EVALUATION OF BREAKAWAY LIGHTPOLES FOR USE IN HIGHWAY MEDIANS

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The crash tests were carried out by personnel of the Highway Safety Research Center of Texas Transportation Institute under the direction of Dr. T. J. Hirsch, principal investigator of Research Study 2-8-69-146. The relative hazard index was conceived by Dr. T. J. Hirsch and developed by personnel of Research Study 2-8-69-137 under the direction of Dr. N. J. Rowan, principal investigator.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Federal Highway Administration.

ABSTRACT

Crash tests were conducted to determine the impact behavior of median-mounted luminaire supports and secondary collisions of vehicles striking downed poles on a traffic lane. A relative hazard index was developed to describe the relative hazard created by the proximity and frequency of luminaire supports.

It was concluded that a 20° impact by a 2900 lb vehicle at 45 mph would not cause a pole to encroach on the opposing traffic lane if the median is 40 ft wide. A 4000 lb vehicle impacting at 25° and 60 mph would cause a pole to encroach approximately 11 ft into the opposing lane. Under both conditions, the impacting vehicle would cross into the opposing lanes and may be more of a hazard than the poles themselves. A medium size vehicle impacting a downed pole within the traffic lane presents no more hazard than the original impact. From a relative hazard standpoint, median-mounted luminaire systems produce less hazard than house-side systems for median widths of 30 ft or greater.

Key Words: Roadway lighting, luminaire supports, impact attenuation, breakaway devices, hazard index, medians.

IMPLEMENTATION STATEMENT

Preliminary tests of the impact behavior of downed luminaire supports indicate that the severity of impact is no more serious than the original vehicle-support collision. Safe consideration may be given to the use of median-mounted supports 50 ft in height for median widths 30 ft or greater (including shoulders).

SUMMARY

Median-mounted luminaires have become very popular for the illumination of freeway facilities. Objection has been voiced, however, to the use of median mountings where the height of support exceeds the median width. The objection has been based on the premise that secondary collisions may occur with a downed pole occupying a traffic lane. This research is in response to this objection.

Three full-scale crash tests were conducted to determine the impact behavior of median-mounted supports and secondary vehicle-downed pole collisions. The first test revealed that a 20° impact by a 2900 lb vehicle at 45 mph would probably not cause a pole to encroach on the opposing traffic lane if the median width is 40 ft wide (including shoulders). The second test, involving a 4000 lb vehicle impacting at 25° and 60 mph, indicated an approximate encroachment of 11 ft into the opposing inside traffic lane, if the median is 40 ft wide (including shoulders). The third test, involving a medium size vehicle at 60 mph impacting a downed pole across the traffic lane, revealed that this secondary collision would be no worse than the original vehicle-pole impact. The vehicle would probably be able to continue straight ahead until control is regained.

A relative hazard index was developed to describe the relative hazard created by the proximity and frequency of luminaire supports.

This index suggests that median-mounted luminaire systems produce less hazard than house-side systems for median widths of 30 ft or greater.

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INTRODUCTION

THE PROBLEM

As substantial mileage of the Interstate Highway System was being completed, there arose a need for safer and more efficient methods of lighting those facilities. Previous methods had consisted of relatively low luminaire mounting heights and frequent spacings with the supports located close to the roadway edge on rigid bases. These practices were acceptable for the low operating speeds and volumes found on city streets, but unacceptable for the high-speed, high-volume characteristics of the freeway. The low mounting heights and frequent spacings produced uncomfortable environments for drivers as they passed through "hot spots" and "dark spots" on the roadway.[1*] The frequent spacings and location of the supports close to the roadway edge on rigid bases produced even more unacceptable environments. Frequent collisions with the supports by out-of-control vehicles resulted in severe vehicle damage and injury or death to the occupants.[2]

The advent of higher output light sources provided partial solutions to the unacceptable conditions. Higher mounting heights with corresponding longer spacings and setbacks from the roadway were possible with the higher output light sources[3]. This provided for a reduction in the "ladder" effect created by the "hot and dark spots." There remained, however, the potential for vehicle-support

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*Refer to corresponding numbers in Selected References.

impact.

A similar problem had already been encountered with roadside signs mounted close to the roadway edge. This problem was successfully solved through the development and use of sign supports that would shear or breakaway when struck by an errant vehicle[4]. Success with the breakaway sign supports led to the development of similar techniques for luminaire supports.

Slip joints, cast aluminum transformer bases, cast aluminum inserts, notched bolt inserts, progressive-shear bases and cast aluminum flanged bases have all been used with a high rate of success[2]. These devices have provided for great flexibility in the location of luminaire supports.

As a result of the safer supports, median-mounted luminaires have become very popular for the illumination of freeway facilities. Quality of illumination provided by this location and economy have contributed to the popularity. Objection has been voiced, however, to the use of median mountings where the height of support exceeds the median width. This objection has been based on the premise that secondary collisions may occur with a downed pole occupying a traffic lane. This report is in response to this objection.

OBJECTIVES

The objectives of this research are:

1. Investigate the impact behavior of median-mounted luminaire supports.

2. Investigate the behavior of secondary vehicle-support impact.

3. Develop a hazard index to describe the relative hazard created by the proximity and frequency of luminaire supports

DETAILS OF TESTS

GENERAL

Three vehicle crash tests were conducted on 50 ft, double-mast arm luminaire supports with frangible transformer bases. The first two tests simulated accidents in which vehicles ran off the road and struck the breakaway supports. The third test simulated an accident in which an oncoming vehicle ran over a luminaire support which had been knocked into the traffic lane by a second vehicle which had left the opposing roadway.

In the first two tests, the vehicles were equipped with accelerometers attached to each longitudinal frame member. The tests were recorded on documentary and high-speed films for time-displacement analysis. The third test was recorded photographically, but no electronic accelerometers were used. Instead, a mechanical device called an Impact-O-Graph was used to measure triaxial accelerations.

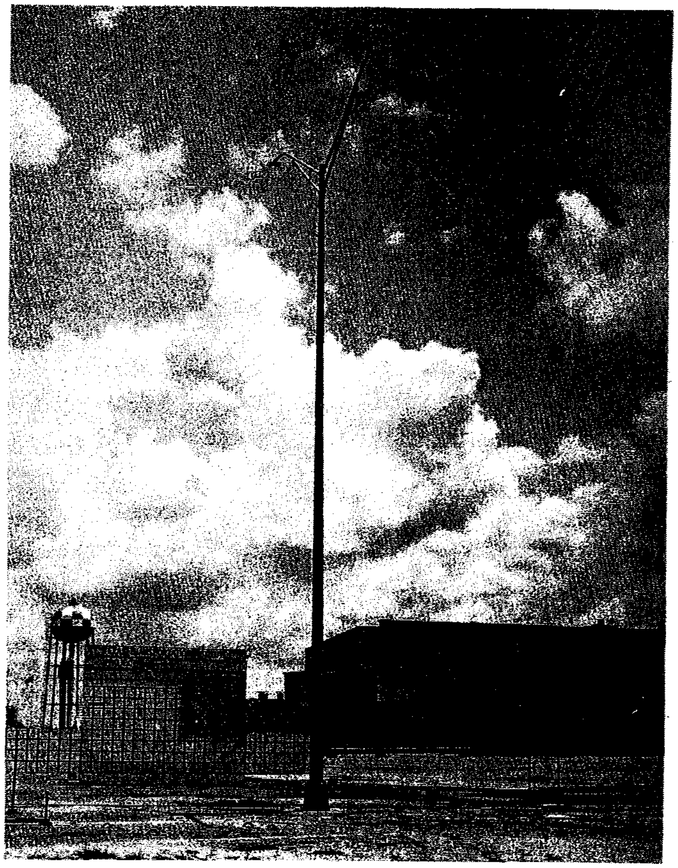
In the first two tests the poles and mast arms were oriented at angles to the direction of vehicle travel. The orientations were such that a vehicle would be veering to the right of its normal traffic lane in these tests. The supports were oriented in this manner due to space and hardware restrictions. However, the double-mast arm supports are designed for median installations and would normally be exposed to impacts by vehicles running off the road to the left of the normal traffic flow. Since the supports and the front ends of the vehicles are symmetrical, the response of the poles in such impacts is a mirror image of that in an impact at the same angle from the other side. Therefore, the final positions of the supports are shown in the drawings as they would have been if struck in the same manner by a vehicle encroaching the median. For purposes of these simulations, a 40 ft wide median (including shoulders) has been assumed.

TEST LS-1

This test simulated a relatively lightweight vehicle striking the support at 45 mph and 20 degrees to the direction of the roadway. The octagonal galvanized pole was mounted on a frangible aluminum transformer base as shown in Figure 1.

The vehicle contacted the pole 18 inches to the right of the vehicle's centerline, but the base shattered, allowing the support to rotate up and clear the vehicle as intended. Sequential photographs of the test are shown in Figure 2. Figure 3 shows the fragmented base after the test. The front of the vehicle before and after the impact is shown in Figure 4. The vehicle sustained a residual deformation to the right front of 0.6 ft.

Time-displacement data from the high-speed films and reproductions of the accelerometer traces are included in the appendix. Table 1 contains the pertinent vehicle data. The speeds from the films are average speeds over about 3 ft intervals preceding contact and following the interval of accelerometer activity. The accelerometer data in Table 1 is the average of the right and left frame accelerometers.



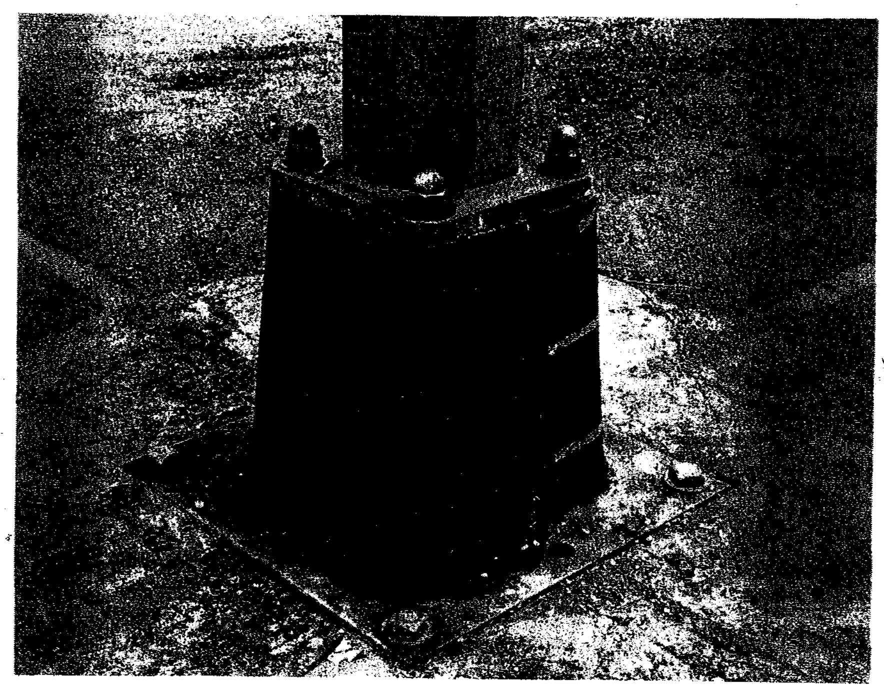


FIGURE 1, LUMINAIRE SUPPORT AND BASE BEFORE TEST LS-1.

t = 0 sec

t = .020 sec

t = .116 sec

t = .241 sec

t = .359 sec

t = .568 sec

FIGURE 2, SEQUENTIAL PHOTOGRAPHS OF TEST LS-1 (Continued).

t = 1.020 sec

t = 1.101 sec

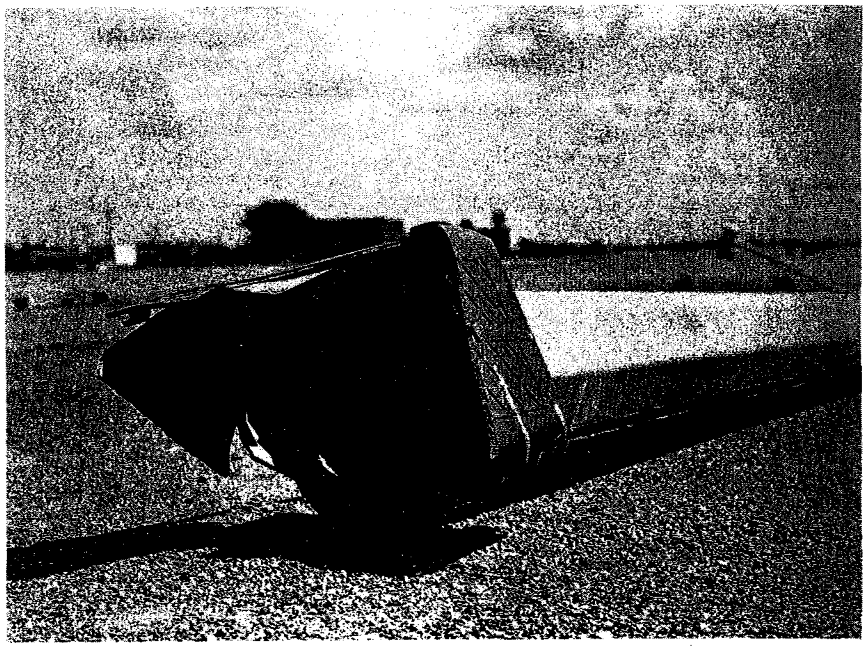
t = 1.231 sec

t = 1.332 sec

t = 1.545 sec

t = 1.764 sec

FIGURE 2, (Concluded).



