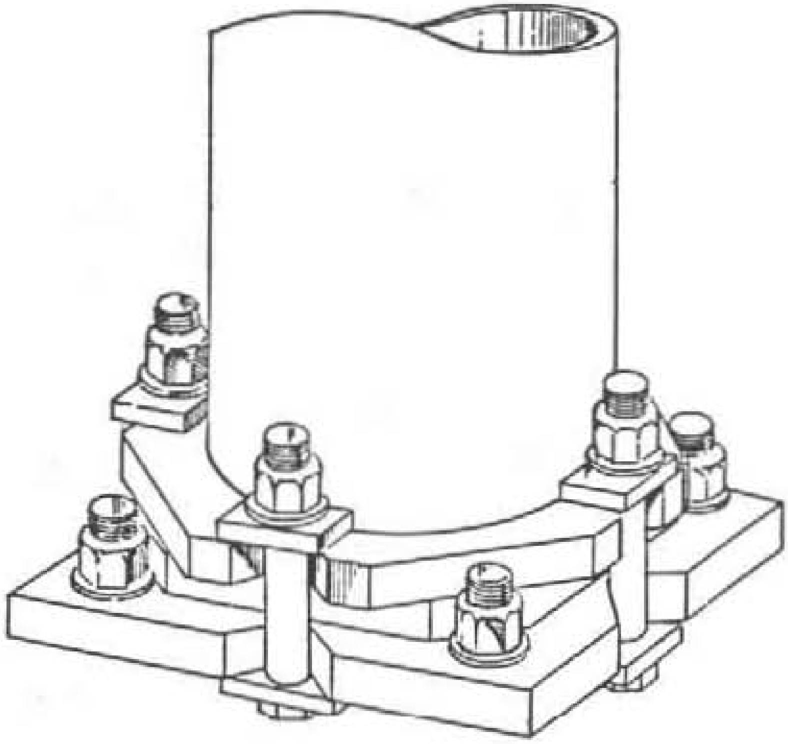
FULL-SCALE 1,800 LB. VEHICLE CRASH TESTS ON A 4-BOLT BREAKAWAY SLIPBASE DESIGN



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ABSTRACT

The breakaway luminaire support concept has existed for many years and has proven to be a very effective safety device. The 4-bolt breakaway slipbase design was originally developed in the State of Utah and has been very successful in 20 years of field implementation. The State Transportation Departments of Utah, Montana, Idaho, Wyoming, and Nevada requested that the 4-bolt breakaway system be evaluated for possible use on Federal-aid highway projects. Two full-scale 1,800 lb vehicle crash tests were conducted. Both tests had a centerline impact location; Test USBLM-1 was conducted at 15.0 mph and Test USBLM-2 was conducted at 57.5 mph.

The full-scale vehicle crash tests were evaluated according to the performance criteria in NCHRP Report 230 and the 1985 AASHTO Specifications for Structural Supports. "Design Standards for Highways: Standard Specifications for Highway Signs, Luminaires and Traffic Signals," Federal Register, 23 CFR 625, which is an update to the 1985 AASHTO Specifications, was also used in the evaluation.

The tests easily met all of the criteria set forth by the publications mentioned above. As a result of this, the safety performance of the 4-bolt breakaway slipbase design was determined to be satisfactory.

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1 INTRODUCTION

1.1 Problem Statement

At the request of the Utah Department of Transportation and the State Transportation Departments of Montana, Idaho, Wyoming and Nevada, the 4-bolt breakaway slipbase design was evaluated for possible use on Federal-aid highway projects.

1.2 Background

The breakaway concept, which has existed for many years, has recently been tested under a comprehensive program at the Federal Outdoor Impact Laboratory. The previous testing was conducted on the 3-bolt breakaway slipbase design. These designs and the test results are shown in Appendix A.

The 4-bolt breakaway design concept was originally developed in the State of Utah. In nearly 20 years of field implementation, this design has proven to be very successful; so successful, in fact, that in most cases the vehicle and its occupants were able to drive away from the scene of the accident, escaping serious injury.

1.3 Objective of Study

The objective of the research study was to evaluate the safety performance of the 4-bolt breakaway slipbase luminaire support by conducting two full-scale vehicle crash tests in accordance with the "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances," NCHRP 230 (1), the "Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals," AASHTO 1985 (2), and the Federal Register, 23 CFR 625 (3).

2 TEST CONDITIONS

2.1 Test Facility

2.1.1 Test Site

The test site facility was located at Lincoln Air Park on the NW end of the west apron of the Lincoln Municipal Airport. The test facility, shown in Figure 1, is approximately 5 mi. NW of the University of Nebraska-Lincoln.

An 8 ft. high chain-link security fence surrounds the test site facility to ensure that no vandalism occurs to the test articles or test vehicles which could possibly disrupt the results of the tests.

2.1.2 Vehicle Tow System

A reverse cable tow, with a 1:2 mechanical advantage, was used to propel the test vehicle. The distance traveled and the speed of the tow vehicle are one-half that of the test vehicle. A sketch of the cable tow system is shown in Figure 2. The test vehicle was released from the tow cable 10 feet before impact with the 4-bolt Breakaway Slipbase Luminaire Support. Photographs of the tow vehicle and the attached fifth-wheel are shown in Figure 3. The fifth-wheel, built by the Nucleus Corporation, was used for accurately towing the test vehicle at the required target speed with the aid of a digital speedometer in the tow vehicle.

2.1.3 Vehicle Guidance System

A vehicle guidance system developed by Hinch (4) was used to steer the test vehicle. The guidance system is shown in Figure 2. The guide flag, which was attached to the front left wheel and the guide cable, was sheared off 10 ft before impact with the 4 bolt breakaway slipbase luminaire support. The 3/8 in. diameter guide cable was tensioned to 3,000 lb and supported laterally and vertically every 100 ft by hinged stanchions. As the test

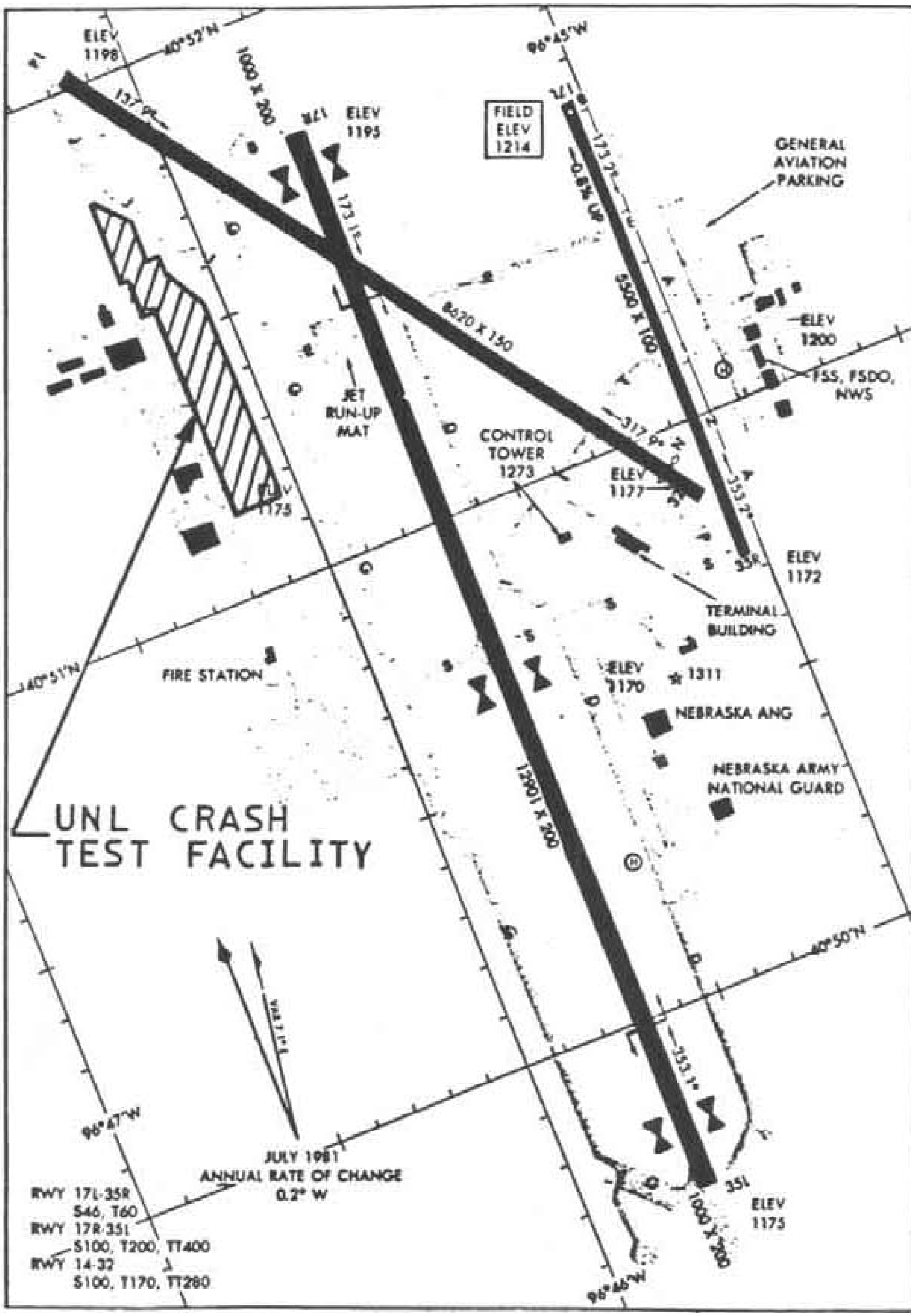


FIGURE 1. Full-scale Vehicle Crash Test Facility.

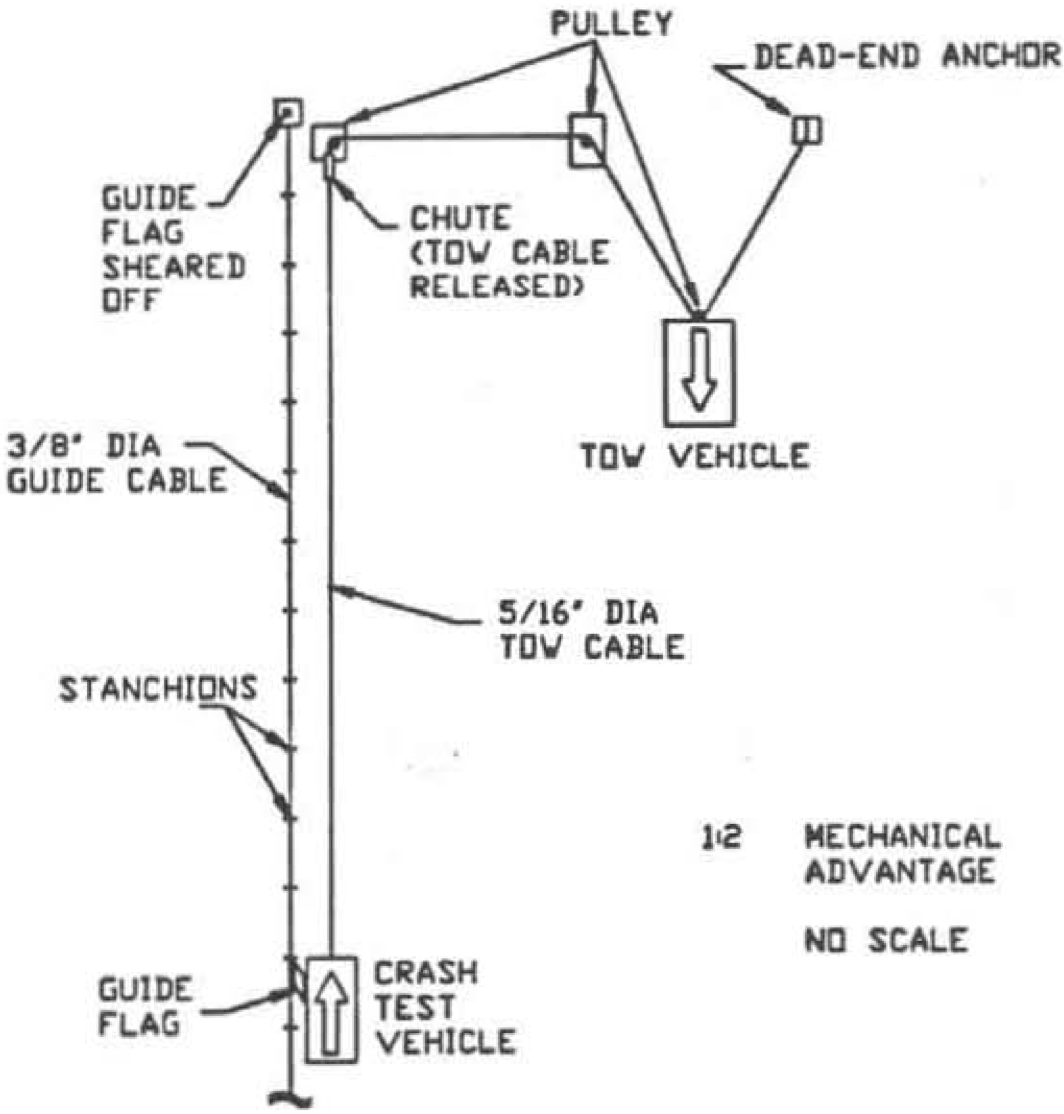


FIGURE 2. Cable Tow and Guidance System.

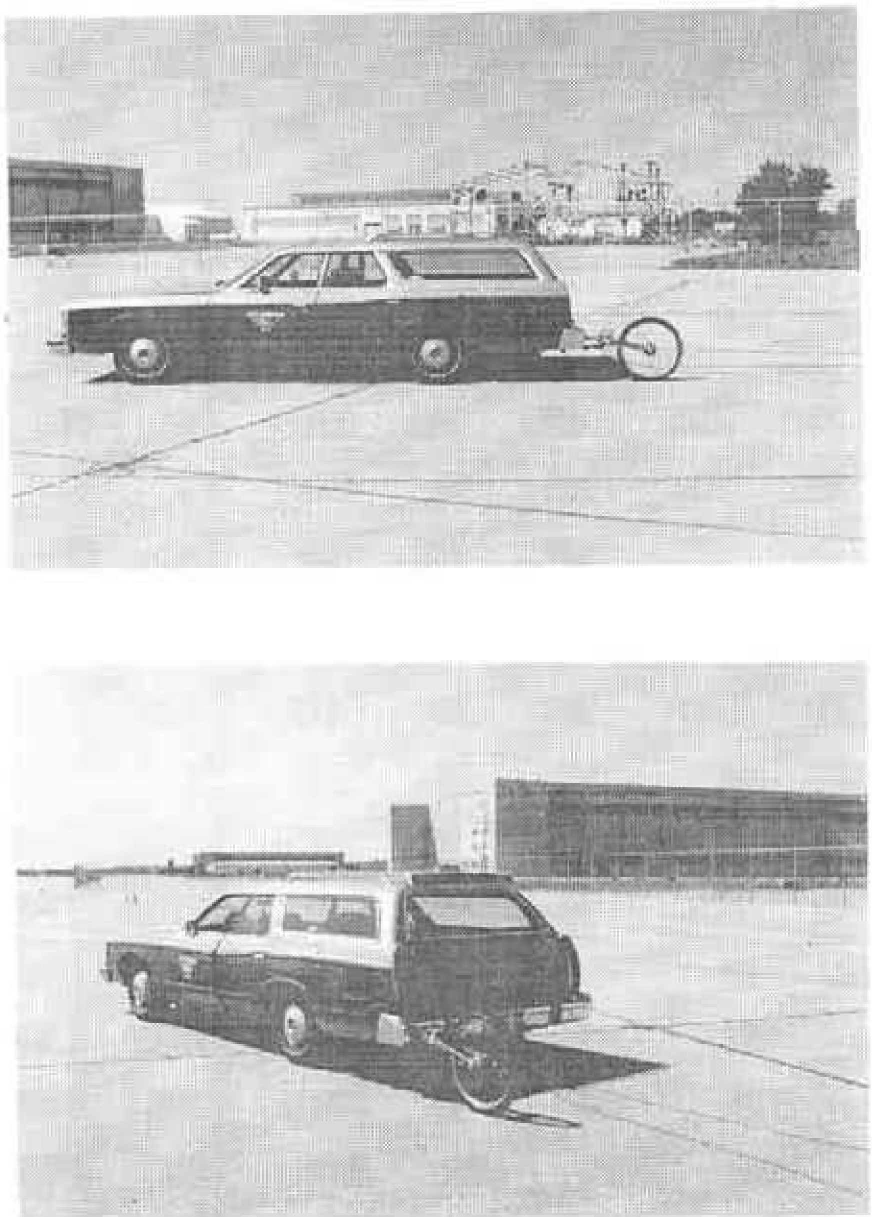


FIGURE 3. Tow Vehicle and Fifth Wheel.

vehicle passed each stanchion, the attached guide flag struck the stanchion, knocking it to the ground. The test vehicle guidance cable was approximately 800 ft long.

2.2 4-Bolt Breakaway Slipbase Design Details

The 4-bolt breakaway slipbase luminaire support design details are shown in Figure 4, and photographs of the slipbase are shown in Figure 5. The luminaire support consisted of three major structural components: the luminaire support pole, the two mast arms, and the permanent lower slipbase assembly (photographs are shown in Figure 6).

The luminaire support had a maximum mounting height of 52-ft 0-in. from the ground to the top of the mast arms. The height to the top of the luminaire pole (excluding rain cap) was 50-ft 4-in. from the ground. The permanent lower slipbase assembly had a stub height of 4 in.

