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CALIBRATION PROCEDURES OF TEST
DUMMIES FOR SIDE IMPACT TESTING

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<p>16. Abstract The objectives of this study were to develop and establish recommended tests, testing procedures and calibration criteria by which test dummies can be characterized and qualified for side impact compliance testing. The test procedures developed in this program were based on a review of available biomechanics literature, car crash tests, accident investigation data and impact sled tests.</p> <p>The tests which were developed are simple to perform and can be done using the apparatus for existing Part 572 frontal tests. The tests, with the exception of the lateral neck test, do not require disassembly of the test dummy. The tests are repeatable and sensitive enough to detect variabilities in the construction and response of the dummy. In evaluation tests of three test dummies, the test procedures produced repeatable results, but variations in response levels were also noted. The major source of variation in the direct impact tests were considered to be lack of control of the simulated flesh thickness overlying the dummy skeletal structures, and, in the shoulder and thorax, structural load path variations.</p> <p>In view of the limited knowledge of the biomechanics of lateral impact response and the variabilities in test dummy construction, the test procedures and calibration criteria developed by this program should be considered preliminary until additional biomechanical information and more uniformly constructed dummies become available.</p>					
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1.0 INTRODUCTION

This report is a summary of the work performed by the Highway Safety Research Institute (HSRI) of the University of Michigan on a project entitled, "Calibration Procedures of Test Dummies for Side Impact Testing," conducted for the National Highway Traffic Safety Administration under contract number DOT-HS-6-01296. The overall objectives of the program were to:

1. Review available data on actual or simulated side impacts -- both from biomechanical and test dummy studies -- and review dummy testing and calibration procedures currently being employed in the field.
2. Identify, through analysis of available data and limited sled impact tests, those dummy components which have a major effect on the overall dummy response during side impacts.
3. Develop and establish recommended tests, testing procedures and calibration criteria by which test dummies shall be characterized and qualified for side impact compliance testing.

The subject of side impact injury protection in automobile crashes has received relatively little emphasis when compared to the research conducted on frontal impact protection. This is mainly due to the high priority of protecting vehicle occupants in frontal type crashes. As this goal is approached, attention has been shifted to consideration of the side impact problem. Protection of vehicle occupants sitting on the near side of a vehicle subjected to a side impact presents several difficulties, the major ones being:

1. Minimal crush distance to attenuate and control the forces of the crash.
2. Penetration of the occupant compartment space.
3. Partial ejection of the occupant through the side windows -- thereby allowing interaction with outside objects.
4. Difficulty of adequate lateral restraint of the occupant by conventional restraint systems.

The sequence of events which happen to a near side occupant in a side impact depend somewhat on the seating position relative to the point of impact and upon the geometry of the impacting structure.

In the case of an unrestrained occupant seated near the point of impact, the initial acceleration of the vehicle due to the crash is not transmitted to the occupant -- instead the vehicle undergoes a velocity change while the unrestrained occupant continues at the velocity he had in that direction at the start of the crash. Eventually, the side structure of the vehicle (which may be moving toward the occupant due to intrusion) and the occupant meet in a second impact with a relative velocity which depends upon the crash velocity and the rate of intrusion. The forces generated by the impact of the occupant with the side structure depend on their relative velocity and the mechanical properties of both the occupant and the side structure. In many side impacts, the window glazing shatters upon the initial impact and is gone by the time the occupant reaches the side structure of the vehicle. This leads to additional concentration of the occupant impact loads into the thorax since the glazing no longer can serve as a load bearing surface on the upper portions of the body. The shape of the interior surfaces of the side structure also influences the load distribution developed when the occupant's body impacts the side structure.

The protection of occupants in side impacts depends primarily upon controlling the magnitude and distribution of impact forces applied to the occupant's body as the vehicle side structure and the occupant collide. The design of the side structure interior surfaces to achieve this goal depends on a knowledge of the biomechanical characteristics of the human body under lateral impact -- particularly of the shoulder, thorax and pelvis -- and the development of test devices based on such knowledge.

1.1 Review of Past Biomechanics Research

1.1.1 Biomechanics of Whole Body Lateral Impact. The bulk of the biomechanics research which deals with lateral loading as a part of whole body lateral ($\pm G_y$) acceleration has been associated with restrained test subjects which do not actually impact any surfaces but rather are loaded inertially due to a test sled acceleration. In contrast to studies of impact tolerance involving vertical, forward, or rearward-facing body orientations, few studies have been conducted with subjects facing sideward relative to the impact direction. Animal tests have

been primarily conducted relative to aerospace programs. In support of Apollo tests, one American black bear, wearing full Apollo restraint, except for the helmet, was exposed to a peak lateral acceleration of 46 G with a velocity change of 32 ft/sec and onset rate of 4180 G per second, without reported injury (1).

Robinson, et al. (2) have exposed rhesus monkeys to repeated lateral impacts of up to 75 G at 32 ft/sec while restrained in half-body molds. They found electrocardiographic evidence of transient abnormalities in both conduction and rhythm following impacts at accelerations higher than 55 G. Comparison of radiographs taken pre- and post-impact revealed an increase in the percent of the total heart shadow on the dependent side of the midline following the test. Abnormalities of the heart occurred twice as often in those monkeys receiving left lateral impacts as those impacted on their right side.

Stapp (3) reported no injuries to five chimpanzees decelerated on the Holloman rocket tract at 20.8 to 47G (calculated) input lateral accelerations (right, $+G_y$) at 929 to 1180 G/sec for 0.118 to 0.170 seconds duration. Lombard, et al. (4), exposed guinea pigs to 240 g for 0.033 seconds at 100,000 G/sec rate of onset in a fully contoured rigid support system.

More recent tests utilizing baboon subjects have resulted in findings which indicate that significantly greater injury occurs in lateral ($+G_y$) impact, relative to either forward or rearward facing exposures, at every level of impact studies from 15 to 44 G (5). These tests, contrary to the bear, chimpanzee, and rhesus tests noted, were conducted with minimal restraint of a lap belt only, and may be of greater significance to the lap-belted human automobile occupant than the previous tests with full body support. Injuries fell into several categories. Five animals received ruptured bladders, an injury which only occurred in the lateral impacts. Contusions, tears, or lacerations and a complete severance of the uterus also occurred in five cases. In three instances, cervical fractures occurred with complete atlanto-occipital separation and transection of the spinal cord occurring in one 30 G impact. Such cervical trauma did not occur in either rear-facing or forward-facing impacts. The most significant finding, and quite unexpected, was that of pancreatic hemorrhage in

all lateral cases autopsied. Subsequent investigations were conducted of baboon subjects exposed to lateral impact wearing 3-point, Y-yoke, and an upper torso single diagonal belt only (6, 7). Ninety degree side impacts at 22 G, with the 3-point system, resulted in severe dural and urinary bladder hemorrhage, and fatal dislocation of the atlanto-occipital joint at 30 G. These tests indicate that in any future side-impact studies particular attention should be paid to kidney, dural, and myocardial trauma, injuries.

Human lateral impact tests in support of Apollo have been conducted under conditions of maximum restraint protection including use of a 3-inch lap belt, a thigh strap, leg restraints, full torso restraint vest with integrated shoulder straps, a pressure suit helmet with restraining straps, and full body support by a contoured micro-ballon mattress backed by 0.25 inch aluminum plate (8). Sixteen volunteer subjects were impacted in a series of 32 tests. No adverse subjective reactions were reported to peak accelerations of up to 22 G produced with velocity changes of up to 19.3 ft/sec., at a maximum onset rate up to 1350 G/sec. However, in view of the fact that these were young healthy male subjects in superb physical condition, utilizing the most sophisticated restraint protection yet tested, the extrapolation of these findings to the general population and to the automotive side-impact is difficult. A subsequent study by Brown, Rothstein and Foster (9) of 11 human tests, using a 3-inch lap belt, double shoulder harness, inverted "V" pelvic straps, and head restraint, found no significant injury from lateral impact at forces to 14 G on the sled, although effects reported by subjects included extended chest pain, muscle spasms, shoulder or abdominal pain.

Human tests with subjects protected by Project Mercury restraint and helmets were conducted in 21 right 90° lateral impacts and 23 left 90° lateral impacts at up to 23 peak G (27.5 ft.sec velocity change). Only transient injuries were reported without reaching a tolerance endpoint for this system (10).

Lateral impact tests have been conducted on 64 Air Force volunteers protected by various military aircraft and spacecraft restraint systems at up to 18.7 sled G at 20 ft/sec entrance velocity. Without significant injury (11).

Royal Air Force tests of the F-111 restraint (both GD F-111 and RAF 1AM versions) involved 18 lateral impacts to five human subjects up to 17.7 G at 390 G/sec. Subject symptoms ranged from chest, groin, throat and collar bone discomforts to eye blood vessels ruptures, faintness, and breathing difficulties, but no irreversible injury (12).

Zabrowski (13) on the Holloman "bopper" performed 87 tests on 52 male Air Force subjects at impact up to 11.59 G and durations of 0.22 to 0.09 sec while restrained with both lap belt and shoulder harness and side restraint panel. No permanent physiological changes were noted. Minor subjective physical complaints were reported by more than 60% of the subjects when exposed to 8.8 average G's or greater. The possibility of cardiovascular trauma halted the experiments after two subjects were exposed to 11.59 average G's at 13.3 and 14.6 ft/sec entrance velocities. Whitehouse (14) reported finding no pulmonary damage in 18 lateral (-G_y) impacts conducted on nine human subjects impacted at 15 G, using head and torso restraint.

There apparently has been only one published study involving impact tolerances on the human while restrained by lap belt only. Zabrowski, Rothstein, and Brown (15) published the first medical investigation on humans (restrained by lap belt only) in lateral impact and these had to be discontinued at 9 G (with impact durations of 0.1 sec) due "to subject discomfort with prolonged stiffness and soreness in the neck musculature." Fifty percent of the subjects complained of physical discomfort at 6 G.

States and States (16) found in a study of 48 lateral automotive accidents that fractures of the acetabulum with intrapelvic protrusion of the hip and fractures of the pubic rami are characteristic of direct side impacts to the occupant compartment. The vehicle door was the structure producing the most injuries in such cases. They also noted that head injuries in lateral impact were frequent and that chest injury was the most common life threatening injury.

Friedberg, et al. (17) studied data from 1490 automotive side collisions, concluding that the frequency of dangerous or fatal injury is twice as great for occupants seated on the side of the car impacted, as for those away from the impact. Subsequently, Lister and Neilson (18), studying automotive side impacts in the United Kingdom, reported that such collisions account for about 13% of all accidents involving cars in which some occupant was seriously or fatally injured.

Head injuries in side-impact collisions have been found to be the most common cause of fatal injury in studies by Huelke and by Siegel and Nahum (19).

1.1.2. Biomechanics of Local Lateral Impact. A biomechanical test technique which is an alternative to whole body lateral impact test methods is that of localized impacts applied directly to the stationary body structure of animals and human cadavers. One of the few studies of this type in lateral impact was conducted by Stalnaker et al. (20) at HSRI on NHTSA Contract No. DOT-HS-2-382. A series of lower primates (the squirrel monkey, the Rhesus monkey, the baboon and the chimpanzee) and unembalmed human cadavers, were impacted laterally to the head, thorax, and abdomen with flat and contoured impactors. All impacts were carried out by pneumatically operated testing machine specially constructed for impact studies. The stroke of the impactor was precisely controlled by its initial position, and its velocity was controlled by the reservoir pressure. The impactor was instrumented with an accelerometer and an inertia-compensated force transducer. High-speed motion pictures (3000 frames/s) were taken for photometric analysis. The thorax and abdominal body areas were divided into three major impact regions. Region I consisted of the thorax as located between the jugular notch of the sternum and the diaphragm. Region II was defined as including the area between the diaphragm (ninth rib) and a horizontal plane transecting the abdomen along the inferior margin of the liver and the stomach, and located approximately 0.50 - 1.40 inches superior to the umbilicus on the surface. Region III included the entire thorax and abdominal area, from the jugular notch to the iliac crest.

Two types of impactors were used in the study, a flat circular disc (6 inches in diameter for the cadavers and scaled accordingly for the animals) and a contoured deformable simulation of an armrest. The flat impactor was used on some tests in all the body regions and the contoured impactor was used in some thoracic and abdominal tests.

The test data from the animal tests was analyzed using the techniques of dimensional analysis to extrapolate the injury data to estimate the in vivo human tolerance to side injury for the three body regions. The human cadaver data was used to enhance the results of the scaling analysis. The threshold of closed brain injury to humans was estimated to be 76 G peak lateral acceleration with a duration of 20 msec at an impact velocity of 43 fps. for a padded impact. For a rigid impact to the side of the head, the tolerable impact velocity was found to be 22 fps. In the thorax, a deflection or penetration criteria was used and an extrapolated value of 3.7 inches (31% penetration) was estimated for a severe (not life-threatening) injury level. (Note: In the original work, an error in the calculation of the effective penetration led to an incorrect estimate of 2.65 inches). In the cadaver impacts, rib fractures did not occur for an average impact velocity of 20.4 fps and an average penetration of 2.1 inches, while rib fractures did occur at an average velocity of 29.2 fps with an average penetration of 3.0 inches.

The data recorded for the lateral thoracic impacts was in a form that was useful for biomechanical response characterization of the thorax. In general, the load-deflection response for a flat rigid impact to the side was similar in general shape to the frontal response of the thorax under similar test conditions but the initial force levels were somewhat lower than those produced in frontal impacts.

Scaling of the abdominal impact results to humans was accomplished by employing a factor that relates impact contact area, animal mass, impact force, and pulse duration to injury severity. The maximum tolerable (i.e. severe injury-producing) contact pressure to the upper abdomen of the human was estimated to be 32 psi.

In a subsequent study supporting the development of the HSRI

anthropometric test dummy under sponsorship of the Motor Vehicle Manufacturers Association (21) a series of cadaver side head rigid impacts were conducted at 10-13 fps. to obtain response data. The results were an average peak acceleration of approximately 160 G with a duration of 4 msec. In contrast, similar frontal impacts produced an average peak acceleration of approximately 200 G with a duration of 3 msec.

1.1.3 Side Impact Tests With Dummies. One of the most comprehensive series of simulated side impact tests with dummies in cars was the series of tests performed by the Calspan Corp. on NHTSA Contract No. DOT-HS-00922 (22). A series of seven baseline impact simulations in that program are of particular interest in the present program. In those seven tests, which used 1973 Ford 4-door, pillared hardtop automobiles having a nominal curb weight of 4300 lbs. for both striking and struck cars, the interiors of the cars were of conventional design. Five different impact configurations were simulated:

Configuration Number	Struck Vehicle Velocity (mph)	Striking Vehicle Velocity (mph)	Impact Axis Relative to Struck Vehicle Long. Axis (degrees)
1	0	30	0
2	30	30	0
3	0	30	30
4	30	30	30
5	0	40	0

Test dummies (Humanoid Part 572) were placed in the front and rear seats on the struck side of the car with no restraint systems. The peak acceleration readings from the head, chest and pelvis accelerometers are listed for those tests in Table 1.1.

TABLE 1.1 SUMMARY OF PEAK DUMMY ACCELERATION DATA FOR CALSPAN BASELINE LATERAL COLLISION TESTS

Test Number	Configuration Number	Dummy Position	HEAD ACCELERATION				CHEST ACCELERATION				PELVIC ACCEL.
			AP	LR	SI	RES	AP	LR	SI	RES	LR
1	1	F	7	15	8	15	6	35	8	39	33
		R	18	17	27	37	8	44	8	45	51
2	2	F	27	12	24	35	8	28	9	28	26
		R	32	28	34	40	7	61	14	62	42
3	3	F	4	19	28	30	10	42	11	45	38
		R	31	79	34	94	12	38	9	41	16
4	4	F	26	12	26	34	17	26	13	26	22
		R	53	72	50	104	7	67	11	70	54
5	5	F	3	25	35	39	7	46	9	48	86
		R	7	30	28	37	8	72	4	73	66
6	3	F	15	36	49	55	15	63	13	66	56
		R	8	30	19	32	14	35	3	35	17
7	4	F	8	27	31	39	9	61	10	61	37
		R	46	87	41	100	13	47	7	47	22

The averaged results and their ranges from the above tests are the following:

<u>Body Region</u>	<u>Front Seat Occupant</u>	<u>Rear Seat Occupant</u>
Head Resultant Acceleration	37.5 G (15 - 55)	62.9 G (32 - 104)
Chest Resultant Acceleration	50.3 G (26 - 66)	49.2 G (41 - 73)
Pelvis L-R Acceleration	42.6 G (22 - 86)	38.3 G (16 - 66)

This data can be used to assess the realism of sled test simulations with respect to car crash tests in terms of the general severity of the acceleration environment.

1.2 Analysis of Accident Investigation Data on Side Impact Collisions

Information on the real-world injury patterns associated with side impact collisions was obtained through the use of computerized occupant data files of the Collision Performance and Injury Report (CPIR) programs available at HSRI. These files contain a total of 14275 cases of occupant injuries for all types of accidents. A filter was devised to select only those cases which met the following criteria:

1. Only passenger car occupants were considered [V117 = 01 - 10, 17-20]
2. Impact was to the side of the vehicle [V144 = 2,4]
3. Impact directions were from 2 to 4 o'clock and from 8-10 o'clock [V137 = 02 - 04, 08 - 10]
4. Only occupants aged 16 years or over were considered [V582 = 02 - 11]
5. Only occupants that were not ejected were considered [V604 = 2]

The data that was generated by using this filter on the CPIR file was then stratified into near-side and far-side occupants. The total number of occupants in the resulting file was 2432 which included 1147 near-side occupants and 1285 far-side occupants. For the purpose of identifying injury patterns associated with lateral impact to the body, only the near-side cases were used. This was done to minimize the effect of uncontrolled impact configurations associated with unrestrained far-side occupants moving across the car before impacting the interior.

The near-side occupant data was then stratified into the eight categories based on the following variables:

1. Sex; Male or female
2. Position; left or right
3. Overall Injury Severity; low (AIS < 2) or high (AIS \geq 2)

The resulting information was then analyzed for each body region. The body regions of greatest interest to this program were considered to be brain, neck, shoulder girdle, thorax, lumbar spine, abdomen, and pelvis. Some of the regions in which differences between the categories were noted were:

1. Brain -- males showed a higher frequency of fatal head injury in the left position than females.
2. Neck -- females showed a greater tendency for both low level and high level injuries than males.
3. Thorax -- males showed a higher frequency of higher severity injuries than females in the left position.
4. Lumbar Spine -- females showed a higher frequency of injury than males in the right position.
5. Abdomen -- males had a higher frequency of severe injuries than females in the left position.
6. Pelvis -- females had a higher frequency of injury than males.

An aggregate of the near-side occupant data is listed in Table 1.2. In the table the actual number of cases at each injury severity and body region is shown with the relative overall frequency in percent shown in parentheses. From this table it is possible to note the importance of the brain, thorax, abdomen and pelvis as sources of high level injury (AIS \geq 3).

TABLE 1.2 Distribution of Injury Severity by Body Region for 1147 Near-Side Occupants in Side Impact Collisions.

Body Region	Abbreviated Injury Scale						
	0	1	2	3	4	5	6
Brain	926 (80.8%)	50 (4.4%)	64 (5.6%)	24 (2.1%)	9 (0.8%)	22 (1.9%)	50 (4.4%)
Neck	937 (81.7%)	170 (14.8%)	11 (0.7%)	7 (0.6%)	5 (0.4%)	2 (0.2%)	15 (1.0%)
Shoulder Girdle	925 (80.6%)	151 (13.2%)	50 (4.4%)	7 (0.5%)	0 (0%)	0 (0%)	1 (0.1%)
Thorax	736 (64.2%)	186 (16.2%)	52 (3.5%)	98 (8.5%)	30 (2.6%)	15 (1.3%)	28 (2.4%)
Lumbar Spine	1062 (92.6%)	68 (5.9%)	10 (0.8%)	5 (0.4%)	1 (0.1%)	0 (0%)	1 (0.1%)
Abdomen	1027 (89.5%)	68 (5.9%)	9 (0.8%)	14 (1.2%)	8 (0.7%)	8 (0.7%)	12 (1.0%)
Pelvis	898 (78.3%)	151 (13.2%)	35 (3.1%)	51 (4.4%)	9 (0.8%)	1 (0.1%)	1 (0.1%)

2.0 RESULTS OF LATERAL IMPACT-TESTS ON NHTSA CONTRACT NO. DOT-HS-4-00921

One phase of an ongoing NHTSA program entitled "Quantification of Thoracic Response and Injury," (NHTSA Contract No. DOT-HS-4-00921) being conducted at HSRI which has particular application to this program was a series of lateral impact tests conducted with the HSRI Impact Sled Facility and reported at the 6th Experimental Safety Vehicle Conference (23). The test subjects used in the study were unembalmed human cadavers, a Part 572 anthropometric test device and a prototype side impact test device developed by Transport and Road Research Laboratory (TRRL).

The unembalmed human cadavers were stored under refrigeration (5° C) except when being surgically prepared and were allowed to reach room temperature (25° C) prior to testing. Testing took place typically 5-7 days post mortem, and the effects of rigor mortis were past at the time of testing. Instrumentation surgically attached to the cadavers included the following:

1. An externally mounted array of uniaxial Endevco 2264-2000 piezo-resistive accelerometers on the right side of the head oriented one each in the anterior-posterior (A-P), superior-inferior (S-I) and left-right (L-R) directions.

2. An array of 10 uniaxial Endevco 2264-2000 accelerometers mounted on the thorax in a manner described in detail by Robbins, et al. (24). Briefly, this array consists of biaxial arrays on the first thoracic vertebra (T1) (A-P and S-I) and the twelfth vertebra (T12) (A-P and L-R) as well as various uniaxial mounts on individual ribs and the sternum.

3. An externally mounted triaxial array of uniaxial Endevco 2764-2000 accelerometers in the A-P, S-I and L-R directions on the rear of the pelvis in the mid-sagittal plane.

All accelerometers were attached in a rigid manner to the bony structures indicated. In addition to the accelerometers, pressure transducers (Kulite miniature piezoresistive units) were inserted into the trachea and aortic arch to measure airway and vascular system pressures. The vascular system of the cadavers was fluid filled and the lungs were air-filled; both were pressurized to physiological levels prior to testing. The cadaver test subject data is listed in Table 2.1 for the seven cadavers

TABLE 2.1
Cadaver Test Subject Data

Test No.	Age yrs.	Sex	Stature cm.	Weight kg
003	60	M	181	102.1
009	75	F	156	44.1
010	84	M	162	87.8
011	69	M	170	74.9
029	67	M	167	62.5
039	72	M	187	73.9
042	58	F	178	64.5

used in this study. The cadavers were clothed in vinyl exercise suits to minimize moisture loss and then suited in cotton thermal underwear to provide an appropriate outer surface for testing.

The Part 752 anthropometric test device used in the study was instrumented with triaxial arrays of uniaxial Endevco 2264-2000 accelerometers mounted internally in the required head, thorax and pelvic locations. The dummy was suited in the same type of cotton thermal underwear as the cadavers.

The TRRL side impact test device was instrumented with triaxial arrays of uniaxial Endevco 2264-2000 accelerometers in the head, thorax and pelvis in the same manner as the Part 572 dummy. In addition, this test device features load cells built into the various side structures of the dummy. The load cells are contained in the shoulder, the four individual ribs which comprise the thorax, the iliac crest and the hip. The details of this design can be found in the paper of Harris (25). A notable feature of the device is the absence of arms, -- the shoulder load cells take their place. This dummy was also suited in cotton thermal underwear for the tests.

2.1 Test Methods

All tests in this study were performed at the HSRI Impact Sled Facility. The sled is a deceleration type which operates on the rebound principle. Since the tests were to simulate an unrestrained vehicle occupant in a side impact, the test technique utilized a test fixture consisting of a rigid bench seat mounted in a side impact configuration on the sled with a rigid wall structure representing the side of the vehicle at the left end of the seat. The test subject was placed a predetermined distance from the impact surface such that the subject was free to translate along the seat during the sled deceleration and impact the surface only after the sled deceleration had terminated. This technique produced an impact situation in which the test subject and the impact surface came together at the desired relative impact velocity while allowing the test subject decelerations to be determined solely by the interaction between the subject and the impact surface rather than the sled deceleration profile. Three test relative velocities were used: 15, 20, and 25 mph, designated as

low, medium and high velocities, respectively. In addition, a special low velocity (10 mph) test was performed on the TRRL dummy only.

The impact surface configurations consisted of a flat rigid wall and a contoured energy absorbing structure. The flat wall buck configuration (shown in Figure 2.1) was constructed on one inch plywood backed by a steel beam reinforcing structure tied to the sled. The energy absorbing structure (shown in Figure 2.2) consisted of a thorax and pelvis bolsters developed in the NHTSA RSV program. The thorax bolster was constructed of 6 inches of polystyrene foam drilled with lateral holes to adjust crush strength and covered with 0.5 inches of Ensolite energy absorbing vinyl foam. The pelvis bolster was constructed of 6 inch thick Hexcell cardboard honeycomb also covered with Ensolite. The bolsters were attached to the rigid wall surface of the buck, as shown in Figure 2.2.

Lateral and overhead view high speed movies were taken of every test at 1000 pictures/second.

2.2 Test Results

The results of the test program are presented in the following sections, first in terms of general kinematic and then followed by tabular summaries of transducer response and cadaver injury rating. The transducer signals were filtered according to SAE J211a specifications: head accelerations - Channel Class 1000, thorax and pelvis accelerations - Channel Class 180, and load cells, Channel Class 600.

2.2.1 Test Subject Kinematics. During the phase of the test when the test subject is sliding towards the impact surface, all three types of test subjects behaved similarly and exhibited uniform translation of the body with no relative motion of body parts. As soon as impact with the side structure begins, each type of test subject starts to exhibit individual impact behavior unique to the structural characteristics of the subject. The differences were most marked in the rigid wall impact tests. In the case of the Part 572 dummy, the side of the torso contacts the wall and then deforms slightly due to the low compliance of the dummy internal structure. This is quite pronounced in the shoulder region where the shoulder linkage transmits the forces directly to the base of the neck and thereby starts the head to rotate toward the wall. The resulting lateral flexion of the neck

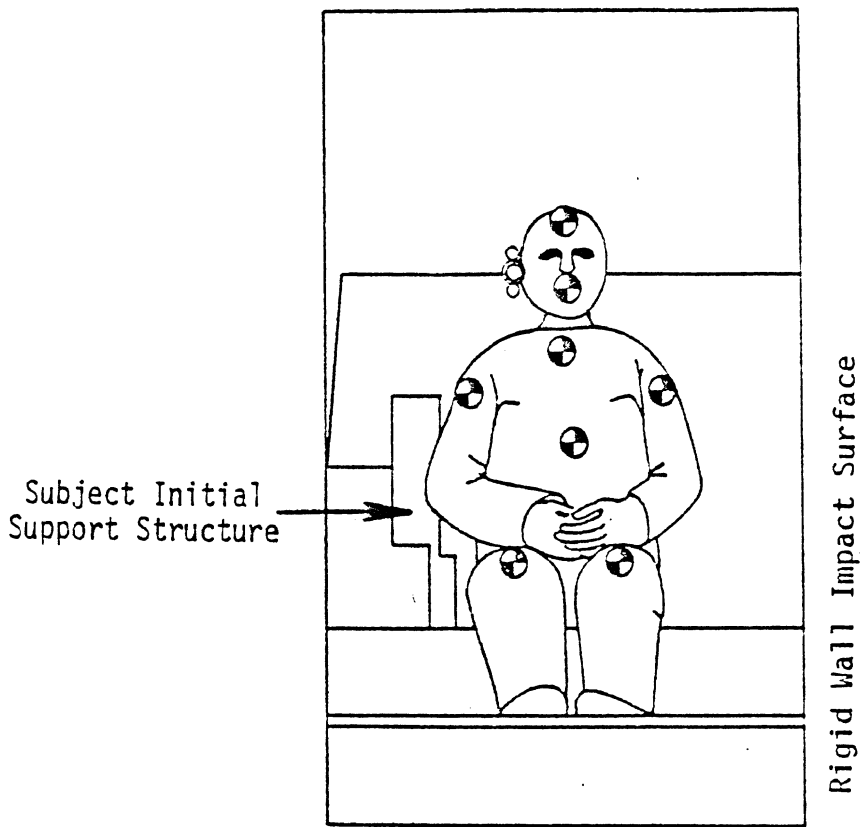


Figure 2.1 Test Set Up Configuration for Rigid Wall Impact Tests

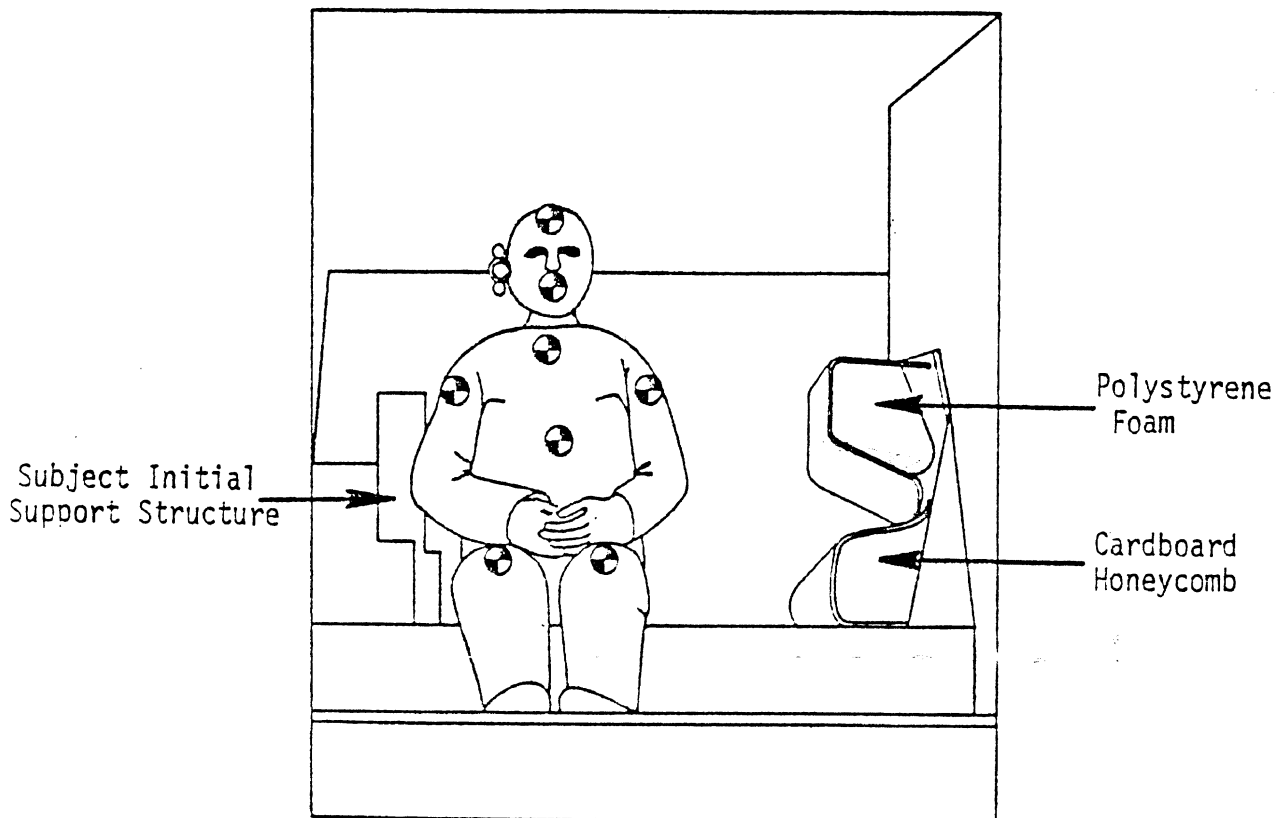


Figure 2.2 Test Set Up Configuration for Energy Absorbing Contoured Side Structure Tests

rotates the head almost horizontally, but the shoulder structure does not let the head fully contact the wall -- it barely grazes it at the higher test velocities. With the TRRL dummy, the lack of arms allows the head to be much closer to the wall and thus the head contacts the wall more directly, although only after lateral neck flexion on the order of 30° - 45° occurs.

The cadaver subjects exhibited a completely different head-neck response in the rigid wall tests. The shoulder linkage of the cadaver displaced laterally with little apparent resistance and the head-neck system does not undergo appreciable lateral flexion. The result is that the head strikes the wall in an upright position, and the loads are carried by the lower parietal and temporal bone regions.

For the case of the padded structure impacts, the differences in head-neck response diminished somewhat due to the spacing of the torso impact surface away from the wall. The highly compliant cadaver shoulder structure still reduces the lateral neck flexion and allows head contact with the wall but the contact is more onto the parietal bone region. It should be noted that the shoulder bones were not broken or dislocated in any of the tests.

The general motions of the rest of the body below the shoulders were similar in all three types of test subjects. The pelvis region tended to rebound first followed by the thoracic region -- leading to a marked tendency of the subject to rotate out of the seat in a counterclockwise manner when viewed from above.

2.2.2 Head Impact Response. The results of the head accelerometer peak readings are summarized in Table 2.2. The lower acceleration values of the Part 572 dummy in all the tests is attributable to the lack of lateral shoulder compliance and its effect on head kinematics as discussed above. The lack of arms on the TRRL dummy allowed head impacts more like those produced with the cadavers to take place. Direct comparison of the A-P and S-I values between cadavers and dummies is questionable due to the external mounting of the accelerometers on the cadaver head. In those cases where skull fracture took place, it can be expected that high peak values may occur in various directions depending on the direction of impact.

TABLE 2.2

Head Peak Accelerations (G)

A. Rigid Wall Impact Tests

Subject	Low Velocity			Medium Velocity					High Velocity	
	CAD	572	TRRL	CAD	CAD	572	572	TRRL	CAD	572
Test No.		012	016	010	011	013	014	017	005	015
A-P	-	6	38	57	125	14	23	25	309	47
S-I	-	50	53	174	138	83	85	157	415	135
L-R	-	64	135	293	179	82	41	197	468	104

B. Padded Side Structure Tests

Subject	Low Velocity			Medium Velocity			High Velocity		
	CAD	572	TRRL	CAD	572	TRRL	CAD	572	TRRL
Test No.	029	028	045	039	043	030	042	044	046
A-P	-	3	5	38	5	-	27	22	38
S-I	-	17	36	278	38	-	233	72	183
L-R	-	12	17	137	28	-	103	49	767

2.2.3 Thorax Impact Response. The results of the thorax accelerometer peak readings are summarized in Table 2.3. Due to the different accelerometer placement on the cadaver thorax, a direct comparison of transducers is not possible. The A-P and S-I values were taken from the biaxial accelerometer pair mounted on the first thoracic vertebra (T1) while the L-R values were taken from a uniaxial accelerometer mounted on the 4th rib on the right hand side of the body (opposite the impacted side).

Comparison of the L-R peaks in the rigid impacts shows that the values produced in the cadaver thorax were generally comparable to those obtained in the Part 572 dummy, while the TRRL dummy gave lower values. It is of interest to note that in the low velocity rigid test, the FMVSS 208 level of 60G for durations exceeding 3 msec was exceeded by the cadaver and the Part 572 dummy while in the padded low velocity test, only the cadaver exceeded the 45 G level, and none exceeded the FMVSS208 level.

2.2.4 Pelvis Impact Response. The results of the pelvis accelerometer peak readings are summarized in Table 2.4. The external placement of the accelerometers on the cadaver pelvis is most likely the cause of the large differences which appear in the A-P and S-I values when comparing the cadaver values to the dummy values. The L-R values are, for the most part, quite comparable in both the rigid wall and padded structure tests. The exception to this is the low velocity padded test.

2.2.5 Cadaver Injury Ratings. The injuries sustained by the cadavers in the various rigid wall impact tests are listed in Table 2.5 along with the assessments of the Abbreviated Injury Scale (AIS) ratings of the injuries. The moderate injuries sustained in the 15 mph impact escalate sharply at the 20 mph level indicating that in rigid wall impacts the AIS 3 level is most likely reached in the 17-18 mph velocity range. The severity of the injuries at the 25 mph level point out the serious need to manage the occupant kinetic energy in impacts at velocities considerably lower than those associated with frontal crashes.

TABLE 2.3

Thorax Peak Accelerations (G)

A. Rigid Wall Impact Tests

Subject	Low Velocity			Medium Velocity					High Velocity	
	CAD	572	TRRL	CAD	CAD	572	572	TRRL	CAD	572
Test No.	003	012	016	010	011	013	014	017	009	015
A-P	73	15	5	56	95	17	18	42	100	40
S-I	196	18	16	107	81	35	22	42	96	84
L-R	82	61	42	120	149	139	147	89	150	162

B. Padded Side Structure Tests

Subject	Low Velocity			Medium Velocity			High Velocity		
	CAD	572	TRRL	CAD	572	TRRL	CAD	572	TRRL
Test No.	029	028	045	049	043	030	042	044	046
A-P	14	5	5	25	4	11	44	14	13
S-I	24	8	5	37	12	7	51	24	26
L-R	56	28	37	19	102	40	175	145	88

TABLE 2.4
Pelvis Peak Accelerations (G)

A. Rigid Wall Impact Tests

Subject	Low Velocity			Medium Velocity					High Velocity	
	CAD	572	TRRL	CAD	CAD	572	572	TRRL	CAD	572
Test No.	003	012	016	010	011	013	014	017	009	015
A-P	22	10	8	41	-	21	24	28	54	42
S-I	65	14	93	63	70	63	47	96	47	61
L-R	53	60	49	70	149	286	278	147	279	379

B. Padded Side Structure Tests

Subject	Low Velocity			Medium Velocity			High Velocity		
	CAD	572	TRRL	CAD	572	TRRL	CAD	572	TRRL
Test No.	029	028	045	039	043	040	042	044	046
A-P	42	3	4	7	7	-	35	9	23
S-I	20	5	6	19	15	-	43	35	43
L-R	78	28	34	39	44	-	106	121	74

TABLE 2.5

Cadaver Injury Summary - Rigid Wall Impact Tests

Test No.		Injuries	AIS Rating
003 25 kph	Thorax	Left side - minor rib fracture directly under fourth rib accelerometer mount	2
010 33 kph	Head	Superficial bruising of brain at the base of the frontal lobe	4/5
	Thorax	Left side - fracture of ribs 1, 2, 3, 4, 5, 6, 7, and 8 in front and 3 and 4 in rear Right side - fractures of ribs 1, 2, 3, 4 and 5 in front	4
011 33 kph	Head	Depressed fracture of the left side of the skull, free blood in the cavity right side: subarachnoid hemorrhage left side: frontal lobe hemorrhage	5
	Thorax	Left side - fractures of ribs 2, 3, 4, 5, 6, 7, and 9 Right side - fractures of ribs 2, 3, 4, 5 and 6 Spinal dislocation between C4/C5	4
	Abdomen	Liver - small tear on surface Spleen - crushed	4
009 43 kph	Head	Left side - massive depressed skull fractures and extensive hemorrhaging in scalp, muscle, and dura mater	6
	Neck	Cervical spine fractures at C1 and dislocation between C2/C3	6
	Thorax	Left side - 15 rib fractures in front and 11 rib fractures in rear Right side - 13 rib fractures in front and 2 rib fractures in rear 7 cm. tear of left lung with free blood 2 cm. tear of pulmonary artery	6
	Abdomen	Crushed left kidney	5
	Pelvis	Left side iliac crest crushed severely with soft tissue damage	5

The results of the injuries sustained in the padded structure tests are given in Table 2.6. Although the severity of the injuries was reduced at the high velocity in comparison to the rigid wall test, the padded structures did not change the injury level of the thorax at the medium velocity and actually raised it slightly in the low velocity test. The padded structure did help to reduce head injuries in the low and medium test velocities even though the head hit the wall in the medium velocity test.

Some insight into the factors affecting injury production in the padded side structures can be gained by examining the resulting deformation patterns in the energy absorbing materials used in the structures. The Part 752 dummy consistently produced larger localized penetrations of the thorax padding and in the medium and high velocity tests most likely bottomed the foam out, that is, completely penetrated it. This was due to the rigidity of the arm structure which penetrated the foam at lower load levels than produced by more distributed loading on the side of the cadaver thorax. The TRRL dummy with no arms produced thorax padding deformation patterns similar to those of cadavers.

An additional feature was noted in the deformations of the pelvis honeycomb padding. The cadaver tests tended to produce crushing distributed along the honeycomb in contrast to the more localized crushing associated with the pelvis and knees of the dummies. This behavior may be due to the more concentrated masses of the dummy pelvis and knee structures as opposed to the more evenly distributed soft tissue masses of the cadavers.

2.3 Summary and Conclusions

A series of comparative side impact tests using unembalmed human cadavers, a Part 572 test device and the TRRL side impact test device has been presented in brief. The results of the program indicate the following:

1. Significant differences in head-neck kinematics exist in the side impact behaviors of the three types of test subjects; the lack of lateral compliance of the shoulder structure in dummies contributes to this effect.

TABLE 2.6

Cadaver Injury Summary - Padded Side Structure Tests

Test No.		Injuries	AIS Rating
029 25 kph	Thorax	Left side - 4 rib fractures	3
039 33 kph	Thorax	Left side - 11 rib fractures, very slight surface hemorrhage on heart	4
042 43 kph	Head	Left side - massive depressed skull fracture with fractures extending to the right side. Extensive hemorrhage over the right temporal and parietal lobes of the brain	5
	Thorax	Left side - 12 rib fractures Mid shaft fracture of left humerus	4

2. The peak responses of the thorax accelerometers were similar in the three types of test subjects, but the resulting injuries in the limited cadaver test sample did not correlate well with suggested tolerance levels for lateral acceleration.

3. The peak responses of the pelvis accelerometers were similar for the three types of test subjects.

4. The differences between dummy and cadavers in lateral compliance of the shoulder and arm structures and in the distribution of masses in the lower body must be considered in the design of energy-absorbing side impact structures.

3.0 SLED TEST PROGRAM

A series of nine side impact tests using a single Part 572 dummy (Alderson Research Laboratories Model HybridII Serial No. 658) were conducted with the HSRI Impact Sled Facility. The purpose of these tests was to aid in identifying those dummy components which exert a major influence on the overall dummy response during side impact. The sled used was a deceleration type which operates on the rebound principle. Since the tests were to simulate an unrestrained vehicle occupant in a side impact, the test technique utilized a test fixture consisting of a rigid bench seat mounted in a side impact configuration on the sled with a rigid wall structure representing the side of the vehicle at the left end of the seat. The test subject was placed a predetermined distance from the impact surface such that the subject was free to translate along the seat during the sled deceleration and impact the surface only after the sled deceleration had terminated. This technique produced an impact situation in which the test subject and the impact surface came together at the desired relative impact velocity, while allowing the test subject decelerations to be determined solely by the interaction between the subject and the impact surface, rather than the sled deceleration profile. Three basic impact surface/dummy configurations were used. These configurations were:

Configuration 1. (Figure 3.1) Purpose: This configuration was designed to produce nominally simultaneous impact to the head, chest (through the shoulder and arm) and pelvis (through the leg). The configuration was based on the results of human cadaver tests conducted under NHTSA Contract No. DOT-HS-4-00921, where the cadavers impacted a flat rigid wall in a head-upright manner due to high compliance of the shoulder structure in the cadaver.

Dummy: Seated in a normal manner with arms at the side and hands together in the lap.

Impact Surface: Stepped rigid surface consisting of end grain balsa wood blocks faced with one half inch thick plywood. A modified version of this surface was used for padded head impacts with two inches of Ensolite vinyl foam padding shown in Figure 3.2.

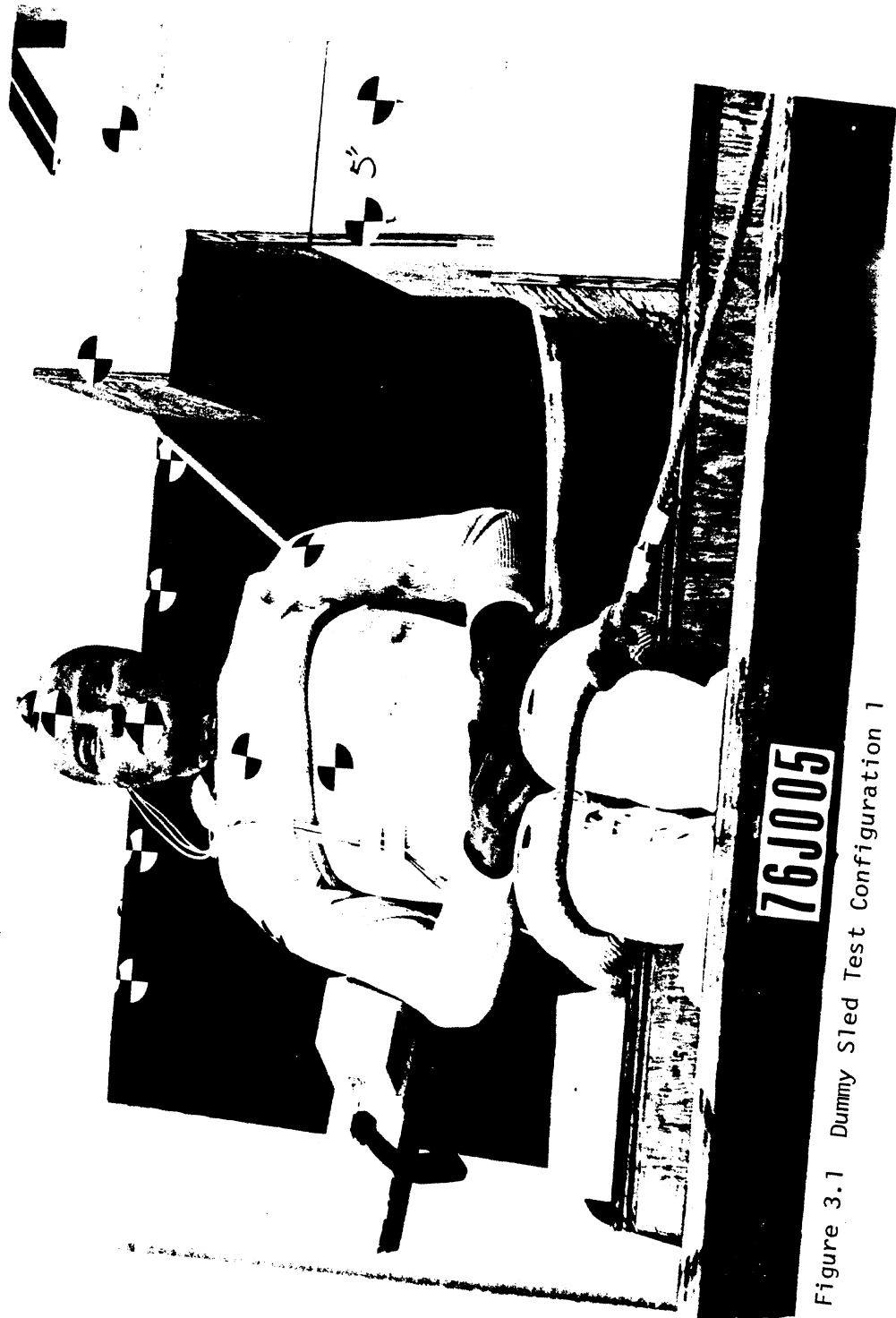


Figure 3.1 Dummy Sled Test Configuration 1

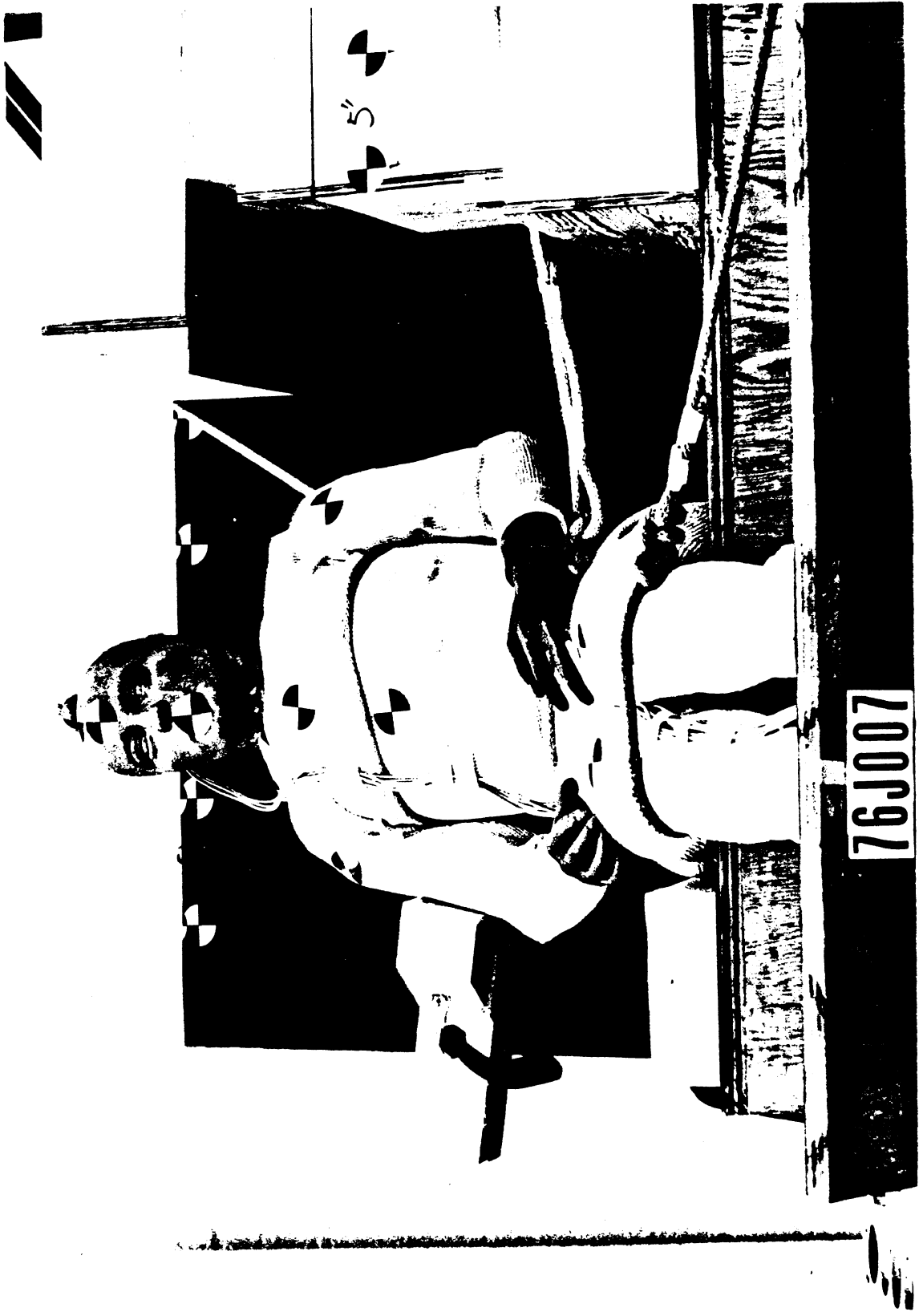


Figure 3.2 Dummy Sled Test Configuration 1 (with head Padding)

Configuration 2. (Figure 3.3) Purpose: This configuration was designed to produce a torso side impact including the arm and shoulder but with no head contact. The intention was to simulate a side impact where there is no side window (due many times to shattering of the window during the initial exterior side impact in a vehicle).

Dummy: Seated in a normal manner with the arms at the side and the hands together in the lap.

Impact Surface: Stepped rigid surfaces without the head impact surface of Configuration 1. -- to allow simultaneous arm and pelvis contact.

Configuration 3. (Figure 3.4) Purpose: This configuration was designed to produce a torso side impact without loading the arm and shoulder of the dummy -- in order to obtain direct loading of the dummy chest structure.

Dummy: Seated in a normal manner but with the left arm raised up and folded across the upper thorax.

Impact Surface: Stepped rigid surface to allow simultaneous chest and pelvis contact.

Instrumentation for the sled test series consisted of head, chest, and pelvis triaxial accelerometer units (triaxial sets of uni-axial Endevco 2264-2000 accelerometers), sled acceleration and velocity and high speed movie coverage at 1000 pictures/second - side and overhead views. Transducer data was recorded unfiltered on magnetic tape at 30 ips. For display purposes, the data was played back at 1 7/8 ips and filtered at the following SAE Channel Class filter levels:

- a. Head acceleration -- Class 1000
- b. Chest acceleration -- Class 180
- c. Pelvis acceleration -- Class 180
- d. Sled acceleration -- Class 60

The filtered analog data for all of the sled tests is displayed in Appendix A of this report.

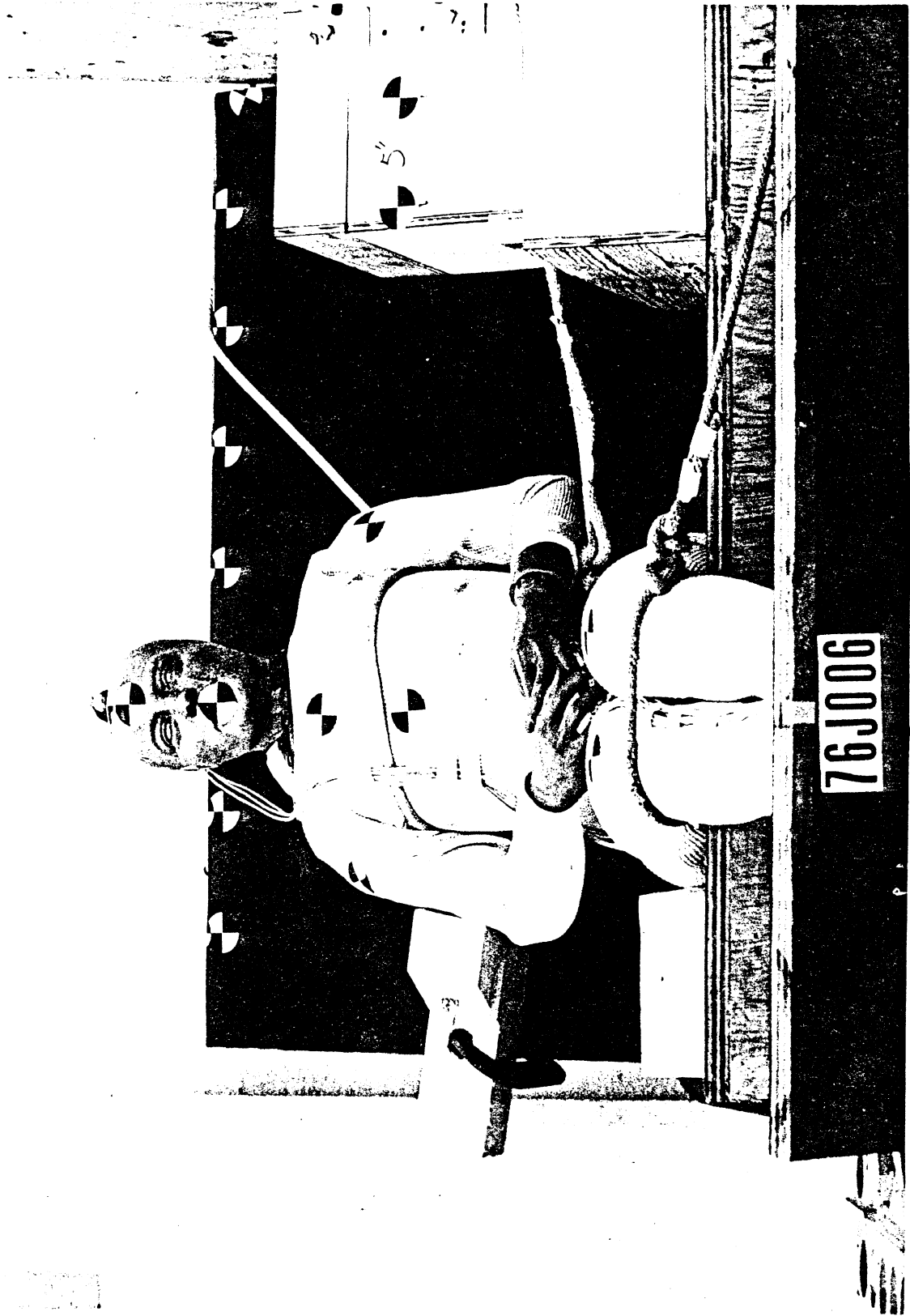


Figure 3.3 Dummy Sled Test Configuration 2

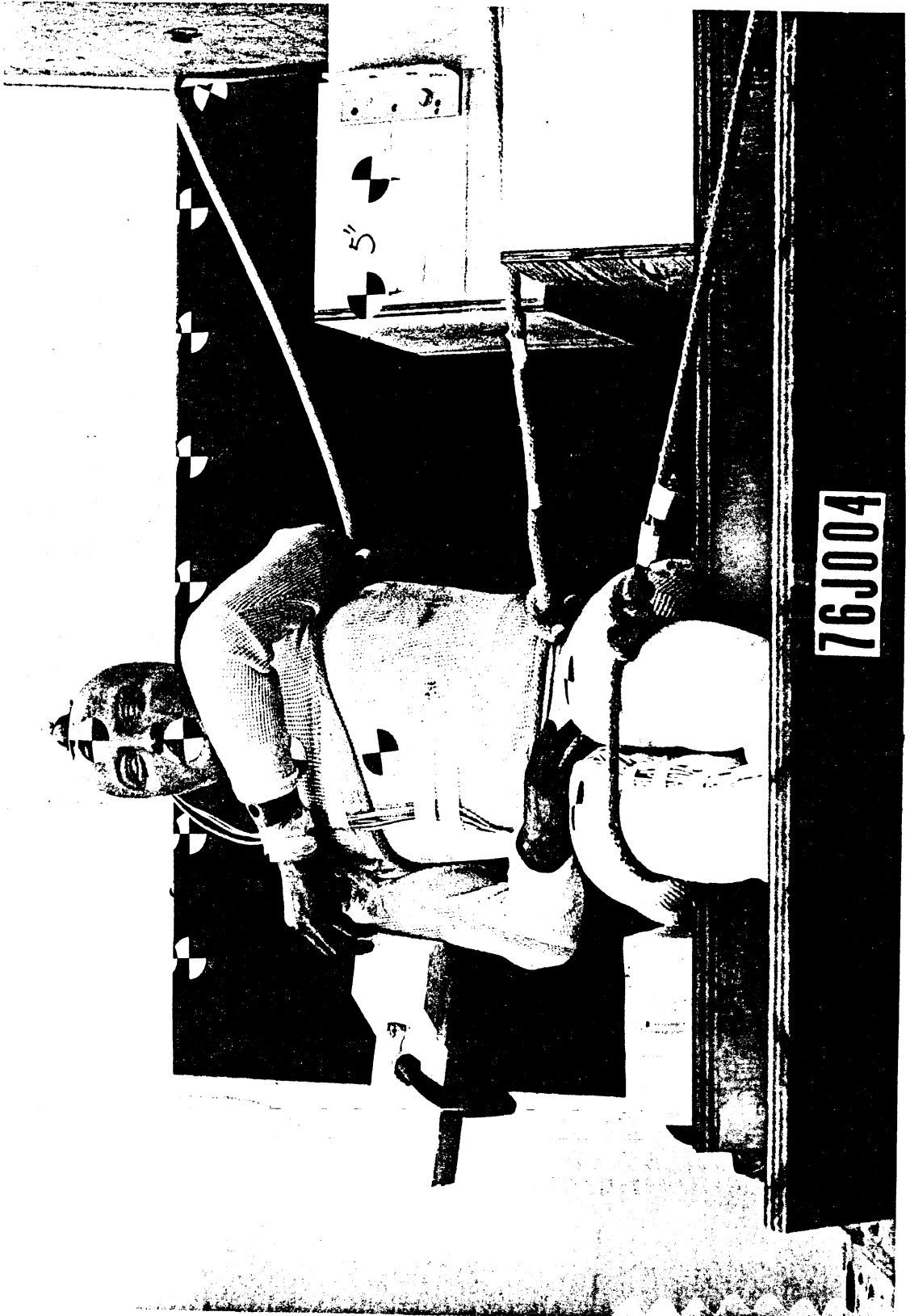


Figure 3.4 Dummy Sled Test Configuration 3

3.1 Initial Sled Test Series

An initial test series of three tests were conducted, one each of the above basic configurations. A sled velocity was chosen to produce approximately a 15 mph relative velocity between the dummy and the impact surface, a condition similar to the lowest velocity used with cadavers in the test program of DOT-HS-4-00921. The dummy was clothed in cotton thermal underwear in a manner similar to the cadaver tests. This allowed the dummy to slide freely along the rigid seat surface prior to impact with the vertical surface.

The results of the three initial tests (76J001, 76J002, and 76J003) are presented in Table 3.1 in terms of the peak accelerations recorded in each of the anatomical coordinate directions A-P (anterior-posterior), S-I (superior-inferior) and L-R (left-right) for each body region. In many of the regions, the peak L-R accelerations were higher than obtained in comparable cadaver-dummy tests, and it was judged that a lower test velocity would be more appropriate to avoid overdriving the system. Thus, a second series of tests were performed.

3.2 Second Sled Test Series

The second sled test series were performed with a relative velocity between subject and impact surface of 8-10 mph. The same test configurations were used as in the previous tests, with the addition of the padded head impact surface (test numbers 76J007 and 76J008). The test results in terms of the peak accelerations recorded in each of the anatomical coordinate directions for each body region are listed in Table 3.2. These results were judged to be more satisfactory in terms of the acceleration levels produced in the chest and pelvis but the head acceleration level of 439 G in the rigid impact was still too severe. The padded impact tests produced much lower head accelerations (53-65 G).

The head/neck response of the test number 76J009 was analyzed photometrically to obtain the angular response of the head relative to the torso. This is shown in Figure 3.5 as a function of time. The analog traces of the body region accelerations judged most representative of the test series are shown for the L-R direction in Figures 3.6 (head), 3.7 (chest) 3.8 (shoulder) and 3.9 (pelvis).

