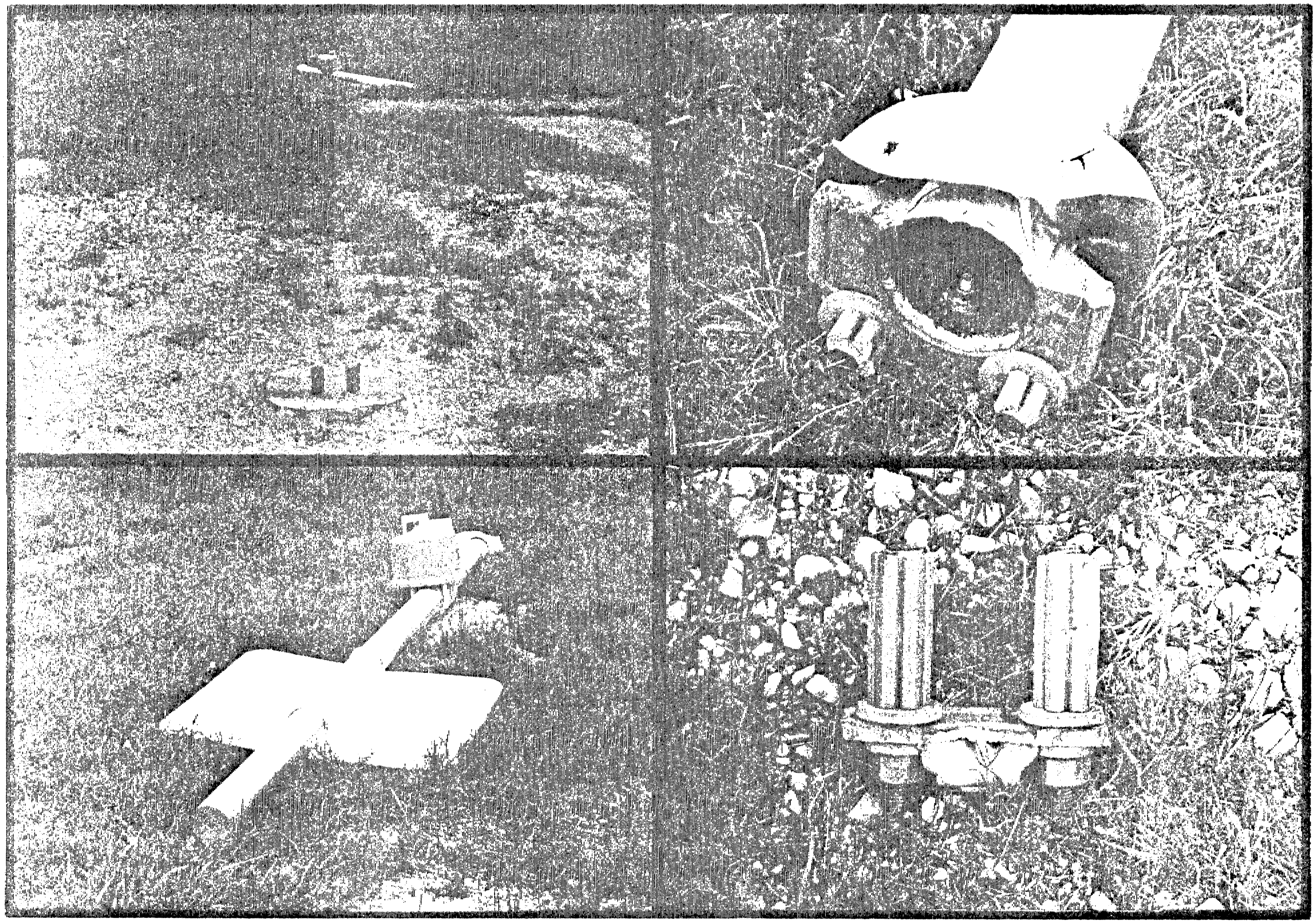
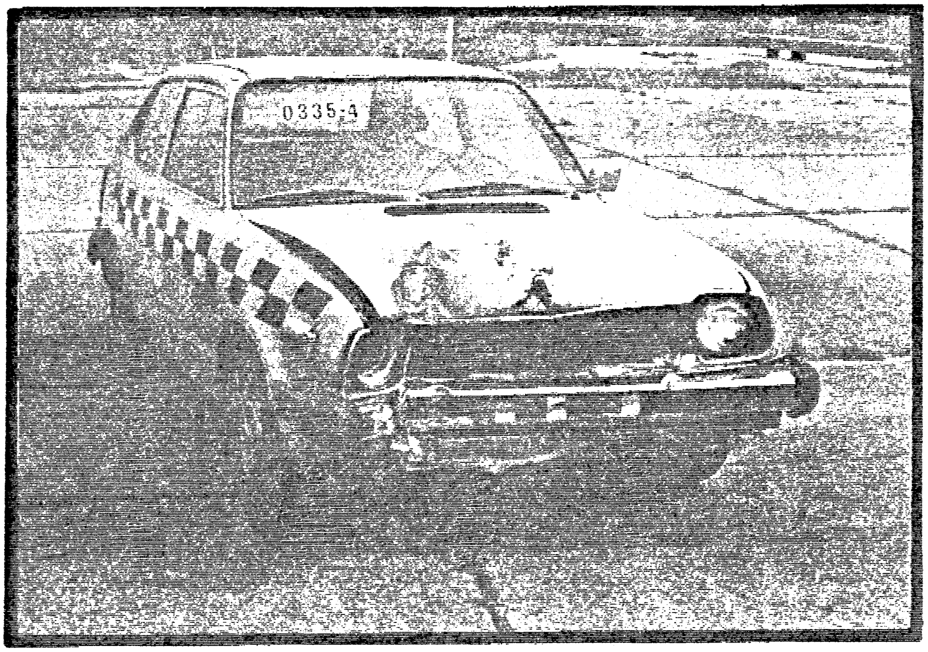


Figure 33. Call box installation after test 0335-4.



