

0070910

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 DODGE ST. REGIS
AND A BREAKAWAY LUMINAIRE SUPPORT

TEST RESULTS REPORT

TEST NUMBER 1469-SI#7-85

Hinch, J. A.

Prepared for:

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

February 1986

Prepared by:

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

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

<u>Section Number</u>	<u>Title</u>	<u>Page</u>
1.0	SUMMARY AND CONCLUSIONS	1
2.0	OBJECTIVE	4
3.0	APPURTENANCE DESCRIPTION	6
4.0	VEHICLE DESCRIPTION	7
5.0	TEST INSTRUMENTATION	9
6.0	TEST RESULTS	11
7.0	TEST ANALYSIS	15
	7.1 Impact Velocity Analysis	15
	7.2 Analysis of Vehicle Mounted Accelerometers	16
	7.3 Comparison of Predicted Results to Test Observables	29
	7.4 Head Injury Criteria Evaluation	30
	7.5 Occupant Severity Index Evaluation	30
	7.6 Thoracic Injury Evaluation	35
8.0	SAFETY ASSESSMENT OF TEST	55
9.0	REFERENCES	57

LIST OF FIGURES

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
1	Pre-Test Photos of Vehicle	8
2	Post Test Photos of Vehicle	12
3	NHTSA Vehicle Damage Measurements	14
4	Vehicle Acceleration, X-Axis, 100 Hz	17
5	Vehicle Acceleration, Y-Axis, 100 Hz	18
6	Vehicle Acceleration, Z-Axis, 100 Hz	19
7	Vehicle Acceleration, X-Axis, 300 Hz	20
8	Vehicle Acceleration, Y-Axis, 300 Hz	21
9	Vehicle Acceleration, Z-Axis, 300 Hz	22
10	Event Marker, Impact	23
11	Vehicle Roll Rate, 100 Hz	24
12	Vehicle Yaw Rate, 100 Hz	25
13	Vehicle Roll Rate, 10 Hz	26
14	Vehicle Yaw Rate, 10 Hz	27
15	Driver's Head Acceleration, X-Axis, 1650 Hz	31
16	Driver's Head Acceleration, Y-Axis 1650 Hz	32
17	Driver's Head Acceleration, Z-Axis, 1650 Hz	33
18	Driver's Head Acceleration, Resultant, 1650 Hz	34
19	Driver's Upper Spine Acceleration, T01X, 189 Hz	36
20	Driver's Upper Spine Acceleration, T01YA, 189 Hz	37
21	Driver's Upper Spine Acceleration, T01Y1, 189 Hz	38
22	Driver's Upper Spine Acceleration, T01Z, 189 Hz	39
23	Driver's Upper Spine Acceleration, Resultant, 189 Hz	40

LIST OF FIGURES (Cont'd)

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
24	Driver's Lower Spine Acceleration, T12X, 189 Hz	41
25	Driver's Lower Spine Acceleration, T12YA, 189 Hz	42
26	Driver's Lower Spine Acceleration, T12Y, 189 Hz	43
27	Driver's Lower Spine Acceleration, T12Z, 189 Hz	44
28	Driver's Pelvic Acceleration, X-Axis, 189 Hz	45
29	Driver's Pelvic Acceleration, Y-Axis, 189 Hz	46
30	Driver's Pelvic Acceleration, Z-Axis, 189 Hz	47
31	Driver's Left Upper Rib Acceleration, LURY, 189 Hz	48
32	Driver's Left Upper Rib Acceleration, LURYA, 189 Hz	49
33	Driver's Left Lower Rib Acceleration, LLRY, 189 Hz	50
34	Driver's Left Lower Rib Acceleration, LLRYA, 189 Hz	51
35	Driver's Left Upper Rib Acceleration, LURY, NHTSA FIR Filter	52
36	Driver's Upper Spine Acceleration, T01Y, NHTSA FIR Filter	53
37	AIS Probability Factors	54
38	NCHRP 230 Safety Evaluation Guidelines	56

LIST OF TABLES

<u>Table Number</u>	<u>Title</u>	<u>Page</u>
1	Summary of Test Conditions and Results for Test Number 1469-SI#7-85	2
2	Properties of Test Pole	6
3	Weight Distribution of Test Vehicle Prior to Testing	7
4	Description of Film Data Acquisition System for Full Scale Crash Test 1469-SI#7-85	9
5	Transducer Data for Test 1469-SI#7-85	10
6	Residual Vehicle Crush	14
7	Test Vehicle Impact Speed Evaluation Using High Speed Film Analysis	16
8	Change in Velocities and Ride Down Accelera- tion From Analysis of Class 180 Data Using NCHRP 230 Technique	28
9	Head Injury Criteria Evaluated for Full Scale Crash Test 1469-SI#7-85	35

1.0 SUMMARY AND CONCLUSIONS

This test investigated the impact severity of a large sedan (4500S) during a low speed broadside collision with a breakaway luminaire support. The test vehicle was a Dodge St. Regis. 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 31.8 mph (14.2 m/s) was 685 lb-sec. The velocity change corresponding to the observed vehicle momentum change was 3.3 mph or 4.9 ft/sec. The integrity of the vehicle was maintained throughout the test although some intrusions occurred at the center of the driver's door. Maximum residual crush of the side of the vehicle was 8.5 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.

The acceleration data from the anthropomorphic dummy was also analyzed using NHTSA side impact 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 very mild impact. Analysis of the acceleration data from the head of the anthropomorphic dummy yielded a Head Injury Criteria (HIC) of 4. This result is low because the head did not impact anything. The result is much lower than the limit specified in FMVSS 208. Also, measurements made at the upper spine when processed using standard chest techniques produce results which were much less than 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#7-85

1.	Contract Number	DTFH61-81-C-00036
2.	Date of Test	October 18, 1985
3.	Test Vehicle	Dod St. Regis, 1979
4.	Delivered Vehicle Weight	3724 lbs
5.	Vehicle Weight, Test Inertial Planned Actual	4,500 ±200 lbs 4,335 lbs
6.	Vehicle Weight, Gross Static Actual (One Occupant)	4,500 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

Table 1 (Cont'd)
 Summary of Test Conditions and
 Results for Test Number 1469-SI#7-85

22.	Impact Speed, Observed	31.8 mph
23.	Speed Reduction	
	Acceleration Data, TRC 191	3.4 mph
	Tire Friction Effect	<u>1.9 mph</u>
	Total	5.3 mph
24.	Exit Speed, Observed	24.3 mph
25.	Impact Point, Observed	Left Door, Driver Loca- tion, 10.7" behind cg
26.	Traffic Accident Data, TAD	9-LP-2
27.	Vehicle Damage Index, VDI	09LPAN3
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	30 ft/sec
	Observed	No head impact
31.	Head Injury Criteria (HIC)	
	Design Limit	1000
	Driver, Observed	4
32.	Upper Spine Acceleration Data	
	Acceleration with Duration	
	Greater than .003 sec	9.7
	CSI	5.0
33.	Thoracic Injury Results	
	Fatal Injury	6.00
	AIS	Less than 3
34.	Momentum Change from Pole	685 lb-sec

1 lb = .454 kg
 1 ft = .3048 m
 1 in = .0254 m

1 lb-sec = 4.448 N-s
 1 ft-kip = 1,355 N-m

2.0 OBJECTIVE

The objective of this test was to investigate the impact severity of a large sedan (4500S) during a low speed broadside collision with a breakaway luminaire support. This test is the seventh of a series of eight 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 through 8 impacted a breakaway luminare.

The vehicle used for this test was a 1979 Dodge St. Regis. A triaxial accelerometer package was mounted on the lateral center-line 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 was also 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 assembly located in the upper spine of the occupant was used to evaluate the severity index and maximum sustained acceleration experienced by the occupant 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 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 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 Dodge St. Regis. The delivered weight of the vehicle prior to incorporating the instrumentation for the test was 3724 pounds. The test inertial weight for the vehicle was 4335 pounds and the gross static weight which includes the occupant (dummy) was 4500 pounds. The longitudinal center of gravity of the vehicle with the occupant was located approximately 57.9 inches behind the centerline of the front axle. The gross 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 test vehicle is shown in figure 1.

Table 3
Weight Distribution of Test Vehicle Prior to Testing

	<u>Left</u> <u>(lbs)</u>	<u>Right</u> <u>(lbs)</u>	<u>Subtotal</u> <u>(lbs)</u>
Front	1,104	1,197	2,301
Rear	<u>1,132</u>	<u>1,067</u>	<u>2,199</u>
Subtotals	2,236	2,264	4,500

1 lb. = .454 kg

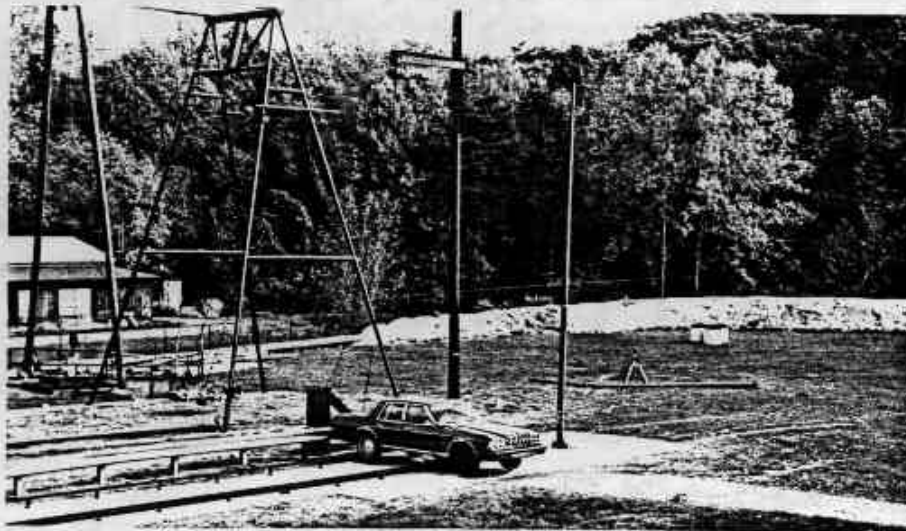


Figure 1. Pre-Test Photos of Vehicle

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. Several of the thoracic transducers produced excessive noise during the test. These units were checked very carefully prior to the test for problems but none were found.

Table 4
Description of Film Data Acquisition
System for Full Scale Crash Test 1469-SI#7-85

<u>Camera</u>	<u>Model</u>	<u>Position</u>	<u>Speed Setting</u>	<u>Lens</u>
1	Redlake, Hycam	Rt. Side	500 pps	10 mm
2	Redlake, Locam	Front Rt.	500 pps	25 mm
3	Redlake, Locam	Front Lt.	500 pps	50 mm
4	Redlake, Locam	Onboard	500 pps	5.7 mm
5	Redlake, Locam	Rt. Side	500 pps	50 mm
6	Redlake, Locam	Rt. Side	500 pps	50 mm
7	Arrieflex	Documentation	24 pps	Zoom

Table 5

Transducer Data for Test 1469-SI#7-85

<u>Channel No.</u>	<u>Channel Description</u>
1	Upper Spine Accel, T01XG
2	Upper Spine Accel, T01YGA
3	Upper Spine Accel, T01YG1
4	Upper Spine Accel, T01ZG
5	Left Lower Rib Accel, LLRYGA
6	Left Lower Rib Accel, LLRYG1
7	Left Upper Rib, Accel, LURYGA
8	Left Upper Rib, Accel, LURYG1
9	Lower Spine Accel, T12XG
10	Lower Spine Accel, T12YGA
11	Lower Spine Accel, T12YG1
12	Lower Spine Accel, T12ZG1
13	Vehicle Accel, cg-x
14	Vehicle Accel, cg-y
15	Vehicle Accel, cg-z
16	Driver Door, Impact Marker
17	Vehicle c.g., Roll Rate
18	Vehicle c.g., Yaw Rate
19	Head Accel, X
20	Head Accel, Y
21	Head Accel, Z
22	Pelvis Accel, X
23	Pelvis Accel, Y
24	Pelvis Accel, Z

6.0 TEST RESULTS

The impact conditions were 31.8 mph (14.2 m/s) at a point on the left door in line with the occupant 10.7 inches (.27 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 8.5 inches (.22 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 .016 seconds after impact. The force levels at the time of initiation of the breakaway fracture mechanism of the luminaire support were about 27,000 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 26.7 f/s (8.14 m/s) with a rotation rate of 2.7 rad/sec. The luminaire support rotated up and over the test vehicle with the top of the pole hitting the runway near the impact point about .7 second after impact. The pole broke as it hit the runway and then fell on the roof of the car bending at the break. As the support rotated away, the vehicle slid off the end of the runway with very little yawing. The final resting position of the vehicle was about 8 feet to the right of the impact approach path and 28 feet downstream. 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 Photos of Vehicle

Table 6
Residual Vehicle Crush

C1 = 0.00	L = 94.00"
C2 = -1.50"	D = -14.10"
C3 = 2.25"	
C4 = 8.50"	
C5 = 3.00"	
C6 = 0.00	
Max = 8.50"	

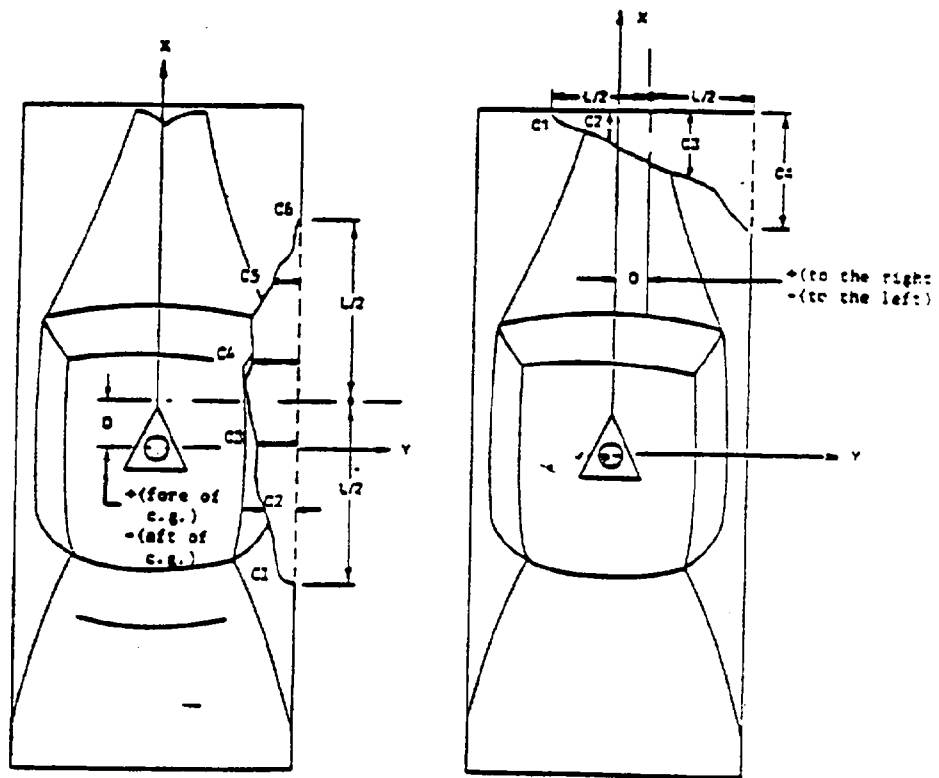


Figure 3. NHTSA Vehicle Damage Measurements

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 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 189 Hz 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 189 Hz. In addition, thoracic injury parameters associated with side impact conditions were analyzed using the latest NHTSA's technique 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 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

<u>Camera</u>	<u>Position</u>	<u>Impact Speed (ft/sec)</u>	<u>Impact Speed (mph)</u>
1	Right Side (close)	46.6	31.8

A speed trap and additional camera were installed to measure the speed of the vehicle as it left the end of the monorail. This speed was 48.2 ft/sec from the camera and 49.0 ft/sec from the speed trap. The vehicle slowed down as it slid toward the test pole. The distance from the speed trap to the pole was 11 ft. For the large car, about 3.5 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 coefficient of friction of .75 then the vehicle would scrub off about 11.8 kip-ft of energy. Deducting this loss from the speed trap/film data results in a impact speed of 46.4 ft/sec. This speed is slightly lower than the film data but due to the unknowns in the adjusted 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 31.8 mph (14.2 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 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 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 4.9 ft/sec and 685 lb-sec, respectively. This does not account for the tire sliding forces since the accelerometer signal was debiased during