The permanent lower slipbase assembly was held in place with four 1-in. diameter by 12 in. ASTM A325 threaded rods doweled into the existing concrete apron with a high-modulus, high-strength epoxy bonding/grouting adhesive. The embedment depth of the threaded rods was 8.25 in. The threaded rods extended 3.75 in. above the existing concrete surface. The bottom and top surfaces of the permanent lower slipbase assembly were mounted at a height of 1.5 in. and 4 in., respectively, above the existing concrete apron. The permanent lower slipbase assembly manufacturing requirements are with a steel with a minimum of 36 ksi yield strength. The steel assembly was hot-dipped galvanized in accordance with ASTM A123. A concrete grout mix was placed below the lower edge of the permanent lower slipbase assembly.

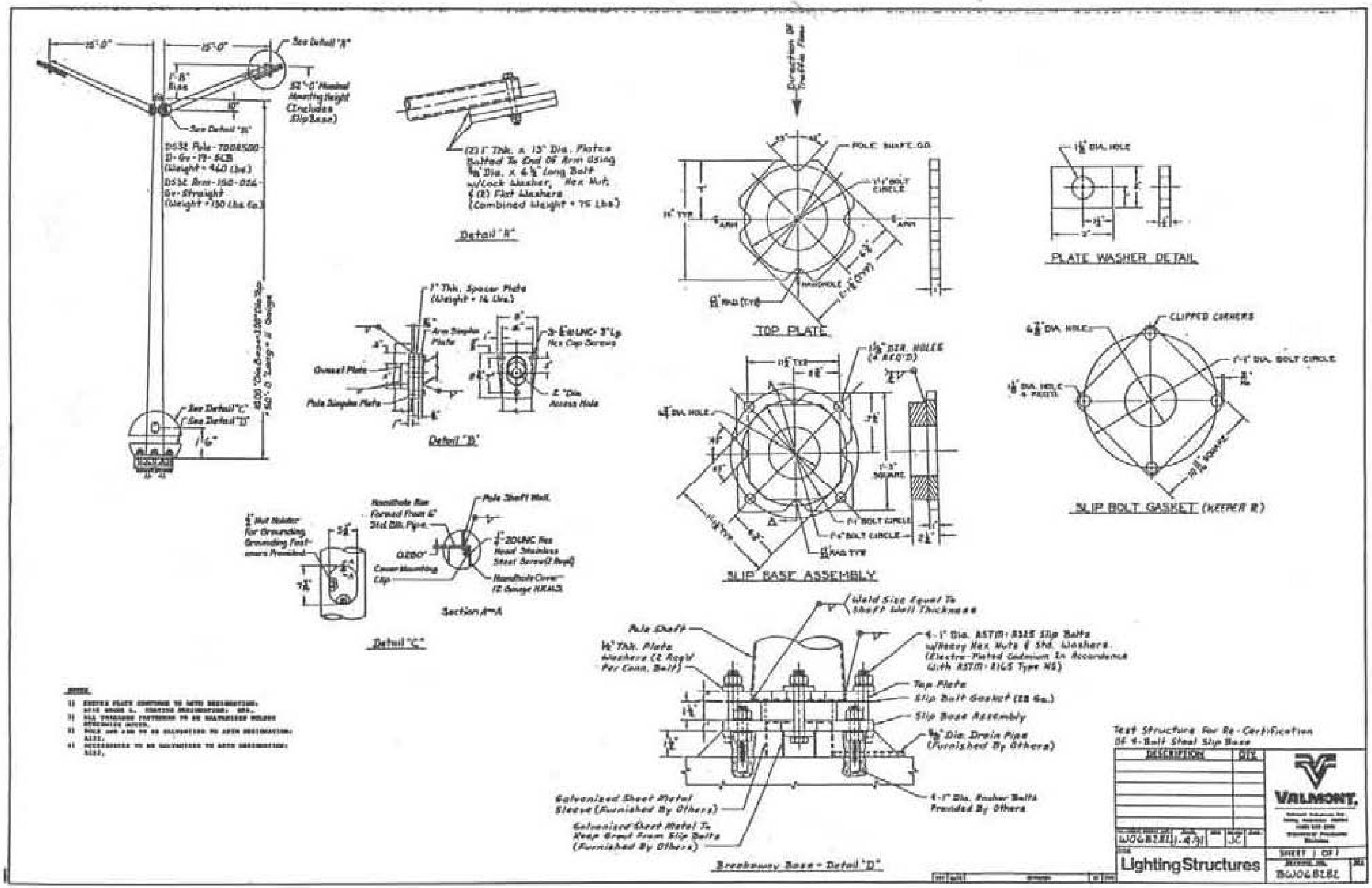


FIGURE 4. Design Details of the 4-Bolt Breakaway Slipbase Luminaire Support.

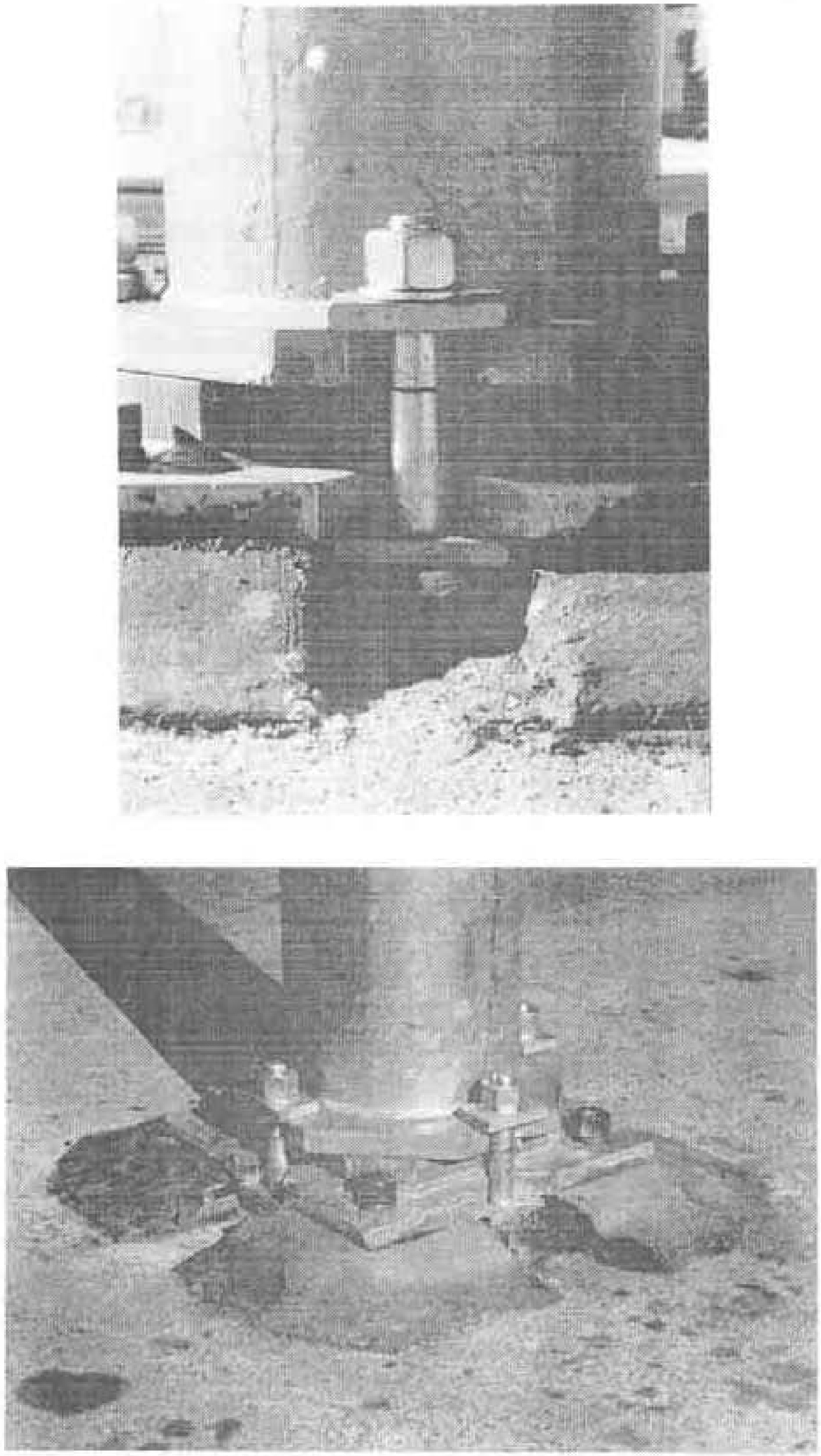


FIGURE 5. 4-Bolt Breakaway Slipbase.

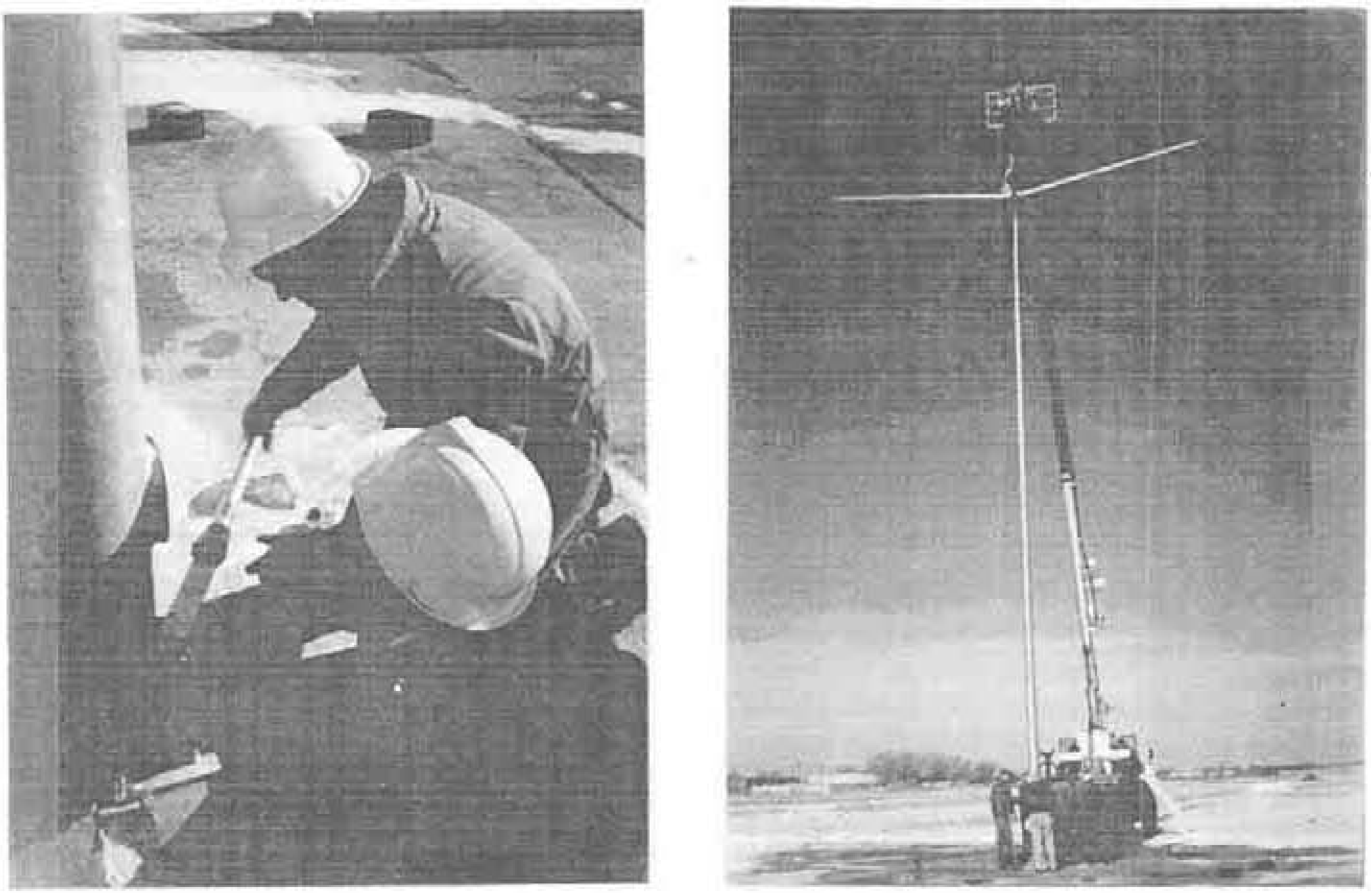


FIGURE 6. Luminaire Support Installation.

The 50-ft 0-in. luminaire pole was mounted on the permanent lower slipbase assembly with four 1-in. diameter ASTM A325 slip bolts. The high-strength slip bolts, nuts, and washers were electroplated cadmium in accordance with ASTM A165. The four slip bolts were torqued to 80 foot-pounds, and then released and retorqued to 70 foot-pounds. The Utah Department of Transportation conducted torque versus tension tests on four 1-in. diameter A325 high-strength bolts. It was determined that a torque of 70 foot-pounds would develop approximately 4,300 lbs of tension per bolt. The results of the test are presented in Appendix B.

The four 1-in. diameter slip bolts were held in place within the slots with a slip bolt gasket. The slip bolt gasket conformed to ASTM A446 Grade A steel with a 0.0149 in. thickness (gauge 28) before coating.

The luminaire support pole had a diameter of 10 in. at the base, tapering off to 3 in. at the top, with an 11 gauge wall thickness. The luminaire support pole was manufactured to ASTM A595, Grade A and hot-dipped galvanized in accordance with ASTM A123.

The two steel mast arms were attached to the luminaire at a location 10 in. below the top of the luminaire support pole. The mast arms extended outward from the face of the luminaire pole a total of 15 ft, and upward above the top of the luminaire pole a total of 1-ft 8-in. The angle of inclination of the mast arms was approximately 9.5 deg. The two mast arms extended outward perpendicular to the direction of the impact. On the end of each mast arm, weights were mounted to simulate an actual luminaire. These weights totaled 75 lb per mast arm.

A reinforced hand hole opening was located approximately 1-ft 10-in. above the existing concrete apron. The luminaire support was installed so that the hand hole opening was located on the side of the luminaire pole opposite that impacted by the test vehicle.

The slipbase was oriented with one of the slip bolts directly in line with the test vehicle impact location. This orientation was determined to give the maximum resistance to the breakaway action.

2.3 Test Vehicle

One test vehicle was used to evaluate the 4-bolt breakaway slipbase design. After test USBLM-1, the vehicle was repaired and used for test USBLM-2. The test vehicle was a 1984 Dodge Colt weighing 1,750 lbs. Photographs of the test vehicle are shown in Figure 7. Dimensions of the test vehicle are shown in Figure 8.

The front wheels of the test vehicle were aligned for camber, caster, and toe-in values of zero so that the vehicle would track properly along the guide cable.

Three 8-in. square, black and white checkered targets were placed on the driver's side of the vehicle to aid in the analysis of the high-speed film. The center target was placed over the center of gravity of the vehicle, while the front target was placed 3 ft ahead and the rear target 5 ft. behind the center target. Targets were also placed on the top and back of the vehicle to aid in the evaluation process.

Two No. 5 flash bulbs were mounted on the roof of the test vehicle to pinpoint the time of impact with the luminaire support on the highspeed film. The flash bulbs were fired by a pressure tape switch mounted on the front face of the bumper.

