

IMPACT BEHAVIOR OF LUMINAIRE SUPPORTS

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Research Report Number 75-8

Supplementary Studies in Highway Illumination

Research Project Number 2-8-64-75

Sponsored by

The Texas Highway Department

In Cooperation with the

Department of Transportation, Federal Highway Administration

Bureau of Public Roads

October, 1967

TEXAS TRANSPORTATION INSTITUTE  
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College Station, Texas

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# IMPACT BEHAVIOR OF LUMINAIRE SUPPORTS

## INTRODUCTION

Experience and research have shown that continuous lighting on freeways as well as city streets improves the driving environment and thus reduces the hazards of nighttime driving. However, the advantages of lighting may be offset by the hazards introduced by the maze of lighting poles used to support the lighting system. Experience over the years has shown that lighting poles have contributed significantly to the trend toward an increase in fixed object collisions, mainly because of the frequency with which they must be used to provide continuous lighting for nighttime operation.

R. L. Moore of the Road Research Laboratory of Great Britain has pointed out that a vehicle leaving the roadway at 60 miles per hour on a dry road would have 20% chance of striking a lighting pole if the poles were spaced at 120-foot intervals.<sup>1</sup> In wet weather, the probability of collision under the same conditions would be approximately 33%. These predictions were based on realistic assumptions for coefficients of friction for dry and wet pavements. The importance of the problem is thus established.

Several alternatives have been suggested as solutions to the problem: moving the lighting poles to a point well away from the traveled way, or controlling the impact behavior of the lighting poles to reduce the severity of collisions. In fact, a combination of the two alternatives may provide an even better solution. Moving the lighting poles back from the traveled way would enhance the opportunity for a driver to regain control of his vehicle and stop or return to the roadway before a collision occurred. There are limitations on how far the lighting units can be placed from the roadway and thus the distance that the poles can be removed may be limited. Regardless, it would seem desirable to take advantage of some method of reducing the severity of collision because many drivers may not be able to regain control of their vehicles before striking a pole.

For several years, engineers of the Texas Highway Department have recognized the potential hazard of collisions with lighting poles. Accordingly, they have taken steps to minimize this hazard as rapidly as possible. By experience alone they found that the collisions with lighting poles on cast aluminum transformer bases were far less severe than collisions with poles on steel transformer bases. As a result, design engineers are encouraged to use the aluminum transformer bases for lighting standards, especially where the standards are not protected by guard rails.

As a remedial measure, engineers of the Texas Highway Department have developed a cast aluminum insert to be placed under the steel transformer bases of existing lighting systems.

## DESCRIPTION OF RESEARCH

Since 1964 TTI has been engaged in research on highway illumination with the Texas Highway Department in cooperation with the Bureau of Public Roads. Initially, this research was concerned only with the illumination aspects, but the severity of collisions with lighting poles on Texas highways prompted the inclusion of a phase dealing with the impact behavior of lighting poles. Part of this research has been referred to as a "state of the art" study, a study to determine the impact characteristics of the various pole and base mounting designs now in use on Texas highways. In addition, part of the research effort has been devoted to the development and evaluation of a slip base design similar to that used in the break-away sign support.<sup>2,3,4</sup>

The lighting pole designs included in the "state of the art" study were representative of the new standards for roadway illumination recently adopted by the Texas Highway Department. These standards call for 40-foot mounting heights for 400-watt luminaires and 50-foot mounting heights for 1000-watt luminaires. In order to have a single design representative of both the 40- and 50-foot mounting heights, a 45-foot mounting height was selected. This was accomplished by using a 1'-8" base, a 38'-4" shaft and a 10-foot mast arm with an upsweep of 5 feet. In addition, one design of a 30-foot mounting height was used to evaluate the cast aluminum inserts designed to be placed under steel transformer bases of poles that were already in existence. A description of the various designs tested is presented in Table A. The designs are also illustrated in Figure 1.

### METHOD OF STUDY

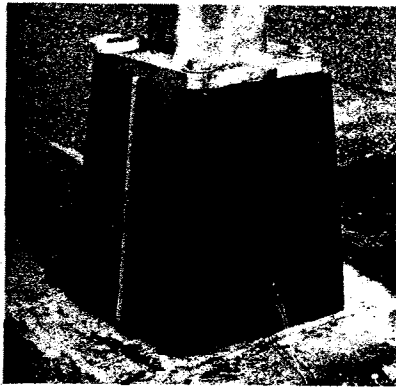
All of the crash tests were conducted as head-on collisions with the lighting poles. Standard sedans of 1954 to 1959 vintage were used except for one test which involved a 2100-pound compact sedan. These tests were conducted using the crash test facilities previously developed for sign support research. The procedure for creating the collisions is referred to as the "reverse tow" procedure. This procedure is well documented in earlier reports.<sup>2,3</sup> The crash vehicle was towed along the rail by a vehicle moving in the opposite direction, and released when it reached the end of the guide rail, to strike the intended target. The lighting pole under test was placed approximately 35 feet beyond the end of the guide rail.

High speed motion picture photography was used as the principal means of obtaining data on the crash tests. Several cameras including a camera capable of filming speeds of 1000 pictures per second were used. Electronic instrumentation was used to a limited extent.

TABLE A  
 POLE AND BASE COMBINATIONS  
 TESTED IN THE "STATE OF THE ART" STUDY

Combination	Number of Tests	Impact Speed, MPH
Steel Pole-Aluminum Transformer Base	3	22.2 44.8 45.7 (Compact Sedan)
Aluminum Pole-Aluminum Transformer Base	2	21.3 43.2
Steel Pole-Steel Transformer Base-Aluminum Insert	2	32.2 53.2
Flange-Mounted Steel Pole	1	40.5
Flange-Mounted Aluminum Pole	1	44.0
Steel Pole-Steel Transformer Base	1	39.4
*Flange-mounted Fiberglass Pole	1	55.8

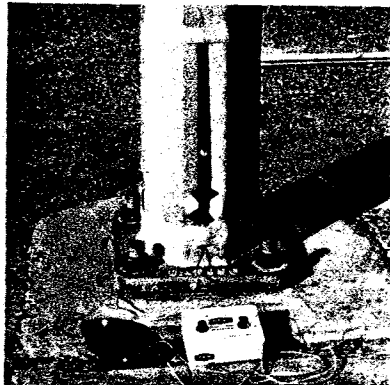
\*This pole was an experiemtnal design only.



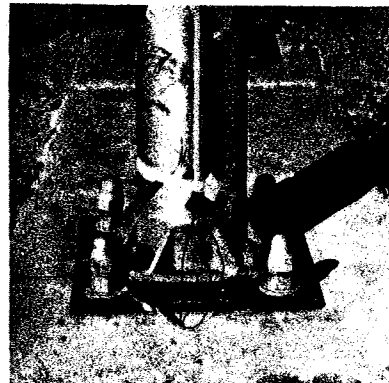
STEEL POLE - STEEL  
TRANSFORMER BASE



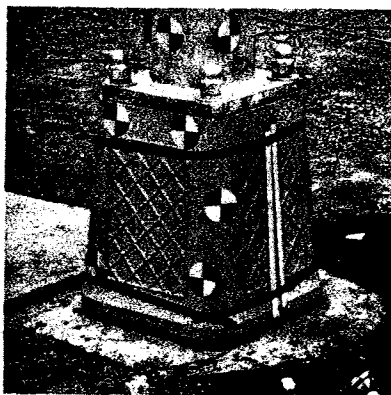
STEEL POLE - STEEL TRANSFORMER  
BASE WITH ALUMINUM INSERT



FLANGE MOUNTED STEEL POLE



FLANGE MOUNTED ALUMINUM POLE



STEEL POLE - ALUMINUM  
TRANSFORMER BASE



ALUMINUM POLE - ALUMINUM  
TRANSFORMER BASE

FIGURE I  
VARIOUS POLE AND BASE  
COMBINATIONS TESTED

## DATA ANALYSIS

The high speed motion picture films of the crash tests were analyzed to provide vehicle speeds before and after impact. Speeds could be computed using a motion picture analyzer which facilitates linear measurements of displacement to the nearest 1/1000 of an inch on a projected image of each frame of the high speed film. Time measurements were obtained from a large clock which rotated at 1800 revolutions per minute. The clock was mounted on the background screen within the field of view of the high speed camera. Vehicle speeds before impact were obtained from time and distance measurements over a five-foot increment of travel immediately prior to impact. Speeds after impact were obtained by time and distance measurements for a five-foot interval of vehicular travel from five to ten feet beyond the point of impact. The data for the first few feet of travel during and immediately following impact were not used because of the inconsistency of readings in that interval. The speeds before and after impact, and the resulting reduction in speeds are summarized for all tests in Table B.

## ANALYTICAL COMPARISON

In order to obtain a relative comparison of the severity of impact in each of the collisions, a comparison is made of the momenta of the vehicles before and after collision with the pole. This method requires only that the speeds of the vehicle before and after impact be known since momentum is obtained as the product of the vehicle mass and speed.<sup>5</sup> The change in momentum of the vehicle due to the collision is equal to the impulse force delivered to the vehicle by the pole. This impulse is simply the time integral of force during impact. The time duration of the impact is unknown, but it is dependent upon the vehicle's speed. The greater the speed of the vehicle before impact, the greater would be the average force delivered to the vehicle by the pole, but since the duration of the collision will be less for higher speed, the product of the average force and the time will remain relatively constant. Thus, the change in momentum of a vehicle in a collision gives an indication of the severity of collision and the force that the pole exerts on the vehicle. The momentum lost during the impact was calculated for each test and the results are summarized in Table C which shows the relative impact severity of the several designs tested.

A comparison of the various designs tested made on the basis of change in momentum is illustrated in Figure 2. This comparison shows that there are only small differences in the change in momentum with the exception of the flange-mounted steel pole and the steel pole on the steel transformer base. On the basis of this comparison it would appear that the frangible base such as the cast aluminum transformer base or the cast aluminum insert produces satisfactory impact behavior of lighting poles.

