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16. Abstract The Texas Department of Transportation (TxDOT) is currently using or considering to use various plastic traffic control devices in work zones. Of special interest are chevron signs, vertical panels, and flashing or steady burn lights mounted on plastic drums. Since there are no existing standards or guidelines governing the impact performance of these traffic control devices and the devices have not been subjected to full-scale crash testing, there is a need to evaluate the impact performance of these traffic control devices. This is the third study in the continuing effort by TxDOT to evaluate the impact performance of these traffic control devices. The specific objectives of this study are to: (1) evaluate an add-on sand-filled compartment for the base of a plastic drum manufactured by Flex-O-Lite, (2) evaluate the impact performance of various sign substrates, and (3) develop specifications for plastic drums.			
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**TESTING AND EVALUATION OF WORK ZONE
TRAFFIC CONTROL DEVICES**

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I. INTRODUCTION

The Texas Department of Transportation (TxDOT) is currently using or considering to use various plastic traffic control devices in work zones. Of special interest are chevron signs, vertical panels, and flashing or steady burn lights mounted on plastic drums. Since there is no existing standards or guidelines governing the impact performance of these traffic control devices and the devices have not been subjected to full-scale crash testing, there is a need to evaluate the impact performance of these traffic control devices.

This study was sponsored by the Division of Maintenance and Operation, Traffic Engineering Section (D-18TE), of the TxDOT in the continuing effort to evaluate the impact performance of selected traffic control devices. Two previous studies had been conducted and the results reported ^(1,2). This study had the following specific objectives:

1. Evaluation of add-on sand-filled compartments for bases of plastic drums manufactured by Flex-O-Lite.
2. Evaluation of sign substrates.
3. Development of Specifications for Plastic Drums.

II. STUDY APPROACH

As mentioned previously, this study had three specific objectives:

1. Evaluation of add-on sand-filled compartments for bases of plastic drums manufactured by Flex-O-Lite.
2. Evaluation of sign substrates.
3. Development of Specifications for Plastic Drums.

Brief descriptions on the study approach to meet each of these three objectives are presented as follows.

2.1 EVALUATION OF ADD-ON SAND-FILLED COMPARTMENTS FOR BASES OF PLASTIC DRUMS

An add-on sand-filled compartment is recently available for bases of plastic drums manufactured by Flex-O-Lite. Two crash tests (test nos. 1938-1 and 1938-2) were conducted to evaluate the impact performance of the plastic drum and base with this add-on sand-filled compartment:

1. Test No. 1938-1. An 1,800-pound passenger car impacting the plastic drum head-on at 60 miles per hour (mi/h), i.e., the centerline of the vehicle was aligned with the centerline of the plastic drum.
2. Test No. 1938-2. An 1,800-pound passenger car impacting the plastic drum at 60 mi/h with a glancing impact, i.e., the centerline of the tire of the vehicle was aligned with the centerline of the plastic drum.

The test installation for each of the two tests consisted of a single plastic drum manufactured by Flex-O-Lite. The plastic drum was outfitted with a fiber-reinforced plastic (FRP) sign panel and a flashing light unit, both of which were rigidly attached to the top of the plastic drum. The add-on compartment was filled with 50 pounds of sand for ballast.

As will be presented in the section on "Study Results", the windshield of the vehicle was cracked in the head-on impact test (test no. 1938-1) and shattered in the glancing impact test (test no. 1938-2). In an attempt to determine if this problem was associated with the plastic drum or with the sign substrate, it was decided to repeat these two crash tests using a different make of plastic drums for comparison purposes (test nos. 1938-7 and 1938-8). Plastic drums manufactured by Traffix Devices, Inc. with san-fil bases (a trade name for a one-piece base with a built-in compartment for filling with up to 50 pounds of sand) were used in these two tests.

2.2 EVALUATION OF SIGN SUBSTRATES

A wide variety of substrates are available for use as sign panels. In the two previous studies, three different sign substrates had been tested for their impact performance: plywood (1/2 inch thick), plastic (3 mm thick), and fiberglass (3 mm thick). The plastic and fiberglass sign panels were found to perform satisfactorily in the crash tests, but not the plywood sign panels. It appeared that a plywood sign panel, with its weight and rigidity, could impact and shatter the windshield of an impacting vehicle. Thus, plywood sign panels were not recommended for use with plastic drums in the field.⁽¹⁾

Five (5) additional sign substrates were tested in this study:

1. Fiber-Reinforced Plastic (FRP),
2. Polycarbonate,
3. Plastic (6 mm thick),
4. Medex, and
5. Aluminum.

The FRP sign substrate was evaluated in conjunction with the evaluation of the add-on sand-filled compartment, as described previously. For the other four sign substrates, each was evaluated with a single crash test of an 1,800-pound passenger car impacting the plastic drum assembly head-on at 60 mi/h (test nos. 1938-3 through 1938-6).

The test installation consisted of a single plastic drum with the sign panel and a flashing light unit rigidly attached to the top of the plastic drum. Note that the plastic drums used in the four tests were all of the same manufacturer and make (Traffix Devices, Inc. with san-fil bases) to minimize any variability introduced by the use of different plastic drums.

2.3 DEVELOPMENT OF SPECIFICATIONS FOR PLASTIC DRUMS

The project staff worked with TxDOT personnel to review and propose recommendations concerning the existing specifications for plastic drums, especially with regard to developing and recommending standardized test procedures. Specifically, information was sought to better define the following characteristics and properties of plastic drums:

1. Physical properties of the drum, such as the weight of the drum body, the thickness of the plastic, the flexibility (ease of

deformation) and the memory recall (ability to be restored to near its normal shape) of the drum body, etc.

2. Properties of the locking mechanism between the drum body and base, such as the force required to separate the drum body from the base, both statically (in normal use or transport) and dynamically (upon impact by an errant vehicle), etc.

A number of test procedures were developed in the effort to better define the characteristics and properties of the plastic drums:

1. Dimensional measurements. The purpose of these measurements is to document the physical dimensions of the plastic drum.
2. Fixed base vertical pull test. The purpose of this test is to determine the vertical pull force required to separate the drum from a fixed base.
3. Horizontal tip force test. The purpose of this test is to determine the horizontal force required to tip the plastic drum.
4. Static crush test. The purpose of this test is to determine the horizontal force required to induce a given crush or deformation in the plastic drum.
5. Dynamic drum/base separation test. The purpose of this test is to determine the speed required to separate the drum body from its base when dynamically impacted by a pendulum.

These tests were conducted on the various plastic drums provided to the study by TxDOT and various manufacturers.

III. TEST PROCEDURES

As mentioned in the previous section on "Study Approach", various dimensional measurements, static and dynamic (pendulum) tests, and full-scale crash tests were conducted in this study, including:

1. Dimensional measurements,
2. Fixed base vertical pull test,
3. Horizontal tip force test,
4. Static crush test,
5. Dynamic drum/base separation test, and
6. Full-scale crash test.

Brief descriptions of these test procedures are presented as follows. More detailed specifications of these test procedures, with the exception of full-scale crash test, are presented in Appendix A. The writeup of the test procedures presented in Appendix A is structured in the format of an ASTM standard so that it may be used directly as part of the TxDOT specifications on plastic drums. Note that the test procedures described in Appendix A are slightly different from those described in this section since some of the test procedures were modified based on experience gained from this study.

3.1 DIMENSIONAL MEASUREMENTS

Some general measurements of the plastic drums and bases were recorded, including:

1. The total height of the plastic drum and base assembly, measured from a hard smooth surface on which the drum assembly sits to the top of the drum, but not including any fixtures on the top of the drum or molded attachment points.
2. The height of the base without the drum body, again measured from a hard smooth surface on which the base sits to the highest point of the base.
3. The diameter of the drum at the point of smallest diameter, measured either directly or from calculation by measuring the circumference.
4. The wall thickness of the plastic drum body, measured with a micrometer on samples taken from the side of the drum body at the center and near the top and bottom, avoiding contours and reinforced areas when the wall thickness may be different from average.

5. The weight of the drum body, measured with an electronic or mechanical scale.

3.2 FIXED BASE VERTICAL PULL TEST

The purpose of this fixed base vertical pull test is to determine the vertical pull force required to separate the drum body from its base. The base was rigidly attached to a concrete floor through the following attachment. A 1/2-inch threaded rod was screwed into a concrete floor anchor. A 1/2-inch hole was drilled in the center of the base unit to accommodate the rod and the base was then placed over the rod. A 1-foot diameter, 1/4-inch thick steel plate with a 1/2-inch hole in the center was placed over the base unit and the plate and base were secured by a finger tight nut.

The drum body was attached to the fixed base in the normal manner. A vertical force was applied to the geometric center of the top of the drum body by a simple hand-operated chain hoist. A force transducer or load cell was used to measure the vertical force applied in a continuous manner. The vertical force was then increased in a slow and controlled manner until the drum body separated from the base. The highest force value just prior to separation was recorded.

3.3 HORIZONTAL TIP FORCE TEST

The purpose of this horizontal tip force test is to determine the horizontal force required to tip the plastic drum. The drum and base, ballasted to a known weight, e.g., 75 pounds, was placed on a hard, smooth and level surface against a slide stop. The stop was a piece of plywood no greater than 1 inch high placed on the floor and against the base of the plastic drum to prevent sliding. A horizontal force was then applied to the top of the drum using a cord. An electronic or mechanic measuring device was used to measure this horizontal force in a continuous manner. The horizontal force was gradually increased until the drum and base assembly tipped over. The highest force observed during the pull over was recorded. The test was repeated a total of three times and the average reported as the tip force.

3.4 STATIC CRUSH TEST

The purpose of this static crush test is to determine the horizontal force required to induce a given crush or deformation in the plastic drum. The test drum, with the base attached but no ballast, was placed horizontally across the

narrow portion of the scale at the vertical center of the drum. The scale used was an electronic platform scale with a top surface measuring 18 inches by 12 inches and 5 inches above the floor or any reference surface.

The weight of the drum resting on the scale was first recorded. The drum was then manually pressed downward by applying forces at the top and bottom ends of the drum. The downward force was increased slowly and evenly on each end until the ends of the drum touched the floor or the reference surface. The maximum force observed during force application or when pressed against the floor or reference surface was recorded. The empty weight of the drum was then subtracted from the maximum force observed to obtain the static crush force.

3.5 DYNAMIC DRUM-BASE SEPARATION (PENDULUM) TEST

The purpose of this dynamic drum/base separation test is to determine the speed required to separate the drum body from its base when dynamically impacted by a pendulum. The pendulum facility consisted of a striking mass that swung in a circular arc suspended by cables from a main frame. The pendulum had a mass of 2,370 pounds and remained horizontal throughout the entire swing. A rigid cylinder, 6 inches in diameter and 24 inches in length, was mounted horizontally to the nose of the pendulum, perpendicular to the direction of travel. The pendulum mass was so suspended that, when stationary, the center of the cylinder is 18 inches above the ground.

