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16. Abstract  Various new work zone traffic control devices are currently being used or considered for use in work zones throughout the State of Texas. The impact performance of plastic drum, sign and flashing unit assemblies was evaluated in this study, with particular interest on the effect of the weight of the ballast and the performance of the devices under glancing impact conditions. A total of 14 crash tests were conducted under this study. The plastic drum, sign and flashing unit assemblies all performed satisfactorily in either head-on or glancing impacts, snapping free of the base readily upon impact and either flipped over or to the side of the vehicle or stayed with the vehicle. The separated drum assemblies did not penetrate or intrude into the occupant compartment or constitute a hazard to adjacent traffic or to the workers. There was no appreciable difference in impact performance among the different ballast weights within the range of 25 to 75 pounds. Since plastic drums ballasted at 50 pounds have been found to be blown over or moved by air disturbances generated by passing traffic, the use of 75-pound ballast weights appear to be the logical choice.			
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**TESTING AND EVALUATION OF  
WORK ZONE TRAFFIC CONTROL DEVICES**

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Crash Testing and Evaluation of Work Zone  
Traffic Control Devices

Sponsored by

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Texas A&M University System  
College Station, Texas 77843

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## I. INTRODUCTION

Several new work zone traffic control devices are currently being used or considered for use in work zones throughout the State. The impact performance of a selected number of these work zone traffic control devices was evaluated during a recent study sponsored by the Houston District (District 12) of the Texas State Department of Highways and Public Transportation (SDHPT).<sup>(1)</sup> The objective of that study was to assess the impact performance of these devices, with the major emphasis on evaluating the desirability of mounting traffic control devices on top of plastic drums (e.g. vertical panels, fiberglass, plastic, or plywood chevrons, flashing light units). After completing that study, it was found that other areas regarding the impact performance of these selected traffic control devices needed to be investigated. Of particular interest are the effects of different ballast weights for the plastic drums and glancing impacts.

During the previous study, the drums were ballasted at 50 pounds and performed satisfactorily during full-scale crash tests; however, it has been reported that the plastic drums are being blown down or moved by air disturbances generated by passing traffic. Increasing the weight of the ballast from 50 to 75 pounds is proposed as a solution to this problem. The effect of increasing the weight of the ballast on impact performance needs to be evaluated. Also of interest is the effect of using lighter ballast weights, such as 25 pounds, on the impact performance of the plastic drums.

In the previous study, all the crash tests conducted were direct head-on impacts. The performance of the traffic control devices under glancing impact conditions needs to be assessed to determine if the plastic drums would become projectiles and pose a hazard to workers and other traffic.

The objective of this study is to assess the impact performance of selected work zone traffic control devices, with particular interest on the effect of the weight of the ballast and the performance of the devices under glancing impact conditions. The results of this study will also be helpful in formulating guidelines and policies in the use of work zone traffic control devices. Given the current and anticipated level of construction activities in the State, the results of this study will have immediate application that could improve on the safety of work zones to both the travelling public and to workers in the construction zones.



## II. STUDY APPROACH

Currently, there are no established standards or guidelines governing the impact performance of work zone traffic control devices. Under the previous study, the project staff, in consultation with SDHPT personnel, developed a study approach including items such as test installations, test procedures, and evaluation criteria which was based on information from available literature and experience from other crash testing programs. The same study approach was adopted for evaluation of the crash tests performed under this study and a brief discussion of each item of the approach is presented in this section.

### TEST INSTALLATIONS

Fourteen crash tests were conducted as shown in the test matrix below. The traffic control devices used in each of the tests were all the same with the exception of the bases and the weight of the ballast. Each ballast/configuration combination was tested at 45 mi/h and then at 60 mi/h.

<u>Test No.</u>	<u>Type of Base/Ballast</u>	<u>Ballast Weight</u>	<u>Impact Conditions</u>	
			<u>Configuration</u>	<u>Speed</u>
1	San-fill + 1 Sandbag	75 lb	Head-on	45 mi/h
2	San-fill + 1 Sandbag	75 lb	Head-on	60 mi/h
3	3 Sandbags	75 lb	Head-on	45 mi/h
4	3 Sandbags	75 lb	Head-on	60 mi/h
5	San-fill	50 lb	Glancing	45 mi/h
6	San-fill	50 lb	Glancing	60 mi/h
7	2 Sandbags	50 lb	Glancing	45 mi/h
8	2 Sandbags	50 lb	Glancing	60 mi/h
9	San-fill + 1 Sandbag	75 lb	Glancing	45 mi/h
10	San-fill + 1 Sandbag	75 lb	Glancing	60 mi/h
11	3 Sandbags	75 lb	Glancing	45 mi/h
12	3 Sandbags	75 lb	Glancing	60 mi/h
13	1 Sandbag	25 lb	Head-on	60 mi/h
14	1 Sandbag	25 lb	Glancing	60 mi/h

A "Traffix" plastic drum and chevron sign assembly was used in each of the ballast/configuration combinations. The "Traffix" plastic drum was 38.25 inches tall and weighed 8 pounds. The top diameter of the drum was 18 inches and the bottom diameter 22.5 inches. Two molded loops on top of the drum provided for attachment of chevron signs and flashing light units. The chevron signs were made of fiberglass, 0.125 inch thick, 18 inches wide by 24 inches tall, and

weighed 2.5 pounds. The standard flashing light unit, with batteries installed, weighed 4.25 pounds. The "San-fill" bottom used in some of the tests was an enclosed plastic container which was filled with 50 pounds of sand and fitted to the plastic drum. In all the other tests a flat plastic bottom weighed down with 25-pound sandbag(s) was fitted to the drum.

In the four 75-pound/head-on tests (tests 1 through 4), four sign assemblies arranged in a straight line were used. The first two assemblies were outfitted as described above with flashing light units while the last two were not. The spacing between assemblies was directly proportional to the impact speed, one foot of spacing for each mile per hour (mi/h) impact, i.e., 45-foot spacing for 45 mi/h impact and 60-foot spacing for 60 mi/h impact speed. Typical test geometry for the head-on impacts is shown in Figure 1. For the remaining 10 tests, i.e., the glancing impact configurations and the 25-pound head-on test (tests 5 through 14), only one sign assembly was used in each of the tests, as shown in Figure 2.

## TEST PROCEDURES

Two virtually identical 1980 Honda Civic 3-door vehicles were used during the testing. Test inertia weight of each vehicle was 1,800 pounds and gross static weight was 1,970 pounds. The first Honda (shown in Figure 3) was used for all the 45 mi/h tests, tests 1, 3, 5, 7, 9, and 11. The damages during these tests were minor and cosmetic in nature and the vehicle was repaired to the extent possible after each test. This vehicle was also used during some of the 60 mi/h tests, tests 2, 6, 8 and 10. During test 6, the windshield was cracked and had to be replaced before running tests 8 and 10 (see Figure 4). The second Honda, shown in Figure 5, was used for the remaining four tests, tests 4, 12, 13 and 14, and was repaired after each test.

The vehicle was driven into the sign assemblies for all the 45 mi/h test configurations. During the 60 mi/h tests, the vehicle was directed into the sign assemblies using a cable-reverse tow and guidance system. The vehicle was released to be free-wheeling and unrestrained just prior to impact with the assemblies. Pressure sensitive contact switches on the bumper of the vehicle were actuated just prior to impact by wooden dowels to indicate the elapsed time over a known distance to provide a measurement of impact velocity. The initial contact also produced an "event" mark on the data record to establish the exact instant of impact as well as actuate a flash unit placed in view of the videotape



Figure 1. Typical geometry for the head-on impact test condition (tests 1917 - 1 through 4)



Figure 2. Typical geometry for the glancing impact test condition (tests 1917 - 5 through 14)





Figure 3 . Vehicle used for tests 1917 -  
5,7,9,11,1,3,2,6,8 & 10  
(windshield replaced for test  
1917 - 8 & 10)



Figure 4. Vehicle after replacement of windshield  
(used in test 1917 - 8 & 10)



Figure 5. Vehicle used for tests 1917 - 13,14,4 & 12

cameras. The vehicle remained free-wheeling, i.e., no steering or braking inputs, until the vehicle cleared the sign assemblies, at which time brakes on the vehicle were actuated to bring the vehicle to a safe, controlled stop.

The vehicle was instrumented with three solid-state angular rate transducers to measure roll, pitch, and yaw rates, and a triaxial accelerometer near the center-of-gravity to measure longitudinal, lateral, and vertical acceleration levels. The electronic signals from the accelerometers and transducers were transmitted to a base station by means of constant band width FM/FM telemetry link for recording on magnetic tape and for display on a real-time strip chart. Provision was made for the transmission of calibration signals before and after the tests, and an accurate time reference signal was simultaneously recorded with the data.

The multiplex of data channels, transmitted on one radio frequency, was received at the data acquisition station, and demultiplexed into separate tracks of Intermediate Range Instrumentation Group (IRIG) tape recorders. After each test, the data were played back from the tape machines, filtered with a Class 180 filter, and digitized using a microcomputer, for analysis and evaluation of performance. The digitized data were then processed using two computer programs: DIGITIZE and PLOTANGLE. Brief descriptions of the functions of these two computer programs are provided as follows.

The DIGITIZE program uses digitized data from the vehicle-mounted linear accelerometers to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the highest 10-msec average ridedown acceleration. The DIGITIZE program also calculates a vehicle impact velocity and the change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50-msec intervals in each of the three directions are computed. Acceleration versus time curves for the longitudinal, lateral, and vertical directions are then plotted from the digitized data of the vehicle-mounted linear accelerometers using a commercially available software package (LOTUS 123).

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

Photographic coverage of the test included two (2) 3/4-inch videotape cameras, one perpendicular to the point of impact of the assembly, and the other placed downstream from the point of impact. The videotapes were used for analysis and documentation of the crash tests. In addition, still cameras were used for documentary purposes.

## EVALUATION CRITERIA

Since there are no established criteria for evaluating the impact performance of work zone traffic control devices, the criteria developed under the previous study were used for evaluation. These criteria were based on information from such sources as NCHRP Report 230<sup>(2)</sup> and TRC 191<sup>(3)</sup>, keeping in mind the uniqueness of the work zone environment. The following is a brief description of the evaluation criteria developed under the previous study.

1. Occupant risk. Occupant risk is a measure of the probability for serious injury to occupant(s) of the impacting vehicle, measured in terms of the occupant impact speed and maximum 10-msec ridedown acceleration as outlined in NCHRP Report 230. This provides an indication of the severity of impact with the traffic control device itself.
2. Damages to vehicle and traffic control devices. Damages to the vehicle and the traffic control devices provide an indication of the impact severity and the associated property damages.
3. Vehicle trajectory. Vehicle trajectory is a subjective assessment of the potential hazard associated with the trajectory of the vehicle after impact. Items of consideration include such factors as the roll, pitch, and yaw of the vehicle induced by impact with the traffic control devices, the stability of the vehicle (e.g., instability caused by the traffic control device wedged beneath a tire, excessive yaw or pitch, etc.), and the path of the vehicle after impact and the potential for intrusion into adjacent traffic lanes.
4. Debris from traffic control devices. This evaluation criterion provides a subjective assessment of the potential hazard caused by debris formed by the impact. This potential hazard can be viewed from three different perspectives:
  - a. Potential intrusion into the passenger compartment. This is considered unacceptable because of the significant increase in the risk of injury to its occupants. This may include intrusion through

the windshield, firewall, floor, or body panels by parts of the test device, or intrusion into the windshield by the vehicle hood. Of particular concern is debris impacting the windshield which may break the windshield resulting in broken glass entering the passenger compartment or adversely affecting the ability of the driver to see out of the windshield, which may in turn lead to secondary collisions. Finally, puncture of the fuel tank resulting in fuel leakage was considered unacceptable because of fire risk.

- b. Debris thrown into adjacent traffic lanes could pose a potential hazard by causing oncoming drivers to make emergency evasive action leading to loss of control and a secondary collision. Sand or other debris scattered on the pavement may also lead to loss of control of other vehicles, especially motorcycles.
- c. Debris thrown into the work zone could present a hazard to the workers because of the close proximity of construction workers to the traffic control devices or fragments thrown by an impact may present a hazard. This involves a subjective assessment of whether the debris would constitute a hazard, based on such factors as size, rigidity, and trajectory of the debris.



