Report No. (to be assigned by NHTSA)

DEVELOPMENT OF A TEST METHODOLOGY FOR EVALUATING CRASH COMPATIBILITY AND AGGRESSIVENESS

TEST REPORT 4
1975 PLYMOUTH FURY-TO-NHTSA TEST DEVICE

Dynamic Science, Inc.
A Talley Industries Company
1850 West Pinnacle Peak Road
Phoenix, Arizona 85027

Contract DOT-HS-7-01758

March 1979

FINAL REPORT

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16. Abstract

This report presents the results of two full-scale, head-on collisions between the NHTSA Test Device and 1975 Plymouth Fury four-door sedans. The objective of these tests was to help establish a test methodology for evaluating crash compatibility and aggressiveness. The Test Device is a unique, honeycomb-faced, load-measuring tool which is adaptable to both moving barrier and fixed barrier collisions.

Data contained in this report includes graphical and tabular presentations of vehicle deformation, Test Device load cell data, vehicle and simulated occupant acceleration, velocity and displacement values, dynamic displacement of string potentiometers, and restraint survival distances. Also included are tabular summaries of occupant injury criteria, exterior and interior static vehicle deformation, and restraint system loads and vehicle descriptions. Data for a 40-mph fixed Test Device collision is compared to that for an "equivalent" moving Test Device collision.

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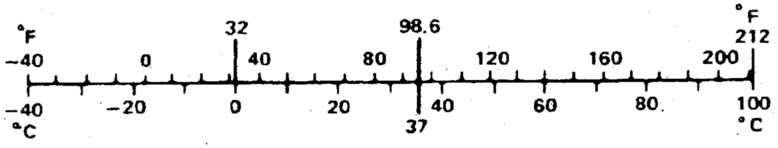
METRIC CONVERSION FACTORS

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	metric ton	t
		VOLUME		
tsp	teaspoons	5	milliliters	mL
Tbsp	tablespoons	15	milliliters	mL
in^3	cubic inches	16	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	degrees Fahrenheit	5/9 (after subtracting 32)	degrees Celsius	°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 (10 000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	metric ton (1000 kg)	1.1	short tons	
		VOLUME		
mL	milliliters	0.03	fluid ounces	fl oz
mL	milliliters	0.06	cubic inches	in^3
L	liters	2.1	pints	pt
L	liters	1.06	quarts	qt
L	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	degrees Celsius	9/5 (then add 32)	degrees Fahrenheit	°F



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1.0 INTRODUCTION

A series of eight full-scale crash tests was conducted to establish a test methodology for evaluating vehicle crash compatibilities and aggressiveness. The objectives of these tests were:

- To obtain the necessary data for establishing appropriate criteria for evaluating vehicle aggressiveness of intermediate, subcompact, and lightweight subcompact-size cars. The vehicles tested were all 1975 model cars which included Honda Civic CVCC, Volvo 244DL, Ford Torino, and Plymouth Fury.
- To investigate the Dynamic Science segmented load cell Test Device concept for sensitivity to measure the basic types of aggressiveness, namely, architectural, mass, and structural aggressiveness.

A summary of the car-to-Test Device test conditions is shown in Table 1-1. This test report presents the results of Tests No. 7 and 8, head-on collisions between the NHTSA Test Device and the 1975 Plymouth Fury four-door sedans.

The Test Device is a unique honeycomb-faced load-measuring tool which is adaptable to both moving barrier collisions (see Figure 1-1) and fixed-barrier collisions (see Figure 1-2). The barrier face of the Test Device is made up of 40 six-inch-thick energy-absorbing aluminum honeycomb modules, each individually connected to load cells. At selected locations, 6 string potentiometers were added to record honeycomb dynamic displacement. The Plymouth car was first crashed into the fixed Test Device (Test 7), and then a similar model was tested into the moving Test Device (Test 8). The closing speed for the moving Test Device tests was selected to give the same energy change (ΔE) as in the corresponding fixed Test Device test. (See Appendix A for determination of equivalent closing speed for moving Test Device collisions.)

TABLE 1-1. SUMMARY OF CAR-TO-TEST DEVICE TEST CONDITIONS

Test Number	Test Date	Test Configuration	Car Model	Car Weight (lb)	Barrier Weight (lb)	Closing Velocity (mph)
1	April 17, 1978	Honda Front-to-Fixed Test Device (Head-on)	1975 Honda CVCC 2-door sedan	2205	Fixed**	40.83
2	April 20, 1978	Honda Front-to-Moving Test Device (Head-on)	1975 Honda CVCC 2-door sedan	2205	3994	62.24***
3	May 9, 1978	Ford Front-to-Fixed Test Device (Head-on)	1975 Ford Torino 4-door sedan	4550	Fixed**	40.52
4	May 16, 1978	Ford Front-to-Moving Test Device (Head-on)	1975 Ford Torino 4-door sedan	4550	4002	59.10*
5	June 6, 1978	Volvo Front-to-Fixed Test Device (Head-on)	1975 Volvo 244DL 4-door sedan	3351	Fixed**	45.11
6	June 8, 1978	Volvo Front-to-Moving Test Device (Head-on)	1975 Volvo 244DL 4-door sedan	3353	4007	61.38*
$\boxed{7}$	June 13, 1978	Plymouth Front-to-Fixed Test Device (Head-on)	1975 Plymouth Fury 4-door sedan	4439	Fixed**	40.73
$\boxed{8}$	June 16, 1978	Plymouth Front-to-Moving Test Device (Head-on)	1975 Plymouth Fury 4-door sedan	4444	4012	58.02*

*Based on equal energy absorption (ΔE).

**Fixed barrier test device weight > 100,000 pounds.

***Based on equal velocity change (ΔV).

6/20/78

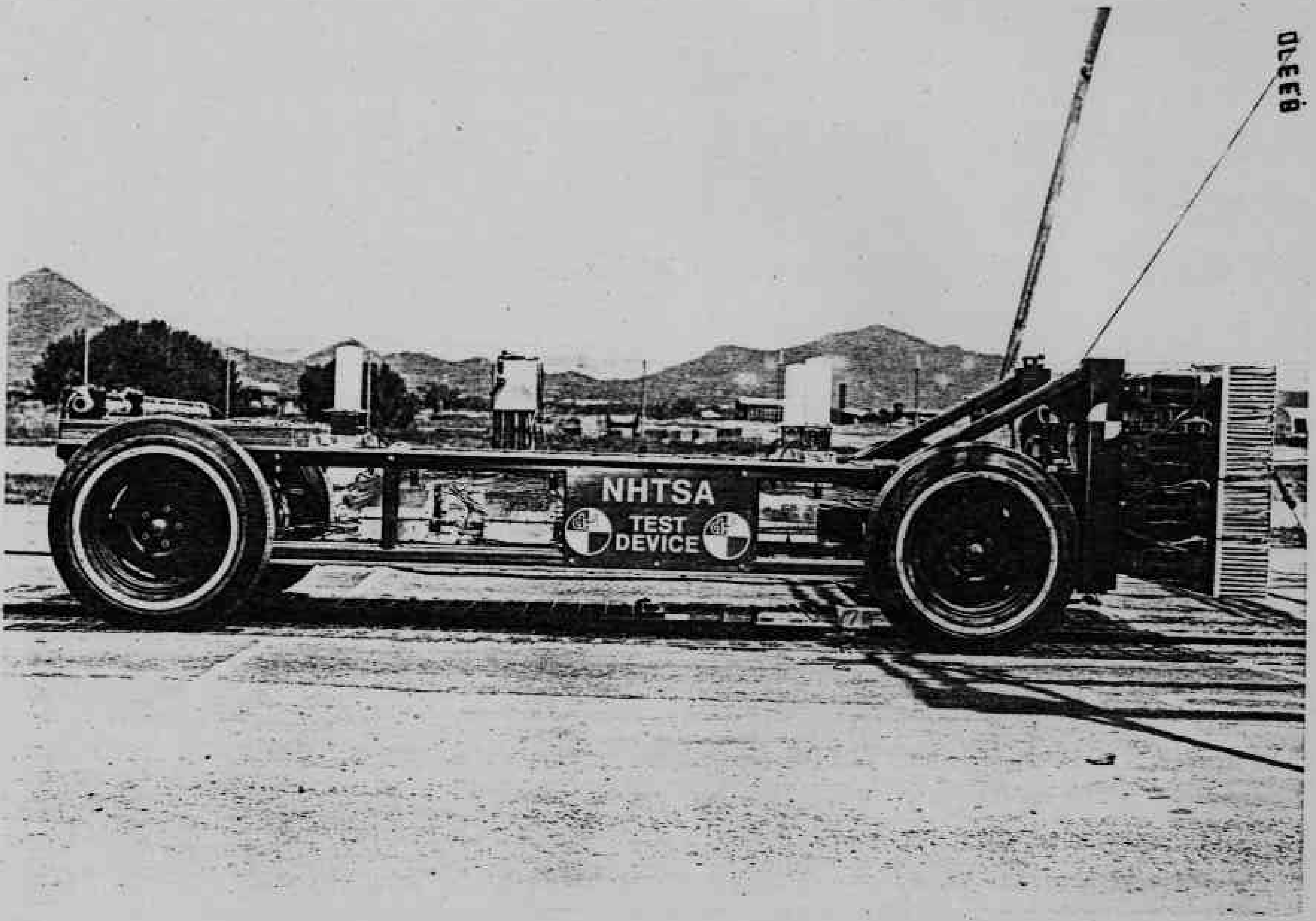

Figure 1-1. Moving Test Device Configuration.

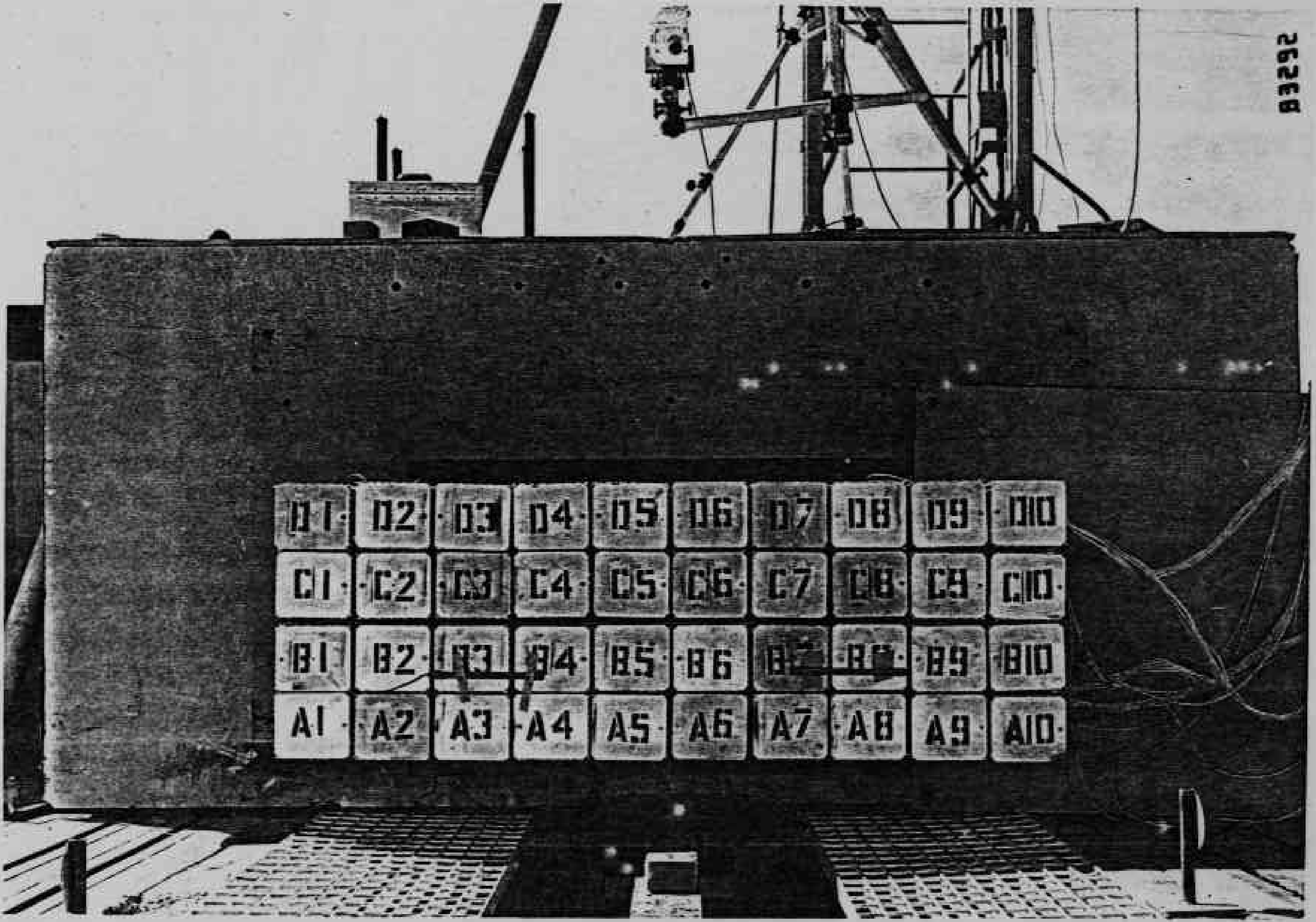

Figure 1-2. Fixed Test Device Configuration.

2.0 TEST METHODOLOGY AND PROCEDURE

This section presents a brief description of the test methodology and procedures used for conducting the Plymouth-to-Test Device head-on collisions.

2.1 VEHICLE DESCRIPTION

The vehicles used in these tests were both 1975 Plymouth Fury four-door sedans. Tables 2-1 and 2-2 present the incoming vehicle inspection performed on each car used for the fixed and moving Test Device tests, respectively.

For the tests to be conducted, two Part 572, male 50th percentile Alderson anthropomorphic dummies (GFE) were in the two front seating positions of the car. Each occupant was properly restrained with the vehicle's lap and shoulder belt restraint system. The seat tracks were welded in their midposition with the seat back latches secured to prevent breakaway and rotation. Test weights for the Plymouths were determined by averaging test weights of cars used in other crashes. Both collisions were head-on with no lateral offset distance between car and Test Device face.

2.2 FIXED TEST DEVICE TESTS

The Plymouth-to-fixed Test Device test was conducted at the barrier impact facility (see Figure 2-1) with the centerline of the test car in line with the centerline of the fixed Test Device face. The vehicle impact velocity (see Table 1-1) was controlled to within ±1 mph.

TABLE 2-1. VEHICLE DESCRIPTION - FIXED TEST DEVICE

Contractor: Dynamic Science, Inc. Contract No.: DOT-HS-7-01758

VIN NO.: RH41G5A153914 Make: Plymouth

NHTSA No.: --

Year: 1975 Color: Green Model: Fury

Auto Trans: [✓ yes] no Pwr Steering: [✓ yes] no Seats (front): Bench: X

Pwr Brakes: [✓ yes] no Auto Speed Cont: yes [✓ no] Bucket: ____

Pwr Seats: yes [✓ no] Anti Skid Brake: yes [✓ no] Split Bench: ____

Pwr Windows: yes [✓ no] Air Conditioning: [✓ yes] no

Tinted Glass: [✓ yes] no Rear Window Def.: yes [✓ no] Split Back Bench: ____

Radio: [✓ yes] no Brakes: drum: R disc: F

Clock: yes [✓ no]

Tire Size: GR78-15 Ply Rating: 4 Mfg. & Line: General Dual Steel

Bias Ply: ____ Belted: ____ Steel Radial x / Eng. Type: V-8 Cylinders: 8 Total Displ: 318 CID

Trans, # Fwd. Speeds: ____ Shipping Weight: 4058 lb Odometer: 54208 miles

Dealer (name, address, and phone number)

Auto Driveaway
Los Angeles, CA.

Cal Worthington, Chrysler
Los Angeles, CA.

Remarks (list additional accessories not listed above)

Date of Manufacture: 1.75 Dynamic Science No.: 638 Date Received: 2-16-78

Tilting Steering Wheel: yes [✓ no] Telescoping Steering Wheel: yes [✓ no]

Fuel Capacity: ____ (from owner's manual) "Space Saver" Spare Tire yes [✓ no]

Restraint System: Std. Production 3-point Belts

1. Is the vehicle stock throughout? Describe: No. 30 lb of water added to fuel tank to meet weight goal.

2. Does vehicle show evidence of prior accident history? Describe: No

3. Does vehicle show any significant corrosion? Describe: No

4. Check condition of the front bumper and frame: Includes two front bumper guards.

TABLE 2-2. VEHICLE DESCRIPTION - MOVING TEST DEVICE

Contractor: Dynamic Science, Inc. Contract No.: DOT-HS-7-01758

VIN NO.: RH41G5A123309 Make: Plymouth

NHTSA No.: --

Year: 1975 Color: Gold Model: Fury

Auto Trans: [✓ yes] no Pwr Steering: [✓ yes] no Seats: (front) Bench: X

Pwr Brakes: [✓ yes] no Auto Speed Cont: yes [✓ no] Bucket:

Pwr Seats: yes [✓ no] Anti Skid Brake: yes [✓ no] Split Bench:

Pwr Windows: yes [✓ no] Air Conditioning: [✓ yes] no Split Back Bench:

Tinted Glass: [✓ yes] no Rear Window Def.: yes [✓ no]

Radio: [✓ yes] no Brakes: drum: R disc: F

Clock: yes [✓ no]

Tire Size: H75-15 Ply Rating: 4 Mfg. & Line: Goodyear Polyglass

Bias Ply: Belted: Radial / Eng. Type: V-8 Cylinders: 8 Total Displ: 318 CID

Trans, # Fwd. Speeds: Shipping Weight: 3958 lb Odometer: 72,781 miles

Dealer (name, address, and phone number)

Auto Driveaway
Los Angeles, CA.

Cal Worthington Chrysler
Los Angeles, CA.

Remarks (list additional accessories not listed above)

Date of Manufacture: 9-74 Dynamic Science No.: 639 Date Received: 2-16-78

Tilting Steering Wheel: yes [✓ no] Telescoping Steering Wheel: yes [✓ no]

Fuel Capacity: (from owner's manual) "Space Saver" Spare Tire yes [✓ no]

Restraint System: Std. Production 3-point Belts

1. Is the vehicle stock throughout? Describe: No, 40 pounds of water added to fuel tank as ballast to meet weight goal.

2. Does vehicle show evidence of prior accident history? Describe: No

3. Does vehicle show any significant corrosion? Describe: No

4. Check condition of the front bumper and frame: Includes two front bumper guards.

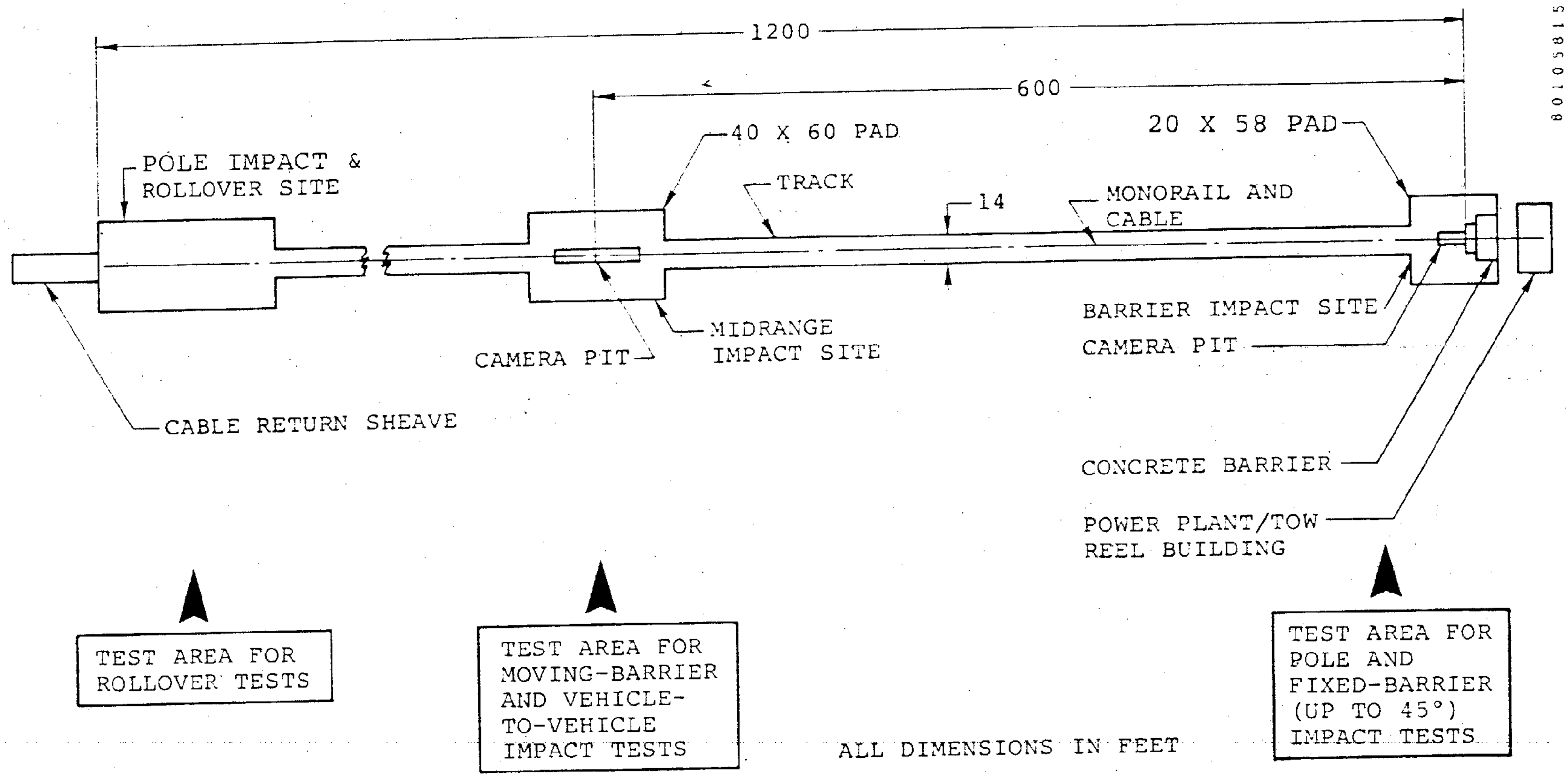

Figure 2-1. Monorail Impact Facility.

The test vehicle was instrumented with 16 accelerometers, 1 string potentiometer, 6 seat belt loads, and an impact sensor. The test vehicle was placed at the head of the test track facing the barrier where it was attached to the tow and guidance system. The fixed Test Device was instrumented with 40 load cells, 6 string potentiometers, 2 strain gauges, and an impact sensor.

Upon completion of the pre-crash checkout of the instrumentation, the vehicle was towed to the specified test speed and released from the tow system just prior to impact. The data from the test vehicle was transmitted to the data acquisition center via umbilical cable with telemetry as a backup. The data from the fixed Test Device were transmitted by umbilical cable only (see Figure 2-2). In order to achieve the weight goal outlined in the test plan, 30 pounds of water was added to the fuel tank of the test vehicle prior to testing. See Table 2-3 for a crash test summary of the fixed Test Device configuration.

2.3 MOVING TEST DEVICE TESTS

The Plymouth-to-moving Test Device test was conducted at the midrange station of the crash track facility (see Figure 2-1) with the centerline of the test car in line with the center of the moving Test Device face. The vehicle impact velocity of each test vehicle (see Table 1-1) was controlled to within ±1 mph.

The test vehicle was instrumented exactly the same as the vehicle used in the fixed Test Device tests with the abort bottle placed inside the trunk of the vehicle. This was done for safety reasons. The test vehicle was placed at the head of the test

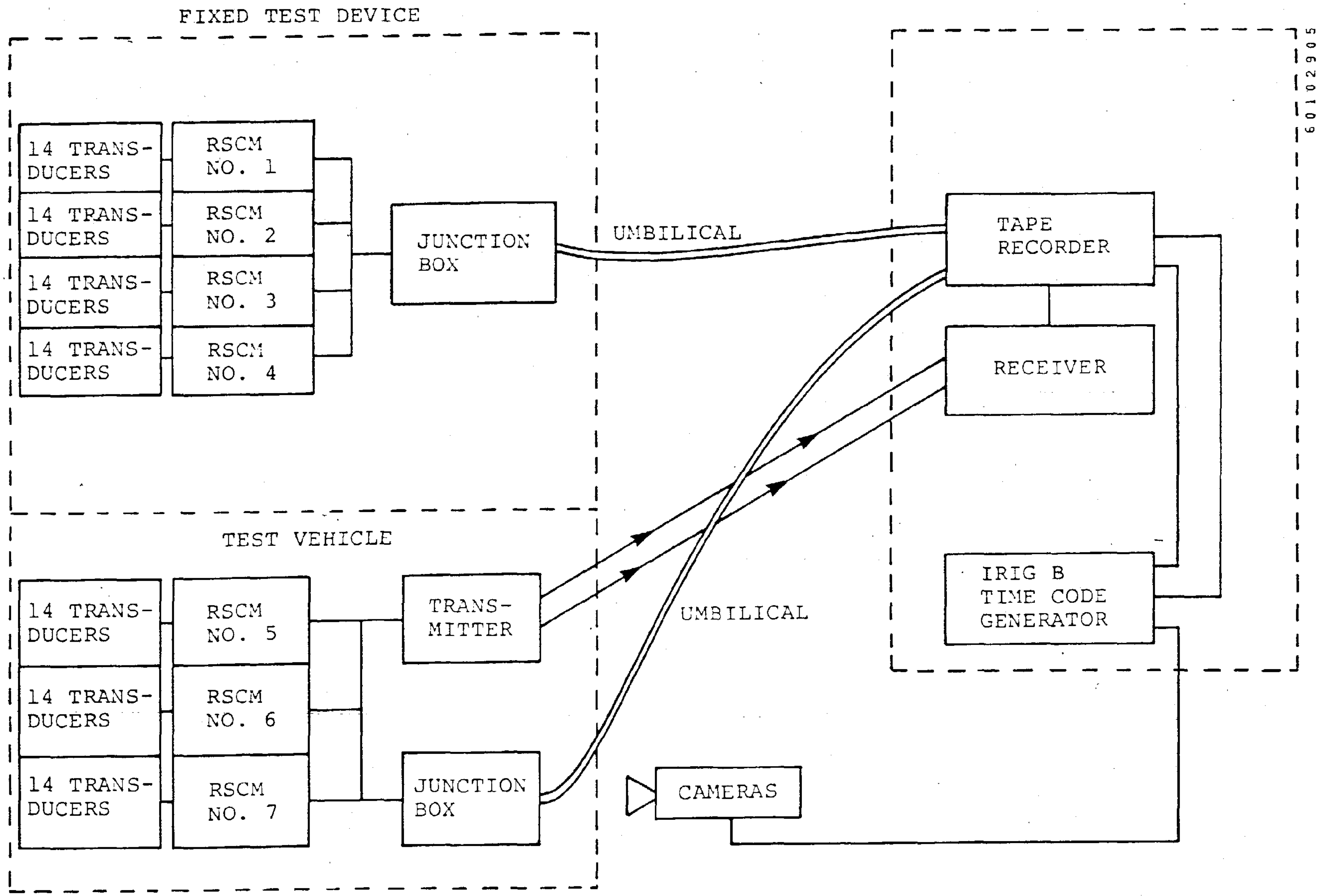

Figure 2-2. Data Acquisition - Vehicle-to-Fixed Barrier Tests.

TABLE 2-3. CRASH TEST SUMMARY 8316-7

Test No. 8316-7 Contract DOT-HS-7-01758

Test Date June 13, 1978 Time 1242 Temperature 101°F

Test Configuration Front-to-Front, Head-on

Vehicle No. 1 (A) 1975 Plymouth Fury 4-door Sedan

Vehicle No. 2 (B) Fixed Test Device

VEHICLE DATA	Vehicle A	Vehicle B
Test Weight (lb)	4439	>100,000
Impact Angle (deg)*	0°	180°
Offset Distance (in.)	0	0
Impact Velocity (mph)**	40.73	0
DUMMY DATA		
Type	Part 572 Alderson	None
Locations	LF (Driver) - # 759***	-
	RF (Passenger) - # 760***	-
Restraints	Lap/Shoulder Belt	None
	Lap/Shoulder Belt	
INSTRUMENTATION		
Number of Data Channels	41	48
Number of Cameras	7	

---

*With respect to tow track centerline facing fixed barrier.

**Speed trap measurement.

***Alderson Dummy Serial No.

track, facing the barrier. The moving Test Device was instrumented the same as the fixed Test Device with the addition of 2 longitudinal accelerometers and an additional strain gauge attached to the frame rails of the moving Test Device. The moving Test Device was placed at the barrier end of the track. See Table 2-4 for a crash test summary of the moving Test Device configuration. To meet the test weight of the vehicle called out in the test plan, 40 pounds of water was used as ballast and added to the fuel tank.

Both vehicles were attached to the tow and guidance system. After the pre-crash checkout of the instrumentation, the vehicles were towed to the specified test speed and released from the tow system just prior to impact. The data from the test vehicle and moving Test Device were transmitted to the data acquisition center via umbilical cable with telemetry as a backup (see Figure 2-3).

TABLE 2-4. CRASH TEST SUMMARY 8316-8

Test No. 8316-8 Contract DOT-HS-7-01758

Test Date June 16, 1978 Time 1119 Temperature 95 °F

Test Configuration Front-to-Front, Head-on

Vehicle No. 1 (A) 1975 Plymouth Fury 4-door Sedan

Vehicle No. 2 (B) Moving Test Device

	VEHICLE A	VEHICLE B
VEHICLE DATA		
Test Weight (lb)	4444	4012
Impact Angle (deg)*	0°	180°
Offset Distance (in.)	0	0
Impact Velocity (mph)**	29.01	29.01
DUMMY DATA		
Type	Part 572 Alderson	None
Locations	LF (Driver) - # 759***	-
	RF (Passenger) - # 760***	-
Restraints	Lap/Shoulder Belt	None
	Lap/Shoulder Belt	
INSTRUMENTATION		
Number of Data Channels	41	53
Number of Cameras	7	

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*With respect to tow track centerline facing fixed barrier.

**Speed trap measurement.

***Alderson Dummy Serial No.

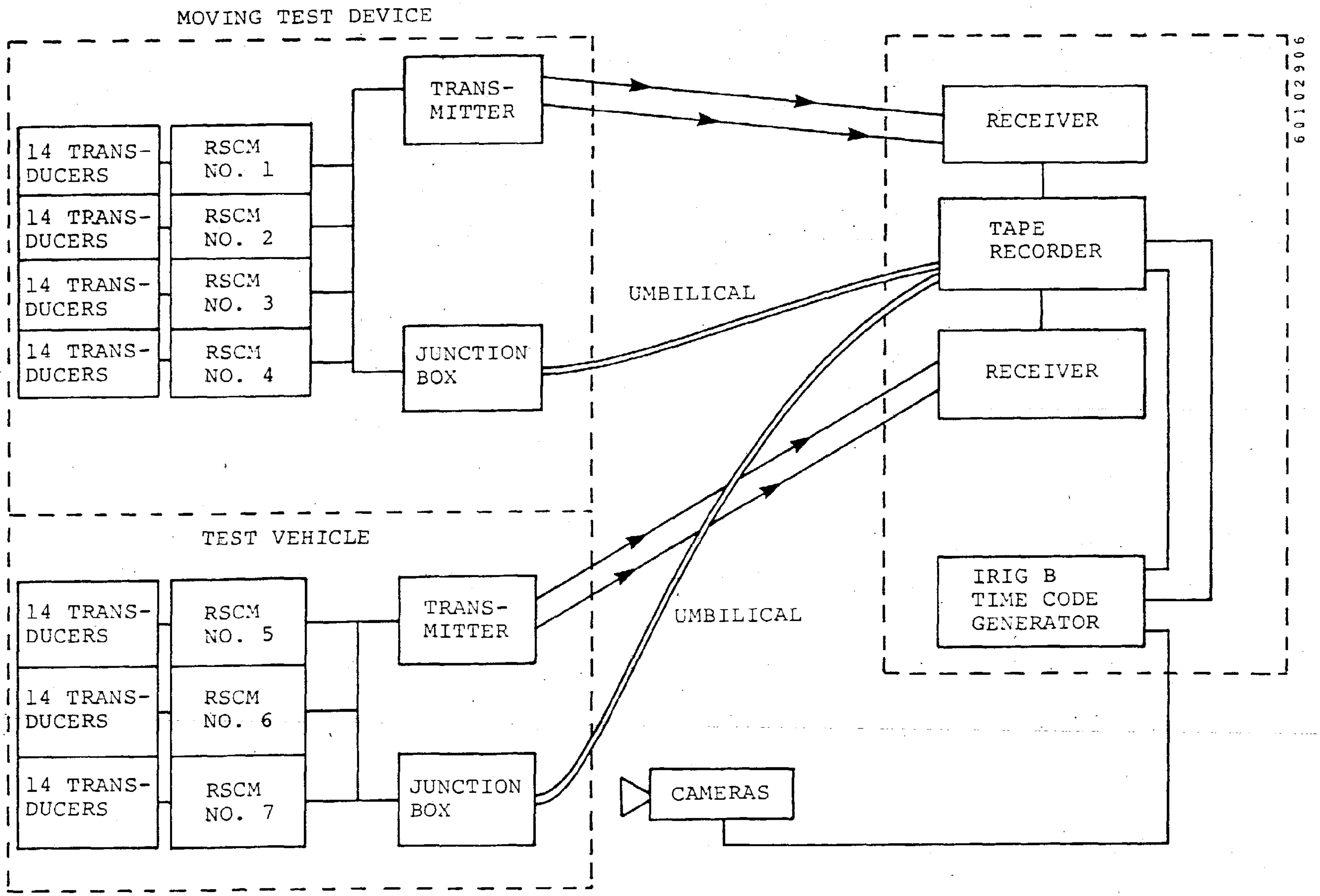


Figure 2-3. Data Acquisition - Vehicle-to-Moving Test Device Tests.

3.0 DATA ACQUISITION

3.1 DATA ACQUISITION METHODS

The overall plan for obtaining the necessary data is outlined in Table 3-1. The table defines the test parameter, measurement method, and recording method used during the conduct of this program.

TABLE 3-1. DATA REQUIREMENTS

Test Parameter	Measurement Method	Magnetic Tape	Written Log	Photo-graphic Analysis
Impact Time	Contact switch signal impressed on millisecond time base	X		
Approach Velocity	Tow cable velocity sensor	X		
Impact Velocity	Speed trap entrance and exit signals from speed trap	X*		
Rebound Velocity	Calculated from high-speed film analysis and compartment accelerometer data	X		X
Test Device and Vehicle Acceleration Measurements	Accelerometers, unbound strain gauge type	X		
Test Device Honeycomb Crush	String potentiometer and direct linear measurement	X	X	
Stress in Test Device Frame and Horizontal Beams	Strain gauges	X		
Forces on Test Device Honeycomb	Load cells	X		

*Velocity is also measured by electronic counter.

TABLE 3-1. DATA REQUIREMENTS (CONTD)

Test Parameter	Measurement Method	Magnetic Tape	Written Log	Photographic Analysis
Vehicle Structural Deformation	Direct linear measurement		X	
Vehicle Static Crush	Direct linear measurement		X	
Vehicle Dynamic Crush	Film analysis			X
Restraint Survival Distance	Direct linear measurement		X	
Steering Column Intrusion	Direct linear measurement		X	
Firewall Intrusion	String potentiometer and static measurements	X	X	
Fuel Leakage	Observation and timed measurement		X	
Windshield Retention	Direct measurement and observation		X	
Occupant Head and Chest Acceleration	Triaxial accelerometers	X		
Occupant Femur Loads	Load cells	X		
Seat Belt Loads	Load cells	X		
Vehicle Weight by Wheel	Direct pre-test measurement using balance scales		X	
Ballast Weight	Balance scale		X	

3.2 INSTRUMENTATION

3.2.1 Test Vehicle Instrumentation

The test vehicle contained two Part 572 anthromorphic dummies positioned in the left and right front seating locations. Prior to each test use, the dummies were inspected and adjusted to meet the torque and characteristic requirements for these devices. Sixteen structural accelerometers and one string potentiometer were installed on the vehicle and consisted of the following (see Figure 3-1):

1. A biaxial (X, Z) mount located on the left rocker panel near the B-piller to measure accelerations of the occupant compartment.

2. A biaxial (X, Z) mount similar to No. 1, but on the right side of the vehicle.

3. A biaxial mount (X, Z) located on the rear floor structure over the rear axle.

4. A biaxial mount (X, Z) located on the upper centerline of the firewall in the engine compartment to measure acceleration of the forward section of the passenger compartment.

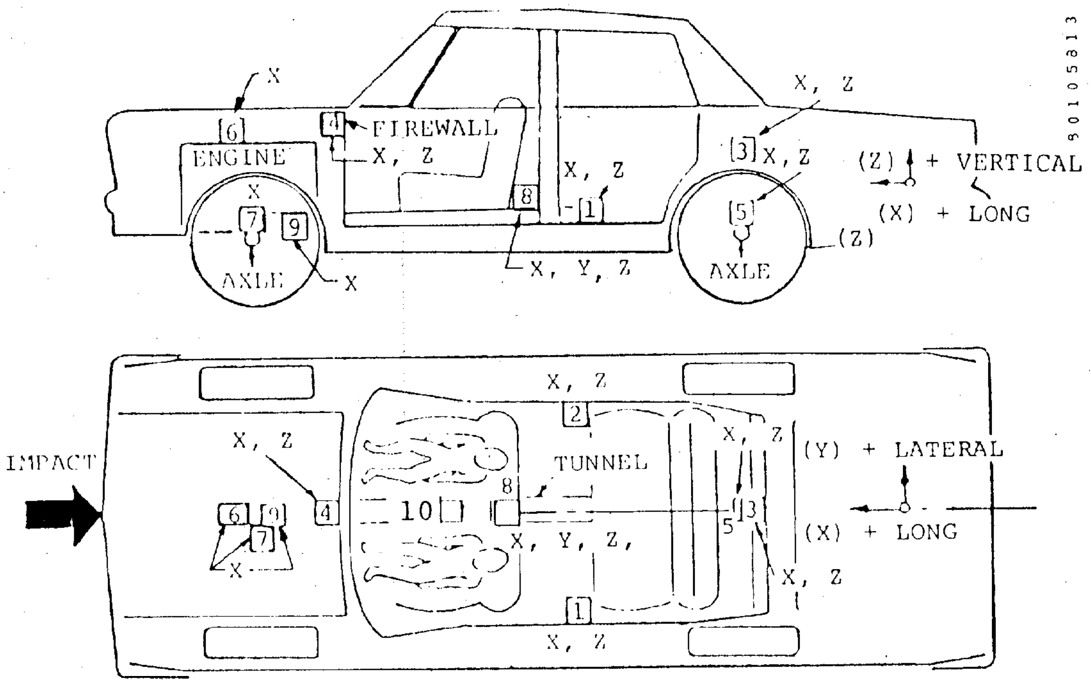
5. A biaxial mount (X, Z) located on the centerline of the rear axle to measure acceleration of the rear drive train and rear suspension assembly.

6. A single mount (X) located on the top of the engine block in a protective case to measure acceleration of the engine.

7. A single mount (X) located on the front frame crossmember in a protective case to measure axial acceleration of the front frame.

8. A triaxial mount (X, Y, Z) located near the vehicle center of gravity on the drive tunnel at the longitudinal C.G. to measure acceleration of the compartment.

9. A single mount (X) located in a position similar to that in No. 6, but on the bottom of the engine.



	VEHICLE ACCELEROMETER LOCATIONS AND PHYSICAL COORDINATES				MAXIMUM EXPECTED READINGS		
NO.	DESCRIPTION OF LOCATION	X**	Y**	Z**	LONG*	LAT*	VERT*
1	Rocker panel near B-pillar behind driver's seat	88	-26	14	50		50
2	Rocker panel near B-pillar behind passenger's seat	88	26	14	50		50
3	Centerline of rear deck above rear axle	60	0	25	50		50
4	Centerline of firewall at A-pillar inside engine compartment	157	0	33	100		100
5	Centerline of rear axle	58	0	8	100		100
6	Engine block (Top centerline)	170	0	30	200		
7	Front crossmember	181	0	7	200		
8	Longitudinal center of gravity of car	124	0	18	50	50	50
9	Engine block (Bottom centerline)	174	0	7	200		
10	String Potentiometer	134	3	20	15 in.		

*In G.

**Reference points:

X - Direction - Centerline of rear bumper

Y - Direction - Centerline of vehicle - left centerline (-), right centerline (+)

Z - Direction - Ground level

Figure 3-1. Vehicle Accelerometer Instrumentation.

10. A string potentiometer installed on the interior firewall to measure the intrusion of the firewall into the occupant compartment.

11. A tape switch mounted onto the forwardmost portion of the car to record impact.

3.2.2 Test Vehicle Occupant Instrumentation

The following test dummy instrumentation was installed for the driver and right front passenger positions:

1. A triaxial accelerometer mount located in the head to measure its acceleration.

2. A triaxial accelerometer mount located in the chest cavity to measure chest acceleration.

3. A femur load cell mounted in the femur of each leg to measure femur loads.

4. Two seat belt load cells were mounted onto the lap belt with an additional seat belt load cell mounted onto the shoulder belt for each of the two front occupant restraint systems. The lap belt load cells were mounted on each side of the occupant.

The instrumentation requirements for the dummy occupants are given in Table 3-2.

3.2.3 Moving Test Device Instrumentation

The moving Test Device was instrumented with 40 load cells, 6 displacement string potentiometers, 3 strain gauges, 2 accelerometers, and 1 tape switch. Their purposes and locations were as follows:

1. A load cell mounted between each honeycomb module and Test Device rigid face to measure impact forces.

2. A string potentiometer displacement transducer mounted at selected honeycomb locations to measure dynamic honeycomb displacement.

TABLE 3-2. OCCUPANT INSTRUMENTATION

Occupant Accelerometer and Load Cell Locations				Maximum Expected Readings		
Description of Locations	Long	Lat	Vert	Long*	Lat*	Vert*
Driver head accelerometer	X	X	X	200	100	200
Passenger head accelerometer	X	X	X	200	100	200
Driver chest accelerometer	X	X	X	100	50	100
Passenger chest accelerometer	X	X	X	100	50	100
Driver left and right femur load cell				3000 lb		
Passenger left and right femur load cell				3000 lb		

*In G.

3. A single (X) accelerometer mounted on the longitudinal frame rails (mounted on each side) to measure acceleration of the Test Device.

4. Two strain gauges mounted on selected horizontal impact face beams to measure strains developed in the front structure due to the impact force.

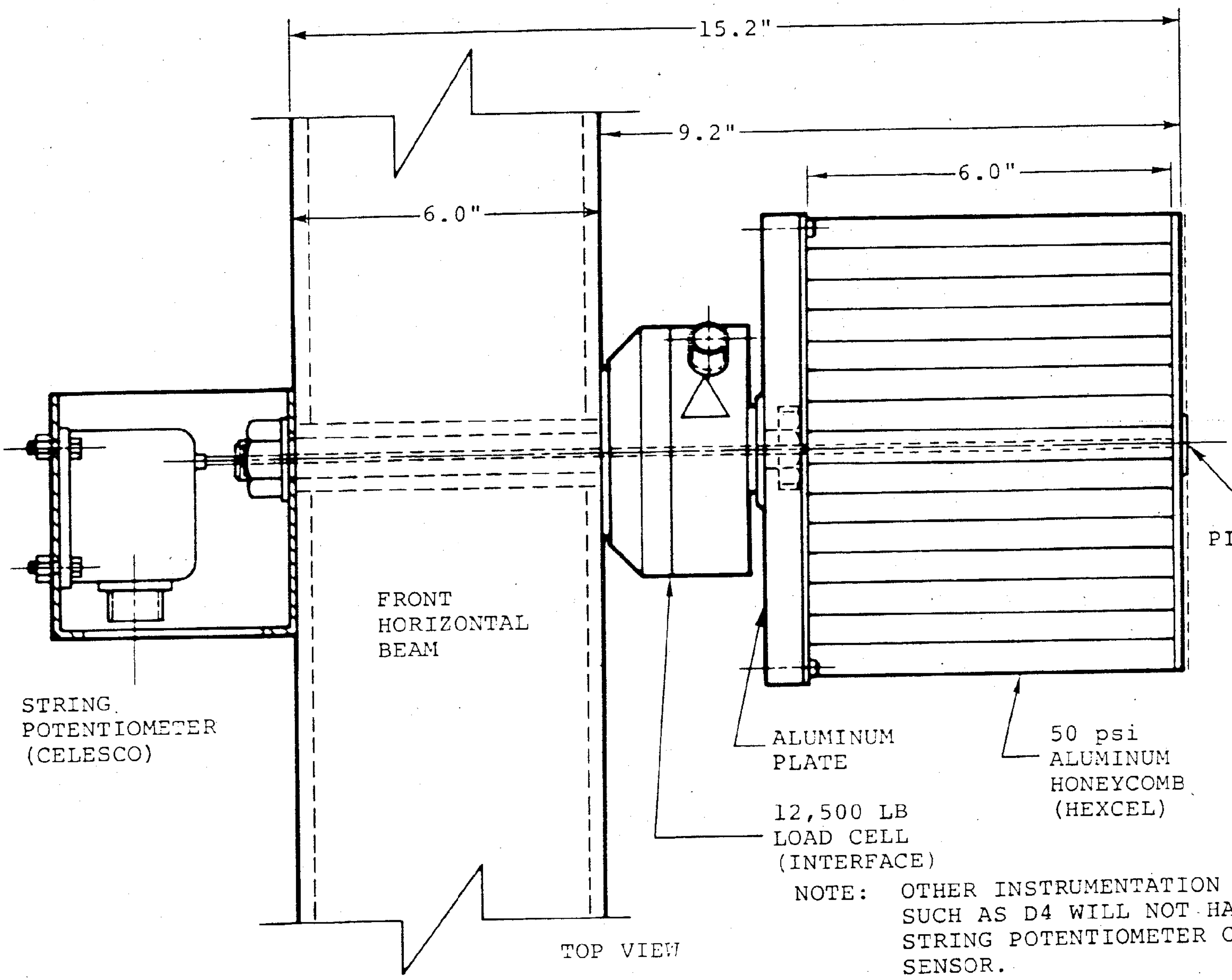
5. One strain gauge mounted on the right side of the Test Device longitudinal frame rail to measure strain in the vehicle frame structure.

6. One tape switch mounted onto a selected honeycomb module to record the time of impact.

Figure 3-2 defines the typical instrumentation honeycomb module; Figure 3-3 describes the location of instrumentation on the Test Device impact face; and Figure 3-4 shows the location of the instrumentation on the Test Device vehicle structure.

3.2.4 Fixed Test Device Instrumentation

The instrumentation on the fixed Test Device was the same as on the moving Test Device except that the strain gauges and accelerometers on the Test Device frame were deleted (Figure 3-5).



NOTE: OTHER INSTRUMENTATION MODULES SUCH AS D4 WILL NOT HAVE A STRING POTENTIOMETER OR IMPACT SENSOR.

Figure 3-2. Typical Instrumentation Model (B5).

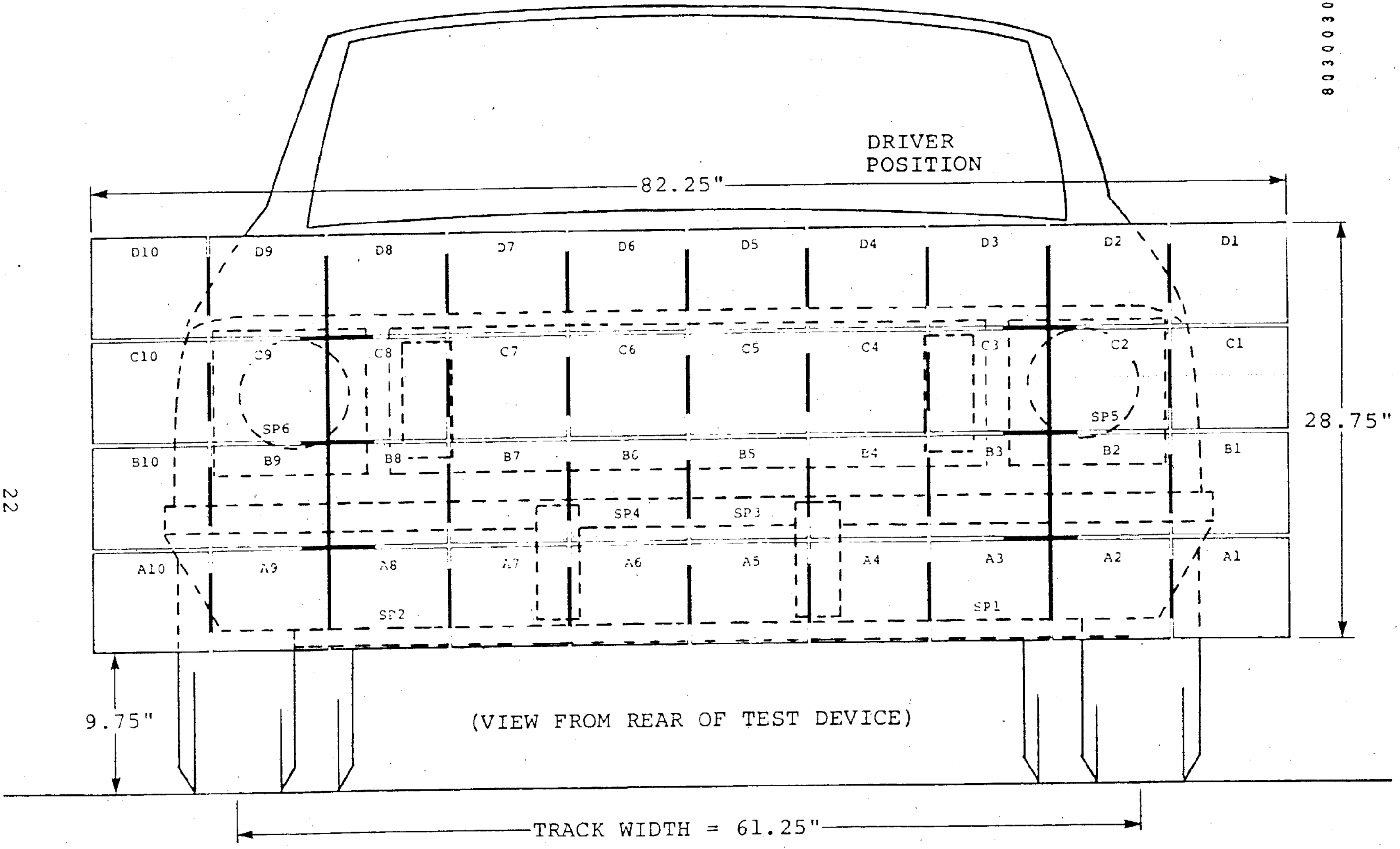
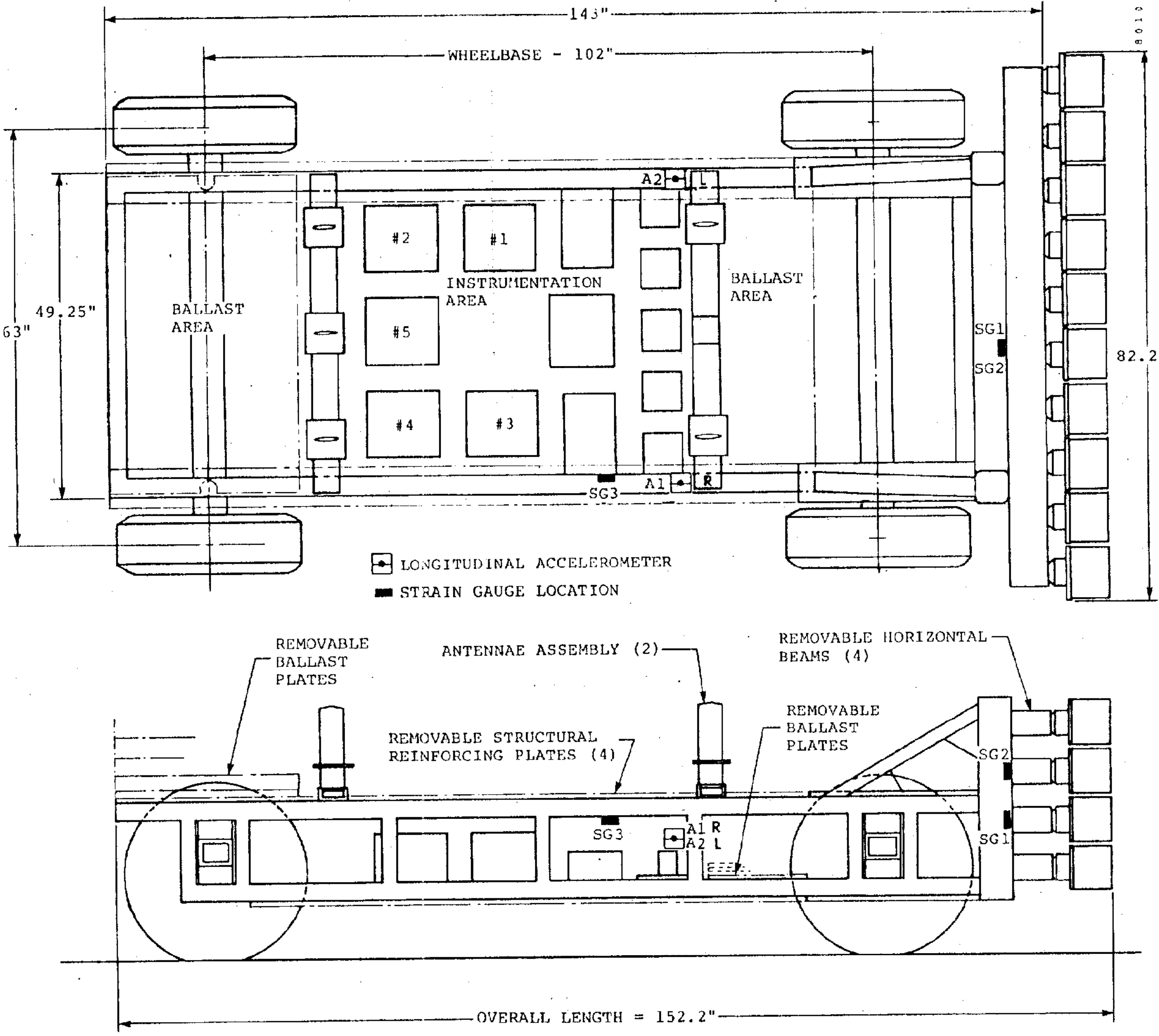


Figure 3-3. 1975 Plymouth Fury/Test Device Honeycomb Interface and String Potentiometer Locations.



VEHICLE INSTRUMENTATION LOCATIONS AND PHYSICAL COORDINATES					MAXIMUM EXPECTED READINGS		
NO.	DESCRIPTION OF LOCATION	X*	Y*	Z*	LONG	LAT	VERT
A1R	Test Device Accelerometer frame rail right side	84	46	20	100 G		
A2L	Test Device Accelerometer frame rail left side	84	-46	20	100 G		
SG1	Row B horizontal beam	140	0	20	7500 μ in./in.		
SG2	Row C horizontal beam	140	0	28	7500 μ in./in.		
SG3	Test device frame rail right side	78	46	21	7500 μ in./in.		
40	Load cells				15.0 Klb		

*Reference Points:

X Direction - Rear End of Test Device
Y Direction - Centerline of Test Device - Left ℄ (-), Right ℄ (+)
Z direction - Ground Level.

Figure 3-4. Moving Test Device Instrumentation.

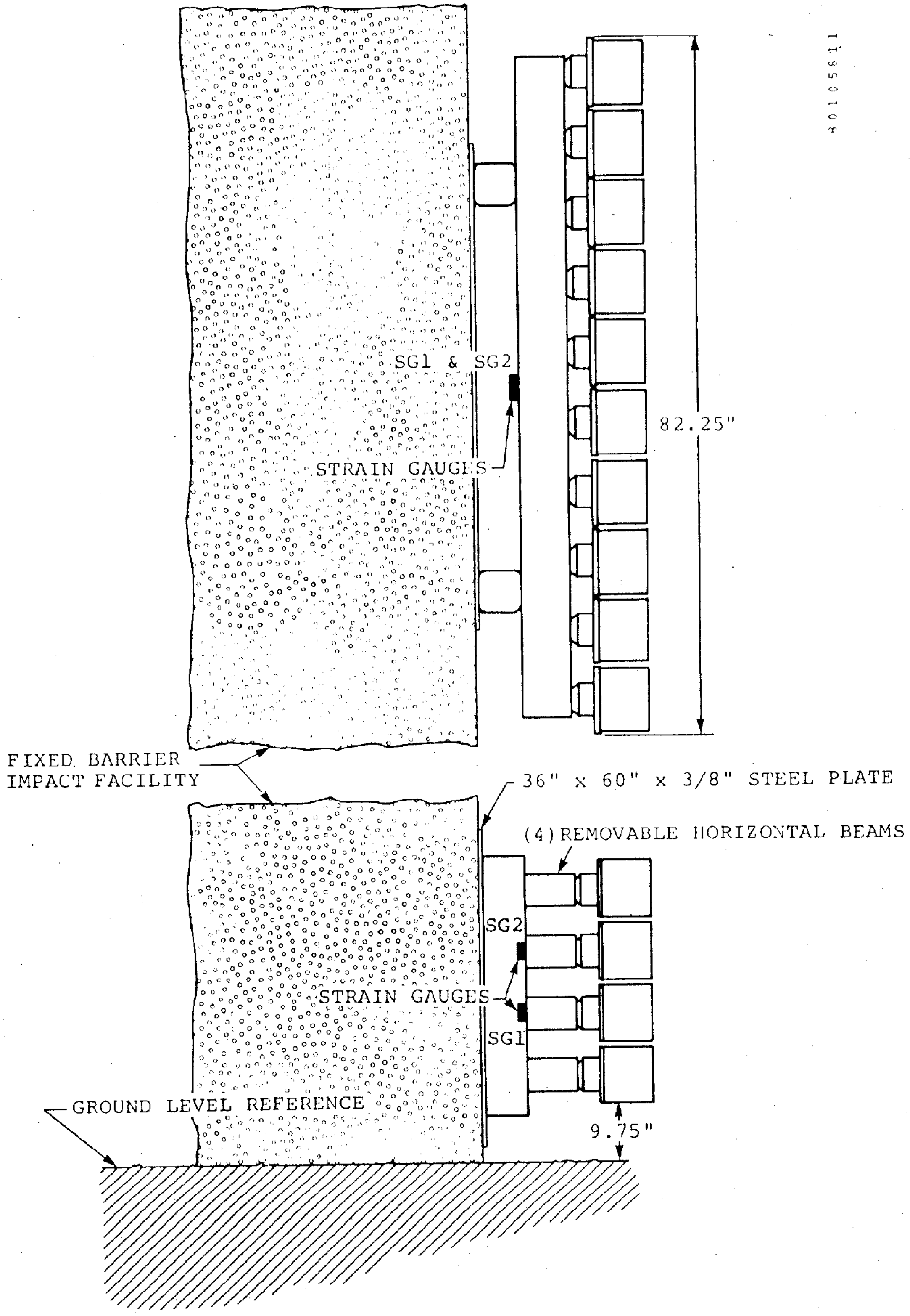


Figure 3-5. Fixed Test Device Installation and Strain Gauge Location.

3.3 PHOTO-INSTRUMENTATION REQUIREMENTS

3.3.1 Fixed Test Device Photography

Six high-speed (four 1000 fps and two 500 fps) cameras and one panning (24 fps) camera were used as shown in Table 3-3 for the fixed Test Device/moving vehicle tests.

The panning camera documented the instrumentation, pre-test and post-test configurations, pre-test and post-test dummy positions, and the Test Device and vehicle crush profiles.

3.3.2 Moving Test Device Photography

Six high-speed (four 1000 fps and two 500 fps) cameras and one panning (24 fps) camera were used as shown in Table 3-4 for the moving Test Device/moving vehicle tests.

TABLE 3-3. CAMERA LOCATIONS - FIXED TEST DEVICE

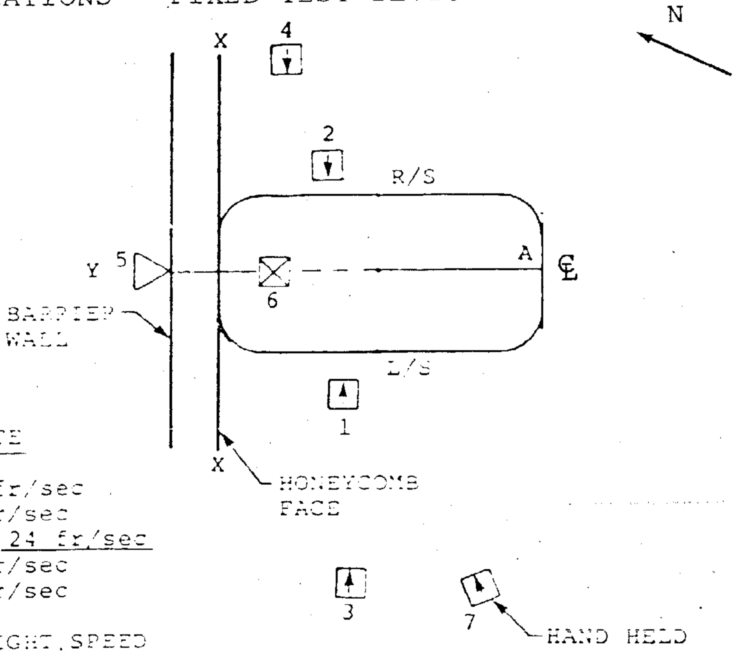
Test No: 8316-7 Test Date: 6/13/78

Test Type: Car-to-Fixed Test Device Head-on

Vehicle A (Away): 1975 Plymouth Fury

Vehicle B (Barrier): Fixed Test Device

Comments: Camera locations are approximate and may be moved at the discretion of the Test Engineer.



CAMERA	YES
STILLS	✓
SLIDES	✓
MOVIE	✓
POLAROID	

CAMERA SYMBOLS

- ⊡ PIT
- ⍐ GROUND
- △ BARRIER
- ☒ OVERHEAD
- ☐ ON-BOARD

FRAME RATE

①. 1000 fr/sec
2. 200 fr/sec
③. Other 24 fr/sec
4. 400 fr/sec
⑤. 500 fr/sec

TIMING LIGHT SPEED

①. 100 Hz (10 msec/light)
2. 200 Hz (5 msec/light)
3. Other ______

Loc. No.	Location	Field of View	Lens Size	Frm Rate	Tmng Spd
1	Left Side**	Left Front Occupant Compartment	25mm	1	1
2	Right Side**	Right Front Occupant Compartment	25mm	1	1
3	Left Side**	Overall of Car and Barrier Wall	13mm	1	1
4	Right Side**	B-Pillar of Car and Honeycomb Crush	13mm	1	1
5	Barrier	Occupants Through Front Windshield	10mm	5	1
6	Overhead at Centerline**	B-Pillar of Car and Honeycomb Crush	16mm	5	1
7	Left Side	Panning Test and Overall Results		3	

**Camera perpendicular to line of vehicle travel.

TABLE 3-4. CAMERA LOCATIONS - MOVING TEST DEVICE

80105810

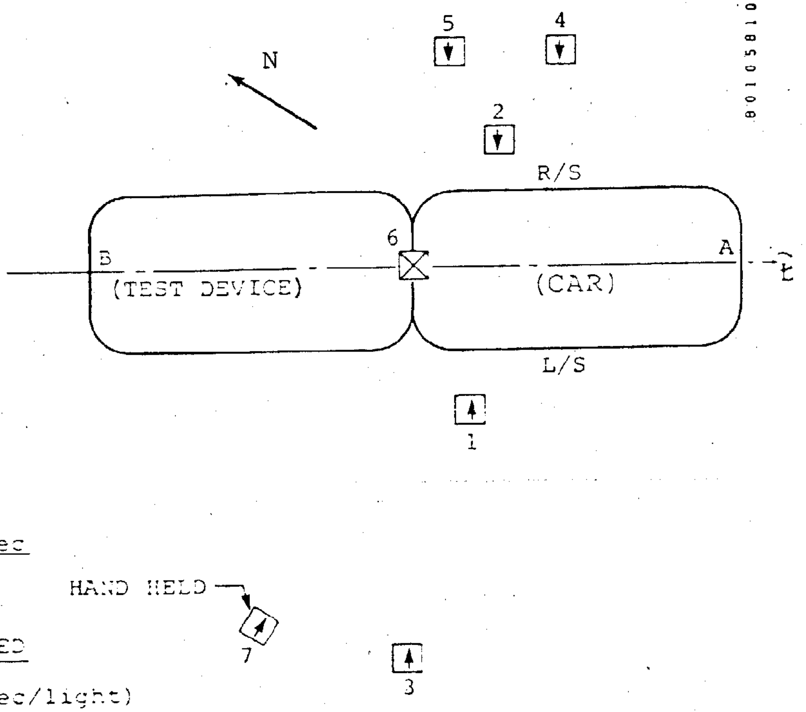
Test No: 8316-8 Test Date: 6/16/78

Test Type: Car-to-Moving Test Device Head-on

Vehicle A (Away): 1975 Plymouth Fury

Vehicle B (Barrier): Moving Test Device

Comments: Camera locations are approximate and may be moved at the discretion of the Test Engineer



CAMERA	YES
STILLS	✓
SLIDES	✓
MOVIE	✓
POLAROID	

CAMERA SYMBOLS

- Ⓒ PIT
- ⊡ GROUND
- △ BARRIER
- ☒ OVERHEAD
- ☐ ON-BOARD

FRAME RATE

① 1000 fr/sec
2. 200 fr/sec
3. Other 24 fr/sec
4. 400 fr/sec
⑤ 500 fr/sec

TIMING LIGHT SPEED

① 100 Hz (10 msec/light)
2. 200 Hz (5 msec/light)
3. Other

Loc. No.	Location	Field of View	Lens Size	Frm. Rate	Tmng Spd
1	Left Side **	Right Front Occupant Compartment	25mm	1	1
2	Right Side**	Left Front Occupant Compartment	25mm	1	1
3	Left Side**	Overall of Moving Barrier and Car A	13mm	1	1
4	Right Side**	B-Pillar to B-Pillar of Both Vehicles	13mm	1	1
5	Right Side **	Overall of Car A	Var	5	1
6	Overhead at Centerline**	Front Half of Both Vehicles at Impact	10mm	5	
7	Left Side	Panning Test and Overall Results		3	

**Cameras perpendicular to line of vehicle travel.

4.0 SUMMARY OF TEST RESULTS

This section of the report presents the results of the Plymouth-to-Test Device crash tests performed under Task 4. Copies of instrumentation data traces (Calcomp plots) are included in Appendix B for Test No. 7 and in Appendix C for Test No. 8.

4.1 TEST SUMMARY: PLYMOUTH-TO-TEST DEVICE TESTS

A summary of pertinent pre-test and post-test Test Device conditions are given in Tables 4-1 through 4-7. Pre-test and post-test views of crash configurations are shown in Figures 4-1 and 4-2 for fixed Test Device tests and in Figures 4-3 and 4-4 for moving Test Device tests.

Test weights for each vehicle were determined by weighing each wheel of the car to obtain a total weight. The vehicle was then rotated 180 degrees and the weighing procedure repeated to obtain an average weight for the vehicle.

Compartment and engine acceleration was determined by an averaging of accelerometers located near the B-pillar of the vehicle and the top and bottom of the engine block (see Figure 3-1).

Maximum mutual dynamic crush data, as well as the chronology of events for each vehicle, were determined by high-speed film analysis. Maximum dynamic crush on the car was determined by subtracting 6 inches of honeycomb crush from the maximum mutual dynamic crush for each test.

4.1.1 Fixed Test Device Test

In the fixed Test Device test, the Plymouth impacted the aluminum honeycomb modules at a speed of 40.7 mph, causing approximately 25.6 inches of static crush to the vehicle. The final speed of the Plymouth was -6.7 mph, giving a total velocity change of 47.4 mph.

TABLE 4-1. CRASH TEST SUMMARY

Test No.	3	4
Test Date	May 9, 1978	May 16, 1978
Time	1000	1422
Temperature	83°F	88°F
Test Configuration	Front-to-Front Head-on	Front-to-Front Head-on
Vehicle A	1975 Ford Torino	1975 Ford Torino
Vehicle B	Fixed Test Device	Moving Test Device
	VEHICLE A DATA	
Test Weight by Wheel (lb)	LF-1284 RF-1277 LR-991 RR-998	LF-1290 RF-1243 LR-1017 RR-1000
Total Weight (lb)	4550	4550
Longitudinal C.G. (from center of front axle) (in.)	51.6	52.3
Impact Angle (deg)*	0	0
Offset Distance (in.)	0	0
Impact Velocity (mph)**	40.52	59.10
	OCCUPANTS	
Type	Part 572 Alderson	Part 572 Alderson
Locations	LF (driver) - Serial No. 759 RF (passenger) - Serial No. 760	LF (driver) - Serial No. 759 RF (passenger) - Serial No. 760
Restraints	Standard production lap/shoulder belt	Standard production lap/shoulder belt
	INSTRUMENTATION	
Number of Data Channels	Vehicle A - 41 Vehicle B - 48	Vehicle A - 41 Vehicle B - 53
Number of Cameras	7	7

*With respect to tow track centerline facing fixed barrier.
**Closing speed using speed trap measurement.

TABLE 4-2. SUMMARY OF CAR TEST DATA

VEHICLE: 1975 Plymouth Fury 4-door Sedan

Vehicle Parameter	Test 7 (Fixed Test Device)	Test 8 (Moving Test Device)
Car Test Weight (lb)	4439	4444
Overall Vehicle Length/Width (in.)	218.1/77.7	218.2/77.7
Car Speed (mph)	40.7	29.0
Final Speed (mph @ msec)	-6.7 @ 179	-2.6 @ 132
Coefficient of Restitution	0.16	0.10
Velocity Change (mph @ msec)	47.4 @ 179	31.6 @ 132
Maximum Compartment Acceleration (G @ msec)	-31.1 @ 78	-29.2 @ 20
Maximum Engine Acceleration (G @ msec)	-74.3 @ 52	-124.7 @ 40
Maximum Dynamic Crush (in.)	38.9 (F)	34.2 (F)
Maximum Static Crush		
• Hood Level (in.)	24.9	25.8
• Between Bumper/Hood (in.)	27.5	26.7
• Bumper Level (in.)	25.2	25.3
Maximum Post-test Intrusion (in.)	12.1	3.7
Maximum Mutual Dynamic Crush (in.)	44.9 (F)	40.2 (F)
Maximum Individual Load Cell Force (klb @ msec)***	11.3 @ 87 (B5)	15.4 @ 45 (B6)
Maximum Total Load Cell Force (klb @ msec)***	77.7 @ 34	98.4 @ 23
Normalized Maximum Force* (lb/lb)	17.5	21.1
Vehicle Damage Index**	12FCAW9	12FCAW9

(F) = Film Data
*Maximum total load cell force/car test weight.
**Refer to SAE J224A.
***Some load may have been lost due to load cell contact with backing plate (see Figures 4-32 and 4-33). Lower loads in Test 7 also attributable to failure of bolt holding Row B beam.

TABLE 4-3. SUMMARY OF PRE-TEST ENGINE/BUMPER/ FIREWALL CHARACTERISTICS

Test No.	7	8
Type of Test	Fixed Test Device	Moving Test Device
Impact Velocity (Closing, mph)	40.73	58.02
Engine Size (CID)	318	318
Engine Weight* (lb)	666	666
Engine Height/Width (in.)	13.9/25.2	13.9/25.2
Bumper to Engine (in.)	35.5	35.5
Engine Length (in.)	24.0	24.0
Engine to Firewall (in.)	4.0	4.0
Bumper to Firewall (in.)	63.5	63.5
Bumper to "Hard Point" (in.)	30.0	30.0

*Total dressed engine weight dry.

TABLE 4-4. SUMMARY OF PRE-TEST DUMMY POSITION DATA CHARACTERISTICS

	Test 7 Fixed Test Device		Test 8 Moving Test Device	
	Left Front Occupant	Right Front Occupant	Left Front Occupant	Right Front Occupant
Seat Range (in.)	5.5	5.5	5.4	5.5
Seat Position* (in.)	2.7	2.7	2.7	2.7
Front Seat to Firewall (in.)	25.6	27.0	27.2	27.9
Forehead to Windshield (in.)	20.3	19.3	20.5	19.3
Torso to Steering Wheel** (in.)	12.0	21.0	12.8	21.8
Left/Right Knee to Dash Panel (in.)	6.3/6.3	7.0/7.0	6.8/6.5	8.3/9.0

*From rearmost position to midpoint.
**To dash panel for right front passenger.

TABLE 4-5. SUMMARY OF POST-TEST OBSERVATIONS

VEHICLE: 1975 Plymouth Fury 4-door Sedan

Test No. 7 (Fixed Test Device)

Dummy Contact Points:	Left Front	Right Front
Head-------------------	Dash Panel	Dash Panel
Chest------------------	Steering Wheel	None
Knees------------------	Knee Bolsters	Glove Compartment

Glazing: Cracked and 90% retained.

Doors: Required tools to open all doors.

Seat Belt Anchorages: Okay

Restraints: Okay

Fuel Leakage: None

General Observations: Hood latch failed. Radiator leakage. Steering wheel rotated downward. Modules D1 and D10 were sheared off by car at impact. Row B beam separated from test fixture. Row C and D attach bolts bent upwards from impact. Rear of vehicle rotated 2 inches counterclockwise. Vehicle rebound was 39 inches from impact location. Front bumper rotated downward.

TABLE 4-5. SUMMARY OF POST-TEST OBSERVATIONS (CONTD)

VEHICLE: 1975 Plymouth Fury 4-door Sedan

Test No. 8 (Moving Test Device)

Dummy Contact Points:	Left Front	Right Front
Head	Barely Touched Dash Panel	Dash Panel
Chest	Steering Wheel	None
Knees	Knee Bolsters	Glove Compartment

Glazing: Small crack in windshield and 98% retained.

Doors: Front doors required tools to open.

Seat Belt Anchorages: Okay

Restraints: Okay

Fuel Leakage: None

General Observations: Hood latch failed. Radiator leakage. Steering wheel rotated downward. Modules D1, D9, C10, and B10 sheared off by car at impact. No rotation of vehicle. Vehicle left at impact point. Vehicle pushed Test Device back 23.3 feet from impact point.

TABLE 4-6. INJURY CRITERIA SUMMARY

Occupant Position	Left Front			
TEST 7 (FIXED TEST DEVICE)				
HIC	1695 @ 83-120			
Head G* @ msec	93.9 @ 95		—	
CSI	749 @ 200		656 @ 200	
Chest G* @ msec	73.1 @ 89		64.8 @ 115	
Femur Load (lb)	Left	Right	Left	Right
	-265	-1465	-864	-741
RSD (in.)**	Pre	Post	Pre	Post
	8.9	9.7	10.6	6.6
TEST 8 (MOVING TEST DEVICE)				
HIC	949 @ 76-123		1125 @ 98-111	
Head G* @ msec	68.7 @ 107		107.4 @ 103	
CSI	394 @ 200		284 @ 200	
Chest G* @ msec	55.8 @ 77		37.4 @ 114	
Femur Load (lb)	Left	Right	Left	Right
	-494	-924	-670	-756
RSD (in.)**	Pre	Post	Pre	Post
	8.0	9.6	7.3	9.1

*3-msec clip.
**RSD computed with 7-msec time shift to correct for honeycomb crush of Test Device.

TABLE 4-7. CHRONOLOGY OF CRASH EVENTS

VEHICLE: 1975 Plymouth Fury 4-door Sedan

Time (msec)	Test 7 - Fixed Test Device Event
0	Impact (visual)
15	Hood begins to buckle
50	Damage to Rows B, C, and D of Test Device begins
64	Hood hits barrier wall
73	Roof begins to buckle
75	Dash begins to move into passenger compartment
82	Driver contacts steering wheel with chin
96	Passenger contacts dash with nose
97	Driver contacts dash with forehead
108	Maximum mutual dynamic crush (44.87 in.)
117	Passenger and driver forward motion stops
119	Rows B, C, and D of Test Device damaged
130	Rear wheels leave ground
208	Driver recontacts headrest
259	Vehicles separate
279	Maximum vehicle inclination 9.4°
366	Passenger rearward motion stops
408	Rear wheels recontact ground

Time (msec)	Test 8 - Moving Test Device Event
0	Impact (visual)
11	Hood begins to buckle
70	Roof begins to buckle
87	Maximum mutual dynamic crush (40.22 in.)
95	Passenger contacts dash with face
96	Driver forward motion stops
107	Maximum vehicle inclination 3.0°
110	Passenger forward motion stops
202	Vehicles separate
251	Driver recontacts headrest

Figure 4-1. Pre-test Vehicle Configuration - Test 7.

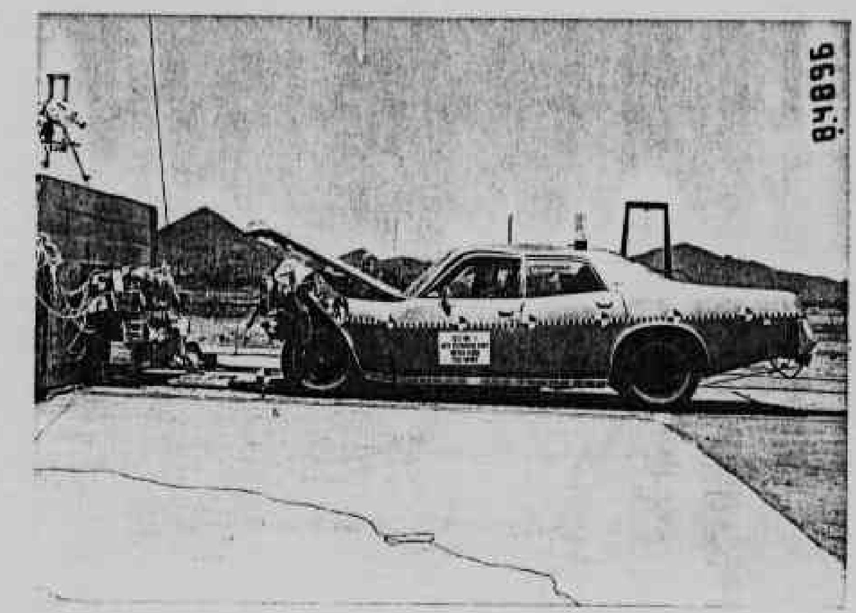


Figure 4-2. Post-test Vehicle Configuration - Test 7.

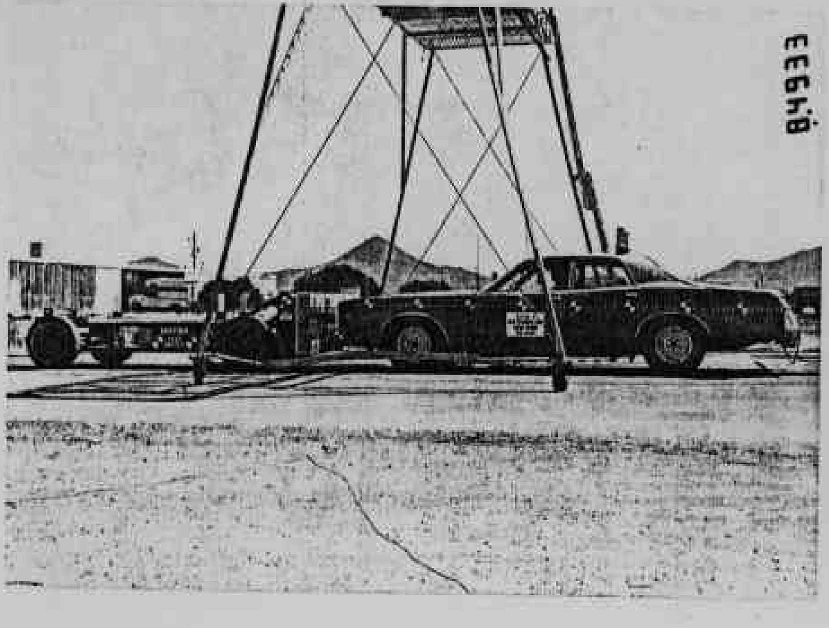


Figure 4-3. Pre-test Vehicle Configuration - Test 8.

NOTE: TEST DEVICE PUSHED BACK BY CAR APPROXIMATELY 23 FEET.

Figure 4-4. Post-test Vehicle Configuration - Test 8.

The maximum dynamic crush on the car was 38.9 inches a milliseconds with a pitch angle of 9.4 degrees. Rebound of mouth off the face of the Test Device caused the rear of the car to rotate approximately 2 inches counterclockwise from the barrier centerline. Rebound of the Plymouth from the initial impact point was 39 inches. The fixed Test Device structure was damaged due to the geometric aggressiveness of the Plymouth bumper, and failure of the attachment bolts of the vertical member. The extent of this damage, and resulting modifications will be discussed later in this report.

4.1.2 Moving Test Device Test

In the moving Test Device test, the Plymouth impacted the aluminum honeycomb module at a closing speed of 58.0 mph, causing approximately 26.1 inches of static crush to the vehicle. The final speed of the Plymouth was -2.6 mph. The final speed of the Test Device was -3.0 mph, indicating the Test Device was pushed backwards by the car after impact due to the fact the car was 444 pounds heavier than the Test Device. The total velocity change to the car was 31.6 mph. The maximum dynamic crush on the car was 40.2 inches at 37 milliseconds and a pitch angle of 3.0 degrees.

Moving Test Device tests conducted for this program have been adjusted to give similar change in energy (ΔE) as in comparable fixed Test Device tests. Upon impact, the Plymouth remained close to the area of impact while the Test Device was pushed backwards, stopping 23.3 feet from the car. There was no rotation of either vehicle and no damage to the Test Device structure.

Vehicle data, including all pre-test and post-test measurements and summaries of vehicle accelerometer data, are discussed in Section 4.2. Test Device data, including summaries of load cell, string potentiometer, accelerometer, strain gauge data, and honeycomb crush profiles, are discussed in Section 4.3. Occupant response data is discussed in Section 4.4.

4.2 VEHICLE STRUCTURAL RESPONSE

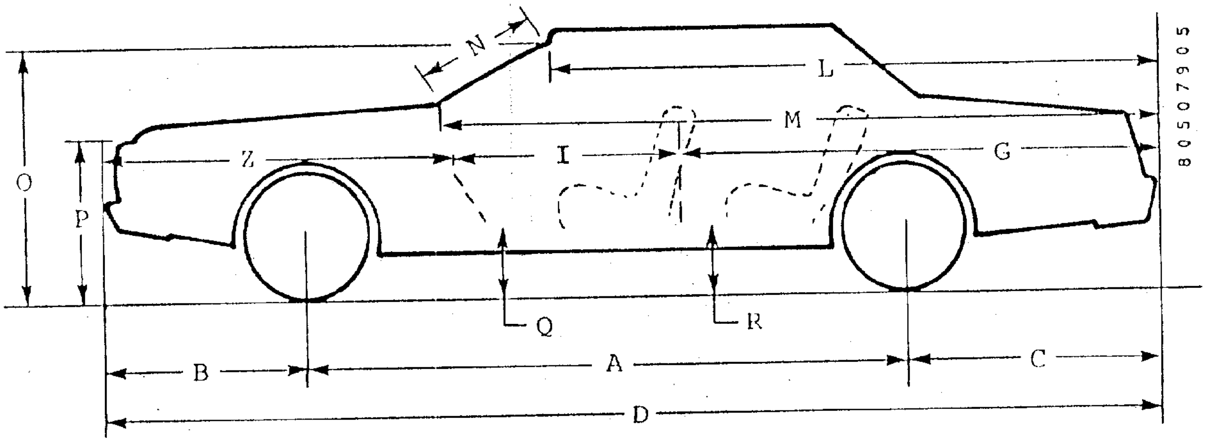
This section of the report presents data on the Plymouth's structural response to the collision with the fixed and moving Test Devices. This includes pre-test and post-test measurements made at selected locations on the vehicle, steering wheel displacements, vehicle exterior and interior profiles, and accelerometer data.

Static crush measurements of the Plymouth for both fixed and moving Test Device tests are shown in Table 4-8. Pre-test and post-test bumper match-ups are shown in Figures 4-5 through 4-8. In both tests, the car deformed uniformly with the flat surface of the Test Device. Since the closing speed for the moving Test Device test was selected to give the same change in energy (ΔE), most of the crush measurements were very similar for both tests. In both tests, the hood latch of the Plymouth failed, which did not allow the hood to aid in resisting the structural crush of the car.

Exterior profiles are given in Tables 4-9 and 4-10. Measurements for the frontal exterior profile of the Plymouth were made at three levels: the hood level, the bumper level, and a level between the hood and bumper level. In Test 7, the bumper of the Plymouth rotated down slightly from the force caused by the impact, while in Test 8, the bumper showed no rotation. The cars used in both tests contained bumper guards which were highly responsible for concentrated loads to be recorded by the load cells. In both tests the frontal crush was fairly flat across the face of the cars.

Vehicle interior intrusion profiles and steering wheel displacement values are given in Tables 4-11 through 4-13. Compartment intrusion is shown in Figures 4-9 through 4-12. In both tests, the dash panel remained attached to the frame of the car, but elongation of the seat belt allowed the occupants to come

TABLE 4-8. PRE- AND POST-TEST DIMENSION MEASUREMENTS



VEHICLE: 1975 Plymouth Fury 4-door sedan

	(Fixed Test Device Test) Test 7						(Moving Test Device Test) Test 8					
	Pre-test		Post-test		Difference		Pre-test		Post-test		Difference	
	LS	RS	LS	RS	LS	RS	LS	RS	LS	RS	LS	RS
A	117.9	117.7	113.2	113.2	4.7	4.5	117.4	117.3	113.5	113.8	3.9	3.5
B	45.0	45.3	24.4	24.4	20.6	20.9	45.7	45.6	23.1	23.1	22.6	22.5
C	55.1	55.2	54.9	54.9	0.2	0.3	55.2	55.2	55.5	55.2	-0.3	0.0
D	218.0	218.2	192.5	192.5	25.5	25.7	218.3	218.1	192.1	192.1	26.2	26.0
I	36.9	36.9	35.6	35.8	1.3	1.1	37.0	36.9	36.4	36.5	0.6	0.4
G	103.3	103.2	103.6	103.4	-0.3	-0.2	103.5	103.5	103.4	103.4	0.1	0.1
L	120.9	121.5	124.5	124.2	-3.6	-2.7	121.4	121.7	121.4	121.3	0.0	0.4
M	138.9	138.8	138.4	138.3	0.5	0.5	139.5	140.0	138.9	139.1	0.6	0.9
N	23.9	23.8	24.0	24.0	-0.1	-0.2	24.7	24.7	24.7	24.6	0.0	0.1
O	53.0	52.7	51.7	51.6	1.3	1.1	53.5	53.5	52.7	52.6	0.8	0.9
P	33.6	33.0	34.9	38.0	-1.3	-5.0	32.1	32.0	35.5	34.5	-3.4	-2.5
Q	15.7	15.3	11.8	10.3	3.9	5.0	16.0	15.9	14.5	14.4	1.5	1.5
R	15.6	15.3	12.5	11.0	3.1	4.3	15.6	15.5	13.9	13.9	1.7	1.6
Z	77.8	78.1	53.3	53.3	24.5	24.8	77.8	77.7	52.3	52.2	25.5	25.5

NOTE: ALL MEASUREMENTS IN INCHES.

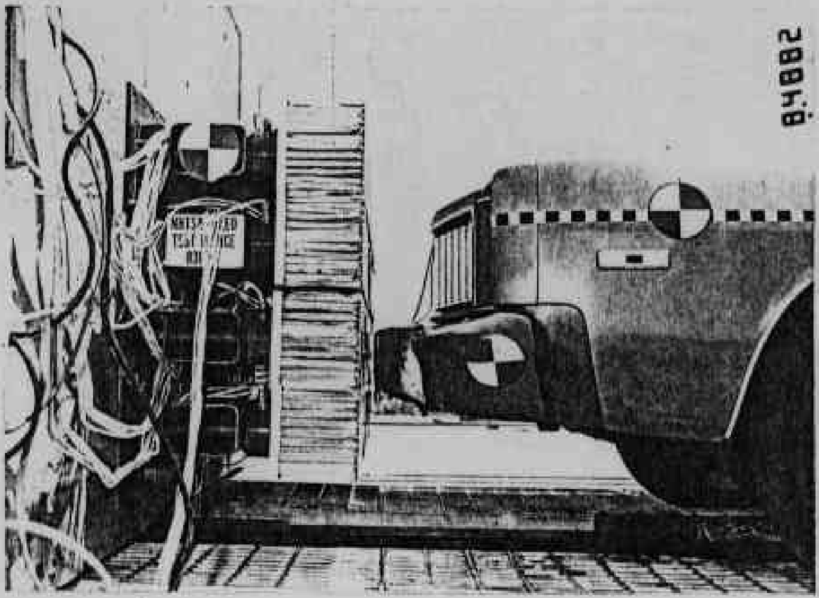


Figure 4-5. Pre-test Bumper Match - Test 7.

