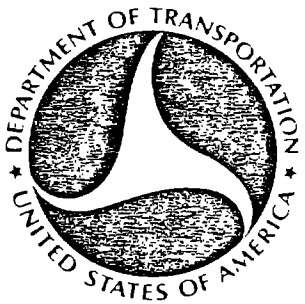
SAFETY ASSESSMENT OF SEVERAL TRAFFIC CHANNELIZING DEVICES

VOLUME I - EXECUTIVE SUMMARY



JUNE 1983

FINAL REPORT

Prepared For

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
400 Seventh Street, S.W.
Washington, D.C. 20590

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1. REPORT NO.	2. GOVERNMENT ACCESSION NO.
FHWA/RD-83/024	PB88-216536/AS
	3. PB88-216536
4. TITLE AND SUBTITLE SAFETY ASSESSMENT OF SEVERAL TRAFFIC CHANNELIZING DEVICES VOLUME I - EXECUTIVE SUMMARY	5. REPORT DATE March 1983
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR (S) L. E. Carlson, A. G. Hoffman	8. PERFORMING ORGANIZATION REPORT NO. P1111F
9. PERFORMING ORGANIZATION NAME AND ADDRESS MOBILITY SYSTEMS AND EQUIPMENT COMPANY 6151 West Century Boulevard, Suite 912 Los Angeles, California 90045	10. WORK UNIT NO. 31V3-242
	11. CONTRACT AND GRANT NO. DTFH61-81-C-00074
12. SPONSORING AGENCY NAME AND ADDRESS U.S. DEPARTMENT OF TRANSPORTATION FEDERAL HIGHWAY ADMINISTRATION 400 Seventh Street, S.W. Washington, D.C. 20590	13. TYPE OF REPORT AND PERIOD COVERED Final Report July 1981 to March 1983
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

FHWA Contract Manager: Martin W. Hargrave, HSR-20

— Volume II Research Results is available

16. ABSTRACT

Five channelizing devices were evaluated for safety via full-scale crash tests at 60 mph using a minicompact sedan, a Volkswagen Rabbit. The five channelizing devices tested were the Plastibarrel 400-PB, the Channelizer, 55 gallon drums, the Wyoming WC-4 Barricade and the Virginia Simulated Barrel Panel. All impacts were survivable by the vehicle occupants. Impact accelerations, occupant velocity, and occupant displacement data and plots of the vehicle accelerations for each device tested are included. Windshield impacts were also performed using a warning light. The light opened a hole in the test windshield but did not pass through at speeds between 40 mph and 60 mph.

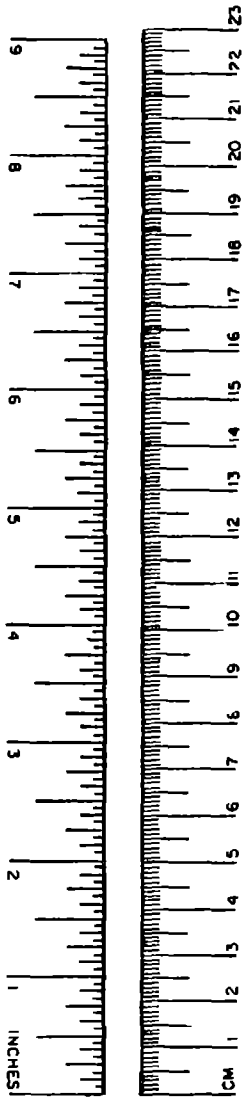
17. KEY WORDS		18. DISTRIBUTION STATEMENT
Safety	Warning Light	This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161
Channelizing	Windshield	
Minicompact Sedan	Impact	

19. SECURITY CLASSIFICAT (of this report)	20. SECURITY CLASSIF. (of this report)	21. NO. OF PAGES	22.
Unclassified	Unclassified	28	

METRIC CONVERSION FACTORS

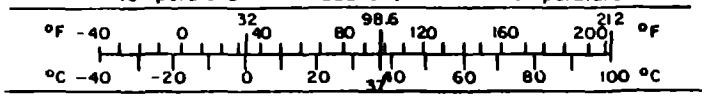
APPROXIMATE CONVERSIONS FROM METRIC MEASURES

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
AREA				
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.6	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
MASS (weight)				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons(2000lb)	0.9	tonnes	t
VOLUME				
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



APPROXIMATE CONVERSIONS FROM METRIC MEASURES

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
AREA				
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares(10,000m^2)	2.5	acres	
MASS (weight)				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000kg)	1.1	short tons	
VOLUME				
ml	milliliters	8.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
TEMPERATURE (exact)				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

Mobility Systems and Equipment Company (MSE) conducted a project entitled "Safety Assessment of Several Traffic Channelizing Devices" for the Department of Transportation, Federal Highway Administration under Contract No. DTFH61-80-C-00074 from July 1981 through March 1983.

The project was sub-divided into the following tasks:

Task A - Review of Prior Research

Task B - Calculation and/or Measurement of Selected Parameters

Task C - Full Scale Crash Testing

This report presents the work performed and the results for each task.

SECTION 1

TASK A

Review of prior research information was collected from Data Centers, Testing Organizations, Libraries, Equipment Manufacturers, Designers, and State Highway Departments regarding the designs and uses of traffic channelizing devices.

1.1 DATA SEARCH

Five specific devices were identified as equipment to be considered within the scope of the project. The identified devices and the manufacturer or designer are listed below.