### III. STUDY RESULTS

A summary of the results for each of the crash tests are presented in this section. Detailed descriptions of the test installations were given in the previous section, therefore, only essential information will be repeated herein.

#### Test 1917-1

This test installation consisted of four sign assemblies, arranged in a straight line, spaced 45 feet apart for impact at 45 mi/h. Only the first two assemblies had flashing light units bolted to the top of the plastic drum. The assembly was ballasted with a San-fill base (50 pounds) and one 25-pound sandbag for a total of 75 pounds. The centerline of the vehicle was aligned with the centerline of the first device.

The test vehicle was travelling at a speed of 44.1 mi/h as it contacted the first device. The plastic drum snapped loose from the first base and travelled with the vehicle as it contacted the second device. The chevron of the first drum slapped the hood of the vehicle as the drum snapped loose from the second base, and then both drums went up, over, and to the left of the vehicle. The drum snapped loose from the third base and travelled with the vehicle until it came to rest. The fourth drum also snapped loose from the base and travelled with the vehicle for a short distance, and then went off to the left side on the ground. The test site before and after the test is shown in Figure 6.

The base of the first device moved back 4 inches as shown in Figure 7, and the sandbag was found bursted 28 feet down and 10 inches to the left. The drum came to rest 150 feet down and 16 feet to the left of its original position. As shown in Figure 8, the second base moved back 2 inches and the sandbag was bursted 45 feet down and 10 inches to the left. The drum was found 158 feet down and 3 feet to the left of its original position. The third base moved back 2 inches (see Figure 9), and the sandbag was bursted 35 feet down and 18 inches to the right. The drum travelled down with the vehicle to its final rest. The base of the fourth device rotated slightly and moved back 10 inches as shown in Figure 10. The bursted sandbag was found 21 feet down and 12 inches to the right and the drum was 240 feet down and 15 feet to the left.

The San-fill bases were not damaged, but sand from the sandbags was strewn along the vehicle path. The drums were dented and scratched, and the vehicle received only minor scratches which were quickly repaired.

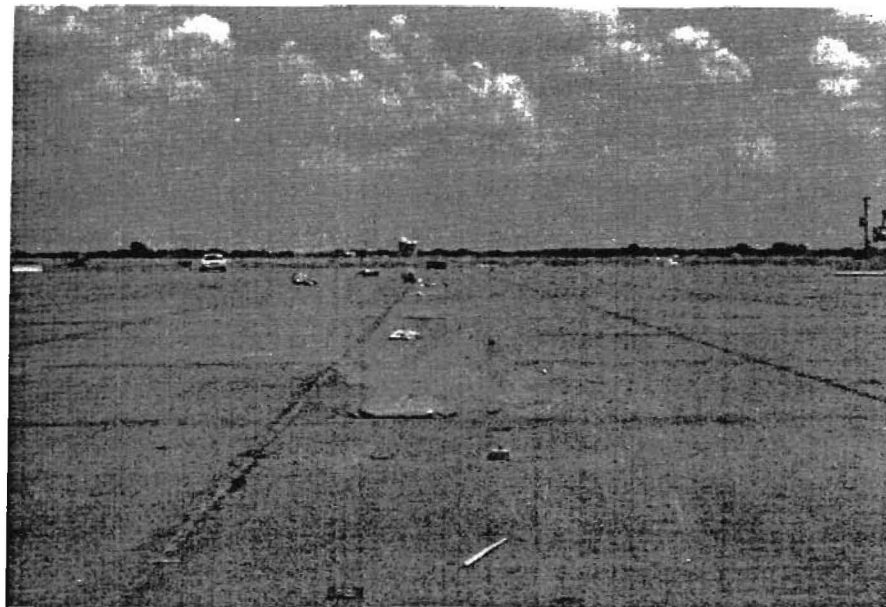
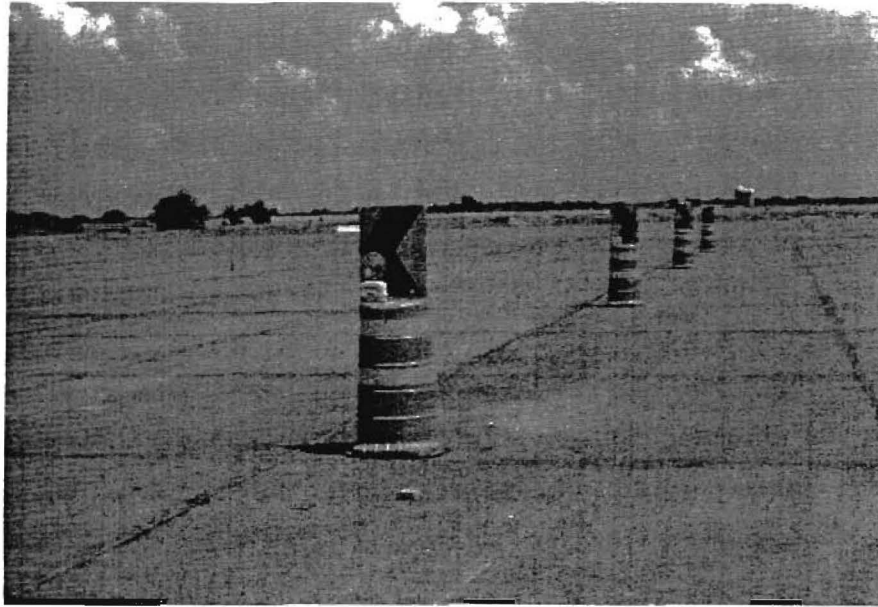
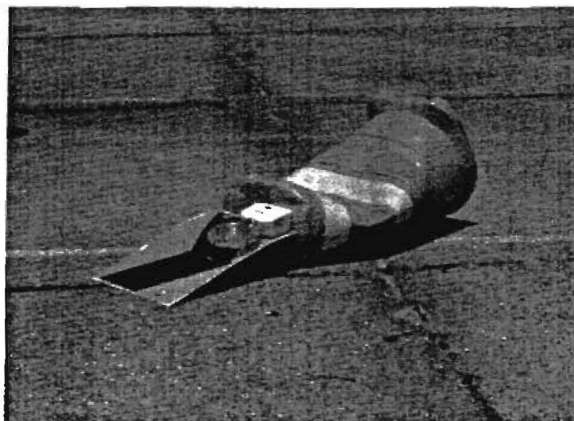


Figure 6. Test site before and after test 1917-1



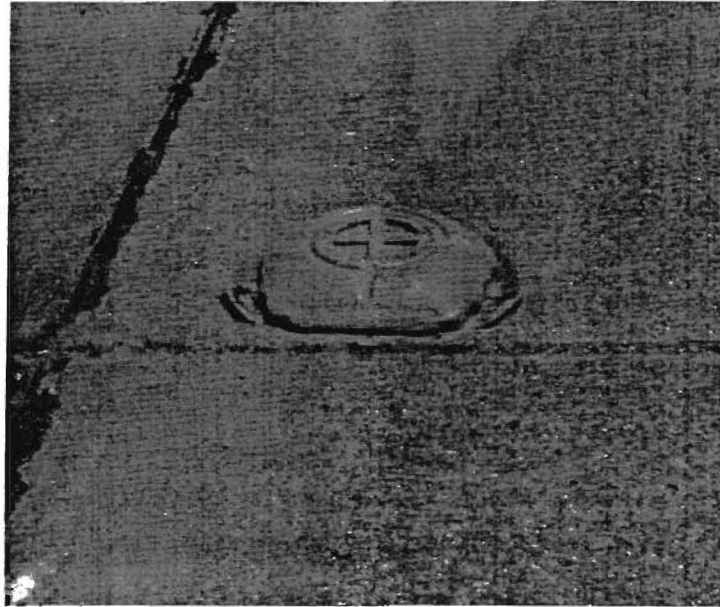


Base moved 4 in down



Drum 150 ft down, 16 ft left

Figure 7. Damage to first device, test 1917-1



Base moved 2 in down



Drum 158 ft down, 3 ft left

Figure 8. Damage to second device, test 1917-1



Base moved 2 in down

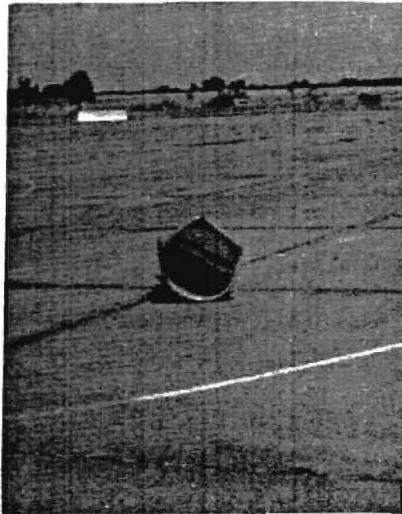


Drum stayed with vehicle

Figure 9. Damage to third device, test 1817-1



Base moved 10 in down, rotated slightly



Drum 240 ft down, 15 ft left

Figure 10. Damage to fourth device, test 1917-1

There was no occupant impact during the test period. The 50-msec averages were -1.0 g between 4 and 54 msec in the longitudinal direction and -0.4 g between 290 and 340 msec in the lateral direction.

The vehicle received cosmetic damages only and there was no penetration or intrusion of the occupant compartment of the vehicle. The vehicle remained on a straight, smooth path through the test site with no intrusion into adjacent traffic lanes. The vehicle remained stable throughout the test sequence. The plastic drum, chevron sign, and flashing light assemblies snapped free of the bases and rode to the side of or along with the vehicle as it travelled through the test site. All the bases remained near the points of impact. Any sand spilled from the sandbags was minimal and was judged not to present undue hazard to other traffic.

#### Test 1917-2

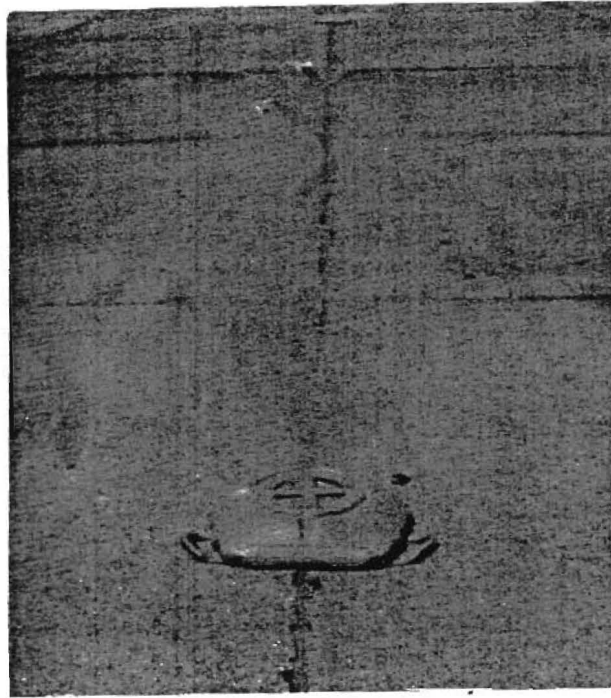
The installation for this test was the same as the first test except the spacing between the devices was increased to 60 feet (see Figure 11) for impact at 60 mi/h.

The plastic drum snapped loose from the first base as the vehicle impacted it travelling at 62.1 mi/h. The drum rode up into the windshield and then over the vehicle. As the vehicle impacted the second device, the drum snapped loose from the base and rode along the front of the vehicle until it impacted the third device. The second drum went up and hit the upper right corner of the windshield while the third drum went off to the left side of the vehicle. The fourth drum also snapped loose from the base and went off the left side of the vehicle. It was noted that as the vehicle struck the first three devices, the front of the vehicle pitched up slightly and made contact with the third and fourth devices with the left front corner of the bumper.

