DOT0909

FHWA Contract No. DTFH61-81-C-00036

LABORATORY PROCEDURES TO DETERMINE THE BREAKAWAY BEHAVIOR OF LUMINAIRE SUPPORTS IN MINI-SIZED VEHICLE COLLISIONS

SIDE IMPACT - RIGID POLE
TEST RESULTS REPORT
TEST NO'S: SI#1, SI#2, SI#3, AND SI#8
PHASE II - TASK C

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16. Abstract

Four side impacts were conducted with the test vehicle impacting a segmented, instrumented rigid pole at speeds up to 25 mph. The side crush properties of a Honda Civic, a VW Rabbit, a Dodge Colt and a Dodge St. Regis are presented. The tests were conducted using the FHWA Federal Outdoor Impact Laboratory (FOIL) located in McLean, VA.

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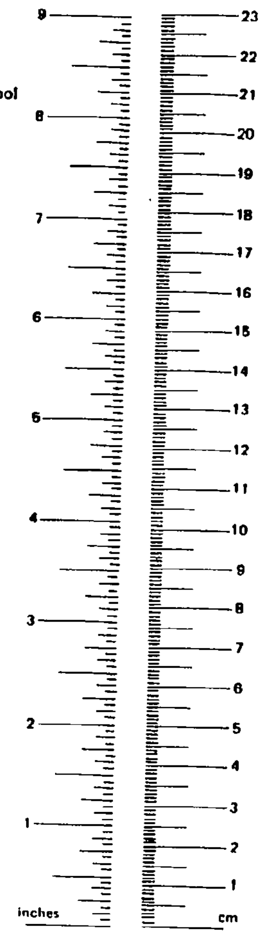
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

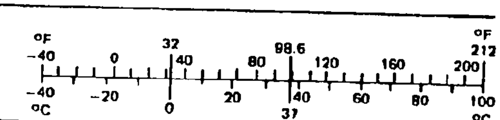
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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 (2000 lb)	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

*1 in. = 2.54 cm (exactly). For other exact conversions and more detail tables see NBS Misc. Publ. 286. Units of Weight and Measures. Price $2.25 SD Catalog No. C13 10 286.



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 (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	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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1.0 INTRODUCTION

This report documents the results of the first three tests and the last test performed under Task C of phase II of the referenced contract. Four additional tests were also conducted and are reported on under separate test reports.

The four tests covered in this test report are test numbers 1469-SI#1-85, 1469-SI#2-85, 1469-SI#3-85, and 1469-SI#8-85. The tests used three different test vehicles to investigate the side crush stiffness of typical small cars and one large car currently in the national car fleet.

During each small car test the test vehicle impacted a segmented instrumented rigid pole at 25 mph. The large car test used an impact speed of 10 mph. The rigid pole was designed to measure the forces generated by the car in three zones: 1) roof structure, 2) door and door beam, and 3) side sill of the vehicle. The pole can also provide information on the location of the center of force.

2.0 TEST DESIGN

The test plan for side impact testing consisted of a total of eight vehicle tests. The rigid pole tests are reported on in this report. The test series was designed to look at three mini-sized vehicles and one 4500 lb vehicle under worst case side impact conditions. The results of this testing program provides the data to address the following questions:

- What is the importance of the vehicle selected for side impact testing?
- What are the characteristics of the impact force and what part is played by the sill structure, the door and the roof structure for three different vehicles in the 1800S class and one vehicle in the 4500S class.
- How is the injury producing mechanism related to vheicle measured data, and what methodology can be developed to quanify the relationship?

The test plan which was used to perform these tests, is based on the results of the Phase II Task A Report which addressed selection of the vehicles for side impact testing and selection of impact test conditions.

2.1 TEST MATRIX

The test matrix for these tests is presented in Table 1. Each of the tests were designed to provide information about the side crush characteristics. In each of small car tests the test speed was 25 mph while an impact speed of 10 mph was used for the large car. All test vehicles were orientated 90 degrees into a rigid pole. The impact point on the vehicle was a point on the left side door (driver's side) equating to the shoulder of an occupant. No anthropormorphic dummy was used for rigid pole testing. A three segment rigid pole was used to measure the impact force at the side sill, door and roof levels.

Table 1

Actual Test Matrix

Number	Vehicle	Year	Structure	Dummies	Speed
1469-SI-1-85	Honda Civic	1979	Rigid Pole	Not Used	25 mph
1469-SI-2-85	VW Rabbit	1979	Rigid Pole	Not Used	25 mph
1469-SI-3-85	Dodge Colt	1979	Rigid Pole	Not Used	25 mph
1469-SI-8-85	Dodge St Regis	1979	Rigid Pole	Not Used	10 mph

2.2 TEST VEHICLES

The selection of the test vehicles for the side impact series was based on the data and analysis provided in Reference 1 "Selection of Side Impact Test Vehicle and Impact Conditions, Task A.4".

The three small vehicles selected are detailed in Table 2. Figure 1 shows the key dimensions of a Honda Civic. Figure 2 shows the dimensions for the VW Rabbit. The dimensions of the Dodge Colt are shown in Figure 3. Key properties of the large car are presented in Table 3.

All vehicles used were in good condition and free of any major body damage. The battery and gas tanks were removed for safety reasons and the rear seat and backrest were removed for onboard instrumentation installation.

The vehicle weight in test condition was approximately 1800 lb for the mini-sized vehicles and 4500 lb for the large car.

2.3 SIDE IMPACT SYSTEM

The Federal Outdoor Impact Laboratory (FOIL) is presently designed for both frontal and side impacts. The facility uses a

Table 2

Small Vehicle Characteristics

Symbol	Parameter	Honda Civic	VW Rabbit	Dodge Colt
A	Height to top of bumper	20.0	19.5	19.5
B	Bumper thickness	3.5	3.5	3.5
C	Front edge to grill	7.0	6.0	3.8
D	Front edge to front wheel centerline	29.0	31.0	29.5
E	Front edge to engine block	17.0	19.0	20.0
F	Front edge to fire wall	31.0	43.0	39.5
G	Front edge to a pillar	47.0	50.0	49.0
H	Hood height (above headlights)	28.0	31.0	28.0
I	Lowest ground clearance*	5.5	5.5	7.0
J	Engine length	17.0	20.0	18.0
K	Engine block width	7.0	13.0	15.0
L	Left side to engine	18.0	24.0	9.5
M	Transmission length	13.0	14.0	14.0
N	Radiator length	24.0	27.0	18.0
O	Right side to radiator	12.0	19.6	8.0
P	Front edge to radiator	11.0	13.5	12.0
Q	Roof height	53.0	56.0	55.0
R	Rocker panel height	5.5	5.0	4.8
S	Ground clearance below rocker panel	9.0	9.0	9.0
T	Door length (2 door)	46.0	50.0	48.5
TT	Door Thickness (widest point)	4.8	4.5	4.8
U	Door overall height	39.0	40.0	40.0
V	Center seat to outside edge	17.5	18.5	17.5
W	Lower door height	23.0	22.5	22.5
X	Wheelbase	86.6	94.5	90.6
Y	Overall length	148.0	156.0	157.0
Z	Trackwidth FT/RR	53.5 53.9	54.7 53.1	53.9 52.8
AA	Overall width	62.6	64.0	63.0
CC	Curb weight range (lbs)	1610-1643	1719-1900	1730-2020

*With no passengers.

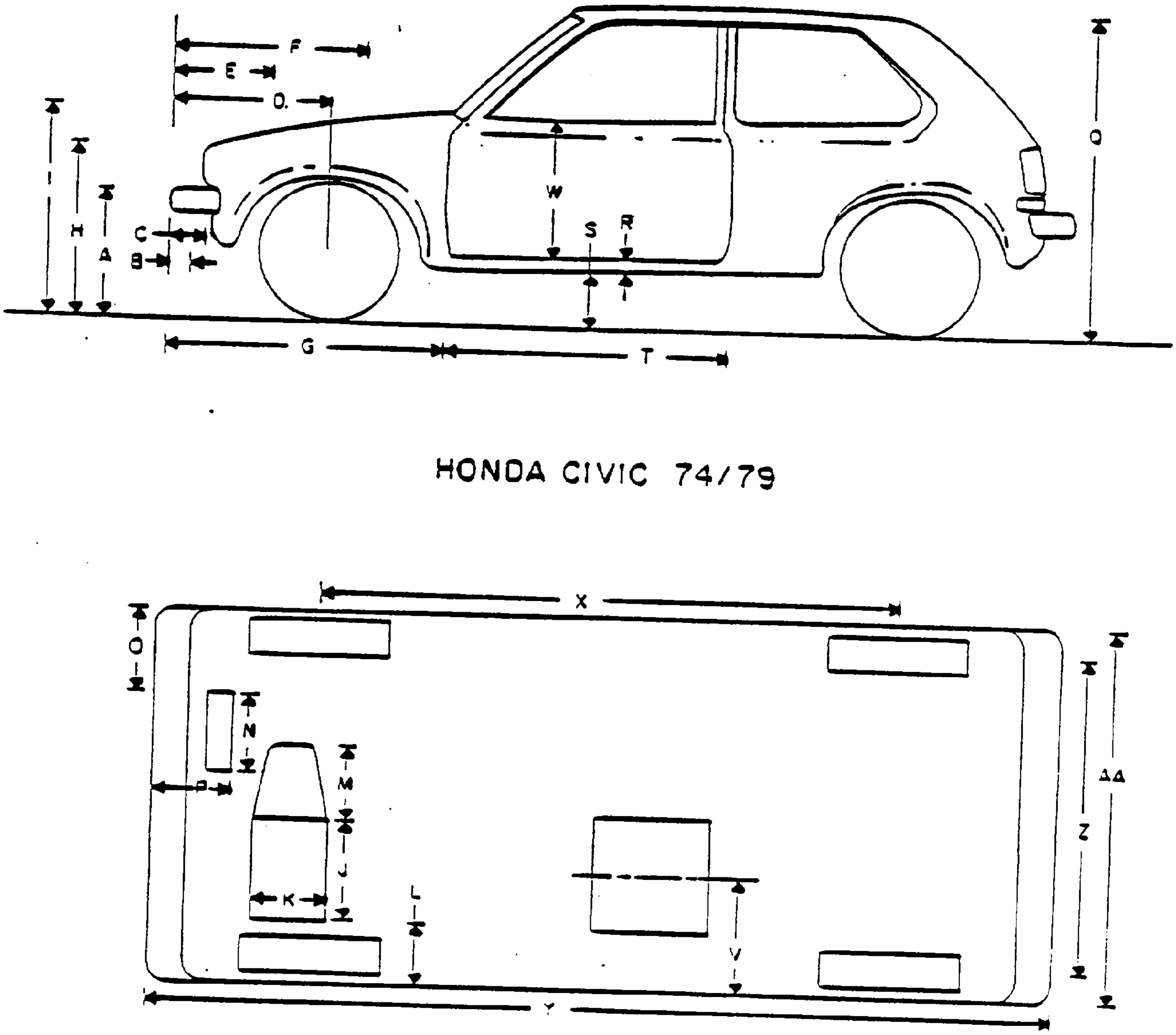


Figure 1. Key Dimensions for 1974-1979 Honda Civic

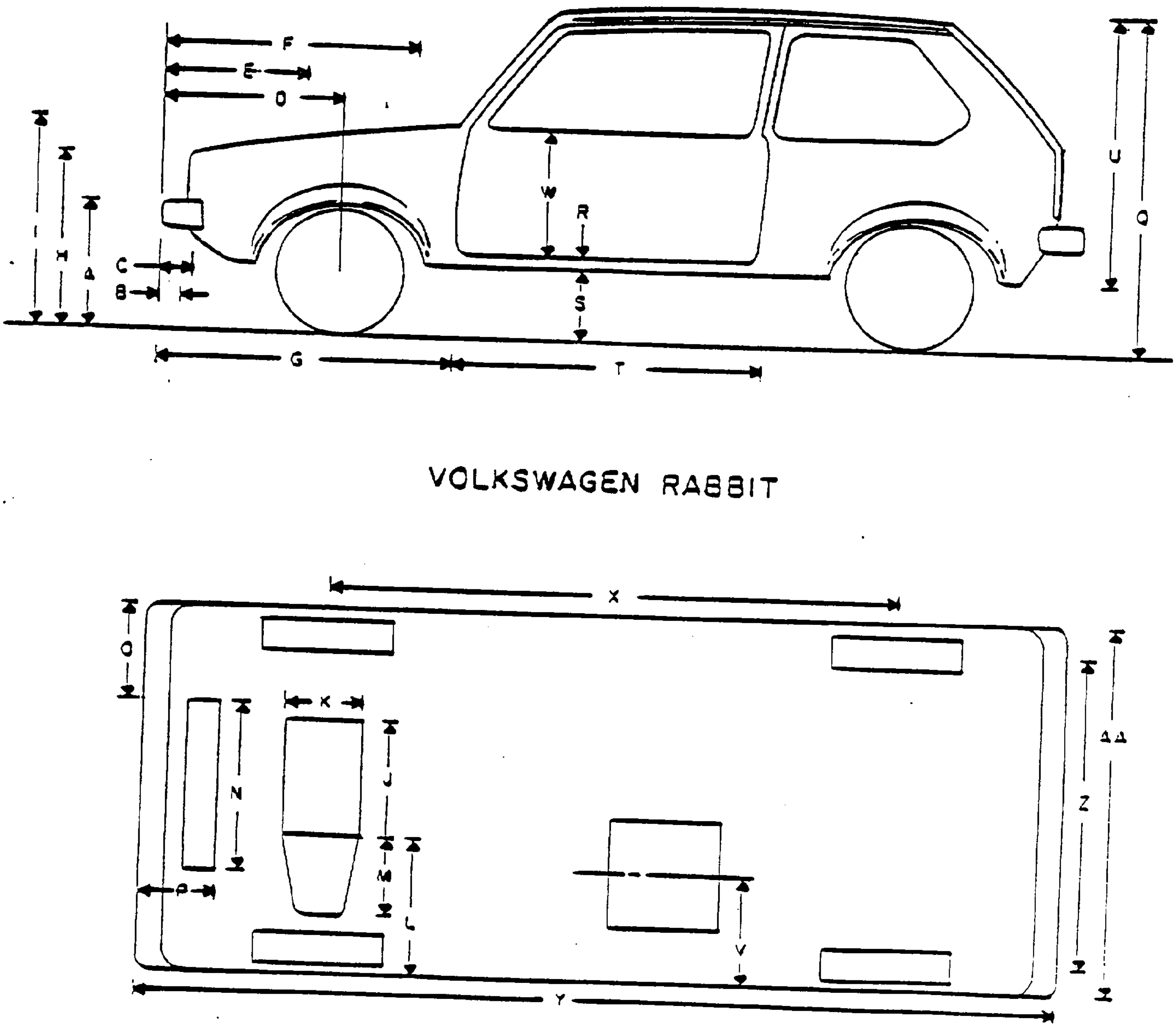


Figure 2. Key Vehicle Dimensions for VW Rabbit

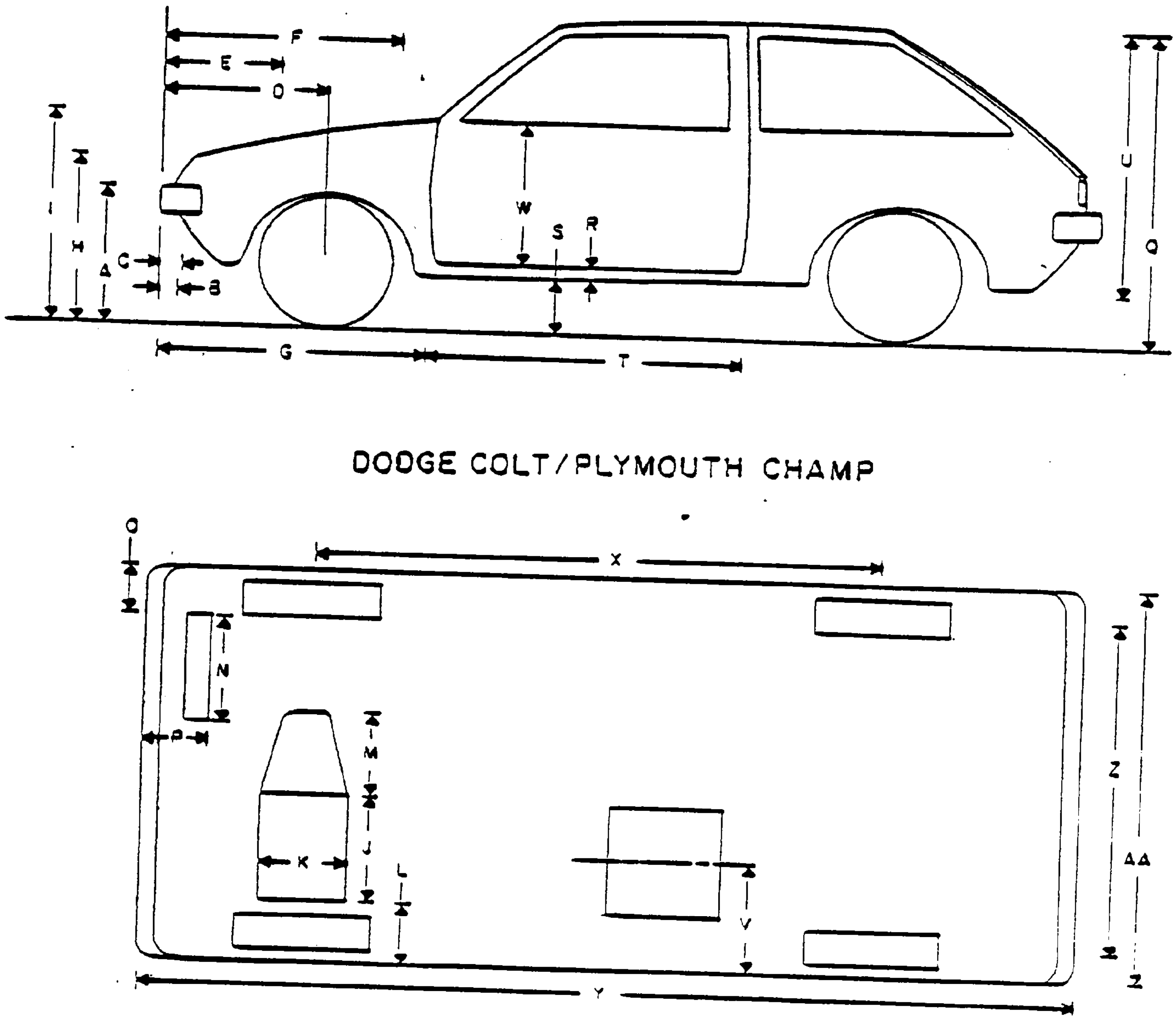


Figure 3. Key Vehicle Dimensions for Dodge Colt

Table 3

Key Properties of the Large Test Vehicle

1	Manufacturer	Dodge
2	Model	St. Regis
3	Model year	1979
4	Length	221 in
5	Width	78
6	Wheel base	118.5 in
7	Curb weight range	3600-3800 lbs
8	Test weight	4500 lbs

drop weight propulsion system and a rigid rail guidance system. For side impact testing, a monorail approximately 140 feet long is used for guidance as well as to carry the majority of the vertical load and all of the yawing and pitching moment. The second rail (the guide rail used for frontal impacts) is used to support only a small portion (10%) of the vehicle weight and provide for roll stability. The new side impact system does compliment the present FOIL design in that it is simple in design and easy to operate. Speed capability for the Side Imapct System is up to a maximum of 45 mph.

2.3.1 DESCRIPTION OF MAJOR COMPONENTS

The FOIL side impact system is shown in Figure 4. The following sections describe several of the major components.

Main Carriage

The main carriage is made of two aluminum angles welded together to form a 4" x 3-1/2" x 1/4" box beam. The beam is 48" overall in length and has two wheels, one at each end. Each wheel has two flanges, with a wheel diameter of 3" and a flange diameter of 4". Each wheel is supported by a 3/4 inch axle and two flange block bearings. The tow pin is a welded integral part of the main carriage. It is cantilivered off the side of the main carriage using two supporting wedges. The main carriage is attached to the vehicle using supporting braces.

Outrigger

The outrigger attaches to the rear of the vehicle and rides on the frontal impact guidance rail. The outrigger carries only 10% of the load. It is comprised of a main plate, 2 load wheels, 2 flange wheels, 3 cam-followers for lateral location and a rail keeper to prevent any uplift from derailing the outrigger. The fore and aft wheel assemblies are supported by three aluminum vertical support plates. These plates carry the axle. The wheel and flange both have roller bearings pressed in which allow the

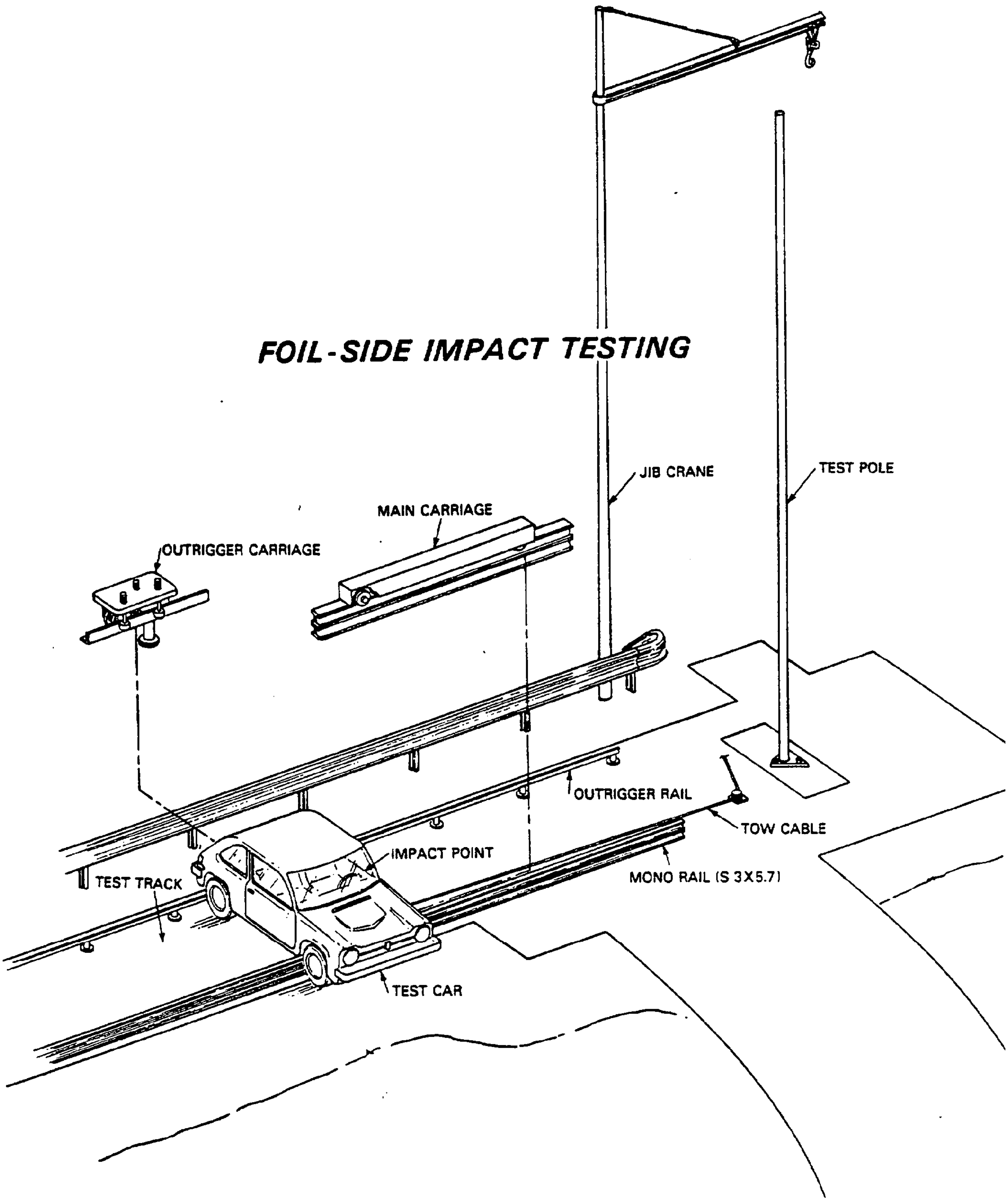


Figure 4. Side Impact Concept

3/4" axle to carry the load. The cam-followers are 2 inches in diameter and are supported by 5/8 inch bolts and spacers. The outrigger is attached to the vehicle using a bracket.

Monorail

The monorail is made of two S3 x 5.7 beams sitting one on top of the other which are welded on top of a 2 inch stands thus making the height of the top of the rail about 8 inches. The beams are joined end to end using splice bars and welded together to hold the beams one on top of the other. The bottom plate is attached to the concrete runway using concrete anchors.

2.4 RIGID INSTRUMENTED SEGMENTED POLE

For each of these tests, the vehicle impacted the Instrumented Rigid Pole. This pole was designed to be operated at the FHWA FOIL Facility to measure vehicle crush properties.

Side as well as frontal impact crush characteristics can be determined using the instrumented pole. The impact face is made in three sections positioned to isolate forces of a side impact test in the sill, door and roof areas. The sections may be rearranged for frontal tests in which one section to takes the total force. Reinforced semicircular sections of 8" extra heavy steel pipe (8 5/8" dia) are used for the impact face. Four 7" channels attached to 1/2" side plates support three pairs of load cells to which the three sections of the impact face are mounted. The box beam (which the channels and plates form) is slightly narrower than the impact face which allows for unlimited crush depth in the shadow of the impact face.

Each segment of the impact face is supported by two connecting rods which run through guide bearings and attach to the load cells, one load cell per connecting rod. Each connecting rod is 2 inches in diameter. The load cells may be wired together to give the total force on the segment or they may be read out separately to indicate the center of pressure on each segment. Load cells offer the advantage of accuracy, low cost, fast response, ruggedness and ease of replacement, but moments caused by eccentric loading and lateral loads must be removed to retain accuracy. To remove the bending moment and lateral loads, two support guides are installed on the 8 in x 24 in box beam. The distance between the guide supports is 22 in. Each guide is comprised of a self-aligning flange block bearing with an oil-lite bronze insert pressed in the bearing.

For side impact testing, a three segment configuration was used. The three segments are designed to cover the range defined below:

	Bottom (in)		Top (in)
Segment 1	2	to	14-1/2
Segment 2	14-1/2	to	36
Segment 3	36	to	60

All distances are measured from ground level.

Prior to and after completion of the test series, a complete calibration of the rigid pole was performed to insure that the pole was operating correctly.

2.5 ELECTRONIC INSTRUMENTATION

The electronic instrumentation for the test series is comprised of:

- o Vehicle borne instrumentation
- o Test article instrumentation

The vehicle instrumentation consisted of three lateral accelerometers and a yaw angular rate transducers. One lateral accelerometer was located near the longitudinal cg of the vehicle with the other two being forward and rearward of the cg.

The test article instrumentation consisted of a total of six load cells to measure the force on the pole. Each segments (three total) used two load cells, an upper cell and lower cell.

Data from the load cells was sent via data cable to the signal conditioning (Vishay Amplifiers #2300) then onto a 14 channel FM recorder. A 32 KHz reference signal and speed trap impulse were recorded directly on the recorder. Vehicle data was collected in the same manner however a second data cable was used to send the data from the vheicle to the signal conditioner.

2.6 PHOTOGRAHIC COVERAGE

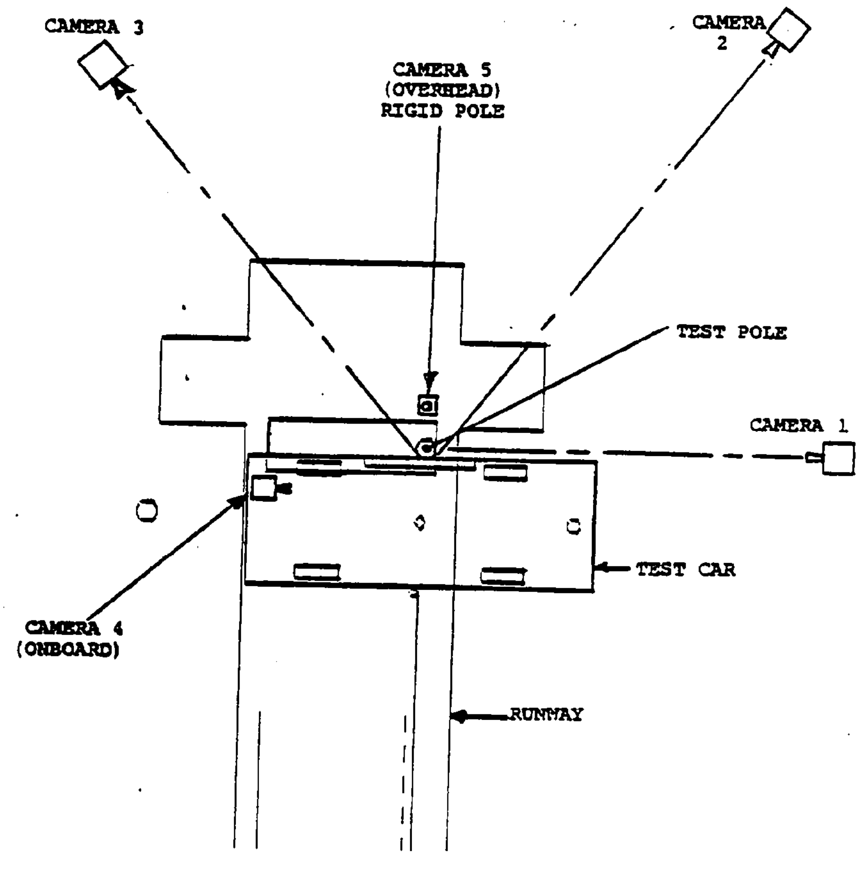
Five high speed (500 frames/second) cameras were used during the test program. The position of these cameras are shown in figure 5. All test used an onboard camera to document the pole intrusion, passenger compartment crush and impact point. One overhead camera was used on the rigid pole tests to observe external crush of the vehicle. The remaining three high speed camera showed side views and angled views of the test.

One normal speed (24 frames/second) camera was used to document the pre-test conditions, a real time view of the test and the post-test results of the vehicle and test rigid pole.

Still photos were taken with two 35mm SLR cameras. Photo's were taken with color slides and black and white prints. All high speed film was Kodak 7251 and 7239 16mm color film.