The Plastibarrel, Catalog No. 400PB, a plastic barrel surrogate manufactured by Best Barricade of Itasca, Illinois.

The Channelizer, a plastic barrel surrogate manufactured by Signal Division of Lear Siegler Inc., Los Angeles, California.

Metal drums of 55 gallon capacity having approximately a 22 inch diameter and 34 inch height.

The Wyoming Highway Department Standard WC-4 Barricade designed by the Wyoming Highway Department, Cheyenne, Wyoming and Manufactured by J & S Contractor's Supply, Denver, Colorado.

The Virginia Department of Highways simulated barrel panel. Richmond, Virginia.

TABLE 1 - INFORMATION SEARCH SUMMARY

DEVICES	STATE HIGHWAYS DEPARTMENTS USING DEVICES	USES	METHODS FOR PLACEMENT & BALLASTING	SAFETY TEST OR RESEARCH DATA	DEVELOPERS	WEAKNESSES	STRONG POINTS
"PLASTI BARREL" CATALOG NO: 400-PB MANUFACTURED BY BEST BARRICADES	DELAWARE ILLINOIS UTAH MINNESOTA OHIO TEXAS (AUSTIN)	WARN TRAFFIC CHANNELIZING FUNCTION (LOW VOLUME TRAFFIC AREAS)	SECURED WITH SAND BAGS PLACED INSIDE	NOT AVAILABLE	PLASTIC BARREL SURROGATES OF SIMILAR DESIGN BAR-I-CADE MFG BY KELCH CORP FITCH SAFETY MARKER MFG BY FIBCO CO. FLEX DRUM & DURA LAST SAFETY MARKER MFG BY NVF CO. TUFF BOY BARREL & FLASHER CONE MFG BY TODD ENTERPRISES & INC.	NARROW BASES DO NOT PROVIDE SUFFICIENT STABILITY TRAPS WATER WHICH FREEZES	EASY HANDLING AND STORAGE (CAN BE NESTED) EXCELLENT TARGET VALUE
"THE CHANNELIZER" MANUFACTURED BY ROYAL INDUSTRIES DIVISION OF LEAR SIEGLER INC.	NEW JERSEY KANSAS OHIO LOUISIANA MISSISSIPPI NEW MEXICO OKLAHOMA NEW HAMPSHIRE ARKANSAS MARYLAND	CHANNELIZING FUNCTION IN CONSTRUCTION ZONES	SAND BAGS ON THE BASE PIECE	COMPARISON WITH STEEL REFLECTORIZED DRUM (MISSOURI) INFORMAL TEST NO RESULTS AVAILABLE		NO SIGNIFICANT WEAKNESSES	WITHSTANDS NUMEROUS HITS HIGHLY RELIABLE AND DURABLE EXCELLENT TARGET VALUE
METAL DRUM 55 GALLON CAPACITY	TENN, MAINE, CONN, DEL, ILL, IND, KAN, UTAH, MINN, LA, ARK, W. VIR, N. DAK, VT, PA, OKL, SO. CAR, NO. CAR, MASS, TX (AU), MISS	CHANNELIZING FUNCTION IN CONSTRUCTION & MAINTENANCE AREAS WARN TRAFFIC MOUNT SIGNS	NO PLACEMENT ADJACENT TO WORKMEN & BETWEEN OPPOSING TRAFFIC BALAST WITH WATER OR LOOSE SAND (UP TO 1/3 BARREL)	COMPARISON WITH THE CHANNELIZER (MISSOURI) INFORMAL TEST NO RESULTS AVAILABLE	UNKNOWN	DIRECT HITS CAUSE UNUSABILITY BECOME PROJECTILES HANDLING & STORAGE ROLLING HAZARDS	LOW COST READILY AVAILABLE SATISFACTORY RESULTS EXCELLENT TARGET VALUE NOT PRONE TO INTENTIONAL HITS
WC-4 BARRICADE THE WYOMING HIGHWAY DEPARTMENT	WYOMING SOUTH CAROLINA	CONSTRUCTION & MAINTENANCE AREA MOUNT SIGNS	SAND BAGS ON THE BASE (IF NECESSARY)	NOT AVAILABLE	WYOMING HIGHWAY DEPARTMENT	DIFFICULT TO TRANSPORT	PROVEN SUCCESSFUL NOT PRONE TO INTENTIONAL HITS
"SIMULATED BARREL PANEL" THE VIRGINIA HIGHWAY DEPARTMENT	VIRGINIA	CHANNELIZING FUNCTION & WARN TRAFFIC	CAN BE PLACED BETWEEN TWO-WAY TRAFFIC SOMETIMES BALLASTED WITH SAND BAGS	NOT AVAILABLE	VIRGINIA HIGHWAY DEPARTMENT	LIGHTING DEVICES SHOULD NOT BE USED DUE TO INSTABILITY	GOOD TARGET VALUE LIGHTWEIGHT PORTABLE

1.1.1 STATE HIGHWAY DEPARTMENTS INFORMATION

All Continental U.S. State Highway Departments were contacted for information regarding the ballasting, placement and support including road surface and soil conditions. Most State Highway Departments had limited or no use of many of the specific items identified for this project.

1.2 TESTING

No State Highway Department had formally tested the channelizing devices nor has any in-service performance data been collected. No testing organizations contacted had performed formal testing of any of the channelizing devices which had been identified and located in the market place.

