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

FHWA CONTRACT NO.
DTFH61-81-C-00036

THIRTY MPH BROADSIDE IMPACT OF A VW RABBIT AND A BREAKAWAY LUMINAIRE SUPPORT

TEST RESULTS REPORT

TEST NUMBER 1469-SI#5-85

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1.0 SUMMARY AND CONCLUSIONS

This test investigated the impact severity of a minicompact sedan (1,800S) during a low speed broadside collision with a breakaway luminaire support. The test vehicle was a 1979 VW Rabbit. The breakaway luminaire support was a 30 foot steel pole with a California type 31 slip base.

The test vehicle momentum change due to impacting the pole at a speed of 28.4 mph (12.7 m/s) was 556 lb-sec. The velocity change corresponding to the observed vehicle momentum change was 6.2 mph or 9.0 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 11.1 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. No lateral impact of the hypothetical occupant using the flail space model approach was detected for the 1 foot flail distance. However, the actual impact velocity of the occupant with the interior of vehicle was approximately 42 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 of AIS greater than 3 or 4 was 100%, while the probability of an AIS being greater than was at least 28%. This 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 3892. This result exceeds the limit specified in FMVSS 208. It should be noted that HIC's obtained during side imapcts may not measure the head injury correctly since the head form of the dummy was deisnged for frontal impacts. Also, measurements made at the upper spine when processed using standard chest techniques produce results which exceeded the limit values. 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 1469-SI#5-85

1.	Contract Number	DTFH61-81-C-00036
2.	Date of Test	July 31, 1985
3.	Test Vehicle	VW Rabbit, 1979
4.	Delivered Vehicle Weight	1699 lbs
5.	Vehicle Weight, Test Inertial Planned Actual	 1,800 ±50 lbs 1,835 lbs
6.	Vehicle Weight, Gross Static Actual (One Occupant)	 1,990 lbs
7.	Number of Occupants	One
8.	Occupant Type	Anthropomorphic Dummy, 50th Percentile Male, Side Impact Thorax-SN017
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)	292 lbs
15.	Base Type	Triangular Slip Base, 3-Bolt (Type 31)
16.	Slip Plane Mounting Height Above Grade	4.0 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
22.	Impact Speed, Observed	28.4 mph

Table 1 (Cont'd)
Summary of Test Conditions and
Results for Test Number 1469-SI#5-85

23.	Speed Reduction	
	Acceleration Data, TRC 191	6.2 mph
	Tire Friction Effect	2.5 mph
	Total	8.7 mph
24.	Exit Speed, Observed	19.7 mph
25.	Impact Point, Observed	Left Door, Driver Location, (18.75" behind cg)
26.	Traffic Accident Data, TAD	9-LP-3
27.	Vehicle Damage Index, VDI	09LPAN2
28.	Hypothetical Occupant Impact Velocity (1' flail)	
	Design Limit	20 ft/sec
	Observed	None Detected
29.	Hypothetical Occupant Ride-down Acceleration (1' flail)	
	Design Limit	15.00 g
	Observed, NCHRP 230	None Detected
30.	Actual Occupant Impact Velocity	
	Limit (NCHRP 230)	30 ft/sec
	Observed	42 ft/sec
31.	Head Injury Criteria (HIC)	
	Design Limit	1000
	Driver, Observed	3892
32.	Upper Spine Acceleration Data	
	Acceleration with Duration Greater than .003 sec	124
	CSI	909
33.	Thoracic Injury Results	
	Fatal Injury	6.00
	Probability of:	
	AIS greater than 3	100%
	AIS greater than 4	100%
	AIS greater than 5	28% age 0, 38% age 20, 50% age 40
34.	Momentum Change from Pole	556 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 fifth of a series of six full scale crash tests conducted under Phase II, Task C of Contract Number DTFH61-81-C-00036. Tests 1, 2 and 3 were conducted using a rigid instrumented impact pole while tests 4, 5, and 6 impacted a breakaway luminare.

The vehicle used for this test was a 1979 VW Rabbit. The selection of the vehicle was based upon the results of a limited engineering study conducted by ENSCO, Inc. during a Phase II, Task A study. 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 left door of the vehicle was instrumented with four accelerometers to characterize the acceleration environment of the door at the impact location. 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. 017) 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 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 imapcts 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 20 mph momentum change of 667 lb-sec when hit by the FOIL bogie set up for a 1800 lb vehicle.

3.0 APPURTENANCE DESCRIPTION

The physical properties of the breakaway luminaire support are contained in table 2. 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 did not have a mast arm attached during this test. 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.

Table 2
Properties of Test Pole

Manufacturer:	Ameron
Material:	Steel
Weight:	292 lbs
Height:	30 ft
Height, c.g.:	11 ft
Top diameter:	3-1/2 in
Bottom diameter:	8 in
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

4.0 VEHICLE DESCRIPTION

The test vehicle was a 1979 VW Rabbit. The weight of the vehicle prior to incorporating the instrumentation for the test was 1699 pounds. The test inertial weight for the vehicle was 1835 pounds and the gross static weight when the occupant was included in the vehicle was 1990 pounds. The longitudinal center of gravity of the vehicle with the occupant was located approximately 36.5 inches behind the centerline of the front axle. The weight distribution of the vehicle in its instrumented configuration is given in table 3.

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. The vehicle's left door was instrumented with four accelerometers mounted to the inside of the door. Two were located about 6 inches forward and rearward from the impact point along mid-height of the door. The remaining two were located about 6 inches above and below mid-height of the door at the impact point. The test vehicle is shown in figure 1.

Table 3
Weight Distribution of Test Vehicle Prior to Testing

	Left (lbs)	Right (lbs)	Subtotal (lbs)
Front	637	587	1,224
Rear	392	374	766
Subtotals	1,029	961	1,990

1 lb. = .454 kg

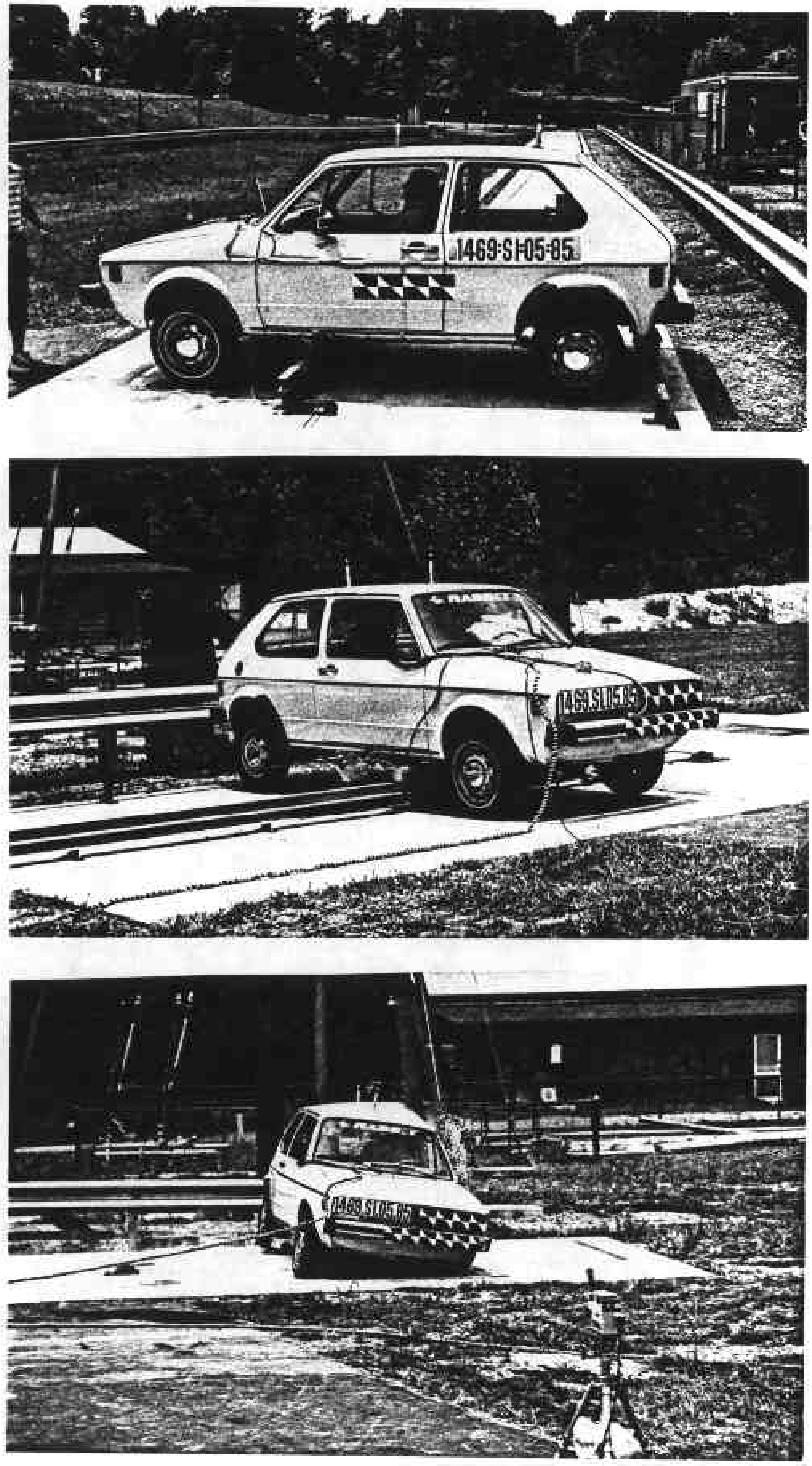


Figure 1. Pre-Test Photos of Vehicle

5.0 TEST INSTRUMENTATION

Film data of the test was taken as described in table 4. Transducer data was recorded as listed in table 5. 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 by the tape switch 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.

Table 4

Description of Film Data Acquisition
System for Full Scale Crash Test 1469-SI#5-85

Camera	Model	Position	Speed Setting	Lens
1	Redlake, Hycam	Rt. Side	500 pps	12.5 mm
2	Redlake, Locam	Front Rt.	500 pps	50 mm
3	Redlake, Locam	Front Lt.	500 pps	25 mm
4	Redlake, Locam	Onboard	500 pps	5.7 mm
5	Redlake, Locam	Rt. Side	500 pps	50 mm
6	Arrieflex	Documentation	24 pps	Zoom

Table 5

Transducer Data for Test 1469-SI#5-85

Channel No.	Channel Description
1	Upper Spine Accel., T01XG
2	Not Used
3	Upper Spine Accel., T01YG1
4	Upper Spine Accel., T01ZG
5	Left Lower Rib Accel., LLRYGA
6	Left Lower Rib Accel., LLRYG1
7	Not Used
8	Not Used
9	Lower Spine Accel, T12XG
10	Lower Spine Accel, T12YGA
11	Lower Spine Accel, T12YG1
12	Lower Spine Accel, T12ZG1
13	Driver Door Accel., Upper Center
14	Driver Door Accel., Middle Forward
15	Driver Door Accel., Middle Rearward
16	Driver Door Accel., Lower Center
17	Vehicle Accel., cg-x
18	Vehicle Accel., cg-y
19	Vehicle Accel., cy-z
20	Driver Door, Impact Marker
21	Vehicle c.g., Roll Rate
22	Vehicle c.g., Yaw Rate
23	Left Upper Rib, Accel., LURYGA
24	Left upper Rib, Accel., LURYG1
25	Head Accel, X
26	Head Accel, Y
27	Head Accel, Z
28	Pelvis Accel, X
29	Pelvis Accel, Y
30	Pelvis Accel, Z

6.0 TEST RESULTS

The impact conditions were 28.4 mph (12.7 m/s) at a point on the left door in line with the occupant 18.75 in (.48 m) behind the longitudinal location of the center of gravity of the vehicle measured with the dummy in the vehicle. The vehicle had a 7° 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 11.1 inches (.28 m). Photographs of the vehicle and luminaire support after the collision event are shown in figure 2.

Initiation of the breakaway fracture mechanism of the luminaire support occurred at approximately .020 seconds after impact. The force levels at the time of initiation of the breakaway fracture mechanism of the luminaire support were about 22,000 pounds based on the vehicle acceleration data filtered at SAE Class 60.

After the initial separation from the vehicle the luminaire support translated forward at a speed of 18.7 f/s (5.7 m/s) with a rotation rate of 1.72 rad/sec. The luminaire support rotated up and over the test vehicle with the top of the pole hitting the right rear corner of the test car about .6 second after impact. As the support rotated away, vehicle yawed counter clockwise and rolled up on its left tires and wheels. The maximum roll angle was about 15° based on observation of the high speed film. The vehicle then settled back on all 4 tires and continued forward away from the impact area after yawing a total of about 90°. As the vehicle rolled away from the impact area it steered slightly to its left. The final resting position of the vehicle was about 33 feet to the left of the impact approach path and 54 feet down stream. The residual test vehicle crush measured using the 6 point NHTSA guide is given in table 6. See figure 3 for reference.

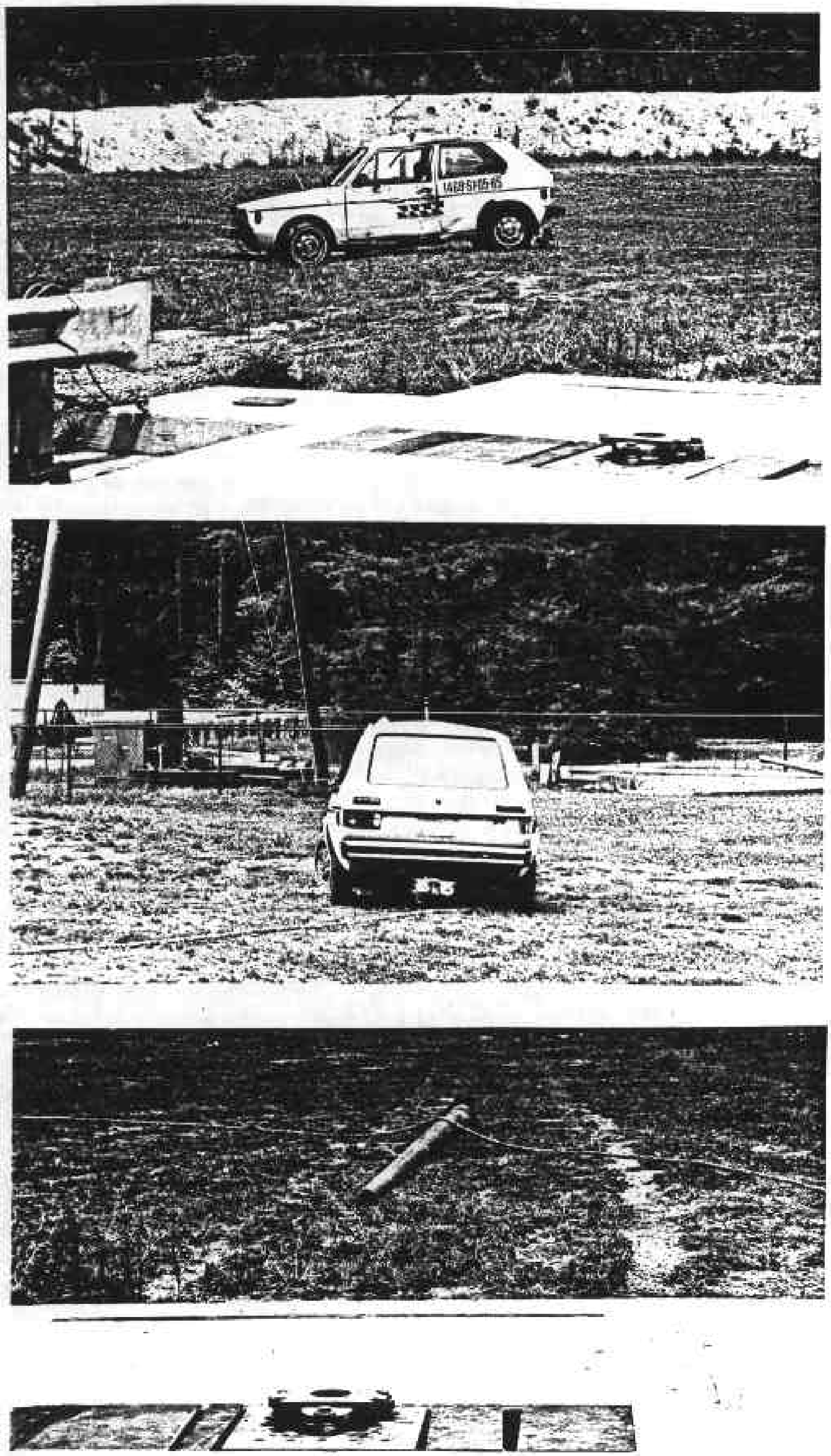


Figure 2. Post Test Photos of Vehicle

Figure 2 (Cont'd). Post-Test Photographs of Vehicle

Table 6

Residual Vehicle Crush

C1 = 0.00		L = 75.00"
C2 = 3.50"		D = -19.25"
C3 = 9.50"		
C4 = 4.25"		
C5 = 1.25"		
C6 = 0.00		
Max = 11.10"		

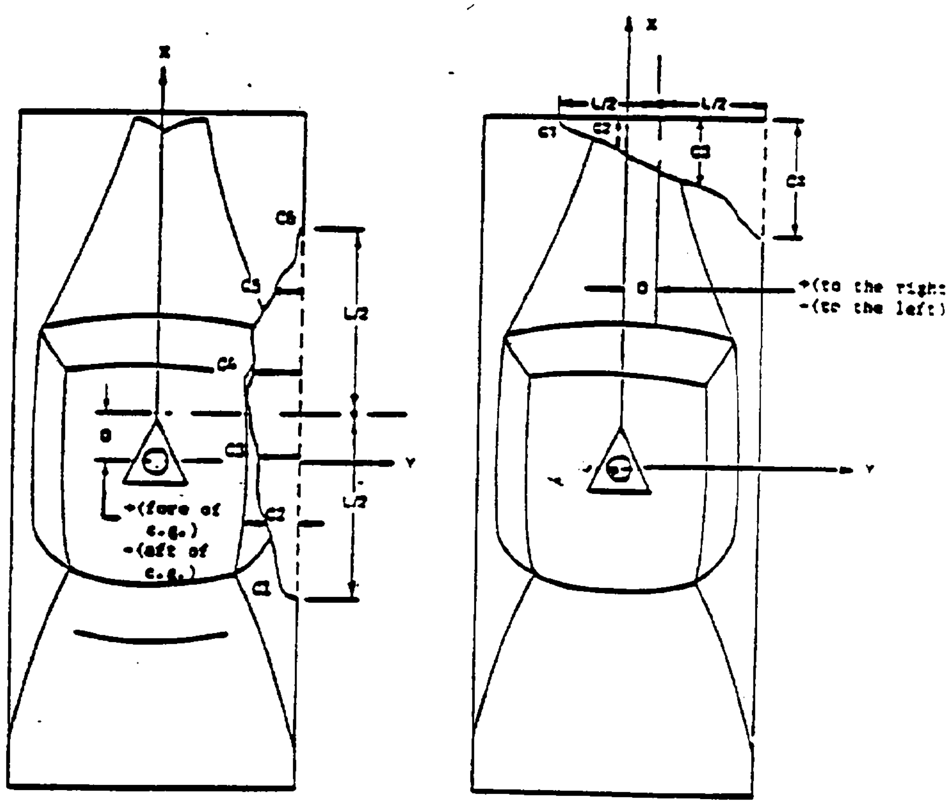


Figure 3. NHTSA Vehicle Damage Measurements

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 accelerometers mounted on the left door of the vehicle were debiased and filtered at SAE Class 180 and are presented to characterize the acceleration environment on the door at the impact location.

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's latest technique to determine side imapct occupant injury.

7.1 IMPACT VELOCITY ANALYSIS

The speed that the test vehicle impacted the luminaire support was determined from the high speed films and speed trap. Results from the speed analysis of the film data are contained in table 7.

Table 7

Test Vehicle Impact Speed Evaluation
Using High Speed Film Analysis

Camera	Position	Impact Speed (ft/sec)	Impact Speed (mph)
1	Right Side	41.7	28.4
2	Right Side	41.7	28.4
	Average	41.7	28.4

A speed trap was installed to measure the speed of the vehicle as it left the end of the mono-rail. This speed was 45.0 ft/sec. The vehicle slowed down as it slid toward the test pole. The distance from the speed trap to the pole was 11 ft. About 4 ft of this distance was slide zone with the remaining being the area where the vehicle is in the air or settling onto the runway. Assuming a dry concrete coefficent of friction of .7 then the vehicle would scrub off about 5 kip ft of energy. Deducting this loss from the speed trap data results in a impact speed of 43.1 ft/sec. This speed is slightly higher then the film data but due to the unknowns in the adjustment technique it provides a measurement of confidence to the film data.