Table 3.1 Body Region Peak Accelerations -- Initial Test Series

Test Number	Test Configuration	Body Region Peak Accelerations, G								
		Head			Chest			Pelvis		
		AP	SI	LR	AP	SI	LR	AP	SI	LR
76J001	1	42	75	665	0	0	187	20	17	115
76J002	2	13	38	65	13	8	204	19	19	102
76J003	3	4	24	59	11	18	75	12	7	145

Table 3.2 Body Region Peak Accelerations -- Second Test Series

Test Number	Test Configuration	Body Region Peak Accelerations, G								
		Head			Chest			Pelvis		
		AP	SI	LR	AP	SI	LR	AP	SI	LR
76J004	3	3	16	14	5	10	36	3	8	35
76J005	1	24	47	439	2	2	52	3	5	29
76J006	2	2	24	24	0	1	71	4	6	36
76J007	1 (padded)	6	12	53	3	19	71	2	7	41
76J008	1 (padded)	4	8	65	5	7	56	4	6	32
76J009	2	2	18	24	8	7	47	4	10	29

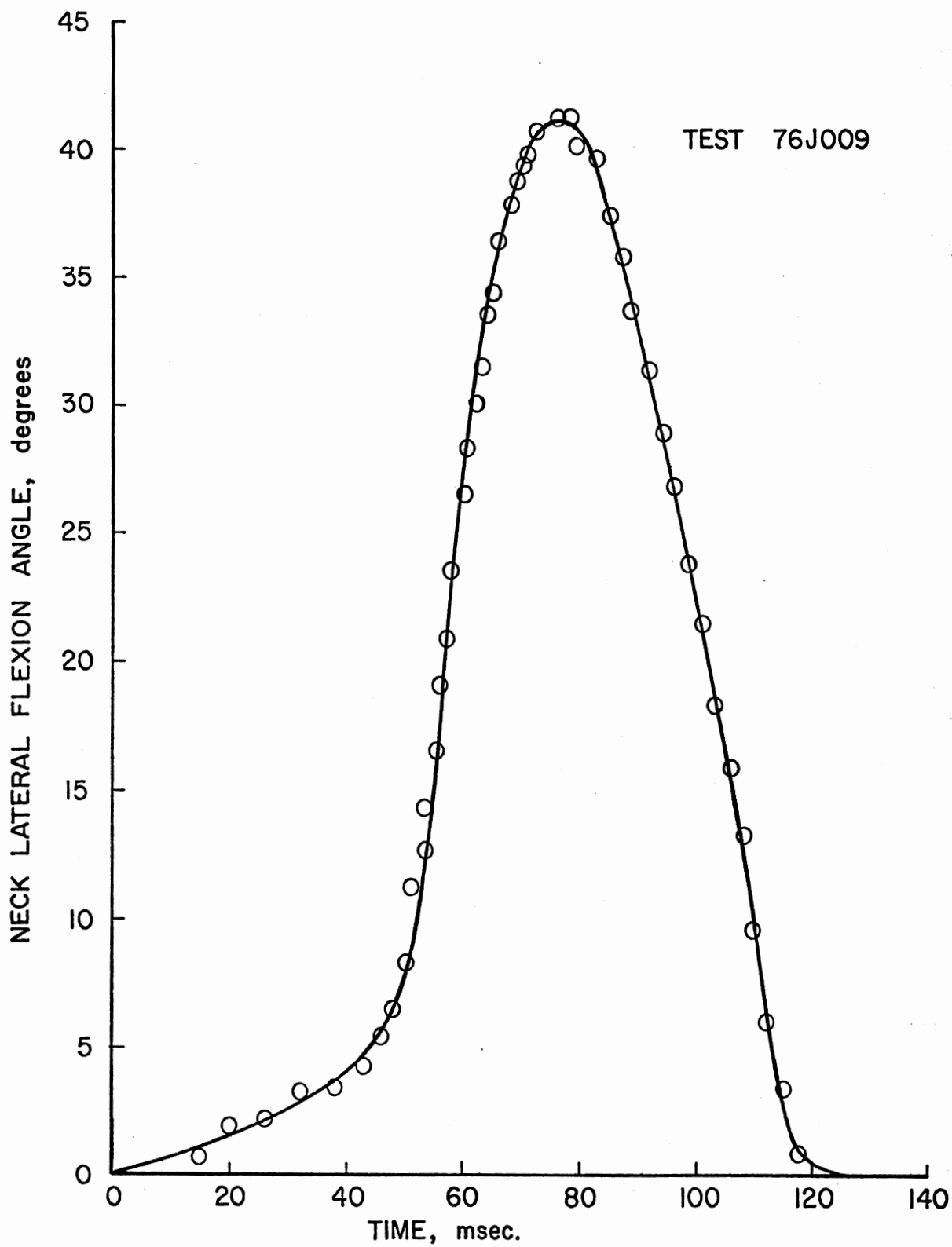


Figure 3.5 Dummy Neck Lateral Flexion Angle-Time History, Sled Test 76J009

Test 76J008 Head Acceleration

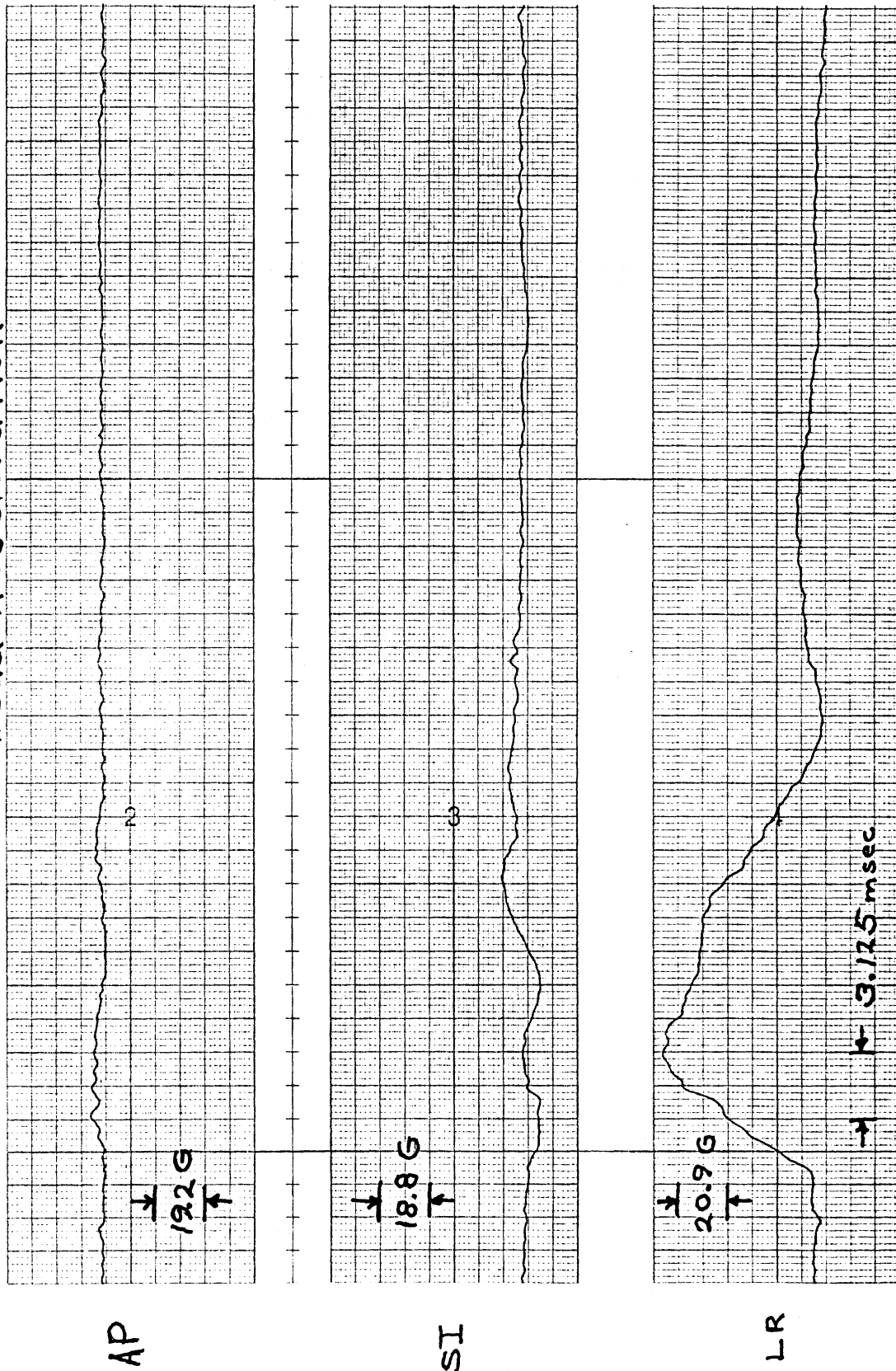


Figure 3.6 Dummy Head Acceleration-Time History, Sled Test 76J008

Test 76J004 Thorax Acceleration

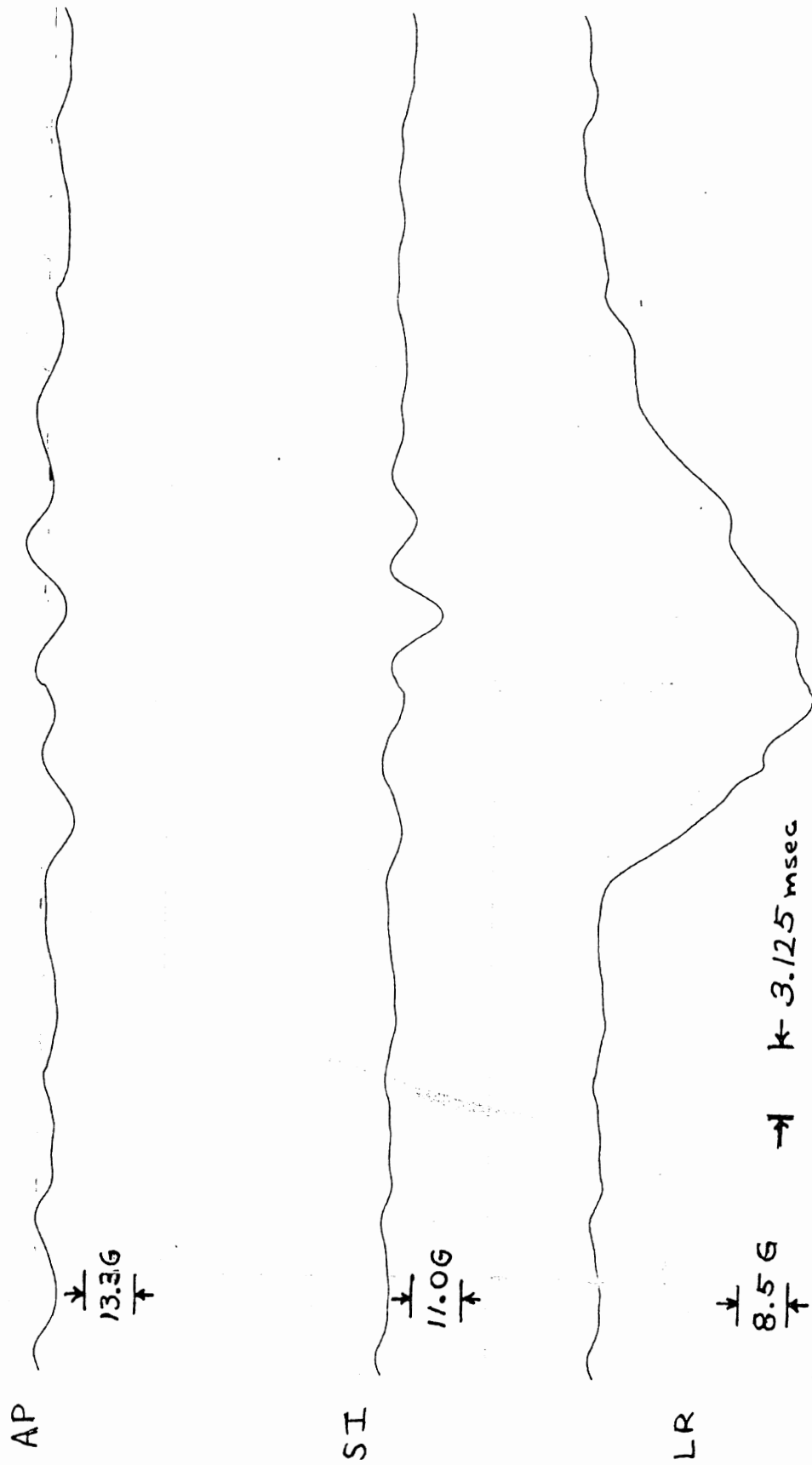


Figure 3.7 Dummy Thorax Acceleration-Time History, Sled Test 76J004 - Direct Thorax Loading

Test 76J009 Thorax Acceleration

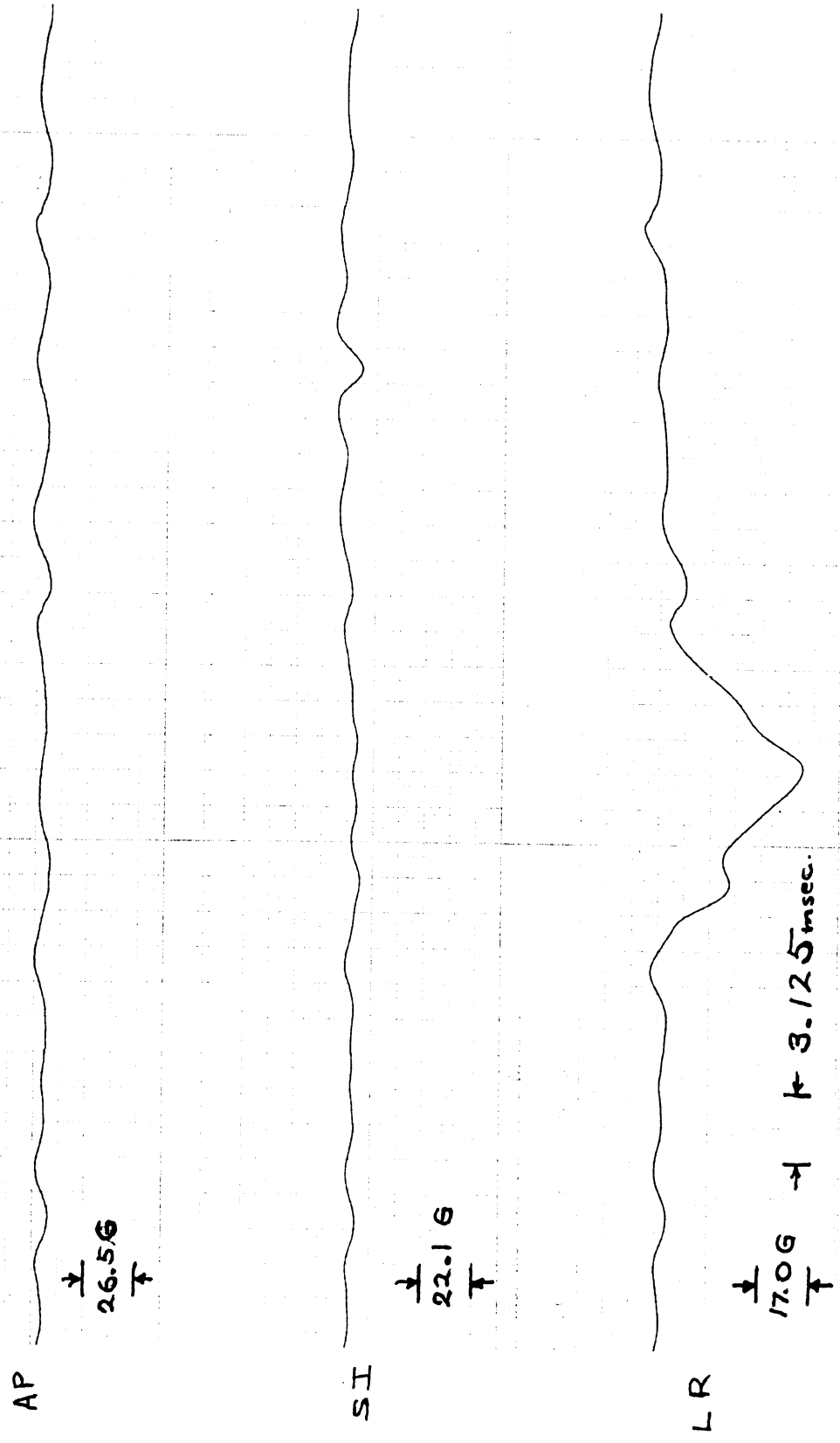


Figure 3.8 Dummy Thorax Acceleration-Time History, Sled Test 76J009 - Shoulder Loading

Test 76J004 Pelvis Acceleration

↓
10.0 G
↑

AP



↓
9.3 G
↑

SI



↓
10.6G
↑

→ ← 3.125 msec

LR

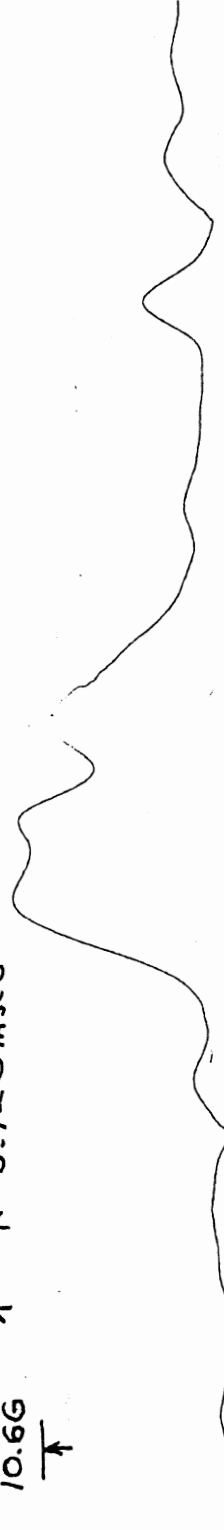


Figure 3.9 Dummy Pelvis Acceleration-Time History, Sled Test 76J004

The response data produced in the second series of sled tests was found to be the most comparable in general to the Calspan side impact dummy crash test data (Section 1.1.3) and the low velocity cadaver test data (Section 2.0). The rigid impacts to the thorax and pelvis in the second test series produced responses that were similar in level to realistic crash simulations using deformable side structures. The padded head impacts also produced appropriate response levels. Thus, the response data and the impact velocities produced in the second series of sled tests was used as a guide in the development of calibration procedures.

4.0 DEVELOPMENT OF TESTS, TESTING PROCEDURES AND CALIBRATION CRITERIA FOR TEST DUMMY SIDE IMPACT

Analysis of the results of the sled testing program in combination with the results of other biomechanical research programs (Sections 1.1 and 2.0) and accident investigation data (Section 1.2) indicated that the body regions of greatest importance in the side impact situation in terms of combination of injury potential, frequency of injury, and control of response are:

1. Head
2. Neck
3. Thorax (also including shoulder and arm loading)
4. Pelvis (including hip and thigh)

Other regions such as the abdomen and lumbar spine were studied but were considered to be of lesser importance, either due to lack of involvement in accidents (lumbar spine) or lack of effect on side impact response (abdomen). In both these regions there is a total lack of any biomechanical response data.

4.1 Development of Test Equipment

The criteria used to select the test configurations and equipment for performing calibration tests were:

1. Simplicity of design and instrumentation.
2. Degree of control of trajectory and repeatability of test conditions.
3. Effectiveness and relevance of the tests in producing realistic responses.

After review of the calibration testing procedures now in use for frontal impacts, it was concluded that, whenever possible, it would be useful to apply existing equipment and test techniques to side impact testing. The goal of simplicity of design and minimization of diverse test equipment for conducting the tests led to consideration of the test probe device used in frontal calibration impact tests for the chest and knees of dummies. The probe consists of a 51.5 lb. cylindrical impact mass which has a 6 inch diameter impact face

and is guided during impact to produce a linear motion with no significant lateral, vertical or rotational movement. The acceleration of the probe along its axis is transduced by an axially positioned accelerometer. Typically, this probe is suspended by 4 or 8 cables and is pulled back, up and away from the test subject, and allowed to swing freely into the subject at the desired test velocity. HSRI decided to decouple the impactor probe and the velocity producing process in order to obtain more versatility of use and control of the trajectory of the probe. This was achieved by supporting the impact probe, in the form of a steel cylinder 2.5 inches in diameter with a 6 inch diameter test face on one end, in a linear ball bearing fixture. The housing for the bearing also served as a stroke limiting device for the probe. The energy source for driving the probe at any desired velocity was a modified version of the neck test pendulum used in frontal dummy calibration testing. The pendulum as installed at HSRI was somewhat longer than a standard pendulum (105.6 inches versus 65.25 inches) and more massive. The addition of weight to the standard pendulum can produce the same pendulum response as the modified pendulum at HSRI, however. A schematic drawing of the overall test system arrangement is shown in Figure 4.1.

The probe stroke is limited by the bearing support structure through the use of a butyl rubber compression ring to attenuate the snubbing force. Strokes up to 15 inches can be obtained with the present design. An overall view of the device is shown in Figure 4.2 Note also the use of a conventional automobile tubular hydraulic shock absorber as a snubber for any excess pendulum kinetic energy following the transfer of the pendulum energy to the probe.

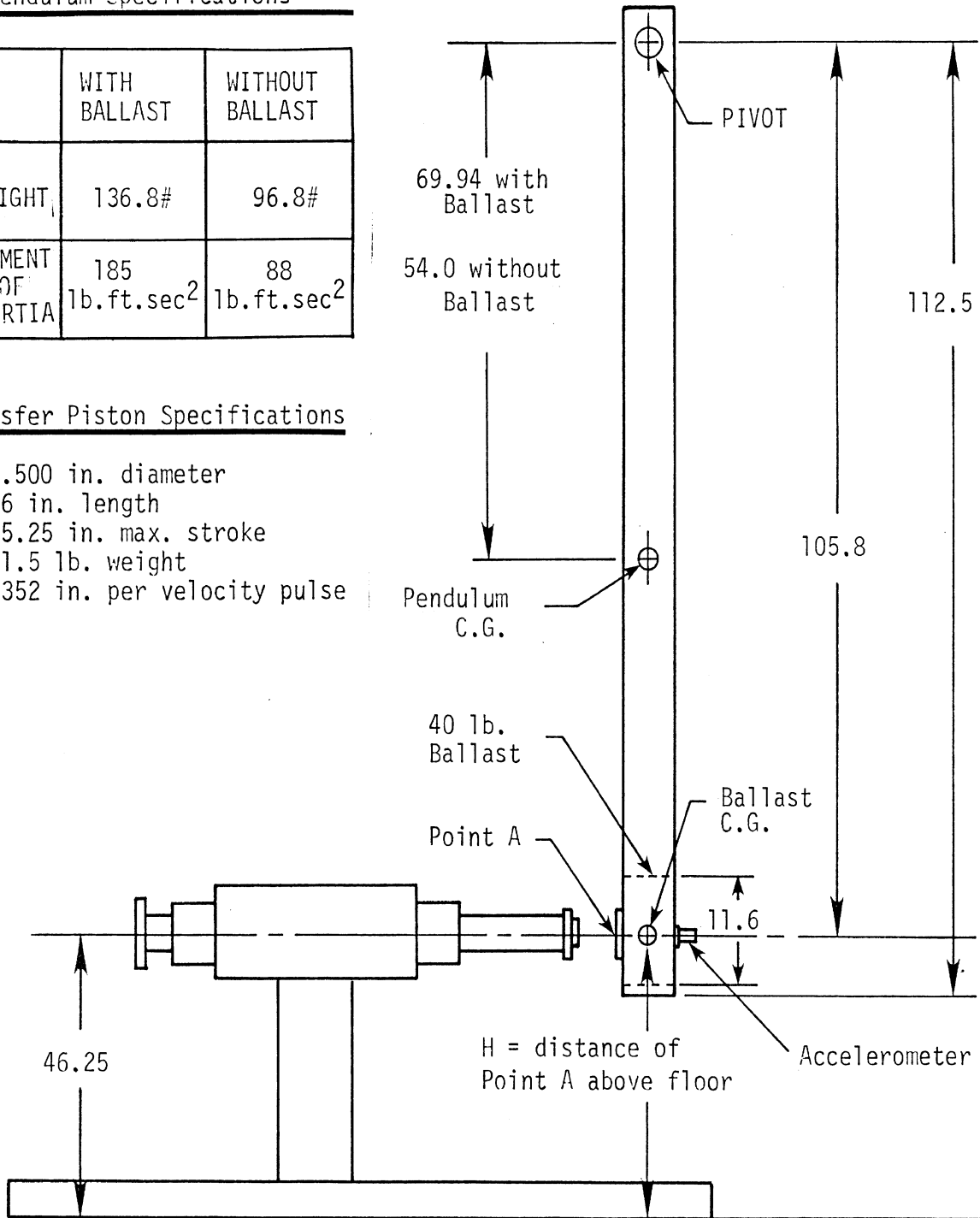
A magnetic pick-up is incorporated into the bearing housing design to allow probe velocity measurement. A serrated metal strip which is part of the probe shaft passes under the pick-up and produces a sawtooth voltage output which can be recorded as a function of time. The velocity of the probe can be calculated from the frequency of the sawtooth waveform and the known spacing of the serrations.

Pendulum Specifications

	WITH BALLAST	WITHOUT BALLAST
WEIGHT	136.8#	96.8#
MOMENT OF INERTIA	185 lb.ft.sec ²	88 lb.ft.sec ²

Transfer Piston Specifications

2.500 in. diameter
 36 in. length
 15.25 in. max. stroke
 51.5 lb. weight
 .352 in. per velocity pulse



All lengths are in inches.

Figure 4.1 Schematic Layout of the HSRI Pendulum Impactor System

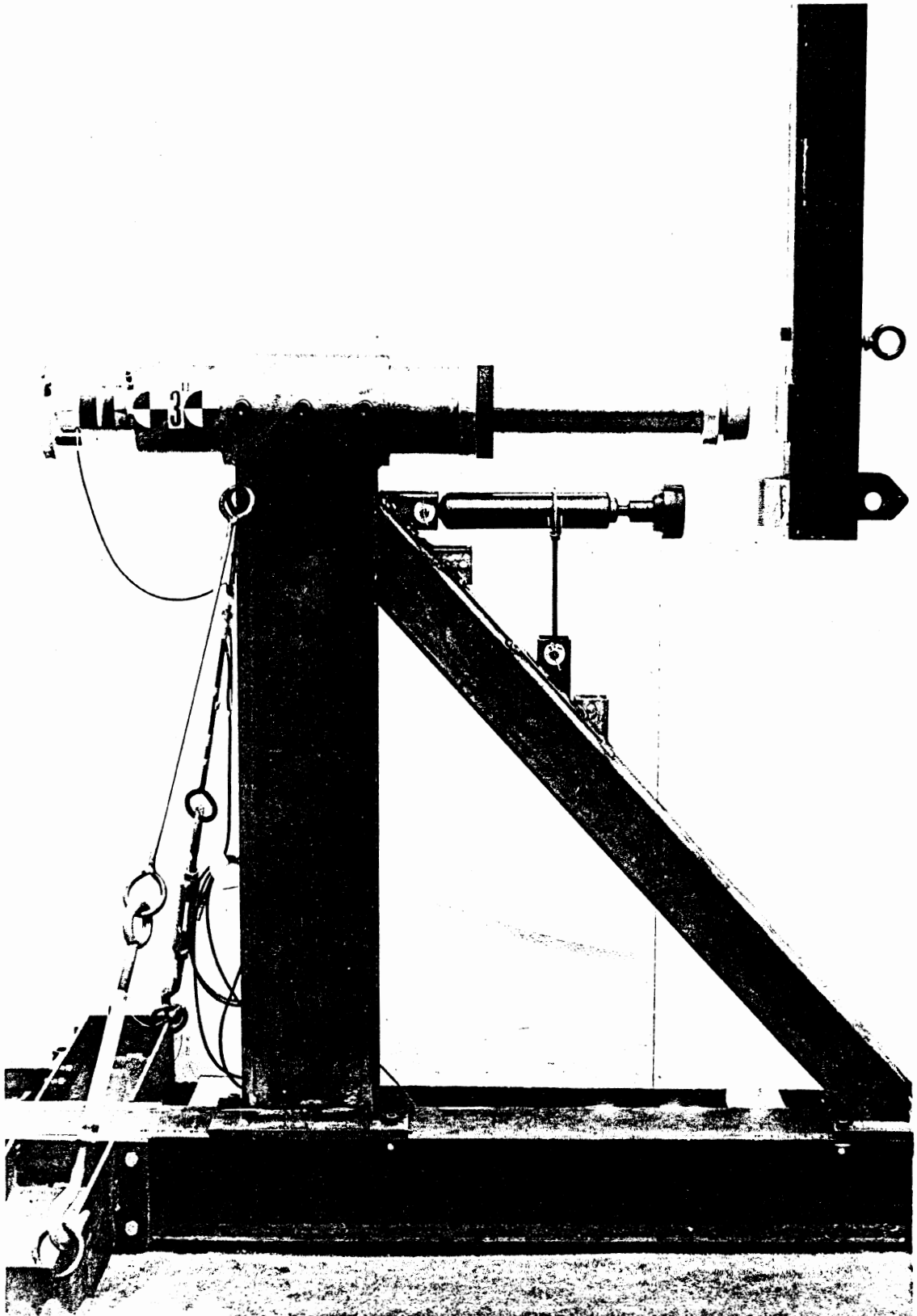


Figure 4.2 HSRI Pendulum Impactor System

The impact probe and its bearing support structure were mounted rigidly to a beam structure which was, in turn, fastened to the laboratory floor. A simple flat horizontal seat surface, adjustable for height, was also mounted on the beam near the impact surface side of the probe. This seat was provided with an adjustment height range sufficient to allow the probe axis to coincide with any point between the dummy pelvis and the head c.g. axis.

In order to use the neck test pendulum as a means of testing dummy necks, rather than as an energy source for the impact probe, it is only necessary to block the impact probe into a suitable position, add an adapter plate to the end of the probe and place an aluminum honeycomb crush material on the adapter plate. The system then functions as the decelerator for the neck pendulum as shown in Figure 4.7.

4.2 Development of Test Procedures

The regions of the dummy that were chosen to be impacted with the probe device were:

1. Side of the head through the head center of gravity.
2. Shoulder-arm structure at the same height from the seat surface as the Part 572 frontal chest impact height (17.7 inches).
3. Side of the thorax (with the arm raised out of the way) at the level of 17.7 inches from the seat surface.
4. Side of the hip (thigh-pelvis structure) through the H-point of the thigh-pelvis structure.

In addition, a lateral neck response test was chosen which was similar to the Part 572 frontal test but with the head/neck system oriented for lateral impact.

The development of the test procedures centered around determining appropriate speeds for the various tests which would produce the desired acceleration and time duration response levels with respect to the sled test and car crash side impact data. It was felt that, whenever possible, the calibration testing procedures should be conducted with the intact dummy to minimize the efforts of tearing down and assembly for each calibration.

4.2.1 Head Test Procedures. Initially, consideration was given to developing a padded head impact test with a probe velocity in the 14 fps range and some preliminary experiments of this type were conducted. Although the tests were successful using one inch of Ensolite padding, there was a concern over the possible influence on the test repeatability that padding property variations might exert. As a result it was concluded that a rigid impact surface would eliminate this problem, but that it would require a lower probe velocity in order to produce reasonable levels of head acceleration. Thus, a 7 fps test velocity was chosen for further investigation. This test condition produced a L-R peak acceleration on the order of 240 G for a pulse duration of about 2 msec. The response is similar to the Part 572 frontal head impact response and if the test were applied to more biomechanically realistic head designs it should produce an acceptable test condition for such heads as evidenced in the HSRI dummy development effort (22). The test configuration is shown in Figure 4.3. The dummy is seated in a stable upright position and the seat height is adjusted to allow the probe centerline to pass through the center of gravity of the dummy head. The test procedure is to be conducted on both the left and the right side of the dummy head. The duration of the rigid impact is so brief, that the fact that the head is attached to the rest of the dummy is of little or no consequence in determining the head response to such an impact at the 7 fps velocity level.

4.2.2 Shoulder Test Procedures. The purpose for developing a shoulder test procedure is twofold. First, the shoulder and arm structure influences the loading of the thorax in a major manner in lateral impact and therefore its response should be calibrated. Secondly, if appropriate biomechanical data were available for shoulder and arm structural response, its specification and calibration would be an important improvement in test dummy development. In view of the complete lack of any definitive data on shoulder structural response, only the first purpose can presently be served by a calibration test. With this in mind it was decided to position the dummy and seat such that the probe axis was at a level of 17.7 inches above the seating surface and centered on the upper arm fore and aft when the upper arm is straight down and the lower arm horizontal as shown in Figure 4.4. Although cotton underwear was worn, the padding was removed

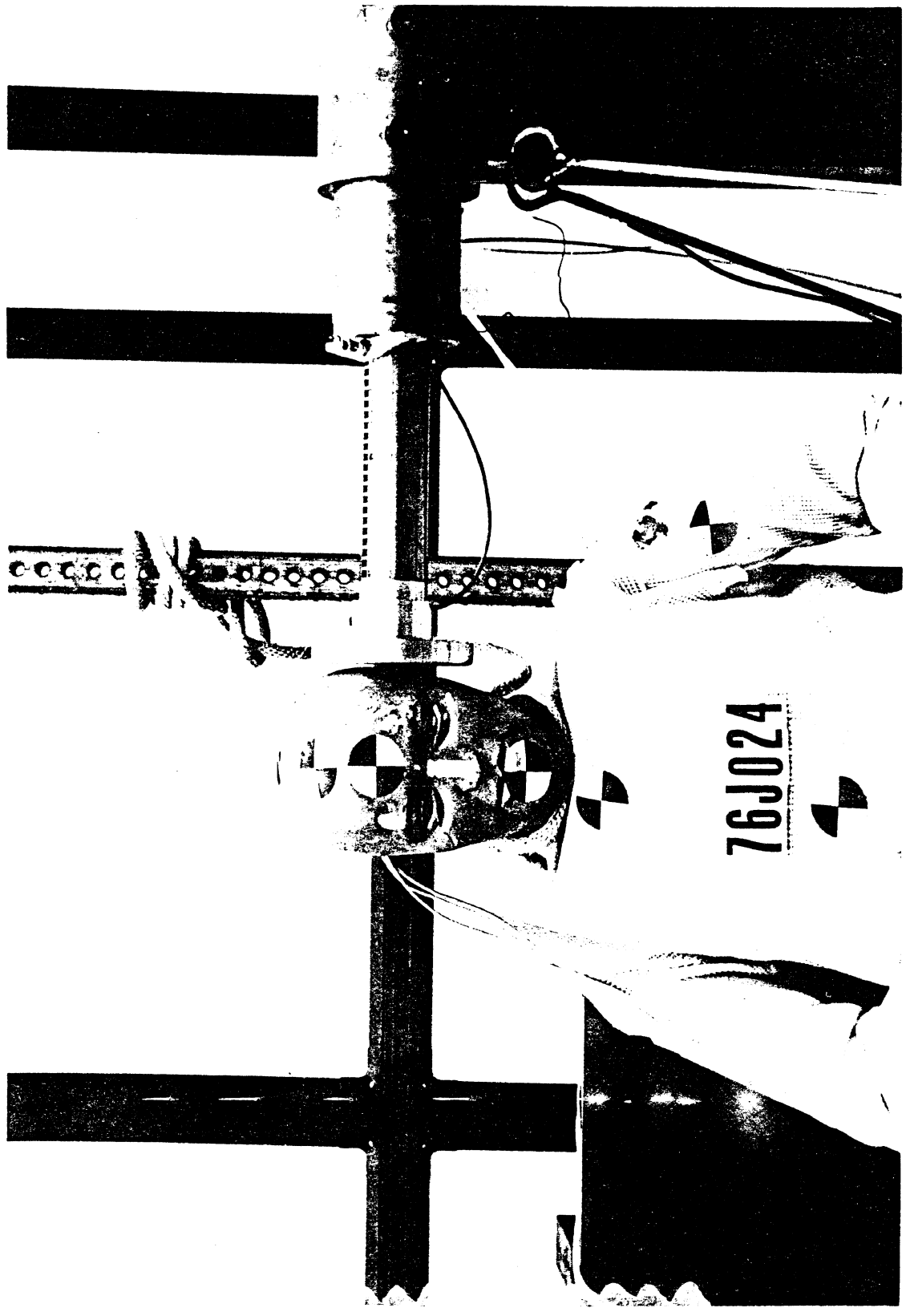


Figure 4.3 Rigid Head Impact Calibration Test Configuration

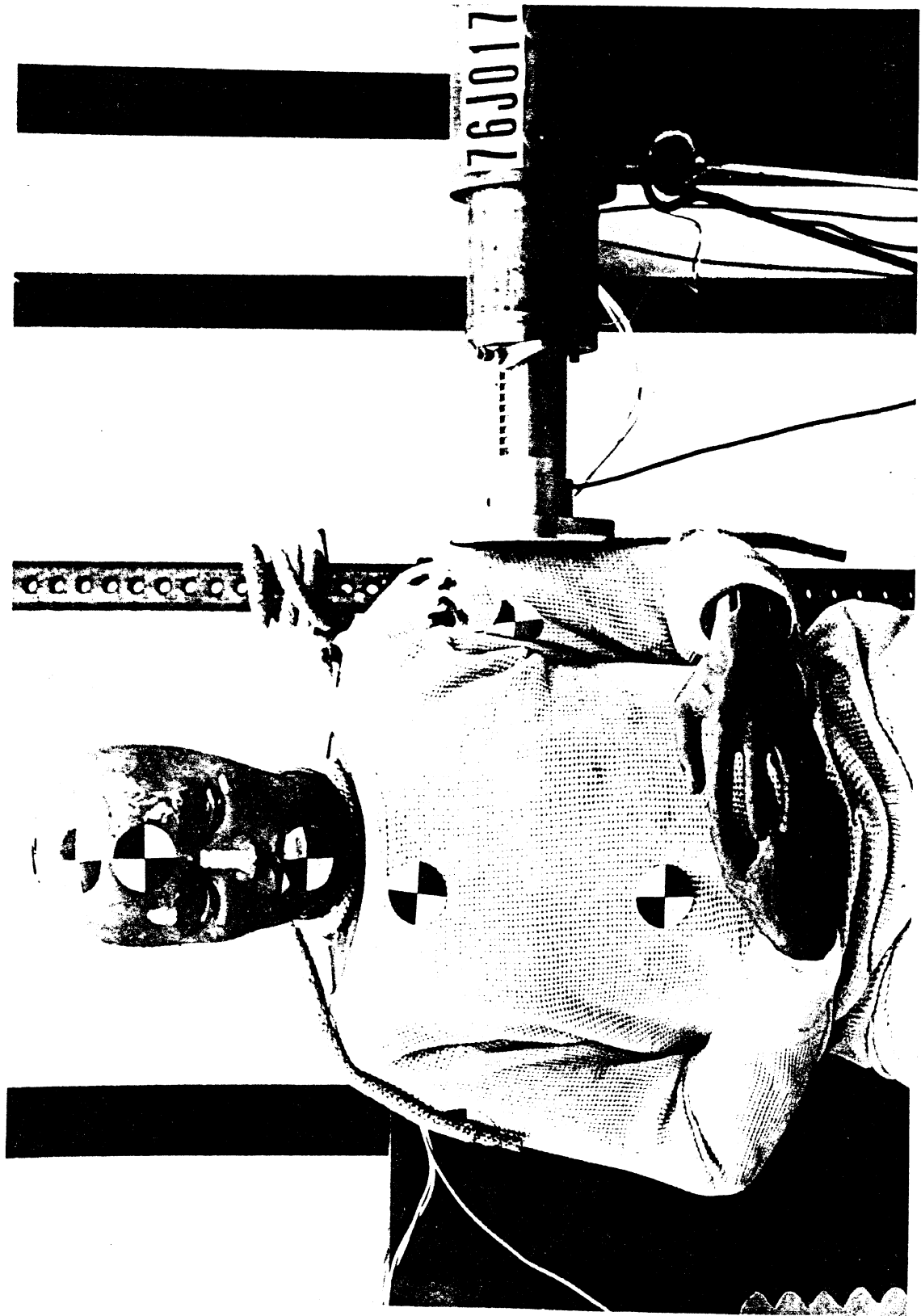


Figure 4.4 Shoulder Impact Calibration Test Configuration

for testing purposes in subsequent work.

An impact velocity of 14 fps was used in testing and with the rigid impactor it produced peak resultant accelerations of 40-50 G with a duration on the order of 12 msec. These values are quite comparable to those produced in the sled tests at similar impact velocities.

4.2.3 Thorax Test Procedures. The thorax test procedure that was developed was essentially the same as that used with the shoulder test except that the dummy arm is rotated up out of the way of the probe impact surface to allow a direct impact to the thoracic structure. The test configuration is shown in Figure 4.5. Although there are some load deflection response data available on lateral thoracic response (20) there is no adequate way to measure lateral rib cage deflection at this time. Thus, a load-time response or an acceleration-time response would appear to be the most effective method of quantifying thoracic lateral response for calibration purposes. Again a test velocity of 14 fps was chosen and this produced a peak resultant acceleration in the thorax of 25-30 G with a duration on the order of 17 msec -- similar in waveform to the sled test results at the same velocity. The peak load obtained from the probe accelerometer and the probe mass was typically on the order of 1290 lbs.

4.2.4 Pelvis Test Procedures. The pelvis test procedure involved positioning the dummy such that the H-point was on the probe centerline (3.9 inches above the seat surface). This configuration is shown in Figure 4.6. The pelvis in the human is essentially a rigid structure as it is in the dummy. Thus, the soft tissue or the dummy synthetic covering is the main determining factor for forces generated in a rigid impact to the side of the pelvis. Acceleration of the pelvis was chosen as the response measure and a test velocity of 14 fps was used. The development tests showed the peak resultant acceleration to be 50-60 G with a duration on the order of 14 msec -- similar to the waveform generated in the sled tests at the same velocity.

4.2.5 Neck Test Procedures. The neck test procedure represents a modification of the existing Part 572 test procedure for frontal neck response. The modifications involve mounting the head/neck system at 90 degrees to the impact direction, using a probe velocity of 13 fps and increasing the weight of the probe from 130.0 lbs.

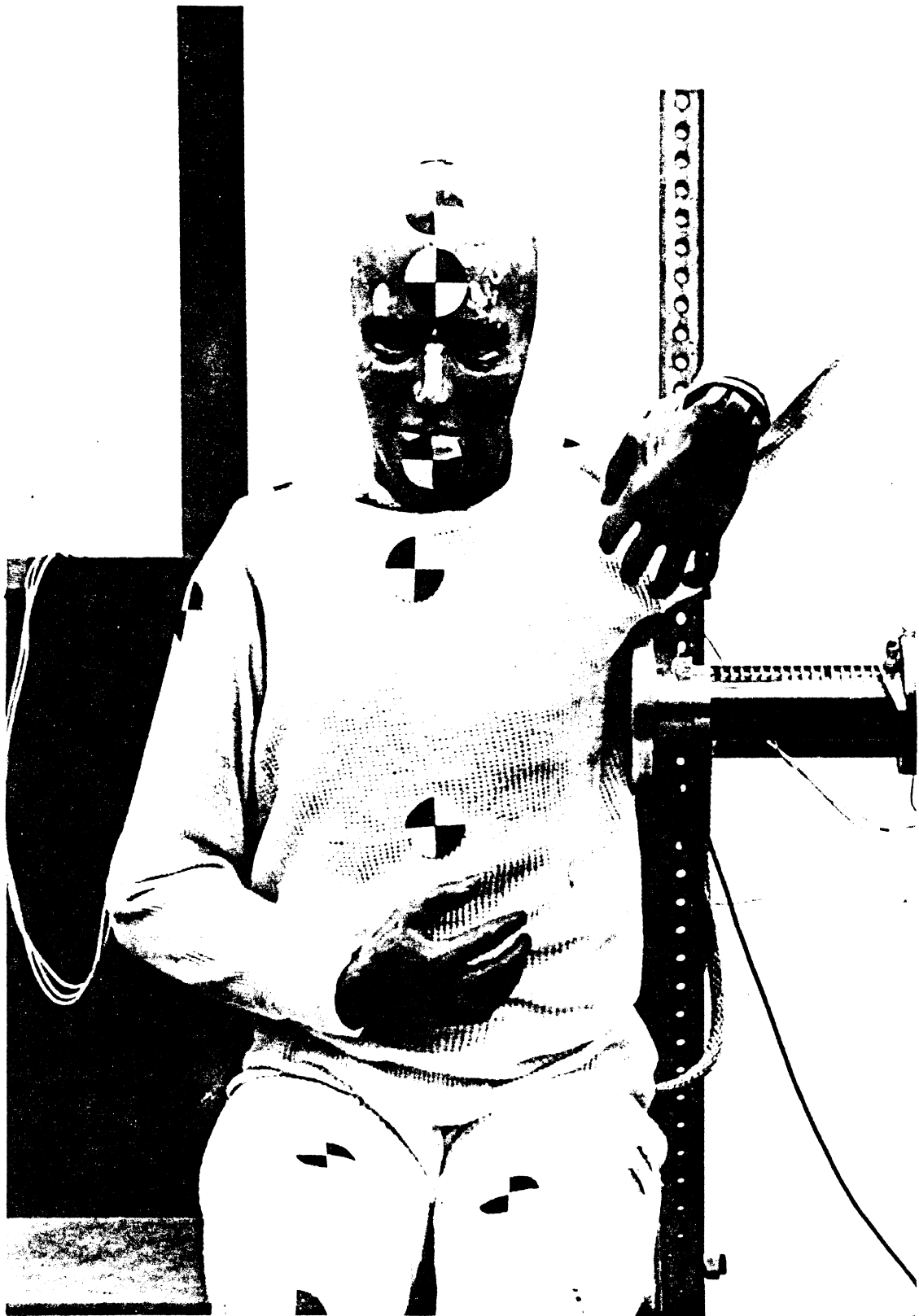


Figure 4.5 Thorax Impact Calibration Test Configuration

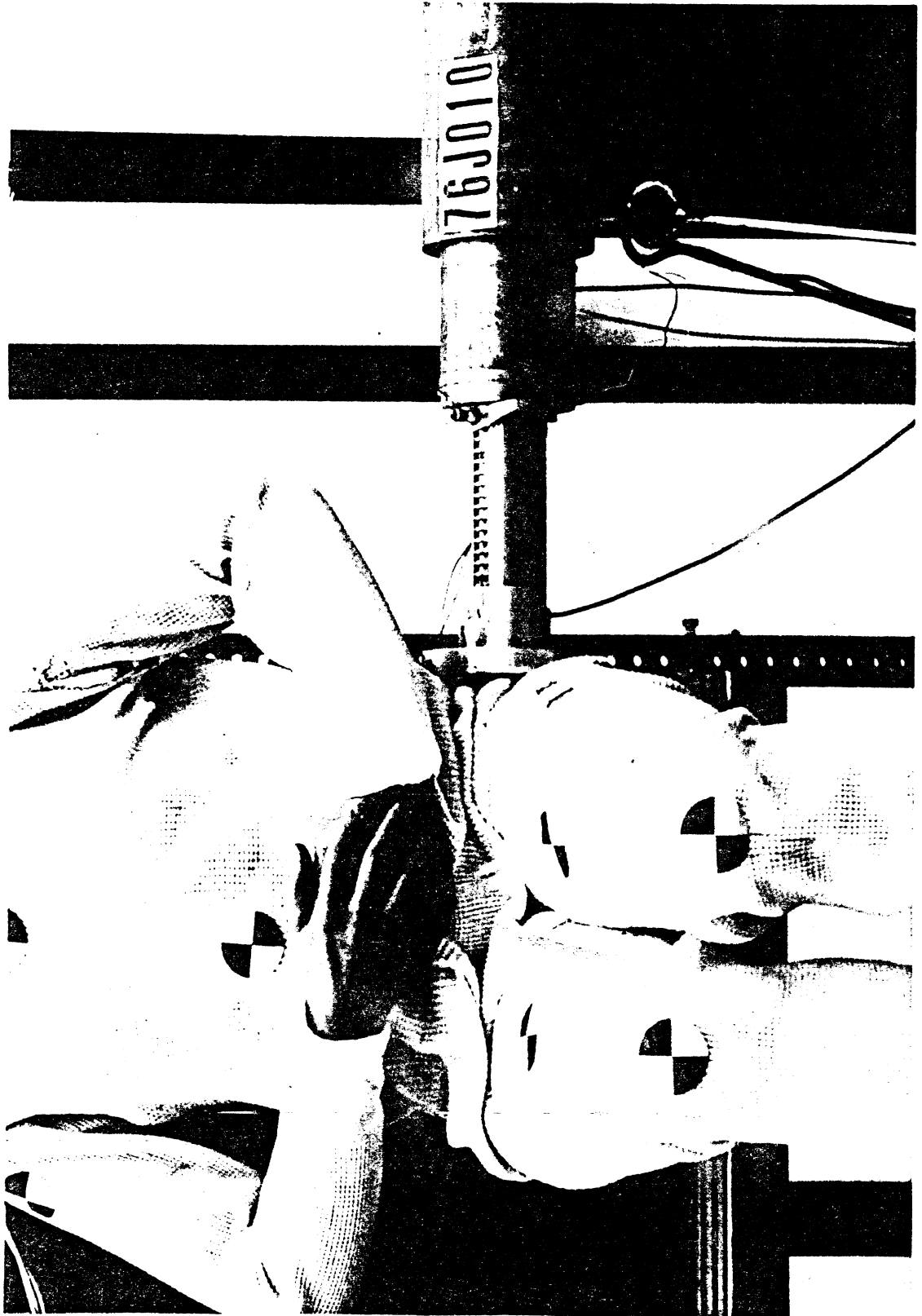


Figure 4.6 Pelvis Impact Calibration Test Configuration

(as opposed to 65.2 lbs) with the moment of inertia about the pivot axis measuring to 185 lb.ft.sec² (as opposed to 24.5 lb.ft.sec²). In order for the standard neck test pendulum to produce an equivalent energy level at 13 fps, it would be necessary to add approximately 55.6 lbs inside the pendulum arm at the impact end. The same deceleration material (Hexcell 1.8 lb/cu.ft aluminum honeycomb) was used. The 13 fps velocity was found to give good agreement with the neck response measured in the sled test (76J009). During the test, no great tendency for the head to rotate about its S-I axis was noted. The head/neck angle and the head chordal displacement were determined from photometric analysis of high speed movies taken at 1000 frames/second. Figure 4.7 shows the general neck configuration.

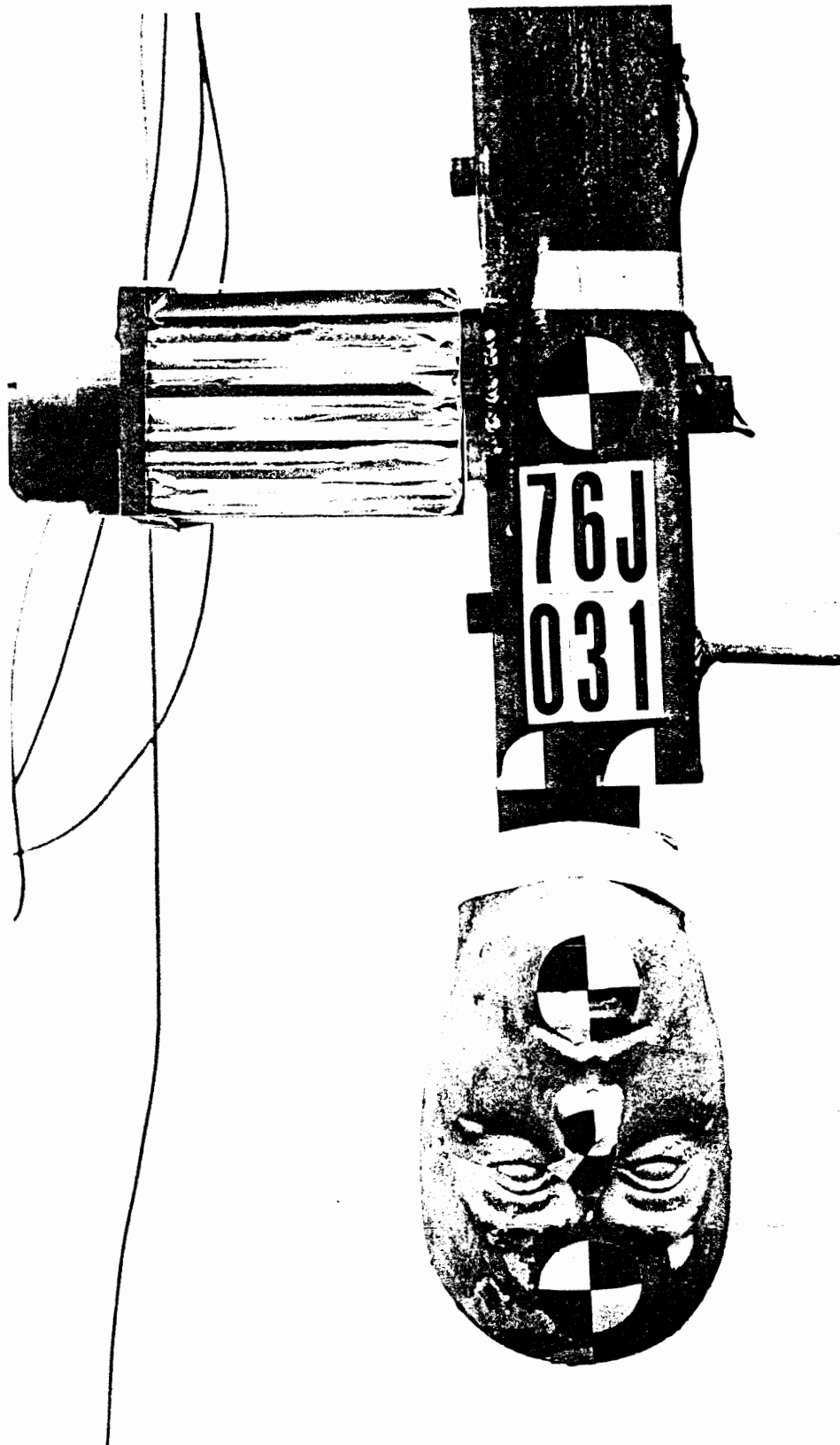


Figure 4.7 Lateral Neck Calibration Test Configuration

4.3 Evaluation of the Calibration Procedures for Side Impact Testing

In order to study the effectiveness of the test procedures developed in the program and discussed in the previous sections, the procedures were applied to three test dummies specified by NHTSA regulation. One of the dummies was the same dummy that was used in the sled and developmental tests, while the other two were obtained expressly for the evaluation tests. The pertinent dummy information is as follows:

Dummy Designation	Manufacturer	Model Number	Serial Number
Dummy No. 1	Alderson Research Labs	Hybrid II	658
Dummy No. 2	Alderson Research Labs	ATD30016	613
Dummy No. 3	Humanoid Systems	572	155

A series of three tests on each side of each dummy were performed. Multiple tests were also conducted on the necks of each dummy in both left and right directions. The data traces from all of these tests are included in Appendix B of this report.

4.3.1 Head Impact Tests. A summary of the peak acceleration values for the 18 head impact tests conducted at 7 fps with a rigid impactor are given in Table 4.1. The data tends to be fairly consistent with the exception of the right side of Dummy #3. Examination of this dummy head and of the others revealed that a major factor in controlling the response level in this test is the thickness of the vinyl skin material at the impact site. This factor is discussed in general later in the report in Section 4.3.5. With this one exception, the test results were similar in magnitude and range to those produced in acceptable Part 572 frontal tests.

4.3.2 Shoulder Impact Tests. A summary of the peak acceleration values for the 18 shoulder impact tests conducted at 14 fps with a rigid impactor are given in Table 4.2. The average peak response values vary greatly from dummy to dummy. The worst case is the right side of Dummy #1. The high peak values are apparently due to load transmission through the shoulder structure to the thorax accelerometer mounting hardware. This is characterized by a sharp spikelike acceleration

TABLE 4.1 Peak Acceleration Response in G 7 fps Rigid Head Side Impacts

Dummy #1						
Test No.	Side	LR	SI	AP	RES	PROBE
76J025	L	234	15	13	235	
76J026	L	246	26	12	248	
76J027	L	<u>251</u>	<u>21</u>	<u>6</u>	<u>252</u>	
AVERAGE		244	21	10	245	
76J113	R	228	12	14	229	10
76J114	R	239	30	13	241	10
76J115	R	<u>255</u>	<u>26</u>	<u>9</u>	<u>256</u>	<u>10</u>
AVERAGE		240	23	12	242	10
Dummy #2						
096	L	209	5	8	209	10
098	L	219	5	13	219	10
100	L	<u>235</u>	<u>5</u>	<u>7</u>	<u>235</u>	<u>10</u>
AVERAGE		221	5	9	221	10
097	R	261	6	13	261	10
099	R	257	5	7	257	10
101	R	<u>264</u>	<u>7</u>	<u>4</u>	<u>264</u>	<u>10</u>
AVERAGE		261	6	8	261	10
Dummy #3						
057	L	286	16	7	269	10
059	L	269	29	12	270	10
061	L	<u>238</u>	<u>11</u>	<u>21</u>	<u>239</u>	<u>10</u>
AVERAGE		258	19	13	259	10
056	R	321	16	8	321	9
058	R	390	36	25	392	9
060	R	<u>338</u>	<u>19</u>	<u>8</u>	<u>339</u>	<u>9</u>
AVERAGE		350	24	14	351	9

TABLE 4.2. Peak Acceleration Response in G, 14 fps, Rigid Shoulder Side Impacts

Test No.	Side	Dummy #1				Probe
		LR	SI	AP	RES	
76J017	L	47	8	10	49	
76J018	L	42	9	8	44	
76J019	L	<u>43</u>	<u>9</u>	<u>10</u>	<u>45</u>	
AVERAGE		44	9	9	46	
76J119	R	83	18	15	86	40
76J120	R	102	19	14	105	43
76J121	R	<u>77</u>	<u>15</u>	<u>10</u>	<u>79</u>	<u>40</u>
AVERAGE		87	17	13	90	41
Test No.	Side	Dummy #2				Probe
		LR	SI	AP	RES	
76J039	L	38	10	15	42	29
76J041	L	53	9	11	55	38
76J043	L	<u>41</u>	<u>9</u>	<u>21</u>	<u>47</u>	<u>29</u>
AVERAGE		44	9	16	48	32
76J038	R	30	4	19	36	29
76J040	R	33	7	22	40	49
76J042	R	<u>40</u>	<u>5</u>	<u>18</u>	<u>44</u>	<u>41</u>
AVERAGE		34	5	20	40	39
Test No.	Side	Dummy #3				Probe
		LR	SI	AP	RES	
76J076	L	30	5	12	33	25
76J078	L	39	2	9	40	29
76J080	L	<u>35</u>	<u>5</u>	<u>10</u>	<u>37</u>	<u>26</u>
AVERAGE		35	4	10	37	27
76J077	R	34	3	9	35	24
76J079	R	37	4	-	38	28
76J081	R	<u>36</u>	<u>4</u>	<u>7</u>	<u>37</u>	<u>26</u>
AVERAGE		36	4	8	37	26

trace in those tests when compared to the other test waveforms (See Appendix B). An additional factor that is responsible for some of the variation in the responses of the other dummies is the vinyl flesh thickness variation. (See Section 4.3.5).

4.3.3 Thorax Impact Tests. The results of the 18 lateral rigid impacts at 14 fps directly onto the thorax are given in Table 4.3. As in the other tests the procedure seems to be repeatable but variances in the dummy construction influence the response. In this case the main influence was skin-flesh thickness, although other construction variables may also have contributed to the difference between the right and left side responses of Dummy #1 (See Section 4.3.5).

4.3.4 Pelvis Impact Tests. The test results of the 18 lateral rigid impacts to the pelvis at 14 fps are given in Table 4.4. A consistent bias due to a thickness difference in all three dummies produced higher left side readings than the right side.

4.3.5 Influence of Dummy Flesh Thickness on Impact Response. As shown by the data produced during the evaluation tests, the vinyl skin-flesh thickness on the dummy appears to exert a strong influence on the response of the dummy to impact. This is not unexpected, particularly with the head and pelvis because of their rigid structure, when a rigid impactor strikes a deformable surface. The skin-flesh thickness was measured on all the three dummies at the various impact sites and tabulated in Table 4.5. Considerable variations can be noted. Some are random, but in the case of the pelvis the thicknesses are consistently different. A plot of peak response versus the reciprocal of the skin-flesh thickness is shown in Figure 4.8 which demonstrates the effect of this factor on response. Although it is not the only factor (note that the response of the right thorax of Dummy #2 does not correlate with thickness), since variation in the skeletal construction of the dummy is also important, it is still a factor which must be controlled before calibration values of dummy side impact response can be developed.

