

DOT 1220

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#7-88

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16. Abstract This report documents the full scale side impact test of a 1980 Dodge Colt impacting into a breakaway luminaire support. The impact speed was 30 mi/h and the impact angle was broadside with the impact point align 24 inches ahead of the driver's shoulder. The impacted pole was a slip base mounted steel unit with mast arm and luminaire. The pole broke away with a low change in velocity of the vehicle, with some intrusion of the pole into the passenger compartment. Dummy parameters were all low in magnitude.			
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1.0 SUMMARY AND CONCLUSIONS

This test investigated the impact severity of a minicompact sedan (1,800S) during a ~~low speed~~ broadside collision with a breakaway luminaire support. The test vehicle was a 1980 Dodge Colt. 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 28.9 mi/h (12.9 m/s) was 935 lb-sec. The velocity change corresponding to the observed vehicle momentum change was 10.2 mph or 15.0 ft/sec. The integrity of the vehicle was maintained throughout the test with the exception of the drivers door being crushed slightly near the hinge point. Maximum residual crush of the side of the vehicle was 7.5 inches.

Vehicle acceleration data was processed to determine the impact velocity of a hypothetical front seat passenger against the vehicle interior in accordance with the flail space model recommended in NCHRP 230. The lateral impact velocity of the hypothetical occupant using the flail space model approach with a one foot threshold was 14.7 ft/sec. This lateral impact velocity is within the design limit of 20 ft/sec (6.10 m/s) specified for lateral impacts of other forms of highway safety appurtances in NCHRP 230.

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 very mild 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,

4 or 5 was 0%. This values, based on the T12Y, 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 150. This result is within 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 impact. 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#7-88

1.	Contract Number/FOIL Test No.	DTFH61-86-Z-00047/88S008
2.	Date of Test	May 26, 1988
3.	Test Vehicle	Dodge Colt, 1980
4.	Delivered Vehicle Weight	1958 lbs
5.	Vehicle Weight, Test Inertial	
	Planned	1,800 ±50 lbs
	Actual	1,847 lbs
6.	Vehicle Weight, Gross Static	
	Actual (One Occupant)	2,007 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	4.0 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 1785-SI#7-88

22.	Impact Speed, Observed	28.9 mph
23.	Speed Reduction Acceleration Data, TRC 191	10.2 mph
24.	Exit Speed	18.7 mph
25.	Impact Point, Observed	Left Door, Driver Location, (at cg)
26.	Traffic Accident Data, TAD	9-LP-01
27.	Vehicle Damage Index, VDI	09LPAN1
28.	Hypothetical Occupant Impact Velocity (NCHRP 230)	
	Design Limit	20 ft/sec
	Observed (1' flail)	14.7 ft/sec
	Observed (.5' flail)	9.3 ft/sec
29.	Hypothetical Occupant Ride-down Acceleration (NCHRP 230)	
	Design Limit	15.00 g
	Observed, (1' flail)	-3.5 g
	Observed, Actual (.5' flail)	-12.0 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	150
32.	Upper Spine Acceleration Data Acceleration with Duration Greater than .003 sec	16 g's
	CSI	46
33.	TTI-86, age=0	14
34.	Thoracic Injury (age=0)	
	Fatal Injury	6.00
	Probability of:	
	AIS greater than 3	0%
	AIS greater than 4	0%
	AIS greater than 5	0%
35.	Momentum Change from Pole	935 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 seventh 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 Dodge Colt. A triaxial accelerometer package was mounted on the lateral centerline of the vehicle near the longitudinal location of the center of gravity of the vehicle in its inertial test configuration. The data from these accelerometers were used to measure vehicle impact behavior and occupant injury potential based upon criteria set forth in TRC 191 and NCHRP 230. One rate gyro was also mounted to the accelerometer block to measure the 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 (7 actual)	90	+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

³Slipbase 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 planned test number and actual test number 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

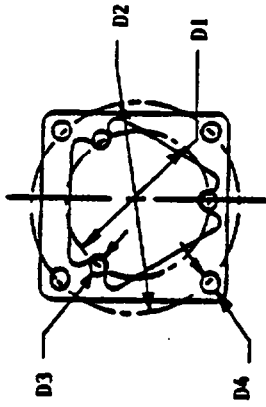
Manufacturer:	Ameron
Material:	Steel
Weight:	416 lbs
Height, c.g.:	21 ft
Top diameter:	3-1/2 in
Bottom diameter:	7.5 in
Mast Arm Length:	15 ft - 9 in.
Luminaire Height:	35 ft - 10 in.
Luminaire Weight:	51 lbs
Base Type:	California Type 31 slip base
Number of bolts:	3
Size:	1 in diameter
Type:	Instrumented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

SLIP BASE WITH TRUSS MAST ARM

Manufacturer: Ameron Part Nos

Ref. FOIL Tests:

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



HEIGHTS (LB)

Poles: 275 (W1)
 Mast Arms: 90 (W2)
 Luminares: 51 (W3)
 Total Assys: 416 (WT)

DEASBLED LENGTHS (IN)

Mounting Heights: 36' (H1) No. Slip Bolts: 3
 Pole Heights: 30'3" (H2) Slip BC Dia (in): 14 (D1)
 Pole CB Height: 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)
 Lumina CB Ht: 35'10" (H4) Dia Found Bolt (in): 1 (D4)
 Lumina CB Offsets: 15'9" (L1) 8 Bolt Clamp Force (lb): 14,000
 Stub Ht: 4.0 (H7) Keeper Plate, Y/N: Y

Slip Base Thick (in): 1

POLE PARAMETERS
 Base Dia (in): 7.5 Wall Thick (in): .125
 Tip Dia (in): 3.5 Material: Steel

ORIGINAL ASSEMBLY CB LOCATION (IN)
 Total Assy CB Ht = 21' (H3)
 Total Assy CB Offset = 3'4" (L3)

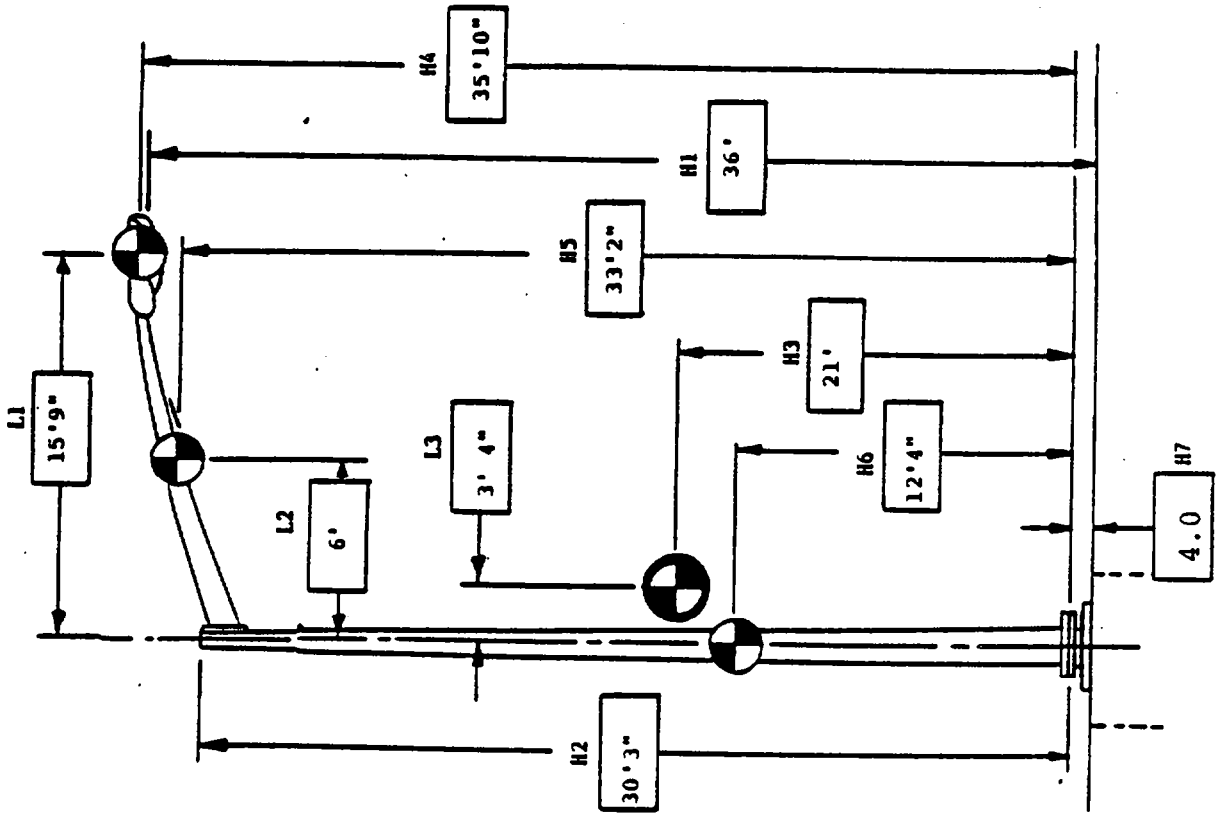


Figure 1. Mechanical Properties of Pole

4.0 VEHICLE DESCRIPTION

The test vehicle was a 1980 Dodge Colt. The weight of the vehicle prior to incorporating the instrumentation for the test was 1958 lbs. The test inertial weight for the vehicle was 1847 lbs and the gross static weight when the occupant was included in the vehicle was 2007 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. One gyro was also installed to the same mounting block to measure the 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 system also had a yaw and roll rate gyro 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 Dodge Colt
Serial Number	4H24KA4602952
Build Date	September 1979
Delivered Weight	1958 lbs
Delivered cg-x	32" behind front axle center line
Delivered cg-y	at vehicle centerline
Delivered cg-z	19.8" above ground
Delivered Roll Inertia	212 slug-ft ²
Delivered Pitch Inertia	901 slug-ft ²
Delivered Yaw Inertia	913 slug-ft ²
As tested weight, inertial	1847 lbs
As tested weight, gross	2007 lbs
As tested cg-x	32" behind front axle centerline
As tested cg-y	at vehicle centerline
As tested cg-z	20.2" above ground
As tested Roll Inertia	195 Slug-ft ²
As tested Pitch Inertia	762 Slug-ft ²
As tested Yaw Inertia	843 Slug-ft ²

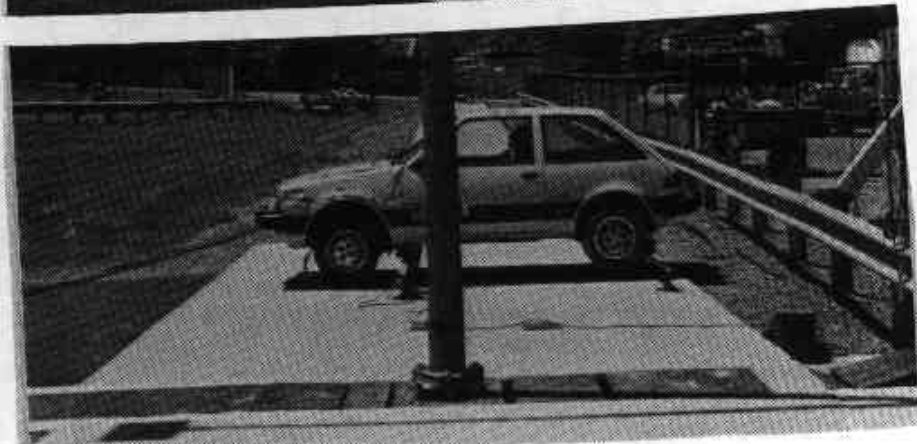
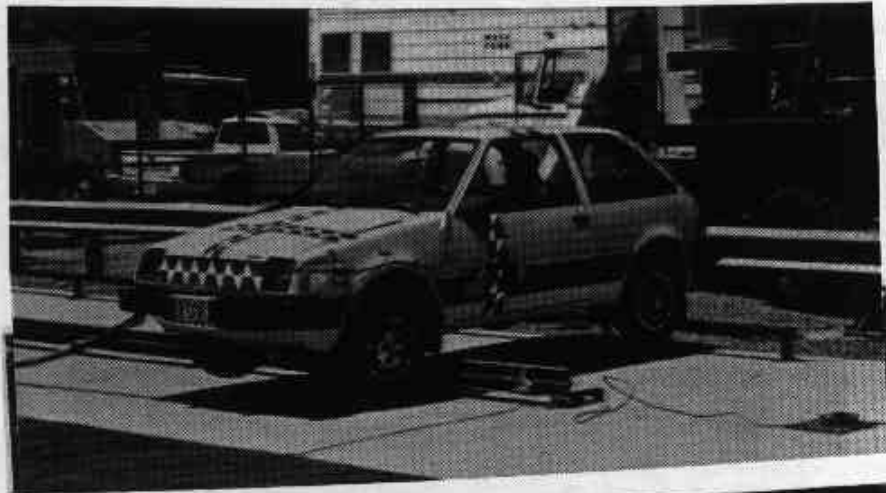


Figure 2. Pre-Test Photos of Vehicle

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 and gyros 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., T0LXG1
5	Upper Spine Accel., T0LZG1
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 28.9 mi/h (12.9 m/s) at a point on the left door 24 inches (0.3 m) forward of the occupant, which coincides with the longitudinal location of the center of gravity of the vehicle measured without the dummy in the vehicle. The vehicle had a 6.0 deg 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 7.5 inches (.19 m). Photographs of the vehicle and luminaire support after the collision event are shown in Figure 3.

After the initial separation from the vehicle the luminaire support translated forward at a speed of 24.7 f/s (7.5 m/s) with a rotation rate of 1.8 rad/sec. The luminaire support rotated up and over the test vehicle with the top of the pole hitting the ground about 1.07 seconds after impact. Just prior to impact with the ground, the center position of the pole impacted the hood of the car. At the time of impact of the pole on the hood, the vehicle had yawed clockwise. It continued yawing for a total yaw angle of 90 deg. The vehicle did not pitch or roll very much but remained stable during this transition. The final resting position of the vehicle was about 36 ft downstream and 8' to the left of the impact point. The pole base ended up next to the vehicle with the top near the impact point. The residual test vehicle crush measured using the 6 point NHTSA guide is given in Table 7. See figure 4 for reference.

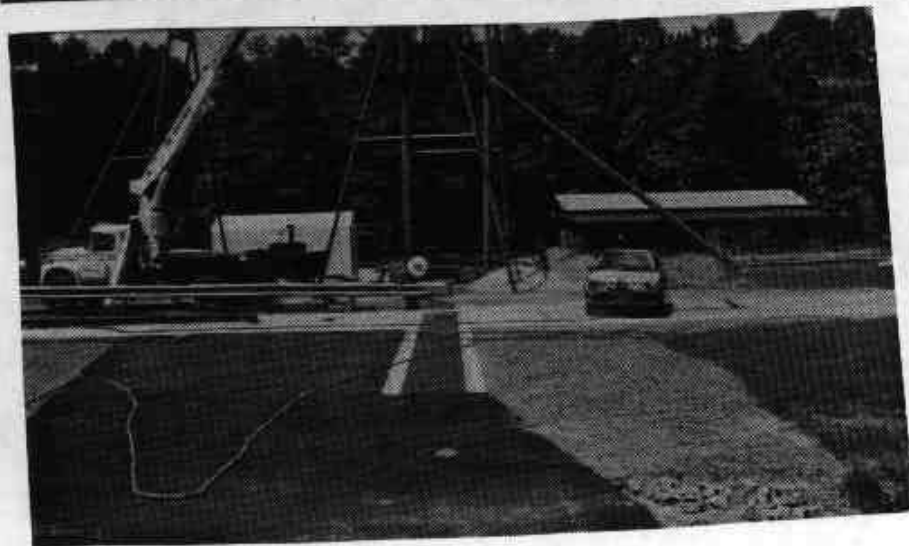


Figure 3. Post-Test Photos of Vehicle



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

Table 7
Residual Vehicle Crush

C1 = 0.0 in	L = 47.5 in
C2 = 4.0 in	D = -9.8 in
C3 = 5.5 in	Maximum crush = 7.7 in
C4 = 7.5 in	
C5 = 7.0 in	
C6 = 0.0 in	

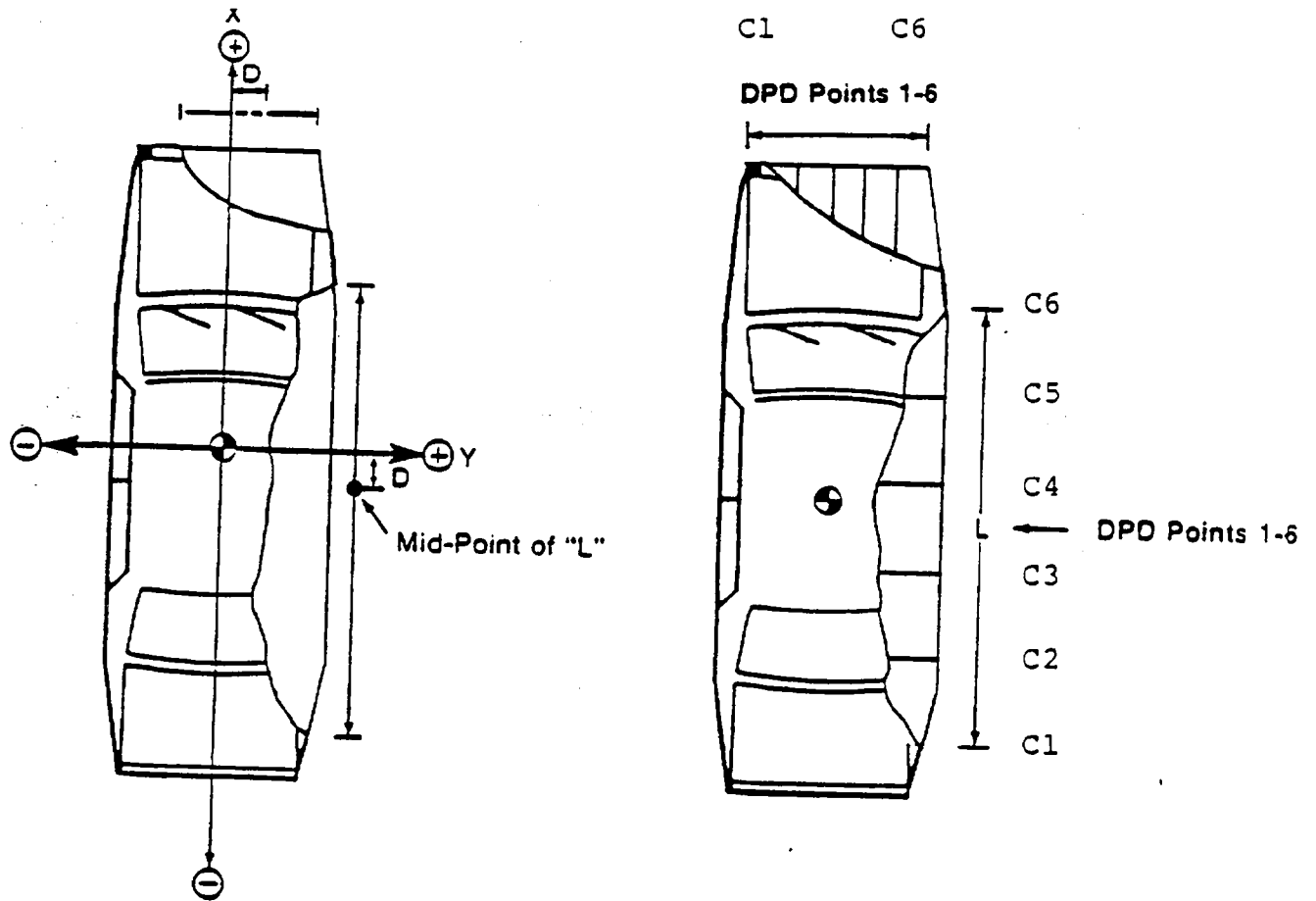


Figure 4. NHTSA Vehicle Damage Measurements

7.0 TEST ANALYSIS

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

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

7.1 IMPACT VELOCITY ANALYSIS

The speed that the test vehicle impacted the luminaire support was determined from the high speed 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	43.6	29.7
2	Right Side	<u>41.2</u>	<u>28.1</u>
Avg		42.4	28.9

A speed trap was installed to measure the speed of the vehicle as it left the end of the mono-rail. During this test the speed trap indicated a speed of 31.13 mi/h. 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 42.1 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 28.9 mi/h (12.93 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). Figure A8 presents the yaw angle of this plot.

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 15.0 ft/sec and 935 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 17.5 ft/sec and 1090 lb-sec.

Analysis of the impact velocity of a hypothetical front seat passenger against the vehicle interior, calculated from the vehicle lateral Class 180 acceleration yielded the results shown in Table 9. Using the standard one foot flail distance, a hypothetical front seat occupant would have impacted the interior of the vehicle in the lateral direction at an approximate impact velocity of 14.7 ft/sec (4.5 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 -3.5 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	-14.7	- 3.5
.50 ft	- 9.2	- 12.0

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

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:

$$x_{cg} = \frac{1}{M_p} I_3$$

and

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

where

x_{cg} = Longitudinal velocity of the luminaire support c.g.,

r = Rotational rate of luminaire support

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

M_p = Mass of luminaire support = 12.9 slugs

I_p = Mass moment of inertia of the luminaire support
= 2069 slug ft²

and I_3 = Momentum change occurring during Phase 3.

From the film data $x_{cg} = 24.7$ f/s (7.5 m/s) and $r = 1.8$ rad/sec. Using these two numbers the momentum change occurring during Phase 3 is given by

$$I_3 = M_p \times c_g$$

$$= 319 \text{ lb-sec (1410 N-s)}$$

or

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

$$= 201 \text{ lb-sec (900 N-s)}.$$

The average momentum change associated with the third phase of the vehicle momentum change is 260 lb-sec (1150 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 ($f_c = 1,650 \text{ Hz}$) filtering techniques are presented in Figures A9 through A12. The results of the HIC evaluation calculated for the occupant during this test is shown in table 10. Comparing the results to the acceptable limit of 1000 indicates that the collision event was very mild.

