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16. Abstract

The Texas Department of Transportation (TxDOT) developed a draft specification for plastic drums which outlines the desired properties and characteristics of a plastic drum and specifies certain dimensions and static force tests that a plastic drum must pass in order to be acceptable to TxDOT for purchase and use in work zones. These tests are intended as surrogates to the full-scale crash tests used to evaluate the safety performance of plastic drums. However, prior to adopting the specification, it is necessary to first determine how well commercially available plastic drums conform to the proposed specification and if the proposed specification describes a plastic drum that will perform in a predictable manner when impacted by a vehicle. The objectives of this study are to (1) conduct dimensional measurements and static force tests on plastic drums submitted by various manufacturers to determine if they conform with the proposed draft specification; (2) conduct full-scale crash tests on plastic drums to validate the results of the dimensional measurements and static force tests; and (3) analyze the test results and recommend modifications to the specification as appropriate. The study was conducted in two phases. Phase I involved dimensional measurements and static force tests of various plastic drums submitted by manufacturers for consideration by TxDOT in accordance with the draft specification. Phase II of the study involved full-scale crash tests of the same plastic drums to validate the results of the dimensional measurements and static force tests. This report summarizes the results of the study.

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EVALUATION OF PLASTIC DRUM SPECIFICATIONS

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Research Report 2924-1F
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Research Study Title: Evaluation of Plastic Drum Specifications

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TEXAS TRANSPORTATION INSTITUTE
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IMPLEMENTATION STATEMENT

The Texas Department of Transportation (TxDOT) developed a draft specification to evaluate and qualify plastic drums for use in work zones. The draft specification provides a simple and inexpensive means of testing the plastic drums to make sure that they will perform in a predictable and satisfactory manner when impacted by errant vehicles. This report covers activities conducted in the two-phased study. Phase I of the study involved static tests of various plastic drums submitted by manufacturers for consideration by TxDOT in accordance with the draft specification. Phase II of the study involved full-scale crash tests of the same plastic drums to validate the results of the static tests. Results of the research will be available for immediate implementation at the end of the study and will include the following: (a) an assessment of various plastic drums submitted by manufacturers for consideration by TxDOT in accordance with the draft specification; (b) validation of the draft specification through full-scale crash testing; and (c) recommendations on modifications to the draft specification. This will provide TxDOT with the necessary information to finalize the draft specification for plastic drums and to pre-qualify plastic drums submitted by the various manufacturers for purchase or use in work zones by the Department.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. The engineer in charge of the project was King K. Mak, P.E. # 51502.

It is the policy of Texas Transportation Institute (TTI) and the Texas A&M University not to endorse any specific manufacturers, trademarks, or products. However, it is necessary in the report to identify the specific plastic drums tested in the study. It should therefore be noted that the mention of specific manufacturers, trademarks, and products in the report does not constitute endorsement of such manufacturers, trademarks, or products by TTI or the Texas A&M University.

ACKNOWLEDGMENT

This study is sponsored by the Texas Department of Transportation (TxDOT). Mr. Lewis Rhodes (512) 416-3330 is the Research Project Director for TxDOT, and his guidance and support are deeply appreciated.

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SUMMARY

The Texas Department of Transportation (TxDOT) developed a draft specification for plastic drums which outlines the desired properties and characteristics of a plastic drum and specifies certain dimensions and a series of static force tests that a plastic drum must pass in order to be acceptable to TxDOT for purchase and use in work zones. These tests are intended as surrogates to the full-scale crash tests used to evaluate the safety performance of plastic drums. However, prior to adopting the specification, it is necessary to first determine how well commercially available plastic drums conform to the draft specification and if the draft specification describes a plastic drum that will perform in a predictable manner when impacted by a vehicle.

The objectives of this study are to (1) conduct tests on plastic drums submitted by various manufacturers to determine if they conform with the draft specification; (2) conduct full-scale crash tests on plastic drums to validate the draft specification; and (3) analyze the test results and recommend modifications to the draft specification as appropriate. Researchers conducted the study in two phases. Phase I involved dimensional measurements and static force tests of various plastic drums submitted by manufacturers for consideration by TxDOT in accordance with the draft specification. Phase II of the study involved full-scale crash tests of the same plastic drums to validate the results of the dimensional measurements and static force tests.

This report summarizes the results of the study. Six manufacturers provided a total of eleven models of plastic drums for testing. For each model of plastic drum, researchers conducted dimensional measurements and static force tests in accordance with the draft specification. Additional tests not included in the draft specification, including horizontal tip/slide force and fixed base horizontal pull force tests, were also conducted in the evaluation of the plastic drums. These plastic drum models were further evaluated with full-scale crash testing to validate the results of the dimensional measurements and static force tests. This report presents results of these tests together with findings and recommendations.

I. INTRODUCTION

1.1 BACKGROUND

Safety of work zones is a major area of concern since it is not always possible to maintain a level of safety comparable to that of a normal highway not under construction. Proper traffic control is critical to the safety of work zones. However, even traffic control devices pose a safety hazard when impacted by errant vehicles. It is important therefore to ensure that the traffic control devices used in the work zones meet certain safety performance standards and specifications. For the past few years, the Texas Department of Transportation (hereinafter referred to as TxDOT or the Department) has sponsored a number of studies at the Texas Transportation Institute (TTI) to assess the impact performance of various work zone traffic control devices, including plastic drums, sign substrates, barricades and temporary sign supports (1-3). A summary of the highlights of the findings from these studies are summarized as follows:

- Plastic drums posed little hazard to the impacting vehicle from the occupant risk standpoint due to their light weight and ready disengagement from the bases.

- The vehicle exhibited very stable behavior during impact with the plastic drums and did not appear to pose any potential threat to traffic in adjacent lanes.

- The flashing light units should be rigidly attached to the top of the plastic drums to avoid the possibility of the flashing light units being dislodged from the plastic drums and becoming projectiles.

- Six sign substrates were evaluated: (1) plywood, (2) fiber-reinforced plastic (FRP), (3) polycarbonate, (4) 6 mm (0.24 in) thick plastic, (5) Medex, and (6) aluminum. Results of the crash tests indicate that the plywood and Medex sign substrates did not perform satisfactorily and are not recommended for use with plastic drums. The other four sign substrates performed satisfactorily and are considered acceptable for use with plastic drums.

Based on results of these studies, the Department developed a draft specification for plastic drums (see copy in Appendix A.) The draft specification outlines the desired properties and characteristics of a plastic drum and specifies certain dimensions and static force tests a plastic drum must pass in order to be acceptable to TxDOT for purchase and use in work zones. Full-scale crash testing is the best means to assess the safety performance of plastic drums, but it is also relatively expensive. Thus, the Department developed a number of surrogate, less expensive, test procedures, to provide a reliable indicator of the impact performance of the plastic drums. However, prior to adopting the specification, it is necessary to first determine how well commercially available plastic drums conform to the draft specification, and if the draft specification describes a plastic drum that will perform in a predictable manner when impacted by a vehicle.

1.2 OBJECTIVES OF THE STUDY

The objectives of this study are as follows:

1. Conduct dimensional measurements and static force tests on plastic drums submitted by various manufacturers to determine if they conform with the draft specification;

2. Conduct full-scale crash tests on the same plastic drums to validate the results of the dimensional measurements and static force tests; and

3. Analyze the test results and recommend modifications to the draft specification as appropriate.

Researchers conducted the study in two phases. Phase I involved dimensional measurements and static force tests of various plastic drums submitted by manufacturers for consideration by TxDOT in accordance with the draft specification. Phase II of the study involved full-scale crash tests of the same plastic drums to validate the results of the dimensional measurements and static force tests.

II. STUDY APPROACH

Researchers conducted the following dimensional measurements, static force tests, and full-scale crash tests on the plastic drums submitted by various manufacturers:

- Dimensional measurements
  - Height,
  - Diameter,
  - Wall thickness, and
  - Weight;

- Static force tests
  - Fixed base vertical pull force test,
  - Static crush test,
  - Horizontal tip force test, and
  - Fixed base horizontal pull force test;

- Full-scale crash test.

Researchers conducted dimensional measurements, fixed base vertical pull force tests, and the static crush tests in accordance with procedures outlined in the draft specification. The horizontal tip force and the fixed base horizontal pull force tests were added to the list of tests after consultation with the Research Project Director. Finally, full-scale crash tests were conducted to validate the results of the dimensional measurements and static force tests.

Brief descriptions of the test procedures follow.

2.1 DIMENSIONAL MEASUREMENTS

Section VI, "Materials and Construction Requirements," Items D, E and J, of the specification pertain to the dimensional measurements:

D. Dimensions: Minimum height of 914 mm (36 in.) and minimum diameter of 457 mm (18 in.), regardless of vertical orientation. Wall thickness at top of the drum body shall not be less than 2.03 mm (0.080 in.) and not more than 2.29 mm (0.090 in.). Wall thickness at middle of drum body shall not be less than 1.52 mm (0.060 in.) and not more than 1.78 mm (0.070 in.). Wall thickness at bottom of drum body shall not be less than 1.78 mm (0.070 in.) and not more than 2.03 mm (0.080 in.). Samples shall be cut 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 standard micrometer graduated to 0.025 mm (0.001 in.). Contours and reinforced areas shall be avoided when sampling.

E. Unballasted weight of drum body shall weigh no less than 3.4 kg (7.5 lb) and no more than 3.9 kg (8.5 lb). The actual weight of any drum body shall not vary more than +/- 0.23 kg (0.5 lb) from that of the pre-qualification sample.

J. The base is to be domed shaped from all approaching directions and is to be a maximum of 102 mm (4 in.) in height. A self-contained base shall be large enough to hold up to 22.7 kg (50 lb) of sand. Bases with a corrugated bottom shall be stiff enough to maintain their shape even when filled with sand.

Researchers performed the dimensional measurements of the plastic drum bodies and bases in accordance with the draft specification, 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 plastic drum body, measured from a hard smooth surface on which the drum body sits to the top of the drum, but not including any fixtures on the top of the drum or molded attachment points;

3. 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;

4. The diameter of the drum at the point of smallest diameter, calculated from measurement of the circumference;

5. The diameter of the drum at the point of largest diameter, calculated from measurement of the circumference;

6. The weight of the drum body, measured with an electronic scale;

7. The weight of the unballasted drum base, measured with an electronic scale; and

8. 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.

2.2 STATIC FORCE TESTS

Researchers conducted four different static force tests for the evaluation of the plastic drums, including

- Fixed base vertical pull force test;

- Static crush test;
- Horizontal tip force test; and
- Fixed base horizontal pull force test.

2.2.1 Fixed Base Vertical Pull Force Test

Section VI, "Materials and Construction Requirements," Item X, of the draft specification pertains to the vertical pull test, which states as follows:

X. The fixed base vertical pull force shall not be less than 64.5 kg (140 lb) and not more than 136 kg (300 lb) when tested as described below.

Apparatus

Base attachment fixture - A means of attaching the drum base rigidly to the floor shall be provided. This may be a 12.7-mm (0.5-in.) threaded rod screwed into a concrete floor. A 14.3-mm (9/16-in.) hole is drilled in the center of the base section to accommodate the rod. The base is placed over the rod followed by a 305-mm (1-ft) diameter, 6.4-mm (1/4-in.) thick steel plate with a 14.3-mm (9/16-in.) hole in the center. The plate and base are secured by a finger-tight nut.

Force application fixture - Vertical force is applied to top of the drum body by a simple hoist with a capacity of at least 227 kg (500 lb). A very slow and controlled force increase is needed just prior to separation of the drum body from the drum base. This may be a manually operated chain or rope hoist.