The test drum, complete with the base unit and 75 pounds of sand ballast was placed in position, centered and just touching the nose of the pendulum. The pendulum was raised to a height equivalent to the desired impact speed and then released to dynamically impact the plastic drum and base assembly.

For each manufacturer and make of plastic drum, the pendulum tests started with an impact speed of 5 mi/h and repeated in increments of 5 mi/h until the drum body was separated from the base unit. The speed at which the drum body separated from the base unit was recorded.

3.6 FULL-SCALE CRASH TEST

A total of eight full-scale crash tests were conducted in this study, as shown in Table 1. Brief descriptions on the test procedure and evaluation criteria are presented as follows.

Table 1. List of Full-Scale Crash Tests

<u>Test No.</u>	<u>Manufacturer</u>	<u>Type of Base</u>	<u>Type of Sign Panel</u>	<u>Impact Configuration</u>
1	Flex-0-Lite	Add-on sand-filled Compartment	Fiber reinforced Plastic	Head-on
2	Flex-0-Lite	Add-on sand-filled Compartment	Fiber reinforced Plastic	Glancing
3	Traffix	San-fil	Polycarbonate	Head-on
4	Traffix	San-fil	Plastic - 6 mm	Head-on
5	Traffix	San-fil	Medex	Head-on
6	Traffix	San-fil	Aluminum	Head-on
7	Traffix	San-fil	Fiber reinforced Plastic	Glancing
8	Traffix	San-fil	Fiber reinforced Plastic	Head-on

Notes. All tests with 1,800-pound passenger car at 60 mi/h.
 Head-on - centerline of vehicle to centerline of plastic drum.
 Glancing - centerline of tire to centerline of plastic drum.
 Each test installation consists of one plastic drum equipped with sign panels and flashing light units.

3.6.1 Test Procedure

Each test installation consisted of a single plastic drum with a sign panel and a flashing light unit rigidly attached to the top of the plastic drum. The base was ballasted with 50 pounds of sand.

A 1981 Honda Civic was used for all eight tests. The test inertia weight, i.e., empty weight, of the test vehicle was 1,800 lb. The gross static weight, i.e., actual test weight, was 1,970 lb which included the weight of the driver. The vehicle was driven into the test installation by a test driver. The driver released control of the vehicle just prior to impact so that the vehicle was free-wheeling and unrestrained, i.e., no steering or braking inputs, at impact with the plastic drum. After the vehicle cleared the immediate area of the test site, the driver then braked the vehicle to a safe and controlled stop.

The vehicle was instrumented with three rate transducers to measure roll, pitch, and yaw rates, and a triaxial accelerometer mounted near the vehicle center-of-gravity to measure acceleration levels. The electronic signals were telemetered to a base station and recorded on magnetic tape. Provisions were made for transmission of calibration signals before and after the test, and accurate time reference signals were simultaneously recorded with the data.

Contact switches were installed on the bumper of the vehicle, which would be 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 would produce 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 cameras.

Photographic coverage of the test included two (2) 3/4-inch videotape cameras, one perpendicular to the point of impact for the first 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.

After each test, the vehicle was repaired to the extent possible. Most of the damages were very minor and cosmetic in nature and could be repaired very quickly, except for tests 2 (test no. 1938-2) and 5 (test no. 1938-5) in which the windshield of the vehicle was broken and damaged from the impact and had to be replaced.

The analog data from the accelerometers and transducers were digitized for use in data analysis and performance evaluation. The digitized data were then

analyzed using two proprietary computer programs: DIGITIZE, PLOTANGLE, and commercially available QUATTRO PRO software. Brief descriptions on each of these computer programs are provided as follows.

The DIGITIZE program uses digitized data from vehicle-mounted linear accelerometers to calculate the vehicle impact velocity, the change in vehicle velocity at the end of a given impulse period, and the maximum average accelerations over 0.050-second (50 msec) intervals for the longitudinal, lateral, and vertical directions. In addition, the DIGITIZE program computes occupant displacement, time of occupant/compartment impact after vehicle impact, occupant/compartment impact velocities, and the highest 0.010-second (10 msec) average occupant ridedown accelerations.

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 of yaw, pitch, and roll versus time. It should be noted that these angular displacements are sequence dependent, the sequence being yaw-pitch-roll for the data presented in this report. 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.

The QUATTRO PRO program plots acceleration versus time curves for the longitudinal, lateral, and vertical directions using digitized data from the vehicle mounted linear accelerometers.

3.6.2 Evaluation Criteria

There are currently no established criteria for evaluating the impact performance of work zone traffic control devices. NCHRP (National Cooperative Highway Research Program) Report 230 ⁽³⁾ and Transportation Research Circular 191 ⁽⁴⁾ set forth guidelines and recommended limits for full-scale crash tests to evaluate the performance of permanent highway safety appurtenances. Evaluation factors include structural adequacy of the appurtenance tested, occupant risk of injury, and post-impact trajectory of the vehicle. Most of these evaluation factors are not really applicable to work zone traffic control devices. Furthermore, there are other evaluation factors that should be considered given that these devices are installed much closer to traffic lanes and often in very close proximity to opposing traffic lanes, construction workers, and pedestrians.

The New York State Department of Transportation recently performed evaluation testing of various types of work zone traffic control devices. ⁽²⁾ In that study, specific, but subjective, criteria were developed with the work zone environment in mind.

Based on information from these references and other considerations, evaluation criteria were established for use in the two previous studies and were again used in this 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.

IV. STUDY RESULTS

The study results are presented in accordance with the three specific objectives of the study:

1. Evaluation of add-on sand-filled compartment for plastic drums manufactured by Flex-O-Lite.
2. Evaluation of various sign substrates.
3. Development of Specifications for Plastic Drums.

4.1 EVALUATION OF ADD-ON SAND-FILLED COMPARTMENT FOR PLASTIC DRUMS

Two crash tests (test nos. 1938-1 and 1938-2) were conducted to evaluate the impact performance of this add-on sand-filled compartment for plastic drums manufactured by Flex-O-Lite. Results of the two crash tests are presented as follows.

4.1.1 Test 1938-1

The test installation consisted of a plastic drum manufactured by Flex-O-Lite attached to a base with an add-on sand-filled compartment. A fiber reinforced plastic (FRP) sign panel and a flashing light unit were rigidly attached to the top of the plastic drum. The base was ballasted with 50 pounds of sand in the add-on compartment. The test vehicle impacted the plastic drum head-on (centerline of vehicle aligned with centerline of the drum), as shown in Figure 1, at a speed of 60.6 mi/h.

Upon impact, the plastic drum body was separated from the base, rotated up onto the vehicle hood and the sign panel skimmed the windshield. The drum body then flipped up and over the vehicle, landed on the lower edge of the drum, and came to rest 126 ft down and 3 ft to the left of its position at the time of impact. The drum body and the sign panel received only minor scratches as shown in Figure 2. The base with the add-on sand-filled compartment did not move as a result of the impact with the plastic drum.

As the vehicle left the immediate test site, the brakes were applied and the vehicle came to a controlled stop. The vehicle sustained minor scratches and dents to the hood, as shown in Figure 3. There was an 8-in long crack in the windshield from impact by the sign panel, but there was no intrusion into the passenger compartment and the crack in the windshield was not considered to be

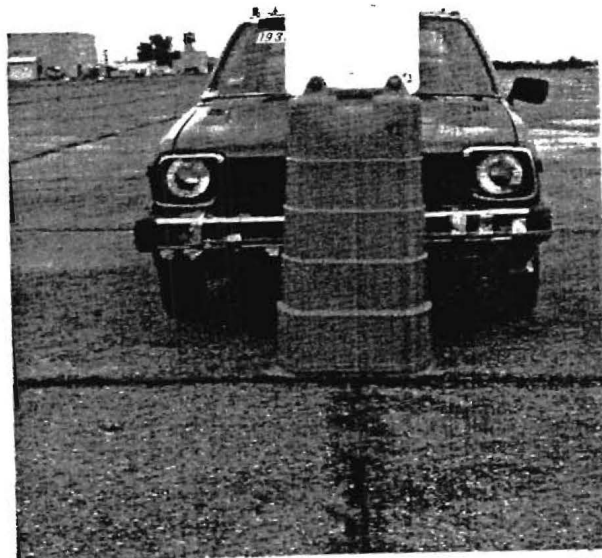


Figure 1. Vehicle and support before test 1938-1.

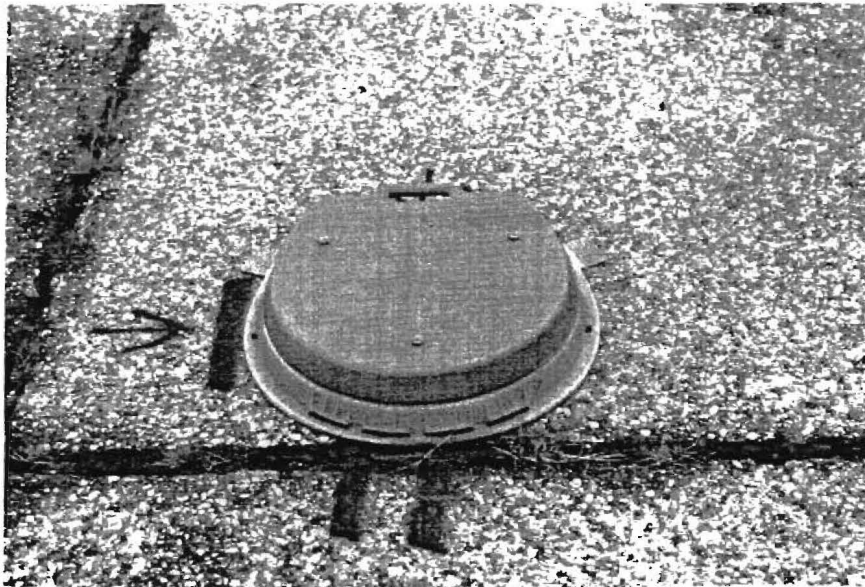
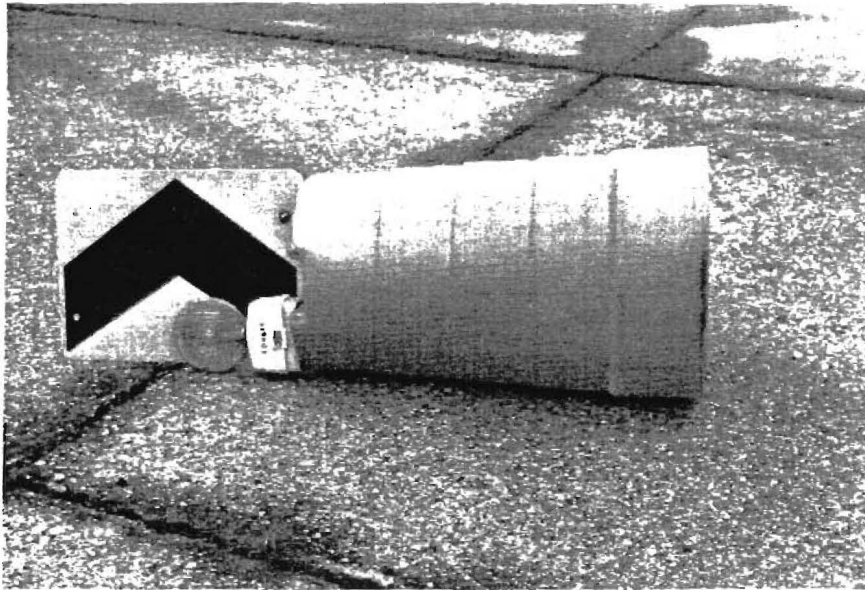


Figure 2. Support after test 1938-1.

