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Highway Standards

HIGHWAY RESEARCH REPORT

DYNAMIC TESTS OF FIVE BREAKAWAY LIGHTING STANDARD BASE DESIGNS

By
Eric F. Nordlin
Wallace H. Ames and Robert N. Field

Presented at the 48th Annual Meeting
of the Highway Research Board
January, 1969

STATE OF CALIFORNIA

TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

RESEARCH REPORT

NO. M & R 636408

69-4

Prepared in Cooperation with the U.S. Department of Transportation, Bureau of Public Roads January, 1969

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State of California
Department of Public Works
Division of Highways
Materials and Research Department

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FIVE BREAKAWAY LIGHTING STANDARD BASE DESIGNS

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DYNAMIC TESTS OF FIVE BREAKAWAY LIGHTING STANDARD BASE DESIGNS

Informative Abstract

A study to determine the effectiveness of five breakaway lighting standard base designs in reducing the severity of vehicle impacts is reported. Ten head-on full scale dynamic tests involving identical 1966 sedans weighing 4,540 lbs were conducted on 30 ft lighting standards mounted on the various frangible or slip base designs. All of the standards were steel with the exception of one aluminum design.

The impact tests were conducted as follows: (1) Three 40 mph tests on a 6-in. high cast aluminum insert base, one on the basic design and two on modified versions, (2) three tests on a notched bolt insert design, two at 40 mph and one at 15 mph, (3) two tests on a multi-directional steel slip base design developed by Texas Transportation Institute, one at 40 mph and one at 15 mph, (4) one 15 mph test on a 20-in. high aluminum transformer base, and (5) one 40 mph test on an aluminum standard fitted and epoxy cemented to an 18-in. high cast aluminum sleeve type base.

All of the breakaway base designs tested at moderate impact speeds (± 40 mph) broke away with tolerable impact resistance. The Texas slip base and the notched bolt insert designs offered the least resistance at this speed. The impact resistance of the notched bolt insert showed a marked increase when the impact speed was reduced to 15 mph. Similar resistance was experienced in the 15 mph test on the 20-in. high aluminum transformer base. However, the impact resistance of the multi-directional slip base was essentially the same when impacted at 15 mph as it was at 40 mph, supplementing and substantiating the findings of T.T.I. that this is one of the most effective designs for reducing the severity of vehicle impacts into lighting standards at all speeds and angles.

- -

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ABSTRACT

REFERENCE: Nordlin, Eric F., Ames, Wallace H., and Field, Robert N., "Dynamic Tests of Five Breakaway Lighting Standard Base Designs", State of California, Transportation Agency, Department of Public Works, Division of Highways, Materials and Research Department.

ABSTRACT: A study to determine the effectiveness of five breakaway lighting standard base designs in reducing the severity of vehicle impacts is reported. Ten head-on full scale dynamic tests involving identical 1966 sedans weighing 4,540 lbs were conducted on 30 ft lighting standards mounted on the various frangible or slip base designs. All of the standards were steel with the exception of one aluminum design.

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KEY WORDS: Dynamic tests, impact tests, vehicle dynamics, lighting standards, luminaire supports, breakaway devices.

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ACKNOWLEDGEMENTS

This work was accomplished in cooperation with the United States Department of Transportation, Federal Highway Administration, Bureau of Public Roads, as Item D-4-71 of Work Program HPR-1 (4), Part I, Research. The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Bureau of Public Roads.

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TABLE OF CONTENTS

		Page
I.	INTRODUCTION	1
II.	CONCLUSIONS	2
III.	DESIGN AND PERFORMANCE	2
IV.	GENERAL OBSERVATIONS	11
V.	REFERENCES	12
VI.	APPENDIX	13
TABLE I	Dynamic Data	
Plate 1	Sequence Photos (Test Nos. 181, 182, 183, 191, 192)	
Plate 2	Sequence Photos (Test Nos. 193, 194, 195, 196, 197)	
Plate 3	Deformation of Vehicles	
Plate 4	Pole Locations Before and After Impact	
Plate 5	Frangible Al. Base Insert (Unmodified) (Test 182)	
	Frangible Al. Base Insert (Modification #1) (Test 183)	
	Frangible Al. Base Insert (Modification #2) (Test 191)	
	Notch Bolt Insert Detail (Tests 181, 192, 194)	
Plate 6	Cast Al. Sleeve Base (Test 193)	
	Cast Al. Transformer Base (Test 197)	
Plate 7	Texas Slip Base (Tests 195, 196)	
Plate 8	Impactograph Data	

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I. INTRODUCTION

California's increased emphasis on highway safety has included a concentrated effort to minimize the potential hazard of fixed objects on the roadside. The 1967 accident statistics for "ran-off-the-road; hit-fixed-object" fatal accidents in California show an improvement over those for 1966. However, this type of accident continues to be the most prevalent on California freeways with impacts into lighting standards accounting for 15 fatalities in 1967. At the present time, in excess of 30,000 rigidly mounted lighting standards are located along California's highways and present potential hazards of varying degrees to the motoring public.

The primary purpose of the research project reported herein was to determine or develop, through full scale dynamic impact testing, the most effective breakaway device that can be utilized in a traffic vulnerable lighting standard installation to reduce the severity of vehicle impacts at highway operating speeds. Data from other researchers[1,2] were thoroughly analyzed and considered fully in deciding which breakaway base designs to test.

After reviewing the data from the initial six 40 mph tests of this series, there were some reservations regarding low speed impact performance. The first low speed test at 15 mph confirmed our suspicions that a base design that breaks away effectively when impacted at 40 mph can, in fact, be an almost immovable object when subjected to low speed impacts approaching a static loading condition. A review of resulting damage in low speed tests reveals severe vehicular front end deformations, which we consider to be relatable to the damage that is often sustained by a broad-sliding vehicle impacting a fixed object within the limits of the passenger compartment (see Plate 3). After reviewing the data films from the low speed tests, consideration was given to continuing the research project by simulating side impacts. However, no matter how conclusive the results would be for a given vehicle, they would be representative only of the damage that could be expected from side impacts on that particular vehicle. Furthermore, in the final analysis it appears that the most effective breakaway base simply offers the least resistance to vehicle impact at all angles yet is capable of resisting the operational loads imposed upon it.

It was significant to note that with an 18 ft setback from the edge of pavement, just one of the three standards tested at low speeds would have fallen into the traveled way (Plate 4). In general, the pole reactions in this test series correlate well with work by other researchers with mathematical models, dynamic tests, and field performance[2,3,4]. Of particular significance is the post-impact position of the lighting standard supported on the slip base design for the 15 mph impact.

Discussion of the data reported herein is limited to the most significant findings. Sequence photos, damage photos, and dynamic data derived from high speed photography are presented as evidence of the relative efficiency of the five devices tested.

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II. CONCLUSIONS

All designs tested offer a significant reduction in impact resistance at moderate impact speeds (± 40 mph) when compared to conventional rigid base designs. The Texas Transportation Institute multi-directional slip base and the notched bolt designs offer the greatest reductions in impact resistance of those tested at this speed in this test series. However, the commonly used 20-in. high cast aluminum transformer base and the experimental notched-bolt insert designs offer little reduction in impact resistance when impacted at lower speeds (15 mph). Based on the data derived from the ten impact tests, the over-all breakaway performance of the T.T.I. multi-directional slip base design at both high and low speed impacts is considered to be superior to all other designs tested in this project.

Caution should be used in locating any breakaway lighting standard close to the traveled way. Pole trajectories after impact indicate that the problem of pole encroachment into the traveled way is minimized with the T.T.I. slip base design. Even at a 15 mph impact speed, the slip base was carried approximately 40 ft beyond the foundation and in the direction of impact, resulting in the least encroachment toward the traveled way of the three designs tested at that speed.

III. DESIGN AND PERFORMANCE

Common to all tests was the 28-ft 6-in. high lighting standard with 12-ft mast arm and 30-ft luminaire mounting height. For all tests except 193, the lighting standards and mast arms were steel (California Type XV). For Test 193, the lighting standard and mast arm were aluminum. All luminaires were 400 watt mercury vapor that weighed 25 lbs with aluminum shell. Radio controlled vehicles were impacted head-on into the standards with the planned point of contact near the midpoint of the bumper. The path of the impacting vehicles was parallel to the simulated edge of a highway pavement in the direction of travel. The test vehicles were 1966 sedans weighing 4,540 lbs gross, including all test equipment and the dummy, with a bumper height of 22 in. This 22-in. height is to the leading edge near the top of the bumper where it makes initial contact with the pole. Crash vehicles for the 40 mph tests were under power through impact. For the 15 mph tests, the ignition was turned off 10 ft before contact and the vehicle was permitted to coast through impact. The anthropometric dummy was unrestrained for all tests.

Table I presents the dynamic data from all ten tests and Plates 1 and 2 show sequence photos of each dynamic test.

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It is important to note that load transfer from the vehicle to the lighting standard occurs at a point approximately 22 in. above the ground. In all tests conducted during this series, local deformation of the pole at this 22-in. height is coincident with the bumper height of the typical 1966 and later vehicles. Breakaway lighting standards impacted with older test vehicles with lower bumper heights would likely indicate more effective breakaway performance than is warranted under current operating conditions. In other words, the lower the impact point, the more effectively the load will be transmitted into any base type breakaway device before collapse of the pole occurs. Therefore, when comparing test results of other researchers with the results of this series, correlation as to the effectiveness of any particular device may not, in all cases, be evident.

Cast Aluminum Insert Base (Tests 182, 183, and 191)

The 6-in. high frangible aluminum insert bases used for these three tests were cast from material conforming to the requirements of ASTM Designation: B-108, alloy SG70A, heat treated to a T-6 temper. The side wall thickness of the casting was 1/4 in.

Test 182 was conducted at 40 mph on an unmodified cast aluminum insert with the hand hole facing away from the traveled way. See Figure 1A and Plate 5 for design details. As the base failed on impact the standard was kicked up and ahead of the test vehicle (Figure 1B).

