

DOT 867

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 COLT
AND A BREAKAWAY LUMINAIRE SUPPORT

TEST RESULTS REPORT

TEST NUMBER 1469-SI#6-85

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	5
3.0	APPURTENANCE DESCRIPTION	7
4.0	VEHICLE DESCRIPTION	8
5.0	TEST INSTRUMENTATION	10
6.0	TEST RESULTS	12
7.0	TEST ANALYSIS	16
	7.1 Impact Velocity Analysis	16
	7.2 Analysis of Vehicle Mounted Accelerometers	17
	7.3 Comparison of Predicted Results to Test Observables	30
	7.4 Head Injury Criteria Evaluation	35
	7.5 Occupant Severity Index Evaluation	35
	7.6 Thoracic Injury Evaluation	53
8.0	SAFETY ASSESSMENT OF TEST	61
9.0	REFERENCES	64

LIST OF FIGURES

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
1	Pre-Test Photos of Vehicle	9
2	Post Test Photos of Vehicle	13
3	NHTSA Vehicle Damage Measurements	15
4	Vehicle Acceleration, X-Axis, 100 Hz	18
5	Vehicle Acceleration, Y-Axis, 100 Hz	19
6	Vehicle Acceleration, Z-Axis, 100 Hz	20
7	Vehicle Acceleration, X-Axis, 300 Hz	21
8	Vehicle Acceleration, Y-Axis, 300 Hz	22
9	Vehicle Acceleration, Z-Axis, 300 Hz	23
10	Event Marker, Impact	24
11	Vehicle Roll Rate, 100 Hz	25
12	Vehicle Yaw Rate, 100 Hz	26
13	Vehicle Roll Rate, 10 Hz	27
14	Vehicle Yaw Rate, 10 Hz	28
15	Vehicle Driver's Door Acceleration, Upper Center, 300 Hz	31
16	Vehicle Driver's Door Acceleration, Middle Forward, 300 Hz	32
17	Vehicle Driver's Door Acceleration, Middle Rear, 300 Hz	33
18	Driver's Head Acceleration, X-Axis, 1650 Hz	34
19	Driver's Head Acceleration, Y-Axis 1650 Hz	36
20	Driver's Head Acceleration, Z-Axis, 1650 Hz	37
21	Driver's Head Acceleration, Resultant, 1650 Hz	38
22	Driver's Upper Spine Acceleration, T01X, 300 Hz	39

LIST OF FIGURES (Cont'd)

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
23	Driver's Upper Spine Acceleration, T01Y, 300 Hz	41
24	Driver's Upper Spine Acceleration, T01Z, 300 Hz	42
25	Driver's Upper Spine Acceleration, Resultant, 300 Hz	43
26	Driver's Lower Spine Acceleration, T12X, 300 Hz	44
27	Driver's Lower Spine Acceleration, T12YA, 300 Hz	45
28	Driver's Lower Spine Acceleration, T12Y, 300 Hz	46
29	Driver's Lower Spine Acceleration, T12Z, 300 Hz	47
30	Driver's Lower Spine Acceleration, Resultant, 300 Hz	48
31	Driver's Pelvis Acceleration, X-Axis, 300 Hz	49
32	Driver's Pelvis Acceleration, Y-Axis, 300 Hz	50
33	Driver's Pelvis Acceleration, Z-Axis, 300 Hz	51
34	Driver's Pelvis Acceleration, Resultant, 300 Hz	52
35	Driver's Left Upper Rib Acceleration, LURY, NHTSA FIR Filter	54
36	Driver's Left Upper Rib Acceleration, LURYA, NHTSA FIR Filter	55
37	Driver's Left Upper Rib Acceleration, LLRY, NHTSA FIR Filter	56
38	Driver's Left Upper Rib Acceleration, LLRYA, NHTSA FIR Filter	57
39	Driver's Upper Spine Acceleration, T01Y, NHTSA FIR filter	58
40	Driver's Lower Spine Acceleration, T12Y, NHTSA FIR filter	59
41	Thoracic Trauma Index Scale	60
43	NCHRP 230 Safety Evaluation Guidelines	62

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#6-85	3
2	Properties of Test Pole	7
3	Weight Distribution of Test Vehicle Prior to Testing	8
4	Description of Film Data Acquisition System for Full Scale Crash Test 1469-SI#6-85	10
5	Transducer Data for Test 1469-SI#6-85	11
6	Residual Vehicle Crush	15
7	Test Vehicle Impact Speed Evaluation Using High Speed Film Analysis	17
8	Change in Velocities and Ride Down Accelera- tion From Analysis of Class 180 Data Using NCHRP 230 Technique	30
9	Head Injury Criteria Evaluated for Full Scale Crash Test 1469-SI#6-85	40

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 Dodge Colt. 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 30.1 mph (13.5 m/s) was 597 lb-sec. The velocity change corresponding to the observed vehicle momentum change was 6.7 mph or 9.8 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 17.25 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 was 9.8 ft/sec. This lateral impact velocity is within the design limit of 20 ft/sec (6.10 m/s) specified for 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 sever 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 or 4 was 100%, while the probability of an AIS greater than 5 was at least 47%. 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 anthropomorphic dummy yielded a Head Injury Criteria (HIC) of 9305. This result exceeds the limit specified in FMVSS 208. It should be noted that HIC's obtained during side impacts may not measure the head injury correctly since the head form of the dummy was designed 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#6-85

1.	Contract Number	DTFH61-81-C-00036
2.	Date of Test	August 2, 1985
3.	Test Vehicle	Dodge Colt, 1979
4.	Delivered Vehicle Weight	1783 lbs
5.	Vehicle Weight, Test Inertial Planned Actual	1,800 ±50 lbs 1,807 lbs
6.	Vehicle Weight, Gross Static Actual (One Occupant)	1,962 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#6-85

22.	Impact Speed, Observed	30.1 mph
23.	Speed Reduction	
	Acceleration Data, TRC 191	6.7 mph
	Tire Friction Effect	<u>2.5 mph</u>
	Total	9.2 mph
24.	Exit Speed, Observed	21.9 mph
25.	Impact Point, Observed	Left Door, Driver Loca- tion, (17.3" behind cg)
26.	Traffic Accident Data, TAD	9-LP-5
27.	Vehicle Damage Index, VDI	09LPAN3
28.	Hypothetical Occupant Impact Velocity (1' flail)	
	Design Limit	20 ft/sec
	Observed	9.8 ft/sec
29.	Hypothetical Occupant Ride-down Acceleration (1' flail)	
	Design Limit	15.00 g
	Observed, NCHRP 230	1.40 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	9307
32.	Upper Spine Acceleration Data	
	Acceleration with Duration Greater than .003 sec	188
	CSI	2145
33.	Thoracic Injury	
	Fatal Injury	6.00
	Probability of:	
	AIS greater than 3	100%
	AIS greater than 4	100%
	AIS greater than 5	47% age 0, 50% age 7
34.	Momentum Change from Pole	597 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 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 Dodge Colt. 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 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 1300 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 Colt. The weight of the vehicle prior to incorporating the instrumentation for the test was 1785 pounds. The test inertial weight for the vehicle was 1807 pounds and the gross static weight when the occupant was included in the vehicle was 1962 pounds. The longitudinal center of gravity of the vehicle with the occupant was located approximately 36.8 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

	<u>Left</u> <u>(lbs)</u>	<u>Right</u> <u>(lbs)</u>	<u>Subtotal</u> <u>(lbs)</u>
Front	599	567	1,166
Rear	<u>406</u>	<u>390</u>	<u>796</u>
Subtotals	1,005	957	1,962

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#4-85

<u>Camera</u>	<u>Model</u>	<u>Speed</u>		<u>Lens</u>
		<u>Position</u>	<u>Setting</u>	
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	Documen- tation	24 pps	Zoom

Table 5
 Transducer Data for Test 1469-SI#6-85

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 30.1 mph (13.45 m/s) at a point on the left door in line with the occupant 17.3 in (.44 m) behind the longitudinal location of the center of gravity of the vehicle measured with the dummy in the vehicle. The vehicle had a 6° 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 17.3 inches (.44 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 .018 seconds after impact. The force levels at the time of initiation of the breakaway fracture mechanism of the luminaire support were about 25,000 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 13.6 f/s (4.15 m/s) with a rotation rate of 1.36 rad/sec. The luminaire support rotated up and over the test vehicle with the top of the pole hitting the ground about 1.25 seconds 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 film analysis. The vehicle then settled back on all 4 tires and continued forward away from the impact area after yawing a total of about 90°. The final resting position of the vehicle was about 75 feet downstream from the impact point. 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 (Con't). Post - Test Photographs of Vehicle

Table 6
Residual Vehicle Crush

C1 = 0.0	L = 70.00
C2 = 6.0"	D = -17.25"
C3 = 15.0"	
C4 = 5.0"	
C5 = 1.5"	
C6 = 0.0	
Max = 17.3"	

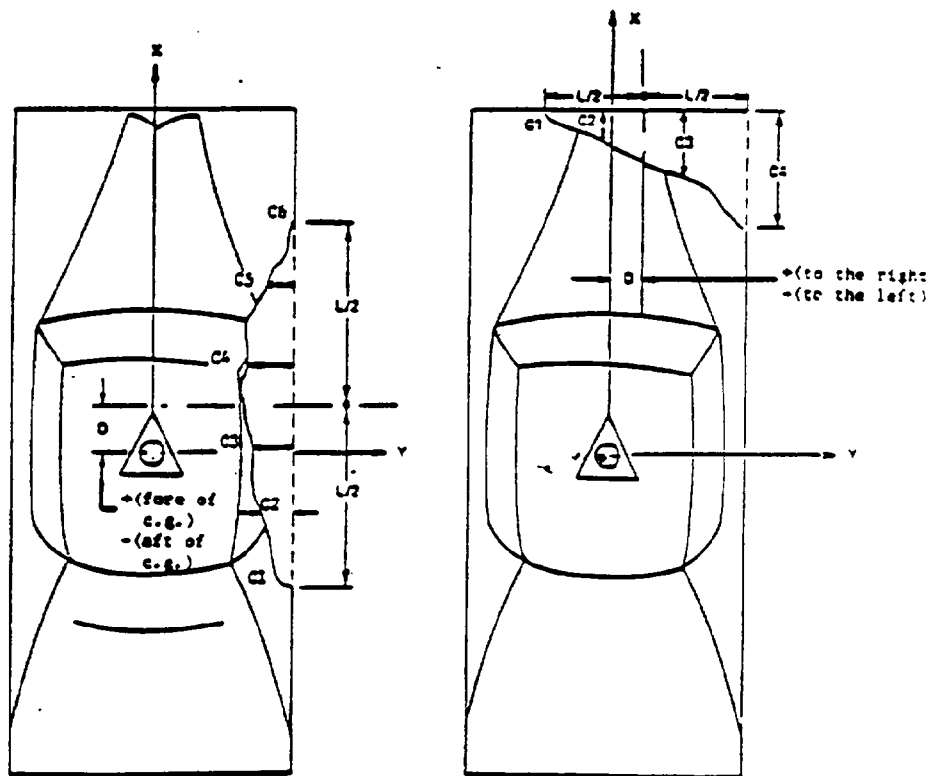


Figure 3. NHTSA Vehicle Damage Measurements

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 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	44.1	30.1
2	Right Side	<u>44.1</u>	<u>30.1</u>
	Average	44.1	30.1

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 did not work thus no speed trap data is available.

Based upon the results of this analysis, the speed of the vehicle upon impacting the support was 30.1 mph (13.5 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 9.8 ft/sec and 597 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

ENSO, INC. CONTRACT NUMBER DTFH61-81-0-00036 TEST NUM#1469-SI*6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 17 VEHICLE O.G. ACCELERATION, X-AXIS
 FILTER CUTOFF FREQ. 100 PEAKS -15.22 , 13.66

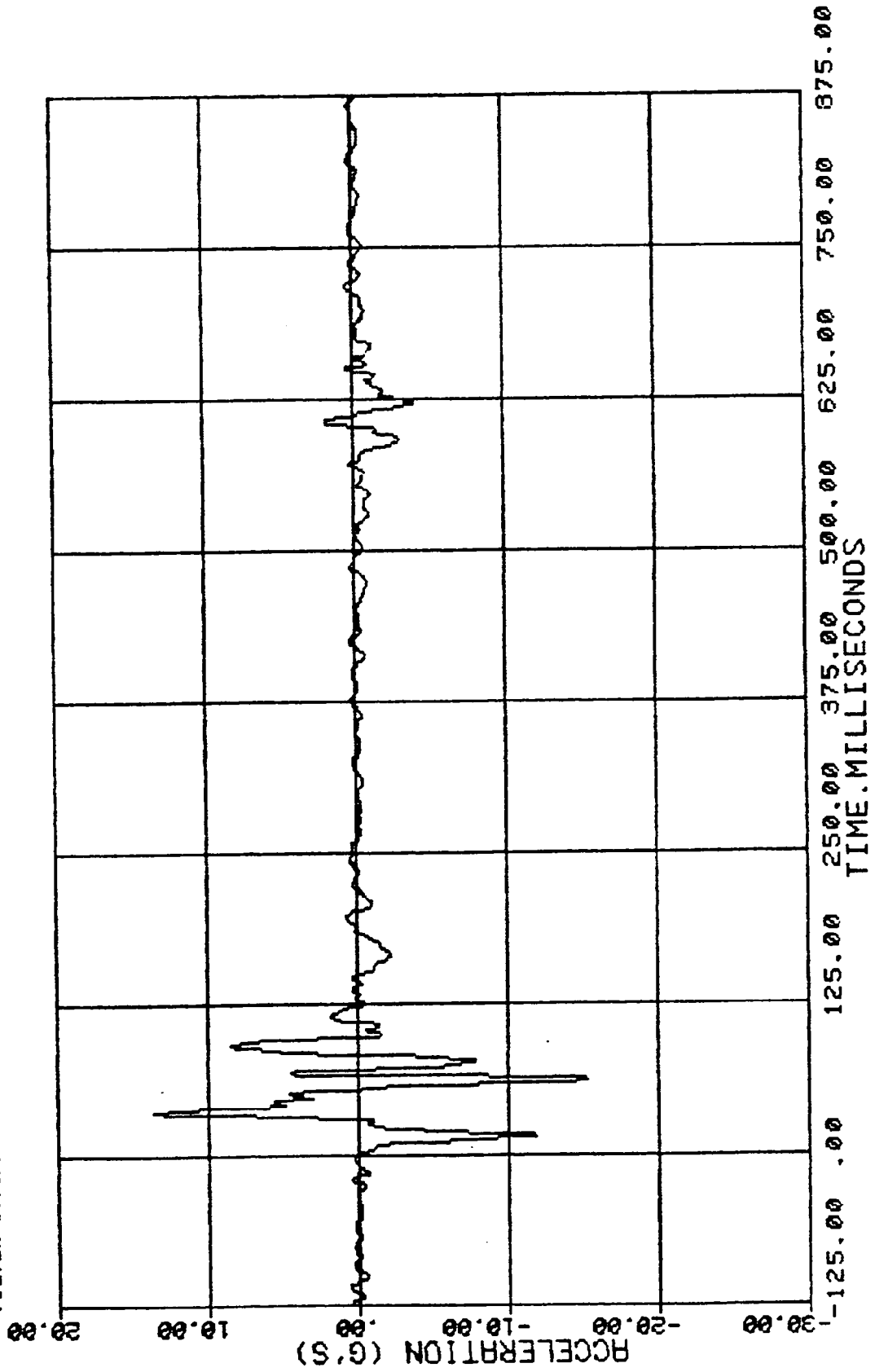


Figure 4. Vehicle Acceleration, X-Axis, 100 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-81-O-00036 TEST NUM#1469-SI#6
 30 MPH BROADSIDE IMPACT OF 79 DODGE DOLT INTO LUMINAIRE SUPPORT
 CHANNEL 18 VEHICLE O.G. ACCELERATION, Y-AXIS
 FILTER CUTOFF FREQ. 100 PEAKS -23.58 , 18.80

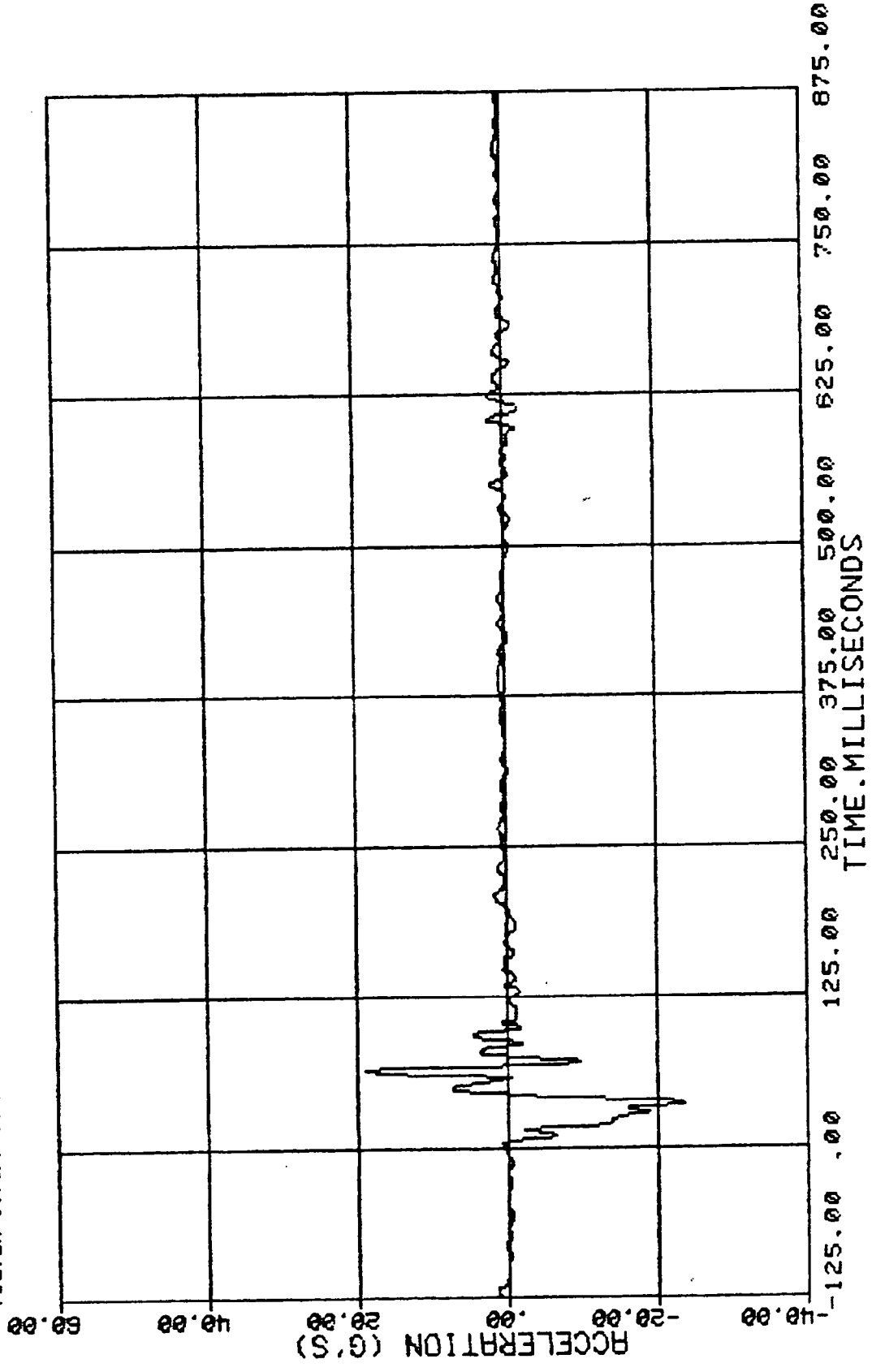


Figure 5. Vehicle Acceleration, Y-Axis, 100 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-81-0-00036 TEST NUM 1469-SI 6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 13 VEHICLE O.G. ACCELERATION, Z-AXIS
 FILTER CUTOFF FREQ. 100 PEAKS -24.91 18.41