The first base was not moved and the bursted sandbag was lying 32 feet from the base as shown in Figure 12. The drum was 173 feet down and 13 feet to the right of its original position. The second base was not moved either, but the sandbag was bursted and lying beside the third base (75 feet down). The second drum was 240 feet down and 13 feet to the right (shown in Figure 13). The third base moved 15 feet back and was on top of a sandbag. The drum was 65 feet down and 2 feet to the left of its original position. The positions of the base and drum after the test are shown in Figures 14 and 15. The fourth base did not move and as the drum snapped loose from the base, it threw the sandbag backwards



Figure 11. Test site before test 1917-2

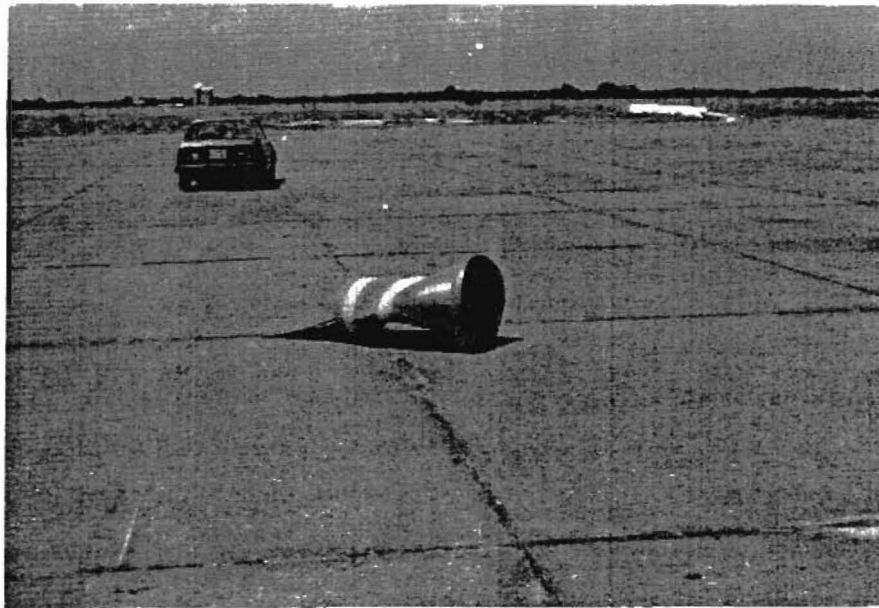


Base did not move



Base did not move

Figure 12. Base 1 and 2 after test 1917-2

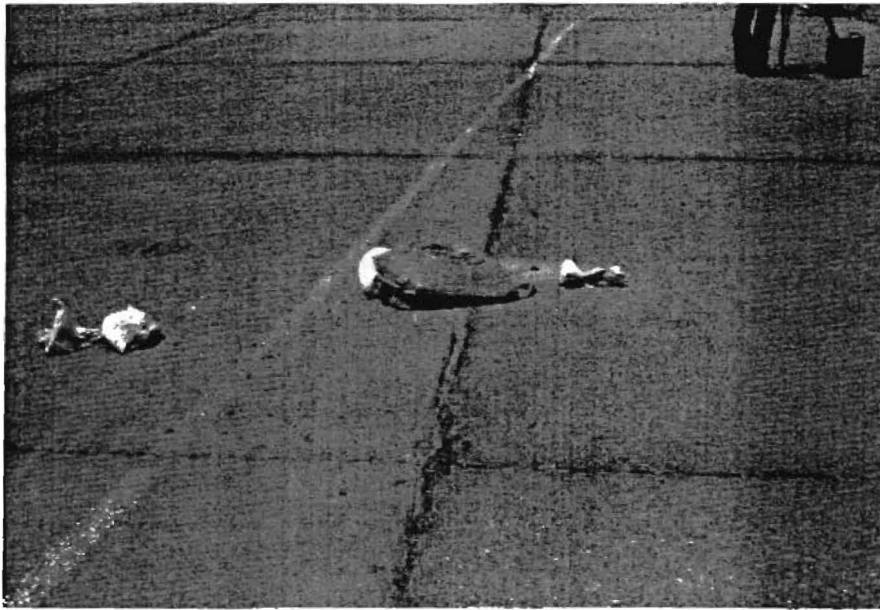


Drum 240 ft down, 13 ft right

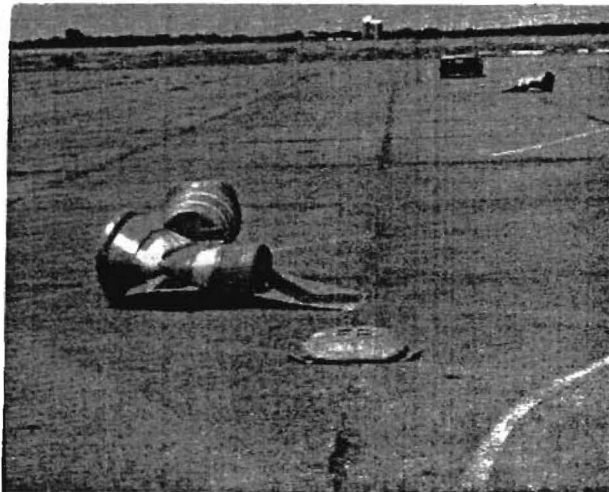


Figure 13. Second drum after test 1917-2



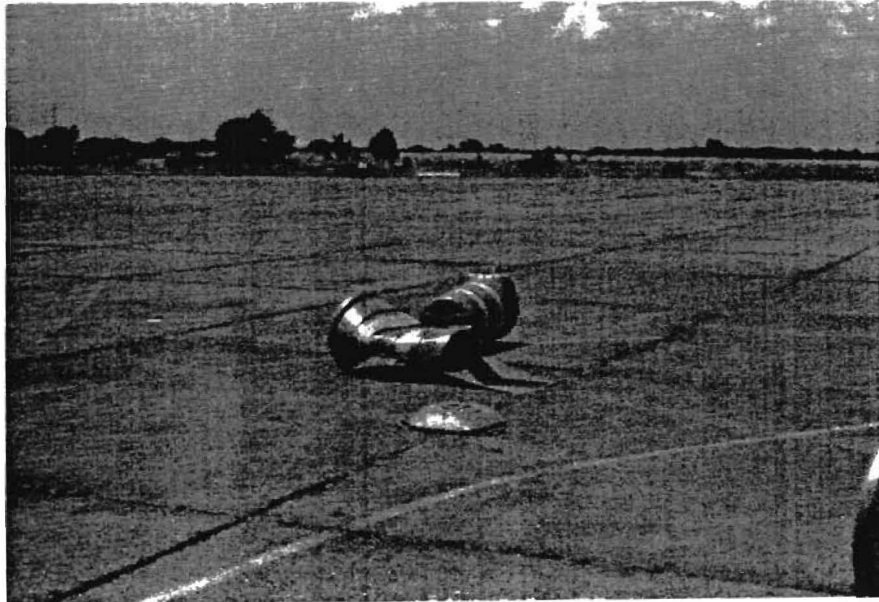


Base moved down 15 ft

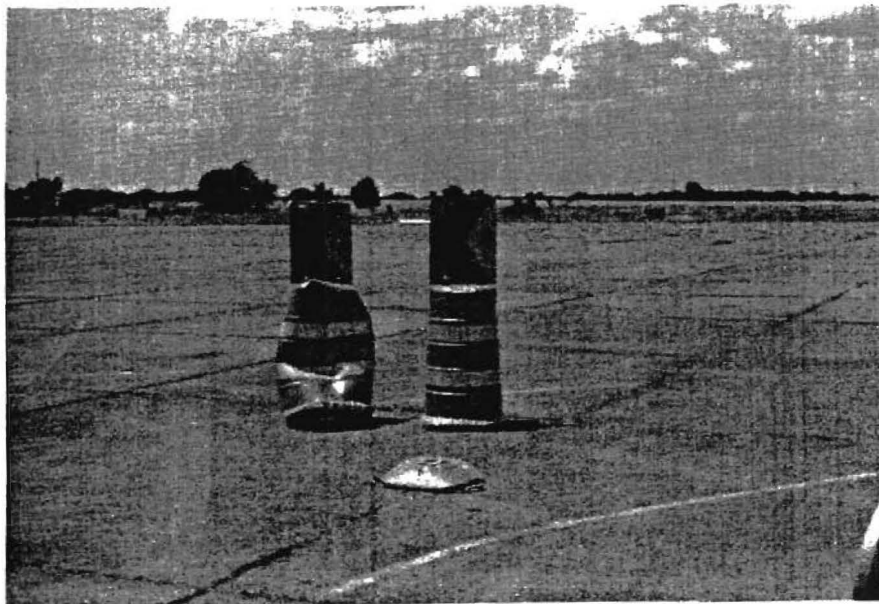


Base did not move

Figure 14. Base 3 and 4 after test 1917-2



Drum #3 65 ft down, 2 ft left



Drum #4 8 ft down, 5 ft left

Figure 15. Third and fourth drums after test 1917-2

toward the third base where it bursted (see Figure 14). The drum landed next to the third drum, 8 feet down and 5 feet right of its original location (shown in Figure 15).

The San-fill bases were not damaged, however, sand from three of the sandbags was scattered along the vehicle path. The drums were dented and scraped, and the vehicle received only minor scratches which were repaired quickly.

There was no occupant impact during the test period. The longitudinal 50-msec average was -1.0 g between 2 and 52 msec and the lateral 50-msec average was -0.2 g between 50 and 100 msec.

The vehicle received cosmetic damages only and there was no penetration or intrusion of the occupant compartment of the vehicle. The vehicle remained on a straight course through the test site with no intrusion into adjacent traffic lanes and was relatively stable throughout the test sequence. The plastic drum, chevron sign, and flashing light assemblies snapped free of the bases and rode slightly to the side of the vehicle as it travelled through the test site while all the bases remained near the points of impact. Any sand spilled from the sandbags was minimal and was judged not to present undue hazard to other traffic.

### Test 1917-3

This test installation consisted of four sign assemblies, arranged in a straight line, spaced 45 feet apart to be impacted at 45 mi/h. Only the first two assemblies had flashing light units bolted to the top of the plastic drum. The base of the assembly was the flat plastic base weighed down with three 25-pound sandbags for a total ballast of 75 pounds. The centerline of the vehicle was aligned with the centerline of the first device.

The vehicle contacted the first device at a speed of 47.6 mi/h. The drum snapped loose from the base and rode along on the front of the vehicle. As the vehicle impacted the second device, the drum snapped loose from its base and went up and over the left side of the vehicle moving the first drum up onto the hood. The first drum rode along on the windshield until the vehicle made contact with the third device when it went over the vehicle. The third drum snapped loose from its base and rode along with the vehicle until it came to a complete stop. When the vehicle contacted the fourth device, the drum snapped loose from the base and went off to the left side of the vehicle. The test site before and after the test is shown in Figure 16.



Figure 16. Test site before and after test 1917-3.

The first base moved back 4 feet and 12 inches to the left. One sandbag was found split open on the edge of the base 5 feet down and 12 inches to the left, another was bursted 7 feet down and 4 inches to the right, and the third was also bursted 12 feet down and 18 inches to the right. The drum was 180 feet down and 16 feet to the left of its original location. The positions of the base, sandbags, and drum is shown in Figure 17.

The second base rotated and moved back 3 feet and all the sandbags bursted. One sandbag was lying 3 feet down and 6 inches to the left on the edge of the base, one was 6 feet down and the last was 6 feet down and 4 inches to the right. The drum was 120 feet down and 4 feet to the right as shown in Figure 18.

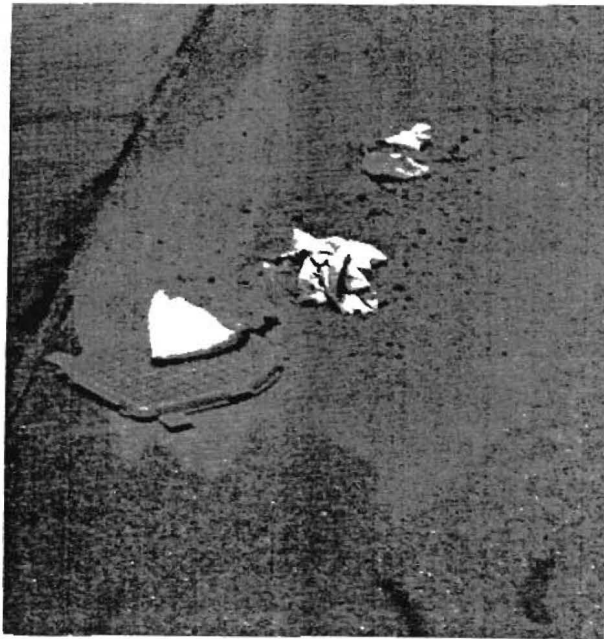
The third base, shown in Figure 19, was found 9 feet back and 18 inches to the left of its initial position. All three sandbags bursted; one was found 10 feet down and 12 inches to the left, the second 11 feet down and 12 inches to the left while the third was 24 feet down and 2 feet to the right. The drum stayed with the vehicle.