TABLE 4.3. Peak Acceleration Response in G, 14 fps, Rigid Thorax Side Impacts

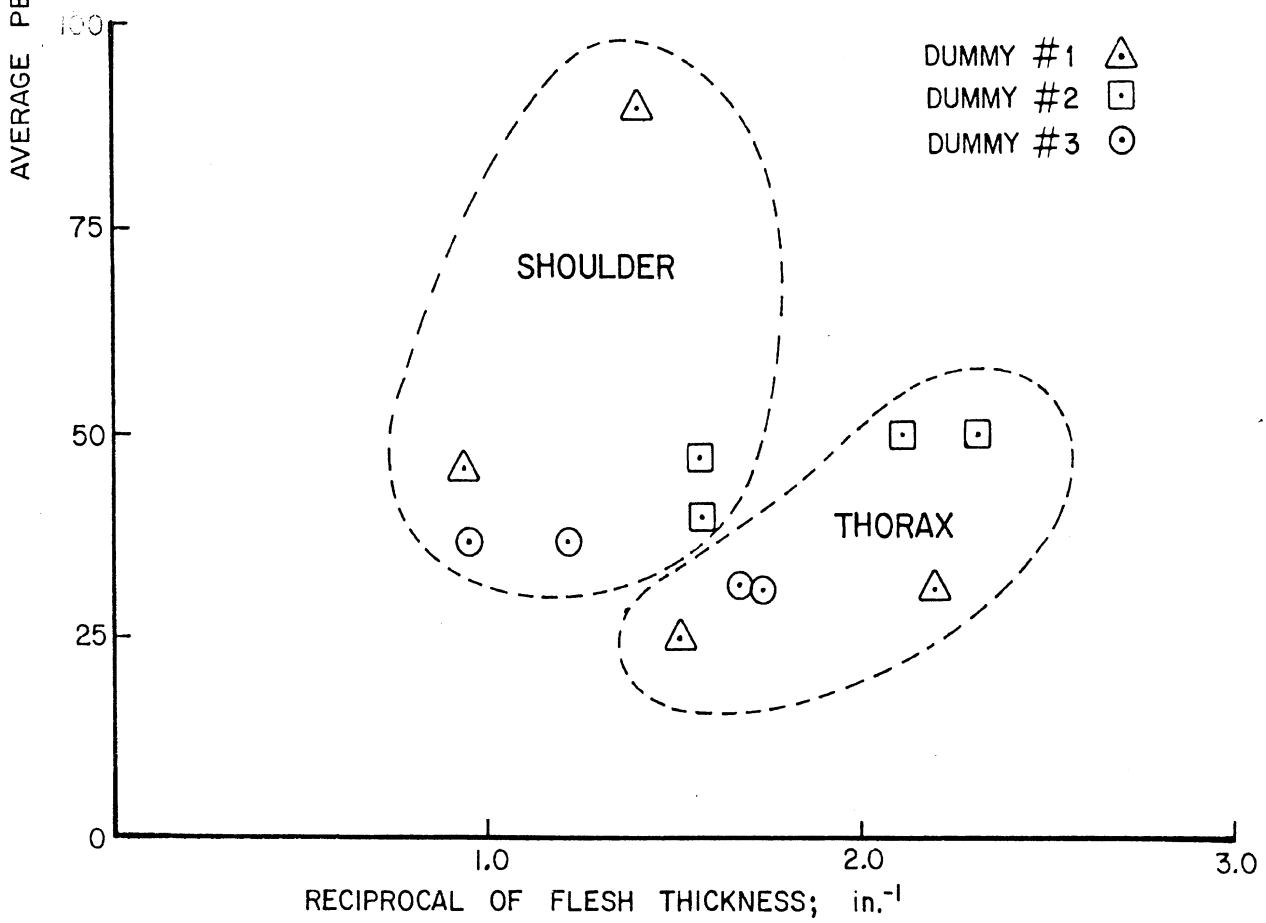
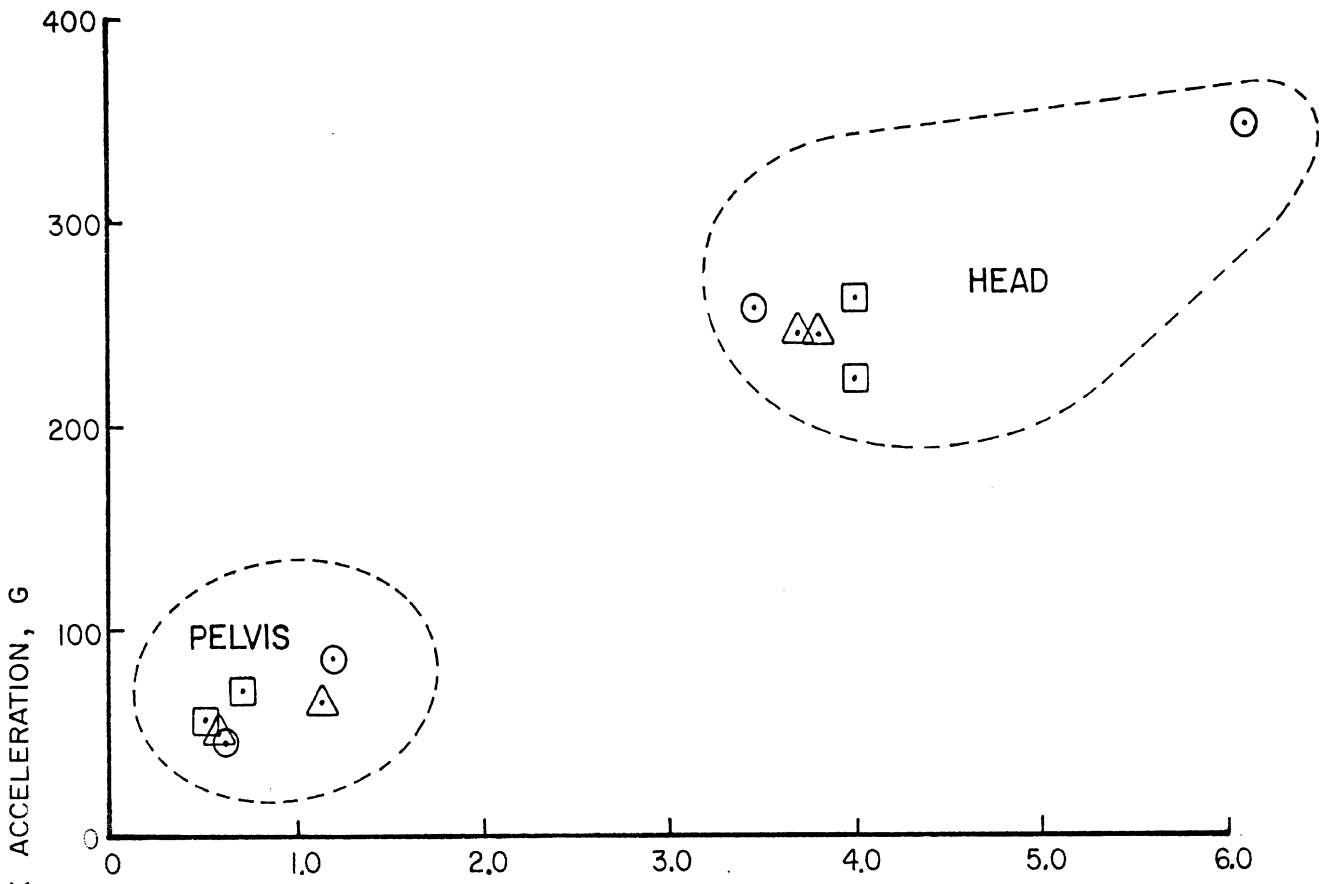
Dummy #1						
Test No.	Side	LR	SI	AP	RES	Probe
76J020	L	25	2	7	26	
76J021	L	26	2	7	26	
76J022	L	<u>22</u>	<u>4</u>	<u>7</u>	<u>23</u>	
AVERAGE		24	3	7	25	
76J116	R	30	2	16	34	25
76J117	R	28	3	16	32	25
76J118	R	<u>27</u>	<u>3</u>	<u>14</u>	<u>31</u>	<u>25</u>
AVERAGE		28	3	16	32	25
Dummy #2						
76J032	L	44	10	14	47	25
76J033	L	50	5	14	52	26
76J035	L	<u>49</u>	<u>4</u>	<u>12</u>	<u>51</u>	<u>24</u>
AVERAGE		48	6	13	50	25
76J034	R	48	5	12	50	24
76J036	R	49	6	14	51	24
76J037	R	<u>47</u>	<u>5</u>	<u>12</u>	<u>49</u>	<u>25</u>
AVERAGE		48	5	13	50	24
Dummy #3						
76J070	L	32	3	3	32	27
76J072	L	29	3	1	29	27
76J074	L	<u>32</u>	<u>2</u>	<u>3</u>	<u>32</u>	<u>27</u>
		31	3	2	31	27
76J069	R	30	3	8	31	26
76J071	R	28	1	11	30	26
76J075	R	<u>27</u>	<u>2</u>	<u>20</u>	<u>34</u>	<u>26</u>
AVERAGE		28	2	13	32	26

TABLE 4.4. Peak Acceleration Response in G, 14 fps, Rigid Pelvis Side Impact

Dummy #1						
Test No.	Side	LR	SI	AP	RES	Probe
76J014	L	62	3	10	63	
76J015	L	59	4	9	60	
76J016	L	<u>69</u>	<u>9</u>	<u>8</u>	<u>70</u>	
AVERAGE		63	5	9	64	
<hr/>						
76J122	R	50	4	9	51	35
76J123	R	53	4	7	54	36
76J124	R	<u>56</u>	<u>4</u>	<u>11</u>	<u>57</u>	<u>36</u>
AVERAGE		53	4	9	54	36
<hr/>						
Dummy #2						
76J044	L	60	5	9	61	44
76J046	L	67	6	12	68	44
76J048	L	<u>75</u>	<u>3</u>	<u>13</u>	<u>76</u>	<u>44</u>
AVERAGE		67	5	11	68	44
<hr/>						
76J045	R	49	4	6	50	41
76J047	R	65	8	11	66	42
76J049	R	<u>53</u>	<u>6</u>	<u>7</u>	<u>54</u>	<u>40</u>
AVERAGE		56	6	8	57	41
<hr/>						
Dummy #3						
76J082	L	77	5	5	77	45
76J084	L	85	7	6	86	45
76J087	L	<u>87</u>	<u>7</u>	<u>8</u>	<u>88</u>	<u>44</u>
AVERAGE		83	6	6	84	45
<hr/>						
76J083	R	46	4	6	47	37
76J085	R	46	5	7	47	37
76J086	R	<u>52</u>	<u>6</u>	<u>6</u>	<u>53</u>	<u>38</u>
AVERAGE		48	5	6	49	37
<hr/>						

TABLE 4.5 Dummy Flesh Thickness Values for the Three Test Evaluation Dummies

Body Region		Dummy Number		
		#1 (inches)	#2 (inches)	#3 (inches)
Head	L	0.270	0.250	0.290
	R	0.268	0.250	0.164
Shoulder	L	1.060	0.630	1.040
	R	0.713	0.630	0.824
Thorax	L	0.662	0.472	0.570
	R	0.454	0.433	0.592
Pelvis	L	0.863	1.380	0.831
	R	1.661	1.770	1.625



Flesh Thickness Effects on Dummy Response

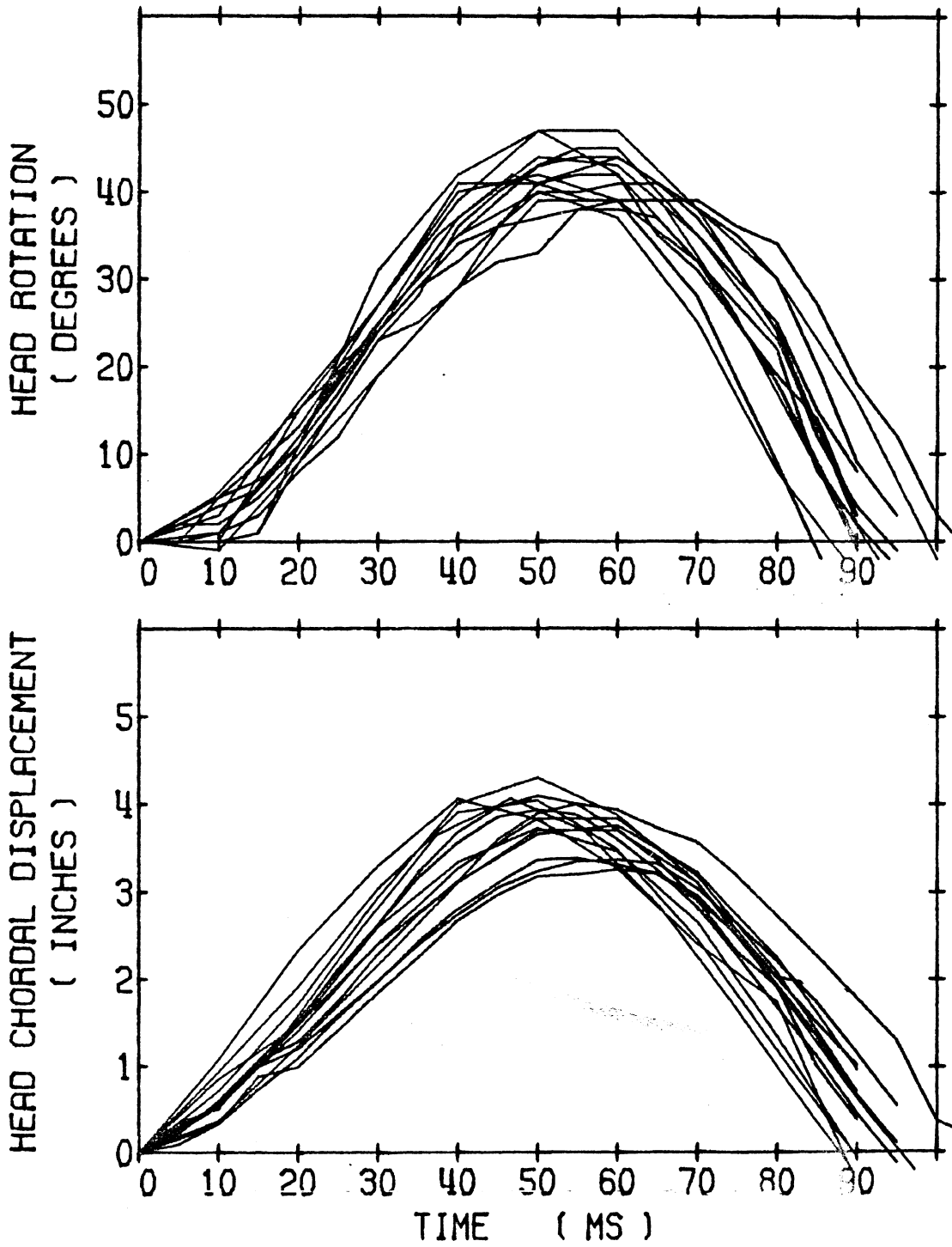
4.3.6 Neck Response Test Results. The results of 14 pendulum neck tests are summarized in Table 4.6 in terms of maximum head/neck angle and maximum head center of gravity chordal displacement values. The data is quite consistent and indicates only minor left-right differences in response. A composite curve of a series of angle time curves for the various tests is shown in Figure 4.9. The mean maximum angle was 42.5 degrees while the mean maximum chordal displacement was 3.81 inches.

TABLE 4.6 Dummy Neck Test Peak Values

Dummy #1				
TEST NO.	SIDE	Velocity fps	Maximum Head/ Neck Angle degrees	Maximum Head C.G. Chordal Displacement inches
76J102	L	14.2	42	4.0
76J103	R	12.7	40	3.7
76J104	L	13.0	47	4.0
76J105	R	13.1	40	3.8
Dummy #2				
76J090	L	11.4	39	4.0
76J091	R	12.6	41	3.4
76J092	L	12.8	38	4.0
76J093	R	12.8	44	3.4
76J094	L	13.1	42	4.1
76J095	R	12.7	45	3.2
Dummy #3				
76J106	L	14.1	42	4.0
76J107	R	13.3	44	3.8
76J108	L	12.9	44	4.2
76J109	R	14.7	47	3.7

LATERAL
13 FPS (NOM.)

ALL



NECK PENDULUM TEST

Figure 4.9 Du... ..me Histories

5.0 DISCUSSION OF PROGRAM RESULTS

The review of existing biomechanical literature (Section 1.1 and 2.0) has indicated that very limited data is available on human tolerance to lateral impact -- and even less is known about the biomechanical response to lateral loading. There is some data on head lateral impact response to rigid impact at velocities of 10 - 13 fps (21) and on thorax lateral impact response at velocities of 20 - 30 fps (20). The most common type of response data available for the head, thorax and pelvis is acceleration-time histories for rigid impact inputs. For such an impact, whole-body impact velocities on the order of 22 fps appear to cause little or no skeletal trauma (23) when distributed over the entire side of the body.

Accident investigation data (Section 1.2) emphasizes the importance of the head, thorax, abdomen and pelvis as locations of severe injuries to occupants of vehicles involved in lateral collisions. Whole-body lateral impact tests with human cadavers have indicated the importance of head-neck-shoulder kinematics in lateral impact and have shown present dummy designs to be deficient in this respect.

The test procedures developed in this program are intended to evaluate the performance of critical regions of the body with respect to kinematic control and injury evaluation. Due to the lack of biomechanical knowledge in many of these regions the tests can only be considered as preliminary procedures until more and better information becomes available. This is particularly true for the lateral neck test and the shoulder test. The monolithic rubber necks of present dummies would not be expected to exhibit marked differences in flexural response for different directions of loading, but the human neck does and advanced test dummy designs may incorporate such directionality effects. Thus, such a test was deemed necessary to cover those possible situations. Similarly, present dummy shoulder designs do not provide for lateral compliance but advanced dummies should, for it is an important factor in controlling lateral impact kinematics of the body. Therefore a shoulder test is necessary to calibrate such a response. The present shoulder test has already shown its usefulness in pointing out shoulder transmitted load spikes -- a phenomena that occurred in only one side of the three dummies tested in this program.

Further investigation of the source of the load path responsible for such an effect could lead to its elimination through redesign.

The choice of impact mass, test velocity and the resulting response levels used in the test procedures represents a combination of input from car crash tests at realistic crash velocities, dummy tests into rigid surfaces, and biomechanical experiments on whole-body and local impacts with human cadavers. Although other masses and other test velocities could have been used, the ones chosen also represent an efficient use of test equipment which already exists in many testing laboratories.

The test procedures have proven to be simple and repeatable when applied to a Part 572 test dummy. Lack of control on the thickness of the flesh of the dummy led to large variations in side-to-side and dummy-to-dummy response levels in the direct impact type tests. Control of this problem must be effected before a suitable range of acceptable response values for a dummy can be established. However, from the ranges of test responses determined in the program for the most symmetrical dummy (Dummy No. 2) it appears that the following response levels could be expected for the body regions listed:

Head	220 - 260 G
Shoulder	40 - 50 G
Thorax	40 - 50 G
Pelvis	50 - 70 G

In the case of the lateral neck test, adequate control of the existing neck structures appears to be present and the response of the necks as determined by the test procedure can be considered representative of the response of the Part 572 dummy neck under the calibration test conditions. This data suggests the following response corridors:

HEAD-NECK ROTATION ANGLE, degrees	TIME RANGE msec	CHORDAL DISPLACEMENT OF HEAD C.G., inches
0	0	0
20	20-35	1.5-3.0
Maximum	47-70	3.0-4.25
20	70-90	1.0-2.5
0	80-105	0-0.5

6.0 CONCLUSIONS AND RECOMMENDATIONS

A series of test procedures have been developed for determining the response of the head, neck, shoulder, thorax and pelvis to lateral impact. The test procedures reflect considerations of the available biomechanical data, car crash test data, and accident investigation data as well as a series of special dummy lateral impact tests designed to further identify those dummy components which exert a major influence on overall lateral impact response.

The tests which were developed are simple to perform using existing Part 572 test apparatus and, with the exception of lateral neck test, do not require disassembly of the test dummy. The tests are repeatable and have demonstrated the ability to indicate dummy conditions which can produce artifactual test data. The test procedures produce repeatable results, but in evaluation tests on three different test dummies, variations in response levels were noted. The major sources of variation in the direct impact tests were considered to be lack of control of the simulated flesh thickness overlying the dummy skeletal structures and, in some body components (shoulder and thorax), structural load path variations.

In view of the limited knowledge of the biomechanics of lateral impact response, the test procedures must be considered preliminary procedures which will be subject to revision or modification as more knowledge in this area becomes available.

Specific recommendations for future work which can be made based on the work performed in this program are:

1. More research on the biomechanics of lateral impact, particularly on shoulder-neck-head kinematics, is needed to aid in developing definitive test procedures for assessing lateral impact protection.
2. The load path variations which can occur in the present Part 572 dummy shoulder structure should be investigated and modifications made to eliminate spurious responses.
3. Careful control of simulated flesh thicknesses and properties must be maintained in the critical contact regions of the sides of the test dummies in order to minimize response variations.

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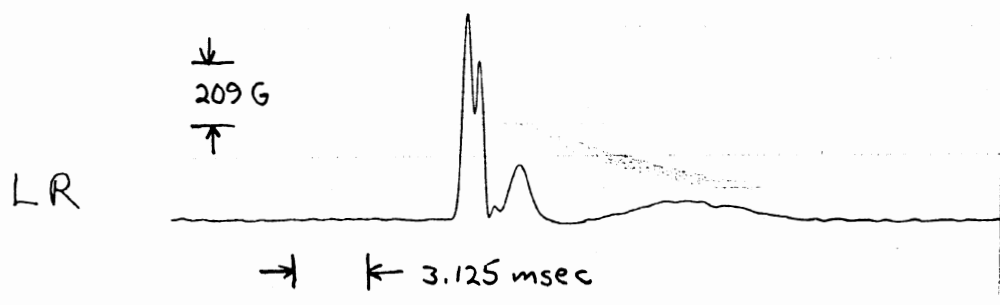
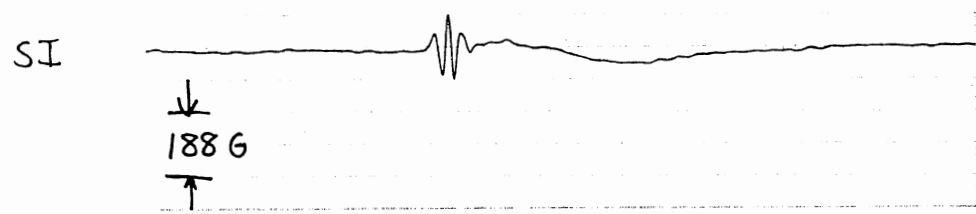
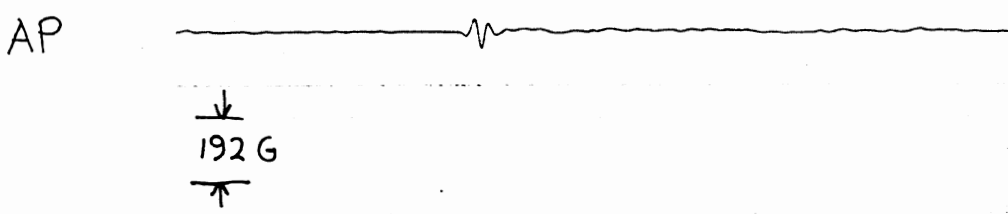
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APPENDIX A SLED TEST DATA

TEST 76J001 Head Acceleration



Test 76J001 Thorax Acceleration

AP

↓
132.5 G
↑

SI

↓
111 G
↑

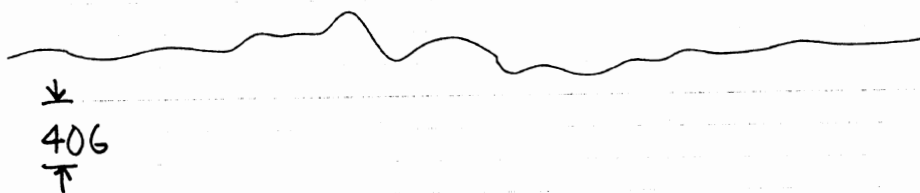
LR

↓
85 G
↑

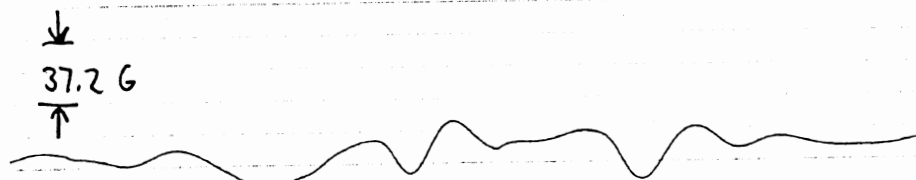
→ ← 3.125 msec

Test 76J001 Pelvis Acceleration

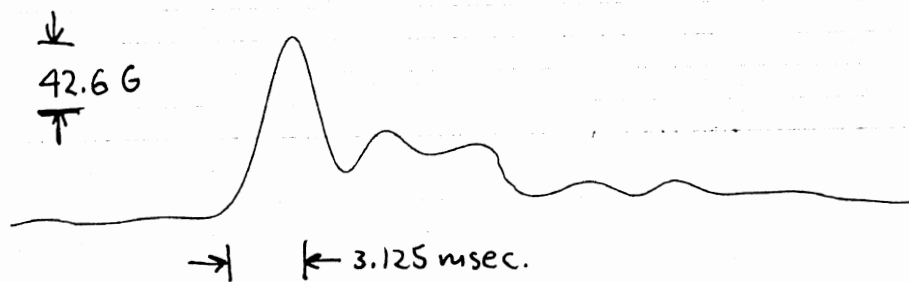
AP



SI



LR



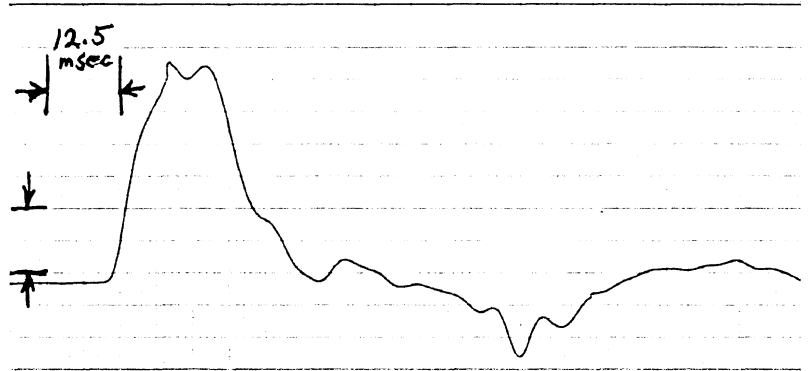
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 002 DUMMY NO. 1 SIDE L BODY REGION HEAD

IMPACT SLED
DECELERATION

10 G =

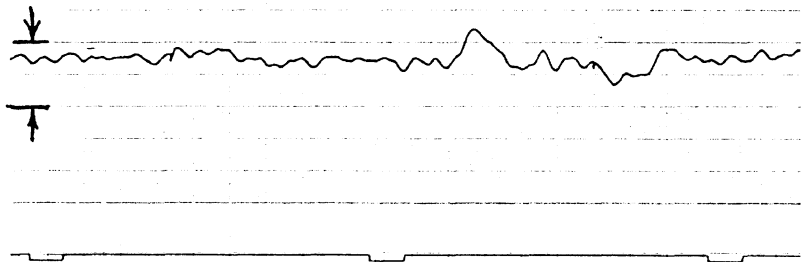
Filtered Class 60



ANTERIOR-POSTERIOR
ACCELERATION

19.2 G =

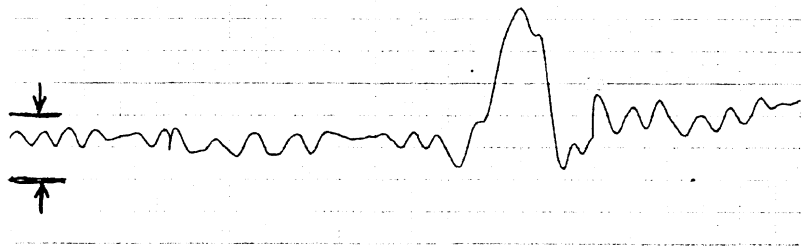
Filtered Class 1000



SUPERIOR-INFERIOR
ACCELERATION

18.8 G =

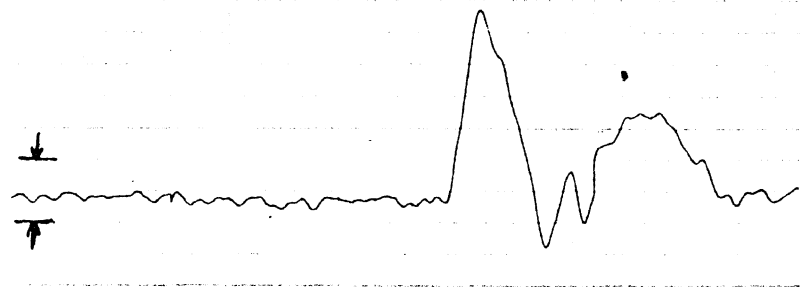
Filtered Class 1000



LEFT-RIGHT
ACCELERATION

20.9 G =

Filtered Class 1000



Test 76J002 Thorax Acceleration

AP

↓
132.5 G
↑

SI

↓
111 G
↑

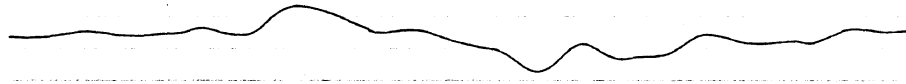
LR

↓
85 G
↑

→ ← 3.125 msec

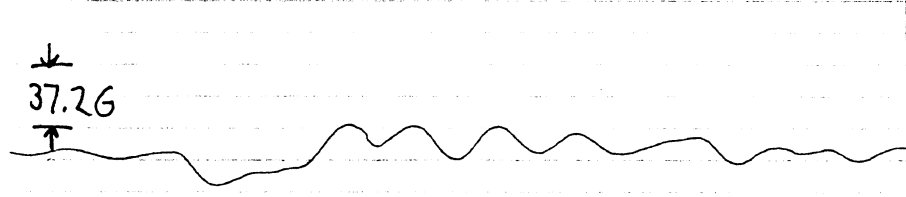
Test 76J002 Pelvis Acceleration

AP



↓
40G
↑

SI



↓
37.2G
↑

LR



↓
42.6G
↑

→ ← 3.125 msec

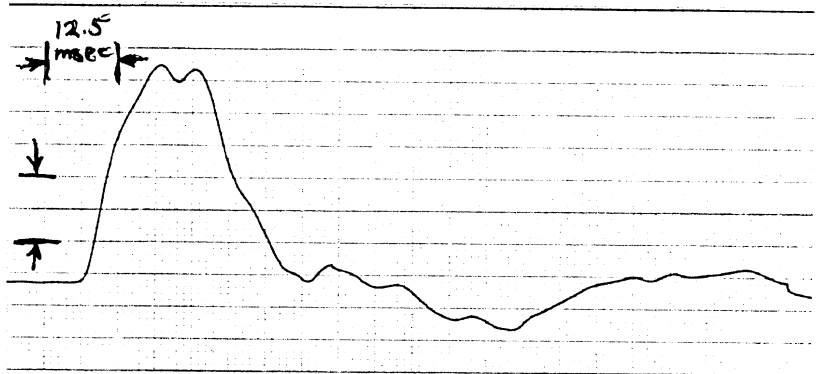
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 003 DUMMY NO. 1 SIDE L BODY REGION HEAD

IMPACT SLED
DECELERATION

10 G =

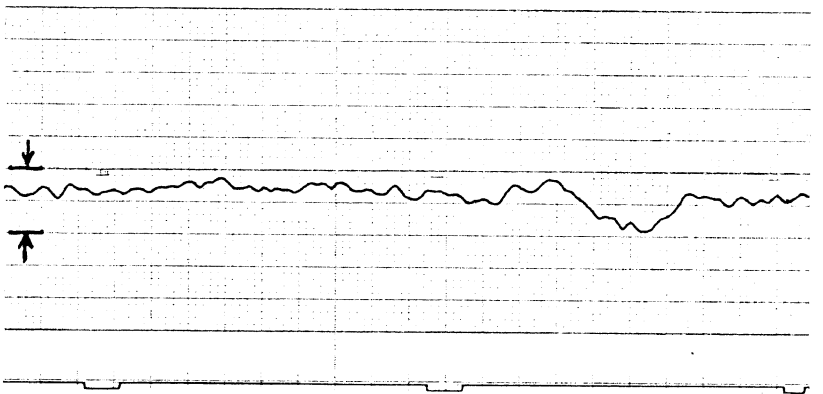
Filtered Class 60



ANTERIOR-POSTERIOR
ACCELERATION

19.2 G =

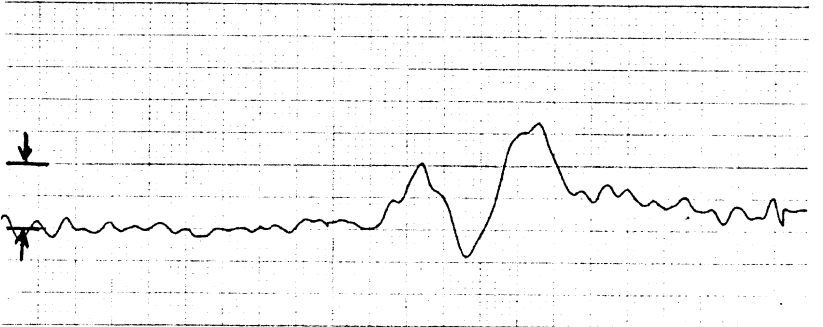
Filtered Class 1000



SUPERIOR-INFERIOR
ACCELERATION

18.8 G =

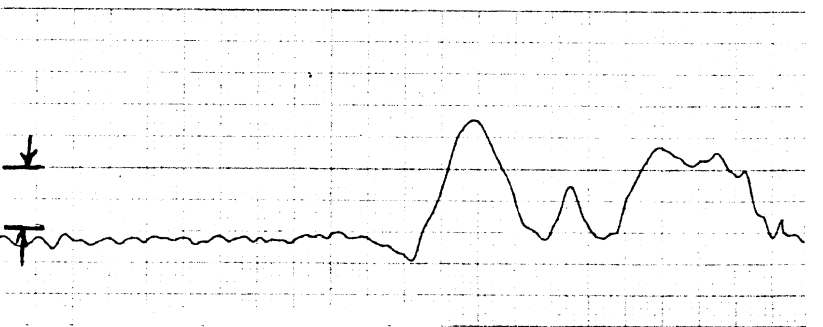
Filtered Class 1000



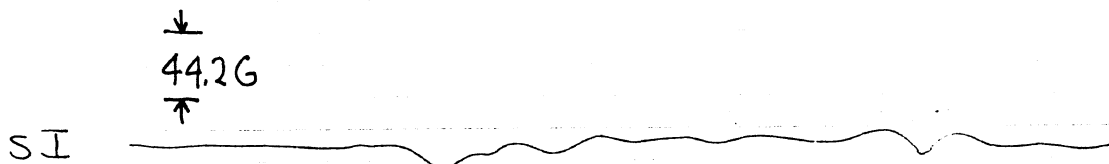
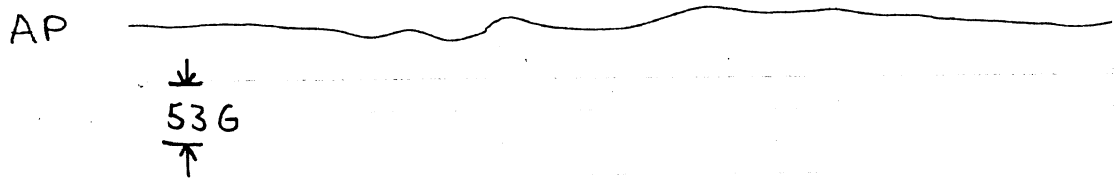
LEFT-RIGHT
ACCELERATION

20.9 G =

Filtered Class 1000



Test 76J003 Thorax Acceleration



Test 76J003 Pelvis Acceleration

AP

↓
40G
↑

SI

↓
37.2G
↑

LR

↓
42.6G
↑

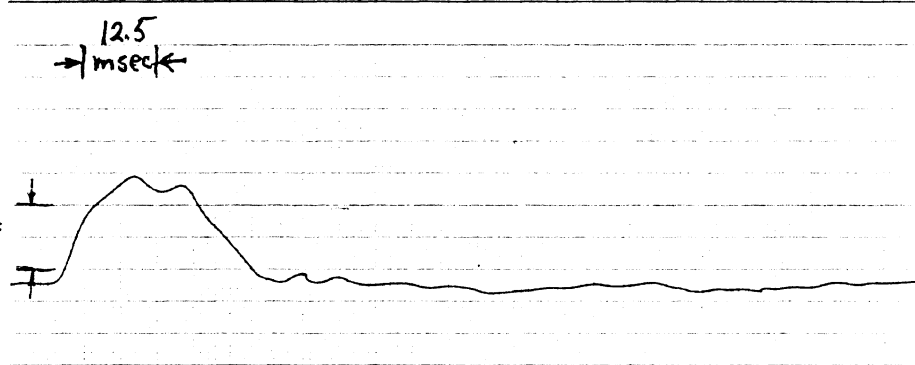
→ ← 3.125 msec

DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 004 DUMMY NO. 1 SIDE L BODY REGION HEAD

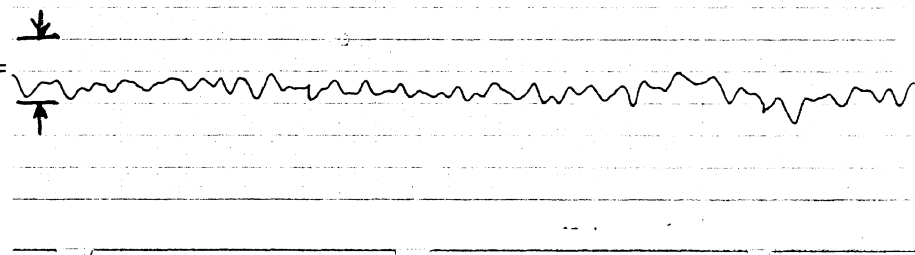
IMPACT SLED
DECELERATION

10 G =
Filtered Class 60



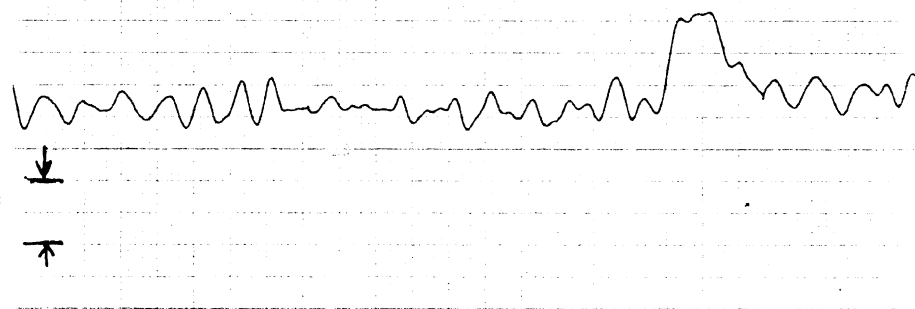
ANTERIOR-POSTERIOR
ACCELERATION

9.6 G =
Filtered Class 1000



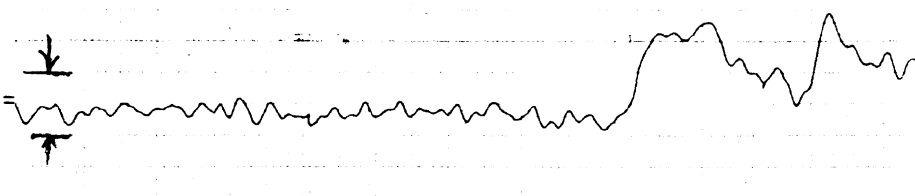
SUPERIOR-INFERIOR
ACCELERATION

9.4 G =
Filtered Class 1000



LEFT-RIGHT
ACCELERATION

10.5 G =
Filtered Class 1000



TEST 76J004 Thorax Acceleration

See Figure 3.7 in main text

TEST 76J004 Pelvis Acceleration

See Figure 3.9 in main text

TEST 76J005 Head Acceleration

AP

↓
96G
↑

SI

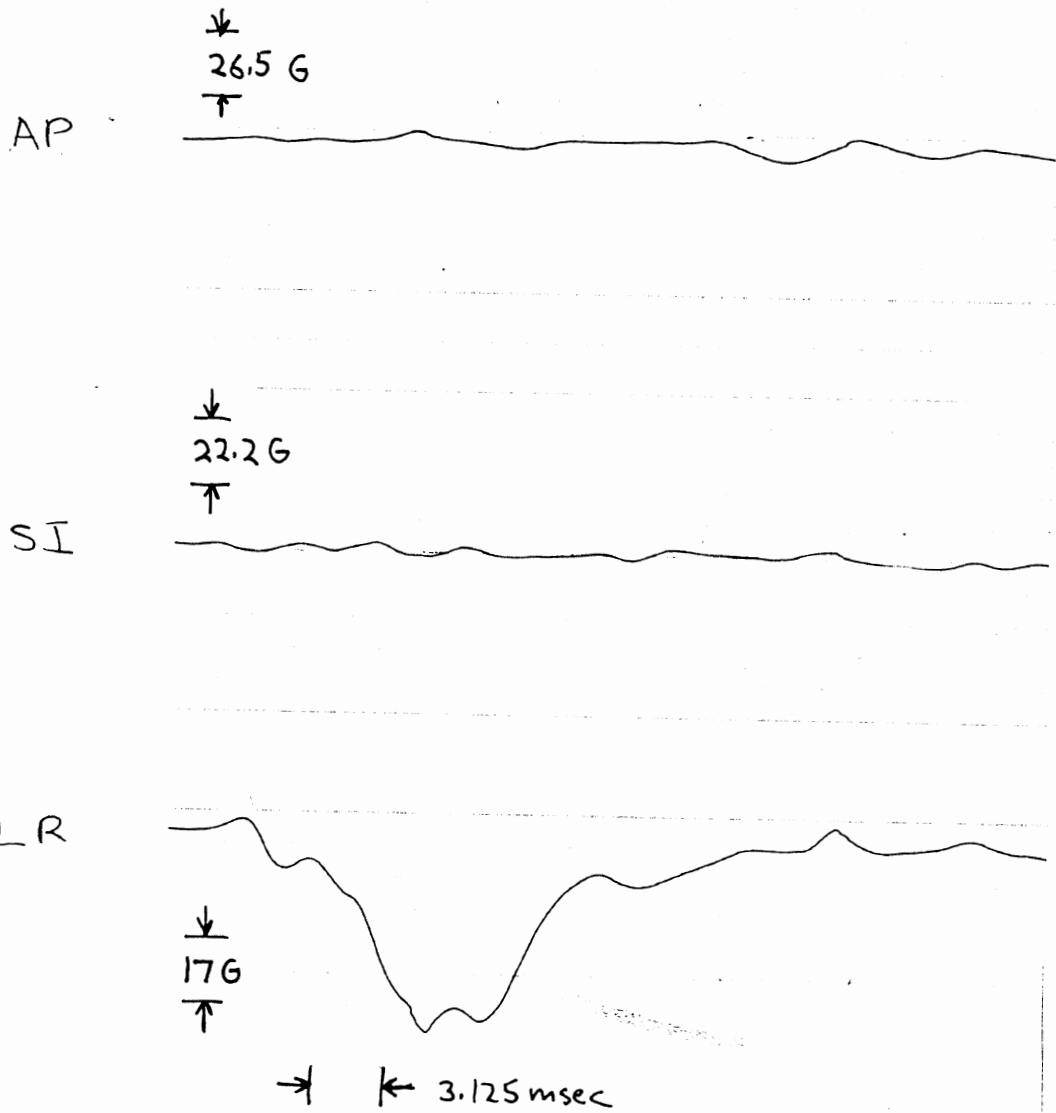
↓
94G
↑

LR

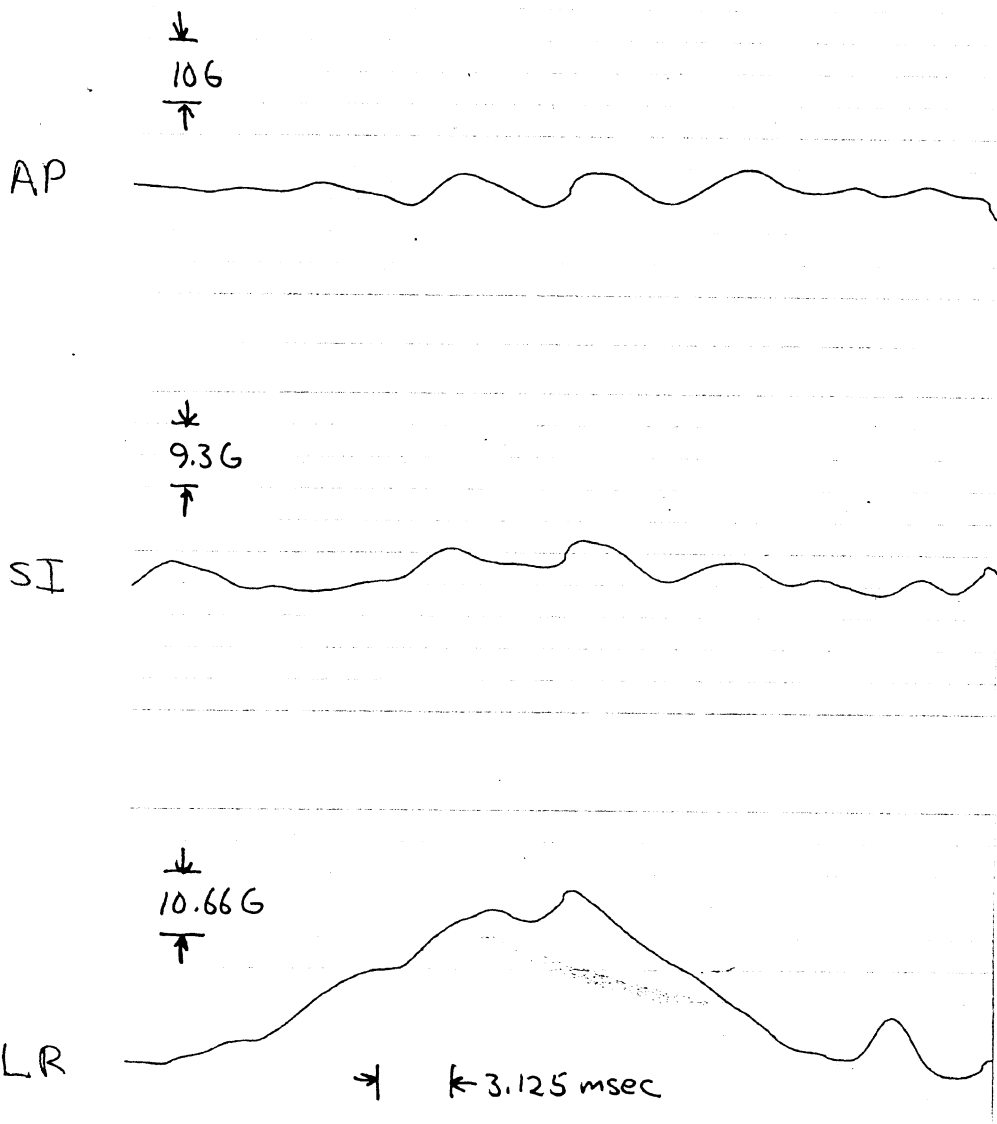
→ ← 3.125 msec

↓
104.6G
↑

Test 76J005 Thorax Acceleration



Test 76J005 Pelvis Acceleration

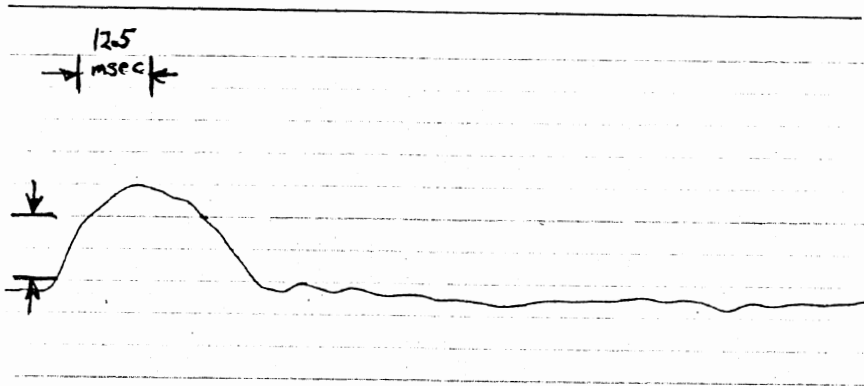


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J006 DUMMY NO. 1 SIDE L BODY REGION HEAD

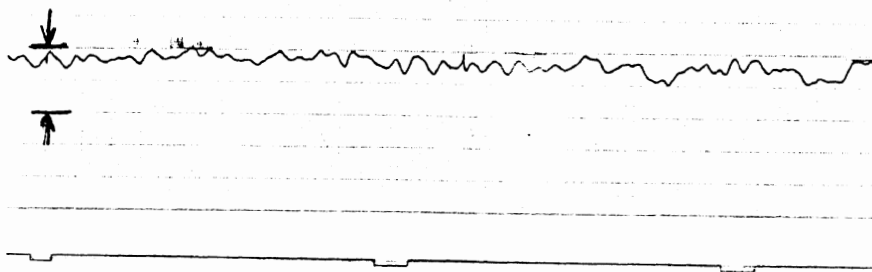
IMPACT SLED
DECELERATION

10 G =
Filtered Class 60



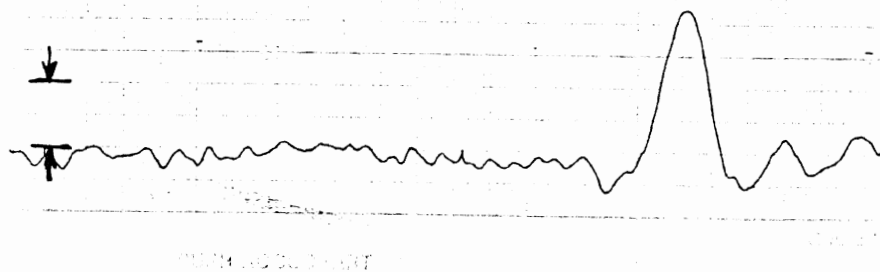
ANTERIOR-POSTERIOR
ACCELERATION

9.6 G =
Filtered Class 1000



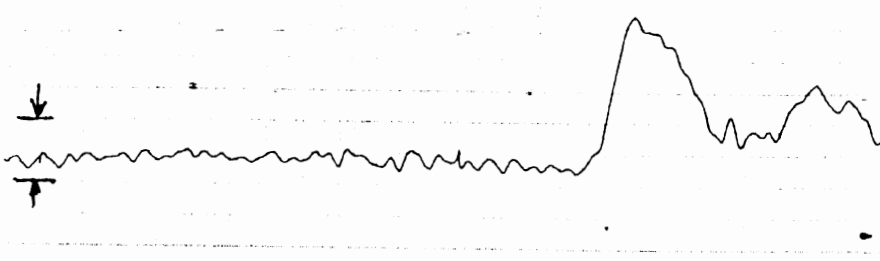
SUPERIOR-INFERIOR
ACCELERATION

9.4 G =
Filtered Class 1000

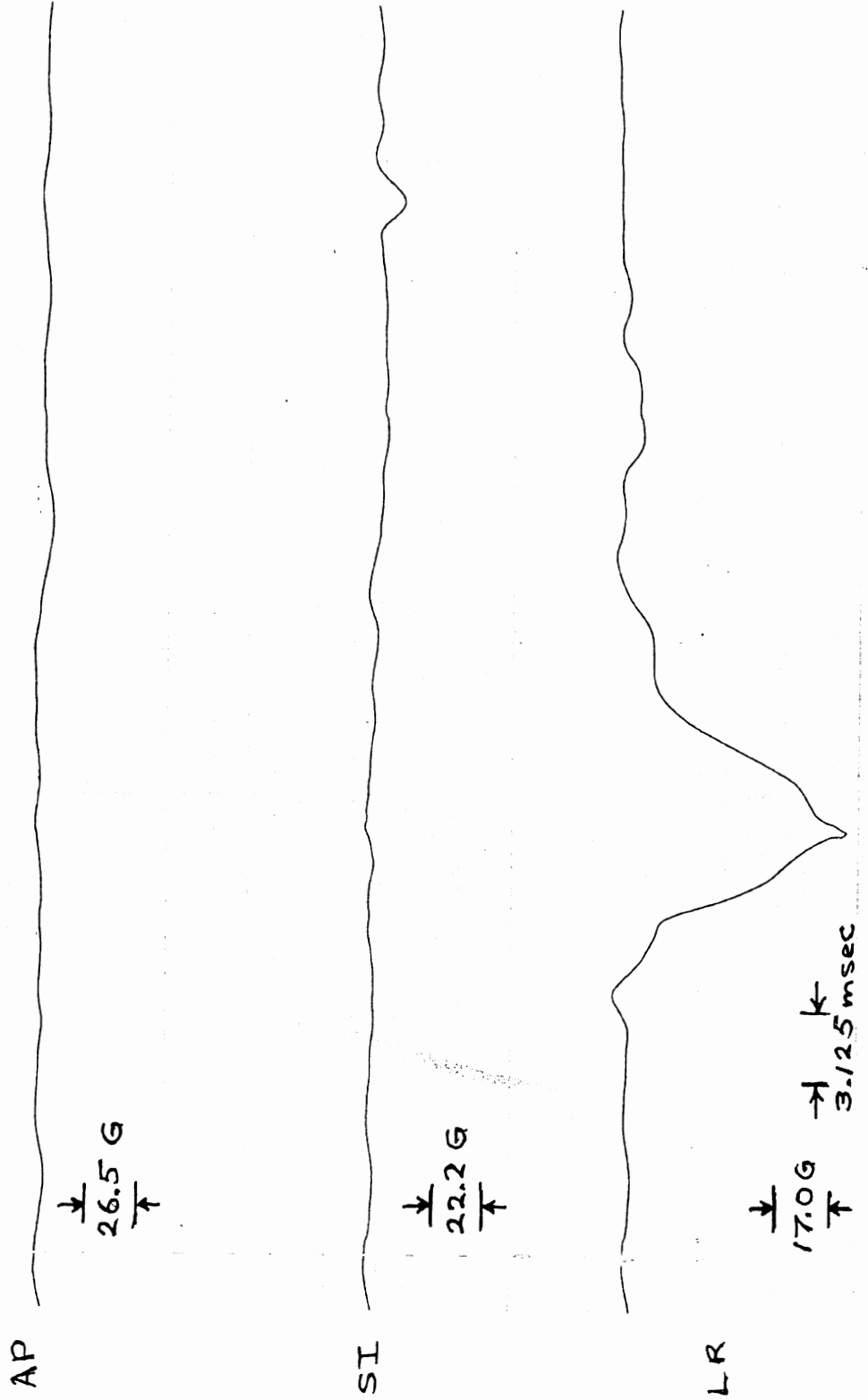


LEFT-RIGHT
ACCELERATION

10.5 G =
Filtered Class 1000



Test 76J006 Thorax Acceleration



Test 76J006 Pelvis Acceleration

↓
10.0G
↑

AP



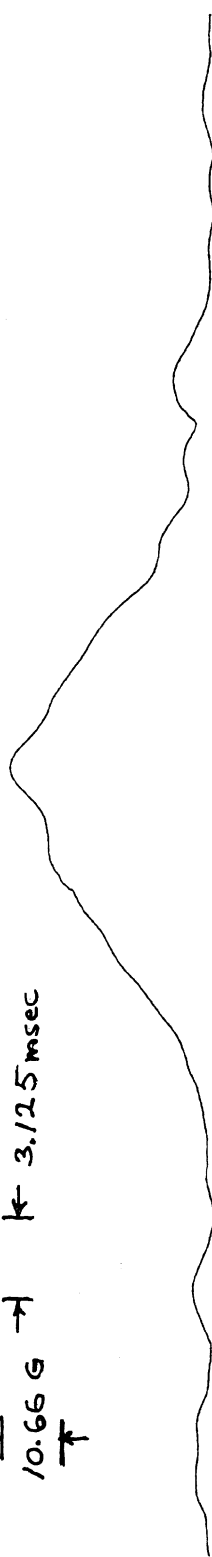
↓
9.3G
↑

SI



↓
10.66G → ← 3.125msec
↑

LR

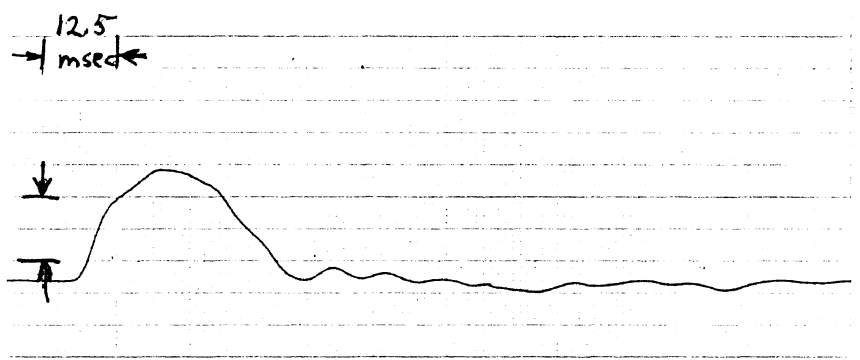


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 007 DUMMY NO. 1 SIDE L BODY REGION HEAD