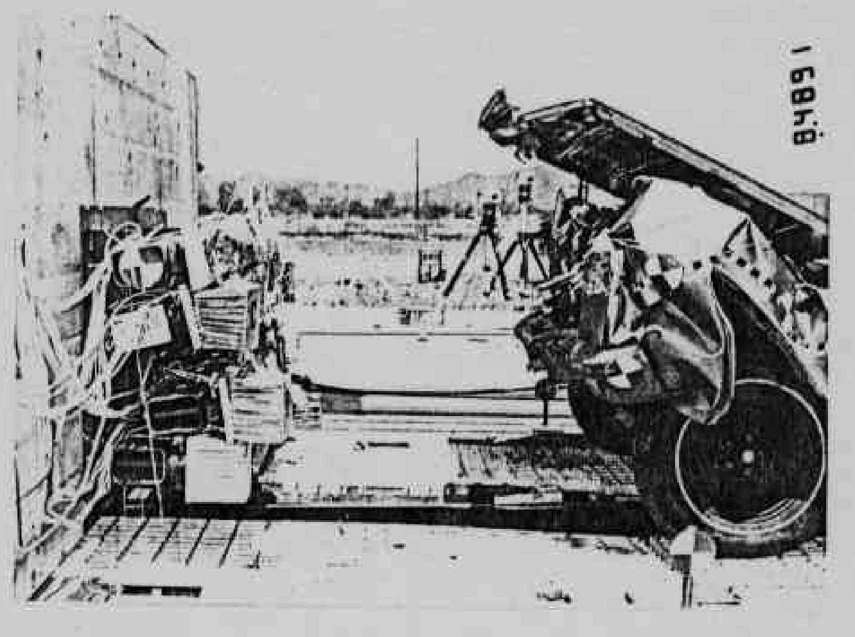


Figure 4-6. Post-test Bumper Match - Test 7.

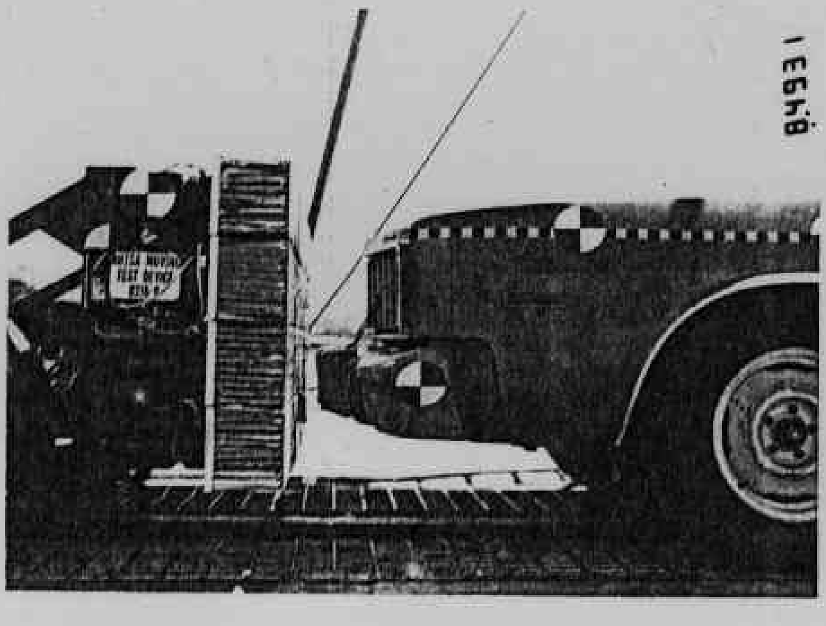


Figure 4-7. Pre-test Bumper Match - Test 8.

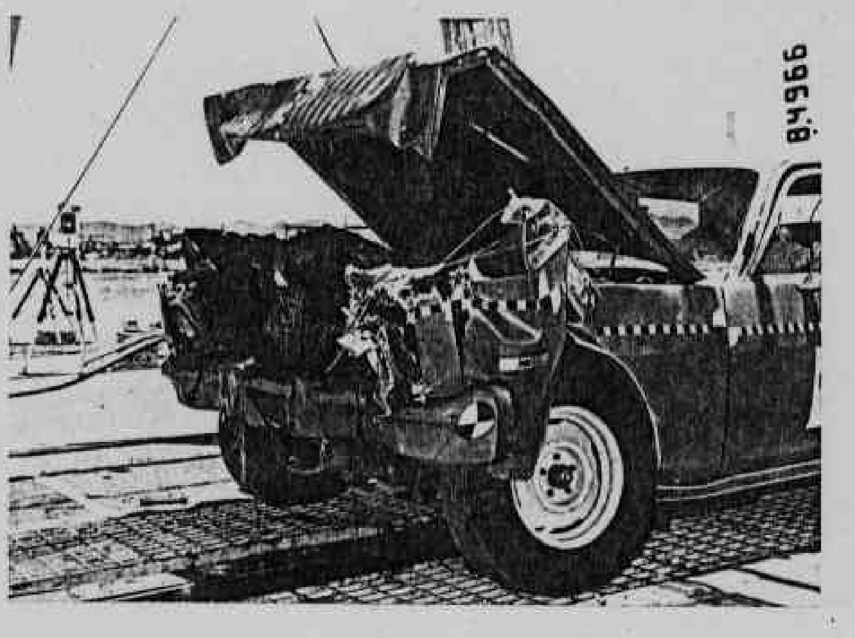


Figure 4-8. Post-test Bumper Match - Test 8.

TABLE 4-9. CAR EXTERIOR PROFILES AND STATIC CRUSH FOR TEST 7

			Distance Left of Center (in.)*							Distance Right of Center (in.)*					
Location	R.P.** (in.)	Height (in.)	36† 34	30	24	18	12	6	0	6	12	18	24	30	36† 34
			Pre-test Profile (Distance from R.P. - in.)												
Hood Level	220	33.6	10.9	11.3	11.9	10.2	9.2	8.3	7.4	8.3	9.3	10.3	12.0	11.4	11.0
Between Bumper/ Hood	220	28.4	10.9	12.6	12.7	11.1	10.1	9.2	7.9	9.2	10.2	11.2	12.8	12.8	10.9
Bumper Level	220	20.1	8.8†	6.4	6.4	6.6	5.6	4.5	3.4	4.4	5.5	6.6	6.4	6.4	8.5†
			Post-test Profile (Distance from R.P. - in.)												
Hood Level	195	37.4	5.4	6.9	6.1	7.1	7.4	7.1	6.9	8.2	8.9	9.5	8.6	9.3	9.7
Between Bumper/ Hood	195	31.8	5.2	8.2	8.3	8.8	12.0	11.7	8.9	9.4	10.9	8.9	11.9	12.4	10.2
Bumper Level	195	22.4	7.4†	5.4	5.6	6.1	5.5	4.7	3.6	4.4	4.9	5.3	4.5	4.0	5.5†
			Post-test Static Crush (in.)												
Hood Level		-3.8	19.5	20.6	19.2	21.9	23.2	23.8	24.5	24.9	24.6	24.2	21.6	22.9	23.7
Between Bumper/ Hood		-3.4	19.3	20.6	20.6	22.7	26.9	27.5	26.0	25.2	25.7	22.7	24.1	24.6	24.3
Bumper Level		-2.3	23.6†	24.1	24.2	24.5	24.9	25.2	25.2	25.0	24.4	23.7	23.1	22.6	22.0†

*As viewed from driver position in car.
**Reference plane from rear bumper of car.
†Taken at 36 inches.

TABLE 4-10. CAR EXTERIOR PROFILES AND STATIC CRUSH FOR TEST 8

			Distance Left of Center (in.)*							Distance Right of Center (in.)*					
Location	R.P.** (in.)	Height (in.)	36† 34	30	24	18	12	6	0	6	12	18	24	30	36† 34
			Pre-test Profile (Distance from R.P. - in.)												
Hood Level	220	33.0	10.5	11.1	11.5	9.8	8.8	7.9	7.0	7.9	8.9	9.9	11.7	11.1	10.5
Between Bumper/ Hood	220	28.9	10.5	12.4	12.9	10.6	9.7	8.8	7.4	8.6	9.6	10.5	12.3	12.3	10.4
Bumper Level	220	19.1	8.6†	6.5	6.3	6.6	5.5	4.4	3.3	4.5	5.6	6.8	6.4	6.5	8.6†
			Post-test Profile (Distance from R.P. - in.)												
Hood Level	200	39.5	7.7	8.6	9.0	10.5	12.9	12.8	12.6	13.7	14.2	11.5	8.9	9.6	9.2
Between Bumper/ Hood	200	31.2	8.7	6.0	9.4	15.3	15.9	15.5	11.5	14.7	15.5	15.3	11.0	12.5	9.7
Bumper Level	200	22.9	12.3†	10.1	10.0	10.4	9.9	9.2	8.6	9.1	9.5	9.7	8.9	8.5	10.1†
			Post-test Static Crush (in.)												
Hood Level		-6.5	17.2	17.5	17.5	20.7	24.1	24.9	25.6	25.8	25.3	21.6	17.2	18.5	18.7
Between Bumper/ Hood		-2.3	18.2	13.6	16.5	24.7	26.2	26.7	24.1	26.1	25.9	24.8	18.7	20.2	19.3
Bumper Level		-3.8	23.7†	23.6	23.7	23.8	24.4	24.8	25.3	24.6	23.9	22.9	22.5	22.0	21.5†

*As viewed from driver position in car.
**Reference plane from rear bumper of car.
†Taken at 36 inches.

TABLE 4-11. CAR INTERIOR PROFILES AND STATIC INTRUSION FOR FIXED TEST DEVICE - TEST 7

VEHICLE: 1975 Plymouth Fury 4-Door Sedan

Location	R.P.* (in.)	Height (in.)	Left Front Occupant			At String Potentiometer Centerline	Right Front Occupant		
			L**	C**	R**		L**	C**	R**
Pre-test Profile (Distance from R.P. - in.)									
Dash Level	119	39.4	12.6	12.7	12.6	14.8	14.9	14.7	14.6
Knee Level	119	28.0	18.0	18.2	18.3	20.1	20.0	19.6	19.5
Floor Level	130.5	15.7	18.3	18.9	18.9	23.4	19.5	19.5	19.6
Post-test Profile (Distance from R.P. - in.)									
Dash Level	117	35.6	13.0	13.2	13.2	15.2	16.0	15.9	15.8
Knee Level	117	23.3	18.5	17.6	18.4	18.6	19.4	20.1	20.3
Floor Level	130.4	10.3	15.6	16.0	15.6	11.4	15.5	17.0	17.7
Post-test Static Intrusion (in.)									
Dash Level		3.8	1.6	1.5	1.4	1.6	0.9	0.8	0.8
Knee Level		4.7	1.5	2.6	1.9	3.5	2.6	1.5	1.2
Floor Level		4.4	2.8	3.0	3.4	12.1	4.1	2.6	2.0

*Reference plane from rear bumper of car.
**L = Left, C = Center, R = Right side of occupant seating positions.

TABLE 4-12. CAR INTERIOR PROFILES AND STATIC INTRUSION FOR MOVING TEST DEVICE TEST 8

VEHICLE: 1975 Plymouth Fury 4-Door Sedan

Location	R.P.* (in.)	Height (in.)	Left Front Occupant			At String Potentiometer Centerline	Right Front Occupant		
			L**	C**	R**		L**	C**	R**
		Pre-test Profile (Distance from R.P. - in.)							
Dash Level	119	39.9	13.7	13.8	13.7	16.2	16.2	16.0	15.8
Knee Level	119	27.9	18.5	18.4	18.8	20.4	20.3	20.0	20.1
Floor Level	131.1	14.7	19.1	19.1	19.0	18.2	19.5	19.5	19.5
		Post-test Profile (Distance from R.P. - in.)							
Dash Level	113	38.4	18.0	18.4	18.2	20.7	20.7	20.8	20.4
Knee Level	113	26.2	23.9	23.6	23.7	24.4	25.0	25.2	25.3
Floor Level	130.6	14.3	12.6	17.5	16.7	15.0	17.1	16.9	18.8
		Post-test Static Intrusion (in.)							
Dash Level		1.5	2.7	1.4	1.5	1.5	1.5	1.2	1.4
Knee Level		1.7	0.6	0.8	1.1	2.0	1.3	0.8	0.8
Floor Level		0.4	2.0	2.1	2.8	3.7	3.0	3.1	1.2

*Reference plane from rear bumper of car.
**L = Left, C = Center, R = Right side of occupant seating positions.

TABLE 4-13. STEERING WHEEL DISPLACEMENT VALUES

VEHICLE: 1975 Plymouth Fury

	Displacement (in.)					
	Test 7 (Fixed Test Device)			Test 8 (Moving Test Device)		
Wheel Location	X*	Y*	Z*	X*	Y*	Z*
Top	-2.1	-0.1	-10.6	-3.1	-0.5	-2.1
Hub	-1.1	-0.1	-7.9	-2.2	-0.5	-1.8
Bottom	-1.5	-0.0	-7.9	-2.4	-0.5	-2.1

*Reference for X, Y, Z measurements are the rear bumper (+ forward), vehicle centerline (+ right), and ground level (+ up), respectively.

into contact with the dash area. This caused large pulses to be seen by the occupant head accelerometers. In Test No. 8, the steering wheel rim was not bent by the left front occupant, resulting in smaller crash pulses to be seen on data from the driver's chest.

A summary of Plymouth accelerometer and string potentiometer data for both tests is given in Tables 4-14 through 4-19. Refer to Figure 3-1 for their locations in the vehicle. Compartment accelerometers and engine accelerometers were averaged to obtain a more representative picture of what was occurring at those locations. String potentiometer data was used to measure firewall intrusion in the occupant compartment. However, if the peak intrusion does not occur at the location where the measurement was taken, the readings could be low compared to the post-test static measurements.

In both tests, since the amount of crush was high, rotation of firewall and engine accelerometers (Nos. 4, 6, and 9) occurred, giving erroneous velocity and displacement peaks. In Test 8, the lower engine accelerometer (location 9) was lost due to a cut

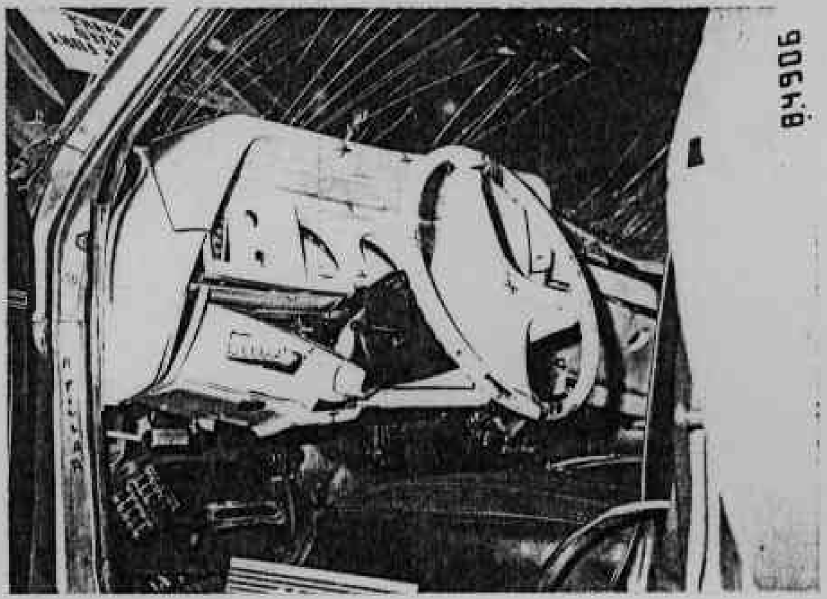


Figure 4-9. Post-test Driver Compartment - Test 7.

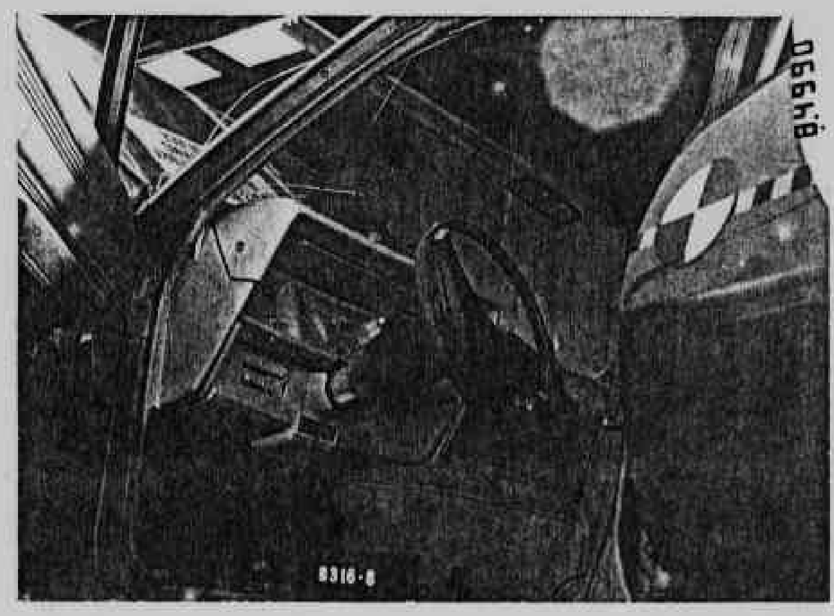


Figure 4-10. Post-test Driver Compartment - Test 8.

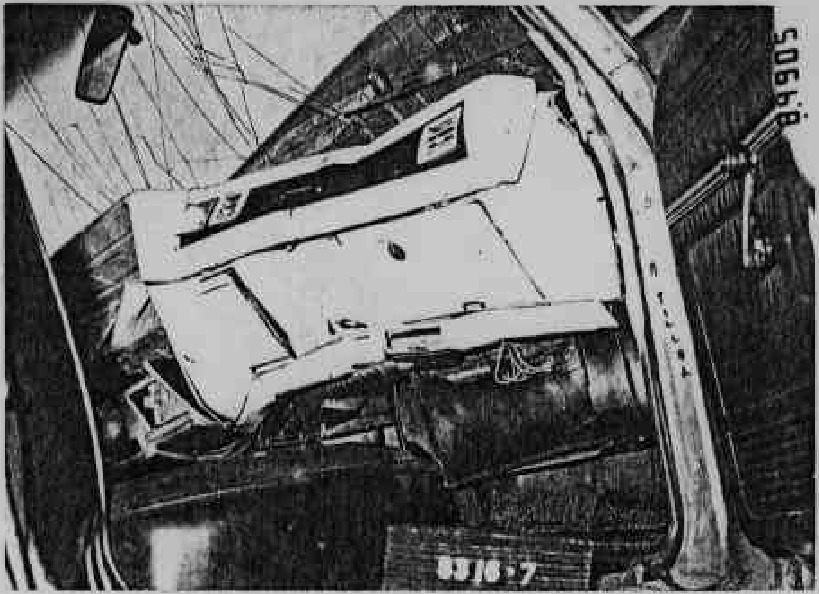


Figure 4-11. Post-test Passenger Compartment - Test 7.

Figure 4-12. Post-test Passenger Compartment - Test 8.

TABLE 4-14. SUMMARY OF CAR ACCELEROMETER DATA FOR FIXED TEST DEVICE TEST 7

	Maximum Acceleration		Minimum Velocity		Maximum Displacement	
Accelerometer Number	A (G)	Time (msec)	V (mph)	Time (msec)	S (in.)	Time (msec)
1X	-35.52	39	-6.25	178	+47.32	111
1Z	+31.06	47	-0.07	10	+7.84	200
2X	-33.31	23	-7.36	168	+46.18	109
2Z	+19.60	63	-0.02	8	+9.48	200
3X	-55.77	58	-8.16	181	+47.05	110
3Z	-26.08	83	-2.68	107	+1.14	200
4X	-93.66	61	+7.65*	200	+66.39*	200
4Z	-53.04	55	-3.93	182	+2.66	86
5X	-80.34	57	+6.89*	144	+63.07*	200
5Z	+32.09	103	-0.80	37	+27.36	200
6X	-92.37	52	-4.81	65	+31.00*	55
7X	-64.20	36	-2.54	179	+45.04	135
8X	-48.09	70	-3.56	186	+46.09	134
8Y	-27.39	50	-3.40	194	0.00	10
8Z	+44.48	57	-5.16	176	+2.01	81
9X	-59.61	45	-3.09	179	+41.81*	128

See Figure 3-1 for definition of accelerometer numbers.
*Data questionable because of rotation of accelerometer.

TABLE 4-15. SUMMARY OF CAR ACCELEROMETER AVERAGED DATA FOR FIXED TEST DEVICE TEST 7

	Maximum Acceleration		Minimum Velocity		Maximum Displacement	
Accelerometer Number	A (G)	Time (msec)	V (mph)	Time (msec)	S (in.)	Time (msec)
Average of 1X and 2X	-31.07	78	-6.74	179	46.75	110
Average of 6X and 9X	-74.27	52	-2.83	180	35.60	121

TABLE 4-16. SUMMARY OF CAR ACCELEROMETER DATA FOR MOVING TEST DEVICE TEST 8

	Maximum Acceleration		Minimum Velocity		Maximum Displacement	
Accelerometer Number	A (G)	Time (msec)	V (mph)	Time (msec)	S (in.)	Time (msec)
1X	-26.94	37	-1.70	135	+27.20	103
1Z	27.34	19	-0.11	5	+8.27	200
2X	-31.81	20	-3.51	123	+24.12	93
2Z	-28.27	59	-2.63	111	+2.08	80
3X	-51.79	19	-4.10	123	+24.87	93
3Z	+33.56	57	-1.45	26	+2.01	200
4X	-65.27	56	+4.50*	137	+39.82*	200
4Z	-83.49	47	-5.85	110	+1.99	70
5X	+74.02	53	+8.22*	174	+54.65*	200
5Z	+17.95	45	-0.23	25	+15.37	200
6X	-124.73	40	-11.32	49	+18.11	200
7X	-121.92**	57	17.03**	69	+133.76**	200
8X	-45.17	38	-0.58	137	+28.73	200
8Y	+34.61	54	-0.91	22	+9.87	200
8Z	+60.79	57	-4.08	54	+0.10	34
9X	-129.68**	68	-166.15**	200	+17.86**	45

See Figure 3-1 for definition of accelerometer numbers.
*Questionable data due to rotation of accelerometer.
**Data system failure.

TABLE 4-17. SUMMARY OF CAR ACCELEROMETER AVERAGED DATA FOR MOVING TEST DEVICE TEST 8

	Maximum Acceleration		Minimum Velocity		Maximum Displacement	
Accelerometer Number	A (G)	Time (msec)	V (mph)	Time (msec)	S (in.)	Time (msec)
Average of 1X and 2X (Compartment)	-29.23	20	-2.59	132	25.61	98
Average of 6X and 9X (Engine)	-104.44*	40	-82.66*	200	17.42*	42

*Data system failure.

TABLE 4-18. SUMMARY OF CAR STRING POTENTIOMETER DATA FOR FIXED TEST DEVICE TEST 7

Displacement Potentiometer		Maximum Dynamic Displacement	
(Number)	(Location)	D (in.)	Time (msec)
SP7	Firewall	4.9	106

TABLE 4-19. SUMMARY OF CAR STRING POTENTIOMETER DATA FOR MOVING TEST DEVICE TEST 8

Displacement Potentiometer		Maximum Dynamic Displacement	
(Number)	(Location)	D (in.)	Time (msec)
SP7	Firewall	Data System Failure	

cable. Data used in analysis used only data from the upper engine accelerometer (location 6). In addition, data from the accelerometer located on the vehicle front crossmember (location 7) was lost, also due to instrumentation failure during impact.

4.3 TEST DEVICE SUMMARY

This section of the report presents a summary of data gathered from the fixed and moving Test Devices. This includes summaries of load cell, string potentiometer, strain gauge, and accelerometer data, and post-test honeycomb profiles for both fixed and moving Test Device tests.

Post-test Test Device configurations for fixed and moving Test Device tests are shown in Figures 4-13 and 4-14.

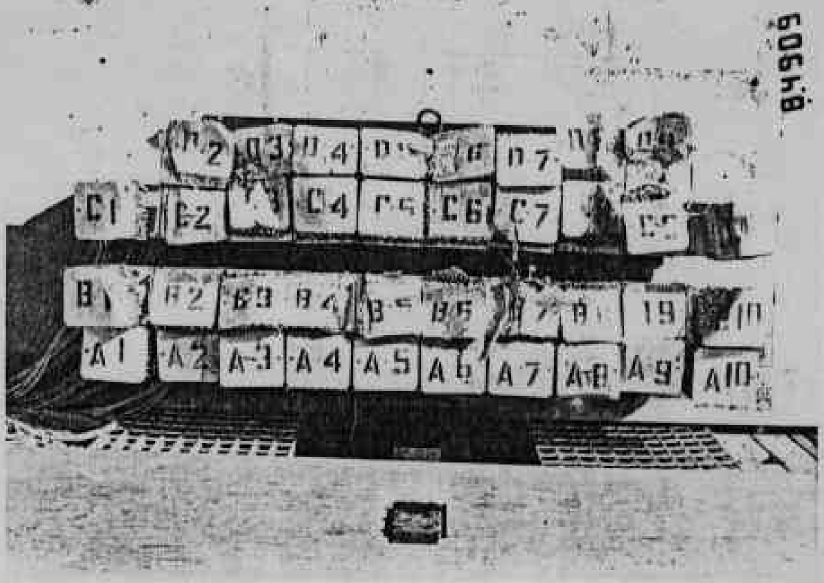


Figure 4-13. Post-test Fixed Test Device Configuration - Test 7.

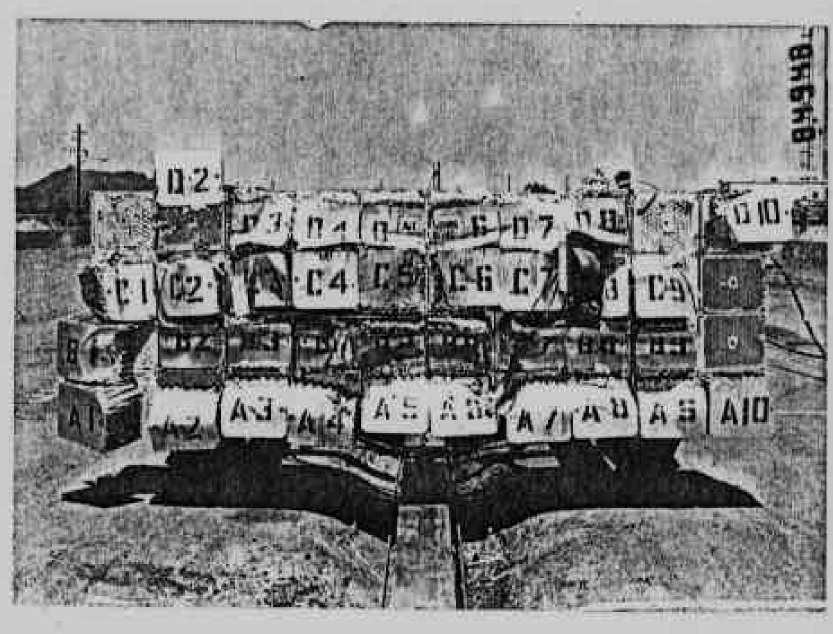


Figure 4-14. Post-test Moving Test Device Configuration - Test 8.

A summary of peak values of load cell data is shown in Table 4-20 for Test 7 and Table 4-21 for Test 8. These were the maximum measured forces for each load cell along with its corresponding time recorded during the event. Tables 4-22 and 4-23 present a summary of grouped load cell data for each test. The front face of the Test Device was divided into six areas of loading. These data show which areas of the car tended to be more aggressive. Load cell forces for individual load cells are shown in Figures 4-15 through 4-22. These plots also show the relative lateral symmetry of car data recorded with the Test Device face. Some loads may have been lost during the period 25-50 msec in Test 7 and 24-40 msec in Test 8, due to load cell contact with the backing plate (B5, B6, B9).

A load cell distribution at selected time intervals for the car/Test Device interface for each test is shown in Figures 4-23 through 4-28. These values are shown for forces over 1,000 pounds at a particular time segment. Any location with a value below 1,000 pounds was not considered an aggressive part of the car at that particular time frame. Calcomp plots of all load cell data by columns and grouped load cell summations are shown in Appendix B for Test 7 and Appendix C for Test 8.

In the fixed Test Device test, the maximum total load cell force was 77,740 pounds at 34 msec after impact and the maximum individual load cell force recorded was 11,300 pounds on module B5 at 87 msec.

The fixed Test Device structure was damaged when the bumper of the car wedged between Rows B and C. This caused the aluminum

TABLE 4-20. SUMMARY OF MAXIMUM LOAD CELL DATA FOR FIXED TEST DEVICE - TEST 7

Parameter	Right Half of Car					Left Half of Car				
Load Cell (No.)	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1
Force (klb)	1.78	6.33	2.48	1.83	2.34	2.23	1.64	3.07	5.99	0.95
Time (msec)	35	37	31	18	17	17	19	33	49	36
Load Cell (No.)	C10	C9	C8	C7	C6	C5	C4	C3	C2	C1
Force (klb)	1.18	1.98	2.83	2.56	2.94	2.35	1.73	2.89	2.49	0.70
Time (msec)	32	27	37	56	46	135	53	36	36	35
Load Cell (No.)	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1
Force (klb)	0.87	10.40	2.54	6.38	10.26	11.31*	4.21	3.27	7.34	0.73
Time (msec)	14	30	16	32	66	87	94	32	48	15
Load Cell (No.)	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
Force (klb)	0.24	2.38	0.77	0.35	0.62	0.65	0.40	0.40	2.32	0.48
Time (msec)	37	103	108	27	14	14	16	17	95	103

*Maximum measured force.

TABLE 4-21. SUMMARY OF MAXIMUM LOAD CELL DATA FOR MOVING TEST DEVICE - TEST 8

Parameter	Right Half of Car					Left Half of Car				
Load Cell (No.)	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1
Force (klb)	1.66	3.92	2.80	2.61	1.99	2.33	2.54	4.16	6.14	2.95
Time (msec)	48	26	21	31	12	30	30	28	28	27
Load Cell (No.)	C10	C9	C8	C7	C6	C5	C4	C3	C2	C1
Force (klb)	0.52	4.36	3.20	2.30	2.68	2.84	2.38	2.79	3.63	3.53
Time (msec)	28	25	25	40	39	38	37	26	27	20
Load Cell (No.)	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1
Force (klb)	0.39	11.21	2.92	5.86	15.43*	13.87	5.85	2.95	12.54	1.18
Time (msec)	11	32	22	46	45	40	32	12	35	10
Load Cell (No.)	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
Force (klb)	0.26	0.87	1.29	3.47	3.75	2.09	3.12	0.98	1.04	0.36
Time (msec)	17	10	12	15	11	21	102	12	10	17

*Maximum measured force.

TABLE 4-22. SUMMARY OF GROUPED LOAD CELL DATA - TEST 7

Parameter	Right Side of Car	Center of Car	Left Side of Car
Load Cells (No.)	D8 - D10 & C8 - C10	D4 - D7 & C4 - C7	D1 - D3 & C1 - C3
Force (klb)	14.59	15.37	14.82
Time (msec)	35	54	36
Load Cells (No.)	B8 - B10 & A8 - A10	B4 - B7 & A4 - A7	B1 - B3 & A1 - A3
Force (klb)	13.01	30.24	9.39
Time (msec)	30	67	48

TABLE 4-23. SUMMARY OF GROUPED LOAD CELL DATA - TEST 8

Parameter	Right Side of Car	Center of Car	Left Side of Car
Load Cells (No.)	D8 - D10 & C8 - C10	D4 - D7 & C4 - C7	D1 - D3 & C1 - C3
Force (klb)	15.48	15.71	20.99
Time (msec)	26	39	27
Load Cells (No.)	B8 - B10 & A8 - A10	B4 - B7 & A4 - A7	B1 - B3 & A1 - A3
Force (klb)	12.95	43.14	14.16
Time (msec)	23	35	23

plates of the Test Device to undergo high torquing forces which overstressed the attachment bolts holding the horizontal beams to the vertical member of the Test Device (see Figure 4-6). Post-test inspection of the Test Device fixture showed the 5/8-inch grade nine attachment bolts of Row B pulled completely out of the vertical member. Attachment bolts on Rows C and D were bent upward due to the failure of Row B. The aggressive areas of the

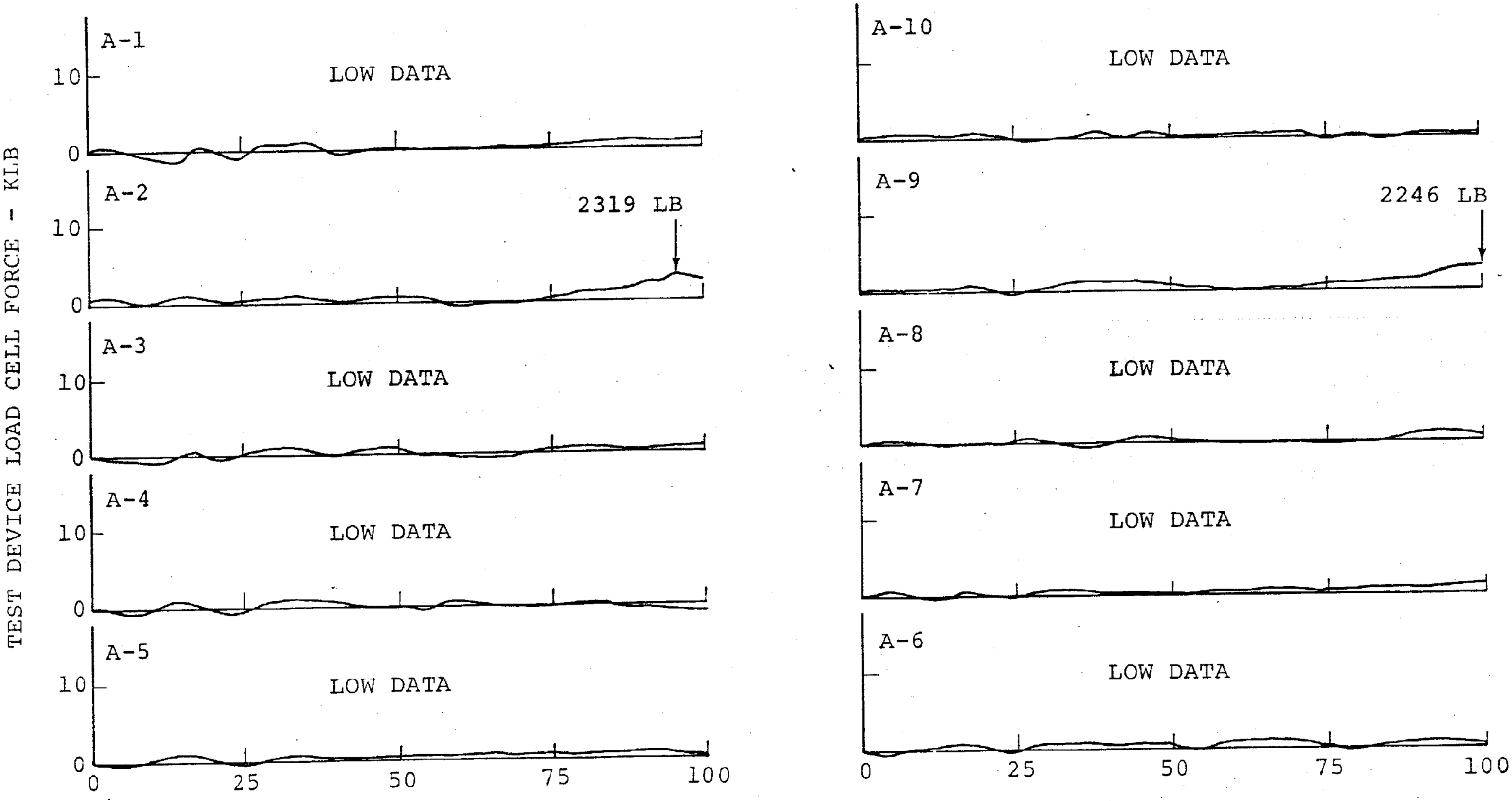


Figure 4-15. Test Device Load Cell Forces on Row A for Test 8316-7.

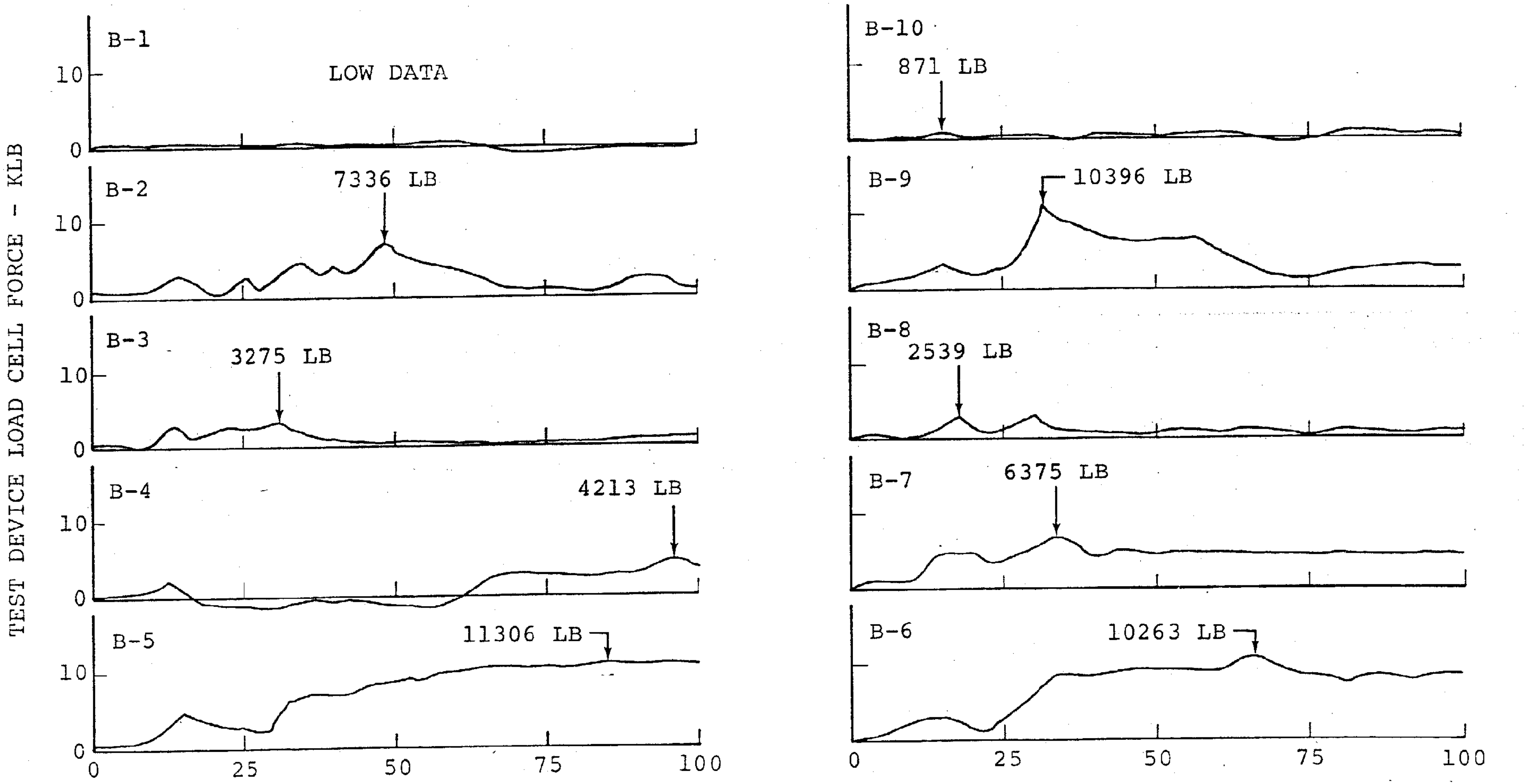


Figure 4-16. Test Device Load Cell Forces on Row B for Test 8316-7.

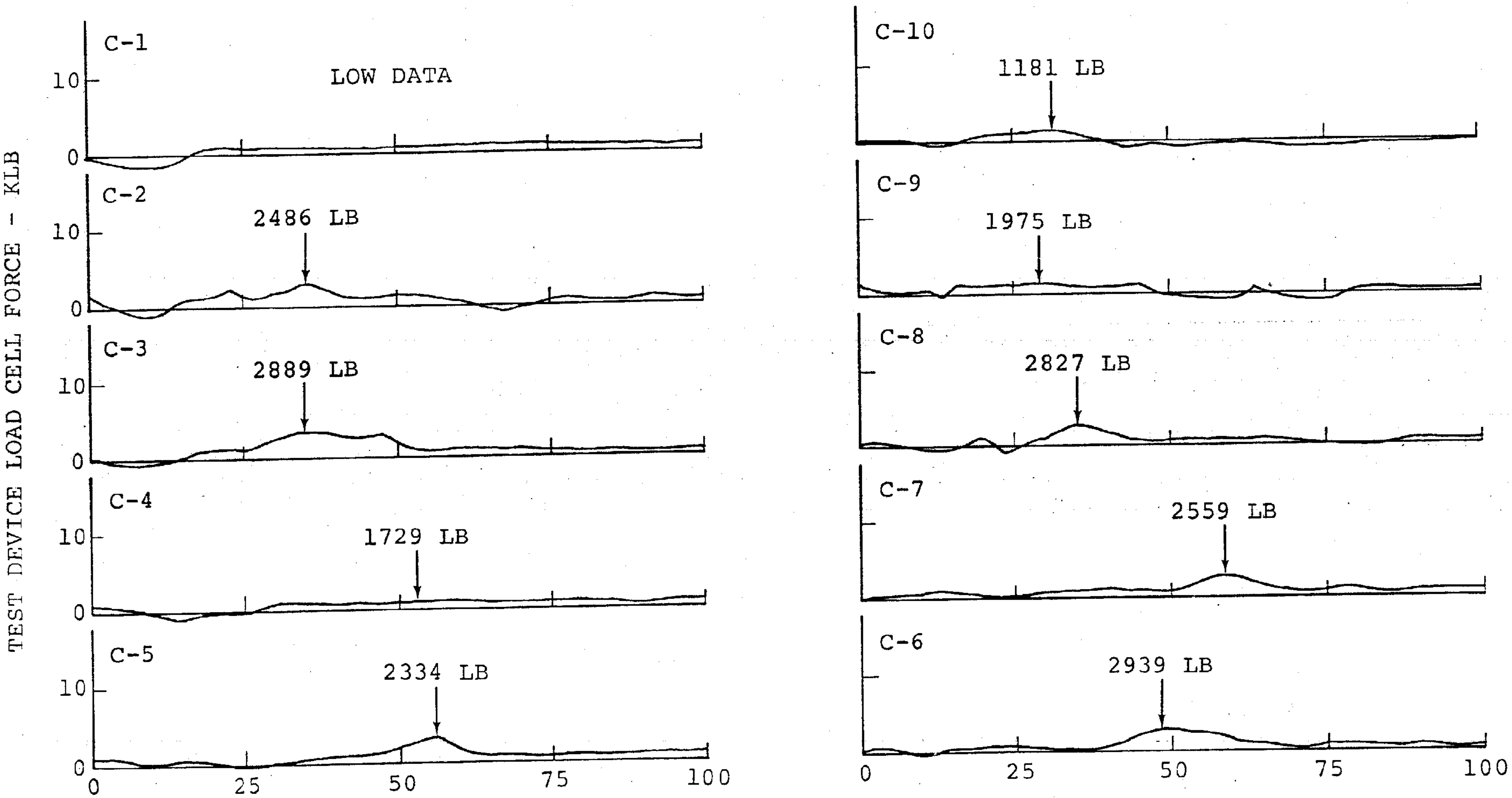


Figure 4-17. Test Device Load Cell Forces on Row C for Test 8316-7.

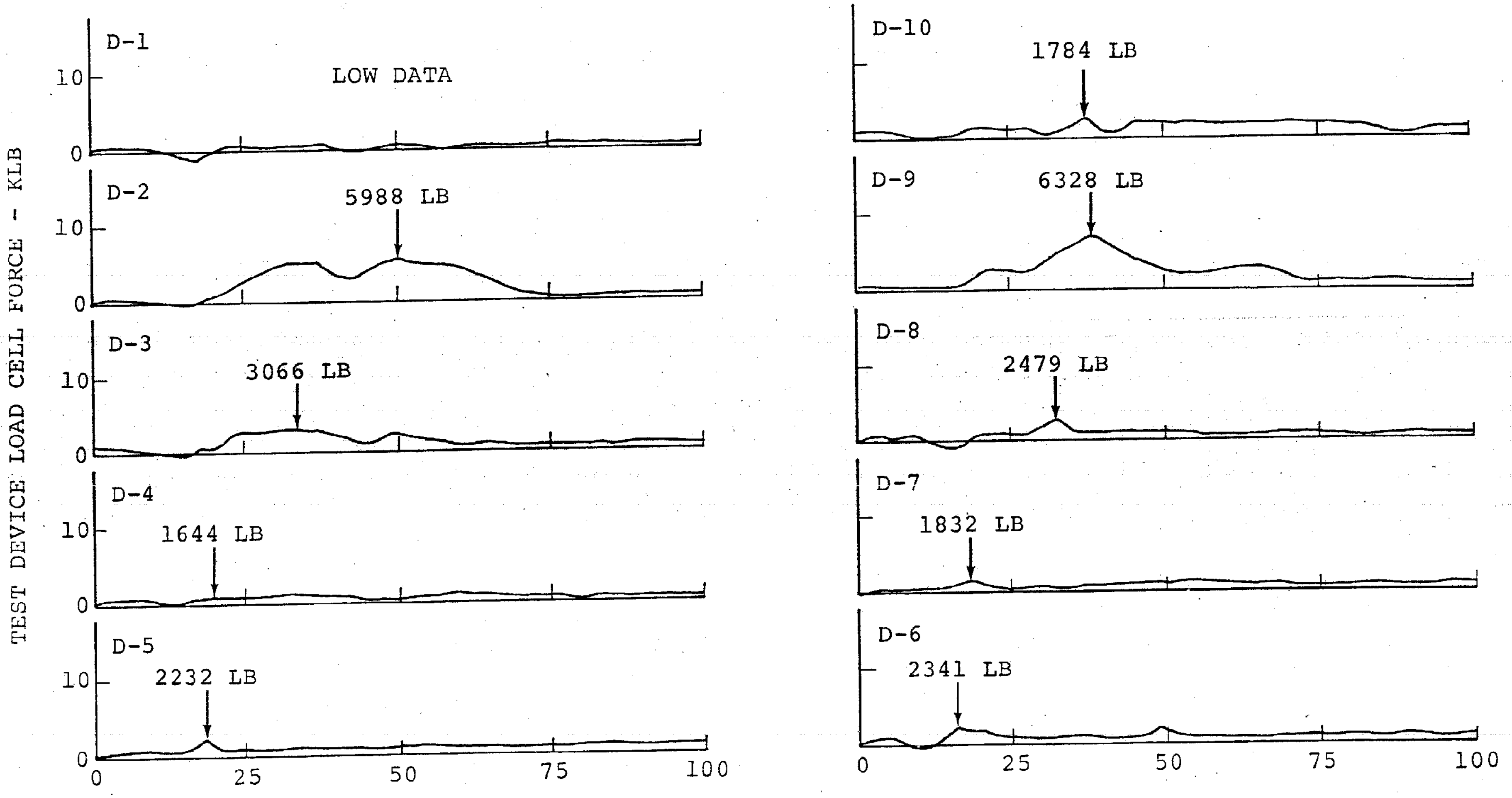


Figure 4-18. Test Device Load Cell Forces on Row D for Test 8316-7.

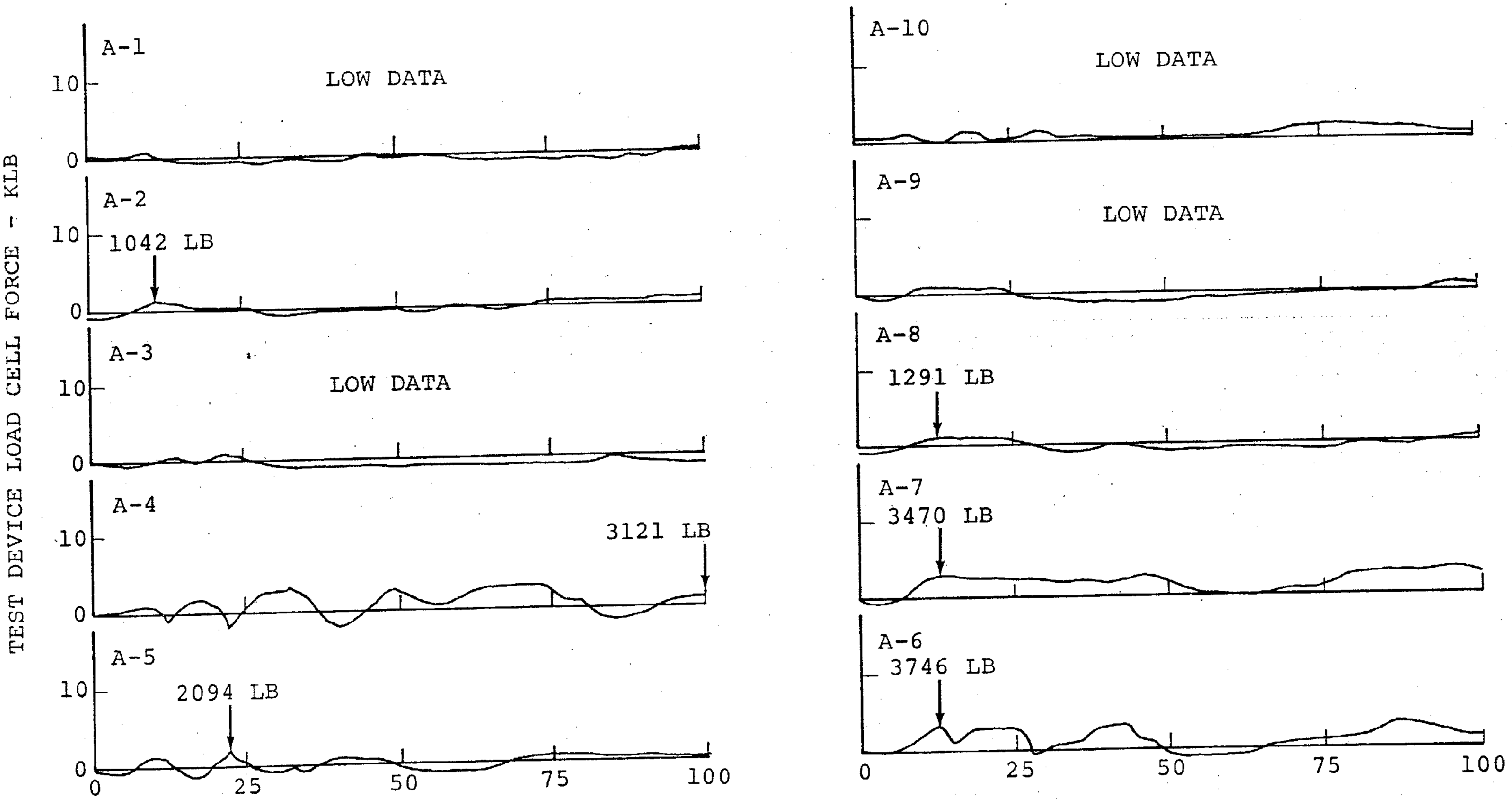
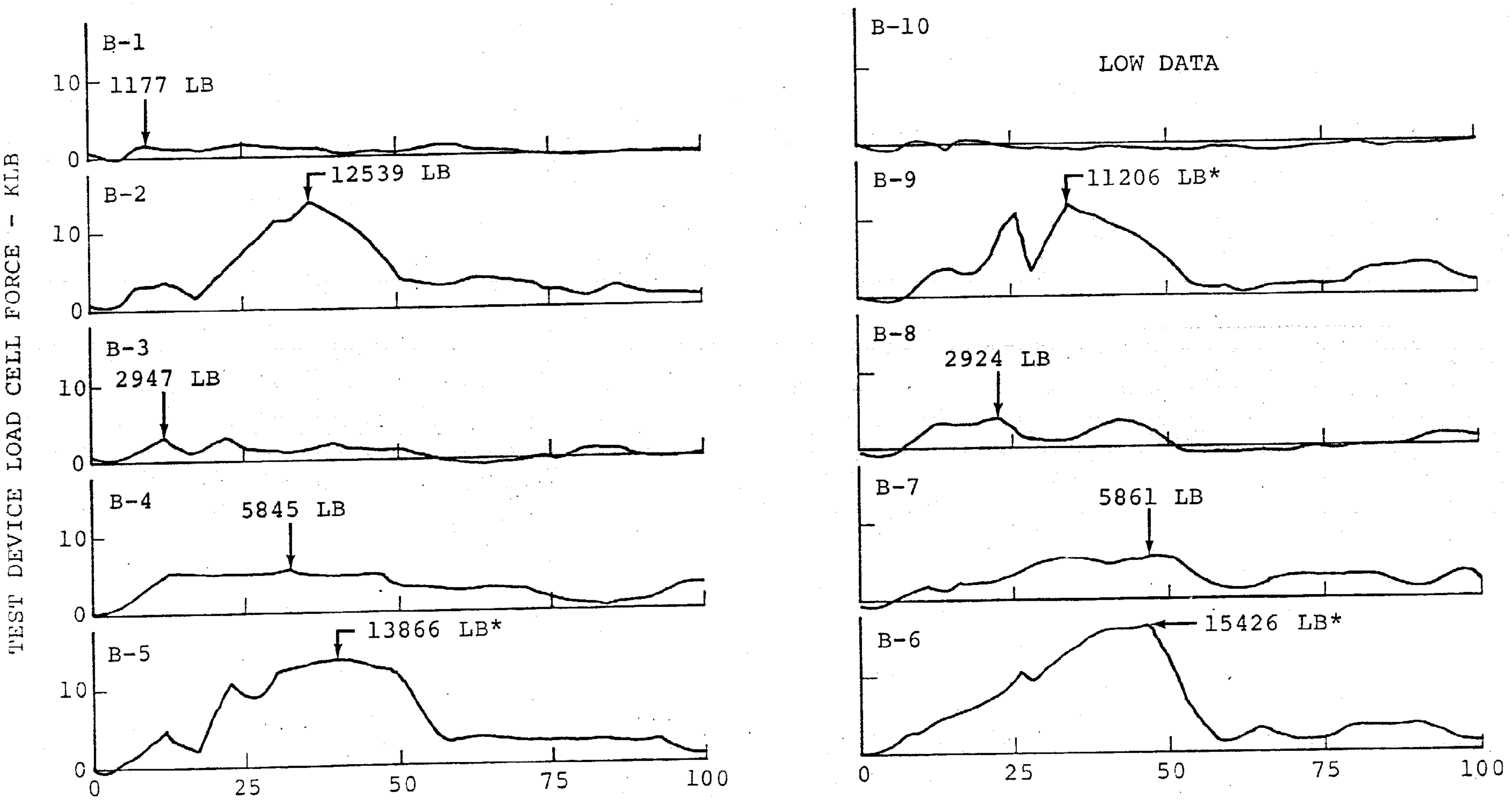


Figure 4-19. Test Device Load Cell Forces on Row A for Test 8316-8.



*Some load may have been lost between 24 and 40 msec (see Figure 4-33).

Figure 4-20. Test Device Load Cell Forces on Row B for Test 8316-8.

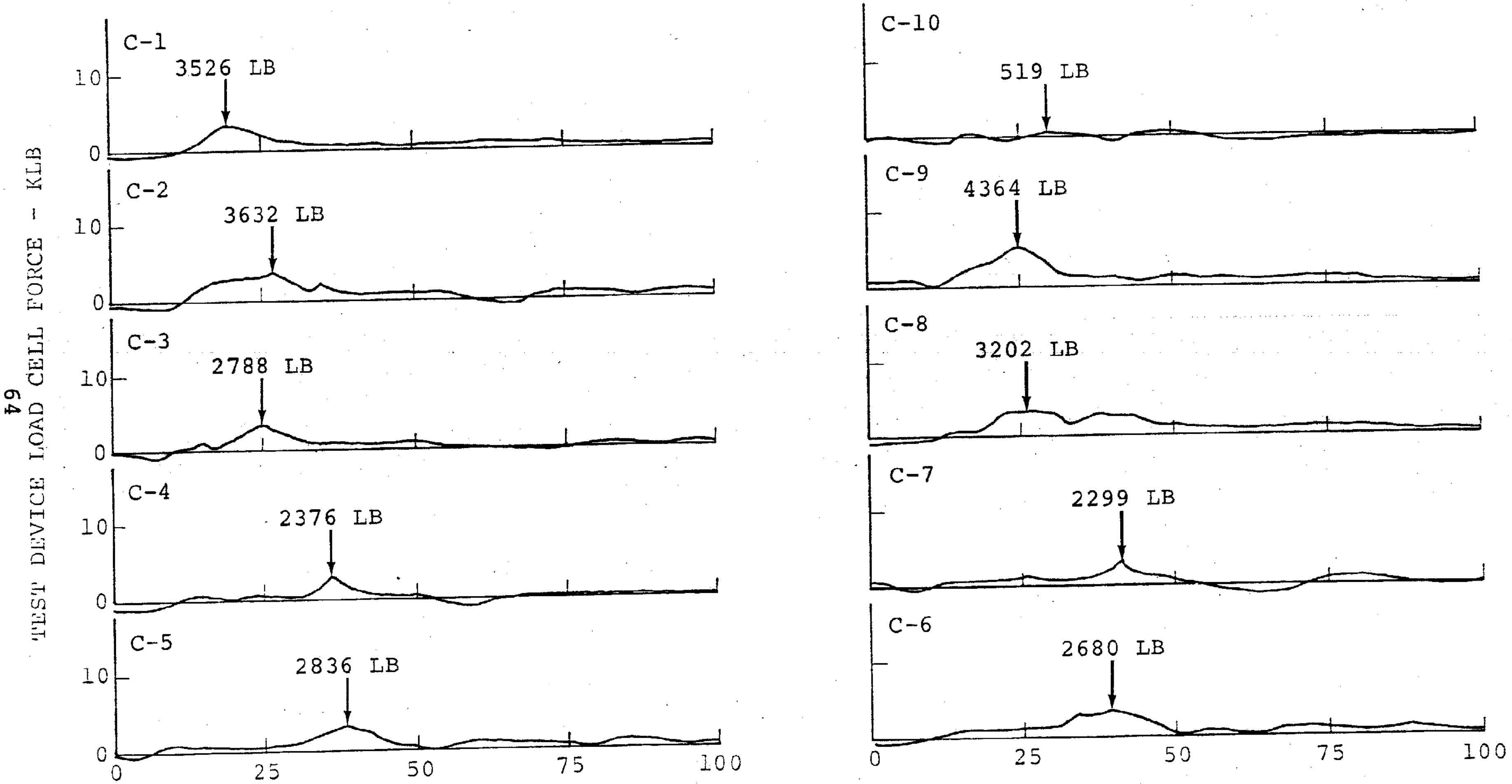


Figure 4-21. Test Device Load Cell Forces on Row C for Test 8316-8.

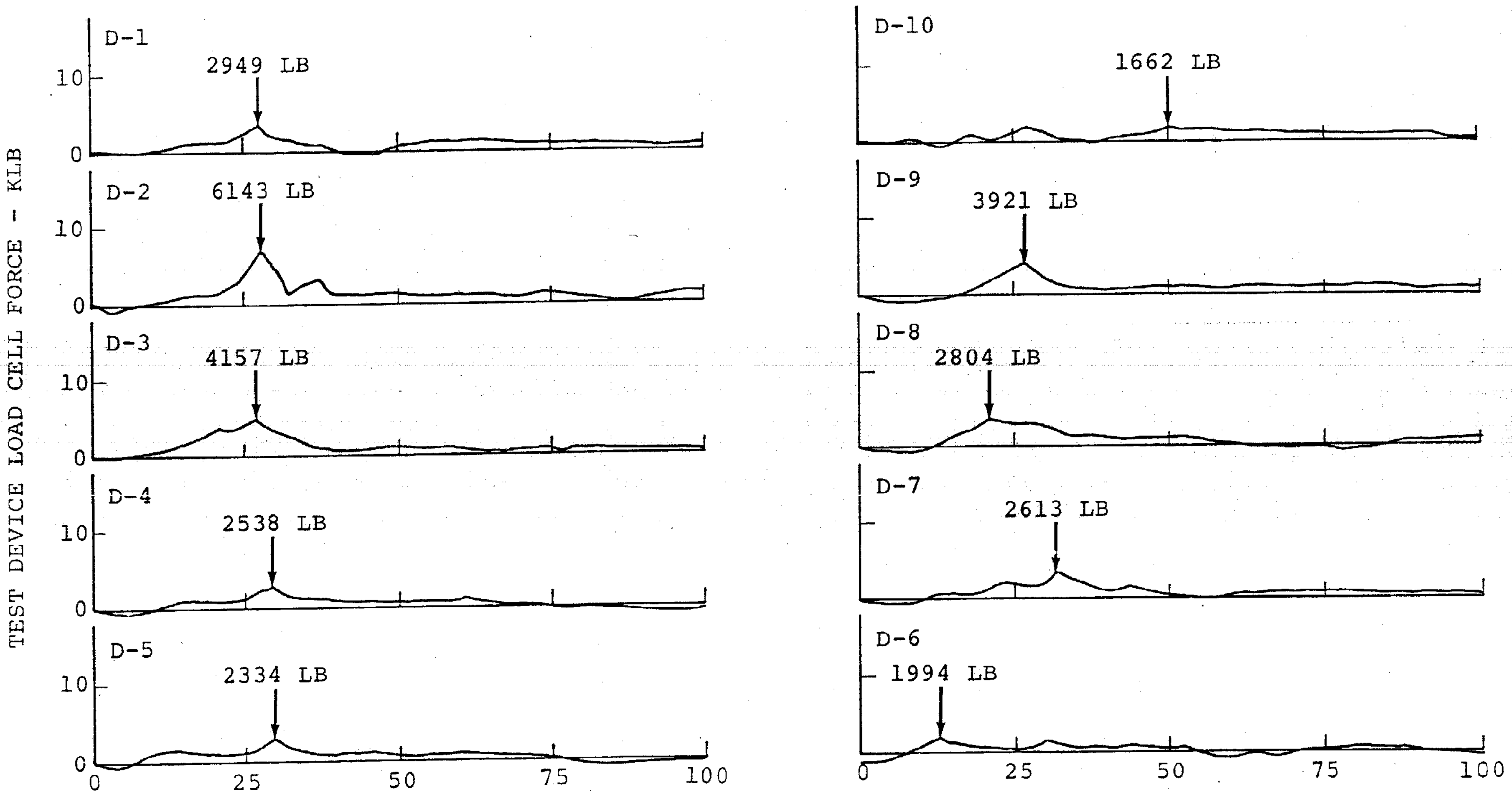


Figure 4-22. Test Device Load Cell Forces on Row D for Test 8316-8.

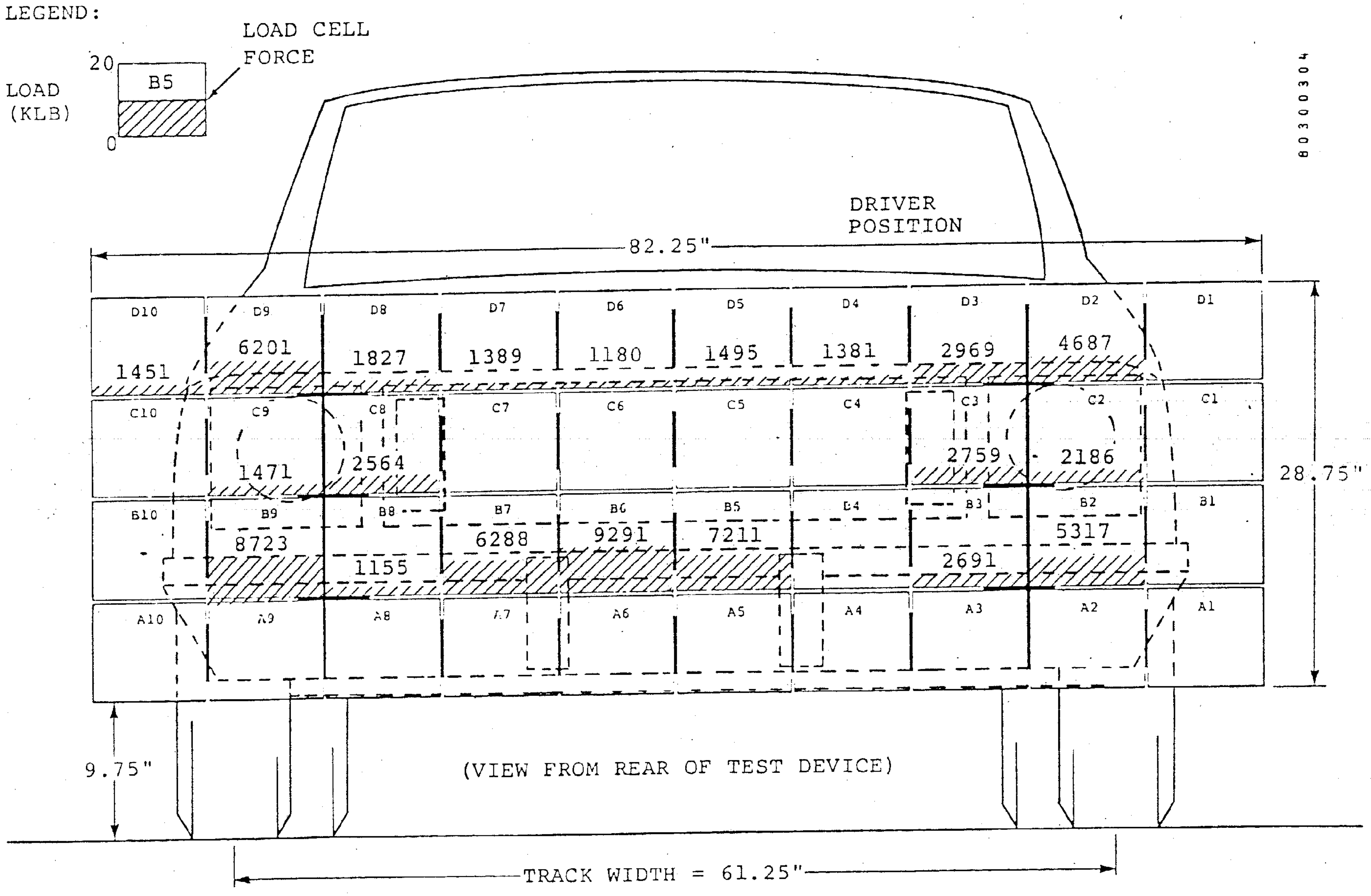


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Figure 4-23. 1975 Plymouth Fury/Fixed Test Device Load Distribution at 34 msec.

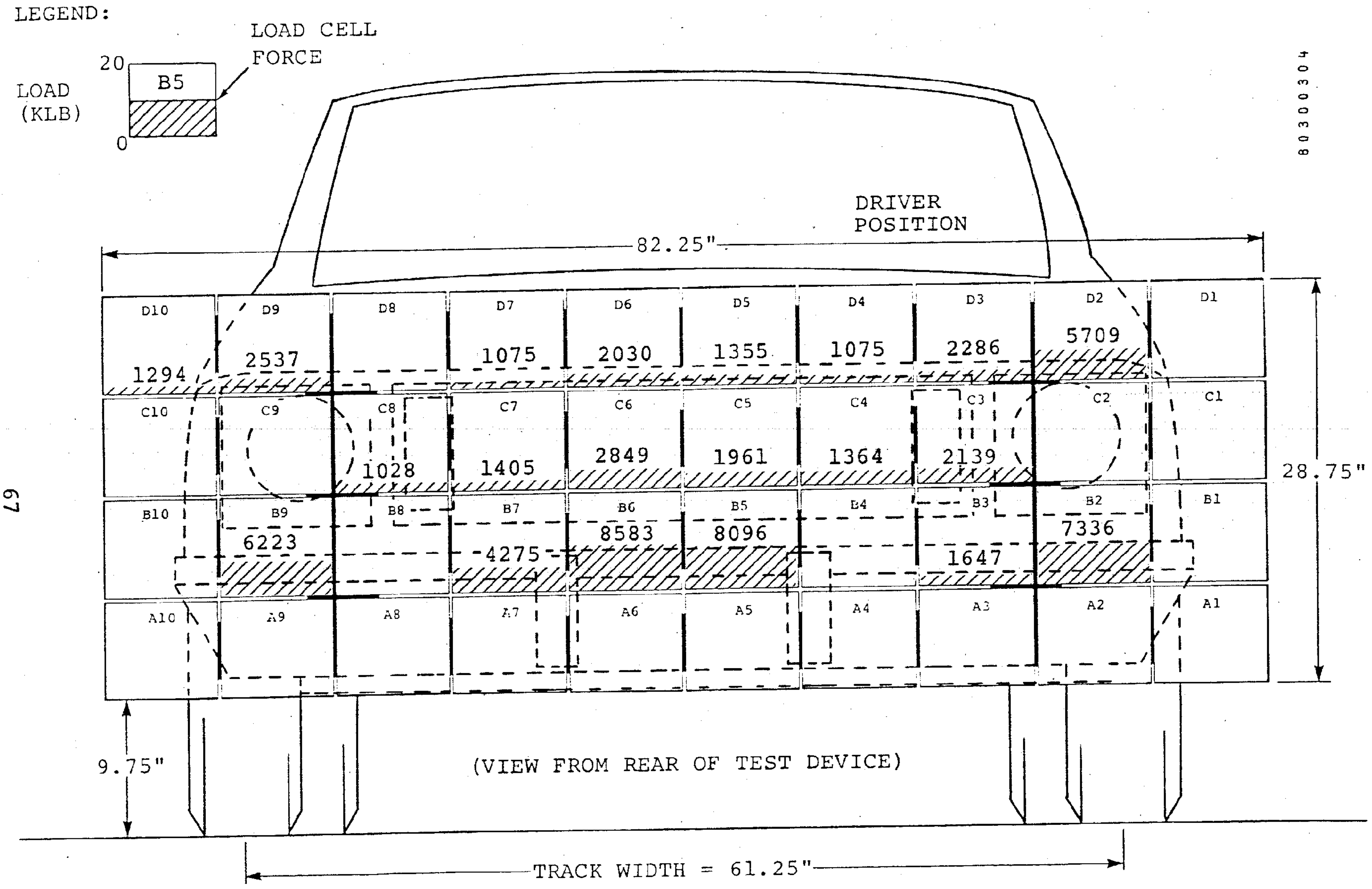

Figure 4-24. 1975 Plymouth Fury/Fixed Test Device Load Distribution at 48 msec.

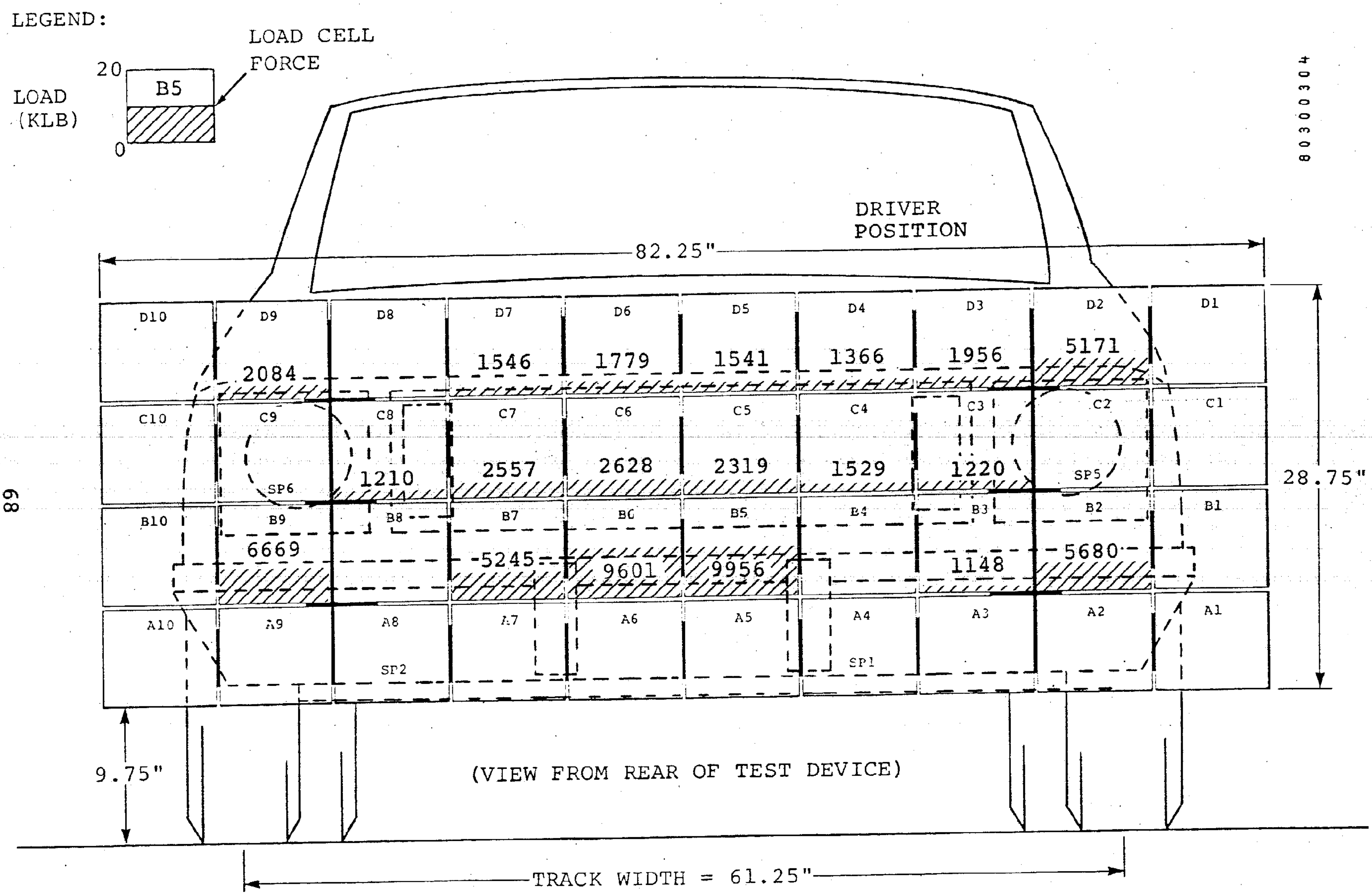

Figure 4-25. 1975 Plymouth Fury/Fixed Test Device Load Distribution at 55 msec.

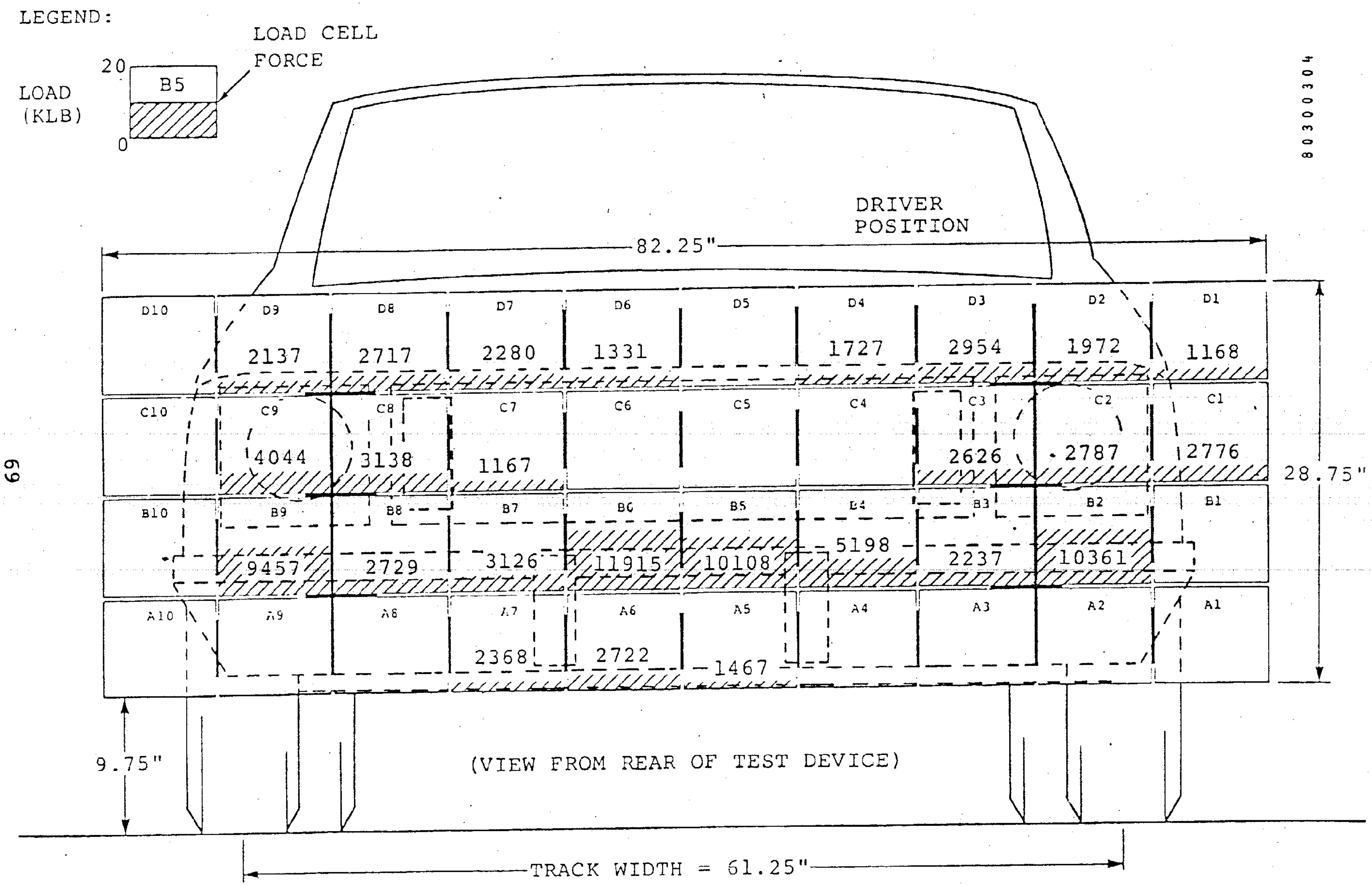

Figure 4-26. 1975 Plymouth Fury/Moving Test Device Load Distribution at 23 msec.

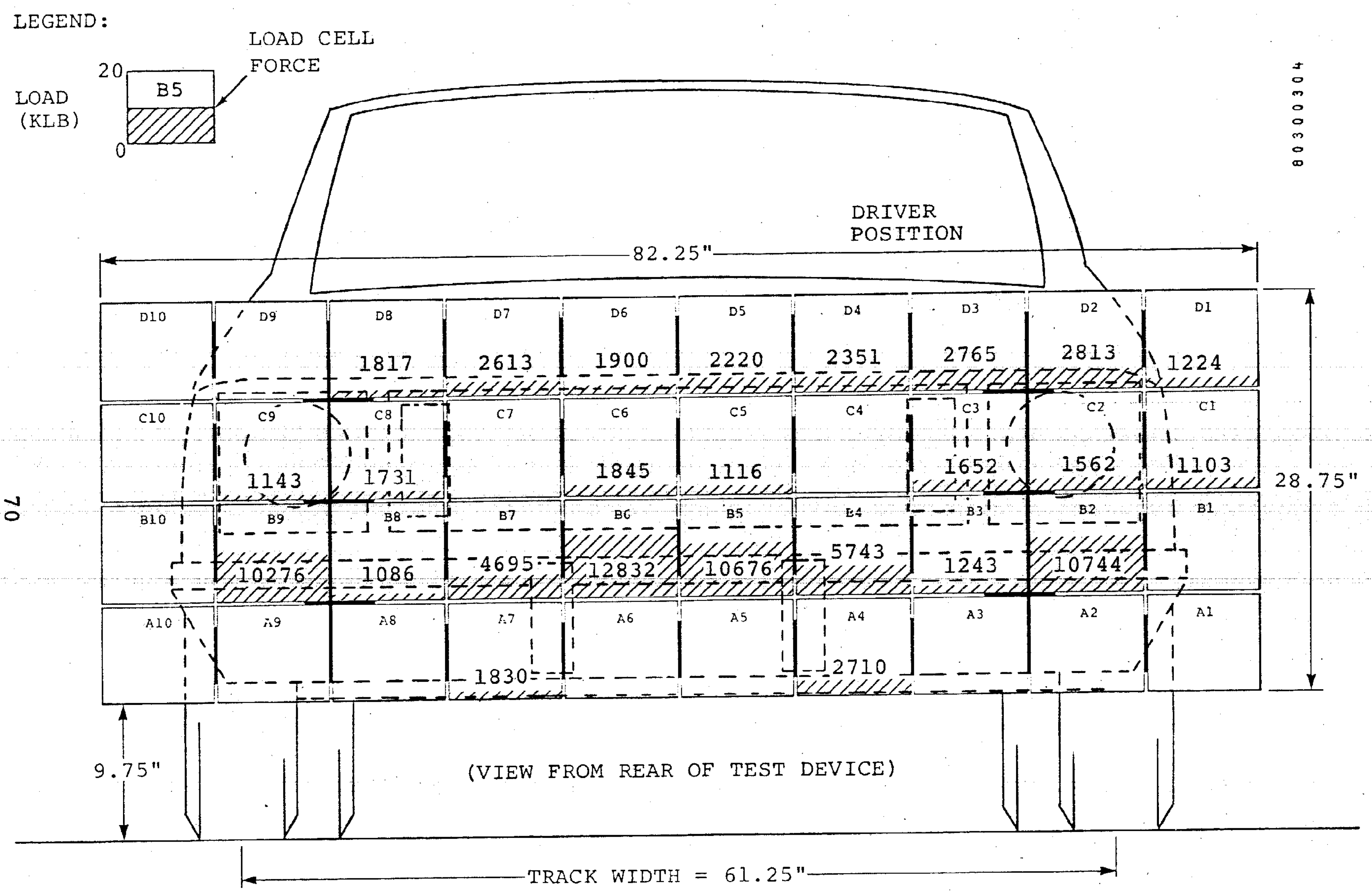

Figure 4-27. 1975 Plymouth Fury/Moving Test Device Load Distribution at 31 msec.

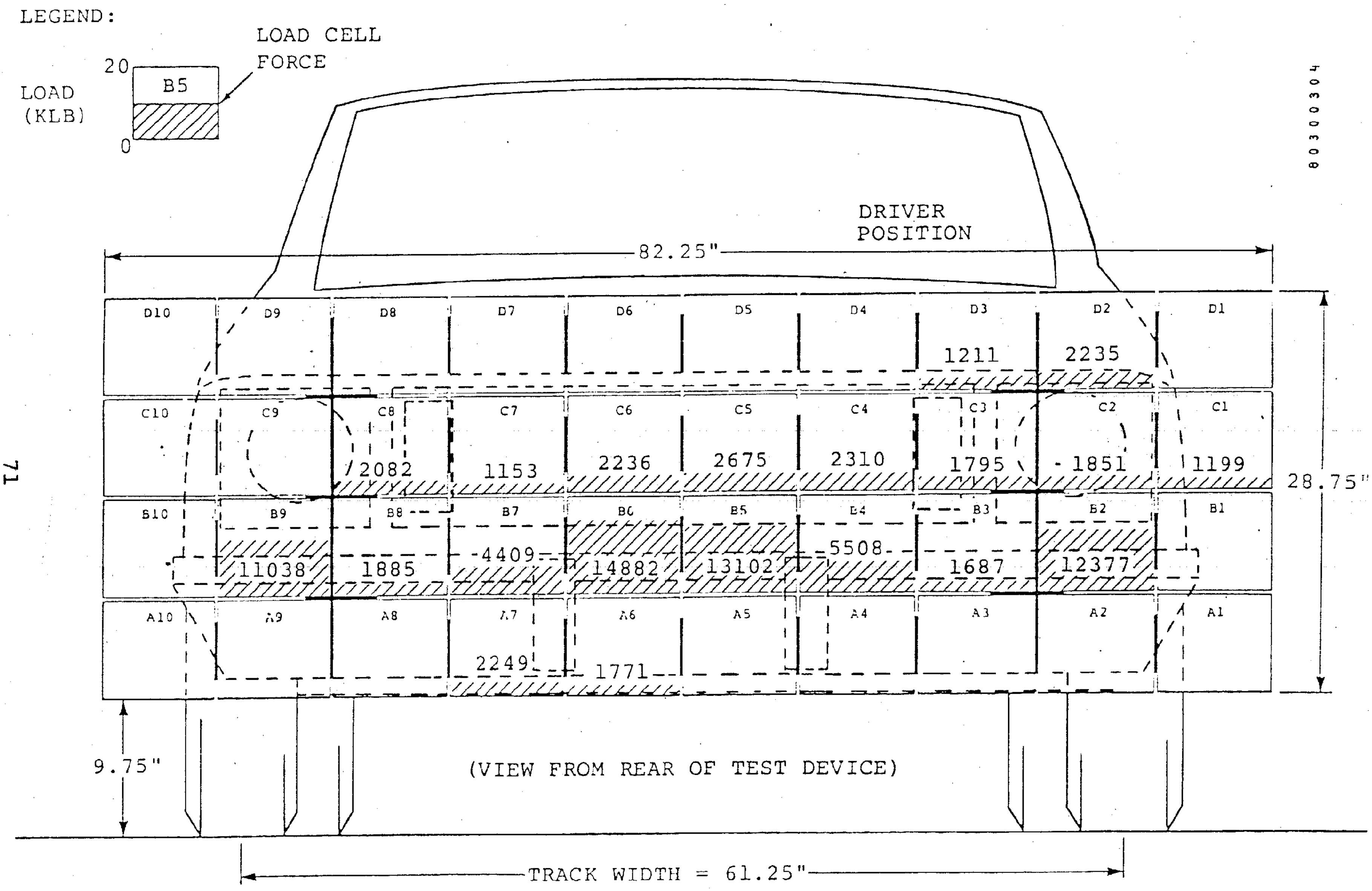

Figure 4-28. 1975 Plymouth Fury/Moving Test Device Load Distribution at 36 msec.

car appeared to be the bumper/engine area, bumper guards, hood line, and outer edges of the front of the car. Loads measured were not all recorded due to bottoming out of some Row B mounting plates, and load lost in damaging the Test Device Structure.

For the moving Test Device test, the total load cell force was 98,370 pounds* at 23 msec after impact and the maximum individual load cell force recorded was 15,400 pounds on module B6 at 45 msec. Due to the damage done to the fixed Test Device structure, modifications were made to the moving Test Device to aid in strengthening its structure. This consisted of the following modifications done before Test 8:

- Welding 4" x 4" x 1/4" steel plate to back of horizontal beams at the point of attachment to the vertical beam to prevent vertical rotation.
- Bolting on to front of the four horizontal beams a 25-3/4" x 2-1/2" x 1/4" vertical stiffener to each side of the Test Device to prevent vertical rotation.
- Redrilling and tapping the vertical beam on the Test Device from 5/8" to 3/4" to give the attachment bolts more thread support.
- Due to localized bending of the material behind two of the load cells on Row B horizontal beam, the beam was exchanged with the Row A horizontal beam and reattached.

Accelerometer data recorded from the moving Test Device are given in Table 4-24. Accelerometers were located on the right and left frame members of the Test Device and were averaged to give acceleration, velocity, and displacement curves for the Test Device. These data were used in comparing the total force from both load cell and accelerometer data for both tests, which are presented in Tables 4-25 and 4-26.

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*The actual force may have reached 158,000 pounds (see Figure 4-33).

TABLE 4-24. SUMMARY OF MOVING TEST DEVICE ACCELEROMETER DATA

Accelerometer Number	Maximum Acceleration A (G)	Maximum Acceleration Time (msec)	Minimum Velocity V (mph)	Minimum Velocity Time (msec)	Maximum Displacement S (in.)	Maximum Displacement Time (msec)
A1R	-39.4	40	-3.6	119	18.2	81
A2L	-39.8	38	-2.3	114	18.2	86
Average of A1R and A2L	-39.4	39	-3.0	116	18.2	83

TABLE 4-25. COMPARISON OF TOTAL FORCE FROM LOAD CELL AND ACCELEROMETER DATA - FIXED TEST DEVICE

Parameter	Fixed Test Device Force Data*	Fixed Test Device Acceleration Data**	Engine/Car Acceleration Data***
Force (lb)	77,740	N/A	150,300
Time (msec)	34		39

*Sum of 40 load cells.

**Average of Test Device accelerometers 1 and 2 times Test Device weight.

***Average of car accelerometers 1 and 2 times car weight plus average of engine accelerometers 6 and 9 times engine weight.

TABLE 4-26. COMPARISON OF TOTAL FORCE FROM LOAD CELL AND ACCELEROMETER DATA - MOVING TEST DEVICE

Parameter	Moving Test Device Force Data*	Moving Test Device Acceleration Data**	Engine/Car Acceleration Data***
Force (lb)	98,370	158,070	160,800
Time (msec)	23	39	37

*Sum of 40 load cells.

**Average of Test Device accelerometers 1 and 2 times Test Device Weight.

***Average of car accelerometers 1 and 2 times car weight plus average of engine accelerometers 6 and 9 times engine weight.