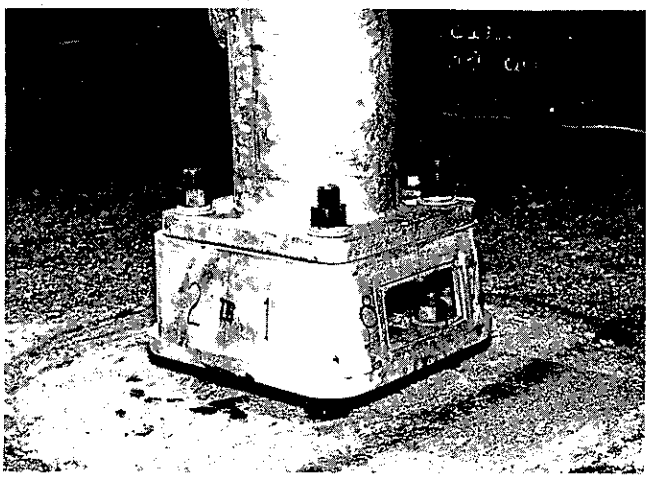

Figure 1A

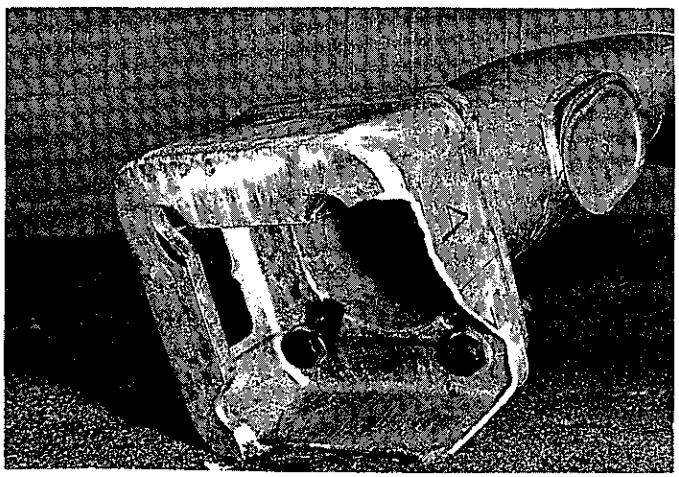

Figure 1B

The lower portion of the pole shaft hit the roof as the test vehicle progressed under it. The top of the pole shaft came to rest about 30 ft beyond the foundation.

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The force of impact not only collapsed the front end of the test vehicle about 24 in. but the pole shaft was damaged beyond repair with a 30 deg bend at the point of contact. In addition the foundation anchor bolts were bent approximately 30 deg away from the direction of impact.

Test 183 was conducted at 40 mph on a cast aluminum insert base modified by drilling a series of four one-inch dia. holes at 2-1/2-in. centers in each of the three side walls (modification #1) and the hand hole was oriented toward impact. See Figure 2A and Plate 5 for design details. It was anticipated that the base would fracture through this weakened cross section, thus reducing the impact resistance. However, upon impact, the base failed through the base flange in much the same manner as in the preceding Test 182. There was no evidence of fracture through the weakened plane of the drilled holes (Figure 2B).

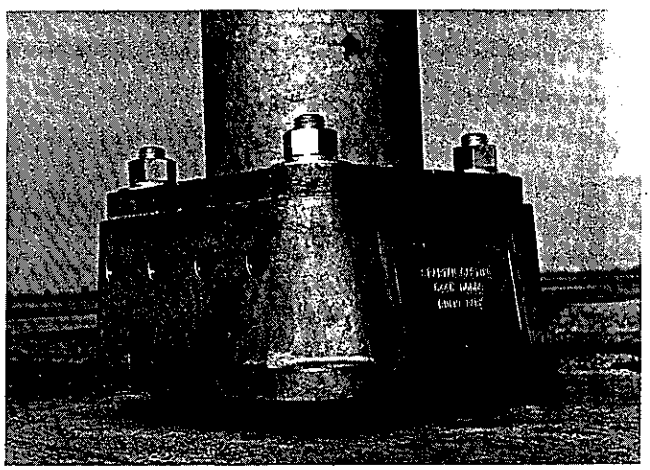

Figure 2A

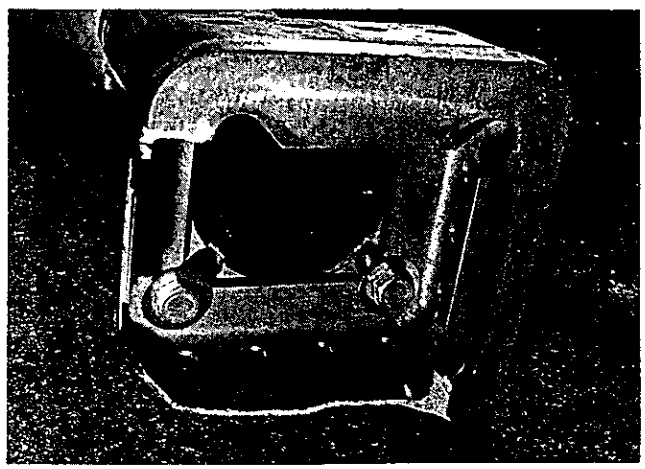

Figure 2B

The lighting standard was kicked ahead and up, clearing the vehicle by 3 ft as it passed through the impact zone. It settled to the pavement with the top approximately 35 ft beyond the anchorage. The shaft was bent to approximately 25 deg at the point of first contact and was damaged beyond repair. The anchor bolts were bent approximately 30 deg. Vehicle damage was much the same as sustained during Test 182 with 20-in. deformation to the front end.

Test 191 was conducted at 48 mph on the cast aluminum insert base mounted on the same anchorage as was used for Test 182 (the previously damaged bolts were repaired by straightening and welding on new studs). In a further effort to reduce the impact resistance noted in Tests 182 and 183, two 1-in. by 3-1/4-in. slots were milled through the three side walls near the base flange (modification #2) where the fracture occurred in the insert

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bases in the preceding two tests. See Figure 3A and Plate 5 for design details. The hand hole was oriented facing away from the traveled way. Upon impact, the aluminum insert again failed in a combination of shear and tension with the fracture taking place through the milled slots as anticipated (Figure 3B).

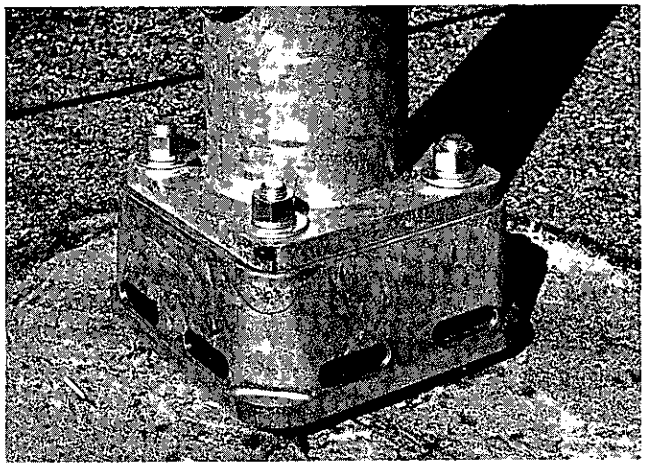

Figure 3A

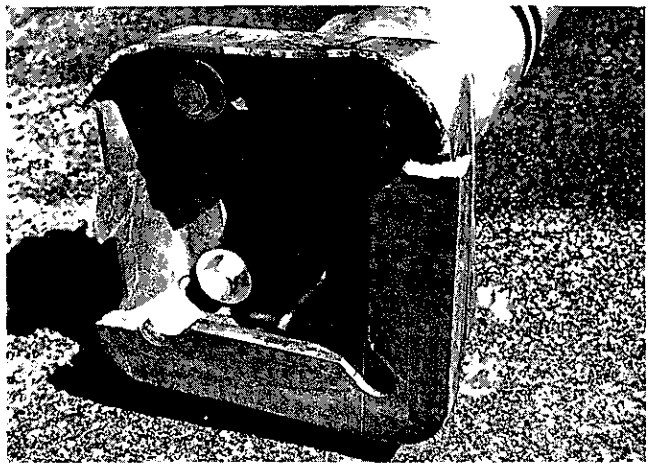

Figure 3B

The two right hand bolts were bent 30 deg and the two left hand bolts were sheared off at the surface of the concrete foundation. The lighting standard was kicked ahead and up, clearing the vehicle by 7 ft as it passed through the impact zone. The top of the pole settled to the pavement 25 ft beyond the anchorage. The shaft was dented 2 in. and was not considered salvageable. The vehicle sustained the least front end deformation (19 in.) observed in the three frangible aluminum insert tests.

The performance of the 6-in. cast aluminum insert with the second modification as in Test 191 under moderate impact was satisfactory. However, due to concern over the loss of side wall cross section induced by the slots, it was concluded that this device should not be adopted as a design standard unless subsequent cyclic vibration tests are performed to insure that wind loads would not cause premature operational fatigue failure. Such tests were not within the scope of this research study.

Notched Bolt Inserts (Tests 181, 192, and 194)

A notched bolt insert concept designed to provide structural support equivalent to that provided by the conventional ASTM A-307 anchor bolt but with a notch machined therein to induce instantaneous shear failure under lateral impact was proposed as a breakaway device. Three impact tests were performed on

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installations incorporating the notched bolt inserts, two at 40 mph and one at 15 mph. The notched bolts were fabricated from 17-4 PH stainless steel which is a martensitic precipitation hardening stainless steel of high tensile strength and low impact resistance. Although maximum strength and hardness are achieved by hardening at 850 F., in this condition, the material is brittle and the fatigue characteristics are questionable for this application. As the hardening temperature is increased the material has better fatigue characteristics, better corrosion resistance, and is less susceptible to stress corrosion cracking. However, as the heat treating temperature is increased, the impact resistance is also increased.

Test 181 was conducted on bolts heat treated at 950 F and Tests 192 and 194 used bolts heat treated at 1050 F. Prior to heat treating, a notch is machined in the bolt insert to reduce its diameter from the standard 1 in. to 7/16 in. See Plate 5 for details. The notched inserts are threaded into 3-in. long sleeve nuts which in turn are threaded onto the regular anchor bolt.

Test 181 was conducted at 40 mph on the assembly shown in Figure 4. Upon impact the lighting standard was kicked ahead and up and cleared the vehicle by 6 ft as it passed through the impact zone. The top of the pole came to rest 16 ft beyond the anchorage. Damage to the lighting standard consisted of a minor dent at the point of contact with the vehicle. Although the A-307 anchor bolts bent 30 deg, they were successfully straightened for use in a succeeding test. Vehicle deformation (18 in.) was less than sustained during any of the frangible aluminum insert tests. From the standpoint of impact resistance at 40 mph, the notched bolts performed efficiently and dummy driver decelerations were almost negligible. However, there is some concern as to the possibility of stress corrosion cracking occurring in this material in a 950° heat treatment condition after extended exposure to wind loading and accompanying vibration. It was therefore agreed that the heat treatment temperature should be increased to improve the fatigue characteristics. However, since an increase in treatment temperature also increases the impact resistance, another proof test was conducted using the revised heat treatment.