Force measurement - A force transducer or load cell with a minimum capacity of 227 kg (500 lb) is required between the force application fixture and the top of the drum. The transducer and readout shall have an accuracy and resolution of 0.45 kg (1 lb) or better. Preferably, the force readout shall 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 0.9 kg (2 lb) per second.

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 or more of the sign panel attachment points, through a pulley connected to the load cell and back to the other attachment point.

Procedure

Secure the drum base to the floor. 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. With slack in the load cell to drum connection, adjust the load cell readout to zero kg (lb) force and verify that the calibration is correct. Operate the hoist to remove slack from the system and to indicate a few kg (lb) of force. Slowly increase the force, at a rate of up to 2.3 kg (5 lb) per second if using a strip chart to record the force readout or less than 0.9 kg (2 lb) per second if the force readout is observed and recorded manually, until the drum body separates from the base or a force of 159 kg (350 lb) is reached, whichever occurs first. Record the highest force value just prior to separation or until a force of 159 kg (350 lb) is reached. Repeat the procedure a total of three times and average the three readings for the reported value. If the pull force is less than 63.5 kg (140 lb) for one of the three pulls, repeat the test a fourth time and exclude the low value if the fourth pull exceeds 63.5 kg (140 lb). If no separation occurred at the 159-kg (350-lb) force level, report as ">159 kg (350 lb)."

Researchers conducted the fixed base vertical pull test in accordance with the draft specification with the following exception. The vertical pull force was applied with a pneumatic cylinder at the rate of 2.3 kg (5 lb) per second instead of a manual chain hoist. Researchers conducted a total of three tests on each specimen and recorded the average value of the three tests.

2.2.2 Static Crush Test

Section VI, "Materials and Construction Requirements," Item Y, of the draft specification pertains to the static crush test, which states as follows:

Y. The static crush test results shall not be less than 32 kg (70 lb) and not more than 41 kg (90 lb) when tested as described below.

Apparatus

Scale - an electronic or mechanical platform scale with a top surface measuring 457 mm by 305 mm (18 in. x 12 in.) and 127 mm (5 in.) above a reference surface such as the floor. The accuracy and resolution of the scale shall be 0.11 kg (0.25 lb) or better with a full-scale capacity of at least 113 kg (250 lb).

Procedure

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. The weight of the drum as it rests on the scale shall be recorded and subtracted from the final values. With a person at each end (top and bottom) 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. 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.

Researchers conducted the tests in accordance with the draft specification. A total of four tests were conducted on each specimen and the average value of the four tests was recorded.

2.2.3 Horizontal Tip Force Test

A horizontal tip force test was also added to the list of tests outlined in the draft specification. Two sets of tests were conducted, one with the horizontal force applied to the top of the drum and one with the horizontal force applied to the center of the drum. The purpose of this horizontal tip force test is to evaluate the force required to cause the drum to tip over or slide on its base, such as that caused by a passing truck. A description of the test procedure follows:

Apparatus

Force application fixture - Horizontal force is applied to the drum by a pneumatic cylinder at a rate of no more than 2.3 kg (5.0 lb) per second.

Force measurement - A force transducer or load cell with a capacity of 226.8 kg (500 lb) and an accuracy and resolution of 0.45 kg (1.0 lb) or better is attached between the force application fixture and the drum. The force readout is continuously recorded.

Attachment - For tests with the horizontal pull force applied to the top of the drum, the horizontal pull by the pneumatic cylinder/load cell is at the geometric center of the top of the drum body. This is done by attaching a suitable nylon rope from one or more of the sign panel attachment points, through a pulley connected to the load cell and back to the other attachment point. For tests with the horizontal pull force applied to the center of the drum, a 50-mm (2-in.) wide strap is wrapped around the drum at the geometric center of the drum body and attached to a rope, through a pulley, and attached to a load cell.

Procedure

The drum assembly is placed on a hard, smooth, and level surface. The drum assembly is ballasted with 22.7 kg (50.0 lb) of sandbags for a plain base, filled with 22.7 kg (50.0 lb) of sand for a self-contained base, or use a self-contained base with built-in ballast such as a solid rubber base. A horizontal force is applied to the rope, either at the top or center of the drum depending on the test being conducted, with a pneumatic cylinder at the rate of 2.3 kg (5.0 lb) per second. The horizontal pull force is applied in the zero degree orientation, i.e., the position as viewed by a driver facing the sign panel when attached to the drum. The other orientations or positions are not deemed necessary since the base diameter is generally uniform and there is

no reason to believe that the required horizontal tip force would vary with the orientation of the drum.

The horizontal force is applied until the drum tips over, slides on its base, or when the drum body separates from the base. The highest force observed during the pull and the action of the drum, i.e., whether the drum tips over, slides on its base, or the drum body separates from the base is recorded. The test is repeated a total of three times and the average is reported as the horizontal pull force. Two sets of tests are conducted, one with the horizontal force applied at the top of the drum and the other at the center of the drum.

2.2.4 Fixed Base Horizontal Pull Force Test

A horizontal pull force test was added to the list of tests outlined in the draft specification. The purpose of this test is to simulate the drum being struck by a vehicle at low speed. A description of the test procedure follows:

Apparatus

Base attachment fixture - The drum base is rigidly attached to the floor in the same manner as that for the fixed based vertical pull test.

Force application fixture - Horizontal force is applied to the drum by a pneumatic cylinder at a rate of no more than 2.3 kg (5.0 lb) per second.

Force measurement - A force transducer or load cell with a capacity of 226.8 kg (500 lb) and an accuracy and resolution of 0.45 kg (1.0 lb) or better is attached between the force application fixture and the drum. The force readout is continuously recorded.

Attachment - A 51-mm (2-in.) wide strap is wrapped around the drum at a height of 533 mm (21 in.) above the ground and attached to a rope, through a pulley and the load cell, and attached to a pneumatic cylinder.

Procedure

The drum is anchored to the floor in a manner similar to that used with the fixed base vertical pull force test. A 51-mm (2-in.) wide strap is wrapped around the drum at a height of 533 mm (21 in.) above the ground and attached to a rope, through a pulley, and attached to a load cell. A horizontal force is applied to the rope with a pneumatic cylinder at the rate of 2.3 kg (5 lb) per second. The load cell measures this horizontal force in a continuous manner. The horizontal force at which the drum separates from the base is recorded. If the drum body simply buckles and does not separate from the base, it is noted.

Researchers conducted the test for all four orientations of the plastic drum. The baseline or zero degree position is the front of the drum, i.e., the position as viewed by a driver facing the sign panel when attached to the drum. The other orientations or positions are compass bearings clockwise from the baseline or zero degree position. The rationale for conducting this test for the various orientations is that some of the drums and their latching mechanisms are not symmetrical.

2.3 FULL-SCALE CRASH TESTS

Researchers conducted full-scale crash tests on the plastic drums submitted by the various manufacturers in accordance with guidelines set forth in National Cooperative Highway Research Program (NCHRP) Report 350 (4). A 820-kg (1,808-lb) passenger car was used in the crash tests. Due to the minor nature of the impact with plastic drums, the vehicle was driven under its own power instead of the cable reverse tow and guidance system typically used with full-scale crash testing. A protective wire mesh was installed inside the windshield of the test vehicle to minimize any potential hazard associated with breaking or penetration of the windshield from the plastic drums. The driver wore a helmet and protective clothing and was restrained with a five-point seat belt. The vehicle was not instrumented. Previous crash tests with plastic drums indicated that the acceleration level experienced by the vehicle during the impact was too low to be of any significance.

The centerline of the vehicle was aligned with the centerline of the plastic drum which was placed directly on the concrete pavement surface. The location of the drum was marked on the pavement for reference in post-impact measurements. Figure 1 shows photographs of a typical test setup. The nominal speed for the impact was 100 km/h (62.2 mph). The actual impact speed was measured with a calibrated radar gun and recorded for each test. The tests were documented with two video camcorders: a Betacam camera and recorder for the pan shot and a VHS-format camcorder for a close-up shot of the impact.

Figure 1. Photographs of Typical Setup for Full-Scale Crash Tests

III. STUDY RESULTS

Six (6) manufacturers provided a total of eleven (11) models of plastic drums for testing, as shown in Table 1. Lakeside Plastics provided only two samples of its "TRI-TIX" model. The other manufacturers all provided five samples of each model. The two models provided by Plastic Safety Systems, Inc. have bases made from sidewalls of truck tires. The base looks like a donut and slips onto the drum body from the top. Due to the unusual configuration of the base for these two plastic drum models, the test procedures for the fixed base vertical pull force test and the fixed base horizontal pull force test were not applicable without major modifications. Thus, researchers did not include these two plastic drum models in these tests.

The two models of plastic drums provided by Flex-O-Lite have two different types of bases: a plain base to be used with sandbags and a solid rubber base. Similarly, the two models of plastic drums provided by Radiator Specialty Co. also have a plain base and a solid rubber base. These Flex-O-Lite and Radiator Specialty Co. models were each tested with each of the two different bases, which effectively increased the total number of models tested to 15. Table 2 lists the sample numbers and the corresponding manufacturer, model number, and type of base.

Results of the dimensional and static force tests and full-scale crash tests for each of the 15 plastic drum models follow. Also presented are comparisons of the results with the criteria outlined in the draft specification.

3.1 DIMENSIONAL MEASUREMENTS

Table 3 shows the dimensional measurements of the 15 plastic drum models tested. Comparisons of the results with the draft specification are shown in Table 4. Results are denoted as pass (meeting specification), fail (not meeting specification), or N/A (not applicable or not specified). The measurements include the following: height of the drum with and without the base and height of the base; smallest and largest diameters of the drum; wall thicknesses at the top, center and bottom of the drum; and the weight of the drum and the base. Brief descriptions of the test results and comparisons of the results with the criteria outlined in the draft specification follow.

Height. The heights of the drums with bases attached range from 991 to 1056 mm (39 to 41.6 in.). The heights of the drums without the bases range from 918 to 1041 mm (36.2 to 41 in.) and the heights of the bases range from 48 to 102 mm (1.88 to 4 in.). The two drum models by Plastic Safety Systems, Inc. use bases made from sidewalls of truck tires and slip onto the drum bodies. Consequently, the bases do not affect the height of the drums.

The draft specification requires a minimum height of 914 mm (36 in.), but does not specify if the height is measured with or without the base. However, all the drums have heights well above the required minimum, with or without the base. The specification requires a maximum height of 102 mm (4 in.) for the base, which is met by all the models. As may be expected, the self-contained bases are typically higher than the plain bases with corrugated bottoms.