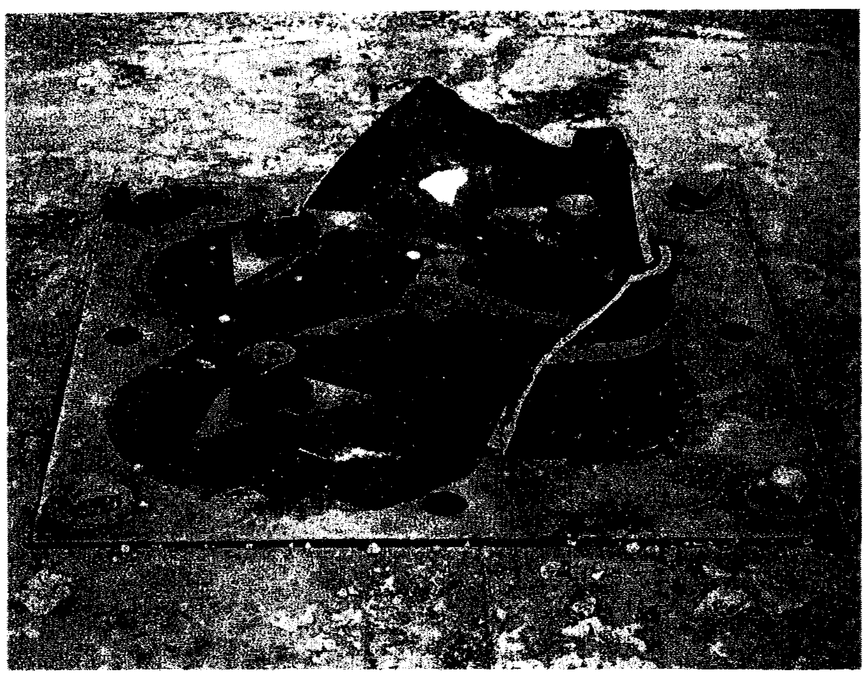


FIGURE 3, FRANGIBLE TRANSFORMER BASE AFTER TEST LS-1.

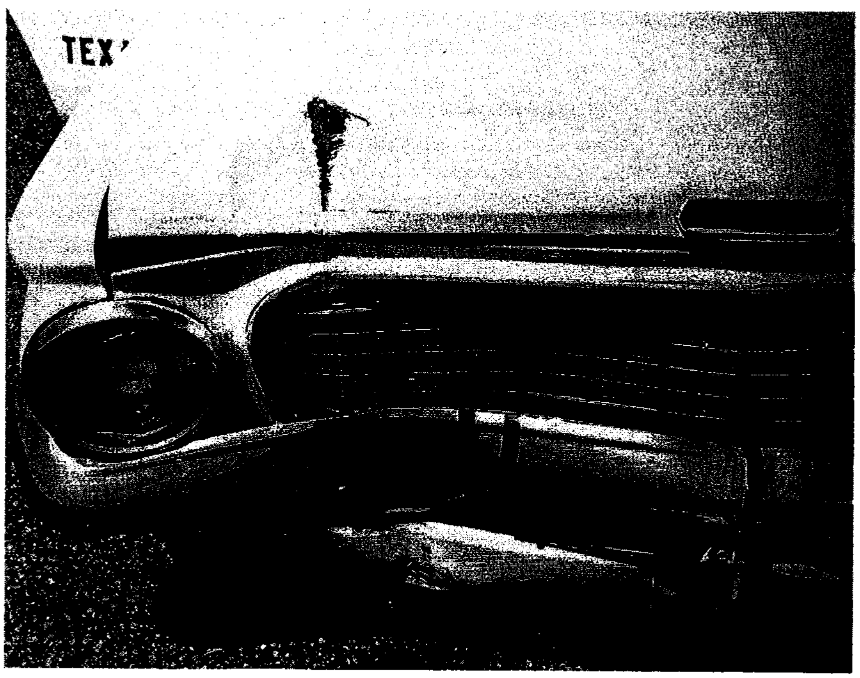


FIGURE 4, FRONT OF VEHICLE BEFORE AND AFTER TEST LS-1.

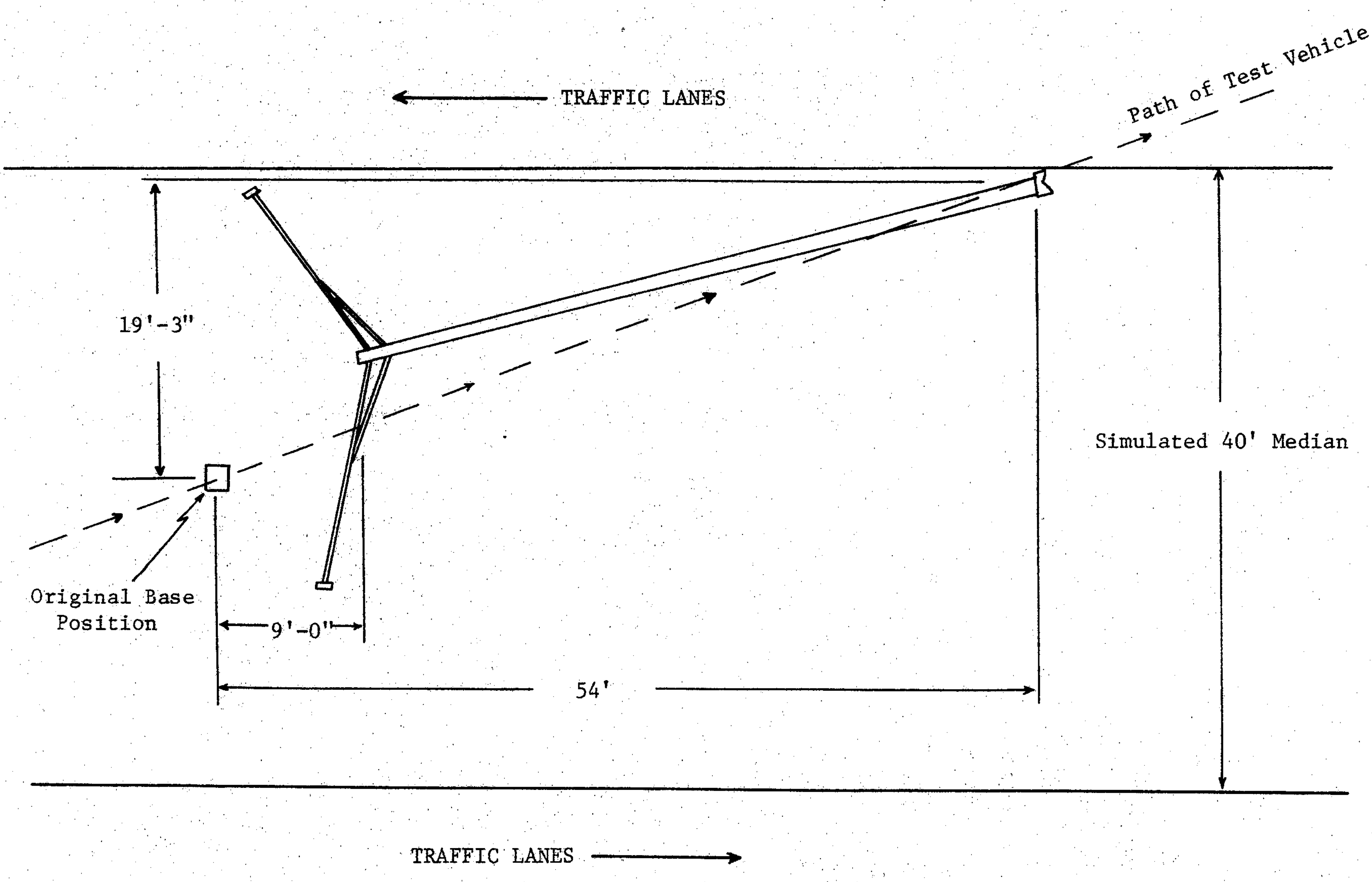


FIGURE 5, FINAL POSITION OF LUMINAIRE SUPPORT IN TEST LS-1.

TABLE 1

TEST DATA, TESTS LS-1 AND LS-2

	LS-1	LS-2
VEHICLE		
Year	1963	1961
Make	Plymouth	Chevrolet
Weight, lbs	2900	4040
Angle of Approach, deg	20	25
Residual Deformation, ft	0.6	1.5
FILM DATA		
Initial Speed, ft/sec	67.2	87.6
mph	45.8	59.7
Final Speed, ft/sec	60.7	78.4
mph	41.4	53.3
Average Longitudinal Deceleration		
$V_i^2 - V_f^2 / 2gS = g's$	2.0	4.1
Change in Momentum		
$\Delta P = (W/g)(\Delta V) = lb\text{-}sec$	585	1155
ACCELEROMETER DATA		
Maximum Longitudinal Deceleration, g's	14.4	8.2
Average Longitudinal Deceleration, g's	2.5 over 0.110 sec	3.6 over 0.072 sec

The final position of the luminaire support in relation to its original position and a hypothetical 40 ft median strip is shown in Figure 5. In this case, the support would have remained within the median. However, the errant vehicle entered the oncoming traffic lanes without significantly altering its course. The only conclusion that can be drawn from this is that if the vehicle was traveling straight at an angle to the road upon impact with no driver control, and if the median was flat and level, then such an impact would cause encroachment of the oncoming traffic lanes by the errant vehicle.

TEST LS-2

This test was similar to LS-1 except the vehicle was heavier, the impact angle was increased to 25 degrees, and the impact speed was 60 mph instead of 45 mph.

The cast aluminum transformer base, shown in Figures 6 and 7, shattered as expected and the pole rotated up and cleared the vehicle as the vehicle continued on its course. Sequential photographs of the test are shown in Figure 8.

The front end of the vehicle had a residual deformation of 1.5 ft, as shown in Figure 9. The increased damage is primarily due to the higher impact speed.

The vehicle data given in Table 1 shows that the significant deceleration period was about two-thirds as long as that in Test LS-1, which was conducted at a lower speed.

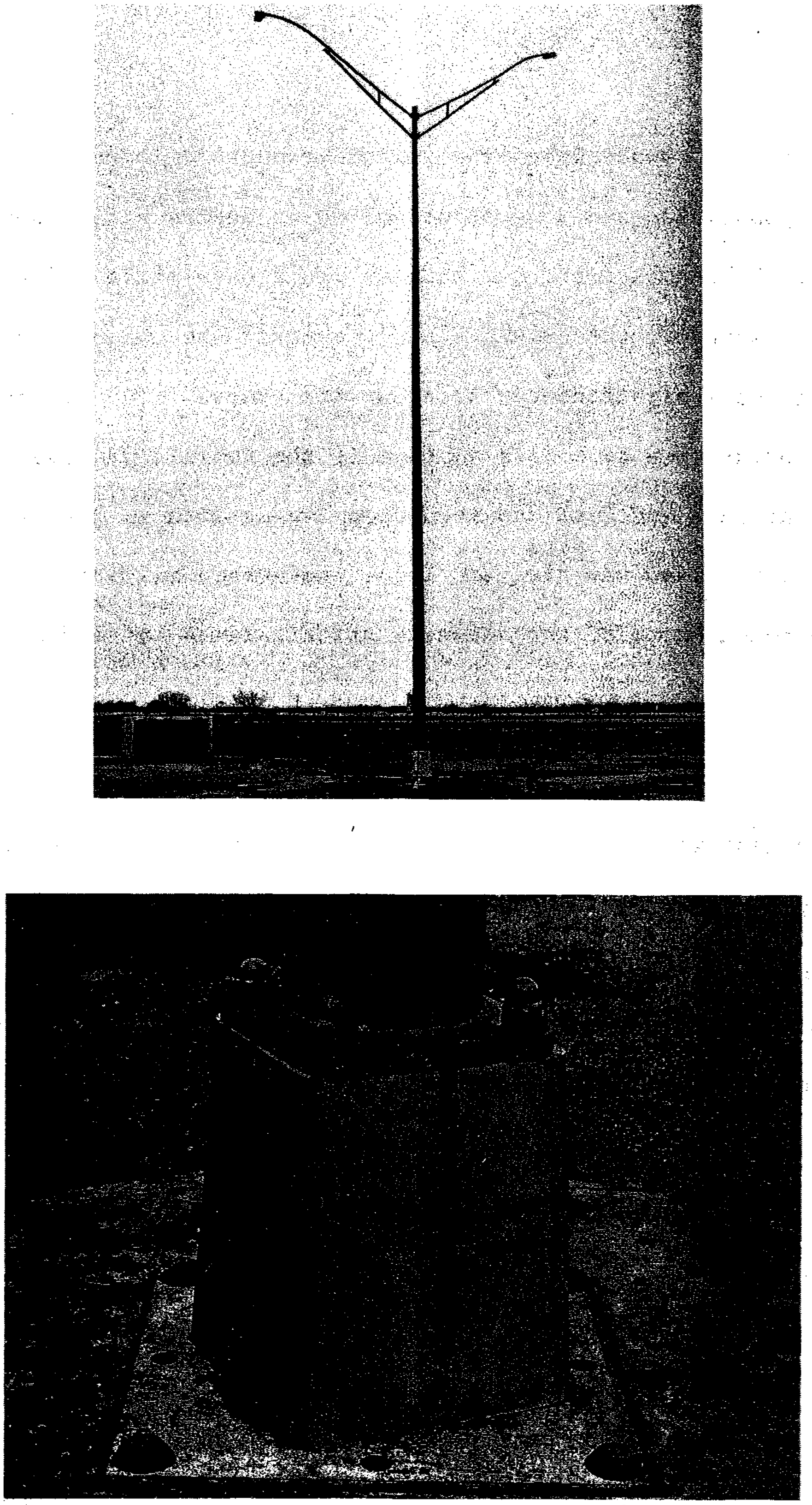
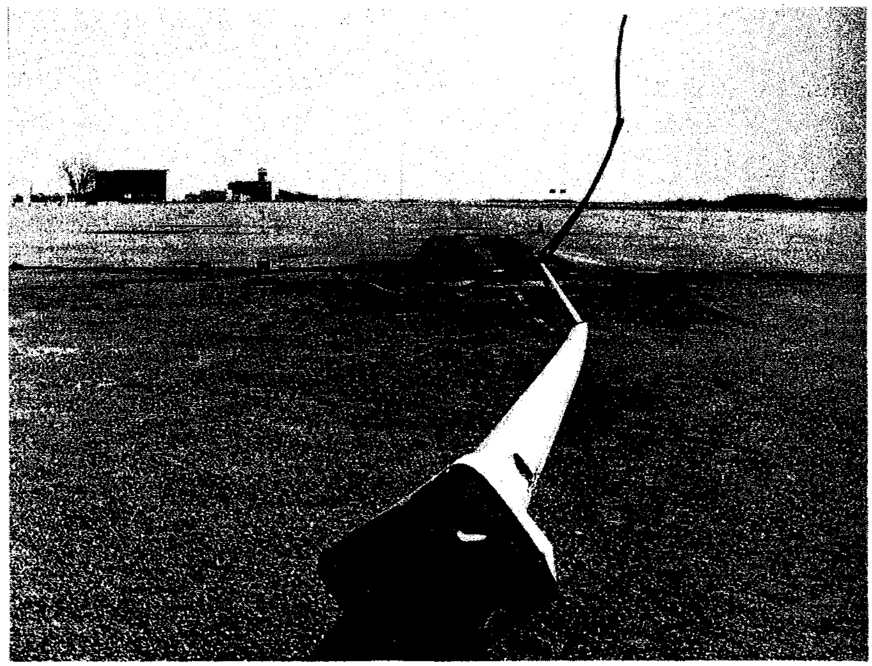