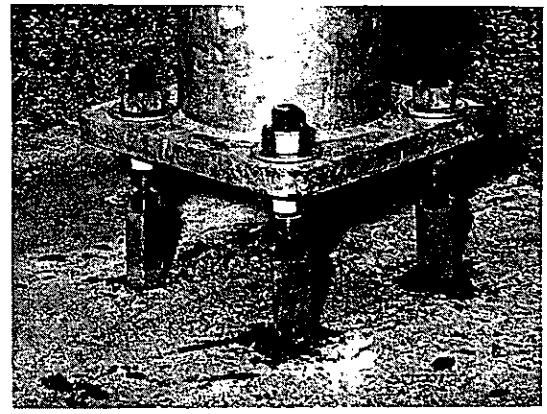

Figure 4

Test 192 was conducted at 40 mph on the same notched bolt insert design as was used for Test 181 with the following

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modifications: (1) heat treatment was increased from 950 deg to 1050 deg and (2) a 3-in. high grout pad was cast around the sleeve nuts and was epoxy bonded to the concrete foundation (Figure 5). Upon impact the notched bolts failed as before and the standard was kicked ahead and up 4 ft over the vehicle as it passed through the impact zone. The standard came to rest with the top approximately 12 ft beyond the anchorage. The point of impact was off-center on the vehicle bumper and close to the supporting brackets. Consequently, the vehicle sustained only very minor damage consisting of a 1-1/2-in. dent in the bumper and a slight dent in the grill and hood. The light standard was bent 10 deg and the steel pole base plate was deformed. The grout pad was damaged and broken out around the right sleeve nut. No discernible decelerations were recorded in the unrestrained dummy. Due to the off-center point of impact by the vehicle on the reinforced section of the bumper, no valid correlation could be made between the results of Tests 181 and 192 concerning the increase in impact resistance presented by the notched studs with the higher temperature treatment.

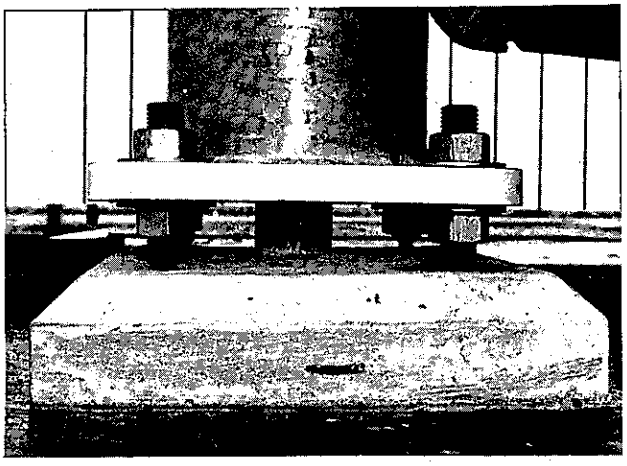

Figure 5

In the first notched bolt test (181) the vehicle experienced most of the damage, whereas the principal damage in Test 192 was sustained by the pole. Although the performance of this design when impacted at 40 mph was very satisfactory, a third test was considered necessary to determine the impact characteristics of the notched bolts at a lower speed under loading approaching a static condition.

Test 194 was conducted on the same notched bolt design as was used for Test 192 (1050 deg treatment and 3-in. grout pad around sleeve nuts) but with a 15 mph vehicle impact speed and the ignition cut off prior to contact (Figure 6). Upon impact, the bolts failed primarily in tension and the standard remained vertical and in contact with the car, "walking" for 6 ft before falling forward and to the left. The pole came to rest within 3 ft of the 18-ft offset line used to simulate the edge of pavement. The base of the standard remained under the front bumper 18-in. from the anchorage. The vehicle sustained

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extensive damage (21-in. deformation) but the lighting standard was only slightly dented. The test results from this 15 mph test indicate the performance of this device as a breakaway design to be marginal under low speed impact. Further research into the metallurgical properties of the 17-4PH steel is necessary before this concept could be accepted as an effective breakaway device for the inevitably wide range of operational impact conditions.

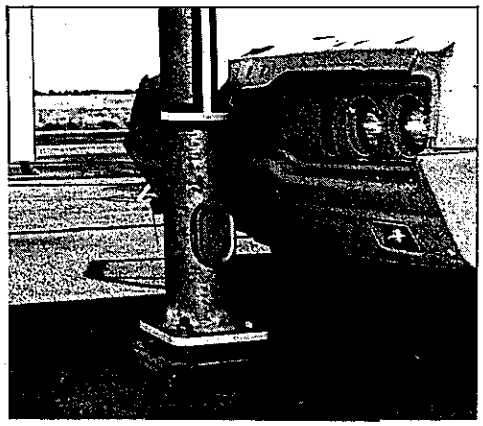

Figure 6

Cast Aluminum Sleeve Base W/Aluminum Pole (Test 193)

In this test the lighting standard consisted of a tapered, welded aluminum pole fitted and epoxy cemented to an 18-in. high cast aluminum sleeve shoe base (Figure 7A). The base extends 12-in. inside the aluminum pole. This serves not only as an effective structural connection but also reinforces the pole to resist collapse on impact and to more effectively transmit the impact load into the frangible base. See Plate 6 for design details.

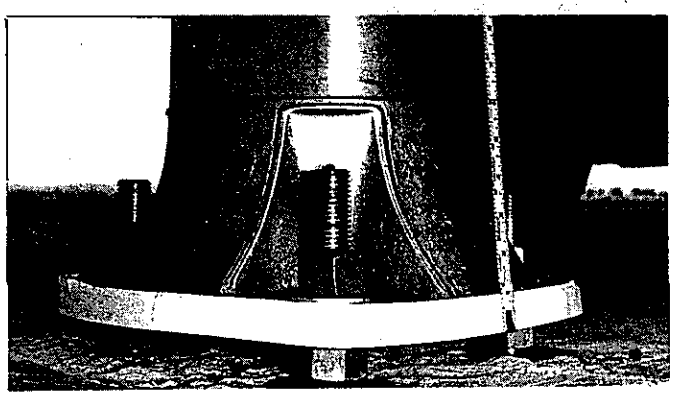

Figure 7A

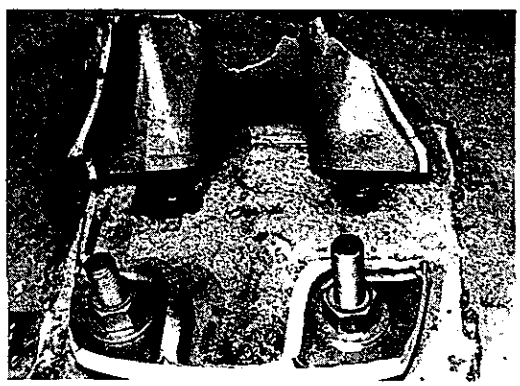

Figure 7B

The vehicle impacted the pole head-on at 40 mph. Upon contact the pole collapsed and bent to an angle of approximately 90 deg at a point 35 in. above the concrete foundation. As the cast aluminum base failed (see Figure 7B) the car bumper was deformed 19 in. into and back under the vehicle. The collapse

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and bending of the pole caused it to hang up under the bumper and remain in contact with the vehicle for a relatively long period of time. However, after releasing from the car, the pole cleared the vehicle by 4 ft and the top of the pole came to rest about 25 ft beyond impact. Vehicle decelerations were low and dummy decelerations were negligible. With the 22-in. bumper height (typical of most American passenger vehicles now in operation and production), the pole was contacted above the reinforced section. Consequently, as the pole collapsed, the load was transmitted to the base primarily in bending rather than in shear. The Texas Transportation Institute reported a more favorable breakaway action in a test on this base design using a 1958 model test vehicle with a 14-in. bumper height.

Cast Aluminum Transformer Base (Test 197)

The 20-in. high tapered cast aluminum alloy transformer base tested conforms to the requirements of ASTM Designation: B-108, alloy SG70A, heat treated to a T-6 temper. The top of the base accepts the 11-1/2-in. bolt circle steel lighting standard base and the bottom requires a 15-in. bolt circle. See Figure 8A and Plate 6 for design details.

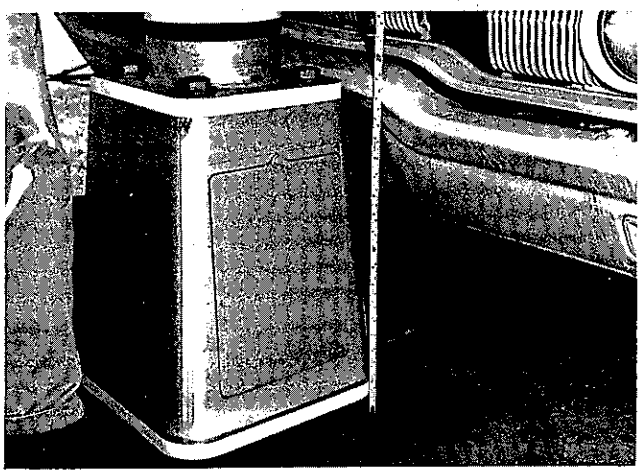

Figure 8A

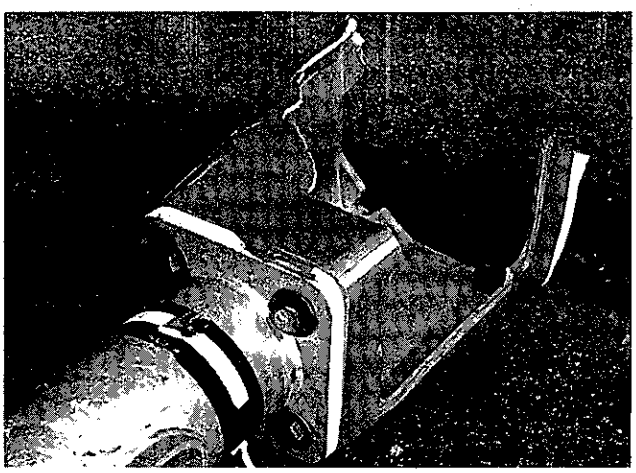

Figure 8B

The vehicle impacted near the top of the transformer base at a speed of 15 mph. The impact side of the base fractured but remained hung up on the anchor bolts. The remainder of the base (see Figure 8B) and lighting standard remained in contact with the vehicle and was pushed along in the vertical position for about 10 ft before falling ahead and to the left of the vehicle. A portion of the pole and the entire mast arm protruded 16 ft beyond the 18-ft offset simulating the edge of the traveled way. This test, as did that on the notched bolt insert design, illustrates the significant increase in impact resistance that might

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be expected with any frangible system as the impact velocity is decreased from the 40 mph to the 15 mph range.