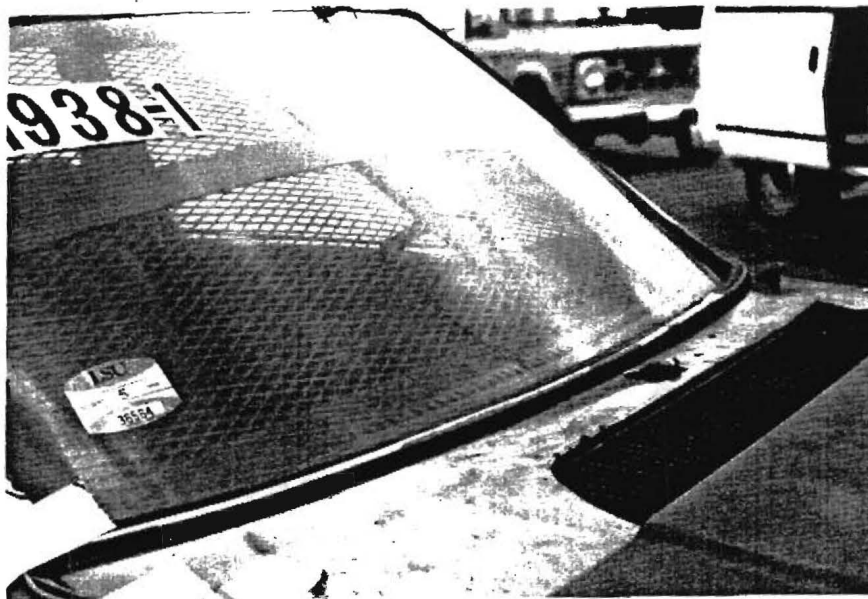


Figure 3. Vehicle after test 1938-1.

significant. The crack was marked and the dents repaired and the vehicle was ready for use in the next test.

A brief summary of the electronic data is shown in Table 2. The vehicle impacted the plastic drum travelling at a speed of 60.6 mi/h. There was no occupant impact during the test period, i.e., the deceleration on the vehicle was too low for the occupant risk factors to be calculated. The maximum 50-ms average acceleration was -0.2 g in the longitudinal direction and -0.1 g in the lateral direction.

There was no deformation or intrusion into the occupant compartment of the vehicle. However, the windshield did sustain a minor crack. The vehicle traversed the test site on a straight, smooth path with no indication of potential loss of control or intrusion into adjacent traffic lanes. The sign panel and light assembly remained with the drum body with no detached debris.

4.1.2 Test 1938-2

The test installation was the same as that for test no. 1, consisting of a plastic drum manufactured by Flex-O-Lite attached to a base with an add-on sand-filled compartment. A fiber reinforced plastic (FRP) sign panel and a flashing light unit were rigidly attached to the top of the plastic drum. The base was ballasted with 50 pounds of sand in the add-on compartment. The test vehicle impacted the plastic drum such that the centerline of the right front vehicle tire was aligned with the centerline of the plastic drum (glancing impact), as shown in Figure 4. The vehicle was travelling at a speed of 59.8 mi/h at the point of impact.

The drum body was separated from the base and rotated onto the hood of the vehicle. The top edge of the sign panel struck the lower right corner of the windshield and shattered the windshield. The drum body then continued to rotate up and over the vehicle and came to rest 120 ft down and 15 ft to the right of the impact point. The plastic drum received minor scrapes and the sign panel was cracked, as shown in Figures 5 and 6. The right tires of the vehicle rode over the base with the add-on sand-filled compartment. The base was moved slightly (1 in) to the right, but did not sustain any damage.

The vehicle pitched and rolled slightly as the right tires rode over the base, but otherwise the vehicle remained stable throughout the test sequence. The vehicle was braked to a smooth and controlled stop after the vehicle cleared the immediate area of the test site. There were minor scratches and dents in the

Table 2. Summary of Crash Test Results

<u>Test No.</u>	<u>Impact Speed</u>	<u>Occupant Impact Velocity</u>	<u>Highest 10-ms Average Ridedown Acceleration</u>	<u>Highest 50-ms Average Acceleration</u>
1938-1	60.6 mi/h	None*	N/A**	-0.2 g 451-501 ms
1938-2	59.8 mi/h	None	N/A	-0.7 g 66-116 ms
1938-3	59.2 mi/h	None	N/A	-0.3 g 3- 53 ms
1938-4	58.3 mi/h	None	N/A	-0.4 g 308-358 ms
1938-5	57.8 mi/h	None	N/A	-0.5 g 0- 50 ms
1938-6	58.5 mi/h	None	N/A	-0.9 g 776-826 ms
1938-7***	60 mi/h	-	-	-
1938-8***	60 mi/h	-	-	-

Notes.

- * The deceleration was too low for the calculation of occupant impact velocity.
- ** The highest 10-ms average ridedown acceleration is not applicable since there is no occupant impact.
- *** The vehicle was not electronically instrumented for tests 7 and 8. The impact speed reported was the nominal speed and not the actual speed.



Figure 4. Vehicle and support before test 1938-2.

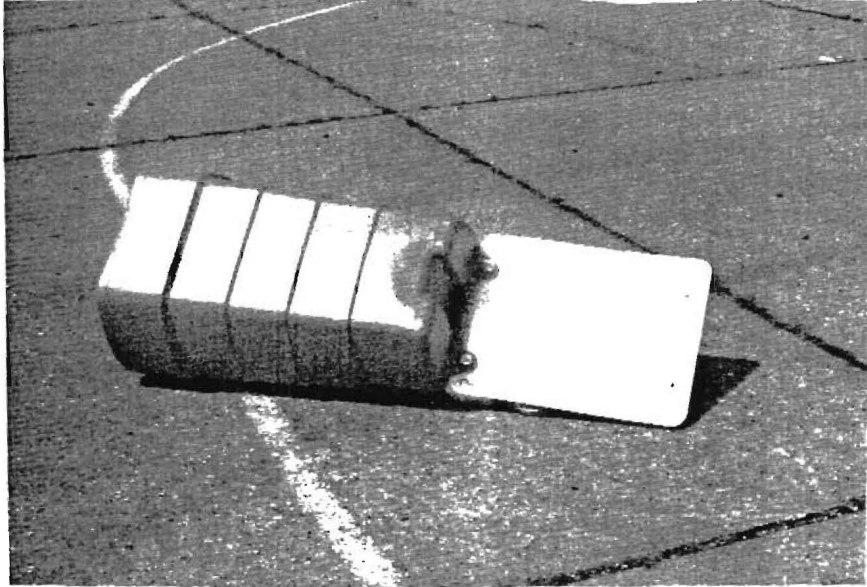


Figure 5. Support after test 1938-2.

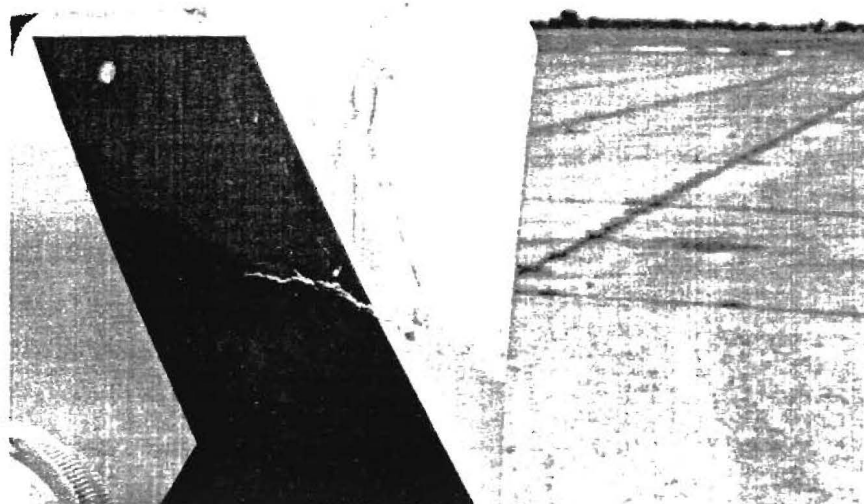
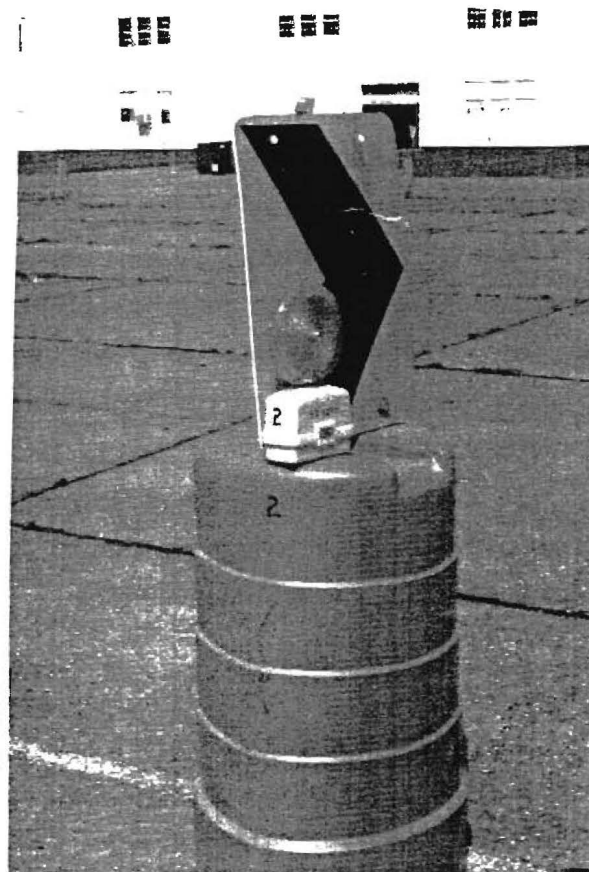


Figure 6. Damage to panel (test 1938-2).

vehicle's hood, and the windshield was shattered in the lower right corner as shown in Figure 7.