FIGURE 6, LUMINAIRE SUPPORT AND BASE BEFORE TEST LS-2.



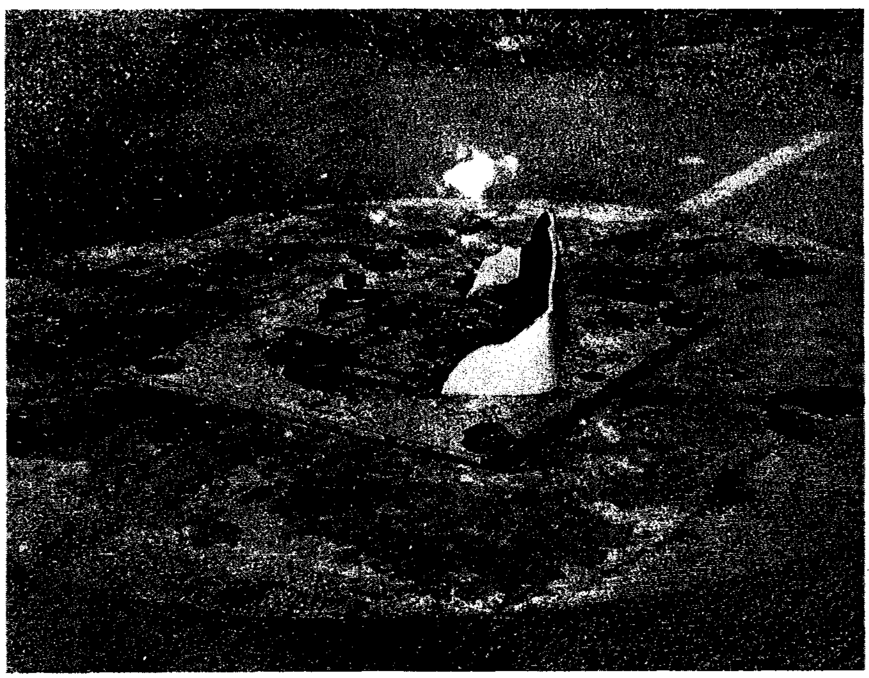
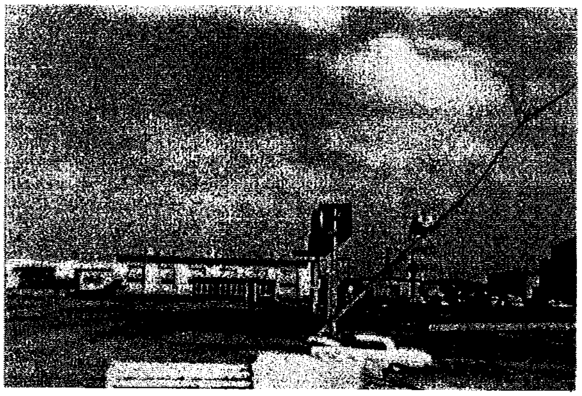


FIGURE 7, FRANGIBLE TRANSFORMER BASE AFTER TEST LS-2.

t = 0 sec

t = .078 sec

t = .260 sec



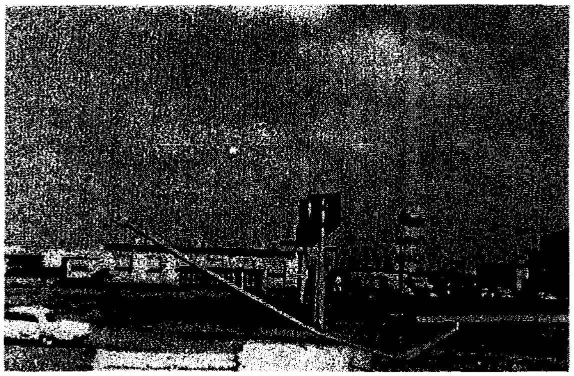
t = .396 sec

t = .502 sec

t = .737 sec

FIGURE 8, SEQUENTIAL PHOTOGRAPHS OF TEST LS-2 (Continued).

t = .917 sec

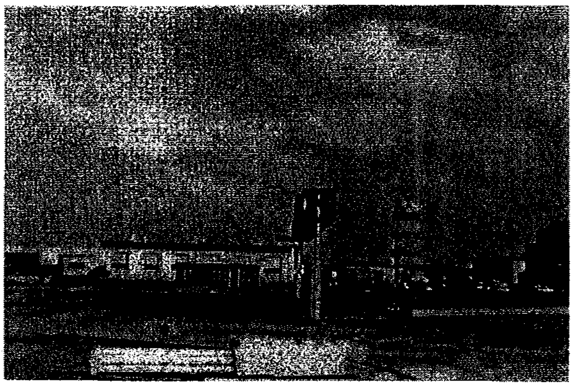


t = 1.015 sec

t = 1.091 sec

t = 1.419 sec

t = 1.800 sec



t = 2.326 sec

FIGURE 8, (Concluded).

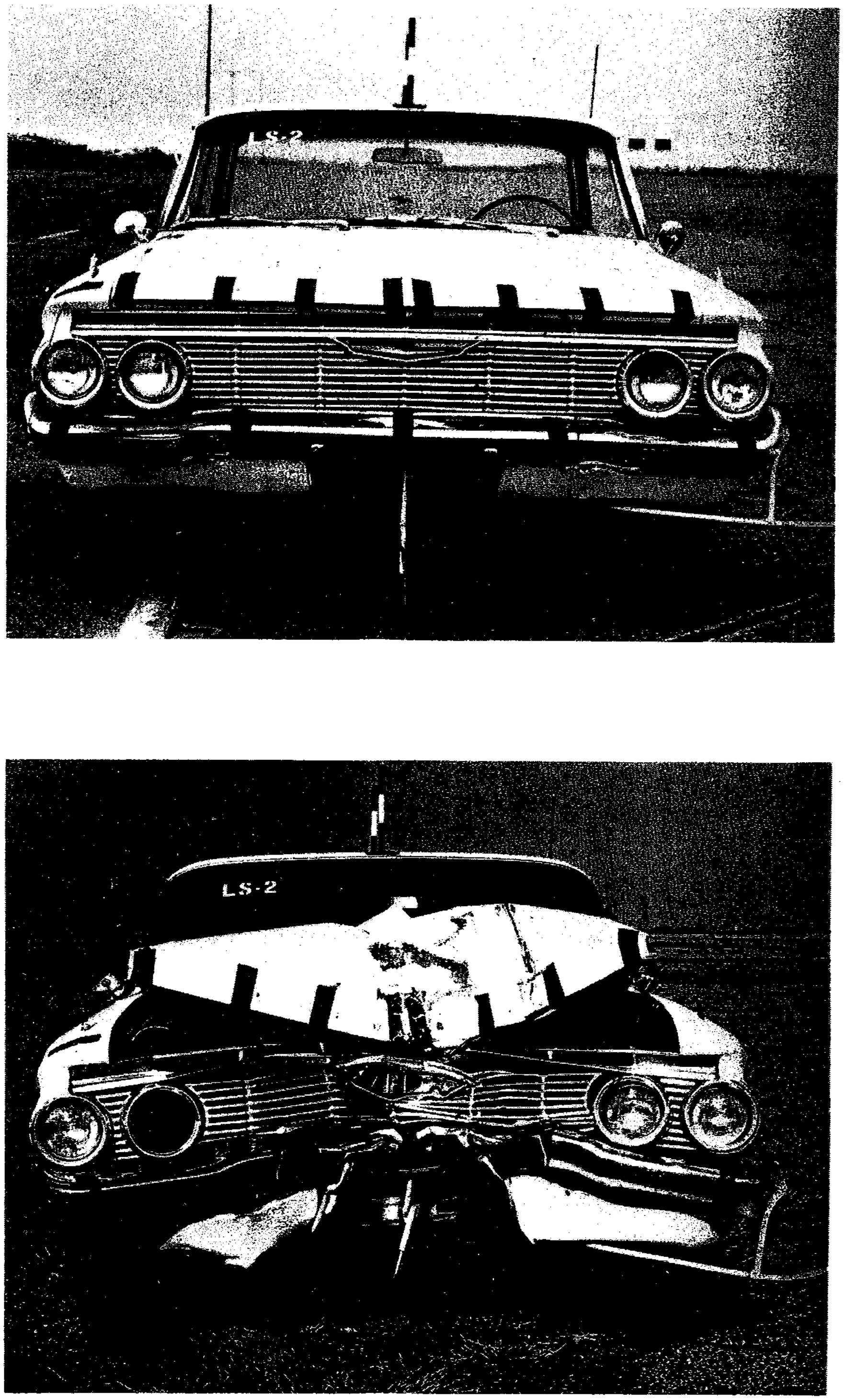


FIGURE 9, FRONT OF TEST VEHICLE BEFORE AND AFTER TEST LS-2.

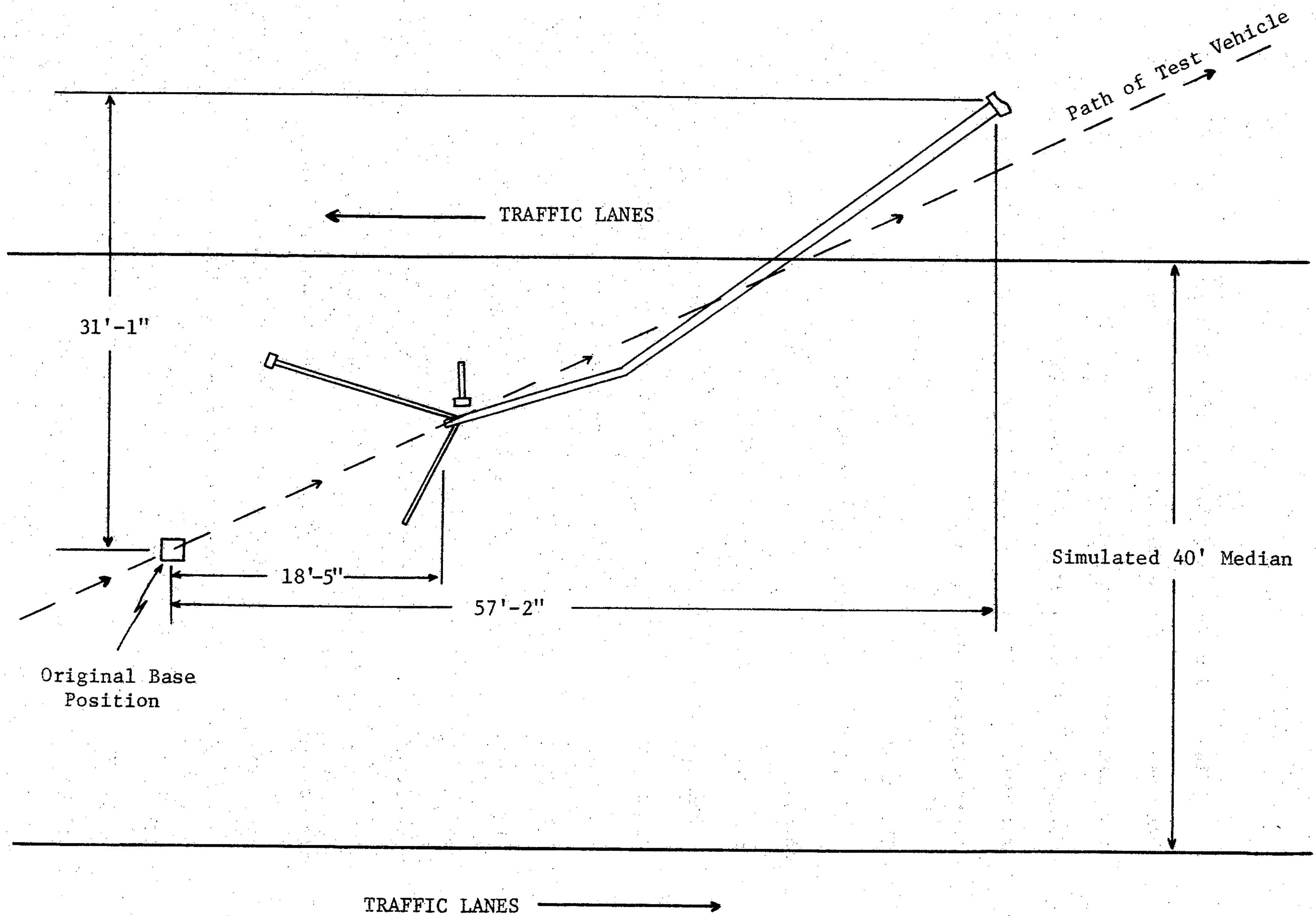


FIGURE 10, FINAL POSITION OF LUMINAIRE SUPPORT IN TEST LS-2.