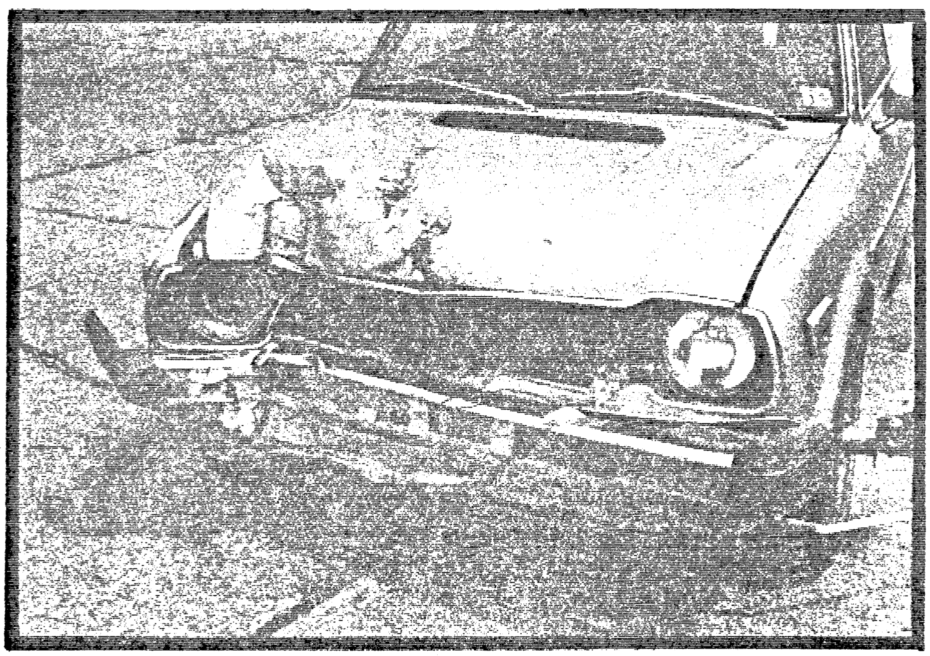
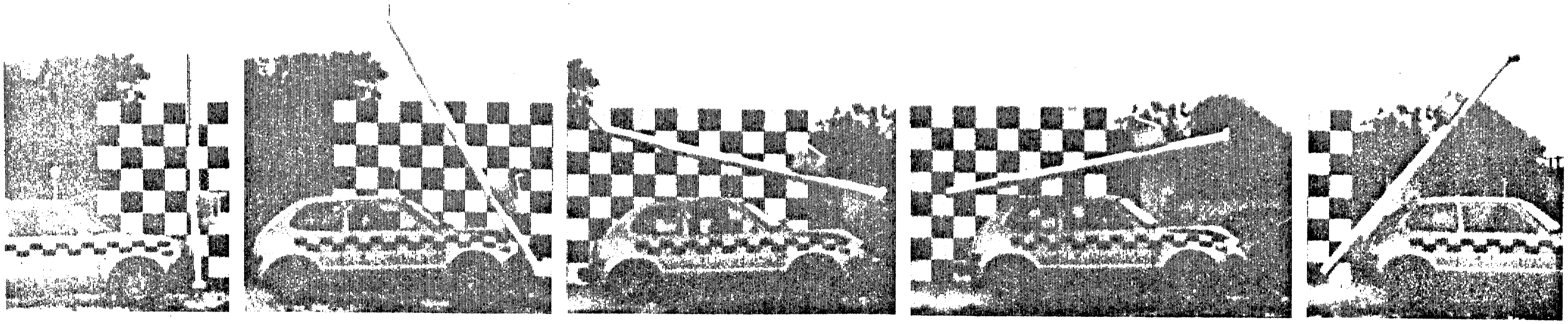
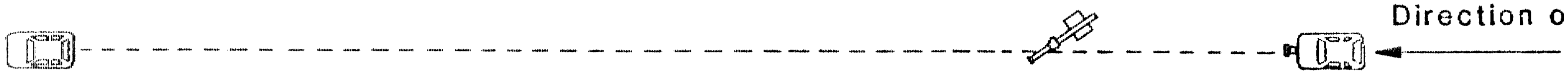


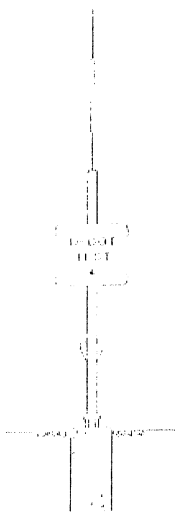
Figure 34. Vehicle after test 0335-4.



0.000 s 0.050 s 0.113 s 0.151 s 0.226 s



Direction of travel



Test No.	0335-4
NCHRP Report 230 Test No .	63
Date	5/7/86
Test Article	Motorist aid call box installation with 54 in (137 cm) mounting height
Vehicle.	1979 Honda Civic
Vehicle Weight	
Test Inertia	1,783 lb (809 kg)
Gross Static	1,953 lb (887 kg)
Vehicle Damage Classification	
TAD.	12-FR-4
SAE.	12FREN2

Impact Speed.	60.9 mi/h (98.0 km/h)
Change in Velocity. . .	6.6 mi/h (10.6 km/h)
Change in Momentum. . .	536 lb-s (243 kg-s)
Vehicle Accelerations .	(Max. 0.050-sec Avg)
Longitudinal.	-4.2 g
Lateral	-1.1 g
Occupant Impact Velocity	
Longitudinal.	7.9 ft/s (2.4 m/s)
Lateral	5.1 ft/s (1.6 m/s)
Occupant Ridedown Accelerations	
Longitudinal.	-0.86 g
Lateral	-0.85 g
Maximum Vehicle Crush at	
Bumper Height	13.7 in (34.8 cm)

Figure 35. Summary of results for test 0335-4.

Performance Evaluation

This call box installation met the evaluation criteria recommended in NCHRP Report 230[1] for Test 63 for structural adequacy, occupant risk and vehicle trajectory.

The installation readily activated by breaking away. The manner of activation was not completely expected, however, due to the nature of breakaway devices. The flange and anchor bolts at two of the four supports fractured rather than the breakaway couplings. A similar activation would be predicted in a duplicate test. The detached elements from the test article did not penetrate nor show potential for penetrating the passenger compartment, nor presented undue hazard to other traffic due to the off-road location of the elements. The vehicle remained upright during and after the collision. The calculated longitudinal occupant impact velocity against the vehicle interior was below the limit of 15 ft/s (4.6 m/s). The absolute value of the measured maximum 0.010-second average longitudinal occupant ridedown acceleration was below the limit of 15 g. After collision, the vehicle trajectory and final stopping position was such that the vehicle did not intrude into adjacent traffic lanes. The vehicle trajectory behind this test article was acceptable.

SUMMARY AND CONCLUSIONS

Four full-scale vehicle crash tests were performed for the Delaware Department of Transportation at the Texas Transportation Institute Proving Grounds to evaluate the safety performance of a motorist aid call box system with a top-of-call box mounting height of 54 in (137 cm). All tests were performed in accordance with NCHRP Report 230[1].

Test 1 used a 1800 lb (817 kg) vehicle impacting the call box installation at a velocity of 20 mi/h (32 k/h). The call box was oriented to face 90 degrees from the direction of traffic. This test was performed to evaluate the test article by observing the breakaway mechanism of the installation, the risk to an occupant, and any penetration into the occupant compartment by detached test article debris. Analyses of the first test revealed the following:

- The installation readily activated by breaking away.
- The detached elements from the test article did not penetrate nor show potential for penetrating the passenger compartment, nor presented undue hazard to other traffic.
- The vehicle remained upright during and after the collision.
- The longitudinal occupant impact velocity of 8.1 ft/s (2.5 m/s) was below the limit of 15 ft/s (4.6 m/s).
- The absolute value of the longitudinal occupant ridedown acceleration of 0.73 g was below the limit of 15 g.
- The after collision vehicle trajectory and final stopping position was acceptable.

Test 2 used a 1800 lb (817 kg) vehicle impacting the call box installation at a velocity of 60 mi/h (97 k/h). The call box was oriented to face 90 degrees from the direction of traffic. This test was performed to evaluate the test article by observing vehicle stability and trajectory, the risk to an occupant, and any penetration into the occupant compartment by detached test article debris. Analyses of the second test revealed the following:

- The installation readily activated by breaking away.
- The call box housing penetrated into the occupant compartment.