CHANNEL 17 VEHICLE O.O. ACCELERATION, X-AXIS
FILTER CUTOFF FREQ. 100 PEAKS -5.07, 8.24

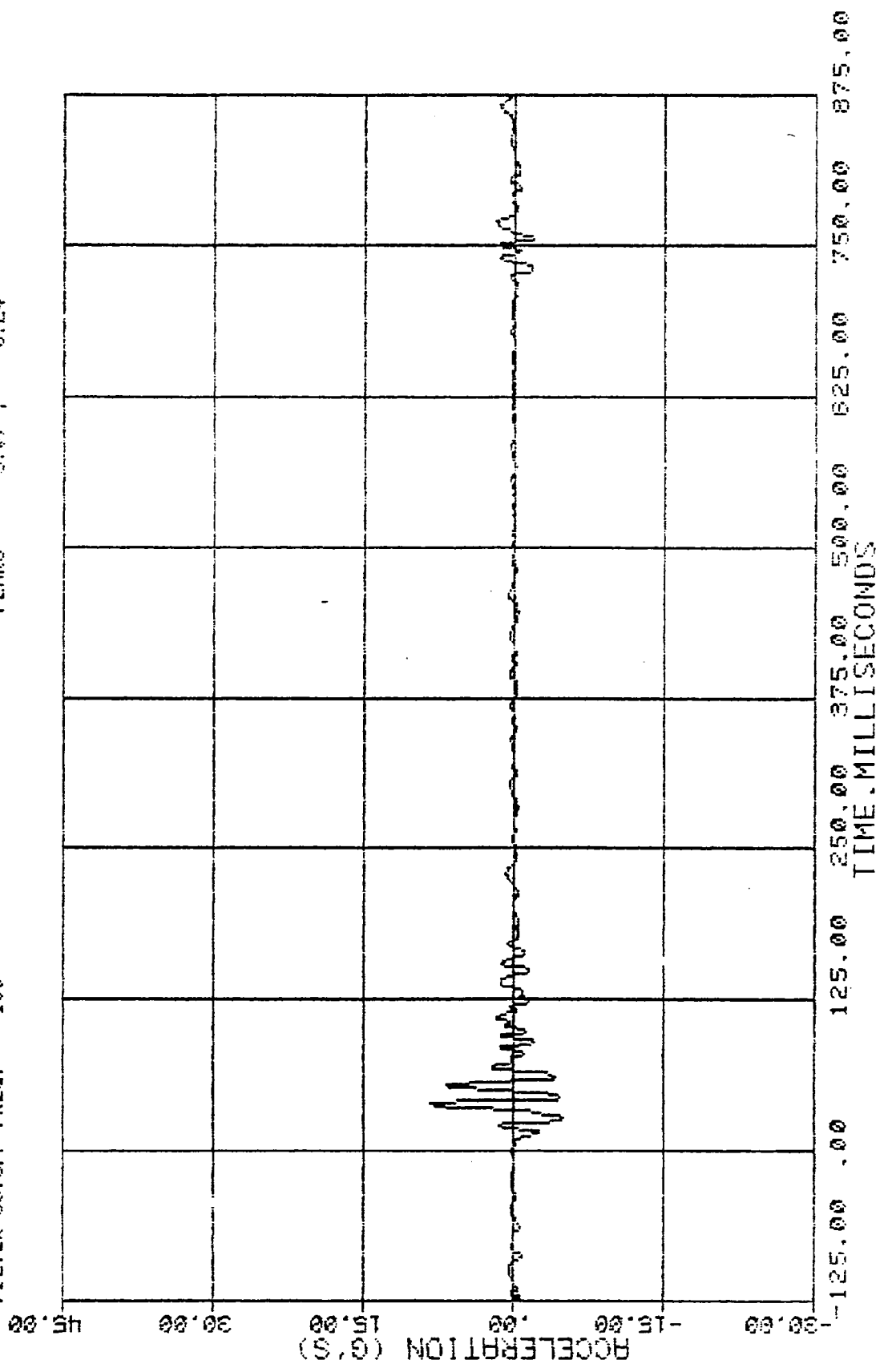


Figure 4. Vehicle Acceleration, X-Axis, 100 Hz

CHANNEL 18 VEHICLE O.O. ACCELERATION, Y-AXIS
FILTER CUTOFF FREQ. 100 PEAKS -10.73 4.23

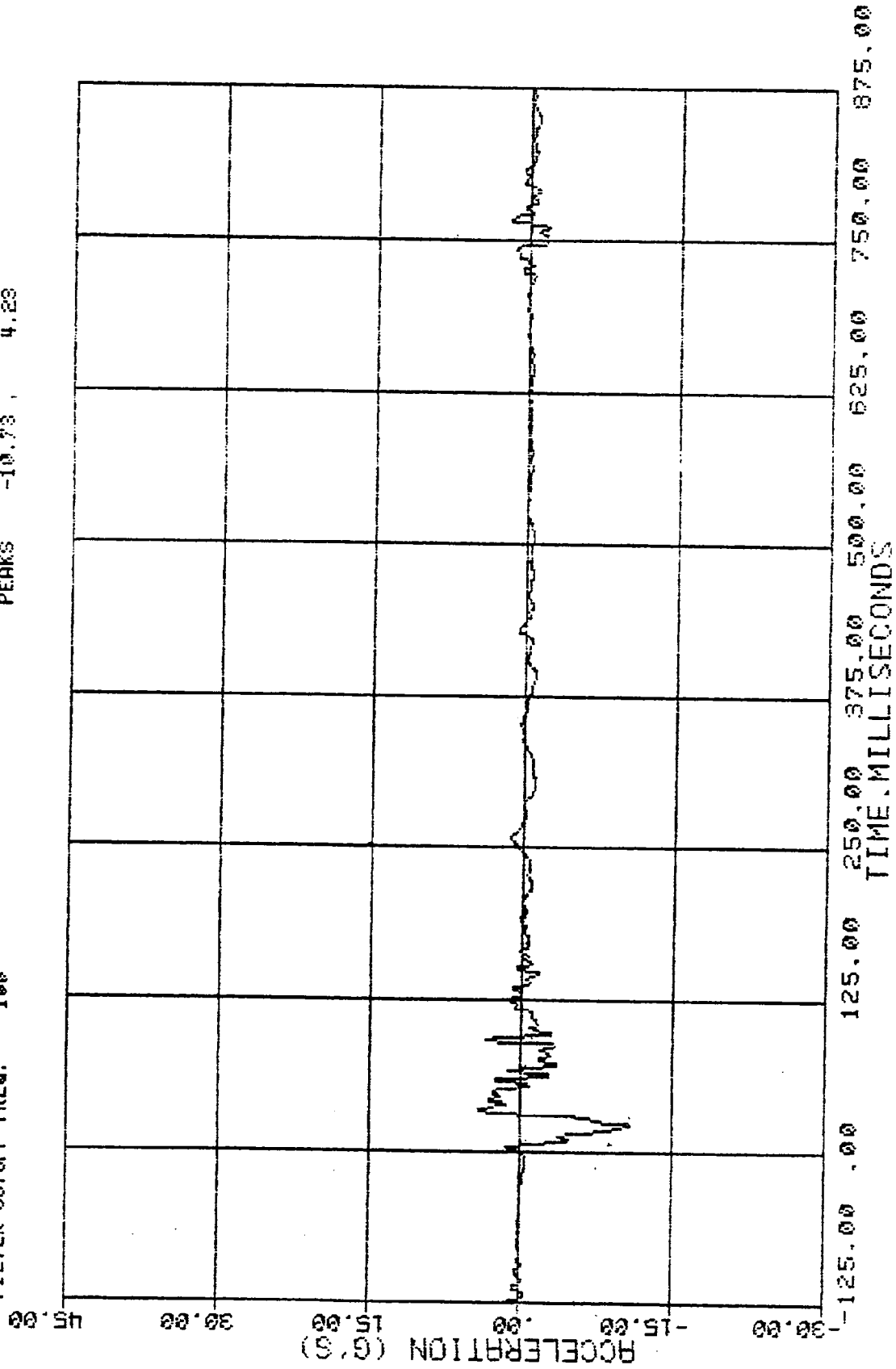


Figure 5. Vehicle Acceleration, Y-Axis, 100 Hz

CHANNEL 19 VEHICLE O.B. ACCELERATION, Z-AXIS
FILTER CUTOFF FREQ. 100 PEAKS -16.07 9.05

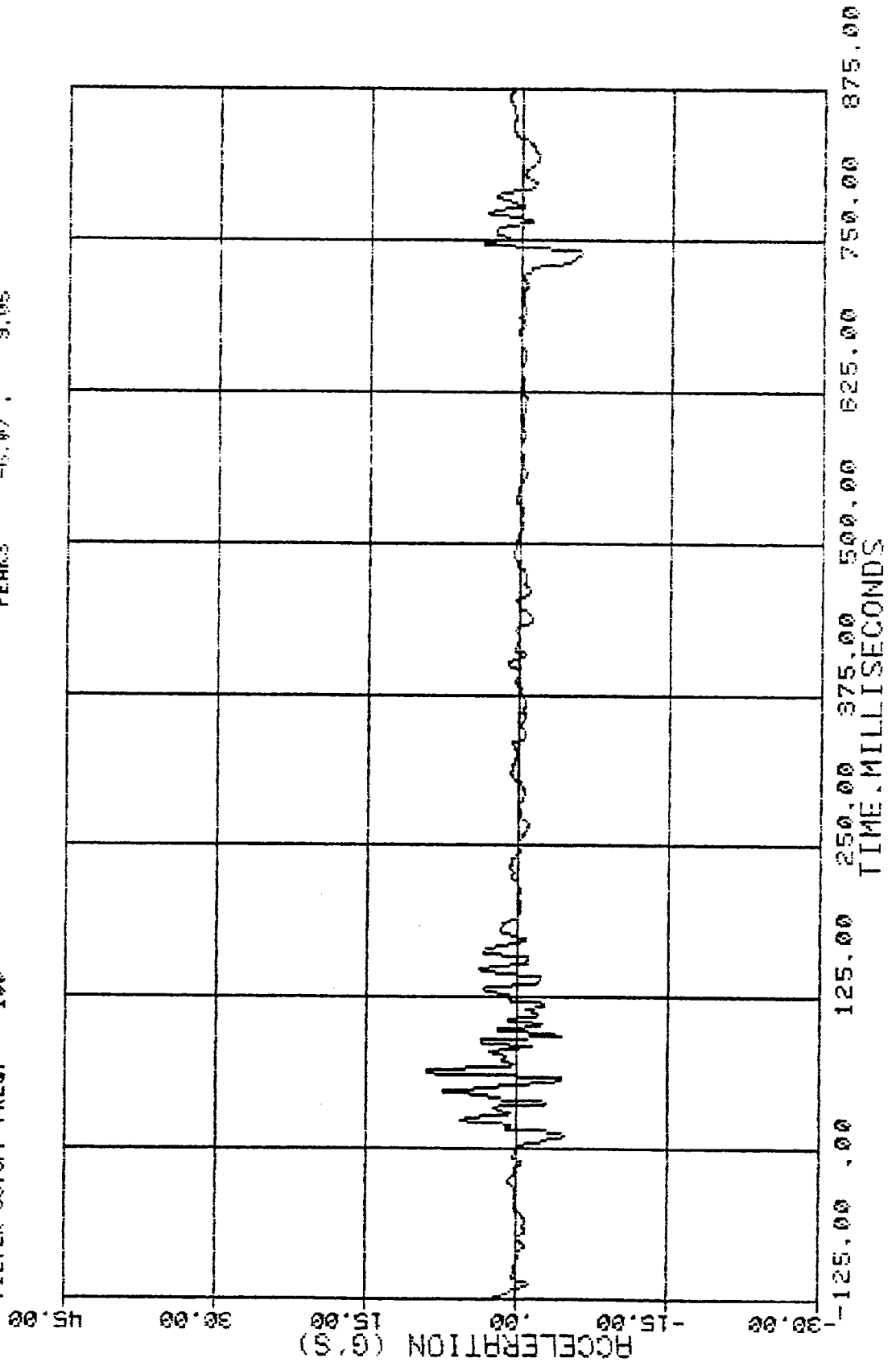


Figure 6. Vehicle Acceleration, Z-Axi, 100 Hz

CHANNEL 17 VEHICLE O.G. ACCELERATION, X-AXIS
FILTER CUTOFF FREQ. 300 PEAKS -13.67 , 14.23

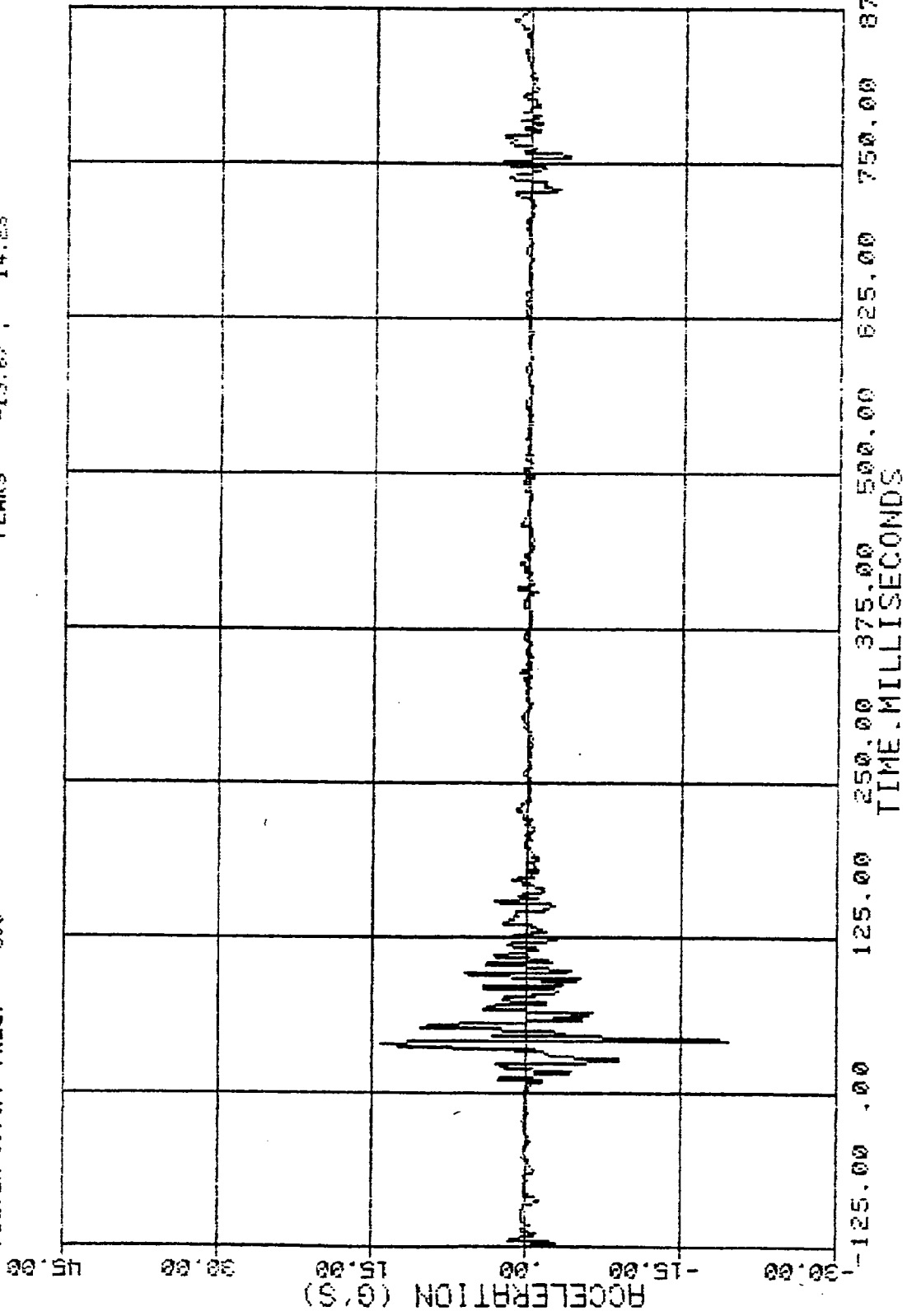


Figure 7. Vehicle Acceleration, X-Axis, 300 Hz

CHANNEL 13 VEHICLE 0.0. ACCELERATION, Y-AXIS

FILTER CUTOFF FREQ. 300

PEAKS -15.90 , 13.25

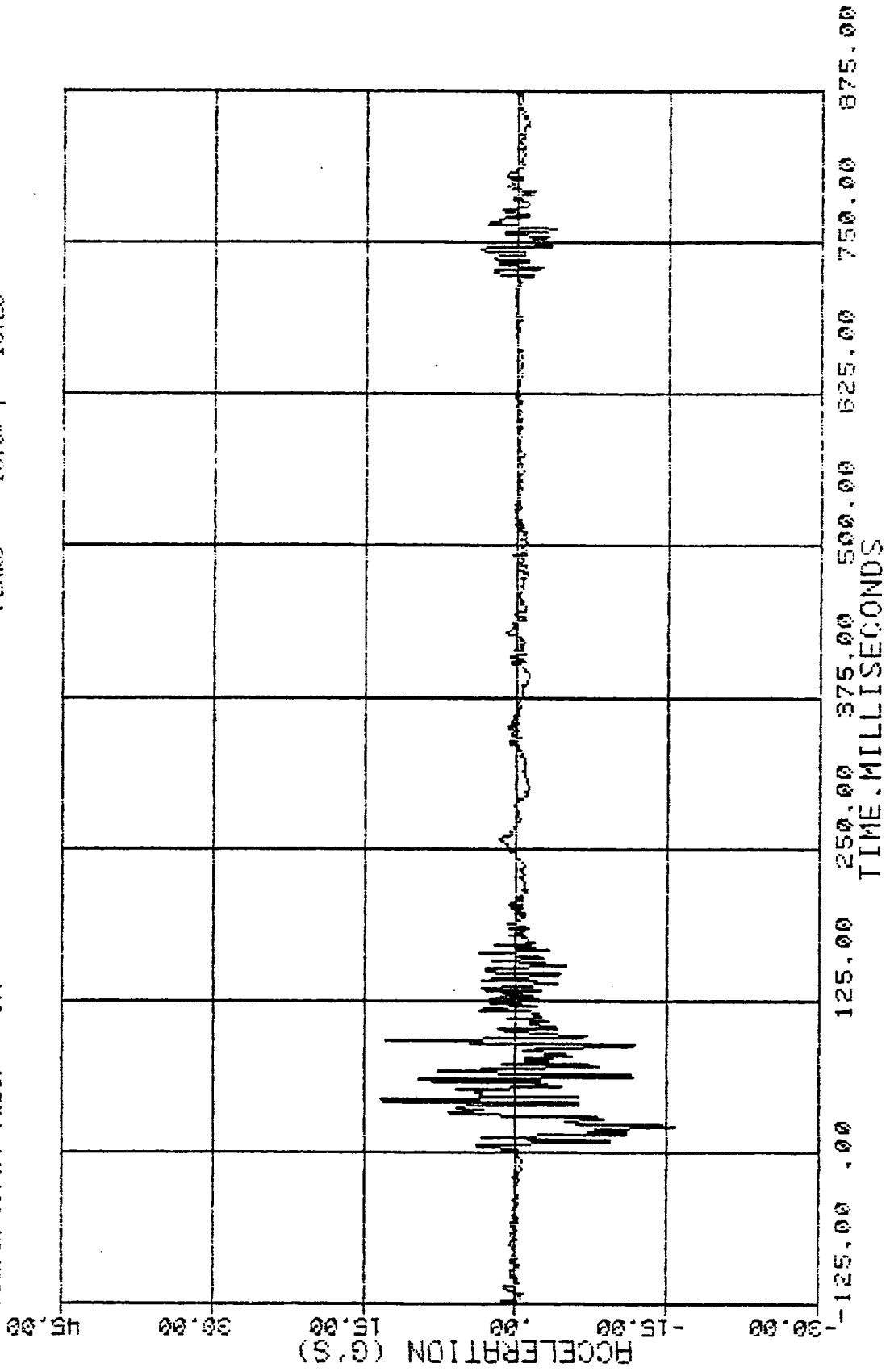


Figure 8. Vehicle Acceleration, Y-Axis, 300 Hz

CHANNEL 13 VEHICLE O.G. ACCELERATION, Z-AXIS
FILTER CUTOFF FREQ. 300

PEAKS -17.63, 14.57

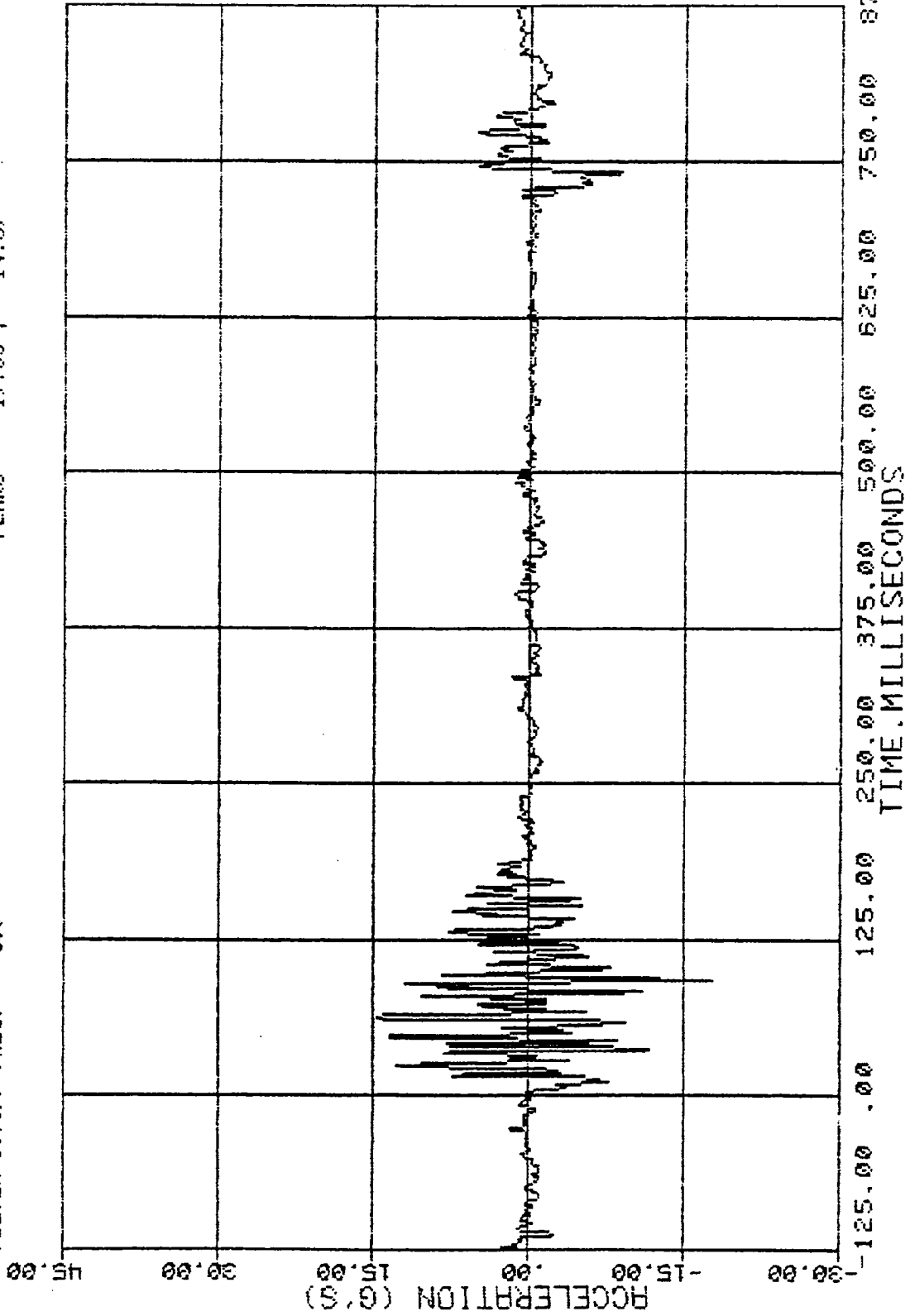


Figure 9. Vehicle Acceleration, Z-Axis, 300 Hz