Table 10
Head Injury Criteria

	<u>Driver</u>
HIC	150
t(Start)	.043125 sec
t(Stop)	.046875 sec
t(Duration)	.00375 sec

7.5 OCCUPANT SEVERITY INDEX EVALUATION

The data obtained from the triaxial accelerometer packages located in the upper spine (T01), lower spine (T12), all left ribs and the sternum were filtered at SAE Class 180. The T01, T12 and pelvis data was combined to yield a 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 was selected to evaluate chest parameters since it was the closest data to the location of standard chest accelerometers. The CSI was 46 and the maximum acceleration was 16 g's at 58.7 milliseconds. These results should not be compared directly with the design limits for the severity index of 1000 and sustained acceleration level of 60g specified in FMVSS 208 since none of the accelerometers are located at the center of gravity of the upper thorax location. The CSI and max acceleration in data for the pelvis was 62 and 43 g's at 18.3 msec. The T12 data produced a CSI of 34 and a maximum chest of 17 at 37.7 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 A13 through A16 for the upper spine (T01) location, Figures A17 through A20 for the lower spine (T12) location, Figures A21 through A24 for the pelvis and Figures A25 for the sternum location. 300 Hz data traces for the rib accelerometers are presented in Figures A26 through A29.

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 A30 through A35.

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

$$TTI = 1.4 * Age + .5 * (T12Y + MAX (LLRY, LURY)) * (Mass/165)$$

The following data was determined from the FIR filtered data:

T01Y	-	17.4 g's
T12Y	-	15.3 g's
LURYG1	-	8.9 g's
LURYGA	-	10.7 g's
LLRYG1	-	13.4 g's
LLRYGA	-	15.6 g's

The two rib data points were averaged together to obtain 14.5 g's for the lower rib and 9.8'g for the upper rib. Table 11 presents a matrix for AIS values for ages 0, 23 and 41 years. See Figure 5 for TTI-86 values.

Table 11
Matrix of TTI-86 vs AIS Values

<u>Age</u>	<u>TTI-86</u>	<u>Probability of Injury</u>		
		<u>AIS +3</u>	<u>AIS +4</u>	<u>AIS +5</u>
0	14	0%	0%	0%
23	46	0%	0%	0%
41	71	0%	0%	0%

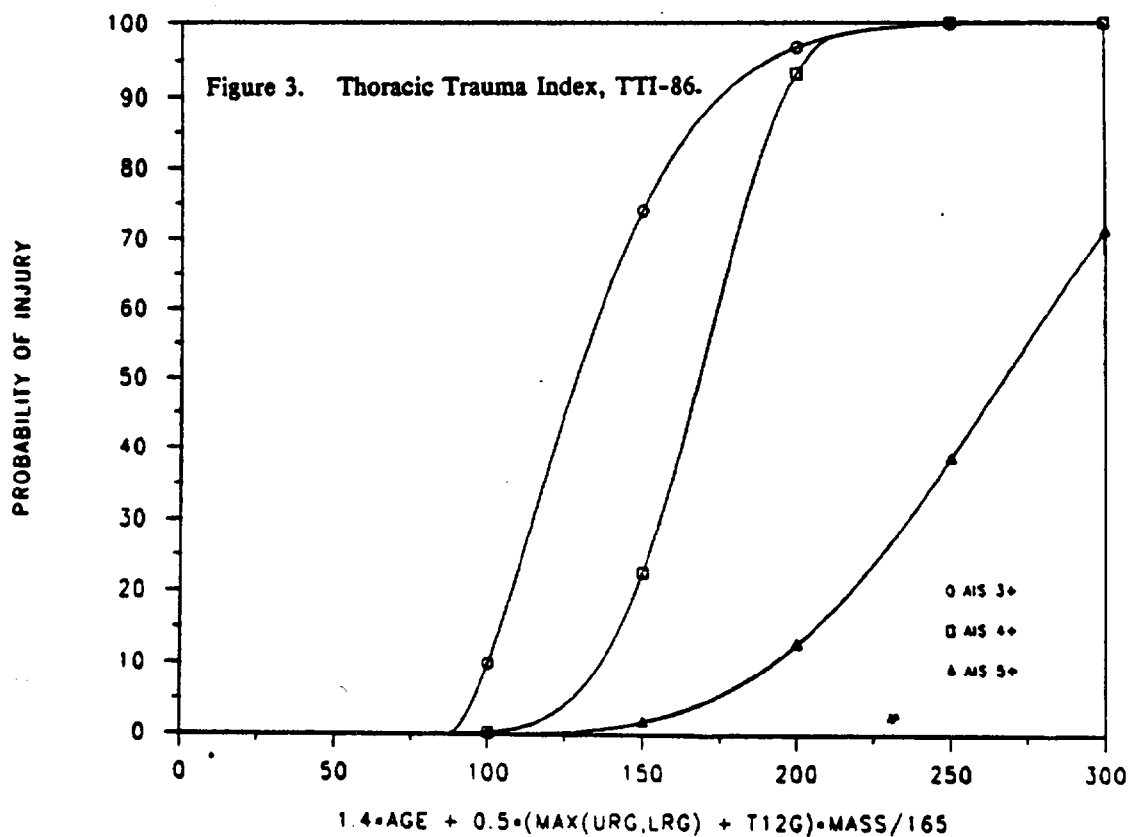


Figure 12. Thoracic Trauma Index Scale

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 = 42.3 ft/sec

$$KE = 56.1 \text{ kip-ft}$$

Post Impact Energy Sources

1) Exit kinetic Energy

$$KE_E = .5MV_E^2$$

Where VE = exit velocity

= V_I - Reduction

= 42.3 - 15 = 27.3 ft/sec

$$KE_E = 23.2 \text{ kip-ft.}$$

2) Rotational energy of vehicle

Rotational Energy of vehicle

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

Where: I_V = Yaw inertia of vehicle = 838 slug ft²

W_V = rotational rate

= 20/57.3 rad/sec (see Figure A7)

$$RE_V = .5 \text{ kip-ft}$$

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.

Work at 7.5 crush = 2.7 kip-ft

4) Tire friction

Work = fWd

Where f = tire sliding friction = .8

W = vehicle weight = 2007 lbs

d = 10 ft

Tire work = 16.0 kip-ft

5) Slip base work

Work = fLd

Where f = friction of steel on steel = .2

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

d = Slide distance to release = .5"/12 = 0.0417 ft

Base work = .3 kip-feet

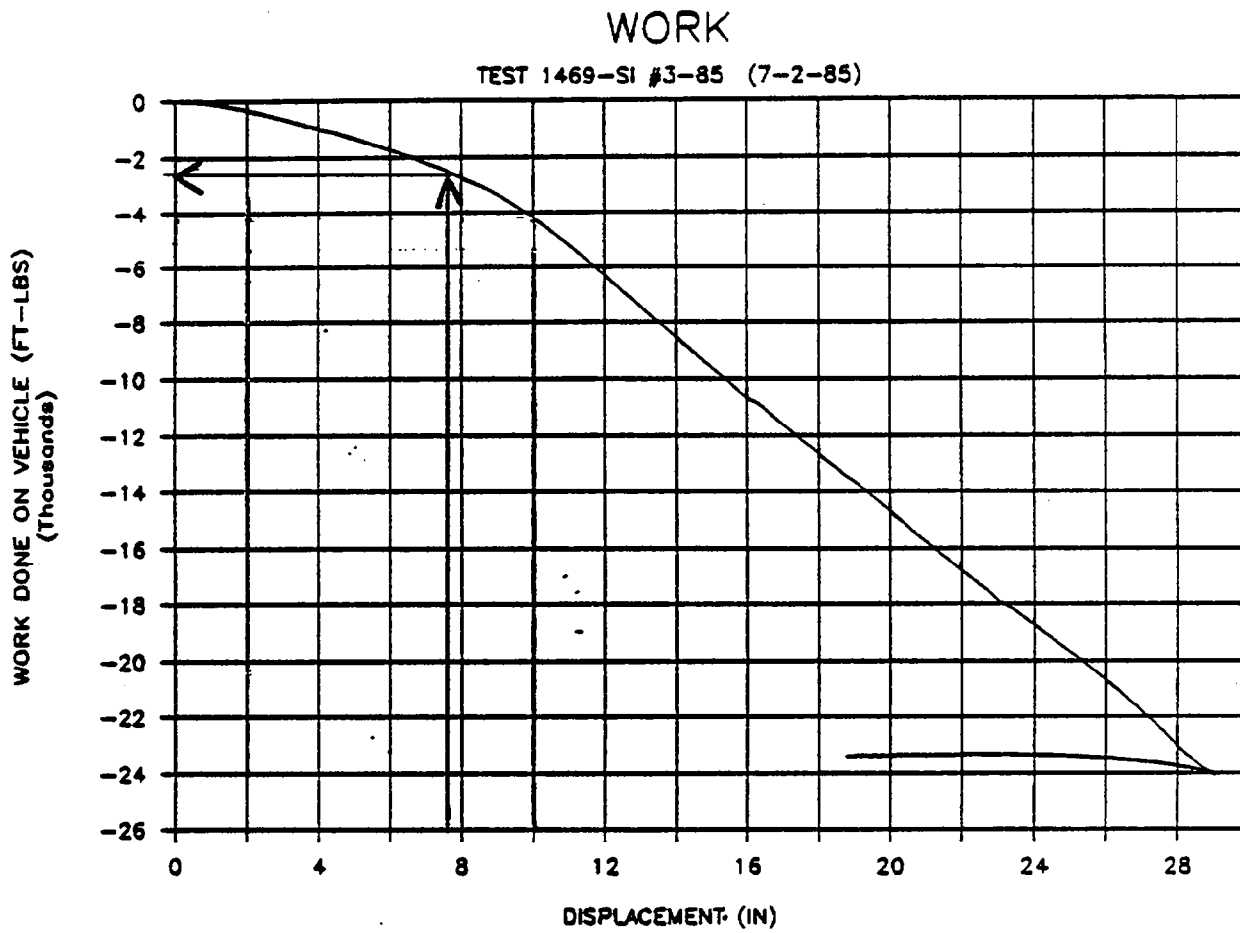


Figure 6. Crush Energy for Dodge Colt During Side Impact

6) Rotational energy of pole

$$KE_{PR} = .5I_p W_p^2$$

Where I_p = Inertia of pole = 2070 slug-ft²

W_p = Rotational rate of pole

$$= 1.8 \text{ rad/sec}$$

$$KE_{PR} = 3.3 \text{ kip-ft}$$

7) Translational energy of pole

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

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

V_p = pole velocity

$$= 24.7 \text{ ft/sec}$$

$$KE_{PT} = 3.9 \text{ kip-ft}$$

Totaling the post impact sources the following is determining:

1. 23.2 kip-ft
2. 0.5 kip-ft
3. 2.7 kip-ft
4. 16.0 kip-ft
5. .3 kip-ft
6. 3.3 kip-ft
7. 3.9 kip-ft

Total 49.9 kip-ft

This is in fair agreement with the energy upon impact of 56.1 kip-ft.

8.0 SAFETY ASSESSMENT OF TEST

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

STRUCTURAL ADEQUACY

The test pole readily activated in the predicted manner. There was 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 as most likely safe. This was due to the forward impact location of the pole on the vehicle. HIC, CSI and max chest accelerations were low and within the limits. The thoracic injury also indicated a very mild accident rating with a zero probability of an AIS greater than 3, 4 or 5.

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

VEHICLE TRAJECTORY

Vehicle trajectory after the test was acceptable.

OVERALL RATING

Although severe intrusion did occur, this pole/vehicle combination with the discussed impact conditions could be rated acceptable based on occupant measured parameters.

Evaluation Factors	Evaluation Criteria	Applicable to Minimum Matrix Test Conditions (see Table 3)
Structural Adequacy	A. Test article shall smoothly redirect the vehicle; the vehicle shall not penetrate or go over the installation although controlled lateral deflection of the test article is acceptable.	10, 11, 12, 30, 40
	B. The test article shall readily activate in a predictable manner by breaking away or yielding.	60, 61, 62, 63
	C. Acceptable test article performance may be by redirection, controlled penetration, or controlled stopping of the vehicle	41, 42, 43, 44, 45, 50, 51, 52, 53, 54
	D. Detached elements, fragments or other debris from the test article shall not penetrate or show potential for penetrating the passenger compartment or present undue hazard to other traffic.	All
Occupant Risk	E. The vehicle shall remain upright during and after collision although moderate roll, pitching and yawing are acceptable. Integrity of the passenger compartment must be maintained with essentially no deformation or intrusion.	All
	<p>F. Impact velocity of hypothetical front seat passenger against vehicle interior, calculated from vehicle accelerations and 24 in. (0.61m) forward and 12 in. (0.30m) lateral displacements, shall be less than:</p> $\frac{\text{Occupant Impact Velocity-fps}}{\begin{matrix} \text{Longitudinal} & \text{Lateral} \\ 40/F_1 & 30/F_2 \end{matrix}}$ <p>and vehicle highest 10 ms average accelerations subsequent to instant of hypothetical passenger impact should be less than:</p> $\frac{\text{Occupant Ridedown Accelerations—g's}}{\begin{matrix} \text{Longitudinal} & \text{Lateral} \\ 20/F_3 & 20/F_4 \end{matrix}}$ <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.

APPENDIX A

ENSOO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 18 VEHICLE X
 FILTER CUTOFF FREQ: 100 PEAKS -5.49 , 4.62

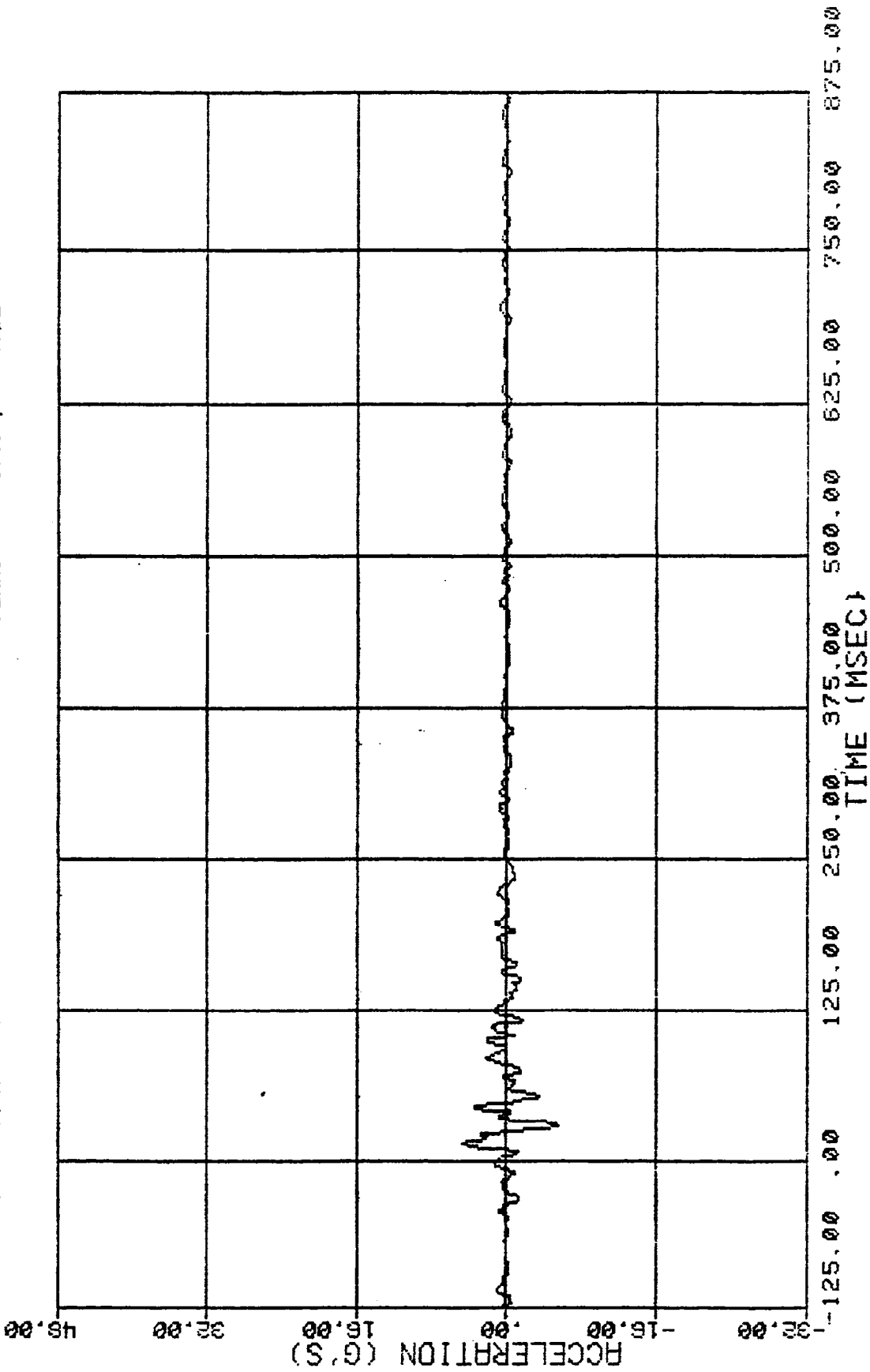


Figure A1. Vehicle X Acceleration, 100 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST * 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 19 VEHICLE Y
 FILTER CUTOFF FREQ: 100 PEAKS -27.54 , 26.58

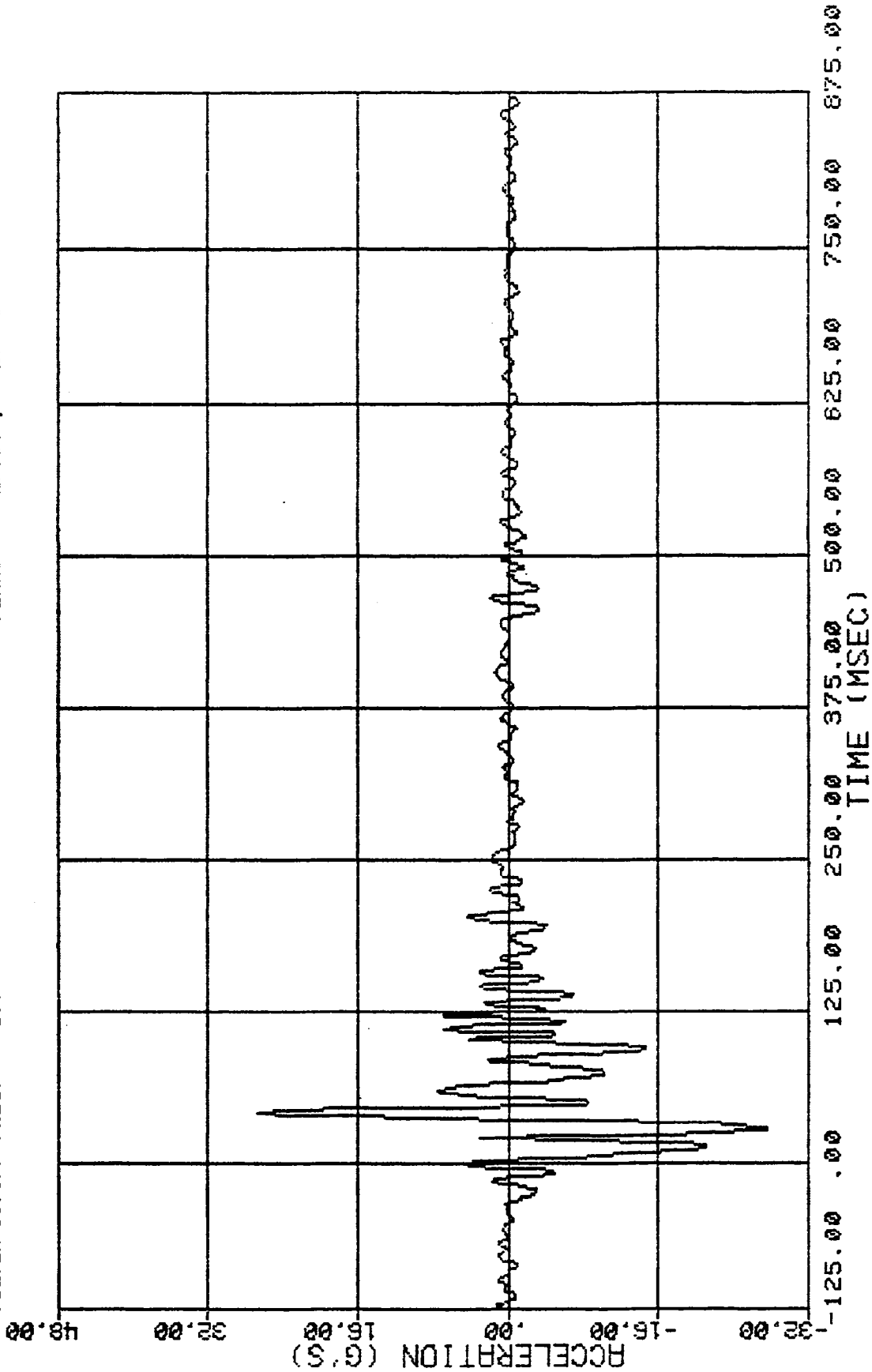


Figure A2. Vehicle Y Acceleration, 100 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 18 VEHICLE X
 FILTER CUTOFF FREQ: 300 PEAKS -9.03 , 8.18