Table 1. List of Plastic Drum Manufacturers and Models

Manufacturer	Model No.	Number of Units Provided	
		Drum Body	Base
TrafFix Devices, Inc.	1800 HDPE(LW)	5	10 San-Fil Bases
	1800 HDPE	5	
	1800 LDPE	5	5 San-Fil Bases
Flex-O-Lite	HDPE	5	7 Plain Bases and 5 Rubber Bases
	LDPE	5	
Services & Materials	HDPE (Bouncer)	5	5 Plain Bases
Lakeside Plastics	TRI-TIX	2	2 Plain Bases
Plastic Safety Systems, Inc.	Lifegard HDPE	5	25 Bases made from Truck Tire Sidewalls
	Lifegard LDPE	5	
Radiator Specialty Co.	HD 8	5	5 Plain Bases and 5 Rubber Bases
	LD 10	5	

Table 2. List of Plastic Drum Models Tested

Sample No.	Manufacturer	Model No.	Base Type
1, 2	TrafFix Devices, Inc.	1800 HDPE(LW)	San-Fil
3, 4	TrafFix Devices, Inc.	1800 LDPE	San-Fil
5, 6	TrafFix Devices, Inc.	1800 HDPE	San-Fil
7, 8	Lakeside Plastics	TRI-TIX	Plain
9, 10	Flex-O-Lite	HDPE	Plain
11, 12	Flex-O-Lite	HDPE	Rubber
13, 14	Flex-O-Lite	LDPE	Plain
15, 16	Flex-O-Lite	LDPE	Rubber
17, 18	Services & Materials	BOUNCER	Plain
19, 20	Plastic Safety Systems	Lifegard HDPE	Truck Tire Sidewall
21, 22	Plastic Safety Systems	Lifegard LDPE	Truck Tire Sidewall
23	Radiator Specialty	HD 8	Rubber
24	Radiator Specialty	LD 10	Plain
25	Radiator Specialty	HD 8	Plain
26	Radiator Specialty	LD 10	Rubber

Table 3. Plastic Drum Dimensional Measurements

Manufacturer	Model No.	Base Type	Dimensional Measurements				
			Height , mm (in.)			Diameter, mm (in.)	
			w/Base	w/o Base	Base	Smallest	Largest
TrafFix Devices	1800 HDPE(LW)	San-Fil	1020 (40.16)	941 (37.03)	102 (4.0)	460 (18.10)	524 (20.63)
TrafFix Devices	1800 LDPE	San-Fil	1015 (39.97)	944 (37.16)	102 (4.0)	460 (18.13)	524 (20.63)
TrafFix Devices	1800 HDPE	San-Fil	1022 (40.25)	945 (37.19)	102 (4.0)	461 (18.16)	527 (20.75)
Lakeside Plastics	TRI-TIX	Plain	1018 (40.10)	940 (37.00)	102 (4.0)	461 (18.16)	511 (20.13)
Flex-O-Lite	HDPE	Plain	993 (39.10)	950 (37.41)	52 (2.06)	489 (19.25)	559 (22.00)
Flex-O-Lite	HDPE	Rubber	997 (39.25)	941 (37.06)	76 (3.0)	489 (19.25)	559 (22.00)
Flex-O-Lite	LDPE	Plain	991 (39.00)	918 (36.16)	52 (2.06)	491 (19.31)	559 (22.00)
Flex-O-Lite	LDPE	Rubber	1012 (39.84)	945 (37.19)	59 (2.31)	491 (19.31)	559 (22.00)
Services & Materials	BOUNCER	Plain	1003 (39.47)	922 (36.28)	48 (1.88)	464 (18.25)	540 (21.25)
Plastic Safety Systems, Inc.	Lifegard HDPE	Truck Tire Sidewall	1041 (41.00)	1041 (41.00)	87 (3.44)	465 (18.31)	549 (21.68)
Plastic Safety Systems, Inc.	Lifegard LDPE	Truck Tire Sidewall	1035 (40.75)	1035 (40.75)	81 (3.19)	464 (18.25)	541 (21.31)
Radiator Specialty	HD 8	Rubber	1051 (41.38)	-	86 (3.38)	455 (17.91)	560 (22.03)
Radiator Specialty	LD 10	Plain	1056 (41.56)	-	87 (3.44)	455 (17.91)	561 (22.09)
Radiator Specialty	HD 8	Plain	1056 (41.56)	-	87 (3.44)	455 (17-91)	560 (22.03)
Radiator Specialty	LD 10	Rubber	1051 (41.38)	-	86 (3.38)	455 (17.91)	561 (22.09)

Table 3. Plastic Drum Dimensional Measurements (Continued)

Manufacturer	Model No.	Base Type	Dimensional Measurements				
			Wall Thickness, mm (in.)			Weight, kg (lb.)	
			Top	Center	Bottom	Drum	Base
TrafFix Devices	1800 HDPE(LW)	San-Fil	2.29 (.090)	1.75 (.069)	2.03 (.080)	3.29 (7.25)	1.70 (3.75)
TrafFix Devices	1800 LDPE	San-Fil	2.0 (.079)	2.03 (.080)	3.07 (.121)	4.11 (9.05)	1.61 (3.55)
TrafFix Devices	1800 HDPE	San-Fil	1.91 (.075)	1.73 (.068)	2.11 (.083)	3.67 (8.1)	1.61 (3.55)
Lakeside Plastics	TRI-TIX	Plain	2.21 (.087)	2.11 (.083)	2.44 (.096)	3.88 (8.55)	1.54 (3.4)
Flex-O-Lite	HDPE	Plain	2.08 (.082)	3.00 (.118)	2.69 (.106)	4.13 (9.1)	1.04 (2.3)
Flex-O-Lite	HDPE	Rubber	2.08 (.082)	3.00 (.118)	2.69 (.106)	4.13 (9.1)	18.42 (40.6)
Flex-O-Lite	LDPE	Plain	2.11 (.083)	3.28 (.129)	3.00 (.118)	4.56 (10.05)	1.09 (2.4)
Flex-O-Lite	LDPE	Rubber	2.11 (.083)	3.28 (.129)	3.00 (.118)	4.56 (10.05)	18.42 (40.6)
Services & Materials	BOUNCER	Plain	1.78 (.070)	2.51 (.099)	2.46 (.097)	3.65 (8.05)	0.98 (2.15)
Plastic Safety Systems, Inc.	Lifegard HDPE	Truck Tire Sidewall	1.60 (.063)	1.27 (.050)	1.32 (.052)	2.95 (6.5)	14.22 (31.35)
Plastic Safety Systems, Inc.	Lifegard LDPE	Truck Tire Sidewall	2.56 (.101)	2.16 (.085)	2.95 (.116)	4.20 (9.25)	12.04 (26.55)
Radiator Specialty	HD 8	Rubber	2.54 (.100)	2.03 (.080)	1.83 (.072)	3.27 (7.2)	13.52 (29.8)
Radiator Specialty	LD 10	Plain	2.74 (.108)	1.65 (.065)	3.05 (.120)	3.99 (8.8)	0.82 (1.8)
Radiator Specialty	HD 8	Plain	2.54 (.100)	2.03 (.080)	1.83 (.072)	3.27 (7.2)	0.82 (1.8)
Radiator Specialty	LD 10	Rubber	2.74 (.108)	1.65 (.065)	3.05 (.120)	3.99 (8.8)	13.52 (29.8)

Table 4. Comparison of Dimensional Measurements with Draft Specification

Manufacturer	Model No.	Base Type	Dimensional Measurements				
			Height			Diameter	
			w/Base	w/o Base	Base	Smallest	Largest
TrafFix Devices	1800 HDPE(LW)	San-Fil	Pass	Pass	Pass	Pass	N/A
TrafFix Devices	1800 LDPE	San-Fil	Pass	Pass	Pass	Pass	N/A
TrafFix Devices	1800 HDPE	San-Fil	Pass	Pass	Pass	Pass	N/A
Lakeside Plastics	TRI-TIX	Plain	Pass	Pass	Pass	Pass	N/A
Flex-O-Lite	HDPE	Plain	Pass	Pass	Pass	Pass	N/A
Flex-O-Lite	HDPE	Rubber	Pass	Pass	Pass	Pass	N/A
Flex-O-Lite	LDPE	Plain	Pass	Pass	Pass	Pass	N/A
Flex-O-Lite	LDPE	Rubber	Pass	Pass	Pass	Pass	N/A
Services & Materials	BOUNCER	Plain	Pass	Pass	Pass	Pass	N/A
Plastic Safety Systems, Inc.	Lifegard HDPE	Truck Tire Sidewall	Pass	Pass	Pass	Pass	N/A
Plastic Safety Systems, Inc.	Lifegard LDPE	Truck Tire Sidewall	Pass	Pass	Pass	Pass	N/A
Radiator Specialty	HD 8	Rubber	Pass	-	Pass	Fail	N/A
Radiator Specialty	LD 10	Plain	Pass	-	Pass	Fail	N/A
Radiator Specialty	HD 8	Plain	Pass	-	Pass	Fail	N/A
Radiator Specialty	LD 10	Rubber	Pass	-	Pass	Fail	N/A

Table 4. Comparison of Dimensional Measurements with Draft Specification (Continued)

Manufacturer	Model No.	Base Type	Dimensional Measurements				
			Wall Thickness			Weight	
			Top	Center	Bottom	Drum	Base
TrafFix Devices	1800 HDPE(LW)	San-Fil	Pass	Pass	Pass	Fail	N/A
TrafFix Devices	1800 LDPE	San-Fil	Fail	Fail	Fail	Fail	N/A
TrafFix Devices	1800 HDPE	San-Fil	Fail	Pass	Fail	Pass	N/A
Lakeside Plastics	TRI-TIX	Plain	Pass	Fail	Fail	Pass	N/A
Flex-O-Lite	HDPE	Plain	Pass	Fail	Fail	Fail	N/A
Flex-O-Lite	HDPE	Rubber	Pass	Fail	Fail	Fail	N/A
Flex-O-Lite	LDPE	Plain	Pass	Fail	Fail	Fail	N/A
Flex-O-Lite	LDPE	Rubber	Pass	Fail	Fail	Fail	N/A
Services & Materials	BOUNCER	Plain	Fail	Fail	Fail	Pass	N/A
Plastic Safety Systems, Inc.	Lifegard HDPE	Truck Tire Sidewall	Fail	Fail	Fail	Fail	N/A
Plastic Safety Systems, Inc.	Lifegard LDPE	Truck Tire Sidewall	Fail	Fail	Fail	Fail	N/A
Radiator Specialty	HD 8	Rubber	Fail	Fail	Pass	Fail	N/A
Radiator Specialty	LD 10	Plain	Fail	Pass	Fail	Fail	N/A
Radiator Specialty	HD 8	Plain	Fail	Fail	Pass	Fail	N/A
Radiator Specialty	LD 10	Rubber	Fail	Pass	Fail	Fail	N/A

Diameter. The smallest diameters of the drums range from 455 to 491 mm (17.9 to 19.3 in.) and the largest diameters range from 511 to 561 mm (20.1 to 22.1 in.). The draft specification requires a minimum diameter of 457 mm (18 in.), which is met by all the plastic drum models tested except for those manufactured by Radiator Specialty Co.

Wall Thickness. The draft specification requires a wall thickness between 2.03 and 2.29 mm (0.080 and 0.090 in.) at the top, between 1.52 and 1.78 mm (0.060 and 0.070 in.) at the middle, and between 1.78 and 2.03 mm (0.070 and 0.080 in.) at the bottom of the drum body. Except for the TrafFix Devices model 1800 HDPE(LW), all the other plastic drum models tested failed to meet at least one of the wall thickness requirements, as shown in Table 4. The TrafFix Devices models 1800 LDPE and 1800 HDPE are too thin at the top and too thick at the bottom. The Lakeside Plastics TRI-TIX model and all four Flex-O-Lite models are too thick at the middle and bottom. The Services & Materials BOUNCER model is too thin at the top and too thick at the middle and bottom. The Plastic Safety Systems Lifegard HDPE model is too thin at all three locations while the LDPE model is too thick at all three locations. The Radiator Specialty HD 8 model is too thick at the top and center and the LD 10 model is too thick at the top and bottom.

Weight. The draft specification requires the unballasted weight of the drum body to be between 3.4 and 3.9 kg (7.5 and 8.5 lb). Again, most of the models tested failed to meet this requirement, as shown in Table 4. TrafFix Devices model 1800 HDPE(LW), Plastic Safety Systems model Lifegard HDPE, and Radiator Specialty model HD 8 weigh less than the minimum weight of 3.4 kg (7.5 lb) while TrafFix Devices model 1800 LDPE, all Flex-O-Lite models, Plastic Safety Systems model Lifegard LDPE, and Radiator Specialty model LD 10 weigh more than the maximum weight of 3.9 kg (8.5 lb). The Flex-O-Lite solid rubber bases (18.4 kg [40.6 lb]), the Plastic Safety Systems truck tire sidewall bases (12.0 and 14.2 kg [26.55 and 31.35 lb]), and the Radiator Specialty solid rubber bases (13.5 kg [29.8 lb]) weigh less than the specified 23 kg (50 lb) for self-contained bases. Note that the weights of the Plastic Safety Systems truck tire sidewall bases differ considerably between the two samples which is not unexpected since the bases are cut from used truck tires.

