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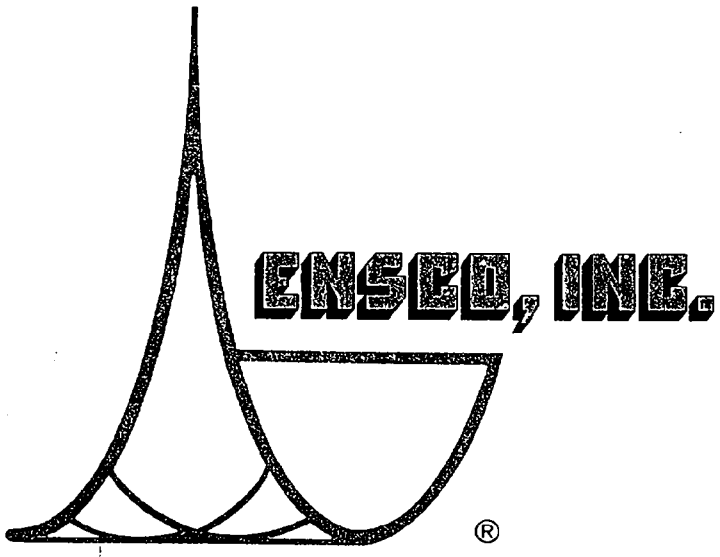

ENSCO, INC.

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

FHWA CONTRACT NO.
DTFH61-81-C-00036

HIGH SPEED OFFCENTER FRONTAL IMPACT OF A MINICOMPACT SEDAN AND A VALIDATED SURROGATE BREAKAWAY LUMINAIRE SUPPORT

TEST RESULTS REPORT

TEST NUMBER 1469-2A82

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1.0 SUMMARY

The objective of this test was to investigate the impact behavior and post-impact stability of a minicompact sedan (1,800 S) during a high speed offcenter collision with a surrogate breakaway luminaire support.[1,2] The vehicle chosen for this test was a Volkswagon Rabbit based upon the results of a limited engineering study conducted by ENSCO, Inc.[3] The surrogate breakaway luminaire support was chosen since it was known to induce a momentum change close to the upper limit of the acceptable standard of 1,100 lb-sec (4,893 N-s) when impacted by a 1971 Chevrolet Vega at an impact speed of 60 mph (26.8 m/s).[4,5]

The test vehicle momentum change at the impact speed of 61.6 mph (27.5 m/s) was 972 lb-sec (4,323 N-s) based on the analysis techniques specified for processing acceleration data given in NCHRP 230.[6] The corresponding velocity change of the vehicle due to the collision with the surrogate breakaway luminaire support was 9.97 mph (4.46 m/s).

Both instrumented anthropmorphic test dummies located in the front seats of the test vehicle survived the collision event based on the analysis of the acceleration and load cell data in accordance with NCHRP 230, TRC 191 and FVMSS 208.[6,7,8] However, vehicle yawing motion induced by the offcenter collision with the surrogate breakaway luminaire support caused the post-impact behavior of the vehicle to be unstable and rollover twice thereby significantly increasing vehicle damage and risk to the occupants. A summary of the test conditions and results for this full scale crash test are given in Table 1.

TABLE 1

SUMMARY OF TEST CONDITIONS AND
RESULTS FOR TEST NUMBER 1469-2A82

1	Contract Number	DTFH61-81-C-00036
2	Date of Test	February 10, 1982
3	Test Vehicle	Volkswagon Rabbit, 1976
4	Vehicle Weight, Test Inertial	
	Planned	1,800 ±50 lbs
	Actual	1,813 lbs
5	Vehicle Weight, Gross Static	
	Planned (One Occupant)	1,950 ±50 lbs
	Actual (One Occupant)	1,971 lbs
6	Vehicle Weight, Gross Static	
	Actual (Two Occupants)	2,140 lbs
7	Number of Occupants	Two
8	Occupant Model	Anthropomorphic Dummy 50th Percentile Male
9	Occupant Locations	Front, Driver and Passenger Seats
10	Occupant Conditions	
	Driver	Restrained, Lap and Shoulder Belts
	Passenger	Unrestrained
11	Impact Speed	
	Planned	56.7 to 64.6 mph[6]
	Observed	61.6 mph
12	Exit Speed, Observed	
	Acceleration Data, NCHRP 230	51.63 mph[6]
	Acceleration Data, TRC 191	51.80 mph[7]
	Speed Trap and Film (Avg)	52.2 mph
13	Speed Reduction, Observed	
	Acceleration Data, NCHRP 230	9.97 mph[6]
	Acceleration Data, TRC 191	9.80 mph[7]
	Speed Trap & Film (Avg)	9.4 mph

14	Impact Point Planned Observed	 Front, Left of Centerline, 14¼ in Front, Left of Centerline, 14¼ in
15	Impact Angle of Vehicle with Respect to Theoretical Mast Arm	30 Degrees[9]
16	Exit Angle of Vehicle with Respect of Theoretical Mast Arm	38.5 Degrees
17	Vehicle Crush Residual Dynamic	 18½ in 24½ in
18	Bolt Size	1 in - 8 NC x 5 in long
19	Bolt Circle	14 in
20	Slip Plane Mounting Height Above Grade	4.25 in
21	Foundation	W, 3 ft; L, 4 ft; D, 4 ft
22	Ground Conditions	Dry
23	Traffic Accident Data, TAD[10]	12FLEN3
24	Vehicle Damage Index, VDI[11]	12-FC-3
25	Test Article	Surrogate Breakaway Luminaire Support
26	Support Length (w/o Base)	34 ft
27	Support Type	Steel 8-in (Nom.) Pipe (Schedule 40)
28	Support Weight (w/Base)	1,003 lbs
29	Base Type	Triangular Slip Base, 3-Bolt

reversed

30	Bolt Load (Strain Gaged)	14,000 lbs each
31	Momentum Change	
	Acceleration Data, NCHRP 230	972 lb-sec[6]
	Accelerations Data, TRC 191	955 lb-sec[7]
	Speed Trap & Film (Avg)	916 lb-sec

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1 lb = .454 kg
1 ft = .3048 m
1 in = .0254 m
1 lb-sec = 4.448 N-s
1 ft-kip = 1,355 N-m

2.0 OBJECTIVE

The objective of this test was to investigate the impact behavior and post-impact stability of a minicompact sedan (1,800 S) during a high speed offcenter collision with a surrogate breakaway luminaire support. This test is the second of a series of five full scale crash tests to be conducted under Task A of Contract Number DTFH61-81-C-00036.[1,2]

The vehicle chosen for this test was a Volkswagon Rabbit based upon the results of a limited engineering study conducted by ENSCO, Inc.[3] The vehicle contained two instrumented 50th percentile anthropomorphic test dummies located in the front driver and passenger seats, respectively. A triaxial accelerometer package was mounted on the lateral centerline of the vehicle at the longitudinal location of the center of gravity. These were used to measure vehicle impact behavior and occupant injury potential based upon criteria set forth in TRC 191 and NCHRP 230.[6,7] The vehicle also was instrumented with a contact switch mounted on the front bumper to permit vehicle and occupant data to be measured relative to the time of impact. Each of the instrumented dummies had two triaxial accelerometer packages located at the center of gravity of the head and at the upper thorax region, respectively. These were used to yield the acceleration levels experienced in the respective regions of the test dummies and to analyze the Head Injury Criteria (HIC) and Chest Severity Index (CSI) for each occupant as specified in FMVSS 208 and SAE Information Report J885a.[8,12] The legs of each occupant contained load cells implanted in the femur to measure the load applied to the legs of the occupants during the collision.

The surrogate breakaway luminaire support was chosen since it was known to induce a momentum change close to the upper limit of the acceptable standard of 1,100 lb-sec (4,893 N-s) when impacted by a 1971 Chevrolet Vega at an impact speed of 60 mph (26.8 m/s).[4,5] The actual momentum change induced by the surrogate breakaway luminaire support when impacted by a 1971 Chevrolet Vega at an impact speed of 60 mph (26.8 m/s) during full scale crash test 1469-1A81 was 1,131 lb-sec (5031 N-s).[5] The primary point of investigation is whether the reduced rotational moments of inertia of the lightweight vehicle (1800 S) would induce post-impact instability in the vehicle, therefore significantly increasing the potential for damage to the vehicle and risk of injury to the occupants.

3.0 APPURTENANCE DESCRIPTION

The physical properties of the surrogate breakaway luminaire support are contained in Table 2. The surrogate breakaway luminaire support incorporated a triangular 3-bolt slip base which was designed using the California state plan for a Type 31 support.[13] The luminaire support was installed using the guidelines provided by the California DOT.[13] The slip base was positioned so impact would occur against the lead bolt, which is equivalent to a 30° impact angle with respect to the mast arm.[9] The luminaire support did not have a mast arm attached during this test. The slip base was clamped together with three strain gaged bolts which were tightened to 14,000 pounds (62,300 N) each just prior to the test. The surrogate breakaway luminaire support is shown in Figure 1.

TABLE 2

SUMMARY OF PHYSICAL PROPERTIES OF
THE SURROGATE BREAKAWAY LUMINAIRE SUPPORT

Length (Support)	34 feet
Material (Support)	Steel 8-inch (Nom.) Pipe (Schedule 40)
Outside Diameter (Support)	8.625 inches (Actual)
Weight (Support)	28.55 lb/ft; 970.7 pounds
Wall Thickness (Support)	0.322-inch
Base Type	Triangular Slip Base, 3-Bolt (Type 31)
Base Thickness	1 inch
Weight (Base)	32 pounds
Weight (Total, M_t)	1002.7 pounds (31.14 slugs)
Base Bolts	1 inch diam. (Strain Gaged)
Bolt Circle	14 inch diam.
Bolt Load	14,000 pounds
Mounting Height (Base)	0.25 feet
Mass Moment of Inertia, I_p	3183.8 lb-ft-sec^2
Center of Gravity, X_{cg}	16.56 feet

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1 lb = .454 kg
1 ft = .3048 m
1 in = .0254 m
1 lb-sec = 4.448 N-s
1 lb-ft-sec^2 = 1.356 N-m-s^2

Figure 1. Pre-Crash Photograph of Surrogate Breakaway Luminaire Support

4.0 VEHICLE DESCRIPTION

The test vehicle was a 1976 Volkswagon Rabbit. The weight of the vehicle prior to incorporating the instrumentation for the test was 1,791 pounds. The test inertia weight for the vehicle was 1,813 pounds and the gross static weight when both occupants were included in the vehicle was 2,140 pounds. The longitudinal center of gravity of the vehicle without the occupants was located 34.3 inches behind the centerline of the front axle. The weight distribution of the vehicle with and without the occupants is given in Tables 3 and 4, respectively.

TABLE 3

WEIGHT DISTRIBUTION OF TEST VEHICLE WITHOUT OCCUPANTS

	Left (lbs)	Right (lbs)	Subtotal (lbs)
Front	584	571	1,155
Rear	354	304	658
Subtotal	938	875	1,813

TABLE 4

WEIGHT DISTRIBUTION OF TEST VEHICLE WITH OCCUPANTS

	Left (lbs)	Right (lbs)	Subtotal (lbs)
Front	676	667	1,343
Rear	417	380	797
Subtotal	1,093	1,047	2,140

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. The vehicle was also equipped with a contact switch mounted on the front bumper to permit vehicle and occupant data to be measured relative to the time of impact. The test vehicle is shown in Figures 2 through 5.

Figure 2. Pre-Test Photograph of Test Vehicle, Left Side View

Figure 3. Pre-Test Photograph of Test Vehicle, Front View

Figure 4. Pre-Test Photograph of Test Vehicle Shown in Contact with Surrogate Luminaire Support, Left Front Angle View

Figure 5. Pre-Test Photograph of Test Vehicle Shown in Contact with Surrogate Luminaire Support, Left Side View

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 to 300 kHz. The speed trap data was recorded in frequency modulated mode with a bandpass of 0 to 20 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.[14] The test data was analyzed on a DEC 11/70 using the ENSCO general purpose highway research analysis programs. The 32 kHz control signal was initiated by the tape switch approximately two seconds prior to the vehicle impacting the luminaire support. This control signal was used to externally trigger the digitizing unit and automatically synchronized all data channels. The speed trap system used two sets of roadway contact switches which were positioned 46.25 inches apart. The first set was located three feet prior to the impact point and the remaining sets were located eight feet from the impact point. 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.[15]

TABLE 5

DESCRIPTION OF FILM DATA FOR
FULL SCALE CRASH TEST NUMBER 1469-2A82

Camera	Model	Position	Speed
1	Redlake Locam	Right Side	500 pps
2	Redlake Locam	Overhead	500 pps
3	Redlake Hycam	Left Side	500 pps
4	Redlake Locam	Left Front	500 pps
5	Arrieflex	Documentation	24 pps

TABLE 6

TRANSDUCER DATA CHANNEL DESCRIPTION FOR
FULL SCALE CRASH TEST NUMBER 1469-2A82

Data Channel	Recorder Channel	Channel Description	Transducer Model	Transducer Serial Number	Multiplex Frequency	Deviation Frequency
1	1	D Head X	ENDEVCO 2264-2000	AN83	32 kHz	-14.80 Hz/g
2	1	D Head Y	ENDEVCO 2264-2000	AR36	48 kHz	+15.32 Hz/g
3	1	D Head Z	ENDEVCO 2264-2000	AT31	64 kHz	+19.69 Hz/g
4	1	D Chest X	ENDEVCO 7231C-750	CM19	80 kHz	+19.60 Hz/g
5	1	D Chest Y	ENDEVCO 7231C-750	CM20	96 kHz	-19.87 Hz/g
6	1	D Chest Z	ENDEVCO 7231C-750	CQ44	112 kHz	-22.23 Hz/g
7	1	D Femur L	GSF 2430	673	128 kHz	+1.475 Hz/lb
8	1	D Femur R	GSF 2430	682	144 kHz	+1.563 Hz/lb
9	2	P Head X	ENDEVCO 7231C-750	CS10	32 kHz	+22.63 Hz/g
10	2	P Head Y	ENDEVCO 7231C-750	CS74	48 kHz	-19.54 Hz/g
11	2	P Head Z	ENDEVCO 7231C-750	CV52	64 kHz	-19.52 Hz/g
12	2	P Chest X	ENDEVCO 7231C-750	CT78	80 kHz	+19.37 Hz/g
13	2	P Chest Y	ENDEVCO 7231C-750	CZ17	96 kHz	-19.28 Hz/g
14	2	P Chest Z	ENDEVCO 7231C-750	CZ39	112 kHz	-19.73 Hz/g
15	2	P Femur L	GSF 2430	683	128 kHz	+1.693 Hz/lb
16	2	P Femur R	GSF 2430	684	144 kHz	+1.646 Hz/lb
17	3	Vehicle X	Statum AG9TC-25-350	18062	32 kHz	-91.90 Hz/g
18	3	Vehicle Y	Statum A69TC-25-350	18181	48 kHz	-88.57 Hz/g
19	3	Vehicle Z	Statum A69TC-25-350	18176	64 kHz	+93.87 Hz/g
20	3	Impact	Tape Switch No. 107-LS	N/A	80 kHz	+2kHz/Contact
22	6	Speed Trap	Tape Switch, Model RB-S	N/A	N/A	N/A
23	7	Sync. 32 kHz	N/A	N/A	N/A	N/A

6.0 TEST RESULTS

The impact conditions were 61.6 mph (27.5 m/s) at the planned impact point of 14.25 inches (0.36 m) to the left of the lateral centerline of the vehicle. The residual crush of the vehicle at the impact point was 18½ inches (.47 m). The dynamic crush as measured from the film data was 24½ inches (.62 m). Photographs of the vehicle crush resulting from the collision with the luminaire support and subsequent rollover of the vehicle are shown in Figures 6 through 10.

The base of the luminaire support started moving approximately 10 msec after impact with final release of the base support from its mounting plate occurring approximately 16 msec after the impact of the vehicle with the luminaire support. The luminaire support translated forward at a speed of 27.7 ft/sec (8.4 m/sec) and rotated at a rate of 4.09 rad/sec. The luminaire support rotated up and over the vehicle creating no potential for secondary impacts under the prescribed test condition. The top of the luminaire support impacted the ground at a distance of 2.8 feet (.85 m) from the centerline of the luminaire support prior to the impact. The rotation angle of the luminaire support relative to its original position was 131° The final resting position of the luminaire support was parallel to the direction of impact with the centerline of the luminaire support offset to the left .9 feet (.28 m). The top of the luminaire support in its final resting position was 8.5 feet (2.60 m) from the centerline of the luminaire support prior to the impact. The luminaire support was bent .38 feet (.11 m) approximately 1 foot (.30 m) above the location of its center of gravity.

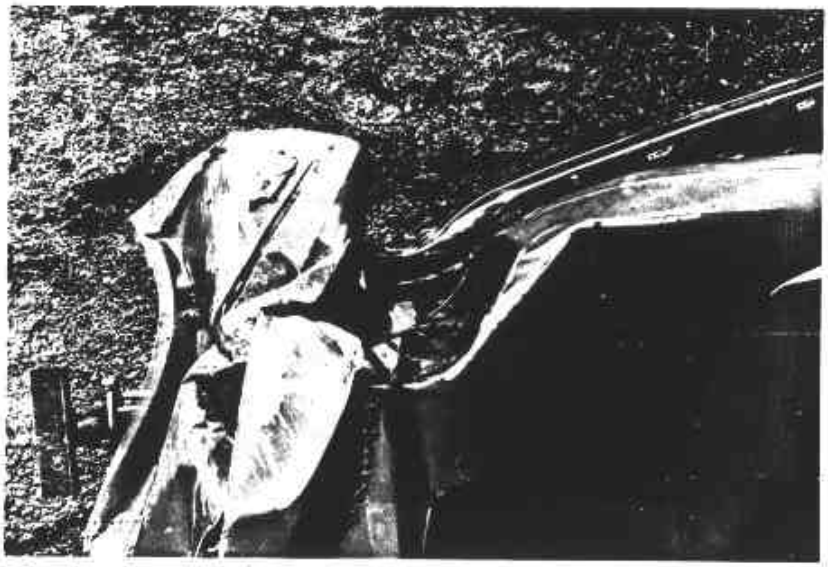


Figure 6. Post-Test Photograph of Test Vehicle, Overhead View of Impact Location

Figure 7. Post-Test Photograph of Test Vehicle, Left Side View

Figure 8. Post-Test Photograph of Test Vehicle, Right Side View

Figure 9. Post-Test Photograph of Test Vehicle, Front View

Figure 10. Post-Test Photograph of Test Vehicle, Rear View

The front left tire locked up approximately 44 msec after the vehicle impacted the luminaire support due to the crushing of the front end of the vehicle. The yawing motion of the vehicle as measured from the overhead film is shown in Figure 11. At approximately 135 msec after the impact the vehicle had yawed approximately 8.5 degrees relative to its original direction and the left rear tire impacted the luminaire support mounting plate attached to the foundation. The vehicle continued to yaw to angle of approximately 60 degrees relative to its original direction and initiated the first rollover at .9 sec after the impact. The vehicle hit the ground at approximately 2.6 sec completing the first rollover. The vehicle completed the second rollover at approximately 3.6 seconds and came to rest at 4.2 seconds after the initial impact at a distance of 135 feet (41.15 m) from the impact point. The test trajectory is depicted in Figure 12 and the test sequence is depicted in Figure 13.

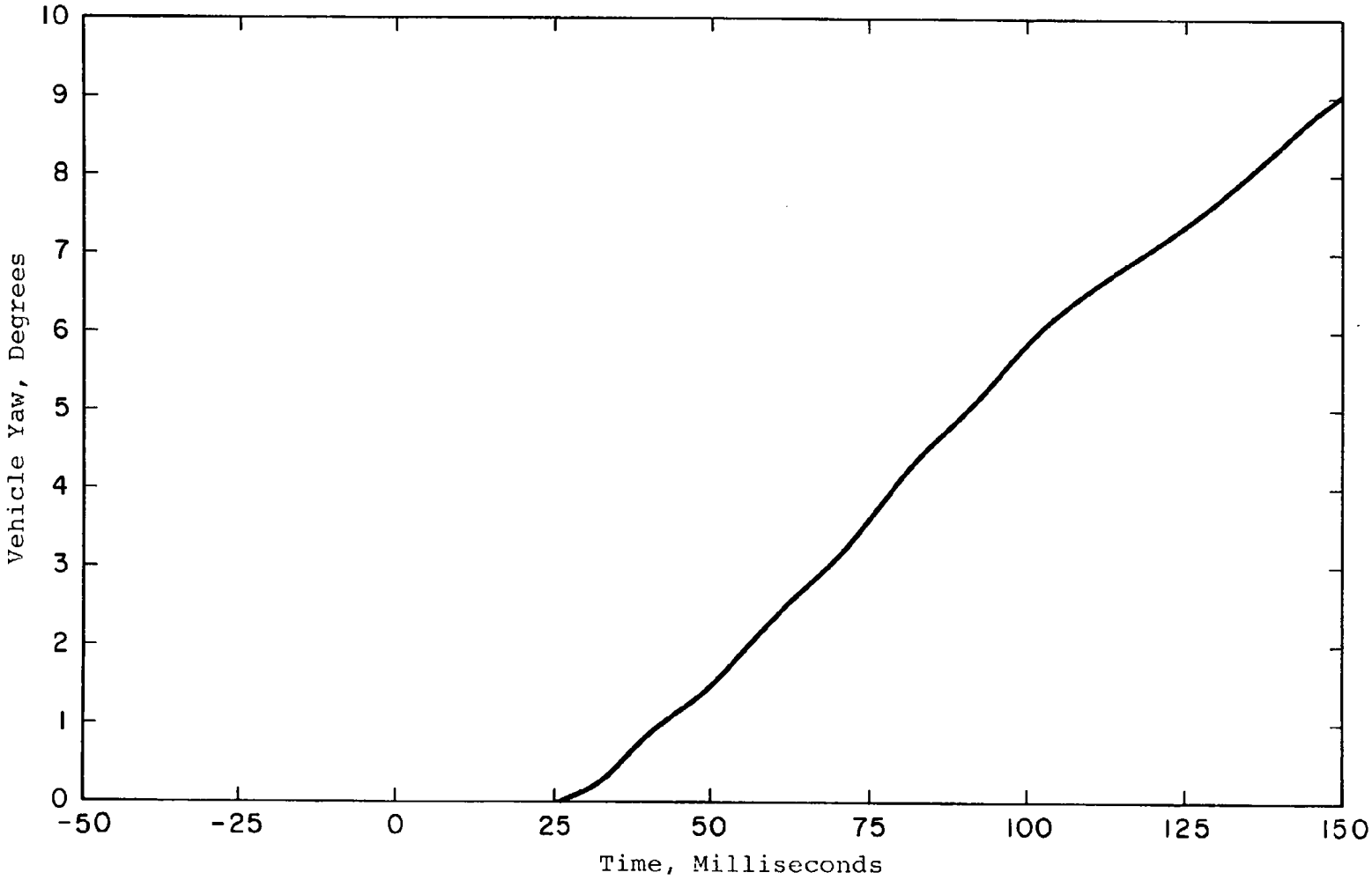


Figure 11. Vehicle Angle Relative to Impact Angle From Film Data, Overhead View

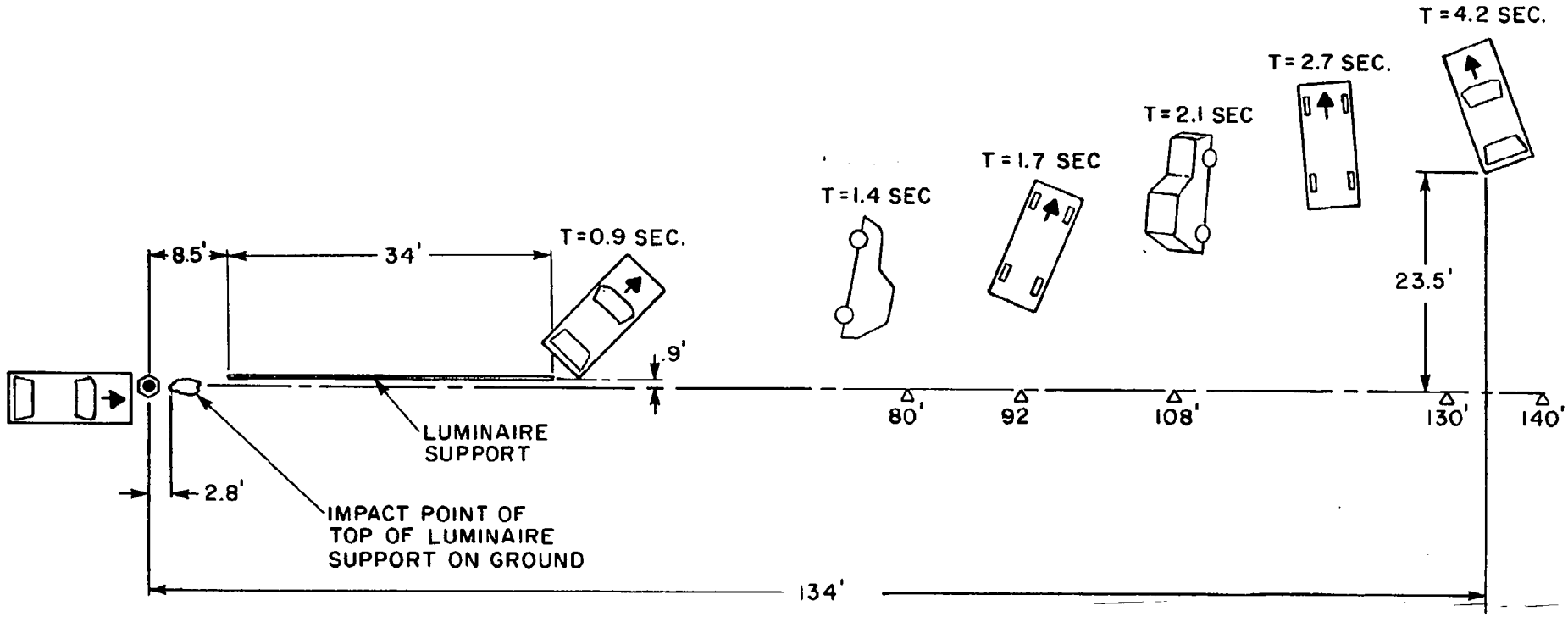
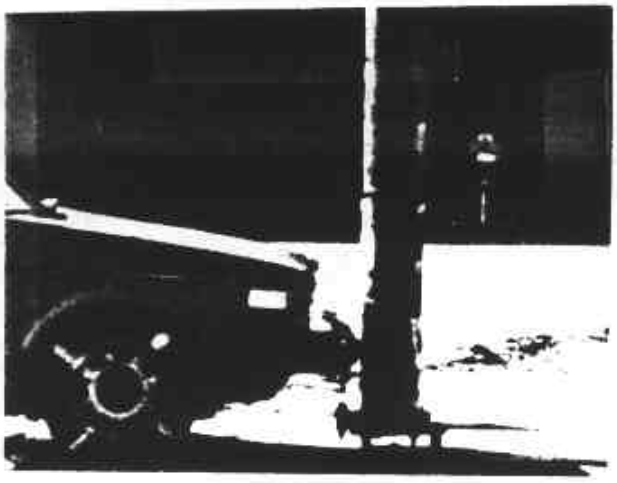


Figure 12. Vehicle Trajectory For Full Scale Crash Test Number 1469-2A82



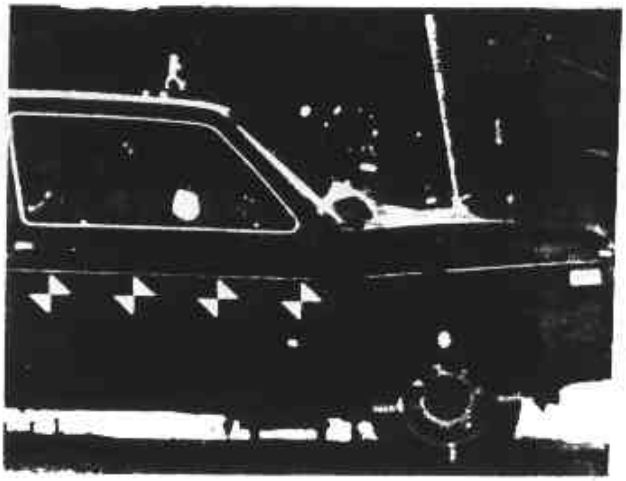
t = 0.00 sec

t = 0.036 sec

t = 0.012 sec

t = 0.048 sec

t = 0.024 sec



t = 0.060 sec

Figure 13. Test Sequence for the Collision Event of Full Scale Crash Test Number 1469-2A82

7.0 TEST ANALYSIS

Data from this test were evaluated using several techniques. The pre-impact and post-impact speeds were determined from the speed traps and high speed films. The pre-impact and post-impact speeds from the available sources were then averaged and used to calculate the change in vehicle speed and the associated momentum change occurring during the impact event. The signals from the accelerometers mounted on the vehicle were 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.[7] This filtered data was then used to yield the impact velocity of a hypothetical front seat passenger against the vehicle using the techniques described in NCHRP 230 as specified in the approved test plan.[1,6] The signals from the accelerometers mounted on the vehicle were also filtered at SAE Class 180 and processed to yield vehicle change in speed and the associated occupant injury parameters in accordance with NCHRP 230.[6]

The accelerometers mounted in the head of each of the test dummies were used to yield resultant accelerations and the Head Injury Criteria as specified in FMVSS 208.[8] The accelerometers mounted in the upper thorax of the test dummies were filtered at SAE Class 180 and processed to yield resultant accelerations. The peak resultant accelerations whose duration exceeded 3 milliseconds were reported in accordance with FMVSS 208.[8] Also, the chest severity indices were calculated by the method described in SAE Information Report J885a.[12]

Finally, the femur loads experienced by the test dummies were filtered at SAE Class 600 and examined to yield peak loads and compared to the limits presented in FMVSS 208.[8]

7.1 FILM AND SPEED TRAP VELOCITY ANALYSIS

The impact and post-crash velocities were determined from the high-speed films through the use of the Vanguard motion analyzer provided by FHWA. The associated speeds were determined from the speed traps by referencing the distance base of 46.25 in (1.17 m) located prior to the impact point and after the crash event to a crystal controlled 1,000 Hz time reference recorded during the test. Results from the speed analysis are contained in Table 7. Based upon this analysis, the impact speed of the vehicle was 61.6 mph (27.54 m/s) and the exit speed of the vehicle was 52.2 mph (23.34 m/s). The change in the speed of the vehicle during the collision was, therefore, 9.4 mph (4.20 m/s). The impact speed was measured within five feet of the impact point and the exit speed was measured at the end of the impact event, i.e., when the acceleration levels within the vehicle indicated that the impact event was completed. The luminaire support visually started to separate from the vehicle at approximately 96 msec and the secondary impact with the luminaire support mounting plate occurred at approximately 135 msec after the initial impact.