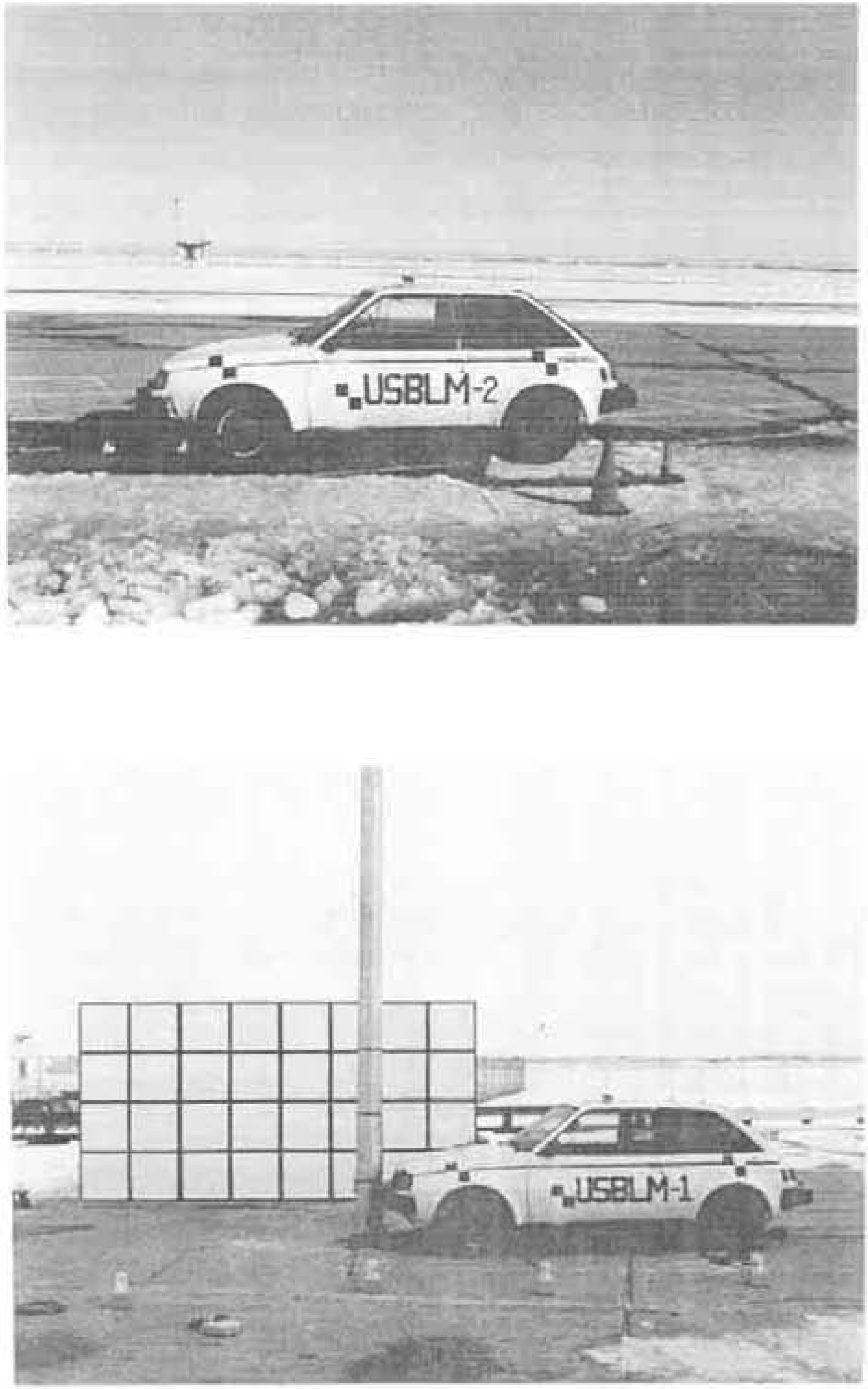
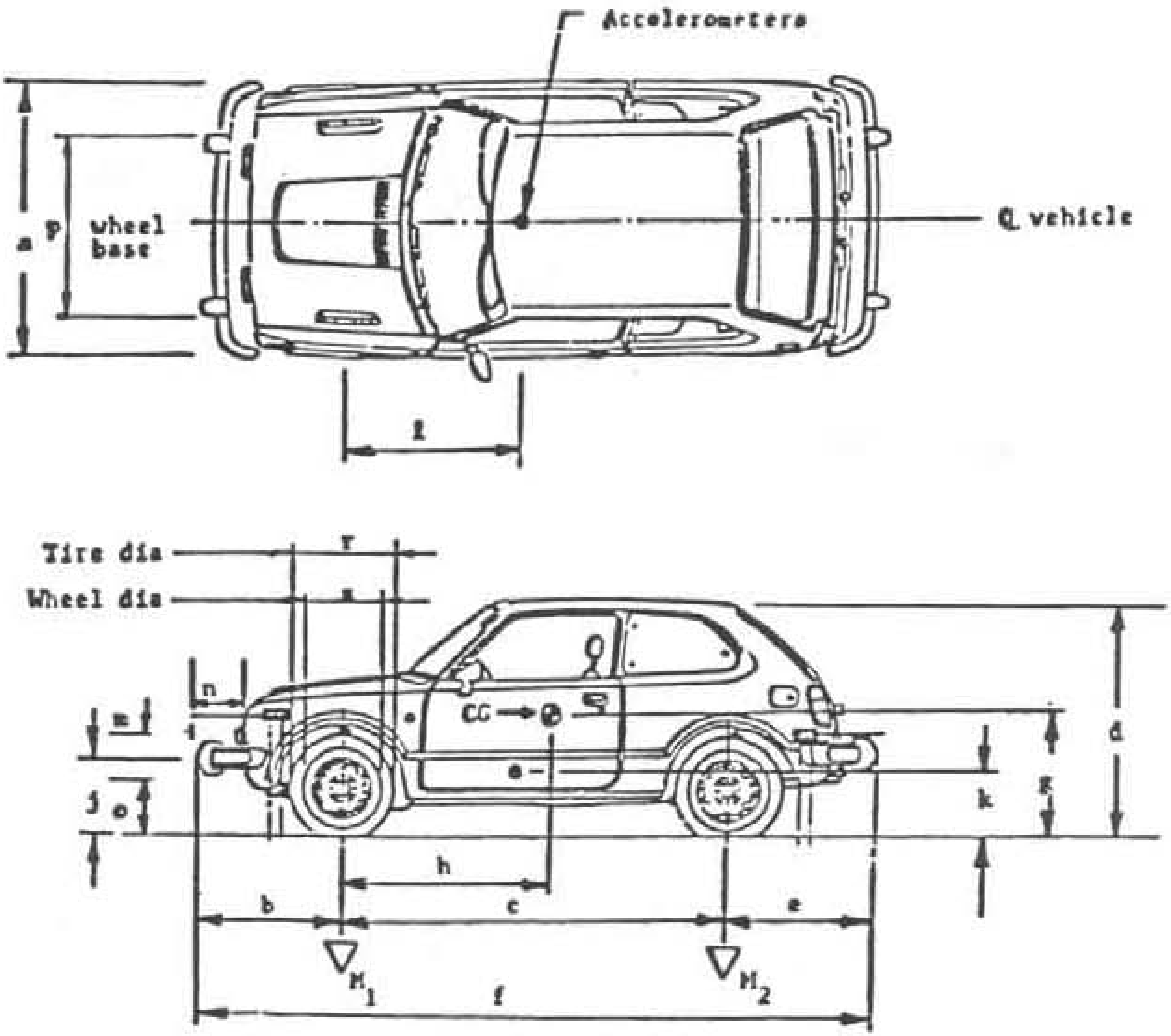


FIGURE 7. Test Vehicle.



Geometry - in. (in.)

a	60	d	52	j	20	m	5	p	53.5
b	30	e	30	k	20.5	n	3	r	23
c	92	f	152	ℓ	31	o	17.5	s	14.25

Mass - lb (kg)	Curb	Test Inertial	Gross Static
M_1	1280	1230	1230
M_2	710	520	520
M_T	1990	1750	1750
h - in. (m)	31		
g - in. (m)	20.5		

FIGURE 8. Test Vehicle Dimensions.

2.4 Data Acquisition Systems

2.4.1 Accelerometers

Two Endevco triaxial piezoresistive accelerometers (Model 7264) with a range of ± 200 g's were used to measure the accelerations in the longitudinal direction of the test vehicle. Two accelerometers were mounted in the same direction in order to provide a comparison of results and to use as a back-up system. The accelerometers were rigidly attached to a metal block mounted at the center-of-mass. The signals from the accelerometers were received and conditioned by an on-board vehicle Metraplex Unit. The multiplexed signal was then radio transmitted to the Honeywell 101 Analog Tape Recorder in the central control van. A flow chart of the accelerometer data acquisition system is shown in Figure 9, and photographs of the system located in the centrally controlled step van are shown in Figure 10. State-of-the-art computer software, "Computerscope and DSP", was used to analyze and plot the accelerometer data on a Cyclone 386/AT, which uses a high-speed data acquisition board.

2.4.2 High-Speed Photography

Two high-speed 16 mm cameras were used to film the crash tests. The cameras operated at approximately 500 frames/sec. The parallel camera, a Photec IV with an 80 mm lens, was placed 300 ft downstream of the luminaire support for test USBLM-1 and 324 ft downstream for test USBLM-2. The perpendicular camera was a Photec IV with a 55 mm lens. It was placed 136.5 ft from the vehicle point of impact for both tests. A schematic of the camera locations is shown in Figure 11.

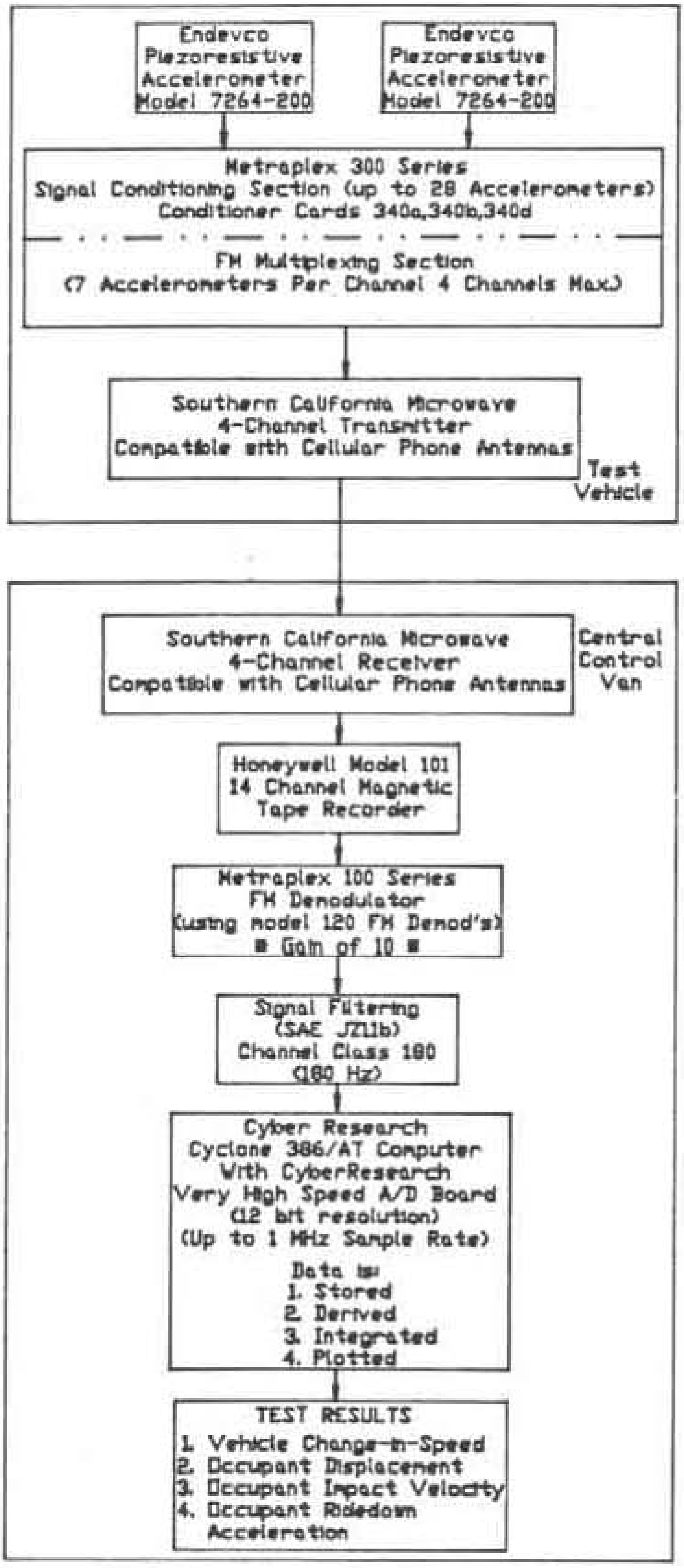


FIGURE 9. Flow Chart of Accelerometer Data Acquisition System.

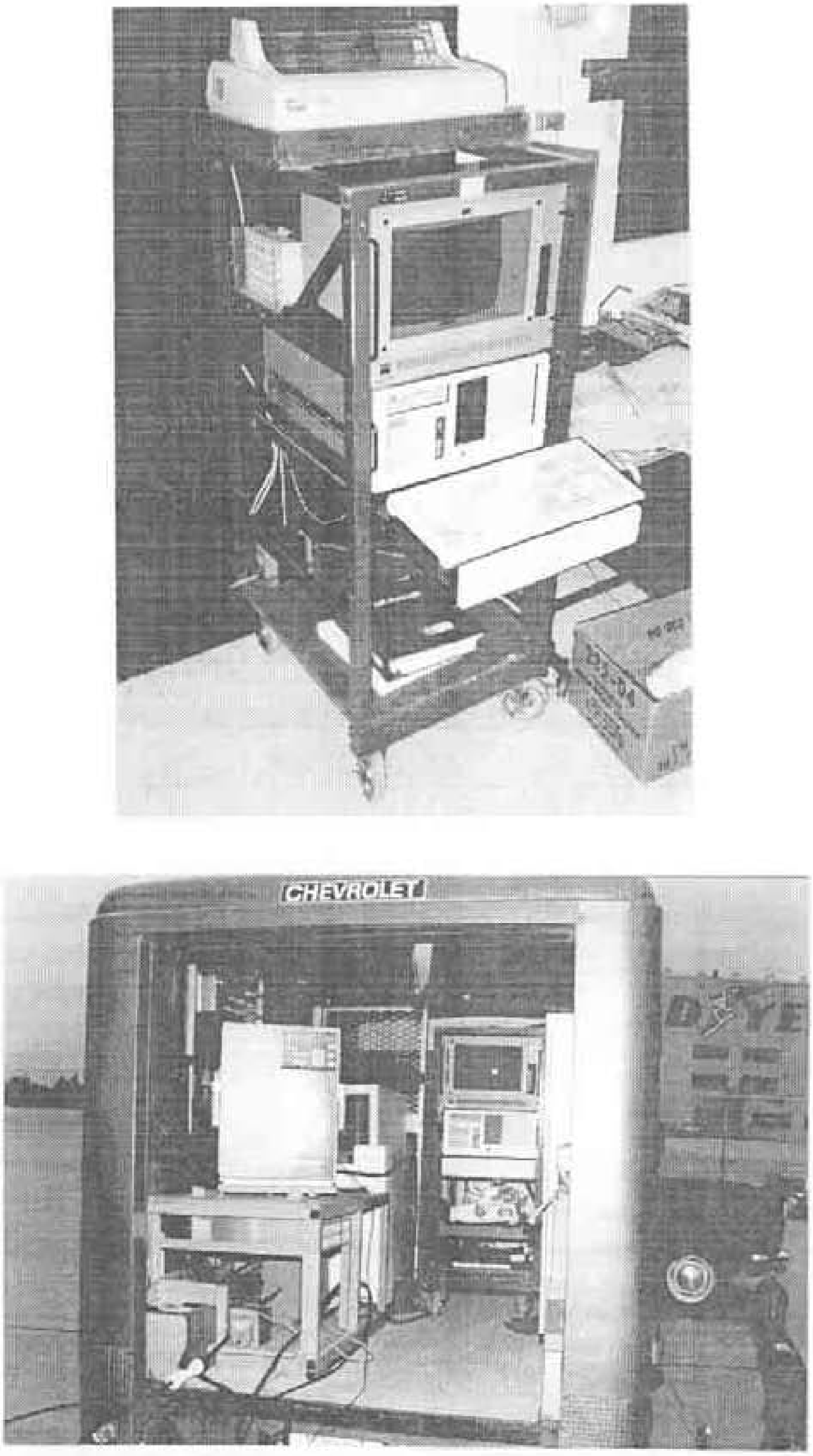


FIGURE 10. Data Recorder and 386/AT Computer.

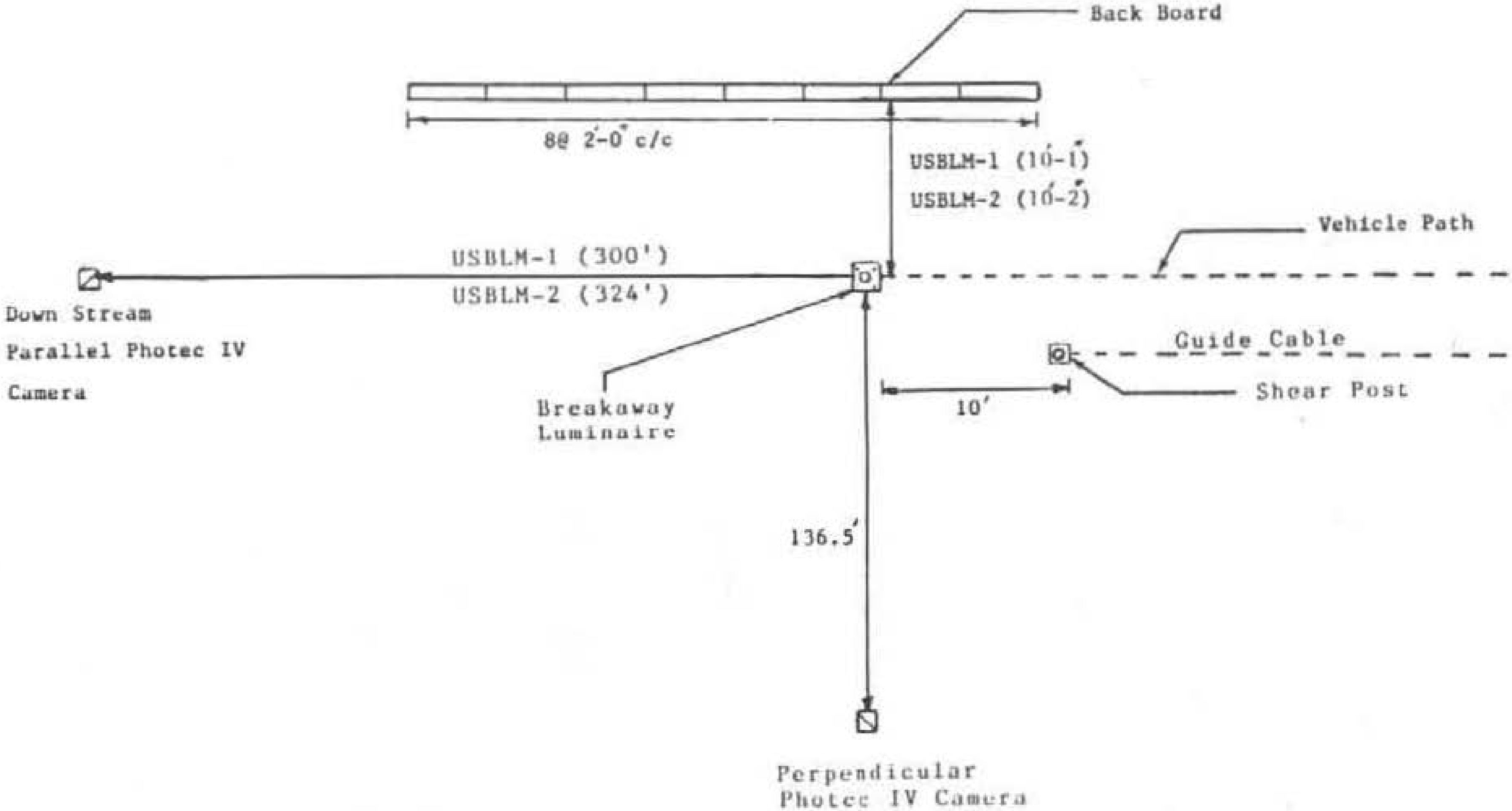


FIGURE 11. Schematic of Camera Locations.

