Crash Tests of Work Zone Traffic Control Devices

JAMES E. BRYDEN

RESEARCH REPORT 147

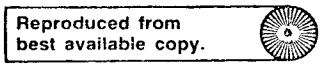
ENGINEERING RESEARCH AND DEVELOPMENT BUREAU
NEW YORK STATE DEPARTMENT OF TRANSPORTATION
Mario M. Cuomo, Governor/Franklin E. White, Commissioner

CRASH TESTS OF WORK ZONE TRAFFIC CONTROL DEVICES

James E. Bryden, Civil Engineer III

Final Report on Research Project 102-13

Research Report 147
February 1990



ENGINEERING RESEARCH AND DEVELOPMENT BUREAU
New York State Department of Transportation
State Campus, Albany, New York 12232

ABSTRACT

Full-scale vehicle crash tests evaluated performance of typical work zone traffic control devices. Modified test procedures and evaluation criteria from NCHRP Report 230 were used in 108 tests, providing significant insight into impact performance. Plastic drums used as channelizing devices, cones, tubes, and vertical panels performed well in most tests, presenting no hazards in terms of passenger compartment intrusion, interference with vehicle control, or threat to workers and other traffic from impact debris. Various nonstandard forms of ballast placed on top of or inside channelizing devices detracted from performance, and sometimes posed a severe threat to test vehicle occupants, workers, and other traffic. Similarly, impact debris formed in several tests on Types I and III barricades and portable signs and supports posed a threat, and was often thrown long-distance through work zones. Warning lights attached to traffic control devices were also thrown free in a number of tests, and appeared to threaten workers and other traffic.

CONTENTS

I. INTRODUCTION

A. Background

With increased emphasis on repairing and rehabilitating the existing infrastructure, work zones have become commonplace on the nation's highways. A wide variety of signs, channelizing devices, and other traffic control devices (TCDs) guide and control traffic in these zones. Primarily, TCDs are meant to convey information to the motorist (1), and a number of recent studies have developed a wide array of work zone TCDs that effectively accomplish this purpose (2,3). However, work zone TCDs must also fulfill an important secondary function. Work zone traffic accidents are common occurrences, and TCDs are often involved because of their close proximity to the traveled lanes. Thus, in addition to transferring information, they must perform safely when impacted by errant vehicles.

Performance criteria for permanent highway safety appurtenances such as traffic barriers and sign supports have existed for some time (4), and also apply to such temporary work zone safety devices as portable traffic barriers. Considerable research (5,6) on traffic barriers and related features for highway work zones has provided information on their performance. However, only limited published data describe impact performance of work zone TCDs (7), and no performance criteria to judge their performance have been proposed or accepted for widespread use.

This report describes a 1988 study by the New York State Department of Transportation to evaluate impact performance of TCDs commonly encountered in New York work zones. Test procedures were modified to deal specifically with the TCD types tested, and performance criteria were developed to evaluate the test results. In all, 108 full scale tests were conducted on 62 different combinations of TCDs and installation conditions.

B. Test Procedures and Evaluation Criteria

These tests were performed during the summer of 1988 at the Department's Highway Safety Test Center in Scotia, New York, near Albany. It had been in use for about 10 years for a test program involving highway safety appurtenances, and was equipped with a vehicle towing and guidance system and data acquisition systems. All tests were conducted on a level paved area, with adequate space available to observe post-impact trajectories of the test vehicles. For most tests, vehicles were propelled by a cable towing system powered by a heavy-duty pickup truck. The tow cable was released before

impact. A tensioned cable attached to a front wheel through a steel wing provided steering control, and also disconnected before impact. A remote brake package was installed in each towed vehicle for operational safety during tests. For a few of the simplest tests involving no risk of windshield breakage or loss of control, vehicles were driven by a research technician rather than towed.

All tests were recorded by two electronic video cameras/recorders, and one 35-mm movie camera. In addition, still photographs documented the devices tested and the test results. Because size and weight of the devices tested were small, they were not expected to result in any significant vehicle deceleration on impact. To simplify test procedures and permit completion of a much greater number of tests within the time available accelerometers thus were not installed in the test vehicles. After each test, damage to the vehicle and test device was noted. Particular attention was given to any tendency of test devices to penetrate the passenger compartment, and to windshield damage. Post-impact location of the test device was noted, and all debris formed by the impact was recorded.

Two categories of test vehicles were used -- 1800-lb Honda front-wheel-drive sedans, and full-size rear-wheel-drive sedans of various makes and models weighing about 4500 lb. A substantial number of windshields were broken in these tests, and cost and scheduling considerations dictated that some tests use vehicles with previously damaged windshields. However, care was taken to ensure that undamaged or at least sound and intact windshields were in all tests where assessment of windshield damage was important. Windshield condition before and after impact was recorded in detail to assess actual damage from each test. Test speeds varied from 20 to 60 mph, representing the range of speeds typically encountered in work zones. Test speeds were observed using a radar speed device mounted in the tow vehicle, and were reported to the nearest 5 mph. For the tow system used, speed control within $\pm$ 2 mph was generally attained.

NCHRP Report 230 (4) presents safety evaluation guidelines for crash tests involving highway safety appurtenances. Those evaluation factors include structural adequacy of the device tested, risk of injury to vehicle occupants, and post-impact trajectory of the test vehicle. Devices typically evaluated using these factors are generally intended to alter trajectory of the test vehicle -- i.e., to redirect or stop it. In some cases, it is desirable to minimize the degree to which trajectory is altered, but because of structural requirements those devices usually have a substantial effect even when this is not desirable. Traffic control devices evaluated in this study, however, serve a different function, and are not intended to alter vehicle trajectory when impacted. In fact, most are not structurally adequate to significantly alter trajectory of even 1800-lb sedans.

In addition to differences in structural capacity and intended function, the environment in which work zone TCDs are used varies considerably from that of typical permanent safety appurtenances. Many are installed much closer to the travel lanes, often in areas otherwise available to serve as a recovery or buffer space before an errant vehicle contacts a more severe hazard. In

addition, these devices are often used very near to opposing travel lanes and to pedestrians and construction workers.

Considering the evaluation factors in NCHRP Report 230, as well as the intended function of work-zone TCDs and the environment in which they must function, three specific criteria were developed for evaluating these tests:

1. Passenger Compartment Intrusion

   Intrusion into the vehicle by any debris from the test device formed by the impact was considered unacceptable because this greatly increases risk of injury to its occupants. This included intrusion through the windshield, firewall, floor, or body panels by parts of the test device, or intrusion into the windshield by the vehicle hood. Partial windshield intrusion to the extent that broken glass entered the passenger compartment was also considered unacceptable. Finally, puncture of the fuel tank resulting in fuel leakage (test vehicle tanks were filled with water) was considered unacceptable because of fire risk.

2. Loss of Vehicle Control

   Because work zones often provide restricted operating space for vehicles and numerous hazards are frequently located closely adjacent to the designated travel lanes, interference with driver control of the vehicle resulting from a TCD impact is considered unacceptable. Loss of control may occur in any of four ways. First is physical interference with vehicle steering and braking by the test device. A typical example is a TCD that wedges under a vehicle, resulting in loss of contact between tires and pavement. Second is windshield damage restricting driver visibility or startling the driver so that vehicle control is lost. A severely shattered windshield may prohibit the driver from avoiding secondary impacts after striking a TCD. Third, debris thrown into opposing traffic lanes may appear hazardous to an oncoming driver, causing emergency evasive action leading to loss of control and a secondary collision. A typical example is a driver braking abruptly to avoid a displaced channelizing device, only to be rear-ended by a following vehicle. Finally, sand or other debris scattered on the pavement may lead to loss of control of other vehicles, especially motorcycles.

3. Physical Threat to Workers or Other Vehicles

   Because of close proximity of construction workers and other traffic to the TCDs, devices or fragments thrown by an impact may present a hazard. Size, shape, weight, composition, and distribution of debris was recorded for each test, and evaluated to determine whether it constituted a hazard. Factors considered included rigidity of the debris -- rigid steel or wood fragments may cause serious injury, but soft plastic fragments of a similar weight are less likely to be harmful. Debris that stayed in contact with a

Table 1. Summary of evaluation factors.

PASSENGER COMPARTMENT INTRUSION

1. Windshield Intrusion
    a. No windshield contact
    b. Windshield contact, no damage
    c. Windshield contact, no intrusion
    d. Device embedded in windshield, no significant intrusion
    e. Partial intrusion into passenger compartment
    f. Complete intrusion into passenger compartment
2. Body Panel Intrusion (yes or no)

LOSS OF VEHICLE CONTROL

1. Physical Loss of Control
2. Loss of Windshield Visibility
3. Perceived Threat to Other Vehicles From Debris
4. Debris on Pavement

PHYSICAL THREAT TO WORKERS OR OTHER VEHICLES

Harmful Debris (yes or no)

VEHICLE AND DEVICE CONDITION

1. Vehicle Damage
    a. None
    b. Minor scrapes, scratches, or dents
    c. Significant cosmetic dents
    d. Major dents to grill and body panels
    e. Major structural damage
2. Windshield Damage
    a. None
    b. Minor chip or crack
    c. Broken, no interfererence with visibility
    d. Broken and shattered, visibility restricted but remained intact
    e. Shattered, remained intact but partially dislodged
    f. Large portion removed
    g. Completely removed
3. Device Damage
    a. None
    b. Superficial
    c. Substantial, but can be straightened
    d. Substantial, replacement parts needed for repair
    e. Cannot be repaired

test vehicle, followed its path along the pavement, or remained near the point of impact was less objectionable. Devices or debris thrown through the air, especially at some angle to the impact path, were considered more likely to strike a worker or impact another vehicle.

Following completion of the test program, each test was rated according to these three criteria. In addition, cosmetic damage to the vehicle and TCD damage were noted because each represents a cost factor. Rating factors for each criterion are summarized in Table 1.

Table 2. Summary of traffic control devices and test parameters.

Device and Description	Device and Description
STEEL DRUM (55 gal)	BALLAST
PLASTIC DRUM	Sandbag internal
Two-piece, detachable base	Sandbag external
One-piece, base tab	Sandbag on top
One-piece, base fingers	Sandbag suspended
Open top	Water
Two-piece, split middle	Gravel
SIGN SUPPORTS	Concrete block on top
Steel tripod	Miscellaneous material
Low wood, portable	Does not apply, none
Tall wood, portable	WARNING LIGHTS
Tall wood, fixed	Light not attached
Metal, miscellaneous	Light attached with bolt
BARRICADES, TYPE I	Light attached with bolt and washer
8-ft wood, plastic legs	Light attached with bolt and cable
2-ft plywood, metal legs	No light
3-ft metal, metal legs	
5-ft metal, metal legs	
BARRICADES, TYPE III	
Wood	
PVC	
Metal	
MISCELLANEOUS CHANNELIZING DEVICES	
Cones	
Tube	
Vertical panels	

II. TRAFFIC CONTROL DEVICES AND TEST PARAMETERS

Six specific types of traffic control device were tested -- steel channelizing drums, plastic channelizing drums, temporary traffic signs and supports, Types I and III barricades, and miscellaneous small channelizing devices. In addition, a variety of ballast procedures, warning lights, and other parameters were tested. The following TCDs and other parameters are summarized in Table 2:

1. Steel Channelizing Drums

   Steel 55-gal drums once widely used as channelizing devices in highway work zones are no longer permitted on New York projects. Five empty drums weighing 50 to 55 lb were tested, all with closed tops.

2. Plastic Channelizing Drums

   Twelve different models were tested from six manufacturers or suppliers, including five specific types:

   a. Two-Piece with Detachable Base

      These had a closed top and open bottom and snap over a low base unit. Ballast may be placed inside on the base. On impact, the two pieces separate, with the ballast and base intended to stay near the impact point.

   b. One-Piece with External Ballast Tabs

      These have a closed top and open bottom. External tabs are provided at the bottom for ballast.

   c. One-Piece with Base Fingers

      These are closed top and bottom, but the base is slotted to form radial "fingers." The drum is inverted, ballast is inserted through the slotted fingers, and the drum is then placed with the slots down.

   d. Open-Top Drums

      These have an open top, and the ballast is simply placed inside on the base. They may be specifically designed for use in this manner, or two-piece-units purchased without a base and inverted for use.

e. Two-Piece Split at the Middle

This drum consists of upper and lower pieces separated at about mid-height. Ballast may be placed inside, and the top is fitted over the bottom to form a closed unit.