String potentiometer and strain gauge data for each test are presented in Tables 4-27 through 4-30. String potentiometers were placed at selected locations on the Test Device to measure dynamic crush of the honeycomb. The displacement measured on the honeycomb is an indication of the dynamic crush at the particular point on the honeycomb modules, in all cases, the center of the module. Since the vehicle striking the honeycomb is not a uniformly flat surface, the crush measurement at the center of the module is not

TABLE 4-27. SUMMARY OF FIXED TEST DEVICE STRING POTENTIOMETER DATA

Displacement Potentiometer (Number)	Maximum Dynamic Displacement	
	D (in.)	Time (msec)
Individual Units		
● SP1 @ A3	0.2	3
● SP2 @ A8	1.9*	46
● SP3 @ B5	2.3	31
● SP4 @ B6	3.1	106
● SP5 @ C2	3.2	49
● SP6 @ C9	1.2	38

*Questionable Data.
**Instrumentation Failure.

TABLE 4-28. SUMMARY OF FIXED TEST DEVICE STRAIN GAUGE DATA

Strain Gauge		Maximum Strain (μin./in.)	Maximum Stress (psi)*	Maximum Time (msec)
(Number)	(Location)			
SG1	Front Beam (B)	2477	74,310	32
SG2	Front Beam (C)	528	15,840	52

*Stress = strain x E (E = 30 x 10^6 for steel).

TABLE 4-29. SUMMARY OF MOVING TEST DEVICE STRING POTENTIOMETER DATA

Displacement Potentiometer (Number)	Maximum Dynamic Displacement D (in.)	Maximum Dynamic Displacement Time (msec)
Individual Units		
• SP1 @ A3	1.8*	93
• SP2 @ A8	0.5	89
• SP3 @ B5	3.0	80
• SP4 @ B6	3.2	112
• SP5 @ C2	1.5	25
• SP6 @ C9	1.0	47

*Questionable data.

TABLE 4-30. SUMMARY OF MOVING TEST DEVICE STRAIN GAUGE DATA

Strain Gauge (Number)	Strain Gauge (Location)	Maximum Strain (μin./in.)	Maximum Stress (psi)*	Maximum Time (msec)
SG1	Front Beam	2530	75,900	39
SG2	Front Beam	255	7,650	17
SG3	Frame Rail	-282	-8,460	30

*Stress = strain x E (E = 30 x 10^6 for steel).
**Questionable data.

necessarily a true indication of crush to the remainder of the aluminum honeycomb. Strain gauge data was used to see how typical loads would affect key structural members of the Test Device. Figure 4-29 shows typical strain gauge curves for the most highly stressed member. The maximum allowable (yield) strain was 3350 μin./in., which is quite adequate for the strain data recorded for this test.

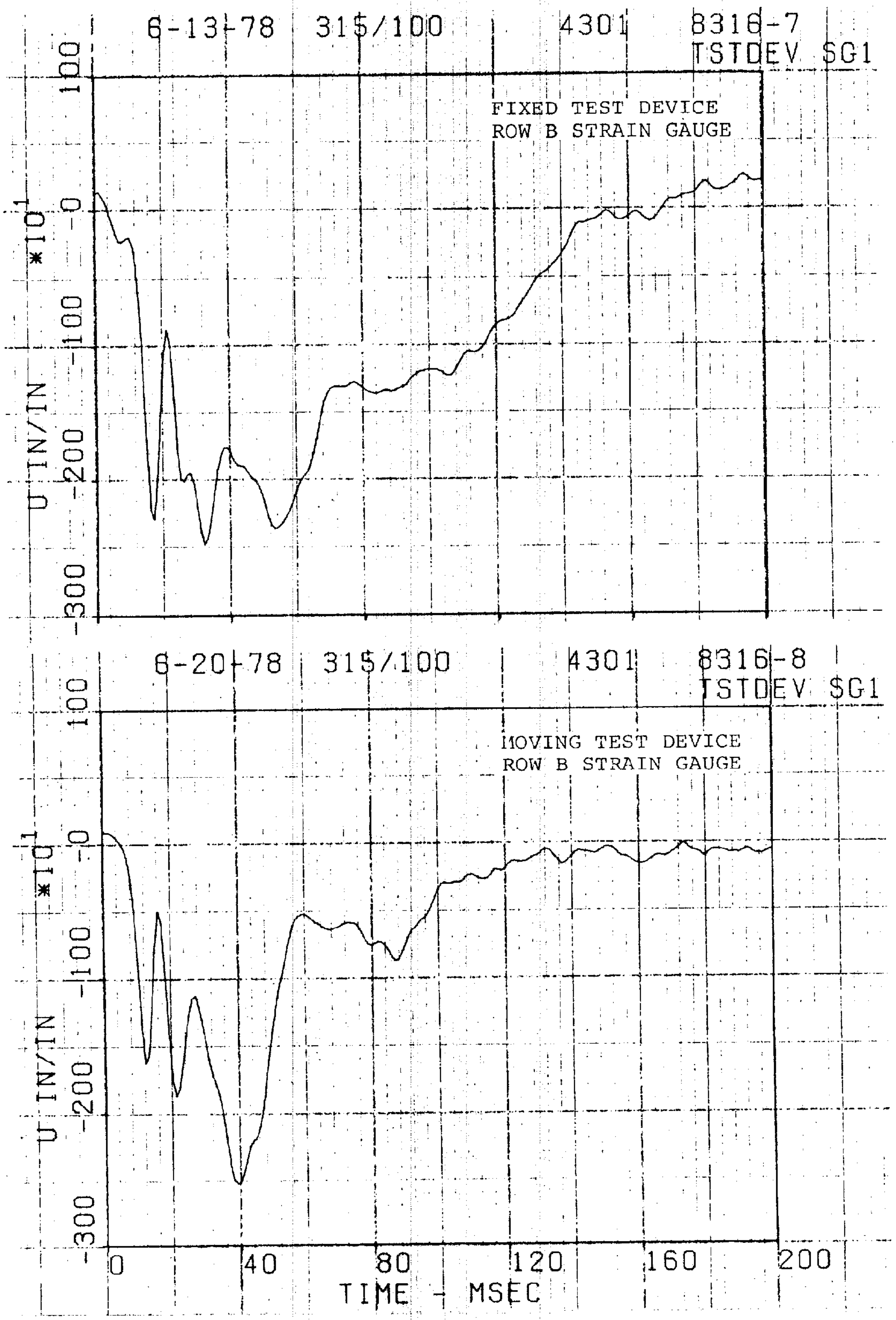


Figure 4-29. Strain Gauge Data - Row B Horizontal Beam.

The aluminum honeycomb crush profiles for fixed and moving Test Device tests are presented in Tables 4-31 and 4-32. Refer to Figures 4-13 and 4-14 for a view of the post-test configuration of the honeycomb. In Test 7, since the horizontal beams which the aluminum honeycomb attaches to were deformed, the entire load transmitted by the Plymouth was not reflected in the crush of the honeycomb. Modules D1 and D10 were sheared off the Test Device face by the car on impact. In Test 8, crush of the honeycomb was more consistent to what should have been observed in Test 7. Modules D1, D9, B10, and C10 were sheared off by the car on impact. In both tests, the main areas responsible for crush were the bumper/engine, bumper guards, hood line, and the front edges of each fender near the headlights.

A comparison of dynamic crush from accelerometer data and film analysis is shown in Figures 4-30 and 4-31. Since the vehicle does not act as a rigid body during the test, and vehicle accelerometer data is only representative of one location in an elastic body (at the B-pillar of the car), this data tends to be consistently higher than the data from film analysis. The data from film analysis is considered more accurate since a visual measurement of crush versus time is taken.

Total load cell force data and calculated inertia force from accelerometer data are shown in Figure 4-32 for Test 7 and Figure 4-33 for Test 8. Since the fixed Test Device is not instrumented with accelerometers, the inertia force was calculated using the car data, namely, the vehicle's averaged accelerometer data along with its test weight. In this case, the engine and car mass were considered as separate masses, since their dynamics during the

TABLE 4-31. FIXED TEST DEVICE HONEYCOMB CRUSH PROFILE

VEHICLE: 1975 Plymouth Fury

Crush Location	Height Above Ground (in.)	Distance Right of Center (in.)						Distance Left* of Center (in.)					
		37.1	28.9	20.6	12.4	4.1	℄	4.1	12.4	20.6	28.9	37.1	Average
Row D	34.3	**	5.8	2.4	0.6	2.4	3.0	1.3	0.6	2.4	5.5	**	2.7
Row C	27.0	0.9	0.3	2.0	0.0	2.0	2.5	1.0	0.4	2.3	0.0	-0.6	1.0
Row B	19.8	0.0	5.5	3.4	3.6	3.3	3.8	3.3	3.4	3.0	5.1	-0.3	3.1
Row A	12.5	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.2
Column		10	9	8	7	6		5	4	3	2	1	

*The left side of the test device is as viewed from the car driver's position.
**Modules sheared off at impact with car.

TABLE 4-32. MOVING TEST DEVICE HONEYCOMB CRUSH PROFILE

VEHICLE: 1975 Plymouth Fury

Crush Location	Height Above Ground (in.)	Distance Right of Center (in.)					℄	Distance Left* of Center (in.)					Average
		37.1	28.9	20.6	12.4	4.1		4.1	12.4	20.6	28.9	37.1	
Row D	34.4	0.0	**	5.0	2.9	4.4	5.8	4.2	2.6	4.5	3.5	**	3.7
Row C	27.0	**	1.4	2.8	0.3	2.0	5.8	1.9	0.6	3.0	0.5	4.5	2.3
Row B	19.8	**	5.4	4.9	3.8	5.4	5.7	4.7	4.8	4.9	5.5	-0.7	4.4
Row A	12.5	0.0	0.1	0.1	0.1	0.8	0.8	1.1	-0.2	-0.1	-0.2	-0.6	0.1
Column		10	9	8	7	6		5	4	3	2	1	

*The left side of the test device is as viewed from the car driver's position.
**Modules sheared off at impact with car.

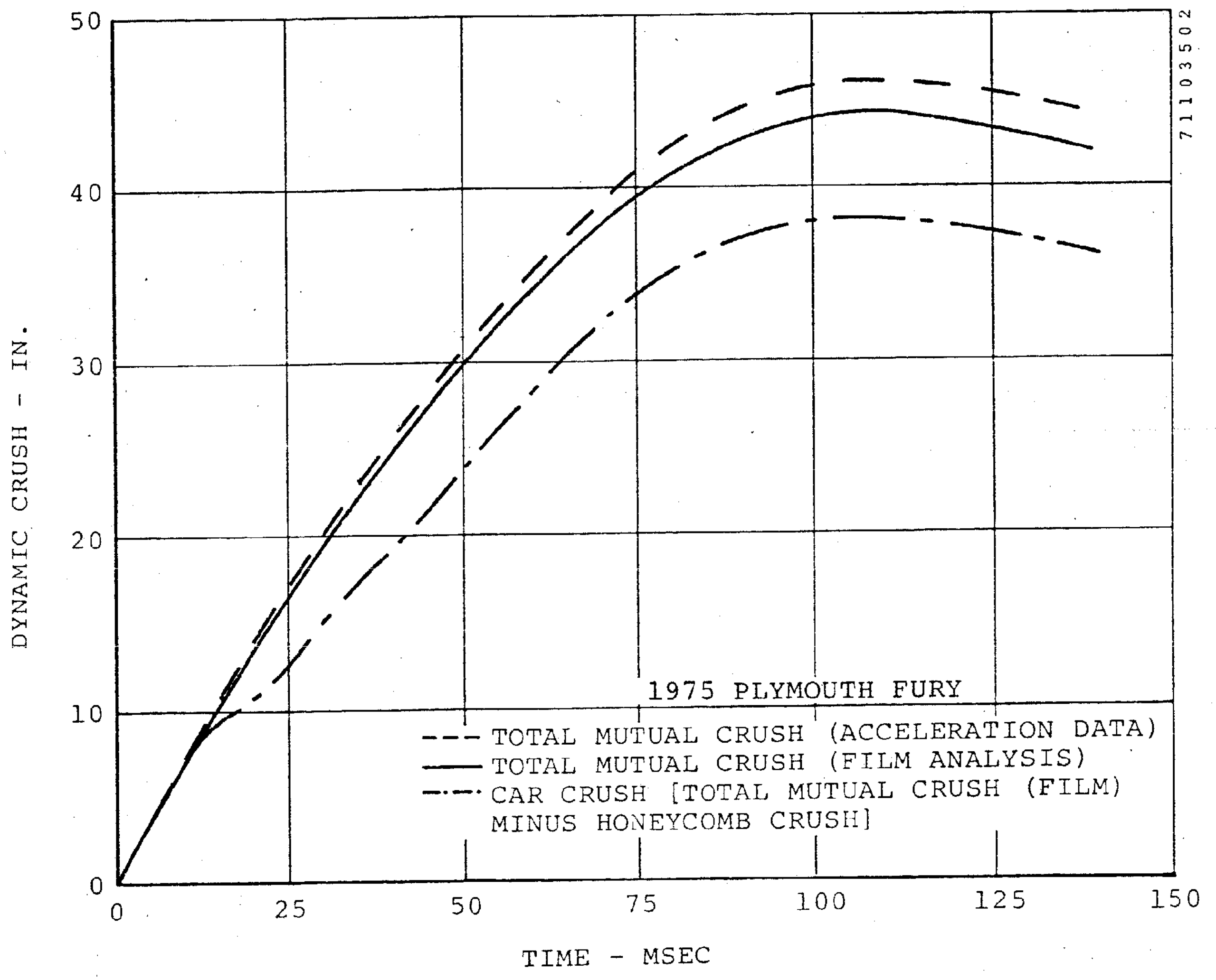


Figure 4-30. Dynamic Crush During Collision for Fixed Test Device - Test 7.

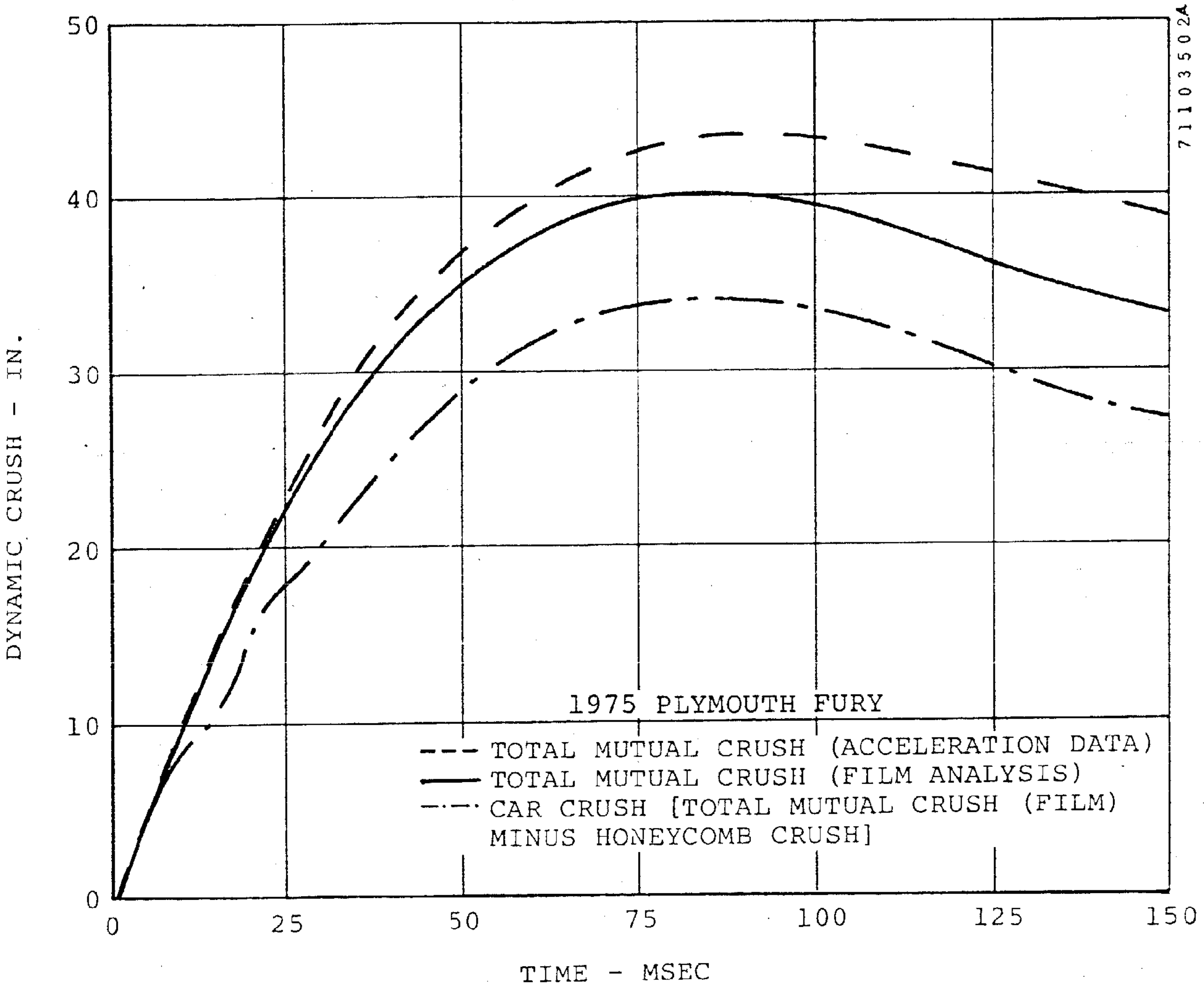


Figure 4-31. Dynamic Crush During Collision for Moving Test Device - Test 8.

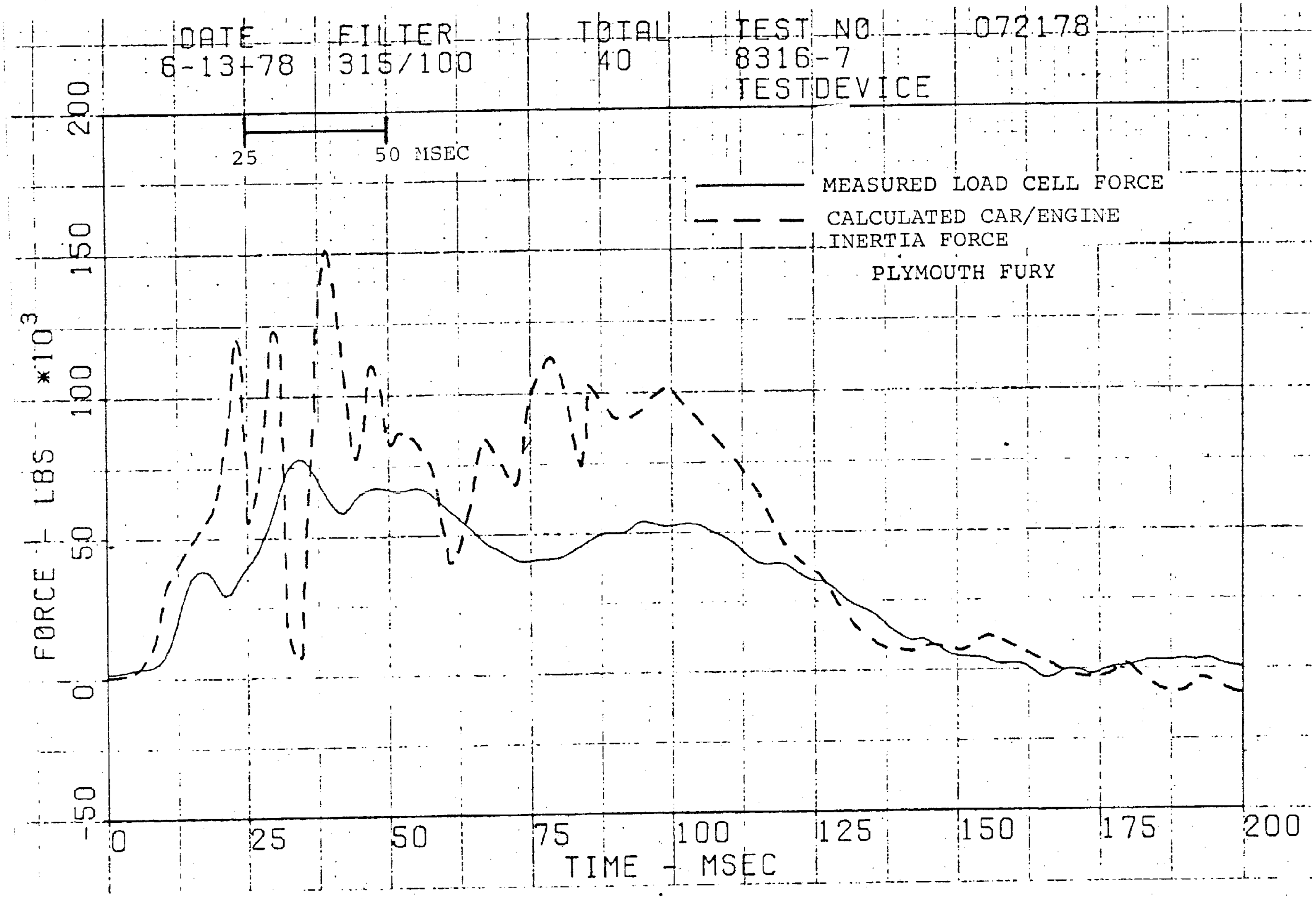


Figure 4-32. Comparison of Total Load Cell Force From Fixed Test Device Load Cell and Car Accelerometer Data for Test 7.

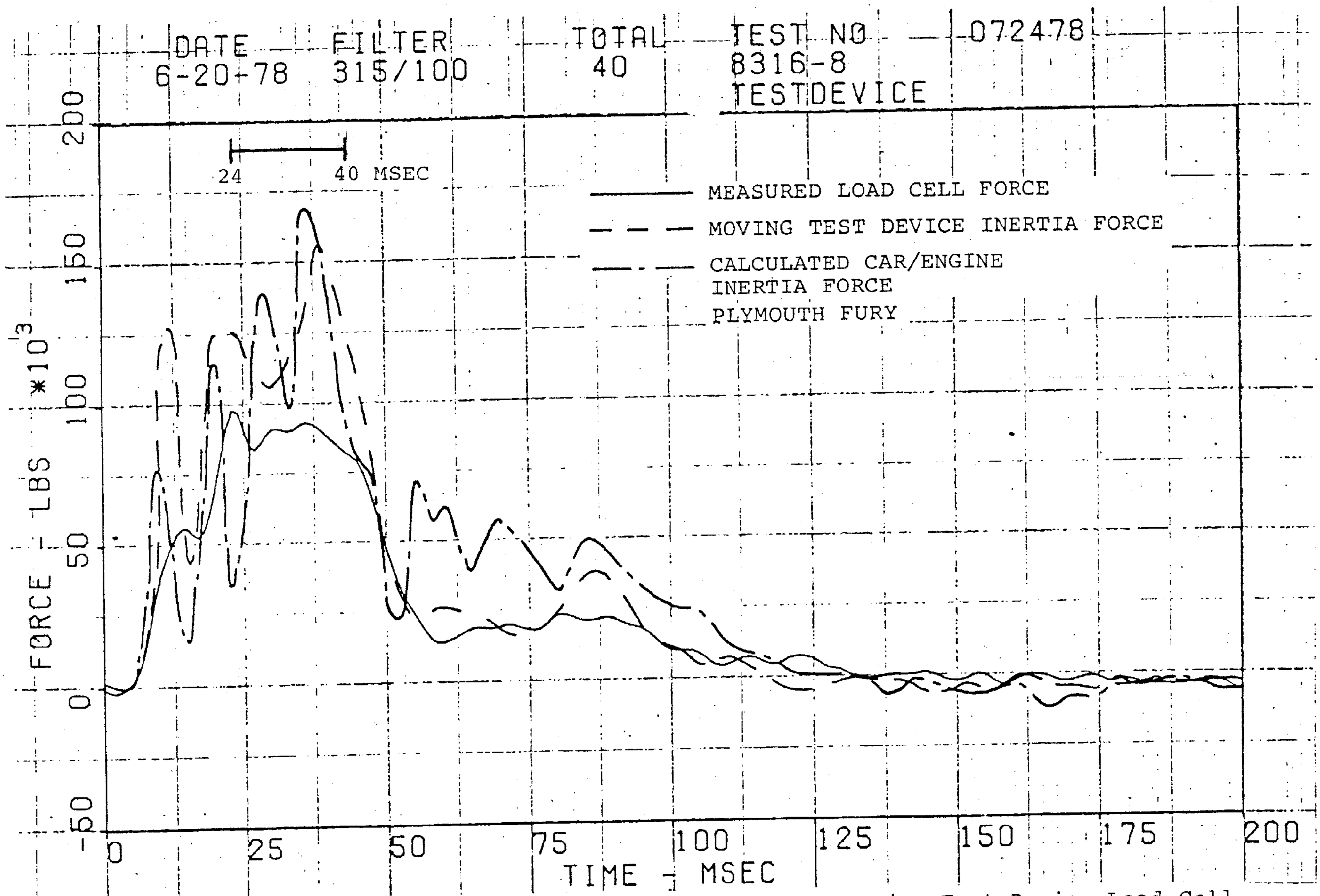


Figure 4-33. Comparison of Total Load Cell Force From Moving Test Device Load Cell and Car Accelerometer Data for Test 8.

event are different. The total inertia force was calculated by using F = ma for the engine and car mass separately, and adding the two together. In the moving Test Device test, the inertia force can also be calculated using accelerometer data from the Test Device. In this case, the Test Device test is considered a rigid body. Figure 4-34 shows the load cell force-deflection characteristics for both tests. The vehicle rate of stiffness as load is applied is given in Table 4-33.

Car interior intrusion is plotted against exterior dynamic crush of the vehicle in Figures 4-35 through 4-37. Dynamic interior crush was measured by means of a string potentiometer located along the centerline of the vehicle. A difficulty sometimes occurs during impact when outside influences interfere with the displacement of the string potentiometer, causing misleading data.

A crash pulse may be monitored on the Test Device face to determine the "hard" points on the vehicle. Figures 4-38 and 4-39 show where on the Test Device face the centroid of the total load cell force was acting, as a function of time.

4.4 OCCUPANT KINEMATICS

This section of the report presents the results of dummy response during peak values for each occupant's head, chest, and femur, restraint survival distance, and restraint system summaries.

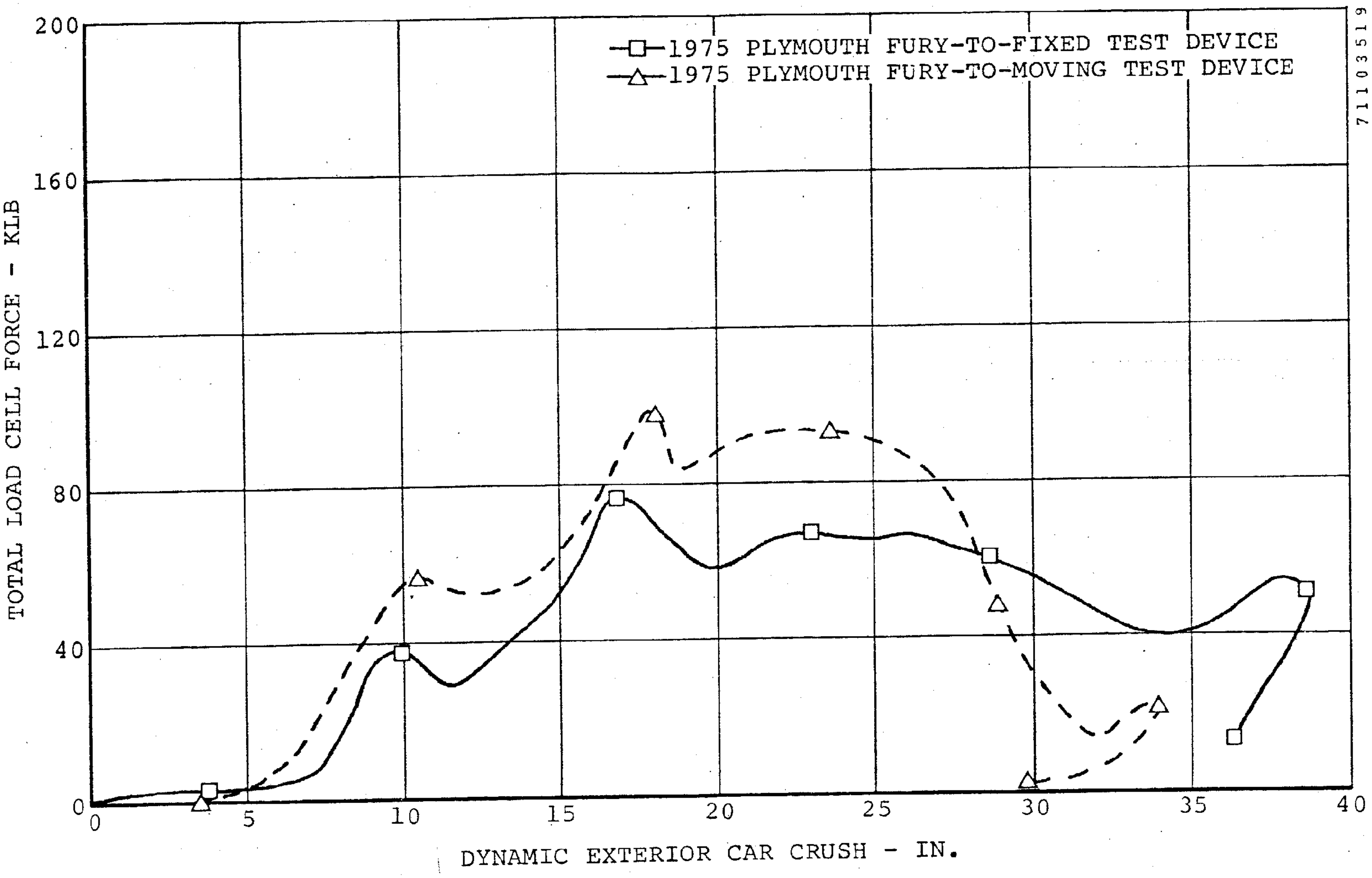


Figure 4-34. Comparison of Load Cell Force-Deflection Characteristics for 1975 Plymouth Fury.

TABLE 4-33. FRONTAL STIFFNESS OF CARS AS A FUNCTION OF CRUSH DISTANCE

		For 6" Crush			For 12" Crush			For 18" Crush			For 24" Crush			For 30" Crush		
Test No.	Car Model	Peak (klb)	Avg. (klb)	Rate (*)	Peak (klb)	Avg. (klb)	Rate (*)	Peak (klb)	Avg. (klb)	Rate (*)	Peak (klb)	Avg. (klb)	Rate (*)	Peak (klb)	Avg. (klb)	Rate (*)
7	Plymouth	3.9	2.0	0.67	38.2	13.3	2.22	77.7	27.6	3.06	77.7	36.8	3.06	77.7	42.1	2.81
8	Plymouth	10.7	1.2	0.39	56.1	20.2	3.37	98.4	36.1	4.01	98.4	45.8	3.82	98.4	51.5	3.43

*Rate in klb/in.

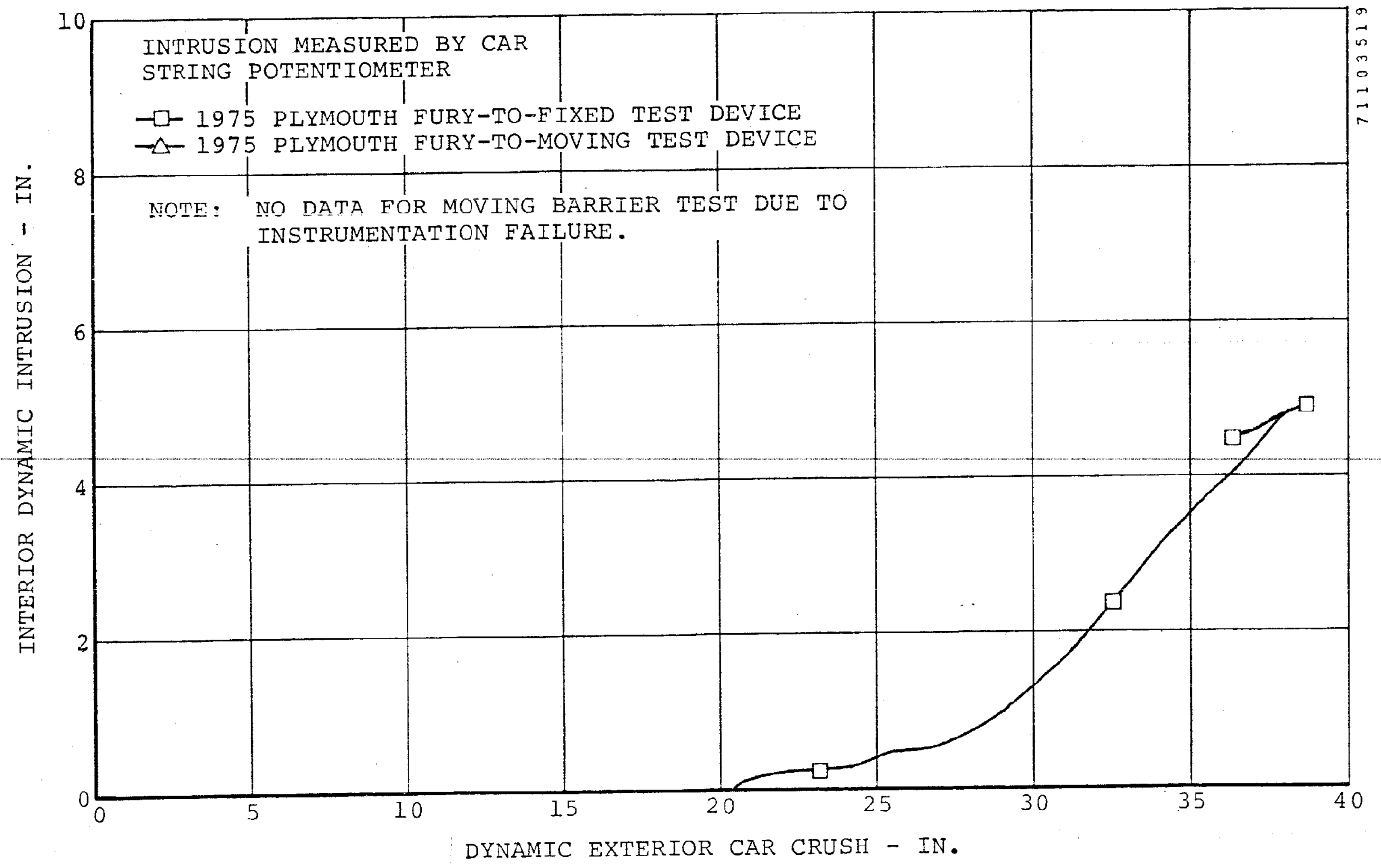


Figure 4-35. Car Interior Intrusion Versus Exterior Crush.

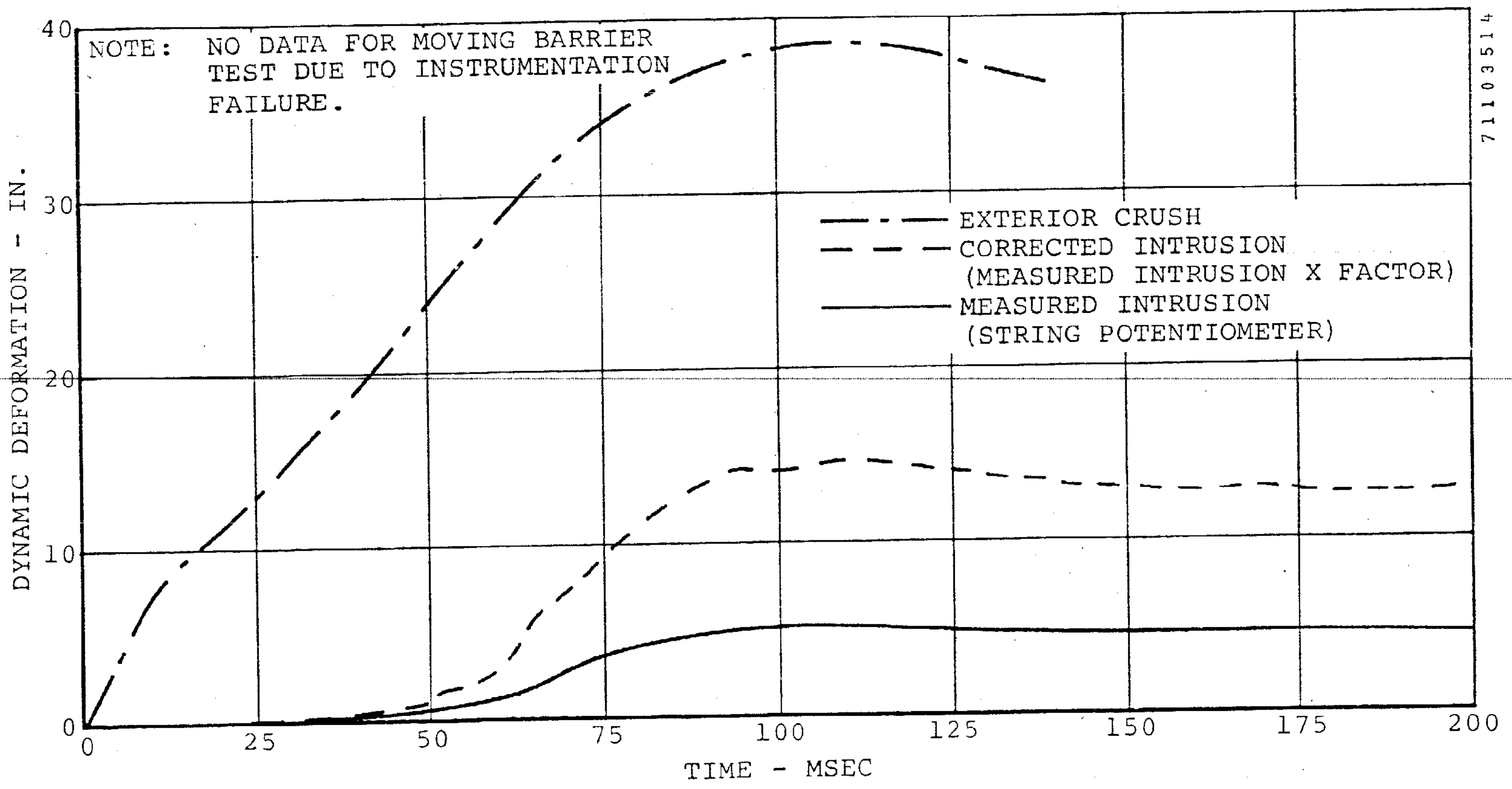


Figure 4-36. Car Exterior Crush and Interior Intrusion Versus Time for Fixed Test Device - Test 7.

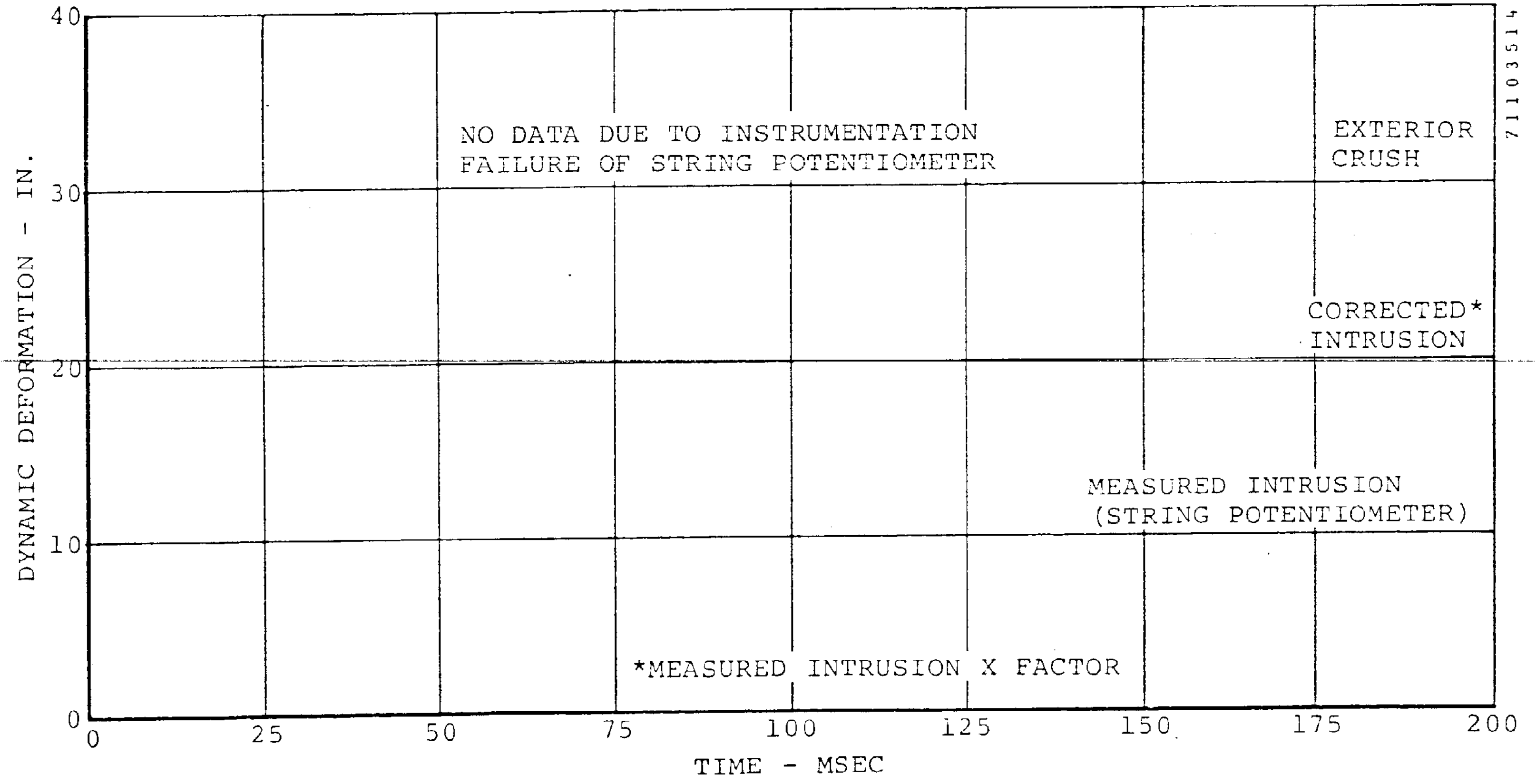
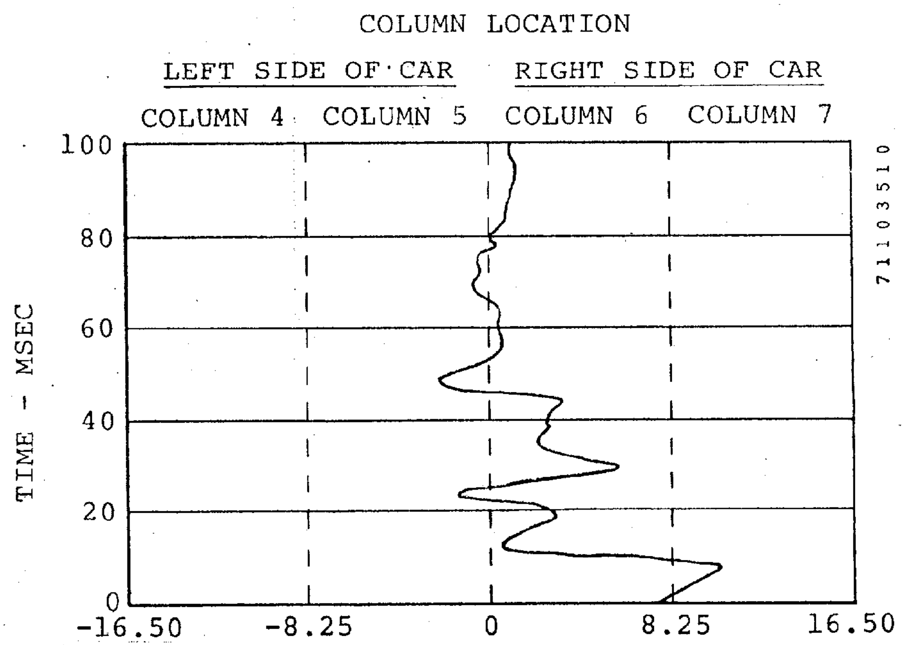
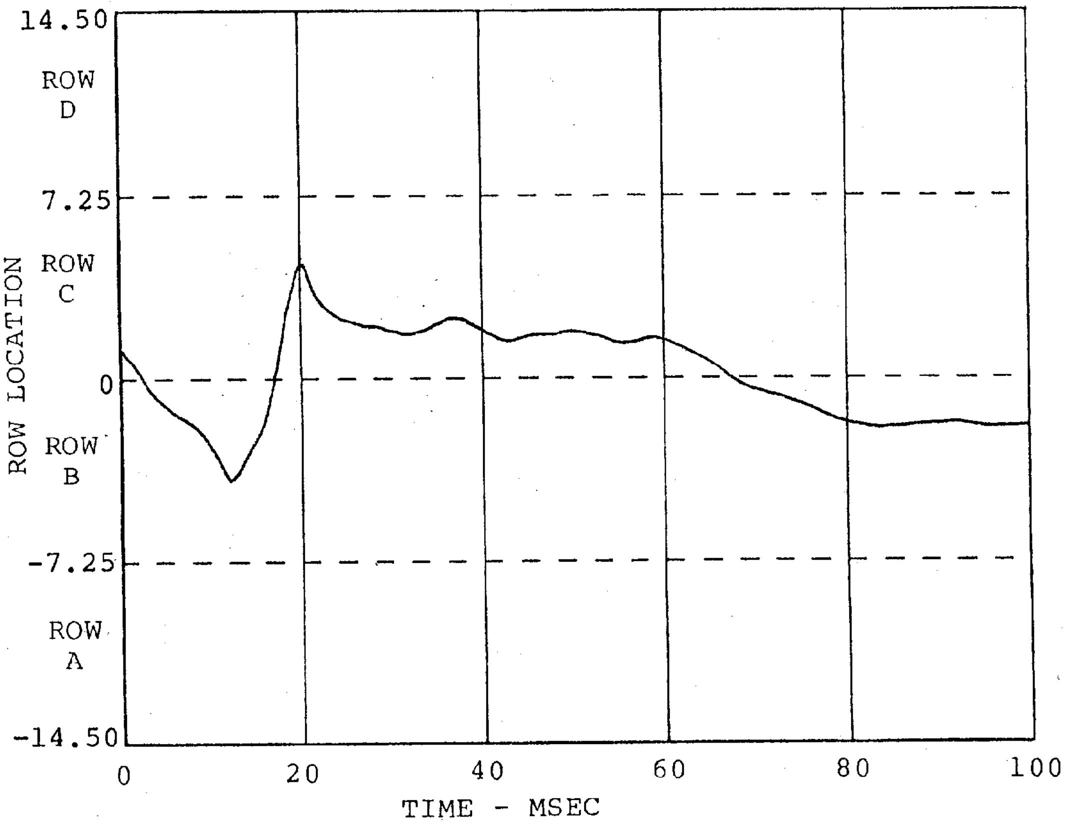


Figure 4-37. Car Exterior Crush and Interior Intrusion Versus Time for Moving Test Device - Test 8.

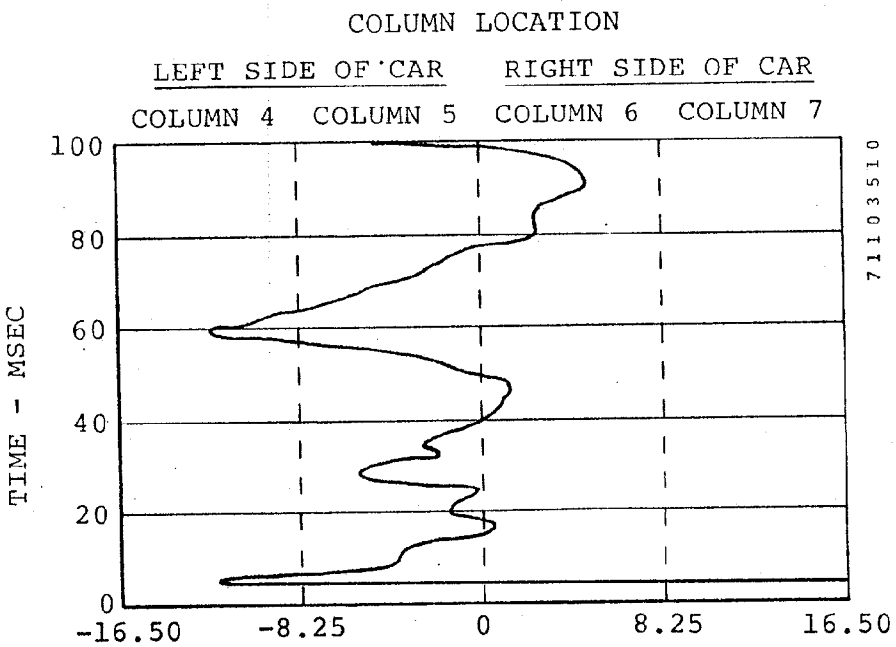


a) Horizontal Centroid of Load Cell Force

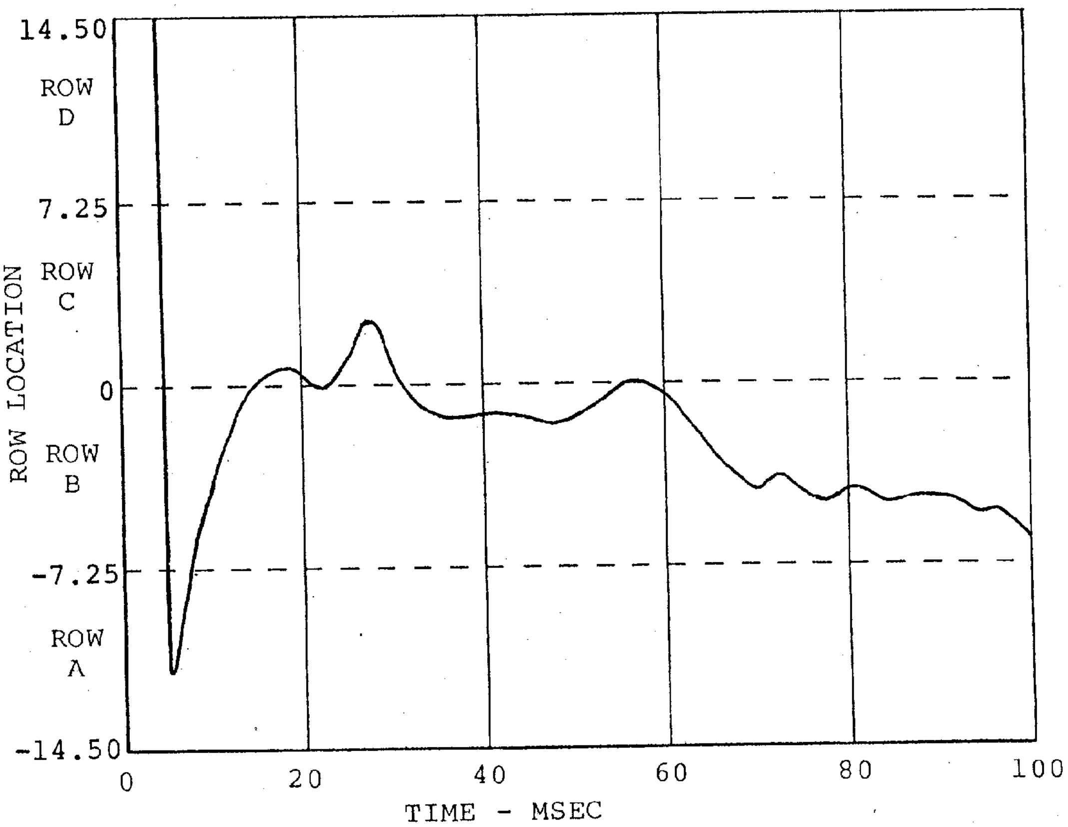


b) Vertical Centroid of Load Cell Force

Figure 4-38. Centroid of Load Cell Force for Fixed Test Device Test.



a) Horizontal Centroid of Load Cell Force



b) Vertical Centroid of Load Cell Force

Figure 4-39. Centroid of Load Cell Force for Moving Test Device Test.

In evaluating occupant response data, it must be remembered that, because of the high crash speeds, pulses measured by each occupant are very high and may exceed FMVSS 208 Standards. Figures 4-40 through 4-47 show pre-test and post-test configurations of the occupant for each test. A summary of occupant response data is presented in Table 4-34 with restraint system data presented in Table 4-35.

In both tests, the left front occupant's head and chest made contact with the steering wheel and dash panel. Compartment intrusion in the Plymouth was less than in previous tests, resulting in lower occupant responses. The driver's head in Test 7 had a maximum displacement relative to ground of 84.4 inches at t = 200 msec, while in Test 8, the maximum displacement was 50.8 at t = 120 msec. Post-test observations showed the driver femurs both made contact with the knee bolsters, causing damage to that area. In both tests, the driver's chest struck the steering wheel hub, which showed little sign of yielding and caused high acceleration values to appear.

The right front passenger's head in the Plymouth made contact with the dash panel. Post-test observations showed that the knees struck the glove compartment area, leaving signs of deformation to that area. The occupant compartment in both tests showed some signs of intrusion, but it was less severe than in other tests. The passenger's chest loads were mainly caused by the shoulder belt restraint system. No visible contact was made with the passenger's chest in the occupant compartment.

Figure 4-40. Pre-test Driver Position - Test 7.

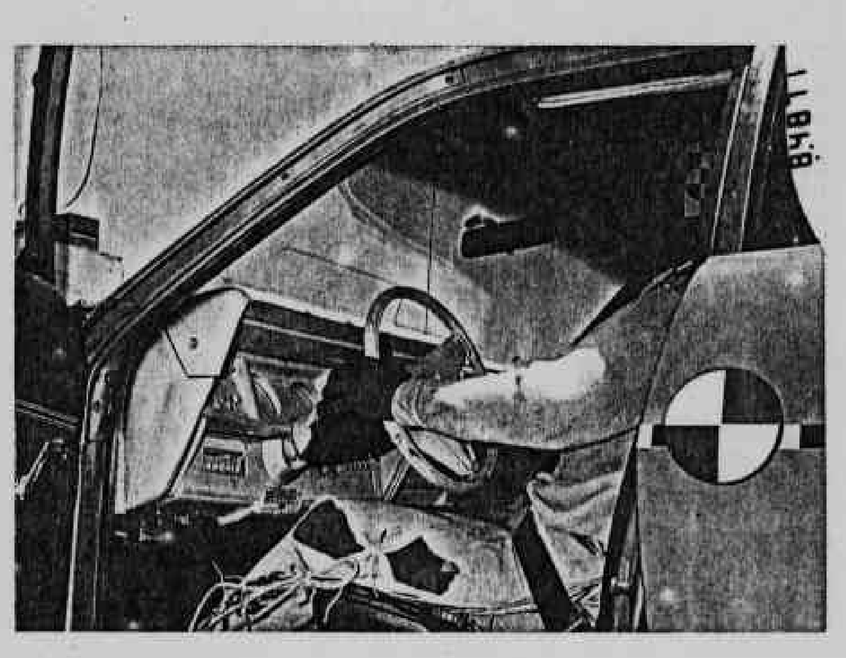


Figure 4-41. Post-test Driver Position - Test 7.

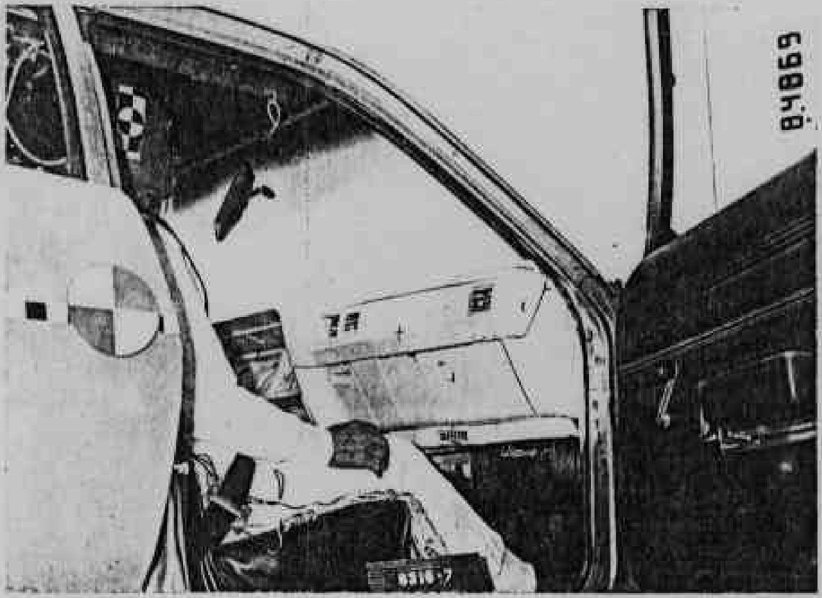


Figure 4-42. Pre-test Passenger Position - Test 7.

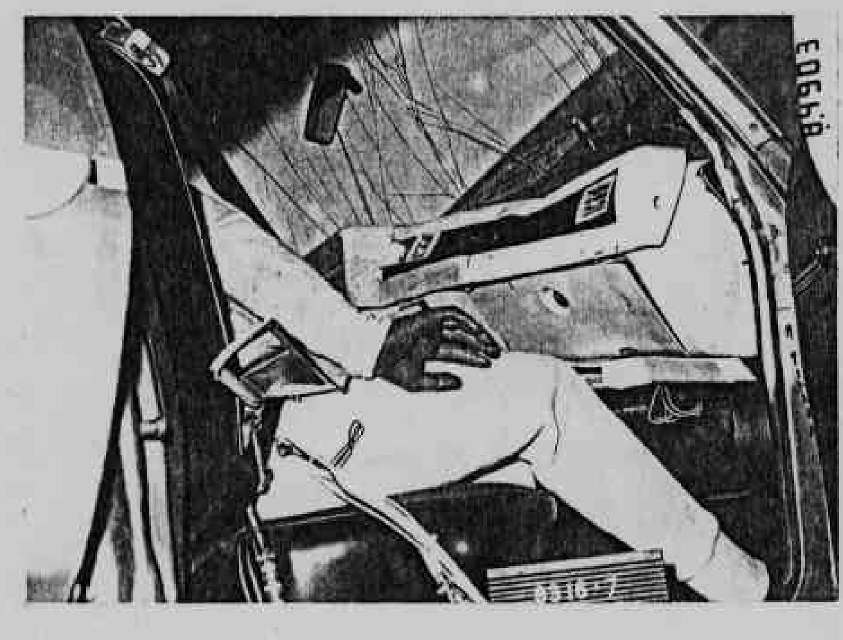


Figure 4-43. Post-test Passenger Position - Test 7.

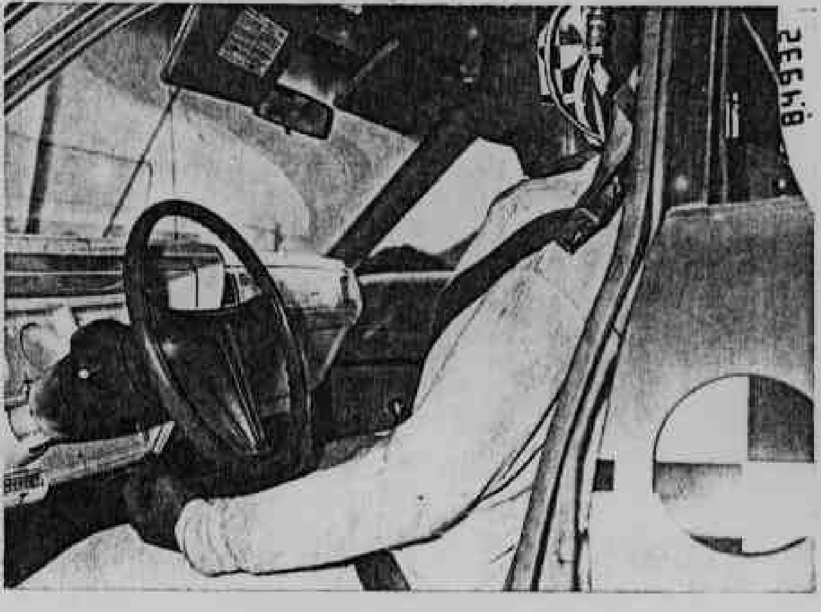


Figure 4-44. Pre-test Driver Position - Test 8.

Figure 4-45. Post-test Driver Position - Test 8.

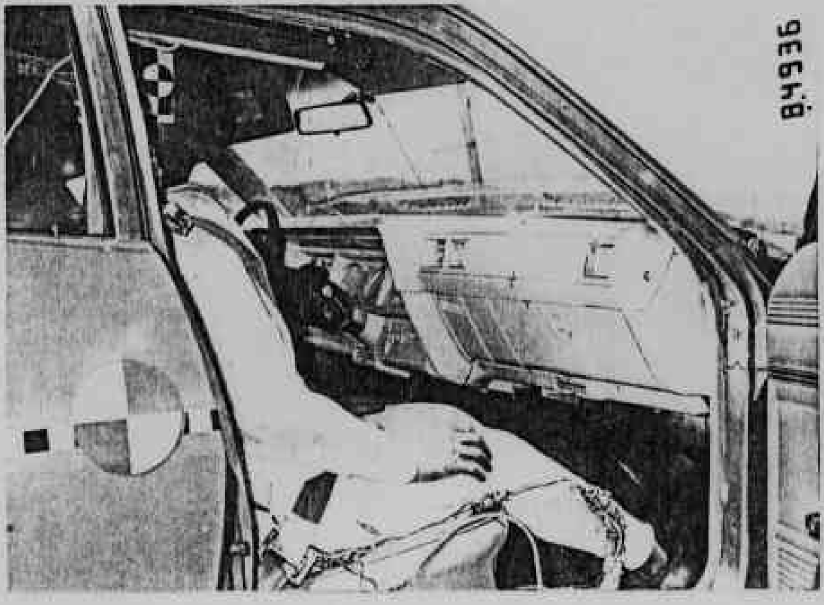


Figure 4-46. Pre-test Passenger Position - Test 8.

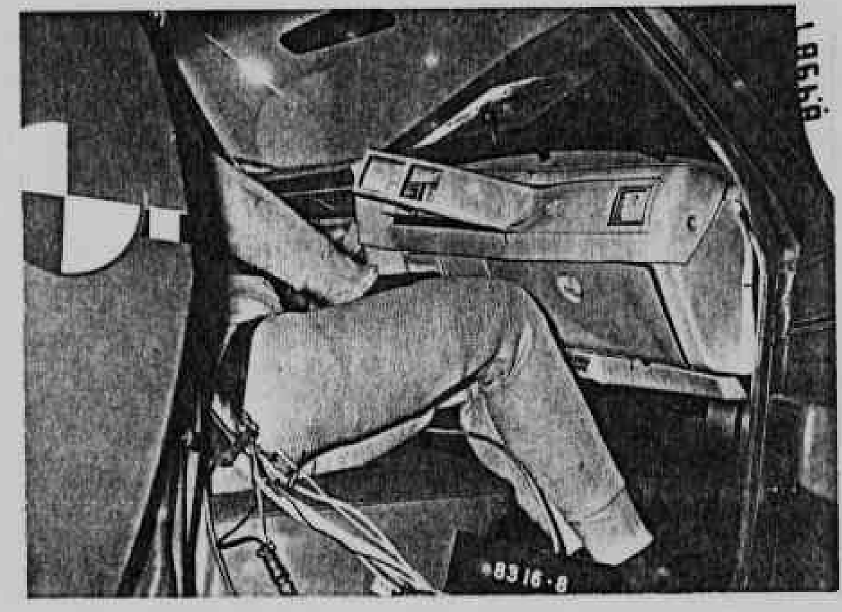


Figure 4-47. Post-test Passenger Position - Test 8.

TABLE 4-34. OCCUPANT RESPONSE DATA SUMMARY

VEHICLE: 1975 Plymouth Fury

	Test 7 (Fixed Test Device)				Test 8 (Moving Test Device)			
	Left Front Occupant		Right Front Occupant		Left Front Occupant		Right Front Occupant	
	Maximum Value (G)	T (msec)	Maximum Value (G)	T (msec)	Maximum Value (G)	T (msec)	Maximum Value (G)	T (msec)
<u>Head</u>								
X	-80.5	101	-117.7	101	-59.1	107	-99.7	105
Y	+22.8	89	+60.8	101	-16.5	109	+55.7	105
Z	+103.8	101	+75.9	103	+78.8	94	+73.0	101
R*	93.9	95	121.6	109	68.7	107	107.4	103
HIC	1695 @ 83-120		1759 @ 99-117		949 @ 76-123		1125 @ 98-111	
<u>Chest</u>								
X	-78.1	87	-48.5	116	-55.3	80	-27.8	70
Y	-25.1	82	+44.9	118	-16.5	86	+30.6	111
Z	+25.7	105	+16.9	104	+10.5	68	-14.9	117
R*	73.1	89	64.8	115	+55.8	77	+37.4	114
SI	749 @ 200		656 @ 200		394 @ 200		284 @ 200	
<u>Femurs</u>								
LF	-265	52	-864	74	-494	74	-670	47
RT	-1465	77	-741	74	-924	65	-756	55

*3-msec clip.

Restraint Survival Distance (RSD) criteria is presented in Table 4-36. This value was used in efforts to determine relative vehicle crashworthiness. Values in this table reflect RSD values with and without a 7-millisecond shift. This shift is to account for crush of the honeycomb on the Test Device. The vehicle compartment deceleration pulse and restraint system pulse were used

TABLE 4-35. SUMMARY OF RESTRAINT SYSTEM DATA

VEHICLE: 1975 Plymouth Fury

Fixed Test Device	Load (lb)	@	Time (msec)
Left Front Occupant			
Peak Shoulder Belt Load	1047	@	101
Peak Left Lap Belt Load	1157	@	61
Peak Right Lap Belt Load	1669	@	65
Right Front Occupant			
Peak Shoulder Belt Load	2088	@	110
Peak Left Lap Belt Load	2083	@	69
Peak Right Lap Belt Load	1189	@	69
Moving Test Device			
Left Front Occupant			
Peak Shoulder Belt Load	1065	@	73
Peak Left Lap Belt Load	1037	@	67
Peak Right Lap Belt Load	1233	@	56
Right Front Occupant			
Peak Shoulder Belt Load	1259	@	86
Peak Left Lap Belt Load	2028	@	66
Peak Right Lap Belt Load	1111	@	63

to compare available compartment space with the space necessary to decelerate the occupant. A critical element in calculating this value is the relative positioning of the dummy in the occupant compartment. Figures 4-48 through 4-51 show the pre-test and post-test occupant compartments for each test. Refer to Appendix D for an explanation of the methodology used to determine RSD values.

TABLE 4-36. SUMMARY OF OCCUPANT RESTRAINT SURVIVAL DISTANCE (RSD)

Test No.	Vehicle	Occupant	t' (msec)	D_c (in.)	D_p (in.)	AID (in.)		RSD (in.)		RSD* (in.)	
						Pre	Post	Pre	Post	Pre	Post
7	1975 Plymouth Fury 4-door sedan	Driver	50.0	31.2	34.6	13.9	14.7	10.5	11.3	8.9	9.7
		Passenger	49.0	30.3	33.8	16.6	12.6	13.1	9.1	10.6	6.6
8	1975 Plymouth Fury 4-door sedan	Driver	50.0	20.7	24.3	14.0	15.6	10.4	12.0	8.0	9.6
		Passenger	52.0	19.9	24.8	14.3	16.1	9.4	11.2	7.3	9.1

t' = time when occupant velocity = compartment velocity
D_c = displacement of compartment from initial impact to t = t'
D_p = displacement of occupant from initial impact to t = t'
AID = Available Interior Distance
RSD = Restraint Survival Distance = AID - $(D_p - D_c)t = t'$

NOTE: AID and RSD are shown for pre- and post-crash vehicle geometry, respectively.
*Seven-msec shift in time made to RSD value to correct for crush of honeycomb of Test Device.

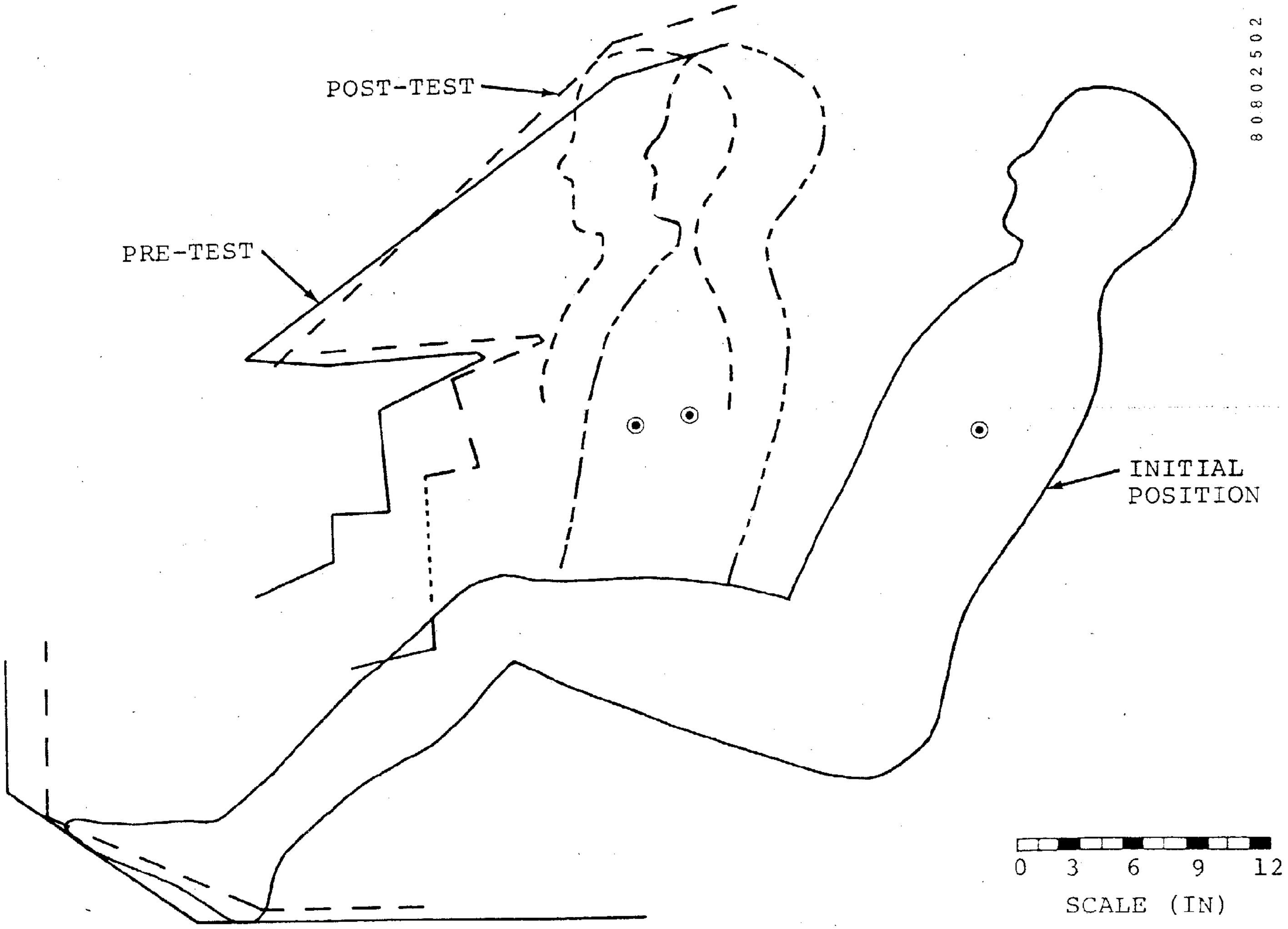


Figure 4-48. 1975 Plymouth Fury Driver Profile - Test 7.

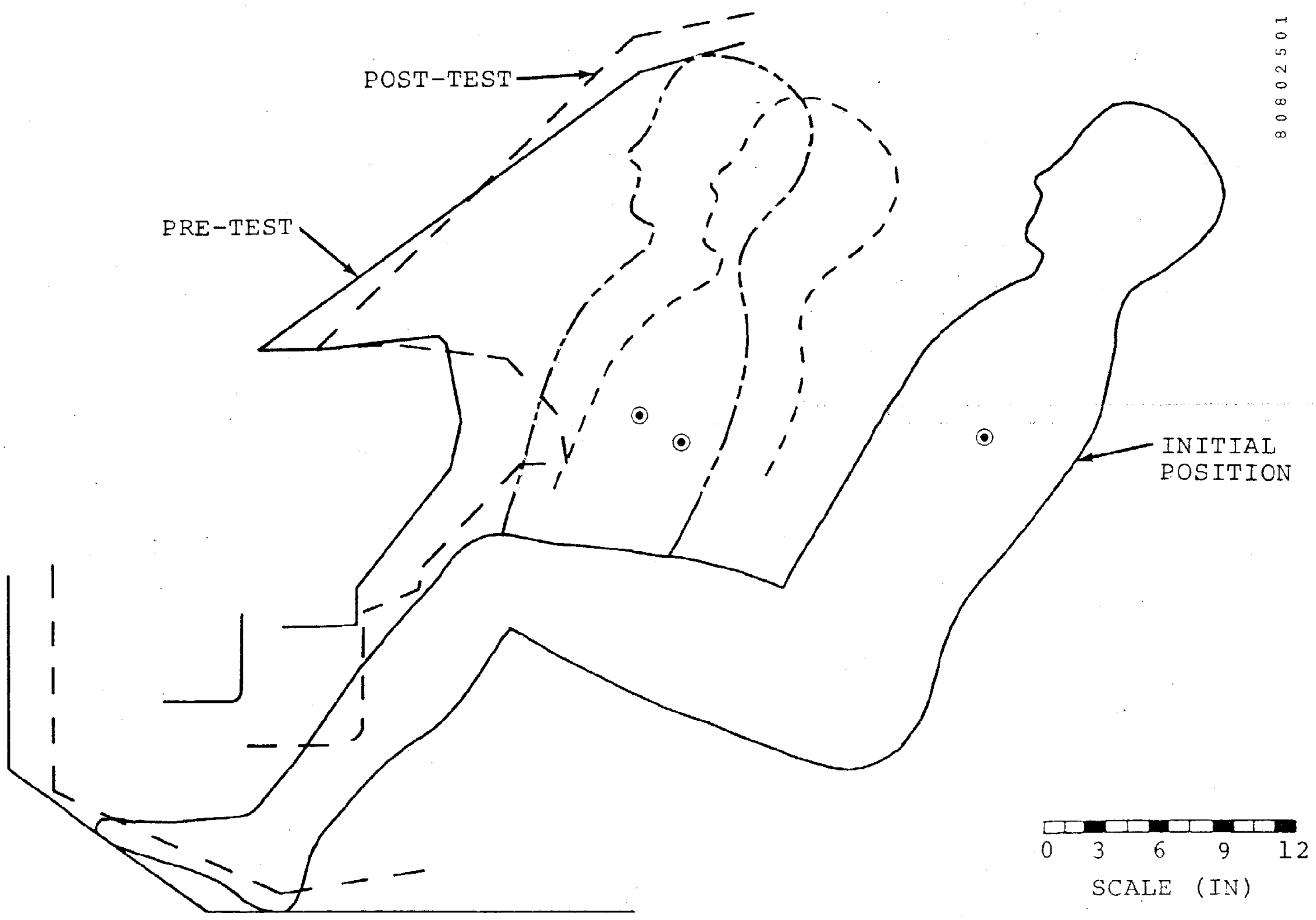


Figure 4-49. 1975 Plymouth Fury Passenger Profile - Test 7.

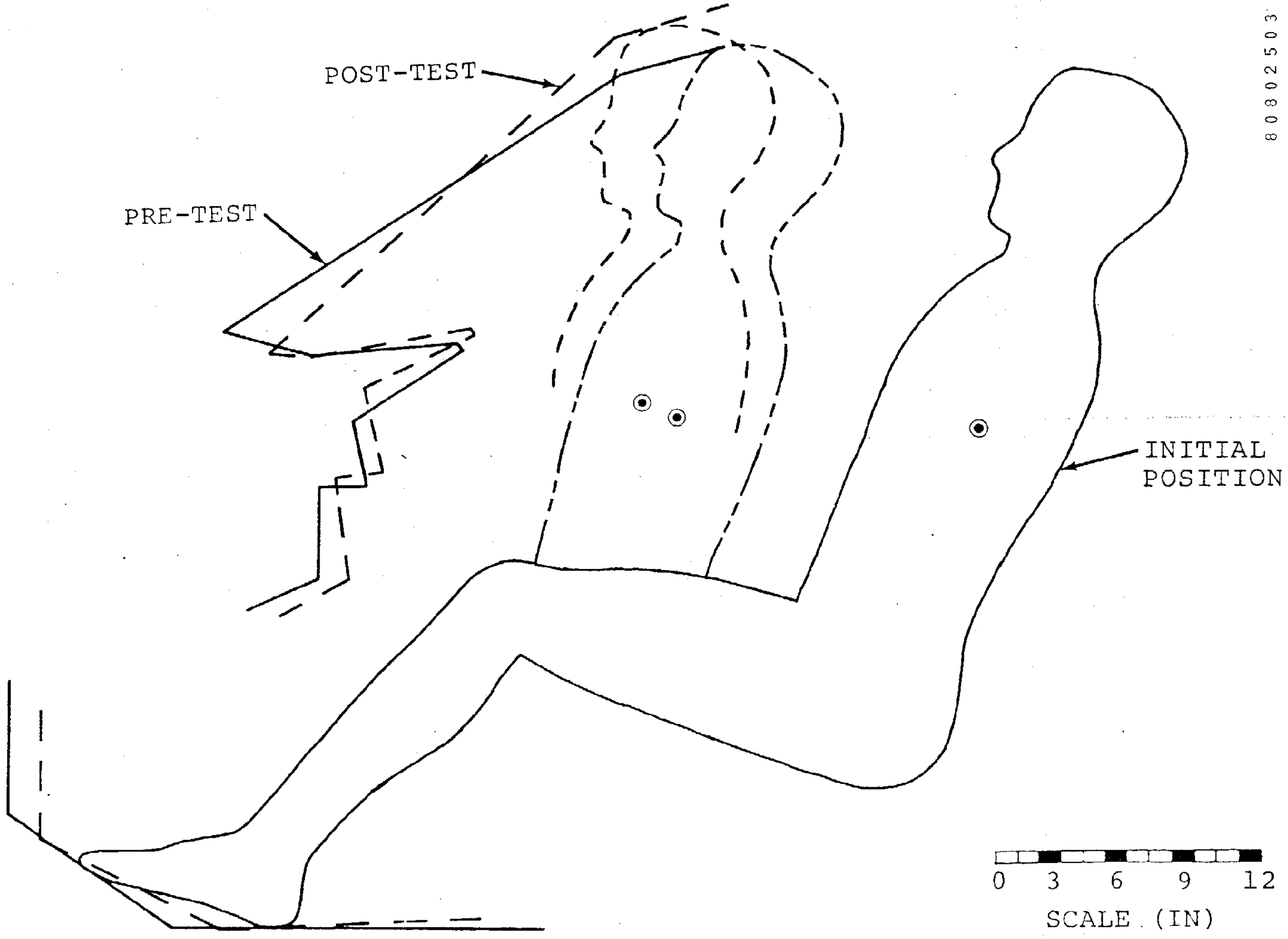


Figure 4-50. 1975 Plymouth Fury Driver Profile - Test 8.

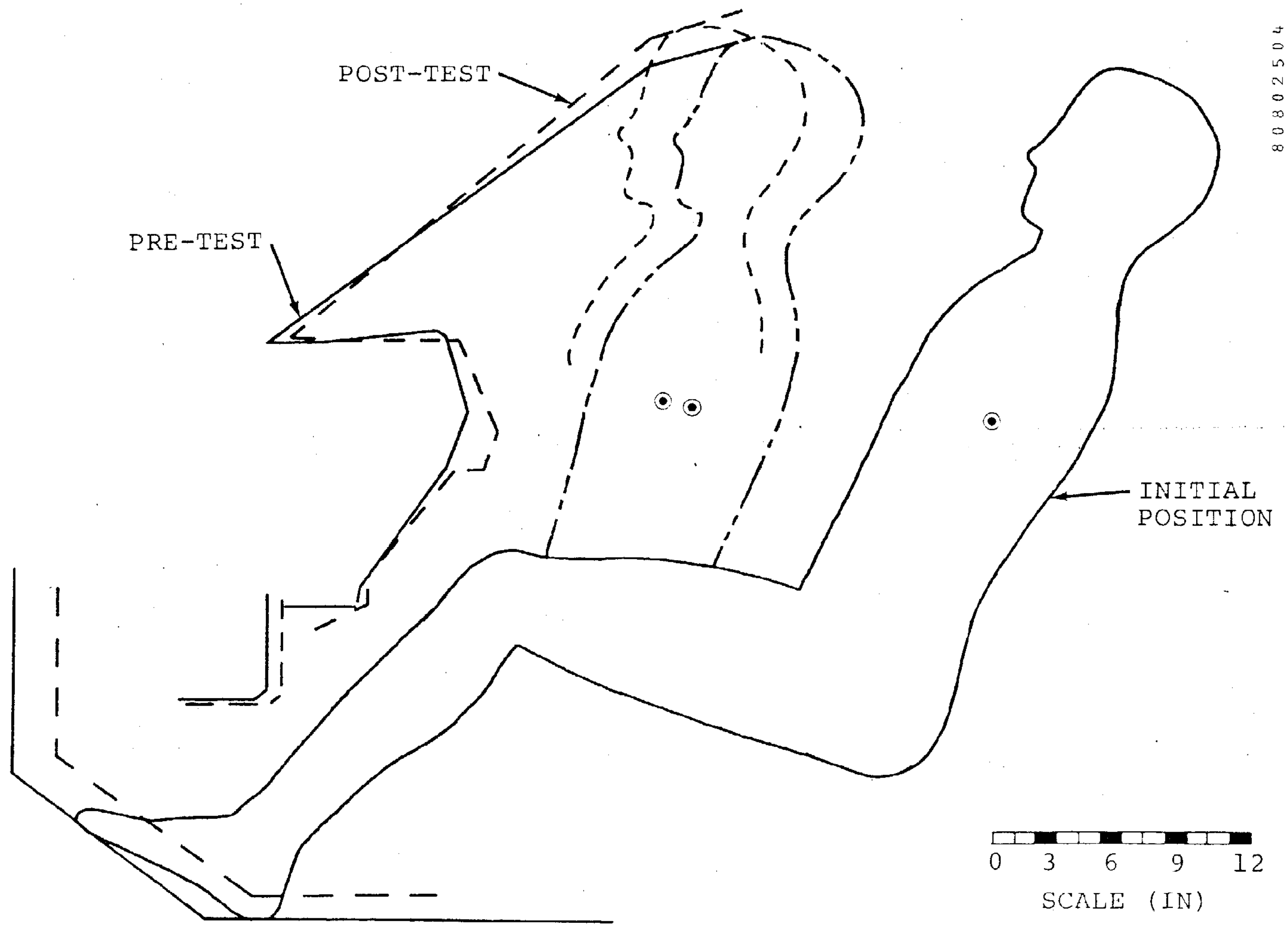


Figure 4-51. 1975 Plymouth Fury Passenger Profile - Test 8.

5.0 TEST FACILITIES AND EQUIPMENT

5.1 GENERAL

The impact tests in this program were conducted at the Monorail Impact Facility, shown in Figure 2-1. The barrier impact and midrange impact sites were used for the fixed Test Device/vehicle and moving Test Device/vehicle tests, respectively.

Table 5-1 describes the test equipment and its function as it applies to the test parameters.

TABLE 5-1. TEST EQUIPMENT LIST AND FUNCTION

Item	Manufacturer	Model	Purpose
Timing Trap	Dynamic Science	None	Determine impact speed by furnishing a start and stop signal to recording oscillograph.
Oscillograph	Bell and Howell	5-134	Records timing start and stop signals from timing traps, cable drum drive rpm, and impact switch.
Speed Control	Dynamic Science	None	Precision control of cable drive drum rpm.
Beam Scales	Western	WP2000	Used to determine vehicle test weights.
High-speed Motion Picture Cameras	Photosonics	16-1B	Used for side, overhead, barrier, pit, and on-board film coverage as required.
Motion Picture Camera	Bolex	H-16	Panning and documentation.
Still Camera	Kowa	6	Documentary photo coverage.

TABLE 5-1. TEST EQUIPMENT LIST AND FUNCTION (CONTD)

Item	Manufacturer	Model	Purpose
100 and 1000 Hz Time Code Generators	Dynamic Science	None	Furnish timing signal for high-speed cameras and a 1 millisecond timing for velocity determination.
Stop Watch	Brietling	None	Time for collection of fuel leak samples.
Containers	-	-	Collection for fuel leak samples.
Graduated Cylinder	Kimes	-	Fuel volume measurement.
Calibrated Steel Rule	Starret	48 in.	Precision measurement of velocity trap spacing.
Anthropomorphic Dummies	Alderson	(GFE)	To ballast the vehicle and to gather occupant response data.
Dummy and Vehicle Accelerometers	Endevco	7233C	Measures acceleration.
String Pots	Celesco	PT-101-15	Measures displacement.
12.5K Load Cells	Interface	1210 FS 1210 LT	Force on honeycomb modules.
3K Load Cell (Femur)	GSE	2435	Determines femur load forces.
3500-pound Load Cell (Belt)	LeBow	3419	Measures belt loads.
F.M. Multiplexor Tape Recorder	Sangamo	Sabre III	Records instrumentation signals.
Oscillograph	Bell and Howell	5-134	Records real-time quick-look data.
Signal Conditioner	Ectron	M140	Conditions instrument output signal for recording.

5.2 FACILITY AND EQUIPMENT DESCRIPTION

The following paragraphs briefly describe the track facility and equipment, their function, and mode of operation.

5.2.1 Test Track and Guidance System

The test track consists of 1,200 feet of asphalt pavement (SN = 75 ±5), 14 feet in width. The length allows sufficient acceleration distance to accommodate impact speeds in excess of 60 mph with sufficient distance remaining to abort the test if necessary. Guidance for the test vehicle is provided by a sliding shoe attached to the vehicle. The sliding shoe rides on the monorail embedded in the test track. Prior to impact, the shoe is mechanically released from the test vehicle.

5.2.2 Tow System and Velocity Control

The tow system consists of a drum-driven endless cable powered by a pair of 390-cubic-inch engines driven in tandem driving a modified three-speed C-6 automatic truck transmission. The tow system can propel a 6,000-pound vehicle into the fixed barrier at 75 mph or two 4,000-pound vehicles into each other at a closing speed of 90 mph. Velocity control is achieved through a manually controlled throttle system. A visual readout of speed versus distance is provided and compared with the "ideal curve." Velocity control under ±0.5 mph is realizable down to 20 mph and ±2.0 percent down to zero mph.

5.2.3 Abort System

Automatic abort capability is provided through the vehicle service brakes which are actuated by releasing high-pressure air into the hydraulic system. Abort criteria consists of vehicle speed, data acquisition and instrumentation system readiness, and stability of the vehicle on the test track. The first two criteria are automatically monitored by the test control system while the third criterion is visually monitored by the test conductor. Manual abort provisions are available to the test conductor. Upon verifying vehicle speed, the test control system automatically deactivates the abort system to preclude an inadvertent test abort immediately prior to impact.

5.2.4 Master Control System

The master control system used for impact tests controls and monitors all primary system functions that must operate throughout a predetermined interval during a test. This includes the starting and stopping of the FM multiplexer tape recorder, high-speed cameras, and oscillograph, and the control of the power winch which propels the test vehicle. The operations of the various devices is confirmed, including vehicle velocity and tape recorder speed synchronization, before it passes through a "commit" window. When the vehicle is committed, the abort system is disarmed, preventing an accidental abort after the point of no return is reached.

Any system malfunction, including improper vehicle velocity up to the commit window, generates an abort. The control system uses the pulse output from the IRIG time base generator as a clock with a manual push button defining time zero. The logic circuits compare pulse counts from time zero to preset values dialed in at the control panel. As each control circuit gets an equal comparison, that circuit is turned on. If the self-test circuit does not verify, the abort system is automatically activated. After a successful vehicle test, the last control circuit shuts the entire system down. The manual backup control system provides the test conductor with the option of manually aborting the test if the need arises.

5.2.5 Fixed Impact Barrier

The basic fixed impact barrier consists of a reinforced concrete structure, 6 feet high, 6 feet thick, and 12 feet wide, weighing approximately 100,000 pounds and complying with SAE J850. This barrier can be fitted with various modules including a flat-faced barrier adjustable to angles up to 45 degrees, as well as a pole barrier. This barrier system conforms to the definition of a "fixed collision barrier" as defined in Federal Register, Vol. 35, No. 135, page 11242 (July 14, 1970).

A camera pit is located immediately in front of the impact barrier and is 6 feet wide, 8 feet deep, and 20 feet long. The pit is covered with a metal grid which supports the vehicle as it passes over, yet allows photographing of the vehicle underside when required. Electrical outlets are provided for powering floodlights and high-speed cameras. A fixed overhead camera tower cantilevered over the barrier test site provides over-site photography.

5.2.6 Midrange Impact Site

The midrange test site consists of a 40-foot by 60-foot asphalt pad. Centrally located within this area is a camera pit constructed of reinforced concrete which is 6 feet wide, 8 feet deep, and 24 feet long. A metal grid covers the camera pit, allowing photographs to be taken of the vehicle underside. A movable overhead camera tower is provided for over-site photography.

5.2.7 High-speed Photography

Six high-speed 16mm cameras with 100 Hz timing marks and one panning camera are used for photographic test documentation. Precise field of view monitoring is accomplished by bore sighting with the vehicle at the impact side prior to the test.