An 8-ft high by 16-ft long backboard, with a 2-ft line grid layout was used as a reference for the analysis of the high speed film. The backboard was placed facing the perpendicular camera 10 ft behind the luminaire support.

The film was analyzed using the Vanguard Motion Analyzer. The camera divergence correction factors were also taken into consideration in the analysis of the high-speed film.

2.4.3 Speed Trap Switches

Eight tape pressure switches spaced at 5 ft intervals were used to determine the speed of the vehicle before and after impact. Each tape switch fired a strobe light as the left front tire of the test vehicle passed over it. The average speed of the test vehicle between the tape switches was determined by knowing the distance between pressure switches, the calibrated camera speed, and the number of frames from the high-speed film between flashes. In addition, the average speed was determined from electronic timing mark data recorded on the oscilloscope software used with the 386/AT computer as the test vehicle passed over each tape switch.

3 PERFORMANCE EVALUATION CRITERIA

The safety performance objective of a highway appurtenance is to minimize the consequences of an off-road accident. This safety goal is met when the appurtenance (4-Bolt Breakaway Slipbase Luminaire Support) allows vehicle occupants to escape major injury-producing forces. Safety performance of the highway appurtenance cannot be measured directly but can be evaluated according to four major factors: (1) breakaway mechanism worthiness, (2) vehicle stability and trajectory, (3) occupant risk, and (4) test object penetration. These factors are defined and explained in NCHRP 230 (1). Similar criteria are presented in AASHTO (2).

The 4-bolt breakaway slipbase design was evaluated according to the performance criteria in "Recommended Procedures for the Safety Performance of Highway Appurtenances," NCHRP Report 230 (1), the "Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals 1985," AASHTO (2), and the Code of Federal Regulation, 23 CFR 625 (3).

The standards used to evaluate the crash tests were Test Designation Numbers 62 and 63 of NCHRP 230 (1), and AASHTO (2). These criteria require 20 mph and 60 mph tests in which the vehicle contacts the luminaire support at the centerpoint of the bumper.

The safety evaluation guidelines are shown in Table 1 (1,2,3). These guidelines require an occupant impact velocity of less than or equal to 15 fps and an occupant ridedown acceleration of less than or equal to 15 g's. The Federal Register (3) requires a vehicle change in velocity of less than or equal to 16.0 fps. After each test, vehicle damage was assessed by the traffic accident data scale (TAD) (5) and the vehicle damage index (VDI) (6).

TABLE 1. Crash Test Conditions for the 4-Bolt Breakaway Slipbase Design.

Test Number	Test Agency	Test Designation	Appurtenance	Test Vehicle	Impact Conditions	
					Speed (mph)	Impact Point
USBLM-1	NCHRP 230	62	Breakaway Support	1800S	20	Center of Bumper
USBLM-2	NCHRP 230	63	Breakaway Support	1800S	60	Center of Bumper*

* Refer to AASHTO (2).

TABLE 2. Safety Evaluation Guidelines.

Evaluation Factors	Evaluation Criteria	NCHRP 230	AASHTO	FHWA
Structural Adequacy	1. The test article shall readily activate in a predictable manner by breaking away or yielding.	A	A	NA
	2. Detached elements, fragments or other debris from the test article shall not penetrate or show potential for penetrating the passenger compartment or present undue hazard to other traffic.	A	A	NA
Occupant Risk	3. The vehicle shall remain upright during and after collision although moderate roll, pitching and yawing are acceptable. Integrity of the passenger compartment must be maintained with essentially no deformation or intrusion.	A	A	NA
	4. Longitudinal Occupant Impact Velocity (fps).	≤15	≤15	NA
	5. Longitudinal Occupant Ridedown Decelerations (g).	≤15	≤15	NA
	6. Vehicle Change in Velocity (fps).	NA	≤15	≤16
Vehicle Trajectory	7. After collision, the vehicle trajectory and final stopping position shall intrude a minimum distance, if at all, into adjacent traffic lanes.	A	A	NA
	8. Vehicle trajectory behind the test article is acceptable.	A	A	NA

A: Applicable
NA: Not applicable

4 TEST RESULTS

4.1 Test No. USBLM-1

This test was conducted with a 1,750 lb 1984 Dodge Colt. The vehicle impacted the luminaire support at the center point of the bumper with a speed of 15.0 mph. A summary of the test results is shown in Figure 12. The sequential photographs are shown in Figure 13.

The impact speed of 15 mph was less than the required speed of 20 mph due to technical difficulties. However, since this was a low speed test, this represented a more severe case so it was actually a more demanding test than what was required.

Upon impact with the luminaire support, the front bumper of the vehicle crushed inward until approximately 0.075 sec. after impact. At that time the luminaire support began to slip from the base. The luminaire support remained approximately vertical until 0.385 sec. after impact when it started to fall toward to the vehicle. The luminaire support continued to fall towards the vehicle until it hit the roof approximately 2.330 sec. after impact. The top of the luminaire support hit the ground 2.734 sec. after impact. The vehicle was stopped 40 ft from the point of impact with the base of the luminaire pole resting on the roof. The vehicle and installation damage is shown in Figures 14 and 15 respectively. The TAD (5) and VDI (6) vehicle damage classification are shown in Figure 12.

As a result of signal transmission problems, the accelerometer data for this test contained noise spikes which made it necessary to analyze the high speed film to determine the occupant risk. The noise spikes did not affect the part of the accelerometer data needed to calculate the duration of contact, so the vehicle change in speed was calculated using a combination of the film and accelerometer data.

The occupant impact velocity was determined to be 7.6 fps which is much less than the 15.0 fps maximum impact velocity suggested by NCHRP 230 (1). The maximum occupant ridedown deceleration was 3.5 g's, which is less than the 15.0 g maximum allowed by NCHRP 230 (1). The vehicle change in speed was 6.1 fps, which is lower than the 15.0 fps required by NCHRP 230 (1) and AASHTO (2), and the 16.0 fps required by the Federal Register (3). The determination of these results are shown graphically in Appendix C.

Impact — 0.383 sec — 0.583 sec — 1.339 sec — 2.338 sec

- Test Number USBLM-1
- Date 1/24/91
- Installation .... 4-Bolt Breakaway Slipbase Luminaire Support
- Luminaire Height .... 52-ft 0-in.
- Mast Arm Span Width .... 30-ft 10-in.
- Luminaire System Weight ...... 902 lbs
- Permanent Lower Slipbase Assembly
  - Bolt Type .... four 1-in. Diameter ASTM A325 Bolts
  - Bolt Circle Diameter ...... 1-ft 4-in.
  - Stub Height .... 4 in.
- Luminaire Pole
  - Base Diameter .... 10 in.
  - Top Diameter .... 3 in.
  - Length .... 50 ft.
  - Slipbolt Type .... four 1-in. Diameter ASTM A325 Slipbolts
  - Bolt Circle Diameter ...... 1-ft 1-in.
  - Slip Bolt Gasket Thickness 0.0149 in. (28 gauge)
  - Initial Bolt Torque .... 80 ft-lbs.
  - Final Bolt Torque .... 70 ft-lbs.
  - Clamping Bolt Force ...... 4 @ 4,300 lbs each

- Vehicle Model .... 1984 Dodge Colt
- Vehicle Weight
  - Curb .... 1,990 lbs.
  - Test Inertial .... 1,750 lbs.
  - Gross Static .... 1,750 lbs.
- Vehicle Impact Speed .... 15.0 mph
- Vehicle Impact Angle .... 0 deg.
- Vehicle Impact Location ...... Center of Bumper
- Vehicle Snagging .... None
- Vehicle Stability .... Satisfactory
- Occupant Impact Velocity ..... 7.6 fps
- Occupant Ridedown Deceleration 3.5 g's
- Vehicle Change-In-Speed ...... 6.1 fps
- Vehicle Damage .... Minimal
  - TAD 12-FC-2
  - VDI 12FCEN1, 12TZ6W2
- Vehicle Front-End Deflection .. 9 in.
- Vehicle Stopping Distance ..... 40 ft.
- Luminaire Support Damage .... Small Permanent Set Deflection Near Luminaire Pole Top
- Final Luminaire Support Location . 35 ft to Base

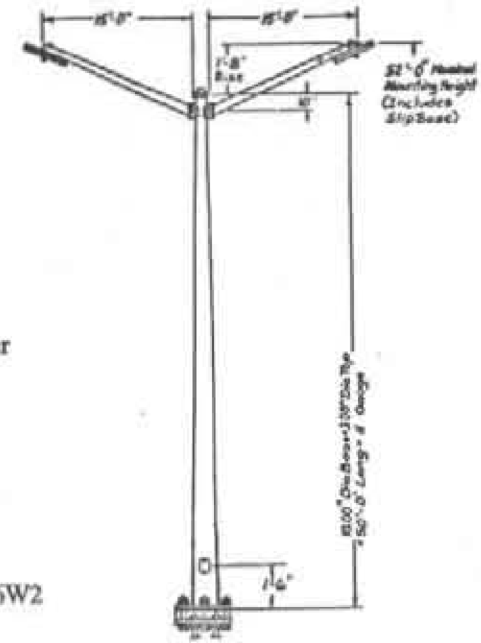


FIGURE 12. Summary and Sequential Photographs, Test USBLM-1.

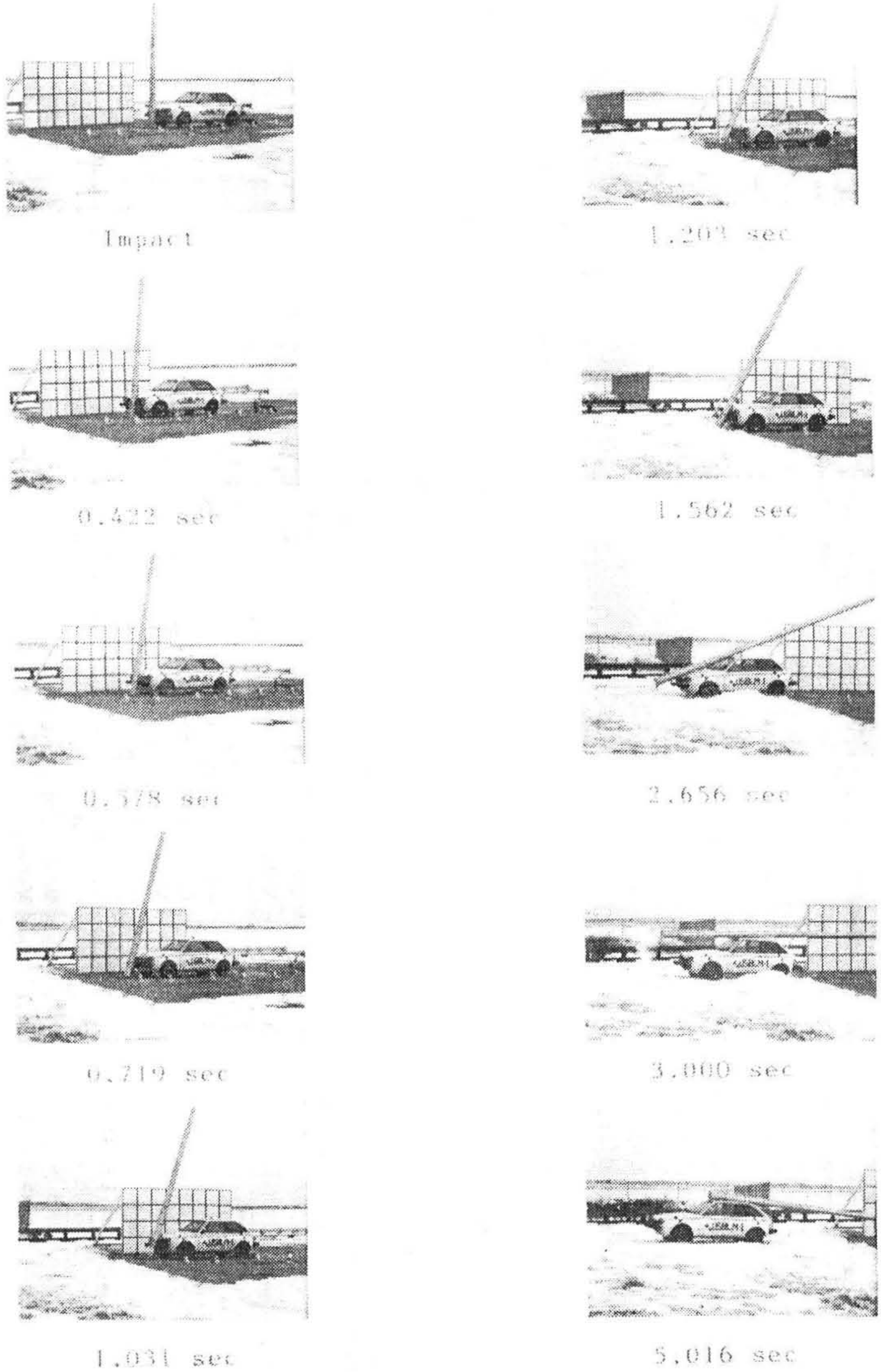


FIGURE 13. Sequential Photographs, Test USBLM-1.

FIGURE 14. Vehicle Damage, Test USBLM-1.

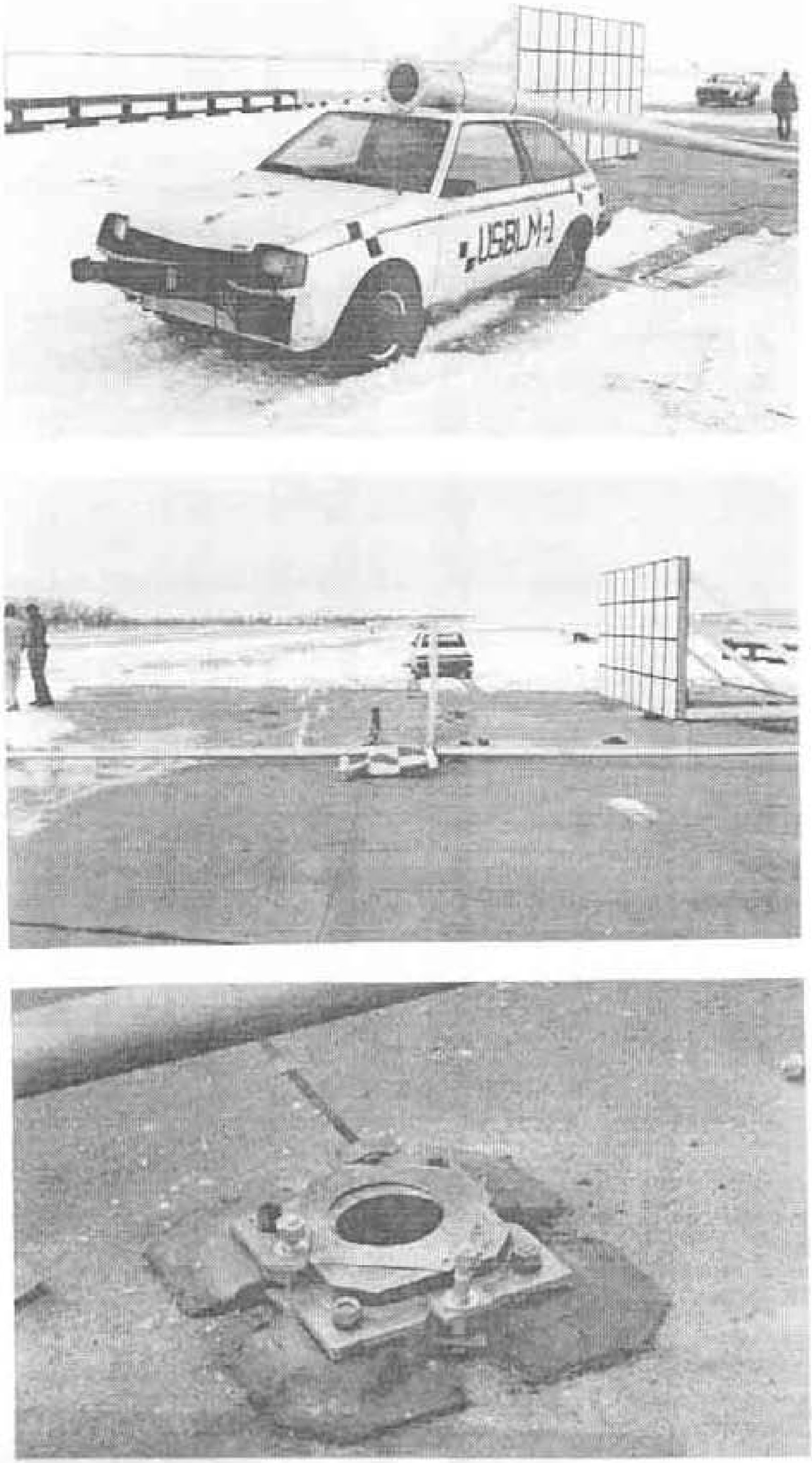


FIGURE 15. Installation Damage, Test USBLM-1.

4.2 Test No. USBLM-2

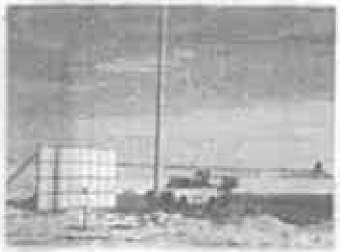
The 1984 Dodge Colt used for Test No. USBLM-1 was repaired and used for Test USBLM-2. The vehicle impacted the luminaire support at the center point of the bumper with a speed of 57.5 mph. A summary of the test results is shown in Figure 16. The sequential photographs are shown in Figure 17.