Figure 10 shows the final position of the support. If the pole had been mounted in the center of a 40 foot median, the base after the test would have projected eleven feet horizontally into the oncoming "inside" traffic lane at an angle of 33 degrees to the roadway. Under these simulated conditions, the vehicle would have crossed the oncoming lanes.

TEST LS-3

This test was designed to determine the behavior of an automobile striking a "downed" luminaire support under conditions which would have resulted from a crash such as that of Test LS-2. The support from Test LS-2 was placed in such a way that the 12.5 ft wide concrete slabs that comprise the test apron would simulate the oncoming "inside" traffic lane. That is, the base extended 11 ft into the simulated lane at an angle of 33 degrees and pointed toward the approaching test vehicle as shown in Figures 11 and 12. The test vehicle, which was traveling in the center of the simulated traffic lane, struck the support at 61 mph, passed over it, and continued virtually straight ahead as shown in the sequential photographs of Figure 13. Figures 14 and 15 show the support after the test, while Figure 16 shows the path of the vehicle.

Table 2 gives the film and Impact-O-Graph data on the vehicle. The Impact-O-Graph, being primarily mechanical, is not as accurate as electronic devices for measuring accelerations of this nature, but it has been found to give representative data. Note that the average

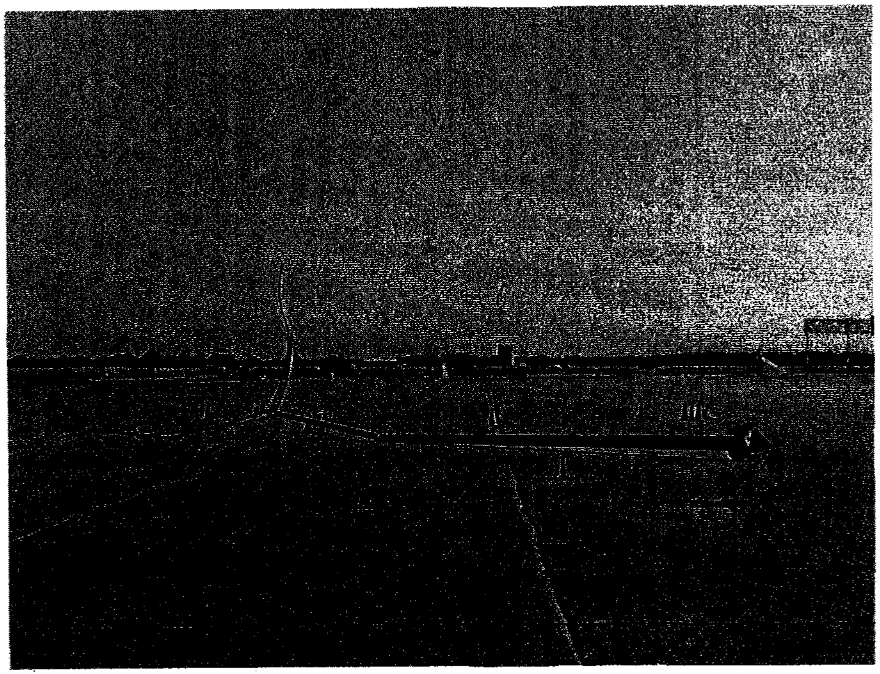


FIGURE 11, LUMINAIRE SUPPORT BEFORE TEST LS-3.
(Looking Parallel To and In The Direction Of Vehicle Travel.)

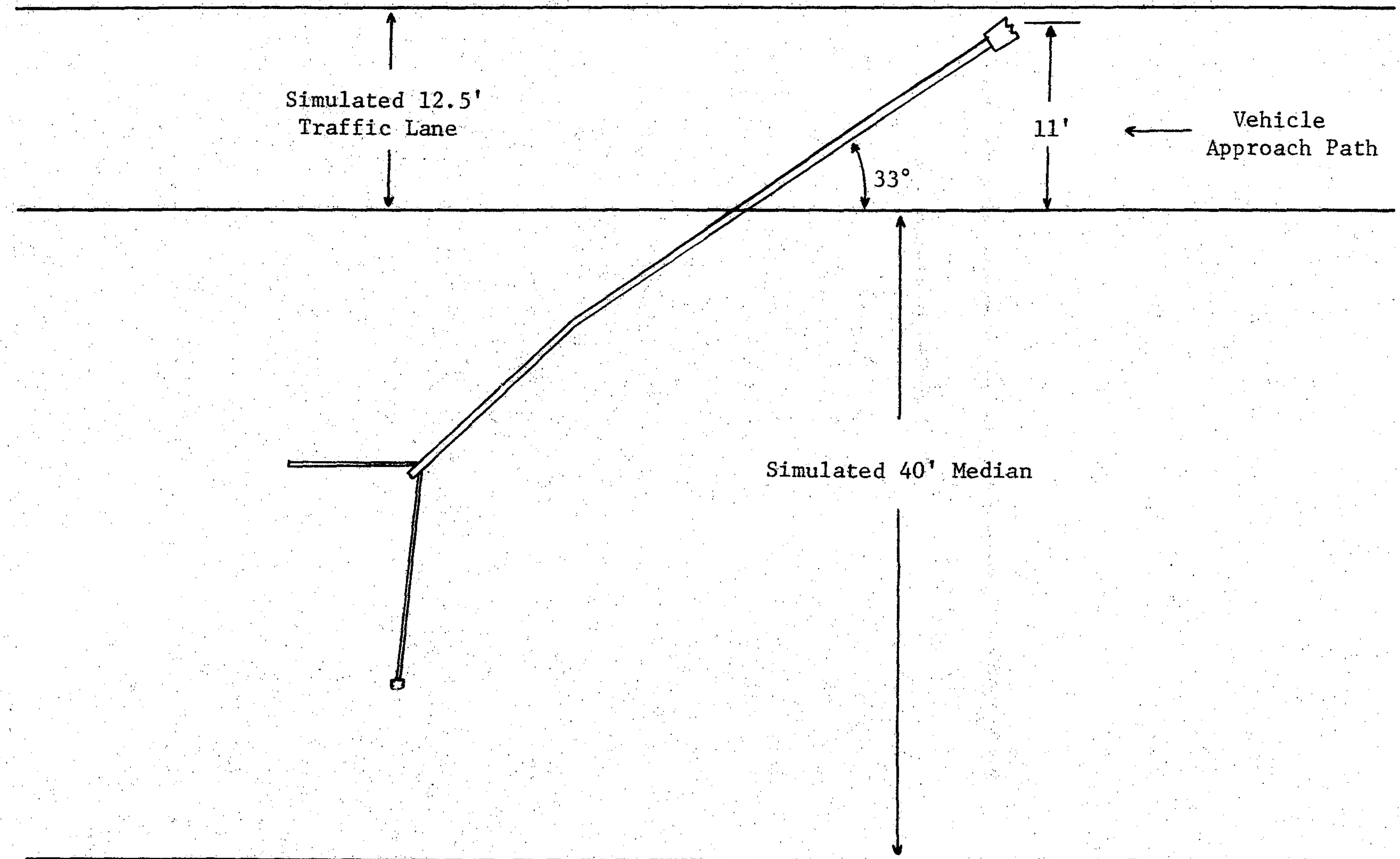
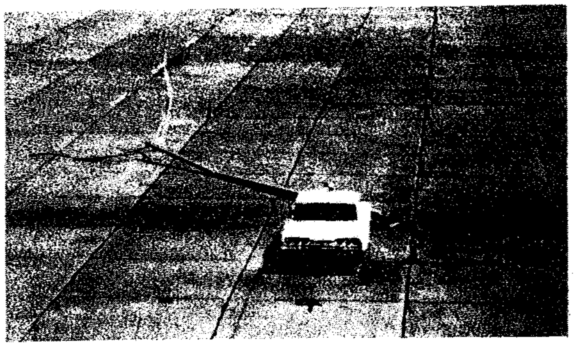
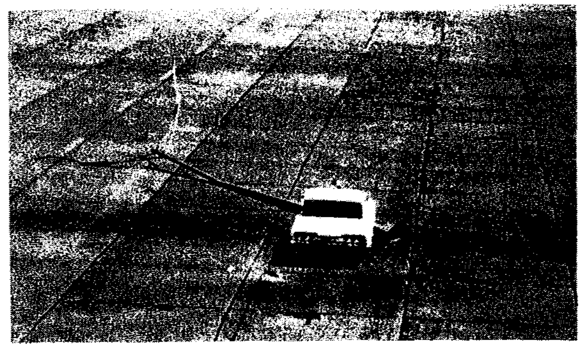


FIGURE 12, POSITION OF LUMINAIRE SUPPORT BEFORE TEST LS-3.

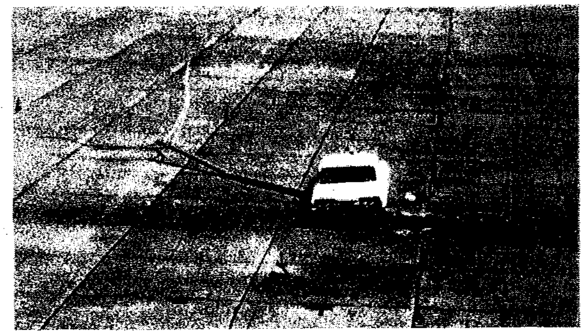


t = 0 sec

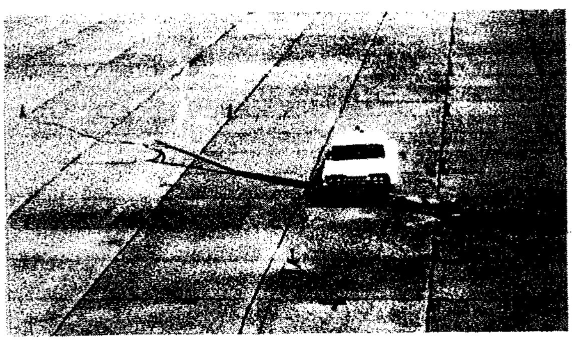


t = .091 sec

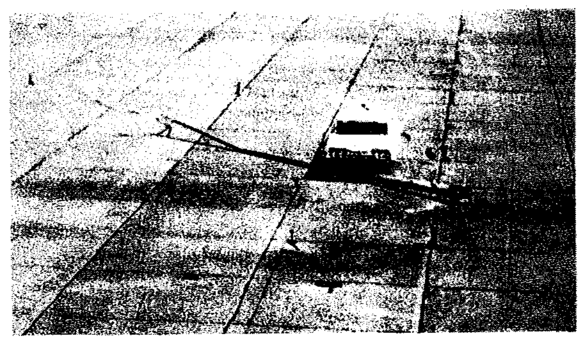
t = .152 sec



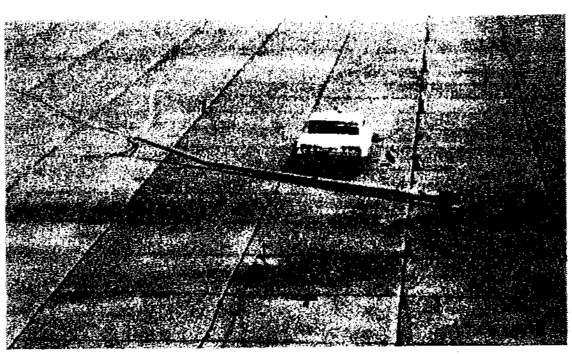
t = .253 sec



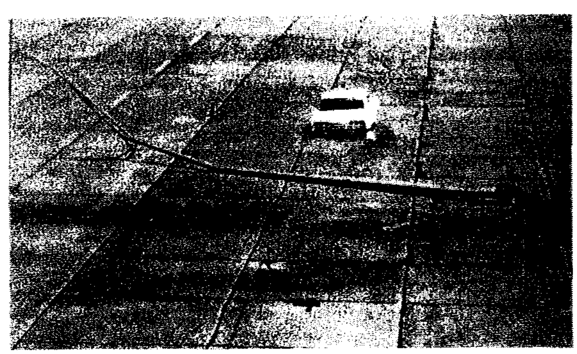
t = .354 sec



t = .404 sec



t = .495 sec



t = .889 sec

FIGURE 13, SEQUENTIAL PHOTOGRAPHS OF TEST LS-3.