The high speed film was used to determine impact and rebound speed. This delta-V was compared to the integrated result of the acceleration trace to insure data quality. In all tests the film and electronic data agreed. After making corrections to accelerometer data (see Sec. 7.1 for discussion).

All movies of each test were edited together into a master set of films complete with title blocks which describe test conditions and the test article.



Camera	Model	Position	Speed Setting	Lens
1	Redlake Hycam	Rt. Side	500 fps	25 mm
2	Redlake Locam	Rt. Side	500 fps	50 mm
3	Redlake Locam	Lt. Side	500 fps	50 mm
4	Redlake Locam	On Board	500 fps	5.7 mm
5	Redlake Locam	Overhead	500 fps	12.5 mm
6	Arrieflex	Document-ation	24 fps	Zoom

Figure 5. Description of Film Data Acquisition System for Side Impact Tests

3.0 TEST 1469-SI#1-85

3.1 TEST CONDITIONS

In Test SI#1 the Honda Civic impacted the rigid instrumented pole at 27.5 mph with an impact angle of 90°. Table 4 summarizes the test results. The vehicle yawed clockwise during the impact with a total yaw angle of about 87°. Figure 6 presents photos of the test vehicle prior to testing.

3.2 TEST RESULTS

During the impact the vehicle actually bent about the longitudinal centerline. There was considerable dynamic deflection beyond the static deflection. The static deflection of the test vehicle measured using the NHTSA 6 point technique is presented in Table 5. Figure 7 is presented as reference for these measurements. Figure 8 presents photos of the vehicle after the test. The vehicle damage index was 09 LPAN3. The NCHRP 230 delta V for a 1 foot flail space was -22.8 ft/sec. The associated ridedown acceleration was -6.3 g's at .193 seconds.

Table 4

Test Summary for Test 1469-SI#1

Test Date:	June 28, 1985
Weather:	Clear
Vehicle Make and Model:	1979 Honda Civic
Delivered Weight:	1568 lbs
Test Weight:	1806 lbs
Ballast Added:	270 lbs
Vehicle Longitudinal cg:	32.7" behind front tire C.L.
Impact Location:	52.4" behind front tire C.L.
Impact Device:	3 segment rigid pole
Impact Speed:	25.7 mph (37.7 ft/sec)
Delta MV Vehicle:	2114 lb-sec
Delta MV Upper Segment:	212 lb-sec
Delta MV Center Segment:	668 lb-sec
Delta MV Lower Segment:	963 lb-sec
Delta MV Pole Total:	1843 lb-sec
Delta MV from Vehicle Sliding:	271 lb-sec
Vehicle Crush Static:	19 in
Dynamic Deflection:	23.7 in
Vehicle Dyanage Index (SAE):	09LPAN3

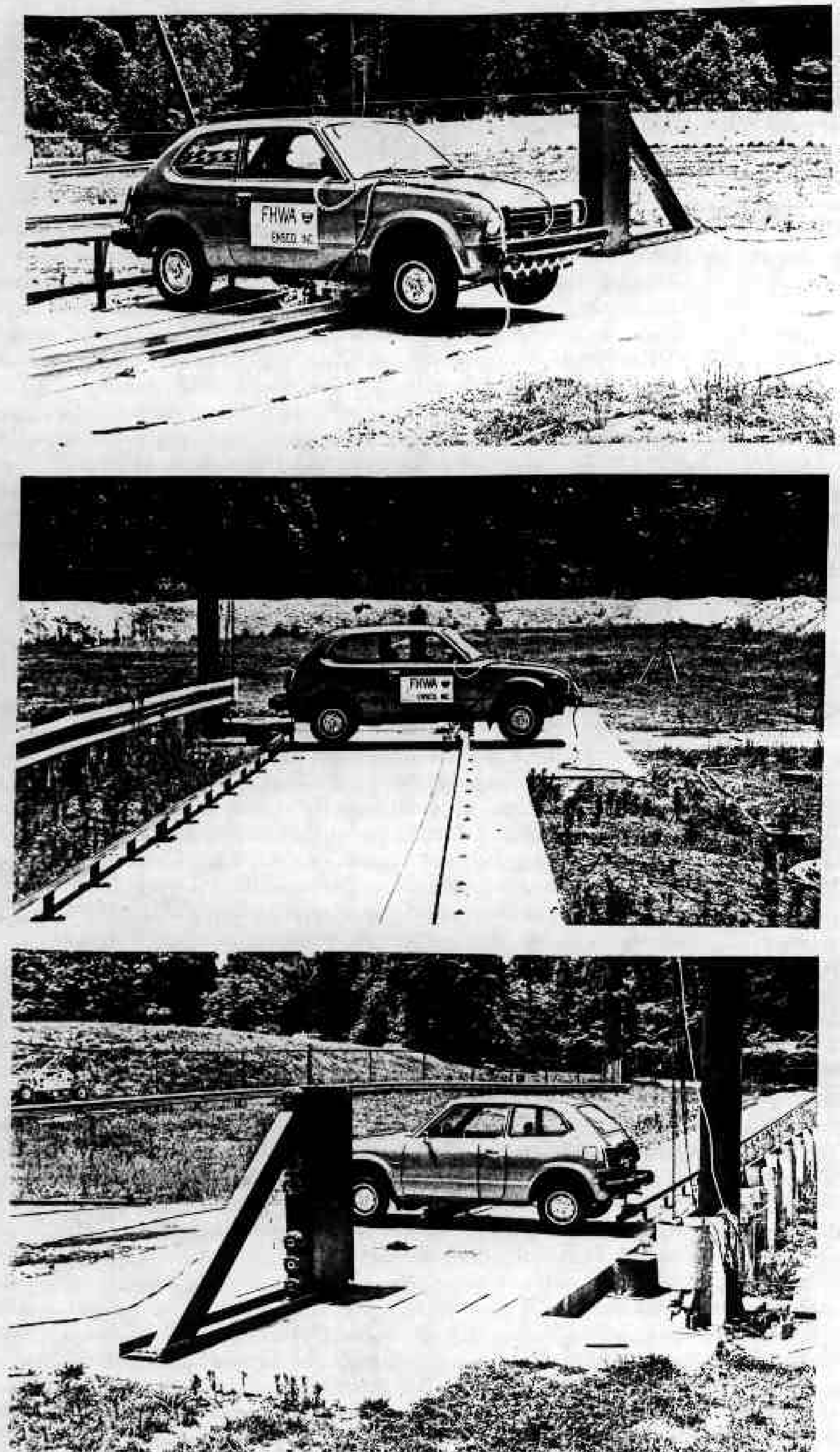


Figure 6. Pre-Test Photos for Test 1469-SI#1

Table 5
Vehicle Crush Measurements

C1 = 0		L = 68"	
C2 = 1"		D = -22.3"	
C3 = 5"			
C4 = 17"			
C5 = 10"			
C6 = 0"			
Max = 19"			

MaxLoc = 48" behind front tire C.L.

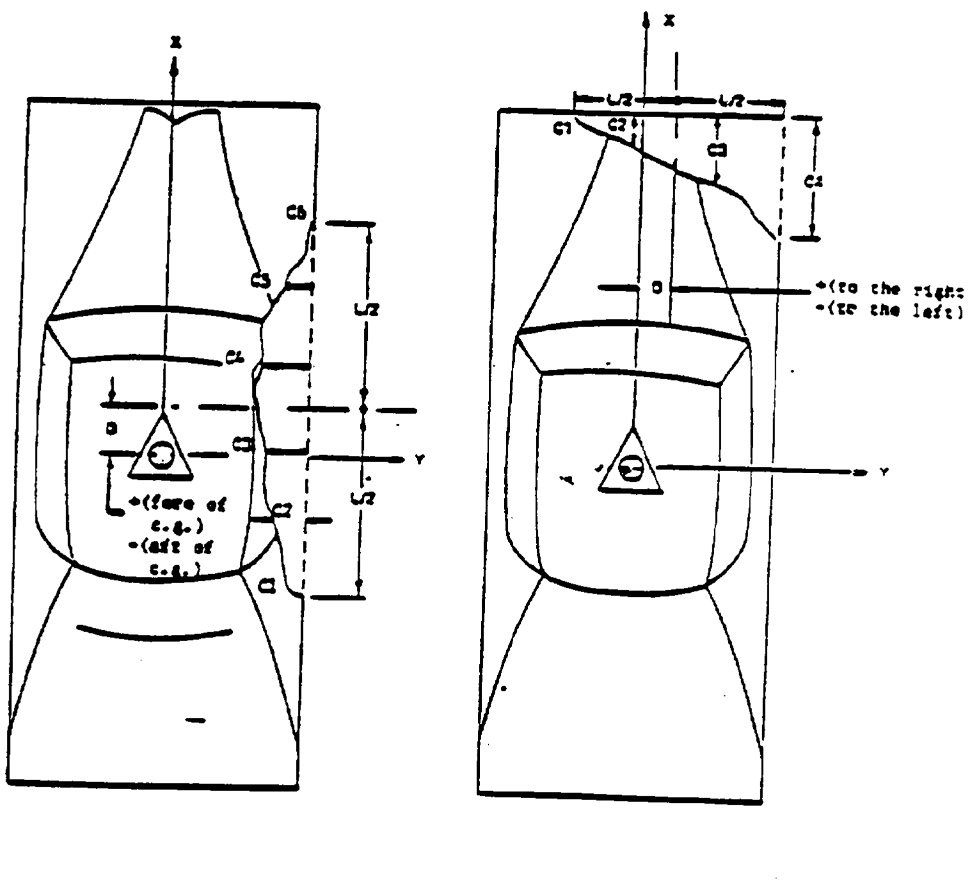


Figure 7. Vehicle Crush Measurement Reference Guide

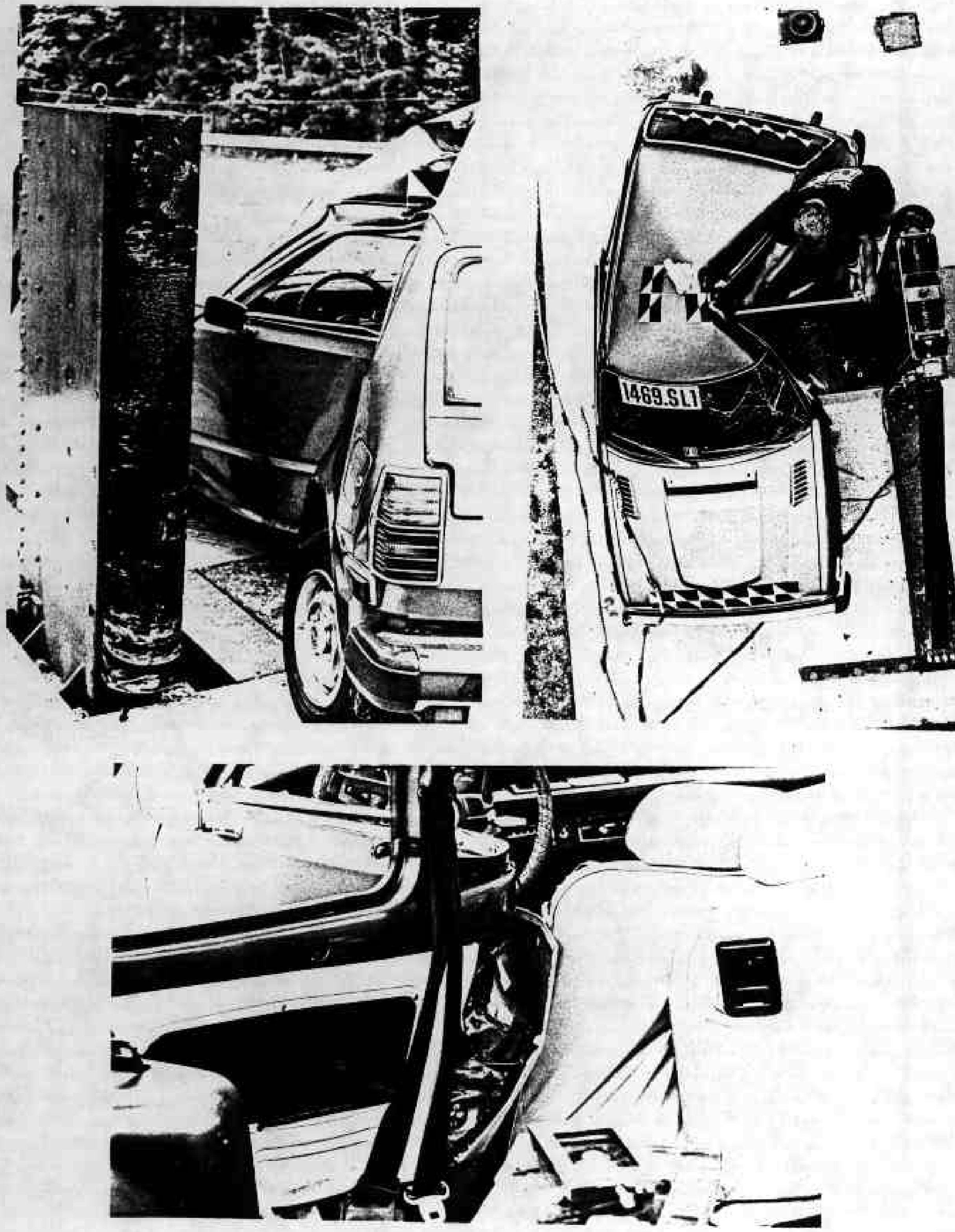


Figure 8. Post-Test Photos for Test 1469-SI#1

4.0 TEST 1469-SI#2-85

4.1 TEST CONDITIONS

In Test SI#2 the VW Rabbit impacted the rigid instrumented pole at 24.7 mph with an impact angle of 90°. Table 6 summarizes the test results. The vehicle yawed clockwise during the impact with a total yaw angle of about 75°. Figure 9 presents photos of the test vehicle prior to testing.

4.2 TEST RESULTS

During the impact the vehicle actually bent about the longitudinal centerline. There was considerable dynamic deflection beyond the static deflection. The static deflection of the test vehicle measured using the NHTSA 6 point technique is presented in table 7. Figure 10 is presented as reference for these measurements. Figure 11 presents photos of the vehicle after the test. The vehicle damage index was 09LPAN3. The NCHRP 230 delta V fora one foot flail space was -23.9 ft/sec. The associated ridedown acceleration was -5.7 g's at .209 seconds.

Table 6

Test Summary for Test 1469-SI#2

Test Date:	July 1, 1985
Weather:	Clear
Vehicle Make and Model:	1979 VW Rabbit
Delivered Weight:	1861 lbs
Test Weight:	1835 lbs
Ballast Added:	0 lbs
Vehicle Longitudinal cg:	31" behind front tire C.L.
Impact Location:	49.8" behind front tire C.L.
Impact Device:	3 segment rigid pole
Impact Speed:	24.7 mph (36.3 ft/sec)
Delta MV Vehicle:	2069 lb-sec
Delta MV Upper Segment:	194 lb-sec
Delta MV Center Segment:	857 lb-sec
Delta MV Lower Segment:	894 lb-sec
Delta MV Pole Total	1945 lb-sec
Delta MV from Vehicle Sliding	124 lb-sec
Vehicle Crush Static:	22 in
Dynamic Deflection:	29.8
Vehicle Damage Index (SAE):	09LPAN3

Figure 9. Pre-Test Photos for Test 1469-SI#1

Table 7

Vehicle Crush Measurements

C1	=	0"	L	=	55"
C2	=	6"	D	=	-18.5"
C3	=	13"			
C4	=	21"			
C5	=	7-1/2"			
C6	=	0"			
Max	=	22"			

MaxLoc = 46" behind front tire C.L.

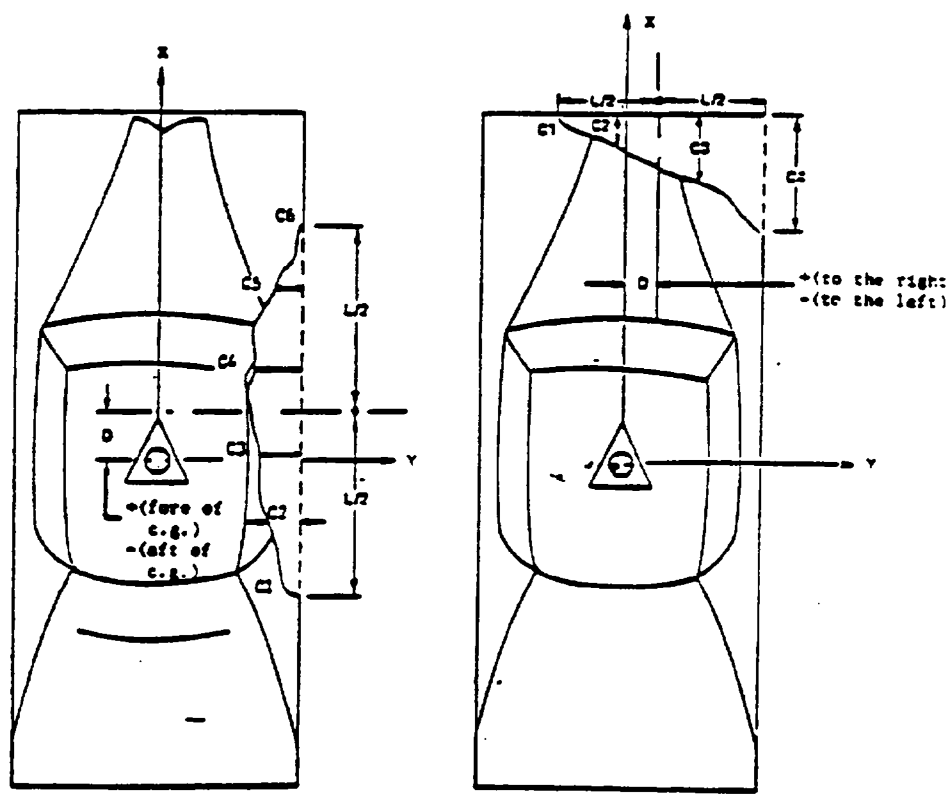


Figure 10. Vehicle Crush Measurement Reference Guide

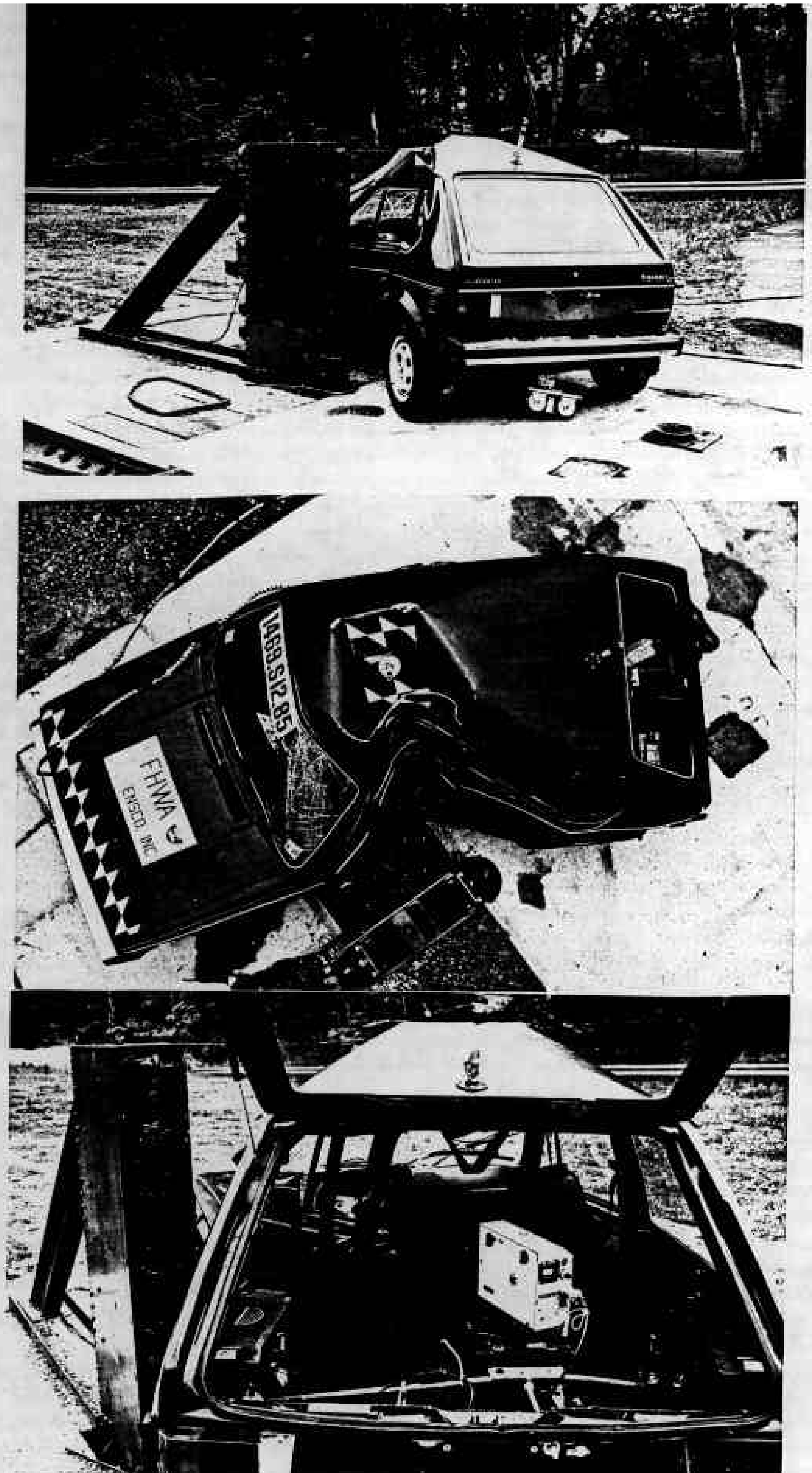


Figure 11. Post-Test Photos for Test 1469-SI#2

5.0 TEST 1469-SI#3-85

5.1 TEST CONDITIONS

In Test SI#3 the Dodge Colt impacted the rigid instrumented pole at 24.6 mph with an impact angle of 90°. Table 8 summarizes the test results. The vehicle yawed clockwise during the impact with a total yaw angle of about 95°. Figure 12 presents photos of the test vehicle prior to testing.

5.1 TEST RESULTS

During the impact the vehicle actually bent about the longitudinal centerline. There was considerable dynamic deflection beyond the static deflection. The static deflection of the test vehicle measured using the NHTSA 6 point technique is presented in table 9. Figure 13 is presented as reference for these measurements. Figure 14 presents photos of the vehicle after the test. The vehicle damage index was 09LPAN3. The NCHRP 230 delta V for a one foot flail space was -20.8 ft/sec. The associated ridedown acceleration was -6.5 g's at .198 seconds.

Table 8

Test Summary for Test 1469-SI#3

Test Date:	July 2, 1985
Weather:	Clear
Vehicle Make and Model:	1979 Dodge Colt
Delivered Weight:	1737 lbs
Test Weight:	1800 lbs
Ballast Added:	140 lbs
Vehicle Longitudinal cg:	32.5" behind front tire C.L.
Impact Location:	50.8" behind front tire C.L.
Impact Device:	3 segment rigid pole
Impact Speed:	24.6 mph (36.0 ft/sec)
Delta MV Vehicle:	2012 lb-sec
Delta MV Upper Segment:	168 lb-sec
Delta MV Center Segment:	920 lb-sec
Delta MV Lower Segment:	793 lb-sec
Delta MV Pole Total:	1881 lb-sec
Delta MV for Vehicle Sliding:	131 lb-sec
Vehicle Crush Static:	23 in
Dynamic Deflection:	29 in
Vehicle Damage Index (SAE):	09LPAN3

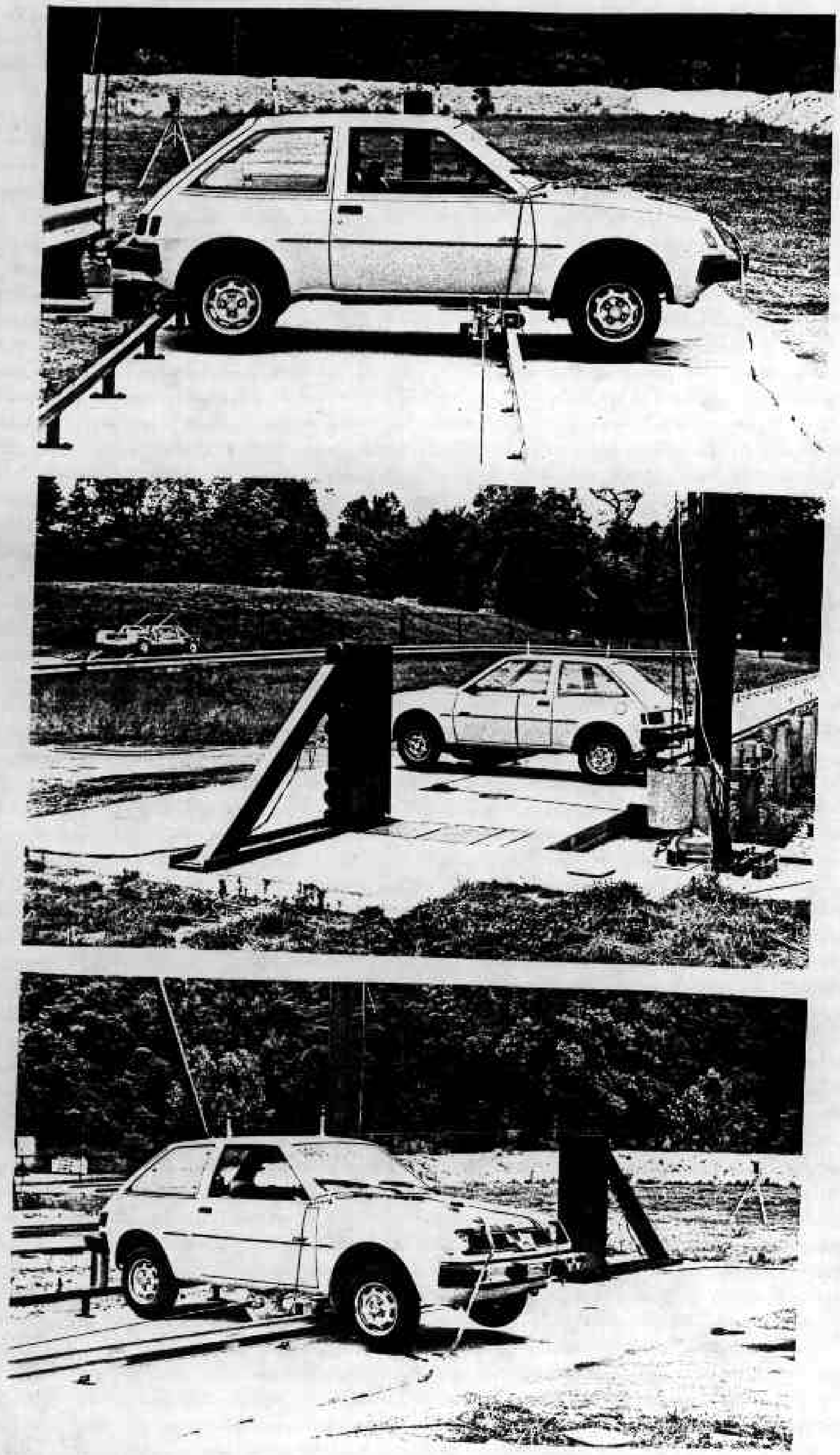


Figure 12. Pre-Test Photos for Test 1469-SI#3

Table 9

Vehicle Crush Measurements

C1 = 0"		L = 53"	
C2 = 7"		D = -16"	
C3 = 19"			
C4 = 13"			
C5 = 6"			
C6 = 0"			
Max = 23"			
MaxLoc = 46" behind front tire C.L.			