TABLE 7

TEST VEHICLE SPEED RESULTS BASED UPON THE SPEED TRAP AND FILM ANALYSIS

	Impact Speed (mph)	Exit Speed (mph)
Left Side	62.0	52.1
Right Side	62.0	N/A
Overhead	61.0	52.5
Speed Trap	61.4	52.1
Average	61.6	52.2

1 mph = .44704 m/sec

This average change in velocity was used to determine the vehicle change in momentum. The final momentum change for the vehicle at an impact speed of 61.6 mph (27.54 m/s) based on this analysis was 916 lb-sec (4,076 N-s) when using the gross static mass of the vehicle as the basis for the momentum evaluation. Justification for using the gross static versus the inertial mass is based upon the fact that the driver was restrained and had clearly imparted energy back into the vehicle through the restraint system. Further, the passenger had impacted the dash and had imparted energy back into the vehicle through that collision. Subsequent analysis of the luminaire support presented in this report also dictates that the gross static mass of the vehicle must be used for momentum evaluations to obtain meaningful comparisons between the results obtained from the vehicle and the luminaire support.

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.[6,7] The three individual accelerometer signals were in each case combined to yield the resultant accelerations occurring during the impact event. For comparison purposes, a resultant was evaluated with and without the data from the accelerometer whose sensitive axis was aligned vertically. The acceleration traces and resultants obtained with the use of the SAE Class 60 (f_c = 100 Hz) filtering technique are presented in Figures 14 through 18. The acceleration traces and resultants obtained with the use of the SAE Class 180 (f_c = 300 Hz) filtering technique are presented in Figures 19 through 23.

Table 8 contains several pertinent details regarding the data obtained from the vehicle mounted accelerometers. The resulting change in velocity and momentum change of the vehicle based upon integrating the acceleration signals in the fixed vehicle coordinate system are shown in Table 9.