Based upon the results of this analysis, the speed of the vehicle upon impacting the support was 28.4 mph (12.7 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 4 through 6. The acceleration traces obtained with the use of the SAE Class 180 (f_c = 300 Hz) filtering technique are presented in figures 7 through 9. Figure 10 presents the impact marker channel. Figures 11 through 14

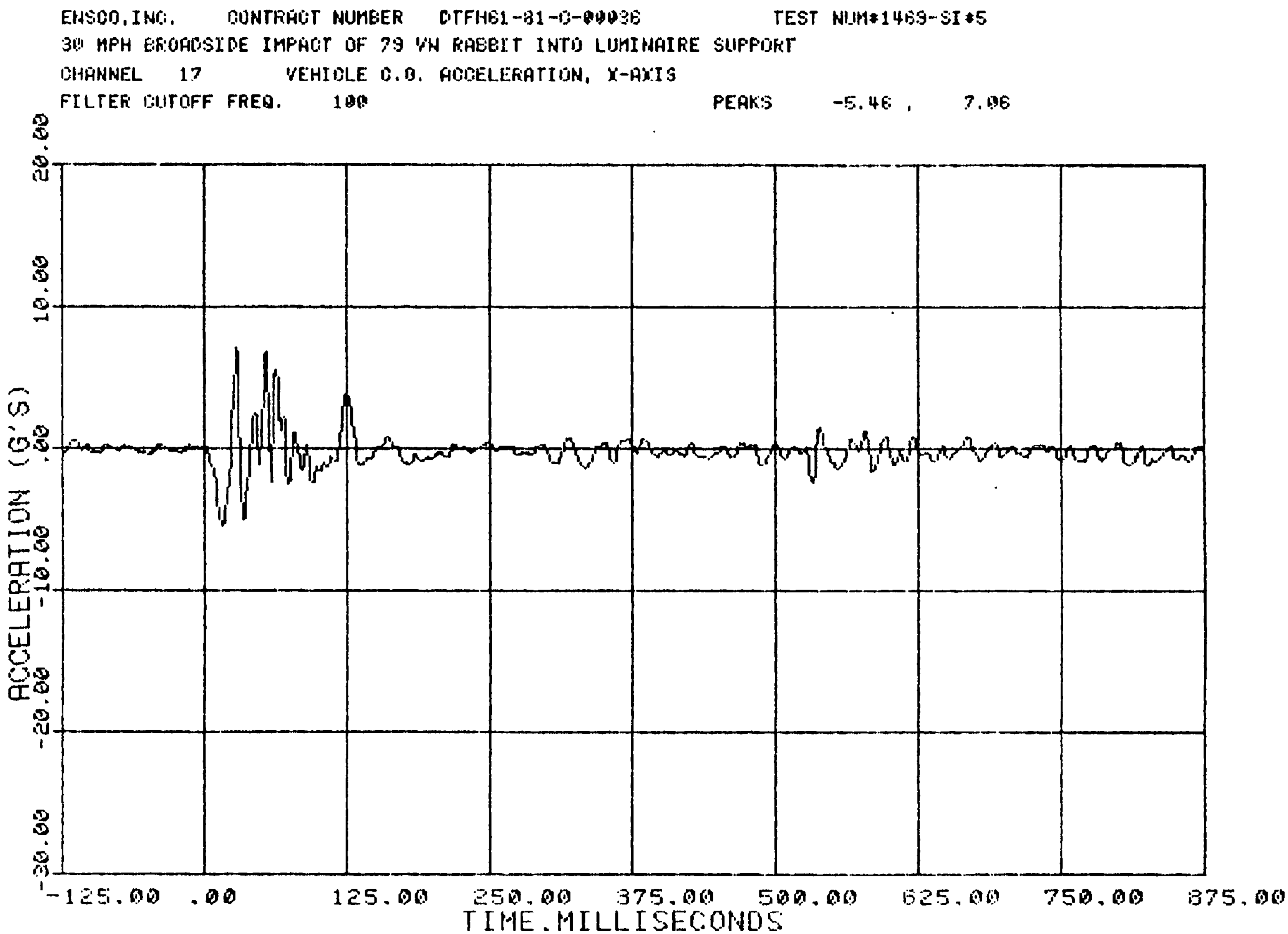


Figure 4. Vehicle Acceleration, X-Axis, 100 Hz

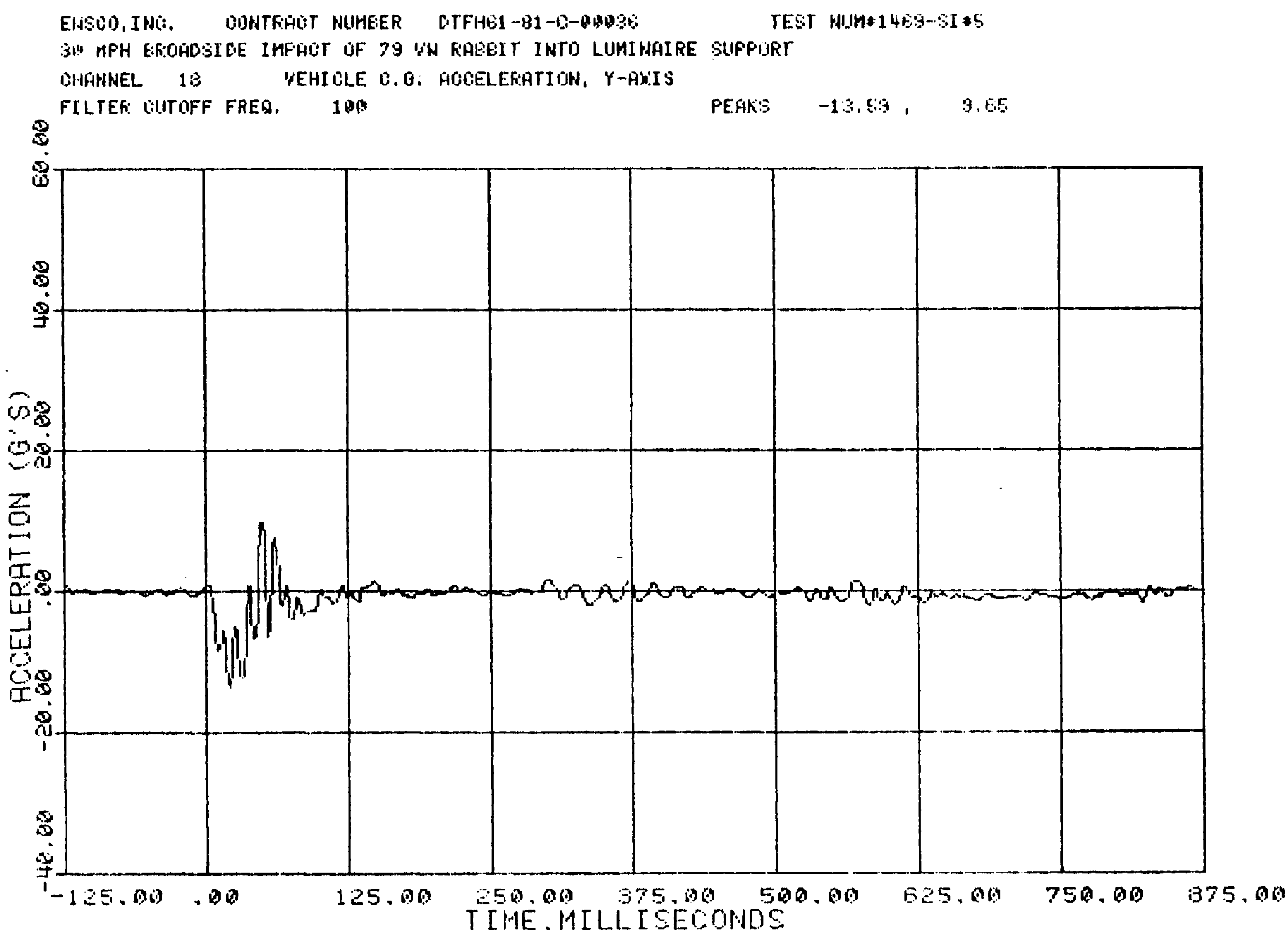


Figure 5. Vehicle Acceleration, Y-Axis, 100 Hz

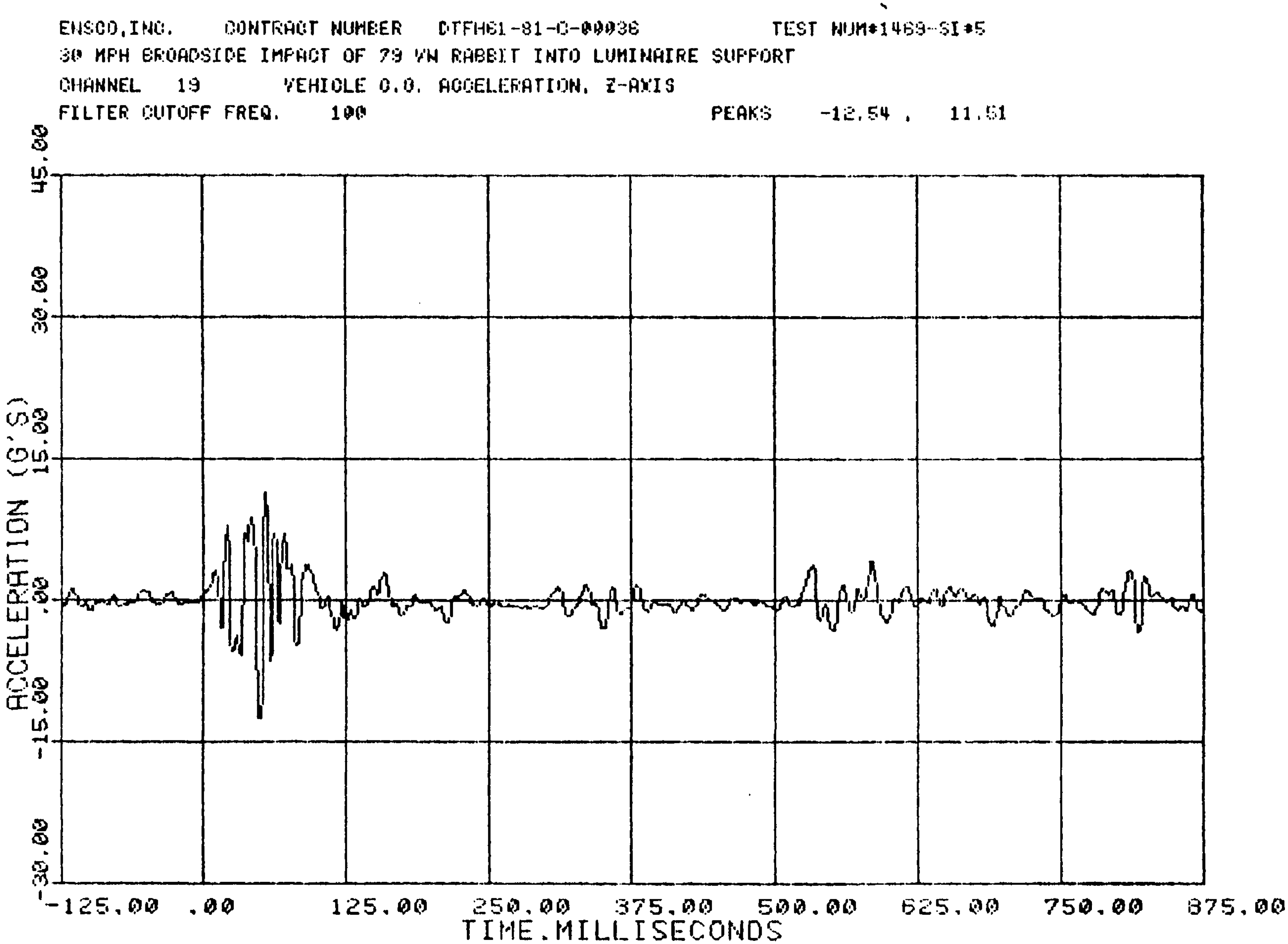


Figure 6. Vehicle Acceleration, Z-Axis, 100 Hz

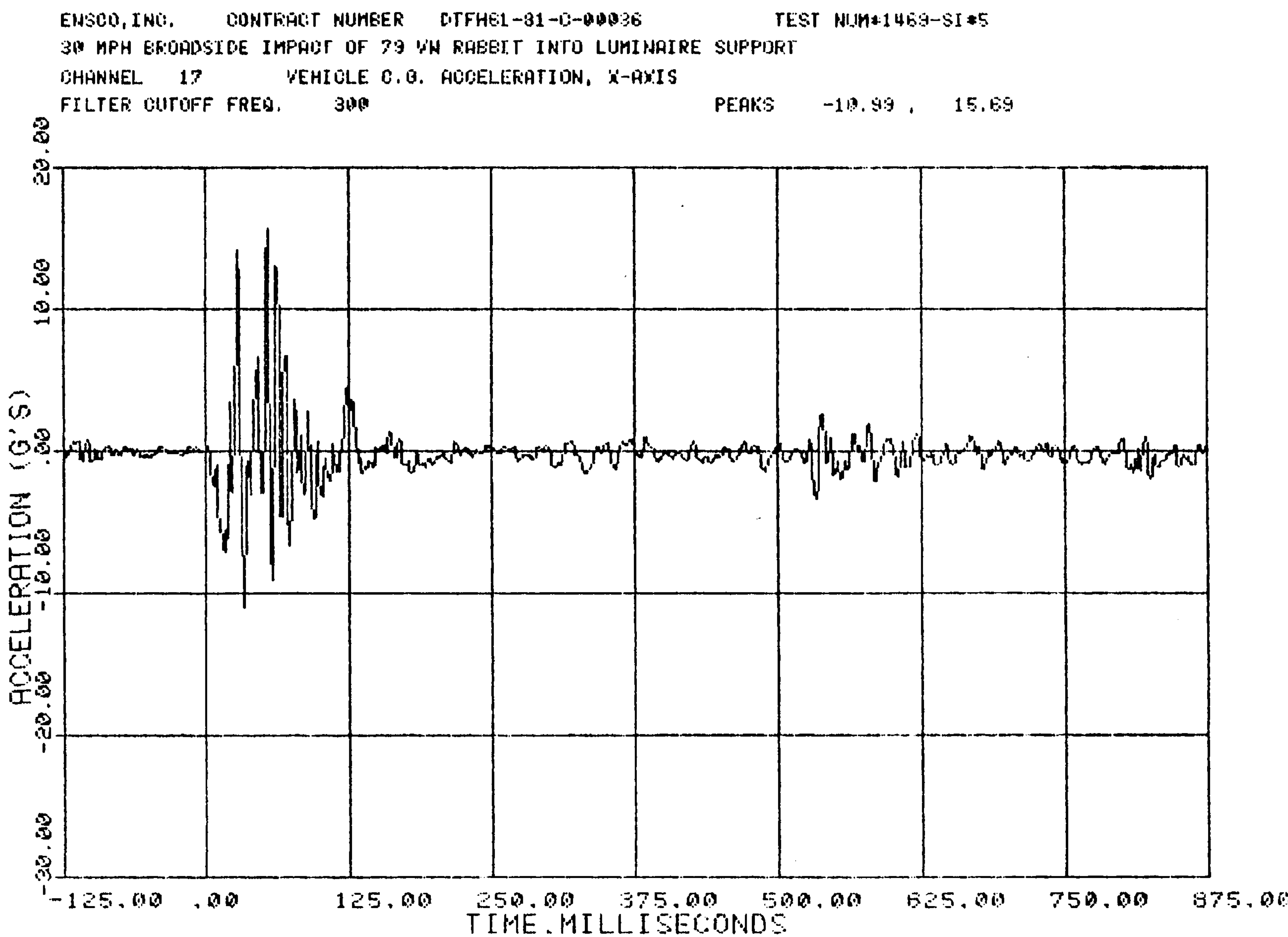


Figure 7. Vehicle Acceleration, X-Axis, 300 Hz

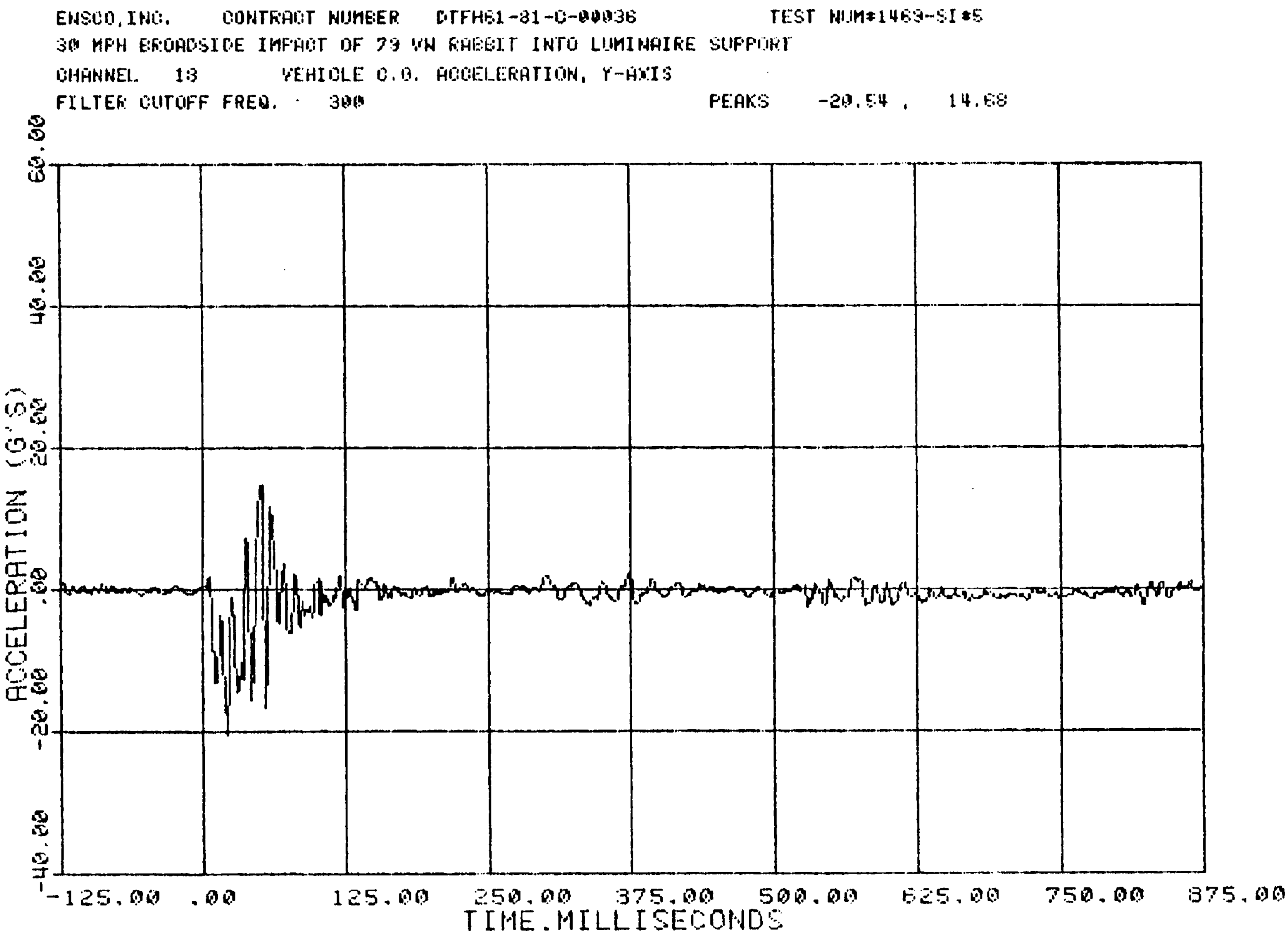


Figure 8. Vehicle Acceleration, Y-Axis, 300 Hz

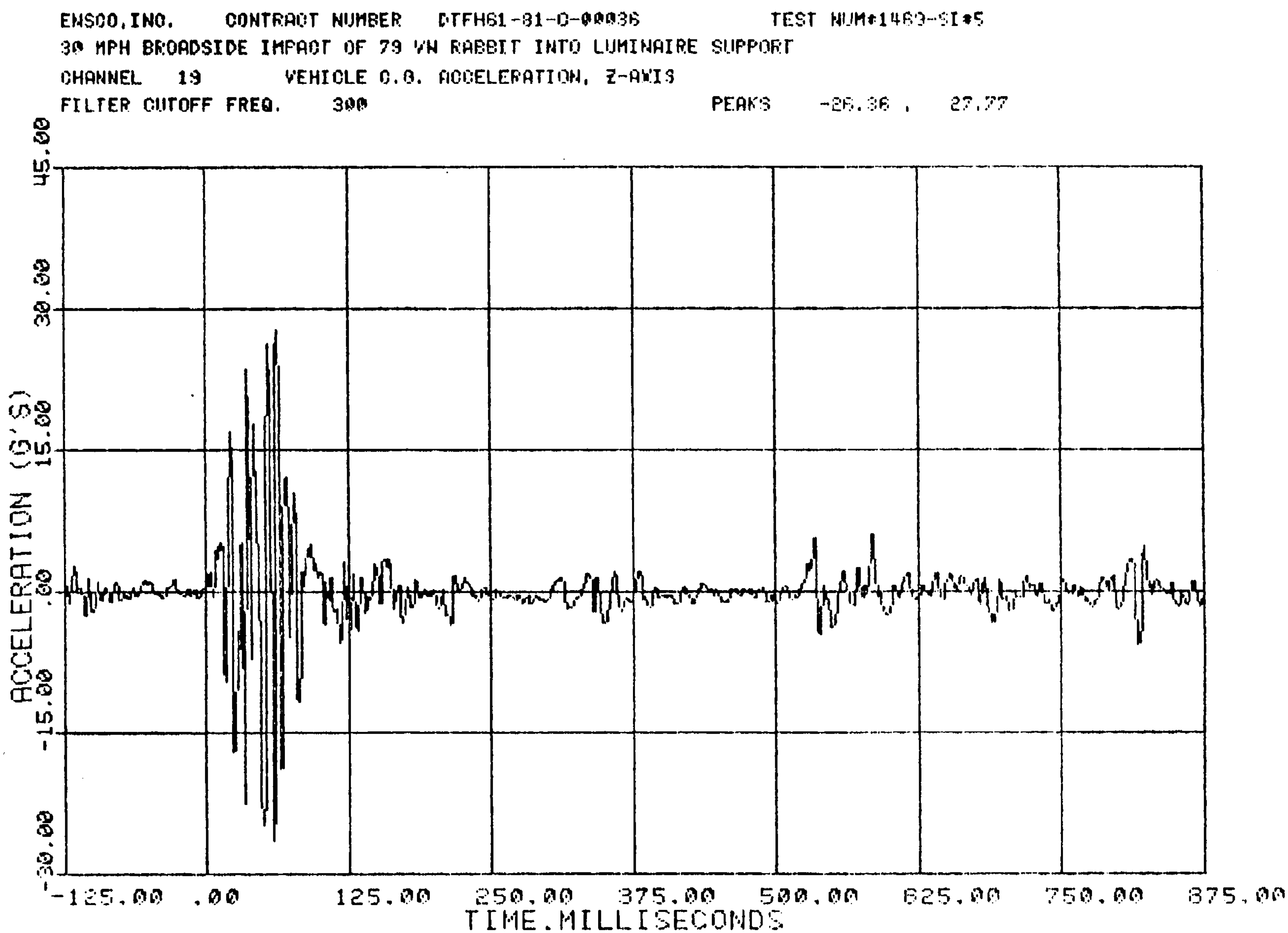


Figure 9. Vehicle Acceleration, Z-Axis, 300 Hz

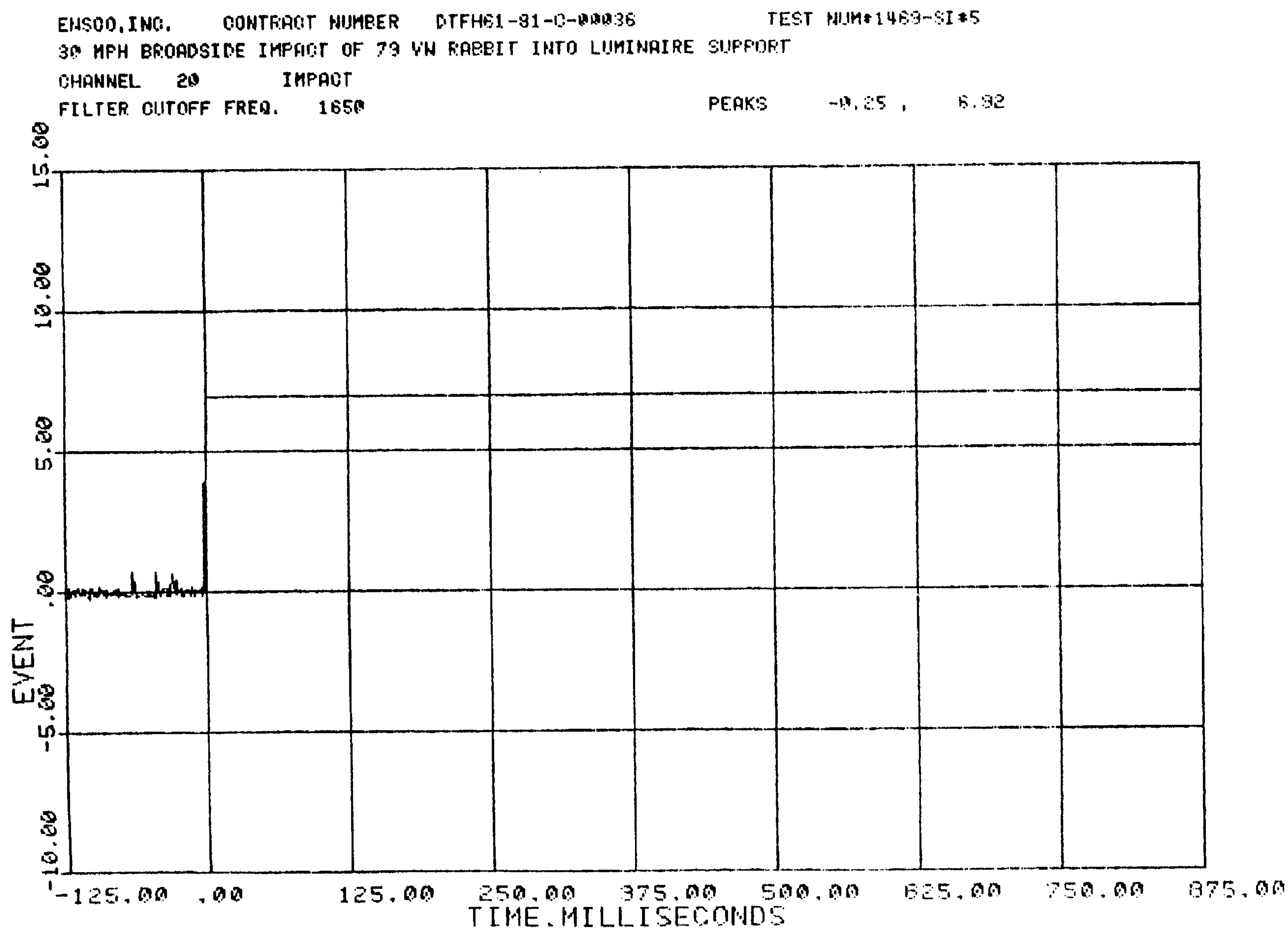


Figure 10. Event Marker, Impact

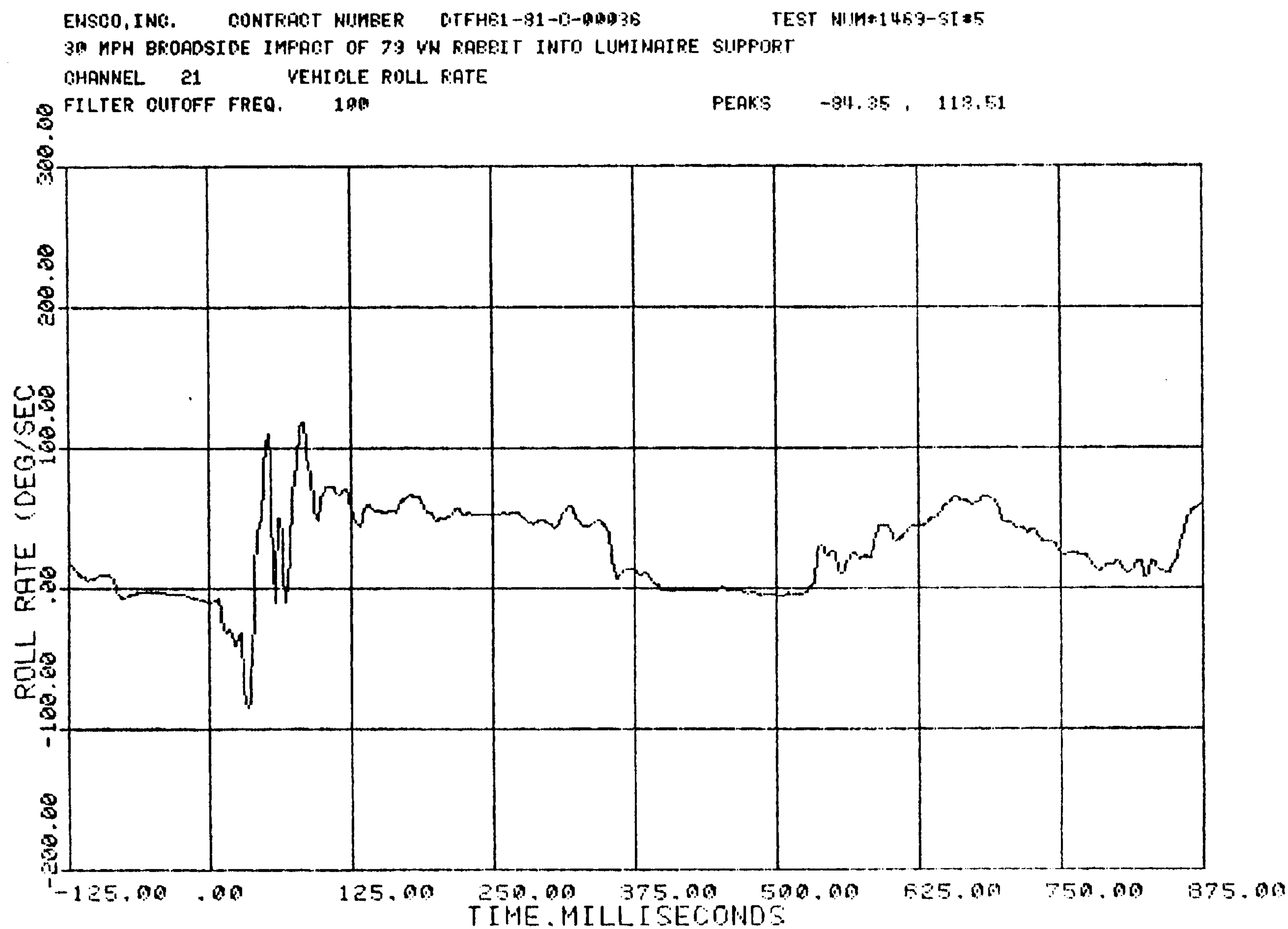


Figure 11. Vehicle Roll Rate, 100 Hz

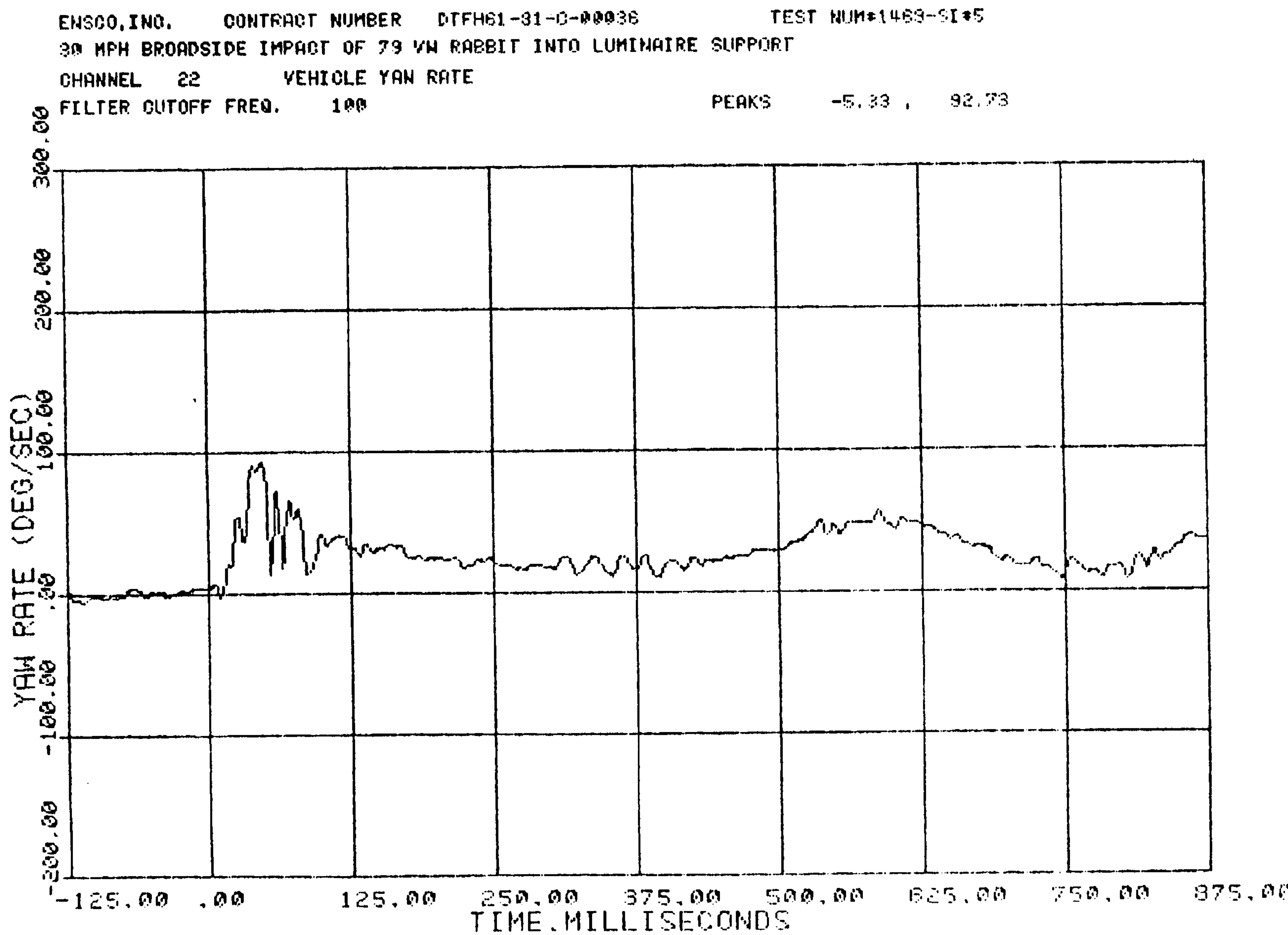


Figure 12. Vehicle Yaw Rate, 100 Hz

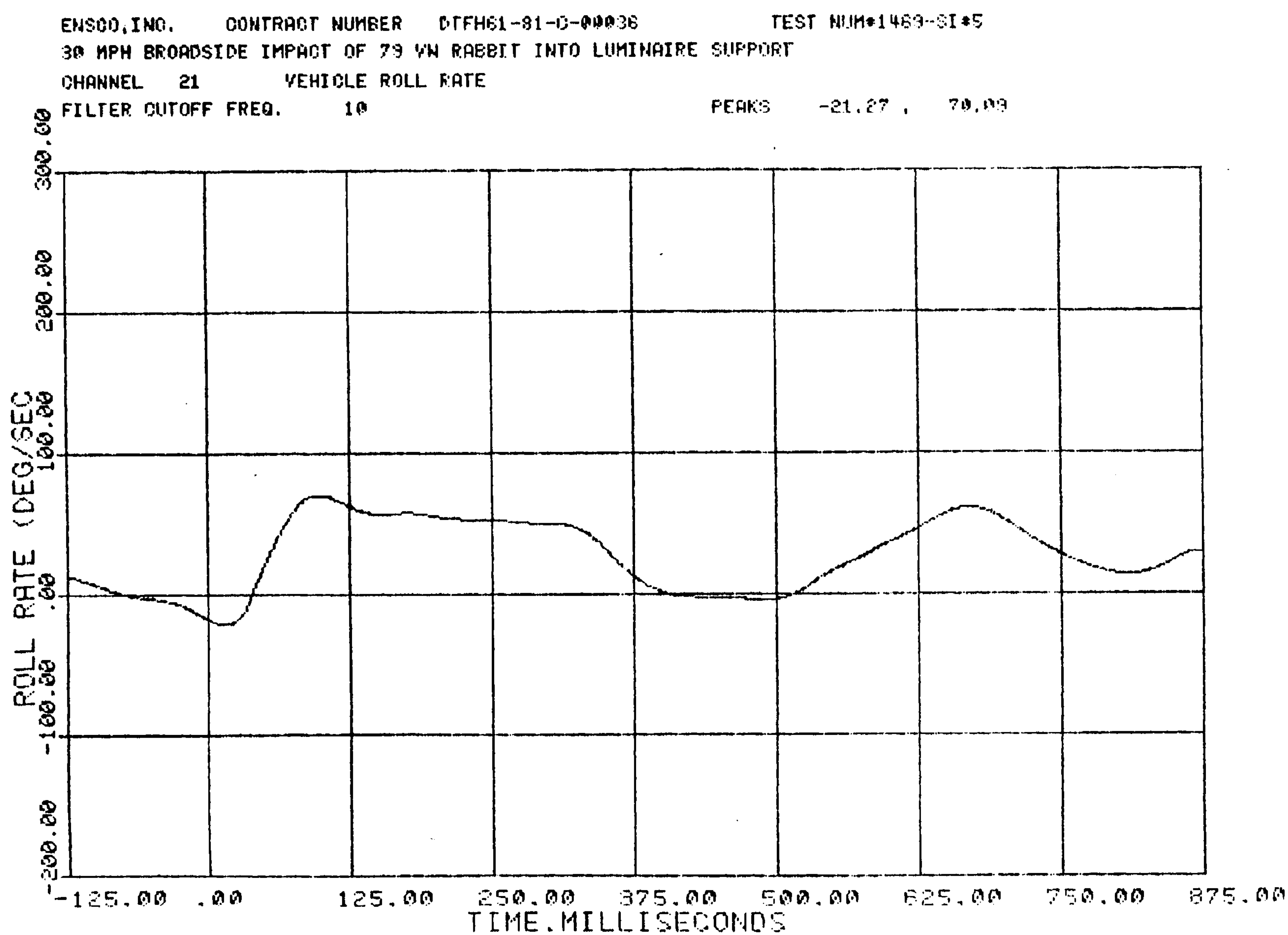


Figure 13. Vehicle Roll Rate, 10 Hz

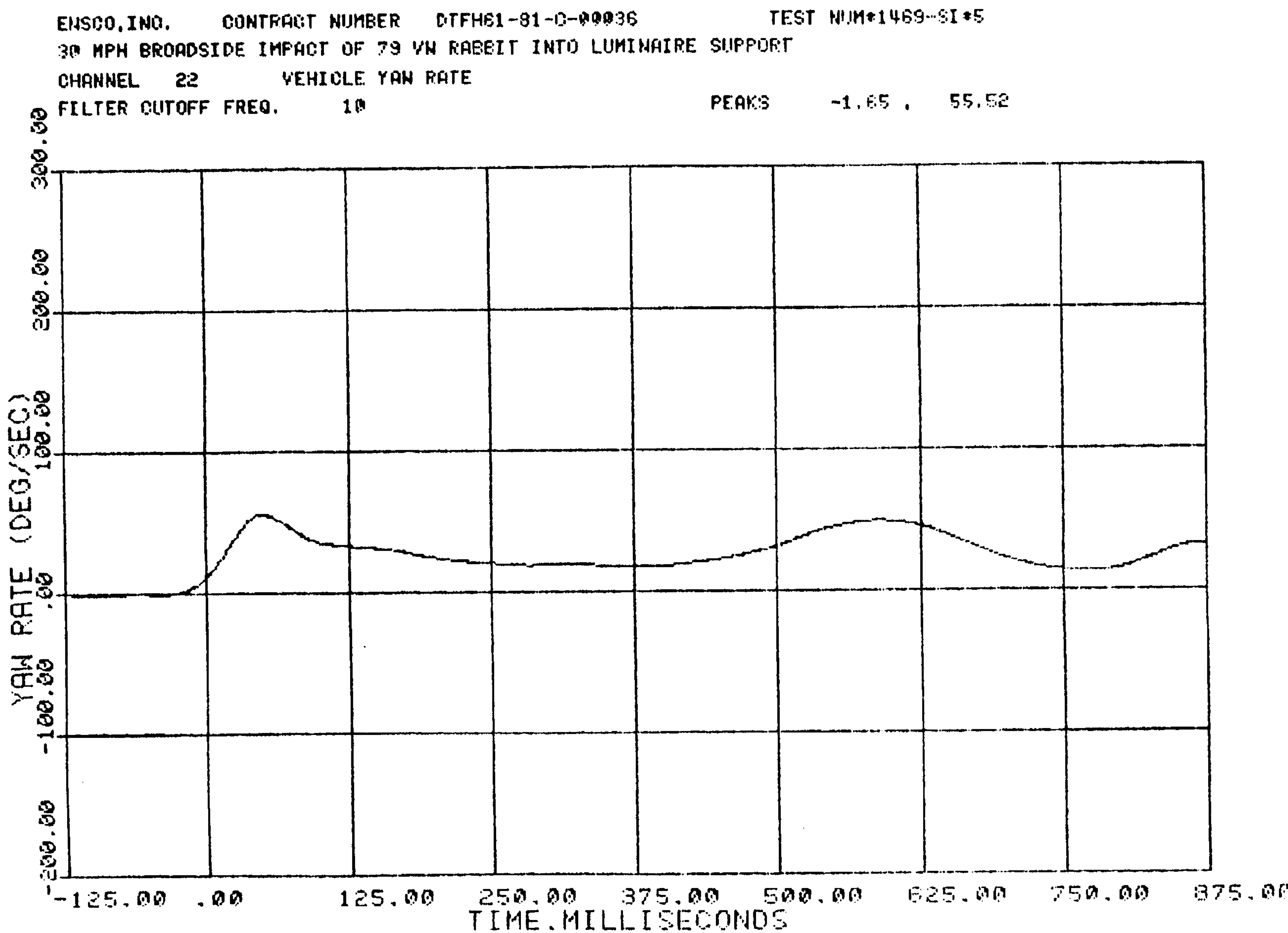


Figure 14. Vehicle Yaw Rate, 10 Hz

contain the rate gyro data filtered at 100 Hz and 10 Hz (SAE Class 60 and 6).

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 9.0 ft/sec and 556 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 momentum change of the vehicle due to the pole and tire sliding was 711 lb-sec.