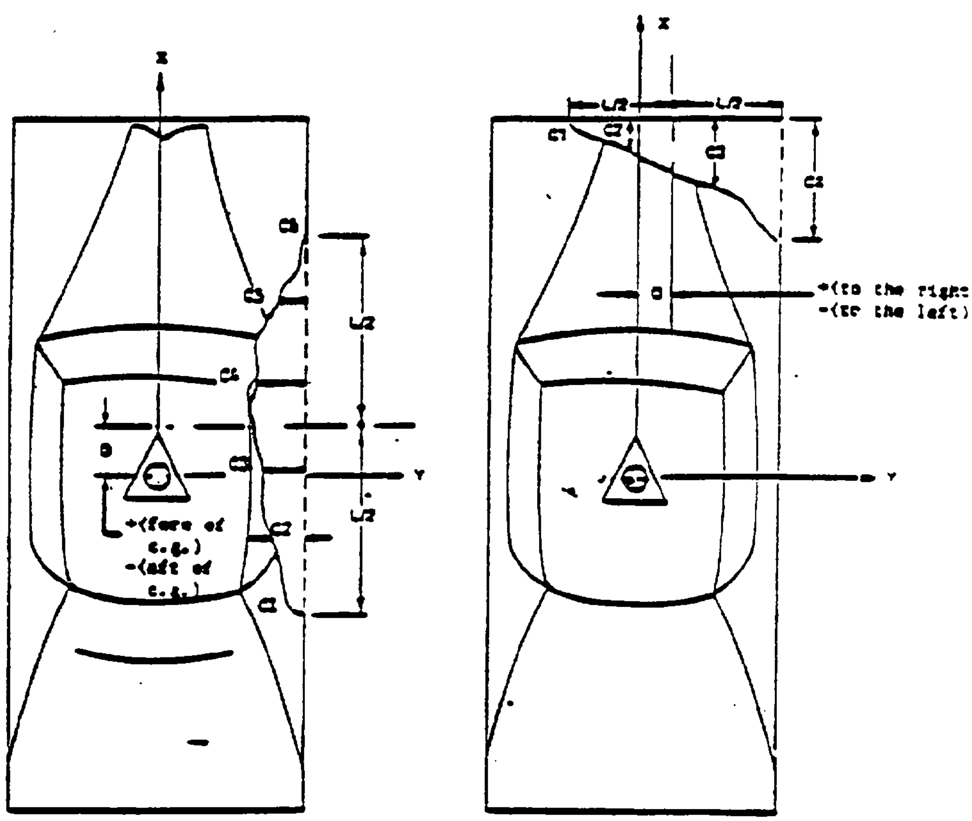


Figure 13. Vehicle Crush Measurement Reference Guide

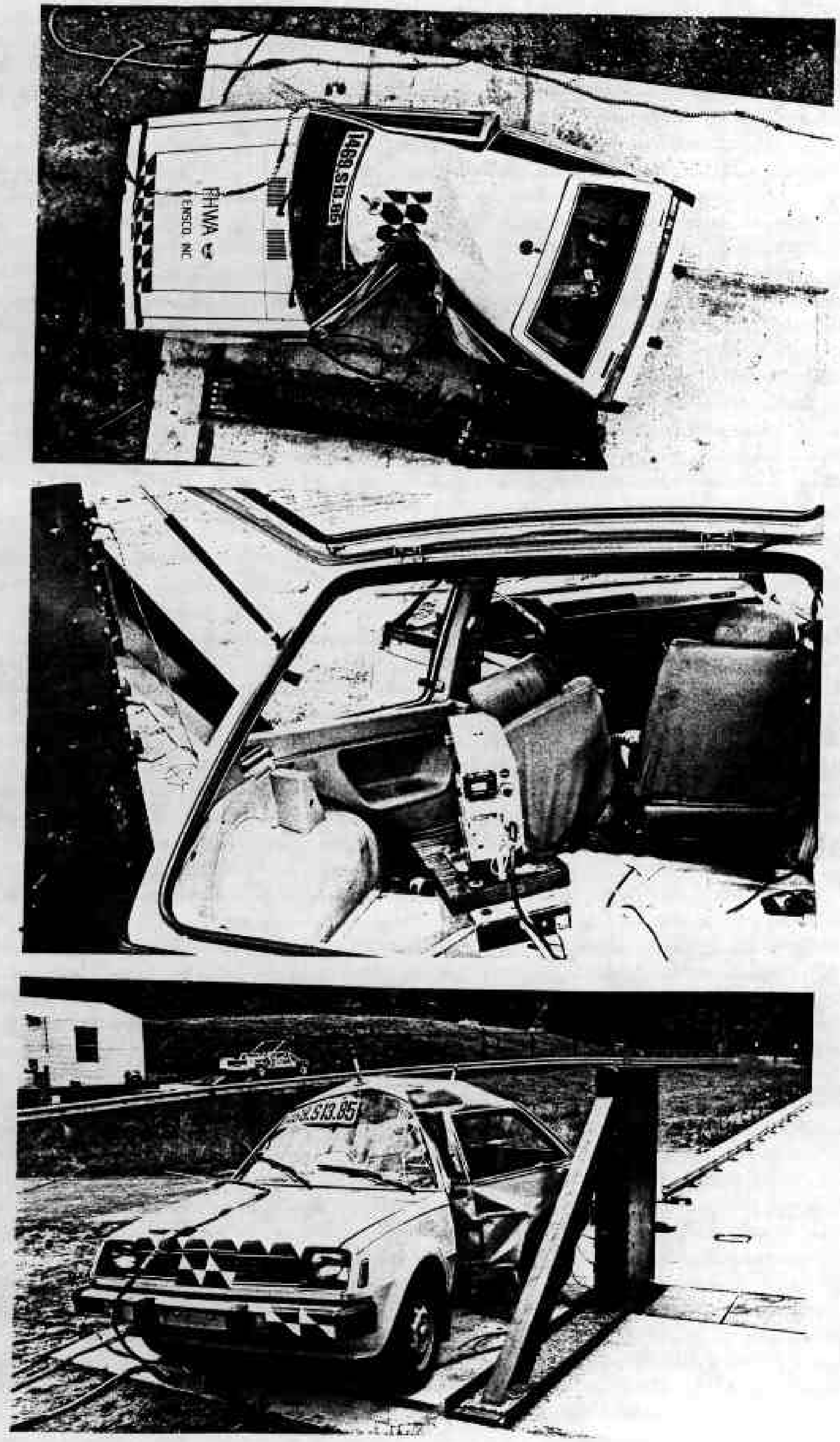


Figure 14. Post-Test Photos for Test 1469-SI#3

6.0 TEST 1469-SI#8-85

6.1 TEST CONDITIONS

In Test SI#8 the Dodge St. Regis impacted the rigid instrumented pole at 10.3 mph with an impact angle of 90°. Table 10 summarizes the test results. The vehicle yawed slightly clockwise during the impact with a total yaw angle of about 2°. Figure 15 presents photos of the test vehicle prior to testing.

6.1 TEST RESULTS

During the impact the vehicle actually bent about the longitudinal centerline. There was considerable dynamic deflection beyond the static deflection. The static deflection of the test vehicle measured using the NHTSA 6 point technique is presented in table 11. Figure 16 is presented as reference for these measurements. Figure 17 presents photos of the vehicle after the test. The vehicle damage index was 09LPAN3. The NCHRP 230 delta V for a one foot flail space was -17.3 ft/sec. The associated ridedown acceleration was 2.1 at .381 seconds.

Table 10

Test Summary for Test 1469-SI#8

Test Date:	December 4, 1985
Weather:	Cloudy
Vehicle Make and Model:	1979 Dodge St. Regis
Delivered Weight:	3677 lbs
Test Weight:	4490 lbs
Ballast Added:	904 lbs
Vehicle Longitudinal cg:	57.9" behind front tire C.L.
Impact Location:	69.0" behind front tire C.L.
Impact Device:	3 segment rigid pole
Impact Speed:	10.3 mph (15.1 ft/sec)
Delta MV Vehicle:	2412 lb-sec
Delta MV Upper Segment:	640 lb-sec
Delta MV Center Segment:	1479 lb-sec
Delta MV Lower Segment:	116 lb-sec
Delta MV Pole Total:	2235 lb-sec
Delta MV for Vehicle Sliding:	117 lb-sec
Vehicle Crush Static:	12"
Dynamic Deflection:	15.2"
Vehicle Damage Index (SAE):	09LPAN3

Figure 15. Pre-Test Photos for Test 1469-SI#8

Table 11

Vehicle Crush Measurements

C1	=	0"	L	=	92-1/2"
C2	=	4-1/2"	D	=	-14.4"
C3	=	10 3/4"			
C4	=	6"			
C5	=	1"			
C6	=	0"			
Max	=	12"			

MaxLoc = 68" behind front tire C.L.

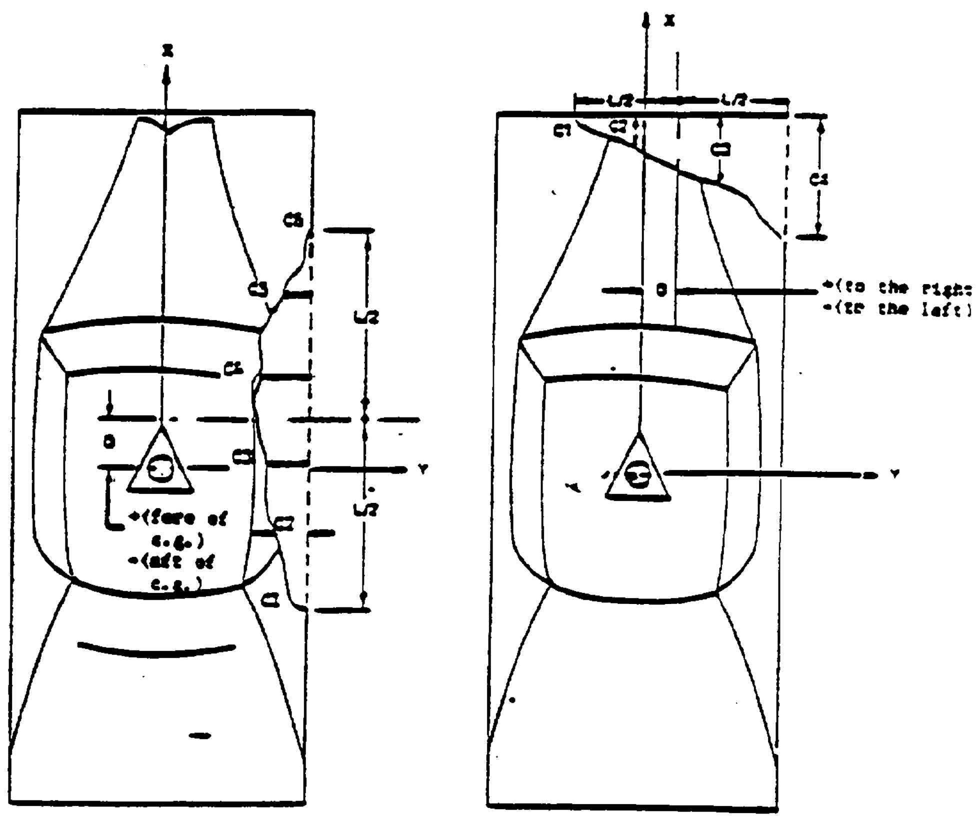


Figure 16. Vehicle Crush Measurement Reference Guide

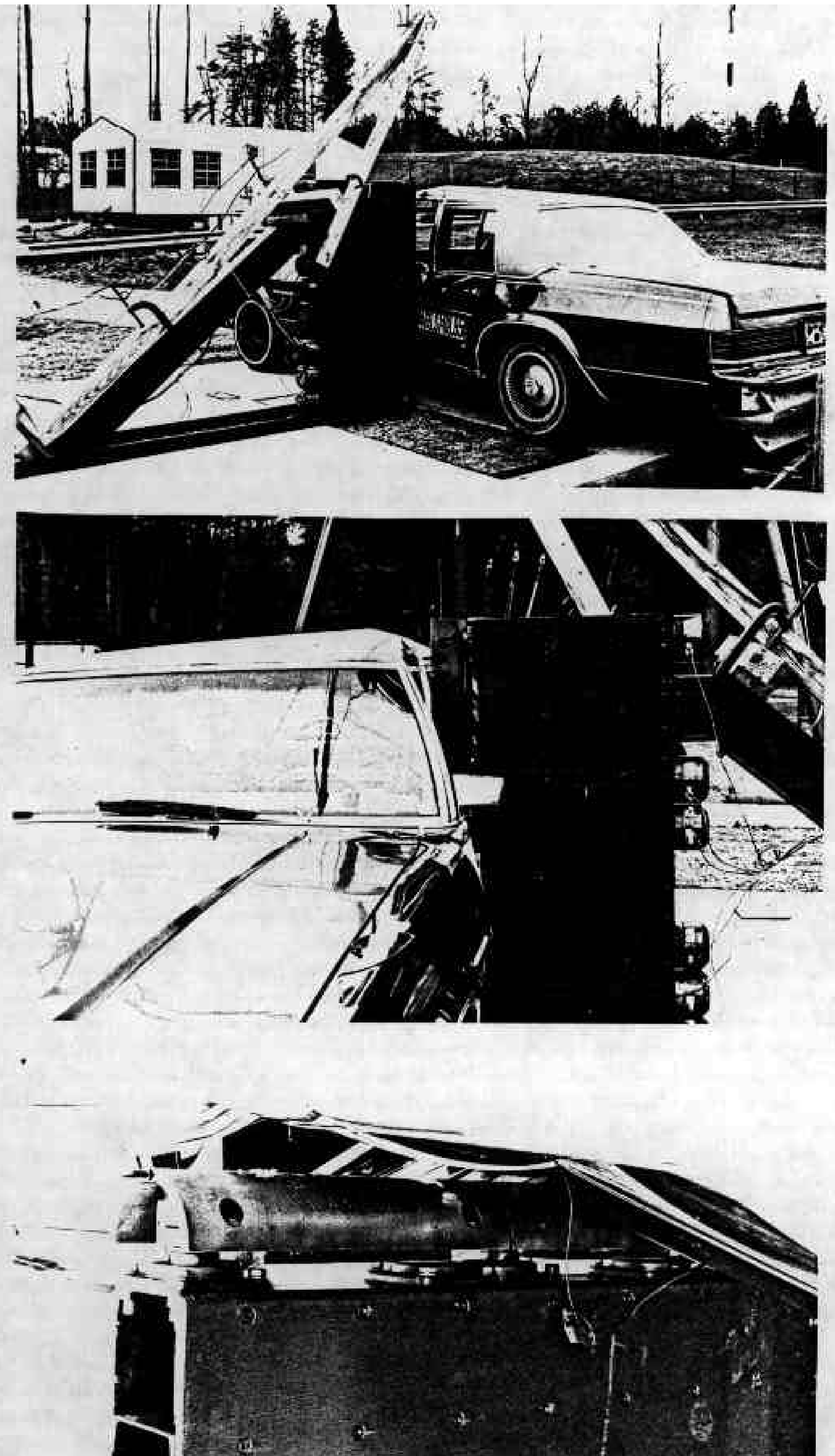


Figure 17. Post-Test Photos for Test 1469-SI#8

7.0 DATA ANALYSIS

The data from each test was analyzed to determine the force-deflection characteristics of each vehicle. Data traces from each load cell were recorded and then digitized. The digitized data was entered into a "LOTUS 123" data base. Accelerometer and rate gyro data was likewise assebmled into the data base. Deflection data was obtained from two sources: 1) double integration of the vehicle accelerometer data and 2) direct mesurment form the high speed film.

7.1 DEFLECTION CONSIDERATIONS

The two displacement-time measurements were generated and compared. It was found that the displacement generated from the accelerometer data did not agree with the visually observed. After lengthly investigation into this nonagreement, it was found that the yaw motion of the vehicle during impact was generating an additional acceleration on the vehicle body. The centrifugal accelerations effect on the lateral accelerometer resulted in non-pure measurement of the lateral acceleration of the vehicle. Because of this affect is was decided to use the displacement-time series of data obtained from the overhead film to generate force-deflection data.

7.2 FORCE DEFLECTION GENERATION

Force deflection characteristics are generated as follows. First the force time data and displacement-time data are obtained. In this case the force data was obtained from the rigid pole while the displacement data was obtained from high speed film data. The two data traces are then synchronized with the instant of impact. Then the time variable is removed by cross plotting the two curves. The result is a force-displacement characteristic of a given vehicle.

Force deflection characteristics were made for the entire vehicle by summing the output off all measuring load cells. (Note: there are 6 load cells in all, 2 each for segment. They measure the body sill, door and roof forces.) Besides the overall vehicle characteristic, force-deflection curves were generated for each segment of the rigid pole.

7.3 LOAD POINT CALCULATIONS

Along with force deflections the load point for each segment was calculated. The load point was determined using the individual load cell outputs for each segment in a moment summarization. The load point curve shows how the effective point of the load on a given segment moves with time. The overall effective load point of the vehicle on the pole was determined.

7.4 POLE AND VEHICLE FORCES

The external forces acting on the vehicle are generated by the impact of the pole and the sliding forces on the tires. The acceleration times the mass will always be higher than the pole forces because of the tire friction. The tire frcition accounts for a consideratbel percentage of the momentum change of the vehicle during the test. The force level acting on the vehicle due to tire friction can be estimated by the vehicle weight times the coefficient of tire friction. Assuming a friction coefficient of .7 and an approximate weight of 1800 lbs then the force retarding motion is 1240 lbs. This times a typical stopping time of a quarter second yields a momentum change due to the tires side forces of 300 lb-secs.

7.5 TEST SI#1 ANALYSIS

Test SI#1 was the Honda Civic impact. The vehicle had a static crush of 19 inches with a dynamic crush of 23.7 inches. The force deflection characteristics of the test vehicle is given in Figure 18. The effective center of load for the entire vehicle is shown in Figure 19. The force deflection of the upper, middle

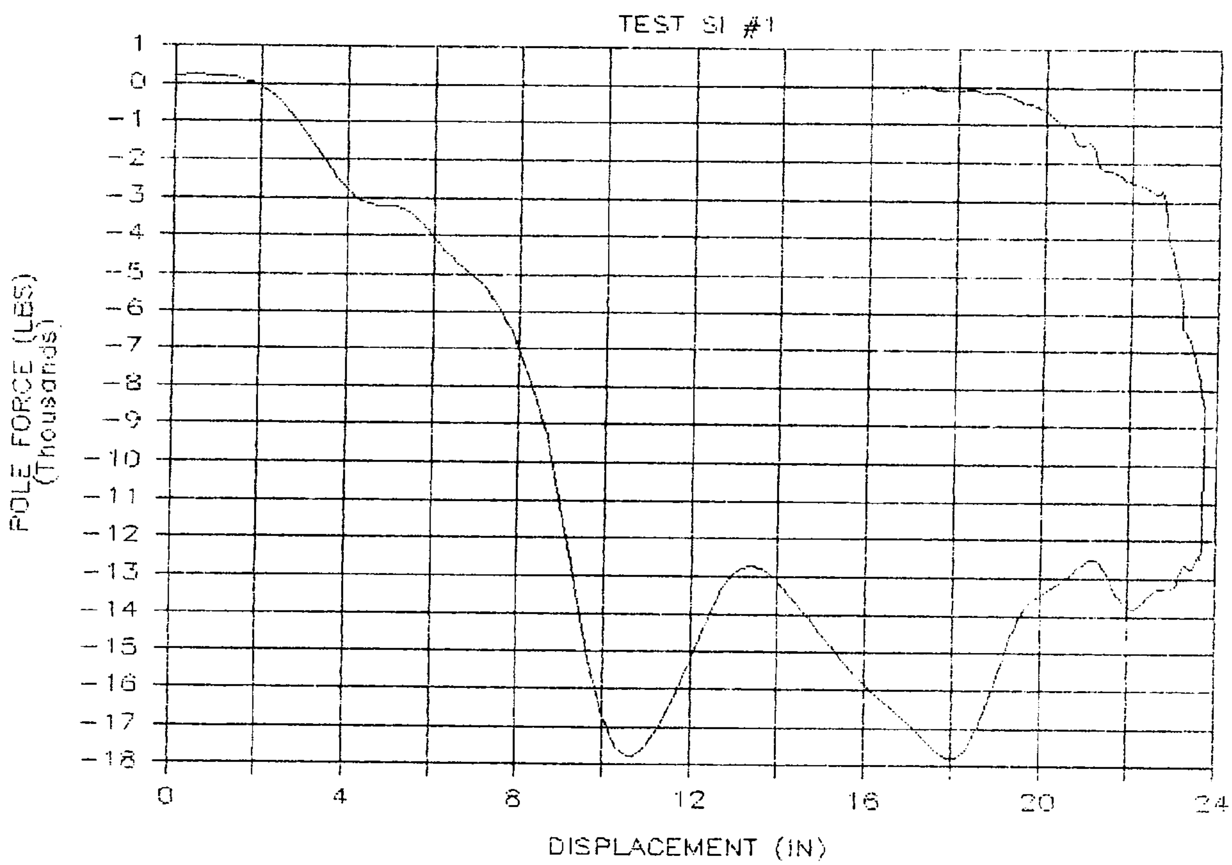


Figure 18. Overall Force Displacement Characteristic for Test SI#1

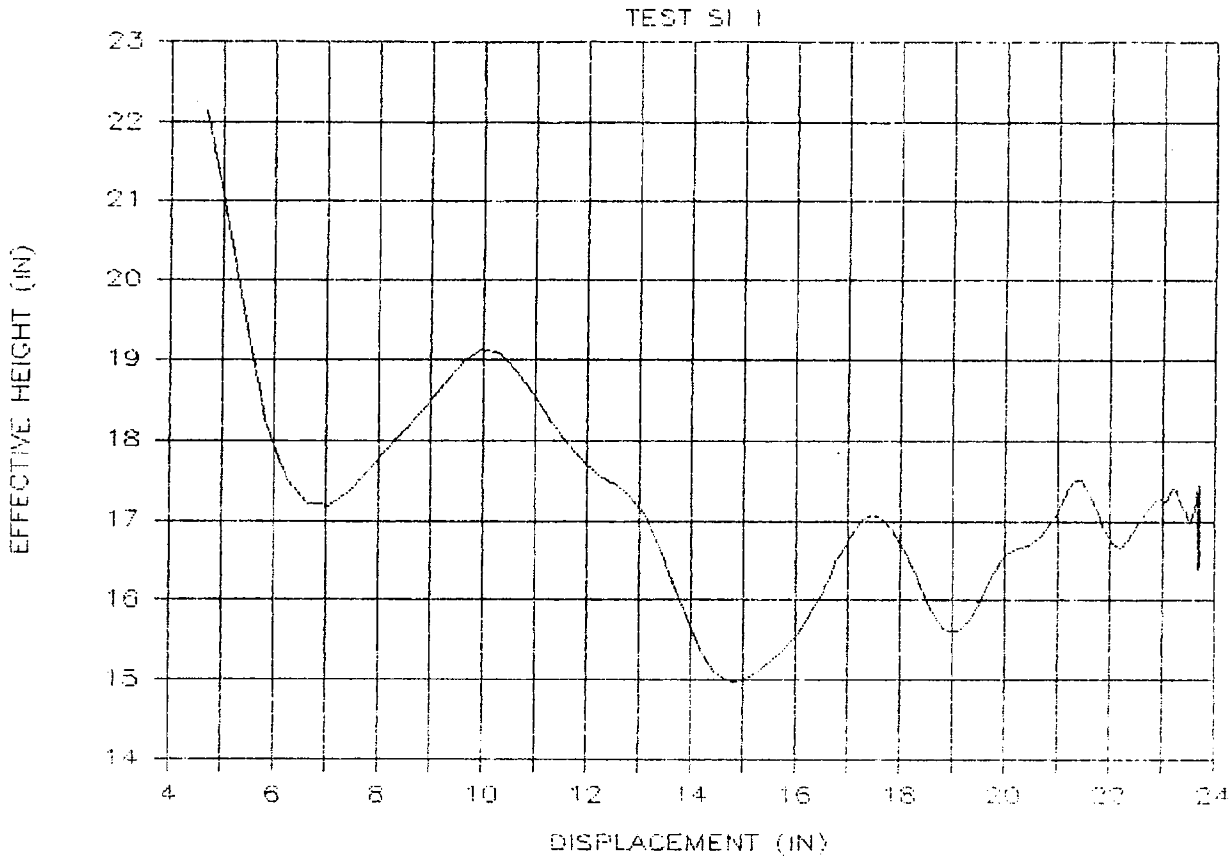


Figure 19. Overall Effective Center of Force for Test SI#1

and lower segment is given in Figures 20, 21 and 22. Figures 23, 24, and 25 present the load point calculated form the ratio of the two loads on a given segment and their associated geometry.

The acceleration-time traces for the vehicle, the force, the traces for the pole, and the yaw rate gyro output are presented in Figures 26, 27, and 28.

7.6 TEST SI#2 ANALYSIS

Test SI#2 was the VW Rabbit impact. The vehicle had a static crush of 22 inches with a dynamic crush of 29.8 inches. The force deflection characteristics of the test vehicle is given in Figure 29. The effective center of load for the entire vehicle is shown in Figure 30. The force deflection of the upper, middle and lower segment is given in Figures 31, 32 and 33. Figures 34, 35, and 36 present the load point calculated form the ratio of the two loads on a given segment and their associated geometry.

The acceleration-time traces for the vehicle, the force time traces for the pole, and the yaw rate gyro output are presented in Figures 37, 38, and 39.

7.7 TEST SI#3 ANALYSIS

Test SI#3 was the Dodge Colt impact. The vehicle had a static crush of 23 inches with a dynamic crush of 29 inches. The force deflection characteristics of the test vehicle is given in Figure 40. The effective center of load for the entire vehicle is shown in Figure 41. The force deflection of the upper, middle and lower segment is given in Figures 42, 43, and 44. Figures 45, 46, and 47 present the load point calculated form the ratio of the two loads on a given segment and their associated geoemtry.

The acceleration-time traces for the vehicle, the force time traces for the pole and the yaw rate gyro output are presented in