3. Temporary Sign Support

Six different types were tested:

a. Steel Tripod

This 12-lb support can accommodate sign panels up to 48 in. square, either rectangular or diamond shaped.

b. Fixed Wood Support

The nominal 4- by 4-in. by 16-ft wood post was imbedded 4 ft in the ground, and stiffened by 2- by 4-in. by 8-ft diagonal braces attached to stakes driven into the ground and attached to the post 6 ft above the ground. It was tested both with the longitudinal brace facing the impact vehicle and away from it. Height from the ground to the bottom of the 4- by 4-ft by 5/8-in. plywood diamond sign panel was 7 ft.

c. Tall Portable Wood Supports

These were constructed from 2-by-4-in. and 2-by-6-in. wood elements. Base dimensions were 3- by 4-ft for one support and 27 in. by 5 ft for the other. Two 2-by-4-in. vertical supports were stiffened by one lateral and two longitudinal 2-by-4-in. diagonal braces. Tests were conducted with the longitudinal braces facing both toward and away from traffic. A 4- by 4-ft rectangular plywood panel 52 in. above ground was included. Both were ballasted using two 50-lb sandbags.

d. Low Portable Wood Support

A support constructed from 2-by-4-in. wood elements was tested with diagonal braces facing both toward and away from the impacting vehicle. Base dimensions were 3 by 4 ft. A 4 ft wide by 3 ft high plywood sign panel was mounted 12 in. above the pavement. Ballast was provided by two 50-lb sandbags.

e. Steel Proprietary Support

This had four horizontal legs in an X pattern and an adjustable steel vertical support attached to the legs through a spring mechanism. A 4 ft diamond aluminum sign panel was mounted about 4 ft above ground. Ballast was provided by four 50-lb sandbags, one on each leg.

f. Thruway Steel Support

A generic design developed by the New York State Thruway Authority was constructed using 1-1/2 and 1-3/4 in. square perforated steel tube. Two 1-3/4 in. square 5-ft long legs with vertical stubs supported two 1-1/2 in. square vertical supports that slipped into the base stubs. Two transverse braces connected the vertical supports. A 4- by 5-ft plywood panel was mounted 6 ft above the pavement. Four 50-lb sandbags (one on the end of each leg) provided ballast.

4. Type I Barricades

Four different models were tested:

a. 2-ft Plywood and Metal

This was fabricated from steel angle legs and 2-ft by 6-in. plywood panels and lateral braces, weighing 19.3 lb.

b. 3-ft Metal

This included round tubular-steel legs and a 3-ft by 6-in. sheet metal panel with a weight of 18.2 lb.

c. 5-ft Metal

This consisted of square tubular steel legs and a 5-ft by 8-in. sheet metal panel. Weight was 31.8 lb.

d. 8-ft Wood and Plastic

This included a 2-by 8-in. by 8-ft wood panel and molded plastic legs, weighing 29.9 lb.

5. Type III Barricades

Four models were tested:

a. Wood

This was constructed from 2-by-6-in. wood elements, and was 4 ft wide by 5 ft high. It had three panels and weighed 60 lb. Because of its weight, no extra ballast was used.

b. PVC Plastic

Two variations, 4 ft wide by 5 ft high, were tested. These are shown on NYSDOT Standard Sheet 619-4R1 as Alternates A and B. Alternate A had glued joints, while Alternate B is not glued but included an external tie wire to provide stability, plus an internal rope to retain debris on impact. Both were constructed using 3-in. diam pipe meeting ASTM D 2665.

c. Metal

This was constructed from 1-1/2 in. square 12-gage perforated steel tube, and was also 4-ft wide by 5-ft high. Panels are light weight aluminum, and total weight was 57 lb. This device included hinges attaching the vertical members to the base, and was intended to fold down on impact. No ballast was used.

6. Miscellaneous Channelizing Devices

Devices tested included cones, a tabular marker, and vertical panels:

a. Cones

Three types were tested. Two were one-piece cones fabricated from flexible plastic 34.5 and 36 in. high. The third was a rigid plastic two-piece cone 36.5 in. high. The detachable base can be filled with sand or water for ballast and slipped over the cone body. Weight was about 11 lb for all three cones.

b. Tubular Marker

The 42-in. high plastic two-piece tubular marker weighed 13 lb and included a heavy plastic base for stability.

c. Vertical Panels

Two panels were tested. One included a 6- by 36-in. plastic panel mounted on a fiberglass vertical support attached to a 16-in. square steel base plate to provide ballast. Weight was 33 lb. The other was an 8- by 24-in. plastic panel mounted on a nylon support, and attached to a 13- by 18-in. PVC plastic base. Its total weight was 22.5 lb.

7. Ballast

Eight different methods of ballast, plus unballasted TCDs, were included in these tests:

a. Sandbags

A single sandbag weighing 50 lb was the standard ballast device for these tests. This consisted of dry gravel inside a reinforced polypropylene sample bag closed with packing twine. For the channelizing drums, a single sandbag was placed inside on the base, externally on the ballast tab at ground level, or on top of the drum. For sign supports and barricades, up to four sandbags were placed on the base supports, according to the number required to provide stability against overturning from wind loads. For one drum test a 30-lb sandbag was suspended inside the drum, hung from the top by a cable. Two traffic cones were tested with suspended sandbags weighing 8 lb.

b. Water

One inverted drum was filled halfway with water, weighing about 150 lb.

c. Gravel

One open-top drum was ballasted with 180 lb of loose gravel inside.

d. Concrete Block

A concrete block weighing 42 lb was placed on top of plastic drums in two tests. This ballast is similar in size and weight to heavy-duty batteries sometimes placed on top of drums to power warning lights. Pieces of rock or broken concrete pavement provide similar ballast.

e. Miscellaneous Materials

Construction debris consisting of a broken 42-lb concrete block and 13 lb of wood scraps were placed inside one open-top plastic drum.

8. Warning Lights

Type A warning lights were attached to a number of devices by various means as listed in Table 2.

Table 3. Summary of full-scale test results.

Device	Total Tested	Satisfactory	Failed Evaluation Factor*		
			Passenger Compartment Intrusion	Loss of Control	Threat of Debris
Steel Drums	5	0	0	5	2
Plastic Drums					
50-lb Sandbags	24	18	0	6	0
Unballasted	15	11**	0	4	0
Nonstandard Ballast	7	2***	2	3	3
Warning Lights	19	5	1	3	14
Temporary Signs and Supports	10	1	0	9	9
Types I and III Barricades	9	1	2	8	7
Small Channelizing Devices	19	16	0	1	2
Total	108	54	5	39	37

*Some devices failed more than one factor, thus total failures may exceed total devices tested.

**Four tests included drums thrown to one side, but not judged to threaten other traffic.

***One test rated satisfactory for primary criteria resulted in extensive vehicle damage.

III. RESULTS

Table 3 summarizes full-scale tests in this investigation. Detailed information on individual tests is provided in the Appendix.

A. Steel Drums

None of the five tests on steel drums provided satisfactory results in terms of all evaluation criteria. None resulted in passenger compartment intrusion, but all five interfered in some measure with vehicle control. Two 1800-lb cars and one 4500-lb car rode up onto the collapsed drum, with partial or full loss of steering control in 45- and 60-mph tests. In addition, the small car nearly rolled over in the 45-mph test before coming to rest partially on the drum. In the other two tests, at 30 and 45 mph with 1800-lb cars, the drum bounded ahead of the car, threatening injury to workers as well as loss of control by other drivers resulting from severe evasive maneuvers. Figure 1 shows an 1800-lb vehicle riding up on a 55-gal drum in a 60-mph impact.

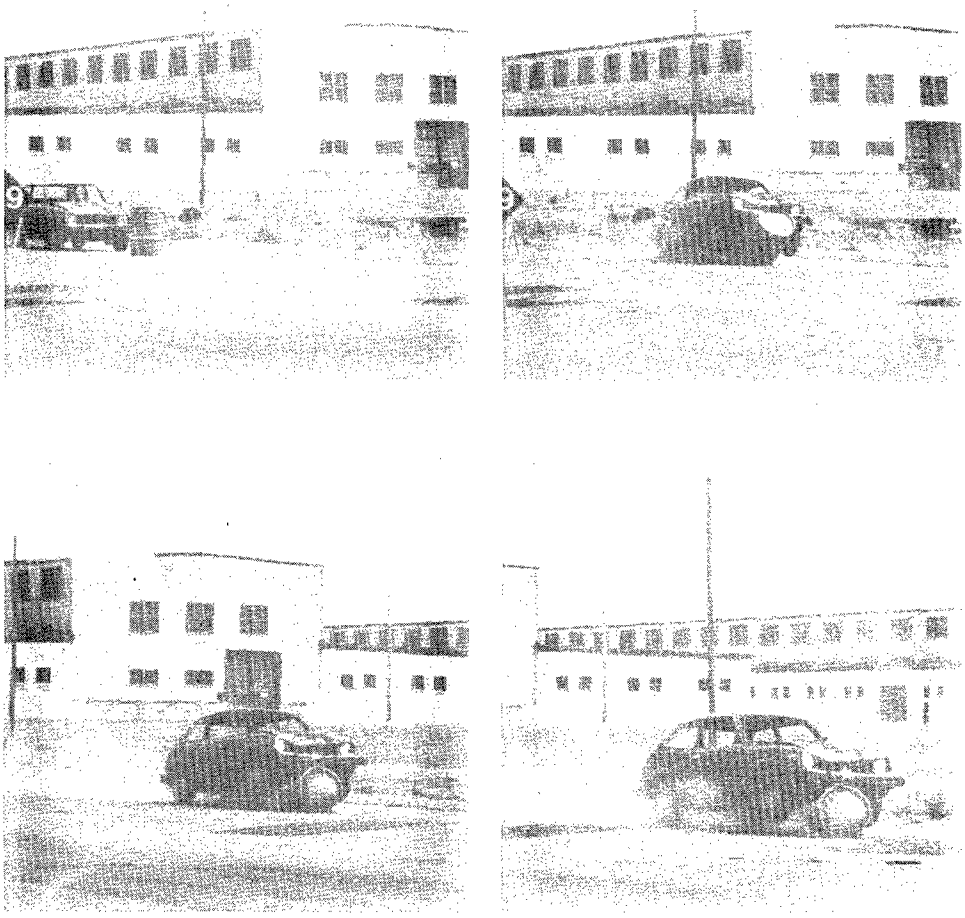
B. Plastic Drums with Sandbag Ballast

Drums ballasted with 50-lb sandbags at ground level (Fig.2) underwent 24 tests with satisfactory results in 18 tests. Five of the six unsatisfactory tests had drum parts flying into traffic areas with potential for causing severe evasive maneuvers. In one case, a two-piece drum with detachable base tore apart on a brushing impact, and a large part of the drum was thrown to the side. A similar drum was also thrown to the side by a brushing impact. Two tests on two-piece drums split at mid-height, resulted in the top being thrown high into the air and potentially interfering with other traffic. One open-top drum was shattered on impact, with a substantial part thrown by the impact. The sixth unacceptable test resulted from sandbag ballast in an open-top drum scattering across the pavement, and causing a skidding hazard.

Typical impact performance by plastic drums ballasted with sandbags at ground level consisted of the sandbag and base (if used) remaining near the point of impact, with the drum staying against the front of the car or under it. This was experienced with both small and large cars at speeds from 30 to 60 mph. Even in several impacts with the front corner of the vehicle, drums wrapped around the car's front and stayed there or came to rest under it. Drums with detachable bases, external base tabs, or slotted base fingers all displayed similar behavior.

Damage to plastic drums was variable, 11 tests resulting in only superficial damage. Seven drums were completely destroyed, and the other six experienced

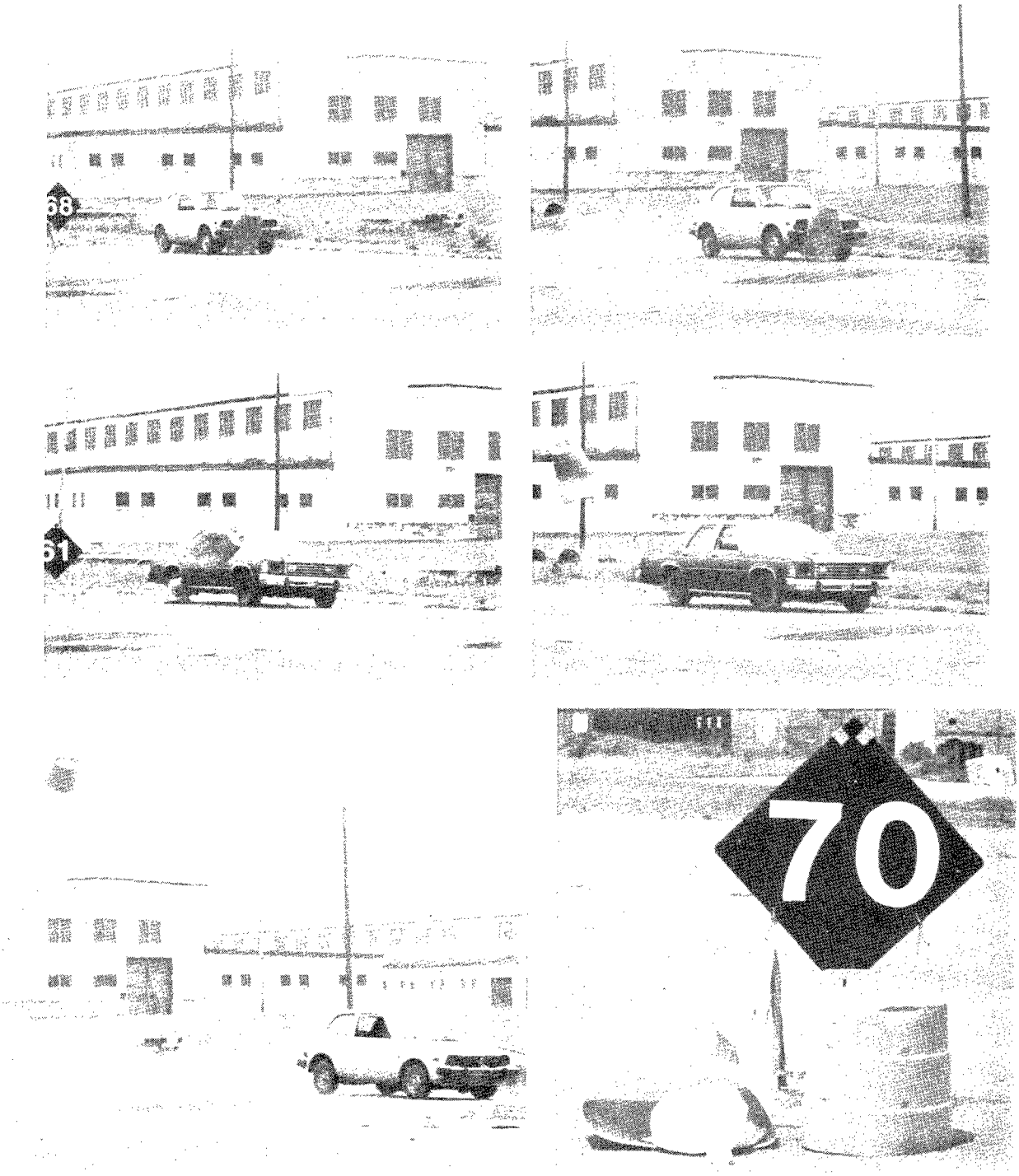
Figure 1. An 1800-lb car impacting a 55-gal steel drum at 60 mph resulted in loss of vehicle control.