Data from the longitudinal accelerometer are summarized in Table 2. As stated previously, the impact speed was 59.8 mi/h. There was no occupant impact during the test period. The maximum 50-ms average was -0.7 g in the longitudinal direction and 0.7 g in the lateral direction.

The windshield was shattered at the lower right hand corner from impact by the sign panel and fragments of the shattered glass could be found in the dash and front passenger seat area. However, there was no actual penetration or intrusion of the occupant compartment. The vehicle remained on a straight and smooth path through the test site with no indication of potential loss of control or intrusion into adjacent traffic lanes. The sign panel and light assembly remained with the drum body with no detached debris.

4.1.3 Evaluation and Analysis

The base with an add-on sand-filled compartment performed satisfactorily in the two crash tests. The drum body readily separated from the base upon impact. The base was undamaged and remained essentially unmoved from the point of impact, even with the glancing impact configuration in which the right tires of the vehicle rode over the base and the add-on sand-filled compartment. There was no indication that the base with the add-on sand-filled compartment would pose any potential threat to the stability of the vehicle.

However, there was grave concern over the fact that the windshield was shattered in this glancing impact test and cracked in the head-on impact test. Further investigation was therefore conducted in an attempt to determine what happened in the crash tests that led to the cracking and shattering of the windshield.

Review of the videotapes from these two crash tests revealed that the Flex-O-Lite plastic drum body deformed very little from the initial impact by the front of the vehicle. The drum body quickly separated from the front of the vehicle and started to rotate and flip up in the air, thus allowing the sign panel to impact the windshield directly. In comparison, review of videotapes of other crash tests involving plastic drum manufactured by Traffix Devices, Inc., showed that the drum body deformed readily upon impact by the front the vehicle, resulting in the drum body wrapping around the front of the vehicle. The drum body stayed with the front of the vehicle for some time prior to rotating and



Figure 7. Vehicle after test 1938-2.

flipping up in the air and over the vehicle, resulting in the sign panel slapping the windshield instead of impacting the windshield directly. Thus, the difference in how the drum body deforms under impact could have contributed to the manner under which the sign panel struck the windshield.

Another possibility is the sign panel itself. The fiber-reinforced plastic (FRP) sign substrate is somewhat heavier and more rigid than either the plastic or the fiberglass substrates previously tested. It is possible that the rigidity of the FRP sign substrate could have contributed to the severity of the impact of the windshield by the sign panel. Finally, it is also possible that the cracking and shattering of the windshield were simply freakish occurrences that are not repeatable.

In order to obtain more insights into this matter, it was decided that the two crash tests (1938-1 and 1938-2) would be repeated, but with plastic drums by another manufacturer, Traffix Devices, Inc. Since the purpose of these two tests was to evaluate how the drum body and sign panel would interact with the windshield and the deceleration rates were found to be negligible, it was decided that electronic instrumentation of the vehicle was not necessary.

4.1.4 Test 1938-7

The setup for this test was identical to that of test 2 except for the plastic drum. A plastic drum manufactured by Traffix Devices, Inc. was used in place of the plastic drum manufactured by Flex-O-Lite. A fiber reinforced plastic (FRP) sign panel and flashing light unit were rigidly attached to the drum. A San-fil base filled with 50 pounds of sand was used with the plastic drum. The vehicle was travelling at approximately 60 mi/h when it struck the plastic drum such that the centerline of the right front tire of the vehicle was aligned with the centerline of the plastic drum (see Figure 8).

The drum body was separated from the base upon impact, slapped the hood, flipped up and over the vehicle, and landed on its side 125 feet down and 15 feet to the left of its original position. The base was pushed back 6 inches. The drum body, sign panel, and flashing light unit received minimal damage as shown in Figure 9. The vehicle was braked to a smooth and controlled stop after clearing the immediate test site. Damage to the vehicle was limited to only scratches on the hood, as can be seen in Figure 10.

In summary, there was no penetration or intrusion of the occupant compartment of the vehicle during this test. The vehicle remained on a straight



Figure 8. Vehicle and support before test 1938-7.

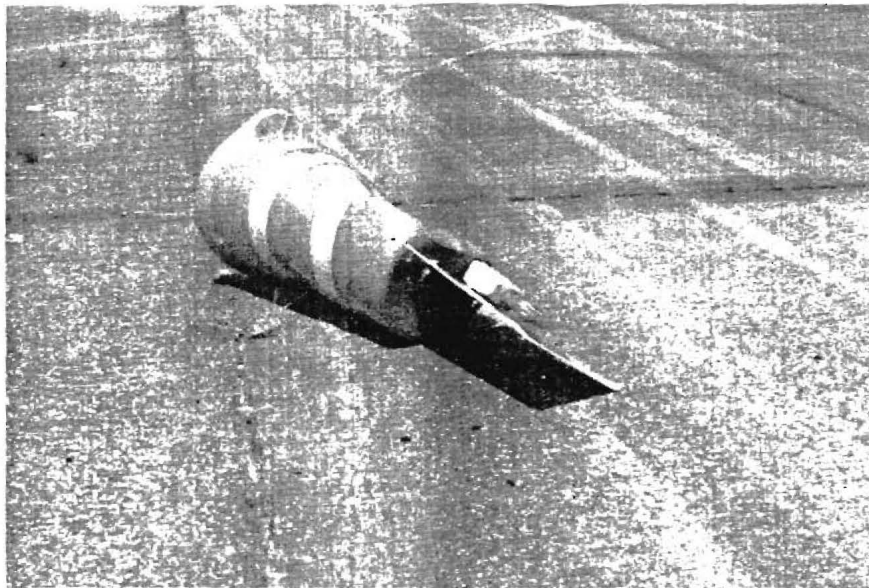
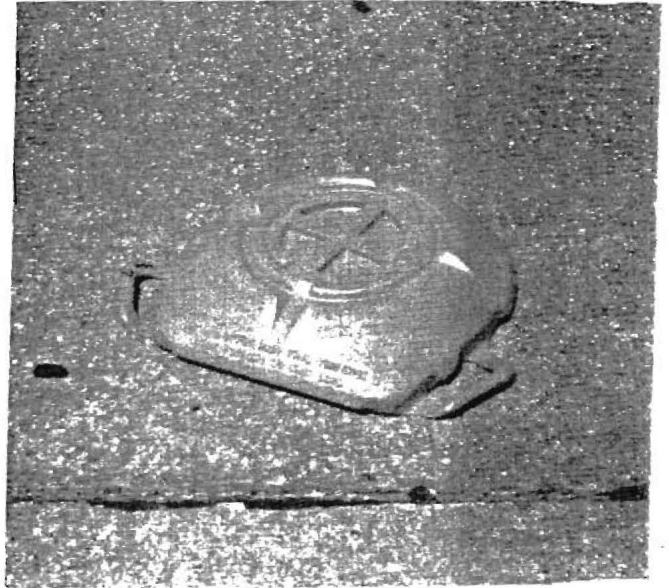


Figure 9. Support after test 1938-7.



Figure 10. Vehicle after test 1938-7.

and stable course through the test area and did not intrude into adjacent traffic lanes. The plastic drum, sign panel and light assembly snapped free of the base and were thrown over and to the side of the vehicle path. The base remained near the point of impact.

4.1.5 Test 1938-8

The setup for this test was identical to that of test 1 except for the plastic drum. A plastic drum manufactured by Traffix Devices, Inc. was used in place of the plastic drum manufactured by Flex-0-Lite. A fiber reinforced plastic (FRP) sign panel and flashing light unit were rigidly attached to the drum. A San-fil base filled with 50 pounds of sand was used with the plastic drum. The vehicle was travelling at approximately 60 mi/h when it struck the plastic drum head-on, i.e., the centerline of the vehicle was aligned with the centerline of the support (see Figure 11).

The drum body, with the sign panel and light assembly, snapped free from the base upon impact. The sign panel skimmed the windshield and the drum body then flipped up and over the vehicle. The drum body landed on the sign panel and came to rest 125 feet down from impact. The base did not move as shown in Figure 12. The drum body and sign panel were dented and scraped. The vehicle was braked to a smooth and controlled stop after the vehicle cleared the immediate area of the test site. The hood of the vehicle was dented and scratched, as shown in Figure 13.

There was no penetration or intrusion of the occupant compartment of the vehicle during this test. The vehicle remained on a straight and stable course through the test area and did not intrude into adjacent traffic lanes. The plastic drum, sign panel and light assembly snapped free of the base and were thrown over and slightly to the side of the vehicle path. The base remained at the point of impact.

4.1.6 Summary

As stated earlier, the base with an add-on sand-filled compartment for use with plastic drums manufactured by Flex-0-Lite performed satisfactorily in the crash tests. However, there was grave concern over the fact that the windshield was shattered in this glancing impact test and cracked in the head-on impact test. Even after further investigation, including two additional crash tests with plastic drums from another manufacturer, it was still not possible to

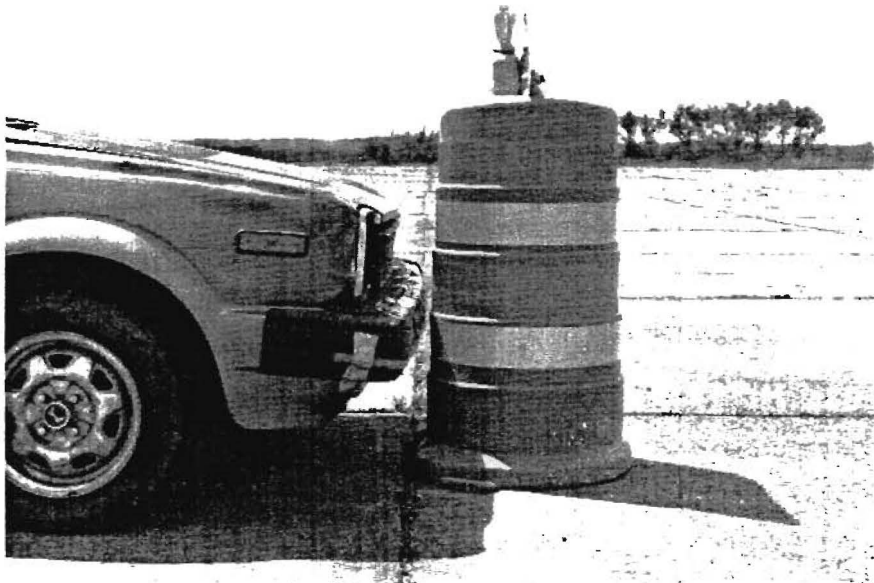


Figure 11. Vehicle and support before test 1938-8.