Multi-directional Slip Base (Tests 195 and 196)

Two impact tests were conducted using a multi-directional slip base adapter patterned after (and very similar to) that developed and tested by the Texas Transportation Institute. However, some modifications were necessary to accommodate the California Type XV steel pole base configuration. Details of the design tested are shown in Plate 7.

The two 18-1/4-in. diameter 1-in. thick mild steel plates on the slip base were held together with three 1-1/4-in. black bolts conforming to ASTM Designation A-307 (Figures 9 and 10). Bolt torque was approximately 50 ft-lb which is equivalent to about 2000 lbs. bolt tension. Each of the top washers was pinned to the upper 1-in. plate with two 1/8-in. shear pins to prevent the bolts from walking out of the slots due to wind vibration.

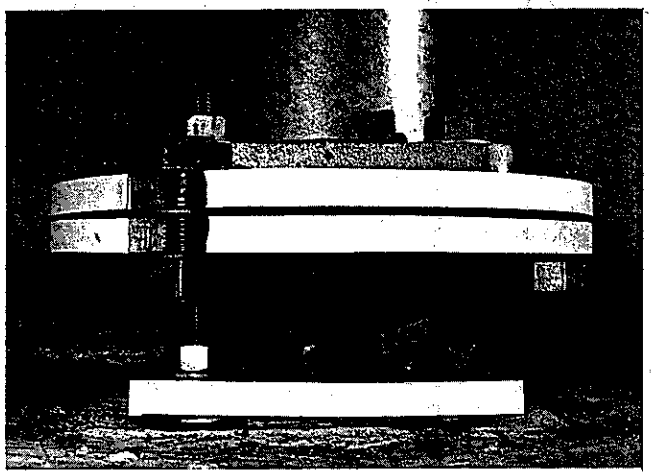

Figure 9

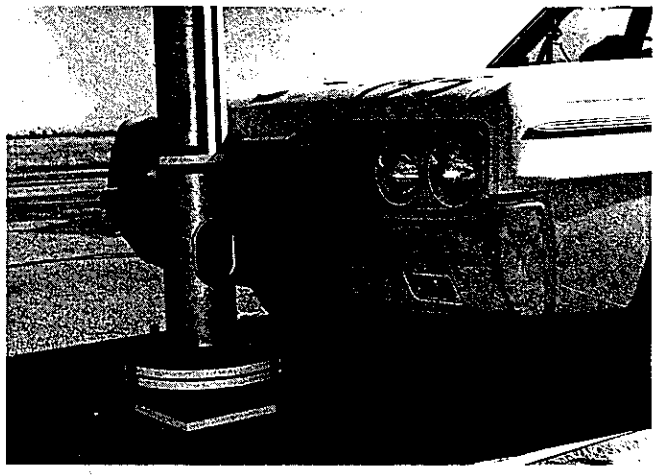

Figure 10

Test 195 was a 40 mph head-on impact. Upon contact, the base parted instantaneously and the pole kicked up and ahead, clearing the vehicle passing underneath by 5 ft. The luminaire broke loose from the mast arm and fell directly over the foundation. While falling the mast arm rotated 180 deg in the clockwise direction and the pole came to rest approximately on line 25 ft beyond impact. Vehicle damage was mild with only a 9-in. penetration into the hood and bumper.

Test 196 utilized the same slip base adapter as that used in Test 195. In fact, the installation and parameters were identical except that impact speed was reduced to 15 mph and the ignition on the test vehicle was cut off 10 ft prior to impact.

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As in the previous test, the pole again parted instantaneously on impact with very little damage to the front of the test vehicle (3-in. bumper penetration). However, because of the low impact speed, the pole did not kick up high enough to clear the test vehicle and fell back on top of it as it passed under, denting the roof and cracking the windshield. As the car continued under the pole, the pole base struck the rear part of the roof shattering the rear window. Judging by the minor extent of roof denting and by the broken glass, injuries to occupants of the vehicle, if any, would likely have been minor. This reaction (the pole falling on the vehicle) although not desirable, will doubtless occur with any breakaway device at certain critical low speeds.

Based on front end damage, high speed film analysis, and impactograph intensity readings, this low speed test was an extremely mild impact. Excluding the secondary impact, there was a momentum change of only 210 lb-sec. as compared with a 290 lb-sec. change for the 40 mph impact using this same base. This indicates that the impact resistance of the multi-directional slip base is relatively independent of impact speed, whereas other breakaway concepts, particularly when breakaway requires a frangible metal failure, are highly dependent on the rate of load application.

IV. GENERAL OBSERVATIONS

Vehicle Deformation:

Although the depth of the deformation of the bumper and hood of the vehicles used in this test series is subjective and should not be used as the sole criteria for basing the relative effectiveness of the various breakaway base designs, a close examination of the damage indicates that this information generally correlates with the change in speed through impact, and particularly the reaction of the dummy driver. The difference between 19, 20, and 21-in. deformation on the same model vehicle is important when observing the intimacy of adjacent collapsed parts and, particularly, the displacement of the engine and any localized buckling of the frame and body. Measurements indicate that a 20-in. deformation of the hood and bumper of the 1966 sedan is the maximum the vehicle can sustain before engine displacement and frame buckling occurs. For instance, the vehicle in Test 181 with 18-in. maximum deformation after impact required only a bumper, grill, radiator and fan to place it back in operating condition. Test vehicle 193, sustaining a 19-in. maximum deformation, required the same repair as 181 plus replacement of the water pump. The 21-in. maximum deformation of both hood and bumper resulting from Tests 194 and 197 displaced the engine and warped the frame resulting in the total loss of those vehicles. Plate 3 shows relative deformation of the test vehicles for the various tests.

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Consideration must also be given to the manner in which the lighting standard separates from the frangible base during impact. When the vehicle overrides the pole, such as experienced in Tests 182 and 193, extensive bumper deformation was noted, yet only moderate hood deformation and subsequent low dummy decelerations were recorded. Critical examination of the damage is therefore important and deformations reported in Table I must be interpreted subjectively along with photographs of the actual damage.

Impactograph Recordings:

Deceleration recordings traced by tri-axial mechanical stylus impact type instruments located in the chest cavity of the dummy and on the rear floor of the vehicle are presented in Plate 8. Deceleration readings from the impactograph are filtered values due to the low frequency response (23 cps) of the instrument. In effect, this means that the relatively smooth traces recorded in the dummy cover durations in excess of 40 milliseconds. However, the data is significant for comparison purposes with other tests.

As can be seen from the dummy's impactograph traces, the only tests showing deceleration forces of any significant magnitude were the low speed impacts using the notched bolt inserts and the 20-in. high cast aluminum transformer base as breakaway devices. This would likely be true of any breakaway system dependent on frangible metal failure.

V. REFERENCES

1. Edwards, T. C., "Multidirectional Slip Base for Breakaway Luminaire Supports", Research Report 75-10 Texas Transportation Institute, August 1967.

2. Rowan, N. J. and Edwards, T. C., "Impact Behavior of Luminaire Supports", Highway Research Record 222, 47th Annual Meeting HRB, January 1968.

3. Lazenby, J. G., "Progress Report on the Design Concept and Field Performance of Breakaway Devices for Illumination Poles in Texas", Region 6, Bureau of Public Roads, Fort Worth, Texas, February 1967.

4. Martinez, J. E., "An Analytical Solution of the Impact Behavior of Luminaire Support Assemblies", Highway Research Record 222, 47th Annual Meeting HRB, January 1968.

5. Hignett, H. J., "High Speed Impact Test On a 40 ft Lighting Column Fitted with a Breakaway Joint", Road Research Laboratory, Ministry of Transport, PRL Report LR 67.

6. Nordlin, E. F., "Dynamic Tests of Five Breakaway Lighting Standard Base Designs", California Division of Highways, Test Series XVIII and XIX, October 1968.

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VI. APPENDIX

TABLE I	Dynamic Data
Plate 1	Sequence Photos (Test Nos. 181, 182, 183, 191, 192)
Plate 2	Sequence Photos (Test Nos. 193, 194, 195, 196, 197)
Plate 3	Deformation of Vehicles
Plate 4	Pole Locations Before and After Impact
Plate 5	Frangible Al. Base Insert (Unmodified) (Test 182)
	Frangible Al. Base Insert (Modification #1) (Test 183)
	Frangible Al. Base Insert (Modification #2) (Test 191)
	Notch Bolt Insert Detail (Tests 181, 192,194)
Plate 6	Cast Al. Sleeve Base (Test 193)
	Cast Al. Transformer Base (Test 197)
Plate 7	Texas Slip Base (Tests 195, 196)
Plate 8	Impactograph Data

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BREAKAWAY LIGHTING STANDARDS

(Vehicle: 1966 Sedan – Weight 4,540 lbs. w/ instrumentation and dummy)

TEST NO.	181	182	183	191	192	193	194	195	196	197
SHAFT TYPE AND HEIGHT	Steel 28'-6"	Steel 28'-6"	Steel 28'-6"	Steel 28'-6"	Steel 28'-6"	Alum. 28'-6"	Steel 28'-6"	Steel 28'-6"	Steel 28'-6"	Steel 28'-6"
BASE TYPE	Notch bolts H-950°F	6" Frang. Alum. Insert	6" Frang. Al. Insert (Modif.#1)	6" Frang. Al. Insert (Modif.#2)	Notch bolts H-1050°F	Cast Al. Sleeve Base	Notch bolts H 1050°F	Texas Slip base	Texas Slip base	Alum. Trans. base
INITIAL (MPH)* VELOCITY	40±	39.7	41.2	47.7	39.9	38.2	14.8	40.4	15.8	15.8
FINAL (MPH)** VELOCITY	NO DATA	35.6	37.6	45.2	38.0	34.6	0	39.0	14.8	0
Δ VELOCITY (MPH)	NO DATA	4.1	3.6	2.5	1.9	3.6	14.8	1.4	1.0	15.8
Δ MOMENTUM (LB. SEC.)	NO DATA	850	750	510	390	740	3040	290	210	3270
TIME IN POLE CONTACT (SEC.)	NO DATA	0.170	0.212	0.136	0.107	0.197	2.54	0.114	0.130	3.76
TIME TO POLE RELEASE (SEC.)	NO DATA	0.024	0.025	0.018	0.009	0.027	0.115	0.009	0.010	0.470
DEFORMATION OF POLE	Minor	30° Bend	25° Bend	5° Bend	10° Bend	90° Bend	Minor	None	None	None
MAXIMUM VEHICLE DEFORM. HOOD	12"	12.5"	12"	12"	2"	9"	21"	9"	1.5"	21"
MAXIMUM VEHICLE DEFORM. BUMPER	18"	24"	20.5"	19"	2"	19"	21"	9"	3"	21"

* Initial Velocity – average velocity calculated over 1' interval prior to impact.