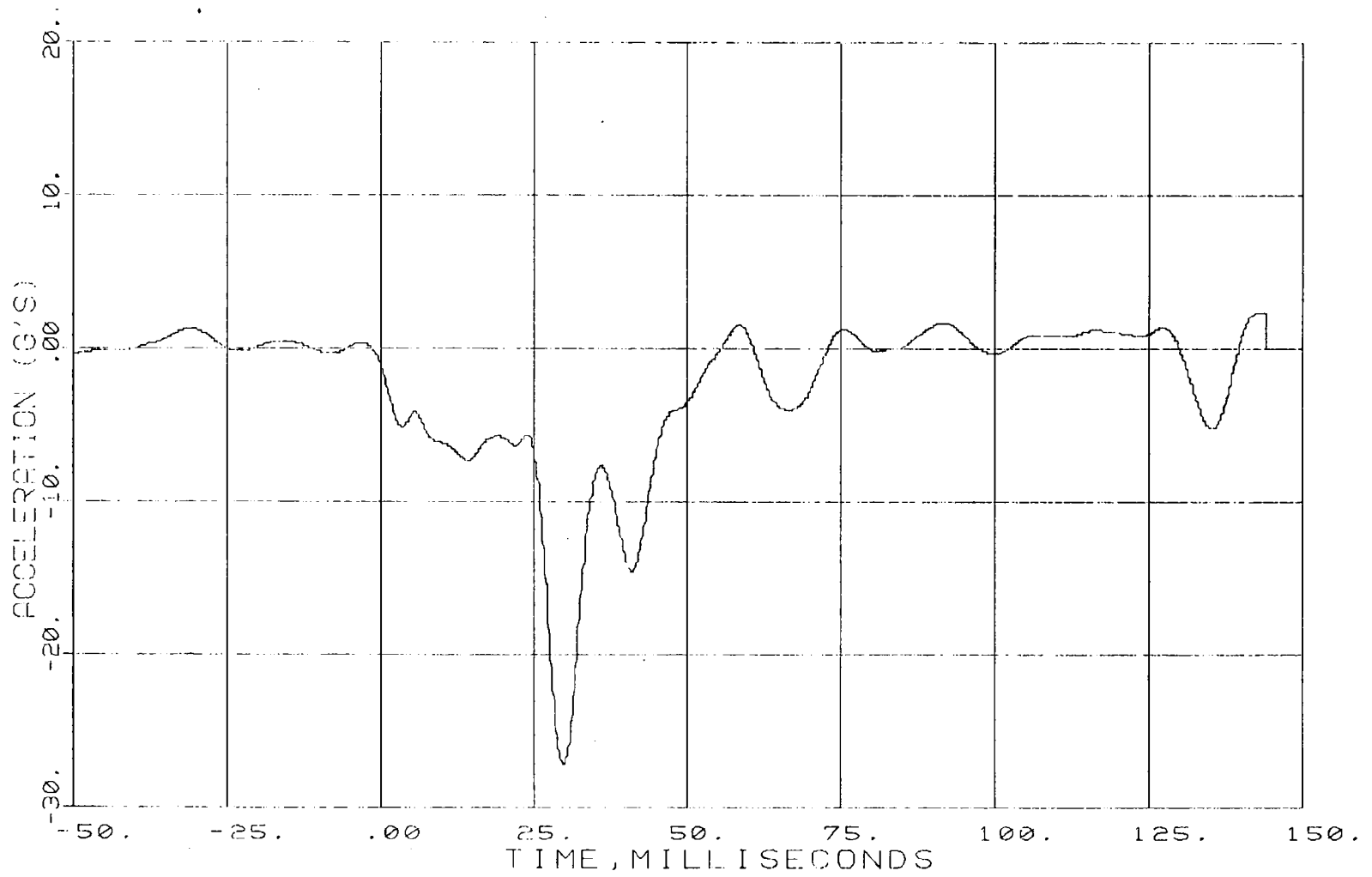


Figure 14. Vehicle C.G. Acceleration, X Axis

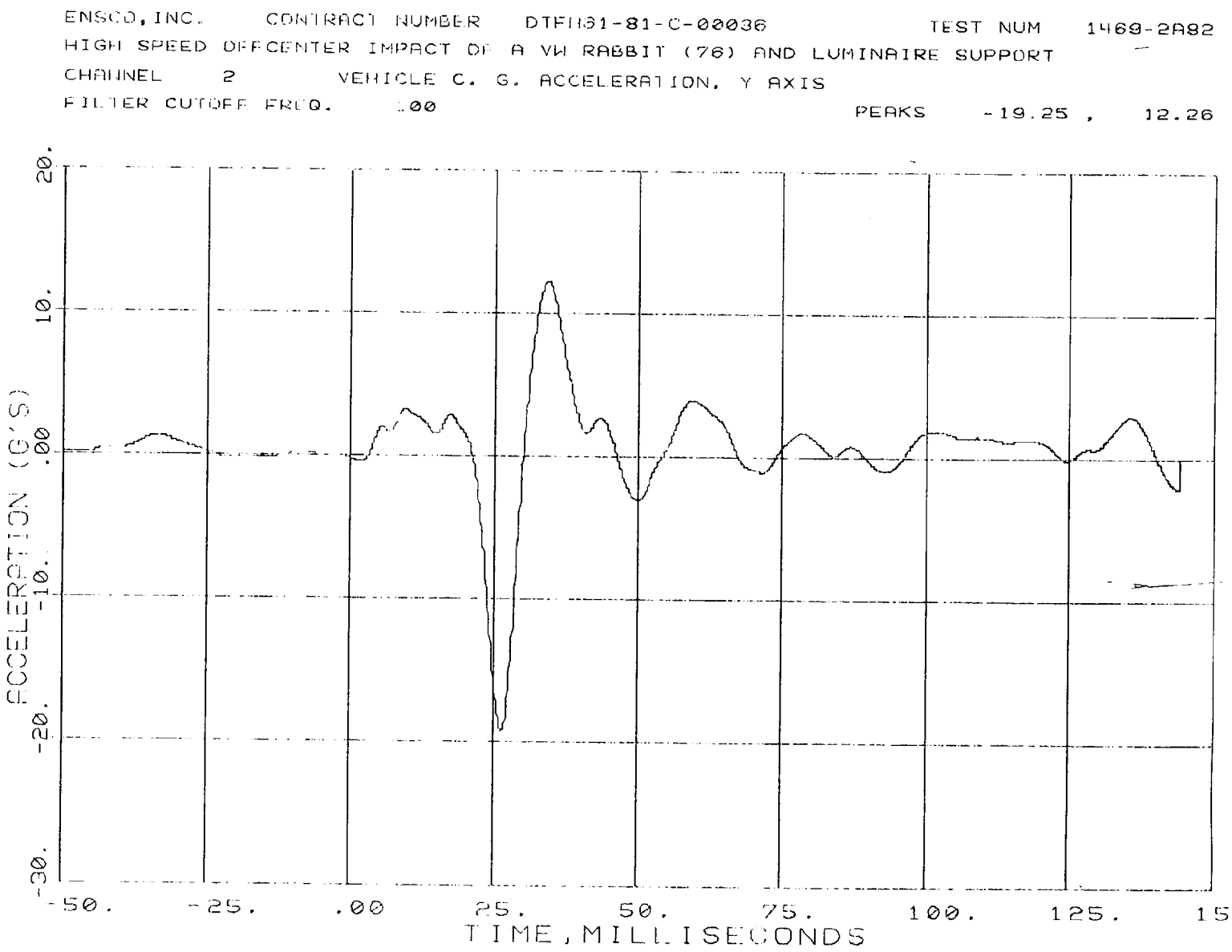


Figure 15. Vehicle C.G. Acceleration, Y Axis

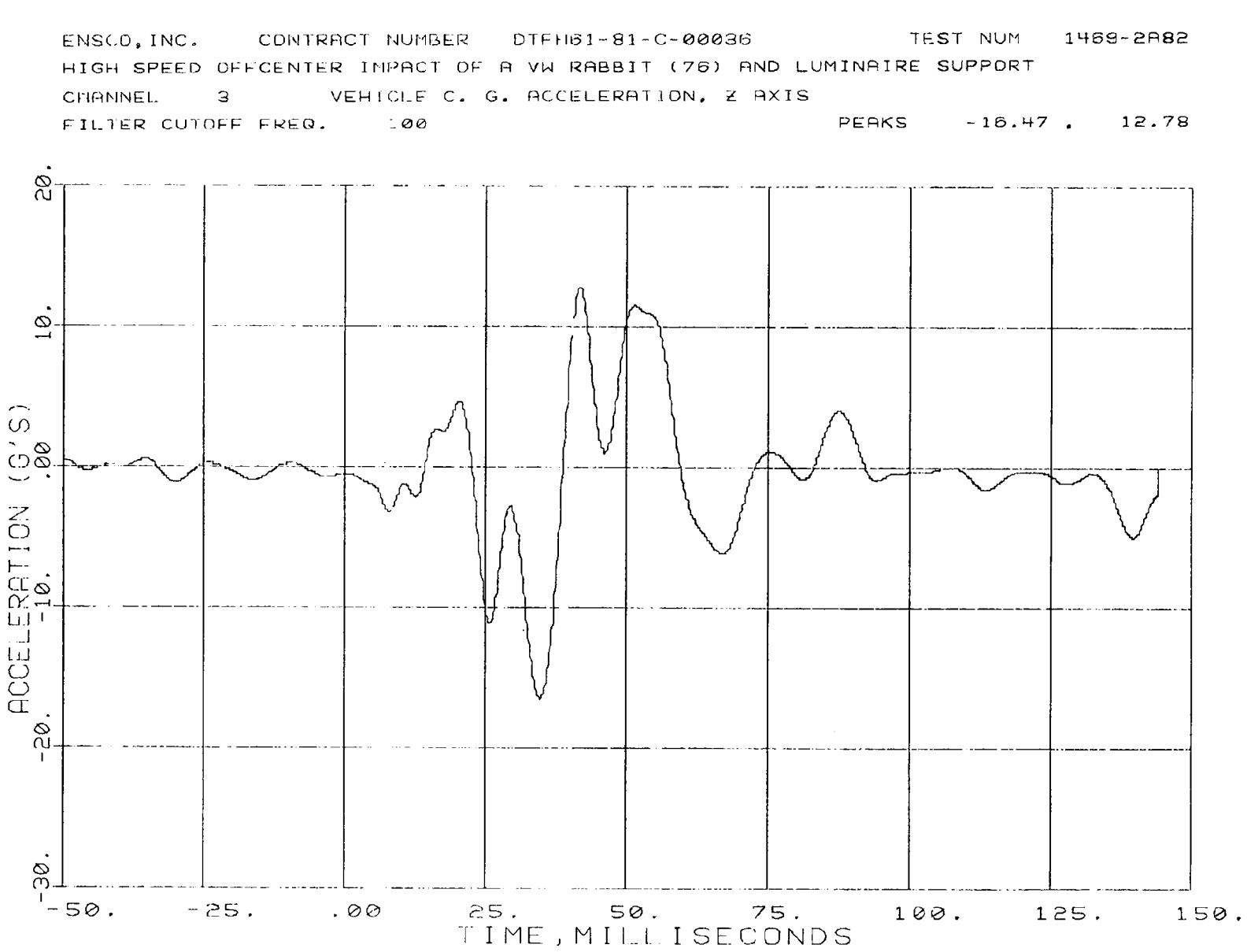


Figure 16. Vehicle C.G. Acceleration, Z Axis

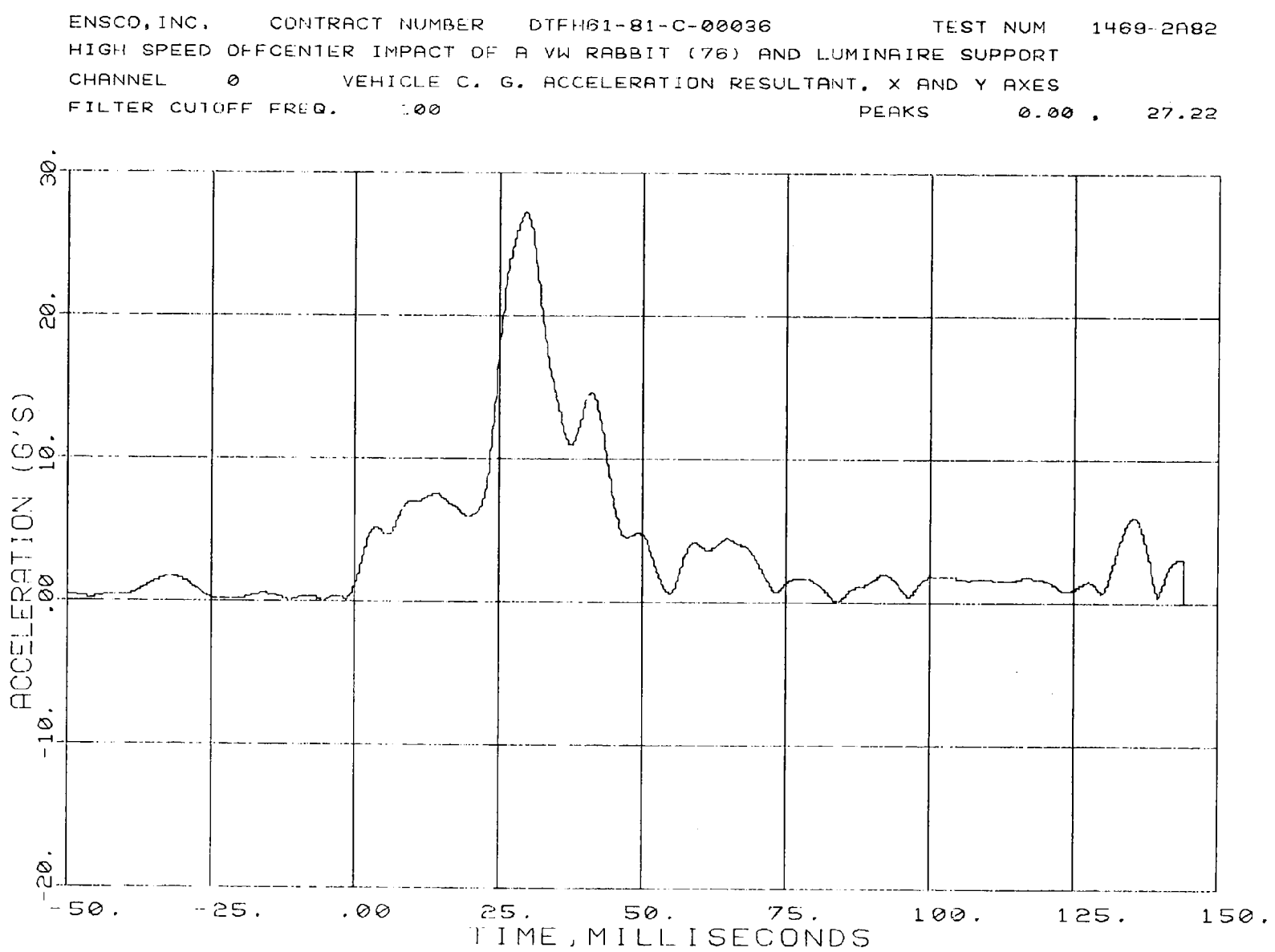


Figure 17. Vehicle C.G. Acceleration Resultant, X and Y Axes

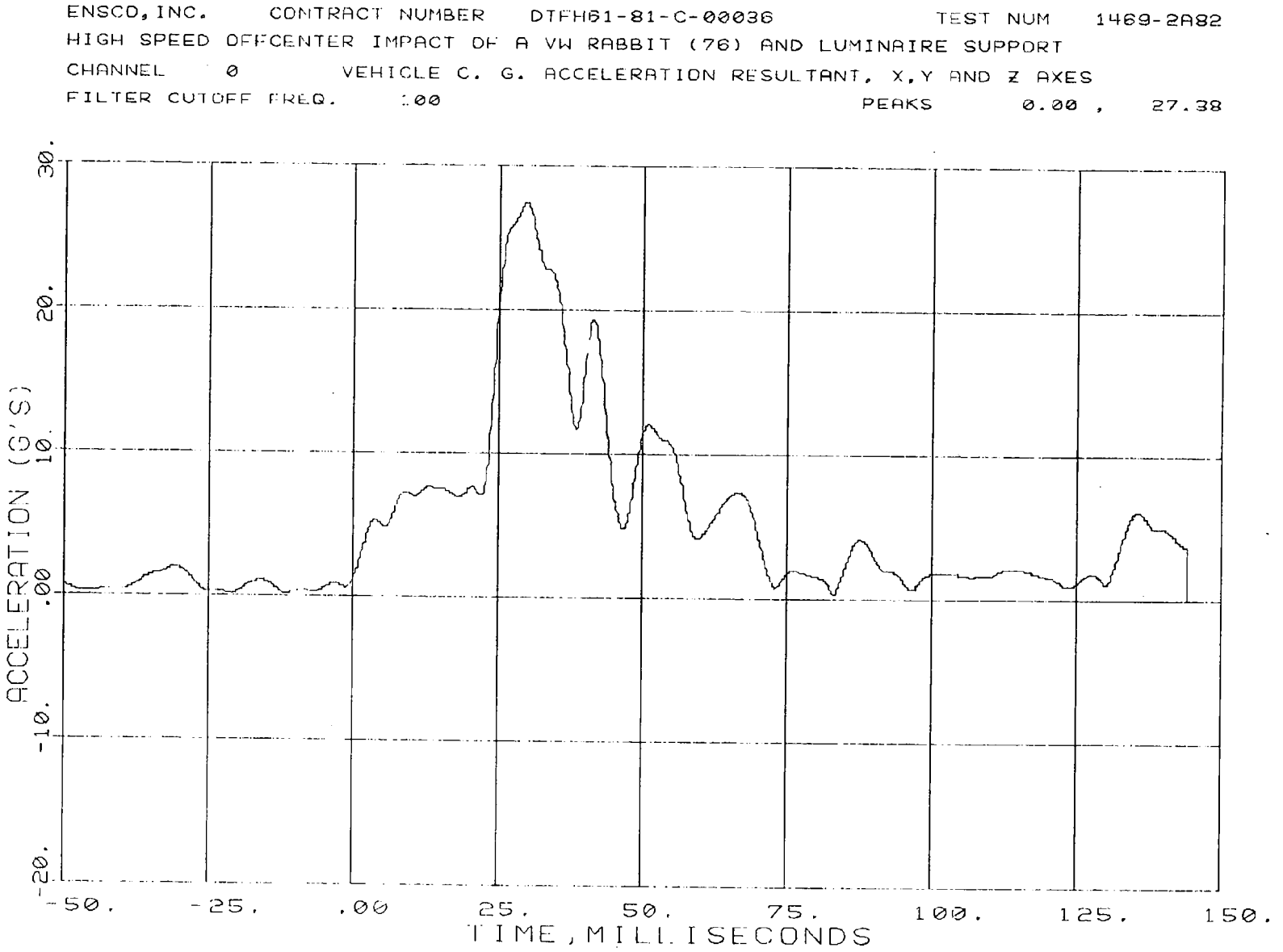


Figure 18. Vehicle C.G. Acceleration Resultant, X, Y and Z Axes

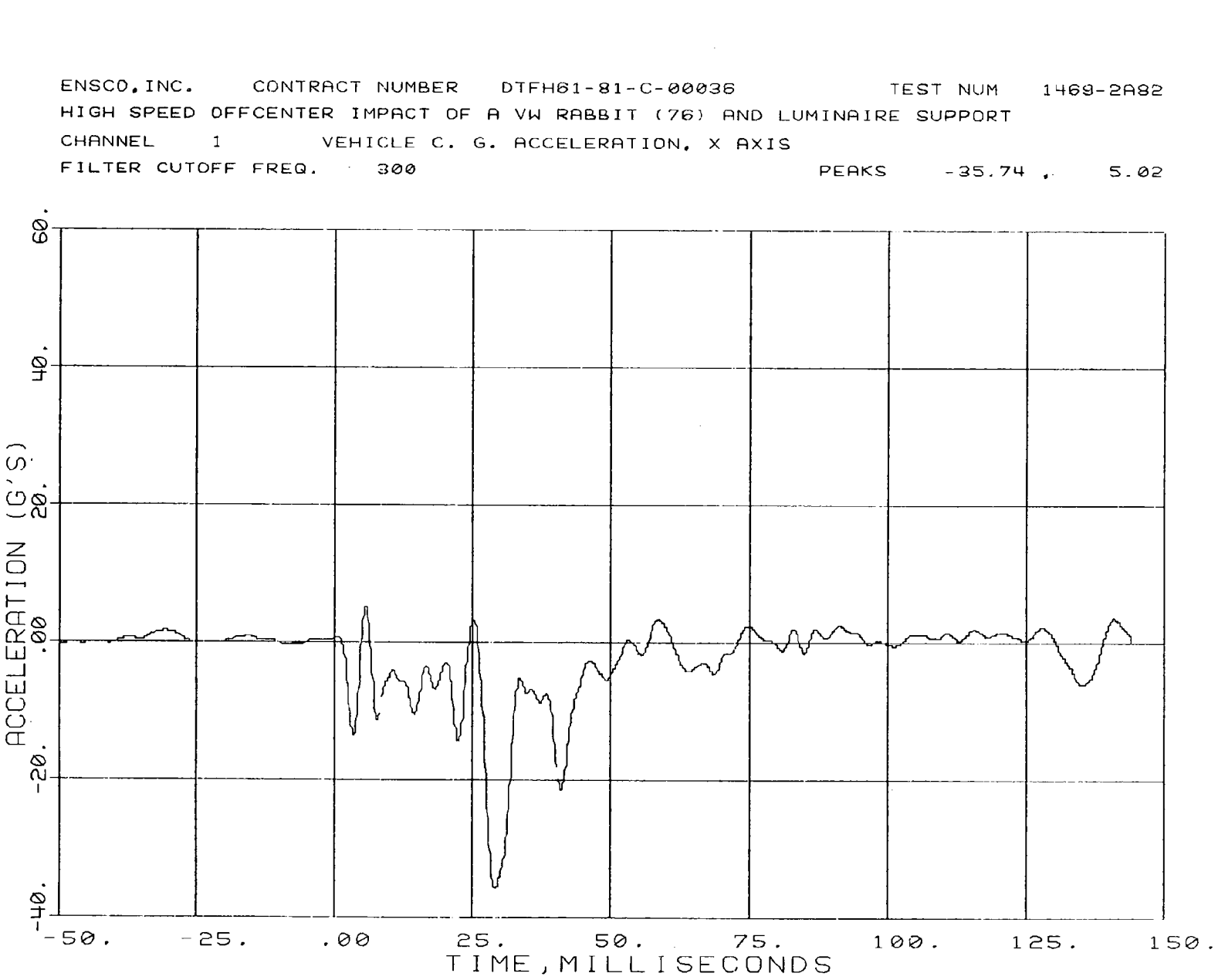


Figure 19. Vehicle C.G. Acceleration, X Axis

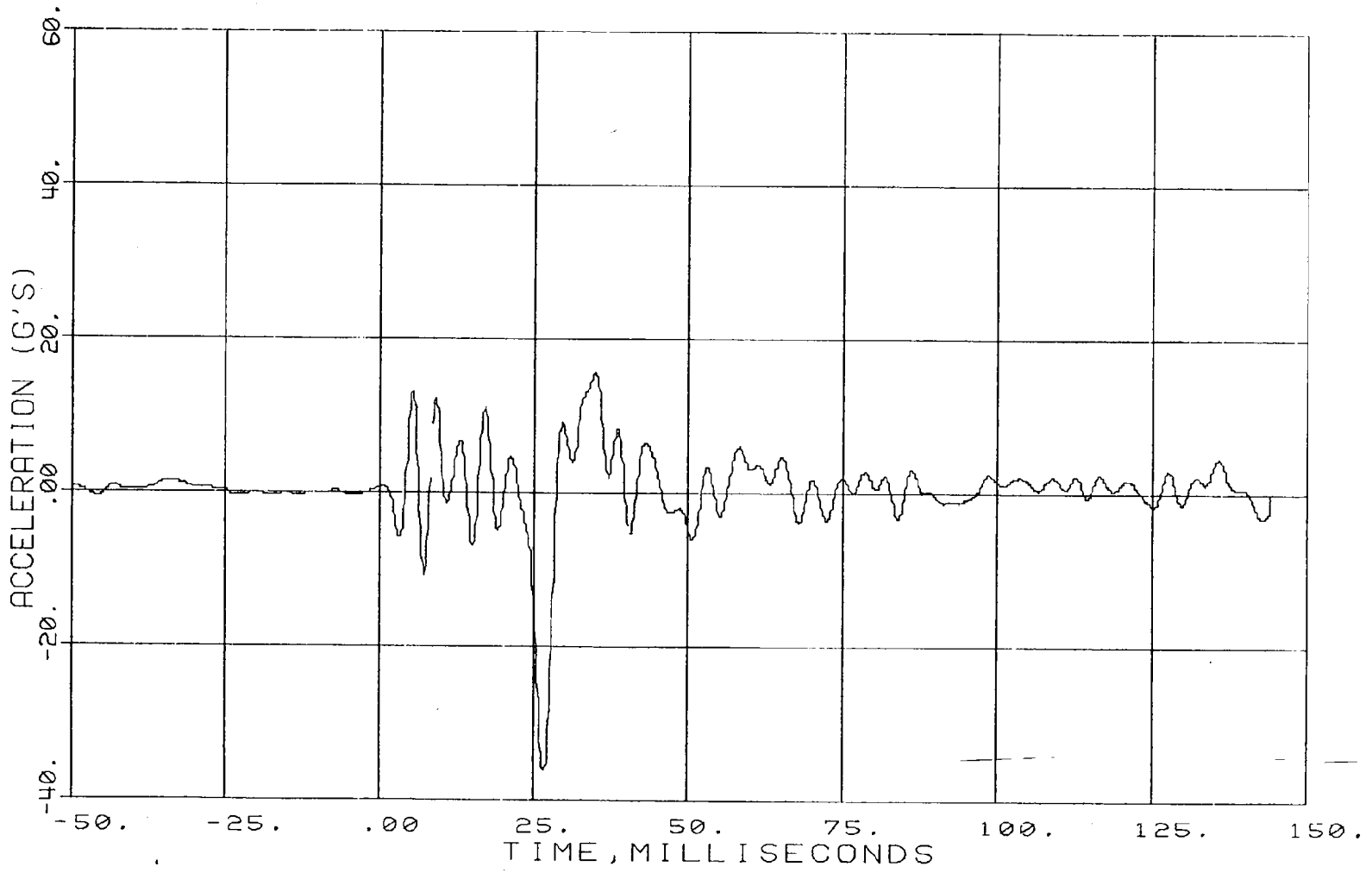


Figure 20. Vehicle C.G. Acceleration, Y Axis

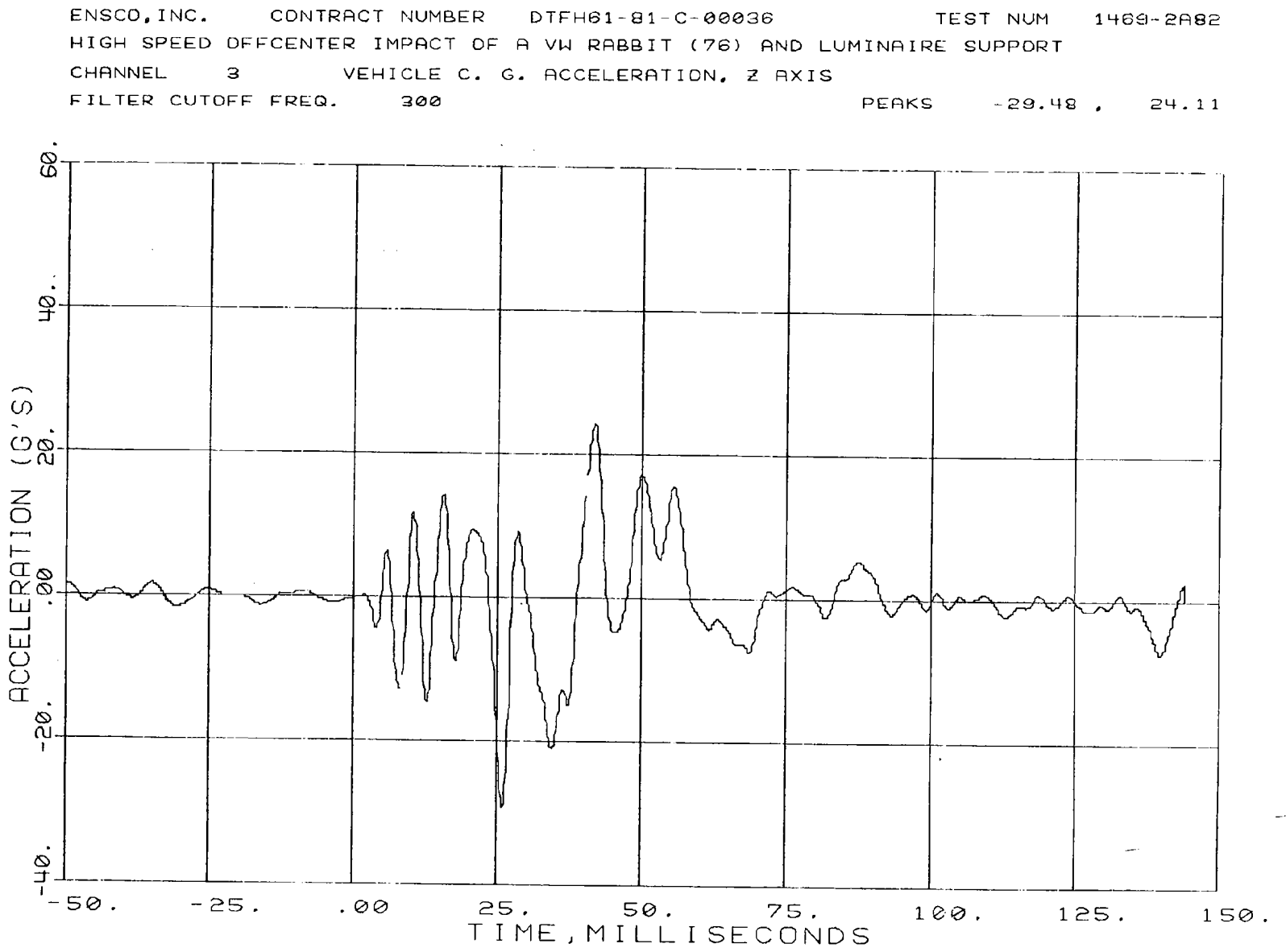


Figure 21. Vehicle C.G. Acceleration, Z Axis

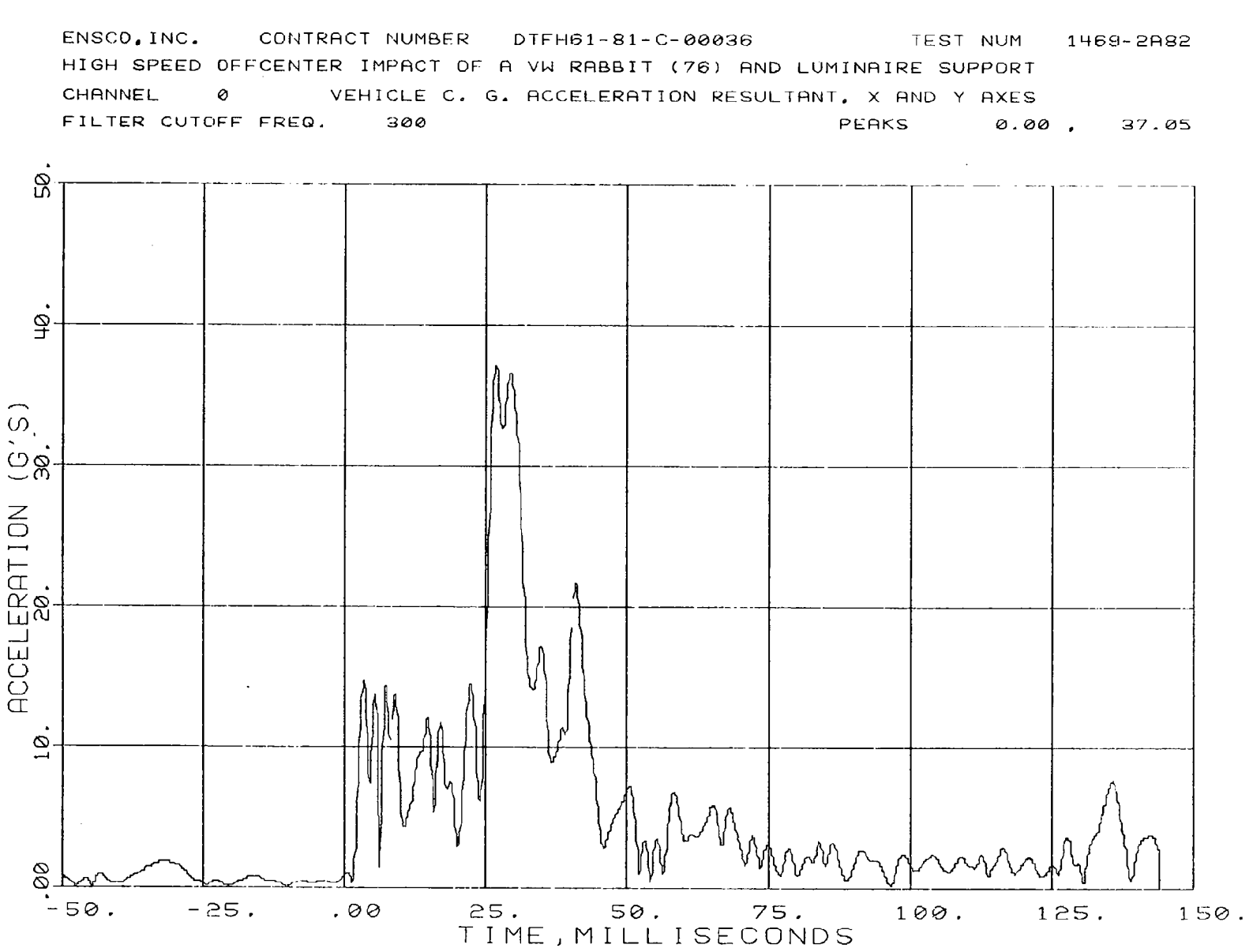


Figure 22. Vehicle C.G. Acceleration Resultant, X and Y Axes

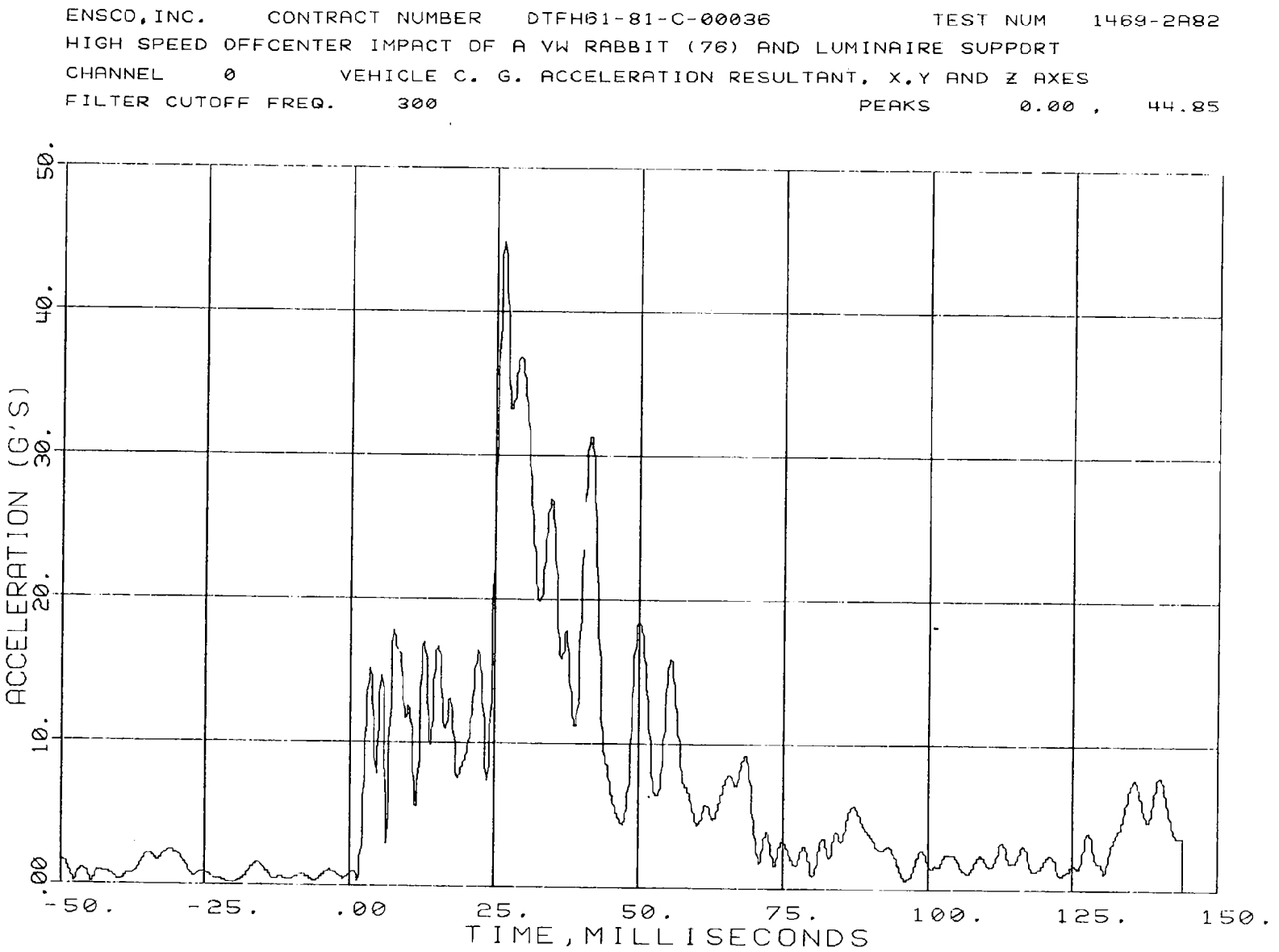


Figure 23. Vehicle C.G. Acceleration Resultant, X Y and Z Axes

TABLE 8

PEAK ACCELERATIONS OBTAINED FROM
VEHICLE MOUNTED ACCELEROMETERS

	SAE Class 60 Data		SAE Class 180 Data	
Description	Peak (g's)	Time (m sec)	Peak (g's)	Time (m sec)
X Axis	-27.18	29.6	-35.74	29.1
Y Axis	-19.25	26.3	-36.22	26.6
Z Axis	-16.47	34.6	-29.48	26.0
Resultant, X and Y	+27.22	29.5	+37.05	26.8
Resultant, X, Y and Z	+27.38	29.6	+44.85	26.3

TABLE 9

VEHICLE VELOCITY AND MOMENTUM
CHANGE OCCURRING DURING IMPACT EVENT

	SAE Class 60 Data	SAE Class 180 Data
X Axis	-10.26 mph	-10.01 mph
Y Axis	2.28 mph	1.99 mph
$M_s \Delta V$(61.6 mph)	995 lb-sec	972 lb-sec

1 mph = .44704 m/sec

Analysis of the impact velocity of a hypothetical front seat passenger against the vehicle interior, calculated from the vehicle accelerations and 24 in (0.61 m) forward and 12 in (0.30 m) lateral displacements yielded the results shown in Table 10.[6] The results indicate that a hypothetical front seat passenger would not have impacted against the inside of the vehicle interior based upon vehicle acceleration and the 24 in (0.61 m) forward and 12 in (0.30 m) lateral displacements in the time interval for which valid data was collected during this test. However, the impact event of the vehicle colliding with the luminaire support had ended at the time the results were evaluated for Table 10. This implies that a hypothetical front seat occupants would have impacted the interior of the vehicle in the longitudinal direction at an approximate impact velocity of 15.05 ft/sec and 14.68 ft/sec based upon SAE Class 60 and 180 data, respectively. Both of these numbers are at the impact velocity design limit of 15 ft/sec specified in NCHRP 230.[6] Further, no significant ride down decelerations would have occurred after the impact of the hypothetical occupant with the interior of the vehicle since the impact event would have already been completed. Secondary impacts due to vehicle rollover are not considered in this analysis.

TABLE 10

IMPACT VELOCITIES OF HYPOTHETICAL FRONT SEAT PASSENGER EVALUATED IN ACCORDANCE WITH NCHRP 230

SAE Class 60 Data	SAE Class 180 Data
Longitudinal	
ΔV = 15.05 ft/sec ΔD = 1.74 ft	ΔV = 14.68 ft/sec ΔD = 1.71 ft
Lateral	
ΔV = 3.35 ft/sec ΔD = 0.21 ft	ΔV = 2.91 ft/sec ΔD = 0.18 ft

7.3 COMPARISON OF PREDICTED RESULTS TO TEST OBSERVABLES

Several comparisons between the observable and predicted data can be made from the results of this test.[16] Basically, the impact of the vehicle and luminaire support can be separated into three phases:

1. Crushing of the automobile with insignificant motion of structure being impacted.
2. Activation and completion of the breakaway failure mechanism.
3. Acceleration of structure by the impacting vehicle.

These three phases are shown graphically in Figure 24. The expression for the momentum change in the three phase description is given by:

$$M\Delta V = \int_{t_1}^{t_3} F_c dt$$

$$= \int_0^{t_1} F_c dt + \int_{t_1}^{t_3} F_b dt + \int_{t_1}^{t_3} (F_c - F_b) dt$$

$$= \int_0^{t_1} F_c dt + \int_{t_1}^{t_2} F_b dt + \int_{t_1}^{t_3} (F_c - F_b) dt$$

$$\triangleq I_1 + I_2 + I_3$$

where the terms in the above equation are given in Figure 24.

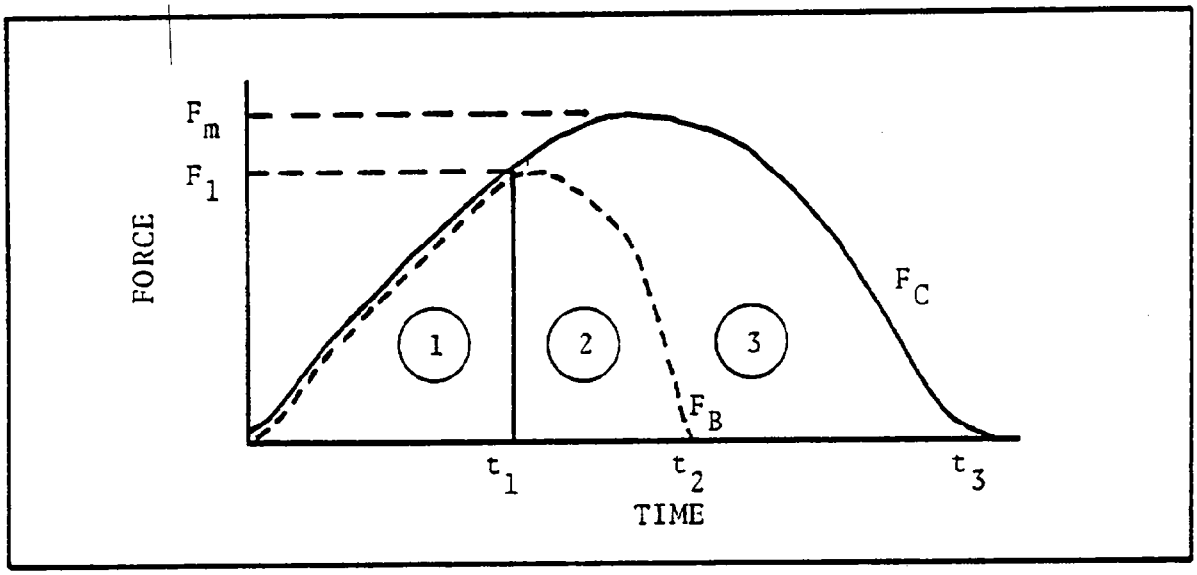


Figure 24. Graphic Representation of Three Phase Analysis of Momentum Change Occurring During the Impact of a Vehicle with a Breakaway Support

The downstream speed and rotational rate of the luminaire support can be related to the third phase of the vehicle momentum change by the following:

$$\dot{x}_{cg} = \frac{1}{M_p} I_3,$$

and

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

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

$\dot{\theta}$ = rotational rate of luminaire support,

D_I = distance from effective impact point to luminaire support c.g. during Phase 3,

M_p = mass of luminaire support,

I_p = rotational inertial of the luminaire support,

and I_3 = momentum change occurring during Phase 3.[17]

From the film data $\dot{x}_{cg}$ = 27.7 f/s (8.44 m/s) and 4.09 rad/sec. Using these two numbers the momentum change occurring during Phase 3 is given by

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

$$= 862 \text{ lb-sec } (3{,}834 \text{ N-s})$$

or

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

$$= 848 \text{ lb-sec } (3{,}772 \text{ N-s}).$$

The average momentum change associated with the third phase of the vehicle momentum change is 855 lb-sec.

The change in vehicle momentum occurring during the first and second phases of the impact event can be found by subtracting the third phase momentum from the total momentum change, i.e., $I_{1\&2} = I_T - I_3$. The vehicle change in momentum occurring during the second phase remains unchanged at 30 lb-sec.[5] The change in momentum during the first phase is calculated by subtracting the change in momentum during the second phase from the total of the first and second phases, $I_1 = I_{1\&2} - I_2$. The results of this analysis for acceleration data filtered at SAE Class 60 and 180 are shown in Table 11.

TABLE 11

EXAMINATION OF THE MOMENTUM
TRANSFER DURING THE COLLISION EVENT

I_T	=	995 (1)	972 (2)
I_3	=	-855 (3)	-855 (3)
$I_{1\&2}$	=	140	117
I_2	=	-30	-30
$\simeq I_1$		110	87
I_1	=	84 (4)	86 (5)

Notes:
(1) Total change in vehicle momentum occurring during the impact event evaluated from acceleration data processed in accordance with TRC 191.

(2) Total change in vehicle momentum occurring during the impact event evaluated from acceleration data processed in accordance with NCHRP 230.

(3) Phase 3 change in momentum of vehicle evaluated from luminaire support translational and rotational data.

(4) Phase 1 change in momentum of vehicle evaluated from acceleration data processed in accordance with TRC 191.

(5) Phase 1 change in momentum of vehicle evaluated from acceleration data processed in accordance with NCHRP 230.

7.4 HEAD INJURY CRITERIA EVALUATION

The data obtained from the three accelerometers located in the head of the occupants during the test were filtered at SAE Class 1000 and combined to yield a resultant acceleration occurring during the impact event. The HIC were evaluated in accordance with the procedures outlined in FMVSS 208.[8] The acceleration traces and resultants obtained with the use of the SAE Class 1000 (f_c = 1,650 Hz) filtering techniques are presented in Figures 25 through 28 for the driver and Figures 29 through 32 for the passenger.

The resultant accelerations calculated for the driver's head was for all practical purposes self-contained within the collision event. The HIC evaluated for the driver was 52 within the time interval of .049 to .125 seconds for a time duration of .076 seconds. However, the resultant acceleration for the passenger was prematurely terminated due to an equipment malfunction which occurred .01425 seconds after the initial impact. The HIC could, therefore, not be evaluated. The HIC number evaluated for the driver indicates that from an occupant's point of view the initial collision was relatively mild.

7.5 CHEST SEVERITY INDEX EVALUATION

The data obtained from the three accelerometers located in the chest of the occupants during the test were filtered at SAE Class 180 and combined to yield a resultant accelerations occurring during the impact event. The CSI were evaluated in accordance with SAE Information Report J885.[12] In addition, the maximum resultant acceleration whose cumulative duration is not more than 3 milliseconds was evaluated in accorance with FMVSS 208.[8] The acceleration traces and resultants obtained with the use of the SAE Class 180 (f_c = 300 Hz) filtering techniques are presented in Figures 33 through 36 for the driver and Figures 37 through 40 for the passenger.