TABLE B  
 CHANGE IN SPEED AND DEFORMATION  
 OF VEHICLE IN COLLISION WITH LIGHTING  
 POLE AND BASE COMBINATIONS

Combination	Vehicle Make	Vehicle Weight, Lb	Speed Before Impact, MPH	Speed After Impact, MPH	Change in Speed, MPH	Deformation of Vehicle, Inches
Steel Pole - Aluminum Transformer Base	1959 Ford	3460	22.2	18.1	4.1	12.7
	1959 Ford	3700	44.8	41.5	3.3	15.5
	1960 Simca	2140	45.7	38.0	7.7	12.3
Aluminum Pole - Aluminum Trans- former Base	1959 Ford	3680	21.3	17.0	4.3	10.9
	1957 Ford	3600	43.2	38.0	5.2	10.2
Steel Pole - Steel Transformer Base Aluminum Insert	1955 Ford	3460	32.2	27.3	4.9	14.4
	1955 Ford	3580	53.2	47.0	6.2	15.8
Flange-Mounted Steel Pole	1958 Ford	3600	40.5	29.2	11.3	27.4
Flange-Mounted Aluminum Pole	1957 Ford	3500	44.0	37.2	6.8	23.1
Steel Pole - Steel Transformer Base	1958 Ford	3700	39.4	0.0	39.4	30.0
*Flange-Mounted Fiberglass Pole	1958 Ford	3600	55.8	53.7	2.1	3.0

\*This pole was an experimental design only.



TABLE C  
CHANGE IN MOMENTUM OF VEHICLE  
IN COLLISION WITH LIGHTING POLE AND  
BASE COMBINATIONS

Combination	Impact Speed	Momentum Before Collision (Lb-Sec)	Momentum After Collision (Lb-Sec)	Change In Momentum (Lb-Sec)
Steel Pole	22.2	3495	2860	635
Aluminum	44.8	7550	7000	550
Transformer Base (Compact)	45.7	4450	3700	750
Aluminum Pole	21.3	3555	2845	710
Aluminum Trans- former Base	43.2	7070	6120	950
Steel Pole - Steel	32.2	5070	4300	700
Transformer Base - Aluminum Insert	53.2	8660	7660	1000
Flange-Mounted Steel Pole	40.5	6630	4790	1840
Flange-Mounted Aluminum Pole	44.0	7030	5930	1100
Steel Pole - Steel Transformer Base	39.4	6620	0	6620
*Flange-Mounted Fiberglass Pole	55.8	9150	8820	330

\*This pole was an experimental design only.

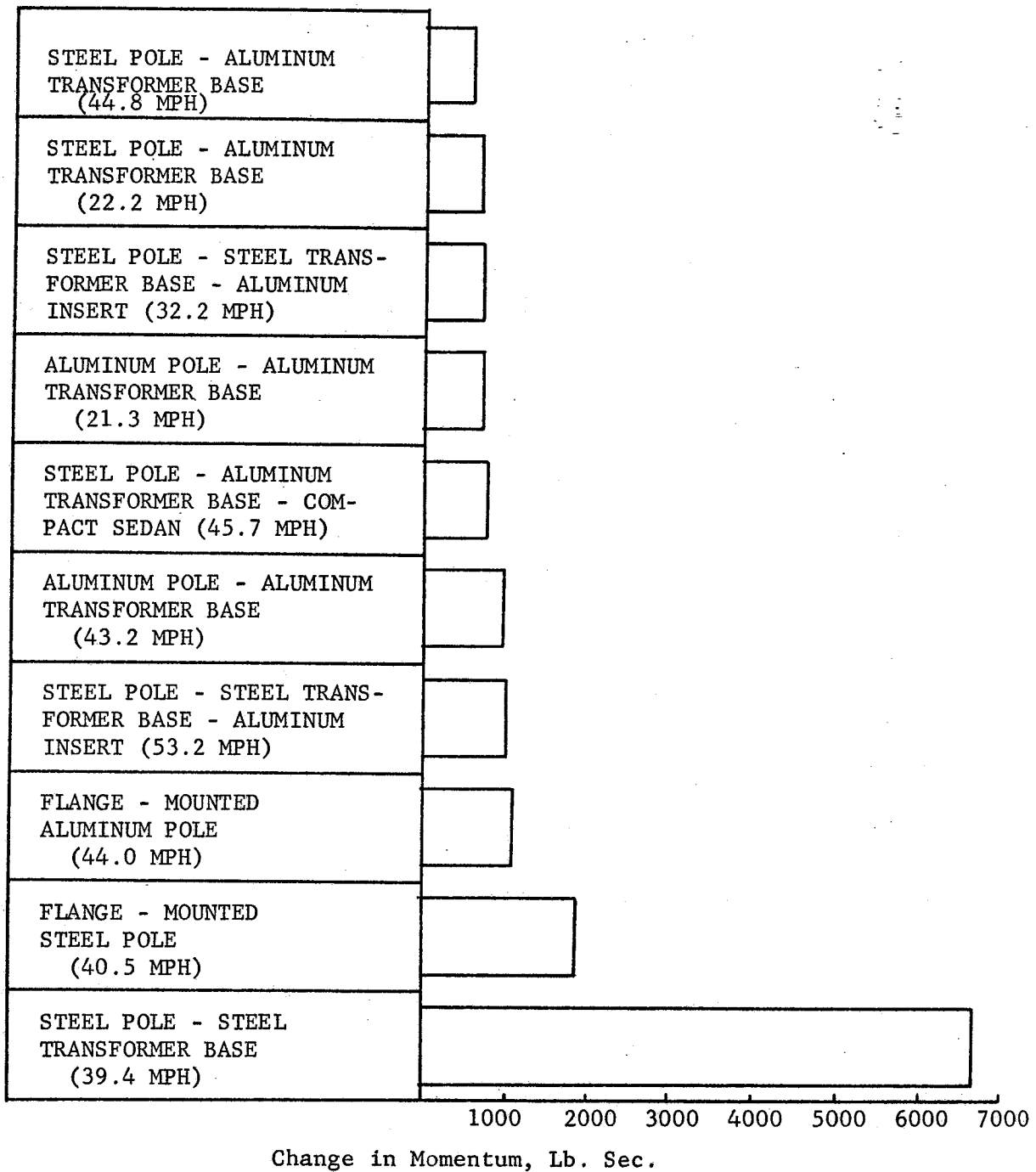


FIGURE 2

COMPARISON OF POLE AND BASE COMBINATIONS ON THE BASIS OF CHANGE IN MOMENTUM

For another means of comparison, the deformation or penetration of the vehicle due to the impact was plotted as shown in Figure 3. This comparison shows essentially the same results as indicated by the comparison of the change in momentum except for the flange-mounted aluminum pole. In comparison, the aluminum pole does not show a great advantage over the steel pole. In both cases the deformation of the front of the vehicle was on the order of 2 feet. From experience, such severity may not cause a fatality but would likely result in personal injury to the vehicle occupants.

### GENERAL OBSERVATIONS

In addition to the comparison of impact severity by the methods described previously, considerable information can be gained by viewing the films and making a subjective evaluation of the behavior of the poles during and after the collision. In fact, this is the best approach for evaluating the conditions of the collision where secondary impacts with the pole may occur. In this section, by way of a general discussion, each of the lighting pole designs will be evaluated.

#### Steel Pole - Steel Transformer Base

In some lighting systems provisions are made for enclosing the transformer or ballast in the base of the lighting pole. This normally involves a transformer base similar to those shown in Figure 1. Such bases may be made of steel or cast aluminum. Many of the earlier lighting systems on Texas highways utilized steel transformer bases principally from the standpoint of economy in construction.

In general, these systems have experienced accidents of the highest order of severity. However, it was considered desirable to include this design in the "state of the art" study for relative comparison. Therefore, one test was conducted at a nominal speed of 40 miles per hour.

The fact that the steel pole with steel transformer base completely stopped the vehicle from an impact of 39.4 miles per hour is sufficient evidence that the design is unsatisfactory from the standpoint of safety. The front of the crash vehicle was deformed approximately 30 inches and the force of the impact actually caused the vehicle to bounce back approximately 24 inches. The severity of the collision is illustrated in the series of photographs in Figure 4. The pole remained in an upright position after the impact but considerable damage was done to the anchor bolts. This test is considered sufficient evidence to completely rule out this design.

#### Flange-Mounted Steel Pole

Experience with the transformer or ballast enclosed in the base of the pole has

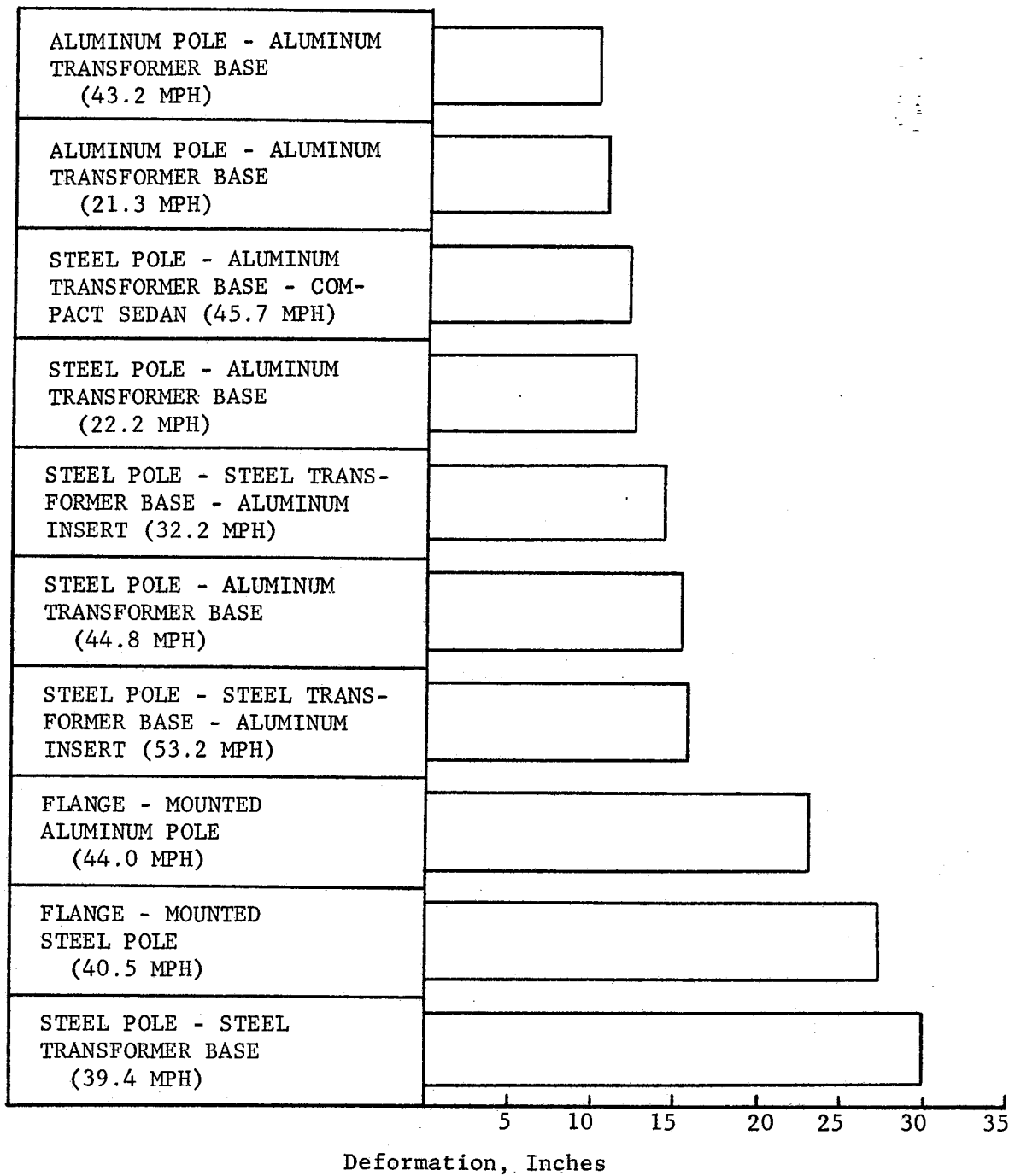
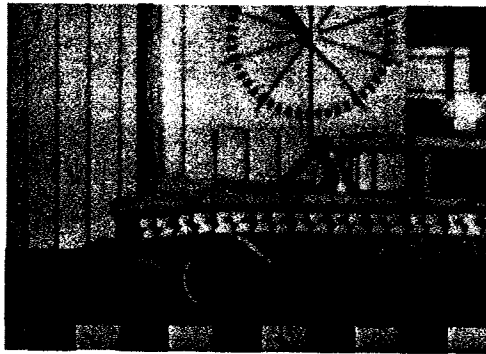
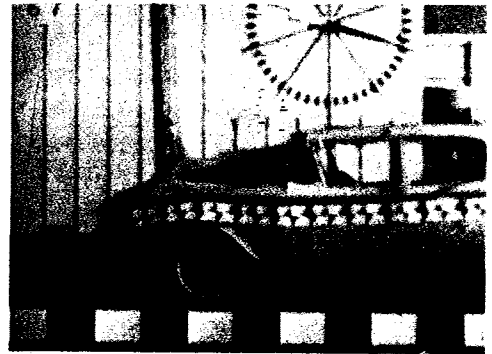