SECTION 2

TASK B CALCULATIONS AND/OR MEASUREMENTS OF SELECTED PARAMETERS

Selected channelizing devices were purchased and/or assembled. Calculations and measurements necessary to determine the following parameters were performed:

- Weight
- Center of Gravity
- Attachment Strength of the Mounting for the Warning Light System
- Degree of Penetration into the Vehicle Windshield caused by the Warning Light during Impact

Two of the selected devices were designs developed by State Highway Departments. Design drawings were obtained of the Wyoming Standard WC-4 Barricade and the Virginia Simulated Barrel Panel. Material was acquired and the devices were constructed with assistance from State Highway Departments supplementing drawings.

2.1 BALLASTING

The Plastibarrel 400PB, Channelizer and 55 gallon drums received two 25 lb (11.3 kg) sandbags as ballast. The Wyoming WC-4 Barricade and Virginia Simulated Barrel Panel received no ballast as the designs were such that ballasting is not required. However, regarding the Virginia Simulated Barrel Panel, it has been noted that ballasting of one sandbag (about 25 lbs) has been observed.

2.2 CENTER OF GRAVITY

The center of gravity of each of the devices to be tested was determined with ballast and warning light (when used) in place. The Wyoming WC-4 Barricade, 55 gallon drum and Virginia Simulated Barrel Panel are of symmetrical design and the center of gravity was determined by calculation.

The plastic barrel surrogates had some assymetry and selected center of gravity coordinates were determined by using a knife edge. Both the vertical and longitudinal coordinates of the center of gravity location were determined for the Channelizer and the vertical coordinate of the center of gravity location was determined for the Plastibarrel using this method.

The individual channelizing devices are illustrated in Figures 1 through 5. These illustrations present all coordinates for the center of gravity of the device. For reference Figure 6 is included showing the test vehicle (a Volkswagen Rabbit sedan) center of gravity.

2.3 WARNING LIGHT

The warning light selected for use on the channelizing devices was selected on the criteria that it not be manufactured by the same manufacturer of the plastic barrel surrogates and that it be a standard available light. This provided the same conditions for each device being tested and was representative of field conditions. The light selected was a Rhodes and Maine model RM 55 and was purchased from a local vendor with batteries and mounting hardware.

The warning light is a potential hazard which could become more severe should it separate from the channelizing device and become airborne. To assess this possibility pull tests were conducted on the light assembly.

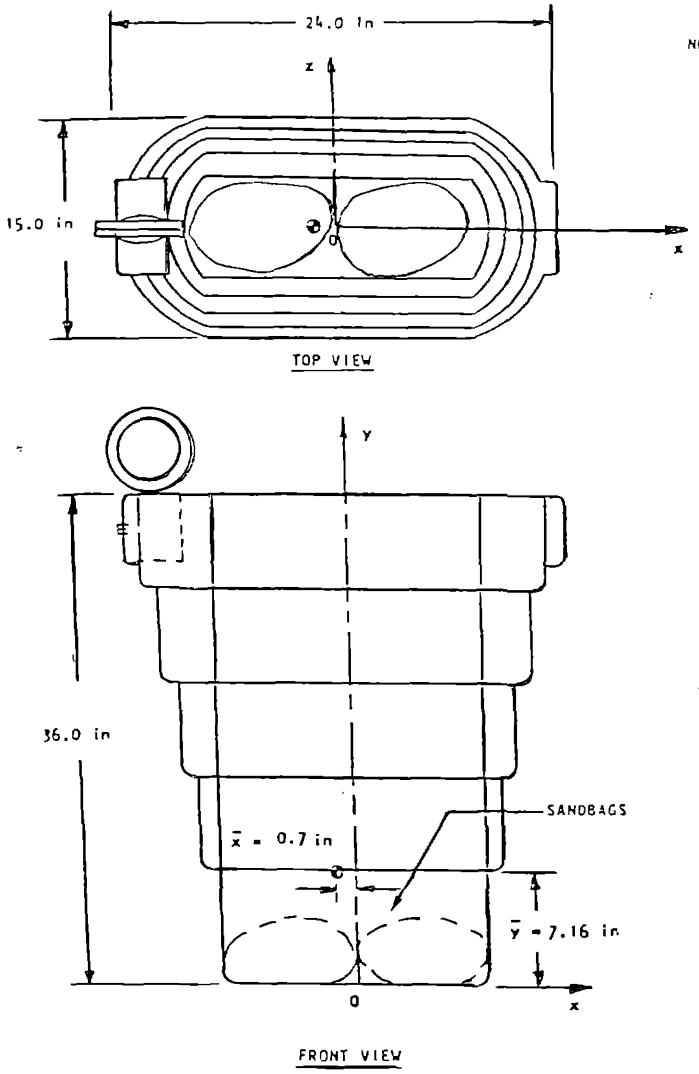
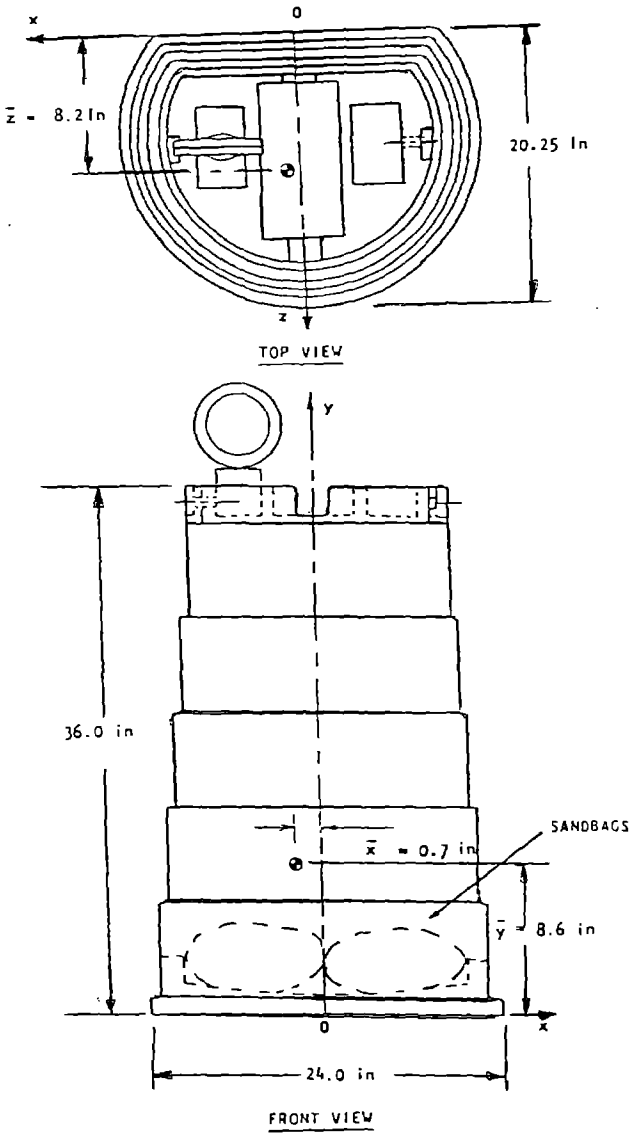