FIGURE 14, LUMINAIRE SUPPORT AFTER TEST LS-3.
(Looking Parallel To and In Direction Of Vehicle Travel.)

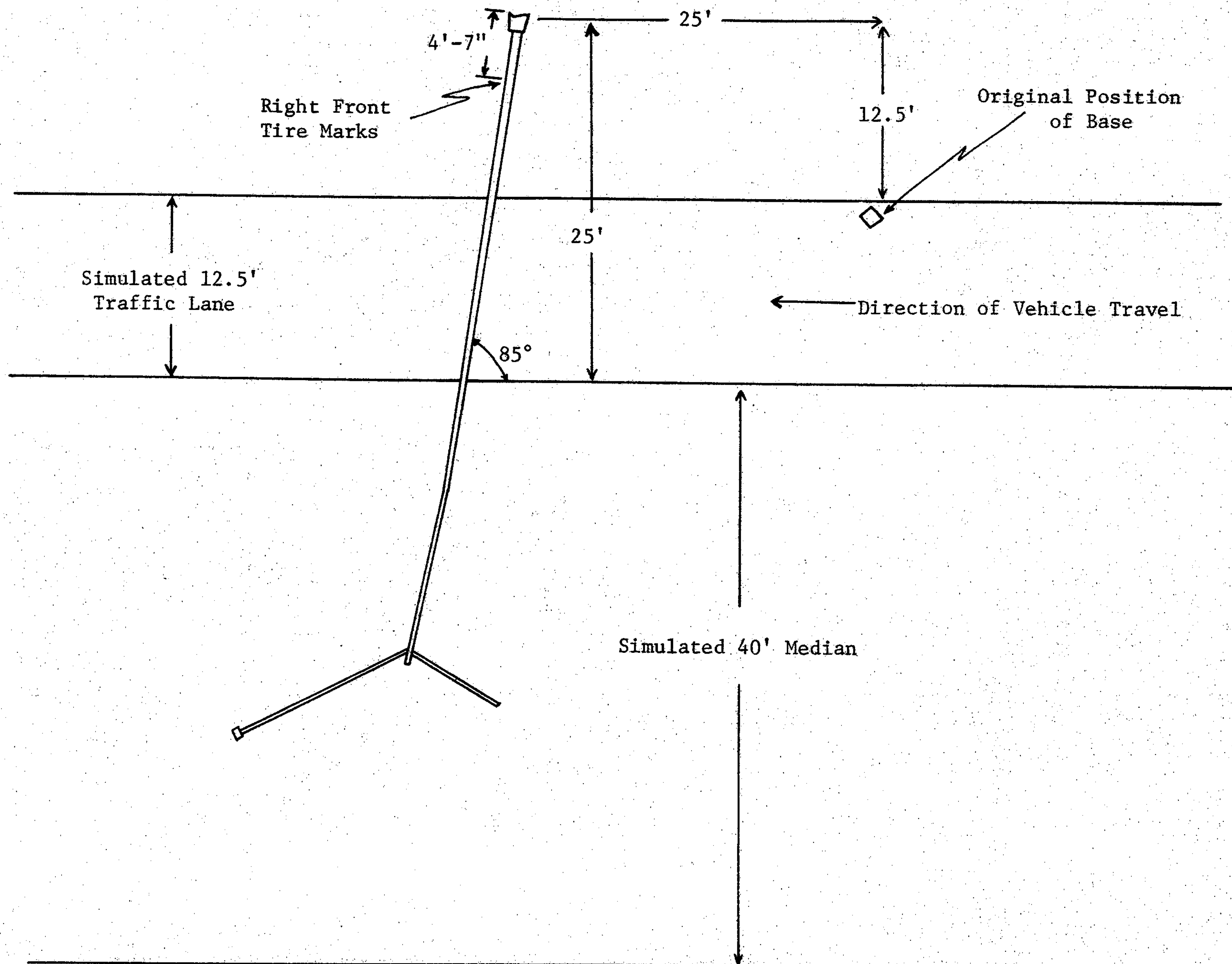


FIGURE 15, POSITION OF LUMINAIRE SUPPORT AFTER TEST LS-3.

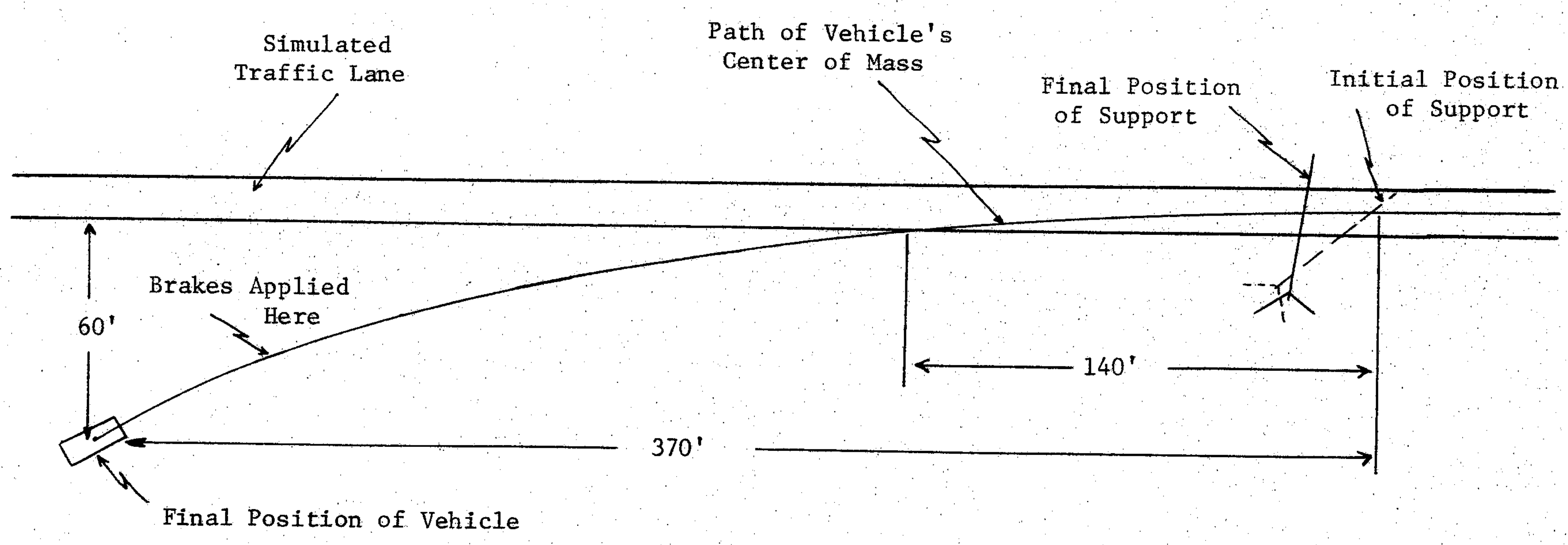


FIGURE 16, PATH OF VEHICLE IN TEST LS-3.

TABLE 2

TEST DATA, TEST LS-3

	LS-3
VEHICLE	
Year	1963
Make	Chevrolet
Weight, lbs	3630
FILM DATA	
Initial Speed, ft/sec	89.6
mph	61.1
Final Speed, ft/sec	84.1
mph	57.3
Time in Contact, sec	0.355
Average Longitudinal Deceleration	
$\Delta V/g\Delta t$ = g's	0.5
IMPACT-O-GRAPH DATA	
Longitudinal Deceleration	
Maximum, g's	3.4
Average, g's	0.1
Time, sec	0.502
Vertical Acceleration	
Maximum, g's	13.5
Average, g's	0.2
Time, sec	0.502
Transverse Acceleration	
Maximum, g's	13.5
Average, g's	0.05
Time, sec	0.502

decelerations (or accelerations) are low, but the peak accelerations are substantial in the vertical and transverse directions. However, these peaks are of short duration, and the vehicle exhibited no tendency to spin out or otherwise deviate significantly from its original path except for a gradual curvature to the left. Both the left front and right rear tires were deflated by the impact.

The luminaire support was pushed around to an angle of 85 degrees to the roadway, and extended 25 feet into the traffic lanes after the test. Note in Figure 13 that the vehicle did not contact the fragmented base, but ran over the shaft only.

DISCUSSION OF TESTS RESULTS

The breakaway behavior of 50 ft double-mast arm luminaire supports with frangible transformer bases is satisfactory under the conditions of the first two tests. The vehicles passed under the supports, after shearing them from their bases, and continued on essentially their original paths.

If the poles were installed in the center of a 40 ft median (including shoulders), a 20° impact by a 2900 lb vehicle at 45 mph would probably not cause the pole to encroach on the opposing traffic lanes. However, in the single test under these conditions, the final position was marginal, the base of the support being 1 ft from the roadway. A 4000 lb vehicle impacting at 25° and 60 mph causes the pole to encroach 11 ft into the opposing inside traffic lane. Both conditions allowed the vehicles to cross into the hypothetical traffic lanes, and this may be more of a hazard than the poles themselves.

If a medium size vehicle encounters a support in its traffic lane and strikes it with all wheels on the pole shaft (not straddle the base and not attempt to maneuver) at 60 mph, it may be able to continue straight ahead until control is regained. However, no firm conclusions can be drawn from one test. The support struck in such a manner would possibly be shifted into the adjacent traffic lane and thereby furnish a further hazard to other traffic.

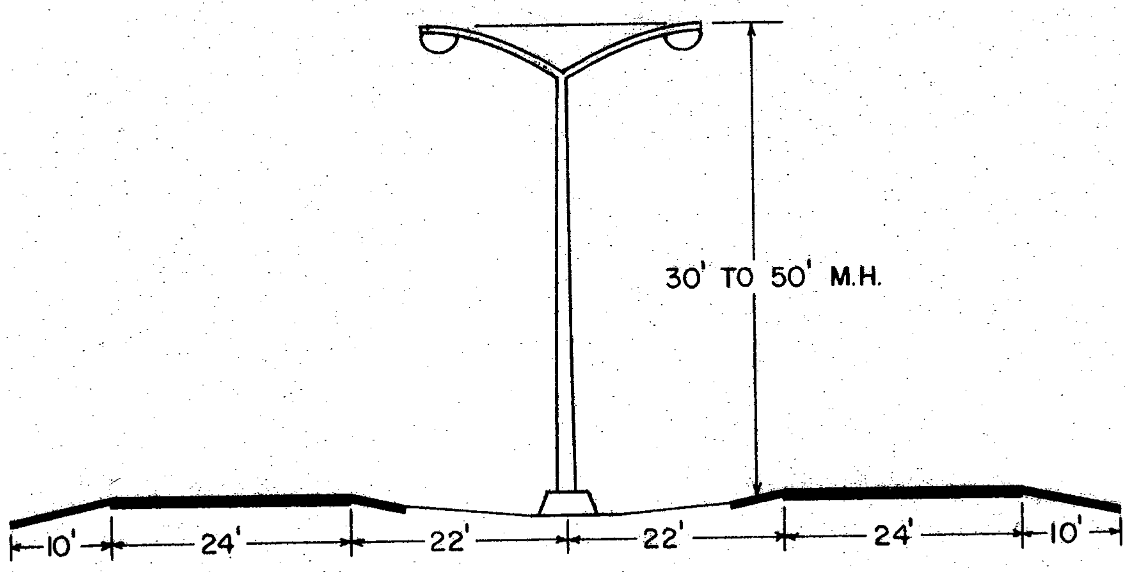
DEVELOPMENT OF A RELATIVE HAZARD INDEX FOR LUMINAIRE SUPPORTS

The purpose of this section is to formulate the procedure for determining a "Relative Hazard Index" for alternative lighting systems on a typical freeway-type facility. Specifically, the "Relative Hazard Index" describes the relative hazard created by the proximity and frequency of luminaire supports.

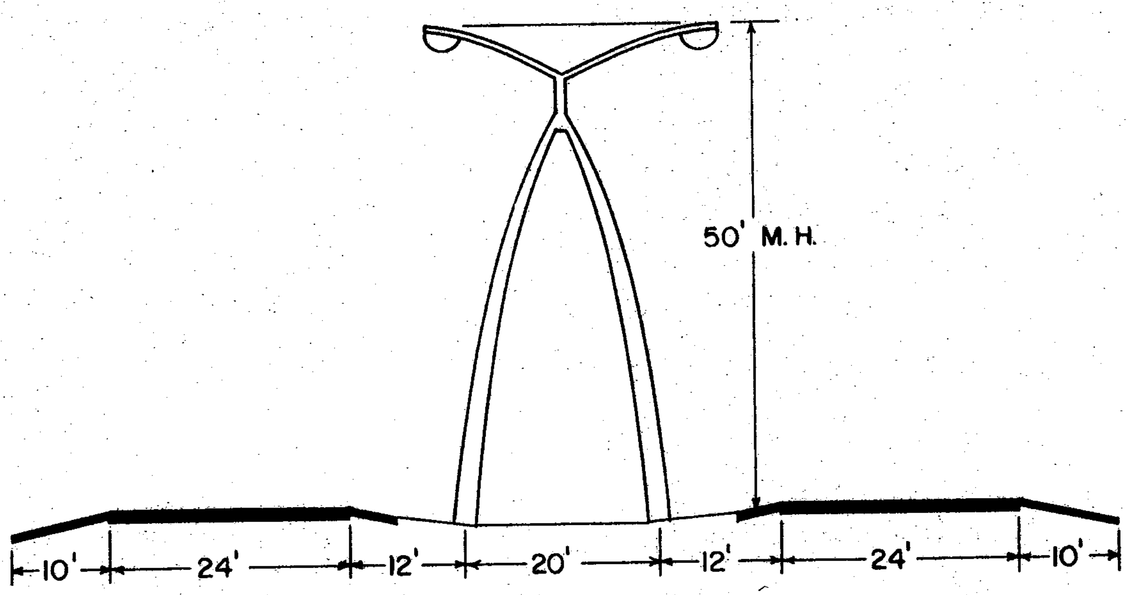
The alternative lighting systems presented in this comparison are basically "median-mounted" and "house-side" lighting systems at mounting heights of 30, 40, 45, and 50 ft at a 5:1 spacing-to-mounting height ratio. Each of the systems is illustrated in Figure 17 and described briefly in Table 3.