Analysis of the impact velocity of a hypothetical front seat passenger against the vehicle interior, calculated from the vehicle lateral Class 180 accelerations and three different lateral displacements, yielded the results shown in table 8. Using the standard one foot flail distance, a hypothetical front seat occupant did not impact the interior of the vehicle in the lateral direction during the event based upon data filtered at SAE Class 180. However, the actual impact velocity of the occupant with the interior of vehicle was approximately 42 ft/sec (12.8 m/s) 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.

Since the occupant did not move 1 foot no ridedown acceleration was observed. Impact velocities and their associated ridedown acceleration were detected with the .5' and .25' flail distance.

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.

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.

Table 8

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

Flail Distance (in)	Change in Velocity (ft/sec)	Ride Down Acceleration (g's)
12	None detected	None detected
6	-8.0	-2.70
3	-7.7	+4.24

The accelerometers located on the driver's door were filtered SAE Class 300 (f_c = 180). During the test the lower center accelerometer was destroyed. The acceleration tire traces for this test are shown in figure 15 through 18.

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

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

where

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

θ = Rotational rate of luminaire support

D_I = Impulse lever arm during Phase 3 = Pole (x_{cg}) - 2.5 ft = 8.5 ft

M_p = Mass of luminaire support = 9.1 slugs

I_p = Mass moment of inertia of the luminaire support = 680 slug ft^2

and I_3 = Momentum change occurring during Phase 3.