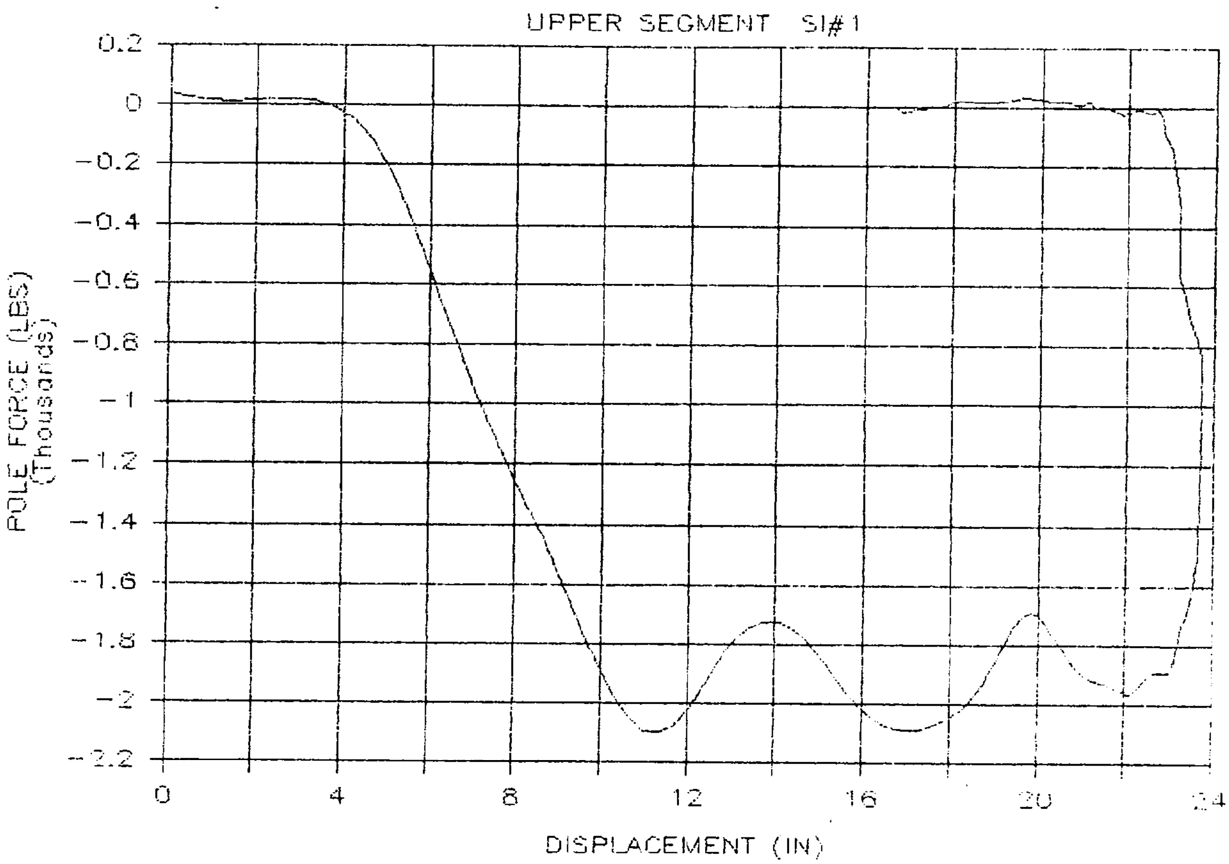


Figure 20. Force Displacement of Upper Segment for Test SI#1

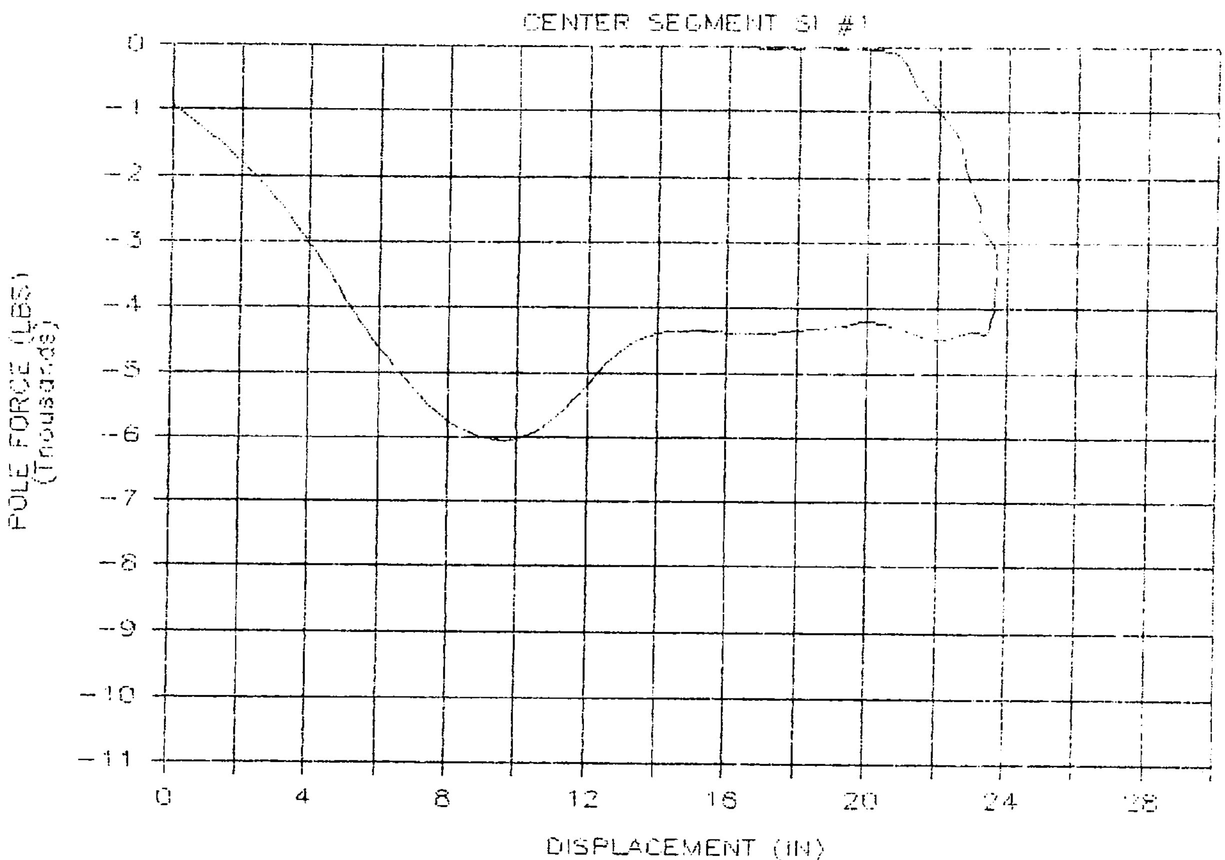


Figure 21. Force Displacement of Center Segment for Test SI#1

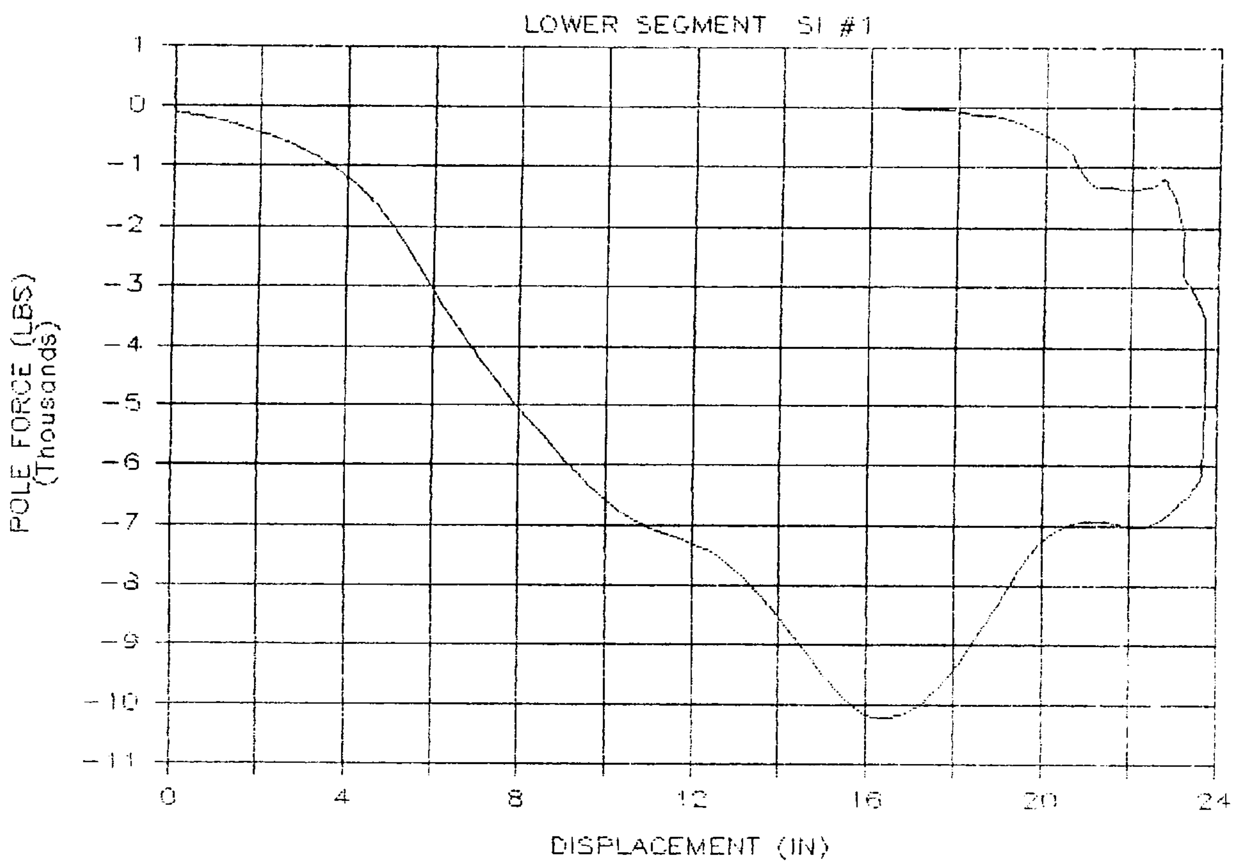


Figure 22. Force Displacement for Lower Segment for Test SI#1

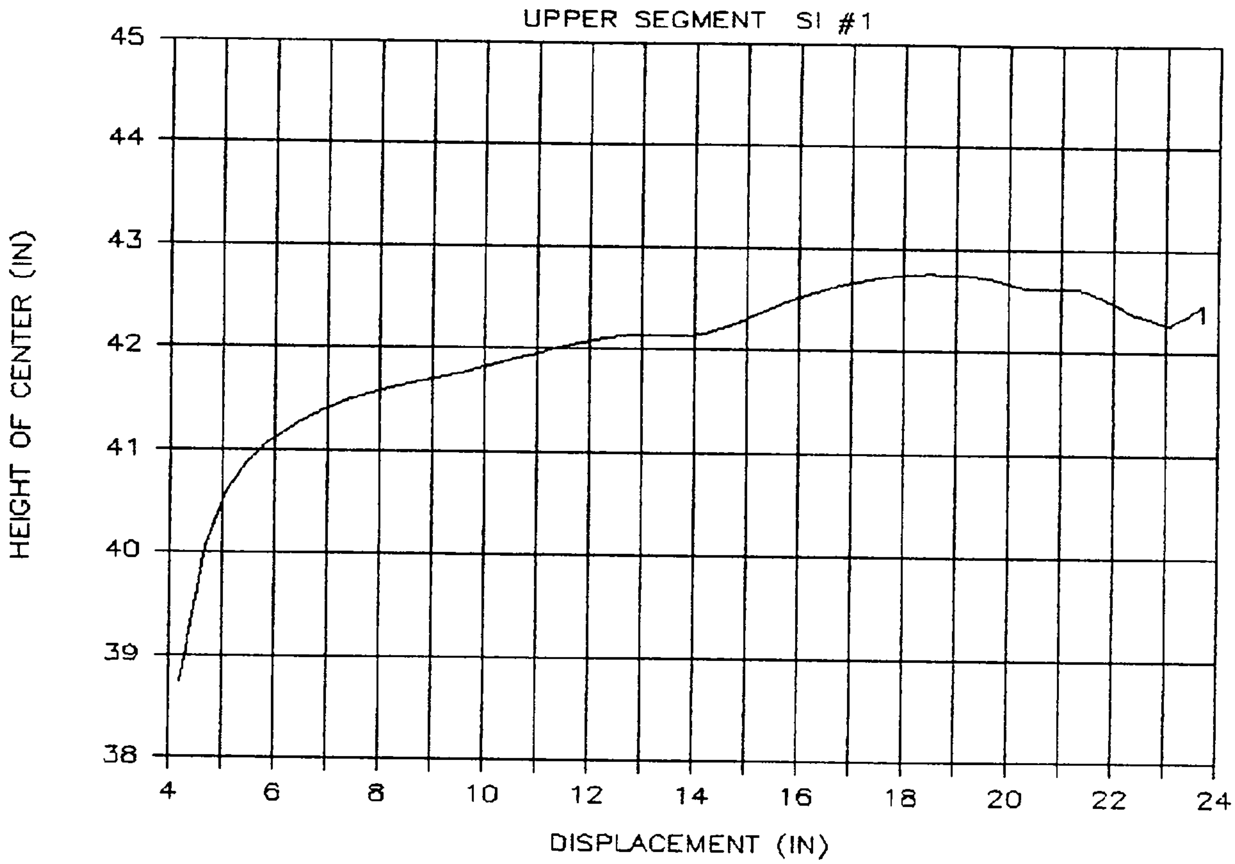


Figure 23. Effective Center of Force for Upper Segment for Test SI#1

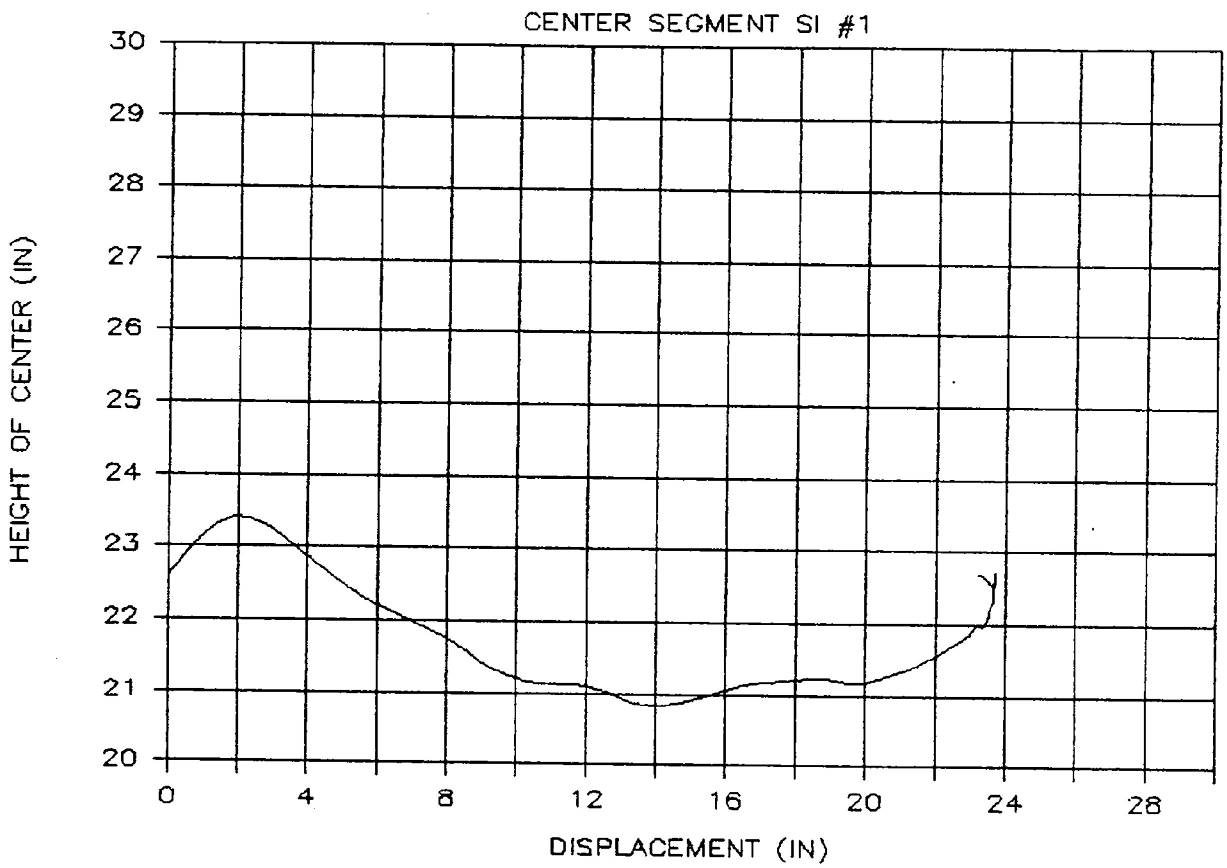


Figure 24. Effective Center of Force for Center Segment for Test SI#1

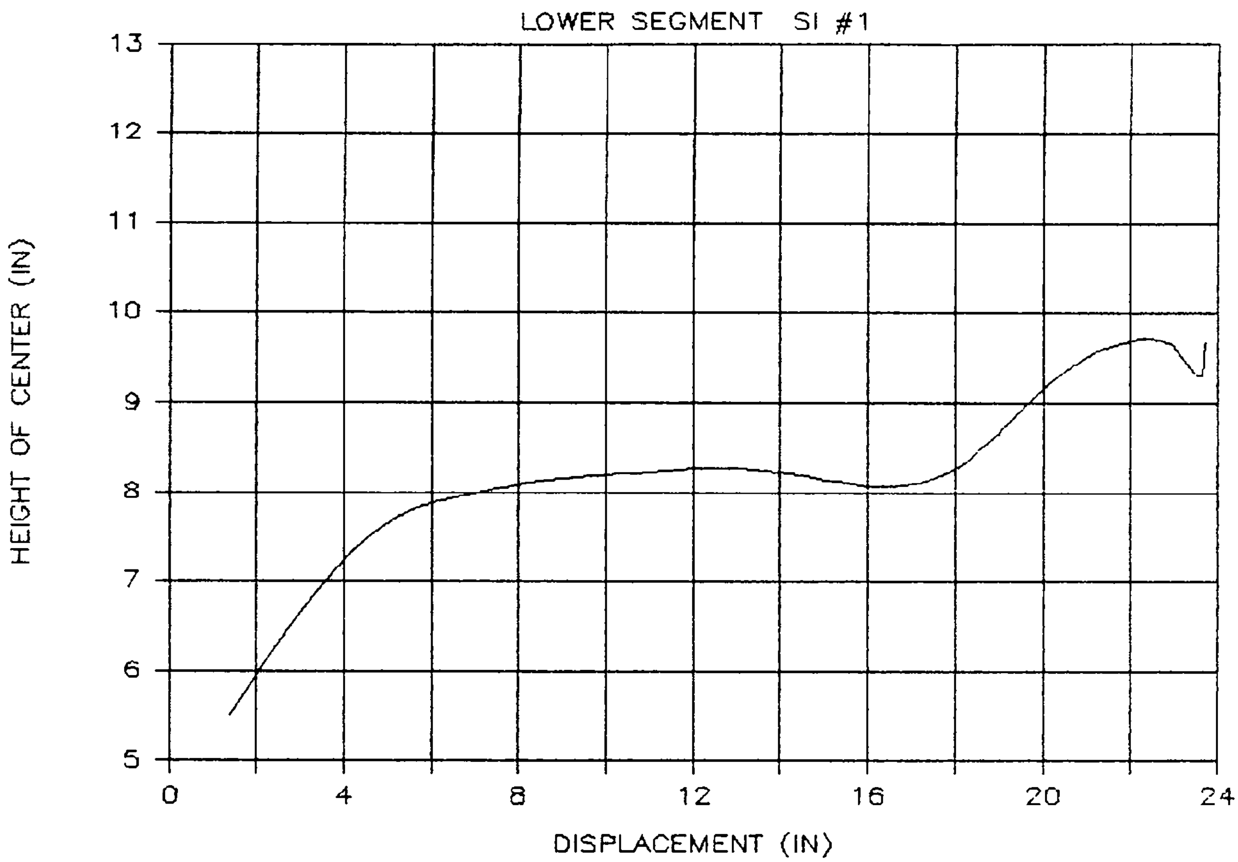


Figure 25. Effective Center of Force for Lower Segment for Test SI#1

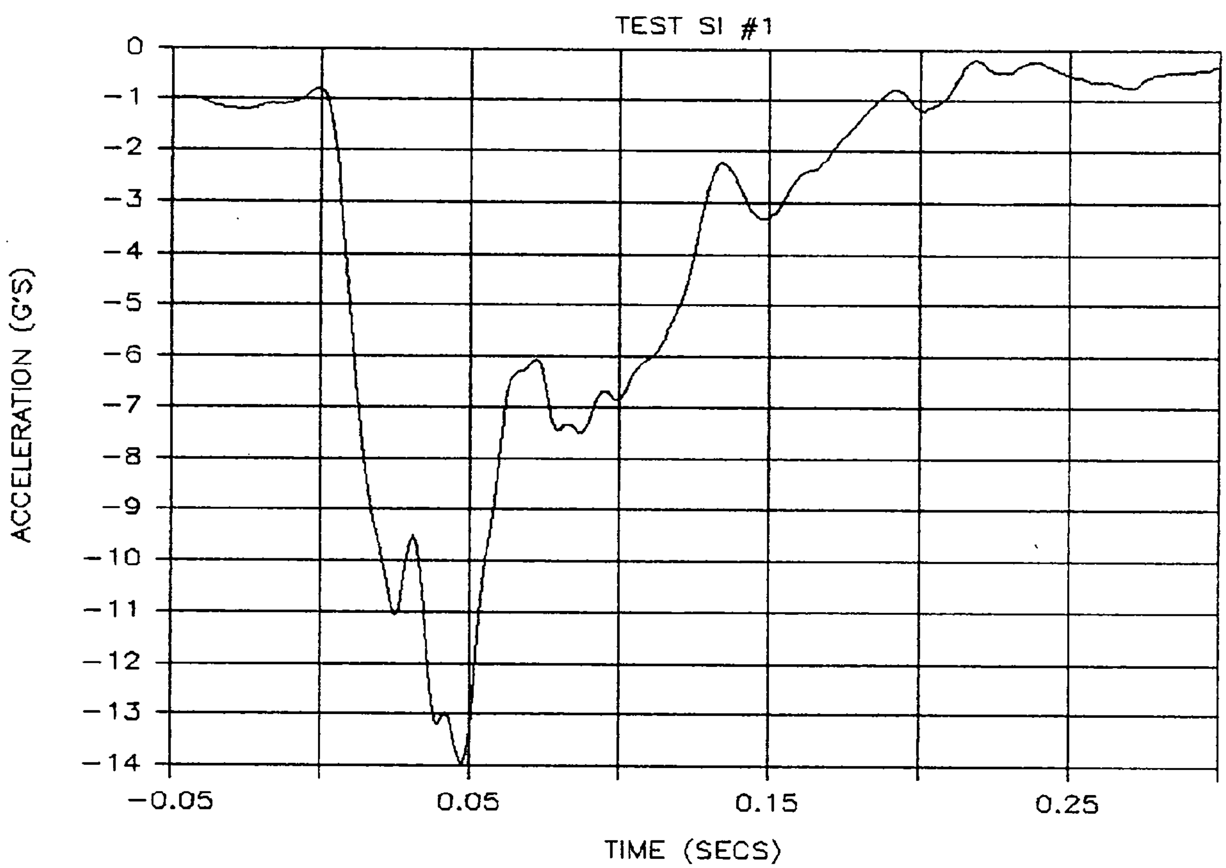
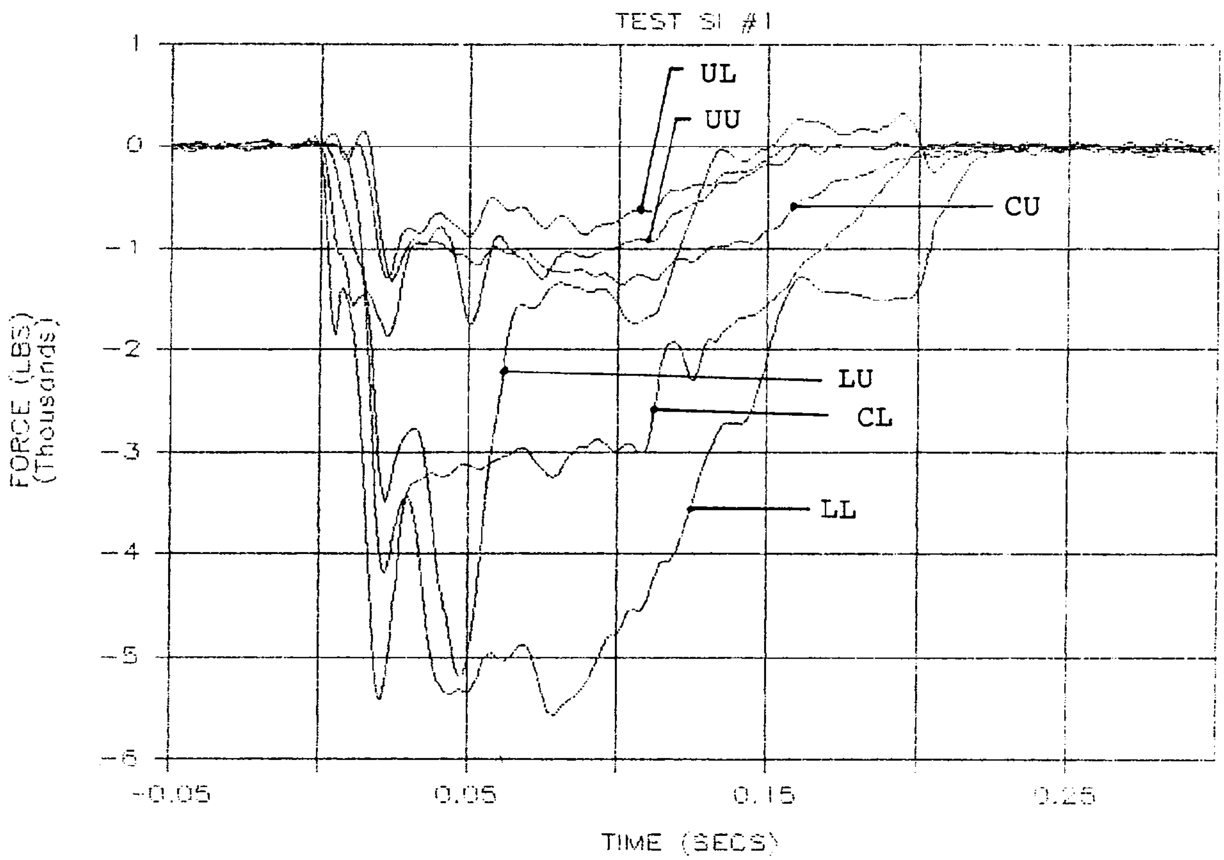


Figure 26. Vehicle Lateral Acceleration vs Time for Test SI#1



LL = Lower Segment Lower Load Cell
LU = Lower Segment Upper Load Cell
CL = Center Segment Lower Load Cell
CU = Center Segment Upper Load Cell
UL = Upper Segment Lower Load Cell
UU = Upper Segment Upper Load Cell