APPENDIX A

CAR-TO-TEST DEVICE CRASH ANALYSIS

Prepared by:

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Jack Beharrell
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5/8/78

1.0 DETERMINATION OF EQUIVALENT CLOSING SPEED FOR MOVING BARRIER COLLISION

- Moving Barrier Collision:

$$\Delta V_A = \frac{W_B}{(W_A + W_B)} [V_A(0) - V_B(0)] = \frac{W_B}{(W_A + W_B)} [\Delta V(0)] \qquad (1)$$

where

ΔV_A = velocity change of Vehicle A in moving barrier impact (mph)

W_A, W_B = weight of Vehicles A and B, respectively (lb)

$V_A(0), V_B(0)$ = initial velocities of Vehicles A and B, respectfully (mph)

$\Delta V(0)$ = initial closing velocity (mph)

- Fixed Barrier Collision:

$$\Delta V'_A = V'_A(0) \qquad (2)$$

where $\Delta V'_A$ = velocity change in fixed barrier impact (mph)

$V'_A(0)$ = initial velocity of Vehicle A (mph)

- Equality Conditions

The desired equality condition (the same vehicle velocity change in the moving barrier and fixed barrier impacts) implies:

$$\Delta V_A = \Delta V'_A \qquad (3)$$

Therefore Equations (1) and (2) result in the following condition for the "equivalent" closing speed, ΔV(0), for the moving barrier test:

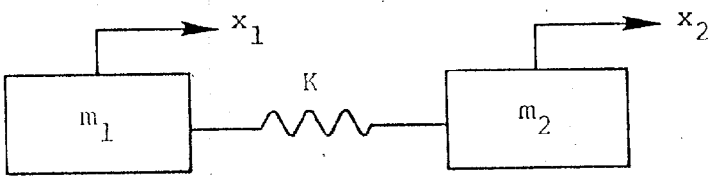
$$\Delta V(0) = V'_A(0) \left[\frac{W_B}{(W_A + W_B)} \right]^{-1} \qquad (4)$$

For W_B = 4000 lb, and $V'_A(0)$ = 40 mph, Equation (4) becomes:

$$\Delta V(0) = 40 \left[\frac{4000}{(W_A + 4000)} \right]^{-1} \qquad (5)$$

2.0 DERIVATION OF EQUATIONS OF MOTION

The vehicle-barrier impact was modeled as a system of two masses connected by a linear spring. m_2 represents the mass of the barrier test device; m_1 that of the car.



The displacements x_1 and x_2 are measured from the positions of static equilibrium. The equations of motion are:

$$m_1 \ddot{x}_1 + K (x_1 - x_2) = 0 \tag{1}$$

$$m_2 \ddot{x}_2 + K (x_2 - x_1) = 0 \tag{2}$$

Substitution of the solutions

$$x_1 = X_1 \cos \omega_n t, \quad x_2 = X_2 \cos \omega_n t$$

leads to the normal mode shape

$$\rho = \frac{X_2}{X_1} = \frac{K}{K - m_2 \omega_n^2} = \frac{- m_1 \omega_n^2 + K}{K} \tag{3}$$

The characteristic equation for the system has the solutions

$$\omega_{n_1}^2 = 0, \quad \omega_{n_2}^2 = K \left(\frac{m_1 + m_2}{m_1 m_2} \right) \tag{4}$$

The solution $\omega_n = 0$ represents a lateral displacement of the system with no spring compression or extension.

The general solution of the equations (1) and (2) is of the form

$$x_1 = B_1 + B_2 t + B_3 \cos \omega_{n_2} t + B_4 \sin \omega_{n_2} t$$

$$x_2 = B_1 + B_2 t + B_3 \rho\cos \omega_{n_2} t + B_4 \rho\sin \omega_{n_2} t \qquad (5)$$

where $B_1 = \frac{x_{20} - \rho x_{10}}{1 - \rho}$, $\quad B_3 = \frac{x_{10} - x_{20}}{1 - \rho}$

$$B_2 = \frac{V_{20} - \rho V_{10}}{1 - \rho}, \quad B_4 = \frac{V_{10} - V_{20}}{(1-\rho)\ \omega_{n_2}} \qquad (6)$$

x_{10}, V_{10}, x_{20}, V_{20} are the initial displacements and velocities of the vehicle and barrier, respectively. We may set $x_{10} = x_{20} = 0$; then $B_1 = B_3 = 0$. Differentiation of (5) with respect to time and substitution of (6) leads to the following relations for the displacements, velocities, and accelerations of the car and barrier:

$$x_1 = \left(\frac{V_{20} - \rho V_{10}}{1 - \rho}\right) t + \left(\frac{V_{10} - V_{20}}{(1-\rho)\ \omega_{n_2}}\right) \sin \omega_{n_2} t$$

$$x_2 = \left(\frac{V_{20} - \rho V_{10}}{1 - \rho}\right) t + \left(\frac{V_{10} - V_{20}}{(1-\rho)\ \omega_{n_2}}\right) \rho \sin \omega_{n_2} t \qquad (7)$$

$$\dot{x}_1 = \frac{V_{20} - \rho V_{10}}{1 - \rho} + \left(\frac{V_{10} - V_{20}}{1 - \rho}\right) \cos \omega_{n_2} t$$

$$\dot{x}_2 = \frac{V_{20} - \rho V_{10}}{1 - \rho} + \left(\frac{V_{10} - V_{20}}{1 - \rho}\right) \rho \cos \omega_{n_2} t \qquad (8)$$

$$\ddot{x}_1 = - \left(\frac{V_{10} - V_{20}}{1 - \rho}\right) \omega_{n_2} \sin \omega_{n_2} t$$

$$\ddot{x}_2 = - \left(\frac{V_{10} - V_{20}}{1 - \rho}\right) \rho\, \omega_{n_2} \sin \omega_{n_2} t \qquad (9)$$

Using equations (3) and (4), the quantities ρ and $1-\rho$ become:

$$\rho = \frac{-m_1}{m_2}$$

$$1-\rho = \frac{m_1 + m_2}{m_2} \qquad (10)$$

For the fixed barrier case, the above equations for ρ and $1-\rho$ reduce to $\rho=0$, $1-\rho = 1$, $\omega_n = (\frac{K}{m_1})^{1/2}$; then x, $\dot{x}$, $\ddot{x}$ become: $(m_2 = \infty$, $V_{20} = 0)$

$$x_1 = V_{10} \left(\frac{m_1}{K}\right)^{1/2} \sin \left(\frac{K}{m_1}\right)^{1/2} t$$

$$x_2 = 0 \qquad (11)$$

$$\dot{x}_1 = V_{10} \cos \left(\frac{K}{m_1}\right)^{1/2} t$$

$$\dot{x}_2 = 0 \qquad (12)$$

$$\ddot{x}_1 = - V_{10} \left(\frac{K}{m_1}\right)^{1/2} \sin \left(\frac{K}{m_1}\right)^{1/2} t$$

$$\ddot{x}_2 = 0 \qquad (13)$$

3.0 CALCULATION OF EQUIVALENT CLOSING VELOCITIES FOR SELECTED CRASH PARAMETERS

Maintaining selected crash parameters constant for both the fixed barrier and the moving barrier conditions, equivalent vehicle-barrier closing velocities were calculated. The applicable equations and some equivalent closing speeds are summarized in Table 1. Table 2 presents a summary of the times of occurrence for selected vehicle parameters. It should be noted that the closing speeds may be obtained by adjusting either the vehicle speed, the barrier speed, or both.

P is the parameter to be maintained constant.

Barred quantities refer to moving barrier case.

(1) P: Initial relative velocity of vehicle and barrier.

Fixed barrier case:

Initial relative velocity = $V_{10} - V_{20} = V_{10}$

Moving barrier case:

Initial relative velocity = $\bar{V}_{10} - \bar{V}_{20}$

The equivalent closing speed is then given by the equality:

$$\bar{V}_{10} - \bar{V}_{20} = V_{10}$$

(2) P: Maximum velocity change of vehicle.
Velocity change = $\Delta V = V_{10} - \dot{x}_{1\ \mathrm{final}}$.

$$\therefore\ \Delta V = V_{10} - \left(\frac{V_{20} - \rho V_{10}}{1 - \rho}\right)$$

$$= \frac{V_{10} - V_{20}}{1 - \rho}$$

Fixed barrier case:

$$\Delta V = V_{10}$$

Moving barrier case:

$$\overline{\Delta V} = \frac{(\bar{V}_{10} - \bar{V}_{20})}{(m_1 + m_2)}\ m_2$$

For $\Delta V = \overline{\Delta V}$

$$\bar{V}_{10} - \bar{V}_{20} = \left(\frac{m_1 + m_2}{m_2}\right) V_{10}$$

(3) P: Maximum momentum change of vehicle.

The condition here is

$$m_1\ \Delta V = m_1\ \overline{\Delta V}$$

Therefore the result is the same as in (2):

$$\bar{V}_{10} - \bar{V}_{20} = \left(\frac{m_1 + m_2}{m_2}\right) V_{10}$$

(4) P: Maximum passenger compartment acceleration (deceleration)

Fixed barrier case:

From equation (13)

$$|\ddot{x}_1|_{max} = V_{10} \left(\frac{K}{m_1}\right)^{1/2}$$

Moving barrier case:

From equation (9)

$$|\ddot{\bar{x}}_1|_{max} = (\bar{V}_{10} - \bar{V}_{20}) \left[K \frac{(m_1 + m_2)}{m_1 m_2}\right]^{1/2} \left(\frac{m_2}{m_1 + m_2}\right)$$

Equating $|\ddot{x}_1|_{max}$ and $|\ddot{\bar{x}}_1|_{max}$ gives

$$\bar{V}_{10} - \bar{V}_{20} = \left(\frac{m_1 + m_2}{m_2}\right)^{1/2} V_{10}$$

(5) P: Maximum spring crush

Maximum spring crush $= |x_1 - x_2|_{max}$

$$= \frac{V_{10} - V_{20}}{\omega_n}$$

Fixed barrier case:

Maximum crush $= V_{10} \left(\frac{m_1}{K}\right)^{1/2}$

Moving barrier case:

$$\text{Maximum crush} = (\bar{V}_{10} - \bar{V}_{20}) \left(\frac{m_1 \; m_2}{K(m_1 + m_2)}\right)^{1/2}$$

The equivalent closing speed for equality of maximum spring crush is then

$$\bar{V}_{10} - \bar{V}_{20} = \left(\frac{m_1 + m_2}{m_2}\right)^{1/2} \quad V_{10}$$

(6) P: Maximum energy absorbed by vehicle.

This calculation is based upon the assumption that all the energy of spring compression represents energy absorbed by the vehicle.

$$\text{Energy absorbed} = \frac{1}{2} K \; (x_1 - x_2)^2$$

Maximum energy absorbed is then given by the quantity

$$\frac{1}{2} K \left[\left(\frac{V_{10} - V_{20}}{\omega_n}\right)\right]^2$$

Fixed barrier case:

$$\text{Maximum energy absorbed} = \frac{1}{2} K \left[V_{10} \sqrt{\frac{m_1}{K}}\right]^2$$

Moving barrier case:

$$\text{Maximum energy absorbed} = \frac{1}{2} K \left[\frac{(\bar{V}_{10} - \bar{V}_{20}) \; (m_1 \; m_2)^{1/2}}{[K(m_1 + m_2)]^{1/2}}\right]^2$$

Equivalent closing speed for equal maximum energy absorption is then:

$$\bar{V}_{10} - \bar{V}_{20} = \left(\frac{m_1 + m_2}{m_2}\right)^{1/2} \quad V_{10}$$

3.1 TIME OF OCCURRENCE OF MAXIMUM VELOCITY AND MOMENTUM CHANGE, MAXIMUM ACCELERATION, MAXIMUM SPRING CRUSH, AND MAXIMUM ENERGY ABSORPTION

From equations (7), (8), and (9), it is apparent that this time of occurrence is given by

$$\omega_n t = \frac{\Pi}{2}$$

$$\text{or } t = \frac{\Pi}{2\omega_n}$$

Fixed barrier case $(t \equiv T)$

$$T = \frac{\Pi}{2} \left(\frac{m_1}{K}\right)^{1/2}$$

Moving barrier case $(t \equiv \tau)$

$$\tau = \frac{\Pi}{2} \left[\frac{m_1 m_2}{K(m_1 + m_2)}\right]^{1/2}$$

$$\text{The ratio } \frac{\tau}{T} = \left(\frac{m_2}{m_1 + m_2}\right)^{1/2}$$

Values for this ratio for several cars are given in Table 2.

4.0 DYNAMIC TEST CONDITIONS AND VEHICLE DATA

4.1 DEFINITIONS OF SYMBOLS

W_2 (m_2) = weight (mass) of barrier test device.

W_1 (m_1) = weight (mass) of vehicle.

V_{10} = initial velocity of vehicle for fixed barrier case.

$\bar{V}_{10}$ = initial velocity of vehicle for moving barrier case

$\bar{V}_{20}$ = initial velocity of moving barrier.

K = spring constant of vehicle crush structure.

T = time of occurrence of vehicle parameter maximum (fixed barrier case).

τ = time of occurrence of vehicle parameter (moving barrier case).

ρ = mode shape.

ω_n = natural frequency of system.

4.2 TEST CONDITIONS

W_2 = 4000 pounds (moving barrier)

$V_{20} = 0$

$W_2 = \infty$ (fixed barrier)

4.3 VEHICLE DATA

Vehicle	Weight (lb)	Velocity V_{10} Fixed Barrier Condition (mph)
Honda	2200	40
Ford	4550	40
Plymouth	4440	40
Volvo	3220	45

TABLE 1. EQUIVALENT CAR-TO-MOVING TEST DEVICE CLOSING SPEEDS FOR SELECTED CRASH PARAMETERS

Crash Parameter Held Constant	Applicable Equations: Moving Device Parameter = Fixed Device Parameter	Equivalent Closing Speeds $(\bar{V}_{10} - \bar{V}_{20})$ (mph)			
		Honda	Ford	Plymouth	Volvo
(1) Initial velocity of vehicle relative to initial velocity of barrier	$\bar{V}_{10} - \bar{V}_{20} = V_{10}$	40.00	40.00	40.00	45.00
(2) Maximum vehicle velocity change	$\bar{V}_{10} - \bar{V}_{20} = \left(\frac{m_1 + m_2}{m_2}\right) V_{10}$	62.00	85.50	84.40	81.22
(3) Maximum vehicle momentum change	$\bar{V}_{10} - \bar{V}_{20} = \left(\frac{m_1 + m_2}{m_2}\right) V_{10}$				
(4) Maximum compartment acceleration (deceleration)	$\bar{V}_{10} - \bar{V}_{20} = \left(\frac{m_1 + m_2}{m_2}\right)^{1/2} V_{10}$	49.80	58.48	58.10	60.46
(5) Maximum spring crush	$\bar{V}_{10} - \bar{V}_{20} = \left(\frac{m_1 + m_2}{m_2}\right)^{1/2} V_{10}$				
(6) Maximum energy absorbed by vehicle	$\bar{V}_{10} - \bar{V}_{20} = \left(\frac{m_1 + m_2}{m_2}\right)^{1/2} V_{10}$				

Note: m_1 = mass of car; m_2 = mass of test device.

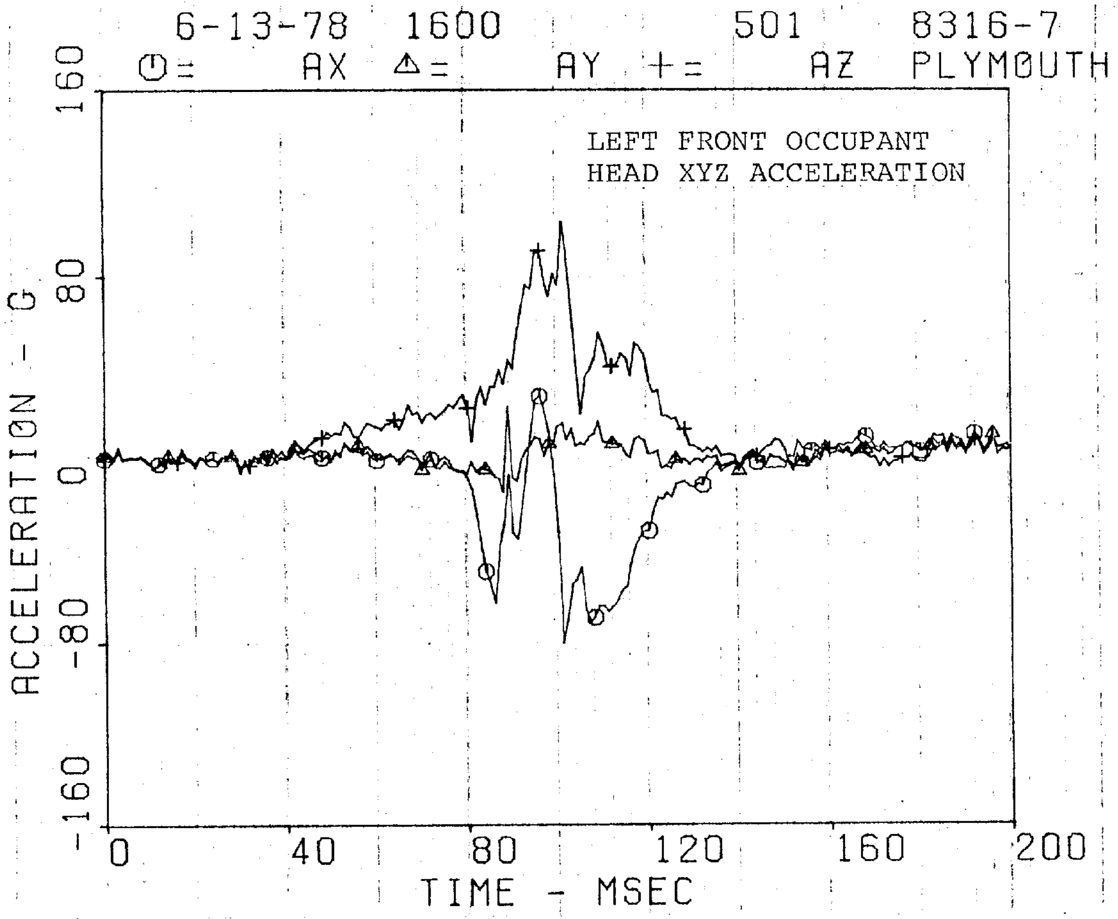
TABLE 2. TIME OF OCCURRENCE RATIO FOR SELECTED CRASH PARAMETERS

Crash Parameter	Time of Occurrence Equations		Ratio for Vehicle Model*			
	Moving Device	Fixed Device	Honda	Ford	Plymouth	Volvo
Maximum velocity change	$\tau = \frac{\frac{\pi}{2}}{K^{1/2}}\left(\frac{m_1\ m_2}{m_1 + m_2}\right)^{1/2}$	$T = \frac{\pi}{2}\ (\frac{m_1}{K})^{1/2}$	.803	.684	.688	.744
Maximum momentum change						
Maximum spring crush						
Maximum energy absorption						
	Ratio: $\tau/T = \left(\frac{m_2}{m_1 + m_2}\right)^{1/2}$					

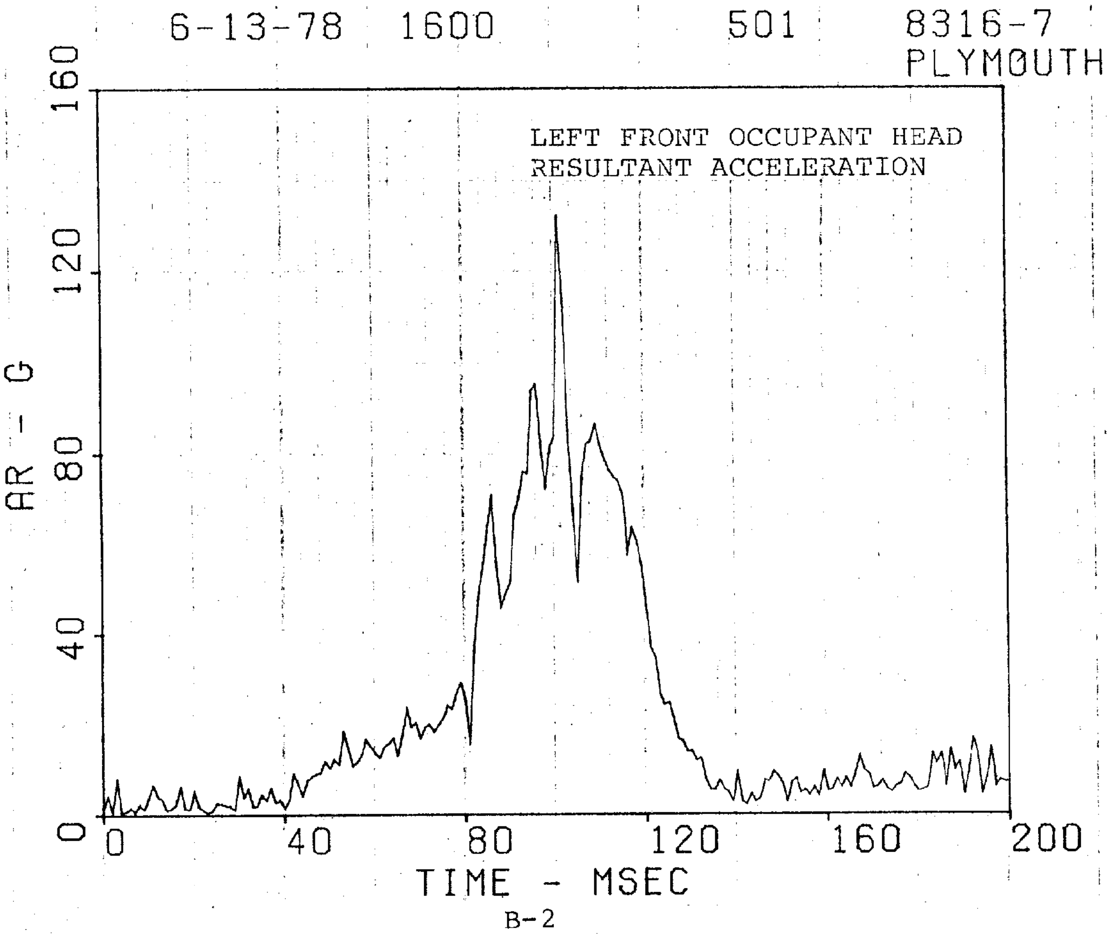
$$*\text{Ratio} = \frac{\text{Time for Moving Device Crash } (\tau)}{\text{Time for Fixed Device Crash } (T)}$$

APPENDIX B

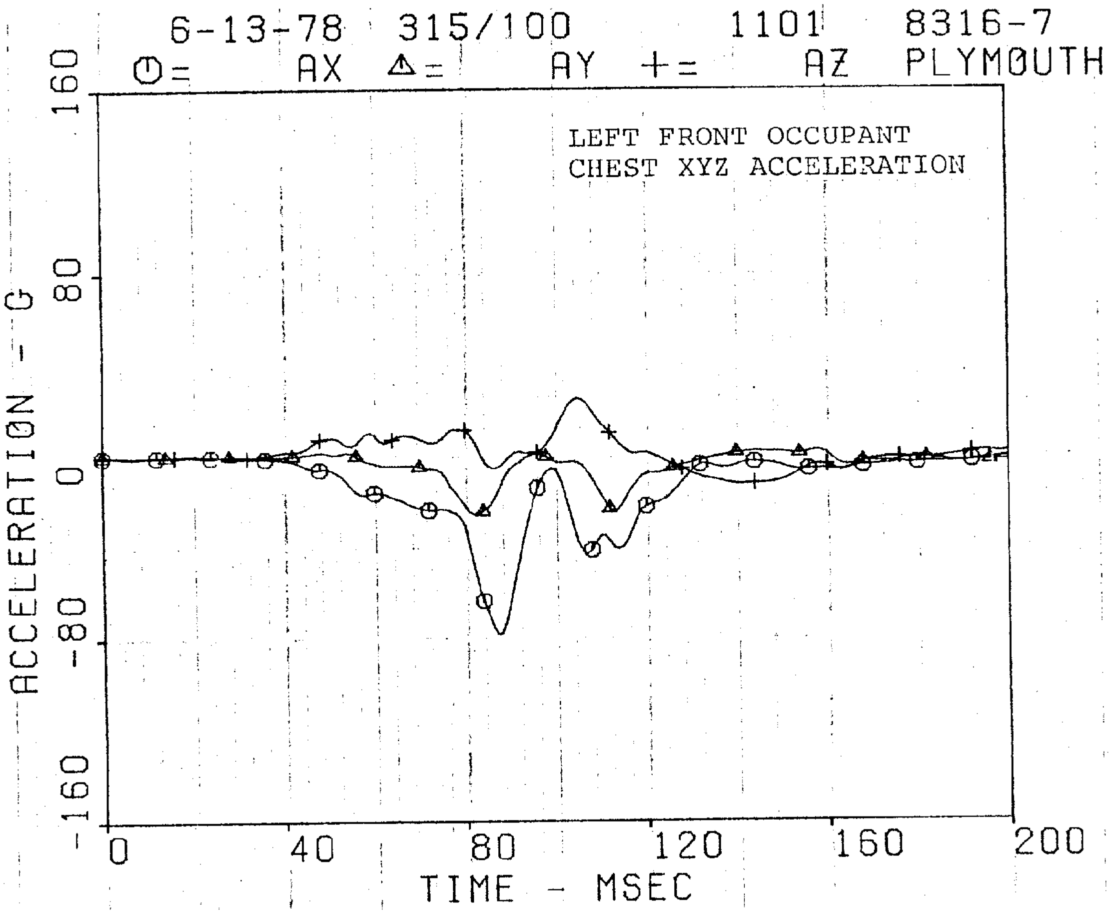
CALCOMP PLOTS
TEST 7
1975 PLYMOUTH FURY-TO-FIXED TEST DEVICE



LEFT FRONT OCCUPANT
HEAD XYZ ACCELERATION



LEFT FRONT OCCUPANT HEAD
RESULTANT ACCELERATION


6-13-78 315/100 1101 8316-7
⦶= AX △= AY += AZ PLYMOUTH
LEFT FRONT OCCUPANT
CHEST XYZ ACCELERATION
ACCELERATION - G
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0
-80
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40
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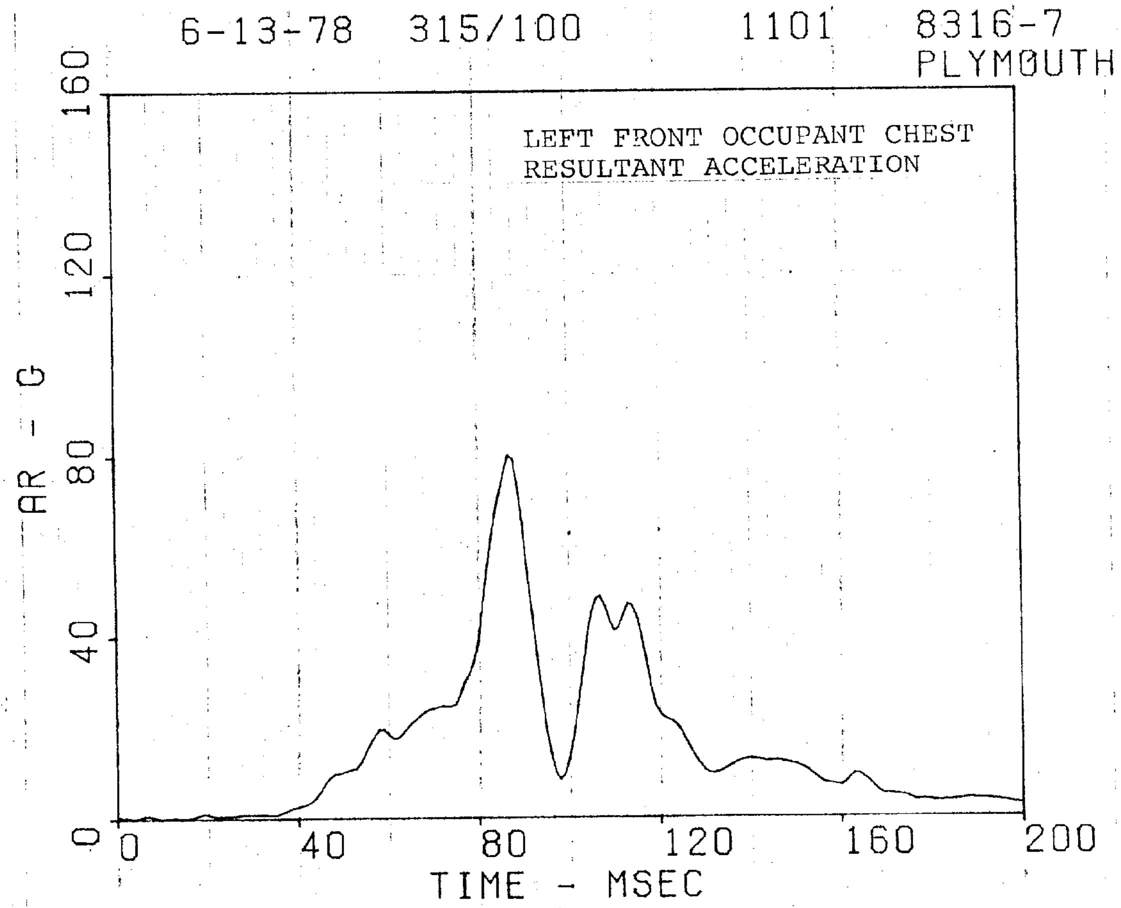
120
160
200
TIME - MSEC


6-13-78 315/100 1101 8316-7
PLYMOUTH
LEFT FRONT OCCUPANT CHEST
RESULTANT ACCELERATION
AR - G
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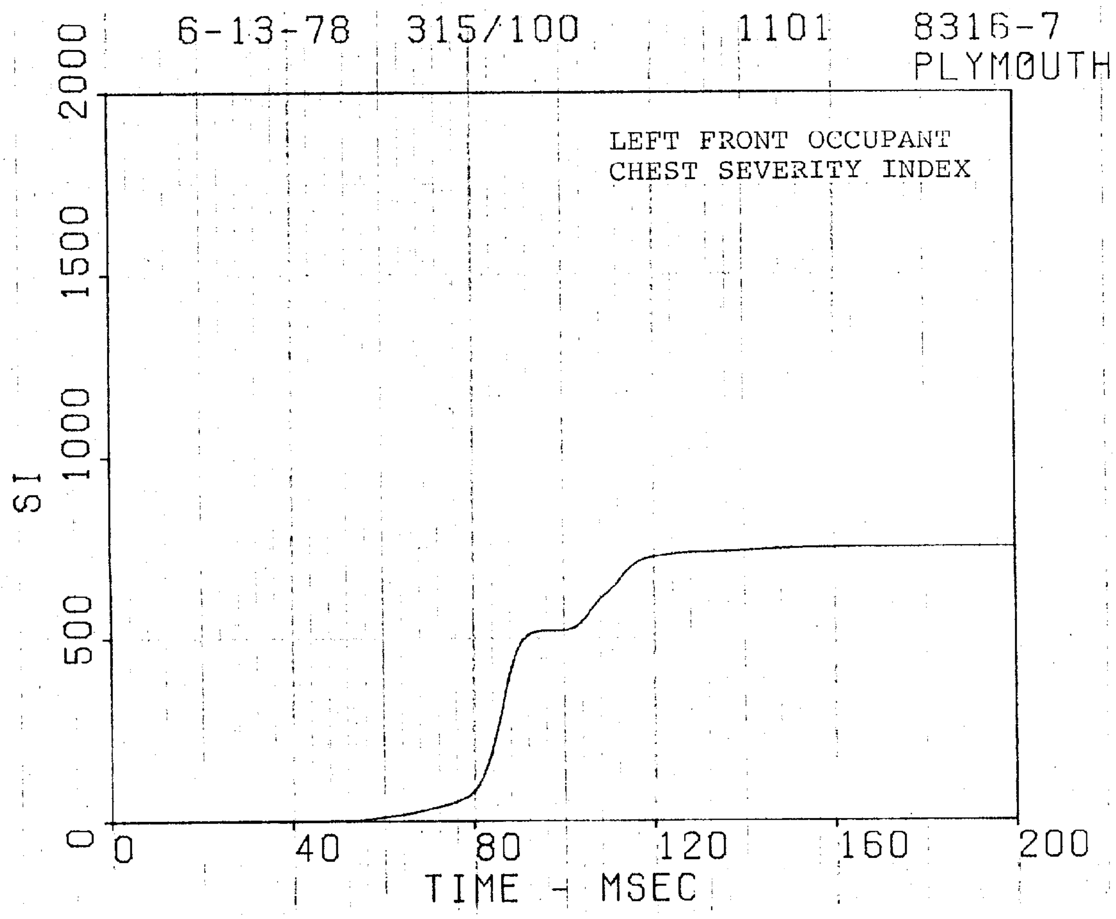
120
80
40
0
0
40
80
120
160
200
TIME - MSEC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315/100
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PLYMOUTH
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CHEST SEVERITY INDEX
SI
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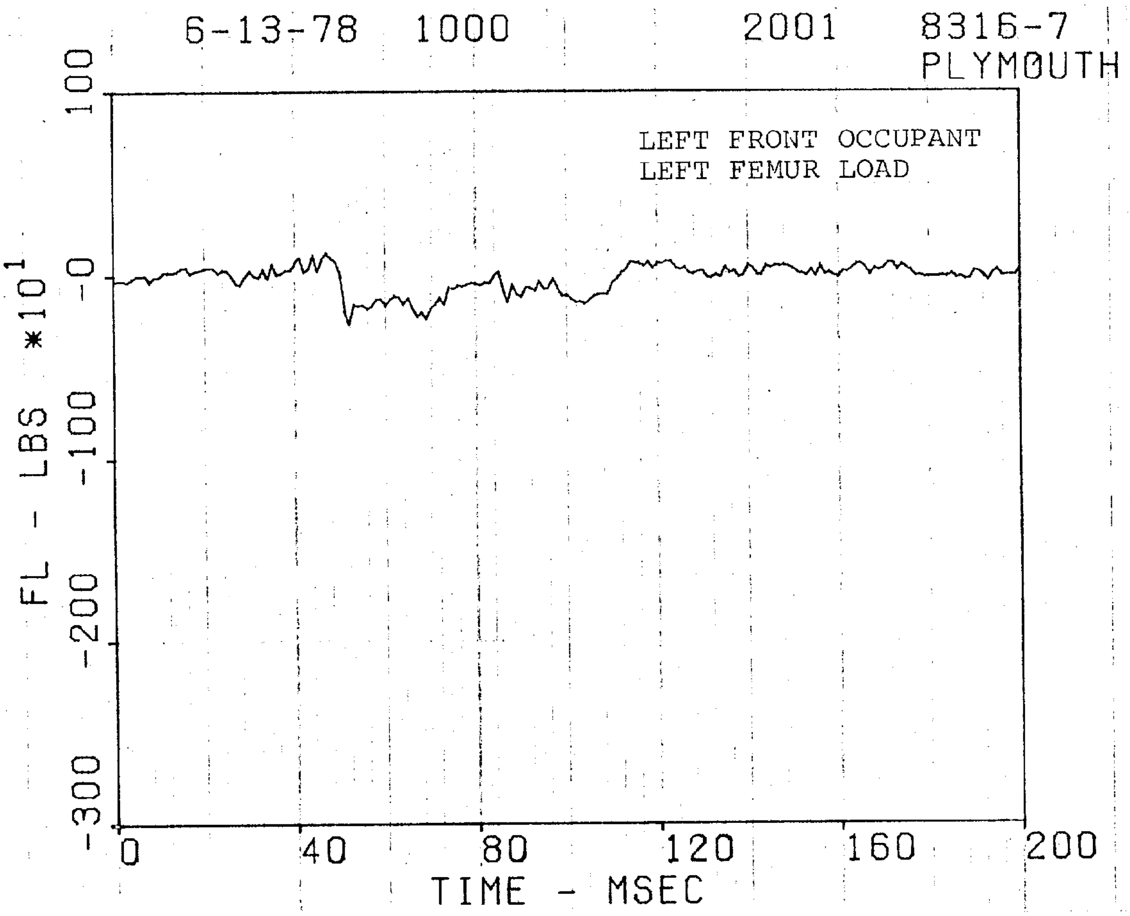
TIME - MSEC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PLYMOUTH
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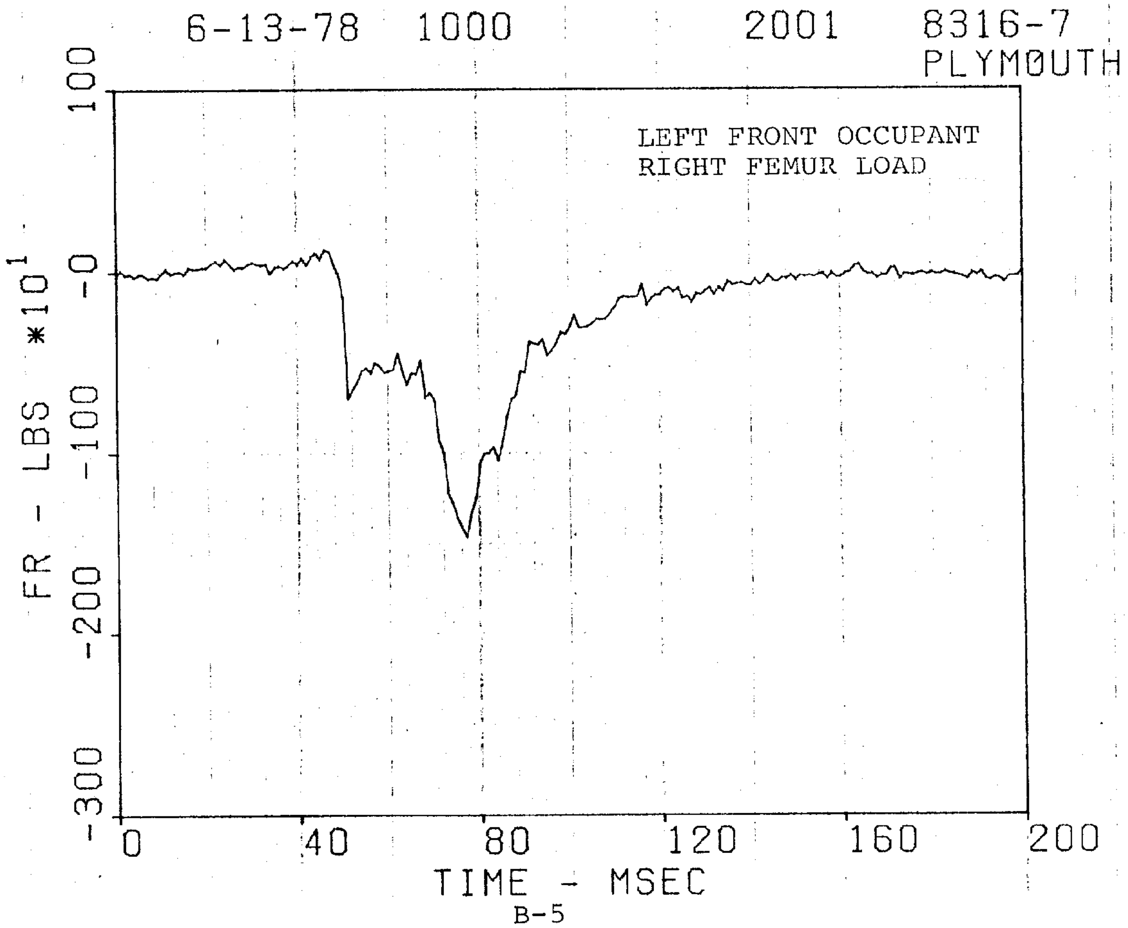
TIME - MSEC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PLYMOUTH
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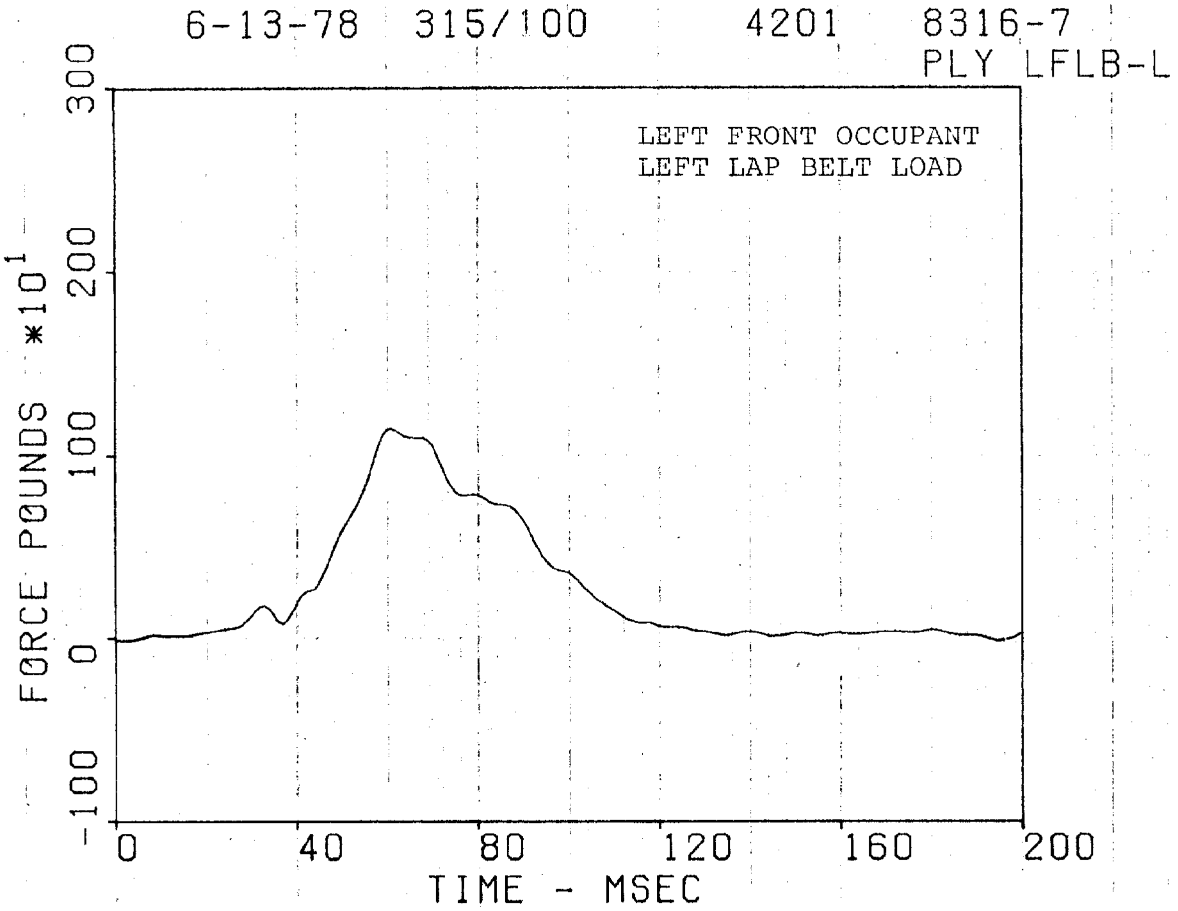
TIME - MSEC


6-13-78 315/100 4201 8316-7
PLY LFLB-L
LEFT FRONT OCCUPANT
LEFT LAP BELT LOAD
FORCE POUNDS *10^1
300
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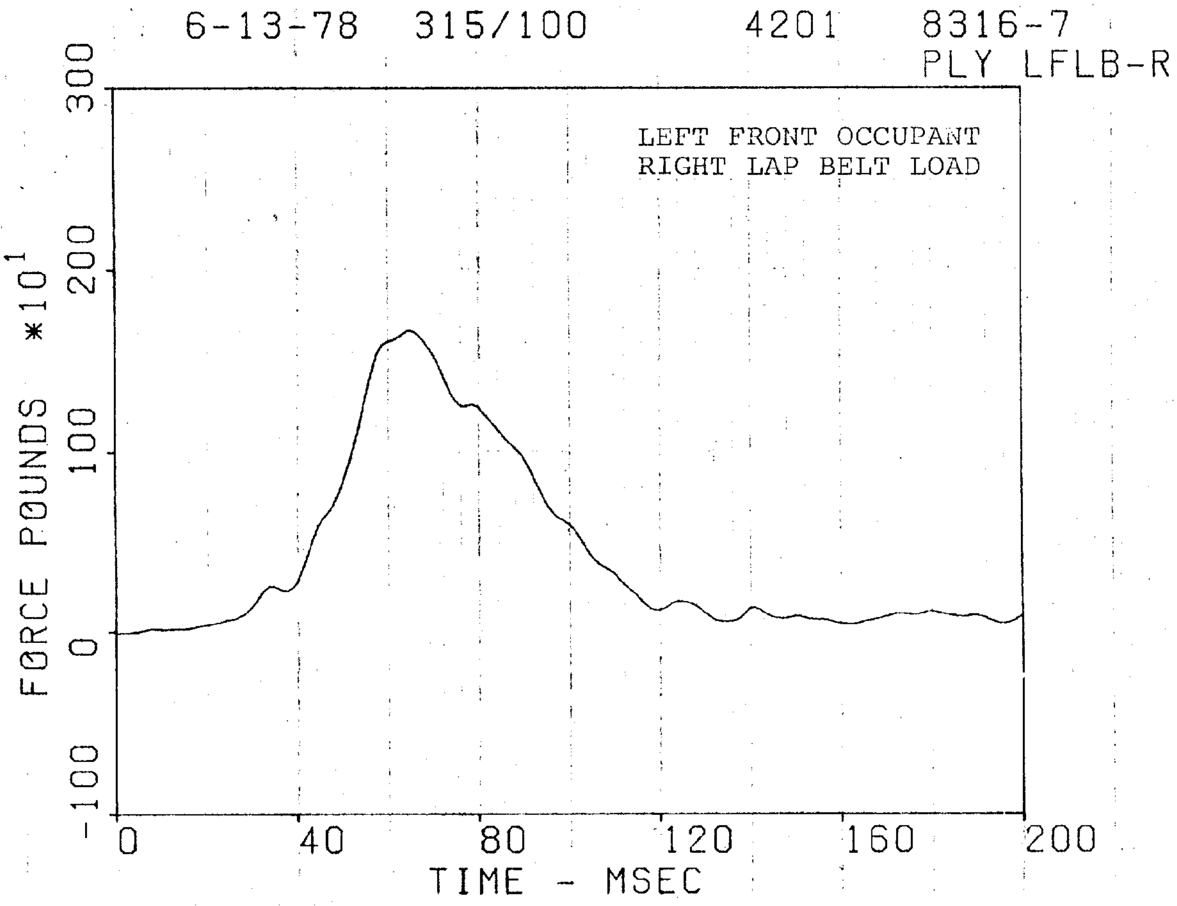
40
80
120
160
200
TIME - MSEC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PLY LFLB-R
LEFT FRONT OCCUPANT
RIGHT LAP BELT LOAD
FORCE POUNDS *10^1
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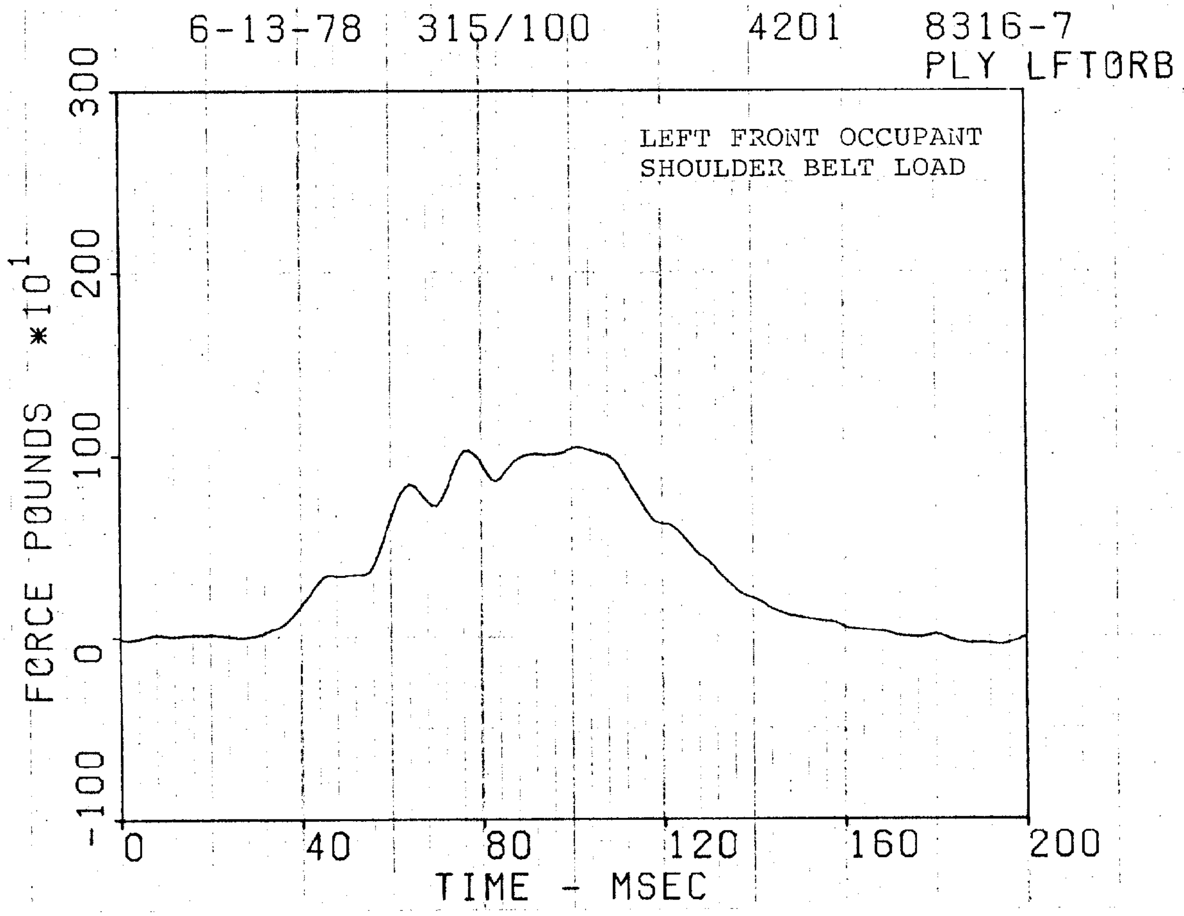
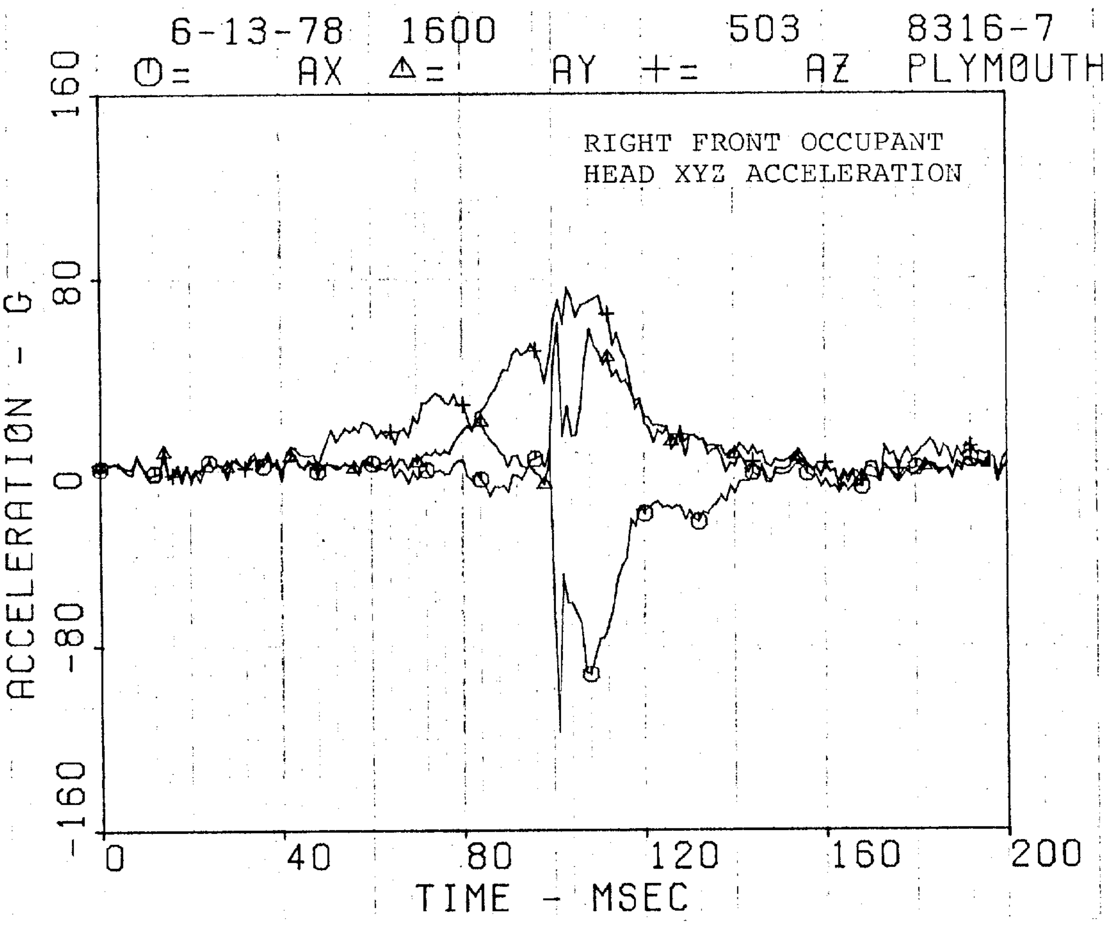
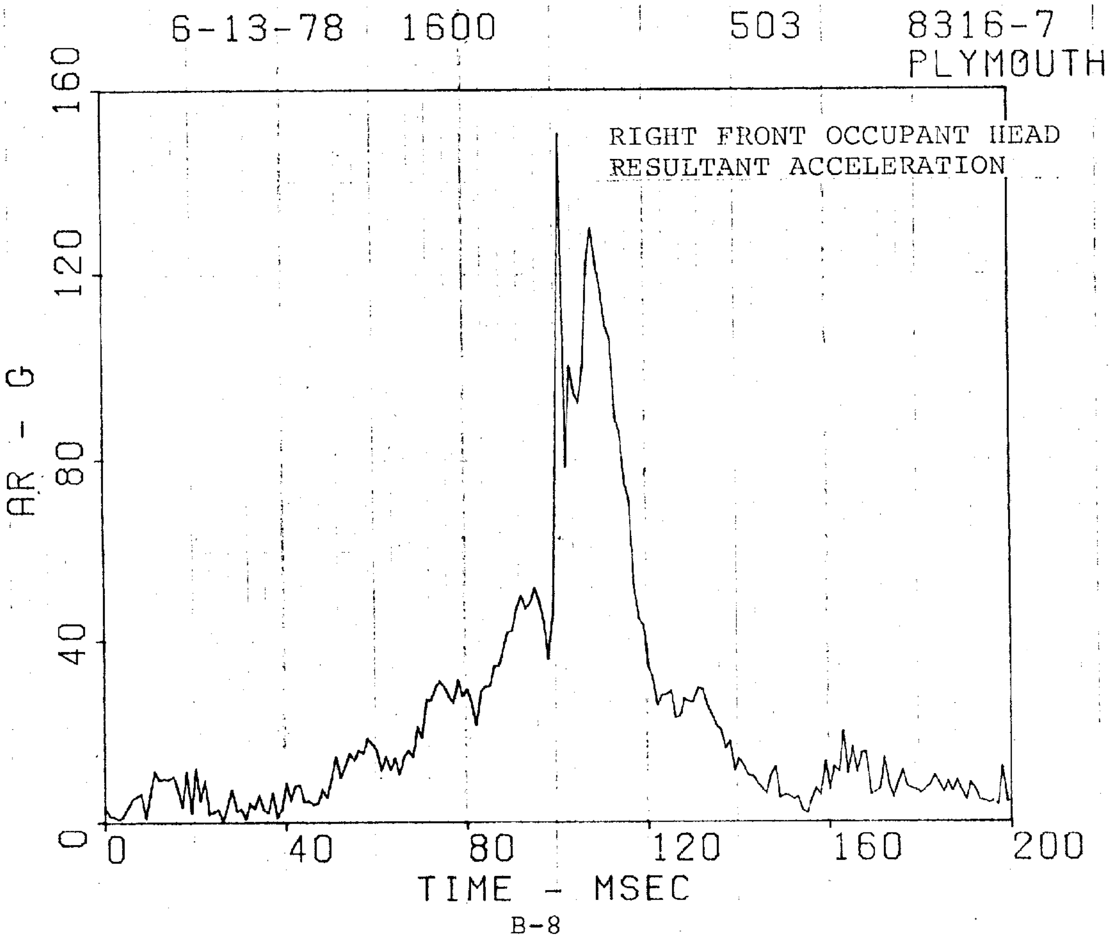
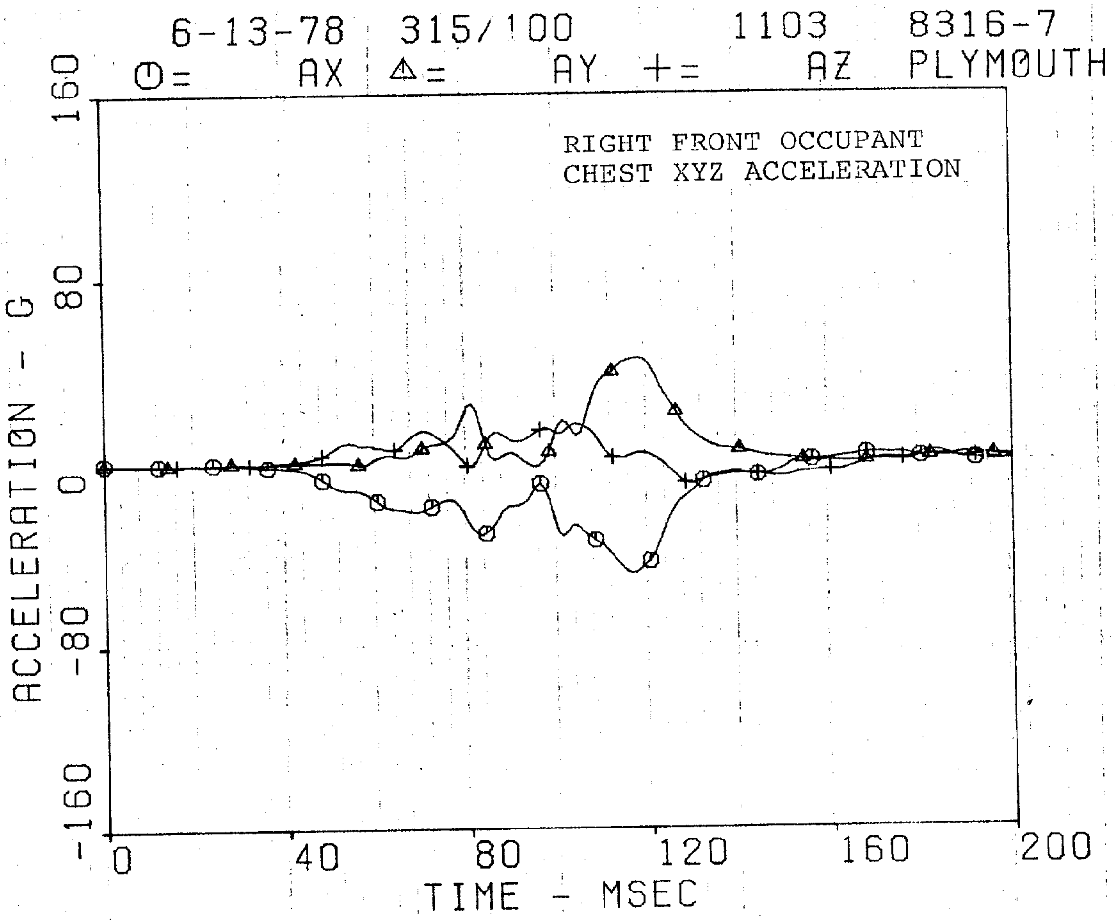
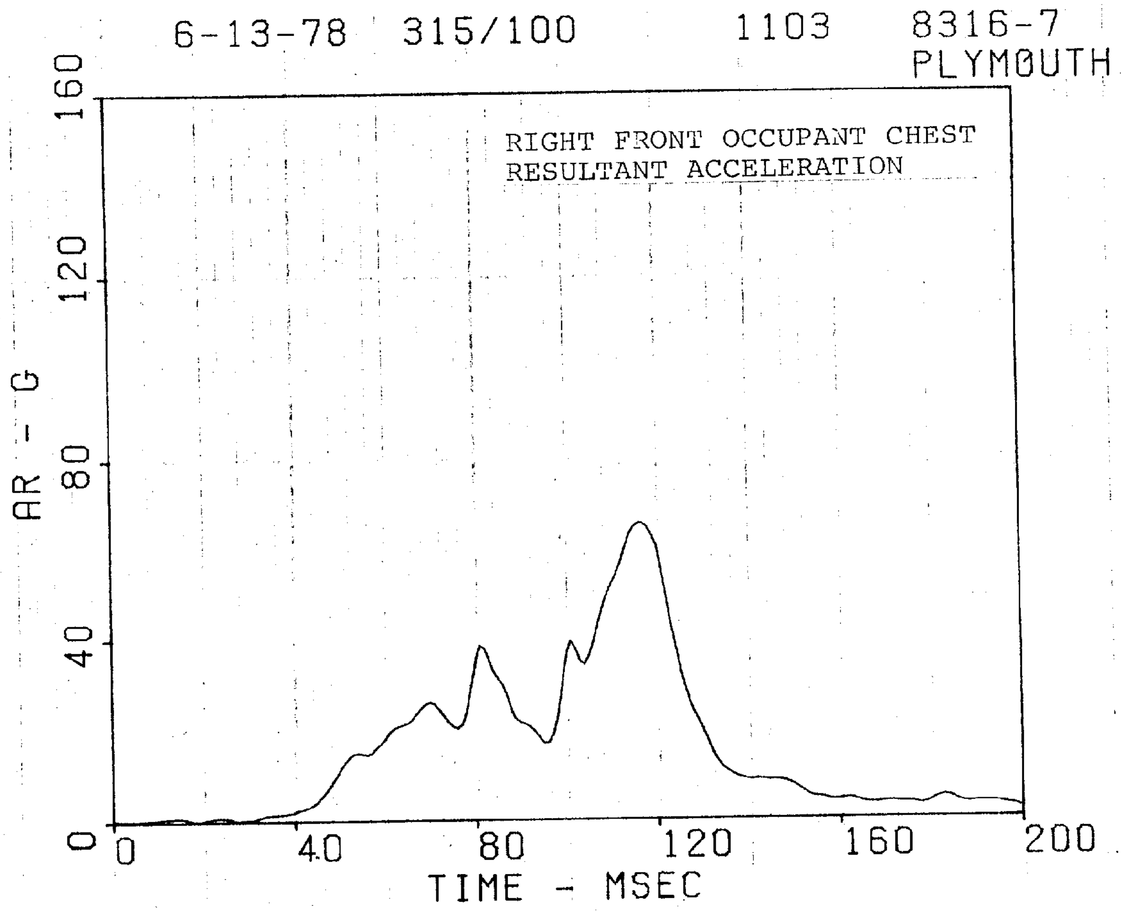
80
120
160
200
TIME - MSEC

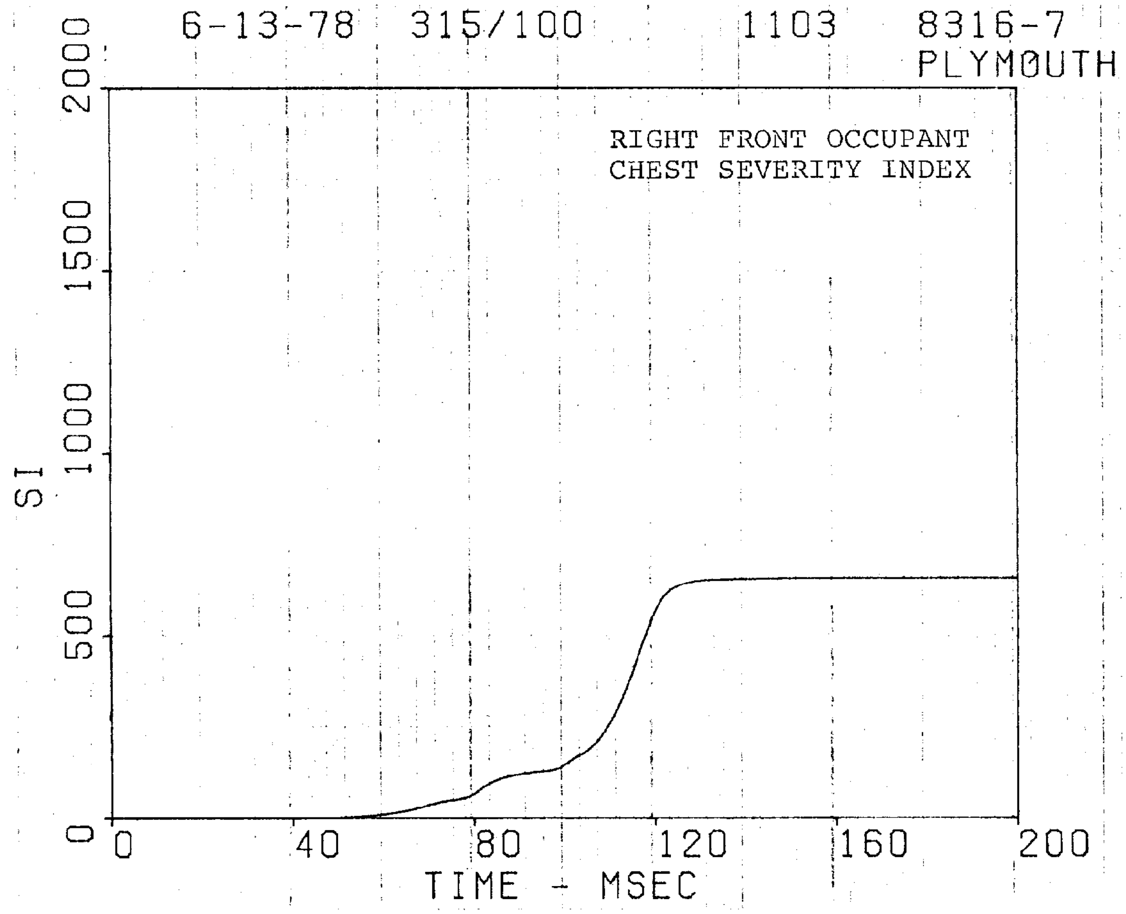

6-13-78
315/100
4201
8316-7
PLY LFTORB
LEFT FRONT OCCUPANT
SHOULDER BELT LOAD
FORCE POUNDS $*10^1$
300
200
100
0
-100
0
40
80
120
160
200
TIME - MSEC

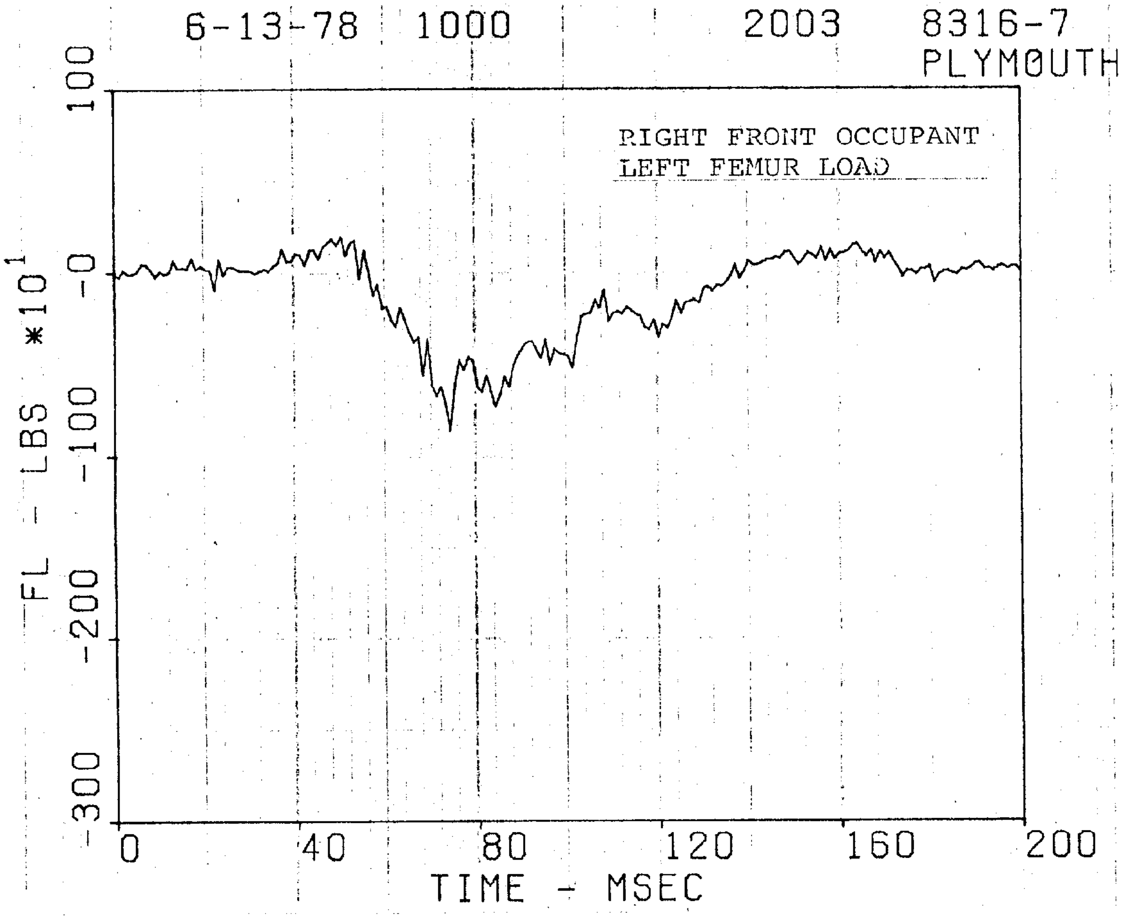

6-13-78 1600 503 8316-7
⊙= AX △= AY += AZ PLYMOUTH
RIGHT FRONT OCCUPANT
HEAD XYZ ACCELERATION
ACCELERATION - G
160
80
0
-80
-160
0
40
80
120
160
200
TIME - MSEC

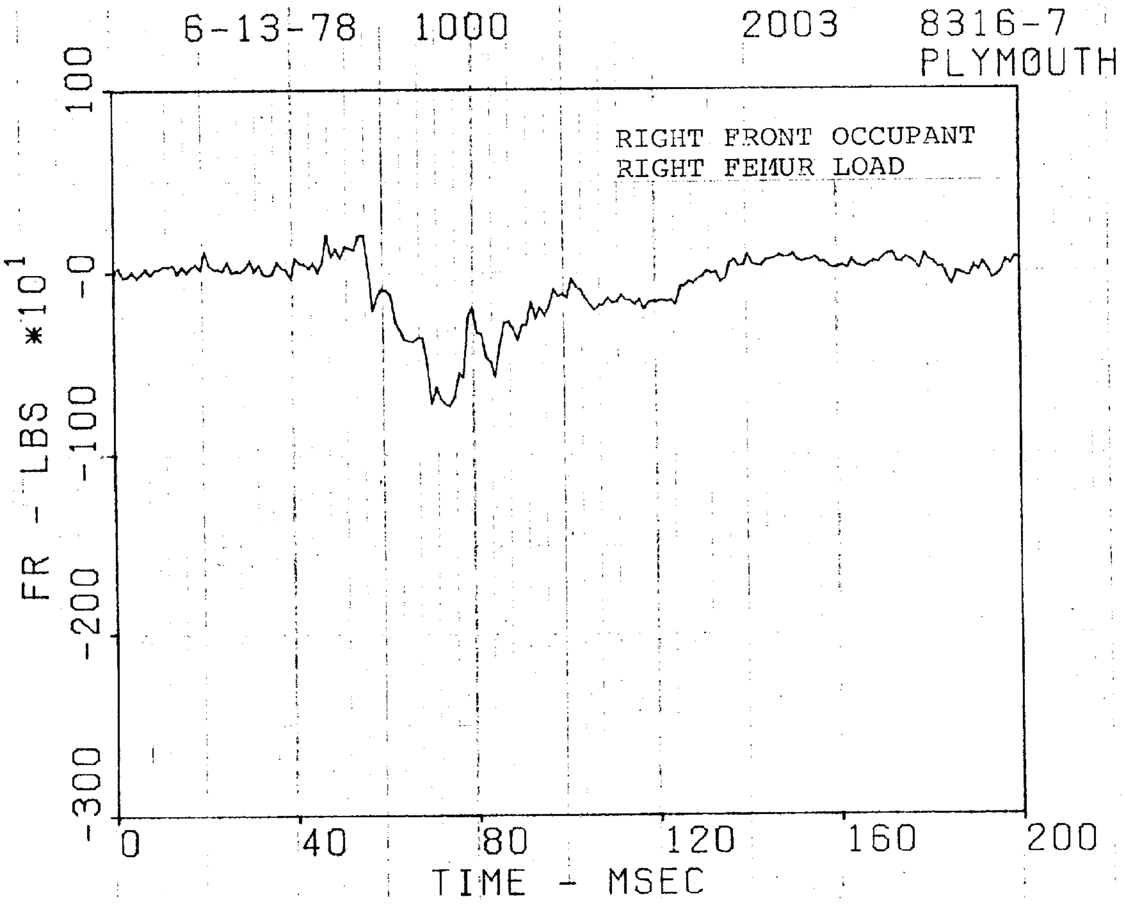

6-13-78 1600 503 8316-7
PLYMOUTH
RIGHT FRONT OCCUPANT HEAD
RESULTANT ACCELERATION
AR - G
160
120
80
40
0
0
40
80
120
160
200
TIME - MSEC

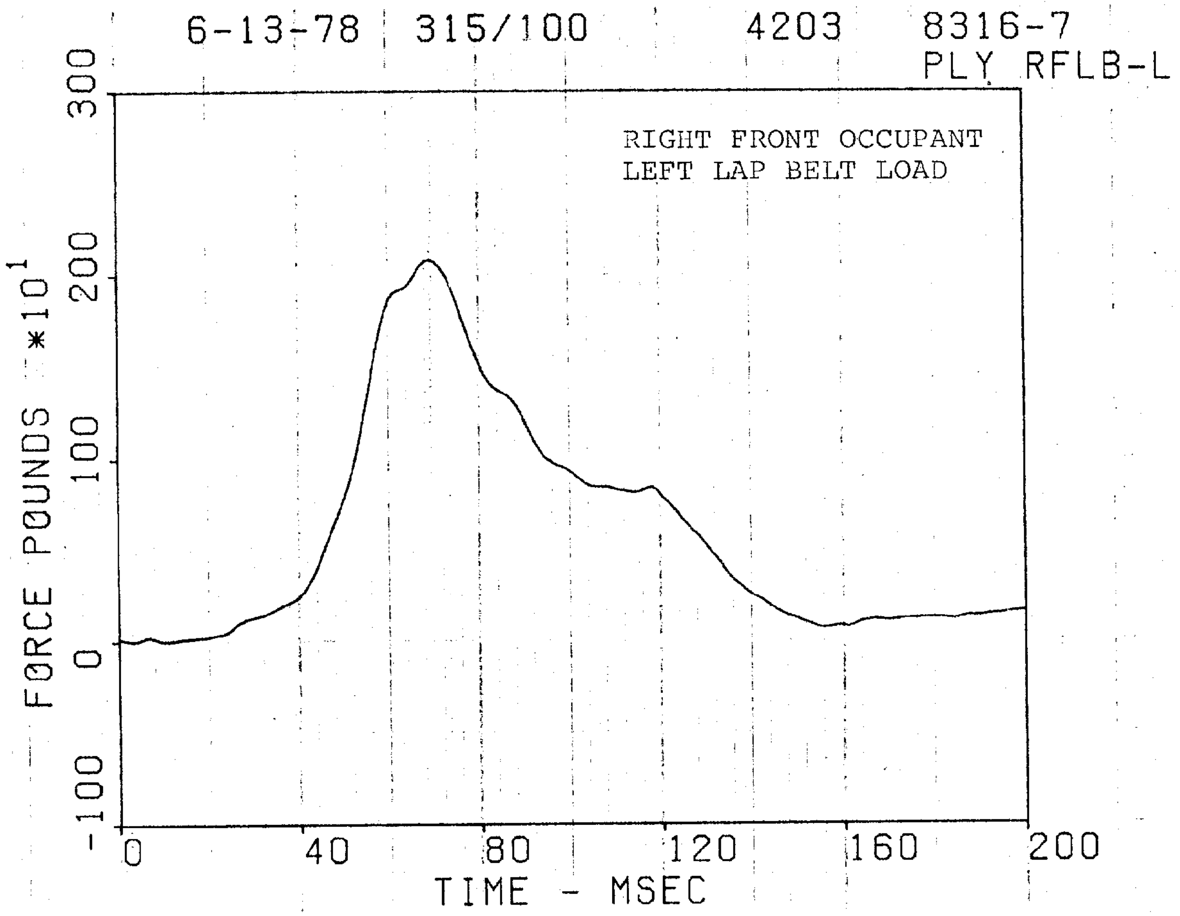

6-13-78 315/100 1103 8316-7
⊕= AX △= AY += AZ PLYMOUTH
RIGHT FRONT OCCUPANT
CHEST XYZ ACCELERATION
ACCELERATION - G
160
80
0
-80
-160
0
40
80
120
160
200
TIME - MSEC

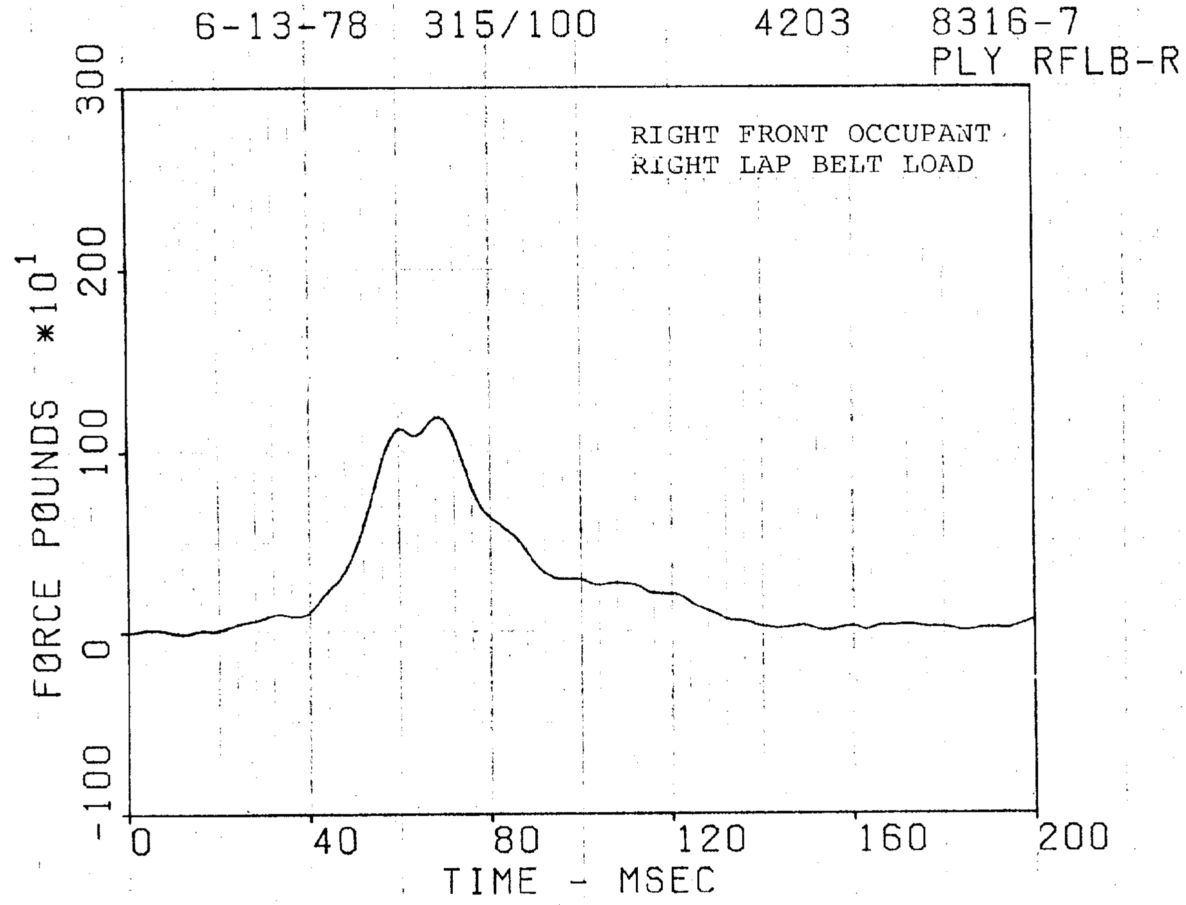

6-13-78 315/100 1103 8316-7
PLYMOUTH
RIGHT FRONT OCCUPANT CHEST
RESULTANT ACCELERATION
AR - G
160
120
80
40
0
0
40
80
120
160
200
TIME - MSEC

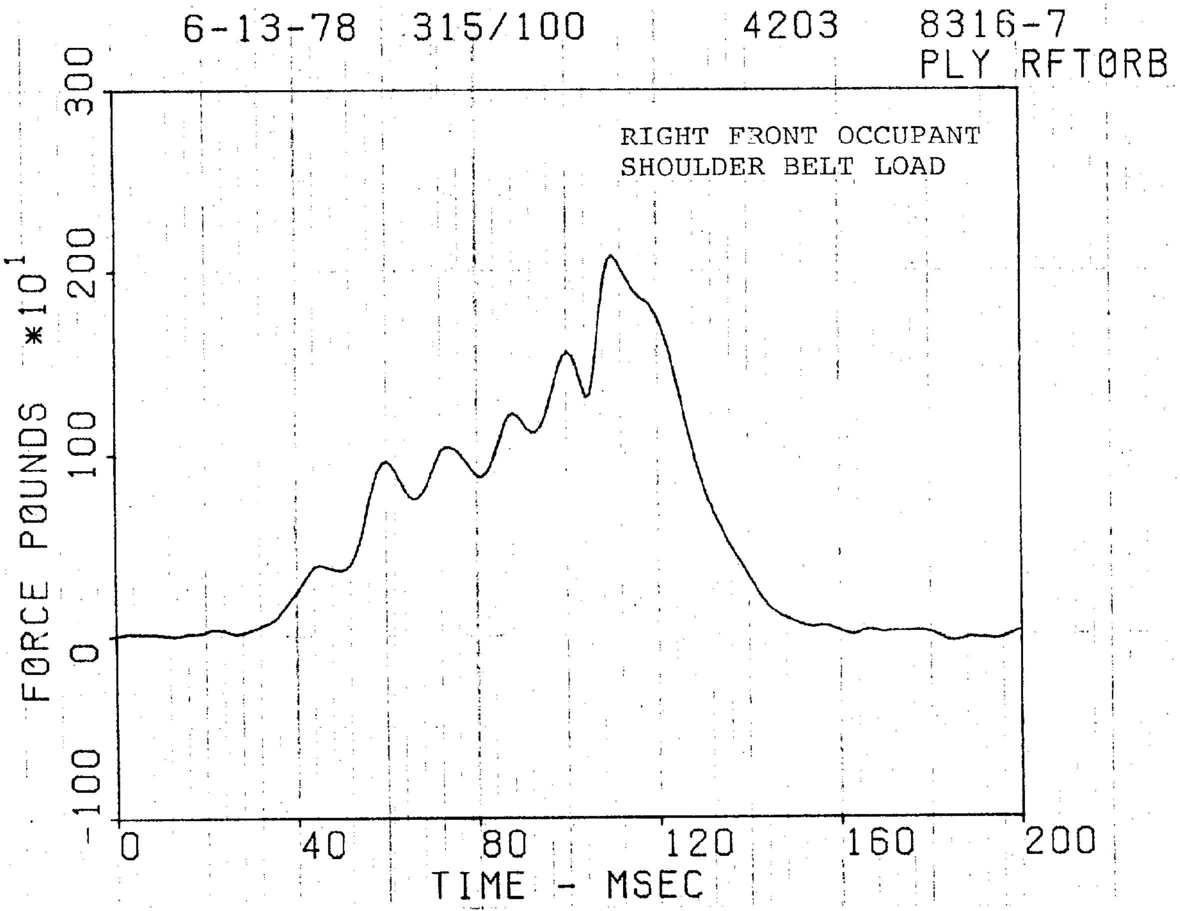

6-13-78
315/100
1103
8316-7
PLYMOUTH
RIGHT FRONT OCCUPANT
CHEST SEVERITY INDEX
SI
2000
1500
1000
500
0
0
40
80
120
160
200
TIME - MSEC

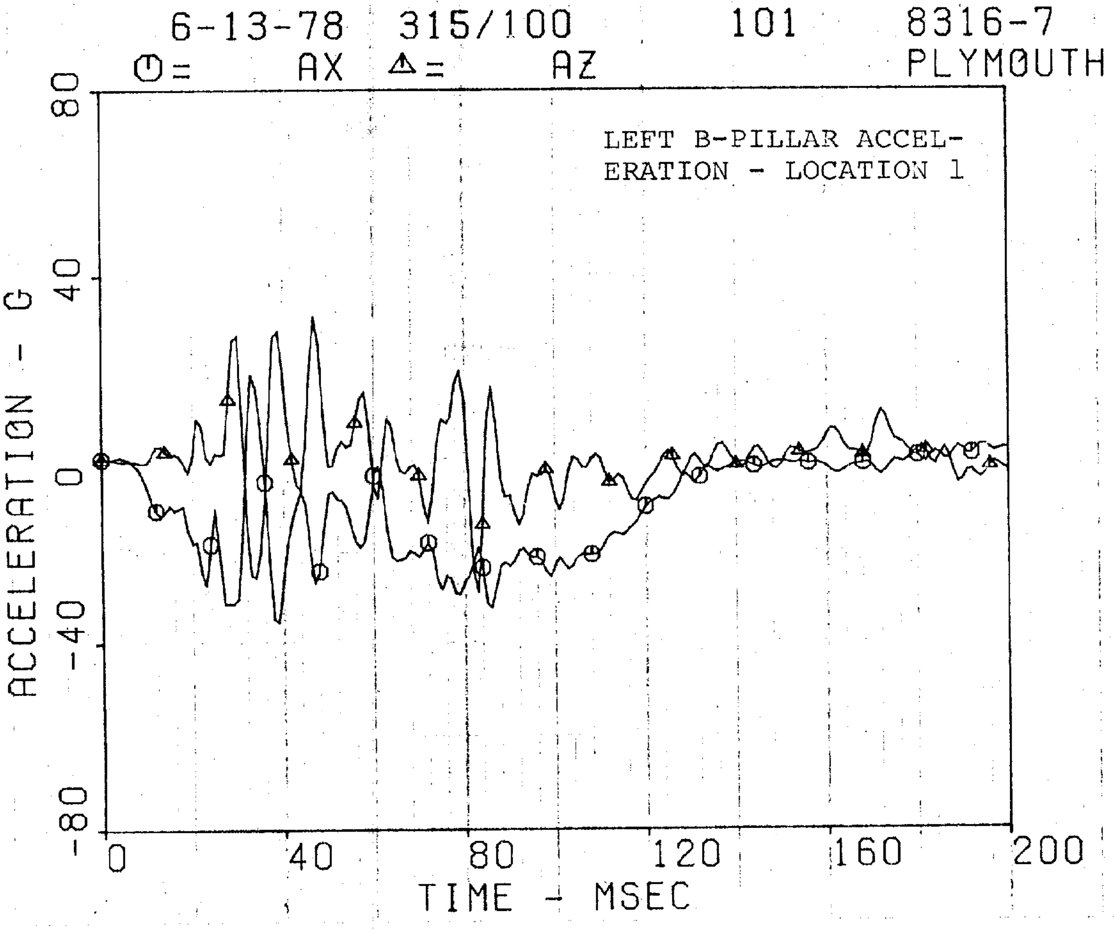

6-13-78
1000
2003
8316-7
PLYMOUTH
RIGHT FRONT OCCUPANT
LEFT FEMUR LOAD
FL - LBS $*10^1$
100
-0
-100
-200
-300
0
40
80
120
160
200
TIME - MSEC