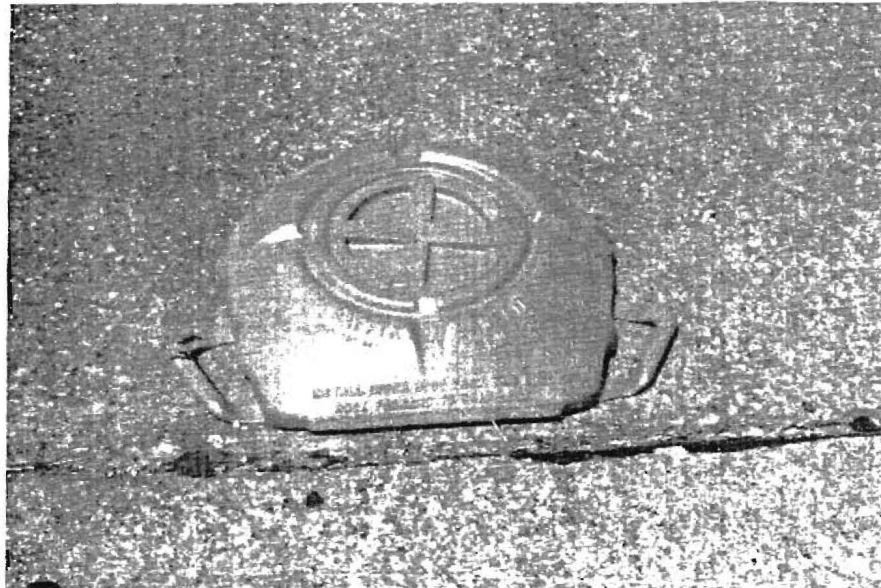
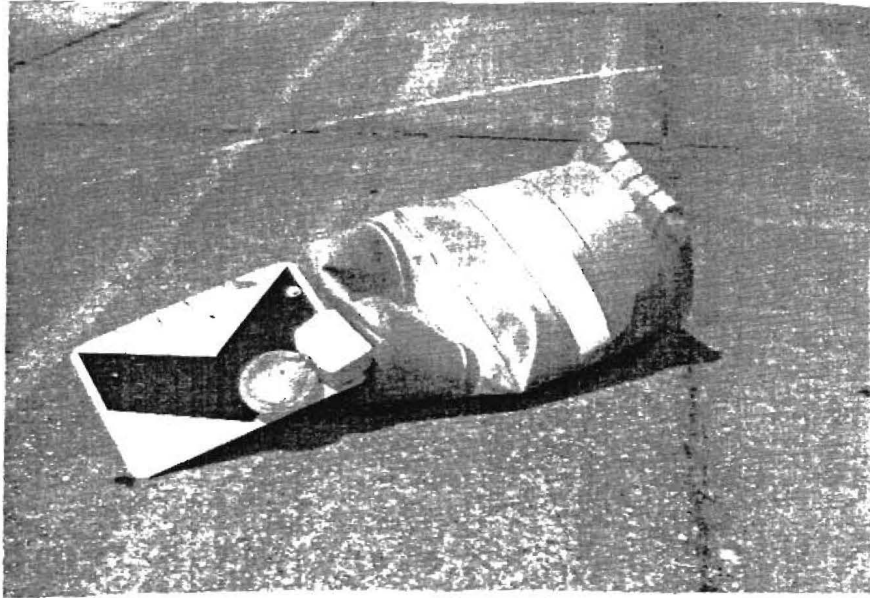


Figure 12 Support after test 1938-8.



Figure 13. Vehicle after test 1938-8.

determine conclusively what happened in the crash tests that led to the cracking and shattering of the windshield.

There is clearly a difference between the deformation sustained by the Flex-O-Lite plastic drum body upon impact by the vehicle, as compared to the Traffix plastic drum body. This difference in the deformation characteristics or flexibility of the drum body resulted in different kinematics of the drum bodies. The sign panel impacted the windshield directly in case of the Flex-O-Lite plastic drum while the sign panel slapped the hood and skimmed the windshield with the Traffix plastic drum. However, it is still unclear if this problem is repeatable or just a freakish occurrence.

While the fiber-reinforced plastic (FRP) sign substrate is somewhat heavier and more rigid than either the plastic or the fiberglass substrates previously tested, it appears that any contribution of the FRP sign substrate to the severity of the impact of the windshield by the sign panel would be minor.

4.2 EVALUATION OF SIGN SUBSTRATES

As stated previously, five sign substrates were evaluated in this study:

1. Fiber-Reinforced Plastic (FRP),
2. Polycarbonate,
3. Plastic (6 mm thick),
4. Medex, and
5. Aluminum.

The FRP sign substrate was evaluated in conjunction with the evaluation of the add-on sand-filled compartment. For the other four sign substrates, each was evaluated with a single crash test of an 1,800-pound passenger car impacting the plastic drum assembly head-on (i.e., centerline of the vehicle aligned with the centerline of the plastic drum) at 60 mi/h. The test installation consisted of a single plastic drum with the sign panel and a flashing light unit rigidly attached to the top of the plastic drum. The plastic drums used in the four tests were all of the same manufacturer and make (Traffix Devices, Inc. with sand-filled bases) to minimize any variability introduced by the use of different plastic drums. Results of these four crash tests are briefly presented as follows.

4.2.1 Polycarbonate Sign Substrate (Test 1938-3)

The polycarbonate sign substrate was evaluated in this crash test. The vehicle impacted the plastic drum head-on, as shown in Figure 14, at a speed of



Figure 14. Vehicle and support before test 1938-3.

59.2 mi/h. The drum body was separated from the base and the sign panel slapped the hood and skimmed the windshield. The drum then rotated up and over the vehicle, and landed on the lower edge of the drum, coming to rest 116 feet down and 25 feet to the left of its original position at impact. The base did not move and the drum body was bent and scraped, as shown in Figure 15.

The vehicle was braked to a smooth and controlled stop after the vehicle cleared the immediate test site. The hood of the vehicle was bent and the crack in the windshield from a previous test (test 1938-1) extended another 19 in, as shown in Figure 16. The crack in the windshield was marked and the vehicle was repaired for use in test 4.

Results of the data obtained from the vehicle's longitudinal accelerometer are summarized in Table 2. The vehicle was travelling at 59.2 mi/h as it impacted the plastic drum assembly. There was no occupant impact during the test period. The maximum 50-ms average accelerations were -0.3 g in the longitudinal direction and 0.2 g in the lateral direction.

No penetration or intrusion into the occupant compartment occurred during this test, although the windshield sustained a 19-inch long crack. The path of the vehicle was straight and stable with no intrusion into adjacent traffic lanes. The plastic drum, sign panel, and light assembly snapped free of the base and followed along with the vehicle for a short distance before flipping up and over the vehicle. The base remained at the point of impact.

4.2.2 Plastic - 6 mm Sign Substrate (Test 1938-4)

A 6-mm thick plastic sign substrate was evaluated in this test. The vehicle impacted the plastic drum assembly head-on, as shown in Figure 17, at a speed of 58.3 mi/h. As the vehicle continued forward, the drum body was separated from its base and the sign panel shattered as it hit the top edge of the hood near the windshield. The drum body then flipped up and over the vehicle, and landed on the lower edge of the drum, coming to rest 112 feet down and 10 feet to the left of the point of impact. The base did not move, the drum was bent and scraped, and the sign panel was broken, as shown in Figure 18.

The vehicle was braked to a smooth and controlled stop after clearing the immediate area of the test site. As shown in Figure 19, the vehicle received only minor scrapes and was repaired for use in test 5.

Data from the vehicle's longitudinal accelerometer are shown in Table 2. The impact speed was 58.3 mi/h. No occupant impact occurred during the test

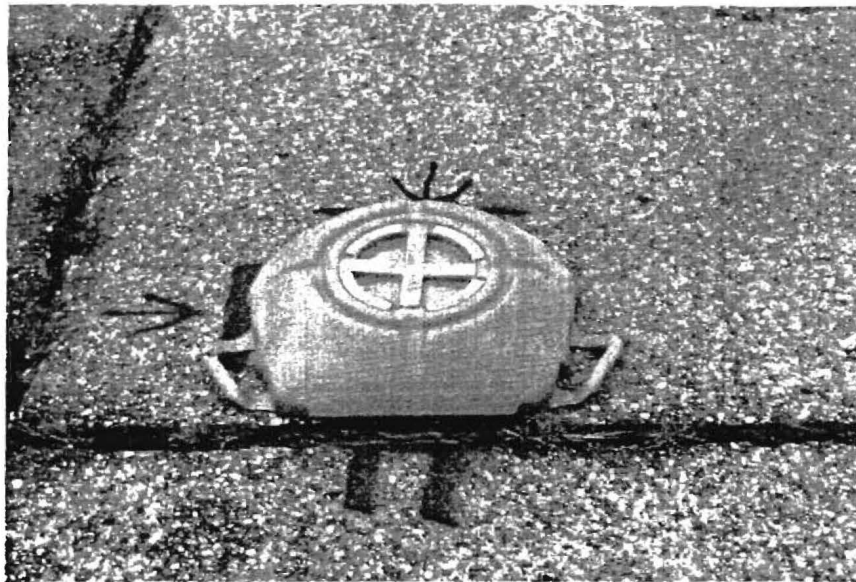
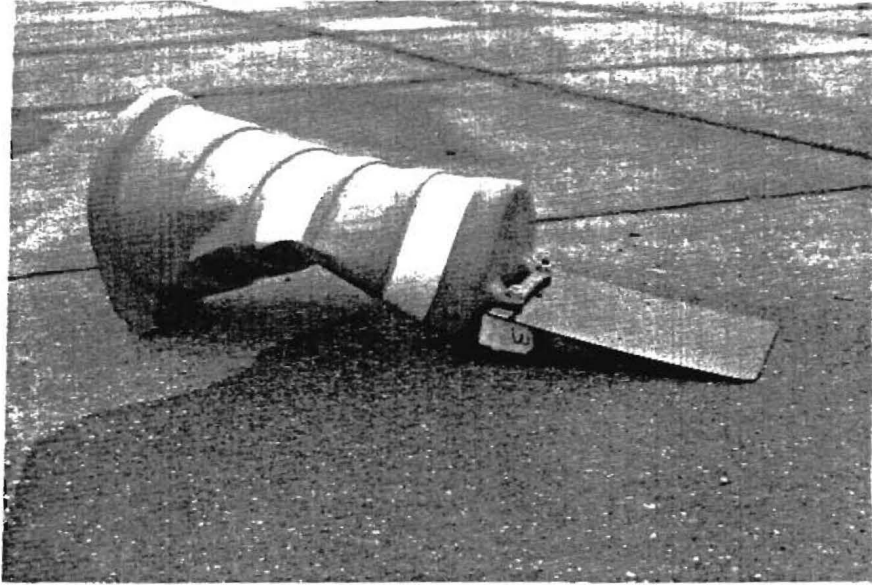


Figure 15. Support after test 1938-3.



Figure 16. Vehicle after test 1938-3.