- The detached elements from the test article did not present undue hazard to other traffic.
- The vehicle remained upright during and after the collision.
- The longitudinal occupant impact velocity of 8.5 ft/s (2.6 m/s) was below the limit of 15 ft/s (4.6 m/s).
- The absolute value of the longitudinal occupant ridedown acceleration of 1.03 g was below the limit of 15 g.
- The after collision vehicle trajectory and final stopping position were acceptable.

Test 3 used a 4500 lb (2043 kg) vehicle impacting the guardrail at a velocity of 60 mi/h (97 k/h) and at a 25 degree angle. The call box was oriented to face 90 degrees from the direction of traffic. This test was performed to evaluate the test article by observing vehicle stability and trajectory, and any penetration into the occupant compartment by detached test article debris. Analysis of the third test revealed the following:

- The guardrail contained and smoothly redirected the test vehicle.
- The detached elements from the guardrail and call box installation did not penetrate nor show potential for penetrating the passenger compartment, nor presented undue hazard to other traffic.
- The vehicle remained upright during and after the collision.
- The after collision vehicle trajectory and final stopping position was acceptable.

Test 4 used a 1800 lb (817 kg) vehicle impacting the call box installation at a velocity of 60 mi/h (97 k/h). The call box was oriented to face 180 degrees from the direction of traffic. This test was performed to evaluate the test article by observing vehicle stability and trajectory, the risk to an occupant, and any penetration into the occupant compartment by detached test article debris. Analysis of the fourth test revealed the following:

- The installation readily activated by breaking away.
- The detached elements from the test article did not penetrate nor show potential for penetrating the passenger compartment, nor presented undue hazard to other traffic.

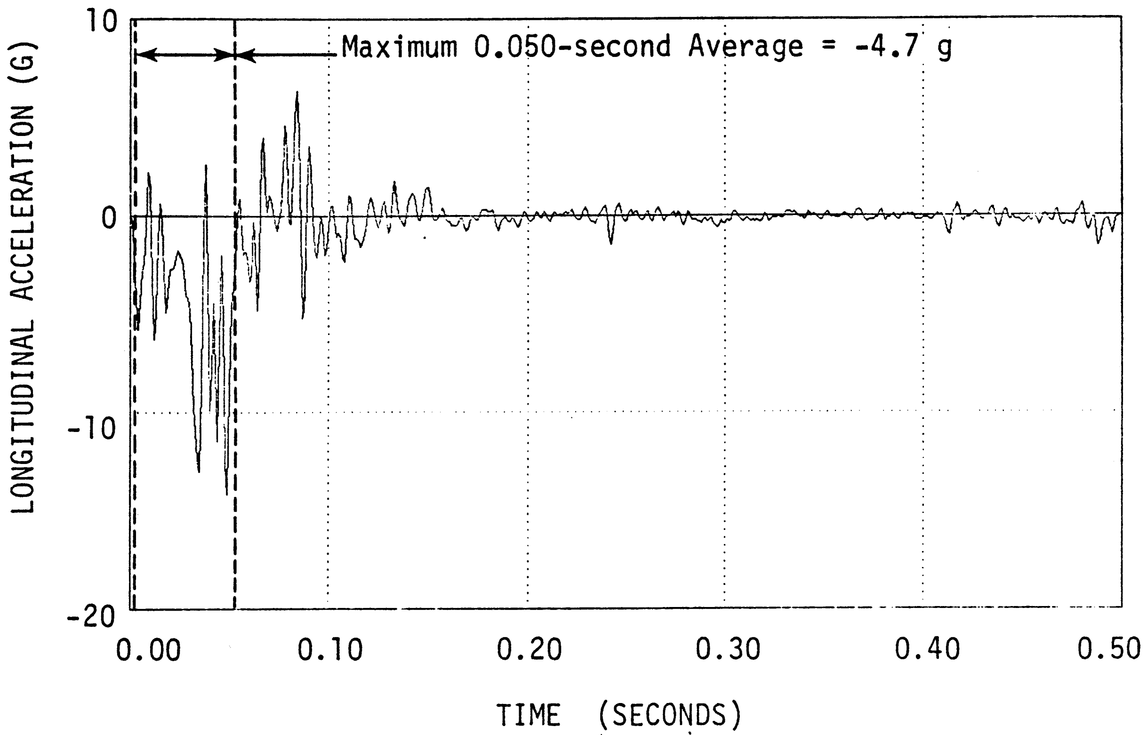
- The vehicle remained upright during and after the collision.
- The longitudinal occupant impact velocity of 7.9 ft/s (2.4 m/s) was below the limit of 15 ft/s (4.6 m/s).
- The absolute value of the longitudinal occupant ridedown acceleration of 0.86 g was below the limit of 15 g.
- The after collision vehicle trajectory and final stopping position was acceptable.

Based upon the above results, the call box installations as tested in tests 1, 3 and 4 met the evaluation criteria recommended in NCHRP Report 230[1], however, the call box installation as tested in test 2 did not meet that criteria.

REFERENCES

1. Michie, Jarvis D., "Recommended Procedures for the Safety Evaluation of Highway Appurtenances," National Cooperative Highway Research Program Report 230, Transportation Research Board, March 1981.

APPENDIX



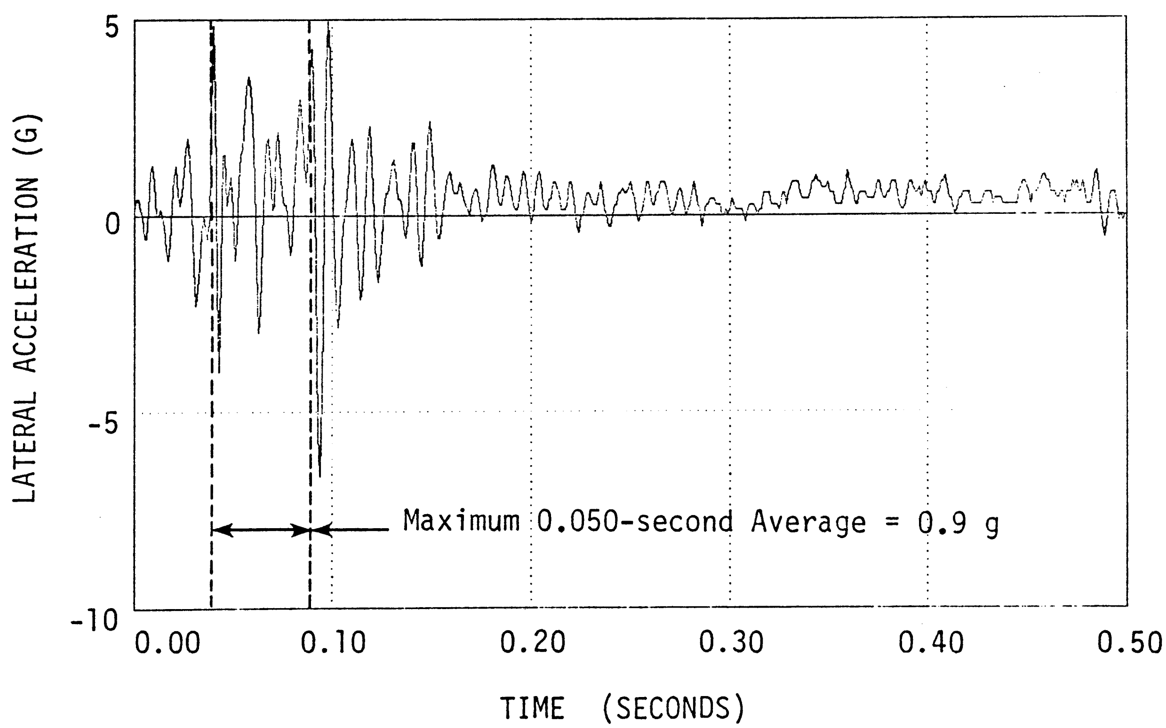
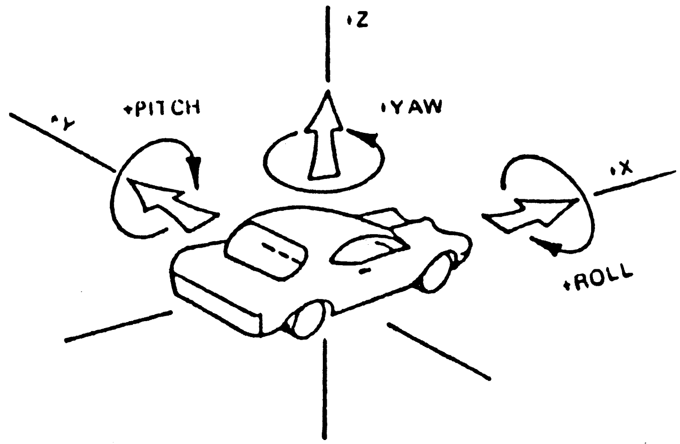