3.2 STATIC FORCE TESTS

Table 5 summarizes the results of the static force tests, including the fixed base vertical pull force test, the static crush test, the horizontal tip force test, and the horizontal pull force test. Table 6 summarizes the comparison of the test results with the specified requirements. Note that the horizontal tip force test and the horizontal pull force test are not included in the draft specification; therefore, comparisons of the results of these two tests with the specified requirements are not applicable.

3.2.1 Fixed Base Vertical Pull Force Test

The draft specification requires that the fixed base vertical pull force be between 63.5 and 136 kg (140 and 300 lb). The purpose of the vertical pull force test is to determine how easy the

Table 5. Results of Vertical Pull, Static Crush, Horizontal Tip and Pull Tests

Manufacturer	Model No.	Base Type	Vertical Pull Force kg (lb)	Static Crush Force kg (lb)	Horizontal Tip			
					Top		Center	
					Tip/ Slide	Force kg (lb)	Tip/ Slide	Force kg (lb)
TrafFix Devices	1800 HDPE(LW)	San-Fil	140.6 (310)	38.1 (84.0)	S	12.2 (27.0)	S	10.9 (24.0)
TrafFix Devices	1800 LDPE	San-Fil	95.3 (210)	35.2 (77.5)	S	12.5 (27.5)	S	11.3 (25.0)
TrafFix Devices	1800 HDPE	San-Fil	133.8 (295)	47.6 (105)	S	10.2 (22.5)	S	9.5 (21.0)
Lakeside Plastics	TRI-TIX	Plain	125.6 (277)	53.5 (118)	S	11.3 (25.0)	S	10.0 (22.0)
Flex-O-Lite	HDPE	Plain	107.5 (237)	72.8 (160.5)	S	11.8 (26.0)	S	10.9 (24.0)
Flex-O-Lite	HDPE	Rubber	146.1 (322)	56.9 (125.5)	T	11.8 (26.0)	T	18.1 (40.0)
Flex-O-Lite	LDPE	Plain	50.3 (111)	39.2 (86.5)	T	12.7 (28.0)	S	13.6 (30.0)
Flex-O-Lite	LDPE	Rubber	88.0 (194)	25.6 (56.5)	T	12.7 (28.0)	S	17.0 (37.5)
Services & Materials	BOUNCER	Plain	123.4 (272)	72.8 (160.5)	T	8.6 (19.0)	S	10.9 (24.0)
Plastic Safety Systems, Inc.	Lifegard HDPE	Truck Tire Sidewall	N/A	20.0 (44.0)	S	7.0 (15.5)	S	6.8 (15.0)
Plastic Safety Systems, Inc.	Lifegard LDPE	Truck Tire Sidewall	N/A	19.1 (42.0)	T	6.8 (14.9)	S	6.3 (13.8)
Radiator Specialty	HD 8	Rubber	44.3 (97.7)	40.8 (90.0)	T	6.4 (14.0)	S	9.1 (20.0)
Radiator Specialty	LD 10	Plain	74.8 (165.0)	51.3 (113.0)	T	13.6 (30.0)	S	13.6 (30.0)
Radiator Specialty	HD 8	Plain	47.6 (105.0)	43.1 (95.0)	T	13.2 (29.0)	S	12.2 (27.0)
Radiator Specialty	LD 10	Rubber	44.5 (98.0)	44.5 (98.0)	T	5.4 (12.0)	T	10.0 (22.0)

*Bent before release. **Bent, did not release. S - Slide. T - Tip. N/A - Not applicable.

Table 5. Results of Vertical Pull, Static Crush, Horizontal Tip and Pull Tests (Continued)

Manufacturer	Model No.	Base Type	Horizontal Pull Force, kg (lb)			
			0 deg.	90 deg.	180 deg.	270 deg.
TrafFix Devices	1800 HDPE(LW)	San-Fil	90.7 (200)	132.7 (292.5)	150.8** (332.5)	117.5 (259)
TrafFix Devices	1800 LDPE	San-Fil	64.6 (142.5)	83.9 (185)	121.8 (268.5)	99.6 (219.5)
TrafFix Devices	1800 HDPE	San-Fil	81.4 (179.5)	124.7* (275)	141.1** (311)	137.7 (303.5)
Lakeside Plastics	TRI-TIX	Plain	51.7 (114)	65.3 (144)	56.2 (124)	54.9 (121)
Flex-O-Lite	HDPE	Plain	55.8 (123)	66.2 (146)	132.7 (292.5)	62.4 (137.5)
Flex-O-Lite	HDPE	Rubber	97.3 (214.5)	137.7 (303.5)	152.4** (336)	122.7 (270.5)
Flex-O-Lite	LDPE	Plain	36.3 (80)	42.0 (92.5)	71.7 (158)	40.4 (89)
Flex-O-Lite	LDPE	Rubber	56.5 (124.5)	80.5** (177.5)	97.5 (215)	70.3 (155)
Services & Materials	BOUNCER	Plain	50.3 (111)	50.1 (110.5)	34.0 (75)	43.8 (96.5)
Plastic Safety Systems, Inc.	Lifegard HDPE	Truck Tire Sidewall	N/A	N/A	N/A	N/A
Plastic Safety Systems, Inc.	Lifegard LDPE	Truck Tire Sidewall	N/A	N/A	N/A	N/A
Radiator Specialty	HD 8	Rubber	-	-	-	-
Radiator Specialty	LD 10	Plain	-	-	-	-
Radiator Specialty	HD 8	Plain	-	-	-	-
Radiator Specialty	LD 10	Rubber	-	-	-	-

*Bent before release. **Bent, did not release.

Table 6. Comparison of Results of Vertical Pull and Static Crush Tests with Draft Specification

Manufacturer	Model No.	Base Type	Vertical Pull Test	Static Crush Test
TrafFix Devices	1800 HDPE(LW)	San-Fil	Fail	Pass
TrafFix Devices	1800 LDPE	San-Fil	Pass	Pass
TrafFix Devices	1800 HDPE	San-Fil	Pass	Fail
Lakeside Plastics	TRI-TIX	Plain	Pass	Fail
Flex-O-Lite	HDPE	Plain	Pass	Fail
Flex-O-Lite	HDPE	Solid Rubber	Fail	Fail
Flex-O-Lite	LDPE	Plain	Fail	Pass
Flex-O-Lite	LDPE	Solid Rubber	Pass	Fail
Services & Materials	BOUNCER	Plain	Pass	Fail
Plastic Safety Systems, Inc.	Lifegard HDPE	Truck Tire Sidewall	N/A	Fail
Plastic Safety Systems, Inc.	Lifegard LDPE	Truck Tire Sidewall	N/A	Fail
Radiator Specialty	HD 8	Rubber	Fail	Pass
Radiator Specialty	LD 10	Plain	Pass	Fail
Radiator Specialty	HD 8	Plain	Fail	Fail
Radiator Specialty	LD 10	Rubber	Fail	Fail

drum body can be separated from the base. A low vertical pull force means that the drum body separates too easily from the base. This could potentially pose a problem when the drum is unintentionally bumped into by workers or equipment or has to be moved or repositioned. Too high a vertical pull force means that the drum body would not separate readily from the base. If, during impact, the drum body remains attached to the base and the accompanying weight, either from sand bags or the self-contained base, the entire plastic drum assembly could be thrown forward as a projectile, creating a hazard to workers or adjacent traffic.

Some of the models tested failed to meet this requirement. Four of the 15 models (Flex-O-Lite model LDPE with plain base, Radiator Specialty model HD 8 with either plain or solid rubber base, and Radiator Specialty model LD 10 with solid rubber base), had lower than specified vertical pull forces, ranging from 44.3 to 50.3 kg (97.7 to 111 lb). Two of the 15 models (TrafFix Devices model 1800 HDPE(LW) and Flex-O-Lite model HDPE with solid rubber base) had higher than specified vertical pull forces, ranging from 140.6 to 146.1 kg (310 to 322 lb).

Note that researchers did not conduct the fixed base vertical pull test for the two Plastic Safety Systems Lifegard models since they used truck tire sidewalls as the base, and cannot be properly affixed to the floor in accordance with the test procedure.

3.2.2 Static Crush Force Test

The draft specification requires that the static crush force be between 32 and 41 kg (70 and 90 lb). The purpose of the static crush force test is to determine how easy the drum body can be crushed. A low crush force means that the drum body can be crushed too easily and may pose a durability problem under normal usage. Too high a crush force means that the drum body may not readily crush upon impact, and result in the drum body not properly separating from the base. If, during impact, the drum body remains attached to the base and the accompanying weight, either from sand bags or the self-contained base, the entire plastic drum assembly could be thrown forward as a projectile, creating a hazard to workers or adjacent traffic.

Most of the models tested failed to meet this requirement. Nine of the 15 models (TrafFix Devices model 1800 HDPE, Lakeside Plastics TRI-TIX, Flex-O-Lite models HDPE with either plain or solid rubber bases, Services & Materials BOUNCER model, Radiator Specialty model HD 8 with plain base, and Radiator Specialty model LD 10 with either plain or solid rubber base) had higher than specified static crush forces, ranging from 43.1 to 72.8 kg (95 to 160.5 lb). Three of the 15 models (Flex-O-Lite model HDPE with solid rubber base and the two models by Plastic Safety Systems) had lower than specified static crush forces, ranging from 19.1 to 25.6 kg (42 to 56.5 lb).

3.2.3 Horizontal Tip Force Test

The horizontal tip force test was not part of the draft specification and was added to the list of tests. Thus, there is no comparison with the specification. The purpose of this test is to evaluate the force required to cause the drum to tip over or slide on its base, such as that caused by a passing truck. Researchers conducted two separate tests. One test was with the horizontal force applied at

the top of the drum to simulate the presence of a sign panel, such as a chevron sign, on top of the drum. The other test was with the horizontal force applied to the middle of the drum to simulate the wind load acting on the drum only with no sign attached. The tipping over of the drum would be more undesirable than the sliding of the drum since a tipped over drum could roll around on its side and pose a potential hazard to adjacent traffic.

Nine of the 15 models tested tipped over with the horizontal force applied to the top of the drum while six models slid on the bases without tipping over. The nine models that tipped over are Flex-O-Lite models HDPE with solid rubber base and LDPE with both plain and solid rubber bases, Services & Materials BOUNCER model, Plastic Safety Systems Lifegard LDPE model and the two Radiator Specialty models with both plain and solid rubber bases. As mentioned previously, models that tipped over could have a potential problem associated with attaching a sign panel to the top of the drum. The horizontal force applied to the top of the drum to cause the drum to tip over or slide is mostly in the range of 10.2 to 13.6 kg (22.5 to 30 lb) except for the Services & Materials BOUNCER model, 8.6 kg (19 lb), the two Plastic Safety Systems Lifegard models, 6.8 and 7.0 kg (14.9 and 15.5 lb), and the two Radiator Specialty models with rubber bases, 5.4 and 6.4 kg (12 and 16 lb).

Only two of the 15 models tested (Flex-O-Lite model HDPE with solid rubber base and Radiator Specialty model LD 10 with solid rubber base) tipped over with the horizontal force applied to the middle of the drum. However, the horizontal force required for the Flex-O-Lite model HDPE with solid rubber base to tip over, 18.1 kg (40 lb), is higher than the forces required for the other models to begin sliding. On the other hand, the horizontal force required for the Radiator Specialty model LD 10 with solid rubber base to tip over, 10.0 kg (22.0 lb), is lower than average, suggesting that this model may be prone to tip over. Most drum models require horizontal forces in the range of 9.5 to 17.0 kg (21 to 37.5 lb). The two Plastic Safety Systems Lifegard models, again, had the lowest horizontal tip/slide force at 6.3 and 6.8 kg (13.8 and 15 lb).

