

DOT/224

FHWA CONTRACT NO.
DTFH61-86-Z-00047

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

TEST RESULTS REPORT.

TEST NUMBER 1785-SI#6-88

Hinch, J. A.
Stout, D.

Prepared for:

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

August 1988

Prepared by:

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

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle "Thirty MPH Broadside Impact a Minisized Vehicle and a Breakaway Luminaire Support," Test Result Report; Test Number 1785-SI#6-88		5. Report Date August 1988	
		6. Performing Organization Code	
7. Author(s) Hinch, J.A. and Stout, D.		8. Performing Organization Report No. 1785-SI#6-88	
9. Performing Organization Name and Address ENSCO, INC. 5400 Port Royal Road Springfield, VA 22151		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No. DTFH61-86-Z-00046	
12. Sponsoring Agency Name and Address Federal Highway Administration Turner Fairbank Highway Research Center 6300 Georgetown Pike McLean, VA 22101		13. Type of Report and Period Covered Test Report	
		14. Sponsoring Agency Code	
15. Supplementary Notes Subcontract from Analysis Group Inc., A. Hansen-PI: FHWA COTR - M. Hargrave			
16. Abstract This report documents the full scale side impact test of a 1980 Plymouth Champ impacting into a breakaway luminaire support. The impact speed was 30 mi/h and the impact angle was broadside with the impact point aligned 12 inches forward of the driver's shoulder. The impacted pole was a slip base mounted steel unit with mast arm and luminaire. The pole did not breakaway causing the vehicle to stop abruptly, with the vehicle body wrapped around the pole. Vehicle intrusion into the passenger compartment was severe. Dummy parameters were moderate.			
17. Key Words Side Impact SID FOIL		18. Distribution Statement Open	
19. Security Classif. (of this report) None	20. Security Classif. (of this page) None	21. No. of Pages	22. Price

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	8
4.0	VEHICLE DESCRIPTION	10
5.0	TEST INSTRUMENTATION	13
6.0	TEST RESULTS	16
7.0	TEST ANALYSIS	20
	7.1 Impact Velocity Analysis	20
	7.2 Analysis of Vehicle Mounted Accelerometers	21
	7.3 Comparison of Predicted Results to Test Observables	23
	7.4 Head Injury Criteria Evaluation	23
	7.5 Occupant Severity Index Evaluation	24
	7.6 Thoracic Injury Evaluation	25
	7.7 Vehicle Energy Balance	27
8.0	SAFETY ASSESSMENT OF TEST	31
9.0	REFERENCES	33
APPENDIX A		A-1

LIST OF FIGURES

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
1	Mechanical Properties of Pole	9
2	Pre-Test Photos of Vehicle	12
3	Post-Test Photos of Vehicle	17
4	NHTSA Vehicle Damage Measurements	19
5	Thoracic Trauma Index Scale	26
6	Crush Energy for Dodge Colt During Side Impact	29
7	NCHRP 230 Safety Evaluation Guidelines	32

LIST OF TABLES

<u>Table Number</u>	<u>Title</u>	<u>Page</u>
1	Summary of Test Conditions and Results for Test Number 1785-SI#6-88	3
2	Test Matrix for Side Impact Test Series	6
3	Properties of Test Pole	8
4	Cg and Inertial Data for Test Vehicle	9
5	Description of Film Data Acquisition System	14
6	Transducer Data Description	15
7	Residual Vehicle Crush	19
8	Test Vehicle Impact Speed Evaluation Using High Speed Film Analysis	21
9	Change in Velocities and Ride Down Acceleration from Analysis of Class 180 Data Using NCHRP 230 Technique	23
10	Head Injury Criteria	24
11	Matrix of AIS vs TTI-86 values	26

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 1980 Plymouth Champ. The breakaway luminaire support was a 30 foot steel pole with a California type 31 slip base. The pole included a mast arm and surrogate luminaire.

The test vehicle momentum change due to impacting the pole at a speed of 28.25 mi/h (12.64 m/s) was 2,590 lb-sec. The velocity change corresponding to the observed vehicle momentum change was the same as impact speed since the vehicle stopped. The integrity of the vehicle was lost during the test due to the extreme amount of intrusion. Maximum residual crush of the side of the vehicle was 36.0 inches measured from a cord stretched from bumper to bumper.

Vehicle acceleration data was processed to determine the impact velocity of a hypothetical front seat passenger against the vehicle interior in accordance with the flail space model recommended in NCHRP 230. The lateral impact velocity of the hypothetical occupant using the flail space model approach with a one foot threshold was 28.8 ft/sec. This lateral impact velocity exceeds the design limit of 20 ft/sec (6.10 m/s) specified for lateral impacts of other forms of highway safety appurtenances in 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 moderate to severe injury as measured on the American Association of Automotive Medicine's Abbreviated Injury

Scale (AIS). Using an age of 0, the probability of an injury level of AIS greater than 3 was 47%, greater than 4 was 4%, and greater than 5 was 0%. These values, based on the TL2Y, LLRY and LURY accelerometers, are within 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 2191. This result is outside 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, during the test, the data system power was interrupted, and only partial data traces were obtained.

During the impact, the pole did not release and the vehicle came to a rest in contact with the pole. The pole remained upright on its base. Failure of the slip base to activate is considered unacceptable. A summary of the test conditions and results for this full scale crash test are given in Table 1.

Table 1
 Summary of Test Conditions and
 Results for Test Number 1785-SI#6-88

1.	Contract Number/FOIL Test No.	DTFH61-86-Z-00047/88S006
2.	Date of Test	April 26, 1988
3.	Test Vehicle	Plymouth Champ, 1980
4.	Delivered Vehicle Weight	1823 lbs
5.	Vehicle Weight, Test Inertial	
	Planned	1,800 ±50 lbs
	Actual	1,850 lbs
6.	Vehicle Weight, Gross Static	
	Actual (One Occupant)	2,010 lbs
7.	Number of Occupants	One
8.	Occupant Type	Anthropomorphic Dummy, 50th Percentile Male, Side Impact Thorax-SN120
9.	Occupant Location	Driver Seat
10.	Occupant Restraint	Unrestrained
11.	Test Article	Breakaway Luminaire Support
12.	Support Length (w/o Base)	30 ft
13.	Support Material	Steel
14.	Support Weight (w/Base, mast arm and luminaire)	416 lbs
15.	Base Type	Triangular Slip Base, 3-Bolt (Type 31)
16.	Slip Plane Mounting Height Above Grade	4 in
17.	Bolt Circle	14 in
18.	Bolt Size	1 in - 8 NC x 5 in long
19.	Bolt Load (Strain Gaged)	14,000 lbs each
20.	Foundation	FOIL Impact Foundation
21.	Ground Conditions	Dry

Table 1 (Cont'd)
 Summary of Test Conditions and
 Results for Test Number 1785-SI#6-87

22.	Impact Speed, Observed	28.25 mph
23.	Speed Reduction Acceleration Data, TRC 191	28.25 mph
24.	Exit Speed	0 mph
25.	Impact Point, Observed	Left Door, Driver Location, (16" behind cg)
26.	Traffic Accident Data, TAD	9-LP-5
27.	Vehicle Damage Index, VDI	09LPAN6
28.	Hypothetical Occupant Impact Velocity (NCHRP 230)	
	Design Limit	20 ft/sec
	Observed (1' flail)	28.8 ft/sec
	Observed Actual (.50')	22.1 ft/sec
29.	Hypothetical Occupant Ride-down Acceleration (NCHRP 230)	
	Design Limit	15.00 g
	Observed, (1' flail)	-4.9 g
	Observed, Actual (.50')	-15.4 g
30.	Actual Occupant Impact Velocity Limit (NCHRP 230)	30 ft/sec
	Observed	0 ft/sec
31.	Head Injury Criteria (HIC)	
	Design Limit	1000
	Driver, Observed	2191
32.	Upper Spine Acceleration Data Acceleration with Duration Greater than .003 sec CSI	82 g's 190
33.	TTI -86 (age=0)	126
34.	Thoracic Injury (age=0) Fatal Injury Probability of:	6.00
	AIS greater than 3	47%
	AIS greater than 4	4%
	AIS greater than 5	0%
35.	Momentum Change from Pole	2,590 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 sixth of a series of eight full scale crash tests to be conducted. The planned and actual test matrix is shown in Table 2.

The vehicle used for this test was a 1980 Plymouth Champ. 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. Rate gyros were also mounted to the accelerometer block to measure the roll and yaw rates. The vehicle also was instrumented with a contact switch mounted on the left door to permit vehicle and occupant data to be measured relative to the time of impact.

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

Table 2

Test Matrix for Side Impact Test Series

<u>Test Number</u>	<u>Angle</u> ¹	<u>Location</u> ²	<u>Article</u> ³
1 (1 actual)	90	0	Slipbase
2 (2 actual)	90	0	T-base
3 (6 actual)	90	+12"	Slipbase
4 (5 actual)	90	-12"	Slipbase
5	90	+6 or +24"	Slipbase
6	90	-6 or -24"	Slipbase
7	60	0	Slipbase
8	120	0	Slipbase
3 actual	90	0	Slipbase
4 actual	90	0	Slipbase

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

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

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

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

Notes:

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

Test number indicates original planned number and actual test numbers used thus far in test program.

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

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

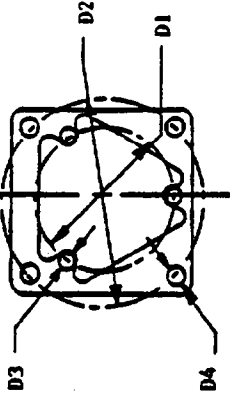
3.0 APPURTENANCE DESCRIPTION

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

Table 3
Properties of Test Pole

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

Manufacturer: Ameron Part No: _____
 Ref. FOIL Tests: _____
 Completed By: C. Brown Date: 7/1/87



HEIGHTS (L#)
 Pole: 275 (W1)
 Mast Arm: 90 (W2)
 Luminaire: 51 (W3)
 Total Assy: 416 (WT)

MEASURED LENGTHS (IN)

Mounting Heights: 36' (H1) No. Slip Bolts: 3
 Pole Heights: 30'3" (H2) Slip BC Dia (in): 14 (D1)
 Pole CB Heights: 12'4" (H6) Dia of Slip Bolts (in): 1 (D3)
 Mast Arm CB Ht: 33'2" (H5) No. Foundation Bolts: 3
 Mast Arm CB Offsets: 6' (L2) Found BC Dia (in): 14 (D2)
 Lumin CB Ht: 35'10" (H4) Dia Found Bolt (in): 1 (D4)
 Lumin CB Offset: 15'9" (L1) S Bolt Clamp Force (lb): 14,000
 Stub Ht: 4.0 (H7) Keeper Plate, Y/Ns: Y

POLE PARAMETERS

Base Dia (in): 7.5 Wall Thick (in): .125
 Tip Dia (in): 3.5 Materials: Steel
 IDIAL_ASSEMBLY_CB_LOCATION (IN): _____
 Total Assy CB Ht = 21' (H3)
 Total Assy CB Offset = 3'4" (L3)

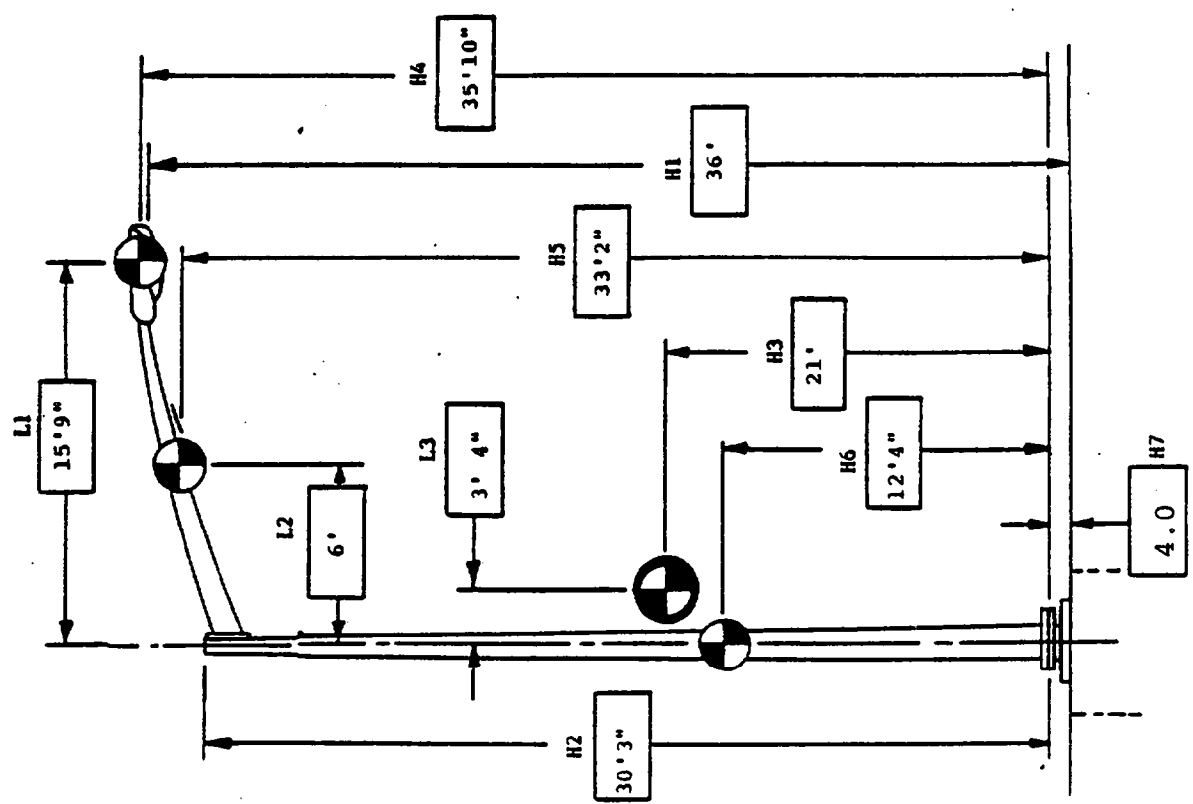


Figure 1. Mechanical Properties of Pole

4.0 VEHICLE DESCRIPTION

The test vehicle was a 1980 Plymouth Champ. The weight of the vehicle prior to incorporating the instrumentation for the test was 1823 lbs. The test inertial weight for the vehicle was 1850 lbs and the gross static weight when the occupant was included in the vehicle was 2010 lbs. The longitudinal center of gravity of the vehicle without the occupant was located approximately 32 inches behind the centerline of the front axle. The weight and inertial data of the vehicle in its as delivered and instrumented configuration are given in table 4. Inertial data was measured using the IMD.

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

Table 4
Cg and Inertial Data for Test Vehicle

Vehicle	1980 Plymouth Champ
Serial Number	IM24JA4912311
Build Date	January 1980
Delivered Weight	1823 lbs
Delivered cg-x	32" behind front axle center line
Delivered cg-y	at vehicle centerline
Delivered cg-z	19.3" above ground
Delivered Roll Inertia	195 slug-ft ²
Delivered Pitch Inertia	755 slug-ft ²
Delivered Yaw Inertia	823 slug-ft ²
As tested weight, inertial	1850 lbs
As tested weight, gross	2010 lbs
As tested cg-x	32" behind front axle centerline
As tested cg-y	at vehicle centerline
As tested cg-z	19.0" above ground
As tested Roll Inertia	201 Slug-ft ²
As tested Pitch Inertia	704 Slug-ft ²
As tested Yaw Inertia	823 Slug-ft ²

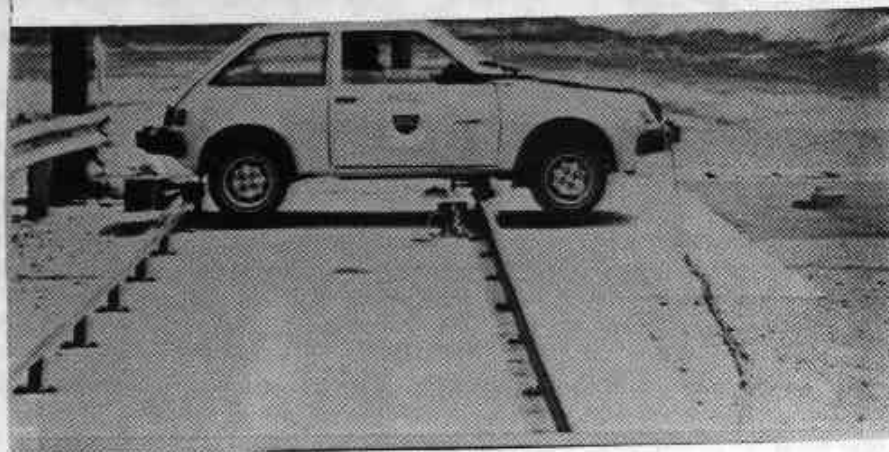


Figure 2. Pre-Test Photos of Vehicle

5.0 TEST INSTRUMENTATION

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

Table 5

Description of Film Data Acquisition System

<u>Camera</u>	<u>Model</u>	<u>Position</u>	<u>Speed Setting</u>	<u>Lens</u>
1	Redlake, Locam	Rt. Side	500 pps	75 mm
2	Redlake, Locam	Rt. Side	500 pps	100 mm
3	Redlake, Locam	Front Rt.	500 pps	20 mm
4	Redlake, Locam	Front Rt.	500 pps	100 mm
5	Redlake, Locam	Front Lt.	500 pps	20 mm
6	Redlake, Locam	Front Lt.	500 pps	100 mm
7	Redlake, Locam	Onboard	500 pps	5.7 mm
8	Redlake, Locam	Overhead	500 pps	12.5 mm
9	Redlake, Locam	Side view	500 pps	5.7 mm
10	Bolex	Documen- tation	24 pps	Zoom

pps - Pictures per second

Table 6
Transducer Data Description

Channel No.	Channel Description
1	Left Lower Rib Accel., LLRYG1
2	Left upper Rib Accel., LURYG1
3	Upper Spine Accel., T0LYG1
4	Upper Spine Accel., T01XG1
5	Upper Spine Accel., T01ZG1
6	Lower Spine Accel, T12XG1
7	Lower Spine Accel, T12YG1
8	Lower Spine Accel, T12ZG1
9	LSTXG1
10	Left Lower Rib Accel., LLRYGA
11	Left Upper Rib, Accel., LURYGA
12	Head Accel, X
13	Head Accel, Y
14	Head Accel, Z
15	Pelvis Accel, X
16	Pelvis Accel, Y
17	Pelvis Accel, Z
18	Vehicle Accel., cg-x
19	Vehicle Accel., cg-y1
20	Vehicle Accel., cg-y2
21	Driver Door, Impact Marker
22	Vehicle c.g., Roll Rate
23	Vehicle c.g., Yaw Rate

6.0 TEST RESULTS

The impact conditions were 28.25 mi/h (12.64 m/s) at a point on the left door 12 inches (0.3 m) forward of the occupant, 16 in (.41 m) behind the longitudinal location of the center of gravity of the vehicle measured without the dummy in the vehicle. The vehicle had a 6.1° 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 36 inches (.91 m). Crush was measured from a straight line cord running from front bumper to rear bumper on the impact side. This was done because the vehicle was bent very severely. Photographs of the vehicle and luminaire support after the collision event are shown in Figure 3.

The vehicle impacted the pole in the desired location, 12 inches forward of the driver's shoulder. The vehicle crushed inward as it slowed. The vehicle stopped without breaking away the pole, thus causing a very large intrusion. The vehicle yawed slightly as it came to a rest. The residual test vehicle crush measured using the 6 point NHTSA guide is given in Table 7. See figure 4 for reference.

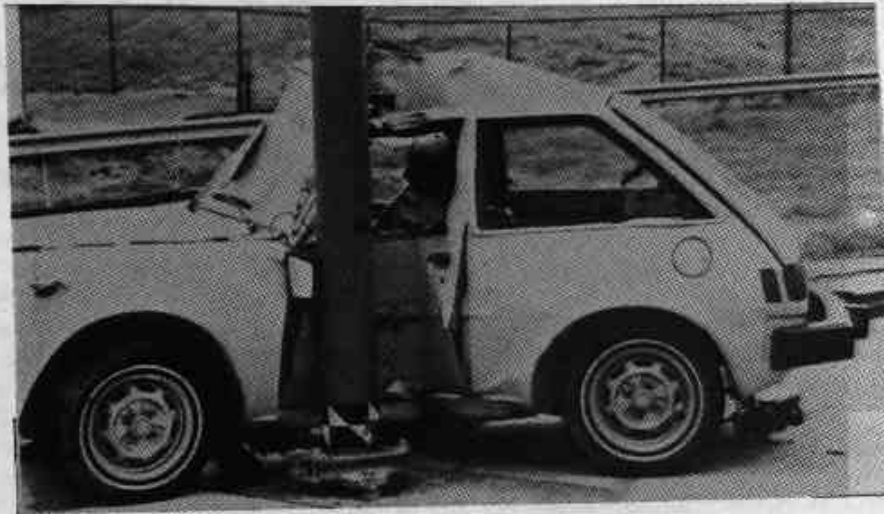


Figure 3. Post-Test Photos of Vehicle



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

Table 7
Residual Vehicle Crush

C1 = 0.0"
C2 = 5.0"
C3 = 12.0"
C4 = 10.0"
C5 = 4.0"
C6 = 0.0"

L = 157"
D = -18.5"
Maximum crush = 36"

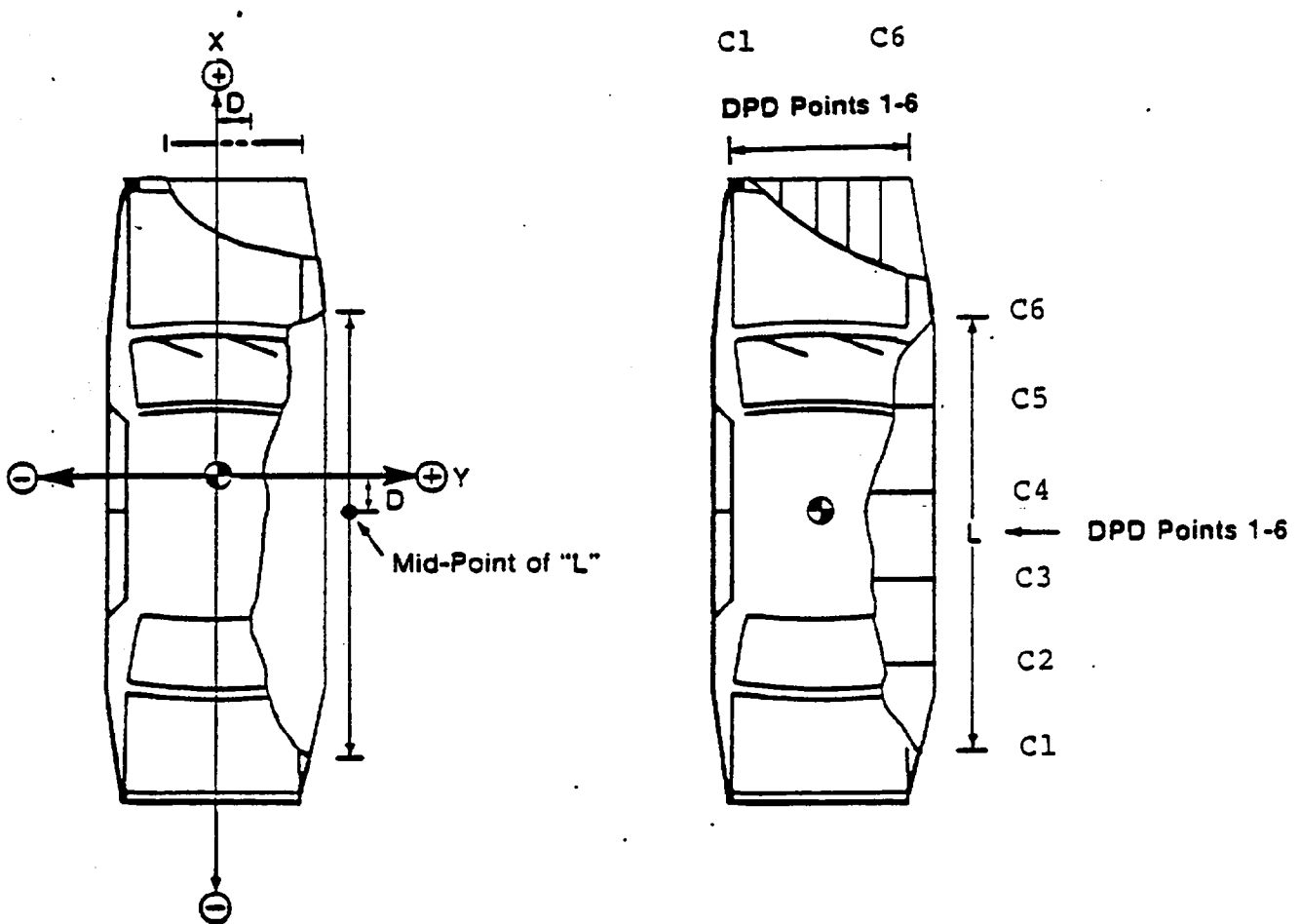


Figure 4. NHTSA Vehicle Damage Measurements

7.0 TEST ANALYSIS

Data from this test were evaluated using several techniques. The pre-impact speed was determined from the high speed film information. The signals from the accelerometers mounted at the center of gravity of the vehicle were terminated during the test due to a loss of power to the data system. This occurred when the violent impact actually warped the vehicle, pulling the wires off the battery. The FOIL accelerometer data was 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.

All data from the dummy was terminated during the test. The partial 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 partial 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 partial data obtained from the accelerometers located on the ribs of the occupant were filtered at SAE Class 180. In addition, thoracic injury parameters associated with side impact conditions were analyzed using NHTSA techniques to determine side impact occupant injury from the partial data traces.

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 8.

Table 8
 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 (mi/h)</u>
1	Right Side	41.4	28.3
2	Right Side	41.5	28.3

A speed trap was installed to measure the speed of the vehicle as it left the end of the mono-rail. During this test the speed trap indicated a speed of 30.3 mph. Assuming a slide distance of 5.5 ft and a coefficient of .8, the scrub off energy is computed to be 9.6 kip ft. Subtracting this from the kinetic energy at the end of the rail and then computing the speed at the end of the slide zone produces an impact speed of 42.2 ft/sec. This is in agreement with the film data and thus confirms the film measurements.

Based upon the results of this analysis, the speed of the vehicle upon impacting the support was 28.25 mi/h (12.64 m/sec).

7.2 ANALYSIS OF VEHICLE MOUNTED ACCELEROMETERS

The data collected from the accelerometers mounted to the vehicle were filtered at SAE Class 60 and 180 per TRC 191 and NCHRP 230 requirements, respectively. The acceleration traces obtained with the use of the SAE Class 60 ($f_c = 100$ Hz) filtering technique are presented in figures A1 and A2. The acceleration traces obtained with the use of the SAE Class 180 ($f_c = 300$ Hz) filtering technique are presented in figures A3 and A4. Figure A5 presents the impact marker channel. Figures A6 and A7 contain the yaw rate gyro data filtered at 100 Hz and 10 Hz (SAE Class 60 and 6). Figures A8 and A9 present similar data plots for the roll gyro. Figures A10 through A20 present the FOIL acceleration and gyro data. These transducers were mounted to the front passenger seat floor panel.

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 36.5 ft/sec and 2280 lb-sec, respectively. This does not account for the tire sliding forces since the accelerometer signal was debiased during the slide zone. The approximate change in velocity due to the sliding is 2.5 ft/sec. Thus the overall velocity change and momentum change of the vehicle due to the pole and tire sliding are 39 ft/sec and 2430 lb-sec. This is slightly lower than the impact velocity and is probably due to the severe bending of the vehicle distorting the signal.

Analysis of the impact velocity of a hypothetical front seat passenger against the vehicle interior, calculated from the vehicle lateral Class 180 acceleration yielded the results shown in Table 9. Using the standard one foot flail distance, a hypothetical front seat occupant would have impacted the interior of the vehicle in the lateral direction at an approximate impact velocity of 28.8 ft/sec (8.8 m/s) based upon data filtered at SAE Class 180. This lateral impact velocity is outside the design limit of 20 ft/sec (6.10 m/s) specified for other forms of highway safety appurtenances in NCHRP 230.

The highest ridedown acceleration after the hypothetical front seat passenger impacted the interior of the vehicle was 4.9 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.

Table 9

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

<u>Flail Distance</u>	<u>Change in Velocity (ft/sec)</u>	<u>Ride Down Acceleration (g's)</u>
1.0 ft	-28.8	-4.9
.50 ft	-22.1	-15.4

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

7.3 LUMINAIRE TEST OBSERVABLES

The luminaire did not break away and thus there are no data to report.