Upon impact with the luminaire support, the front bumper of the vehicle crushed inward for 0.018 sec. At that time the luminaire support began to slip from the base. At 0.174 sec., the front of the car began to lift up, and it continued on its rear wheels until 1.000 sec. after impact. At 0.868 sec., the luminaire support was approximately 16 ft above the ground and parallel to it. The luminaire support impacted the ground at 1.110 sec. The vehicle continued in a straight line path until it slid sideways and came to a stop 310 ft downstream from the base. The vehicle and installation damage is shown in Figures 18 and 19, respectively. The TAD (5) and VDI (6) vehicle damage classification are shown in Figure 16.

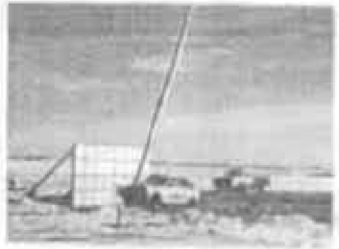
As a result of signal transmission problems, the accelerometer data for this test contained noise spikes which made it necessary to analyze the high-speed film to determine the occupant risk. The noise spikes did not affect the part of the accelerometer data needed to calculate the duration of contact, so the vehicle change in speed was calculated using a combination of the film and accelerometer data.

The occupant impact velocity was determined to be 14.2 fps, which is less than the 15.0 fps maximum impact velocity suggested by NCHRP 230 (1). The maximum occupant ridedown deceleration was 1.0 g, which is much less than the 15.0 g's allowed by NCHRP 230 (1). The vehicle change in speed was 13.5 fps, which is lower than the 15.0 fps required by NCHRP 230 (1) and AASHTO (2), and the 16.0 fps required by the Federal Register (3).

The determination of these results are shown graphically in Appendix C.



Impact



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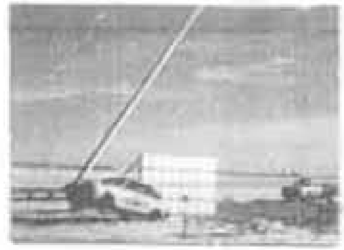
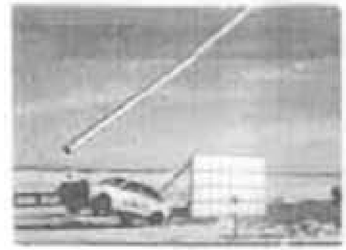


0.500 sec



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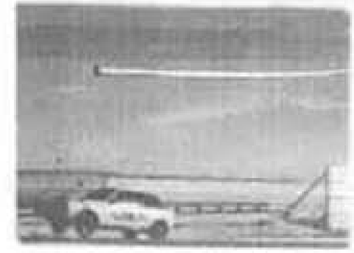


0.906 sec

Test Number	USBLM-2
Date	2/1/91
Installation	4-Bolt Breakaway Slipbase Luminaire Support
Luminaire Height	52-ft 0-in.
Mast Arm Span Width	30-ft 10-in.
Luminaire Support Weight	902 lbs
Permanent Lower Slipbase Assembly	
Bolt Type	four 1-in. Diameter ASTM A325 Bolts
Bolt Circle Diameter	1-ft 4-in.
Stub Height	4 in.
Luminaire Pole	
Base Diameter	10 in.
Top Diameter	3 in.
Length	50 ft.
Slipbolt Type	four 1-in. Diameter ASTM A325 Slipbolts
Bolt Circle Diameter	1-ft 1-in.
Slip Bolt Gasket Thickness	0.0149 in. (28 gauge)
Initial Bolt Torque	80 ft-lbs.
Final Bolt Torque	70 ft-lbs.
Clamping Bolt Force	4 @ 4,300 lbs each

Vehicle Model	1984 Dodge Colt
Vehicle Weight	
Curb	1,990 lbs.
Test Inertial	1,750 lbs.
Gross Static	1,750 lbs.
Vehicle Impact Speed	57.5 mph
Vehicle Impact Angle	0 deg.
Vehicle Impact Location	Center of Bumper
Vehicle Snagging	None
Vehicle Stability	Satisfactory
Occupant Impact Velocity	14.2 fps
Occupant Ridedown Deceleration	1.0 g's
Vehicle Change-In-Speed	13.5 fps
Vehicle Damage	Low to moderate
TAD	12-FC-3
VDI	12FCEN2
Vehicle Front-End Deflection	12 in.
Vehicle Stopping Distance	310 ft.
Luminaire Support Damage	Large Permanent Set Deflection Near Luminaire Pole Top
Final Luminaire Support Location	.70 ft to Base

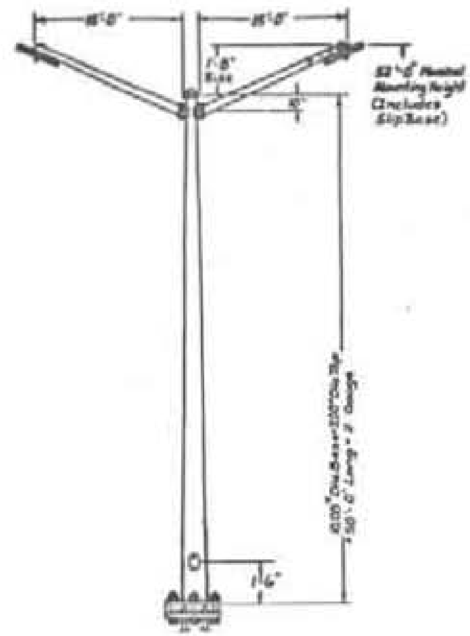
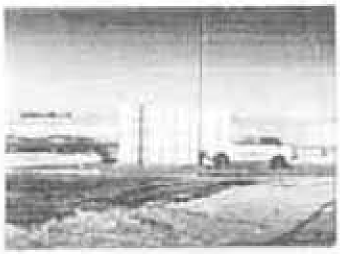
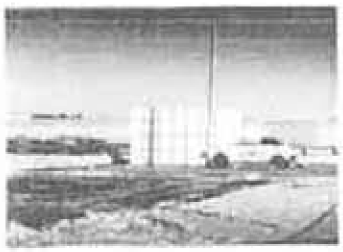


FIGURE 16. Summary and Sequential Photographs, Test USBLM-2.



Impact



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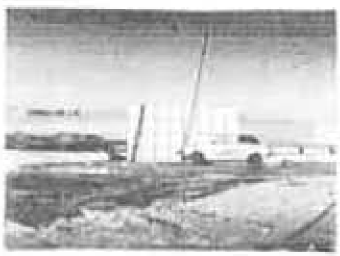

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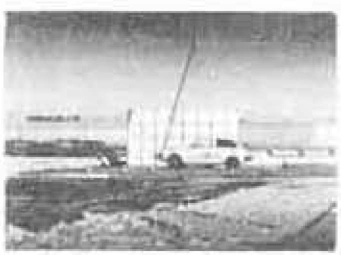

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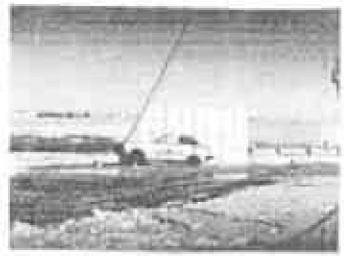

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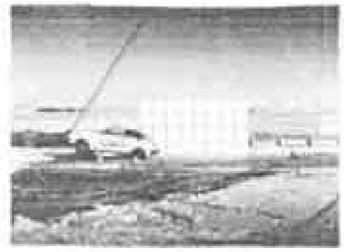

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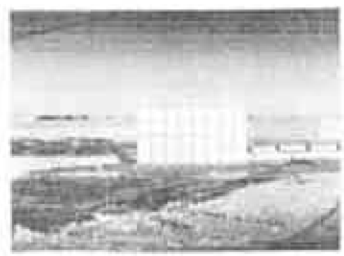

0.276 sec

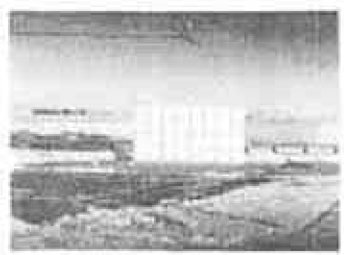

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FIGURE 17. Sequential Photographs, Test USBLM-2.

FIGURE 18. Vehicle Damage, Test USBLM-2.

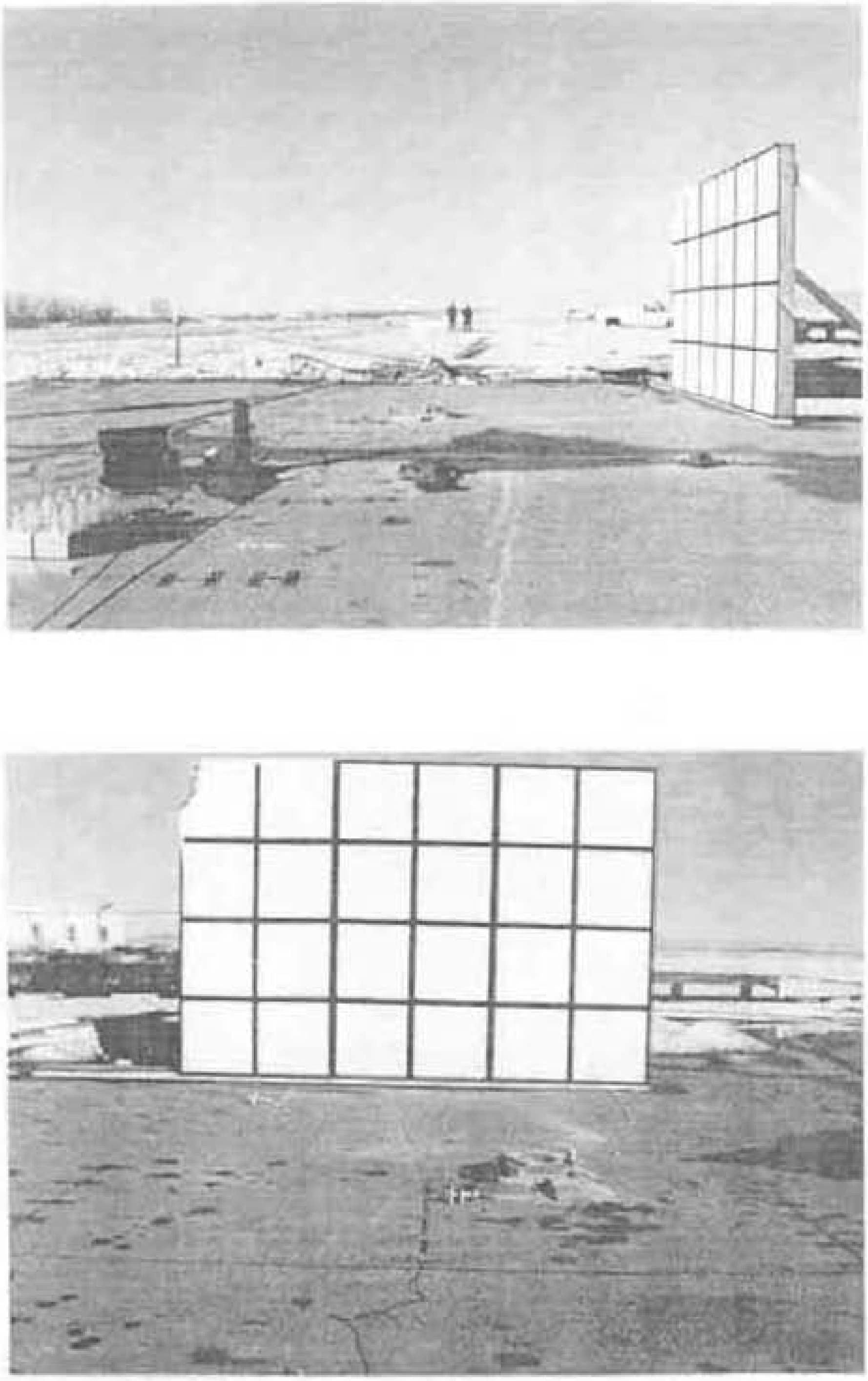


FIGURE 19. Installation Damage, Test USBLM-2.

5 CONCLUSIONS

Two full-scale crash tests were conducted to evaluate the safety performance of the 4-bolt breakaway slipbase design. The tests were evaluated according to the safety performance criteria given in NCHRP Report 230 (1), AASHTO (2), and the Federal Register (3). The safety evaluation results of both tests are summarized in Tables 3 and 4. The analysis of the crash tests revealed the following:

1. The test article activated in a predictable manner by breaking away.
2. Detached elements, fragments and other debris from the test article did not penetrate or show potential for penetrating the passenger compartment or present undue hazard to other traffic.
3. The vehicle remained upright during and after the collision and the integrity of the passenger compartment was maintained.
4. The longitudinal occupant impact velocities for Tests USBLM-1 (7.6 fps) and USBLM-2 (14.2 fps) were less than the 15 fps required by NCHRP Report 230 (1) and AASHTO (2).
5. The longitudinal occupant ridedown decelerations for Test USBLM-1 (3.5 g's) and Test USBLM-2 (1.0 g) were less than 15 g's as recommended by NCHRP 230 (1).
6. The vehicle change-in-speed for Test USBLM-1 (6.1 fps) and Test USBLM-2 (13.5 fps) were less than the 15 fps recommended by AASHTO (2), and the 16 fps recommended by the Federal Register (3).

Based on this analysis, the results of tests USBLM-1 and USBLM-2 are acceptable according to the NCHRP Report 230 (1), AASHTO (2), and Federal Register (3) guidelines.

TABLE 3. Safety Evaluation Results, Test USBLM-1.

Evaluation Factors	Evaluation Criteria	NCHRP 230	AASHTO	FHWA
Structural Adequacy	1. The test article shall readily activate in a predictable manner by breaking away or yielding.	S	S	NA
	2. Detached elements, fragments or other debris from the test article shall not penetrate or show potential for penetrating the passenger compartment or present undue hazard to other traffic.	S	S	NA
Occupant Risk	3. The vehicle shall remain upright during and after collision although moderate roll, pitching and yawing are acceptable. Integrity of the passenger compartment must be maintained with essentially no deformation or intrusion.	S	S	NA
	4. Longitudinal Occupant Impact Velocity (fps).	7.6<15	7.6<15	NA
	5. Longitudinal Occupant Ridedown Decelerations (g).	3.5<15	3.5<15	NA
	6. Vehicle Change in Velocity (fps).	NA	6.1<15	6.1<16
Vehicle Trajectory	7. After collision, the vehicle trajectory and final stopping position shall intrude a minimum distance, if at all, into adjacent traffic lanes.	S	S	NA
	8. Vehicle trajectory behind the test article is acceptable.	S	S	NA

S Satisfactory
M Marginal
U Unsatisfactory
NA Not Applicable

TABLE 4. Safety Evaluation Results, Test USBLM-2

Evaluation Factors	Evaluation Criteria	NCHRP 230	AASHTO	FHWA
Structural Adequacy	1. The test article shall readily activate in a predictable manner by breaking away or yielding.	S	S	NA
	2. Detached elements, fragments or other debris from the test article shall not penetrate or show potential for penetrating the passenger compartment or present undue hazard to other traffic.	S	S	NA
Occupant Risk	3. The vehicle shall remain upright during and after collision although moderate roll, pitching and yawing are acceptable. Integrity of the passenger compartment must be maintained with essentially no deformation or intrusion.	S	S	NA
	4. Longitudinal Occupant Impact Velocity (fps).	14.2<15	14.2<15	NA
	5. Longitudinal Occupant Ridedown Decelerations (g).	1.0<15	1.0<15	NA
	6. Vehicle Change in Velocity (fps).	NA	13.5<15	13.5<16
Vehicle Trajectory	7. After collision, the vehicle trajectory and final stopping position shall intrude a minimum distance, if at all, into adjacent traffic lanes.	S	S	NA
	8. Vehicle trajectory behind the test article is acceptable.	S	S	NA

S Satisfactory
M Marginal
U Unsatisfactory
NA Not Applicable

6 RECOMMENDATIONS

The 4-bolt Breakaway Slipbase Design has met the required performance evaluation criteria set forth by NCHRP 230 (1), AASHTO (2), and the Federal Register (3). Thus, it is our recommendation that the Federal Highway Administration approve this installation for use on Federal Aid Projects.

7 REFERENCES

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

2. "Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals," American Association of State Highway and Transportation Officials, 1985.

3. "Design Standards for Highways: Standard Specifications for Highway Signs, Luminaires, and Traffic Signals," Department of Transportation, Federal Highway Administration, 23 CFR 625, Federal Register, Vol. 54, No. 3, Thursday, January 5, 1989, Rules and Regulations.

4. Hinch, J., Yang, T-L, and Owings, R., "Guidance Systems for Vehicle Testing," ENSCO, Inc., Springfield, VA, 1986.

5. "Vehicle Damage Scale for Traffic Accident Investigators," Traffic Accident Data Project Technical Bulletin No. 1, National Safety Council, Chicago, IL, 1971.

6. "Collision Deformation Classification, Recommended Practice J224 Mar 80," SAE Handbook Vol. 4, Society of Automotive Engineers, Warrendale, PA, 1985.

8 APPENDICES

Appendix A

3-Bolt Breakaway Slipbase Designs

US Department of Transportation
Federal Highway Administration

400 Seventh St., S.W.
Washington, D.C. 20590

Refer to: HNG-14

Dennis H. O'Brien, P.E.
Manager, Product Planning
Industrial & Construction Products Division
Valmont Industries, Inc.
Valley, Nebraska 68064

Dear Mr. O'Brien:

By your September 16 and 22, 1988, letters to Mr. Thomas O. Willett, Director, of Office of Engineering, you requested Federal Highway Administration (FHWA) acceptance of steel breakaway slip-base luminaire supports for use on Federal-aid highway projects. As you know, considerable effort has gone into evaluating steel slip-base luminaire supports since you made your request. Your cooperation and assistance in that effort is much appreciated. Enclosure I summarizes the tests FHWA has evaluated in reaching a decision on the breakaway acceptability of steel slip-base luminaire supports.