intermediate damage. Both open-top drums and one two-piece drum split at mid-height were totally destroyed, as was one with slotted base fingers. This severe damage related to ballast being trapped inside the drum, thus offering greatly increased resistance to movement by the drum on impact. Three drums with detachable bases were destroyed, all from corner impact in which the front tire rode over the drum. It was also apparent that some brands of drums were more resilient than others, experiencing less tearing and breakage in similar impacts. Some drums were used in several tests -- although some were completely destroyed after only one impact, others were still serviceable after several.

Plastic drums with sandbag ballast placed at ground level generally provided excellent performance. However, open-top drums with internal ballast and two-piece drums split mid-height both resulted in debris that could threaten other traffic.

Figure 2. Typical impacts with plastic drums ballasted with 50-lb sandbags resulted in drums staying with the front of the car (top), being pushed aside in a brushing impact (center), and two-piece drum being thrown high into the air (bottom).



C. Unballasted Plastic Drums

Performance was similar to drums ballasted with 50-lb sandbags. Test results were completely satisfactory in 7 of 15 tests, with the drum staying with the car. In four other tests, drums were pushed to the right by brushing impacts. Although drum trajectories were not sufficient to threaten other traffic significantly, they did include thrown debris. Because of their light weight and soft material construction, this debris did not threaten workers. Four of 15 tests, all involving two-piece drums split at mid-height, resulted in the top half being thrown high into the air and a long distance into the work zone, even for 30-mph impacts by 1800-lb cars. This behavior was considered a possible threat to other traffic, and these four tests were classified as unsatisfactory.

Damage was similar to ballasted drums, with 11 of 15 drums suffering only superficial damage. Four drums were destroyed -- two from corner impacts with front tires rolling over the drum, and the other two from shattering and tearing on impact.

Other than reducing the drum damage caused by added resistance of the sandbag ballast, performance of unballasted drums was similar to those with ballast. Based on these tests, bagged sand ballast at ground level, up to 50 lb per drum, does not appear to affect drum performance adversely.

D. Plastic Drums with Nonstandard Ballast

Ballast, other than bagged sand at pavement level, provided satisfactory results in only two of seven tests. A suspended 30-lb sandbag hanging from the top of the drum provided acceptable results. Another drum containing about 20 gal of water met the three primary criteria, although the drum was destroyed and the front of the car sustained substantial damage in a 60-mph test. All five other tests were considered unsatisfactory.

Two tests used 42-lb concrete blocks on top of the drum as ballast. In the 30-mph test, the block entered the passenger compartment through the windshield, and nearly exited the rear window (Fig. 3). In a similar test at 45 mph, the block impacted and severely crushed the leading edge of the roof, but did not enter the passenger compartment. Both these tests represented potentially fatal injuries to vehicle occupants. A sandbag on top of a drum resulted in sand scattered over a wide area of pavement, considered unacceptable debris. An open-top drum ballasted inside with 180 lb of gravel was torn apart on impact, and the drum's top portion was thrown and could have threatened other traffic. Finally, an open-top drum ballasted with construction debris -- broken concrete and 2-by-4 lumber -- resulted in debris thrown throughout the work zone, an unacceptable risk to workers and other traffic.

In addition to unacceptable behavior in terms of the primary evaluation criteria, all three open-top drums and the drum with a sandbag on top were destroyed by the impacts (this last drum had been impacted in four previous

Figure 3. A 42-lb concrete-block ballast placed on a drum resulted in unacceptable intrusion into the passenger compartment.

tests). Added resistance of the heavier ballast and inability of internal ballast to separate from the drum resulted in severe impact forces. In previous tests with standard ballasts, most drums withstood similar impacts with only minor damage.

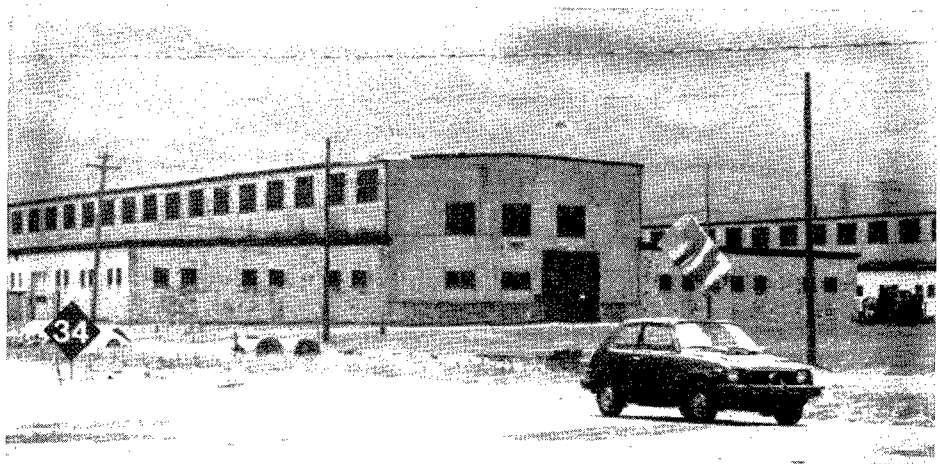
E. Plastic Drums with Warning Lights

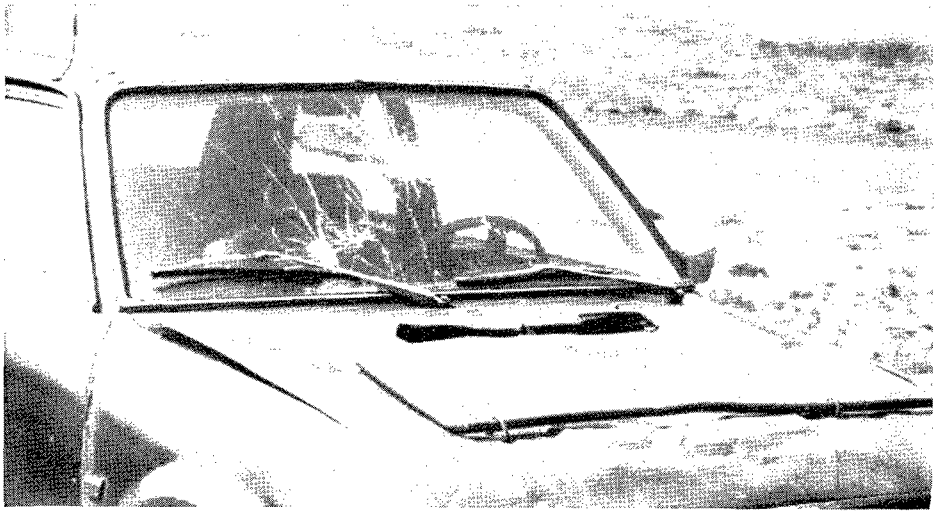
Of 19 tests of plastic drums with Type A warning lights attached (Fig. 4), only five met the primary evaluation criteria. Lights were attached to the drums by various methods. The primary problem was that the lights -- weighing about 6 lb including lantern batteries -- separated on impact and flew through the work zone, creating hazards to workers or other vehicle windshields. In two 60-mph tests, batteries traveled about 250 ft from impact, and in several others over 150 ft from impact.

Several attachment methods were examined. In one test with an unbolted warning light set into a retainer pocket molded into the top of the drum, the light detached on impact as expected. In 11 tests, the light was attached using a 1/2-in. bolt without a washer. Attachment points to the drums included various retainer tabs and pockets, and on open-top drums the light was bolted to the side. In all but two of these 11 tests -- both at 30 mph -- the bolts pulled through the plastic and the lights detached on impact. In one of those two, the light broke free when the drum contacted the pavement, but did not fly through the air. In eight of the nine tests in which lights broke free, they were considered a hazard to workers, and in the ninth the light embedded in a windshield. In three other tests lights impacted and damaged windshields, although there was no penetration, and then were thrown into the work zone.

Of 12 different drum models tested, only one had specific instructions on the drum for light attachment, calling for use of a retainer with the bolt. In an attempt to avoid light detachment, seven additional tests were conducted with 1-in. OD washers installed behind the bolt heads to prevent their pulling through the plastic. In three tests with 4500-lb cars -- two at 60 mph and one at 30 mph -- the lights remained attached to the drums, and the drums stayed with the front of the car on impact, thus providing acceptable results. None of the four tests with 1800-lb cars at 60 mph were acceptable. In one, the bolt and washer pulled through the plastic and the light impacted the windshield. In the second, the top of the drum broke apart, throwing the light into the work zone. In the third, the light unit remained attached but the battery compartment ruptured, throwing the batteries into the work zone. In the fourth, the light remained attached but the increased weight of the light on the top of the drum, combined with the low frontal profile of the small car, resulted in the drum flying over the car rather than staying in front, presenting a potential threat to other traffic and workers. Drums with warning lights attached thus behaved unacceptably in several cases, with lights thrown into the work area and drums flying over the vehicle on impact. Efforts to prevent this problem by adding washers to the attachment bolt were only partially successful.

Figure 4. Attaching warning lights to channelizing drums resulted in lights being thrown on impact and drums flying over the vehicle (top), with varying degrees of windshield damage (center and bottom).