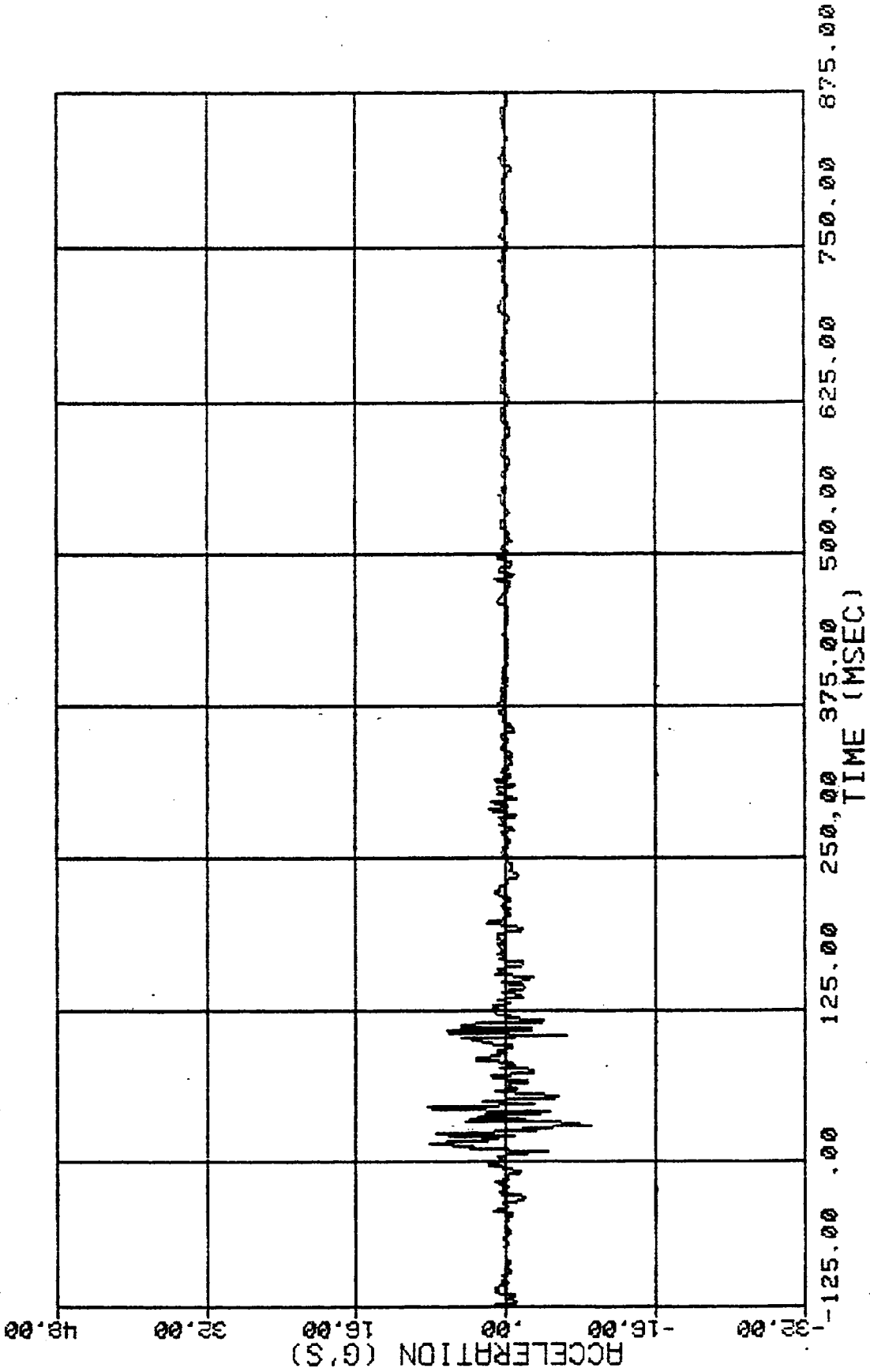


Figure A3. Vehicle X Acceleration, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-66-2-00047 TEST # 1785-SI-7-68
 30 MI/H BROADSIDE IMPACT OF 80 DODGE GOLT INTO LUMINAIRE SUPPORT
 CHANNEL 19 VEHICLE Y PEAKS -31.88 , 30.95
 FILTER CUTOFF FREQ: 300

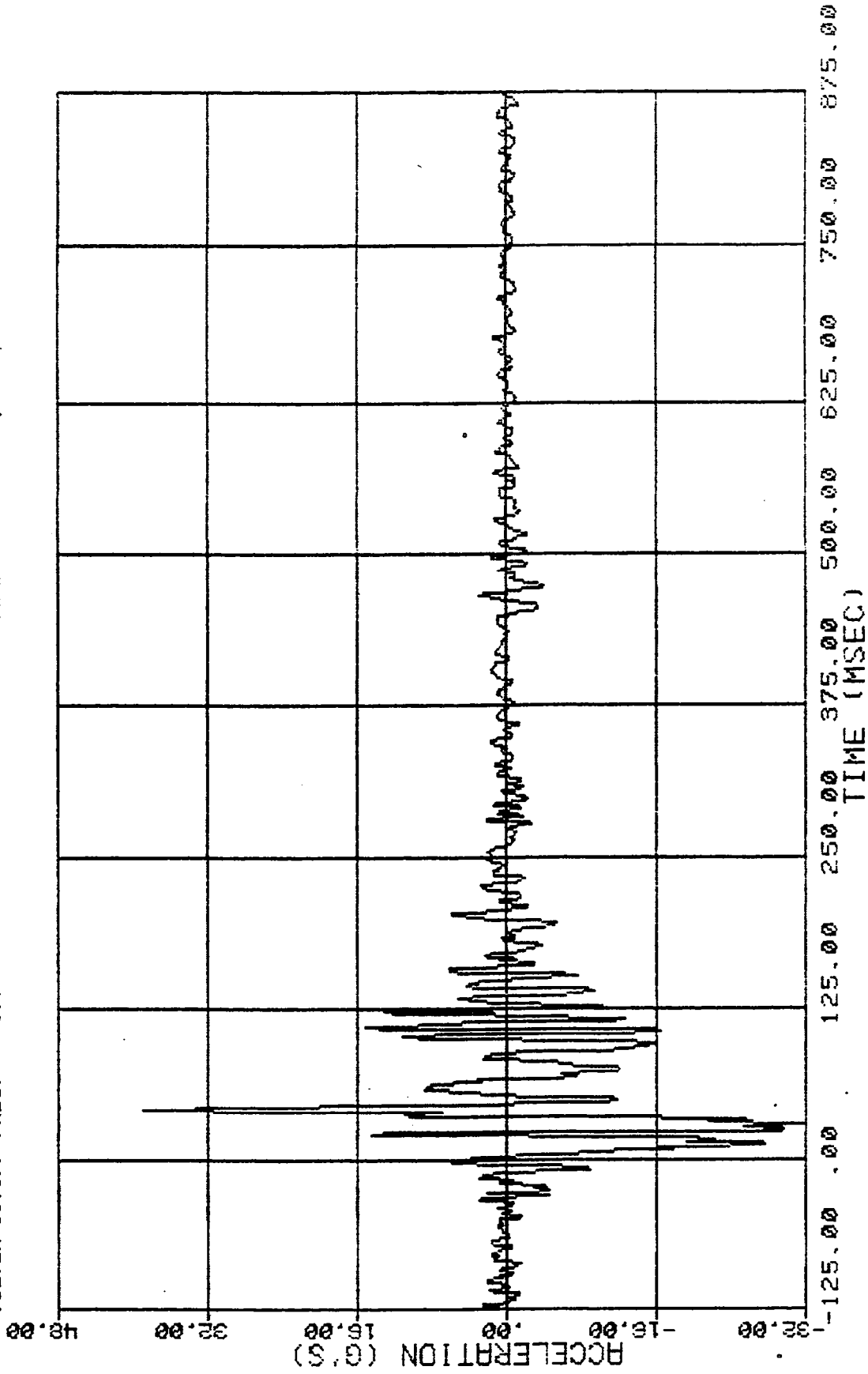


Figure A4. Vehicle Y Acceleration, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-7-88
 80 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 20 IMPACT
 FILTER CUTOFF FREQ: 1650 PEAKS -6.17 9.87

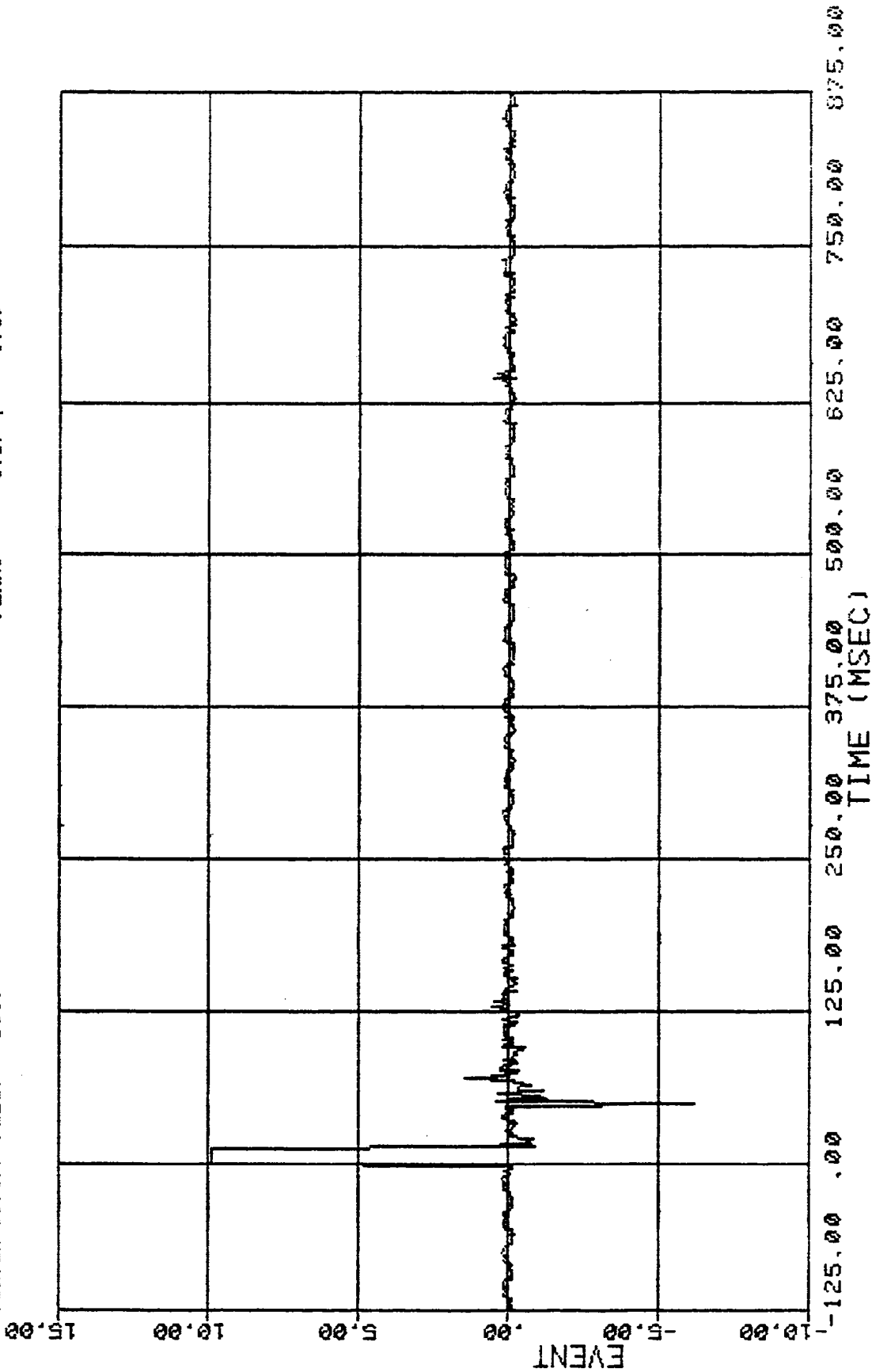


Figure A5. Vehicle Impact Marker

ENSCO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 21 VEHICLE YAW RATE
 FILTER CUTOFF FREQ: 100 PEAKS -174.60 , 155.88

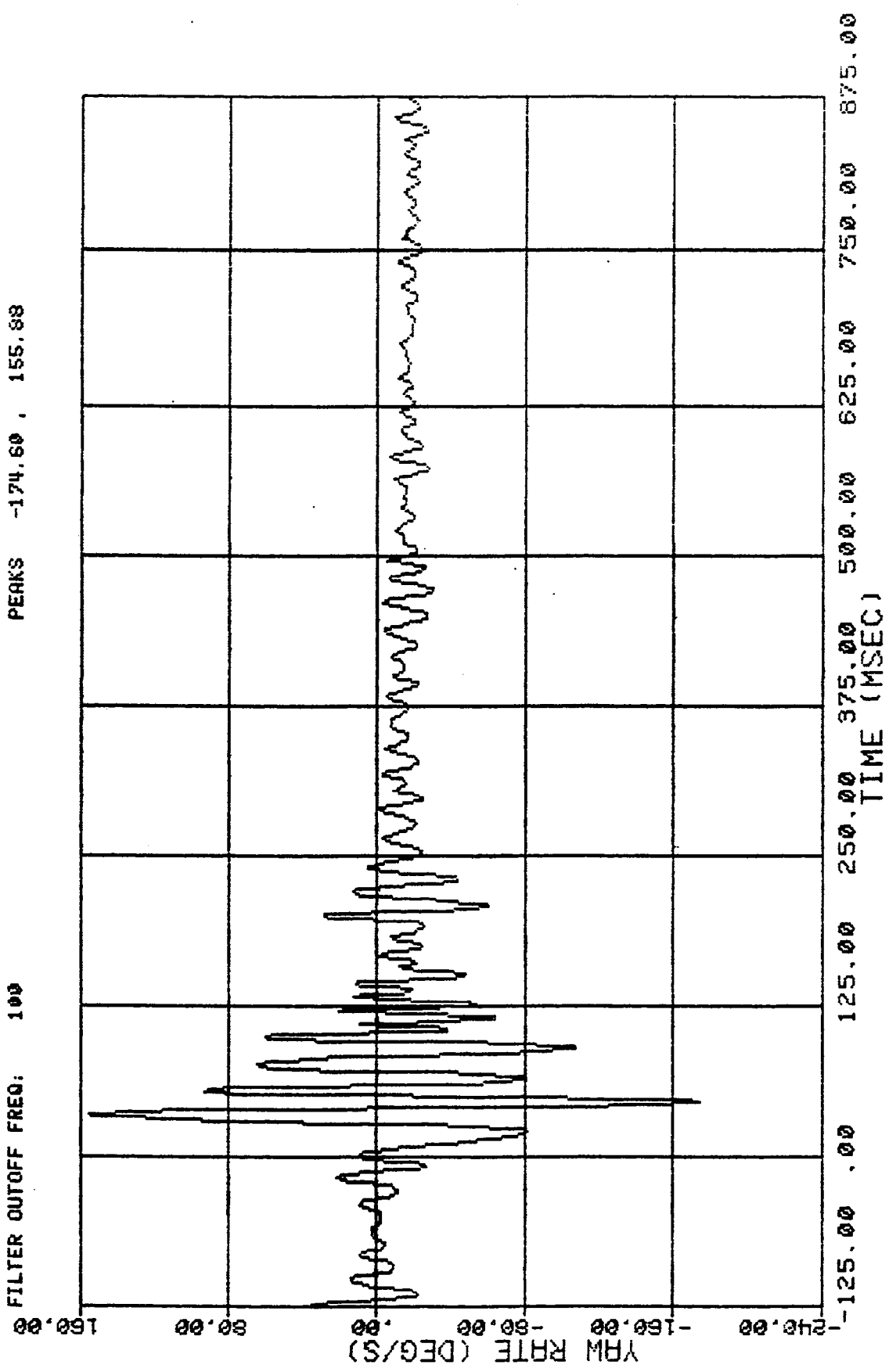


Figure A6. Vehicle Yaw Rate, 100 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 21 VEHICLE YAW RATE
 FILTER CUTOFF FREQ: 10 PEAKS -18.28 , 19.06

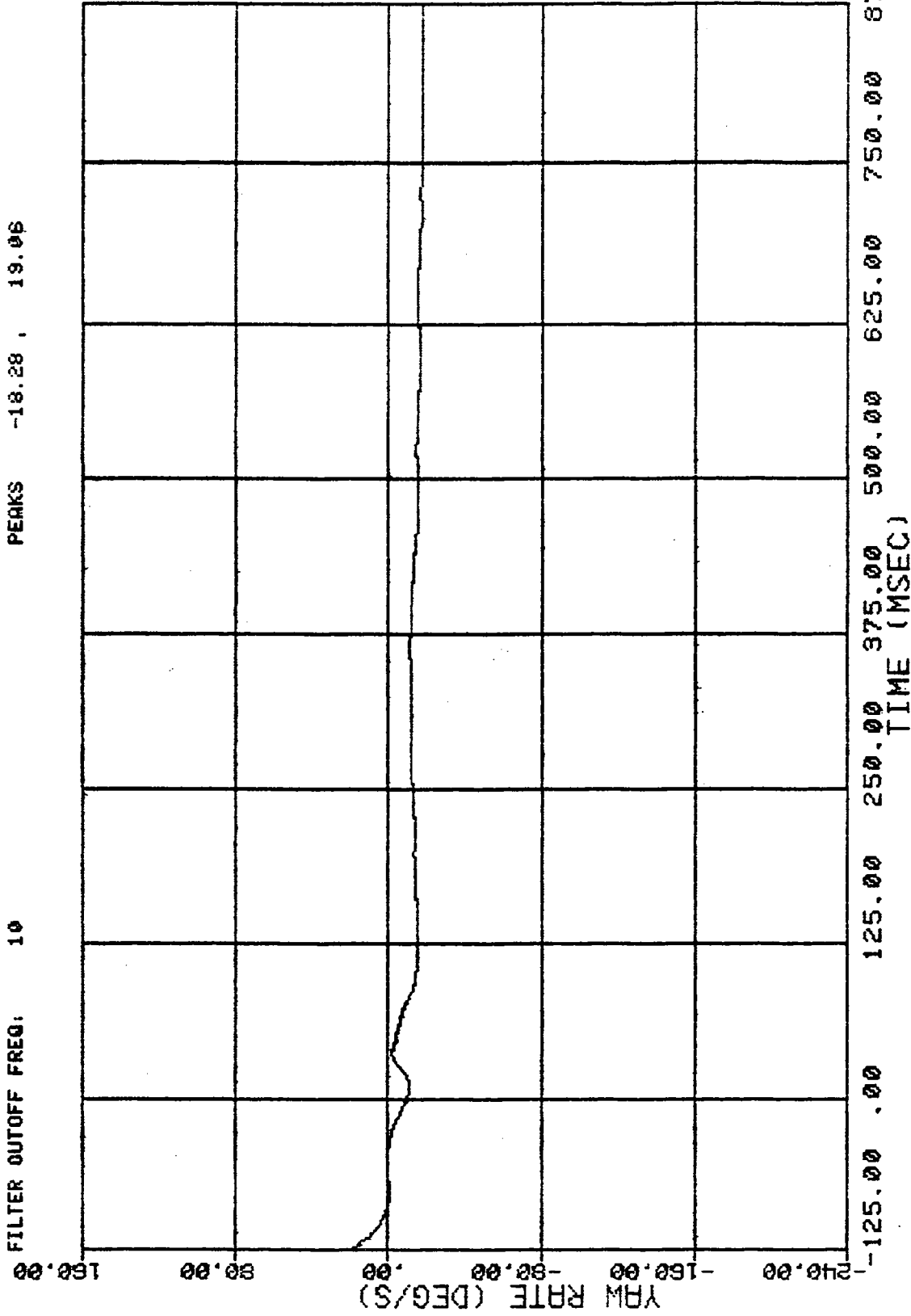


Figure A7. Vehicle Yaw Raw, 100 Hz

ENS00.I NO. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 0 VEHICLE YAW ANGLE (INTEGRATED)
 FILTER CUTOFF FREQ: 10 PEAKS -12.34 0.26

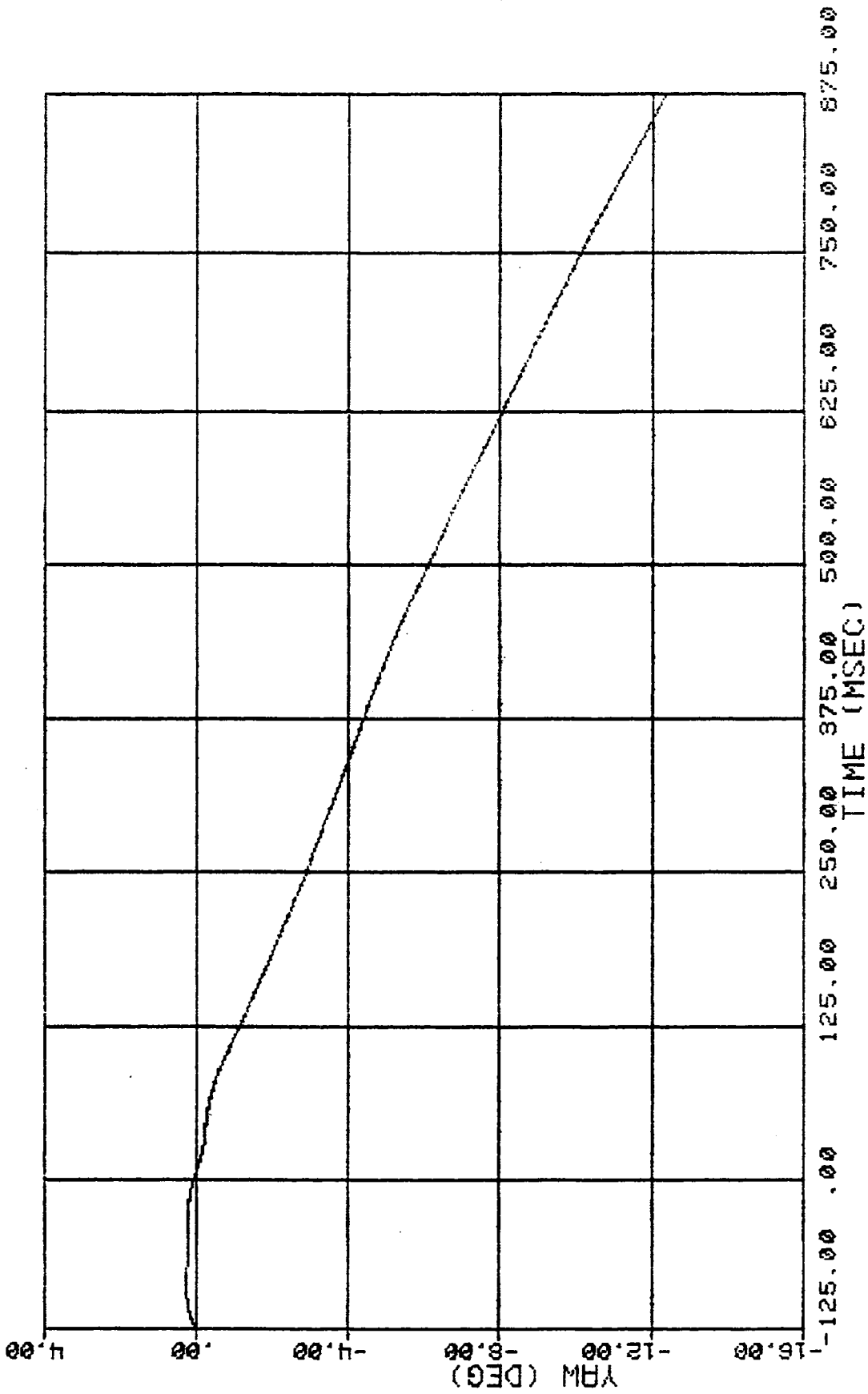


Figure A8. Vehicle Yaw Angle, 100 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 12 DRIVER HEAD X
 FILTER CUTOFF FREQ: 1650 PEAKS -6.37 , 45.94