The fourth base was 11 feet down and 12 inches to the right and all three sandbags were bursted. One sandbag was lying 3 inches down and 12 inches to the left, another was 9 feet down and 12 inches to the left, and the last was 85 feet down and 2 feet to the right. The drum (shown in Figure 20) was found 120 feet down and 12 feet to the left of its original position.

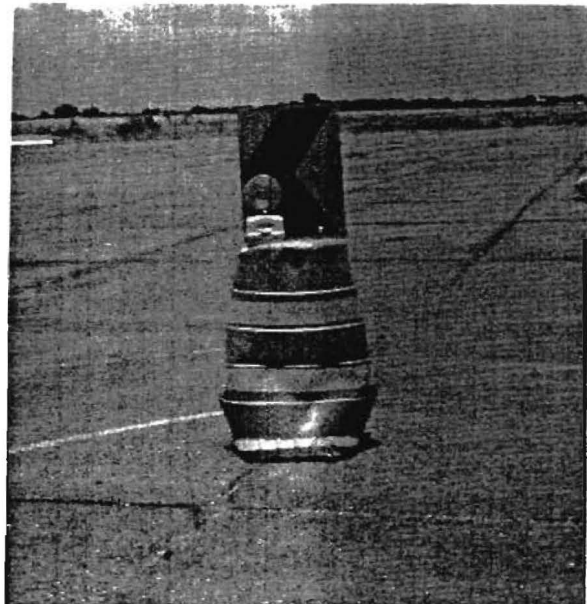
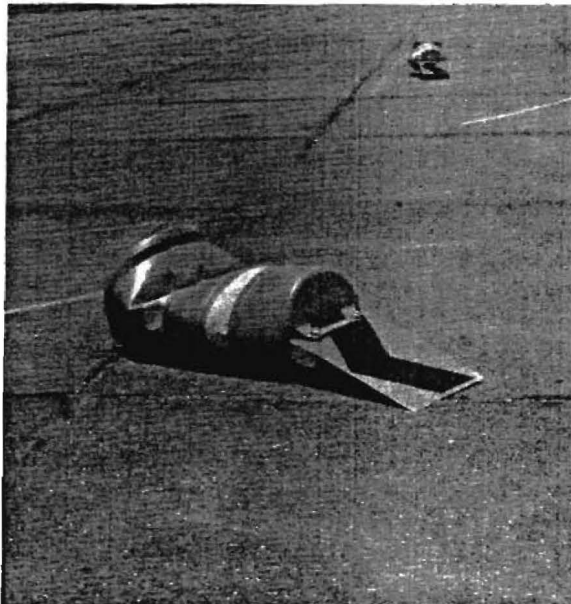
The flat plastic bases were not damaged, however, all 12 sandbags had burst and sand was scattered all through the test site. The drums were dented and scraped, and the hood of the vehicle was scratched slightly.

No longitudinal occupant impact occurred during the test period and the 50-msec average was only -0.8 g. Lateral occupant impact velocity was 3.8 ft/s at 568 msec, the highest 10-msec ridedown acceleration was -0.4 g from 590 to 600 msec, and the maximum 50-msec average was -0.4 g between 260 and 310 msec.

The vehicle received cosmetic damages only and there was no penetration or intrusion of the occupant compartment of the vehicle. The vehicle remained on a straight, smooth path through the test site with no intrusion into adjacent traffic lanes. The vehicle remained stable throughout the test sequence. The plastic drum, chevron sign, and flashing light assemblies snapped free of the bases and rode along with the vehicle or were thrown slightly to the side as the vehicle travelled through the test site. Some of the bases were a distance away from their original positions and sand from the ballast was scattered throughout the test site.

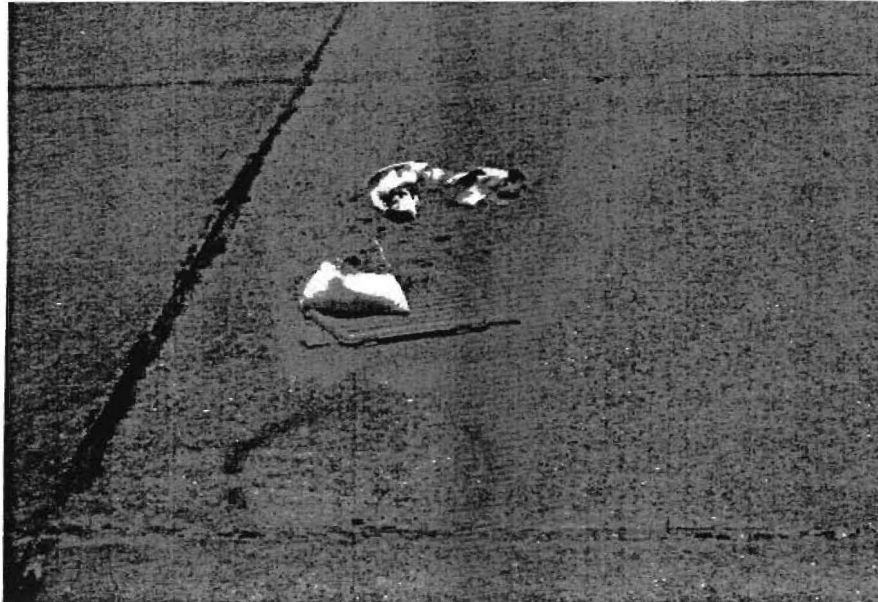


Base moved 4 ft down, 12 in left



Drum 180 ft down, 16 ft left

Figure 17. Damage to first device, test 1917-3

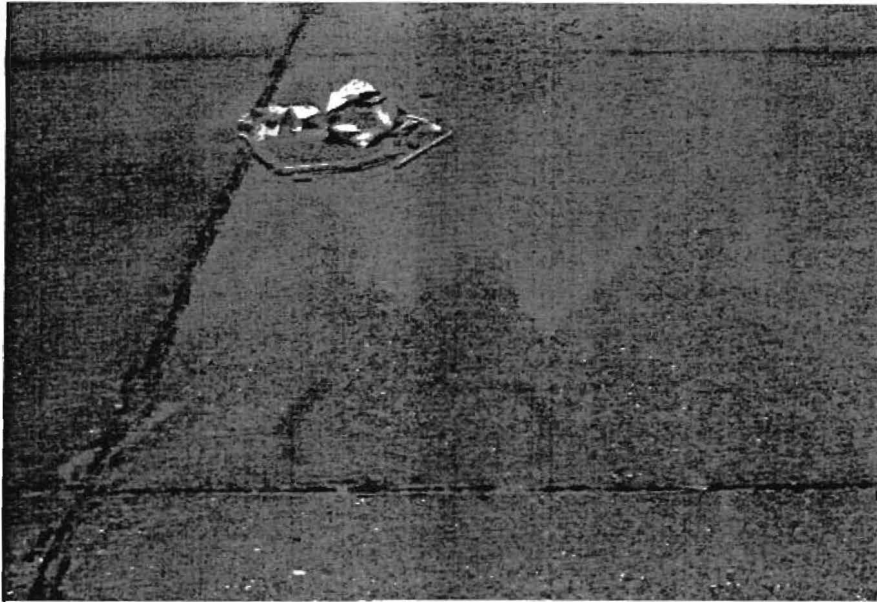


Base moved 3 ft down



Drum 120 ft down, 4 ft right

Figure 18. Damage to second device, test 1917-3



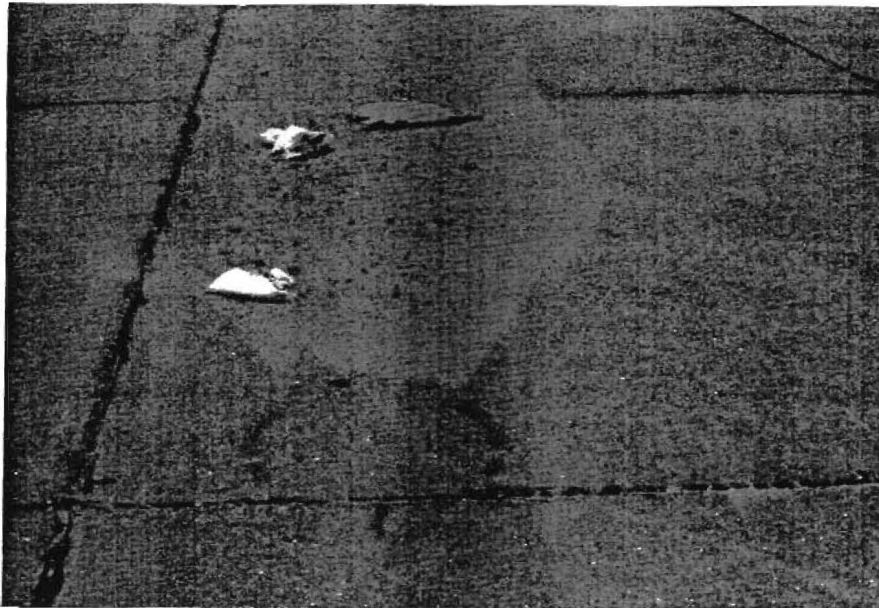
Base moved 9 ft down, 18 in left



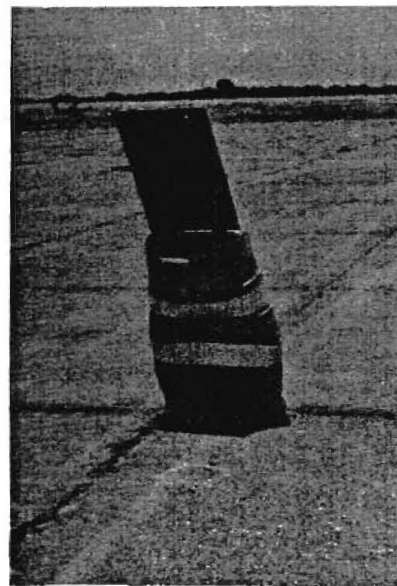
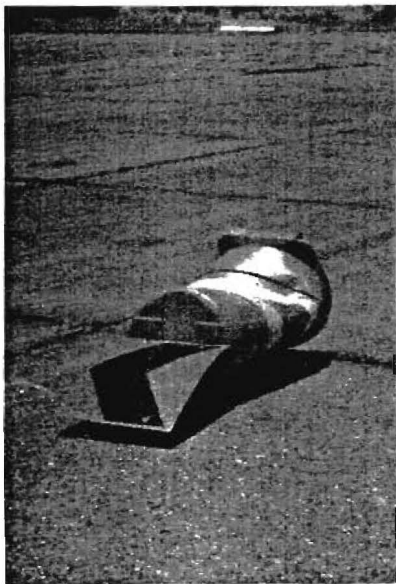
Drum stayed with vehicle

Figure 19. Damage to third device, test 1917-3





Base moved 11 ft down, 1 ft right



Drum 120 ft down, 12 ft left

Figure 20. Damage to fourth device. test 1917-3

#### Test 1917-4

The installation for test 4 was the same as test 3 with the exception of the spacing between the four devices. The devices were 60 feet apart for impact at 60 mi/h.

The vehicle was travelling at 61.6 mi/h when it contacted the first device. As the drum snapped loose from the base, the chevron slapped the hood of the vehicle. The drum rode along with the vehicle as it struck the second device. The drum snapped loose from the second base, rode along the right front side of the vehicle for a short distance, and then went off to the right side. As the vehicle struck the third and fourth devices, the drums snapped loose and rode along with the vehicle and the first drum.

The base of the first device was 6 feet back and 12 inches to the right. All three sandbags had bursted and one was found 4 feet down and 4 inches to the right, another was 5 feet down and 4 inches to the right, and the third was 60 feet down and 18 inches to the right. The drum travelled along the front of the vehicle. The base and drum are shown in Figures 21 and 22.

The second base was 18 feet down and 4 feet to the left, and all three sandbags were bursted as shown in Figure 23. One sandbag was lying 3 feet down and 10 inches to the left, a second was 8 feet down and 12 inches left, and the third was 11 feet down and 12 inches right. The drum was found 135 feet down and 18 feet to the right of its original location.