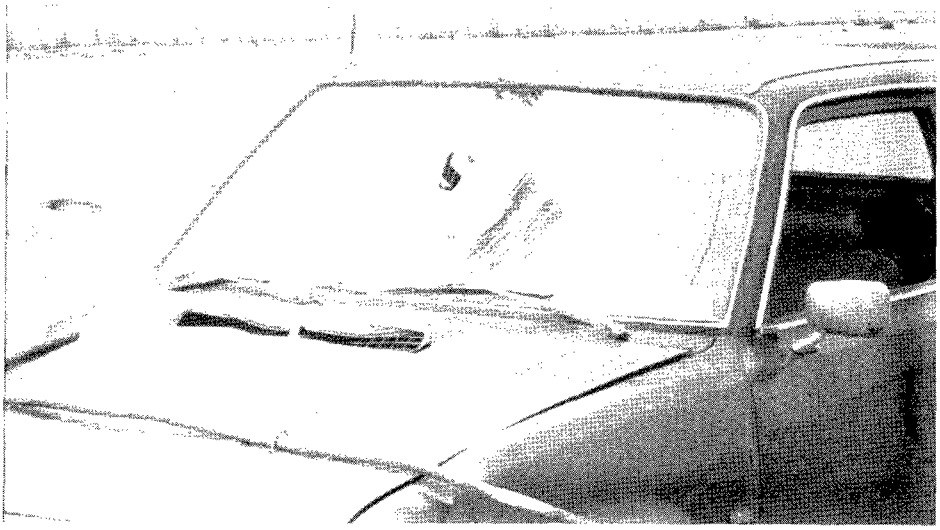
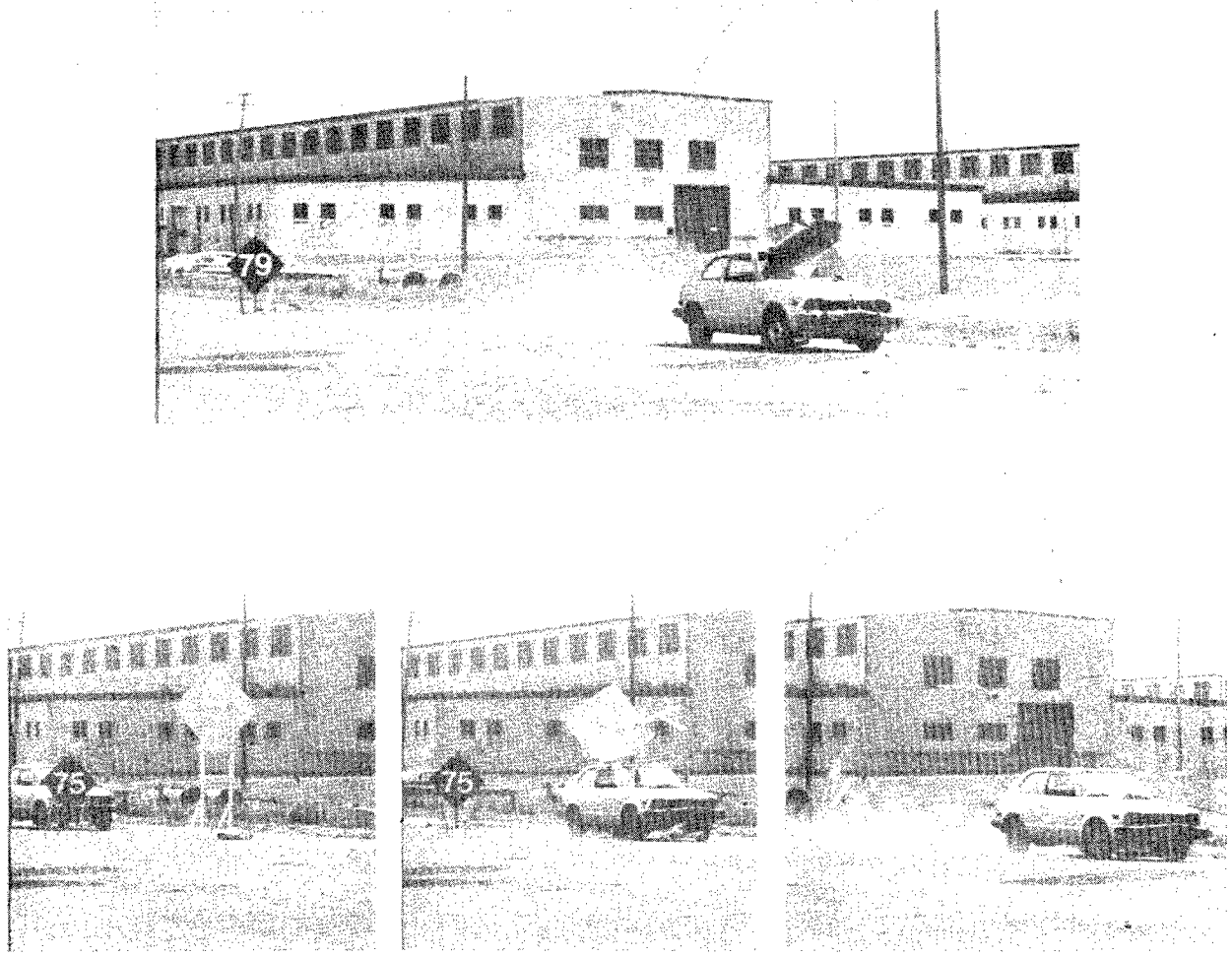


Figure 5. A portable low-mounted sign resulted in windshield penetration and debris (top). A tall portable sign resulted in unacceptable debris, although the panel cleared the car (bottom).



F. Temporary Sign Supports

Of 10 supports tested, only one met the three primary evaluation criteria. Nine other tests resulted in interference with control of the vehicle from windshield impacts or threatening debris, as well as debris considered a threat to workers or the windshields of other vehicles (Fig. 5). In four tests on low-mounted signs, with the bottom of the panel at bumper height, rigid wood or metal panels were flipped back into the car windshield, three of the four resulting in windshield damage. In addition, the steel tripod and wood supports in these four tests were all thrown on impact, threatening other workers and traffic.

In four 60-mph tests on high-mounted signs on timber supports (panels were above the car roof) the panels presented no hazard. In every case the test

vehicle passed under the panel, which dropped to the pavement near its original location. However, in every test, the 2-by-4 lumber braces were thrown on impact and presented a hazard to other vehicles and workers. In three of four tests, debris from the support also impacted and damaged the test vehicle's windshield.

A commercial metal tripod with a 4-ft diamond sign panel mounted 4 ft above the pavement tested at 55 mph resulted in the panel being pulled down into the windshield on impact. The vertical support did not fracture or release on impact, but instead deformed against the front of the car. The panel broke free after striking the hood and windshield and was thrown over the car, presenting a hazard to workers and other traffic. Except for one leg that broke free but remained on the pavement, no harmful debris resulted from the support. If equipped with a flexible rather than rigid panel, this support might perform acceptably.

The metal support constructed by the Thruway Authority was the only one to perform acceptably. The vehicle impacted one leg and passed under the panel. One base support broke free and slid along the pavement, and the panel and remaining support fell at the impact point.

Performance problems thus were observed in all but one test on signs and supports. Impact debris from the supports was thrown into the work zone in all but two tests, and in several others low-mounted sign panels impacted and broke windshields or were thrown through the work zone.

G. Types I and III Barricades

Four tests on Type I barricades resulted in debris thrown into the work zone, threatening workers and other traffic (Fig. 6). In three 60-mph tests, debris was thrown from 102 to 172 ft, and in the single 30-mph test debris was thrown 70 ft. Considering that these barricades weighed from 18 to 32 lb and included various steel and wood members, this debris appeared to present a significant hazard if it were to strike a worker or the windshield of another vehicle. In each case, debris was thrown high in the air, presenting a substantial risk that such contact would occur.

A 45-mph impact on a wood Type III barricade resulted in unacceptable debris -- pieces of 2-by-6 were thrown 150 ft from impact. This was expected, and wood Type III barricades have not been permitted on New York State projects for the last decade.

Three tests of PVC plastic Type III barricades resulted in their shattering, with debris thrown up to 207 ft from impact at 60 mph. Resulting debris was light in weight, and did not appear to represent a significant hazard to workers or other traffic. All three tests resulted in broken windshields on the test vehicles. In two of the three tests, a warning light was attached to the top barricade rail and contributed to windshield damage. In the third (at 60 mph) the windshield of the large sedan was shattered by impact with the top barricade rail (Fig. 7). All three tests with PVC barricades were thus considered unsatisfactory because of windshield damage. These barricades were

Figure 6. Collision with a Type I barricade resulted in unacceptable debris.

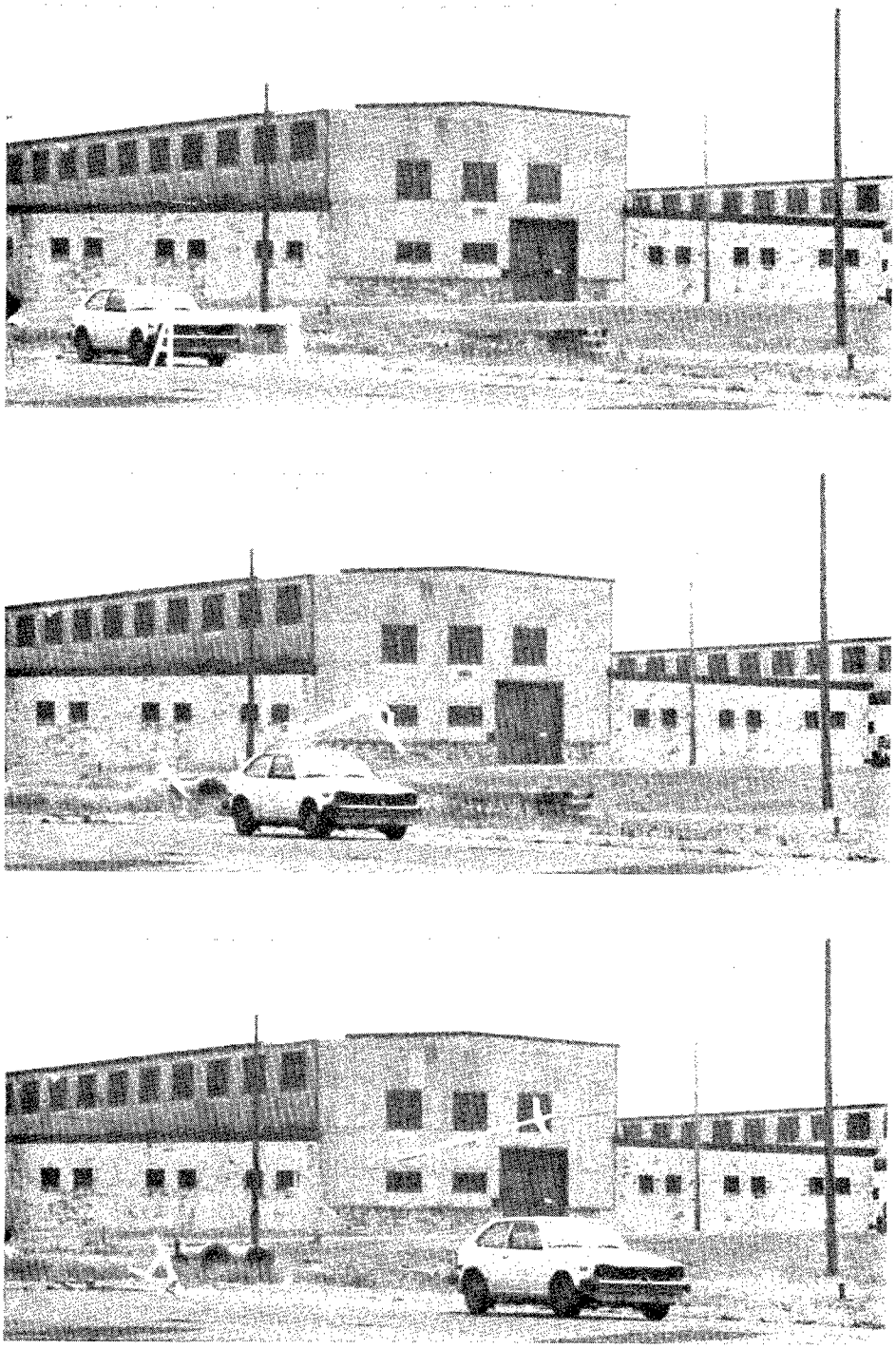
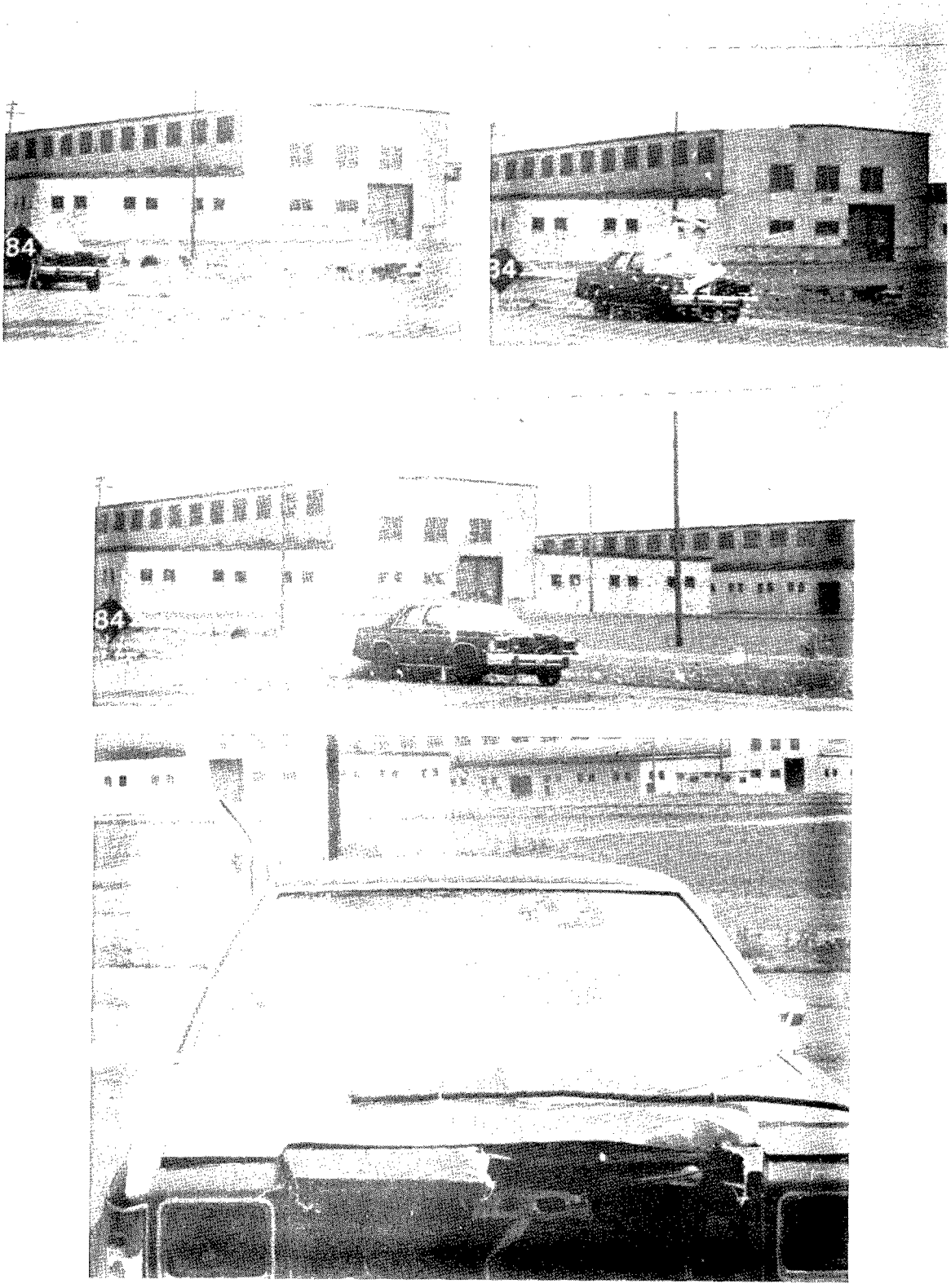


Figure 7. A 60-mph impact with a PVC Type III barricade resulted in a shattered windshield.



all constructed using heavy grade pipe (D 2655) and a lighter grade might prevent this damage.