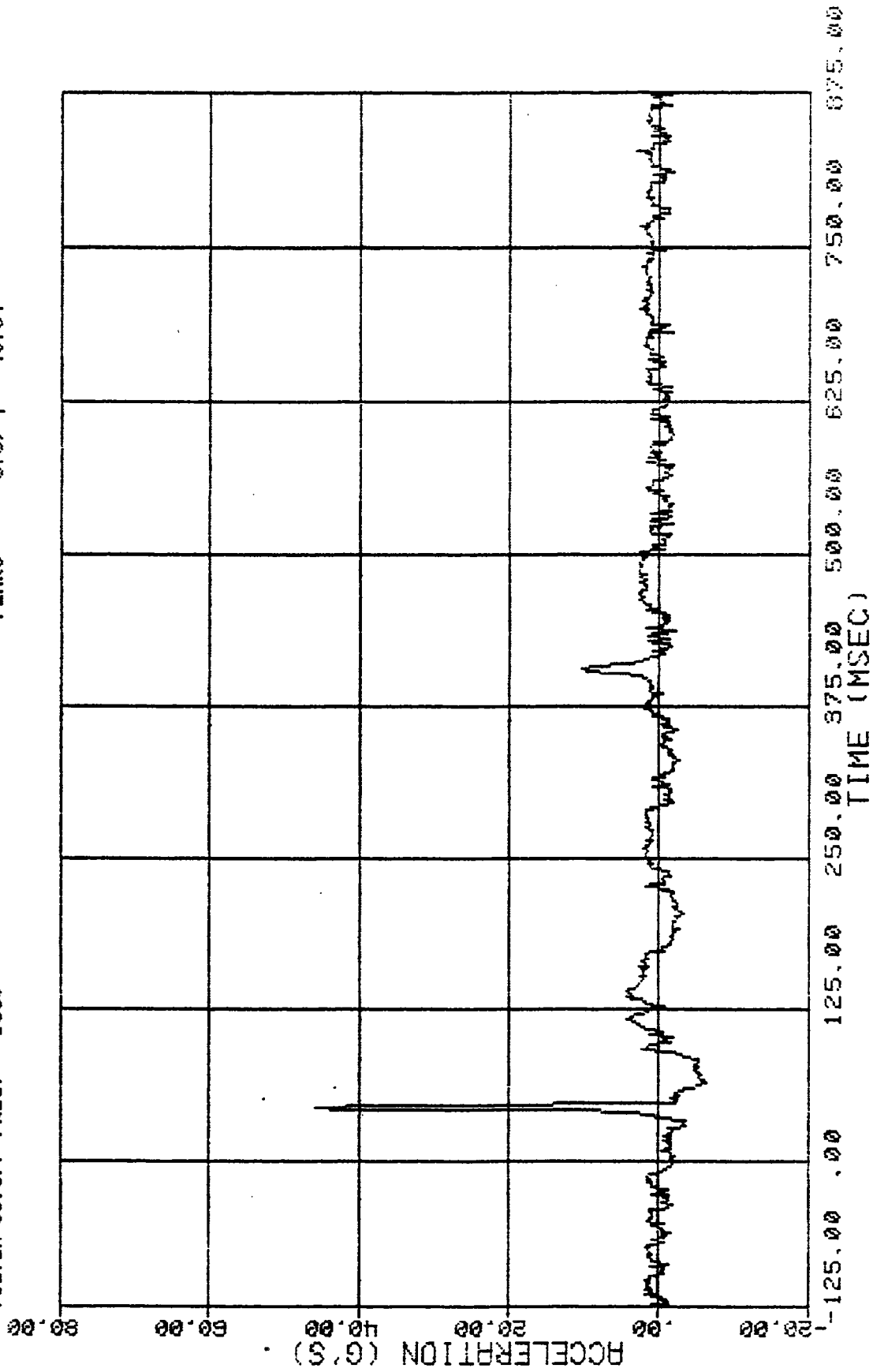


Figure A9. Head X Acceleration, 1650 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-7-88
 30 MI./H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 13 DRIVER HEAD Y
 FILTER CUTOFF FREQ: 1650 PEAKS -3.81 , 76.36

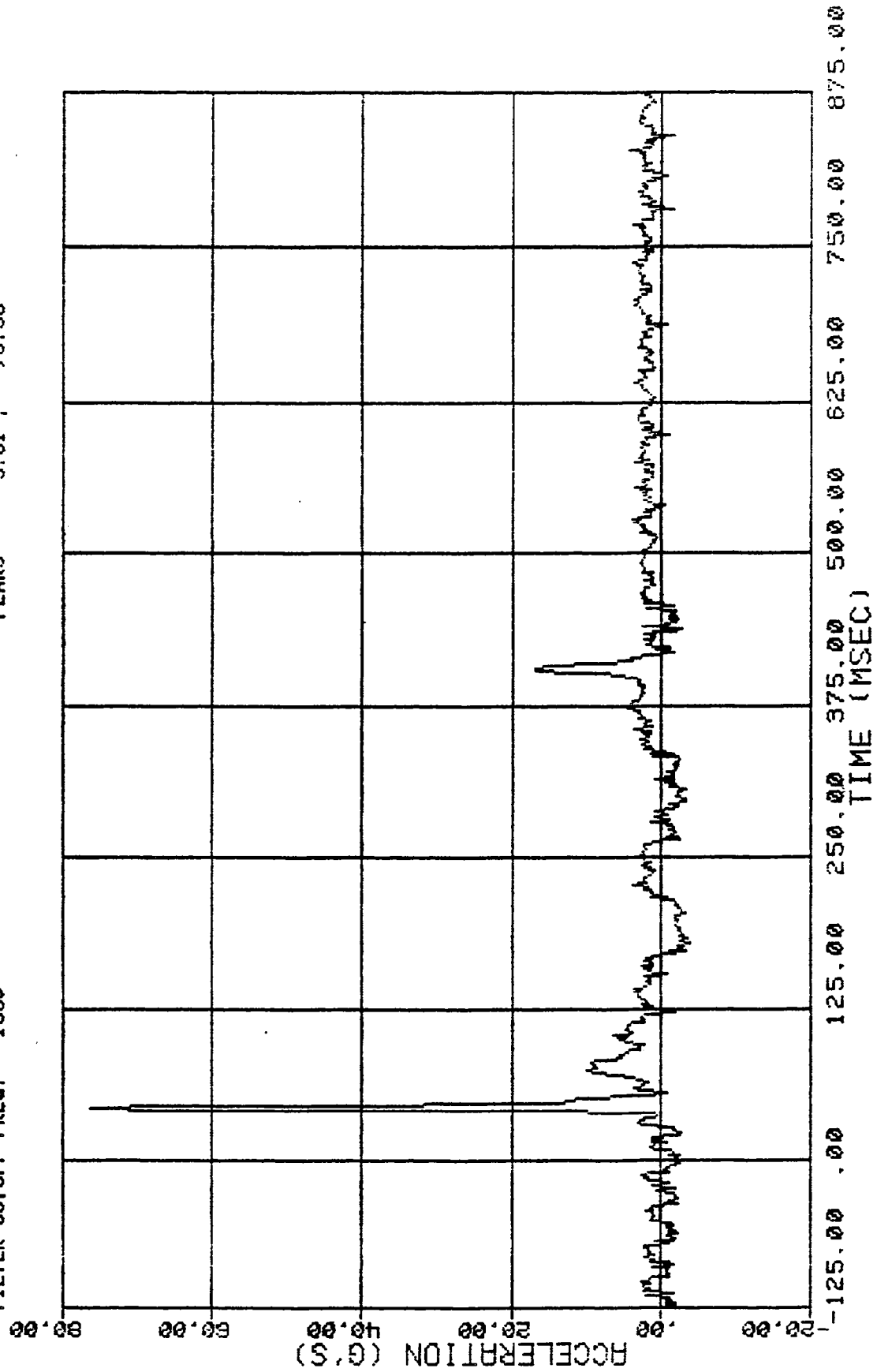


Figure A10. Head Y Acceleration, 1650 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 14 DRIVER HEAD Z
 FILTER CUTOFF FREQ: 1650 PEAKS -12.65 , 21.71

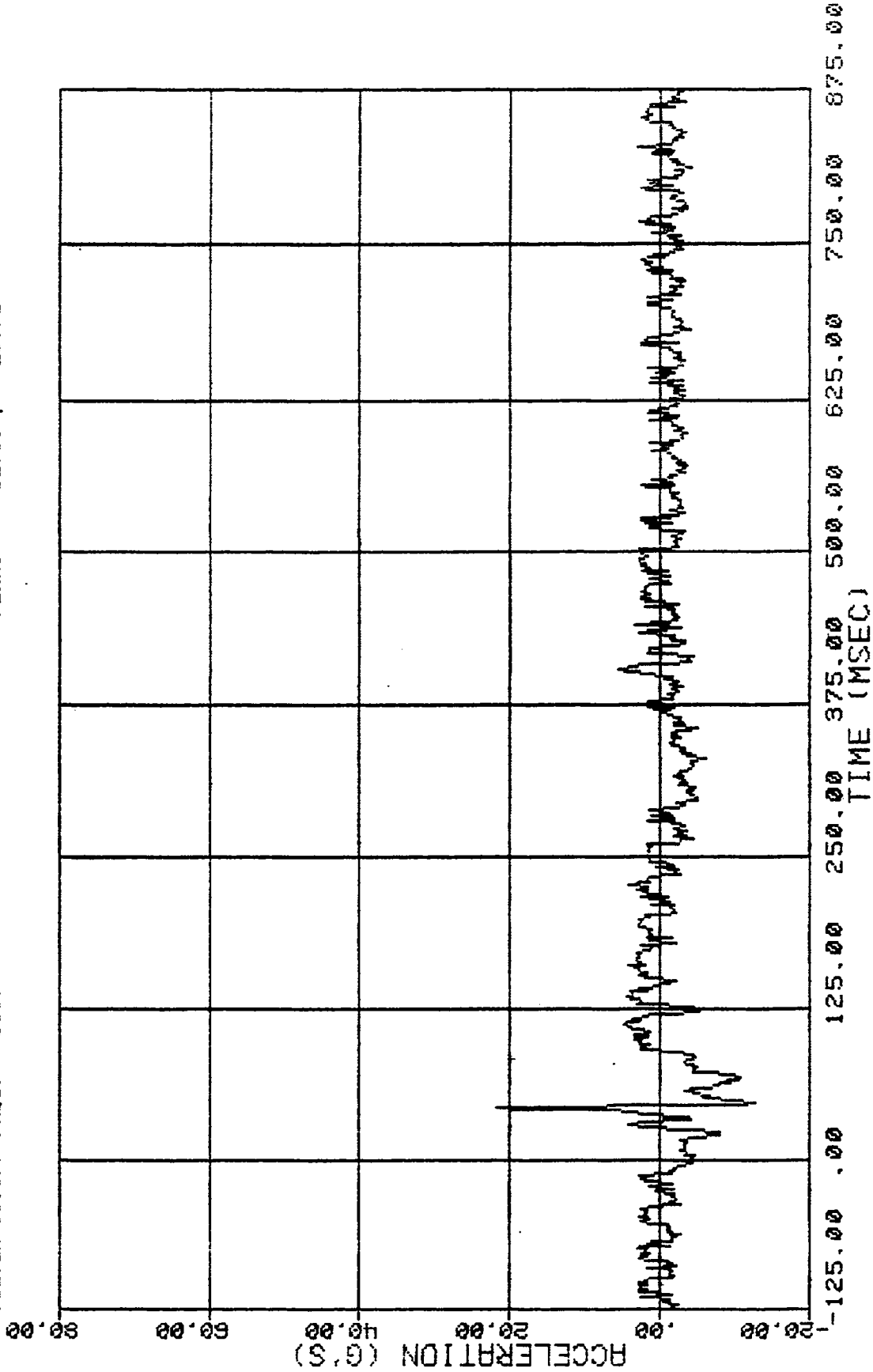


Figure A11. Head Z Acceleration, 1650 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-66-Z-00047 TEST * 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE GOLT INTO LUMINAIRE SUPPORT
 CHANNEL 0 DRIVER HEAD RESULTANT
 FILTER CUTOFF FREQ: 1650 PEAKS 0.74, 91.16

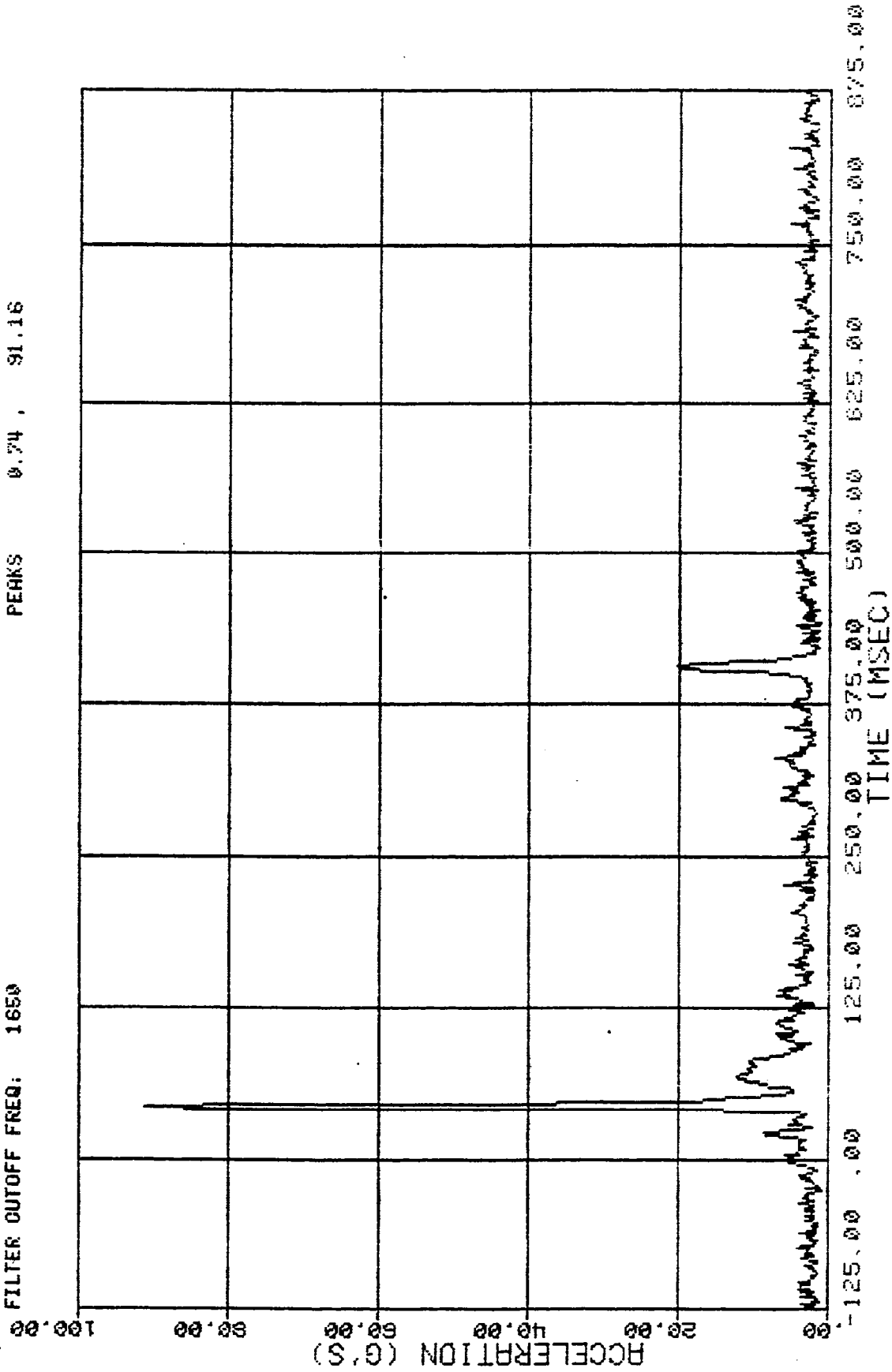


Figure A12. Head Resultant Acceleration, 1650 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-86-2-00047 TEST # 1785-SI-7-88
 30 MI./H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 4 T01X
 FILTER CUTOFF FREQ: 300 PEAKS -5.40 5.42

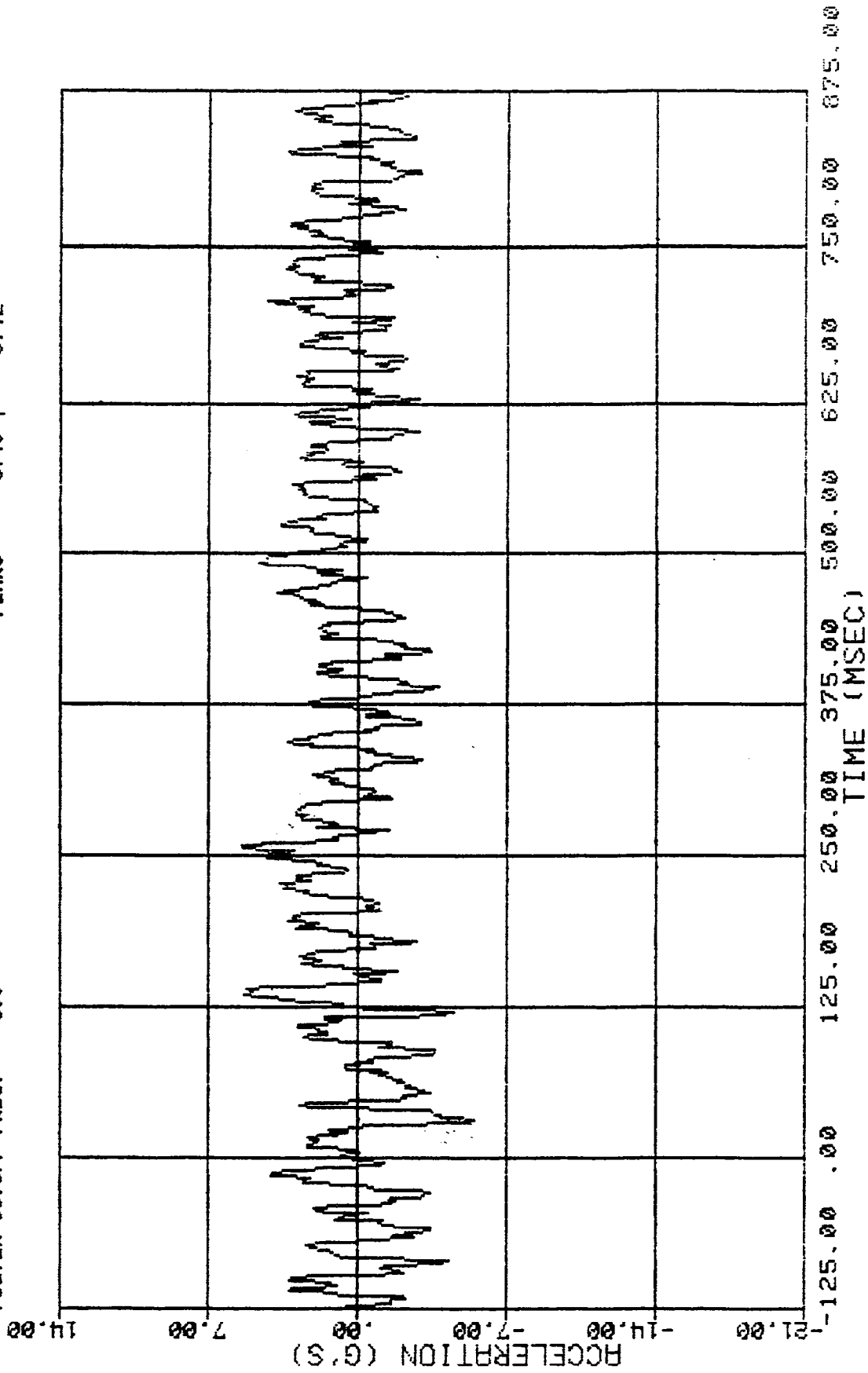


Figure 13. T01 - X Acceleration, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 3 T01Y
 FILTER CUTOFF FREQ: 3000 PEAKS -15.62 , 5.77