Figure 17. Vehicle and support before test 1938-4.



Figure 18. Support after test 1938-4.



Figure 19. Vehicle after test 1938-4.

period. The maximum 50-ms average accelerations were -0.4 g in the longitudinal direction and -0.3 g in the lateral direction.

There was no penetration or intrusion into the occupant compartment of the vehicle. The vehicle did not intrude into adjacent traffic lanes by remaining on a straight and stable course through the test site. The plastic drum, sign panel, and light assembly travelled along with the vehicle for a short distance prior to flipping up and over the vehicle. The base remained at the point of impact.

4.2.3 Medex Sign Substrate (Test 1938-5)

The Medex sign substrate was evaluated in this test. The vehicle was travelling at 57.8 mi/h as it struck the plastic drum assembly head-on (see Figure 20). The drum body was separated from the base and rode up onto the vehicle hood. The top edge of the sign panel hit the windshield and the drum body then flipped up and over the vehicle, landing on the lower edge of the drum and coming to rest 115 feet down and 34 feet to the left of its original position. The base did not move. The drum body was dented and the top of the sign panel was cracked, as shown in Figure 21.

The vehicle was braked to a smooth and controlled stop after clearing the immediate area of the test site. The hood was scratched and the windshield was shattered, as shown in Figure 22. The windshield was replaced and the vehicle was repaired for use in test 6.

Results from the vehicle's longitudinal accelerometer are summarized in Table 2. The vehicle was travelling at 57.8 mi/h when it struck the drum. There was no occupant impact during the test period. The maximum 50-ms average accelerations were -0.4 in the longitudinal direction and 0.4 g in the lateral direction.

The windshield of the vehicle was shattered with minimal intrusion into the occupant compartment. The vehicle travelled through the test site on a straight and stable course with no intrusion into adjacent traffic lanes. The plastic drum, sign panel and light assembly snapped free of the base, flipped up and over the vehicle. The base remained at the point of impact.

4.2.4 Aluminum Sign Substrate (Test 1938-6)

The aluminum sign substrate was evaluated in this test. The vehicle impacted the plastic drum assembly head-on at a speed of 58.5 mi/h (see Figure



Figure 20. Vehicle and support before test 1938-5.

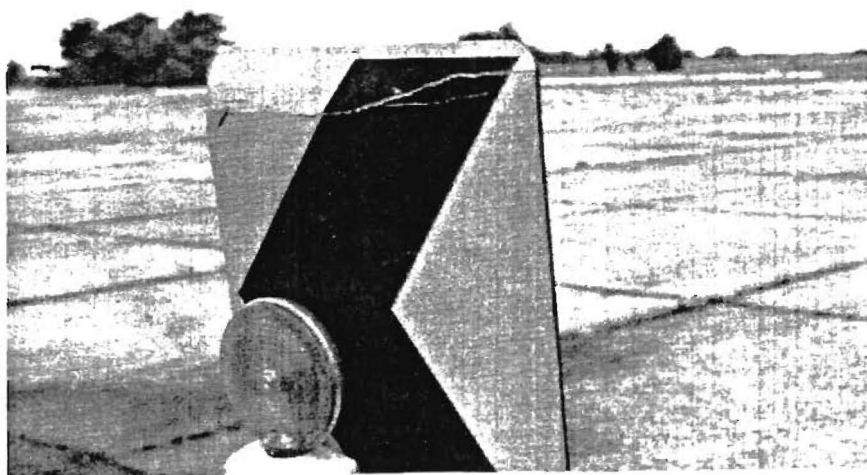
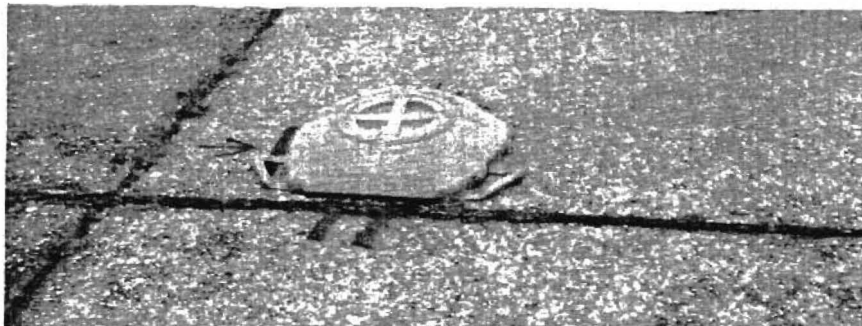
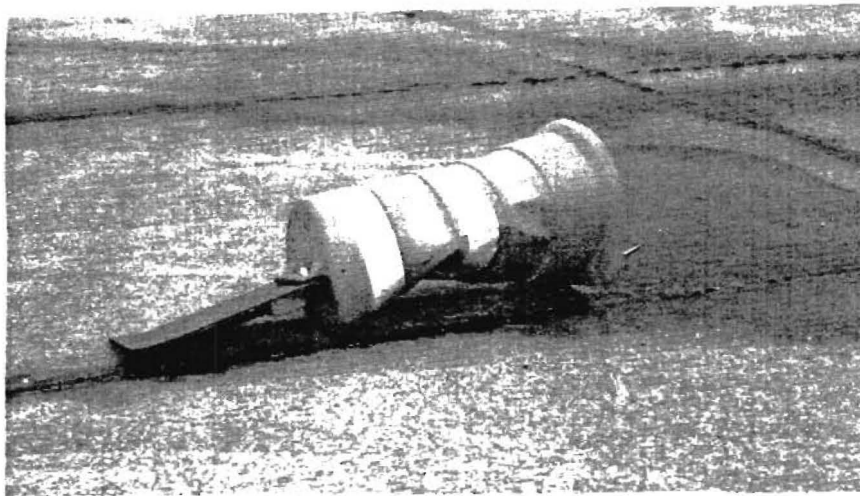


Figure 21. Support after test 1938-5.



Figure 22. Vehicle after test 1938-5.

23). The drum body was separated from the base and the sign panel slapped down onto the hood of the vehicle. The drum then flipped up and over the vehicle, landed on its side, and came to rest 120 feet down and 30 feet to the left of point of impact. As shown in Figure 24, the base did not move, the drum body was bent and scraped, and the sign panel was scraped.

The vehicle was braked to a smooth and controlled stop after clearing the immediate area of the test site. The hood of the vehicle was dented and scratched, as shown in Figure 25. The hood was repaired and painted for use in test 7.

Data taken from the vehicle longitudinal accelerometer are summarized in Table 2. The vehicle was travelling at 58.5 mi/h. There was no occupant impact during the test period. The maximum 50-ms average acceleration was -0.8 g in the longitudinal direction and -0.6 g in the lateral direction.

The hood of the vehicle was dented, but there was no penetration or intrusion into the occupant compartment. The vehicle travelled straight and stable through the test site with no intrusion into adjacent traffic lanes. The plastic drum assembly rode along and over the vehicle and the base remained at the point of impact.

4.2.5 Evaluation Summary

Results of the crash tests indicate that four of the five sign substrates (with the exception of the Medex sign substrate) performed satisfactorily and are acceptable for use with plastic drums. In the crash test involving the Medex sign substrate, the sign panel impacted and shattered the windshield, which was considered unsatisfactory according to the evaluation criteria. Again, it appears that the problem is with the weight and rigidity of the Medex sign substrate, similar to the situation with the plywood sign substrate which was previously tested and found to be unsatisfactory. The use of the Medex sign substrate with plastic drums is therefore not recommended.

As discussed previously, the windshield of the vehicle in test no. 2 was also shattered from the impact of a fiber-reinforced plastic (FRP) sign panel. However, it was determined, upon further investigation, that the sign substrate was not the primary contributory factor, but rather the flexibility of the plastic drum body. The FRP sign substrate was retested with a different manufacturer and make of plastic drum (tests 7 and 8) and found to perform



Figure 23. Vehicle and support before test 1938-6.

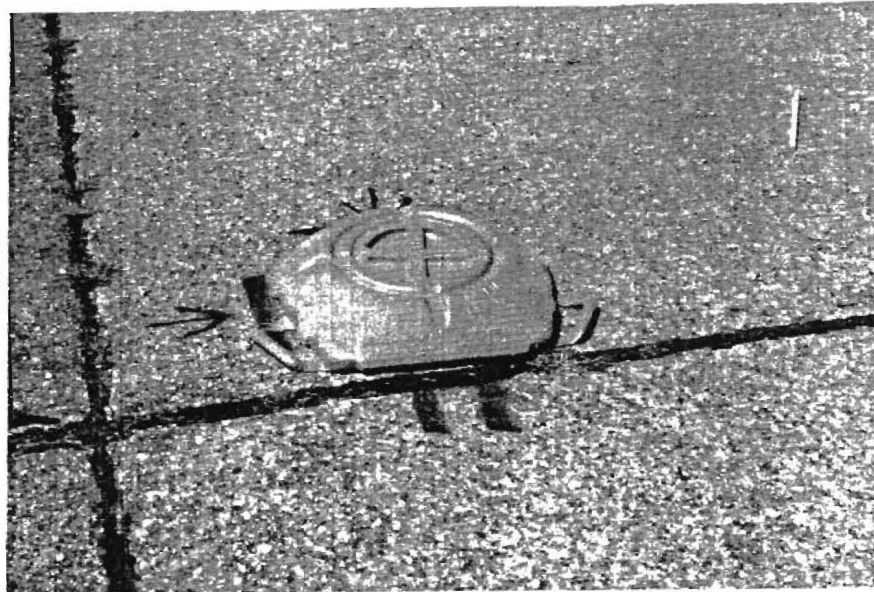
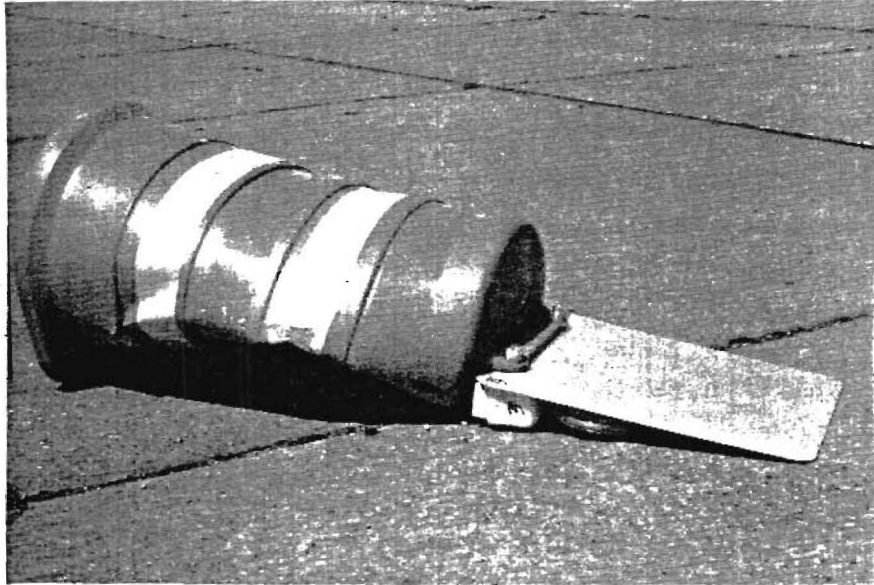


Figure 24. Support after test 1938-6.