Results of a single 60-mph test on a metal Type III barricade were considered acceptable. It deformed around the front of the 1800-lb vehicle and produced no debris or impact with the windshield. The barricade was extensively damaged with some cosmetic damage to the front of the impact vehicle, but no threat to workers, other traffic, or occupants of the test vehicle.

H. Small Channelizing Devices

In 19 tests on cones, tubes, and panels, 16 provided acceptable results. Two of the three unacceptable tests resulted from warning lights attached to the devices thrown on impact. In addition, one vertical panel provided unacceptable results when its base plate was tipped over before impact. A front tire impacted the leading edge of this steel plate, resulting in a blowout and partial loss of steering control. In addition, the plate was thrown into the work zone by the impact, although it remained near pavement level.

Six cone tests at 30 to 60 mph resulted in satisfactory performance except for one in which a warning light mounted in the top of the cone was thrown on impact. Four of the six cones stayed with the front of the car, and two were run over by the vehicle. Although one of those cones skidded along the pavement to the left of the vehicle path, its relatively small size and weight were not considered hazardous.
In each of four tests of tube delineators, the car passed over the device. The tubes traveled along the pavement up to 85 ft from the impact point, but like the traffic cones, were not considered a threat to workers or other traffic.

Seven of nine tests on vertical panels provided acceptable results. However, one panel tipped over before its test and one equipped with a warning light was considered unacceptable. In some tests, the vertical support and panel broke away from the base, which remained near the impact point. In others, the base simply slid some distance along the pavement and thus was not considered a threat because it remained at pavement level. Although the last test indicated that tipped steel base plates may pose a threat, none of the eight devices tested upright resulted in base plates tipping over. Vertical panels with steel base plates thus may not present a significant hazard, provided reasonable care is taken to ensure that plates tipped over by other causes do not remain in place adjacent to traffic lanes. In seven of nine tests, at speeds from 20 to 60 mph, the panels, vertical supports, and base plate connections were damaged to the extent that replacement parts were required to place the device back in service, and one was damaged beyond repair. In this regard, vertical panels were inferior to cones and tubes, with only two of ten devices tested requiring repair after impact.

Except for warning lights added to these devices and an improperly deployed vertical panel, these small channelizing devices appear to perform very well in full-scale impacts, presenting no significant hazard to workers or traffic.

IV. SUMMARY AND FINDINGS

Test procedures and evaluation criteria based on modifications to those in NCHRP Report 230 provided considerable insight into performance of typical work zone traffic control devices. Results of 108 full-scale tests show that some devices create hazards when impacted. Performance deficiencies noted included penetration of the passenger compartment through the windshield, loss or interference with vehicle control, and debris thrown through the work zone that was considered potentially hazardous to workers or passengers of other vehicles.

Although some test results were not considered acceptable, many devices performed well in a number of tests. Plastic channelizing drums, both unballasted and ballasted with 50-lb sandbags, typically performed well, in most cases staying with the car's front after impact. However, open-top drums with ballast inside and two-piece drums split at mid-height generally did not perform as well. Small channelizing devices -- cones, tubes, and vertical panels -- also performed well in most tests. On the other hand, 55-gal steel drums performed poorly, resulting in loss of vehicle control or threatening workers and other traffic when thrown through the work zone.

Nonstandard ballast, especially heavy ballast on top of drums, caused potentially severe results from penetration of the windshield and debris thrown through the work zone. Warning lights attached to channelizing devices also detracted from performance. In some cases, lights were thrown free on impact and damaged the windshield or were thrown through the work zone, causing a hazard to workers and other traffic. In other cases, lights caused drums to fly over the impacting vehicle rather then remaining in front of it, but no lights completely penetrated a windshield.

Most portable sign supports tested did not perform acceptably. Rigid panels mounted at bumper height impacted windshields, threatening intrusion into the passenger compartment. Panels mounted above roof level cleared the car and remained near the impact point. However, debris from temporary timber and steel supports was thrown through the work zone in most tests, causing severe hazard to workers and other vehicles.

Types I and III barricades also provided mixed results. All four Type I barricades tested, even in 30-mph tests, were thrown on impact and appeared to represent a risk to workers and other traffic. PVC-plastic Type III barricades resulted in considerable debris, although this was not considered a significant threat. However, all PVC Type III barricade tests resulted in windshield damage. A steel Type III barricade performed well, with no debris and no windshield damage.

Based on 108 full-scale crash tests on 62 combinations of work zone traffic control devices and installation conditions, the following findings can be stated:

1. Full-scale vehicle tests based on modified NCHRP Report 230 procedures and evaluation criteria provided significant insight into impact performance of work zone traffic control devices.

2. Many typical work zone traffic control devices performed well, but some devices and deployment conditions resulted in potentially hazardous performance in a number of tests.

3. Plastic drums, cones, tubes, and vertical panels performed well in most tests when properly deployed and ballasted.

4. Improperly ballasted channelizing devices, especially ballast placed above ground level, may present a significant hazard to motorists and workers.

5. Warning lights attached to channelizing devices became flying objects in a number of tests. They resulted in windshield damage in some tests although none completely penetrated a windshield. They may also threaten workers when thrown into a work zone.

6. Most temporary sign supports tested did not perform well. Rigid sign panels mounted at bumper height were thrown onto windshields. In addition, debris from several supports threatened workers and other traffic.

7. Types I and III barricades had mixed results. Some performed well, but others resulted in windshield damage, unacceptable debris, or both.

REFERENCES

1. "General Provisions for Traffic Control Devices." Subchapter A, § 200.1, Manual of Uniform Traffic Control Devices, New York State Department of Transportation, July 1, 1983.

2. Pain, R.F., McGee, H. W., and Knapp, B. G. Evaluation of Traffic Controls for Highway Work Zones. Report 236, National Cooperative Highway Research Program, October 1981.

3. Lewis, R. M. Review of Channelizing Devices for Two-Lane Two-Way Operations. Report FHWA/RD-83/056, Federal Highway Administration, June 1983.

4. Michie, J. D. Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances. Report 230, National Cooperative Highway Research Program, March 1981.

5. Hahn, K. C., and Bryden, J. E. Crash Tests of Construction Zone Traffic Barriers. Research Report 82, Engineering Research and Development Bureau, New York State Department of Transportation, June 1980.

6. Bronstad, M. E., and Kimball, C. E., Jr. Temporary Barriers Used in Construction Zones. Report 03-3716-3, Southwest Research Institute, December 1980.

7. Carlson, L. E. and Hoffman, A. G. Safety Assessment of Several Traffic Channelizing Devices. Report FHWA/RD-83/025, Federal Highway Administration, March 1983. (Preliminary Draft.)

APPENDIX

TEST DATA SUMMARY

TEST RESULT CODING SYSTEM

GENERAL TYPE

1. Steel drum
2. Plastic drum
3. Sign supports
4. Barricades, Type I
5. Barricades, Type III
6. Miscellaneous Channelizing devices

SPECIFIC TYPE

1. 55 gallon
2. Two-piece, detachable base
3. One-piece, base tab
4. One-piece, base fingers
5. Open top
6. Two-piece, split middle
7. Steel tripod
8. Low wood, portable
9. Tall wood, portable
10. Tall wood, fixed
11. Metal, miscellaneous
12. 8-ft wood, plastic legs
13. 2-ft plywood, metal legs
14. 3-ft metal, metal legs
15. 5-ft metal, metal legs
16. Wood
17. PVC
18. Metal
19. Cone
20. Tube
21. Vertical panels

LIGHT

10. Type A warning light, not attached
11. Type A warning light, attached with ½-in. bolt
12. Type A warning light, attached with ½-in. bolt and 1-in. OD washer
13. Type A warning light, attached with ½-in. bolt and tether cable
14. Traffic cone light set into cone
20. No Light

MANUFACTURER

1. Generic, constructed by Research personnel

2-9 Names of manufacturers/vendors will be provided upon request

BALLAST MATERIAL

1. Sandbag internal
2. Sandbag external
3. Sandbag on top
4. Sandbag suspended
5. Water
6. Gravel
7. Concrete block on top
8. Miscellaneous material
9. Does not reply, none

MODEL NUMBER (Models of proprietary devices will be supplied upon request)

Drums

1-12
13. Steel 55 gallon

Barricades

20-25

Vertical Panels

30-31

Sign Supports

40. Low wood, portable
41. Tall wood, portable
42-44 Tall wood, fixed
47. Thruway-metal

Miscellaneous Channelizing Devices

50.
51. ER&DB stock 36-in. cone
52. ER&DB stock 36-in. cone with cone light
53. ER&DB stock with suspended sandbag

IMPACT POINT

1. Vehicle center front
2. Inside right headlight
3. Inside left headlight

4. Right tire track
5. Left tire track
6. Right outside corner
7. Left outside corner

DEVICE DAMAGE

1. None
2. Superficial
3. Substantial, can be straightened
4. Substantial, repair parts needed
5. Destroyed

WINDSHIELD CONDITION

1. Intact, no damage
2. Minor chip or crack
3. Broken, no interference with driver vision
4. Broken, shattered, completely intact, interfering with driver vision
5. Shattered, partially dislodged but intact
6. Large portion removed
7. Completely removed

VEHICLE DAMAGE

1. No damage
2. Minor scrapes, scratches, dents
3. Substantial dents
4. Major dents
5. Structural damage

WINDSHIELD INTRUSION

1. No windshield contact
2. Windshield contact, no damage
3. Windshield damaged, no intrusion
4. Embedded in windshield, no significant intrusion
5. Partial passenger compartment intrusion
6. Complete passenger compartment intrusion

DEBRIS DISTRIBUTION DIRECTION

1. Stayed at or near impact point
2. Followed vehicle
3. Right
4. Left
5. Scattered
6. Ahead of vehicle

TEST ITEMS

	DEVICE DESCRIPTION										VEHICLE			DAMAGE REPORT						
	GNRL TYPE	SPEC TYPE	TEST #	SMPL #	SMPL WGT	BAL WGT	BAL MAT	LIGHT	MOD #	MANF	TEST WGT	NOMIN SPEED	IMPACT POINT	DEVICE DAMAGE	DEBRIS DISTRIBUTION DIST. FT.	DEBRIS DISTRIBUTION DIR.	DEBRIS DISTRIBUTION ANGLE DEGR.	VEHICLE CONDITION VEHICLE DAMAGE	VEHICLE CONDITION PROJ. W/S DAMAGE
1	1	1	64	33	53.3	0	9	20	13	1	4500	60	1	5	NC	2	-	3	1
2	1	1	49	32	53.3	0	9	20	13	1	1800	60	1	5	NC	2	-	2	1
3	1	1	92	67	53.3	0	9	20	13	1	1800	45	1	5	NC	2	-	2	1
4	1	1	96	68	53.3	0	9	20	13	1	1800	45	1	5	100	6	0	2	1
5	1	1	48	31	53.3	0	9	20	13	1	1800	30	1	5	168	6	0	2	1
6	2	2	58	24	11.5	50	1	20	10	6	4500	60	1	2	NC	2	-	1	1
7	2	2	59	35	8.6	50	1	20	11	7	4500	60	2	2	NC	2	-	1	1
8	2	2	61	24	11.5	50	1	20	10	6	4500	60	6	2	65	3	31	1	1
9	2	2	52	23	11.5	50	1	20	10	6	4500	30	6	5	NC	2	-	1	1
10	2	2	53	21	7.2	50	1	20	12	7	4500	30	6	3	108	3	2	1	1
11	2	2	3	2	13.3	50	1	20	1	2	1800	60	6	5	NC	2	-	1	1
12	2	2	6	7	10.1	50	1	20	4	3	1800	60	6	2	NC	2	-	1	1
13	2	2	17	19	9.3	50	1	20	11	7	1800	60	2	2	NC	2	-	1	1
14	2	2	68	14	11.1	50	1	20	7	4	1800	60	2	3	NC	2	-	1	1
15	2	2	69	24	11.5	50	1	20	10	6	1800	60	4	3	NC	2	-	1	1
16	2	2	88	34	8.6	50	1	20	11	7	1800	60	1	2	NC	2	-	1	1
17	2	2	93	14	11.1	50	1	20	7	4	1800	60	1	2	NC	2	-	1	1
18	2	2	2	1	13.3	50	1	20	1	2	1800	35	6	5	24	3	45	1	1
19	2	2	1	1	13.3	50	1	20	1	2	1800	30	6	2	NC	2	-	1	1
20	2	3	57	3	9.9	50	2	20	2	5	4500	60	1	3	NC	2	-	1	1
21	2	3	56	3	9.9	50	2	20	2	5	4500	45	2	2	NC	2	-	1	1
22	2	3	50	4	9.9	50	2	20	2	5	4500	30	4	3	68	2	-	1	1
23	2	3	4	3	9.9	50	2	20	2	5	1800	60	2	3	NC	2	-	1	1
24	2	4	60	10	9.5	50	1	20	5	3	4500	60	1	2	NC	2	-	1	1
25	2	4	7	9	9.5	50	1	20	5	3	1800	60	4	5	NC	2	-	1	1
26	2	5	5	5	8.4	50	1	20	3	3	1800	60	1	5	54	4	5	1	1
27	2	5	8	11	9.4	50	1	20	6	3	1800	60	1	5	NC	2	-	1	1
28	2	6	70	26	10.9	50	1	20	9	6	1800	60	6	5	49	3	-	1	1
29	2	6	15	18	11.5	50	1	20	9	6	1800	30	4	2	43	4	18	1	1
30	2	2	10	13	11.1	0	9	20	7	4	1800	60	6	2	50	3	50	1	1
31	2	2	9	13	11.1	0	9	20	7	4	1800	30	6	2	54	3	10	1	1
32	2	2	16	19	9.3	0	9	20	11	7	1800	60	1	2	NC	2	-	1	1
33	2	2	31	17	11.5	0	9	20	10	6	1800	60	6	2	92	3	6	1	1
34	2	2	27	17	11.5	0	9	20	10	6	1800	30	1	2	NC	2	-	1	1
35	2	3	29	4	9.9	0	9	20	2	5	1800	60	2	5	NC	2	-	1	1
36	2	3	25	4	9.9	0	9	20	2	5	1800	30	2	2	NC	2	-	1	1
37	2	5	12	15	11.5	0	9	20	8	6	1800	60	6	5	NC	2	-	1	1
38	2	5	11	15	11.5	0	9	20	8	6	1800	30	2	2	NC	2	-	1	1