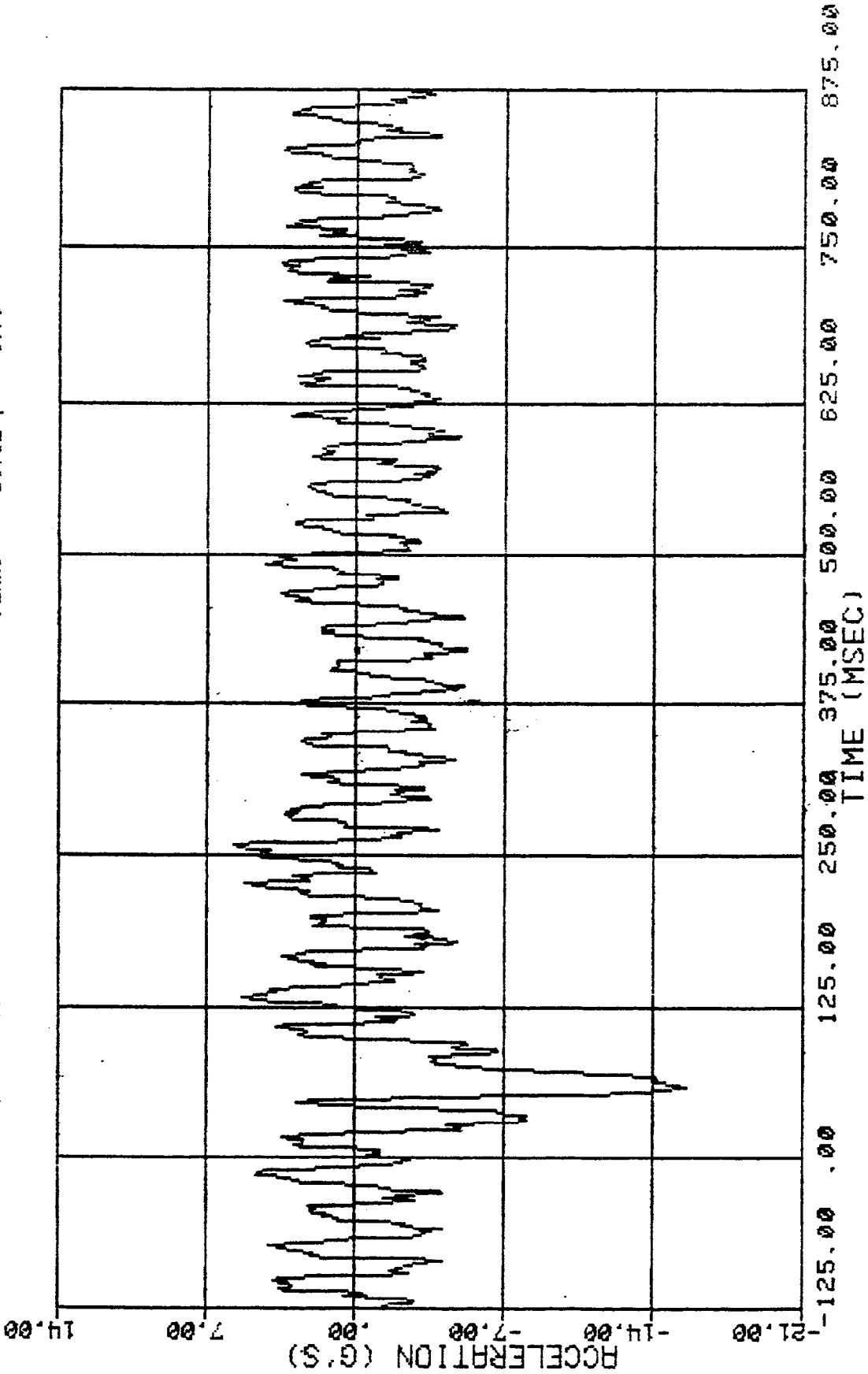


Figure A14. T01 - Y Acceleration, 300 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1705-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE GOLI INTO LUMINAIRE SUPPORT
 CHANNEL 5 T01Z
 FILTER CUTOFF FREQ: 300 PEAKS -5.79 , 12.32

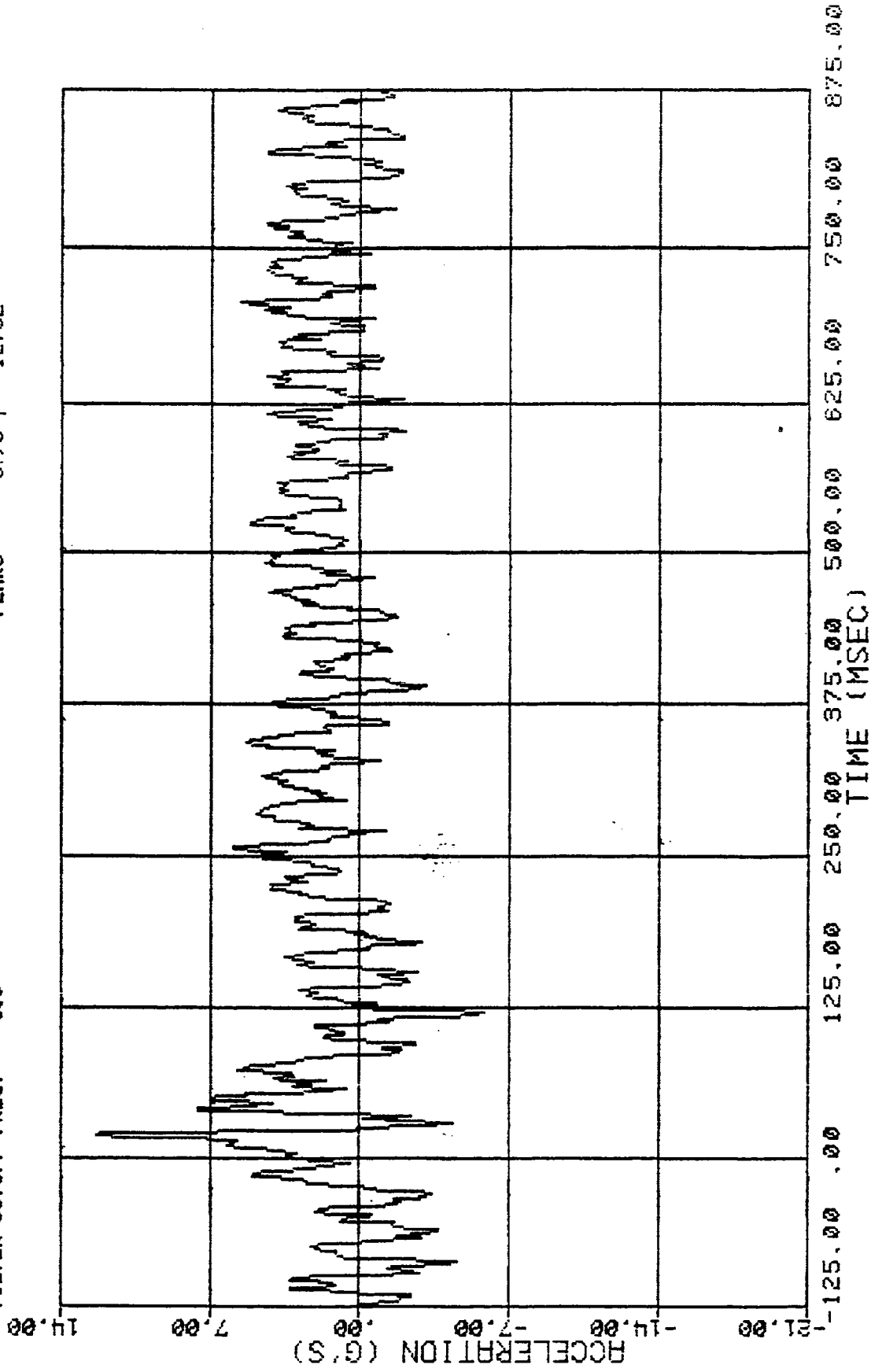


Figure A15. T01 - Z Acceleration, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-86-2-00047 TEST # 1785-SI-7-88
 30 MI./H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 0 T01 RESULTANT
 FILTER CUTOFF FREQ. 300 PEAKS 0.79, 15.69

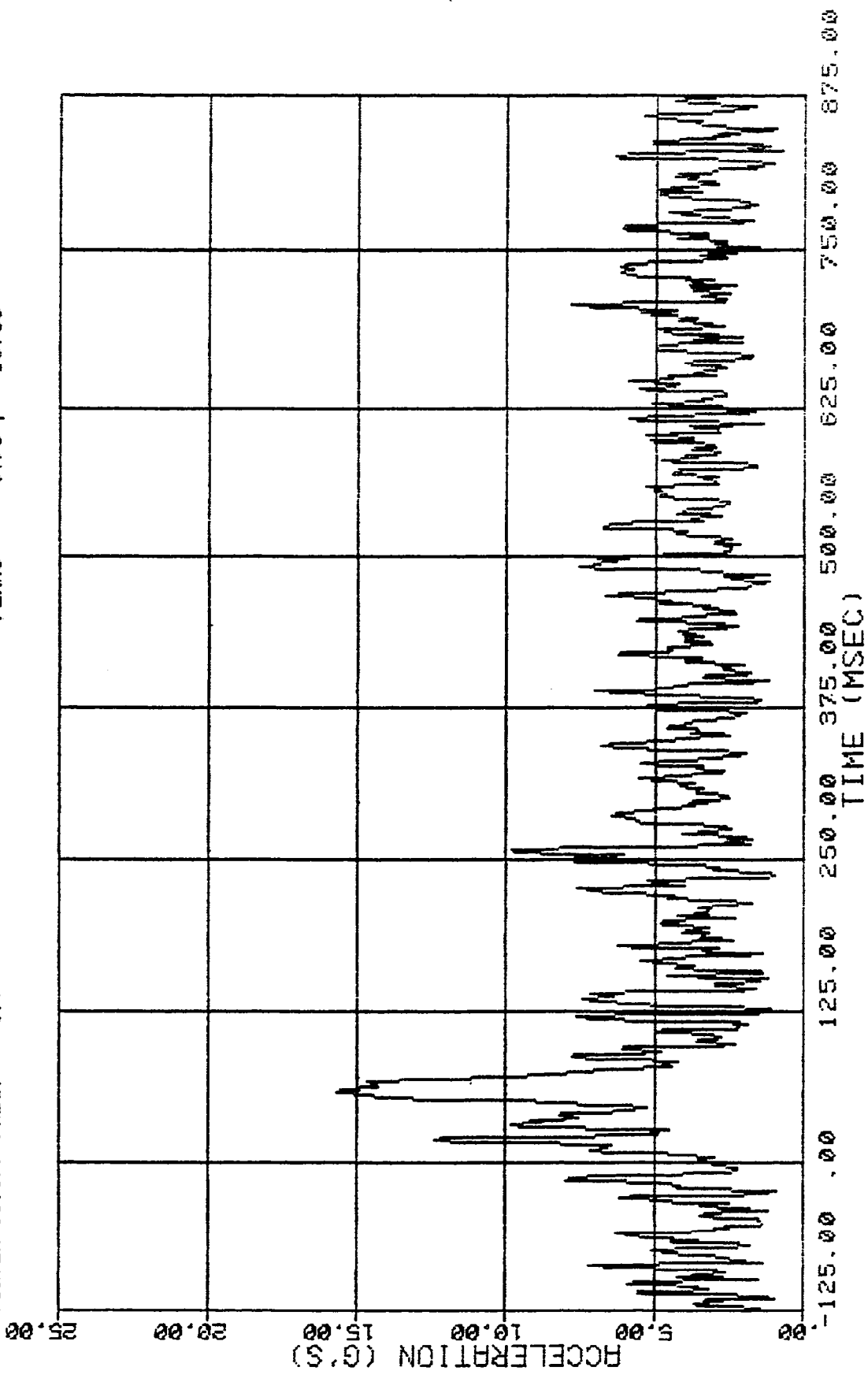


Figure 16. T01 Resultant Acceleration, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 6 T12X
 FILTER CUTOFF FREQ: 300 PEAKS -6.40 8.18

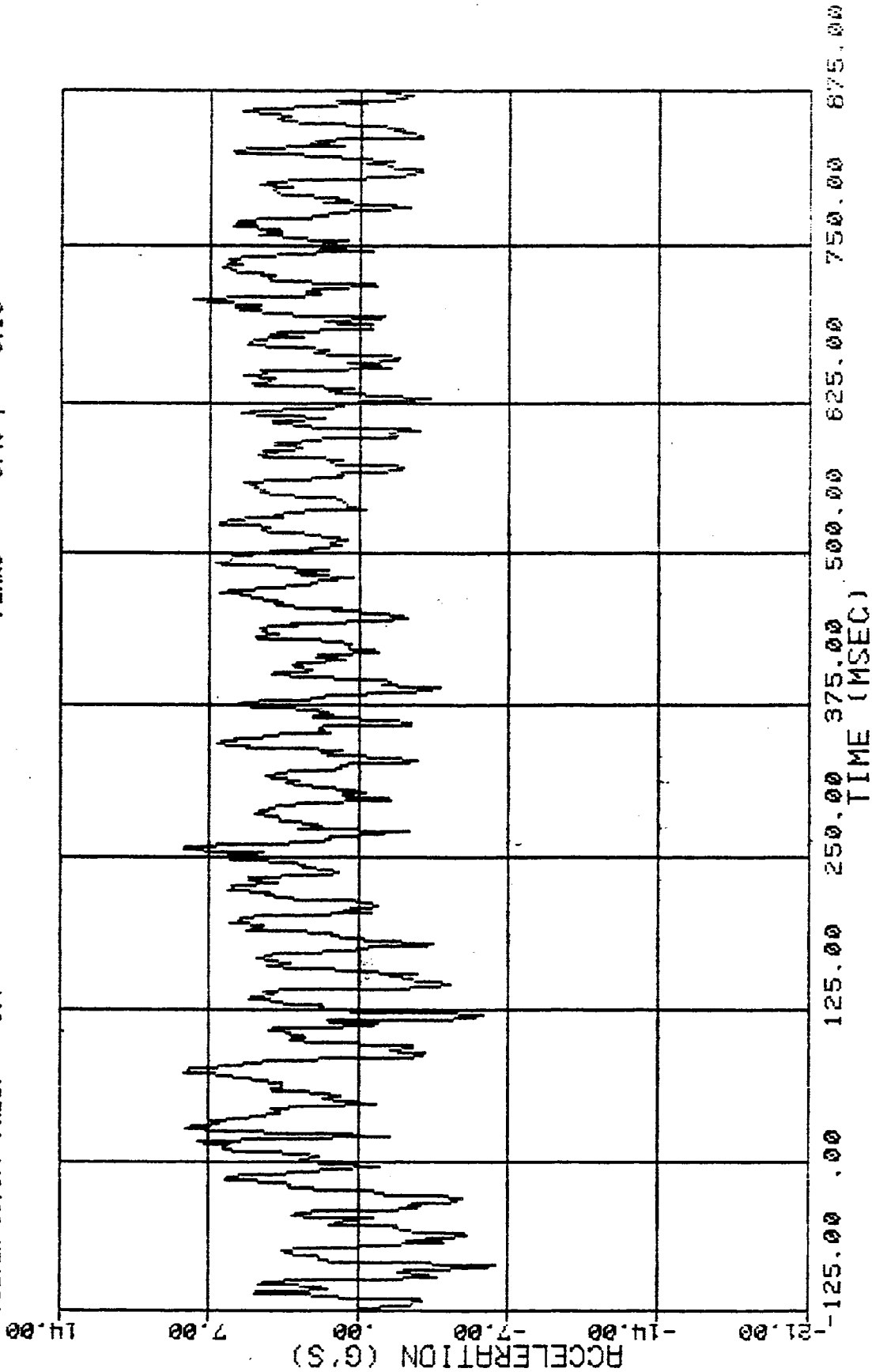


Figure A17. T12 - X Acceleration, 300 Hz

ENSOO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 7 T12Y
 FILTER CUTOFF FREQ: 300 PEAKS -16.58 1.74

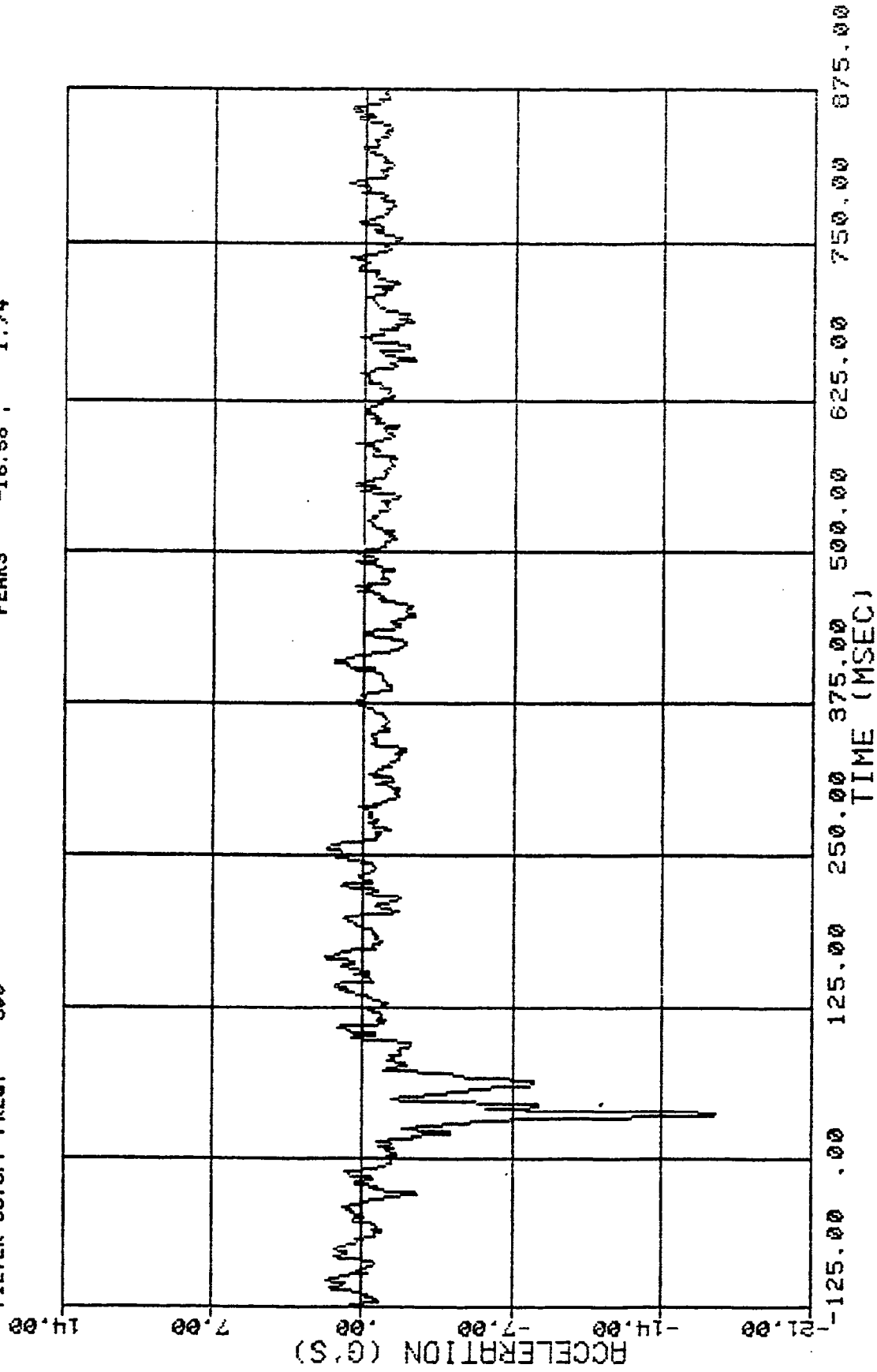


Figure A18. T12 - Y Acceleration, 300 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-7-68
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COULT INTO LUMINAIRE SUPPORT
 CHANNEL 8 T12Z
 FILTER CUTOFF FREQ: 300 PEAKS -3.99 9.88

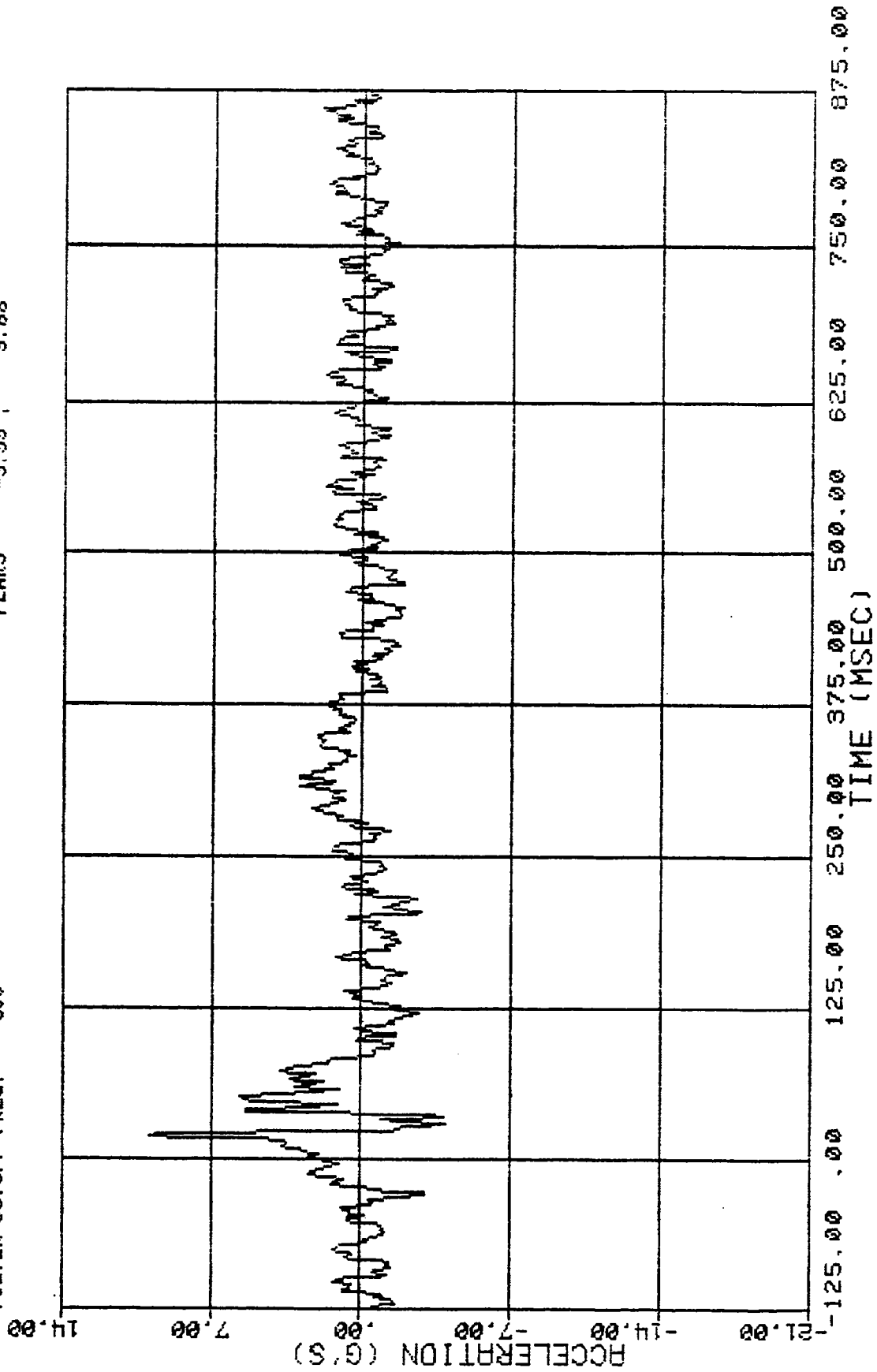


Figure A19. T12 - Z Acceleration, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-66-2-00047 TEST # 1785-SI-2-68
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL # T12 RESULTANT
 FILTER CUTOFF FREQ: 300 PEAKS 0.67 , 17.49