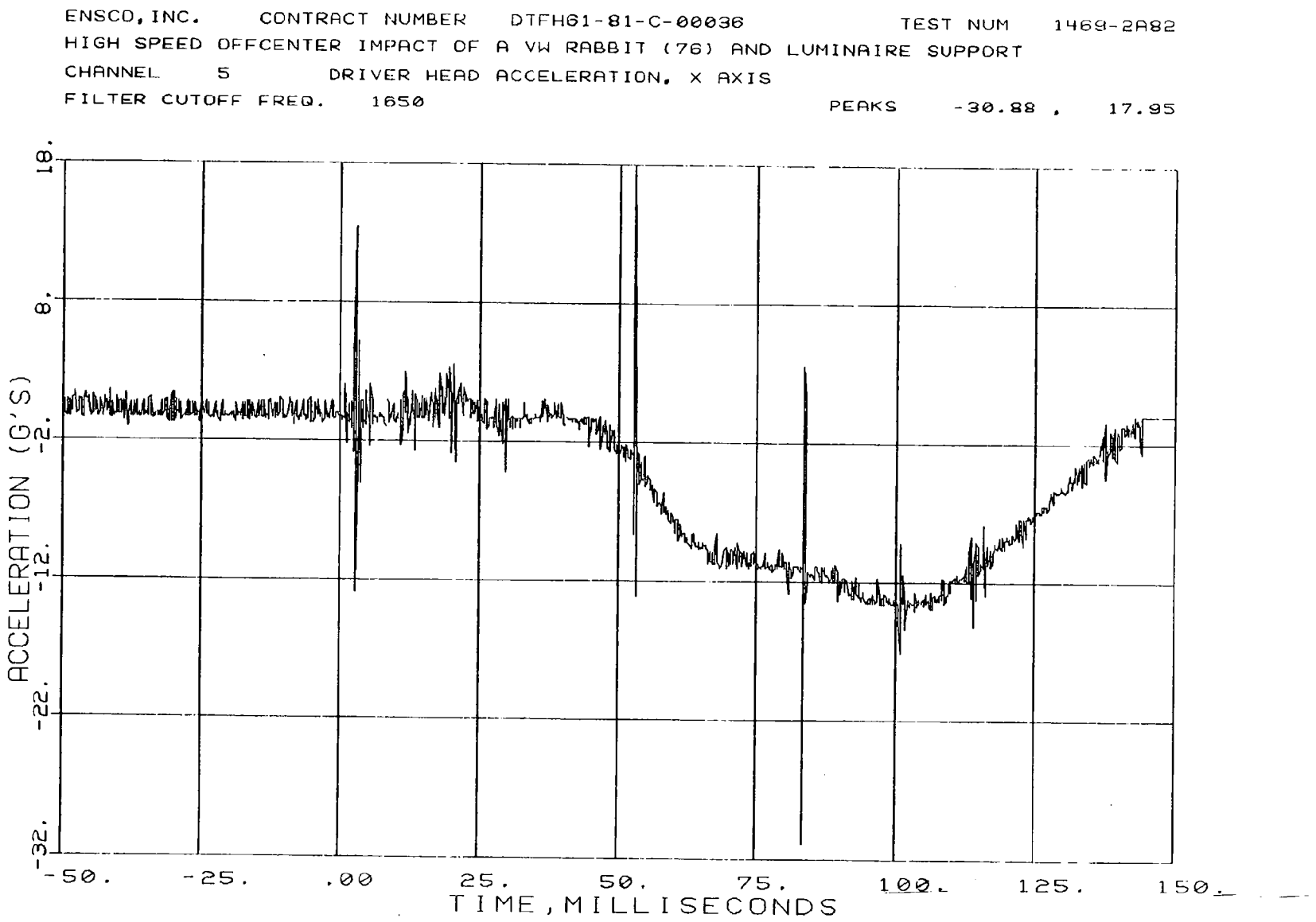


Figure 25. Driver Head Acceleration, X Axis

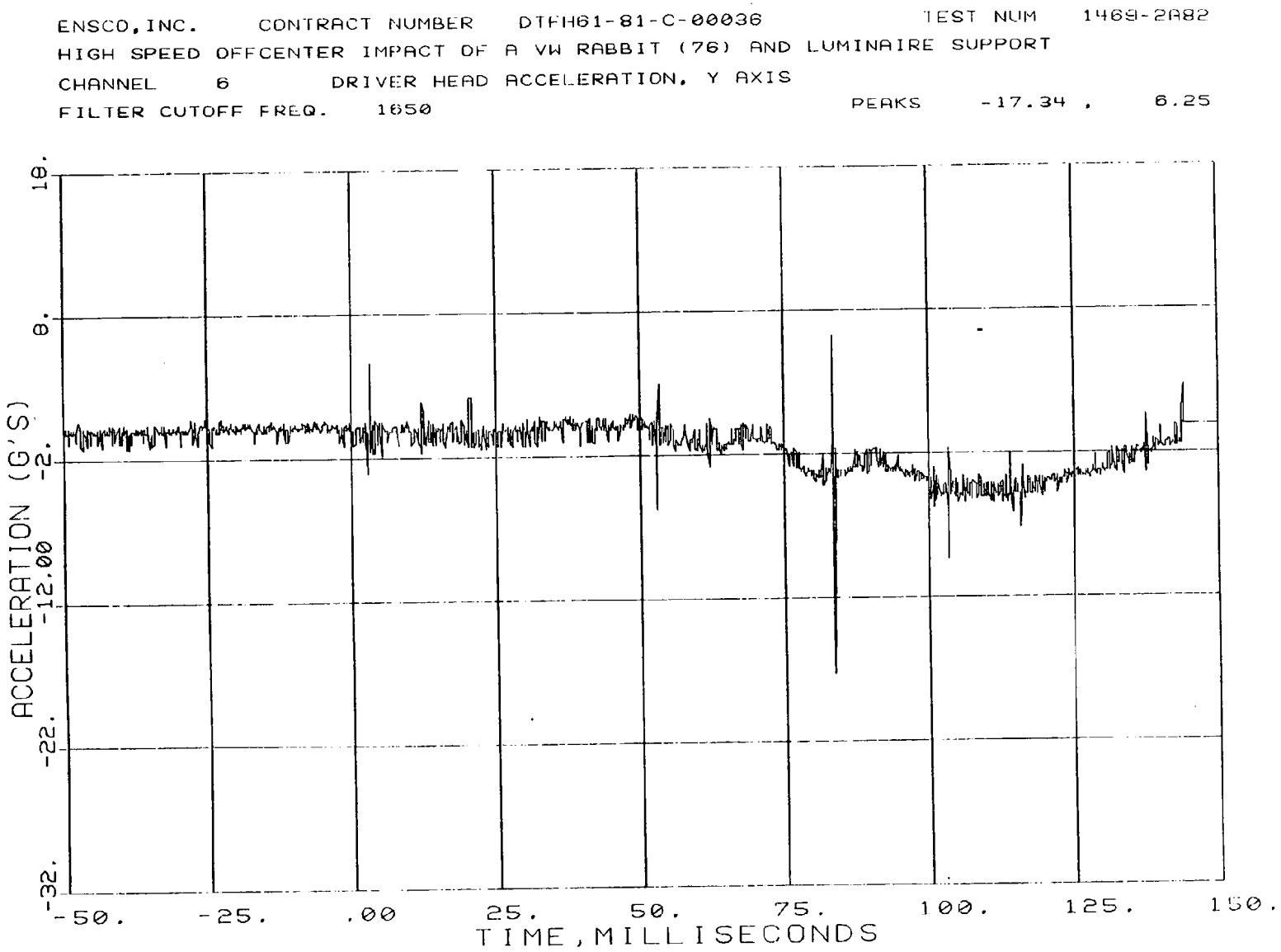


Figure 26. Driver Head Acceleration, Y Axis

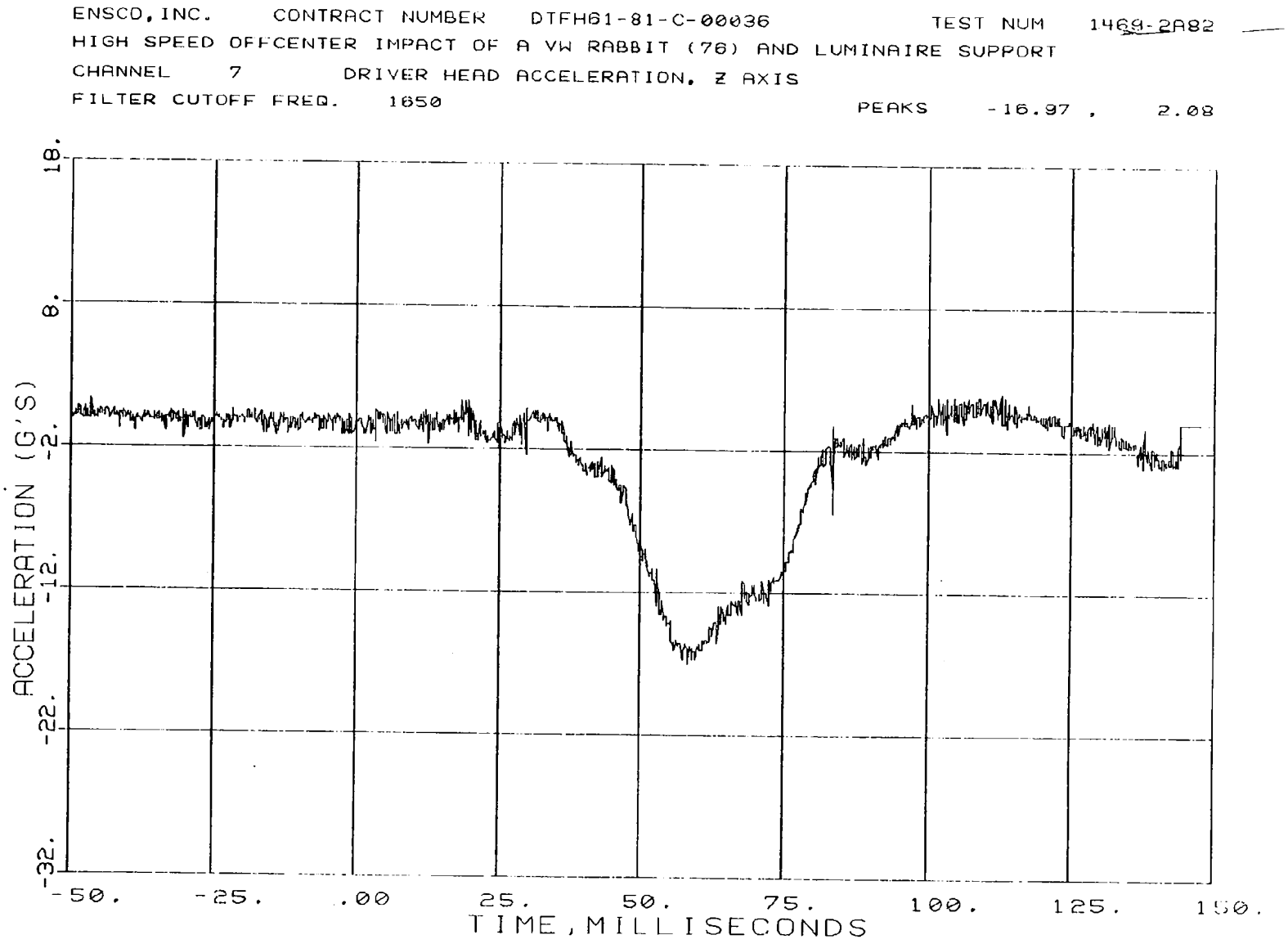


Figure 27. Driver Head Acceleration, Z Axis

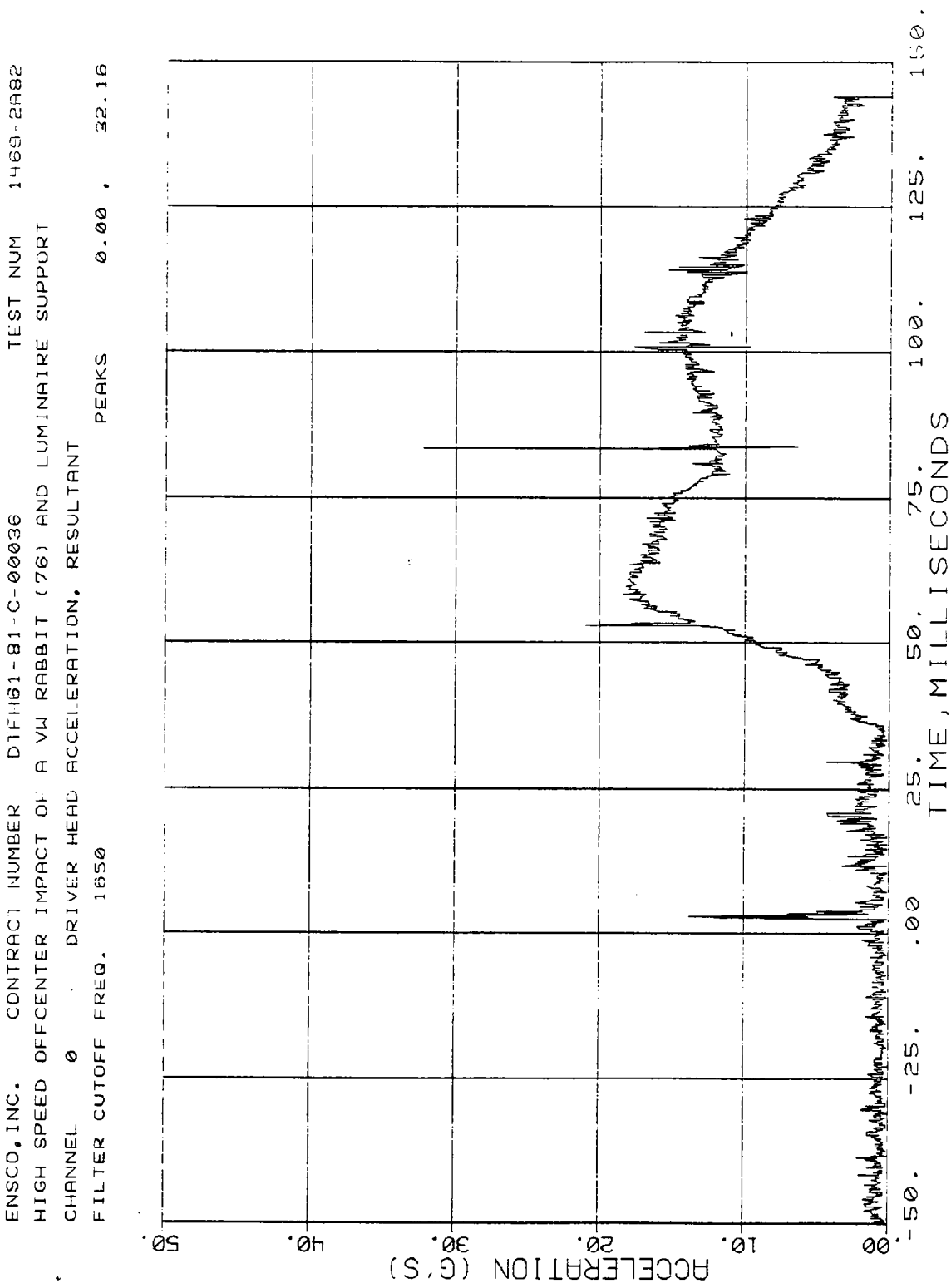


Figure 28. Driver Head Acceleration, Resultant

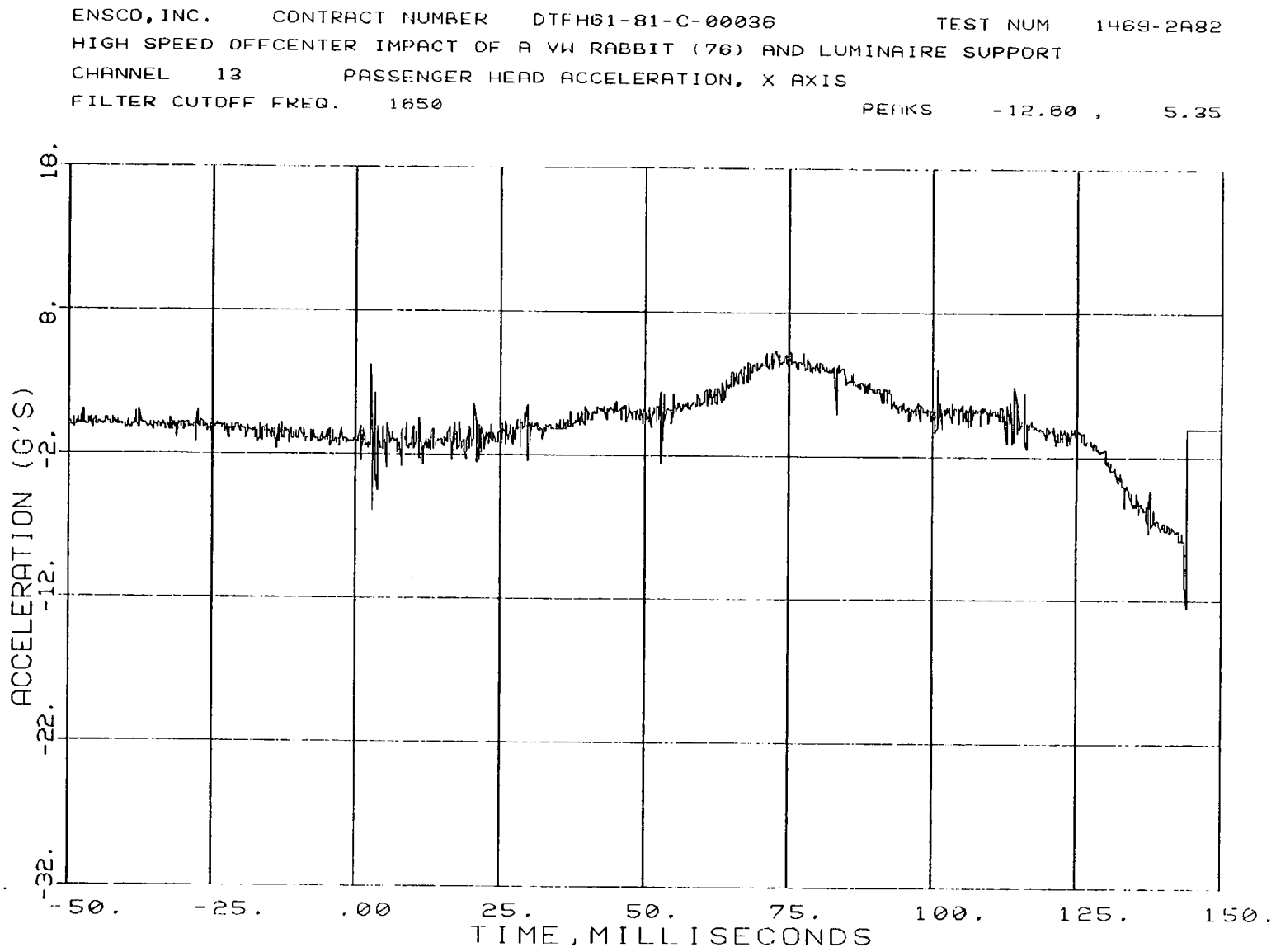


Figure 29. Passenger Head Acceleration, X Axis

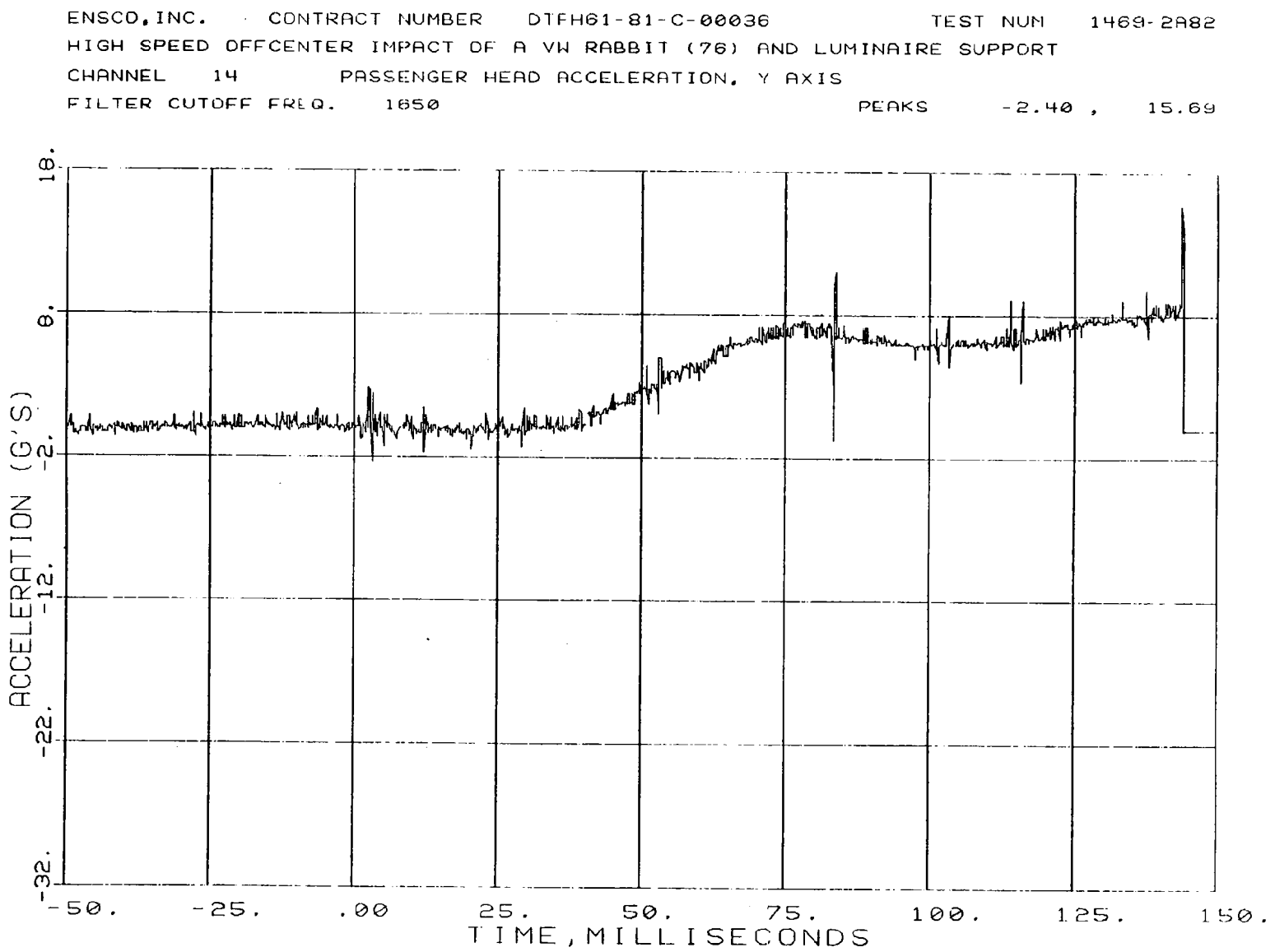


Figure 30. Passenger Head Acceleration, Y Axis

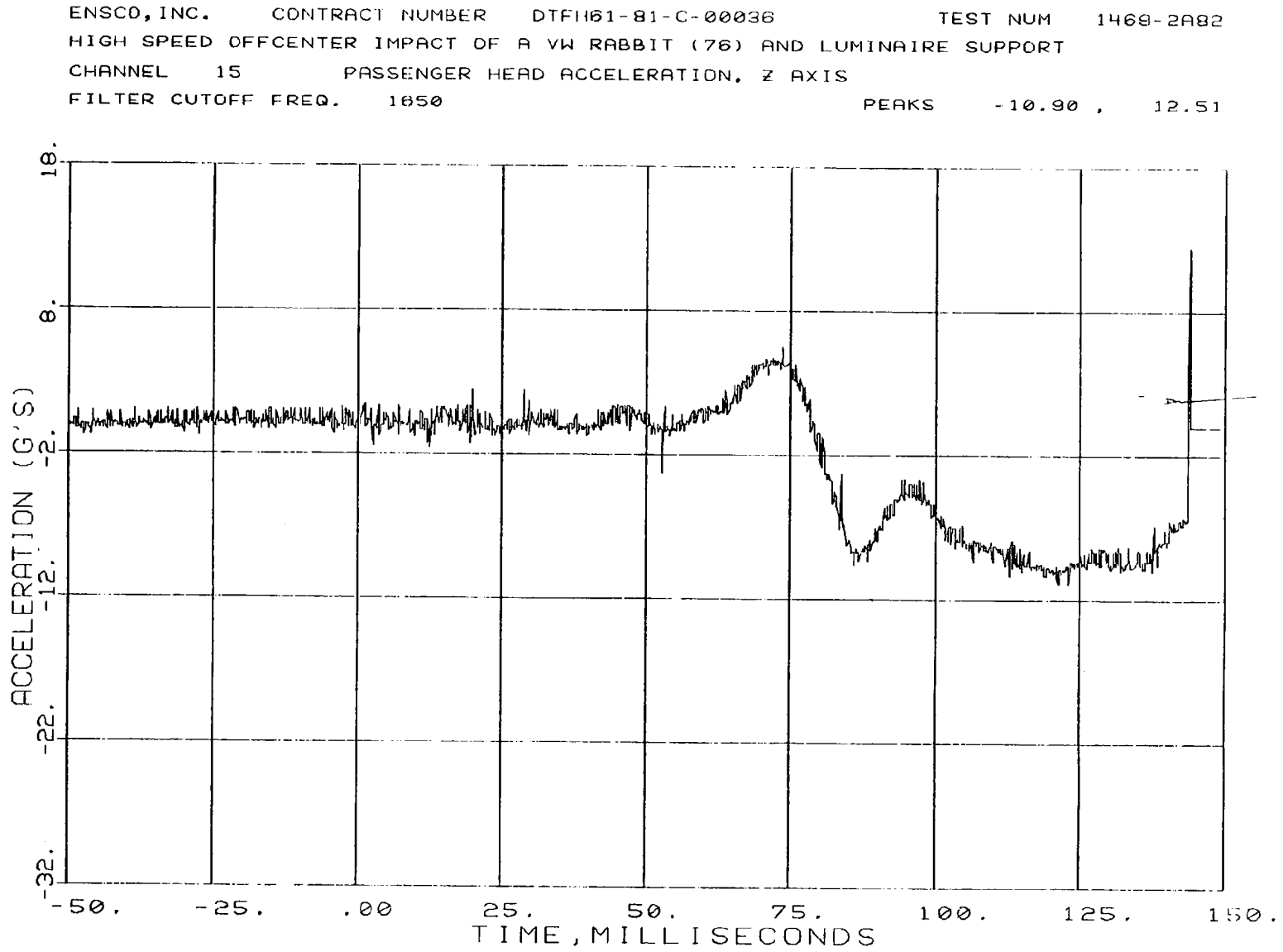


Figure 31. Passenger Head Acceleration, Z Axis

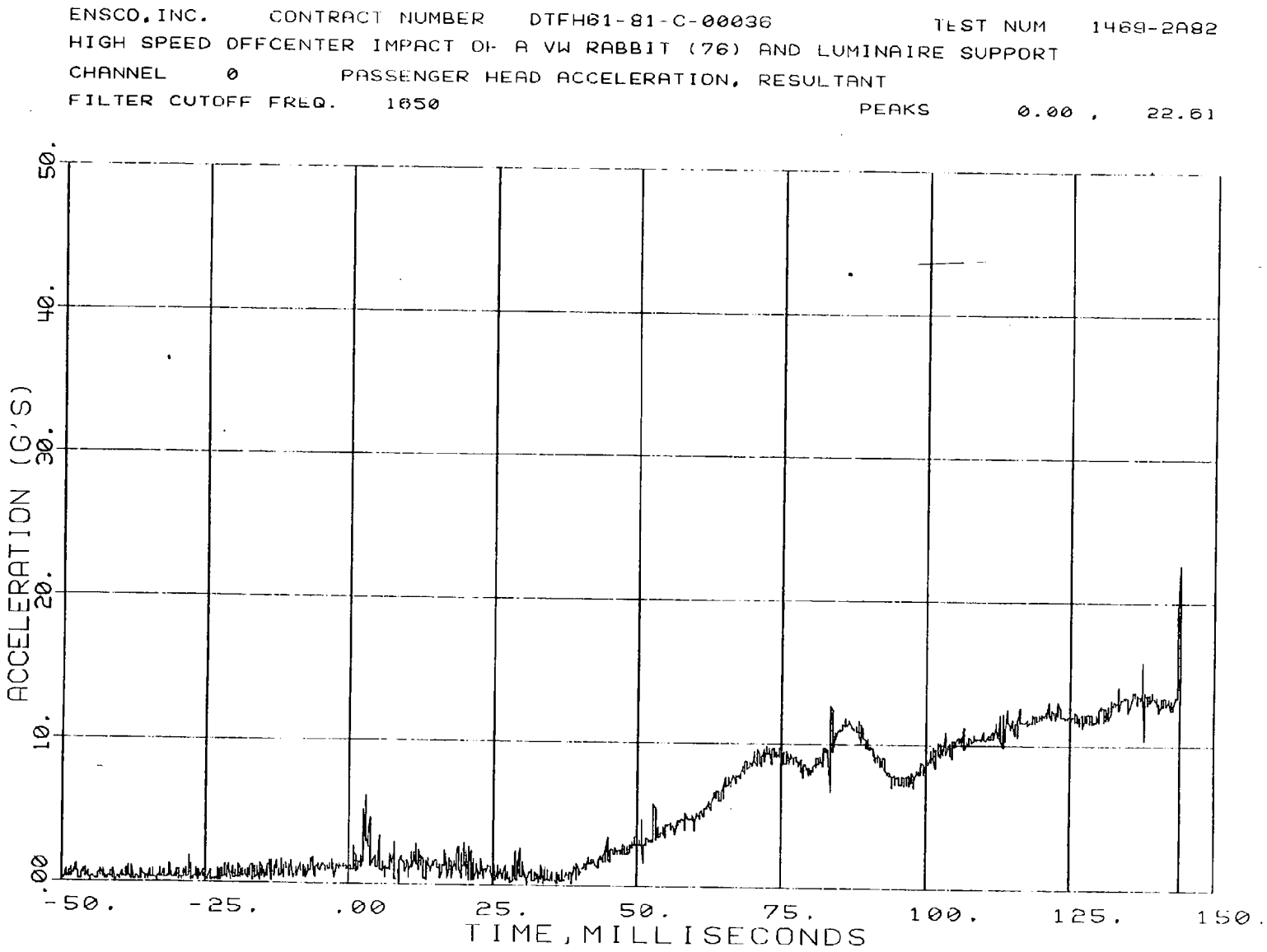


Figure 32. Passenger Head Acceleration, Resultant

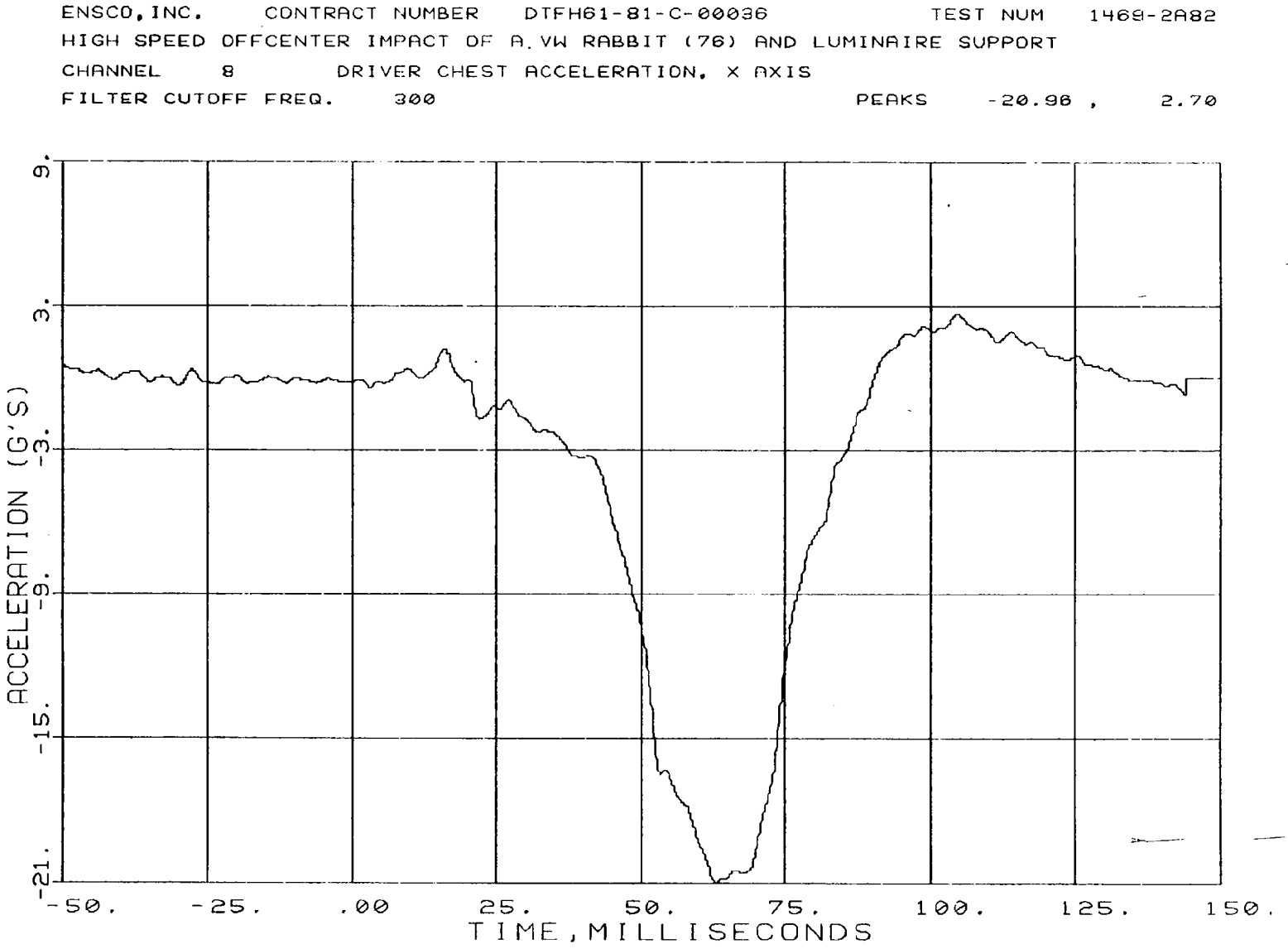


Figure 33. Driver Chest Acceleration, X Axis

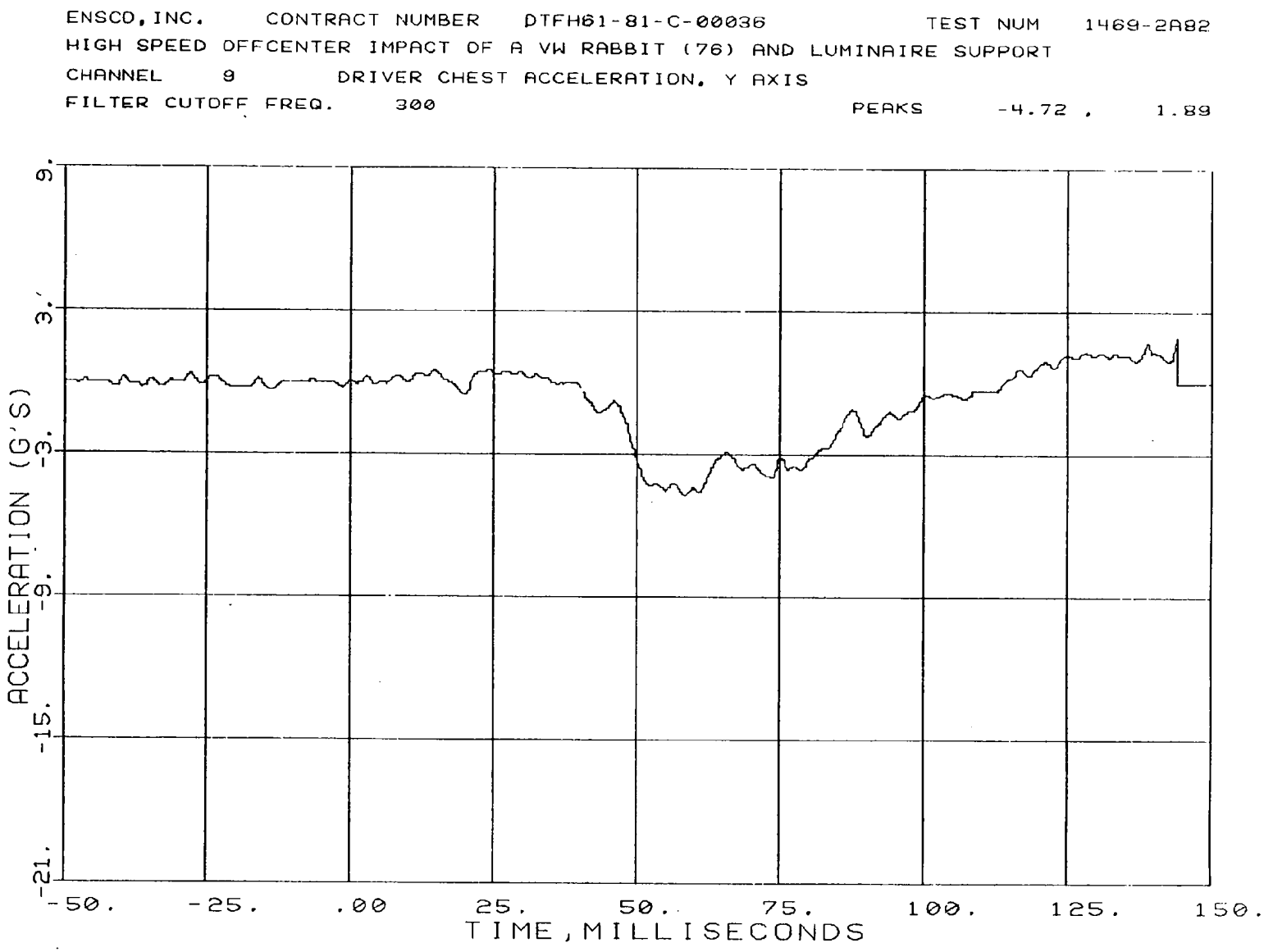


Figure 34. Driver Chest Acceleration, Y Axis

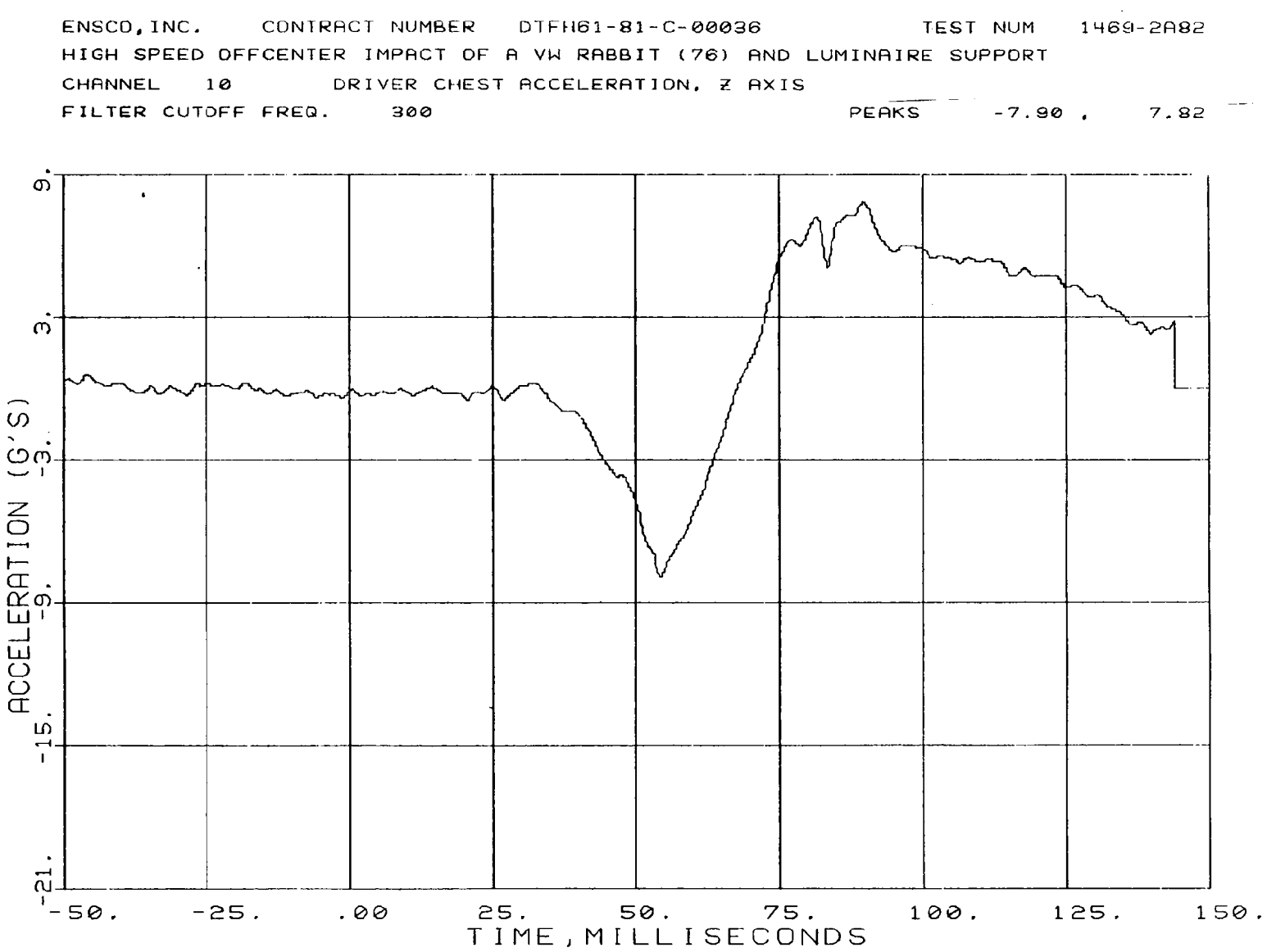


Figure 35. Driver Chest Acceleration, Z Axis

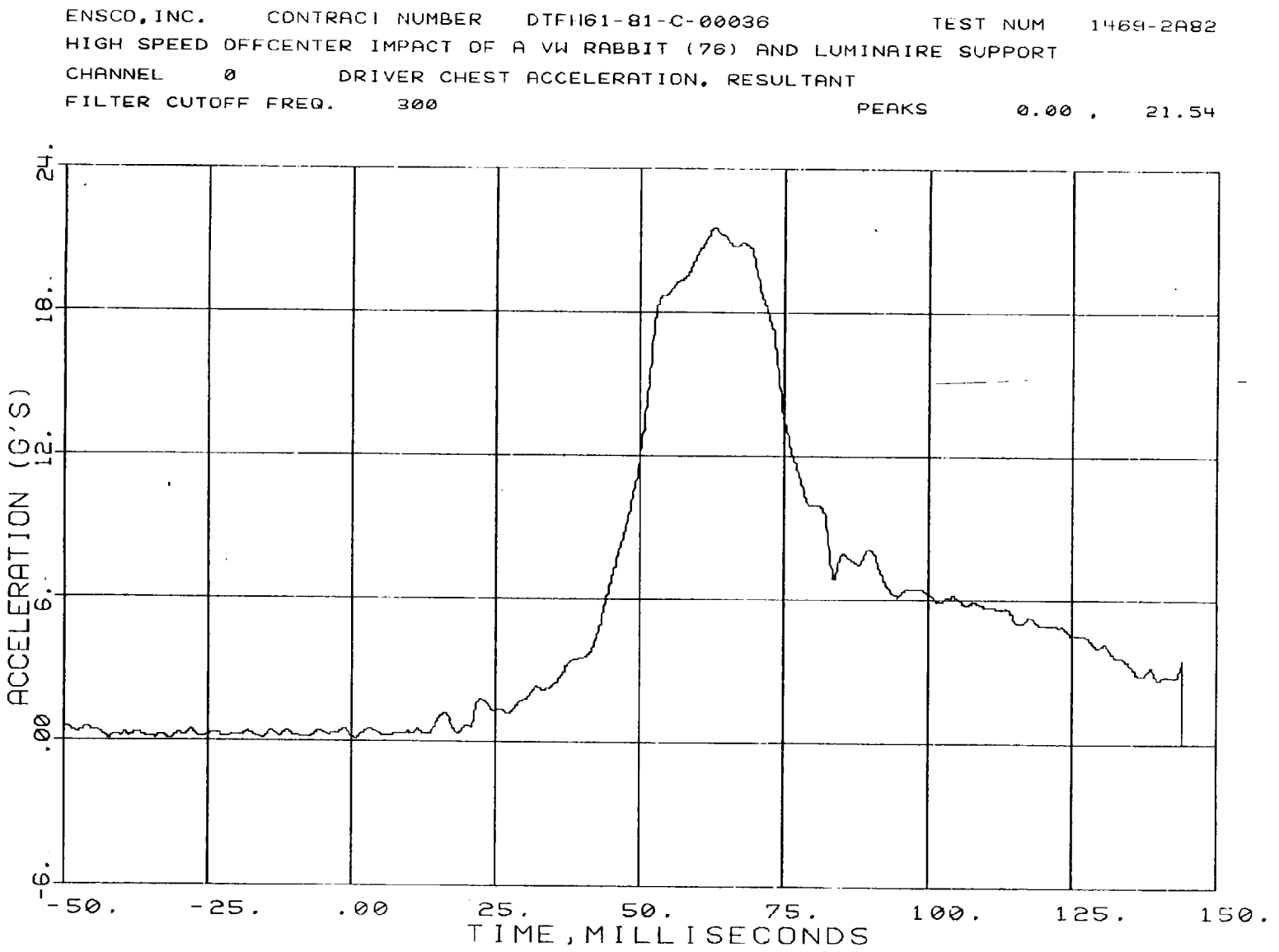


Figure 36. Driver Chest Acceleration, Resultant

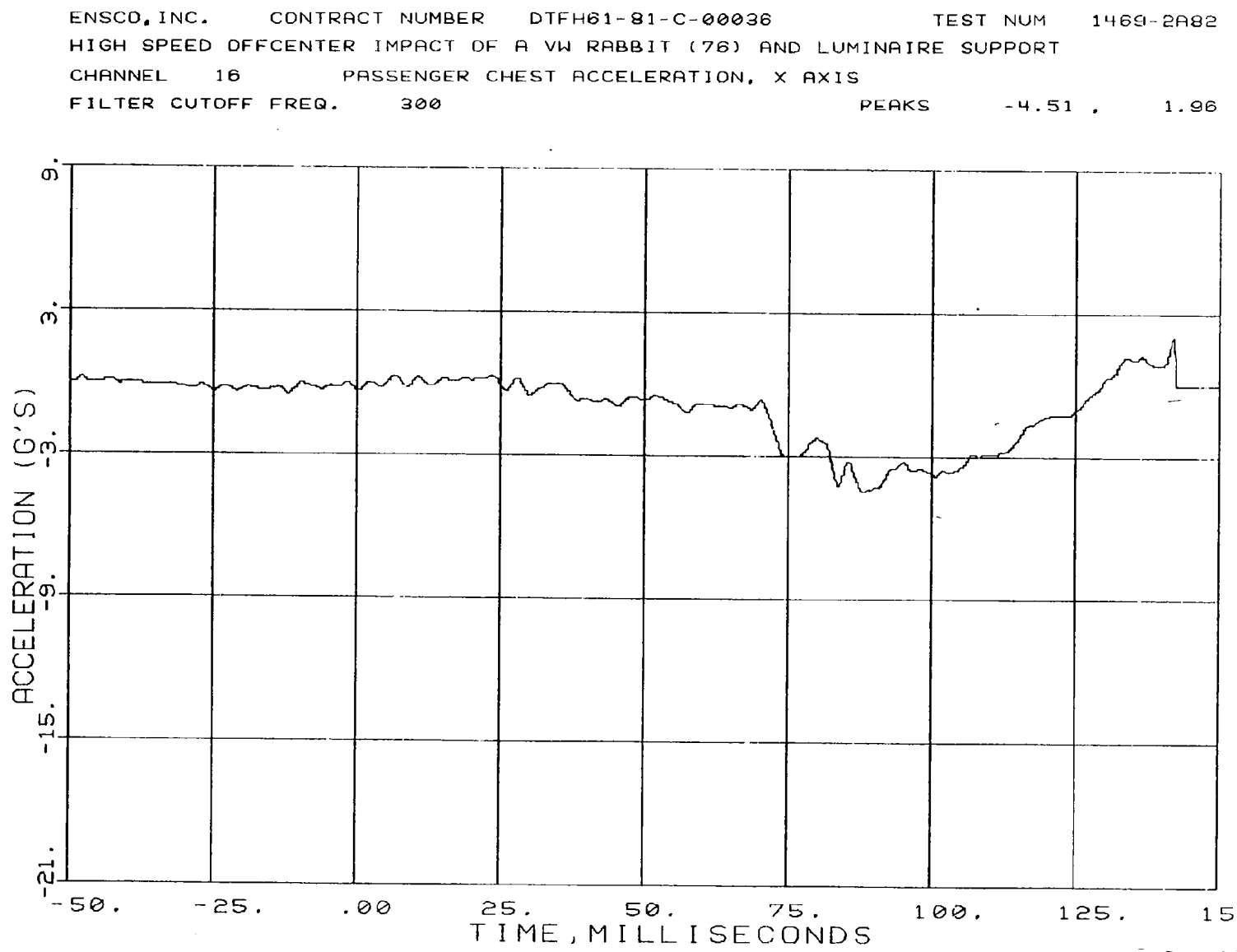


Figure 37. Passenger Chest Acceleration, X Axis

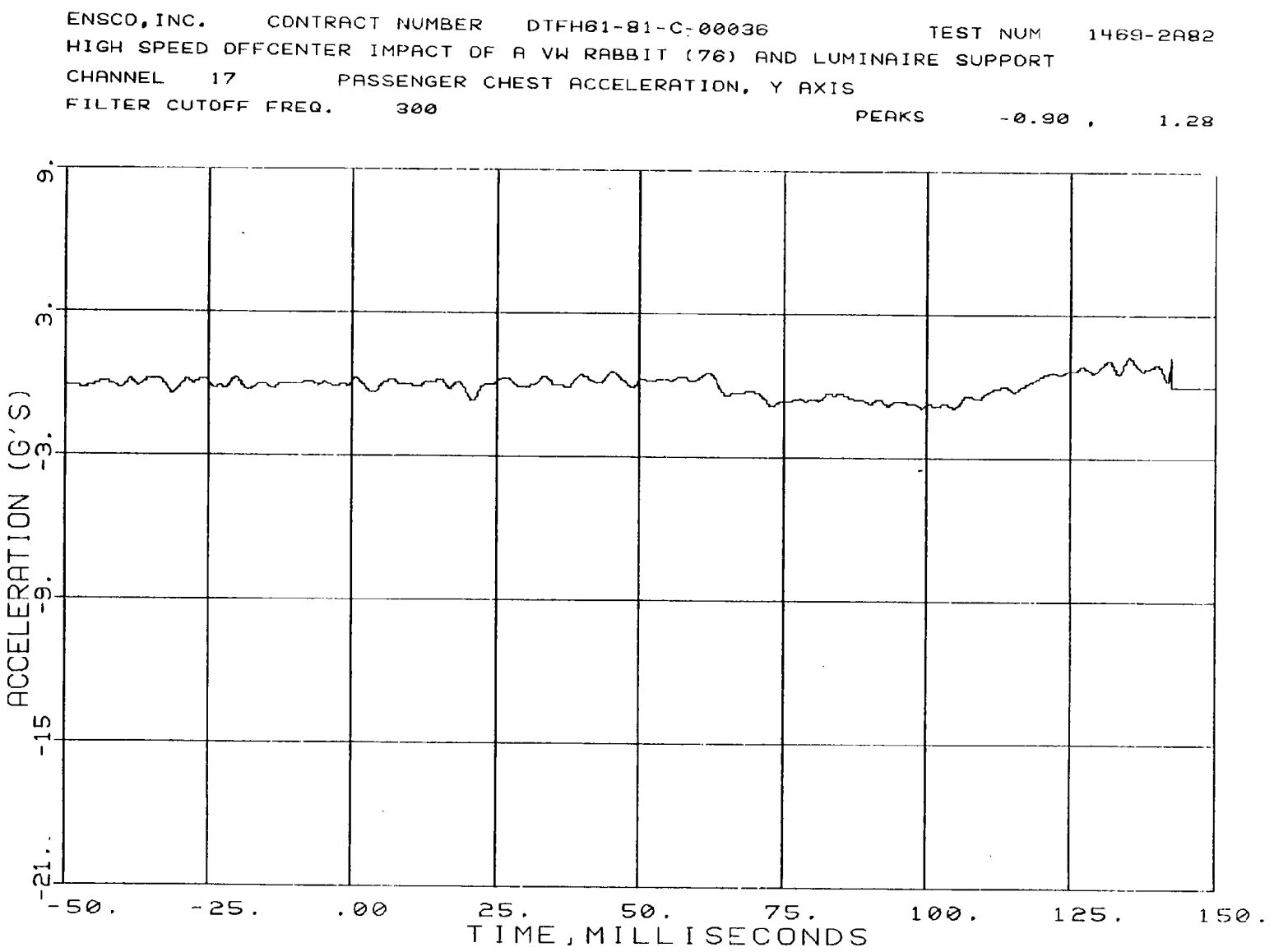


Figure 38. Passenger Chest Acceleration, Y Axis

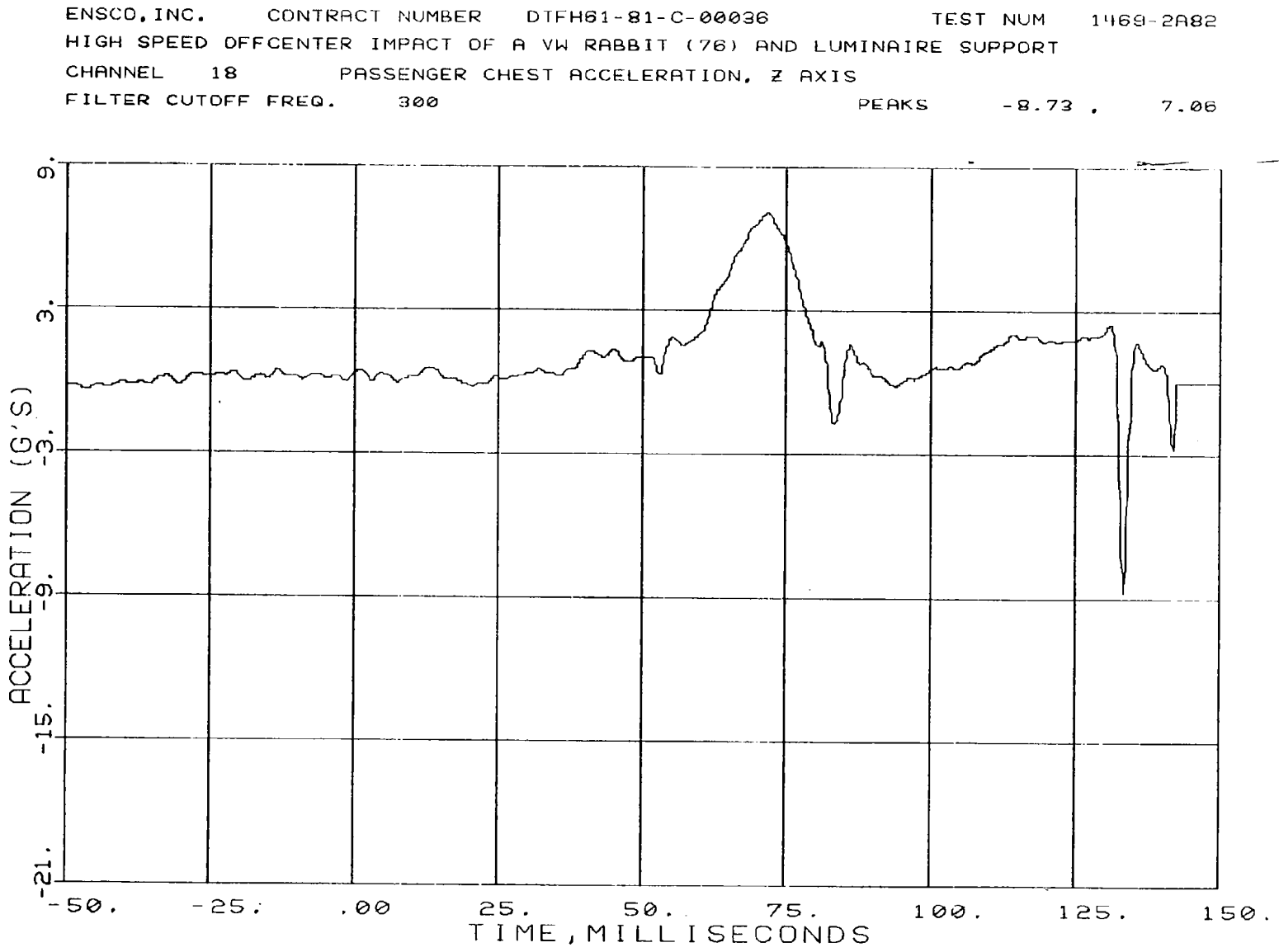


Figure 39. Passenger Chest Acceleration, Z Axis

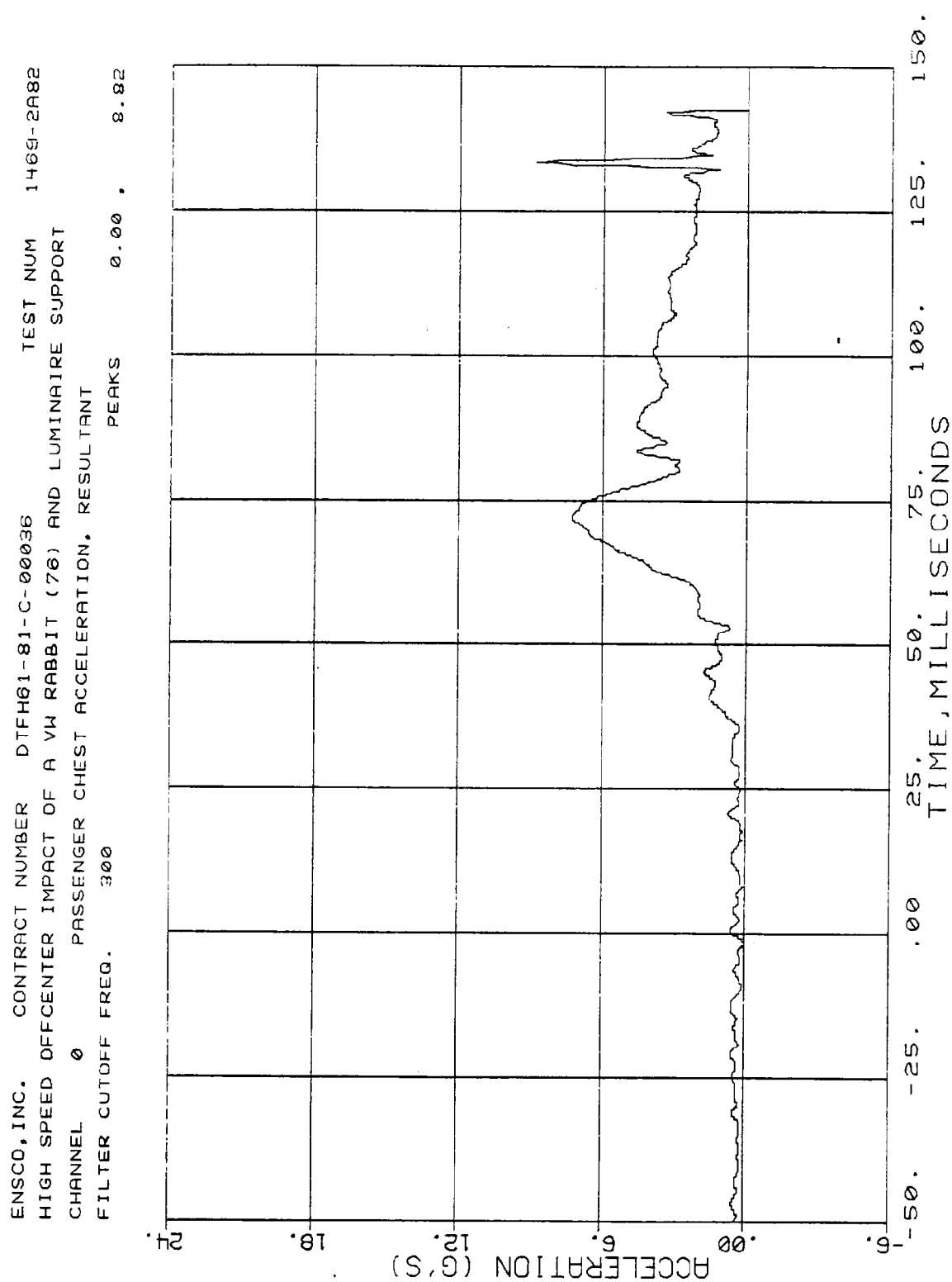


Figure 40. Passenger Chest Acceleration, Resultant