3.2.4 Fixed Base Horizontal Pull Force Test

The horizontal pull force test was also not part of the draft specification and was added to the list of tests. Thus, there is no comparison with the specifications. The purpose of this test is to evaluate the horizontal force required to separate the drum body from the base, which may provide some indication as to how easily the drum body may separate from the base upon impact by a vehicle.

Note that researchers did not conduct the horizontal pull test for the two Plastic Safety Systems Lifegard models since they use truck tire sidewalls as the base, and cannot be properly affixed to the floor in accordance with the test procedure.

During the initial testing, it was noted that the drums do not have symmetrical bases. It was decided therefore to conduct the test for four different orientations of the drum. The zero (0) degree orientation corresponds to the normal position of the drum when a sign panel is attached. The other three orientations are 90, 180, and 270 degrees.

The test results show great variations among the models and among the different orientations. In one test, the drum body was bent before separating from the base. In four other tests, the drum body was bent and not separated from the base. It was difficult to draw meaningful conclusions from the test results due to the wide scatter. Also, the drum will start to tip or slide under much lower force level. Thus, the fixed base horizontal pull test is not realistic and probably of little significance. Therefore researchers performed no further analysis with the results of the fixed base horizontal pull force test.

Researchers received the plastic drum models from Radiator Specialty after conducting and analyzing the tests on the other models. After concluding that the horizontal pull force test was not realistic and of little significance, researchers did not conduct the test for the plastic drum models from Radiator Specialty.

3.3 FULL-SCALE CRASH TESTS

A total of 15 full-scale crash tests were conducted on various plastic drums supplied by the manufacturers, a list of which is shown in Table 7. Note that Lakeside Plastics supplied only two TRI-TIX model plastic drums for testing. These were used in the dimensional measurements and static force tests, thus, no sample was available for the crash test. However, in order to maintain the same numbering scheme as in the dimensional measurements and static force tests, the TRI-TIX model by Lakeside Plastics is shown as test no. 4 in Table 7.

All crash tests, with the exception of test no. 16, involved an 820-kg (1,808-lb) passenger car impacting the plastic drum head-on at a nominal speed of 100 km/h (62.2 mph) with the centerline of the vehicle aligned with the centerline of the drum. In test no. 16, a Plastic Safety Systems Lifegard model plastic drum, which uses a cutout truck tire sidewall as the base, was tested at a low nominal impact speed of 35 km/h (21.8 mph) to evaluate if the plastic drum would readily separate from the base at low impact speed.

Table 8 shows a summary of the crash tests. All the plastic drum models separated cleanly and readily from the bases, including the Plastic Safety Systems Lifegard models, which use cutout truck tire sidewalls as bases. There was some initial concern that the drum body for some models might not separate properly from the base, resulting in the entire drum assembly with the ballast being thrown forward by the impacting vehicle and creating a potential hazard to adjacent traffic and workers. Thus, upper bounds were established for the vertical pull force and the static crush force to assure that the drum body will separate properly from the base. Results of the crash test indicate that the drum body will readily separate from the base upon impact; therefore, upper bounds for the vertical pull force and the static crush force do not appear to be necessary and could be eliminated.

Researchers noted that the two plastic drum models by Radiator Specialty (HD 8 and LD 10) were very loose fitting with both the rubber and plain bases such that the drum body separates from the base with a slight pull by one hand. This is in general agreement with the lower than average vertical pull force measurements of these models.

All the drum bodies were deformed during impact. Some of the drum bodies rebounded to their original shape after the impacts (the two Flex-O-Lite models); others could be restored to their original shape and be reusable (the three TrafFix Devices models, the Services and Materials BOUNCER model, and the Radiator Specialty LD 10 model); others were deformed too severely to be restored to their original shape and were not reusable (the two Plastic Safety System Lifegard models and the Radiator Specialty HD 8 model with the plain base); and one model (the Radiator Specialty HD 8 model with the rubber base) was torn. Also, the drum body of the Plastic Safety System Lifegard LDPE model was deformed in the low-speed test, but could be restored to its original shape and be reusable. There was little or no damage to the test vehicle in all the tests.

It appears that the wall thickness and weight of the drum body provide a good indication of the extent of deformation to the plastic drum body. Of the plastic drum models that were severely deformed and not reusable, the Plastic Safety System Lifeguard HDPE model has the thinnest wall thickness and lowest weight of all models tested. The Radiator Specialty HD 8 model has relatively thin wall thickness at the bottom and is the next to the lowest in weight. However, there appear to be other factors that also affect the extent of deformation, such as the time required for the drum body to be separated from the base during impact and the chemical composition and properties of the plastic. For example, it took longer for the drum body to be separated from the base due to the cutout truck tire sidewall base for the two Plastic Safety System Lifeguard models. The plastic material for the Radiator Specialty HD 8 model appears to be rather brittle and was the only model that was torn in a crash test. It may be desirable to check the chemical composition and properties of the plastic material of this model for conformance with the specification.

The trajectories of the drum bodies upon separation from the base were either going over the top of the vehicle or staying with the front of the vehicle. In the low-speed test of the Plastic Safety System Lifeguard LDPE model, the drum body went underneath the vehicle. There is no clear trend as to when a drum body will go over the vehicle or stay with the front of the vehicle. In any event, the trajectories of the drum bodies did not appear to pose any undue hazards to adjacent traffic or to the workers in all the tests.

Table 7. List of Plastic Drum Models Crash Tested

Crash Test No.	Manufacturer	Model No.	Base Type
1	TrafFix Devices, Inc.	1800 HDPE(LW)	San-Fil
2	TrafFix Devices, Inc.	1800 LDPE	San-Fil
3	TrafFix Devices, Inc.	1800 HDPE	San-Fil
4*	Lakeside Plastics	TRI-TIX	Plain
5	Flex-O-Lite	HDPE	Plain
6	Flex-O-Lite	HDPE	Rubber
7	Flex-O-Lite	LDPE	Plain
8	Flex-O-Lite	LDPE	Rubber
9	Services & Materials	BOUNCER	Plain
10	Plastic Safety Systems	HDPE	Truck Tire Sidewall
11	Plastic Safety Systems	LDPE	Truck Tire Sidewall
12	Radiator Specialty	HD 8	Rubber
13	Radiator Specialty	LD 10	Plain
14	Radiator Specialty	HD 8	Plain
15	Radiator Specialty	LD 10	Rubber
16**	Plastic Safety Systems	LDPE	Truck Tire Sidewall

* Only 2 samples were provided by the manufacturer which were used in the dimensional measurements and static tests. Thus, no sample was available for the crash test.

** Test was conducted at a nominal speed of 35 km/h (21.8 mph).

Table 8. Summary of Performance of Plastic Drum Models Crash Tested

Crash Test No.	Impact Speed km/h (mph)	Separation	Drum Deformation	Drum Trajectory
1	99.8 (62.0)	Clean	Deformed	Went Over Top of Vehicle
2	99.8 (62.0)	Clean	Deformed	Stayed with Vehicle
3	98.1 (61.0)	Clean	Deformed	Went Over Top of Vehicle
4	N/A	N/A	N/A	N/A
5	98.1 (61.0)	Clean	Rebounded	Stayed with Vehicle
6	98.1 (61.0)	Clean	Rebounded	Went Over Top of Vehicle
7	101.4 (63.0)	Clean	Rebounded	Stayed with Vehicle
8	99.8 (62.0)	Clean	Rebounded	Went Over Top of Vehicle
9	99.8 (62.0)	Clean	Deformed	Stayed with Vehicle
10	99.8 (62.0)	Clean	Severely Deformed	Stayed with Vehicle
11	99.8 (62.0)	Clean	Severely Deformed	Stayed with Vehicle
12	99.8 (62.0)	Clean	Torn	Went Over Top of Vehicle
13	98.1 (61.0)	Clean	Deformed	Stayed with Vehicle
14	99.8 (62.0)	Clean	Severely Deformed	Stayed with Vehicle
15	98.1 (61.0)	Clean	Deformed	Stayed with Vehicle
16	30.6 (19.0)	Clean	Rebounded	Went Underneath and Stayed with Vehicle

IV. SUMMARY OF FINDINGS AND RECOMMENDATIONS

Findings and recommendations based on the results of the dimensional measurements, static force tests, and full-scale crash tests, follow.

4.1 SUMMARY OF FINDINGS AND RECOMMENDATIONS

- The specification should clarify whether the minimum height of 914 mm (36 in.) should apply to the drum body only or the total height, including the base. It appears that the total height may be more appropriate and is therefore recommended. Also, it may be desirable to specify a maximum height since sight distance may be a consideration at some work zones.

- All 15 models tested met the requirements for minimum height and minimum diameter except for the models by Radiator Specialty which are 2 mm (0.1 in) less than specified minimum diameter.

- The wall thickness requirements in the draft specification may be too restrictive as evidenced by the fact that only one of the 15 models tested met these requirements for all three locations, i.e., top, center and bottom. Also, there is no apparent need to specify the upper bound for the wall thickness. An upper bound for the weight of the drum body serves the same purpose. It may be simpler to specify only a lower bound for the wall thickness, e.g., 1.75 mm (0.069 in.), for all three locations, but require samples at each of the three locations.

- Similarly, the unballasted weight requirement of 3.4 to 3.9 kg (7.5 to 8.5 lb) for the drum body may also be too restrictive with only three of the 15 models tested meeting this requirement. A broader range, for instance, 3.5 to 5.0 kg (7.7 to 11.0 lb), may be more appropriate given the range of drum body weights measured.

- The definition for self-contained bases may have to be broadened to include not only bases with sand-filled containers, but also solid bases made from rubber or other materials. A range of weight would then be specified for such self-contained bases with built-in ballasts, such as 17.5 to 22.5 kg (38.6 to 49.6 lb).

- Six of the 13 models tested failed to meet the vertical pull force requirement of between 63.5 and 136 kg (140 and 300 lb). Two of the failed models had vertical pull forces that were slightly higher than the maximum and four failed models had vertical pull forces that were too low. The specified range of vertical pull force appears to be reasonable. Results of the full-scale crash tests indicate that the drum bodies separate readily from the bases. Thus, there is no reason to specify an upper bound for the vertical pull force. However, from an operational standpoint, it may be desirable to specify an upper bound to ensure that the drum body can be readily separated from the base by workers when the need arises. An expanded range of forces between 65 and 150 kg (143 and 330 lb) may be appropriate.

It was noted that the footholds for some of the bases are too small, thus making the task of separating the drum body from the base very difficult and cumbersome. It may be desirable to mention in the specification the need for adequate-sized footholds.

- The requirement that the static crush force be between 32 and 41 kg (70 and 90 lb) may be too restrictive as only four of the 15 models tested met this requirement. Again, results of the full-scale crash tests indicate that the drum bodies separate readily from the bases. Thus, there is no reason to specify an upper bound for the static crush force. It may be desirable to specify only lower bound, such as 35 kg (77 lb).

- The horizontal tip force test provides some useful information and is recommended for inclusion in the specifications. The purpose of this test is to evaluate the force required to cause the drum to tip over or slide on its base, such as that caused by a passing truck.

- The truck tire sidewall bases used with the Plastic Safety System Lifeguard models and the rubber bases used with the Radiator Specialty models weigh in the range of 12 to 14.2 kg (26.6 to 31.4 lb), which are substantially less than the specified weight of 22.7 kg (50 lb). The relative light weight of the bases resulted in low horizontal tip force and the propensity for the drums to tip over. It may be desirable to specify a range for the weight of self-contained bases with built-in ballast, such as between 18 and 22.5 kg (39.7 to 49.6 lb).