CHANNEL 20 IMPACT
FILTER CUTOFF FREQ. 1650

PEAKS -3.80 , 6.75

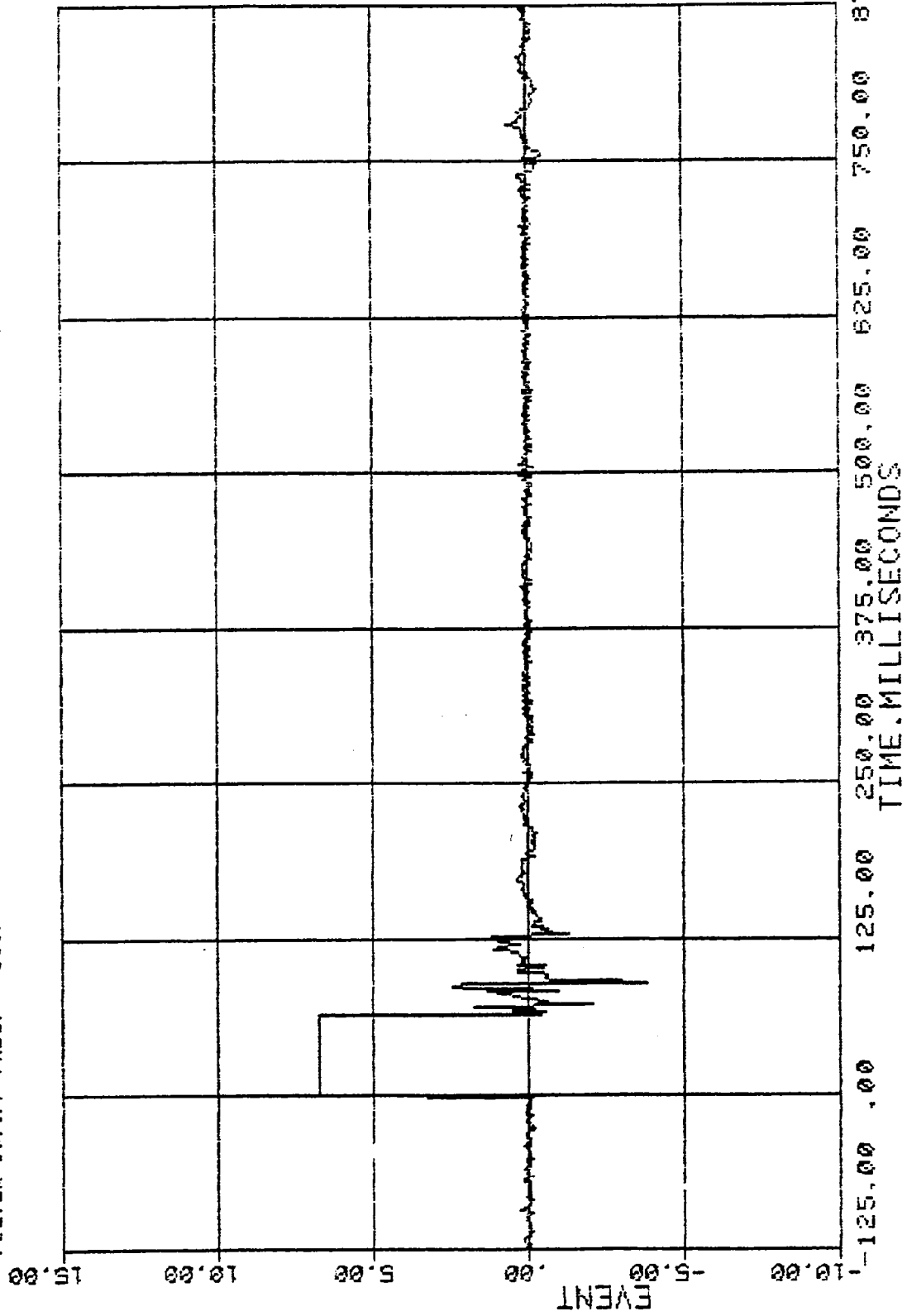


Figure 10. Event Marker, Impact

CHANNEL 21 VEHICLE ROLL RATE
FILTER CUTOFF FREQ. 100

PEAKS -53.15 , 317.79

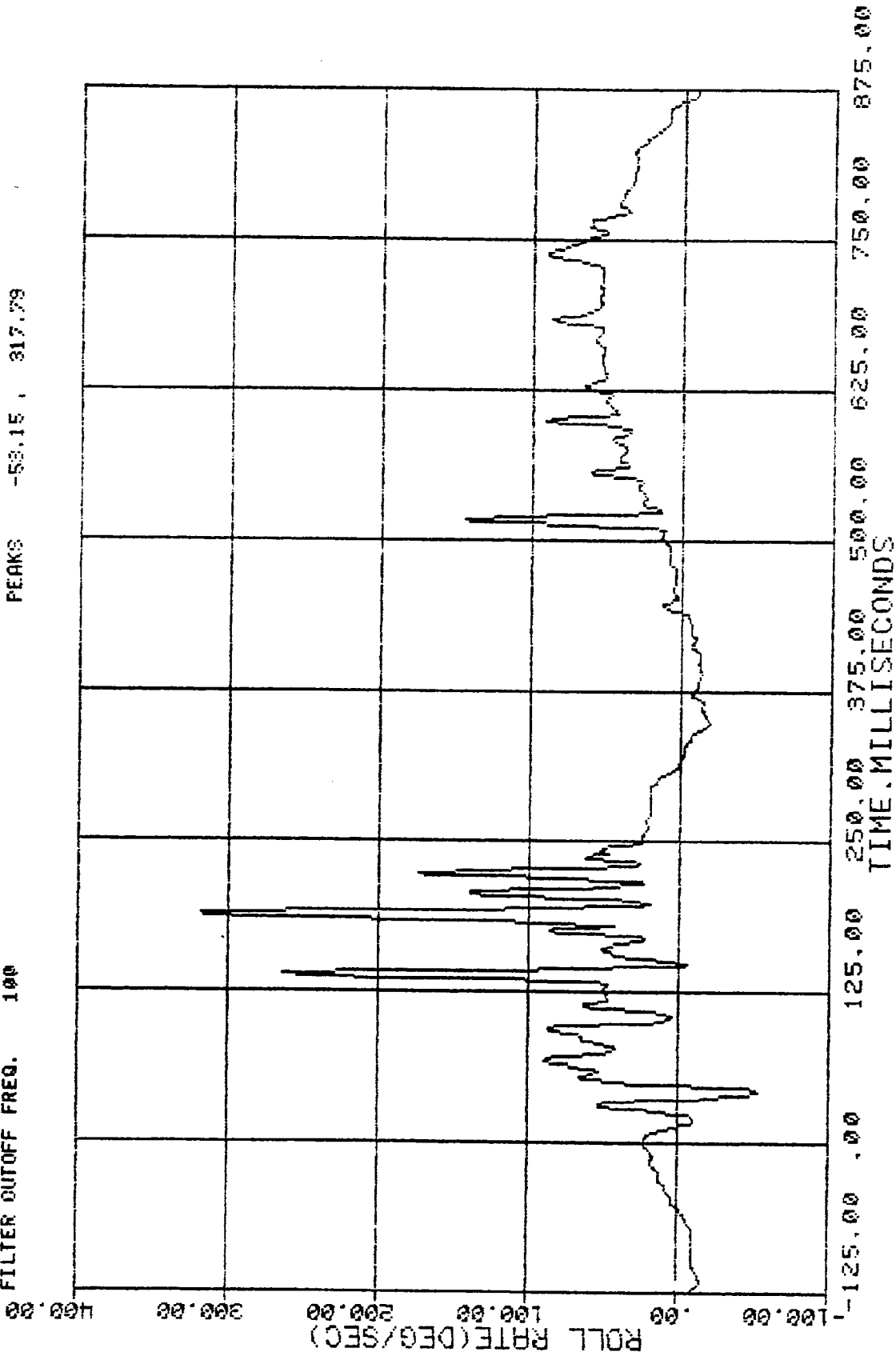


Figure 11. Vehicle Roll Rate, 100 Hz

CHANNEL 22 VEHICLE YAW RATE
FILTER CUTOFF FREQ. 100

PEAKS -20.94 , 31.56

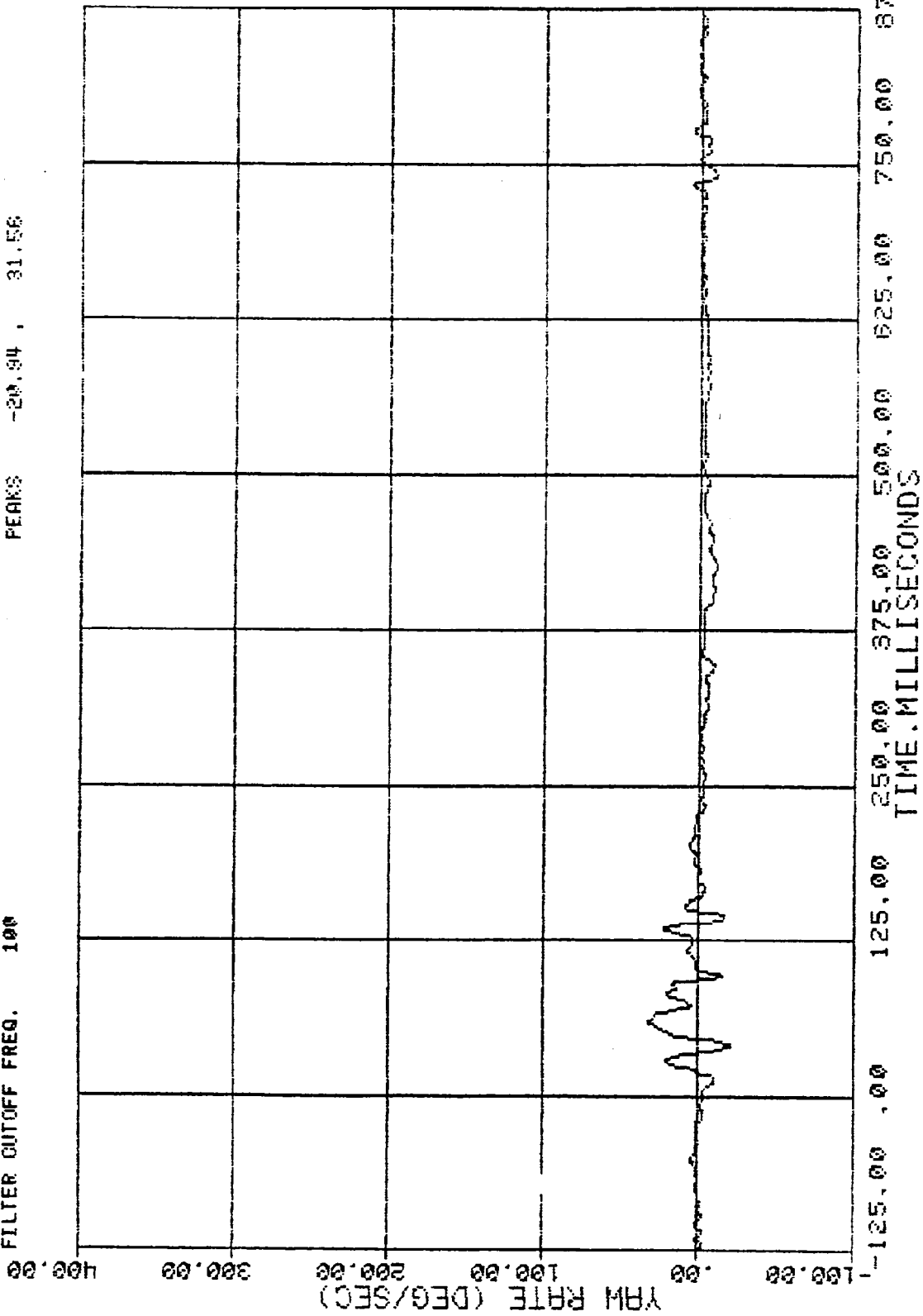


Figure 12. Vehicle Yaw Rate, 100 Hz

CHANNEL 21 VEHICLE ROLL RATE
FILTER CUTOFF FREQ. 10

PEAKS -13.36°, 96.57

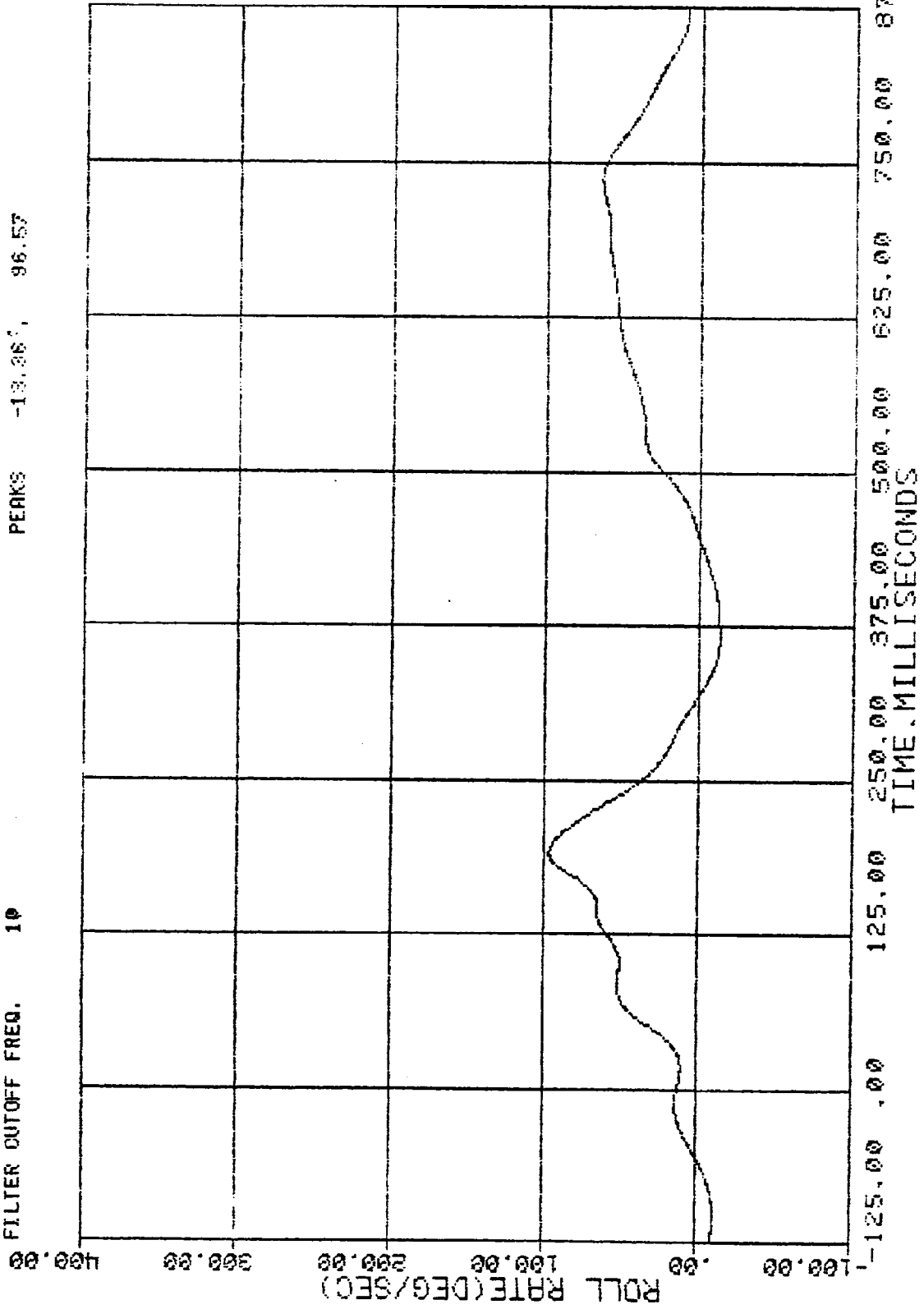


Figure 13. Vehicle Roll Rate, 10 Hz

CHANNEL 22 VEHICLE YAW RATE

FILTER CUTOFF FREQ. 10

PEAKS -0.32 , 13.53

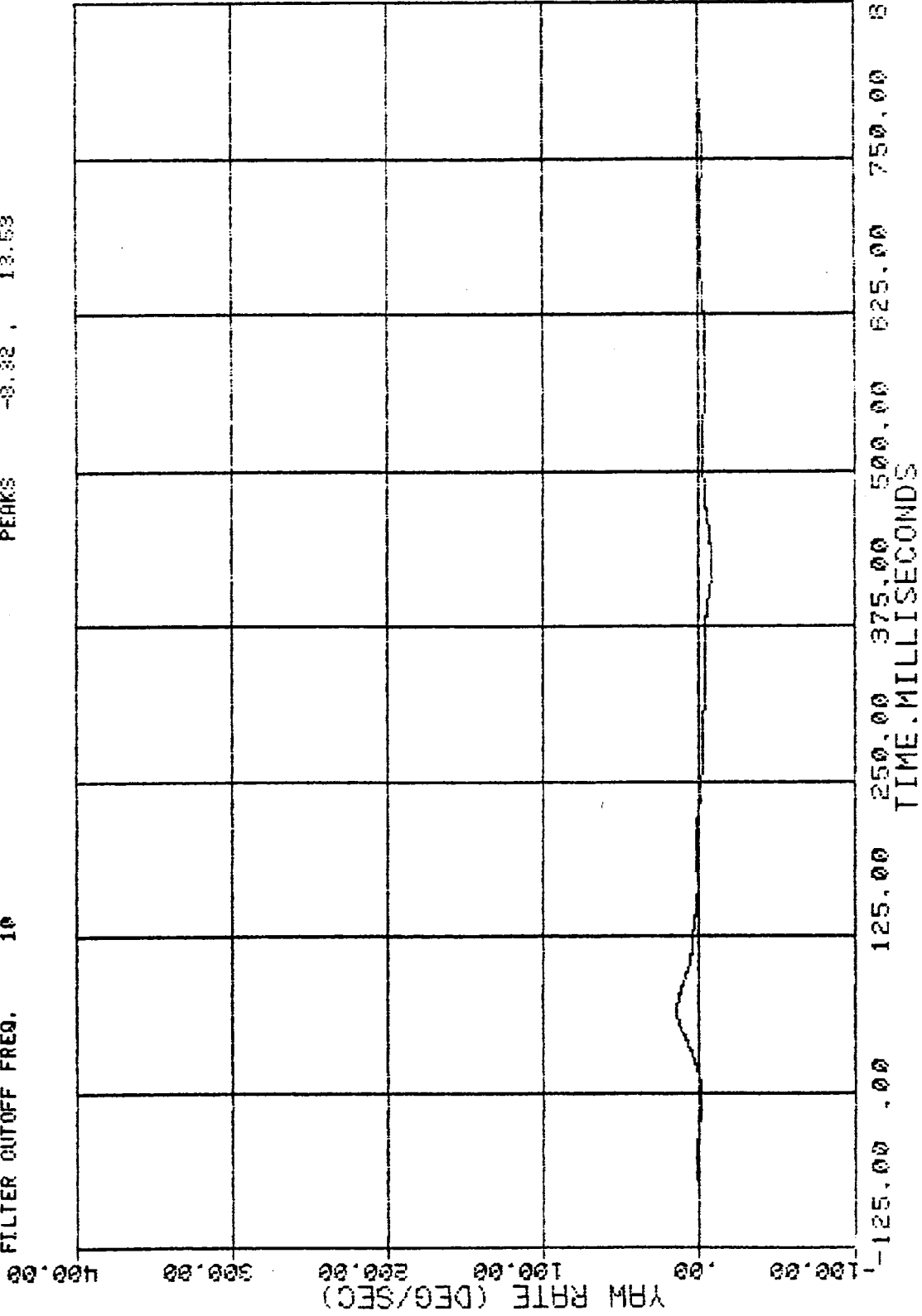


Figure 14. Vehicle Yaw Rate, 10 Hz

the slide zone. The approximate change in velocity due to the sliding is 2.8 ft/sec. Thus the overall momentum change of the vehicle due to the pole and tire sliding was 1070 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. The occupant, in fact, did not impact the interior of vehicle. The limit of NCHRP 230 is 20 ft/sec.