FIGURE 3

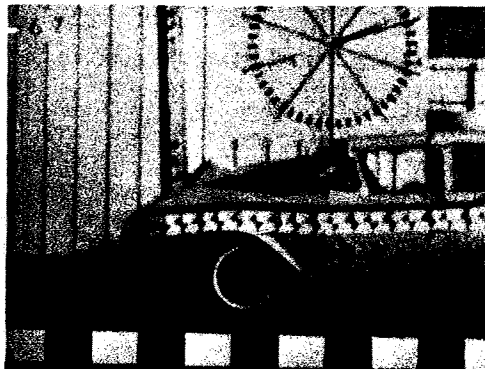
COMPARISON OF POLE AND BASE COMBINATIONS ON THE BASIS  
 OF DEFORMATION OF FRONTAL AREA OF VEHICLE



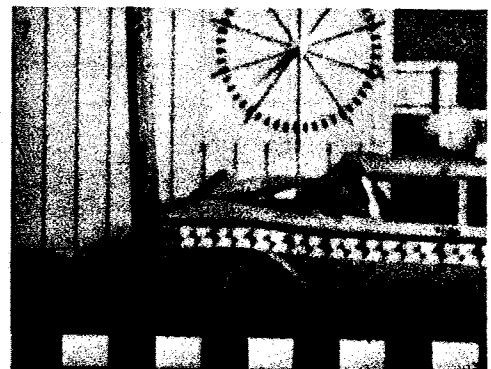
(a)



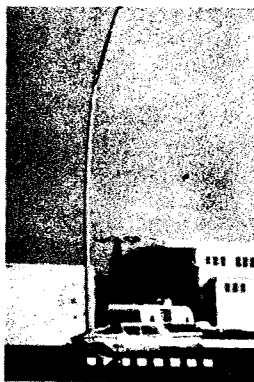
(b)



(c)



(d)



(e)



(f)

**FIGURE 4**  
**SEQUENCE PHOTOGRAPHS OF TEST OF STEEL**  
**POLE-STEEL TRANSFORMER BASE COMBINATION**

proven unsatisfactory. Electrical failures have resulted from excessive moisture and insect damage. As an alternative, the ballast was mounted on or near the top of the pole. Later designs have utilized a ballast integrally mounted with the lighting assembly. Without the necessity of providing an enclosure for the ballast, the lighting poles were erected by bolting the flange base directly to a concrete foundation, as illustrated in Figure 1.

One test was conducted using a flange-mounted pole (sometimes referred to as a "shoe-base" mounting) at a crash speed of 40 miles per hour. The details of the test conditions are given in Table A.

The flange-mounted steel pole produced less severity than the steel-transformer base mounting, but it was still considered quite hazardous. The failure mechanism was the shaft itself. As the crash progressed (see Figure 5), the shaft crushed in the vehicle contact area and sheared across the weld at the flange. The impact force was sufficient to cause 27 inches of deformation before failure occurred. This particular pole was constructed of eleven gauge steel plate; some poles are made of thicker steel plate and they would naturally offer much greater resistance to impact.

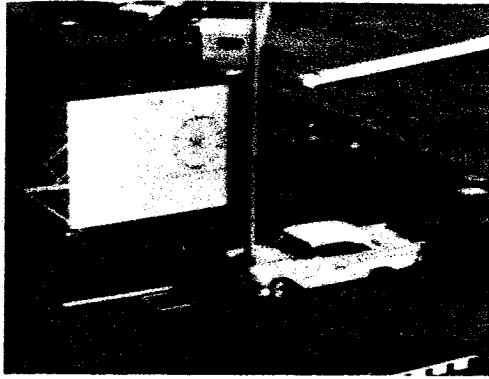
As the vehicle crushed the pole and tore it loose from the flange, a hook was formed on the bottom of the pole which held the pole on the automobile momentarily. The pole finally cleared the automobile at approximately 40 feet beyond the point of impact. The fact that the pole was momentarily hooked to the automobile gave it a forward and downward acceleration and the pole struck the top of the automobile; however, this was comparatively minor damage. The pole finally came to rest with its top approximately 60 feet from the foundation.

#### Flange-Mounted Aluminum Pole

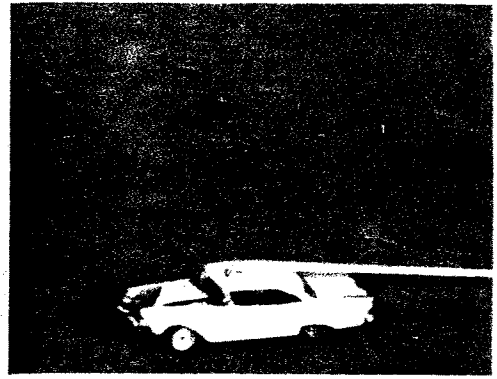
The flange-mounted aluminum pole (see Figure 1) has been accepted as an alternate to the galvanized steel pole on lighting projects on Texas highways. However, economy of construction has ruled in favor of the steel pole in most cases.

A flange-mounted aluminum pole was included in the "state of the art" study to provide a relative comparison with the comparable design in steel. Details of the pole and test conditions are given in Table A.

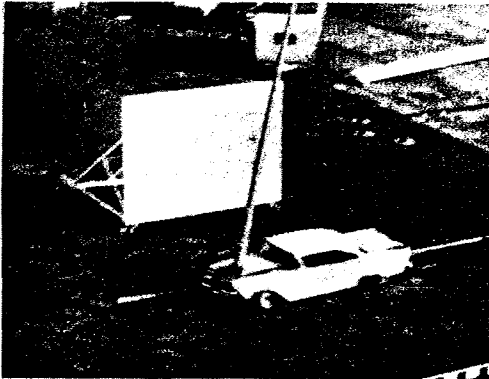
Although this pole was apparently designed to withstand the static forces of wind-loads, it was observed just prior to the crash test that wind velocities of approximately 20 miles per hour produced rather severe vibrations in the pole.



(a)



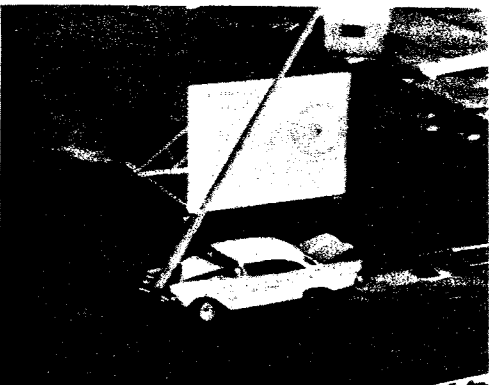
(d)



(b)



(e)



(c)



(f)

**FIGURE 5**  
**SEQUENCE PHOTOGRAPHS OF TEST OF**  
**FLANGE MOUNTED STEEL POLE**

The flange-mounted aluminum pole offered almost as much resistance to impact as did the flange-mounted steel pole, based on observations of the physical damage to the automobile (see Figure 6). This is evidenced by the fact that the deformation of the frontal area of the automobile was 23 inches when the pole finally failed. Failure occurred by the vehicle crushing the impact side of the pole and breaking the cast aluminum flange on the pole. Since the pole was crimped or crushed, a hook was formed and caught on the front bumper of the vehicle momentarily as in the case of the steel pole. This gave the pole an appreciable forward and downward acceleration so that the pole struck the top of the automobile. The pole stayed in contact with the front of the automobile for approximately 45 feet beyond the point of impact. After striking the ground, the pole skidded forward until the top of the pole was approximately 40 feet from the foundation.

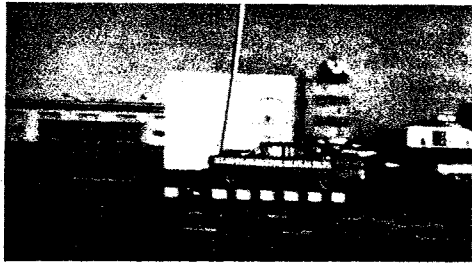
After the pole was torn loose at the base, the mast arm swung through approximately a half-circle before the top of the pole struck the ground.