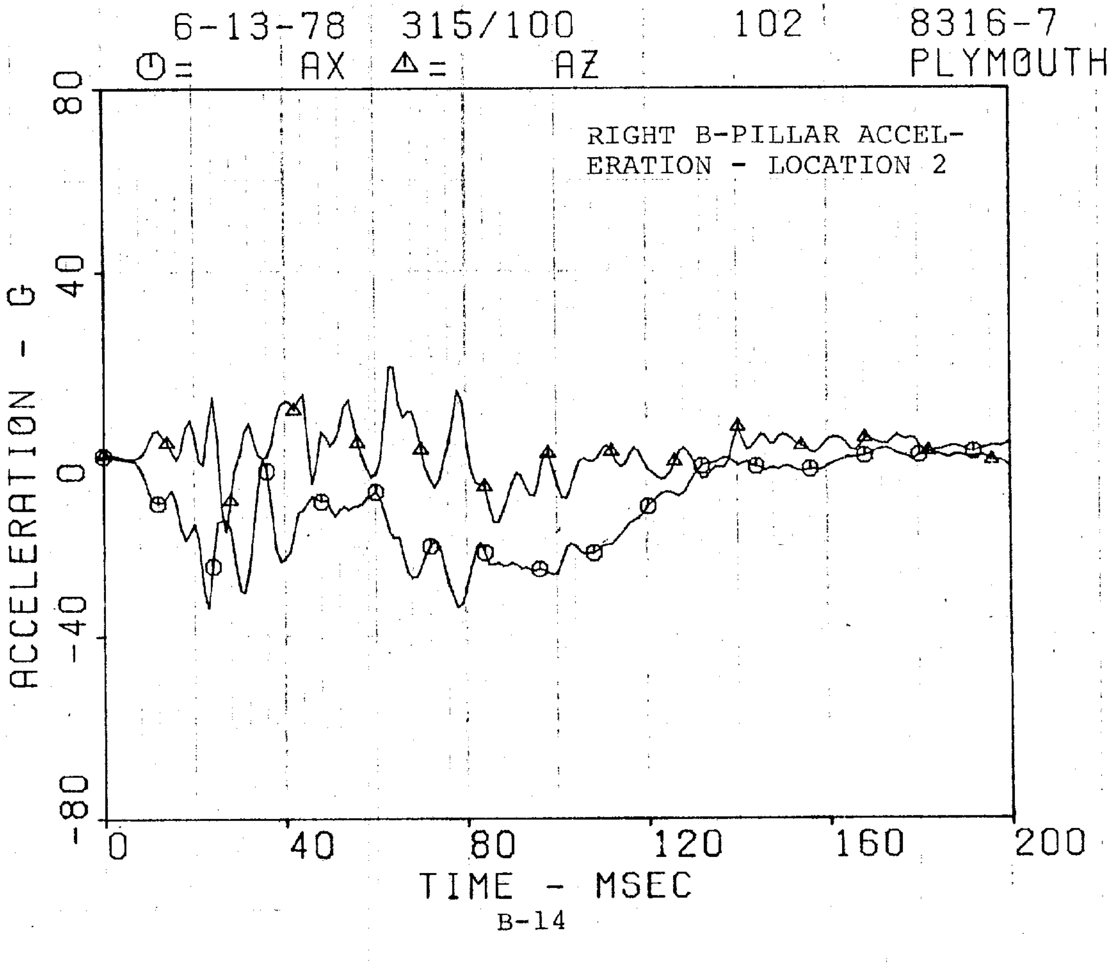

6-13-78
1000
2003
8316-7
PLYMOUTH
RIGHT FRONT OCCUPANT
RIGHT FEMUR LOAD
FR - LBS $*10^1$
100
-0
-100
-200
-300
0
40
80
120
160
200
TIME - MSEC

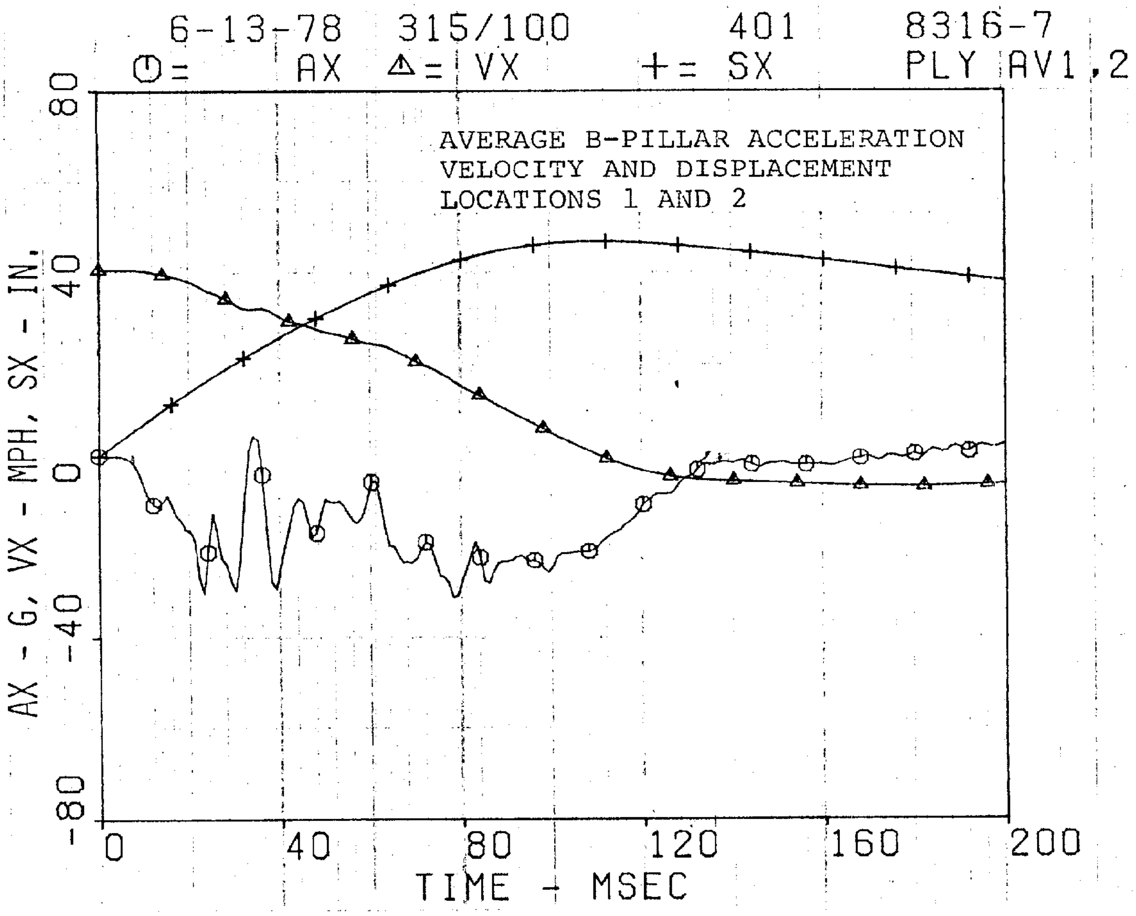

6-13-78
315/100
4203
8316-7
PLY RFLB-L
RIGHT FRONT OCCUPANT
LEFT LAP BELT LOAD
FORCE POUNDS *10^1
300
200
100
0
-100
0
40
80
120
160
200
TIME - MSEC

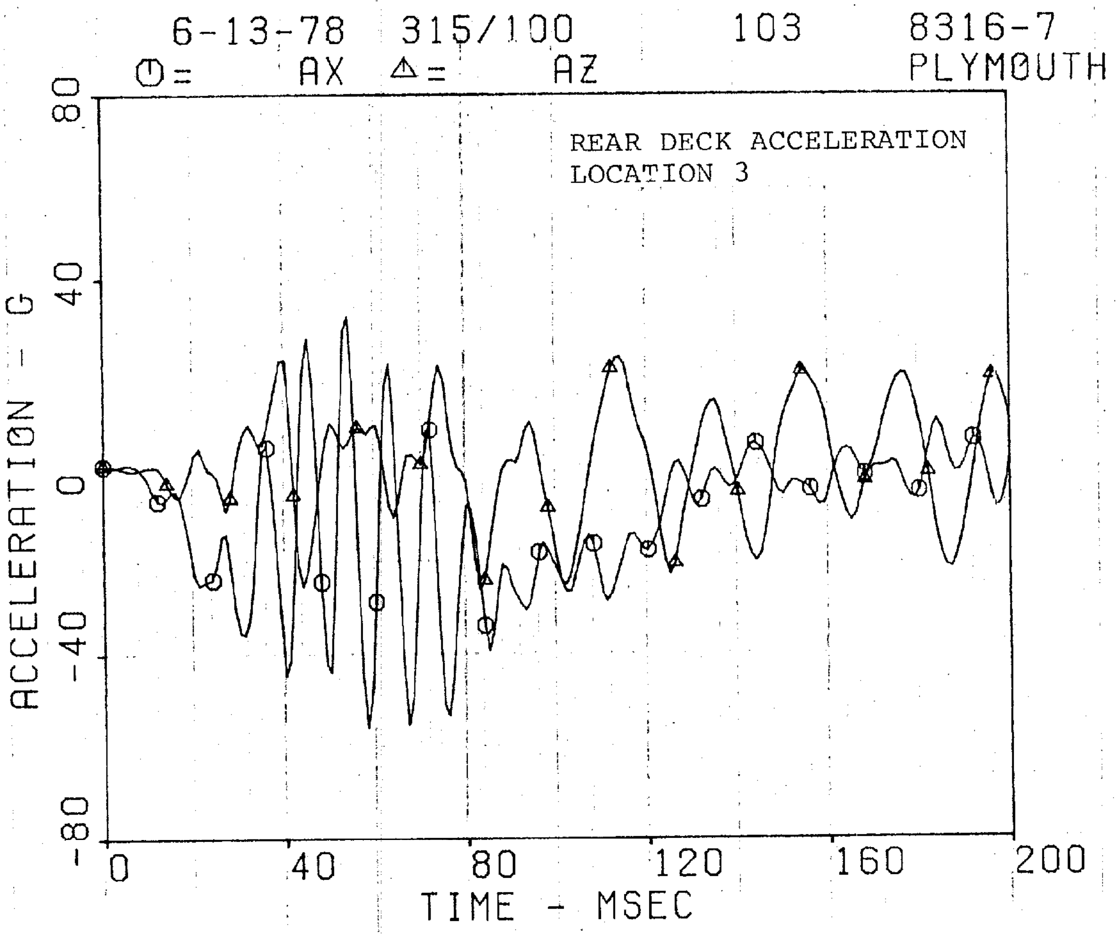

6-13-78
315/100
4203
8316-7
PLY RFLB-R
RIGHT FRONT OCCUPANT
RIGHT LAP BELT LOAD
FORCE POUNDS *10^1
300
200
100
0
-100
0
40
80
120
160
200
TIME - MSEC

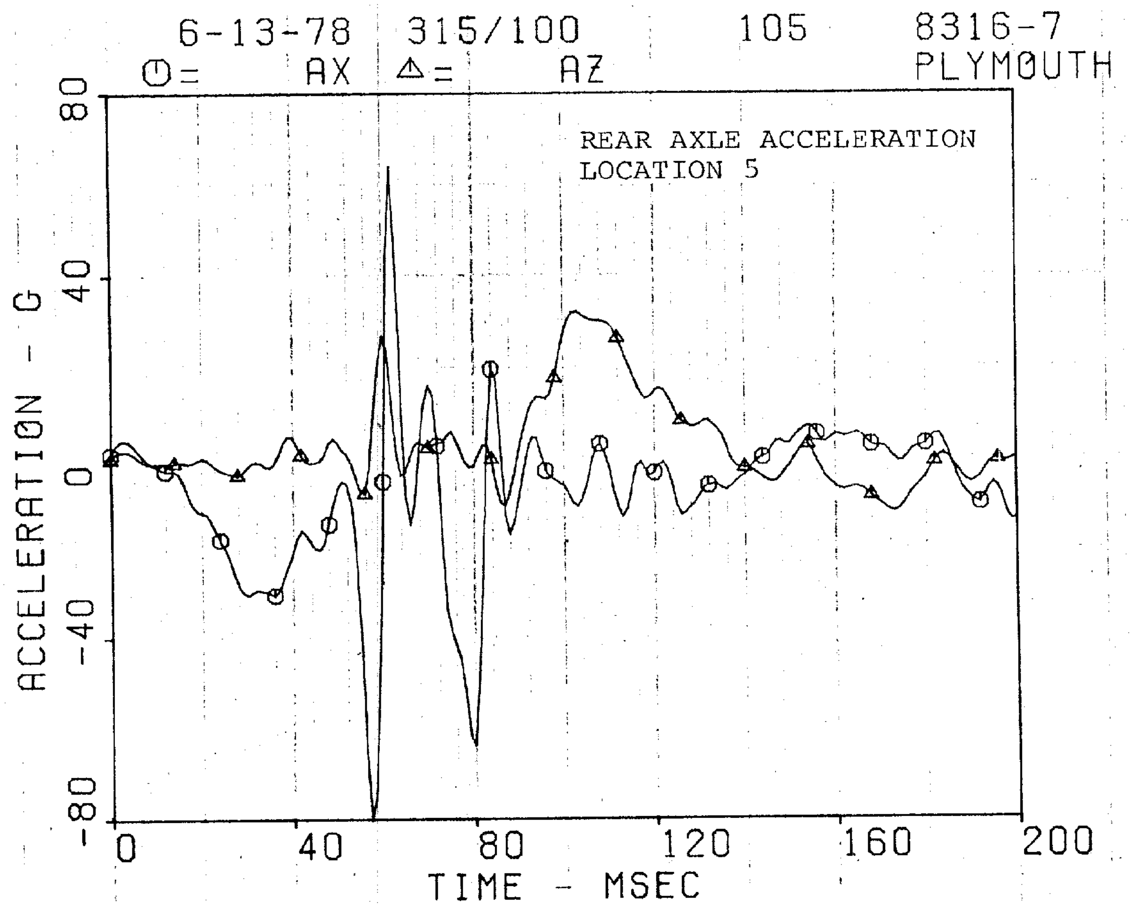

6-13-78 315/100 4203 8316-7
PLY RFTØRB
RIGHT FRONT OCCUPANT
SHOULDER BELT LOAD
FØRCE PØUNDS *10^1
300
200
100
0
-100
0
40
80
120
160
200
TIME - MSEC

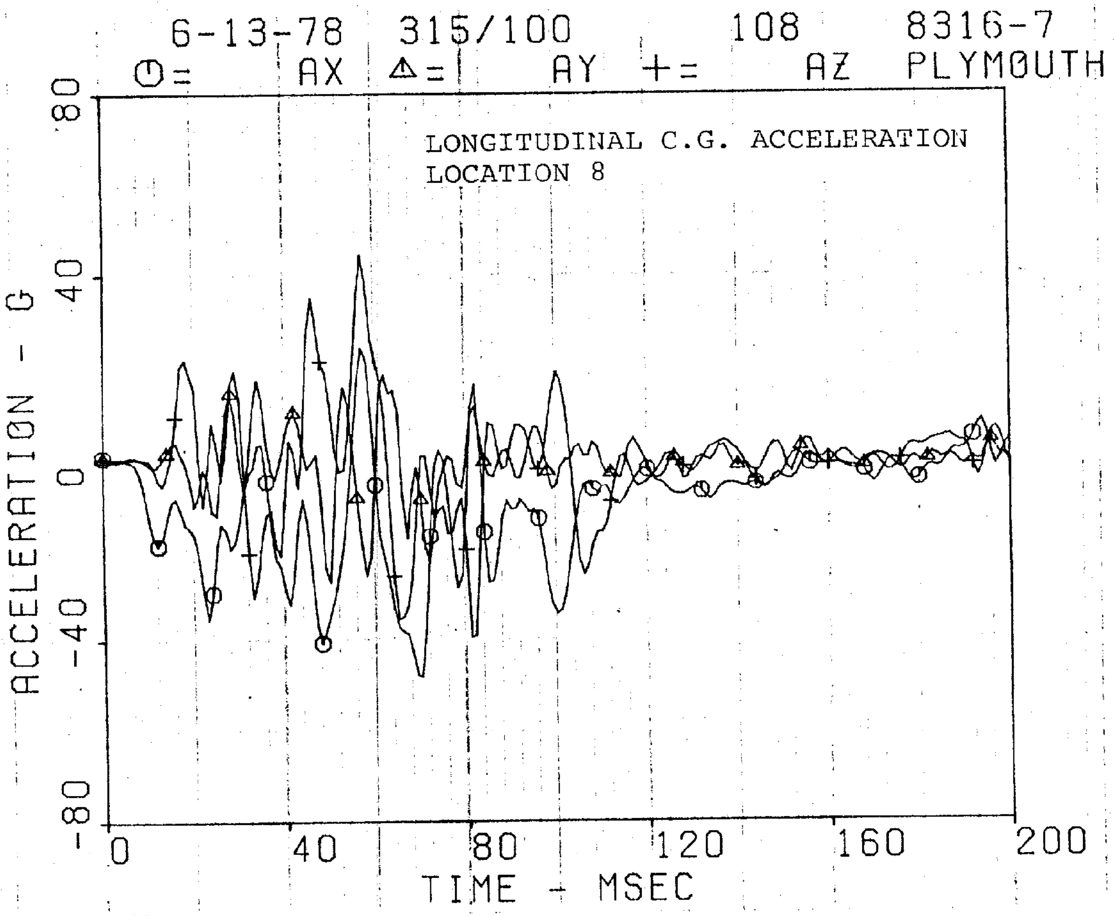

6-13-78 315/100 101 8316-7
⏀= AX △= AZ
PLYMOUTH
LEFT B-PILLAR ACCEL-
ERATION - LOCATION 1
ACCELERATION - G
80
40
0
-40
-80
0
40
80
120
160
200
TIME - MSEC

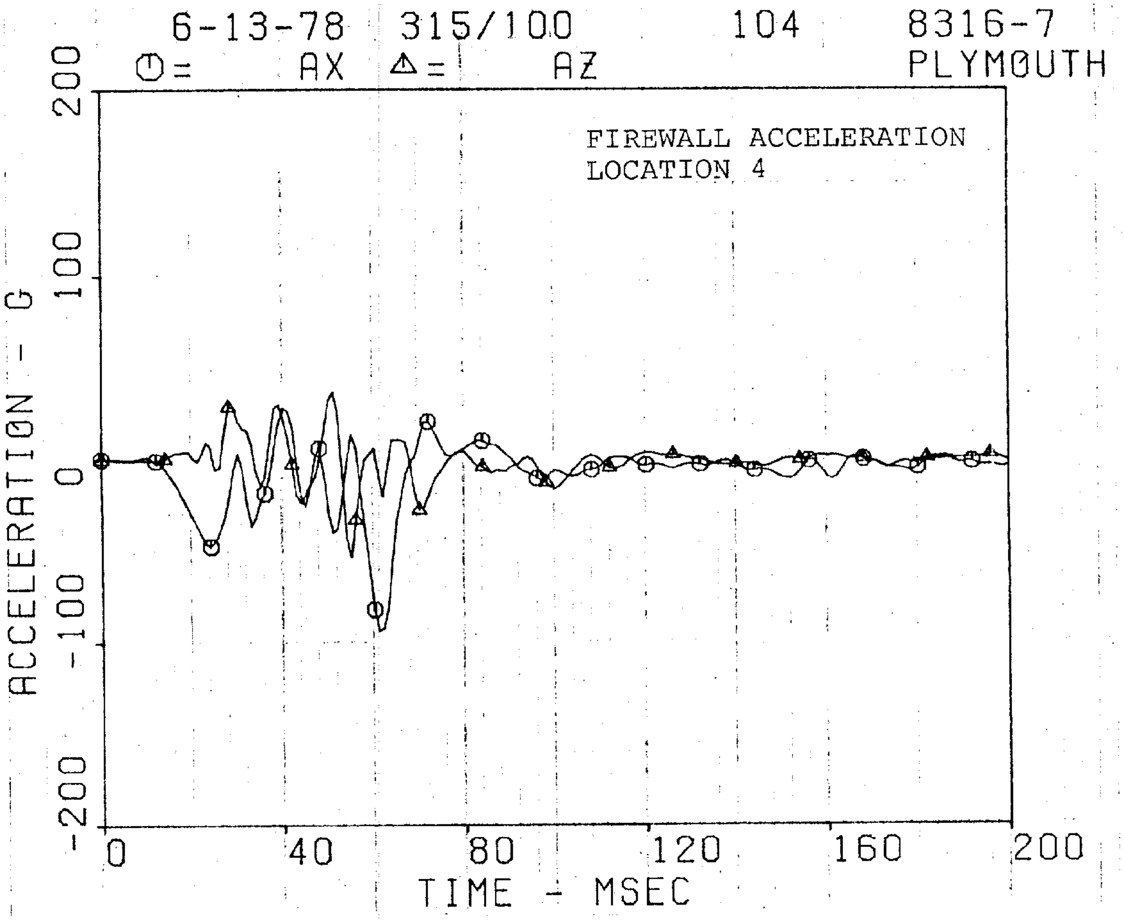

6-13-78 315/100 102 8316-7
⏀= AX △= AZ
PLYMOUTH
RIGHT B-PILLAR ACCEL-
ERATION - LOCATION 2
ACCELERATION - G
80
40
0
-40
-80
0
40
80
120
160
200
TIME - MSEC

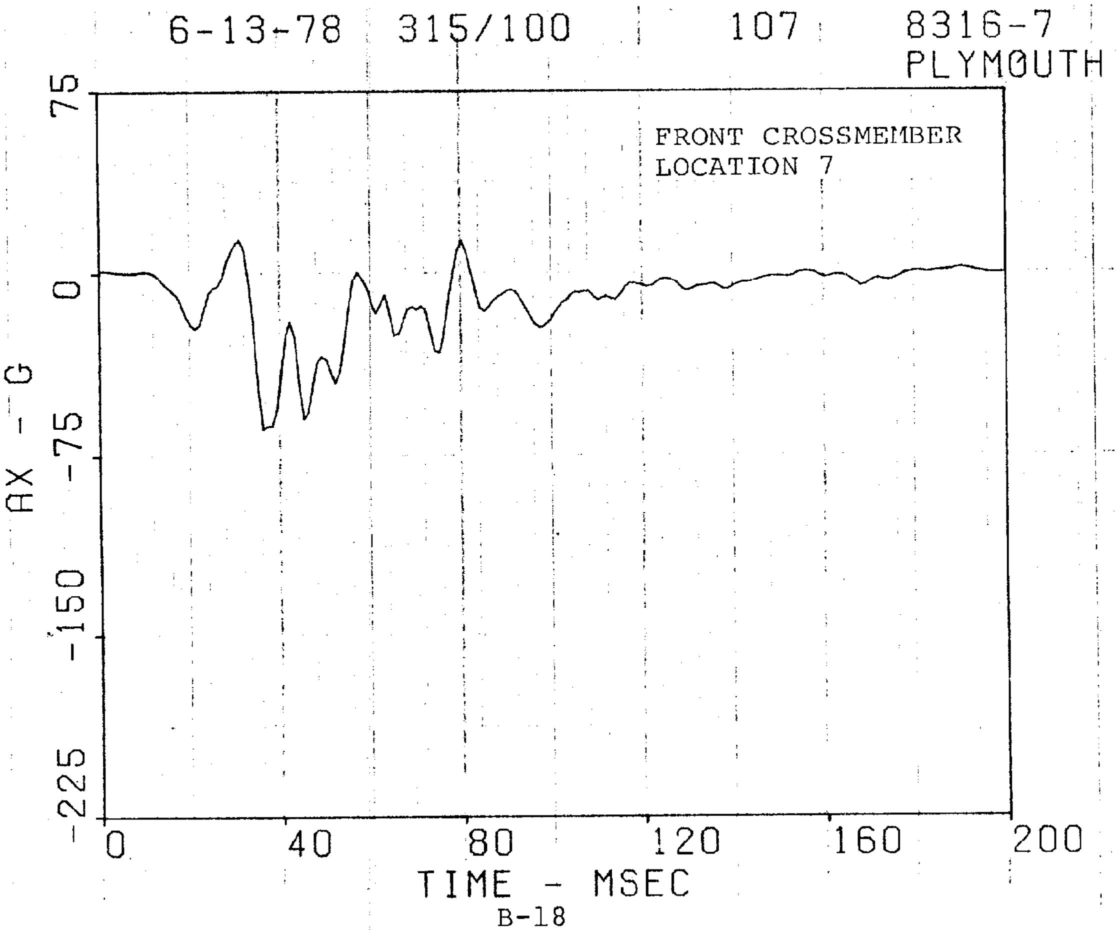

6-13-78 315/100 401 8316-7
⊕= AX △= VX += SX PLY AV1,2
AVERAGE B-PILLAR ACCELERATION
VELOCITY AND DISPLACEMENT
LOCATIONS 1 AND 2
AX - G, VX - MPH, SX - IN.
80
40
0
-40
-80
0
40
80
120
160
200
TIME - MSEC


6-13-78 315/100 103 8316-7
⊕= AX △= AZ PLYMOUTH
REAR DECK ACCELERATION
LOCATION 3
ACCELERATION - G
80
40
0
-40
-80
0
40
80
120
160
200
TIME - MSEC

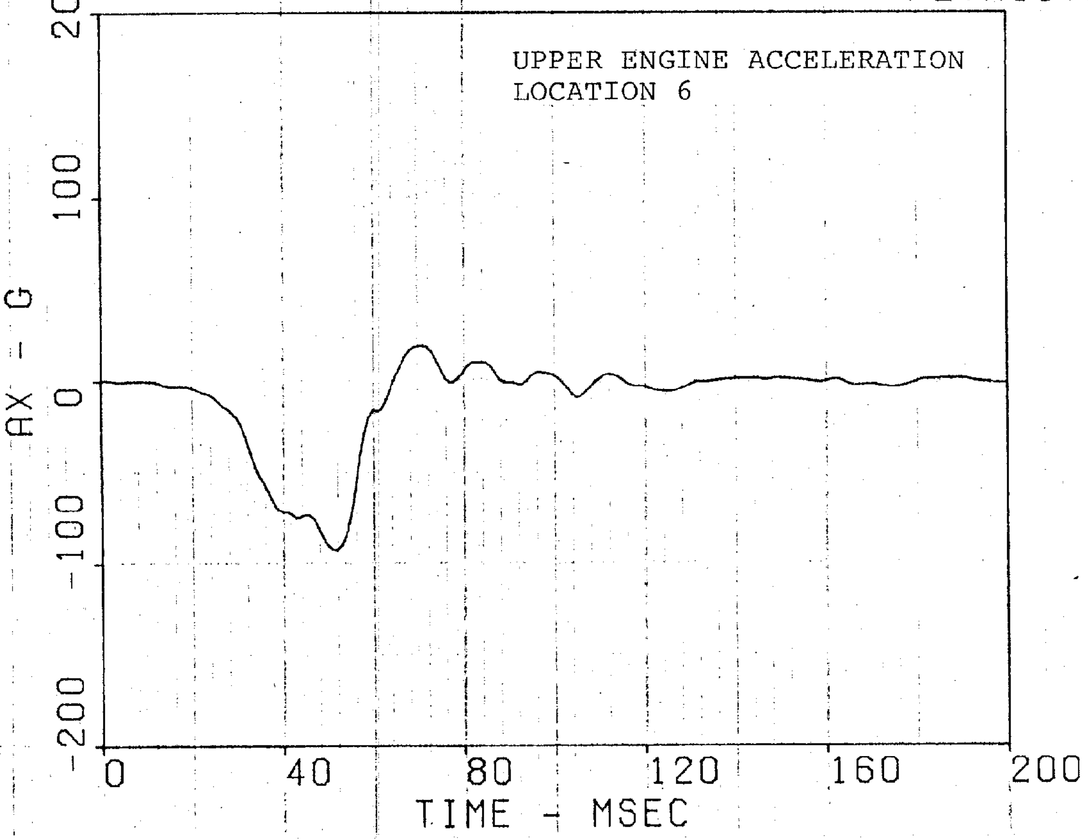

6-13-78 315/100 105 8316-7
⊕= AX △= AZ PLYMOUTH
REAR AXLE ACCELERATION
LOCATION 5
ACCELERATION - G
80
40
0
-40
-80
0
40
80
120
160
200
TIME - MSEC


6-13-78 315/100 108 8316-7
⊙= AX △= AY += AZ PLYMOUTH
LONGITUDINAL C.G. ACCELERATION
LOCATION 8
80
40
0
-40
-80
ACCELERATION - G
0
40
80
120
160
200
TIME - MSEC

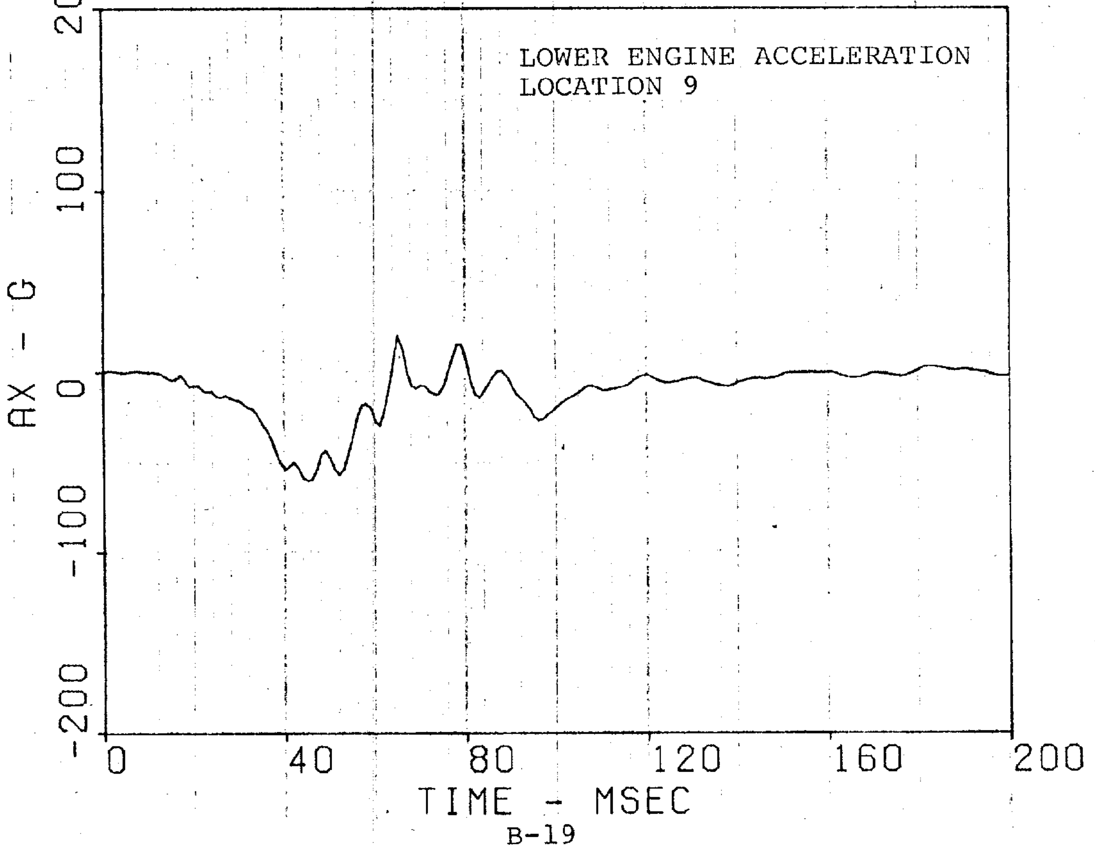

6-13-78
315/100
104
8316-7
PLYMOUTH
○= AX
△= AZ
FIREWALL ACCELERATION
LOCATION 4
ACCELERATION - G
200
100
0
-100
-200
0
40
80
120
160
200
TIME - MSEC

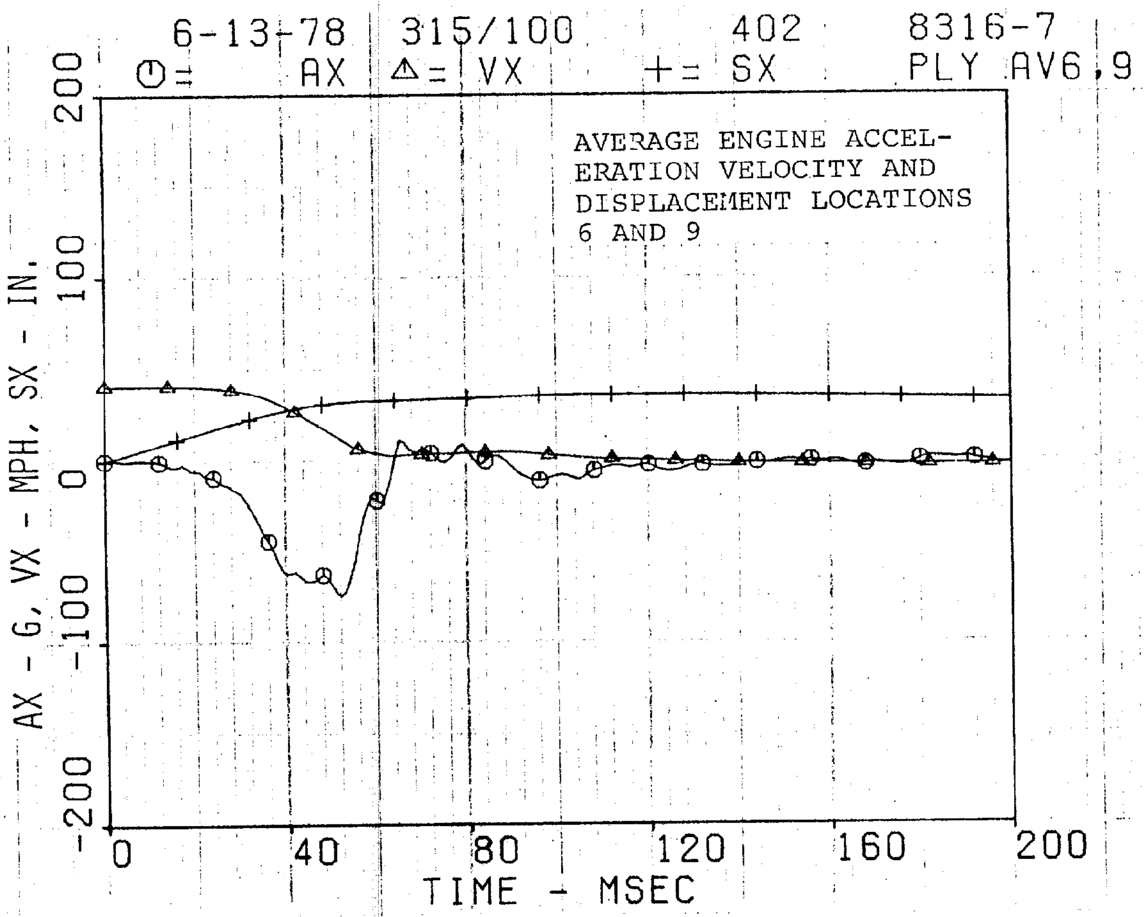

6-13-78
315/100
107
8316-7
PLYMOUTH
FRONT CROSSMEMBER
LOCATION 7
AX - G
75
0
-75
-150
-225
0
40
80
120
160
200
TIME - MSEC

6-13-78 315/100 106 8316-7
PLYMOUTH

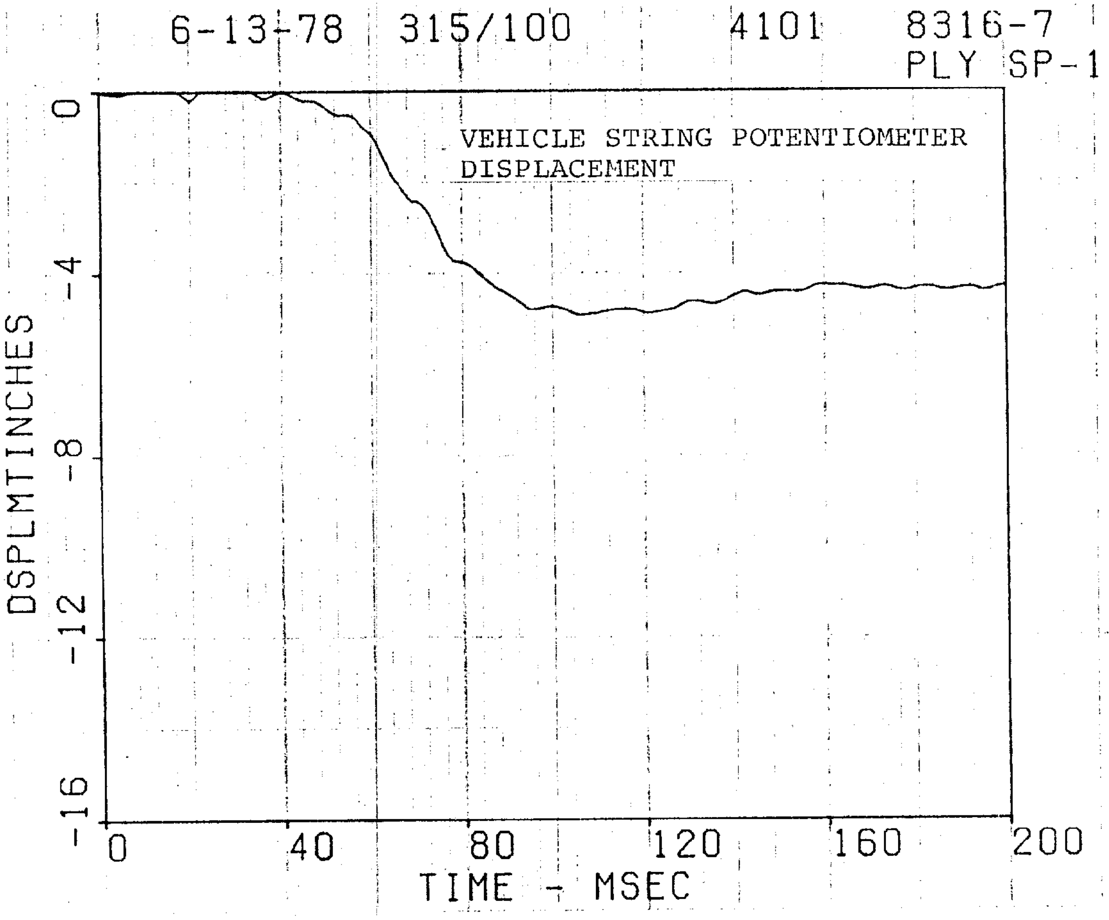


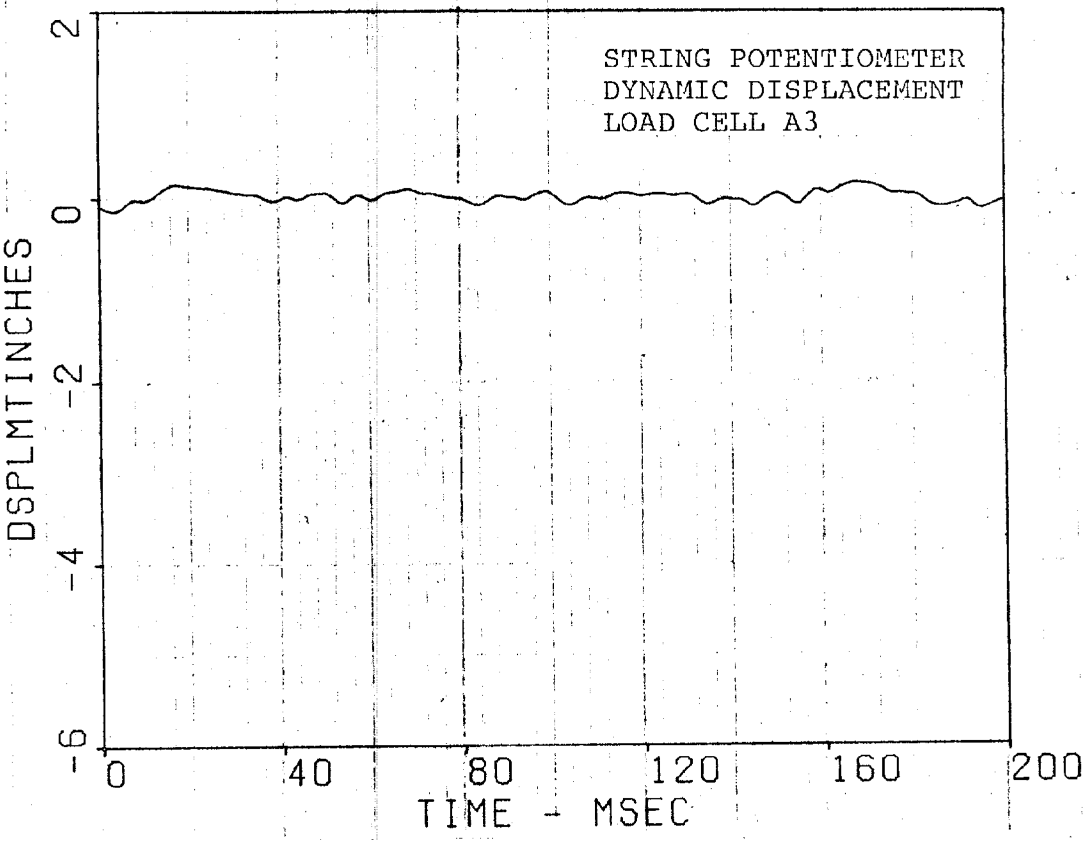
6-13-78 315/100 109 8316-7
PLYMOUTH





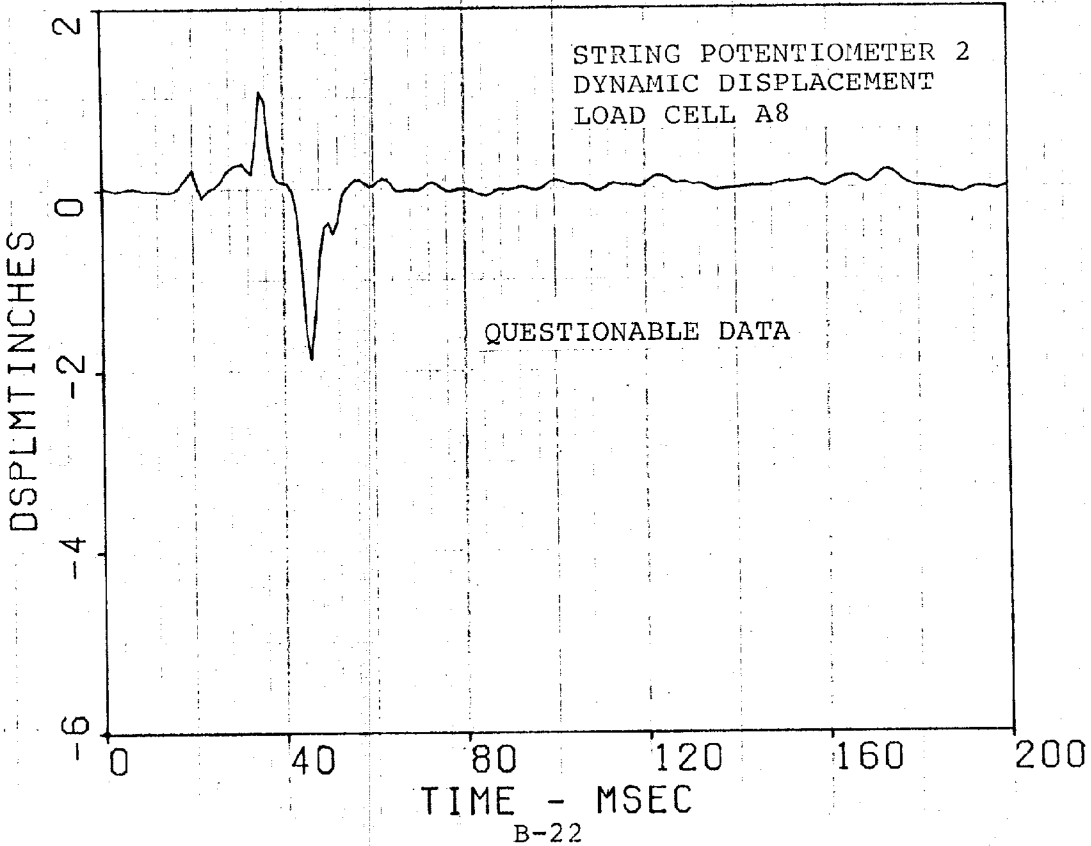
AVERAGE ENGINE ACCELERATION VELOCITY AND DISPLACEMENT LOCATIONS 6 AND 9


6-13-78
315/100
4101
8316-7
PLY SP-1
VEHICLE STRING POTENTIOMETER DISPLACEMENT
DSPLMT INCHES
0
-4
-8
-12
-16
0
40
80
120
160
200
TIME - MSEC



6-13-78 315/100 4001 8316-7
TSTDEV SP1

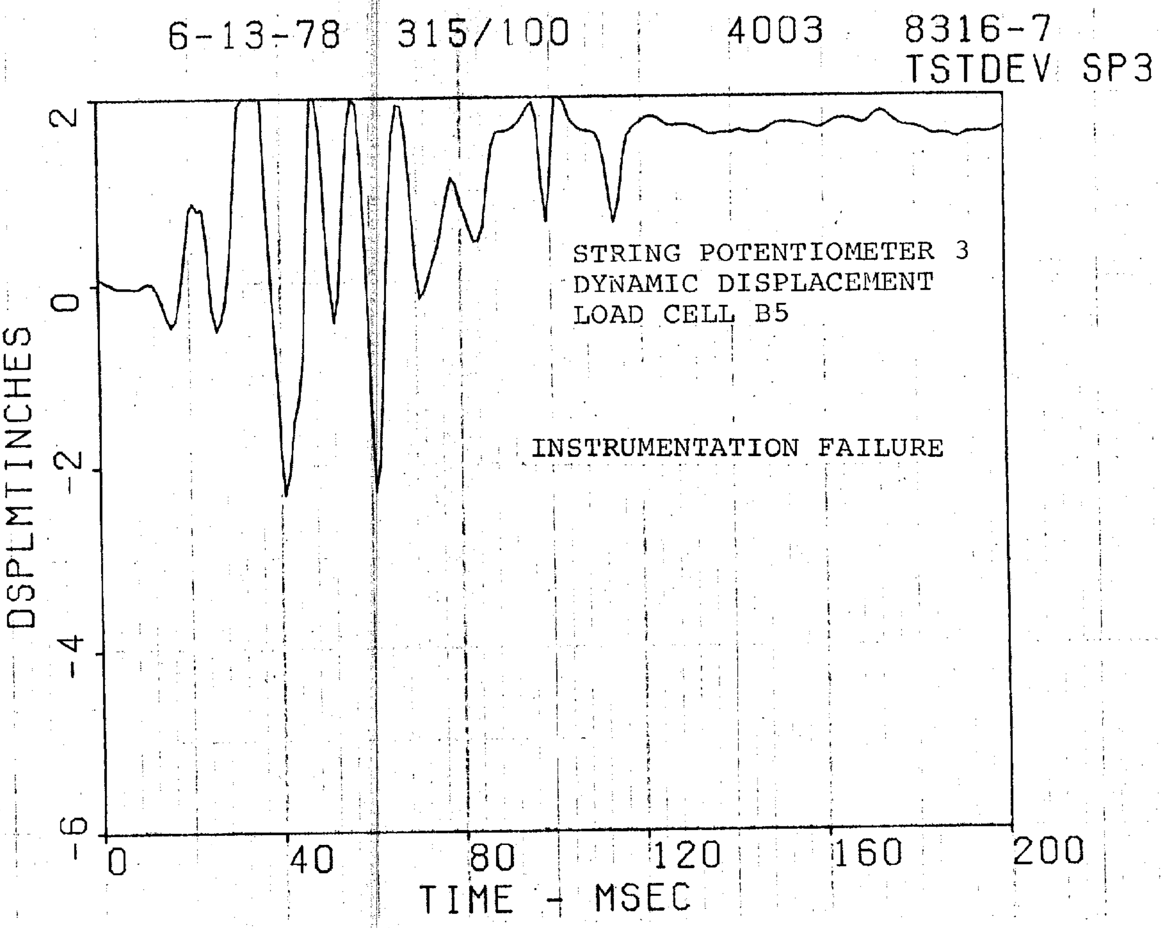
STRING POTENTIOMETER
DYNAMIC DISPLACEMENT
LOAD CELL A3

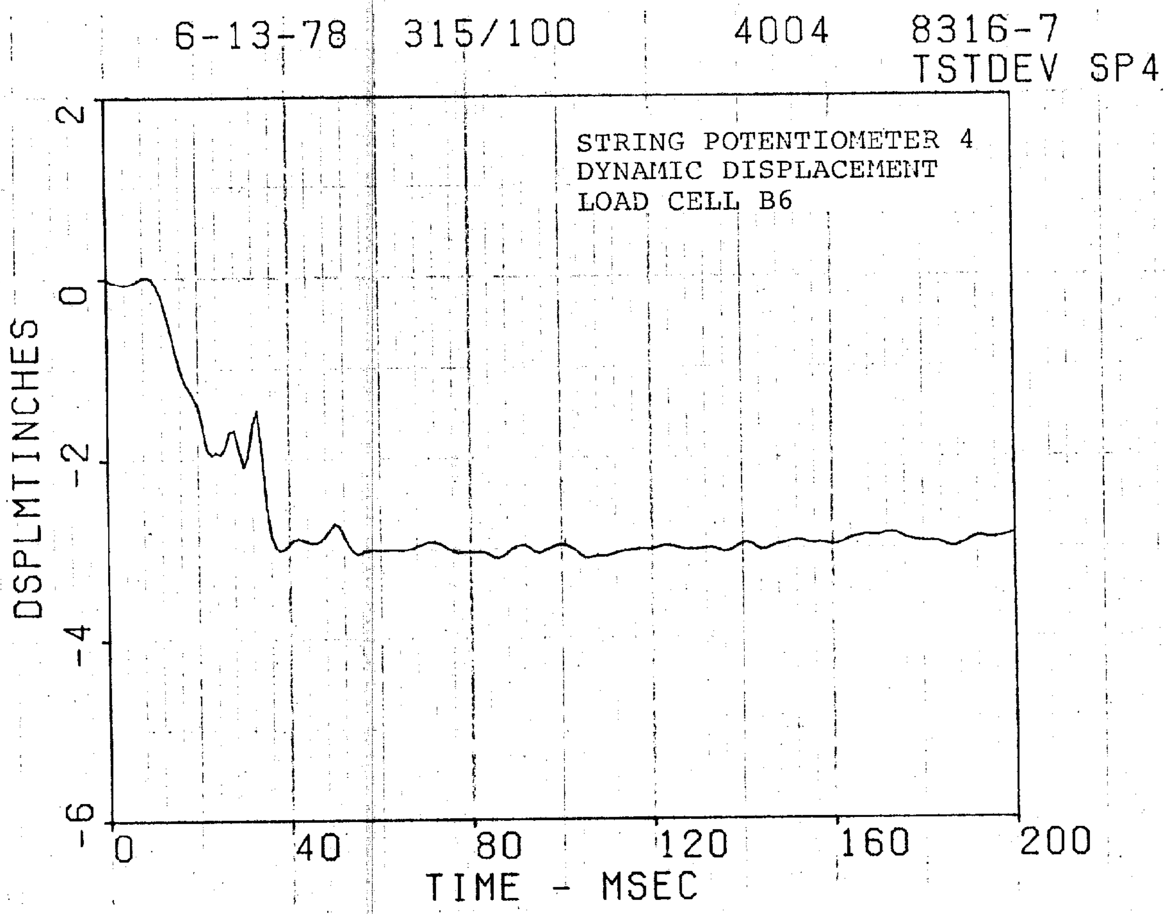


6-13-78 315/100 4002 8316-7
TSTDEV SP2

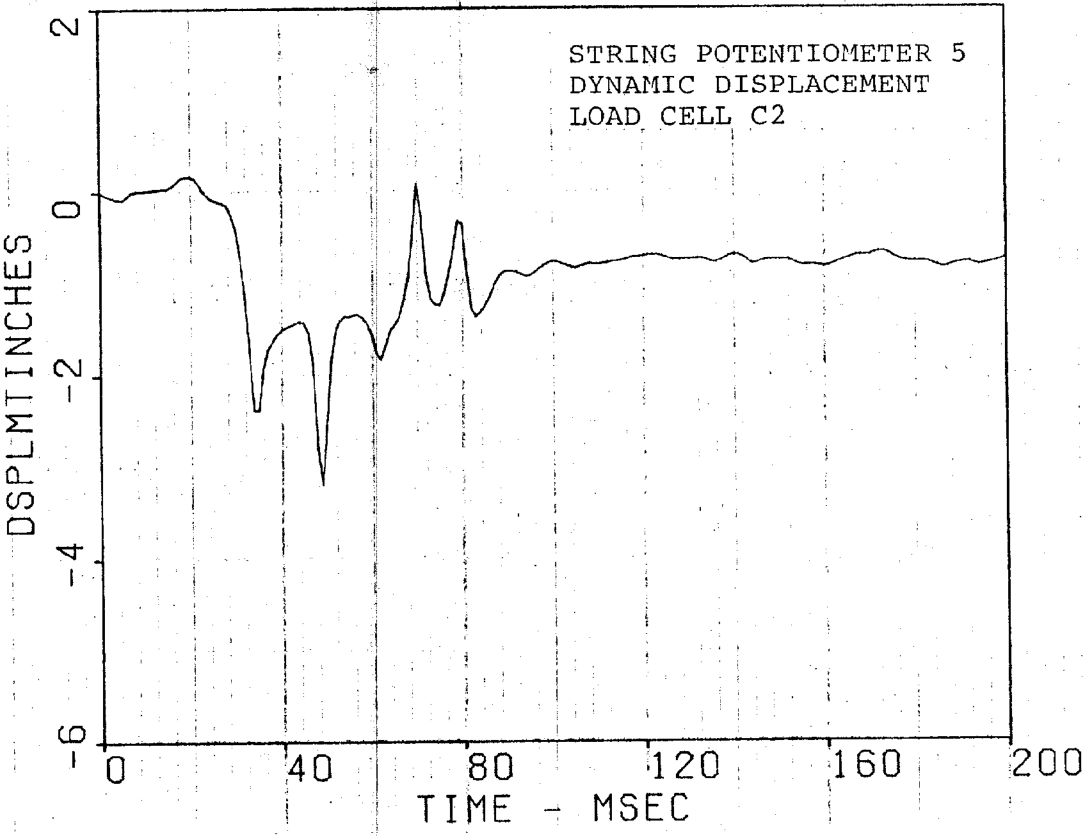
STRING POTENTIOMETER 2
DYNAMIC DISPLACEMENT
LOAD CELL A8

QUESTIONABLE DATA

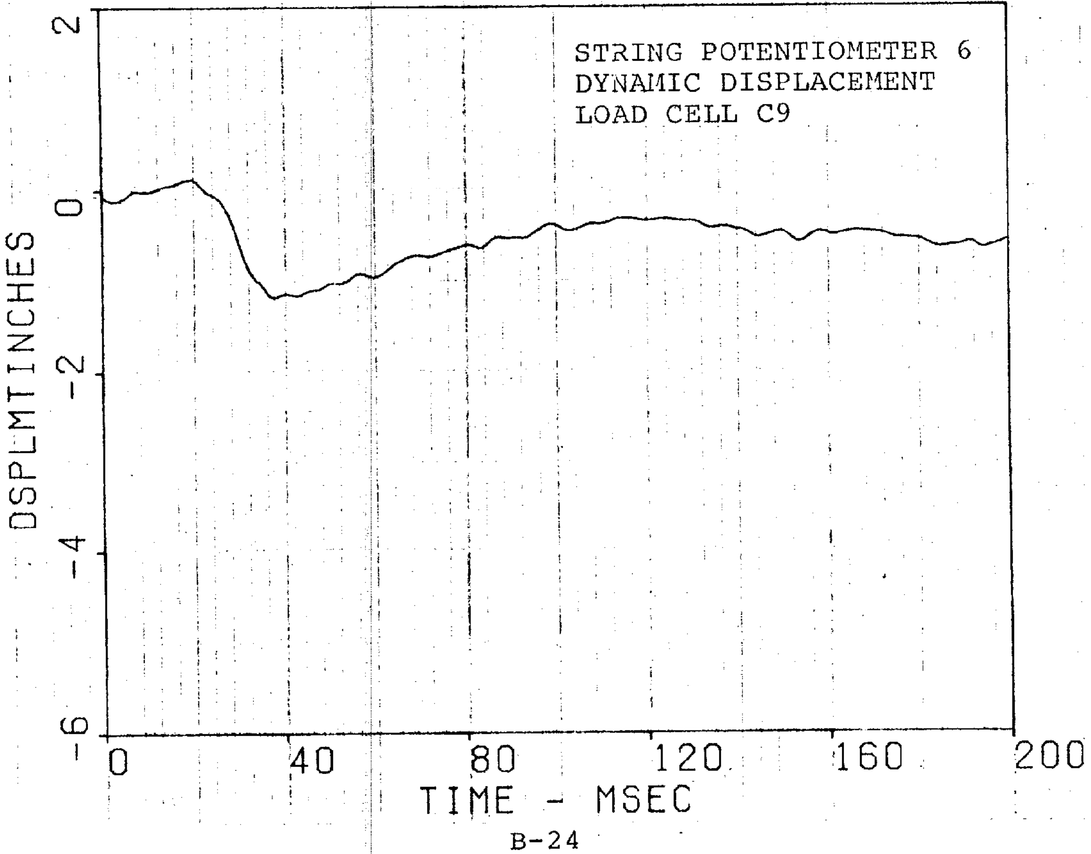

6-13-78 315/100 4003 8316-7
TSTDEV SP3
STRING POTENTIOMETER 3
DYNAMIC DISPLACEMENT
LOAD CELL B5
INSTRUMENTATION FAILURE
DSPLMT INCHES
2
0
-2
-4
-6
0
40
80
120
160
200
TIME - MSEC

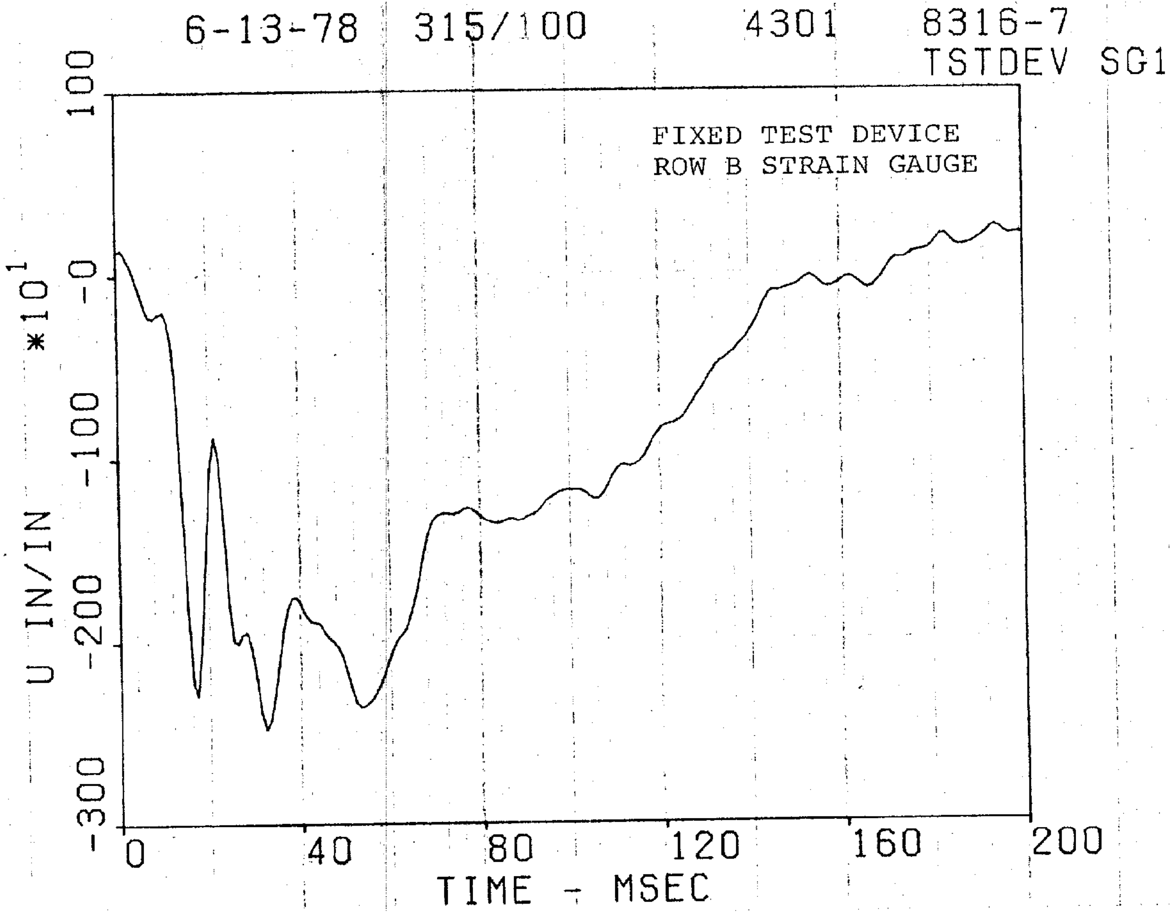

6-13-78 315/100 4004 8316-7
TSTDEV SP4
STRING POTENTIOMETER 4
DYNAMIC DISPLACEMENT
LOAD CELL B6
DSPLMT INCHES
2
0
-2
-4
-6
0
40
80
120
160
200
TIME - MSEC

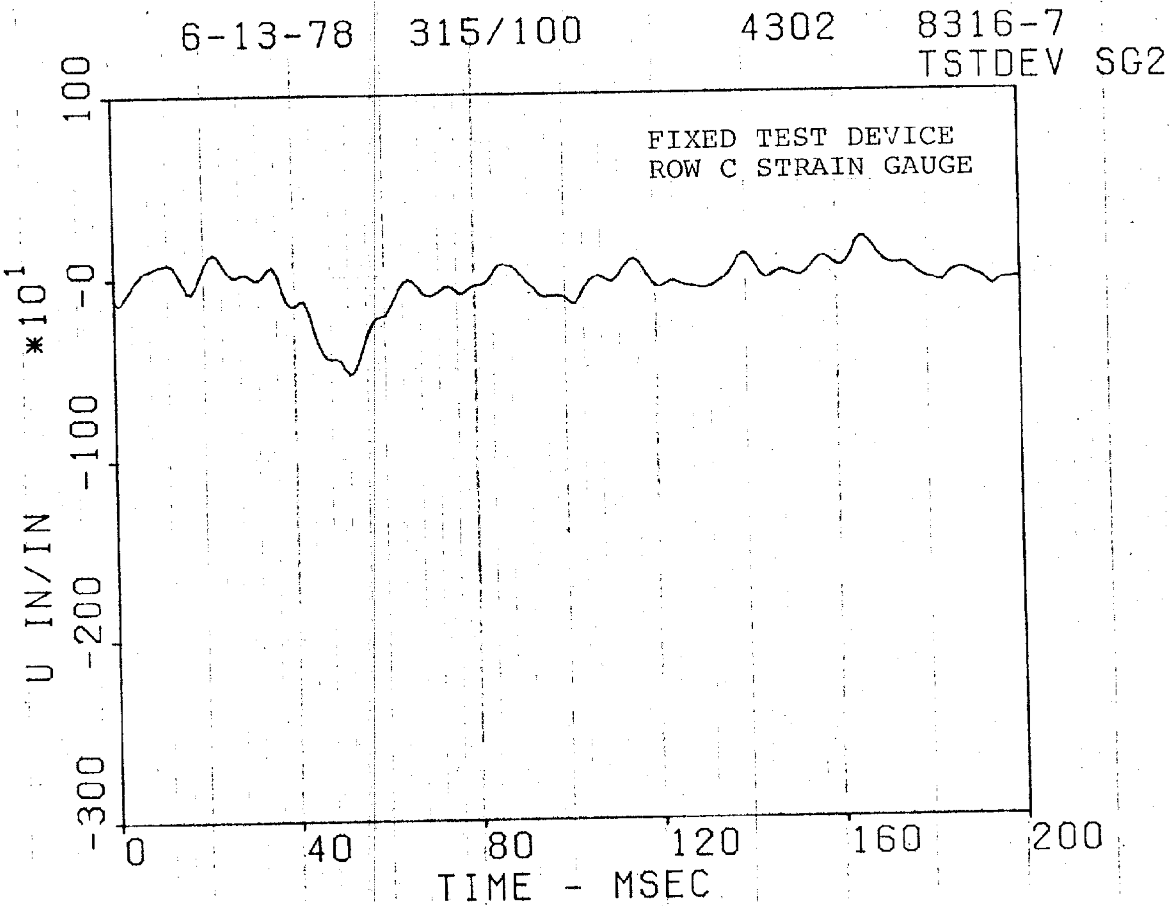
6-13-78 315/100 4005 8316-7
TSTDEV SP5

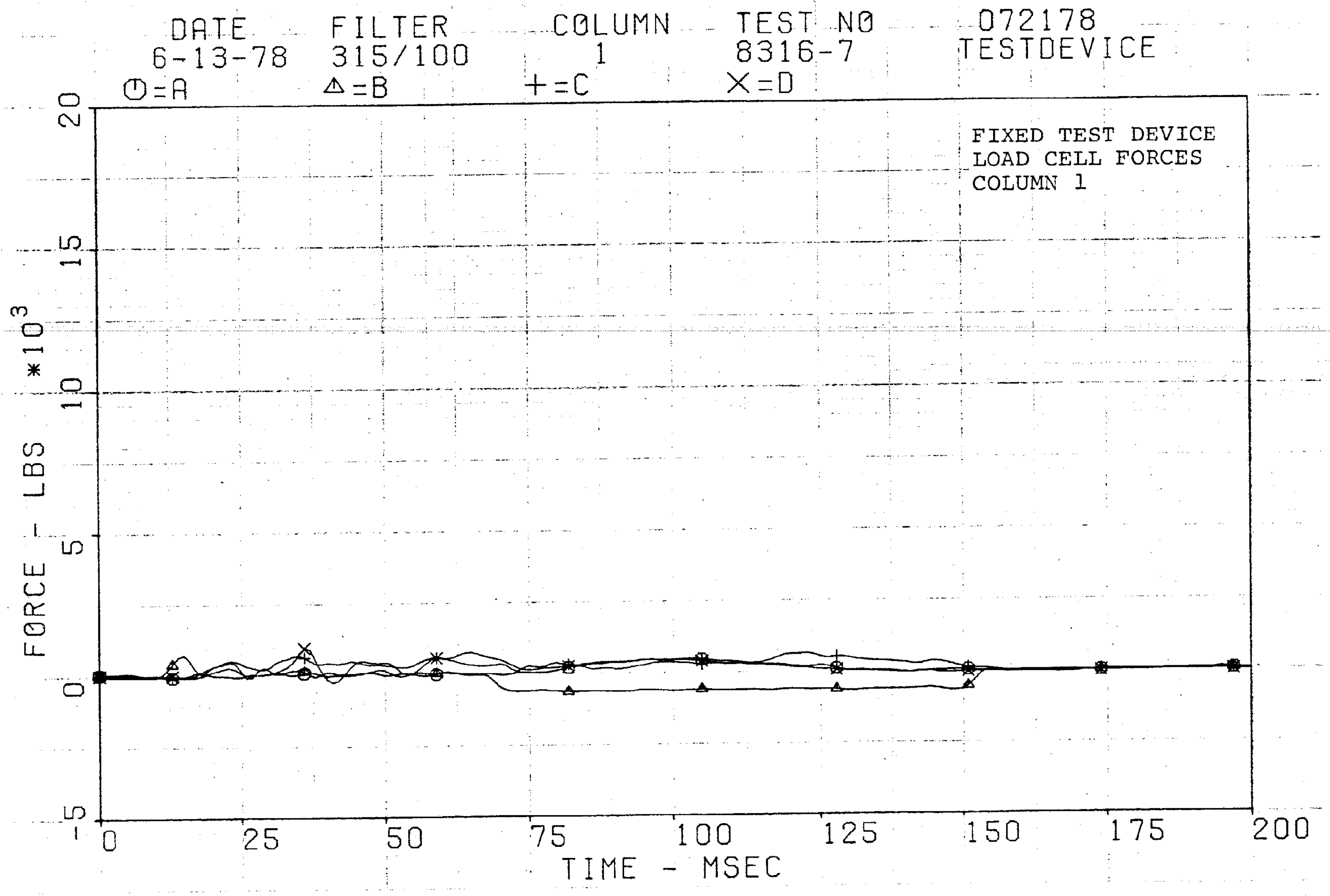


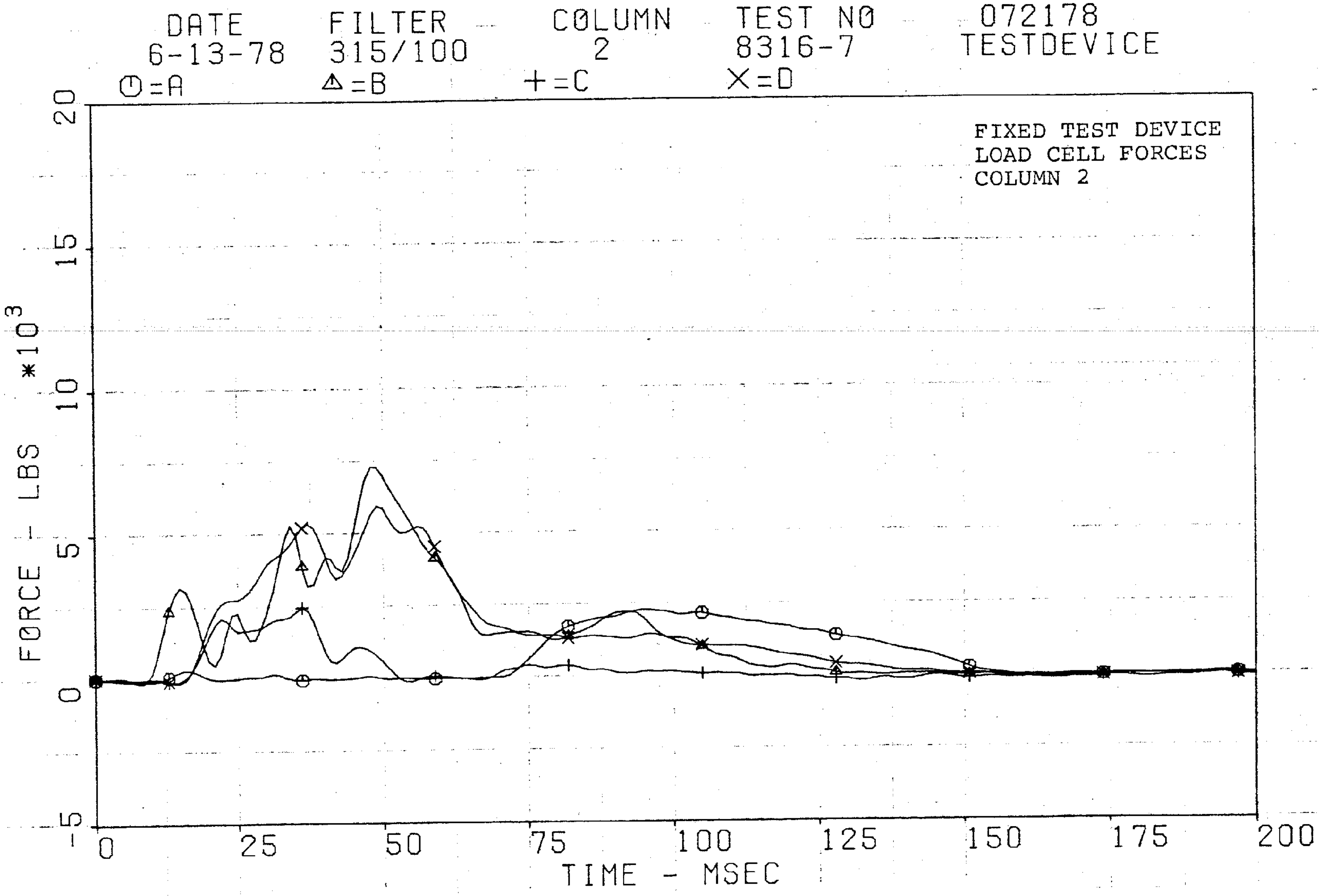
6-13-78 315/100 4006 8316-7
TSTDEV SP6

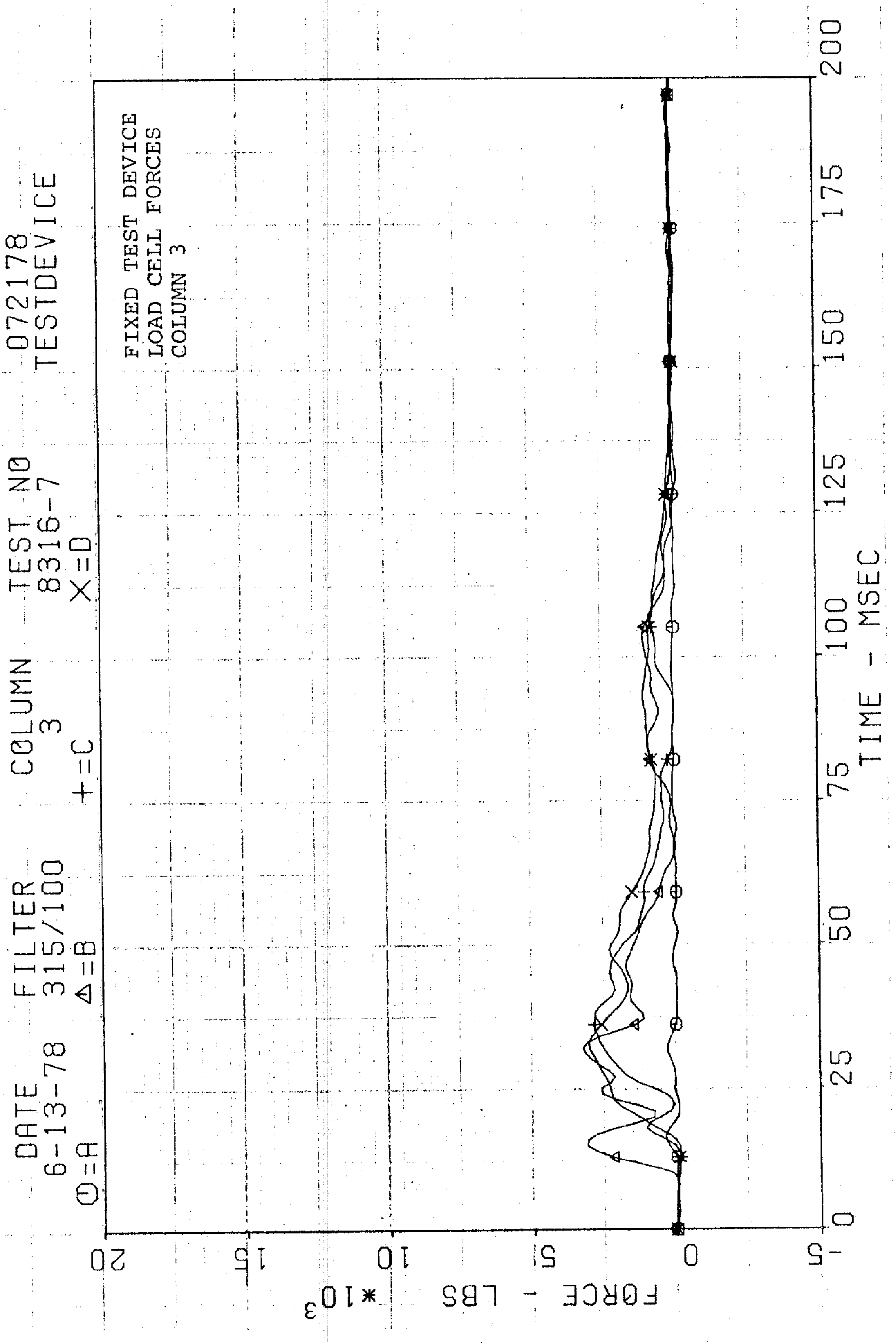


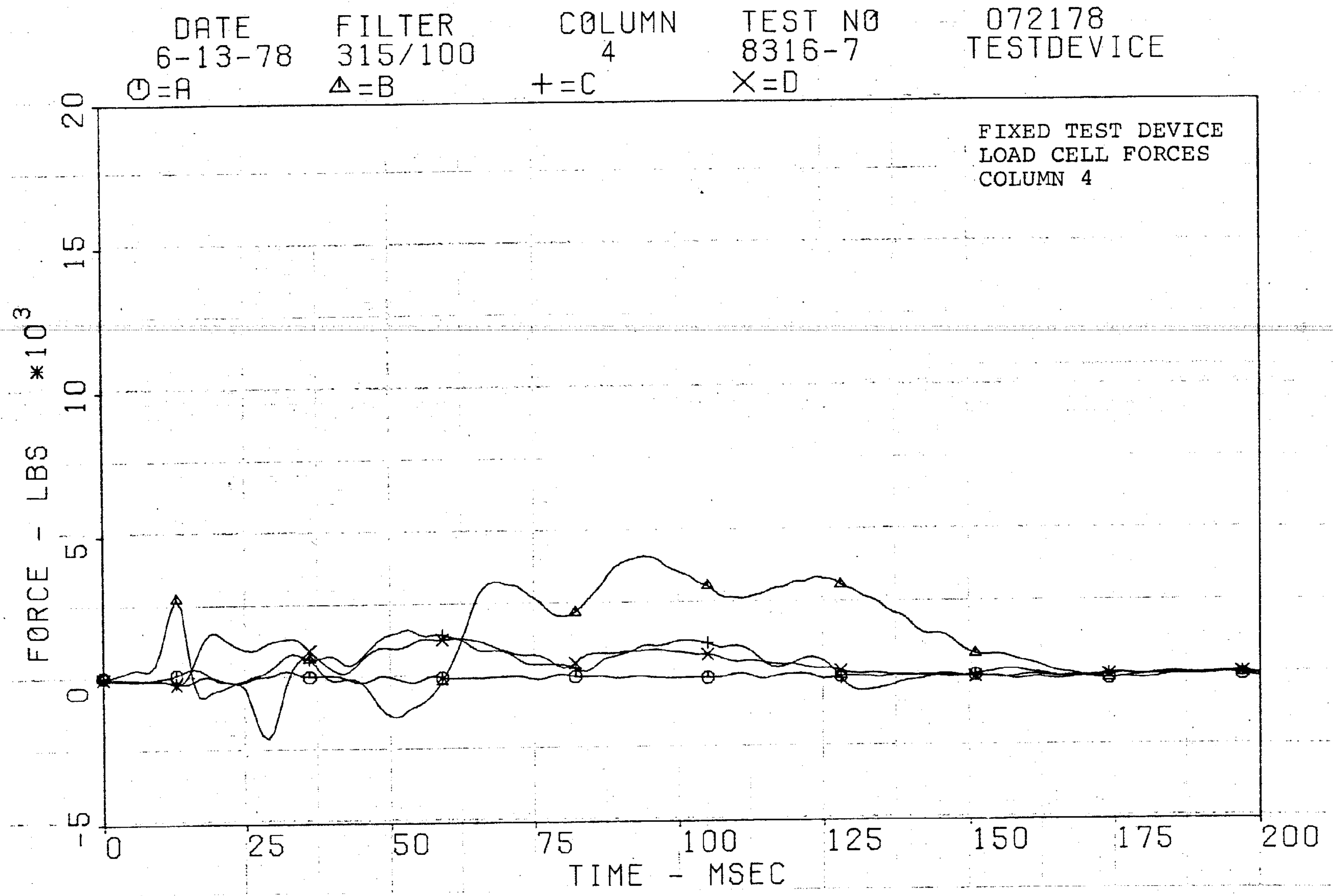

6-13-78
315/100
4301
8316-7
TSTDEV SG1
FIXED TEST DEVICE
ROW B STRAIN GAUGE
U IN/IN $*10^1$
100
-0
-100
-200
-300
0
40
80
120
160
200
TIME - MSEC

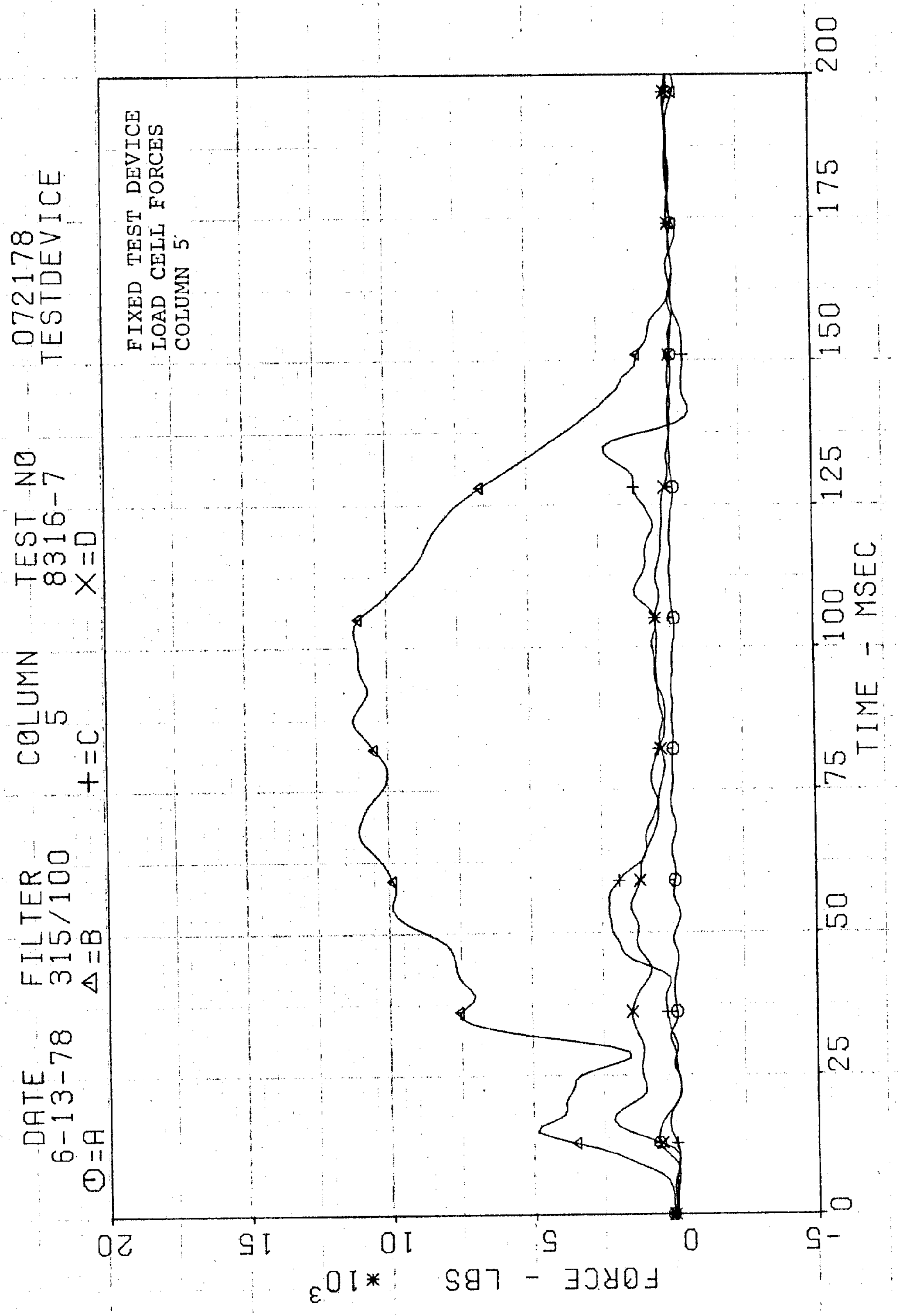

6-13-78
315/100
4302
8316-7
TSTDEV SG2
FIXED TEST DEVICE
ROW C STRAIN GAUGE
U IN/IN $*10^1$
100
-0
-100
-200
-300
0
40
80
120
160
200
TIME - MSEC

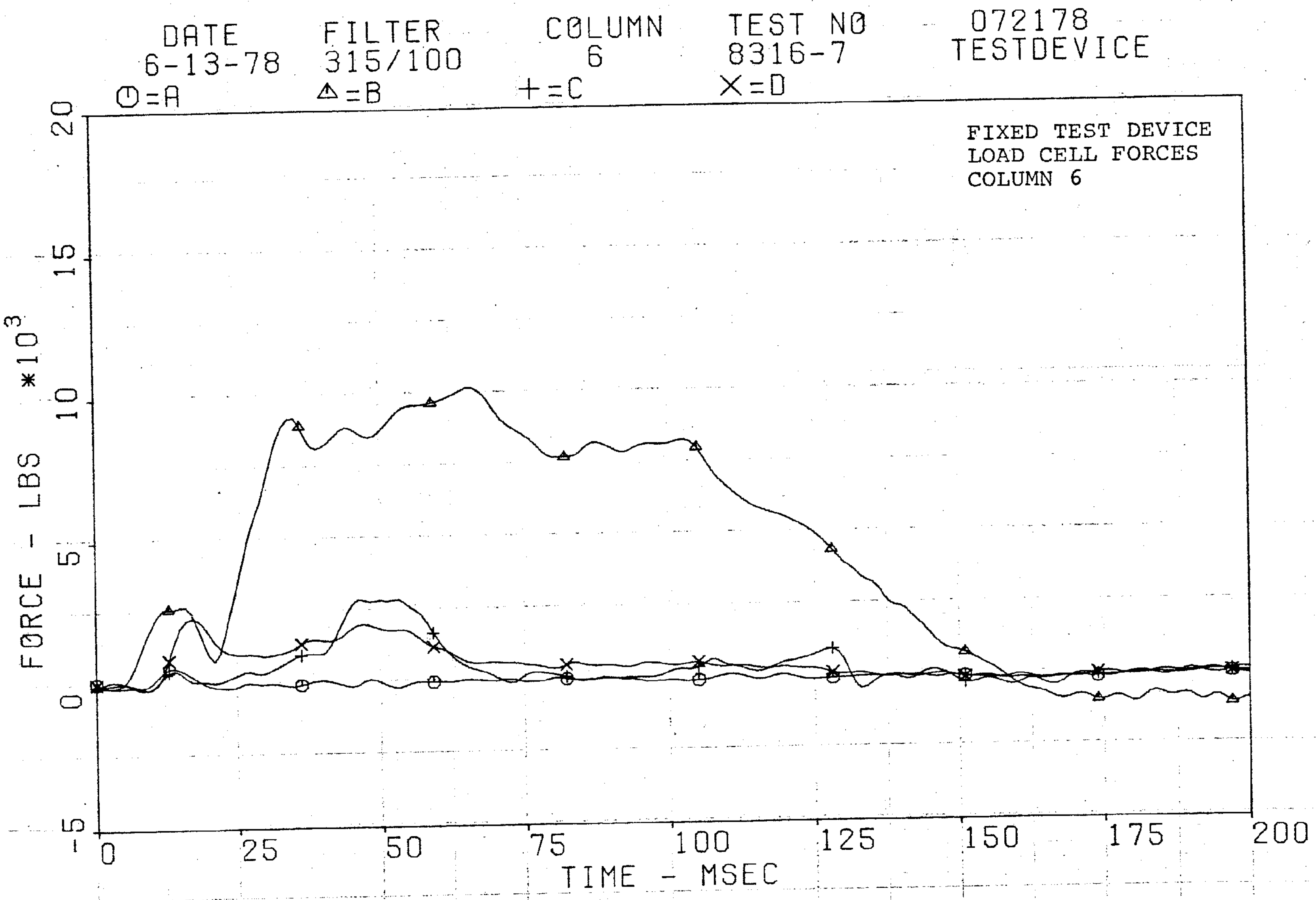

DATE
6-13-78
FILTER
315/100
C0LUMN
1
TEST N0
8316-7
072178
TESTDEVICE
⊖=A
△=B
+=C
×=D
FIXED TEST DEVICE
LOAD CELL FORCES
COLUMN 1
FORCE - LBS *10³
20
15
10
5
0
-5
TIME - MSEC
0
25
50
75
100
125
150
175
200

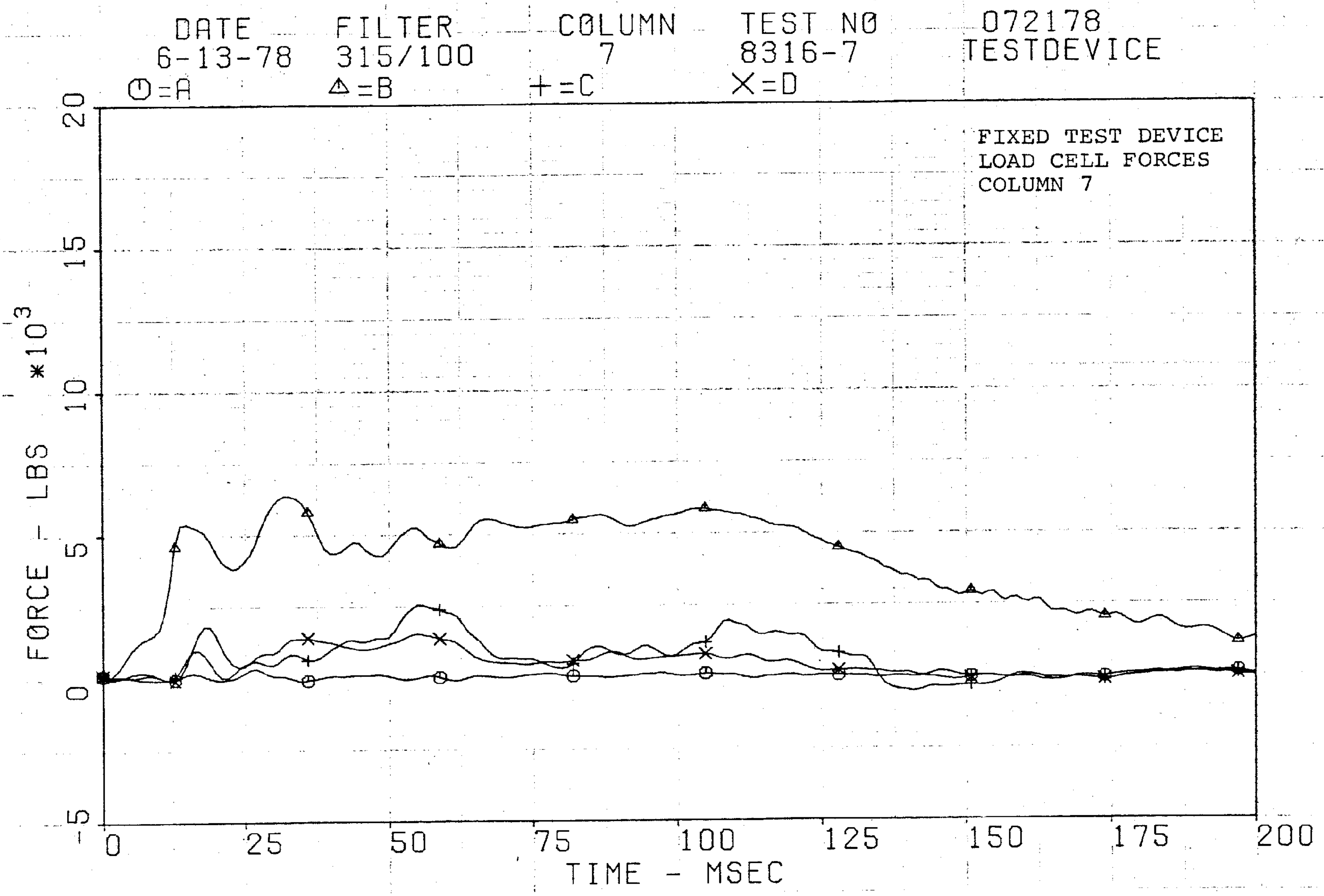

DATE
6-13-78
⊕=A
FILTER
315/100
△=B
CØLUMN
2
+=C
TEST NØ
8316-7
×=D
072178
TESTDEVICE
FIXED TEST DEVICE
LOAD CELL FORCES
COLUMN 2
FØRCE - LBS *10³
20
15
10
5
0
-5
0
25
50
75
100
125
150
175
200
TIME - MSEC