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 first portion of 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 A21 through A24. The results of the HIC evaluation conducted on the partial data trace for the occupant during this test is shown in table 10. Comparing the results to the acceptable limit of 1000 indicates that the collision event could have been serious.

Table 10
Head Injury Criteria

	<u>Driver</u>
HIC	2191*
t(Start)	.04513 sec
t(Stop)	.06262 sec
t(Duration)	.0175 sec

*Note: Evaluated on a partial data trace. Stop time is same as end of data.

7.5 OCCUPANT SEVERITY INDEX EVALUATION

The partial data obtained from the triaxial accelerometer packages located in the upper spine (T01), lower spine (T12) pelvis, all left ribs and the sternum were filtered at SAE Class 180. The T01, T12 and pelvis data was combined to yield a partial resultant acceleration occurring during the impact event. The severity index for each 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 (T01) was selected to evaluate chest parameters since it was the closest data to the location of standard chest accelerometers. The CSI was 190 and the maximum acceleration was 82 g's at 30.1 milliseconds for the partial data trace. These results should not be compared directly with the design limits for the severity index of 1000 and sustained acceleration level of 60g specified in FMVSS 208 since none of the accelerometers are located at the center of gravity of the upper thorax location. The CSI and max acceleration in the partial data traces for the pelvis was 2945 and 158 g's at 26.4 msec. The T12 data produced a CSI of 1017 and a maximum acceleration of 127 at 31.2 milliseconds.

The acceleration traces and associated resultants obtained with the use of the SAE Class 180 ($f_c = 300$ Hz) filtering techniques are presented in Figures A25 through A28 for the upper spine

(T01) location, Figures A29 through A32 for the lower spine (T12) location, Figures A33 through A36 for the pelvis and Figure A37 for the sternum location. 300 Hz data traces for the rib accelerometers are presented in Figures A38 through A41.

7.6 THORACIC INJURY EVALUATION

The data obtained from the accelerometers mounted at the T01Y, T12Y, LLRY and LURY location within the thorax of the occupant was filtered using NHTSA FIR filter and presented in Figure A42 through A47.

The Thoracic Trauma Index (TTI-86) was computed using the following relationship:

$$TTI_{86} = 1.4 * \text{Age} + .5 * (\text{T12Y} + (\text{Max of LURY or LLRY})) * (\text{Mass}/165)$$

The Age was assumed to be 0 and the Mass 165. The following peak data was determined from the FIR filtered data:

T12Y	-	101 g's
LURYG1	-	117 g's
LURYGA	-	127 g's
LLRYG1	-	133 g's
LLRYGA	-	171 g's

The two sets of rib data points were averaged together to obtain 122 g's for upper the rib and 152 for the lower rib. The maximum of these was then averaged with the T12Y to obtain the TTI. The TTI-86 age = 0 index is 126. The TTI-86 was also evaluated for ages 23 and 41. The TTI-86 value for these ages are 158 and 183. The matrix of AIS values for the three TTI-86 values are presented in Table 11. See Figure 5 for TTI - 86 values.

TABLE 11
Matrix of AIS vs TTI - 86 Values

AGE	TTI -86	Probability of Injury		
		AIS 3+	AIS 4+	AIS 5+
0	126	47%	4%	0%
23	158	82%	34%	3%
41	183	93%	77%	7%

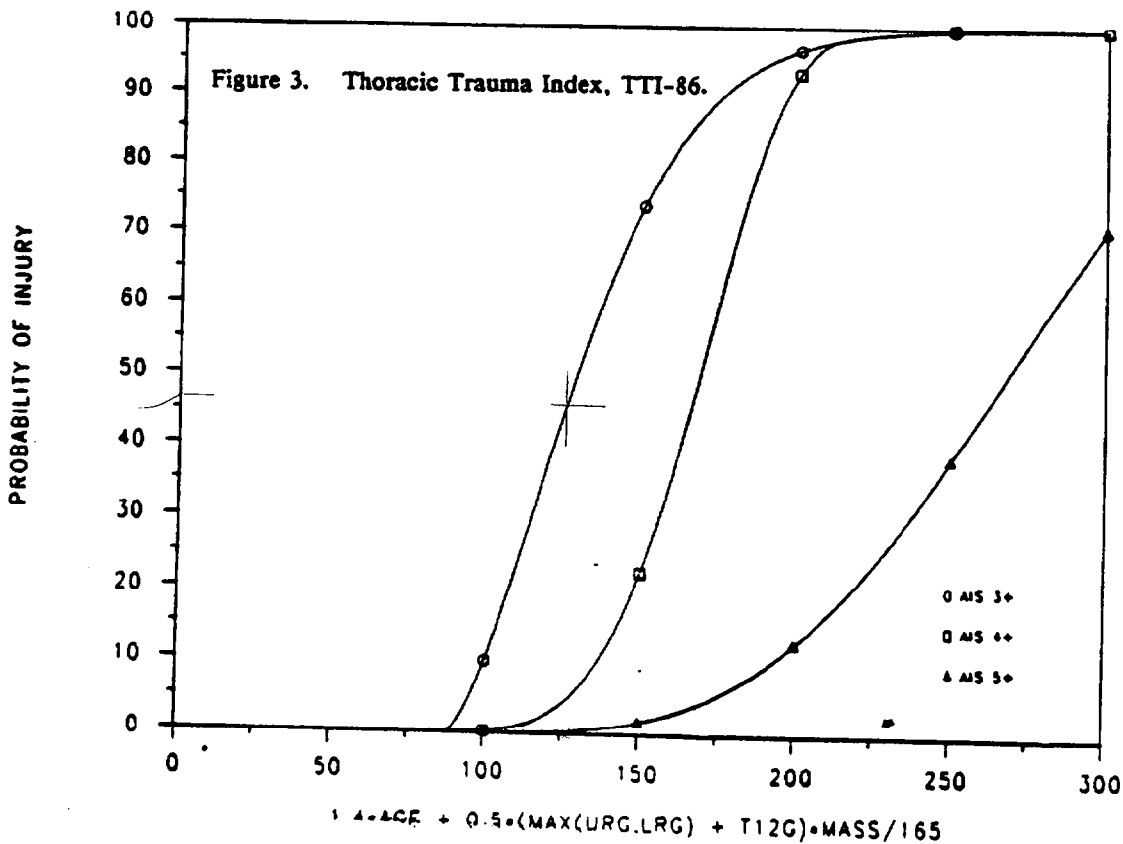


Figure 5. Thoracic Trauma Index-86 Scale

7.7 VEHICLE ENERGY BALANCE

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

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

Impact Energy:

$$KE_I = .5MV_I^2$$

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

V = Impact speed = 41.4 ft/sec

$$KE = 53.4 \text{ kip-ft}$$

Post Impact Energy Sources

1) Exit kinetic Energy

$$KE_E = .5MV_E^2$$

Vehicle stopped thus no exit energy.

$$KE_E = 0$$

2) Rotational energy of vehicle

Rotational Energy of vehicle

$$RE_V = .5 I_V W_V^2$$

Where: I_V = Yaw inertia of vehicle = 823 slug ft²

$\Rightarrow W_V$ = rotational rate

= 190/57.3 rad/sec (see Figure A16)

= 3.3

$$RE_V = 4.5 \text{ kip-ft}$$

3) Work done on crushing vehicle.

In test 1469-SI#3-85 a Dodge Colt was impacted into a rigid pole. The force-displacement characteristic was measured during that test. This data was used to determine the work done on the side of crush depth. This is shown in Figure 6. The data has a maximum crush of 29 inches. This curve was extrapolated to 36" to determine the work at that point.

Work at 36" crush = 30.0 kip-ft

4) Tire friction

Work = fWd

Where f = tire sliding friction = .8

W = vehicle weight = 2007 lbs

d = 3 ft (vehicle travel distance after contact)

Tire work = 4.8 kip-ft

5) Slip base work

The slip base did not release thus no energy was consumed.

Base work = 0 kip-feet

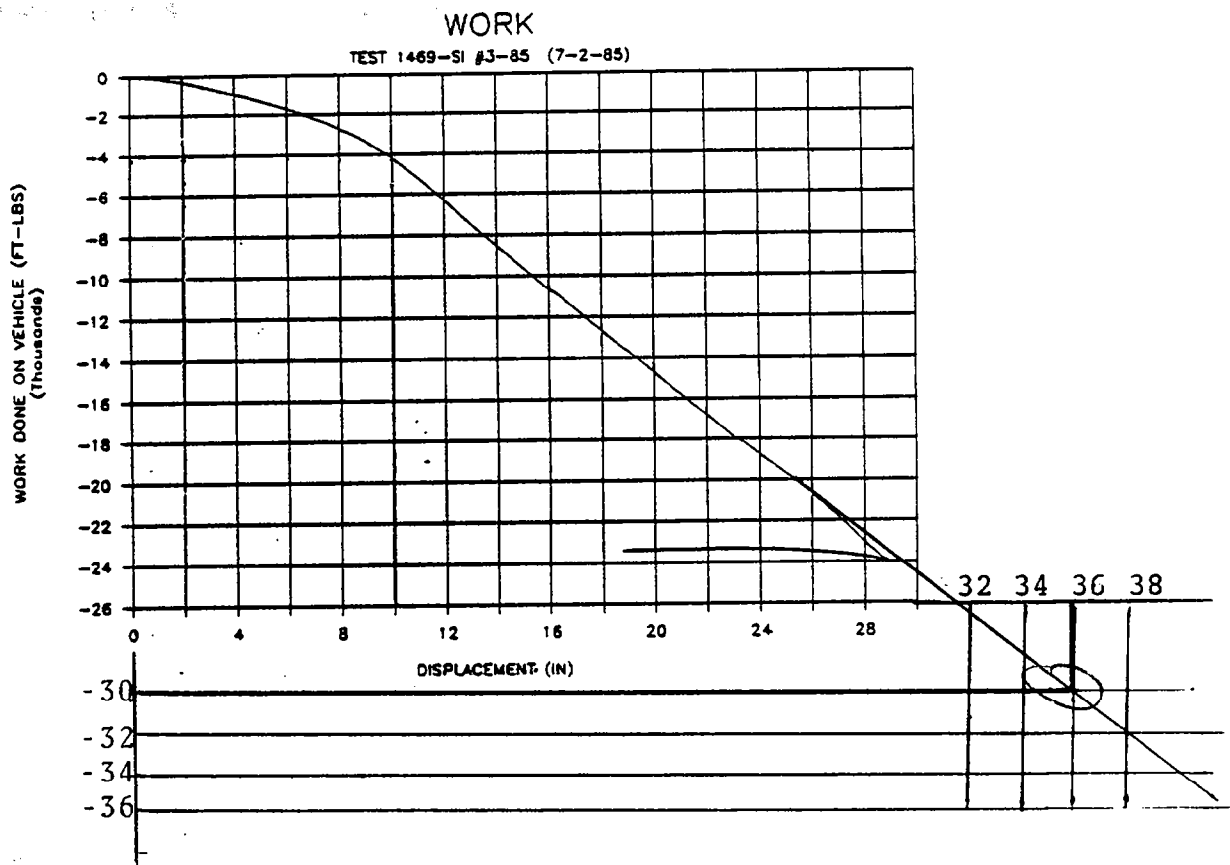


Figure 6. Crush Energy for Dodge Colt During Side Impact

6) Rotational energy of pole

The pole did not release, thus there was no rotational energy

$$KE_{PR} = 0 \text{ kip-ft}$$

7) Translational energy of pole

The pole did not release, thus there was no translational energy.

$$KE_{PT} = 0 \text{ Kip-ft}$$

Totaling the post impact sources the following is determining:

1. 0 kip-ft
2. 4.5 kip-ft
3. 30.0 kip-ft
4. 4.8 kip-ft
5. .0 kip-ft
6. 1.0 kip-ft
7. .0 kip-ft

Total 39.3 kip-ft

This is in fair agreement with the energy upon impact of 53.4 kip-ft. Some of the remaining energy went into actually bending the entire vehicle about the impact point. Also the force-deflection curve may not be linear in the area where it was projected.

8.0 SAFETY ASSESSMENT OF TEST

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

STRUCTURAL ADEQUACY

The test pole did not activate causing the vehicle to stop. There was severe penetration of the passenger compartment (approximity 1/2 of the car) due to the fact that the pole did not release. No undue hazard was generated to other traffic.

OCCUPANT RISK

Occupant risk is rated as very severe. This was due to the impact location of the pole on the vehicle causing high lower body occupant injury predictors.

The NCHRP 230 flail space model data was evaluated and found to be at the limit values. The flail space model was designed to predict injury in cases where no intrusion occurs near the occupant. The NCHRP 230 flail space data indicated a marginally safe test.

VEHICLE TRAJECTORY

There was no post test trajectory.

OVERALL RATING

This pole/vehicle combination with the discussed impact conditions would have to be rated unacceptable due to failure of the pole base to activate and allow the pole to break away.

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> $\frac{\text{Occupant Impact Velocity-fps}}{\frac{\text{Longitudinal}}{40/F_1} \quad \frac{\text{Lateral}}{30/F_2}}$ <p>and vehicle highest 10 ms average accelerations subsequent to instant of hypothetical passenger impact should be less than:</p> $\frac{\text{Occupant Ridedown Accelerations—g's}}{\frac{\text{Longitudinal}}{20/F_3} \quad \frac{\text{Lateral}}{20/F_4}}$ <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 7. NCHRP 230 Safety Evaluation Guidelines

9.0 REFERENCES

1. "Side Impact Test Plan", Rev. 1, J. Hinch, FHWA Contract DTFH61-86-2-00047, November 86.
2. "Test Results Report, Bogie Testing," Task G, Hinch, J.A., Manhard, G. A., and Owings, R. P., Contract DTFH61-81-C-00036, July 1985
3. "Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances," National Cooperative Highway Research Program Report 230, March 1981.
4. "Recommended Procedures for Vehicle Crash Testing of Highway Appurtenances," Transportation Research Circular 191, February 1978.
5. "Occupant Crash Protection in Passenger Cars, Multipurpose Passenger Vehicles, Trucks and Buses," Code of Federal Regulations, Title 49, Transportation, Part 571, Motor Vehicle Safety Standard No. 208.
6. "Vehicle Damage Scale for Traffic Accident Investigators," Traffic Accident Data Project Technical Bulletin No. 1, National Safety Council, 1971.
7. "Collision Deformation Classification," Recommended Practice J224a, Society of Automotive Engineers, New York, February 1971.
8. "Human Tolerance To Impact Conditions As Related to Motor Vehicle Design," Information Report J885a, Society of Automotive Engineers, New York, December 1966.
9. "Standard Plans," California Department of Transportation, January 1981, pp. 209.
10. "Dynamic Crash Test Information Reference Guide," Version II, Automated Sciences Group, Inc., Silver Spring, Maryland, January 1, 1982.
10. "Instrumentation for Impact Tests," Recommended Practice J211b, Society of Automotive Engineers, New York, December 1974.
12. "Safer Sign and Luminaire Supports," Owings, R. P., et al, Final Report, ENSCO, Inc., Contract No. DOT-FH-11-8118, October 1975.
13. "Development of Dummy and Injury Index for NHTSA's Thoracic Side Impact Protection Research Program," R. Eppinger, J. Marcus, and R. Morgan, SAE Report No. 840885.

14. "Update of the NHTSA Research Activity in Thoracic Side Impact Protection for the Front Seat Occupant", Hackney, J. et al. SAE Report 872207

APPENDIX A

DATA PLOTS

ENSOO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 18 VEHICLE X
 FILTER CUTOFF FREQ. 100 PEAKS -6.40 , +9.0

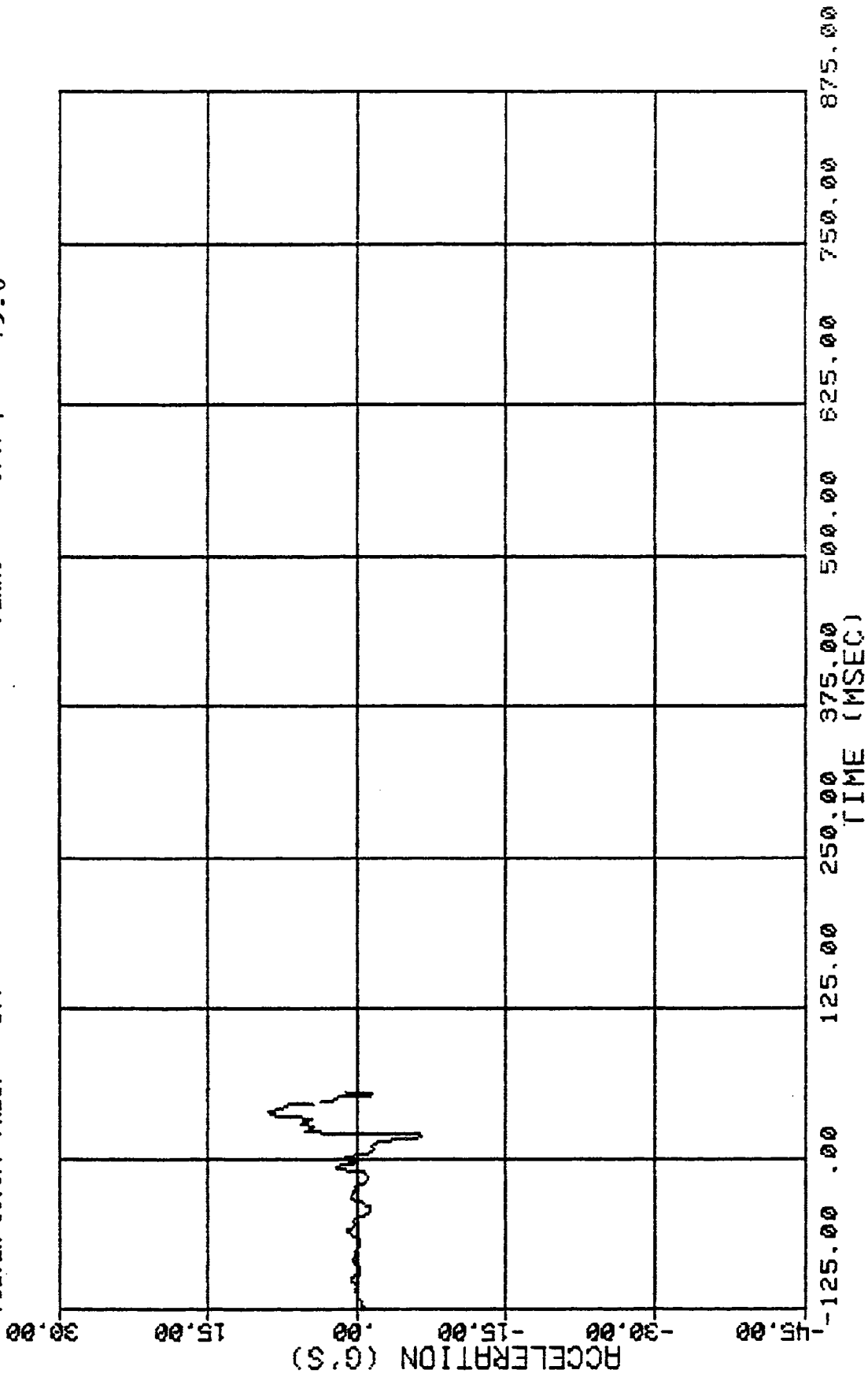


Figure A1. Vehicle X Acceleration, 100 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 19 VEHICLE Y
 FILTER CUTOFF FREQ. 100 PEAKS -21.02 2.6

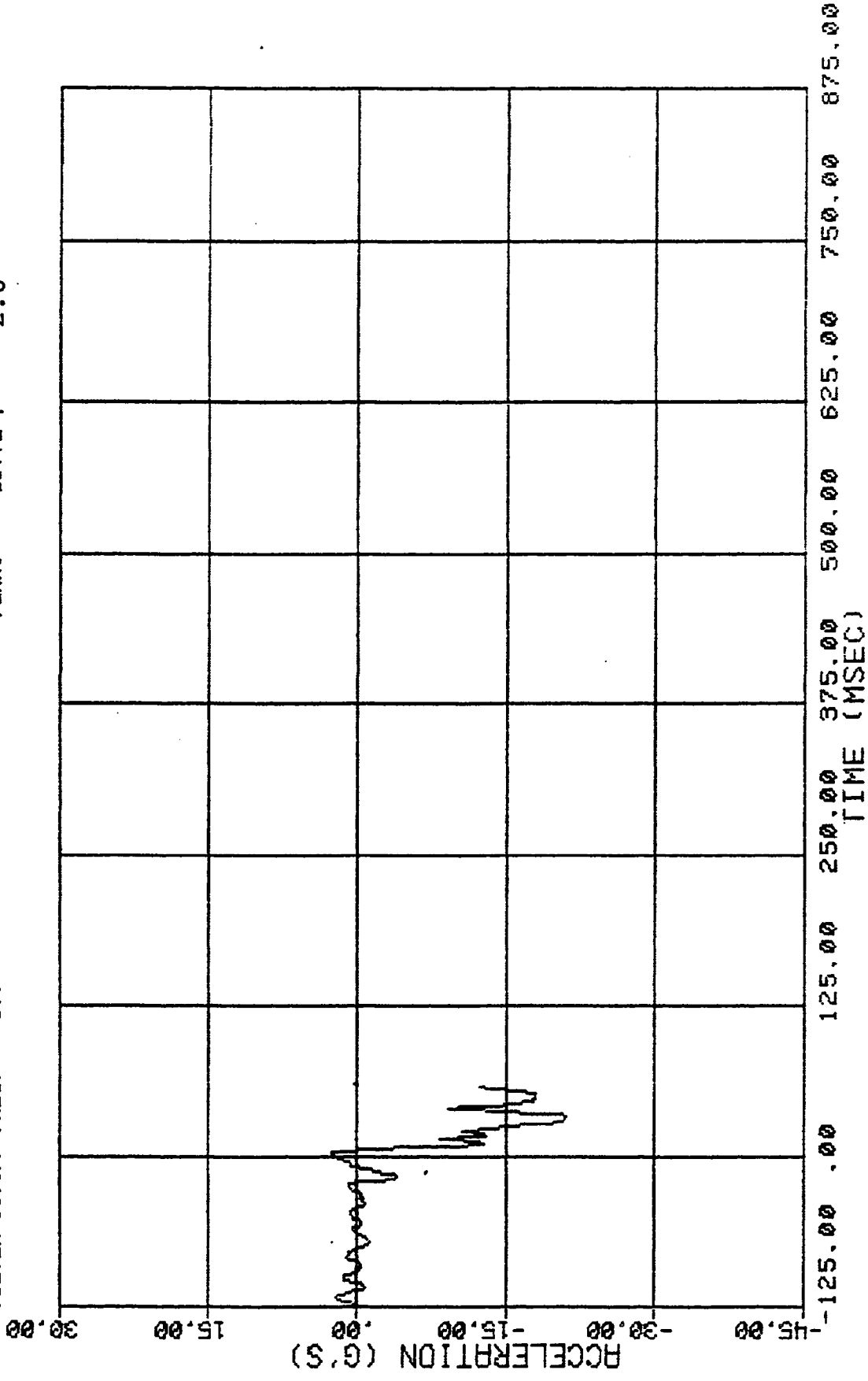


Figure A2. Vehicle Y Acceleration, 100 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 18 VEHICLE X
 FILTER CUTOFF FREQ. 300 PEAKS -23.29 , 16.2

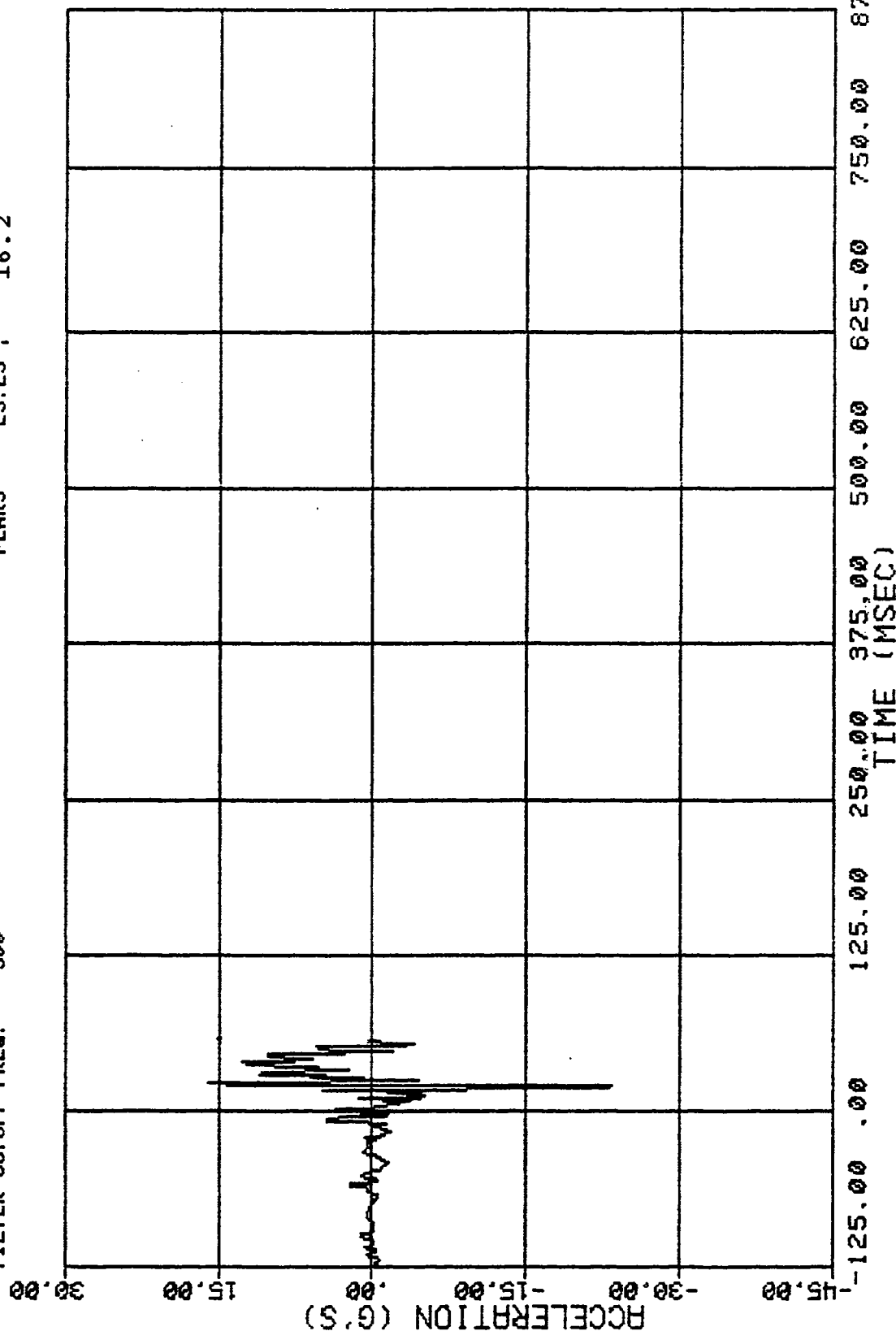


Figure A3. Vehicle X Acceleration, 300 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-86-3-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 13 VEHICLE Y
 FILTER CUTOFF FREQ. 300 PEAKS -31.00 , 13.23