Figure 36. Vehicle accelerometer traces for test 0335-1.



Axes are vehicle fixed.
Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

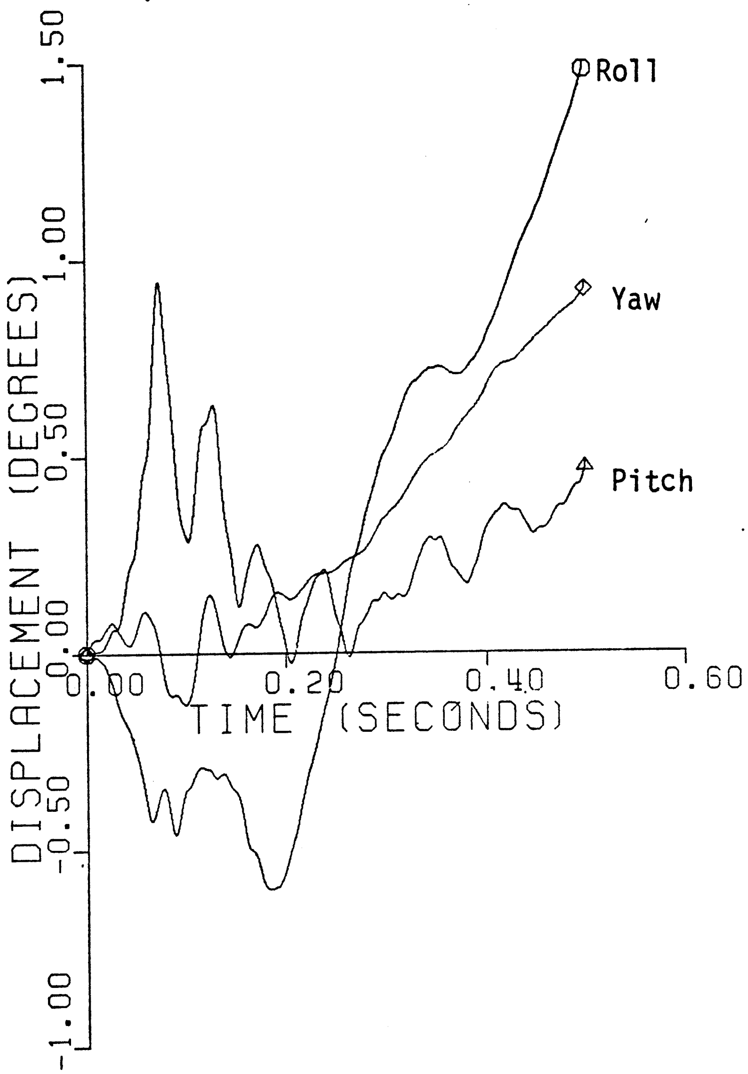


Figure 37. Vehicle angular displacements for test 0335-1.

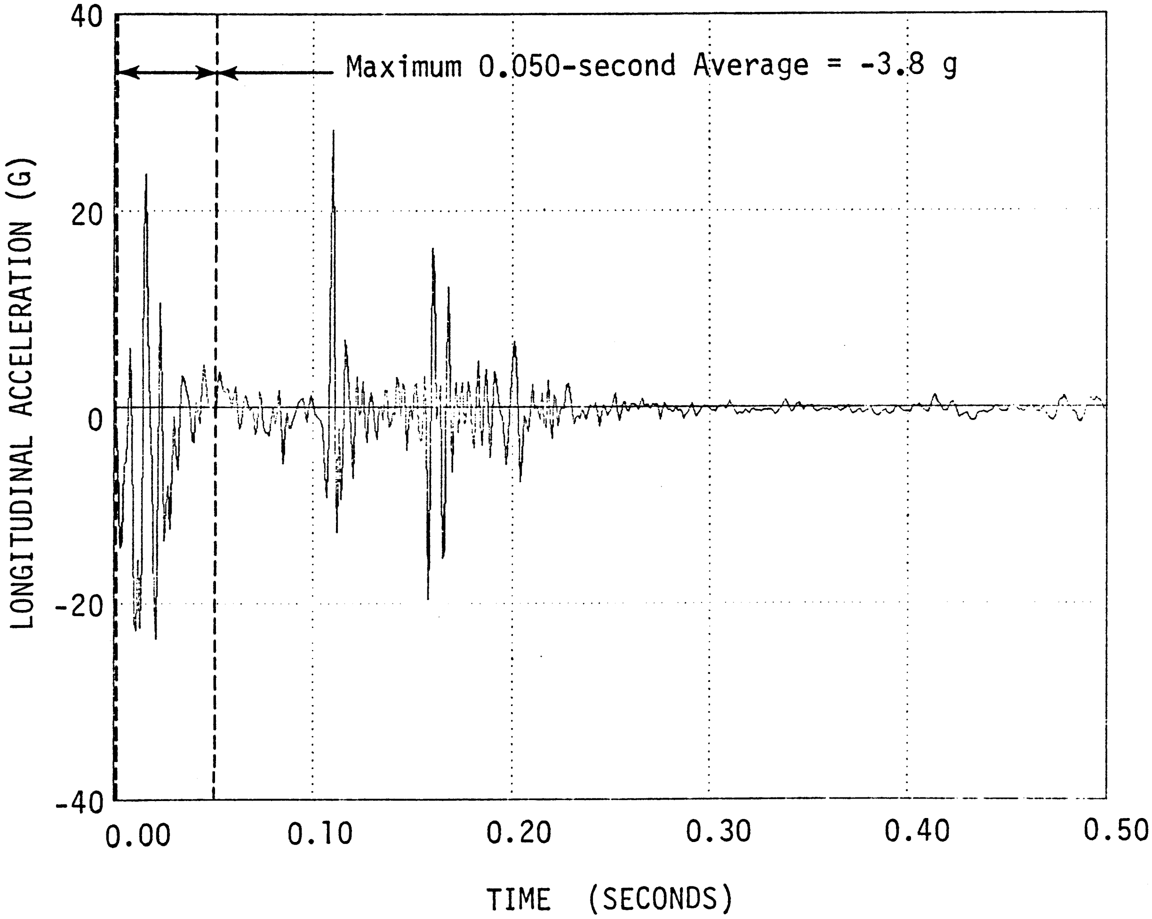


Figure 38. Vehicle longitudinal accelerometer trace for test 0335-2.

