FHWA CONTRACT NO.
DTFH61-86-Z-00047

THIRTY MPH BROADSIDE IMPACT OF A MINI-SIZED VEHICLE AND A BREAKAWAY LUMINAIRE SUPPORT

TEST RESULTS REPORT

TEST NUMBER 1785-SI#4-87

REVISION 1.0

Hinch, J. A.
Stout, D.

Prepared for:

FEDERAL HIGHWAY ADMINISTRATION
Safety Design Division
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101

October 1987

Prepared by:

ENSCO, INC.
Applied Technology and Engineering Division
5400 Port Royal Road
Springfield, VA 22151

Technical Report Documentation Pa

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle
"Thirty MPH Broadside Impact a Minisized Vehicle and a Breakaway Luminaire Support," Test Result Report; Test Number 1785-SI#4-87

5. Report Date
October 1987

6. Performing Organization Code

7. Author(s)
Hinch, J.A. and Stout, D.

8. Performing Organization Report No.
1785-SI#4-87

9. Performing Organization Name and Address
ENSCO, INC.
5400 Port Royal Road
Springfield, VA 22151

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
DTFH61-86-Z-00047

12. Sponsoring Agency Name and Address
Federal Highway Administration
Turner Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101

13. Type of Report and Period Covered
Test Report

14. Sponsoring Agency Code

15. Supplementary Notes

Subcontract from Analysis Group Inc., A. Hansen-PI; FHWA COTR - M. Hargrave

16. Abstract

This report documents the full scale side impact test of a 1980 Plymouth Champ impacting into a breakaway luminaire support. The impact speed was 30 mi/h and the impact angle was broadside with the impact point aligned with the driver's shoulder.
The impacted pole was a slip base mounted steel unit with mast arm and luminaire.

Although the pole did break away with a low change in velocity of the vehicle, severe intrusion of the pole into the passenger compartment provided for a severe accident. The pole intrusion caused the door to come open. Dummy parameters were all very high in magnitude.

17. Key Words
Side Impact
SID
FOIL

18. Distribution Statement
Open

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
None	None		

Form DOT F 1700.7 (8-72)

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof. The contents of this report reflect the views of the contractor, who is responsible for the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policy of the Department of Transportation. This report does not constitute a standard, specification, or regulation.

The United States Government does not endorse products or manufacturers. Trade or manufacturer's names appear herein only because they are considered essential to the object of this document.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 SUMMARY AND CONCLUSIONS

This test investigated the impact severity of a minicompact sedan (1800S) during a low speed broadside collision with a breakaway luminaire support. The test vehicle was a 1980 Plymouth Champ. The breakaway luminaire support was a 30 foot steel pole with a California type 31 slip base. The pole included a mast arm and surrogate luminaire.

The test vehicle momentum change due to impacting the pole at a speed of 30.48 mph (13.63 m/s) was 559 lb-sec. The velocity change corresponding to the observed vehicle momentum change was 6.11 mph or 8.96 ft/sec. The integrity of the vehicle was maintained throughout the test although severe intrusions occurred at the center of the driver's door. Maximum residual crush of the side of the vehicle was 10.0 inches.

Vehicle acceleration data was processed to determine the impact velocity of a hypothetical front seat passenger against the vehicle interior in accordance with the flail space model recommended in NCHRP 230. The lateral impact velocity of the hypothetical occupant using the flail space model approach with a one foot threshold was 9.3 ft/sec. This lateral impact velocity is within the design limit of 20 ft/sec (6.10 m/s) specified for lateral impacts of other forms of highway safety appurtances in NCHRP 230. However, the actual impact velocity of the occupant with the interior of vehicle was approximately 44 ft/sec since the occupant impacted the area where the luminaire support was deforming the interior of the vehicle compartment. This lateral impact velocity exceeds the limits of NCHRP 230.

The acceleration data from the anthropomorphic dummy was also analyzed using NHTSA techniques to determine impact severity based on thoracic measurements. Results of this analysis indicate that from the standpoint of thoracic injuries the occupant suffered a severe injury as measured on the American Association of Automotive Medicine's Abbreviated Injury Scale (AIS). The probability of an injury level of AIS greater than 3 was 100%, of an AIS greater than 4 was 100%, while the probability of an AIS greater than 5 was 28%. This value, based on the T12Y and LURY accelerometers, exceeds the basic design goal for occupant responses of an AIS less than or equal to 3.0. Analysis of the acceleration data from the head of the anthromorphic dummy yielded a Head Injury Criteria (HIC) of 8026. This result exceeds the limit specified in FMVSS 208. It should be noted that HICs obtained during side impacts may not measure the head injury correctly since the head form of the dummy was designed for frontal impacts. A summary of the test conditions and results for this full scale crash test are given in Table 1.

Table 1

Summary of Test Conditions and Results for Test Number 1785-SI#4-87

1.	Contract Number/FOIL Test No.	DTFH61-86-Z00047/87S106
2.	Date of Test	October 1987
3.	Test Vehicle	Plymouth Champ, 1980
4.	Delivered Vehicle Weight	1918 lbs
5.	Vehicle Weight, Test Inertial Planned Actual	 1,800 ±50 lbs 1850 lbs
6.	Vehicle Weight, Gross Static Actual (One Occupant)	 2,010 lbs
7.	Number of Occupants	One
8.	Occupant Type	Anthropomorphic Dummy, 50th Percentile Male, Side Impact Thorax-SN120
9.	Occupant Location	Driver Seat
10.	Occupant Restraint	Unrestrained
11.	Test Article	Breakaway Luminaire Support
12.	Support Length (w/o Base)	30 ft
13.	Support Material	Steel
14.	Support Weight (w/Base, mast arm and luminaire)	416 lbs
15.	Base Type	Triangular Slip Base, 3-Bolt (Type 31)
16.	Slip Plane Mounting Height Above Grade	2.25 in
17.	Bolt Circle	14 in
18.	Bolt Size	1 in - 8 NC x 5 in long
19.	Bolt Load (Strain Gaged)	14,000 lbs each
20.	Foundation	FOIL Impact Foundation
21.	Ground Conditions	Dry

Table 1 (Cont'd)
Summary of Test Conditions and
Results for Test Number 1785-SI#4-87

22.	Impact Speed, Observed	30.48 mph
23.	Speed Reduction Acceleration Data, TRC 191	6.11 mph
24.	Exit Speed	24.37 mph
25.	Impact Point, Observed	Left Door, Driver Location, (28" behind cg)
26.	Traffic Accident Data, TAD	9-LP-4
27.	Vehicle Damage Index, VDI	09LPAN3
28.	Hypothetical Occupant Impact Velocity (NCHRP 230)	
	Design Limit	20 ft/sec
	Observed (1' flail)	9.11 ft/sec
	Observed Actual (.54')	7.61 ft/sec
29.	Hypothetical Occupant Ride-down Acceleration (NCHRP 230)	
	Design Limit	15.00 g
	Observed, (1' flail)	-1.47 g
	Observed, Actual (.54')	+3.79 g
30.	Actual Occupant Impact Velocity	
	Limit (NCHRP 230)	30 ft/sec
	Observed	44 ft/sec
31.	Head Injury Criteria (HIC)	
	Design Limit	1000
	Driver, Observed	8026
32.	Upper Spine (T01) Acceleration Data	
	Acceleration with Duration Greater than .003 sec	2244 g's
	CSI	169 g's
33.	Thoracic Injury	
	Fatal Injury	6.00
	Probability of:	
	AIS greater than 3	100%
	AIS greater than 4	100%
	AIS greater than 5	28%
34.	Momentum Change from Pole	559 lb-sec

1 lb = .454 kg
1 ft = .3048 m
1 lb-sec = 4.448 N-s
1 ft-kip = 1,355 N-m
1 in = .0254 m

2.0 OBJECTIVE

The objective of this test was to investigate the impact severity of a minicompact sedan (1,800S) during a low speed broadside collision with a breakaway luminaire support. This test is the fourth of a series of eight full scale crash tests to be conducted. The planned test matrix is shown in Table 2.

The vehicle used for this test was a 1981 Dodge Colt. A triaxial accelerometer package was mounted on the lateral centerline of the vehicle near the longitudinal location of the center of gravity of the vehicle in its inertial test configuration. The data from these accelerometers were used to measure vehicle impact behavior and occupant injury potential based upon criteria set forth in TRC 191 and NCHRP 230. Two rate gyros were also mounted to the accelerometer block to measure yaw and roll rates. The vehicle also was instrumented with a contact switch mounted on the left door to permit vehicle and occupant data to be measured relative to the time of impact.

The vehicle contained one instrumented 50th percentile male anthropomorphic test dummy equipped with a thorax specifically designed for side impacts. The test dummy (serial no. 120) was positioned in the driver seat and was unrestrained. The data from the triaxial accelerometer sensor assembly in the head of the test dummy was used to evaluate the Head Injury Criteria (HIC). The data obtained from the triaxial accelerometer sensor assemblies located in the upper and lower parts of the spine and in the pelvis of the occupant were used to evaluate severity indices and maximum sustained accelerations experienced by the occupant in the respective locations in accordance with SAE Information Report J885a. The data obtained from the accelerometers located on the ribs of the occupant were used to evaluate the maximum sustained accelerations experienced by the occupant

Table 2

Planned Test Matrix for Side Impact Test Series

Test Number	Angle[1]	Location[2]	Article[3]
1 Actual	90	0	Slipbase
2 Actual	90	0	T-base
3	90	+12"	Slipbase
4	90	-12"	Slipbase
5	90	+6 or +24"	Slipbase
6	90	-6 or -24"	Slipbase
7	60	0	Slipbase
8	120	0	Slipbase
3 Actual	90	0	Slipbase
4 Actual	90	0	Slipbase

[1] 90° = Broadside on Drivers Door
60° = Front of Vehicle Leading

[2] 0" = Centered on Occupant
\+ = Forward of Occupant
\- = Rearward of Occupant

[3] Slipbase pole w/30' pole mast arm and surrogate luminaire.

T-base Union Metal 2849 w/40' steel pole, mast arm and surrogate luminaire.

Notes:
All tests to be run at 30 mph impact speed.
All test vehicles to be Dodge Colts or Plymouth Champs
All vehicles to have 1 SID in driver's position.

in the respective locations. In addition, thoracic injury parameters associated with side impact conditions were analyzed using NHTSA techniques to determine occupant injury.

The breakaway luminaire support was chosen since it was known to induce a momentum change during frontal impacts which was considered very acceptable. The objective was to determine what level and type of injury could be expected during a side impact collision with one of the better performing hardware devices on the highway system. In recent testing at the FHWA FOIL this pole produced a velocity change of less than 15 ft/sec when hit by the FOIL bogie at 20 mph.

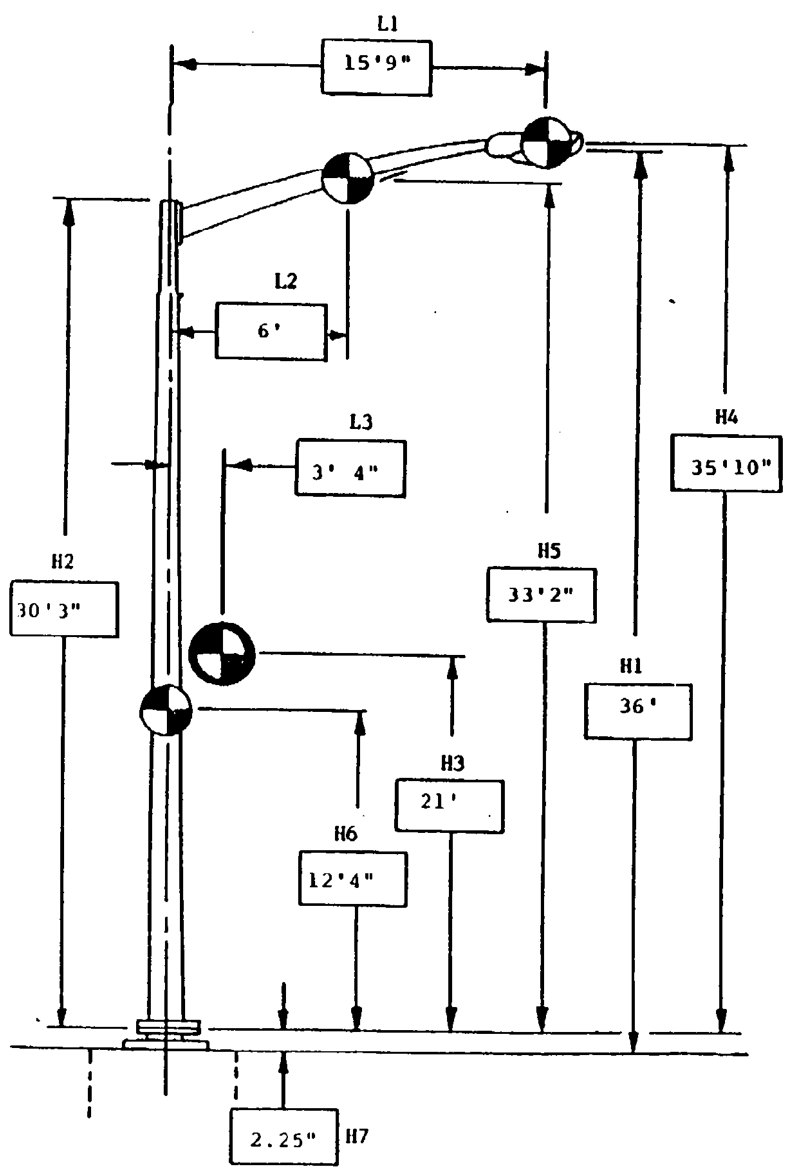
3.0 APPURTENANCE DESCRIPTION

The physical properties of the breakaway luminaire support are contained in Table 3. The breakaway luminaire support incorporated a triangular 3-bolt slip base which is based on a design of the California Type 31 support. The slip base was positioned so impact would occur against an edge which had two bolts aligned. The luminaire support had a mast arm attached during this test as well as a steel weight attached to the end of the arm. The slip base was clamped together with three strain gaged bolts which were tightened to 14,000 pounds (62,300 N) each just prior to the test. The mechanical properties of the pole are shown in Figure 1.

Table 3
Properties of Test Pole

Manufacturer:	Ameron
Material:	Steel
Weight:	416 lbs
Height, c.g.:	21 ft
Top diameter:	3-1/2 in
Bottom diameter:	7.5 in
Mast Arm Length:	15 ft - 9 in.
Luminaire Height:	35 ft - 10 in.
Luminaire Weight:	51 lbs
Base Type:	California Type 31 slip base
Number of bolts:	3
Size:	1 in diameter
Type:	Instrumented to measure bolt load
Bolt Clamp Load:	14 kips

FHWA FOIL TEST FACILITY

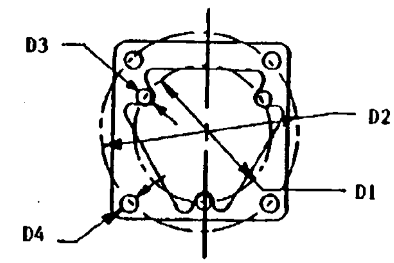


LUMINAIRE SUPPORT PARAMETERS
SLIP BASE WITH TRUSS MAST ARM

Manufacturer: Ameron Part No: ____

Ref. FOIL Tests: ____

Completed By: C. Brown Date: 7/1/87



WEIGHTS (LB)

Pole: 275 (W1)

Mast Arm: 90 (W2)

Luminaire: 51 (W3)

Total Assy: 416 (WT)

MEASURED LENGTHS (IN)

Mounting Height: 36' (H1)

Pole Height: 30'3" (H2)

Pole CG Height: 12'4" (H6)

Mast Arm CG Ht: 33'2" (H5)

Mast Arm CG Offset: 6' (L2)

Lumin CG Ht: 35'10" (H4)

Lumin CG Offset: 15'9" (L1)

Stub Ht: 2.25 (H7)

SLIP BASE PARAMETERS

No. Slip Bolts: 3

Slip BC Dia (in): 14 (D1)

Dia of Slip Bolts (in) 1 (D3)

No. Foundation Bolts: 3

Found BC Dia (in): 14 (D2)

Dia Found Bolt (in): 1 (D4)

S Bolt Clamp Force (lb): 14,000

Keeper Plate, Y/N: Y

Slip Base Thick (in): 1

POLE PARAMETERS

Base Dia (in): 7.5

Tip Dia (in): 3.5

Wall Thick (in): .125

Material: Steel

TOTAL ASSEMBLY CG LOCATION (IN)

Total Assy CG Ht = $\frac{W1*H6 + W2*H5 + W3*H4}{WT}$ = 21' (H3)

Total Assy CG Offset = $\frac{W2*L2 + W3*L1}{WT}$ = 3'4" (L3)

Figure 1. Mechanical Properties of Pole

4.0 VEHICLE DESCRIPTION

The test vehicle was a 1981 Dodge Colt. The weight of the vehicle prior to incorporating the instrumentation for the test was 1918 pounds. The test inertial weight for the vehicle was 1850 pounds and the gross static weight when the occupant was included in the vehicle was 2010 pounds. The longitudinal center of gravity of the vehicle without the occupant was located approximately 32 inches behind the centerline of the front axle. The weight and inertial data of the vehicle in its as delivered and instrumented configuration are given in Table 4. Inertial data was measured using the IMD.

The vehicle was equipped with a triaxial accelerometer package mounted on the lateral centerline of the vehicle at the longitudinal location of the center of gravity. Two rate gyros were also installed to the same mounting block to measure roll and yaw rates. The vehicle was also equipped with a contact switch mounted on the left door to permit vehicle and occupant data to be measured relative to the time of impact. A second triaxial accelerometer package was attached to the floor board located in front of the front right hand seat. This data was collected using the FOIL data system. The test vehicle is shown in Figure 2.

Figure 2. Pre-Test Photos of Vehicle

Table 4

Cg and Inertial Data for Test Vehicle

Vehicle	1980 Plymouth Champ
Serial Number	1H24KA4408599
Build Date	October 1979
Delivered Weight	1918 lbs
Delivered cg-x	32" behind front axle center line
Delivered cg-y	at vehicle centerline
Delivered cg-z	20.6" above ground
Delivered Roll Inertia	197 slug-ft^2
Delivered Pitch Inertia	795 slug-ft^2
Delivered Yaw Inertia	869 slug-ft^2
As tested weight, inertial	1850 lbs
As tested weight, gross	2010 lbs
As tested cg-x	32" behind front axle centerline
As tested cg-y	at vehicle centerline
As tested cg-z	20.7" above ground
As tested Roll Inertia	205 Slug-ft^2
As tested Pitch Inertia	793 Slug-ft^2
As tested Yaw Inertia	852 Slug-ft^2

5.0 TEST INSTRUMENTATION

Film data of the test was taken as described in Table 5. Transducer data was recorded as listed in Table 6. The transducer data was collected in analog form on a Honeywell 5600C recorder at 60 ips. The multiplexed data and the 32 kHz control signal were recorded in direct mode with a bandpass of 300 Hz to 300 kHz. The multiplexed data was played back through SAE Class 1000 filters and each channel was digitized at 8,000 Hz as required by the contract. A digital data tape was created in accordance with the specifications defined by NHTSA. The test data was analyzed on a DEC 11/70 using the ENSCO general purpose highway research analysis programs. The 32 kHz control signal was initiated approximately 2.0 seconds prior to the vehicle impacting the luminaire support. This control signal was used to externally trigger the digitizing unit and automatically synchronize all data channels. The signal conditioning unit onboard the vehicle was a Series 300 FM data multiplexer manufactured by Metraplex Corporation. The instrumentation used to collect the transducer data during the test conformed with SAE Recommended Practice J211b. Data from additional accelerometers, located in front of the right front seat, was recorded using the FOIL data system.

Table 5

Description of Film Data Acquisition System

Camera	Model	Position	Speed Setting	Lens
1	Redlake, Locam	Rt. Side	500 pps	16 mm
2	Redlake, Locam	Rt. Side	500 pps	100 mm
3	Redlake, Locam	Front Rt.	500 pps	16 mm
4	Redlake, Locam	Front Rt.	500 pps	100 mm
5	Redlake, Locam	Front Lt.	500 pps	16 mm
6	Redlake, Locam	Front Lt.	500 pps	100 mm
7	Redlake, Locam	Onboard	500 pps	5.7 mm
8	Redlake, Locam	Overhead	500 pps	10 mm
9	Redlake, Locam	Rt. Side	500 pps	16 mm
10	Bolex	Documen-tation	24 pps	Zoom

pps - Pictures per second

Table 6
Transducer Data Description

Channel No.	Channel Description
1	Left Lower Rib Accel., LLRYG1
2	USTXG1
3	Left Upper Rib, Accel., LURYG1
4	Upper Spine Accel., T01XG1
5	Upper Spine Accel., T01YG1
6	Upper Spine Accel., T01ZG1
7	Lower Spine Accel, T12XG1
8	Lower Spine Accel, T12YG1
9	Lower Spine Accel, T12ZG1
10	LSTXG1
11	Left Lower Rib Accel., LLRYGA
12	Left Upper Rib, Accel., LURYGA
13	Head Accel, X
14	Head Accel, Y
15	Head Accel, Z
16	Pelvis Accel, X
17	Pelvis Accel, Y
18	Pelvis Accel, Z
19	Vehicle Accel., cg-x
20	Vehicle Accel., cg-y
21	Driver Door, Impact Marker
22	Vehicle c.g., Roll Rate
23	Vehicle c.g., Yaw Rate
24	Vehicle Accel., cg-z

6.0 TEST RESULTS

The impact conditions were 29.45 mph (13.18 m/s) at a point on the left door in line with the occupant 28 in (.71 m) behind the longitudinal location of the center of gravity of the vehicle measured without the dummy in the vehicle. The vehicle had a 5.9^{o} roll angle as it leaned toward the test pole due to the side sliding forces acting on the tires. The maximum residual crush of the vehicle at the impact point was 10.0 inches (.25 m). Photographs of the vehicle and luminaire support after the collision event are shown in Figure 3.

After the initial separation from the vehicle the luminaire support translated forward at a speed of 6.9 f/s (2.1 m/s) with a rotation rate of 1.94 rad/sec. The luminaire support rotated up and over the test vehicle with the top of the pole hitting the ground about 1.1 seconds after impact. Just prior to impact with the ground, the center portion of the pole impacted on the left rear corner of the car. As the support rotated away, vehicle yawed counter clockwise and rolled to its left. The maximum roll angle was about 5^{o} based on film observations. The vehicle then became stable and continued forward away from the impact area after yawing a total of about 60^{o}. The vehicle did not pitch or roll very much but remained stable during this transition. The final resting position of the vehicle was about 55 feet downstream and 35' to the right of the impact point. The residual test vehicle crush measured using the 6 point NHTSA guide is given in Table 7. See Figure 4 for reference.