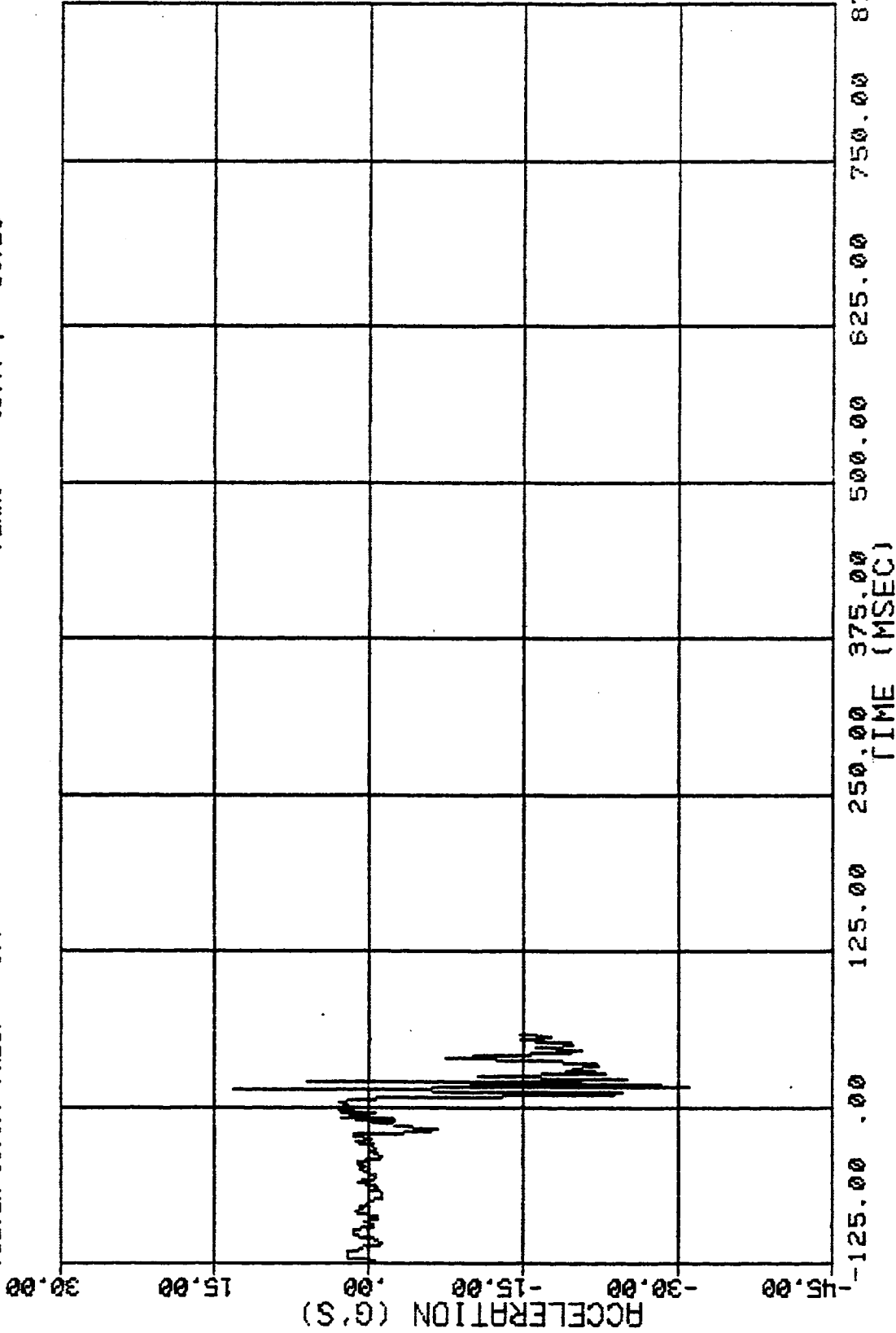


Figure A4. Vehicle Y Acceleration, 300 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-S1-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 21 IMPACT MARKER
 FILTER CUTOFF FREQ. 1650 PEAKS -0.23 , 3.95

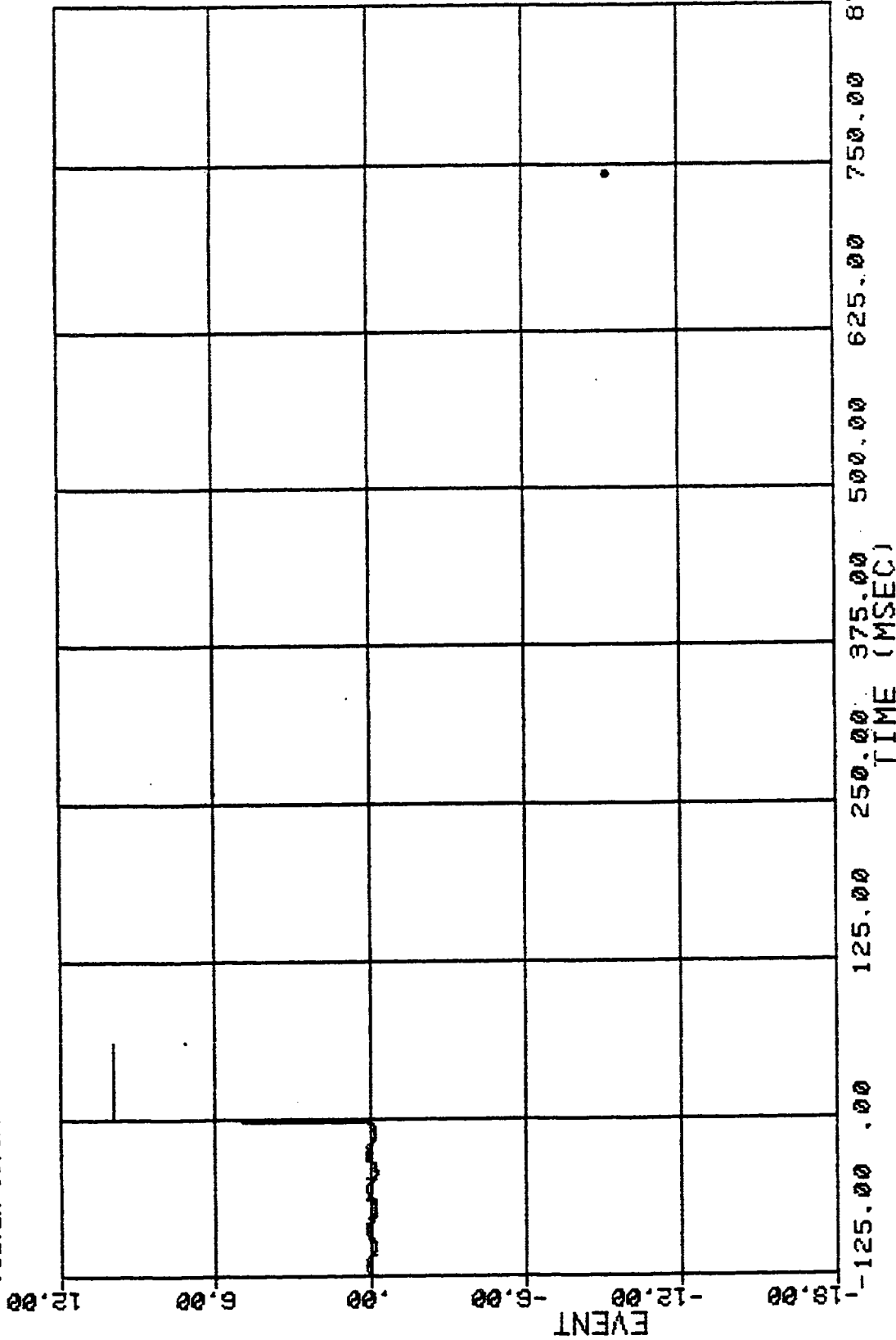


Figure A5. Vehicle Impact Marker

ENSOO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 23 VEHICLE YAW RATE
 FILTER CUTOFF FREQ. 100 PEAKS -64.96 , 403.45

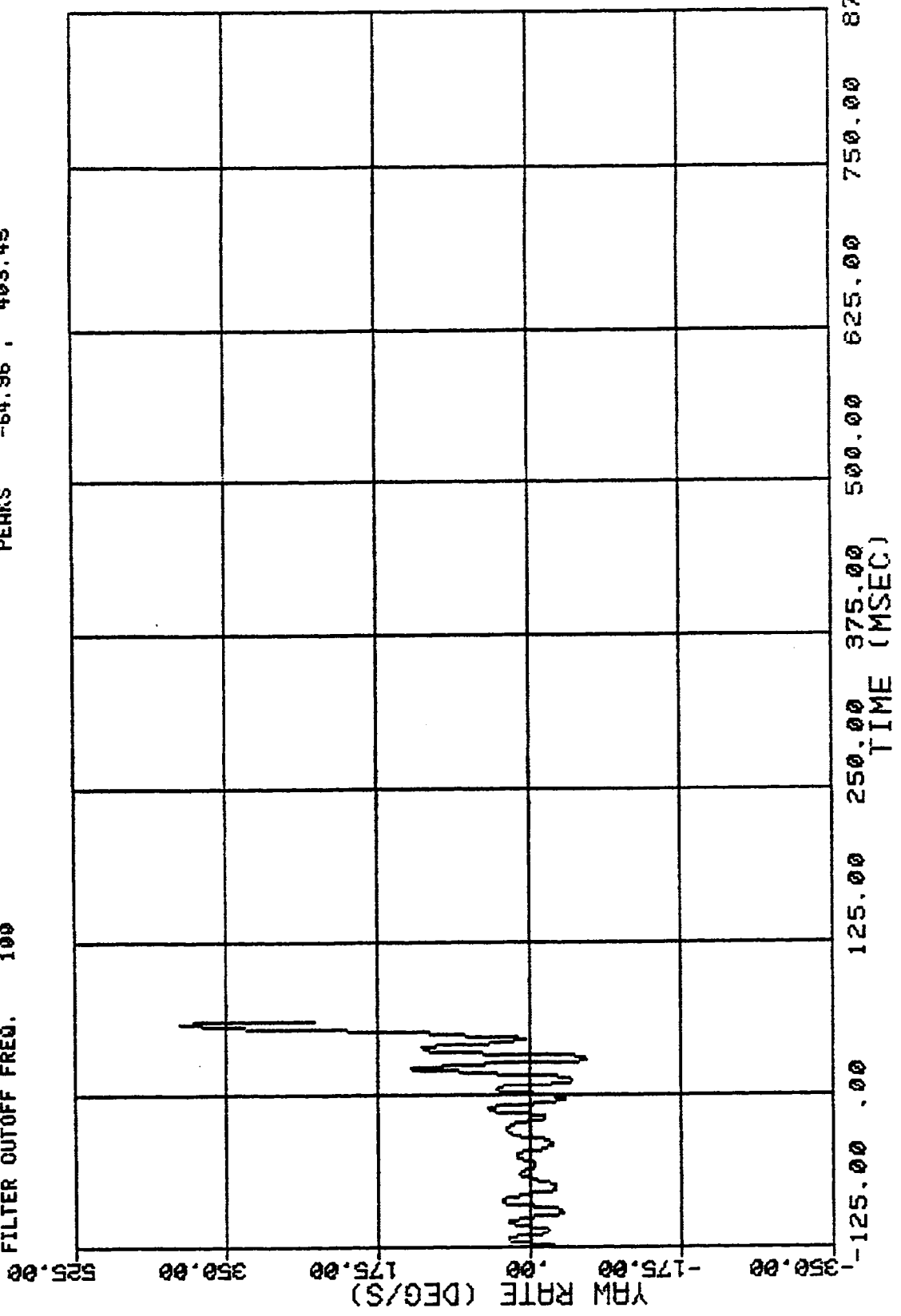


Figure A6. Vehicle Yaw Rate, 100 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 23 VEHICLE YAW RATE
 FILTER CUTOFF FREQ. 10 PEAKS -122.34 , 45.21

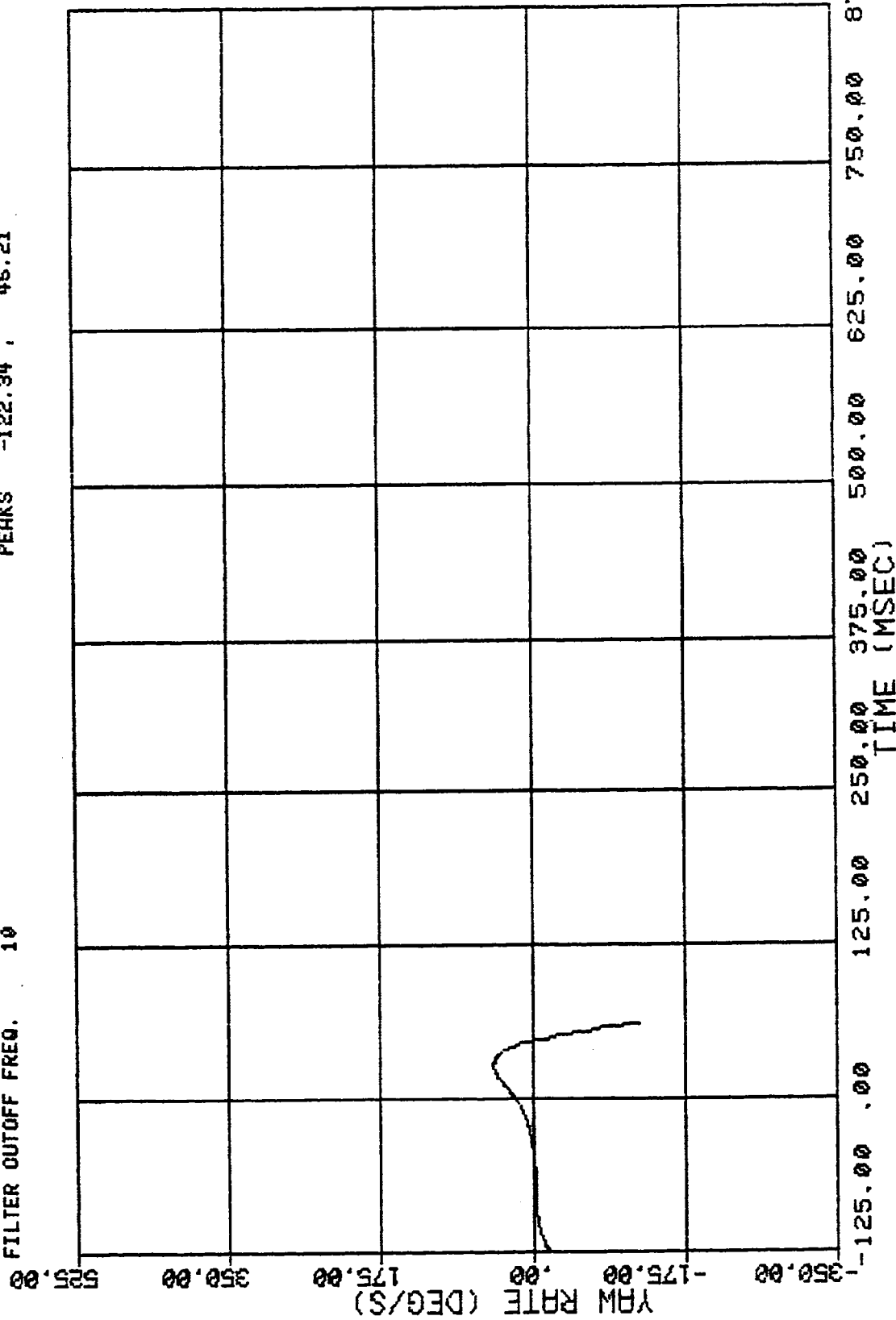


Figure A7. Vehicle Yaw Raw, 10 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-66-Z-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CRAMP INTO LUMINAIRE SUPPORT
 CHANNEL 22 VEHICLE ROLL RATE
 FILTER CUTOFF FREQ. 100 PEAKS -242.04 , 319.77

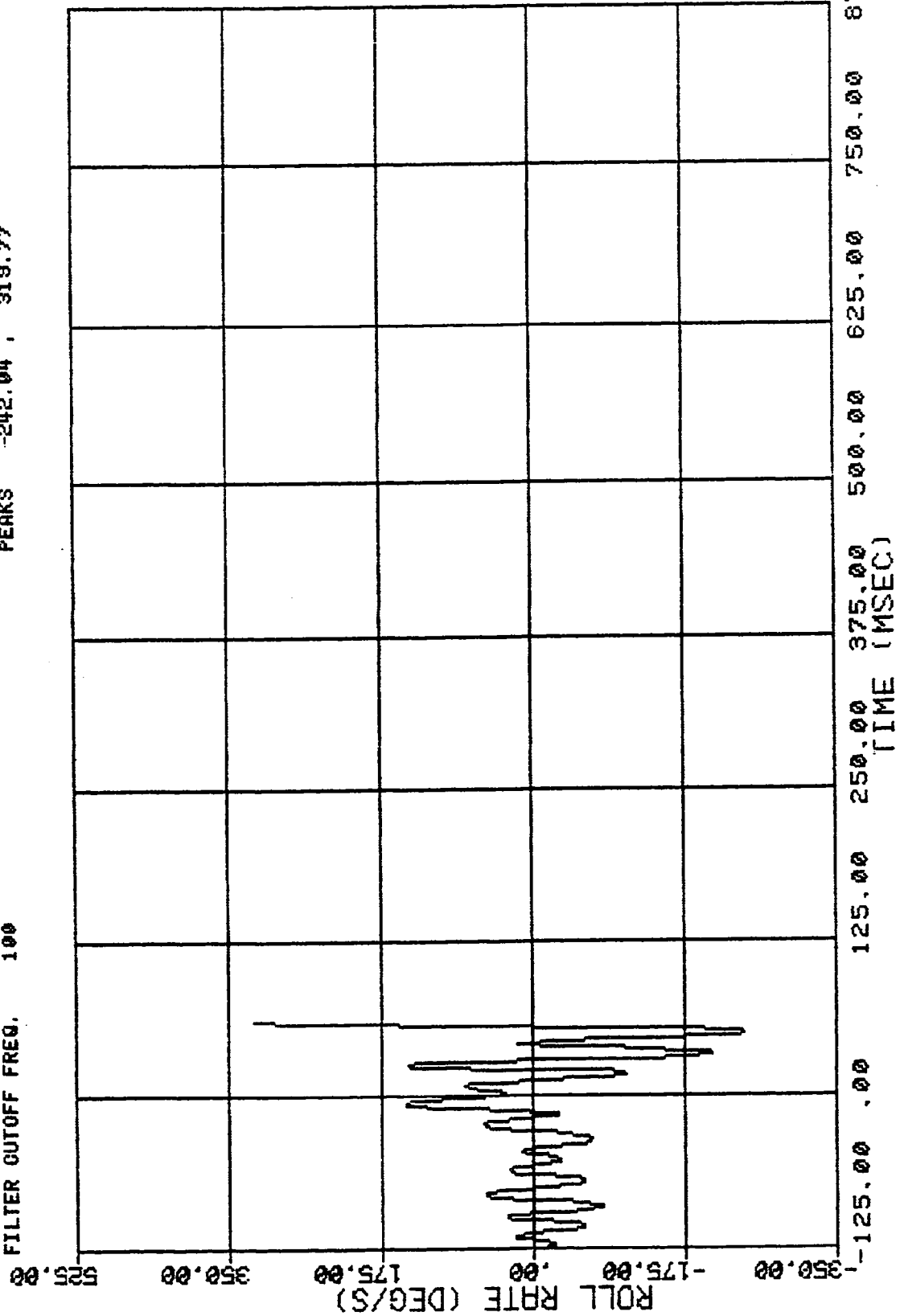


Figure A8. Vehicle Roll Rate, 100 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 22 VEHICLE ROLL RATE
 FILTER CUTOFF FREQ. 10 PEAKS -24.26 , 183.13

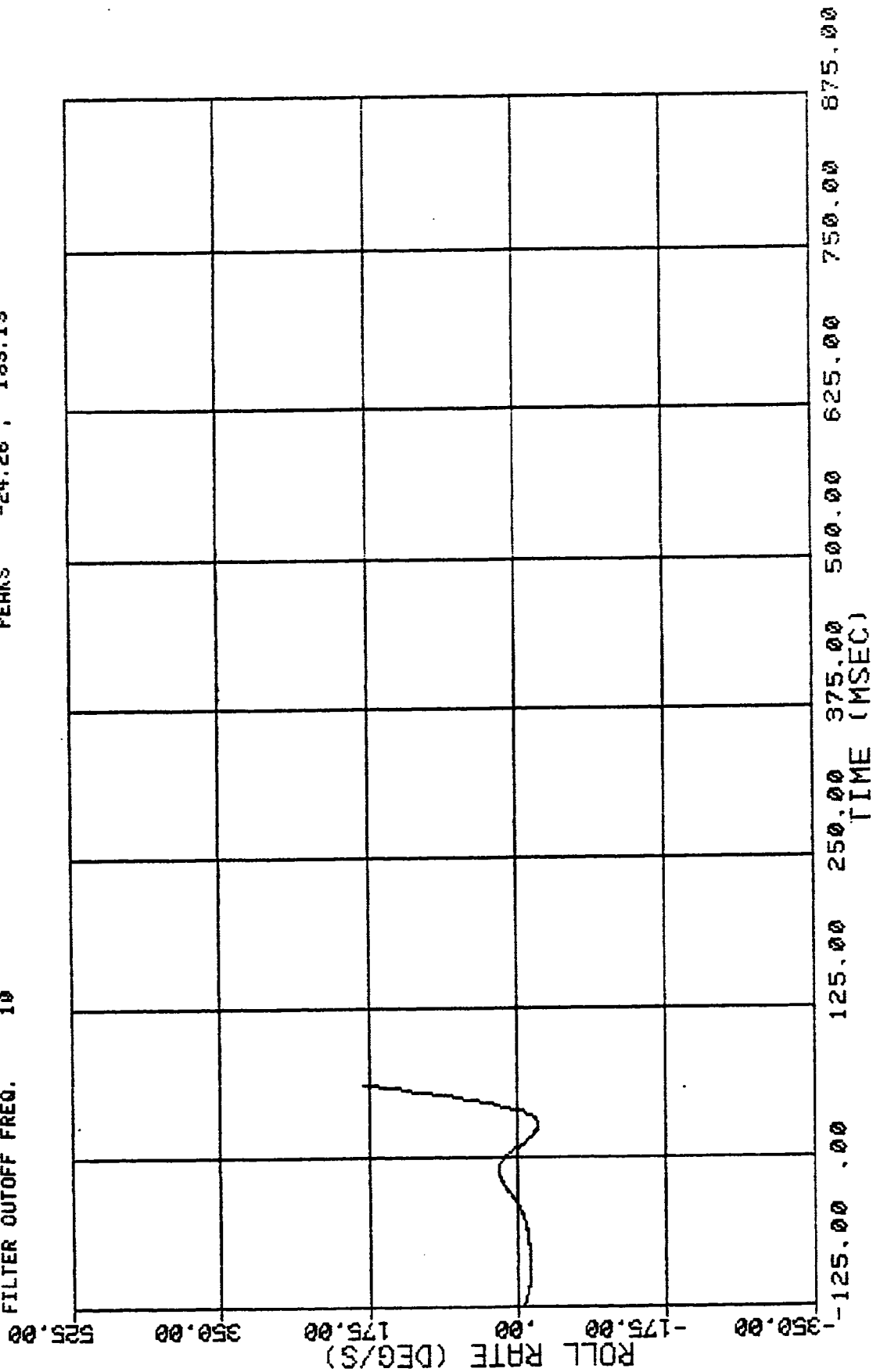
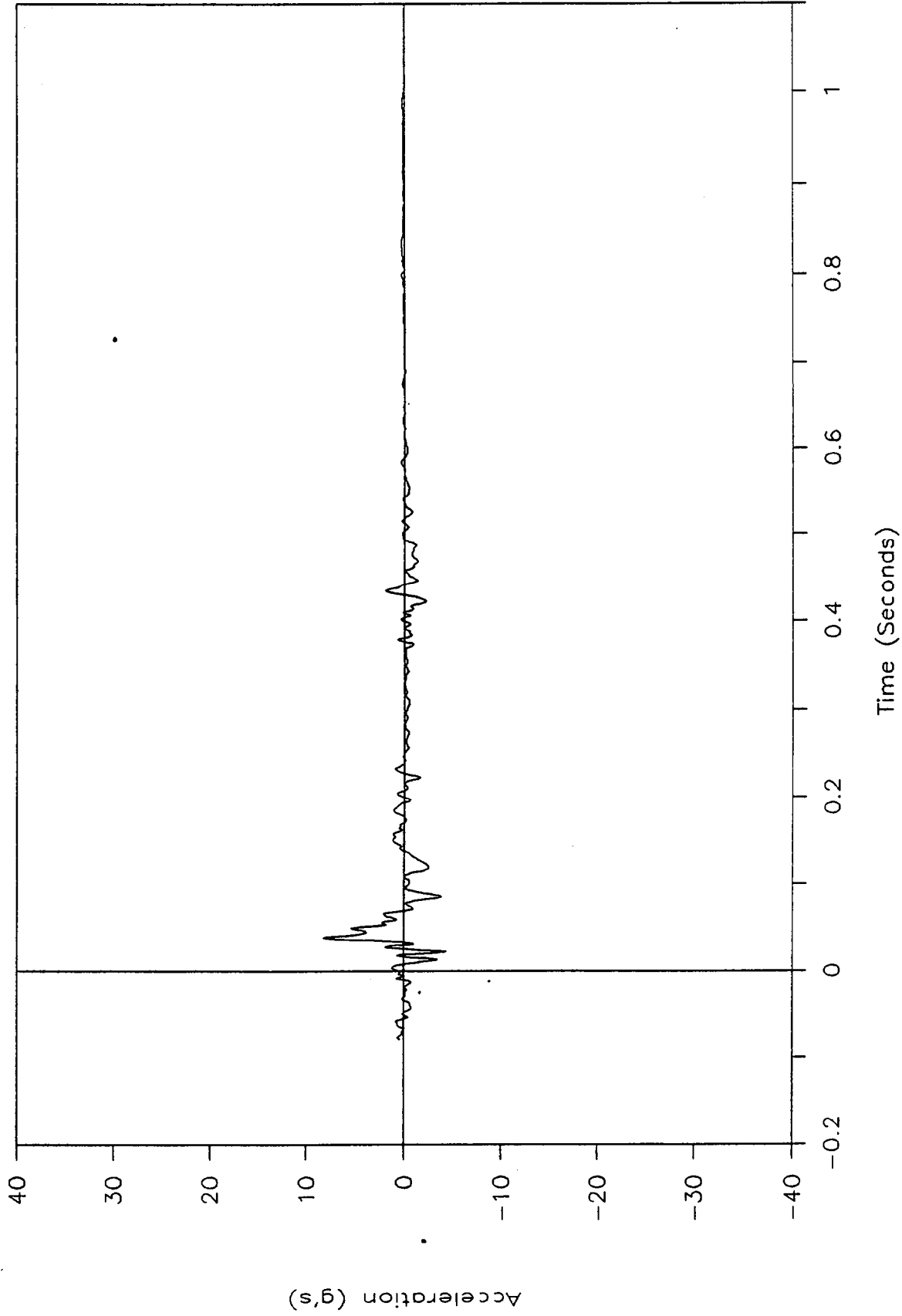