- The fixed base horizontal pull force test results show wide scatter among the models and the different orientations. It was difficult to draw meaningful conclusions from the test results due to the wide scatter. Also, the drum will start to tip or slide under much lower force levels. Thus, the fixed base horizontal pull test is not realistic and is probably of little significance. Therefore the researchers concluded that the fixed base horizontal pull force test is not an appropriate test and should not be considered for inclusion in the specifications.

- All the plastic drum models separated cleanly and readily from the bases in the full-scale crash tests, including the Plastic Safety Systems Lifegard plastic drums, which use cutout truck tire sidewalls as bases.

- All the drum bodies were deformed during impact. Some of the drum bodies rebounded to their original shape after the impacts while others could be restored to their original shape and be reusable. However, the two Plastic Safety Systems Lifegard models were too deformed to be restored to their original shape and were not reusable. This is in agreement with the thin wall thicknesses and the low static crush force measured for these models. The Radiator Specialty HD 8 model was torn in one test and severely deformed in another. The wall thickness for this model is relatively thin and the weight of the drum body is next to the lowest of the models tested. The researchers recommend that the composition and properties of the plastic material on this model, e.g., hardness, ductility (bend test), and tensile strength, be checked in accordance with the draft specification (Section VI, Items O, P and U).

- The trajectories of the drum bodies upon separation from the base were either going over the top of the vehicle or staying with the vehicle. The Plastic Safety System Lifegard LDPE model went underneath and stayed with the vehicle in the low-speed test. However, the

trajectories of the drum bodies did not appear to pose any undue hazards to adjacent traffic or to the workers in all the tests.

- The results of the crash tests indicate that the plastic drums by themselves do not pose any significant hazard to the impacting vehicle or to workers in work zones. Approval and selection of plastic drums should therefore not be based primarily on safety concerns, but on operational considerations, such as durability, ease of handling, and maintenance requirements.

- The two Plastic Safety Systems Lifegard plastic drum models using truck tire sidewalls as the base pose some potential problems. First, there appears to be some quality control problem. The HDPE model has the smallest sidewall thickness among the models tested and the lowest drum body weight. Second, both models have very low crush resistance, as evidenced by the low static crush forces and the severe deformation sustained in the full-scale crash tests. Third, both models have very low horizontal tip/slide force threshold, indicating that the models may be prone to tipping over or sliding on the bases from wind loads induced by passing trucks.

- The two plastic drum models by Radiator Specialty (HD 8 and LD 10) were very loose fitting with both the rubber and plain bases such that the drum body separates from the base with a slight pull by one hand. Also, the HD 8 model was torn in one test and severely deformed in another.

4.2 REVISED DRAFT SPECIFICATION

Based on results of the study, researchers prepared a revised draft specification for plastic traffic drums (see Appendix B). The revisions pertain to Part VI of the specification, "Material and Construction Requirement." Highlights of the revisions follow:

- All English units in the draft specifications are hard converted to metric units with English units shown in parentheses.

- Item D. The height measurements are specified for the drum with base attached. A maximum height is added. A single lower bound of wall thickness is specified for samples taken from all three locations, i.e., at the center and near the top and bottom, of the drum body.

- Item E. The range of weight for the drum body is revised.

- Item J. Specification for a self-contained base with built-in ballast, such as a solid rubber base, is added with a range on the weight of the base. Specification for a plain corrugated base is reworded. Also, specification is added regarding the number and size of footholds for the base.

- Item X. The range of acceptable vertical pull force is revised. Descriptions of the apparatus and procedure are reworded.

- Item Y. The range of acceptable static crash force is revised. Descriptions of the apparatus and procedure are reworded.

- A new Item Z specifying the horizontal tip test is added.

Tables 9 and 10, respectively, show comparisons of the results from the dimensional measurements and static force tests with the revised draft specifications. Again, the results are denoted as pass (meeting specification), fail (not meeting specification), or N/A (not applicable or not specified).

Five of the 15 plastic drum models passed all requirements set forth in the revised draft specification: TrafFix Devices models 1800 LDPE and 1800 HDPE, Lakeside Plastics model TRI-TIX, and Flex-O-Lite HDPE model with either plain or solid rubber base. Another five models failed to meet one requirement of the revised draft specification: TrafFix Devices 1800 HDPE(LW) model (low drum body weight), Flex-O-Lite LDPE model with plain base (vertical pull force), Flex-O-Lite LDPE model with solid rubber base (static crush force), Service and Materials BOUNCER model (horizontal tip force at top of drum), and Radiator Specialty LD 10 model with plain base (wall thickness).

The remaining five plastic drum models failed to meet multiple requirements of the revised draft specification: Plastic Safety System Lifegard HDPE model (wall thickness, drum body and base weight, static crush force, and horizontal tip force at both top and center of drum); Plastic Safety System Lifegard LDPE model (base weight, static crush force, and horizontal tip force at both top and center of drum); Radiator Specialty HD 8 model with solid rubber base (drum body and base weight, vertical pull force, and horizontal tip force at both top and center of drum); Radiator Specialty HD 8 model with plain base (drum body weight and vertical pull force); and Radiator Specialty LD 10 model with solid rubber base (wall thickness, vertical pull force, and horizontal tip force at both top and center of drum).

Table 9. Comparison of Dimensional Measurements with Revised Draft Specification

Manufacturer	Model No.	Base Type	Dimensional Measurements					
			Height		Dia-meter	Wall Thickness	Weight	
			Total	Base			Body	Base
TrafFix Devices	1800 HDPE(LW)	San-Fil	Pass	Pass	Pass	Pass	Fail	Pass
TrafFix Devices	1800 LDPE	San-Fil	Pass	Pass	Pass	Pass	Pass	Pass
TrafFix Devices	1800 HDPE	San-Fil	Pass	Pass	Pass	Pass	Pass	Pass
Lakeside Plastics	TRI-TIX	Plain	Pass	Pass	Pass	Pass	Pass	Pass
Flex-O-Lite	HDPE	Plain	Pass	Pass	Pass	Pass	Pass	Pass
Flex-O-Lite	HDPE	Rubber	Pass	Pass	Pass	Pass	Pass	Pass
Flex-O-Lite	LDPE	Plain	Pass	Pass	Pass	Pass	Pass	Pass
Flex-O-Lite	LDPE	Rubber	Pass	Pass	Pass	Pass	Pass	Pass
Services & Materials	BOUNCER	Plain	Pass	Pass	Pass	Pass	Pass	Pass
Plastic Safety Systems, Inc.	Lifegard HDPE	Truck Tire Sidewall	Pass	Pass	Pass	Fail	Fail	Fail
Plastic Safety Systems, Inc.	Lifegard LDPE	Truck Tire Sidewall	Pass	Pass	Pass	Pass	Pass	Fail
Radiator Specialty	HD 8	Rubber	Pass	Pass	Pass	Pass	Fail	Fail
Radiator Specialty	LD 10	Plain	Pass	Pass	Pass	Fail	Pass	Pass
Radiator Specialty	HD 8	Plain	Pass	Pass	Pass	Pass	Fail	Pass
Radiator Specialty	LD 10	Rubber	Pass	Pass	Pass	Fail	Pass	Fail

Table 10. Comparison of Results of Vertical Pull, Static Crush, and Horizontal Tip Tests with Revised Draft Specification

Manufacturer	Model No.	Base Type	Vertical Pull Test	Static Crush Test	Horizontal Tip Test	
					Top	Center
TrafFix Devices	1800 HDPE(LW)	San-Fil	Pass	Pass	Pass	Pass
TrafFix Devices	1800 LDPE	San-Fil	Pass	Pass	Pass	Pass
TrafFix Devices	1800 HDPE	San-Fil	Pass	Pass	Pass	Pass
Lakeside Plastics	TRI-TIX	Plain	Pass	Pass	Pass	Pass
Flex-O-Lite	HDPE	Plain	Pass	Pass	Pass	Pass
Flex-O-Lite	HDPE	Solid Rubber	Pass	Pass	Pass	Pass
Flex-O-Lite	LDPE	Plain	Fail	Pass	Pass	Pass
Flex-O-Lite	LDPE	Solid Rubber	Pass	Fail	Pass	Pass
Services & Materials	BOUNCER	Plain	Pass	Pass	Fail	Pass
Plastic Safety Systems, Inc.	Lifegard HDPE	Truck Tire Sidewall	N/A	Fail	Fail	Fail
Plastic Safety Systems, Inc.	Lifegard LDPE	Truck Tire Sidewall	N/A	Fail	Fail	Fail
Radiator Specialty	HD 8	Rubber	Fail	Pass	Fail	Fail
Radiator Specialty	LD 10	Plain	Pass	Pass	Pass	Pass
Radiator Specialty	HD 8	Plain	Fail	Pass	Pass	Pass
Radiator Specialty	LD 10	Rubber	Fail	Pass	Fail	Fail

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1. Mak, K. K., and W. L. Campise, "Testing and Evaluation of Traffic Control Devices for Use in Work Zones," Final Report, Project No. 9850B, Texas Transportation Institute, Texas A&M University, College Station, Texas, January 1990.

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4. Ross, H. E., Jr., D. L. Sicking, R. A. Zimmer, and J. D. Michie, "Recommended Procedures for the Safety Performance Evaluation of Highway Features," NCHRP Report 350, National Cooperative Highway Research Program, Transportation Research Board, Washington, D. C., 1993.

APPENDIX A

DRAFT SPECIFICATION FOR PLASTIC DRUMS

DRAFT

TEXAS DEPARTMENT OF TRANSPORTATION

Departmental Materials Specification: D-9-XXXX

Plastic Traffic Drum

I. Description: This specification shall govern for the material, composition, quality, sampling, and testing of breakaway plastic traffic drums for use as channeling devices on highway construction and maintenance activities.

II. Bidder's and/or Supplier's Requirements: All prospective Bidders and/or Suppliers are hereby notified that before any material is considered, it shall be of manufacture and product code or designation shown on the list of approved manufacturers of materials covered by this specification maintained by the Department's Division of Materials and Tests.

III. Payment:

A. Procurement by the State: Payment for all materials under this specification shall be in accordance with the conditions prescribed in the contract awarded by the State.

B. Contracts: All materials under this specification utilized by the Contractor shall be considered subsidiary to *Item "Barricades Signs and Traffic Handling"* or as otherwise specified in the contract.

IV. Prequalification and Performance History:

A. Establishment of Performance History: Prospective Bidders and/or Suppliers who desire to prequalify and establish a performance history for their product governed by this specification, should contact the Texas Department of Transportation, Attention: Division of Equipment and Procurement, 125 E 11th St., Austin, Texas, 78701-2483.

Included with their request for prequalification shall be a notarized certification from an independent laboratory stating that the laboratory has conducted tests in the manner described below on two randomly selected drums representative of those to be supplied for Department use or on Department contract projects. They shall also submit two randomly selected drums representative of those to be supplied for Department use for testing by the Department. These two drums shall be submitted at no cost to the Department.

A new certification will be required every two (2) years upon any modification of the drum or any change in the formulation of the plastics used in its manufacture.

Prospective Bidders and/or Suppliers will be notified, after their material has been evaluated, as to conformance with the requirements of this specification.

The Department reserves the right to perform any or all of the tests required by this specification as a check on the tests reported by the Manufacturer. In the case of any variance, the Departmental tests will govern.

B. Performance History: Some of the tests required by this specification extend over a prolonged period of time. Therefore, testing for acceptance of materials supplied on any contract or State purchase order shall only be considered on those materials which are determined by the Director of Materials and Tests to be identifiable as a material having an established performance history of compliance with the criteria established by this specification.