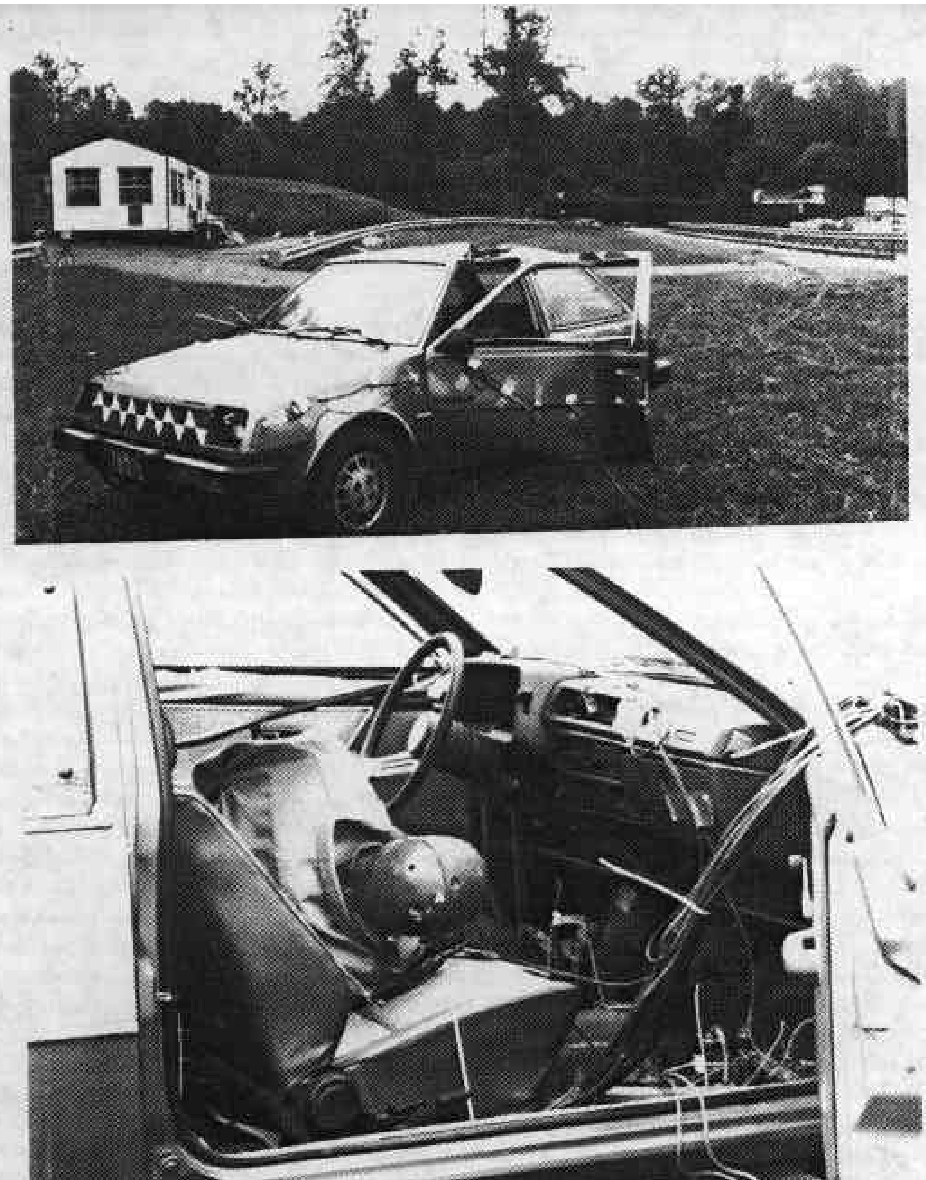


Figure 3. Post-Test Photos of Vehicle

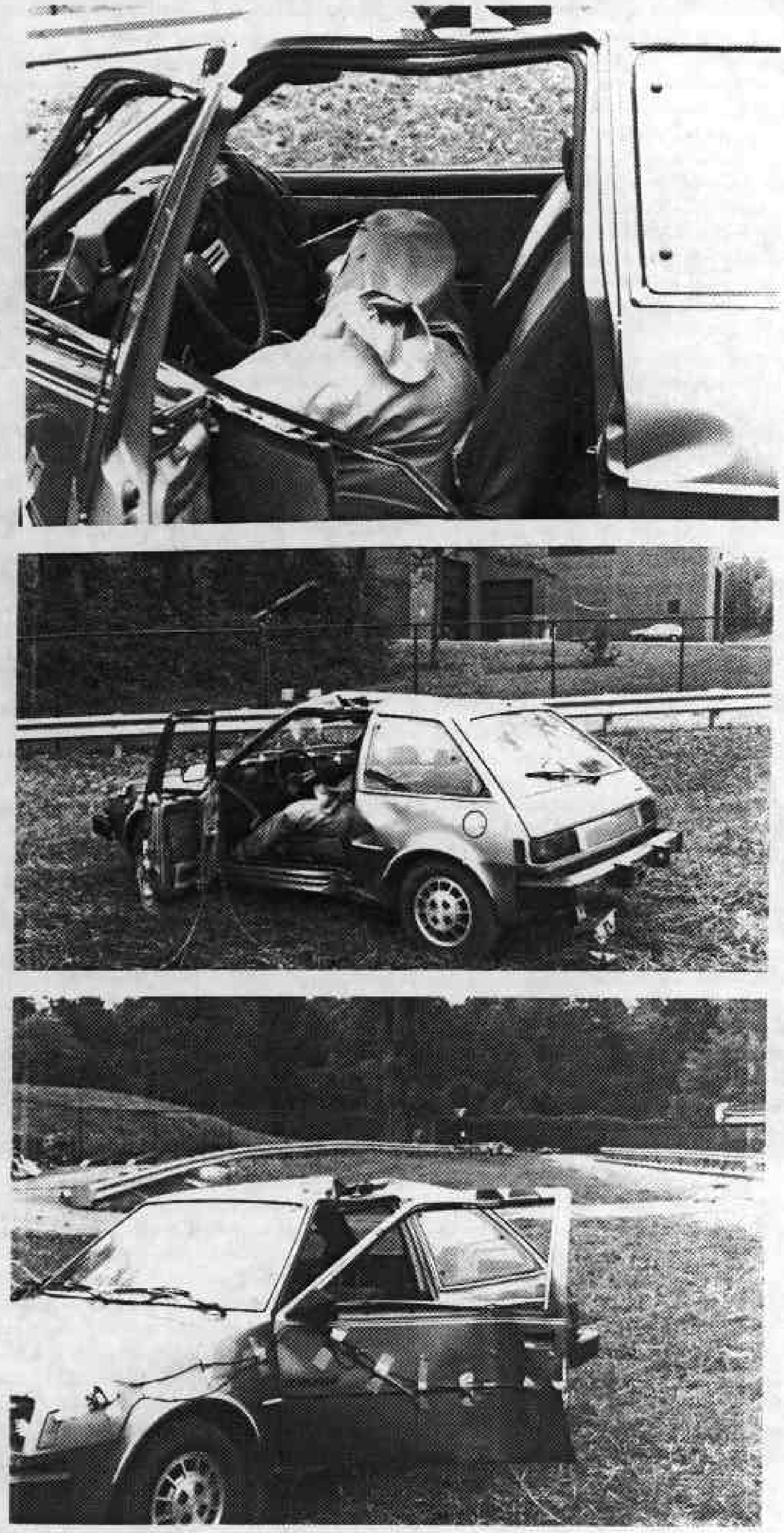


Figure 3 (Con't). Post-Test Photographs of Vehicle

Table 7

Residual Vehicle Crush

C1	= 0.0"	L	= 60.0"
C2	= 1.5"	D	= -18.0"
C3	= 9.0"		
C4	= 6.2"		
C5	= 3.0"		
C6	= 0.0		
Max	= 10"		

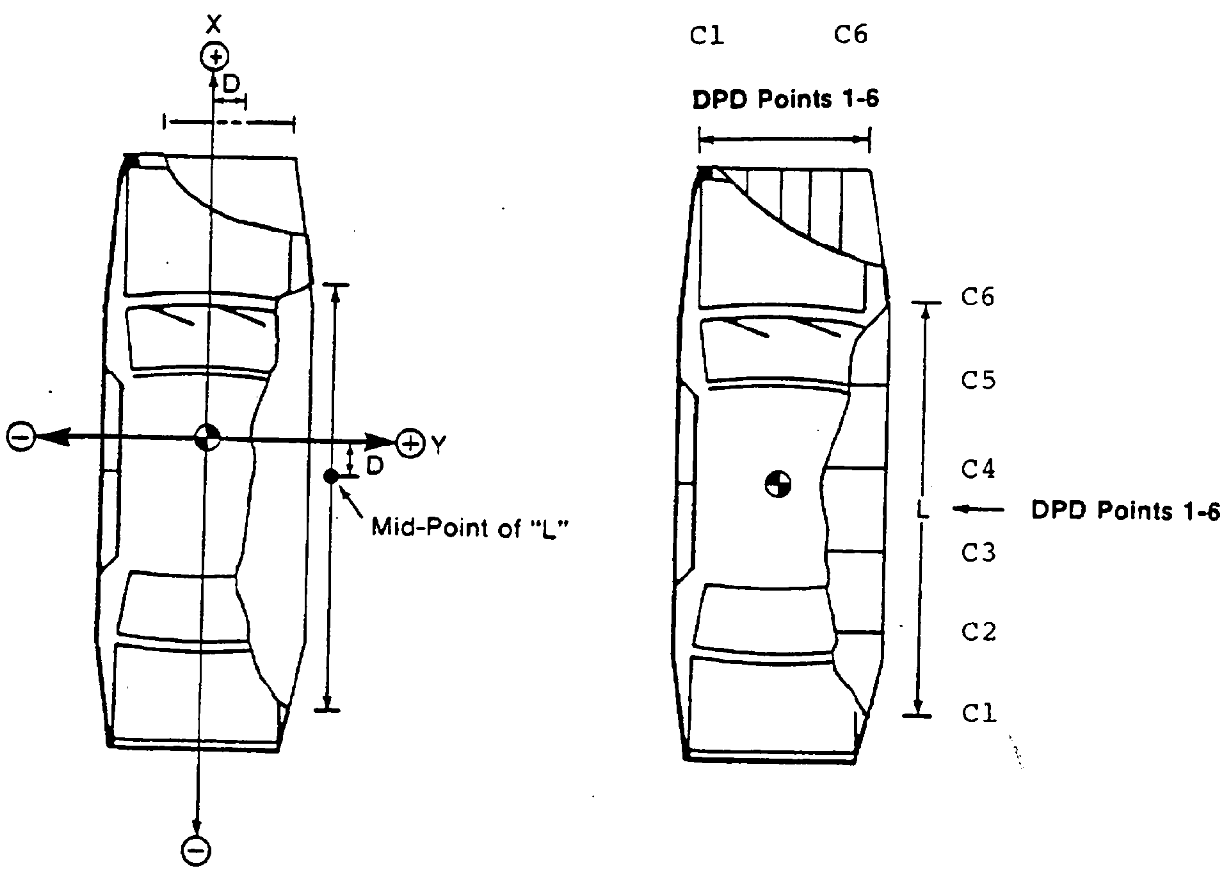


Figure 4. NHTSA Vehicle Damage Measurements

7.0 TEST ANALYSIS

Data from this test were evaluated using several techniques. The pre-impact speed was determined from the high speed film information. The signals from the accelerometers mounted at the center of gravity of the vehicle were debiased and filtered at SAE Class 60 and integrated to yield the change in the speed of the vehicle during the test in accordance with TRC 191. Those signals were also filtered at SAE Class 180 and processed to yield the associated occupant injury parameters in accordance with NCHRP 230.

The data from the triaxial accelerometer sensor assembly in the head of the test dummy was filtered at SAE Class 1000 and used to evaluate the HIC. The data obtained from the triaxial accelerometer sensor assemblies located in the upper spine of the occupant was filtered at SAE Class 180 and was used to evaluate severity indices and maximum sustained accelerations experienced by the occupant. The data obtained from the accelerometers located on the ribs of the occupant were filtered at SAE Class 180. In addition, thoracic injury parameters associated with side impact conditions were analyzed using NHTSA techniques to determine side impact occupant injury.

7.1 IMPACT VELOCITY ANALYSIS

The speed that the test vehicle impacted the luminaire support was determined from the high speed film and speed trap. Results from the speed analysis of the film data are contained in Table 8.

Table 8

Test Vehicle Impact Speed Evaluation
Using High Speed film Analysis

Camera	Position	Impact Speed (ft/sec)	Impact Speed (mph)
1	Right Side	43.2	29.45

A speed trap was installed to measure the speed of the vehicle as it left the end of the mono-rail. During this test the speed trap indicated a speed of 31.5 mph. Assuming a slide distance of 5.5 ft and a coefficient of .8, the scrub off energy is computed to be 9.6 kip ft. Subtracting this from the kinetic energy at the end of the rail and then computing the speed at the end of the slide zone produces an impact speed of 43.0 ft/sec. This is in agreement with the film data and thus confirms the film measurements.

Based upon the results of this analysis, the speed of the vehicle upon impacting the support was 29.45 mph (13.2 m/sec).

7.2 ANALYSIS OF VEHICLE MOUNTED ACCELEROMETERS

The data collected from the accelerometers mounted to the vehicle were filtered at SAE Class 60 and 180 per TRC 191 and NCHRP 230 requirements, respectively. The acceleration traces obtained with the use of the SAE Class 60 (f_c = 100 Hz) filtering technique are presented in Figures A1 through A3. The acceleration traces obtained with the use of the SAE Class 180 (f_c = 300 Hz) filtering technique are presented in Figures A4 through A6. Figure A7 presents the lateral acceleration data collected using the FOIL data system. This is presented since the y-axis accelerometer failed. Figure A8 presents the impact marker channel. Figures A9 and A10 contain the yaw rate gyro data filtered at 100 Hz and 10 Hz (SAE Class 60 and 6). Figure A11 presents the yaw angle. Figures A12 and A14 present this same data for the roll axis.

The resulting change in velocity and momentum change of the vehicle based upon integrating the lateral Class 60 acceleration signal in the fixed vehicle coordinate system was 8.96 ft/sec and 559 lb-sec, respectively. This does not account for the tire sliding forces since the accelerometer signal was debiased during the slide zone. The approximate change in velocity due to the sliding is 2.5 ft/sec. Thus the overall velocity change and momentum change of the vehicle due to the pole and tire sliding are 11.46 ft/sec and 715 lb-sec.

Analysis of the impact velocity of a hypothetical front seat passenger against the vehicle interior, calculated from the vehicle lateral Class 180 acceleration yielded the results shown in Table 9. Using the standard one foot flail distance, a hypothetical front seat occupant would have impacted the interior of the vehicle in the lateral direction at an approximate impact velocity of 9.11 ft/sec (2.78 m/s) based upon data filtered at SAE Class 180. This lateral impact velocity is within the design limit of 20 ft/sec (6.10 m/s) specified for other forms of highway safety appurtenances in NCHRP 230. However, the actual impact velocity of the occupant with the interior of vehicle was approximately 44 ft/sec (13.4 m/s) since the occupant impacted the area where the luminaire support was deforming the interior of the vehicle compartment.

The highest ridedown acceleration after the hypothetical front seat passenger impacted the interior of the vehicle was -2.28 g's using a 10 ms average of the lateral acceleration data filtered at SAE Class 180. This ridedown deceleration is within the design limits of 15 g's specified in NCHRP 230.

The difference in the results for the hypothetical and anthromorphic occupant are due to the fact that the passenger compartment conformed to the struck object in the lateral impact case and remains generally intact for the frontal impact situation.

Table 9

Change in Velocities and Ride Down Acceleration From Analysis of Class 180 Data Using NCHRP 230 Technique

Flail Distance	Change in Velocity (ft/sec)	Ride Down Acceleration (g's)
100 ft	- 9.11	-1.50
.54 ft	- 7.61	+3.79

Based upon this analysis NCHRP 230 indicates that the accident was within design limits for the hypothetical occupant and outside the design limits for the anthromorphic dummy.

7.3 LUMINAIRE TEST OBSERVABLES

The downstream speed and rotational rate of the luminaire support can be related to the third phase of the vehicle momentum change by the following:

$$\dot{x}_{cg} = \frac{1}{M_p} I_3$$

and

$$\dot{r} = \frac{D_I}{I_p} I_3$$

where

$\dot{x}_{cg}$ = Longitudinal velocity of the luminaire support c.g.,

$\dot{r}$ = Rotational rate of luminaire support

D_I = Impulse lever arm during Phase 3 = Pole (x_{cg}) - 2.5 ft = 18.5 ft

M_p = Mass of luminaire support = 12.9 slugs

I_p = Mass moment of intertia of the luminaire support = 2069 slug-ft^2

and I_3 = Momentum change occurring during Phase 3.

From the film data $\dot{x}_{cg}$ = 6.90 f/s (2.10 m/s) and $\dot{r}$ = 1.94 rad/sec. Using these two numbers the momentum change occurring during Phase 3 is given by

$$I_3 = M_p \dot{x}_{cg}$$
$$= 89 \text{ lb-sec } (394 \text{ N-s})$$

or

$$I_3 = \dot{r} \frac{I_p}{D_I}$$
$$= 216 \text{ lb-sec } (957 \text{ N-s}).$$

The average momentum change associated with the third phase of the vehicle momentum change is 152 lb-sec (675 N-s).

7.4 HEAD INJURY CRITERIA EVALUATION

The data obtained from the three accelerometers located in the head of the occupant during the test were filtered at SAE Class 1000 and combined to yield a resultant acceleration occurring during the impact event. The HIC was evaluated in accordance with the procedures outlined in FMVSS 208. The acceleration traces and resultant obtained with the use of the SAE Class 1000 (f_c = 1,650 Hz) filtering techniques are presented in Figures A15 through A18. The results of the HIC evaluation calculated for the occupant during this test is shown in Table 10. Comparing the results to the acceptable limit of 1000 indicates that the collision event was severe with the measured value exceeding the limit by about 8 times.

Table 10
Head Injury Criteria

	Driver
HIC	8026
t(Start)	.02075 sec
t(Stop)	.023375 sec
t(Duration)	.002625 sec

7.5 OCCUPANT SEVERITY INDEX EVALUATION

The T01, T12 and pelvis channels of the occupant were filtered at SAE Class 180. They were combined to yield a resultant acceleration occurring during the impact event. The severity index for the upper spine, lower spine and pelvis location was evaluated in accordance with SAE Information Report J885a. In addition, the maximum resultant acceleration whose cumulative duration is not less than 3 milliseconds was evaluated for the same location in accordance with FMVSS 208. For the upper spine the CSI was 2244 and the maximum acceleration was 169 g's at 26.3 milliseconds. These results should not be compared directly with the design limits for the severity index of 1000 and sustained acceleration level of 60g specified in FMVSS 208 since none of the accelerometers are located at the center of gravity of the upper thorax location. The CSI and max acceleration in data for the pelvis was 1469 and 198.3 g's at 23.3 milliseconds. For the T12 location the CSI was 2274 and the maximum acceleration was 214 g's at 23.8 milliseconds.

The acceleration traces and associated resultants obtained with the use of the SAE Class 180 (f_c = 300 Hz) filtering techniques are presented in Figures A19 through A22 for the upper spine (T01) location, Figures A23 through A26 for the lower spine (T12) location, Figures A27 through A30 for the pelvis and Figures A31 and A32 for the sternum location. Figures A33 through A36 present the 300 Hz filtered data for the left ribs.

7.6 THORACIC INJURY EVALUATION

The data obtained from the accelerometer mounted at the T12Y and LURY locations within the thorax of the occupant was filtered using NHTSA FIR filter and presented in Figure A37 through A39.

The Thoracic Trauma Index (TTI) was computed using the following relationship:

$$TTI = Age + .5*(T12Y + LURY)*(Mass/165)$$

The Age was assumed to be Zero and the Mass 165.

The peak data for the LURY accelerometers and the T12Y accelerometer is as follows:

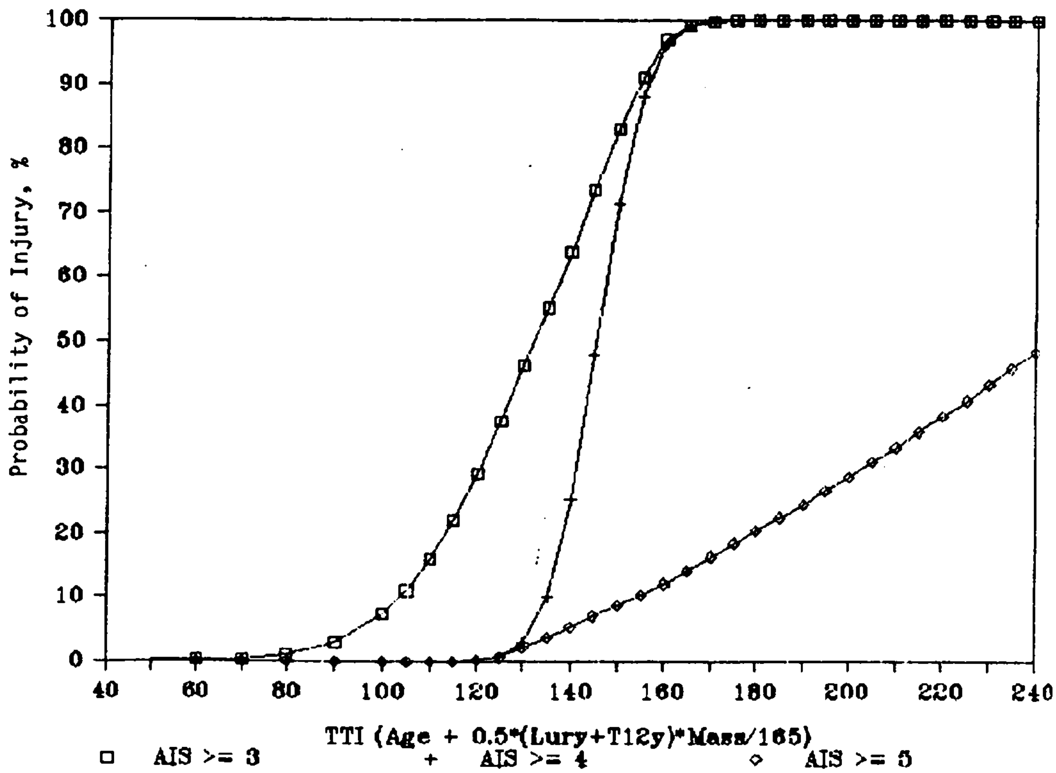
LURYG1	232.0
LURYGA	217.6
T12Y	160.3

The average acceleration at the LURY location is 224.5. This is averaged with the T12Y data to obtain the TTI. The TTI index is 192. This value produces a 100% probability of injury of an AIS greater than 3, 100% probability of injury of an AIS greater than 4 and a 28% probability of injury of an AIS greater than 5 for age 0. See Figure 5 for TTI values.

7.7 <u>VEHICLE ENERGY BALANCE</u>

An energy balance was performed to determine the various components and their magnitude. Prior to impact all the energy is in the moving vehicle and stored as kinetic energy. Upon an impact, such energy is converted to work on the vehicle and pole and into rotating the vehicle. The following is a list of these sources:

1. Remaining kinetic energy
2. Rotational energy of vehicle
3. Work done in crushing vehicle
4. Friction of sliding tires
5. Work done in breaking slip base
6. Rotational energy in pole
7. Translational energy in pole.



From Ref 12

Figure 5. Thoracic Trauma Index Scale

Impact Energy:

$KE_I = .5MV_I^2$

Where M = Vehicle mass = 2010/32.2 = 62.4 slugs

V = Impact speed = 43.2 ft/sec

KE = 58.2 kip-ft

Post Impact Energy Sources

1) Exit kinetic Energy

$KE_E = .5MV_E^2$

Where V_E = exit velocity

= V_I - Reduction

= 43.2 - 8.90 = 34.24 ft/sec

KE_E = 36.6 kip-ft.

2) Rotational energy of vehicle

$RE_V = .5\ I_V W_V^2$

Where: I_V = Yaw inertia of vehicle = 852 slug-ft^2

W_V = rotational rate

= 47.5/57.3 rad/sec (see Figure A9)

= .829

RE_V = .3 kip-ft

3) Work done on crushing vehicle.

In test 1469-SI#3-85 a Dodge Colt was impacted into a rigid pole. The force-displacement characteristic was measured during that test. This data was used to determine the work done on the side of vehicle as a function of crush depth. This is shown in Figure 6.

Work at 10" crush = 4.3 kip-ft

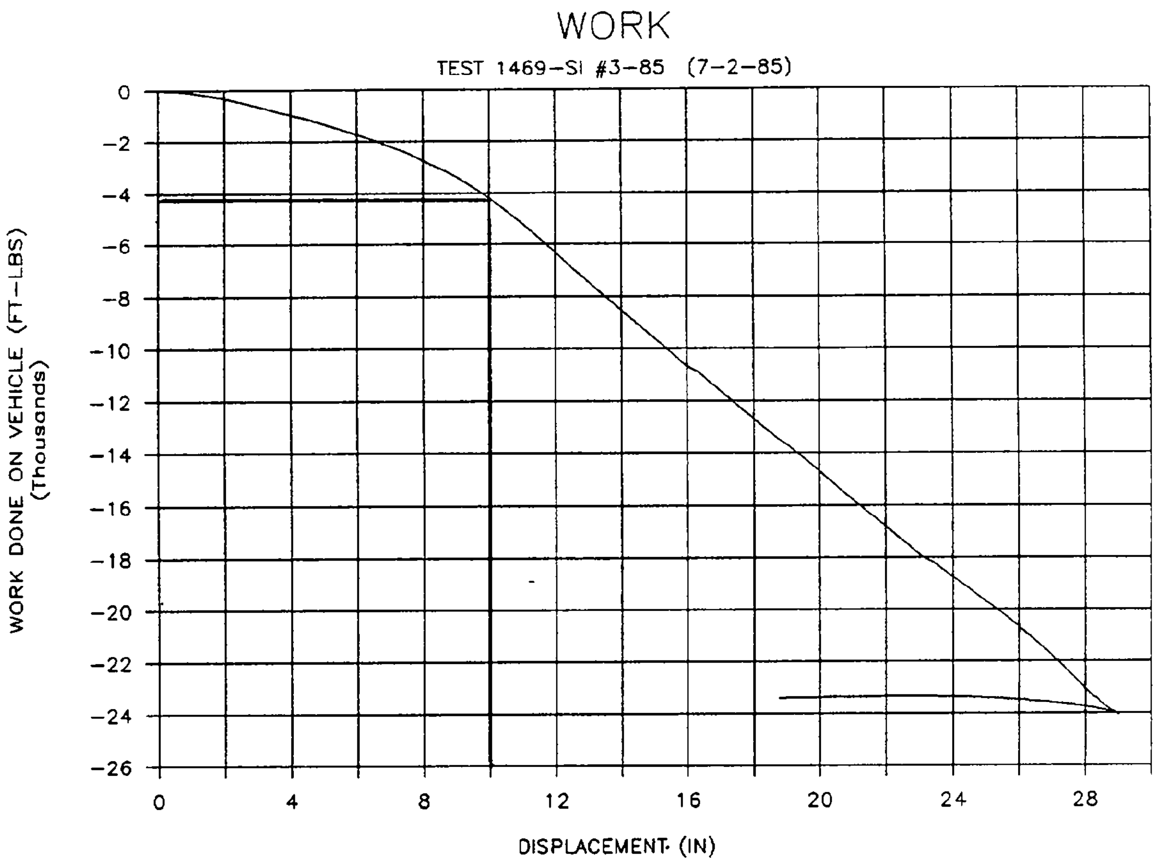


Figure 6. Crush Energy For Dodge Colt During Side Impact

4) Tire friction

Work = fWd

Where f = tire sliding friction = .8

W = vehicle weight = 2010 lbs

d = 6 ft (one car width)

Tire work = 9.6 kip-ft

5) Slip base work

Work = fLd

Where f = friction of steel on steel = .2

L = clamp load = 14000 x 3 = 42,000 lbs

d = Slide distance to release = .5"/12 = .0417 ft

Base work = .3 kip-ft

6) Rotational energy of pole

$KE_{PR} = .5 I_P W_P^2$

Where I_p = Inertia of pole = 2070 slug-ft^2

W_p = Rotational rate of pole = 1.94 rad/sec

KE_{PR} = 3.9 kip-ft

7) Translational energy of pole

$KE_{PT} = .5 M_p V_p^2$

Where M_p = pole mass = 416/32.2 = 12.9 slugs

V_p = pole velocity = 6.9 ft/sec

= .3 kip-ft

Totaling the post impact sources the following is determining:

1.	36.6	kip-ft
2.	.3	kip-ft
3.	4.3	kip-ft
4.	9.6	kip-ft
5.	.3	kip-ft
6.	3.9	kip-ft
7.	.3	kip-ft
Total	55.3	kip-ft

This is in good agreement with the energy upon impact of 58.2 kip-ft.

8.0 SAFETY ASSESSMENT OF TEST

This section of the report assesses the safety performance of the luminaire and vehicle during the impact. The assessment is made in accordance with NCHRP 230 shown in Figure 7.

STRUCTURAL ADEQUACY

The test pole readily activated in the predicted manner. There was, however, severe penetration of the passenger compartment due to the nature of the test. No undue hazard was generated to other traffic.

OCCUPANT RISK

Occupant risk is rated near to fatal. This was due to the impact location of the pole and intrusion of the pole into the passenger compartment. HIC, CSI and max chest accelerations exceeded the limits considerably, with HIC almost twice the limit. The thoratic injury also indicated a very severe accident rating with a high probabilities of an AIS greater than 3, 4, or 5.

The NCHRP 230 flail space model data was evaluated and found to be less than the limit and design values. The flail space model was designed to predict injury in cases where no intrusion occurs. Since severe intrusion occurred at the driver's seat, the NCHRP 230 flail space data is not very meaningful to predict injury.