Figure A9. Vehicle Roll Rate, 10 Hz

Vehicle X-Axis Acceleration - 100 Hz

88S006

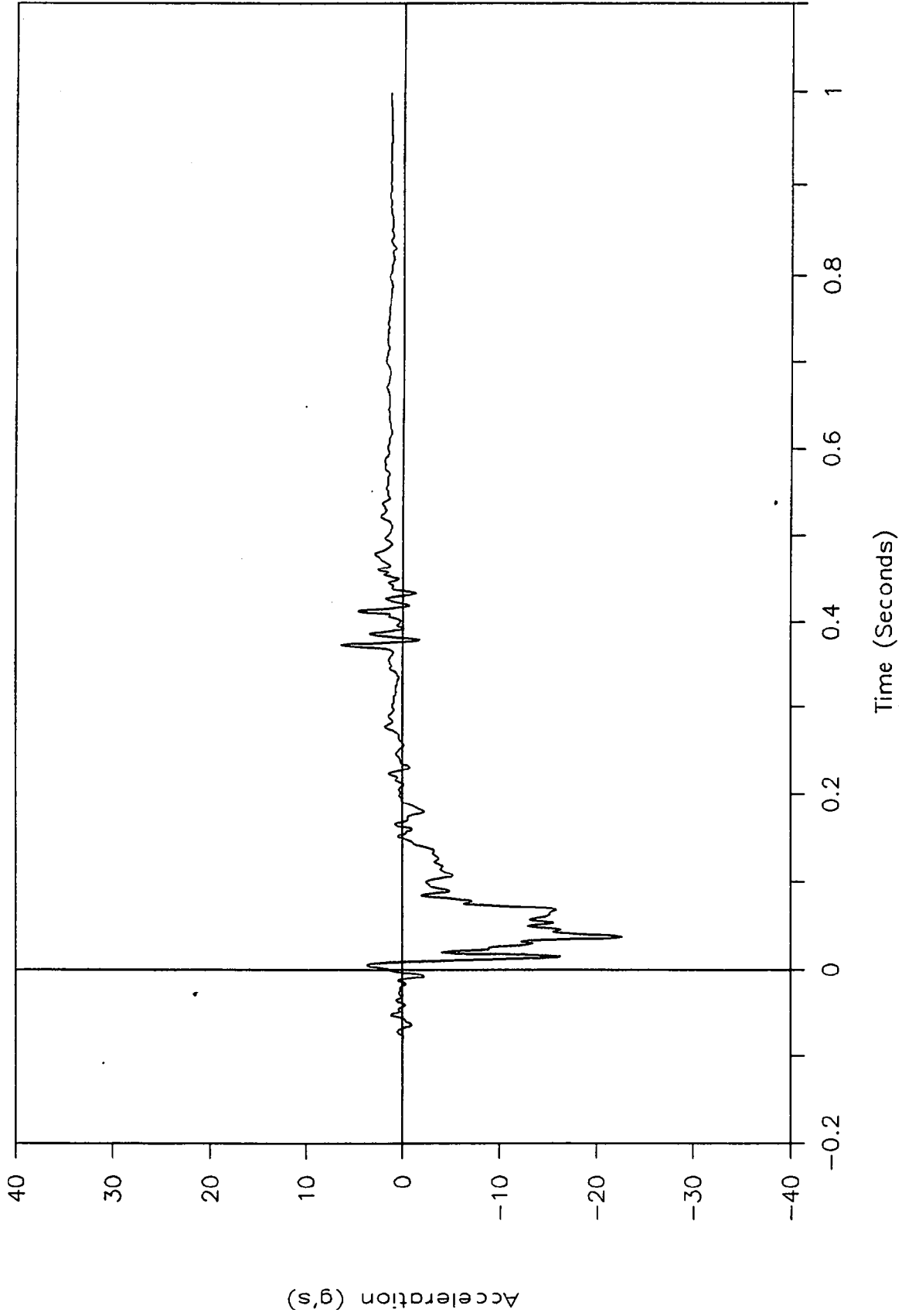


A10

Figure A10. FOIL Vehicle X Acceleration, 100 Hz

Vehicle Y-Axis Acceleration - 100 Hz

88S006

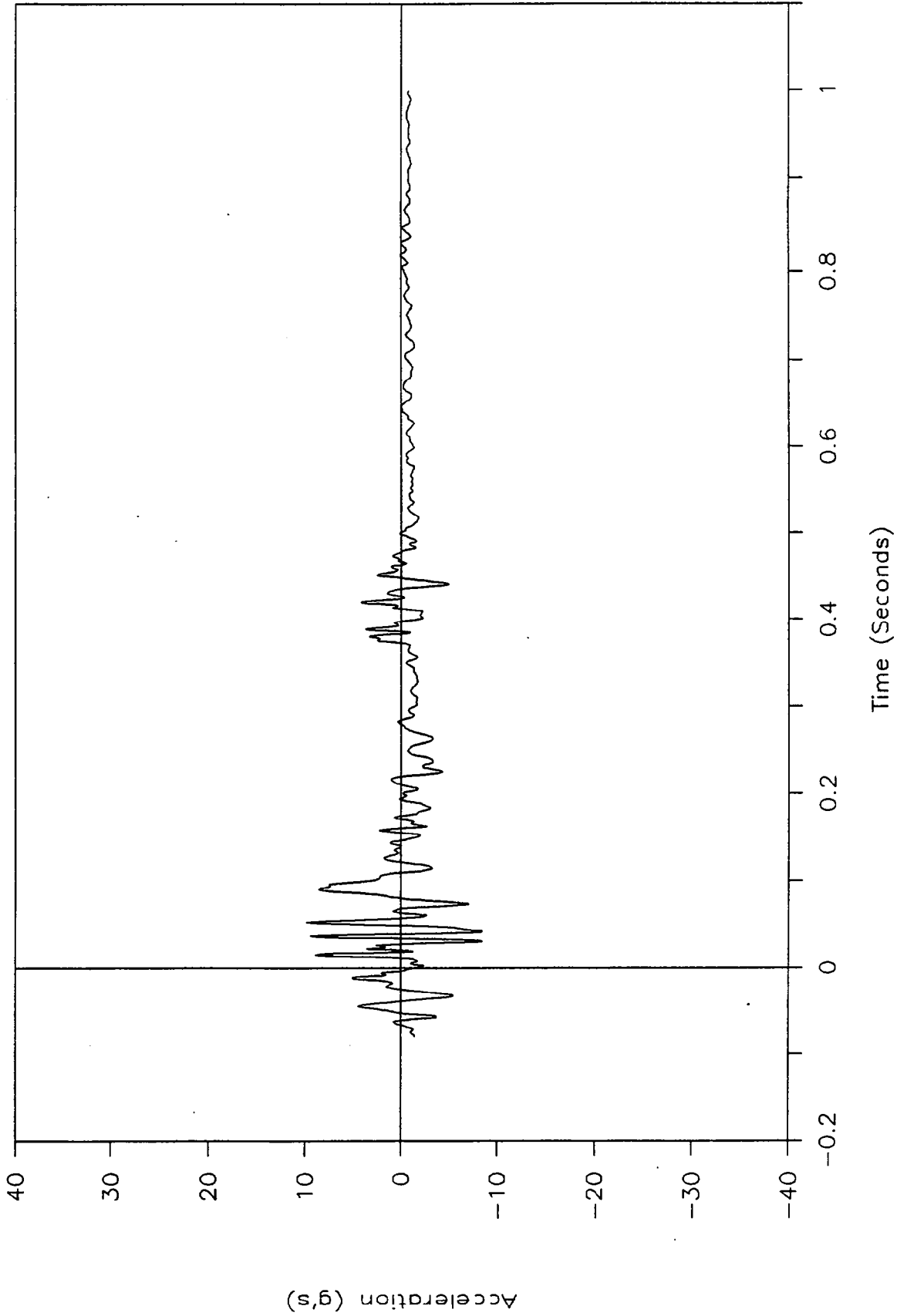


A11

Figure A11. FOIL Vehicle Y acceleration, 100 Hz

Vehicle Z-Axis Acceleration - 100 Hz

88S006

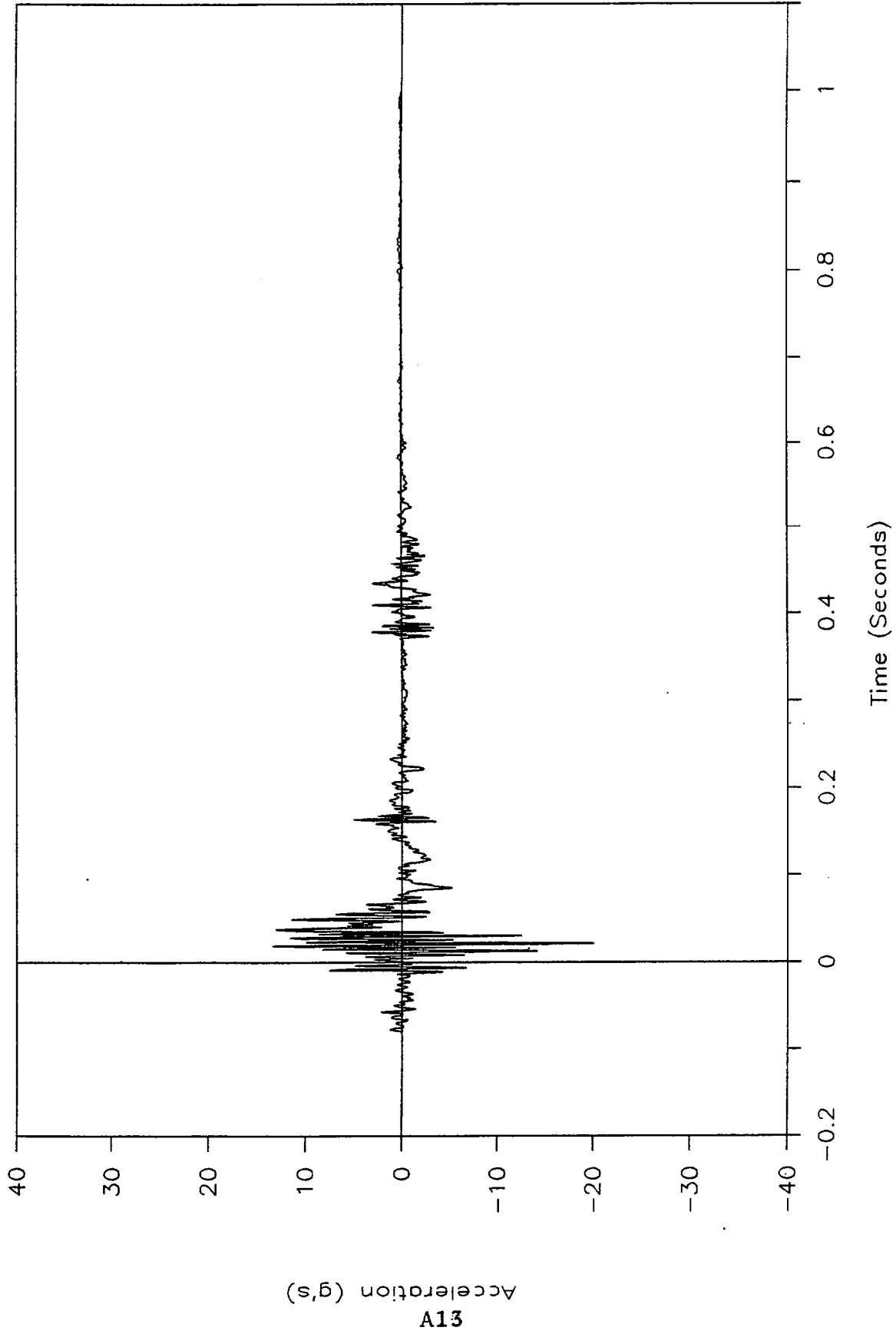


A12

Figure A12. FOIL Vehicle Z Acceleration, 100 Hz

Vehicle X-Axis Acceleration - 300 Hz

88S006



A13

Figure A13. FOIL Vehicle X Acceleration, 300 Hz

Vehicle Y-Axis Acceleration - 300 Hz

88S006

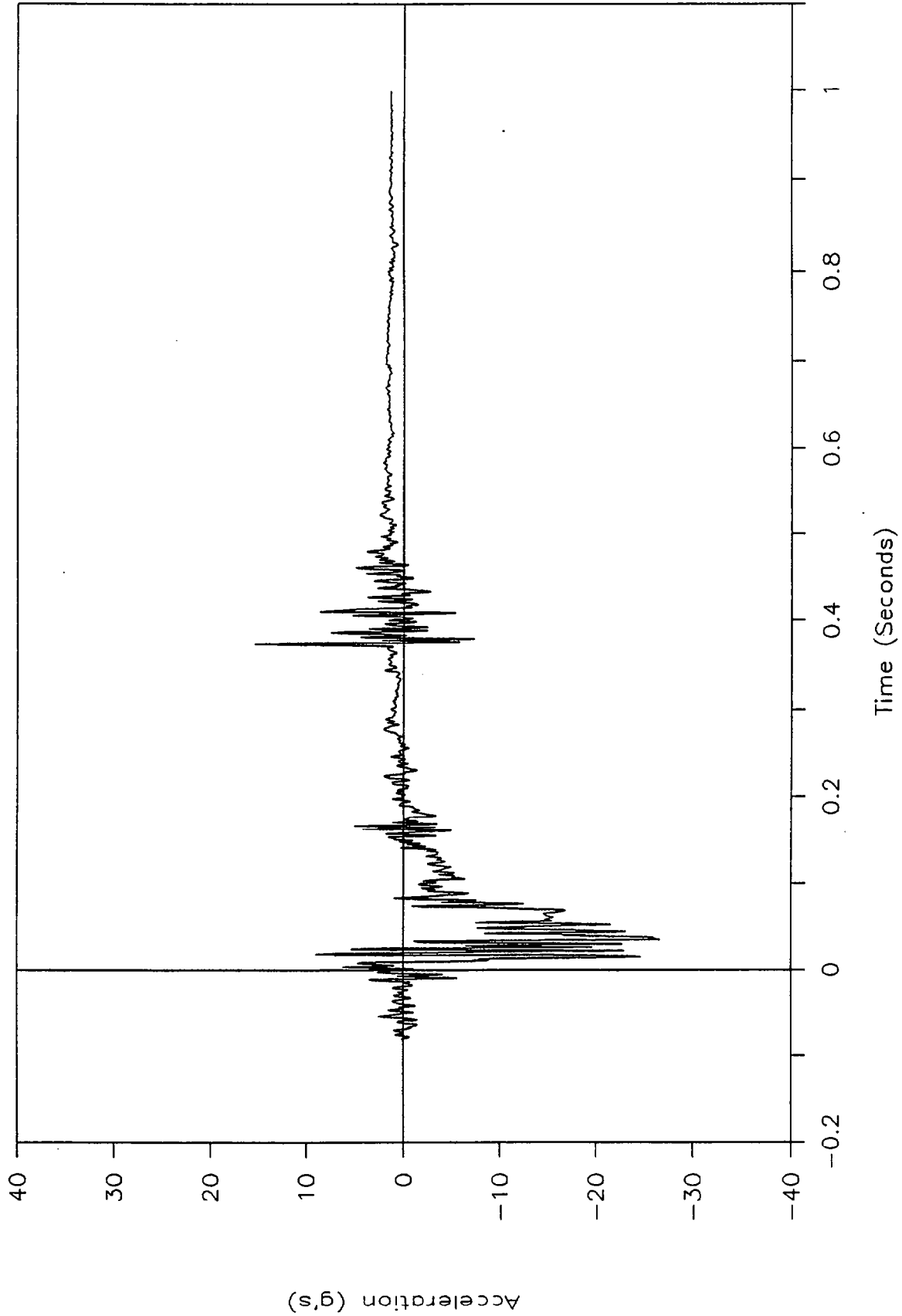
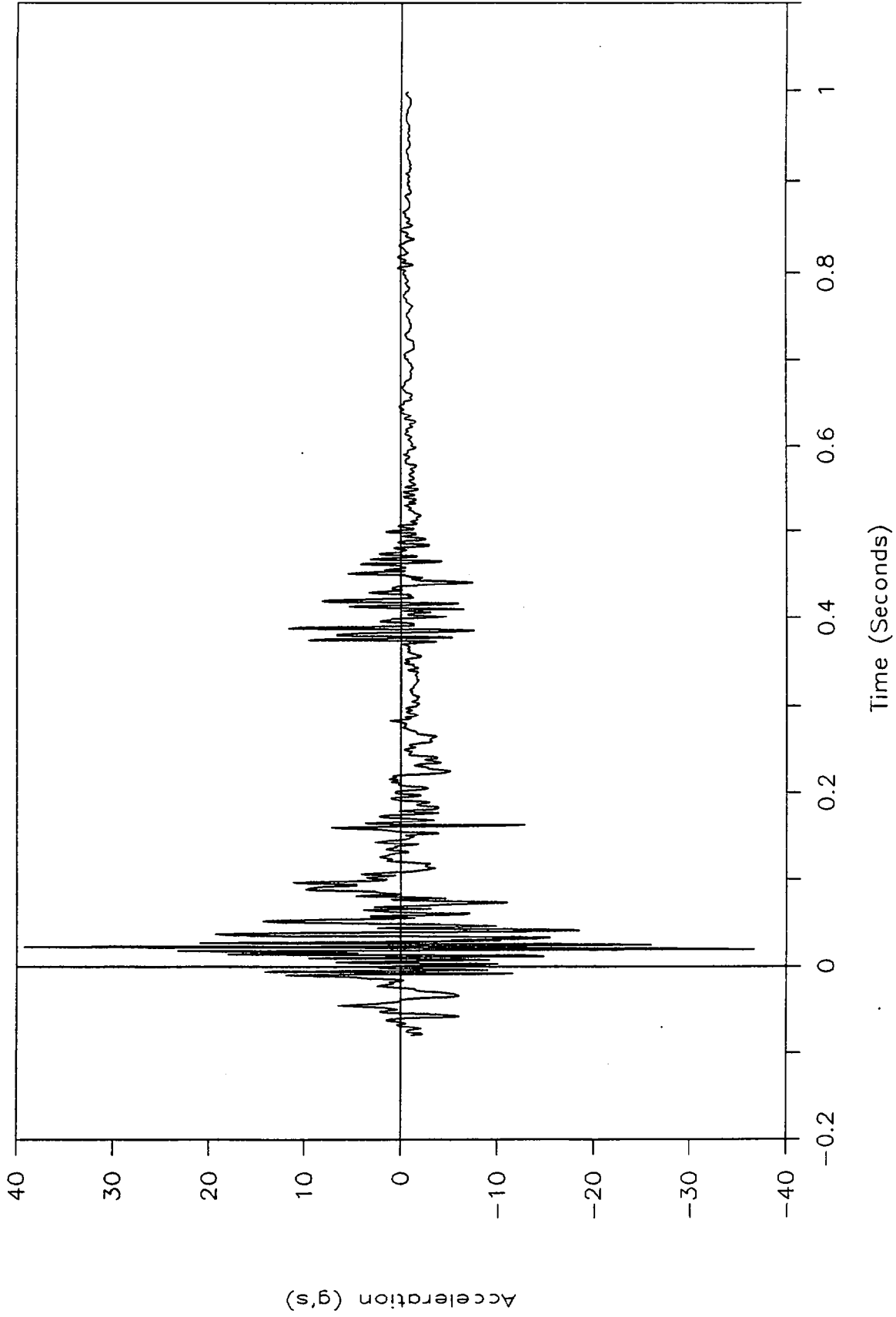


Figure A14. FOIL Vehicle Y Acceleration, 300 Hz

Vehicle Z-Axis Acceleration - 300 Hz

88S006



A15

Figure A15. FOIL Vehicle Z acceleration, 300 Hz

Vehicle Yaw Rate - 100 Hz

88S006

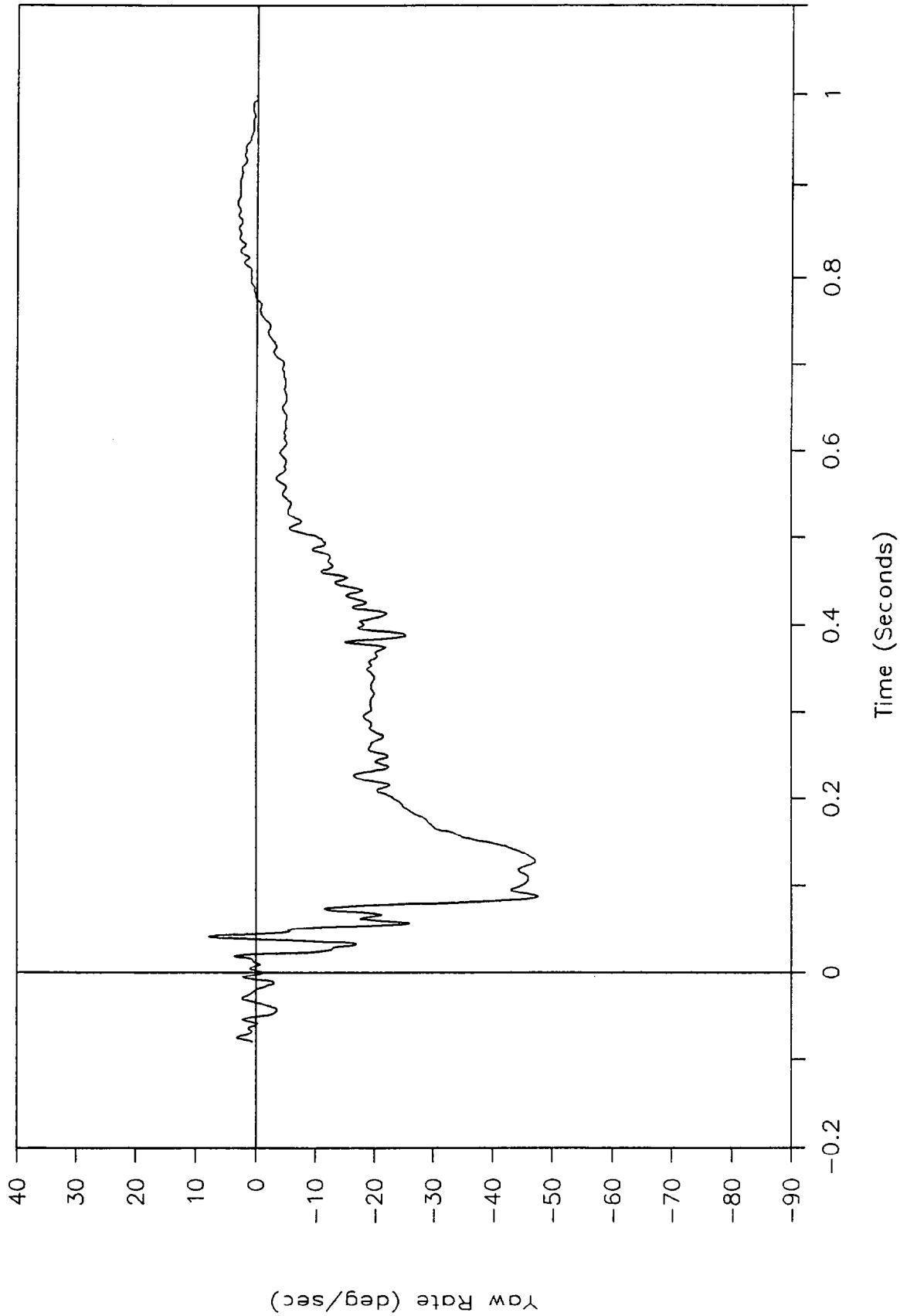


Figure A16. FOIL Vehicle Yaw Rate, 100 Hz

Vehicle Yaw Rate - 10 Hz

88S006

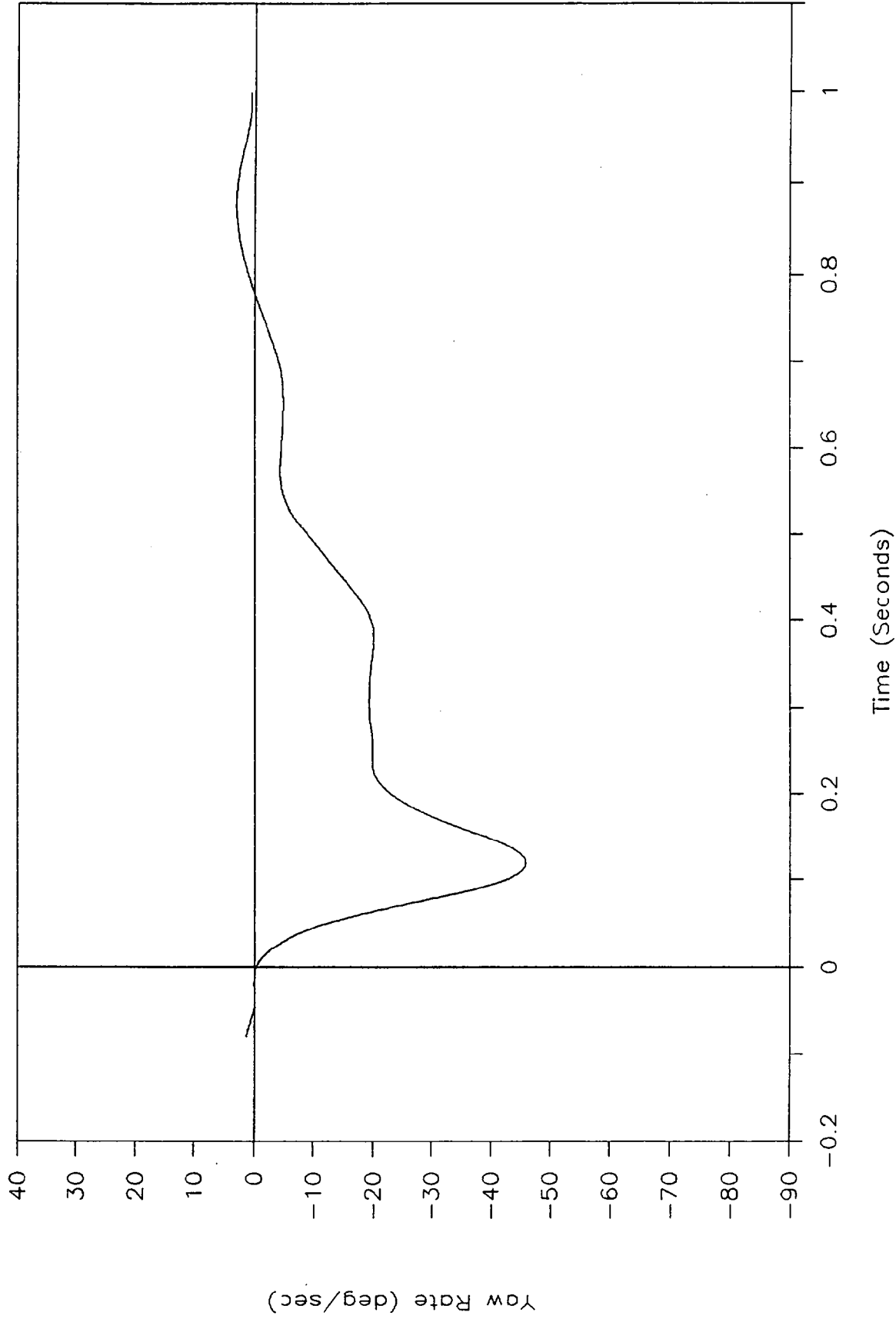


Figure A17. FOIL Vehicle Yaw Rate, 10 Hz

Vehicle Roll Rate - 100 Hz

88S006

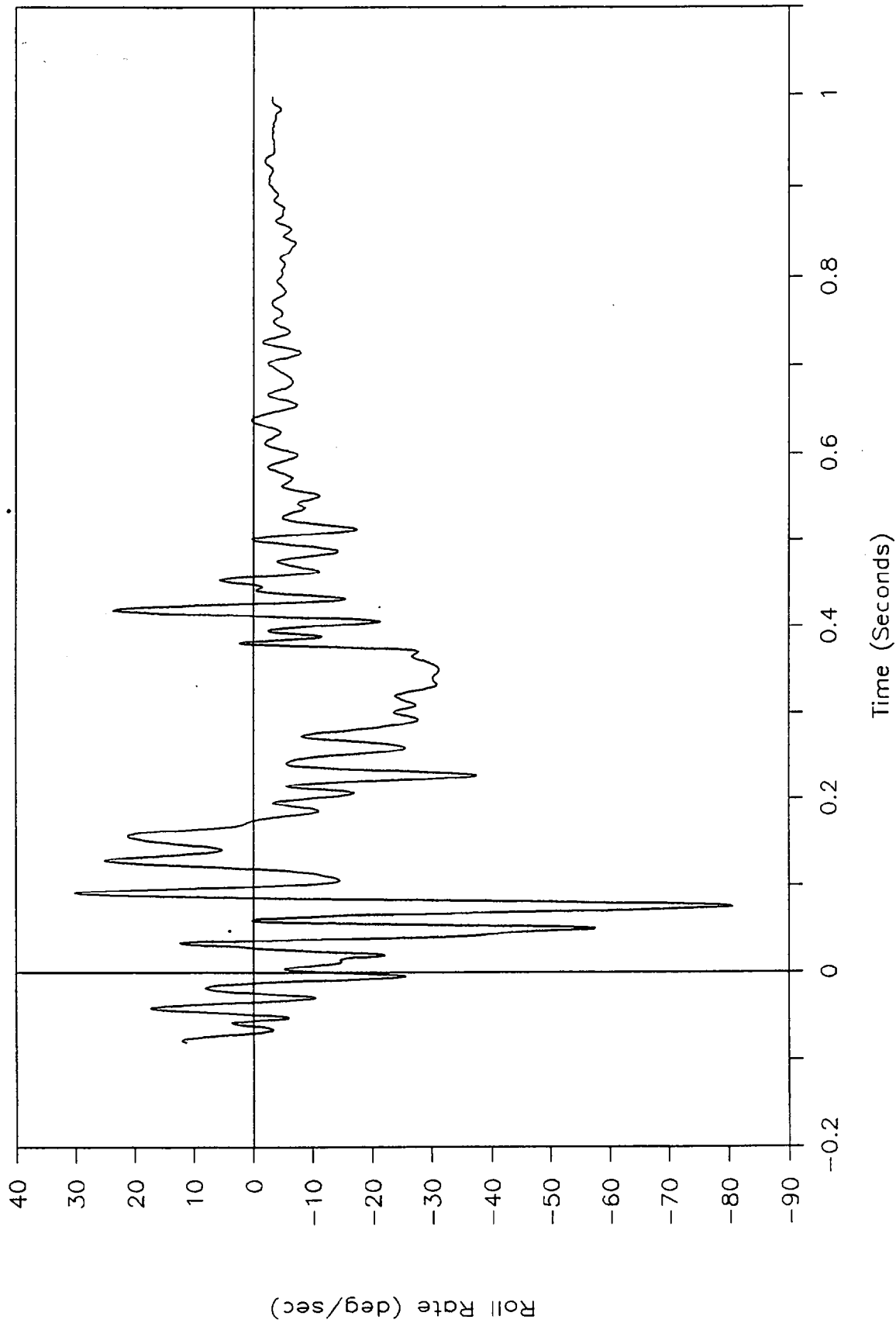
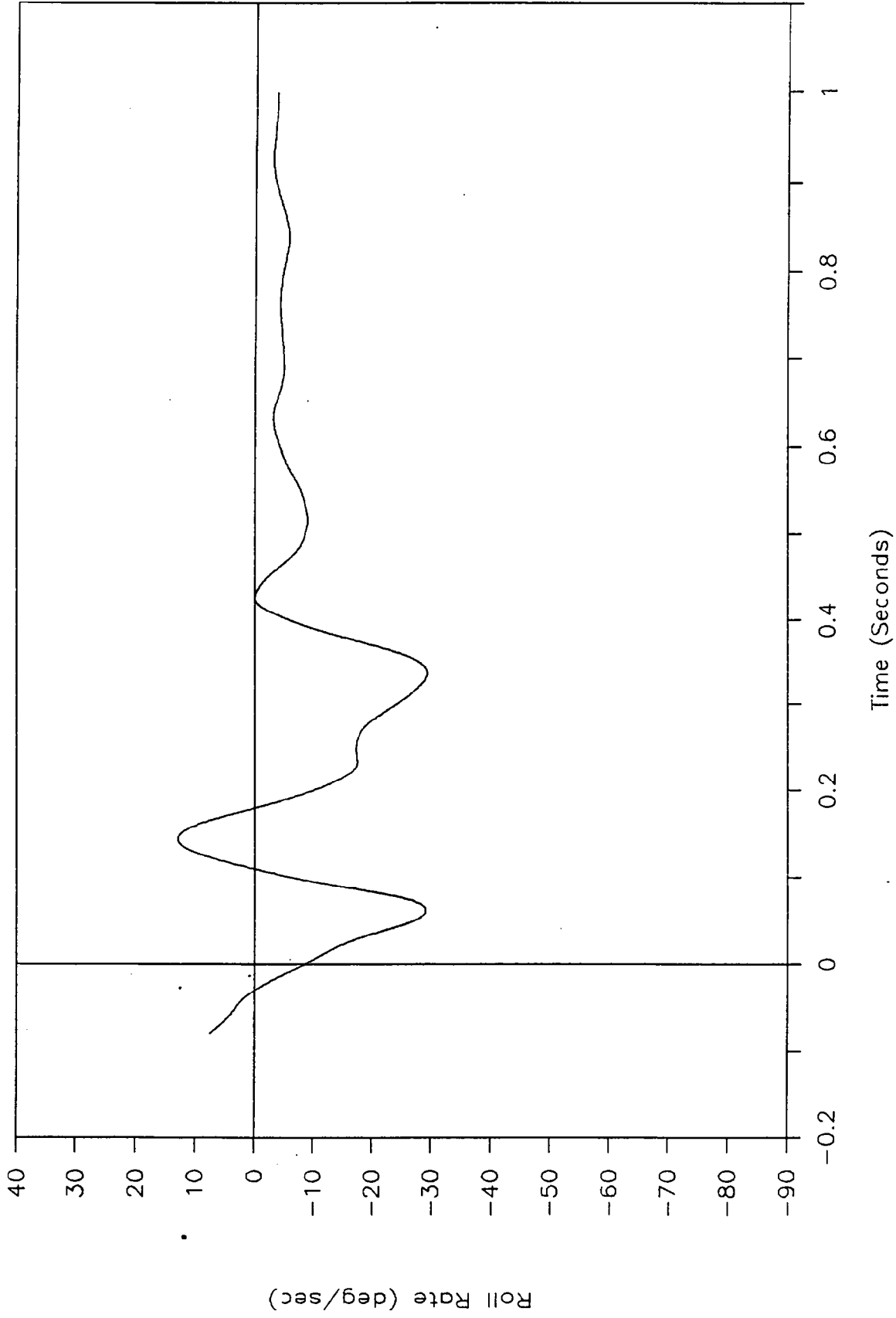