The peak resultant acceleration for the driver whose duration was not less than .003 seconds was 21.5 g's occurring at .063 seconds after the initial impact. The peak resultant acceleration for the passenger whose duration was not less than .003 seconds was 8.7 g's occurring at .1325 seconds after the initial impact. The CSI for the driver was 50. The resultant for the pasenger was terminated as discussed in the previous section and the CSI could, therefore, not be evaluated. The acceptable limits for the peak acceleration and CSI are 60 g and 1000, respectively. The driver, therefore, experienced a relatively mild accident.

7.6 FEMUR LOAD EVALUATION

The data obtained from the two load cells located in the femur of each leg of the occupants were filtered at SAE 600. The maximum load which occurred in each femur was then determined and compared to the acceptable limit of 2,250 lbs as specified in FMVSS 208.[8] The load traces obtained with the use of the SAE Class 600 (f_c = 1000 Hz) filtering technique are presented in Figures 41 through 43. The femur loads for the left leg of the driver indicated that it went into extension since the driver was restrained by the seat belt. The maximum load for this leg was 117.8 pounds. The data for the driver's right leg was lost due to a loose VCO connection within the data acquisition system. This leg probably also went into extension yielding low force levels. The femur loads for the left and right leg of the passenger were -978.4 and -442.0 pounds, respectively. These are well within the acceptable limit of 2,250 pounds.