VEHICLE TRAJECTORY

Vehicle trajectory after the test was acceptable, with some little, if any, encroachment of the adjacent traffic lanes.

Evaluation Factors		Evaluation Criteria	Applicable to Minimum Matrix Test Conditions (see Table 3)
Structural Adequacy	A.	Test article shall smoothly redirect the vehicle; the vehicle shall not penetrate or go over the installation although controlled lateral deflection of the test article is acceptable.	10, 11, 12, 30, 40
	B.	The test article shall readily activate in a predictable manner by breaking away or yielding.	60, 61, 62, 63
	C.	Acceptable test article performance may be by redirection, controlled penetration, or controlled stopping of the vehicle	41, 42, 43, 44, 45, 50, 51, 52, 53, 54
	D.	Detached elements, fragments or other debris from the test article shall not penetrate or show potential for penetrating the passenger compartment or present undue hazard to other traffic.	All
Occupant Risk	E.	The vehicle shall remain upright during and after collision although moderate roll, pitching and yawing are acceptable. Integrity of the passenger compartment must be maintained with essentially no deformation or intrusion.	All
	F.	Impact velocity of hypothetical front seat passenger against vehicle interior, calculated from vehicle accelerations and 24 in. (0.61m) forward and 12 in. (0.30m) lateral displacements, shall be less than: Occupant Impact Velocity-fps Longitudinal: $40/F_1$ — Lateral: $30/F_2$ and vehicle highest 10 ms average accelerations subsequent to instant of hypothetical passenger impact should be less than: Occupant Ridedown Accelerations—g's Longitudinal: $20/F_3$ — Lateral: $20/F_4$ where F_1, F_2, F_3, and F_4 are appropriate acceptance factors (see Table 8, Chapter 4 for suggested values).	11, 12, 41, 42, 43, 44, 45, 50, 51, 52, 54, 60, 61, 62, 63
	G.	(Supplementary) Anthropometric dummy responses should be less than those specified by FMVSS 208, i.e., resultant chest acceleration of 60g, Head Injury Criteria of 1000, and femur force of 2250 lb (10 kN) and by FMVSS 214, i.e., resultant chest acceleration of 60 g, Head Injury Criteria of 1000 and occupant lateral impact velocity of 30 fps (9.1 m/s).	11, 12, 41, 42, 43, 44, 45, 50, 51, 52, 54, 60, 61, 62, 63
Vehicle Trajectory	H.	After collision, the vehicle trajectory and final stopping position shall intrude a minimum distance, if at all, into adjacent traffic lanes.	All
	I.	In test where the vehicle is judged to be redirected into or stopped while in adjacent traffic lanes, vehicle speed change during test article collision should be less than 15 mph and the exit angle from the test article should be less than 60 percent of test impact angle, both measured at time of vehicle loss of contact with test device.	10, 11, 12, 30, 40, 42, 44, 53
	J.	Vehicle trajectory behind the test article is acceptable.	41, 42, 43, 44, 45, 50, 51, 53, 54, 60, 61, 62, 63

Figure 7. NCHRP 230 Safety Evaluation Guidelines

OVERALL RATING

This pole/vehicle combination with the discussed impact conditions would have to be rated unacceptable due to the intrusion and very high occupant injury measurements.

9.0 REFERENCES

1 "Side Impact Test Plan", Rev. 1, J. Hinch, FHWA Contract DTFH61-86-2-00047, November 86.

2. "Test Results Report, Bogie Testing," Task G, Hinch, J.A., Manhard, G. A., and Owings, R. P., Contract DTFH61-81-C-00036, July 1985

3. "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances," National Cooperative Highway Research Program Report 230, March 1981.

4. "Recommended Procedures for Vehicle Crash Testing of Highway Appurtenances," Transportation Research Circular 191, February 1978.

5. "Occupant Crash Protection in Passenger Cars, Multipurpose Passenger Vehicles, Trucks and Buses," Code of Federal Regulations, Title 49, Transportation, Part 571, Motor Vehicle Safety Standard No. 208.

6. "Vehicle Damage Scale for Traffic Accident Investigators," Traffic Accident Data Project Technical Bulletin No. 1, National Safety Council, 1971.

7. "Collision Deformation Classification," Recommended Practice J224a, Society of Automotive Engineers, New York, February 1971.

8. "Human Tolerance To Impact Conditions As Related to Motor Vehicle Design," Information Report J885a, Society of Automotive Engineers, New York, December 1966.

9. "Standard Plans," California Department of Transportation, January 1981, pp. 209.

10. "Dynamic Crash Test Information Reference Guide," Version II, Automated Sciences Group, Inc., Silver Spring, Maryland, January 1, 1982.

10. "Instrumentation for Impact Tests," Recommended Practice J211b, Society of Automotive Engineers, New York, December 1974.

12. "Safer Sign and Luminaire Supports," Owings, R. P., et al, Final Report, ENSCO, Inc., Contract No. DOT-FH-11-8118, October 1975.

13. "Development of Dummy and Injury Index for NHTSA's Thoracic Side Impact Protection Research Program," R. Eppinger, J. Marcus, and R. Morgan, SAE Report No. 840885.

APPENDIX A

DATA PLOTS

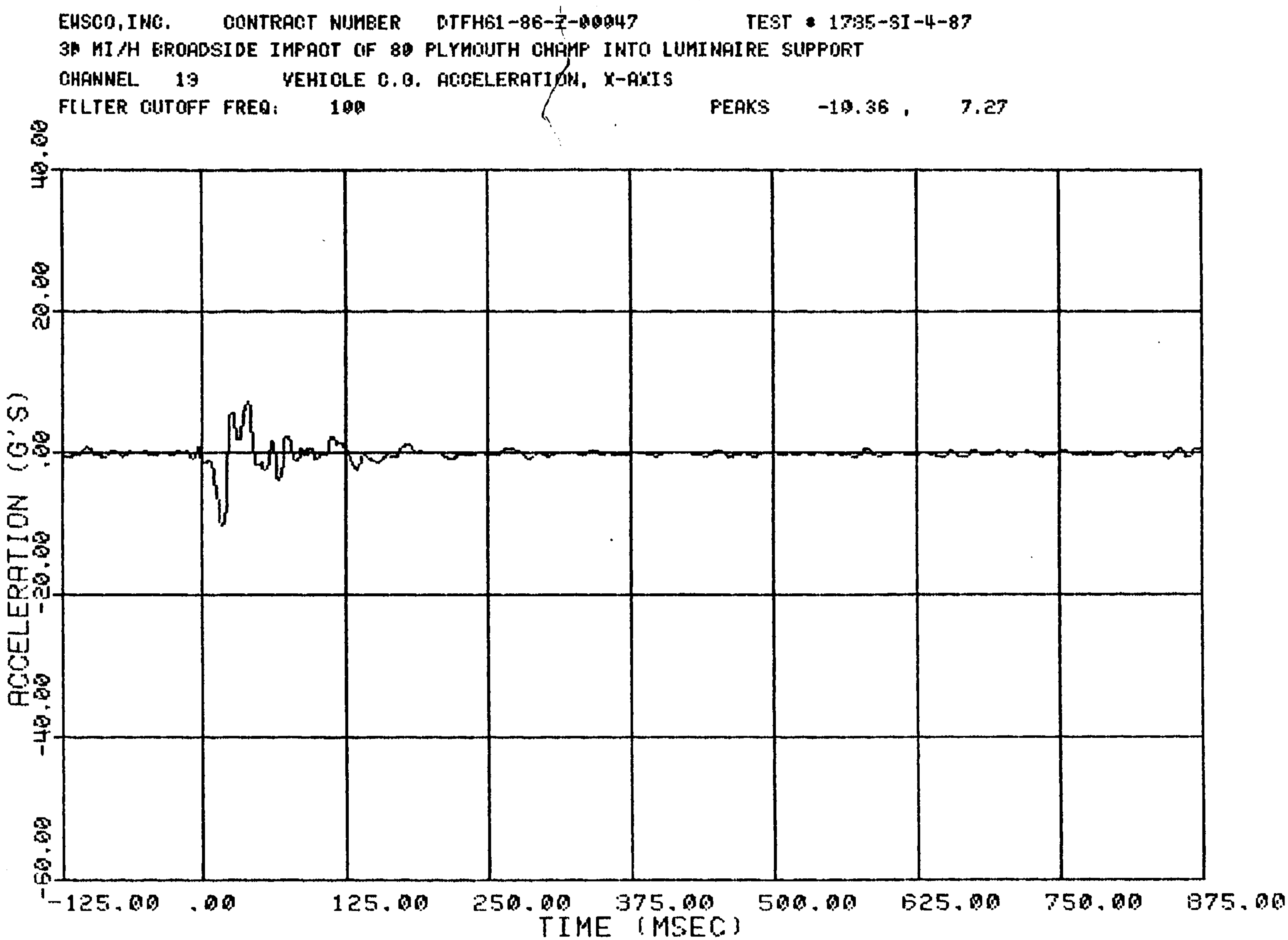


Figure A1. Vehicle Accelration, X-Axis, 100 Hz

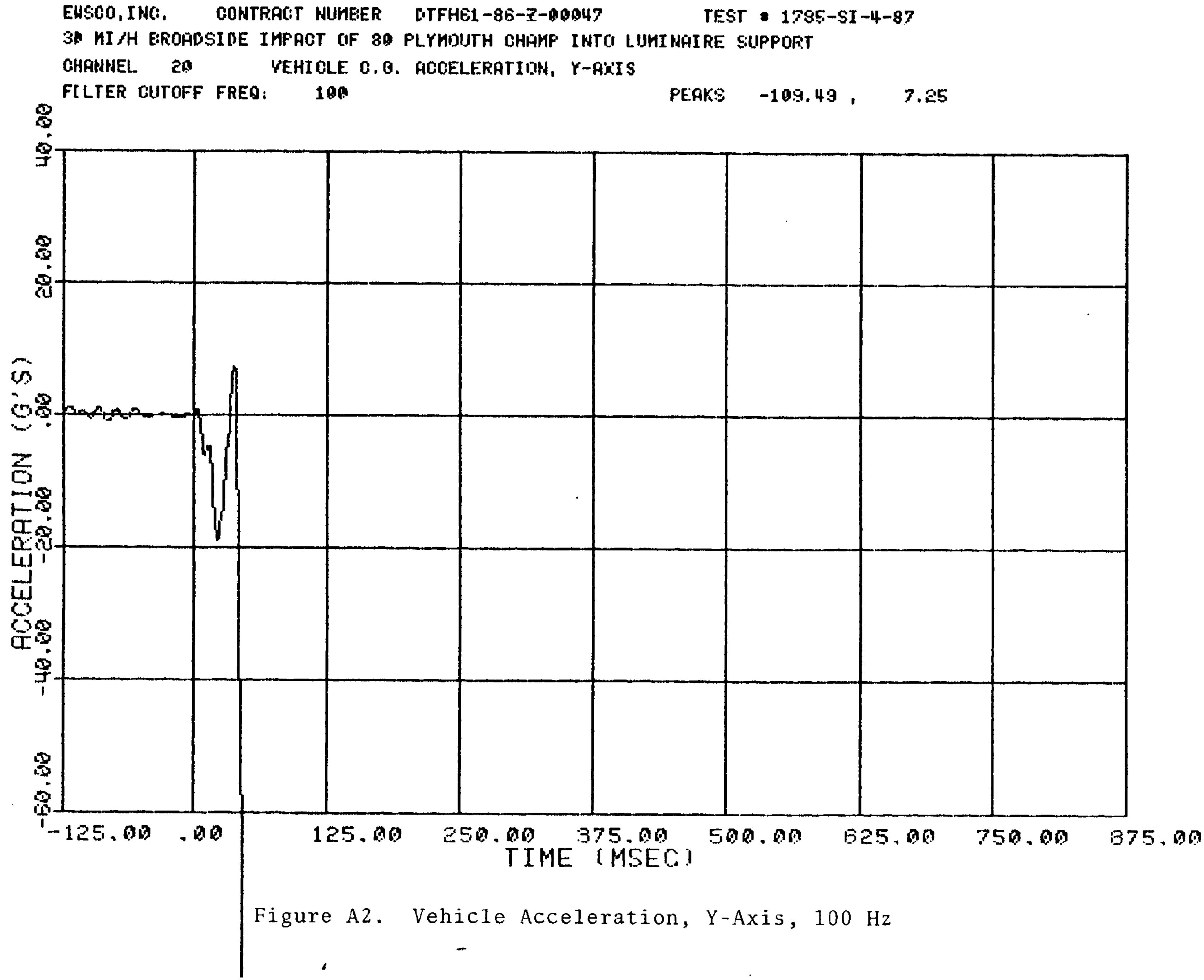


Figure A2. Vehicle Acceleration, Y-Axis, 100 Hz

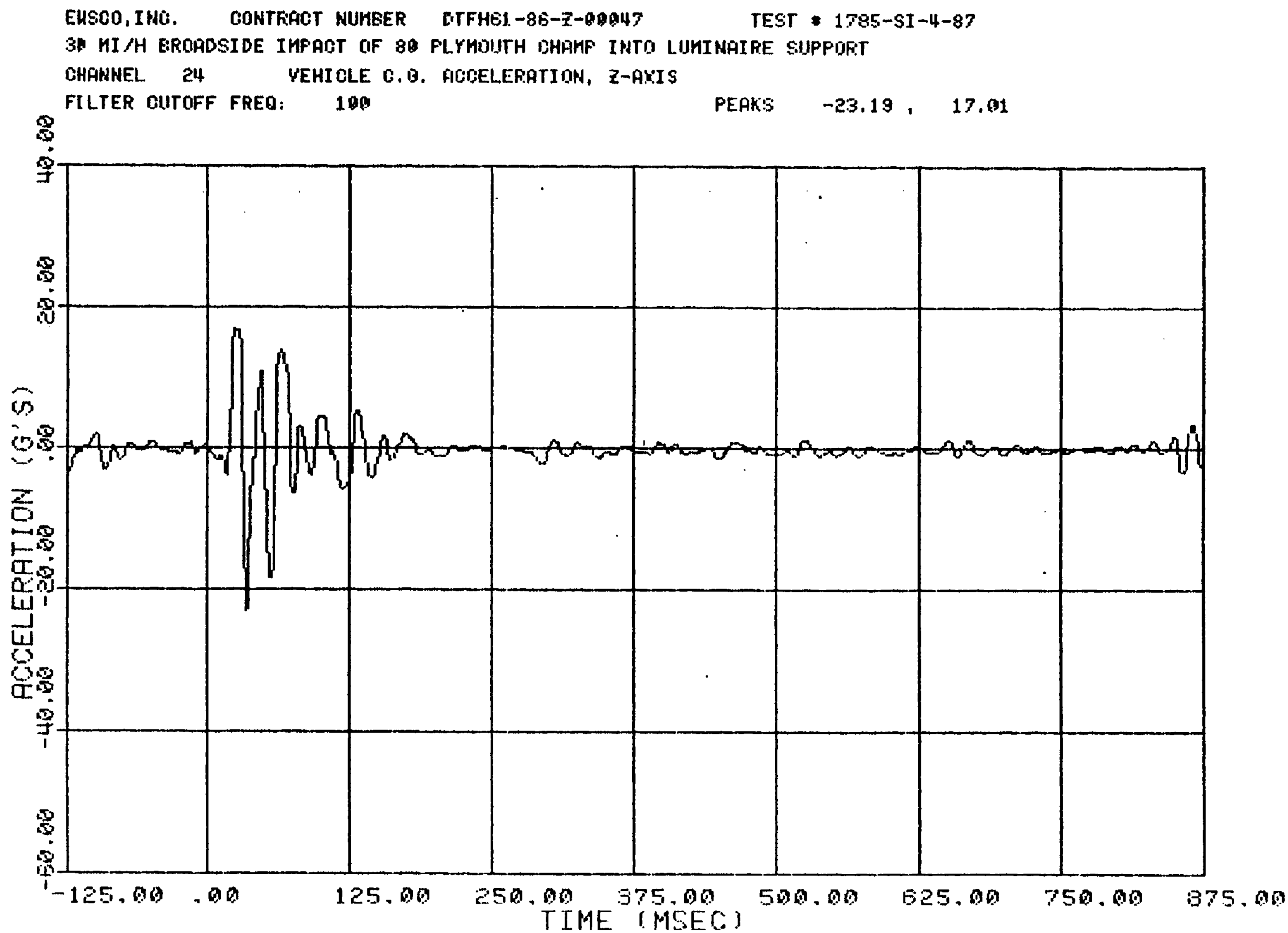


Figure A3. Vehicle Acceleration, Z-Axis, 100 Hz

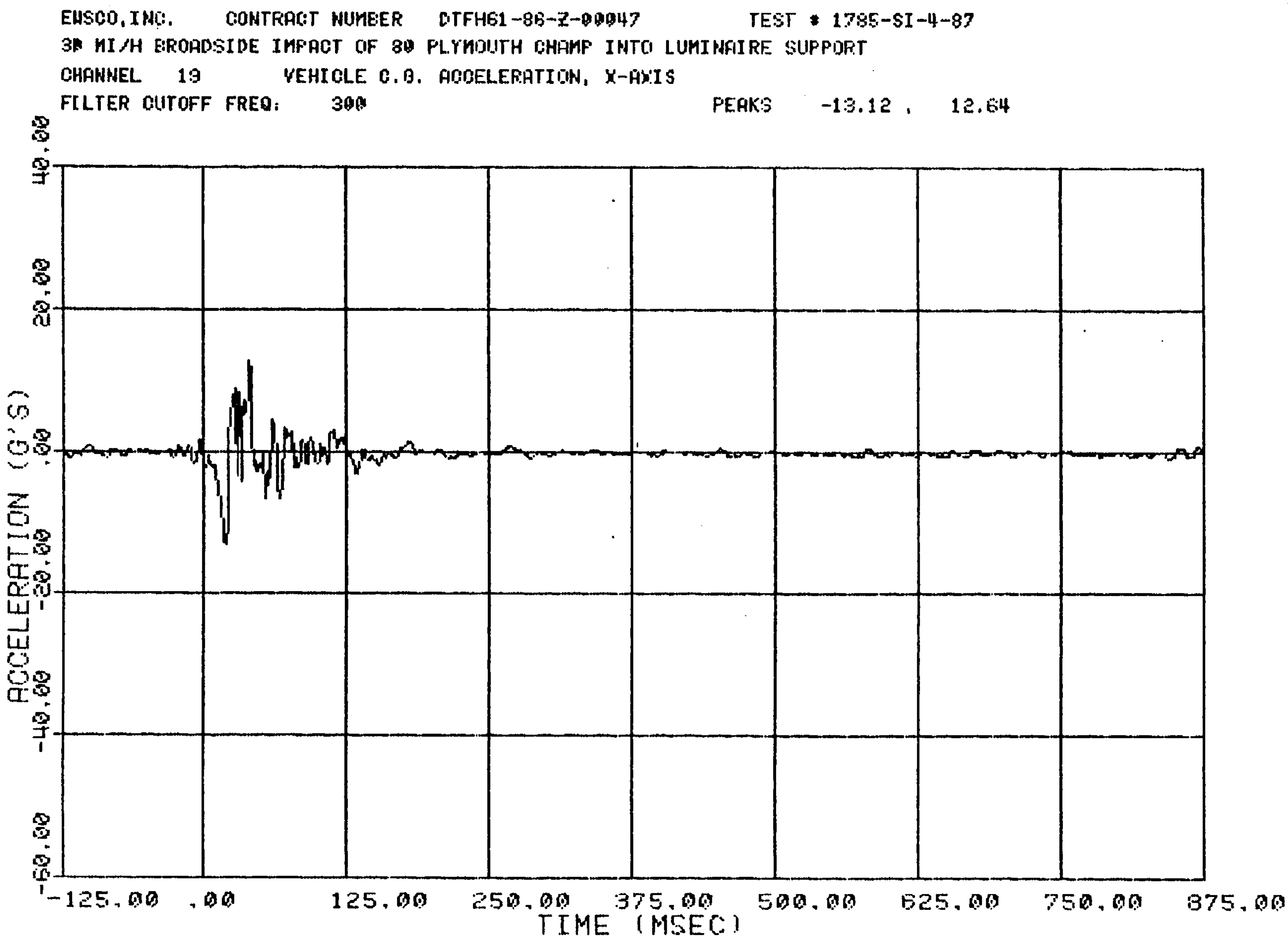


Figure A4. Vehicle Acceleration, X-Axis, 300 Hz

ENSCO,INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-4-87
30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
CHANNEL 20 VEHICLE C.G. ACCELERATION, Y-AXIS
FILTER CUTOFF FREQ: 300 PEAKS -103.75 , 16.42

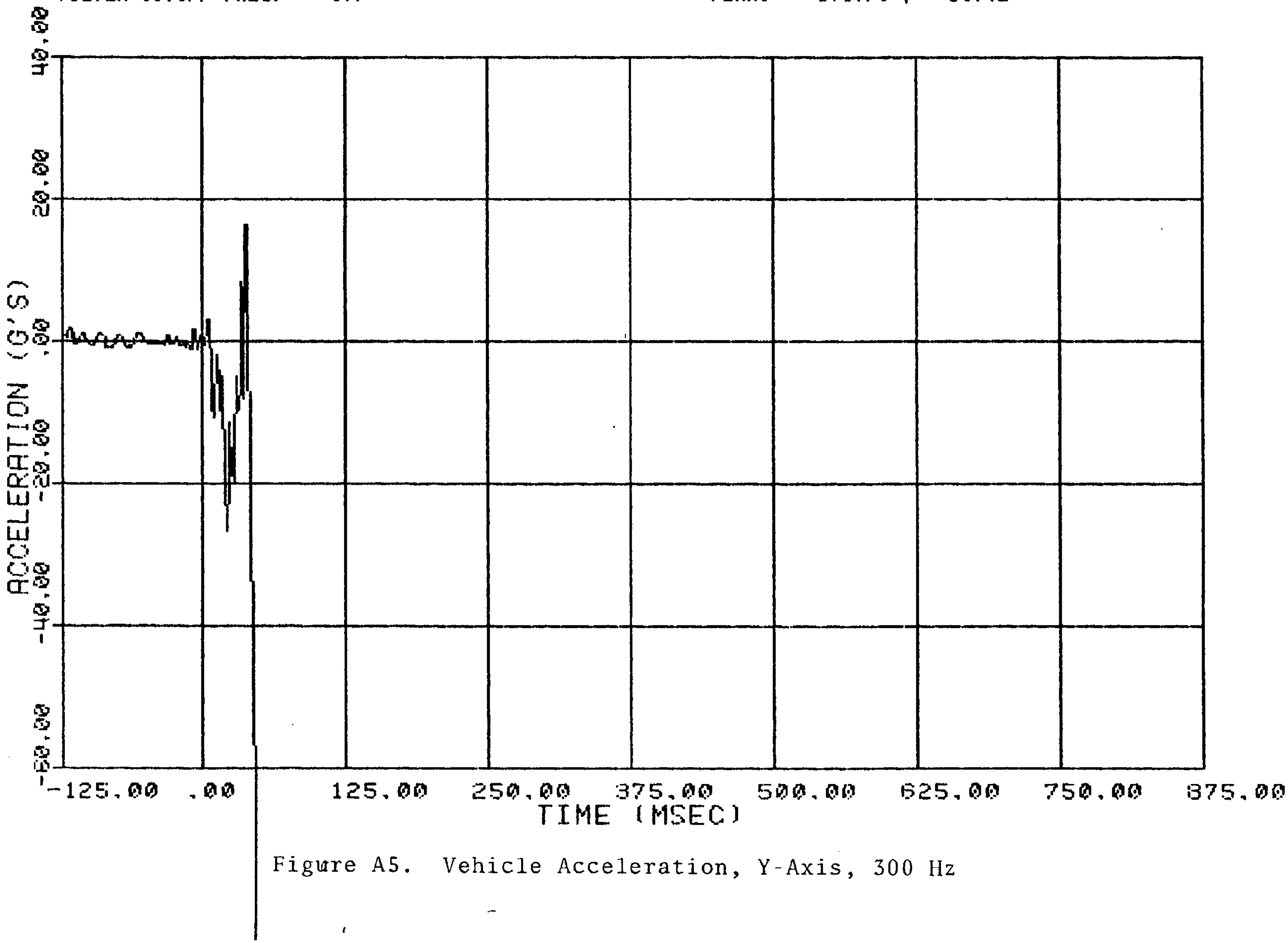


Figure A5. Vehicle Acceleration, Y-Axis, 300 Hz

EWSCO,INC.   CONTRACT NUMBER   DTFH61-86-Z-00047   TEST # 1765-SI-4-87
30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
CHANNEL 24   VEHICLE C.G. ACCELERATION, Z-AXIS
FILTER CUTOFF FREQ: 300   PEAKS -40.89 , 23.58