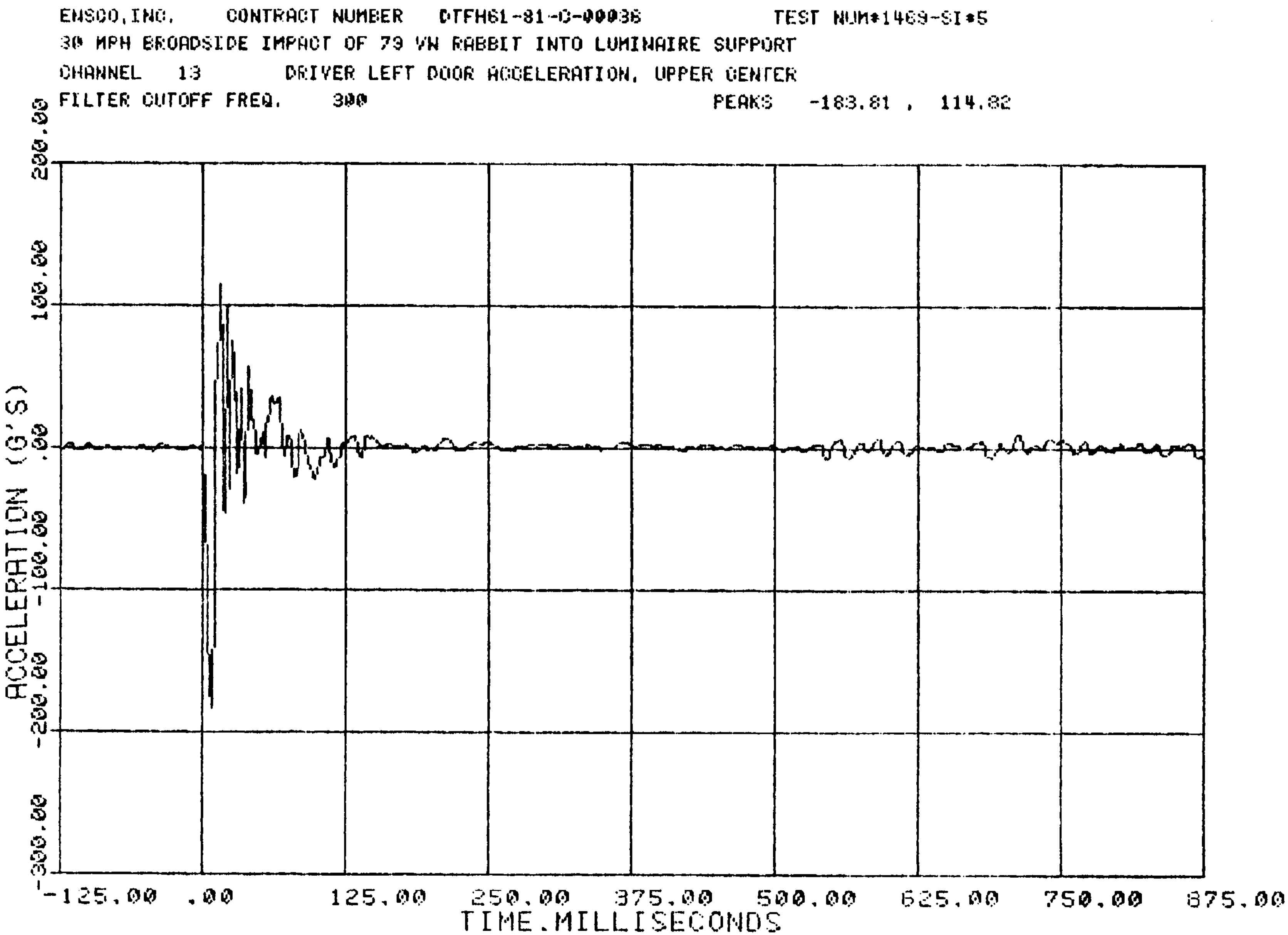


Figure 15. Vehicle Driver's Door Acceleration, Upper Center, 300 Hz

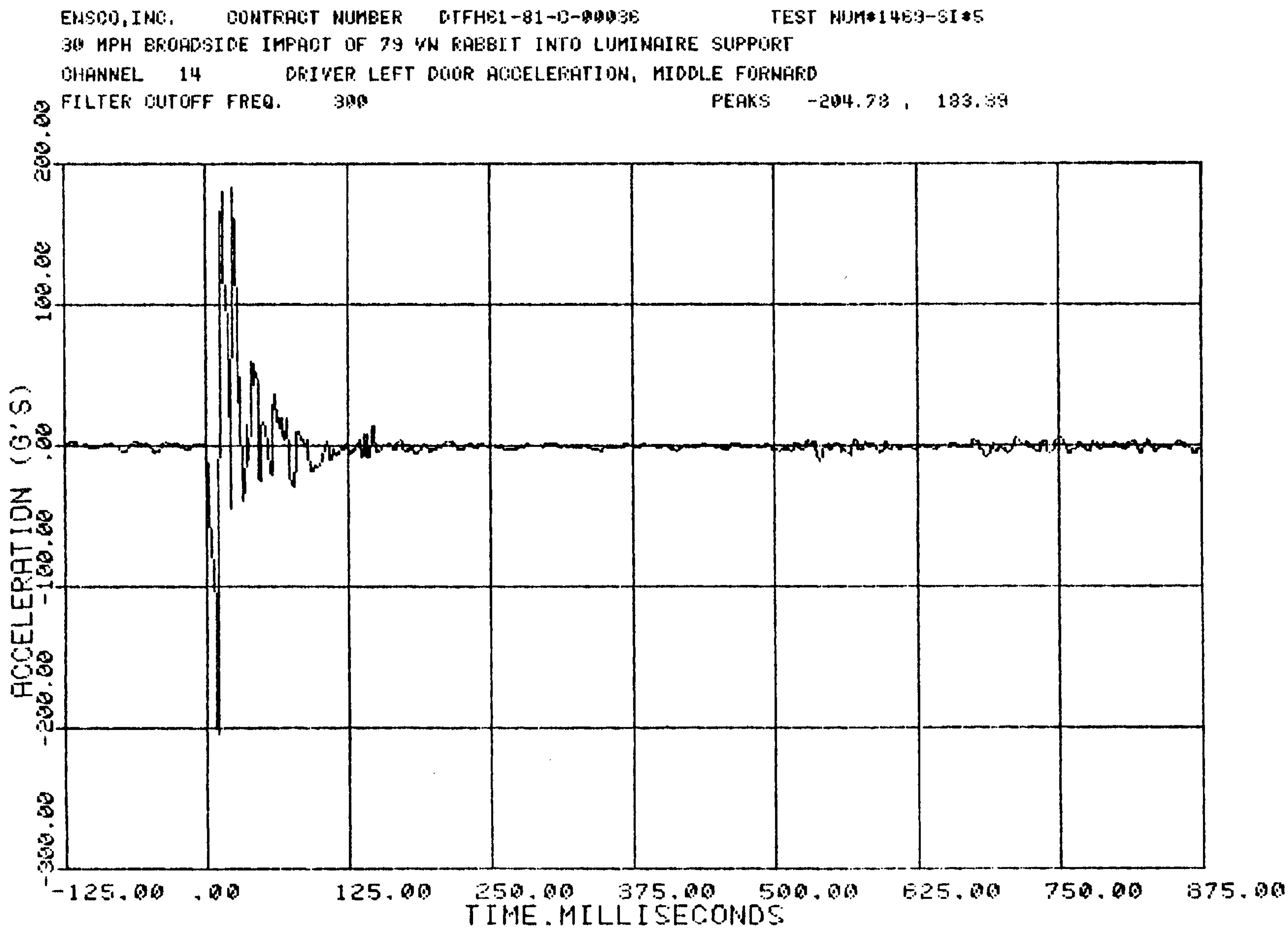


Figure 16. Vehicle Driver's Door Acceleration, Middle Forward, 300 Hz

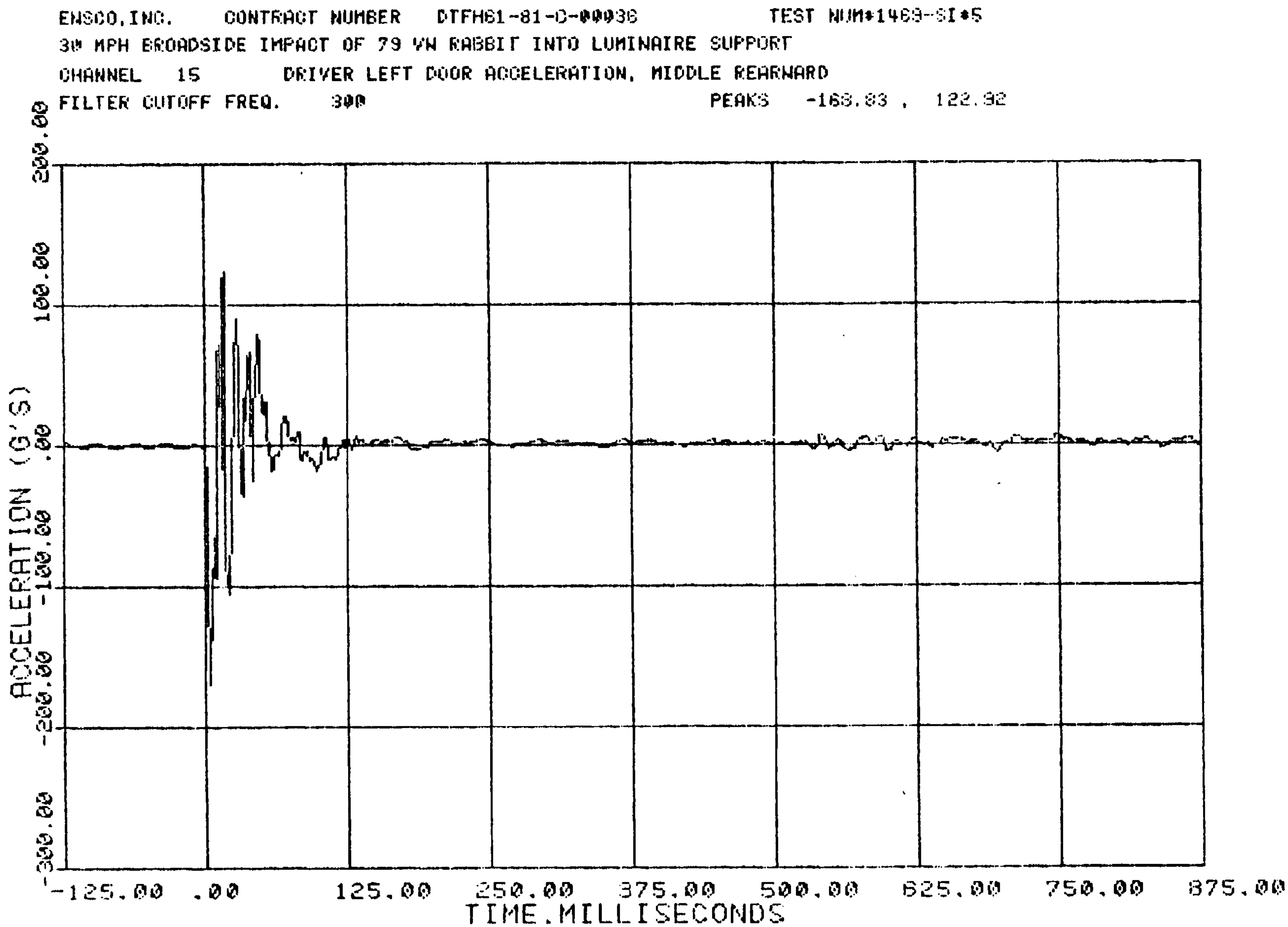


Figure 17. Vehicle Driver's Door Acceleration, Middle Rear, 300 Hz

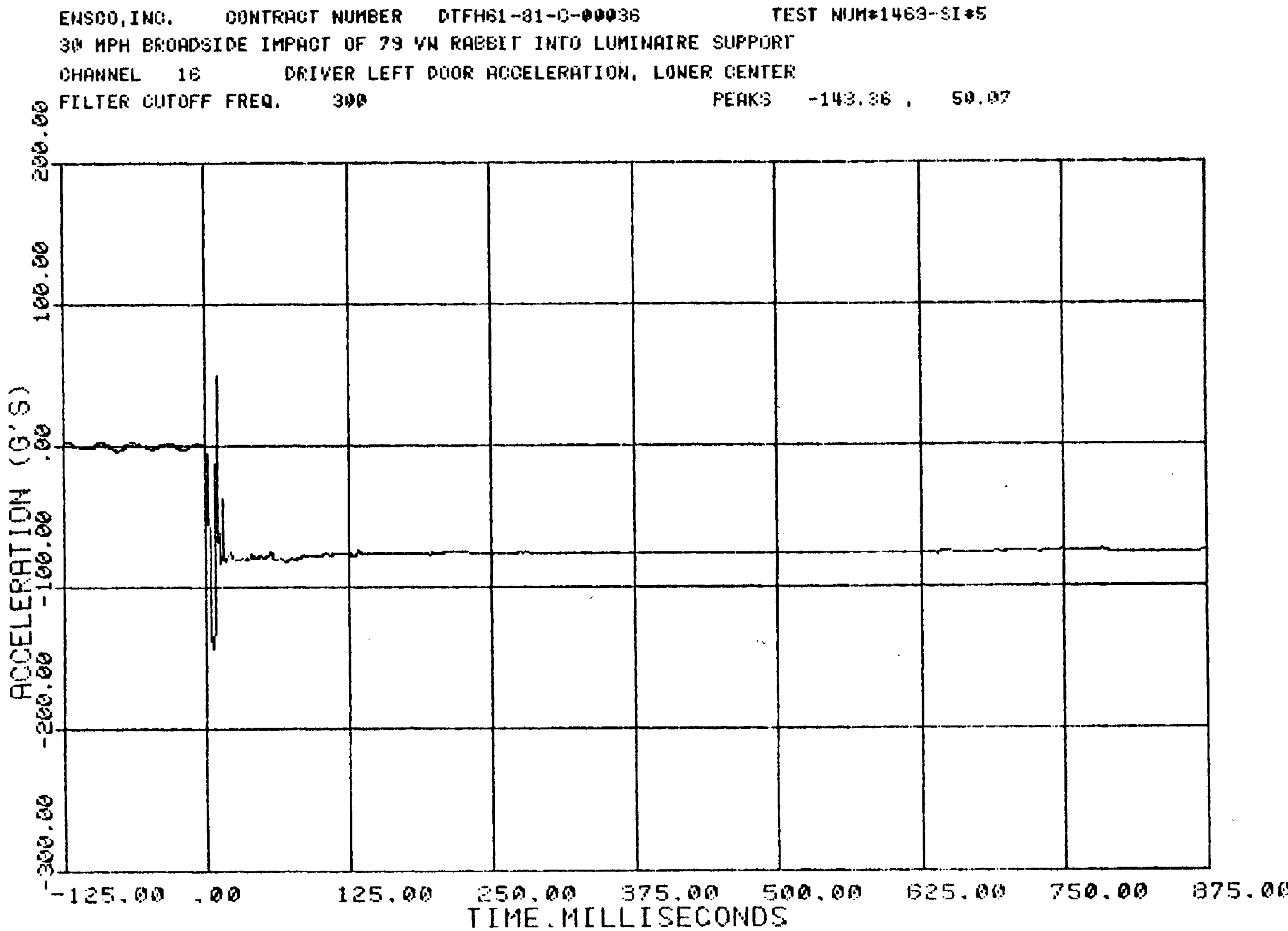


Figure 18. Vehicle Driver's Door Acceleration, Lower Center, 300 Hz

From the film data $\dot{x}_{cg}$ = 18.7 f/s (5.7 m/s) and $\dot{\theta}$= 1.72 rad/sec. Using these two numbers the momentum change occurring during Phase 3 is given by

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

$$= 170 \text{ lb-sec } (756 \text{ N-s})$$

or

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

$$= 137 \text{ lb-sec } (610 \text{ N-s}).$$

The average momentum change associated with the third phase of the vehicle momentum change is 154 lb-sec (681 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 19 through 22. The results of the HIC evaluation calculated for the occupant during this test is shown in table 9. Comparing the results to the acceptable limit of 1000 indicates that the collision event was severe with the measured value exceeding the limit by almost 4 times.

7.5 OCCUPANT SEVERITY INDEX EVALUATION

The data obtained from the triaxial accelerometer packages located in the upper and lower parts of the spine and in the pelvis of the occupant were filtered at SAE Class 180 and combined to yield a resultant acceleration occurring during the impact event for each of the respective locations. The severity

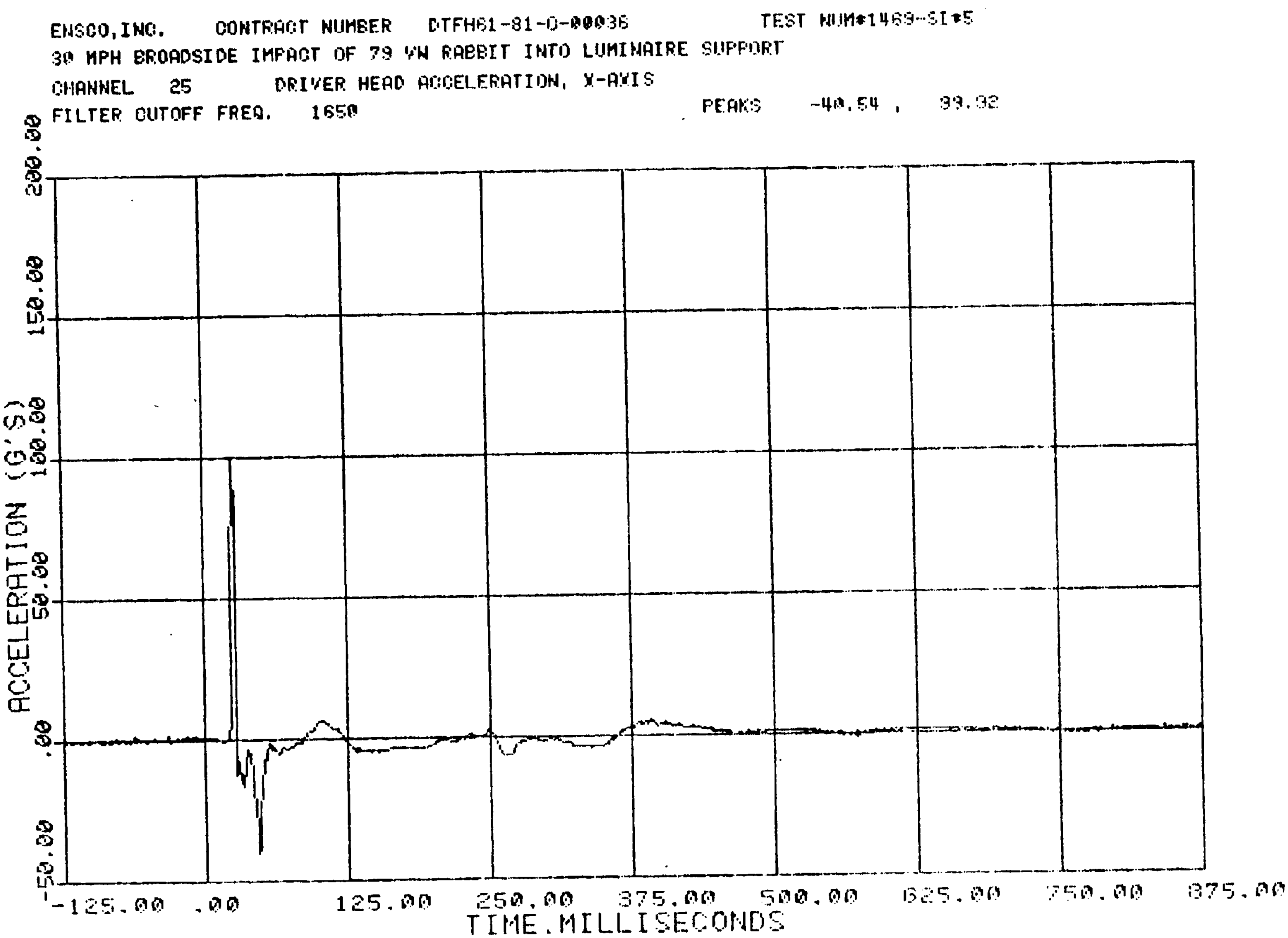


Figure 19. Driver's Head Acceleration, X-Axis, 1650 Hz

ENSCO,INC.   CONTRACT NUMBER   DTFH61-81-C-00036   TEST NUM#1463-SI#5
30 MPH BROADSIDE IMPACT OF 73 VW RABBIT INTO LUMINAIRE SUPPORT
CHANNEL 26   DRIVER HEAD ACCELERATION, Y-AXIS
FILTER CUTOFF FREQ. 1650   PEAKS -332.22 , 33.16