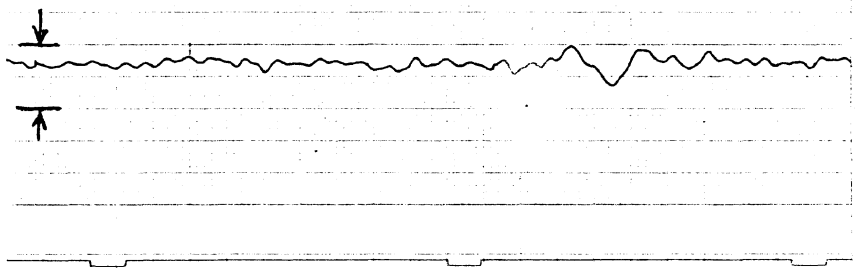
IMPACT SLED
DECELERATION

10 G =
Filtered Class 60



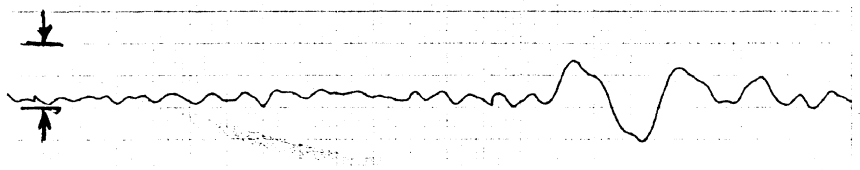
ANTERIOR-POSTERIOR
ACCELERATION

19.2 G =
Filtered Class 1000



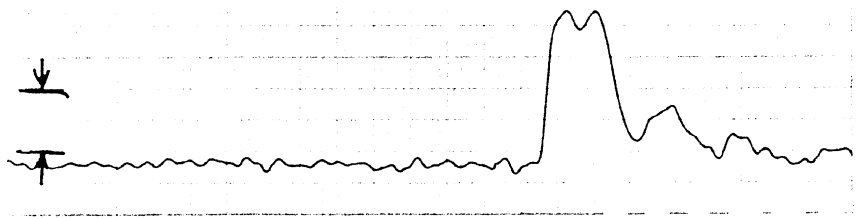
SUPERIOR-INFERIOR
ACCELERATION

18.8 G =
Filtered Class 1000

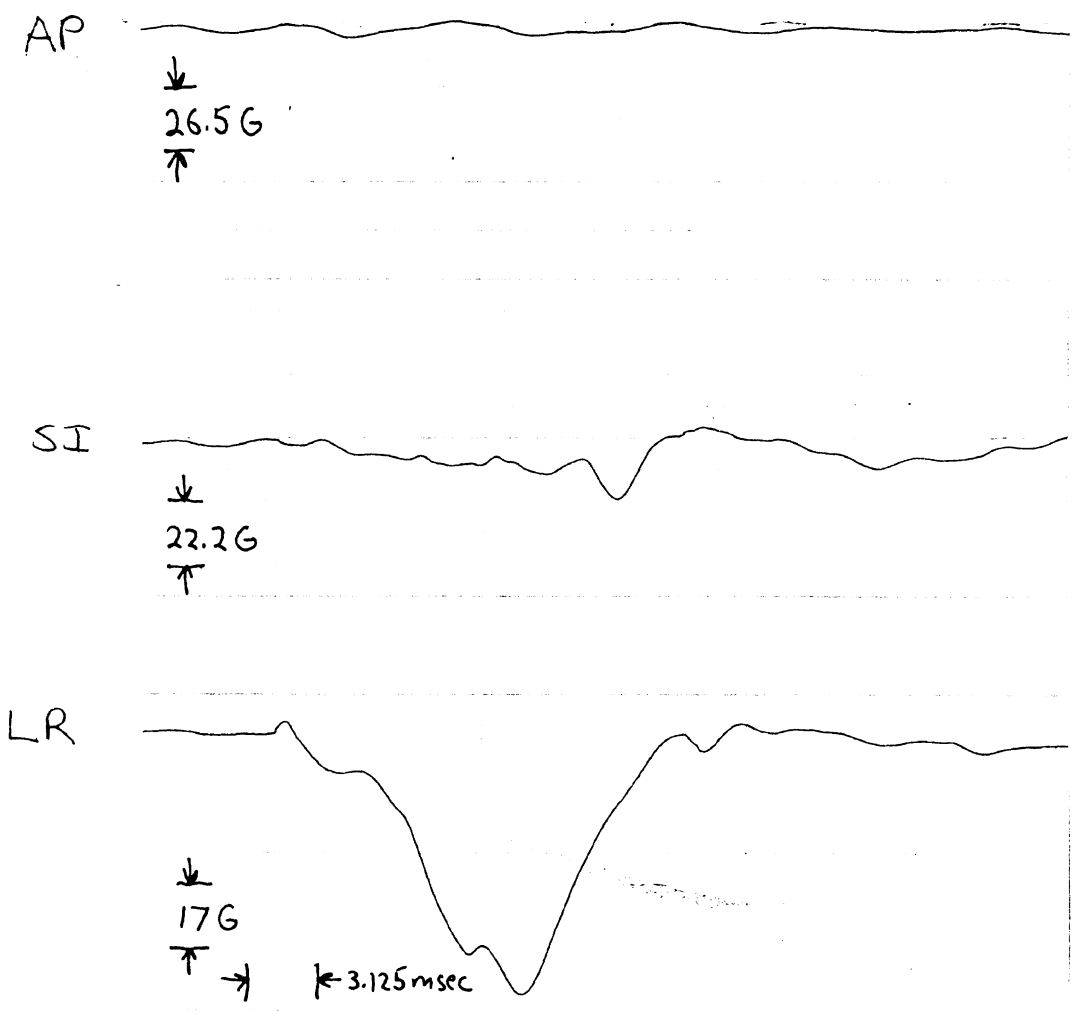


LEFT-RIGHT
ACCELERATION

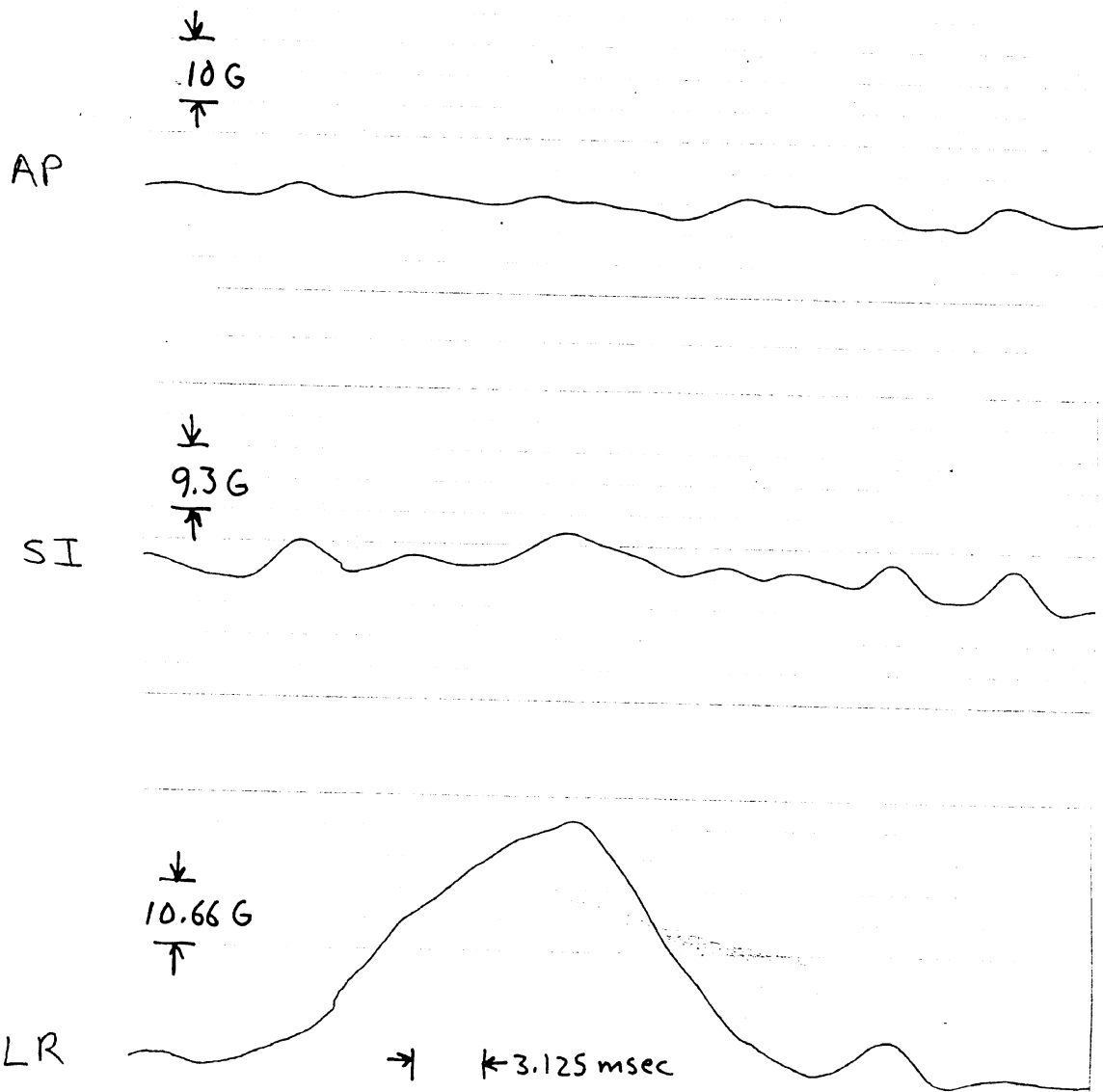
20.9 G =
Filtered Class 1000



Test 76J007 Thorax Acceleration



Test 76 J 007 Pelvis Acceleration



TEST 76J008 Head Acceleration

See Figure 3.6 in main text

Test 76J008 Thorax Acceleration

AP



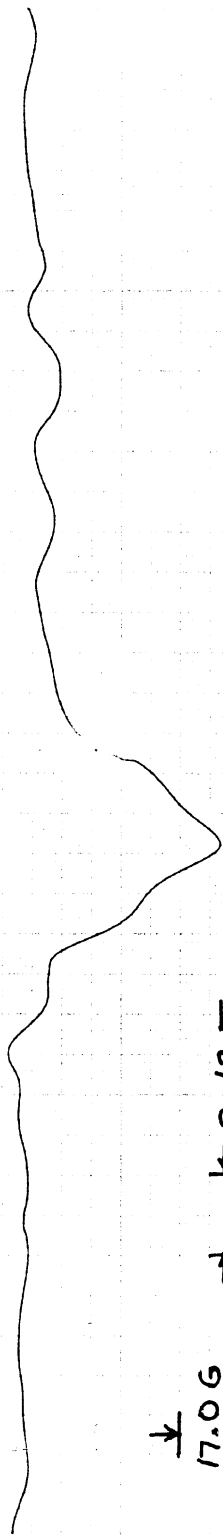
$\frac{1}{26.56G}$
↑

SI



$\frac{1}{22.1G}$
↑

LR



$\frac{1}{17.0G}$ → ← 3.125msec
↑


Test 76J008 Pelvis Acceleration

AP 

$\frac{1}{21.2 G}$

SI 

$\frac{1}{18.6 G}$

LR 

$\frac{1}{21.3 G} \rightarrow \leftarrow 3.125 msec$

Test 76J009 Head Acceleration

↓
9.72 G
↑

AP

↓
9.52 G
↑

SI

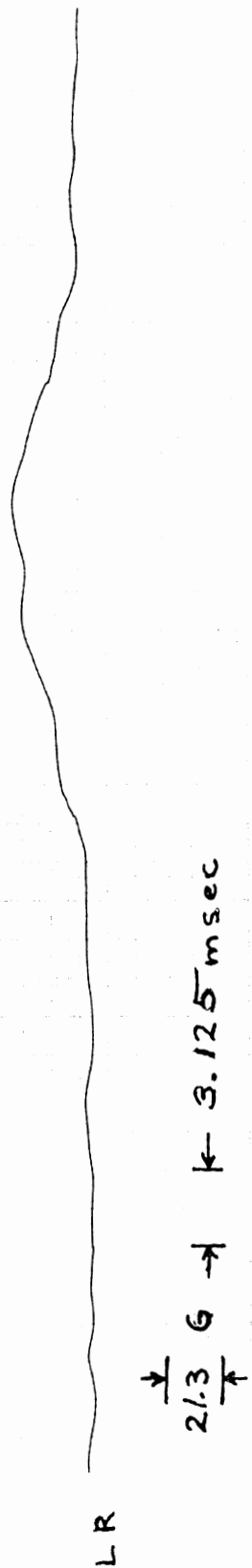
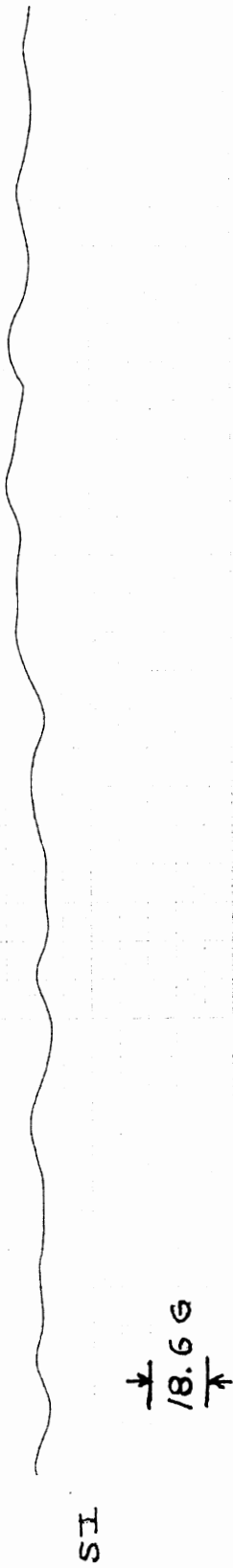
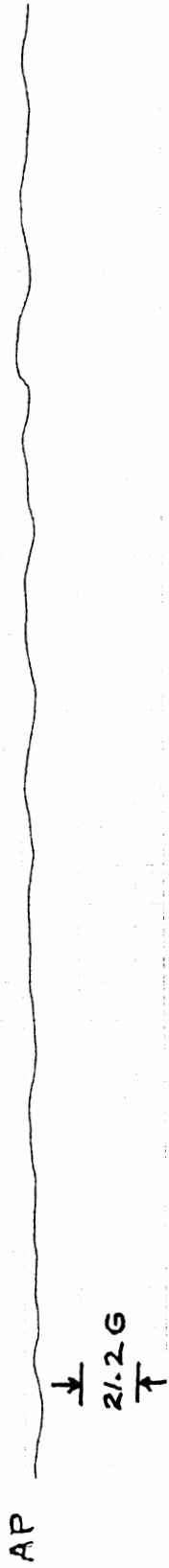
↓
10.52 G
↑

→ ← 3.125 msec

TEST 76J009 Thorax Acceleration

See Figure 3.8 in main text

Test 76J009 Pelvis Acceleration



APPENDIX B
CALIBRATION TEST DATA TRACES

DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

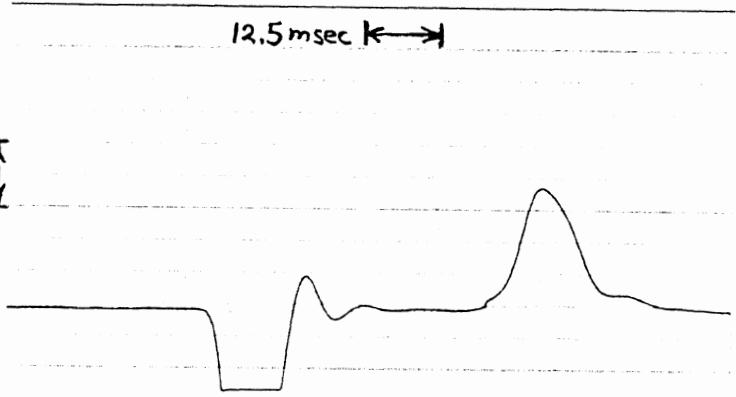
TEST NO. 76J 014 DUMMY NO. 1 SIDE L BODY REGION PELVIS

IMPACT MASS
DECELERATION

12.5 msec \longleftrightarrow

25 G = \updownarrow

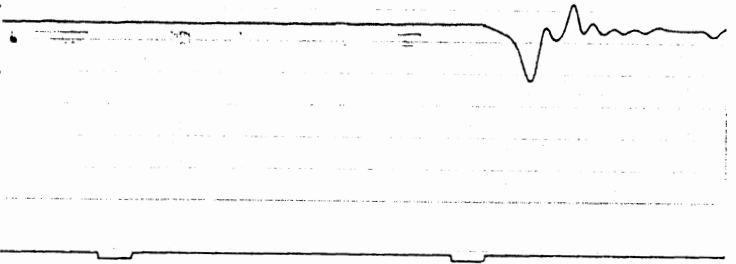
Filtered Class 60



ANTERIOR-POSTERIOR
ACCELERATION

10.1 G = \updownarrow

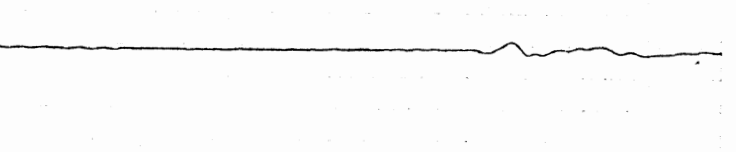
Filtered Class 180



SUPERIOR-INFERIOR
ACCELERATION

21.3 G = \updownarrow

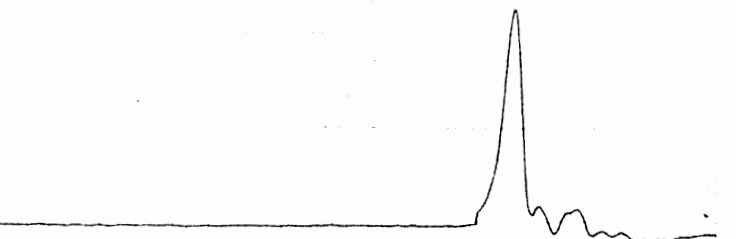
Filtered Class 180



LEFT-RIGHT
ACCELERATION

16.7 G = \updownarrow


Filtered Class 180

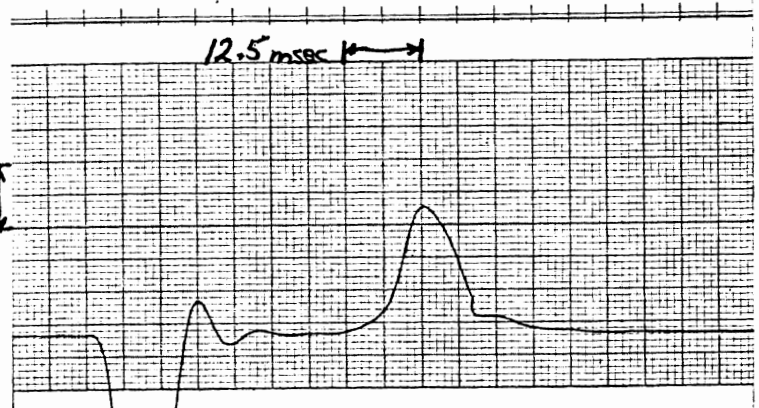


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J 015 DUMMY NO. 1 SIDE L BODY REGION PELVIS

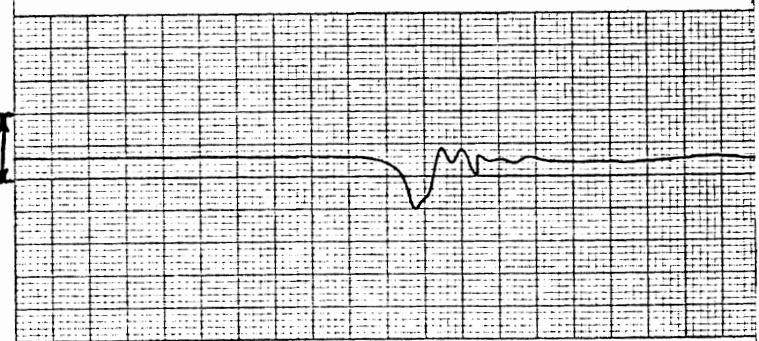
IMPACT MASS
DECELERATION

25 G = 
Filtered Class 60




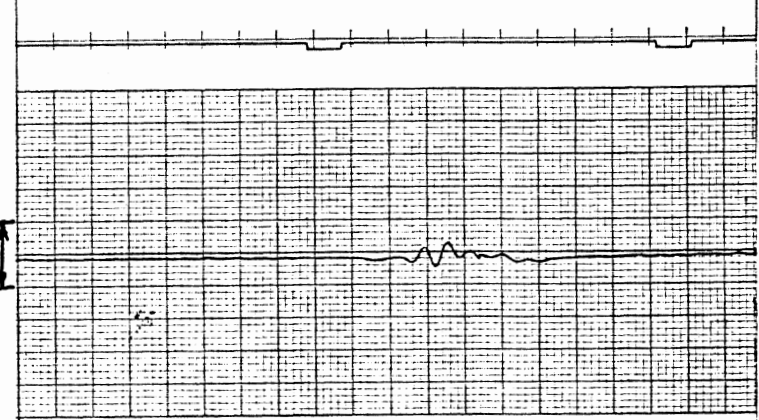
ANTERIOR-POSTERIOR
ACCELERATION

10.1 G = 
Filtered Class 180




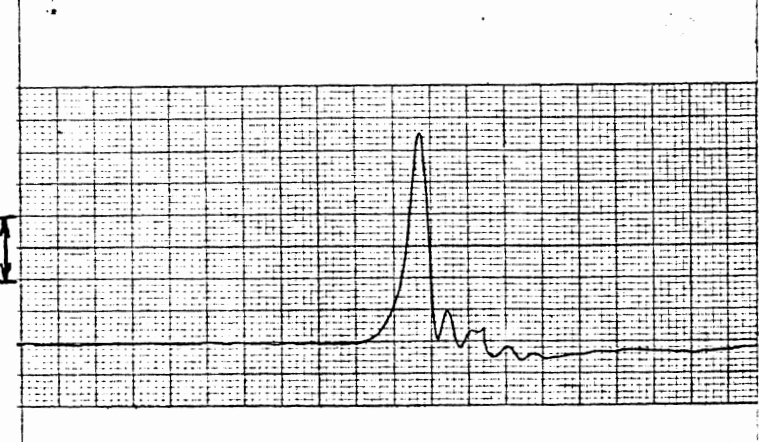
SUPERIOR-INFERIOR
ACCELERATION

21.3 G = 
Filtered Class 180



LEFT-RIGHT
ACCELERATION

16.7 G = 
Filtered Class 180



DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 016

DUMMY NO. 1

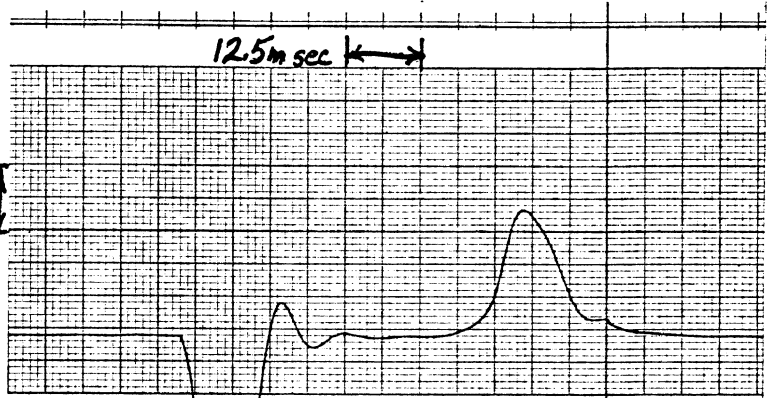
SIDE L

BODY REGION PELVIS

IMPACT MASS
DECELERATION

25 G =

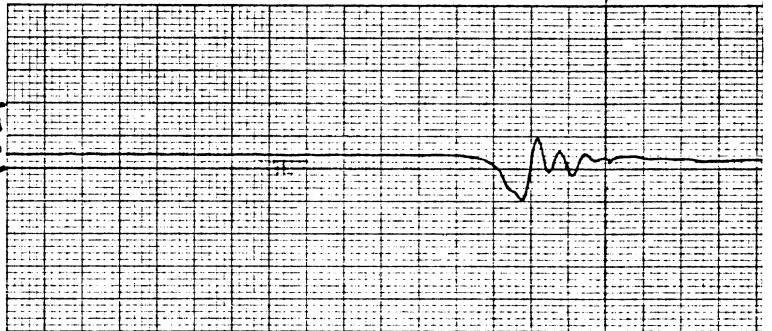
Filtered Class 60



ANTERIOR-POSTERIOR
ACCELERATION

10.1 G =

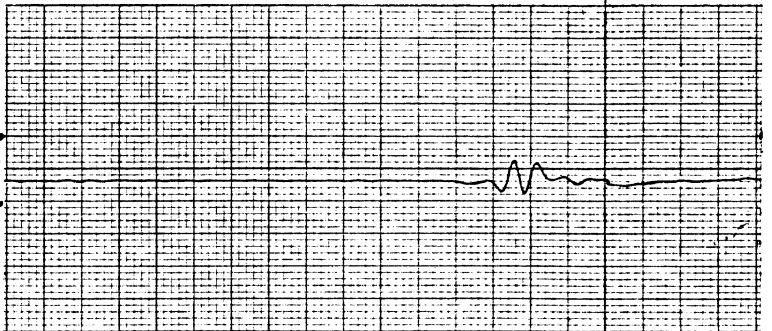
Filtered Class 180



SUPERIOR-INFERIOR
ACCELERATION

21.3 G =

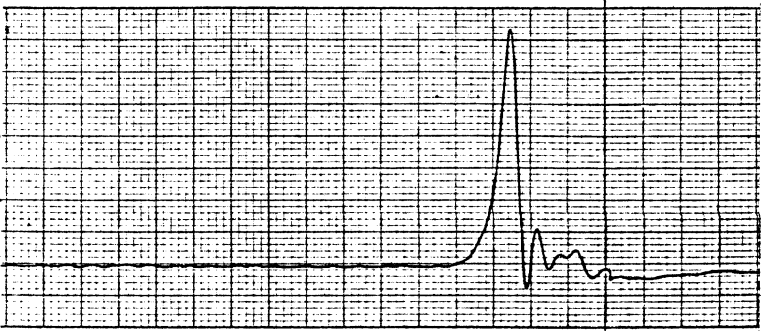
Filtered Class 180



LEFT-RIGHT
ACCELERATION

16.7 G =

Filtered Class 180

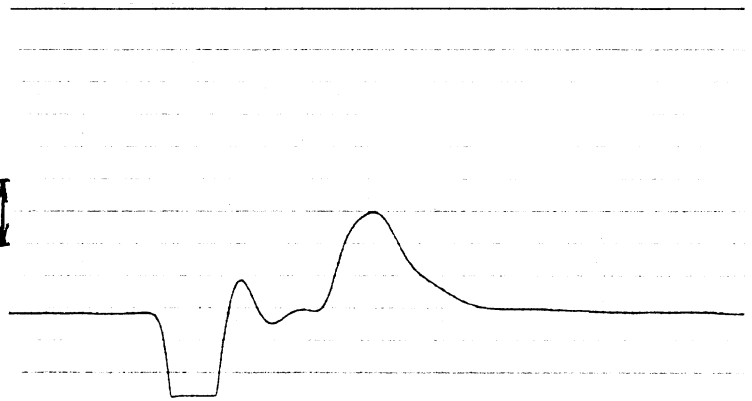


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J 017 DUMMY NO. 1 SIDE L BODY REGION SHOULDER

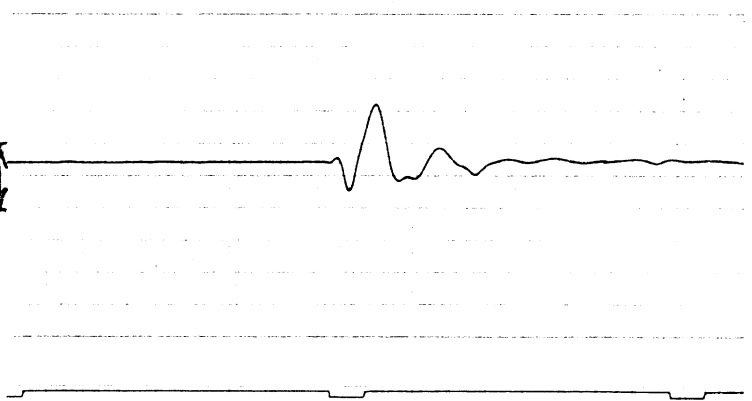
IMPACT MASS
DECELERATION

25 G = 
Filtered Class 60




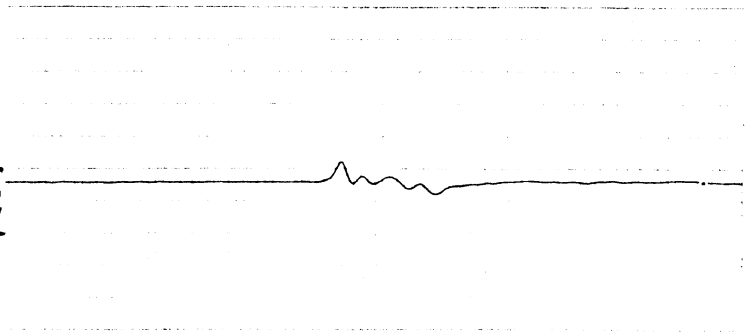
ANTERIOR-POSTERIOR
ACCELERATION

10.1 G = 
Filtered Class 180




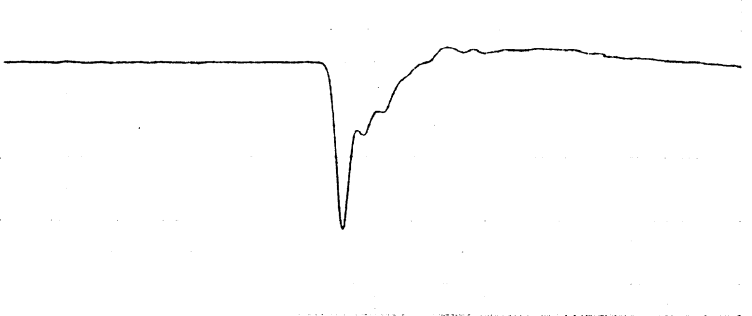
SUPERIOR-INFERIOR
ACCELERATION

2.13 G = 
Filtered Class 180



LEFT-RIGHT
ACCELERATION

16.7 G = 
Filtered Class 180



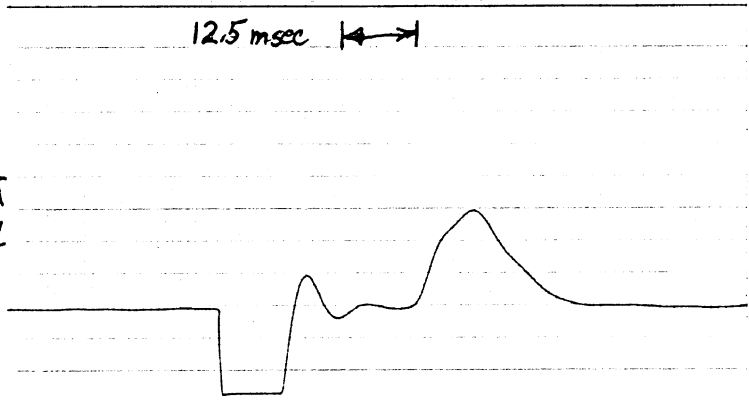
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 018 DUMMY NO. 1 SIDE L BODY REGION SHLDR

IMPACT MASS
DECELERATION

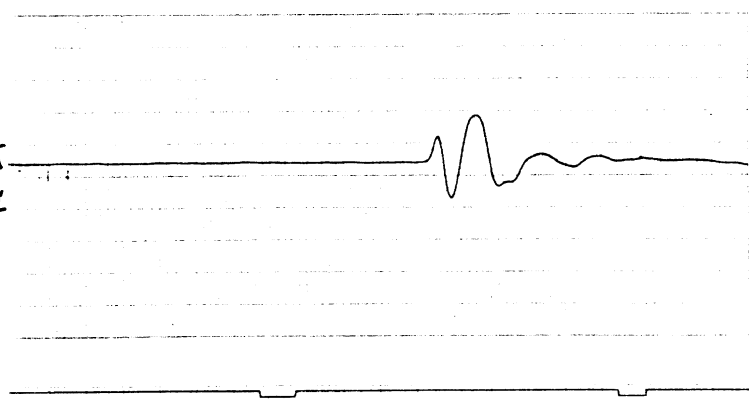
12.5 msec \longleftrightarrow

Filtered Class 25 G = \updownarrow
60



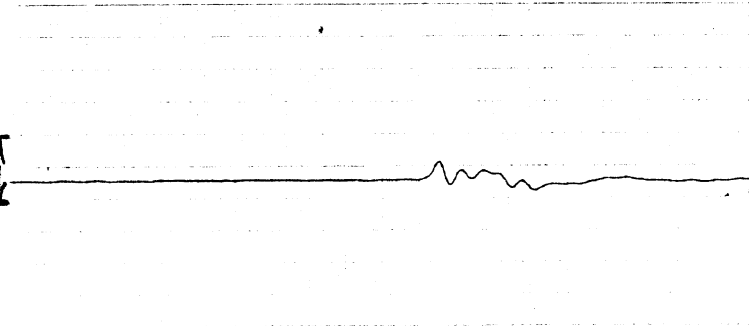
ANTERIOR-POSTERIOR
ACCELERATION

Filtered Class 10.1 G = \updownarrow
180



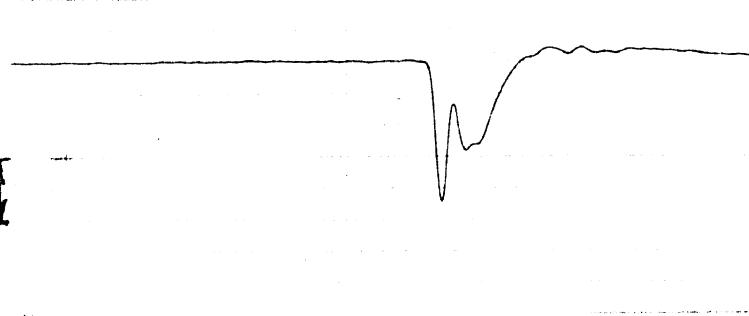
SUPERIOR-INFERIOR
ACCELERATION

Filtered Class 21.3 G = \updownarrow
180



LEFT-RIGHT
ACCELERATION

Filtered Class 16.7 G = \updownarrow
180



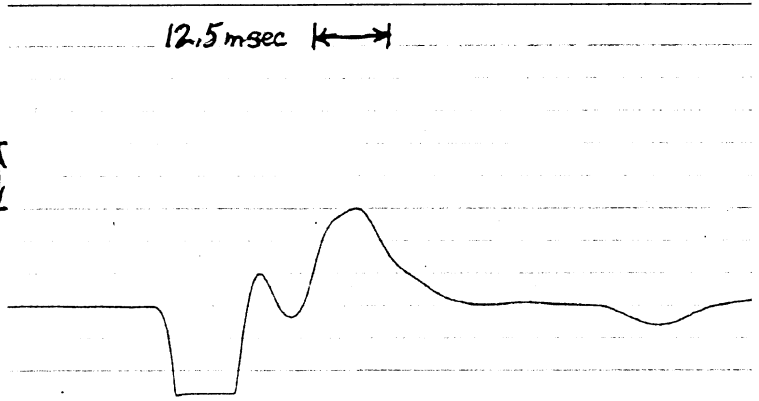
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 019 DUMMY NO. 1 SIDE L BODY REGION SHLDR

IMPACT MASS
DECELERATION

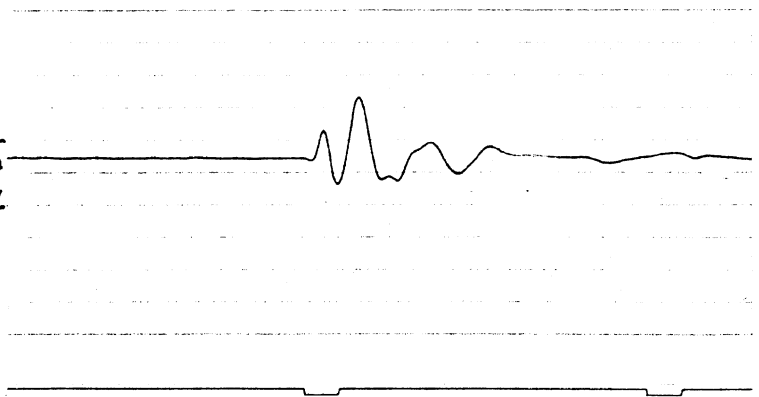
12.5 msec \longleftrightarrow

25 G = \updownarrow
Filtered Class 60



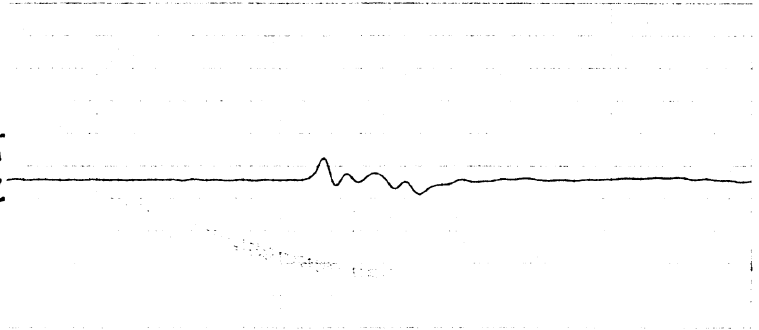
ANTERIOR-POSTERIOR
ACCELERATION

10.1 G = \updownarrow
Filtered Class 180



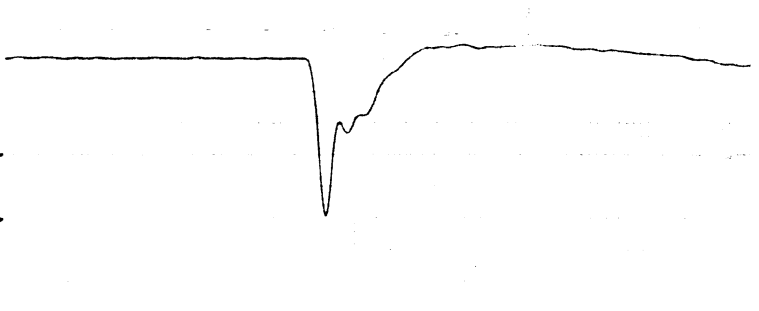
SUPERIOR-INFERIOR
ACCELERATION

21.3 G = \updownarrow
Filtered Class 180



LEFT-RIGHT
ACCELERATION

16.7 G = \updownarrow
Filtered Class 180



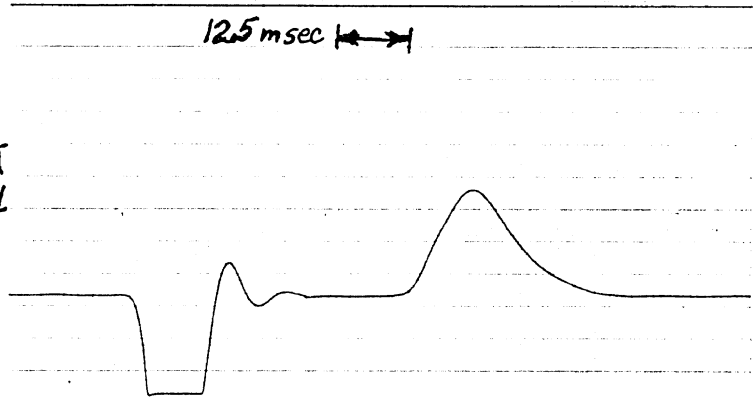
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 020 DUMMY NO. 1 SIDE L BODY REGION THORAX

IMPACT MASS
DECELERATION

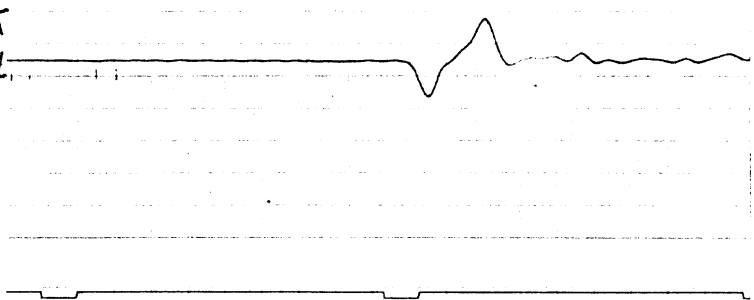
125 msec

25 G = \updownarrow
Filtered Class 60



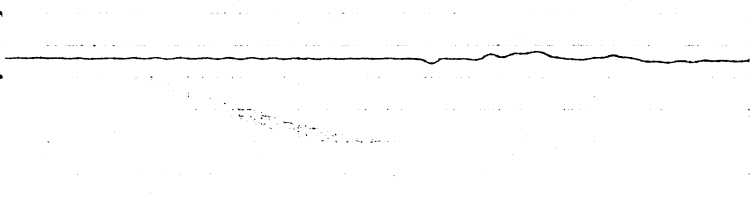
ANTERIOR-POSTERIOR
ACCELERATION

10.1 G = \updownarrow
Filtered Class 180



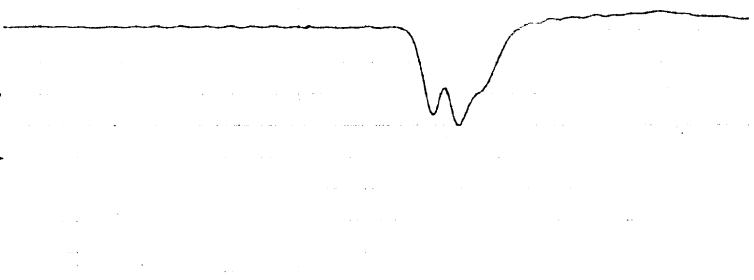
SUPERIOR-INFERIOR
ACCELERATION

2.13 G = \updownarrow
Filtered Class 180



LEFT-RIGHT
ACCELERATION


16.7 G = \updownarrow
Filtered Class 180

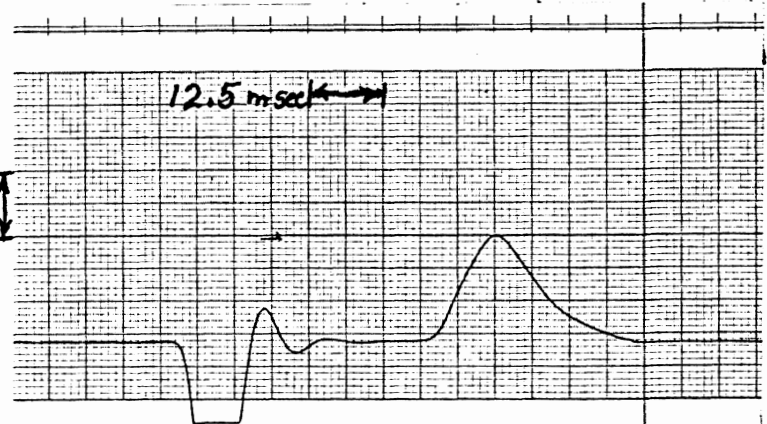


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J 021 DUMMY NO. 1 SIDE L BODY REGION THORAX

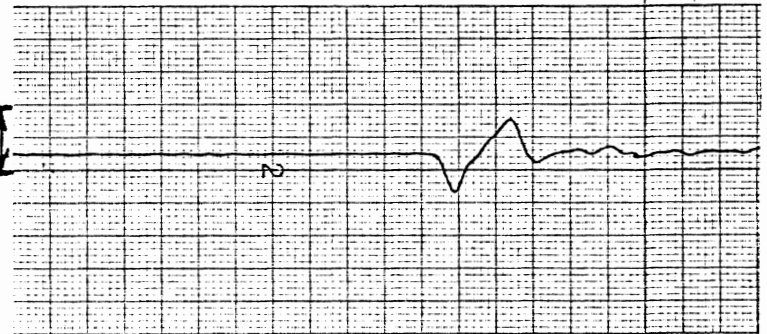
IMPACT MASS
DECELERATION

25 G = 
Filtered Class 60




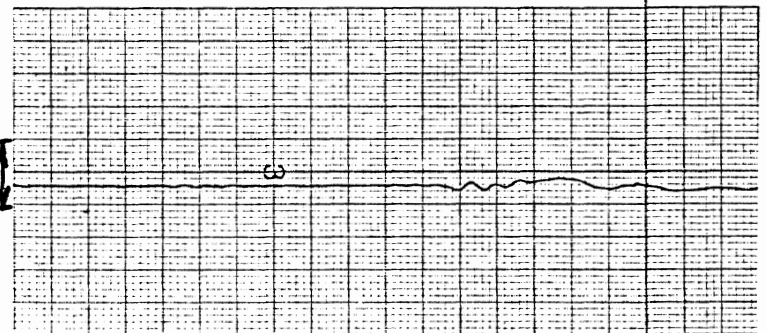
ANTERIOR-POSTERIOR
ACCELERATION

10.1 G = 
Filtered Class 180




SUPERIOR-INFERIOR
ACCELERATION

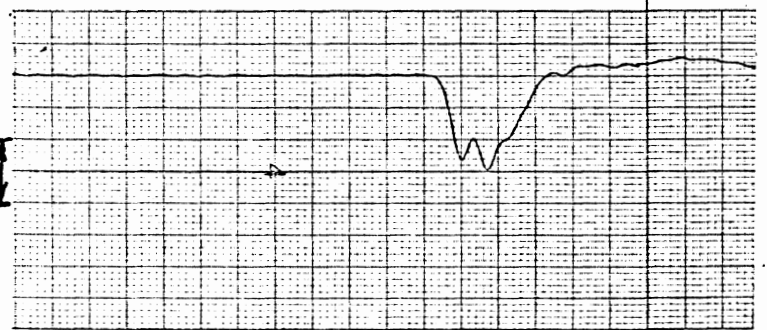
21.3 G = 
Filtered Class 180



BRUSH ACCUCHART

LEFT-RIGHT
ACCELERATION

16.7 G = 
Filtered Class 180

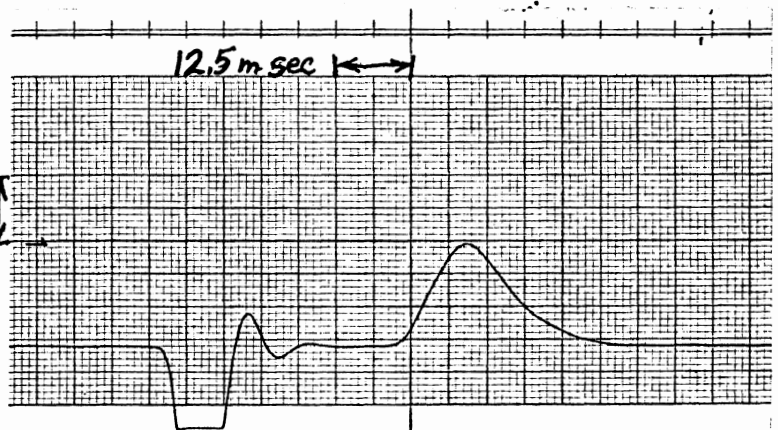


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J022 DUMMY NO. 1 SIDE L BODY REGION THORAX

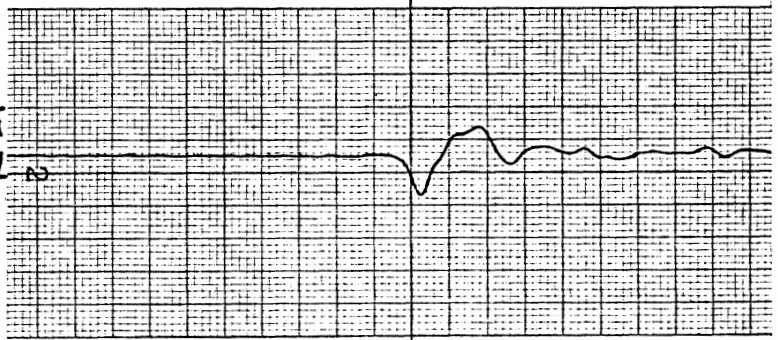
IMPACT MASS
DECELERATION

25 G = \updownarrow
Filtered Class 60



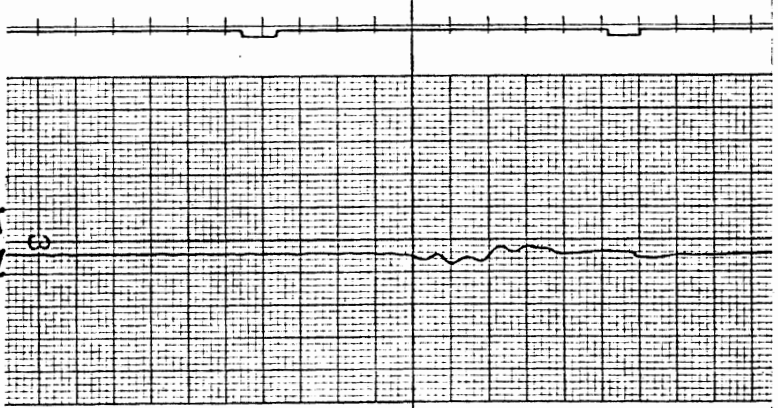
ANTERIOR-POSTERIOR
ACCELERATION

10.1 G = \updownarrow
Filtered Class 180



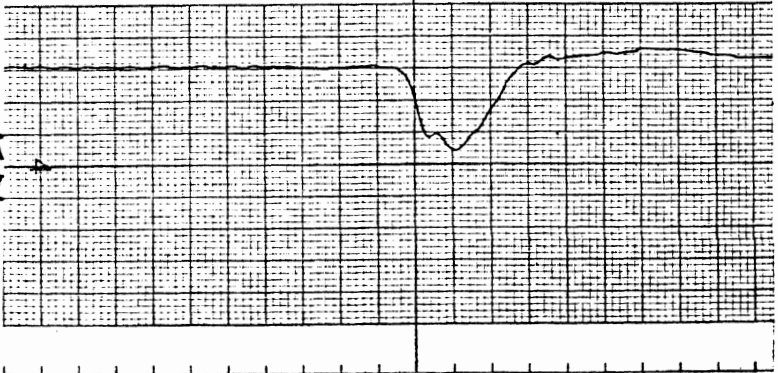
SUPERIOR-INFERIOR
ACCELERATION

21.3 G = \updownarrow
Filtered Class 180



LEFT-RIGHT
ACCELERATION

16.7 G = \updownarrow
Filtered Class 180



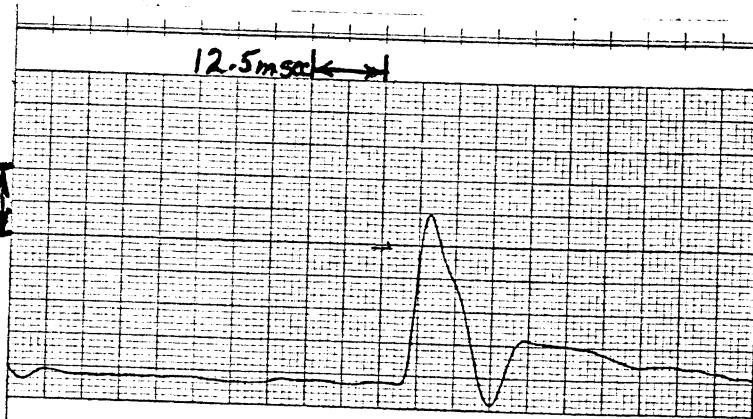
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 025 DUMMY NO. 1 SIDE L BODY REGION HEAD

IMPACT MASS
DECELERATION

5 G =

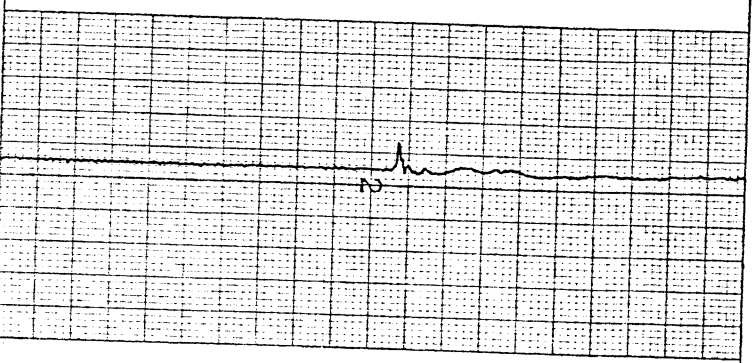
Filtered Class 60



ANTERIOR-POSTERIOR
ACCELERATION

25.1 G =

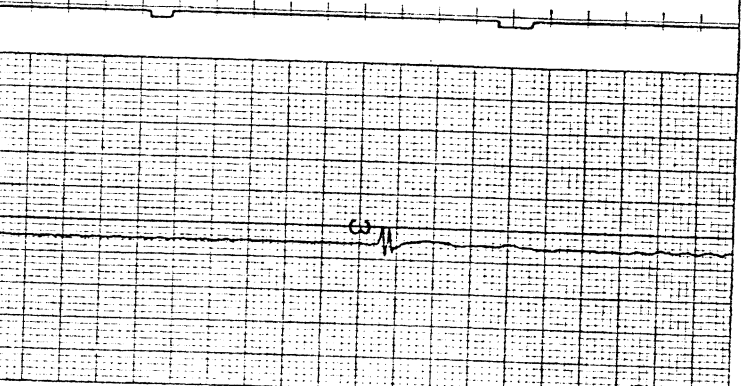
Filtered Class 1000



SUPERIOR-INFERIOR
ACCELERATION

42.5 G =

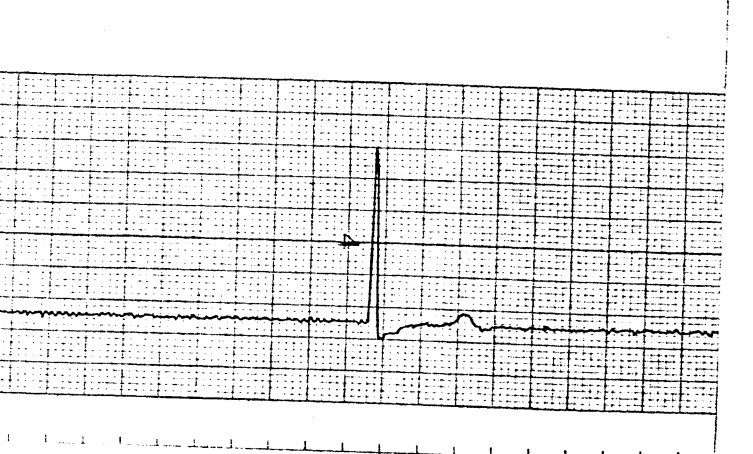
Filtered Class 1000



LEFT-RIGHT
ACCELERATION

83.5 G =

Filtered Class 1000

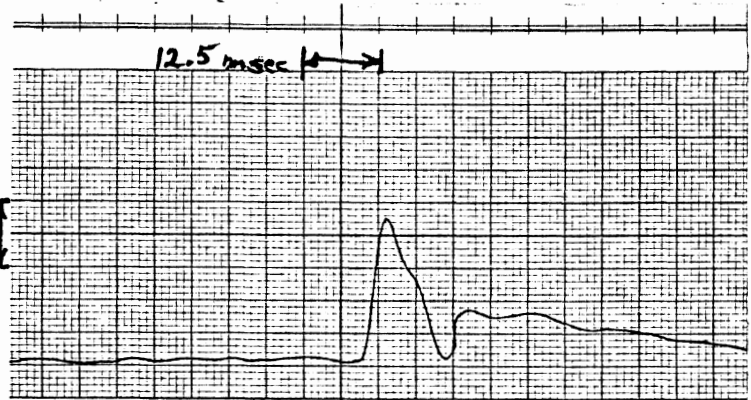


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 026 DUMMY NO. 1 SIDE L BODY REGION HEAD

IMPACT MASS
DECELERATION

5 G =
Filtered Class 60



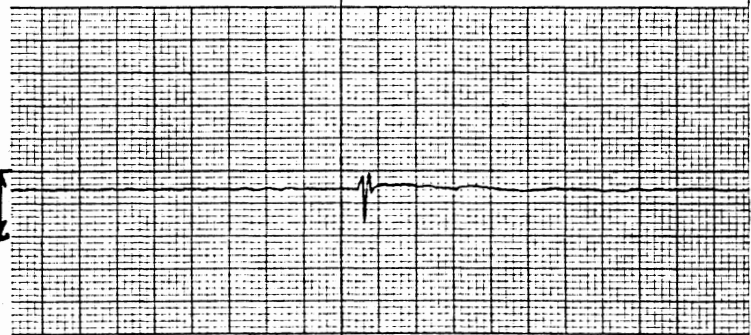
ANTERIOR-POSTERIOR
ACCELERATION

25.1 G =
Filtered Class 1000



SUPERIOR-INFERIOR
ACCELERATION

42.5 G =
Filtered Class 1000



LEFT-RIGHT
ACCELERATION

83.5 G =
Filtered Class 1000

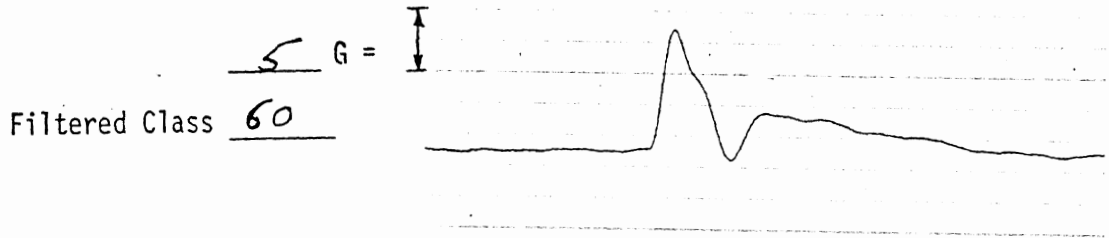


HART
Gould Inc., Instrument S
Cleveland, Ohio Pri

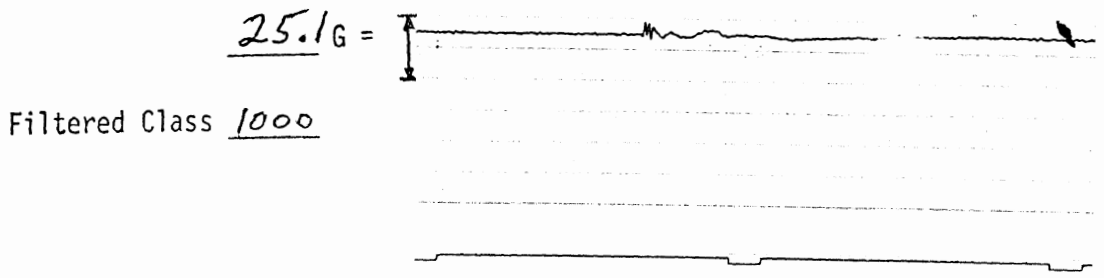
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 027 DUMMY NO. 1 SIDE L BODY REGION HEAD

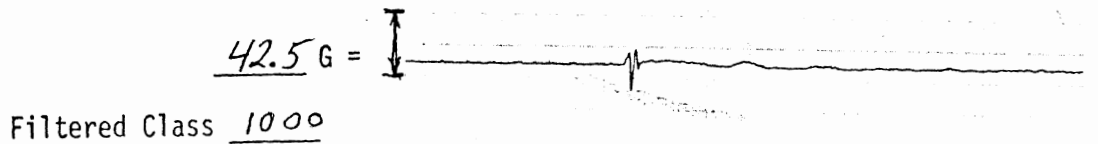
IMPACT MASS
DECELERATION



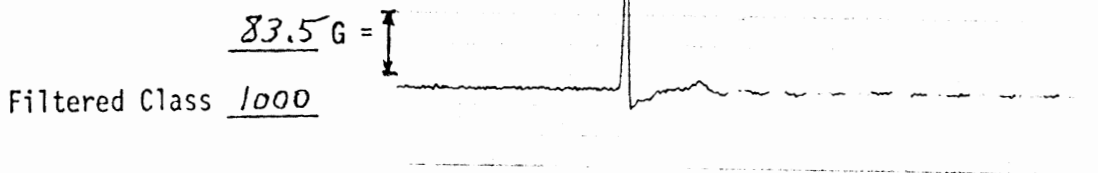
ANTERIOR-POSTERIOR
ACCELERATION



SUPERIOR-INFERIOR
ACCELERATION



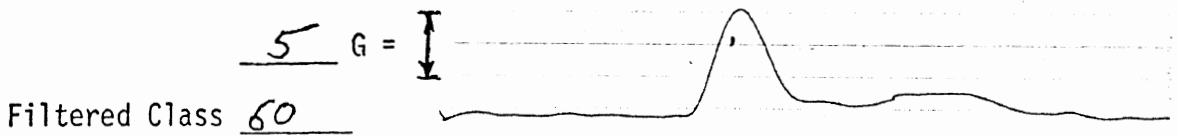
LEFT-RIGHT
ACCELERATION



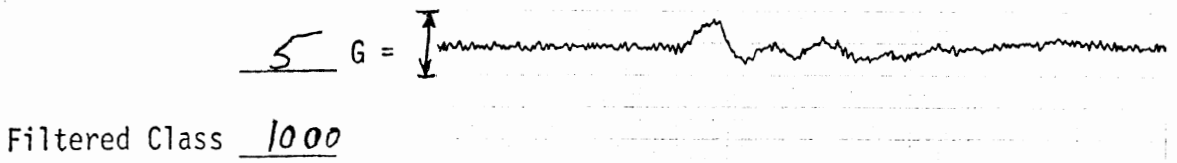
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 028 DUMMY NO. 1 SIDE L BODY REGION HEAD, PAD

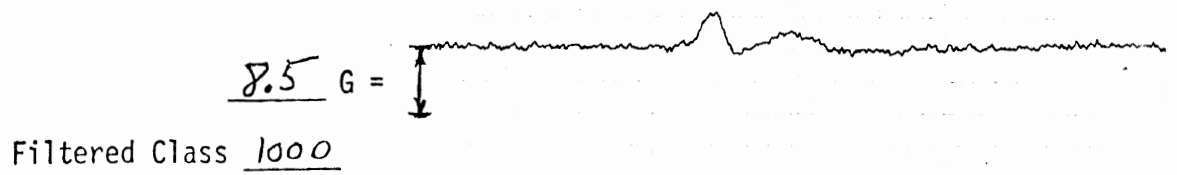
IMPACT MASS
DECELERATION



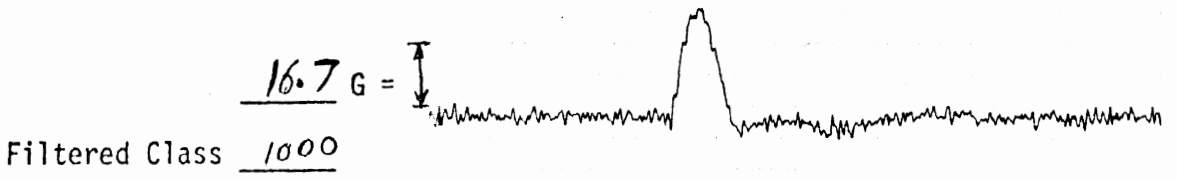
ANTERIOR-POSTERIOR
ACCELERATION



SUPERIOR-INFERIOR
ACCELERATION



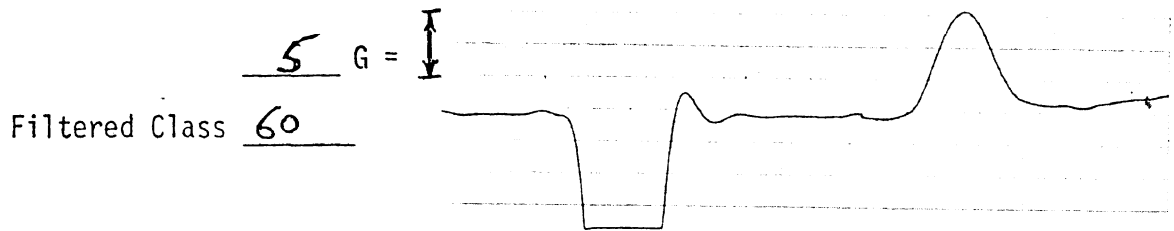
LEFT-RIGHT
ACCELERATION



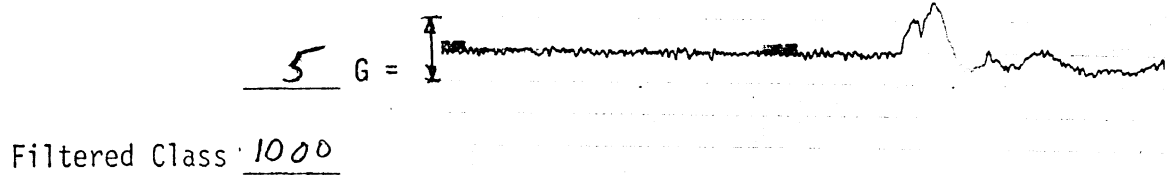
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 029 DUMMY NO. 1 SIDE L BODY REGION HEAD, PAD

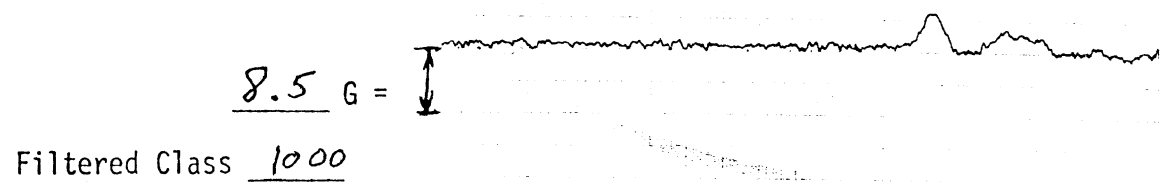
IMPACT MASS
DECELERATION



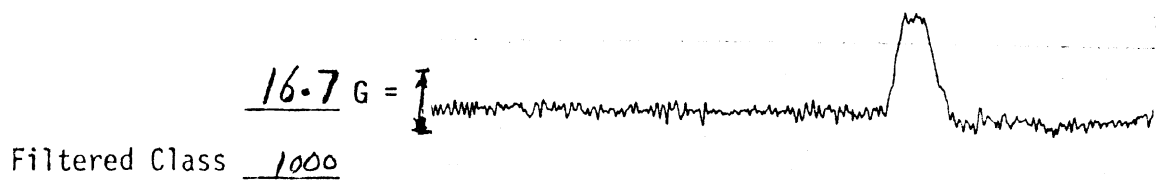
ANTERIOR-POSTERIOR
ACCELERATION



SUPERIOR-INFERIOR
ACCELERATION




LEFT-RIGHT
ACCELERATION

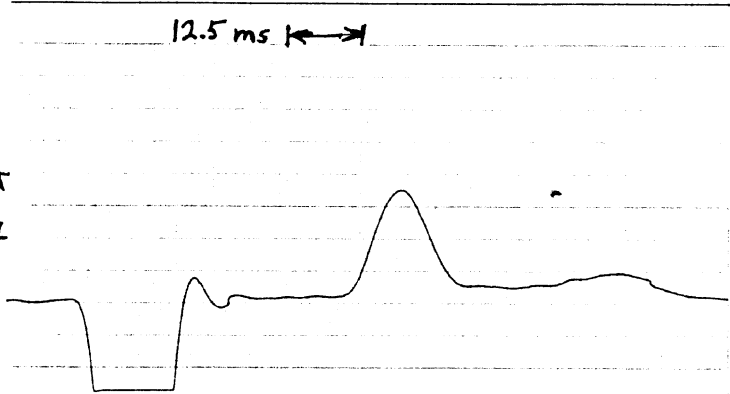


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J 030 DUMMY NO. 1 SIDE L BODY REGION HEAD, PAD