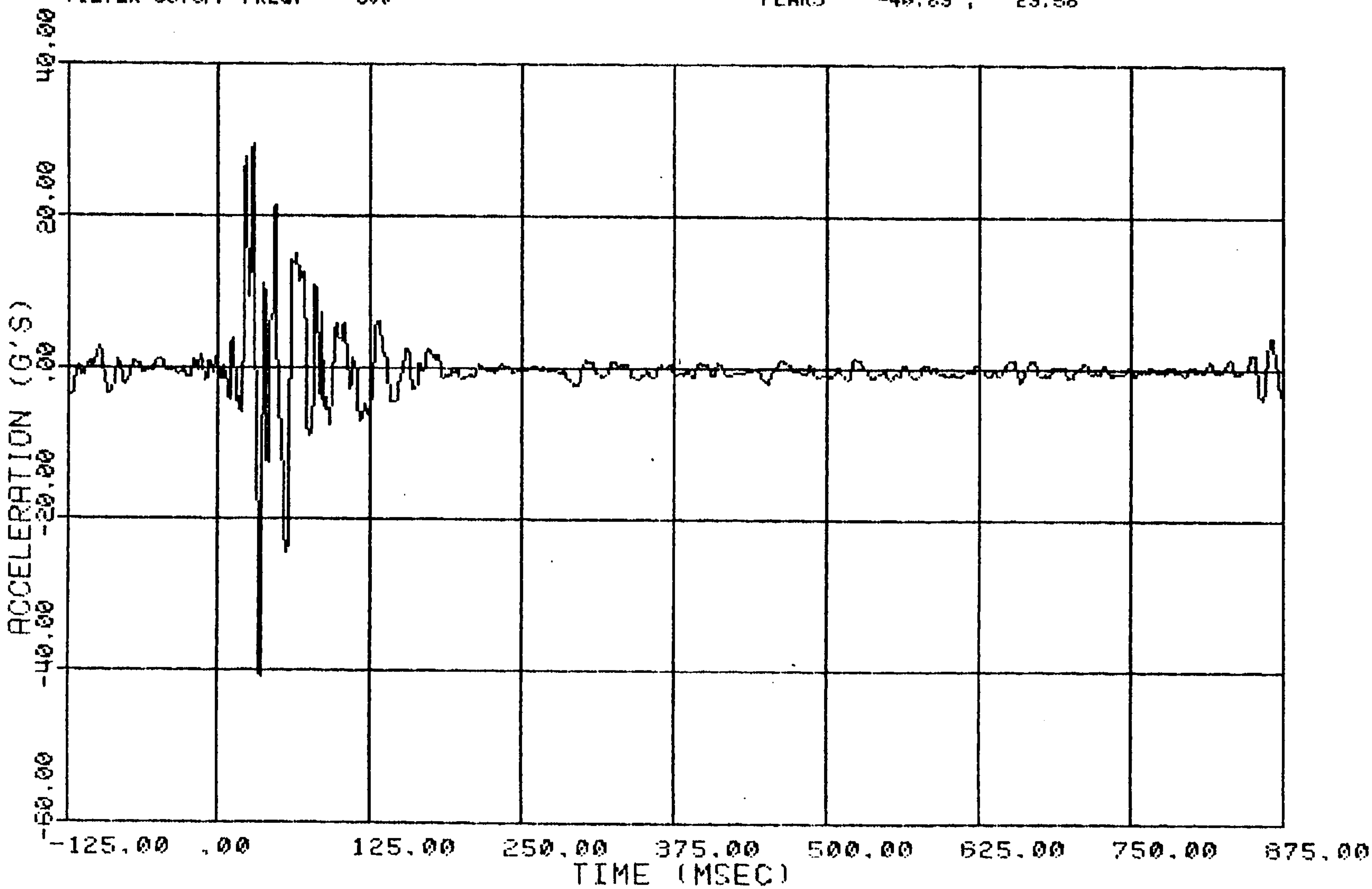


Figure A6. Vehicle Acceleration, Z-Axis, 300 Hz

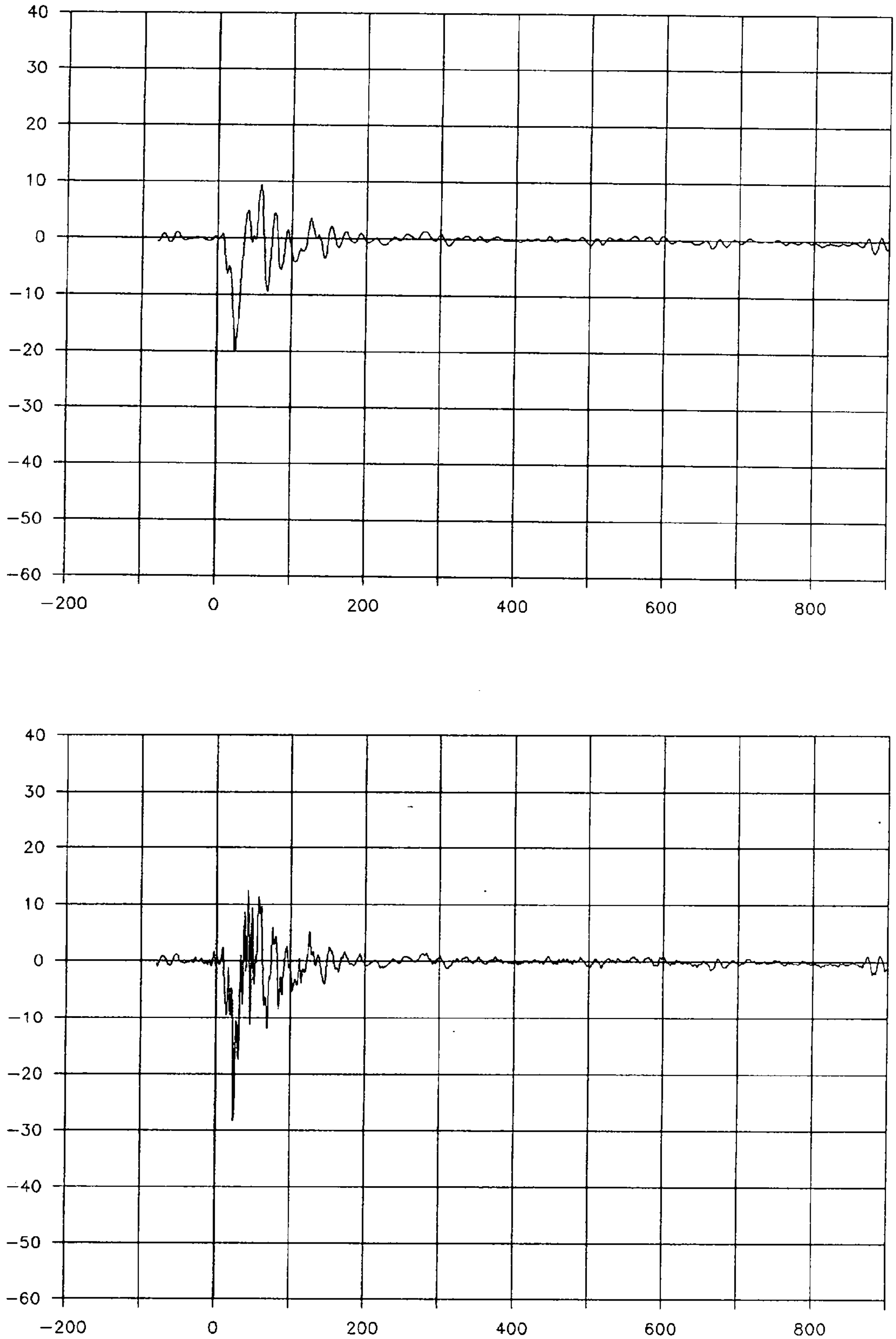


Figure A7. FOIL Vehicle Acceleration, Y-Axis, 100 Hz and 300 Hz

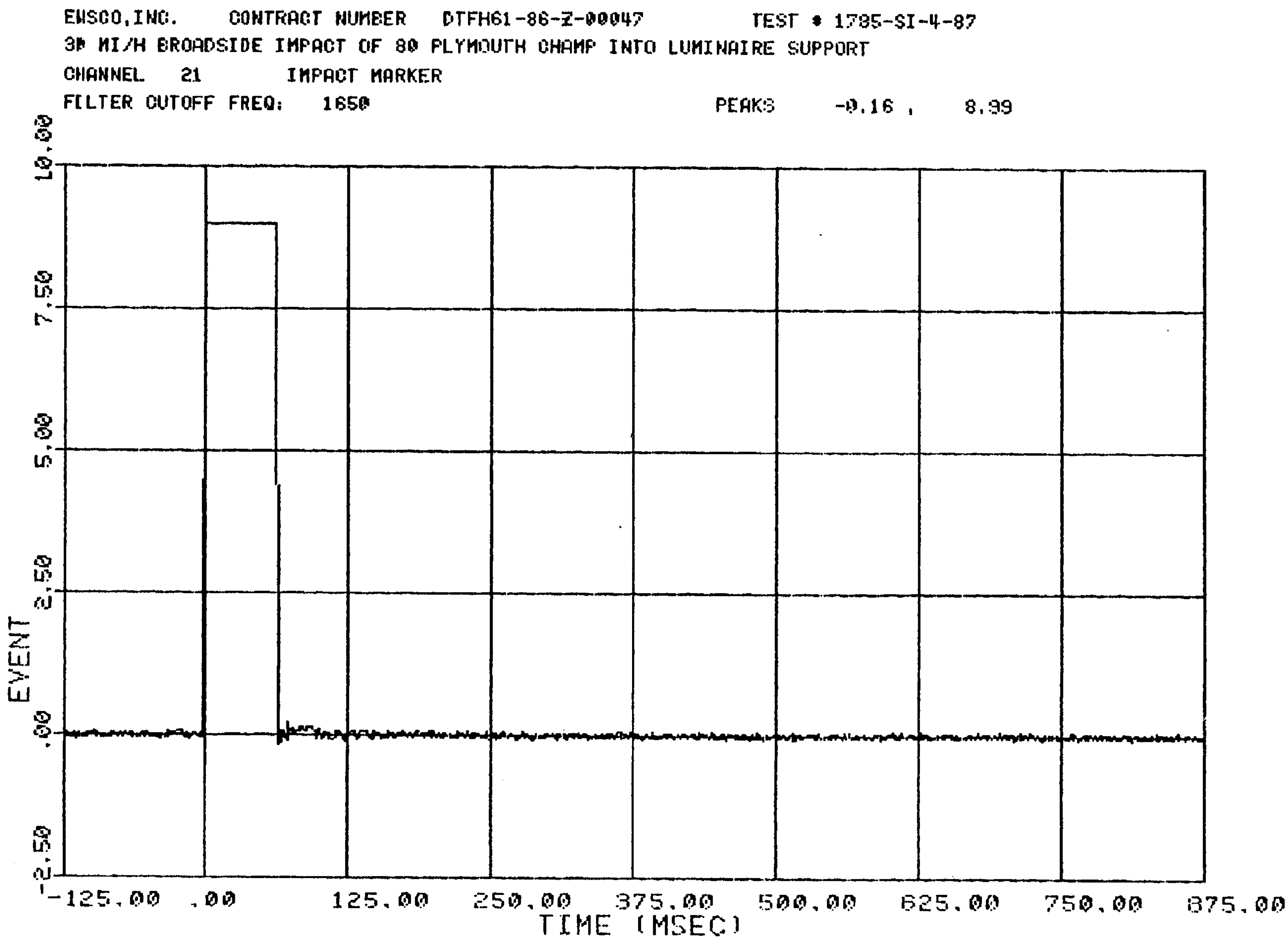


Figure A8. Event Marker, Impact

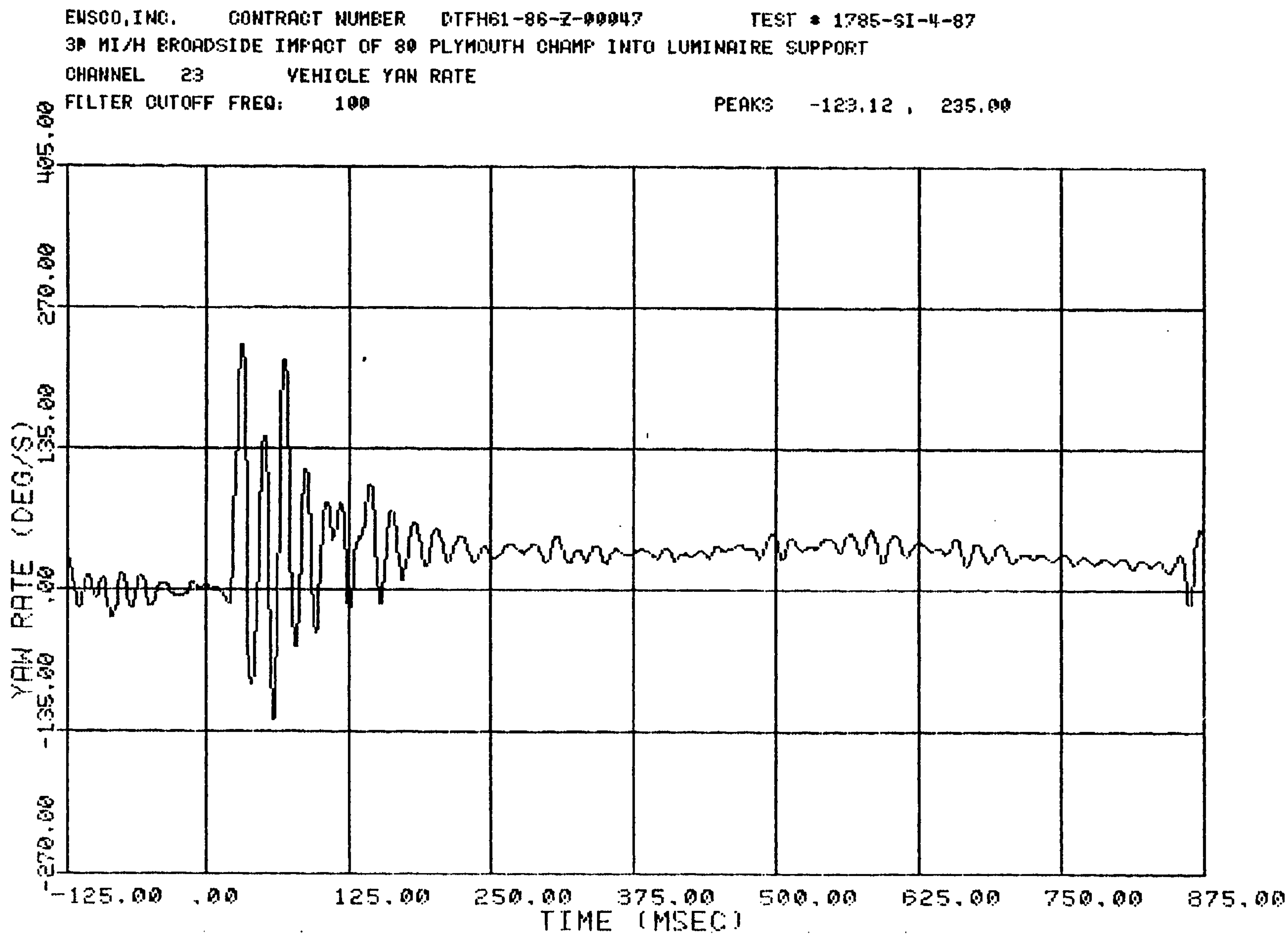


Figure A9. Vehicle Yaw Rate, 100 Hz

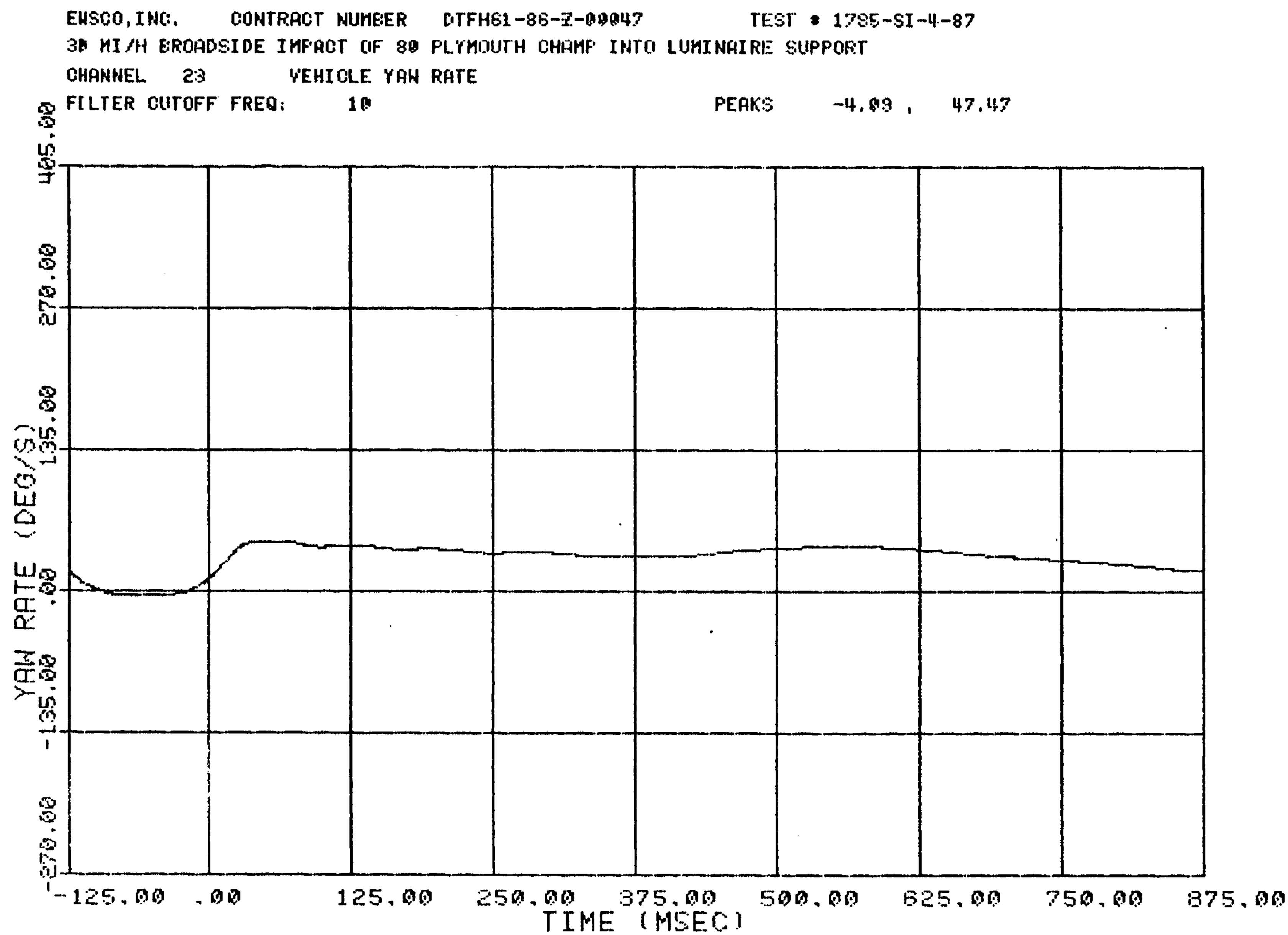


Figure A10. Vehicle Yaw Rate, 10 Hz

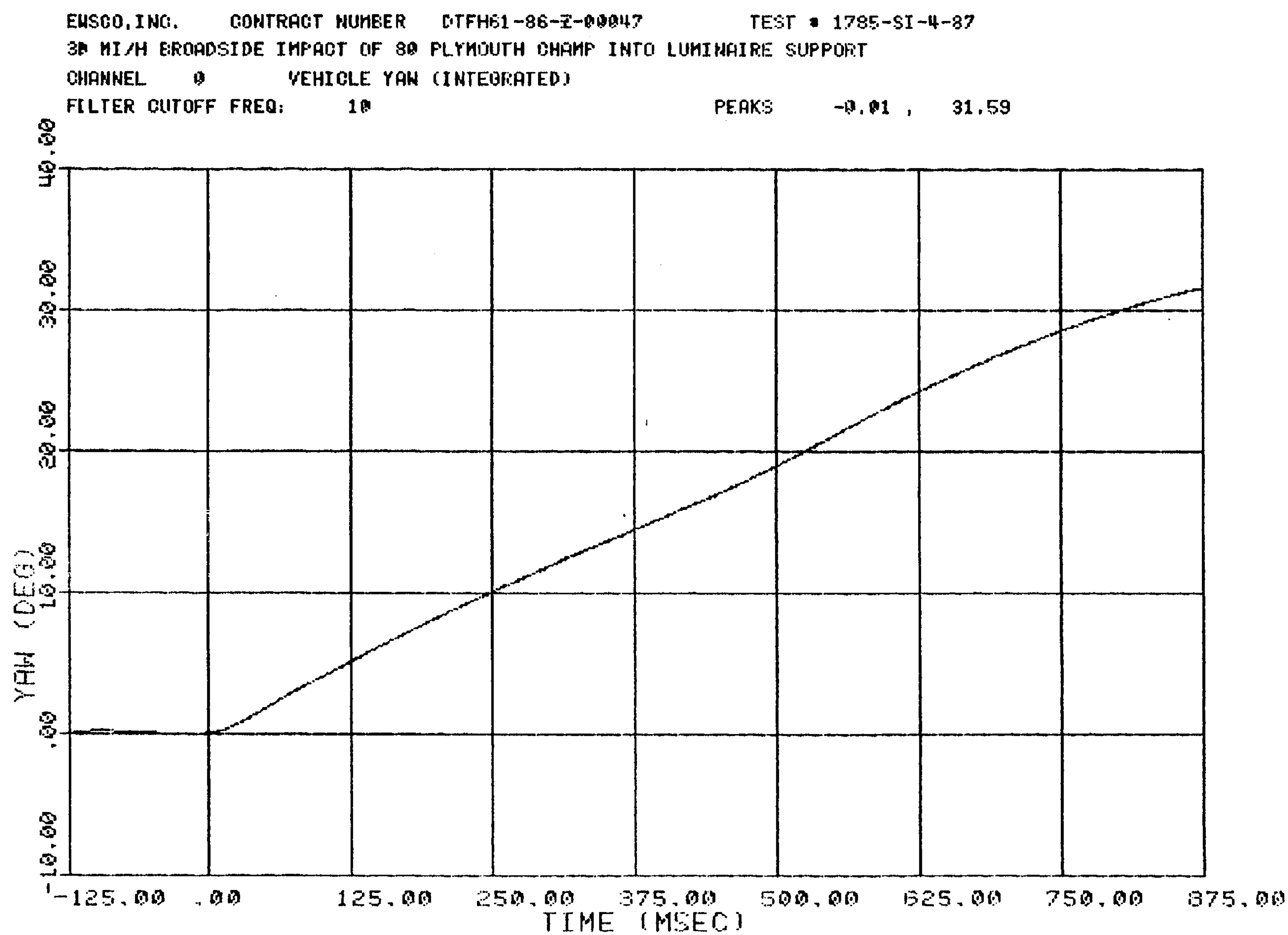


Figure A11. Vehicle Yaw, 10 Hz

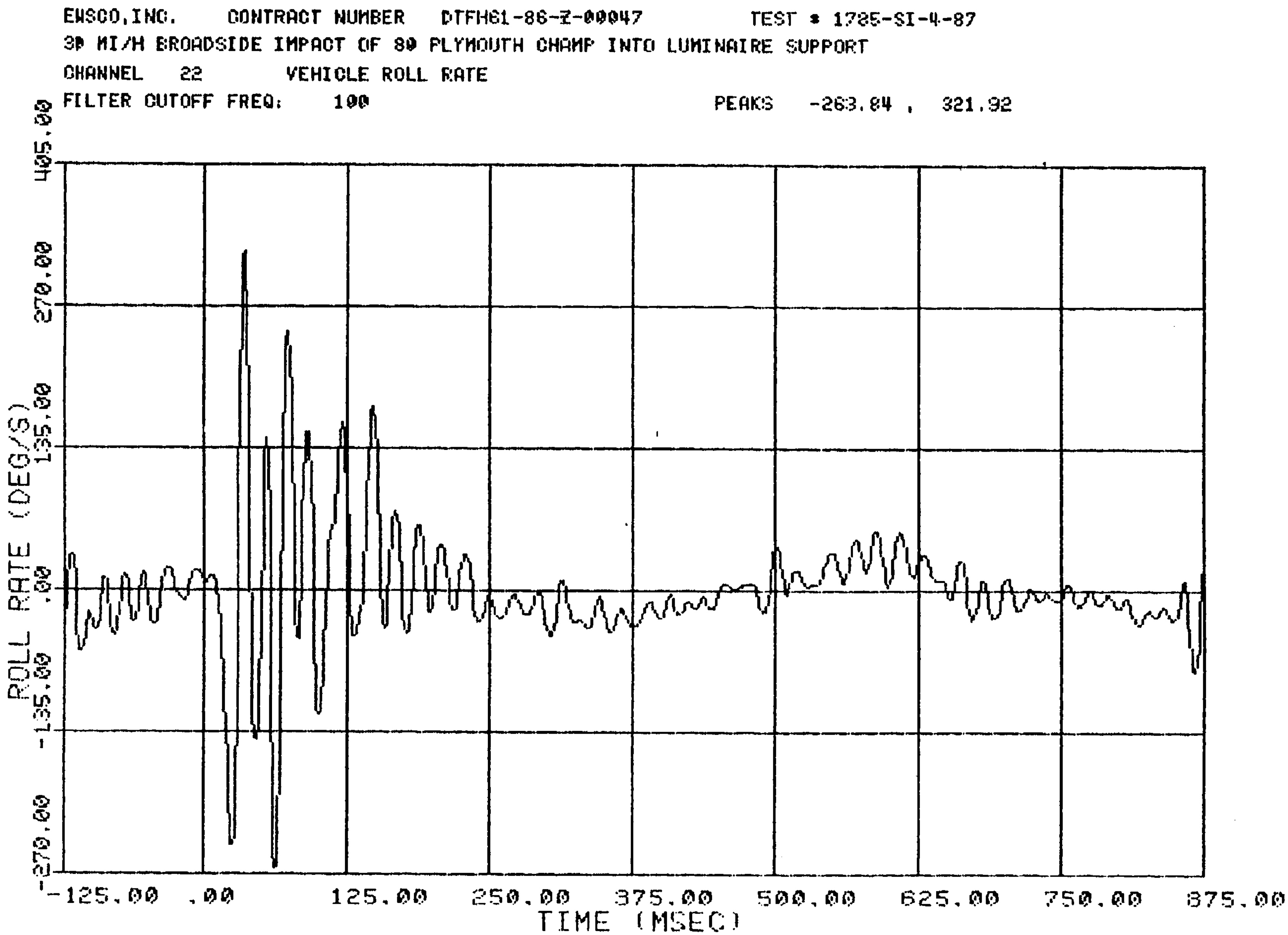


Figure A12. Vehicle Roll Rate, 100 Hz

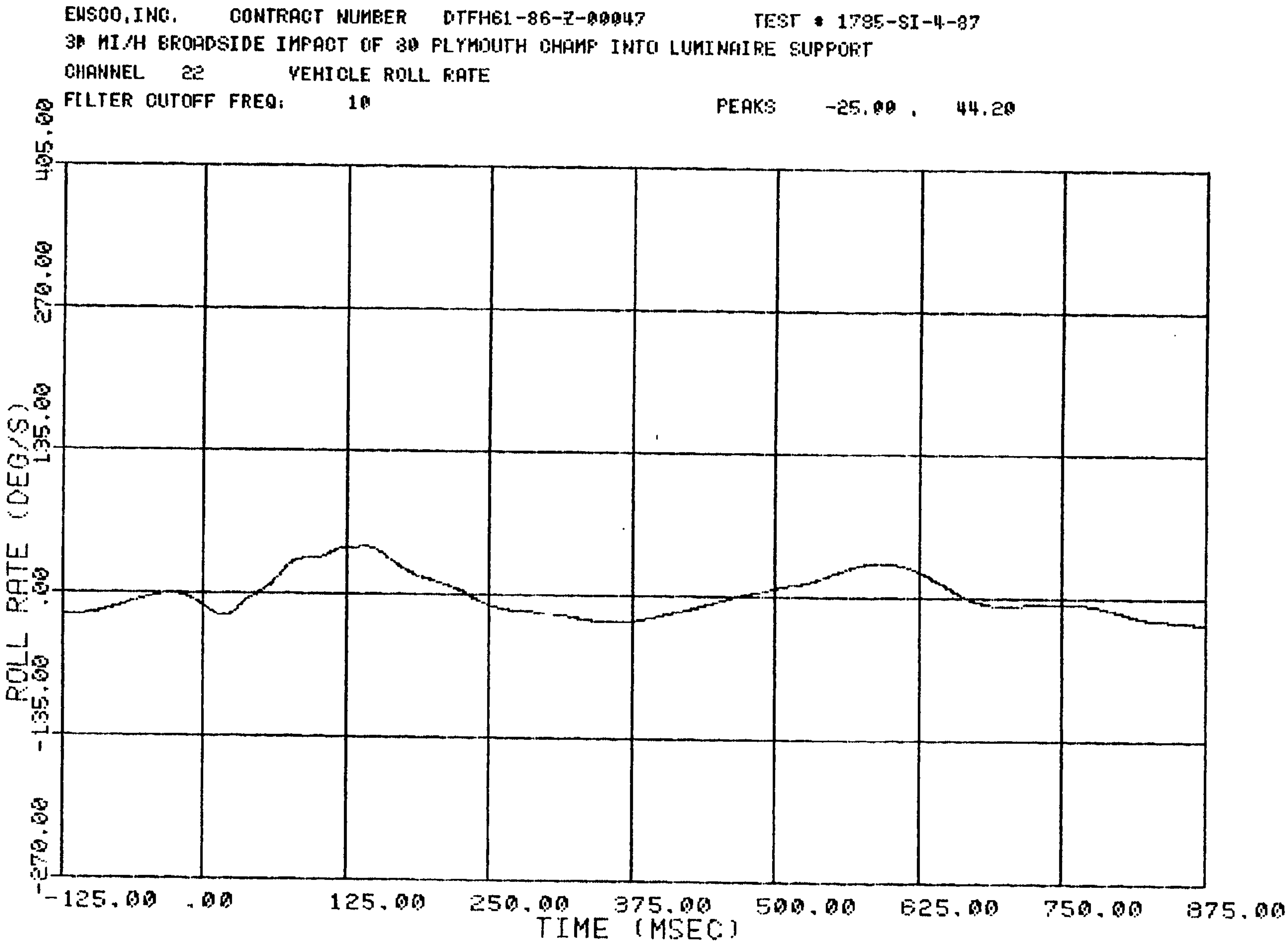


Figure A13. Vehicle Roll Rate, 10 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-4-87
30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
CHANNEL 0 VEHICLE ROLL (INTEGRATED)
FILTER CUTOFF FREQ: 10 PEAKS -1.86 , 2.79