#### Steel Pole - Aluminum Transformer Base

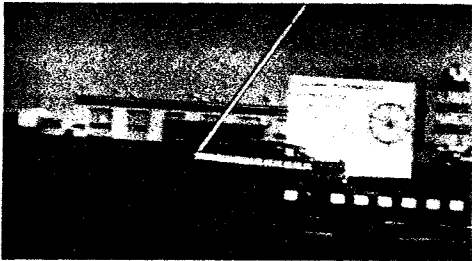
Although the transformer base is no longer needed or used to house the transformer, its use has been continued in Texas because of its favorable accident experience. In fact, it has been adopted as a design standard by the Texas Highway Department. As indicated in Table A three tests were conducted using the aluminum transformer base with a steel pole. Two of the tests were at approximately 45 miles per hour, one with a standard sedan and another with a compact sedan. The third test was conducted at a nominal speed of 20 miles per hour.

In the 45-mile-per-hour test with the standard sedan, the vehicle caused failure in the transformer base after a maximum deformation of the frontal area of the vehicle of 15 1/2 inches, and the pole was thrown clear of the automobile (see Figure 7). As the crash vehicle struck the transformer base, failure occurred by breaking out the front lower portion of the transformer base held by the two anchor bolts on the impact side of the base (see Figure 7f). As this failure occurred, the anchor bolts on the backside actually functioned as a slip joint; the base simply slipped off the two back anchor bolts. It was noted that the pole remained in contact with the front of the automobile for a distance of approximately 15 feet beyond the point of impact. At that time it was thrown clear of the automobile and continued in an upward arc so that the lower end of the pole completely cleared the automobile and struck the ground behind it (see Figure 7c). It is significant to note that the pole continued in the same direction as the impact, and further, that the top of the pole struck the ground very near the foundation. It was observed, however, that the mast arm swung through an angle of approximately 210 degrees in a clockwise direction looking downward from the top of the pole.

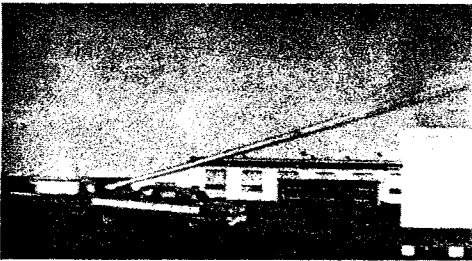




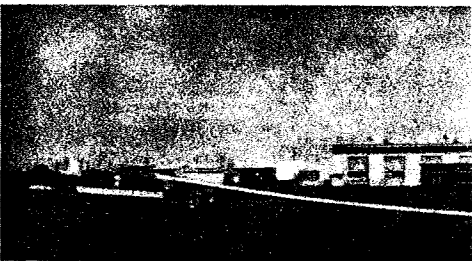
(a)



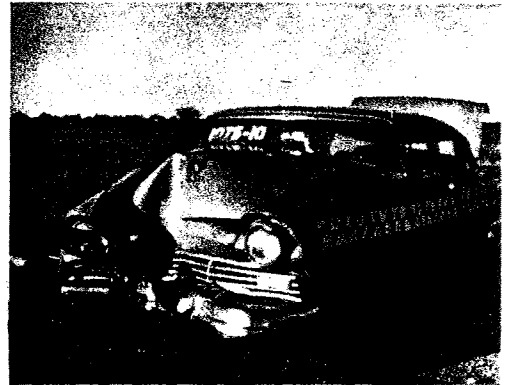
(b)



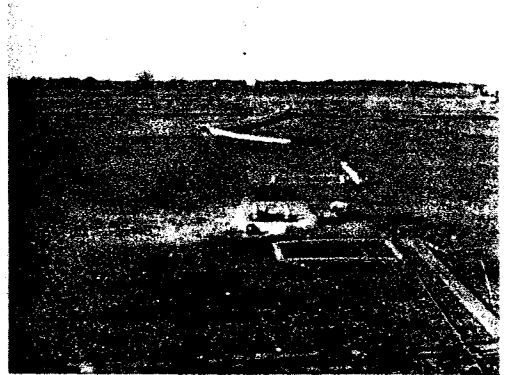
(c)



(d)



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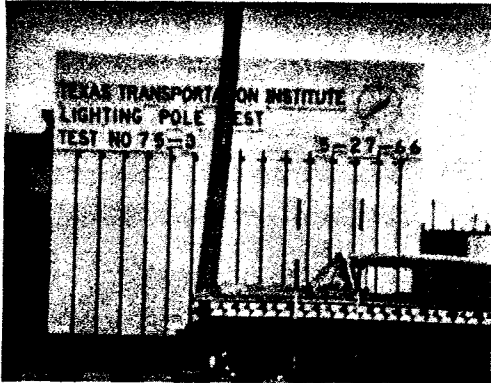


(f)

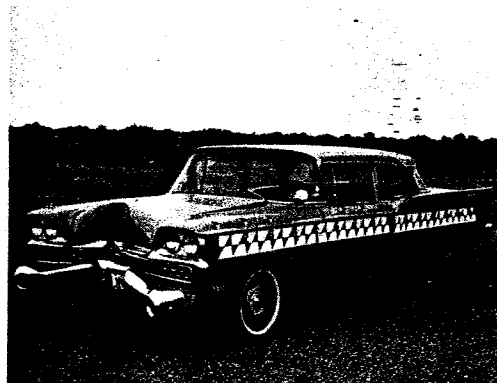


(g)

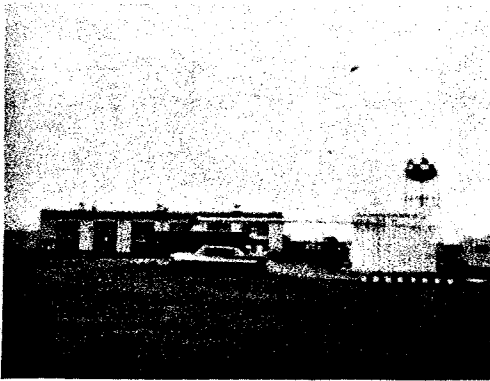
**FIGURE 6**  
**SEQUENCE PHOTOGRAPHS OF TEST OF**  
**FLANGE MOUNTED ALUMINUM POLE**



(a)



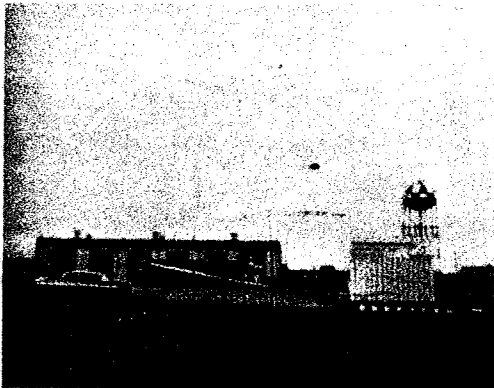
(d)



(b)



(e)



(c)



(f)

FIGURE 7  
SEQUENCE PHOTOGRAPHS OF TEST OF  
STEEL POLE-ALUMINUM TRANSFORMER  
BASE COMBINATION

In the test with the compact sedan, the performance of the automobile and the pole appeared to be the same as that in the test described above (see Figure 8). Analysis of the film indicated that the deformation of the front of the vehicle was slightly less than that of the full-size sedan. This could be attributable to the design of the vehicle. A comparison of the change in speed during the impact shows that the compact sedan was reduced 7.7 miles per hour while the standard sedan was reduced in speed only 3.3 miles per hour. Otherwise, the tests appeared to produce the same results.

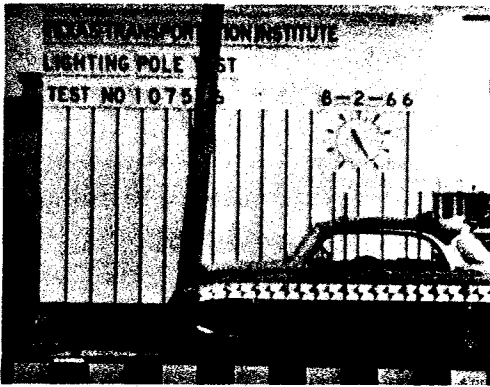
In the 20 mph test, the break-away action was the same as in the two previous tests. As the base was broken loose, it was carried forward approximately 20 feet where the pole slipped downward over the hood and the base became engaged with the paved surface and received a secondary impact by the automobile. This secondary impact caused only minor additional damage to the automobile, but in the following action the pole fell across the hood of the automobile, across the top and finally struck quite severely across the rear of the top breaking the rear glass in the automobile. This action is illustrated in the sequence photographs in Figure 9. It appears that the rear windshield was broken by the whiplash action of the pole when the top of the pole struck the ground. The base of the pole dragged across the top and trunk of the automobile as the vehicle cleared the area.

The fact that the pole strikes the top of the automobile in the slow speed collision is not a desirable feature; however, at the present it appears to be a characteristic that cannot be avoided. When considered in light of the possibility that the pole in any other mounting configuration may not have broken away it appears to be of secondary importance.

#### Aluminum Pole - Aluminum Transformer Base

Two crash tests were conducted using the Aluminum Pole - Aluminum Transformer Base design as illustrated in Figure 1. One of the tests was conducted at a crash speed of 45 miles per hour and the other at approximately 20 miles per hour. It should be pointed out that the transformer base for this design was smaller than the one used for the steel poles. The aluminum pole was constructed for mounting on a 15" bolt circle. The commercial base to accommodate the aluminum pole had a 12" bolt circle at the top and a 15" bolt circle at the bottom. The dimensions of the larger base for the steel pole were 15" and 17" respectively. The approximate weights of the bases were 35 pounds and 50 pounds, respectively.

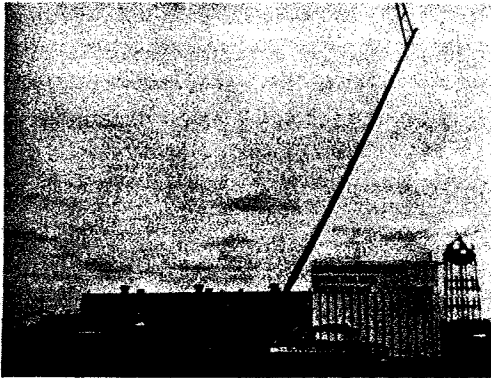
In general, the impact behavior of this design was not greatly different from that of the steel pole with the larger aluminum transformer base. The failure mechanism, that is the fracture and the slippage of the base, was essentially the same as that experienced with the steel pole - aluminum transformer base design.