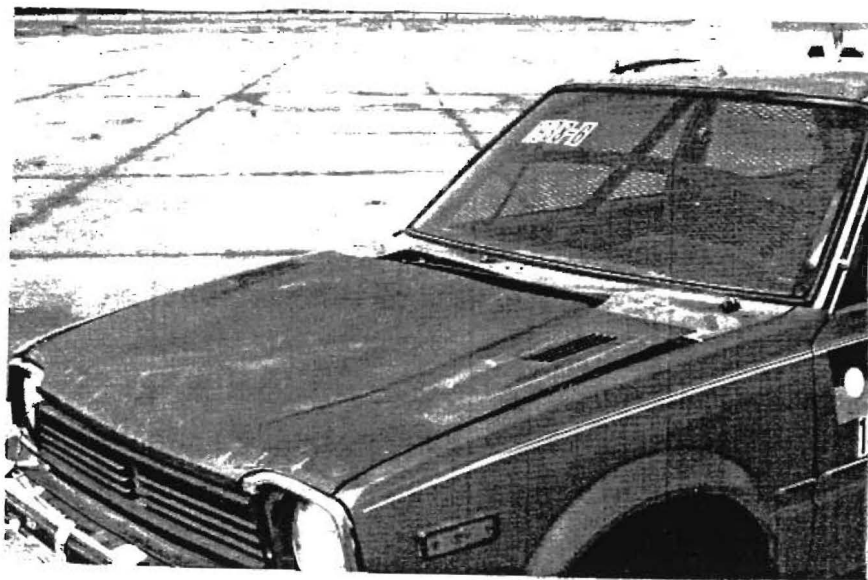
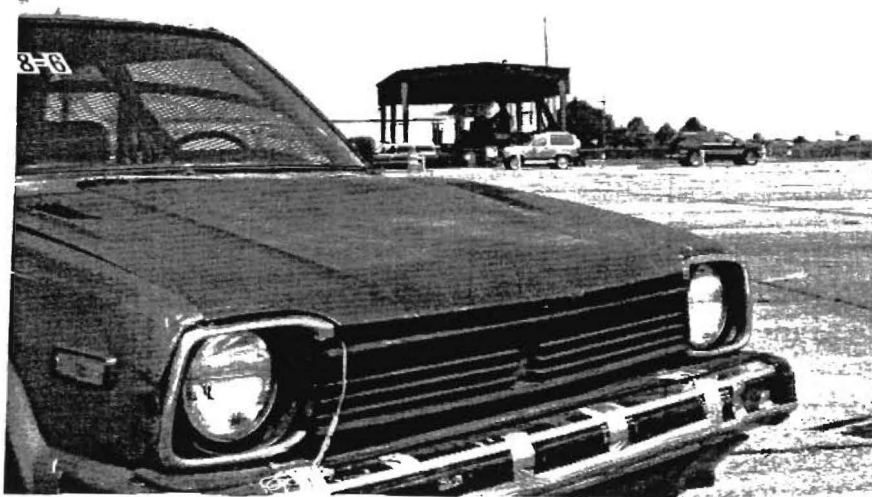


Figure 25. Vehicle after test 1938-6.

satisfactorily. The FRP sign substrate is therefore considered acceptable for use with plastic drums.

4.3 DEVELOPMENT OF SPECIFICATIONS FOR PLASTIC DRUMS

The project staff worked with TxDOT personnel to review and revise the existing specifications for plastic drums, especially with regard to developing and recommending standardized test procedures. A number of test procedures were developed in the effort to better define the characteristics and properties of the plastic drums, including:

1. Dimensional measurements.
2. Fixed base vertical pull test.
3. Horizontal tip/slide test.
4. Static crush test.
5. Dynamic drum/base separation test.

Brief descriptions of these test procedures were presented previously under Section III, "Test Procedures". More detailed specifications of these test procedures, shown in Appendix A, are written in the format of an ASTM standard so that it may be used directly as part of the TxDOT specifications on plastic drums. Again, note that the test procedures outlined in Appendix A may be slightly different from those described in the "Test Procedures" section since some of the test procedures were modified based on experience gained from this study.

These tests were conducted on the various plastic drums provided to the study by TxDOT and various manufacturers and the results are summarized in Table 3. As mentioned previously, the data were intended for better definition of the following characteristics and properties of plastic drums:

1. Physical properties of the drum, such as the weight of the drum body, the thickness of the plastic, the flexibility (ease of deformation) and the memory recall (ability to be restored to near its normal shape) of the drum body, etc.
2. Properties of the locking mechanism between the drum body and base, such as the force required to separate the drum body from the base, both statically (in normal use or transport) and dynamically (upon impact by an errant vehicle), etc.

Brief discussions on the test results and how they may apply to the specifications for plastic drums are presented as follows.

Table 3. Summary of Static and Dynamic Load Test Results

I.D. No.	Manufacturer and Make	Side Thickness (in.) [Top]	Side Thickness (in.) [Middle]	Side Thickness (in.) [Bottom]	Weight Drum Body Only (lb.)	Fixed Base Vertical Pull Force (lb.)	Base-Drum Separation Speed (mph)*	Static Crush Force (lb.)**	Horizontal Tip Force at Top	
									(lb.)	Base***
1	Traffix Devices Inc., San-Fil Base	.090	.062	.076	8.5	295	10 - 15	75	23	on
2	Traffix Devices Inc., Flat Base	.084	.066	.080	8.5	140	5 - 10		28	on
3	Lakeside Plastics	.085	.090	.108	8.5	165	0 - 5	90	25	off
4	Area Protection	.089	.075	.091	9.5	435	0 - 5		22	on
5	Flex-0-Lite	.102	.080	.083	9.3	500	10 - 15	120	24	on
6	Best Barricade - 454RCB	.072	.077	.087	9.5	115	10 - 15		26	on
7	Radiator Specialty	.116	.130	.095	9.0	141	0 - 5	160	19	on

Notes. * 2370-lb pendulum impact at 18" bumper height.

** 12-in high plate pressed in 5 inches at mid height.

*** Base remained attached (on) or separated (off) from the drum body during the tip over test.

4.3.1 Physical Properties of Plastic Drum

The current TxDOT specifications requires a minimum height of 36 inches, a minimum diameter of 18 inches, a maximum height of 4 inches for the base, and a minimum weight of 8 pounds for the complete unit, i.e., drum body and base. All the plastic drums tested met these physical requirements. One question raised is whether the height of the ballast should be included as part of the base height. The 4-inch height requirement is not met when a ballast of 75 pounds is used since it requires either three 25-pound sandbags or one 25-pound sandbag on top of a sand-filled base. However, the sandbags did not pose any problem to the stability of a vehicle as demonstrated in the crash tests. It was, therefore, decided that the 4-inch height for the base will not include the height of the ballast.

Another point is that the minimum weight of 8 pounds should apply only to the drum body. The weight of the base is of little concern since the base is ballasted in actual use. Also, the base would typically separate from the drum body upon impact and remain basically near the point of impact.

The flexibility of the drum body is an area of concern since it could affect the kinematics of the drum assembly and the interaction of the sign panel with the windshield, as discussed previously. It was thought that it might be possible to define flexibility in terms of: (a) sidewall thickness, (b) weight of the drum body, and/or (c) static crash force. The test results, as shown in Table 3, suggest that there is some relationship between flexibility and these three parameters. The Flex-0-Lite plastic drum was observed to deform much less (i.e., less flexible) than the Traffix plastic drum in the crash tests. In turn, the Flex-0-Lite plastic drum was found to have a thicker sidewall (ranging from 0.080 to 0.102 inch with an average of 0.088 inch) than the Traffix plastic drum (ranging from 0.062 to 0.09 inch with an average of 0.076 inch), a greater weight (9.3 versus 8.5 pounds), and a higher static crush force (120 versus 75 pounds). However, there is insufficient information at this time to determine how well flexibility is defined by these parameters and what the appropriate values should be for these parameters.

Memory recall of the drum body, , i.e., the ability to be restored to near its normal shape, is another characteristic of interest. No specific tests were developed or conducted on this characteristic since the assessment would be mostly subjective in nature. One possible way of defining and testing this characteristic is to impact the plastic drum assembly with a vehicle or pendulum

at a specified speed for a specified number of repetitions. The drum would be restored to its normal shape to the extent possible after each impact. At the end of test sequence, the plastic drum is evaluated on how well it can be restored to its normal shape and whether the drum body can still be securely attached to the base.

Another characteristic of interest is the propensity of the plastic drum to tip over under normal field use, as measured by the horizontal tip force test. Desirably, one would like to have as high a horizontal tip force as possible and the base should stay attached to the drum body. Test results indicate that, of the seven plastic drums tested, the horizontal force required to tip over the plastic drum ranges from 19 to 29 pounds. Also, the base unit was separated from the drum body for one of the plastic drums tested (Lakeside Plastics).

4.3.2 Properties of Locking Mechanism

The fixed base vertical pull test and the dynamic drum/base separation test were developed to evaluate the properties of the locking mechanism between the drum body and base. Ideally, the static force required to separate the drum body from the base should be high so that the drum would not separate from the base during normal use or transport. On the other hand, the drum body should disengage from the base readily upon impact by an errant vehicle so that the base, with the ballast, would not be thrown in the air and pose potential hazard to either the motorists or workers.

As shown in Table 3, the vertical pull force ranges widely from a low of 115 pounds to a high of 500 pounds. With a ballast of 75 pounds of sand, it would be easy to exert sufficient force on the base to cause separation from the drum body during transport for those plastic drums with low vertical pull forces. A minimum vertical pull force equal to twice the ballast weight is therefore recommended. On the other hand, the vertical pull force should not be so high as to cause problem for a workman to separate the drum body from the base.

Results of the pendulum tests indicate that all of the plastic drums tested would separate from their bases at a speed of less than 15 miles per hour and some even below 5 miles per hour. It is believed that impacts below 20 miles per hour would not pose any significant hazard even if the drum body does not separate from the base. An impact speed of 20 miles per hour is therefore recommended as the speed at which the drum body must disengage from the base upon impact by the pendulum.

V. SUMMARY

This study was conducted with the following specific objectives:

1. Evaluation of add-on sand-filled compartments for bases of plastic drums manufactured by Flex-0-Lite.
2. Evaluation of sign substrates.
3. Development of Specifications for Plastic Drums.