Figure 27. Load Cell Outputs for Test SI#1

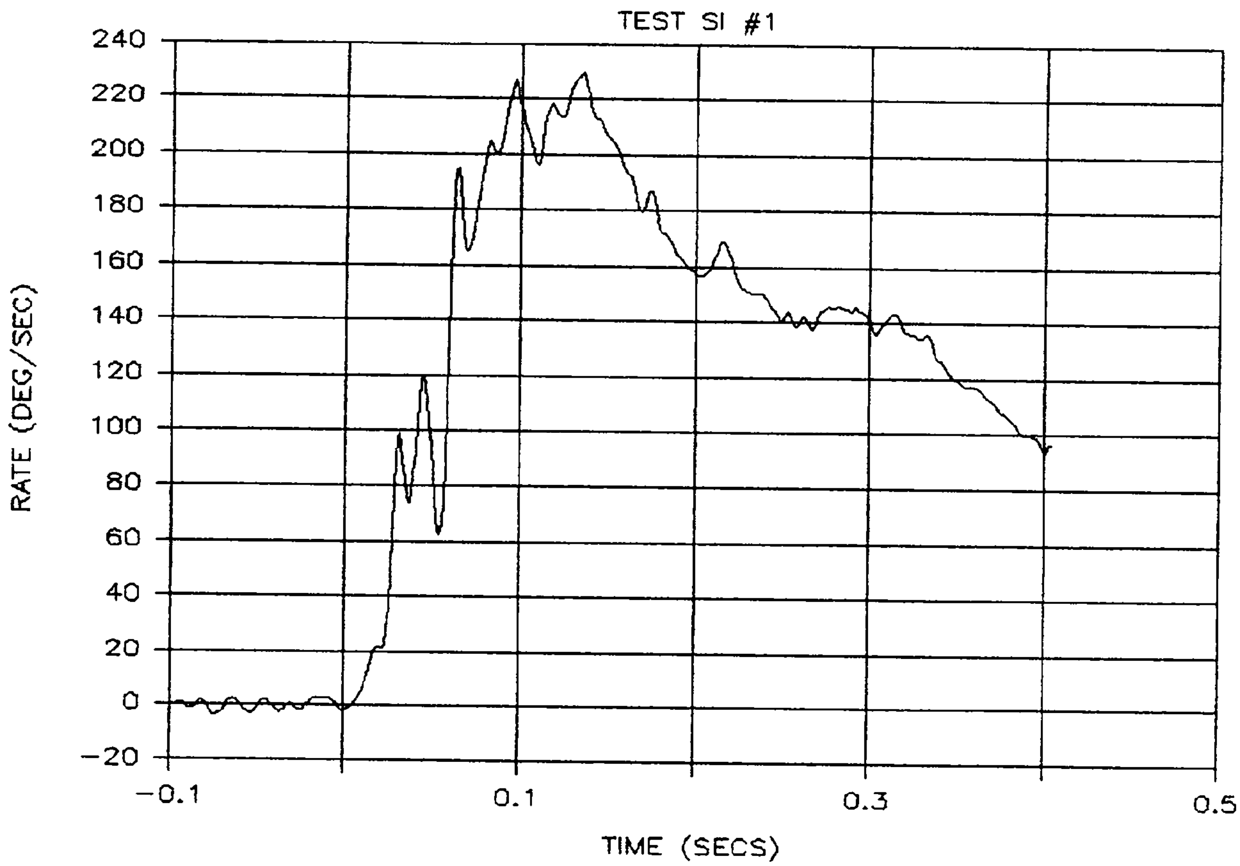


Figure 28. Vehicle Yaw Rate for Test SI#1

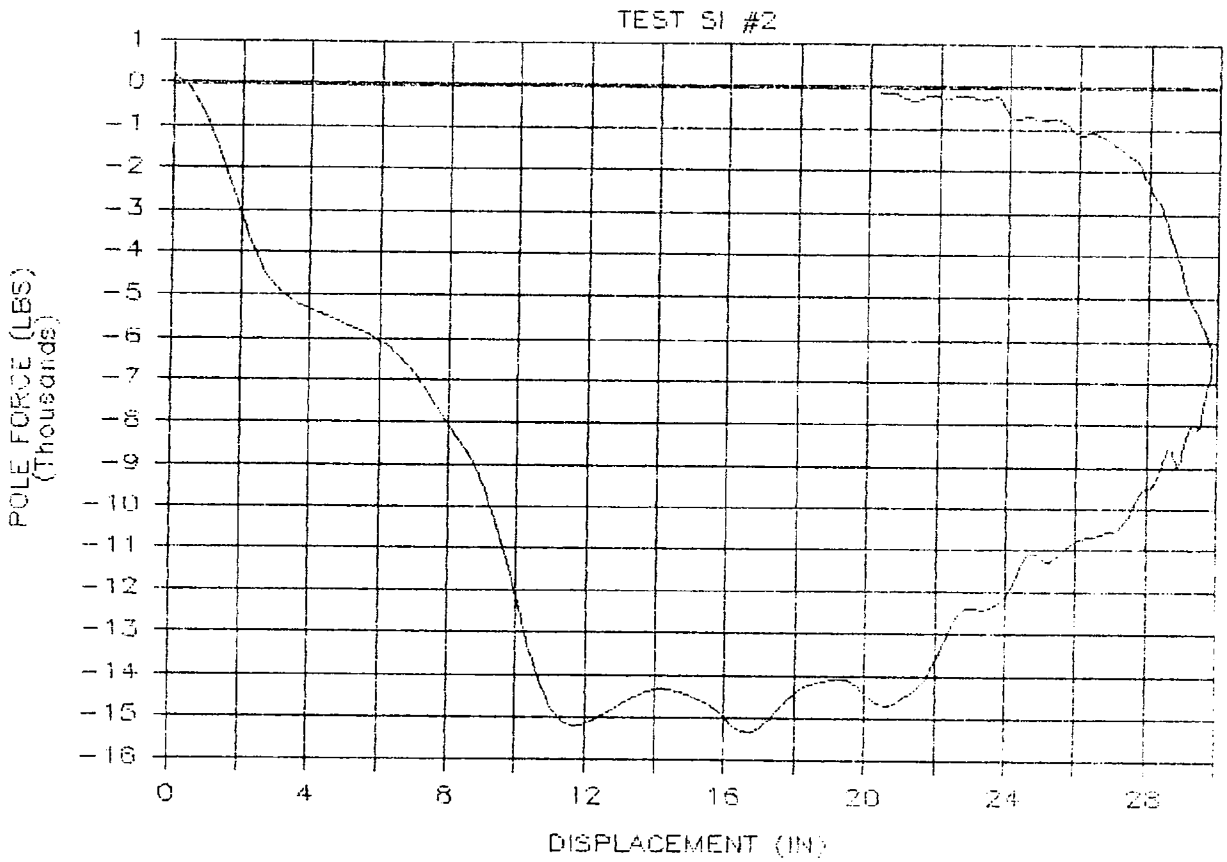


Figure 29. Overall Force Displacement Characteristics for Test SI#2

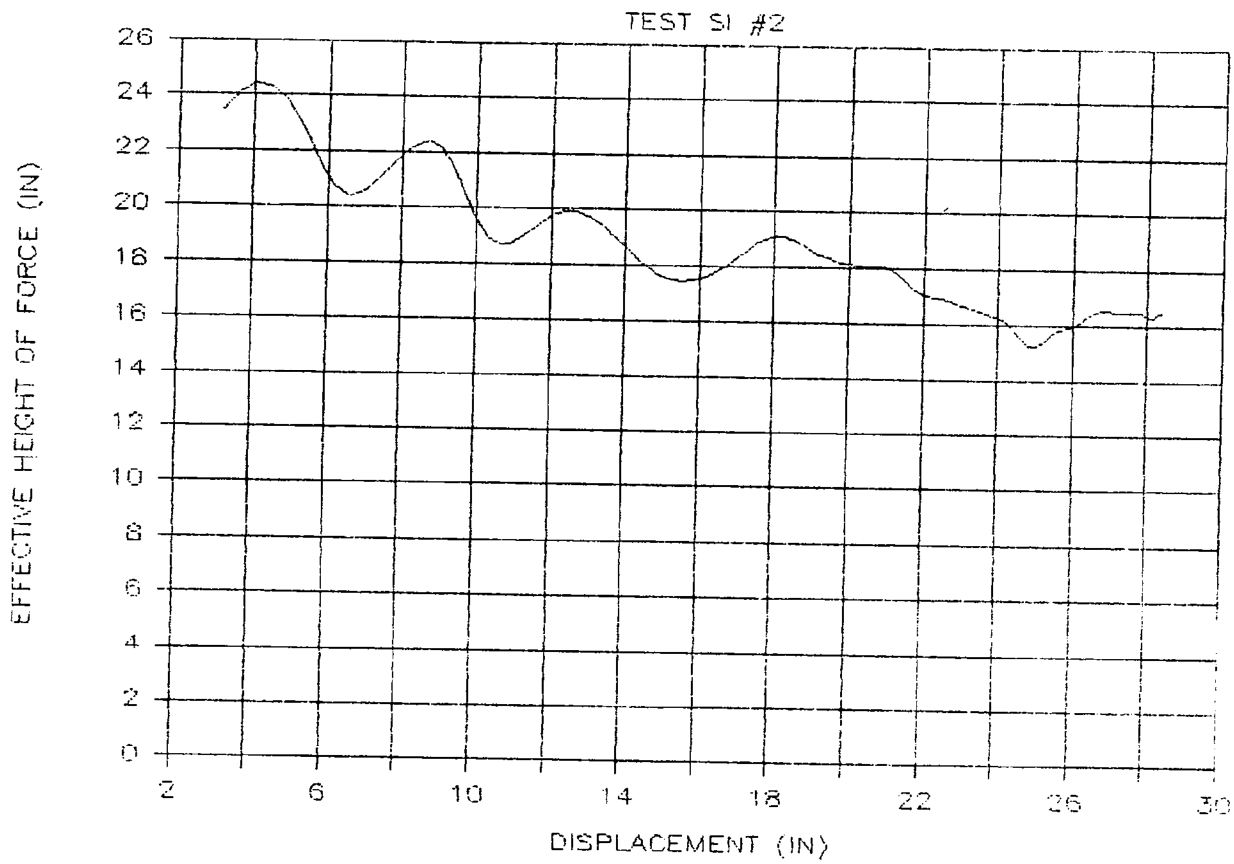


Figure 30. Overall Effective Center of Force for Test SI#2

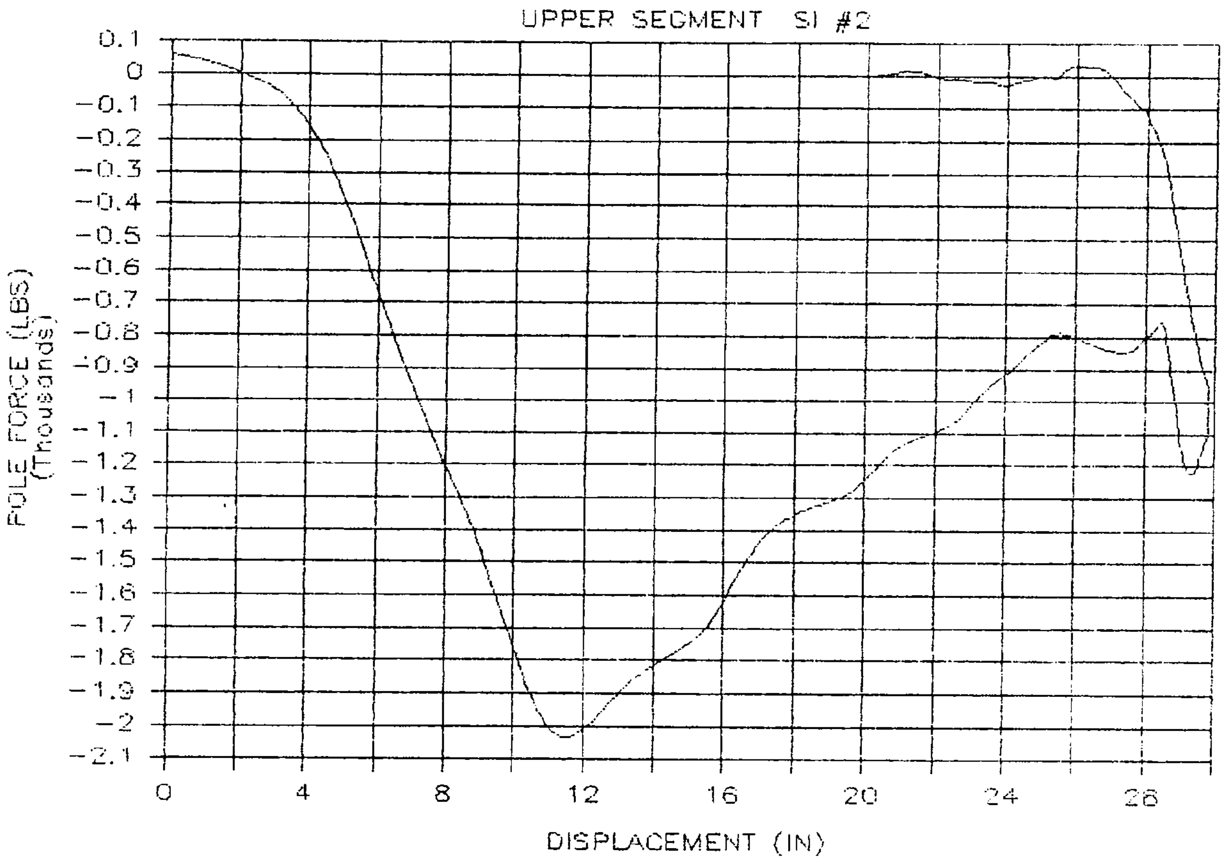


Figure 31. Force Displacement of Upper Segment for Test SI#2

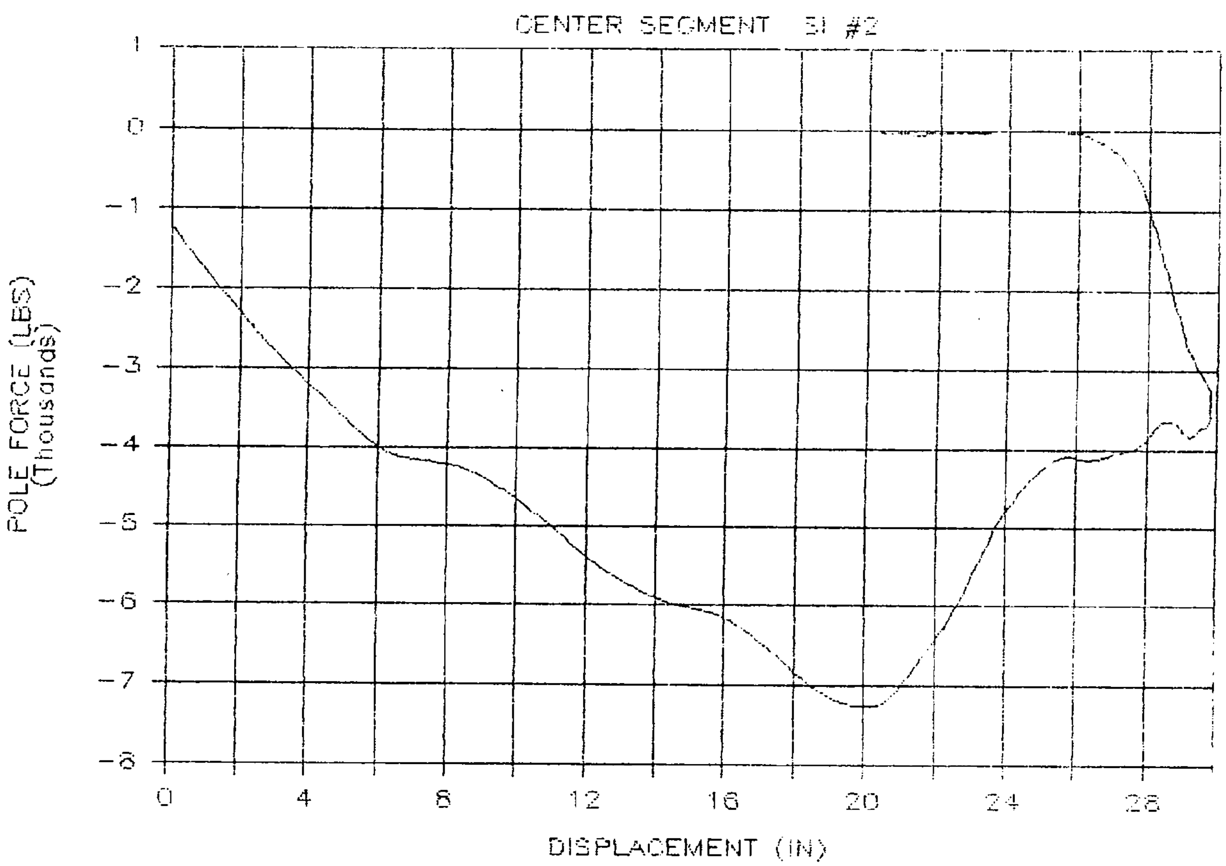


Figure 32. Force Displacement for Center Segment for Test SI#2

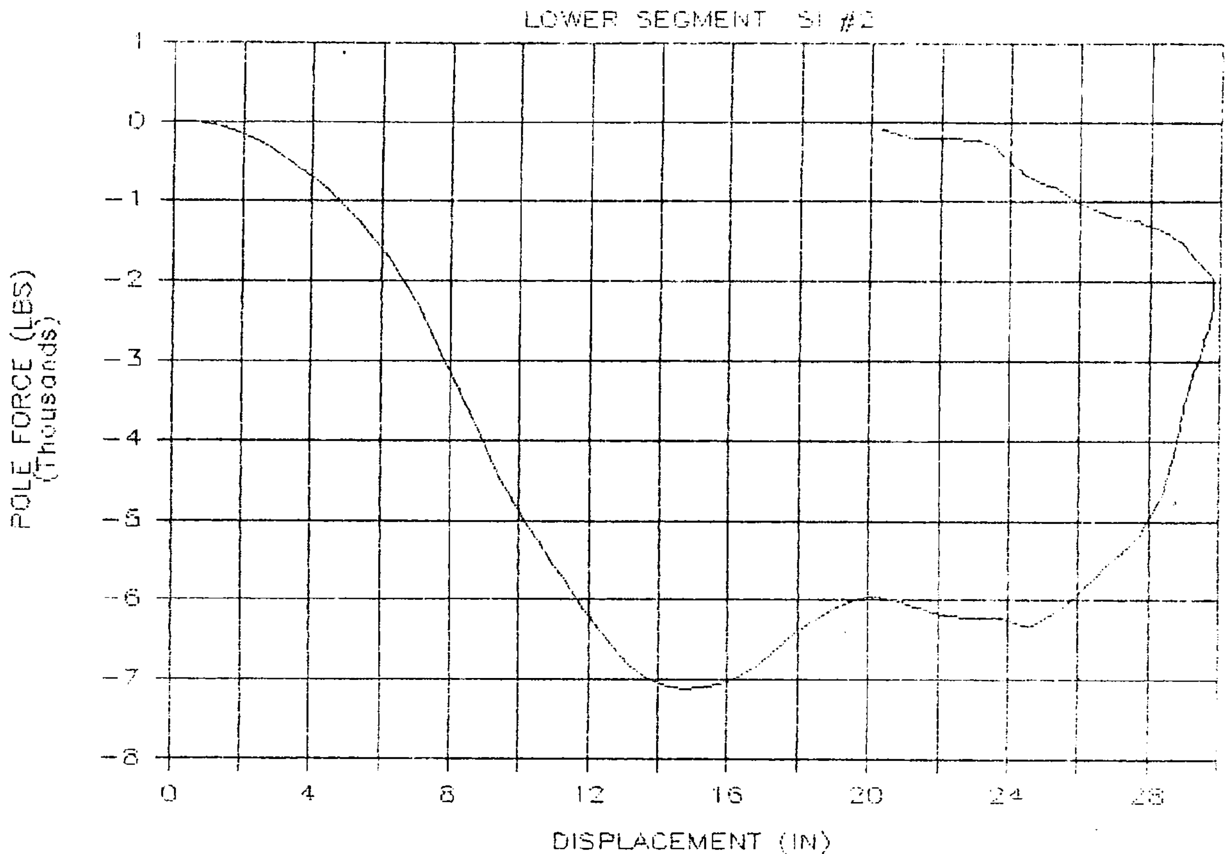


Figure 33. Force Displacement for Lower Segment for Test SI#2

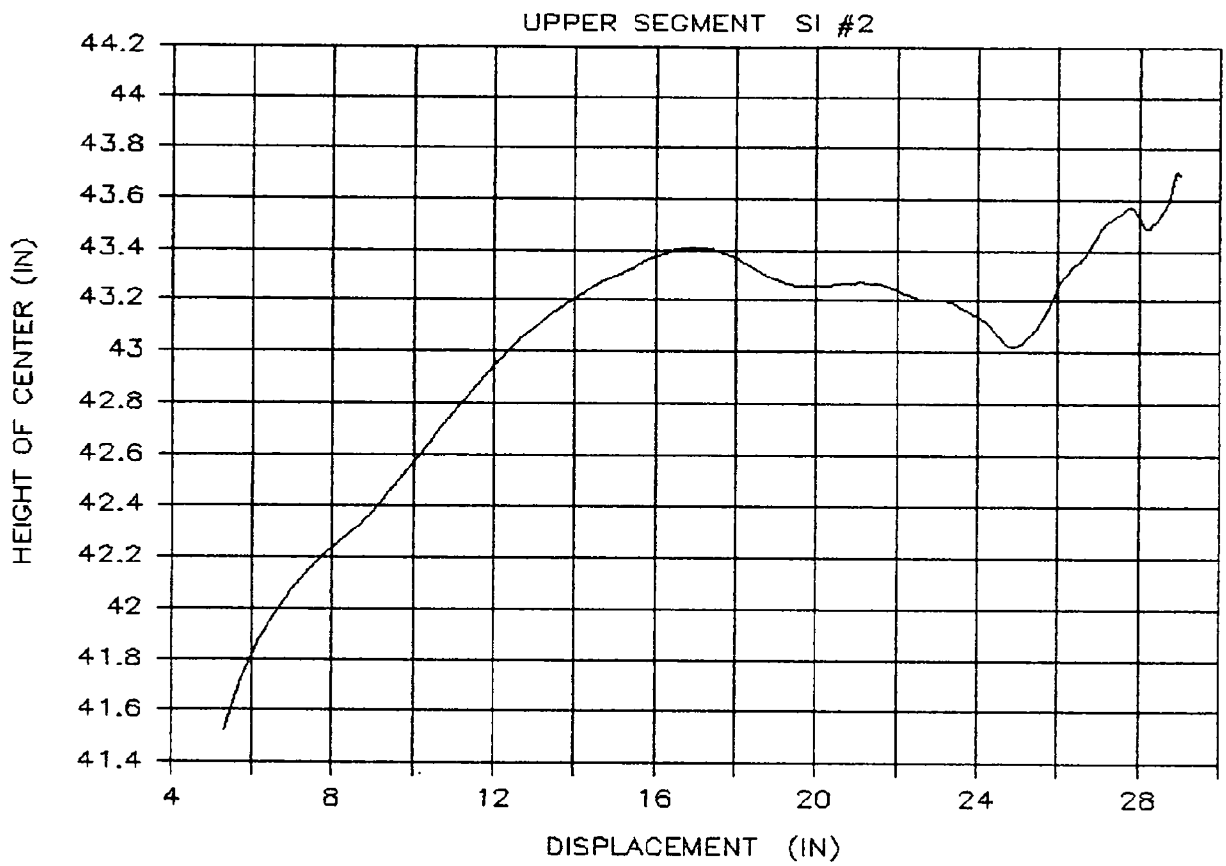


Figure 34. Effective Center of Force for Upper Segment for Test SI#2

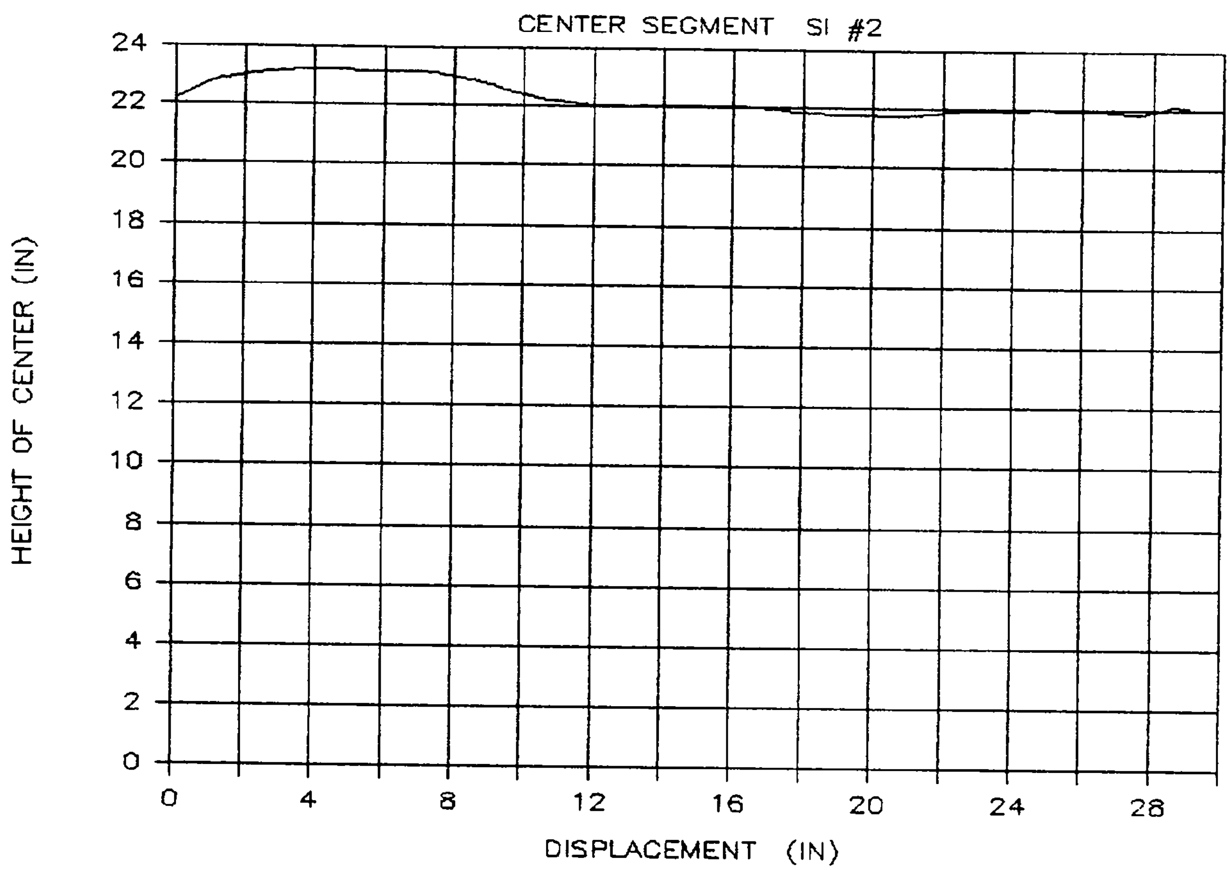


Figure 35. Effective Center of Force for Center Segment for Test SI#2

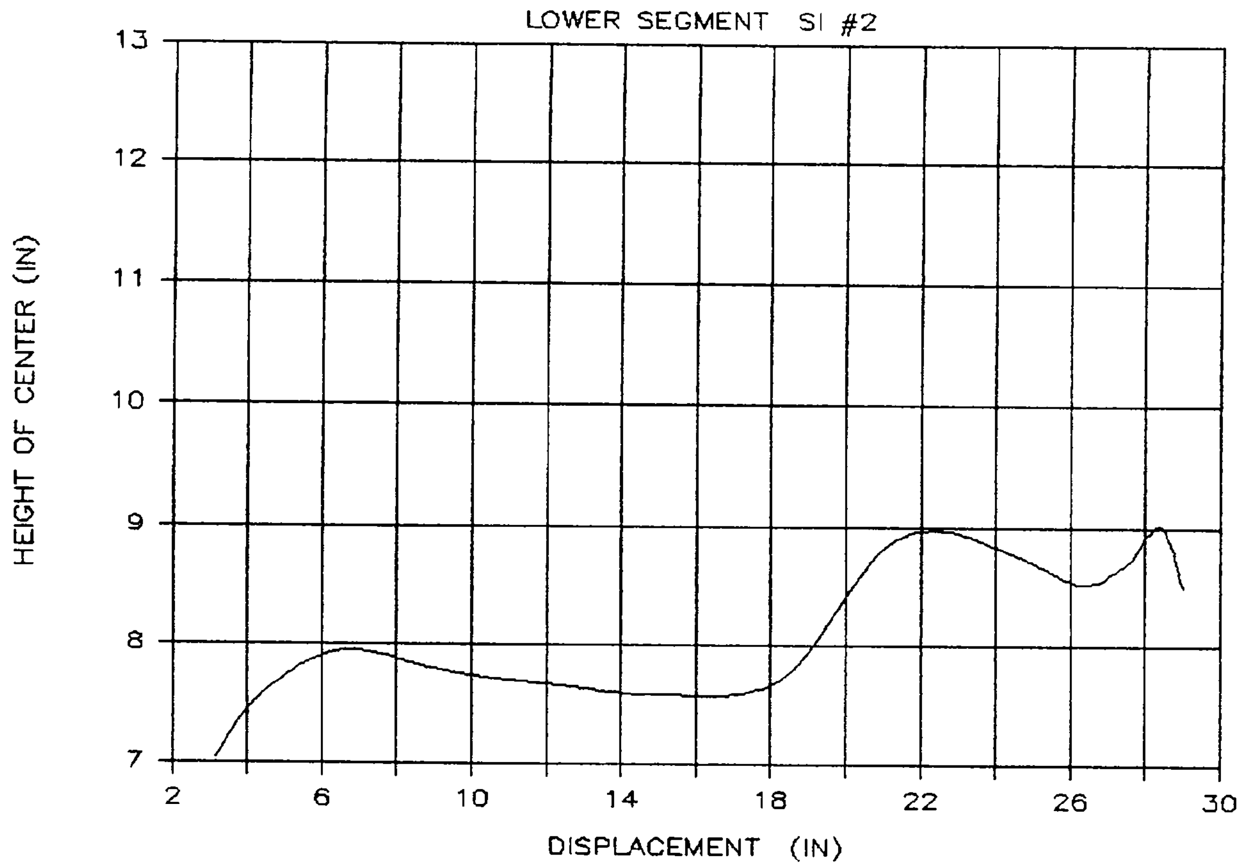


Figure 36. Effective Center of Force for Lower Segment for Test SI#2

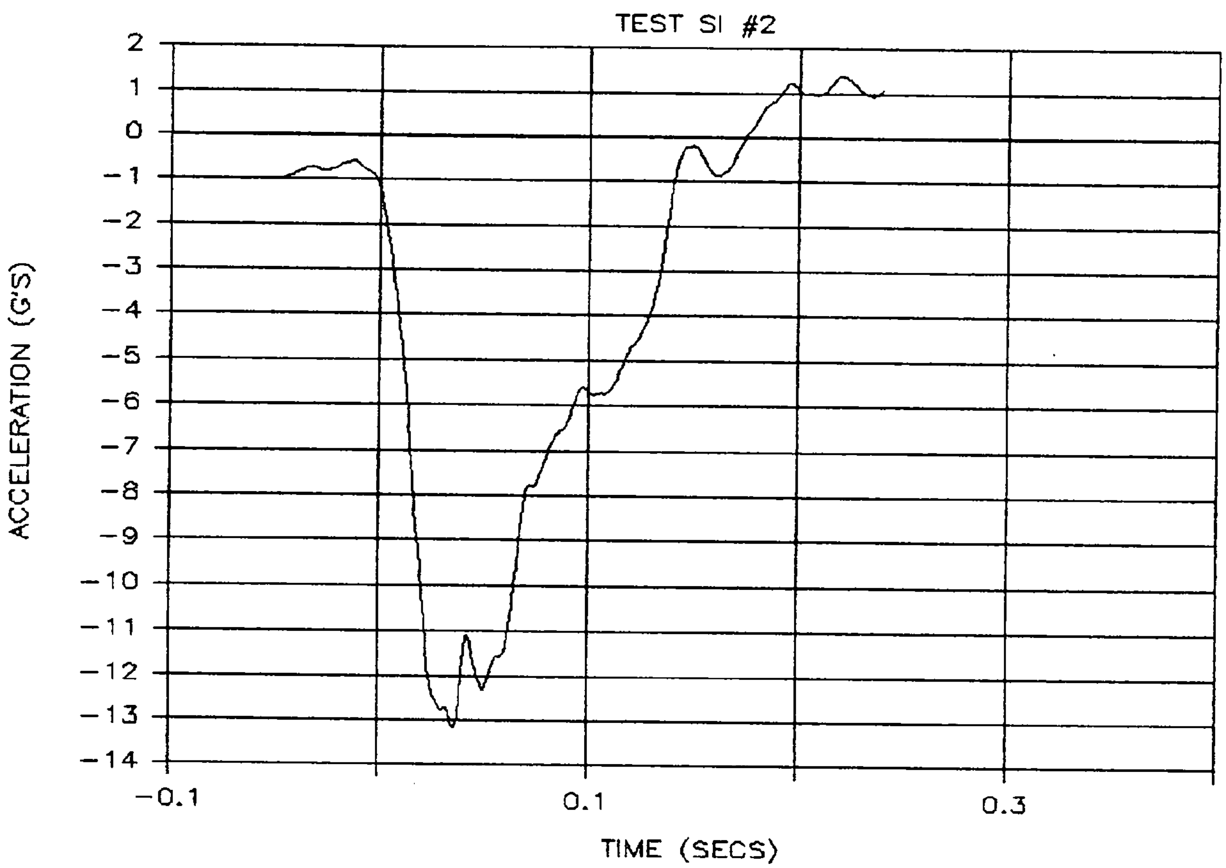
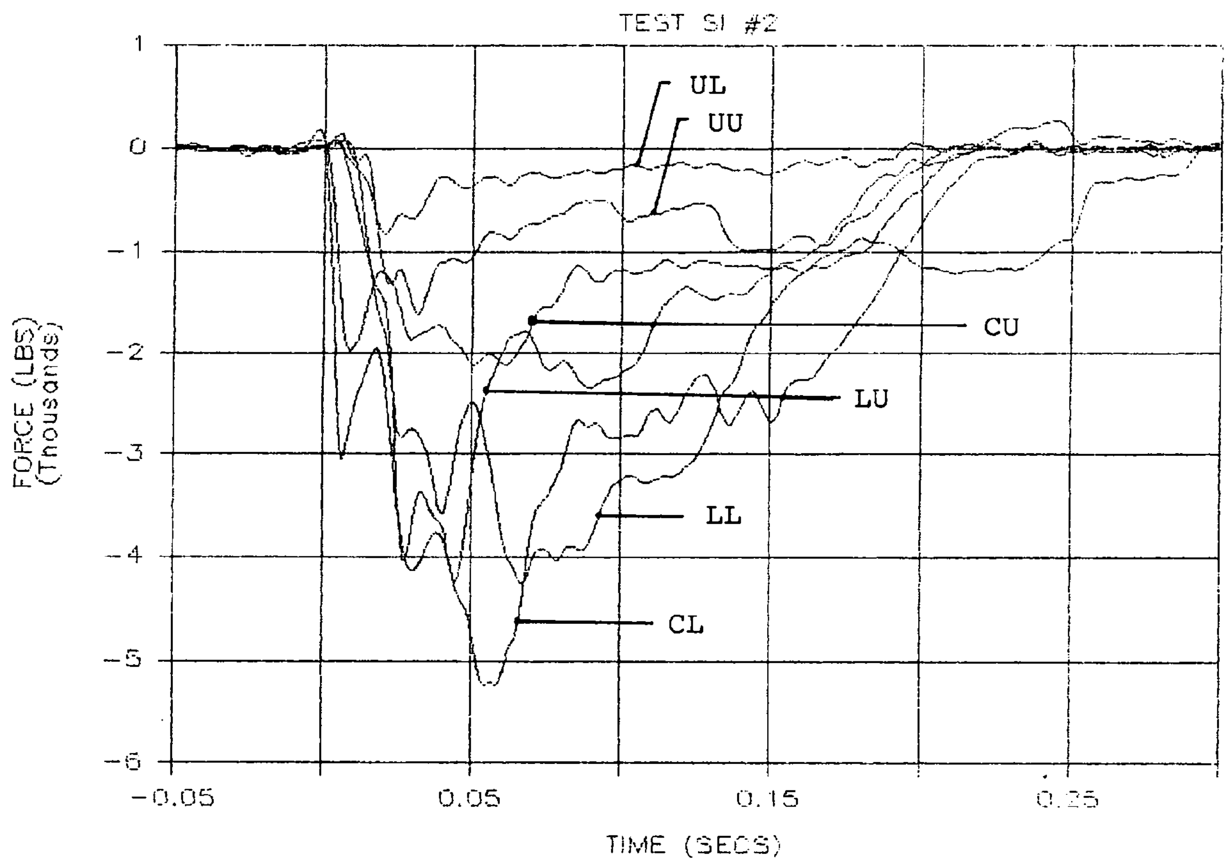


Figure 37. Vehicle Lateral Acceleration vs. Time for Test SI#2



LL = Lower Segment Lower Load Cell
LU = Lower Segment Upper Load Cell
CL = Center Segment Lower Load Cell
CU = Center Segment Upper Load Cell
UL = Upper Segment Lower Load Cell
UU = Upper Segment Upper Load Cell