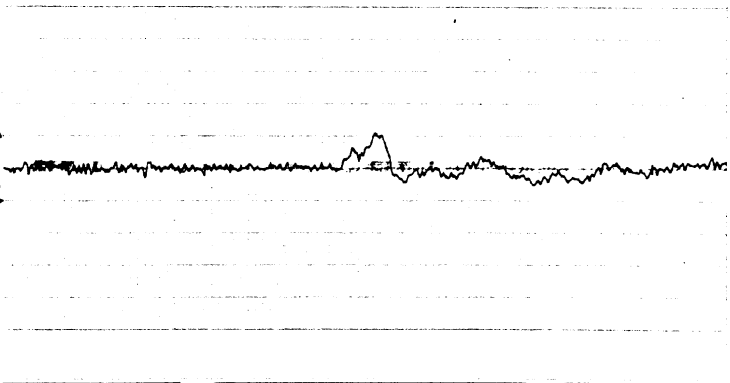
IMPACT MASS
DECELERATION

5 G = 
Filtered Class 60




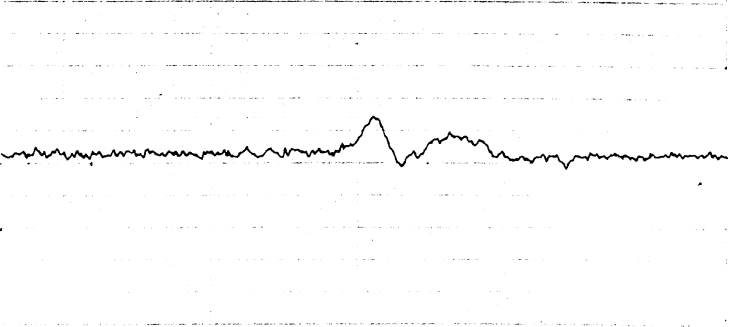
ANTERIOR-POSTERIOR
ACCELERATION

5 G = 
Filtered Class 1000




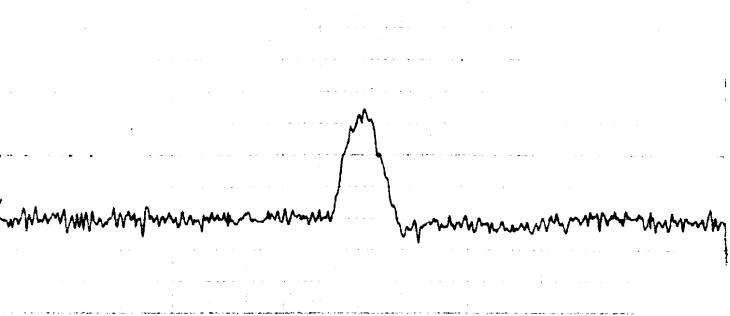
SUPERIOR-INFERIOR
ACCELERATION

8.5 G = 
Filtered Class 1000



LEFT-RIGHT
ACCELERATION

16.7 G = 
Filtered Class 1000



DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

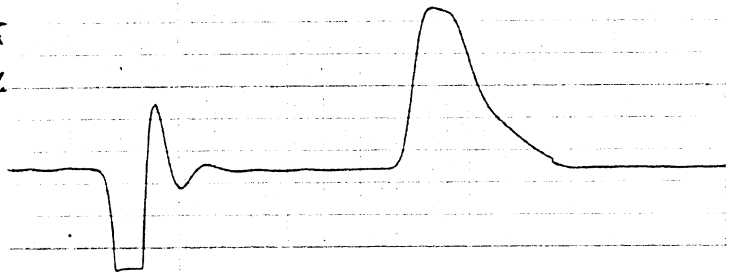
TEST NO. 76J 032 DUMMY NO. 2 SIDE L BODY REGION THORAX

IMPACT MASS
DECELERATION

12.5 ms

10 G =

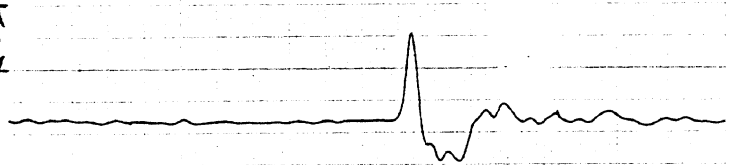
Filtered Class 80



ANTERIOR-POSTERIOR
ACCELERATION

10 G =

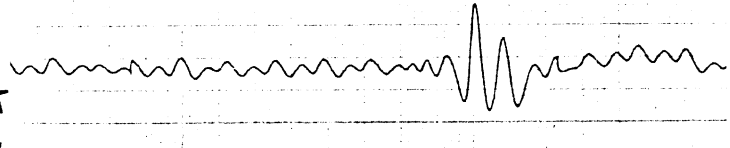
Filtered Class 180



SUPERIOR-INFERIOR
ACCELERATION

10 G =

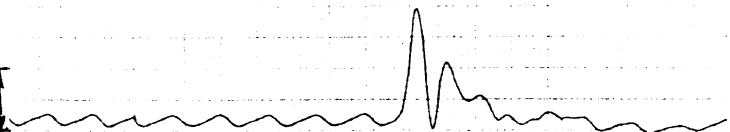
Filtered Class 180



LEFT-RIGHT
ACCELERATION

25 G =

Filtered Class 180



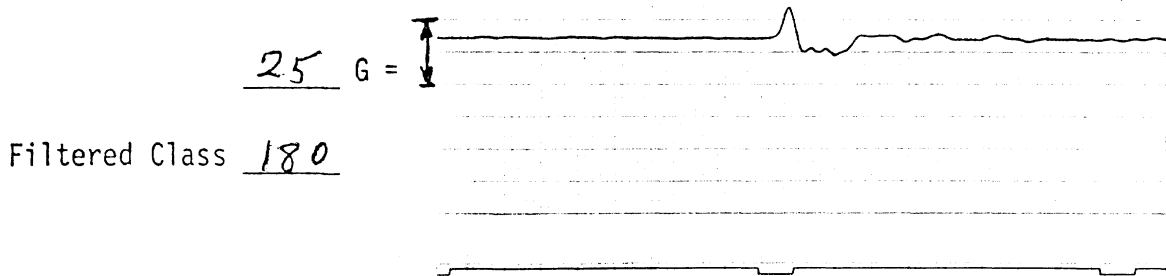
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 033 DUMMY NO. 2 SIDE L BODY REGION THORAX

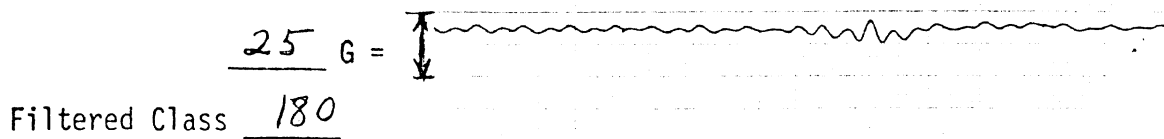
IMPACT MASS
DECELERATION



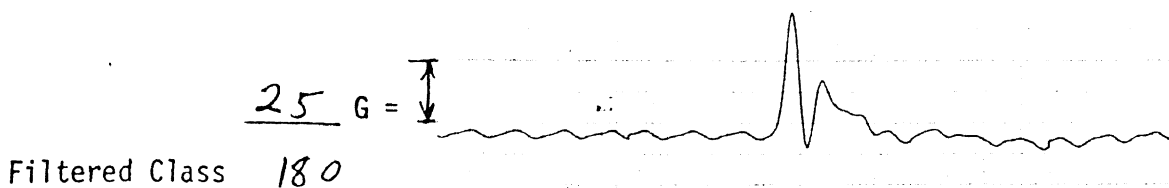
ANTERIOR-POSTERIOR
ACCELERATION



SUPERIOR-INFERIOR
ACCELERATION



LEFT-RIGHT
ACCELERATION

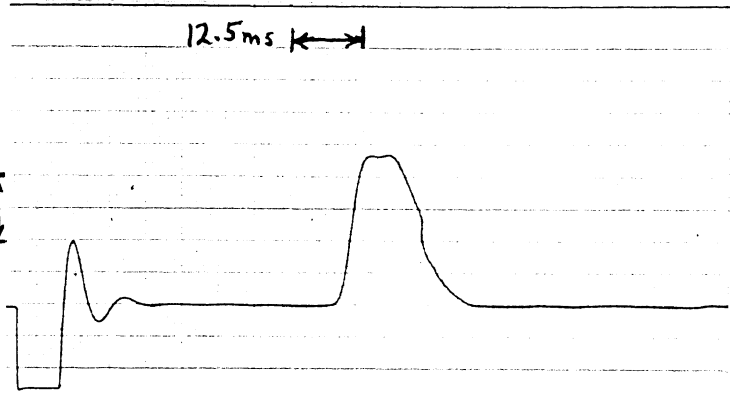


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J034 DUMMY NO. 2 SIDE R BODY REGION THORAX

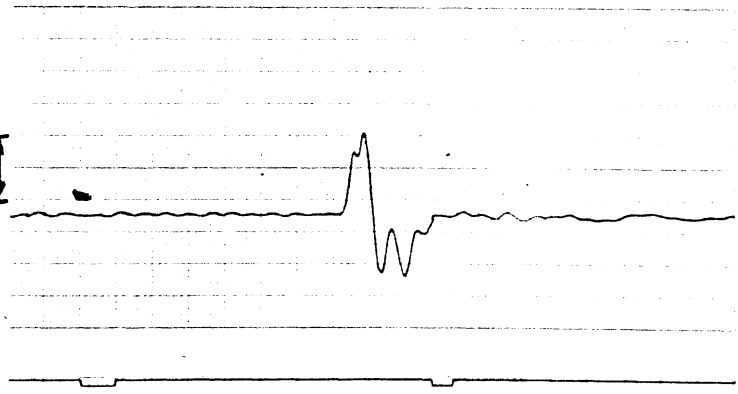
IMPACT MASS
DECELERATION

10 G =
Filtered Class 60



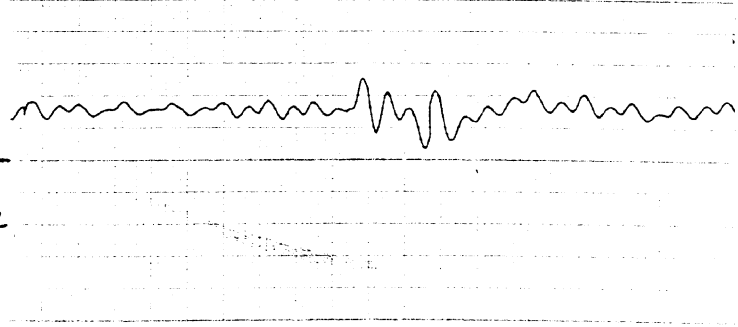
ANTERIOR-POSTERIOR
ACCELERATION

10 G =
Filtered Class 180



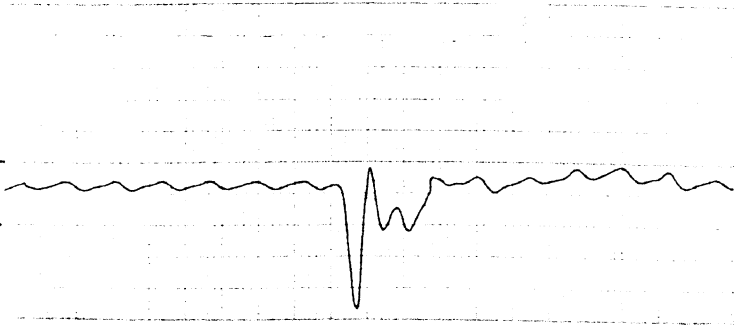
SUPERIOR-INFERIOR
ACCELERATION

10 G =
Filtered Class 180



LEFT-RIGHT
ACCELERATION

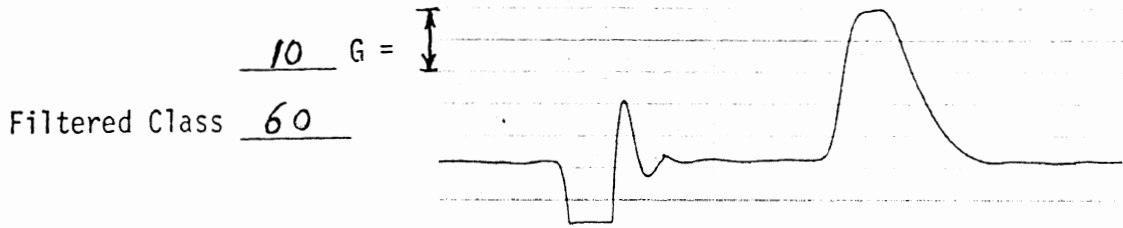
25 G =
Filtered Class 180



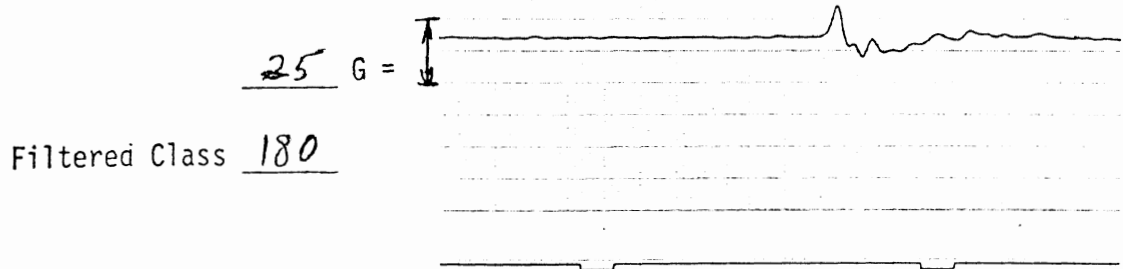
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 035 DUMMY NO. 2 SIDE L BODY REGION THORAX

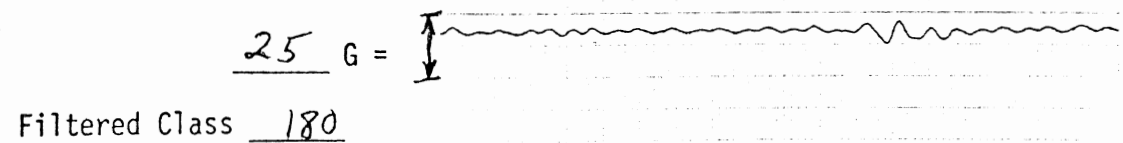
IMPACT MASS
DECELERATION



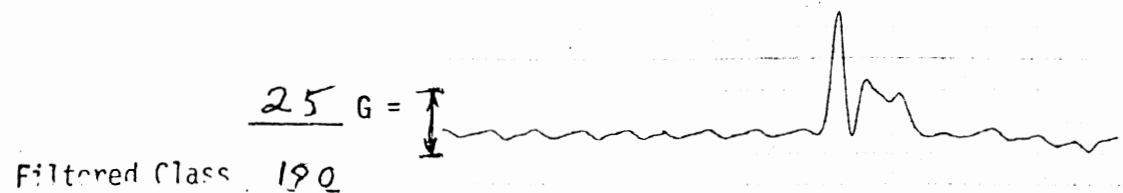
ANTERIOR-POSTERIOR
ACCELERATION



SUPERIOR-INFERIOR
ACCELERATION



LEFT-RIGHT
ACCELERATION

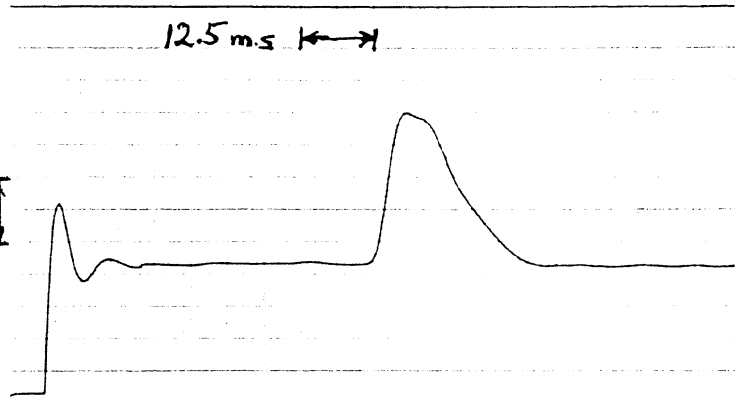


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J036 DUMMY NO. 2 SIDE R BODY REGION THORAX

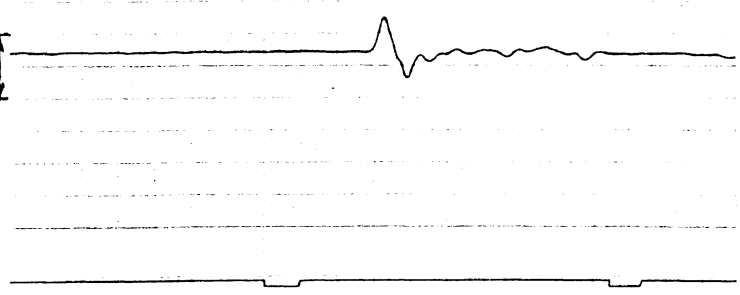
IMPACT MASS
DECELERATION

10 G =
Filtered Class 60



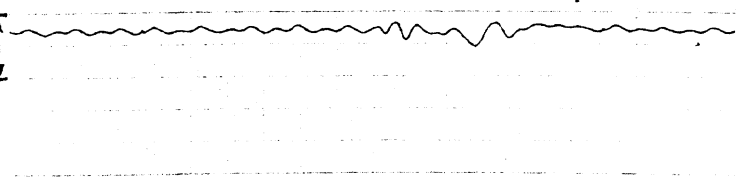
ANTERIOR-POSTERIOR
ACCELERATION

25 G =
Filtered Class 180



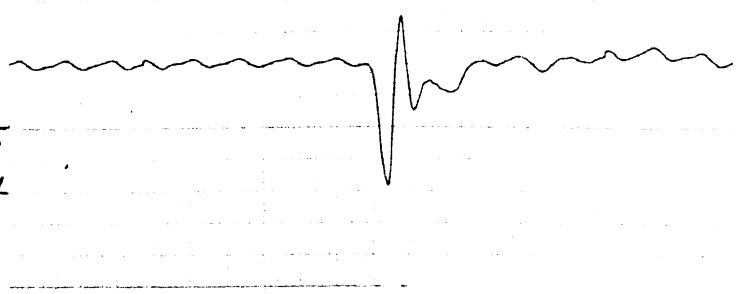
SUPERIOR-INFERIOR
ACCELERATION

25 G =
Filtered Class 180



LEFT-RIGHT
ACCELERATION

25 G =
Filtered Class 180

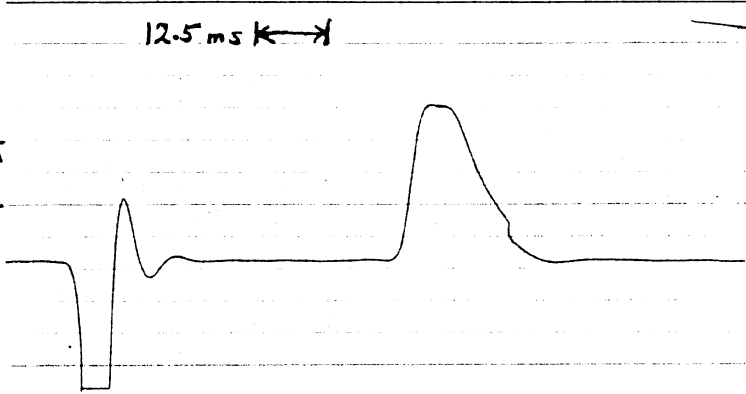


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 037 DUMMY NO. 2 SIDE R BODY REGION THORAX

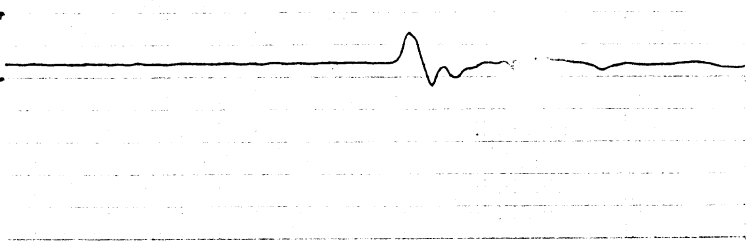
IMPACT MASS
DECELERATION

10 G =
Filtered Class 60



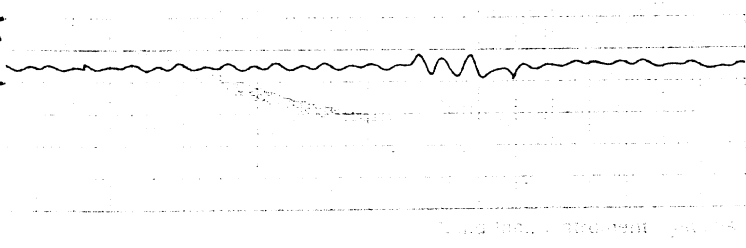
ANTERIOR-POSTERIOR
ACCELERATION

25 G =
Filtered Class 180



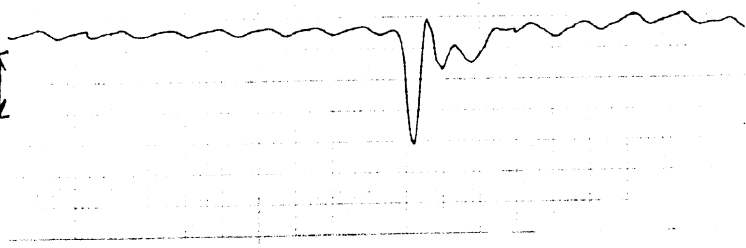
SUPERIOR-INFERIOR
ACCELERATION

25 G =
Filtered Class 180



LEFT-RIGHT
ACCELERATION


25 G =
Filtered Class 180

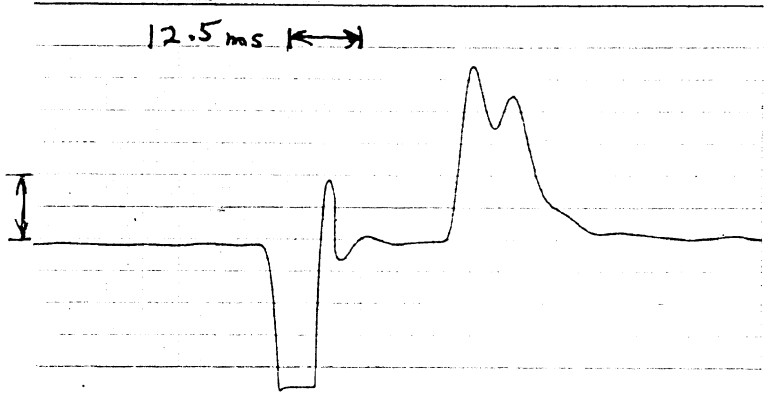


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J 038 DUMMY NO. 2 SIDE R BODY REGION SHLDR

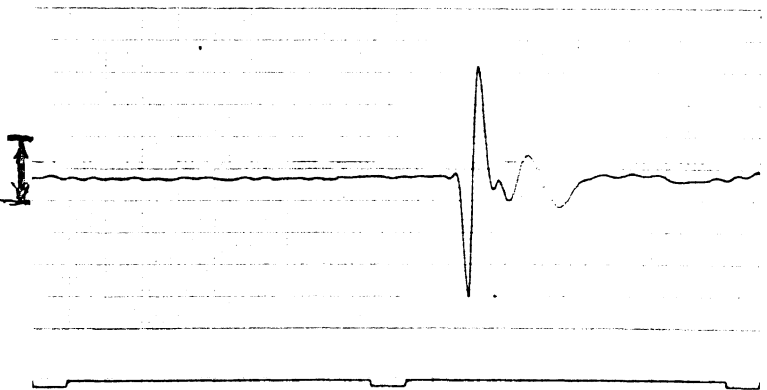
IMPACT MASS
DECELERATION

10 G = 
Filtered Class 60




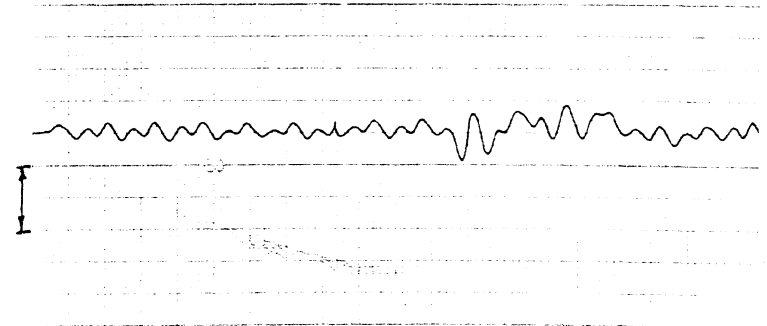
ANTERIOR-POSTERIOR
ACCELERATION

10 G = 
Filtered Class 180




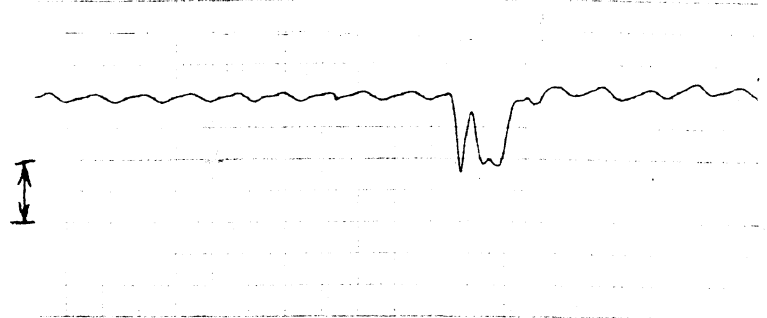
SUPERIOR-INFERIOR
ACCELERATION

10 G = 
Filtered Class 180



LEFT-RIGHT
ACCELERATION

25 G = 
Filtered Class 180

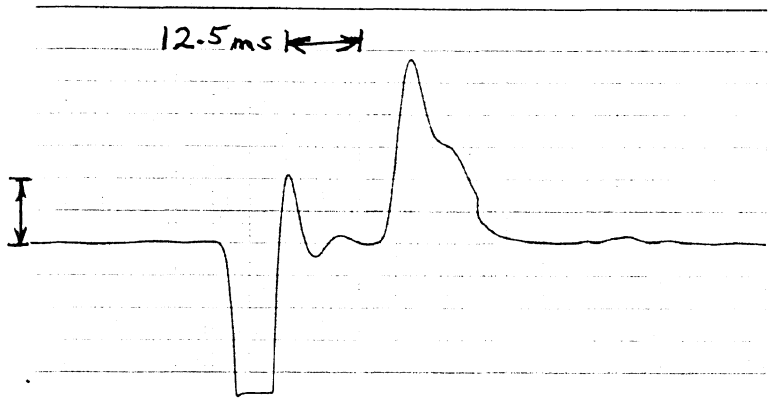


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 039 DUMMY NO. 2 SIDE L BODY REGION SHLDR.

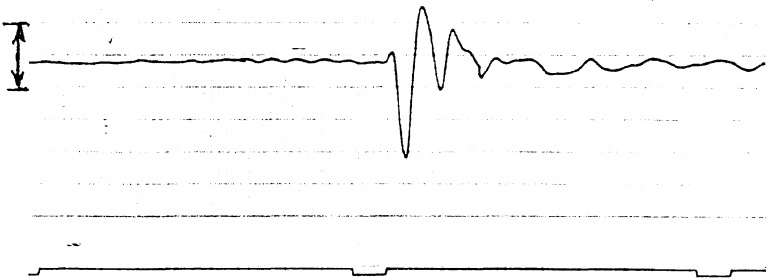
IMPACT MASS
DECELERATION

10 G =
Filtered Class 60



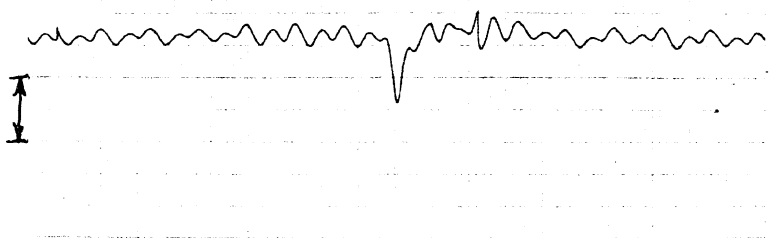
ANTERIOR-POSTERIOR
ACCELERATION

10 G =
Filtered Class 180



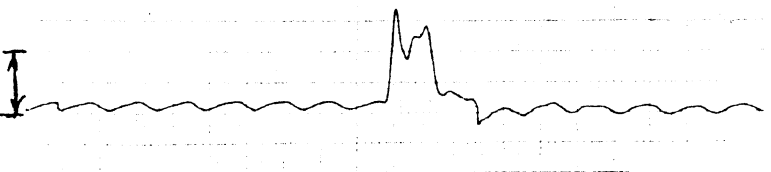
SUPERIOR-INFERIOR
ACCELERATION

10 G =
Filtered Class 180



LEFT-RIGHT
ACCELERATION

25 G =
Filtered Class 180

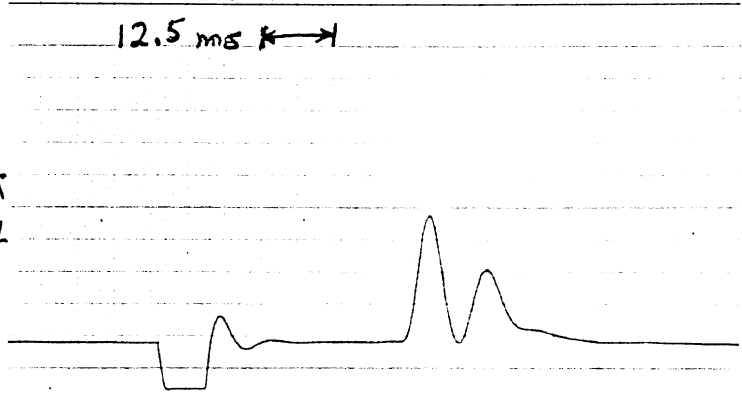


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J040 DUMMY NO. 2 SIDE R BODY REGION SHOULDER

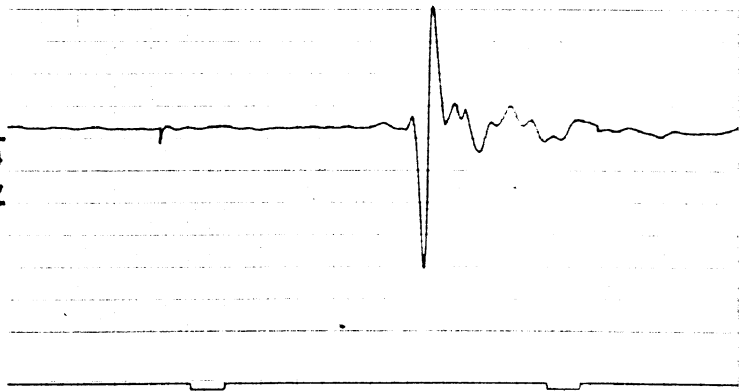
IMPACT MASS
DECELERATION

25 G =
Filtered Class 60



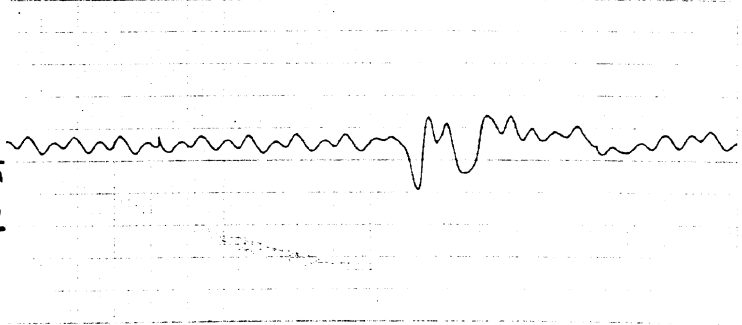
ANTERIOR-POSTERIOR
ACCELERATION

10 G =
Filtered Class 180



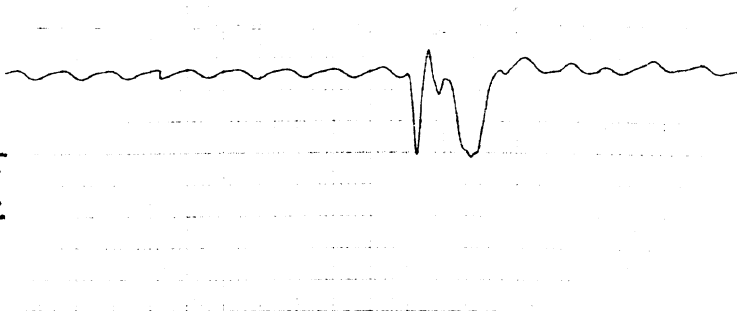
SUPERIOR-INFERIOR
ACCELERATION

10 G =
Filtered Class 180



LEFT-RIGHT
ACCELERATION

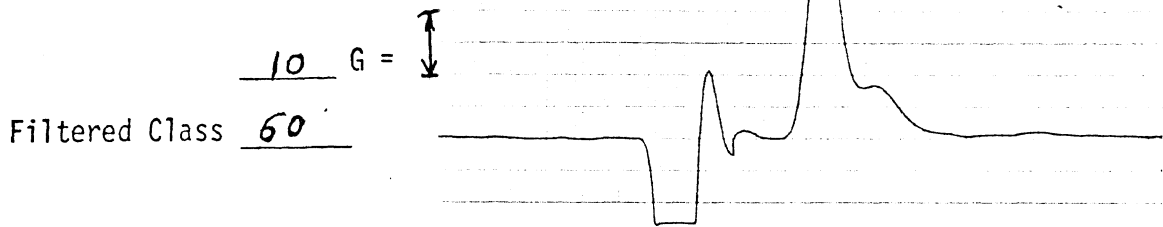
25 G =
Filtered Class 180



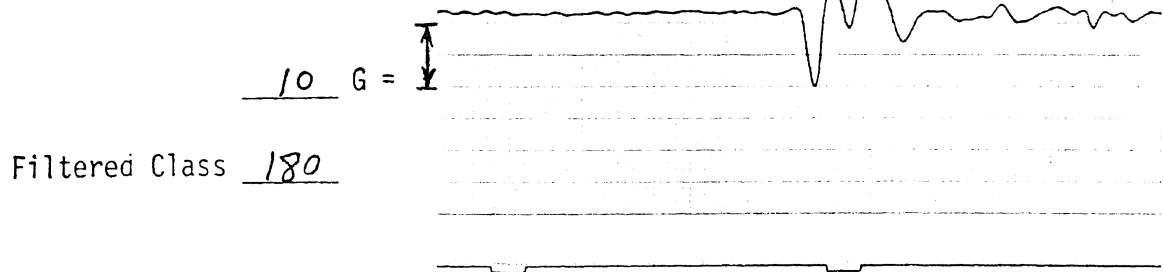
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J041 DUMMY NO. 2 SIDE L BODY REGION SHLDR

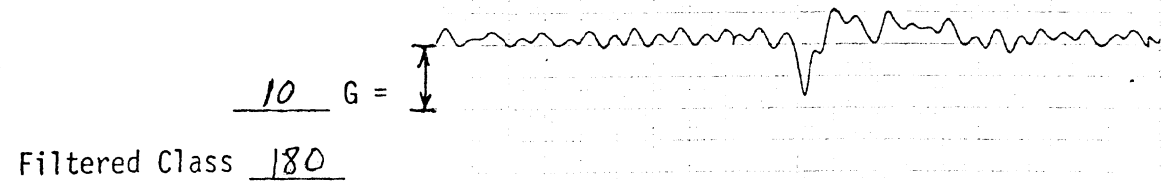
IMPACT MASS
DECELERATION



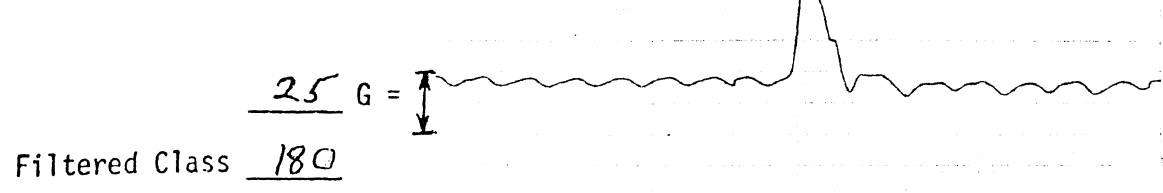
ANTERIOR-POSTERIOR
ACCELERATION



SUPERIOR-INFERIOR
ACCELERATION



LEFT-RIGHT
ACCELERATION

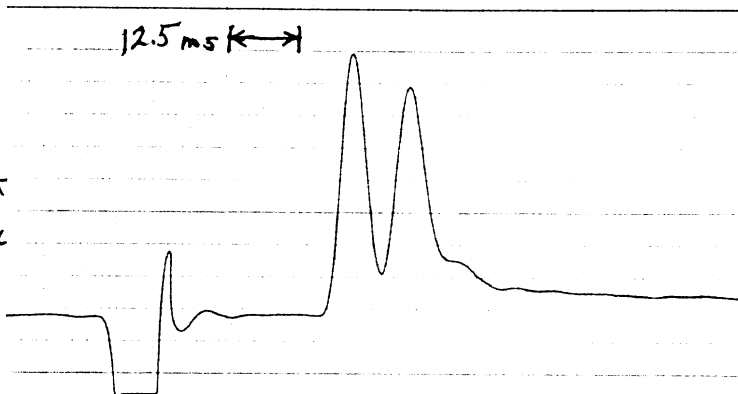


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J 042 DUMMY NO. 2 SIDE R BODY REGION SHLOR

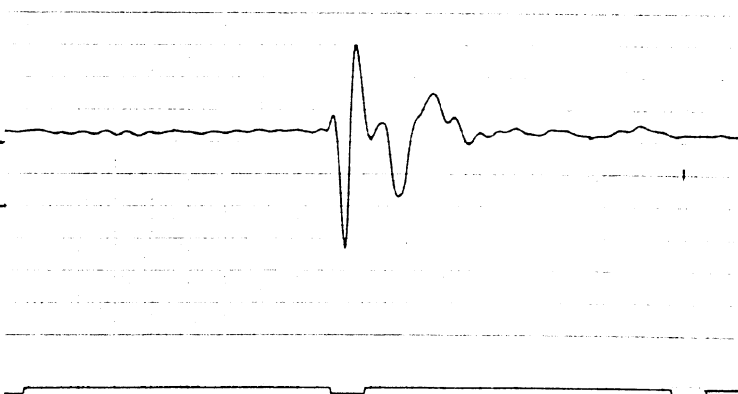
IMPACT MASS
DECELERATION

10 G = 
Filtered Class: 60




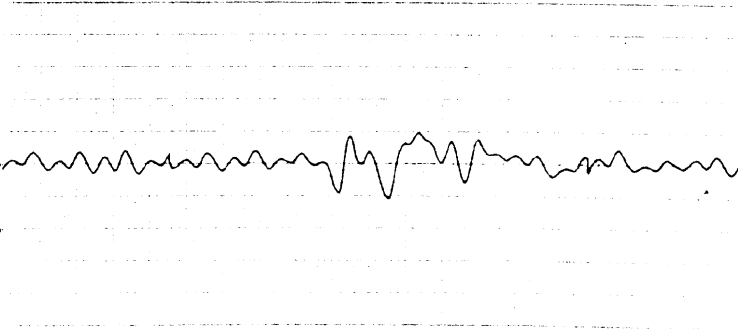
ANTERIOR-POSTERIOR
ACCELERATION

10 G = 
Filtered Class 180




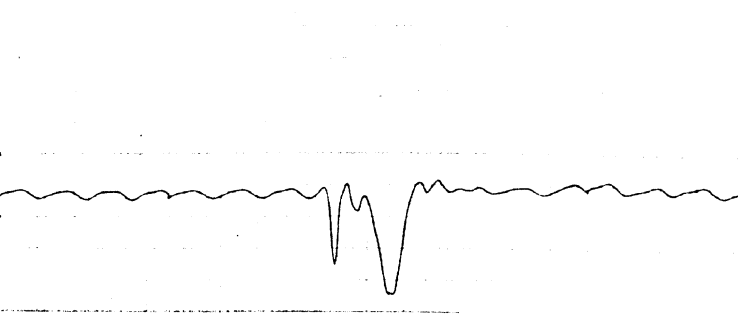
SUPERIOR-INFERIOR
ACCELERATION

10 G = 
Filtered Class 180



LEFT-RIGHT
ACCELERATION

25 G = 
Filtered Class 180

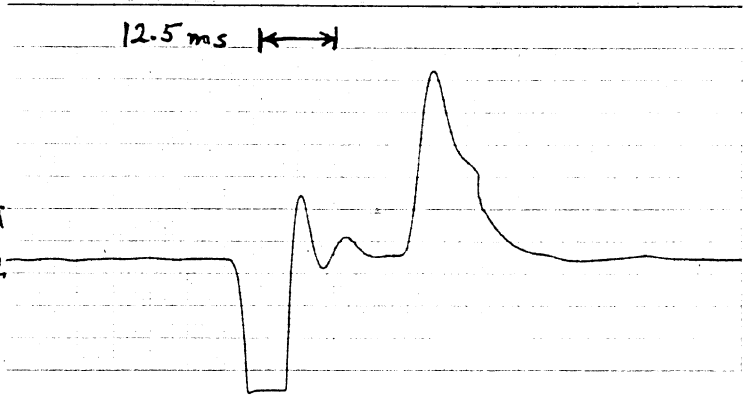


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 043 DUMMY NO. 2 SIDE L BODY REGION SHLDR

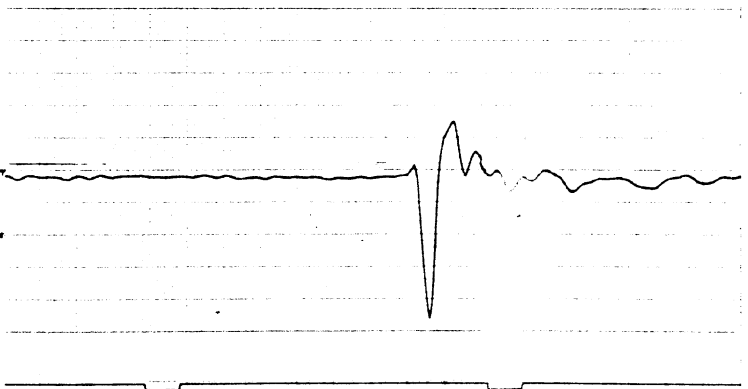
IMPACT MASS
DECELERATION

10 G =
Filtered Class 60



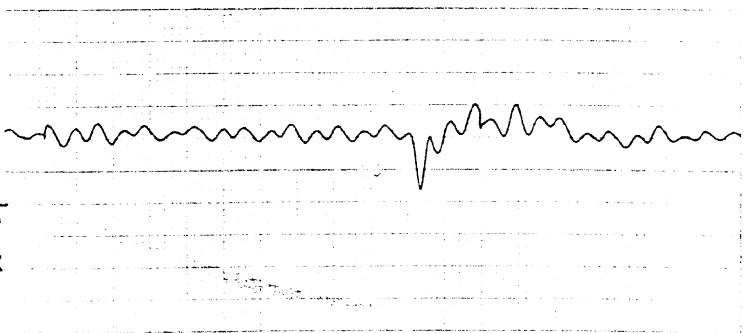
ANTERIOR-POSTERIOR
ACCELERATION

10 G =
Filtered Class 180



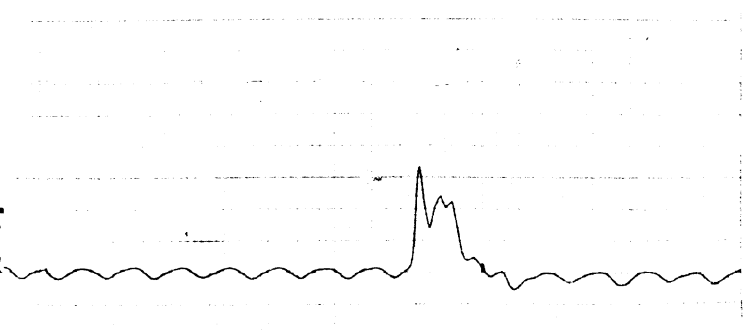
SUPERIOR-INFERIOR
ACCELERATION

10 G =
Filtered Class 180



LEFT-RIGHT
ACCELERATION

25 G =
Filtered Class 180



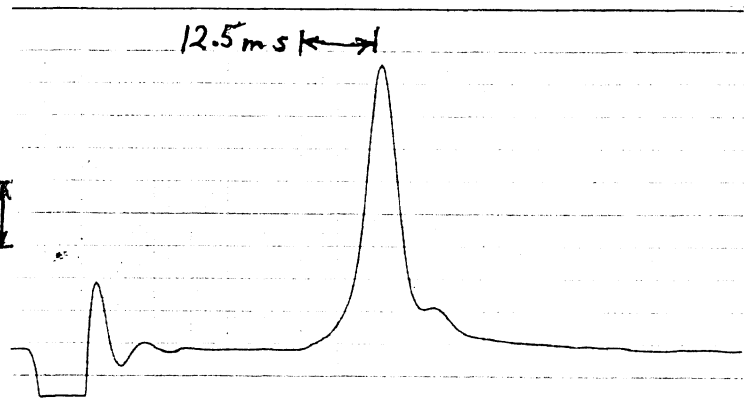
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 044 DUMMY NO. 2 SIDE L BODY REGION PELVIS

IMPACT MASS
DECELERATION

10 G =

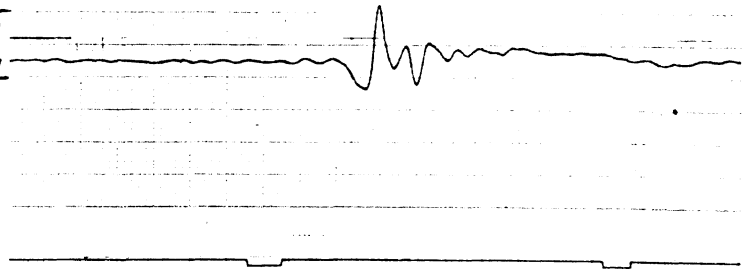
Filtered Class 60



ANTERIOR-POSTERIOR
ACCELERATION

10 G =

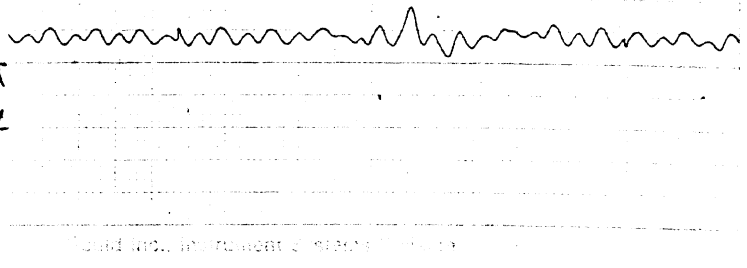
Filtered Class 180



SUPERIOR-INFERIOR
ACCELERATION

10 G =

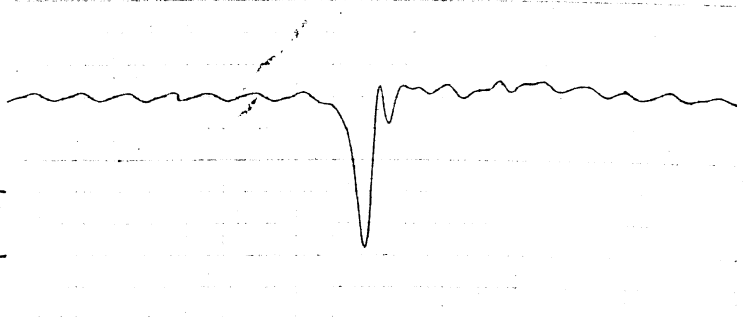
Filtered Class 180



LEFT-RIGHT
ACCELERATION

25 G =

Filtered Class 180

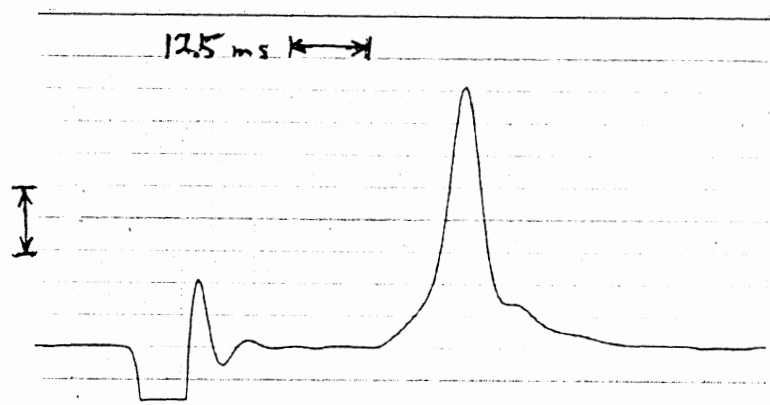


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 045 DUMMY NO. 2 SIDE R BODY REGION PELVIS

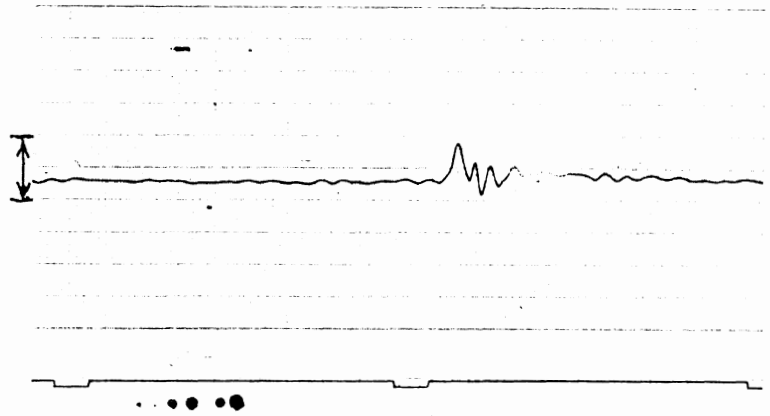
IMPACT MASS
DECELERATION

10 G =
Filtered Class 60



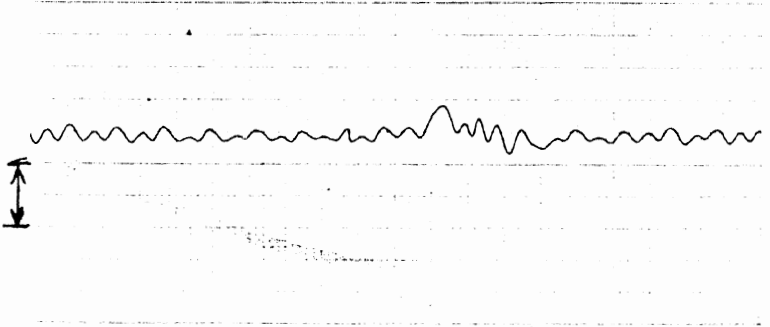
ANTERIOR-POSTERIOR
ACCELERATION

10 G =
Filtered Class 180



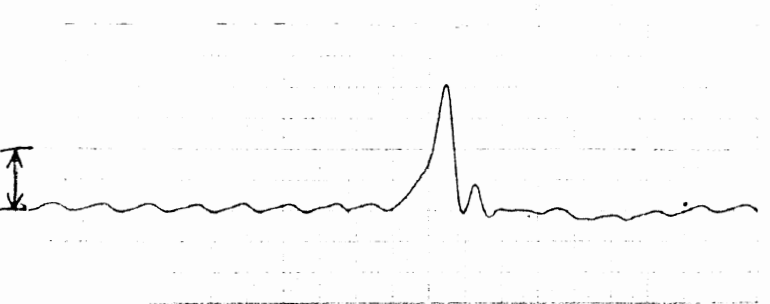
SUPERIOR-INFERIOR
ACCELERATION

10 G =
Filtered Class 180



LEFT-RIGHT
ACCELERATION


25 G =
Filtered Class 180

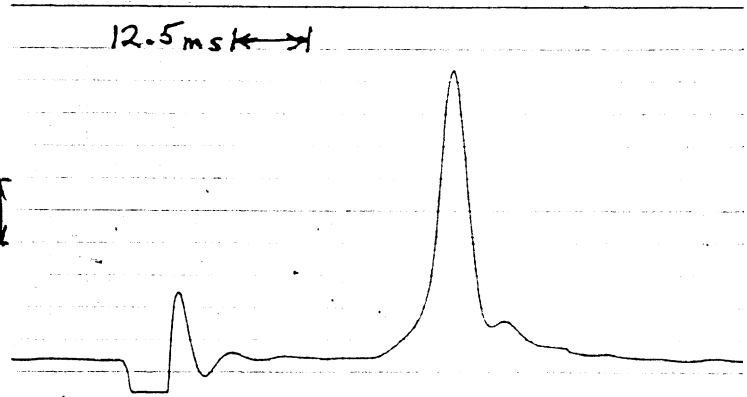


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J 046 DUMMY NO. 2 SIDE L BODY REGION PELVIS

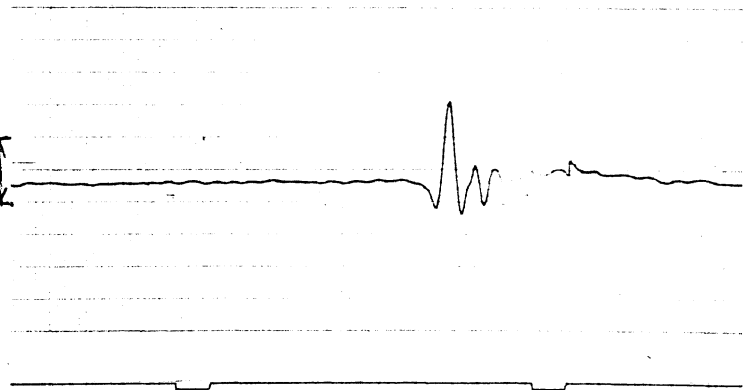
IMPACT MASS
DECELERATION

10 G = 
Filtered Class 60




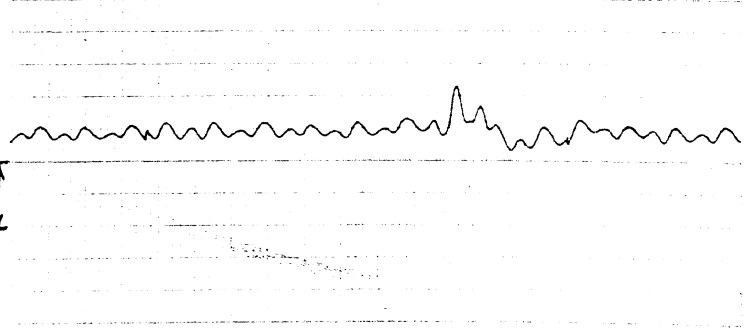
ANTERIOR-POSTERIOR
ACCELERATION

10 G = 
Filtered Class 180




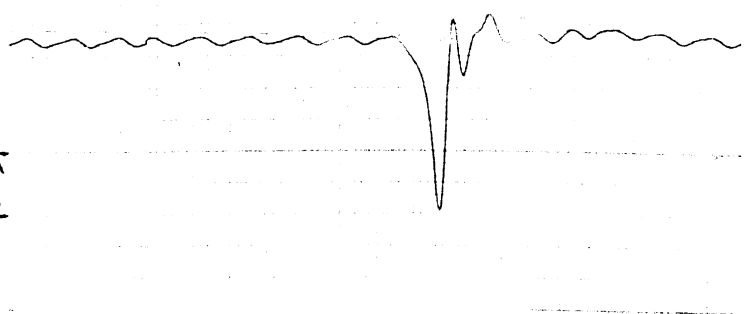
SUPERIOR-INFERIOR
ACCELERATION

10 G = 
Filtered Class 180



LEFT-RIGHT
ACCELERATION

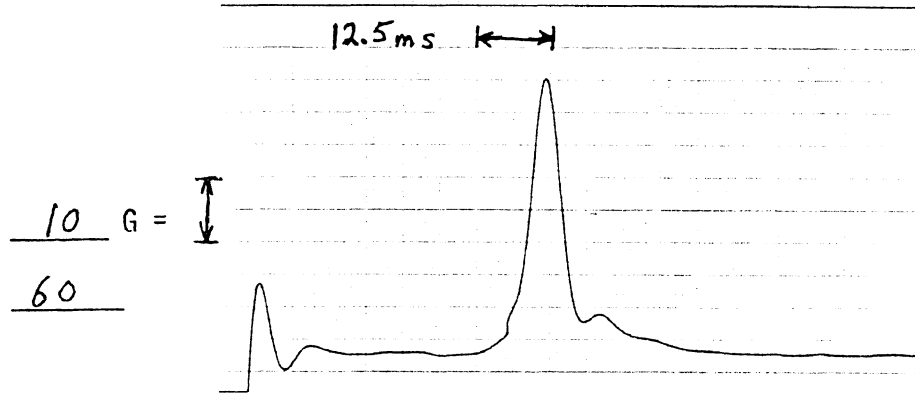
25 G = 
Filtered Class 180



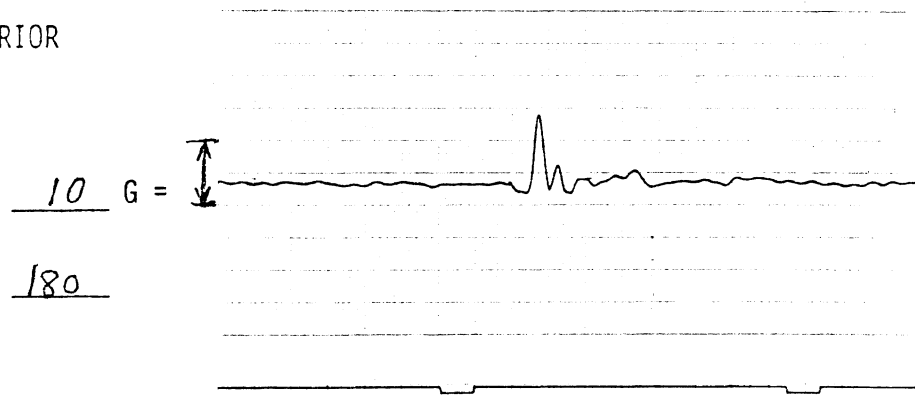
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 047 DUMMY NO. 2 SIDE R BODY REGION PELVIS

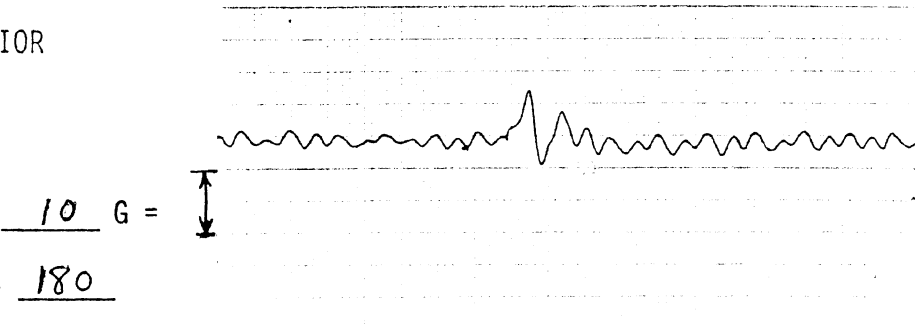
IMPACT MASS
DECELERATION



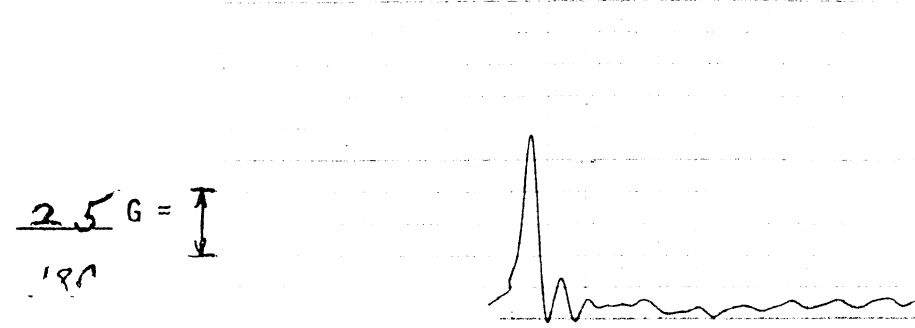
ANTERIOR-POSTERIOR
ACCELERATION



SUPERIOR-INFERIOR
ACCELERATION




LEFT-RIGHT
ACCELERATION

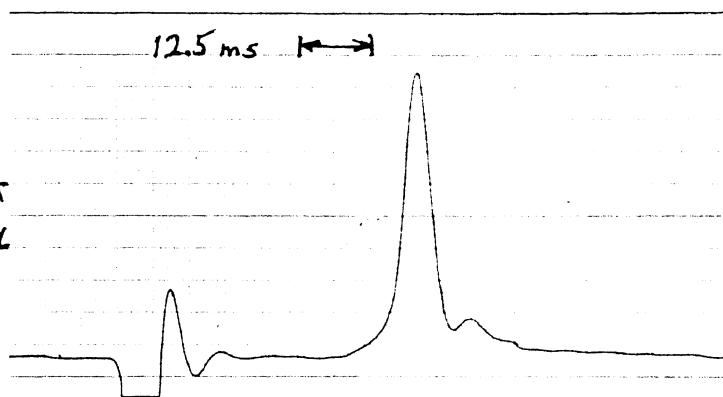


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J 048 DUMMY NO. 2 SIDE L BODY REGION PELVIS

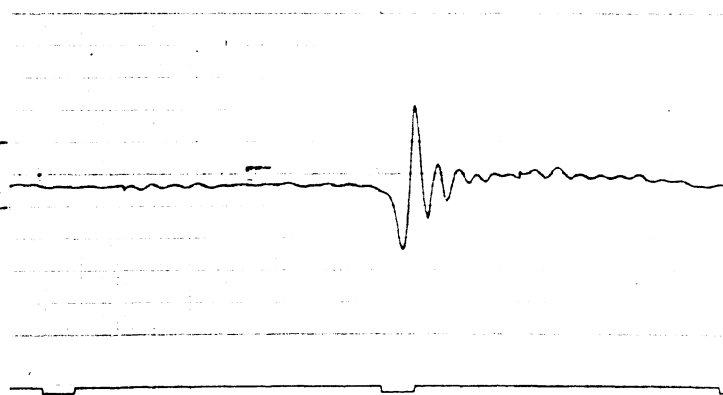
IMPACT MASS
DECELERATION

10 G = 
Filtered Class 60




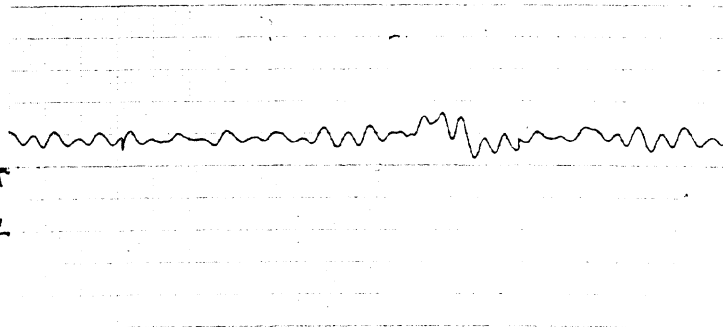
ANTERIOR-POSTERIOR
ACCELERATION

10 G = 
Filtered Class 180




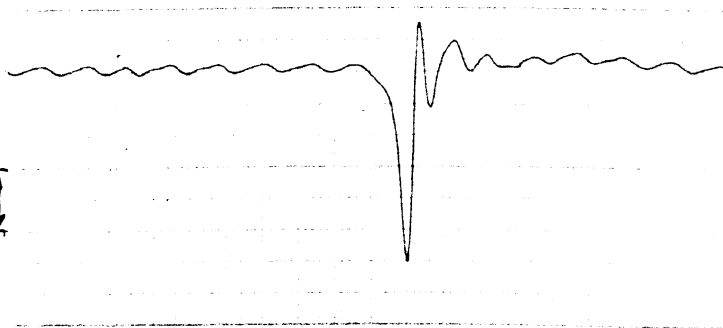
SUPERIOR-INFERIOR
ACCELERATION

10 G = 
Filtered Class 180



LEFT-RIGHT
ACCELERATION


25 G = 
Filtered Class 180

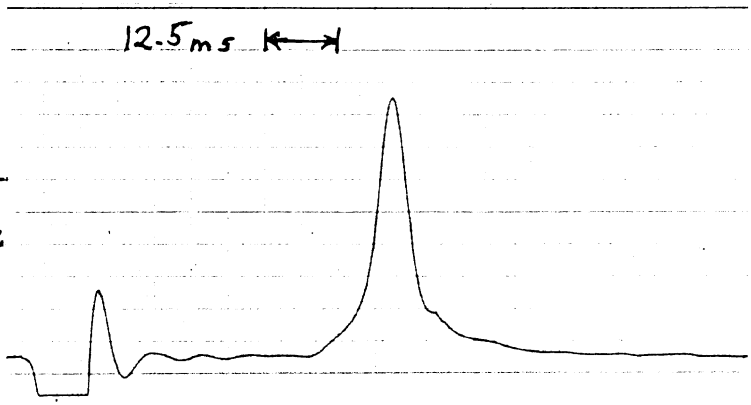


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J 049 DUMMY NO. 2 SIDE R BODY REGION PELVIS