** Final Velocity – average velocity calculated over 1' interval after pole lost contact with test vehicle.

TABLE I

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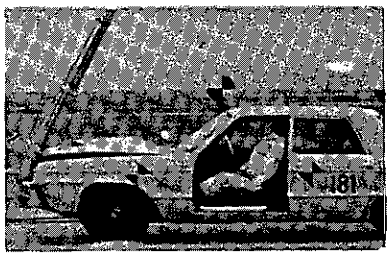
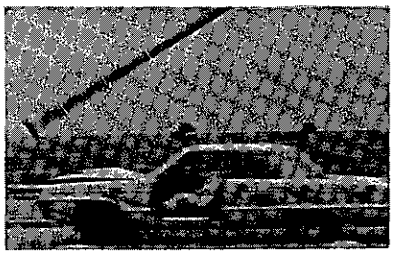
PLATE 1



TEST 181 IMPACT + 0.17 SEC



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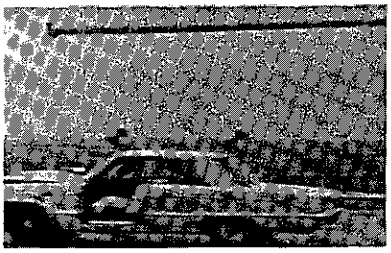
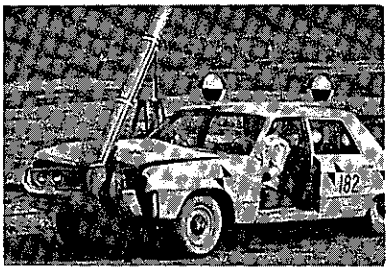
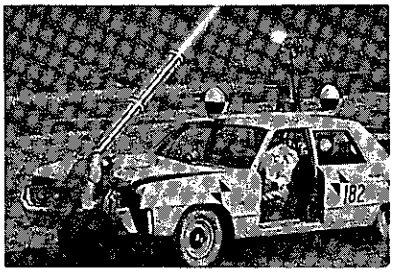


I + 0.59 SEC



TEST 182 IMPACT + 0.20 SEC



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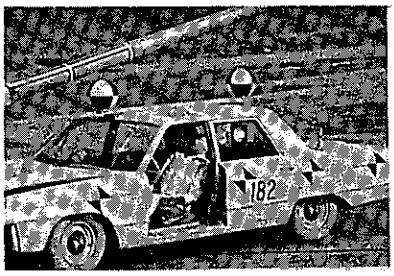

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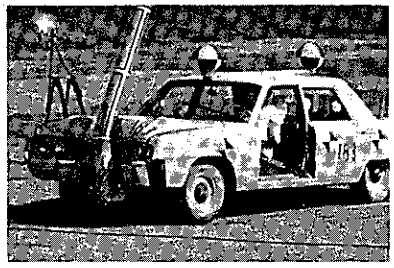
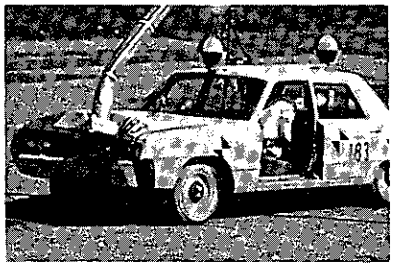
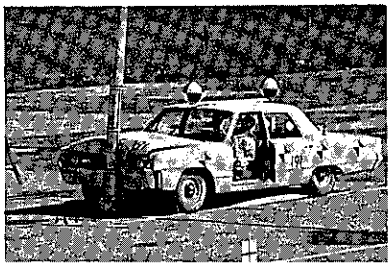


TEST 183 IMPACT + 0.25 SEC



I + 0.40 SEC

I + 0.75 SEC



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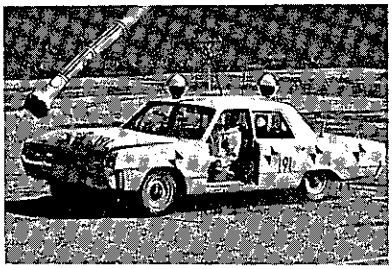

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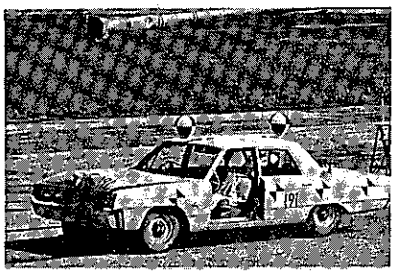
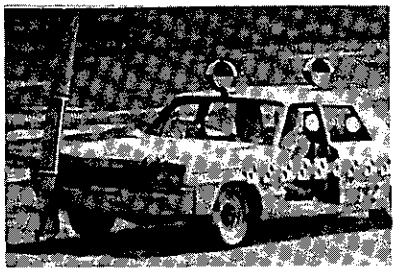


I + 0.55 SEC



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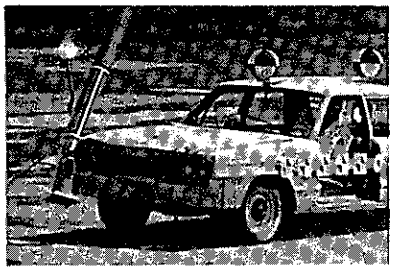

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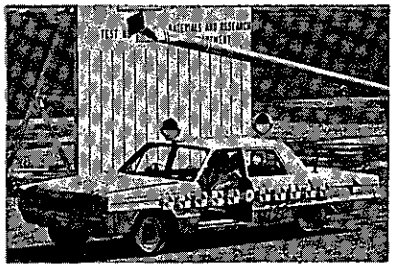

I + 0.75 SEC

TEST SEQUENCE PHOTOS

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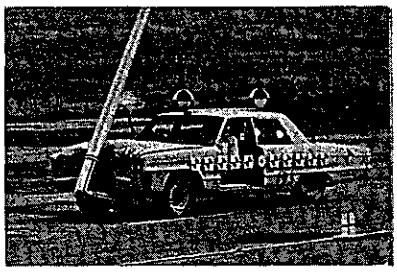

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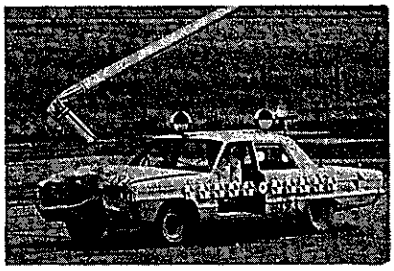

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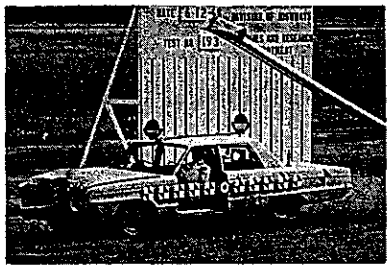
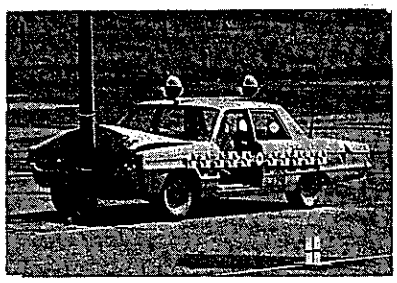
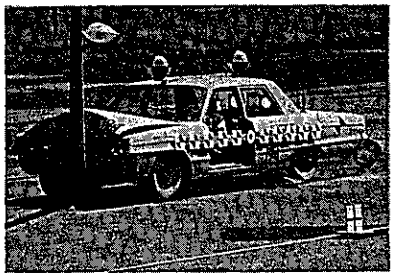


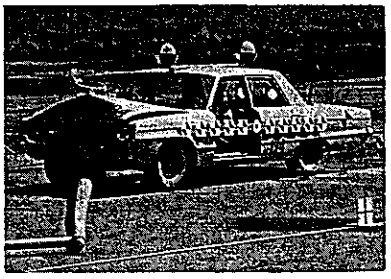
I + 0.95 SEC



TEST 194 IMPACT + 1.25 SEC



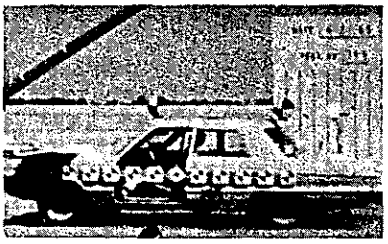
I + 2.35 SEC



I + 2.65 SEC

TEST 195 IMPACT + 0.07 SEC

I + 0.19 SEC



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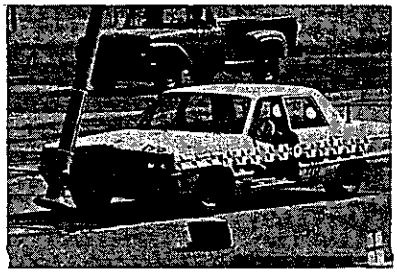
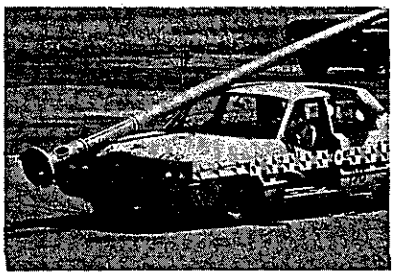
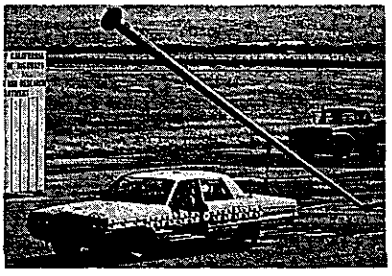