Figure 38. Load Cell Outputs for Test SI#2

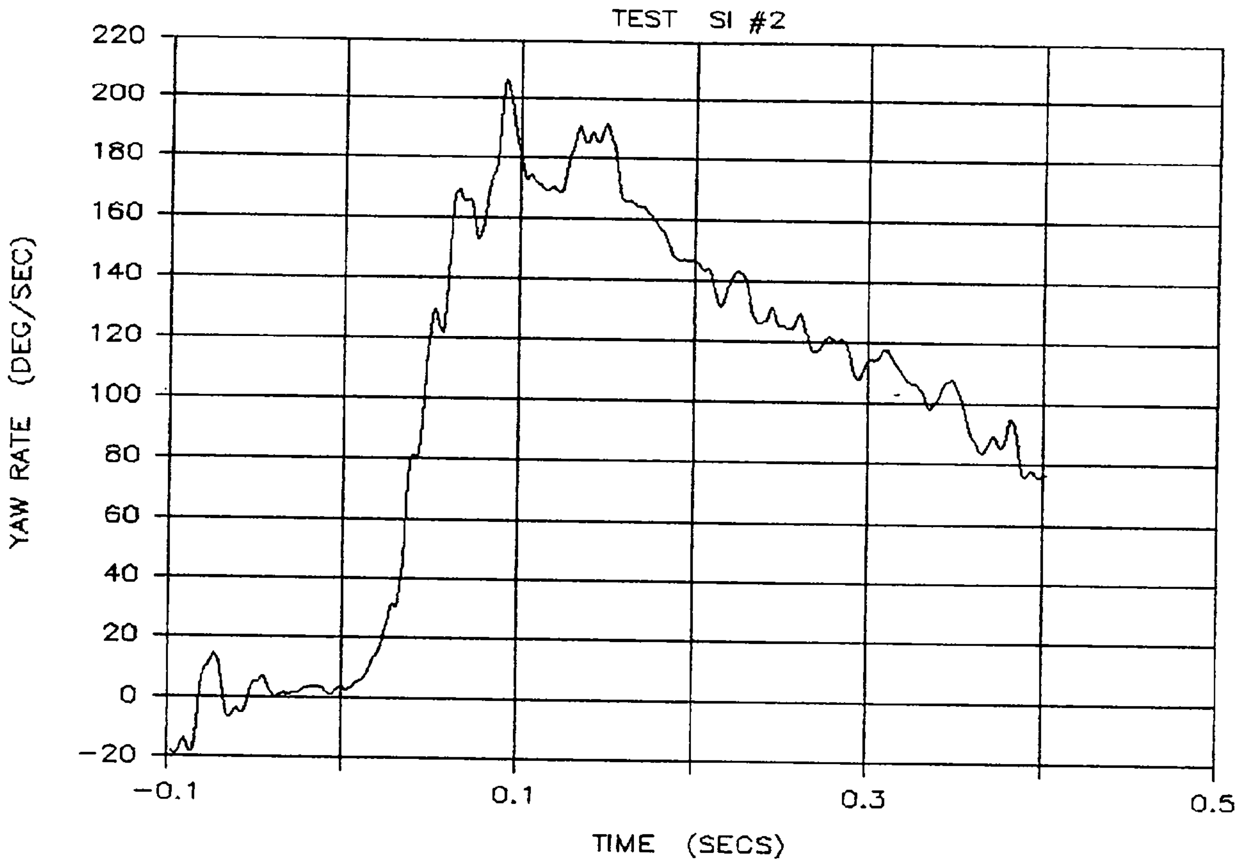


Figure 39. Vehicle Yaw Rate for Test SI#2

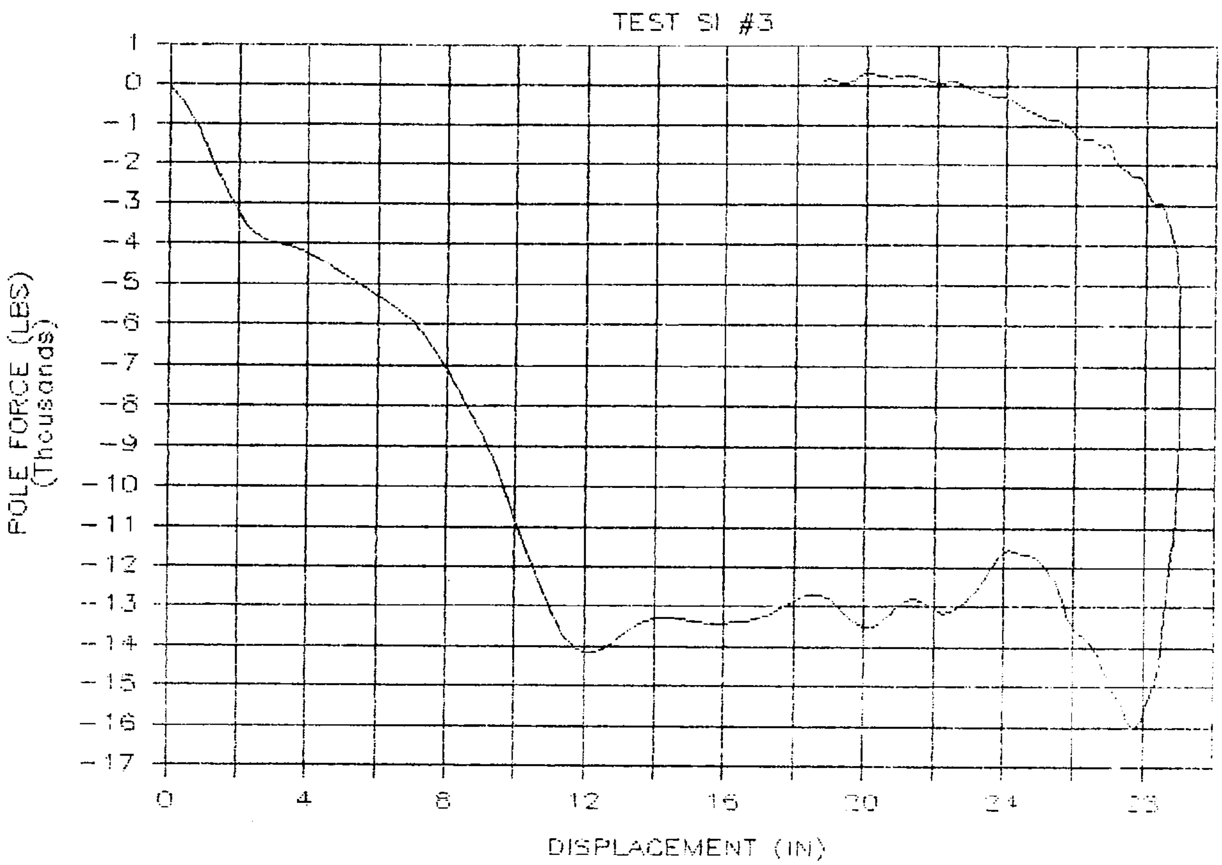


Figure 40. Overall Force Displacement Characteristic for Test SI#3

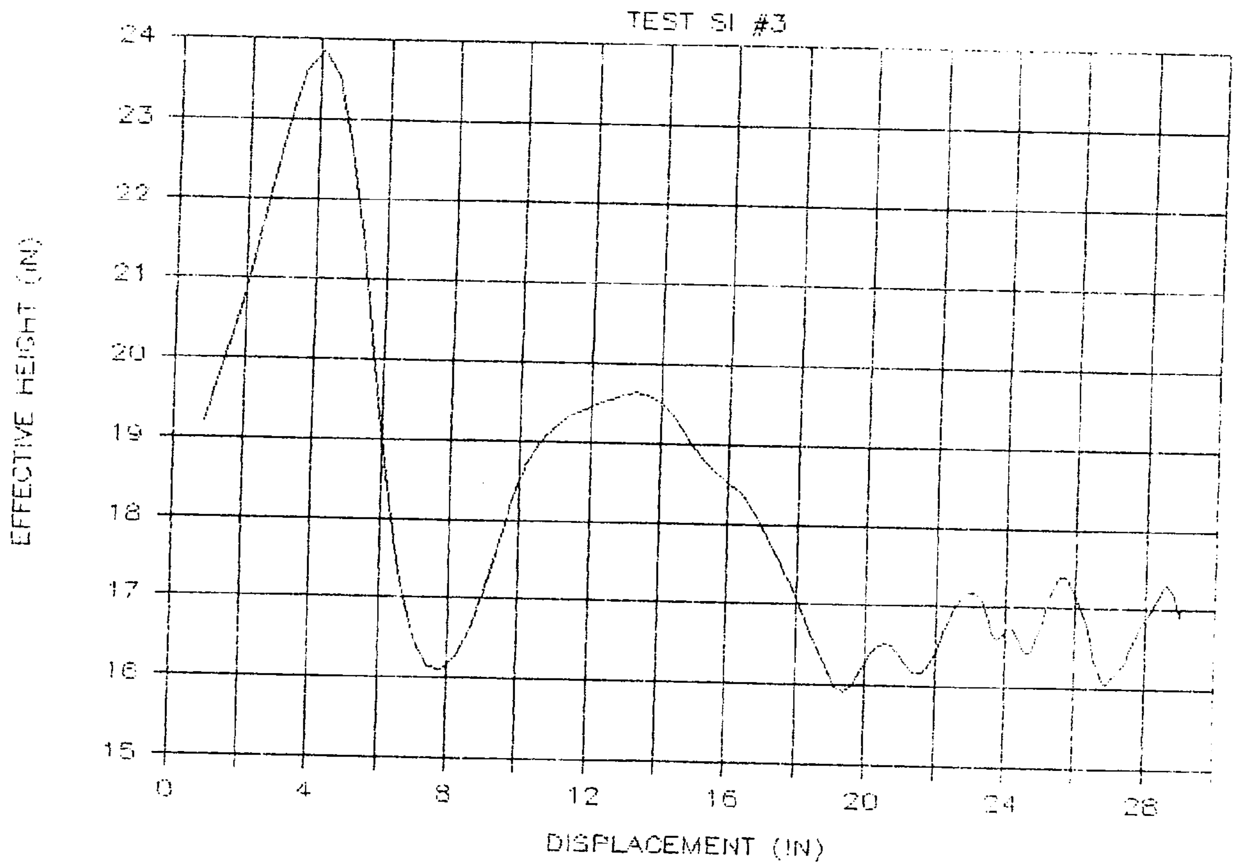


Figure 41. Overall Effective Center of Force for Test SI#3

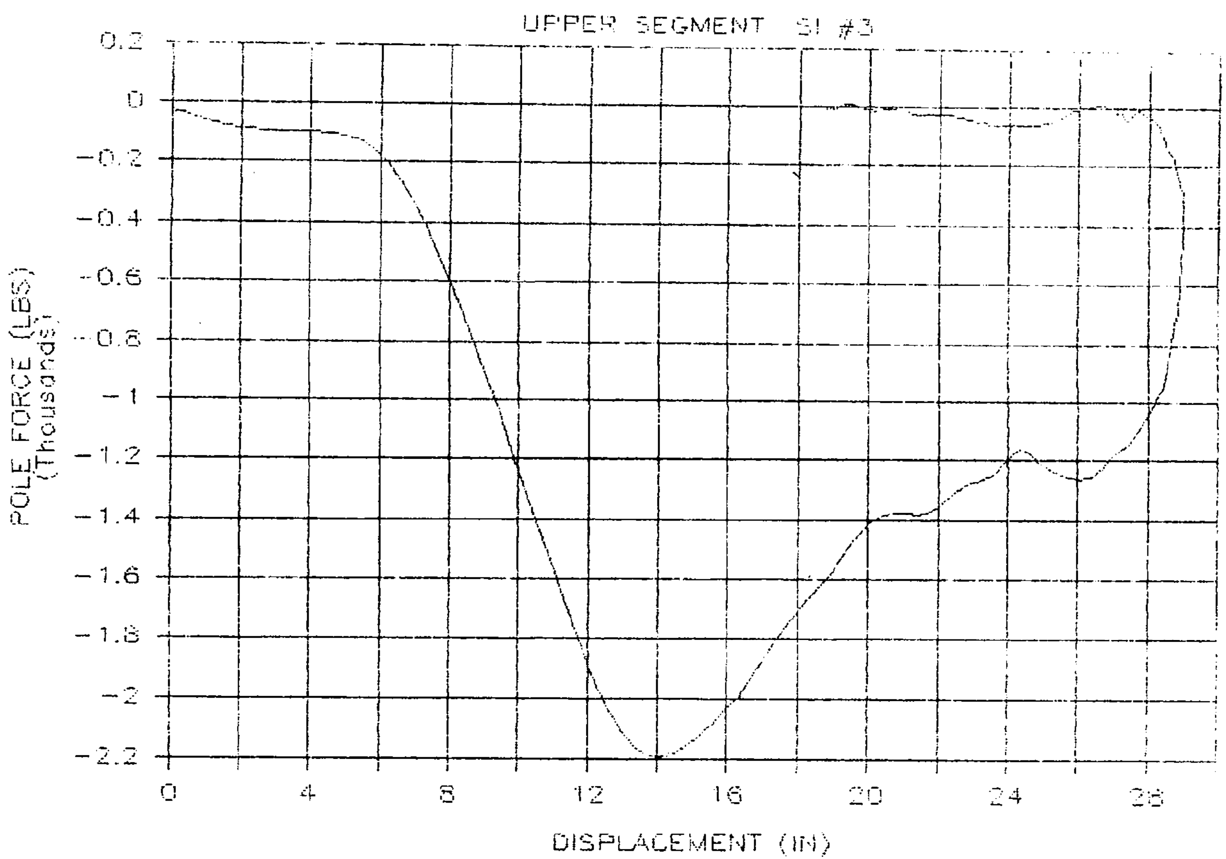


Figure 42. Force Displacement for Upper Segment for Test SI#3

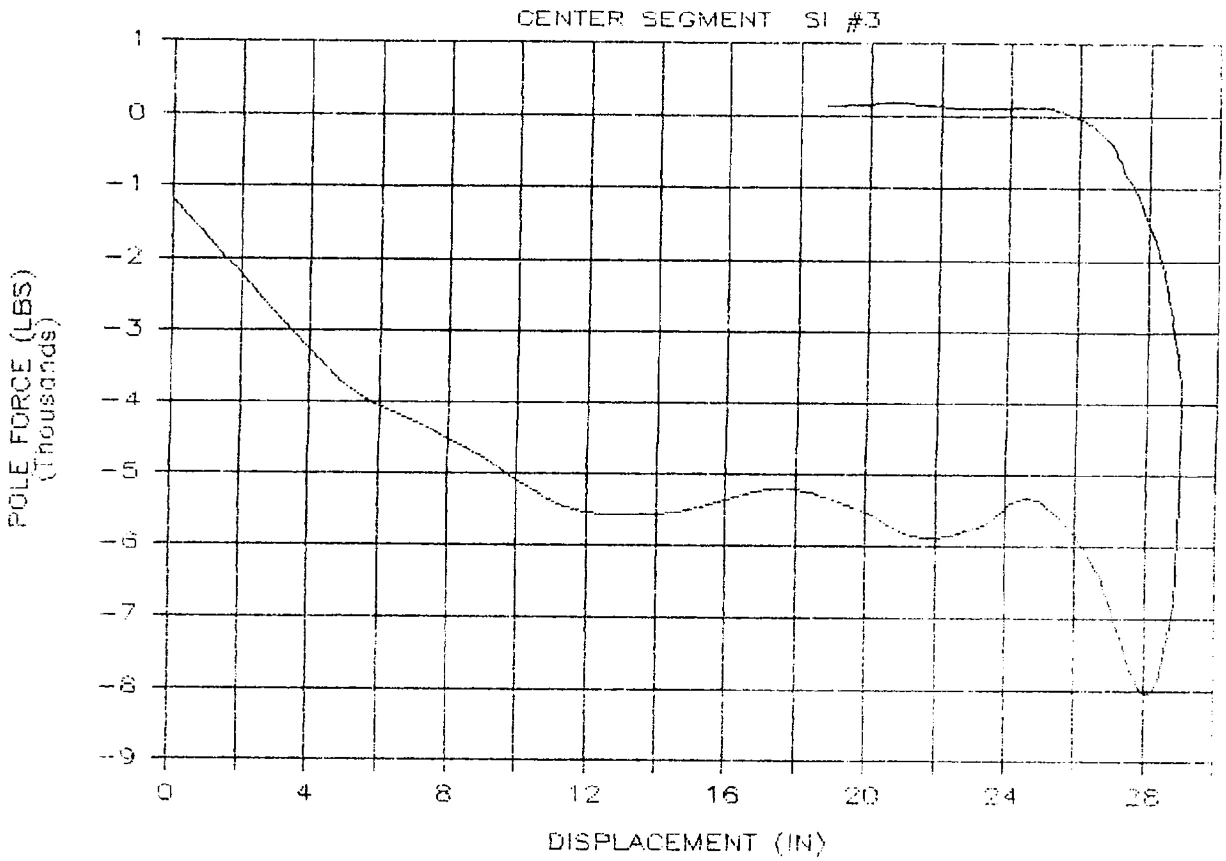


Figure 43. Force Displacement for Center Segment for Test SI#3

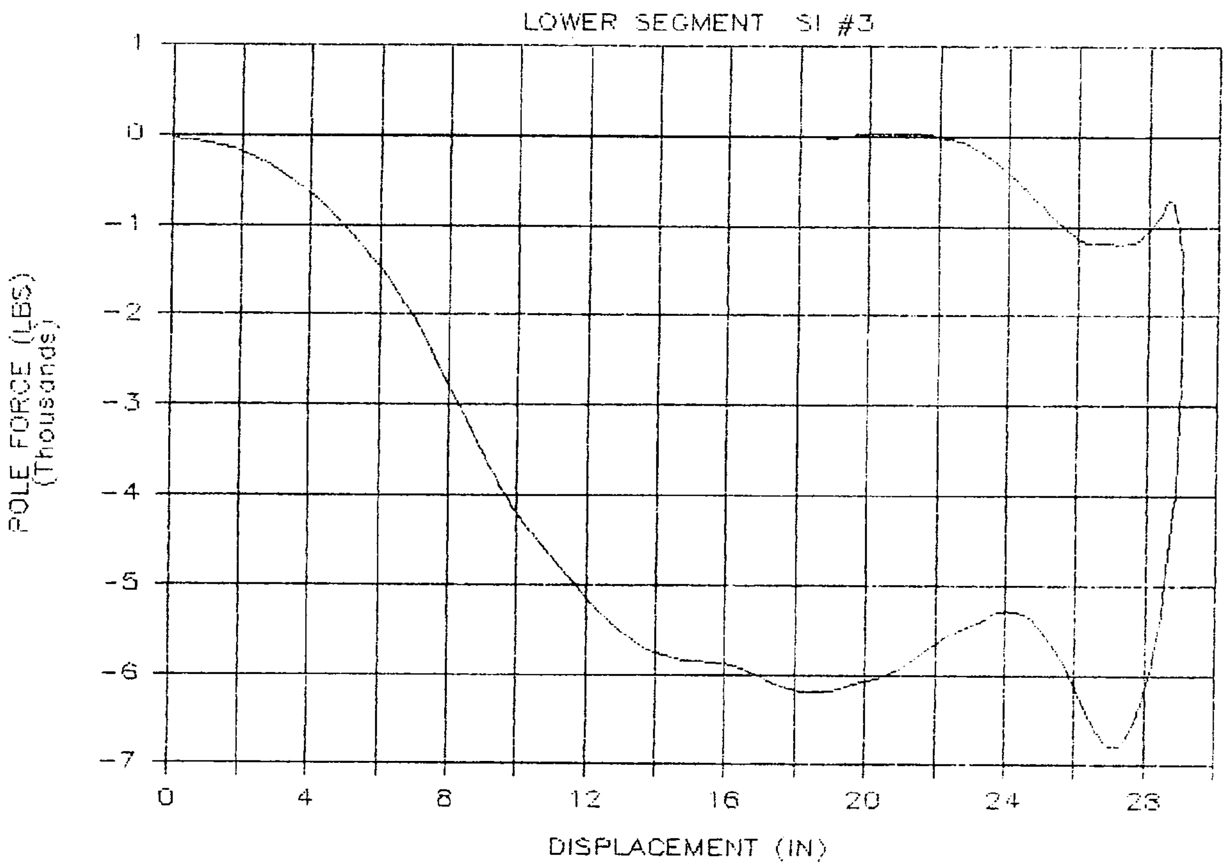


Figure 44. Force Displacement for Lower Segment for Test SI#3

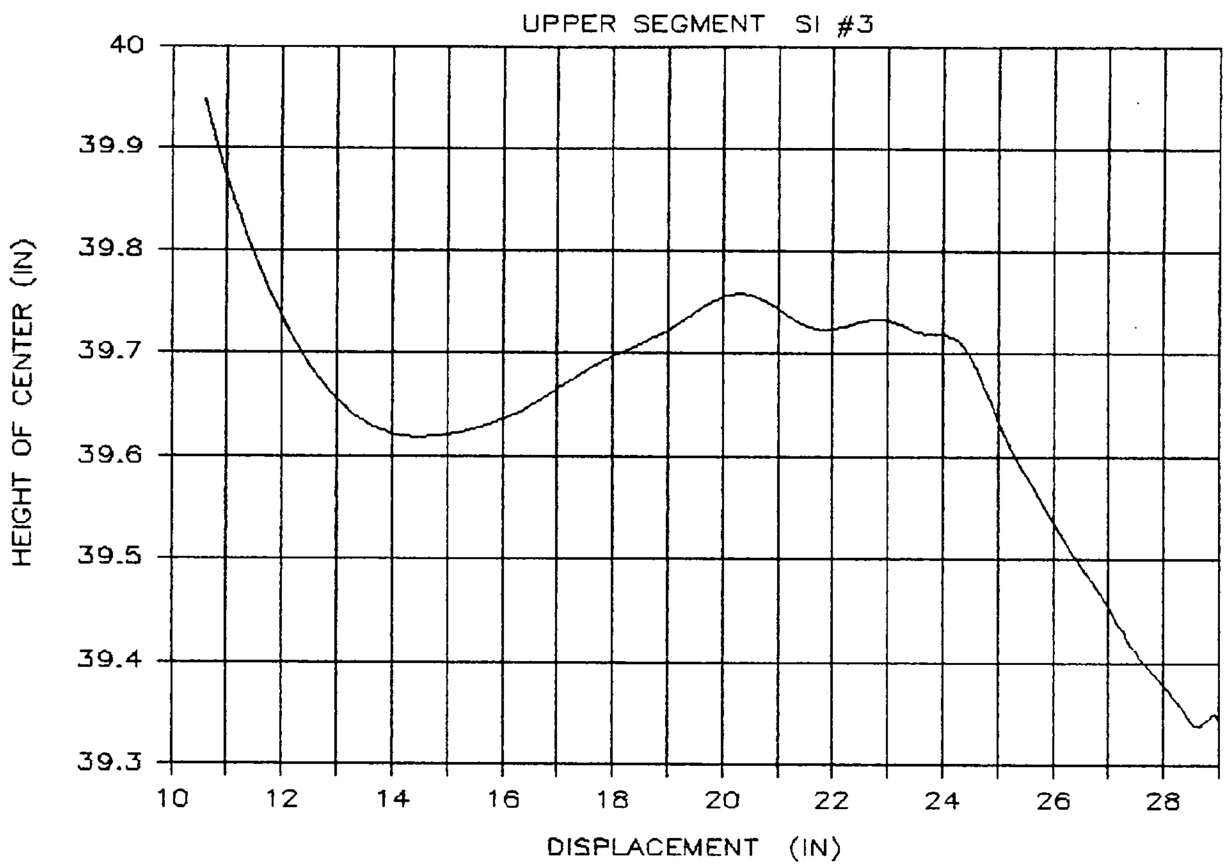


Figure 45. Effective Center of Force for Upper Segment for Test SI#3

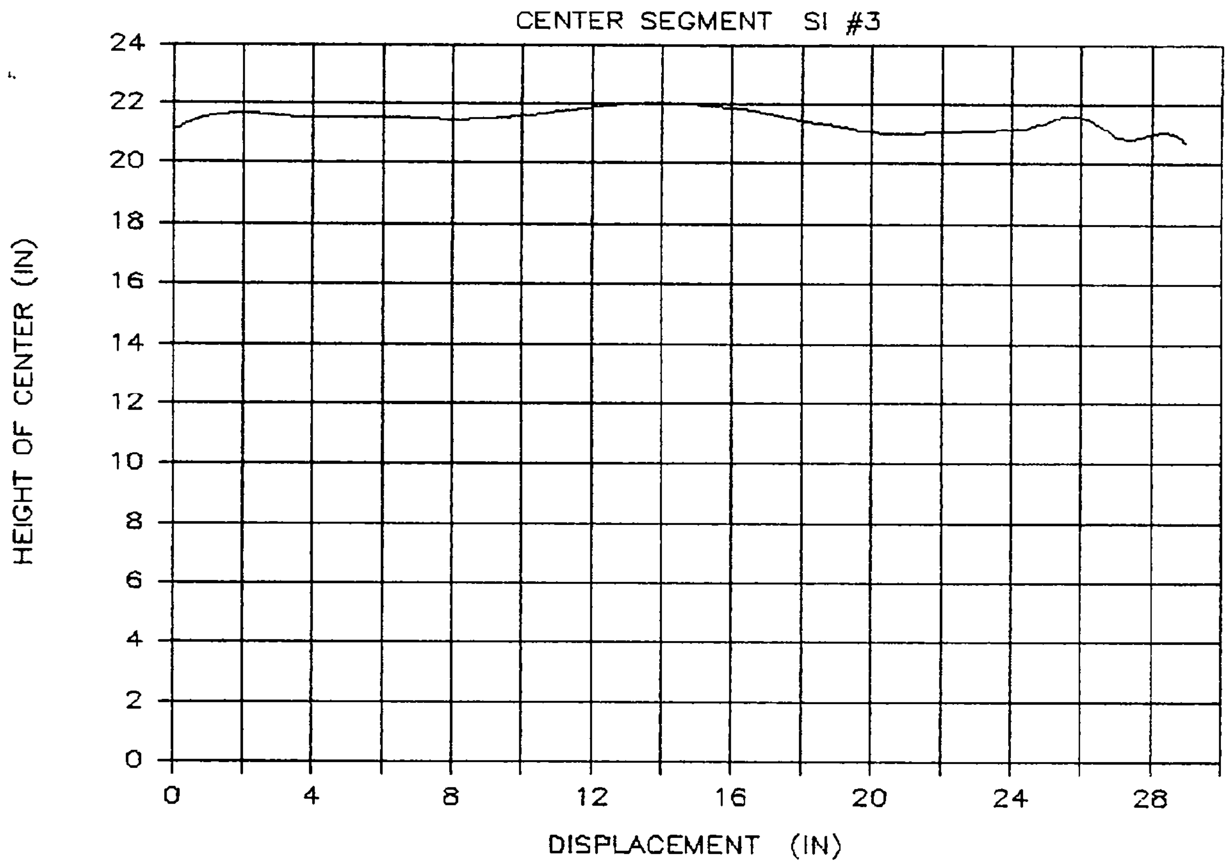


Figure 46. Effective Center of Force for Center Segment for Test SI#3

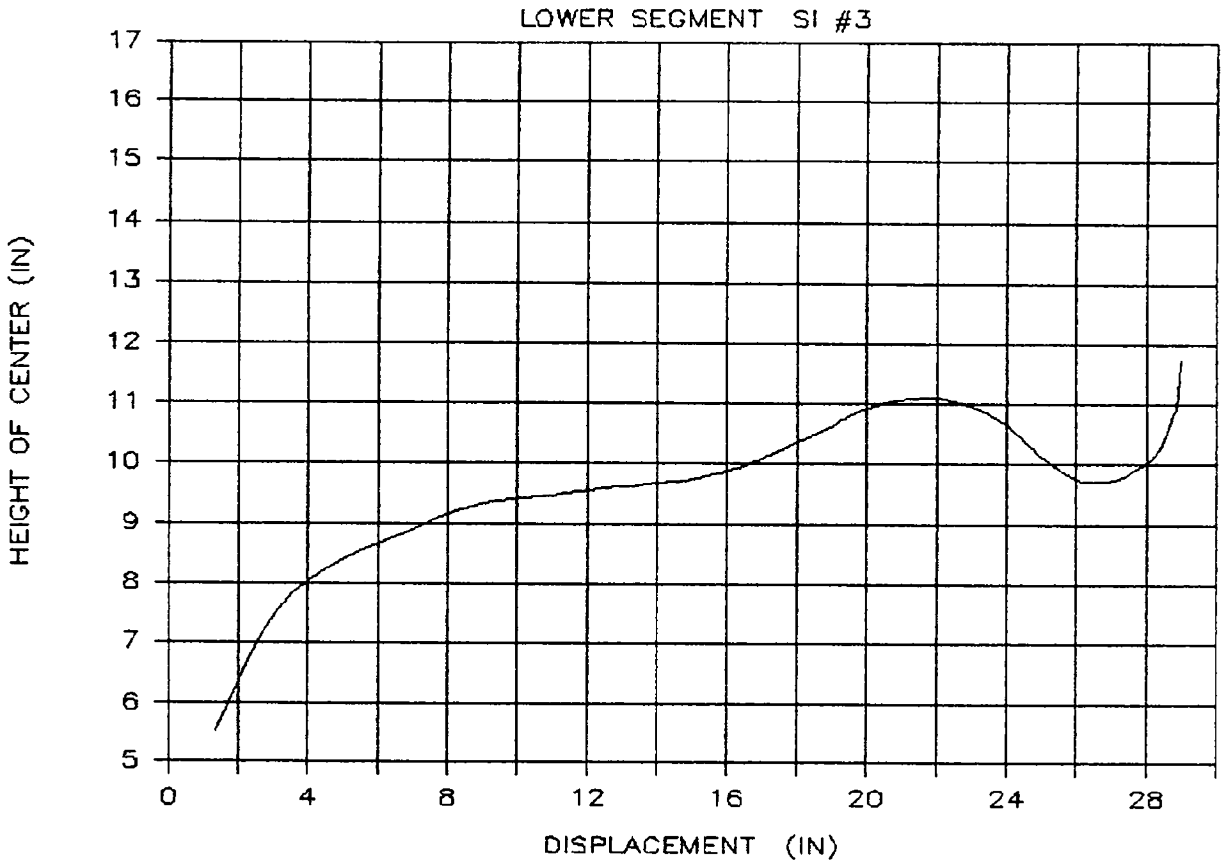


Figure 47. Effective Center of Force for Lower Segment for Test SI#3

Figures 48, 49, and 50.

7.8 TEST SI#8 ANALYSIS

Test SI#8 was (the Dodge St. Regis impact. The vehicle had a static crush of 12 inches with a dynamic crush of 15.2 inches. The force deflection characteristics of the test vehicle is given in Figure 51. The effective center of load for the entire vehicle is shown in Figure 52. The force deflection of the upper, middle and lower segment is given in Figures 53, 54, and 55. Figures 56, 57, and 58 present the load point calculated form the ratio of the two loads on a given segment and their associated geoemtry.

The acceleration-time traces for the vehicle and the force time traces for the pole are presented in Figures 59 and 60.