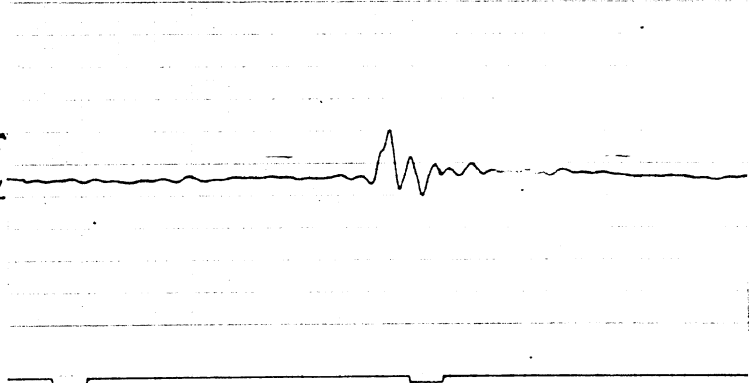
IMPACT MASS
DECELERATION

10 G = 
Filtered Class 60




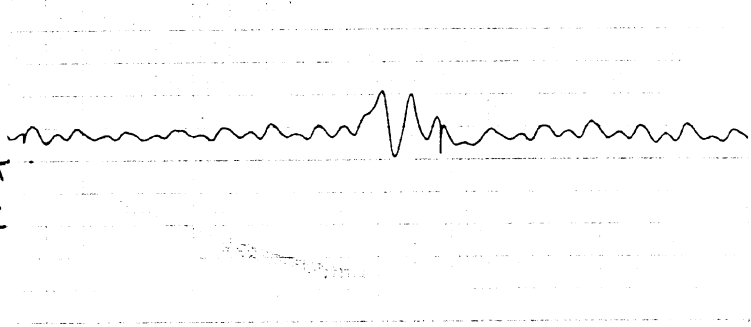
ANTERIOR-POSTERIOR
ACCELERATION

10 G = 
Filtered Class 180




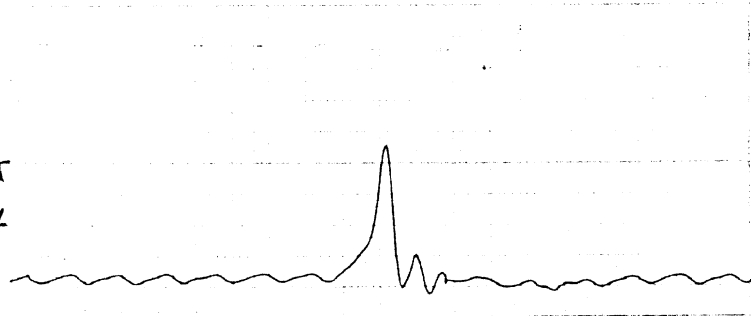
SUPERIOR-INFERIOR
ACCELERATION

10 G = 
Filtered Class 180



LEFT-RIGHT
ACCELERATION

25 G = 
Filtered Class 180



DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

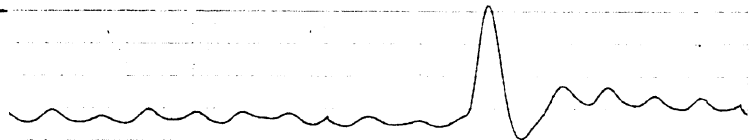
TEST NO. 76J 056 DUMMY NO. 3 SIDE R BODY REGION HEAD

IMPACT MASS
DECELERATION

12.5 m.s \longleftrightarrow

5 G = \updownarrow

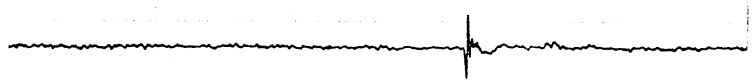
Filtered Class 60



ANTERIOR-POSTERIOR
ACCELERATION

16.7 G = \updownarrow

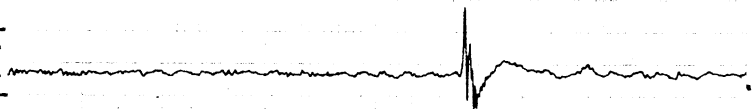
Filtered Class 1000



SUPERIOR-INFERIOR
ACCELERATION

16.3 G = \updownarrow

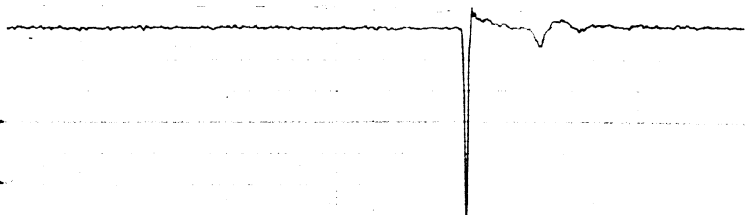
Filtered Class 1000



LEFT-RIGHT
ACCELERATION

107 G = \updownarrow


Filtered Class 1000

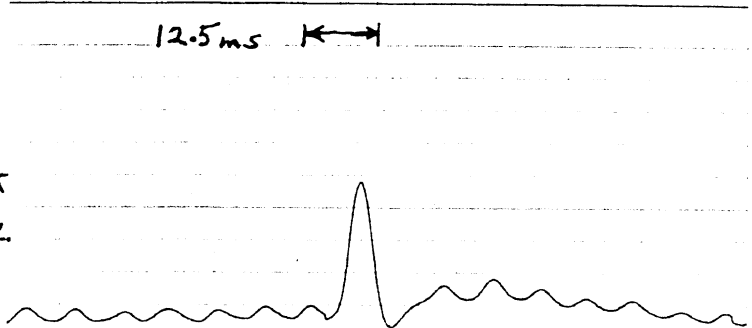


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J 057 DUMMY NO. 3 SIDE L BODY REGION HEAD

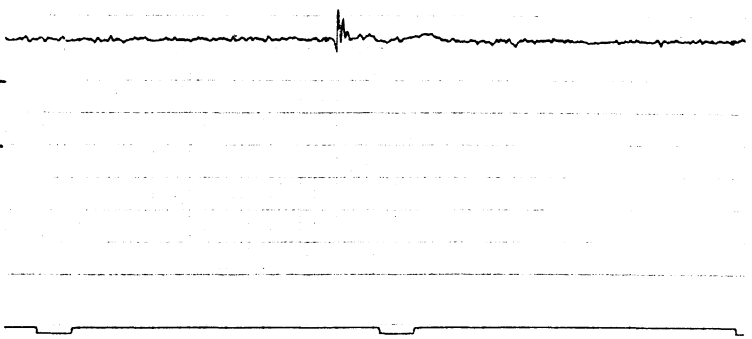
IMPACT MASS
DECELERATION

5* G = 
Filtered Class 60




ANTERIOR-POSTERIOR
ACCELERATION

16.7 G = 
Filtered Class 1000




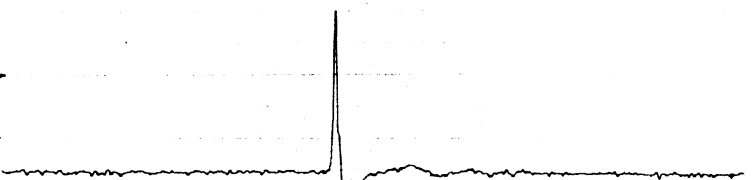
SUPERIOR-INFERIOR
ACCELERATION

163 G = 
Filtered Class 1000



LEFT-RIGHT
ACCELERATION

107 G = 
Filtered Class 1000

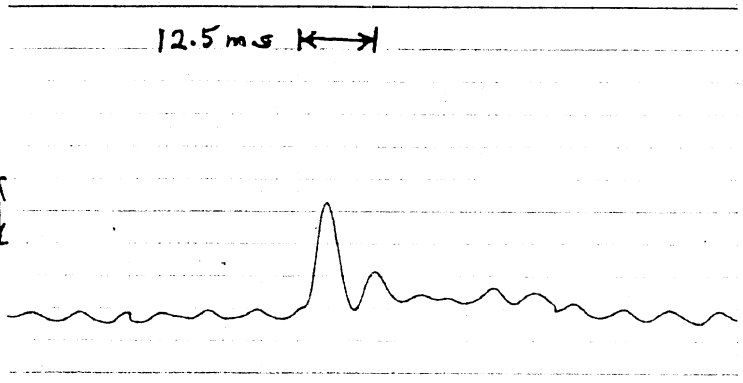


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 058 DUMMY NO. 3 SIDE R BODY REGION HEAD

IMPACT MASS
DECELERATION

5 G = \updownarrow
Filtered Class 60



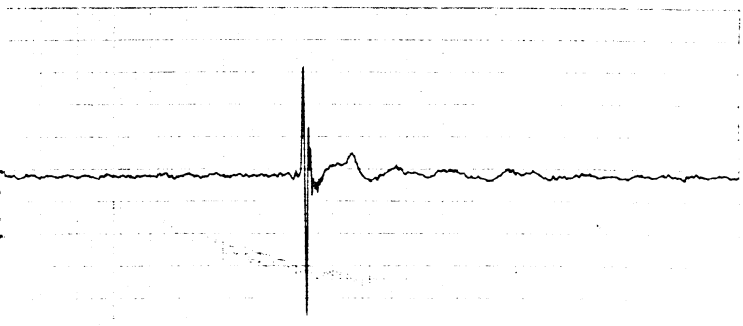
ANTERIOR-POSTERIOR
ACCELERATION

16.7 G = \updownarrow
Filtered Class 1000



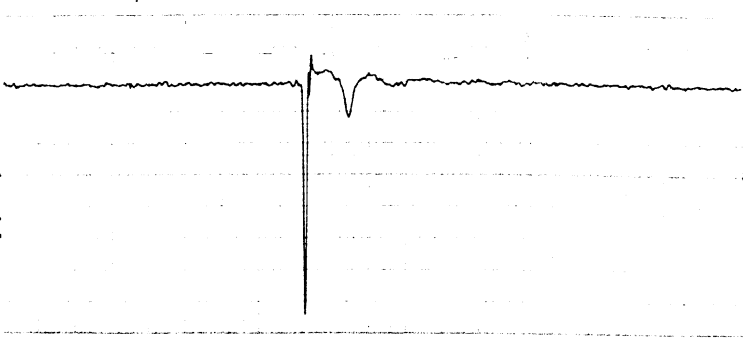
SUPERIOR-INFERIOR
ACCELERATION

16.3 G = \updownarrow
Filtered Class 1000



LEFT-RIGHT
ACCELERATION


107 G = \updownarrow
Filtered Class 1000

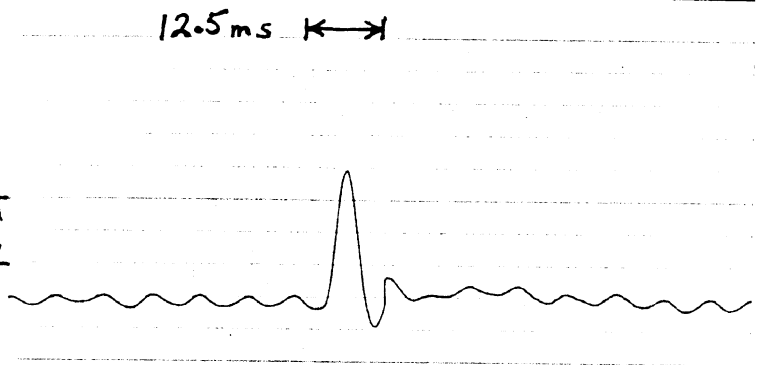


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J 059 DUMMY NO. 3 SIDE L BODY REGION HEAD

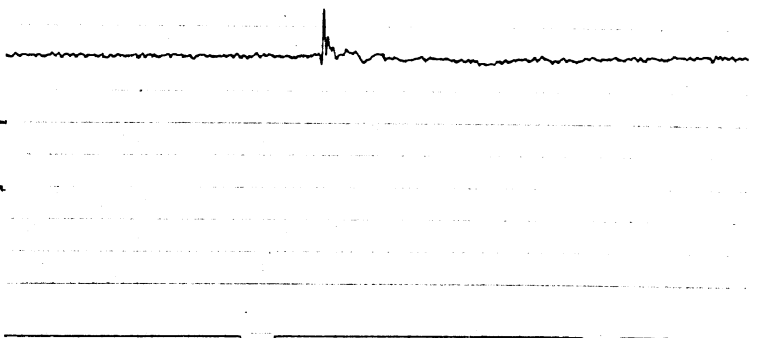
IMPACT MASS
DECELERATION

5 G = 
Filtered Class 60




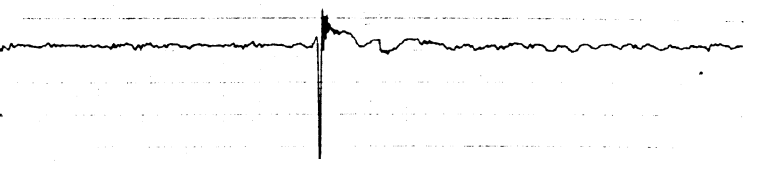
ANTERIOR-POSTERIOR
ACCELERATION

16.7 G = 
Filtered Class 1000




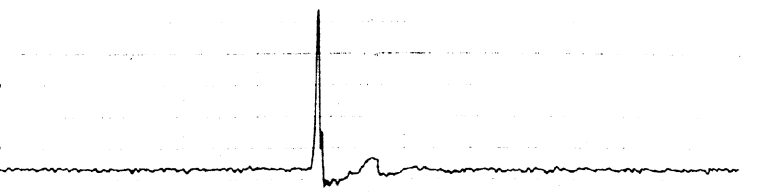
SUPERIOR-INFERIOR
ACCELERATION

16.3 G = 
Filtered Class 1000



LEFT-RIGHT
ACCELERATION

107 G = 
Filtered Class 1000



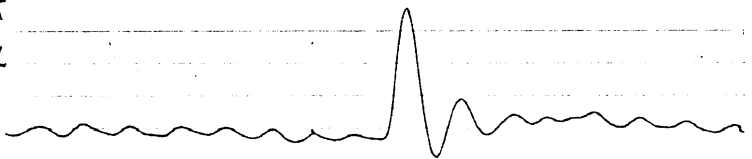
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 060 DUMMY NO. 3 SIDE R BODY REGION HEAD

IMPACT MASS
DECELERATION

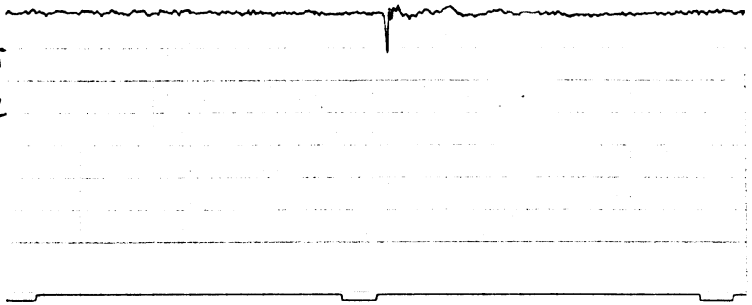
12.5ms \longleftrightarrow

5 G = \updownarrow
Filtered Class 60



ANTERIOR-POSTERIOR
ACCELERATION

16.7 G = \updownarrow
Filtered Class 1000



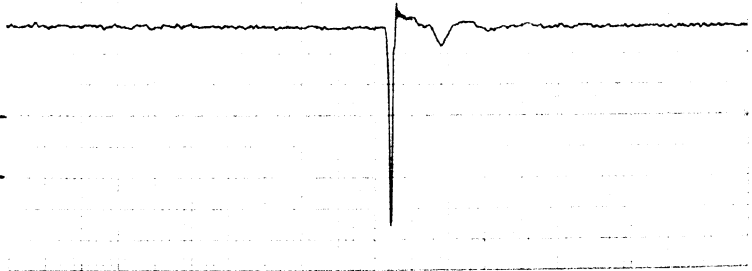
SUPERIOR-INFERIOR
ACCELERATION

16.3 G = \updownarrow
Filtered Class 1000



LEFT-RIGHT
ACCELERATION


107 G = \updownarrow
Filtered Class 1000

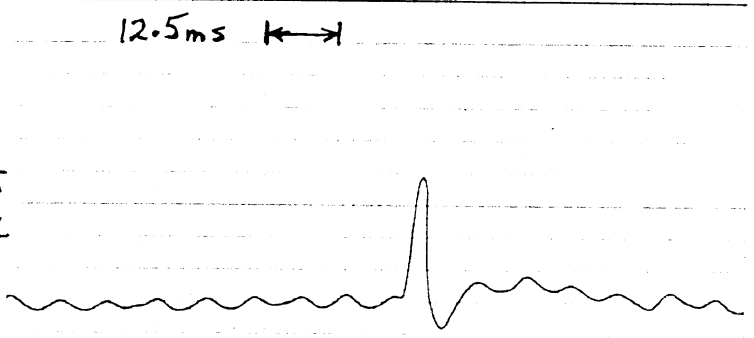


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J 061 DUMMY NO. 3 SIDE L BODY REGION HEAD

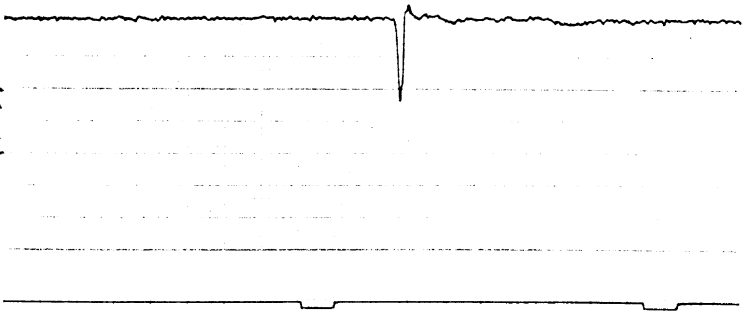
IMPACT MASS
DECELERATION

5 G = 
Filtered Class 60




ANTERIOR-POSTERIOR
ACCELERATION

16.7 G = 
Filtered Class 1000




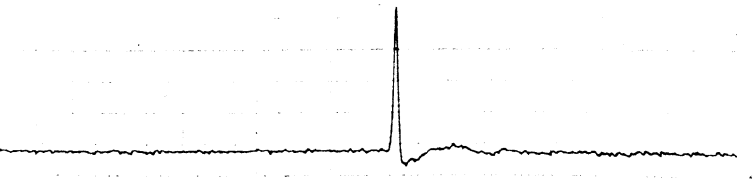
SUPERIOR-INFERIOR
ACCELERATION

16.3 G = 
Filtered Class 1000



LEFT-RIGHT
ACCELERATION

107 G = 
Filtered Class 1000

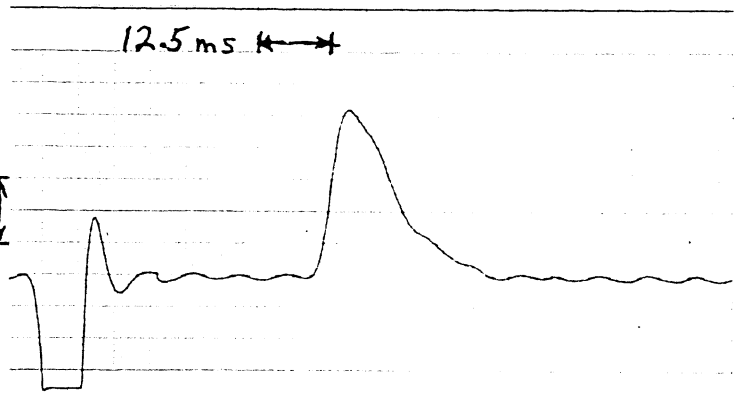


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 069 DUMMY NO. 3 SIDE R BODY REGION THORAX

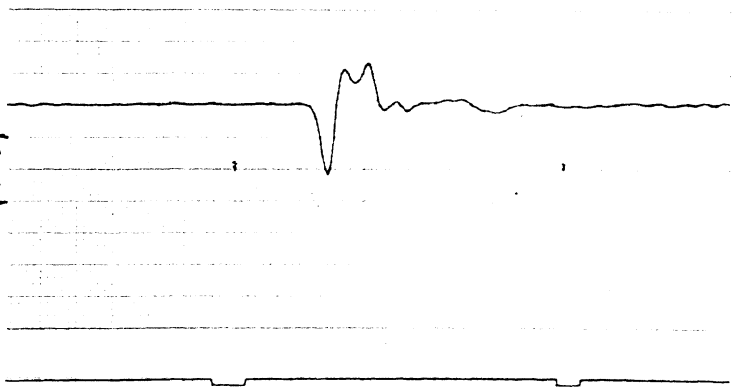
IMPACT MASS
DECELERATION

10 G =
Filtered Class 60



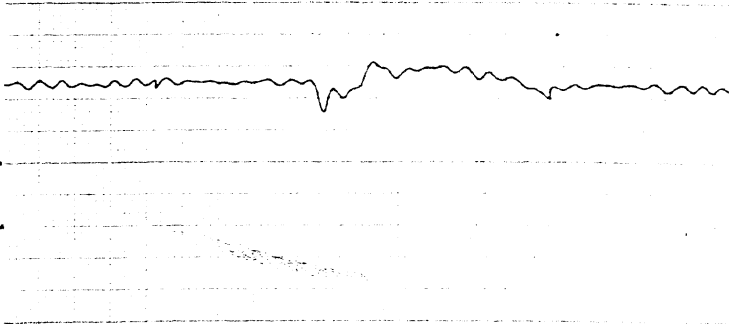
ANTERIOR-POSTERIOR
ACCELERATION

18.6 G =
Filtered Class 180



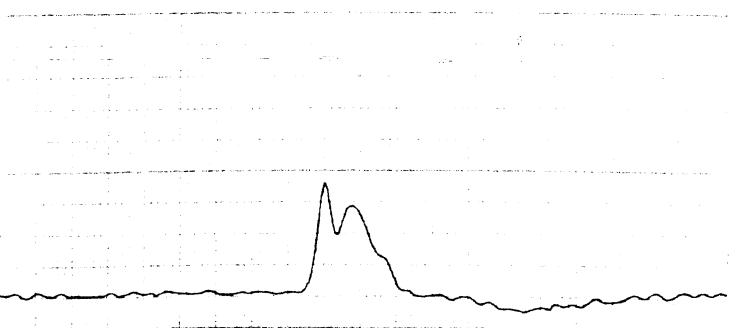
SUPERIOR-INFERIOR
ACCELERATION

7.3 G =
Filtered Class 180



LEFT-RIGHT
ACCELERATION

17 G =
Filtered Class 180



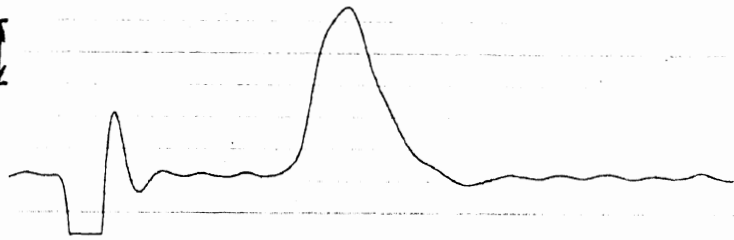
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 070 DUMMY NO. 3 SIDE L BODY REGION THORAX

IMPACT MASS
DECELERATION

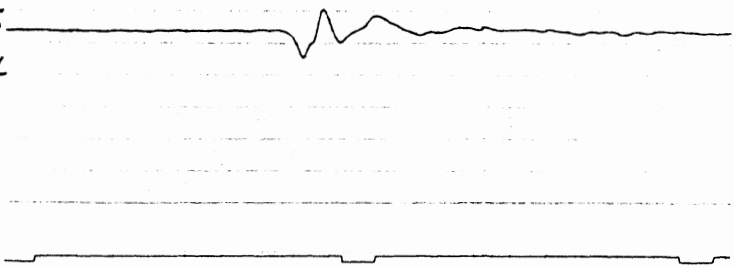
12.5 ms \longleftrightarrow

10 G = \updownarrow
Filtered Class 60



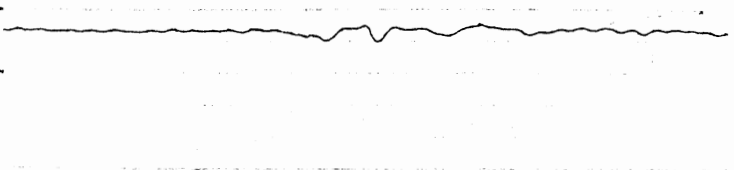
ANTERIOR-POSTERIOR
ACCELERATION

18.6 G = \updownarrow
Filtered Class 180



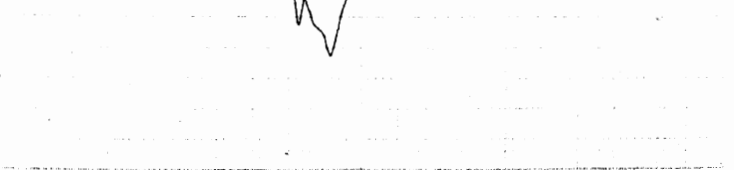
SUPERIOR-INFERIOR
ACCELERATION

18.4 G = \updownarrow
Filtered Class 180



LEFT-RIGHT
ACCELERATION

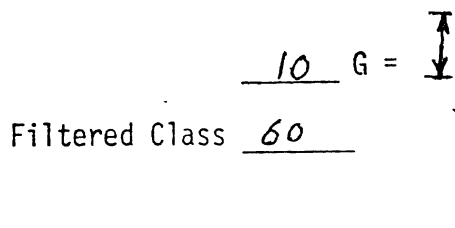
17 G = \updownarrow
Filtered Class 180



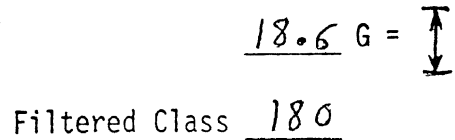
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 071 DUMMY NO. 3 SIDE R BODY REGION THORAX

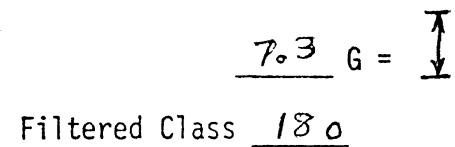
IMPACT MASS
DECELERATION



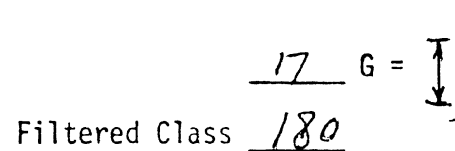
ANTERIOR-POSTERIOR
ACCELERATION



SUPERIOR-INFERIOR
ACCELERATION



LEFT-RIGHT
ACCELERATION

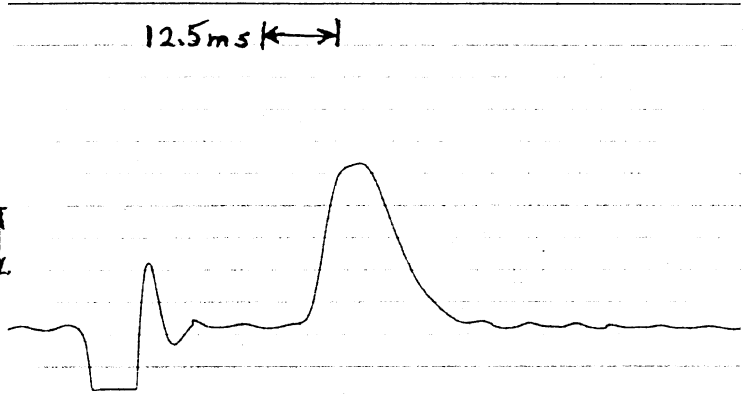


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J072 DUMMY NO. 3 SIDE L BODY REGION THORAX

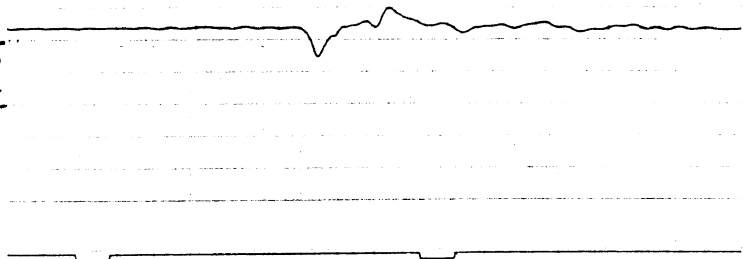
IMPACT MASS
DECELERATION

10 G = 
Filtered Class 60




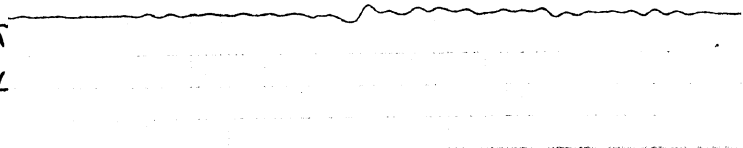
ANTERIOR-POSTERIOR
ACCELERATION

18.6 G = 
Filtered Class 180



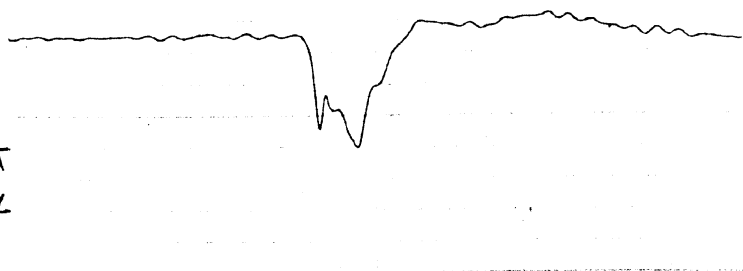
SUPERIOR-INFERIOR
ACCELERATION

18.4 G = 
Filtered Class 180



LEFT-RIGHT
ACCELERATION

17 G = 
Filtered Class 180

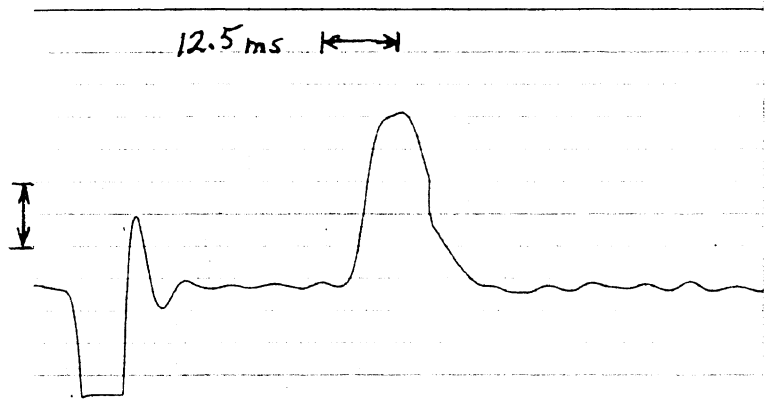


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J074 DUMMY NO. 3 SIDE L BODY REGION THORAX

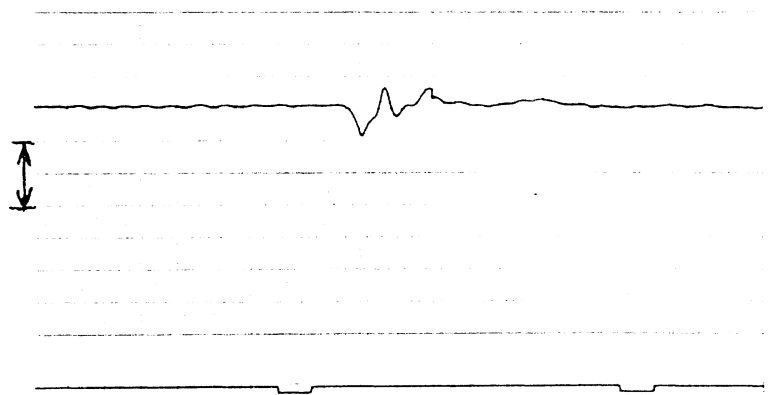
IMPACT MASS
DECELERATION

10 G =
Filtered Class 60



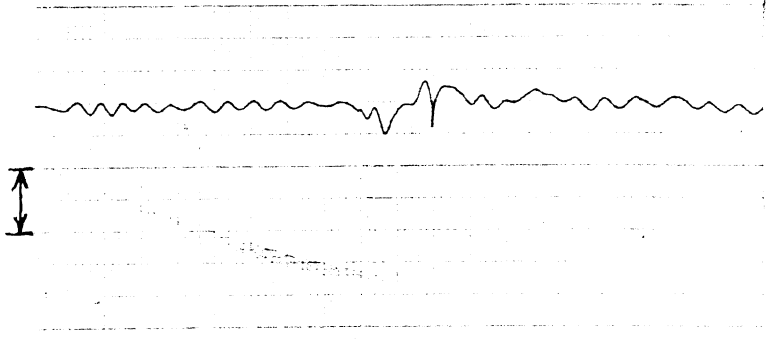
ANTERIOR-POSTERIOR
ACCELERATION

18.6 G =
Filtered Class 180



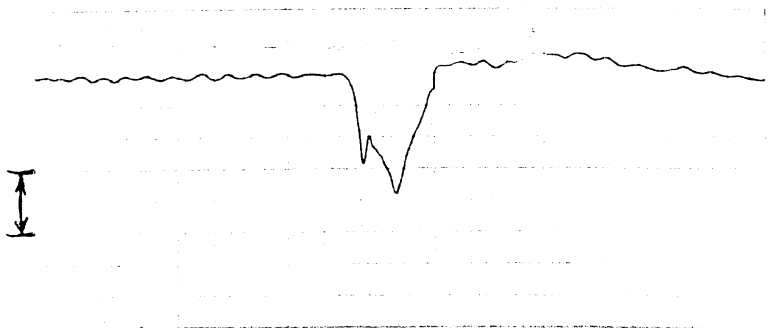
SUPERIOR-INFERIOR
ACCELERATION

73 G =
Filtered Class 180



LEFT-RIGHT
ACCELERATION

17 G =
Filtered Class 180

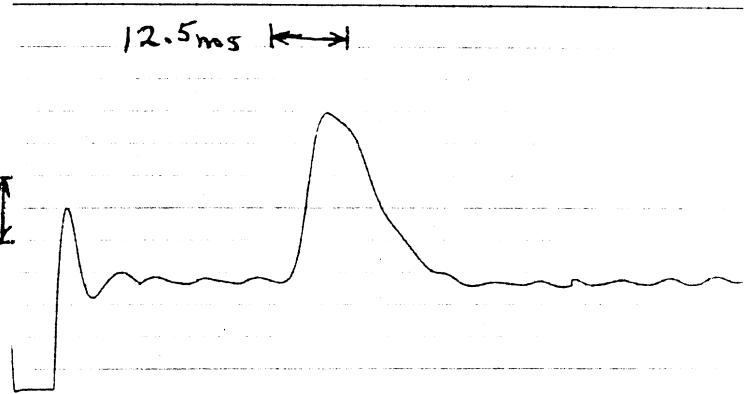


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 075 DUMMY NO. 3 SIDE R BODY REGION THORAX

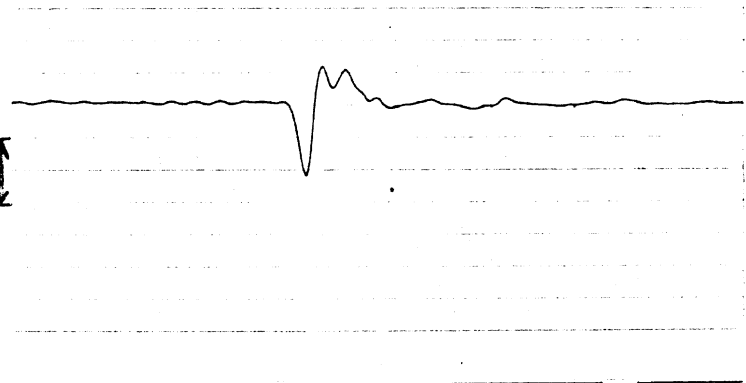
IMPACT MASS
DECELERATION

10 G =
Filtered Class 60



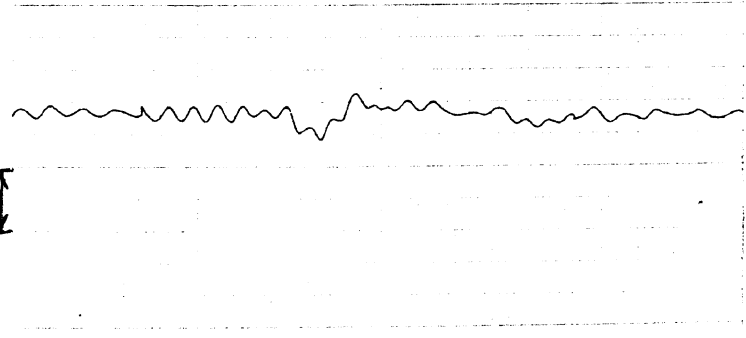
ANTERIOR-POSTERIOR
ACCELERATION

18.6 G =
Filtered Class 180



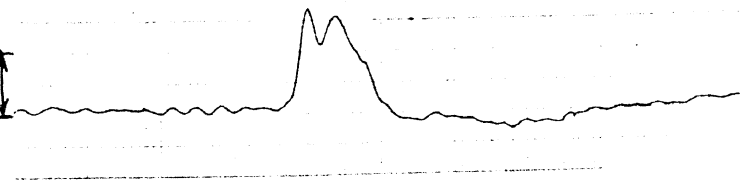
SUPERIOR-INFERIOR
ACCELERATION

7.3 G =
Filtered Class 180



LEFT-RIGHT
ACCELERATION

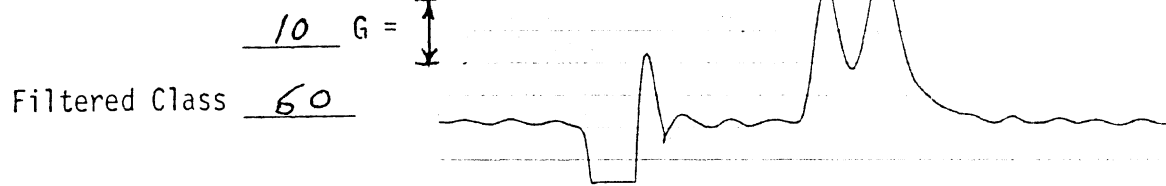
17 G =
Filtered Class 180



DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J076 DUMMY NO. 3 SIDE L BODY REGION SHOULDER

IMPACT MASS
DECELERATION



ANTERIOR-POSTERIOR
ACCELERATION



SUPERIOR-INFERIOR
ACCELERATION



LEFT-RIGHT
ACCELERATION

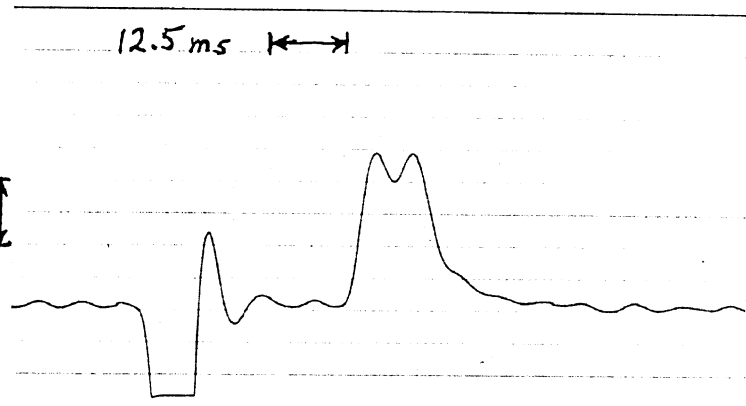


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 077 DUMMY NO. 3 SIDE R BODY REGION SHLDR

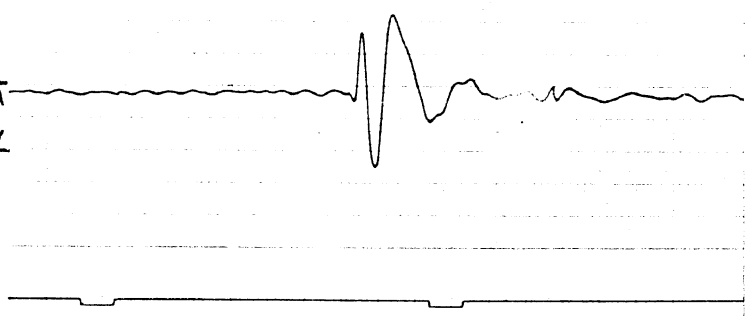
IMPACT MASS
DECELERATION

10 G =
Filtered Class 60



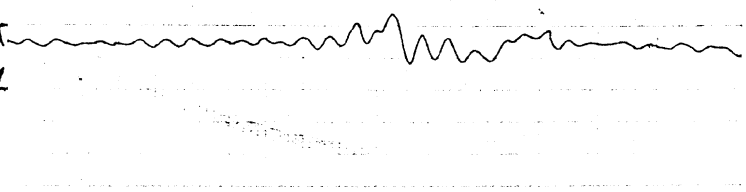
ANTERIOR-POSTERIOR
ACCELERATION

7.4 G =
Filtered Class 180



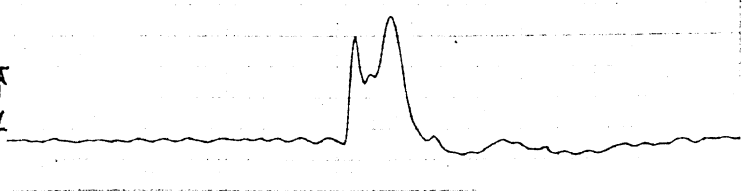
SUPERIOR-INFERIOR
ACCELERATION

7.3 G =
Filtered Class 180



LEFT-RIGHT
ACCELERATION

17 G =
Filtered Class 180

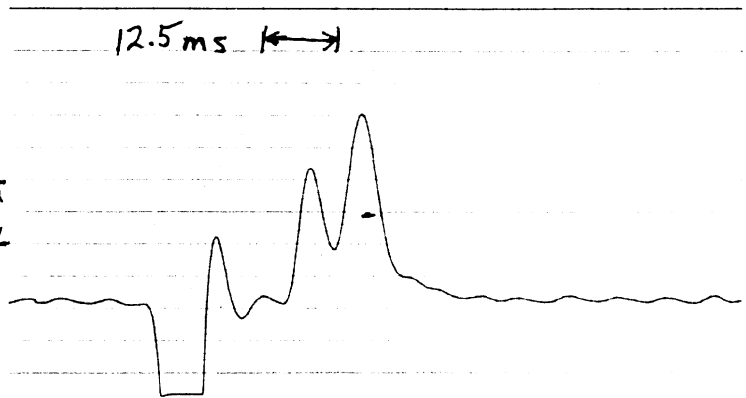


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 078 DUMMY NO. 3 SIDE L BODY REGION SHLDR

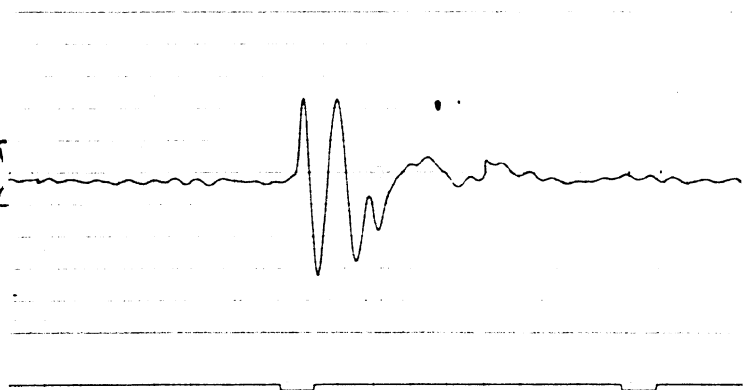
IMPACT MASS
DECELERATION

10 G =
Filtered Class 60



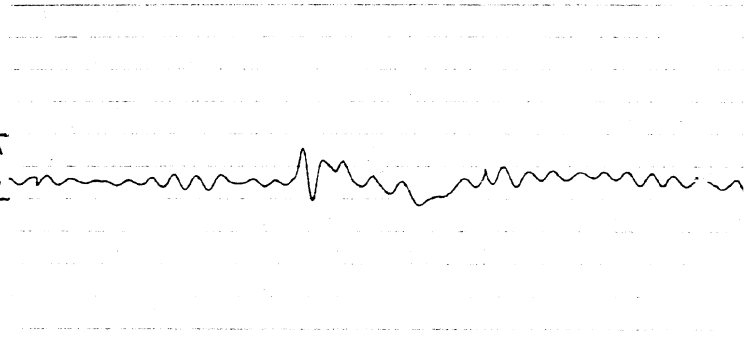
ANTERIOR-POSTERIOR
ACCELERATION

7.4 G =
Filtered Class 180



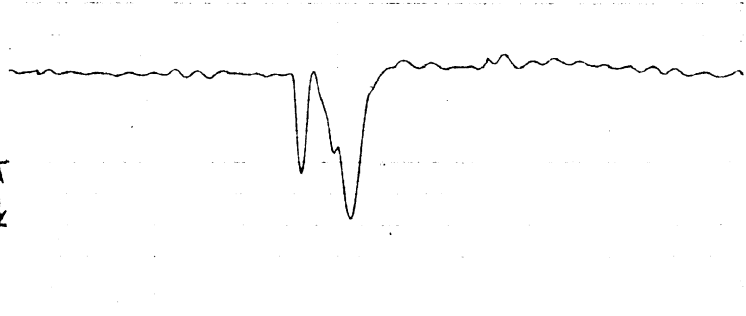
SUPERIOR-INFERIOR
ACCELERATION

7.3 G =
Filtered Class 180



LEFT-RIGHT
ACCELERATION


17.0 G =
Filtered Class 180

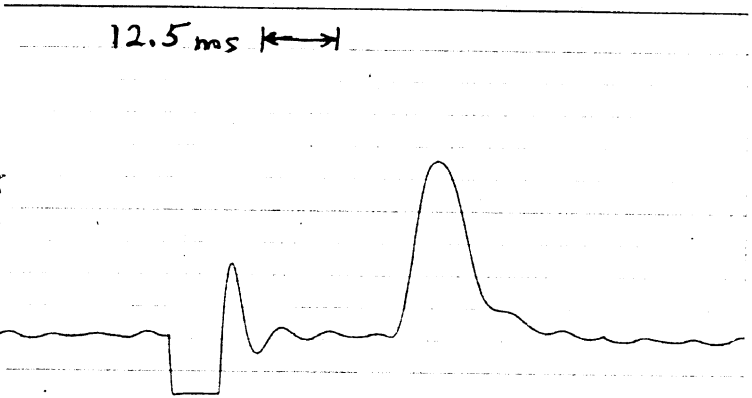


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J 079 DUMMY NO. 3 SIDE R BODY REGION SHLD R

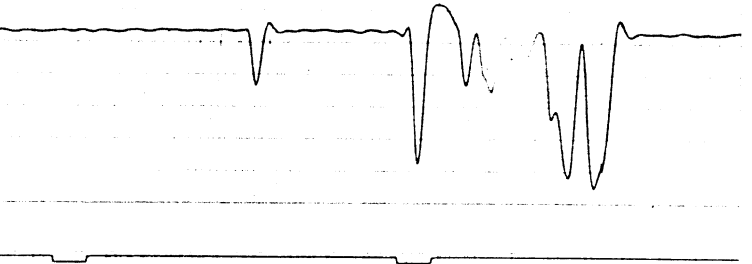
IMPACT MASS
DECELERATION

10 G = 
Filtered Class 60




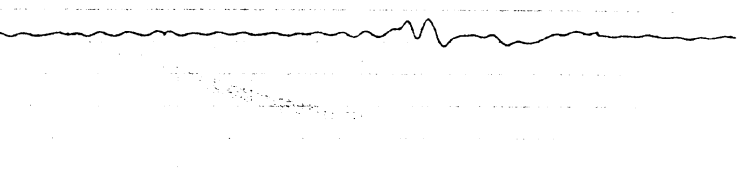
ANTERIOR-POSTERIOR
ACCELERATION

18.6 G = 
Filtered Class 180




SUPERIOR-INFERIOR
ACCELERATION

18.4 G = 
Filtered Class 180



LEFT-RIGHT
ACCELERATION

17 G = 
Filtered Class 180



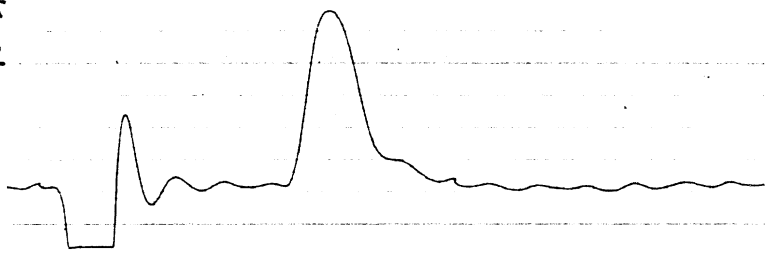
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 079 DUMMY NO. 3 SIDE R BODY REGION SHLDR

IMPACT MASS
DECELERATION

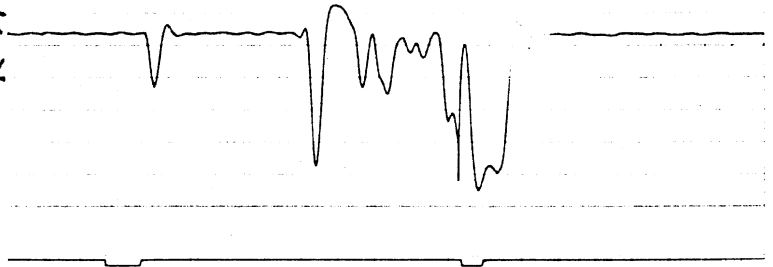
12.5 ms \longleftrightarrow

10 G = \updownarrow
Filtered Class 60



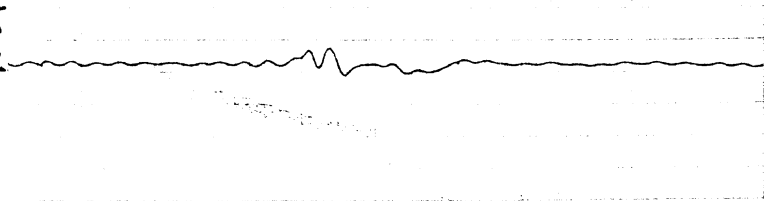
ANTERIOR-POSTERIOR
ACCELERATION

18.6 G = \updownarrow
Filtered Class 180



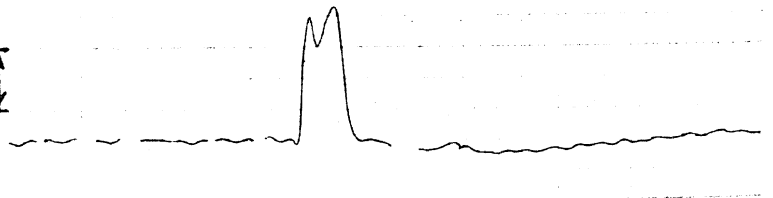
SUPERIOR-INFERIOR
ACCELERATION

18.4 G = \updownarrow
Filtered Class 180



LEFT-RIGHT
ACCELERATION


17 G = \updownarrow
Filtered Class 180

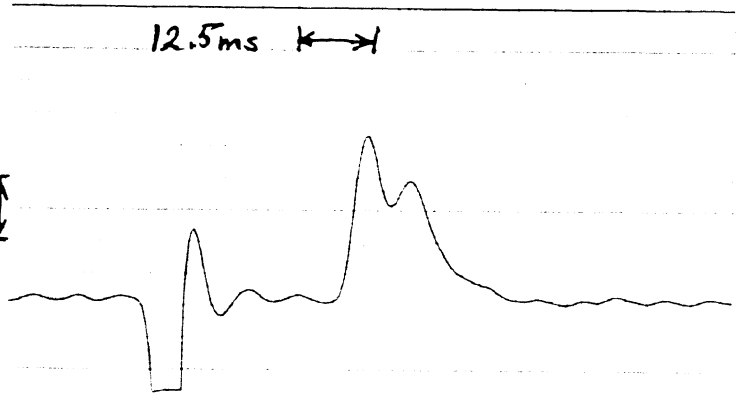


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J 080 DUMMY NO. 3 SIDE L BODY REGION SHLDR.

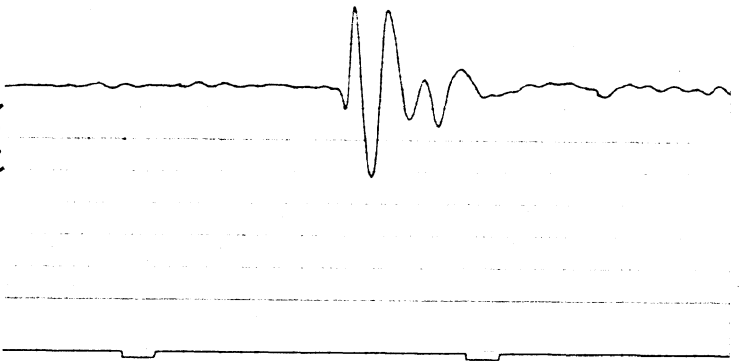
IMPACT MASS
DECELERATION

10 G = 
Filtered Class 60




ANTERIOR-POSTERIOR
ACCELERATION

7.4 G = 
Filtered Class 180




SUPERIOR-INFERIOR
ACCELERATION

7.3 G = 
Filtered Class 180



LEFT-RIGHT
ACCELERATION


17 G = 
Filtered Class 180

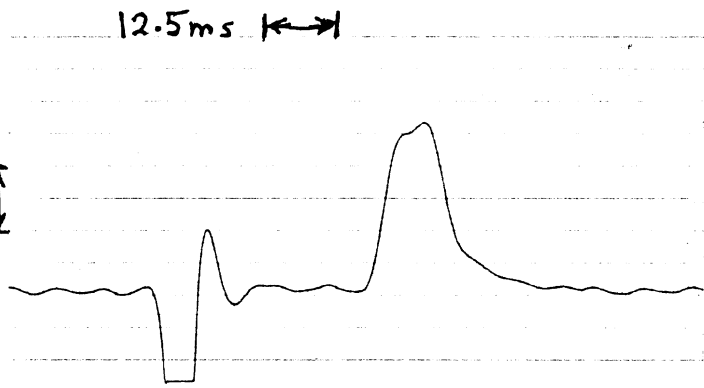


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J 081 DUMMY NO. 3 SIDE R BODY REGION SHLD R

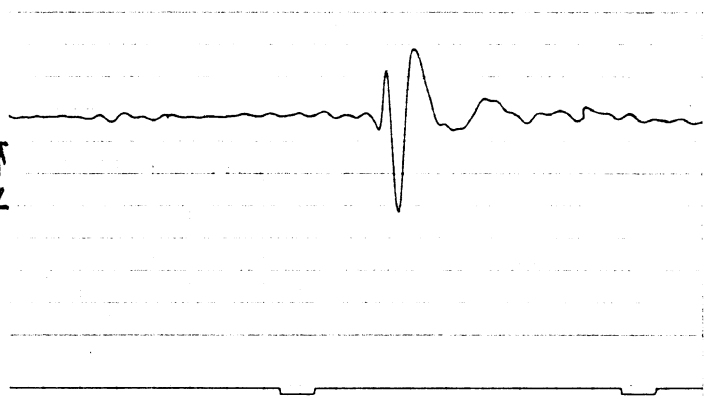
IMPACT MASS
DECELERATION

10 G = 
Filtered Class 60




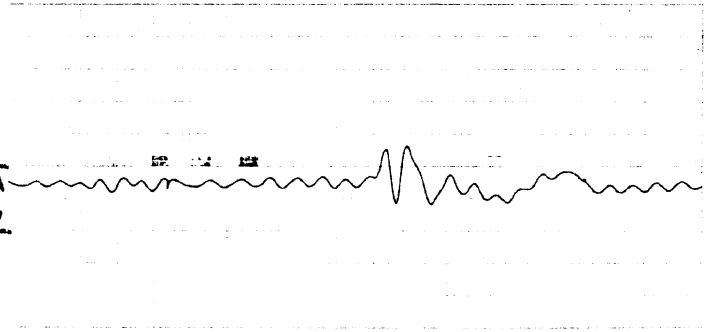
ANTERIOR-POSTERIOR
ACCELERATION

7.4 G = 
Filtered Class 180




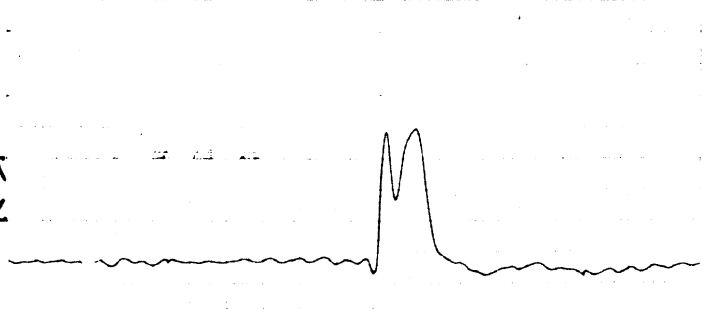
SUPERIOR-INFERIOR
ACCELERATION

7.3 G = 
Filtered Class 180



LEFT-RIGHT
ACCELERATION

17 G = 
Filtered Class 180



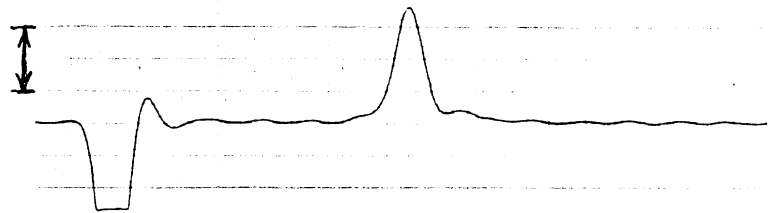
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J082 DUMMY NO. 3 SIDE L BODY REGION PELVIS

IMPACT MASS
DECELERATION

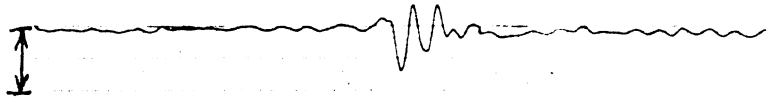
25 G =
Filtered Class 60

12.5ms \longleftrightarrow



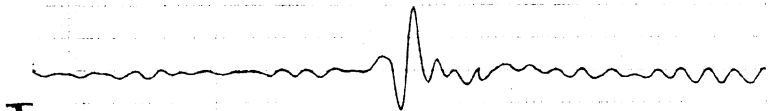
ANTERIOR-POSTERIOR
ACCELERATION

8.5 G =
Filtered Class 180



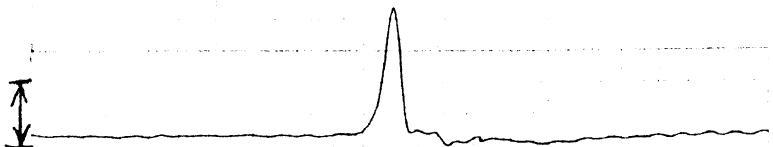
SUPERIOR-INFERIOR
ACCELERATION

8.2 G =
Filtered Class 180



LEFT-RIGHT
ACCELERATION

38.3 G =
Filtered Class 180



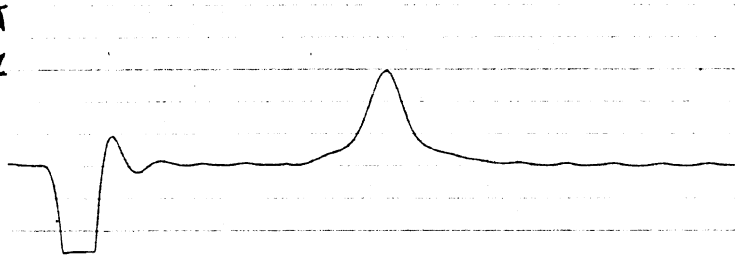
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 083 DUMMY NO. 3 SIDE R BODY REGION PELVIS

IMPACT MASS
DECELERATION

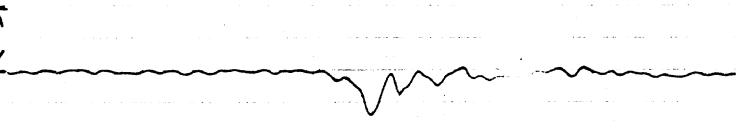
12.5ms \longleftrightarrow

25 G = \updownarrow
Filtered Class 60



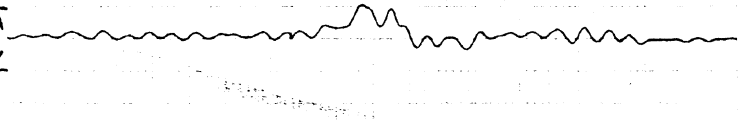
ANTERIOR-POSTERIOR
ACCELERATION

8.5 G = \updownarrow
Filtered Class 180



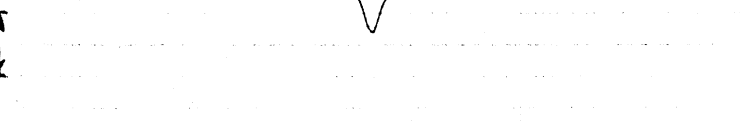
SUPERIOR-INFERIOR
ACCELERATION

8.2 G = \updownarrow
Filtered Class 180



LEFT-RIGHT
ACCELERATION

38.3 G = \updownarrow
Filtered Class 180

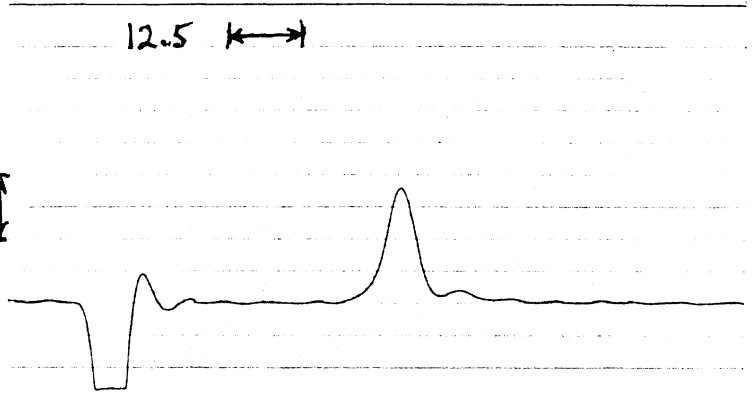


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 084 DUMMY NO. 3 SIDE L BODY REGION PELVIS