FIGURE 1 PLASTIBARREL 400-PB



NOT TO SCALE

$\bar{y}$ = 8.6 in
$\bar{z}$ = 8.2 in
$\bar{x}$ = 0.7 in
Test Wt. = 67 lbs

FIGURE 2 THE CHANNELIZER

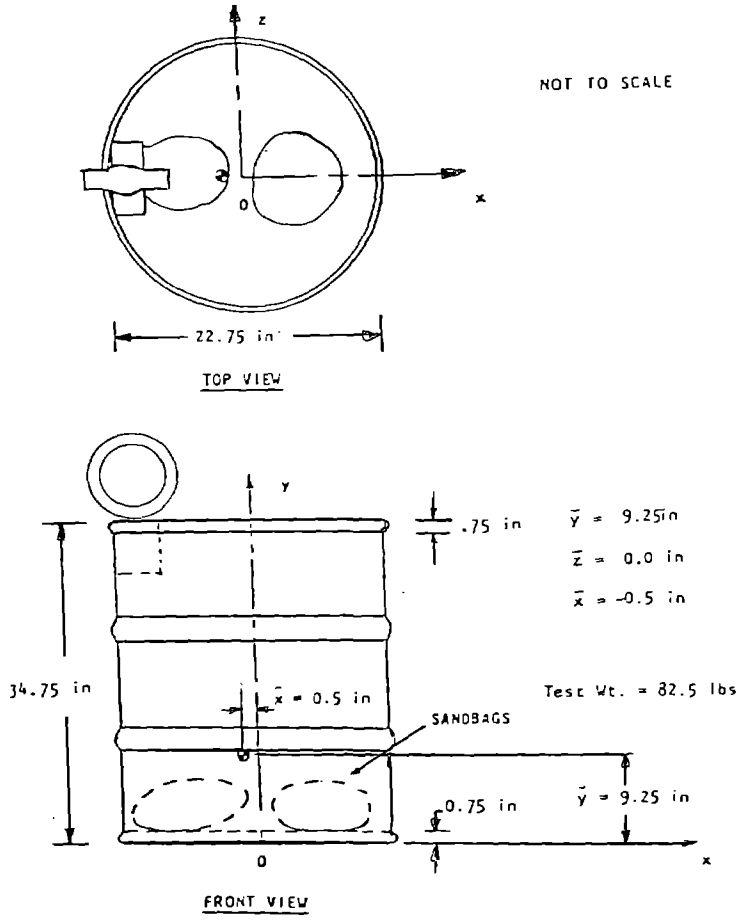


FIGURE 3 55-GALLON STANDARD METAL DRUM

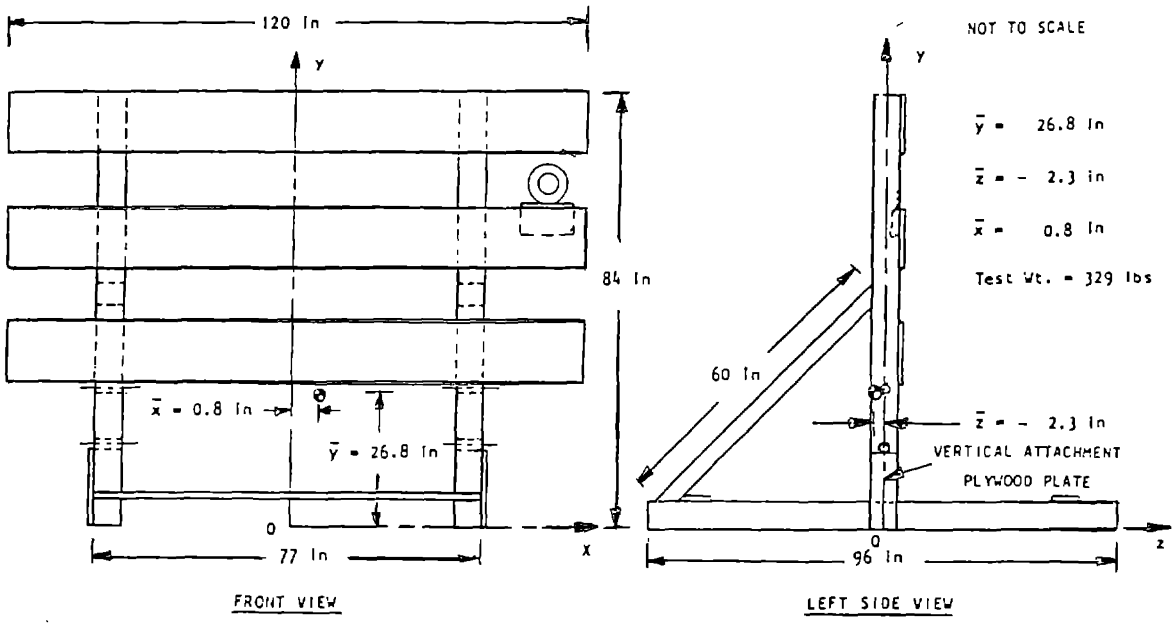


FIGURE 4 WYOMING WC-4 BARRICADE

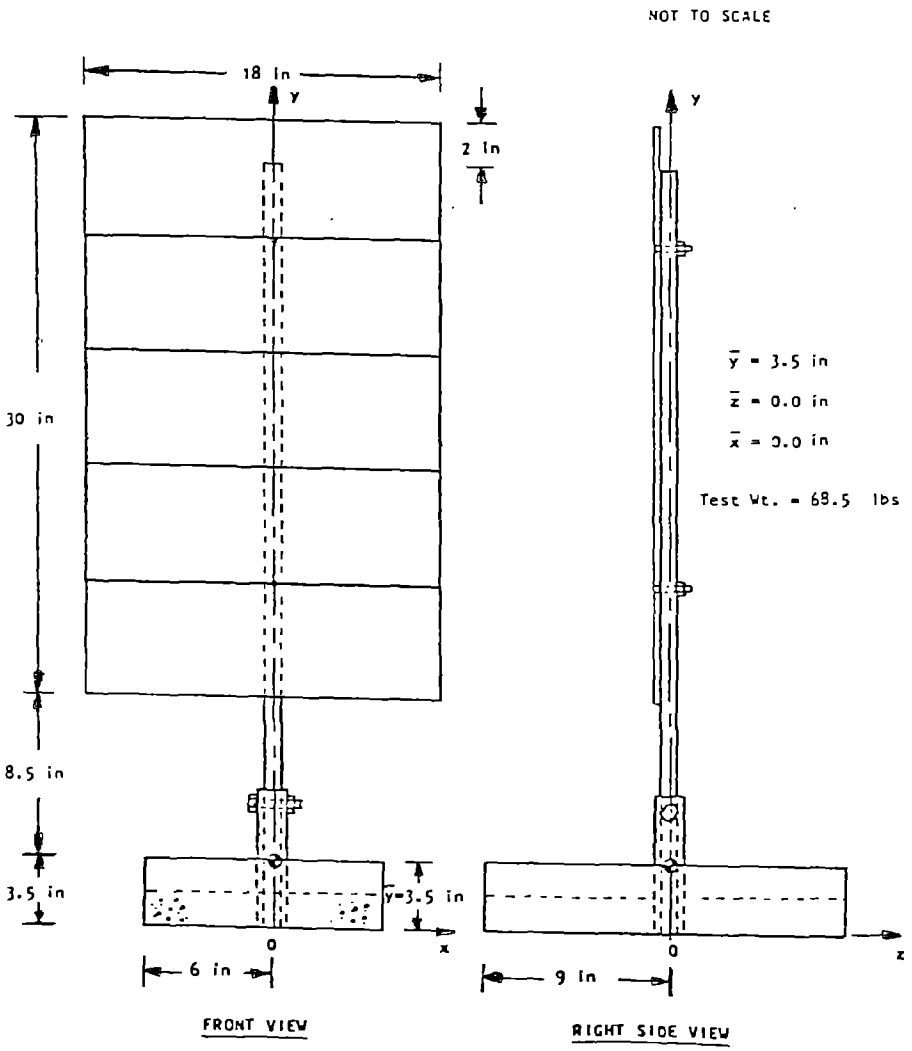