	TEST ITEMS													DAMAGE REPORT					
	DEVICE DESCRIPTION										VEHICLE				DEBRIS DISTRIBUTION			VEHICLE CONDITION	
	GNRL TYPE	SPEC TYPE	TEST #	SMPL #	SMPL WGT	BAL WGT	BAL MAT	LIGHT	MOD #	MANF	TEST WGT	NOMIN SPEED	IMPACT POINT	DEVICE DAMAGE	DIST. FT.	DIR.	ANGLE DEGR.	VEHICLE DAMAGE	PROJ. M/S DAMAGE
39	2	5	30	6	8.4	0	9	20	3	3	1800	60	4	5	54	3	57	1	1
40	2	5	26	6	8.4	0	9	20	3	3	1800	30	1	2	NC	2	-	1	1
41	2	6	14	18	11.5	0	9	20	9	6	1800	60	6	2	67	3	24	1	1
42	2	6	13	18	11.5	0	9	20	9	6	1800	30	6	2	?	3	45	1	1
43	2	6	32	25	10.9	0	9	20	9	6	1800	60	2	5	47	4	42	2	1
44	2	6	28	25	10.9	0	9	20	9	6	1800	30	1	2	29	4	25	1	1
45	2	2	87	35	8.6	30	4	20	11	7	1800	60	1	3	NC	2	-	1	1
46	2	2	51	19	9.3	50	3	20	11	7	4500	30	2	5	NC	2	-	2	1
47	2	2	91	34	8.6	42	7	20	11	7	1800	45	1	2	199	3	11	4	6
48	2	2	46	13	11.1	42	7	20	7	4	1800	30	4	1	NC	2	-	4	6
49	2	5	47	28	11.5	150	5	20	8	6	1800	60	1	5	NC	2	-	3	1
50	2	5	80	12	9.4	55	8	20	6	3	1800	60	2	5	225	3	13	2	1
51	2	5	81	6	8.4	180	6	20	3	3	1800	60	1	5	NC	2	-	1	1
52	2	2	62	35	9.3	50	1	12	11	7	4500	60	6	3	NC	2	-	1	1
53	2	2	54	21	7.2	50	1	12	12	7	4500	30	2	3	NC	2	-	1	1
54	2	2	55	29	14.1	50	1	11	1	2	4500	30	4	5	124	4	5	1	1
55	2	2	33	8	10.1	50	1	11	4	3	1800	60	2	5	147	3	1	2	1
56	2	2	34	17	11.5	50	1	11	10	6	1800	60	2	2	182	4	5	2	1
57	2	2	36	19	9.3	50	1	11	11	7	1800	60	2	2	175	3	2	1	1
58	2	2	38	8	10.1	50	1	12	4	3	1800	60	2	5	160	4	3	1	1
59	2	2	39	19	9.3	50	1	12	11	7	1800	60	2	2	129	2	0	1	1
60	2	2	89	13	11.1	50	1	11	7	4	1800	45	1	2	108	3	6	1	1
61	2	2	89A	30	14.1	50	1	11	1	2	1800	45	5	2	108	4	6	1	1
62	2	2	43	23	11.5	50	1	11	10	6	1800	30	1	2	NC	2	-	1	1
63	2	2	44	10	9.5	50	1	10	5	3	1800	30	1	2	45	4	8	1	1
64	2	3	63	3	9.9	50	2	12	2	5	4500	60	1	2	NC	2	-	1	1
65	2	3	35	4	9.9	50	2	11	2	5	1800	60	4	5	143	3	4	1	1
66	2	3	40	4	9.9	50	1	12	2	5	1800	60	4	2	200+	2	0	2	3
67	2	4	45	10	9.5	50	1	11	5	3	1800	60	1	2	NC	2	-	1	4
68	2	4	42	10	9.5	50	1	11	5	3	1800	30	1	2	79	2	0	1	1
69	2	5	37	16	11.5	50	1	11	8	6	1800	60	4	5	146	3	1	1	1
70	2	5	41	27	11.5	50	1	12	8	6	1800	60	4	5	249	4	5	1	4
71	3	7	79	60	44.2	0	9	20	43	6	1800	60	1	5	134	3	2	3	4
72	3	7	90	47	44.2	0	9	20	43	6	1800	45	1	5	75	4	18	2	4
73	3	8	78	53	N/A	100	2	20	40	1	1800	60	1	5	133	4	3	2	3
74	3	8	77	52	N/A	100	2	20	40	1	1800	60	1	5	134	4	8	2	3
75	3	9	75	54	N/A	100	2	20	41	1	1800	60	1	5	92	4	20	3	1
76	3	9	76	55	N/A	100	2	20	41	1	1800	60	1	5	162	3	5	2	3
77	3	10	83	57	N/A	0	9	20	42	1	1800	60	1	5	134	3	1	2	3

	TEST ITEMS													DAMAGE REPORT					
	DEVICE DESCRIPTION										VEHICLE				DEBRIS DISTRIBUTION			VEHICLE CONDITION	
	GNRL TYPE	SPEC TYPE	TEST #	SMPL #	SMPL WGT	BAL WGT	BAL MAT	LIGHT	MOD #	MANF	TEST WGT	NOMIN SPEED	IMPACT POINT	DEVICE DAMAGE	DIST. FT.	DIR.	ANGLE DEGR.	VEHICLE DAMAGE	PROJ. W/S DAMAGE
78	3	10	82	56	N/A	0	9	20	42	1	1800	60	4	5	215	3	2	2	3
79	3	11	97	70	N/A	200	2	20	44	9	1800	55	2	5	NC	2	-	2	6
80	3	11	98	71	N/A	200	2	20	47	1	1800	45	2	5	200	2	0	2	1
81	4	13	22	45	19.3	0	9	11	22	6	1800	60	2	5	150	3	2	2	1
82	4	14	23	42	18.2	0	9	11	24	6	1800	60	1	5	102	4	1	2	2
83	4	15	86	36	31.8	0	9	11	20	5	1800	60	1	5	172	4	11	2	1
84	4	12	21	46	29.9	0	9	20	25	6	1800	30	1	5	70	3	2	2	2
85	5	16	95	69	N/A	0	9	20	28	1	1800	45	1	5	150	3	4	2	5
86	5	17	84	49	N/A	100	2	20	27	1	4500	60	1	5	207	4	8	1	5
87	5	17	24	48	N/A	100	2	13	26	1	1800	60	4	5	35	4	10	3	5
88	5	17	94	44	22.5	100	2	13	26	1	1800	45	1	5	205	4	3	2	4
89	5	18	85	41	57.2	0	9	20	23	8	1800	60	1	5	NC	2	-	2	1
90	6	19	65	65	11.5	0	9	14	52	1	4500	60	2	4	NC	2	-	1	1
91	6	19	67	63	10.6	0	9	20	51	1	4500	60	1	2	NC	2	-	1	1
92	6	19	113	62	10.6	0	9	20	51	1	4500	30	2	2	NC	2	-	1	1
93	6	19	114	64	11.5	0	9	14	52	1	4500	30	2	4	175	3	13	1	1
94	6	19	71	66	17.5	8	4	20	53	1	1800	60	4	2	223	4	17	1	1
95	6	19	72	66	17.5	8	4	20	53	1	1800	30	4	2	IMP	1	-	1	1
96	6	20	66	61	13.4	0	9	20	50	6	4500	60	1	2	85	5	0	1	1
97	6	20	112	61	13.4	0	9	20	50	6	4500	30	1	2	48	4	21	1	1
98	6	20	73	61	13.4	0	9	20	50	6	1800	60	1	1	55	3	14	1	1
99	6	20	74	61	13.4	0	9	20	50	6	1800	30	1	1	60	3	1	1	1
100	6	21	18	39	N/A	0	9	20	30	8	1800	30	4	2	27	2	-	2	1
101	6	21	20	43	22.5	0	9	11	31	6	1800	60	4	5	193	3	4	2	1
102	6	21	19	43	22.5	0	9	11	31	6	1800	30	2	4	151	3	2	2	1
103	6	21	99	40	32.8	0	9	20	30	8	4500	60	1	4	176	4	30	1	1
104	6	21	100	72	32.8	0	9	20	30	8	4500	20	1	4	IMP	1	-	1	1
105	6	21	101	72	32.8	0	9	20	30	8	4500	50	1	4	156	4	3	1	1
106	6	21	102	73	32.8	0	9	20	30	8	4500	20	4	4	IMP	1	-	1	1
107	6	21	103	73	32.8	0	9	20	30	8	4500	50	4	4	90	4	5	1	1
108	6	21	104	72	32.8	0	9	20	30	8	4500	50	4	4	78	3	15	3	1

EVALUATION FACTORS

TEST #	PASSENGER COMP. INTRUSI		HARMFUL DEBRIS	VEHICLE CONTROL INTERFERENCE				TEST #	WINDSHIELD				
	PROJECTED W/S INTRUSION	BODY PANEL INTRUSION		PHYSICAL	THROWN DEBRIS	WINDSHIELD VISIBILITY	PAVEMENT DEBRIS		ACTUAL COND. BEFORE	ACTUAL COND. AFTER	PROJ. DAMAGE	INTR. RATING ACTUAL	INTR. RATING PROJ.
64	1	N	N	Y	N	N	N	64	1	1	1	1	1
49	1	N	N	Y	N	N	N	49	7	7	1	1	1
92	1	N	N	Y	N	N	N	92	6	6	1	1	1
96	1	N	Y	N	Y	N	N	96	6	6	1	1	1
48	1	N	Y	N	Y	N	N	48	6	6	1	1	1
58	1	N	N	N	N	N	N	58	1	1	1	1	1
59	1	N	N	N	N	N	N	59	1	1	1	1	1
61	1	N	N	N	Y	N	N	61	1	1	1	1	1
52	1	N	N	N	N	N	N	52	1	1	1	1	1
53	1	N	N	N	N	N	N	53	1	1	1	1	1
3	1	N	N	N	N	N	N	3	1	1	1	1	1
6	1	N	N	N	N	N	N	6	1	1	1	1	1
17	1	N	N	N	N	N	N	17	1	1	1	1	1
68	1	N	N	N	N	N	N	68	1	1	1	1	1
69	1	N	N	N	N	N	N	69	1	1	1	1	1
88	1	N	N	N	N	N	N	88	1	1	1	1	1
93	1	N	N	N	N	N	N	93	1	1	1	1	1
2	1	N	N	N	Y	N	N	2	1	1	1	1	1
1	1	N	N	N	N	N	N	1	1	1	1	1	1
57	1	N	N	N	N	N	N	57	1	1	1	1	1
56	1	N	N	N	N	N	N	56	1	1	1	1	1
50	1	N	N	N	N	N	N	50	1	1	1	1	1
4	1	N	N	N	N	N	N	4	1	1	1	1	1
60	1	N	N	N	N	N	N	60	1	1	1	1	1
7	1	N	N	N	N	N	N	7	1	1	1	1	1
5	1	N	N	N	Y	N	N	5	1	1	1	1	1
8	1	N	N	N	N	N	Y	8	1	1	1	1	1
70	1	N	N	N	Y	N	N	70	1	1	1	1	1
15	1	N	N	N	Y	N	N	15	1	1	1	1	1
10	1	N	N	N	Y	N	N	10	1	1	1	1	1
9	1	N	N	N	Y	N	N	9	1	1	1	1	1
16	1	N	N	N	N	N	N	16	1	1	1	1	1
31	1	N	N	N	Y	N	N	31	5	5	1	1	1
27	1	N	N	N	N	N	N	27	5	5	1	1	1
29	1	N	N	N	N	N	N	29	5	5	1	1	1
25	1	N	N	N	N	N	N	25	5	5	1	1	1
12	1	N	N	N	N	N	N	12	1	1	1	1	1
11	1	N	N	N	N	N	N	11	1	1	1	1	1