Figure 18. FOIL Vehicle Roll Rate, 100 Hz

Vehicle Roll Rate - 10 Hz

88S006



A19

Figure A19. FOIL Vehicle Roll Rate, 10 Hz

Vehicle Roll & Yaw - 10 Hz

88S006

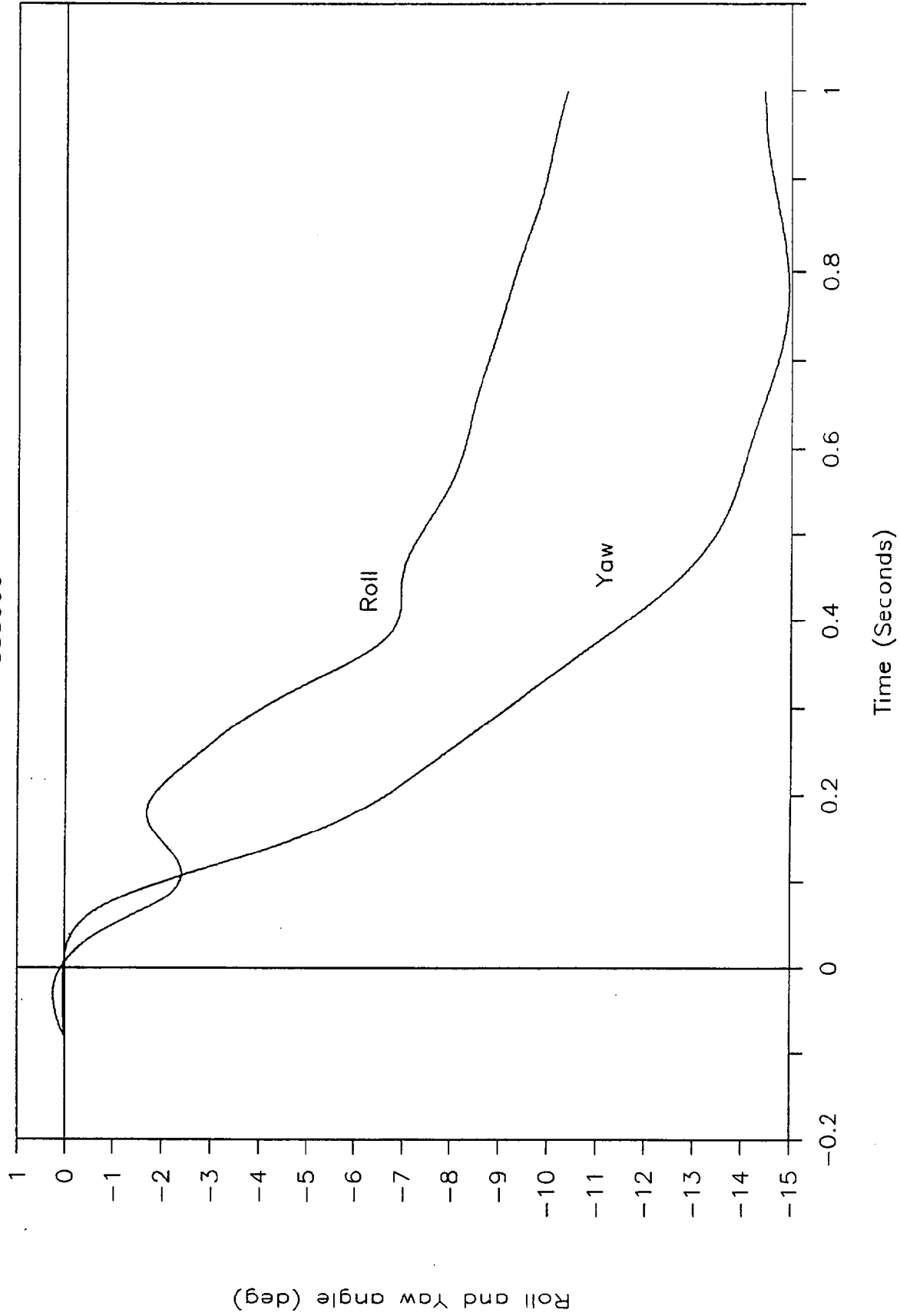
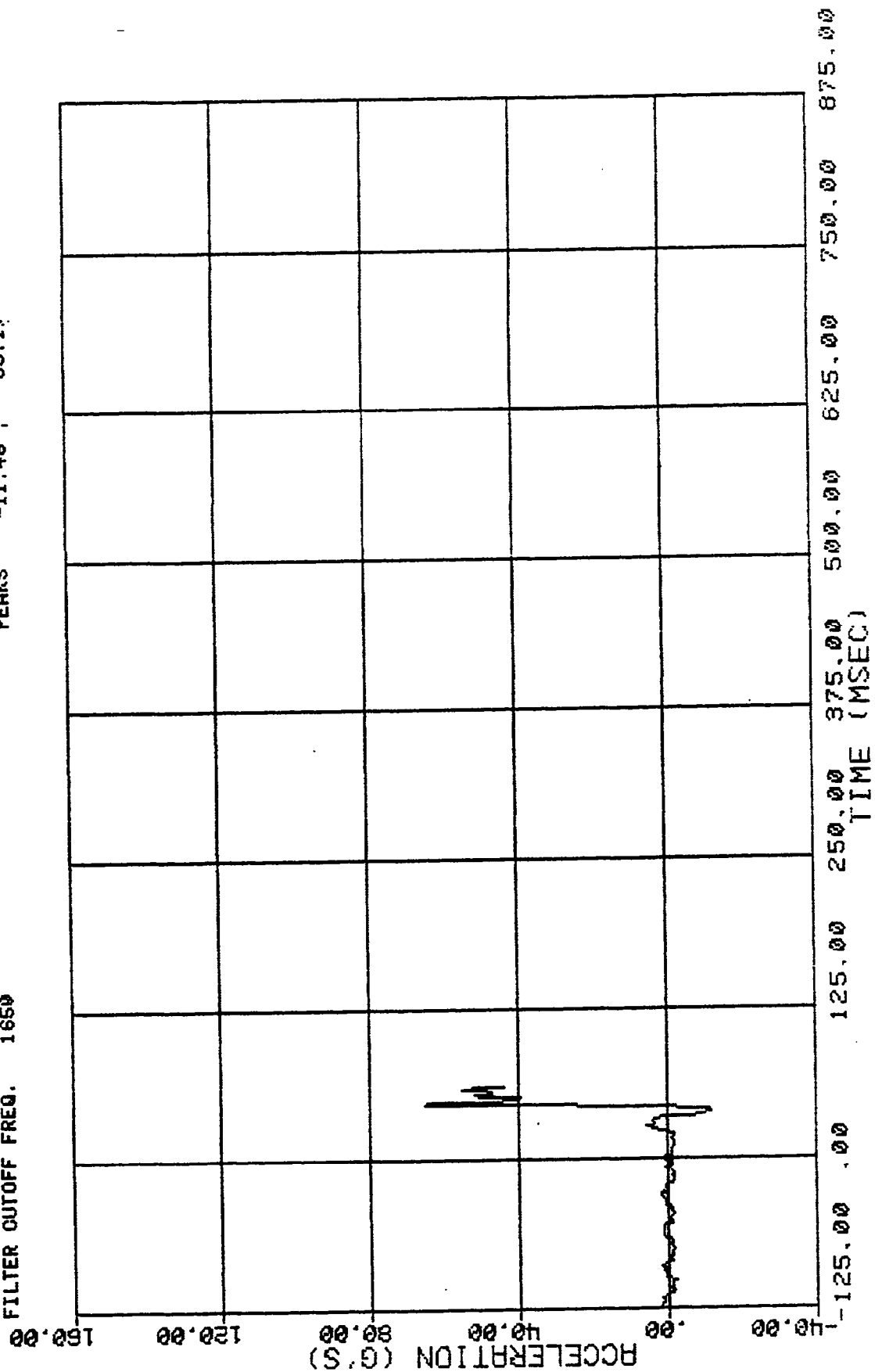


Figure A20. FOIL Vehicle Roll and Yaw, 10 Hz

ENSO, INC. CONTRACT NUMBER D1FH61-26-1-00047
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 12 HEAD X
 FILTER CUTOFF FREQ. 1650
 PEAKS -11.48 65.17



A21

Figure A21. Head X Acceleration, 1650 Hz

ENSU,ING. UNIT NO. 4 7777
30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT

CHANNEL 13 HEAD Y
FILTER CUTOFF FREQ. 1650

PEAKS -8.64 , 117.91

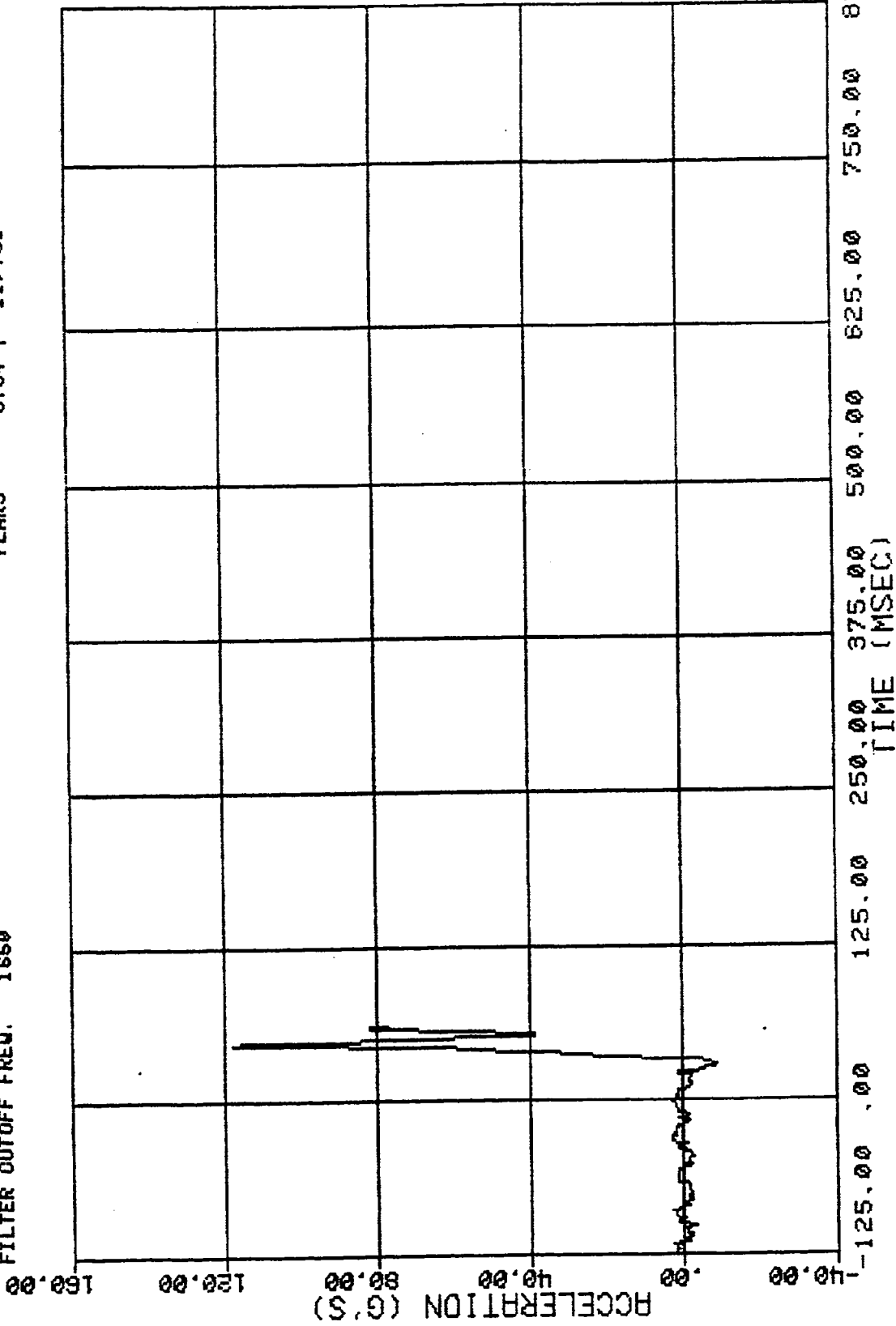
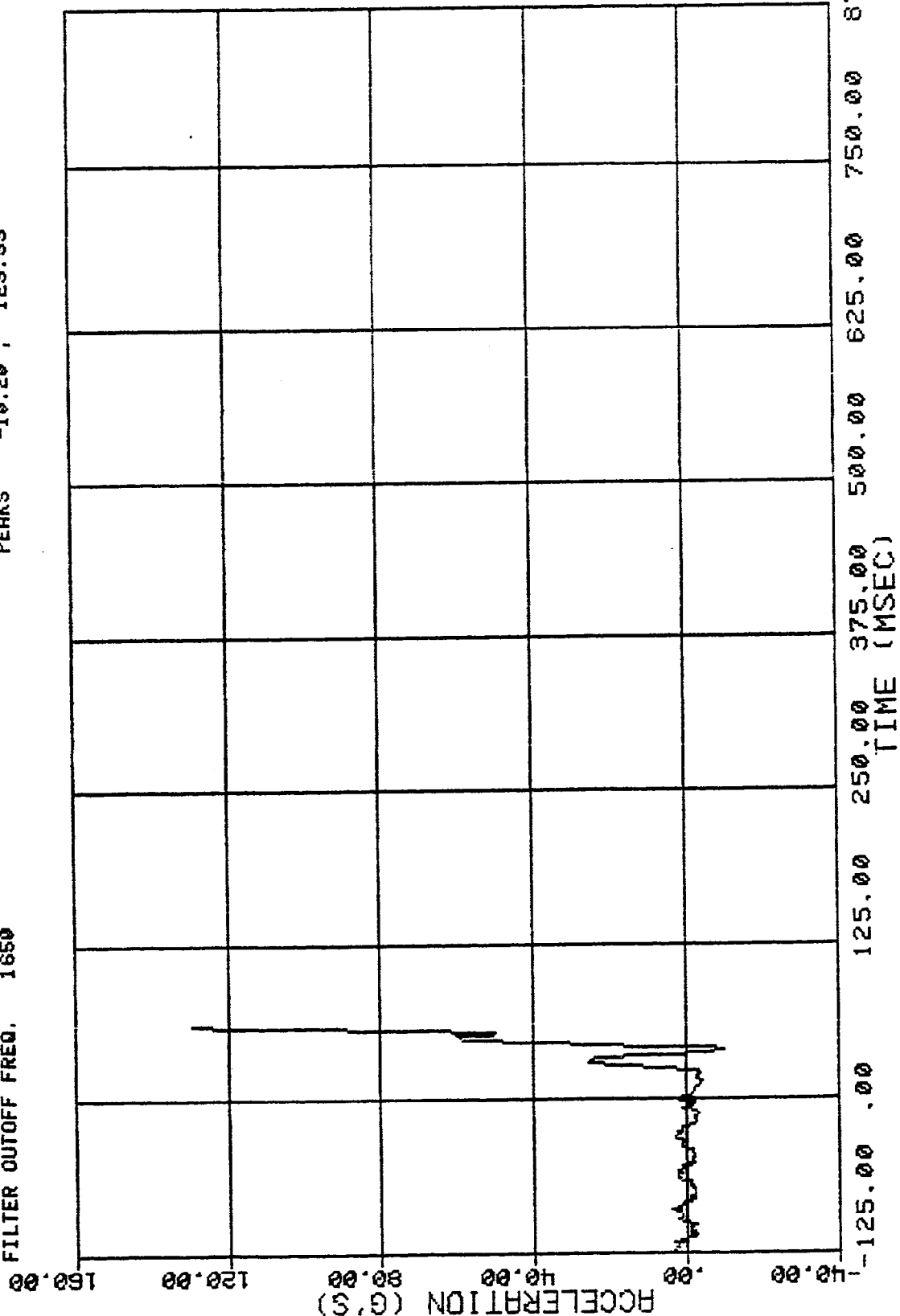


Figure A22. Head Y Acceleration, 1650 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-86-1-00047 1E21 * 1/00-21-0-00
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 14 HEAD Z
 FILTER CUTOFF FREQ. 1650
 PEAKS -10.20 , 129.53



A23

A23. Head Z Acceleration, 1650 Hz

ENSU, 110. SERIAL NUMBER 01101 00 1 0047
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH OHAMP INTO LUMINAIRE SUPPORT
 CHANNEL Ø HEAD RESULTANT
 FILTER CUTOFF FREQ. 1650 PEAKS 0.69 , 159.67

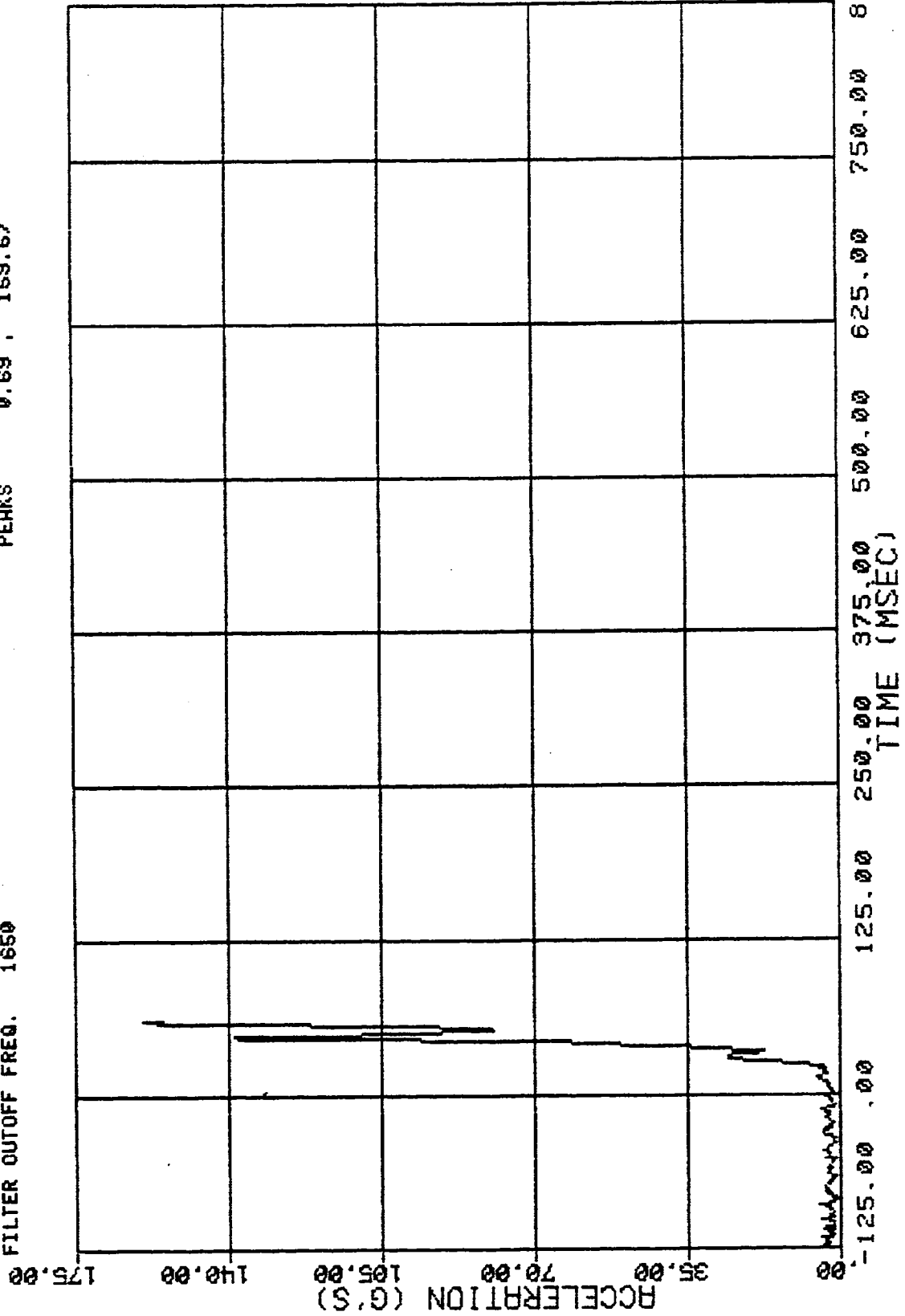


Figure A24. Head Resultant Acceleration, 1650 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 4 T01X
 FILTER CUTOFF FREQ. 300 PEAKS -4.06 , 50.65

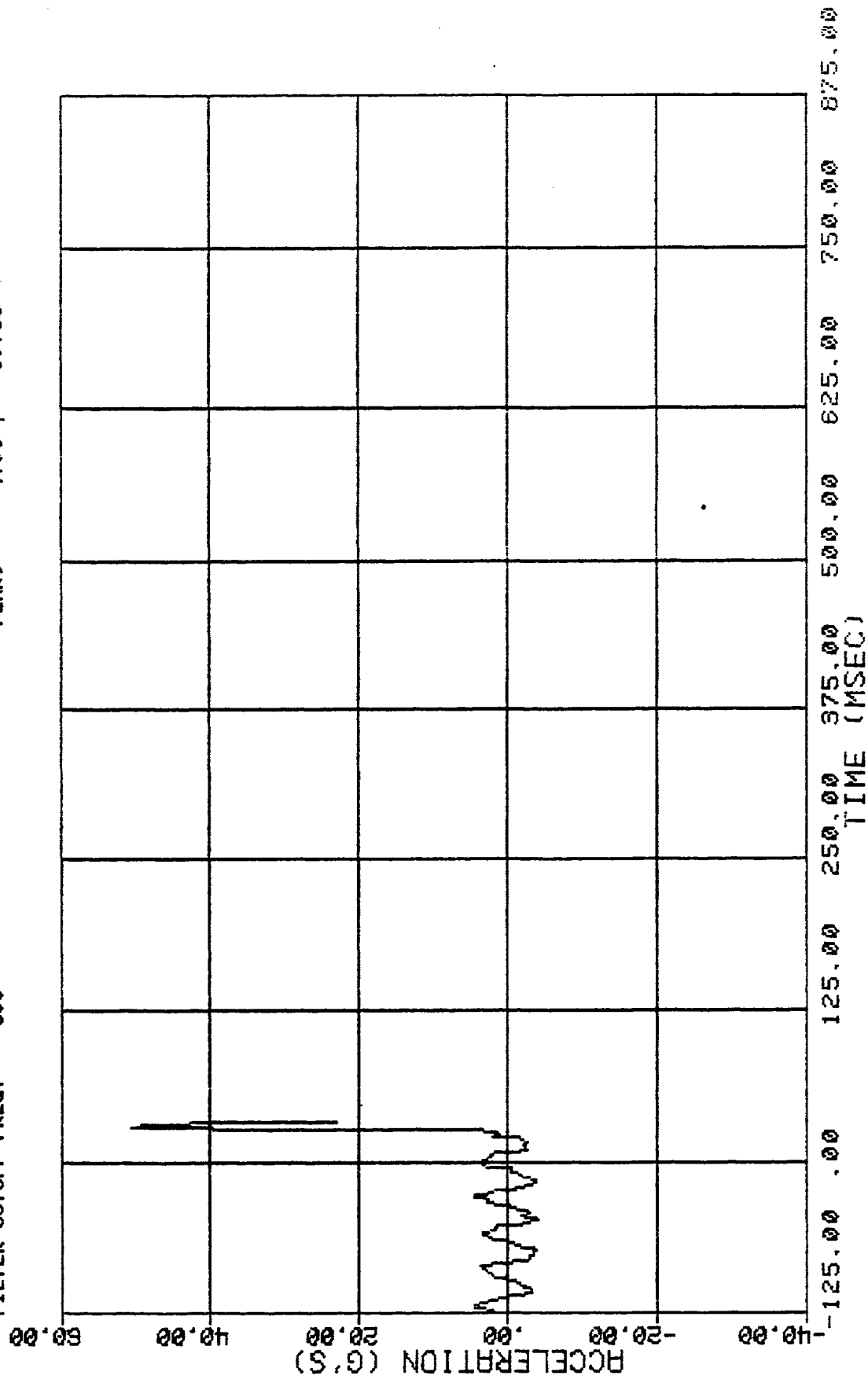


Figure A25. T01 - X Acceleration, 300 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-86-3-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 3 T01Y
 FILTER CUTOFF FREQ. 300 PEAKS -35.10 , 56.60