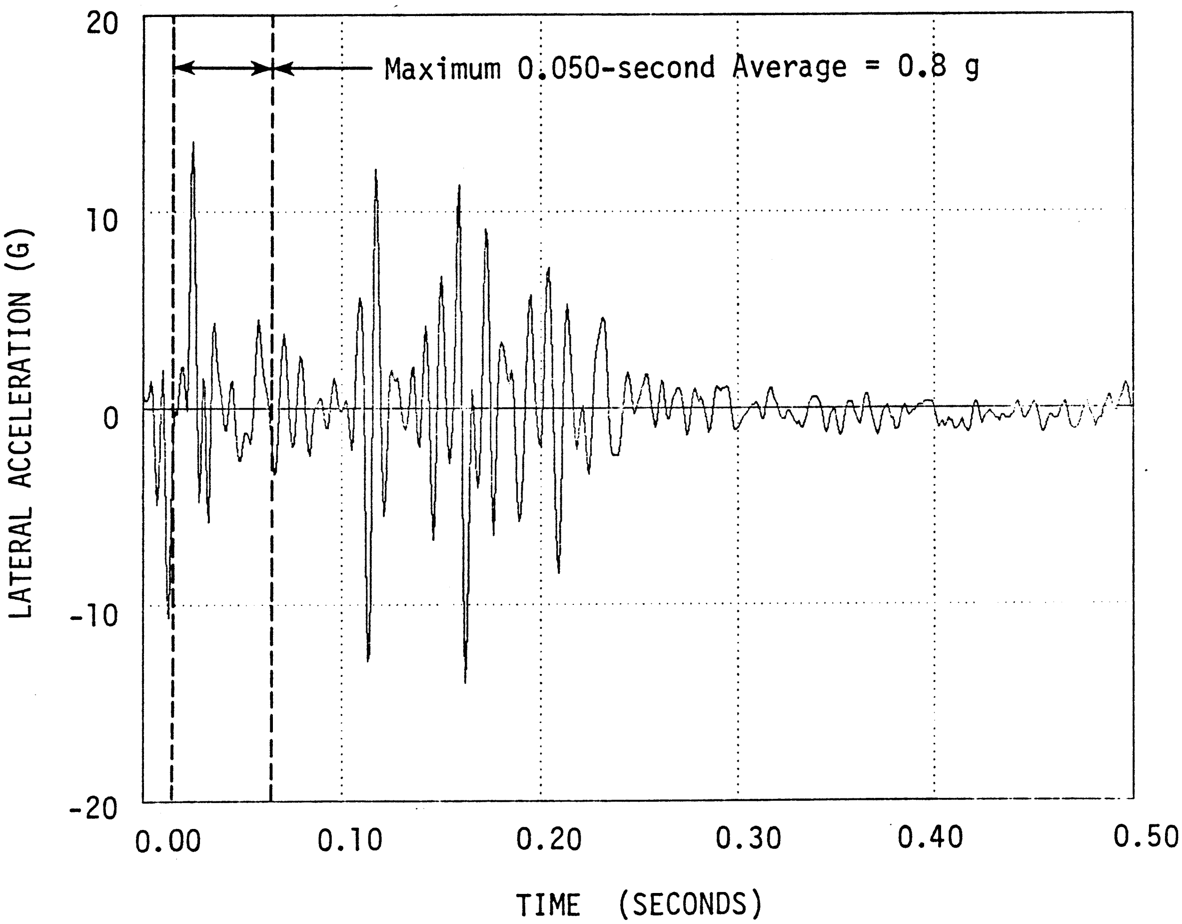


Figure 39. Vehicle lateral accelerometer trace for test 0335-2.

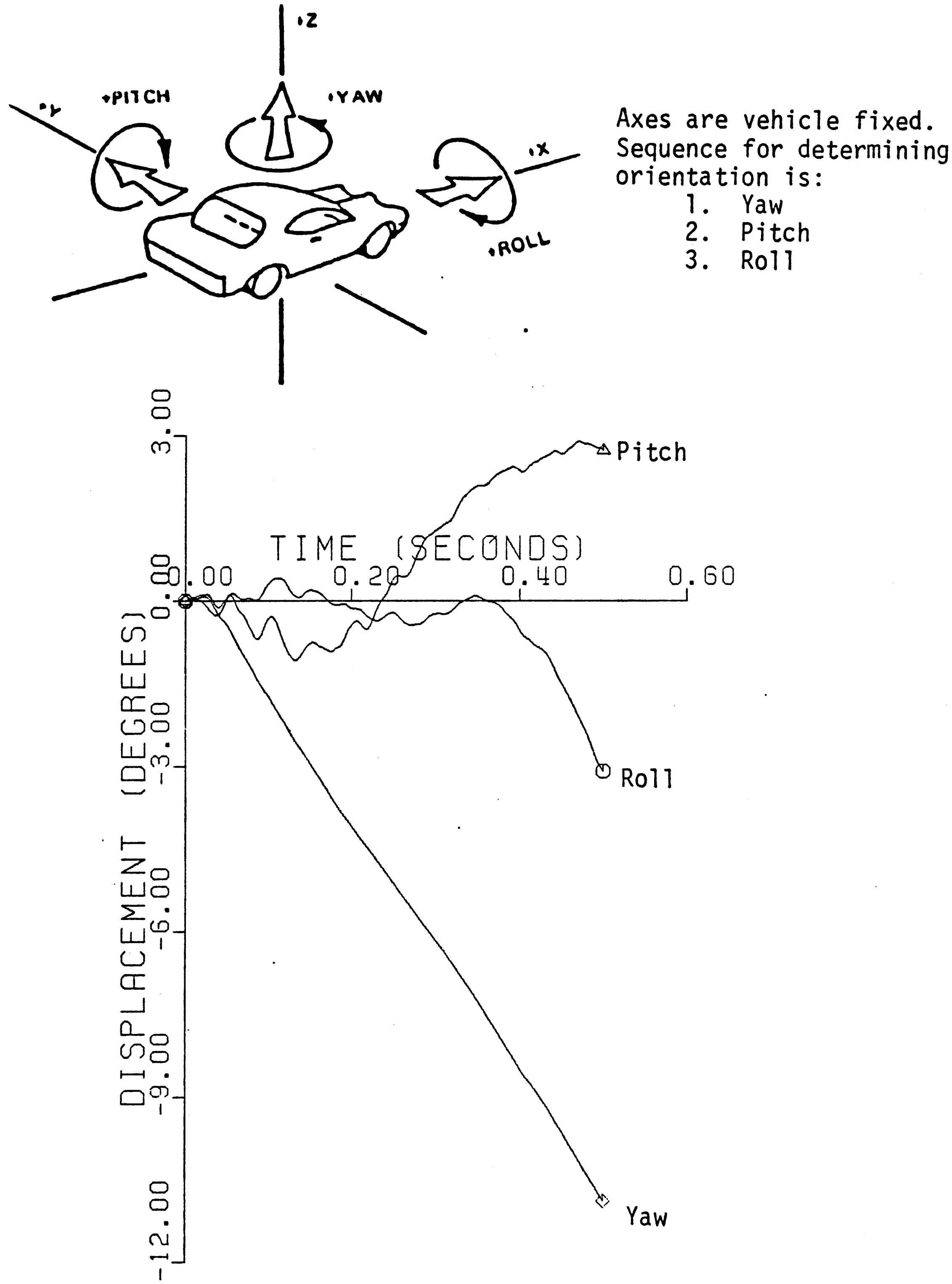


Figure 40. Vehicle angular displacement for test 0335-2.