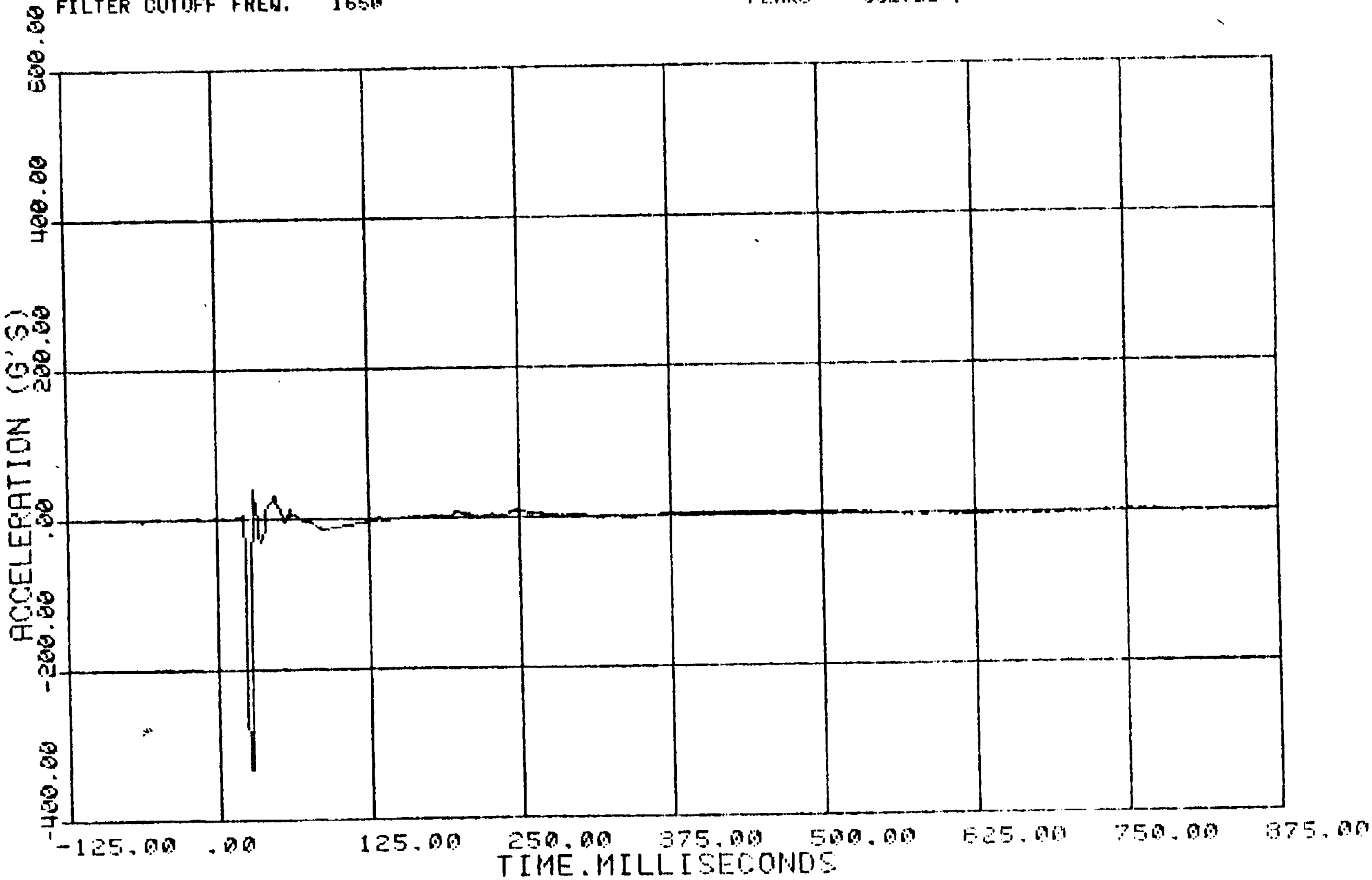


Figure 20. Driver's Head Acceleration, Y-Axis 1650 Hz

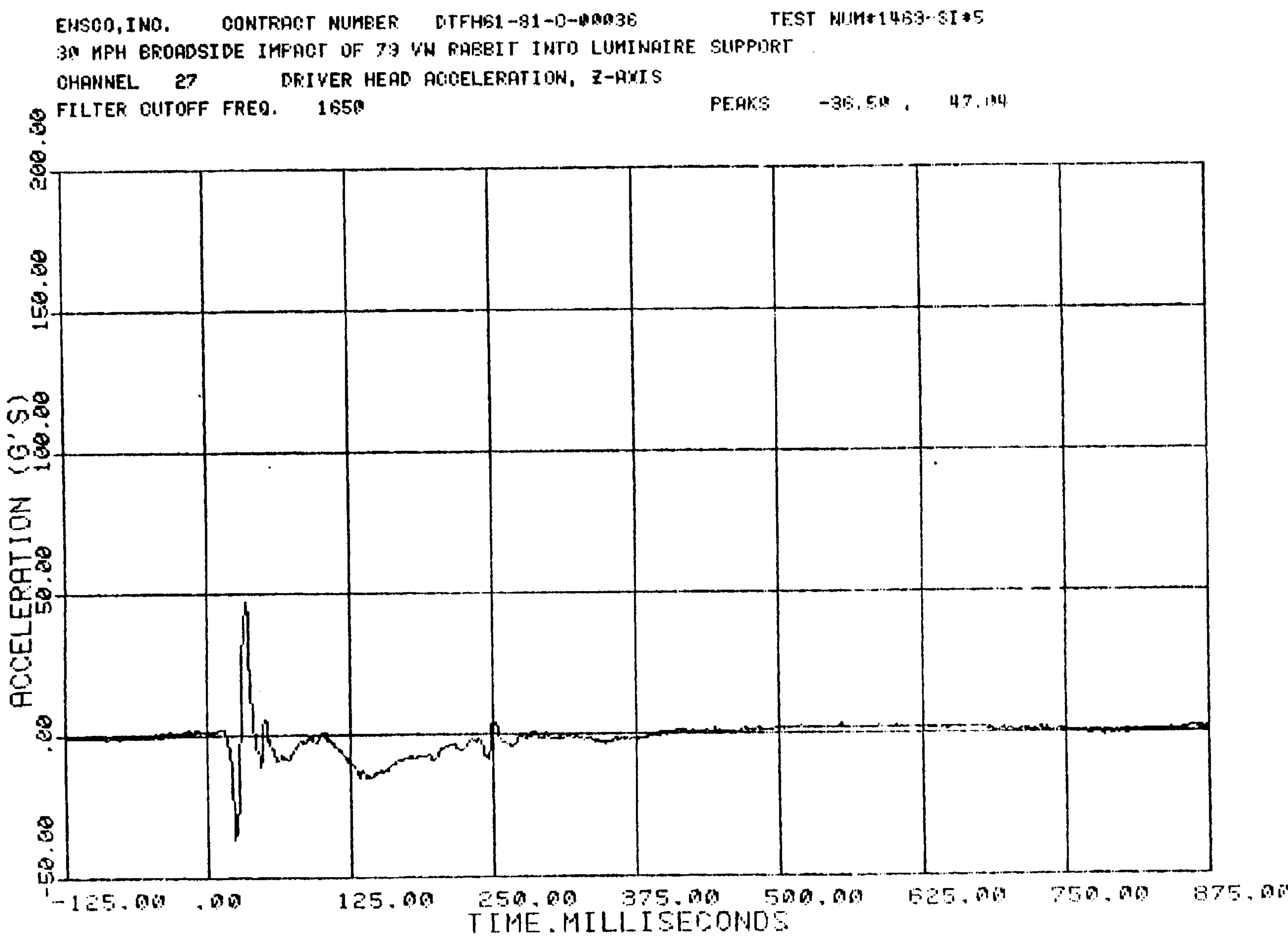


Figure 21. Driver's Head Acceleration, Z-Axis, 1650 Hz

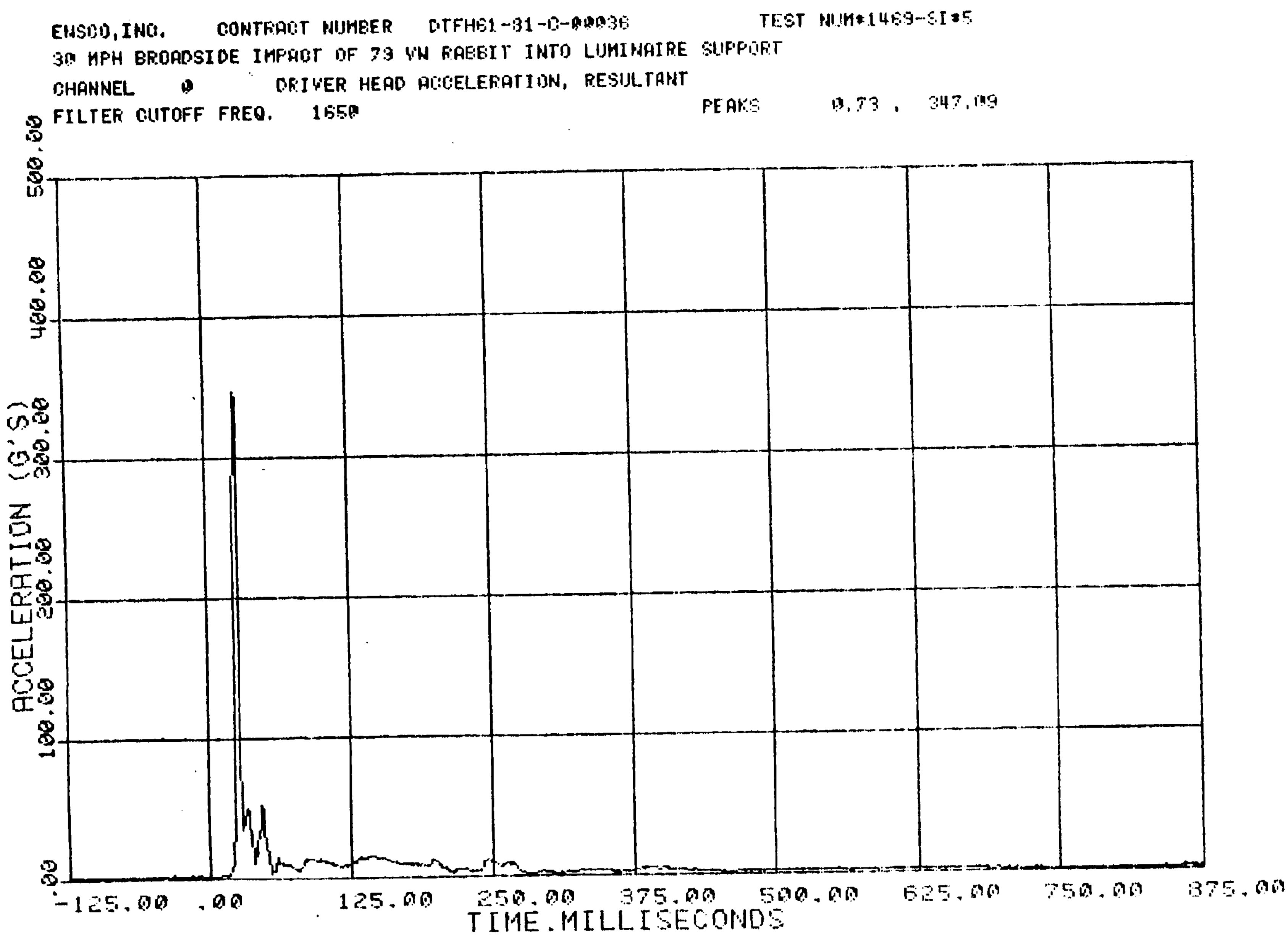


Figure 22. Driver's Head Acceleration, Resultant, 1650 Hz

Table 9

Head Injury Criteria Evaluated for Full Scale Crash Test 1469-SI#5-85

	Driver
HIC	3892
t(Start)	.025 sec
t(Stop)	.027 ms
t(Duration)	.002 sec

index for the upper spine 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. The upper spine was selected to evaluate chest parameters since it was located close to the location of standard chest accelerometers. The CSI was 909 and the maximum acceleration was 124 g's at 27 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. These resultants are presented for relative comparison purposes only.

The acceleration traces and associated resultants obtained with the use of the SAE Class 180 (f_c = 300 Hz) filtering thechniques are presented in figures 23 through 26 for the upper spine location, figures 27 through 31 for the lower spine location and figures 32 through 35 for the pelvis location.

7.6 THORACIC INJURY EVALUATION

The data obtained from the accelerometers mounted on the upper and lower left ribs within the thorax as well as the lateral ones in the T01 and T12 locations of the occupant were filtered using the NHTSA FIR filter and are presented in figures 36 through 42.