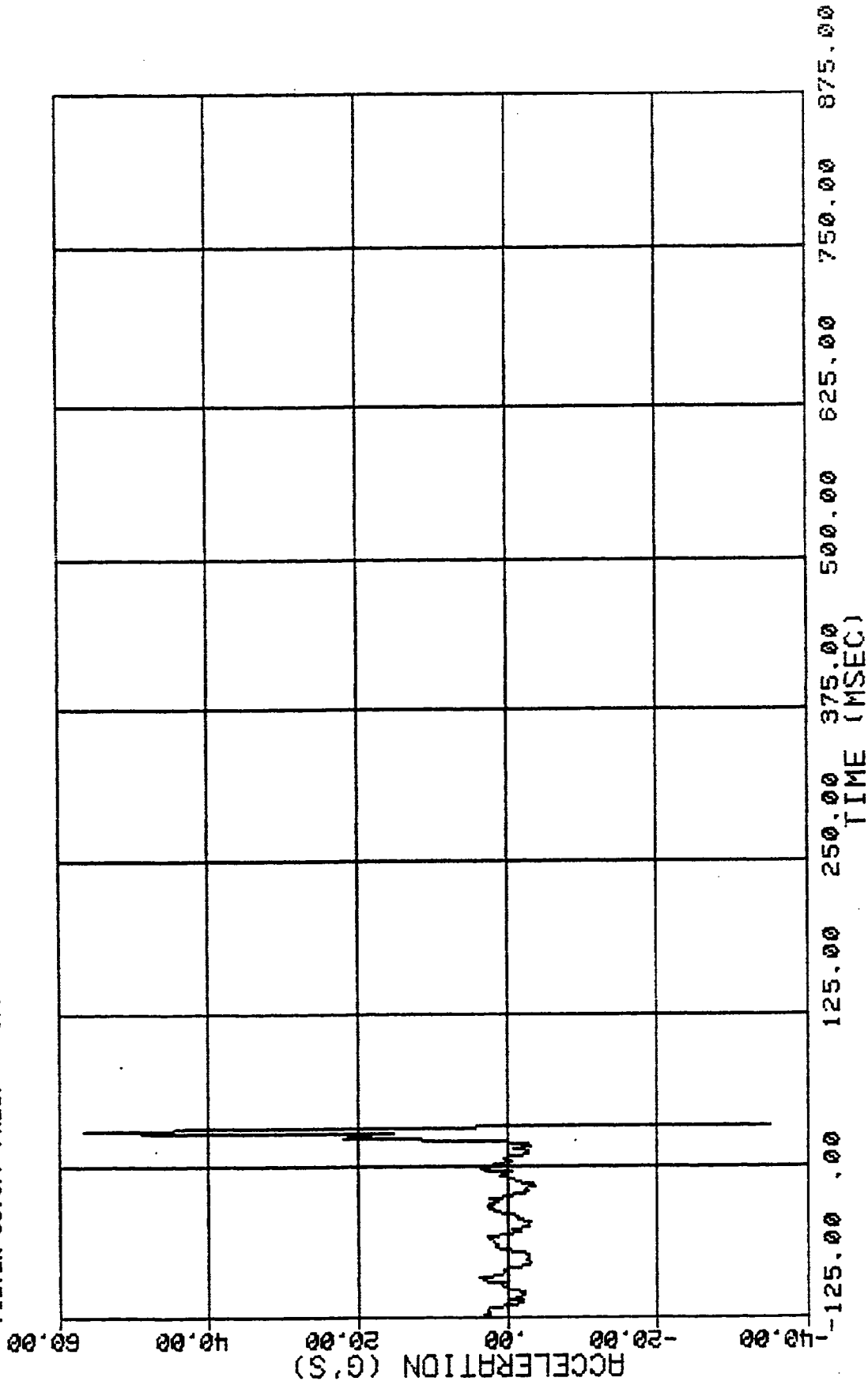


Figure A26. T01 - Y Acceleration, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-86-2-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 5 T01Z
 FILTER CUTOFF FREQ. 300 PEAKS -14.40 , 33.88

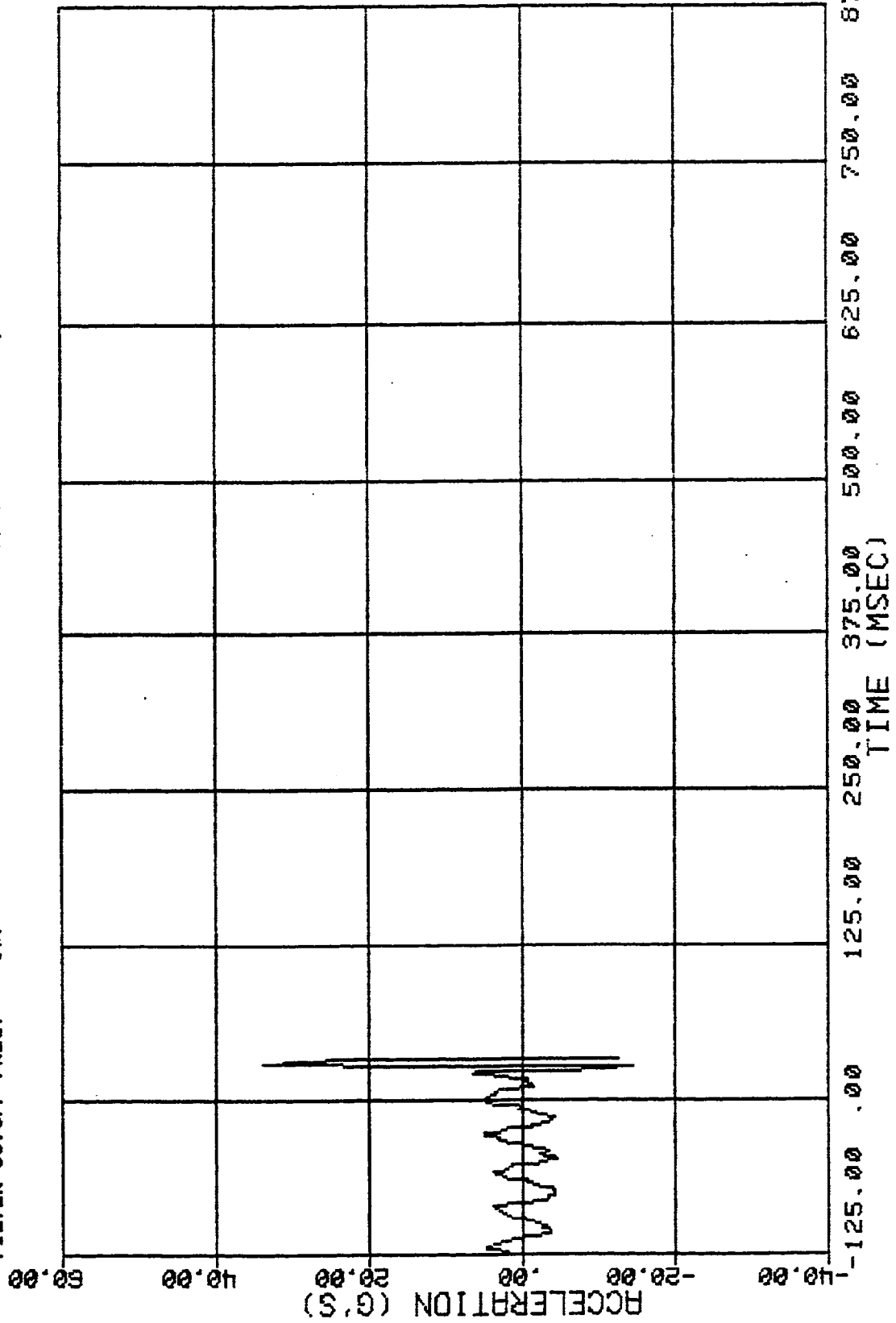
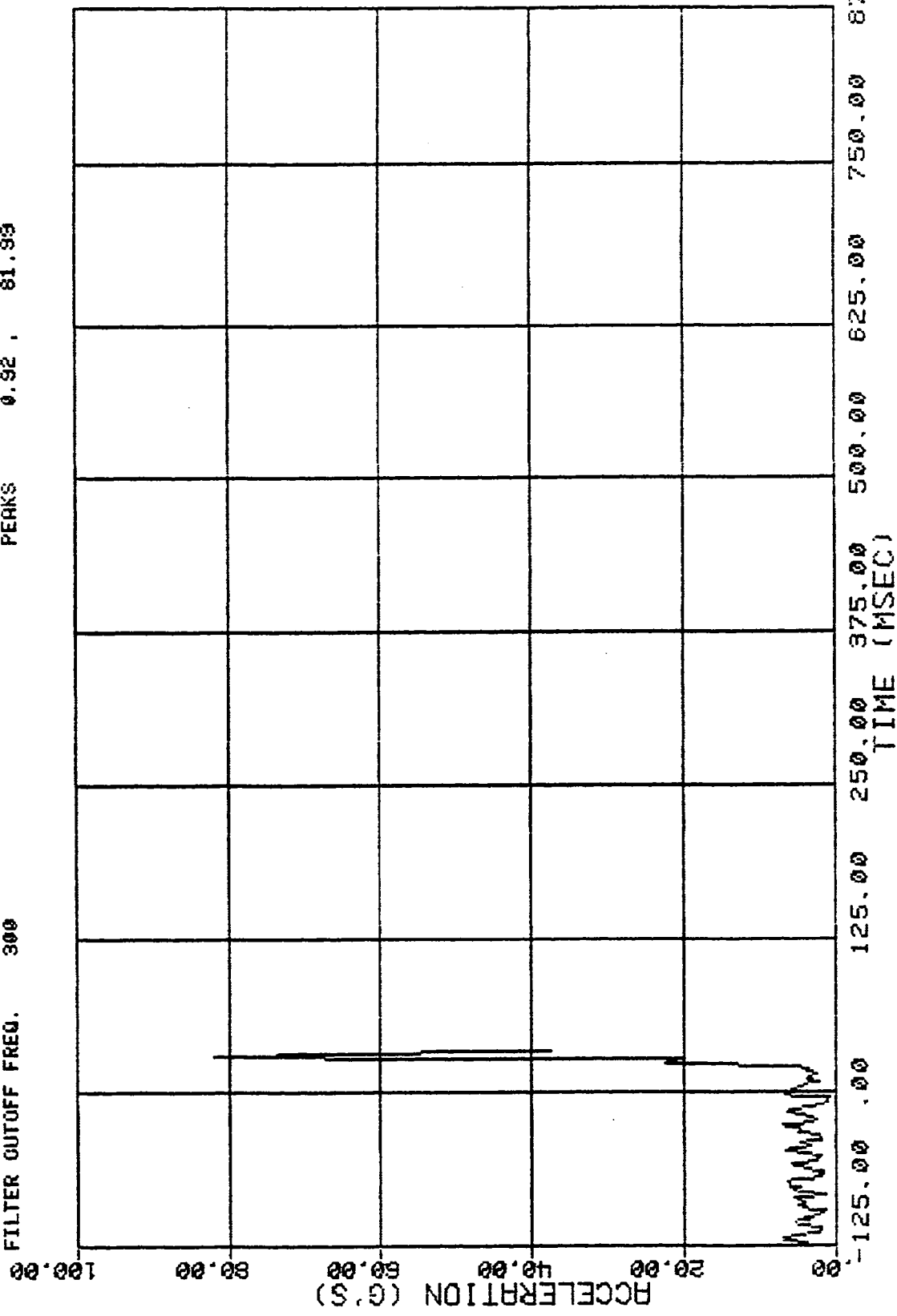


Figure A27. T01 - Z Acceleration, 300 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 0 T01 RESULTANT PEAKS 0.92 , 81.93
 FILTER CUTOFF FREQ. 300



A28

Figure A28. T01 Resultant Acceleration, 300 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-86-2-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH OHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 6 T12X PEAKS -10.17 , 59.83
 FILTER OUTOFF FREQ. 300

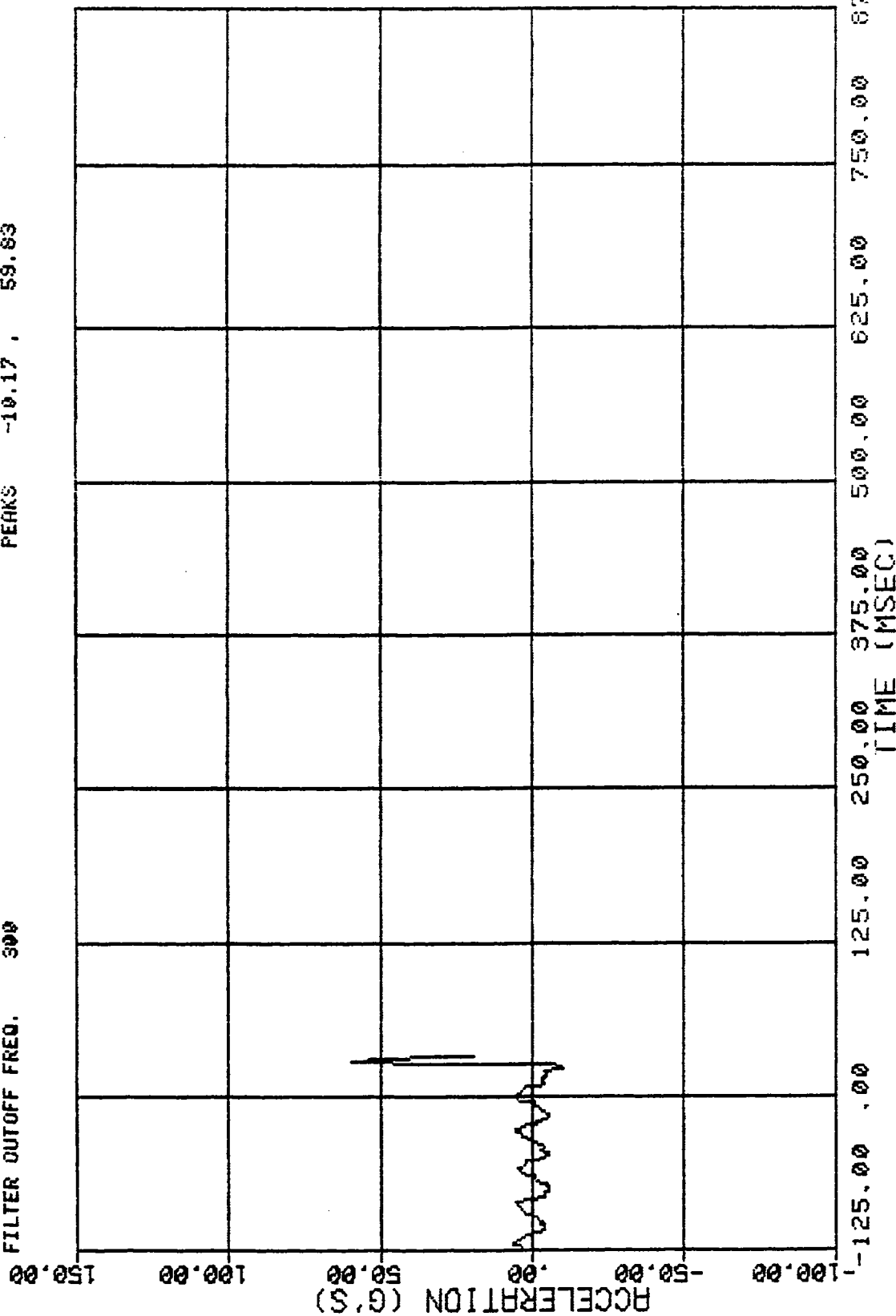


Figure A29. T12 - X Acceleration, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFHS1-86-Z-00047 TEST # 1785-SI-6-08
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 7 T12Y
 FILTER CUTOFF FREQ. 300 PEAKS -82.96 , 1.74

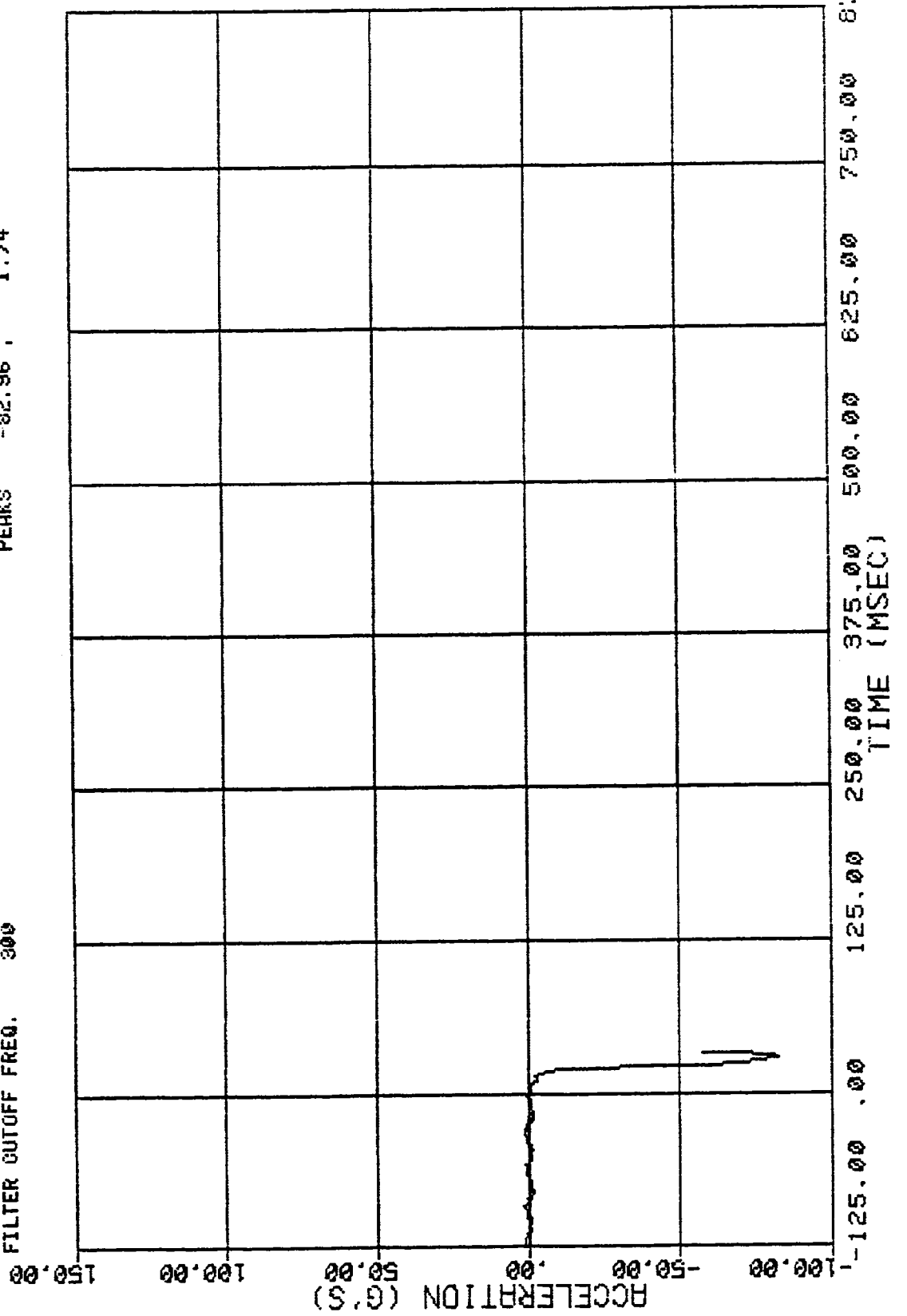


Figure A30. T12 - Y Acceleration, 300 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 8 T12Z PEAKS -10.87 , 34.97
 FILTER CUTOFF FREQ. 300

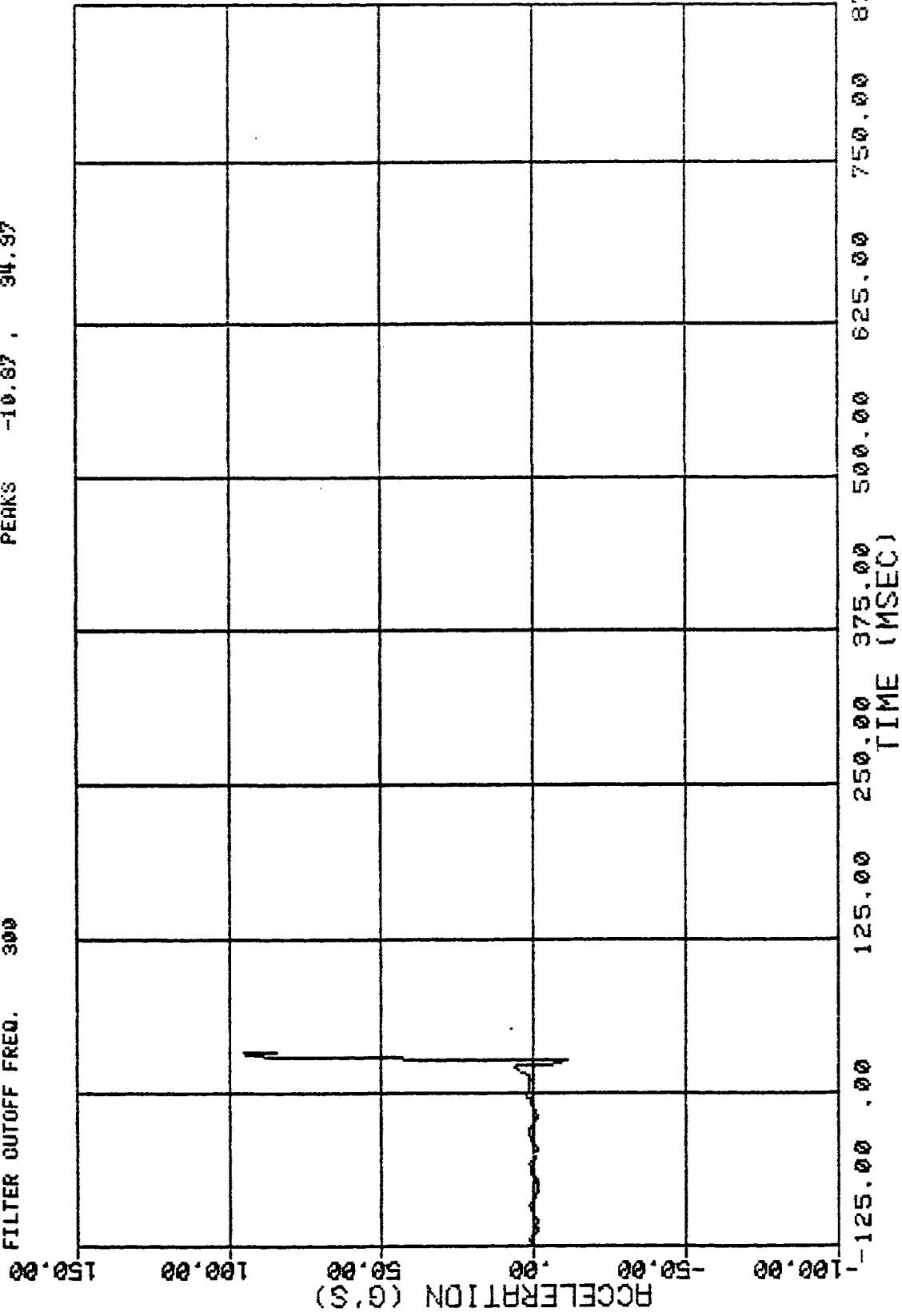


Figure A31. T12 - z Acceleration, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-66-2-00047 TEST # 1785-SI-6-58
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 0 T12 RESULTANT PEAKS 0.87, 126.64
 FILTER CUTOFF FREQ. 300

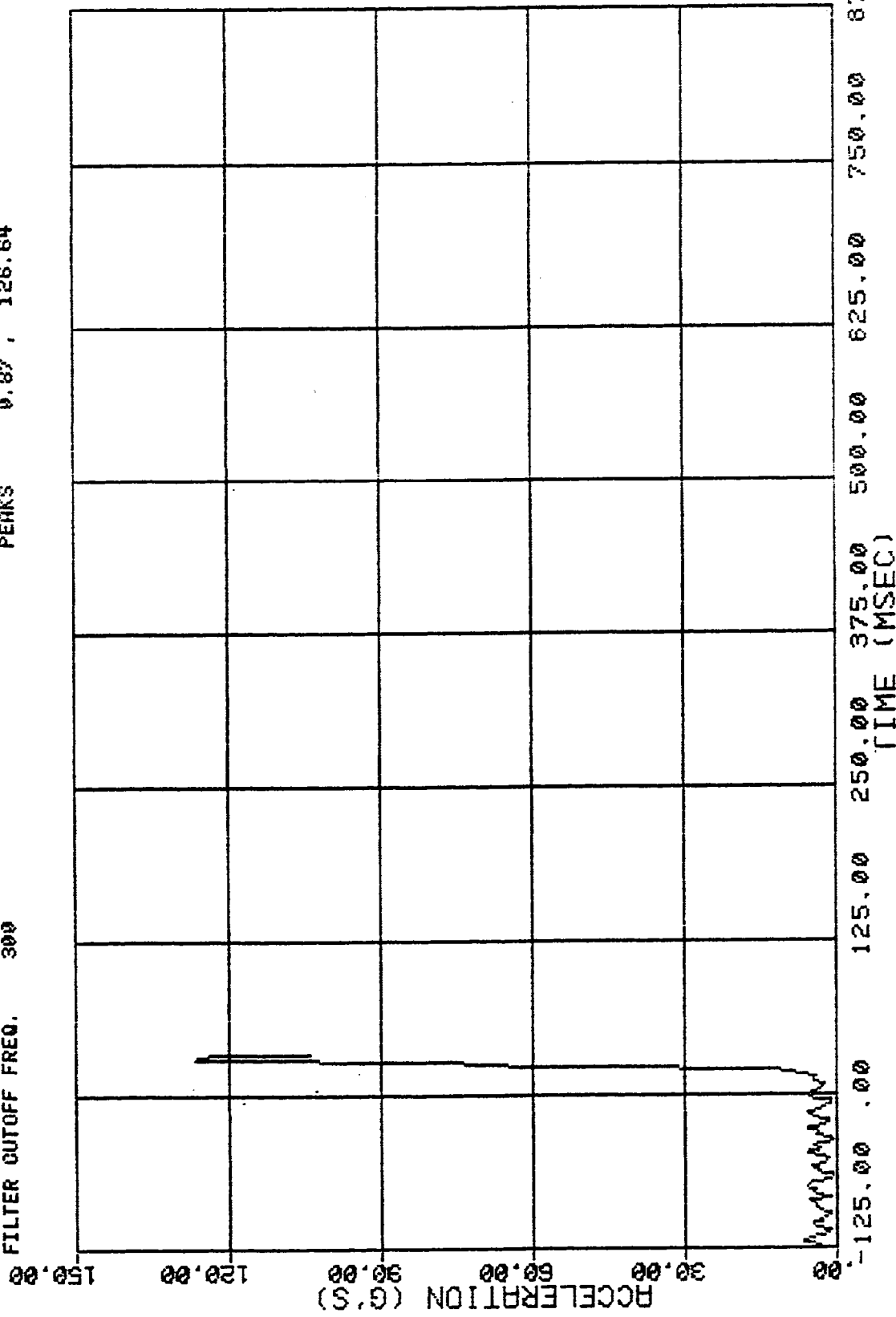


Figure A32. T12 Resultant Acceleration, 300 Hz

ENSCO, INC. CONTRACT NUMBER DIF61-86-1-99947 1231 * 1/00/01-0-00
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 15 PELVIS X
 FILTER CUTOFF FREQ. 300 PEAKS -41.16 , 69.36

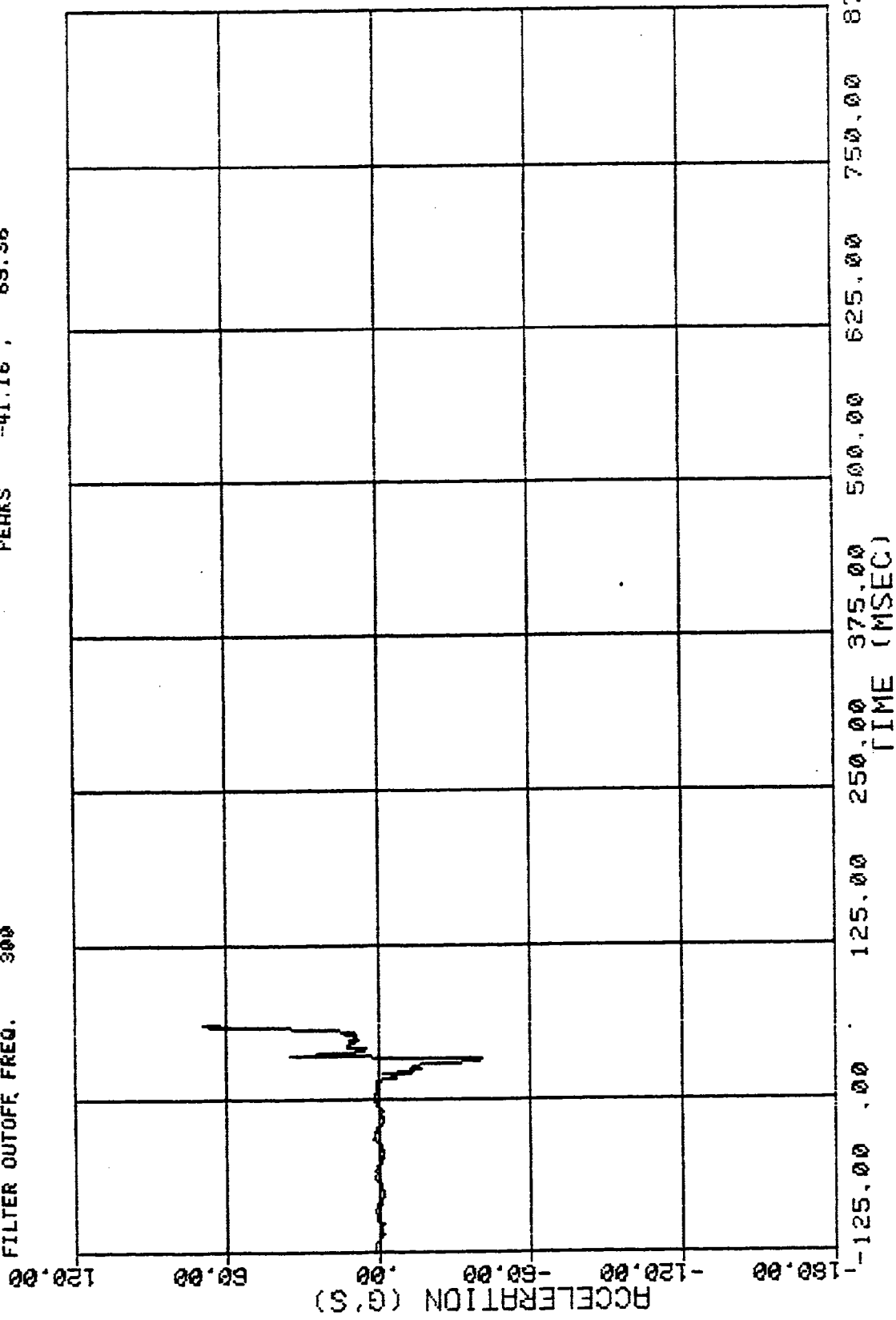


Figure A33. Pelvis X Acceleration, 300 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 LESI # 1786-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 16 PELVIS Y
 FILTER CUTOFF FREQ. 300 PEAKS -156.68 95.72