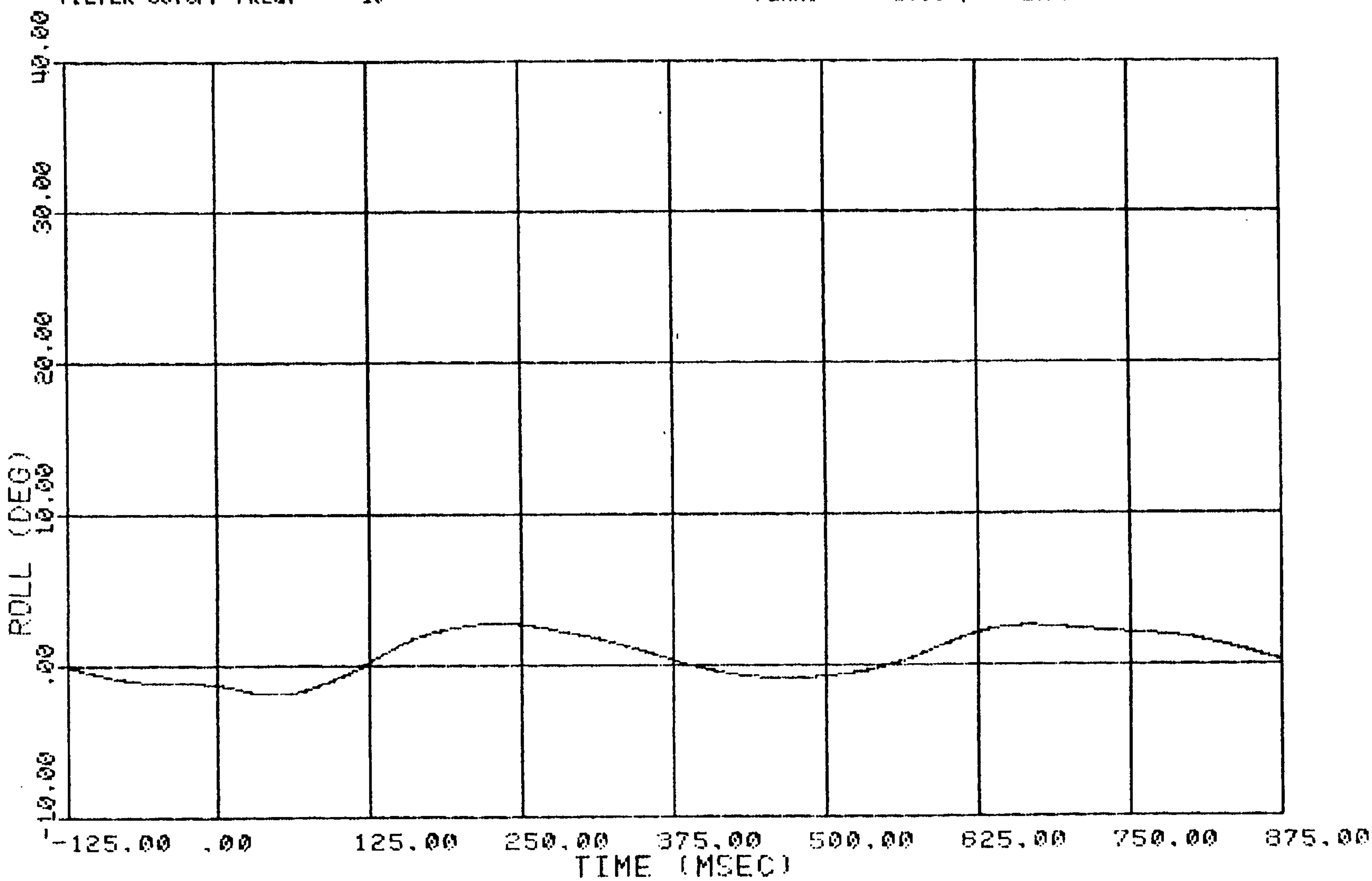


Figure A14. Vehicle Roll, 10 Hz

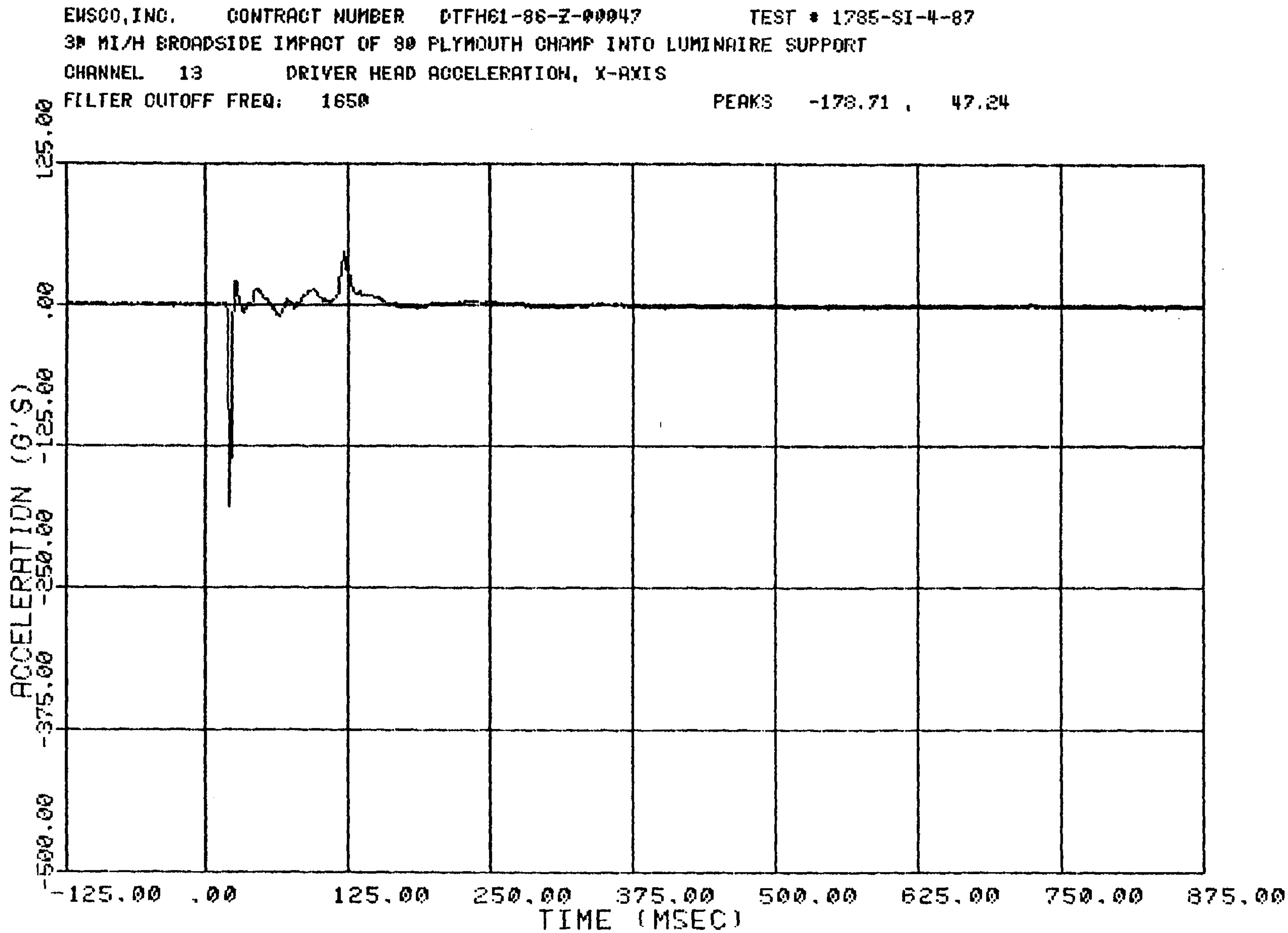


Figure A15. Driver's Head Acceleration, X-Axis, 1650 Hz

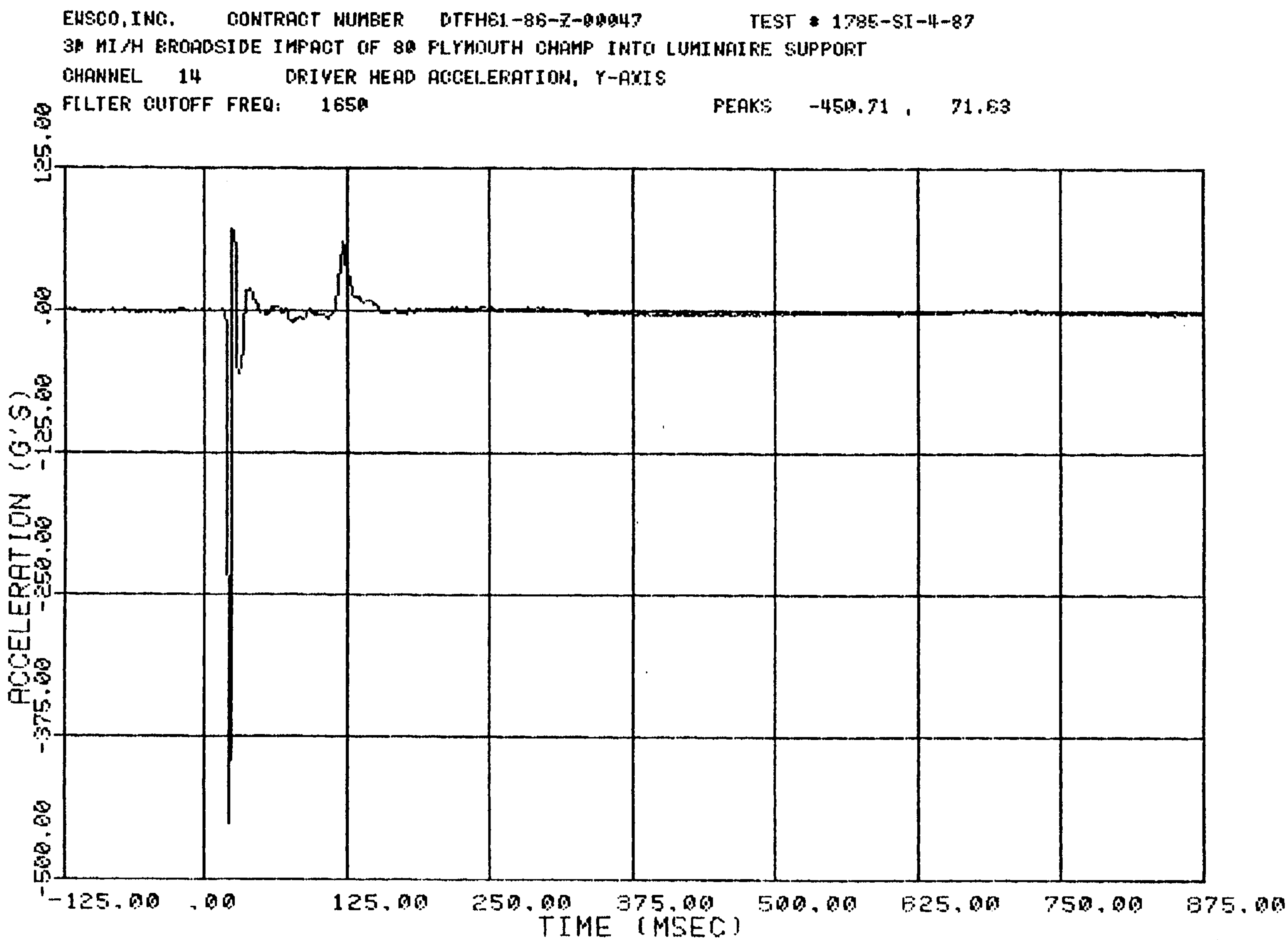


Figure A16. Driver's Head Acceleration, Y-Axis, 1650 Hz

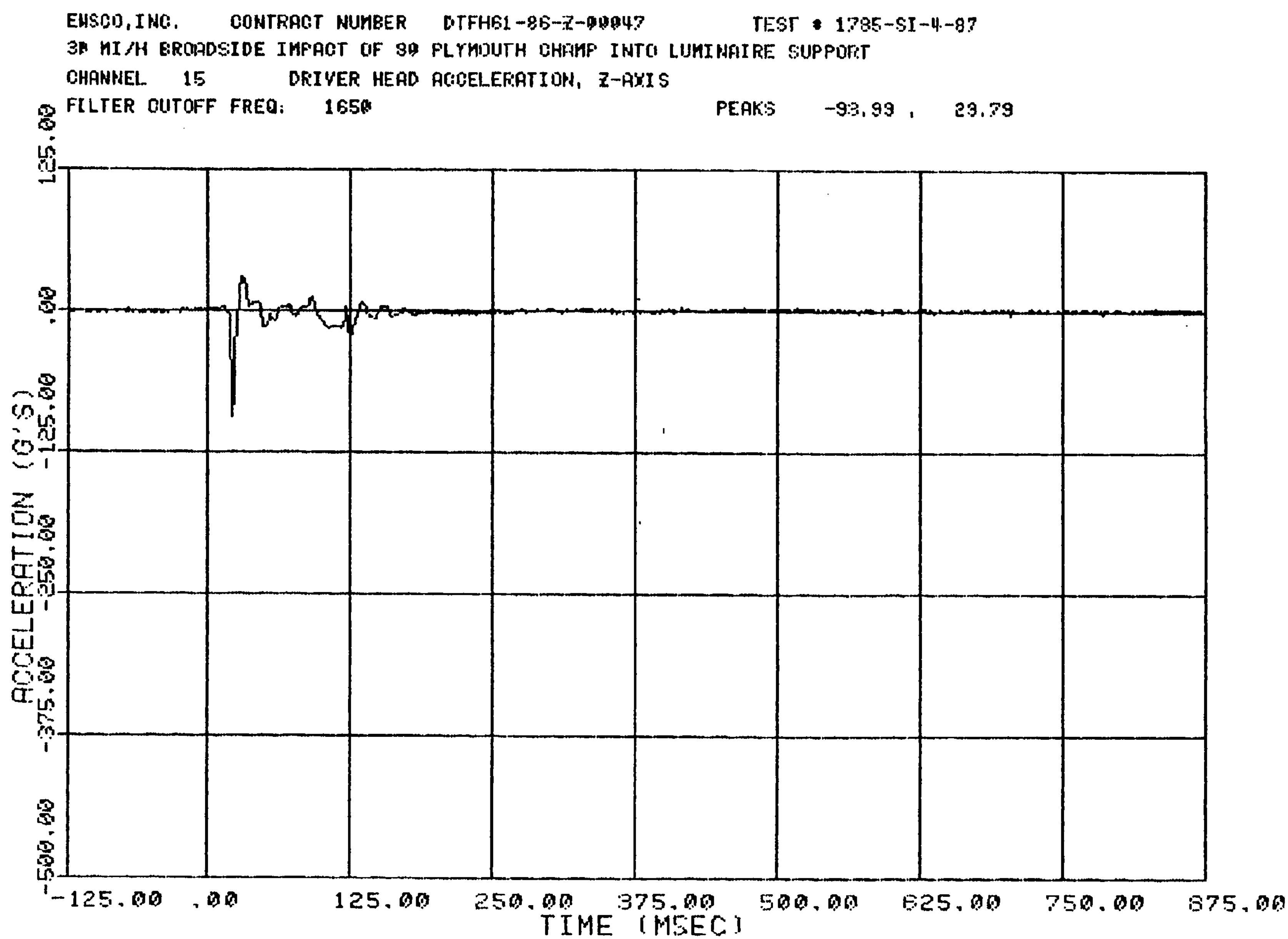


Figure A17. Driver's Head Acceleration, Z-Axis, 1650 Hz

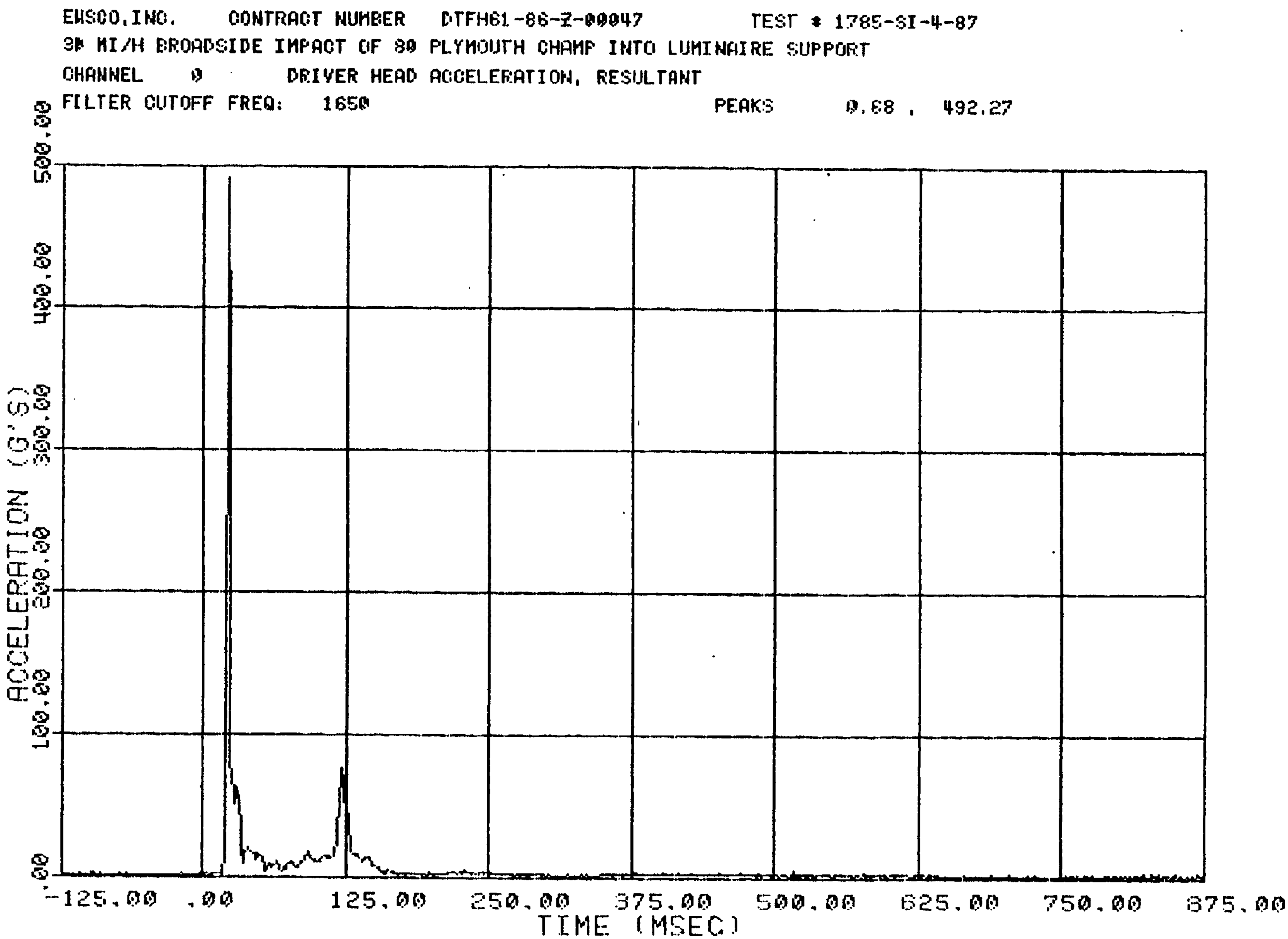


Figure A18. Driver's Head Acceleration, Resultant, 1650 Hz

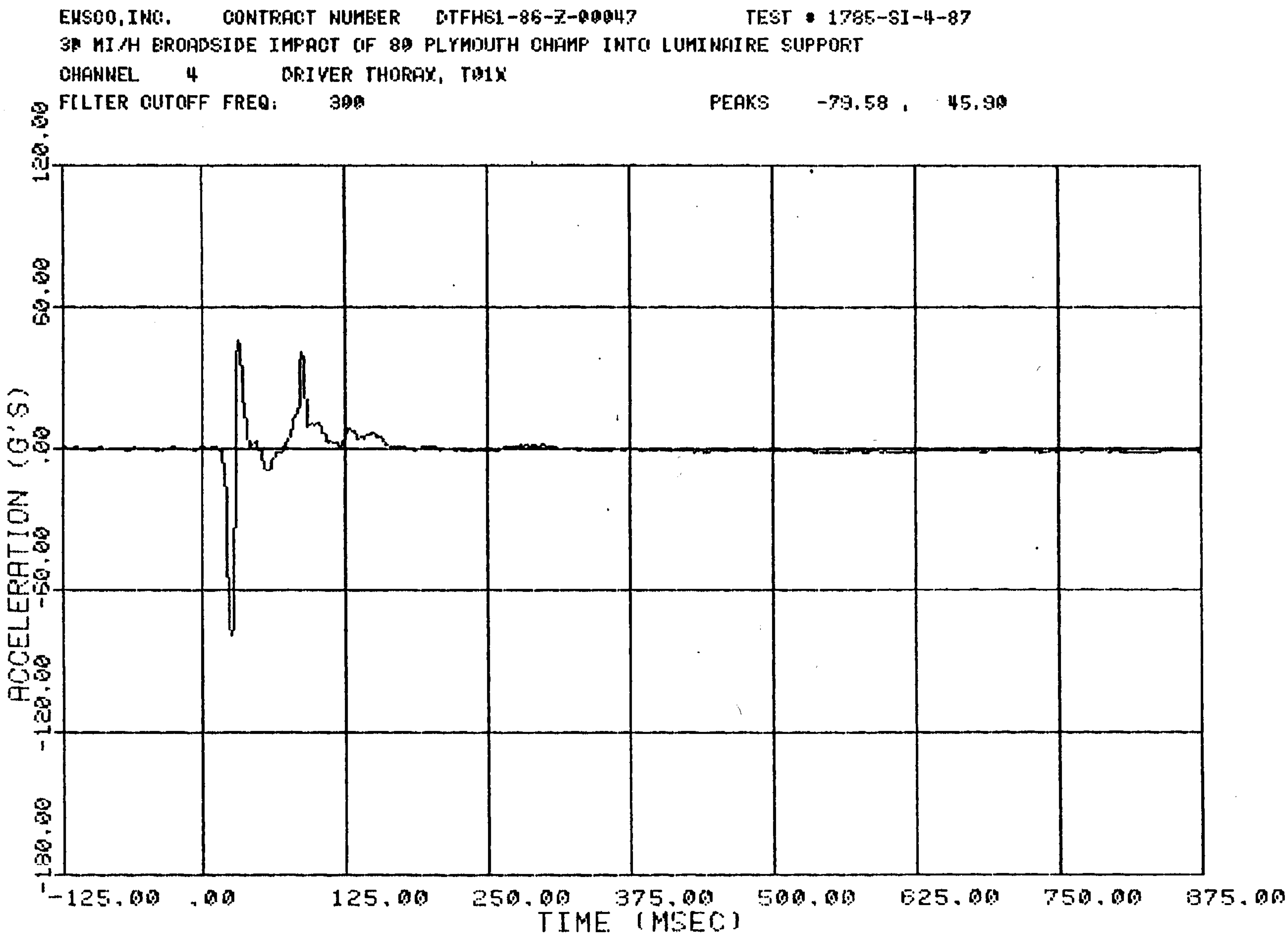


Figure A19. Driver's Upper Spine (T01) Acceleration, X-Axis, 300 Hz

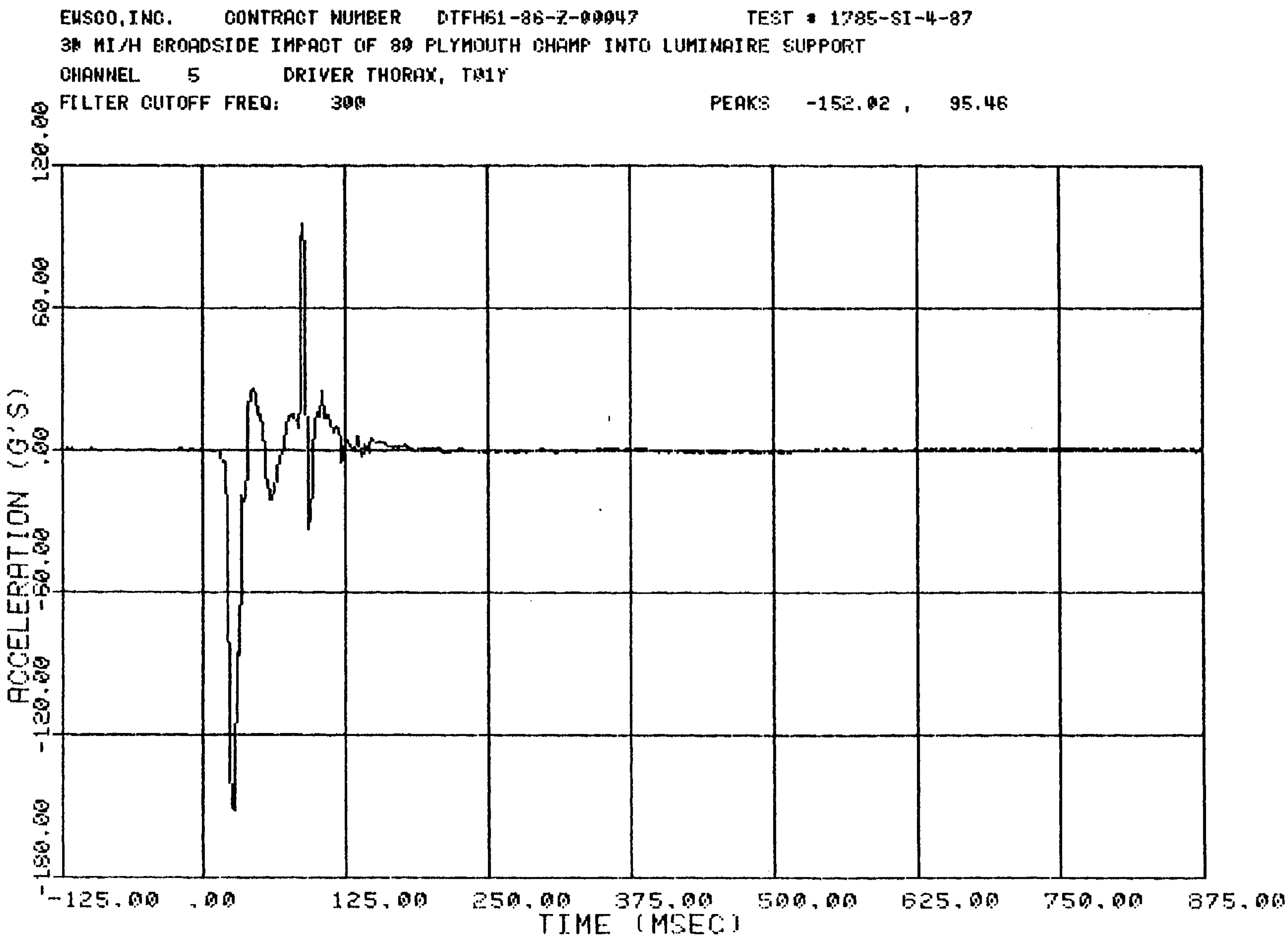


Figure A20. Driver's Upper Spine (T01) Acceleration, Y-Axis, 300 Hz

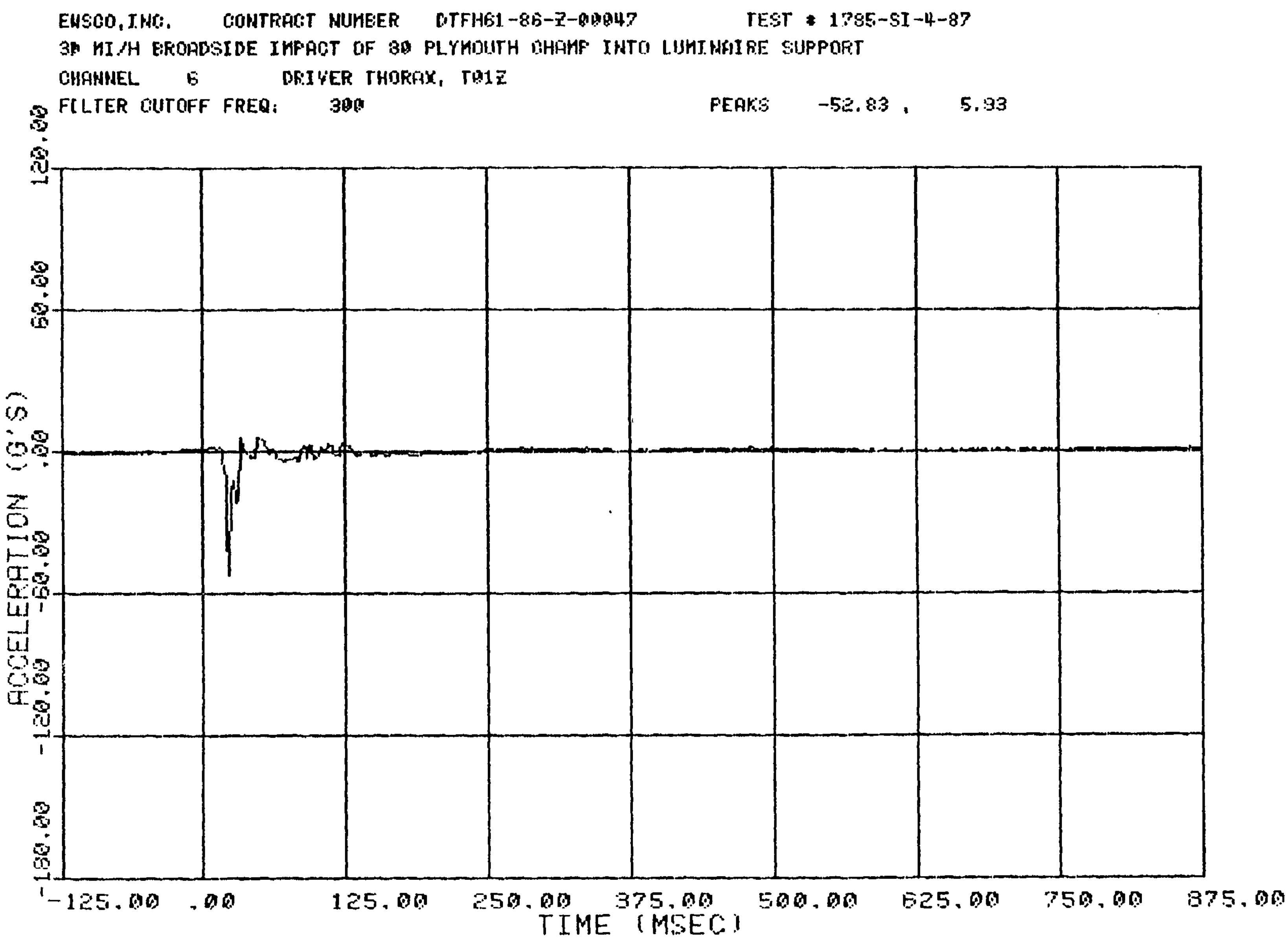


Figure A21. Driver's Upper Spine (T01) Acceleration, Z-Axis, 300 Hz

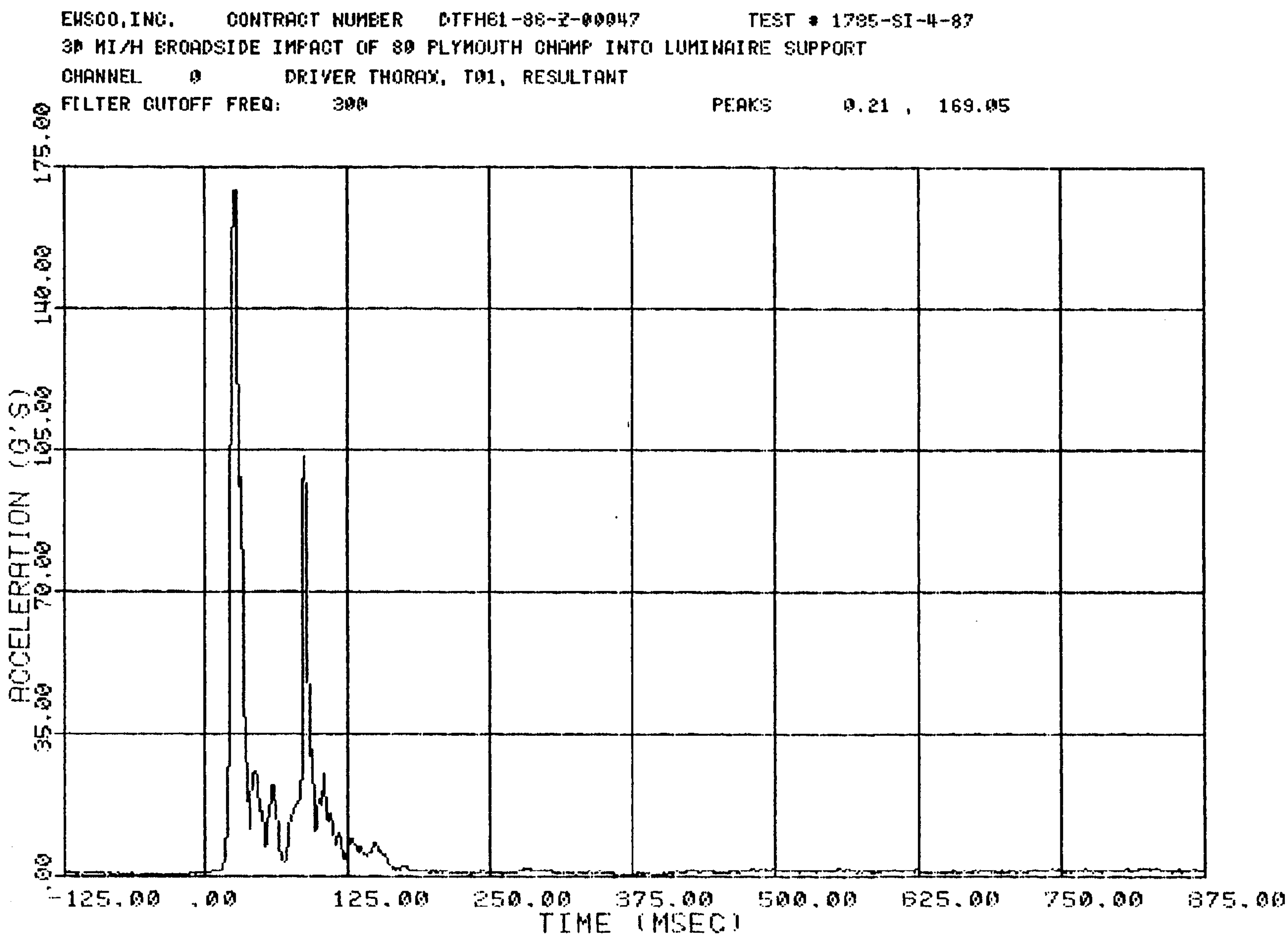