Table 3 summarizes the data for each of the alternative lighting systems and presents the Relative Hazard Index for a 44 ft median, a design of special current interest. A similar comparison can be made for any median width. This Relative Hazard Index is computed as the product of:

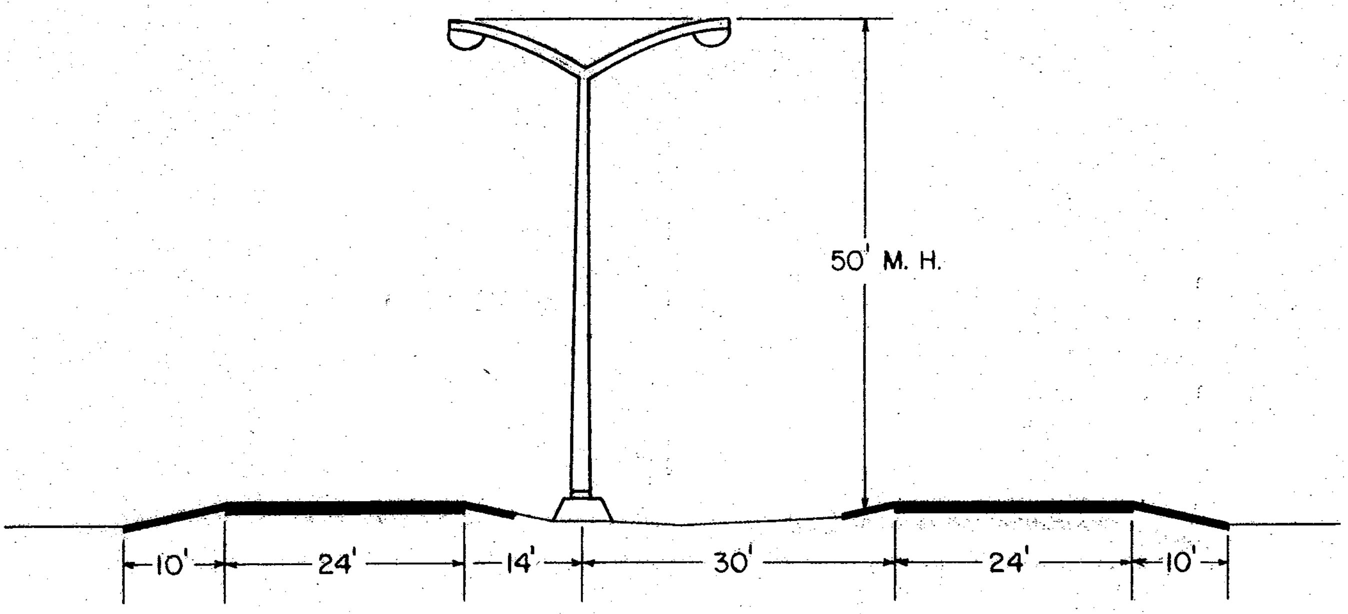
1. The relative index of a vehicle impacting a luminaire support based on lateral distance from the traveled way;
2. The relative number of hazards per unit length of roadway; and
3. The relative number of traffic streams (directions) to which the luminaire supports are exposed.



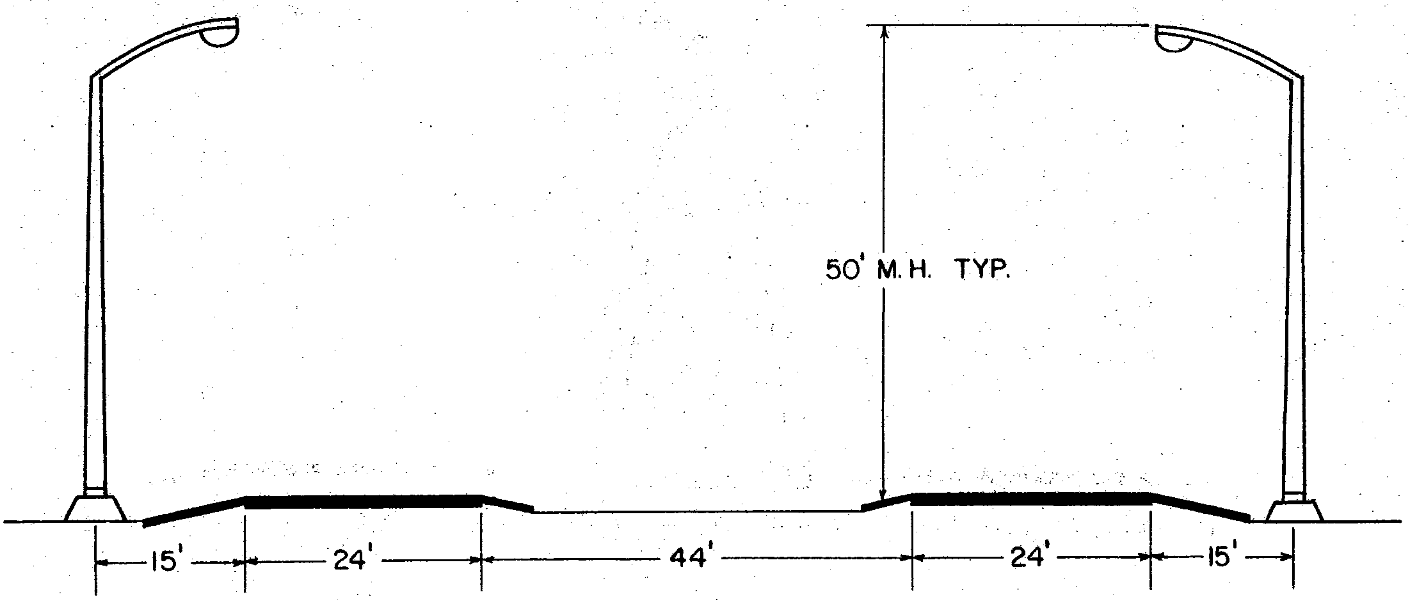
Typical median installation with cast aluminum T-Bases 30, 40, 45, & 50" MH. Alternate Designs 1-4.



A new concept in median-mounted systems. This concept is intended to provide a dual support with either support having the strength to support the lighting units independently should one of the supports be struck by a vehicle. Alternate Design 5.



Median-mounted system offset 30 feet from one direction of traffic. The concept is intended to reduce to a minimum the probability of an impact that would cause the support to enter the opposing traffic. Alternate Design 6.



Typical House-side installation with cast aluminum T-base. Alternate Designs 7-10.

TABLE 3

RELATIVE HAZARD INDEX COMPARISON

FOR A 4-LANE

FREEWAY WITH 44-FOOT MEDIAN

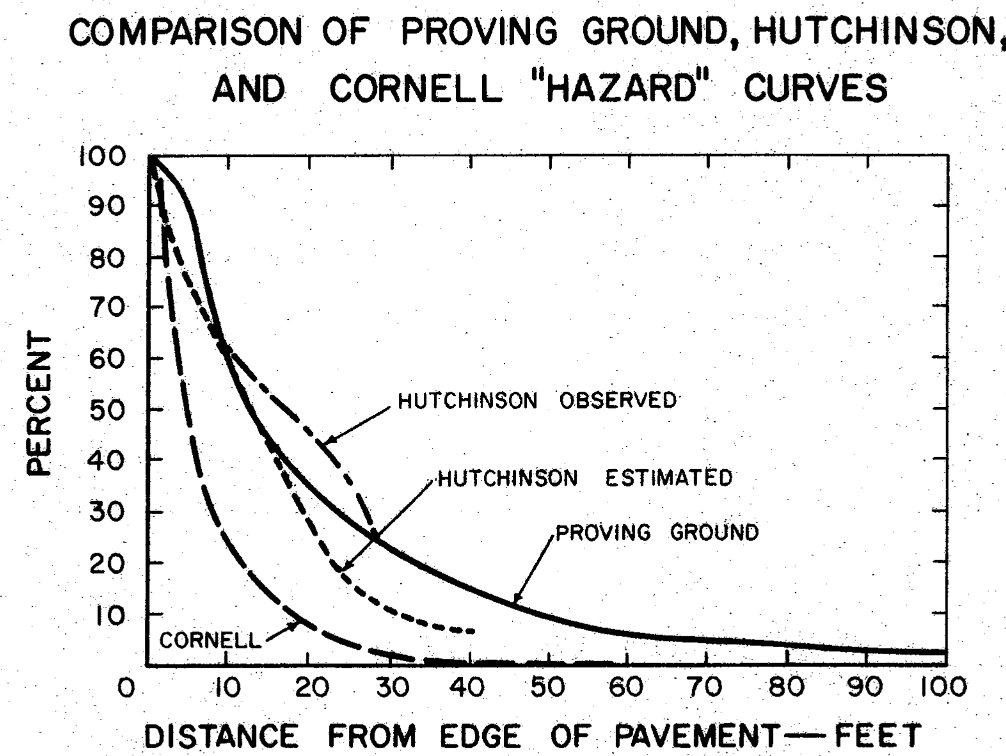
(1) Description of Alternative Lighting Design				(2) Percent Probability of Vehicles Traveling Indicated Distance From Edge of Roadway			(3)		(4)		(5)		(6)	(7)
(a)	(b)	(c)	(d)	(a)	(b)	(c)								
Alternative Design No.	Mounting Height of Luminaires (ft.)	Longitudinal Spacing of Luminaire Support (5:1 S/MH)	Location of Luminaire Support	Distance from Roadway to Luminaire Support (ft.)	Percent Probability (Hutchinson Est.)	Estimated Percent of Impact Angle > 20°	Relative Probability Index of Vehicle Collision with Luminaire Support		Relative No. of Luminaire Supports Per 250'		No. of Traffic Streams Exposed to Luminaire Supports		Total Hazard Index	Relative Hazard Index
1	30'	150'	Median	22'	22%		.22	X	1.66	X	2.00	=	.730	1.58
2	40'	200'	Median	22'	22%		.22	X	1.25	X	2.00	=	.55	1.19
3	45'	225'	Median	22'	22%	5%	.231	X	1.11	X	2.00	=	.513	1.11
4	50'	250'	Median	22'	22%	5%	.231	X	1.00	X	2.00	=	.462	1.00
5	50'	250'	Median	12'	55%									
				32'	9%		.32	X	2.00	X	2.00	=	1.280	2.77
6	50'	250'	Median	30'	11%									
				14'	46%	10%*	.308	X	1.00	X	2.00	=	.616	1.33
7	50'	250'	House-side	15'	45%		.45	X	2.00	X	1.00	=	.900	1.95
8	45'	225'	House-side	15'	45%		.45	X	2.22	X	1.00	=	1.000	2.16
9	40'	200'	House-side	15'	45%		.45	X	2.50	X	1.00	=	1.124	2.43
10	30'	150'	House-side	15'	45%		.45	X	3.32	X	1.00	=	1.492	3.23

*Assumes support may fall across two lanes.

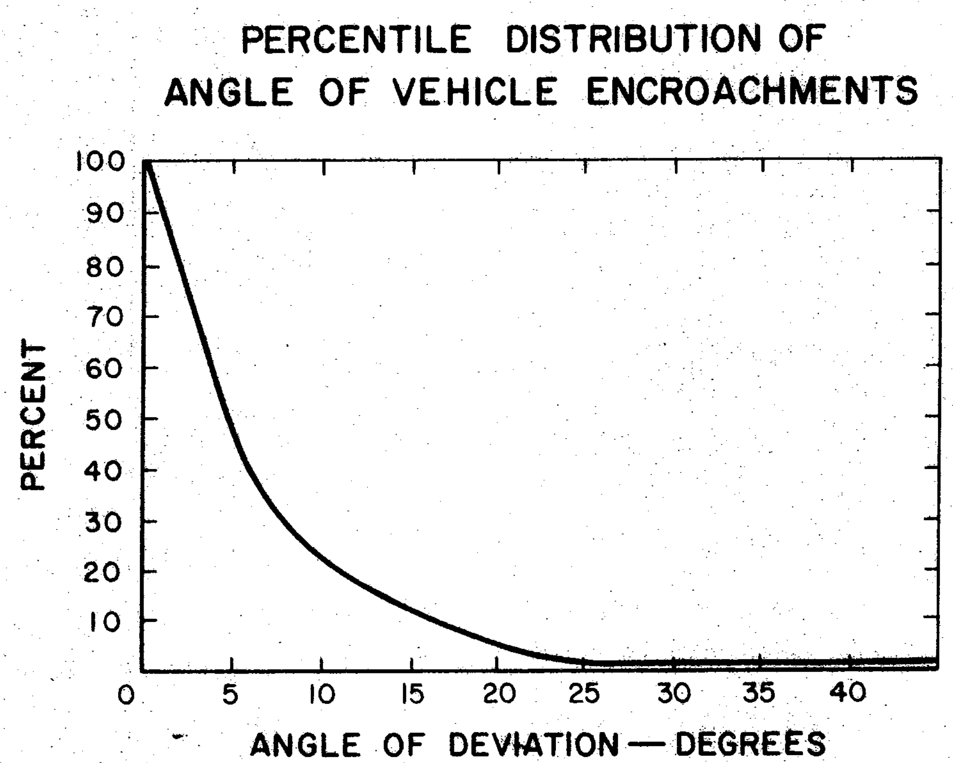
To explain the source of each of these factors, reference is made again to Table 3. Column 2(a) gives the lateral distance of the support from the edge of the traveled way for each of the alternative designs. The two distances given for Alternative Design Numbers 5 and 6 represent two supports in Alternative Design Number 5 and an offset situation in Alternative Design Number 6. Column 2(b) of Table 3 gives the percent probability that an errant vehicle will travel a sufficient lateral distance from the traveled way to become involved in a collision with a support. These values are based on frequently referenced data reproduced in Figure 18(a) from Hutchinson reported by K. A. Stonex[5].