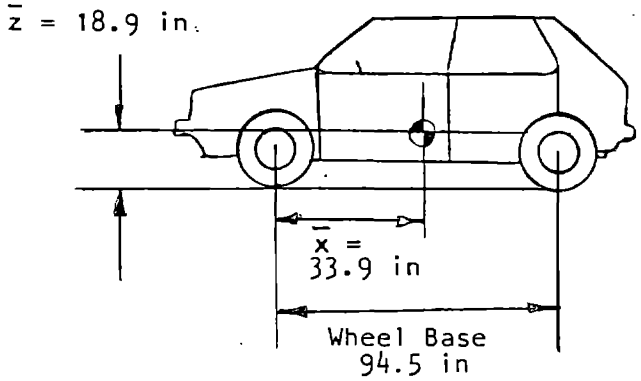
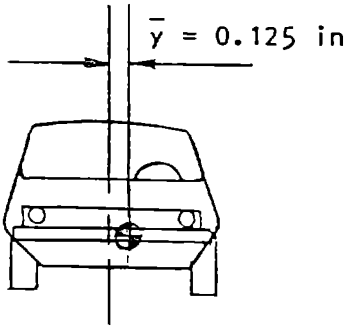


FIGURE 5 VIRGINIA SIMULATED BARREL PANEL





Test Inertial Weight(1) - 1,819 lbs (825 kg)

Test Static Weight (1) - 1,984 lbs (900 kg)

(1) Vehicle weight nomenclature defined in NCHRP Report No. 230 "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances".