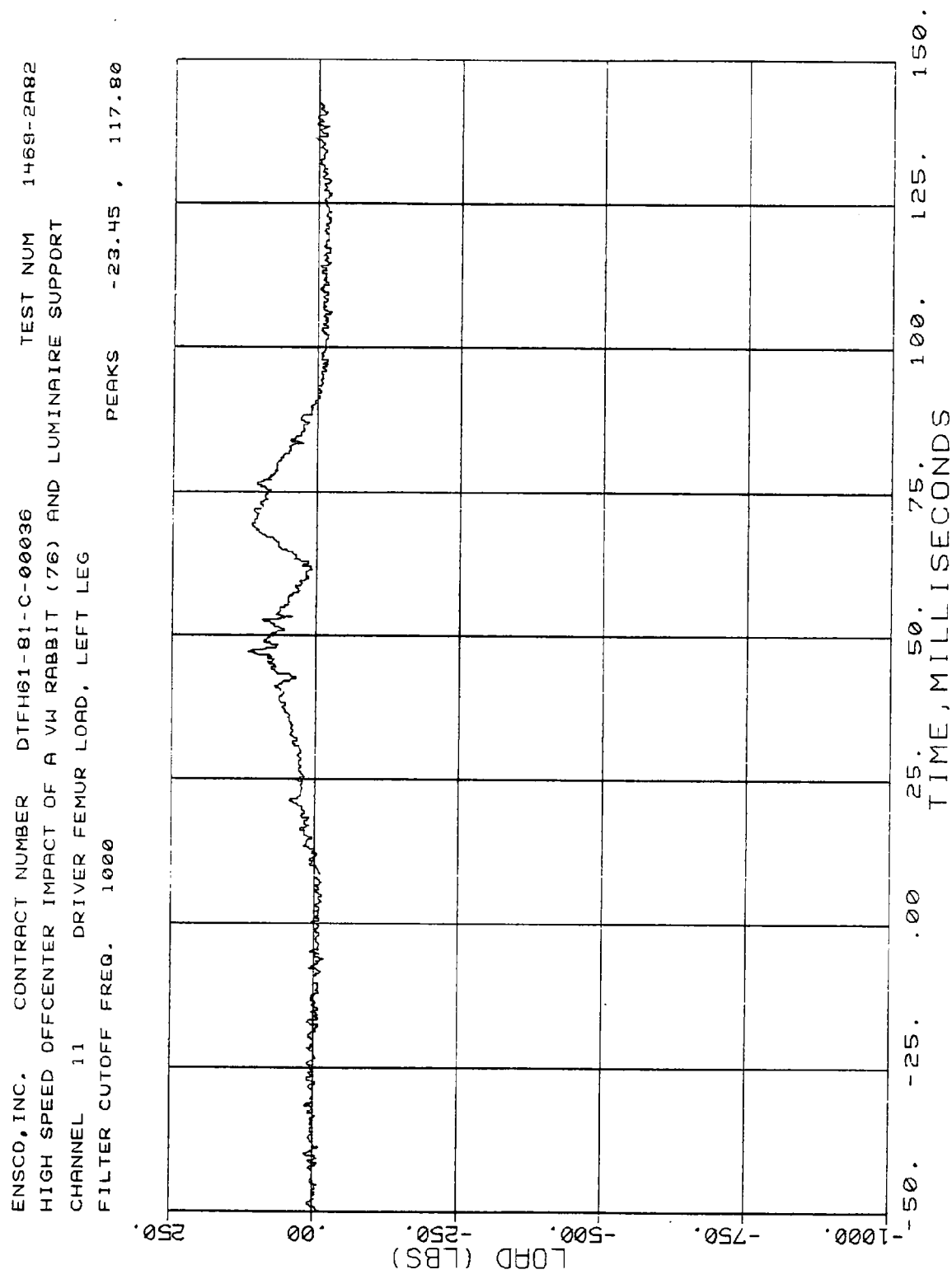


Figure 41. Driver Femur Load, Left Leg

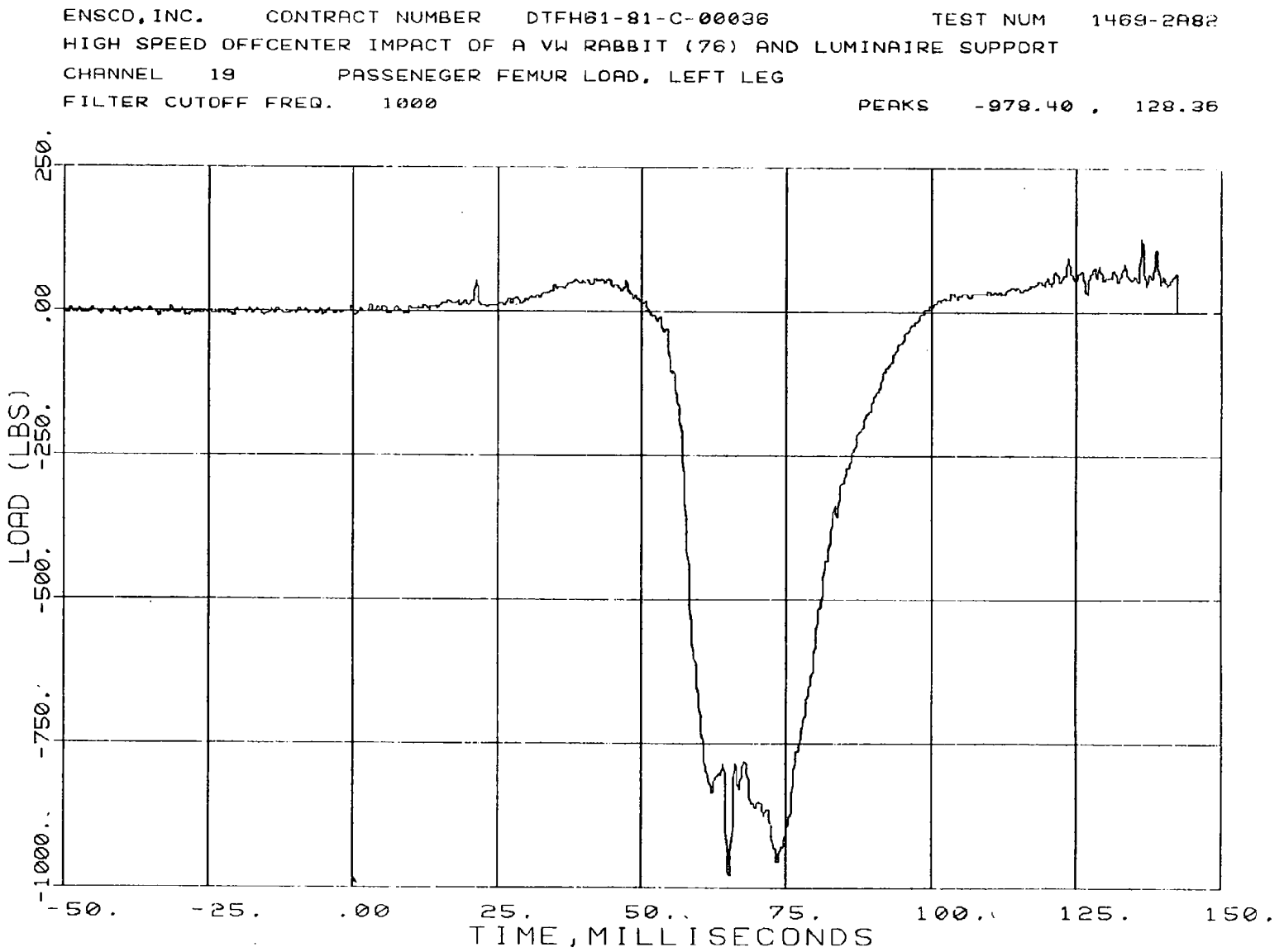


Figure 42. Passenger Femur Load, Left Leg

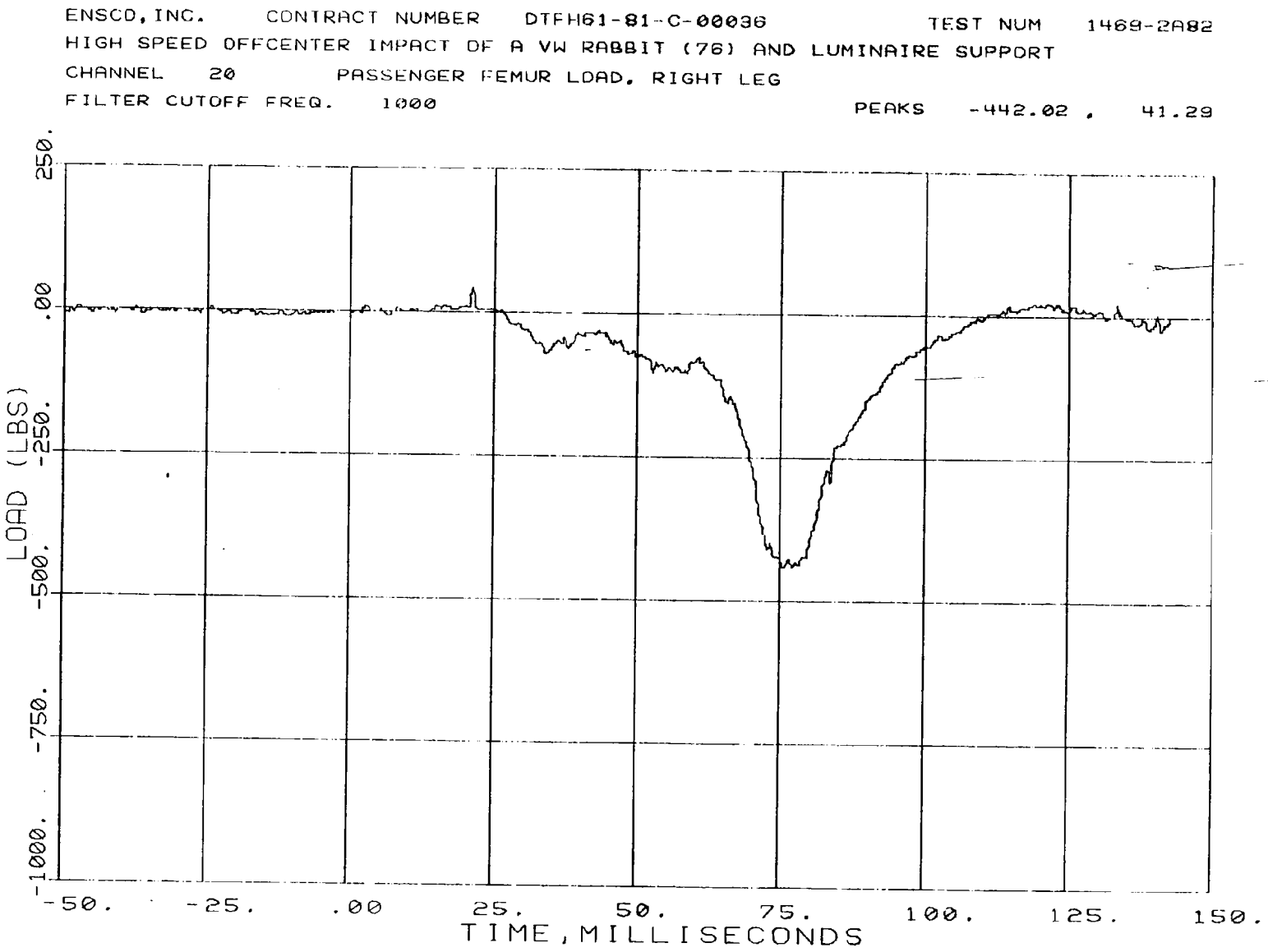


Figure 43. Passenger Femur Load, Right Leg

8.0 CONCLUSIONS

The objective of this test was to investigate the impact behavior and post-impact stability of a minicompact sedan (1,800 S) during a high speed offcenter collision with a breakaway luminaire support. The vehicle chosen for this test was a Volkswagon Rabbit based upon the results of a limited engineering study conducted by ENSCO, Inc. The surrogate luminaire support was chosen since it was known to induce a momentum change close to the upper limit of the acceptable standard of 1,100 lb-sec (4,893 N-s) when impacted by a 1971 Chevrolet Vega at an impact speed of 60 mph (26.8 m/s). The vehicle momentum change at the impact speed of 61.6 mph (27.5 m/s) was determined to be 972 lb-sec (4,323 N-s) when evaluated from the acceleration data in accordance with NCHRP 230.

The corresponding change in the velocity of the vehicle due to the collision with the surrogate luminaire support was 9.97 mph (3.04 m/s). Both instrumented anthropomorphic test dummies located in the front seats of the vehicle survived the collision based on the analysis of the acceleration and load cell data in accordance with TRC 191, NCHRP 230 and FVMSS 208. However, vehicle yawing motion induced by the offcenter collision with the luminaire support caused the post-impact behavior of the vehicle to be unstable and rollover twice significantly increasing vehicle damage and risk to occupant. The front seat passenger compartment maintained its integrity throughout the collision event and subsequent a rollover.

9.0 REFERENCES

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APPENDIX A

CALIBRATION TEST RESULTS FROM TEST SEQUENCE 13
FOR PART 572 B ANTHROPOMORPHIC TEST DUMMY
SERIAL NUMBER 189 (DRIVER)

The pre-test calibration results from Test Sequence 13 for Part 572.B anthropomorphic test dummy Serial Number 189 used as the driver in full scale crash test Number 1469-2A82 are contained in this appendix. In accordance with contractual agreements, post-test calibration of the test dummy will be performed at the completion of the frontal impact tests to be conducted under Task A.

TABLE A-1

CALIBRATION TEST DATA FOR PART 572.B ANTHROPOMORPHIC TEST DUMMY SERIAL NUMBER 189 (DRIVER)

			Pre-Test Calibration	Post-Test Calibration
Date of Dummy Calibration- - - - - - - - - - -			1/6/82	
Calibration Sequential Number For Dummy- - - -			1	
Temperature in Lab. (Spec. = 66 to 78° F)- - -			72°F	
Relative Humidity in Lab. (Spec. = 10 to 70%)-			22%	
TEST PARAMETER		SPECIFICATION		
1. HEAD DROP TEST:				
a. Peak Resultant Accel.-		210 to 260G	239 g	
b. Peak Lateral Accel.- -		≤ 10G	6.7 g	
c. Time above 100G- - - -		0.9 to 1.5 ms	1.32 ms	
2. NECK BENDING TEST:				
a. Pendulum Speed - - - -		21.5 to 25.5 fps	23.5 fps	
b. Pendulum Avg. Decel. (over $t_3 - t_2$) - - - -		20 to 24G	22.7 g	
c. Peak Resultant Head Acceleration - - - - -		26G maximum	24.5 g	
d. Pendulum Decel.(t_2-t_1)		≤ 3 ms	2.2 ms	
e. Pendulum Decel.(t_3-t_2)		25 to 30 ms	29.9 ms	
f. Pendulum Decel.(t_4-t_3)		≤ 10 ms	4.0 ms	
g. Pendulum Direction Reversal Time- - - - -			117 ms	
h. Max. Head Rotation - -		63 to 73°	66°	
i. Chordal Displacement:				
Head Rotation Angle--				
0°	Time	-2 to 2 ms	0 msec	
	Displ.	-.5 to .5 in.	0 in	
30°	Time	25.6 to 34.4 ms	28.0 msec	
	Displ.	2.1 to 3.1 in.	2.4 in	
60°	Time	40.3 to 51.7 ms	44.5 msec	
	Displ.	4.3 to 5.3 in.	4.8 in	
Maximum (66°)	Time	53.2 to 66.8 ms	60.0 msec	
	Displ.	5.0 to 6.0 in.	5.2 in	

TABLE A-1 (Cont)

CALIBRATION TEST DATA FOR PART 572.B ANTHROPOMORPHIC TEST DUMMY SERIAL NUMBER 189 (DRIVER)

TEST PARAMETER		SPECIFICATION	Pre-Test Calibration	Post-Test Calibration
2. NECK BENDING TEST.... Continued:				
i. Chordal Displacement:				
Head Rotation Angle--				
60°	Time	67.0 to 83.0 ms	70.7 ms	
	Displ.	4.3 to 5.3 in.	4.7 in	
30°	Time	85.4 to 104.6 ms	92.6 ms	
	Displ.	2.1 to 3.1 in.	2.2 in	
0°	Time	101.0 to 123.0 ms	108.2 ms	
	Displ.	-.5 to 0.5 in.	0.1 in	
3. ABDOMINAL COMPRESSION TEST:			See Figure A-4	
(Preload = 10 pounds)				
a. Force @ .5" - - - - -		11 to 22 lbs.		
b. Force @ .75" - - - - -		19 to 32 lbs.		
c. Force @ 1.0" - - - - -		26 to 43 lbs.		
d. Force @ 1.3" - - - - -		41 to 63 lbs.		
4. LUMBAR FLEXION TEST:				
a. Force @ 20° - - - - -		22 to 34 lbs.	28 lbs	
b. Force @ 30° - - - - -		34 to 46 lbs.	40 lbs	
c. Force @ 40° - - - - -		46 to 58 lbs.	55 lbs	
d. Return Angle - - - - -		12° maximum	2°	
5. CHEST IMPACT TESTS:				
a. High Speed				
(1) Probe Speed- - -		21.78-22.22 fps	22.14 fps	
(2) Peak Deflection-		1.7" maximum	1.42 in	
(3) Peak Resistive Force- - - - - -		2250 lbs. maximum	2,044 lbs	
(4) Internal Hysteresis - - -		50 to 70%	58%	
b. Low Speed				
(1) Probe Speed- - -		13.86-14.14 fps	14.00 fps	
(2) Peak Deflection-		1.1" maximum	0.90 in	
(3) Peak Resistive Force- - - - - -		1450 lbs. maximum	1,277 lbs	
(4) Internal Hyster.		50 to 70%	55%	

TABLE A-1 (Cont)

CALIBRATION TEST DATA FOR PART 572.B ANTHROPOMORPHIC
TEST DUMMY SERIAL NUMBER 189 (DRIVER)

TEST PARAMETER	SPECIFICATION	Pre-Test Calibration	Post-Test Calibration
6. KNEE IMPACT TESTS:			
a. Right Side--			
(1) Probe Speed - - -	6.76 to 7.04 fps	6.97 fps	
(2) Maximum Force - -	1850 to 2500 lbs.	2,020 lbs	
(3) Time Above 1000#-	1.7 ms minimum	1.9 ms	
b. Left Side--			
(1) Probe Speed - - -	6.76 to 7.04 fps	6.99 fps	
(2) Maximum Force - -	1850 to 2500 lbs.	1,930 lbs	
(3) Time Above 1000#-	1.7 ms minimum	1.9 ms	

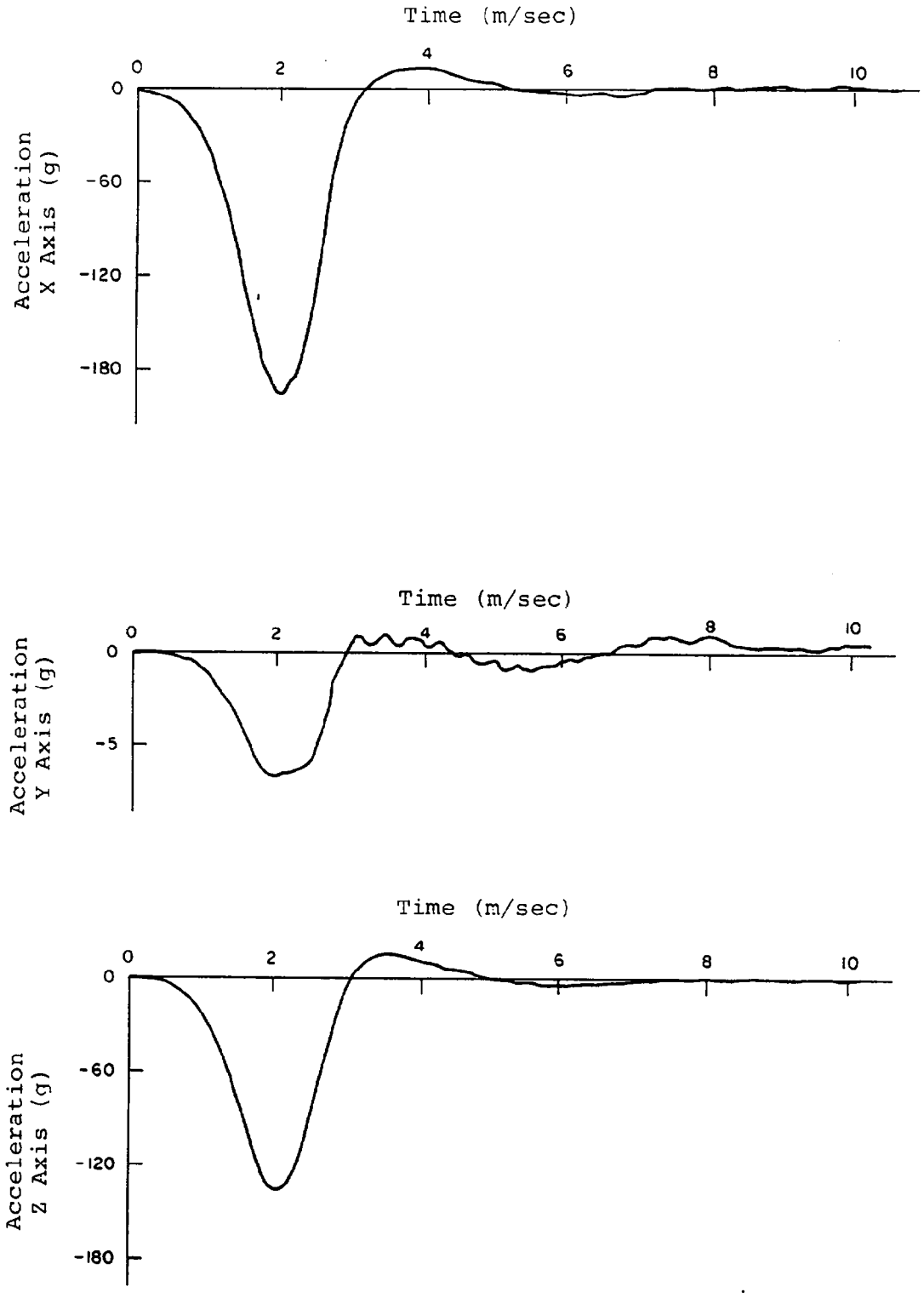


Figure A-1. Acceleration Data From Head Drop Test From Test Sequence 13 for Part 572 Anthropomorphic Dummy S/N 189

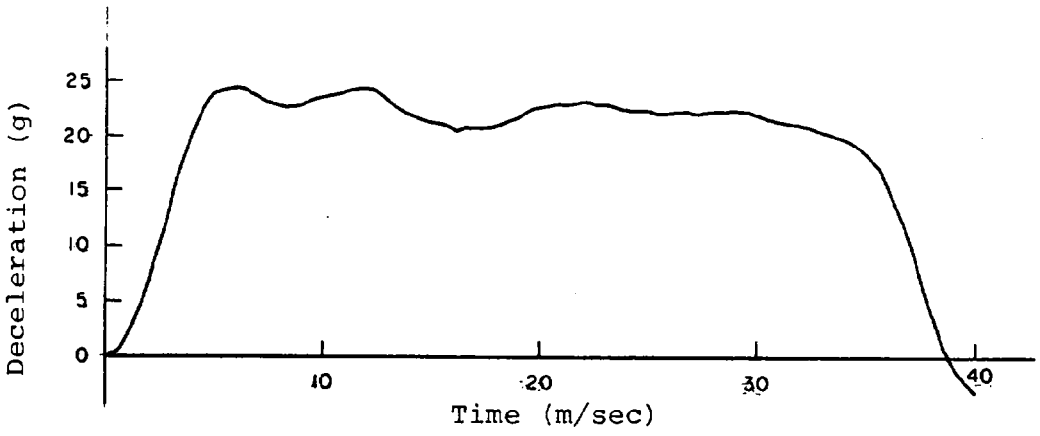


Figure A-2. Pendulum Deceleration From Test Sequence 13 for Part 572 Anthropomorphic Dummy S/N 189

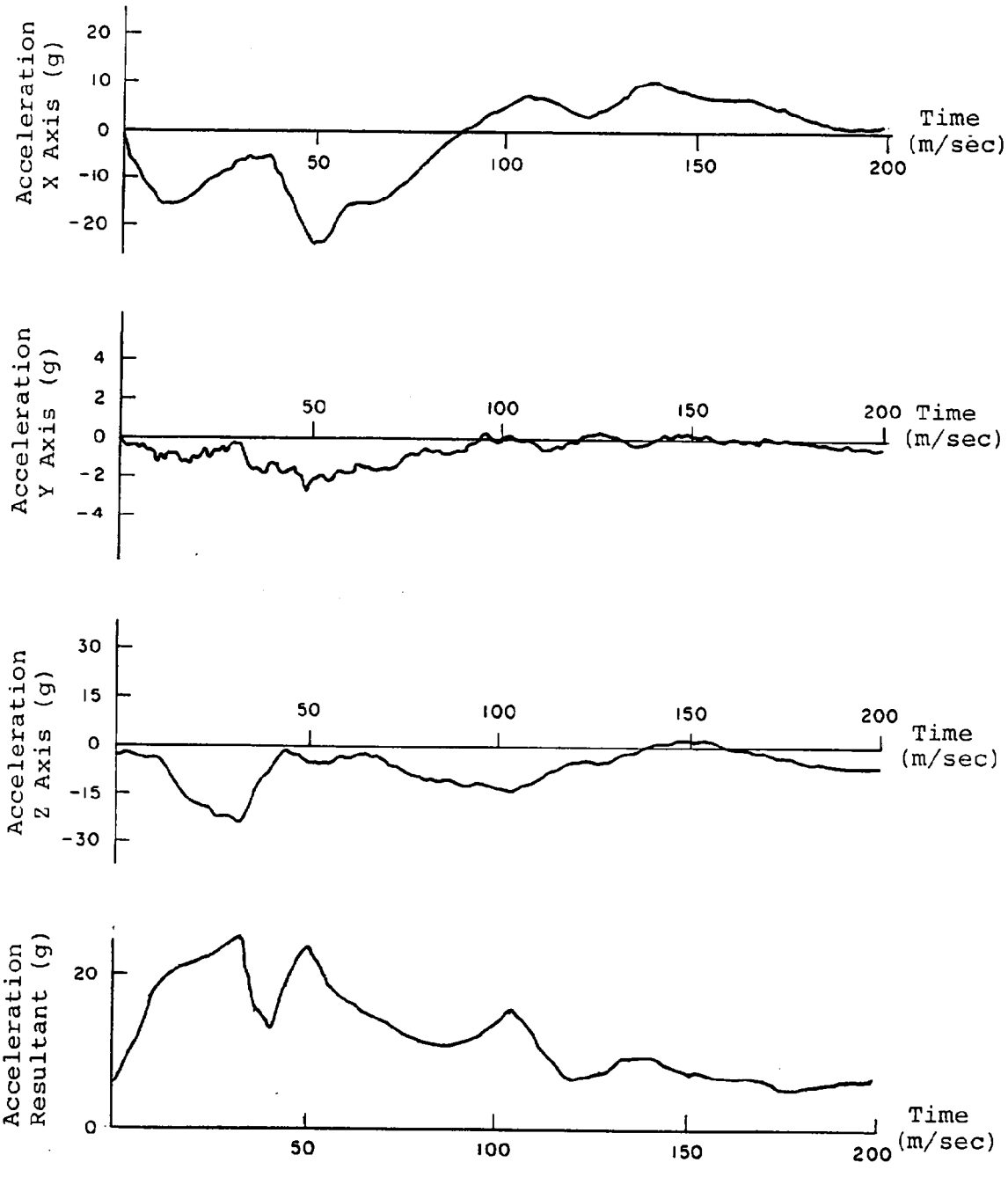


Figure A-3. Acceleration Traces From Neck Bending Test Sequence 13 for Part 572 Anthropomorphic Dummy S/N 189

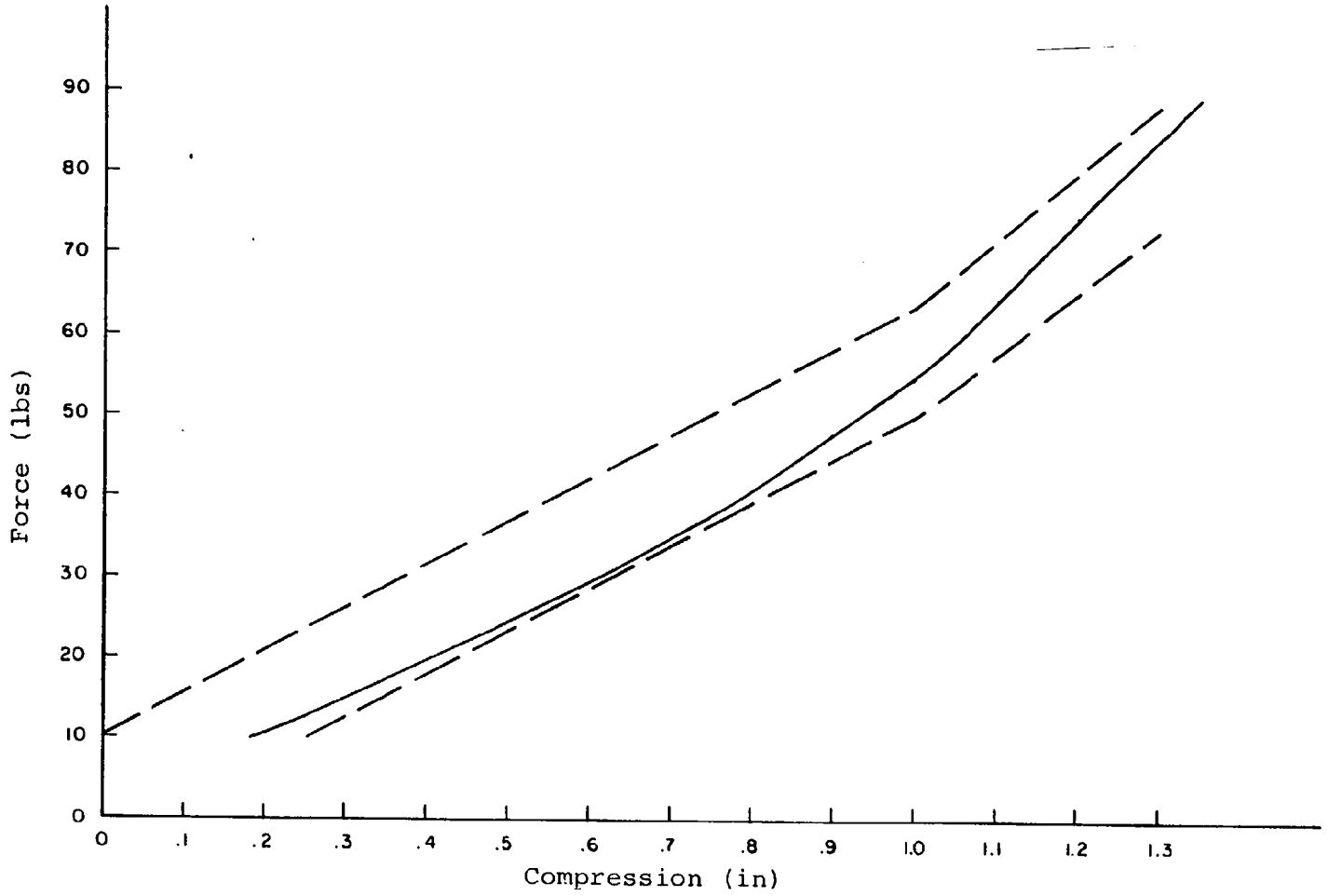


Figure A-4. Abdominal Compression Results For Test Sequence 13 for Part 572 Anthropomorphic Dummy S/N 189

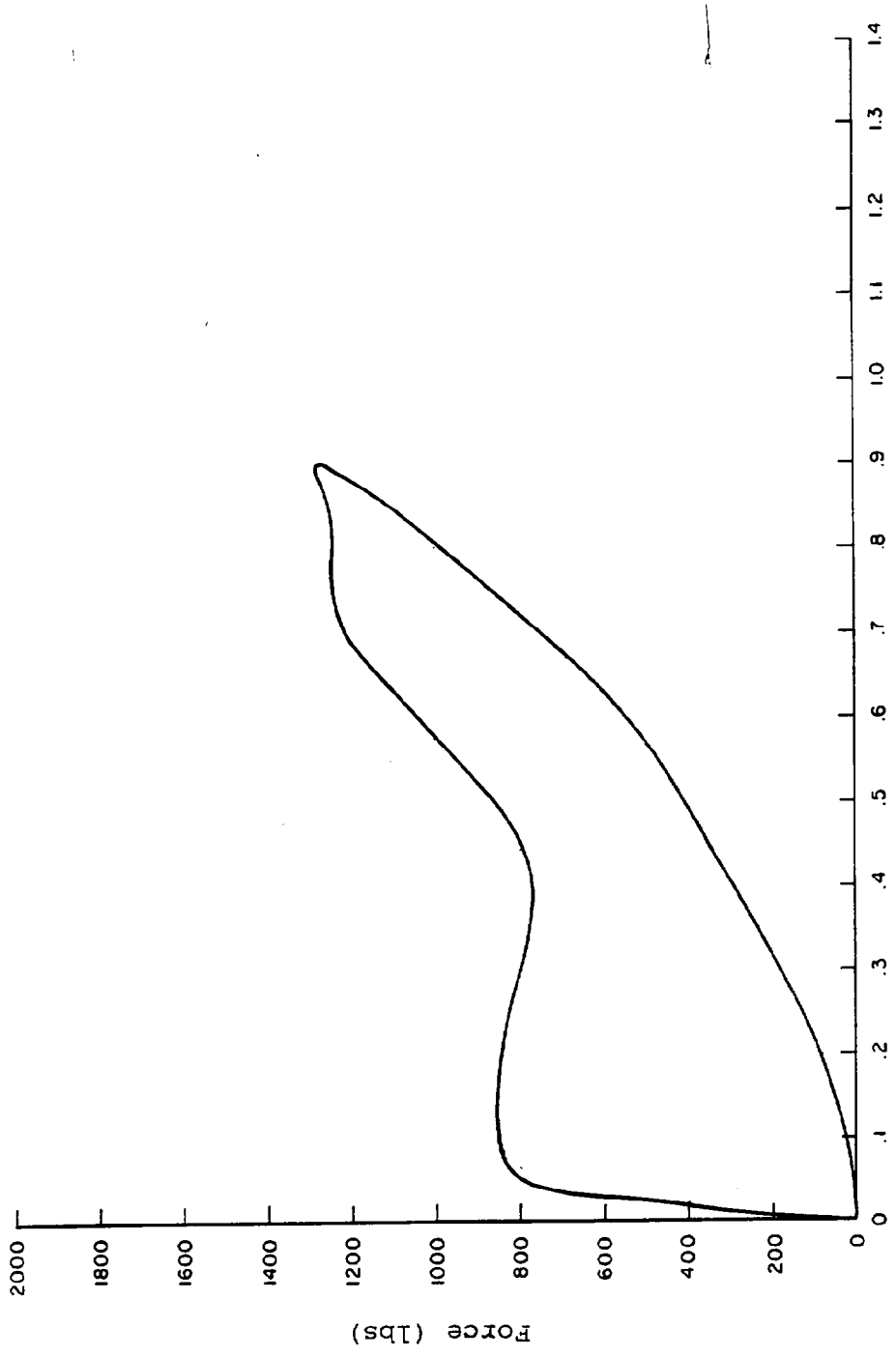


Figure A-5. Low Speed Chest Impact Results for Test Sequence 13 for Part 572 Anthropomorphic Dummy S/N 189