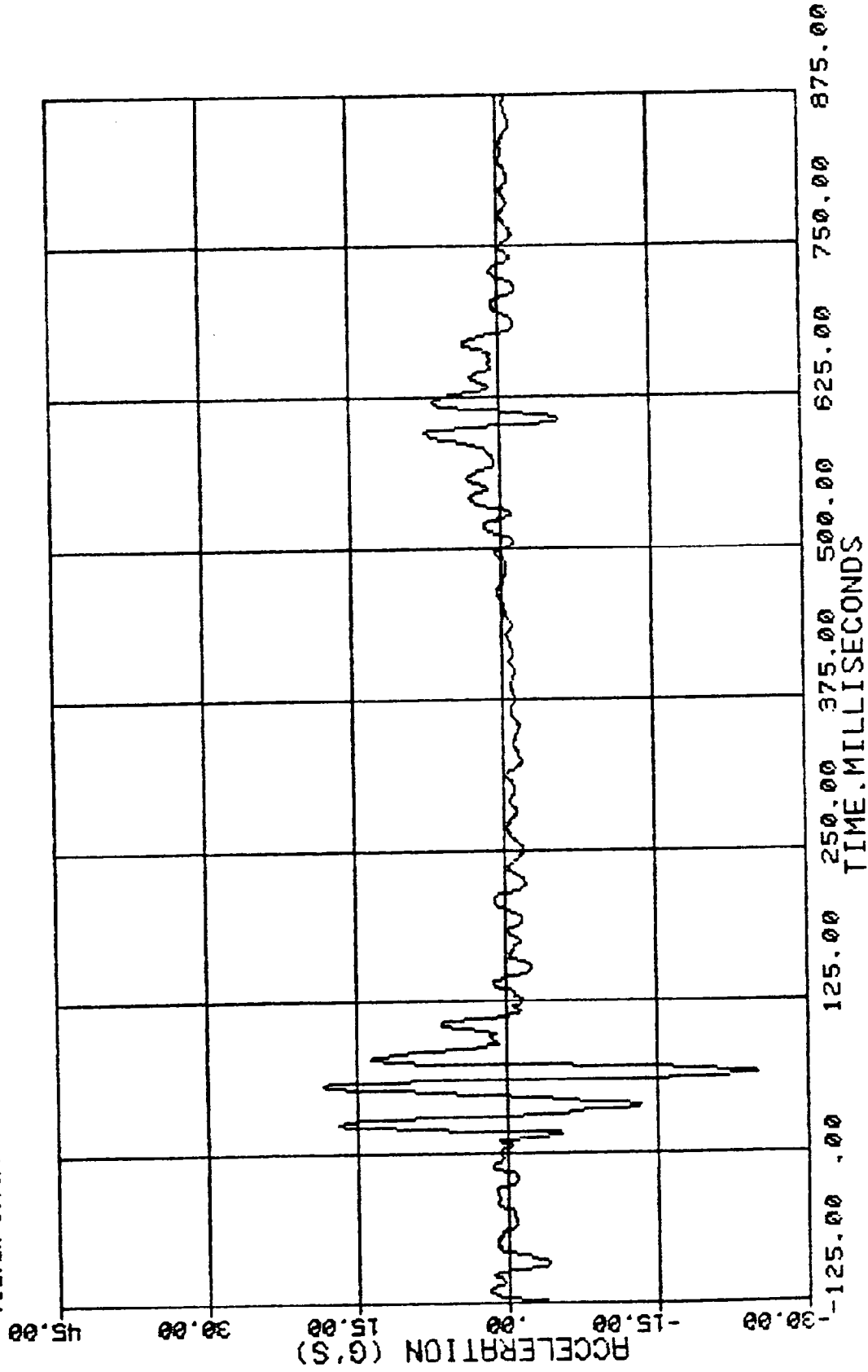


Figure 6. Vehicle Acceleration, Z-Axis, 100 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-81-O-00036 TEST NUM#1469-SI*6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 17 VEHICLE C.O. ACCELERATION, X-AXIS
 FILTER CUTOFF FREQ. 300 PEAKS -26.30 , 18.80

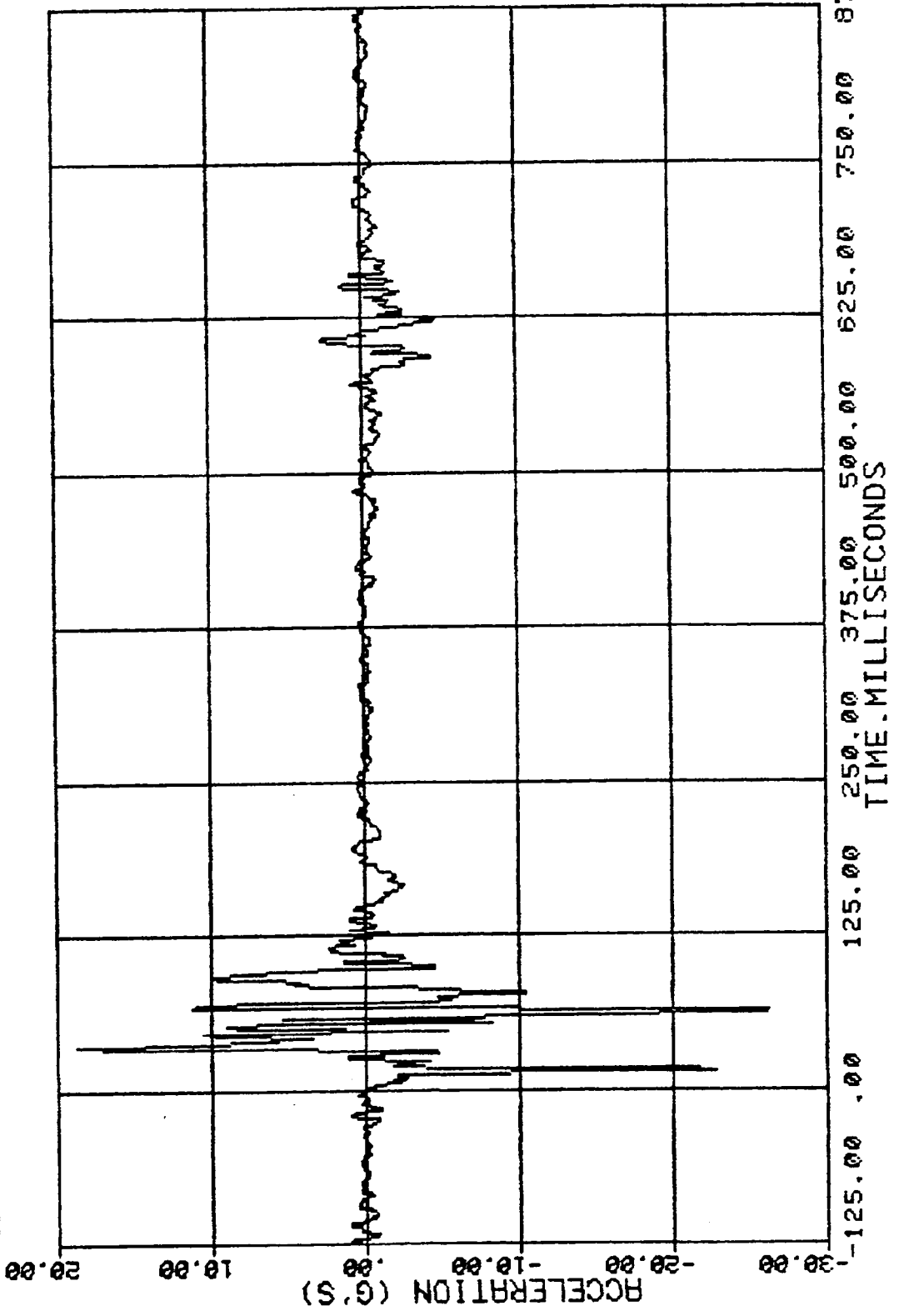


Figure 7. Vehicle Acceleration, X-Axis, 300 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-81-D-00036 TEST NUM#1469-SI#6
 30 MPH BROADSIDE IMPACT OF 79 P000E COLT INTO LUMINAIRE SUPPORT
 CHANNEL 18 VEHICLE O.O. ACCELERATION, Y-AXIS
 FILTER CUTOFF FREQ. 300 PEAKS -29.90 , 29.69

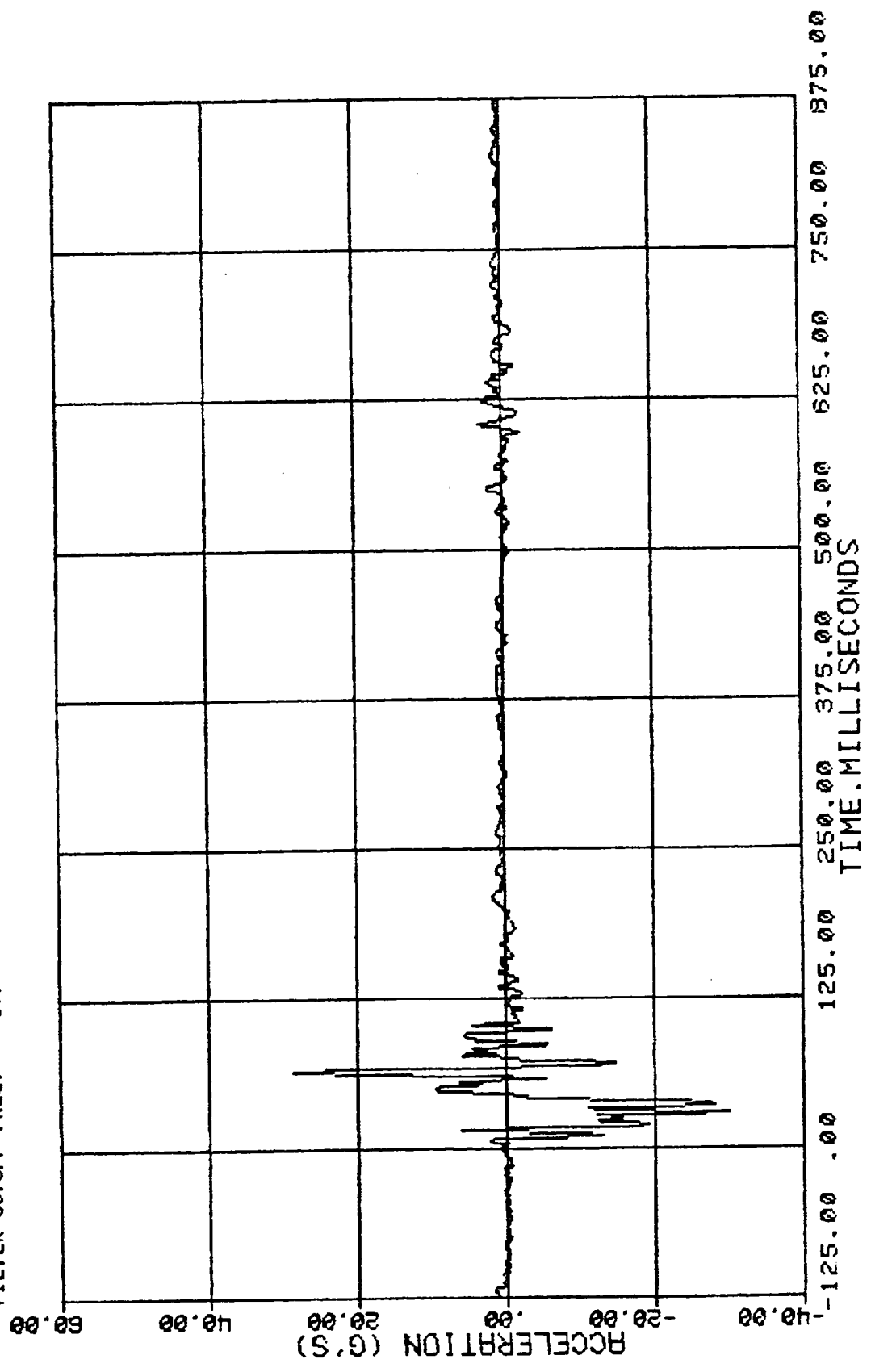


Figure 8. Vehicle Acceleration, Y-Axis, 300 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-81-C-00036 TEST NUM#1469-SI*6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 19 VEHICLE O.G. ACCELERATION, Z-AXIS
 FILTER CUTOFF FREQ. 300 PEAKS -23.95 24.50

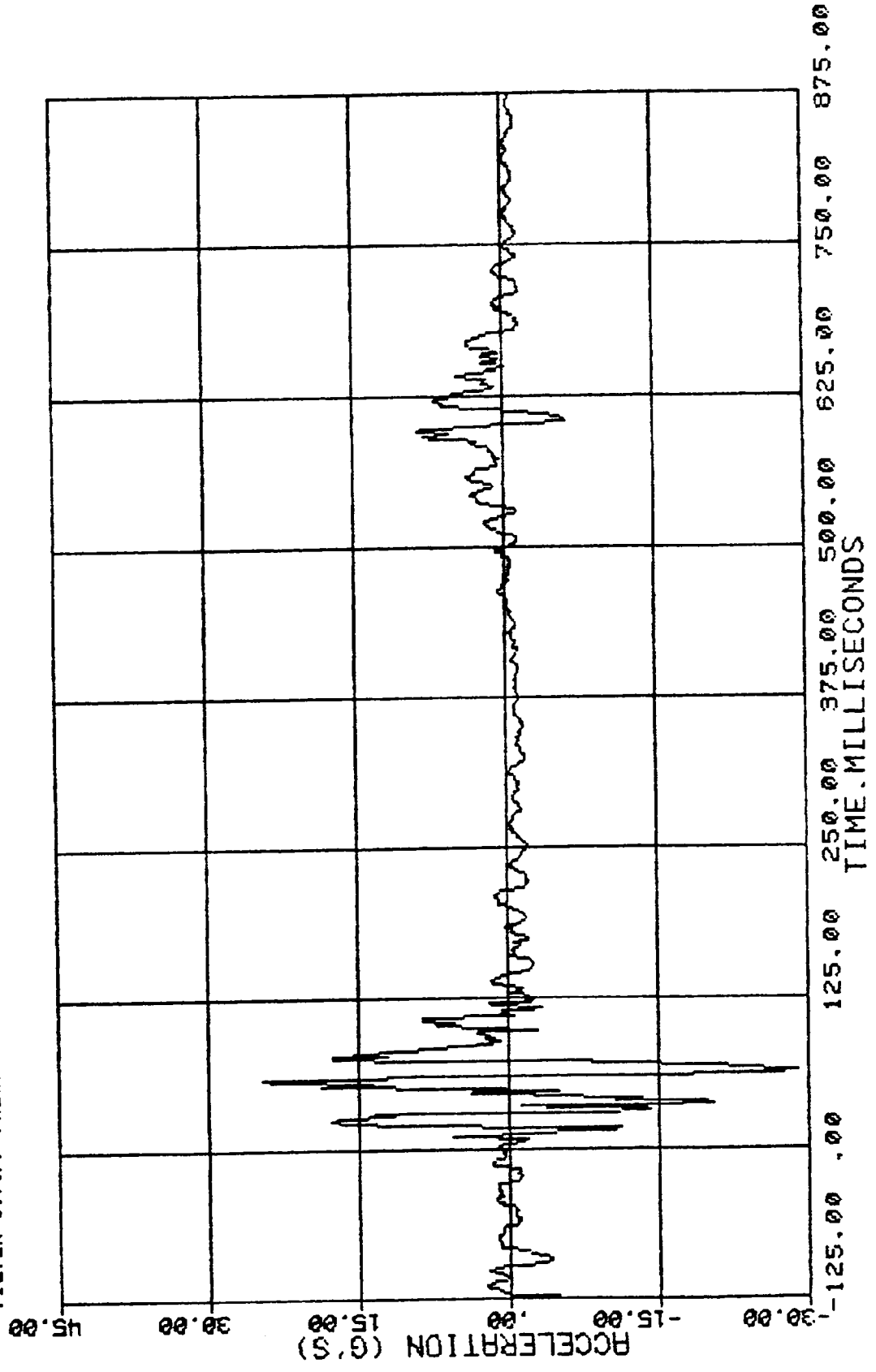


Figure 9. Vehicle Acceleration, Z-Axis, 300 Hz

ENSO0.I.NO. CONTRACT NUMBER DTFH61-81-O-00036 TEST NUM#1469-SI#6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 20 IMPACT
 FILTER CUTOFF FREQ. 1650 PEAKS -0.70 6.95

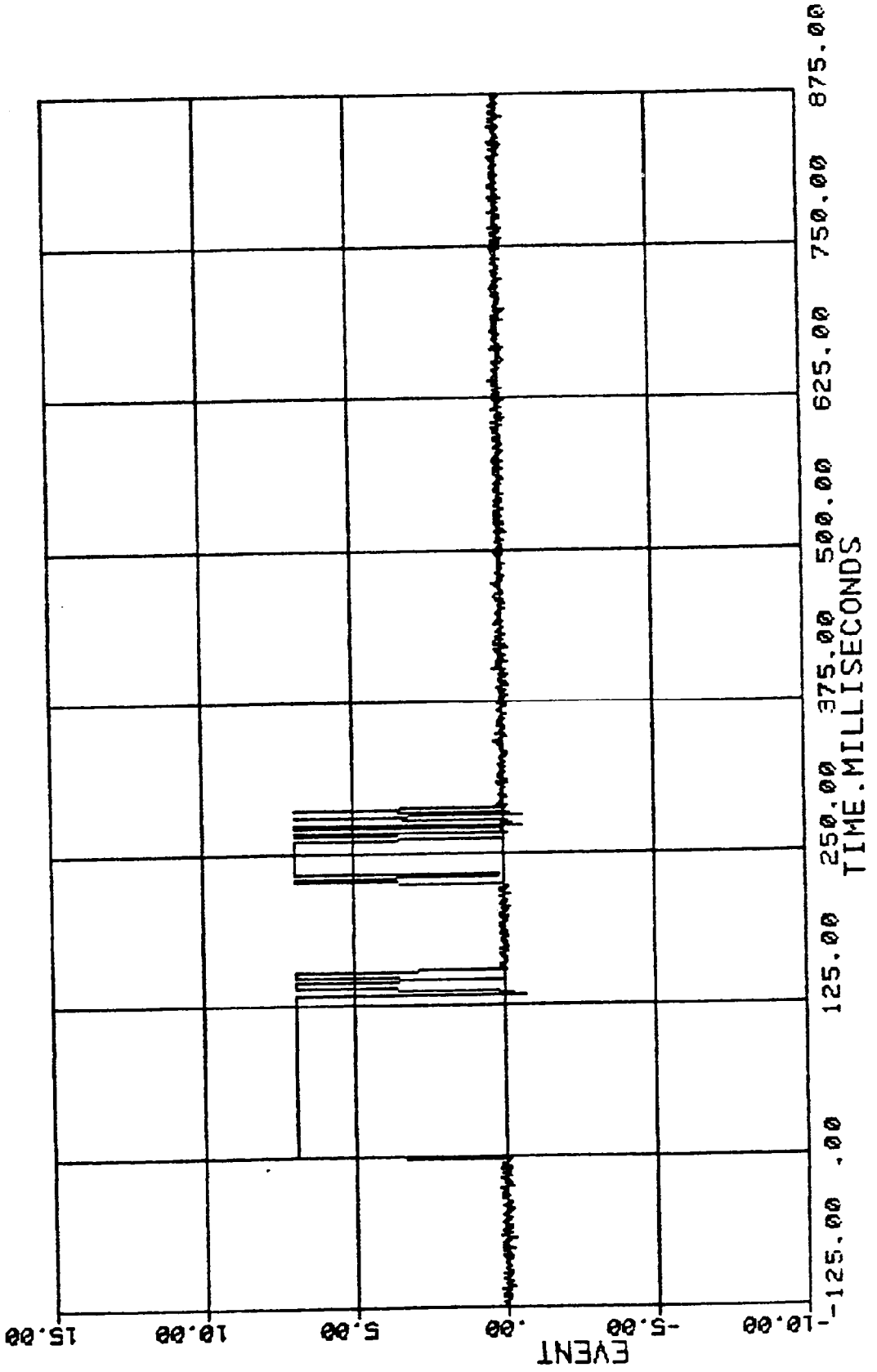


Figure 10. Event Marker, Impact

ENS00.ING. CONTRACT NUMBER DTFH61-81-C-00036 TEST NUM*1469-SI*6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 21 VEHICLE ROLL RATE PEAKS -464.39 , 485.17
 FILTER CUTOFF FREQ. 100

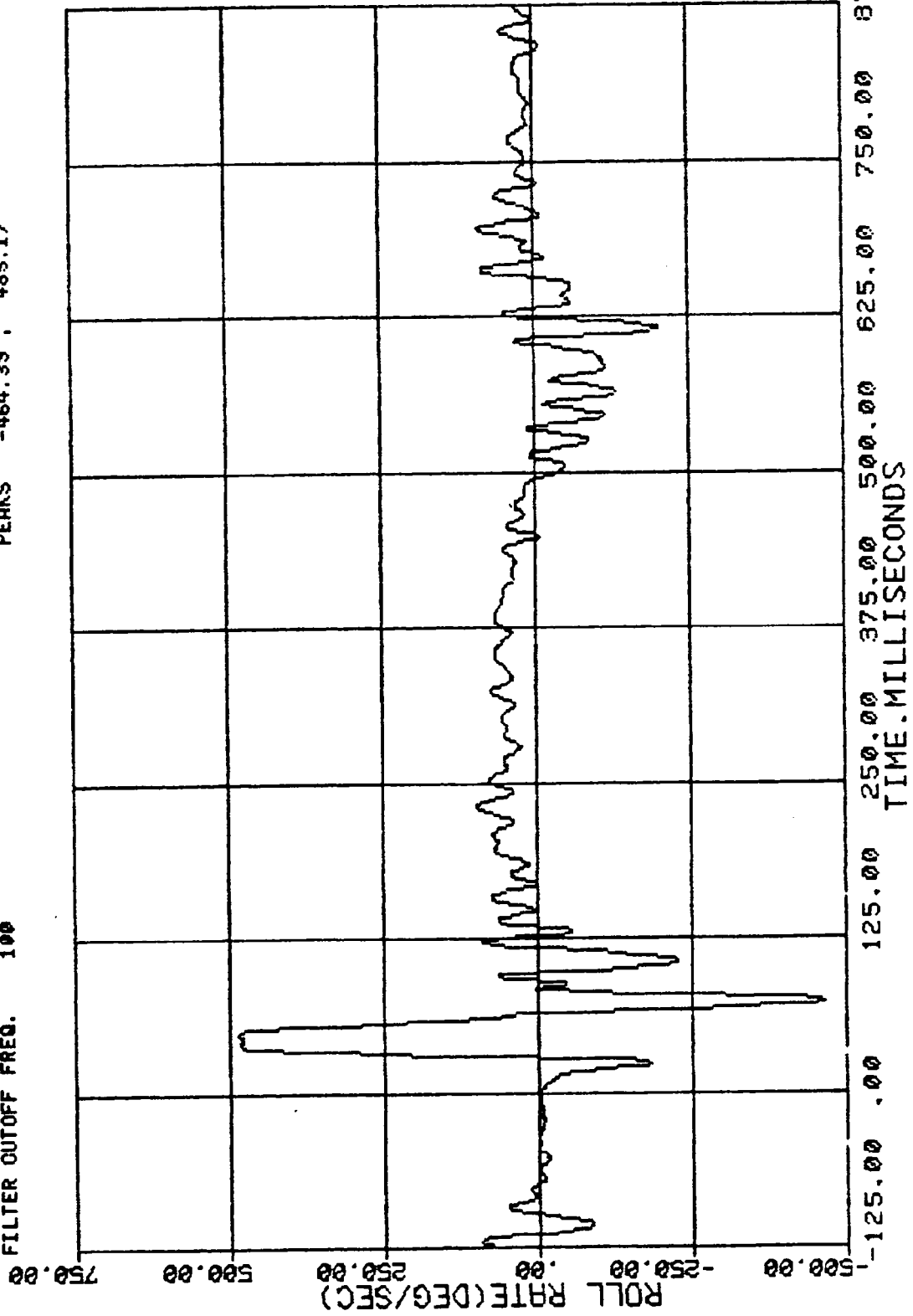


Figure 11. Vehicle Roll Rate, 100 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-81-O-00036 TEST NUM#1469-SI#6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 22 VEHICLE YAW RATE
 FILTER CUTOFF FREQ. 100 PEAKS -66.85 , 259.18