The third base (shown in Figure 21) was 6 feet back and 18 inches to the right. All three sandbags were split; the first was 3 feet down and 12 inches right, the second was 6 feet down and 12 inches left, and the third was 33 feet down and 3 feet right. The drum, shown in Figure 22, rode along the front of the vehicle.

The base of the fourth device was found 12 feet back and 12 inches to the left of its original position. One sandbag was 13 feet down and 12 inches left, another was 14 feet down and 10 inches left, the last was 29 feet down and 6 inches right, and all three were split. The drum stayed with the vehicle. The base and drum after the test are shown in Figures 21 and 22.

The flat plastic bases were not damaged, but the 12 sandbags were split and sand was strewn along the vehicle path. The drums were dented and scratched. The hood of the vehicle was scraped slightly and the spoiler on the lower front of the vehicle was dented.

The longitudinal occupant impact velocity was 5.2 ft/s at 588 msec, the



Base moved 6 ft down, 1 ft right



Base moved 6 ft down,  
18 in right



Base moved 12 ft down,  
1 ft left

Figure 21. First, third and fourth bases after test 1917-4

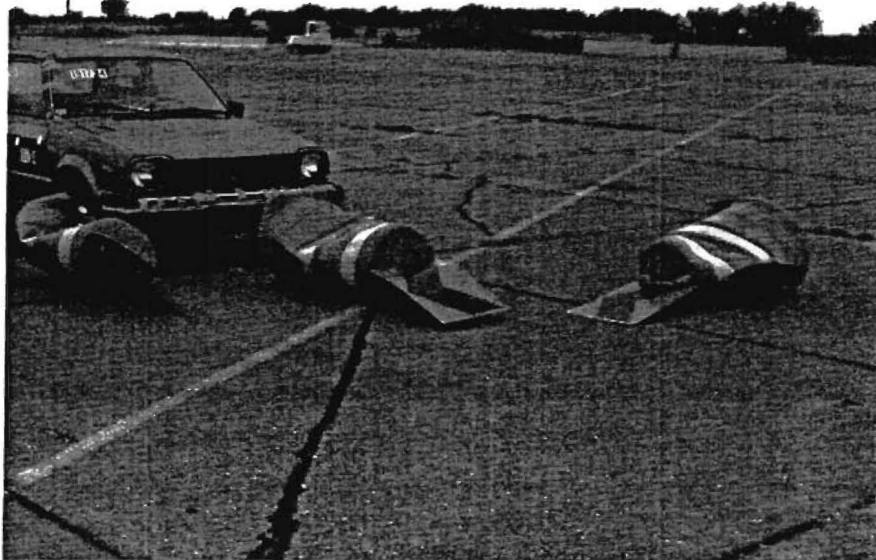


Figure 22. First, third and fourth drums after test 1917-4



Base moved 18 ft down, 4 ft left



Drum 135 ft down, 18 ft right

Figure 23. Damage to second device, test 1917-4

highest 10-msec ridedown acceleration was -0.3 g from 590 to 600 msec, and the maximum 50-msec average was -1.5 g between 1 and 51 msec. There was no occupant impact in the lateral direction, and the maximum 50-msec average was only -0.3 g between 131 and 181 msec.

The vehicle received minor damages only and there was no penetration or intrusion of the occupant compartment of the vehicle. The vehicle remained on a straight, smooth path through the test site with no intrusion into adjacent traffic lanes. The vehicle remained stable throughout the test sequence. The plastic drum, chevron sign, and flashing light assemblies snapped free of the bases and rode along with the vehicle or slightly off to the side as the vehicle travelled through the test site. All the bases remained relatively near the points of impact. Any sand spilled from the sandbags was minimal and was judged not to present undue hazard to other traffic.

#### Test 1917-5

Test 5 was the first of the glancing impact configurations for impact at 45 mi/h. One sign assembly outfitted with the 50-pound San-fill unit was used in this test. The right front corner of the vehicle bumper was aligned with the centerline of the device.

The vehicle contacted the device while travelling at a speed of 42.3 mi/h. The drum snapped loose from the base and flipped over to the right side of the vehicle but did not touch the vehicle. The San-fill base was not damaged and was moved back 4 inches and 2 inches to the left of its initial position. The drum landed 75 feet down and 8 feet to the right and was only dented and scraped slightly. The test site and damage to the device are shown in Figures 24 and 25. The vehicle was not damaged at all.

No contact of the occupant compartment occurred during the test period. The maximum 50-msec average in the longitudinal direction was -0.5 g between 127 and 177 msec and in the lateral direction was -0.4 g also between 127 and 177 msec.

There was no damage to the vehicle and no penetration or intrusion into the occupant compartment of the vehicle. The vehicle remained on a straight, smooth course through the test site with no intrusion into adjacent traffic lanes. The vehicle remained stable throughout the test sequence. The plastic drum, chevron sign, and flashing light assembly snapped free of the base and rode slightly off to the side of the vehicle. The base remained near the point of impact and there

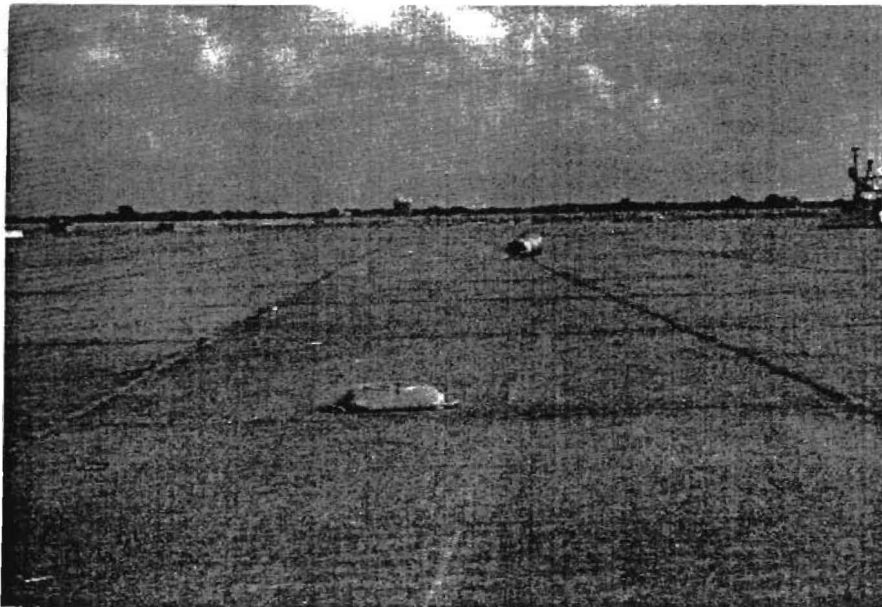


Figure 24. Test site before and after test 1917-5



Base moved 4 in down, 2 in right



Drum moved 75 ft down, 8 ft right

Figure 25. Damage to device, test 1917-5



was no sand to present undue hazard to other traffic.

#### Test 1917-6

The same type installation used in test 5 was impacted in this test at 60 mi/h. The device is shown in Figure 26.

The vehicle was travelling at a speed of 63.2 mi/h as it contacted the device. The drum snapped loose from the base and flipped hard to the right side of the vehicle. The chevron and light unit hit the lower right corner of the windshield and the hood, cracking the windshield and leaving a dent in the top of the hood as shown in Figure 27. The San-fill base was not damaged and was moved 18 inches back and 6 inches to the right of its original position (see Figure 28). The drum was dented and scraped slightly and was found 75 feet down and 14 feet to the right. The windshield of the vehicle had to be replaced and the hood repaired.

No occupant impact occurred during the test period. The maximum 50-msec average in the longitudinal direction was -0.5 g between 4 and 54 msec and in the lateral direction was -0.7 g between 282 and 332 msec.

The hood of the vehicle was dented and the windshield was cracked; however, there was no penetration or intrusion into the occupant compartment. The cracked windshield did not restrict driver visibility. The vehicle travelled straight through the test site with no intrusion into adjacent traffic lanes. The vehicle remained stable throughout the test sequence. The plastic drum, chevron sign, and flashing light assembly snapped free of the base and rode to the side of the vehicle while the base remained near the point of impact. There was no sand to present undue hazard to other traffic.

#### Test 1917-7

Test 7 was of the glancing impact configuration (for impact at 45 mi/h) with one assembly fitted onto a flat base weighed down with two 25-pound sandbags for a total ballast of 50 pounds. The right front corner of the vehicle bumper was aligned with the centerline of the device.

The plastic drum snapped loose from the base as the vehicle impacted it travelling at 42.1 mi/h. The drum flipped over to the right side of the vehicle and the chevron slightly scraped the right front quarter panel. The flat base was not damaged and was moved back 4 feet and 6 inches to the right. The sandbags did not burst; one was 5 feet down and 8 inches to the left while the

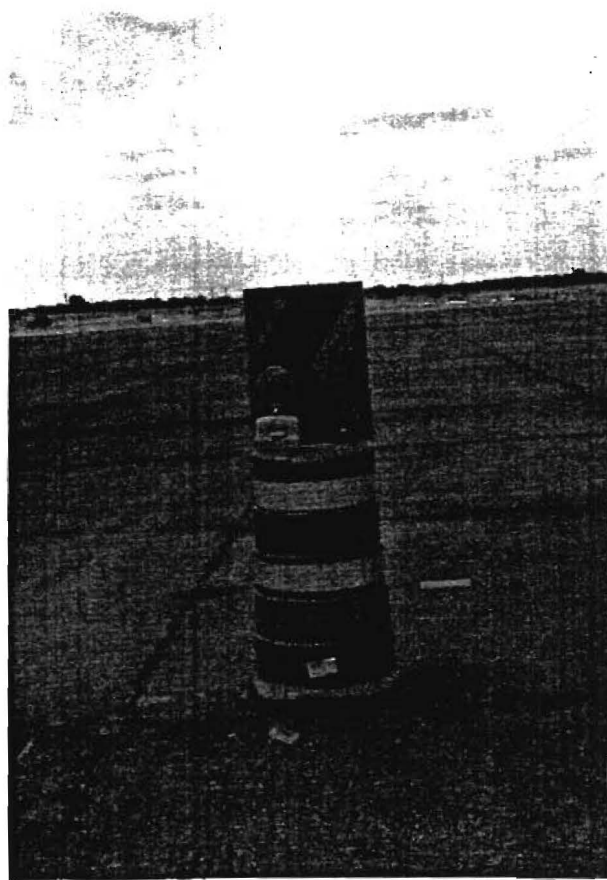
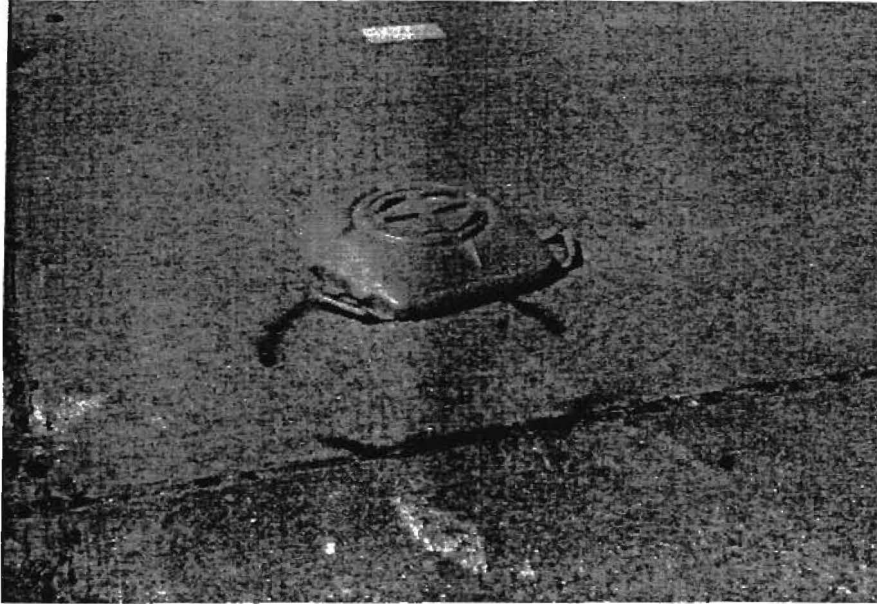


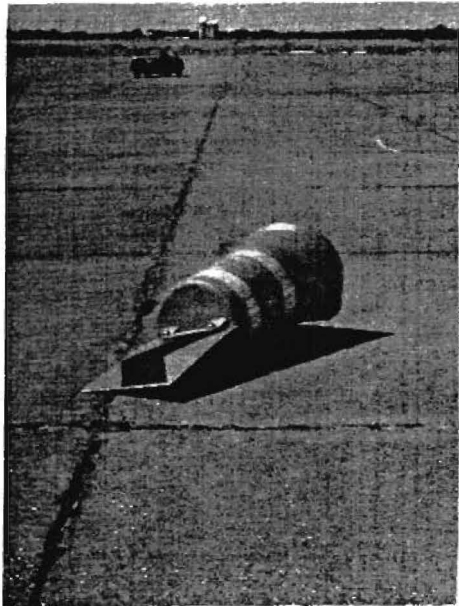
Figure 26. Test site before test 1917-6



Figure 27. Vehicle after test 1917-6



Base moved 18 in down, 6 in right



Drum 75 ft down, 14 ft right

Figure 28. Damage to device, test 1917-6

other was 8 feet down. The drum was dented and scraped and was found 90 feet down and 3 feet to the right of its original position. The test site and device are shown in Figures 29 and 30. The chevron was slightly torn at one of the bolt connections. The vehicle was only scratched slightly on the right side.