Figure A22. Driver's Upper Spine (T01) Acceleration, Resultant, 300 Hz

ENSCO, INC.   CONTRACT NUMBER   DTFH61-86-Z-00047   TEST # 1785-SI-4-87
30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
CHANNEL 7   DRIVER THORAX, T12X
FILTER CUTOFF FREQ: 300   PEAKS -101.18 , 71.42

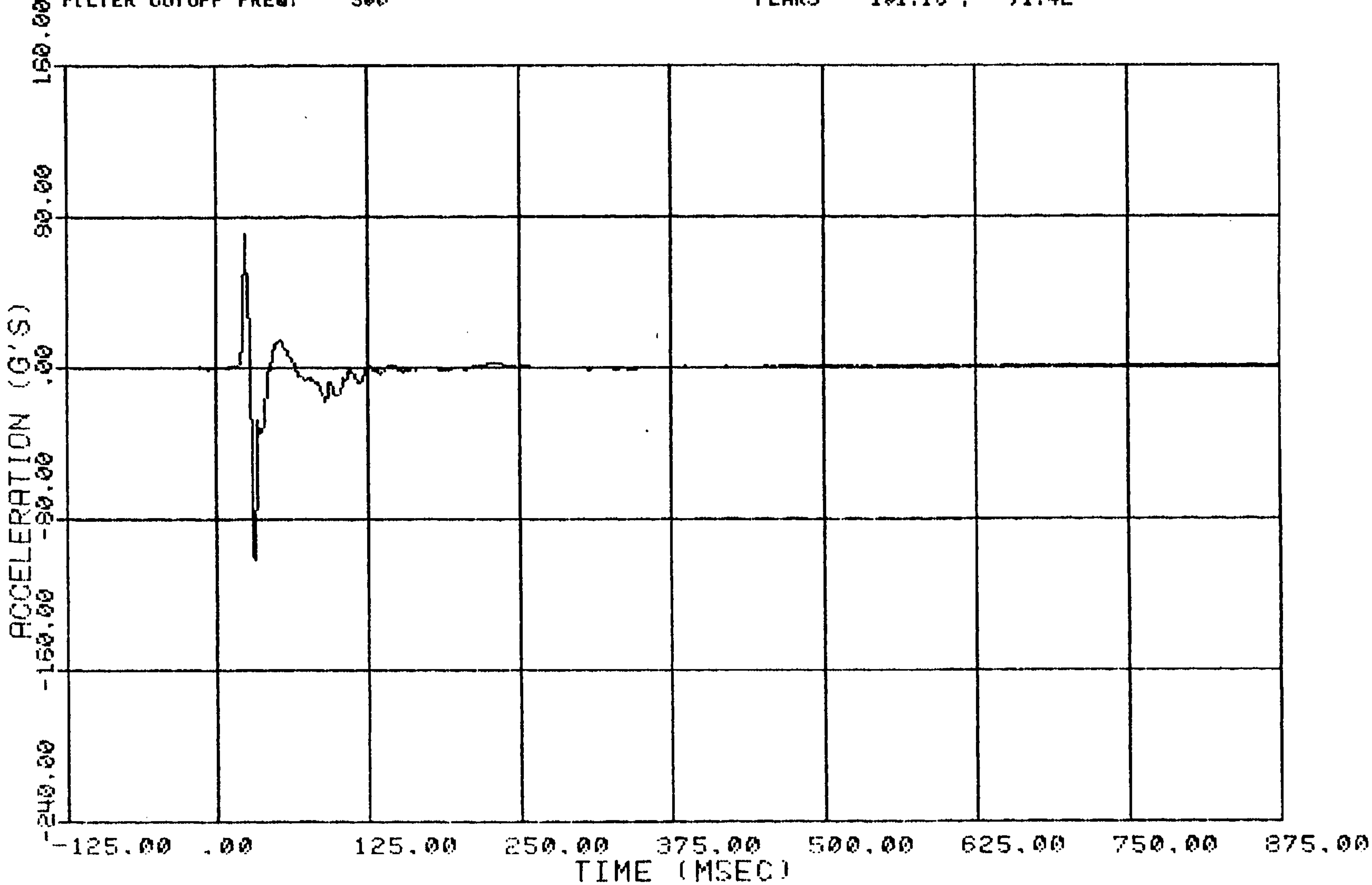


Figure A23. Driver's Lower Spine (T12) Acceleration, X-Axis, 300 Hz

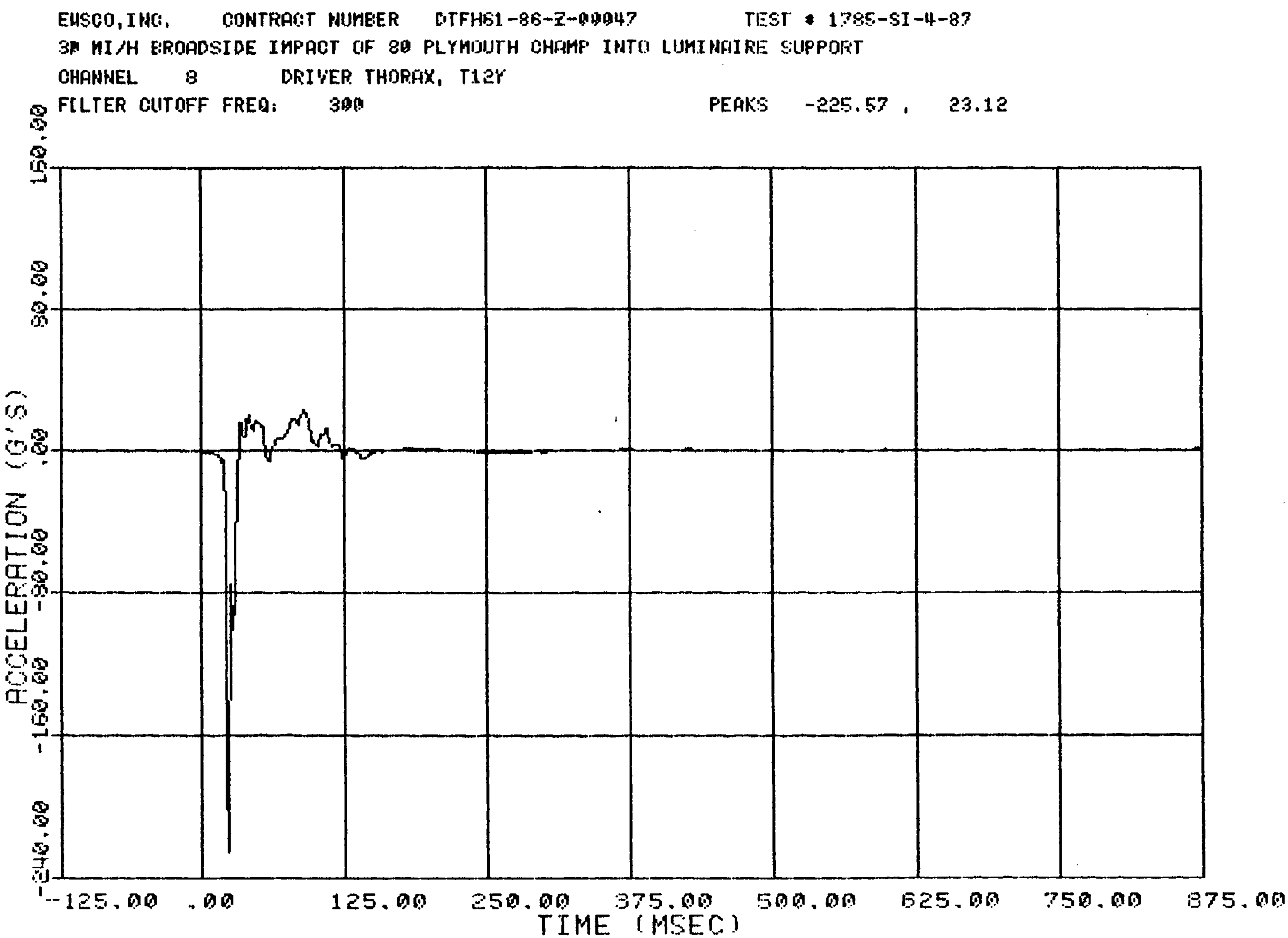


Figure A24. Driver's Lower Spine (T12) Acceleration, Y-Axis, 300 Hz

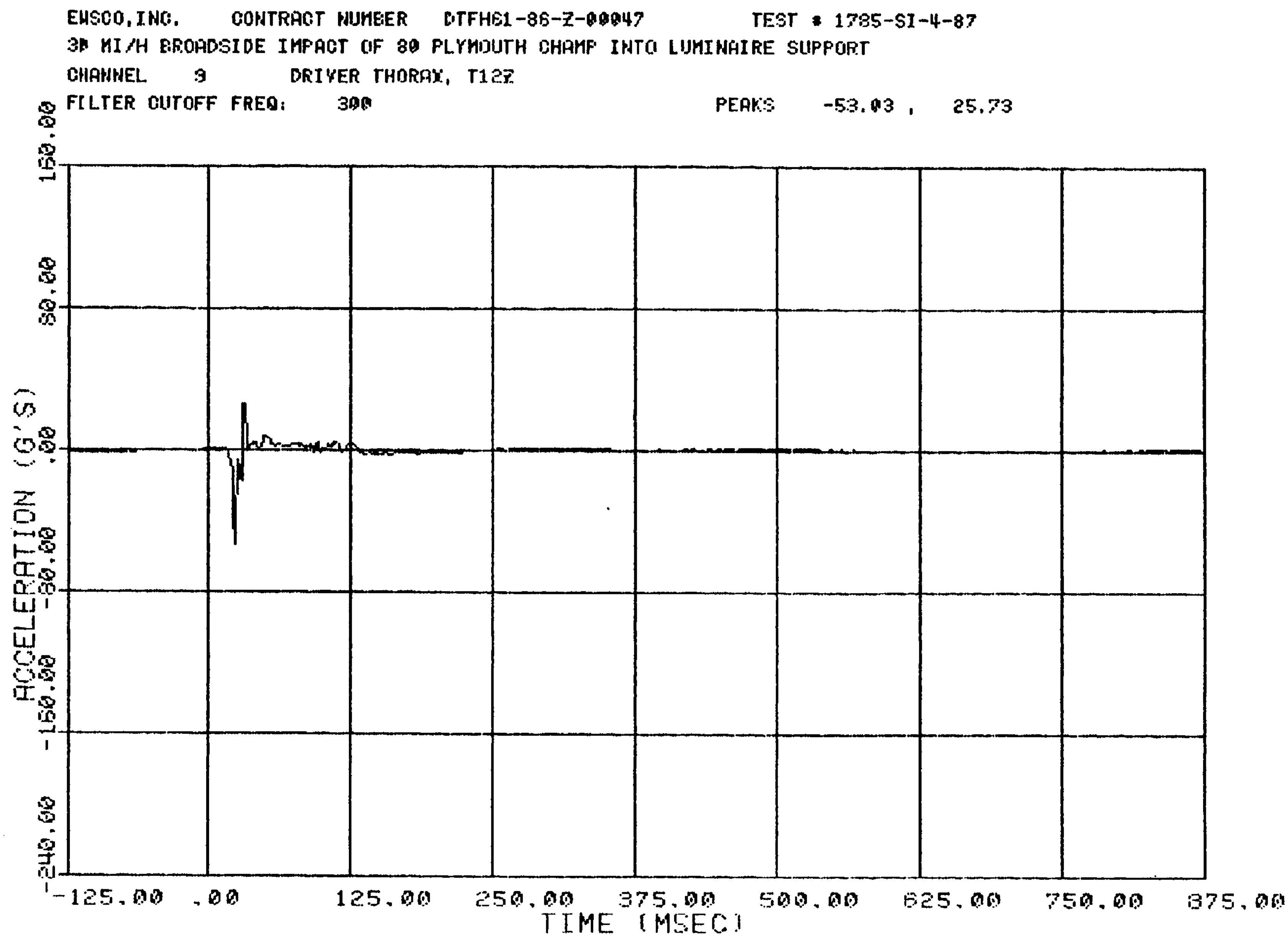


Figure A25. Driver's Lower Spine (T12) Acceleration, Z-Axis, 300 Hz

ENSCO, INC.   CONTRACT NUMBER   DTFH61-86-Z-00047   TEST # 1785-SI-4-87
30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
CHANNEL   0   DRIVER THORAX, T12, RESULTANT
FILTER CUTOFF FREQ: 300   PEAKS   0.11 , 241.70