FIGURE 6 TEST VEHICLE

The center of gravity of a Rhodes and Maine model RM 55 light with batteries included was determined. A harness assembly was constructed of glass filament tape to allow the force to be applied through the center of gravity of the light. The light assembly was attached in the normal manner using the mounting hardware provided and at the location designed by the channelizing device manufacturer.

The force was applied (20 x W) using a jack screw through a spring scale until the 90 lb (40.1 kg) level was reached. The load was then released, the channelizing devices disassembled from the fixture and inspected. No warning light mounting failure occurred. The mounting holes in the channelizing device showed no distortion or fracturing around the mounting hole. It should be pointed out, however, that during actual full scale crash testing the warning light pulled away from two devices, the Plastibarrel and the Channelizer. A significant downward force appears to be applied when the channelizing devices crush. Consideration should be given to vertical and angular forces in future testing.

2.4 DETERMINATION OF THE WINDSHIELD PENETRATION HAZARD POSED BY THE WARNING LIGHT/BATTERY COMBINATION

The Rhodes and Maine model RM 55 warning light and associated batteries, two 6 volt lantern batteries, were suspended by light weight string oriented such that a corner of the warning light is presented to the impacting windshield. A Ford Fiesta windshield was attached to Mobility Systems track dolley. A series of tests were performed to determine the velocity when windshield penetration occurs. The initial test was performed at a velocity of 30 mph (48.5 kph). The windshield was inspected for penetration (air passage through the windshield). Penetration did not occur and the velocity was increased in nominally 5 mph (8 kph) increments. Substantial penetration occured at 60 mph (96.6 kph). Results are presented in Table 1.

TABLE 2 IMPACT PENETRATION DATA

VELOCITY MPH (kph)	COMMENTS
30.1 (48.7)	Cracking mostly in middle 1/2 No penetration No noticeable 2nd impact
34.1 (55.1)	Cracking in middle 5/4 Very close to penetration No actual air passage - 2nd impact
43.7 (70.6)	Total cracking, penetration Opening ≈3/4 in - 2nd impact
46.1 (74.5)	Total cracking, penetration Opening ≈3 in long - 2nd impact
55.2 (88.8)	Total cracking, penetration Opening ≈3 in long at lens - 2nd impact
60.3 (97.0)	Total cracking, penetration Opening ≈8 in long at lens - 2nd impact

NOTE: At low speeds (30 mph) the light moved away from the windshield immediately after impact. Subsequent impacts at high speeds caused the light to stay in contact with the windshield and the body and lens of the light were then impacted by the windshield after initial impact by the corner of the battery compartment of the light.

Penetration (previously defined as allowing air passage) of the vehicle test windshield occurred initially at 40 mph (64.4 kph). Windshield crush increased as the impact velocity increased with an accompanying small increase in hole size, 3/4 in (19 mm) to 3 in (76 mm), until an impact velocity of 60 mph (96.6 kph) was reached. At this velocity a large opening, approximately 8 in (203 mm) long by 1 in (25.4 mm) wide, developed.

These tests demonstrated that the light did not completely penetrate the windshield and thus enter the passenger compartment of the vehicle under the given test conditions. However, it should be noted that the loading caused a large opening and deep crush of the windshield at 60 mph (96.6 kph). As such, different results may occur when windshields from different vehicles are used or impacts at higher speeds occur.

SECTION 3

TASK C FULL SCALE CRASH TESTING

Full scale crash tests were performed to determine the dynamic behavior of a mini-size sedan when impacting channelizing devices. A mini-size vehicle was selected as a realistic "worst case" test vehicle due to a greater tendency toward rollover than large vehicles have. This tendency, caused primarily by lower rotary moments of inertia and narrower wheel bases and track widths, is inherent in the design of small vehicles.

A 50th percentile Part 572 anthropomorphic uninstrumented dummy was placed unrestrained in the drivers seat.

The test vehicle, illustrated in Figure 6, was a Volkswagen Rabbit sedan with a test inertial weight(1) of 1,819 lbs (825 kg) and a test gross weight(1) of 1,984 lbs (900 kg). The bumper height was 17 in (43.2 cm), and c.g. height of 18.9 in (48 cm).

Instrumentation on board the vehicle was two longitudinal accelerometers, one transverse accelerometer, and one vertical accelerometer located essentially at the vehicle c.g. on the front floor pan. The accelerometers were connected to a multichannel FM tape recorder via an umbilical cord.

The accelerometer data recorded on FM tape was played back and digitized through MS data processing equipment using both SAE Class 60 and Class 180 filters. This was done to provide comparative data using both the old test procedures, TRC 191, and the new test procedures,

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(1) Weight nomenclature defined in NCHRP Report No. 230, "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances".

NCHRP 230. The digitized data was then processed by computer to obtain the acceleration (g values) for the 50 msec average for the Class 60 filtered data, and a 10 msec average for the Class 180 filtered data. The occupant velocity expressed as $V_{Ix} = \int_o^t a_x dt$ and occupant displacement expressed as $X = \int_o^t \int_o^t a_x dt^2$ were also calculated.