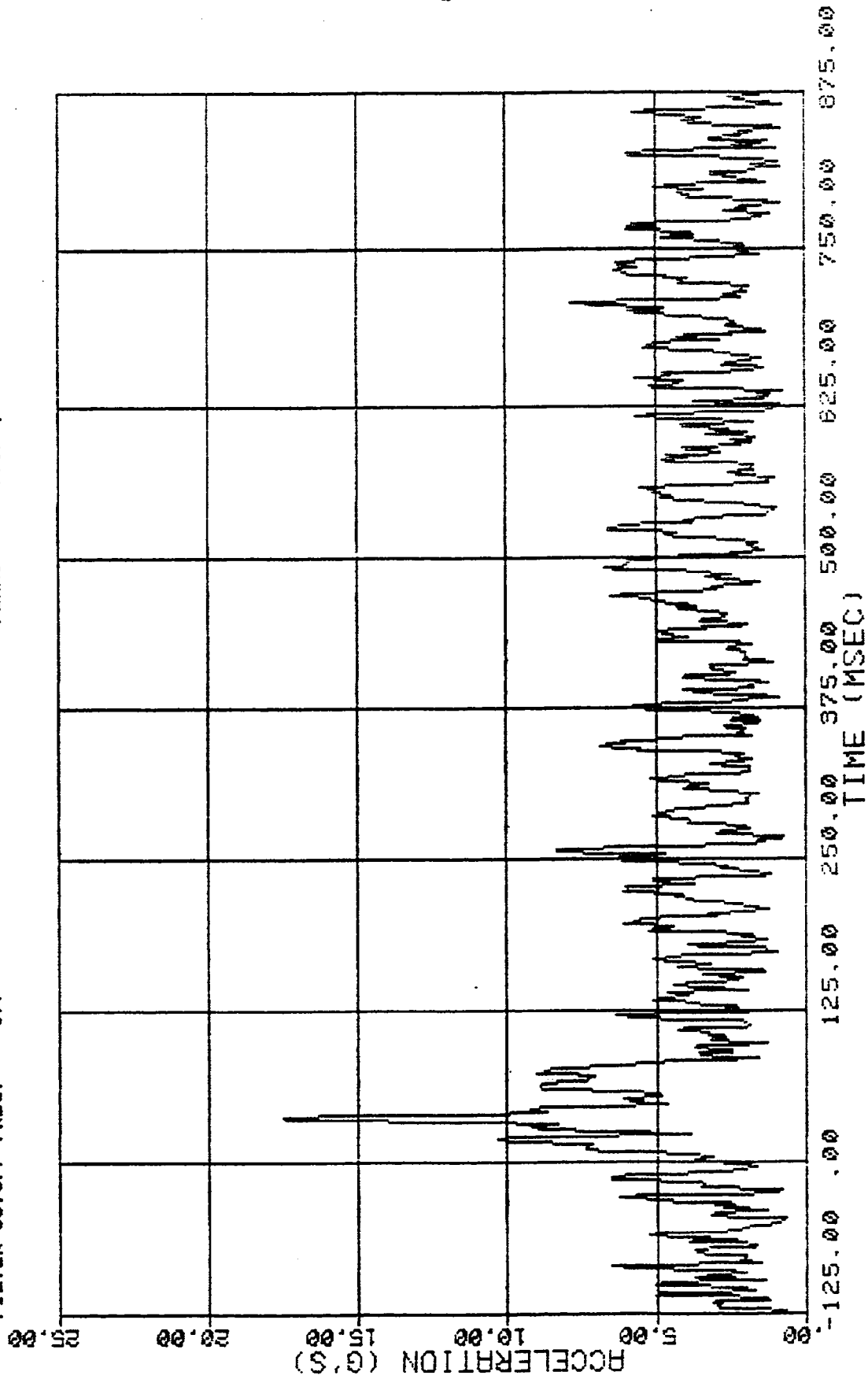


Figure A20. T12.Resultant Acceleration, 300 Hz

EMSCO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-S1-7-88
 30 MI/H BROADSIDE IMPACT OF 80 PDBBE CULVT INTO LUMINAIRE SUPPORT
 CHANNEL 15 DRIVER PELVIS X
 FILTER CUTOFF FREQ: 300 PEAKS -30.80 , 21.42

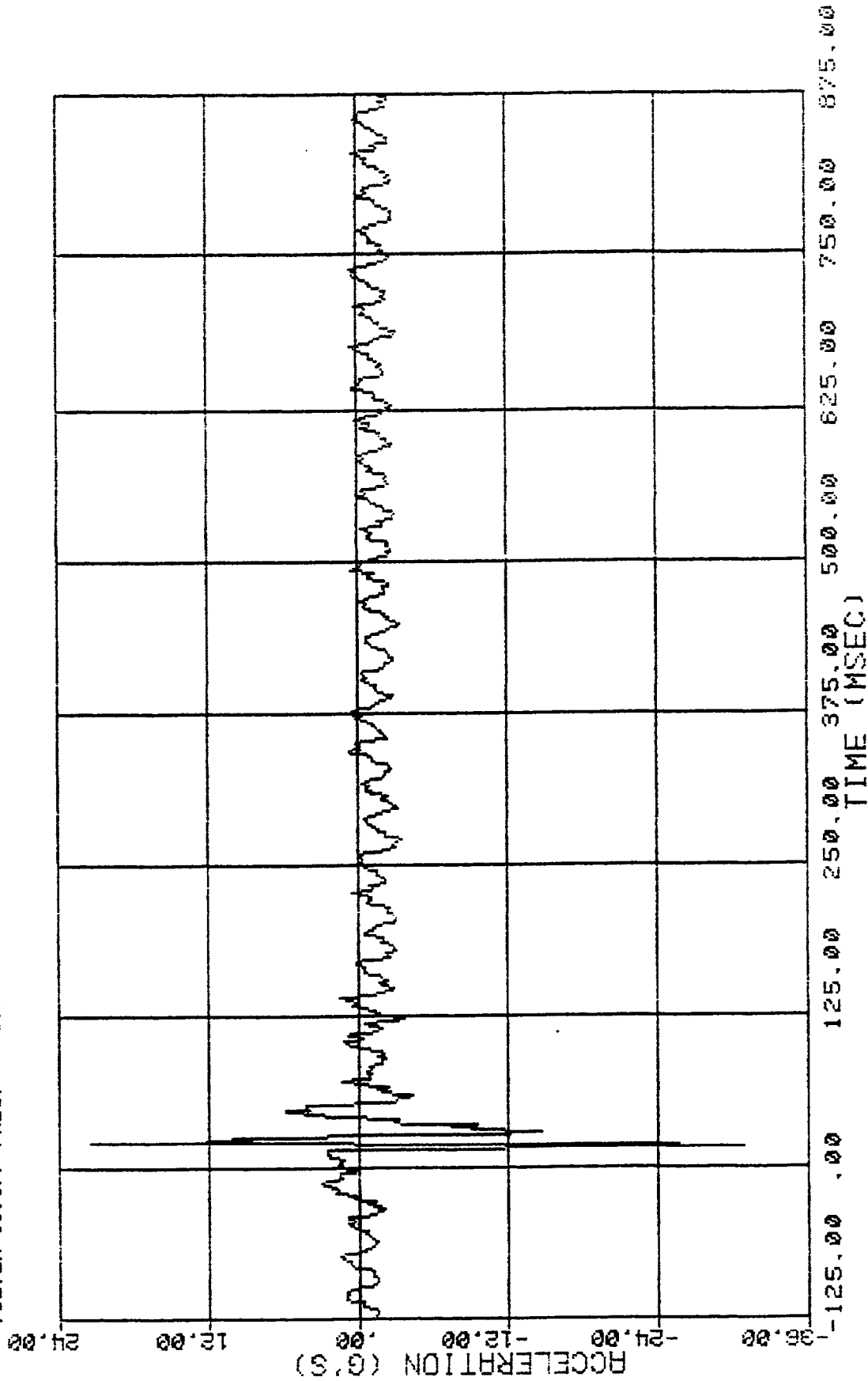


Figure A21. Pelvis X Acceleration, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 16 DRIVER PELVIS Y
 FILTER CUTOFF FREQ: 300 PEAKS -32.57 23.36

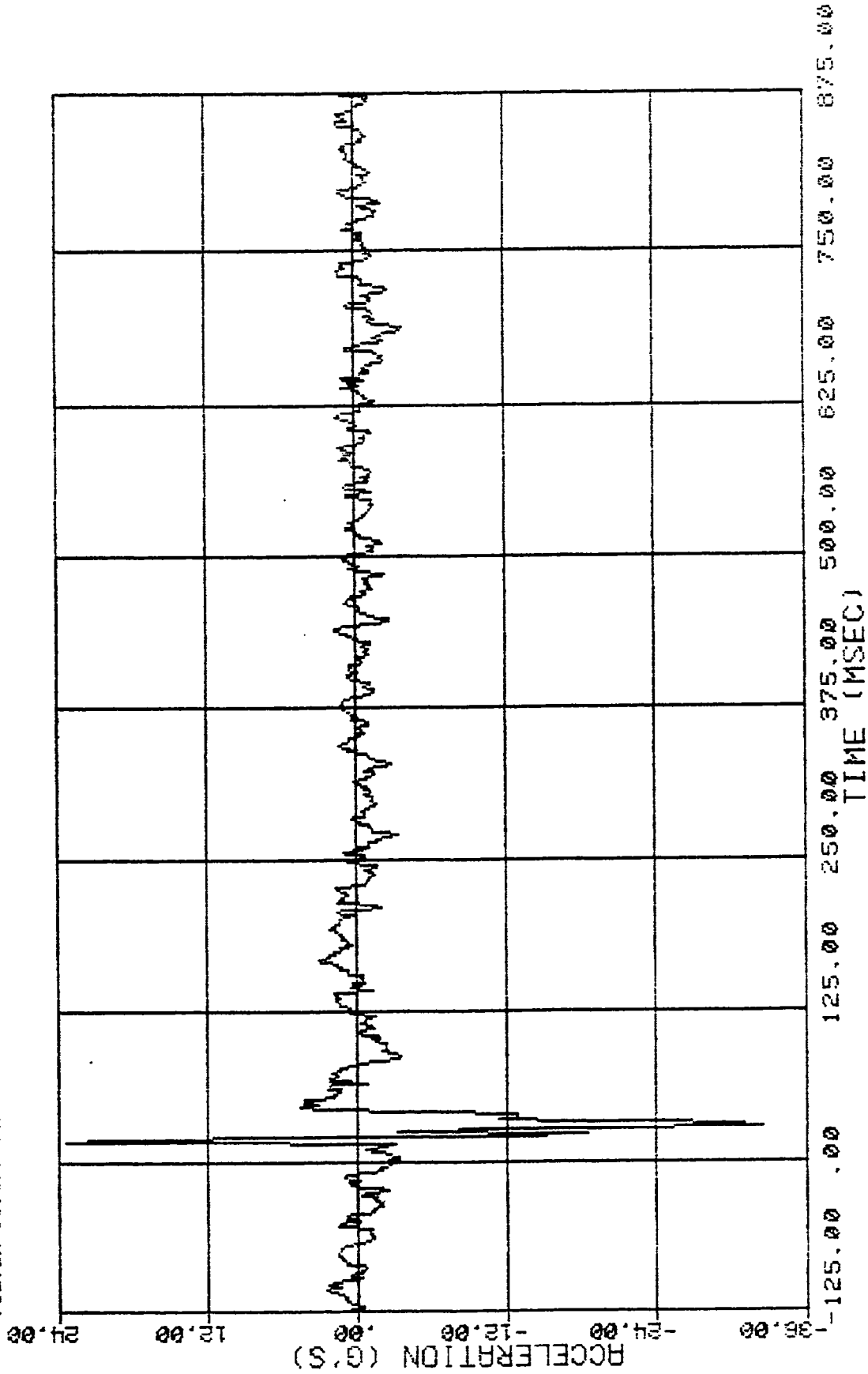


Figure A22. Pelvis Y Acceleration, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-81-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 17 DRIVER PELVIS Z
 FILTER CUTOFF FREQ: 300 PEAKS -7.20 , 20.85

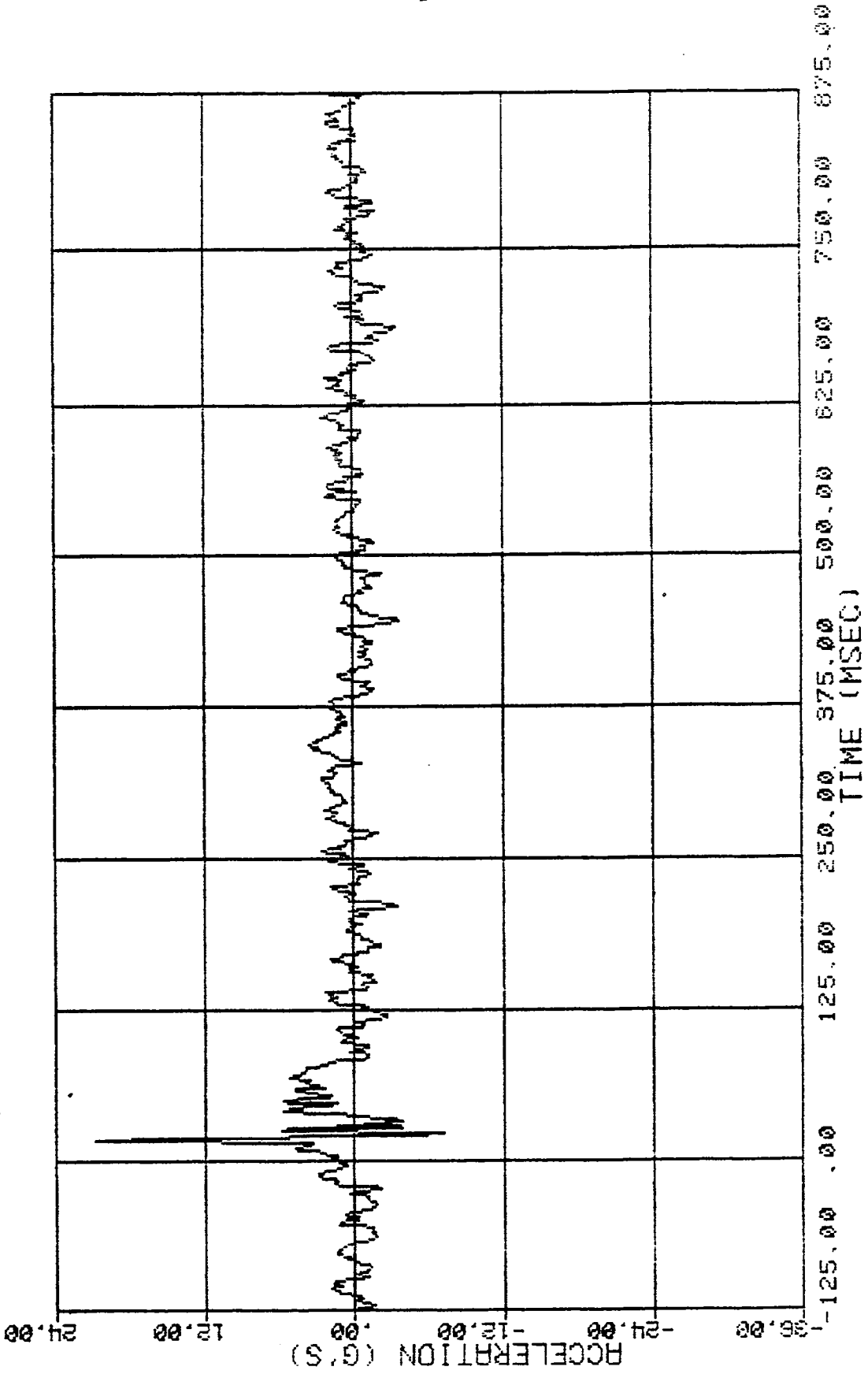


Figure A23. Pelvis Z Acceleration, 300 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-66-2-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COULT INTO LUMINAIRE SUPPORT
 CHANNEL # DRIVER PELVIS RESULTANT
 FILTER CUTOFF FREQ: 300 PEAKS 0.48 , 43.70

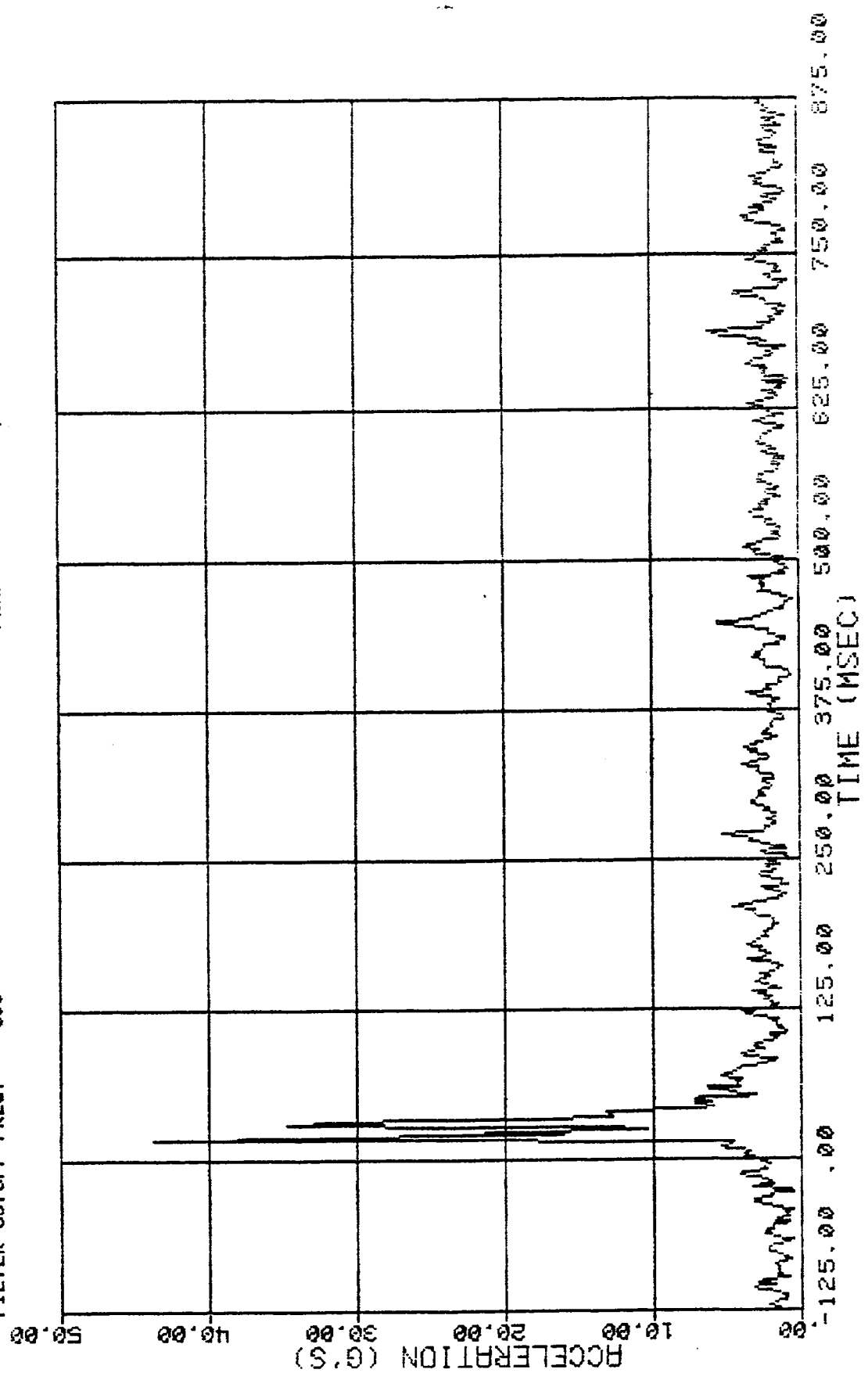


Figure A24. Pelvis Resultant Acceleration, 300 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST * 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 30 WOODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 3 LSTX
 FILTER CUTOFF FREQ: 300 PEAKS -10.78 , 3.79