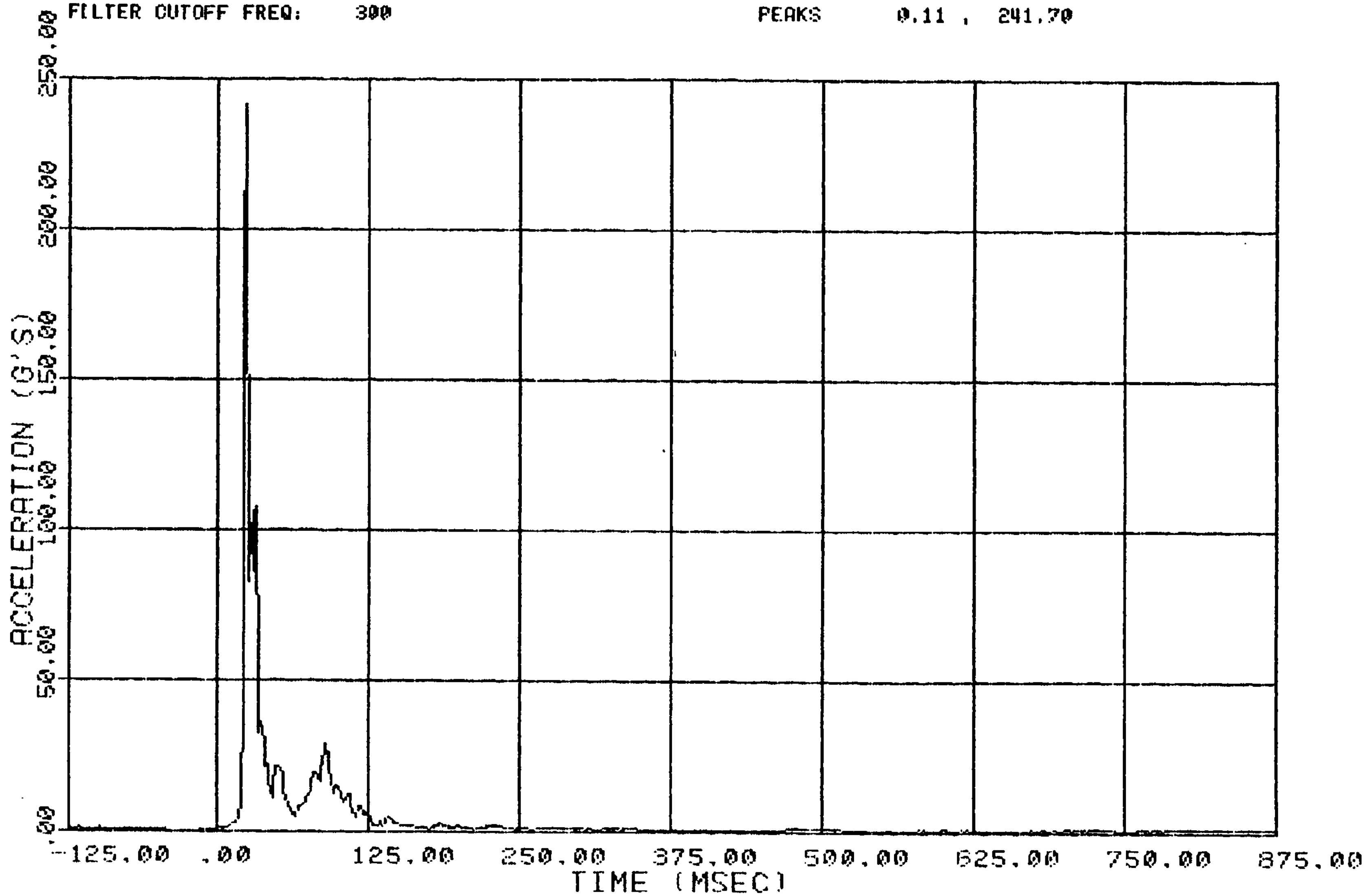


Figure A26. Driver's Lower Spine (T12) Acceleration, Resultant, 300 Hz

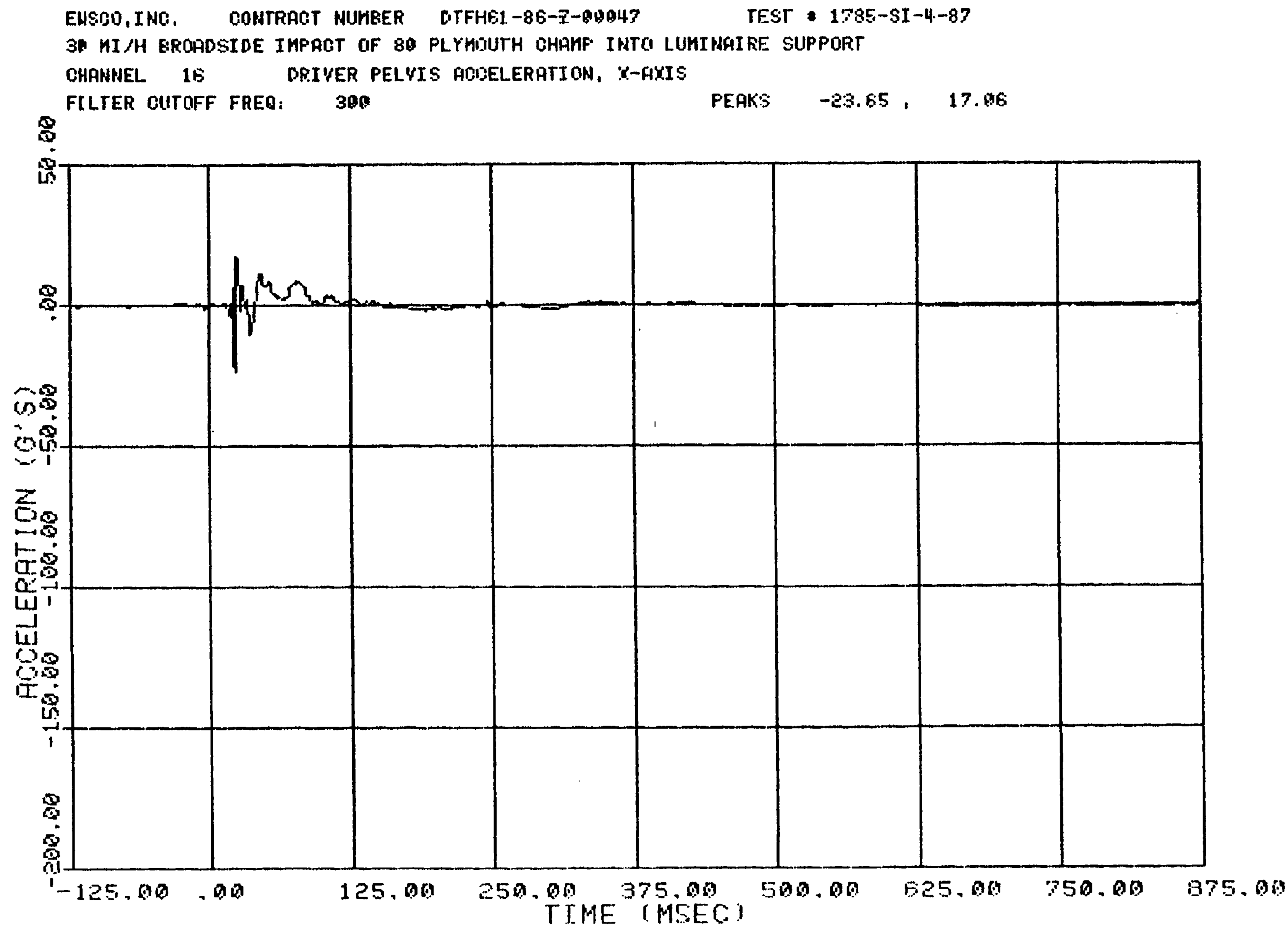


Figure A27. Driver's Pelvis Acceleration, X-Axis, 300 Hz

EWSCO,INC.   CONTRACT NUMBER   DTFH61-86-Z-00047   TEST # 1785-SI-4-87
30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
CHANNEL   17   DRIVER PELVIS ACCELERATION, Y-AXIS
FILTER CUTOFF FREQ: 300   PEAKS   -197.42 ,   18.97

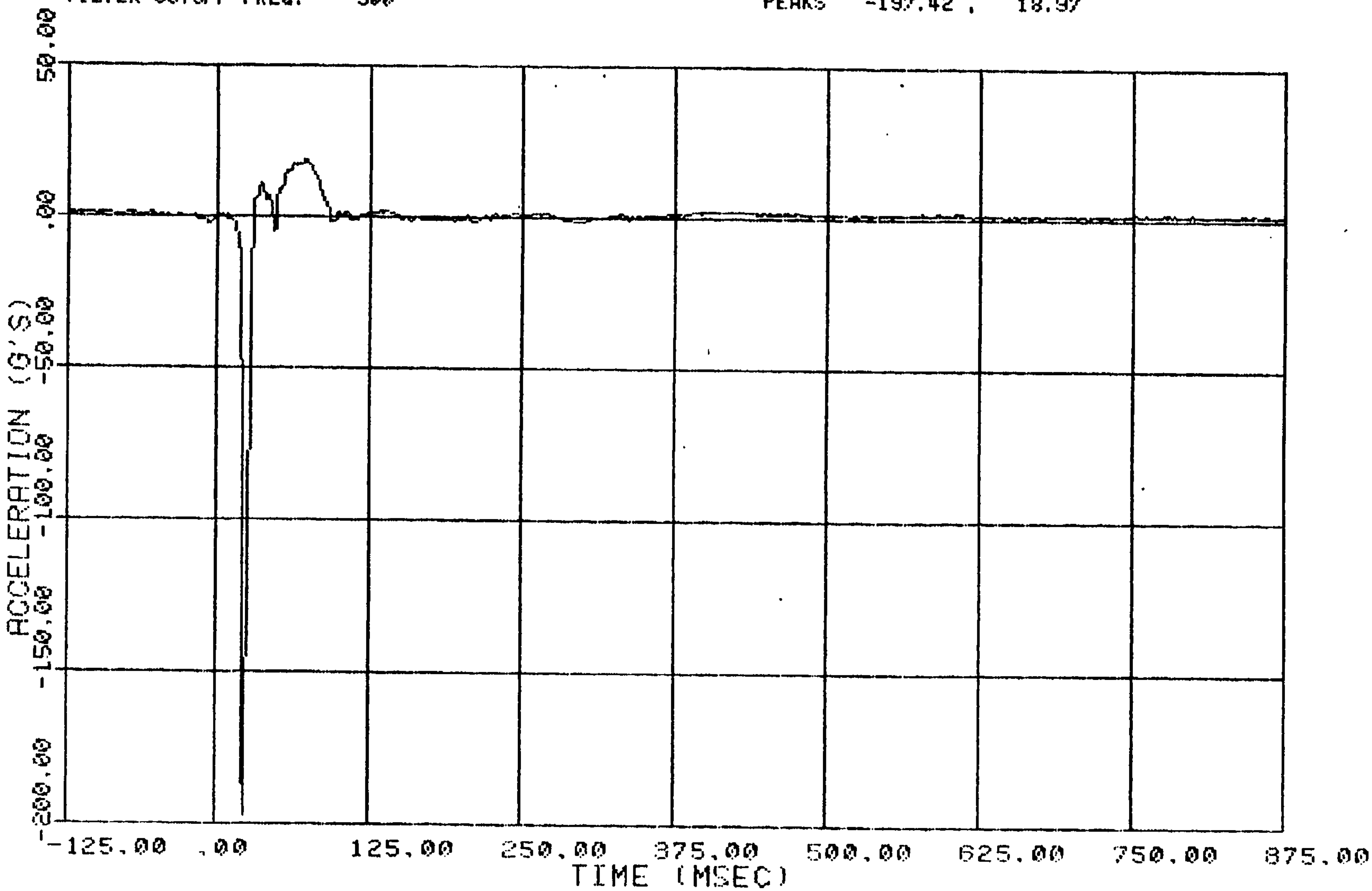


Figure A28. Driver's Pelvis Acceleration, Y-Axis, 300 Hz

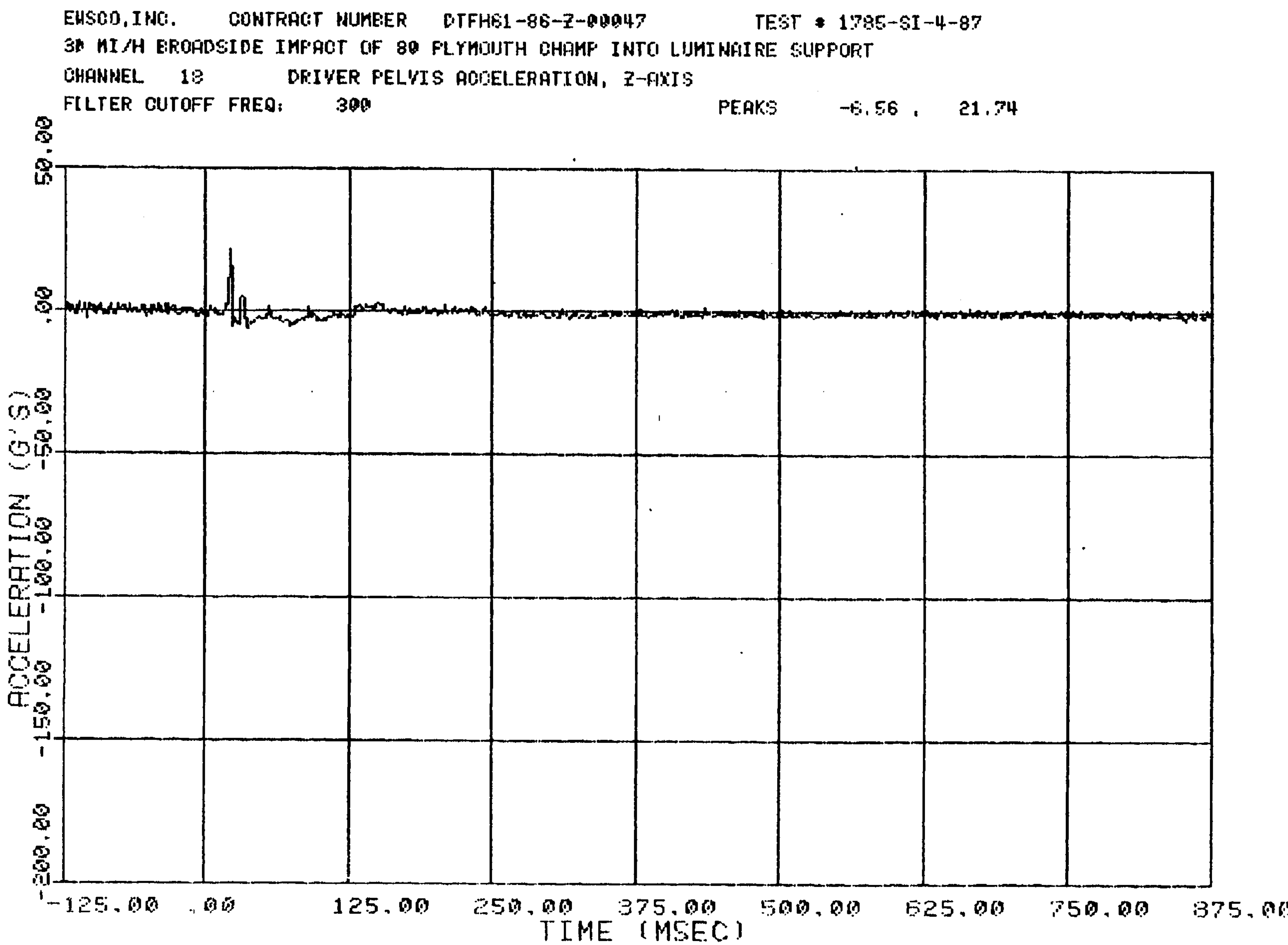


Figure A29. Driver's Pelvis Acceleration, Z-Axis, 300 Hz

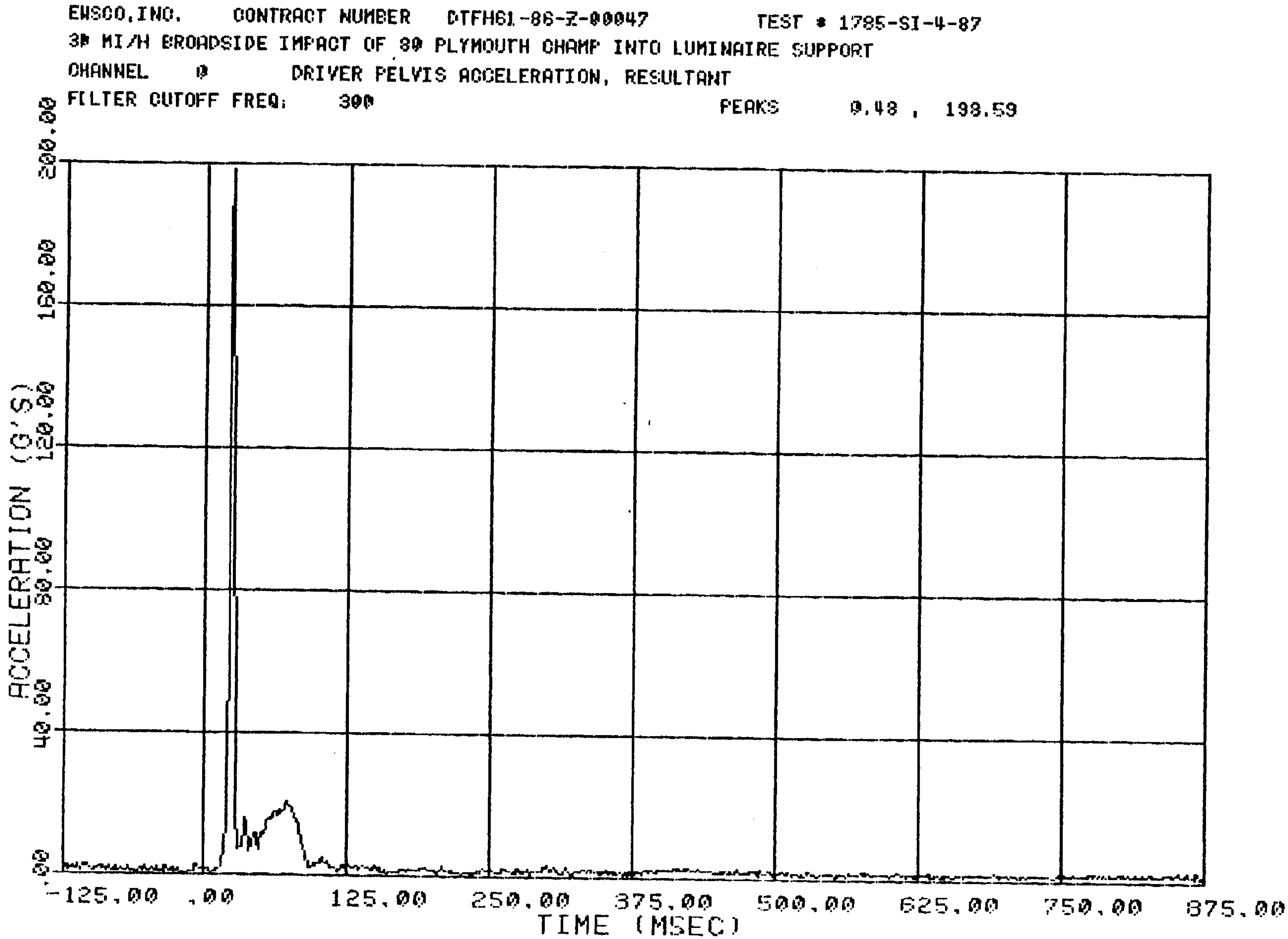


Figure A30. Driver's Pelvis Acceleration, Resultant, 300 Hz

ENSCO,INC.   CONTRACT NUMBER   DTFH61-86-Z-00047   TEST # 1785-SI-4-87
30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
CHANNEL   2   DRIVER THORAX, USTX
FILTER CUTOFF FREQ: 300   PEAKS   -209.15 , 118.73