Column 2(c) of Table 3 gives the estimated percent probability of secondary collisions caused by the luminaire support falling in an opposing traffic lane and being struck by an oncoming vehicle. The percent probability is determined on the basis that only supports struck at angles greater than 20° will fall in the opposing traffic lanes. Further, this effect is considered only for 45 and 50 ft supports. Shorter support lengths are assumed to always fall within the median. The percent probabilities were obtained from Figure 18(b).

In Test LS-3 involving a vehicle running over a downed 50 ft steel luminaire support, there was strong evidence that the secondary collision was of no greater severity than the initial impact with the upright support. Therefore, the relative probability index of collisions (col. 3) was determined by increasing the percent probabilities (col. 2b) by the estimated percent of impact greater than 20° (col. 2c).



18 (a)



18 (b)

FIGURE 18

From Stonex, K. A. Relation of Cross-Section Design and Highway Safety[5]

The percent probability (Column 2b) actually used was a computed average.

In Column 4, the relative frequency of exposure of a vehicle to luminaire supports is computed using the 250 ft spacing of the 50 ft median-mounted system as unity.

Column 5 lists the exposure indices based on the exposure of the traffic streams to luminaire supports. The median-mounted systems can be struck from either direction, whereas the house-side systems can only be struck from one direction.

Column 6 represents the combined total hazard index (of a vehicular collision with a luminaire support) based on lateral distance from the roadway to the luminaire support, the relative number of hazards per mile, and the exposure to traffic flows. It is obtained by computing the product of Columns 3, 4, and 5.

For ease of interpretation, the total hazard index values of Column 6 are converted to a base of unity by dividing all values by the smallest value in the column. These values, called the "Relative Hazard Index", are presented in Column 7.

RELATIVE HAZARD INDEX VS. MEDIAN WIDTH

To compare the relative hazard for various median widths, a similar analysis was made of a 50 ft, median-mounted system in median widths ranging from 10 to 60 ft. The details of the analysis are shown in Table 4.

It should be noted that Column 3(c) of Table 4 contains the relative probability of a secondary collision occurring due to

TABLE 4

MEDIAN WIDTH VS RELATIVE PROBABILITY INDEX
MEDIAN AND HOUSE-SIDE LUMINAIRE SUPPORTS
50' HEIGHT - 250' SPACING

(1)	(2)	Percent Probability of Vehicles Traveling Indicated Distance From Edge of Roadway (3)			(4)	(5)	(6)	(7)	(8)
		(a)	(b)	(c)					
Location	Median Width (ft)	Distance from Roadway to Luminaire Support	Percent Probability (Hutchinson Est.)	Estimated Percent of Impact Angle > 20°	Relative Probability Index of Vehicle Collision with Luminaire Support	No. of Traffic Streams Exposed to Luminaire Supports	Relative No. of Supports Per 250'	Total Hazard Index	Relative Hazard Index
Median	60'	30 '	11%	--	.110	2.00	1.00	.220	1.00
Median	55'	27.5'	13%	--	.130	2.00	1.00	.260	1.18
Median	48'	24.0'	18%	5%	.189	2.00	1.00	.378	1.72
Median	46'	23.0'	20%	5%	.210	2.00	1.00	.420	1.91
Median	44'	22.0'	22%	5%	.231	2.00	1.00	.462	2.10
Median	42'	21.0'	25%	5%	.263	2.00	1.00	.526	2.39
Median	40'	20.0'	28%	5%	.294	2.00	1.00	.588	2.67
Median	35'	17.5'	37%	5%	.388	2.00	1.00	.776	3.53
Median	30'	15.0'	45%	10%	.495	2.00	1.00	.990	4.50
Median	25'	12.5'	52%	10%	.572	2.00	1.00	1.144	5.22
Median	20'	10.0'	59%	10%	.650	2.00	1.00	1.300	5.91
Median	15'	7.5'	67%	10%	.738	2.00	1.00	1.476	6.71
Median	10'	5.0'	75%	10%	.825	2.00	1.00	1.650	7.50
House-side		15 '	45%	--	.45	1.00	2.22*	1.00	4.55

*Recommended Spacing of 225 feet for House-side Installations--discuss in text opposing traffic striking the downed support in the opposing traffic lane. This is based on Test LS-2, a 4000 lb vehicle striking a 50 ft support at 25° and 60 mph, in which the lateral translation of the pole base was 31 ft. Assuming that an encroachment of more than four feet into a traffic lane may result in a collision, the estimated percent of impacts greater than 20° were determined from Figure 18(b).

Figure 19 shows a plot of the values for Relative Hazard Index vs. Median Width for a median-mounted system and for a 50 ft house-side system with supports located 15 ft from the edge of the roadway on both sides. This comparison indicated that median-mounted lighting systems produce less hazard than house-side systems for median widths 30 ft or greater.

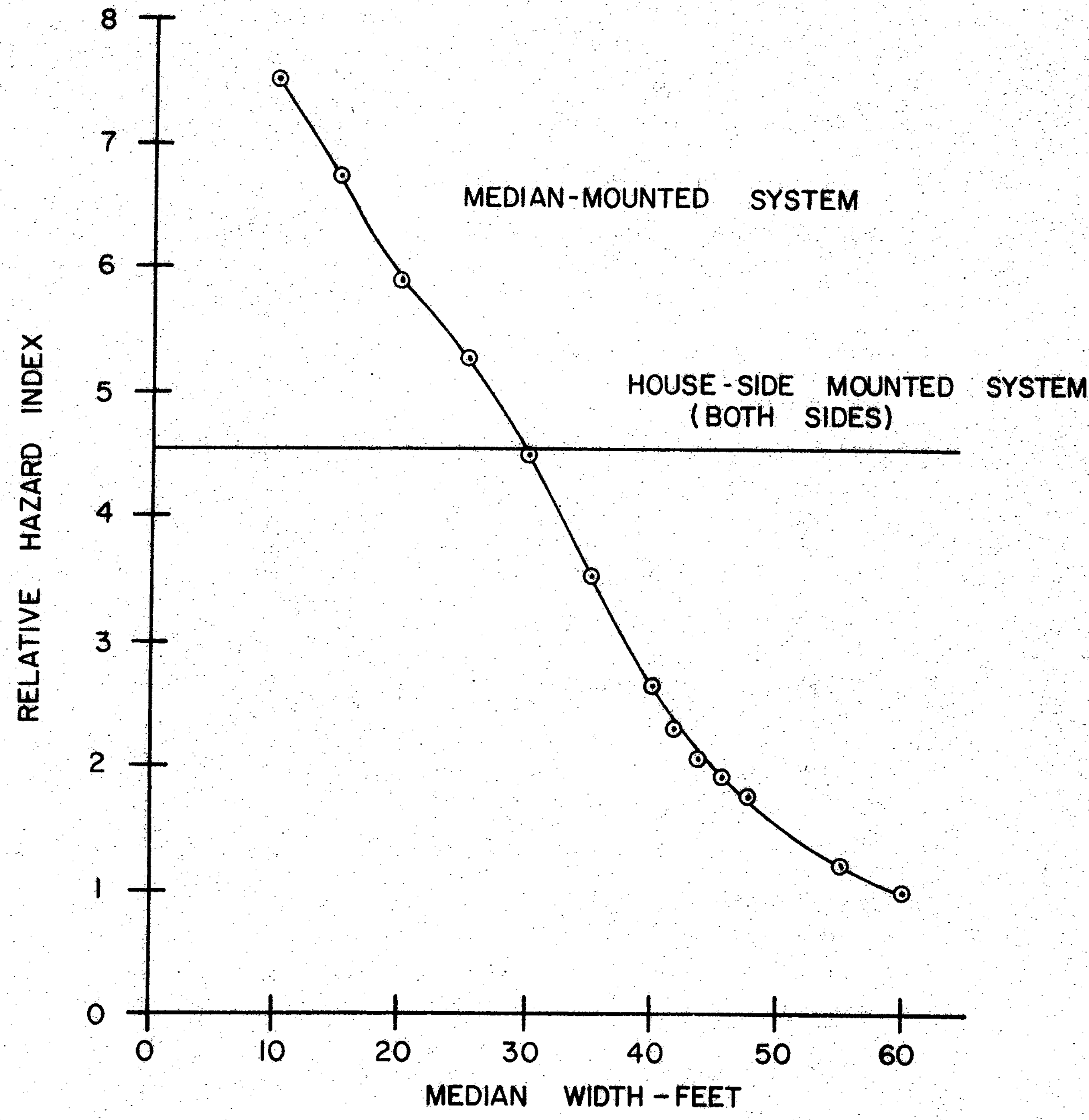


FIGURE 19 – RELATIONSHIP OF RELATIVE HAZARD INDEX TO MEDIAN WIDTH FOR MEDIAN-MOUNTED AND HOUSE-MOUNTED 50 FT. LUMINAIRE SUPPORTS.

CONCLUSIONS

Based on the results of the three crash tests and development of the Relative Hazard Index, the following conclusions are drawn:

1. The breakaway behavior of 50 ft double-mast arm luminaire supports with frangible bases is satisfactory under the conditions of Tests LS-1 and LS-2.
2. A 20° impact by a 2900 lb. vehicle at 45 mph would probably not cause a pole to encroach on the opposing traffic lane if the median is 40 ft wide (including shoulders)
3. A 4000 lb vehicle impacting at 25° and 60 mph would cause a pole to encroach approximately 11 ft into the opposing inside traffic lane if the median is 40 ft wide (including shoulders).
4. Both conditions (2) and (3) above would allow the impacting vehicle to cross into the opposing traffic lanes, and this may be more of a hazard than the poles themselves.
5. A medium size vehicle which encounters a support in its traffic lane and strikes it with all wheels on the pole shaft (not straddle the base and not attempt to maneuver) at 60 mph would probably be able to continue straight ahead until control is regained.

6. From a relative hazard standpoint, 50 ft high median-mounted luminaire systems produce less hazard than house-side systems for median widths of 30 ft or greater.

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1. Rowan, N. J., and McCoy, P. T. An Interim Report on a Study of Roadway Lighting Systems. Research Report 75-1, Texas Transportation Institute, College Station, Texas. April 1966.

2. Edwards, T. C., Martinez, J. E., McFarland, W. F., and Ross, H. E., Jr. Development of Design Criteria for Safer Luminaire Supports. NCHRP Report 77, 1969.

3. Walton, N. E. and Rowan, N. J. Final Report, Supplementary Studies in Highway Illumination. Research Report 75-13F, Texas Transportation Institute, College Station, Texas, August 1969.

4. Break-Away Roadside Sign Support Structures. Final Report of Project HPR-2(104), Contract No. CPR-11-3550. Texas Transportation Institute, College Station, Texas. July 1967.

5. Stonex, K. A. Relation of Cross-Section Design and Highway Safety. Paper presented at the 35th Annual Highway Conference, University of Colorado, Denver, February 23, 1962 (Supplemented January, 1963).

A P P E N D I X

TABLE A-1

FILM DATA FROM TEST LS-1

Time (msec)	Vehicle Displacement (ft)	Position of Luminaire Support	Angle Pole Makes With Vertical (deg)	Axial Rotation (counter-clockwise from top) (deg)	Remarks
-45	-3.0				
-33	-2.2				
-20	-1.3				
- 6	-0.5				
0	0		0	0	Impact.
5	0.3				Base crushing.
10					Pole starts to move.
18	1.2				
30	2.0				Maximum penetration of vehicle (7").
43	2.7				
55	3.6				
68	4.3				
80	5.1				
93	5.8				
105	6.6				
118	7.4				
130	8.1	Base at bumper level in contact with the vehicle.	17		
155	9.6				
168	10.4				
180	11.1				
193	11.9				
205	12.6				

FILM DATA FROM TEST LS-1 (Continued)

Time	Displacement	Position of Support	Pole Angle	Axial Rotation	Remarks
218	13.3				
231	14.1				
243	14.9				Loss of contact with vehicle.
256	15.6	Base 6" below top of hood and moving away.	24		
268	16.4				
281	17.2				
293	17.9				
306	18.7				
318	19.4				
331	20.2				
343	21.0				
377	23.1	Base 1' in front and 1' above hood.	35	2	
503	30.6	Base 1' in front and 2' above hood.	45	3	
628	38.0	Base even with front of hood and 5.5' above it.	60	7	
754	45.2	Base 1' behind bumper and 6' above roof of vehicle.	73	10	
880	52.4	Base 4' behind bumper and 8' above roof.	82	12	
1005	59.3	Base 9' above center of roof.	93	30	
1101	64.7				Tip of left arm touches ground.
1131	66.0	Base 12' above center of trunk.	106	40	
1216					Top of pole touches ground.