+ HARMFUL DEBRIS CONSISTED OF LIGHTS AND BATTERIES, NOT THE DEVICE ITSELF

EVALUATION FACTORS

TEST #	PASSENGER COMP. INTRUSI		HARMFUL DEBRIS	VEHICLE CONTROL INTERFERENCE				TEST #	WINDSHIELD				
	PROJECTED W/S INTRUSION	BODY PANEL INTRUSION		PHYSICAL	THROWN DEBRIS	WINDSHIELD VISIBILITY	PAVEMENT DEBRIS		ACTUAL COND. BEFORE	ACTUAL COND. AFTER	PROJ. DAMAGE	INTR. RATING ACTUAL	INTR. RATING PROJ.
30	1	N	N	N	Y	N	N	30	5	5	1	1	1
26	1	N	N	N	N	N	N	26	5	5	1	1	1
14	1	N	N	N	Y	N	N	14	1	1	1	1	1
13	1	N	N	N	Y	N	N	13	1	1	1	1	1
32	1	N	N	N	Y	N	N	32	1	1	1	1	1
28	1	N	N	N	Y	N	N	28	5	5	1	1	1
87	1	N	N	N	N	N	N	87	1	1	1	1	1
51	1	N	N	N	N	N	Y	51	1	1	1	1	1
91	3	Y	Y	N	N	N	N	91	4	6	6	5	5
46	6	N	Y	N	N	N	N	46	4	6	6	6	6
47	1	N	N	N	N	N	N	47	6	6	1	1	1
80	1	N	Y	N	Y	N	Y	80	7	7	1	1	1
81	2	N	N	N	Y	N	N	81	7	7	1	5	2
62	1	N	N	N	N	N	N	62	1	1	1	1	1
54	1	N	N	N	N	N	N	54	1	1	1	1	1
55	1	N	N	N	N	N	N	55	1	1	1	1	1
33	2	N	*Y	N	N	N	N	33	1	1	1	2	2
34	2	N	*Y	N	N	N	N	34	1	1	1	2	2
36	2	N	*Y	N	N	N	N	36	1	1	1	2	2
38	2	N	*Y	N	Y	N	N	38	1	1	1	2	2
39	3	N	*Y	N	Y	N	N	39	1	1	1	2	2
89	1	N	*Y	N	N	N	N	89	1	1	1	2	2
89A	1	N	*Y	N	N	N	N	89A	1	1	1	2	2
43	1	N	N	N	N	N	N	43	4	4	1	1	1
44	2	N	*Y	N	N	N	N	44	4	4	1	2	2
63	1	N	N	N	N	N	N	63	1	1	1	1	1
35	2	N	*Y	N	N	N	N	35	1	1	1	2	2
40	3	N	*Y	N	N	N	N	40	1	3	3	3	3
45	5	N	*Y	N	N	Y	N	45	4	4	4	5	3
42	1	N	*Y	N	N	N	N	42	4	4	1	1	1
37	2	N	*Y	N	N	N	N	37	1	1	1	2	2
41	3	N	*Y	N	N	Y	N	41	3	4	4	3	3
79	3	N	Y	N	Y	Y	N	79	7	7	4	6	3
90	3	N	Y	N	Y	Y	N	90	1	4	4	3	3
78	3	N	Y	N	Y	N	N	78	7	7	3	6	3
77	3	N	Y	N	Y	N	N	77	7	7	3	6	3
75	1	N	Y	N	Y	N	N	75	1	1	1	1	1
76	3	N	Y	N	Y	N	N	76	7	7	3	6	3
83	3	N	Y	N	Y	N	N	83	7	7	3	6	3

* HARMFUL DEBRIS CONSISTED OF LIGHTS AND BATTERIES, NOT THE DEVICE ITSELF

EVALUATION FACTORS

TEST #	PASSENGER COMP. INTRUSI		HARMFUL DEBRIS	VEHICLE CONTROL INTERFERENCE				TEST #	WINDSHIELD				
	PROJECTED M/S INTRUSION	BODY PANEL INTRUSION		PHYSICAL	THROWN DEBRIS	WINDSHIELD VISIBILITY	PAVEMENT DEBRIS		ACTUAL COND. BEFORE	ACTUAL COND. AFTER	PROJ. DAMAGE	INTR. RATING ACTUAL	INTR. RATING PROJ.
82	3	N	Y	N	Y	N	N	82	7	7	3	2	3
97	3	N	Y	N	Y	N	N	97	6	6	6	3	3
98	1	N	N	N	N	N	N	98	6	6	1	1	1
22	1	N	Y	N	Y	N	N	22	2	2	1	1	1
23	2	N	Y	N	Y	N	N	23	2	2	2	2	2
86	1	N	Y	N	Y	N	N	86	1	1	1	1	1
21	3	N	Y	N	Y	N	N	21	1	2	2	3	3
95	3	N	Y	N	Y	Y	N	95	4	6	5	5	4
84	5	N	N	N	Y	Y	N	84	1	5	5	5	5
24	5	N	*Y	N	Y	Y	N	24	2	5	5	5	5
94	3	N	*Y	N	Y	Y	N	94	1	4	4	3	3
85	1	N	N	N	N	N	N	85	7	7	1	1	1
65	1	N	N	N	N	N	N	65	1	1	1	1	1
67	1	N	N	N	N	N	N	67	1	1	1	1	1
113	1	N	N	N	N	N	N	113	1	1	1	1	1
114	1	N	*Y	N	N	N	N	114	1	1	1	1	1
71	1	N	N	N	N	N	N	71	1	1	1	1	1
72	1	N	N	N	N	N	N	72	1	1	1	1	1
66	1	N	N	N	N	N	N	66	1	1	1	1	1
112	1	N	N	N	N	N	N	112	1	1	1	1	1
73	1	N	N	N	N	N	N	73	1	1	1	1	1
74	1	N	N	N	N	N	N	74	1	1	1	1	1
18	1	N	N	N	N	N	N	18	1	1	1	1	1
20	2	N	*Y	N	N	N	N	20	1	1	1	2	2
19	1	N	N	N	N	N	N	19	1	1	1	1	1
99	1	N	N	N	N	N	N	99	1	1	1	1	1
100	1	N	N	N	N	N	N	100	1	1	1	1	1
101	1	N	N	N	N	N	N	101	1	1	1	1	1
102	1	N	N	N	N	N	N	102	1	1	1	1	1
103	1	N	N	N	N	N	N	103	1	1	1	1	1
104	1	N	N	Y	N	N	N	104	1	1	1	1	1

* HARMFUL DEBRIS CONSISTED OF LIGHTS AND BATTERIES, NOT THE DEVICE ITSELF

TEST#	EVENT DESCRIPTION
64	DRUM TIPPED OVER UNDER FRONT OF CAR - PARTIAL STEERING LOSS. GRILL & RADIATOR DAMAGE, DRUM CRUSHED. CAR SLID STRAIGHT AHEAD
49	CAR RODE UP ON DRUM WITH TWO FRONT WHEELS OFF PAVEMENT & SLID 275', DRUM CRUSHED, SHEET METAL DAMAGE TO CAR
92	DRUM WENT UNDER FRONT OF CAR, 3 WHEELS OFF PAVEMENT, CAR NEARLY ROLLED OVER. DRUM CRUSHED.
96	DRUM PUSHED OVER IN FRONT OF CAR. CONTINUED TO ROLL & BOUNCE FOR 100' AFTER CAR STOPPED, NO LOSS OF STEERING
48	DRUM TIPPED OVER & PUSHED AHEAD OF CAR - CONTINUED TO ROLL 168' AFTER CAR STOPPED
58	DRUM STAYED WITH CAR, SAND BAG STAYED AT IMPACT, DRUM DAMAGED - REUSABLE
59	DRUM STAYED WITH CAR, SAND BAG STAYED AT IMPACT, DRUM HAD MINOR DENT - REUSABLE
61	DRUM THROWN 65 FT - 31 DEG. RT.. BASE SLID 13', DRUM DENTED - REUSABLE
52	DRUM TRAPPED UNDER RT. FRONT OF CAR AND SLID UNDER THE CAR NEAR END OF IMPACT. DRUM MAJOR DENT - NOT REUSABLE
53	DRUM TRAPPED UNDER RT. FRONT, THEN PUSHED OFF TO RT. SIDE. SAND BAG STAYED AT IMPACT. DRUM WENT 108', DRUM DENTED - REUSABLE
3	DRUM STAYED WITH FRONT OF CAR. DRUM RIPPED NEARLY IN HALF ON IMPACT - NOT REUSABLE
6	DRUM STAYED WITH CAR. BASE STAYED AT IMPACT. DRUM DENTED - REUSABLE
17	DRUM STAYED WITH CAR, SAND BAG STAYED AT IMPACT. DRUM MINOR DENTS
68	DRUM STAYED WITH FRONT OF CAR, SAND BAG STAYED AT IMPACT. DRUM HAD MAJOR DENT - REUSABLE.
69	DRUM STAYED WITH FRONT OF CAR, SAND BAG STAYED NEAR IMPACT. DRUM HAD MAJOR DENT - REUSABLE.
88	DRUM STAYED WITH FRONT OF CAR, SAND BAG STAYED AT IMPACT. DRUM MINOR DENT - REUSABLE
93	DRUM STAYED WITH FRONT OF CAR, SAND BAG AT IMPACT. DRUM MINOR DENT - REUSABLE
2	DRUM BROKE IN 2 PIECES FROM PREVIOUS TEAR. BOTH PIECES THROWN TO THE RIGHT. DRUM DESTROYED
1	DRUM PUSHED AHEAD OF CAR. BASE STAYED AT IMPACT, SAND BAG SLID 25'. DRUM TORN & DENTED - REUSABLE
57	DRUM STAYED WITH CAR, SAND BAG SCATTERED ALONG PAVEMENT. DRUM DENTED - REUSABLE
56	DRUM STAYED WITH CAR, SAND BAG SLID ALONG PAVEMENT. DRUM MINOR DENT - REUSABLE
50	DRUM STARTED TO PULL DOWN ON IMPACT, GRADUALLY WENT UNDER CAR - DRUM WENT 68', SAND BAG STAYED AT IMPACT
4	DRUM PUSHED AHEAD OF CAR. SAND BAG STAYED AT IMPACT. DRUM DENTED - REUSABLE
60	DRUM STAYED WITH CAR AND SAND BAG AT IMPACT. DRUM MINOR DENT - REUSABLE
7	DRUM STAYED WITH CAR. SAND BAG STAYED AT IMPACT. DRUM SPLIT OPEN - NOT REUSABLE
5	DRUM BROKE IN PIECES ON IMPACT, BOTTOM PART & SAND BAG SLID 28', TOP HALF WENT WITH CAR 54'.
8	DRUM STAYED UNDERNEATH FRONT OF CAR. SAND BAG BROKE THRU BOTTOM ON IMPACT & SPREAD ALONG PAVEMENT, (DUST CLOUD). DRUM BOTTOM OUT - NOT REUSABLE
70	DRUM TOP SEPERATED ON IMPACT & WENT 49' - 8 FT. RT.(CHAMPAGNE CORK). BASE & SAND BAG WENT 111' - 20'LFT. BUTTOM CRUSHED - NOT REUSABLE
15	DRUM TOP POPPED UP & BASE TRAPPED UNDER CAR. DRUM DENTED - REUSABLE
10	DRUM & BASE THROWN 50' - 45 DEG. RT. ON IMPACT. MINOR DAMAGE TO DRUM
9	DRUM THROWN TO THE RT. SIDE BY IMPACT, BASE SLID 27'- 9 DEG. LFT., DRUM DENTED - REUSABLE
16	DRUM STAYED UPRIGHT WITH FRONT OF CAR. BASE STAYED AT IMPACT. DRUM DENTED - REUSABLE
31	DRUM THROWN OFF TO RIGHT SIDE 92'. BASE STAYED AT IMPACT. DRUM MINOR DAMAGE
27	DRUM STAYED UPRIGHT WITH FRONT OF CAR. BASE AT IMPACT. DRUM DENTED - REUSABLE
29	DRUM STAYED UPRIGHT WITH FRONT OF CAR. DRUM BADLY DENTED - NOT REUSABLE
25	DRUM STAYED UPRIGHT WITH FRONT OF CAR. DAMAGE MINOR
12	DRUM PUSHED AHEAD OF CAR. DRUM CRUSHED ALMOST FLAT.
11	PUSHED AHEAD OF CAR UNDER BUMPER. DRUM DENTED. REUSEABLE