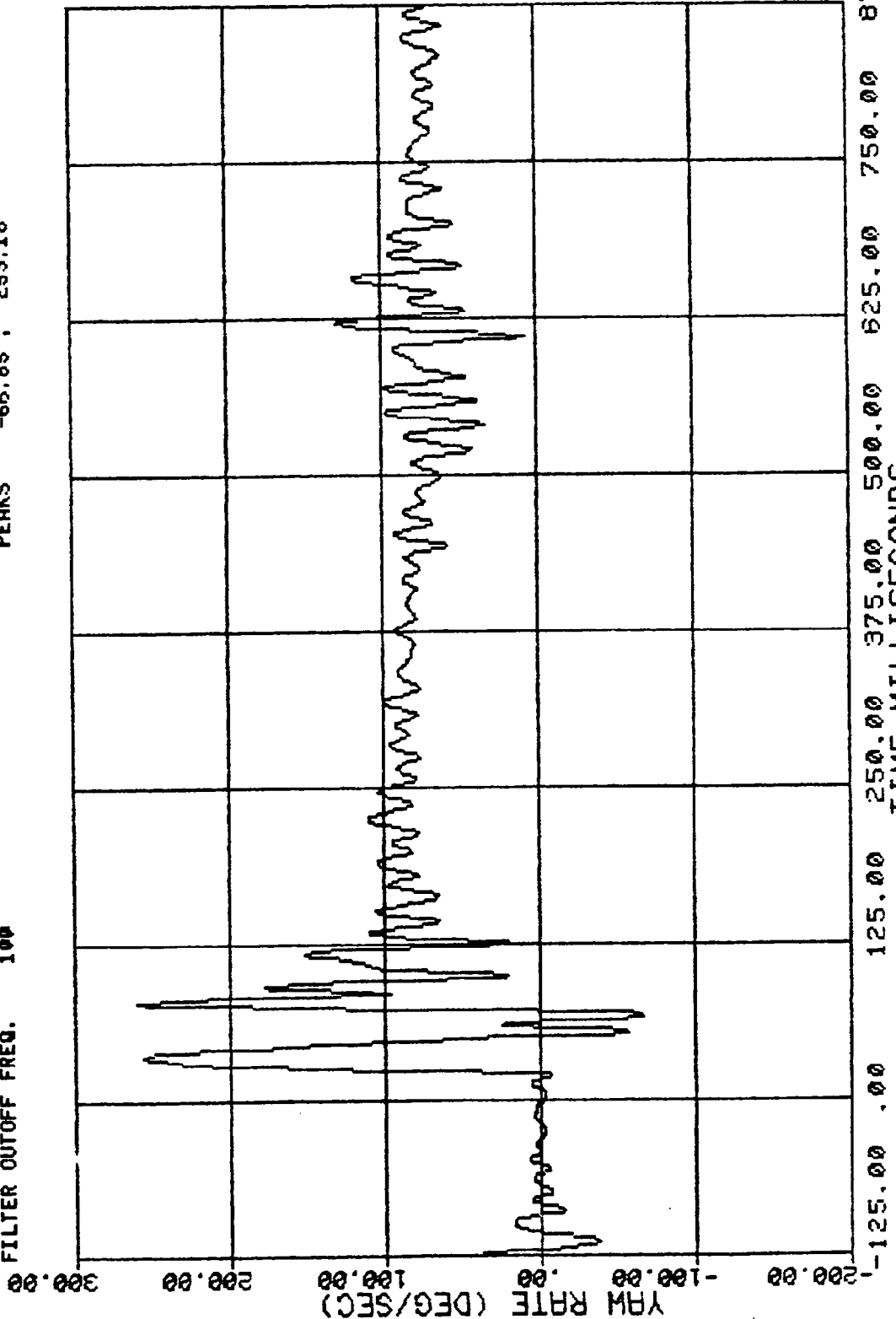


Figure 12. Vehicle Yaw Rate, 100 Hz

ENS00,INO. CONTRACT NUMBER DTFH61-81-D-00036 TEST NIJM1469-SI*6
 30 MPH BROADSIDE IMPACT OF 79 D000E COLT INTO LUMINAIRE SUPPORT
 CHANNEL 21 VEHICLE ROLL RATE
 FILTER CUTOFF FREQ. 10 PEAKS -91.78 , 187.08

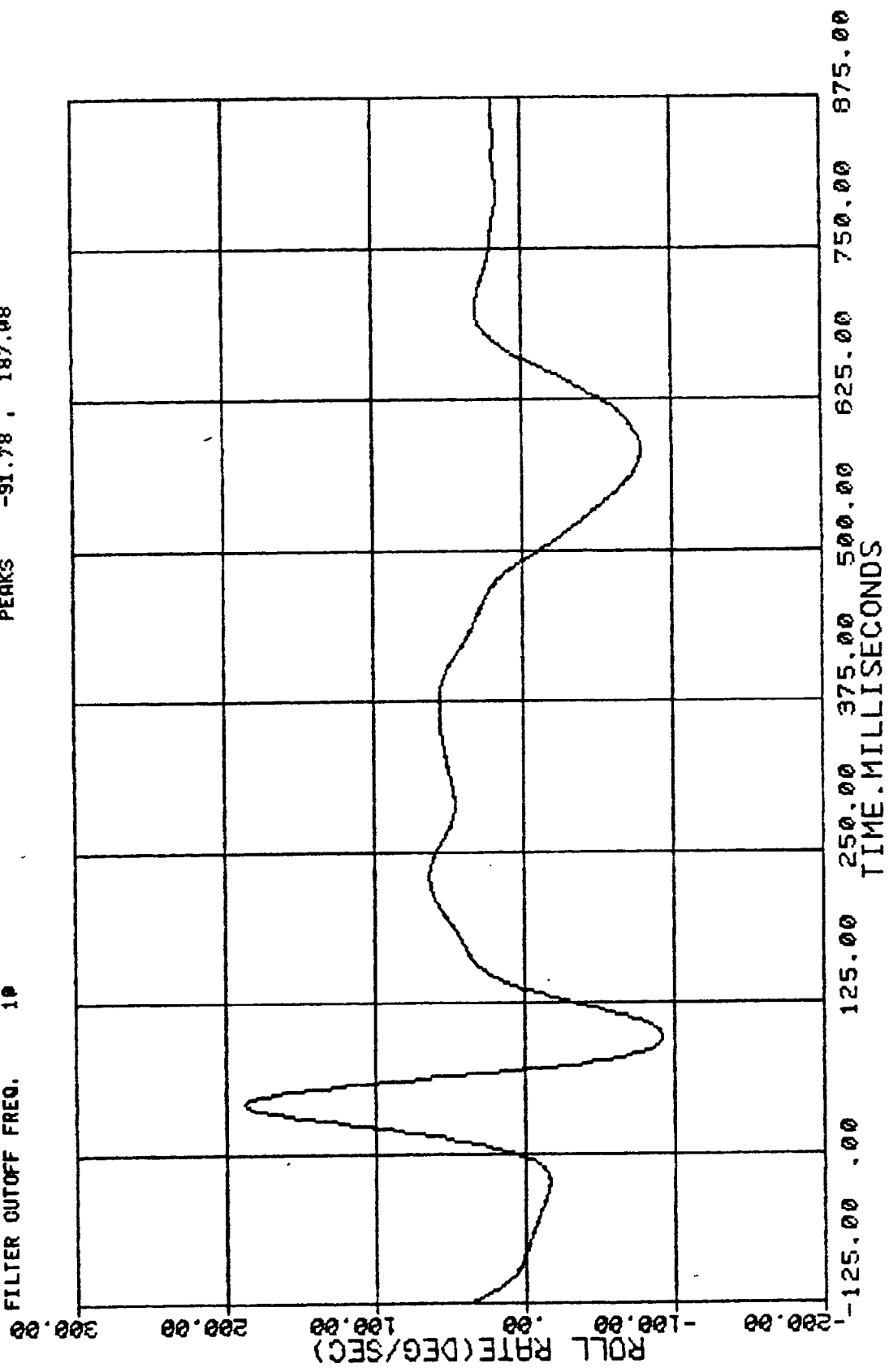


Figure 13. Vehicle Roll Rate, 10 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-81-0-00036 TEST NUM#1469-SI#6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 22 VEHICLE YAW RATE
 FILTER CUTOFF FREQ. 10 PEAKS -3.59 , 99.16

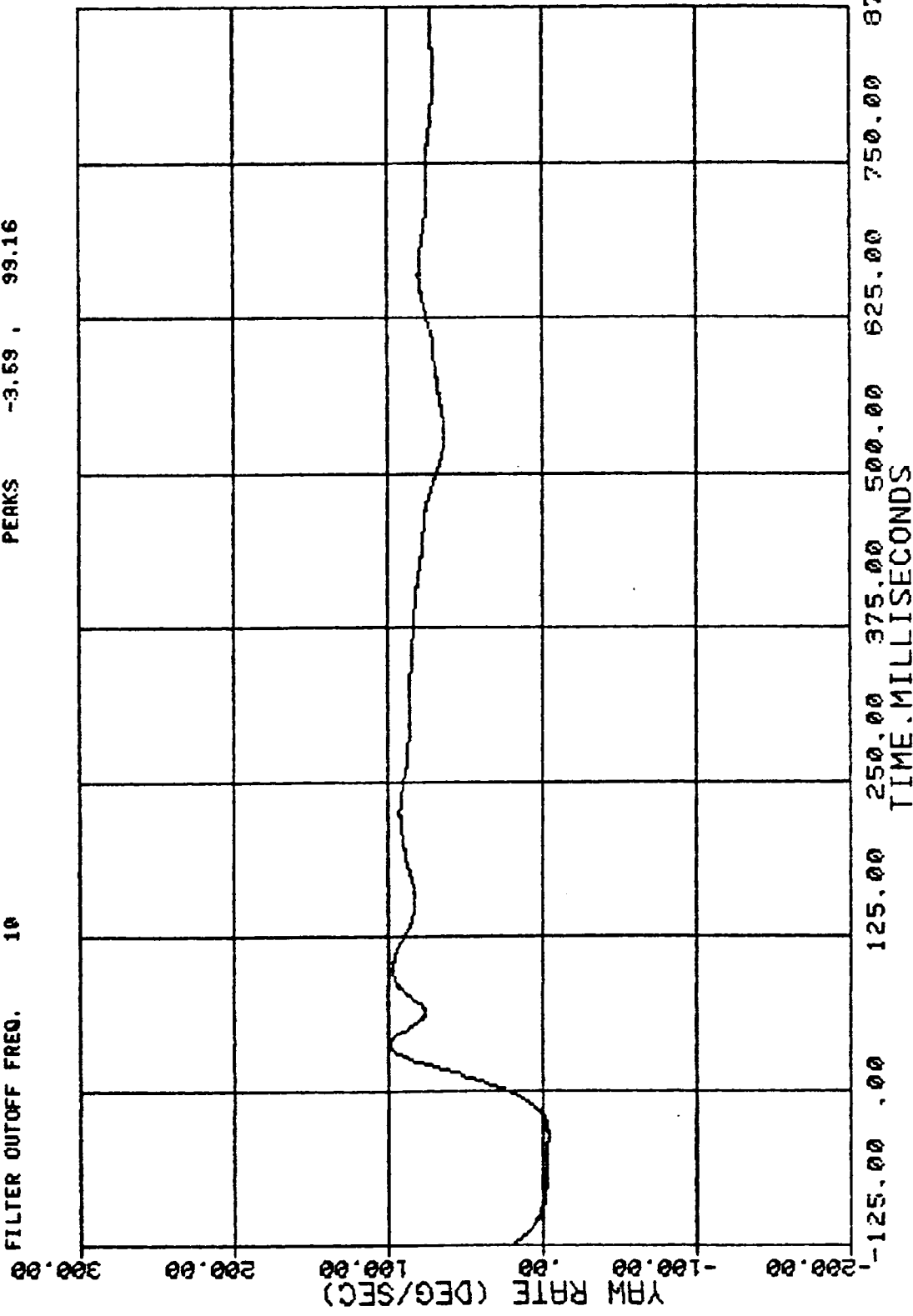


Figure 14. Vehicle Yaw Rate, 10 Hz

sliding is 2.5 ft/sec. Thus the overall momentum change of the vehicle due to the pole and tire sliding was 822 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 would have impacted the interior of the vehicle in the lateral direction at an approximate impact velocity of 9.8 ft/sec (3.0 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 less than 1.4 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 anthropomorphic 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 anthropomorphic dummy.

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	- 9.8	1.4
6	- 8.9	- 5.0
3	-13.8	-10.4

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 and this is not shown. The remaining three are shown in figures 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.,

$\dot{\theta}$ = 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.

ENSCO, INC. CONTRACT NUMBER DTFH61-81-O-00036 TEST NUM#1469-SI#6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 13 DRIVER LEFT DOOR ACCELERATION, UPPER CENTER
 FILTER CUTOFF FREQ. 300 PEAKS -158.83 , 150.16

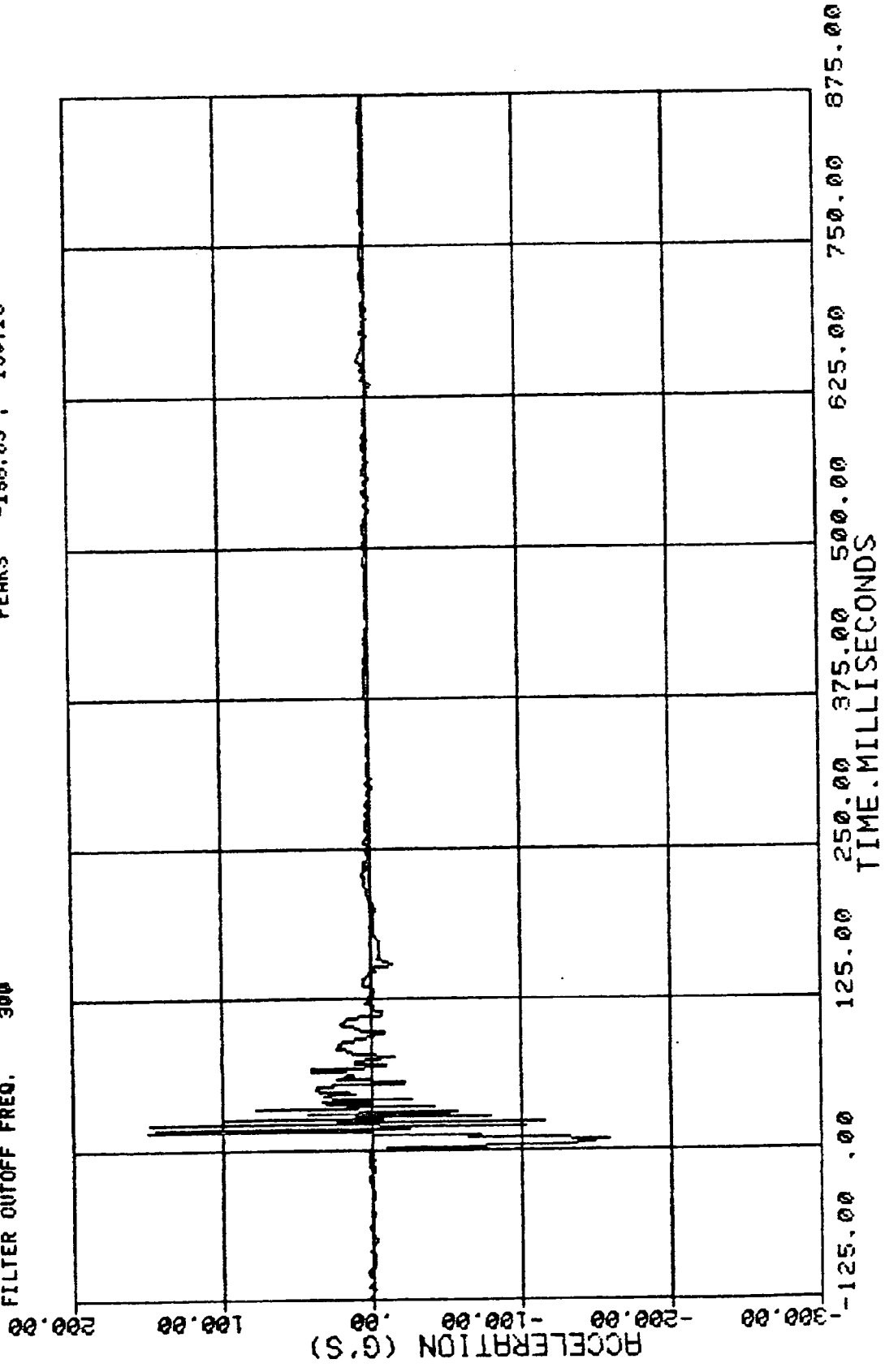


Figure 15. Vehicle Driver's Door Acceleration, Upper Center, 300 Hz

ENSOO, INC. CONTRACT NUMBER DTFH51-81-0-00036 TEST NUM*1469-SI*6
 30 MPH BRODSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 14 DRIVER LEFT DOOR ACCELERATION, MIDDLE FORWARD
 FILTER CUTOFF FREQ. 300 PEAKS -193.31 , 113.92

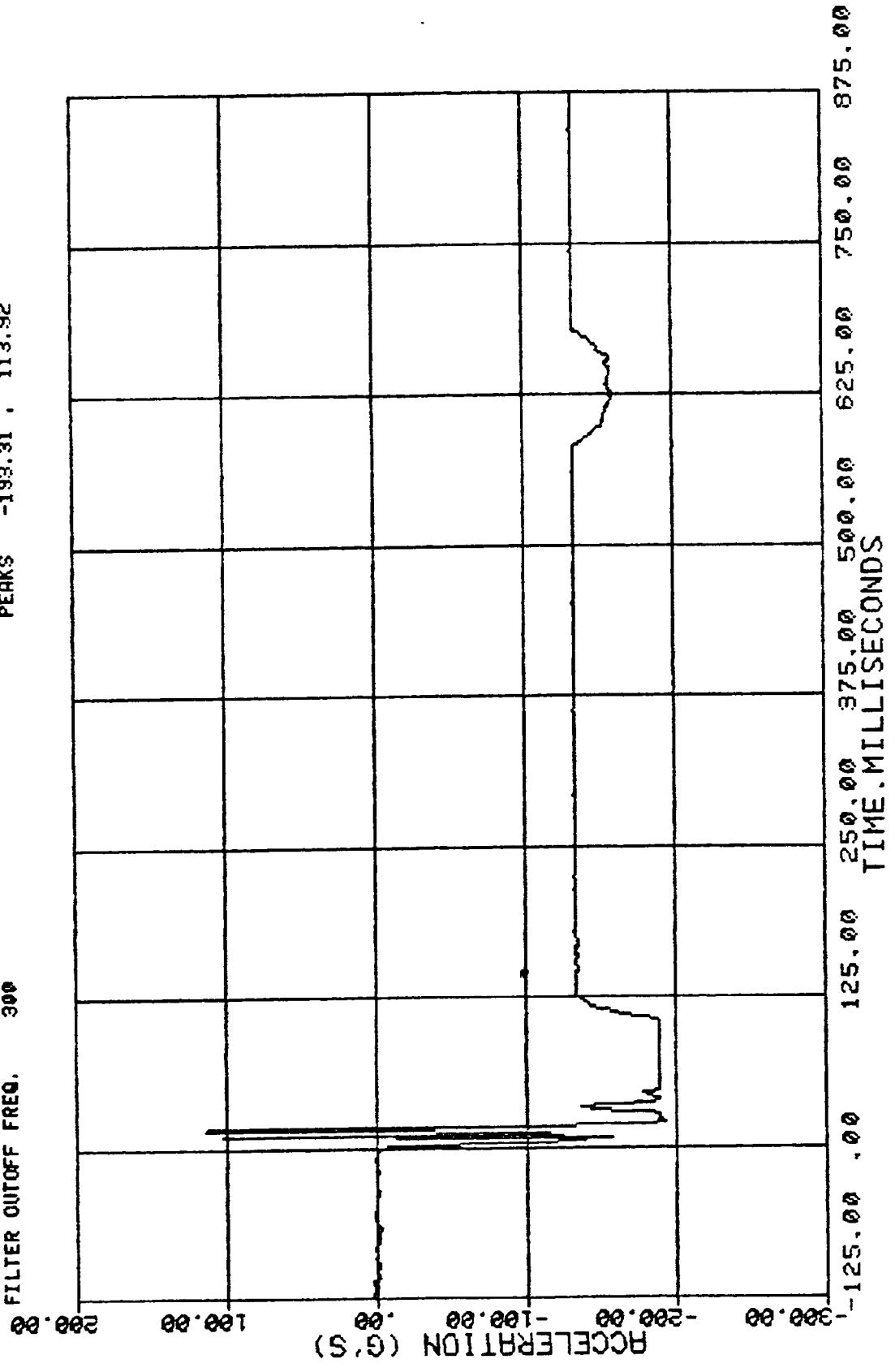


Figure 16. Vehicle Driver's Door Acceleration, Middle Forward, 300 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-81-O-00036 TEST NUM#1469-SI#6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 15 DRIVER LEFT DOOR ACCELERATION, MIDDLE REARWARD
 FILTER CUTOFF FREQ. 300 PEAKS -114.02 , 101.03