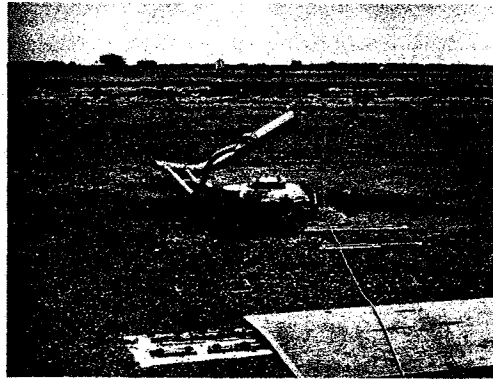
(a)



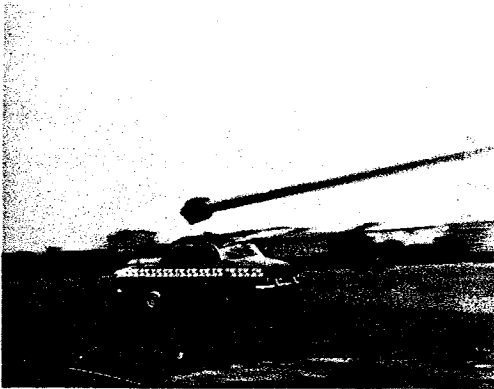
(d)



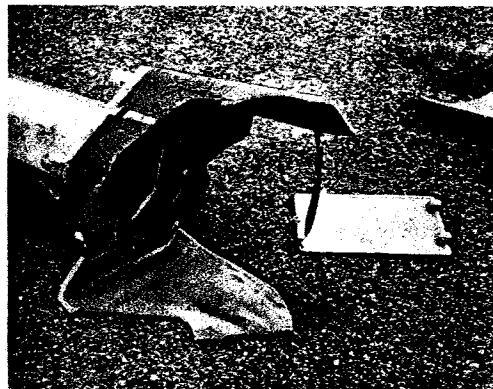
(b)



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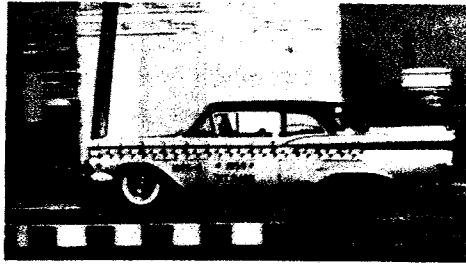


(c)

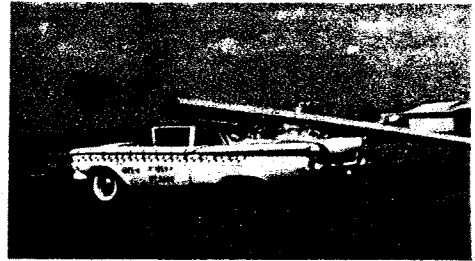


(f)

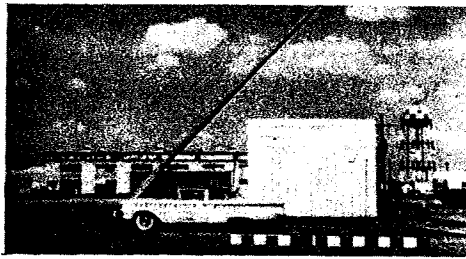
FIGURE 8  
SEQUENCE PHOTOGRAPHS OF TEST OF  
STEEL-POLE-ALUMINUM TRANSFORMER  
BASE COMBINATION



(a)



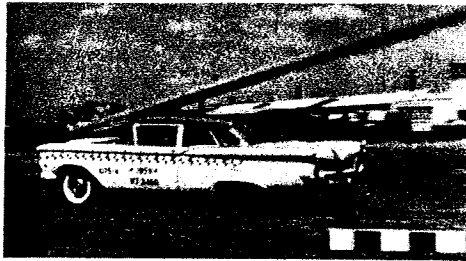
(e)



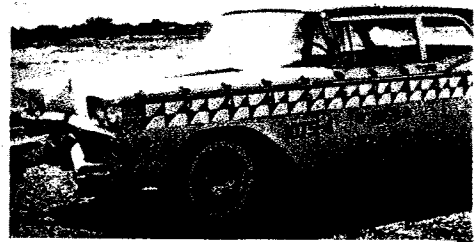
(b)



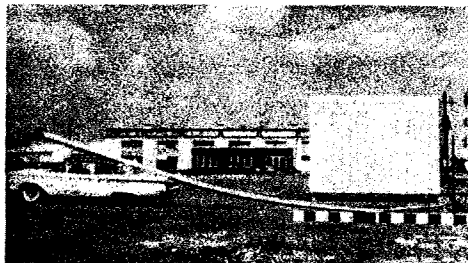
(f)



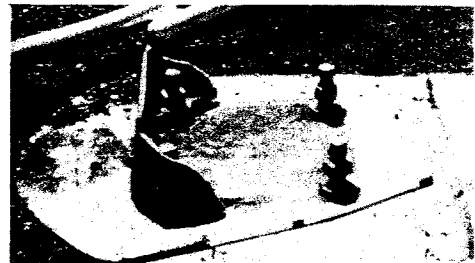
(c)



(g)



(d)



(h)

**FIGURE 9  
SEQUENCE PHOTOGRAPHS OF TEST OF  
STEEL-POLE-ALUMINUM TRANSFORMER  
BASE COMBINATION**

In the high-speed test it was observed that the pole was thrown clear of the automobile, approximately 6 feet beyond the point of impact, whereas the steel pole was not thrown clear until the vehicle had reached a point of approximately 15 feet beyond the point of impact. This difference is attributed primarily to the difference in the weight of the poles. As shown in the sequence photographs in Figure 10, the vehicle passed on through without a secondary impact and the pole fell with its top near the foundation. It was observed that the pole rotated through an angle of approximately 240 degrees during its descent to the ground.

In the slow-speed test, the vehicle veered to the left as it left the end of the guide rail and almost missed the pole. The vehicle struck the pole with its right bumper and right headlight section and forced the pole off at a small angle to the right. The failure mechanism, that is fracture of the base, occurred in the same way but the pole did not fall on the automobile. Quite likely if this had been a head-on collision, as in the other tests, the pole would have struck the top of the automobile.

#### Cast Aluminum Inserts

Two tests were conducted to evaluate the cast aluminum insert which was designed as a remedial measure to be used in conjunction with steel transformer bases already in service. The insert is a six-inch aluminum section placed between the transformer base and the concrete foundation as shown in Figure 1. These inserts have been installed on approximately 300 lighting assemblies in the state with very favorable results. At the last count, there had been five accidents involving the inserts. Of these, one accident resulted in two personal injuries attributable to over-turning after impact with the pole.

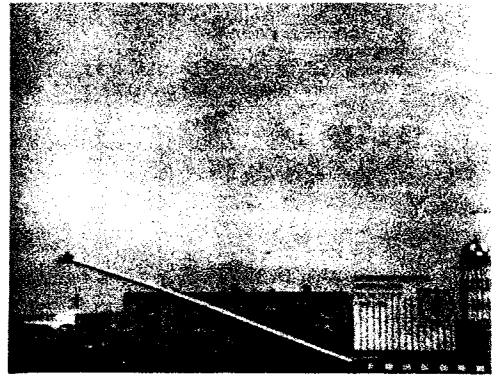
The two crash tests were conducted at nominal speeds of 50 and 30 miles per hour. In the 50 mph test, the performance of the failure mechanism was similar in many respects to the break-away signs (see Figure 11). Initial failure was due to slippage between the transformer base and the insert. After the base slipped the attaching bolts were caught between the front transformer base and the back side of the insert causing the damage to the insert as shown in Figure 11(f).

The front of the vehicle was deformed 15.8" during the impact. Part of this was due to the weight of the steel transformer base, 120 pounds, to be set into motion. Once the base was free, the mounting assembly traveled approximately 75 feet in the direction of the impact. The pole remained airborne long enough for the crash vehicle to clear the area without experiencing a secondary collision.

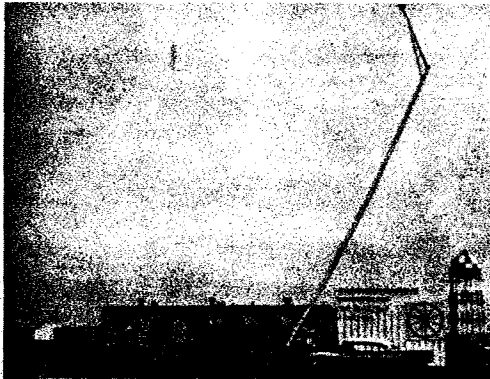
In the slow-speed test, the performance of the mounting assembly was essentially the same except the pole struck the top of the vehicle in a secondary collision (see Figure 12). Once again, the mounting assembly was accelerated in the



(a)



(d)



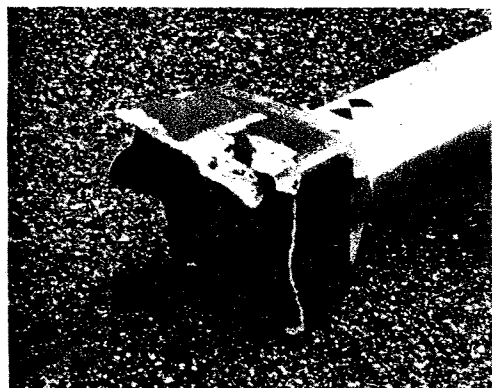
(b)



(e)

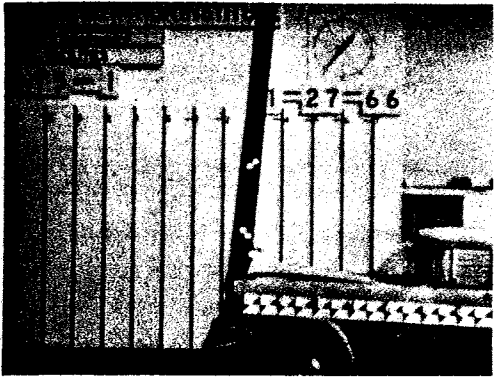


(c)

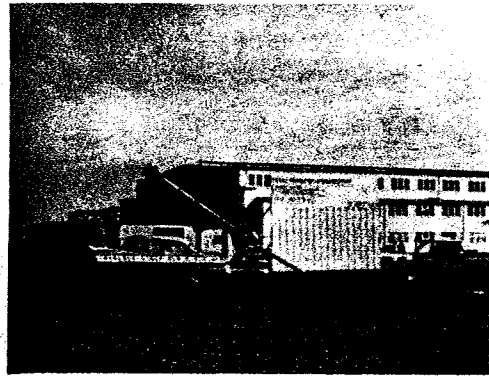


(f)