C. Re-evaluation: The Manufacturer/Supplier shall notify the Director of Materials and Tests of any changes made in the composition or manufacturing process of a prequalified material. A re-evaluation of the material shall be required if, in the opinion of the Director of Materials and Tests, these changes may affect the durability or performance of the material.

Changes that are detected in composition, manufacturing process or quality, that may affect its durability or performance and that have not been reported by the Manufacturer, shall be cause for removal of that material from the list of prequalified materials.

The Department reserves the right to conduct whatever tests are deemed necessary to identify a prequalified material and to determine if a change has been made in composition, manufacturing process, or quality which may affect its durability or performance.

D. Periodic Evaluation: The Department reserves the right to periodically evaluate the performance of these materials. Samples for periodic evaluation of performance will be selected at random from materials submitted to the Department on contracts or direct State purchase orders.

Failure of materials to comply with the requirements of this specification as a result of periodic evaluation, shall be cause for removal of those materials from the list of prequalified materials.

V. Sampling and Testing A minimum of two drums, at the Engineer's option, may be randomly selected for testing from each batch or order supplied on direct State purchase or contract. Sampling shall be done by Department personnel or authorized representative. Costs of sampling and testing are normally borne by the Department. However, the costs of sampling and testing of the materials failing to conform with the requirements of this specification shall be borne by the Contractor or Supplier. Costs of sampling and testing failing material shall be assessed at the rate established by the Director of Materials and Tests and in effect at the time of testing. Amounts due the Department for conducting such tests will be deducted from monthly or final estimates on contracts or from partial or final payments on direct purchases by the State.

VI. Materials and Construction Requirements:

A. The drum shall comply with the current version of the *Texas Manual on Uniform Traffic Control Devices* requirements and *Barricade and Construction Standard Sheets.*

B. Drum and base shall be manufactured from ultra-violet stabilized, orange, high-density polyethylene.

C. The design shall consist of a drum body and one piece base which locks together in a manner that will allow the drum body to separate from the base when impacted by a vehicle at 20 mph or higher, but prevents accidental separation from air turbulence created by such things as passing trucks and normal winds.

D. Dimensions: Minimum height of thirty-six (36) inches and minimum diameter of eighteen (18) inches, regardless of vertical orientation. Wall thickness at top of the drum body shall not be less than 0.080 inches and not more than 0.090 inches. Wall thickness at middle of drum body shall not be less than 0.060 inches and not more than 0.070 inches. Wall thickness at bottom of drum body shall not be less than 0.070 inches and not more than 0.080 inches. Samples shall be cut 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 standard micrometer graduated to 0.001 inches. Contours and reinforced areas shall be avoided when sampling.

E. Unballasted weight of drum body shall weigh no less than seven and one-half (7.5) pounds and no more than eight and one-half (8.5) pounds. The actual weight of any drum body shall not vary more than +/- 0.5 lb from that of the pre-qualification sample.

F. Drum and base shall be marked with manufacturers name, model number, and year and month of manufacture.

G. Drums and bases supplied for Department requisitions shall be hot branded with the letters "TxDOT" and the month and year of manufacture in block letters on the outside top of the drum and base. Letters shall be approximately 3/8 in. in height.

H. Drums are to be a tapered design to allow for stacking a minimum of five (5) drums high.

I. The top of the drum shall be closed with a built-in handle for easy pickup. The handle shall be strong enough to mount a battery operated warning light or reflective chevron sign. The top surface shall be designed to drain.

J. The base is to be domed shaped from all approaching directions and is to be a maximum of four (4) inches in height. A self-contained base shall be large enough to hold up to 50 pounds of sand. Bases with a corrugated bottom shall be stiff enough to maintain their shape even when filled with sand.

K. The drum and base shall maintain integrity upon impact throughout a temperature range of -20 F to +170 F without any noticeable change in performance.

L. The exterior of the drum body shall be covered with alternating white and orange material, circumferential, reflectorized stripes not less than four (4) inches or greater than eight (8) inches in width. The top stripe shall be orange.

M. Nonreflectorized spaces between the reflectorized stripes shall not exceed two (2) inches in width.

N. The retroreflectivity and color characteristics of the reflective sheeting shall conform to the requirements of *Departmental Materials Specification D-9-8300: Flat Surface Reflective Sheeting, Type C.* In addition, the sheeting shall be suitable for use on and adhere to the drum surface such that, upon vehicle impact, the sheeting shall remain adhered in-place and exhibit no internal delaminating, internal and external checking and cracking and loss of reflectivity other than the reflectivity loss due to abrasion of the sheeting surface.

O. The hardness of the drum and base material, determined according to *ASTM D2240 Type D*, shall not vary more than +/- 6 from the prequalification average.

P. Drum material shall show no adverse effect when bend-tested in accordance with Part III of *Test Method Tex-441-A.* Substituted for the post in the procedure will be a piece of drum and/or base material twelve (12) inches by three (3) inches or larger.

Q. The infrared spectra of material from drums and bases furnished shall match the spectra on file with the Department from the prequalified drums and bases.

R. The specific gravity of material from drums and bases furnished for prequalification shall range between 0.941 to 0.965. Routine samples shall not vary more than +/- 0.010 from the specific gravity of the prequalified drums and bases. Specific gravity is determined by using *ASTM D 792*.

S. The drum and base material shall show no significant change in color, flexibility, or integrity, when subjected to 1000 hours exposure in an Atlas Carbon Arc Weather-Ometer fitted with an 18-102 cycle gear and tested in accordance with *ASTM G23-81, Method 1, Type EH.*

T. The color of the drums and bases shall be orange and fall within the CIE color coordinates listed below, both before and after exposure testing. Color shall be determined in accordance with *Test Method Tex-839-B.*

Chromaticity Coordinates	
x	y
0.510	0.350
0.510	0.390
0.640	0.360
0.580	0.420

U. The tensile strength of the drum and base material, tested according to *ASTM D 638*, shall match (within 10%) the results from the prequalification samples. The die used to cut the specimens shall meet *ASTM D 412C.*

V. The melt index of the drum and base material, tested according to *ASTM D 1238* at 190 C and 2160 gram load, shall match (within 10%) the melt index of the prequalification samples.

W. The drum and base shall exhibit good workmanship and shall be free from objectionable marks or defects which would adversely affect appearance or serviceability.

X. The fixed base vertical pull force shall not be less than 140 pounds and not more than 300 pounds when tested as described below.

Apparatus

Base attachment fixture - A means of attaching the drum base rigidly to the floor shall be provided. This may be a half-inch threaded rod screwed into a concrete floor. A nine-sixteenths hole is drilled in the center of the base section to accommodate the rod. The base is placed over the rod followed by a one foot diameter, quarter-inch thick steel plate with a nine-sixteenths hole in the center. The plate and base are secured by a finger-tight nut.

Force application fixture - Vertical force is applied to 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 drum base. This may be a manually operated chain or rope hoist.

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 one pound or better. Preferably, the force readout shall 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 two pounds per second.

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 or more of the sign panel attachment points, through a pulley connected to the load cell and back to the other attachment point.

Procedure

Secure the drum base to the floor. 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. 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 five pounds per second if using a strip chart to record the force readout or less than two pounds per second if the force readout is observed and recorded manually, until the drum body separates from the base or a force of 350 pounds is reached, whichever occurs first. Record the highest force value just prior to separation or until a force of 350 pounds is reached. Repeat the procedure a total of three times and average the three readings for the reported value. If the pull force is less than 140 pounds for one of the three pulls, repeat the test a fourth time and exclude the low value if the fourth pull exceeds 140 pounds. If no separation occurred at the 350-pound force level, report as ">350 pounds."

Y. The static crush test results shall not be less than 70 pounds and not more than 90 pounds when tested as described below.

Apparatus

Scale - an electronic or mechanical platform scale with a top surface measuring eighteen inches by twelve inches (18" x 12") and five inches (5") 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.

Procedure

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. The weight of the drum as it rests on the scale shall be recorded and subtracted from the final values. With a person at each end (top and bottom) 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. 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. Warranty: Drums supplied for Department requisitions shall be warranted against defects in material and workmanship for a period of not less than twenty-four (24) months beginning with the date of acceptance. It the Manufacturer's standard warranty exceeds twenty-four months, then the Manufacturer's warranty shall be in effect. The successful Bidder shall furnish a copy of the Manufacturer's warranty to the Department at time of delivery. Any such defective products brought to Vendor's attention within said period shall be returned to Vendor freight collect and shall be replaced without cost.

APPENDIX B

REVISED DRAFT SPECIFICATION FOR PLASTIC DRUMS

REVISED DRAFT

TEXAS DEPARTMENT OF TRANSPORTATION

Departmental Materials Specification: D-9-XXXX

Plastic Traffic Drum

I. Description: This specification shall govern for the material, composition, quality, sampling, and testing of breakaway plastic traffic drums for use as channeling devices on highway construction and maintenance activities.

II. Bidder's and/or Supplier's Requirements: All prospective Bidders and/or Suppliers are hereby notified that before any material is considered, it shall be of manufacture and product code or designation shown on the list of approved manufacturers of materials covered by this specification maintained by the Department's Division of Materials and Tests.

III. Payment:

A. Procurement by the State: Payment for all materials under this specification shall be in accordance with the conditions prescribed in the contract awarded by the State.

B. Contracts: All materials under this specification utilized by the Contractor shall be considered subsidiary to *Item "Barricades Signs and Traffic Handling"* or as otherwise specified in the contract.

IV. Prequalification and Performance History:

A. Establishment of Performance History: Prospective Bidders and/or Suppliers who desire to prequalify and establish a performance history for their product governed by this specification, should contact the Texas Department of Transportation, Attention: Division of Equipment and Procurement, 125 E 11th St., Austin, Texas, 78701-2483.

Included with their request for prequalification shall be a notarized certification from an independent laboratory stating that the laboratory has conducted tests in the manner described below on two randomly selected drums representative of those to be supplied for Department use or on Department contract projects. They shall also submit two randomly selected drums representative of those to be supplied for Department use for testing by the Department. These two drums shall be submitted at no cost to the Department.

A new certification will be required every two (2) years upon any modification of the drum or any change in the formulation of the plastics used in its manufacture.

Prospective Bidders and/or Suppliers will be notified, after their material has been evaluated, as to conformance with the requirements of this specification.

The Department reserves the right to perform any or all of the tests required by this specification as a check on the tests reported by the Manufacturer. In the case of any variance, the Departmental tests will govern.

B. Performance History: Some of the tests required by this specification extend over a prolonged period of time. Therefore, testing for acceptance of materials supplied on any contract or State purchase order shall only be considered on those materials which are determined by the Director of Materials and Tests to be identifiable as a material having an established performance history of compliance with the criteria established by this specification.

C. Re-evaluation: The Manufacturer/Supplier shall notify the Director of Materials and Tests of any changes made in the composition or manufacturing process of a prequalified material. A re-evaluation of the material shall be required if, in the opinion of the Director of Materials and Tests, these changes may affect the durability or performance of the material.

Changes that are detected in composition, manufacturing process or quality, that may affect its durability or performance and that have not been reported by the Manufacturer, shall be cause for removal of that material from the list of prequalified materials.

The Department reserves the right to conduct whatever tests are deemed necessary to identify a prequalified material and to determine if a change has been made in composition, manufacturing process, or quality which may affect its durability or performance.

D. Periodic Evaluation: The Department reserves the right to periodically evaluate the performance of these materials. Samples for periodic evaluation of performance will be selected at random from materials submitted to the Department on contracts or direct State purchase orders.

Failure of materials to comply with the requirements of this specification as a result of periodic evaluation, shall be cause for removal of those materials from the list of prequalified materials.