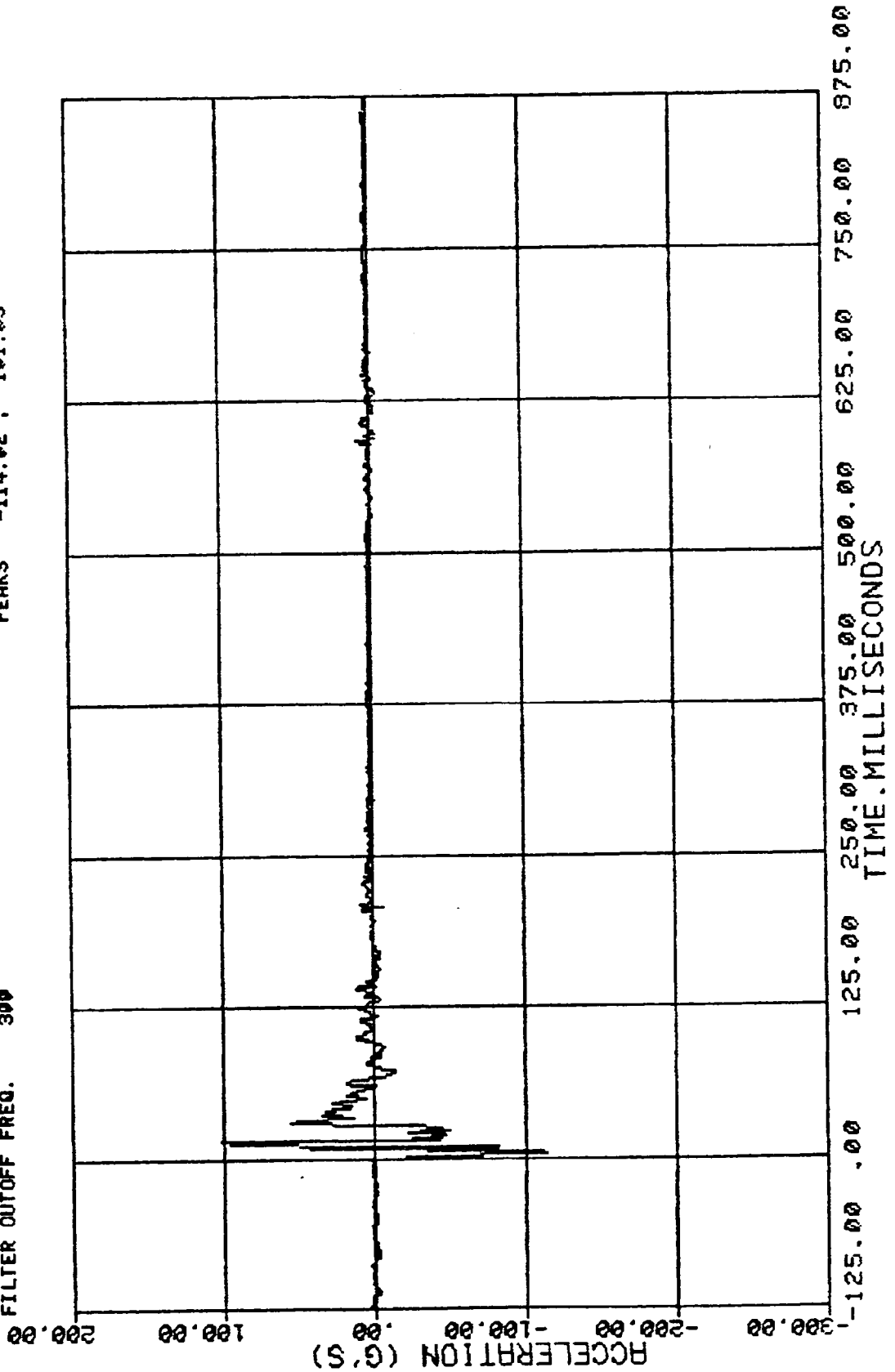


Figure 17. Vehicle Driver's Door Acceleration, Middle Rear, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-81-O-00036 TEST NUM#1469-SI#6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 16 DRIVER LEFT DOOR ACCELERATION, LOWER CENTER
 FILTER CUTOFF FREQ. 300 PEAKS -153.91 , 200.72

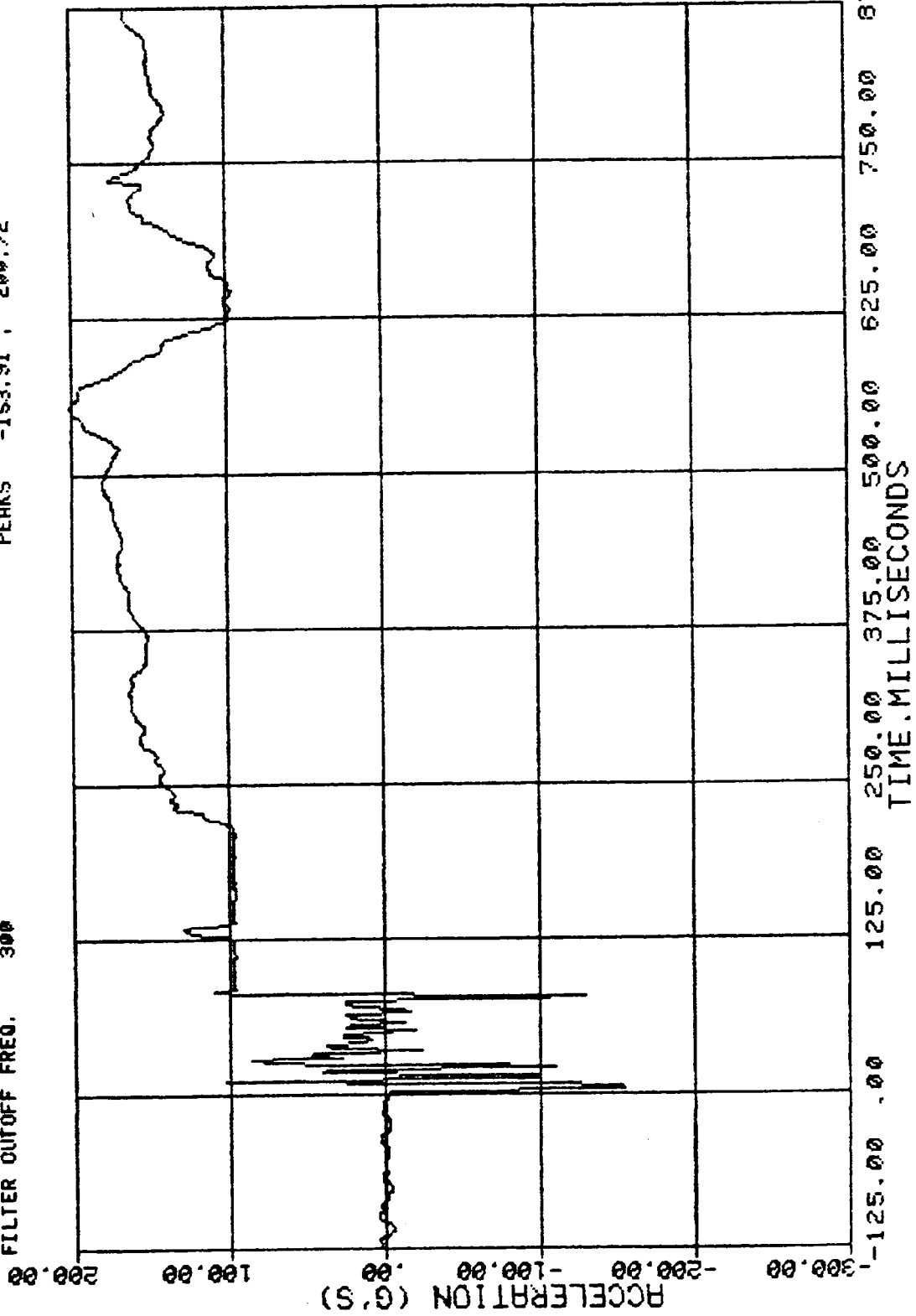


Figure 18. Vehicle Driver's Door Acceleration, Lower Center, 300 Hz

From the film data $\dot{x}_{cg} = 13.6$ f/s (4.15 m/s) and $\dot{\theta} = 1.36$ rad/sec. Using these two numbers the momentum change occurring during Phase 3 is given by

$$I_3 = M_p \dot{x}_{cg}$$
$$= 123 \text{ lb-sec (550 N-s)}$$

or

$$I_3 = \theta \frac{I_p}{D_I}$$
$$= 109 \text{ lb-sec (484 N-s)}.$$

The average momentum change associated with the third phase of the vehicle momentum change is 116 lb-sec (517 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 10 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

ENS00, INC. CONTRACT NUMBER DTFH61-81-D-00036 TEST NUM 1469-SI#6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 25 DRIVER HEAD ACCELERATION, X-AXIS
 FILTER OUTOFF FREQ. 1650 PEAKS -65.82 , 123.61

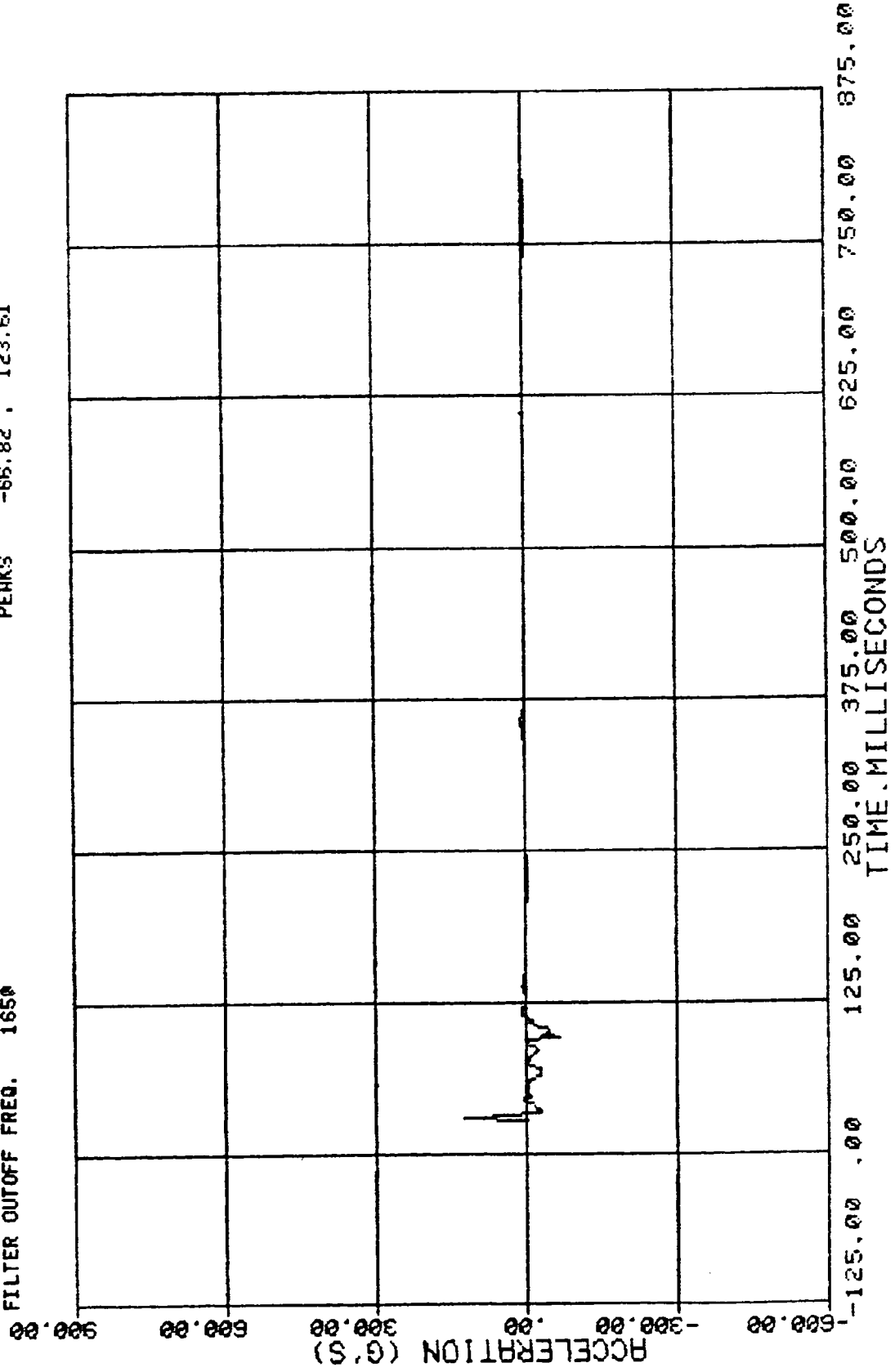


Figure 19. Driver's Head Acceleration, X-Axis, 1650 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-81-C-00036 TEST NUM 1469-SI#6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 26 DRIVER HEAD ACCELERATION, Y-AXIS
 FILTER CUTOFF FREQ. 1650 PEAKS -418.84 ; 70.18

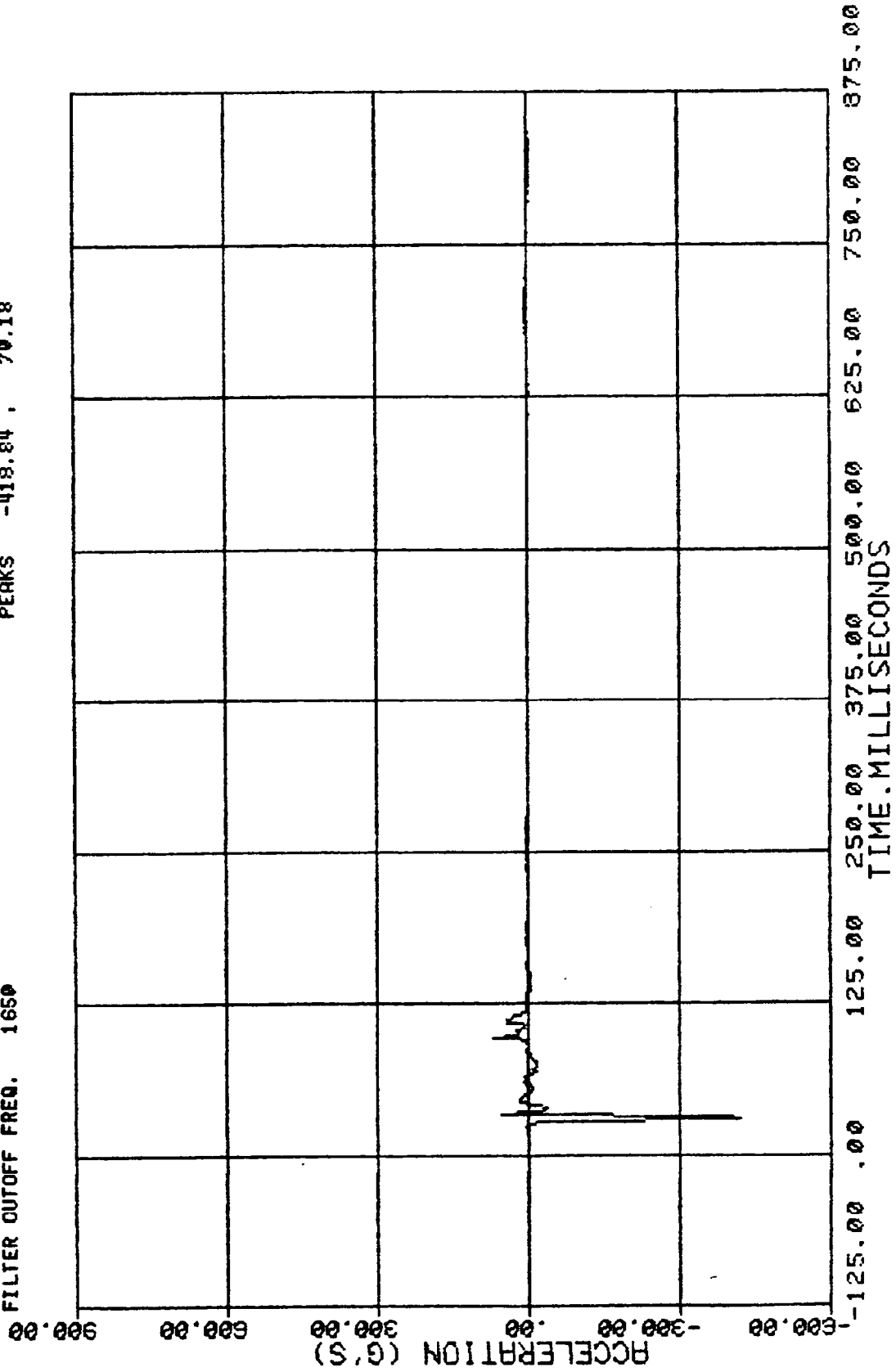


Figure 20. Driver's Head Acceleration, Y-Axis 1650 Hz

ENS00, INO. CONTRACT NUMBER DTFFH61-81-0-00036 TEST NUM 1469-SI#6
 30 MEH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 27 DRIVER HEAD ACCELERATION, Z-AXIS
 FILTER CUTOFF FREQ. 1650 PEAKS -51.59 , 217.21

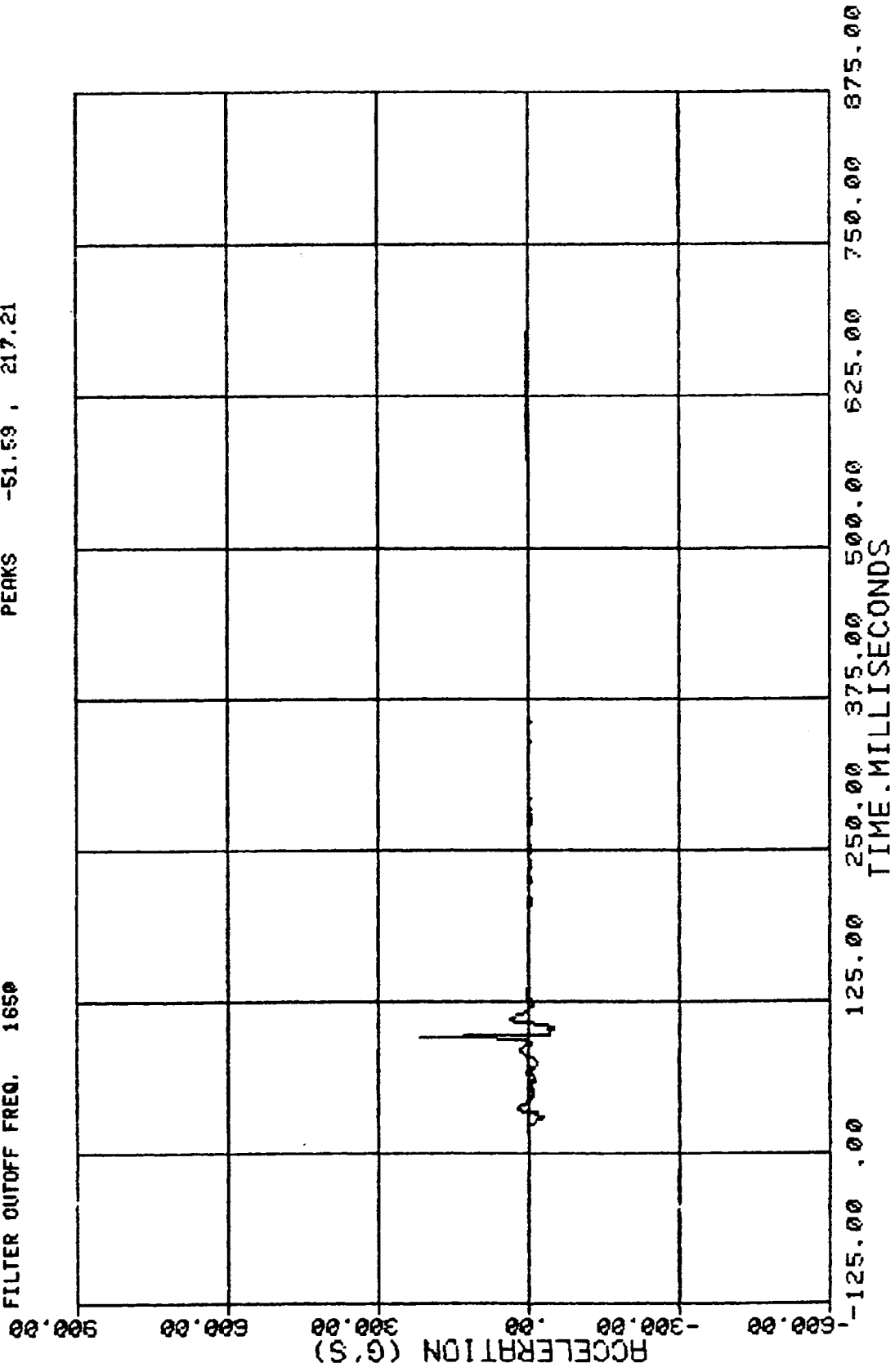


Figure 21. Driver's Head Acceleration, Z-Axis, 1650 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-81-0-00036 TEST NUM 1469-SI#6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL DRIVER HEAD ACCELERATION, RESULTANT PEAKS 0.66 436.70
 FILTER CUTOFF FREQ. 1650