In each of the tests shown in the summary the geometry of the slip-base was nominally the same as California Department of Transportation's (Caltrans) Type 31 base, which is shown on Enclosure II, except that in one series of tests the keeper plate thickness was reduced to 0.0149 inches (28 gage). The pole base plate in the type 31 base is 1 inch thick, the lower slip plate is 1 1/4 inches thick, and the anchor plate is 1 inch thick. We would also point out that in all tests two of the slip-base clamp bolts lay in a line parallel to the direction of traffic and were on the street side of the pole.

From the summarization of tests it can be seen that there is considerable scatter in the results and that in some tests FHWA's maximum 16-foot-per-second breakaway change in velocity requirement was exceeded and in some instances the test device was actually stopped. Because of the apparently unpredictable nature of the slip-base the testing effort was extended and a theoretical analysis of the slip-base release mechanism was undertaken. As a result of this work we are now confident that safe slip-base luminaire supports can be configured that will be within substantial compliance with FHWA's breakaway requirements. Thus, steel slip-base luminaire supports will be acceptable for use on Federal-aid highways if proposed by a State highway agency provided they fall within the limitations setforth below:

Basic Type: Triangular, three-bolt base similar to Caltrans' Type 30 and 31 bases (see Enclosure II).

Minimum Shaft Wall Thickness: 0.1196 inches for diameters up to 10 inches.

Bolt Circle Diameter: 14 inches (minimum).

Base Plate Thickness: 1 inch (minimum), 1 1/4 inches (maximum).

Lower Slip Plate Thickness: 1 1/4 inches (minimum), 1 1/2 inches (maximum).

Anchor Plate Thickness: 1 1/4 inches (maximum).

Steel Keeper Plate Thickness: 0.0149 inches before coating (28 gage) (maximum).

Height Top of Lower Slip Plate from Ground Line: 4 inches (maximum).

Clamp Bolt Type: Galvanized ASTM A325 with dry lubricant (Heads and nuts shall have heavy hex dimensions).

Clamp Bolt Size: 7/8-inch to 1 1/4-inch diameter.

Rectangular Clamp Bolt Washer Size: Length, width, and thickness shall be sufficient to prevent significant deflection (bending) when clamp bolt is loaded to its tensile capacity.

Hole in Clamp Bolt Rectangular Washer: Camp bolt diameter plus 1/16 inch, with edges chamfered to prevent binding with radius under bolt head.

Clamp Bolt Tension: 8,000 pounds per bolt (maximum). In the absence of a more exact method of determining bolt tension the following maximum tightening torques shall be used:

Bolt diameter (inches)	7/8	1	1 1/8	1 1/4
Torque (foot-pounds)	87	95	104	111

Finish: All faying surfaces to be galvanized, free of paint, and smooth and free of ridges, scallops, nicks, and burrs.

Mounting Height: 56 feet, 6 inches measured from bottom of pole base plate to centerline of luminaire mounting tenon (maximum).

Weight: 1,000 pounds (include luminaire, mast arm(s), pole, and base plate) (maximum).

Mast Arm Orientation: Mast arm may be parallel to a flat side of the base <u>provided that side faces approach traffic</u> or may pass over a clamp bolt (see Enclosure III.)

Placement: The terrain about the pole base shall not inhibit translation of the pole and approach topography shall be such that a vehicle leaving the roadway at design speed and an angle of up to 25 degrees will not strike the pole at a height greater than were the pole located at the edge of the pavement. (The approach terrain will not cause an errant vehicle to become airborne.)

While the restrictions listed here are rather extensive and in some instances differ from some current practices, for example the clamp bolt tension, keeper plate thickness, and mast arm oriention prescribed differ from those in the Caltrans standard, one should not infer FHWA is apprehensive about the use of slip-base luminaire supports. It is just that our extensive study of these structures has given us an insight that leads us to believe they will work best and the public will be best served by adhering to the guidance we have outlined.

Sincerely yours,

L. A. Staron

L. A. Staron
Chief, Federal-Aid and Design Division

Enclosures

Agency Test No. Date	Mastarm(s) Length (ft) Weight (#)	Shaft Length (ft) Weight (#)	Mounting Height (ft) Total Weight (#)	Pole Diam. at base (in) Wall Thick. at base (in)	Slip Base Bolt Circle Diameter (in)	Clamp Bolt Diameter (in)	Est. Clamp Bolt Force 3 # (lbs) ea	Keeper Plate Thickness (in)	Impact Angle from Roadway (degrees)	Test Veh. Type and Weight (lbs)	Impact speed (m.p.h.)	Occupant Change in Velocity (f.p.s.)
CALTRANS	CALIFORNIA TYPE 31 SLIP BASE											
404 JUL 26, 84	20 189	35 627	37 883	10.875 0.1793	14	1	11,400	0.0359	30	'79 HONDA 1865	19.9	8.5
405 MAY 23, 85	20 189	35 627	37 883	10.875 0.1793	14	1	11,200	0.0359	30	'79 HONDA 1885	53.9	12.4
406 MAY 8,'87	20 132	35 *	39.25 627.4	10 0.25 *	14	1	18,600	0.0359	30	'79 HONDA 1850	58.8	13.0
407 JUNE 23,'87	20 132	35 *	39.25 639.4	10 0.25 *	14	1	12,200	0.0359	30	'79 HONDA 1840	23.7	8.6
CAPABILITY TESTS - FOIL	VALMONT SLIP BASE											
87F033 MAR 12,'87	1.33 AND 16 115 AND 112	48.5 630	55.5 964	10 0.1793	14	1	12,500	0.0359	0	FOIL BOGIE 1850	19.8	14.5
87F034 MAR 13,'87	1.33 AND 16 115 AND 112	48.5 630	55.5 964	10 0.1793	14	1	12,500	0.0359	0	FOIL BOGIE 1850	58.7	15.5
THIN WALL TESTS - FOIL												
89F023 SEP 21,'89	1.33 AND 15 120 AND 107	46.5833 415	53.42 744	10 0.1196	14	1	12,500	0.0359	0	FOIL BOGIE 1850	20.7	24.4
89F024 SEP 27,'89	1.33 AND 15 120 AND 107	46.5833 415	53.42 744	10 0.1196	14	1	12,500	0.0359	0	'79 RABBIT 1850	19.8	15.8
89F025 OCT 5,'89	1.33 AND 15 120 AND 107	46.5833 415	53.42 744	10 0.1196	14	1	12,500	0.0359	0	'79 RABBIT 1850	59.2	13.2
89F026 OCT 24,'89	1.33 AND 15 120 AND 107	46.5833 415	53.42 744	10 0.1196	14	1	12,500	0.0359	0	FOIL BOGIE 1850	60.6	13.7

Agency Test No. Date	Mastarm(s) Length (ft) Weight (#)	Shaft Length (ft) Weight (#)	Mounting Height (ft) Total Weight (#)	Pole Diam. at base (in) Wall Thick. at base (in)	Slip Base Bolt Circle Diameter (in)	Clamp Bolt Diameter (in)	Est. Clamp Bolt Force 3 @ (lbs) ea	Keeper Plate Thickness (in)	Impact Angle from Roadway (degrees)	Test Veh. Type and Weight (lbs)	Impact speed (m.p.h.)	Occupant Change in Velocity (f.p.s.)
CLAMP FORCE STUDY - FOIL												
89F005 APR 12,'89	None	30.25 275	None 275	7.5 0.1345	14	1	1,965	0.0359	0	FOIL BOGIE 1850	20.6	6.5
89F006 APR 19,'89	*	* *	* *	* *	*	*	3,928	*	0	* *	20.7	5.9
89F007 APR 20,'89	*	* *	* *	* *	*	*	5,891	*	0	* *	20.7	8.3
89F008 APR 24,'89	*	* *	* *	* *	*	*	7,614	*	0	* *	20.5	6.4
89F009 APR 25,'89	*	* *	* *	* *	*	*	9,817	*	0	* *	20.8	23.2
89F010 APR 26,'89	*	* *	* *	* *	*	*	11,780	*	0	* *	20.7	20.6
89F011 APR 26,'89	*	* *	* *	* *	*	*	9,817	*	0	* *	20.5	7.7
89F012 APR 27,'89	*	* *	* *	* *	*	*	11,780	*	0	* *	20.6	36.9 **
89F014 MAY 19,'89	*	* *	* *	* *	*	*	13,743	*	0	* *	20.4	22.7
89F015 MAY 24,'89	*	* *	* *	* *	*	*	7,614	*	0	* *	20.5	14.8
89F016 MAY 25,'89	*	* *	* *	* *	*	*	15,808	*	0	* *	20.4	18.2
89F017 MAY 31,'89	*	* *	* *	* *	*	*	5,891	*	0	* *	20.6	21.4

* A 2-foot high steel tube with 0.25 in. wall thickness was welded to the bottom of a 33 foot tall pole which had a wall thickness of 0.1196 in.

Agency Test No. Date	Mastarm(s) Length (ft) Weight (#)	Shaft Length (ft) Weight (#)	Mounting Height (ft) Total Weight (#)	Pole Diam. at base (in) Wall Thick. at base (in)	Slip Base Bolt Circle Diameter (in)	Clamp Bolt Diameter (in)	Est. Clamp Bolt Force 3 @ (lbs) ea	Keeper Plate Thickness (in)	Impact Angle from Roadway (degrees)	Test Veh. Type and Weight (lbs)	Impact speed (m.p.h.)	Occupant Change in Velocity (f.p.s.)
KEEPER PLATE STUDY - FOIL												
90P023 4/24/90	None None	30.83 486	None 486	10.0 0.1793	14	1	12,500	0.0359	0	FOIL PNDLM 1850	19.9	25.9
90P024 4/25/90	* *	* *	* *	* *	*	*	*	NONE	*	* *	19.8	8.8
90P025 4/25/90	* *	* *	* *	* *	*	*	*	NONE	*	* *	19.8	13.2
90P026 4/26/90	* *	* *	* *	* *	*	*	*	NONE	*	* *	19.9	11.1
90P027 4/26/90	* *	* *	* *	* *	*	*	*	0.0149	*	* *	20	16.9
90P028 5/1/90	* *	* *	* *	* *	*	*	*	0.0149	*	* *	19.8	35 **
90P029 5/2/90	* *	* *	* *	* *	*	*	3,600	0.0149	*	* *	20	5.6
90P032 5/30/90	* *	* *	* *	* *	*	*	3,600	0.0149	*	* *	20	7
90P033 5/31/90	* *	* *	* *	* *	*	*	3,600	0.1049	*	* *	20	6.4
90P034 5/31/90	* *	* *	* *	* *	*	*	9,000	0.0149	*	* *	20	11.8
90P035 6/05/90	* *	* *	* *	* *	*	*	9,000	0.0149	*	* *	20	35.4 **
90P036 6/06/90	* *	* *	* *	* *	*	*	8,000	0.0149	*	* *	20	17.7

** Value includes rebound, thus exceeds impact speed.

Memorandum

US Department of Transportation
Federal Highway Administration

Washington, D.C. 20590

Subject: Breakaway Sign and Luminaire Supports

Date: JUL 6 1990

From: Director, Office of Engineering

Reply to Attn of: HNG-14

To: Regional Federal Highway Administrators
Federal Lands Highway Program Administrator

As indicated in our June 25 ONTYME message to you, the Federal Highway Administration (FHWA), by Federal Register notice dated January 5, 1989, adopted, with a minor modification, Section 7 - Breakaway Supports of the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals - 1985. An approximately 18-month transition period was provided for developing new or revising existing hardware to meet the new specification, and to allow State highway agencies to incorporate the new hardware requirements in construction contracts. That transition period expired on July 1 of this year. The Federal-aid highway projects which have their bid opening after this date shall include breakaway supports which meet the 1985 AASHTO specification, as modified by FHWA. Retrofit of existing highway signs, luminaires and traffic signals is not required but may be done at the State's option. Since existing FHWA policy recommends that obsolete safety hardware be upgraded when being repaired, replaced, or relocated, we suggest hardware meeting the new specification be used in these cases.

There are already several types of breakaway supports or bases available for both signs and luminaires which meet the new standard. The Geometric and Roadside Design Branch, as a service to industry and users, reviews crash test results of new hardware submitted by developers, manufacturers, and highway agencies to assess compliance with applicable requirements. If appropriate, an acceptance letter is sent to the requestor. That letter describes the hardware and the testing program and spells out restrictions, if any, for use of the hardware on Federal-aid projects. Copies of these acceptance letters are provided to the regional offices. Attachments A and B contain the lists of acceptance letters covering breakaway luminaire and breakaway sign supports, respectively. These acceptance letters deal only with the breakaway performance of the hardware and do not imply structural adequacy. One item is listed with a "pending" date. It has been submitted to us for determining acceptability, but our review is continuing. You will receive copies of any new acceptance letters when they are issued.

In addition to hardware manufacturers and State agencies conducting their own tests, an HP&R Pooled fund study, "Small and Large Sign Supports," will crash test hardware selected by the 27 contributing States. Representatives of these States met on April 17 and 18 to vote on which supports were to be tested. Attachment C is the priority ranking of the sign supports to be crash tested under this study. Because no results were available prior to the July 1, 1990, deadline for implementing the 1985 AASHTO standards, all of the sign support systems included in the list in Attachment C will be considered provisionally acceptable for continued use in Federal-aid highway projects. However, some of the designs to be tested appear marginal, particularly the multiple support 4 pound-per-foot base bending flange channel structures. Therefore, we suggest that States not adopt new design standards from this list before testing has been completed. However, should a State find a compelling need to use a design from the list that it is not currently using, such use should be on a project-by-project basis until the design has been qualified through testing. Under the pooled-fund study, if a system passes all recommended tests, its acceptability will be confirmed. If a system fails a test the failure will be documented and the system will no longer be acceptable. Those systems well down the priority list may not be tested owing to lack of funds. If this happens, those systems will no longer be eligible for Federal-aid funds unless crash tested by others.

The pooled fund study does not include rectangular slip bases for large signs. However, since we know that the basic slip-base design will work with a 1,800-pound car (see acceptance letter SS-5), large slip-base roadside sign supports with legs further than 7 feet apart may continue to be installed after July 1 under the following conditions:

(a) Weight of the support is 45 pounds-per-foot or less, and total weight of the support post plus slip plate is less than 600 pounds below the hinge.

(b) Base bolt torques conform to values listed in Table 4.1 of the AASHTO Roadside Design Guide.

(c) Keeper plate, if used, is 28 gauge (0.0149 inches) in thickness or less.

(d) Height of slip-base conforms to the 4-inch stub height requirement in the AASHTO breakaway standard.

To date, FHWA has accepted, for restricted use, breakaway supports that have only been qualified through testing in one of the NCHRP soils. The pooled-fund study cited above will test supports in both "strong" and "weak" soils. In this study testing will be discontinued on any support system that fails in one of the soils and the system will be judged unacceptable unless it is modified and found acceptable in both soils. Furthermore, this office, from now on, will only evaluate the breakaway acceptability of sign support systems where there is assurance that they will meet our breakaway requirements in both soil types. Thus, it seems likely that near the end of the study (last testing is scheduled for late 1992) the FHWA will begin to require that all new breakaway systems installed on Federal-aid highway projects be qualified as breakaway in both "strong" and "weak" soils. For those supports that have been found acceptable by FHWA for use in only one type soil, FHWA will, for the present, continue to accept installation of those supports in the soil within which they have been qualified. Such conditionally qualified supports are identified in Attachment B with a plus sign (+).

Slip-base luminaire supports will be acceptable for use on Federal-aid highways if proposed by a State highway agency provided they fall within the limitations set forth in Attachment D.

In meeting the new breakaway requirements, in some instances, the manufacturers have developed new breakaway concepts, in others, they have only reconfigured older designs. Presumably all the resulting hardware meets the structural requirements of the AASHTO specifications. However, it would be prudent for the States to require evidence of this from the suppliers.