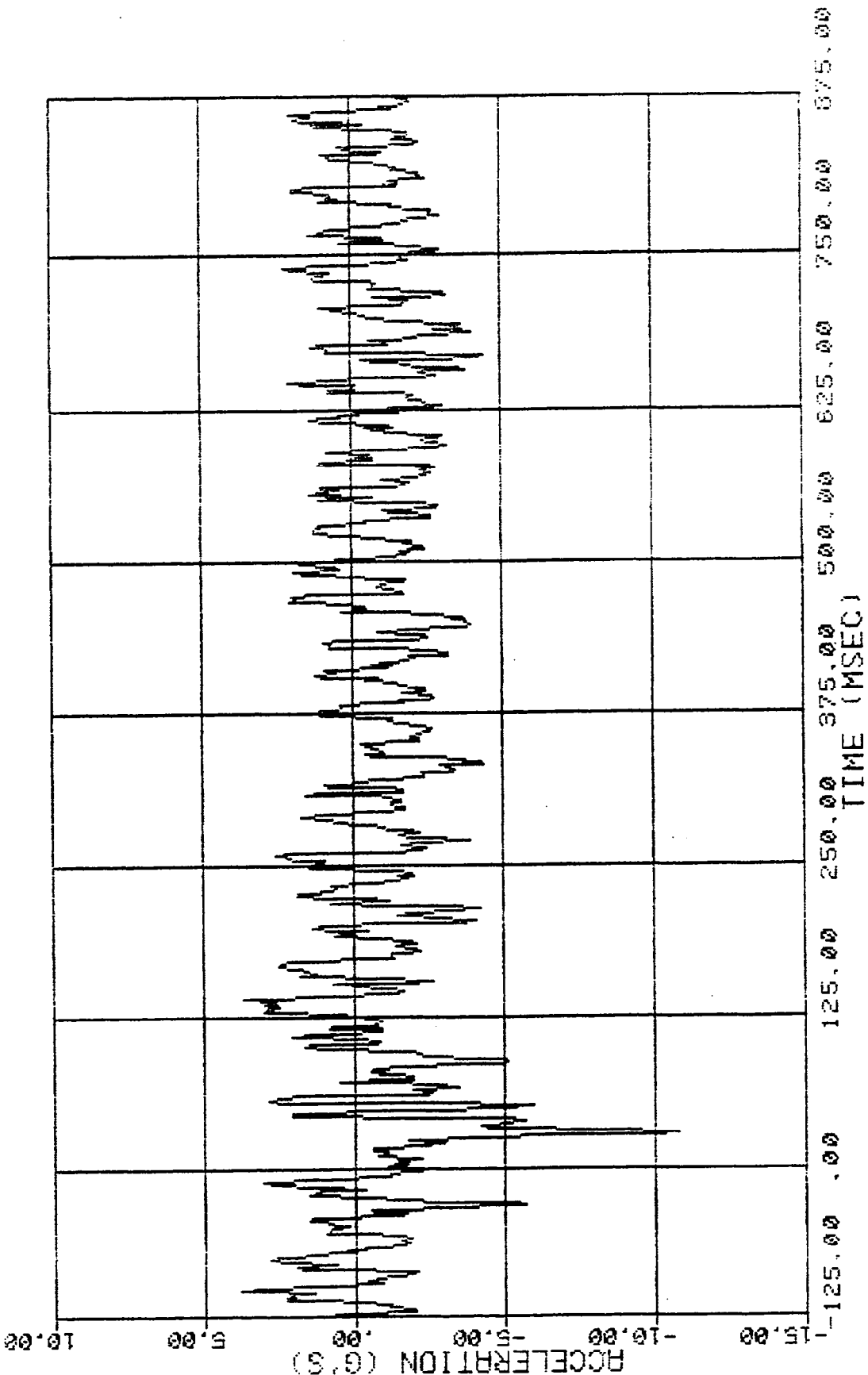


Figure A25. LST - X Acceleration, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-86-2-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 1 LLRY01 PEAKS -2.22 , 14.93
 FILTER CUTOFF FREQ: 300

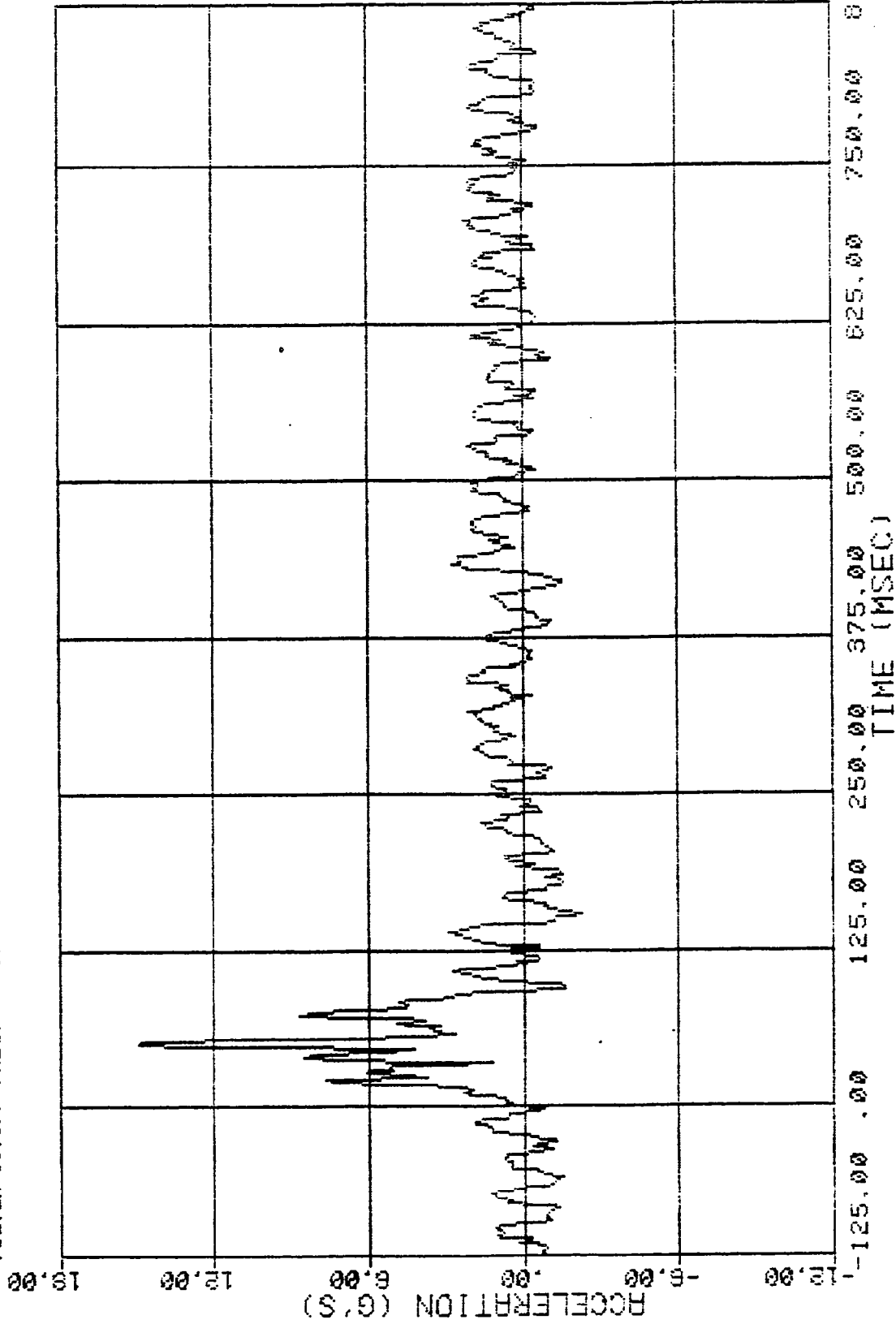


Figure A26. LLR - Y01 Acceleration, 300 Hz

ENSCO, INC. CONTRACT NUMBER 07FH61-86-Z-00047 TEST # 1785-81-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 2 LURY01
 FILTER CUTOFF FREQ: 300 PEAKS -2.00 , 12.11

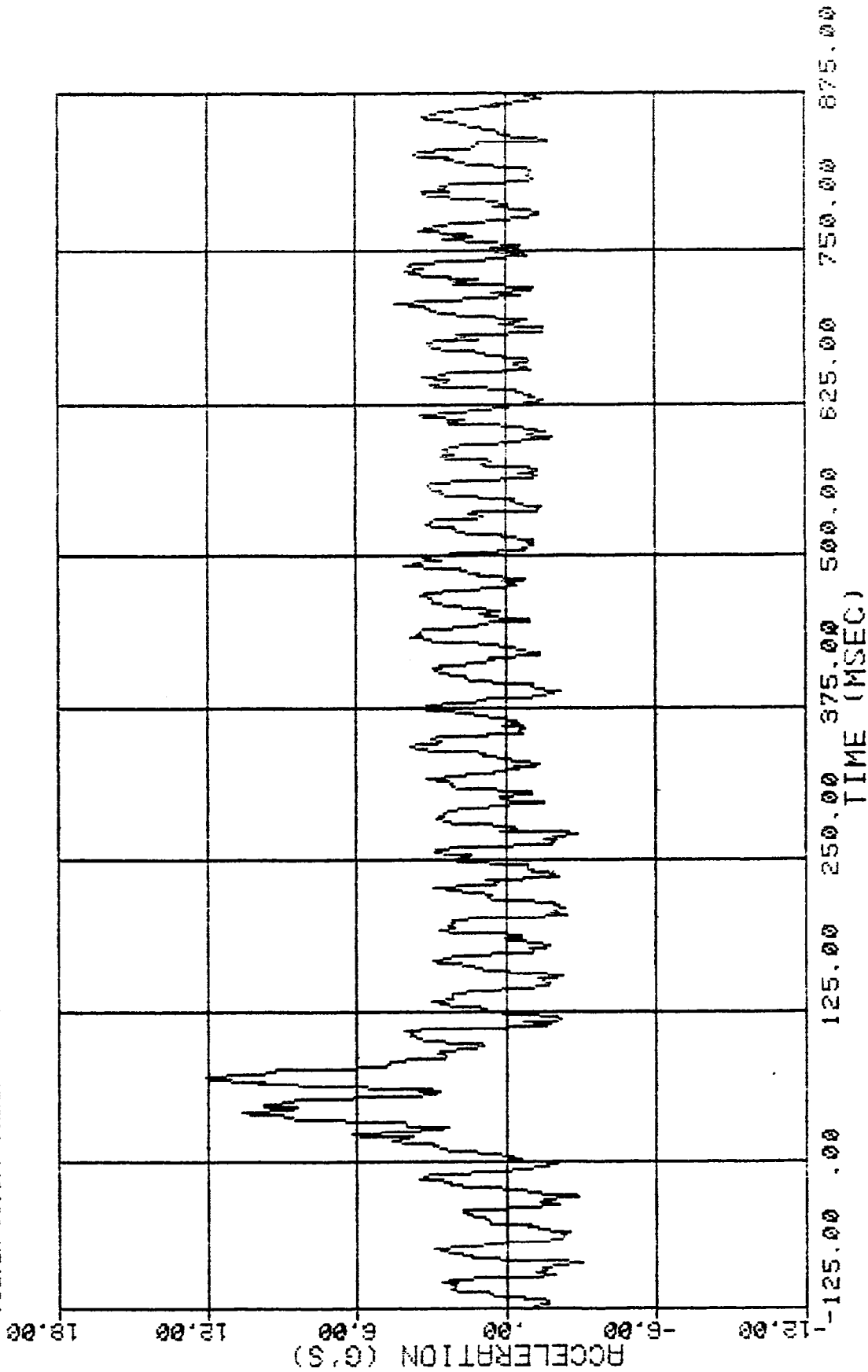


Figure A27. LUR - Y01 Acceleration, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 10 LLRY0A
 FILTER CUTOFF FREQ. 300 PEAKS -5.86 , 15.63

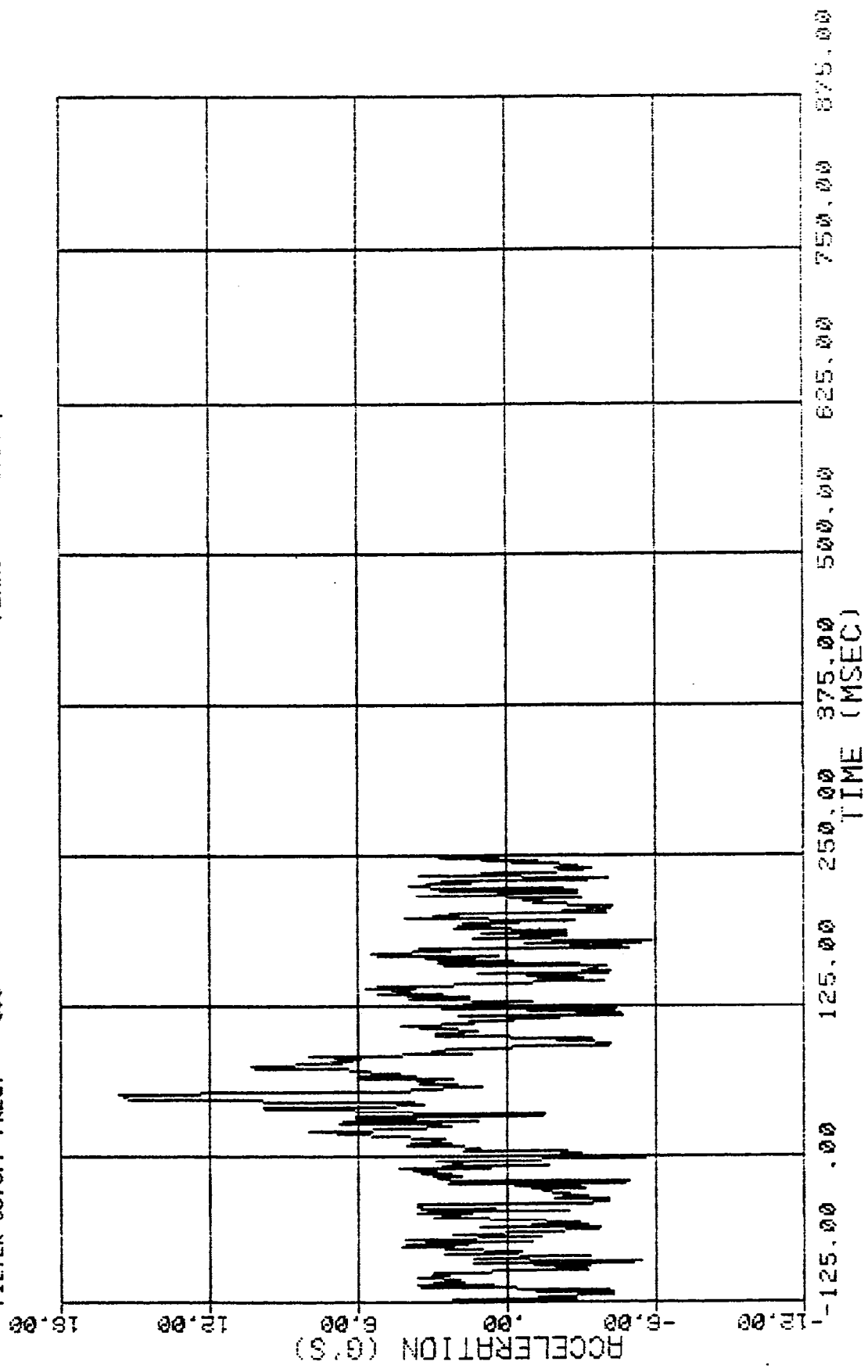


Figure A28. LLR - YGA Acceleration, 300 Hz

ENSO, INC. CONTRACT NUMBER DTFH61-88-Z-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 11 LURYOR
 FILTER CUTOFF FREQ: 300 PEAKS -7.84 , 12.76

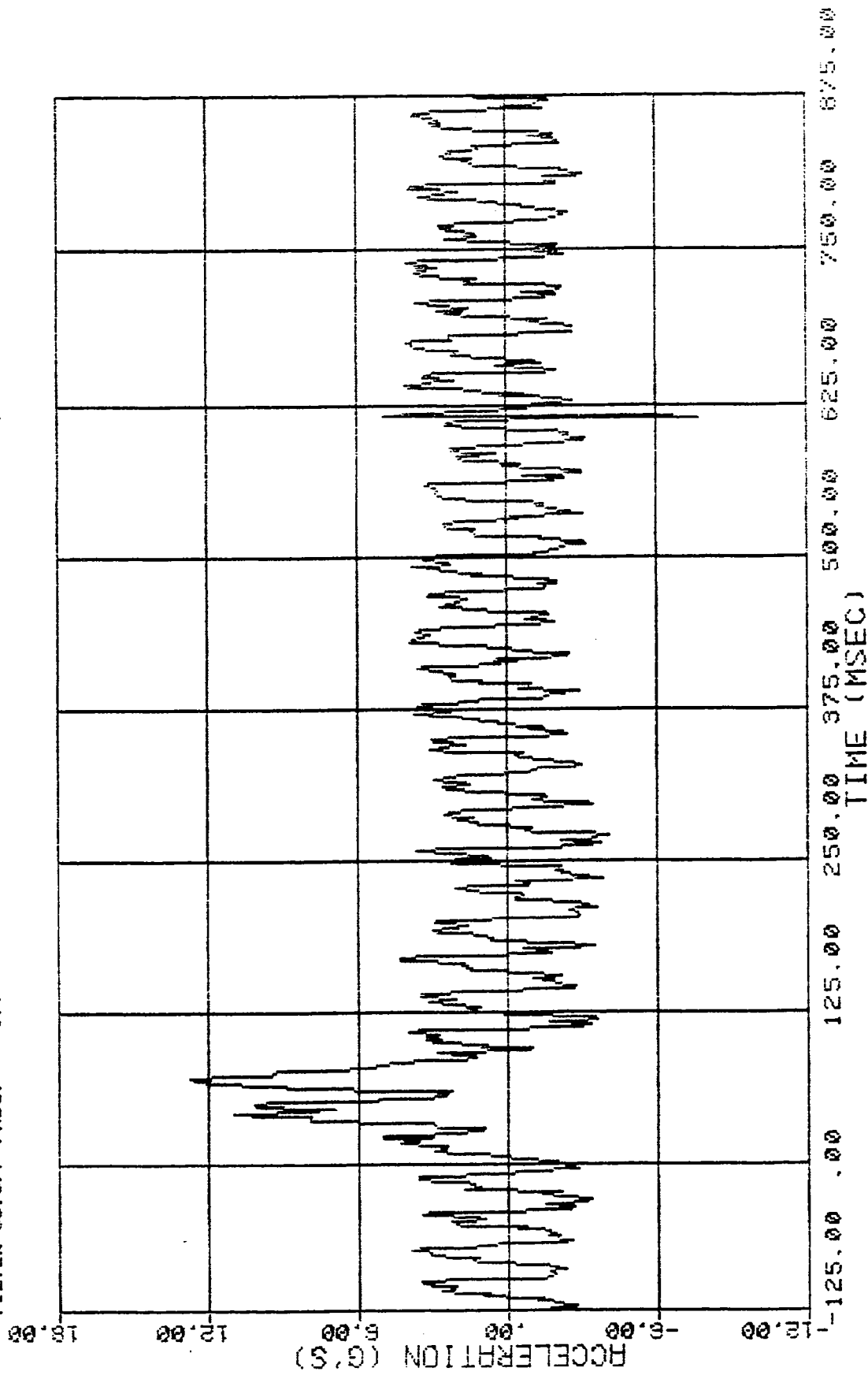


Figure A29. LUR - YGA Acceleration, 300 Hz

ENSCO, INC. CONTRACT NUMBER DTFH61-86-2-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 3 T01Y NHTSA FIR FILTER
 FILTER CUTOFF FREQ. 0 PEAKS -17.42 , 5.27

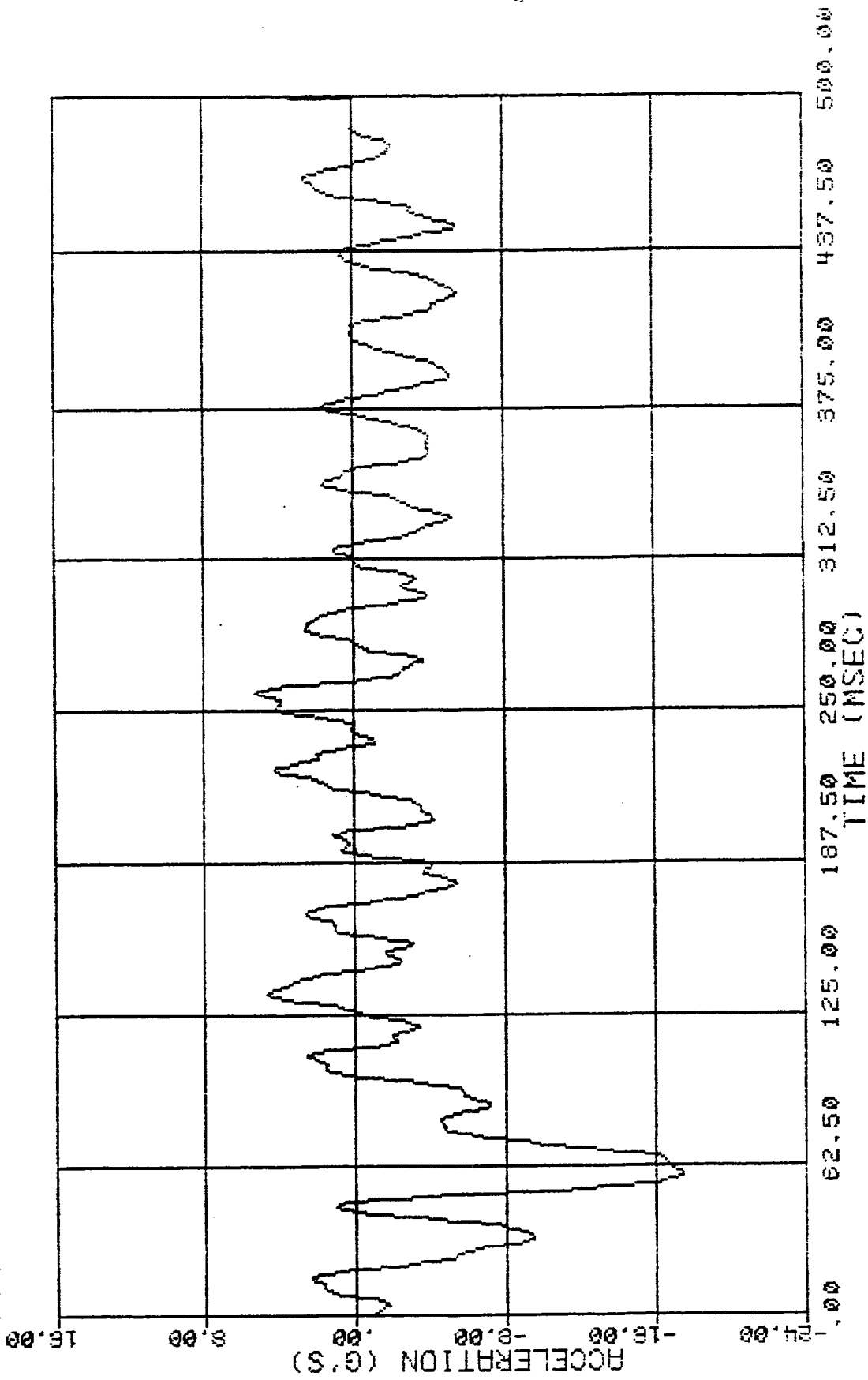


Figure A30. T01 - Y Acceleration, FIR Filter

ENSCO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 7 T12Y NHITSA FIR FILTER
 FILTER CUTOFF FREQ. 0 PEAKS -15.26 , 2.84