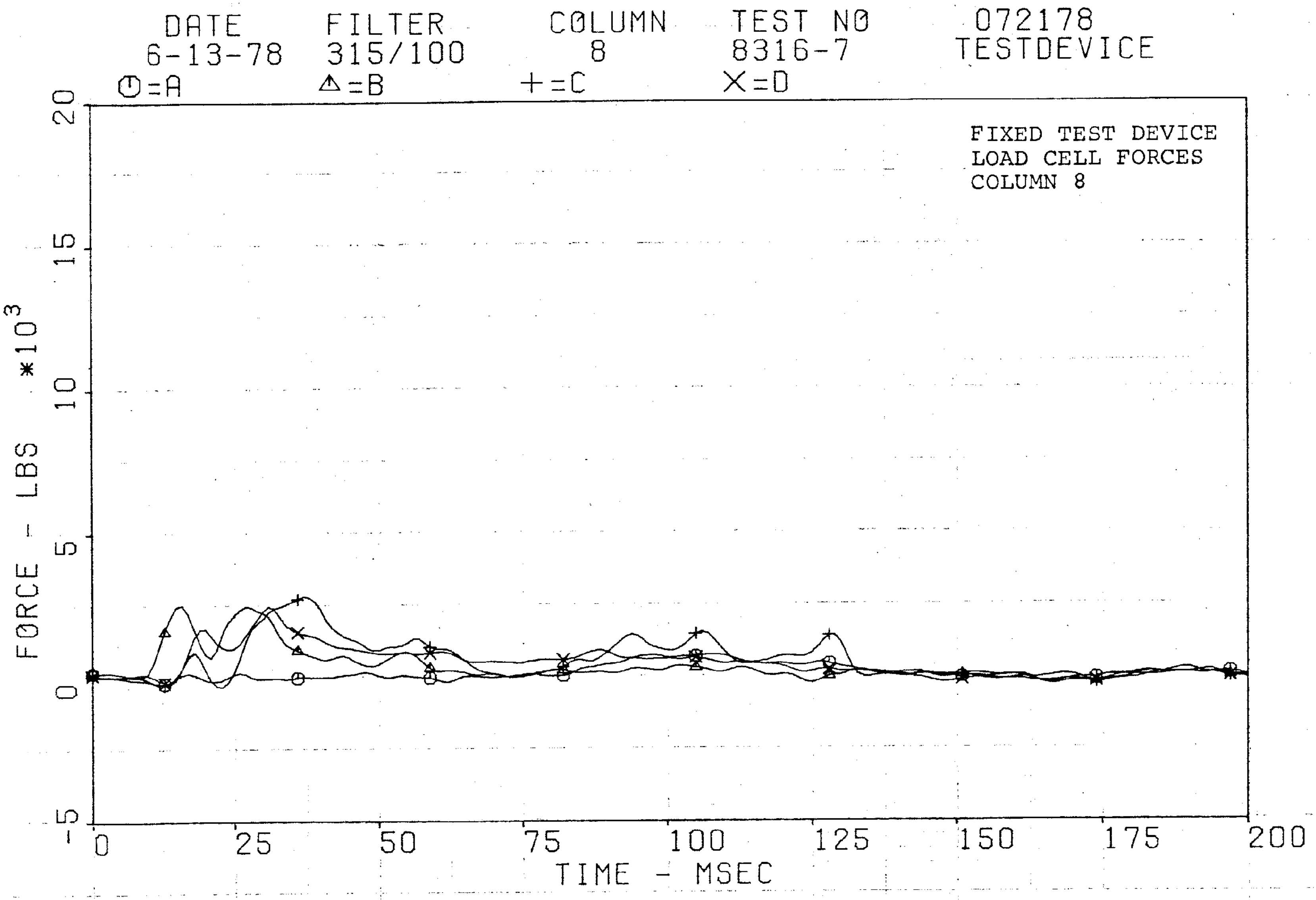

DATE
6-13-78
⊖=A
FILTER
315/100
△=B
COLUMN
3
+=C
TEST NO
8316-7
X=D
072178
TESTDEVICE
FIXED TEST DEVICE
LOAD CELL FORCES
COLUMN 3
FORCE - LBS *10³
20
15
10
5
0
-5
TIME - MSEC
0
25
50
75
100
125
150
175
200

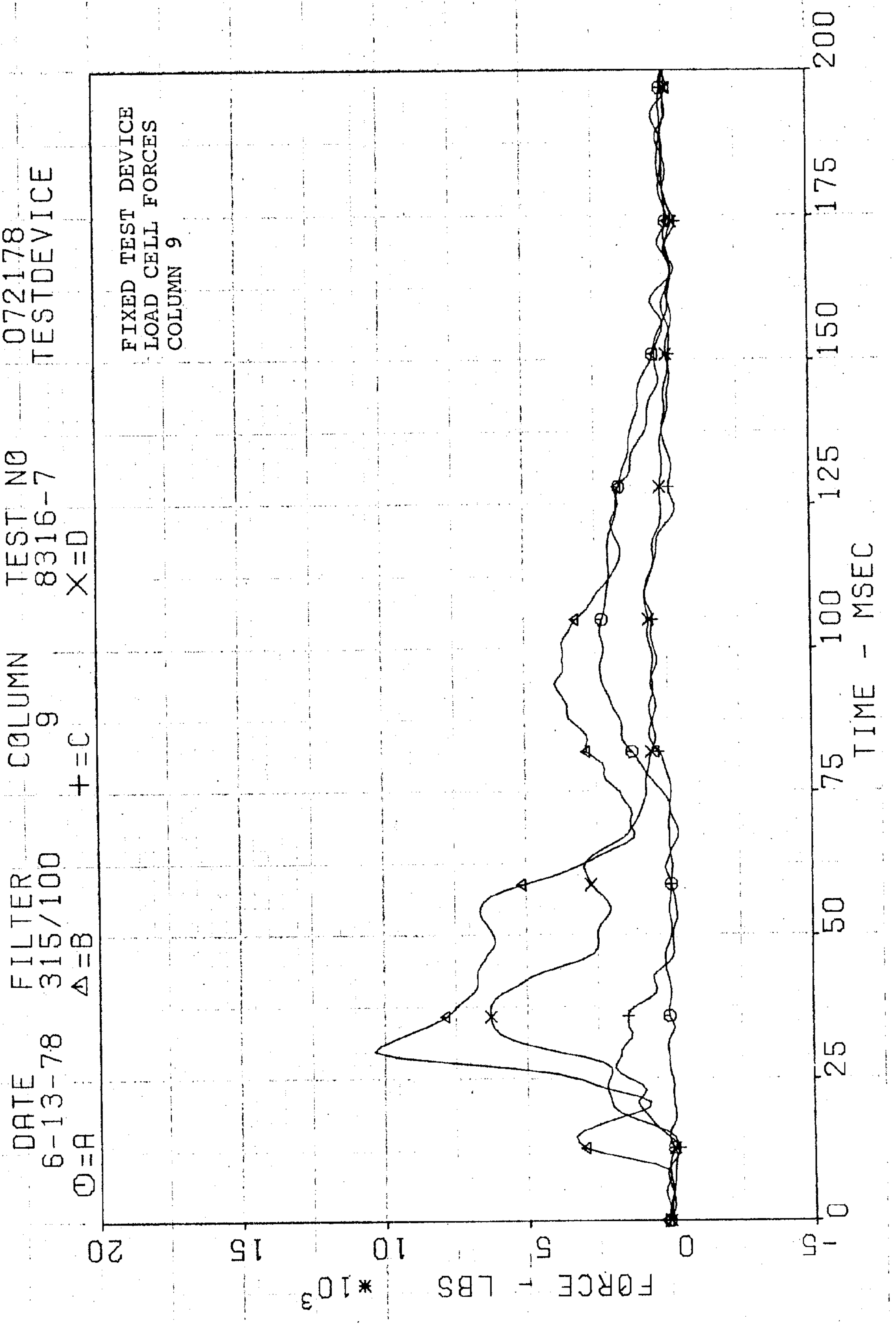

DATE
6-13-78
⦶=A
FILTER
315/100
△=B
COLUMN
4
+=C
TEST NO
8316-7
X=D
072178
TESTDEVICE
FIXED TEST DEVICE
LOAD CELL FORCES
COLUMN 4
FORCE - LBS *10^3
20
15
10
5
0
-5
TIME - MSEC
0
25
50
75
100
125
150
175
200

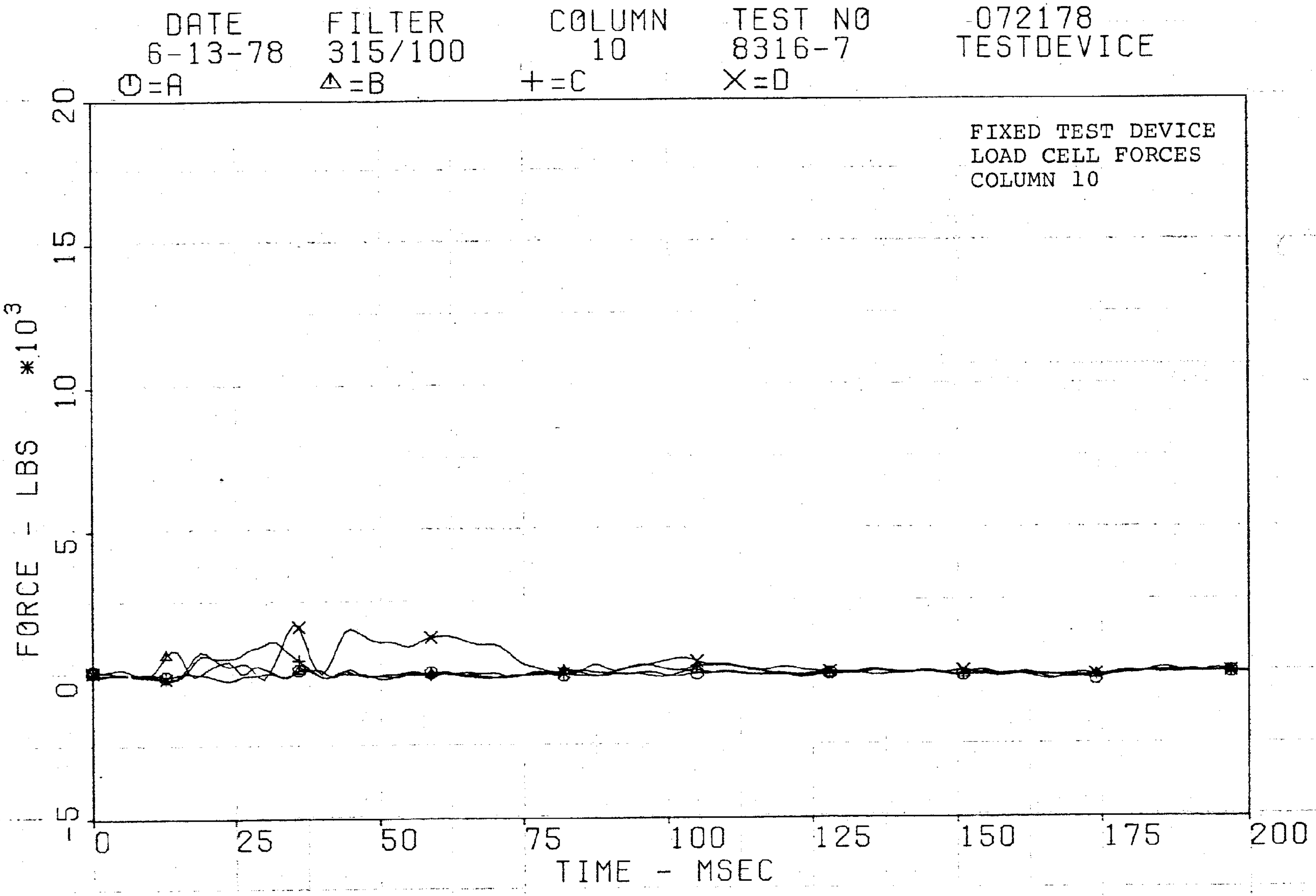

DATE
6-13-78
⊖=A
FILTER
315/100
Δ=B
COLUMN
5
+=C
TEST NO
8316-7
X=D
072178
TESTDEVICE
FIXED TEST DEVICE
LOAD CELL FORCES
COLUMN 5
FORCE - LBS *10^3
20
15
10
5
0
-5
TIME - MSEC
0
25
50
75
100
125
150
175
200

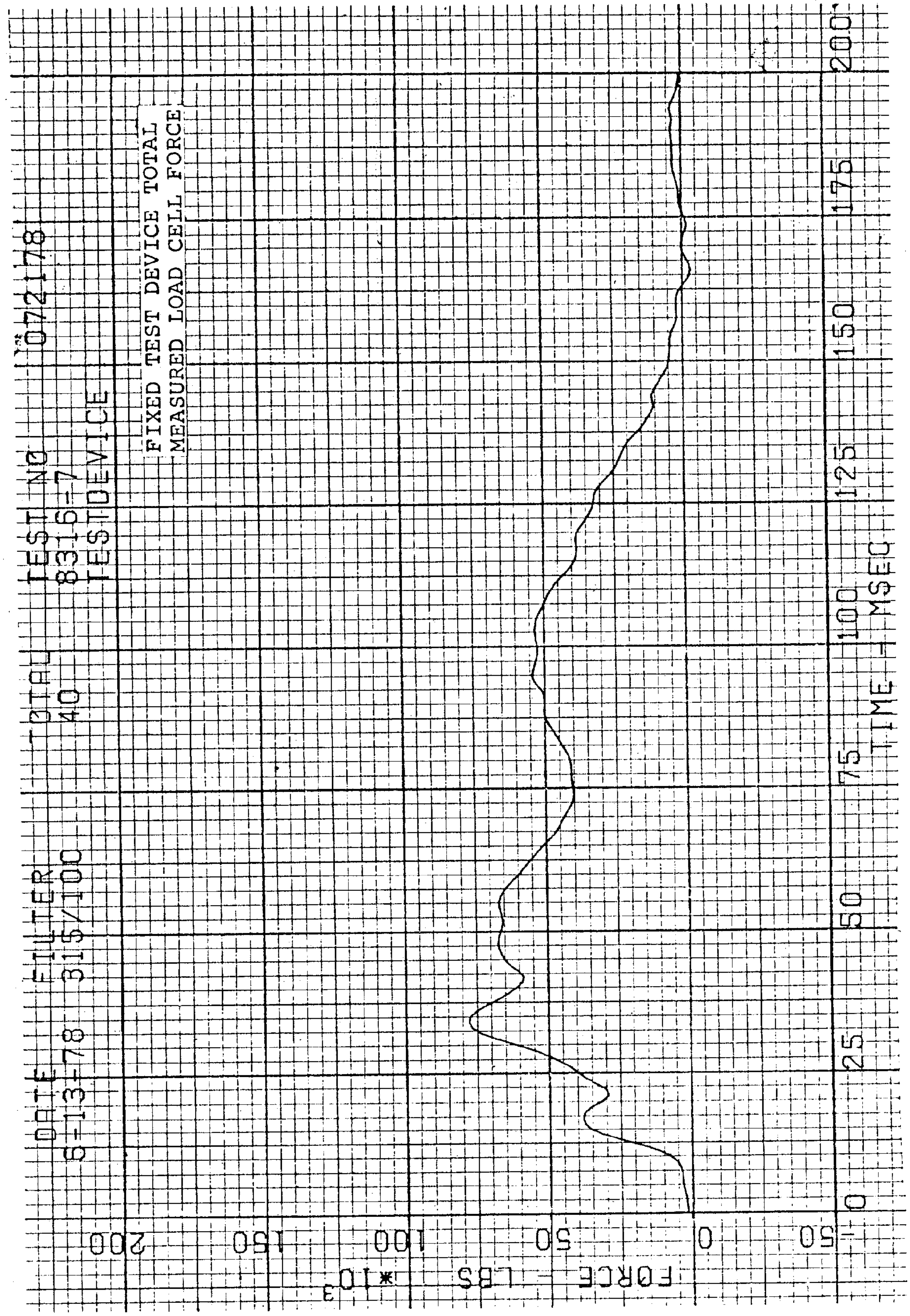

DATE
6-13-78
⊖=A
FILTER
315/100
△=B
COLUMN
6
+=C
TEST NO
8316-7
×=D
072178
TESTDEVICE
FIXED TEST DEVICE
LOAD CELL FORCES
COLUMN 6
FORCE - LBS *10^3
20
15
10
5
0
-5
0
25
50
75
100
125
150
175
200
TIME - MSEC

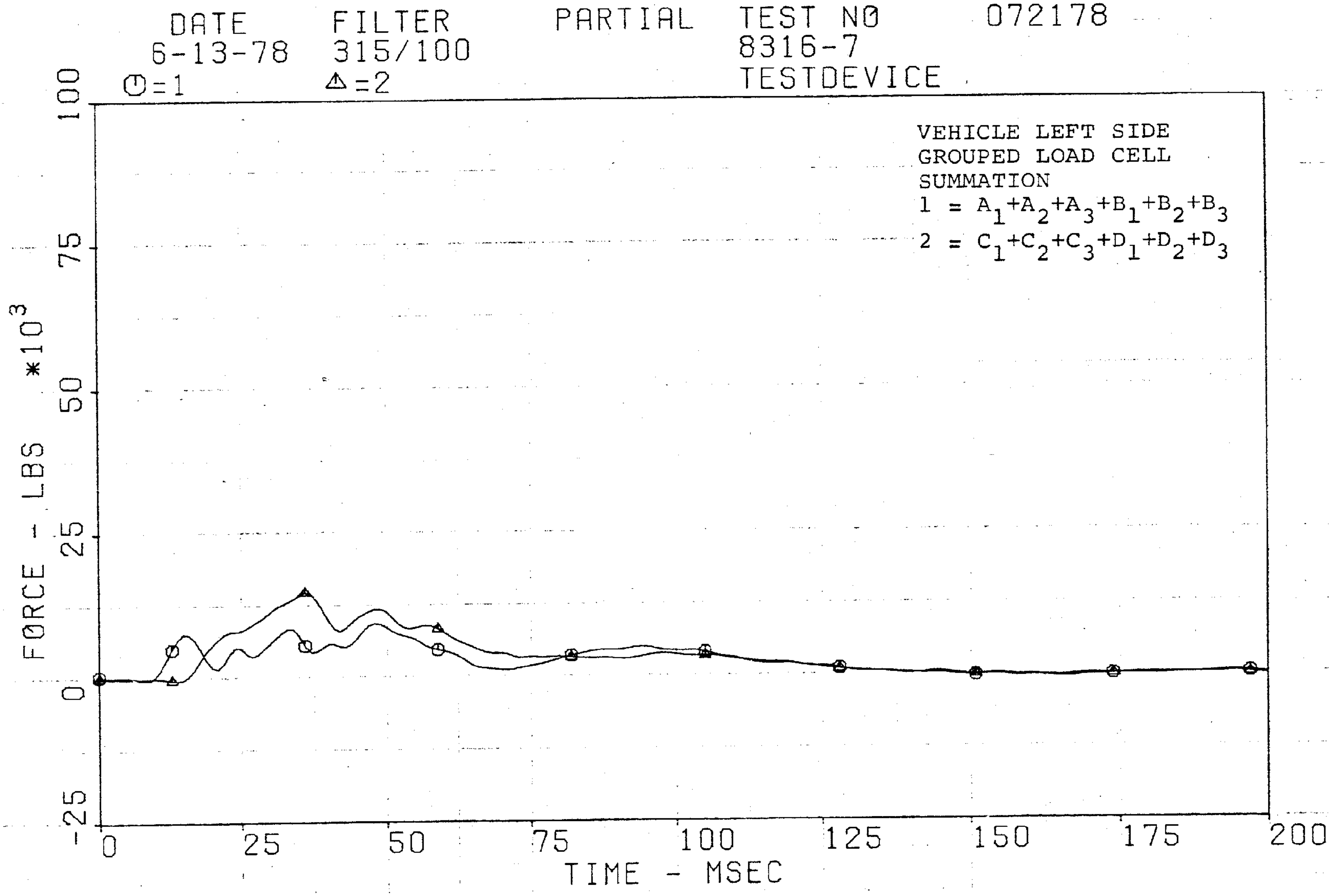

DATE
6-13-78
FILTER
315/100
COLUMN
7
TEST NO
8316-7
072178
TESTDEVICE
⊖=A
△=B
+=C
×=D
FIXED TEST DEVICE
LOAD CELL FORCES
COLUMN 7
FORCE - LBS *10^3
20
15
10
5
0
-5
0
25
50
75
100
125
150
175
200
TIME - MSEC

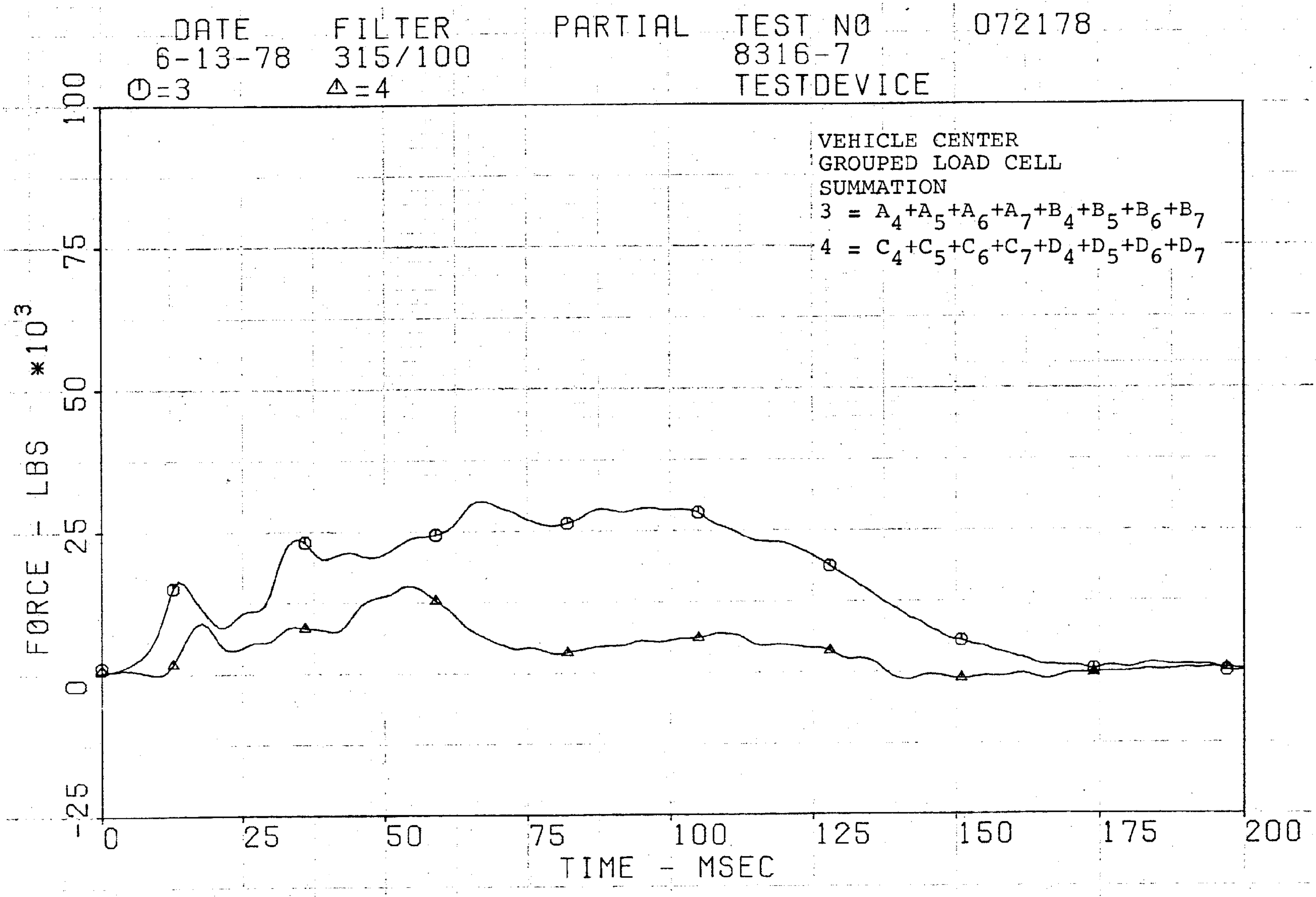

DATE
6-13-78
FILTER
315/100
COLUMN
8
TEST NO
8316-7
072178
TESTDEVICE
⊕=A
△=B
+=C
X=D
FIXED TEST DEVICE
LOAD CELL FORCES
COLUMN 8
FORCE - LBS *10^3
20
15
10
5
0
-5
0
25
50
75
100
125
150
175
200
TIME - MSEC

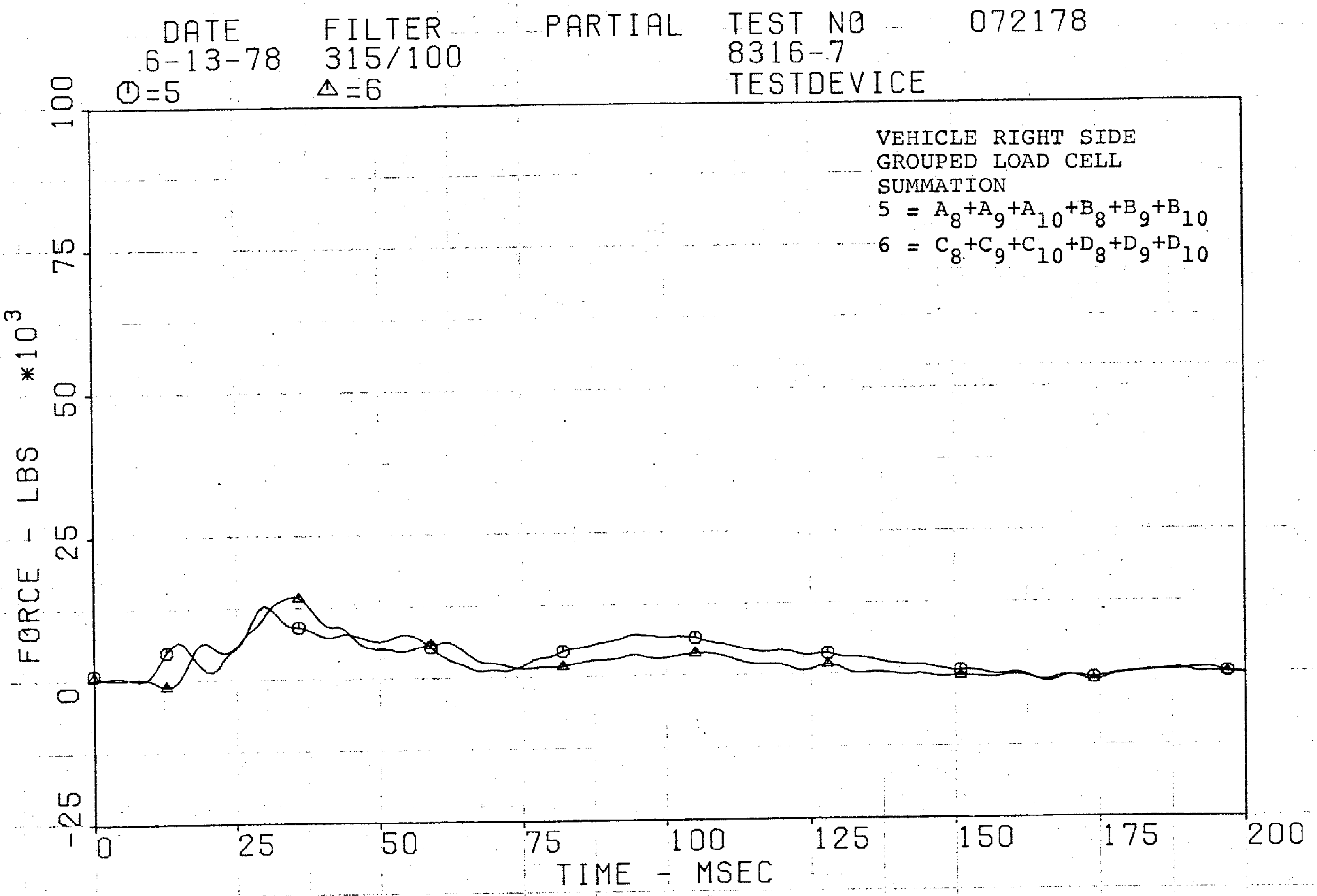

DATE
6-13-78
⊖=A
FILTER
315/100
△=B
COLUMN
9
+=C
TEST NO
8316-7
X=D
072178
TESTDEVICE
FIXED TEST DEVICE
LOAD CELL FORCES
COLUMN 9
FORCE - LBS *10³
20
15
10
5
0
-5
TIME - MSEC
0
25
50
75
100
125
150
175
200

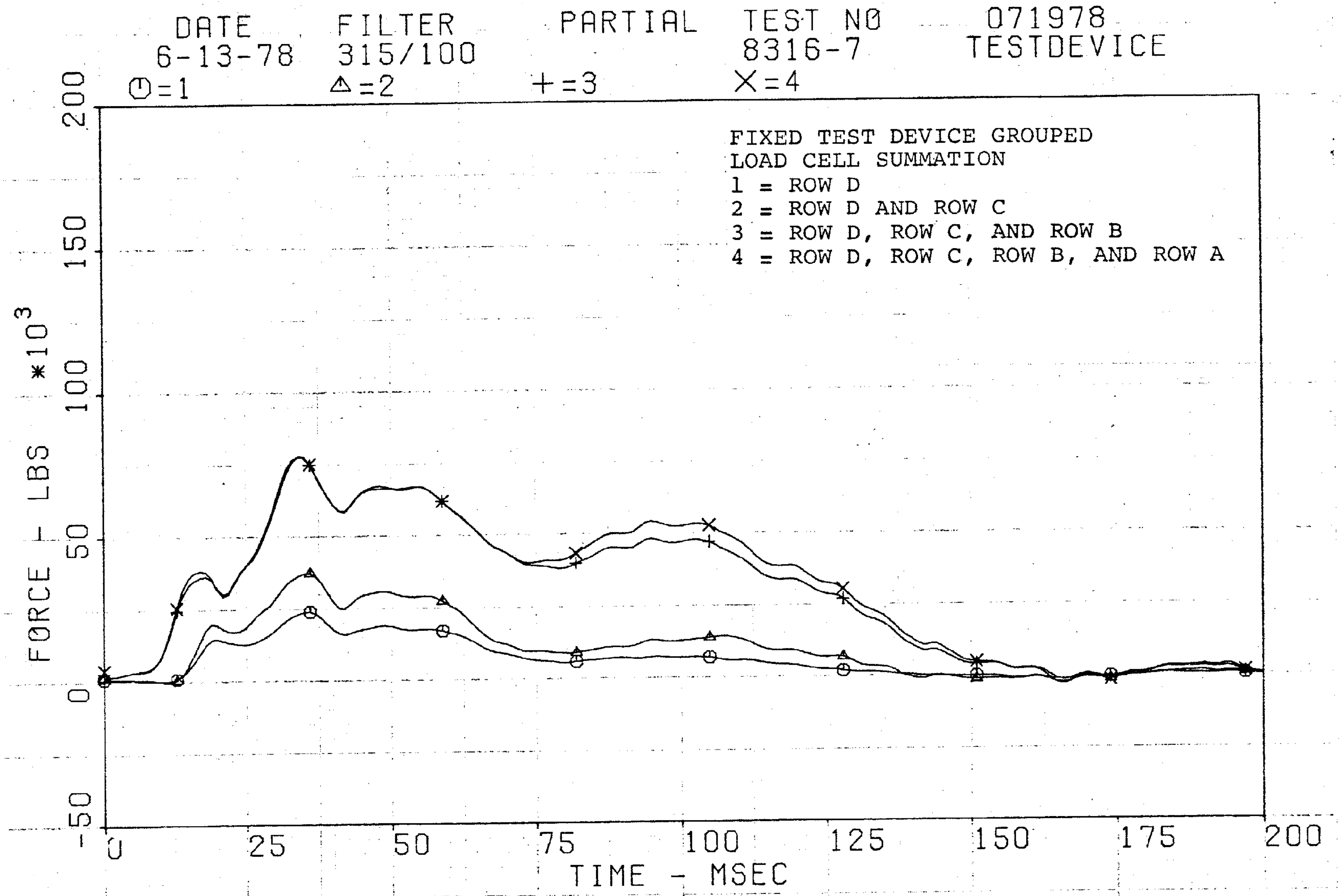

DATE
6-13-78
FILTER
315/100
COLUMN
10
TEST NØ
8316-7
072178
TESTDEVICE
⊕=A
△=B
+=C
X=D
FIXED TEST DEVICE
LOAD CELL FORCES
COLUMN 10
FØRCE - LBS *10^3
20
15
10
5
0
-5
0
25
50
75
100
125
150
175
200
TIME - MSEC


DATE
5-13-78
FILTER
315/100
TOTAL
40
TEST NO
8316-7
TESTDEVICE
072178
FIXED TEST DEVICE TOTAL
MEASURED LOAD CELL FORCE
0
25
50
75
100
125
150
175
200
TIME - MSEC
200
150
100
50
0
50
FORCE - LBS *10³


DATE
6-13-78
⦶=1
FILTER
315/100
△=2
PARTIAL
TEST NØ
8316-7
TESTDEVICE
072178
VEHICLE LEFT SIDE
GROUPED LOAD CELL
SUMMATION
1 = A_1+A_2+A_3+B_1+B_2+B_3
2 = C_1+C_2+C_3+D_1+D_2+D_3
FØRCE - LBS *10^3
100
75
50
25
0
-25
0
25
50
75
100
125
150
175
200
TIME - MSEC


DATE
6-13-78
⊖=3
FILTER
315/100
△=4
PARTIAL
TEST N0
8316-7
TESTDEVICE
072178
VEHICLE CENTER
GROUPED LOAD CELL
SUMMATION
3 = $A_4+A_5+A_6+A_7+B_4+B_5+B_6+B_7$
4 = $C_4+C_5+C_6+C_7+D_4+D_5+D_6+D_7$
FORCE - LBS *10³
100
75
50
25
0
-25
0
25
50
75
100
125
150
175
200
TIME - MSEC


DATE
6-13-78
⊕=5
FILTER
315/100
△=6
PARTIAL
TEST NØ
8316-7
TESTDEVICE
072178
VEHICLE RIGHT SIDE
GROUPED LOAD CELL
SUMMATION
5 = $A_8+A_9+A_{10}+B_8+B_9+B_{10}$
6 = $C_8+C_9+C_{10}+D_8+D_9+D_{10}$
FØRCE - LBS *10^3
100
75
50
25
0
-25
0
25
50
75
100
125
150
175
200
TIME - MSEC

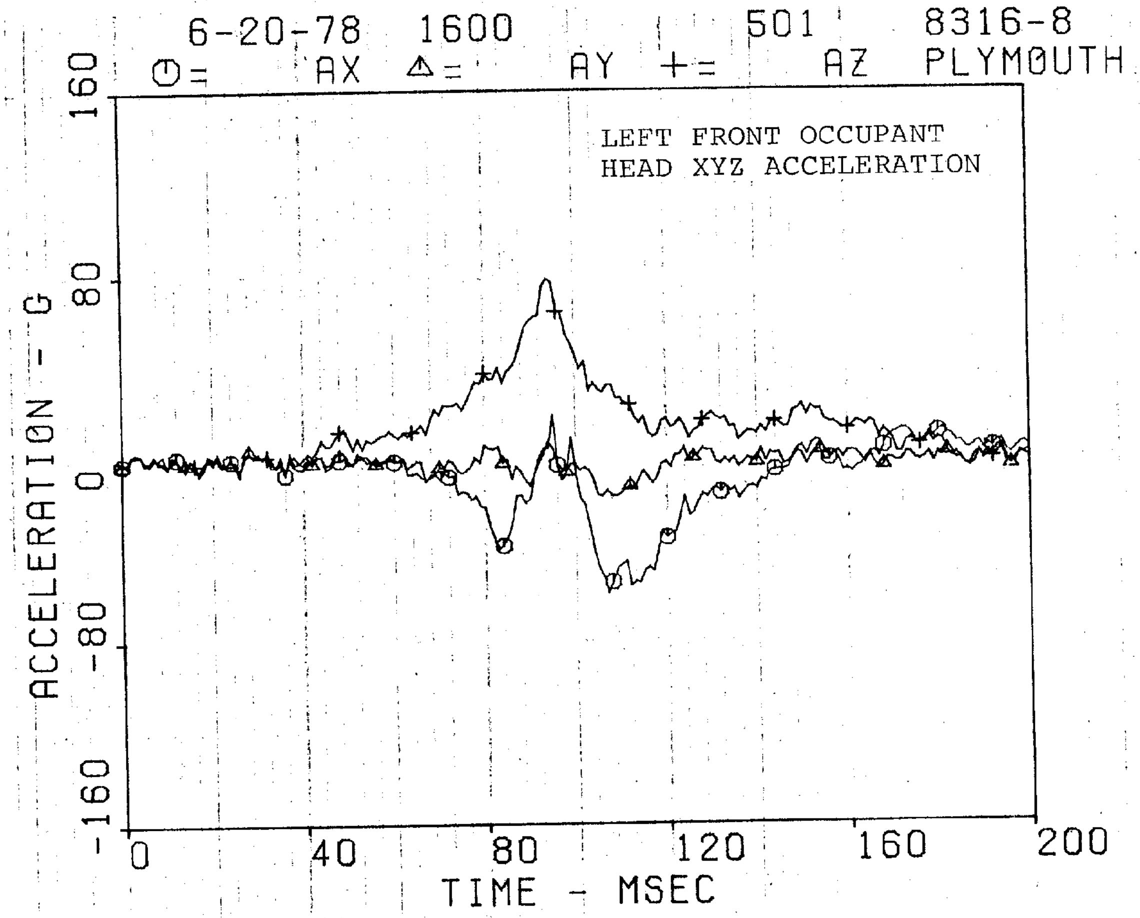

DATE
6-13-78
FILTER
315/100
PARTIAL
TEST N0
8316-7
071978
TESTDEVICE
⊕=1
△=2
+=3
X=4
FIXED TEST DEVICE GROUPED
LOAD CELL SUMMATION
1 = ROW D
2 = ROW D AND ROW C
3 = ROW D, ROW C, AND ROW B
4 = ROW D, ROW C, ROW B, AND ROW A
FORCE - LBS $*10^3$
200
150
100
50
0
-50
0
25
50
75
100
125
150
175
200
TIME - MSEC

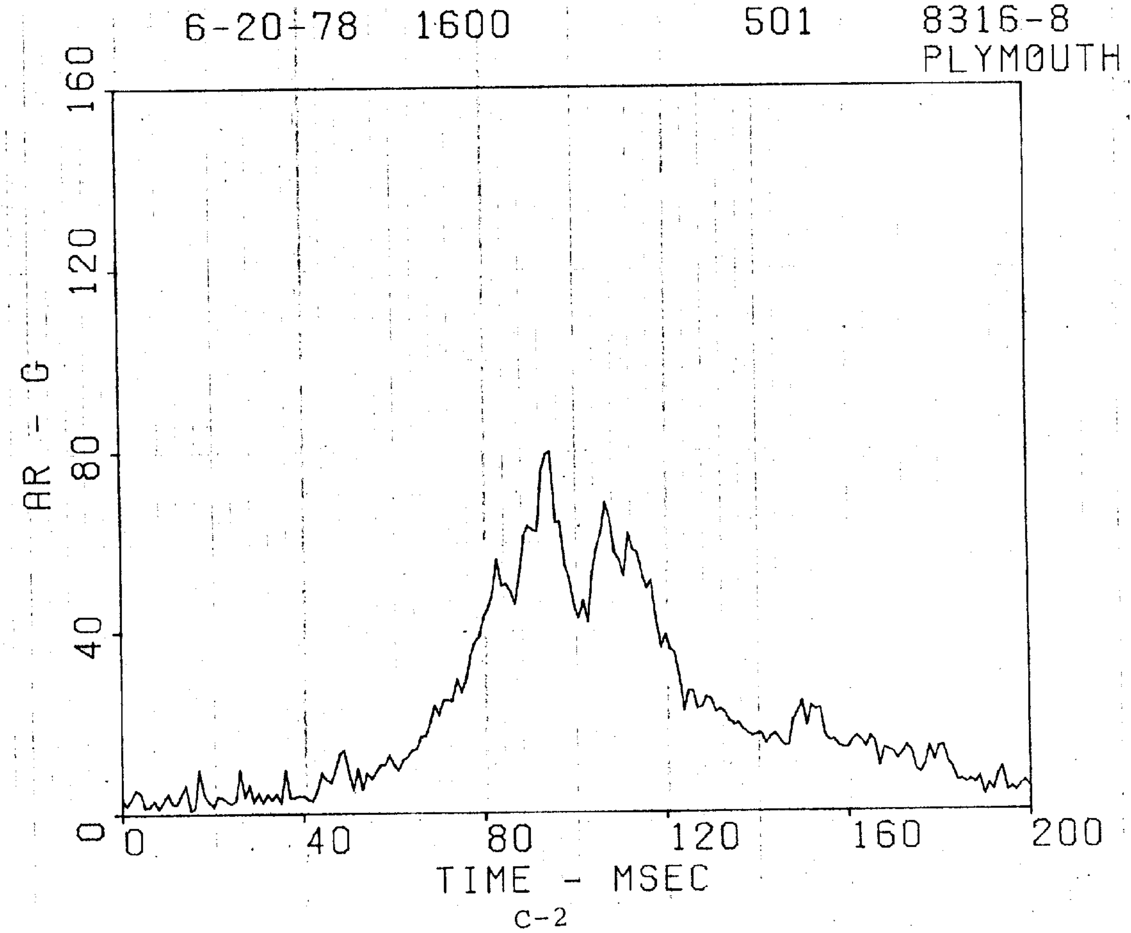
APPENDIX C

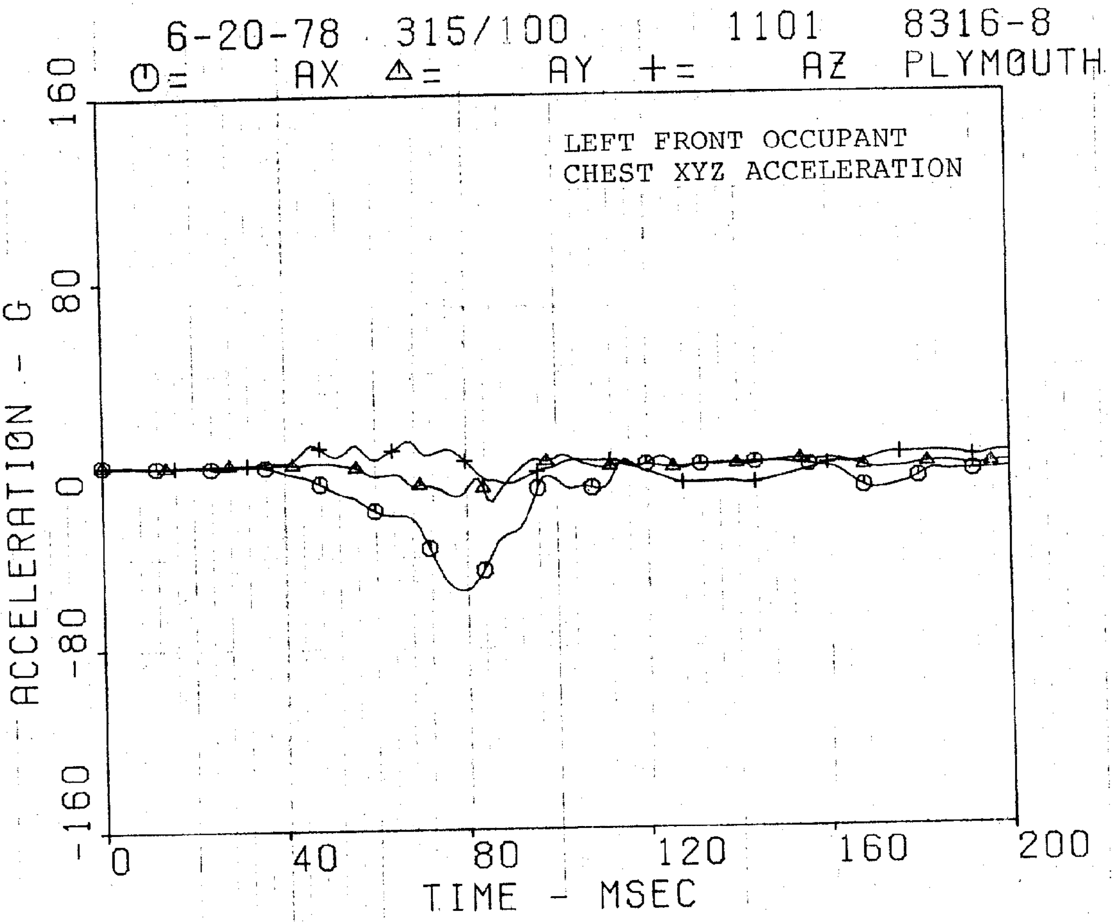
CALCOMP PLOTS

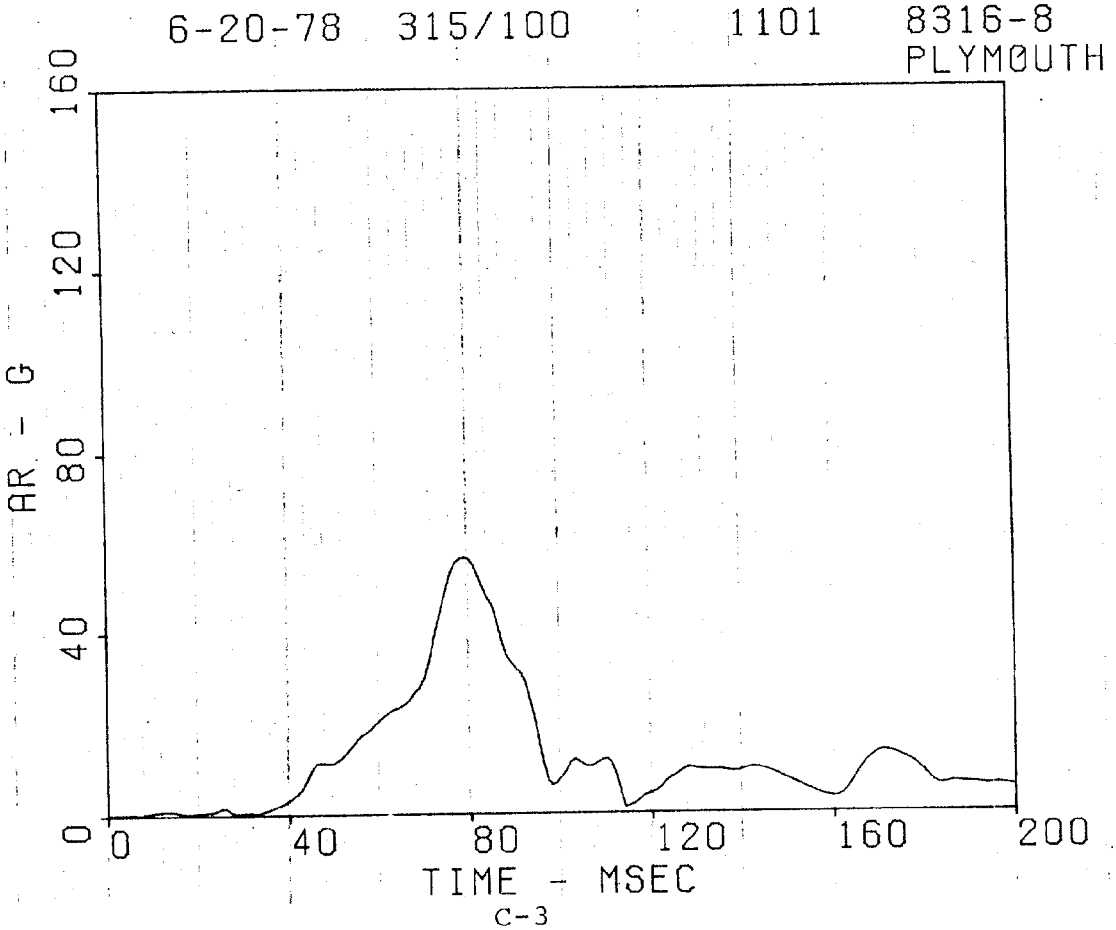
TEST 8

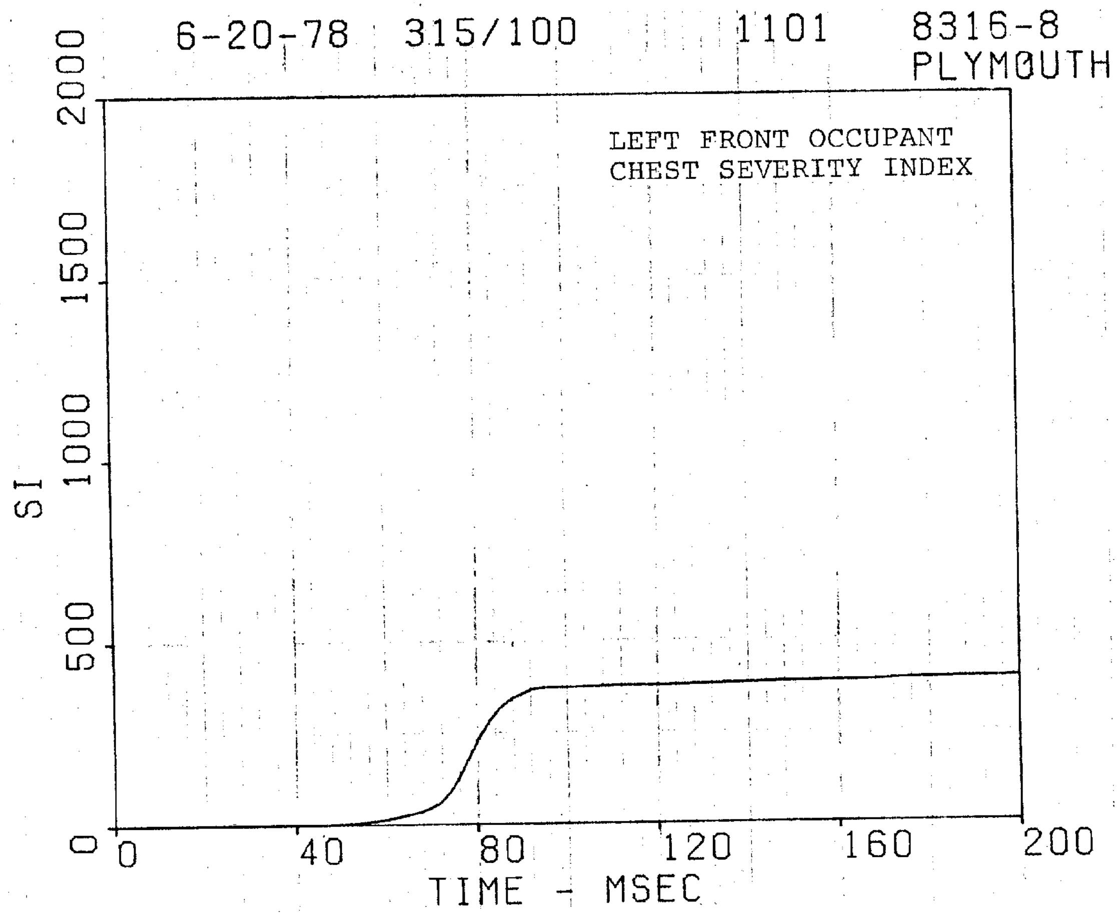
1975 PLYMOUTH FURY-TO-MOVING TEST DEVICE

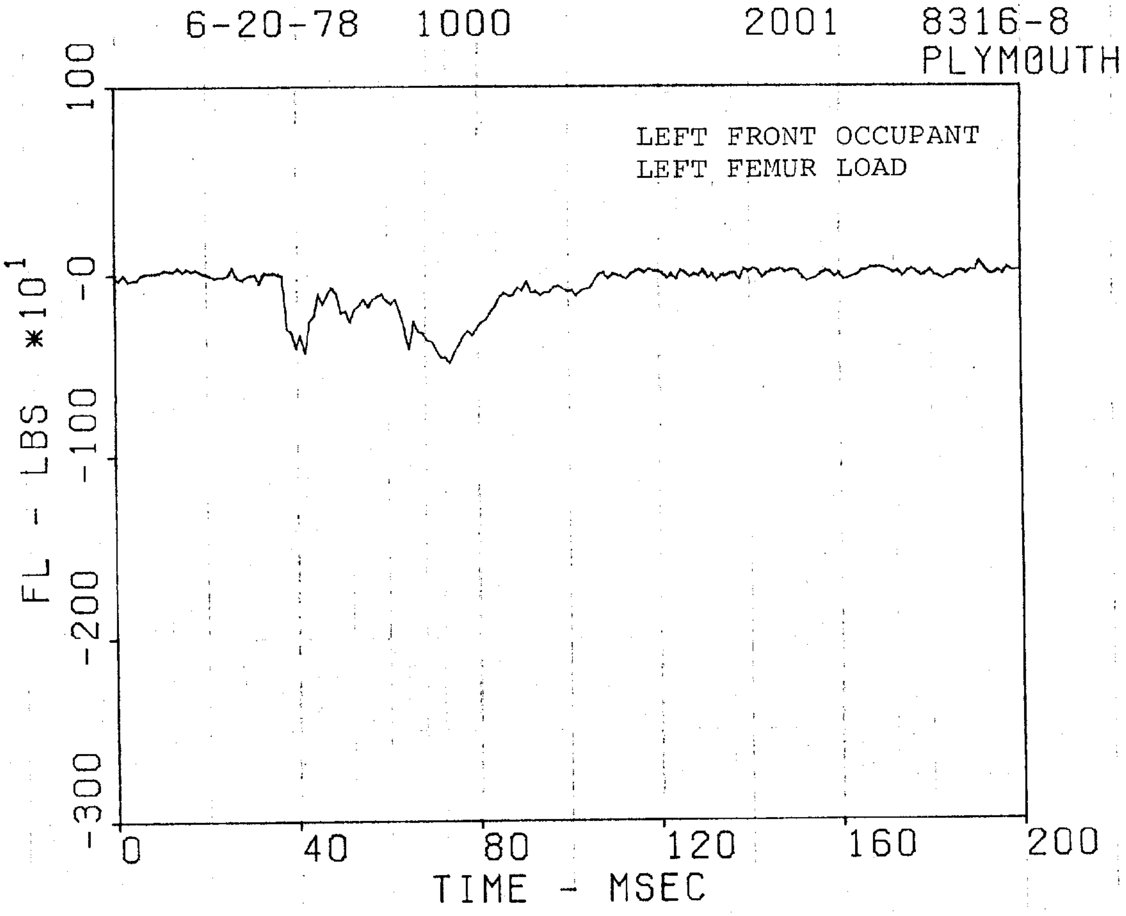

6-20-78 1600 501 8316-8
⊙= AX △= AY += AZ PLYMOUTH
LEFT FRONT OCCUPANT
HEAD XYZ ACCELERATION
ACCELERATION - G
160
80
0
-80
-160
0
40
80
120
160
200
TIME - MSEC

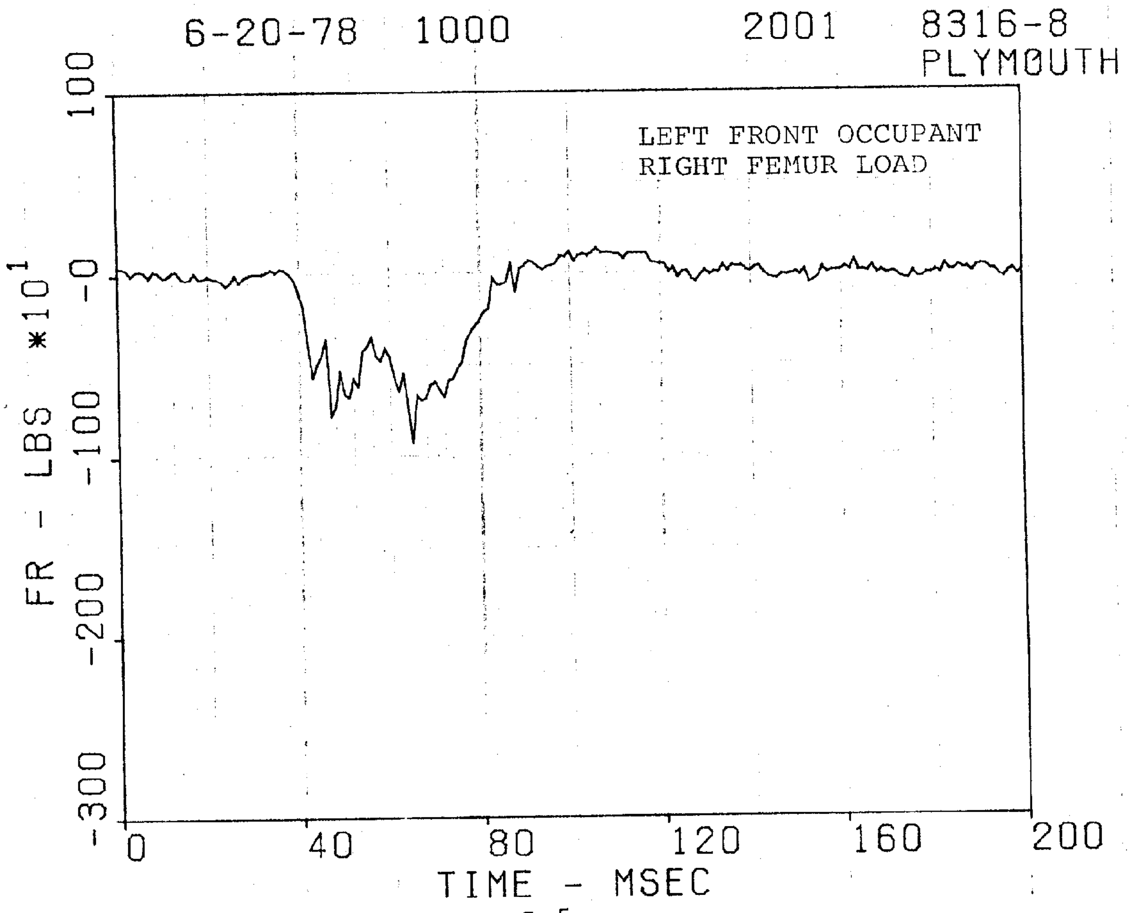

6-20-78 1600 501 8316-8
PLYMOUTH
AR - G
160
120
80
40
0
0
40
80
120
160
200
TIME - MSEC


6-20-78 315/100 1101 8316-8
⊕= AX △= AY += AZ PLYMOUTH
LEFT FRONT OCCUPANT
CHEST XYZ ACCELERATION
ACCELERATION - G
160
80
0
-80
-160
0
40
80
120
160
200
TIME - MSEC

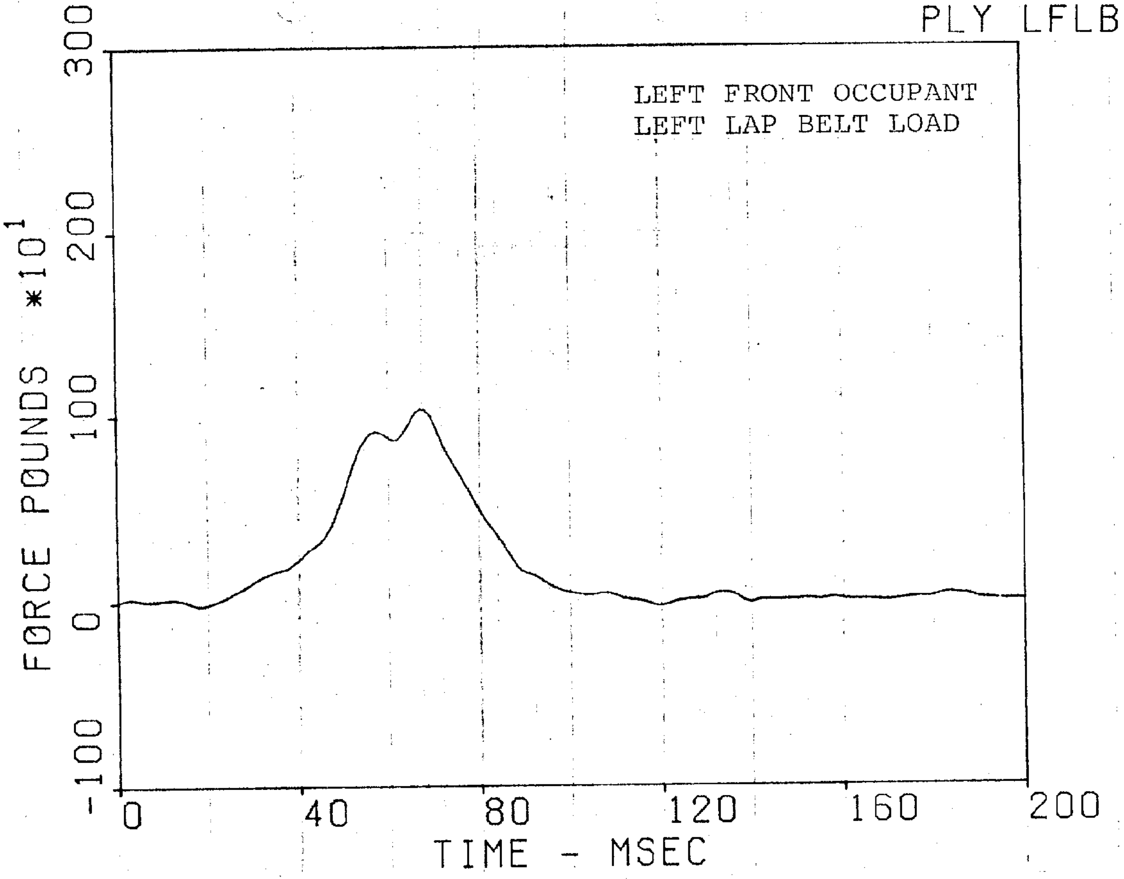

6-20-78 315/100 1101 8316-8
PLYMOUTH
AR - G
160
120
80
40
0
0
40
80
120
160
200
TIME - MSEC


6-20-78
315/100
1101
8316-8
PLYMOUTH
LEFT FRONT OCCUPANT
CHEST SEVERITY INDEX
SI
2000
1500
1000
500
0
0
40
80
120
160
200
TIME - MSEC

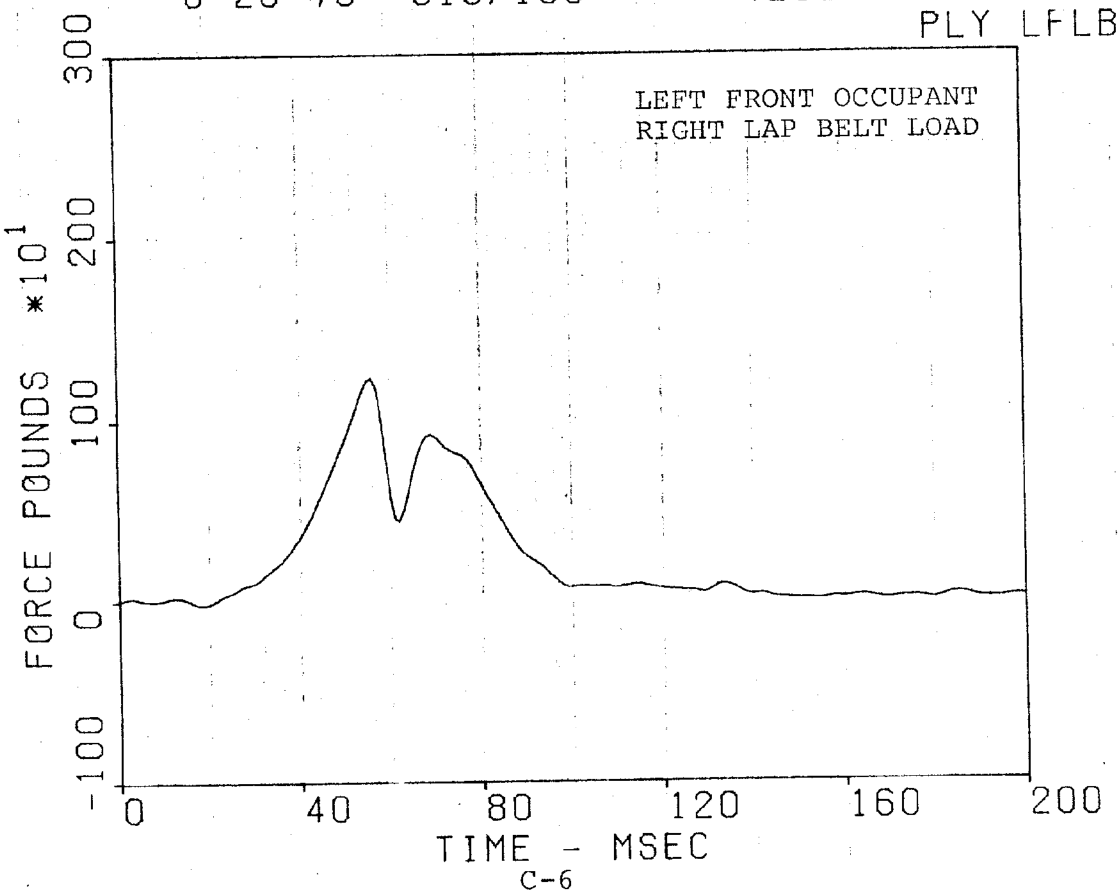

6-20-78 1000 2001 8316-8
PLYMOUTH
LEFT FRONT OCCUPANT
LEFT FEMUR LOAD
FL - LBS *10^{1}
100
-0
-100
-200
-300
0
40
80
120
160
200
TIME - MSEC

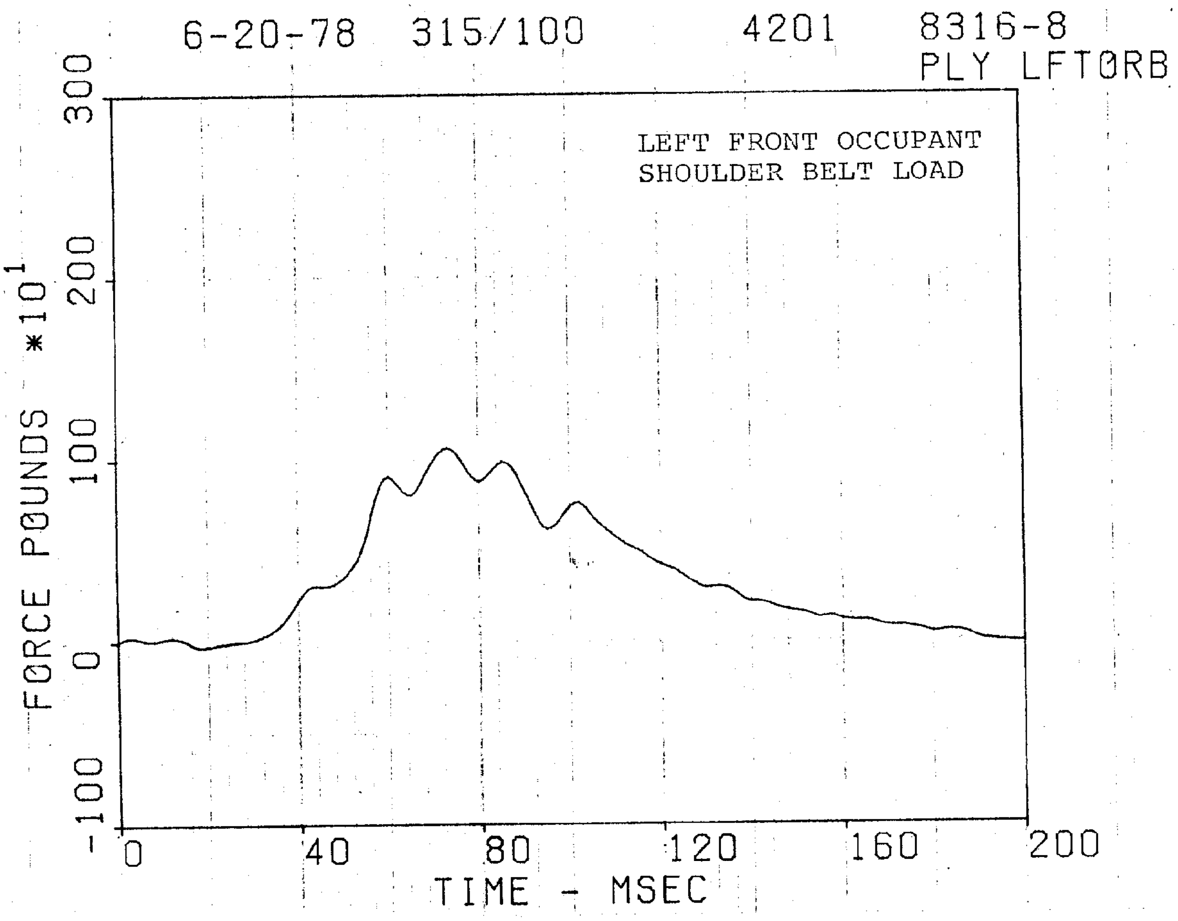

6-20-78 1000 2001 8316-8
PLYMOUTH
LEFT FRONT OCCUPANT
RIGHT FEMUR LOAD
FR - LBS *10^{1}
100
-0
-100
-200
-300
0
40
80
120
160
200
TIME - MSEC

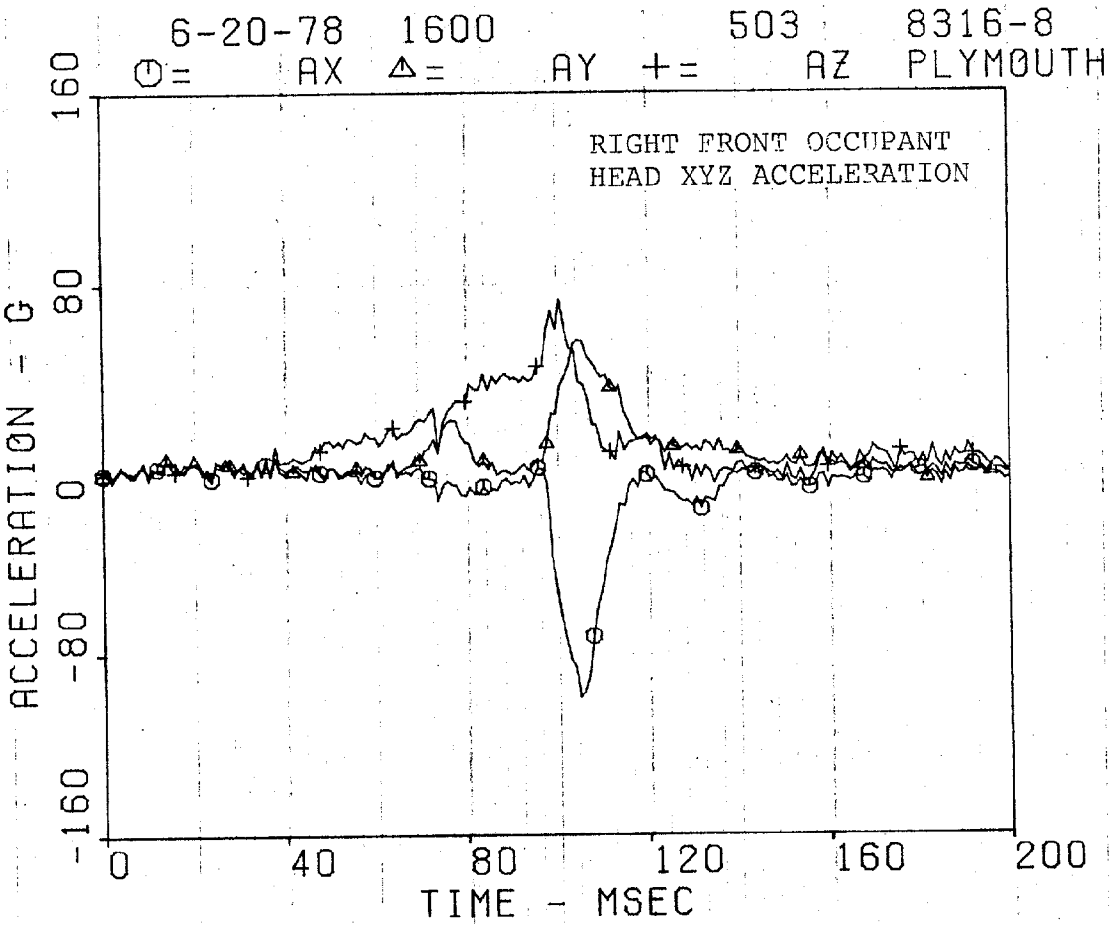
6-20-78 315/100 4201 8316-8
PLY LFLB-L

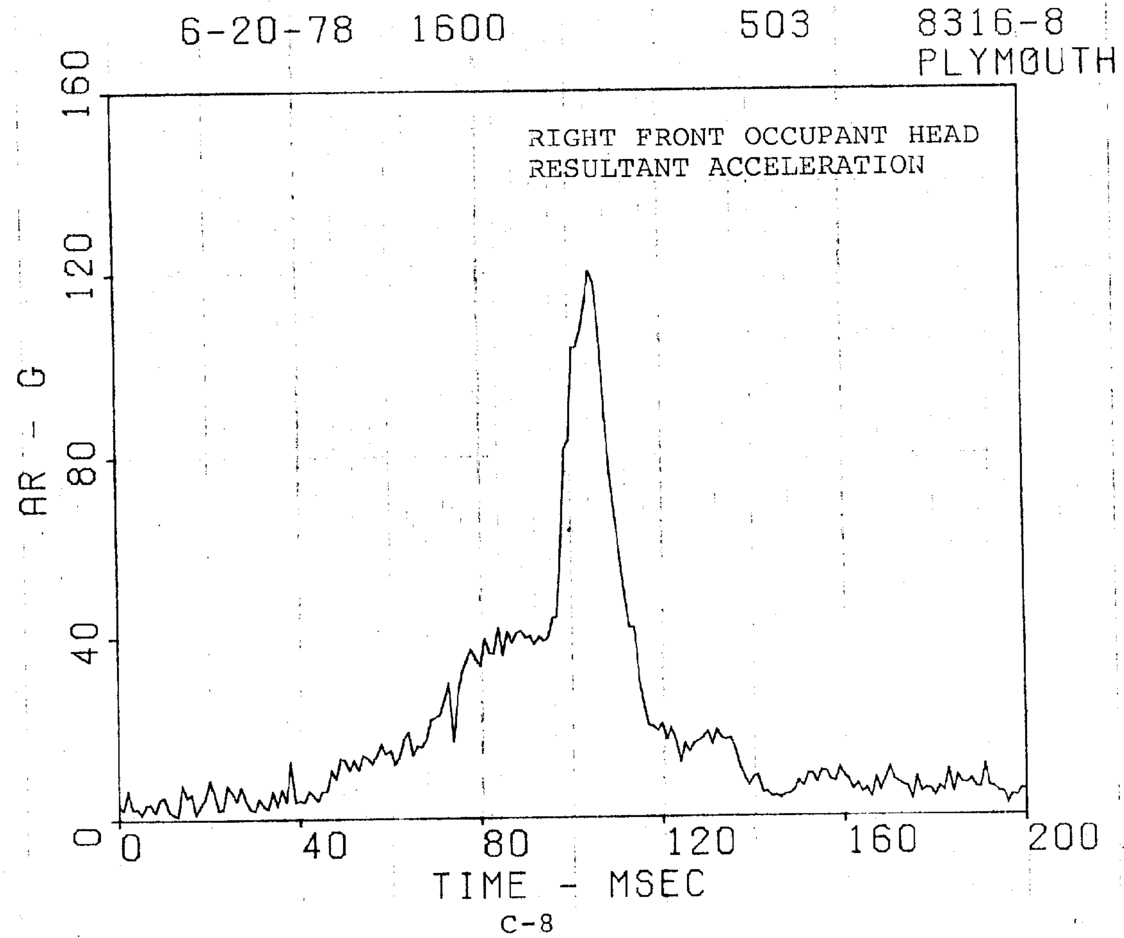


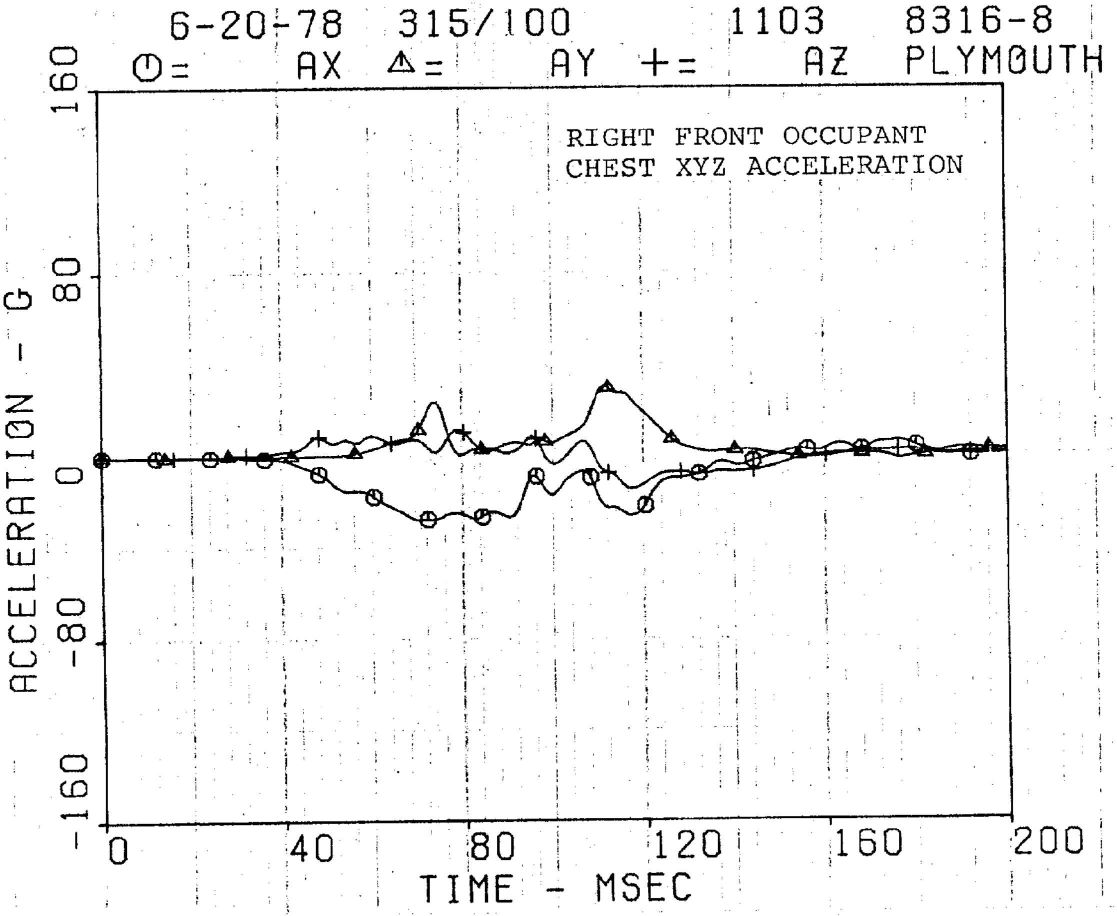
6-20-78 315/100 4201 8316-8
PLY LFLB-R

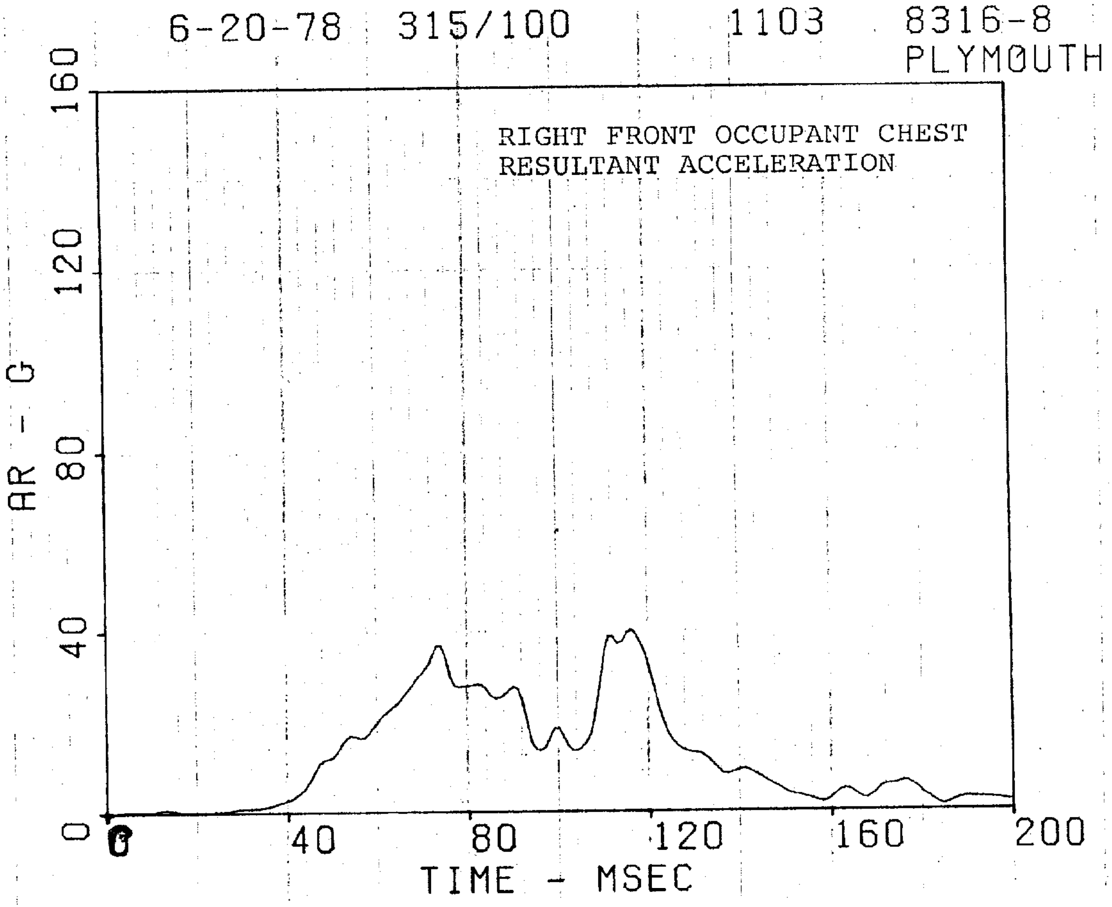


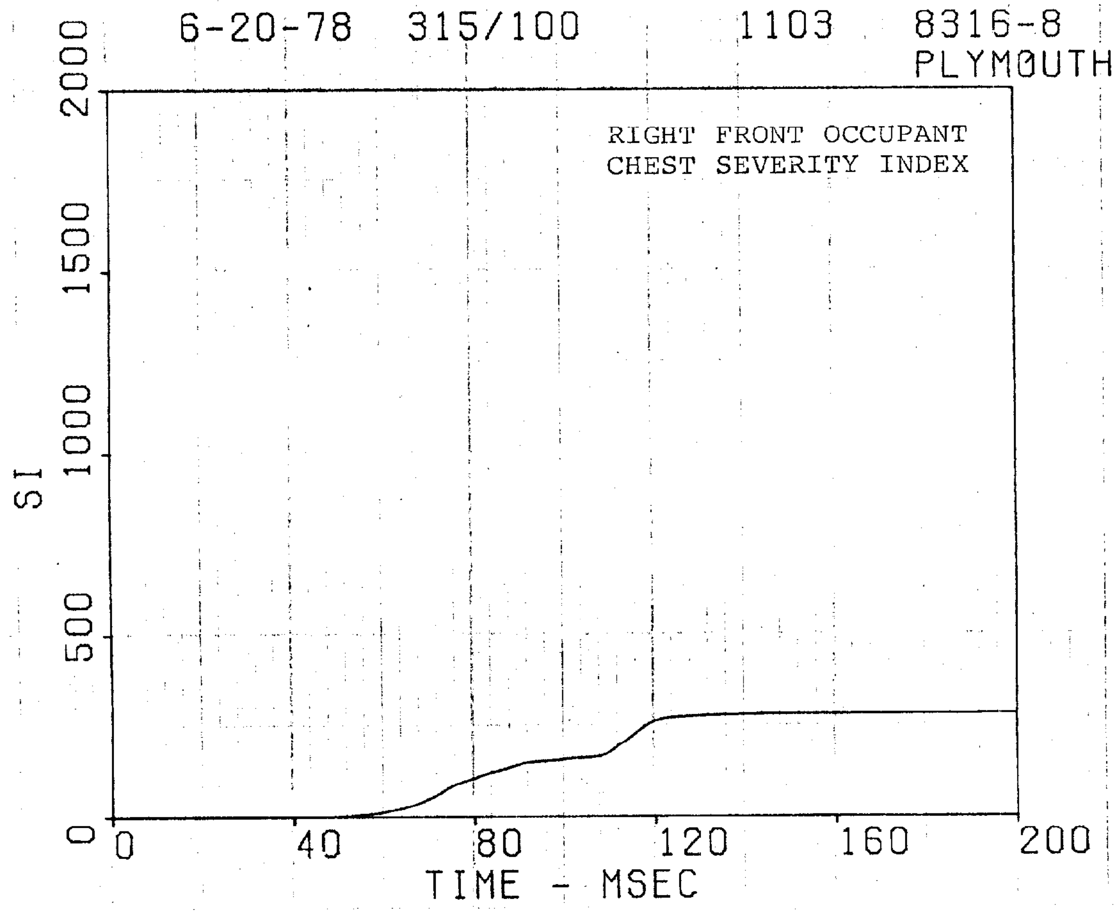

6-20-78 315/100 4201 8316-8
PLY LFTØRB
LEFT FRONT OCCUPANT
SHOULDER BELT LOAD
FØRCE PØUNDS *10^1
300
200
100
0
-100
0
40
80
120
160
200
TIME - MSEC