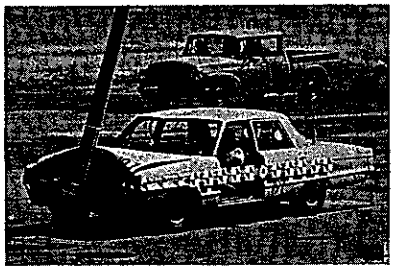
TEST 196 IMPACT + 0.25 SEC



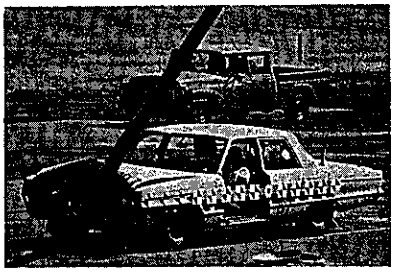
I + 0.95 SEC



I + 1.80 SEC



TEST 197 IMPACT + 1.75 SEC



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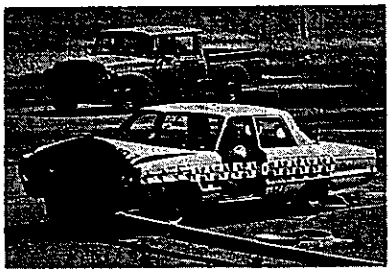

I + 3.55 SEC

TEST SEQUENCE PHOTOS

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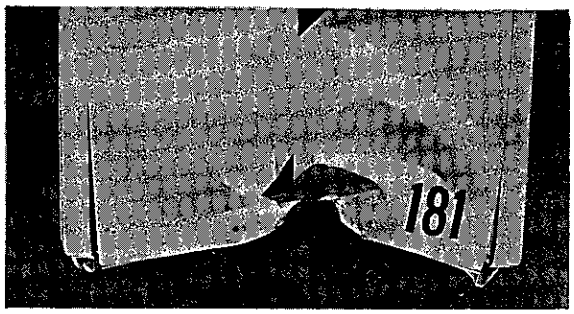
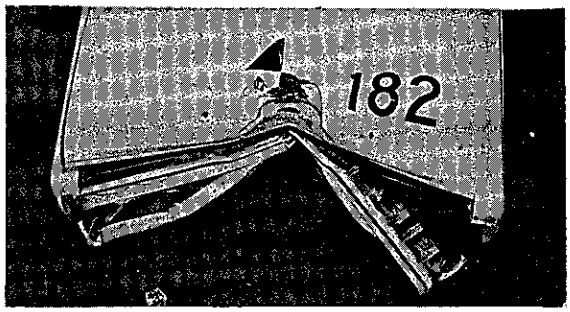
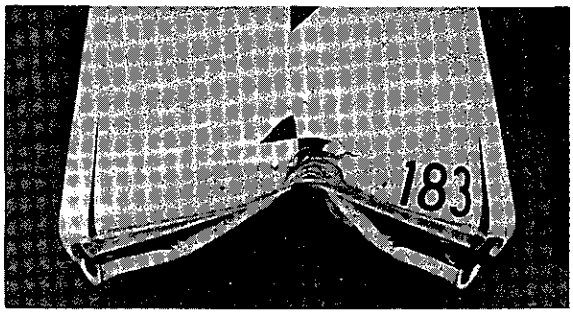
PLATE 3



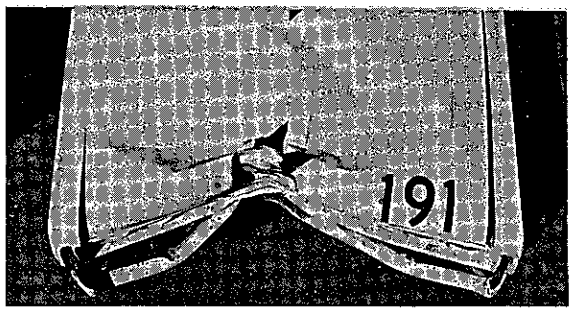
18" Def.



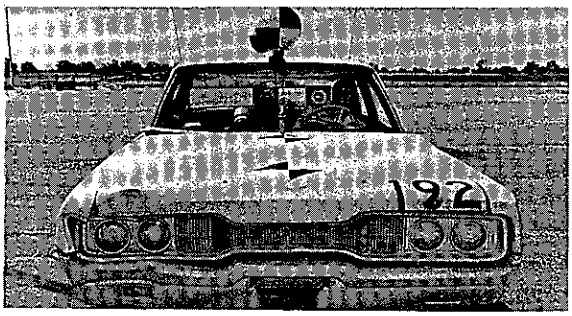
24" Def.



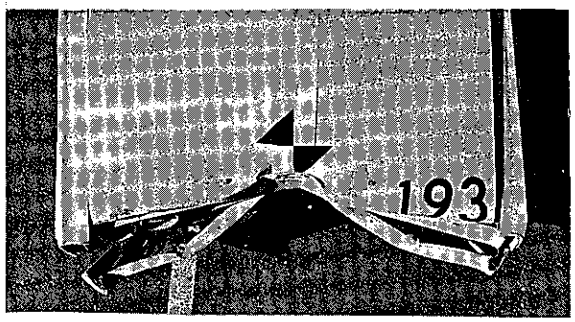
20" Def.



19" Def.



2" Def.



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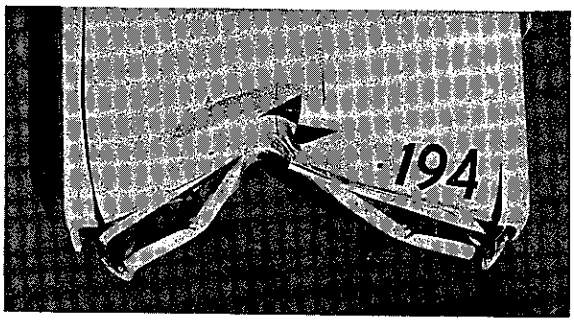
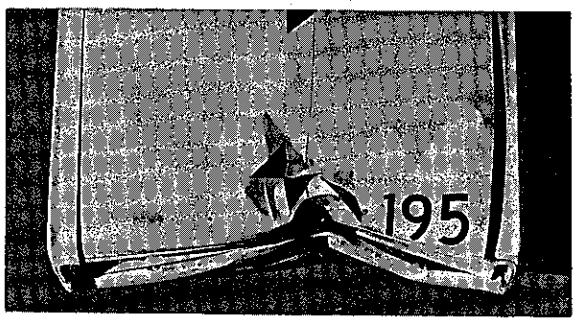
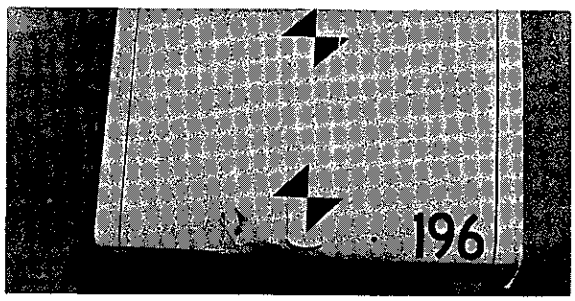


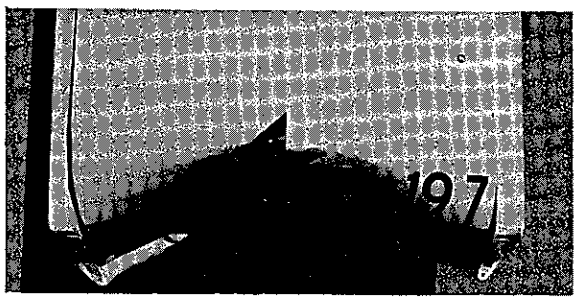
21" Def.



9" Def.



3" Def.



21" Def.

DEFORMATION OF VEHICLES

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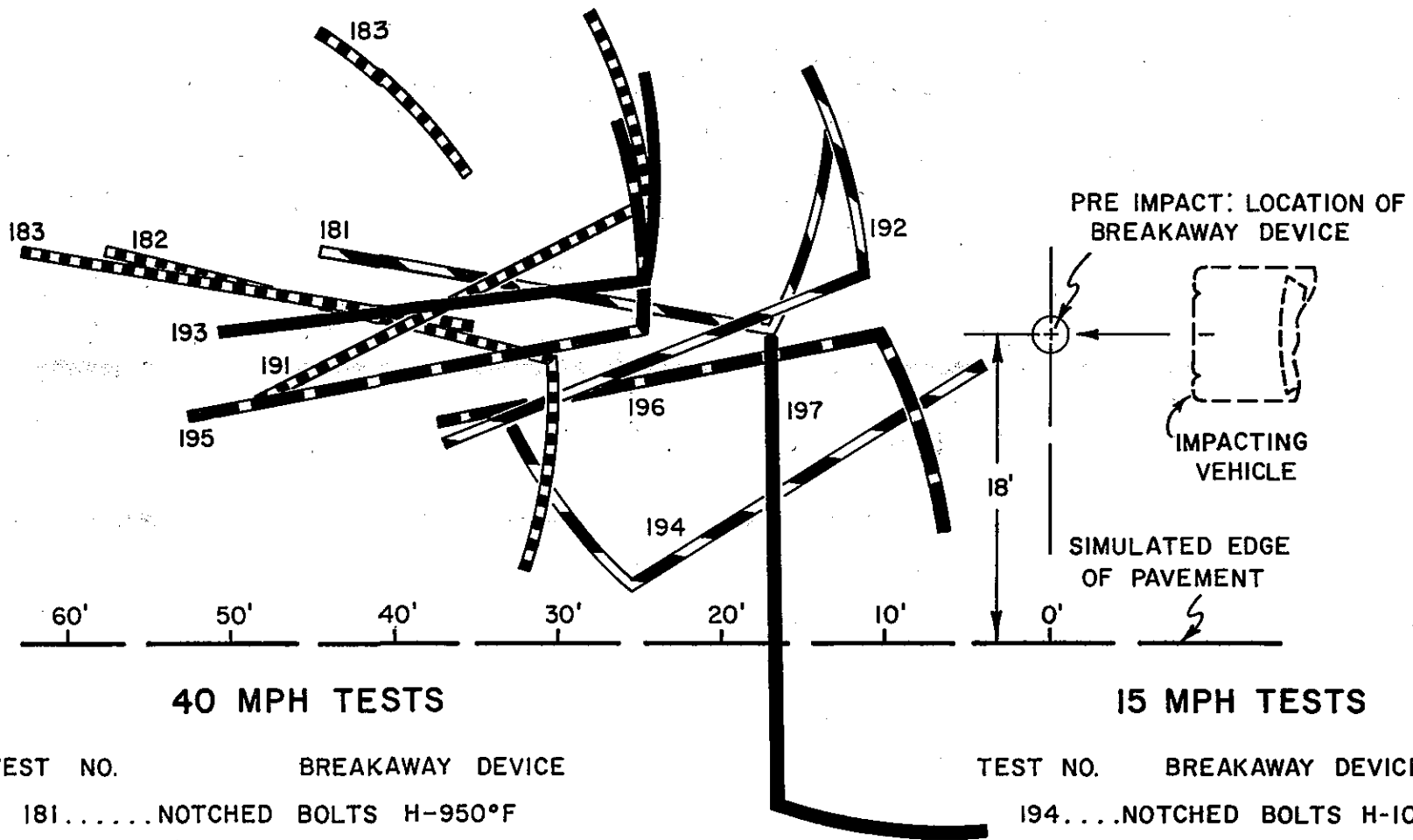