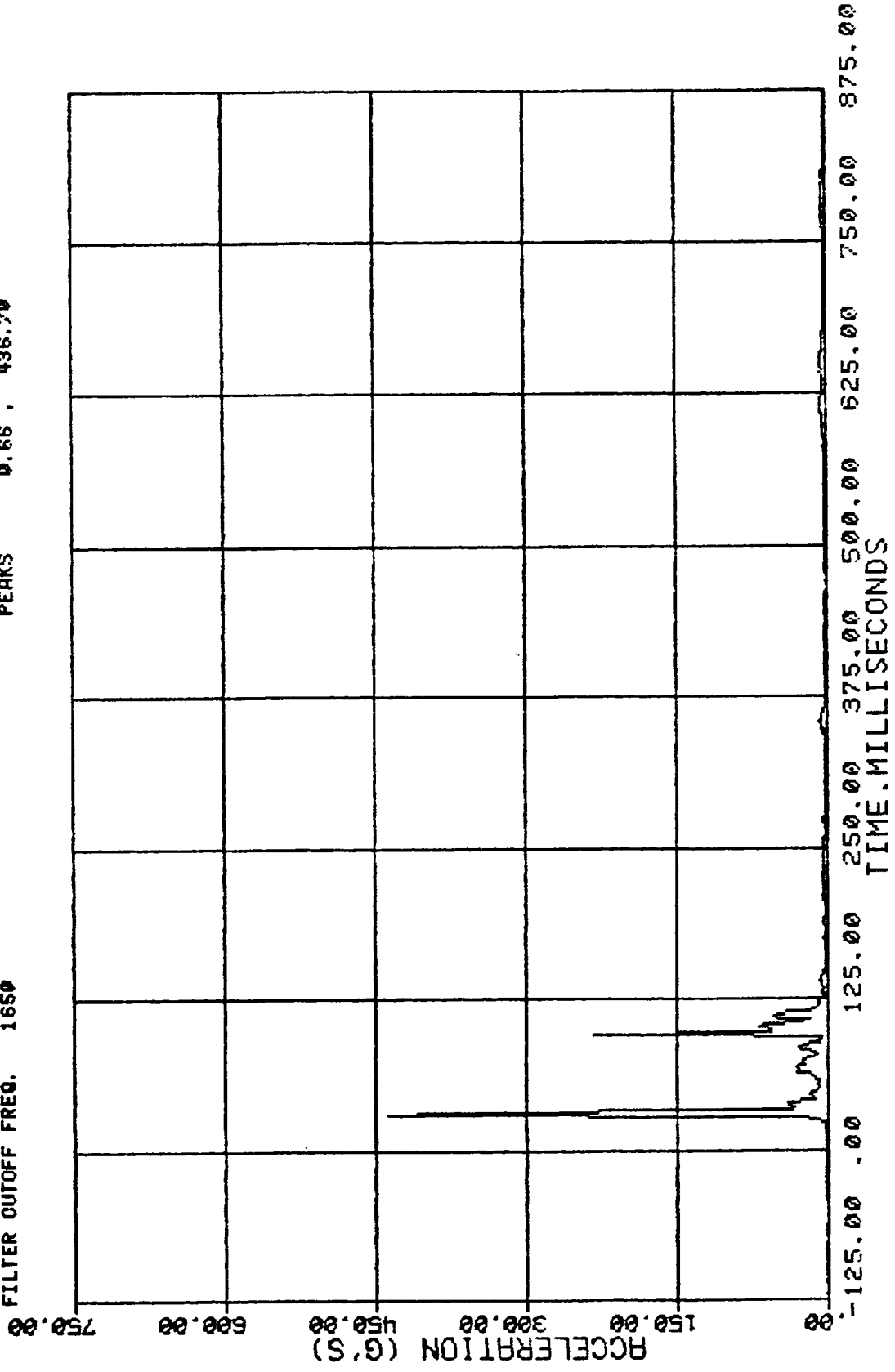


Figure 22. Driver's Head Acceleration, Resultant, 1650 Hz

Table 9
 Head Injury Criteria Evaluated for Full
 Scale Crash Test 1469-SI#6-85

	<u>Driver</u>
HIC	9305
t(Start)	.029 sec
t(Stop)	.032 ms
t(Duration)	.003 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 2145 and the maximum acceleration was 188 g's at 28 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 techniques are presented in figures 23 through 26 for the upper spine location, figures 27 through 30 for the lower spine location and figures 31 through 34 for the pelvis location. The lower spine z-axis accelerometer failed during the test and is not presented here. Also, the resultant for the lower spine is based on the x-axis by y-axis only.

EMSO, INC. CONTRACT NUMBER DTFH61-81-0-00036 TEST NUM#1469-SI#6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 1 DRIVER THORAX-T01XG
 FILTER CUTOFF FREQ. 300 PEAKS -17.10 , 41.05

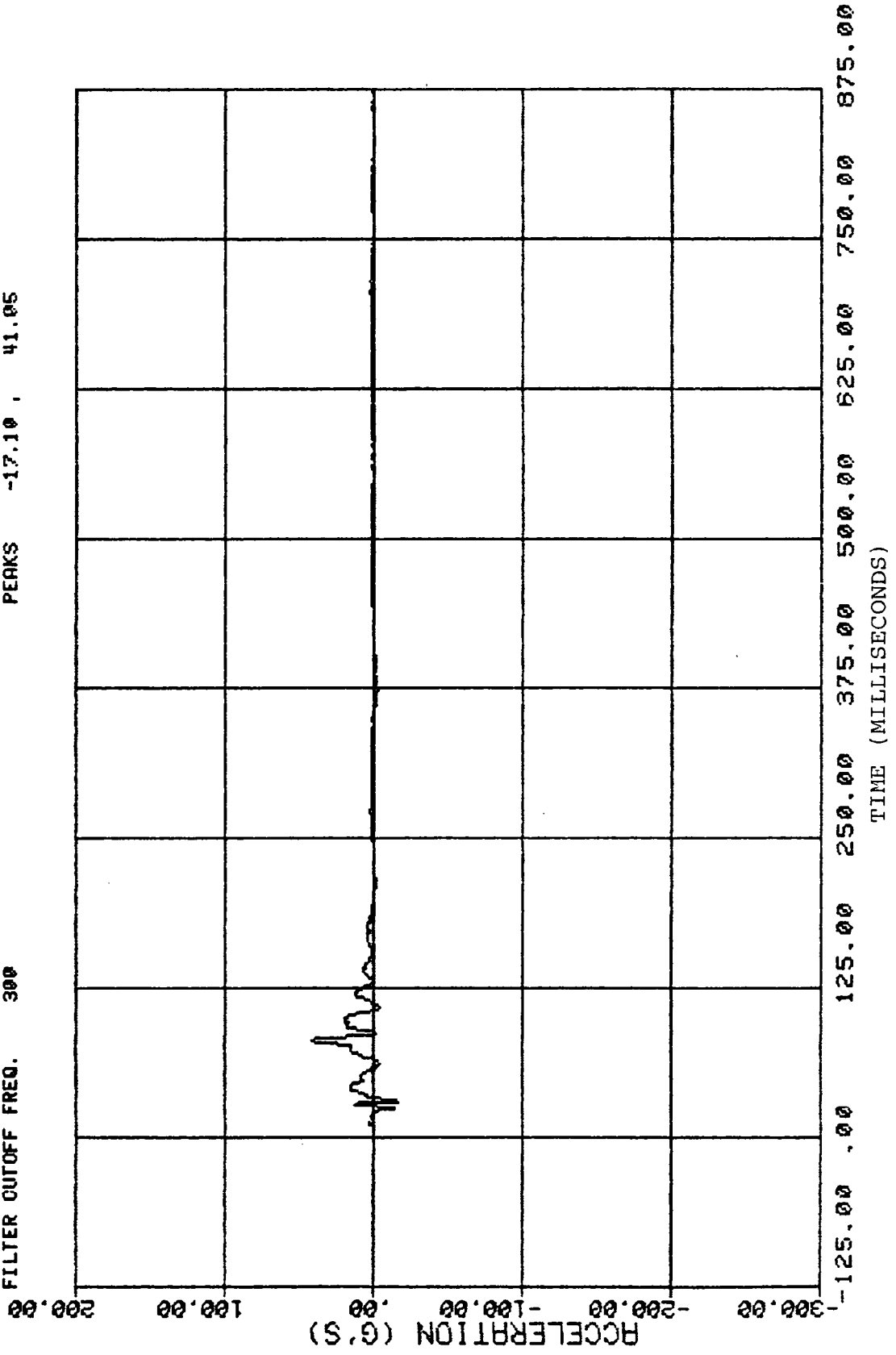


Figure 23. Driver's Upper Spine Acceleration, T01X, 300 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-81-D-00036 TEST NIJM1469-SI*6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 3 DRIVER THORAX-T01Y01 PEAKS -223.98 29.74
 FILTER CUTOFF FREQ. 300

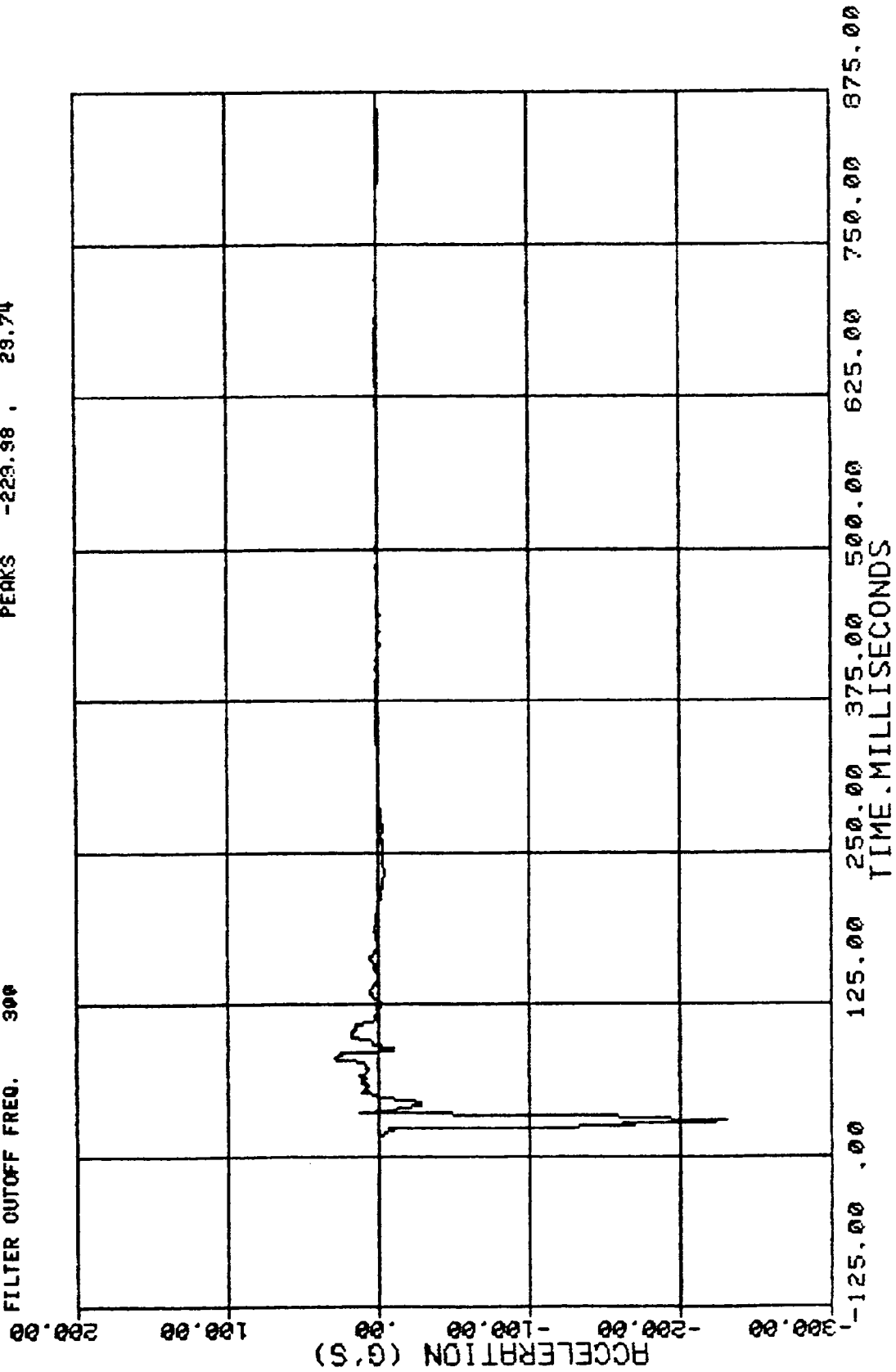


Figure 24. Driver's Upper Spine Acceleration, T01Y, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-81-O-00036 TEST MJM#1469-SI#6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 4 DRIVER THORAX-T01Z0
 FILTER CUTOFF FREQ. 300 PEAKS -22.02 , 8.78

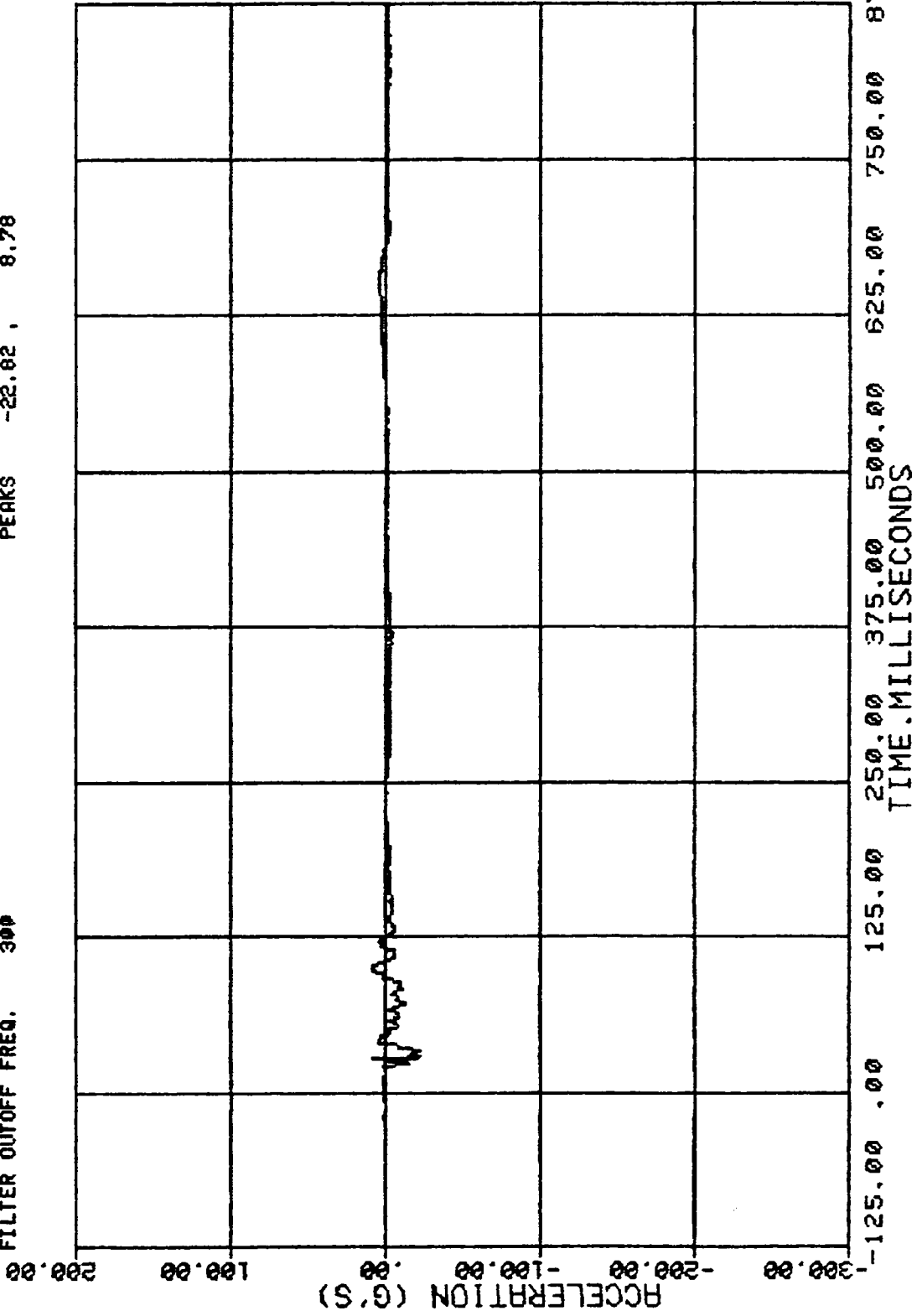


Figure 25. Driver's Upper Spine Acceleration, T01Z, 300 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-81-0-00036 TEST NUM#1469-SI*6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL # DRIVER UPPER SPINE, RESULTANT
 FILTER CUTOFF FREQ. 300 PEAKS 0.10 , 231.19

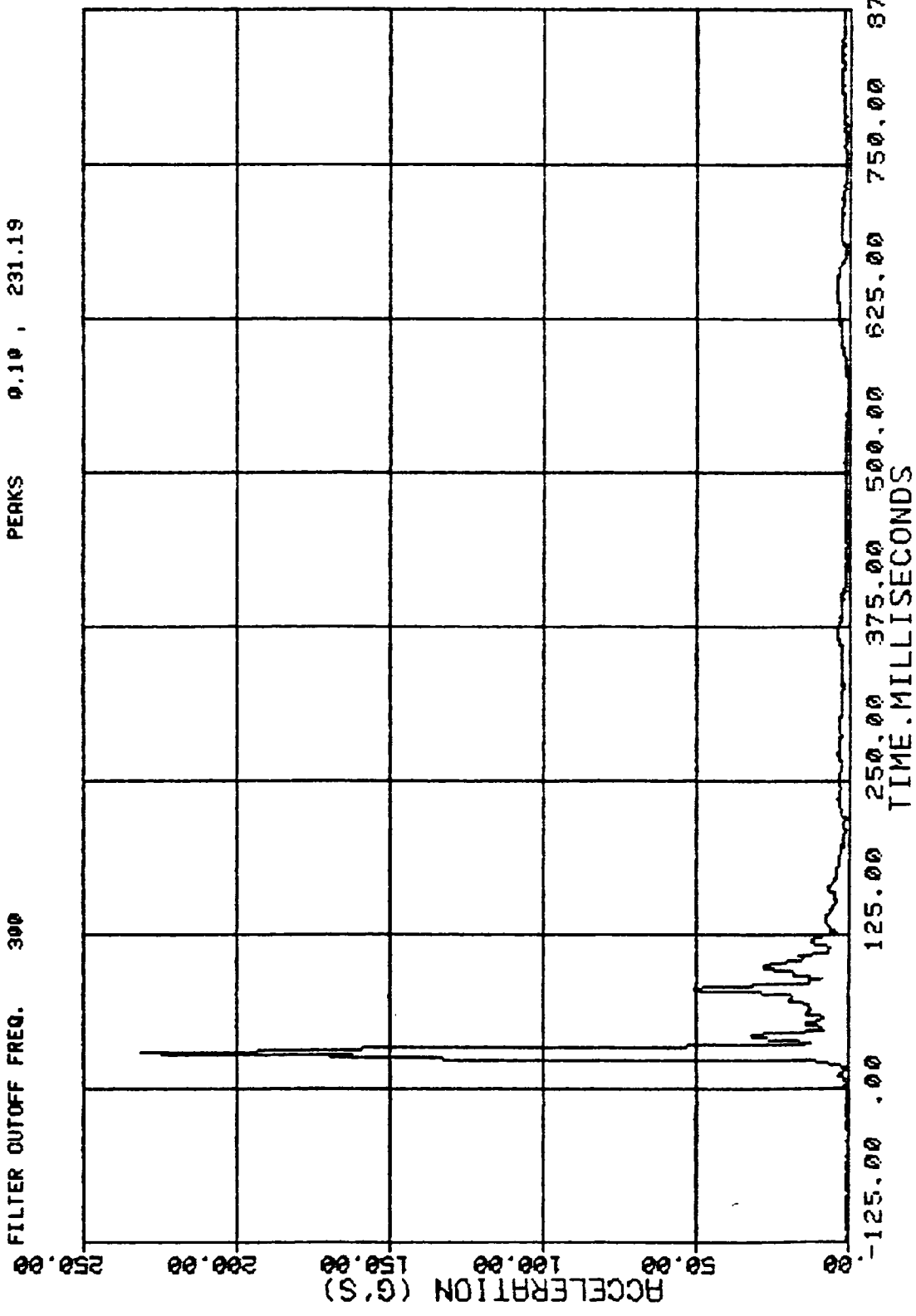


Figure 26. Driver's Upper Spine Acceleration, Resultant, 300 Hz

ENSOO,IND. CONTRACT NUMBER DTFH61-81-0-00036 TEST NUM#1469-SI*6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 9 DRIVER THORAX-T12X0
 FILTER CUTOFF FREQ. 300 PEAKS -43.29 , 83.93