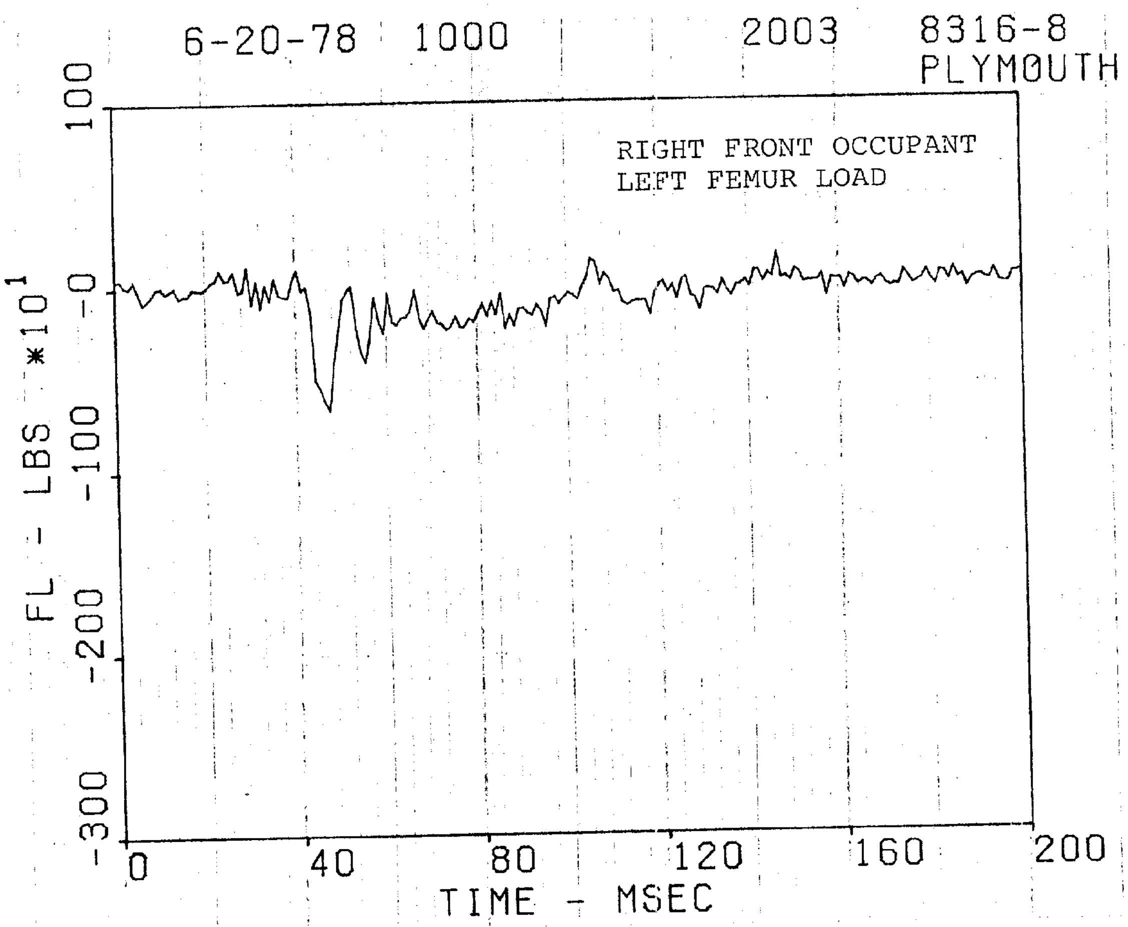

6-20-78 1600 503 8316-8
⊕= AX △= AY += AZ PLYMOUTH
RIGHT FRONT OCCUPANT
HEAD XYZ ACCELERATION
ACCELERATION - G
160
80
0
-80
-160
0
40
80
120
160
200
TIME - MSEC

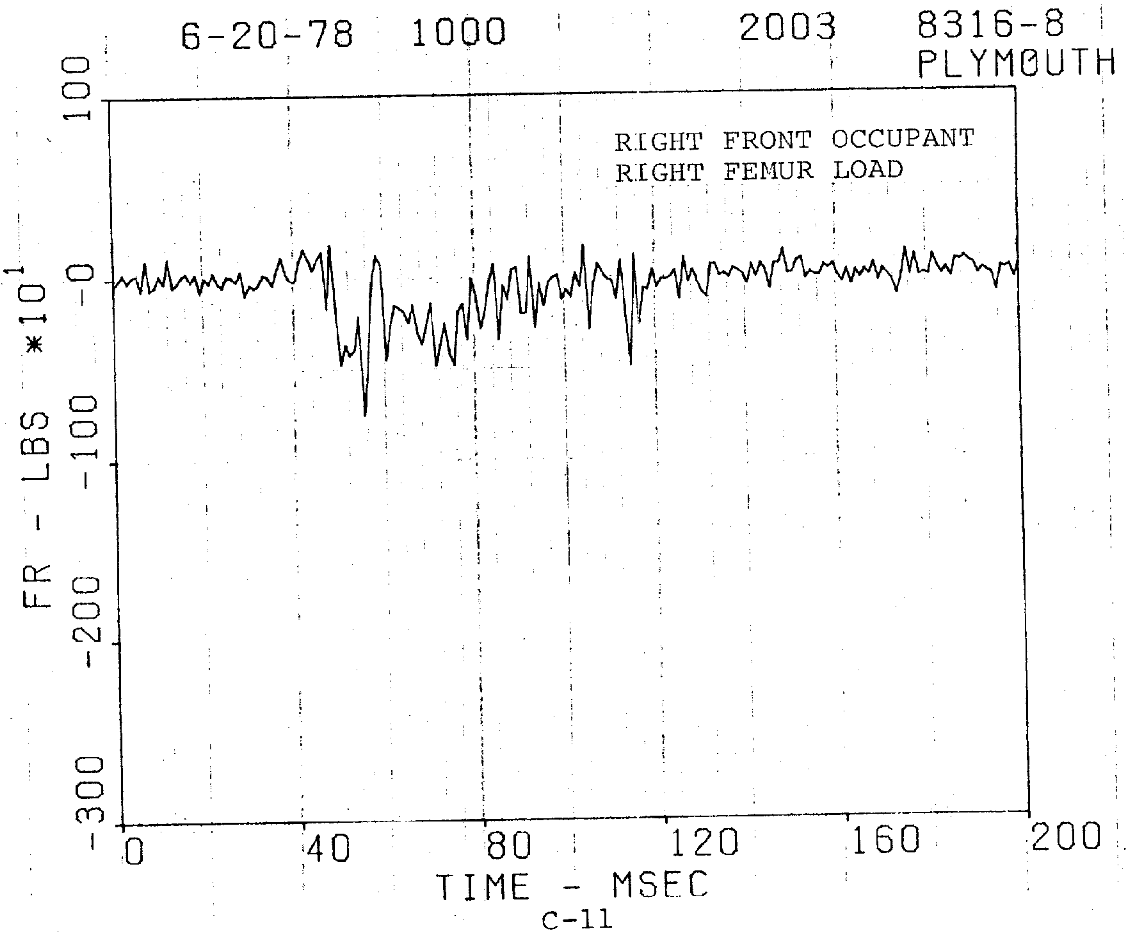

6-20-78 1600 503 8316-8
PLYMOUTH
RIGHT FRONT OCCUPANT HEAD
RESULTANT ACCELERATION
AR - G
160
120
80
40
0
0
40
80
120
160
200
TIME - MSEC

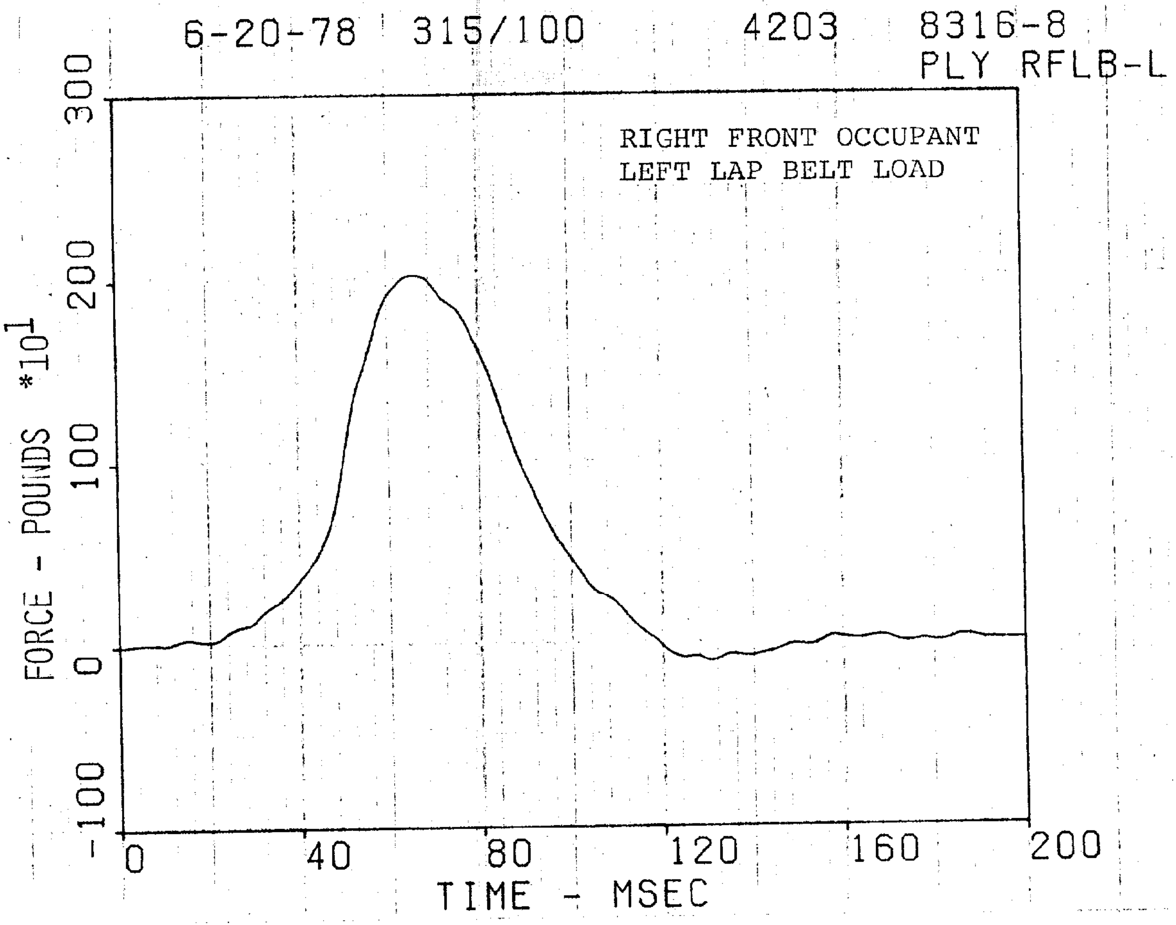

6-20-78 315/100 1103 8316-8
⊕= AX △= AY += AZ PLYMOUTH
RIGHT FRONT OCCUPANT
CHEST XYZ ACCELERATION
ACCELERATION - G
160
80
0
-80
-160
0
40
80
120
160
200
TIME - MSEC

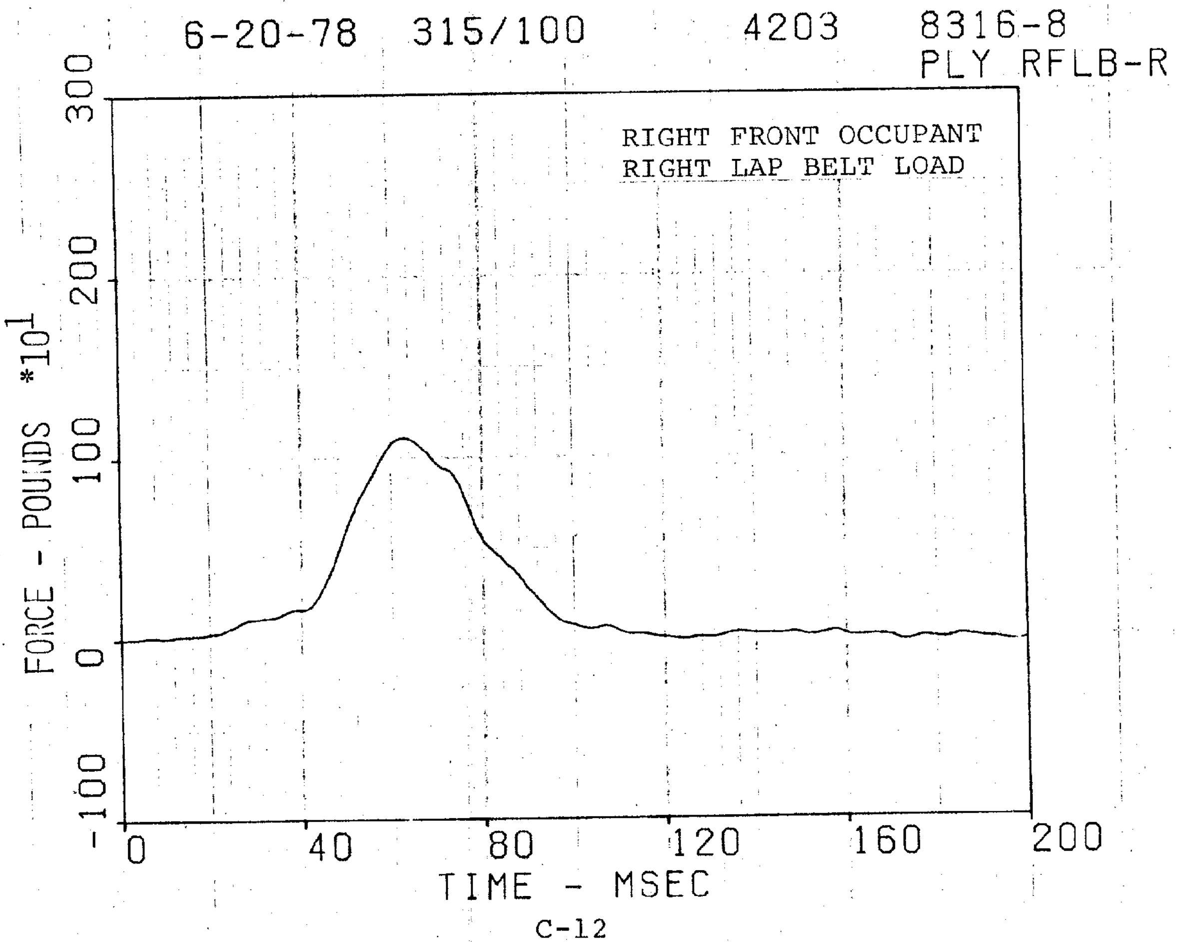

6-20-78 315/100 1103 8316-8
PLYMOUTH
RIGHT FRONT OCCUPANT CHEST
RESULTANT ACCELERATION
AR - G
160
120
80
40
0
0
40
80
120
160
200
TIME - MSEC

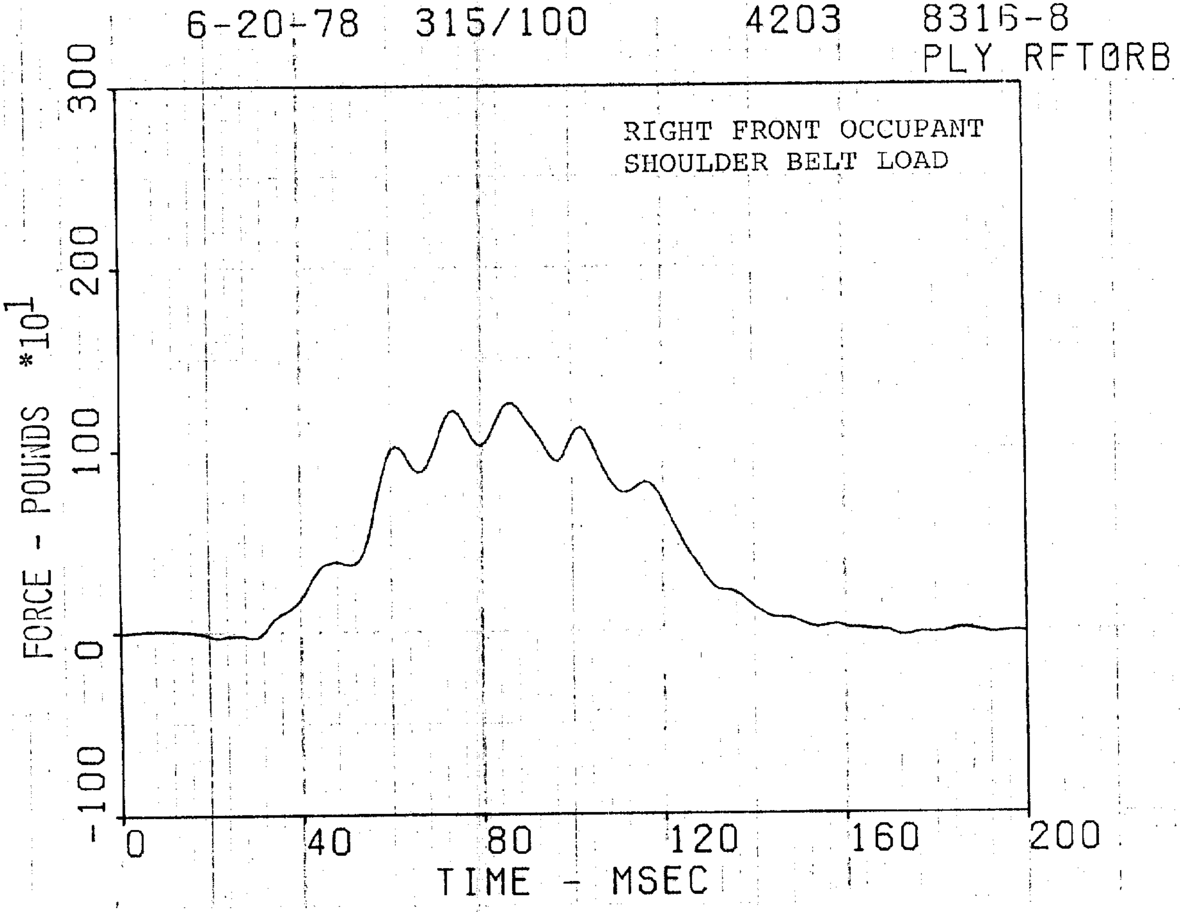

6-20-78 315/100 1103 8316-8
PLYMOUTH
RIGHT FRONT OCCUPANT
CHEST SEVERITY INDEX
SI
0
500
1000
1500
2000
0
40
80
120
160
200
TIME - MSEC

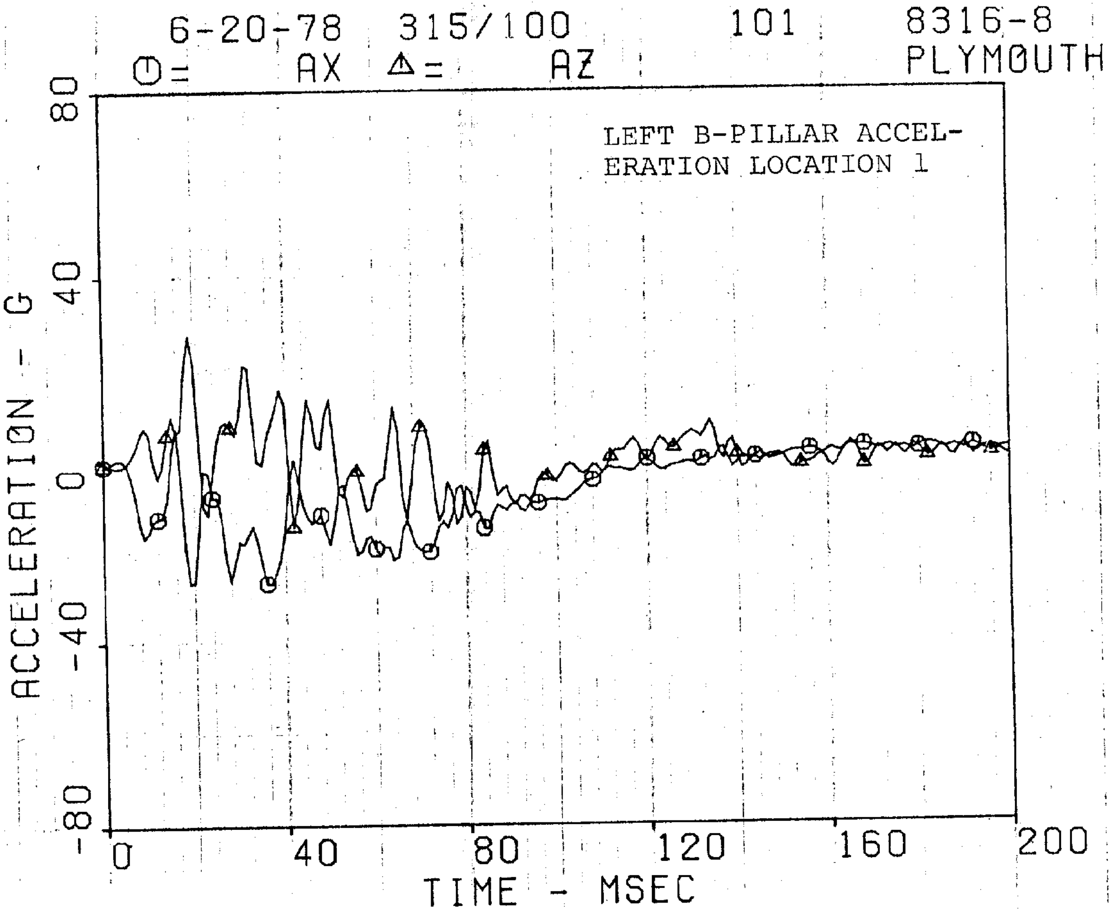

6-20-78 1000
2003 8316-8
PLYMOUTH
RIGHT FRONT OCCUPANT
LEFT FEMUR LOAD
FL - LBS *10^1
100
-0
-100
-200
-300
0
40
80
120
160
200
TIME - MSEC

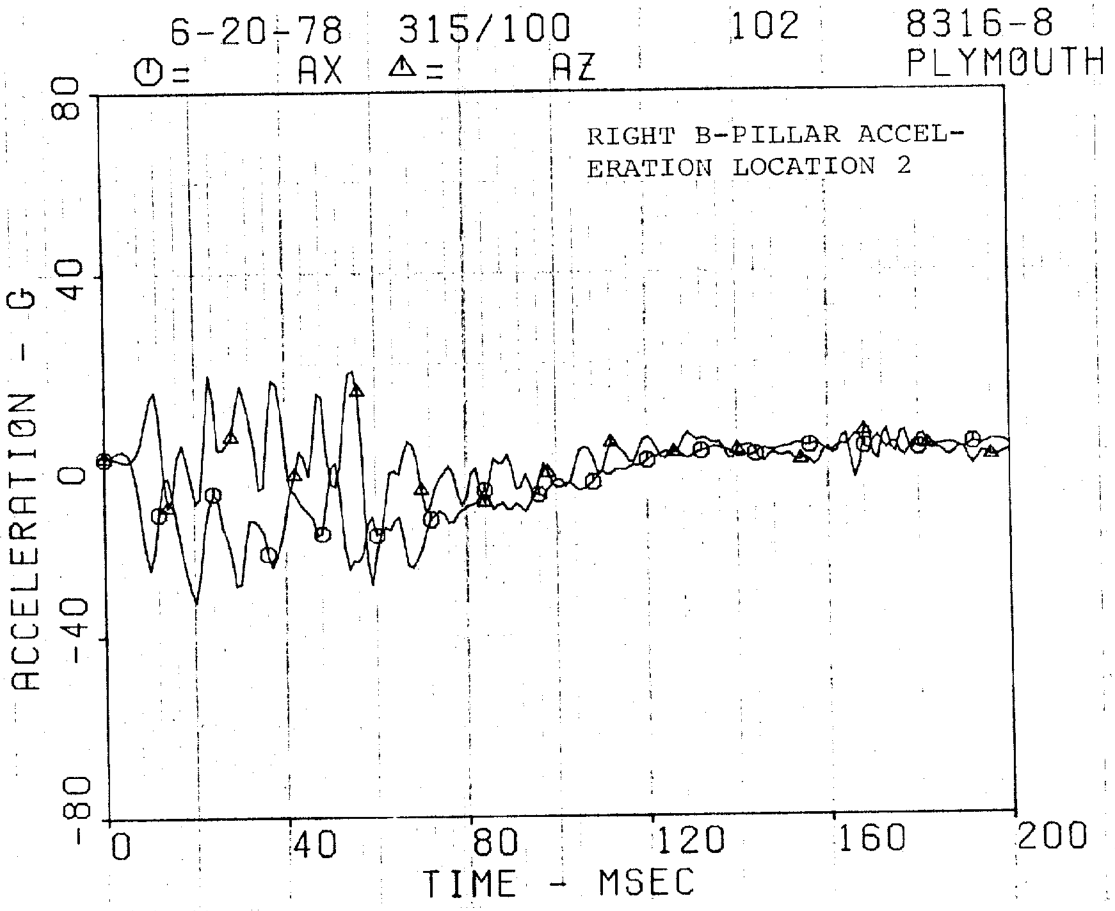

6-20-78 1000
2003 8316-8
PLYMOUTH
RIGHT FRONT OCCUPANT
RIGHT FEMUR LOAD
FR - LBS *10^1
100
-0
-100
-200
-300
0
40
80
120
160
200
TIME - MSEC

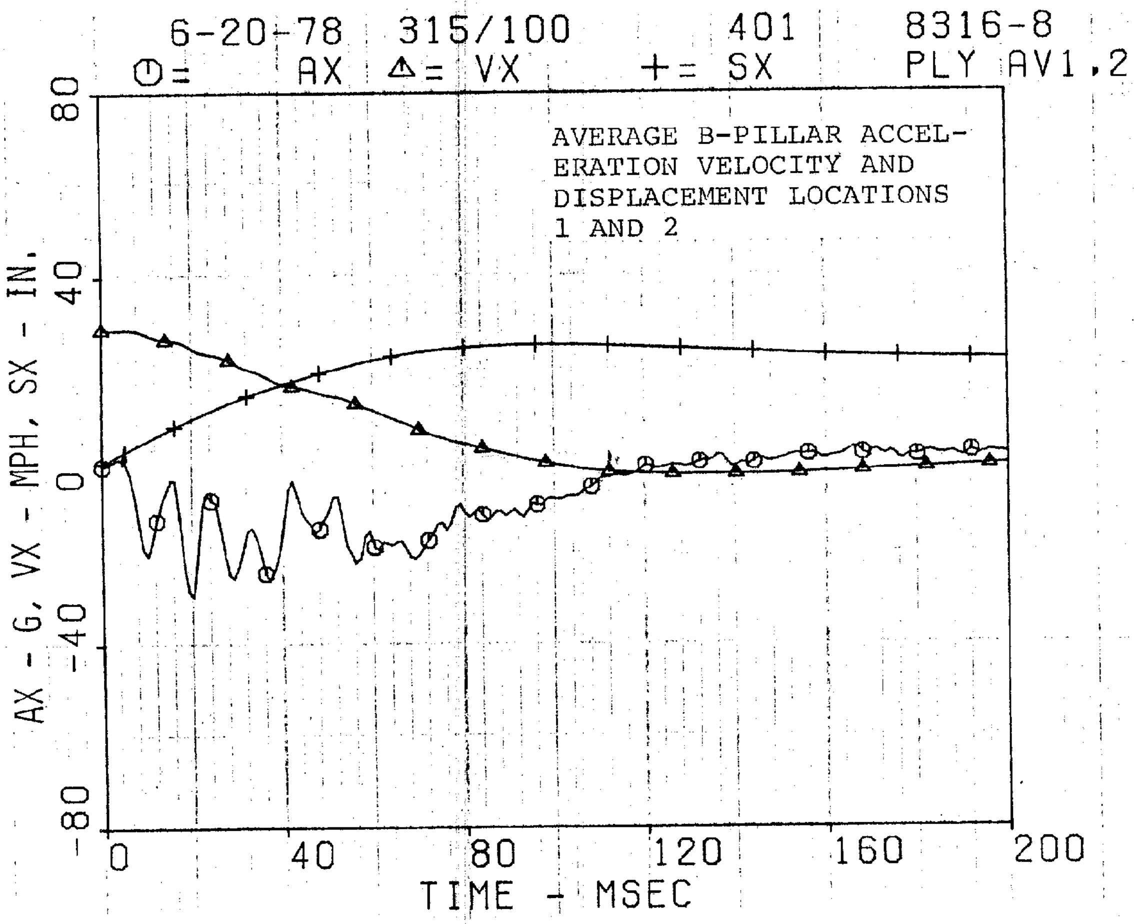

6-20-78 315/100 4203 8316-8
PLY RFLB-L
RIGHT FRONT OCCUPANT
LEFT LAP BELT LOAD
FORCE - POUNDS *10^1
300
200
100
0
-100
0
40
80
120
160
200
TIME - MSEC

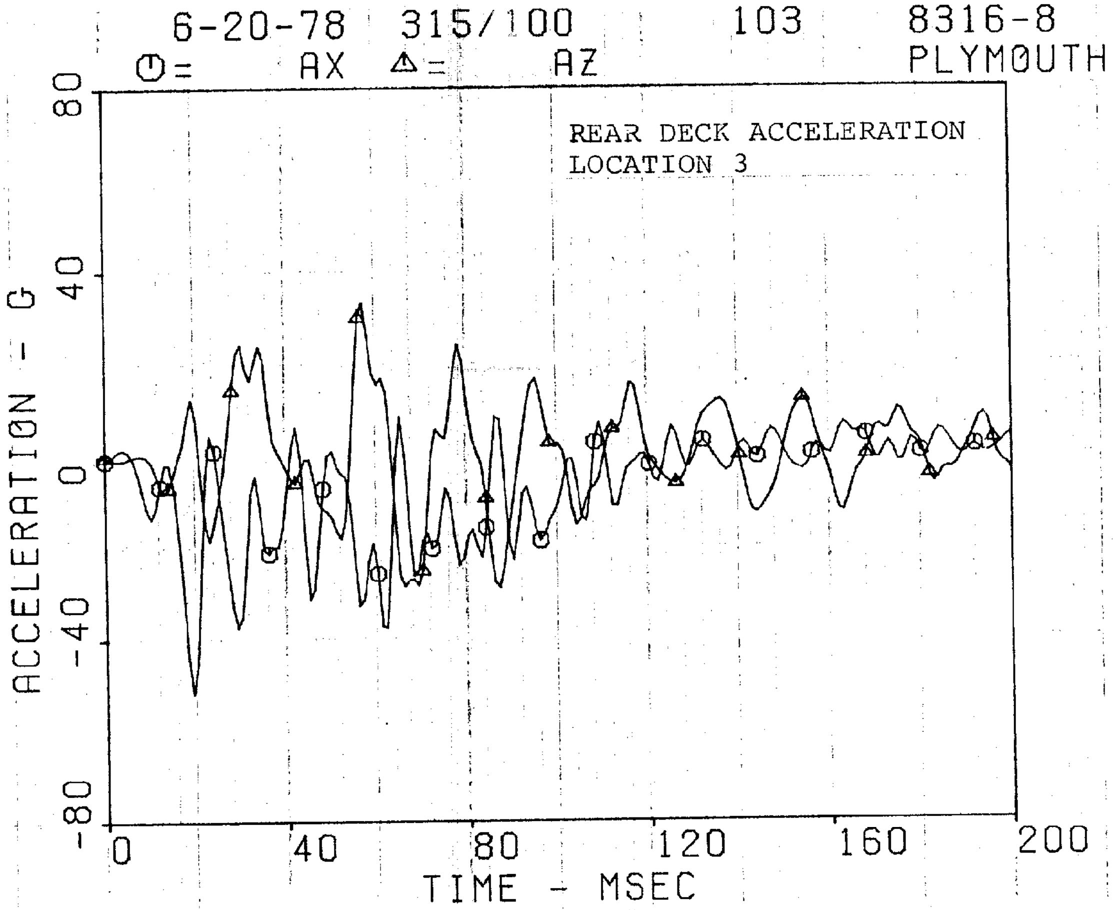

6-20-78 315/100 4203 8316-8
PLY RFLB-R
RIGHT FRONT OCCUPANT
RIGHT LAP BELT LOAD
FORCE - POUNDS *10^1
300
200
100
0
-100
0
40
80
120
160
200
TIME - MSEC

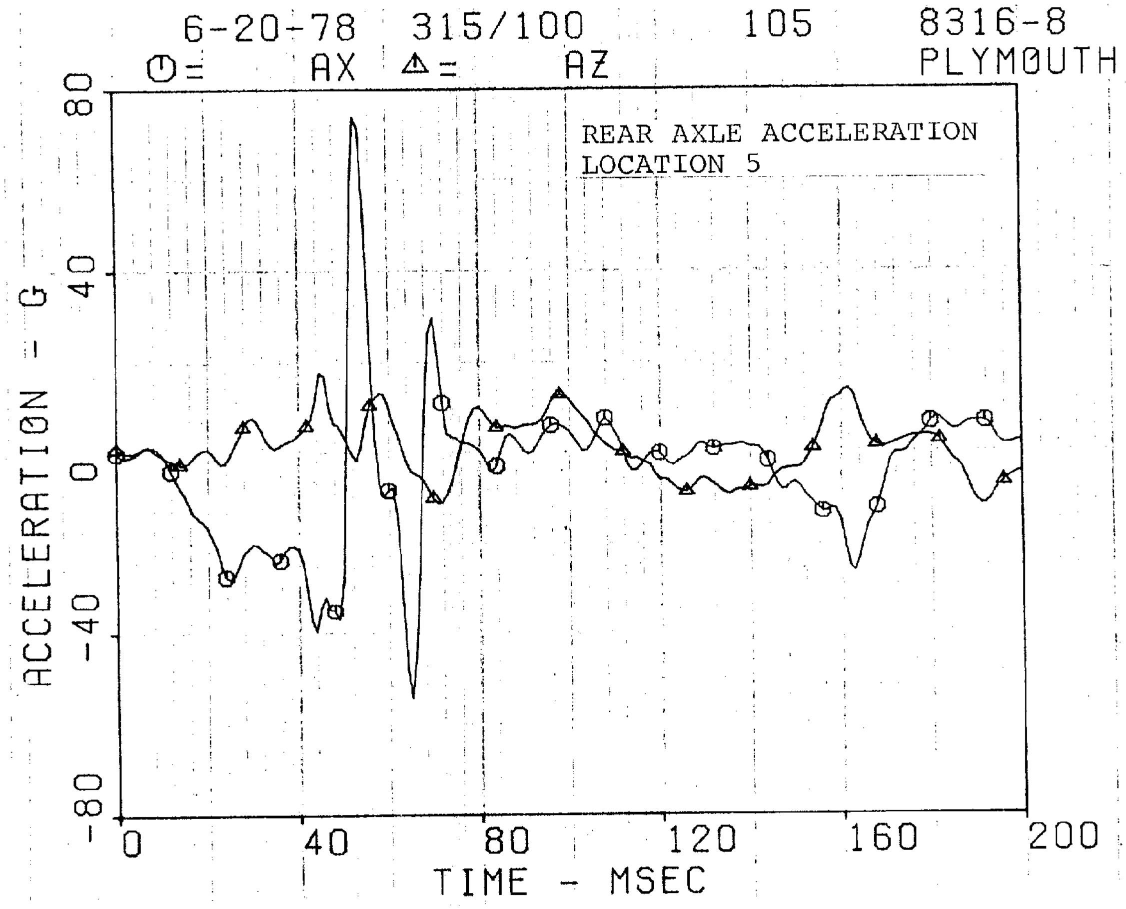

6-20-78 315/100 4203 8316-8
PLY RFT0RB
RIGHT FRONT OCCUPANT
SHOULDER BELT LOAD
FORCE - POUNDS $*10^1$
300
200
100
0
-100
0
40
80
120
160
200
TIME - MSEC

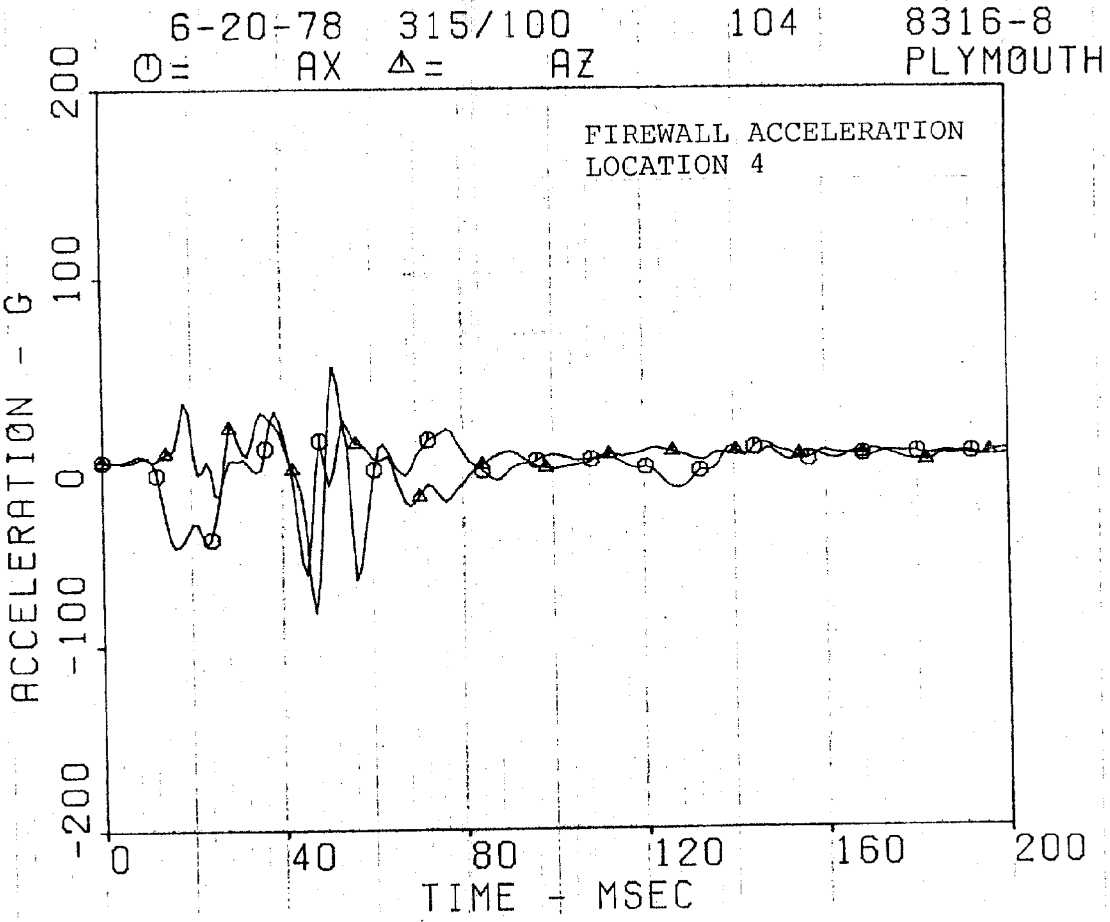

6-20-78 315/100 101 8316-8
⊙= AX △= AZ PLYMOUTH
LEFT B-PILLAR ACCELERATION LOCATION 1
ACCELERATION - G
80
40
0
-40
-80
0
40
80
120
160
200
TIME - MSEC


6-20-78 315/100 102 8316-8
⊙= AX △= AZ PLYMOUTH
RIGHT B-PILLAR ACCELERATION LOCATION 2
ACCELERATION - G
80
40
0
-40
-80
0
40
80
120
160
200
TIME - MSEC

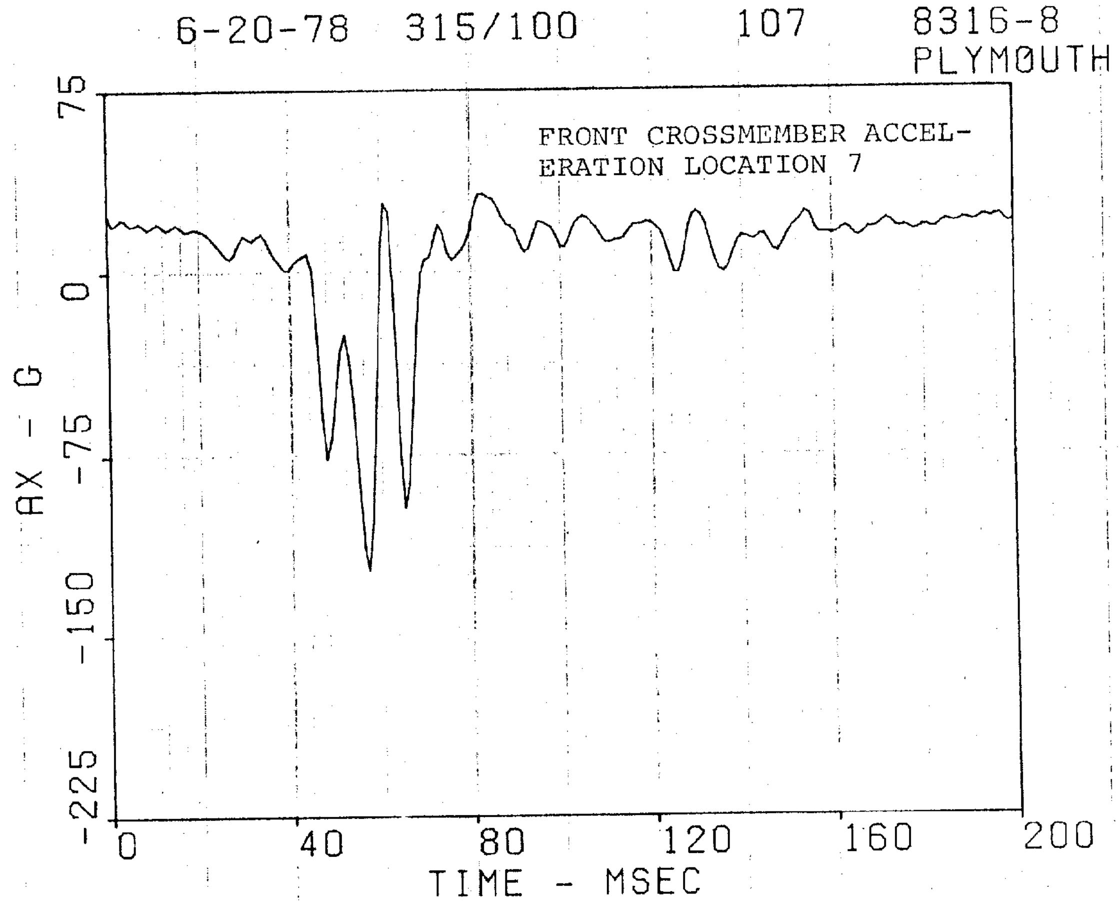

6-20-78
315/100
401
8316-8
⊙= AX
△= VX
+= SX
PLY AV1.2
AVERAGE B-PILLAR ACCELERATION VELOCITY AND DISPLACEMENT LOCATIONS 1 AND 2
AX - G, VX - MPH, SX - IN.
80
40
0
-40
-80
0
40
80
120
160
200
TIME - MSEC


6-20-78 315/100 103 8316-8
PLYMOUTH
○= AX △= AZ
REAR DECK ACCELERATION
LOCATION 3
ACCELERATION - G
80
40
0
-40
-80
0
40
80
120
160
200
TIME - MSEC

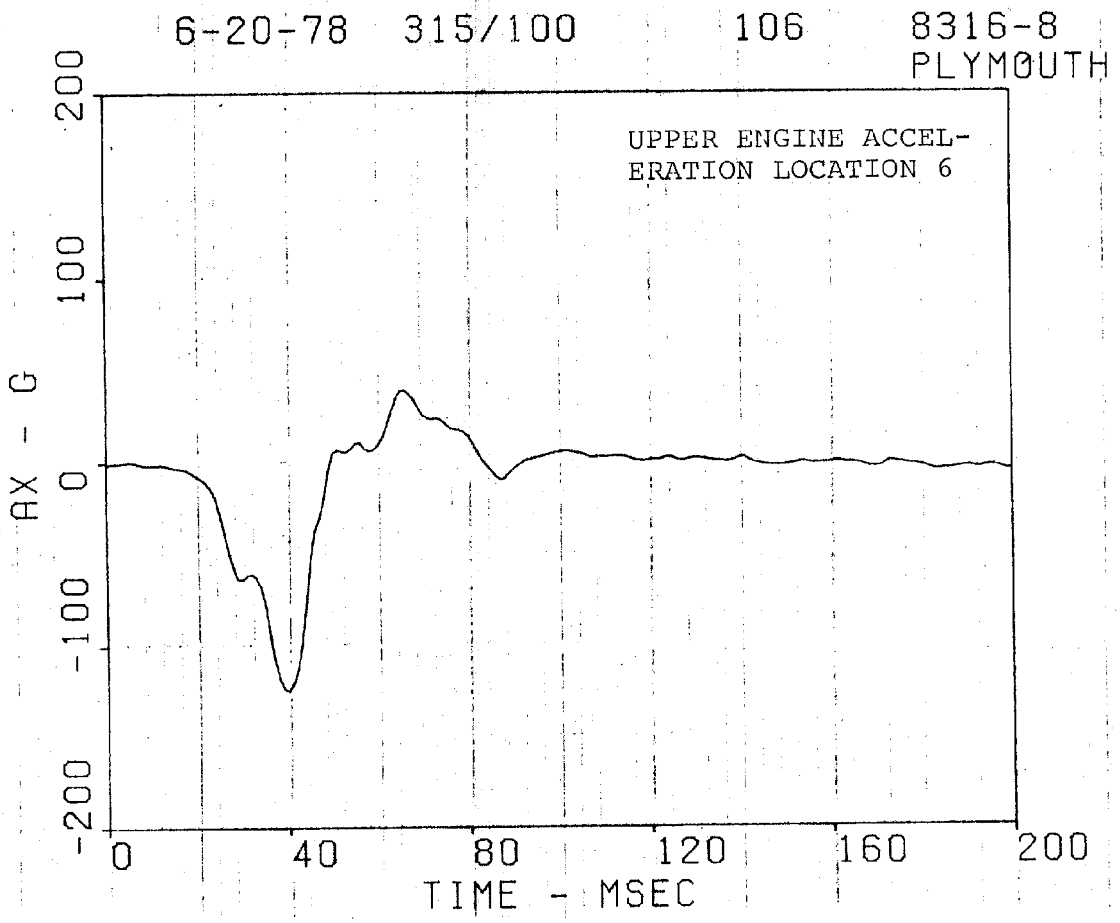

6-20-78 315/100 105 8316-8
PLYMOUTH
○= AX △= AZ
REAR AXLE ACCELERATION
LOCATION 5
ACCELERATION - G
80
40
0
-40
-80
0
40
80
120
160
200
TIME - MSEC

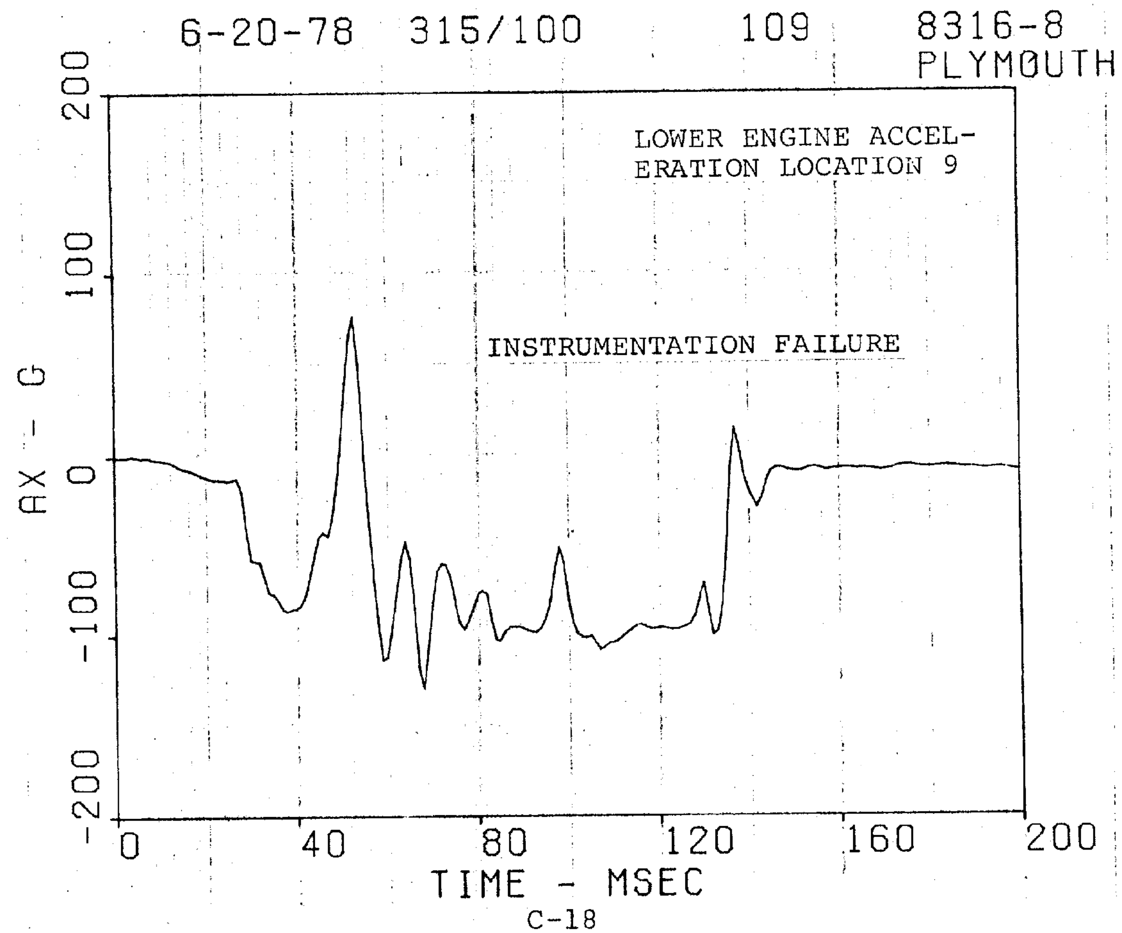


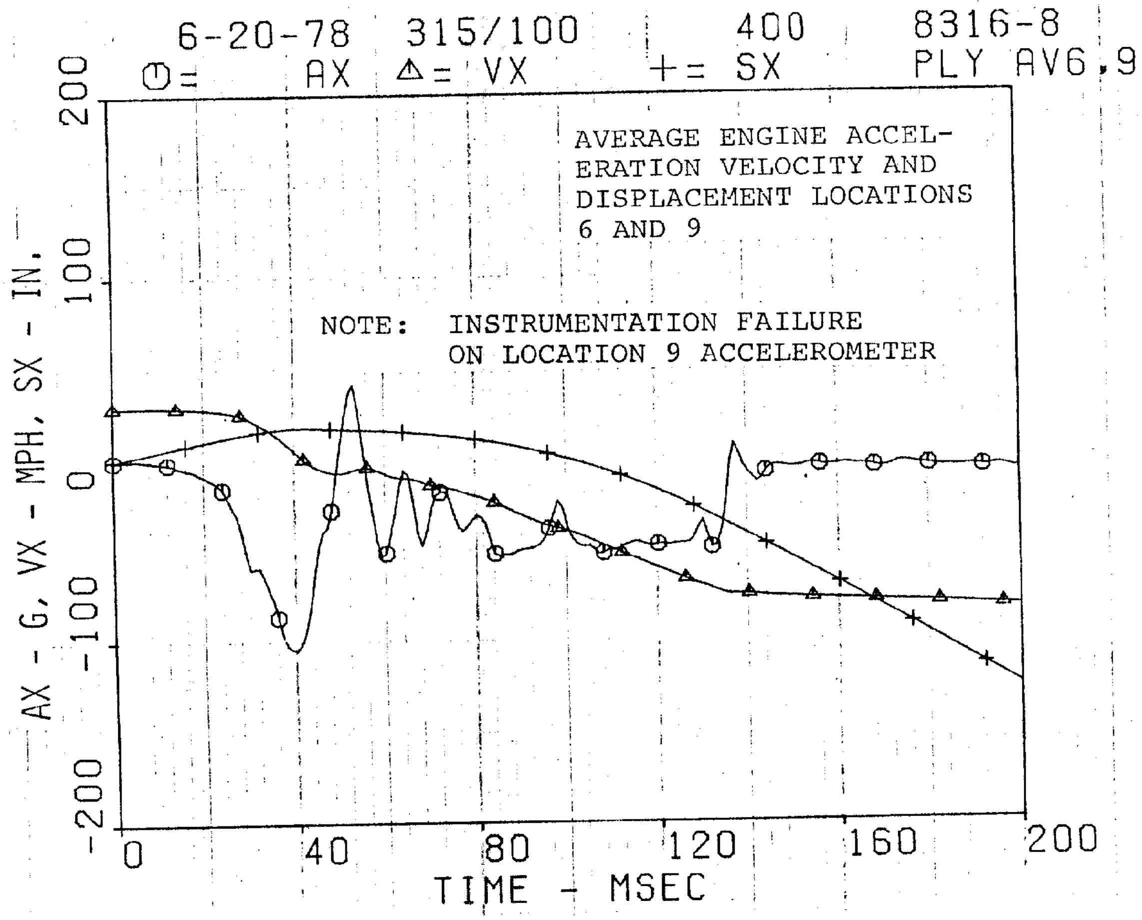
FIREWALL ACCELERATION LOCATION 4



FRONT CROSSMEMBER ACCELERATION LOCATION 7

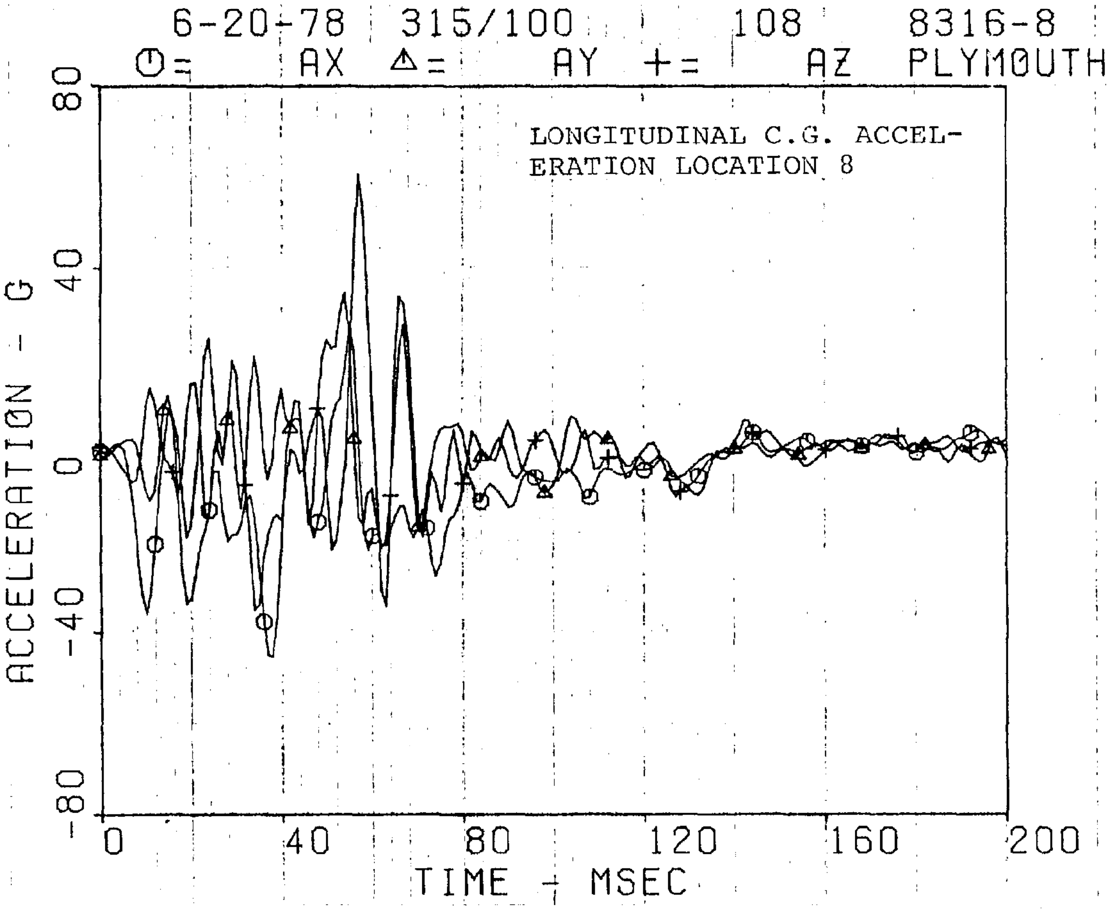

6-20-78 315/100 106 8316-8
PLYMOUTH
UPPER ENGINE ACCEL-
ERATION LOCATION 6
AX - G
200
100
0
-100
-200
0
40
80
120
160
200
TIME - MSEC

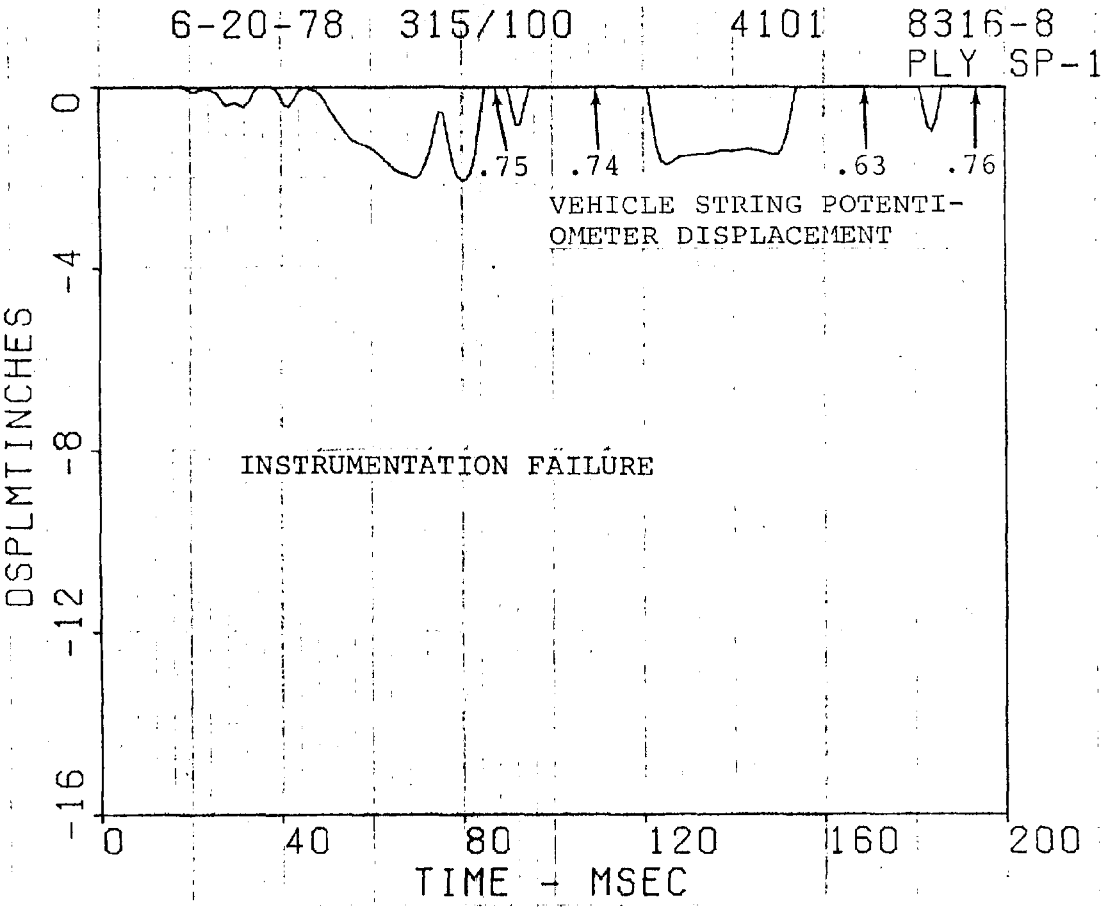

6-20-78 315/100 109 8316-8
PLYMOUTH
LOWER ENGINE ACCEL-
ERATION LOCATION 9
INSTRUMENTATION FAILURE
AX - G
200
100
0
-100
-200
0
40
80
120
160
200
TIME - MSEC

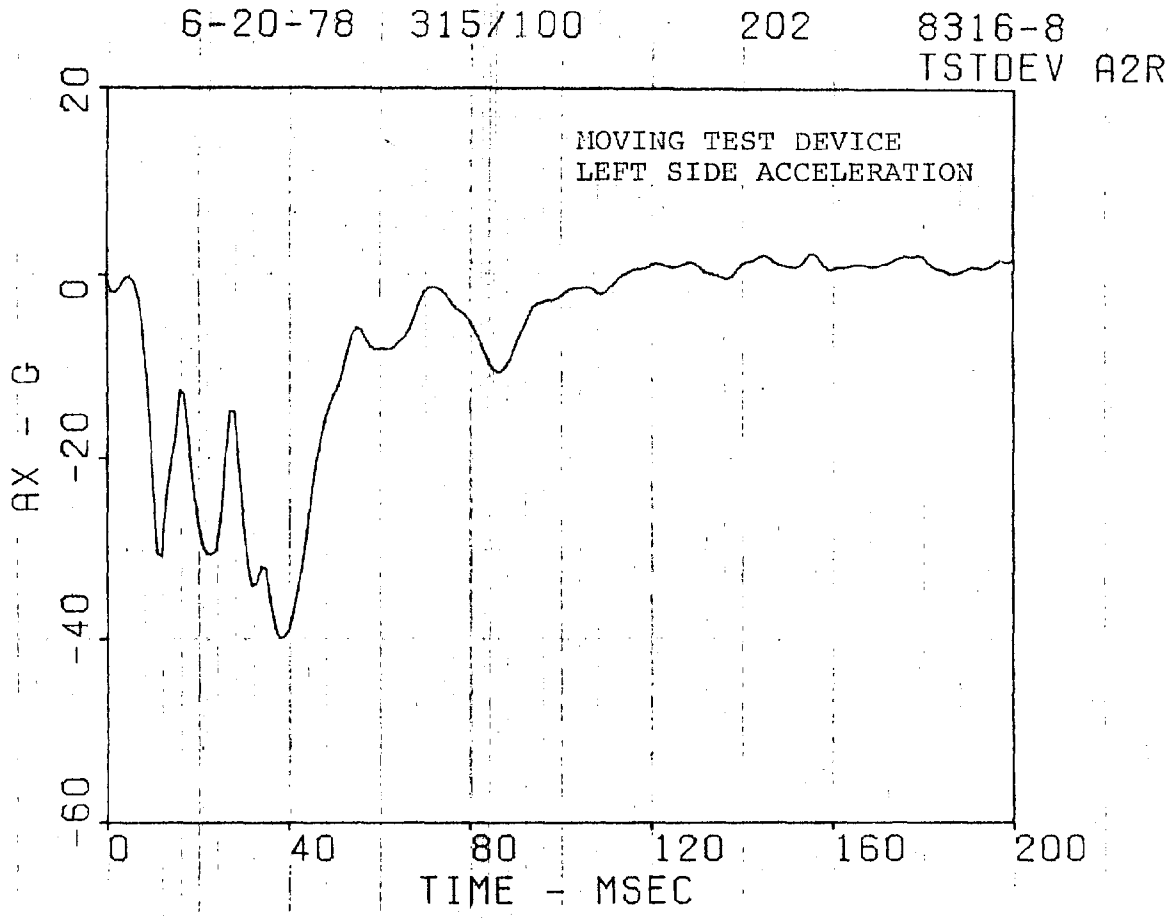


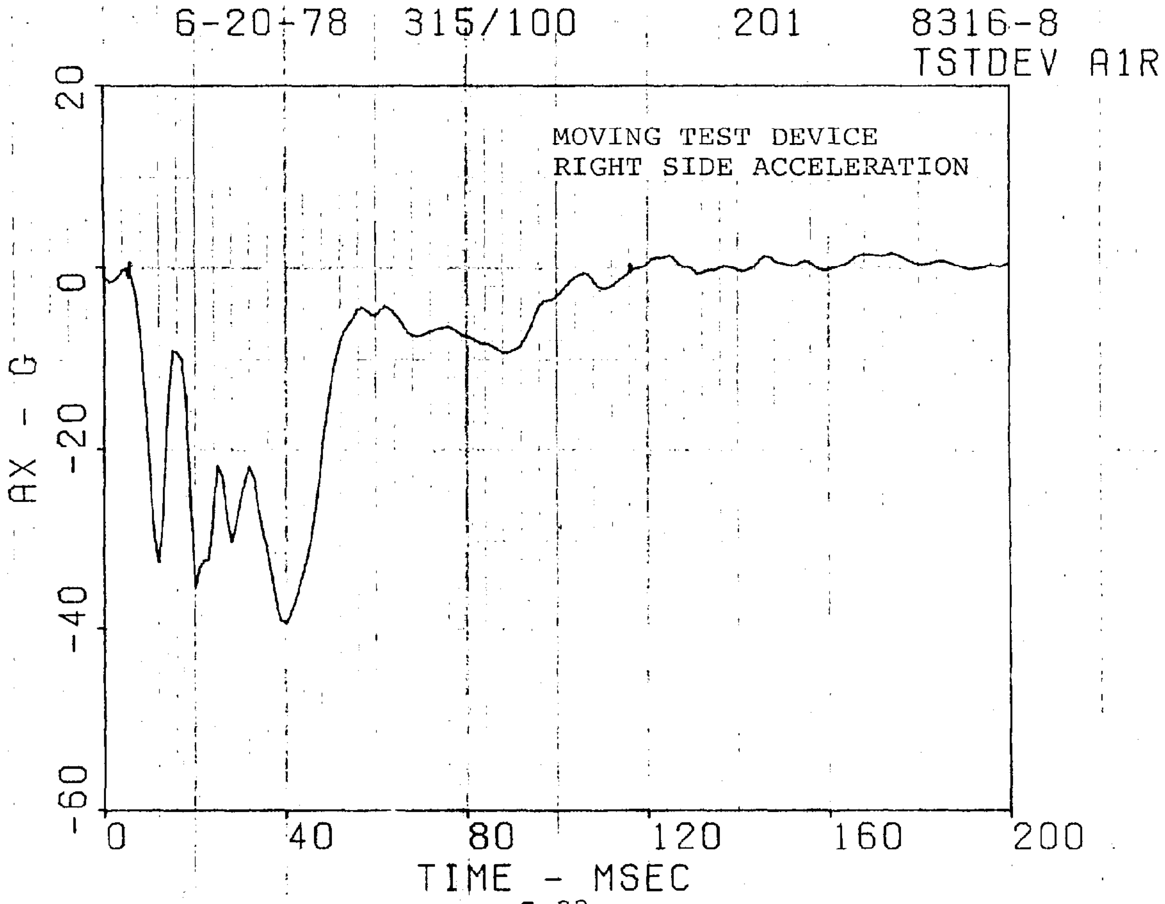
AVERAGE ENGINE ACCELERATION VELOCITY AND DISPLACEMENT LOCATIONS 6 AND 9

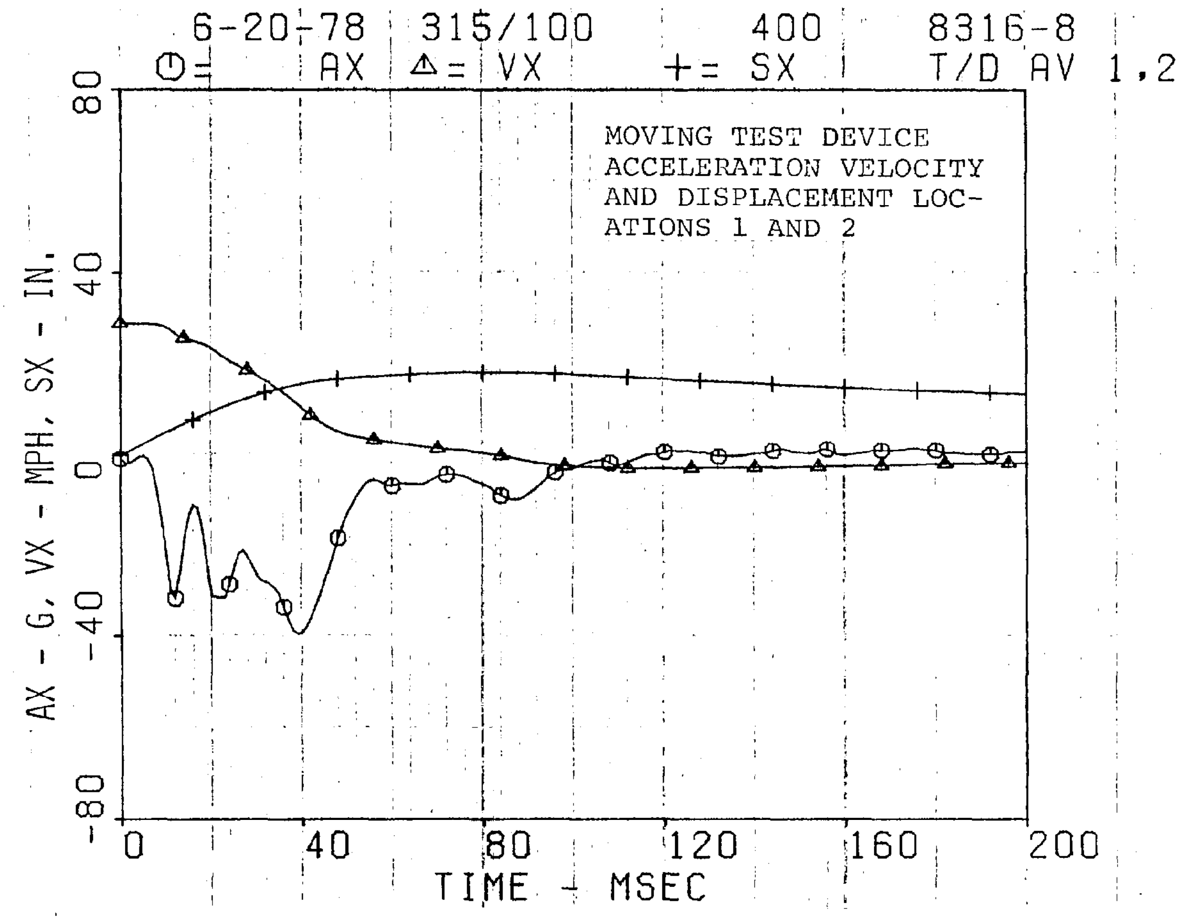
NOTE: INSTRUMENTATION FAILURE ON LOCATION 9 ACCELEROMETER

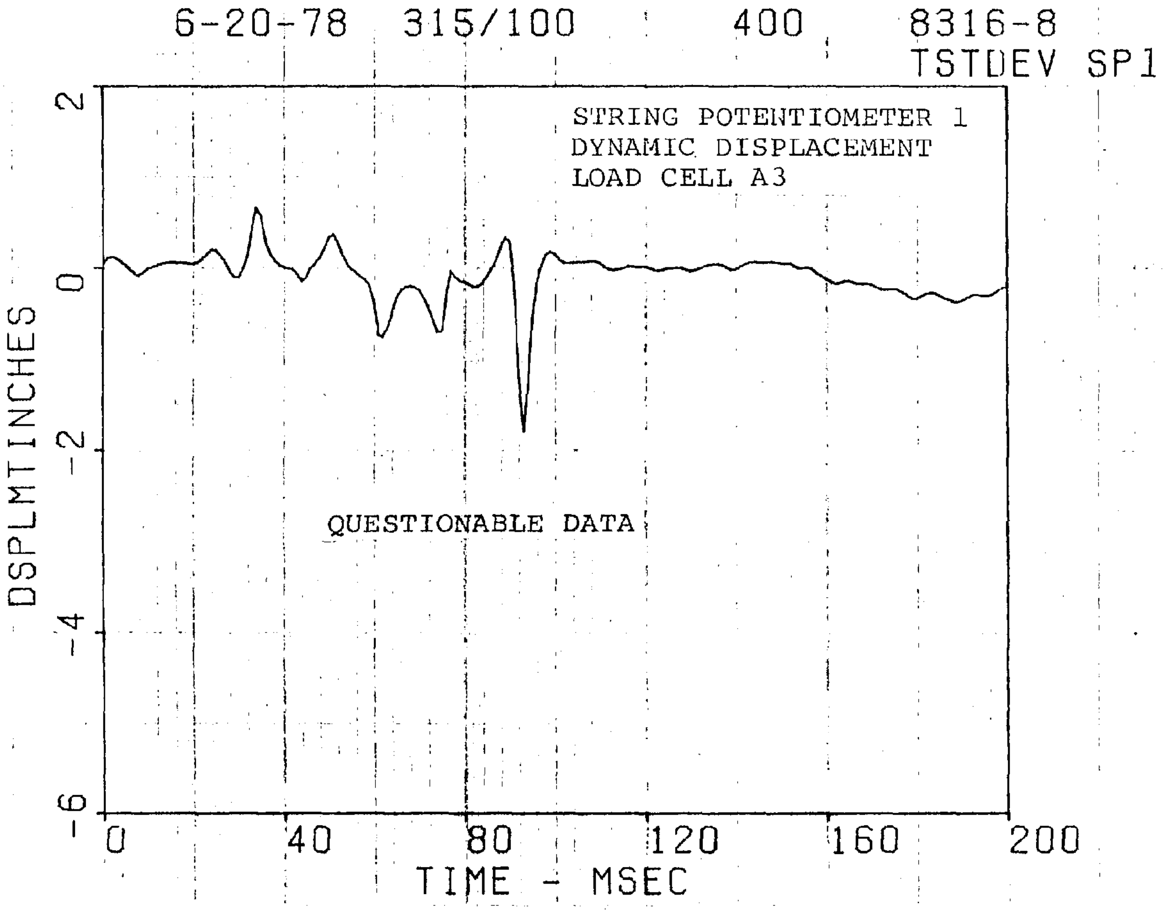

6-20-78 315/100 108 8316-8
○= AX △= AY += AZ PLYMOUTH
LONGITUDINAL C.G. ACCELERATION LOCATION 8
ACCELERATION - G
80
40
0
-40
-80
0
40
80
120
160
200
TIME - MSEC


6-20-78 315/100 4101 8316-8
PLY SP-1
DSPLMT INCHES
0
-4
-8
-12
-16
0
40
80
120
160
200
TIME - MSEC
.75
.74
.63
.76
VEHICLE STRING POTENTIOMETER DISPLACEMENT
INSTRUMENTATION FAILURE

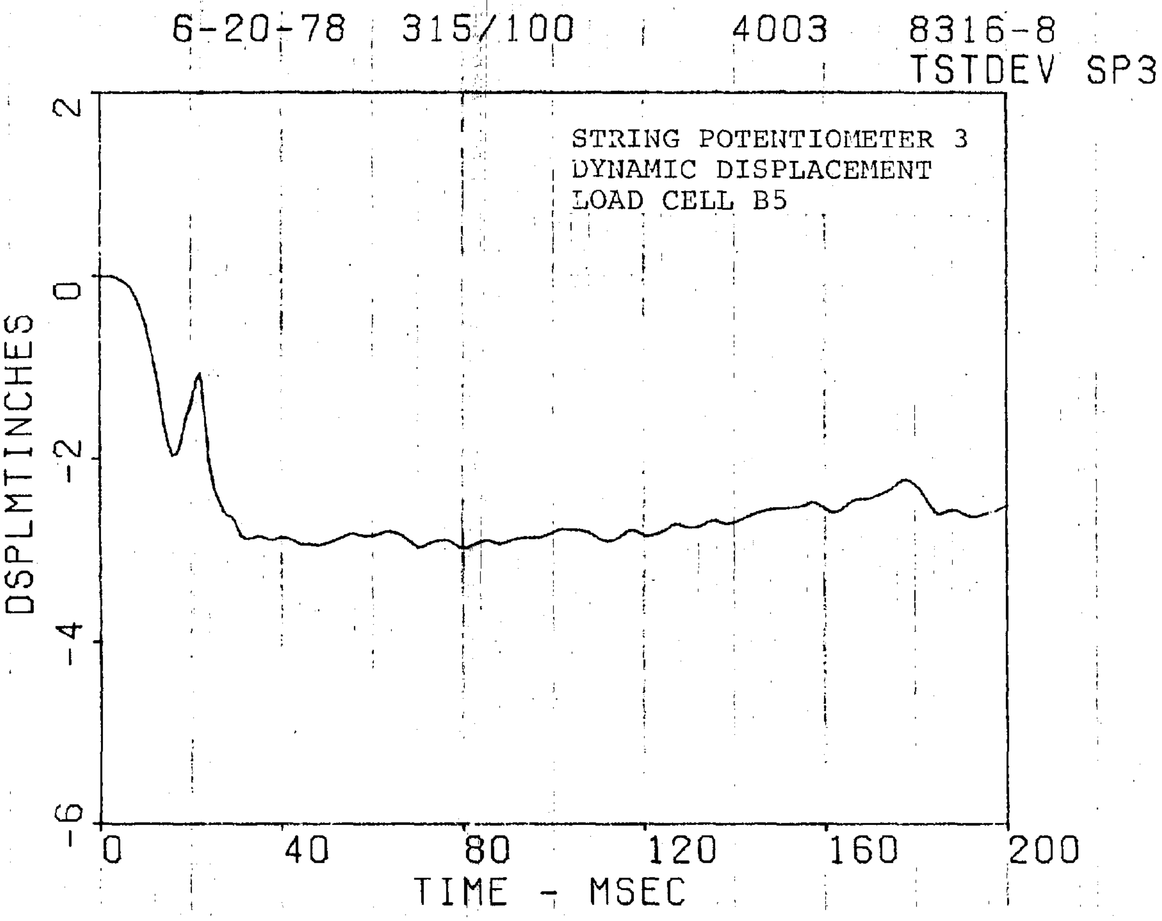

6-20-78 315/100 202 8316-8
TSTDEV A2R
MOVING TEST DEVICE
LEFT SIDE ACCELERATION
AX - G
20
0
-20
-40
-60
0
40
80
120
160
200
TIME - MSEC

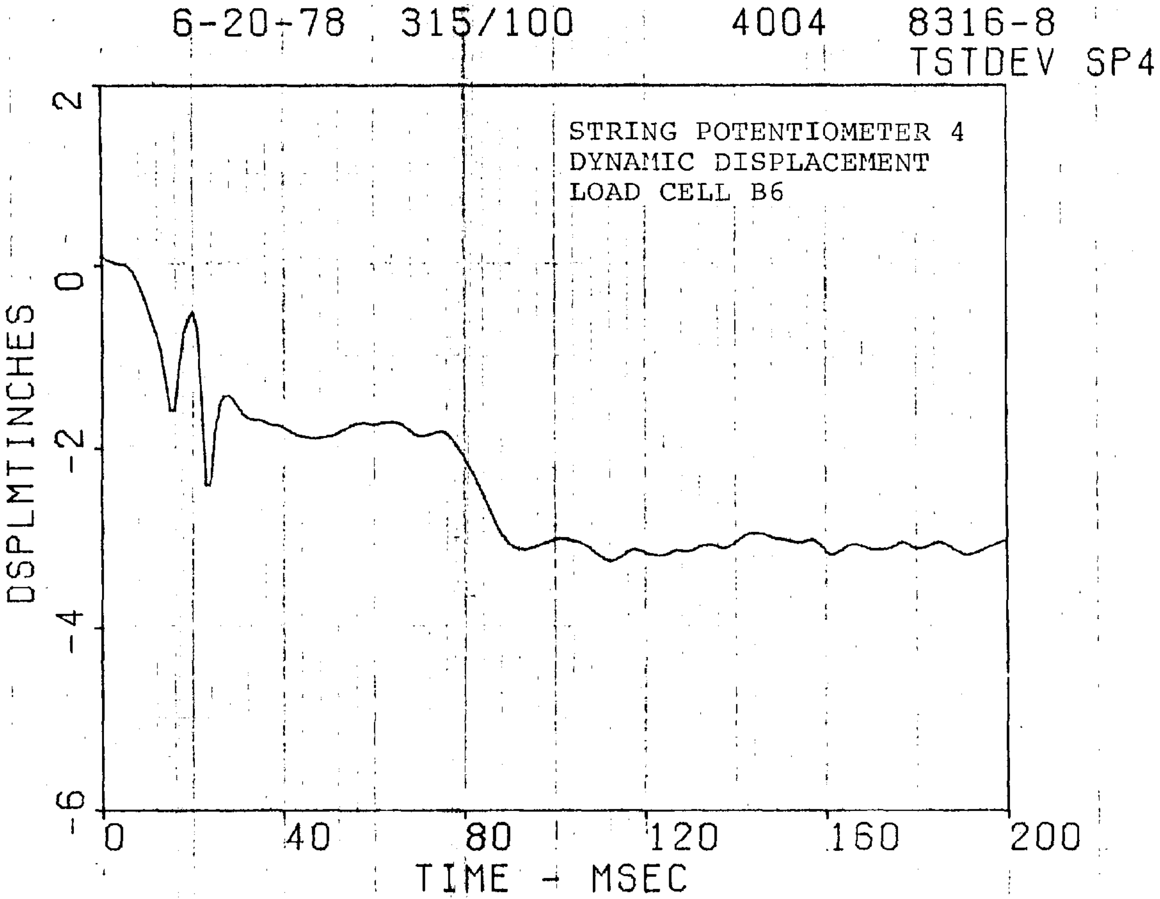

6-20-78 315/100 201 8316-8
TSTDEV A1R
MOVING TEST DEVICE
RIGHT SIDE ACCELERATION
AX - G
20
0
-20
-40
-60
0
40
80
120
160
200
TIME - MSEC

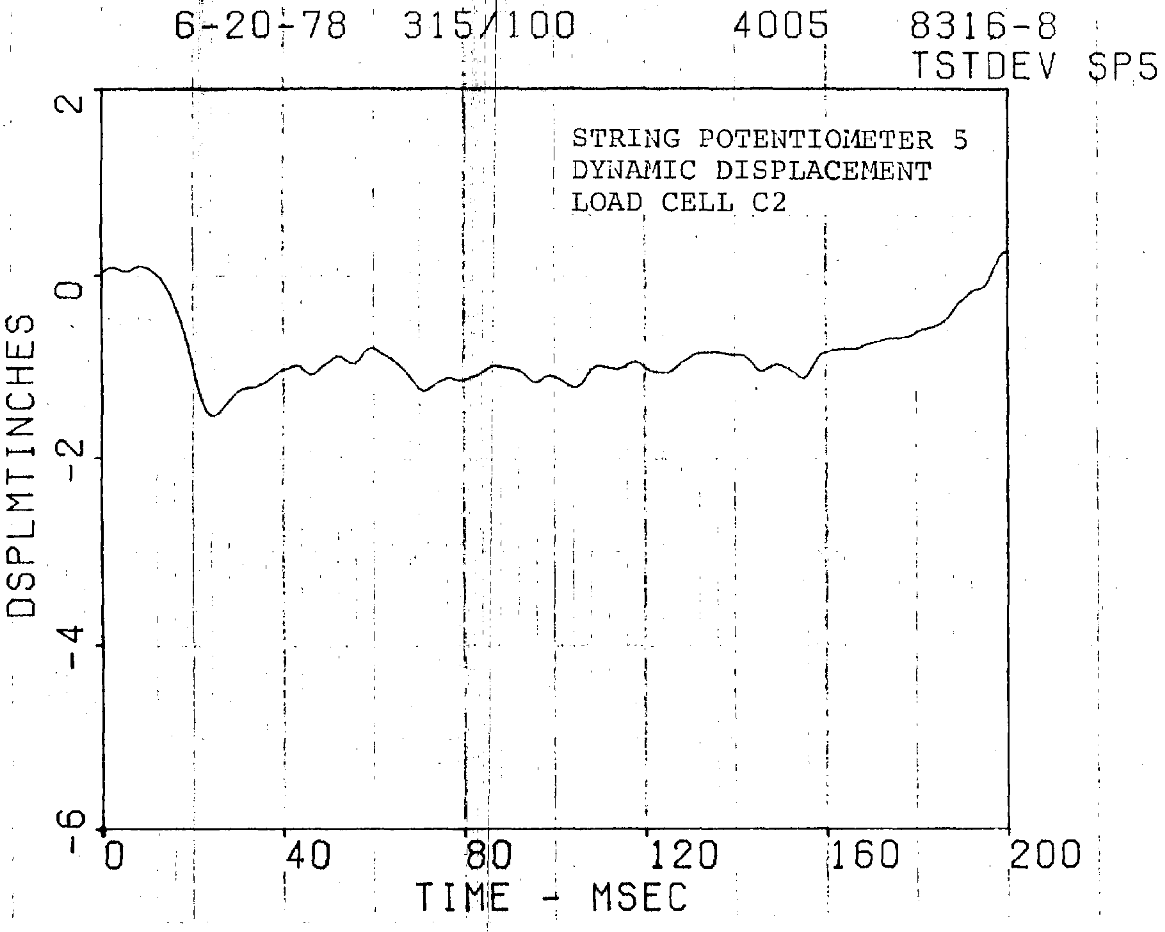

6-20-78
315/100
400
8316-8
⏀= AX
△= VX
+= SX
T/D AV 1,2
MOVING TEST DEVICE ACCELERATION VELOCITY AND DISPLACEMENT LOCATIONS 1 AND 2
AX - G, VX - MPH, SX - IN.
80
40
0
-40
-80
0
40
80
120
160
200
TIME - MSEC

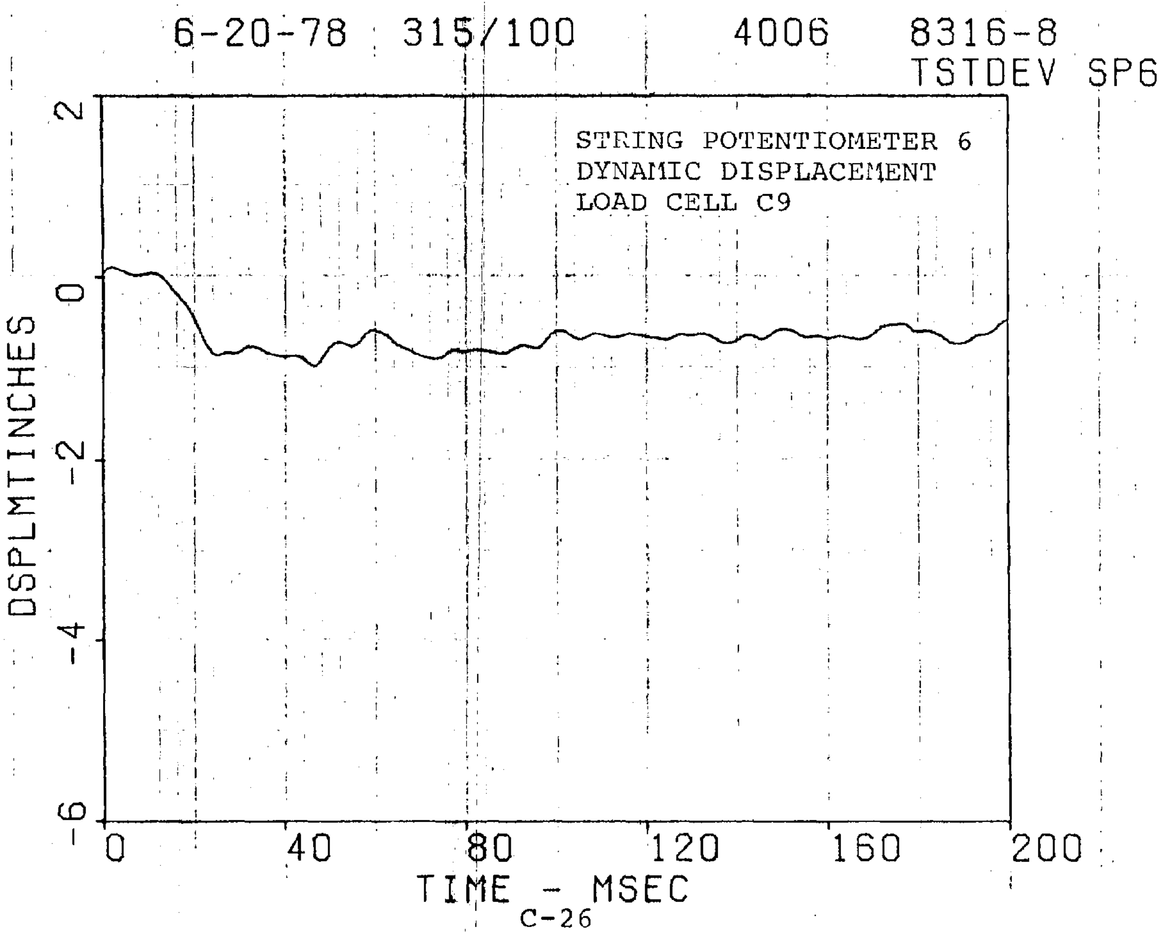


NOTE: STRING POTENTIOMETER 2 DYNAMIC DISPLACEMENT ON LOAD CELL A8 HAD NO MEASUREABLE DATA

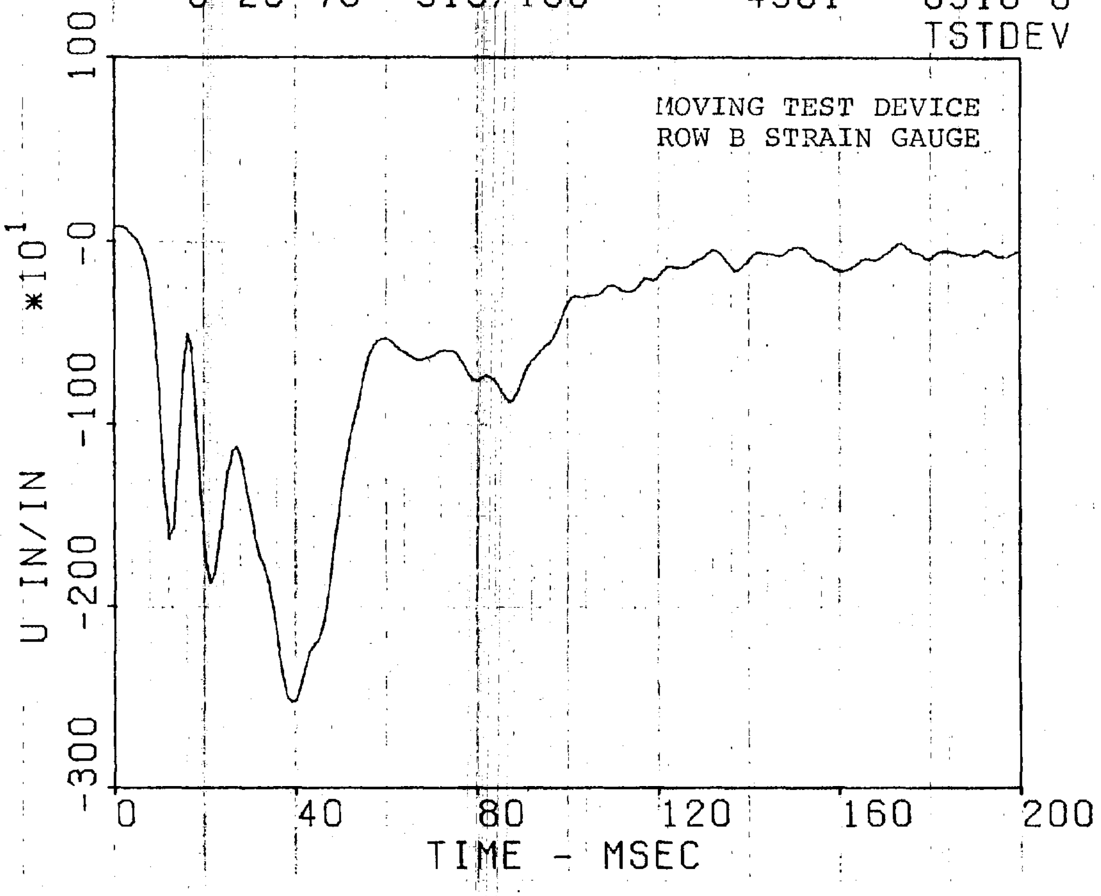

6-20-78 315/100 4003 8316-8
TSTDEV SP3
STRING POTENTIOMETER 3
DYNAMIC DISPLACEMENT
LOAD CELL B5
DSPLMTINCHES
2
0
-2
-4
-6
0
40
80
120
160
200
TIME - MSEC