FILM DATA FROM TEST LS-1 (Concluded)

Time	Displacement	Position of Support	Pole Angle	Axial Rotation	Remarks
1256	72.9			0	Vehicle goes out of view.
1275					Tip of right arm hits the ground.
1344		Top of pole on ground and arm tips equal height above ground (arms bent).	114	-15	
1533		Right arm only touching ground.	100	-18	
1659		No part of pole touching ground.	95	-28	
1784		Pole flat on ground, top and right arm on ground, left arm in air.	90	-40	Base hits ground.
1910		Entire pole 1' above ground.	90	-44	
2008				-47	
2123		Pole base touches ground again, right arm on ground.	87	-44	
2259				-40	
2386				-38	
2510				-32	
2637				-25	
2754		Pole base at rest, top almost on ground, right arm on ground.	90	-19	

Final Positions:

BASE: 19'3" to the right and 54'0" behind its original position.

RIGHT ARM TIP: 18'4" to the right and 1'11" behind original position of base.

LEFT ARM TIP: 6'10" to the left and 7'1" behind original position of base.

TOP OF POLE: 7'11" to the right and 9'0" behind original position of base.

TABLE A-2

FILM DATA FROM TEST LS-2

Time (msec)	Vehicle Displacement (ft)	Position of Luminaire Support	Angle Pole Makes With Vertical (deg)	Remarks
-38	-3.4			
-31	-2.7			
-23	-2.0			
-15	-1.3			
-8	-0.7			
0	0		0	Impact.
7	0.7			Base cracks.
15	1.3			
31	2.6			
46	3.8			
62	5.0			
72	5.9			Accelerometer traces show event over.
88	7.4		15	Pole moving relative to car.
95	---			Pole begins to bend (metal deforms). Until this time, pole is in form of an arc.
100	8.0			
115	9.2			
139	11.1		20	Vehicle front wheels leave ground. (Unable to see when they touch ground again.)
154	12.2			
169	13.4			
184	14.6			
200	15.8			
215	17.0			

FILM DATA FROM TEST LS-2 (Continued)

Time (msec)	Vehicle Displacement (ft)	Position of Luminaire Support	Angle Pole Makes With Vertical (deg)	Remarks
231	18.2			
246	19.4			
261	20.6			
277	21.8			
295	22.7	Base 1' in front of vehicle at headlight level.	40	Loss of contact except for raised part of hood.
439	33.8	Base 1' above front edge of hood.	51	
558	43.0	Base 5' above hood and 1.5' behind front bumper.	64	
634	48.8	Base 7' above hood and 3' behind front bumper.	75	
740	56.5	Base 7' above front edge of roof.	90	
899	68.0	Base 12' above center of trunk.	109	Tip of west arm touches ground. Base has rotated 45° counter-clockwise. Car goes out of view.
992	--	Both arm tips off ground.	117	Top of pole touches ground.
1081	--	Top of pole on ground, west arm in air.	127	Tip of east arm touches ground.
1770	--	Base on ground, two arms and top of pole in air. Base has rotated back to its original position.	90	
1879	--	East arm recontacts ground. Base, top, and west arm in air.	97	
2313	--	Base at rest on ground, east arm on ground, top and west arm in air.	90	

FILM DATA FROM TEST LS-2 (Concluded)

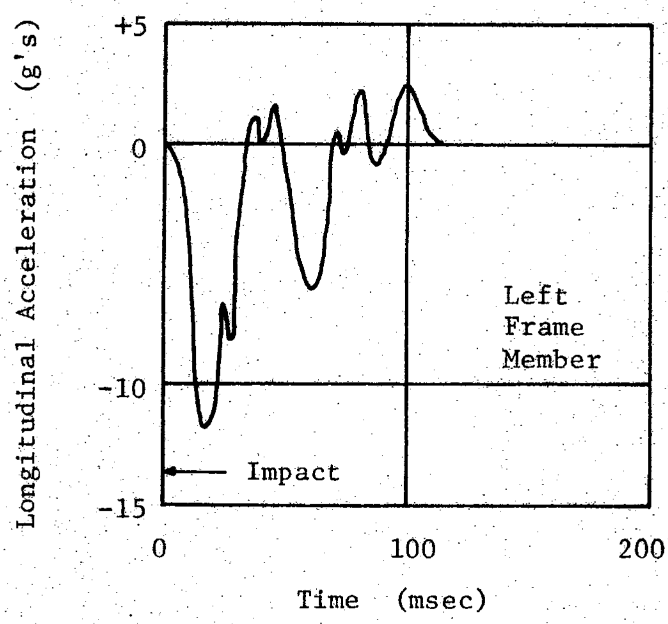
Final Positions of Luminaire Support:

BASE: 31'1" to the right and 57'2" behind base plate.

EAST ARM TIP: 12'11" to the right and 6'6" behind base plate.

WEST ARM TIP: 1'4" to the right and 15'11" behind base plate.

TOP OF POLE: 0'7" to the right and 18'5" behind base plate.



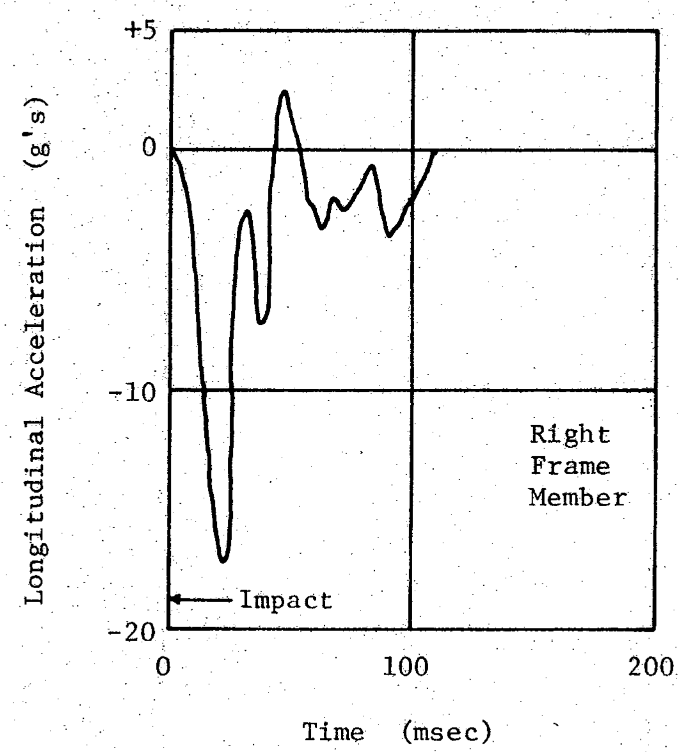
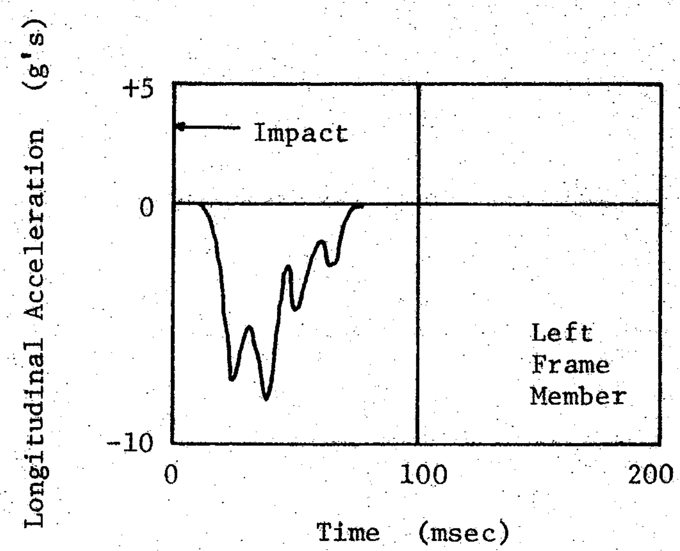


FIGURE A-1

ACCELEROMETER DATA FOR TEST LS-1.

Strain-Gage-Type Accelerometer
80 Hz Low-Pass Filter



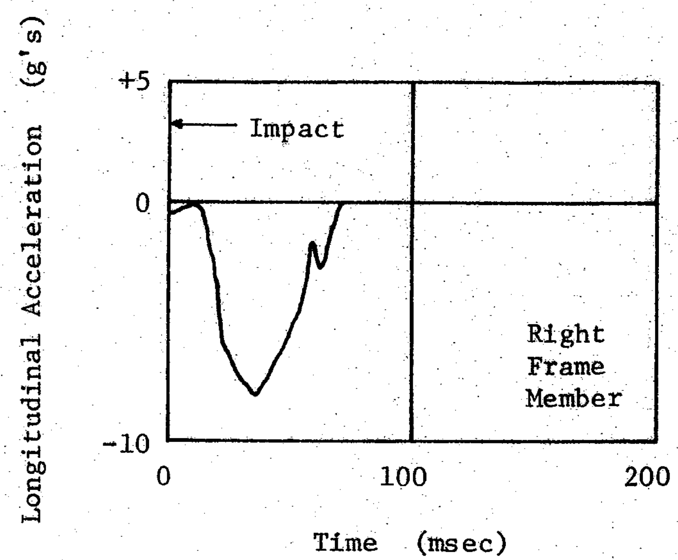


FIGURE A-2

ACCELEROMETER DATA FOR TEST LS-2.

Strain-Gage-Type Accelerometer
80 Hz Low-Pass Filter

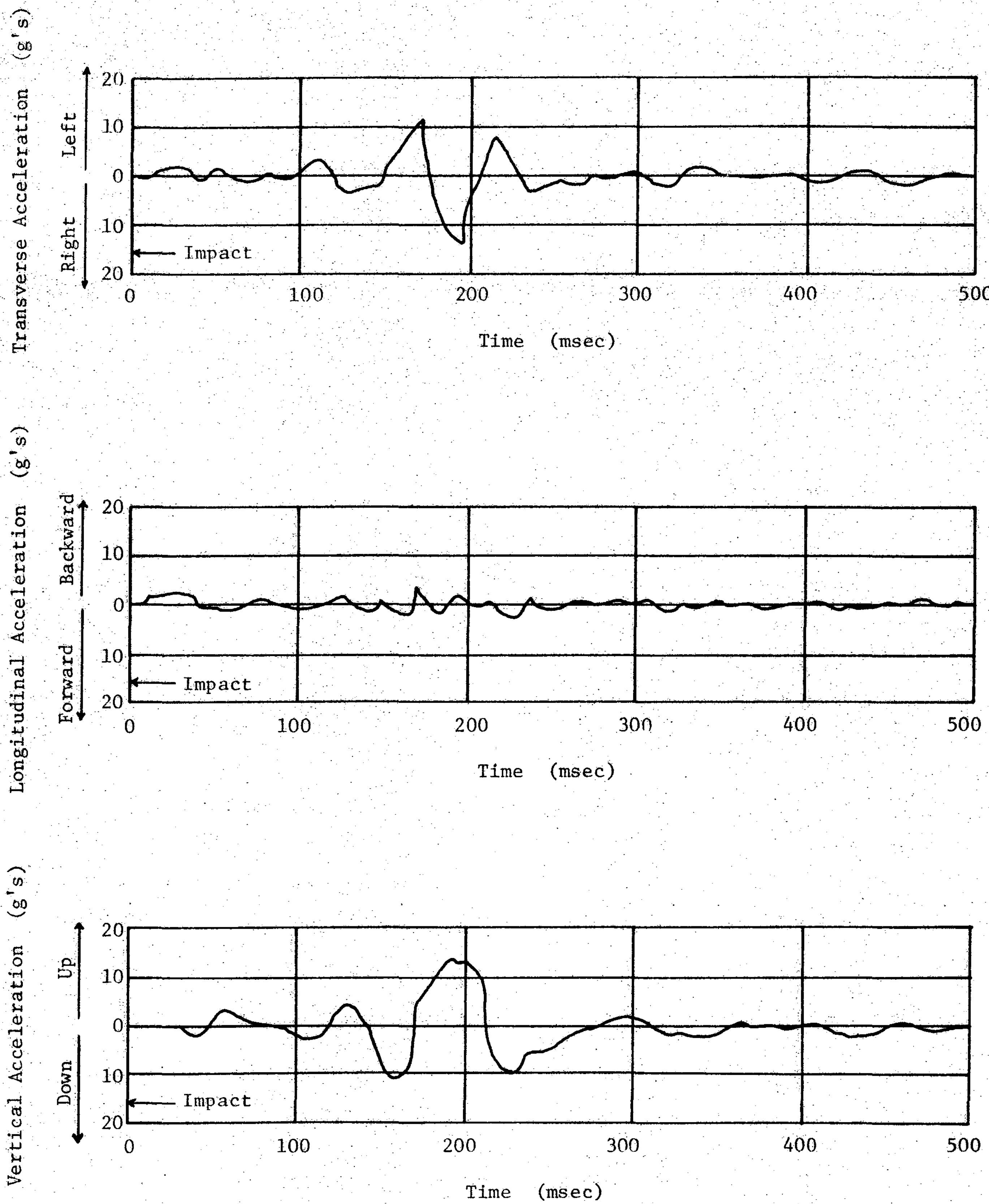


FIGURE A-3

IMPACT-O-GRAPH DATA FOR TEST LS-3.