3.1 TEST CONDUCT

Two channelizing devices were used for each impact event (excluding the Wyoming WC-4 Barricade)[1]. With the exception of the Virginia Simulated Barrel Panel a warning light was attached to each device. The devices were located for impact simulating the placement of two devices being used as a lane taper to channel traffic. The first device was placed at the right quarter point of the vehicle, 17 in (43.2 cm) from the vehicle centerline. The second device was placed 25 ft (7.6 m) behind the first device at the left quarter point of the vehicle 17 in (43.2 cm) from the vehicle centerline. These locations were chosen to provide a realistic but "worst case" force application to the front end of the impacting vehicle, and thus, to maximize the possibility of vehicle yaw and resultant tendency to rollover. Impact speed was a nominal 60 mph (96.6 kph).

The Wyoming WC-4 Barricade had a warning light attached on the right end of the center panel outboard of the vertical support approximately 5 ft (15.24 mm) from ground level. This conforms with the Manual on Uniform Traffic Control Devices (MUTCD) requirements and also places the light in a location that is highly visible to the vehicle driver. It is also in a position to become a possible hazard to the vehicle occupants if knocked free at impact. The WC-4 Barricade was impacted by the quarter point of the bumper on the passenger side of the vehicle striking the right vertical support of the barricade. Impact speed was a nominal 60 mph (96.6 kph).

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(1) A second device not used for Wyoming WC-4 Barricade because it is used primarily as a road closure device and not as a lane taper.

3.2 TEST RESULTS AND CONCLUSIONS

The results of the full scale crash tests indicate that occupants of a minicompact sedan would survive an impact with the five devices selected for testing in this study, namely the;

Plastibarrel 400-PB
Channelizer
55 Gallon Metal Drum (Top Removed)
Wyoming WC-4 Barricade
Virginia Simulated Barrel Panel

3.2.1 STRUCTURAL ADEQUACY

The channelizing devices all appeared to react predictably. The Plastibarrel 400-PB was crushed, folded over the ballast and ejected from beneath the vehicle. The Channelizer separated from the base on which the ballast was located and pushed away. The 55 gallon drum was crushed and folded over the ballast and drawn under the vehicle. Both plastic barrel surrogates, although presenting as formidable appearance at the 55 gallon drum, present an impact hazard of minimal consequence as shown by the preceding data. The warning lights tore loose from both the Plastibarrel and Channelizer when impacted and became free bodies. This may present a serious hazard regarding passenger compartment penetration. Reinforcement around the attachment hole of each channelizing device with a metal (or similar strength) reinforcement is recommended. The warning light did not tear loose from the 55 gallon drum when impacted - a definite plus. However, due to the stiffness of the metal barrels the vehicle was lifted off of the ground because of barrels lodged underneath. A resultant loss of steering control occurred. This may present a hazard to oncoming traffic if the impacting vehicle is redirected back into the travelled way.

The Wyoming WC-4 Barricade, by virtue of the vertical attachment method using nails, provides for breakaway. Although these tests indicate readily survivable conditions exist for occupants, the size and quantity of flying debris (which includes the warning light) as the result of the impact could cause more hazardous conditions to exist both to the impacting and the oncoming vehicle occupants.

The Virginia Simulated Barrel Panel when upright, folded over and tore away from the base creating a minimal hazard, however, the concrete base from the Barrel Panel that was laid on its side caused more vehicle damage. This impact shattered the concrete base and did not overturn the test vehicle. Since this impact was with the sheet metal beneath the bumper, steering and stability were not affected. However, different results may occur with other vehicle designs, particularly those which allow the base to impact the steering linkage and suspension components.

3.2.2 OCCUPANT RISK

All impacts resulted in conditions of vehicle stability after impact. With the exception of the impact with the 55 gallon drum the vehicle was mobile and controllable (after impact the vehicle was atop the 55 gallon drums resulting in loss of driver control).

The acceleration values were within the recommended limits of acceptability as shown in Tables 3, 4, 5, 6 and 7. Occupant displacement did not exceed 24 in forward or 12 in laterally and theoretically no impact existed and therefore no ridedown acceleration was calculated. The maximum acceleration level is presented in the tables as listed above for reference and in summary Table 8.

TABLE 3 MOVING AVERAGE DATA - PLASTIBARREL 400-PB

Class 180 Filter 10 msec Average Acceleration (per NCHRP Report No. 230):

	Maximum Longitudinal Accel - g's	Time - Seconds
Impact with First Device	2.4335 (1)	.1620 to .1720
Impact with Second Device	4.3220 (1)	.3794 to .3894
Recommended Limit	15.0 (2)	

Class 60 Filter 50 msec Averaage Acceleration (per TRB Circular No. 191):

	Maximum Longitudinal Accel - g's	Time - Seconds
Impact with First Device	0.98552	.1424 to .1924
Impact with Second Device	0.86563	.3476 to .3976
Recommended Limit	10.0 (3)	

Occupant Impact Velocity:	Longitudinal Δ Vel - fps
Impact with First & Second Device	≈ 0
Recommended Limit	15.0 (2)

(1) The values listed are maximum values and are presented for reference. Occupant moves less than 24 in and thus ride-down period does not occur.

(2) Reference NCHRP Report No. 230, Pg. 32 (Breakaway signs & luminaires criteria used).

(3) Reference TRB Circular No. 191, Pg. 10 (Redirectional barrier criteria used).