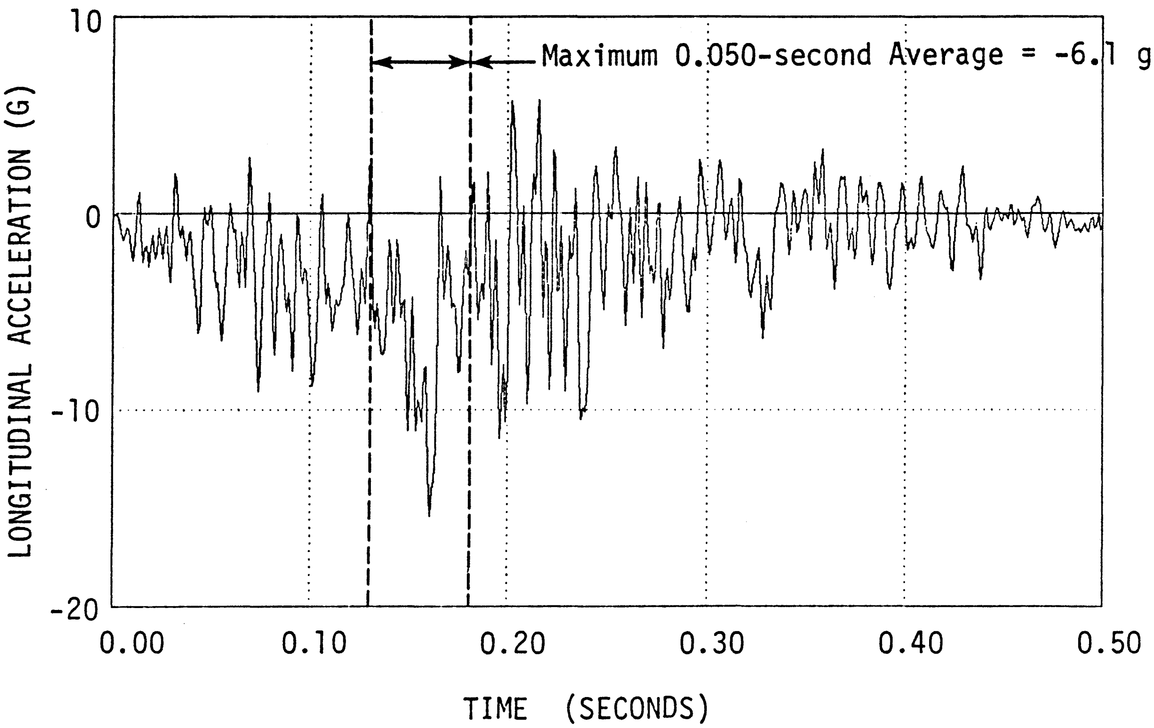


Figure 41. Vehicle longitudinal accelerometer trace for test 0335-3.

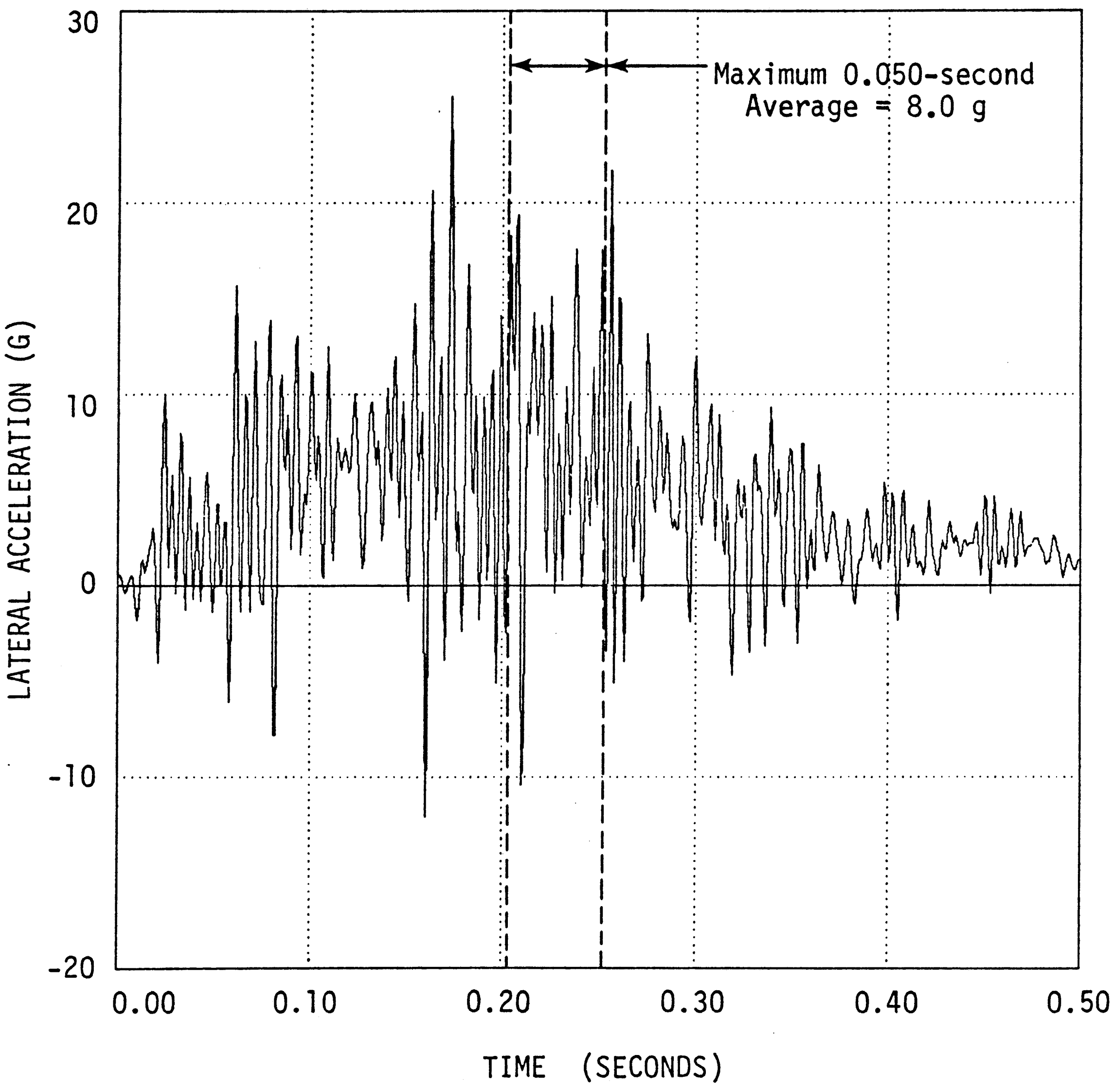


Figure 42. Vehicle lateral accelerometer trace for test 0335-3.