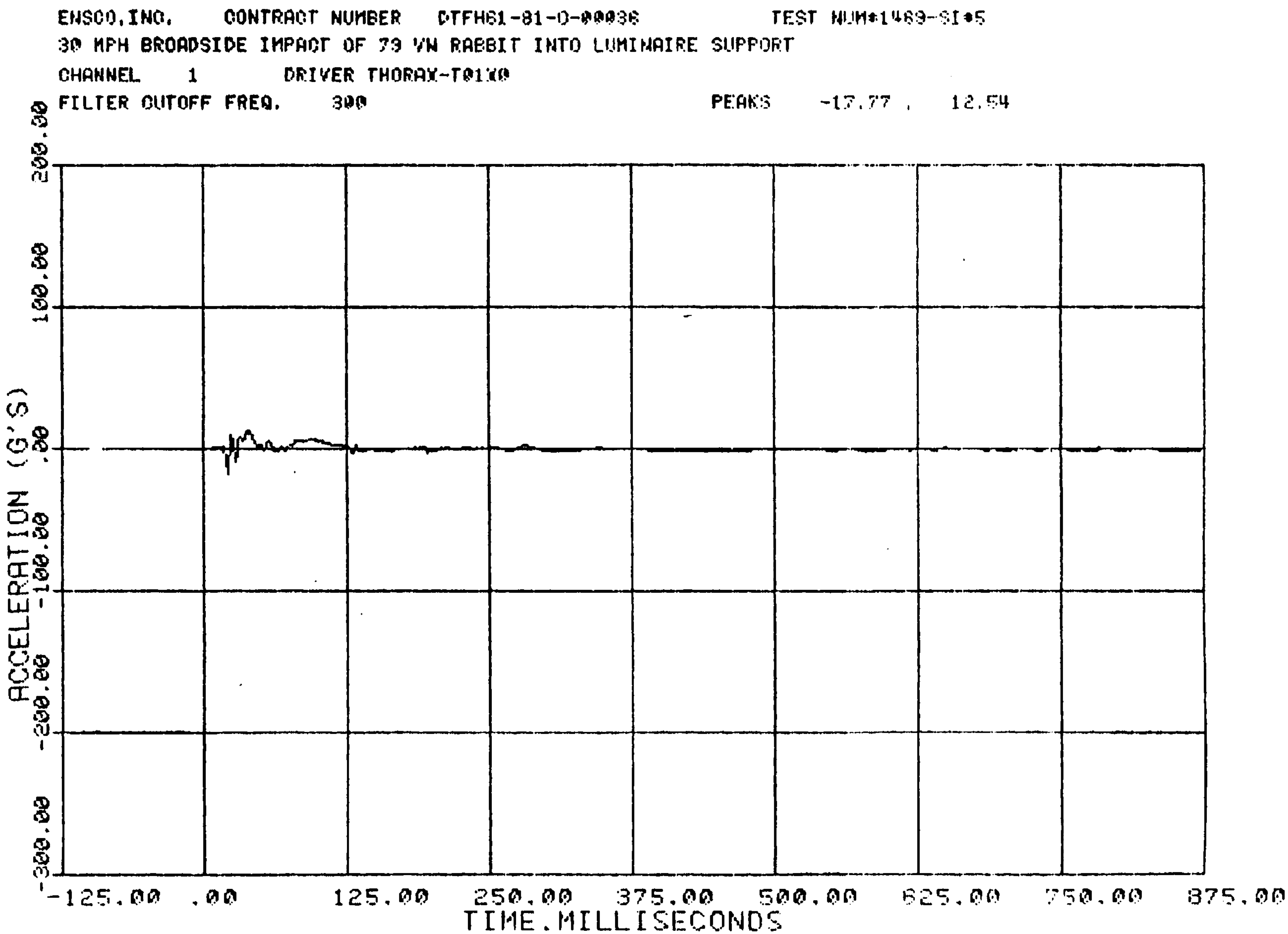


Figure 23. Driver's Upper Spine Acceleration, T01X, 300 Hz

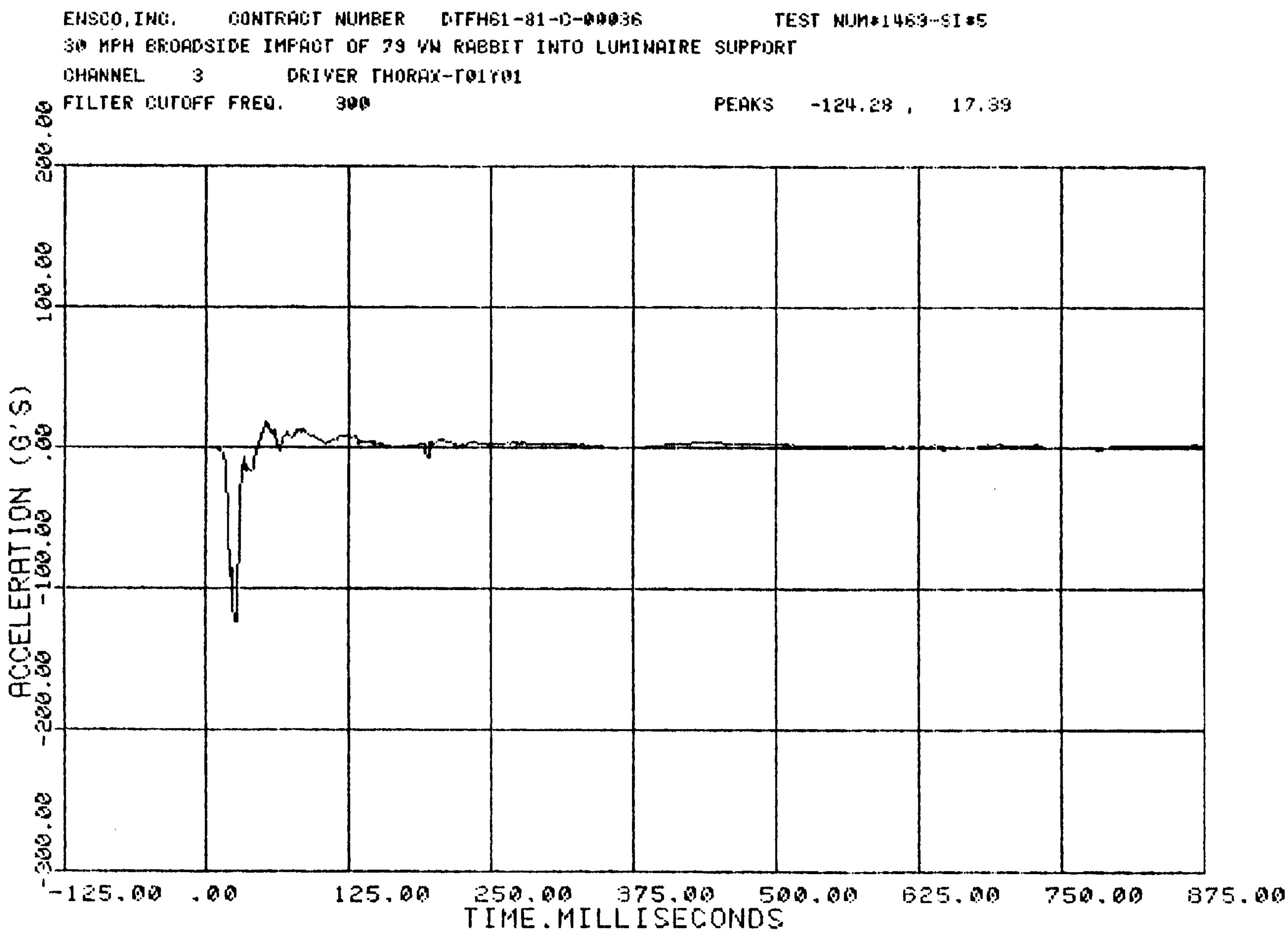


Figure 24. Driver's Upper Spine Acceleration, T01Y, 300 Hz

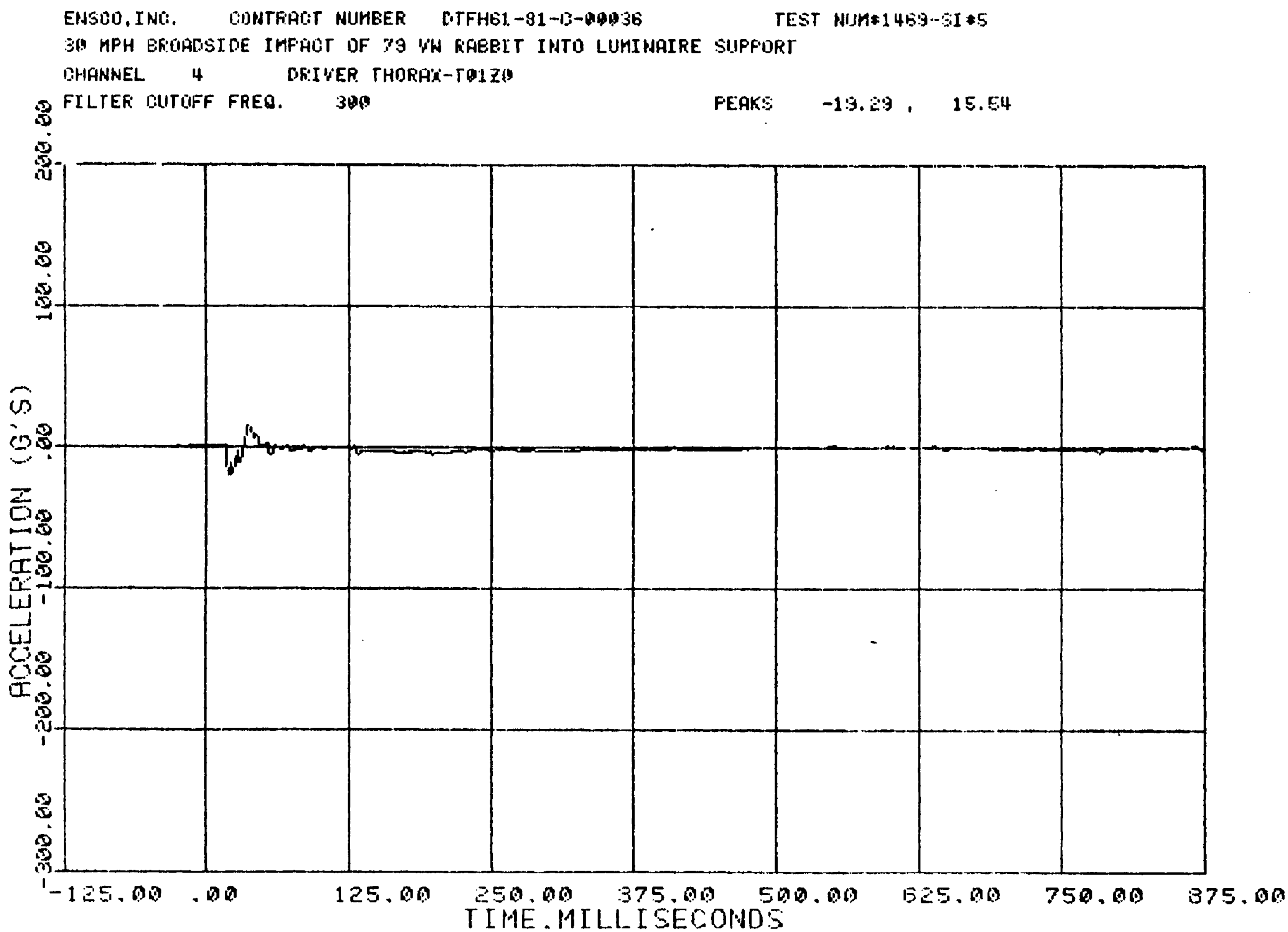


Figure 25. Driver's Upper Spine Acceleration, T01Z, 300 Hz

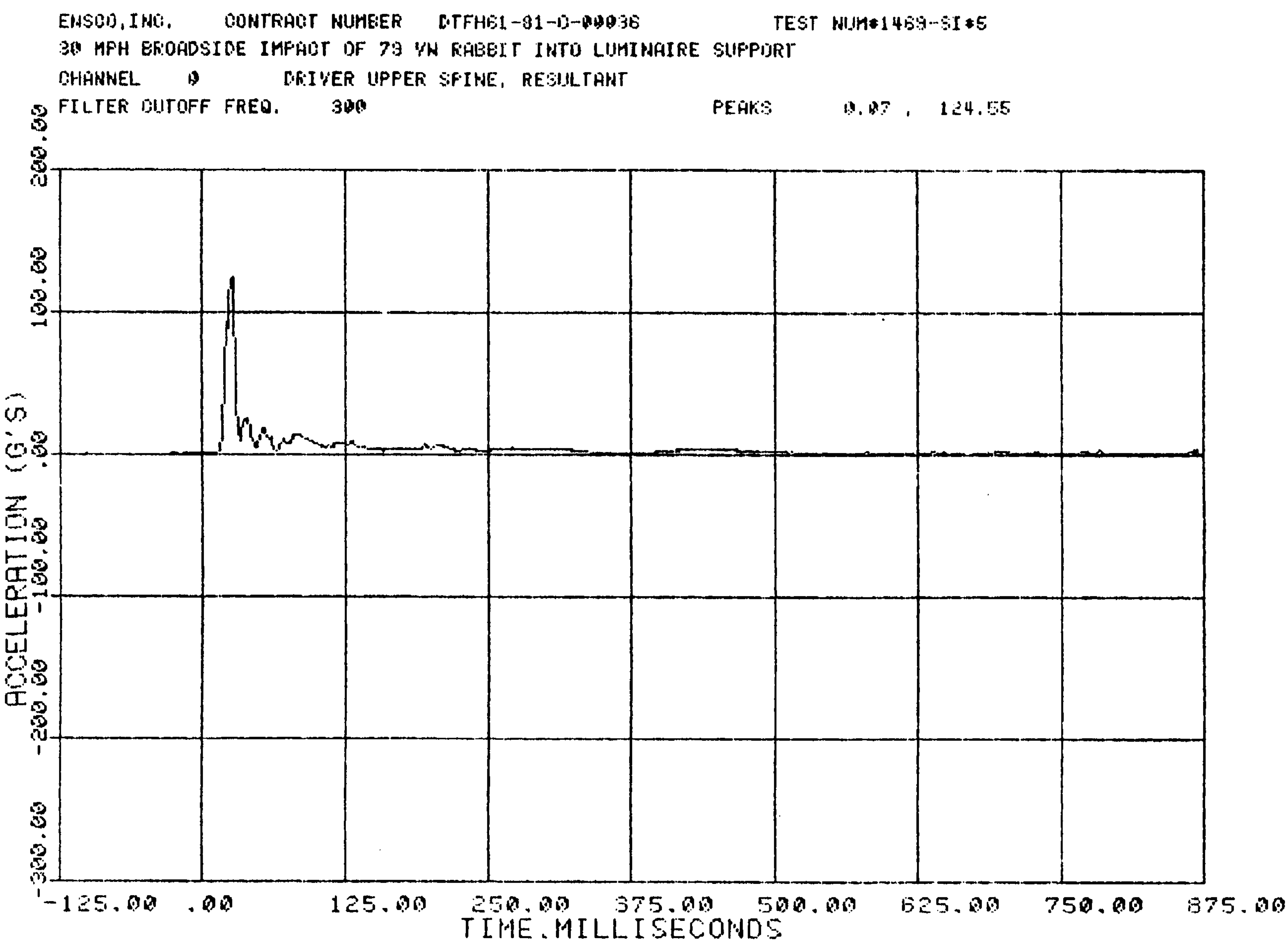


Figure 26. Driver's Upper Spine Acceleration, Resultant, 300 Hz

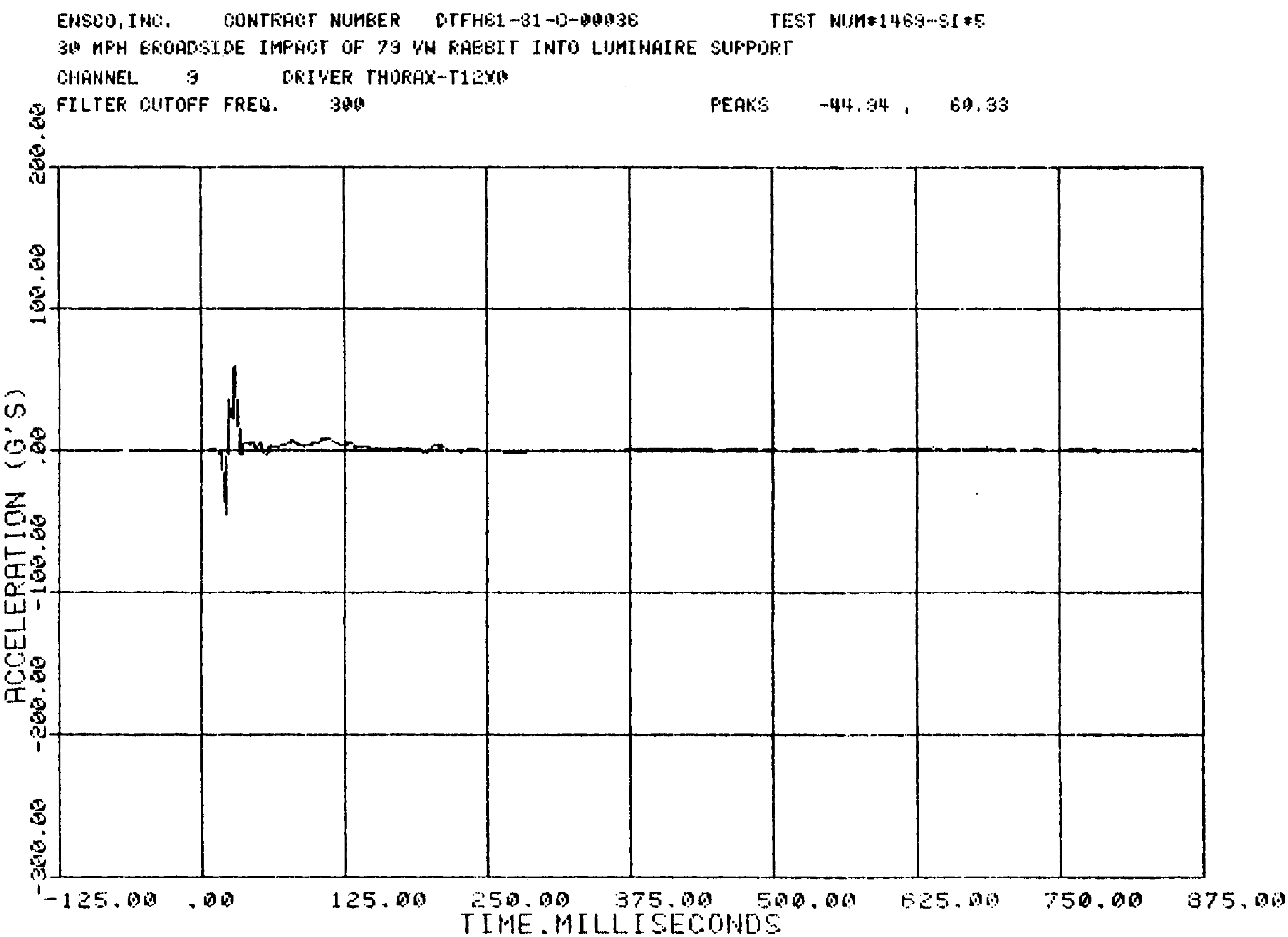


Figure 27. Driver's Lower Spine Acceleration, T12X, 300 Hz

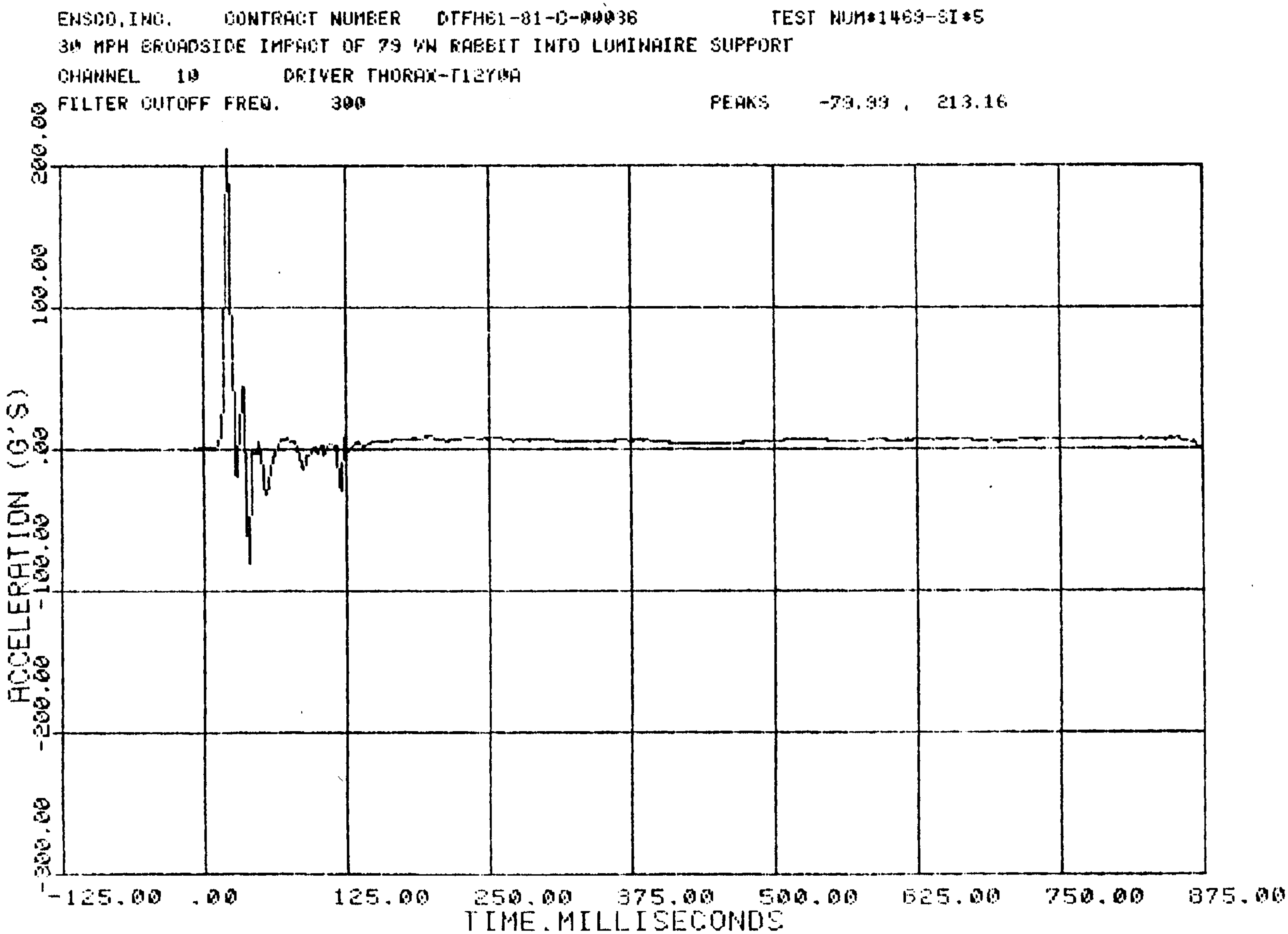


Figure 28. Driver's Lower Spine Acceleration, T12YA, 300 Hz

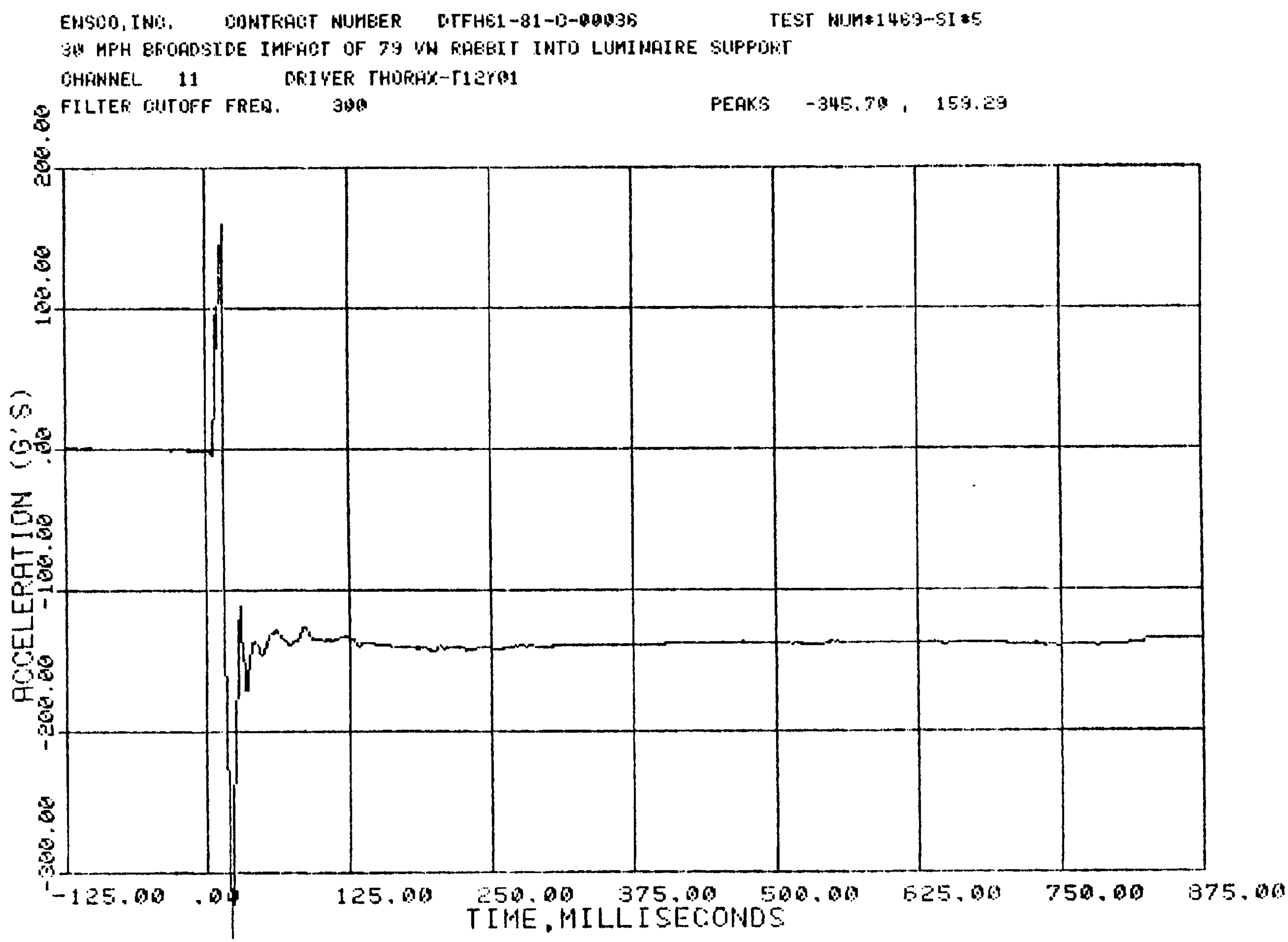


Figure 29. Driver's Lower Spine Acceleration, T12Y, 300 Hz

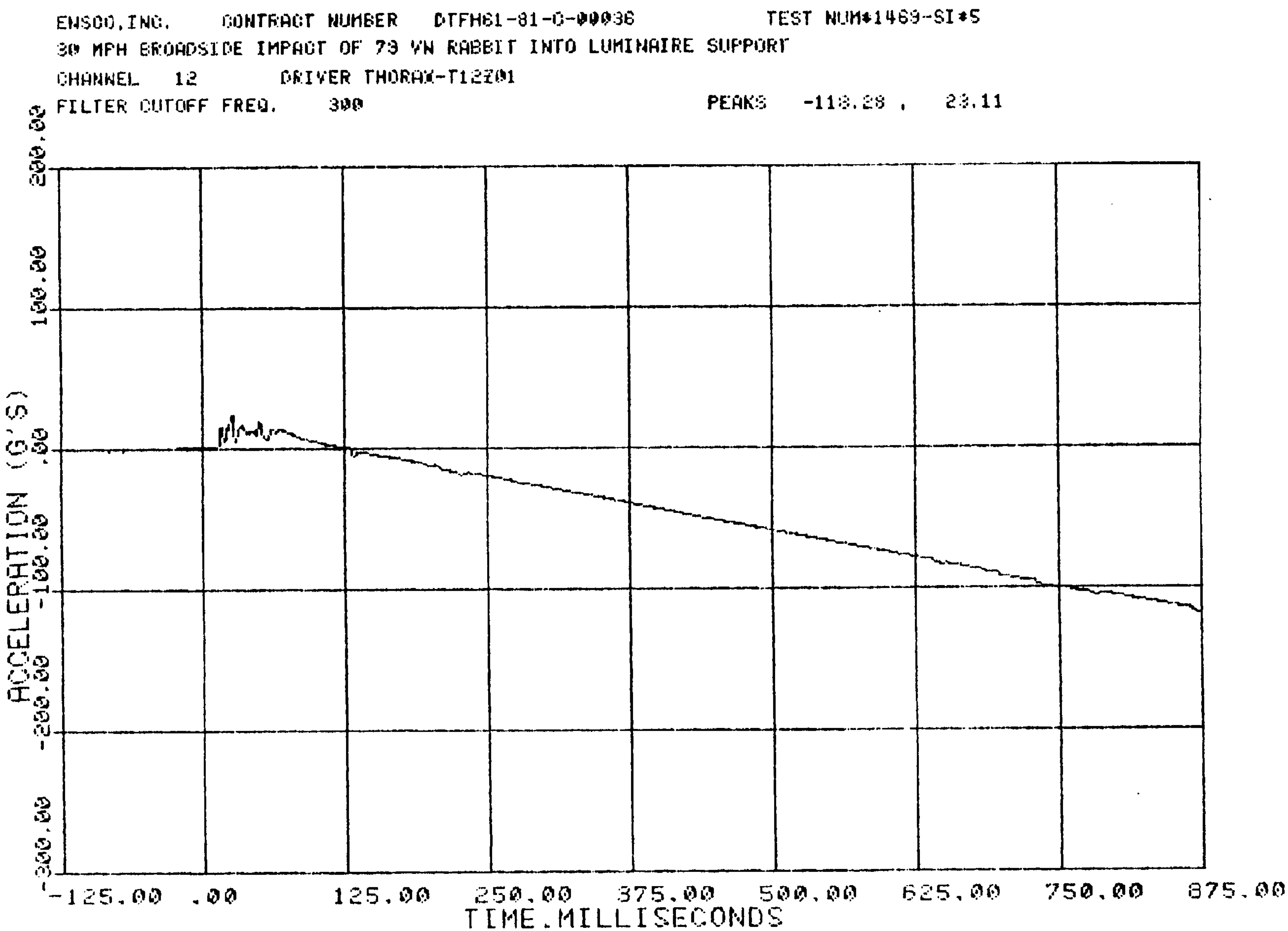


Figure 30. Driver's Lower Spine Acceleration, T12Z, 300 Hz

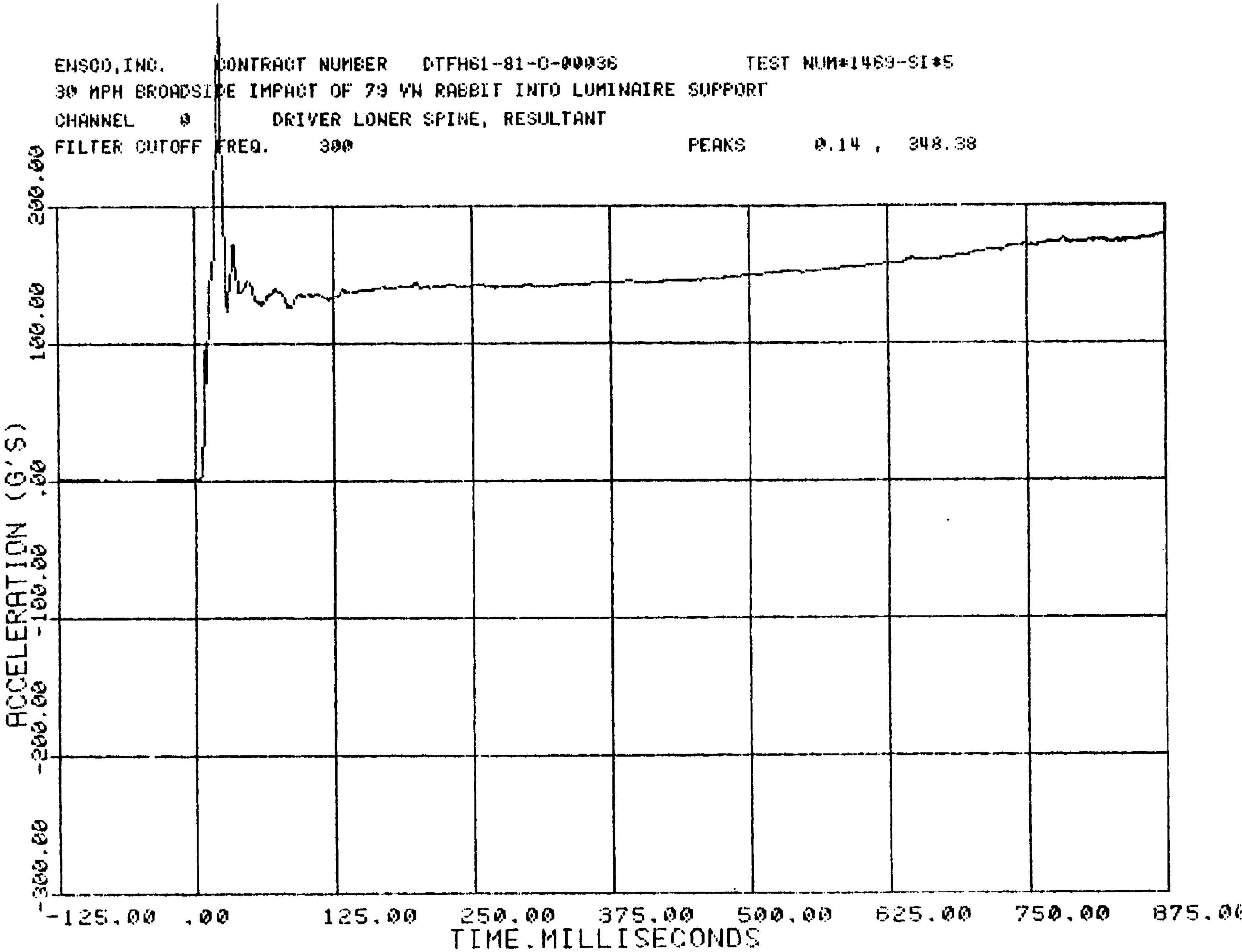


Figure 31. Driver's Lower Spine Acceleration, Resultant, 300 Hz

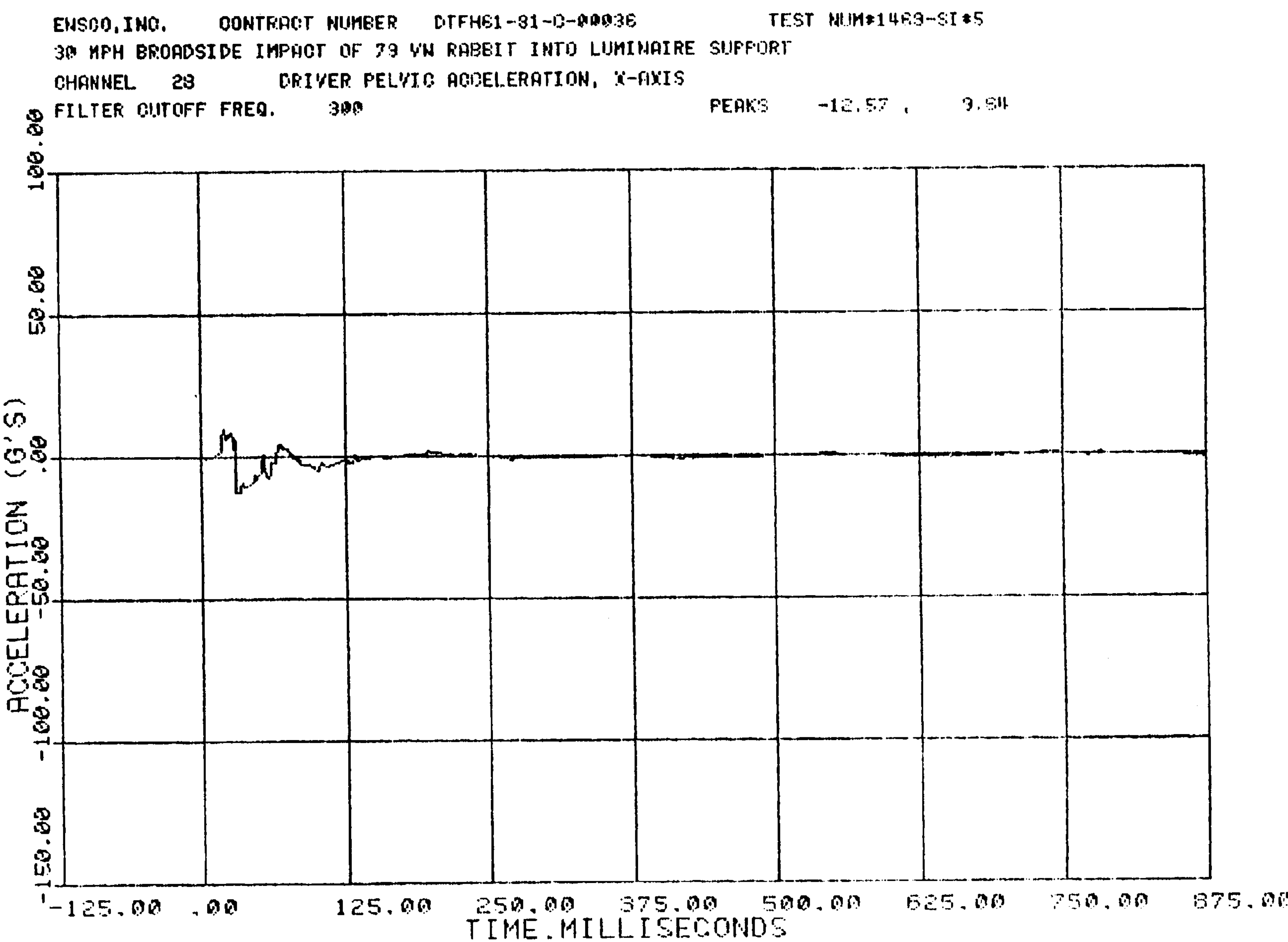


Figure 32. Driver's Pelvis Acceleration, X-Axis, 300 Hz

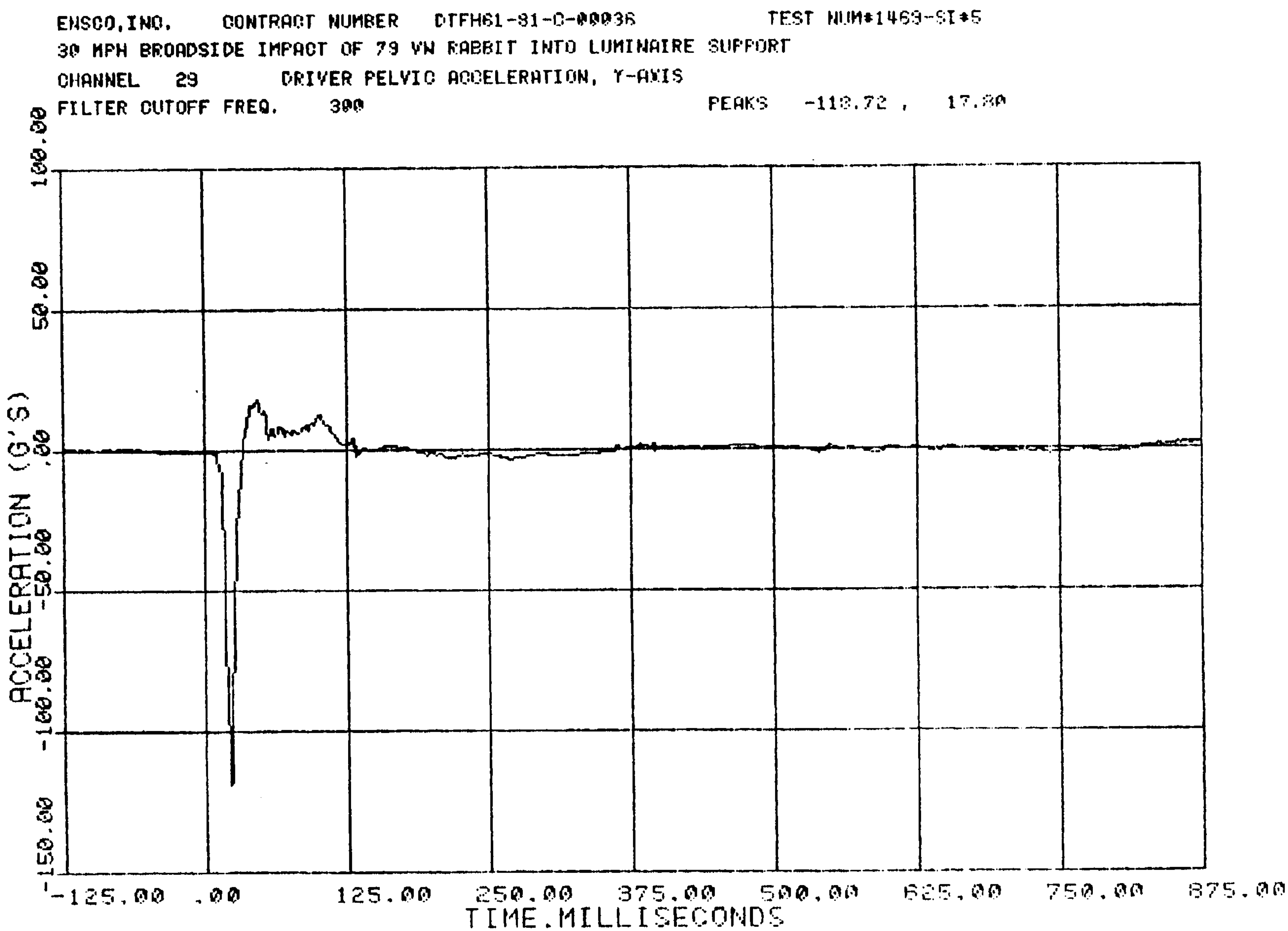


Figure 33. Driver's Pelvis Acceleration, Y-Axis, 300 Hz

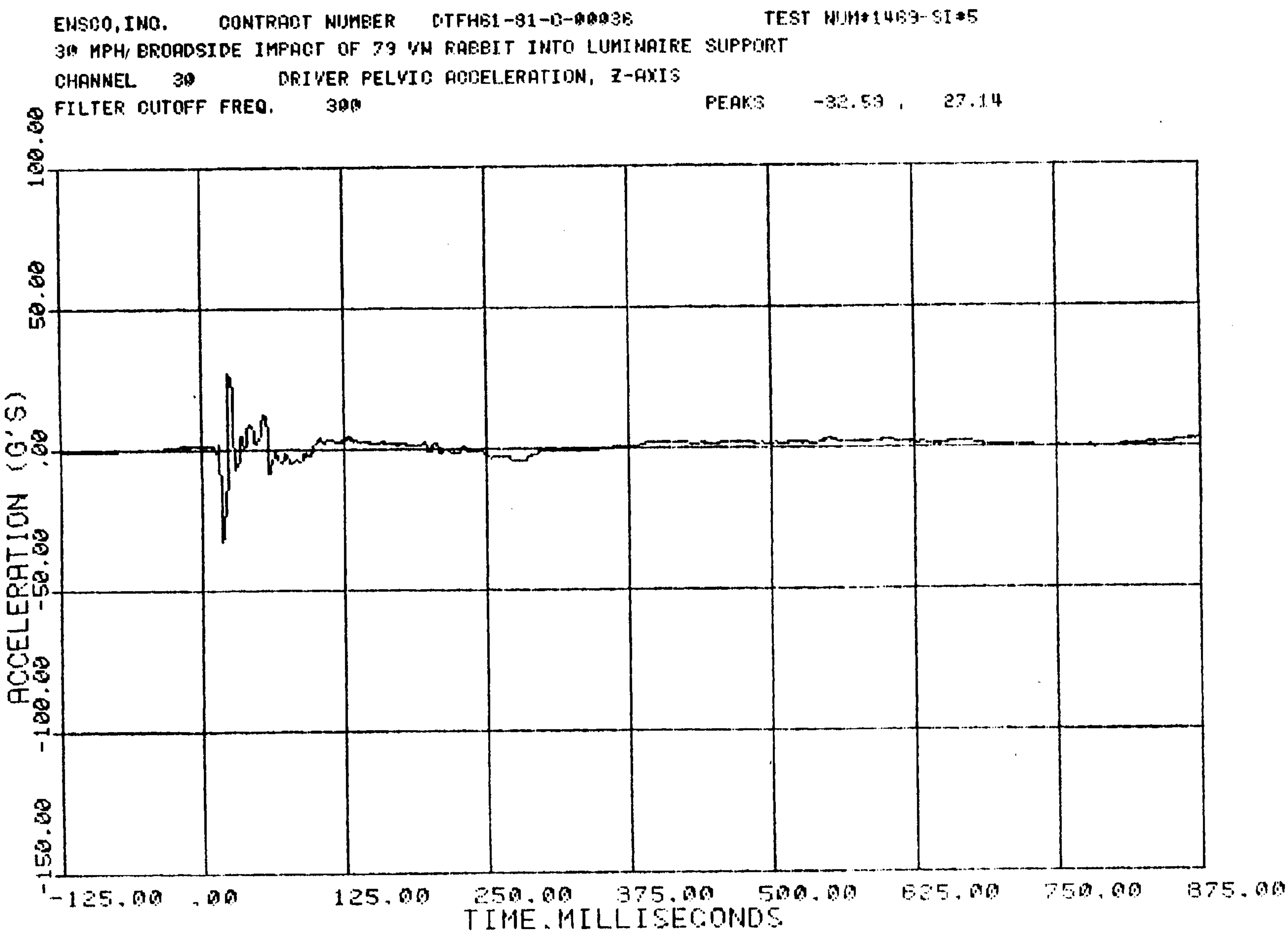


Figure 34. Driver's Pelvis Acceleration, Z-Axis, 300 Hz

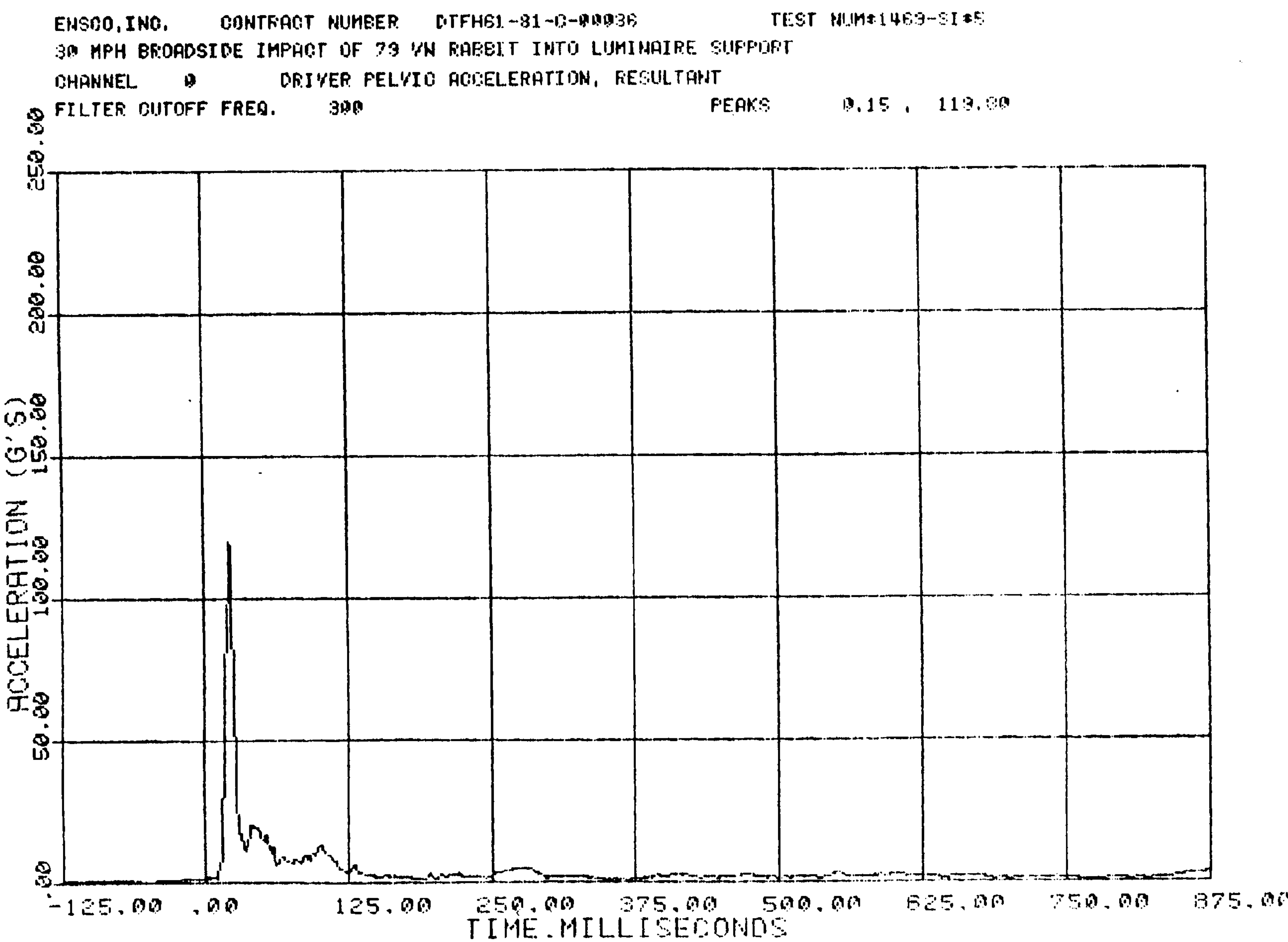


Figure 35. Driver's Pelvis Acceleration, Resultant, 300 Hz

CHANNEL 24

FILTER CUTOFF FREG. NHTSA FIR FILTER PEAKS -198.67, 42.90

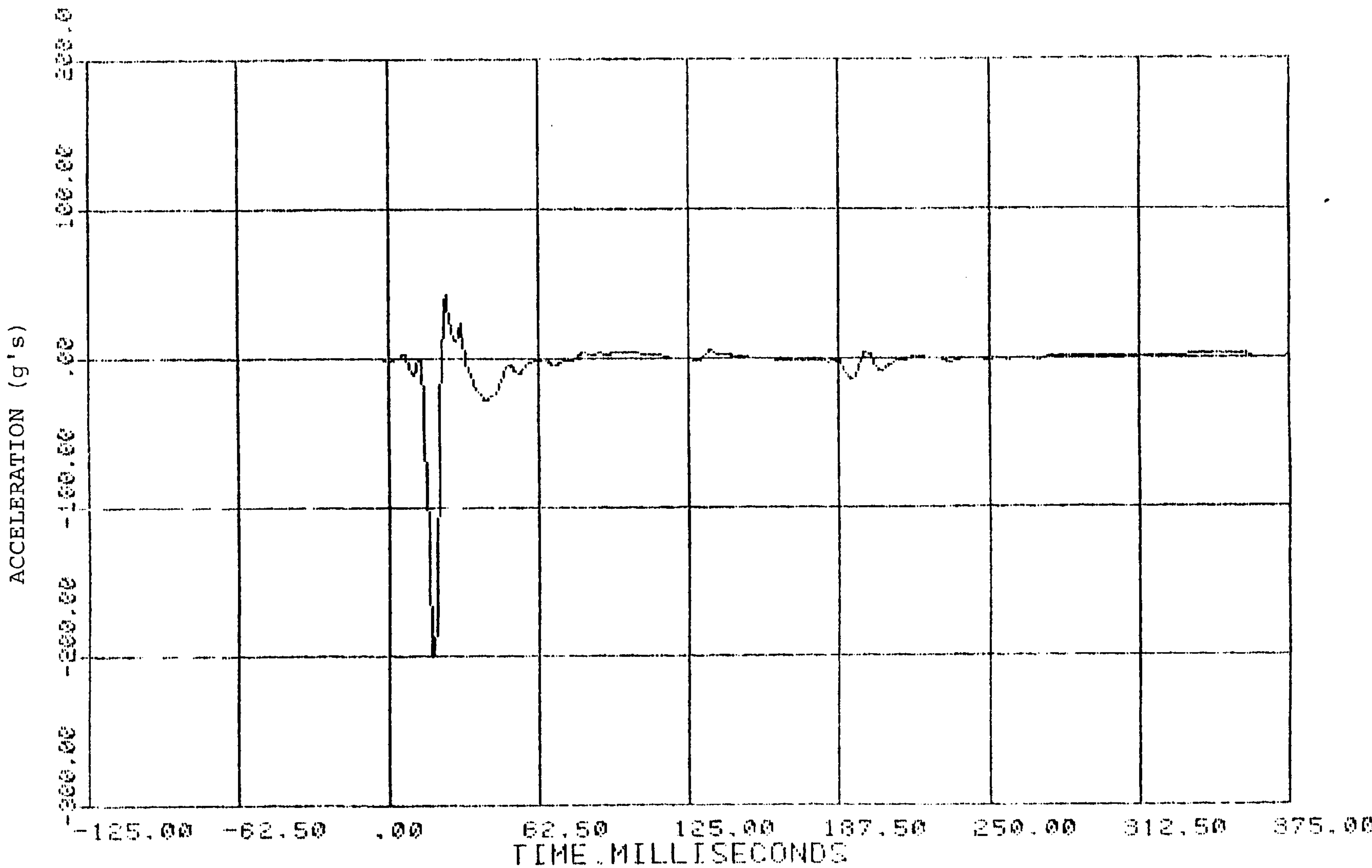


Figure 36. Driver's Left Upper Rib Acceleration, LURY, NHTSA FIR Filter

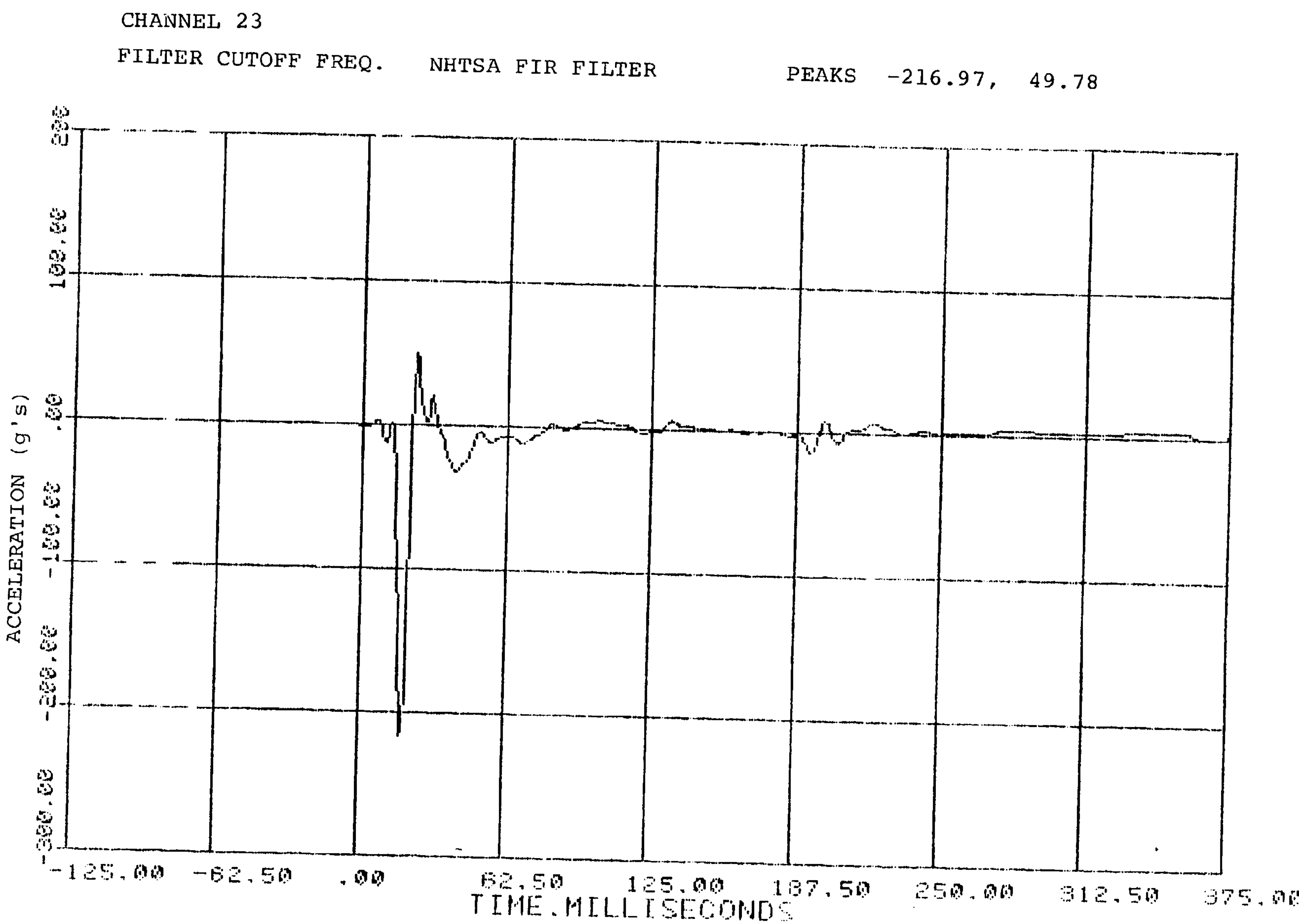


Figure 37. Driver's Left Upper Rib Acceleration, LURYA, NHTSA FIR FILTER