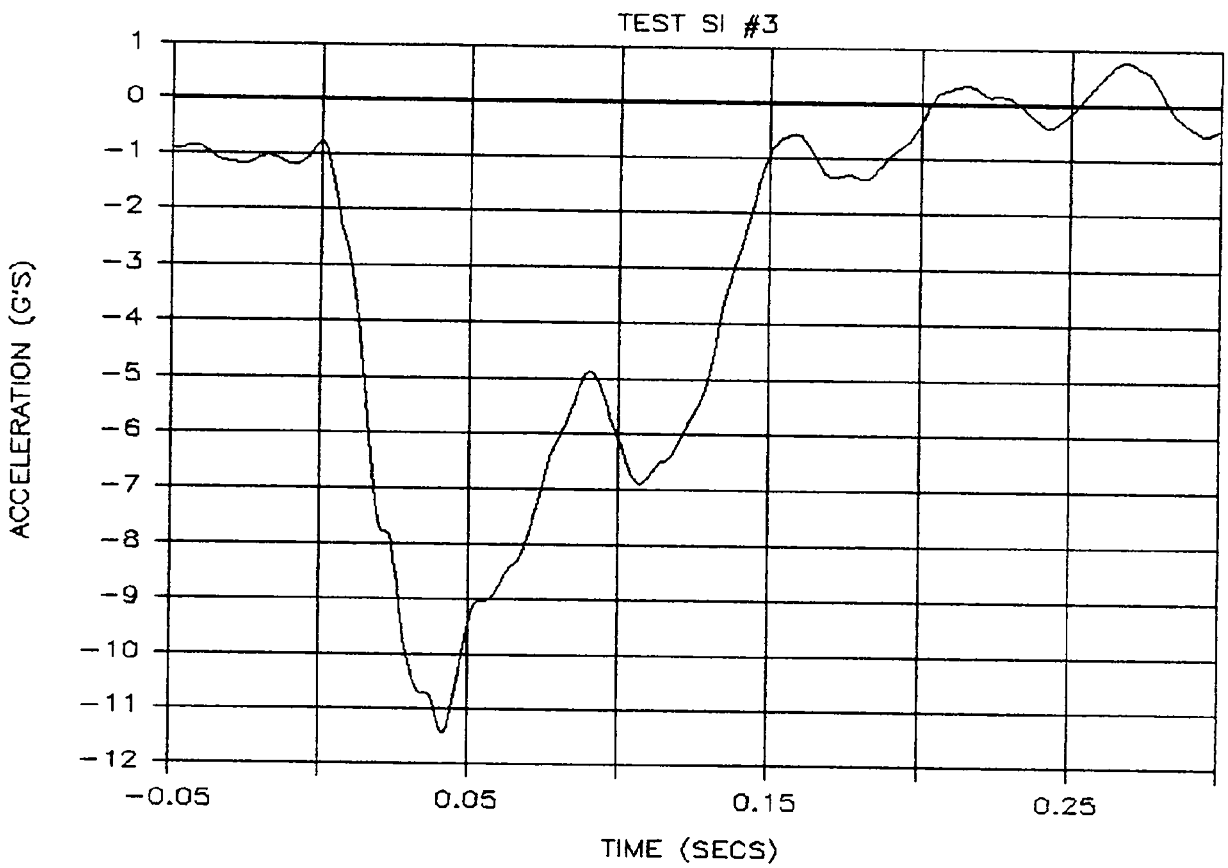
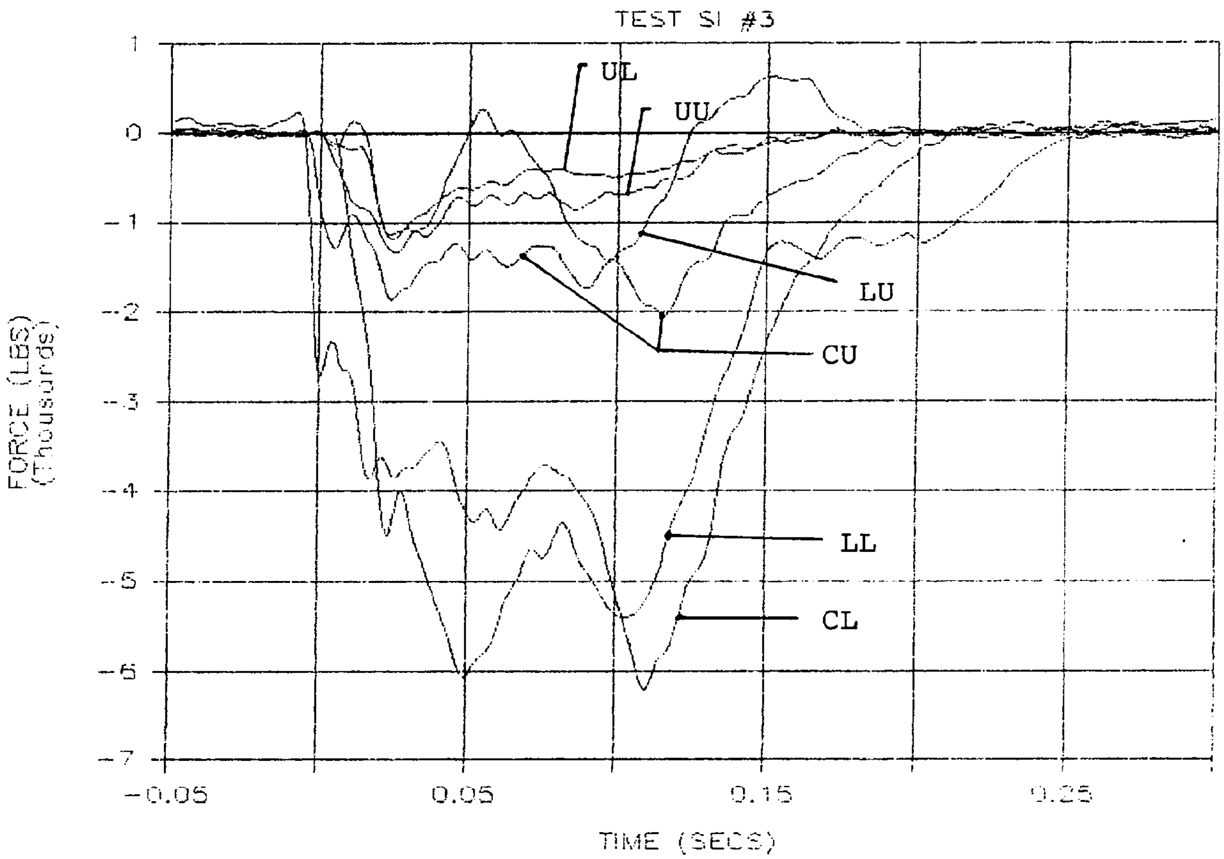


Figure 48. Vehicle Lateral Acceleration vs. Time for Test SI#3



LL = Lower Segment Lower Load Cell
LU = Lower Segment Upper Load Cell
CL = Center Segment Lower Load Cell
CU = Center Segment Upper Load Cell
UL = Upper Segment Lower Load Cell
UU = Upper Segment Upper Load Cell