Since the occupant did not move 0.5 feet no ridedown accelerations were observed for the 1 foot and 0.5 foot flail. Impact velocity and associated ridedown acceleration were detected with the .25 foot flail distance.

Table 8
Change in Velocities and Ride Down
Acceleration from Analysis of Class 180
Data Using NCHRP 230 Technique

<u>Flail Distance (in)</u>	<u>Change in Velocity (ft/sec)</u>	<u>Ride Down Acceleration (g's)</u>
12	None detected	None detected
6	None detected	None detected
3	-4.5	-2.4

Based upon this analysis NCHRP 230 indicates that the accident was within design limits for the hypothetical occupant and anthropomorphic 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

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

where

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

$\dot{\theta}$ = 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 ft²

and I_3 = Momentum change occurring during Phase 3.

From the film data $\dot{x}_{cg} = 26.7$ f/s (8.1 m/s) and $\dot{\theta} = 2.7$ rad/sec. Using these two numbers the momentum change occurring during Phase 3 is given by

$$\begin{aligned} I_3 &= M_p \dot{x}_{cg} \\ &= 243 \text{ lb-sec (1081 N-s)} \end{aligned}$$

or

$$\begin{aligned} I_3 &= \dot{\theta} \frac{I_p}{D_I} \\ &= 216 \text{ lb-sec (961 N-s)}. \end{aligned}$$

The average momentum change associated with the third phase of the vehicle momentum change is 230 lb-sec (1021 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 15 through 18. 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 very mild.

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 130 and combined to yield a resultant acceleration occurring during the impact event for each of the respective locations. The severity 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 5.0 and the maximum acceleration was 9.7 g's at 46 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

30 MPH BROADSIDE IMPACT OF 79 DODGE ST REGIS INTO LUMINAIRE SUPPORT

CHANNEL 25 DRIVER HEAD ACCELERATION, X-AXIS

FILTER CUTOFF FREQ. 1650

PEAKS -1.18 , 3.59

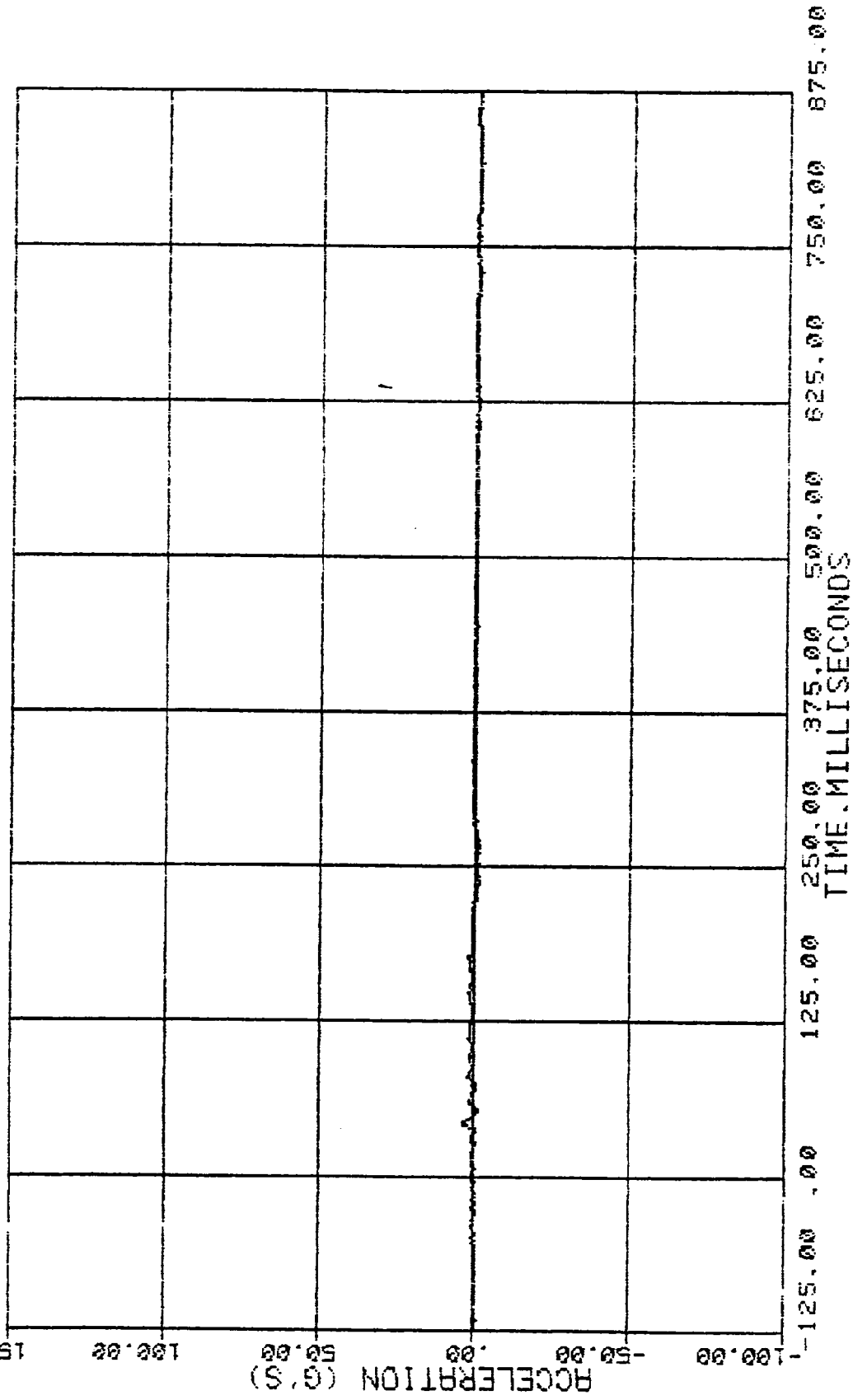


Figure 15. Driver's Head Acceleration, X-Axis, 1650 Hz

CHANNEL 26 DRIVER HEAD ACCELERATION, Y-AXIS
FILTER CUTOFF FREQ. 1650

PEAKS
-49.37 10.22
-74.25 25.44

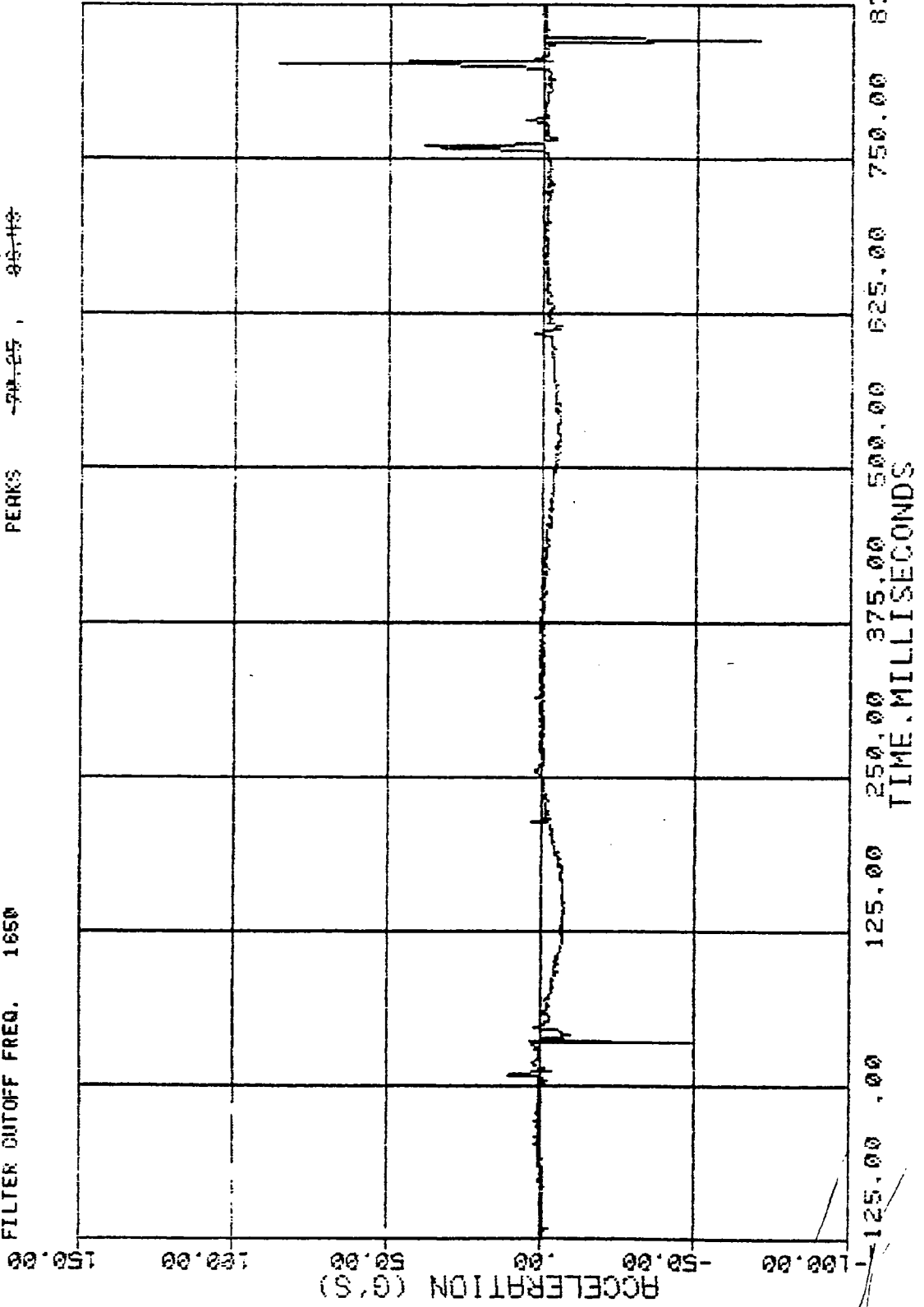


Figure 16. Driver's Head Acceleration, Y-Axis 1650 Hz

30 MPH BROADSIDE IMPACT OF 70 POUND ST REDIS INFO LUMINAIRE SUPPORT

CHANNEL 27 DRIVER HEAD ACCELERATION, Z-AXIS

FILTER CUTOFF FREQ. 1650

PEAKS -3.07 3.01

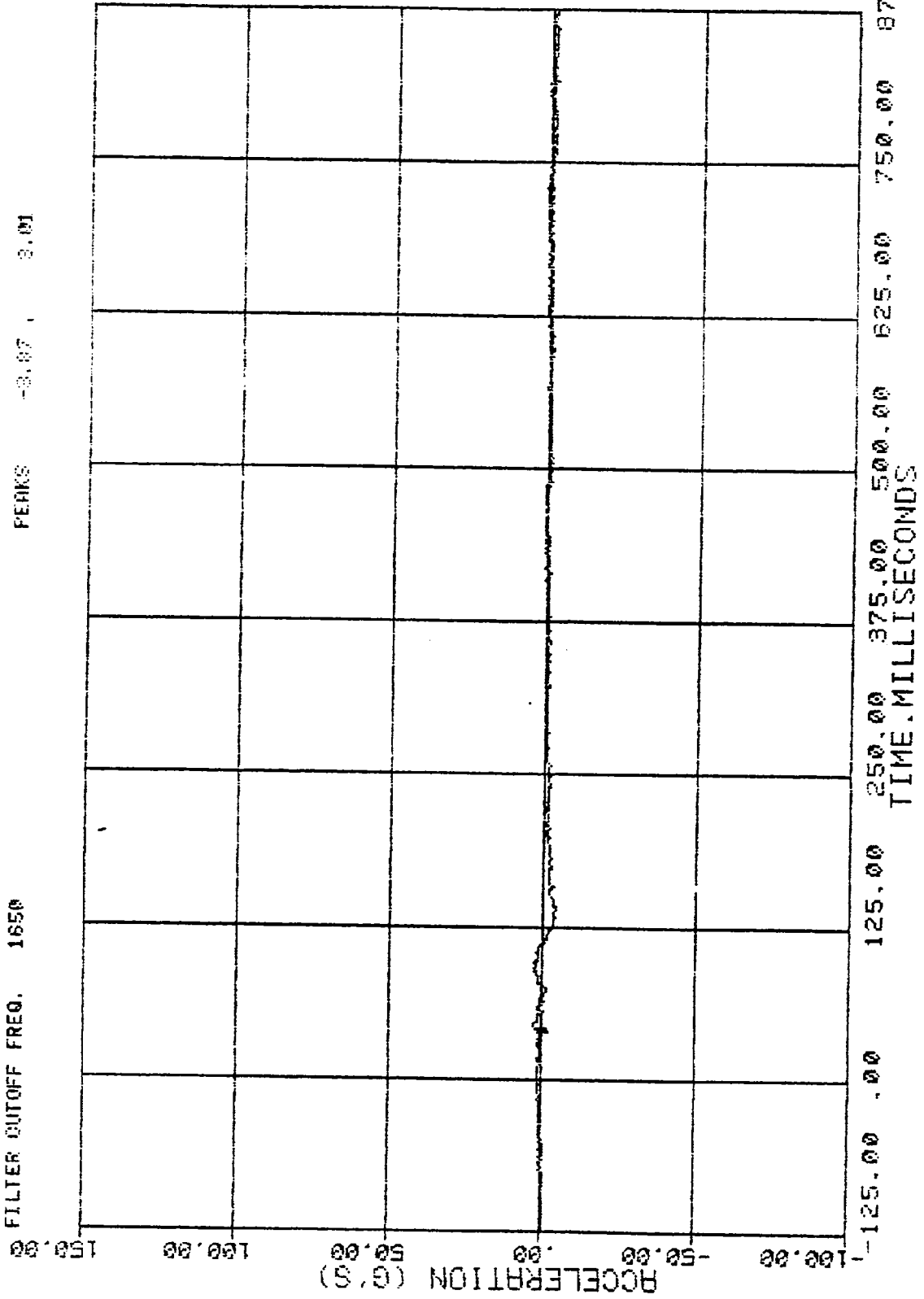


Figure 17. Driver's Head Acceleration, Z-Axi, 1650 Hz

30 MPH BROADSIDE IMPACT OF 79 DODGE ST REGIS INTO LUMINAIRE SUPPORT
 CHANNEL 0 DRIVER HEAD ACCELERATION, RESULTANT
 FILTER CUTOFF FREQ. 1650 PEAKS 0.53 , 86.43

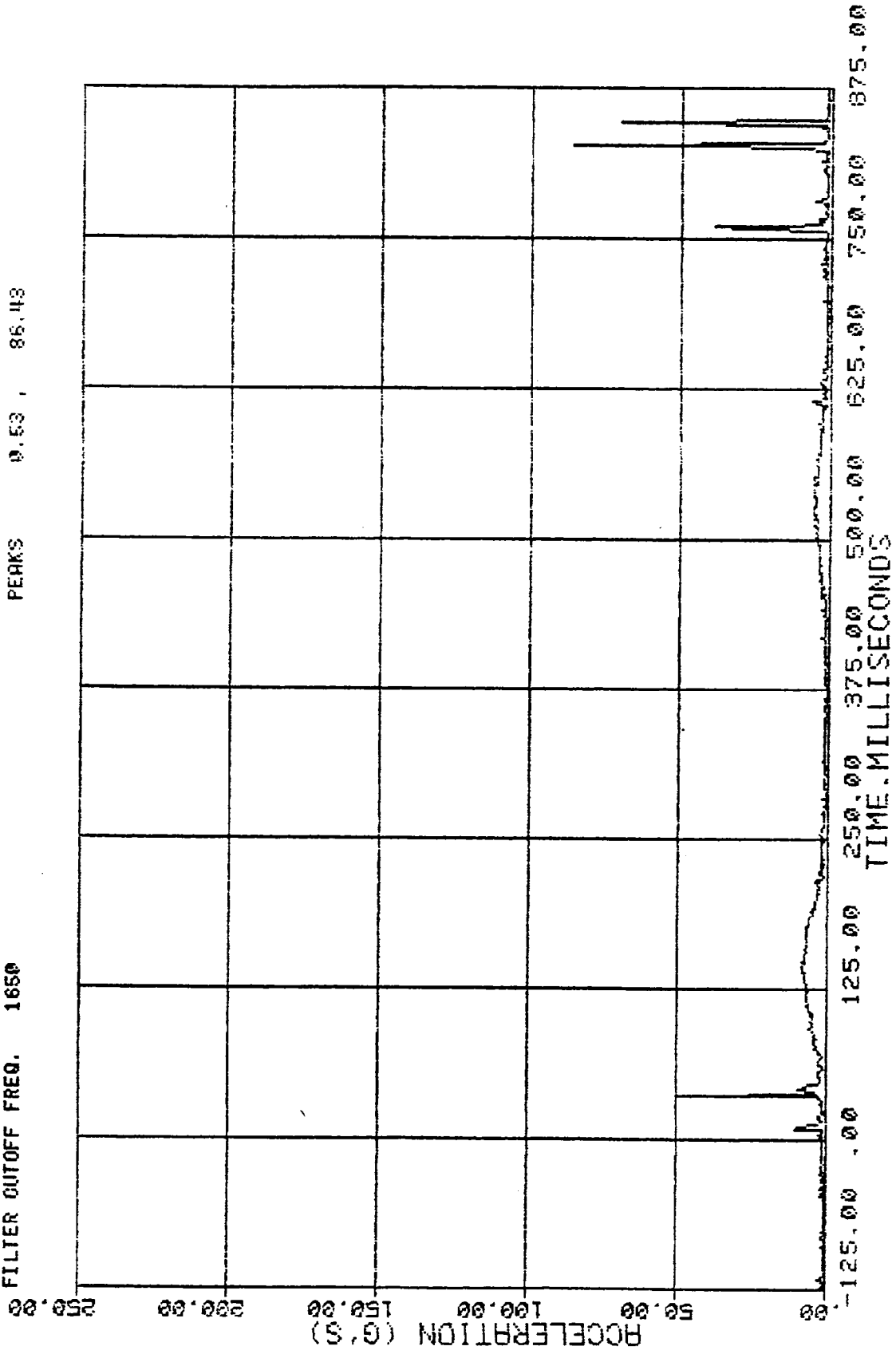


Figure 18. Driver's Head Acceleration, Resultant, 1650 Hz

Table 9
 Head Injury Criteria Evaluated for Full
 Scale Crash Test 1469-SI#7-85

	<u>Driver</u>
HIC	4
t(Start)	.0370 sec
t(Stop)	.0375 sec
t(Duration)	.0005 sec

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 resultant obtained with the use of a 189 Hz filter are presented in figures 19 through 23 for the upper spine location, figures 24 through 27 for the lower spine location and figures 28 through 30 for the pelvis location. Data quality of several channels located in the thoracic was poor.