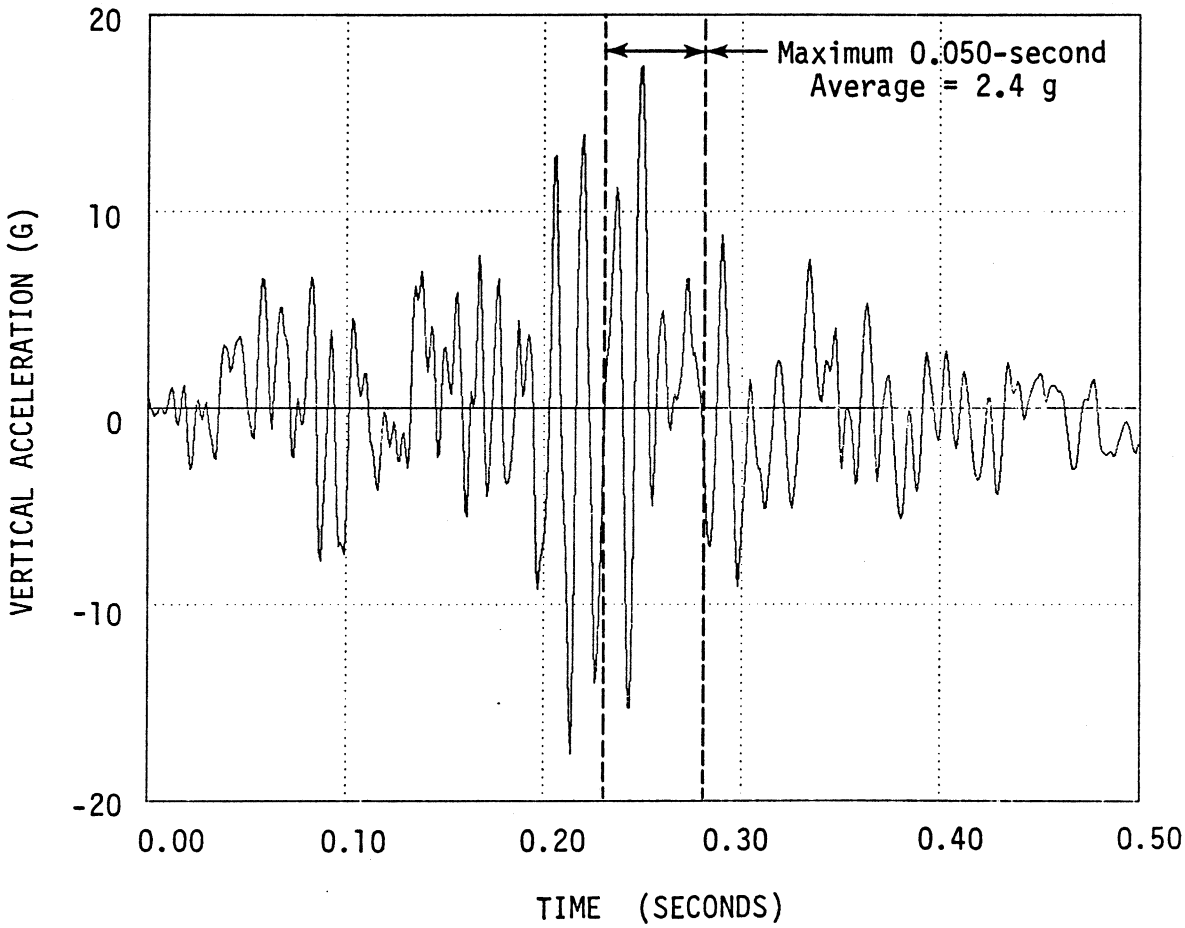
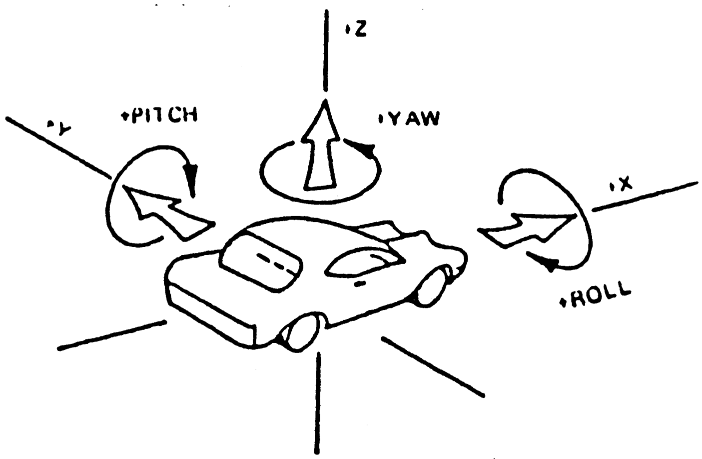


Figure 43. Vehicle vertical accelerometer trace for test 0335-3.



Axes are vehicle fixed.
Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

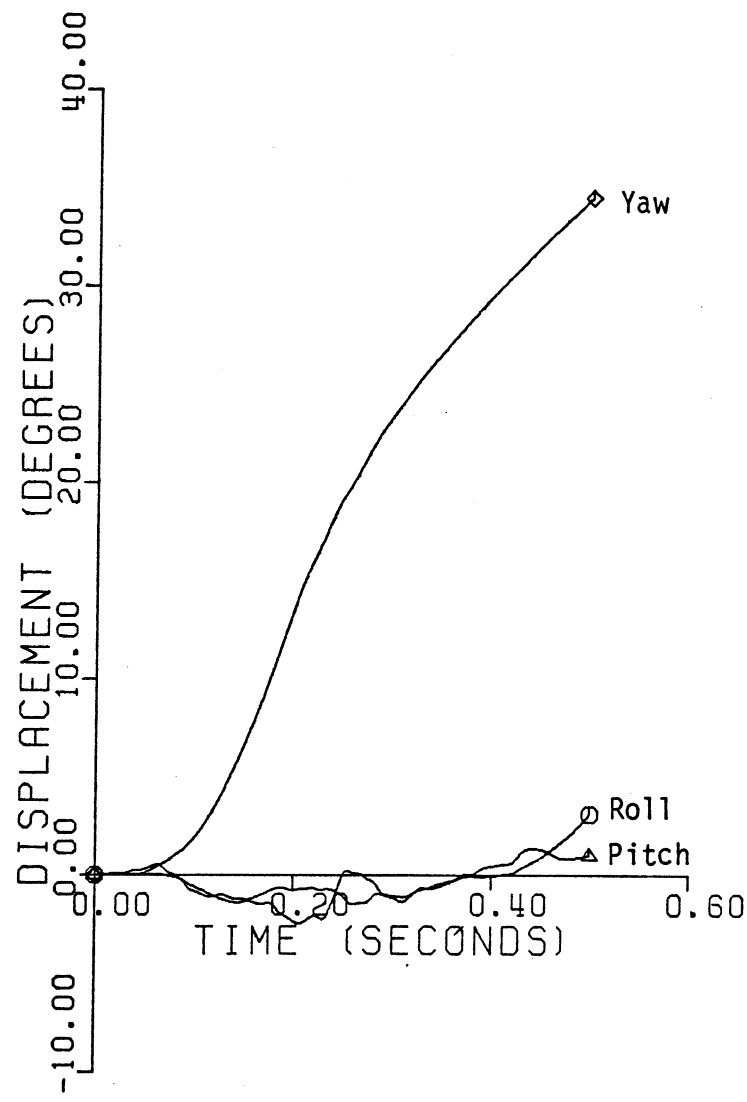


Figure 44. Vehicle angular displacements for test 0335-3.