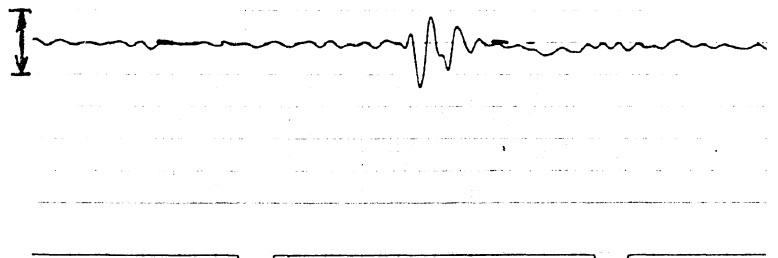
IMPACT MASS
DECELERATION

25 G =
Filtered Class 60



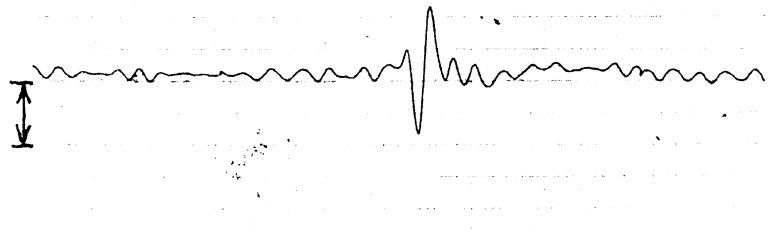
ANTERIOR-POSTERIOR
ACCELERATION

8.5 G =
Filtered Class 180



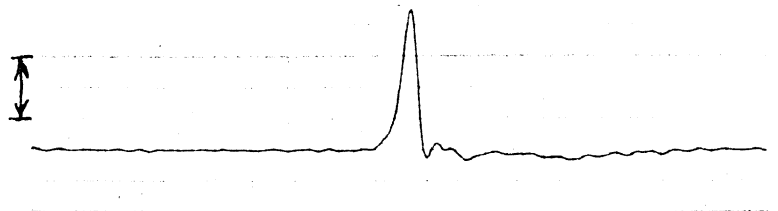
SUPERIOR-INFERIOR
ACCELERATION

8.2 G =
Filtered Class 180



LEFT-RIGHT
ACCELERATION

38.3 G =
Filtered Class 180

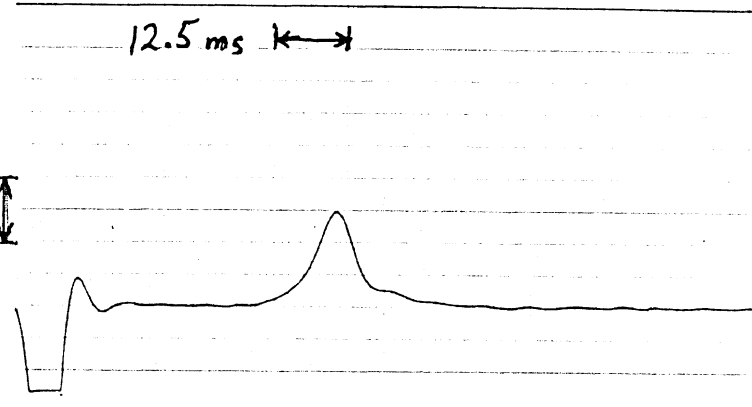


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J085 DUMMY NO. 3 SIDE R BODY REGION PELVIS

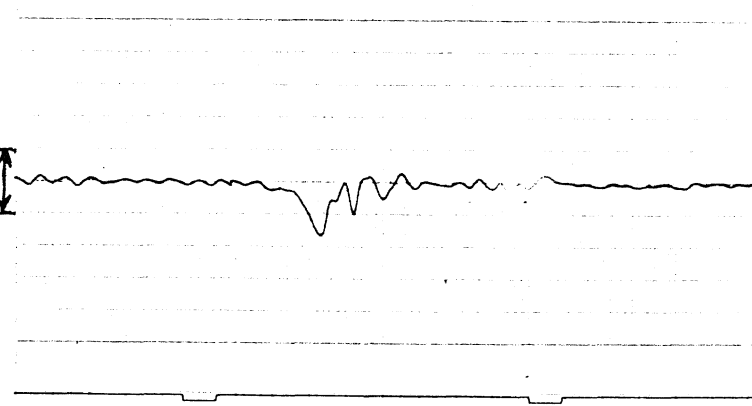
IMPACT MASS
DECELERATION

25 G =
Filtered Class 60



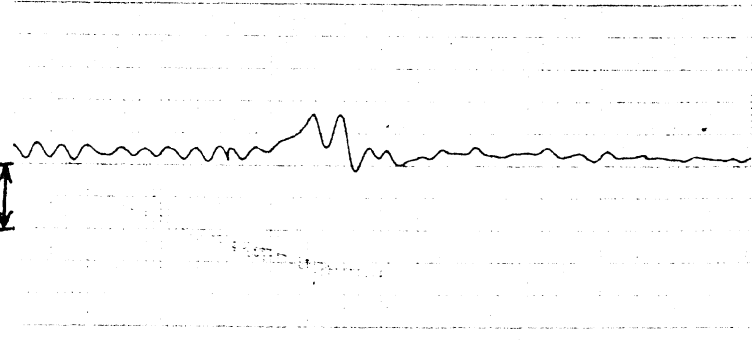
ANTERIOR-POSTERIOR
ACCELERATION

8.5 G =
Filtered Class 180



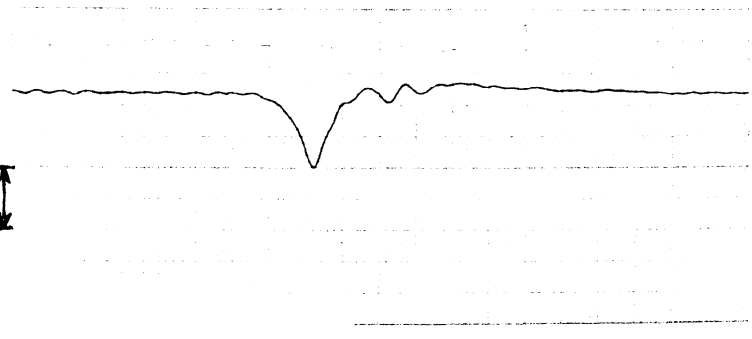
SUPERIOR-INFERIOR
ACCELERATION

8.2 G =
Filtered Class 180



LEFT-RIGHT
ACCELERATION

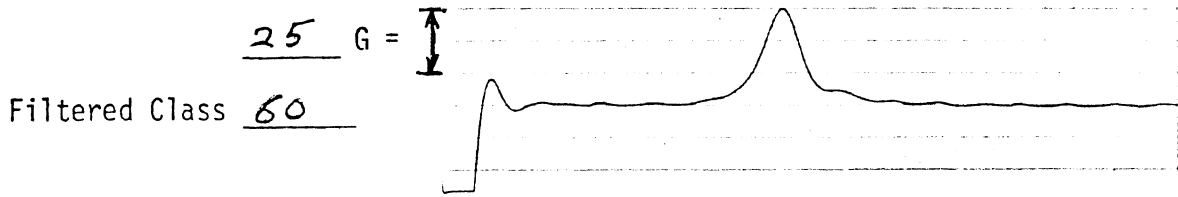
38.3 G =
Filtered Class 180



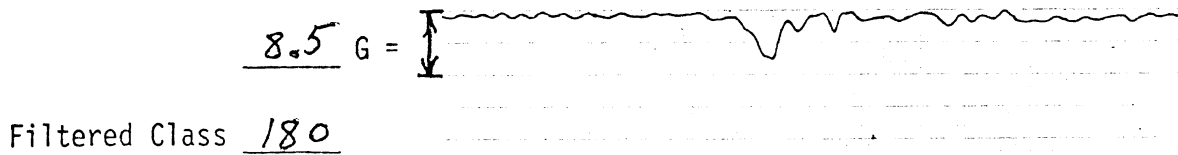
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 086 DUMMY NO. 3 SIDE R BODY REGION PELVIS

IMPACT MASS
DECELERATION



ANTERIOR-POSTERIOR
ACCELERATION



SUPERIOR-INFERIOR
ACCELERATION



LEFT-RIGHT
ACCELERATION



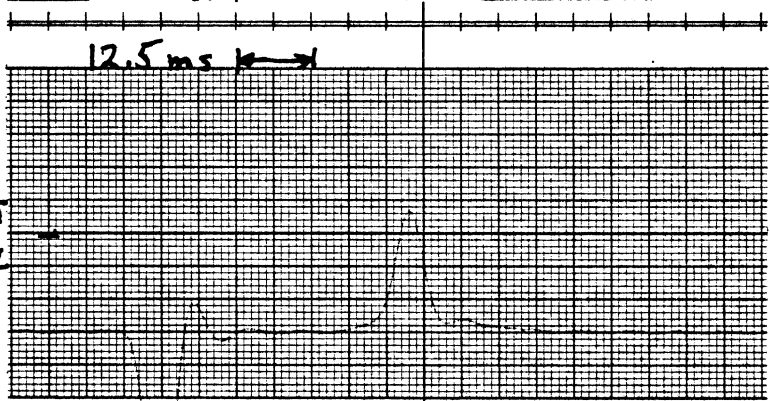
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 087 DUMMY NO. 3 SIDE L BODY REGION PELVIS

IMPACT MASS
DECELERATION

25 G =

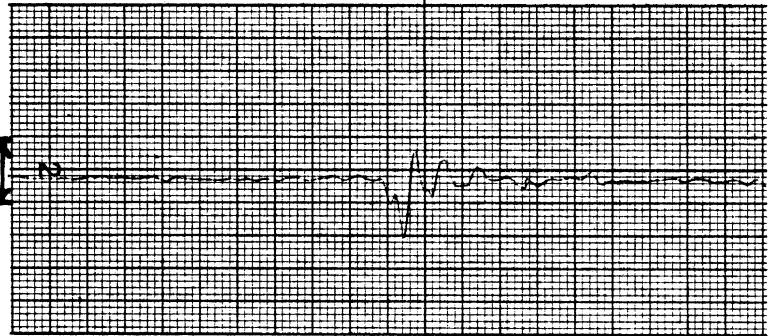
Filtered Class 60



ANTERIOR-POSTERIOR
ACCELERATION

8.5 G =

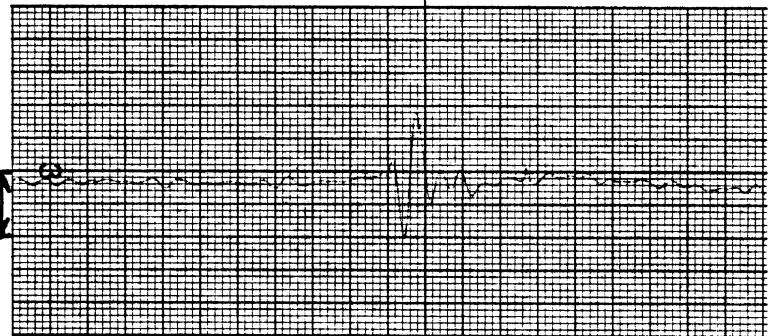
Filtered Class 180



SUPERIOR-INFERIOR
ACCELERATION

8.2 G =

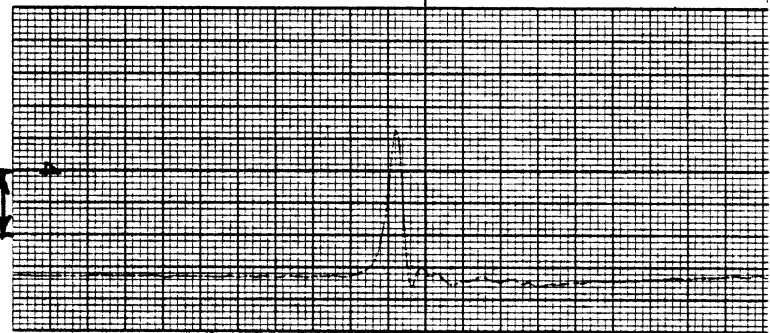
Filtered Class 180



LEFT-RIGHT
ACCELERATION

38.3 G =

Filtered Class 180



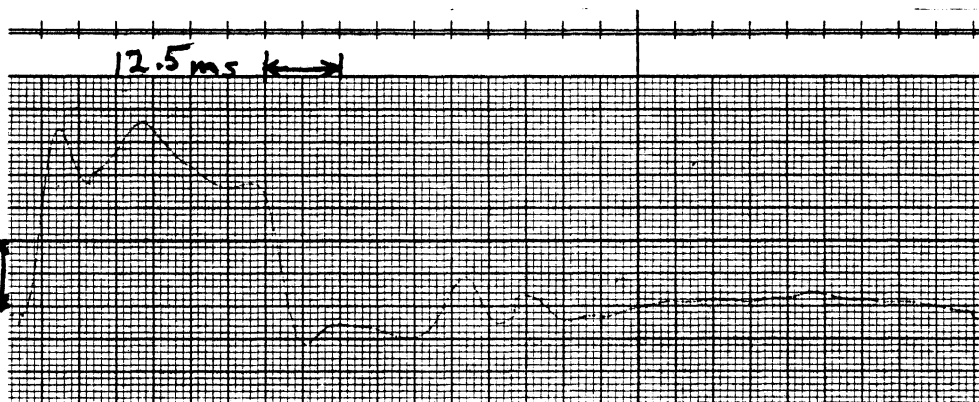
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J090 DUMMY NO. 2 SIDE L BODY REGION HEAD/NECK

IMPACT MASS
DECELERATION

5 G

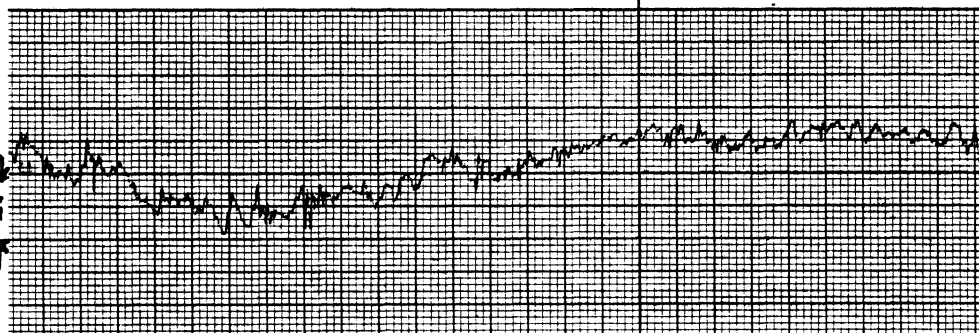
Filtered Class 60



ANTERIOR-POSTERIOR
ACCELERATION

1.7 G

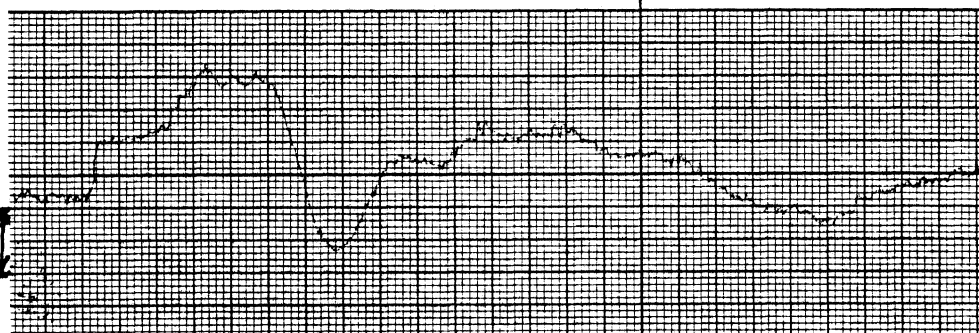
Filtered Class 1000



SUPERIOR-INFERIOR
ACCELERATION

3.3 G

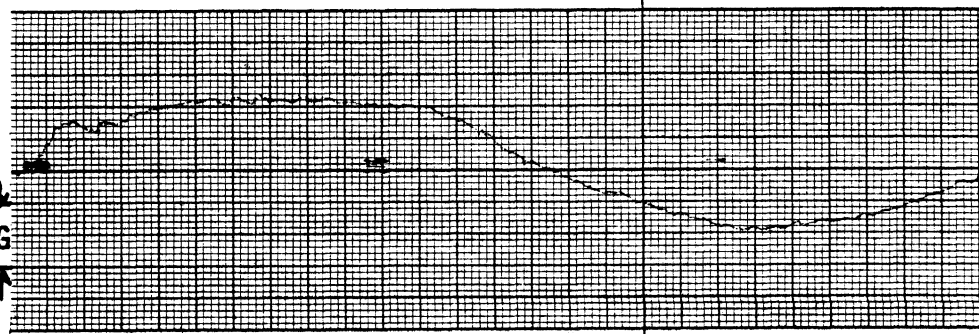
Filtered Class 1000



LEFT-RIGHT
ACCELERATION

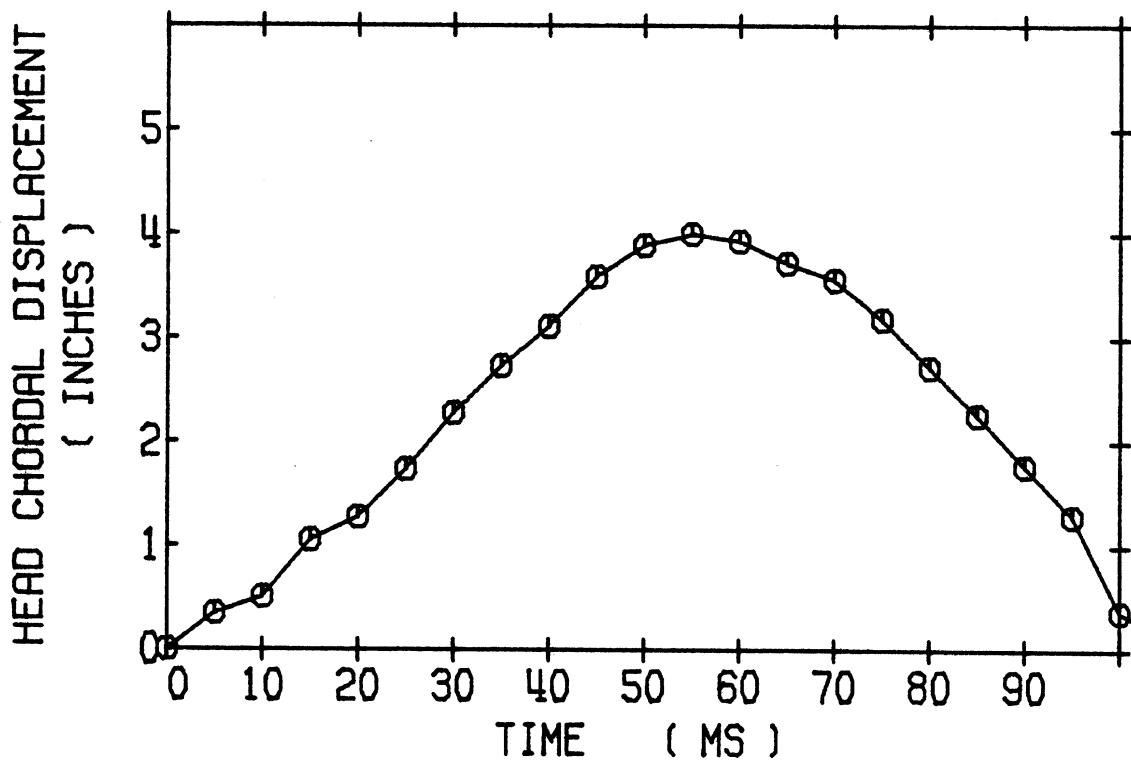
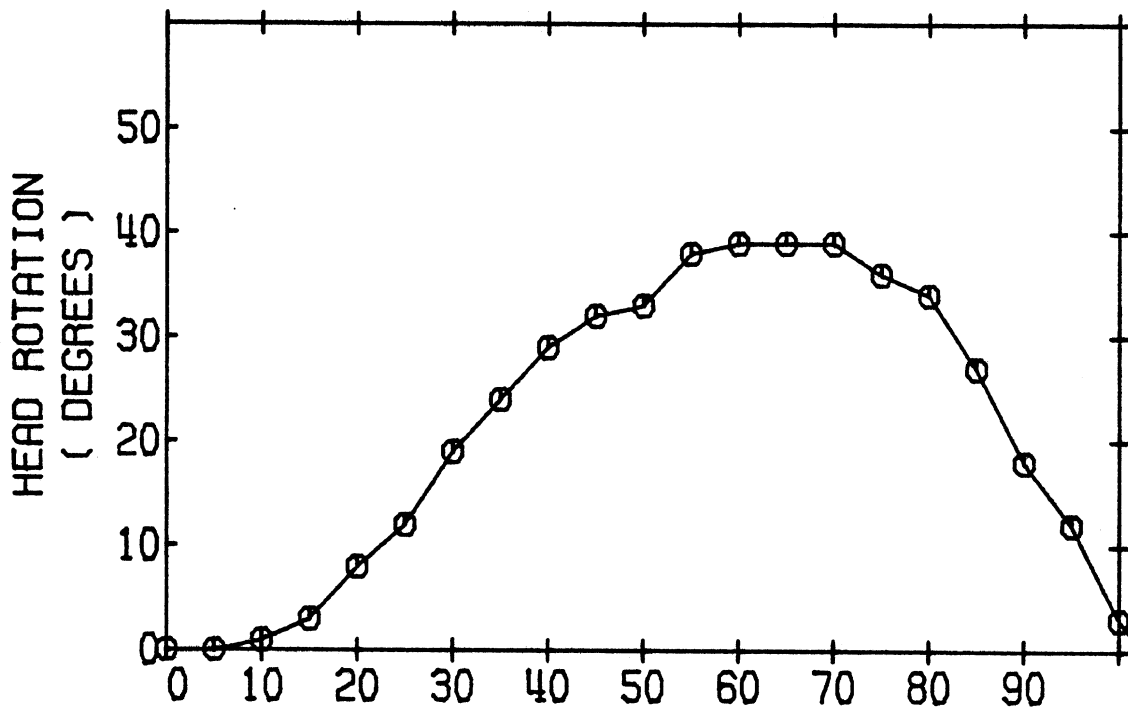
9.6 G

Filtered Class 1000



LATERAL
13 FPS (NOM.)

76J090



NECK PENDULUM TEST

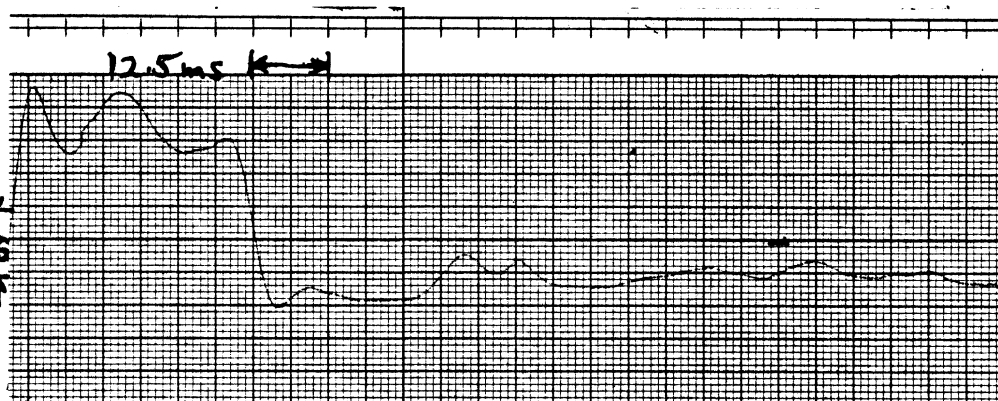
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 091 DUMMY NO. 2 SIDE R BODY REGION HEAD/NECK

IMPACT MASS
DECELERATION

5
G

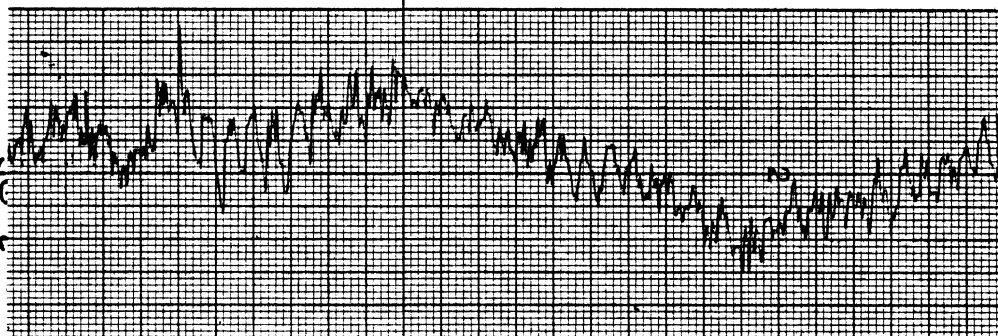
Filtered Class 60



ANTERIOR-POSTERIOR
ACCELERATION

0.8
G

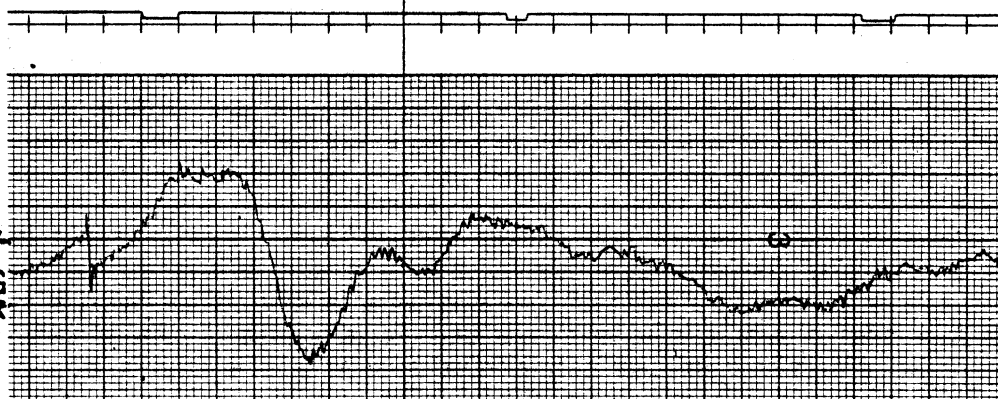
Filtered Class 1000



SUPERIOR-INFERIOR
ACCELERATION

3.3
G

Filtered Class 1000



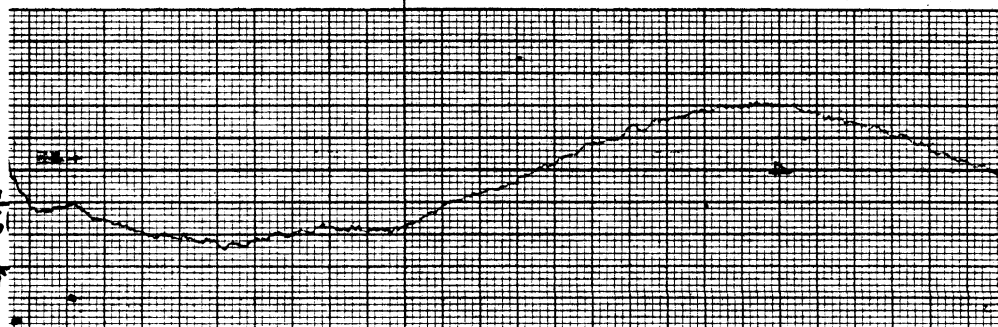
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Printed in U.S.A.

LEFT-RIGHT
ACCELERATION

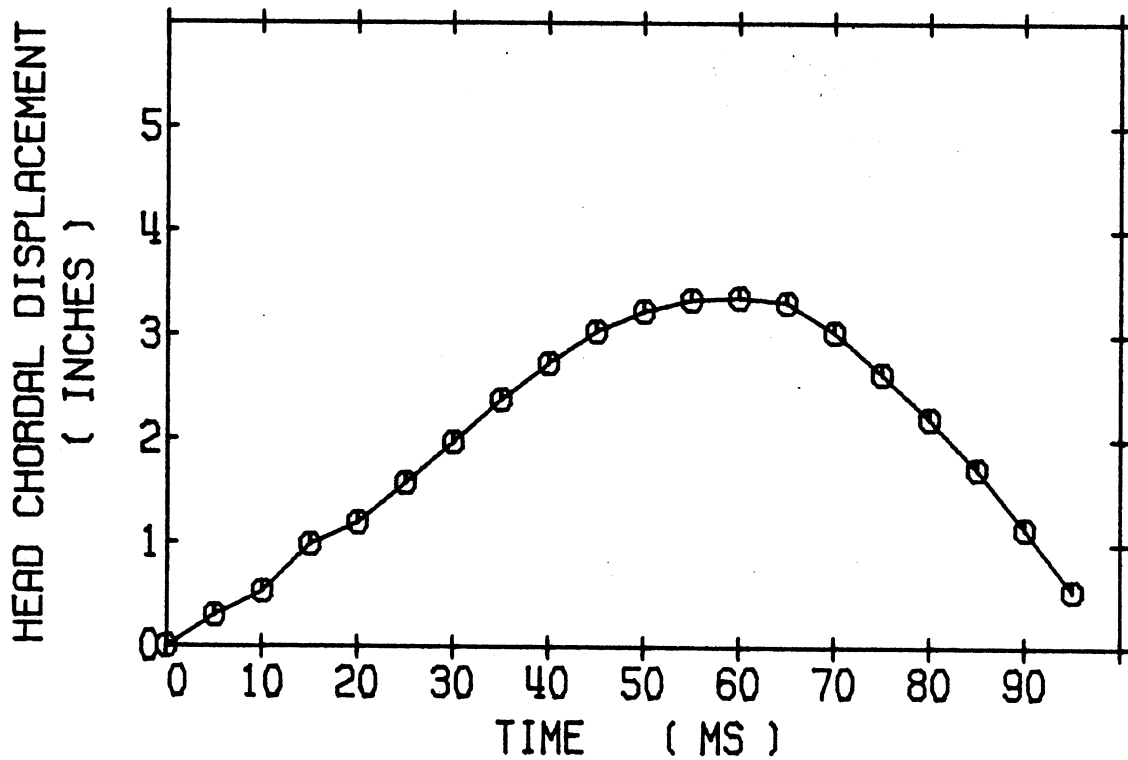
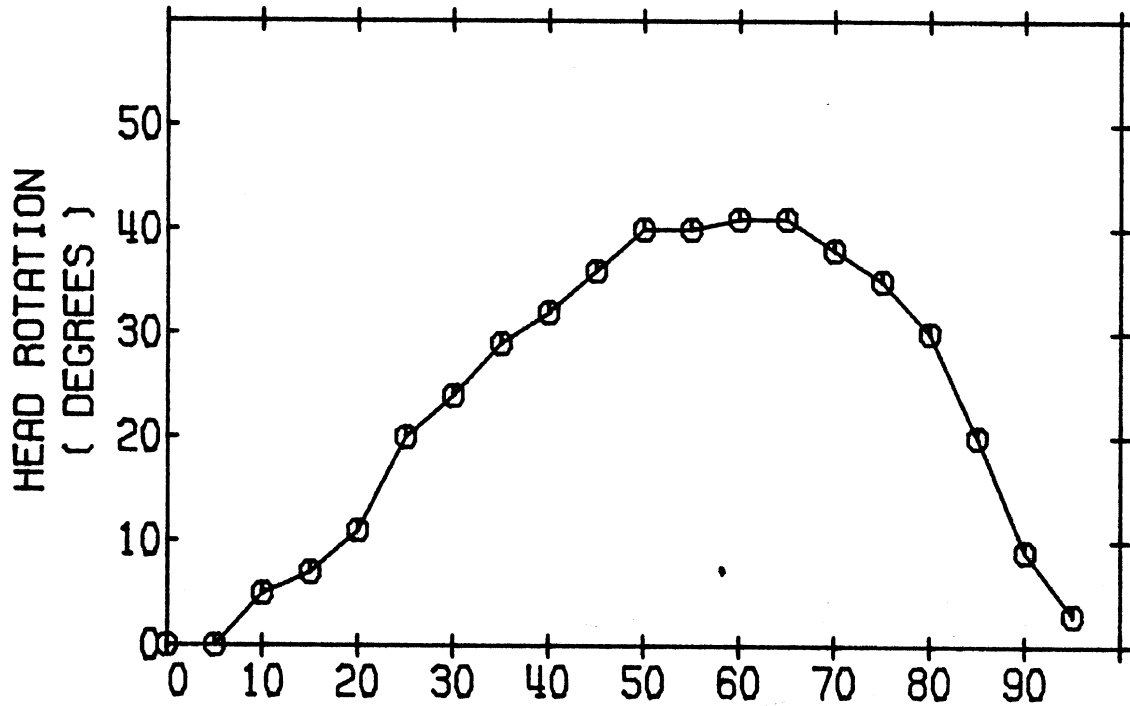
9.6
G

Filtered Class 1000



LATERAL
13 FPS (NOM.)

76J091



NECK PENDULUM TEST

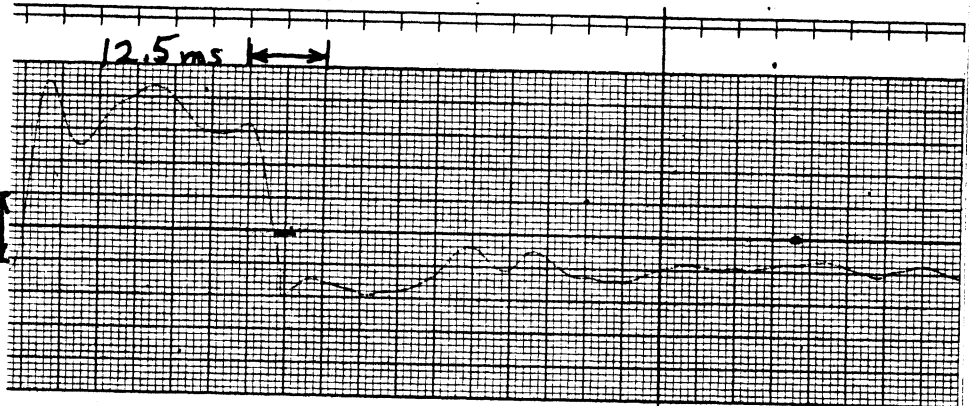
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J092 DUMMY NO. 2 SIDE L BODY REGION HEAD/NECK

IMPACT MASS
DECELERATION

5 G

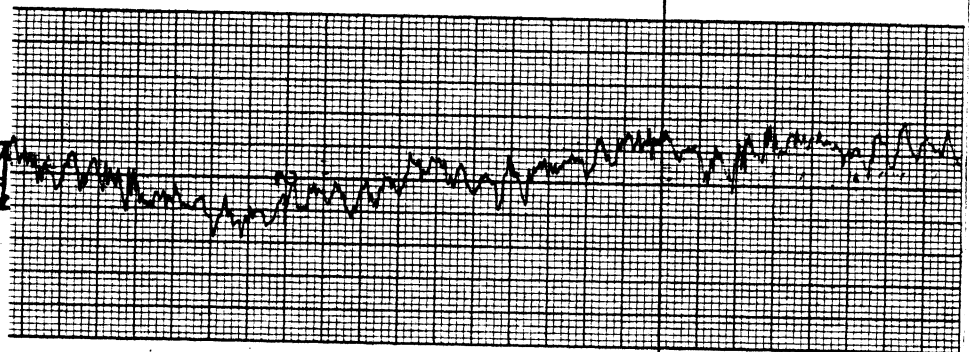
Filtered Class 60



ANTERIOR-POSTERIOR
ACCELERATION

1.7 G

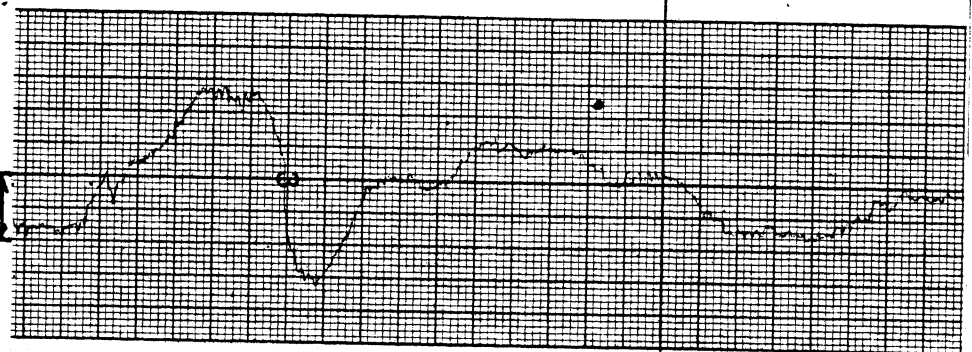
Filtered Class 1000



SUPERIOR-INFERIOR
ACCELERATION

3.3 G

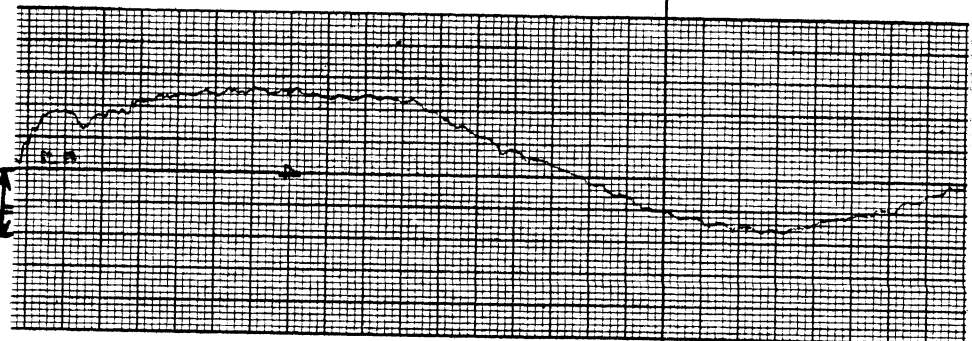
Filtered Class 1000



LEFT-RIGHT
ACCELERATION

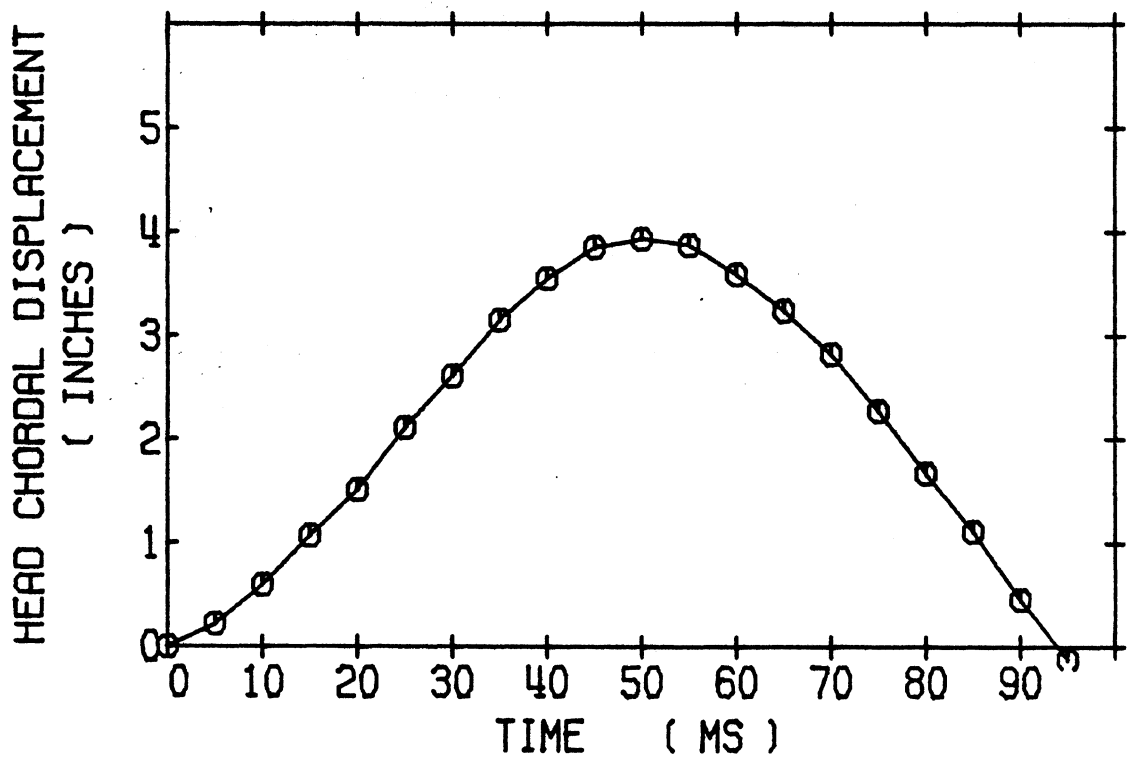
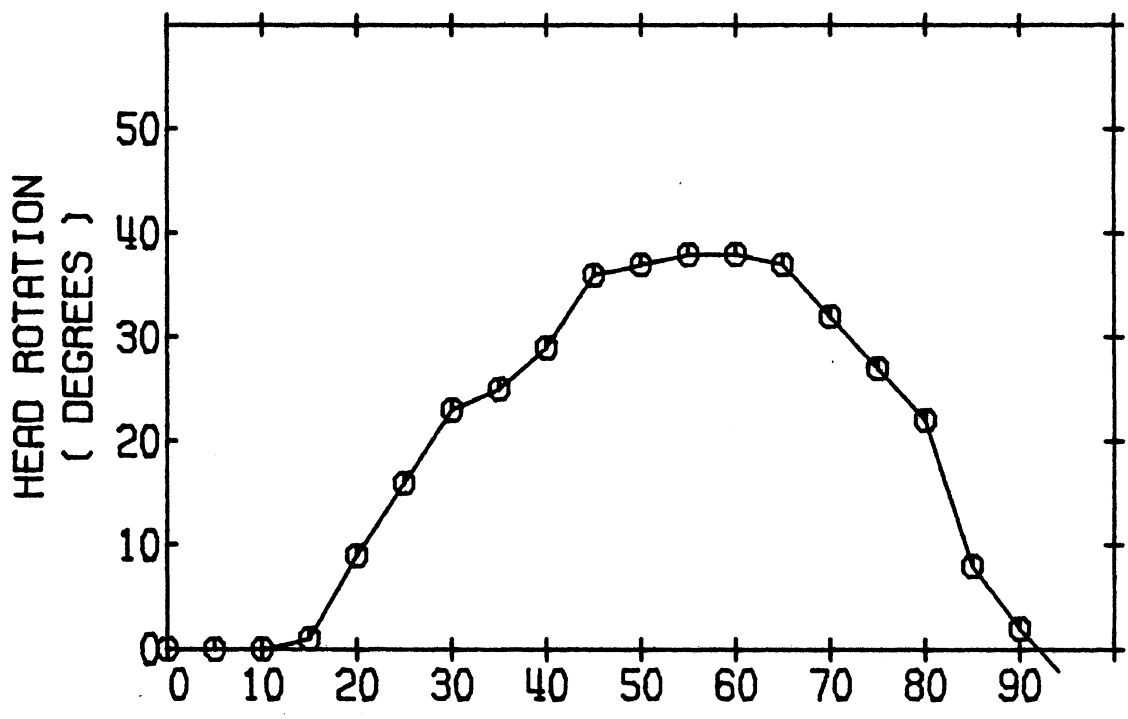
9.6 G

Filtered Class 1000



LATERAL
13 FPS (NOM.)

76J092



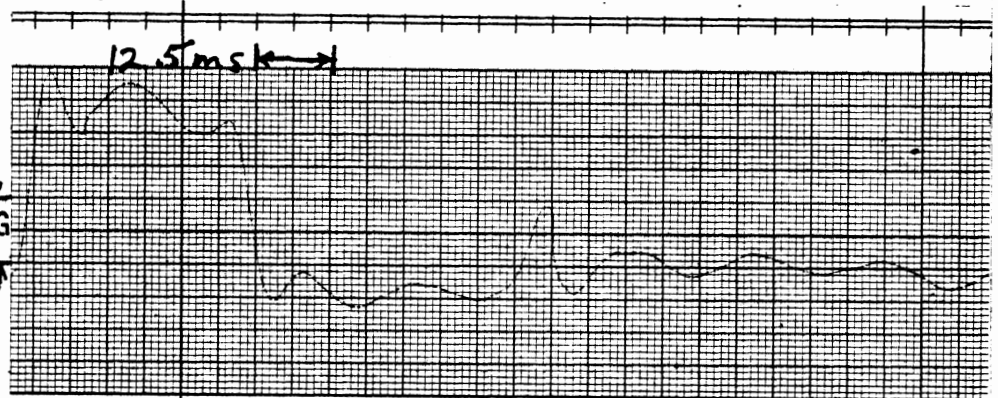
NECK PENDULUM TEST

DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 093 DUMMY NO. 2 SIDE R BODY REGION HEAD/NECK

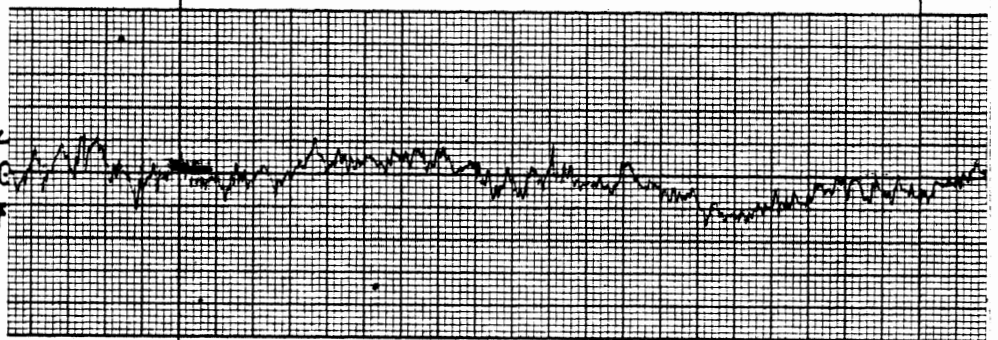
IMPACT MASS
DECELERATION

5 G
Filtered Class 60



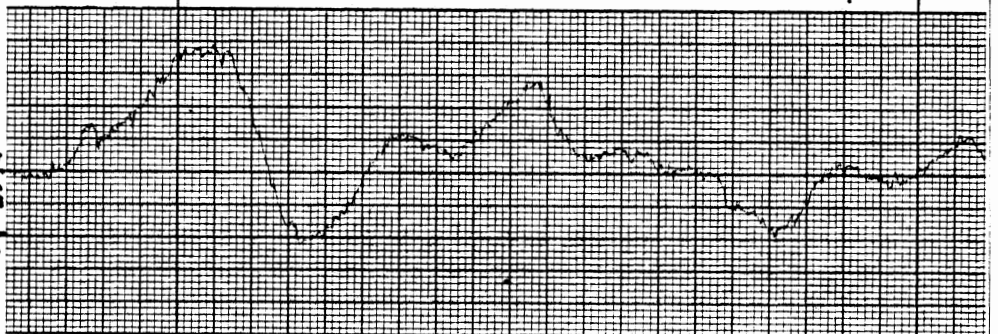
ANTERIOR-POSTERIOR
ACCELERATION

1.7 G
Filtered Class 1000



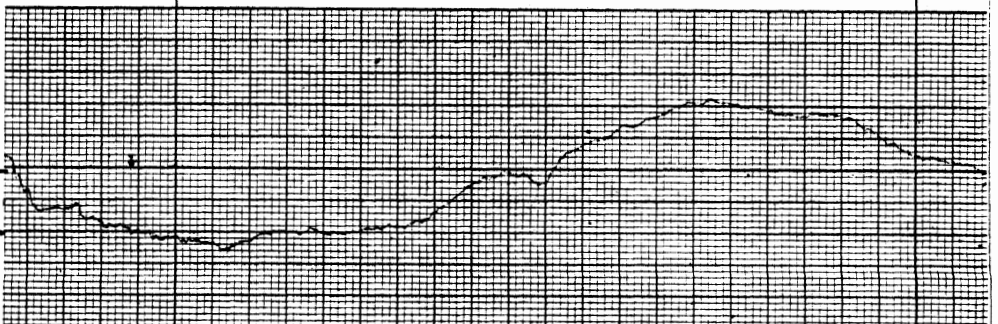
SUPERIOR-INFERIOR
ACCELERATION

3.3 G
Filtered Class 1000



LEFT-RIGHT
ACCELERATION

9.6 G
Filtered Class 1000

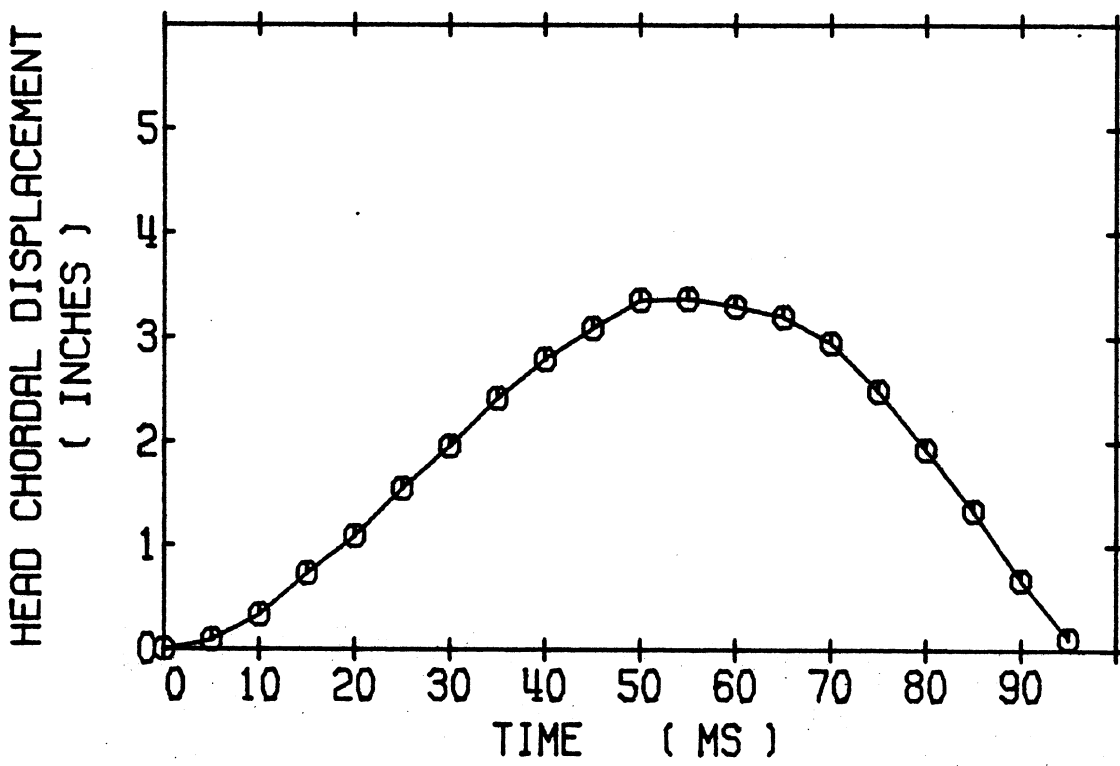
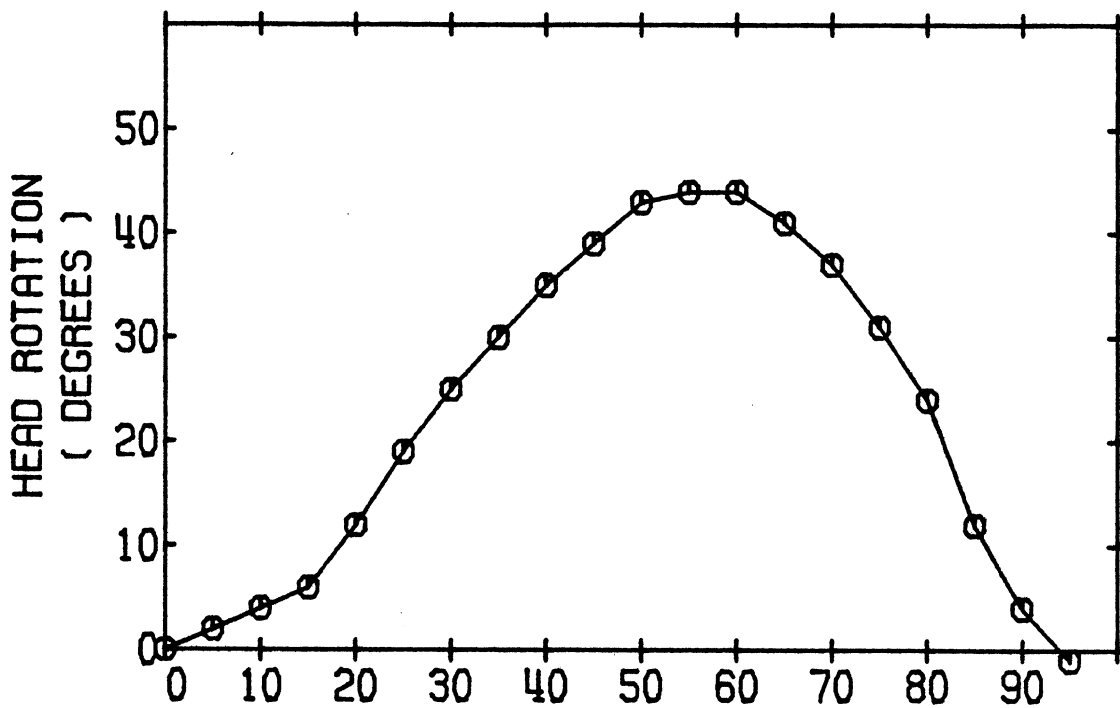


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Cleveland, Ohio Printed in U.S.A.

LATERAL
13 FPS (NOM.)

76J093

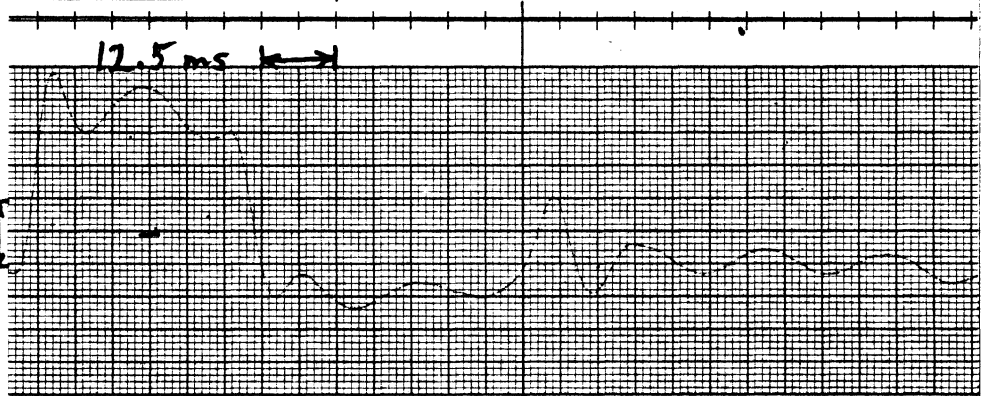


NECK PENDULUM TEST

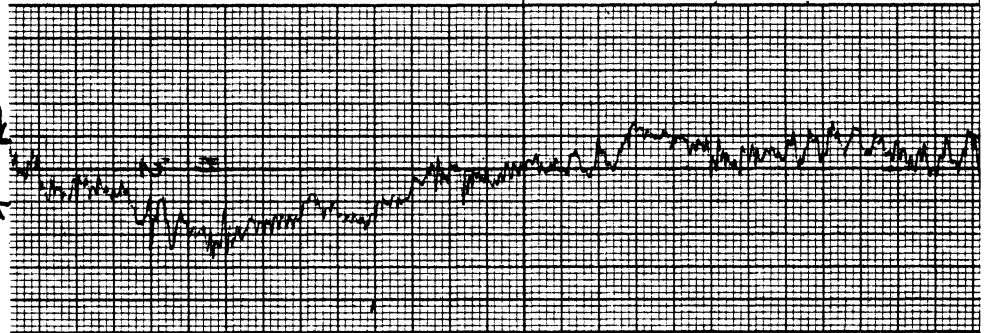
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J094 DUMMY NO. 2 SIDE L BODY REGION HEAD/NECK

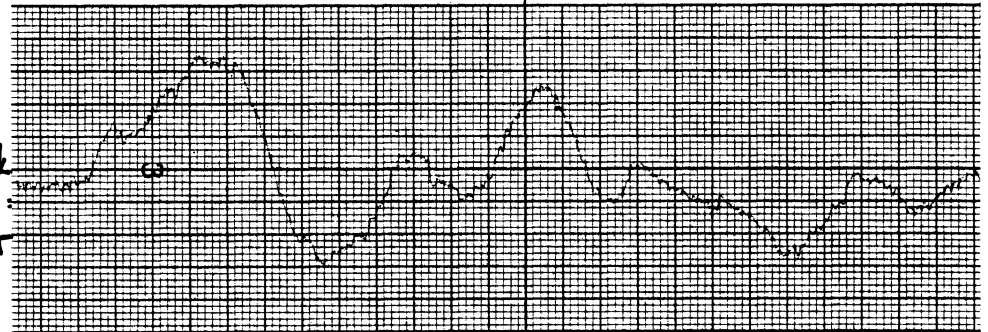
IMPACT MASS
DECELERATION



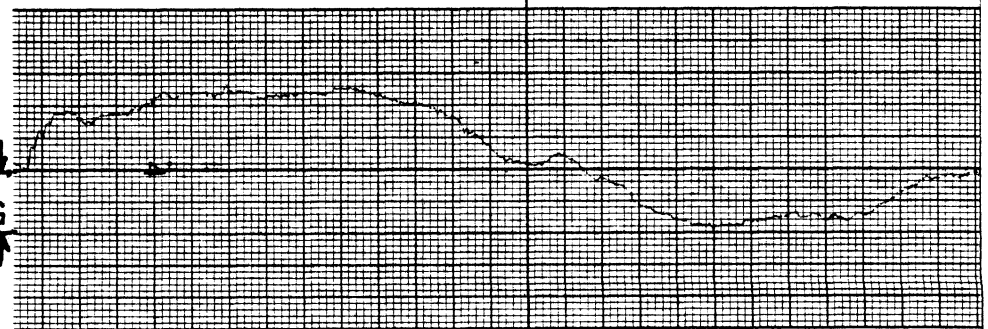
ANTERIOR-POSTERIOR
ACCELERATION



SUPERIOR-INFERIOR
ACCELERATION

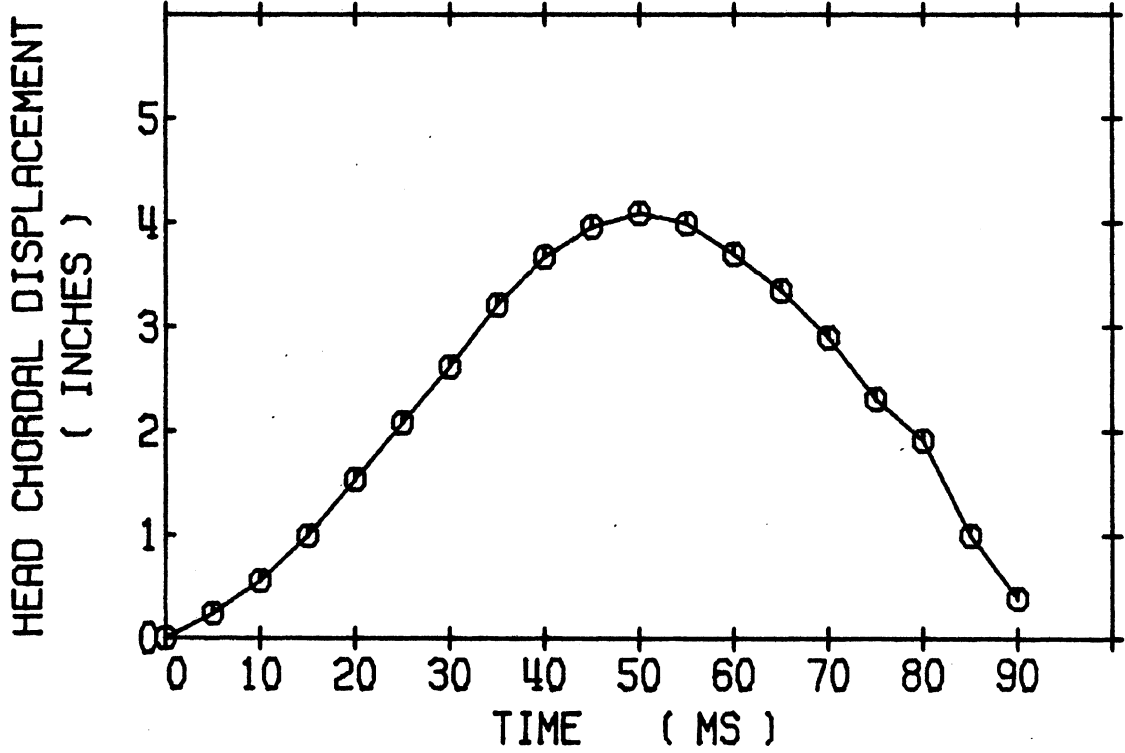
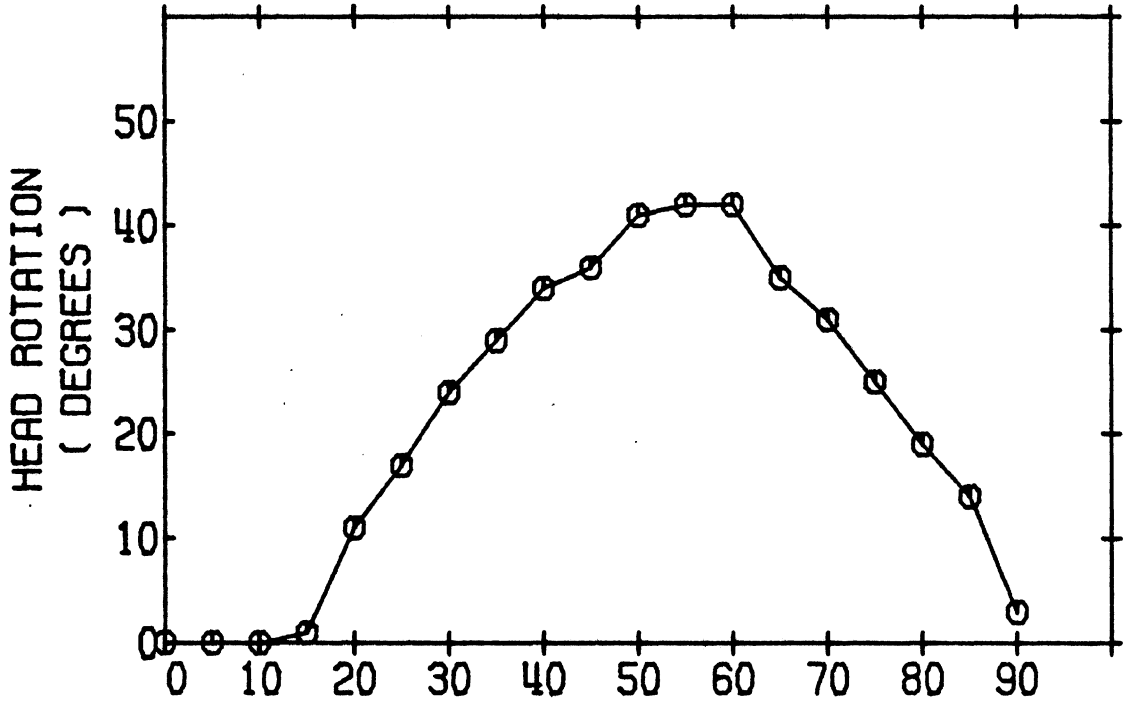


LEFT-RIGHT
ACCELERATION



LATERAL
13 FPS (NOM.)