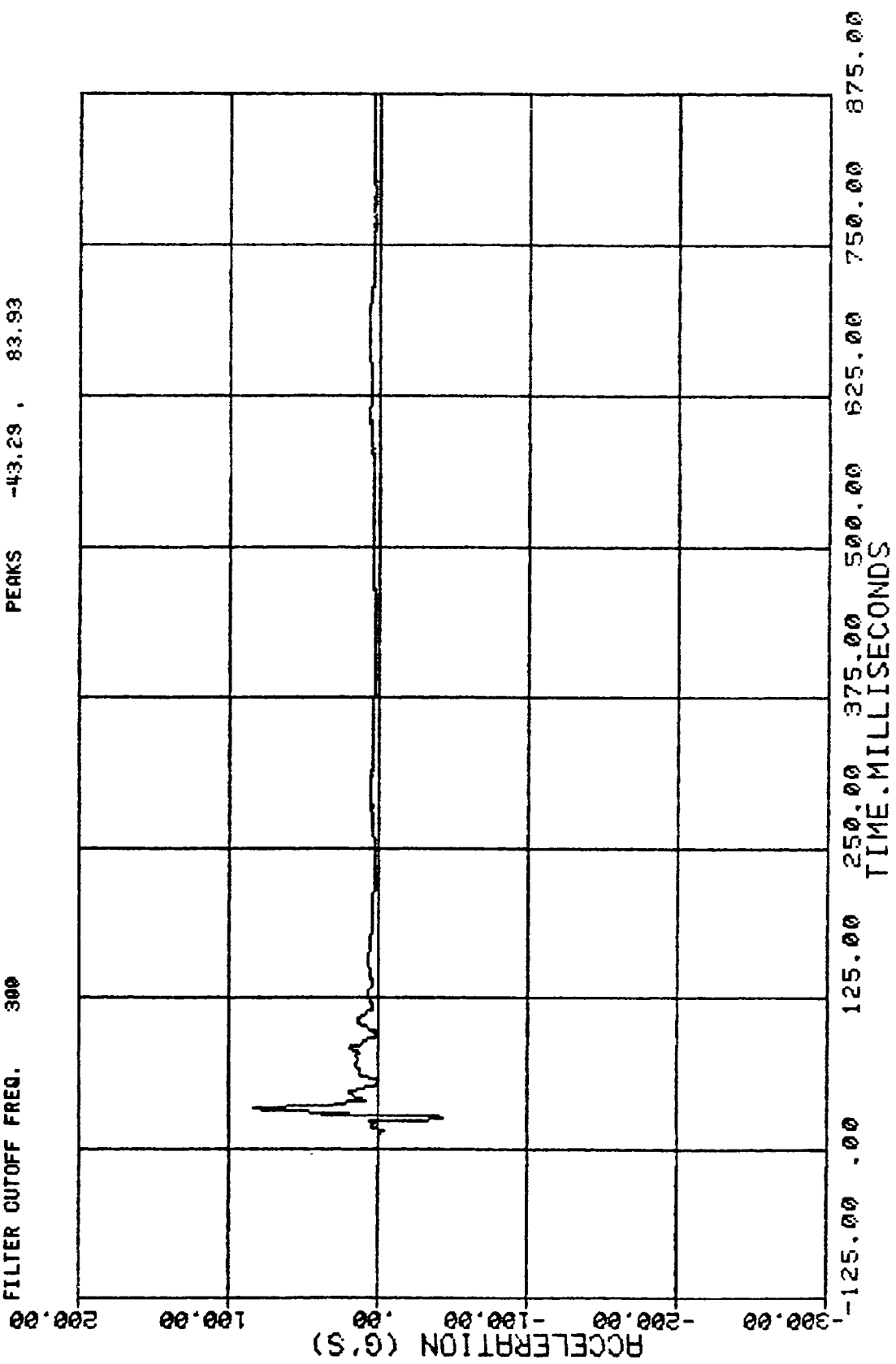


Figure 27. Driver's Lower Spine Acceleration, T12X, 300 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-81-D-00036 TEST NUM#1469-SI#6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 10 DRIVER THORAX-T12Y0A
 FILTER CUTOFF FREQ. 300 PEAKS -24.61 , 265.33

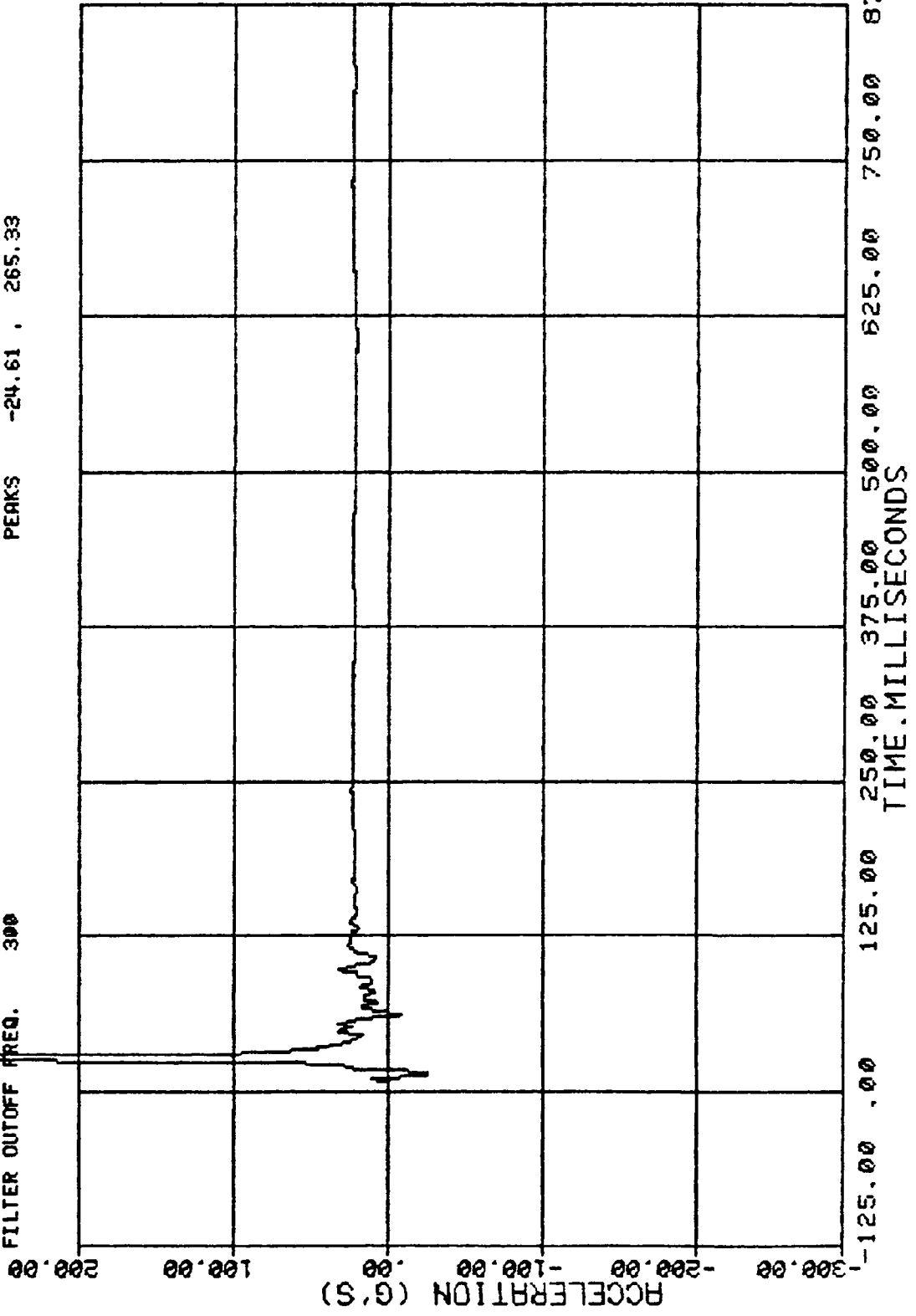


Figure 28. Driver's Lower Spine Acceleration, T12YA, 300 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-81-0-00036 TEST NUM#1469-SI*6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 11 DRIVER THORAX-T12Y01
 FILTER CUTOFF FREQ. 300 PEAKS -252.47 , 34.64

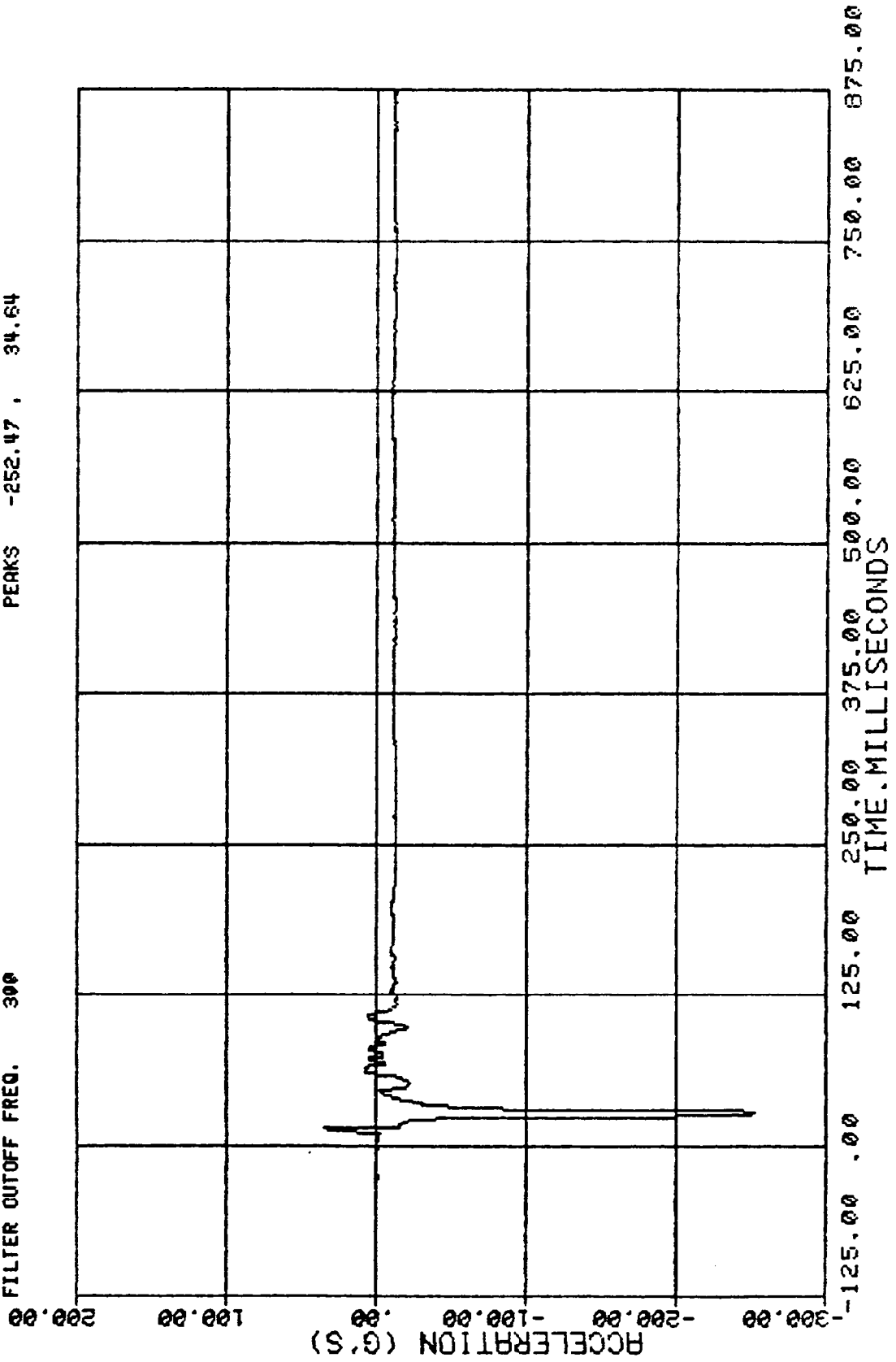


Figure 29. Driver's Lower Spine Acceleration, T12Y, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-81-C-00036 TEST NUM#1469-SI#6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL DRIVER LOWER SPINE, RESULTANT
 FILTER CUTOFF FREQ. 300 PEAKS 0.07 254.15

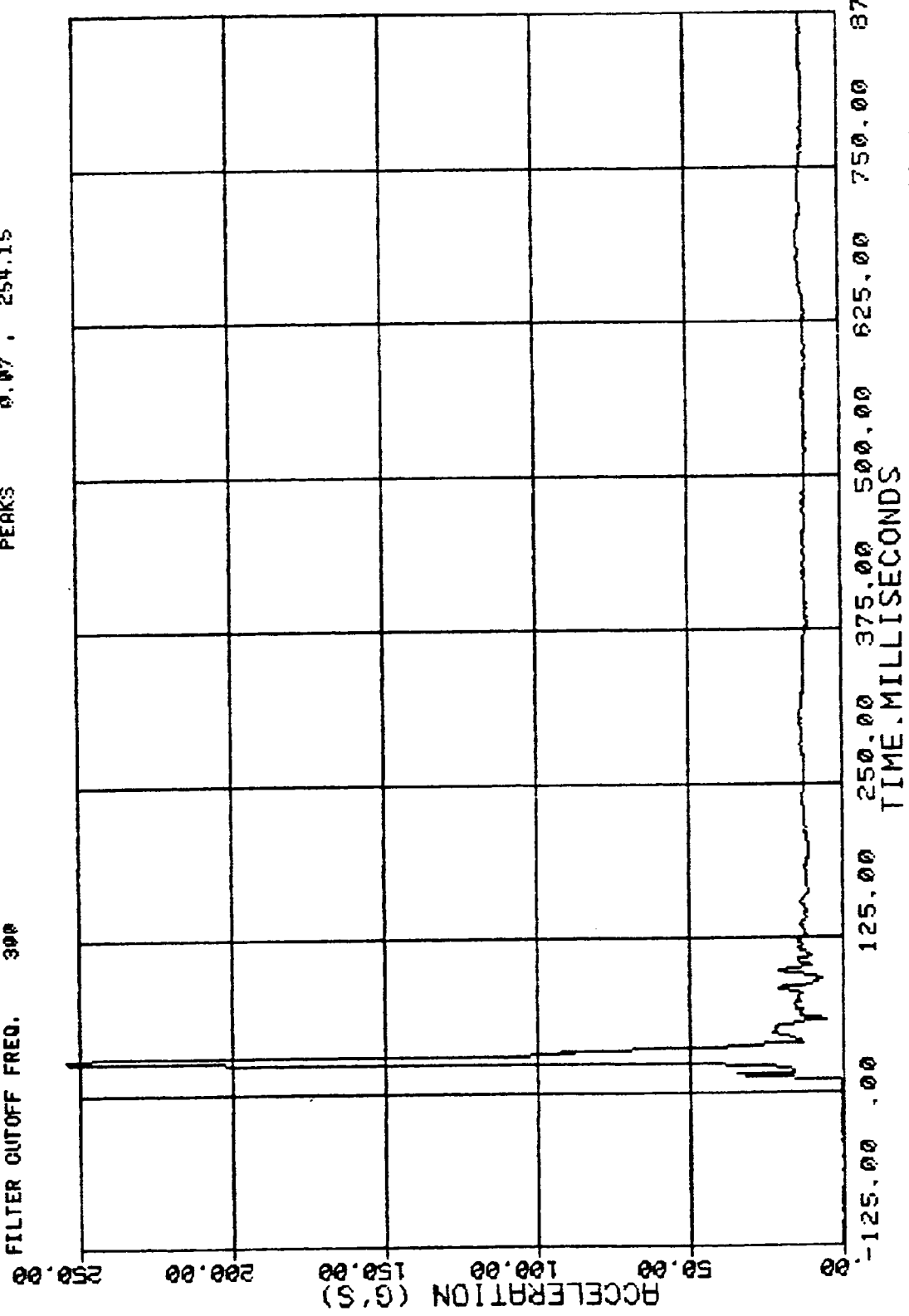


Figure 30. Driver's Lower Spine Acceleration, Resultant, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-81-0-00036 TEST NUM#1469-SI#6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 28 DRIVER PELVIC ACCELERATION, X-AXIS
 FILTER CUTOFF FREQ. 300 PEAKS -23.02 8.35

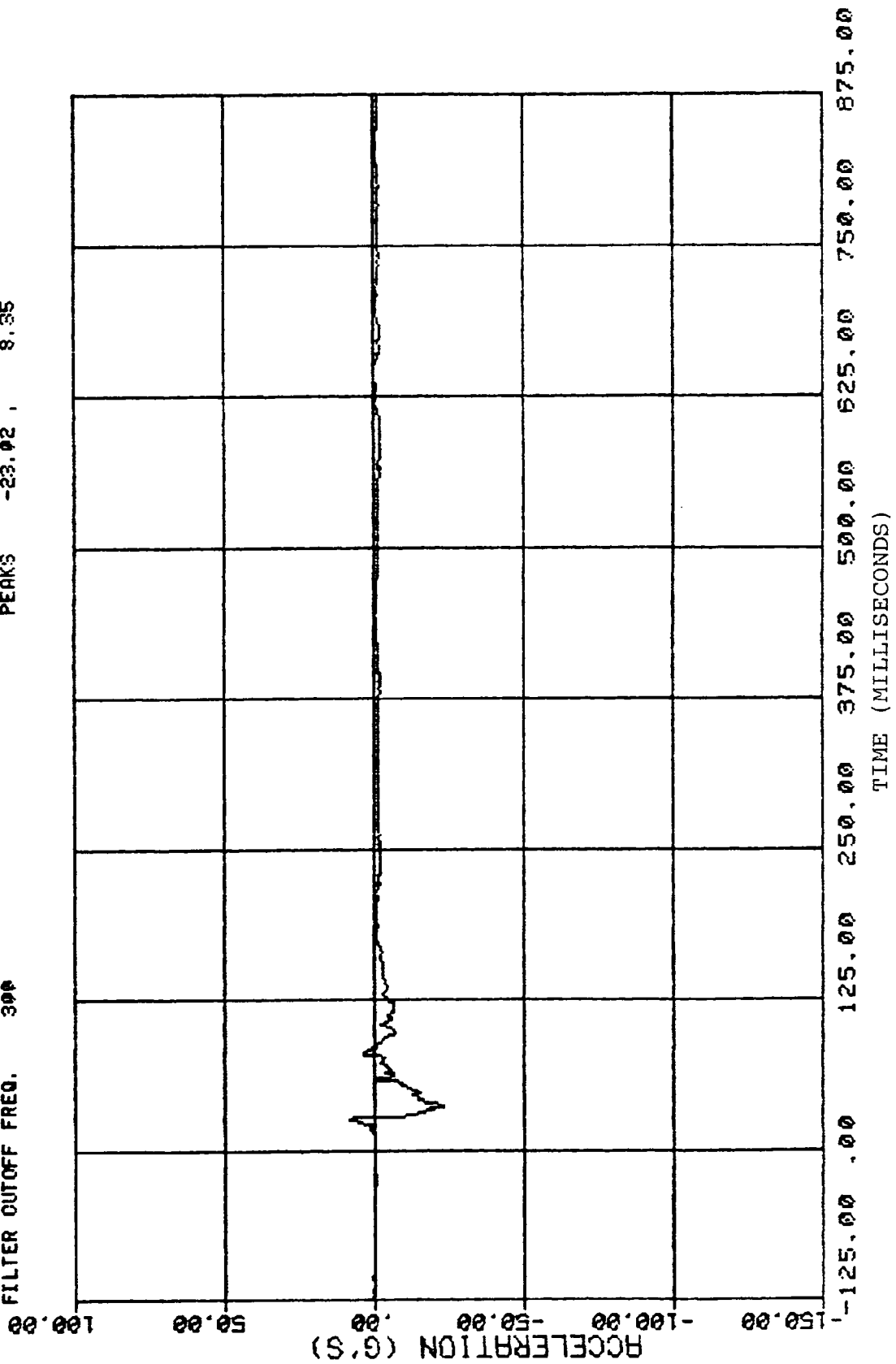


Figure 31. Driver's Pelvis Acceleration, X-Axis, 300 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-81-0-00036 TEST NUM#1469-SI*6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 29 DRIVER PELVIO ACCELERATION, Y-AXIS
 FILTER CUTOFF FREQ. 300 PEAKS -107.26 , 22.35