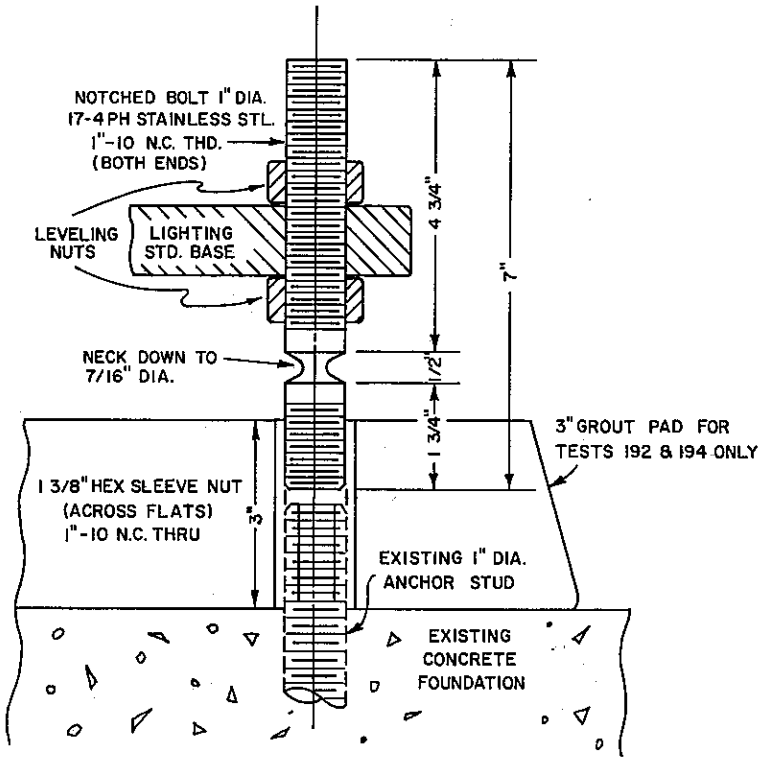
40 MPH TESTS

TEST NO.	BREAKAWAY DEVICE
181	NOTCHED BOLTS H-950°F
182	6" FRANGIBLE AL. INSERT
183	6" FRANGIBLE AL. INSERT (MODIF. #1)
191	6" FRANGIBLE AL. INSERT (MODIF. #2)
192	NOTCHED BOLTS H-1050°F
193	AL. SLEEVE BASE WITH AL. POLE
195	TEXAS SLIP BASE

15 MPH TESTS

TEST NO.	BREAKAWAY DEVICE
194	NOTCHED BOLTS H-1050°F
196	TEXAS SLIP BASE
197	AL. TRANSFORMER BASE

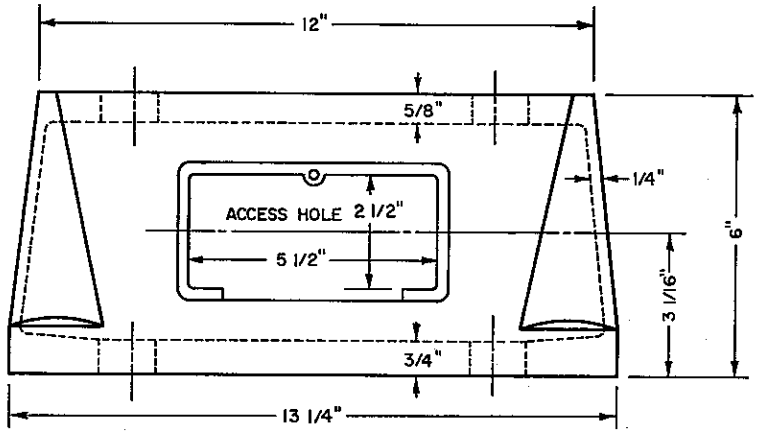
POLE LOCATIONS BEFORE & AFTER IMPACT



NOTCHED BOLT INSERT ASSEMBLY

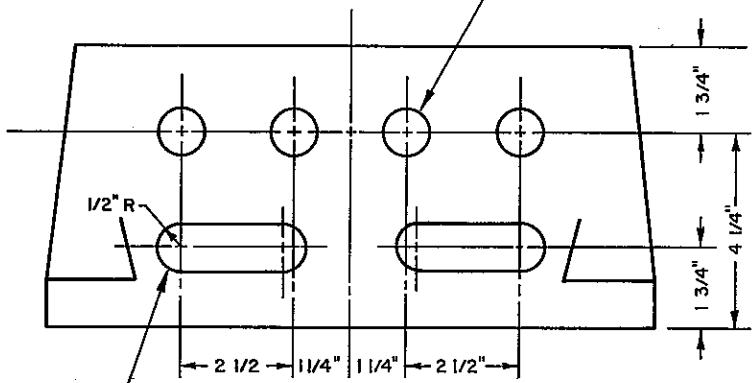
TESTS 181-192 & 194

UNMODIFIED BASE FOR TEST 182



BASE MODIFICATION #1 (TEST 183)

DRILL 1" DIA. THROUGH WALL
4 PLACES ON 3 SIDES
(12 HOLES TOTAL)



BASE MODIFICATION #2 (TEST 191)

MILL 1" x 3 1/4" SLOTS TROUGH WALL
2 PLACES ON THREE SIDES (6 SLOTS TOTAL)

6" FRANGIBLE ALUMINUM INSERT BASE

TESTS 182-183 & 191

Plate 5

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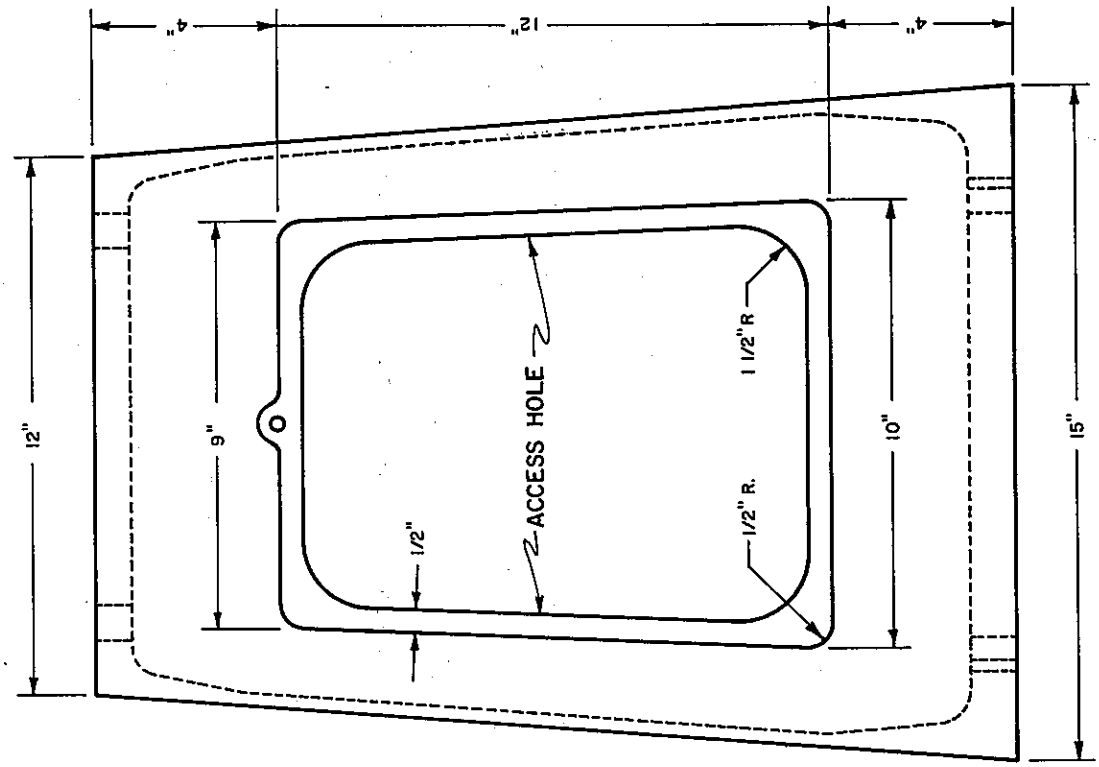
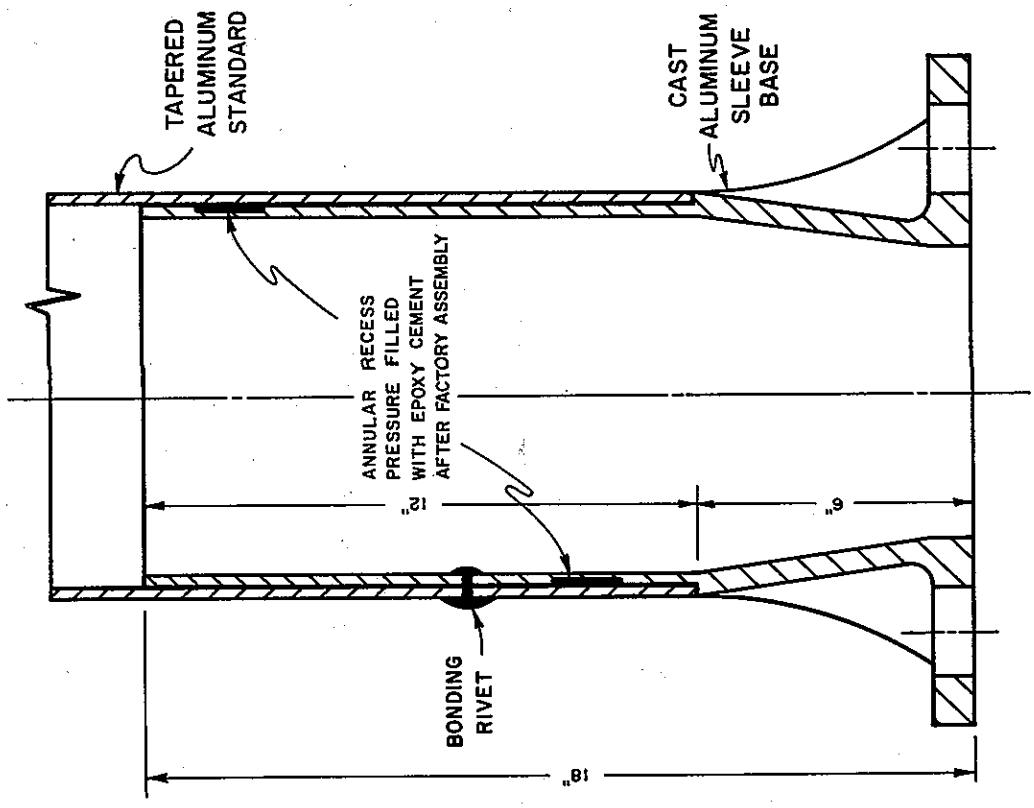