6-20-78 315/100 4004 8316-8
TSTDEV SP4
STRING POTENTIOMETER 4
DYNAMIC DISPLACEMENT
LOAD CELL B6
DSPLMTINCHES
2
0
-2
-4
-6
0
40
80
120
160
200
TIME - MSEC

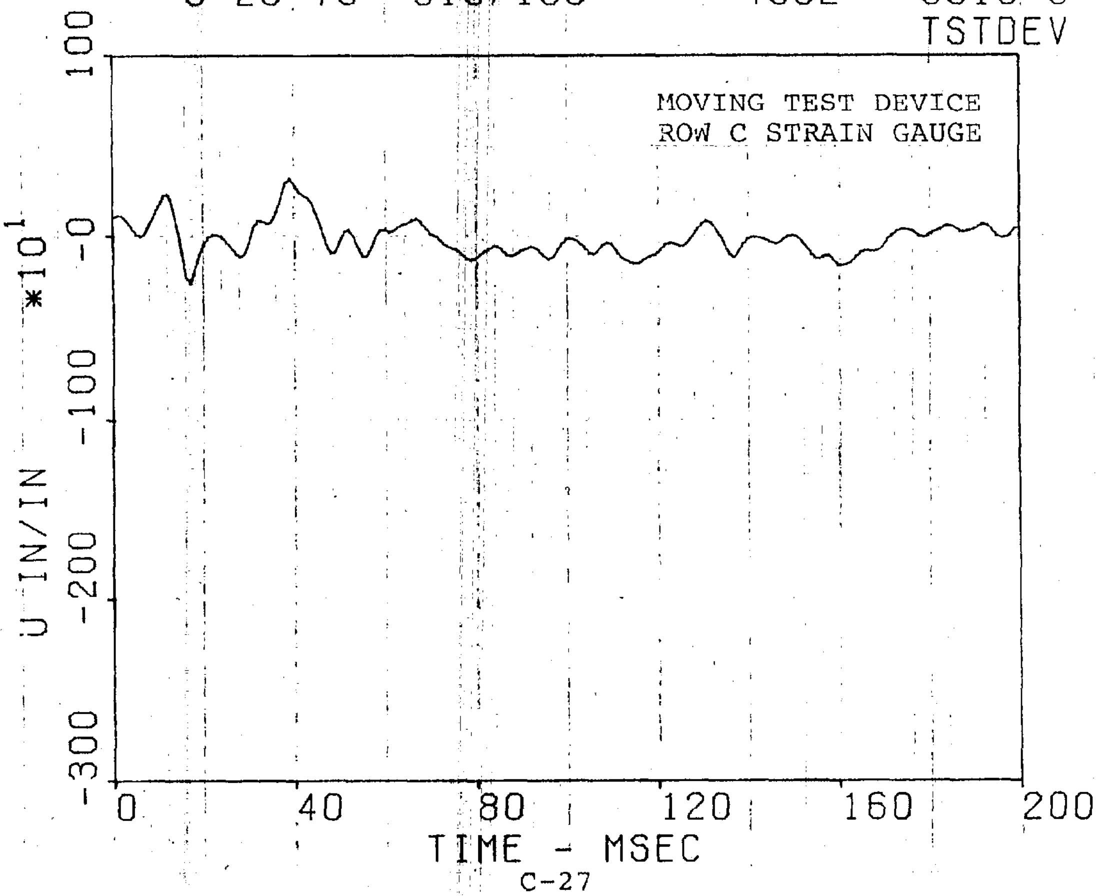

6-20-78 315/100 4005 8316-8
TSTDEV SP5
STRING POTENTIOMETER 5
DYNAMIC DISPLACEMENT
LOAD CELL C2
DSPLMTINCHES
2
0
-2
-4
-6
0
40
80
120
160
200
TIME - MSEC

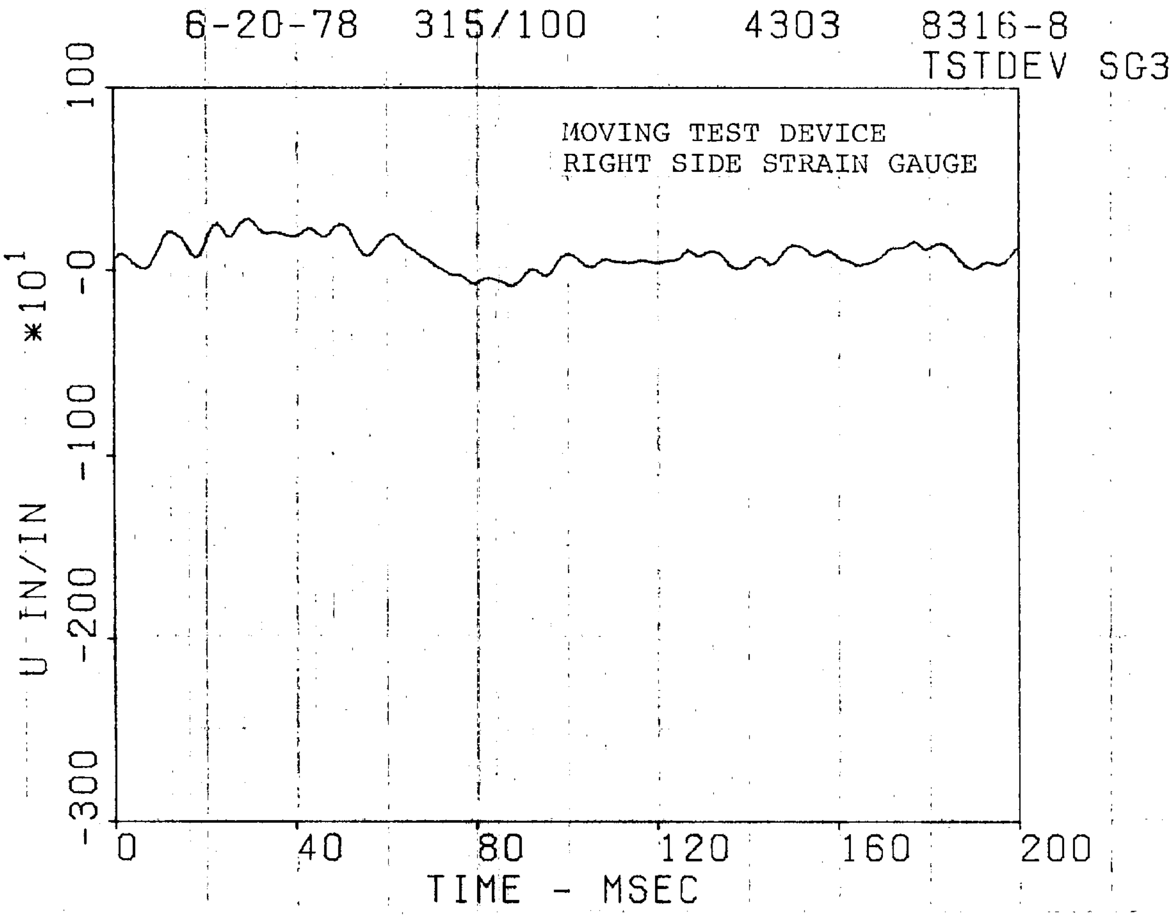

6-20-78 315/100 4006 8316-8
TSTDEV SP6
STRING POTENTIOMETER 6
DYNAMIC DISPLACEMENT
LOAD CELL C9
DSPLMTINCHES
2
0
-2
-4
-6
0
40
80
120
160
200
TIME - MSEC

6-20-78 315/100 4301 8316-8
TSTDEV SG1

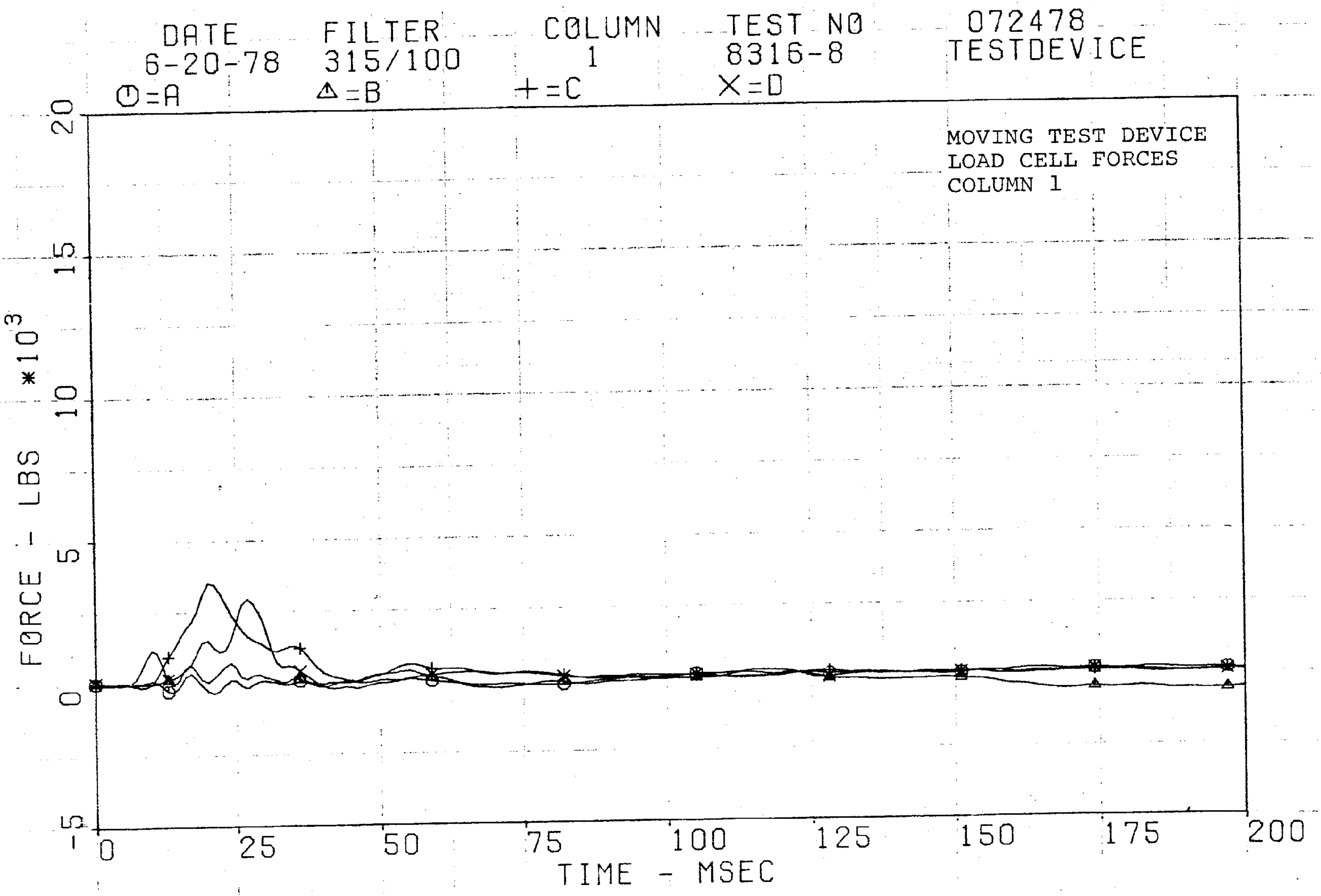


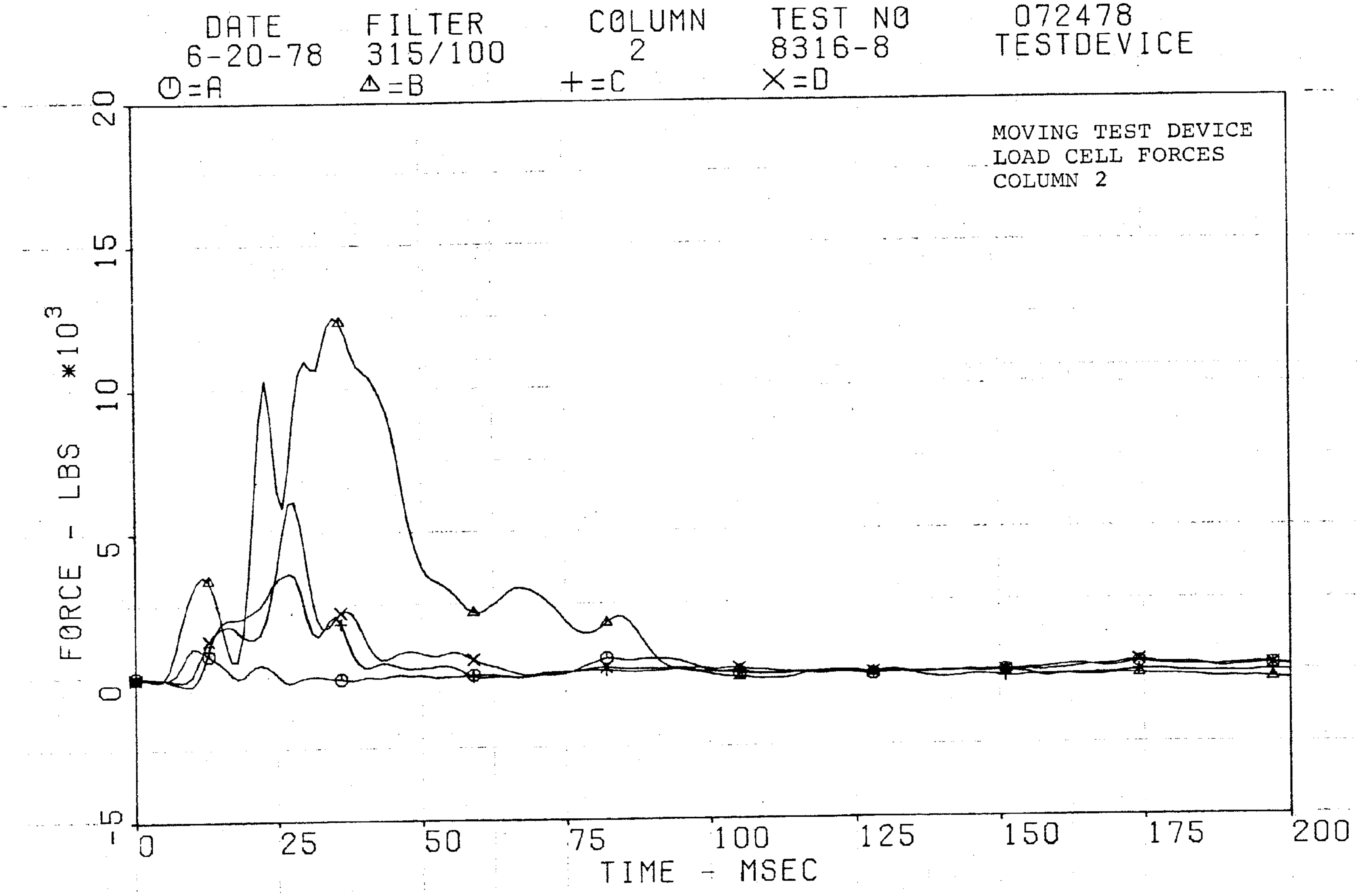
6-20-78 315/100 4302 8316-8
TSTDEV SG2

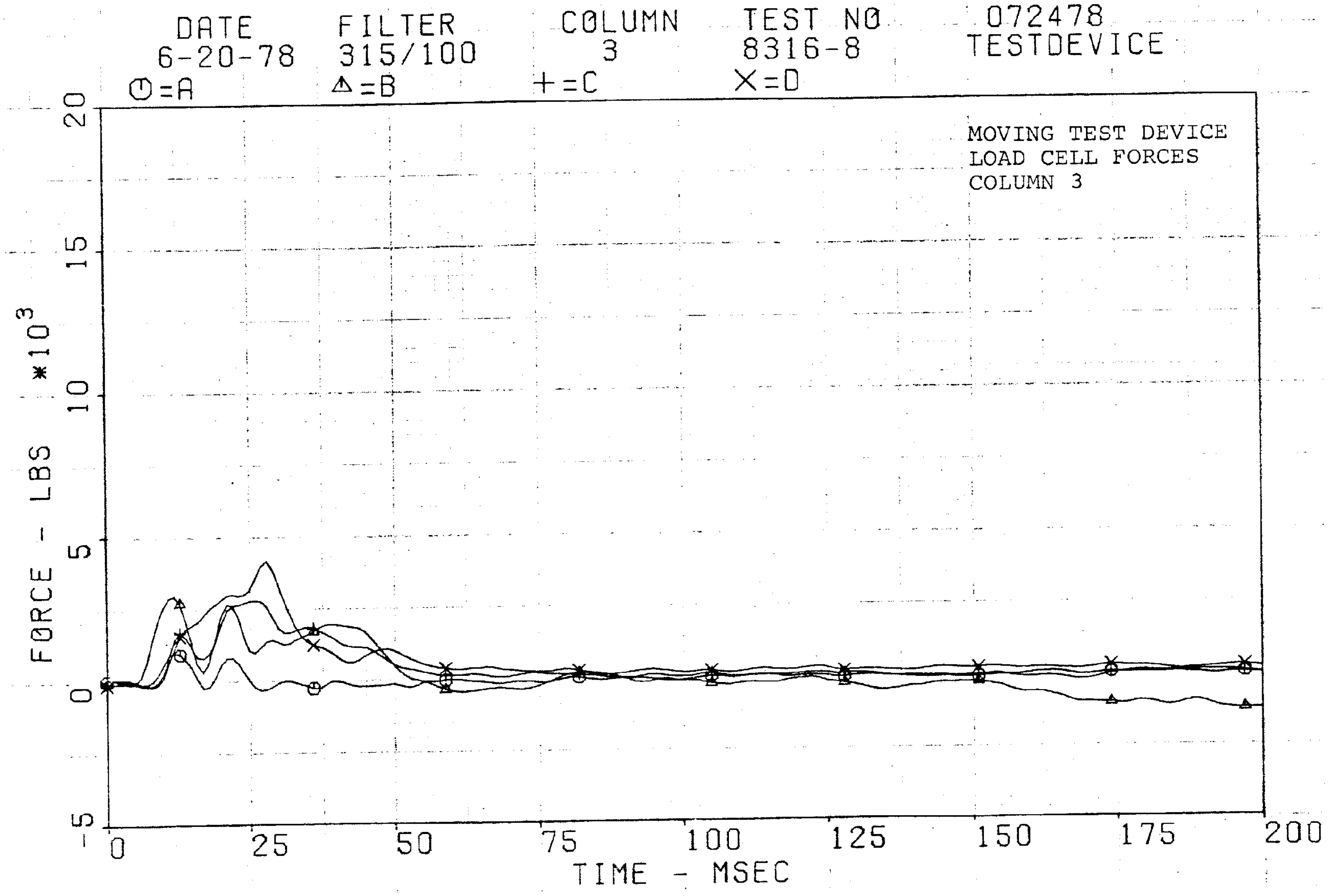


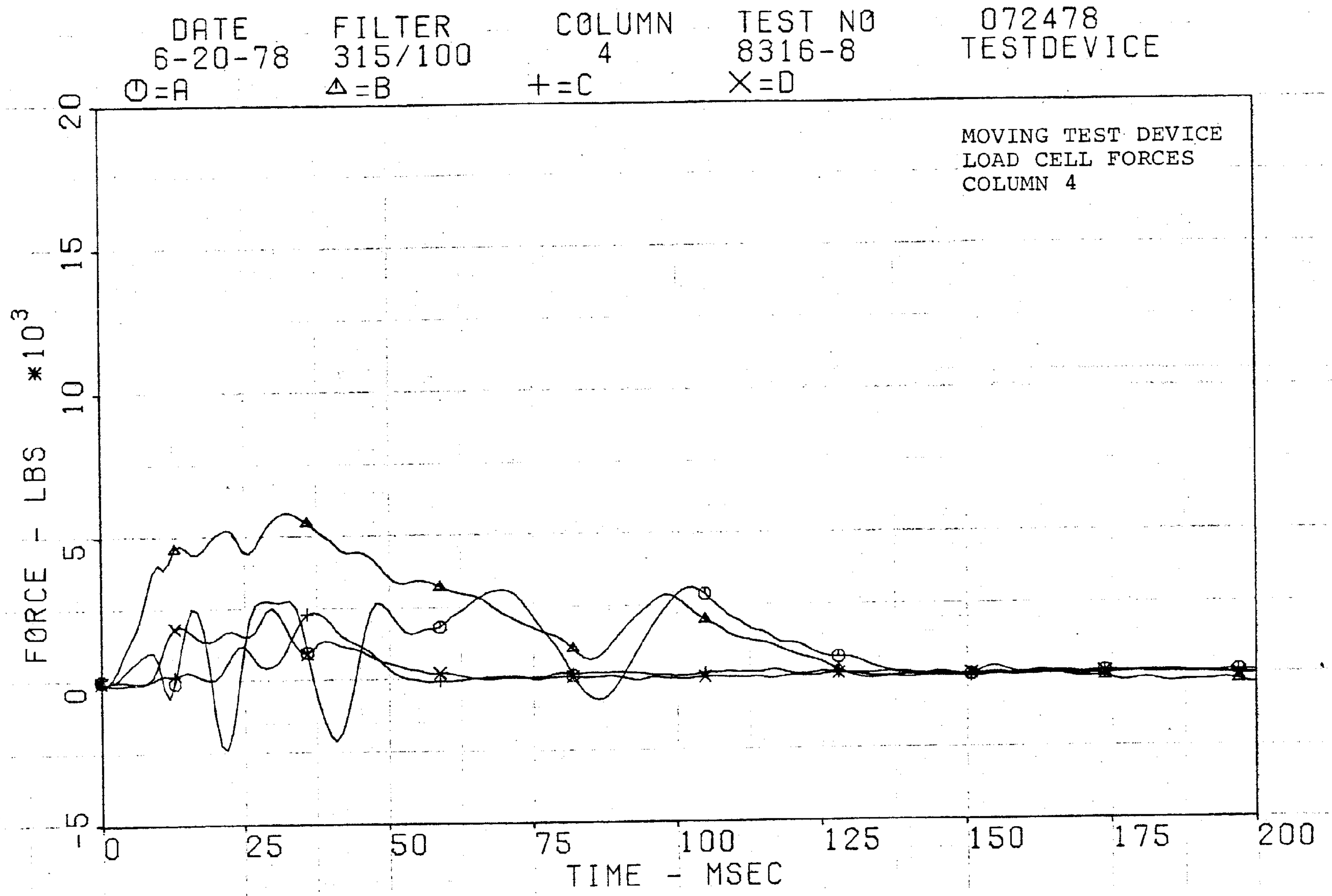


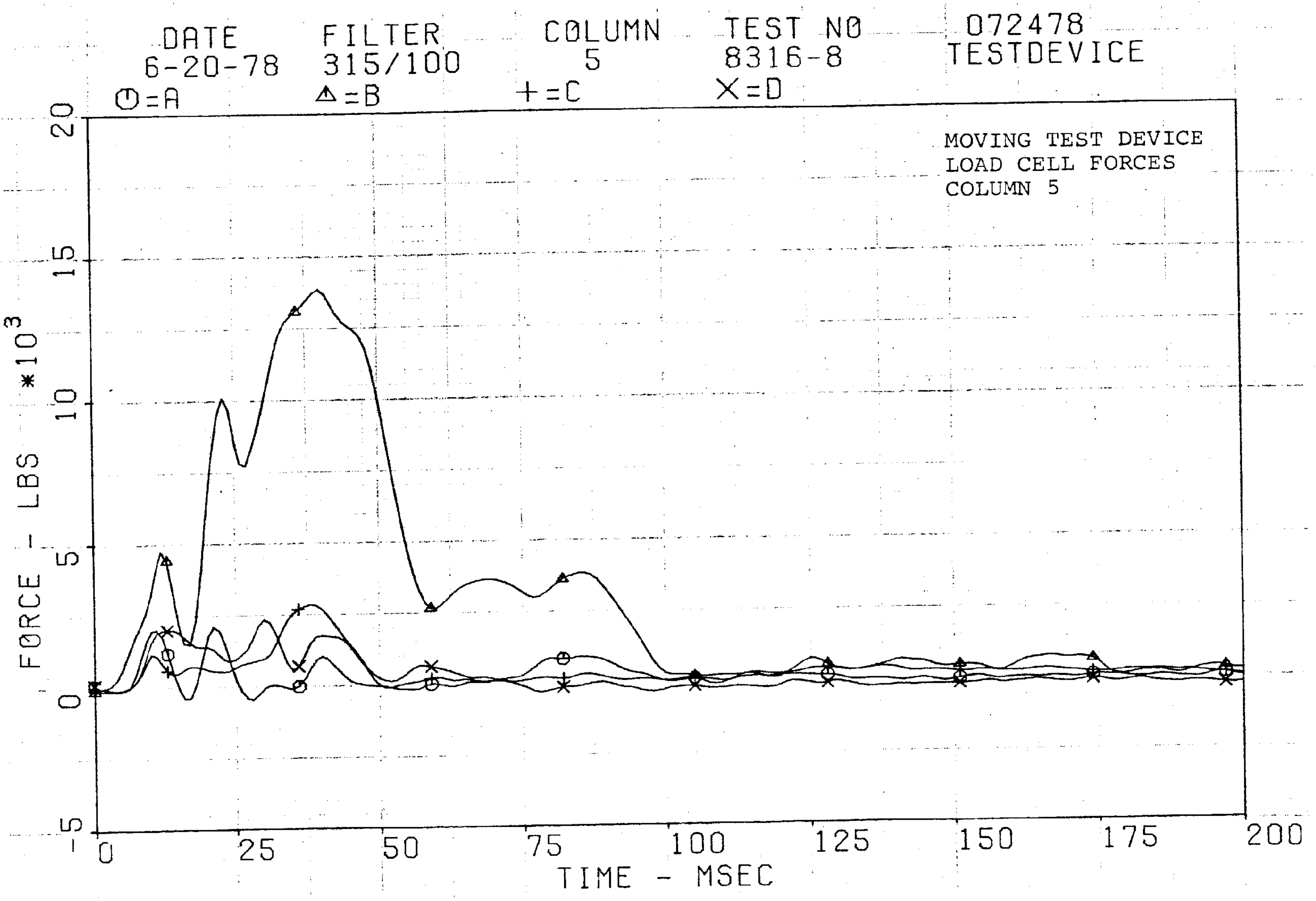
6-20-78 315/100 4303 8316-8
TSTDEV SG3
MOVING TEST DEVICE
RIGHT SIDE STRAIN GAUGE
U IN/IN *10^1
100
-0
-100
-200
-300
0
40
80
120
160
200
TIME - MSEC

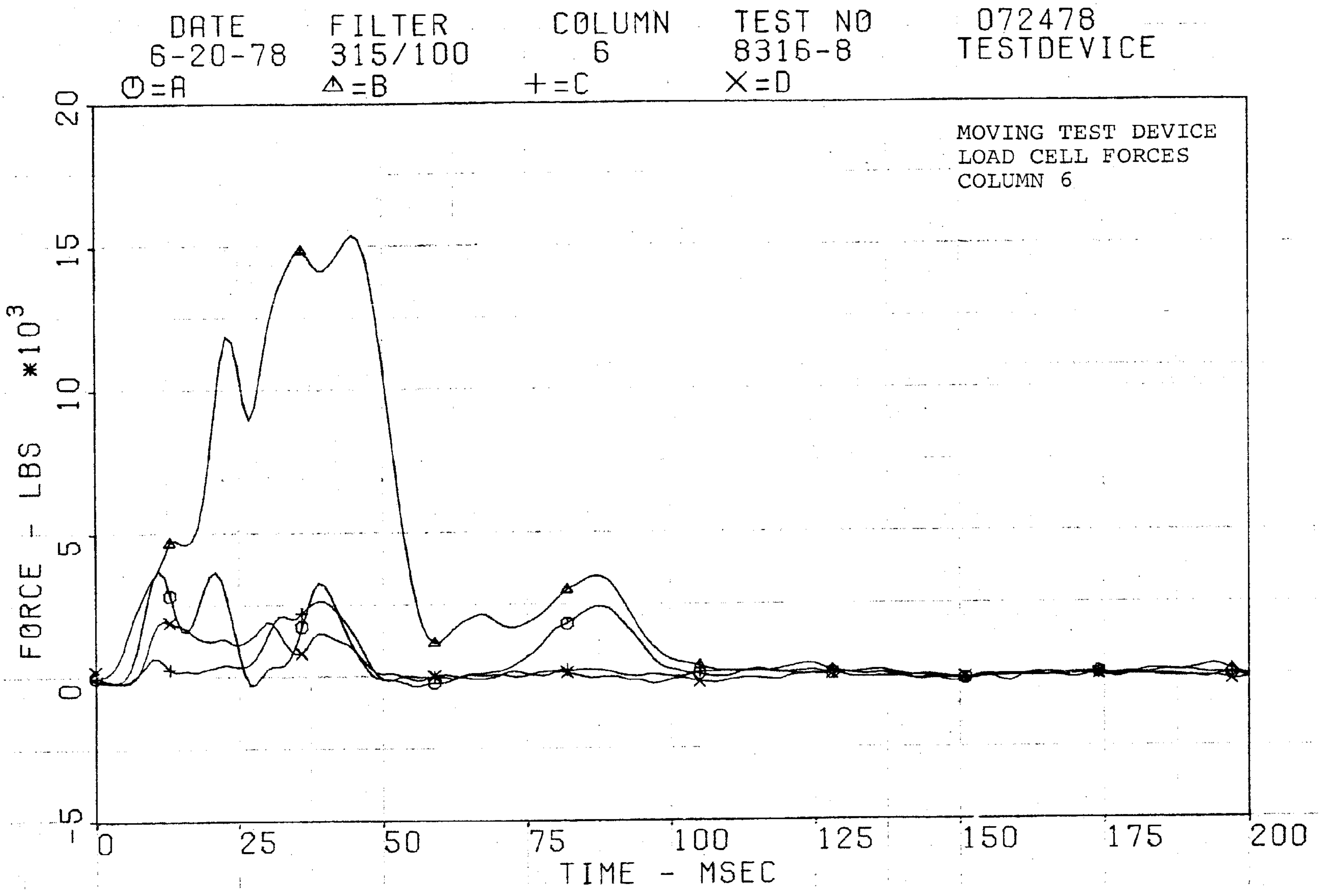

DATE
6-20-78
FILTER
315/100
COLUMN
1
TEST NO
8316-8
072478
TESTDEVICE
○=A
△=B
+=C
X=D
MOVING TEST DEVICE
LOAD CELL FORCES
COLUMN 1
FORCE - LBS *10^3
20
15
10
5
0
-5
0
25
50
75
100
125
150
175
200
TIME - MSEC

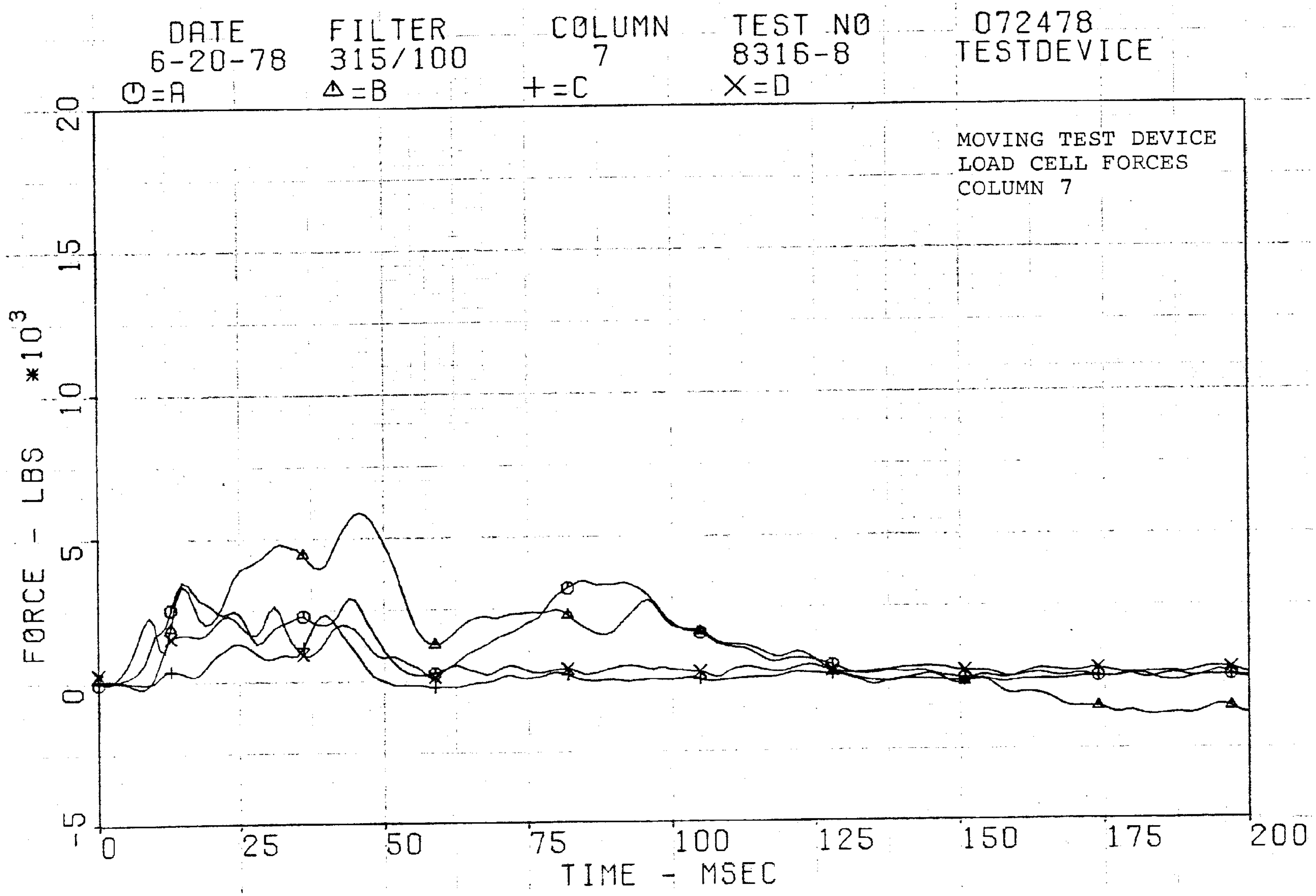

DATE
6-20-78
FILTER
315/100
COLUMN
2
TEST NO
8316-8
072478
TESTDEVICE
○=A
△=B
+=C
X=D
MOVING TEST DEVICE
LOAD CELL FORCES
COLUMN 2
FORCE - LBS $*10^3$
20
15
10
5
0
-5
0
25
50
75
100
125
150
175
200
TIME - MSEC

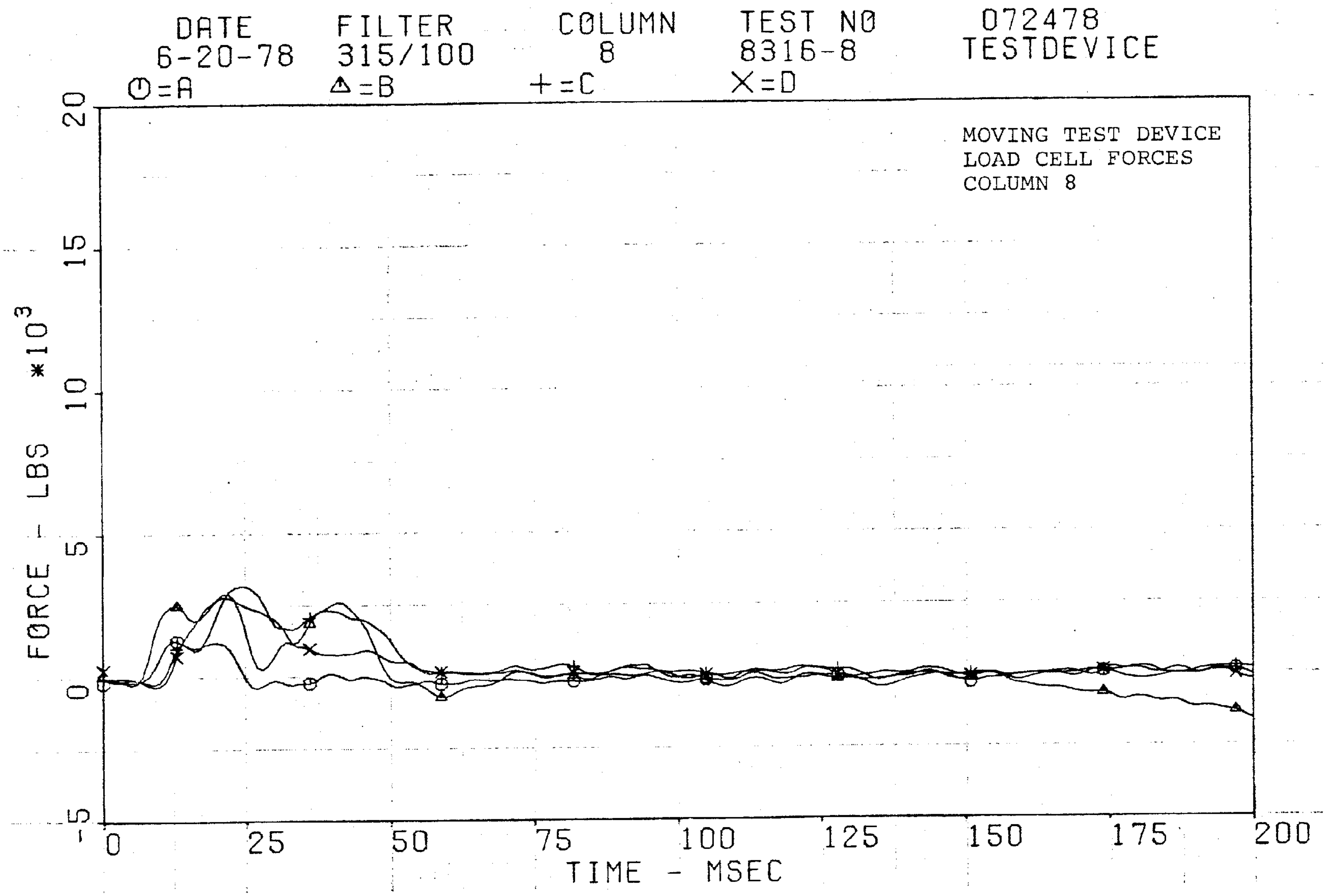

DATE
6-20-78
FILTER
315/100
COLUMN
3
TEST NO
8316-8
072478
TESTDEVICE
⊖=A
△=B
+=C
X=D
MOVING TEST DEVICE
LOAD CELL FORCES
COLUMN 3
FORCE - LBS *10^3
20
15
10
5
0
-5
0
25
50
75
100
125
150
175
200
TIME - MSEC

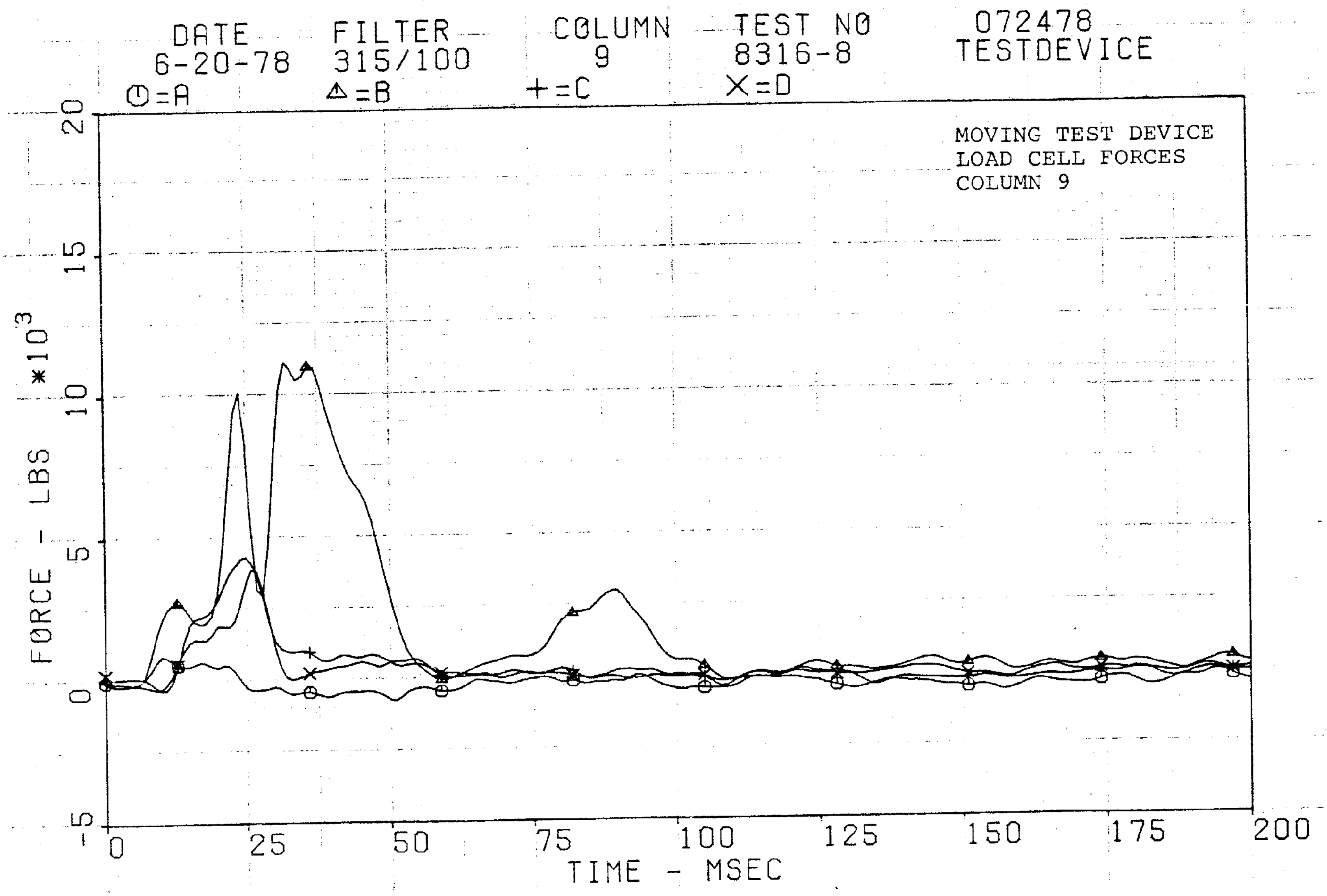

DATE
6-20-78
FILTER
315/100
COLUMN
4
TEST NØ
8316-8
072478
TESTDEVICE
⊕=A
Δ=B
+=C
X=D
MOVING TEST DEVICE
LOAD CELL FORCES
COLUMN 4
FØRCE - LBS *10^3
20
15
10
5
0
-5
0
25
50
75
100
125
150
175
200
TIME - MSEC

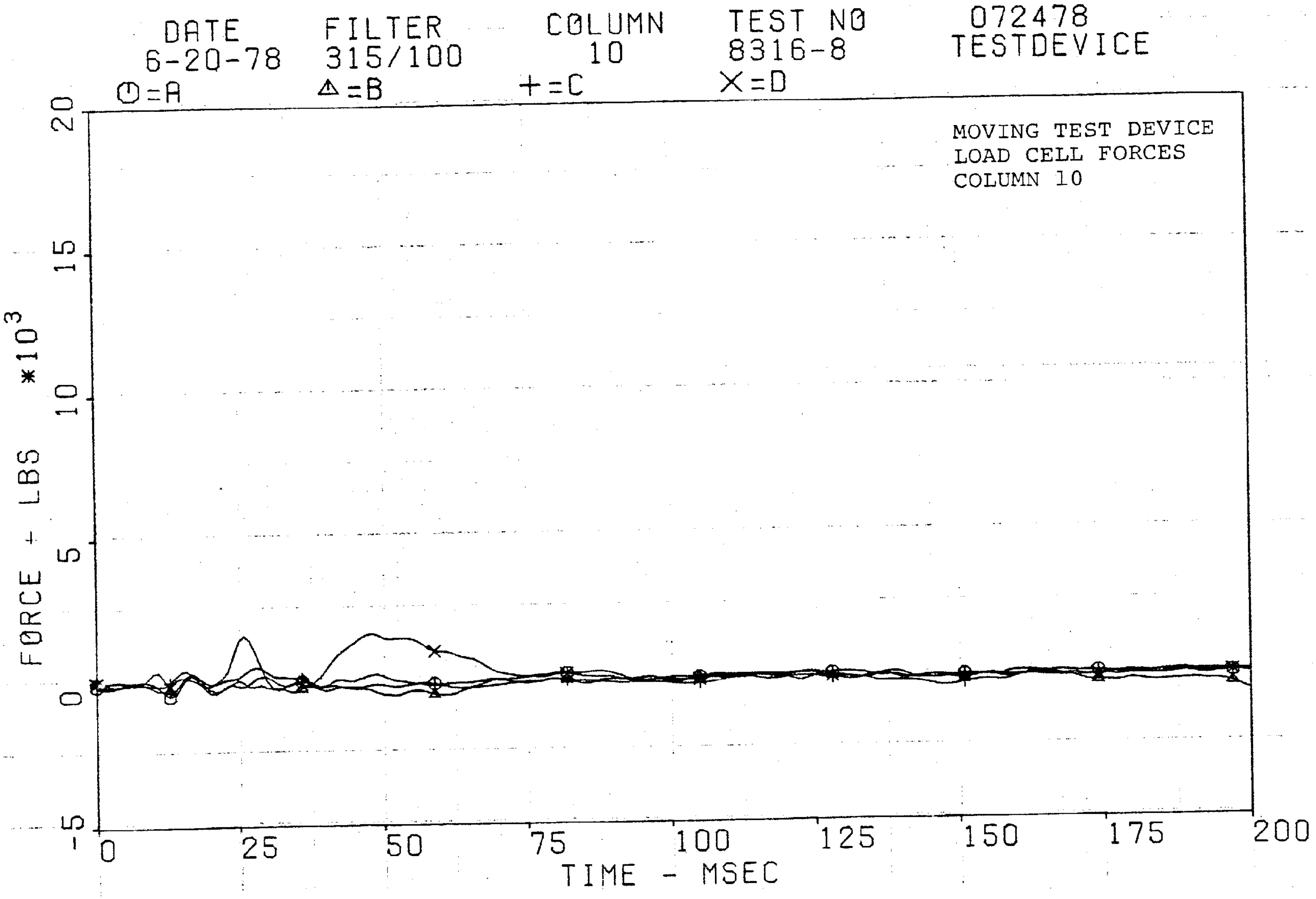

DATE
6-20-78
FILTER
315/100
COLUMN
5
TEST NO
8316-8
072478
TESTDEVICE
⊖=A
△=B
+=C
×=D
MOVING TEST DEVICE
LOAD CELL FORCES
COLUMN 5
FORCE - LBS *10³
20
15
10
5
0
-5
0
25
50
75
100
125
150
175
200
TIME - MSEC

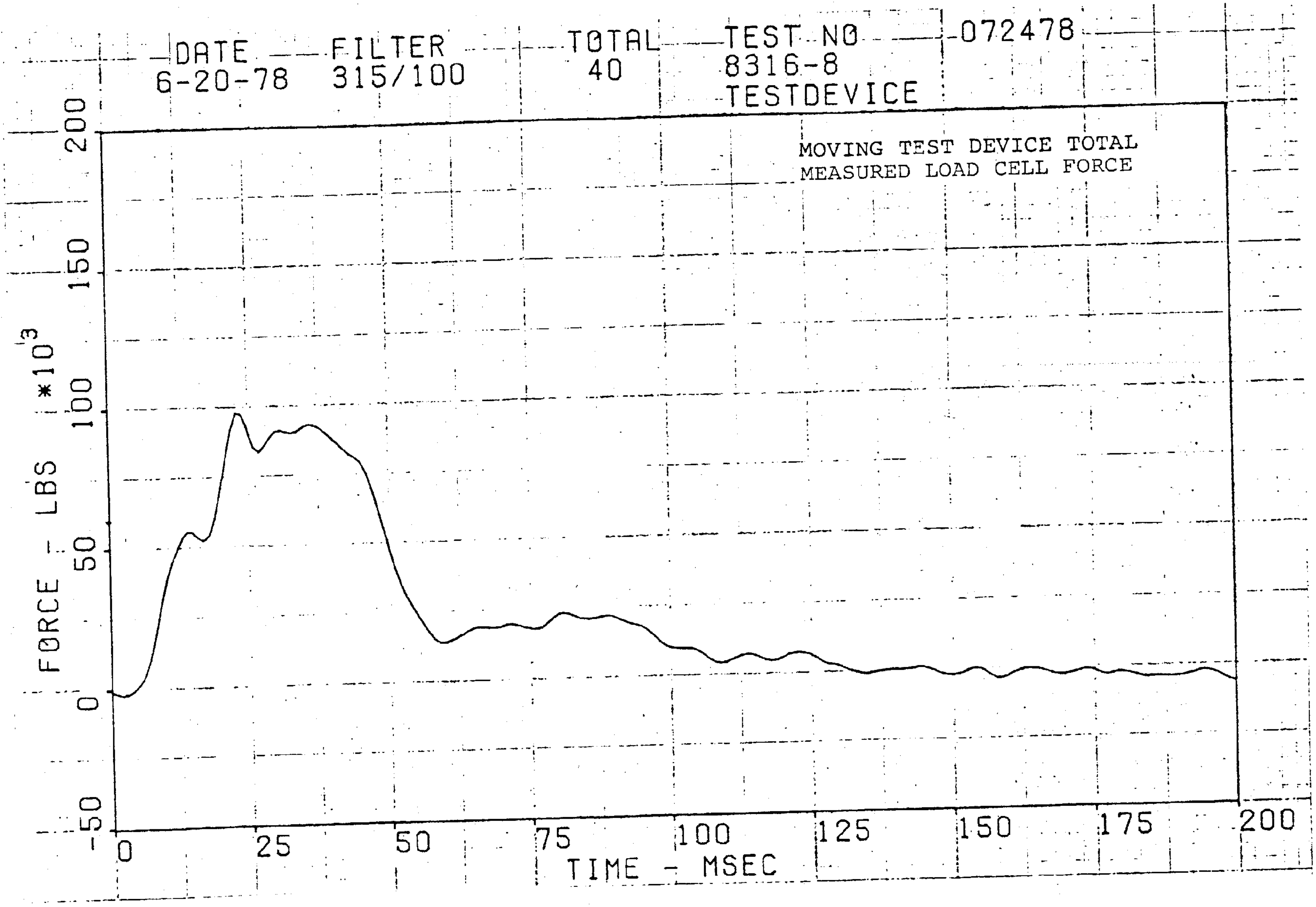

DATE
6-20-78
FILTER
315/100
COLUMN
6
TEST NO
8316-8
072478
TESTDEVICE
⊖=A
△=B
+=C
X=D
MOVING TEST DEVICE
LOAD CELL FORCES
COLUMN 6
FORCE - LBS *10^3
20
15
10
5
0
-5
0
25
50
75
100
125
150
175
200
TIME - MSEC

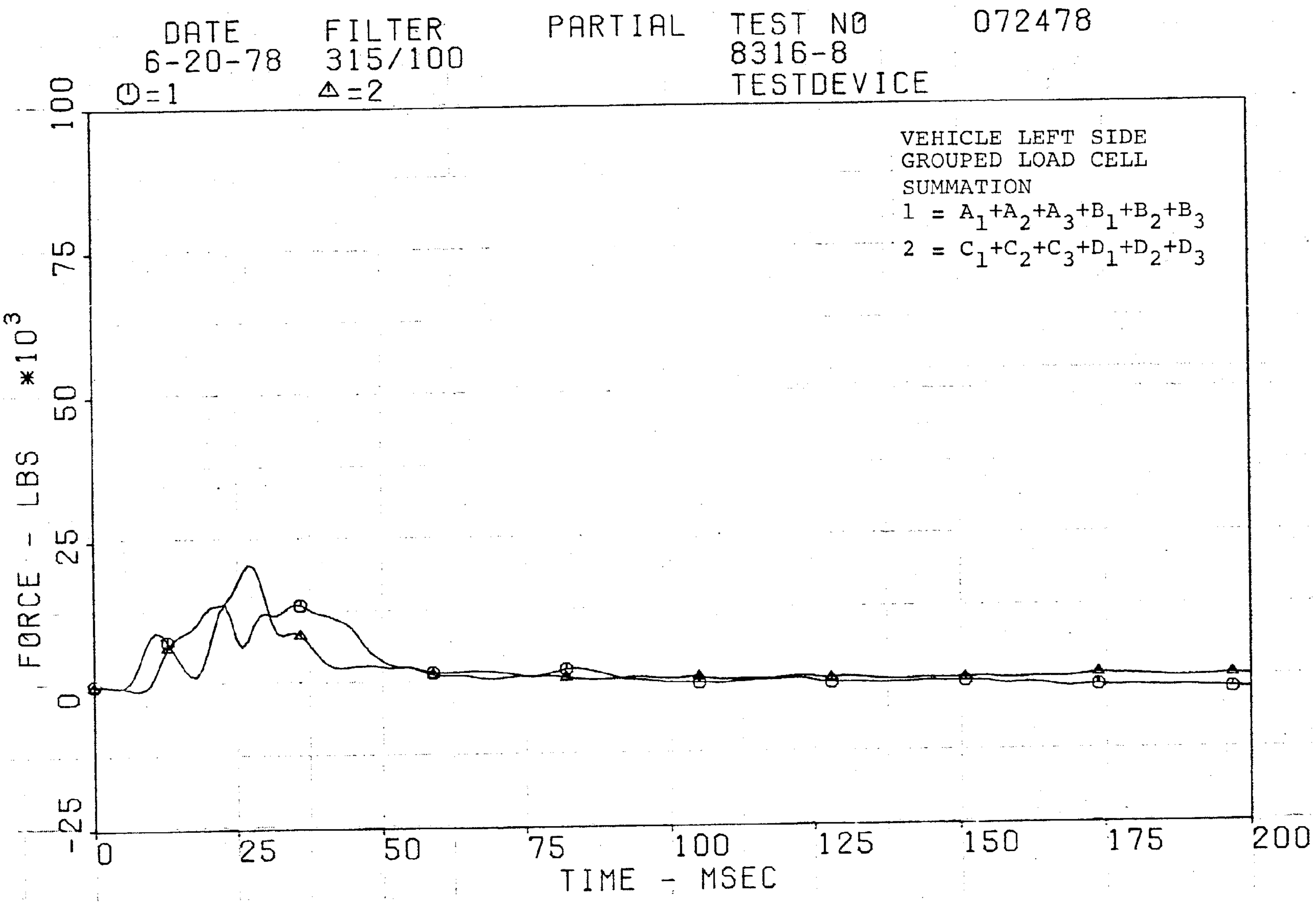

DATE
6-20-78
⊖=A
FILTER
315/100
△=B
COLUMN
7
+=C
TEST NO
8316-8
X=D
072478
TESTDEVICE
MOVING TEST DEVICE
LOAD CELL FORCES
COLUMN 7
FORCE - LBS *10^3
20
15
10
5
0
-5
0
25
50
75
100
125
150
175
200
TIME - MSEC

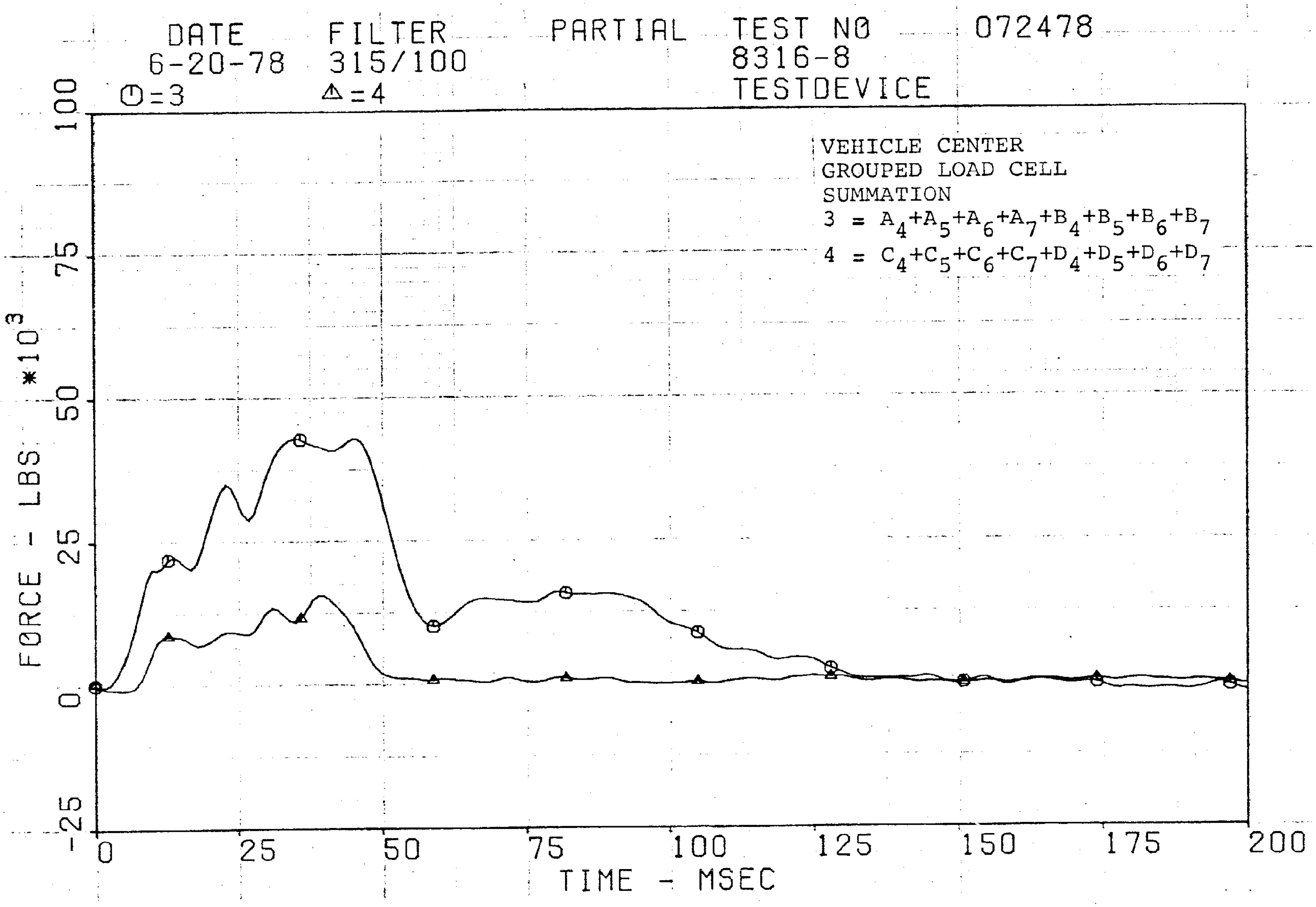

DATE
6-20-78
FILTER
315/100
COLUMN
8
TEST NO
8316-8
072478
TESTDEVICE
⊕=A
△=B
+=C
×=D
MOVING TEST DEVICE
LOAD CELL FORCES
COLUMN 8
FORCE - LBS $*10^3$
20
15
10
5
0
-5
0
25
50
75
100
125
150
175
200
TIME - MSEC

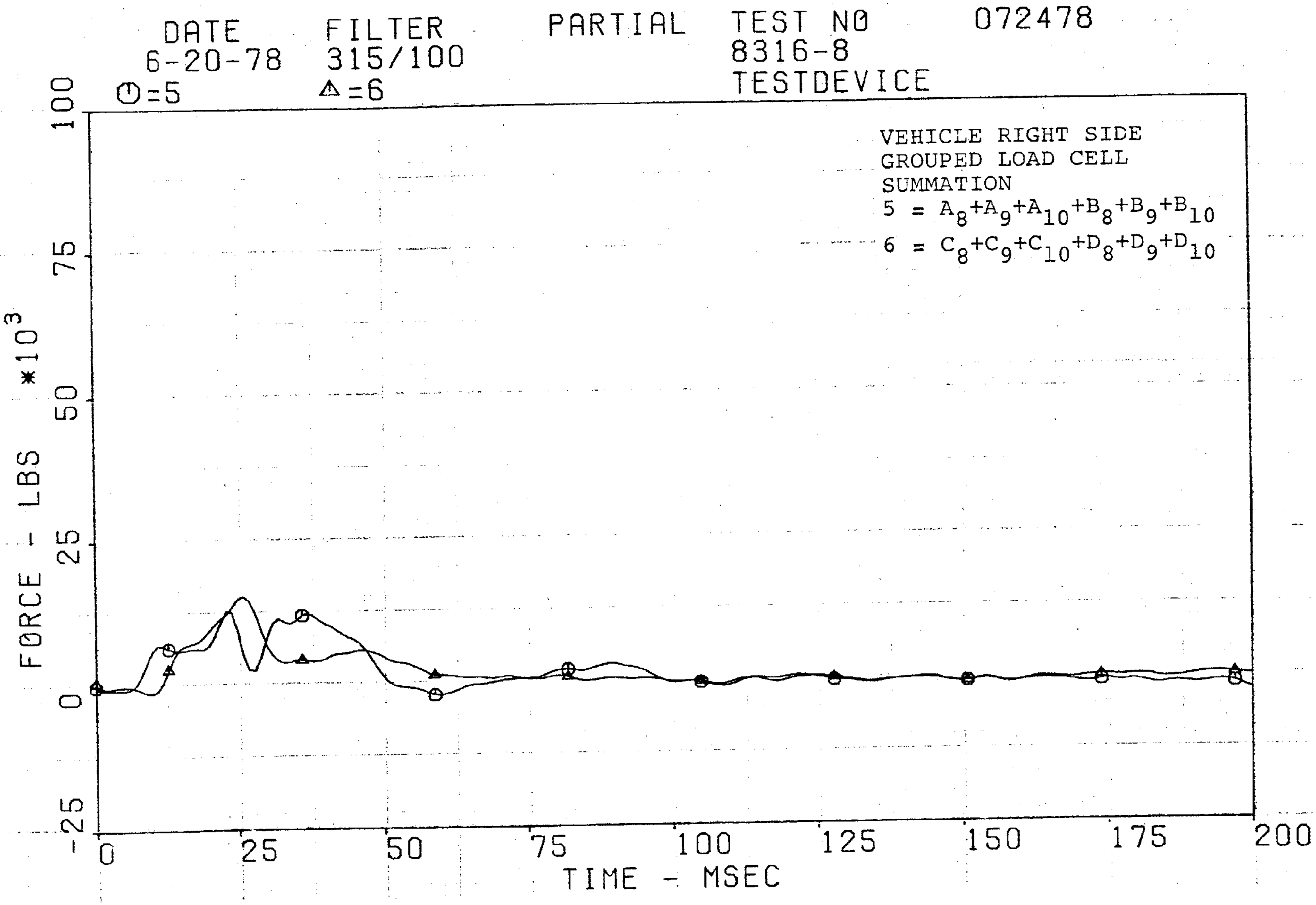

DATE
6-20-78
⊖=A
FILTER
315/100
△=B
COLUMN
9
+=C
TEST NO
8316-8
X=D
072478
TESTDEVICE
MOVING TEST DEVICE
LOAD CELL FORCES
COLUMN 9
FORCE - LBS *10^3
20
15
10
5
0
-5
0
25
50
75
100
125
150
175
200
TIME - MSEC

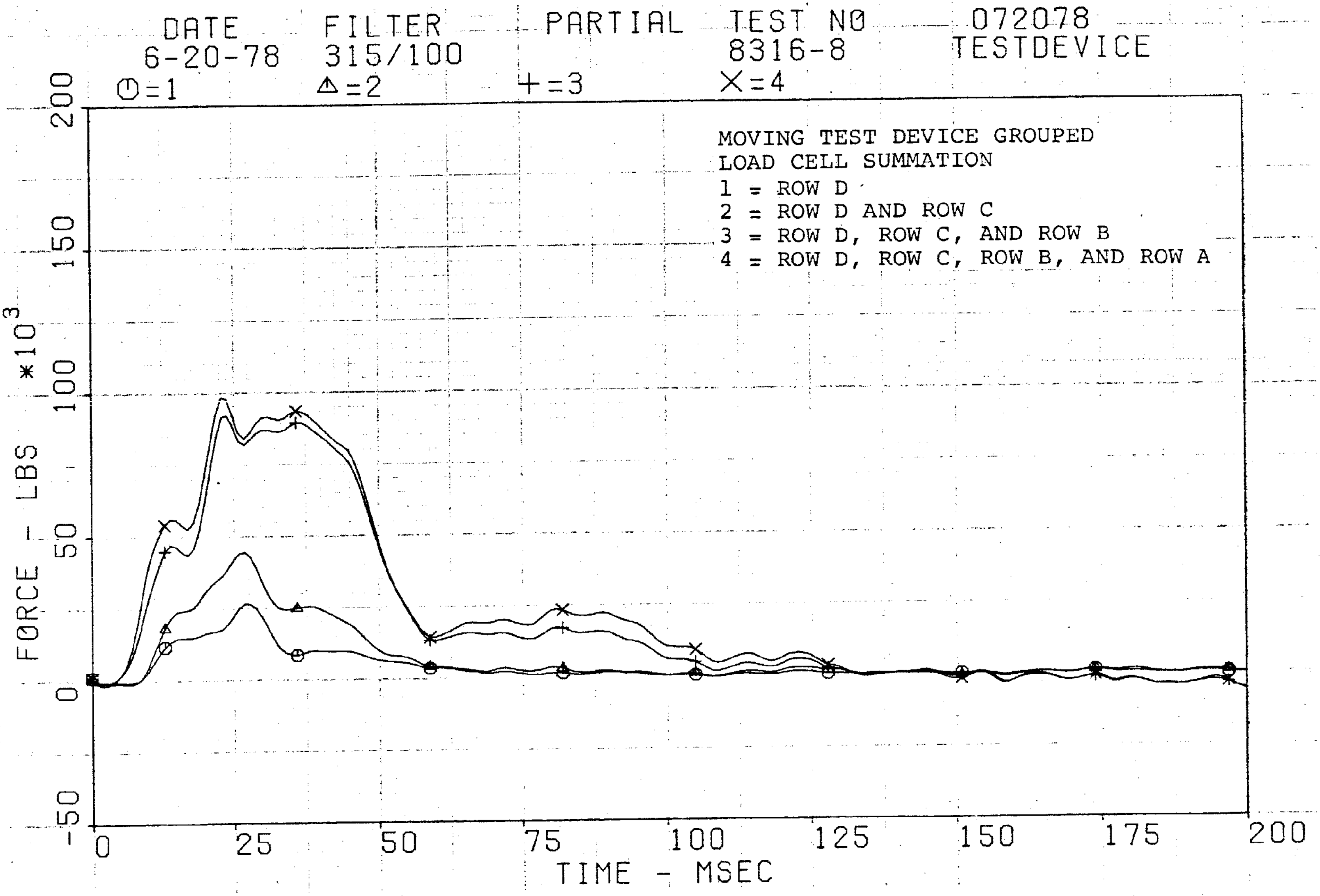

DATE
6-20-78
FILTER
315/100
COLUMN
10
TEST NO
8316-8
072478
TESTDEVICE
⦶=A
△=B
+=C
×=D
MOVING TEST DEVICE
LOAD CELL FORCES
COLUMN 10
FORCE - LBS *10³
20
15
10
5
0
-5
0
25
50
75
100
125
150
175
200
TIME - MSEC


DATE
6-20-78
FILTER
315/100
TOTAL
40
TEST NO
8316-8
TESTDEVICE
072478
MOVING TEST DEVICE TOTAL
MEASURED LOAD CELL FORCE
FORCE - LBS $*10^3$
200
150
100
50
0
-50
0
25
50
75
100
125
150
175
200
TIME - MSEC


DATE
6-20-78
FILTER
315/100
PARTIAL
TEST NØ
8316-8
TESTDEVICE
072478
⊕=1
△=2
VEHICLE LEFT SIDE
GROUPED LOAD CELL
SUMMATION
1 = $A_1+A_2+A_3+B_1+B_2+B_3$
2 = $C_1+C_2+C_3+D_1+D_2+D_3$
FØRCE - LBS $*10^3$
100
75
50
25
0
-25
0
25
50
75
100
125
150
175
200
TIME - MSEC


DATE
6-20-78
⊖=3
FILTER
315/100
△=4
PARTIAL
TEST NØ
8316-8
TESTDEVICE
072478
VEHICLE CENTER
GROUPED LOAD CELL
SUMMATION
3 = $A_4+A_5+A_6+A_7+B_4+B_5+B_6+B_7$
4 = $C_4+C_5+C_6+C_7+D_4+D_5+D_6+D_7$
FØRCE - LBS *10^3
100
75
50
25
0
-25
0
25
50
75
100
125
150
175
200
TIME - MSEC


DATE
6-20-78
⦶=5
FILTER
315/100
△=6
PARTIAL
TEST NØ
8316-8
TESTDEVICE
072478
VEHICLE RIGHT SIDE
GROUPED LOAD CELL
SUMMATION
5 = $A_8+A_9+A_{10}+B_8+B_9+B_{10}$
6 = $C_8+C_9+C_{10}+D_8+D_9+D_{10}$
FØRCE - LBS $*10^3$
100
75
50
25
0
-25
0
25
50
75
100
125
150
175
200
TIME - MSEC


DATE
6-20-78
FILTER
315/100
PARTIAL
TEST NØ
8316-8
072078
TESTDEVICE
○=1
△=2
+=3
×=4
MOVING TEST DEVICE GROUPED
LOAD CELL SUMMATION
1 = ROW D
2 = ROW D AND ROW C
3 = ROW D, ROW C, AND ROW B
4 = ROW D, ROW C, ROW B, AND ROW A
FØRCE - LBS $*10^3$
200
150
100
50
0
-50
0
25
50
75
100
125
150
175
200
TIME - MSEC

APPENDIX D

CALCULATION OF RESTRAINT SURVIVAL DISTANCE (RSD)

Prepared by:

Jack Beharrell

Jack Beharrell
Analysis Engineer
Special Projects Department
May 8, 1978

APPENDIX D

CALCULATION OF RESTRAINT SURVIVAL DISTANCE (RSD)

1.0 METHODOLOGY FOR CALCULATION OF RSD

1.1 INTRODUCTION

A hypothetical air bag restraint system force-deflection characteristic is used in conjunction with barrier crash test results to calculate a relative crashworthiness parameter, the Restraint Survival Distance (RSD).

The RSD involves the occupant stroking distance (which includes the available vehicle interior space plus some portion of the vehicle front structure crush which provides occupant ridedown). The degree of vehicle structural ridedown is determined by the combination of the vehicle crash pulse characteristic and the restraint system force-deflection properties.

1.2 DETERMINATION OF RSD

The Restraint Survival Distance (RSD) is determined from the following relation:

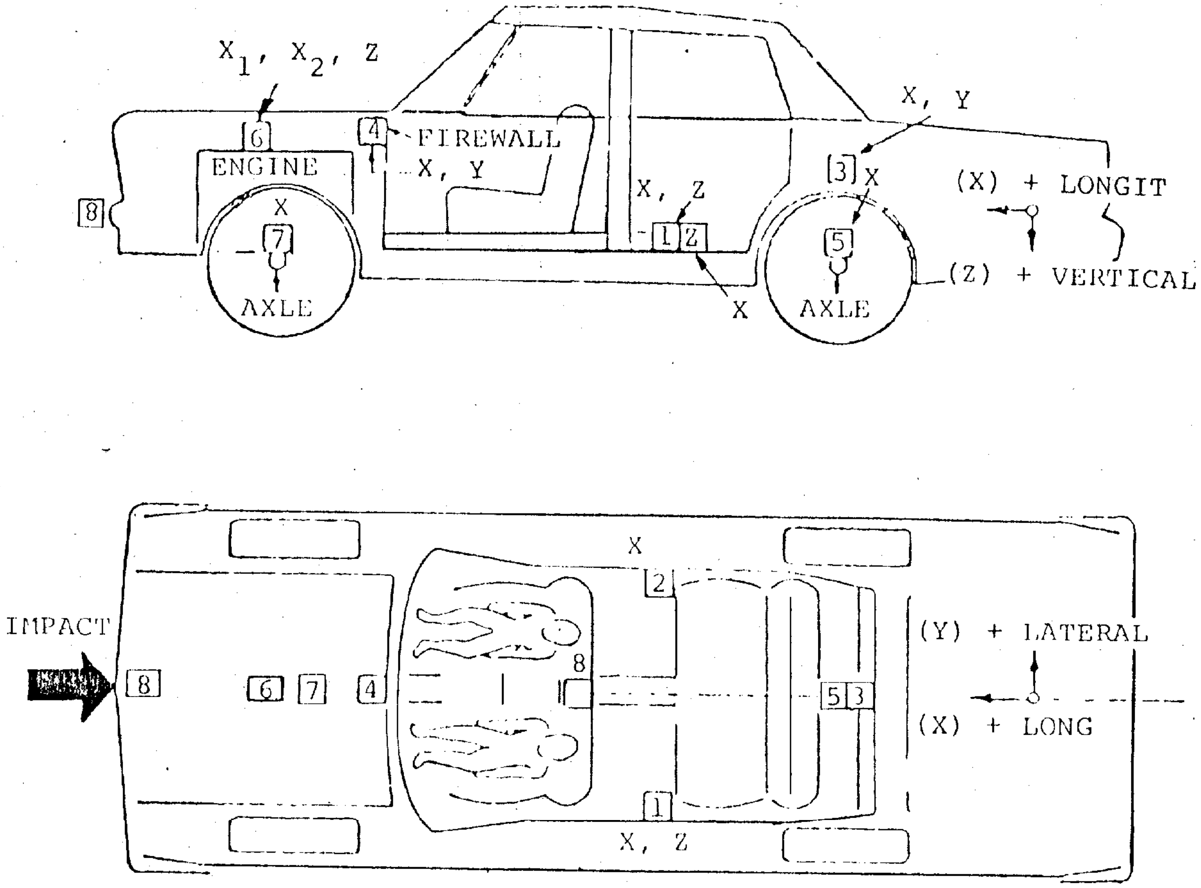
$$RSD = AID - (D_p - D_c)_{(t = t^*)}$$

where: AID is the available interior occupant stroking distance based on vehicle interior dimensions

t^* is the time at which the occupant velocity equals compartment velocity

D_p is the absolute displacement of the occupant from initial crash impact until t^*

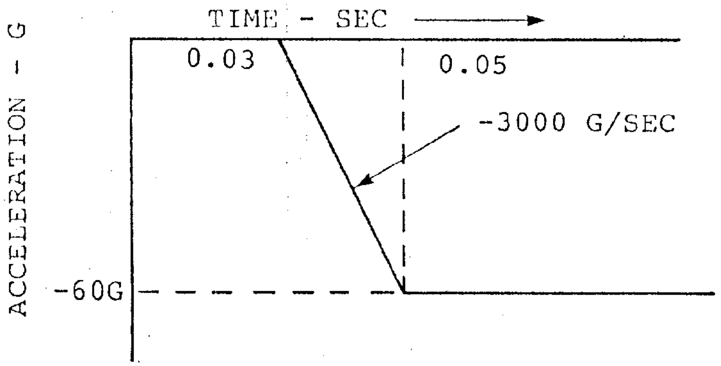
D_c is the absolute displacement of the vehicle compartment from initial impact to t^*. This displacement is determined from longitudinal vehicle accelerometer data at positions (1) and (2) for the driver and passenger, respectively (Figure D-1).



X_1, X_2, Z
6
ENGINE
4
FIREWALL
X, Y
8
X
7
AXLE
X, Z
1
Z
X
X, Y
3
X
5
AXLE
(X) + LONGIT
(Z) + VERTICAL
IMPACT
8
6
7
4
X
2
8
5
3
1
X, Z
(Y) + LATERAL
(X) + LONG

Figure D-1.

The absolute displacement of the occupant (D_p) is determined assuming the following restraint system deceleration pulse (hypothetical air bag system)



Integrating this pulse from 0 to t* gives the occupant velocity history

$$\dot{D}_p = V_i - 43.47 + 2898t^* - 48300t^{*2} \quad (.03 \leq t^* \leq .05) \quad (\text{ft/sec})$$

$$\dot{D}_p = V_i + 77.28 - 1932t^* \quad (t \geq .05) \quad (\text{ft/sec})$$

Integrating once more gives the occupant displacement history.

$$D_p = .4347 + (V_i - 43.47)t^* + 1449t^{*2} -$$

$$16100t^{*3} \quad (.03 \leq t^* \leq .05) \quad (\text{ft})$$

$$D_p = - 1.5778 + (V_i + 77.78)t^* - 966t^{*2} \quad (t \geq 0.05 \text{ sec}) \quad (\text{ft})$$

V_i is the velocity at impact.

The time t* is most easily obtained by plotting the compartment velocity (obtained from test accelerometer data) and superimposing this curve on that obtained from $\dot{D}_p$ above. The time at which the curves cross gives t*. The corresponding compartment displacement is determined from the test accelerometer data. The occupant displacement at time t* is determined from the D_p relation above.

The Available Interior Distance (AID) is determined for both pre-test and post-test compartment geometries under the following assumptions:

1. Knee restraint is located 6 inches forward of occupant's knee (horizontal measurement) if there is sufficient room in the car. The occupant's knee point is located by drawing a line tangent to the knee surface and parallel to the knee-joint to ankle-joint line. (The Calspan knee bar was a crushable honeycomb knee padding. It is part of the assumed passive air bag restraint system.) For the purposes of the AID calculation, the knee restraint is assumed to be 10 inches thick and capable of crushing 8 inches (both measurements are taken horizontally). The knee restraint remains stationary during the collision.

2. The knee will penetrate 8 inches into the restraint, or will translate to a point located 2 inches from the deformed firewall, whichever point is reached by the knee first. This translation is performed under the restriction that the bottom of the foot remains in contact with the sloping part of the firewall (or as close to this as possible). Pivoting therefore takes place about the occupant's ankle bone pivot point.

3. Having located the occupant's knees by the preceding sequence of steps, the occupant is rotated about the hip pivot point until either:

   a. The head hits the header or windshield.

   b. The chest hits the dash (steering column is ignored).

4. The AID is then the horizontal displacement of the chest C.G. from the initial seated position to the position when either 3a or 3b above occurs. The chest C.G. is located 14 inches above the hip pivot point and 4 inches forward of the back of the torso.

2.0 DSI-CALSPAN RSD COMPARISON

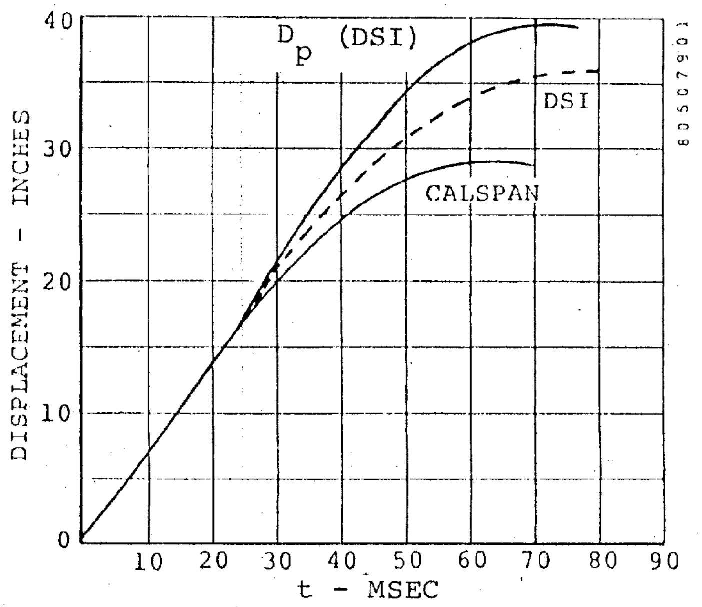
An evaluation was made of the similarities and differences between the Dynamic Science and Calspan (Reference 1) results of fixed-barrier frontal crash tests on presumably identical 1975 Honda CVCC's.

Basic to the calculation of the RSD are the occupant and passenger compartment velocity and displacement time histories. These are derived from the respective acceleration profiles.

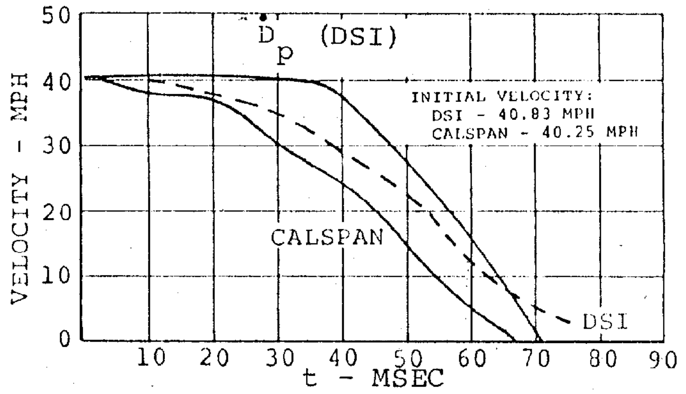
Figures D-2 and D-3 show the left and right compartment acceleration, velocity, and displacement histories for the DSI and for the Calspan tests. Superimposed on the velocity and displacement curves are the occupant velocity and displacement curves for the DSI test conditions (initial velocity 40.83 mph). [The Calspan occupant response curves would differ very little from these, since both are calculated on the basis of the standardized passive restraint deceleration pulse. The Calspan initial velocity was 40.25 mph.]

It is apparent from the acceleration curves (Figures D-2 and D-3) that there is a lag in the DSI acceleration-time history. This is largely due to the difference in test configuration. The DSI fixed barrier includes a 6-inch-thick layer of aluminum honeycomb on the front face. In the DSI tests, initial impact is defined as the instant of vehicle-honeycomb contact, since the test instrumentation detects this contact.

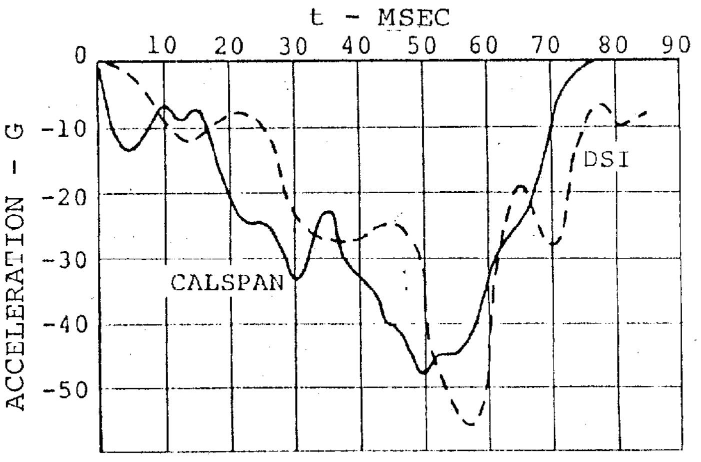
The occupant velocity and displacement curves shown in Figures D-2 and D-3 were calculated on the basis of this initial time instant. However, the occupant velocity and displacement equations are obtained by integrating the restraint deceleration pulse, assuming the initial restraint deployment-triggering signal and bag deployment requires 30 milliseconds. This signal would occur



(A) DISPLACEMENT

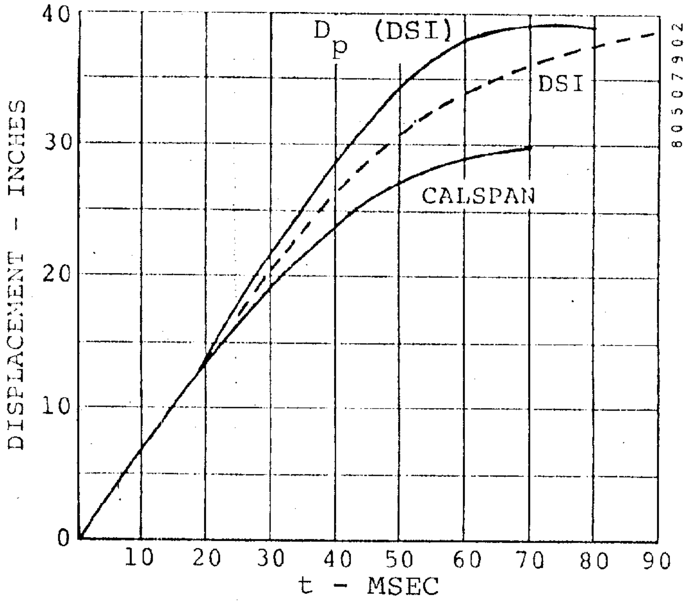


(B) VELOCITY

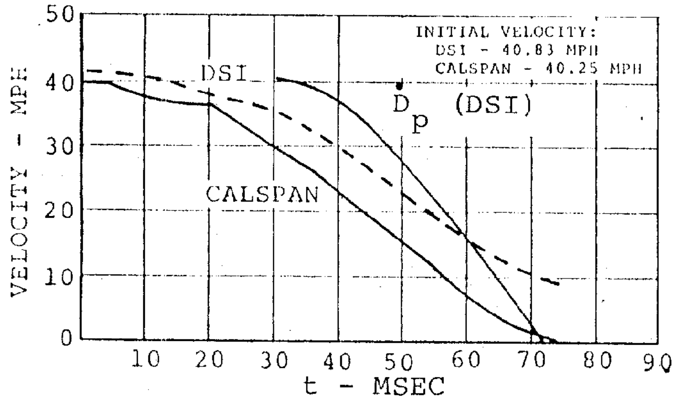


(C) ACCELERATION

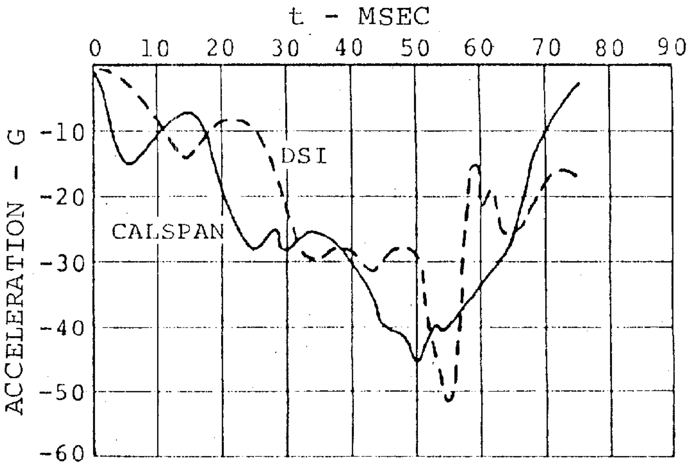
Figure D-2. 1975 Honda CVCC - Fixed Barrier Test
Left Compartment.



(A) DISPLACEMENT



(B) VELOCITY



(C) ACCELERATION

Figure D-3. 1975 Honda CVCC - Fixed Barrier Test Right Compartment.

in the DSI test some time later and thus air bag deployment would be correspondingly delayed.

For purposes of comparison, the RSD's were recalculated assuming a 7-millisecond delay in the DSI restraint deployment signal. This corresponds to a constant velocity traversal of about 5 inches of honeycomb, at 40 mph. This delay produced changes in t*, the time at which occupant velocity equals compartment velocity, and a corresponding change in the quantity (D_p - D_c) which appears in the RSD equation. The AID's are not affected, being dependent only upon compartment geometry. Table D-1 summarizes these results, along with the corresponding Calspan values.

TABLE D-1. COMPARISON OF RSD's DSI VERSUS CALSPAN - 1975 HONDA CVCC-TO-FIXED BARRIER

	Driver		Passenger	
	Pre	Post	Pre	Post
DSI (D_p curves not shifted)	6.2	15.5	6.2	9.6
DSI (D_p curves shifted 7 msec)	1.5	10.8	3.0	6.4
Calspan	1.0	3.9	1.8	4.5

All values are in inches.

It is apparent that taking the triggering signal delay into account produces better correlation between the Calspan and DSI tests. It should be pointed out that the use of a 7-millisecond delay is somewhat arbitrary since the actual restraint deployment signal is generated on the basis of compartment deceleration. Comparison of the acceleration curves of Figures D-2 and D-3 suggests that a 7-millisecond delay is reasonable. However, the comparative results are a good indication of the care that must be taken to ensure equivalent test evaluation procedures.

REFERENCES

1. CLASSIFICATION OF AUTOMOBILE FRONTAL STIFFNESS/CRASHWORTHINESS BY IMPACT TESTING, DOT-HS-801-966, Calspan Corporation, August 1976.