Descriptions of the research approach, test procedures, and test results are presented in previous sections. A number of conclusions and observations can be made based on the study results and are presented as follows.

5.1 EVALUATION OF ADD-ON SAND-FILLED COMPARTMENT FOR PLASTIC DRUMS

- o The base with an add-on sand-filled compartment for use with plastic drums manufactured by Flex-0-Lite was found to perform satisfactorily in two crash tests.
- o There was grave concern over the fact that the windshield was cracked and shattered in these two crash tests. Further investigation was conducted, including two additional crash tests with plastic drums from another manufacturer. It was hypothesized that the flexibility of the drum body might have contributed to this undesirable outcome. However, it was not possible to determine conclusively what happened in the crash tests that led to the cracking and shattering of the windshield.

5.2 EVALUATION OF SIGN SUBSTRATES

- o Five sign substrates were evaluated in this study: (1) fiber-reinforced plastic (FRP), (2) polycarbonate, (3) plastic (6 mm thick), (4) Medex, and (5) aluminum. Results of the crash tests indicate that the Medex sign substrate did not perform satisfactorily and is not recommended for use with plastic drums. The other four sign substrates performed satisfactorily and are considered acceptable for use with plastic drums.
- o While the windshield of the vehicle was cracked and shattered in the crash tests involving the fiber-reinforced plastic (FRP) sign substrate, it was determined that the sign substrate was not the primary contributory factor, but rather the flexibility of the plastic drum body. The FRP sign substrate was retested with a different manufacturer and make of plastic

drum and found to perform satisfactorily. The FRP sign substrate is therefore considered acceptable for use with plastic drums.

5.3 DEVELOPMENT OF SPECIFICATIONS FOR PLASTIC DRUMS

- o** The project staff worked with TxDOT personnel to review and revise the existing specifications for plastic drums, especially with regard to developing and recommending standardized test procedures.
- o** A number of test procedures were developed in the effort to better define the characteristics and properties of the plastic drums, including: (1) dimensional measurements, (2) fixed base vertical pull test, (3) horizontal tip/slide test, (4) static crush test, and (5) dynamic drum/base separation test.

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4. "Recommended Procedures for Vehicle Crash Testing of Highway Appurtenances," Transportation Research Circular 191, Transportation Research Board, Washington, D. C., February 1978.
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APPENDIX A

STANDARD TEST PROCEDURES FOR

PLASTIC TRAFFIC DRUMS

I. GENERAL

1.1 Scope

These test procedures are intended for use in the examination and test of all types of two-piece breakaway plastic traffic drums for use as channeling devices on roadways. The term "plastic" as used in these procedures refers to flexible polyethylene material.

1.2 Applicable Document

National Cooperative Highway Research Program: Report 230, "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances."

1.3 Significance and Use

The purpose of this test specification is to establish recognized dimensional and quality requirements for plastic traffic drums and to provide producers and users with a basis for common understanding of the characteristics of this product.

1.4 Sampling

The test specimens required shall consist of complete units of the finished product, selected randomly from the lot under examination.

1.5 Number of Tests

Test one sample plastic traffic drum for each physical characteristic required in the detailed specifications. If the results do not meet the specified requirements, obtain two additional specimens and repeat the test. If the results of either of these two additional tests do not meet the specified requirements, consider the product to have failed to meet the specifications.

II. DIMENSIONAL MEASUREMENTS

2.1 Dimensional Measurements

2.1.1 Total Height - Determine the height by means of a steel tape or calibrated measuring device. While setting on a hard smooth surface the total height of base and drum shall be measured from that surface to the top of the drum. It shall not include any fixtures on the top of the drum or molded attachment points.

2.1.2 Base Height - Remove the drum body from the base and leave the base on the hard smooth surface. Measure from that surface to the highest point of the base section.

2.1.3 Diameter - Measure the circumference of the drum with a flexible tape at the points of the smallest and the largest diameter. Determine

the diameters by calculation. Use of a pi (π) tape graduated to read the diameter directly is acceptable.

2.1.4 Wall Thickness - Cut samples from the side of the drum body at the center and near the top and bottom of the drum body. The samples shall be of adequate size for measuring with a micrometer. Avoid contours and reinforced areas when selecting the samples. Determine the thickness of the samples by means of a standard micrometer graduated to 0.001 inch.

2.2 Weight

The weight of the drum and base sections shall be determined separately. An electronic or mechanical scale with an accuracy and resolution of 0.1 pound or better shall be used. Report the weight of each section to the nearest 0.1 pound.

III. FIXED BASE VERTICAL PULL FORCE TEST

3.1 Apparatus

3.1.1 Base Attachment Fixture - A means of attaching the drum base rigidly to the floor shall be provided. This may be a $\frac{1}{2}$ -inch threaded rod screwed into a concrete floor anchor. A $\frac{1}{2}$ -inch hole is drilled in the center of the base section to accommodate the rod. The base is placed over the rod followed by a 1-foot diameter, $\frac{1}{2}$ -inch thick steel plate with a $\frac{1}{2}$ -inch hole in the center. The plate and base are secured by a finger tight nut.

3.1.2 Force Application Fixture - Vertical force is applied to the top of the drum body by a simple hoist with a capacity of at least 500 pounds. A very slow and controlled force increase is needed just prior to separation of the drum body from the base. This may be a manually operated chain or rope hoist.

3.1.3 Force Measurement - A force transducer or load cell with a minimum capacity of 500 pounds is required between the force application fixture and the top of the drum. The transducer and readout shall have an accuracy and resolution of 1 pound or better. Preferably, the force readout should be continuously recorded. Alternatively, the force readout may be read off manually provided the increase in force prior to separation between the drum body and the base is less than 2 pounds per second.

3.1.4 Attachment - The vertical pull by the hoist/load cell shall be at the geometric center of the top of the drum body. This may be done by attaching a suitable nylon rope from one of the sign panel attachment points, through a pulley connected to the load cell and back to the other attachment point.

3.2 Procedure

Secure the drum base to the floor in accordance with Section 3.1.1. Attach the drum body to the base in the normal manner. Attach the force application fixture and load cell to the top of the drum body in

accordance with Sections 3.1.2, 3.1.3 and 3.1.4. With slack in the load cell to drum connection, adjust the load cell readout to zero pounds force and verify that the calibration is correct. Operate the hoist to remove slack from the system and to indicate a few pounds of force. Slowly increase the force, at a rate of up to 5 pounds per second if using a stripchart to record the force readout or less than 2 pounds per second if the force readout is observed and recorded manually, until the drum body separates from the base. Record the highest force value just prior to separation or until a force of 500 pounds is reached. Repeat the procedure a total of three times and average the three readings for the reported value. If no separation occurred at the 500-pound force level, report as ">500 pounds".

IV. HORIZONTAL TIP/SLIDE TEST

4.1 Apparatus

4.1.1 Force Measurement - The force measurement device may be electronic or mechanical with a minimum full-scale range of 75 pounds and a resolution and accuracy of 0.5 pound or better.

4.1.2 Test Surface - The test drum assembly shall be placed on a flat, level, and dry concrete surface with a texture depth between 0.015 and 0.025 inch, in accordance with ASTM Test Method E 965. The test surface should be at least 4 feet by 4 feet.

4.2 Procedure

4.2.1 The drum body and base assembly, ballasted to 75 pounds, shall be placed on the test surface. A cord is attached between the force measurement device and the top of the drum body. While maintaining the cord horizontal, the operator manually and slowly pulls, through the measurement device, until the drum tips over or slides. The highest force observed during the pullover is recorded. The test is repeated a total of three times and the average value reported as the top horizontal tip/slide force.

4.2.2 Repeat the tests as in Subsection 4.2.1, but with the cord attached to the geometric center of the drum body or mid-point between the floor and the top of the drum body. Report the average value of the three tests as the center horizontal tip/slide force.

V. DYNAMIC DRUM-BASE SEPARATION TEST

5.1 Scope

This dynamic test determines if a 20-mph impact will separate the drum body from its base. The drum, base and ballast are assembled and placed as would be in normal use.

5.2 Apparatus

5.2.1 *Pendulum* - The facility is characterized by a striking mass that swings in a circular arc suspended by cables from a main frame, approximately 40 feet high, as described in NCHRP Report 230. The pendulum mass shall have a minimum weight of 1,800 pounds and remain horizontal throughout the entire swing. The impacting portion or nose of the pendulum shall be a rigid cylinder, 6 inches in diameter and a minimum of 24 inches in length. The cylinder shall be mounted horizontally, perpendicular to the direction of travel. The cylinder should not be connected directly to the main body of the pendulum but held at least two feet forward by appropriate supports. The pendulum mass shall be suspended so that, when stationary, the center of the cylinder is 18 inches above the ground.

5.2.2 *Test Surface* - The ground surface upon which the test drum assembly sets prior to impact shall be level and constructed of concrete or asphalt extending at least one foot on either side and toward the pendulum mass and 10 feet rearward.

5.3 Procedure

5.3.1 Place the test drum, complete with base and 75-pound ballast, in position, centered and just touching the nose of the pendulum.

5.3.2 Raise the pendulum to a height equivalent to a 20 mph (29.33 fps) impact speed governed by the formula:

$$V_i = \sqrt{2gh}$$

where V_i is the impact speed in feet per second, h is the drop height in feet and $g = 32.2$ feet per second per second. For an impact speed of 20 mph, a drop height of 13.36 feet is required.

5.3.3 Release the pendulum. Observe and record if the base and drum remained attached or separated after the first swing impact.

VI. STATIC CRUSH TEST

6.1 Apparatus

Scale - An electronic or mechanical platform scale with a top surface measuring 18 inches by 12 inches and 5 inches above a reference surface such as the floor. The accuracy and resolution of the scale shall be 0.25 pound or better with a full-scale capacity of at least 250 pounds.

6.2 Procedure

6.2.1 A sample drum with base attached, but no ballast, shall be laid horizontally across the narrow portion of the scale at the vertical center of the drum assembly.

6.2.2 The weight of the drum assembly as it rests on the scale shall be recorded and subtracted from the final values.

6.2.3 With a person each at the top and bottom ends of the drum assembly, manually press the ends of the drum downward. The downward force should be applied slowly and evenly on each end. Observe the force readout and record the maximum value. The manual application of force on the drum should not produce deformations at the ends of the drum where the force is applied.

6.2.4 When both ends of the drum assembly touch the reference surface, record the force value. The static crush force shall be the greater of the peak during force application or the value when the ends of the drum are against the reference surface.

VII. REPORT

7.1 Report

The results of the tests shall be summarized in a test report and shall include the following:

- 1 Identification of the plastic traffic drum by manufacturer and model number,
2. Dimensional measurements in accordance with Section II,
3. Vertical separation force in accordance with Section III,
4. Horizontal tip/slide force in accordance with Section IV,
5. Dynamic separation in accordance with Section V, and
6. Static crush force in accordance with Section VI.