7.6 THORACIC INJURY EVALUATION

The data obtained from the accelerometers mounted on the upper and lower left ribs within the thorax of the occupant were filtered at 189 Hz and are presented in figures 31 through 34. The left upper rib and T01 lateral transducers were also filtered using the NHTSA FIR filter. These are presented in figures 35 and 36. The peak acceleration for these locations was less than 10 g's. This would produce an AIS of less than 3. See figure 37 for AIS curves.

30 MPH BROADSIDE IMPACT OF 79 DODGE ST REGIS INTO LUMINAIRE SUPPORT

CHANNEL 1 DRIVER THORAX-T01X0

FILTER CUTOFF FREQ. 189

PEAKS -1.24 , 5.16

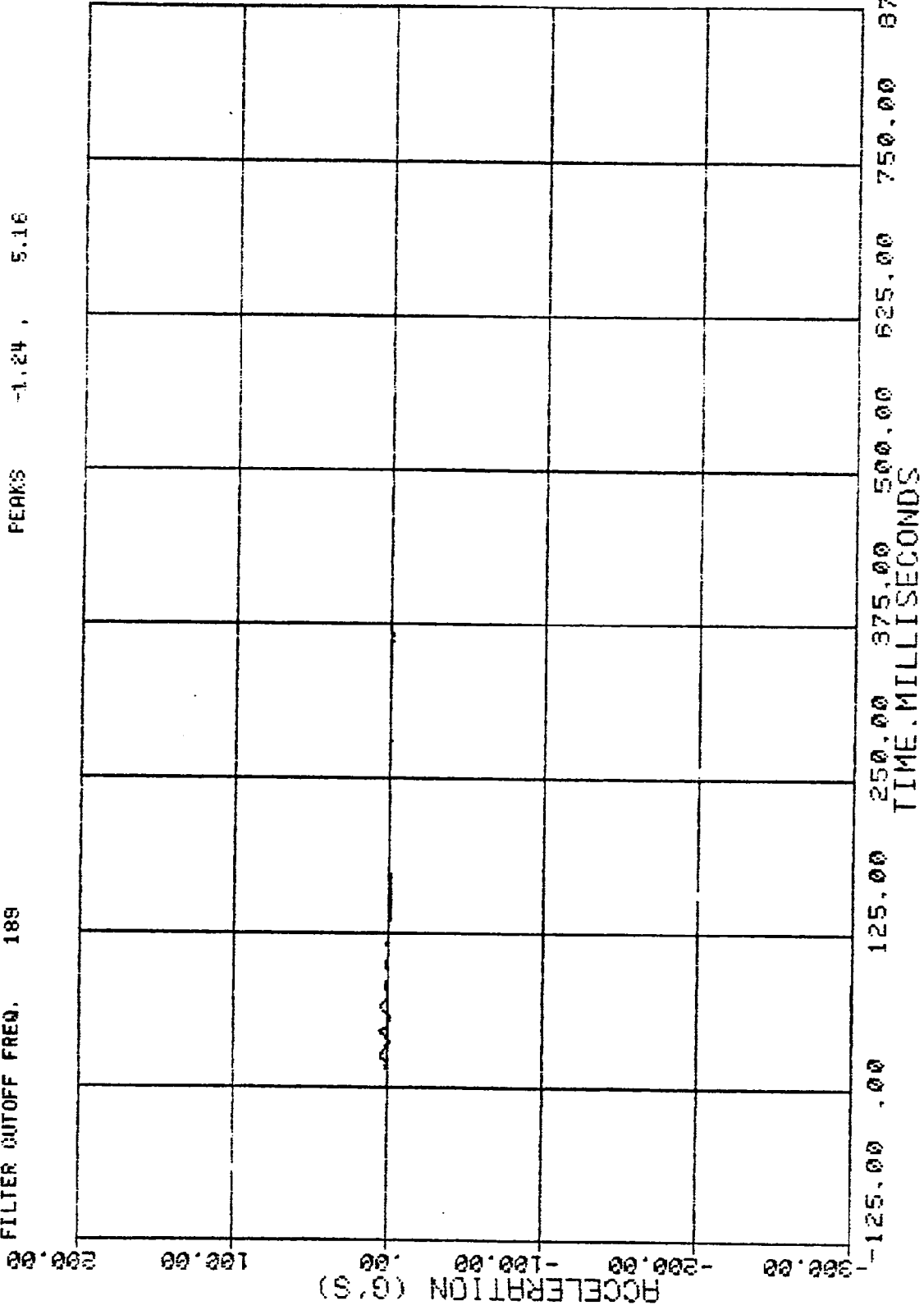
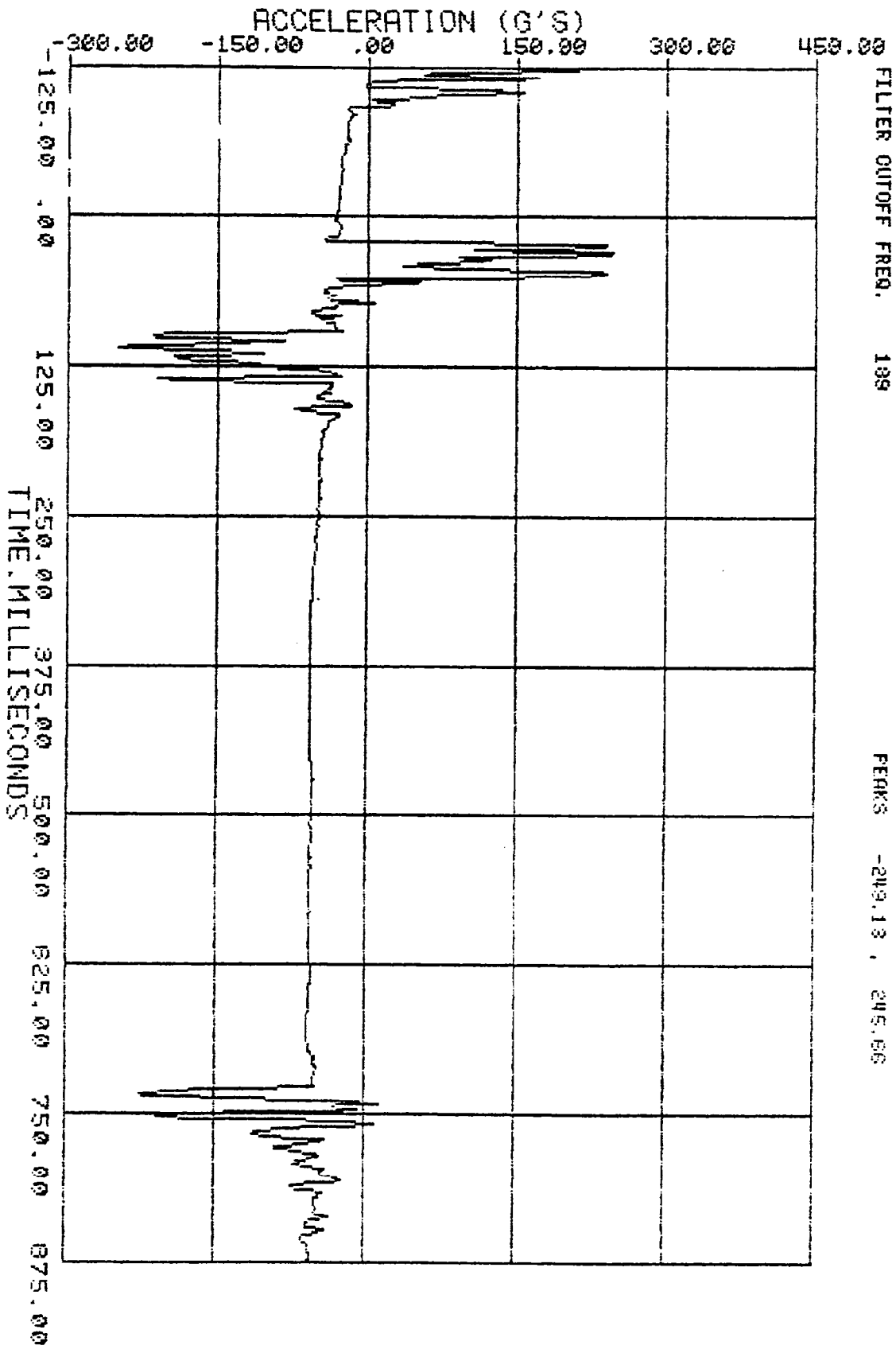


Figure 19. Driver's Upper Spine Acceleration, T01X, 189 Hz



30 MPH BROADSIDE IMPACT OF 79 DODGE ST REGIS INTO LUMINAIRE SUPPORT
 CHANNEL 2 DRIVER THORAX-T01YH
 FILTER CUTOFF FREQ. 189
 PEAKS -249.13 , 245.66

Figure 20. Driver's Upper Spine Acceleration, T01Y, 189 Hz

3P MPH BROADSIDE IMPACT OF 79 PODGE ST REDIS INTO LUMINAIRE SUPPORT
 CHANNEL 3 DRIVER THORAX-T01Y01
 FILTER CUTOFF FREQ. 189

PEAKS -6.14 , 6.98

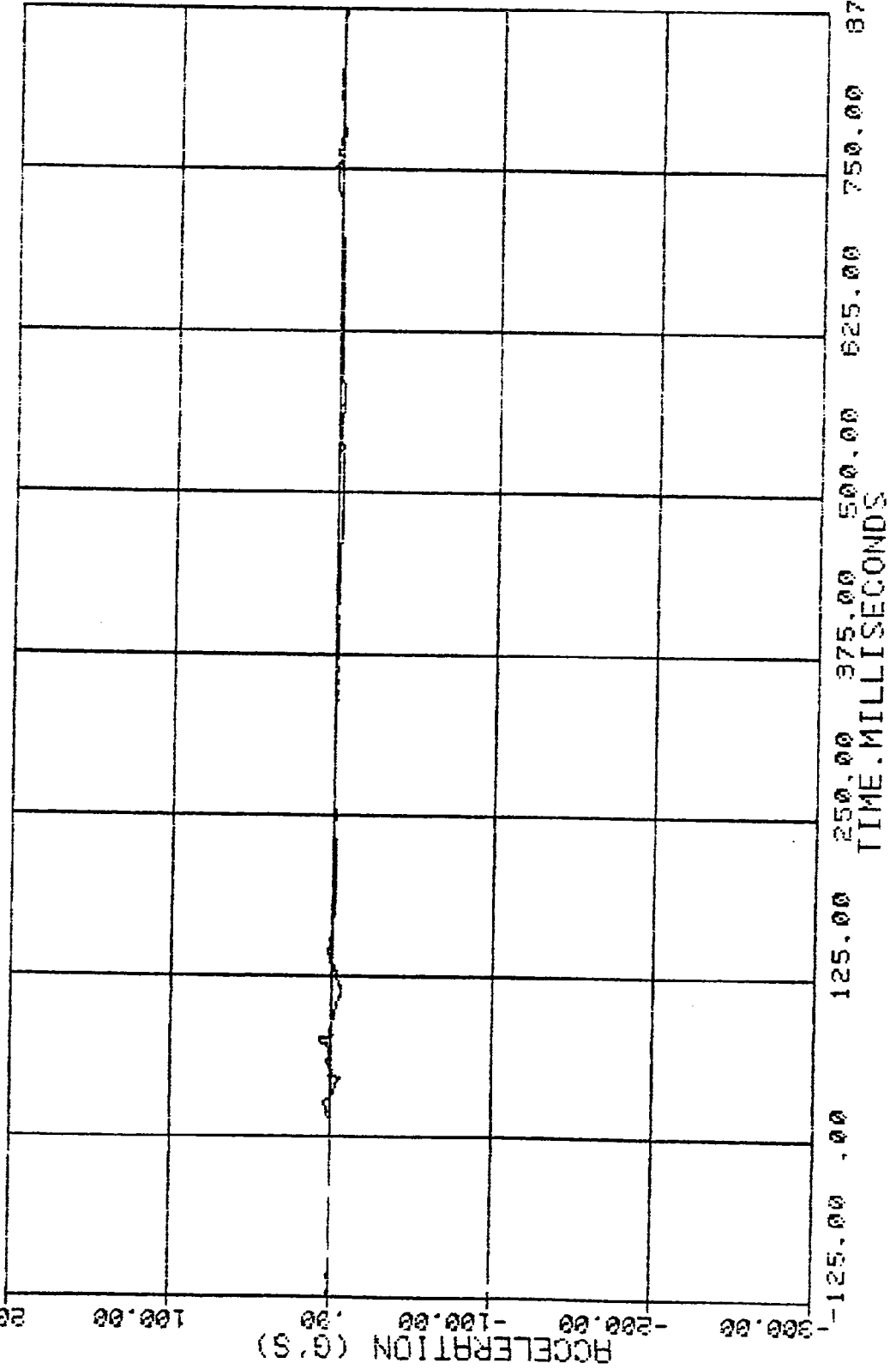


Figure 21. Driver's Upper Spine Acceleration, T01YA, 189 Hz

30 MPH BROADSIDE IMPACT OF 79 DODGE ST REGIS INTO LUMINAIRE SUPPORT

CHANNEL 4 DRIVER THORAX-T01Z0

FILTER CUTOFF FREQ. 189

PEAKS -5.29 , 2.06

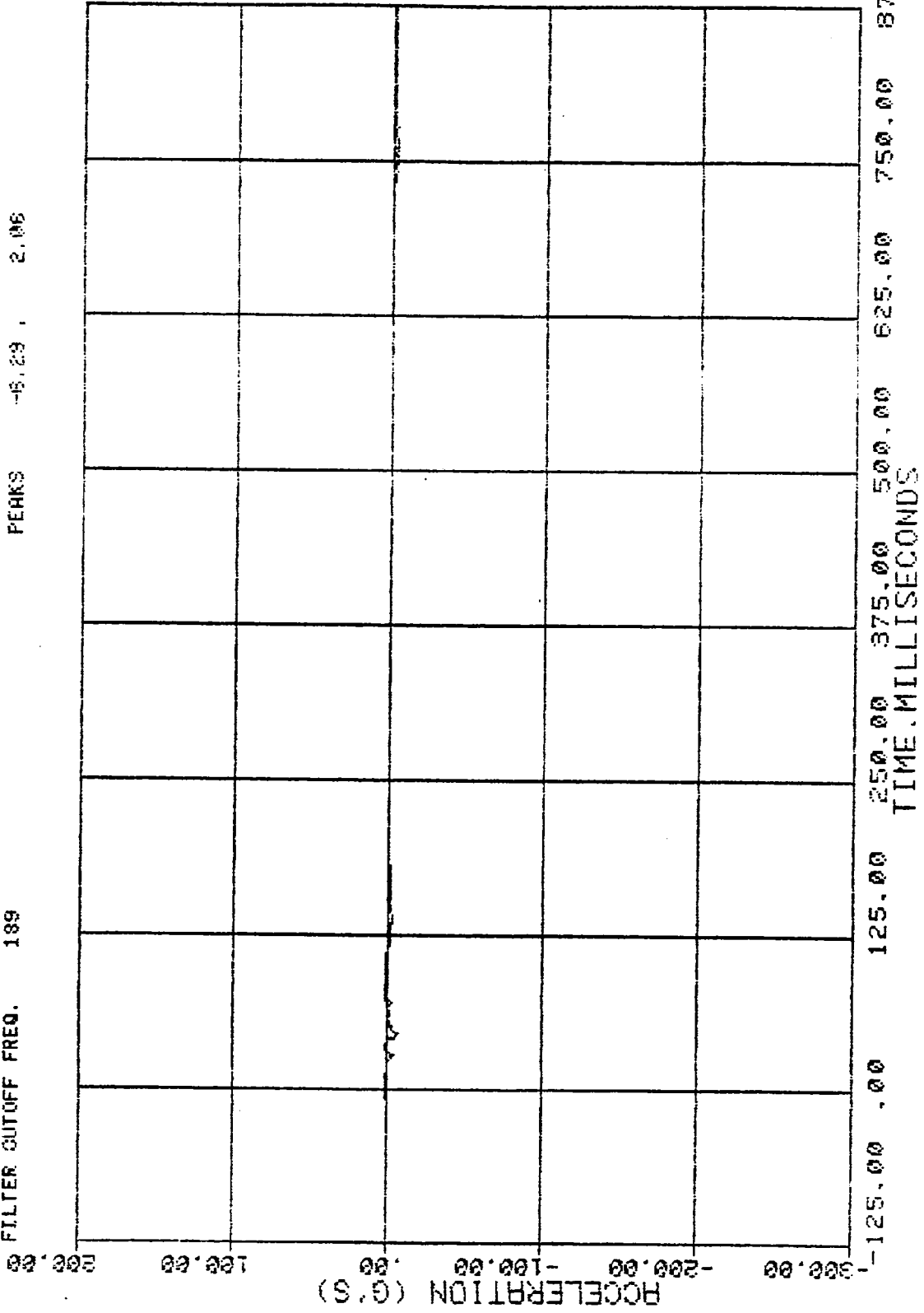


Figure 22. Driver's Upper Spine Acceleration, T01Z, 189 Hz

30 MPH BROADSIDE IMPACT OF 79 DODGE ST REOIS INTO LUMINAIRE SUPPORT
 CHANNEL 8 DRIVER UPPER SPINE, RESULTANT
 FILTER CUTOFF FREQ. 189 PEAKS 0.00 , 9.74