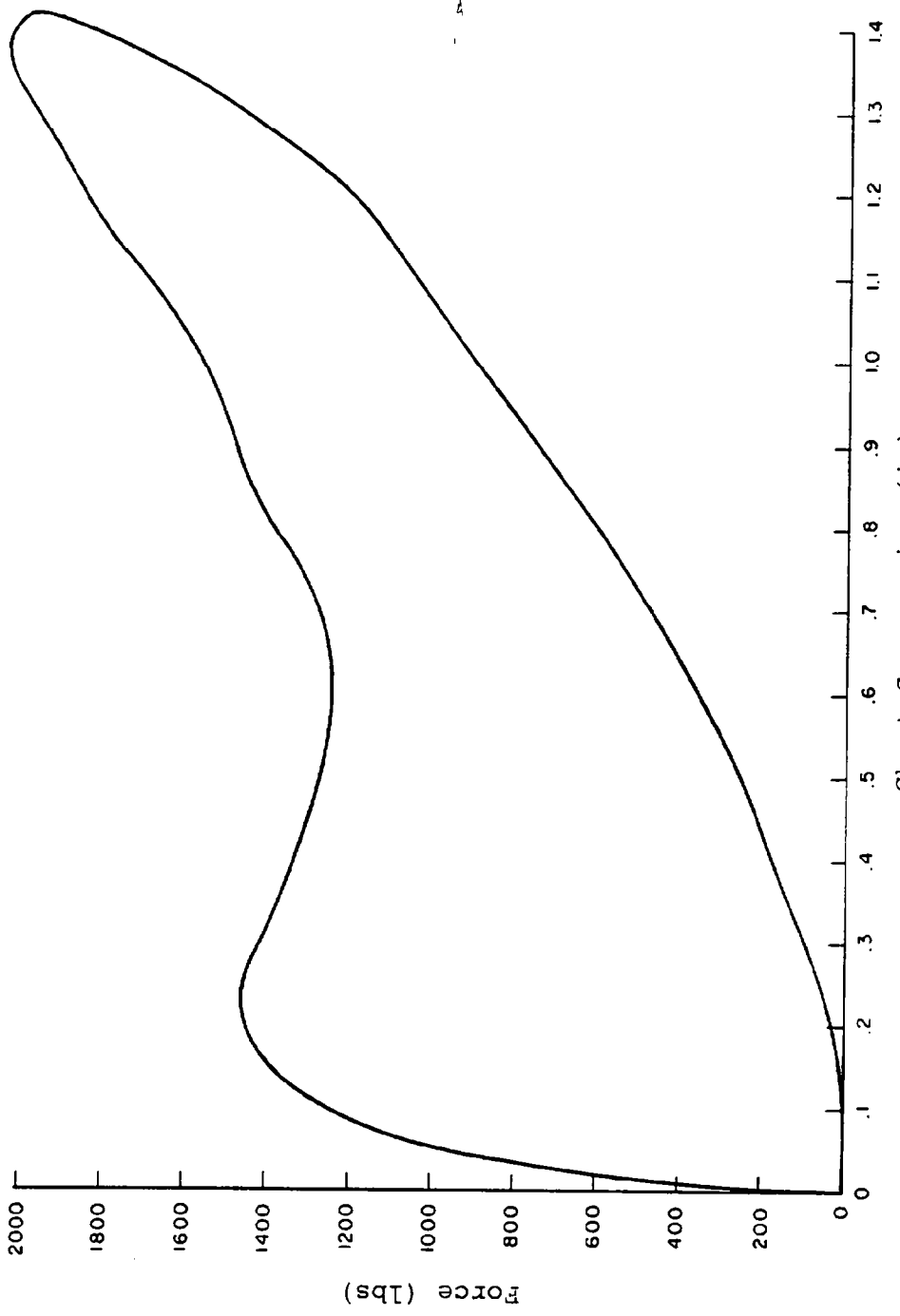
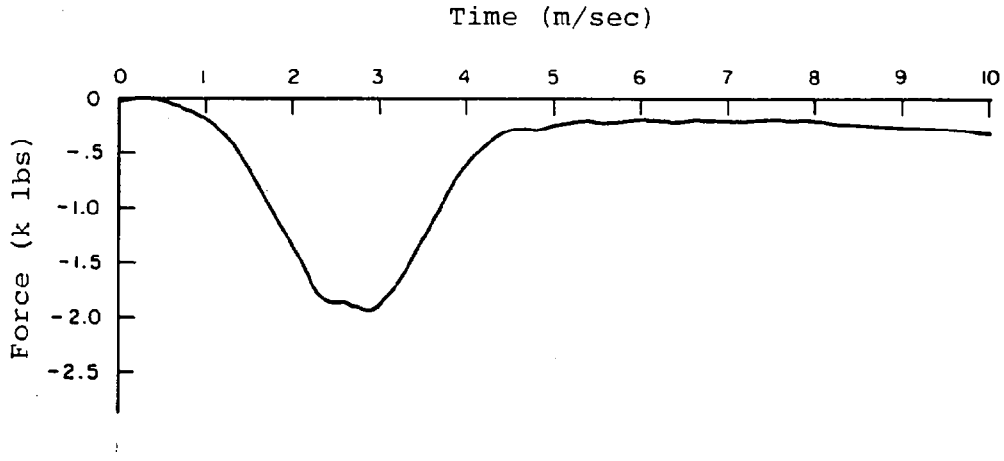
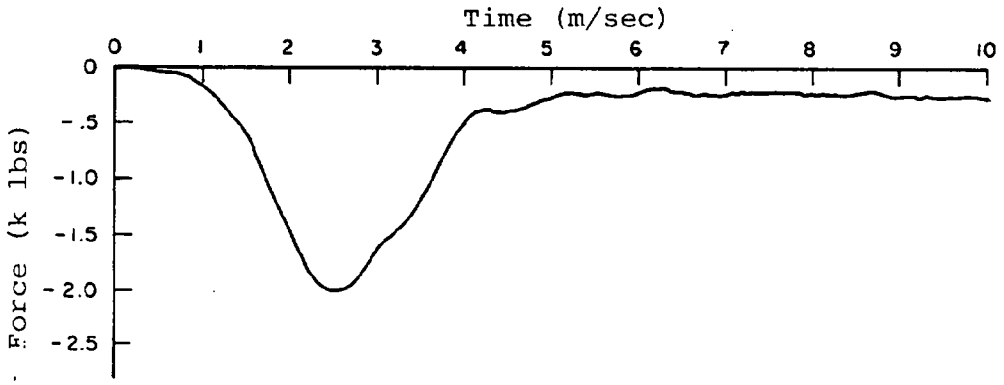


Figure A-6. High Speed Chest Impact Results for Test Sequence 13 for Part 572 Anthropomorphic Dummy S/N 189



(a) Left Knee Impact Test



(b) Right Knee Impact Test

Figure A-7. Knee Impact Results for Test Sequence 13 for Part 572 Anthropomorphic Dummy S/N 189

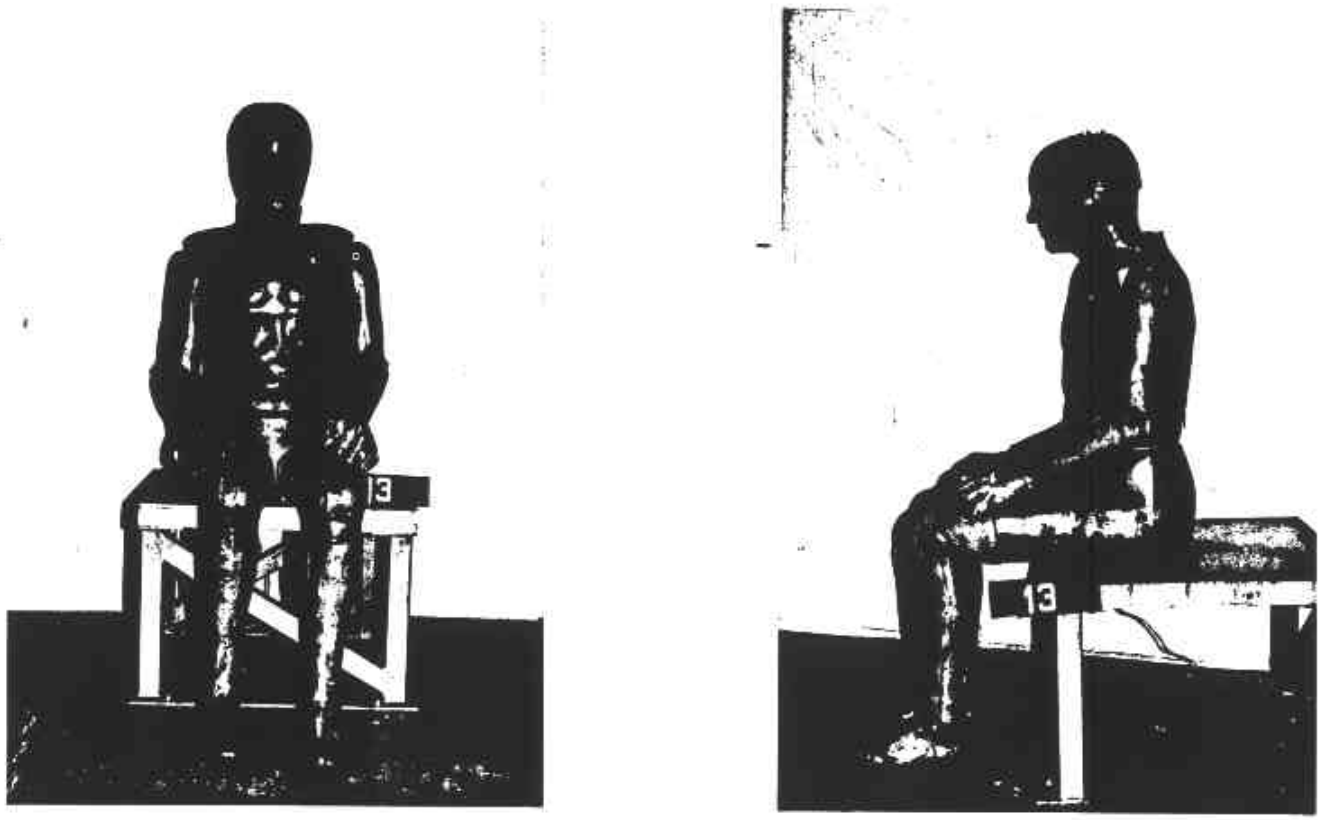


Figure A-8. Part 572.B Anthropomorphic Test Dummy Serial Number 189

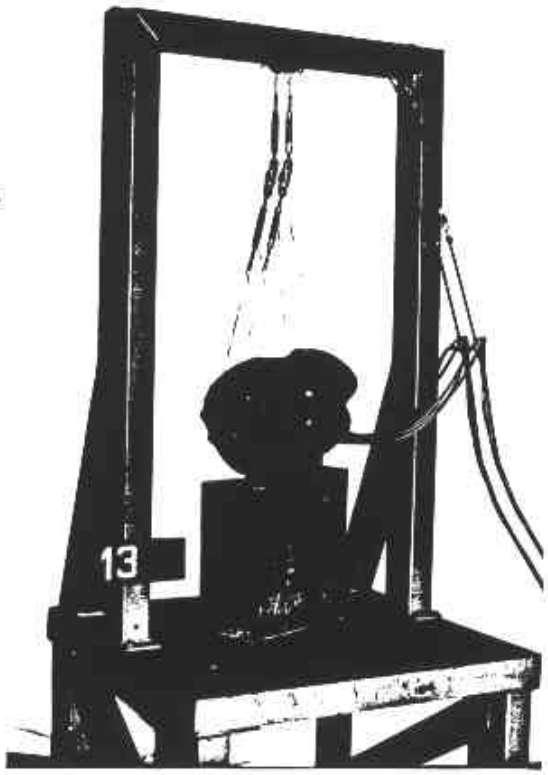


Figure A-9. Head Drop Test Setup with Calibration Block for Part 572.B Anthropomorphic Test Dummy Serial Number 189

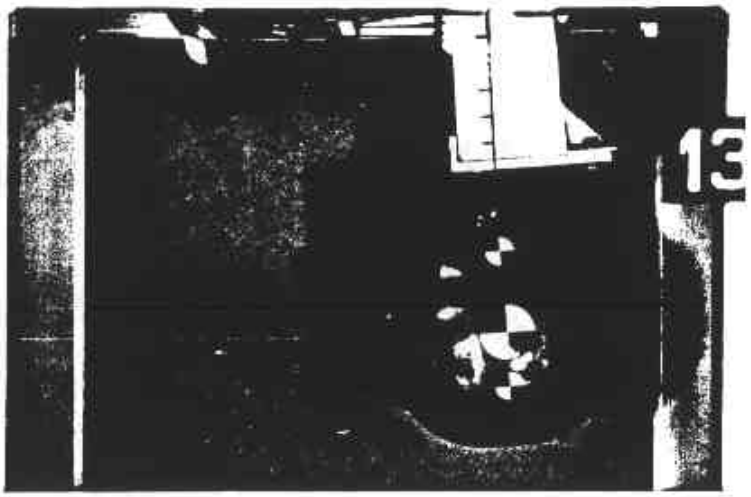


Figure A-10. Neck Bending Test Setup with Head on Pendulum in Pre-Impact Position for Part 572.B Anthropomorphic Test Dummy Serial Number 189

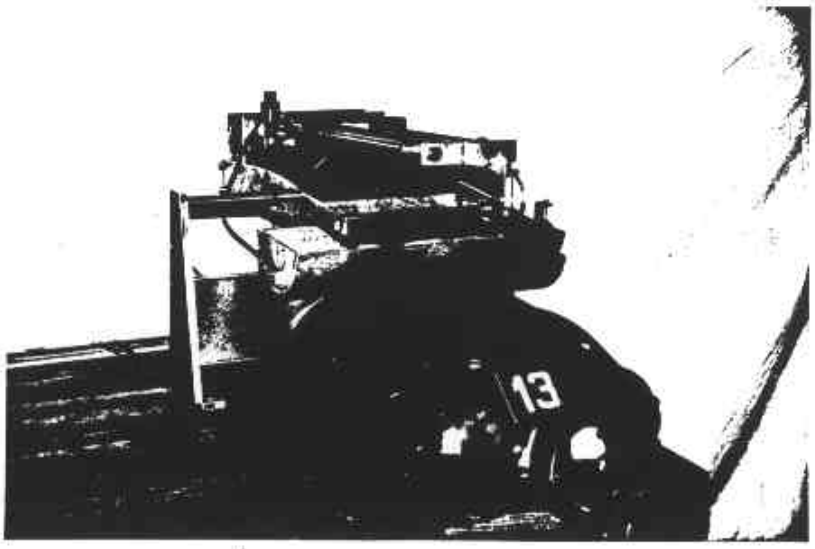


Figure A-11. Abdominal Compression Test Setup with Torso in Place for Testing for Part 572.B Anthropomorphic Test Dummy Serial Number 189

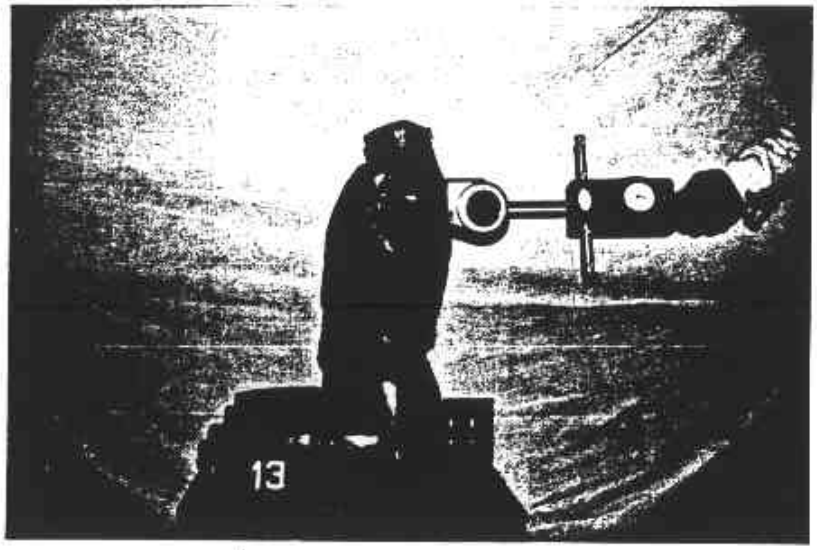


Figure A-12. Lumbar Flexion Test Setup with Torso in Place for Testing for Part 572.B Anthropomorphic Test Dummy Serial Number 189

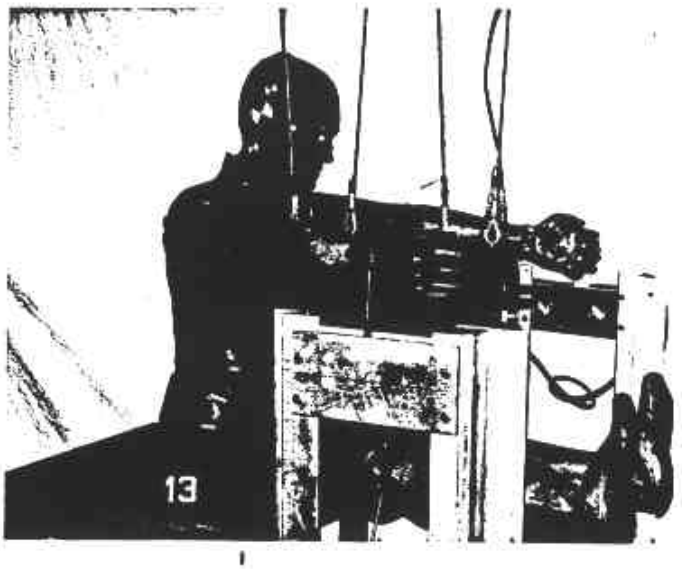


Figure A-13. Chest Impact Test Setup with Probe in Pre-Impact Position for Part 572.B Anthropomorphic Test Dummy Serial Number 189

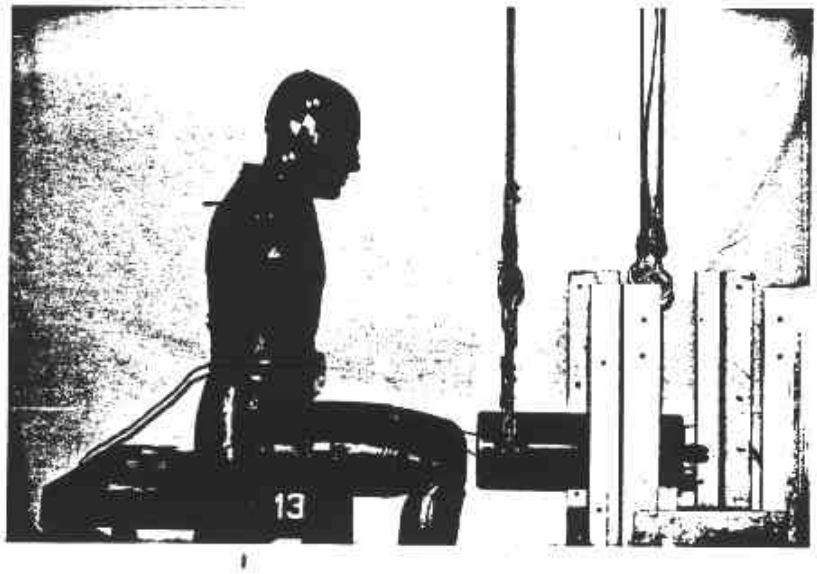


Figure A-14. Knee Impact Test Setup with Probe in Pre-Impact Position for Part 572.B Anthropomorphic Test Dummy Serial Number 189

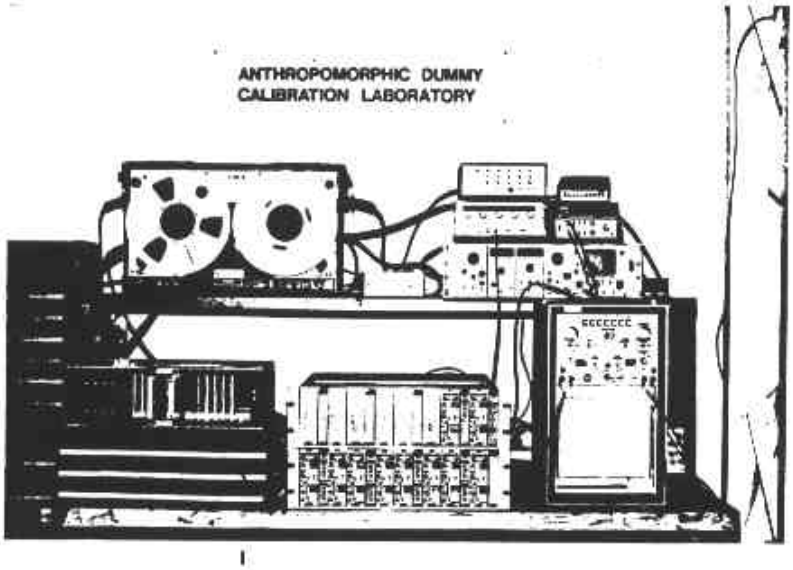


Figure A-15. Anthropomorphic Dummy Laboratory Instrumentation Used for Calibration Tests

APPENDIX B

CALIBRATION TEST RESULTS FROM TEST SEQUENCE 12
FOR PART 572 B ANTHROPORMOPHIC TEST
DUMMY SERIAL NUMBER 16 (PASSENGER)

The pre-test calibration results from Test Sequence 13 for Part 572.B anthropomorphic test dummy Serial Number 186 used as the passenger in full scale crash test Number 1469-2A82 are contained in this appendix. In accordance with contractual agreements, post-test calibration of the test dummy will be performed at the completion of the frontal impact tests to be conducted under Task A.

TABLE B-1

CALIBRATION TEST DATA FOR PART 572.B ANTHROPOMORPHIC TEST DUMMY SERIAL NUMBER 189 (PASSENGER)

			Pre-Test Calibration	Post-Test Calibration
Date of Dummy Calibration- - - - - - - - - - -			1/6/82	
Calibration Sequential Number For Dummy- - - -			1	
Temperature in Lab. (Spec. = 66 to 78° F)- - -			72°F	
Relative Humidity in Lab. (Spec. = 10 to 70%)-			22%	
TEST PARAMETER		SPECIFICATION		
1. HEAD DROP TEST:				
a. Peak Resultant Accel.-		210 to 260G	259 g	
b. Peak Lateral Accel.- -		≤ 10G	6 g	
c. Time above 100G- - - -		0.9 to 1.5 ms	1.14 ms	
2. NECK BENDING TEST:				
a. Pendulum Speed - - - -		21.5 to 25.5 fps	23.0 fps	
b. Pendulum Avg. Decel. (over $t_3 - t_2$) - - - -		20 to 24G	21.7 g	
c. Peak Resultant Head Acceleration - - - - - -		26G maximum	22.1 g	
d. Pendulum Decel.(t_2-t_1)		≤ 3 ms	2.2 ms	
e. Pendulum Decel.(t_3-t_2)		25 to 30 ms	27.5 ms	
f. Pendulum Decel.(t_4-t_3)		≤ 10 ms	6.8 ms	
g. Pendulum Direction Reversal Time- - - - -			117 ms	
h. Max. Head Rotation - -		63 to 73°	64°	
i. Chordal Displacement:				
Head Rotation Angle--				
0°	Time	-2 to 2 ms	0 ms	
	Displ.	-.5 to .5 in.	0 in	
30°	Time	25.6 to 34.4 ms	28.9 ms	
	Displ.	2.1 to 3.1 in.	2.6 in	
60°	Time	40.3 to 51.7 ms	49.1 ms	
	Displ.	4.3 to 5.3 in.	5.1 in	
Maximum (64°)	Time	53.2 to 66.8 ms	60.0 ms	
	Displ.	5.0 to 6.0 in.	5.3 in	

TABLE B-1 (Cont)

CALIBRATION TEST DATA FOR PART 572.B ANTHROPOMORPHIC TEST DUMMY SERIAL NUMBER 186 (PASSENGER)

TEST PARAMETER		SPECIFICATION	Pre-Test Calibration	Post-Test Calibration
2. NECK BENDING TEST.... Continued:				
i. Chordal Displacement:				
Head Rotation Angle--				
60°	Time	67.0 to 83.0 ms	68.0 ms	
	Displ.	4.3 to 5.3 in.	5.1 in	
30°	Time	85.4 to 104.6 ms	92.6 ms	
	Displ.	2.1 to 3.1 in.	2.3 in	
0°	Time	101.0 to 123.0 ms	108.5 ms	
	Displ.	-.5 to 0.5 in.	0.1 in	
3. ABDOMINAL COMPRESSION TEST:			See Figure B-4	
(Preload = 10 pounds)				
a. Force @ .5" - - - - -		11 to 22 lbs.		
b. Force @ .75" - - - - -		19 to 32 lbs.		
c. Force @ 1.0" - - - - -		26 to 43 lbs.		
d. Force @ 1.3" - - - - -		41 to 63 lbs.		
4. LUMBAR FLEXION TEST:				
a. Force @ 20° - - - - -		22 to 34 lbs.	27 lbs	
b. Force @ 30° - - - - -		34 to 46 lbs.	40 lbs	
c. Force @ 40° - - - - -		46 to 58 lbs.	53 lbs	
d. Return Angle - - - - -		12° maximum	5.5°	
5. CHEST IMPACT TESTS:				
a. High Speed				
(1) Probe Speed- - -		21.78-22.22 fps	22.05 fps	
(2) Peak Deflection-		1.7" maximum	1.45 in	
(3) Peak Resistive Force- - - - - -		2250 lbs. maximum	2,050 lbs	
(4) Internal Hysteresis - - -		50 to 70%	56%	
b. Low Speed				
(1) Probe Speed- - -		13.86-14.14 fps	13.99 fps	
(2) Peak Deflection-		1.1" maximum	1.06 in	
(3) Peak Resistive Force- - - - - -		1450 lbs. maximum	1,288 lbs	
(4) Internal Hyster.		50 to 70%	51%	

TABLE B-1 (Cont)

CALIBRATION TEST DAT AFOR PART 572.B ANTHROPOMORPHIC TEST DUMMY SERIAL NUMBER 186 (PASSENGER)

TEST PARAMETER	SPECIFICATION	Pre-Test Calibration	Post-Test Calibration
6. KNEE IMPACT TESTS:			
a. Right Side--			
(1) Probe Speed - - -	6.76 to 7.04 fps	6.96 fps	
(2) Maximum Force - -	1850 to 2500 lbs.	2,040 lbs	
(3) Time Above 1000#-	1.7 ms minimum	1.8 ms	
b. Left Side--			
(1) Probe Speed - - -	6.76 to 7.04 fps	6.92 fps	
(2) Maximum Force - -	1850 to 2500 lbs.	2,190 lbs	
(3) Time Above 1000#-	1.7 ms minimum	1.9 ms	

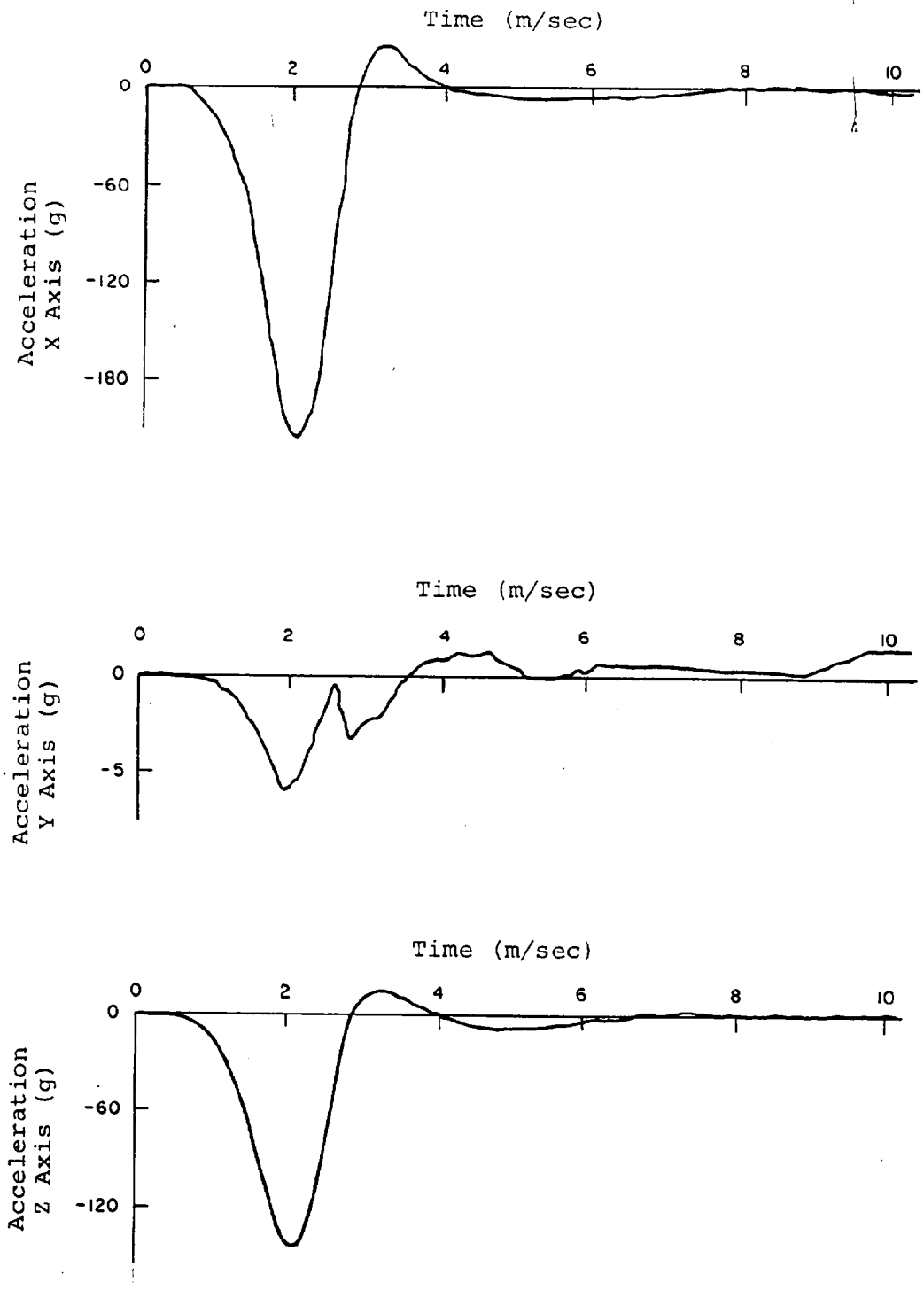


Figure B-1. Acceleration Data From Head Drop Test from Test Sequence 12 for Part 572 Anthropomorphic Dummy S/N 186

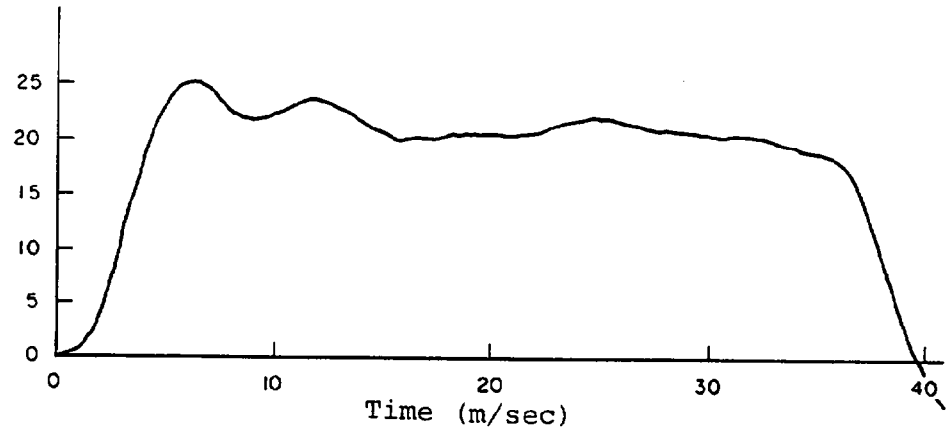


Figure B-2. Pendulum Deceleration From Test Sequence 12 for Part 572 Anthropomorphic Dummy S/N 186