There was no occupant impact during the test period. The maximum 50-msec average in the longitudinal direction was  $-0.8$  g between 14 and 64 msec and in the lateral direction was  $-0.6$  g between 267 and 317 msec.

The vehicle received cosmetic damages only and there was no penetration or intrusion into the occupant compartment of the vehicle. The vehicle travelled through the test site on a straight course with no intrusion into adjacent traffic lanes. The vehicle remained stable throughout the test sequence. The plastic drum, chevron sign, and flashing light assembly snapped free of the base and rode slightly off to the side of the vehicle as it travelled through the test site. The base remained fairly near the point of impact and there was no sand spilled to present undue hazard to other traffic.

#### Test 1917-8

The same type installation tested in test 7 was used for test 8 at impact speed of 60 mi/h.

As the vehicle impacted the device travelling at a speed of 62.0 mi/h, the plastic drum snapped free of the base. The drum flipped hard to the right side of the vehicle, making contact with the right front quarter panel and the right door. The flat base was not damaged and was moved 8 feet back and 6 inches to the right. The first sandbag was not damaged and was found 5 feet down and 3 feet to the right; however, the second sandbag was split and was lying 11 feet down and 1 foot to the right. The drum was found 69 feet down and 15 feet to the right of its initial position. The site and device after the test can be seen in Figures 31 and 32. As shown in Figure 33, the right front quarter panel and right door of the vehicle was scratched.

No longitudinal occupant impact occurred during the test period, and the maximum 50-msec average was only  $-1.1$  g between 0 and 50 msec. Lateral occupant impact velocity was 6.0 ft/s at 471 msec, the highest 10-msec ridedown acceleration was  $-0.5$  g from 482 to 492 msec, and the maximum 50-msec average was  $-1.0$  g between 276 and 326 msec.

The vehicle received only minor damages and there was no penetration or intrusion of the occupant compartment of the vehicle. The vehicle travelled on

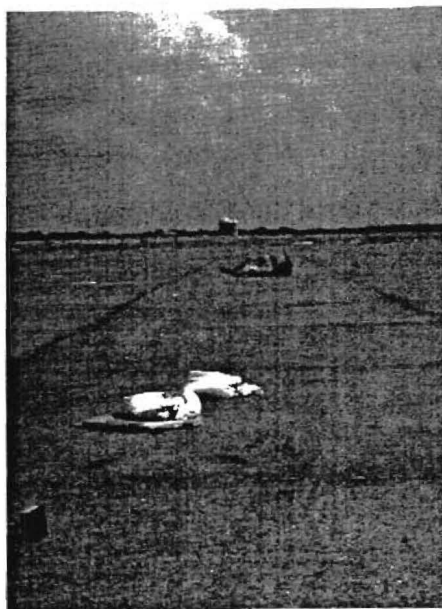
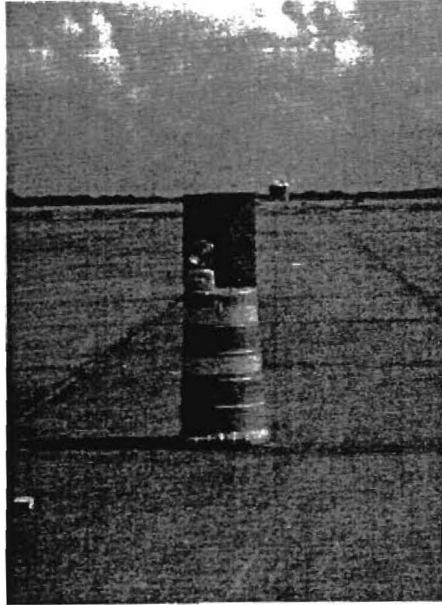
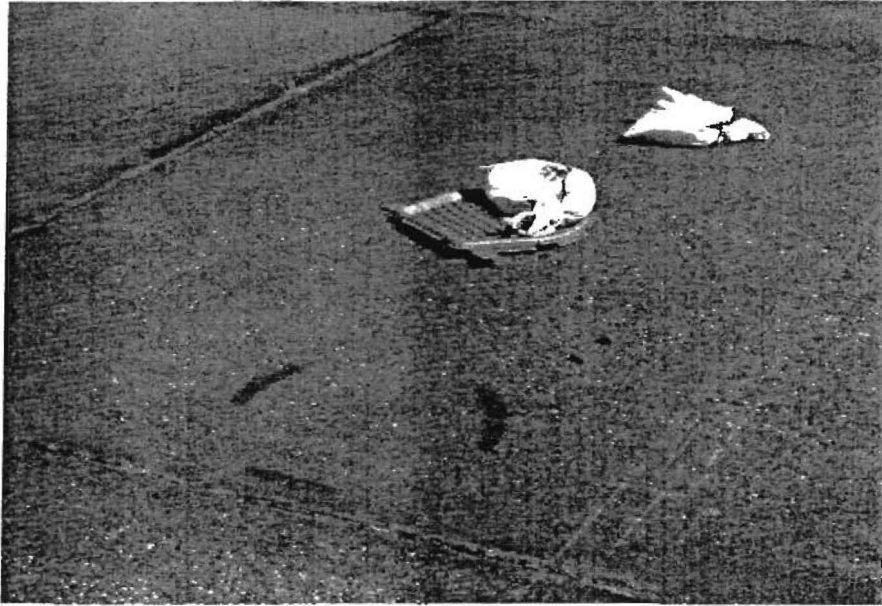
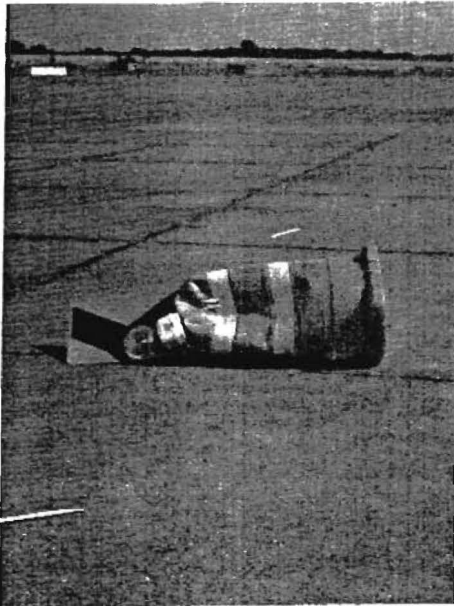


Figure 29. Test site before and after test 1917-7



Base moved 4 ft down, 6 in left



Drum 90 ft down, 3 ft right Chevron torn

Figure 30. Damage to device, test 1917-7

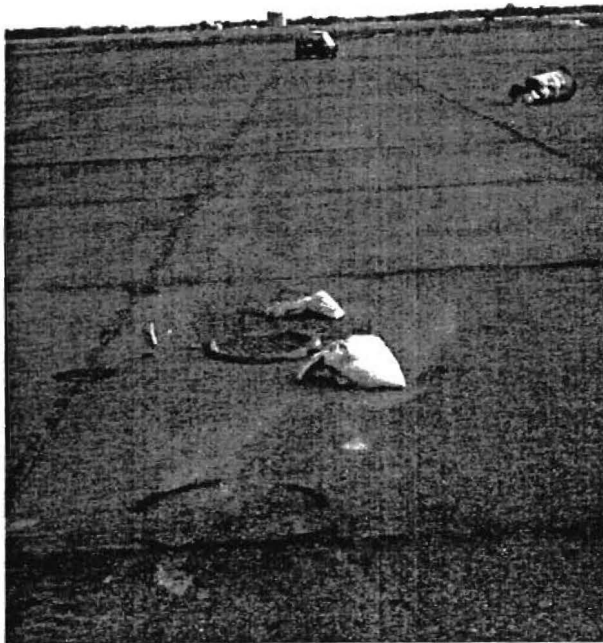
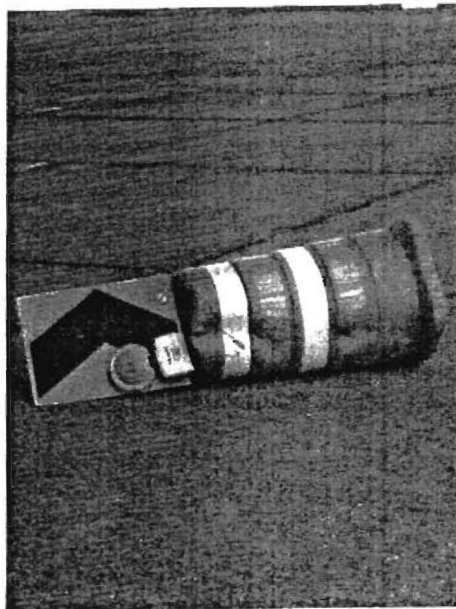


Figure 31. Test site before and after test 1917-8





Base moved 8 ft down, 6 in right



Drum 69 ft down, 15 ft right

Figure 32. Damage to device, test 1917-8



Figure 33. Damage to vehicle after test 1917-8

a straight course through the test site with no intrusion into adjacent traffic lanes and remained stable throughout the test sequence. The plastic drum, chevron sign, and flashing light assembly snapped free of the base and flipped off slightly to the right of the vehicle as it travelled through the test site. The base was a short distance from the point of impact and any sand spilled was minimal and judged not to present undue hazard to other traffic.

#### Test 1917-9

Test 9 was a glancing impact configuration for impact at 45 mi/h, using one sign assembly positioned over a San-fill unit (50 pounds) and one 25-pound sandbag for a total ballast of 75 pounds. The right front corner of the vehicle bumper was aligned with the centerline of the device.

The drum snapped free of the base as the vehicle, travelling at 47.0 mi/h, made contact with the device. The drum flipped over to the right side of the vehicle, but did not make contact with the side of the vehicle. The base was undamaged and was moved 8 inches back and 5 inches to the right. As can be seen in Figures 34 and 35, the sandbag was split and lying 3 feet down and 5 inches to the right. The slightly dented and scratched drum was found 78 feet down and 15 feet to the right of its original location. The vehicle was not damaged.

No longitudinal or lateral impact occurred during the test period. The maximum 50-msec average in the longitudinal direction was -0.8 g between 11 and 61 msec, and was 0.7 g in the lateral direction between 67 and 117 msec.

There was no damage to the vehicle and no penetration or intrusion into the occupant compartment of the vehicle. The vehicle remained on a straight, smooth course through the test site with no intrusion into adjacent traffic lanes. The vehicle remained stable throughout the test sequence. The plastic drum, chevron sign, and flashing light assembly snapped free of the base and rode slightly off to the side of the vehicle. The base remained near the point of impact and any sand spilled was judged not to present undue hazard to other traffic.

#### Test 1917-10

Test 10 was of the same type installation as test 9 except impact speed was at 60 mi/h.