30	DRUM THROWN OFF TO RIGHT SIDE 54'. DRUM MAJOR DENT & TEAR - NOT REUSABLE
26	DRUM STAYED UPRIGHT WITH FRONT OF CAR. DRUM DENTED - REUSABLE
14	DRUM BASE WENT UNDER RT. SIDE OF CAR, TOP HALF POPPED UP & TO THE RT. DRUM MINOR DAMAGE - REUSABLE.
13	DRUM TOP HALF POPPED UP, BOTTOM PUSHED TO RIGHT. DRUM MINOR DAMAGE
32	DRUM TOP POPPED OFF AND WENT 47'. BOTTOM STAYED WITH FRONT OF CAR. TOP REUSABLE - BOTTOM BADLY DENTED - NOT REUSABLE
28	BOTTOM HALF STAYED UPRIGHT WITH FRONT OF CAR, TOP POPPED OFF ON IMPACT & WENT 29'. DRUM DENTED - REUSABLE
87	DRUM STAYED WITH FRONT OF CAR, SAND BAG DROPPED & BROKE AT IMPACT. DRUM MAJOR DENT - REUSABLE
51	SAND BAG BROKE ON IMPACT & PASSED OVER TOP OF CAR. DRUM TRAPPED UNDER FRONT OF CAR. MAJOR DRUM DAMAGE - REUSABLE
91	DRUM PUSHED AHEAD OF CAR, CONCRETE BLOCK IMPACTED ROOF LINE, MAJOR VEHICLE DAMAGE, BLOCK THROWN AHEAD OF STOPPED CAR. DRUM - MINOR DAMAGE
46	DRUM PUSHED AHEAD OF CAR. CONCRETE BLOCK WENT IN THE PASSENGER COMPARTMENT. DRUM NOT DAMAGED
47	DRUM PUSHED AHEAD OF CAR, WATER DISPERSED ON IMPACT. EXTENSIVE SHEET METAL DAMAGE TO FRONT OF CAR. DRUM DESTROYED
80	DRUM PULLED DOWN UNDER CAR. 2X4'S SCATTERED ON IMPACT- BLOCK SLID ALONG PAVEMENT. BBL WENT 97' & DEBRIS WENT 225'. DRUM DESTROYED.
81	DRUM SHEARED AT TOP OF BALLAST, BALLAST & BASE STAYED AT IMPACT, TOP BROKE IN TWO & WENT WITH CAR, TOP PIECE ENTERED CAR WINDSHIELD (WINDSHIELD WAS OUT PREVIOUSLY)
62	DRUM STAYED WITH CAR, LIGHT STAYED ATTACHED BUT LENS BROKE, SAND BAG BROKE & SLID. BARREL MAJOR DENT - REUSABLE
54	DRUM TIPPED FORWARD DOWN TO PAVEMENT THEN PUSHED UNDER CAR, LIGHT REMAINED ATTACHED. SAND BAG STAYED AT IMPACT. DRUM MAJOR DENT
55	DRUM & LIGHT UNIT WENT UNDER CAR, ENTIRE LIGHT UNIT SEPERATED & SLID 124' - 5 DEG. LFT.. SAND BAG STAYED AT IMPACT. DRUM MAJOR DENT - NOT REUSABLE
33	DRUM STAYED WITH FRONT OF CAR. BASE & SAND BAG STAYED AT IMPACT. BOLT PULLED THRU DRUM & LIGHT WAS THROWN VERTICALLY. DRUM HAD MAJOR TEARS
34	DRUM WENT OVER TOP OF CAR. LIGHT TORE OFF & WENT 182'. BASE & BALLAST STAYED AT IMPACT. DRUM DENTED - REUSABLE
36	DRUM STAYED WITH CAR, LIGHT TORE OFF & WENT 175'. BASE & SAND BAG STAYED NEAR IMPACT. DRUM DENTED - REUSABLE
38	DRUM STAYED WITH CAR, LIGHT BROKE OFF TOP OF DRUM, HIT THE WINDSHIELD & FLEW 160'. BASE & SAND BAG STAYED NEAR IMPACT. DRUM DESTROYED
39	DRUM WITH LIGHT ATTACHED WENT OVER TOP OF CAR AND WENT 129'. SAND BAG & BASE STAYED AT IMPACT, DRUM MINOR DAMAGE
89	DRUM PUSHED AHEAD OF CAR, THEN WAS THROWN TO THE RIGHT. LIGHT TORE OFF. SAND BAG & BASE STAYED AT IMPACT. DRUM DENTED - REUSABLE
89A	DRUM PUSHED AHEAD OF CAR, THROWN TO THE LEFT & LIGHT TORE OFF. SAND BAG & BASE STAYED AT IMPACT. DRUM HAD MINOR DAMAGE
43	DRUM STAYED WITH FRONT OF CAR & LIGHT STAYED ATTACHED, LIGHT BOUNCED OFF HOOD ON IMPACT & ALMOST WENT OVER CAR. BASE & SAND BAG STAYED AT IMPACT, DRUM DENTED - REUSABLE
44	DRUM STAYED WITH FRONT OF CAR, LIGHT BOUNCED OFF WINDSHIELD & WENT 45' OVER CAR. WINDSHIELD NOT BROKEN. BASE & SAND BAG STAYED AT IMPACT, DRUM MINOR DAMAGE
63	DRUM STAYED WITH CAR, BATTERY COMPARTMENT STAYED WITH DRUM, LIGHT UNIT DETACHED & FLEW 252', DRUM DENTED - REUSABLE
35	DRUM STAYED WITH CAR, LIGHT TORE OFF & WENT 143'. BASE & SAND BAG STAYED AT IMPACT. DRUM HAD MAJOR DAMAGE - NOT REUSABLE
40	DRUM STAYED WITH FRONT OF CAR WITH LIGHT ATTACHED. BATTERY SEPERATED ON IMPACT & FLEW 200'. SAND BAG & BASE STAYED AT IMPACT
45	DRUM STAYED WITH FRONT OF CAR, LIGHT FLEW OFF AND EMBEDDED IN WINDSHIELD (WINDSHIELD WAS PREVIOUSLY CRACKED). SAND BAG & BASE STAYED AT IMPACT. DRUM DENTED - REUSABLE
42	DRUM STAYED WITH FRONT OF CAR. BOLT PULLED THRU AND LIGHT TORE OFF & WENT OVER TOP OF CAR AND WENT 79'. SAND BAG STAYED AT IMPACT. DRUM DENTED - REUSABLE
37	DRUM BROKE NEAR BOTTOM ON IMPACT, WENT UNDER CAR. SAND BAG WENT 72' & LIGHT FLEW OFF & WENT 146', DRUM WENT 94'. DRUM DESTROYED
41	DRUM PULLED UNDER CAR, LIGHT FLEW OFF & BROKE WINDSHIELD. LIGHT TOP FLEW 90', ONE BATTERY WENT 101', OTHER BATTERY WENT 249'. DRUM DESTROYED
79	PANEL THROWN INTO WINDOW OPENING (PREVIOUSLY OUT). TRIPOD THROWN DOWNSTREAM 134'.
90	PANEL FLIPPED INTO AND BROKE WINDSHIELD AND FLEW 75' TO LEFT. LEGS THROWN HIGH INTO THE AIR & WENT 57'.
78	DEVICE BROKE APART, PANEL & SEVERAL PIECES WERE THROWN DOWNSTREAM 133'
77	PANEL BOUNCED OFF WINDSHIELD (PREVIOUSLY BROKEN) THROWN HIGH INTO THE AIR, REST OF SUPPORT BROKE APART, THROWN DOWNSTREAM 134', ONE PIECE OF 2X4 IN CAR
75	PANEL WENT OVER CAR & LANDED NEAR IMPACT WITH BASE. BRACES & VERTICAL MEMBER THROWN UP IN THE AIR. 2X4 WENT 92'. CAR BUMPER PUSHED IN.
76	SUPPORT SHATTERED ON IMPACT, PANEL WENT OVER CAR & LANDED NEAR IMPACT. PIECES OF SUPPORT THROWN 162'.
83	PANEL & UPPER SUPPORT DROPPED BEHIND CAR AT IMPACT. LOWER SUPPORT & BRACES THROWN DOWNSTREAM 134'.

82	PANEL & MOST OF LEG WENT OVER CAR & LANDED AT IMPACT, BRACES THROWN DOWNSTREAM 215'
97	PANEL HIT WINDSHIELD & WENT OVER ROOF, SUPPORT STAYED WITH FRONT OF CAR. TWO LEGS BROKE OFF, THROWN TO THE RIGHT SIDE. SUPPORT DESTROYED
98	CAR HIT ONE LEG & SIGN ROTATED & FELL AT IMPACT, LEFT BASE PIECE SLID ALONG PAVEMENT 200'.
22	BROKE INTO SEVERAL PIECES ON IMPACT. & THROWN UP IN THE AIR, LEGS FLEW 150'. CAR HOOD - MINOR DENTS - DEVICE DESTROYED
23	THROWN UP IN THE AIR ON IMPACT 102'. HOOD & ROOF DENTED ON CAR - DEVICE DESTROYED
86	LIGHT THROWN INTO THE AIR ON IMPACT & WENT 172'. LIGHT ATTACHED , ONE LEG BROKE OFF - DEVICE DESTROYED - MINOR DENT ON CAR HOOD
21	PANEL BROKE ON IMPACT. ONE LEG STAYED AT IMPACT, PANEL & OTHER LEG WENT OVER CAR. PIECES OF LEG ALSO BROKE OFF. WINDSHIELD CRACKED FROM IMPACT
95	DEVICE BROKE ON IMPACT, SEVERAL LARGE PIECES THROWN DOWNSTREAM - ONE 2X6X8 IMBEDDED IN WINDSHIELD (PREVIOUSLY CRACKED). FARTHEST DEBRIS 150'.
84	DEVICE BROKE APART ON IMPACT. TOP RAIL HIT & SHATTERED WINDSHIELD, SCATTERED DOWNSTREAM 207'. DEVICE DESTROYED
24	DEVICE BROKE INTO SMALL PIECES ON IMPACT & SCATTERED OVER WIDE AREA, LIGHT SHATTERED WINDSHIELD, PANELS WENT OVER CAR. DEVICE DESTROYED
94	DEVICE SHATTERED ON IMPACT. WINDSHIELD SHATTERED, LIGHT WENT 205'.
85	STAYED WRAPPED AROUND FRONT OF CAR. LEGS RELEASED & BOTTOM PART FOLDED, BUT BENT SO TOP STAYED UPRIGHT. DEVICE EXTENSIVELY DAMAGED, SHEET METAL DAMAGE TO CAR
65	CONE TRAPPED UNDER FRONT OF CAR, LIGHT IMBEDDED IN GRILL. CONE O.K., LIGHT BROKE
67	CONE WENT UNDER CAR & SLID ALONG PAVEMENT. CONE & BASE SEPERATED - REUSABLE
113	CONE DRAGGED UNDER FRONT OF CAR. CONE MINOR DAMAGE
114	CONE DRAGGED UNDER CAR - LIGHT THROWN AHEAD OF CAR, BATTERY WENT 175'. CONE MINOR DAMAGE, LIGHT BROKE
71	CONE PASSED UNDER CAR THEN ROLLED LEFT 223', SAND BAG BROKE & STAYED NEAR IMPACT. CONE MINOR DAMAGE
72	CONE WENT UNDER CAR AND STAYED AT IMPACT. SAND BAG BROKE AT IMPACT. CONE MINOR DAMAGE
66	TUBE PUSHED DOWN & WENT UNDER CAR, SLID ALONG PAVEMENT 85'. TUBE & BASE SEPERATED - REUSABLE
112	CONE WENT UNDER CAR & BOUNCED ON PAVEMENT 48'. CONE & BASE SEPERATED - REUSABLE
73	TUBE PASSED UNDER CAR - BASE STAYED AT IMPACT. TUBE WENT 55', NO DAMAGE
74	TUBE PASSED UNDER CAR AND WENT 60', BASE STAYED IMPACT. NO DAMAGE TO TUBE
18	DEVICE PUSHED AHEAD 27' THEN WENT UNDER CAR BUT DIDN'T TIP OVER. PANEL SEPERATED FROM POST - EASILY REPAIRED
20	BROKE APART ON IMPACT. BASE TRAVELED 8', LIGHT WENT OVER CAR, POST & PANEL FLEW 193'. BASE & POST REUSABLE, LIGHT COULDN'T BE REATTACHED
19	PUSHED AHEAD OF CAR & THEN WENT UNDER CAR - TRAVELLED 151' - LIGHT STAYED ATTACHED - MINOR DAMAGE, REPAIRED FOR NEXT TEST
99	CAR MUFFLER MAY HAVE SNAGGED BASE
100	DEVICE STAYED AT IMPACT, FRACTURED VERTICAL SUPPORT. IMPACT CENTER OF VEHICLE
101	DEVICE TRAVELED 156', PLASTIC PANEL TORE. IMPACT CENTER OF VEHICLE
102	DEVICE STAYED AT IMPACT. IMPACT WITH RIGHT FRONT TIRE.
103	BASE STAYED AT IMPACT, VERTICAL SUPPORT WENT 90' - 5 DEG. LFT. IMPACT WITH RIGHT FRONT TIRE.
104	DEVICE PLACED ON EDGE. IMPACT WITH RIGHT FRONT TIRE. BLEW FRONT TIRE OUT