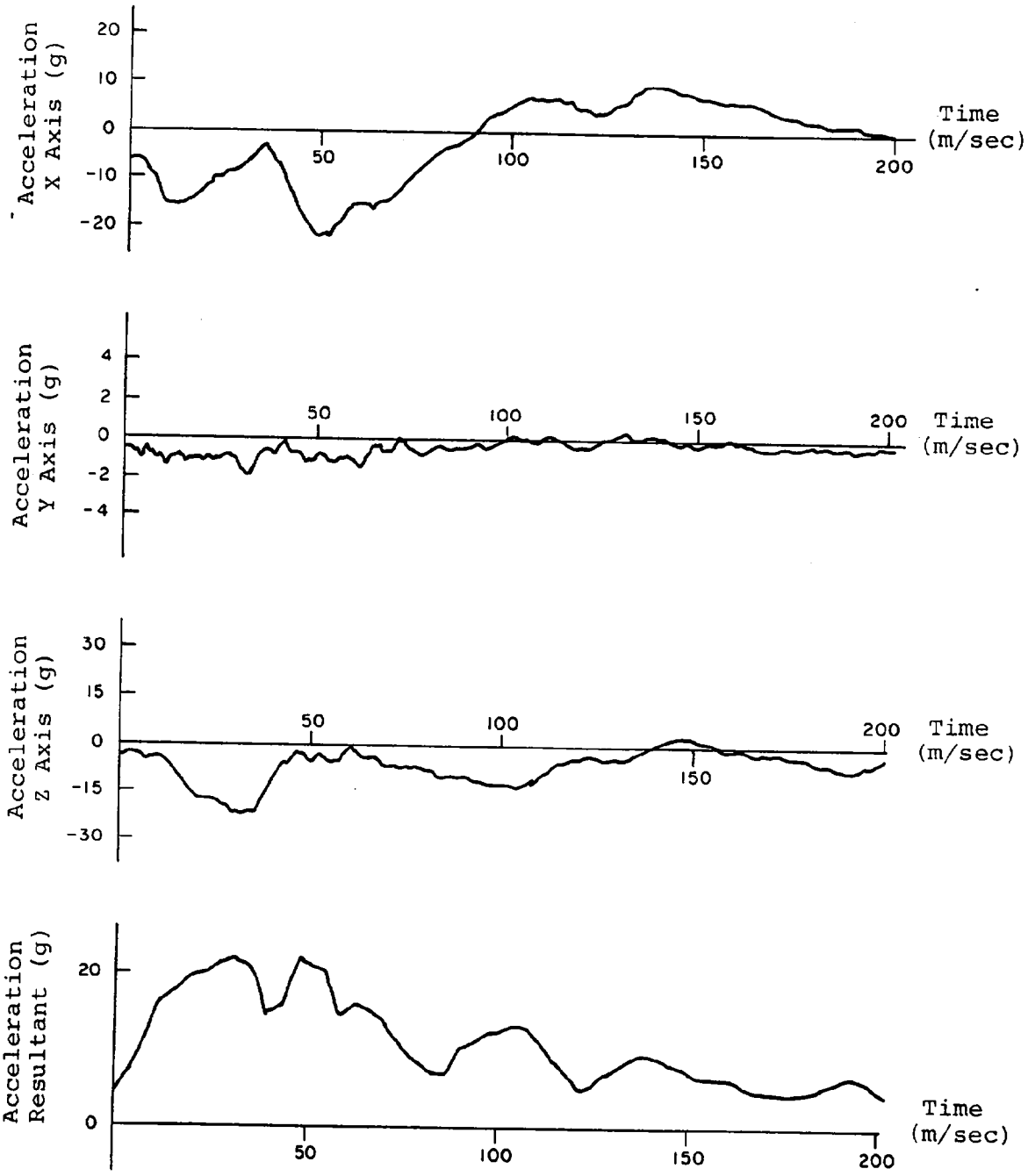


Figure B-3. Acceleration Traces From Neck Bending Test Sequence 12 for Part 572 Anthropomorphic Dummy S/N 186

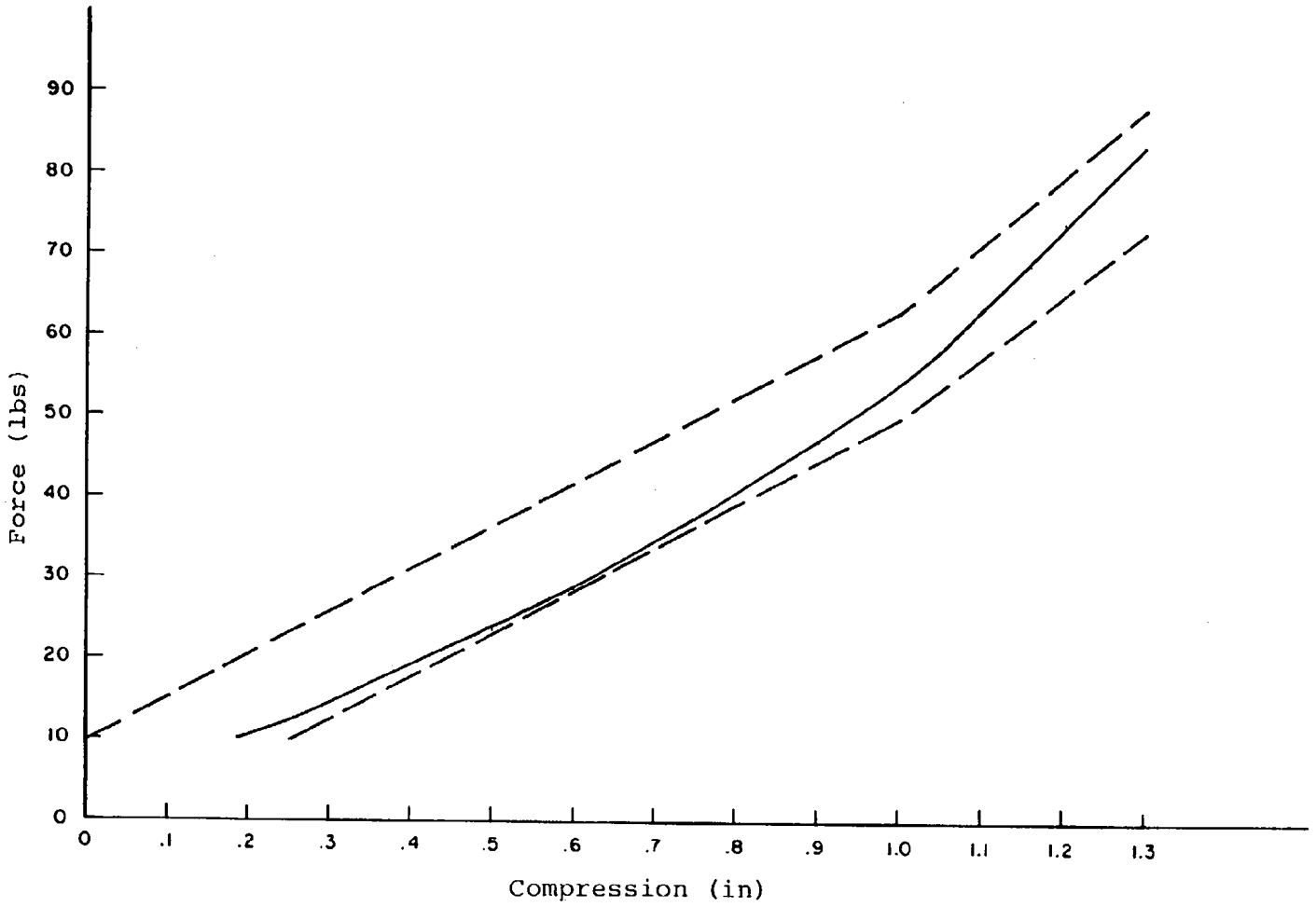


Figure B-4. Abdominal Compression Results For Test Sequence 12 for Part 572 Anthropomorphic Dummy S/N 186

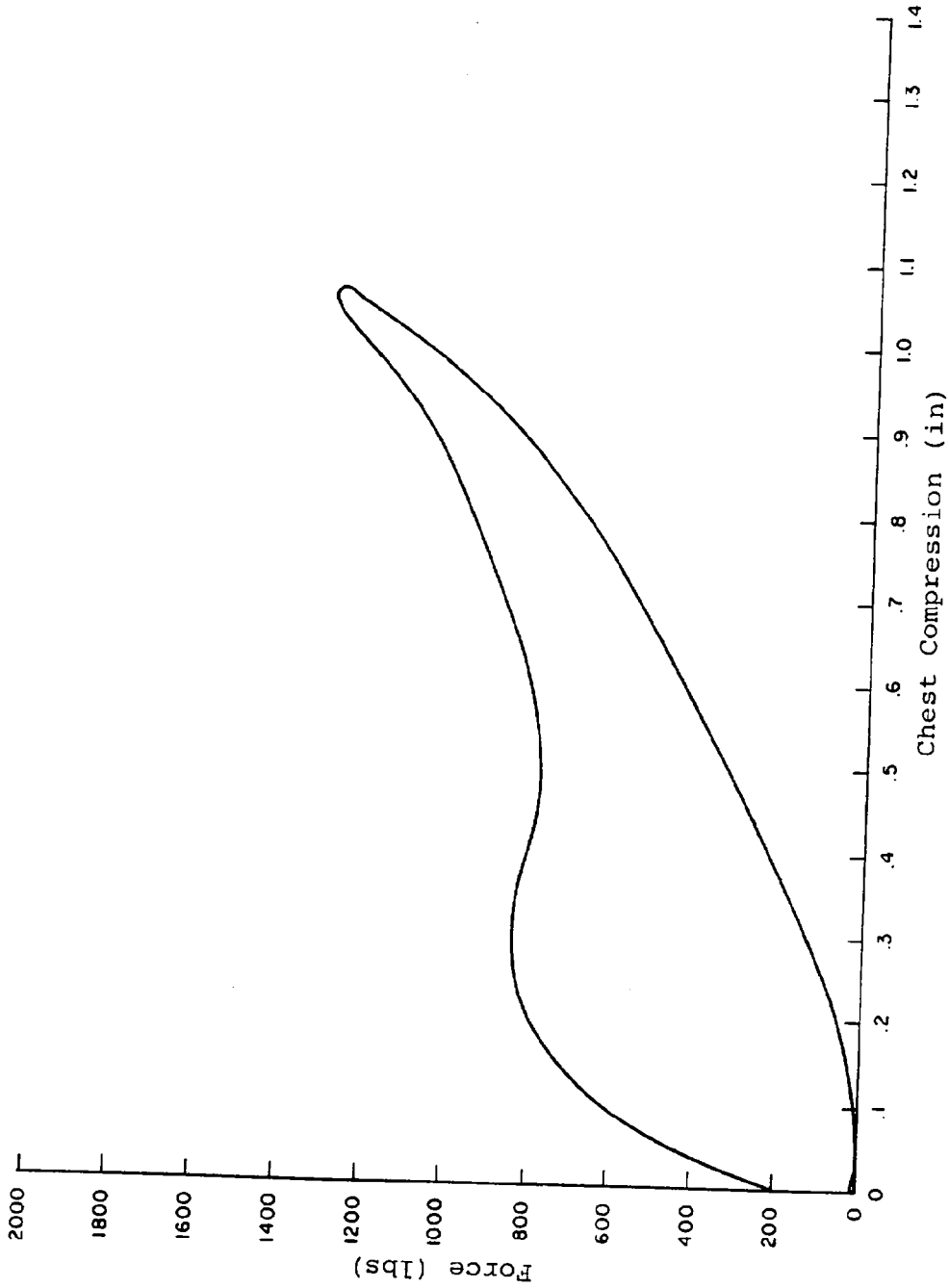


Figure B-5. Low Speed Chest Impact Results for Test Sequence 12 for Part 572 Anthropomorphic Dummy S/N 186

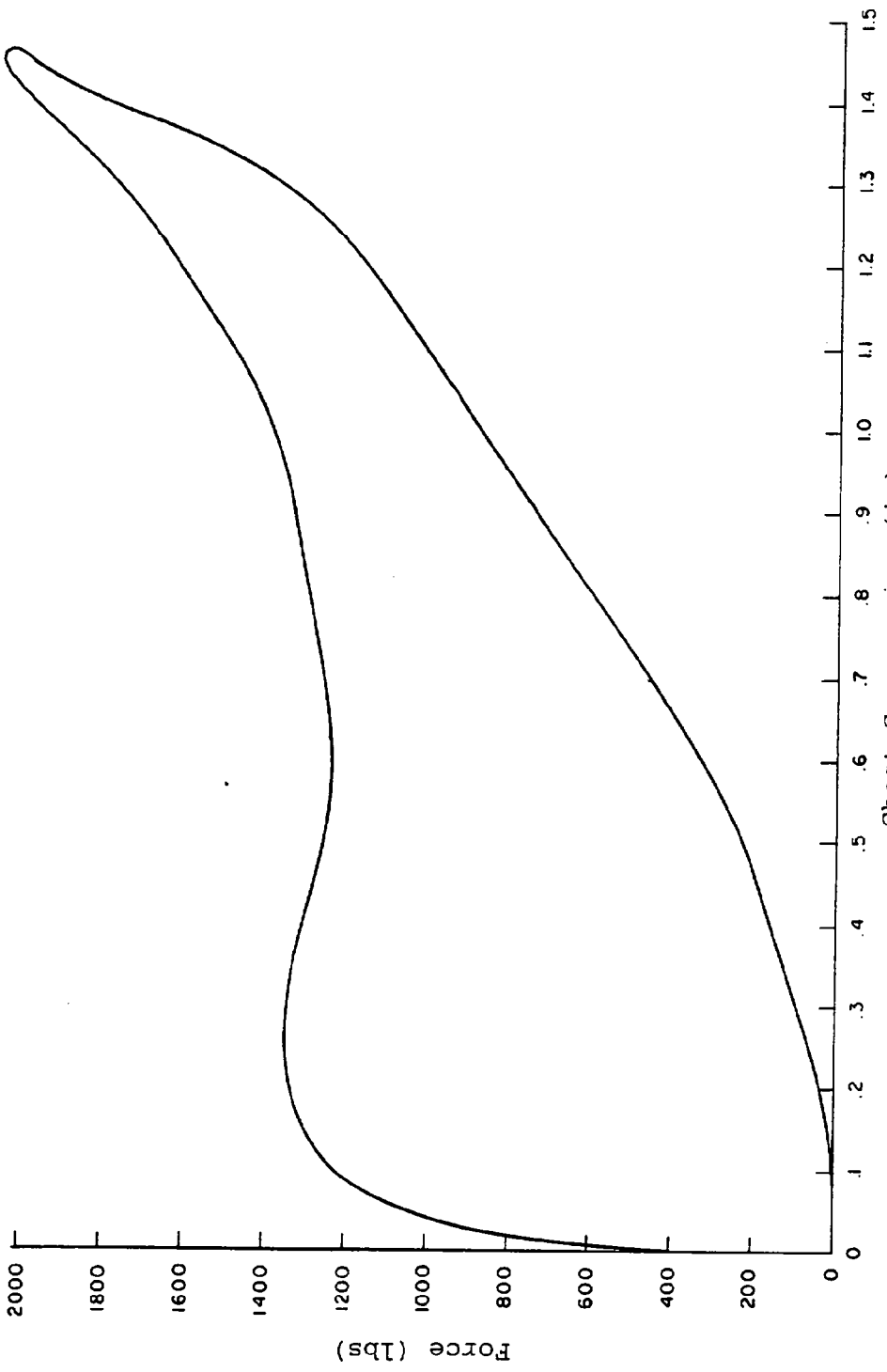
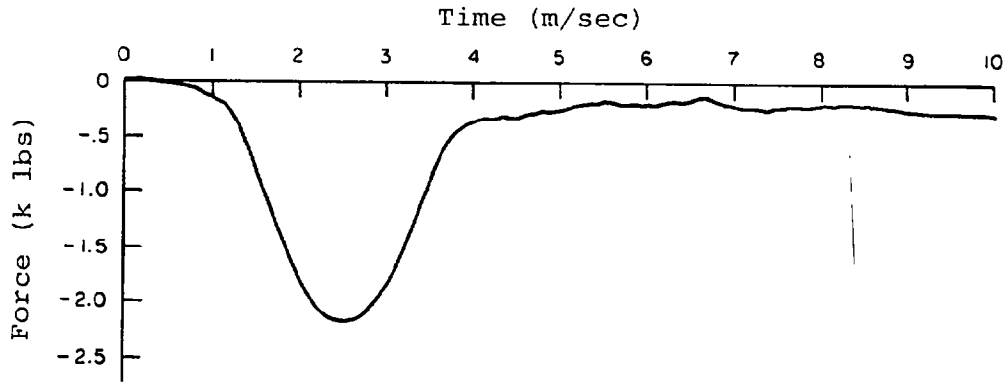
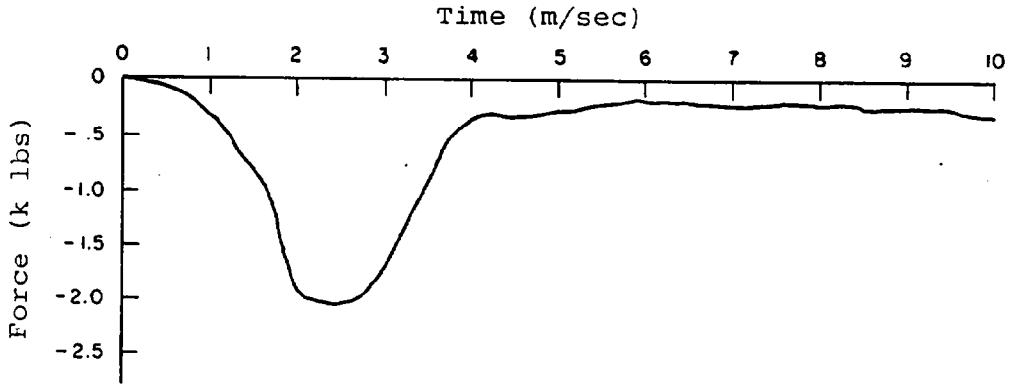


Figure B-6. High Speed Chest Impact Results for Test Sequence 12 for Part 572 Anthropomorphic Dummy S/N 186



(a) Left Knee Impact Test



(b) Right Knee Impact Test

Figure B-7. Knee Impact Results for Test Sequence 12 for Part 572 Anthropomorphic Dummy S/N 186

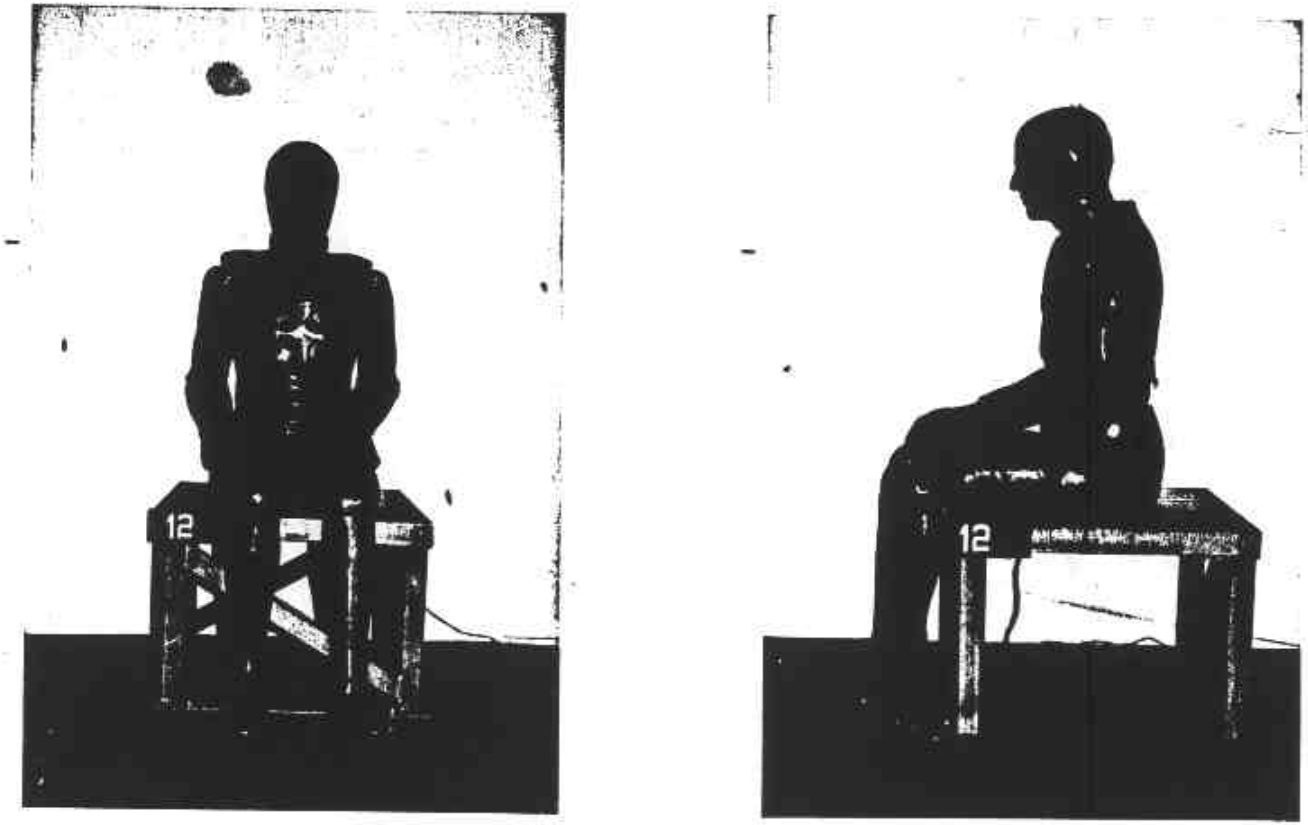


Figure B-8. Part 572.B Anthropomorphic Test Dummy Serial Number 186

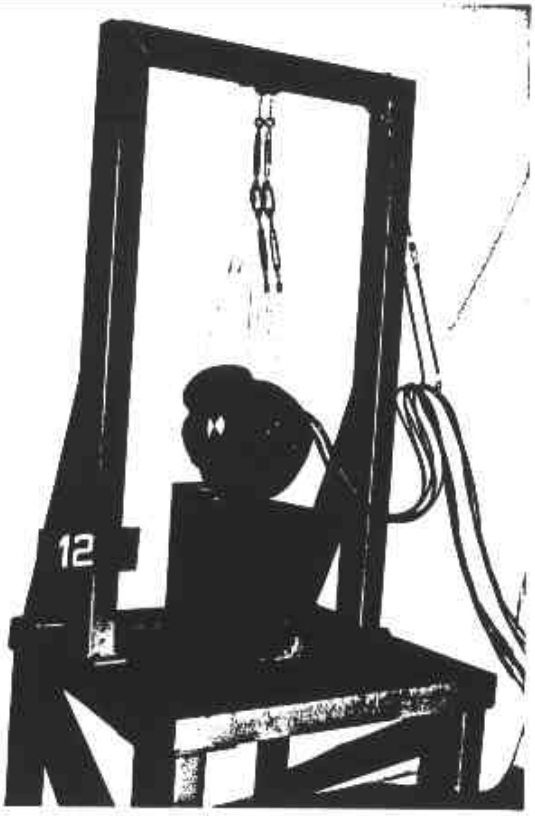


Figure B-9. Head Drop Test Setup with Calibration Block for Part 572.B Anthropomorphic Test Dummy Serial Number 186

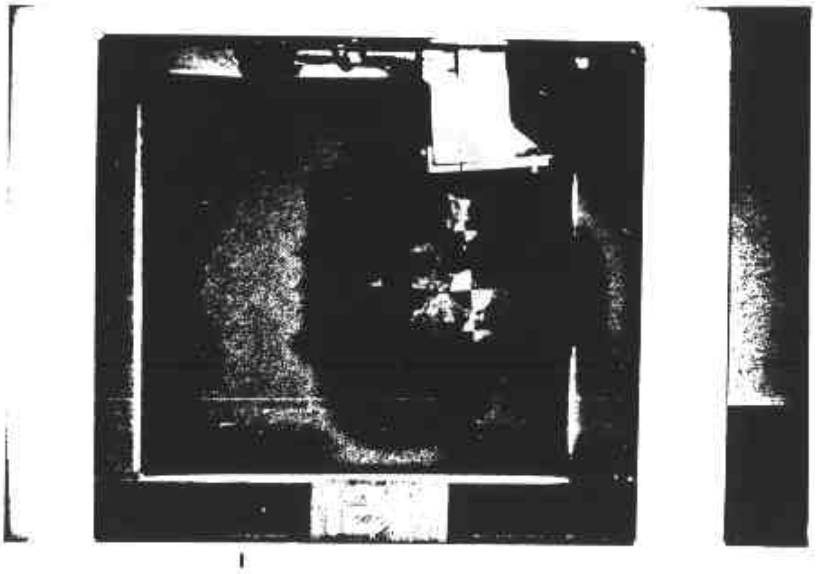


Figure B-10. Neck Bending Test Setup with Head on Pendulum in Pre-Impact Position for Part 572.B Anthropomorphic Test Dummy Serial Number 186

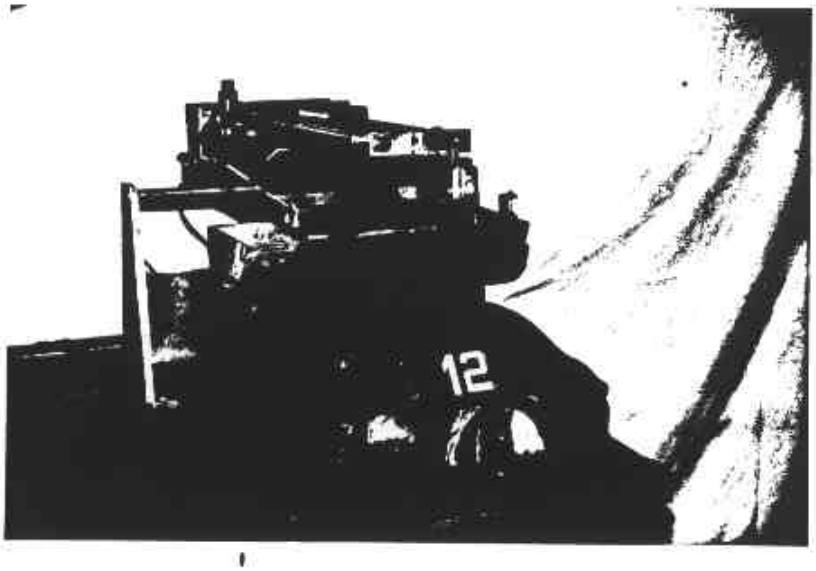


Figure B-11. Abdominal Compression Test Setup with Torso in Place for Testing for Part 572.B Anthropomorphic Test Dummy Serial Number 186

Figure B-12. Lumbar Flexion Test Setup with Torso in Place for Testing for Part 572.B Anthropomorphic Test Dummy Serial Number 186

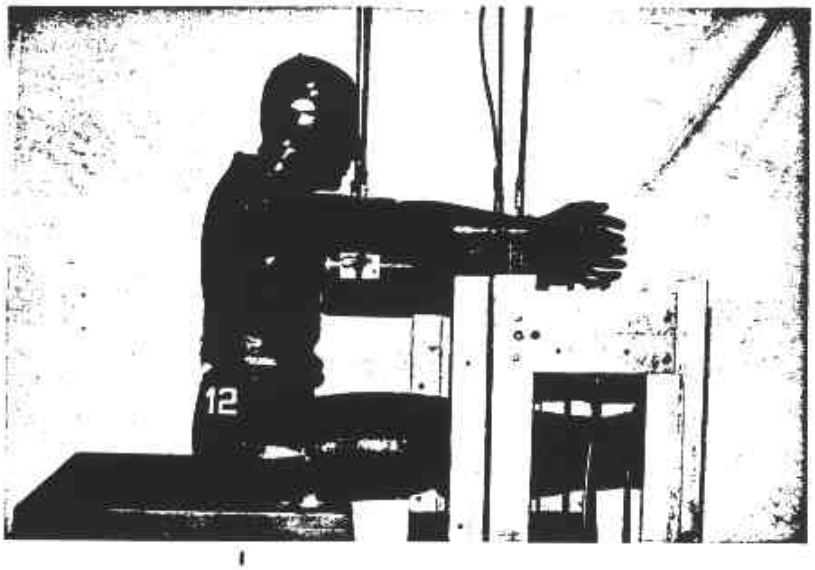


Figure B-13. Chest Impact Test Setup with Probe in Pre-Impact Position for Part 572.B Anthropomorphic Test Dummy Serial Number 186

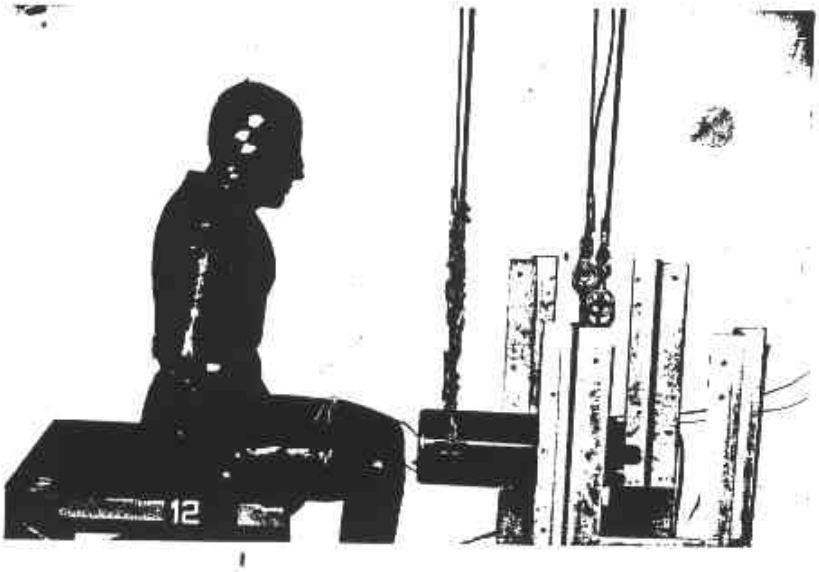


Figure B-14. Knee Impact Test Setup With Probe in Pre-Impact Position for Part 572.B Anthropomorphic Test Dummy Serial Number 186