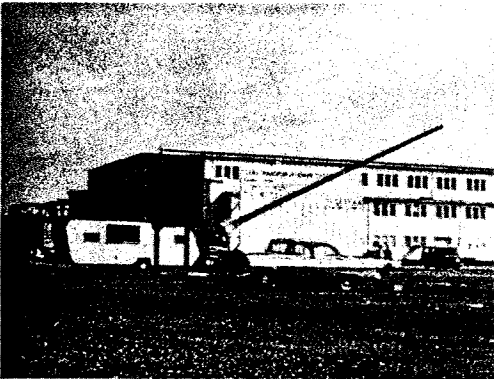
FIGURE 10  
SEQUENCE PHOTOGRAPHS OF TEST OF  
ALUMINUM-POLE-ALUMINUM TRANSFORMER  
BASE COMBINATION



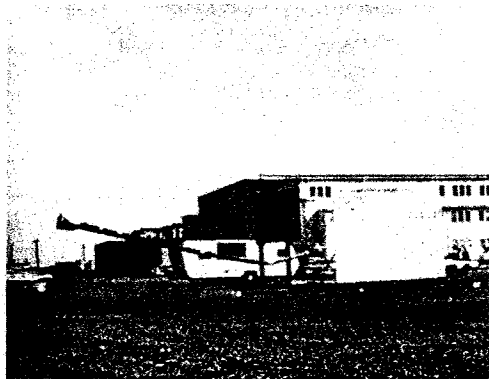
(a)



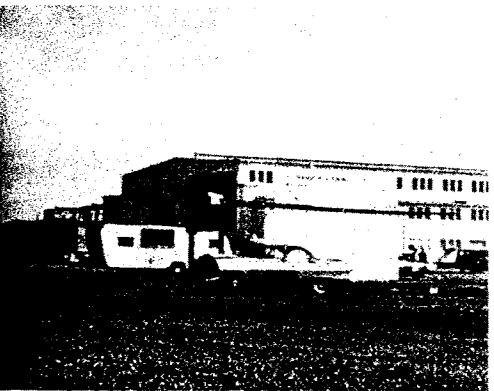
(d)



(b)



(e)



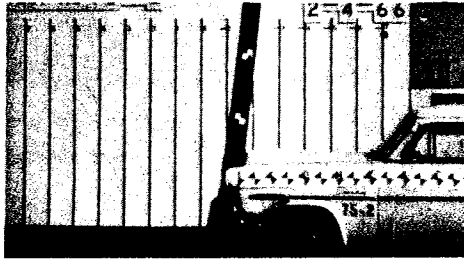
(c)



(f)

**FIGURE II  
SEQUENCE PHOTOGRAPHS OF TEST OF STEEL  
POLE - STEEL TRANSFORMER BASE WITH CAST  
ALUMINUM INSERT COMBINATION**

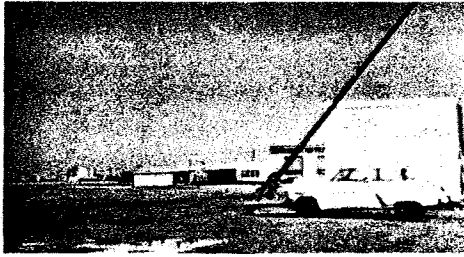




(a)



(e)



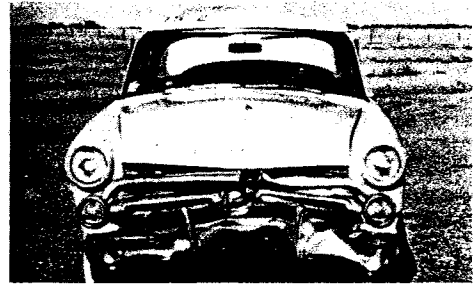
(b)



(f)



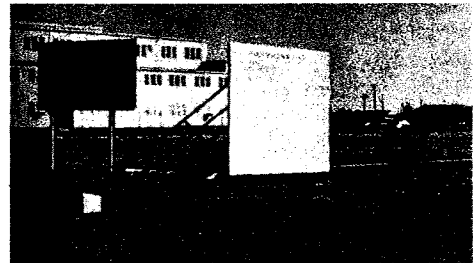
(c)



(g)



(d)



(h)

**FIGURE 12**  
**SEQUENCE PHOTOGRAPHS OF TEST OF STEEL**  
**POLE - STEEL TRANSFORMER BASE WITH CAST**  
**ALUMINUM INSERT COMBINATION**

direction of the impact. This was due primarily to the low mass center of the mounting assembly.

### Flange-Mounted Fiberglass Pole

One test was conducted to determine the impact behavior of an experimental pole utilizing fiberglass as the main structural element. The pole was a prototype model of a filament-wound fiberglass pole still in the development stage by a private concern. It was included in this research as a possible means of reducing the severity of collisions with lighting poles.

The pole used in the crash test was a 40-foot round pole tapered from 8 inches at the base to 4 inches at the top. The pole was attached to a cast aluminum flange for direct connection to the concrete foundation.

The fiberglass pole was crash tested using a standard sedan in a head-on collision at approximately 55 miles per hour. The vehicle suffered very little damage in the collision, as shown in the sequence photographs in Figure 13. Deformation of the front of the vehicle was only 3 inches and its speed was reduced 2.5 miles per hour, from 55.8 to 53.3.

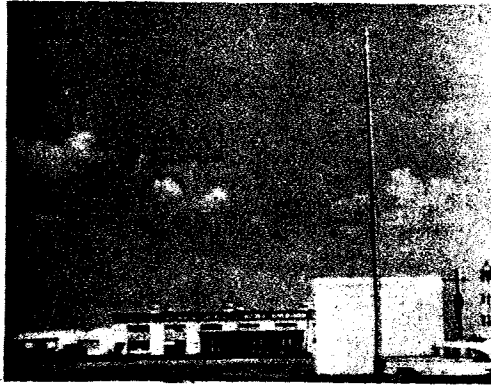
In addition to crash testing of the fiberglass pole, one of the poles was erected for static tests and subjective evaluation. It was observed that normal winds caused considerable deflection. Also, installation of a mast arm and luminaire with integral ballast caused excessive deformation in the pole. On the basis of these observations, it was concluded that the prototype model of the pole was not structurally adequate. The developer has worked towards increasing the strength and rigidity of the pole, but no further tests have been conducted.

## SUMMARY OF RESULTS

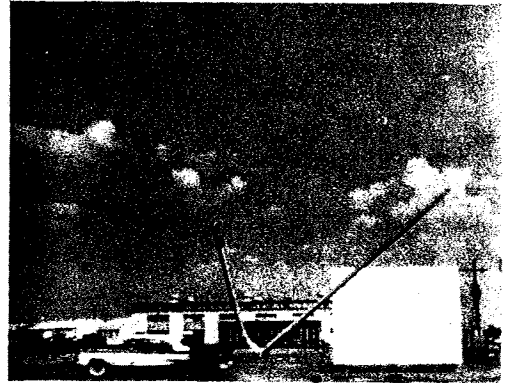
The results of the "state of the art" study and the developmental work on the multi-directional slip base can be summarized as follows:

### State of the Art Study

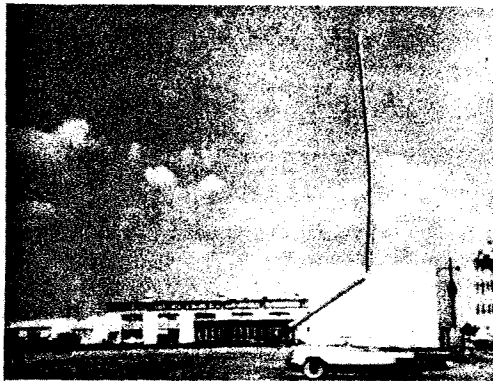
1. The steel transformer base for luminaire supports is definitely an unsatisfactory design and should not be used in any case.
2. The cast aluminum transformer base for luminaire supports appears to be a satisfactory failure mechanism to reduce the impact severity of vehicular collisions with luminaire supports. However, this statement should be conditioned to apply only to head-on collisions at this time. No studies were conducted to determine the behavior of these designs under the conditions of skidding or side impact of the automobile. This is a very important consideration and further study is contemplated.



(a)



(d)



(b)



(e)



(c)



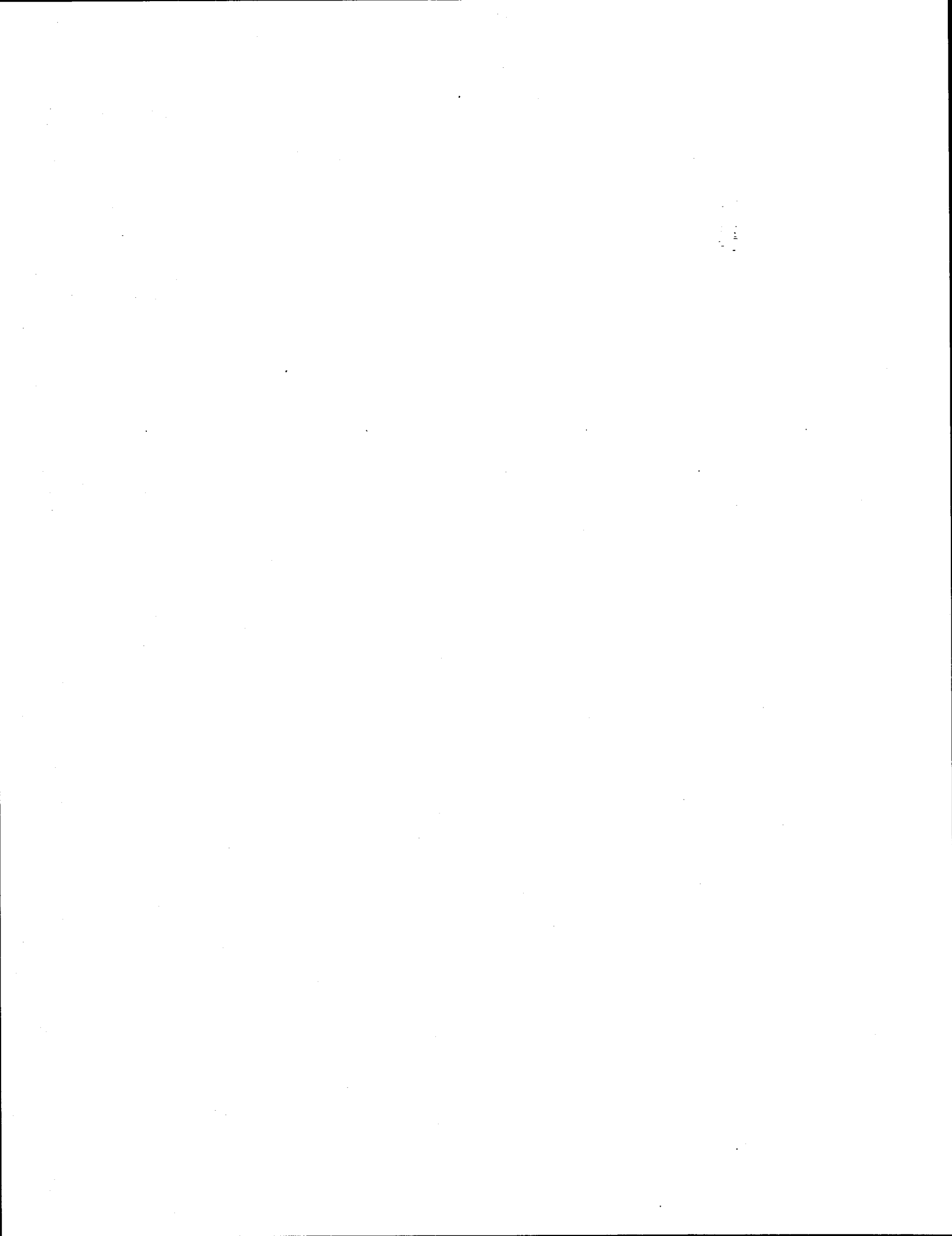
(f)