Thomas O. Willett

Attachments

Attachment A, Page 1 of 2

Code	Date of Letter	Manufacturer or supplier	Breakaway Device or Mechanism	Type of Support	Designation of Tested pole or base	Luminaire Mounting Height (ft.)	Bolt Circle Diameter (inches)	Soil Type	Embed. Depth (inches)	Impact Speed (mph)	Delta V (fps)	Stub Height (inches)	Weight of Pole (lb.)
LS-1	6/15/88 11/10/88	Sherman International, Inc	Separation of pole from base	Fiberglass, Direct Burial	MR 36-D-50-56	30	n/a	strong	60	20.0 60.0	14.4 10.3	none none	
LS-2	6/29/88	Akron Foundry Company	Cast Aluminum Transformer Base	Aluminum	TB1-AF-1315-17	42	15 15	n/a	n/a	20.0 calc60.0	6.7 8.2	none n/a	437.0
				Aluminum	TB-1AF-1315-17 IW	51.2	15 15	n/a	n/a	20.0 calc60.0	7.2 10.2	none n/a	511.0
				Steel	TB-1-AF-1315-17	42	15 15	n/a	n/a	20.0 calc60.0	6.4 14.4	none n/a	812.0
				Steel	TB1-AF-1315-17 IW	50	15 15	n/a	n/a	20.0 calc60.0	10.1 15.8	none n/a	734.0
				Steel	TB1-AF-1315-17 IW	50	15 15	n/a	n/a	20.0 calc60.0	11.2 16.1	3.06 n/a	738.0
				Steel	TB1-AF Modified-17	42	10.5 10.5	n/a	n/a	20.0 calc60.0	9.3 15.4	5.75 n/a	812.0
				Steel	TB1-AF Modified-17	42	10.5 10.5	n/a	n/a	20.0 calc60.0	9.9 15.6	none n/a	812.0
LS-3	6/24/88	Union Metal Corporation	Cast Aluminum Shoe Base	Aluminum, 0.188" wall Aluminum, 0.250" wall	A2940	50	14.5	n/a	n/a	20.0 calc60.0 20.0 calc60.0	14.8 9.7 13.8 10.5	4.0 n/a 4.0 n/a	311.0 485.0
LS-4	1/12/89	Akron Foundry Company	(reaffirmation of TB-1 base)										
LS-5	3/14/89	Hapco Division	Impact Safety Coupling	Aluminum, 10" dia. 0.250" wall	6723R	54	15	n/a	n/a	20.0 calc60.0	5.0 9.6	7.0 n/a	556.0
LS-6	4/4/89 3/5/89	Shakespeare Products Group	Separation of pole from base [acceptance covers these poles: BH20, BH24, BH30, BH35, BS30, BS35, BX30, BX35, BA41, BA47, BB30, BB35, BB41, BB47, BC30, BC35, BC41, BC47]	Fiberglass, Direct Burial	BC47-10N50K44AW	40	n/a	Strong	84"	20.0 calc60.0	12.6 8.9	none n/a	349.5
					BC47-10N50K44BW	40	n/a	Strong	84"	20.0 calc60.0	11.0 8.3	none n/a	349.5
					BH35-10N5HG20	30	n/a	Strong	60"	20.0 calc60.0	3.7 3.3	none n/a	175.0
					BH35-10N5HG20	30	n/a	Strong	60"	20.0 calc60.0	4.0 3.4	none n/a	175.0
					BC47-10N5HK08 BH35-10N7HG20	40 30	n/a n/a	Weak Weak	84" 60"	20.0 20.0	11.0 8.0	none none	unk. unk.
LS-7	11/8/89	Shakespeare Products Group	TranspoSafety 201 or 301 Couplings [acceptance covers series AA, AB, AC, and AD poles for heights from 39' to 47']	Fiberglass	AD45 pole with shoe base no. 37-60-0713-10	45	15.5	n/a	n/a	20.0 calc60.0	7.0 9.4	4.0 n/a	414.0
LS-8	1/11/90	Transpo Industries, Inc.	Pole-Safe Breakaway Couplings Series 201 or 301	Poles weighing no more than 900 pounds	201.8	55	13	n/a	n/a	20.0 calc60.0	17.7 19.4	4.6	897.0
					301.8	55	13	n/a	n/a	20.0 calc60.0	11.8 18.2	4.6	897.0
					201.8	55	13	n/a	n/a	20.0 calc60.0	11.5 16.8	4.6	897.0
					301.8	55	13	n/a	n/a	20.0 calc60.0	11.5 16.6	4.6	897.0

Code	Date of Letter	Manufacturer or supplier	Breakaway Device or Mechanism	Type of Support	Designation of Tested pole or base	Luminaire Mounting Height (ft.)	Bolt Circle Diameter (inches)	Soil Type	Embed. Depth (inches)	Impact Speed (mph)	Delta V (fps)	Stub Height (inches)	Weight of Pole (lbs)
LS-9	1/24/90	Akron Foundry Company	Cast Aluminum Transformer Bases TB-2 and TB-3	Steel	TB2-AF 1012 I.W.-17	40.0	10.5	n/a	n/a	20.0 calc60.0	6.4 12.0	(bolt only)	494.0
					TB3-AF 1517-17	50	17.25	n/a	n/a	20.0 calc60.0	8.3 15.6	2.0 n/a	778.0
					TB3-AF 1517 I.W-17	50	17.25	n/a	n/a	20.0 calc60.0	10.3 16.3	(bolt only)	770.0
					TB3-AF 1517 I.W.-17	50	10.5	n/a	n/a	20.0 calc60.0	6.4 15.0	(bolt only)	778.0
LS-10	2/26/90	PrecisionForm, Inc.	Frangible Coupler	Aluminum (Poles weighing up to 800 pounds may be used)	PFI 200-1	53 53	15 15	n/a n/a	n/a n/a	20.7 61.2	12.4 10.1	2.5 2.5	523.0 523.0
LS-11	5/15/90	Union Metal	Cast Aluminum Transformer Base	Steel	A2H50-C1K10	50	12.5	n/a	n/a	20.0	6.9	2.4/6.4	810.0
LS-12	5/14/90	P&K Pole Products	Aluminum Shoe bases	Aluminum	7" S8-2G	30	11	n/a	n/a	20.0 calc60.0	8.8 5.1	2.1	193.5
					7" S8-2G	30	11	n/a	n/a	20.0 calc60.0	17.2 6.6	2.3	218.0
					8" S8-2G	30	11	n/a	n/a	20.0 calc60.0	9.1 5.8	2.3	212.0
LS-13	5/29/90	P&K Pole Products	Aluminum Slip Base	Aluminum	Aluminum Slip Base	50	21	n/a	n/a	20.0 calc60.0	12.9 14.3	3.5	548.0
LS-14	5/30/90	Valmont Indistries	Cast Aluminum Transformer Base Valmont Number 0283093	Steel	0283093 (base) U560-1008 406-150	55	15	n/a	n/a	20.0 calc60.0	9.5 16.7	3.3/6.7	950.0
LS-15	5/30/90	Akron Foundry Company	Cast Aluminum Transformer Base	Steel	TB2-AF-1012-17-I.W.	40	12	n/a	n/a	20.0 calc60.0	14.6 12.8	3.3/6.0	540.0
			Cast Aluminum Transformer Base	Steel	TB-1-AF-1315-17-I.W.	55	15	n/a	n/a	20.0 calc60.0	9.5 16.7	3.3/6.7	950.0
LS-16	6/29/90	Valmont Industries	Steel Slip Bases (Generic criteria for acceptance)	Steel	Many poles were tested up to a maximum weight of 964 pounds.	55.5 max.	14 (base BC was 15")	(clamp force:) (8,000 lbs) (7,614 lbs) (12,500 lbs) (12,500 lbs)		20.0 20.5 19.8 58.7	17.7 14.8 14.5 15.5	4.0 max.	486.0 275.0 964.0 964.0
LS-??	PENDING	Shakespeare Products Group	Cast Aluminum Shoe Base on poles ASW37 thru ASW35 and AHW27 through AHW35	Fiberglass									

n/a - not applicable

Requirements and Commentary on Use of Steel Slip-base Luminaire Supports

Basic Type: Triangular, three-bolt base similar to Caltrans' Type 30 and 31 bases (see page 3 of this Attachment).

Minimum Shaft Wall Thickness: 0.1196 inches for diameters up to 10 inches.

Bolt Circle Diameter: 14 inches (minimum).

Base Plate Thickness: 1 inch (minimum), 1 1/4 inches (maximum).

Lower Slip Plate Thickness: 1 1/4 inches (minimum), 1 1/2 inches (maximum).

Anchor Plate Thickness: 1 1/4 inches (maximum).

Steel Keeper Plate Thickness: 0.0149 inches before coating (28 gage) (maximum).

Height Top of Lower Slip Plate from Ground Line: 4 inches (maximum).

Clamp Bolt Type: Galvanized ASTM A325 with dry lubricant (Heads and nuts shall have heavy hex dimensions).

Clamp Bolt Size: 7/8-inch to 1 1/4-inch diameter.

Rectangular Clamp Bolt Washer Size: Length, width, and thickness shall be sufficient to prevent significant deflection (bending) when clamp bolt is loaded to its tensile capacity.

Hole in Clamp Bolt Rectangular Washer: Camp bolt diameter plus 1/16 inch, with edges chamfered to prevent binding with radius under bolt head.

Clamp Bolt Tension: 8,000 pounds per bolt (maximum). In the absence of a more exact method of determining bolt tension the following maximum tightening torques shall be used:

Bolt diameter (inches)	7/8	1	1 1/8	1 1/4
Torque (foot-pounds)	87	95	104	111

Finish: All faying surfaces to be galvanized, free of paint, and smooth and free of ridges, scallops, nicks, and burrs.

Mounting Height: 56 feet, 6 inches measured from bottom of pole base plate to centerline of luminaire mounting tenon (maximum).

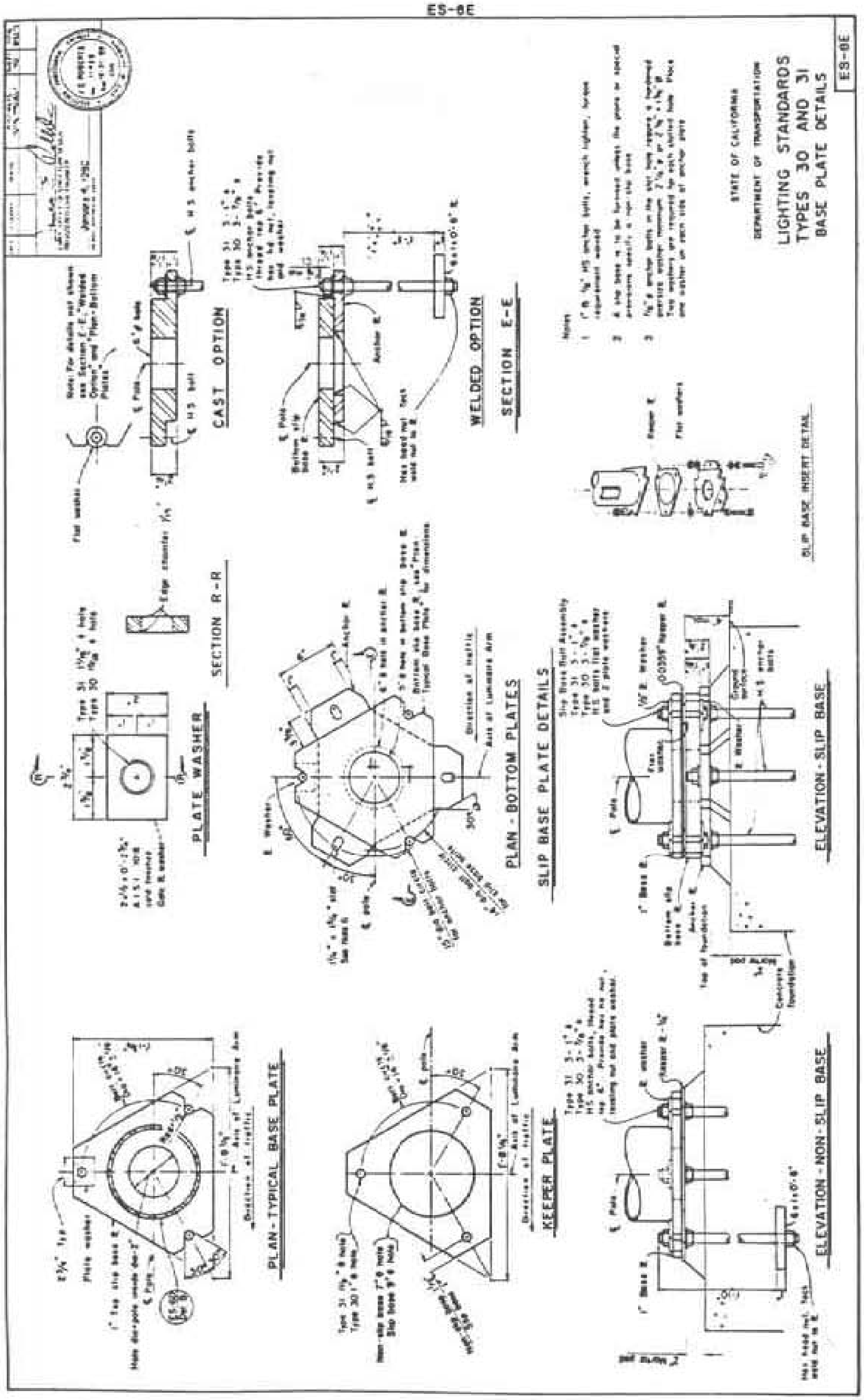
Weight: 1,000 pounds (include luminaire, mast arm(s), pole, and base plate) (maximum).

Mast Arm Orientation: Mast arm may be parallel to a flat side of the base provided that side faces approach traffic or may pass over a clamp bolt (see page 4 of this Attachment).

Placement: The terrain about the pole base shall not inhibit translation of the pole and approach topography shall be such that a vehicle leaving the roadway at design speed and an angle of up to 25 degrees will not strike the pole at a height greater than were the pole located at the edge of the pavement. (The approach terrain will not cause an errant vehicle to become airborne.)

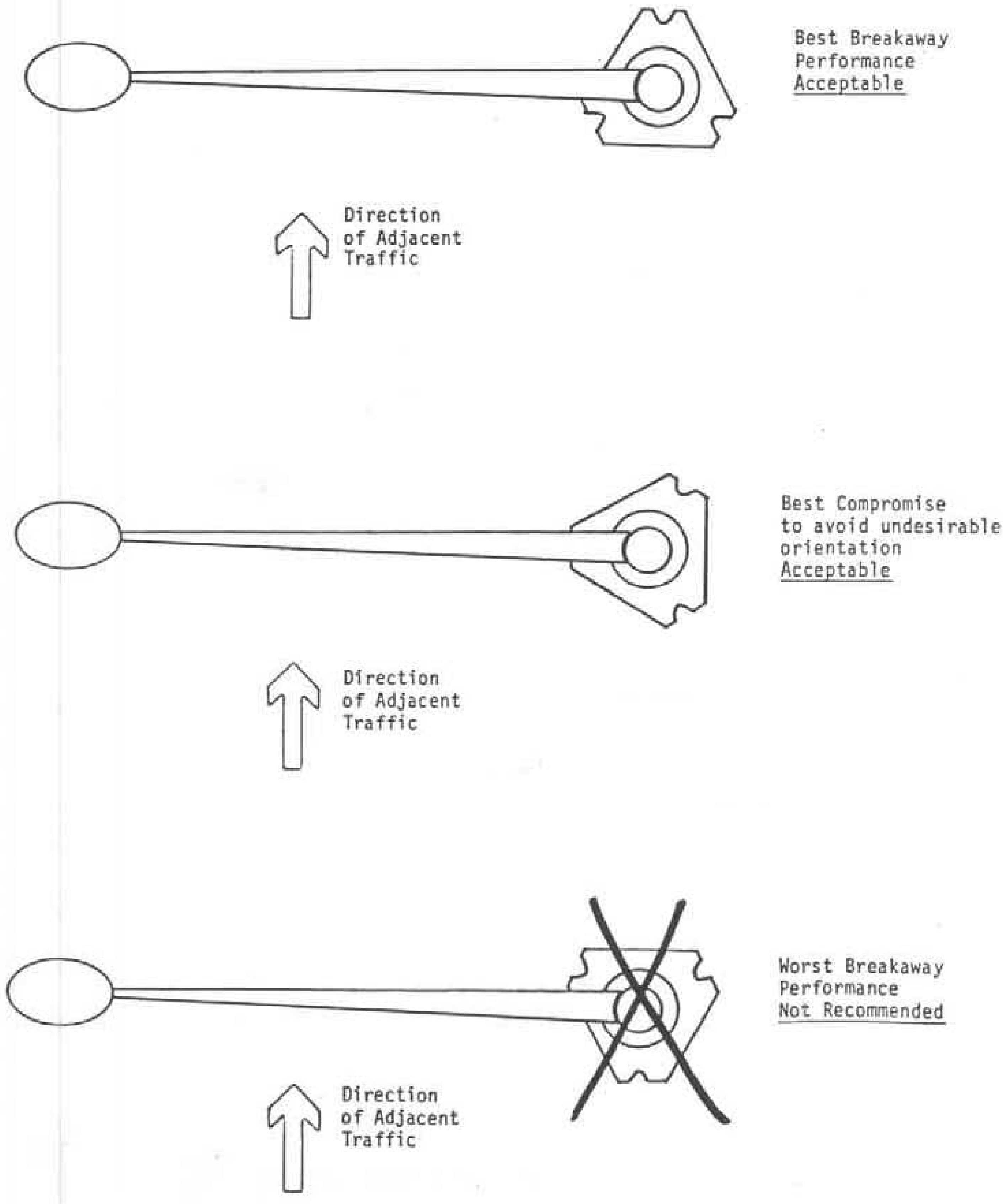
While the restrictions listed here are rather extensive and in some instances differ from some current practices, for example the clamp bolt tension, keeper plate thickness, and mast arm orientiion prescribed differ from those in the Caltrans standard, one should not infer FHWA is apprehensive about the use of slip-base luminaire supports. It is just that our extensive study of these structures has given us an insight that leads us to believe they will work best and the public will be best served by adhering to the guidance we have outlined.

ES-8E



ES-8E
STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
LIGHTING STANDARDS
TYPES 30 AND 31
BASE PLATE DETAILS
PLATE WASHER
SECTION R-R
CAST OPTION
WELDED OPTION
SECTION E-E
PLAN - TYPICAL BASE PLATE
KEEPER PLATE
PLAN - BOTTOM PLATES
SLIP BASE PLATE DETAILS
SLIP BASE INSERT DETAIL
ELEVATION - SLIP BASE
ELEVATION - NON-SLIP BASE

Luminaire Slip Base Orientation



Appendix B

Correspondence

State of Utah
UTAH DEPARTMENT OF TRANSPORTATION

Norman H. Bangerter
Governor
Eugene H. Findlay, C.P.A.
Executive Director
H.H. Richardson, P.E.
Assistant Director

4501 South 2700 West
Salt Lake City · Utah 84119-5998
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Transportation Commission
Samuel J. Taylor
Chairman
Wayne S. Winters
Vice Chairman
Todd G. Weston
James G. Larkin
John T. Dunlop
Elva H. Anderson
Secretary

February 8, 1991

University of Nebraska
Civil Engineering Department
Attention: Ron Faller (402)472-6864

Dear Mr. Faller:

As discussed this morning, we have conducted the torque verses tension testing of four 1 inch diameter A-325 cadmium plated bolts. The bolts and nuts were not lubricated and the nut freely spun onto the bolt. The testing was done using a Wilhelm-Skidmore tension indicating device. The bolts were initially torqued up to 80 foot-lbs. and then backed off and then re-torqued to provide 1000 lbs. tension increments. The maximum tension tested was 10,000 lbs. I have enclosed a copy of the spread sheet and plot of the data for your reference.