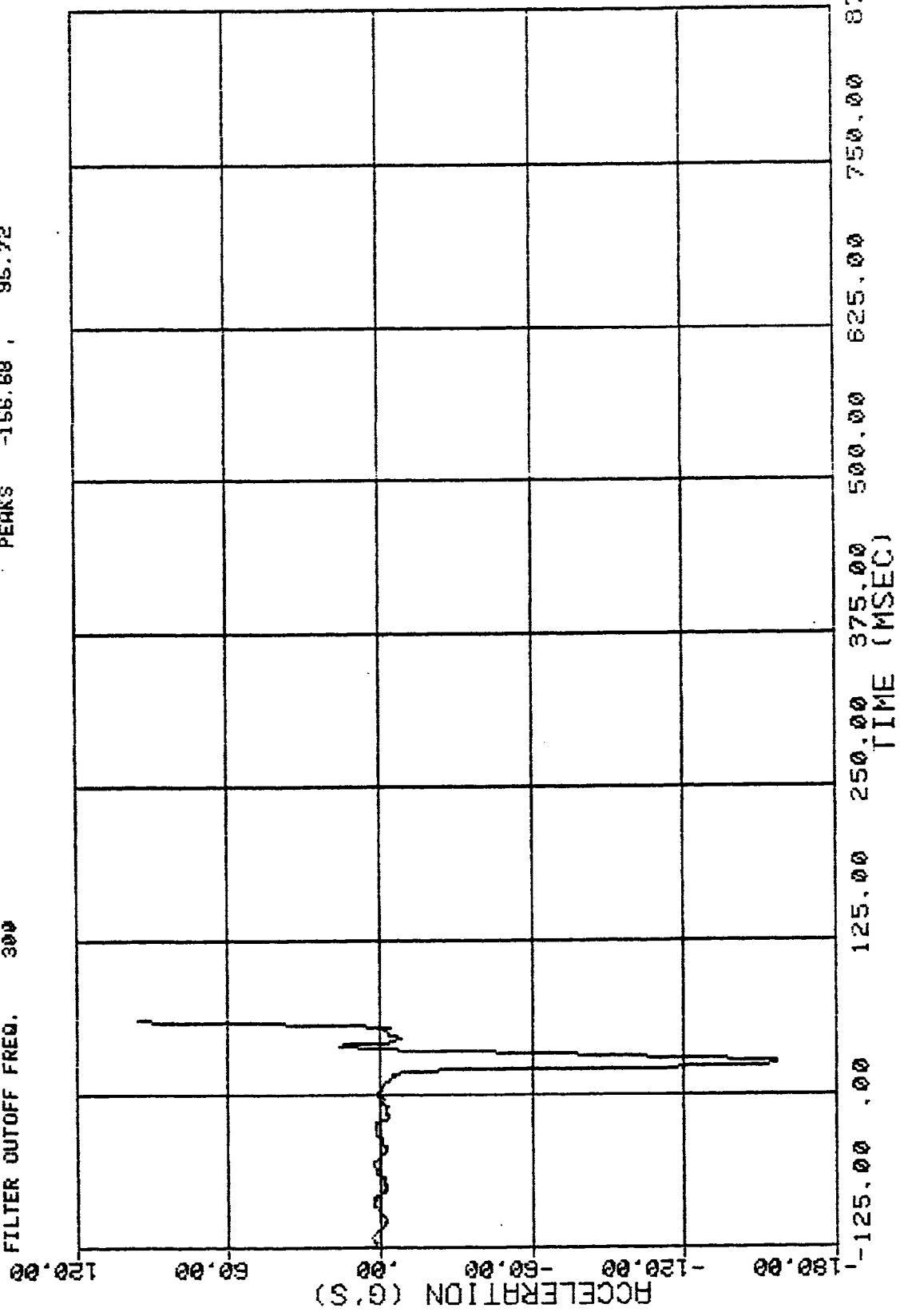


Figure A34. Pelvis Y Acceleration, 300 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1765-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 17 PELVIS Z PEAKS -10.83, 80.21
 FILTER CUTOFF FREQ. 300

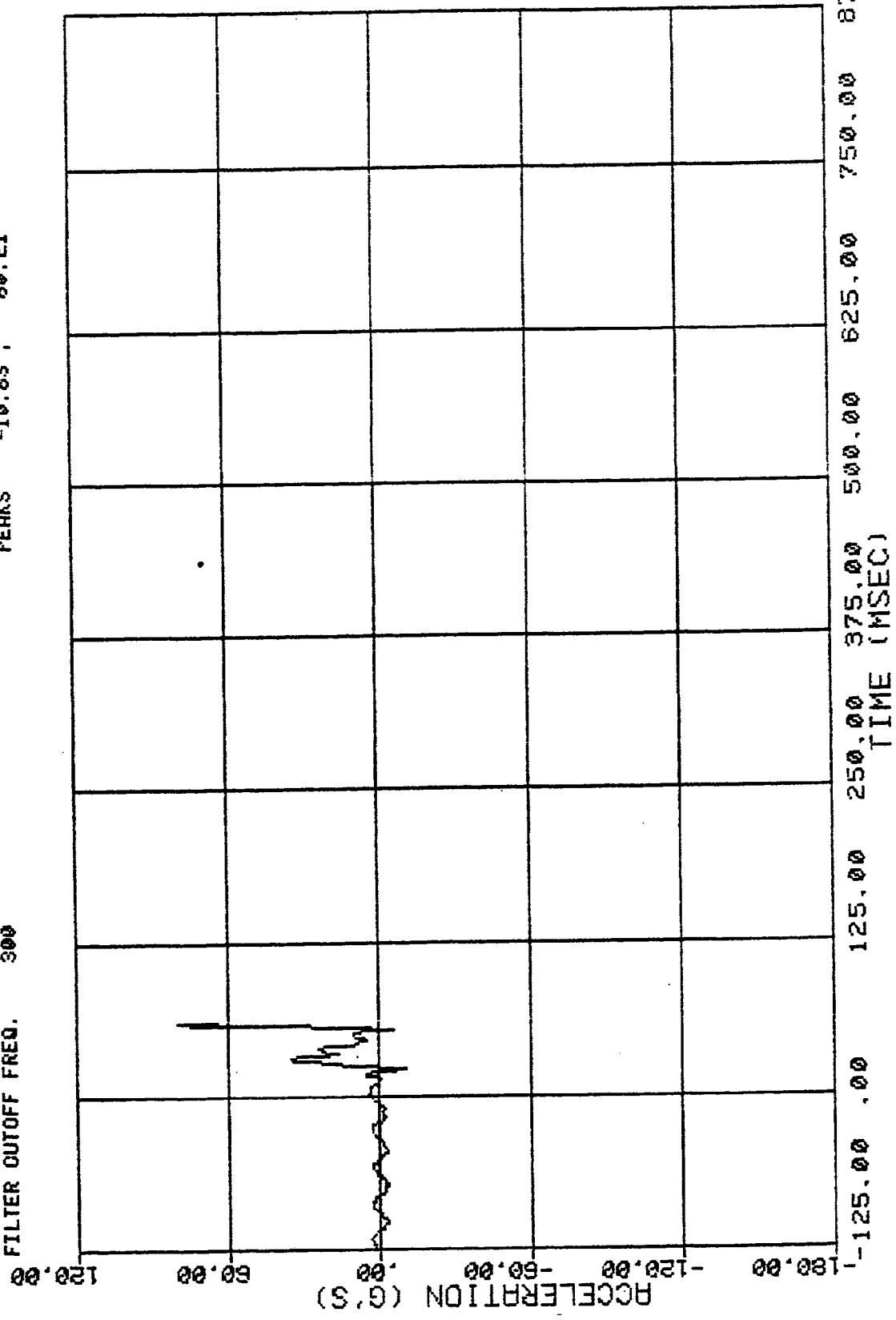


Figure A35. Pelvis Z Acceleration, 300 Hz

ENSGO, INC. CONTRACT NUMBER D17H01-00-1-00047
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 0 PELVIS RESULTANT
 FILTER CUTOFF FREQ. 300 PEAKS 0.83, 157.76

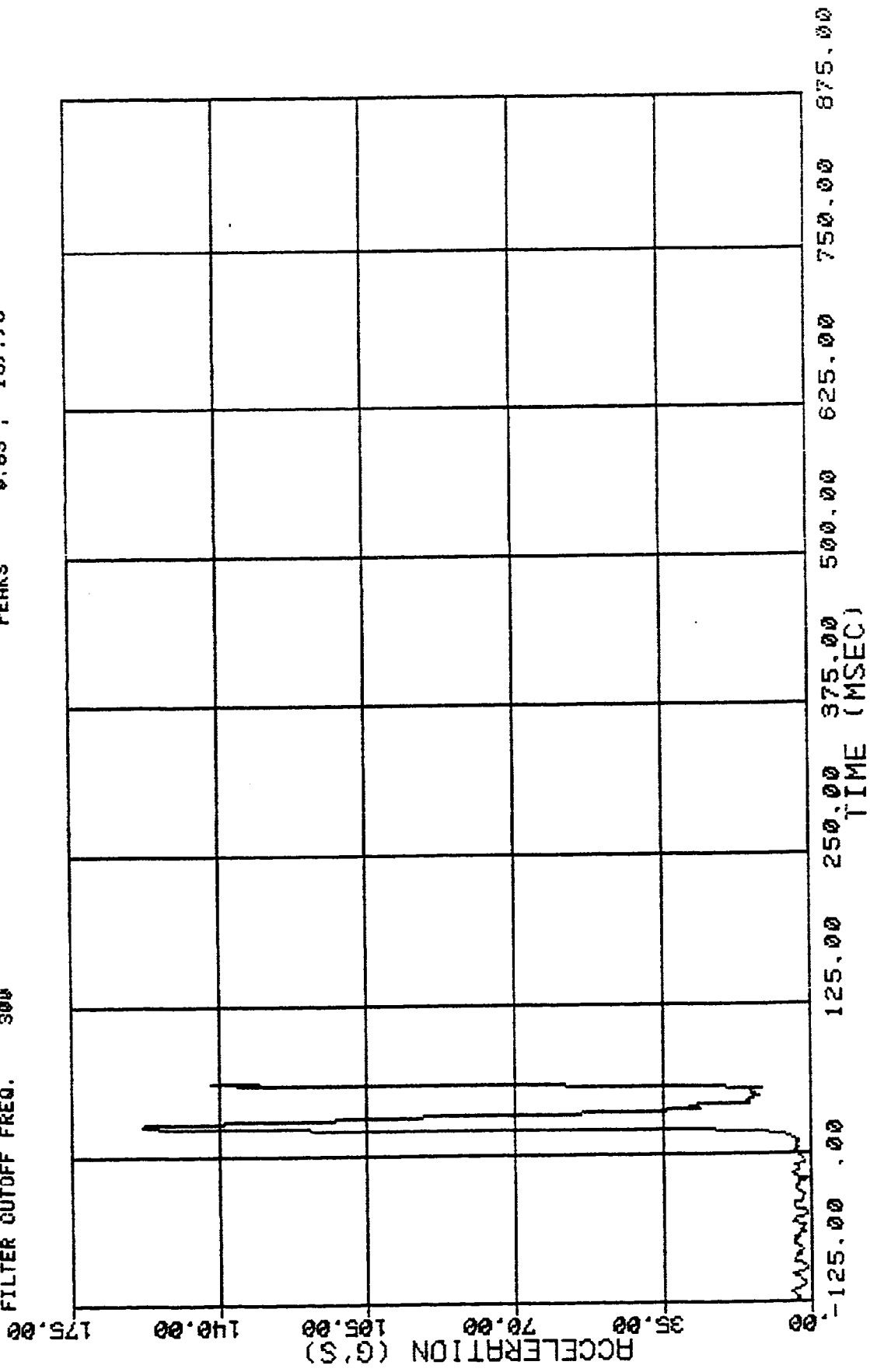


Figure A36. Pelvis Resultant Acceleration, 300 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-8-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 9 LSTX
 FILTER CUTOFF FREQ. 300 PEAKS -22.01 , 113.32

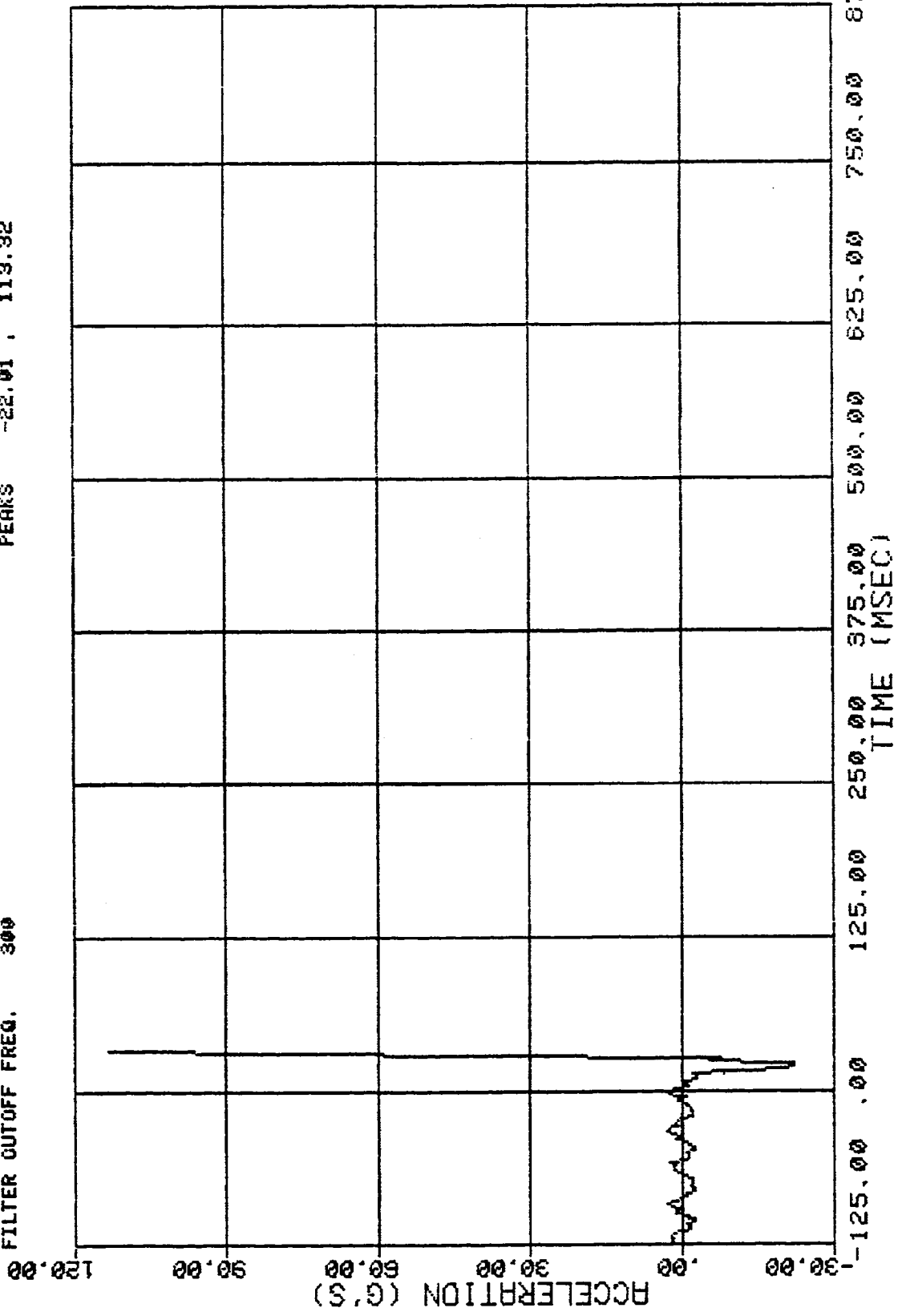


Figure A37. LST - X Acceleration, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 1 LRLRY01
 FILTER CUTOFF FREQ. 300 PEAKS -1.24 , 150.57

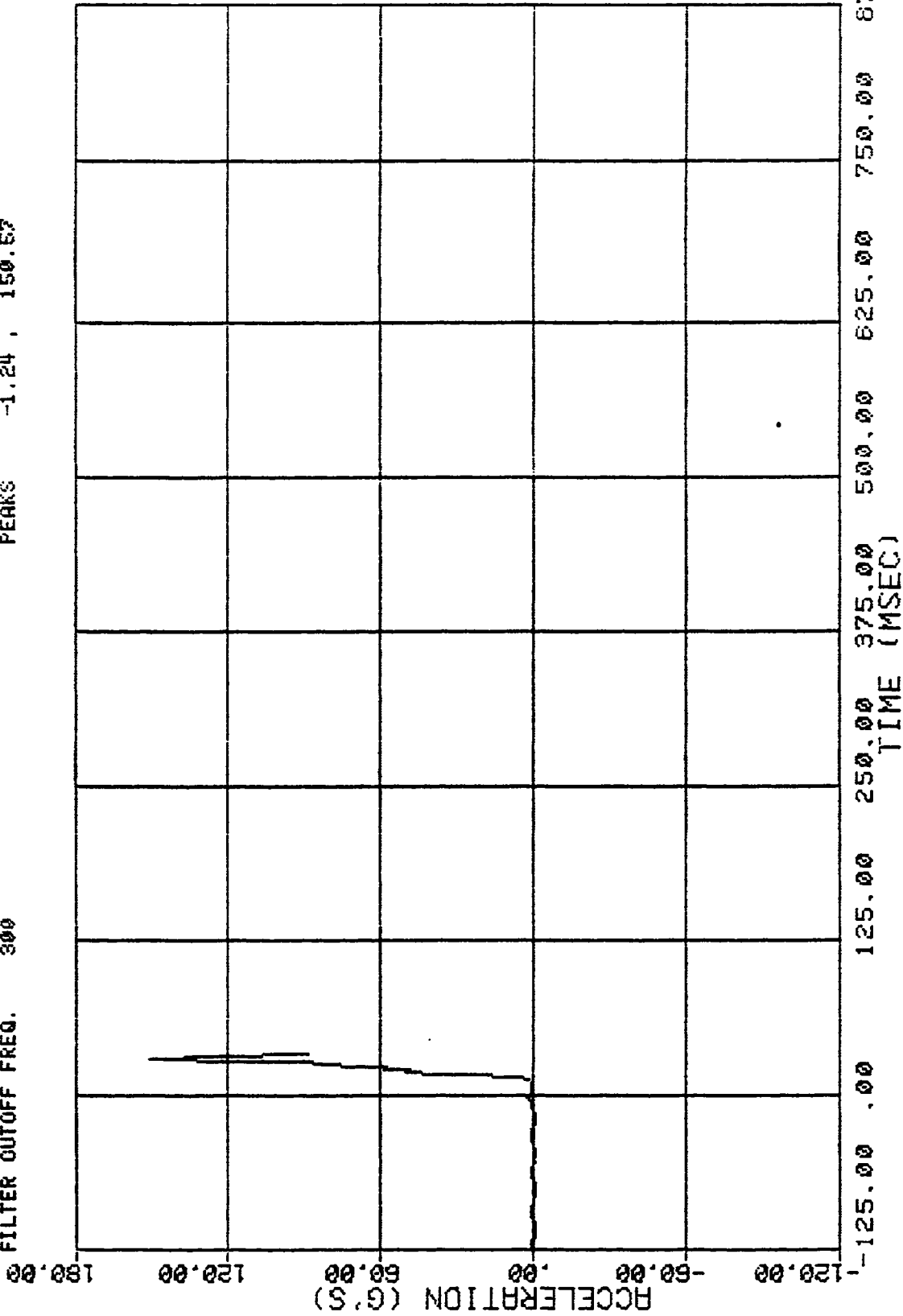
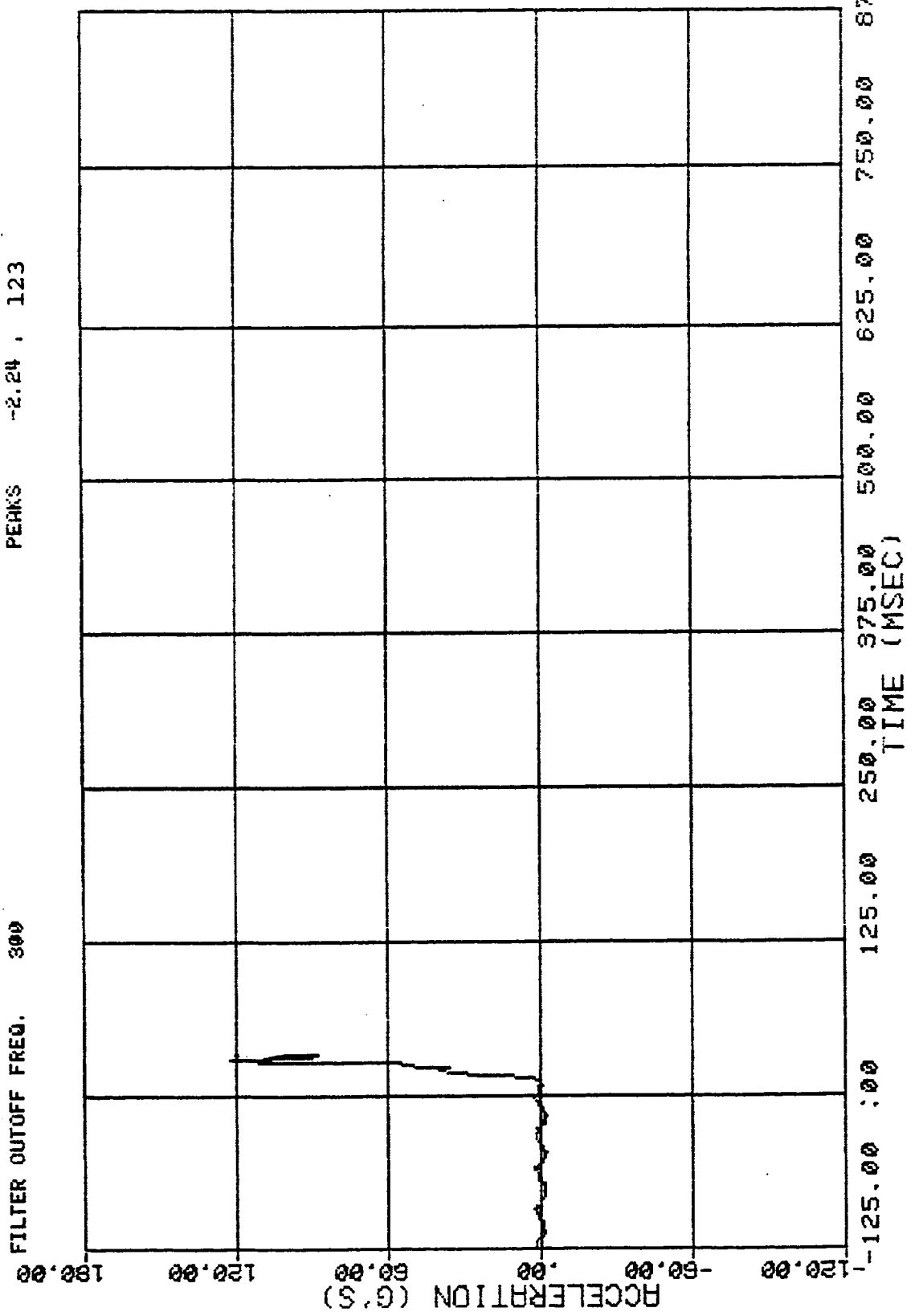


Figure A38. LLR - Y01 Acceleration, 300 Hz

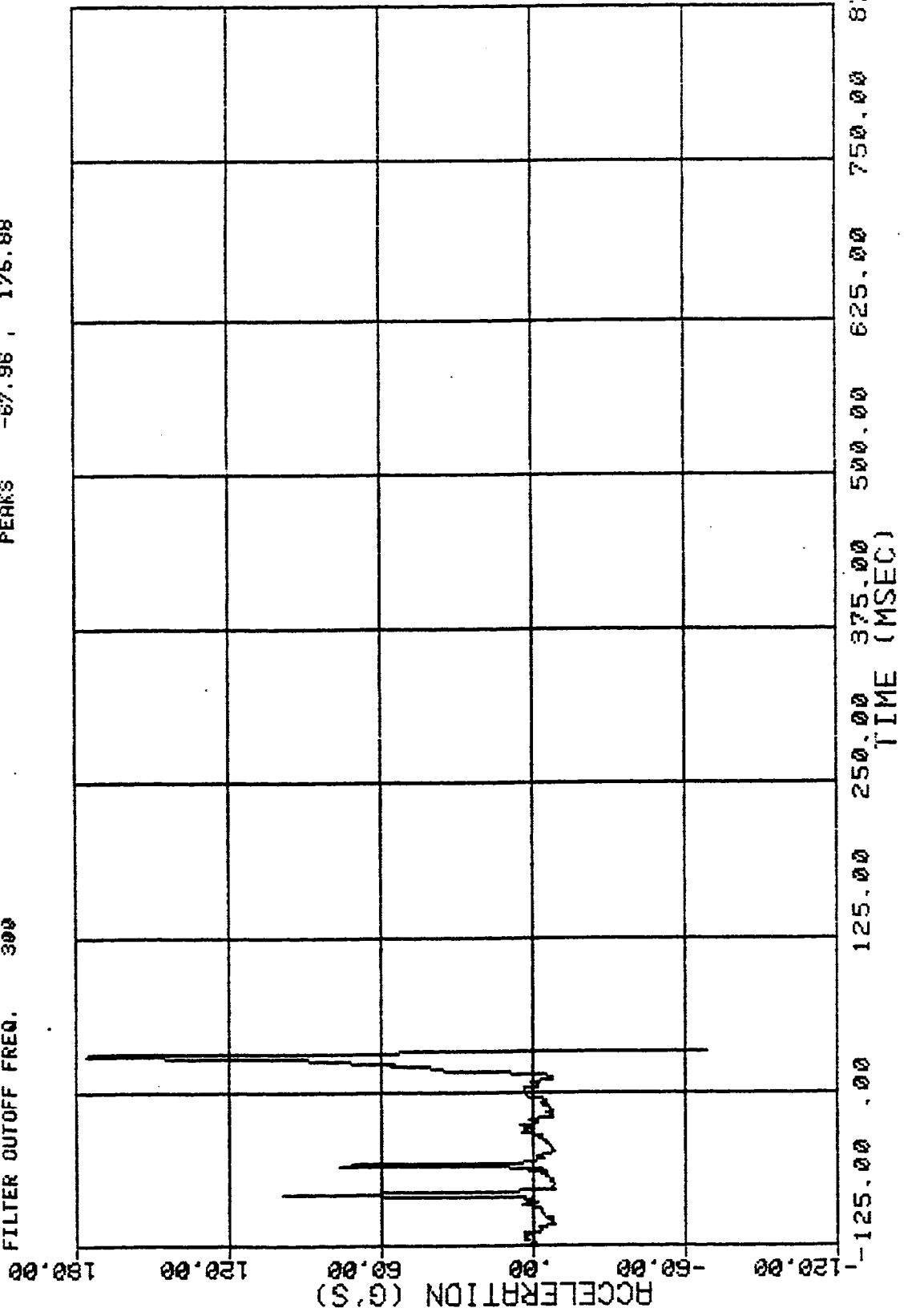
ENSOO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 2 LURY01 PEAKS -2.24 , 123
 FILTER CUTOFF FREQ. 300



A39

Figure A39. LUR - Y01 Acceleration, 300 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-86-3-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 20 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 10 LLRYGA
 FILTER CUTOFF FREQ. 300 PEAKS -67.96 , 175.88



A40

Figure A40. LLR - YGA Acceleration, 300 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 11 LURYGA
 FILTER CUTOFF FREQ. 300 PEAKS -7.49 , 137.5

.