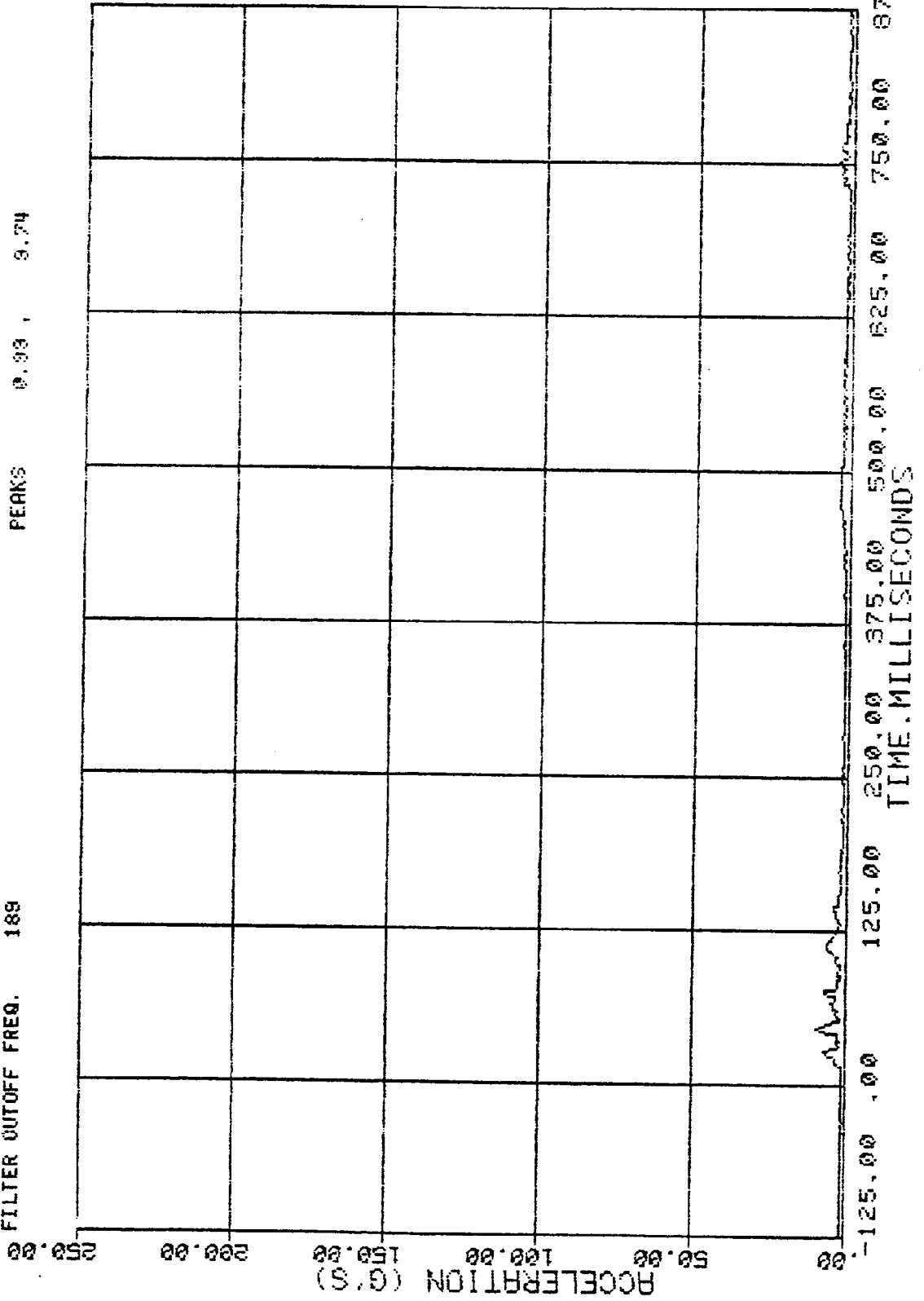


Figure 23. Driver's Upper Spine Acceleration, Resultant, 189 Hz

30 MPH BROADSIDE IMPACT OF 79 DODGE ST REGIS INTO LUMINAIRE SUPPORT

CHANNEL 3 DRIVER THORAX-T12X0

FILTER CUTOFF FREQ. 189

PEAKS -55.83 , 32.50

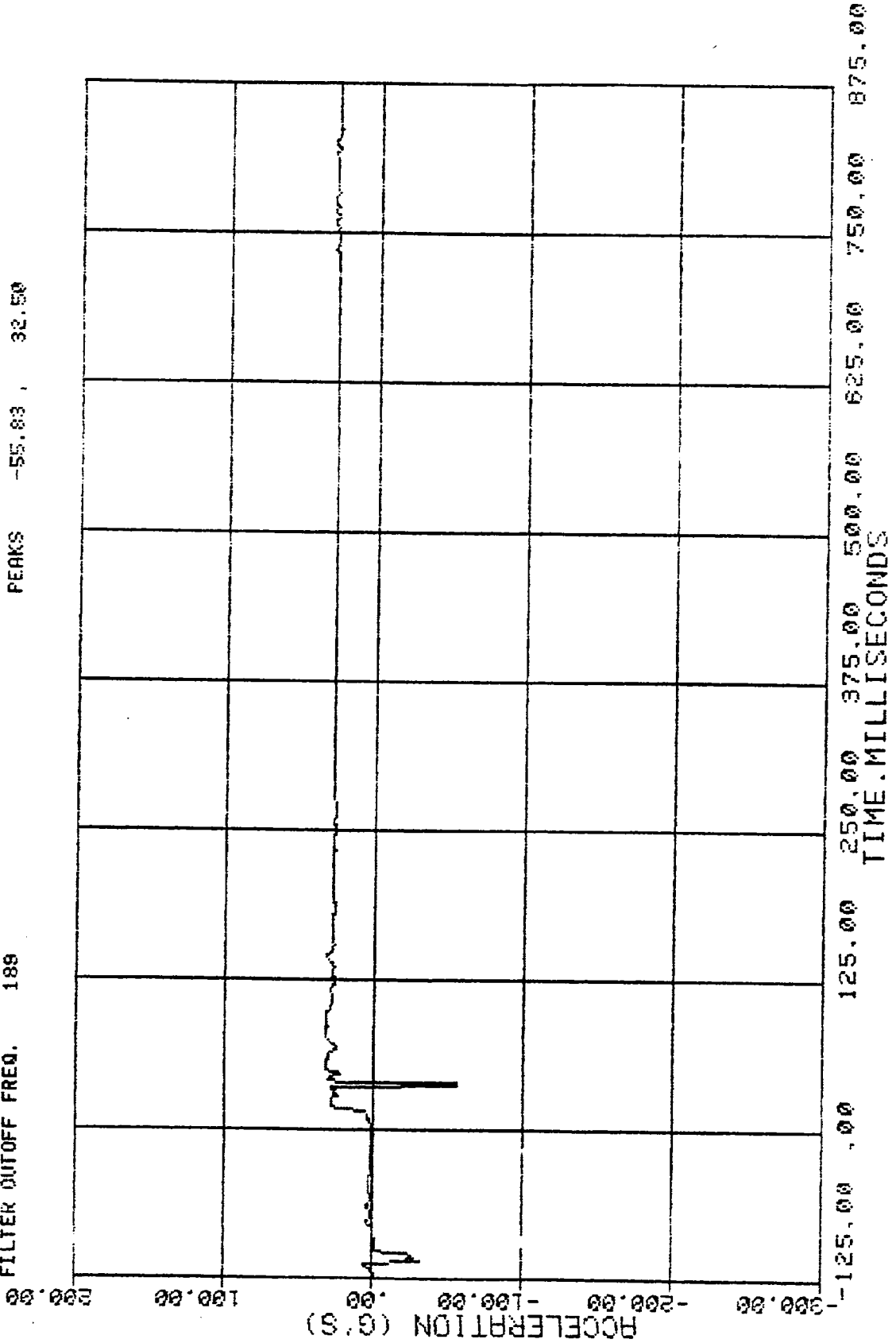


Figure 24. Driver's Lower Spine Acceleration, T12X, 189 Hz

CHANNEL 10 DRIVER THORAX-T12Y0A
FILTER CUTOFF FREQ. 189

PEAKS -52.48 289.65

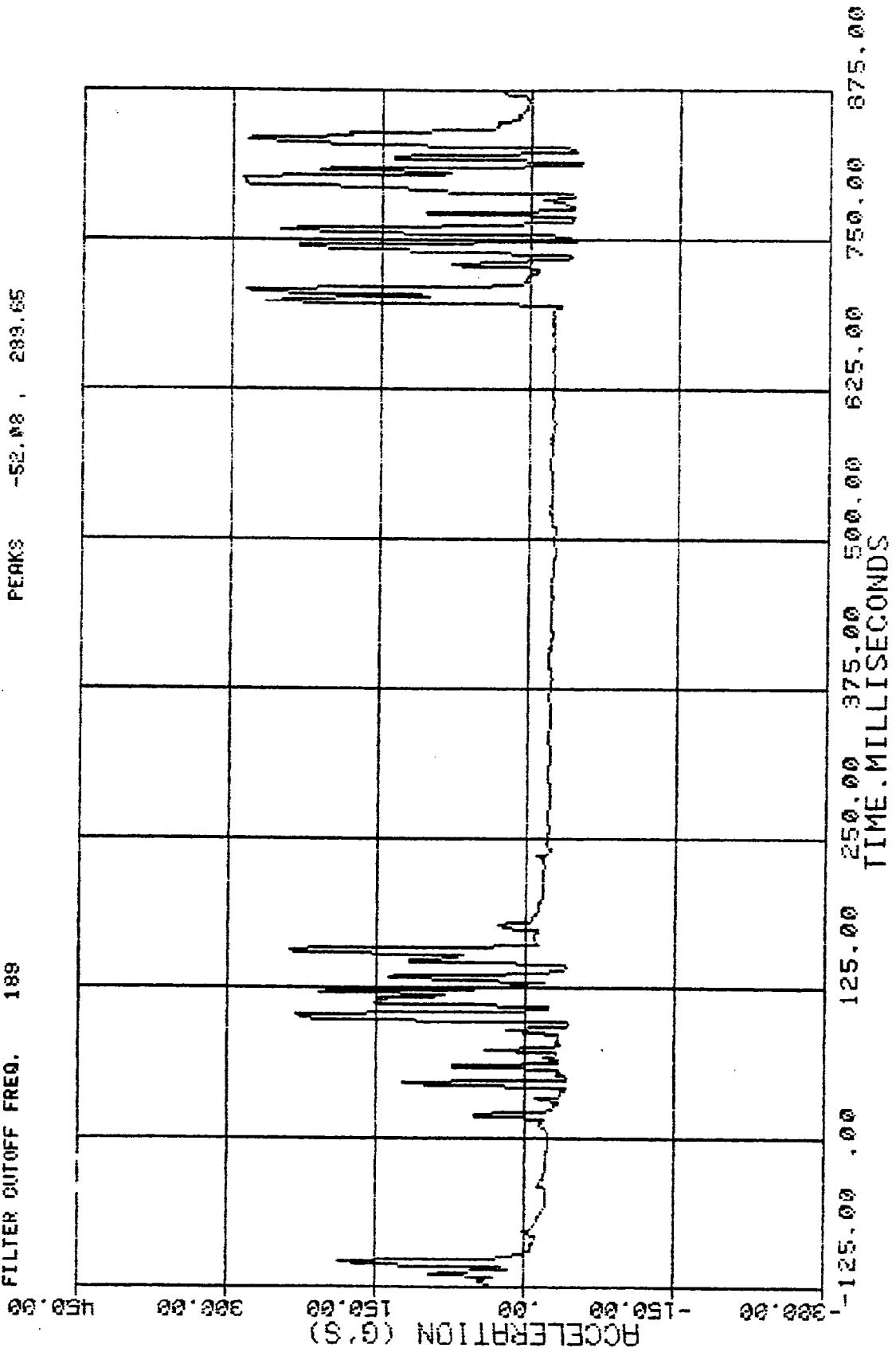


Figure 23. Driver's Lower Spine Acceleration, T12YA, 189 Hz

CHANNEL 11 DRIVER THORAX-T12Y01

FILTER CUTOFF FREQ. 189

PEAKS -143.78 , 214.34

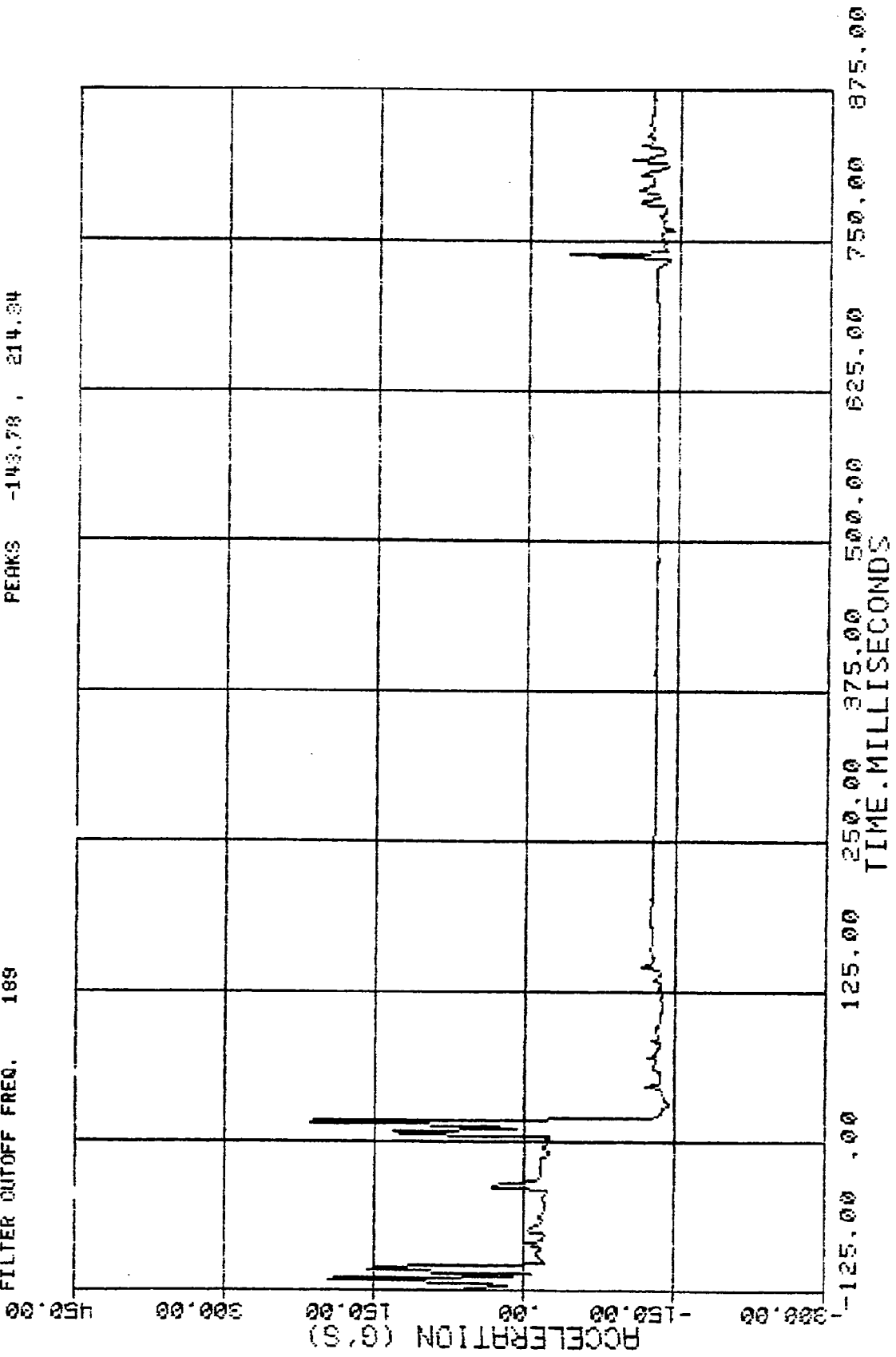


Figure 26. Driver's Lower Spine Acceleration, T12Y, 189 Hz

CHANNEL 12 DRIVER THORAX-T12201
FILTER CUTOFF FREQ. 189

PEAKS -54.74, 30.03

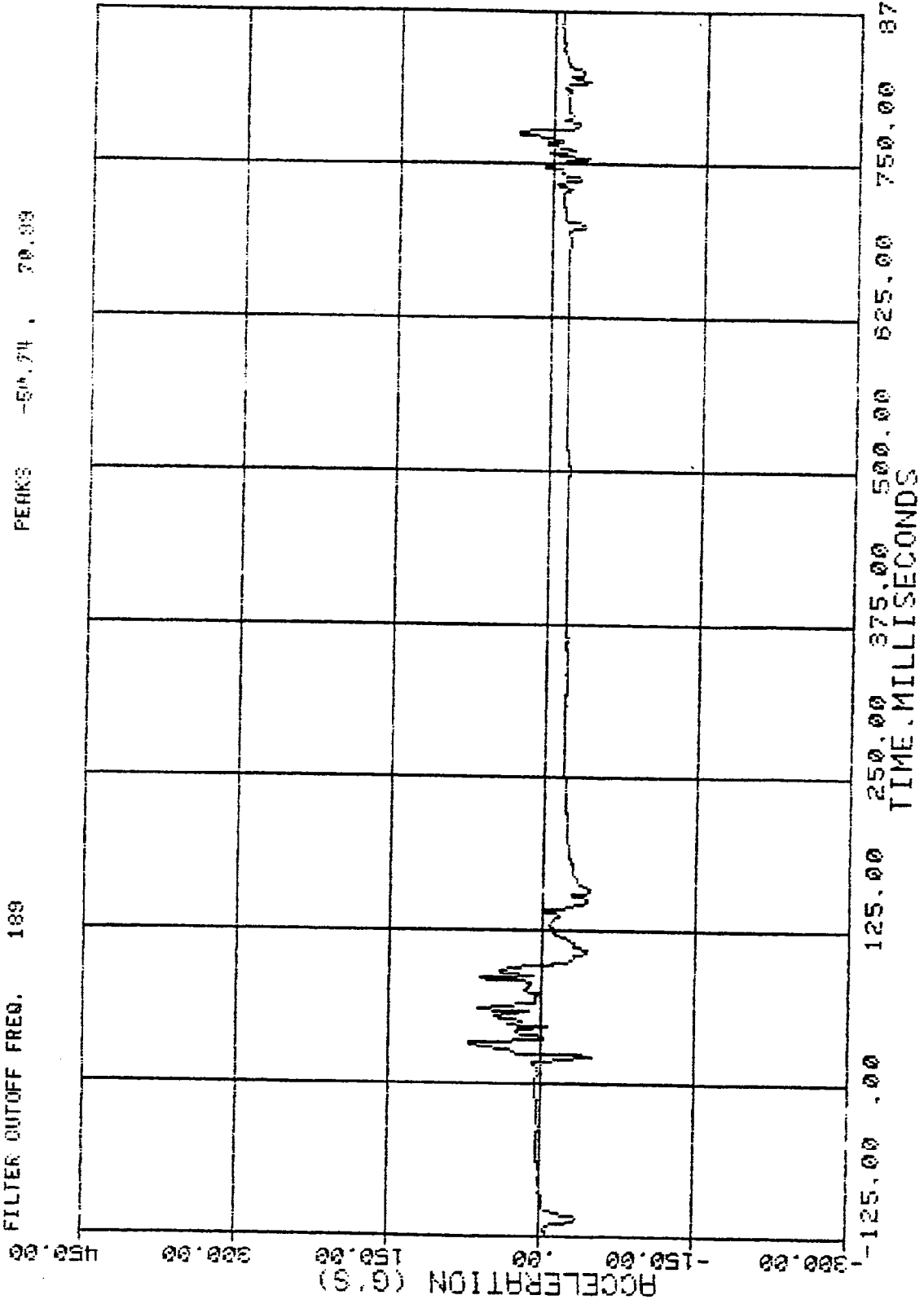


Figure 27. Driver's Lower Spine Acceleration, T12Z, 189 Hz

CHANNEL 28 DRIVER PELVIC ACCELERATION, X-AXIS
FILTER CUTOFF FREQ. 189 PEAKS -1.69 , 2.24

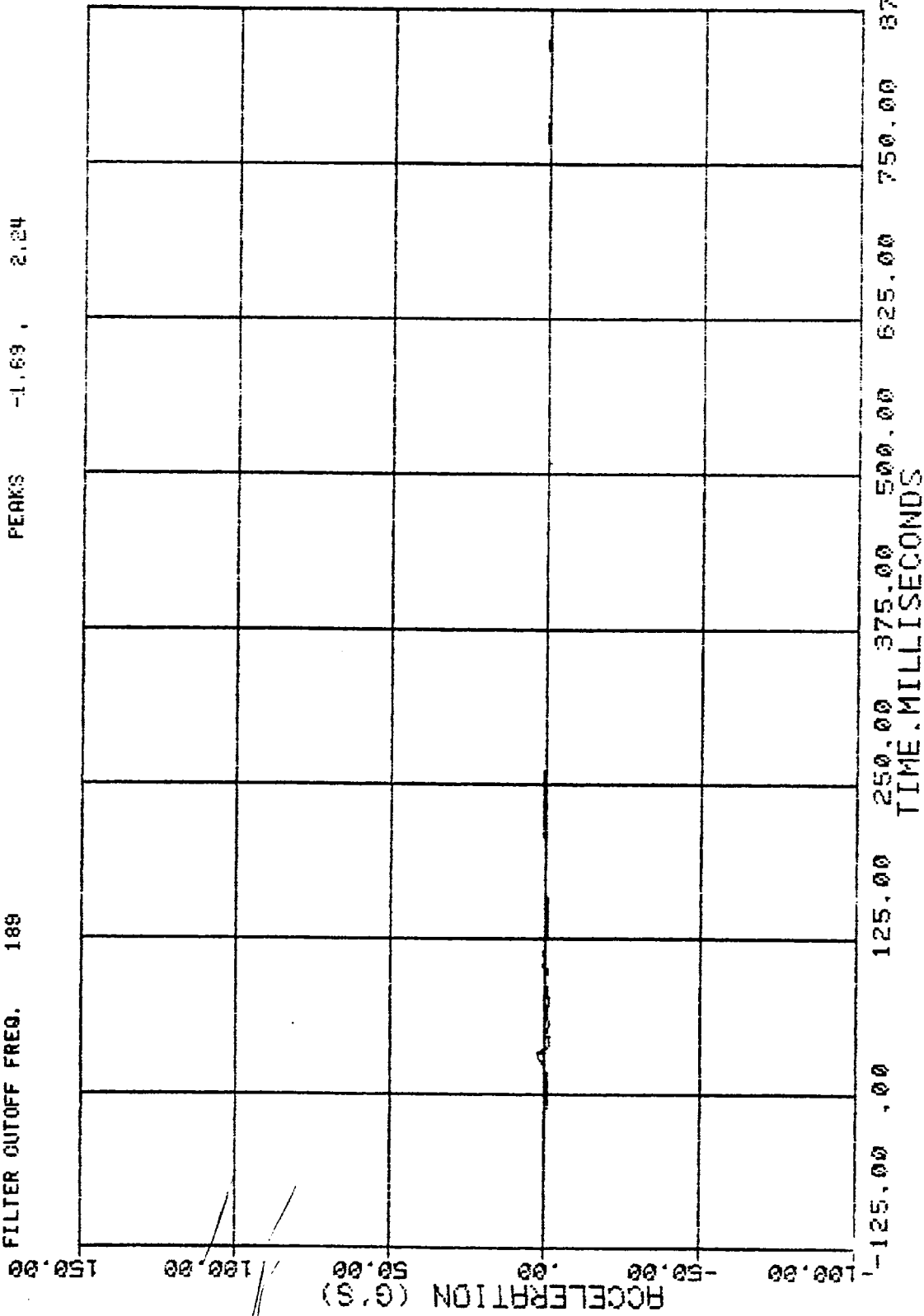


Figure 28. Driver's Pelvic Acceleration, X-Axis, 189 Hz

CHANNEL 29 DRIVER PELVIC ACCELERATION, Y-AXIS
FILTER CUTOFF FREQ. 189

PEAKS -17.67 , 5.06

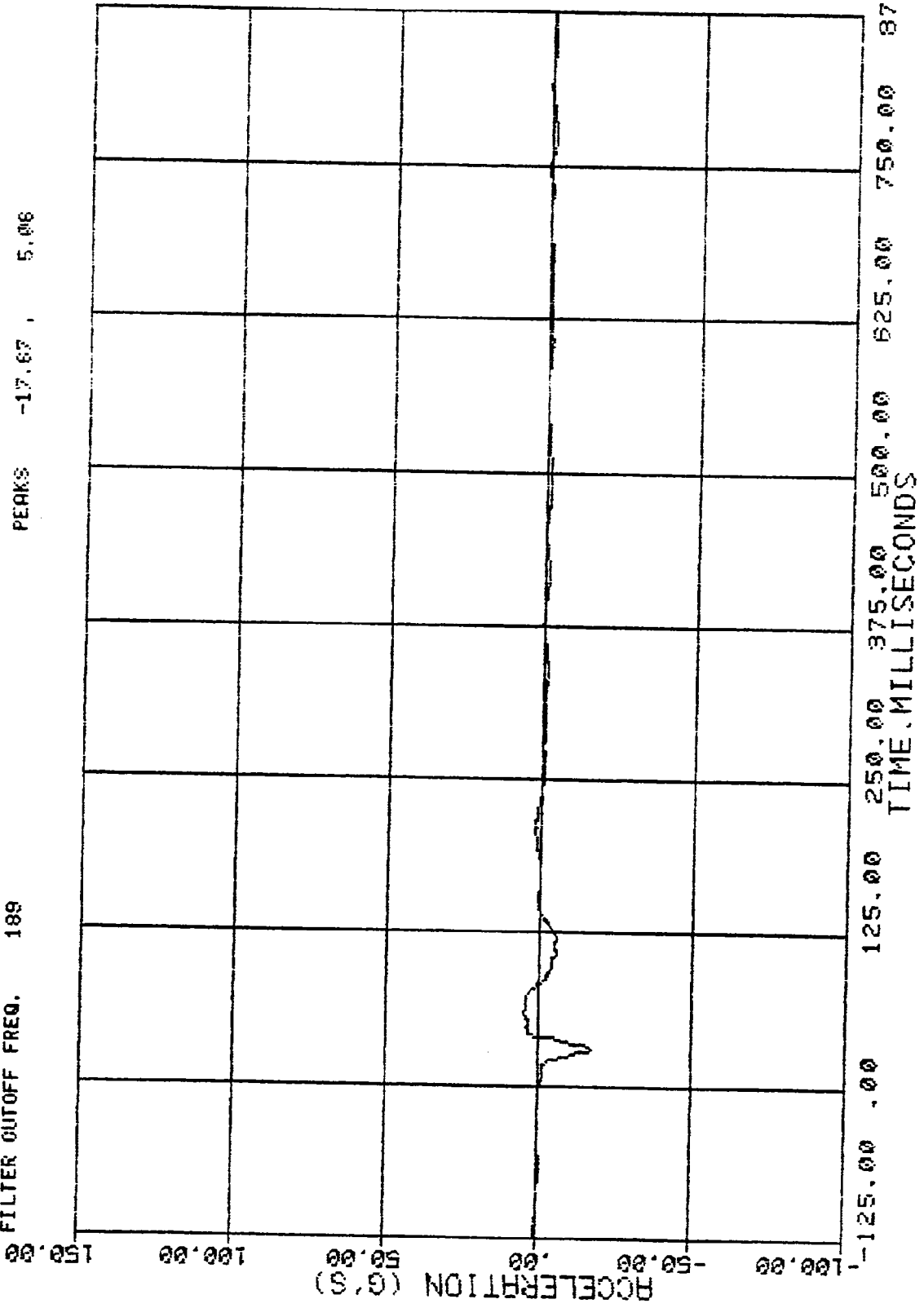


Figure 29. Driver's Pelvis Acceleration, Y-Axis, 189 Hz

30 MPH BROADSIDE IMPACT OF 79 DODGE ST REBIS INTO LUMINAIRE SUPPORT

CHANNEL 30 DRIVER PELVIC ACCELERATION, Z-AXIS

FILTER CUTOFF FREQ. 189

PEAKS -3.89 , 3.57

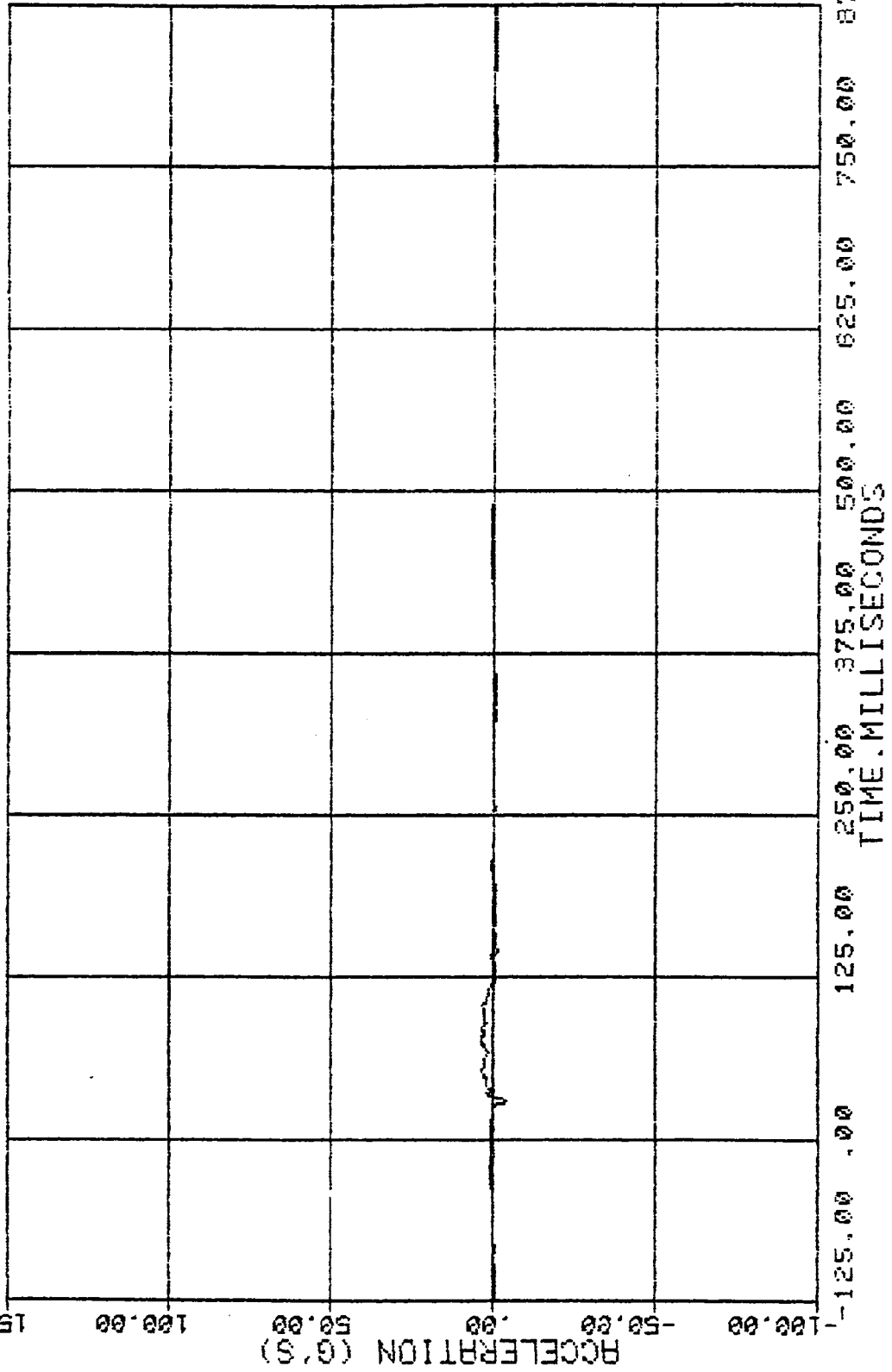


Figure 30. Driver's Pelvis Acceleration, Z-Axis, 189 Hz

30 MPH BROADSIDE IMPACT OF 79 DODGE ST REBIS INTO LUMINAIRE SUPPORT