V. Sampling and Testing A minimum of two drums, at the Engineer's option, may be randomly selected for testing from each batch or order supplied on direct State purchase or contract. Sampling shall be done by Department personnel or authorized representative. Costs of sampling and testing are normally borne by the Department. However, the costs of sampling and testing of the materials failing to conform with the requirements of this specification shall be borne by the Contractor or Supplier. Costs of sampling and testing failing material shall be assessed at the rate established by the Director of Materials and Tests and in effect at the time of testing. Amounts due the Department for conducting such tests will be deducted from monthly or final estimates on contracts or from partial or final payments on direct purchases by the State.

VI. Materials and Construction Requirements:

A. The drum shall comply with the current version of the *Texas Manual on Uniform Traffic Control Devices* requirements and *Barricade and Construction Standard Sheets.*

B. Drum and base shall be manufactured from ultra-violet stabilized, orange, high-density polyethylene.

C. The design shall consist of a drum body and one piece base which locks together in a manner that will allow the drum body to separate from the base when impacted by a vehicle at 35 km/h (21.7 mph) or higher, but prevents accidental separation in normal handling and/or from air turbulence created by such things as passing trucks and normal winds.

D. Dimensions: The height of the drum with base attached shall not be less than 915 mm (36 in.) and not more than 1065 mm (41.9 in.), regardless of vertical orientation. The minimum diameter of the drum shall be 455 mm (17.9 in.), regardless of vertical orientation. Wall thickness of the drum body shall not be less than 1.75 mm (0.069 in.). Samples shall be cut 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 standard micrometer graduated to 0.025 mm (0.001 in.). Contours and reinforced areas shall be avoided when sampling.

E. Unballasted weight of drum body shall weigh no less than 3.5 kg (7.7 lb) and no more than 5.0 kg (11.0 lb). The actual weight of any drum body shall not vary more than +/- 0.25 kg (0.55 lb) from that of the pre-qualification sample.

F. Drum and base shall be marked with manufacturers name, model number, and year and month of manufacture.

G. Drums and bases supplied for Department requisitions shall be hot branded with the letters "TxDOT" and the month and year of manufacture in block letters on the outside top of the drum and base. Letters shall be approximately 9.5 mm (3/8 in.) in height.

H. Drums are to be a tapered design to allow for stacking a minimum of five (5) drums high.

I. The top of the drum shall be closed with a built-in handle for easy pickup. The handle shall be strong enough to mount a battery operated warning light or reflective chevron sign. The top surface shall be designed to drain.

J. The base is to be domed shaped from all approaching directions and is to be a maximum of 100 mm (3.94 in.) in height. A self-contained base shall be large enough to hold up to 22.5 kg (49.6 lb) of sand or shall have a built-in ballast weighing between 18.0 and 22.5 kg (39.7 to 49.6 lb). Bases with a corrugated bottom shall be stiff enough to maintain their shape with up to 22.5 kg (49.6 lb) of sandbags stacked on top. The base shall have a minimum of two footholds of sufficient size for the base to be held down while separating the drum body from the base.

K. The drum and base shall maintain integrity upon impact throughout a temperature range of -20 F to +170 F without any noticeable change in performance.

L. The exterior of the drum body shall be covered with alternating white and orange material, circumferential, reflectorized stripes not less than 100 mm (3.94 in.) or greater than 200 mm (7.9 in.) in width. The top stripe shall be orange.

M. Nonreflectorized spaces between the reflectorized stripes shall not exceed 50 mm (2 in.) in width.

N. The retroreflectivity and color characteristics of the reflective sheeting shall conform to the requirements of *Departmental Materials Specification D-9-8300: Flat Surface Reflective Sheeting, Type C.* In addition, the sheeting shall be suitable for use on and adhere to the drum surface such that, upon vehicle impact, the sheeting shall remain adhered in-place and exhibit no internal delaminating, internal and external checking and cracking and loss of reflectivity other than the reflectivity loss due to abrasion of the sheeting surface.

O. The hardness of the drum and base material, determined according to *ASTM D2240 Type D*, shall not vary more than +/- 6 from the prequalification average.

P. Drum material shall show no adverse effect when bend-tested in accordance with Part III of *Test Method Tex-441-A*. Substituted for the post in the procedure will be a piece of drum and/or base material 300 mm by 75 mm (11.8 in. by 3.0 in.) or larger.

Q. The infrared spectra of material from drums and bases furnished shall match the spectra on file with the Department from the prequalified drums and bases.

R. The specific gravity of material from drums and bases furnished for prequalification shall range between 0.941 to 0.965. Routine samples shall not vary more than +/- 0.010 from the specific gravity of the prequalified drums and bases. Specific gravity is determined by using *ASTM D 792*.

S. The drum and base material shall show no significant change in color, flexibility, or integrity, when subjected to 1000 hours exposure in an Atlas Carbon Arc Weather-Ometer fitted with an 18-102 cycle gear and tested in accordance with *ASTM G23-81, Method 1, Type EH*.

T. The color of the drums and bases shall be orange and fall within the CIE color coordinates listed below, both before and after exposure testing. Color shall be determined in accordance with *Test Method Tex-839-B*.

Chromaticity Coordinates	
x	y
0.510	0.350
0.510	0.390
0.640	0.360
0.580	0.420

U. The tensile strength of the drum and base material, tested according to *ASTM D 638*, shall match (within 10%) the results from the prequalification samples. The die used to cut the specimens shall meet *ASTM D 412C*.

V. The melt index of the drum and base material, tested according to *ASTM D 1238* at 190 C and 2160 gram load, shall match (within 10%) the melt index of the prequalification samples.

W. The drum and base shall exhibit good workmanship and shall be free from objectionable marks or defects which would adversely affect appearance or serviceability.

X. The fixed base vertical pull force shall not be less than 65 kg (143 lb) and not more than 150 kg (330 lb) when tested as described below.

Apparatus

Base attachment fixture - A means of attaching the drum base rigidly to the floor shall be provided. This may be a 12.7 mm (0.5 in.) threaded rod screwed into a concrete floor. A 14 mm (9/16 in.) hole is drilled in the center of the base section to accommodate the rod. The base is placed over the rod followed by a 300 mm (12 in.) diameter, 6.0 mm (0.24 in.) thick steel plate with a 14 mm (9/16 in.) hole in the center. The plate and base are secured by a finger-tight nut.

Force application fixture - Vertical force shall be applied to top of the drum body by a manually operated chain or rope hoist or a pneumatic cylinder with a capacity of at least 225 kg (496 lb). The vertical pull force shall be applied at a rate of no more than 2.5 kg (5.5 lb) per second. Just prior to separation of the drum body from the base, the rate of force increase shall be slowed to no more than 1.0 kg (2.2 lb) per second.

Force measurement - A force transducer or load cell with a minimum capacity of 225 kg (496 lb) is required between the force application fixture and the top of the drum. The transducer and readout shall have an accuracy and resolution of 0.5 kg (1.1 lb) or better. Preferably, the force readout shall 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 1.0 kg (2.2 lb) per second.

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 or more of the sign panel attachment points, through a pulley connected to the load cell and back to the other attachment point.

Procedure

Secure the drum base to the floor. 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. With slack in the load cell to drum connection, adjust the load cell readout to zero kilogram force and verify that the calibration is correct. Operate the hoist or the pneumatic cylinder to remove slack from the system and to indicate a few kilograms of force. Slowly increase the force, at a rate of up to 2.5 kg (5.5 lb) per second if using a strip chart to record the force readout or less than 1.0 kg (2.2 lb) per second if the force readout is observed and recorded manually, until the drum body separates from the base or a force of 170 kg (375 lb) is reached, whichever occurs first. Record the highest force value just prior to separation or as ">170 kg (>375 lb)" if the force of 170 kg (375 lb) is reached without separation.

Repeat the procedure a total of three times and average the three readings for the reported value. If the pull force is less than 65 kg (143 lb) for one of the three pulls, repeat the test a fourth time and exclude the low value if the fourth pull exceeds 65 kg (143 lb). Similarly, if the pull force is more than 150 kg (330 lb) for one of the three pulls, repeat the test a fourth time and exclude the high value if the fourth pull is below 150 kg (330 lb). If no separation occurred at the 170-kg (375-lb) force level, report as ">170 kg (>375 lb)."

Y. The static crush test results shall not be less than 35 kg (77 lb) when tested as described below.

Apparatus

Scale - an electronic or mechanical platform scale with a top surface measuring 450 mm by 300 mm (18 in. x 12 in.) and 125 mm (4.9 in.) above a reference surface such as the floor. The accuracy and resolution of the scale shall be 0.1 kg (0.22 lb) or better with a full-scale capacity of at least 100 kg (220 lb).

Procedure

A 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. The weight of the drum as it rests on the scale shall be recorded and subtracted from the final values. With a person at each end (top and bottom) 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. 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.

Z. The horizontal tip force shall not be less than 10 kg (22 lb) and the drum body shall not separate from the base when tested as described below. Two sets of tests shall be conducted, one with the horizontal force applied to the top of the drum and one with the horizontal force applied to the center of the drum. For the test with the horizontal force applied to the center of the drum, the drum shall not tip over at a horizontal tip force of less than 13.5 kg (29.8 lb) when tested as described below.

Apparatus

Force application fixture - Horizontal force is applied to the drum by a pneumatic cylinder with a capacity of at least 25 kg (55 lb). The horizontal pull force shall be applied at a rate of no more than 2.5 kg (5.5 lb) per second.

Force measurement - A force transducer or load cell with a minimum capacity of 25 kg (55 lb) is required between the force application fixture and the drum. The transducer and readout shall have an accuracy and resolution of 0.5 kg (1.1 lb) or better. Preferably, the force readout shall be continuously recorded. Alternatively, the force readout may be read off manually provided the increase in force is less than 1.0 kg (2.2 lb) per second.

Attachment - For tests with the horizontal pull force applied to the top of the drum, the horizontal pull by the pneumatic cylinder/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 or more of the sign panel attachment points, through a pulley connected to the load cell and back to the other attachment point. For tests with the horizontal pull force applied to the center of the drum, a 50-mm (2-in.) wide strap is wrapped around the drum at the geometric center of the drum body and attached to a rope, through a pulley, and attached to a load cell.

Procedure

Place the drum assembly on a hard, smooth, and level surface. The drum assembly shall be ballasted with 22.5 kg (49.6 lb) of sandbags for a plain base, filled with 22.5 kg (49.6 lb) of sand for a self-contained base, or use a self-contained base with built-in ballast such as a solid rubber base. A horizontal force is applied to the rope, either at the top or center of the drum depending on the test being conducted, with a pneumatic cylinder at the rate of 2.5 kg (5.5 lb) per second if the force is recorded in a continuous manner. The horizontal pull force shall be applied in the zero degree orientation, i.e., the position as viewed by a driver facing the sign panel when attached to the drum. Alternatively, the force readout may be read off manually provided the increase in force is less than 1.0 kg (2.2 lb) per second.

The horizontal force shall be applied until the drum tips over, slides on its base, or when the drum body separates from the base. Record the highest force observed during the pull and the action of the drum, i.e., whether the drum tips over, slides on its base, or the drum body separates from the base. Repeat the test a total of three times and the average is reported as the horizontal pull force. Two sets of tests shall be conducted, one with the horizontal force applied at the top of the drum and the other at the center of the drum.

VII. Warranty: Drums supplied for Department requisitions shall be warranted against defects in material and workmanship for a period of not less than twenty-four (24) months beginning with the date of acceptance. It the Manufacturer's standard warranty exceeds twenty-four months, then the Manufacturer's warranty shall be in effect. The successful Bidder shall furnish a copy of the Manufacturer's warranty to the Department at time of delivery. Any such defective products brought to Vendor's attention within said period shall be returned to Vendor freight collect and shall be replaced without cost.