The vehicle was travelling at a speed of 61.6 mi/h when it contacted the device. The drum snapped loose from the base and flipped hard to the right making contact with the right side of the hood. The base hit the right underside

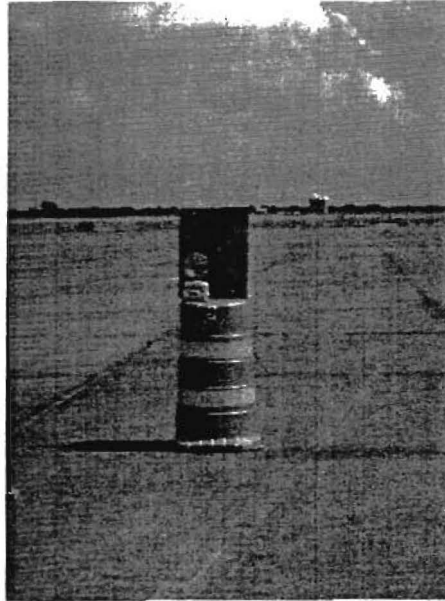
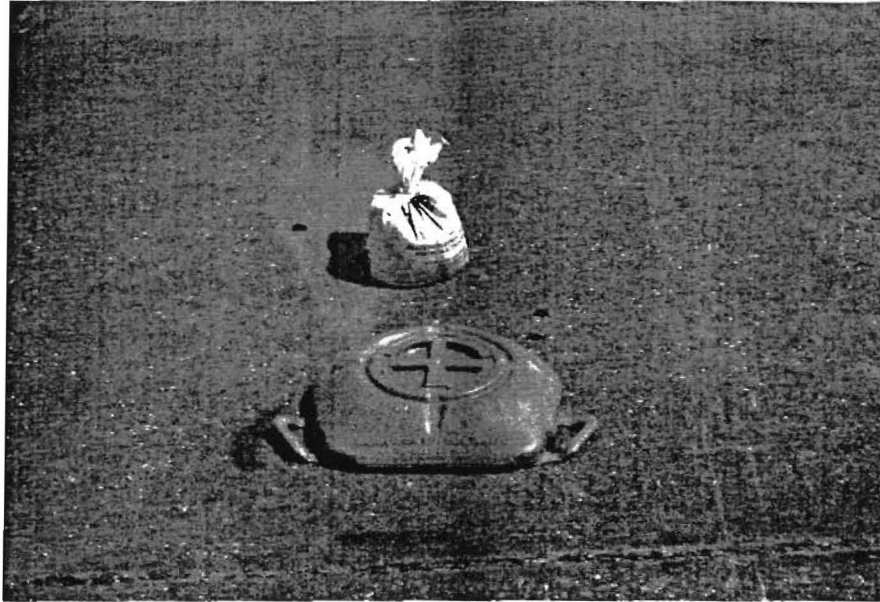


Figure 34. Test site before and after test 1917-9



Base moved 8 in down, 5 in right



Drum moved 78 ft down, 15 ft right

Figure 35. Damage to device, test 1917-9

of the vehicle and the top of the base was knocked off. The site and damage to the base and drum are shown in Figures 36 and 37. The base was moved back 16 feet and 3 feet to the right and the sandbag was bursted 19 feet down and 2 feet to the right. The drum was dented and scraped and came to rest 105 feet down and 12 inches to the left of its initial position. The hood of the vehicle was dented as shown in Figure 38, and the right front strut was damaged. The vehicle was not used for further tests.

There was no occupant impact during the test period. The maximum 50-msec average acceleration in the longitudinal direction was -1.6 g between 0 and 50 msec and in the lateral direction was 1.4 g between 75 and 125 msec.

The vehicle received damages to the hood and underside; however, there was no penetration or intrusion of the occupant compartment of the vehicle. The vehicle travelled through the test site on a straight course with no intrusion into adjacent traffic lanes and remained relatively stable throughout the test sequence. The plastic drum, chevron, and flashing light assembly snapped free of the base and flipped slightly to the right side of the vehicle as it travelled through the test site. The base and sandbag were damaged and were some distance from the point of impact. A small amount of sand was spilled, but was judged not to present hazard to other traffic.

#### Test 1917-11

This installation consisted of one sign assembly placed on a flat base which was weighed down with three 25-pound sandbags for a total of 75 pounds. The right front corner of the vehicle bumper was aligned with the centerline of the device in a glancing impact condition at 45 mi/h.

The speed of the vehicle upon impact with the device was 45.7 mi/h. As the drum snapped free of the base, the chevron and light slapped the right side of the hood of the vehicle and then rode off the side of the vehicle. As shown in Figures 39 and 40, the flat base was undamaged and only moved back 16 inches and 8 inches to the right. The first two sandbags remained intact; one was 18 inches down and 14 inches to the right and the other was 4 feet down and 10 inches to the left. The third sandbag bursted 7 feet down and 10 inches to the left. The drum was dented and came to rest 85 feet down and 16 feet to the right of the point of impact. The hood of the vehicle was dented on the right corner, but repaired quickly.

No occupant impact occurred during the test period. The maximum 50-msec

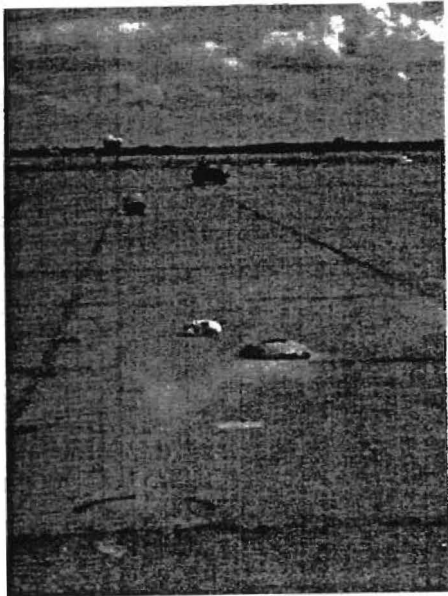
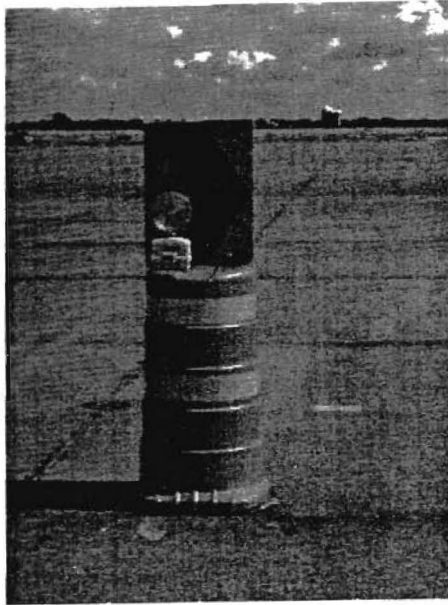
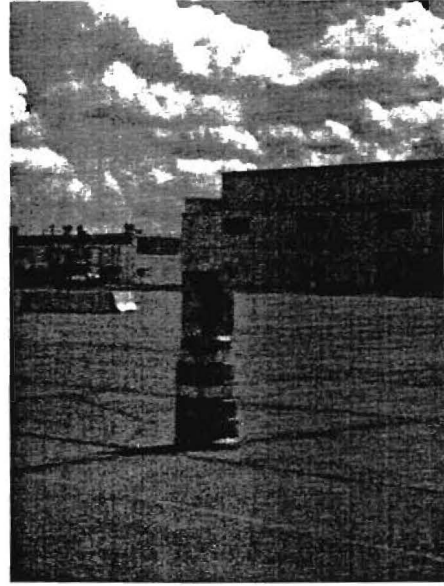
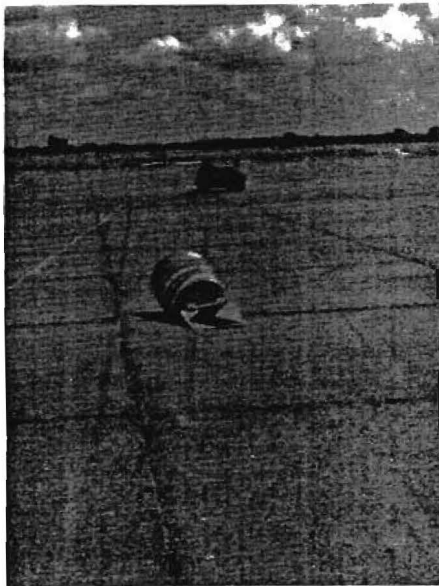


Figure 36. Test site before and after test 1917-10



Base moved 16 ft down, 3 ft right



Drum 105 ft down, 1 ft left

Figure 37. Damage to device, test 1917-10



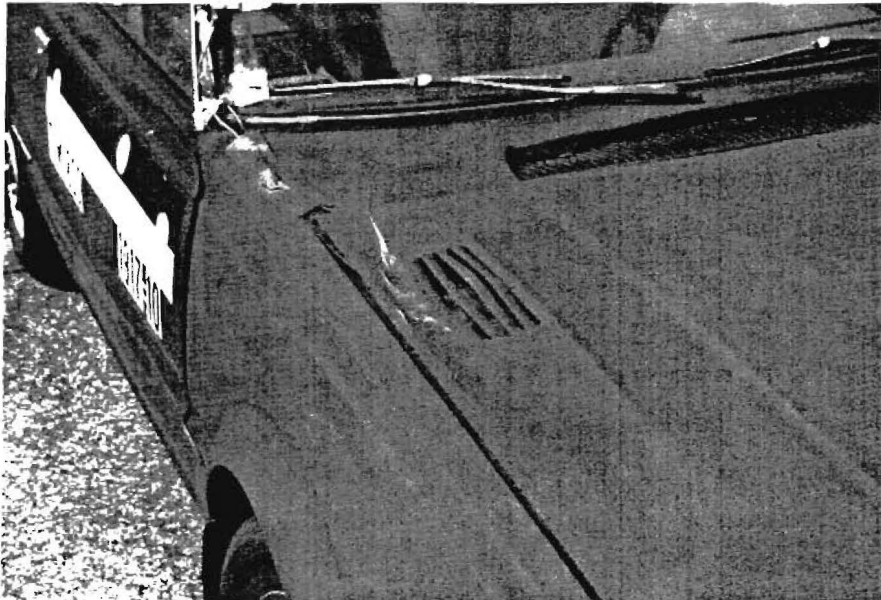


Figure 38. Damage to vehicle, test 1917-10  
(right front strut was also damaged)

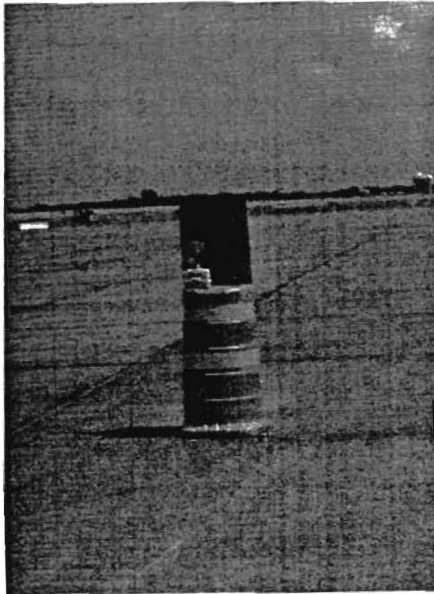
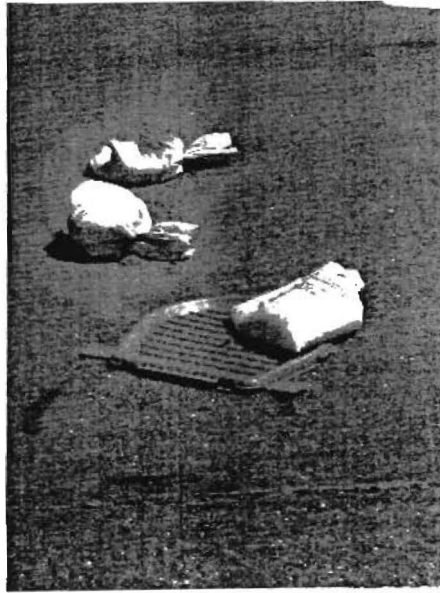
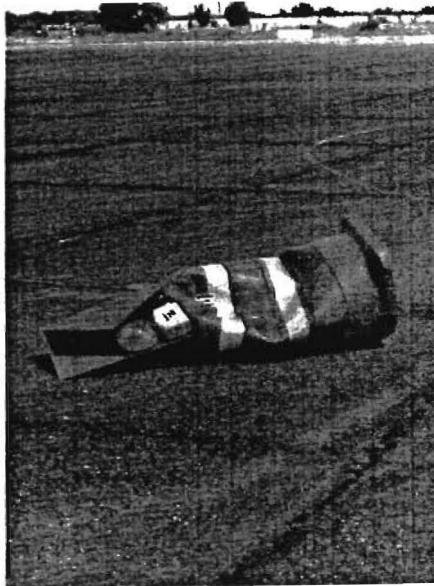


Figure 39. Test site before and after test 1917-11



Base moved 16 in down, 8 in right



Base moved 85 ft down, 16 ft right

Figure 40. Damage to device, test 1917-11

average accelerations were -1.0 g between 9 and 59 msec in the longitudinal direction, and -0.9 g between 266 and 316 msec in the lateral direction.