TABLE 4 MOVING AVERAGE DATA - CHANNELIZER

Class 180 Filter 10 msec Average Acceleration (per NCHRP Report No. 230):

	Maximum Longitudinal Accel - g's	Time - Seconds
Impact with First Device	2.3794 (1)	.1154 to .1254
Impact with Second Device	1.4221 (1)	.3600 to .3700
Recommended Limit	15.0 (2)	

Class 60 Filter 50 msec Averaage Acceleration (per TRB Circular No. 191):

	Maximum Longitudinal Accel - g's	Time - Seconds
Impact with First Device	0.9817	.1126 to .1626
Impact with Second Device	0.3564	.4200 to .4700
Recommended Limit	10.0 (3)	

Occupant Impact Velocity:	Longitudinal Δ Vel - fps
Impact with First & Second Device	≈0
Recommended Limit	15.0 (2)

(1) The values listed are maximum values and are presented for reference. Occupant moves less than 24 in and thus ride-down period does not occur.

(2) Reference NCHRP Report No. 230, Pg. 32 (Breakaway signs & luminaires criteria used).

(3) Reference TRB Circular No. 191, Pg. 10 (Redirectional barrier criteria used).

TABLE 5 MOVING AVERAGE DATA - 55-GALLON DRUM

Class 180 Filter 10 msec Average Acceleration (per NCHRP Report No. 230):

	Maximum Longitudinal Accel - g's	Time - Seconds
Impact with First Device	4.3828 (1)	.1468 to .1568
Impact with Second Device	4.3784 (1)	.4170 to .4270
Recommended Limit	15.0 (2)	

Class 60 Filter 50 msec Averaage Acceleration (per TRB Circular No. 191):

	Maximum Longitudinal Accel - g's	Time - Seconds
Impact with First Device	2.2818	.1446 to .1946
Impact with Second Device	2.1253	.3846 to .4346
Recommended Limit	10.0 (3)	

Occupant Impact Velocity:	Longitudinal Δ Vel - fps
Impact with First & Second Device	≈ 0
Recommended Limit	15.0 (2)

(1) The values listed are maximum values and are presented for reference. Occupant moves less than 24 in and thus ride-down period does not occur.

(2) Reference NCHRP Report No. 230, Pg. 32 (Breakaway signs & luminaires criteria used).

(3) Reference TRB Circular No. 191, Pg. 10 (Redirectional barrier criteria used).

TABLE 6 MOVING AVERAGE DATA - WYOMING WC-4 BARRICADE

Class 180 Filter 10 msec Average Acceleration (per NCHRP Report No. 230):

	Maximum Longitudinal Accel - g's	Time - Seconds
Impact	6.1809 (1)	.0848 to .0948
Recommended Limit	15.0 (2)	

Class 60 Filter 50 msec Averaage Acceleration (per TRB Circular No. 191):

	Maximum Longitudinal Accel - g's	Time - Seconds
Impact	1.0115	.0676 to .1176
Recommended Limit	10.0 (3)	

Occupant Impact Velocity:	Longitudinal Δ Vel - fps
Impact	$\approx$0
Recommended Limit	15.0 (2)

(1) The values listed are maximum values and are presented for reference. Occupant moves less than 24 in and thus ride-down period does not occur.

(2) Reference NCHRP Report No. 230, Pg. 32 (Breakaway signs & luminaires criteria used).

(3) Reference TRB Circular No. 191, Pg. 10 (Redirectional barrier criteria used).

TABLE 7 MOVING AVERAGE DATA - VIRGINIA SIMULATED BARREL PANEL

Class 180 Filter 10 msec Average Acceleration (per NCHRP Report No. 230):

	Maximum Longitudinal Accel - g's	Time - Seconds
Impact with First Device	0.7191 (1)	.1052 to .1152
Impact with Second Device	2.7889 (1)	.4160 to .4260
Recommended Limit	15.0 (2)	

Class 60 Filter 50 msec Averaage Acceleration (per TRB Circular No. 191):

	Maximum Longitudinal Accel - g's	Time - Seconds
Impact with First Device	0.16979	.1046 to .1546
Impact with Second Device	0.4534	.3904 to .4404
Recommended Limit	10.0 (3)	

Occupant Impact Velocity:	Longitudinal Δ Vel - fps
Impact with First & Second Device	≈0
Recommended Limit	15.0 (2)

(1) The values listed are maximum values and are presented for reference. Occupant moves less than 24 in and thus ride-down period does not occur.

(2) Reference NCHRP Report No. 230, Pg. 32 (Breakaway signs & luminaires criteria used).

(3) Reference TRB Circular No. 191, Pg. 10 (Redirectional barrier criteria used).

TABLE 8 SUMMARY DATA

CHANNELIZING DEVICE	10 MSEC ACCEL - G'S		50 MSEC ACCEL - G'S	
	1ST IMPACT	2ND IMPACT	1ST IMPACT	2ND IMPACT
PLASTIBARREL 400PB	2.4335	4.3220	0.98552	0.86563
CHANNELIZER	2.3794	1.4221	0.98170	0.35640
55-GALLON DRUM	4.3828	4.3784	2.2818	2.1253
WYOMINC WC-4 BARRICADE	6.1809	— (1)	1.0115	— (1)
VIRGINIA SIMULATED BARREL PANEL	0.7191	2.7889	0.16979	0.4534

(1) A second device not used for Wyoming WC-4 Barricade because it is used primarily as a road closure device and not as a lane taper.