CHANNEL 3 DRIVER THORAX-LURY01

FILTER CUTOFF FREQ. 189

PEAKS -4.47 , 5.33

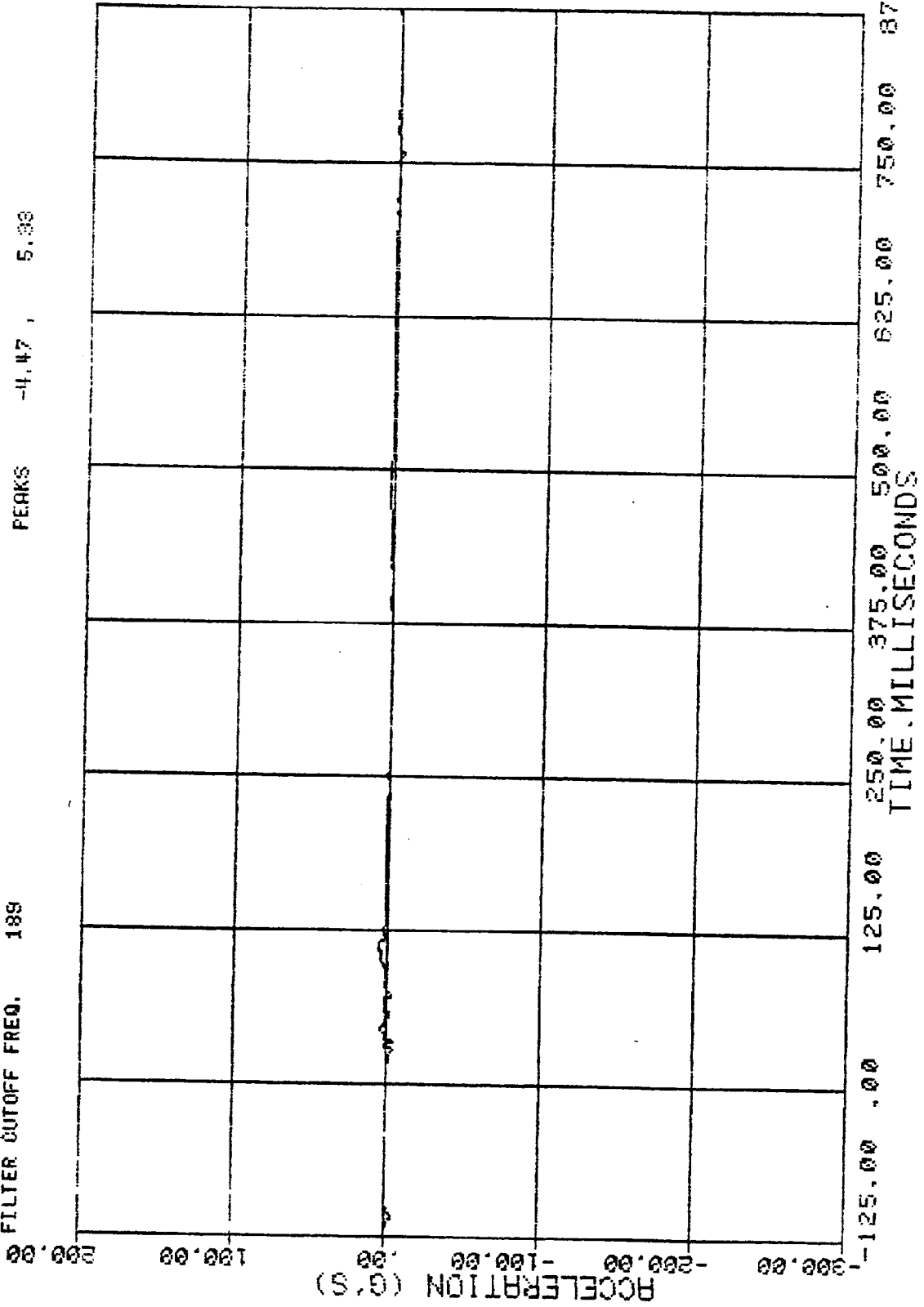


Figure 31. Driver's Left Upper Rib Acceleration, LURY, 189 Hz

CHANNEL 7 DRIVER THORAX-LURYA
FILTER CUTOFF FREQ. 189

PEAKS -106.04 , 302.08

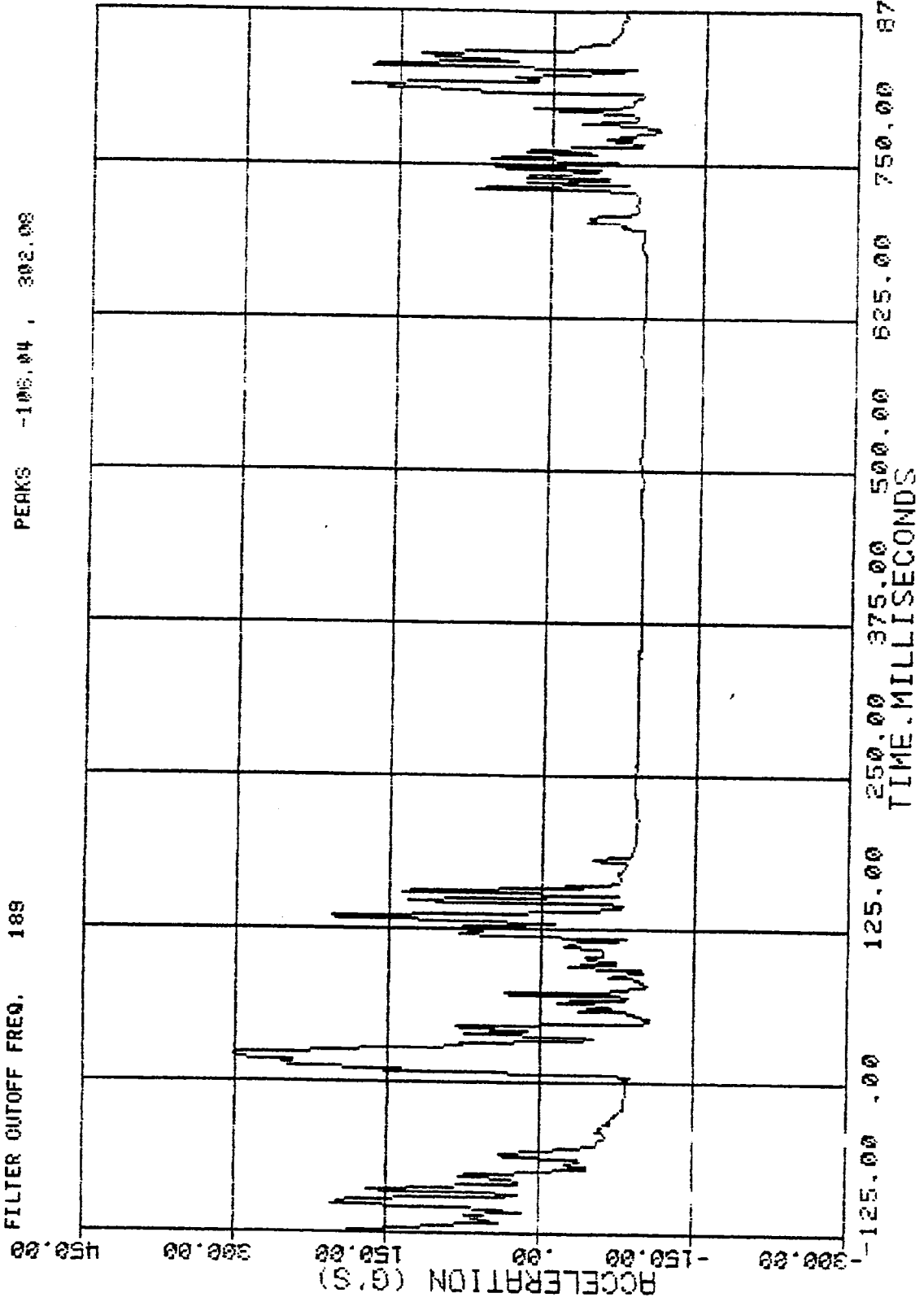


Figure 32. Driver's Left Upper Rib Acceleration, LURYA, 189 Hz

30 MPH BROADSIDE IMPACT OF 79 DODGE ST REGIS INTO LUMINAIRE SUPPORT

CHANNEL 6 DRIVER THORAX-LLRY01

FILTER CUTOFF FREQ. 189

PEAKS -159.86 , 138.97

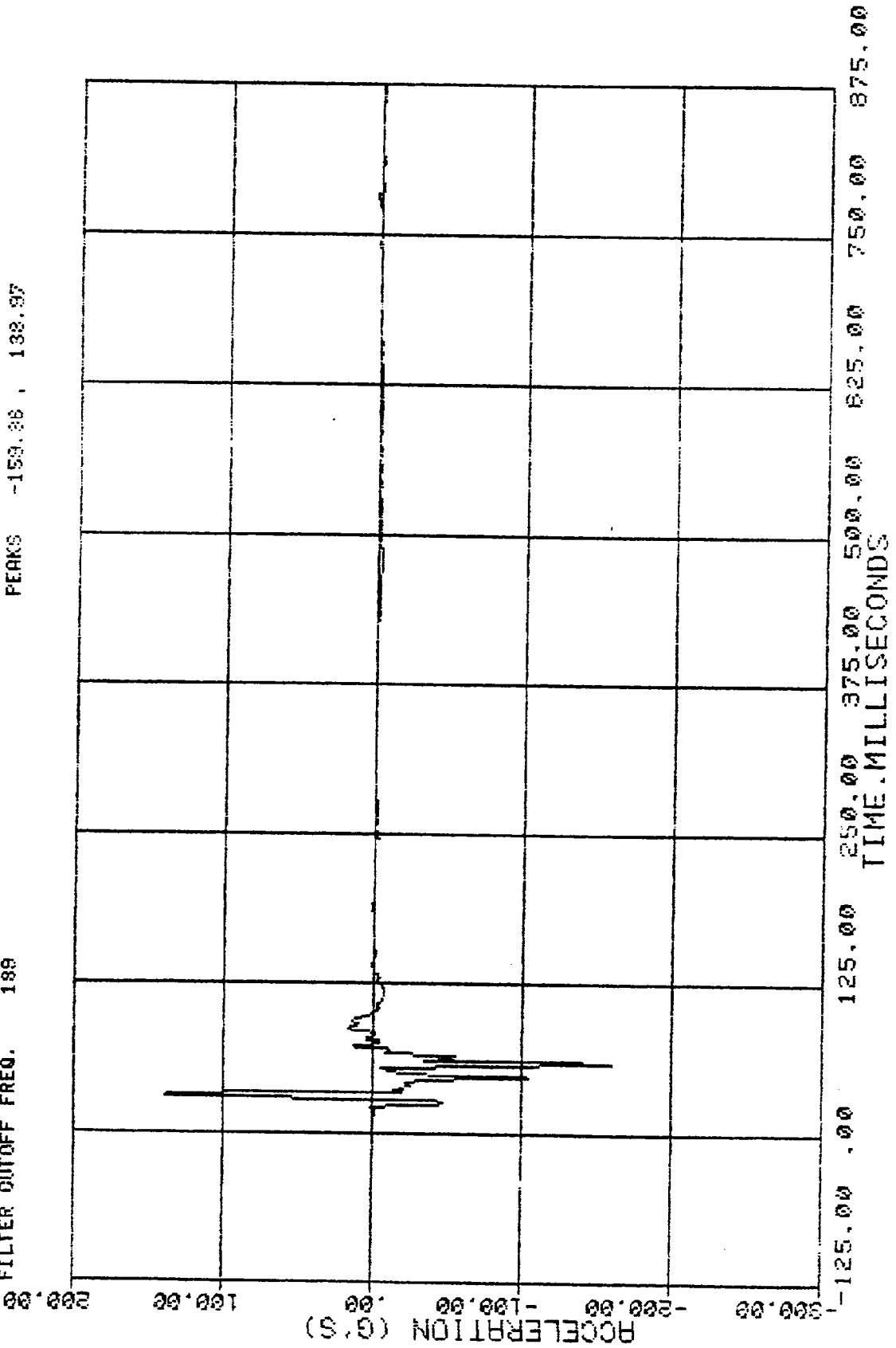


Figure 33. Driver's Left Lower Rib Acceleration, LLRY, 189 Hz

CHANNEL 5 DRIVER THORAX-LLRY0A

FILTER CUTOFF FREQ. 189

PEAKS -19.88 , 253.85

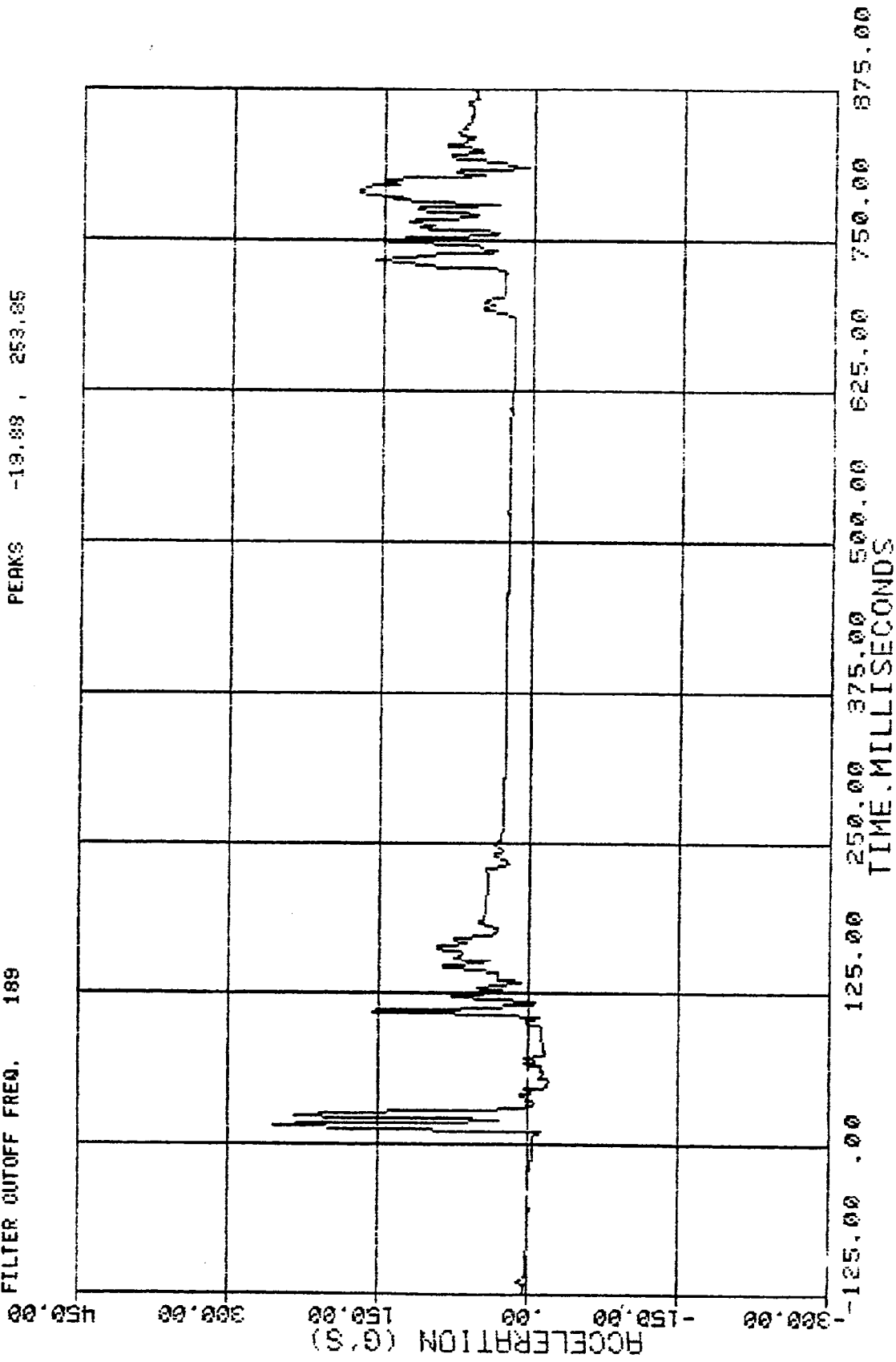


Figure 34. Driver's Left Lower Rib Acceleration, LLRYA, 189 Hz

DRIVER THORAX-LURY

CHANNEL 8

FILTER CUTOFF FREQ. 0

PEAKS -3.71 , 5.93

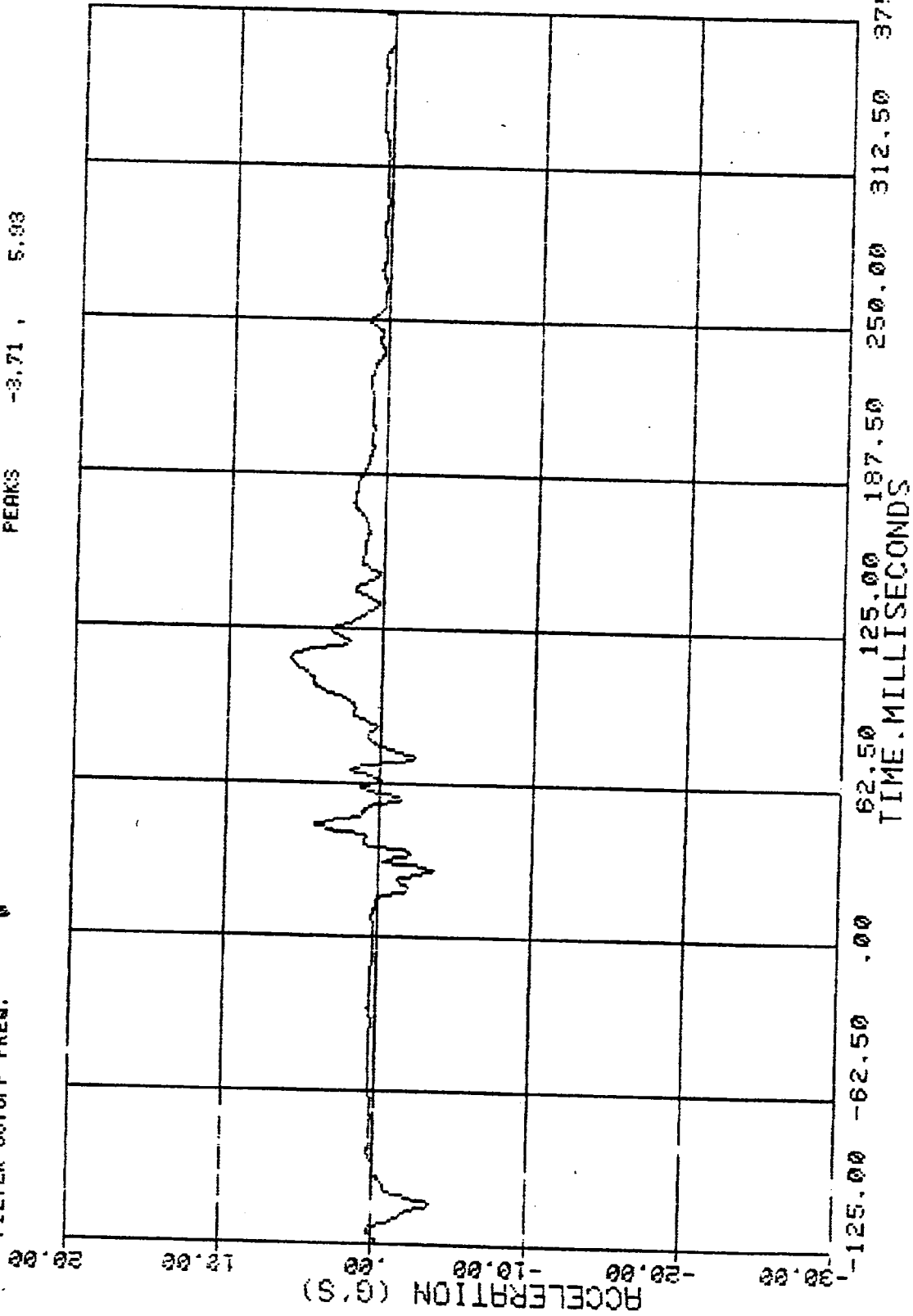


Figure 35. Driver's Left Upper Rib Acceleration, LURY, NHTSA
FIR Filter

CHANNEL 3 DRIVER THORAX-T01Y
FILTER CUTOFF FREQ. 0

PEAKS -6.78 5.78

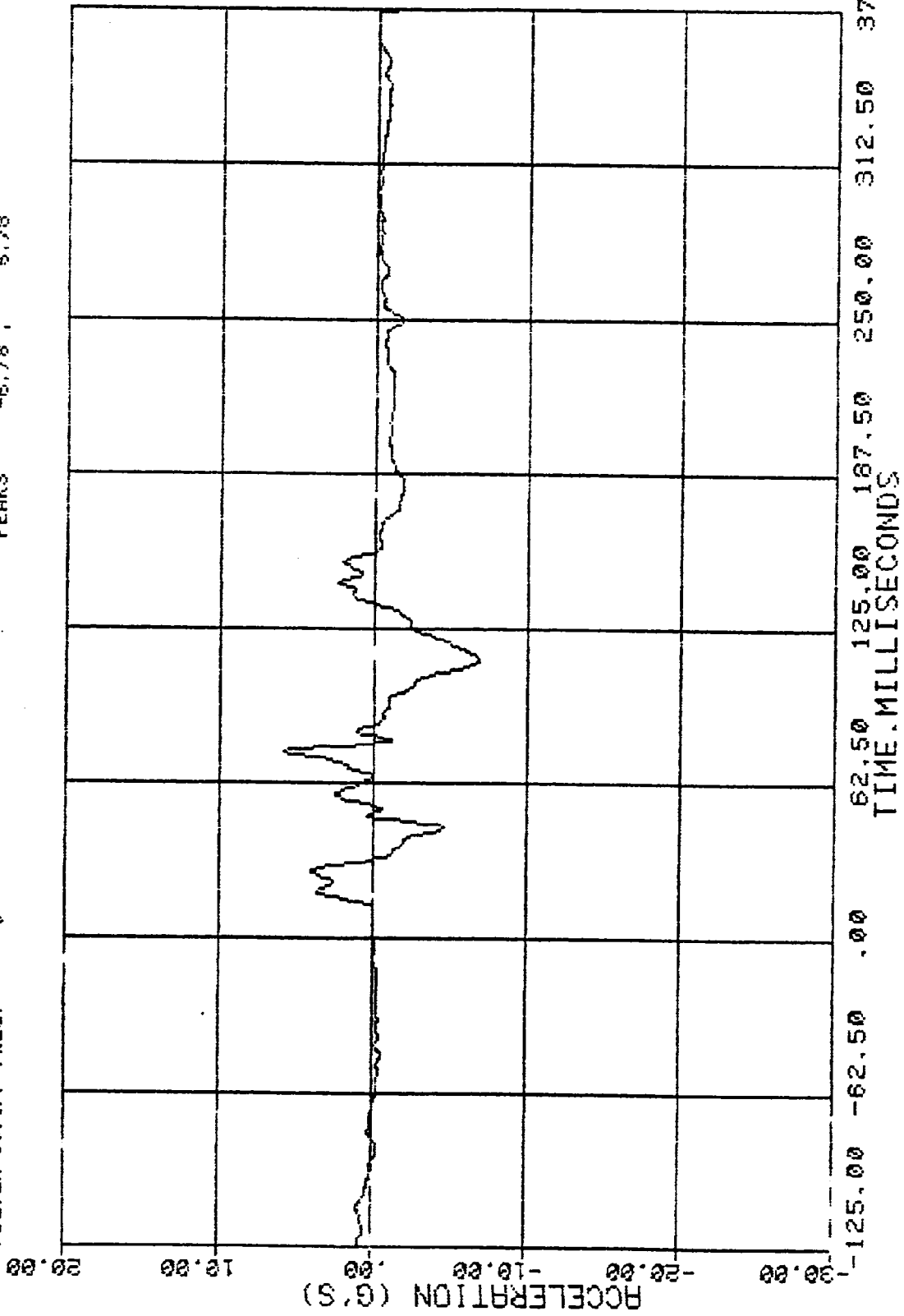


Figure 36. Driver's Upper Spine Acceleration, T01Y, NHTSA
FIR Filter

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 38.

STRUCTURAL ADEQUACY

The test pole readily activated in the predicated manner. The breakaway force was estimated to be 32 kips. There was, however, penetration of the passenger compartment due to the nature of the test. Some hazard was generated to other traffic because the vehicle turned right back toward traffic lanes.

OCCUPANT RISK