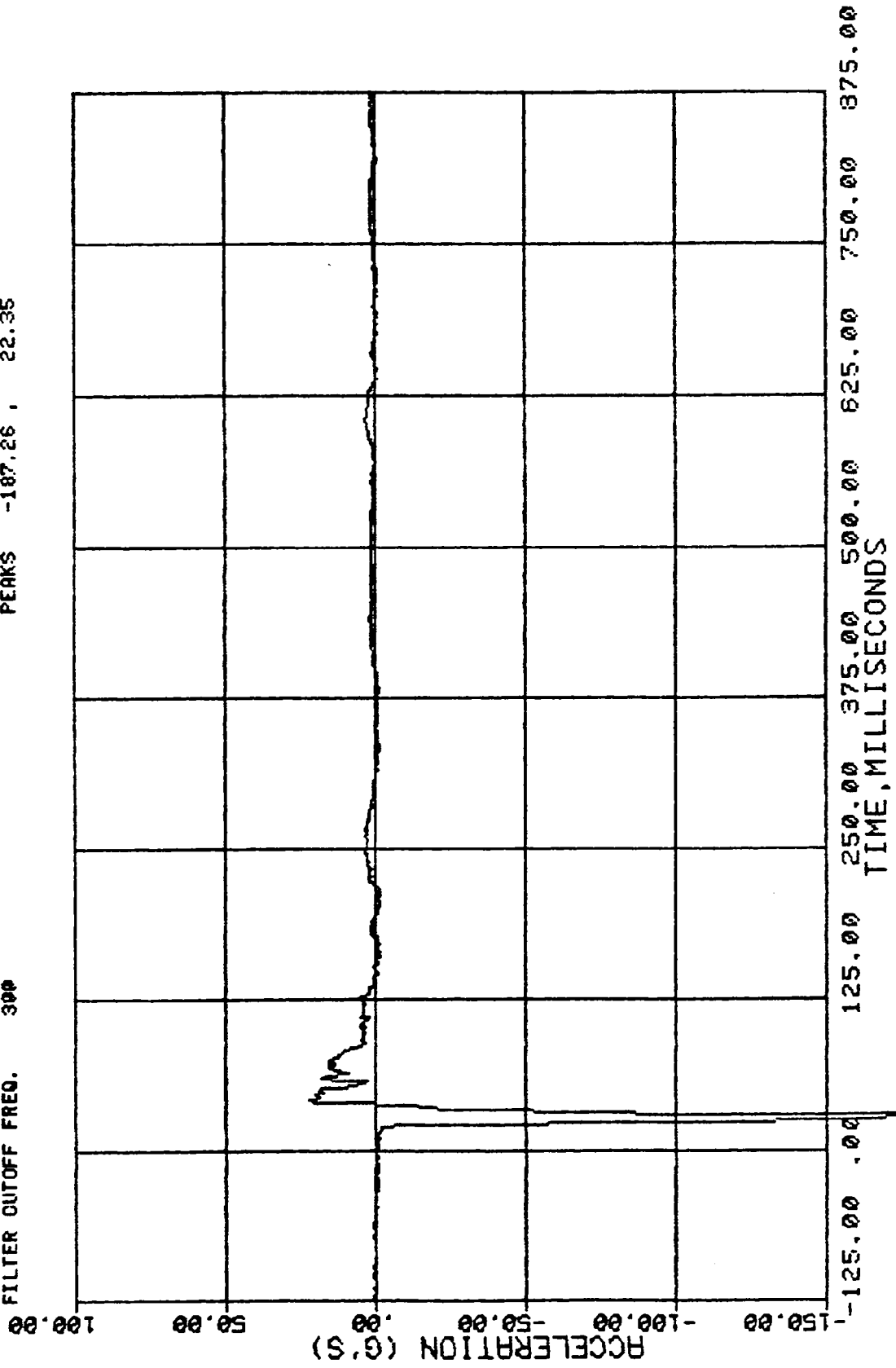


Figure 32. Driver's Pelvis Acceleration, Y-Axis, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-81-D-00036 TEST NUM#1469-SI#6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 30 DRIVER PELVIO ACCELERATION, Z-AXIS PEAKS -37.31 21.46
 FILTER CUTOFF FREQ. 300

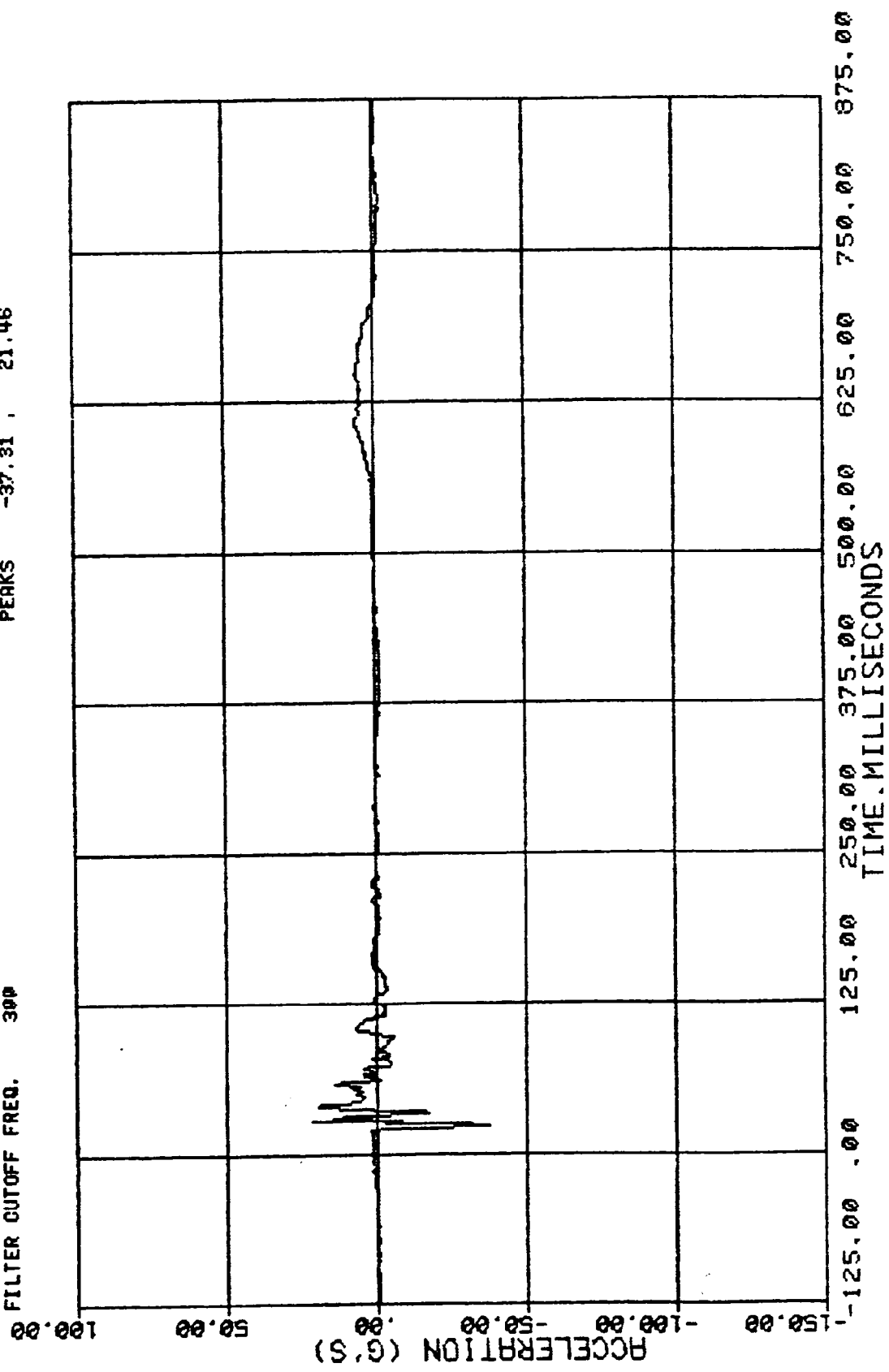


Figure 33. Driver's Pelvis Acceleration, Z-Axis, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFHS1-81-C-00036 TEST NUM#1463-SI#6
 30 MPH BROADSIDE IMPACT OF 79 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL # DRIVER PELVIO ACCELERATION, RESULTANT PEAKS 0.13 , 187.55
 FILTER OFF FREQ. 300

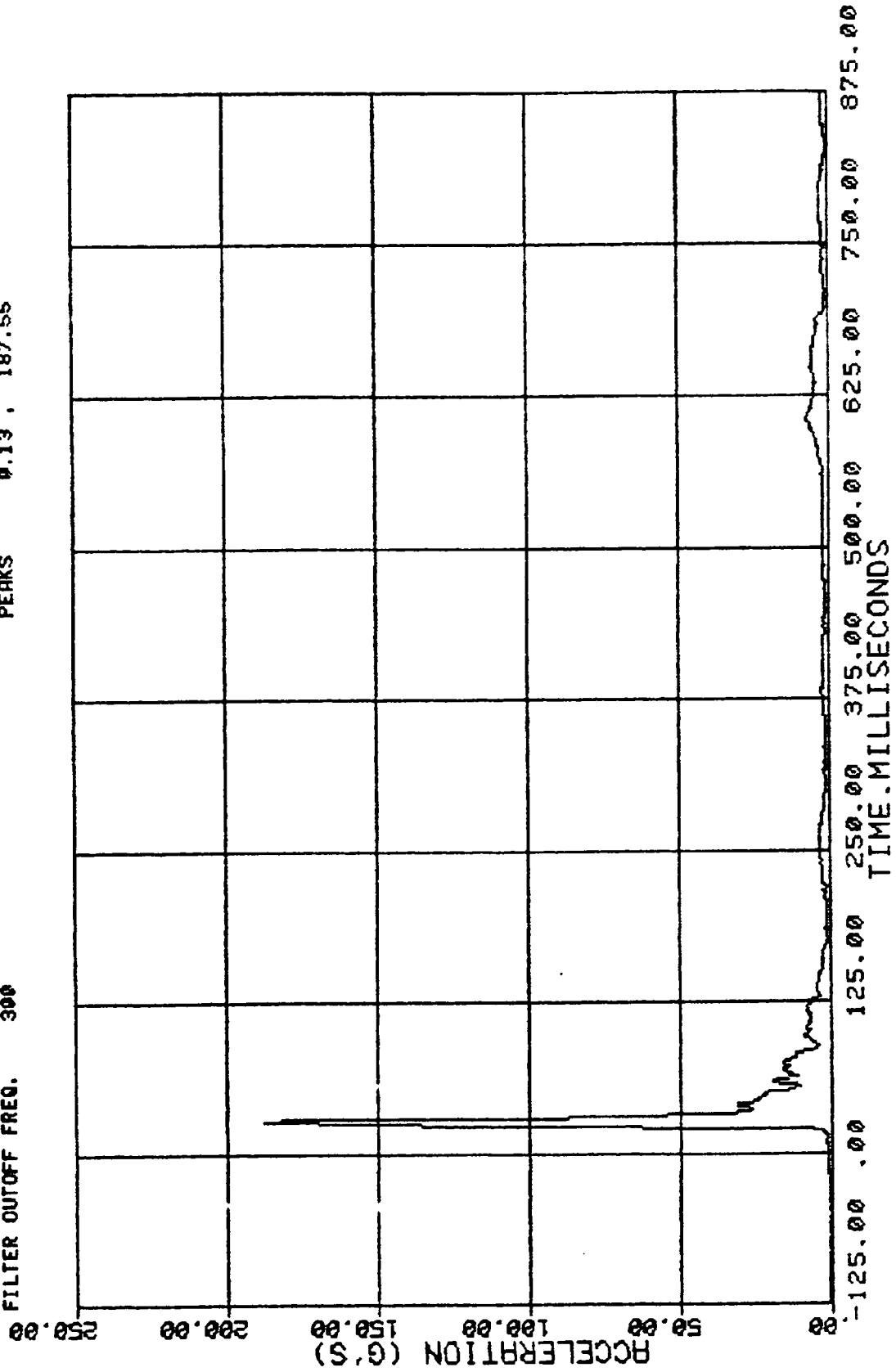


Figure 34. Driver's Pelvis Acceleration, Resultant, 300 Hz

7.6 THORACIC INJURY EVALUATION

The data obtained from the accelerometers mounted on the upper and lower left ribs as well as the lateral accelerometers at the T01 and T12 locations within the thorax of the occupant were filtered using NHTSA FIR filter and are presented in figures 35 through 40.

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 using the following relationship:

$$TTI = \text{Age} + .5 (\text{LURY} + \text{T12Y}) (\text{Mass}/165)$$

LURY was computed from the average of the two transducers located on the upper rib. $\text{LURY} = (190 + 221)/2 = 206$. See figures 35 and 36 for LURY data. T12Y data was taken from figure 40. The value of T12Y is 260. Thus the TTI index is 233 plus occupant age. This value produces a 100% probability of injury of an AIS greater than 3 or 4 and a 47% probability of injury of an AIS greater than 5 for age 0, and 50% probability for age 7. The figure does not exceed 50% for AIS 5. See Figure 41 for TTI values.

ENSO, INC. CONTRACT NUMBER DTFH61-83-C-00140 TEST NUM1489-SI*6-85
 30 MPH BROADSIDE IMPACT OF A DODGE COLT AND A BREAKAWAY LUMINAIRE SUPPORT
 CHANNEL 24 DRIVER THORAX-LURY
 FILTER CUTOFF FREQ. NHTSA FIR FILTER PEAKS -189.91 , 28.66

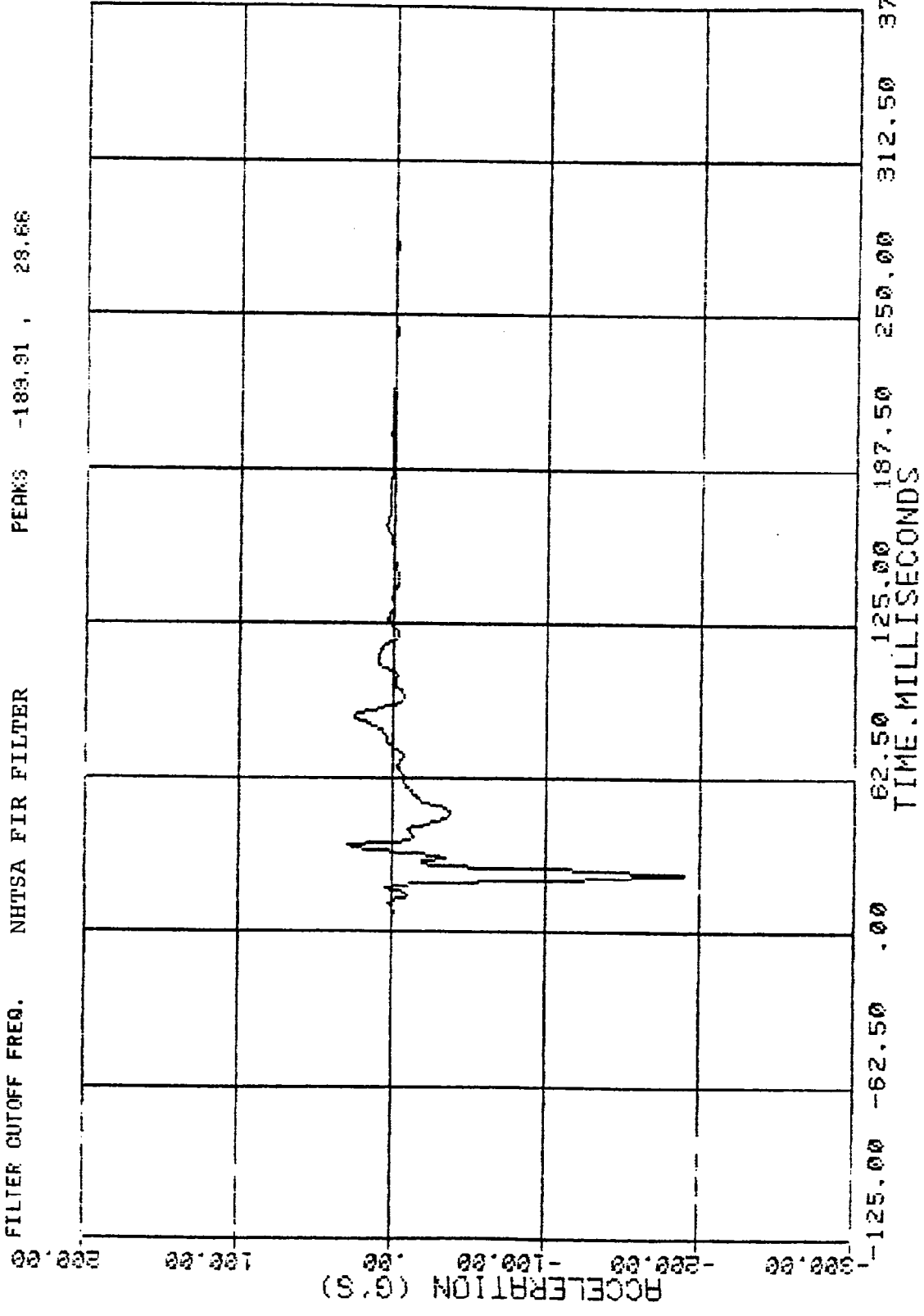


Figure 35. Driver's Left Upper Rib Acceleration, LURY, NHTSA FIR Filter

ENSCO, INC. CONTRACT NUMBER DTFH61-83-0-00148 TEST NUM1489-SI-6-85
 30 MPH BROADSIDE IMPACT OF A DODGE COLT AND A BREAKAWAY LUMINAIRE SUPPORT
 CHANNEL 23 DRIVER THORAK-LURYA
 FILTER CUTOFF FREQ. NHTSA FIR FILTER PEAKS -220.95 42.29

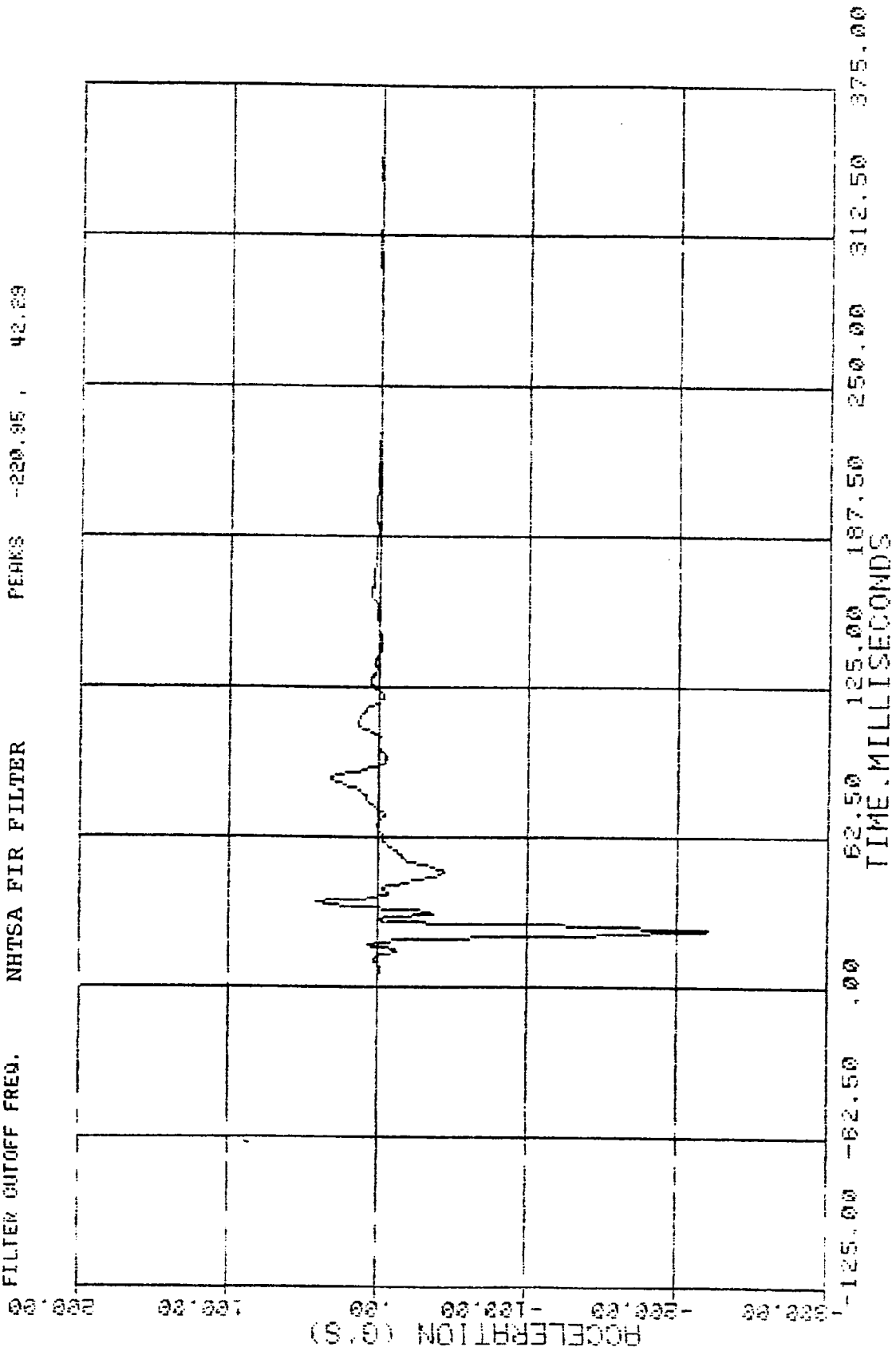


Figure 36. Driver's Left Upper Rib Acceleration, LURYA, NHTSA FIR Filter

ENSDD, INC. CONTRACT NUMBER DTFHS1-83-D-00140 TEST NUM1469-SI#6-85
 30 MPH BROADSIDE IMPACT OF A DODGE COLT AND A BREAKAWAY LUMINAIRE SUPPORT
 CHANNEL 6 DRIVER THORAX-LLRY
 FILTER CUTOFF FREQ. NHTSA FIR FILTER PEAKS -200.87 , 129.112