CHANNEL 6

FILTER CUTOFF FREQ. NHTSA FIR FILTER PEAKS -142.51, 121.02

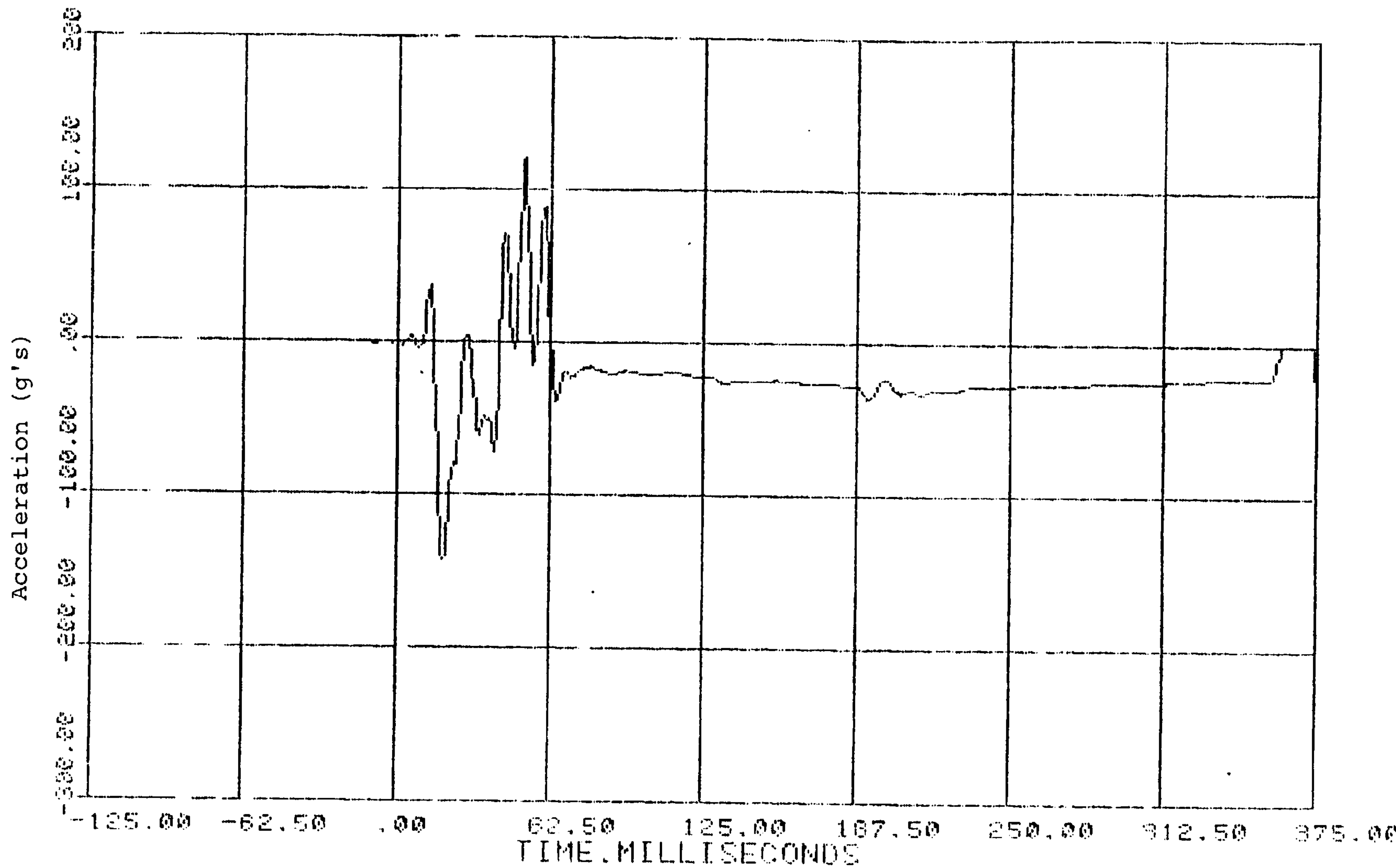


Figure 38. Driver's Left Upper Rib Acceleration, LLRY, NHTSA FIR FILTER

CHANNEL 5

FILTER CUTOFF FREQ. NHTSA FIR FILTER PEAKS: -106.16, 146.97

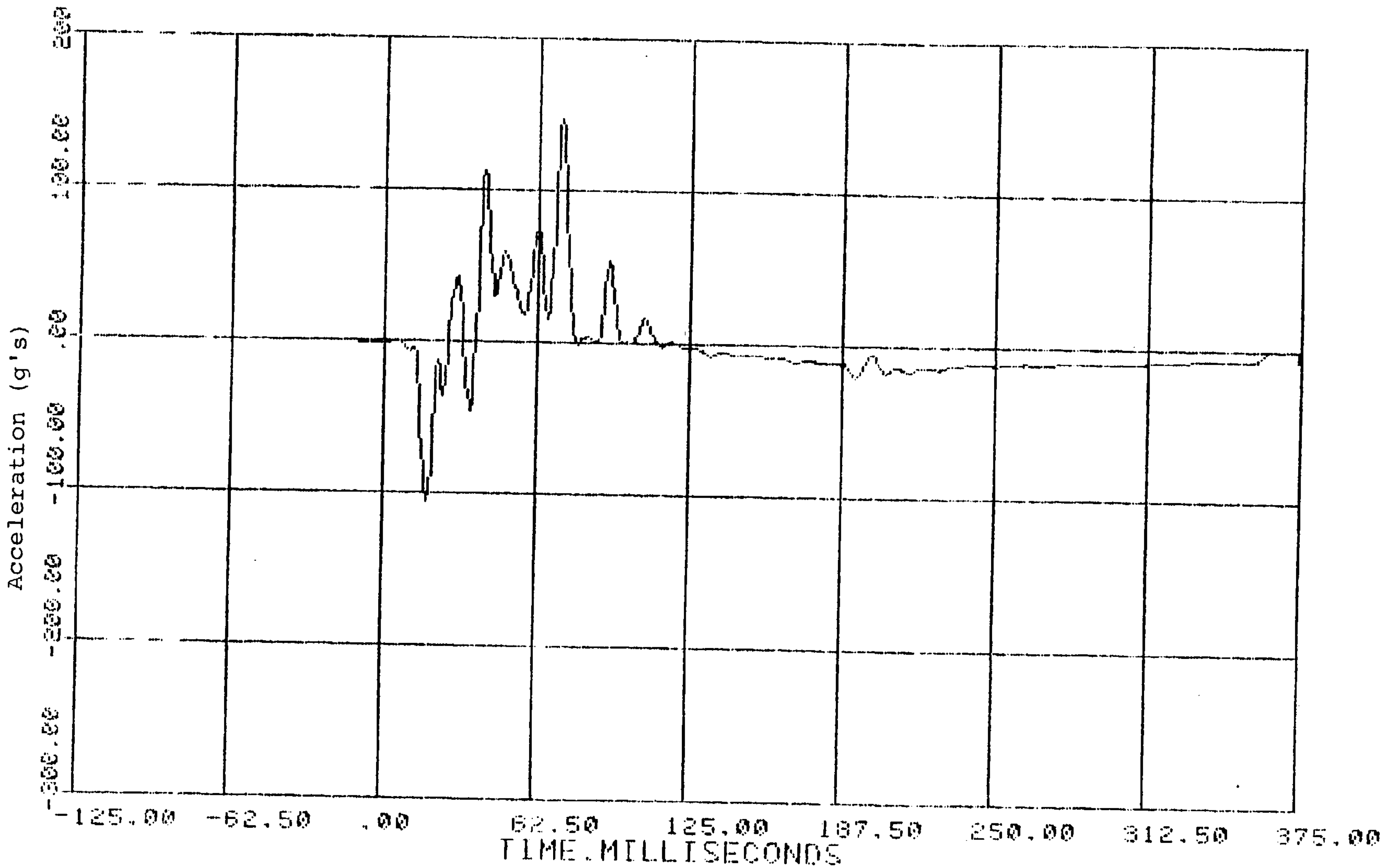


Figure 39. Driver's Left Upper Rib Acceleration, LLRYA, NHTSA FIR Filter

CHANNEL 3

FILTER CUTOFF FREQ. NHTSA FIR FILTER PEAKS -120.51, 18.41

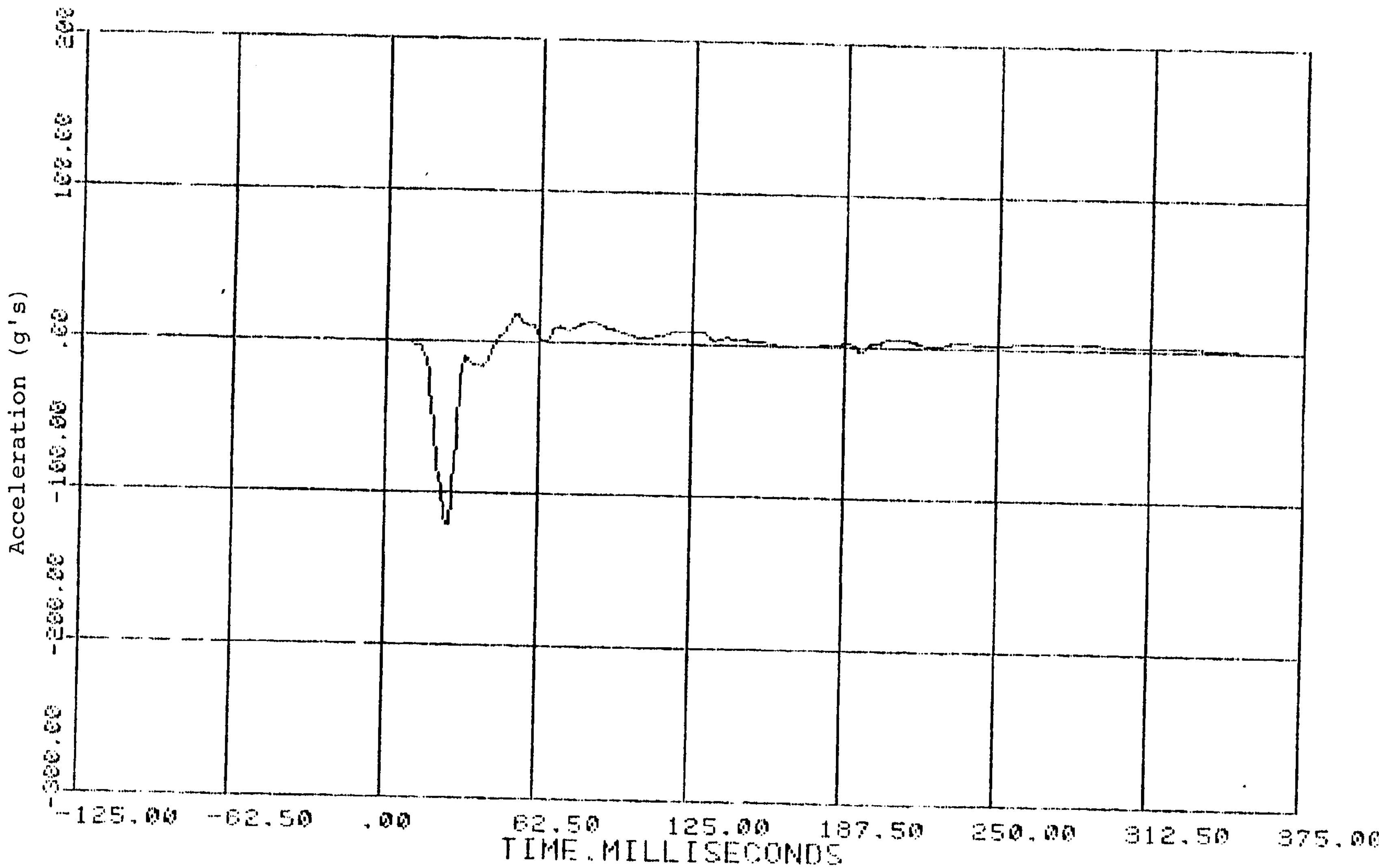


Figure 40. Driver's Upper Spine Acceleration, TOlY, NHTSA FIR Filter

CHANNEL 10

FILTER CUTOFF FREQ. NHTSA FIR FILTER PEAKS: +45.33, -191.44

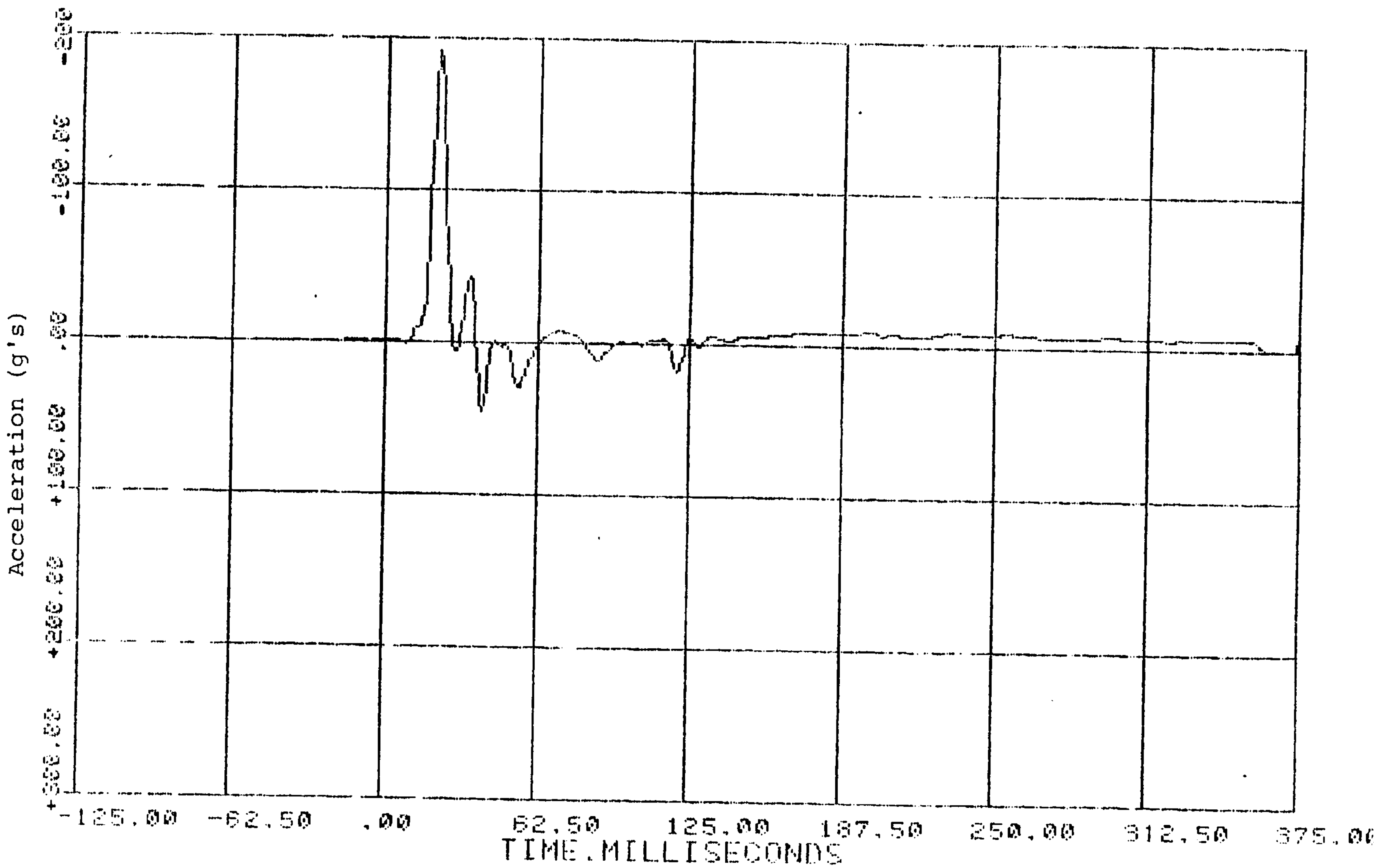


Figure 41. Driver's Lower Spine Acceleration, T12YA, NHTSA FIR Filter

CHANNEL 11

FILTER CUTOFF FREQ. NHTSA FIR FILTER   PEAKS -335.44, 100.12

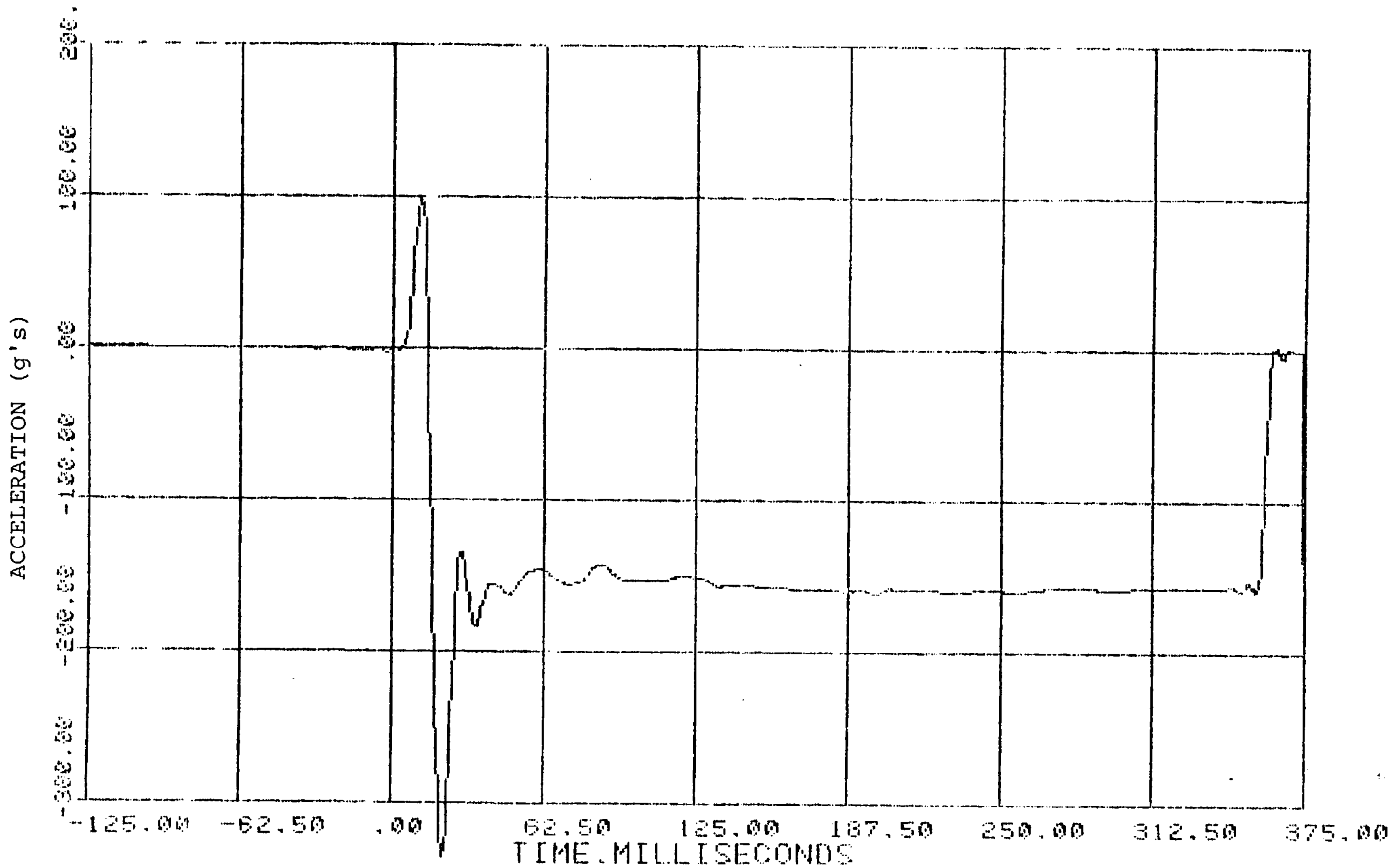
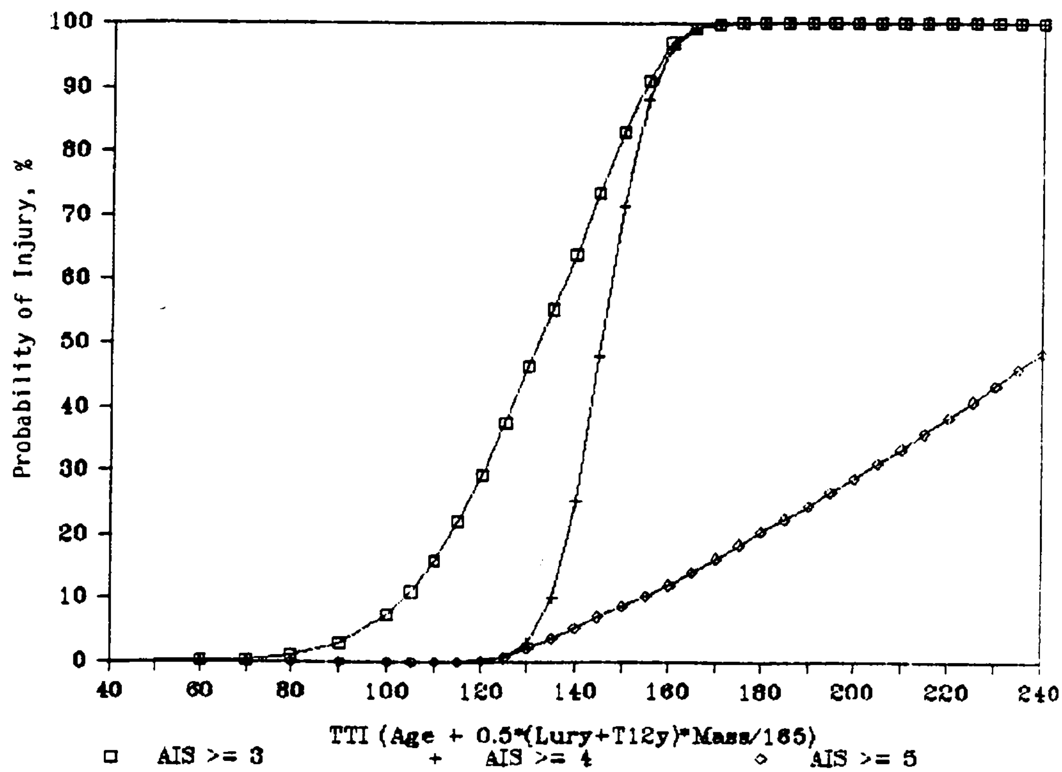


Figure 42. Driver's Lower SpineAcceleration, T12Y, NHTSA FIR Filter

The rib data was combined with the lower spine lateral acceleration data to obtain the input to the thoracic injury model. The Thoracic Trauma Index (TTI) was computed as follows:

$$TTI = (Age + .5\ (LURY + T12Y)\ (MASS/165)\ )$$

The LURY was determined from the peak values of the two accelerometers located at this location. These traces are found in figures 36 and 37. The average of the two peaks is 208 g's. The T12Y value was taken from figure 41. The peak value is 191. Thus, the value of the TTI is 200 plus the occupant age. Referring to figure 43 all age groups would have a 100% probability of AIS greater than 3 or 4. The probability of AIS of 5 or greater for a TTI of 200 is about 28%. At age 20 the probability would be about 38% and at age 40 would be 50% of AIS 5 or greater. The AIS of 5 or greater does not go past 50%.



From Ref 12

Figure 43. Thoracic Tramua Index Scale

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 44.

STRUCTURAL ADEQUACY

The test pole readily activated in the predicated manner. The breakaway force was estimated to be 24 kips. There was, however, severe penetration of the passenger compartment due to the nature of the test. Some hazard was generated to other traffic because the vehicle turned left back toward the traffic lanes.

OCCUPANT RISK

Occupant risk is rated very high to fatal. This was due to the impact location of the pole and intrusion of the pole into the passenger compartment. HIC, and max chest accelerations exceeded the limits considerably, with HIC almost four times the limit. The thoratic injury also indicated a very severe accident rating with a 100% probability of AIS of 3, 4 or greater and at least 38% of AIS of 5 or greater (see figure 43).

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 very little, if any, encroachment of the adjacent traffic lanes.

TABLE 6. SAFETY EVALUATION GUIDELINES

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 44. 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. "Selection of Side Impact Test Vehicle and Impact Conditions," Task A.4 (Phase II), Owings, R.P and Hinch, J.A., Contract DTFH61-81-1-00036, May 1984

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.

11. "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.