As you can see by the plot, three of the bolts were very similar in nature. However, there was one bolt which showed higher tension per torque than the other three. I attempted to the draw a line which showed a lower boundary. At that rate it would appear that for 70 foot-lbs. of torque there would be 4300 lbs. of tension generated. If an average value were used, it would appear that the tension at 70 foot-lbs. of torque would be slightly less than 4000 lbs. It would be my judgment that the average value would be a more meaningful value to use.

I hope that this provides you with the necessary information that you need. If you have any questions or if I can be of any assistance, please feel free to give me a call.

Yours truly,

David L. Christensen, P.E.
Chief Structural Engineer

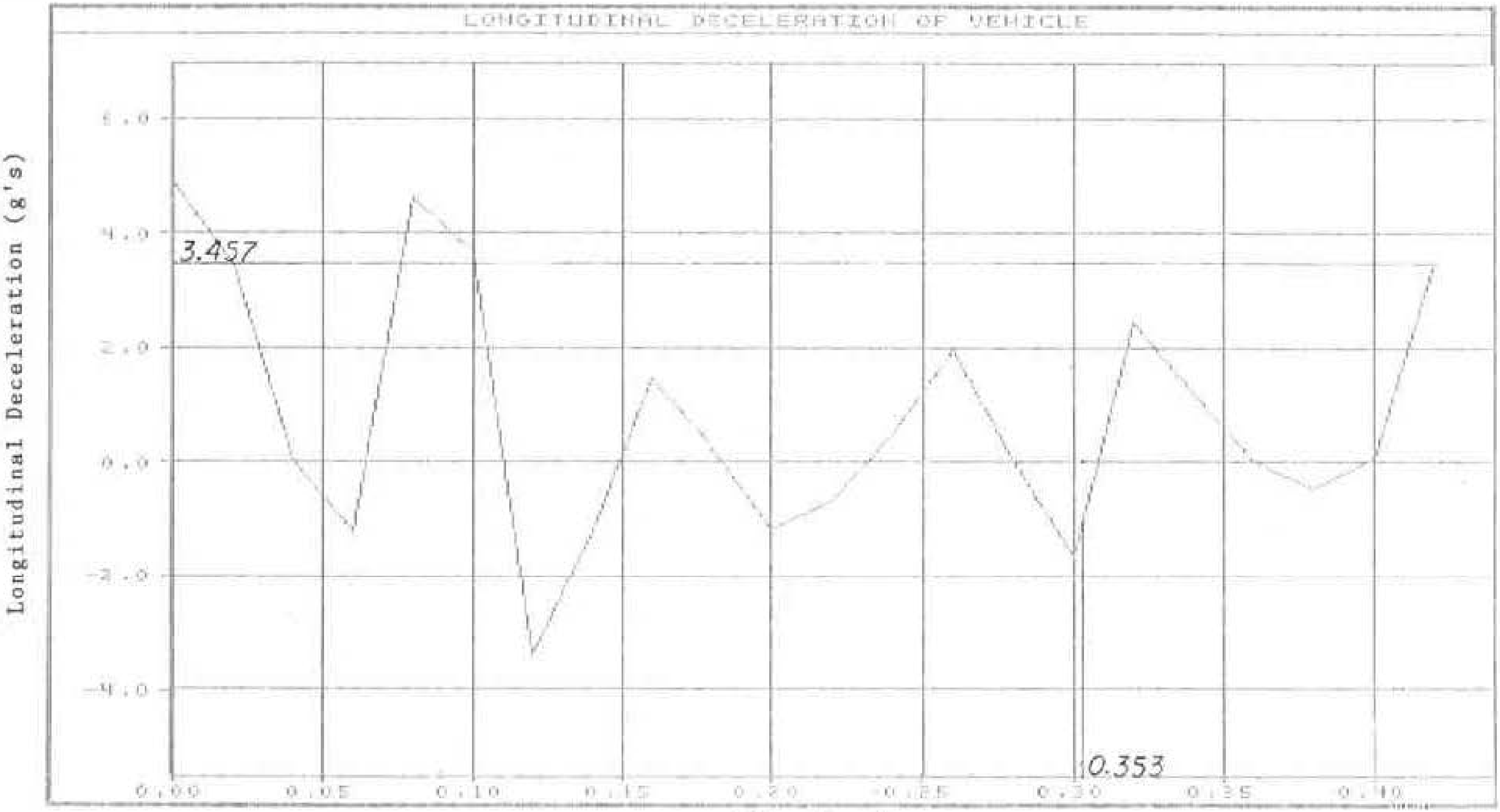
Enclosures

SLIP BOLTS FOR LUMINAIRE BREAKAWAY BASE
TORQUE VS TENSION

TENSION	TORQUE			
	BOLT 1	BOLT 2	BOLT 3	BOLT 4
1000	20	25	20	20
2000	50	45	45	40
3000	60	65	60	50
4000	85	85	80	65
5000	100	100	100	80
6000	125	120	120	100
7000	140	150	150	120
8000	165	165	165	140
9000	175	200	180	155
10000	200	210	205	175

Appendix C

High-Speed Film Analysis



Time (sec)

Figure C-1. Graph of Longitudinal Deceleration, Test USBLM-1

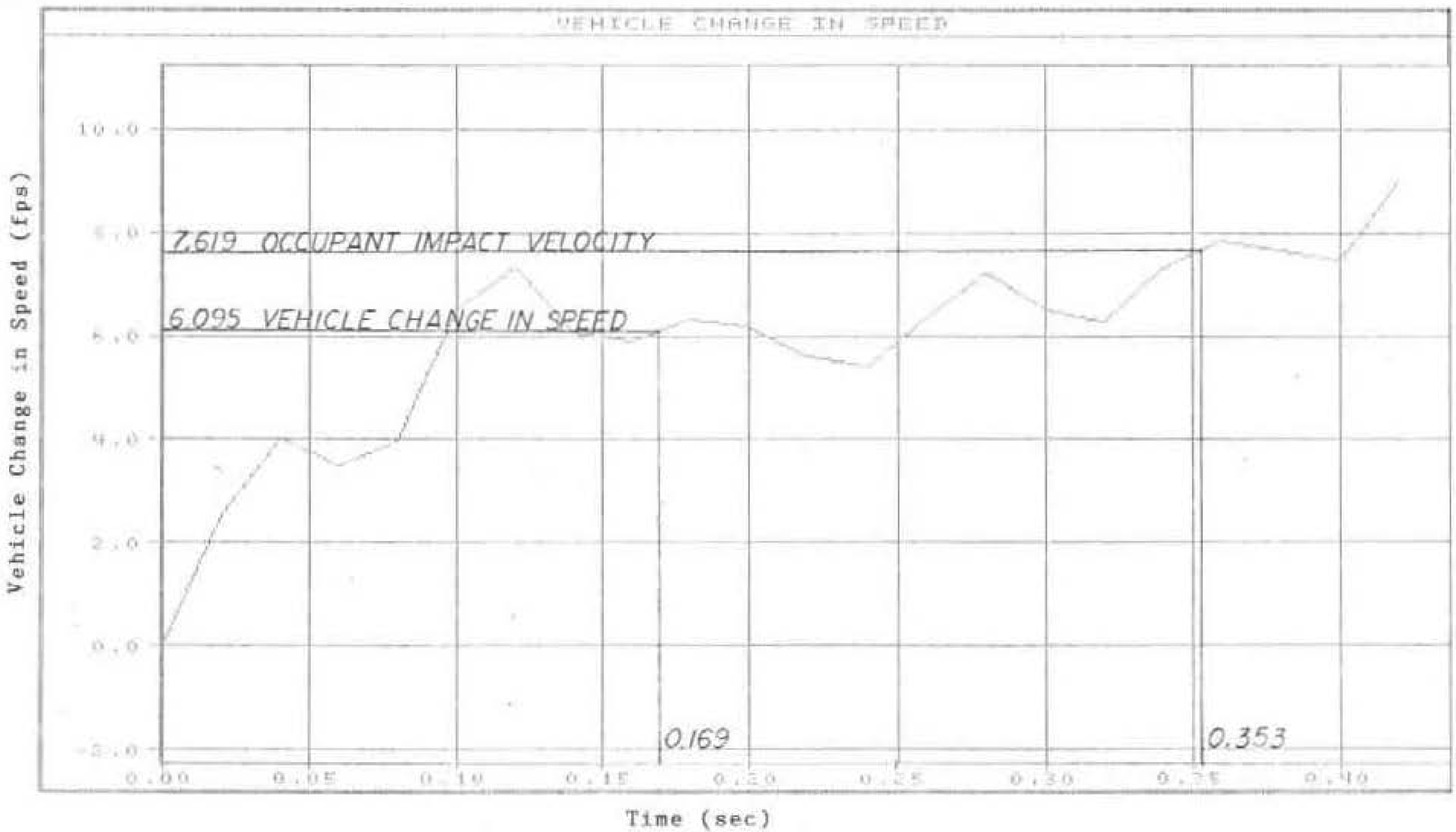


Figure C-2. Graph of Vehicle Change in Speed, Test USBLM-1.

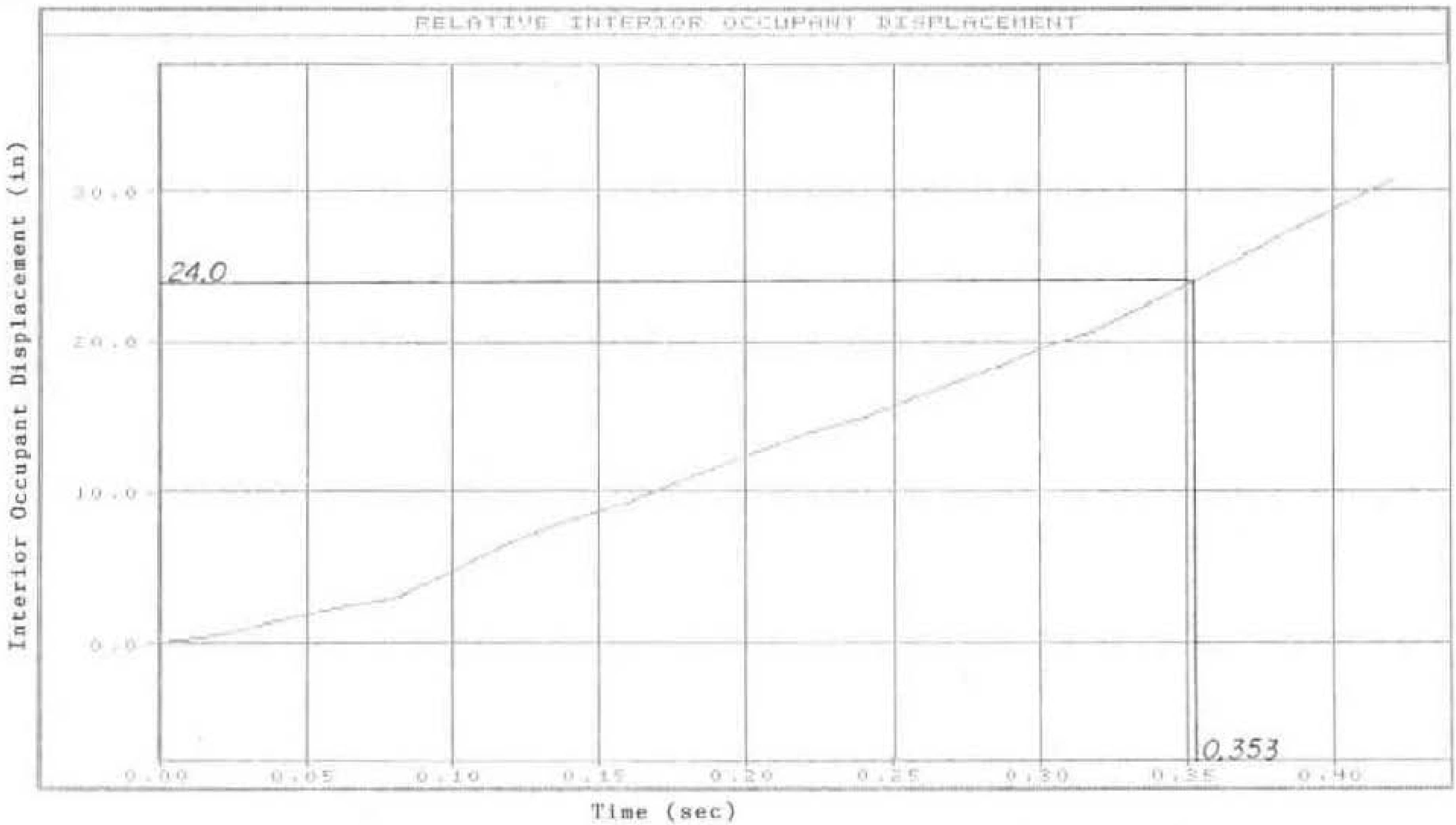


Figure C-3. Graph of Relative Interior Occupant Displacement, Test USBLM-1.

Figure C-4. Graph of Longitudinal Deceleration, Test USBLM-2.

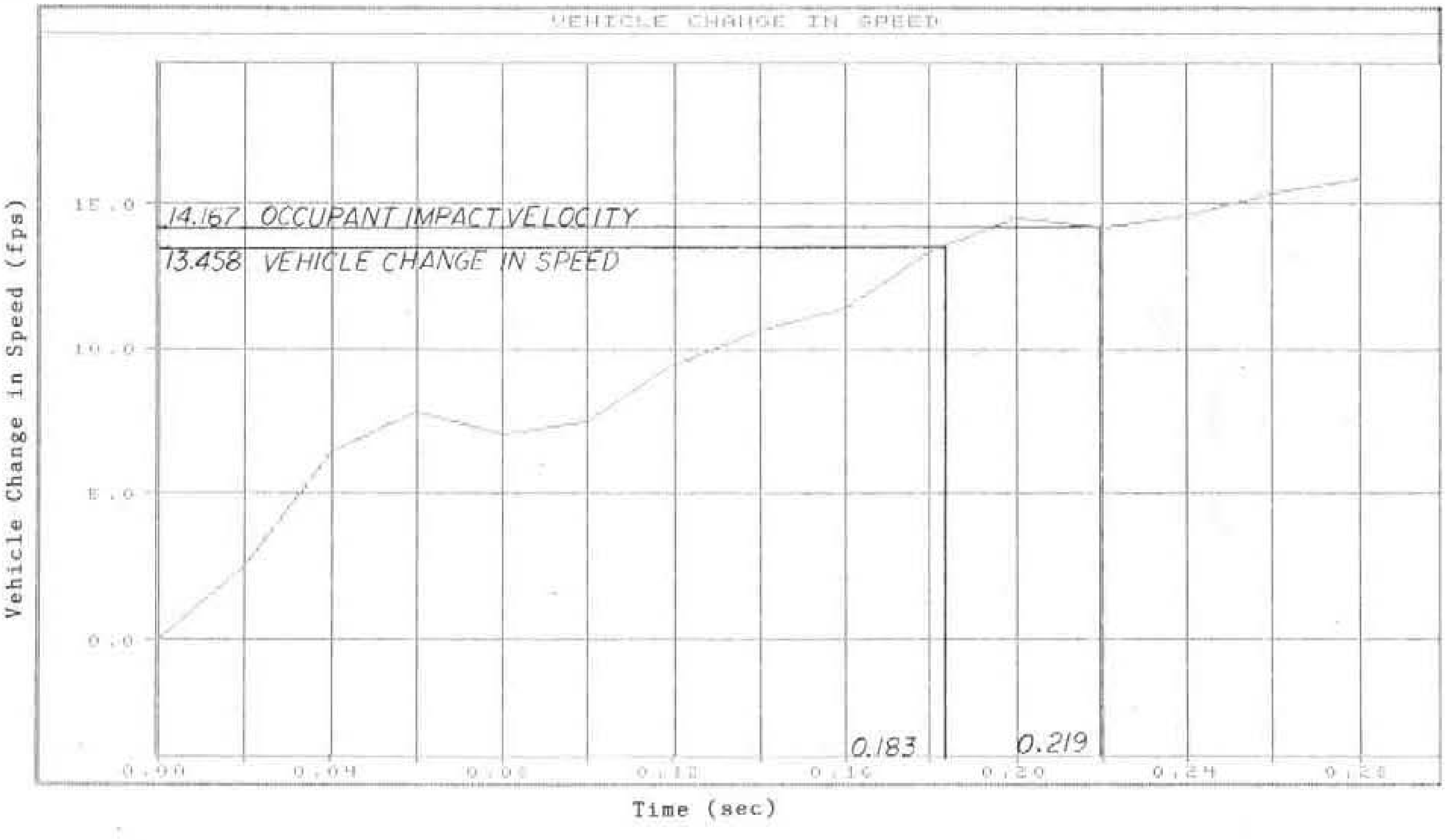


Figure C-5. Graph of Vehicle Change in Speed, Test USBLM-2.

Figure C-6. Graph of Relative Interior Occupant Displacement, Test USBLM-2.