.

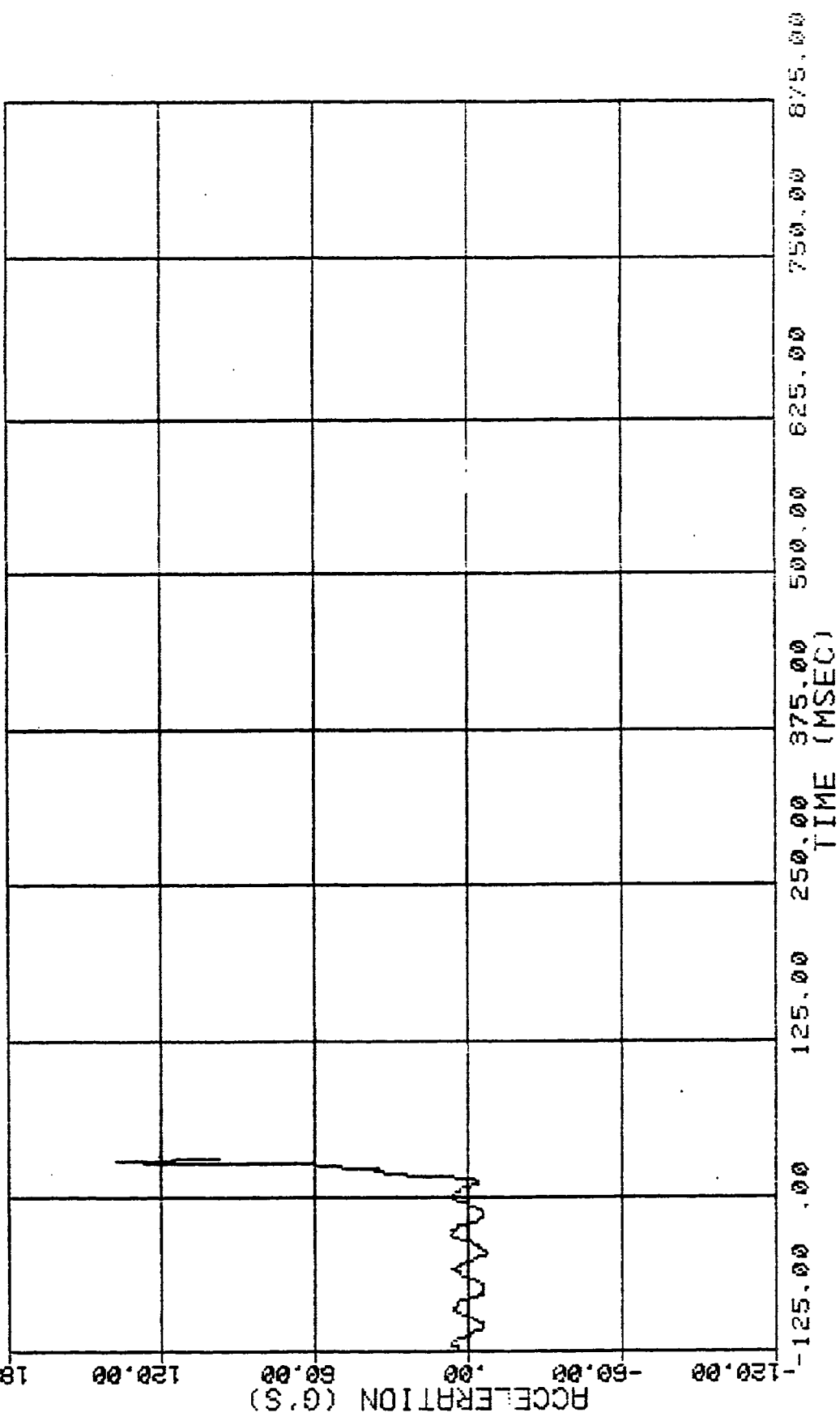


Figure A41. LUR - YGA Acceleration, 300 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-6-88
 80 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 3 T01Y NHISA FIR FILTER PEAKS -3.88 , 50.67
 FILTER CUTOFF FREQ. 0

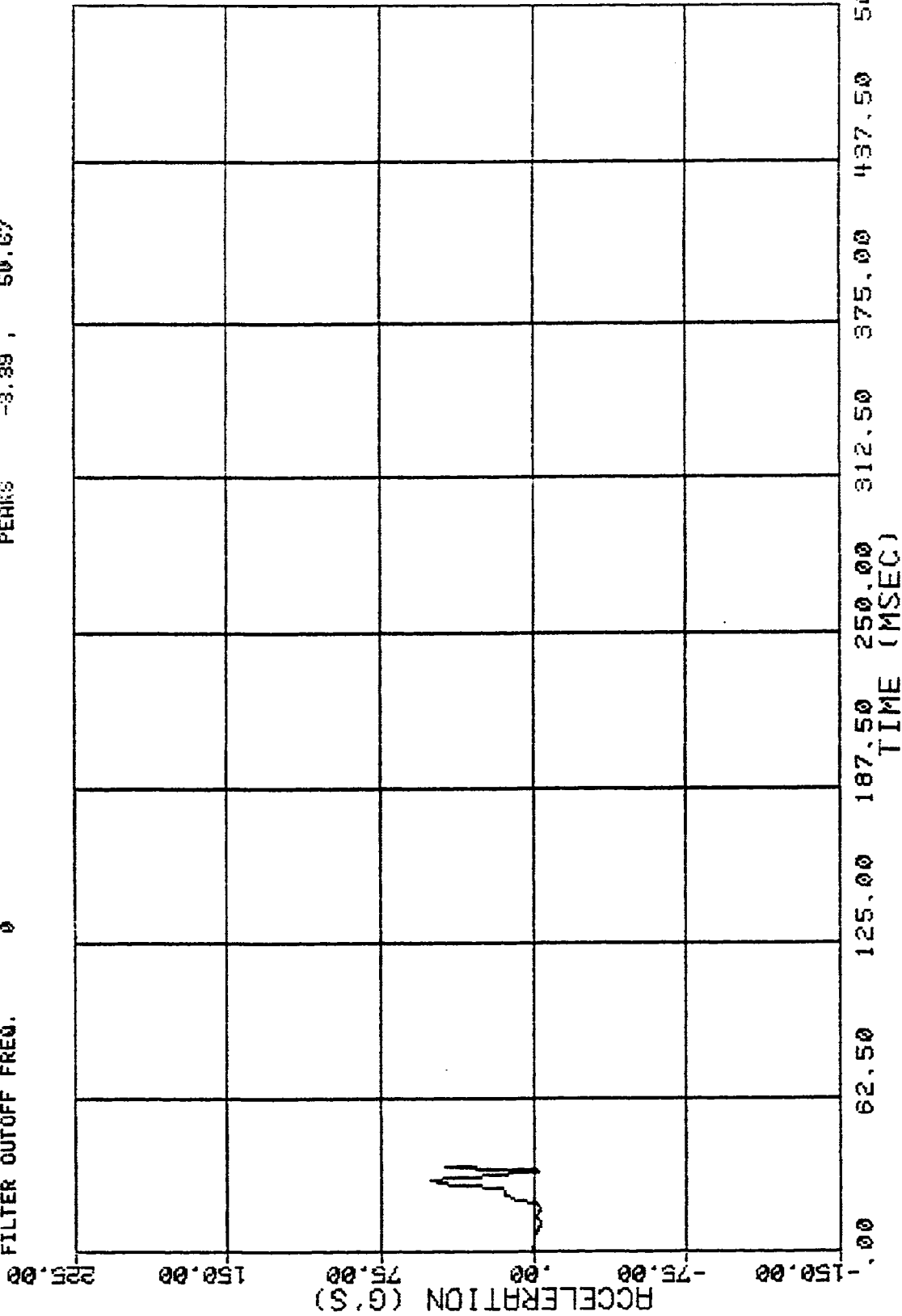


Figure A42. T01 - Y Acceleration, FIR Filter

ENSCO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 7 T12Y NHYSA FIR FILTER
 FILTER CUTOFF FREQ. 0 PEAKS -.7 101.5

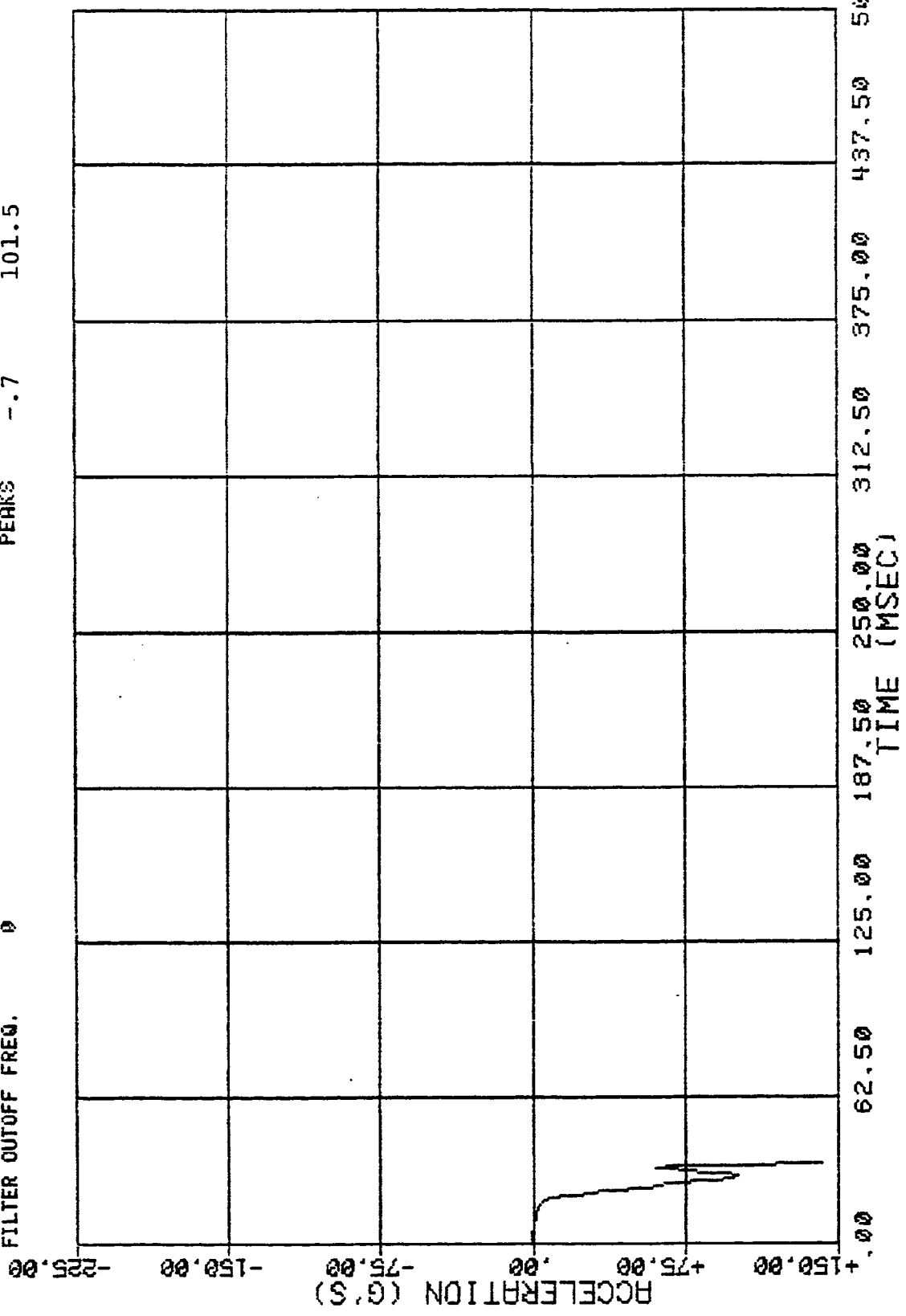


Figure A43. T12 - Y Acceleration, FIR Filter

Note: Sign Change

ENSOO, INC. CONTRACT NUMBER DTFH61-86-2-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 1 LLYG01 NHTSA FIR FILTER
 FILTER CUTOFF FREQ. 0 PEAKS -87.60 , 133.34

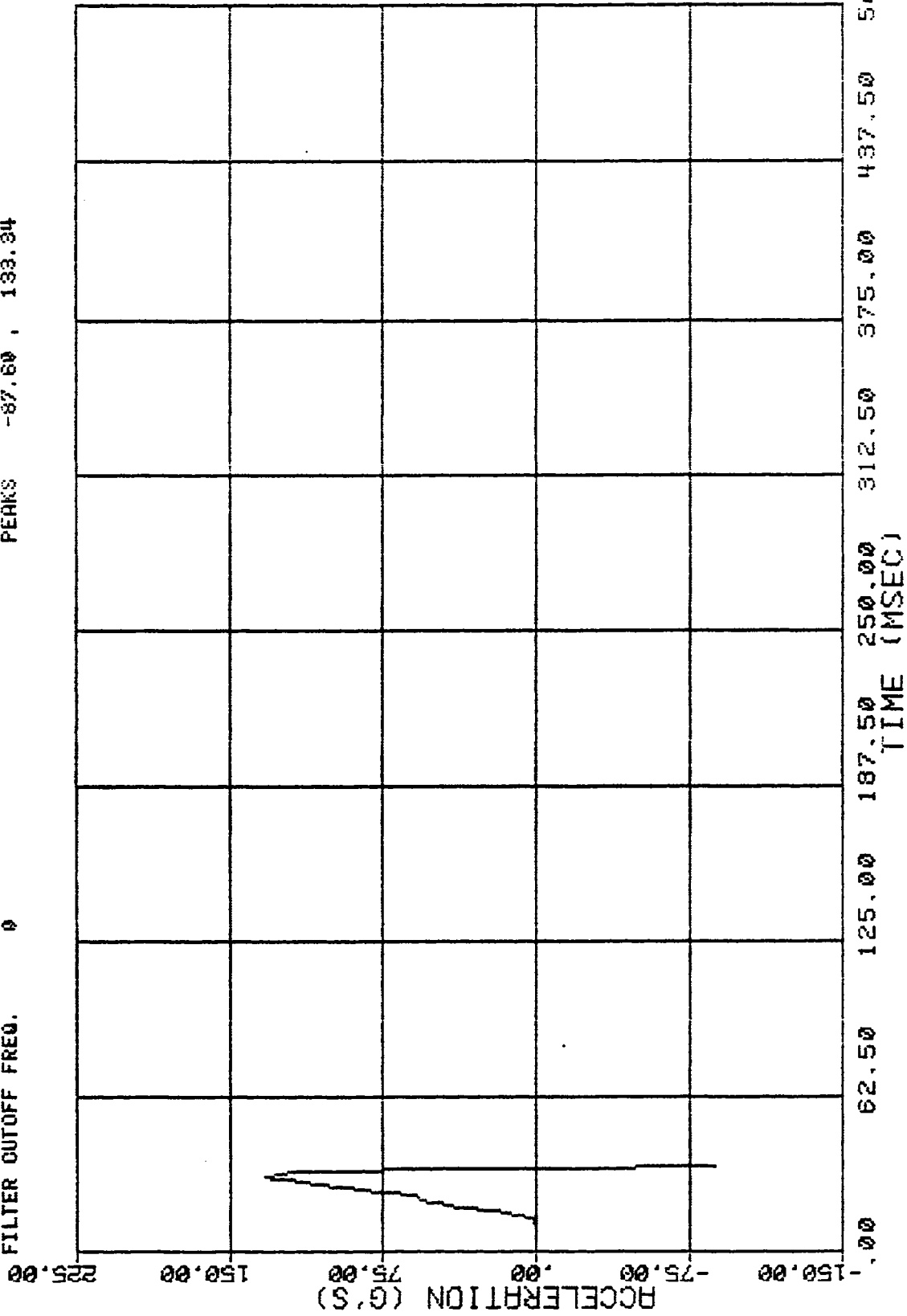
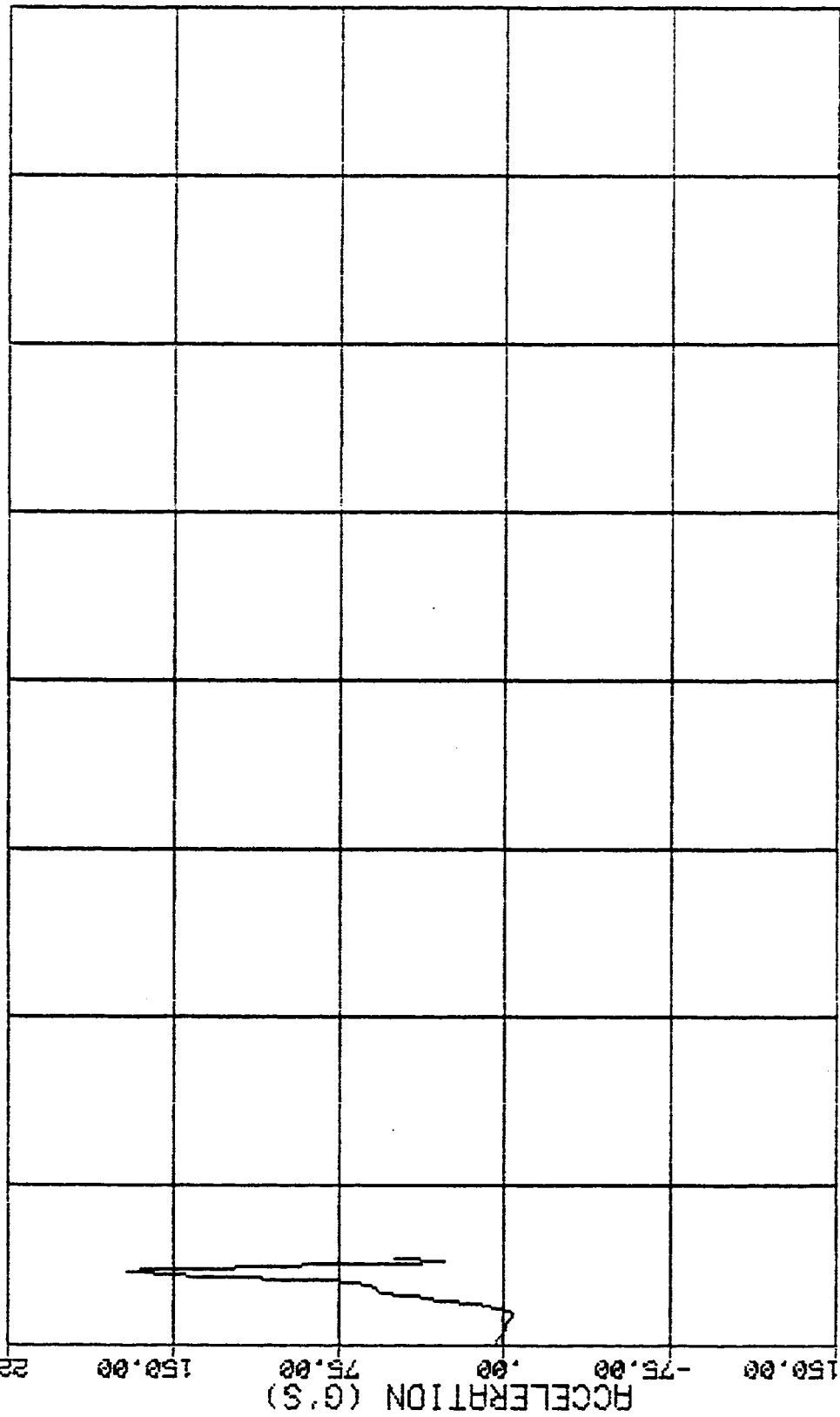


Figure A44. LLR - Y01 Acceleration, FIR Filter

ENSCO, INC. CONTRACT NUMBER DTFH61-86-2-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYHOUGH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 10 LLRYGA NITSA FIR FILTER
 FILTER CUTOFF FREQ. 0 PEAKS -0.56 , 171.17

225.00



-150.00
 -75.00
 .00
 75.00
 150.00
 225.00
 62.50 125.00 187.50 250.00 312.50 375.00 437.50 500.00
 TIME (MSEC)

Figure A45. LLR-YGA Acceleration, FIR Filter

ENSCO, INC. CONTRACT NUMBER DTFH61-86-3-00047 TEST # 1785-SI-6-88
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 2 LURY01 NHTSA FIR FILTER
 FILTER CUTOFF FREQ. 0 PEAKS -0.77 117.0

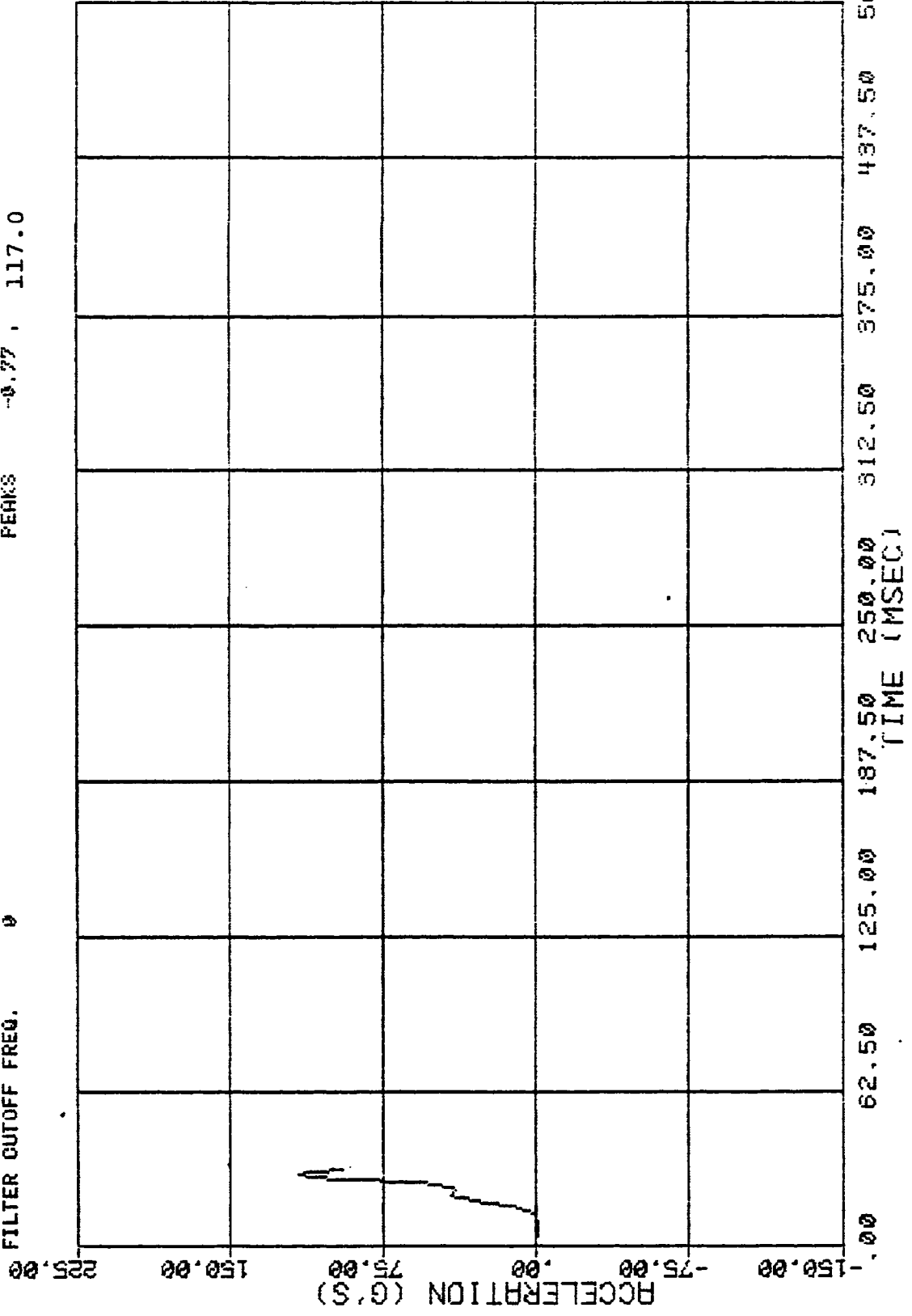


Figure A46. LUR - YG1 Acceleration, FIR Filter

ENSO, INC. VIBRATION NUMBER VIBRATION NO. 1-78877 TEST # 1,000-01-0-00
 30 MI/H BROADSIDE IMPACT OF 80 PLYMOUTH CHAMP INTO LUMINAIRE SUPPORT
 CHANNEL 11 LURYGA NHTSA FIR FILTER
 FILTER CUTOFF FREQ. 0 PEAKS -2.91 127.42

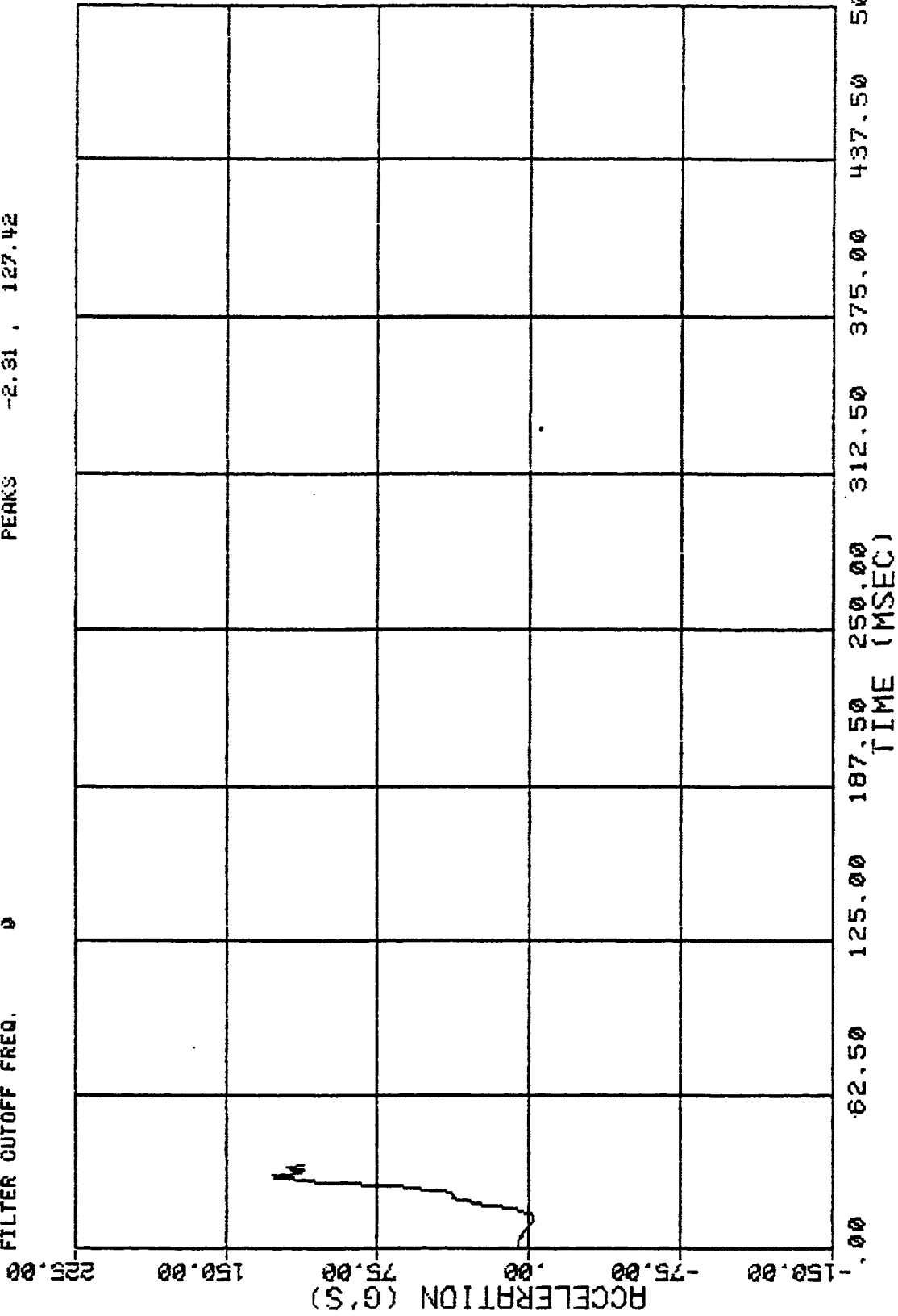


Figure A47. LUR - YGA Acceleration, FIR Filter