Only minor damage was sustained by the vehicle and there was no penetration or intrusion into the occupant compartment of the vehicle. The vehicle travelled a straight course through the test site with no intrusion into adjacent traffic lanes and remained stable throughout the test sequence. The plastic drum, chevron, and flashing light assembly snapped free of the base and rode along to the right of the vehicle as it travelled through the test site. The base and sandbags remained relatively near the point of impact and any sand spilled was considered not hazardous to other traffic.

### Test 1917-12

The same type installation as test 11 was used in test 12, to be impacted at 60 mi/h.

The vehicle was travelling 60.7 mi/h as it impacted the device. As the drum snapped loose from the base, the chevron slapped the right side of the hood, and the drum flipped off to the right. The vehicle rose up and over slightly as it travelled through the site. The test site and damage to the device are shown in Figures 41 and 42. The flat base was not damaged and was 18 inches down and 6 inches to the right. Two of the sandbags remained intact; one 18 inches down and 12 inches to the right, and another 6 feet down and 8 inches to the right. The other sandbag bursted and was 5 feet down and 8 inches to the right. The drum was dented and was found 57 feet down and 9 feet to the right of its original position. The hood of the vehicle was scratched and there was a small dent in the upper right front quarter panel.

There was no occupant impact during the test period. The maximum 50-msec average accelerations were -1.1 g between 4 and 54 msec in the longitudinal direction and -0.8 g between 237 and 287 msec in the lateral direction.

The vehicle received only minor damages and there was no penetration or intrusion of the occupant compartment of the vehicle. The vehicle travelled straight through the test site with no intrusion into adjacent traffic lanes and remained relatively stable throughout the test sequence. The plastic drum, chevron, and flashing light assembly snapped free of the base and remained fairly close to the point of impact. The base and sandbags also remained near the point of impact and the small amount of sand spilled was considered not to present hazard to other traffic.



Figure 41. Test site before and after test 1817-12



Base moved 18 in down, 6 in right



Drum 57 ft down, 9 ft right

Figure 42. Damage to device after test 1917-12

### Test 1917-13

For test 13, one sign assembly was fitted onto a flat base which was weighed down with one 25-pound sandbag. The centerline of the vehicle was aligned with the centerline of the device for a head-on impact at 60 mi/h.

The speed of the vehicle as it contacted the device was 61.0 mi/h. The drum snapped free of the base and rode up onto the hood of the vehicle. The drum continued to roll up the hood, skimmed the windshield and then went over the vehicle. As can be seen in Figure 43, the flat base was undamaged and had rotated and moved back only 2 inches. The sandbag remained intact and was lying on the base. The drum, shown in Figure 44, was dented and came to rest 110 feet down and 10 feet to the right. Other than a slight film of plastic where the drum skimmed the windshield (see Figure 45), there was no damage to the vehicle.

No occupant impact occurred during the test period. The maximum 50-msec average in the longitudinal direction was -0.6 g between 0 and 50 msec and in the lateral direction was -0.3 g between 56 and 106 msec.

The vehicle received cosmetic damage only and there was no penetration or intrusion of the occupant compartment. The vehicle remained on a straight, smooth path through the test site with no intrusion into adjacent traffic lanes. The vehicle remained stable throughout the test period. The plastic drum, chevron, and flashing light assembly snapped free of the base and rode along and then over the vehicle as it travelled through the test site. The base and sandbag remained near the point of impact and there was no sand spilled to present hazard to other traffic.

### Test 1917-14

One sign assembly was fitted onto a flat base which was weighed down with one 25-pound sandbag. The right front corner of the vehicle bumper was aligned with the centerline of the device for a glancing impact at 60 mi/h.

As the vehicle, travelling at a speed of 60.4 mi/h, contacted the device, the drum snapped free of the base and flipped over to the right side of the vehicle, but no contact with the side of the vehicle. The flat base was not damaged and was moved 12 feet down. The sandbag remained intact and was lying 3 feet down. The drum was dented and was found 48 feet down and 12 feet to the right of its original location. The test site and damage to the device are shown in Figures 46 and 47. The vehicle was not damaged.

No occupant impact occurred during the test period, and the maximum 50-msec



Base moved 2 in down

Figure 43. Test site before and after test 1917-13





Drum 110 ft down, 10 ft right

Figure 44. Damage to drum, test 1917-13



Plastic film on windshield

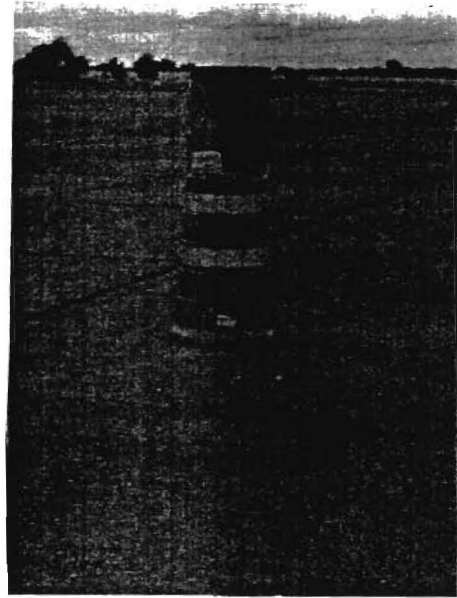
Figure 45. Vehicle after test 1917-13



Figure 46. Test site before and after test 1917-14



Base moved 12 ft down



Drum 48 ft down, 12 ft right

Figure 47. Damage to device, test 1917-14

average acceleration in the longitudinal direction was -0.5 g between 89 and 139 msec, and in the lateral direction was -0.4 g between 101 and 151 msec.

There was no damage to the vehicle and there was no penetration or intrusion into the occupant compartment of the vehicle. The vehicle travelled a straight course through the test site with no intrusion into adjacent traffic lanes. The vehicle remained stable throughout the test period. The plastic drum, chevron, and flashing light snapped free of the base and remained near the path of the vehicle. The base moved a short distance, but the sandbag remained near the point of impact. There was no sand spilled to present undue hazard to other traffic.



#### IV. SUMMARY

Table 1 summarizes the results of the 14 crash tests conducted under this study. The plastic drum, sign and flashing unit assemblies all performed satisfactorily. The plastic drum, sign and flashing unit assemblies snapped free of the base readily upon impact and either flipped over or to the side of the vehicle or stayed with the vehicle. The separated drum assemblies contacted the vehicle hood, windshield or side in some of the tests and the windshield of the impacting vehicle was cracked in one test (test 6). However, the impact force was relatively minor with no penetration or intrusion into the occupant compartment. The separated drum assemblies were generally thrown some distance from the points of impact. However, due to the light weight of the assembly and the low speed when the assembly returned to the ground, it is not considered a hazard to adjacent traffic or to the workers.

The bases and sandbags usually stayed close to the points of impact. The sandbags were mostly bursted, resulting in spillage of sand at the test site. However, the amount of spillage was relatively small and not considered undue hazard to the traffic. In one test (test 6), a sandbag was caught by the undercarriage and right front tire, resulting in damages to the right front strut of the vehicle.

The vehicles received mostly cosmetic damages and there was no penetration or intrusion of the occupant compartment. The vehicles generally travelled through the test site on a straight course with no intrusion into adjacent traffic lanes and remained relatively stable throughout the test sequence.

In the glancing impact configuration, the drum assemblies were generally thrown to the side, but the impact performance was otherwise similar to that of head-on tests.

There was no appreciable difference in impact performance among the different ballast weights within the range of 25 to 75 pounds. The ballast weight was sufficient in all the tests for the plastic drums to properly separate from the bases, resulting in minimal deceleration on the impacting vehicles. Since plastic drums ballasted at 50 pounds have been found to be blown over or moved by air disturbances generated by passing traffic, the use of 75-pound ballast weights appears to be the logical choice.

In order to attain the ballast weight of 75 pounds, one 25-pound sandbag was used with the 50-pound san-fill base or three 25-pound sandbags for the flat

Table 1. Summary of Crash Test Results

Test No.	Type of Base/ Ballast	Impact Configuration	Impact Speed	Longitudinal Direction			Lateral Direction		
				Occupant Impact Velocity	10-ms Ridedown	50-ms Average	Occupant Impact Velocity	10-ms Ridedown	50-ms Average
1917- 1	San-fill + 1 Sandbag	Head-on	44.1 mi/h	None	N/A	-1.0 g 4- 54ms	None	N/A	-0.4 g 290-340 ms
1917- 2	San-fill + 1 Sandbag	Head-on	62.1 mi/h	None	N/A	-1.0 g 2- 52 ms	None	N/A	-0.2 g 50-100 ms
1917 -3	3 Sandbags	Head-on	47.6 mi/h	None	N/A	-0.8 g 1- 51 ms	3.8 ft/s at 568 ms	-0.4 g 590-600 ms	-0.4 g 260-310 ms
1917 -4	3 Sandbags	Head-on	61.6 mi/h	5.2 ft/s at 588 ms	-0.3 g 590-600 ms	-1.5 g 1- 51 ms	None	N/A	-0.3 g 131-181 ms
1917 -5	San-fill	Glancing	42.3 mi/h	None	N/A	-0.5 g 127-177 ms	None	N/A	-0.4 g 127-177 ms
1917 -6	San-fill	Glancing	63.2 mi/h	None	N/A	-0.5 g 4- 54 ms	None	N/A	-0.7 g 282-332 ms
67 1917 -7	2 Sandbags	Glancing	42.1 mi/h	None	N/A	-0.8 g 14- 64 ms	None	N/A	-0.6 g 267-317 ms
1917 -8	2 Sandbags	Glancing	62.0 mi/h	None	N/A	-0.9 g 0- 50 ms	6.0 ft/s at 471 ms	-0.5 g 482-492 ms	-1.0 g 276-326 ms
1917 -9	San-fill + 1 Sandbag	Glancing	47.0 mi/h	None	N/A	-0.8 g 11- 61 ms	None	N/A	0.7 g 67-117 ms
1917-10	San-fill + 1 Sandbag	Glancing	61.6 mi/h	None	N/A	-1.6 g 0- 50 ms	None	N/A	1.4 g 75-125 ms
1917-11	3 Sandbags	Glancing	45.7 mi/h	None	N/A	-1.0 g 9- 59 ms	None	N/A	-0.8 g 266-316 ms
1917-12	3 Sandbags	Glancing	60.7 mi/h	None	N/A	-1.1 g 4- 54 ms	None	N/A	-0.8 g 237-287 ms
1917-13	1 Sandbag	Head-on	61.0 mi/h	None	N/A	-0.6 g 0- 50 ms	None	N/A	-0.3 g 56-106 ms
1917-14	1 Sandbag	Glancing	60.4 mi/h	None	N/A	-0.5 g 89-139 ms	None	N/A	-0.4 g 101-151 ms



plastic base. The additional sandbag raised the height of the base, resulting in contact between the sandbag and the undercarriage of the vehicle. As mentioned above, a sandbag was caught by the undercarriage and the right front tire in test 10, resulting in damages to the right front strut. Also, the amount of sand being spilled at the site was greater with the additional sandbag. It would be desirable to have a san-fill base that can hold 75 pounds of sand or to have sandbags with a lower profile than the ones used in the crash tests.

Similarly, the san-fill base would be preferred over a flat plastic base with sandbags because of the lower profile and the lower potential for spilling of sand at the site. The san-fill base is also easier to install and maintain than the flat base with sandbags. In most of the crash tests involving san-fill bases, the bases remained intact with little or no spillage of sand. On the other hand, sandbags are oftentimes bursted or split, resulting in spillage of sand at the site.



## V. REFERENCES

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