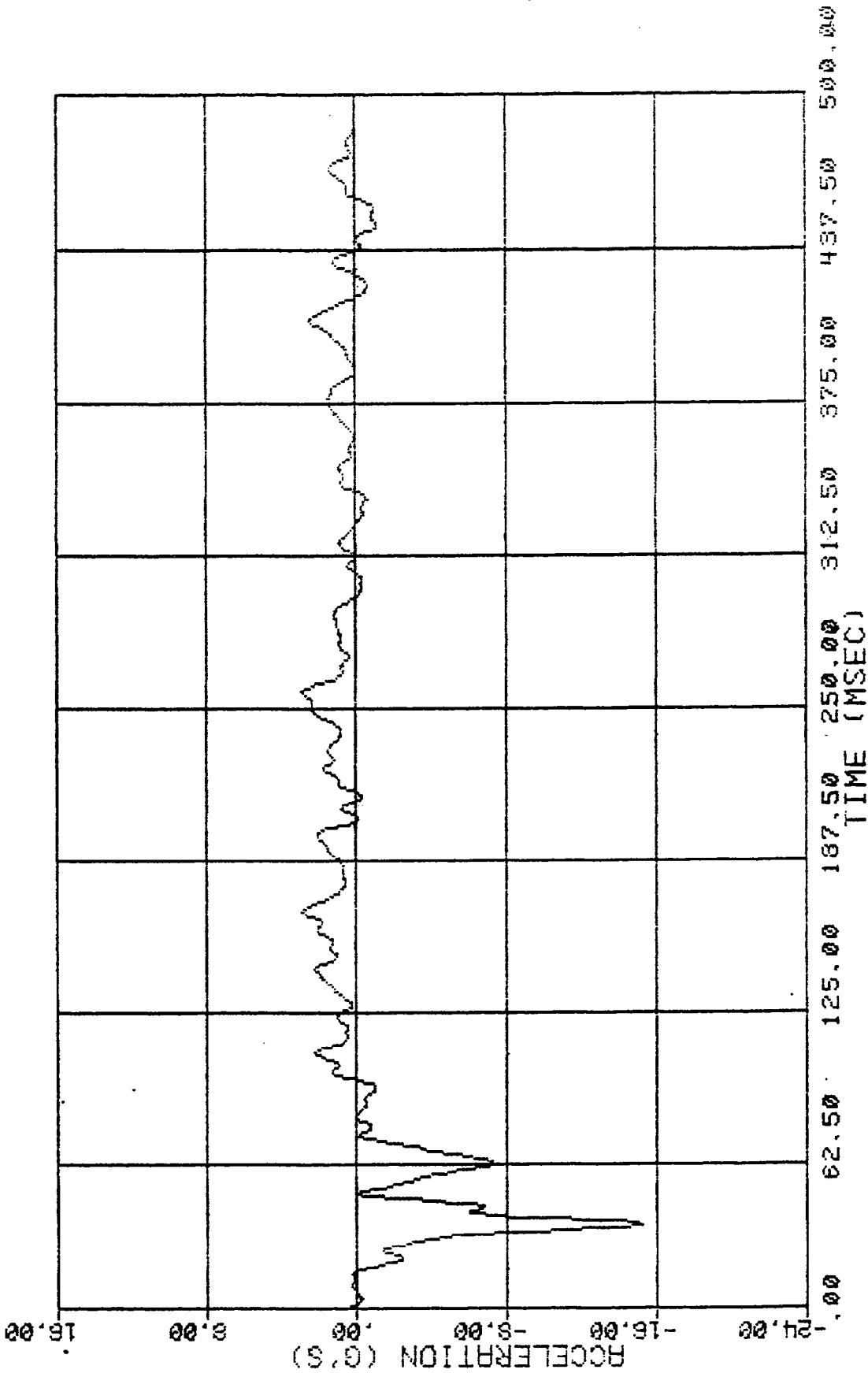


Figure A31. T12 - Y Acceleration, FIR Filter

Note: Sign Change

ENSCO, INC. CONTRACT NUMBER DTFH61-66-2-00047 TEST # 1785-SI-7-68
 30 MI/H BROADSIDE IMPACT OF 80 POUND GOLT INTO LUMINAIRE SUPPORT
 CHANNEL 1 LLY01 NHTSA FIR FILTER PEAKS -3.94 , 13.95
 FILTER CUTOFF FREQ. 0

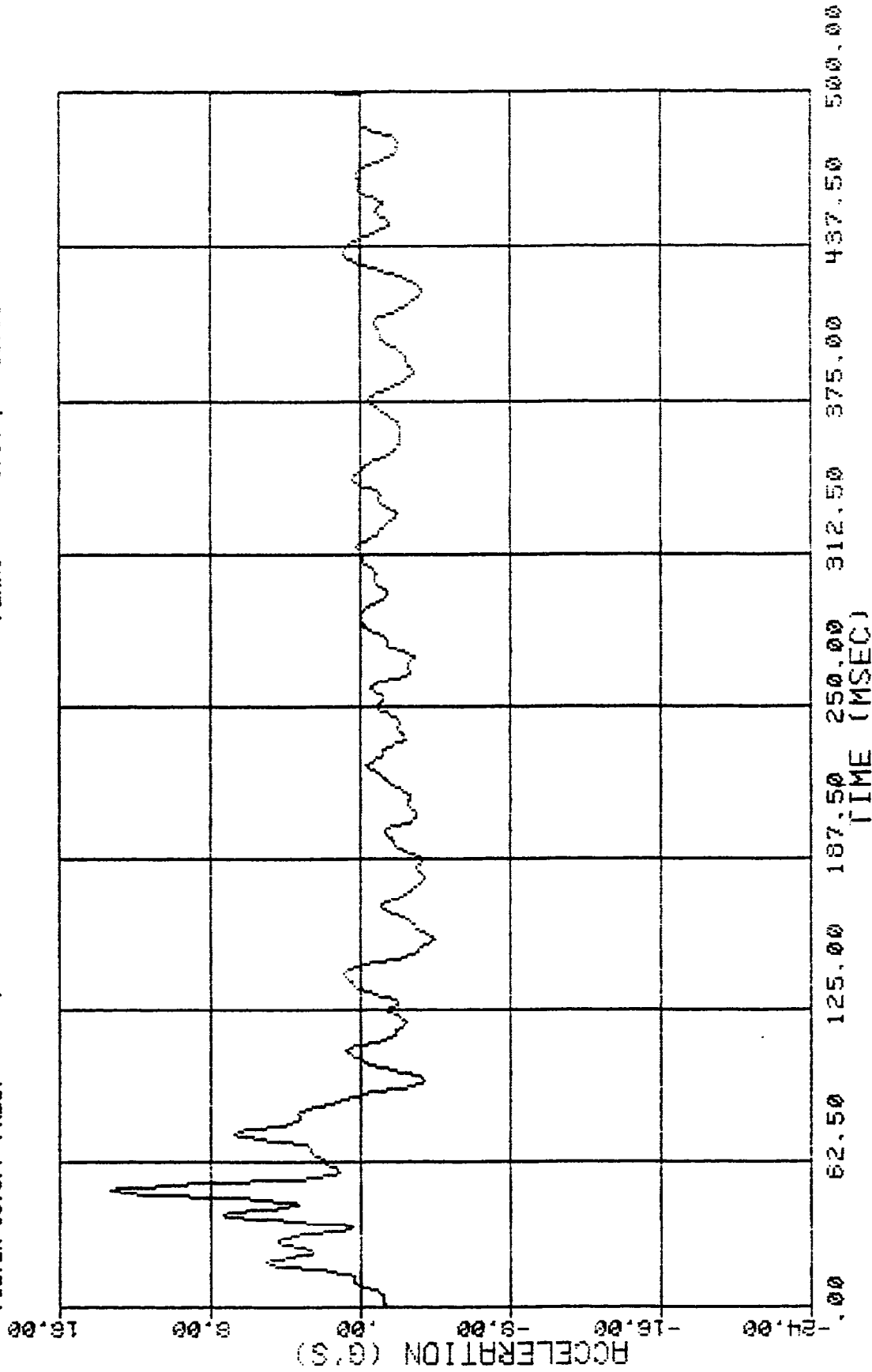


Figure A32. LLR - Y01 Acceleration, FIR Filter

ENSCO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DOGGE GOLT INTO LUMINAIRE SUPPORT
 CHANNEL 10 LLRYOH WHTSA FIR FILTER
 FILTER CUTOFF FREQ. 0' PEAKS -4.69 , 15.55

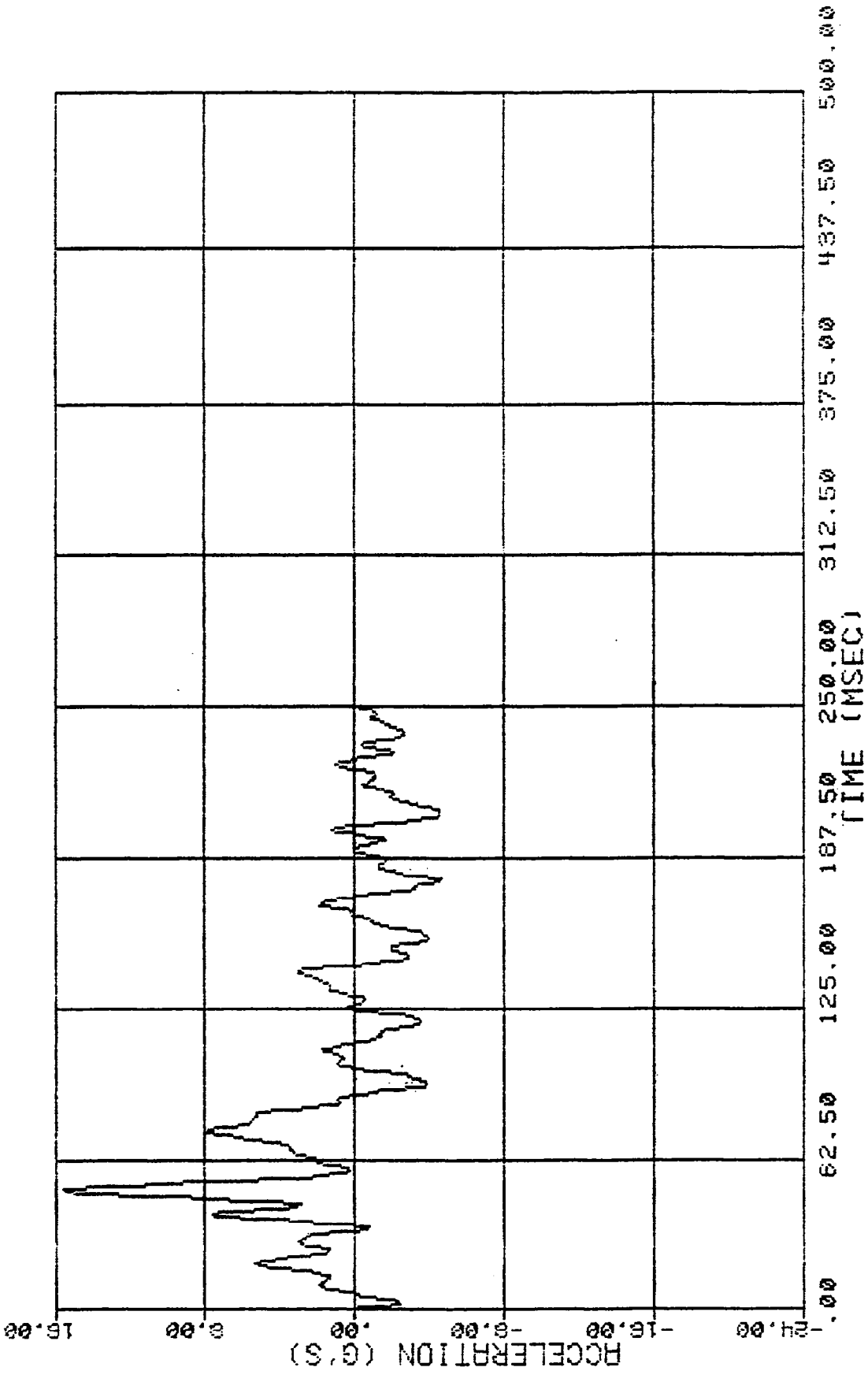


Figure A33. LLR-YGA Acceleration, FIR Filter

ENSCO, INC. CONTRACT NUMBER DTFH61-86-Z-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 2 LUY01 MHTSA FIR FILTER PEAKS -0.24 , 0.06
 FILTER CUTOFF FREQ. 0

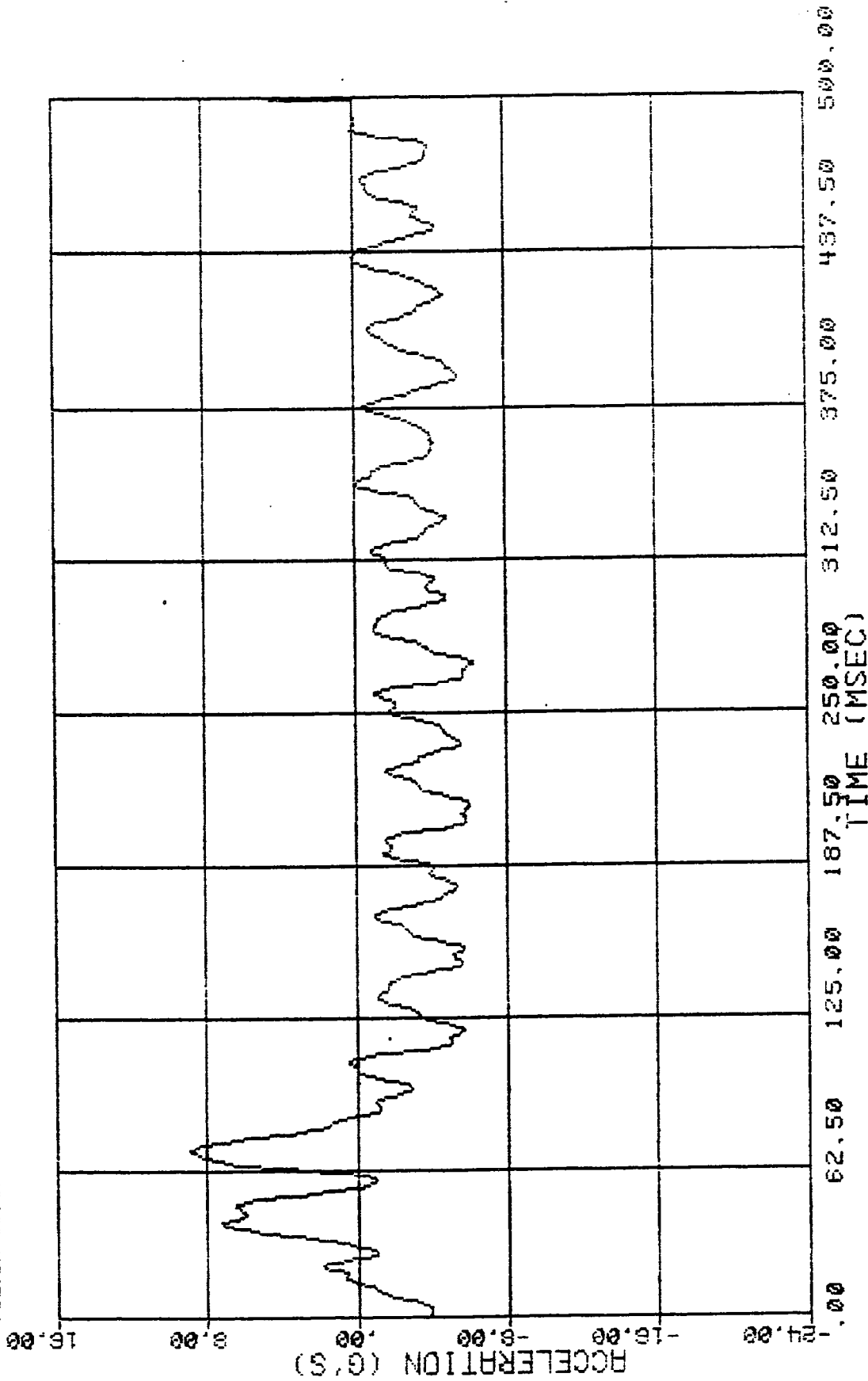


Figure A34. LUR - YG1 Acceleration, FIR Filter

ENSCO, INC. CONTRACT NUMBER DTFH61-86-2-00047 TEST # 1785-SI-7-88
 30 MI/H BROADSIDE IMPACT OF 80 DODGE COLT INTO LUMINAIRE SUPPORT
 CHANNEL 11 LURYGA MHTSA FIRL FILTER
 FILTER CUTOFF FREQ. 0 PEAKS -0.75 , 10.65

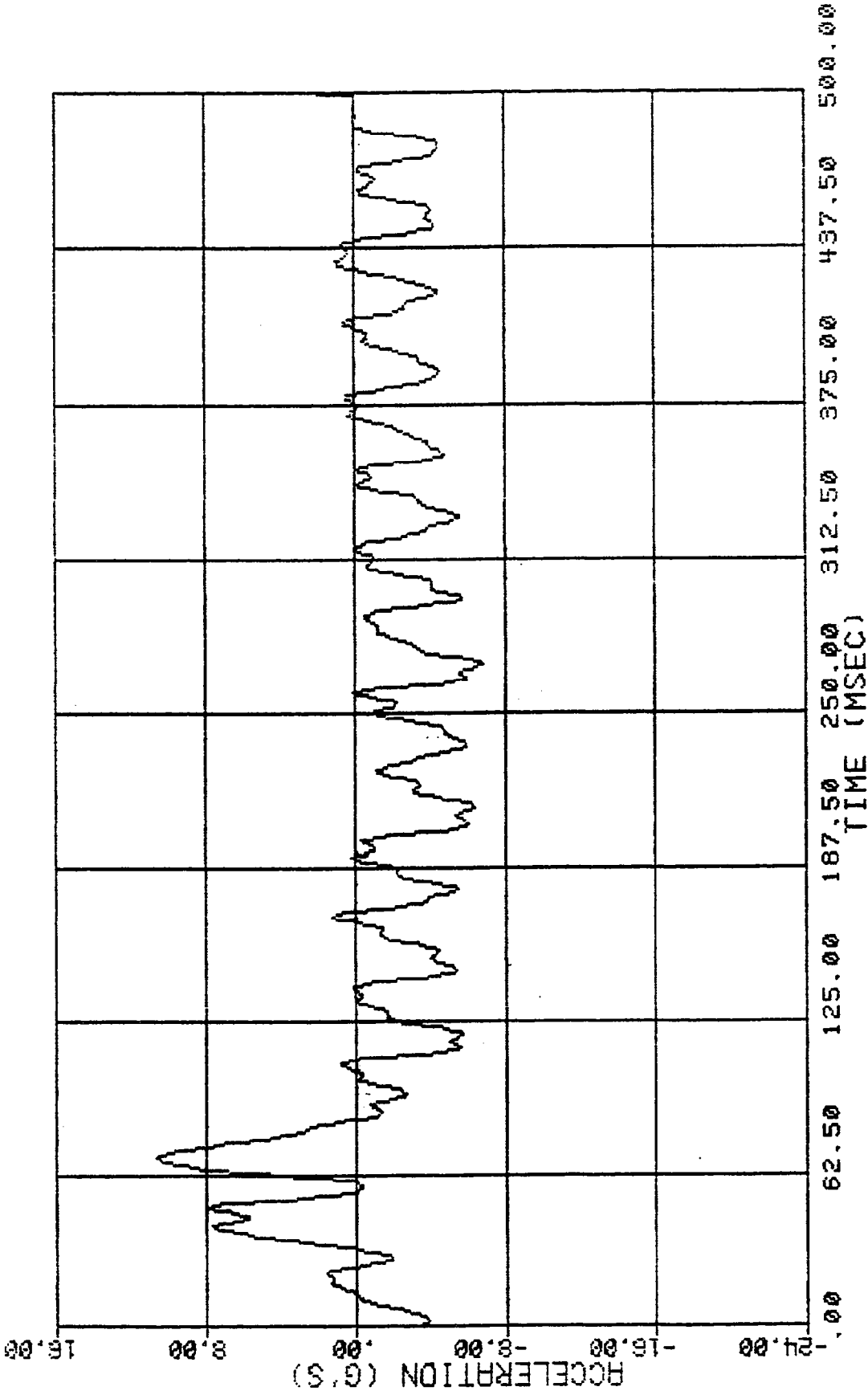


Figure A35. LUR - YGA Acceleration, FIR Filter