Occupant risk is rated mild. HIC, and max chest accelerations were within the limits. The thoracic injury also indicated a mild accident rating with the AIS being less than 3 and most likely being very low.

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. Although intrusion occurred at the driver's seat, the occupant dummy did not impact the intruding pole. Consequently the NCHRP 230 flail space data is not very meaningful to predict injury for this side impact test.

VEHICLE TRAJECTORY

Vehicle trajectory after the test was acceptable, but the possibility of hazard existed due to the vehicle's turn.

OVERALL RATING

This pole/vehicle combination with the discussed impact conditions would have to be rated acceptable.

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
	<p>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:</p> $\frac{\text{Occupant Impact Velocity-fps}}{\begin{matrix} \text{Longitudinal} \\ 40/F_1 \end{matrix}} \quad \frac{\text{Lateral}}{30/F_2}$ <p>and vehicle highest 10 ms average accelerations subsequent to instant of hypothetical passenger impact should be less than:</p> $\frac{\text{Occupant Ridedown Accelerations—g's}}{\begin{matrix} \text{Longitudinal} \\ 20/F_3 \end{matrix}} \quad \frac{\text{Lateral}}{20/F_4}$ <p>where F_1, F_2, F_3, and F_4 are appropriate acceptance factors (see Table 8, Chapter 4 for suggested values).</p>	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 38. NCHRP 230 Safety Evaluation Guidelines

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.
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, an R. Morgan, SAE Report No. 840885.