ALUMINUM TRANSFORMER BASE
TEST 197



CAST ALUMINUM SLEEVE BASE
TEST 193

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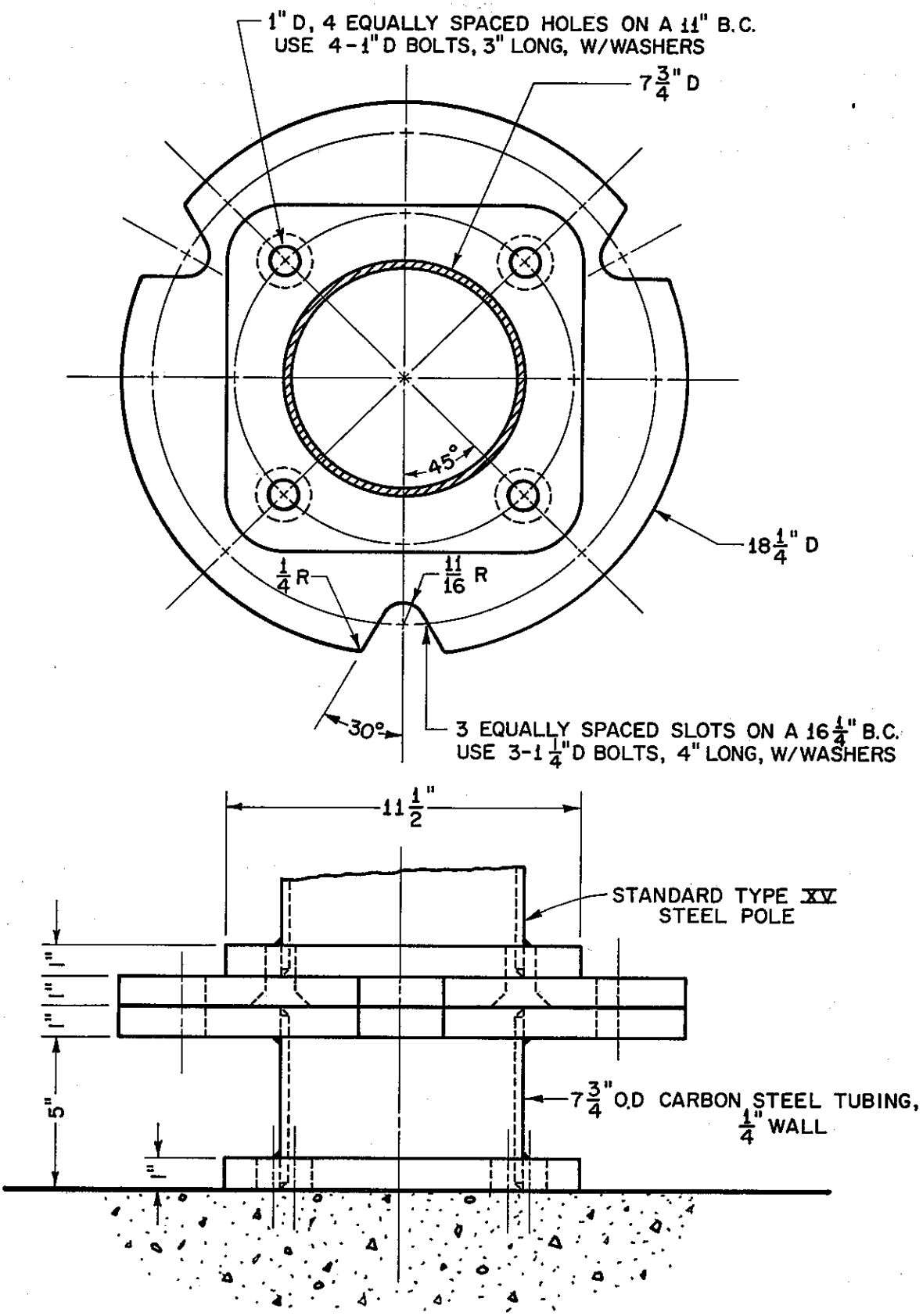
Plate 7



TEXAS SLIP BASE ADAPTER
TESTS 195 AND 196

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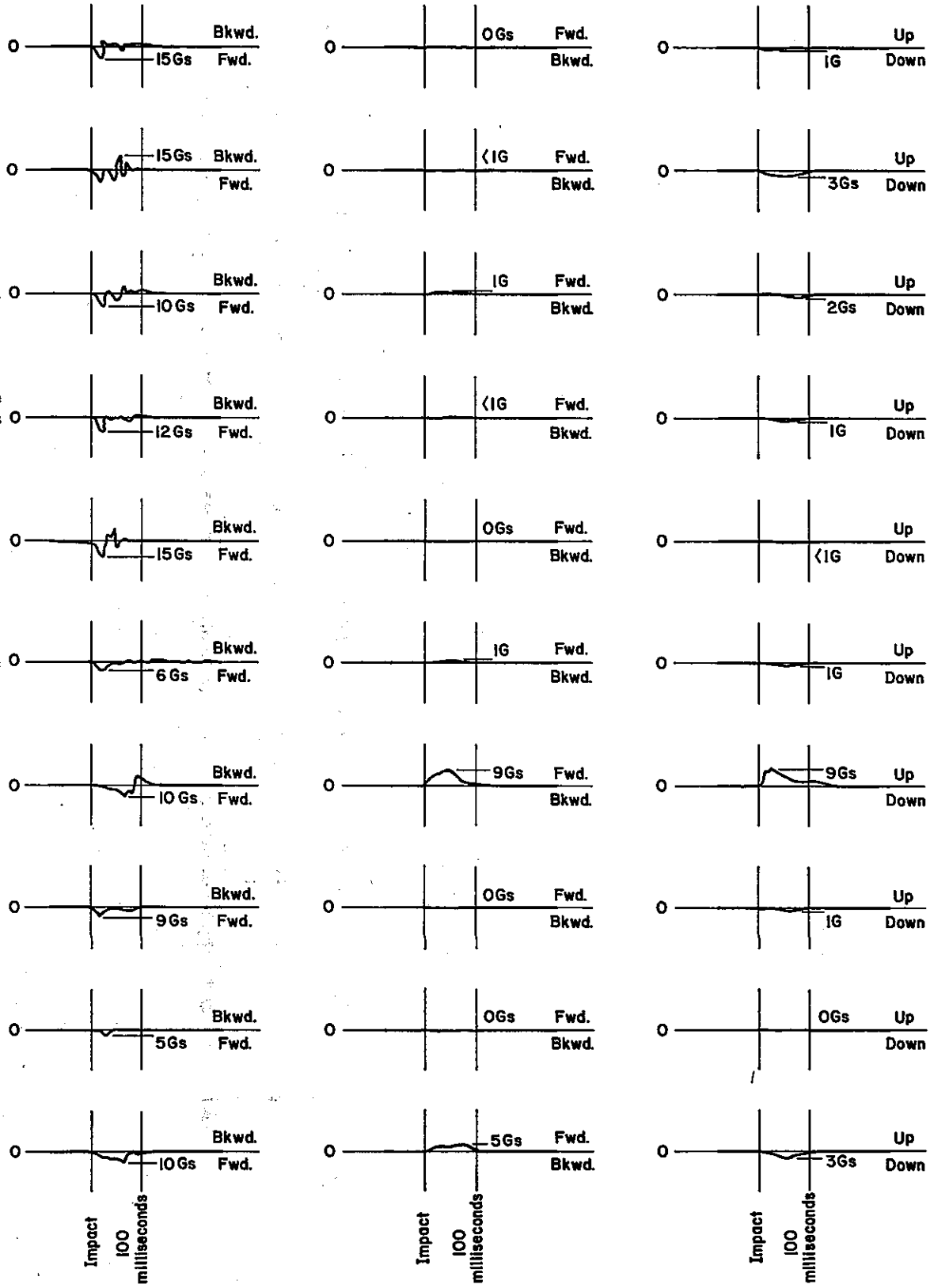
Plate 8

IMPACTOGRAPH DATA

TEST NO.	VEHICLE	DUMMY (unrestrained)	
181 Notched Bolts H-950° 40 m.p.h.	15Gs Bkwd. / Fwd.	0Gs Fwd. / Bkwd.	1G Up / Down
182 6" Frang. Al. Base No Modification 40 m.p.h.	15Gs Bkwd. / Fwd.	<1G Fwd. / Bkwd.	3Gs Up / Down
183 6" Frang. Al. Base Altered with holes (Modif. #1) 40 m.p.h.	10Gs Bkwd. / Fwd.	1G Fwd. / Bkwd.	2Gs Up / Down
191 6" Frang. Al. Base Altered with slots (Modif. #2) 48. m.p.h.	12Gs Bkwd. / Fwd.	<1G Fwd. / Bkwd.	1G Up / Down
192 Notched Bolts H-1050° 40 m.p.h.	15Gs Bkwd. / Fwd.	0Gs Fwd. / Bkwd.	<1G Up / Down
193 Cast. Al. Sleeve Base 40 m.p.h.	6Gs Bkwd. / Fwd.	1G Fwd. / Bkwd.	1G Up / Down
194 Notched Bolts H-1050° 15 m.p.h.	10Gs Bkwd. / Fwd.	9Gs Fwd. / Bkwd.	9Gs Up / Down
195 Texas Slip Base 40 m.p.h.	9Gs Bkwd. / Fwd.	0Gs Fwd. / Bkwd.	1G Up / Down
196 Texas Slip Base 15 m.p.h.	5Gs Bkwd. / Fwd.	0Gs Fwd. / Bkwd.	0Gs Up / Down
197 Transformer Base 15 m.p.h.	10Gs Bkwd. / Fwd.	5Gs Fwd. / Bkwd.	3Gs Up / Down



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