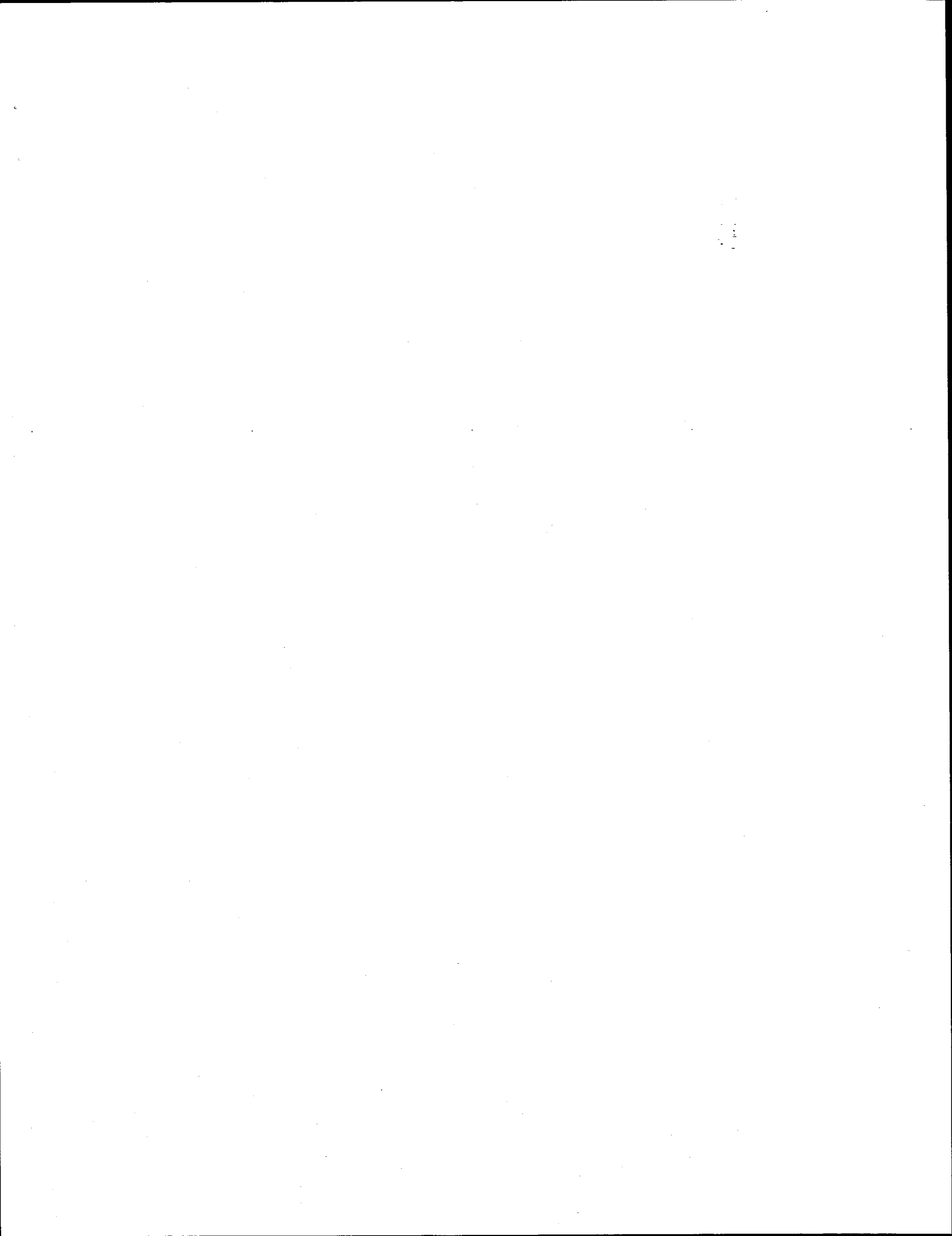
**FIGURE 13**  
**SEQUENCE PHOTOGRAPHS OF TEST OF**  
**FLANGE MOUNTED FIBERGLASS POLE**

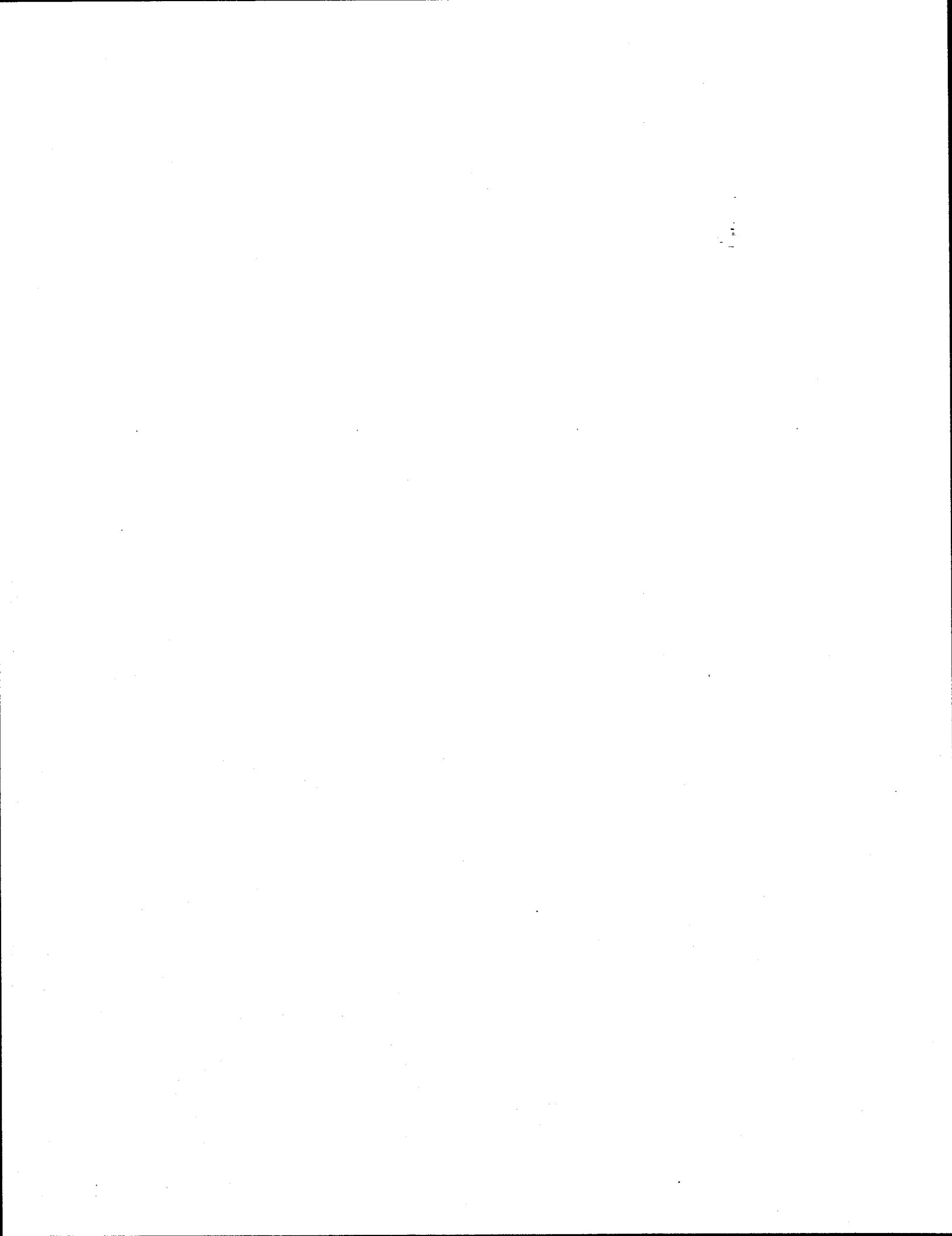
3. A cast aluminum insert placed between the foundation and a steel transformer base for luminaire supports appears to be satisfactory for remedial design measures. However, this does not appear to be a feasible consideration for new design.
4. Forty-foot flange-mounted luminaire supports, both steel and aluminum leave much to be desired in their impact behavior in vehicular collisions. In these tests, the aluminum support exhibited a lower degree of impact severity as indicated by loss in momentum, but both appear critical when vehicle damage and post-collision behavior are considered.
5. In all tests where support failure occurred, it was found that the supports generally aligned themselves with the direction of the crash vehicle. Also, it was observed that the top of the support struck the ground near the foundation in the tests on cast aluminum transformer bases, while the others "traveled" or were carried a considerable distance beyond the point of impact.

## LIST OF REFERENCES

1. Moore, R. L., "Single Vehicle Accidents in Relation to Street Furniture," Sixth International Study Week Traffic Engineering, Salzburg, 1962.
2. "Impact Behavior of Sign Supports," Texas Transportation Institute, Report 68-1, 1965.
3. "Impact Behavior of Sign Supports--II," Texas Transportation Institute, Report 68-2, 1966.
4. Edward, T. C., "Multi-Directional Slip-Base for Break-Away Luminaire Supports," Texas Transportation Institute, Report 75-10, 1967.
5. Severy, D. M. and Markewson, J. H., "Automobile Barrier Impacts," Highway Research Board Bulletin No. 91, pp. 39-54.