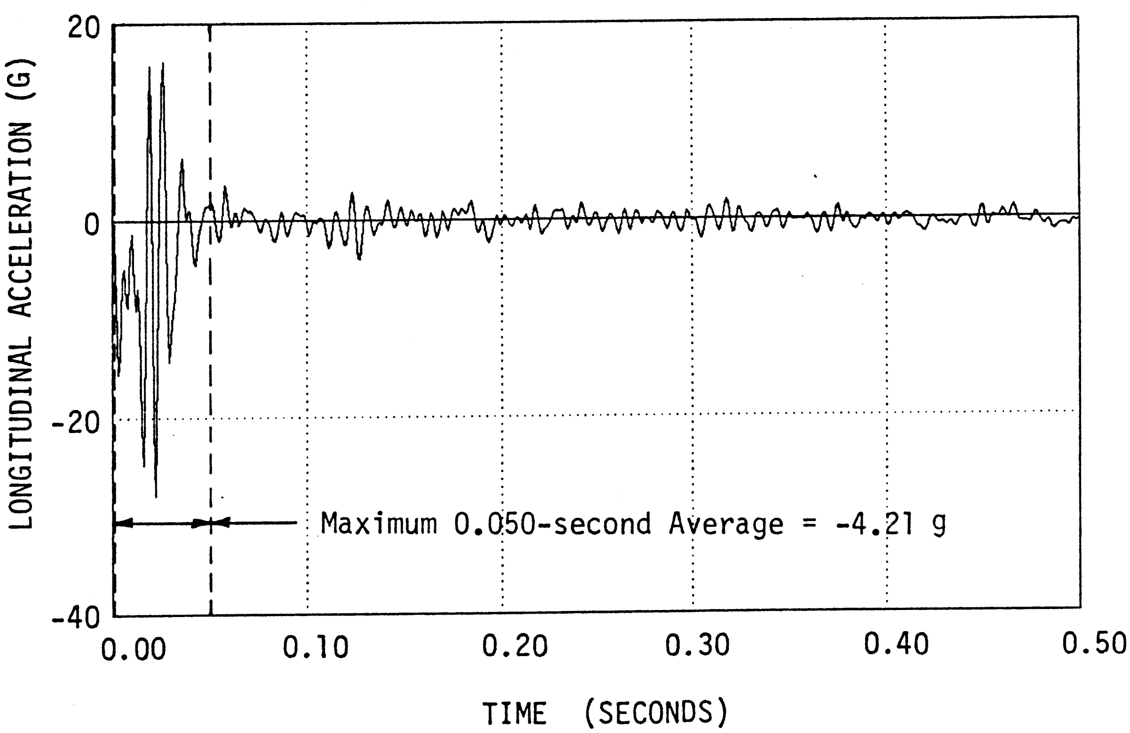


Figure 45. Vehicle longitudinal accelerometer trace for test 0335-4.

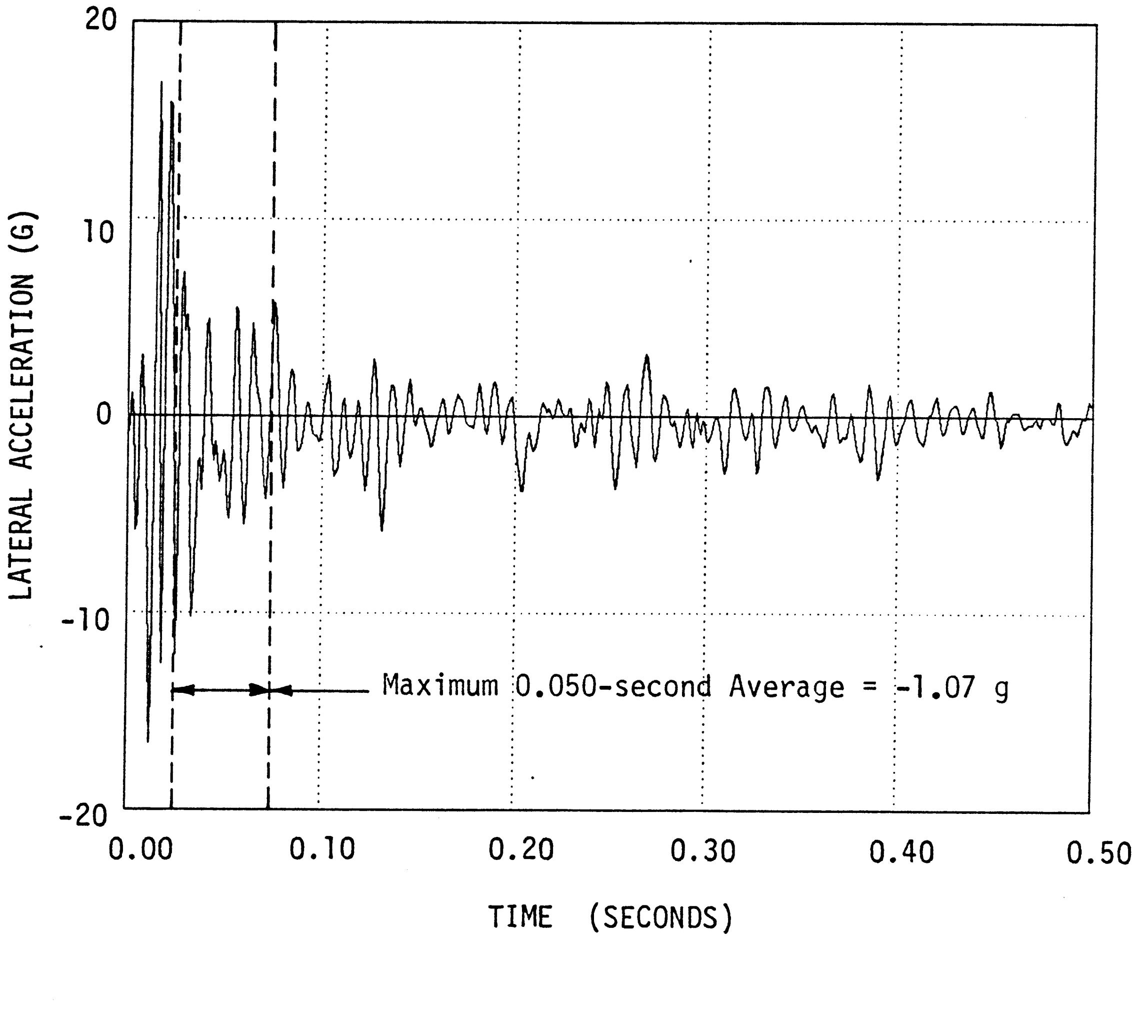


Figure 46. Vehicle lateral accelerometer trace for test 0335-4.