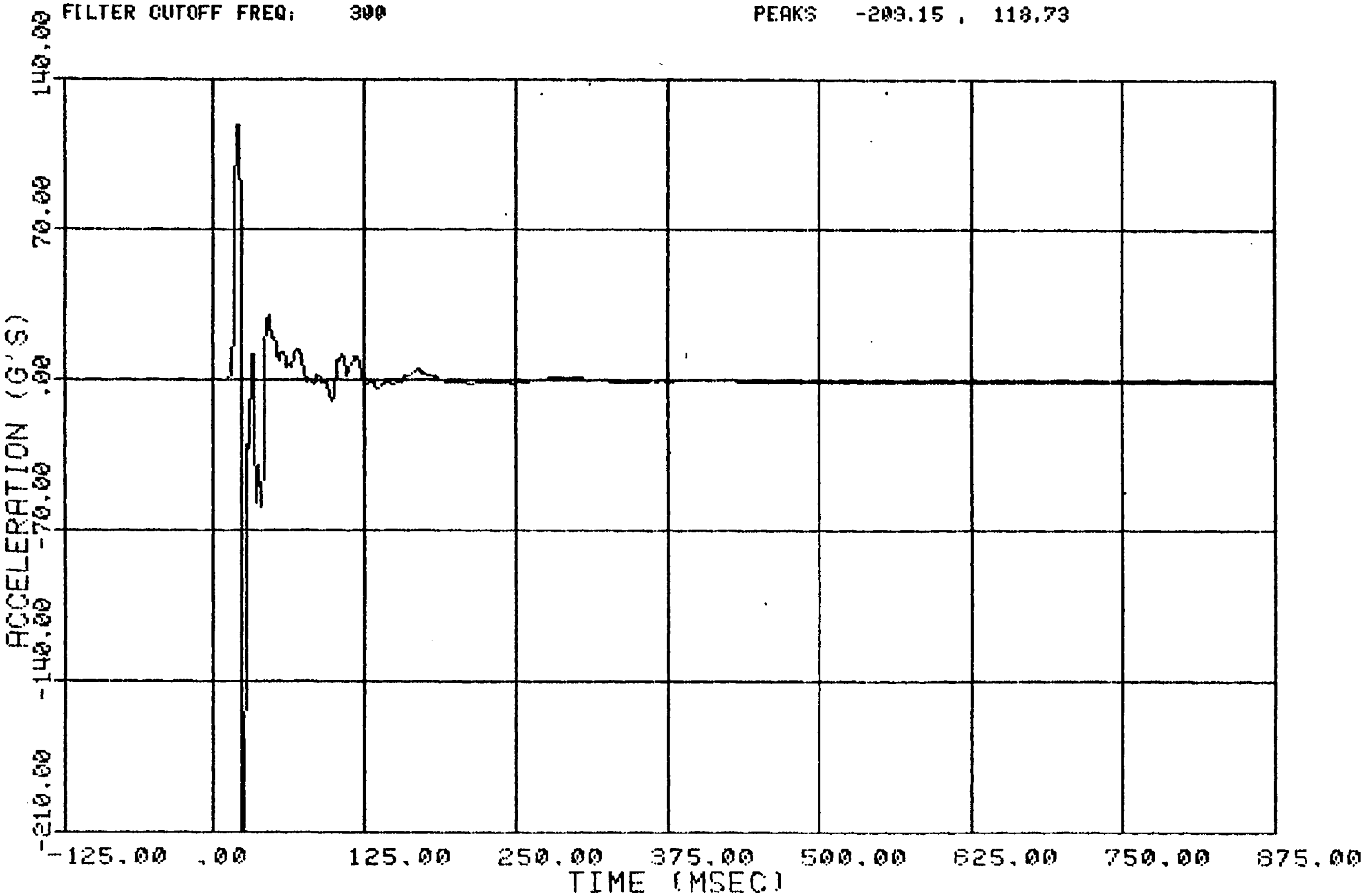


Figure A31. Driver's Upper Sternum Acceleration, USTX, 300 Hz

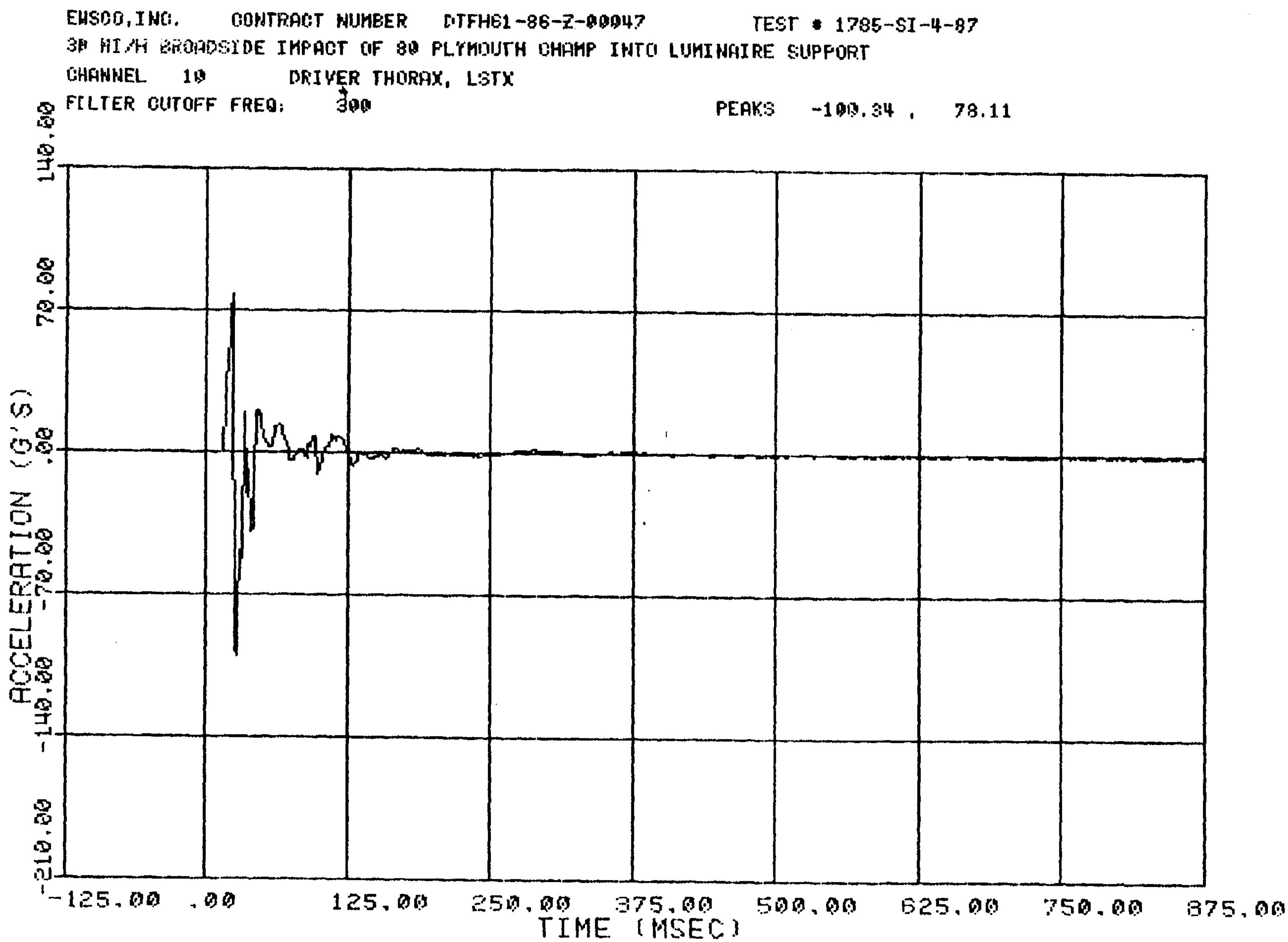


Figure A32. Driver's Lower Sternum Acceleration, LSTX, 300 Hz

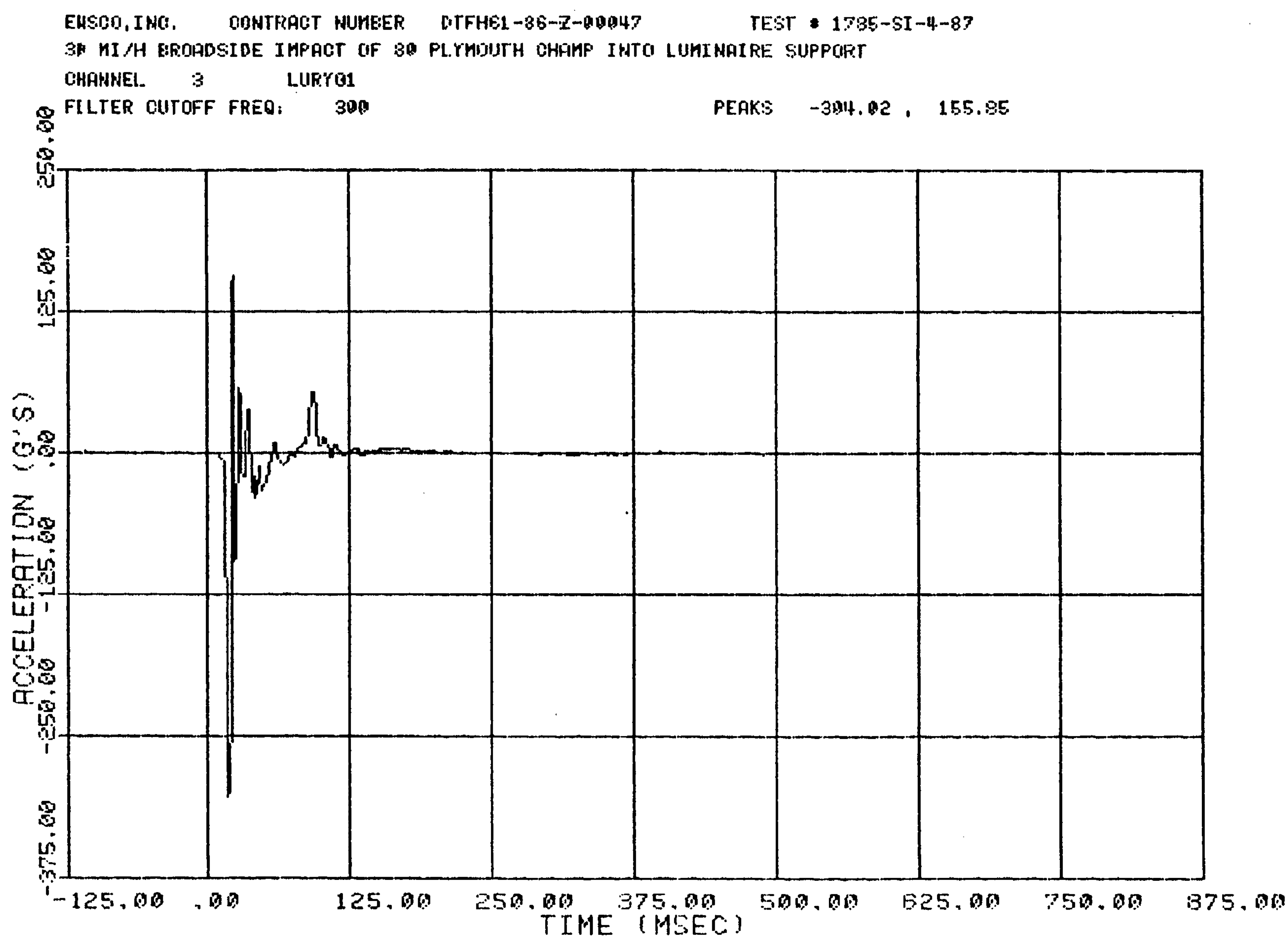


Figure A33. Driver's Left Upper Rib (LURYGI) Acceleration, 300 Hz

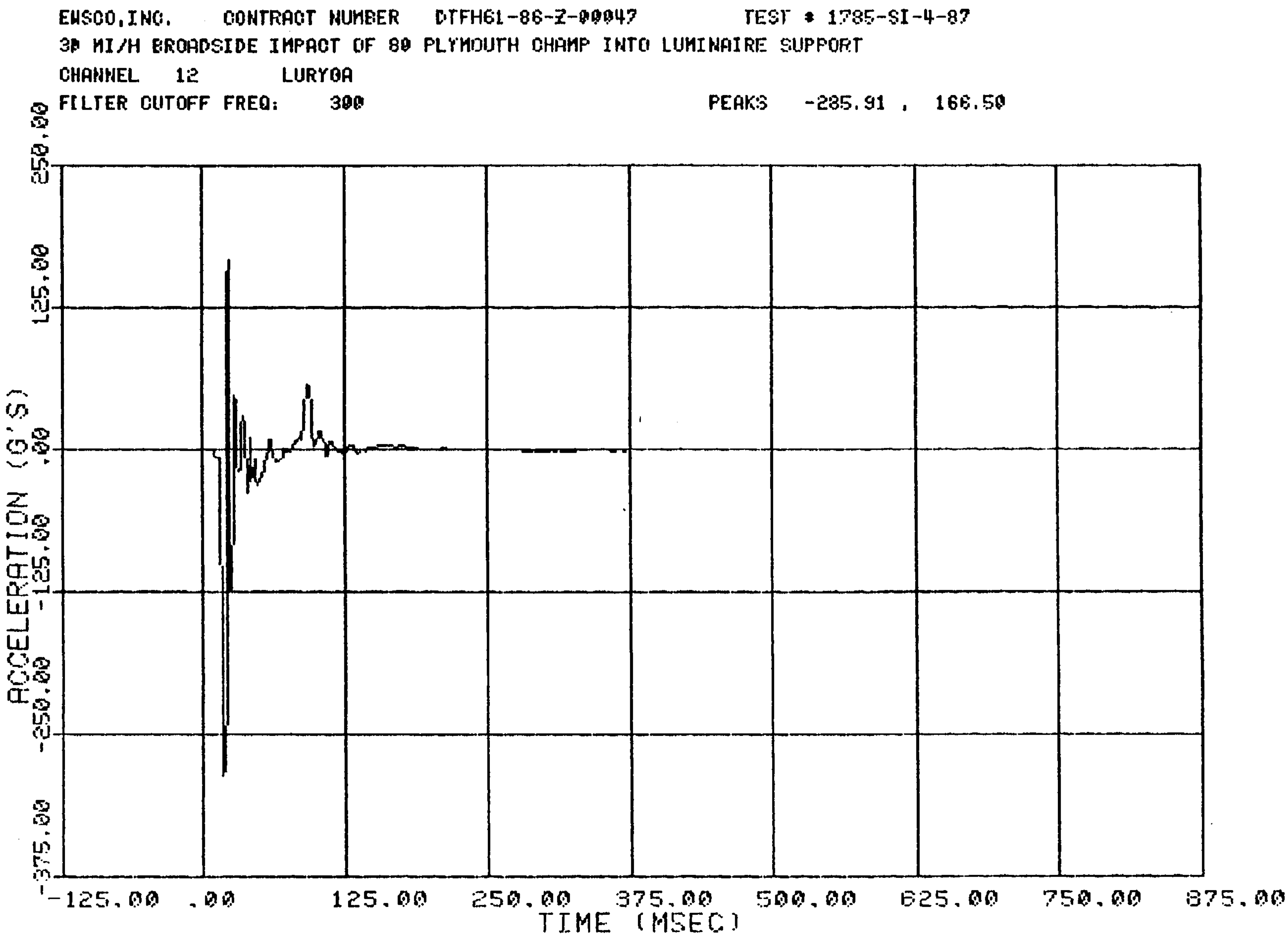


Figure A34. Driver's Left Upper Rib (LURYGA) Acceleration, 300 Hz

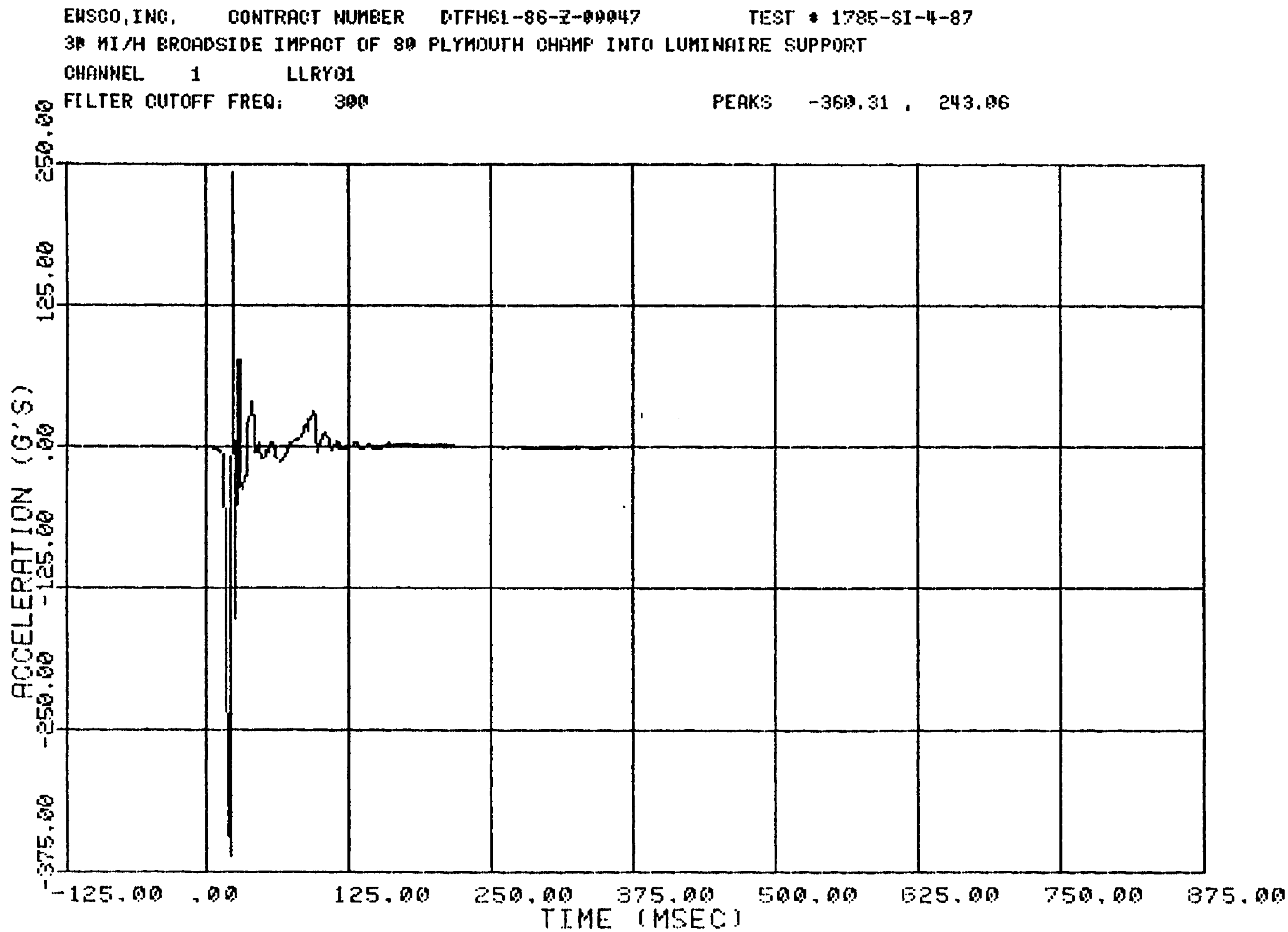


Figure A35. Driver's Left Lower Rib (LLRYGI) Acceleration, 300 Hz

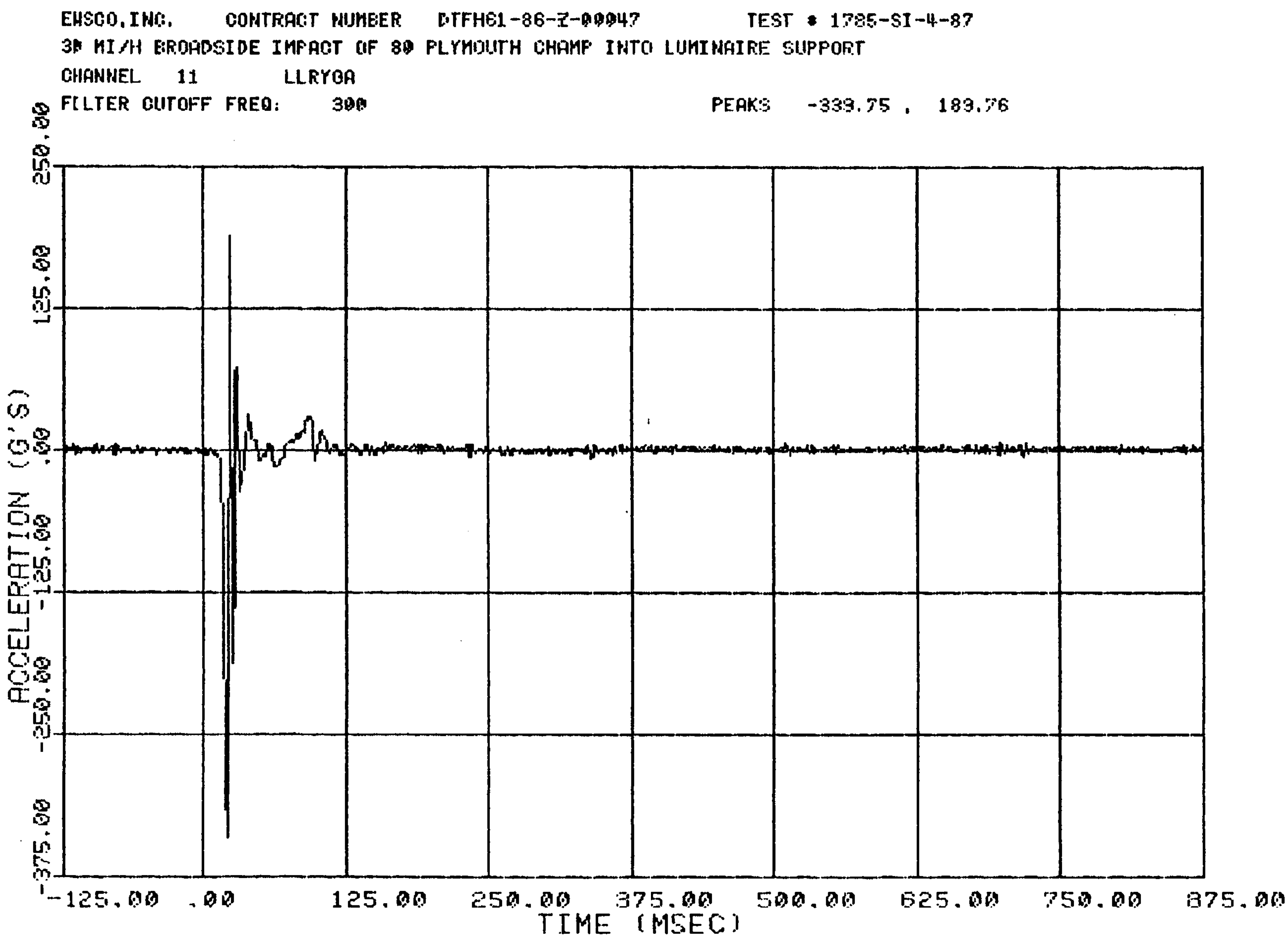


Figure A36. Driver's Left Lower Rib (LLRYGA) Acceleration, 300 Hz

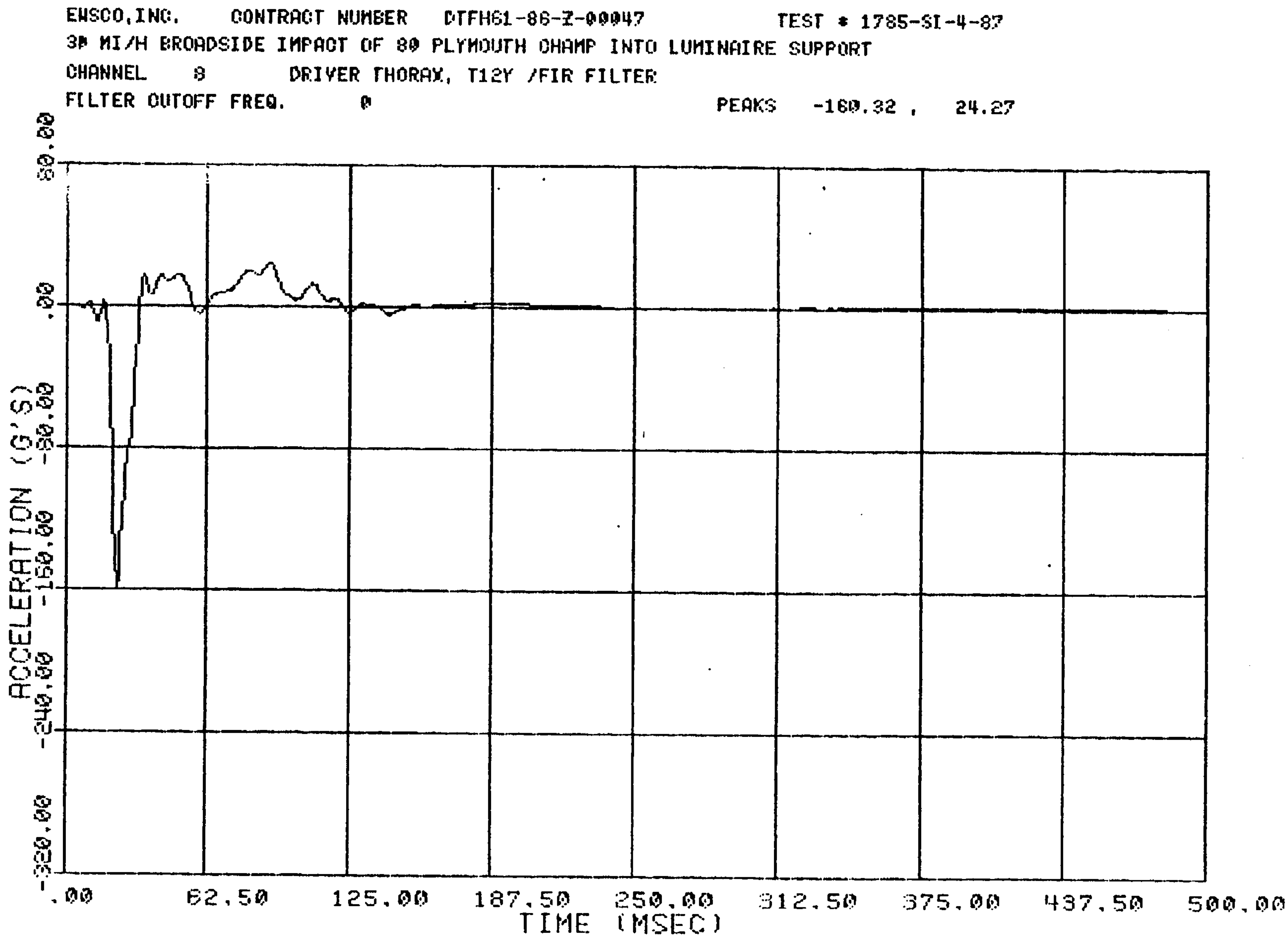


Figure A37. Driver's Lower Spine (T12) Acceleration, Y-Axis, NHTSA FIR Filter

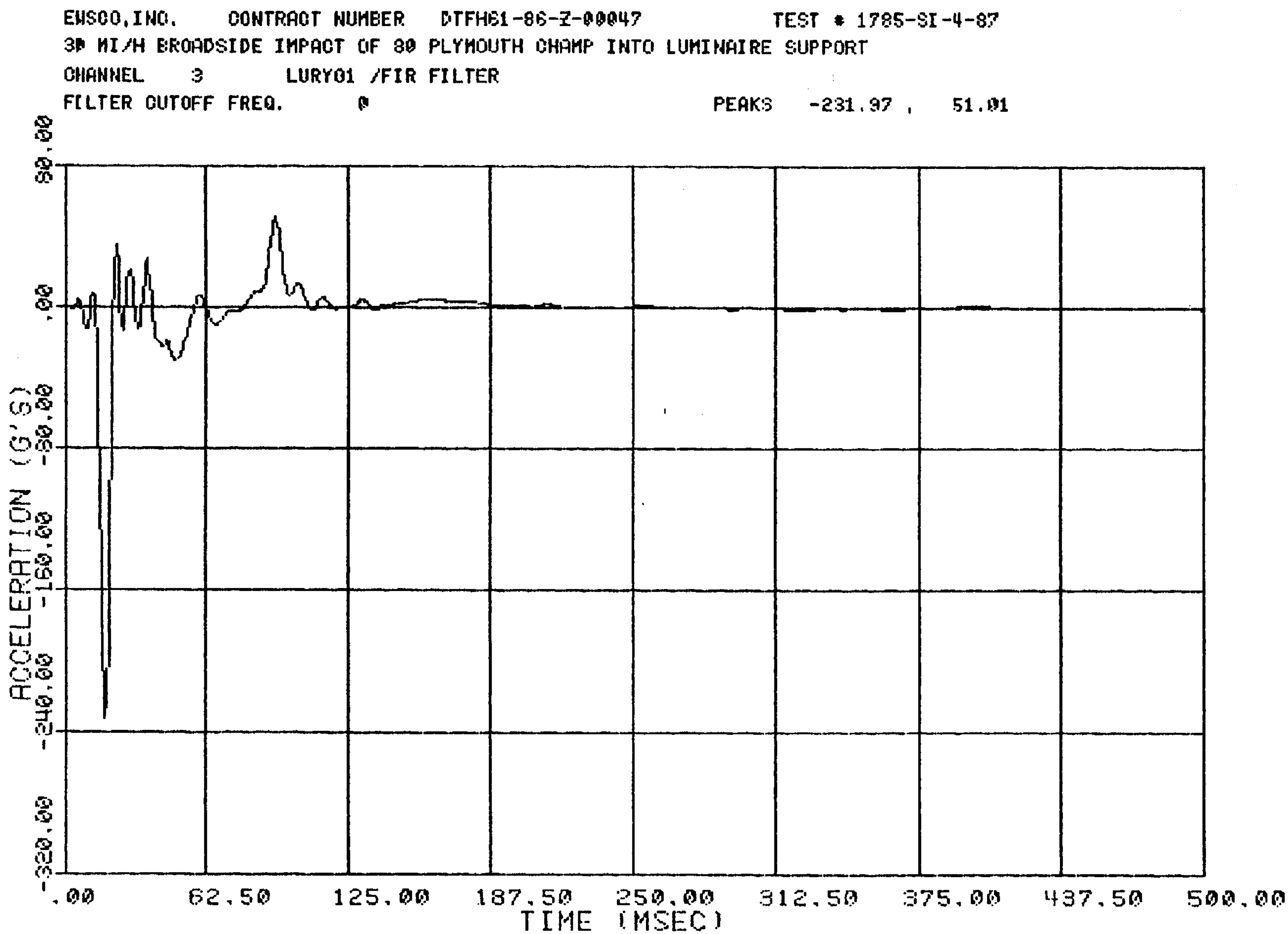


Figure A38. Driver's Left Upper Rib (LURYGI) Acceleration, Y-Axis, NHTSA FIR Filter

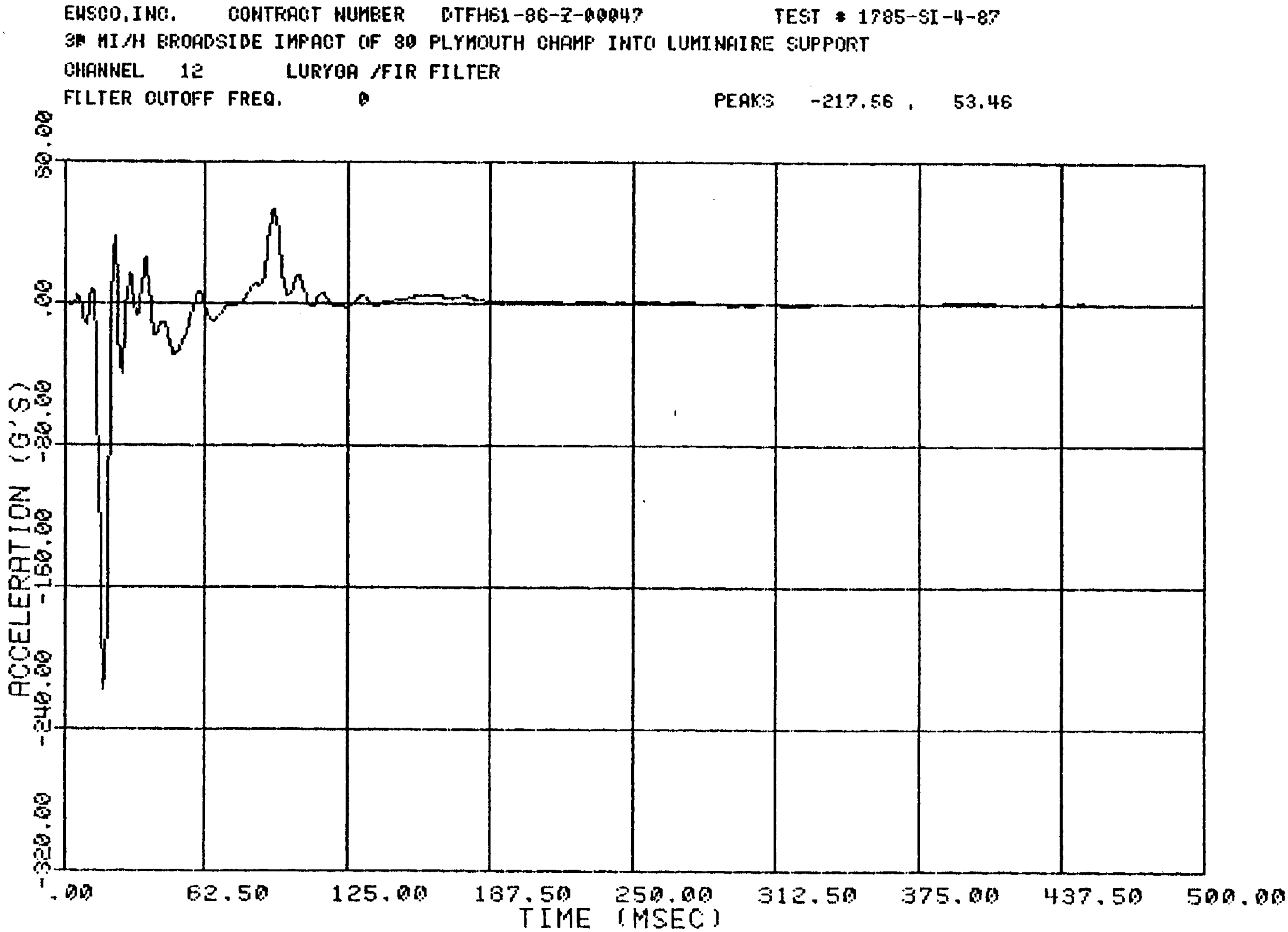


Figure A39. Driver's Left Upper Rib (LURYGA) Acceleration, Y-Axis, NHTSA FIR Filter