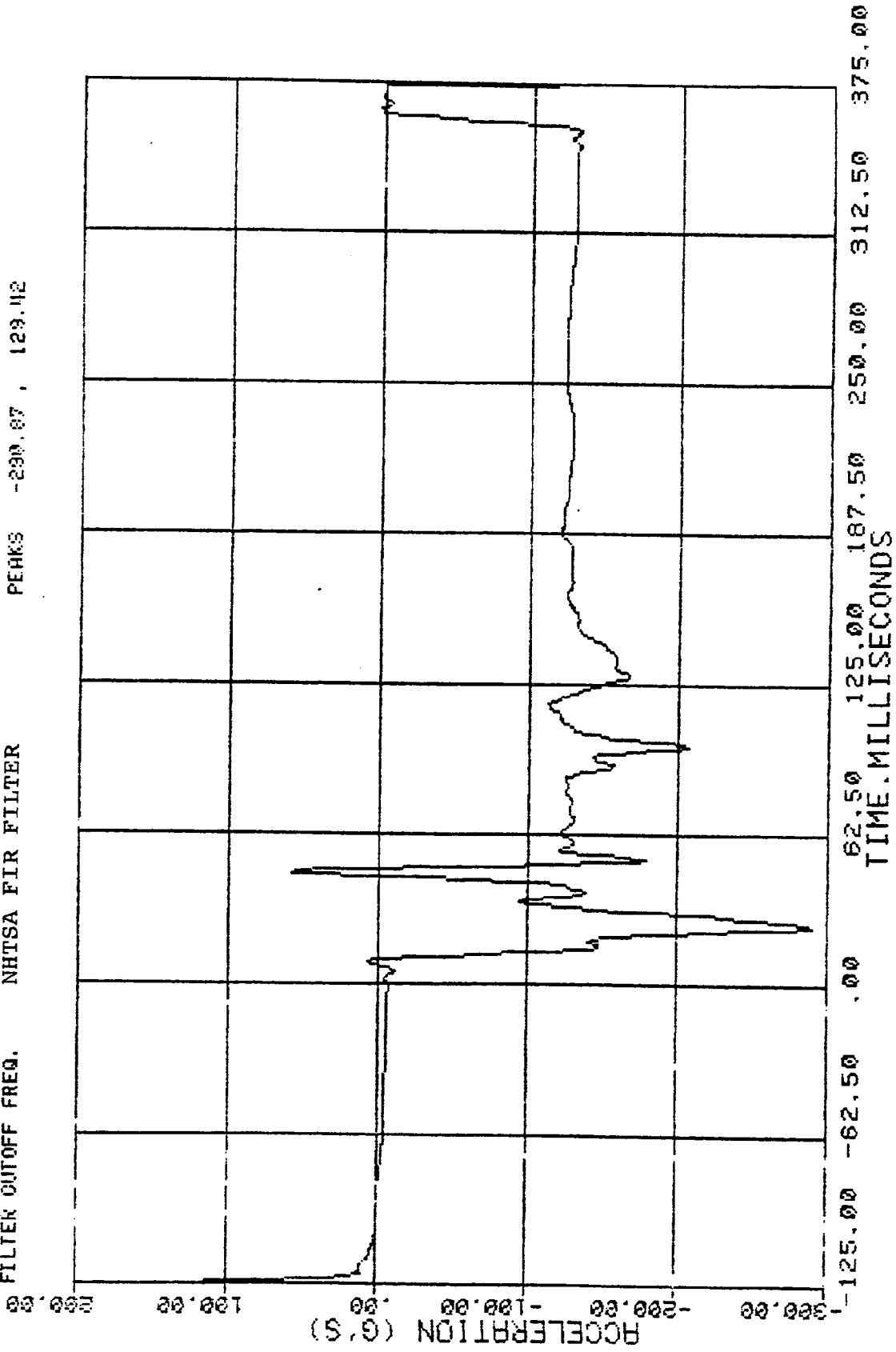


Figure 37. Driver's Left Upper Rib Acceleration, LLRY, NHTSA FIR Filter

ENSCO, INC. CONTRACT NUMBER DTFH61-83-C-00140 TEST NUMBER SI-85-85
 30 MPH BROADSIDE IMPACT OF A DODGE COLT AND A BREAKAWAY LUMINAIRE SUPPORT
 CHANNEL 5 DRIVER THORAX-LLRYA
 FILTER CUTOFF FREQ. NHTSA FIR FILTER PEAKS -126.46 , 135.57

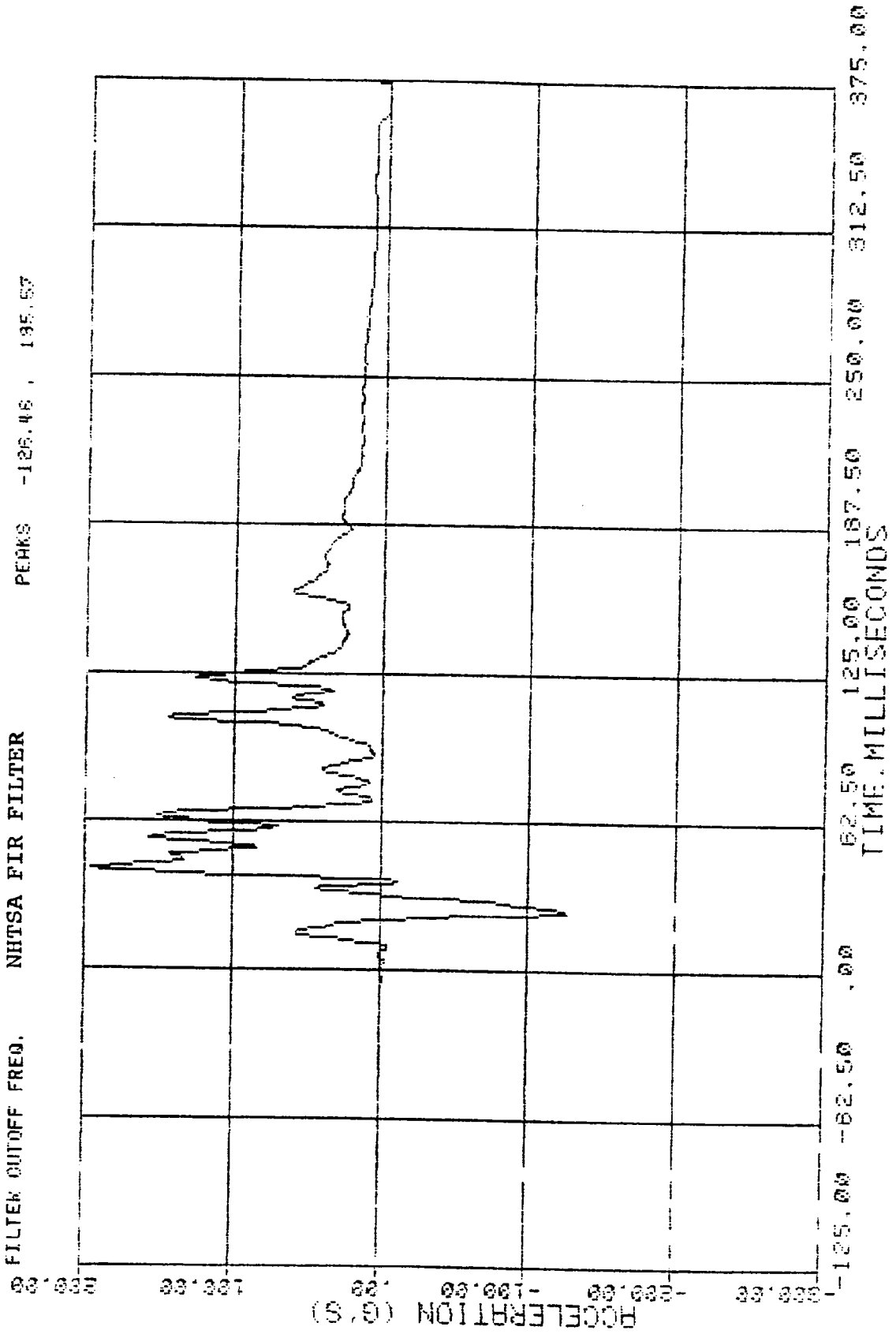


Figure 38. Driver's Left Upper Rib Acceleration, LLRYA, NHTSA FIR Filter

ENSO, INC. CONTRACT NUMBER DTFR1-83-0-00140 TEST NUM1469-SI*6-85
 30 MPH BROADSIDE IMPACT OF A DODGE CULT AND A BREAKAWAY LUMINAIRE SUPPORT
 CHANNEL 3 DRIVER THORAX-T01Y
 FILTER CUTOFF FREQ. NHTSA FIR FILTER PEAKS -221.56 29.36

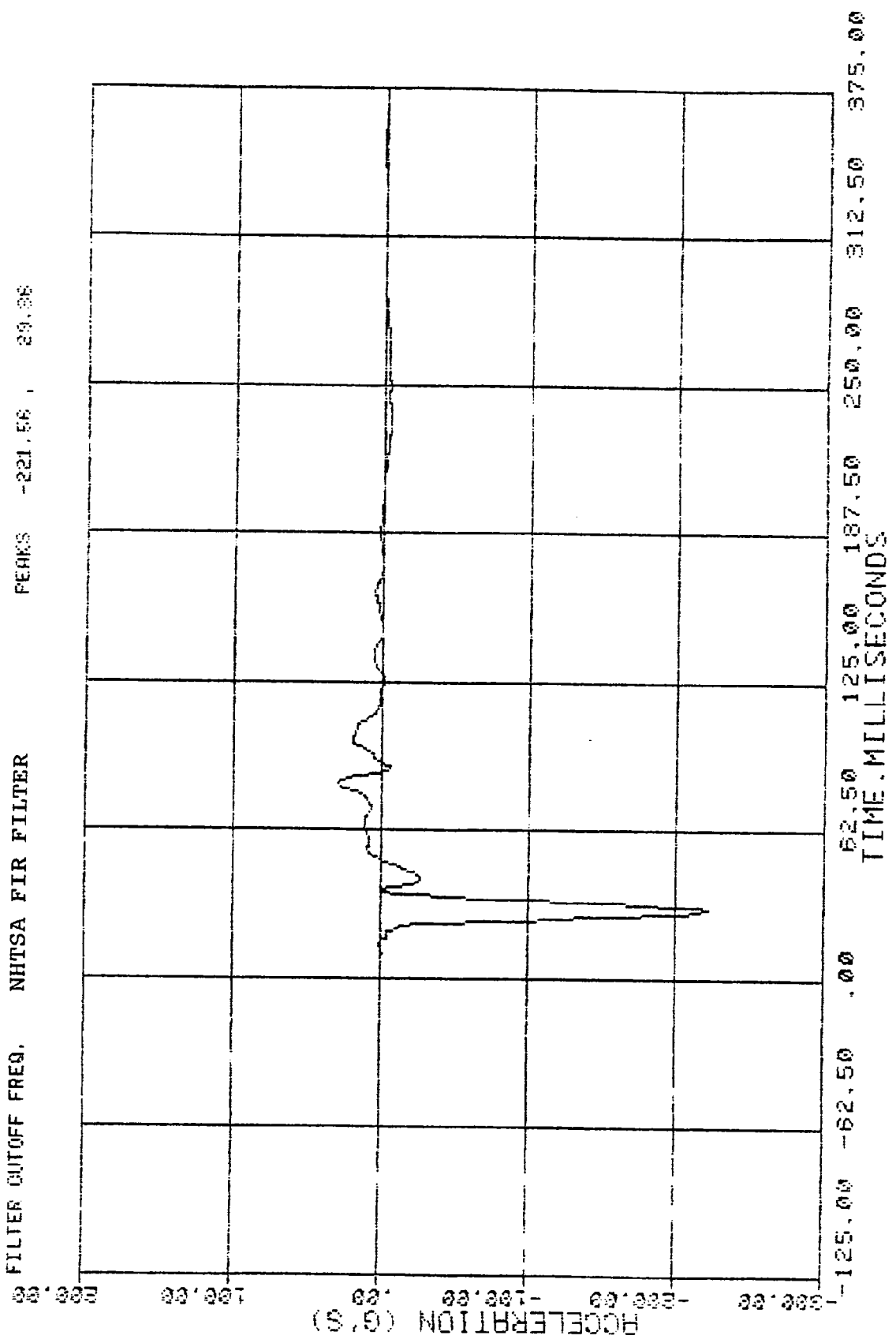


Figure 39. Driver's Upper Spine Acceleration, T01Y, NHTSA FIR Filter

ENSO, INC. CONTRACT NUMBER DTFA81-83-0-00140 TEST NUM 469-S1*6-85
 30 MPU BROADSIDE IMPACT OF A DODGE CULOT AND A BREAKAWAY LUMINOIRE SUPPORT
 CHANNEL 11 DRIVER THORAX-T12Y
 FILTER CUTOFF FREQ. NHTSA FIR FILTER PEAKS -259.95 13.98

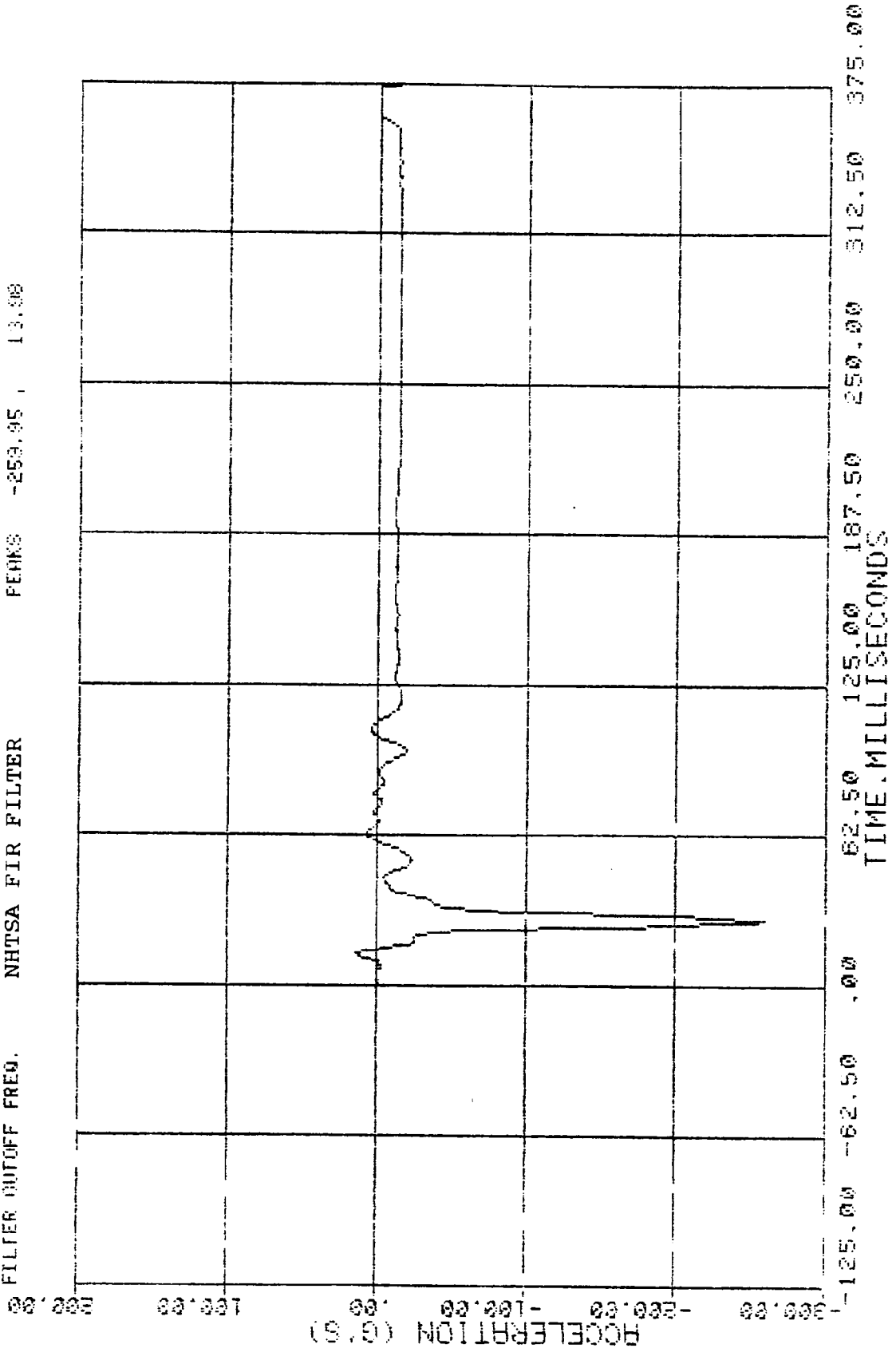
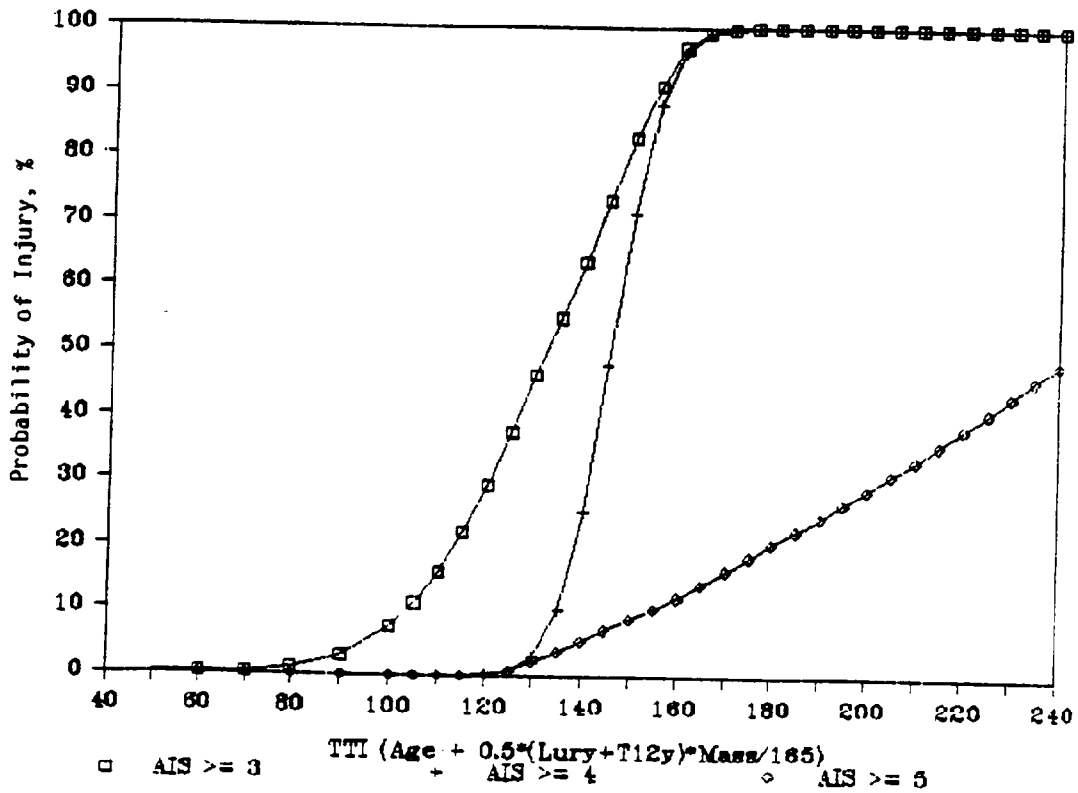


Figure 40. Driver's Lower Spine Acceleration, T12Y, NHTSA FIR Filter



From Ref 12

Figure 41. Thoracic Trauma 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 42.

STRUCTURAL ADEQUACY

The test pole readily activated in the predicated manner. The breakaway force was estimated to be 27 kips. 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 very high 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 ten times the limit. The thoracic injury also indicated a very severe accident rating with a 100% probability of an AIS greater than 3 or 4 and a 47% and 50% probability of an AIS greater than 5 for occupants of age 0 and 7, respectively.

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: $\frac{\text{Occupant Impact Velocity-fps}}{\begin{matrix} \text{Longitudinal} & \text{Lateral} \\ 40/F_1 & 30/F_2 \end{matrix}}$ and vehicle highest 10 ms average accelerations subsequent to instant of hypothetical passenger impact should be less than: $\frac{\text{Occupant Ridedown Accelerations—g's}}{\begin{matrix} \text{Longitudinal} & \text{Lateral} \\ 20/F_3 & 20/F_4 \end{matrix}}$ 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 42. 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.
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.