Figure 49. Load Cell Outputs for Test SI#3

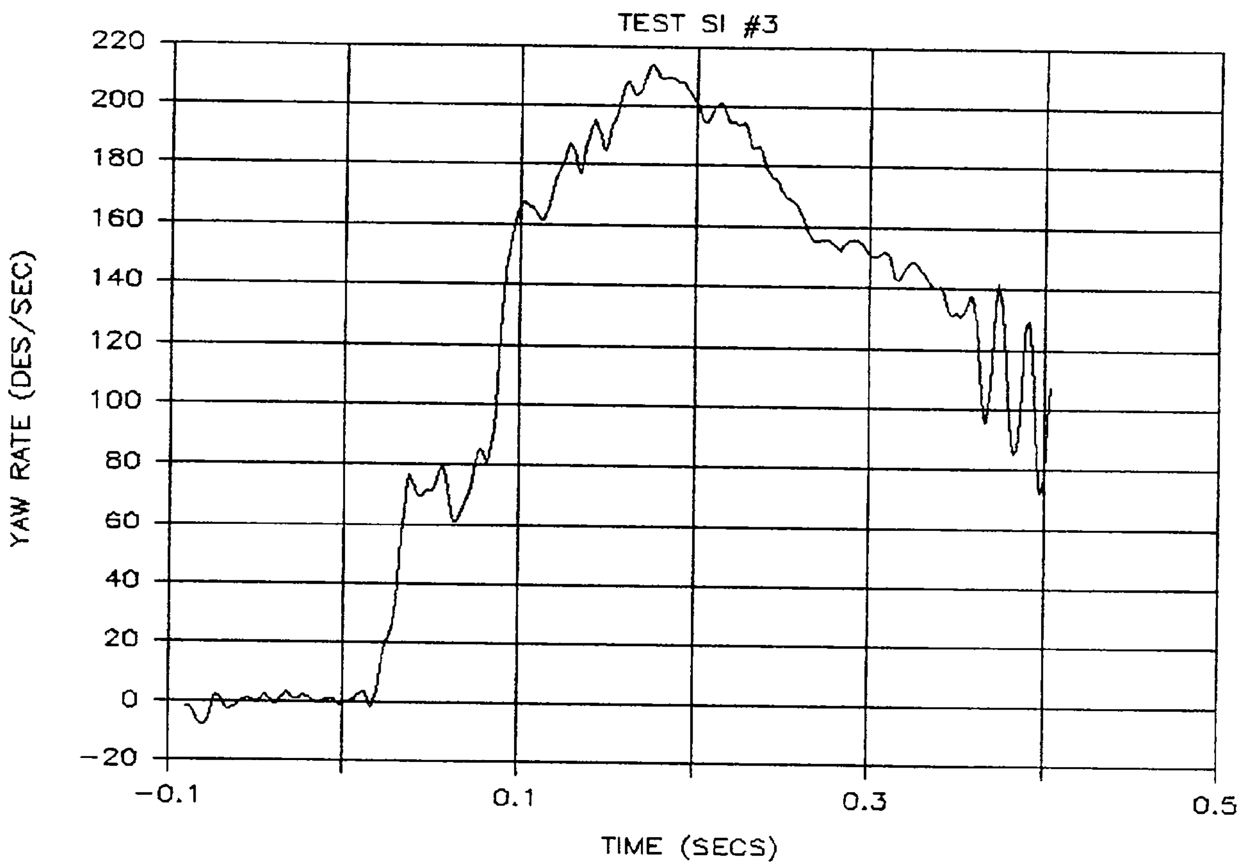


Figure 50. Vehicle Yaw Rate for Test SI#3

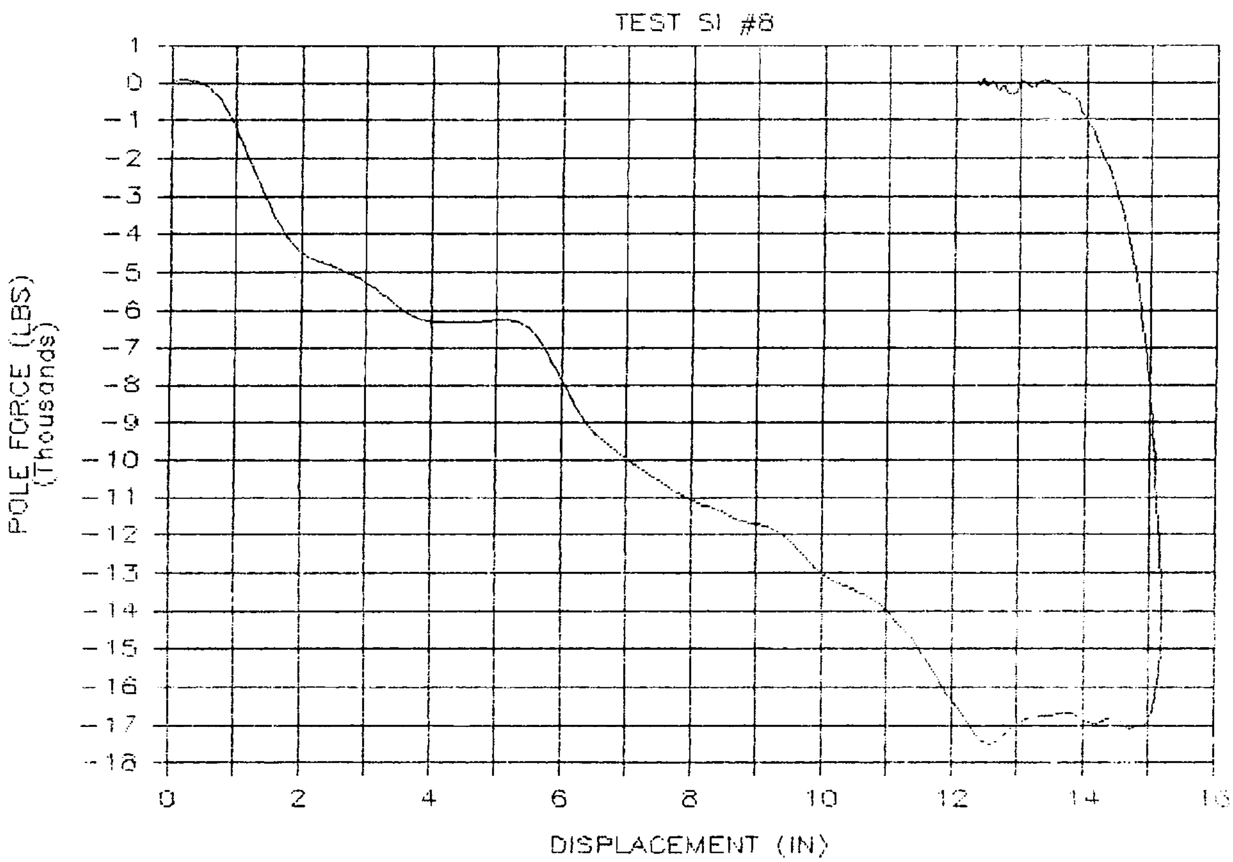


Figure 51. Overall Force Displacement Characteristic for Test SI#8

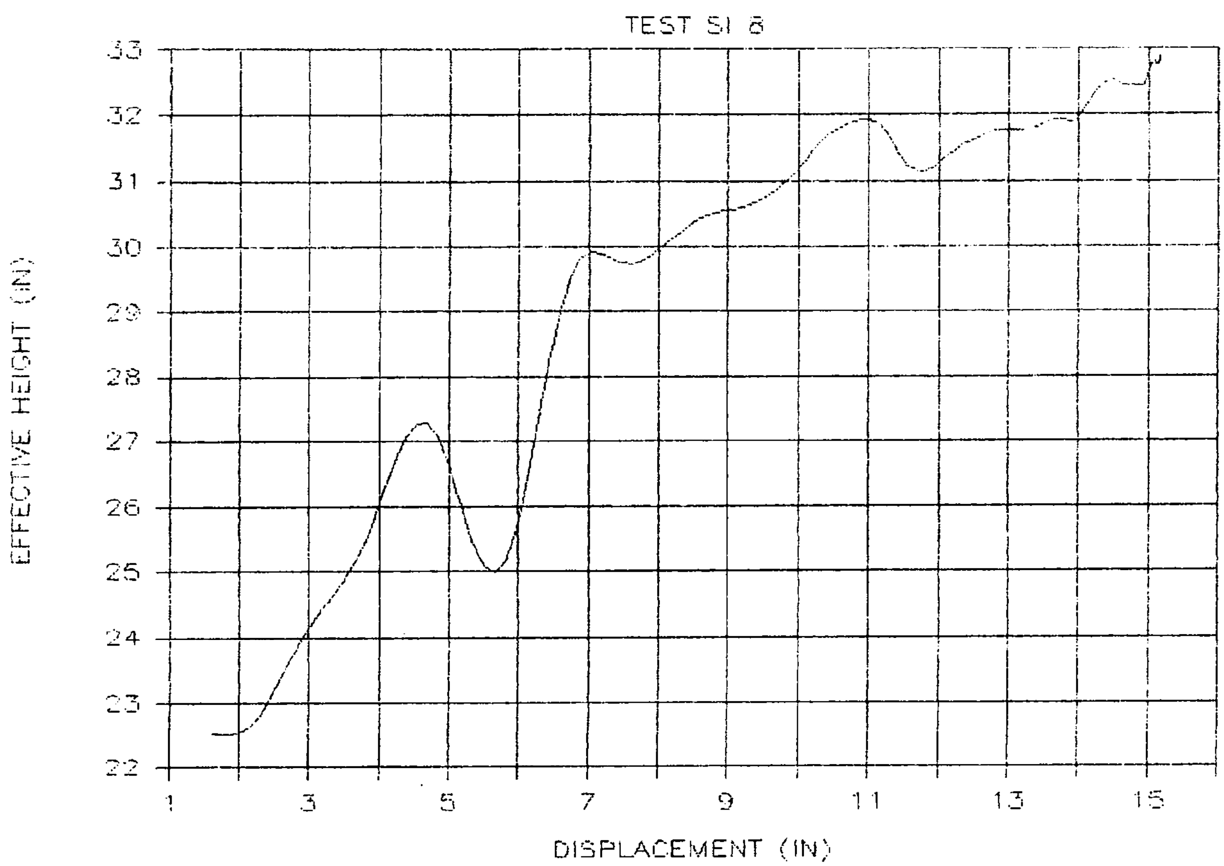


Figure 52. Overall Effective Center of Force for Test SI#8

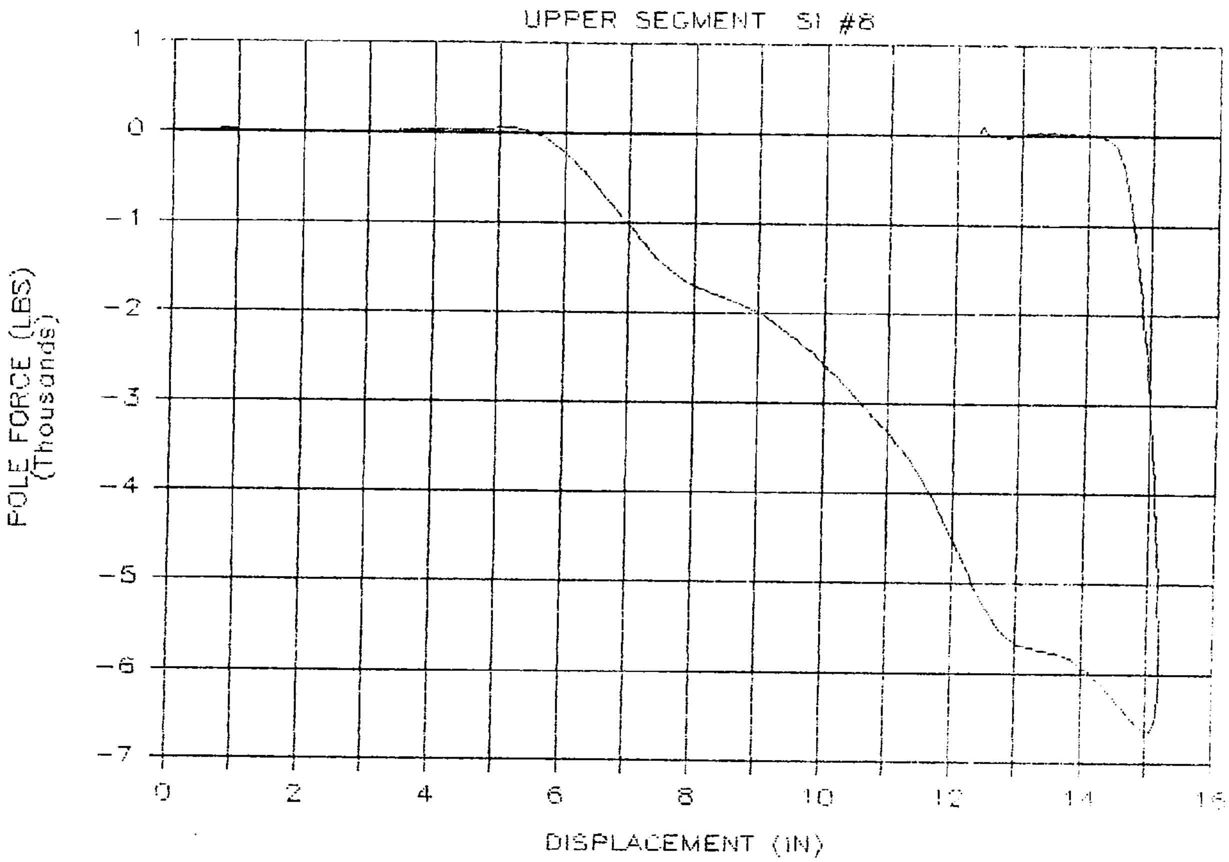


Figure 53. Force Displacement of Upper Segment for Test SI#8

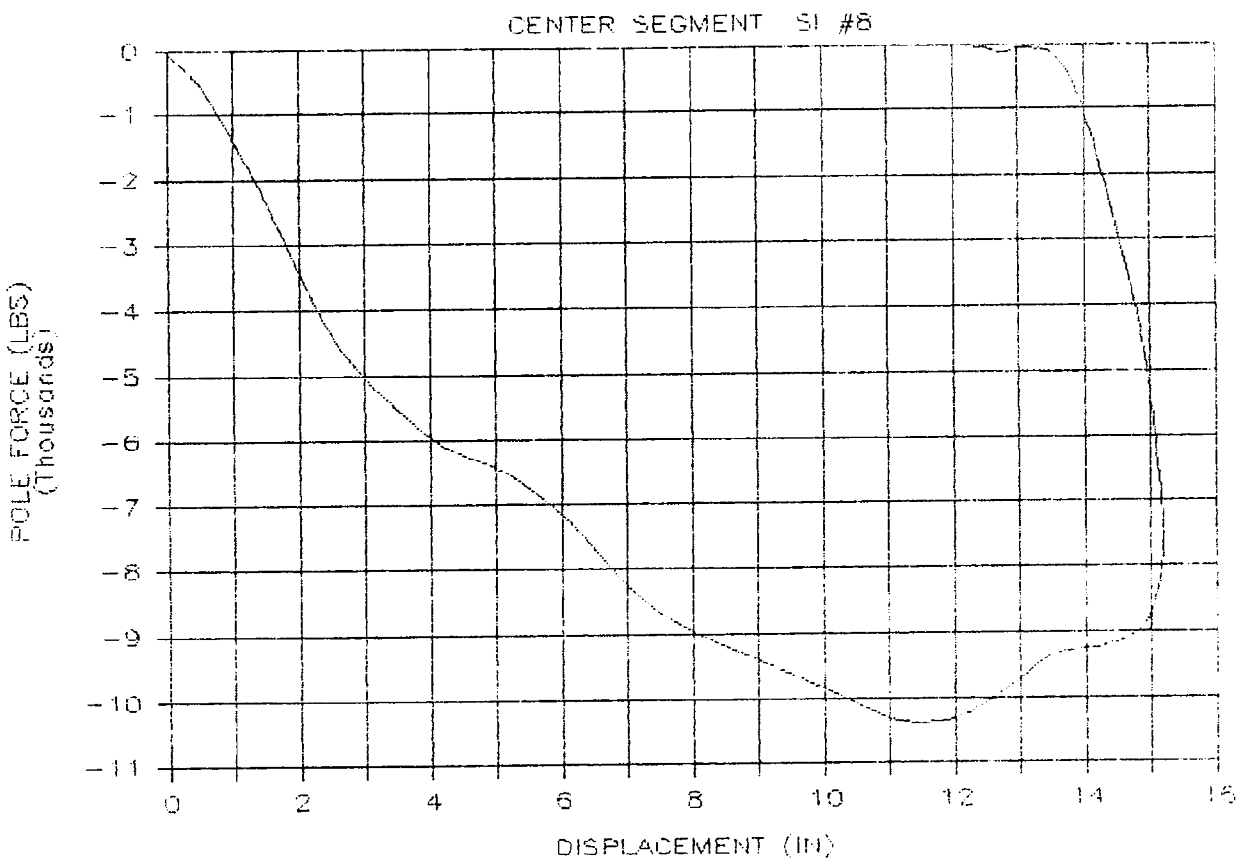


Figure 54. Force Displacement of Center Segment for Test SI#8

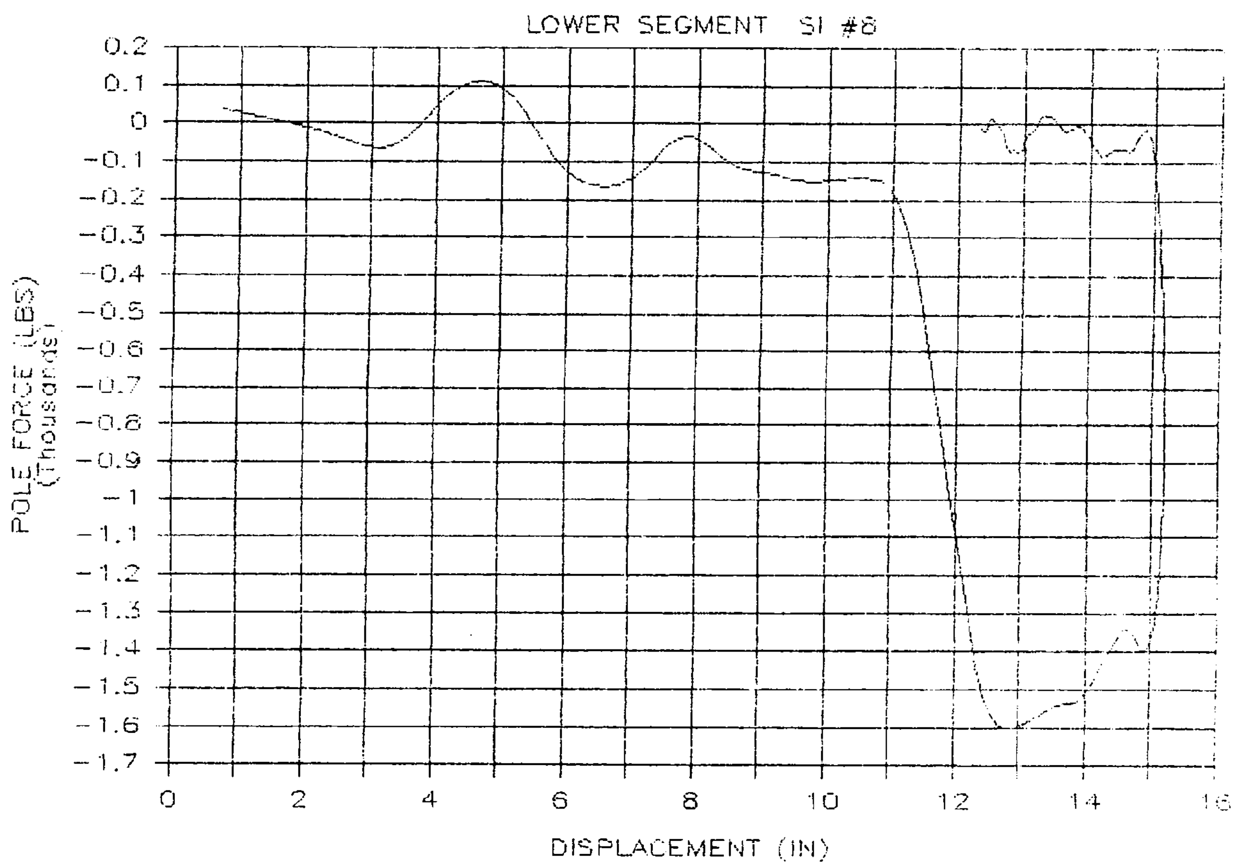


Figure 55. Force Displacement of Lower Segment for Test SI#8

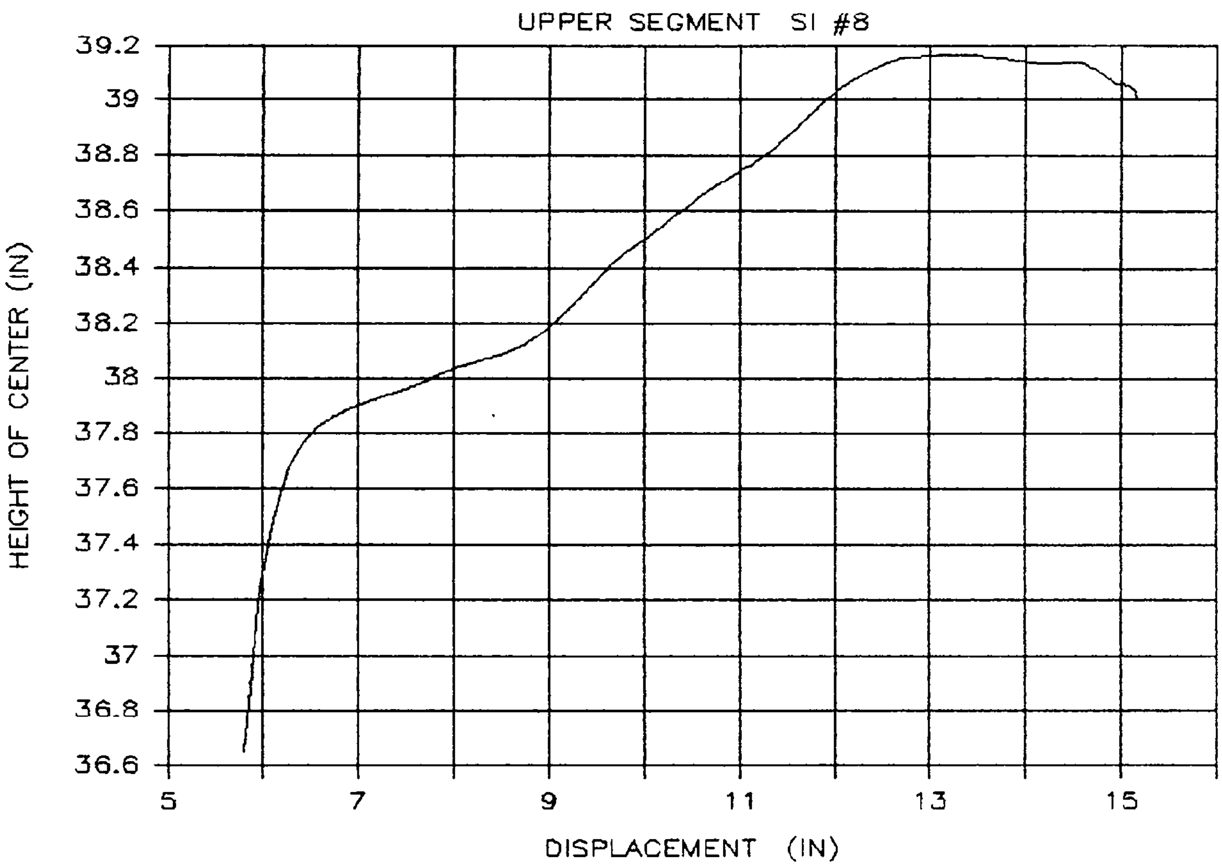


Figure 56. Effective Center of Force for Upper Segment for Test SI#8

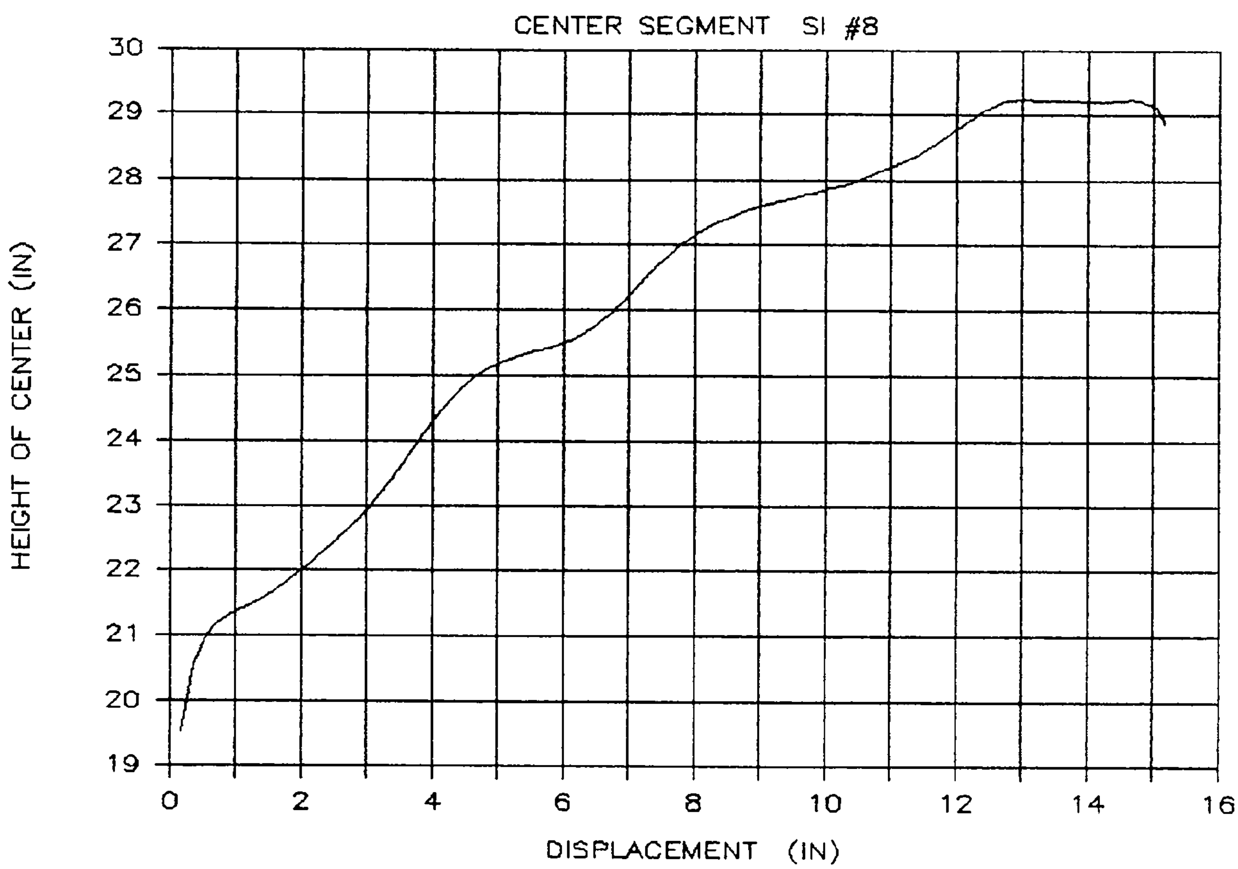


Figure 57. Effective Center of Force for Center Segment for Test SI#8

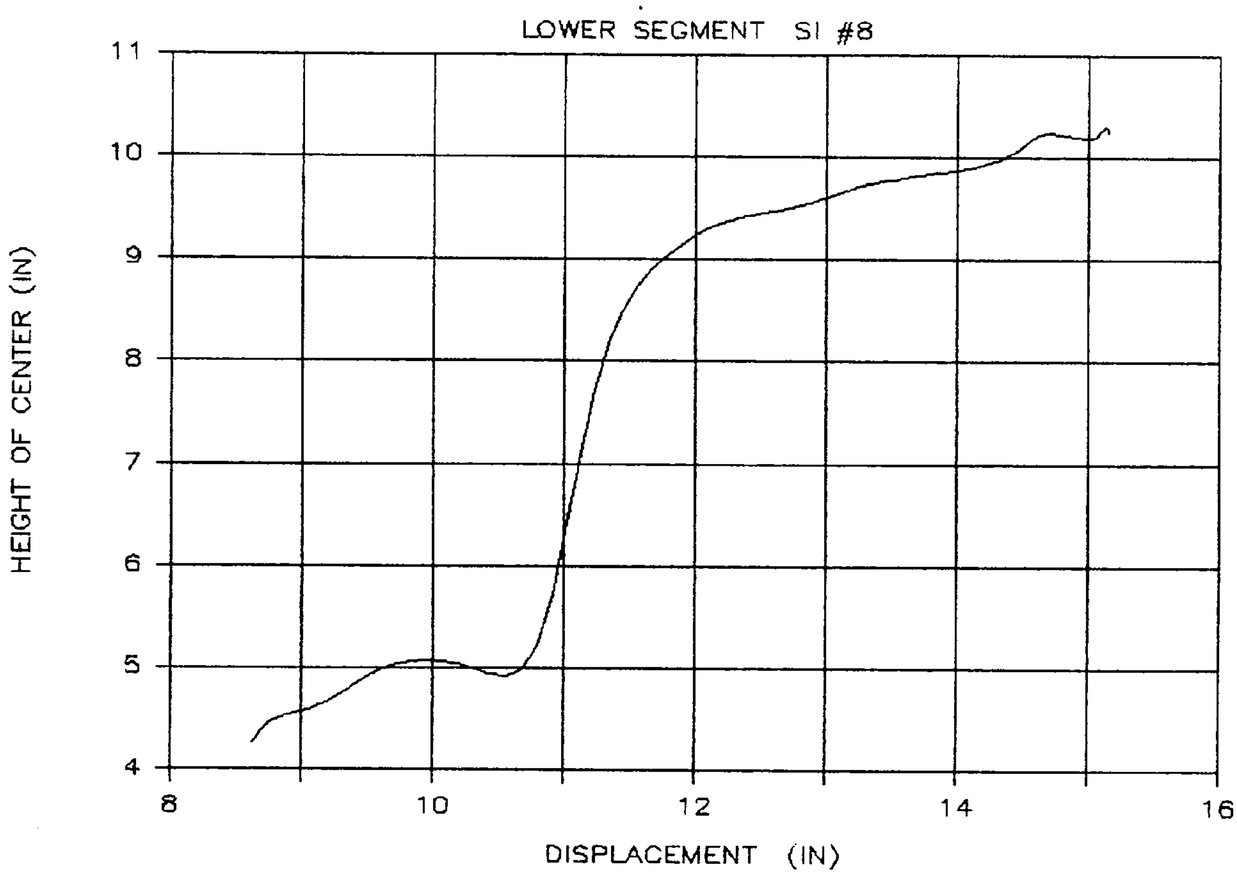


Figure 58. Effective Center of Force for Lower Segment for Test SI#8

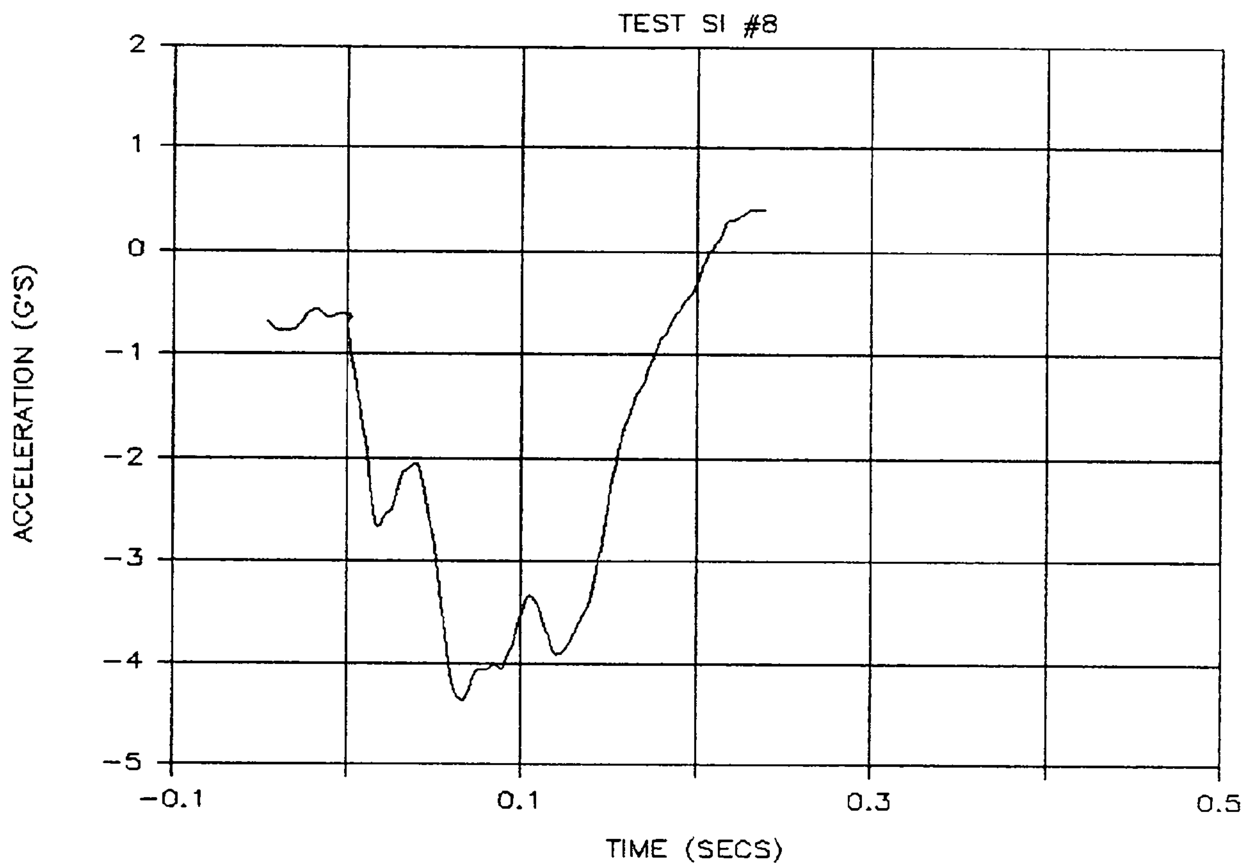
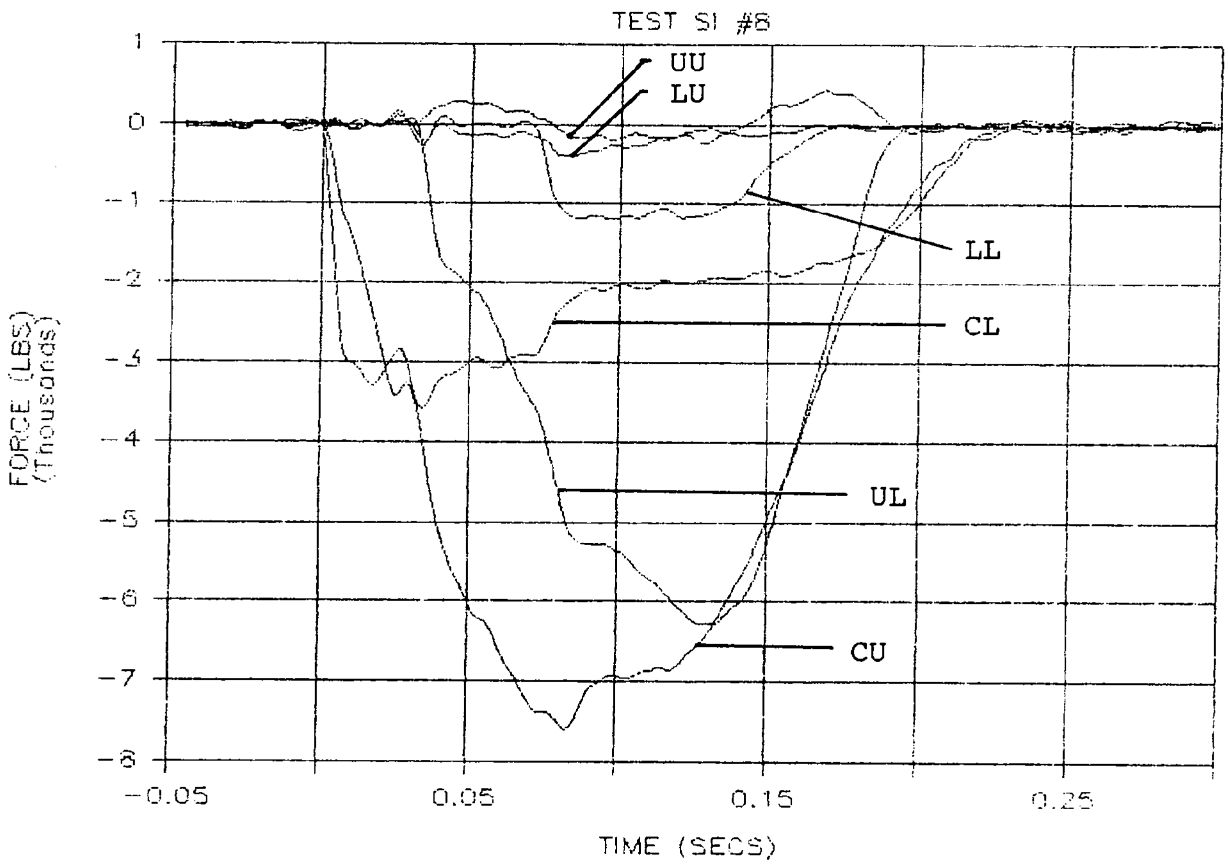


Figure 59. Vehicle Lateral Acceleration vs. Time for Test SI#8



LL = Lower Segment Lower Load Cell
LU = Lower Segment Upper Load Cell
CL = Center Segment Lower Load Cell
CU = Center Segment Upper Load Cell
UL = Upper Segment Lower Load Cell
UU = Upper Segment Upper Load Cell

Figure 60. Load Cell Outputs for Test SI#8

8.0 COMPARISON OF RESULTS

All three of the small vehicles received similar impacts. The Dodge Colt crushed the most. Figure 61 presents the force-deflection characteristics of all four vehicles. Reviewing this figure it can be seen that each vehicle had similar force-deflection properties. All vehicles had an initial onset of force vs. deflection of about 14 kips/ft.

Peak forces were also similar for each car. The peak force obtained on the rigid pole for each car is given in Table 12. The crush property of each car seems to be a 2-phase characteristic. They seem to have a fairly linear range where the force ramps toward the peak then a fairly flat range while the vehicle curshes.

Figure 62, 63, 64, and 65 present a comparison of loads from each segment of the rigid pole for all four tests. Data from each test was divided into 20 millisecond time slices and then averaged to determine the force over each 20 millisecond time period. From this comparison it can be seen that all of the small cars are very similar while the large St. Regis was different from the small cars.

Table 12
Peak Forces for Each Test Vehicle

Test Car	Peak Force (lbs)
Honda Civic	17,828
VW Rabbit	15,316
Dodge Colt	16,007
Dodge St. Regis	17,476

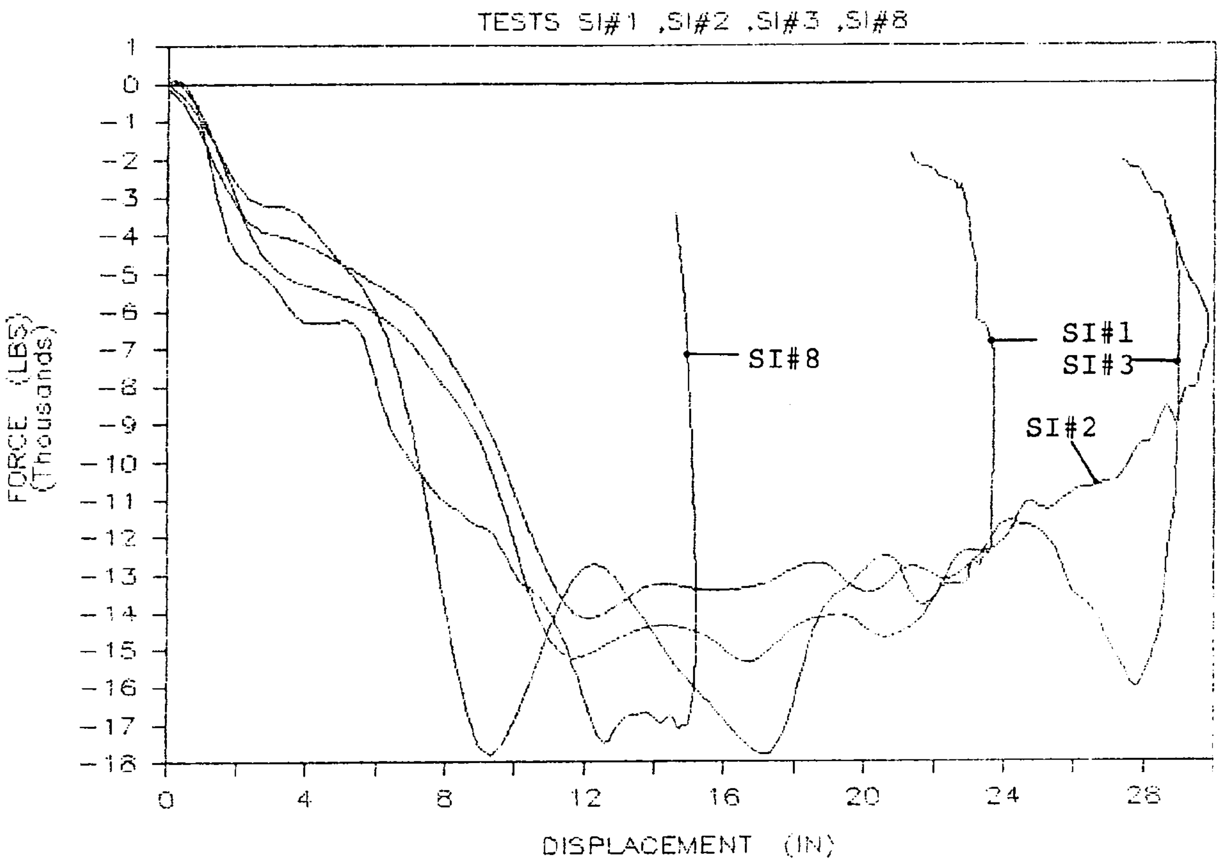


Figure 61. Comparison of Force Displacement Characteristic for all Tests

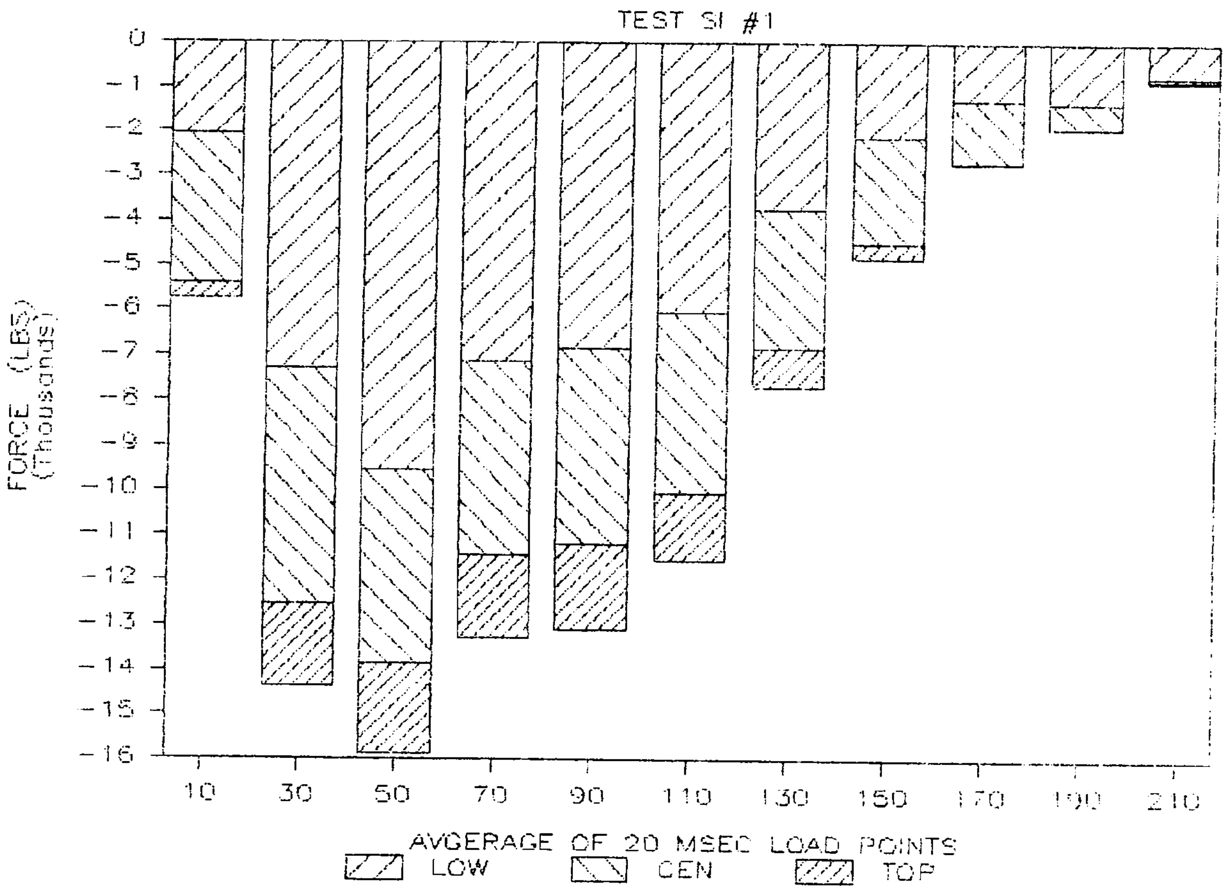


Figure 62. Load Ratio for Test SI#1

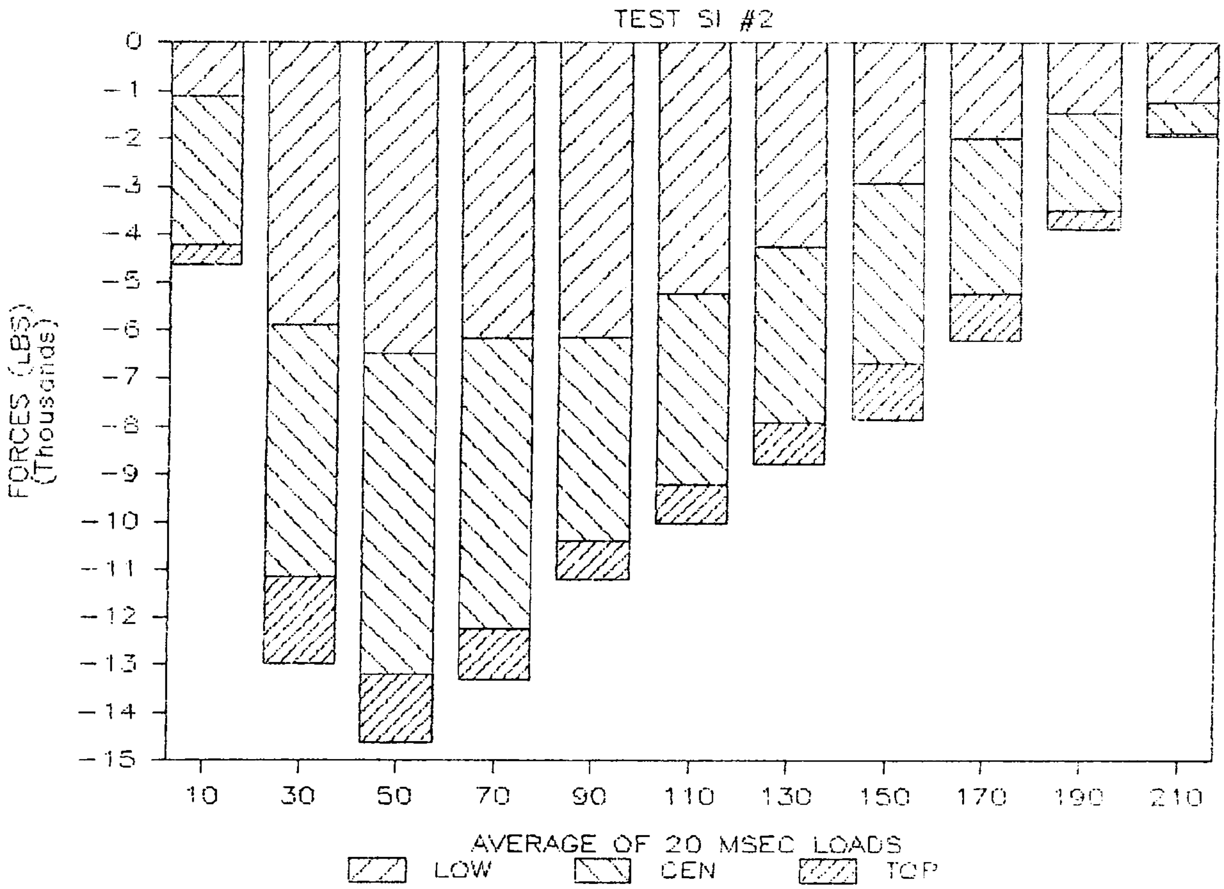


Figure 63. Load Ratio for Test SI#2

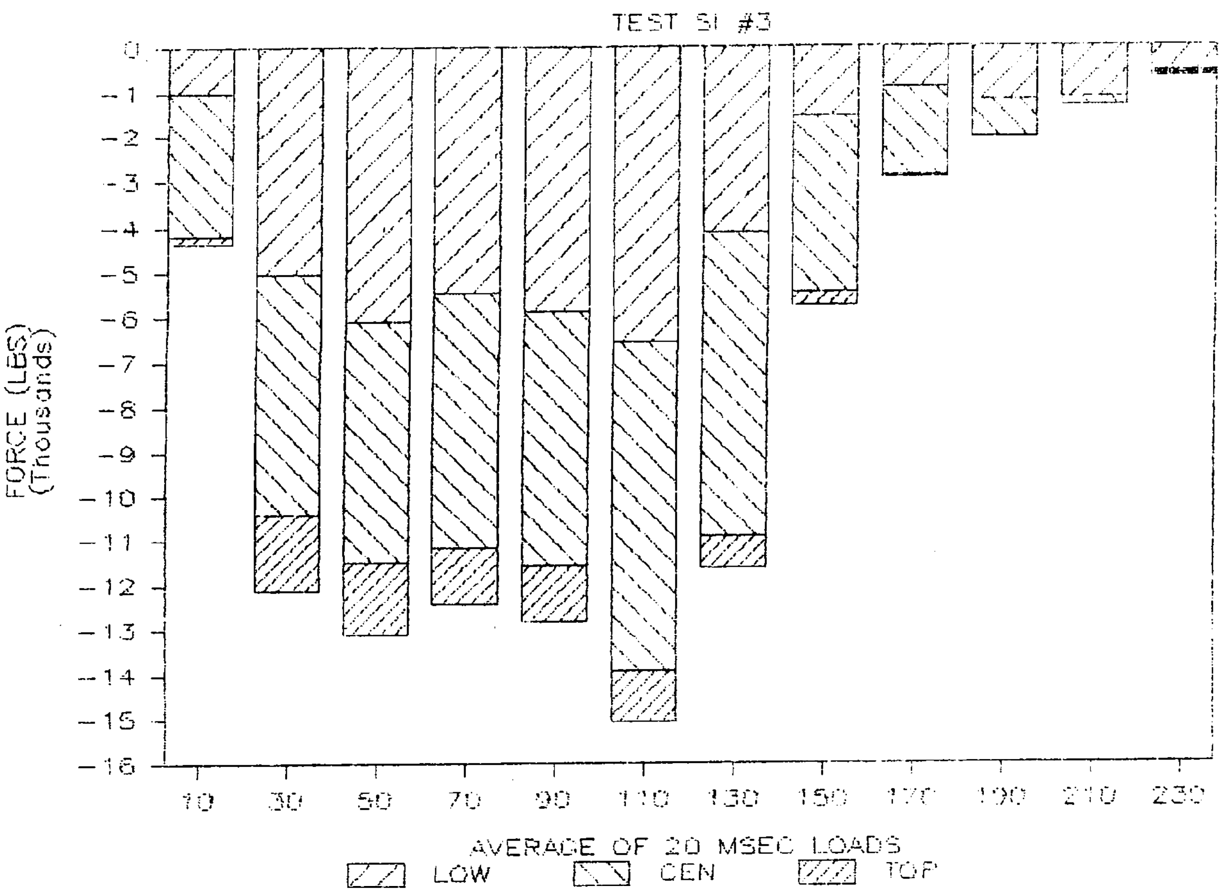


Figure 64. Load Ratio for Test SI#3

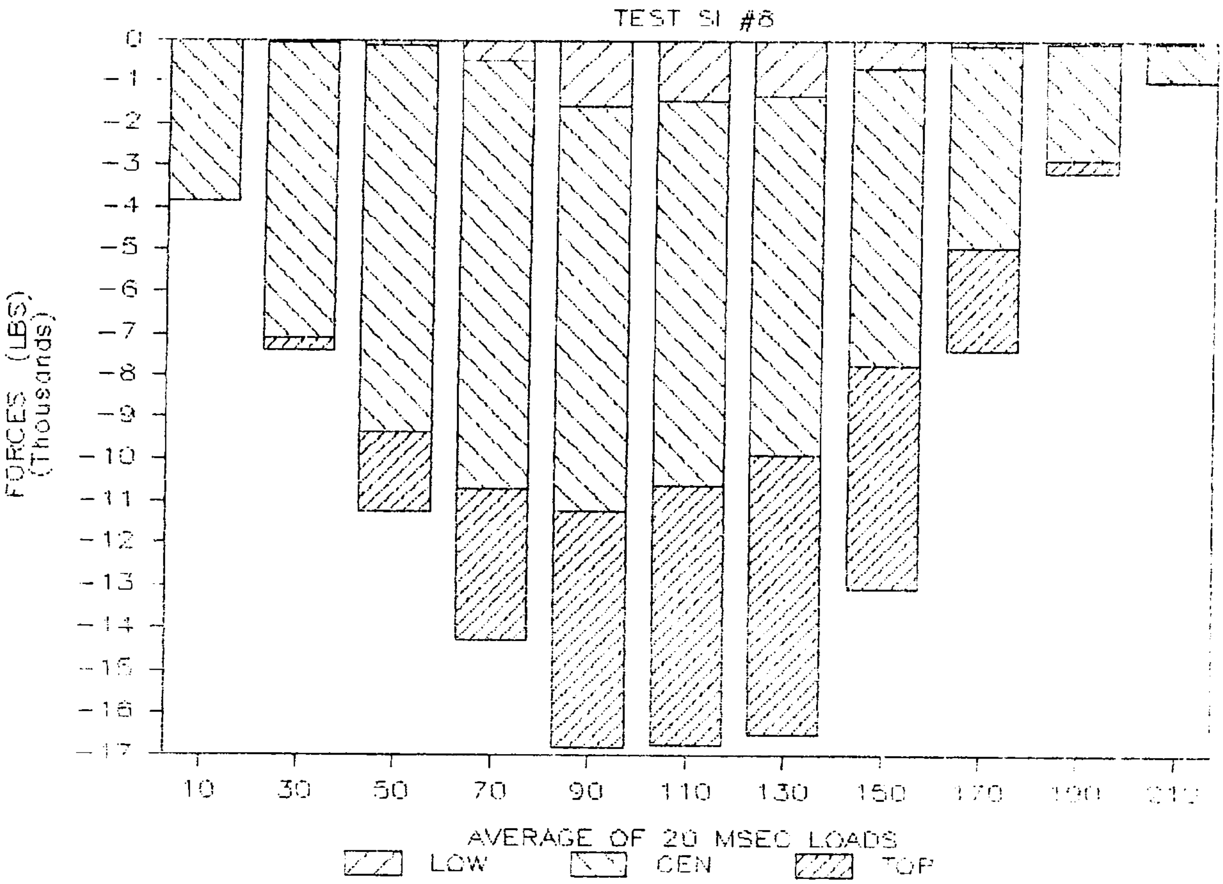


Figure 65. Load Ratio for Test SI#8