TEST NO. 1075-1

Vehicle: 1955 Ford; wt. 3,580 pounds.

Pole: 30-foot steel pole.

Mounting: Steel transformer base with cast aluminum insert.

TIME - DISPLACEMENT MEASUREMENTS

Displacement From Impact (ft)	Clock Revolutions Per 1 ft Displacement		Average Time (sec)	Speed (ft/sec)	Speed (mph)
	Observer 1	Observer 2			
-5	.40	.39			
-4	.40	.40			
-3	.37	.37	.01283	77.9	53.2
-2	.39	.38			
-1	.37	.38			
IMPACT					
1	.39	.43			
2	.44	.44			
3	.41	.46			
4	.58	.43			
5	.42	.47			
6	.43	.42			
7	.44	.44			
8	.43	.43	.01450	68.9	47.0
9	.48	.49			
10	.45	.41			
11	.44	.42			
12	.42	.42			
13	.47	.43			
14	.45	.46			
15	.43	.41			

APPENDIX

TEST NO. 1075-2

Vehicle: 1955 Ford; wt. 3,460 pounds.

Pole: 30-foot steel pole.

Mounting: Steel transformer base with cast aluminum insert.

TIME - DISPLACEMENT MEASUREMENTS

Displacement From Impact (ft)	Clock Revolutions Per 1 ft Displacement		Average Time (sec)	Speed ft/sec	Speed mph
	Observer	Observer			
	1	2			
-5	---	---			
-4	.64	.64			
-3	.65	.65	.02117	47.2	32.2
-2	.64	.64			
-1	.62	.62			
IMPACT					
1	.66	.66			
2	.71	.71			
3	.75	.71			
4	.76	.78			
5	.72	.85			
6	.77	.77			
7	.79	.76			
8	.75	.72	.02500	40.0	27.3
9	.77	.78			
10	.74	.72			
11	.76	.77			
12	.76	.75			
13	.74	.85			
14	.72	.73			
15	.77	.74			

TEST NO. 1075-3

Vehicle: 1959 Ford; wt. 3,700 pounds.

Pole: 40-foot steel pole.

Mounting: Cast aluminum transformer base.

TIME - DISPLACEMENT MEASUREMENTS

Displacement From Impact (ft)	Clock Revolutions Per 1 ft Displacement		Average Time (sec)	Speed ft/sec	Speed mph
	Observer 1	Observer 2			
-5	.50	.46			
-4	.43	.45			
-3	.53	.41	.01523	65.65	44.7
-2	.37	.49			
-1	.47	.46			
IMPACT					
1	.42	.35			
2	.50	.46			
3	.51	.49			
4	.47	.49			
5	.50	.50			
6	.49	.49			
7	.46	.48			
8	.48	.51	.01643	60.86	41.5
9	.51	.51			
10	.51	.50			
11	.50	.46			
12	.48	.52			
13	.52	.51			
14	.47	.47			
15	.53	.50			

TEST NO. 1075-4

Vehicle: 1959 Ford; wt. 3,460 pounds.

Pole: 40-foot steel pole.

Mounting: Cast aluminum transformer base.

TIME - DISPLACEMENT MEASUREMENTS

Displacement From Impact (ft)	Clock Revolutions Per 1 ft Displacement		Average Time (sec)	Speed (ft/sec)	Speed (mph)
	Observer 1	Observer 2			
-5	.97	.91			
-4	.88	.94			
-3	.93	.93	.03079	32.53	22.2
-2	.90	.96			
-1	.91	.91			
IMPACT					
1	.91	.91			
2	1.10	1.04			
3	1.10	1.15			
4	1.13	1.10			
5	1.18	1.17			
6	1.14	1.10			
7	1.11	1.12			
8	1.12	1.11	.03753	26.3	18.1
9	1.10	1.11			
10	1.15	1.09			
11	1.20	1.25			
12	1.28	1.17			
13	1.10	1.17			
14	1.16	1.21			
15	1.21	1.15			

TEST NO. 1075-5

Vehicle: 1959 Ford; wt. 3,680 pounds.

Pole: 40-foot steel pole.

Mounting: Cast aluminum transformer base.

TIME - DISPLACEMENT MEASUREMENTS

Displacement From Impact (ft)	Clock Revolutions Per 1 ft Displacement		Average Time (sec)	Speed (ft/sec)	Speed (mph)
	Observer 1	Observer 2			
-5	1.02	.99			
-4	.90	.92			
-3	.97	.97	.03213	31.12	21.3
-2	1.01	.94			
-1	.93	.99			
IMPACT					
1	.97	1.07			
2	1.21	1.10			
3	1.29	1.20			
4	1.15	1.22			
5	1.25	1.17			
6	1.22	1.24			
7	1.20	1.18			
8	1.21	1.26	.0401	24.9	17.0
9	1.19	1.18			
10	1.13	1.15			
11	1.20	1.26			
12	1.30	1.24			
13	1.24	1.18			
14	1.29	1.29			
15	1.26	1.20			

TEST NO. 1075-6

Vehicle: 1960 Simca; wt. 2,140 pounds.

Pole: 40-foot steel pole.

Mounting: Cast aluminum transformer base.

TIME - DISPLACEMENT MEASUREMENTS

Displacement From Impact (ft)	Clock Revolutions Per 1 ft Displacement		Average Time (sec)	Speed (ft/sec)	Speed (mph)
	Observer 1	Observer 2			
-5	.42	.43			
-4	.46	.46			
-3	.45	.41	.01493	66.9	45.7
-2	.47	.45			
-1	.46	.47			
IMPACT					
1	.49	.50			
2	.51	.50			
3	.49	.51			
4	.55	.52			
5	.53	.54			
6	.54	.54			
7	.51	.51			
8	.56	.53	.01792	55.7	38.0
9	.55	.55			
10	.55	.54			
11	.55	.57			
12	.54	.53			
13	.55	.56			
14	.55	.50			
15	.51	.54			

TEST NO. 1075-7

Vehicle: 1958 Ford; wt. 3,600 pounds.

Pole: 40-foot fiberglass pole.

Mounting: Flange mounted.

TIME - DISPLACEMENT MEASUREMENTS

Displacement From Impact (ft)	Clock Revolutions Per 1 ft Displacement		Average Time (sec)	Speed (ft/sec)	Speed (mph)
	Observer 1	Observer 2			
-5	.34	.35			
-4	.35	.40	.01223	81.76	55.80
-3	.40	.34			
-2	.39	.40			
-1	.35	.35			
IMPACT					
1	.38	.38			
2	.40	.40			
3	.39	.38			
4	.38	.35			
5	.42	.42			
6	.37	.39			
7	.43	.37			
8	.38	.37	.01267	78.9	53.7
9	.37	.37			
10	.37	.38			
11	.38	.38			
12	.40	.40			
13	.37	.38			
14	.39	.38			
15	.38	.38			



TEST NO. 1075-9

Vehicle: 1957 Ford; wt. 3,600 pounds.

Pole: 40-foot aluminum pole.

Mounting: Cast aluminum transformer base.

TIME - DISPLACEMENT MEASUREMENTS

Displacement From Impact (ft)	Clock Revolutions Per 1 ft Displacement		Average Time (sec)	Speed (ft/sec)	Speed (mph)
	Observer 1	Observer 2			
-5	.48	.48			
-4	.50	.47			
-3	.44	.47	.01580	63.29	43.20
-2	.48	.50			
-1	.47	.45			
IMPACT					
1	.47	.55			
2	.50	.53			
3	.47	.45			
4	.53	.50			
5	.58	.54			
6	.52	.53	.01796	55.67	38.00
7	.52	.53			
8	.59	.57			
9	.55	.55			
10	.52	.50			
11	.55	.49			
12	.57	.55			
13	.54	.55			
14	.53	.53			
15	.54	.54			

TEST NO. 1075-10

Vehicle: 1957 Ford; wt. 3,500 pounds.

Pole: 40-foot aluminum pole.

Mounting: Flange mounted.

TIME - DISPLACEMENT MEASUREMENTS

Displacement From Impact (ft)	Clock Revolutions Per 1 ft Displacement Observer		Average Time (sec)	Speed (ft/sec)	Speed (mph)
	1	2			
-5	.47	.48			
-4	.45	.44	.01550	64.51	44.0
-3	.48	.48			
-2	.43	.44			
-1	.49	.49			
IMPACT					
1	.40	.40			
2	.48	.47			
3	.57	.56			
4	.53	.51			
5	.53	.53	.01836	54.5	37.7
6	.54	.50			
7	.60	.60			
8	.50	.50			
9	.54	.58			
10	.59	.56			
11	.53	.50			
12	.46	.51			
13	.56	.57			
14	.58	.56			
15	.37	.48			

TEST NO. 1075-11

Vehicle: 1958 Ford; wt. 3,600 pounds.

Pole: 40-foot steel pole.

Mounting: Flange mounted.

TIME - DISPLACEMENT MEASUREMENTS

Displacement From Impact (ft)	Clock Revolutions Per 1 ft Displacement		Average Time (sec)	Speed (ft/sec)	Speed (mph)
	Observer	Observer			
	1	2			
-5	.47	.49			
-4	.51	.54			
-3	.55	.52	.01686	59.31	40.48
-2	.39	.45			
-1	.57	.57			
IMPACT					
1	.52	.52			
2	.45	.45			
3	.68	.67			
4	.65	.70			
5	.58	.73			
6	.68	.57			
7	.74	.77			
8	.78	.80			
9	.71	.66	.02336	42.8	29.2
10	.78	.52			
11	.70	.71			
12	.76	.69			
13	.74	.74			
14	.74	.66			
15	.73	.71			

TEST NO. 1075-12

Vehicle: 1958 Ford; wt. 3,700 pounds.

Pole: 40-foot steel pole.

Mounting: Steel transformer base.

TIME - DISPLACEMENT MEASUREMENTS

Displacement From Impact (ft)	Clock Revolutions Per 1 ft Displacement		Average Time (sec)	Speed (ft/sec)	Speed (mph)
	Observer 1	Observer 2			
-5	.52	.52			
-4	.50	.52			
-3	.53	.48	.01733	57.70	39.38
-2	.53	.54			
-1	.52	.54			
IMPACT					
1/2	.28	.25			
1	.24	.55			
1 1/2	.31	.26			
2	.27	.39			
2 1/2	.39	.52			

Vehicle was stopped after  
2 1/2 ft penetration