76J094



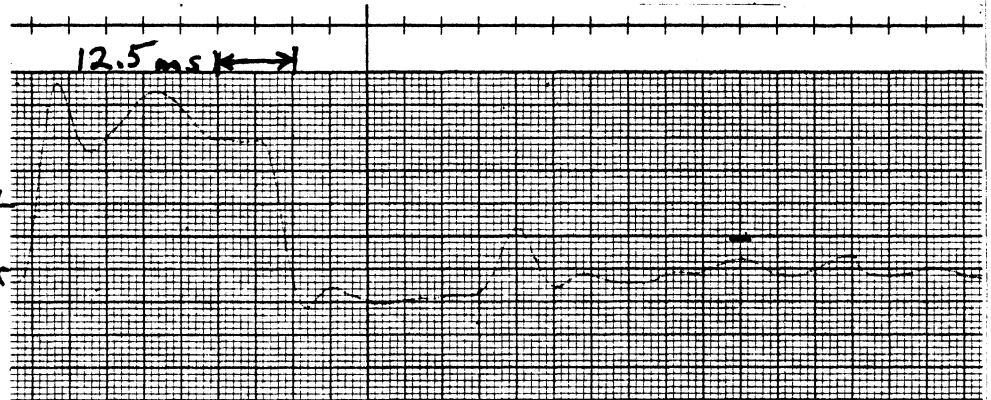
NECK PENDULUM TEST

DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 095 DUMMY NO. 2 SIDE R BODY REGION HEAD/NECK

IMPACT MASS
DECELERATION

5 G
Filtered Class 60



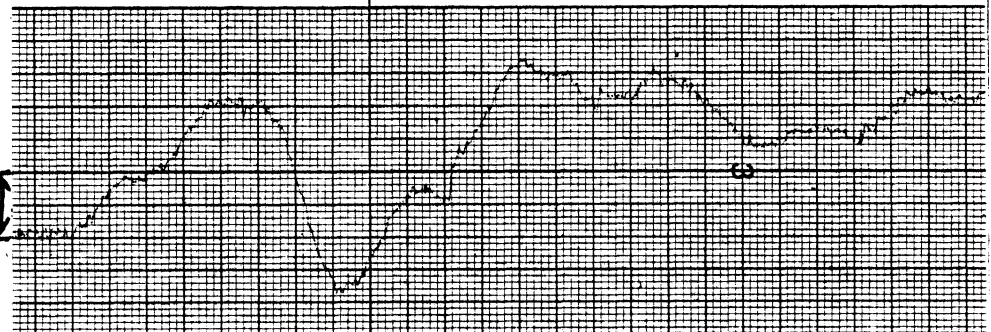
ANTERIOR-POSTERIOR
ACCELERATION

1.7 G
Filtered Class 1000



SUPERIOR-INFERIOR
ACCELERATION

3.3 G
Filtered Class 1000

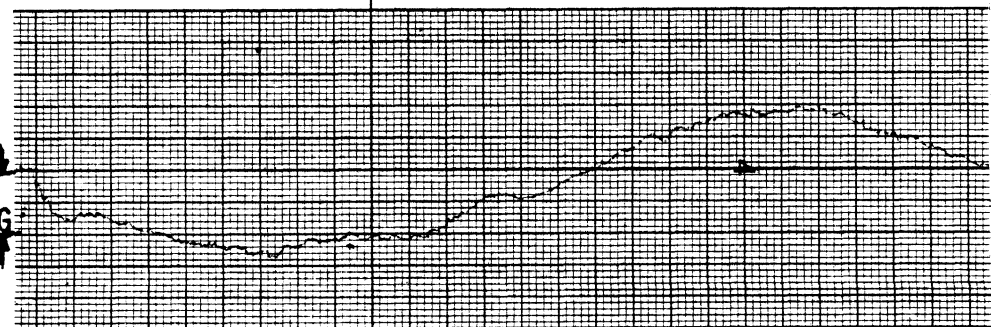


t Systems Division

rinted in U.S.A.

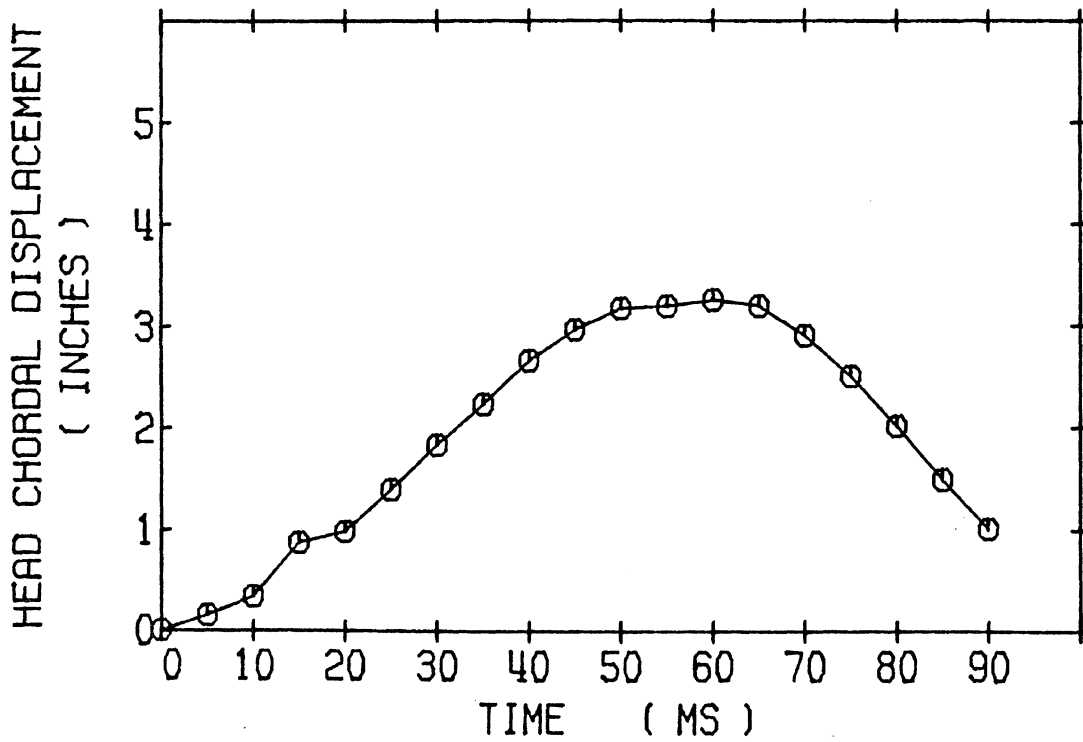
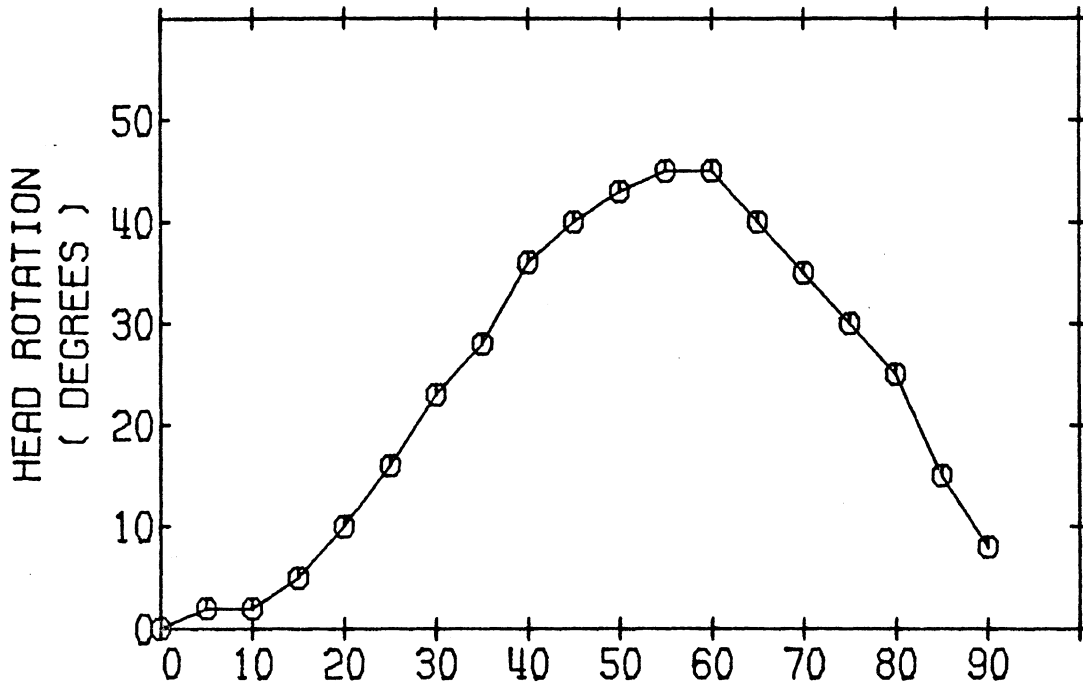
LEFT-RIGHT
ACCELERATION

9.6 G
Filtered Class 1000



LATERAL
13 FPS (NOM.)

76J095



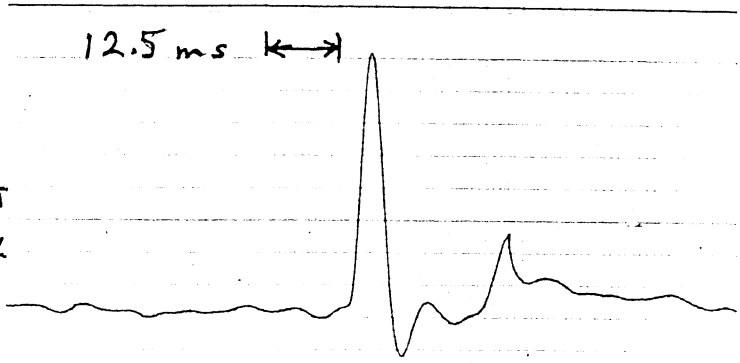
NECK PENDULUM TEST

DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 096 DUMMY NO. 2 SIDE L BODY REGION HEAD

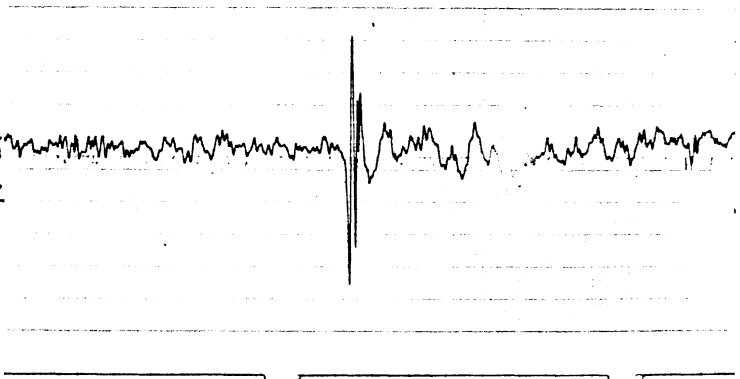
IMPACT MASS
DECELERATION

25 G =
Filtered Class 60



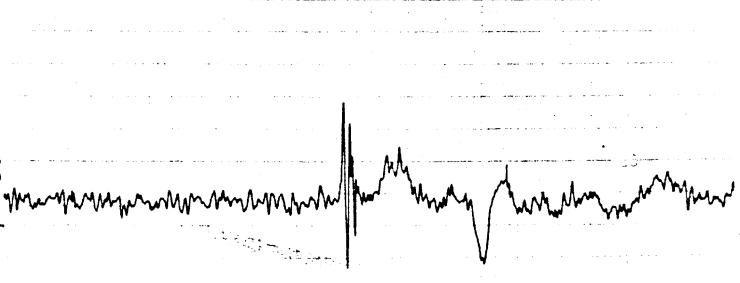
ANTERIOR-POSTERIOR
ACCELERATION

3.3 G =
Filtered Class 1000



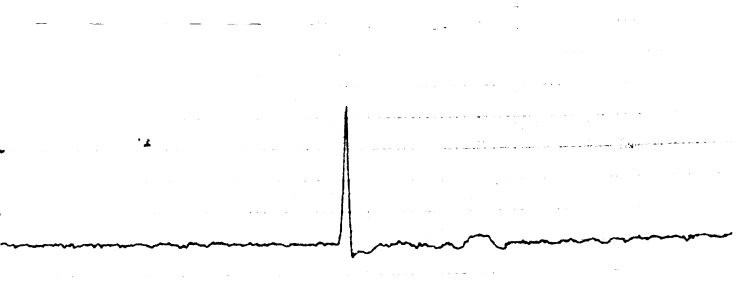
SUPERIOR-INFERIOR
ACCELERATION

3.3 G =
Filtered Class 1000



LEFT-RIGHT
ACCELERATION


96 G =
Filtered Class 1000

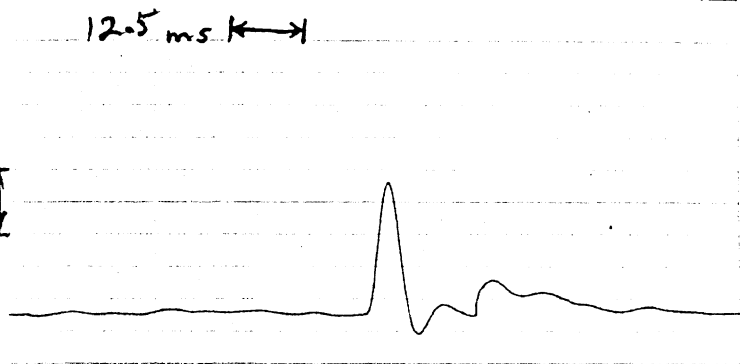


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J 097 DUMMY NO. 2 SIDE R BODY REGION HEAD

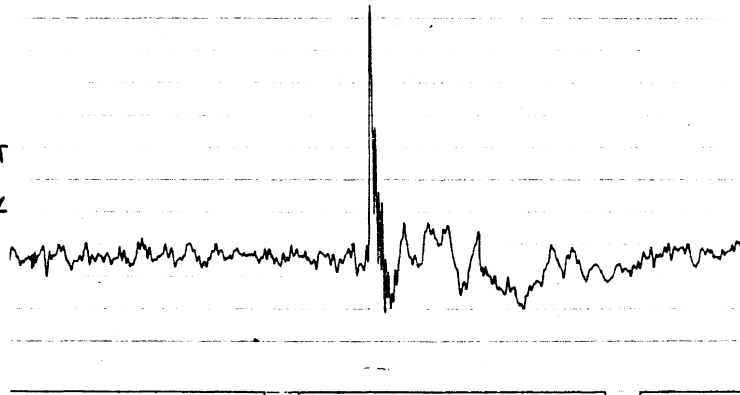
IMPACT MASS
DECELERATION

5 G = 
Filtered Class 60




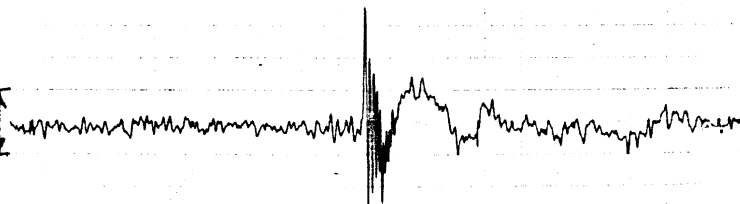
ANTERIOR-POSTERIOR
ACCELERATION

3.3 G = 
Filtered Class 1000




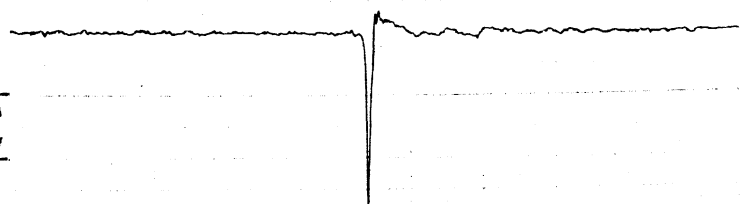
SUPERIOR-INFERIOR
ACCELERATION

3.3 G = 
Filtered Class 1000



LEFT-RIGHT
ACCELERATION

96 G = 
Filtered Class 1000

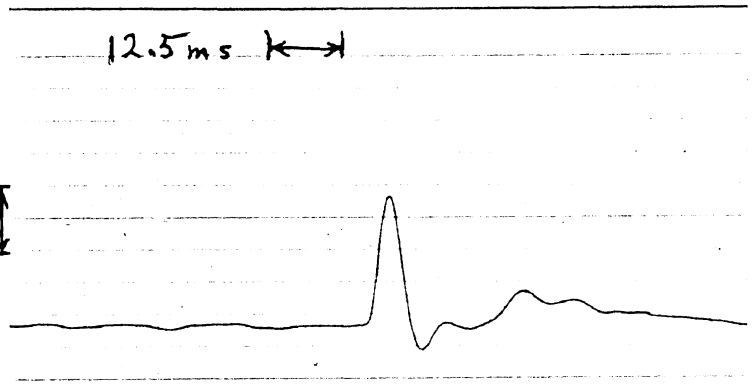


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 098 DUMMY NO. 2 SIDE L BODY REGION HEAD

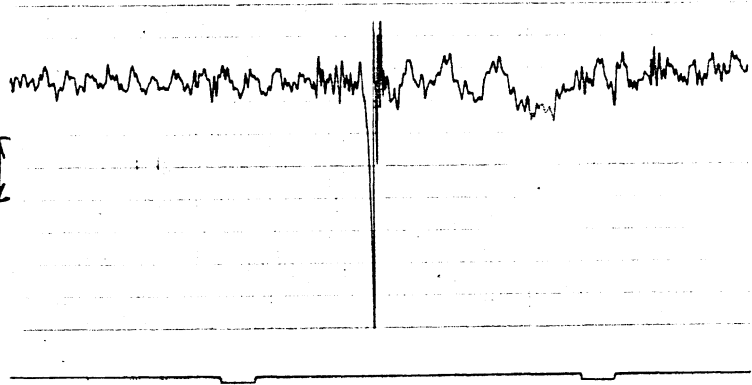
IMPACT MASS
DECELERATION

25 G =
Filtered Class 60



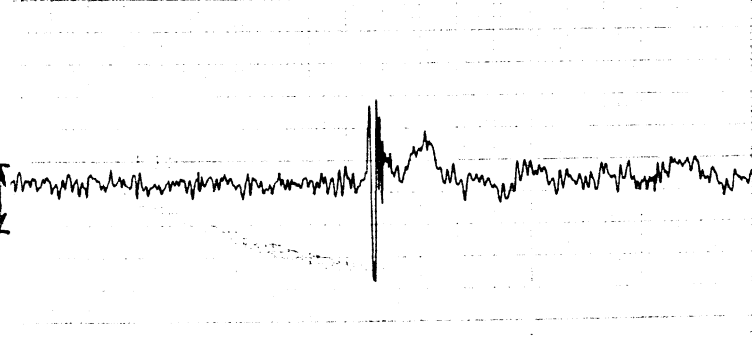
ANTERIOR-POSTERIOR
ACCELERATION

3.3 G =
Filtered Class 1000



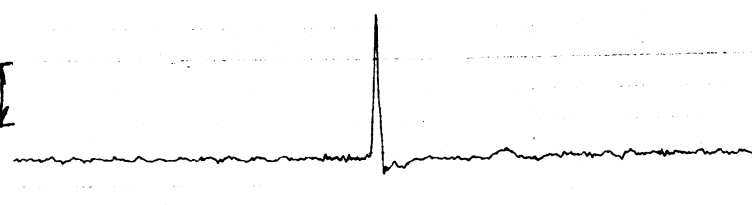
SUPERIOR-INFERIOR
ACCELERATION

3.3 G =
Filtered Class 1000



LEFT-RIGHT
ACCELERATION

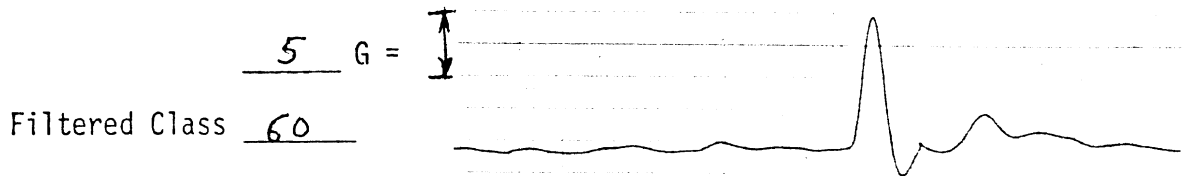
96 G =
Filtered Class 1000



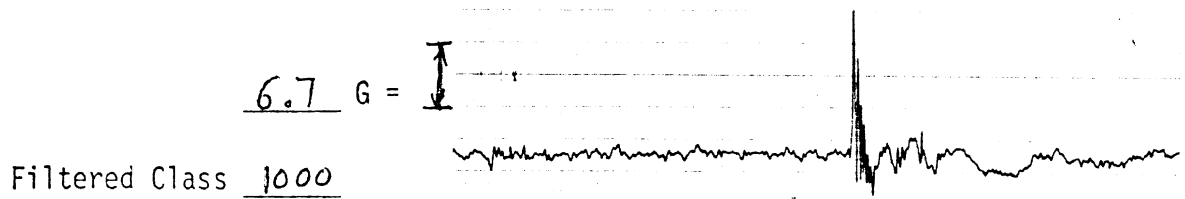
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J099 DUMMY NO. 2 SIDE R BODY REGION HEAD

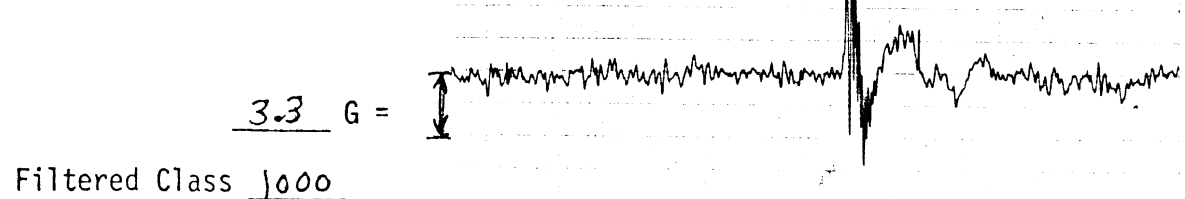
IMPACT MASS
DECELERATION



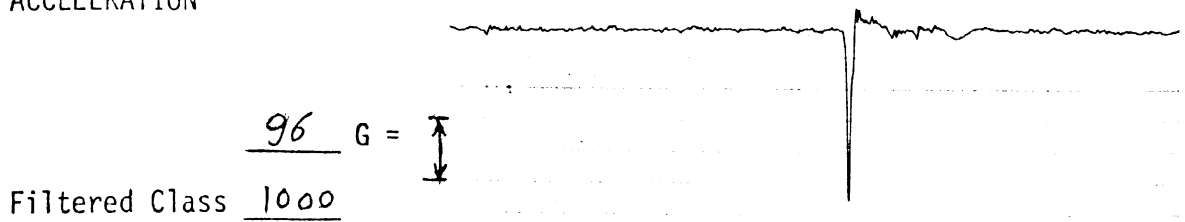
ANTERIOR-POSTERIOR
ACCELERATION



SUPERIOR-INFERIOR
ACCELERATION



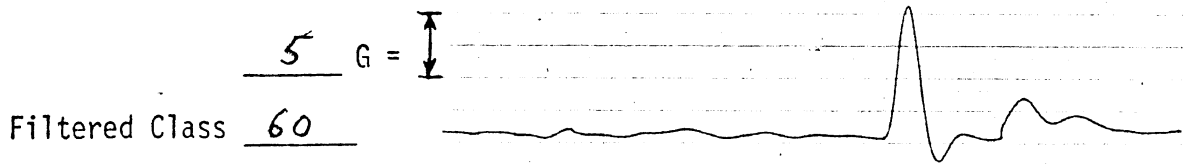
LEFT-RIGHT
ACCELERATION



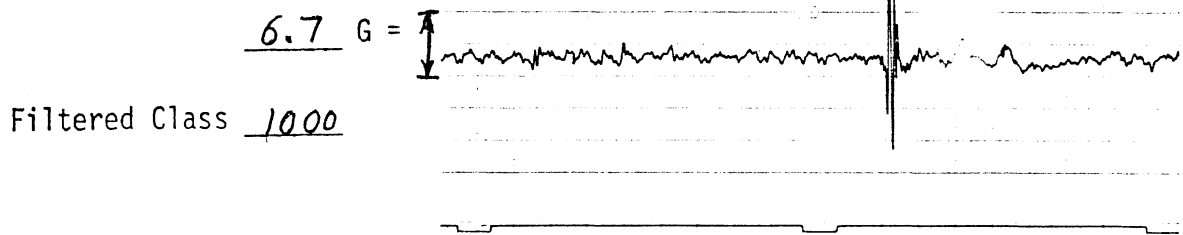
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 100 DUMMY NO. 3 SIDE L BODY REGION HEAD

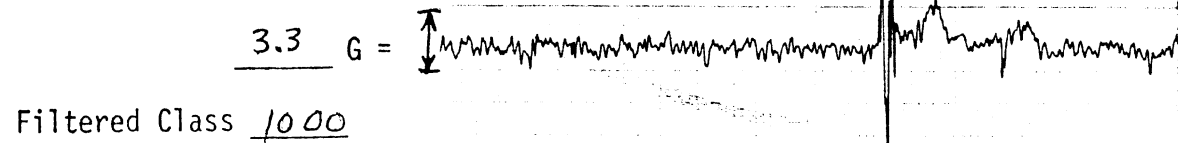
IMPACT MASS
DECELERATION



ANTERIOR-POSTERIOR
ACCELERATION



SUPERIOR-INFERIOR
ACCELERATION



LEFT-RIGHT
ACCELERATION

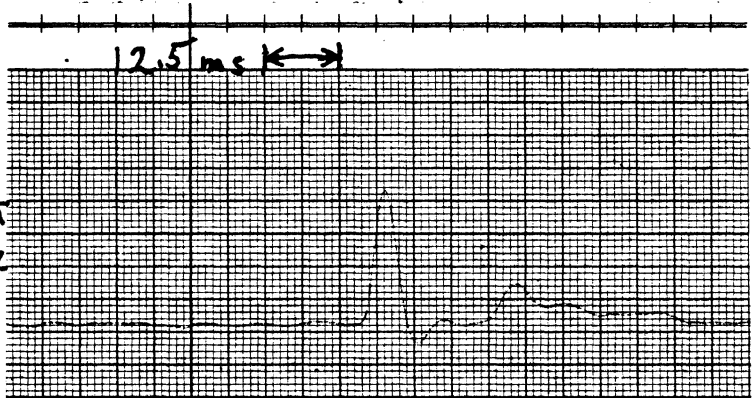


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 101 DUMMY NO. 2 SIDE R BODY REGION HEAD

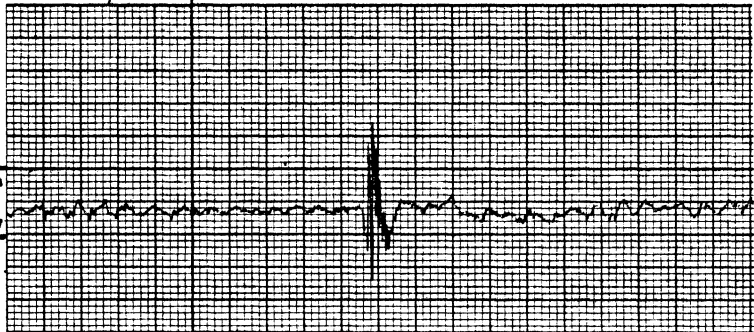
IMPACT MASS
DECELERATION

5 G =
Filtered Class 60



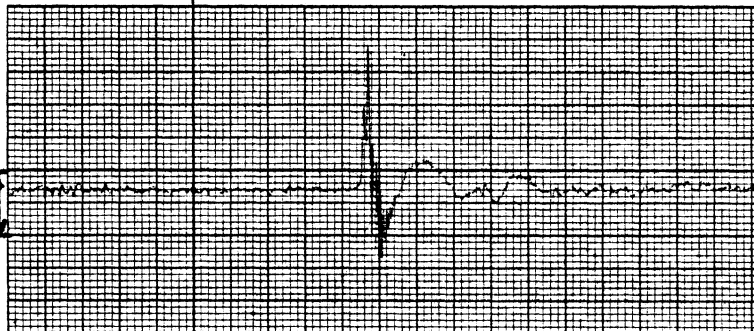
ANTERIOR-POSTERIOR
ACCELERATION

6.7 G =
Filtered Class 1000



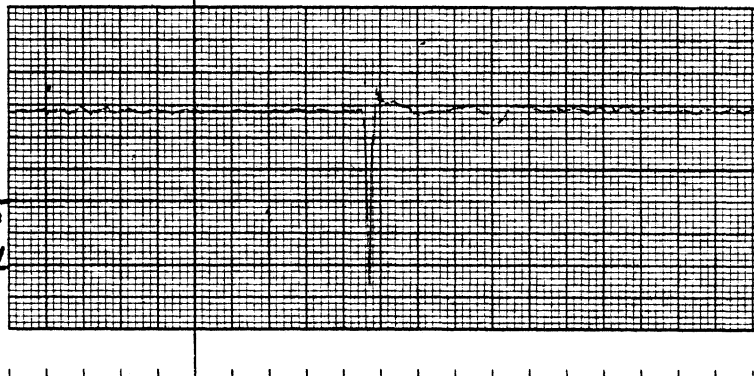
SUPERIOR-INFERIOR
ACCELERATION

6.7 G =
Filtered Class 1000



LEFT-RIGHT
ACCELERATION

96 G =
Filtered Class 1000



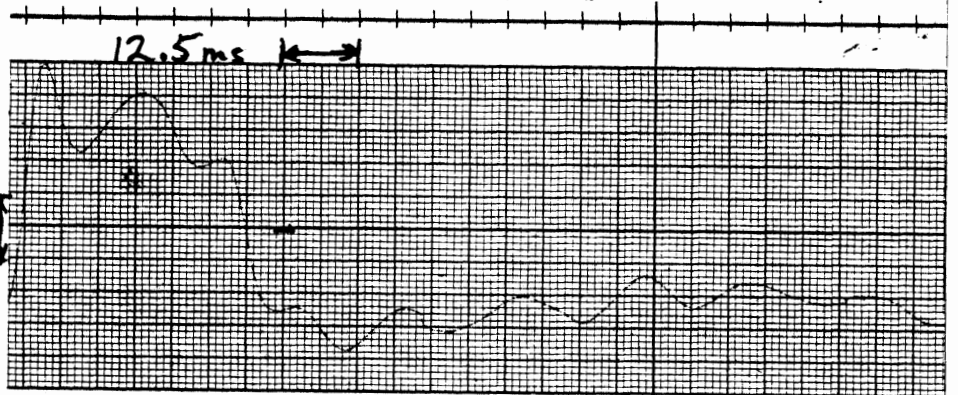
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J102 DUMMY NO. 1 SIDE L BODY REGION HEAD/NECK

IMPACT MASS
DECELERATION

5 G

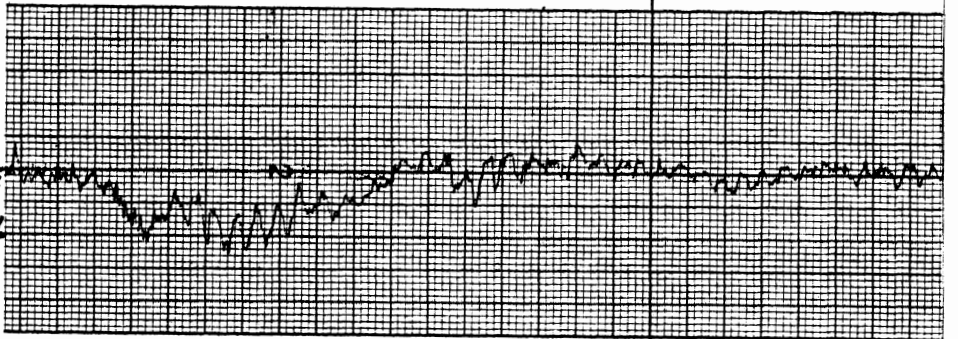
Filtered Class 60



ANTERIOR-POSTERIOR
ACCELERATION

1.7 G

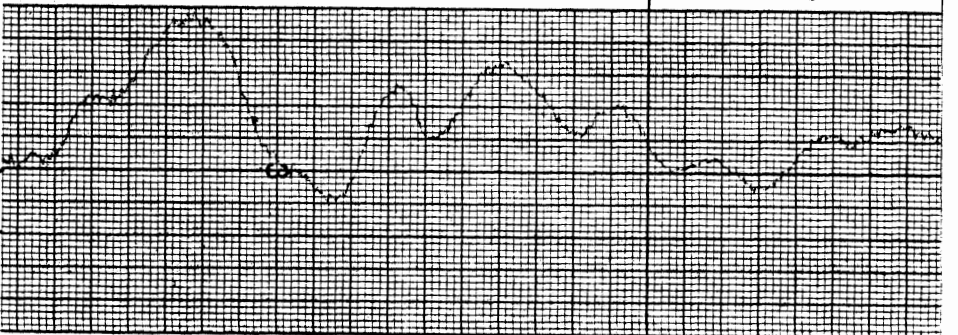
Filtered Class 1000



SUPERIOR-INFERIOR
ACCELERATION

3.3 G

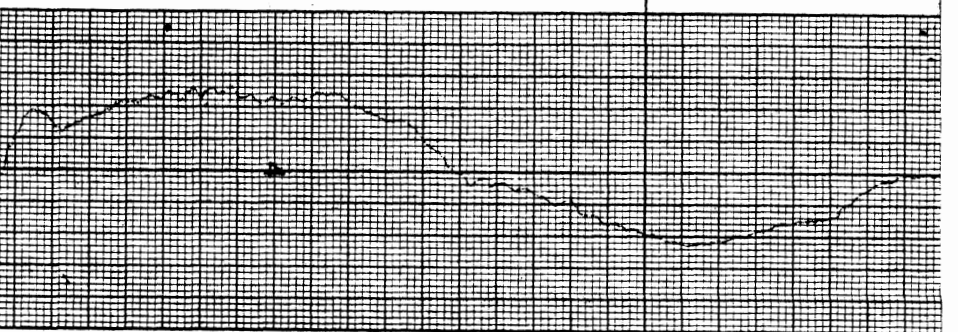
Filtered Class 1000



LEFT-RIGHT
ACCELERATION

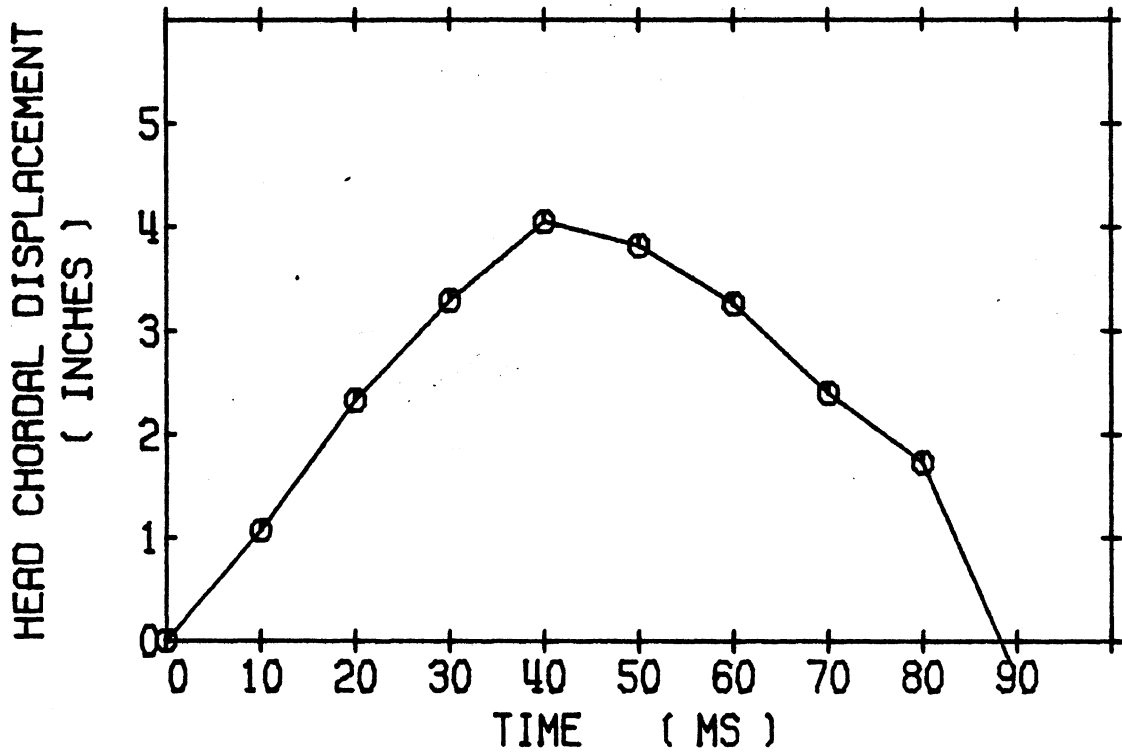
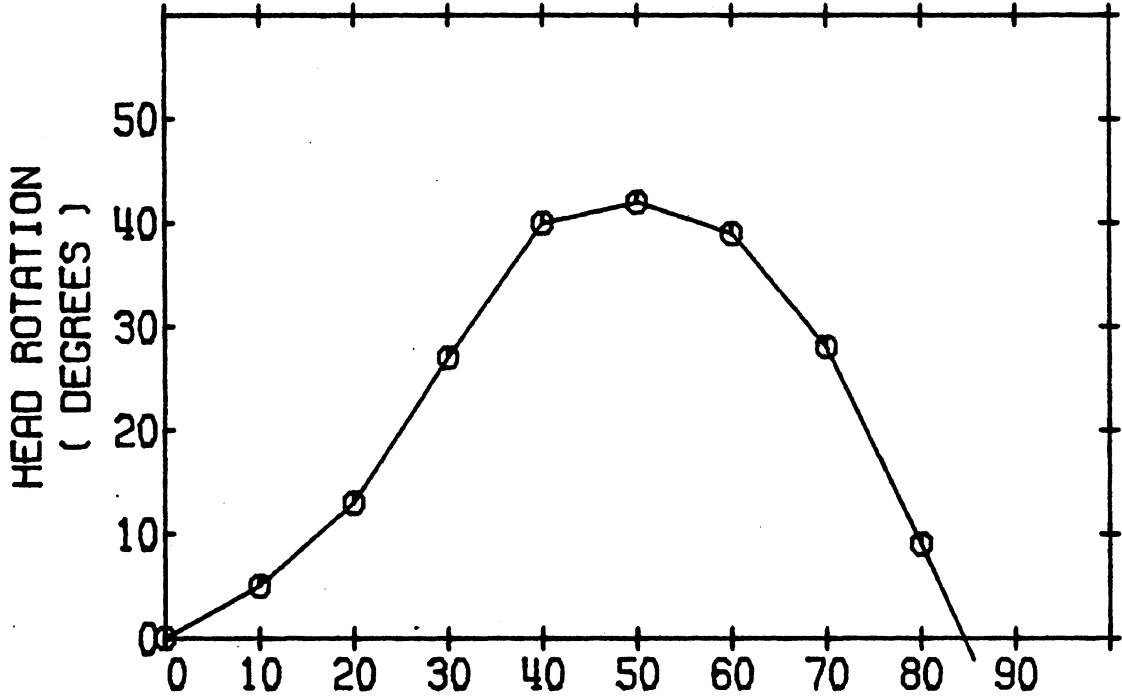
9.6 G

Filtered Class 1000



LATERAL
13 FPS (NOM.)

76J102



NECK PENDULUM TEST

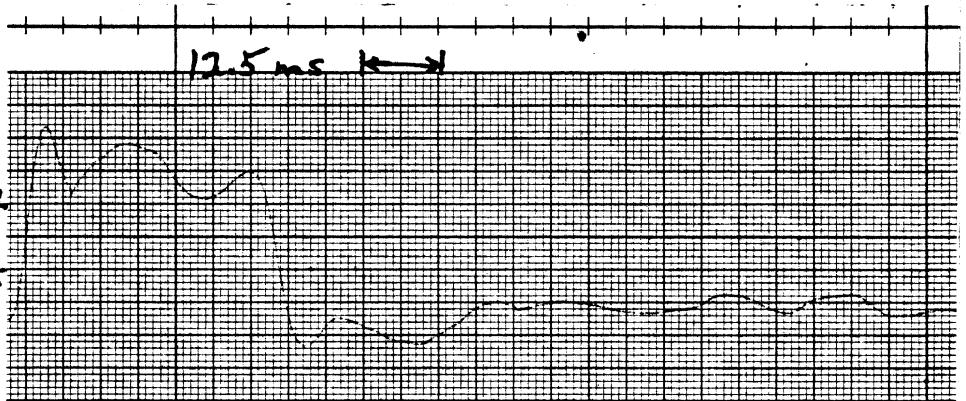
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 103 DUMMY NO. 1 SIDE R BODY REGION HEAD/NECK

IMPACT MASS
DECELERATION

5 G =

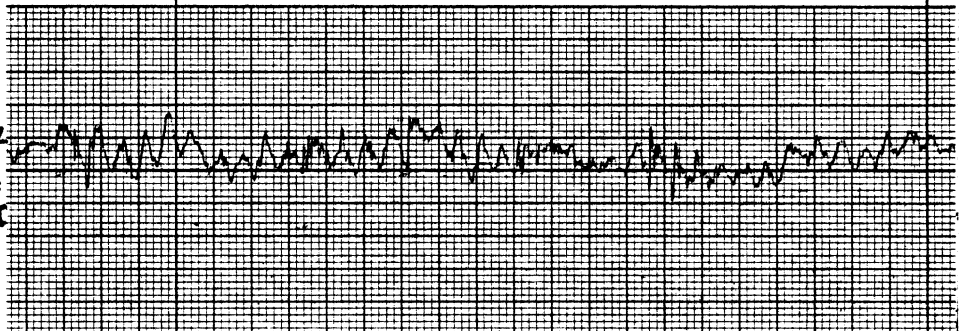
Filtered Class 60



ANTERIOR-POSTERIOR
ACCELERATION

1.7 G =

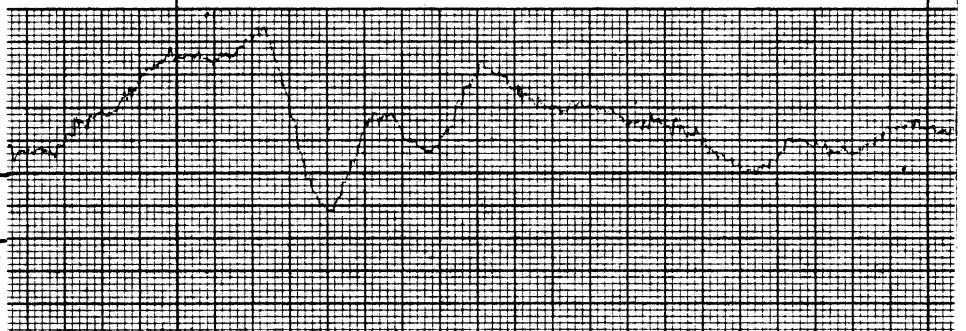
Filtered Class 1000



SUPERIOR-INFERIOR
ACCELERATION

3.3 G =

Filtered Class 1000



Gould Inc., Instrument Systems Division

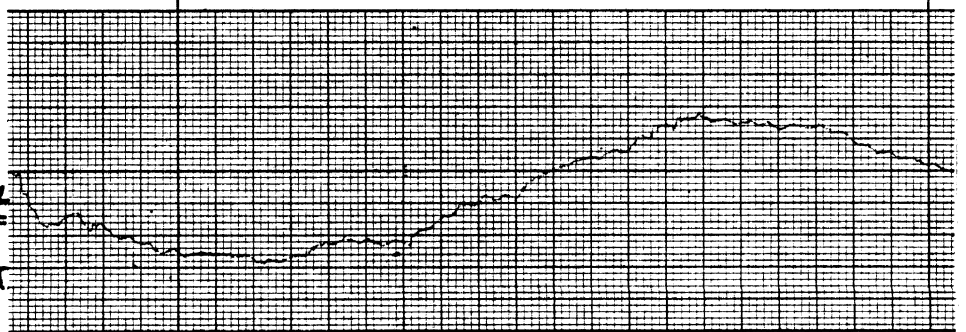
Cleveland, Ohio

Printed in U.S.A.

LEFT-RIGHT
ACCELERATION

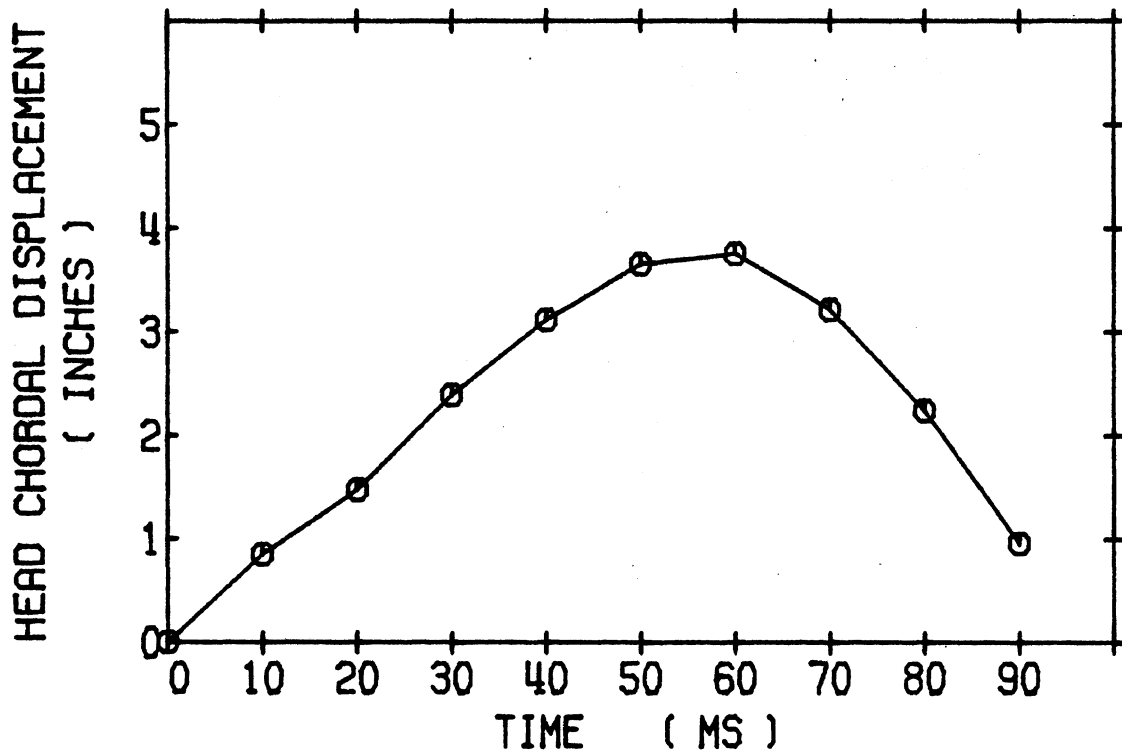
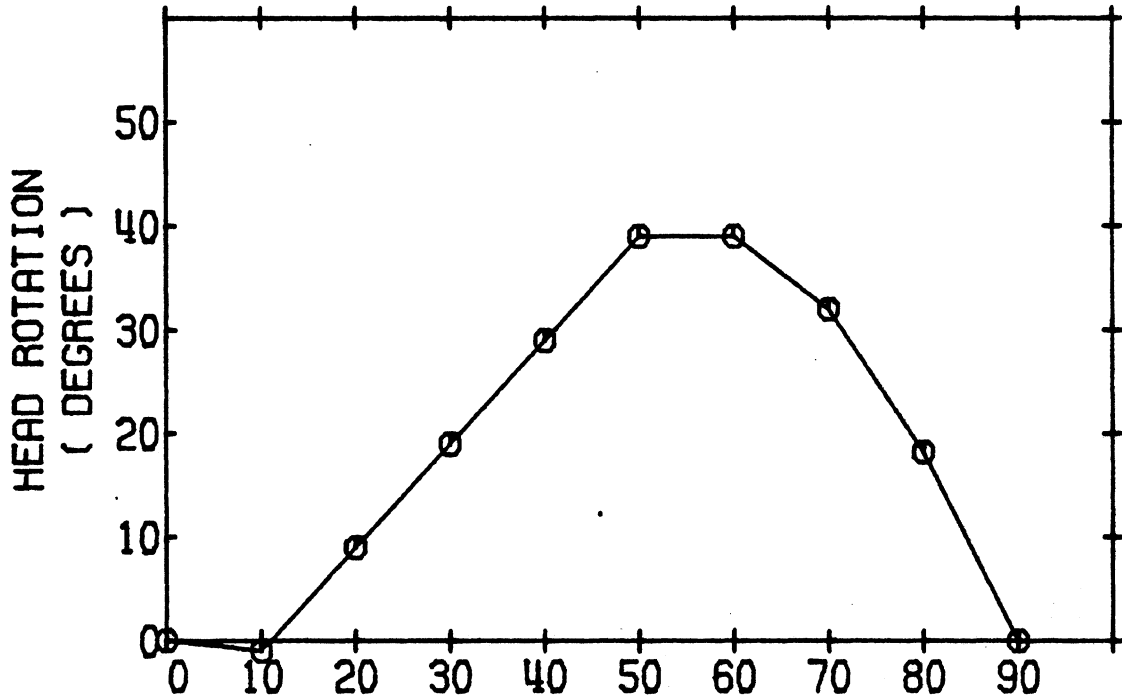
9.6 G =

Filtered Class 1000



LATERAL
13 FPS (NOM.)

76J103



NECK PENDULUM TEST

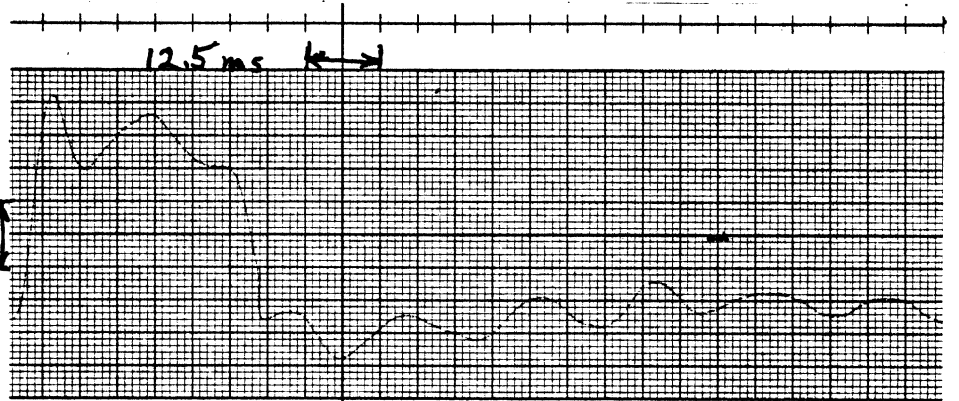
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 104 DUMMY NO. 1 SIDE L BODY REGION HEAD/NECK

IMPACT MASS
DECELERATION

5 G

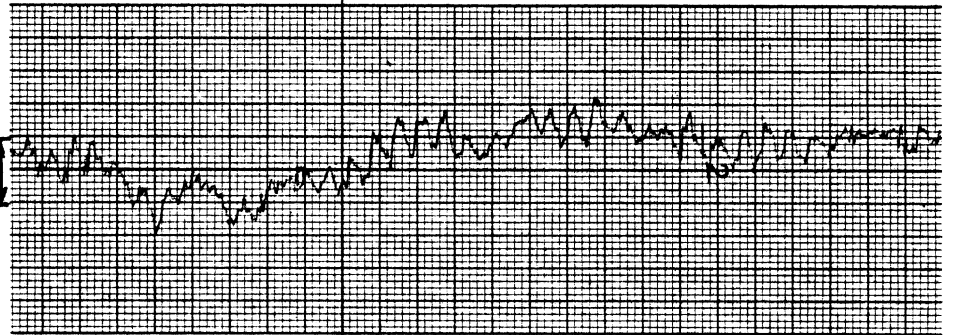
Filtered Class 60



ANTERIOR-POSTERIOR
ACCELERATION

1.7 G

Filtered Class 1000



SUPERIOR-INFERIOR
ACCELERATION

3.3 G

Filtered Class 1000



LEFT-RIGHT
ACCELERATION

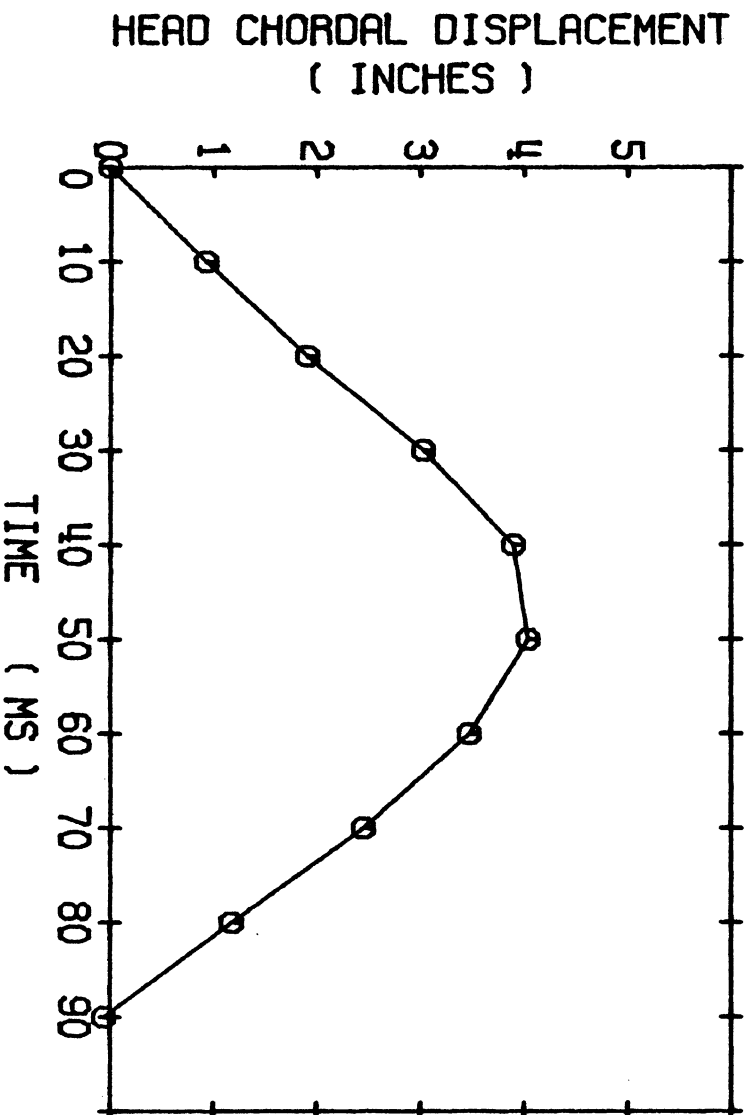
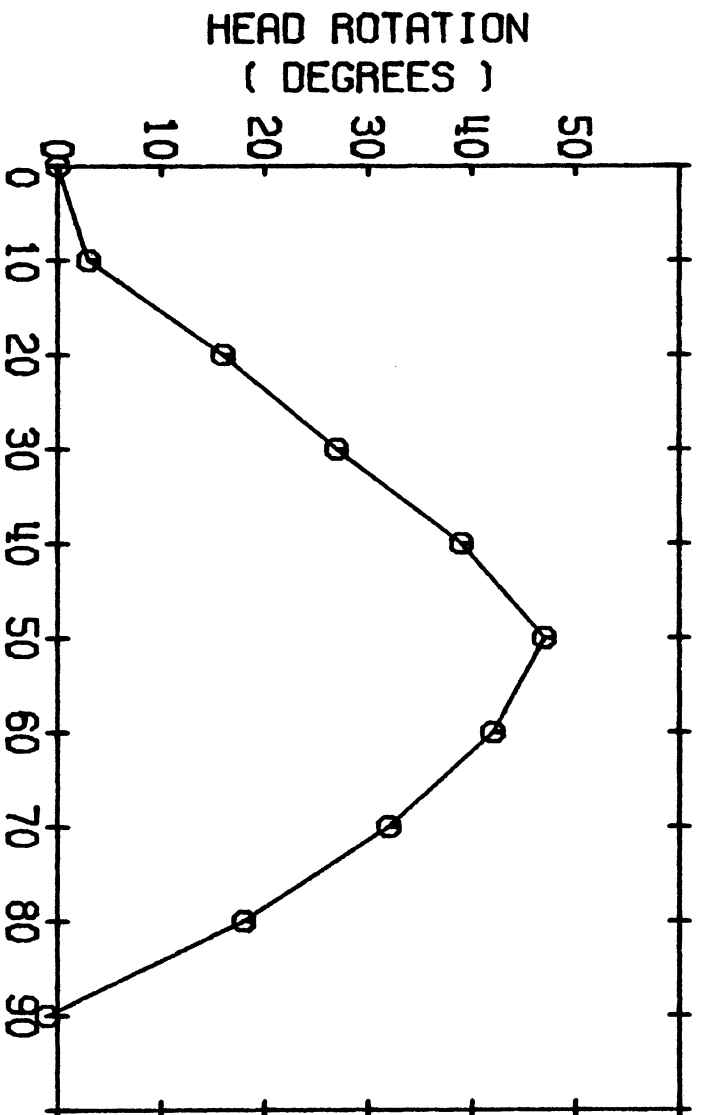
9.6 G

Filtered Class 1000



LATERAL
13 FPS (NOM.)

76J104



NECK PENDULUM TEST

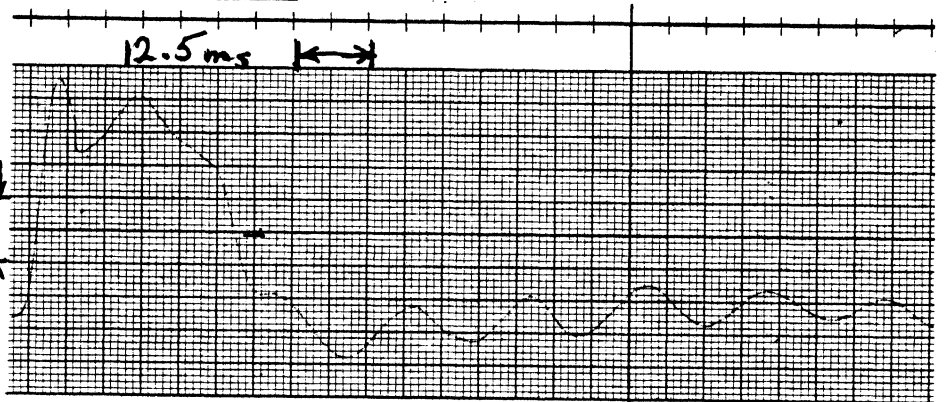
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 105 DUMMY NO. 1 SIDE R BODY REGION HEAD/NECK

IMPACT MASS
DECELERATION

5 G =

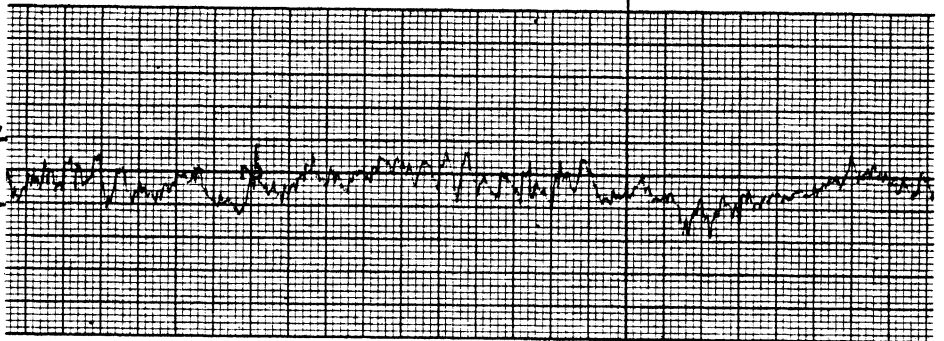
Filtered Class 60



ANTERIOR-POSTERIOR
ACCELERATION

1.7 G =

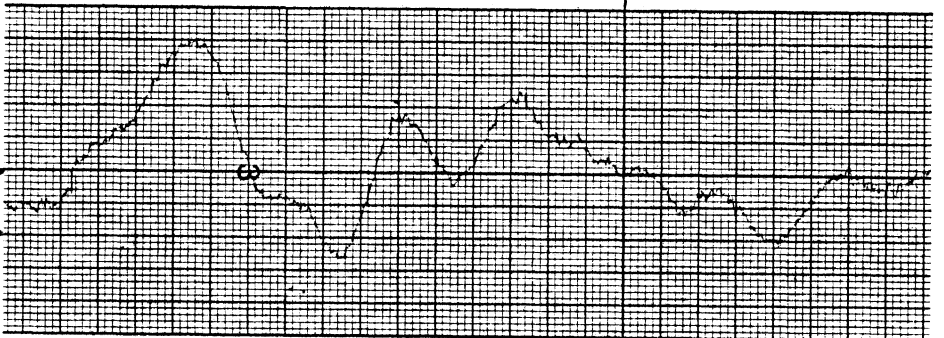
Filtered Class 1000



SUPERIOR-INFERIOR
ACCELERATION

3.3 G =

Filtered Class 1000



BRUSH ACCUCHART

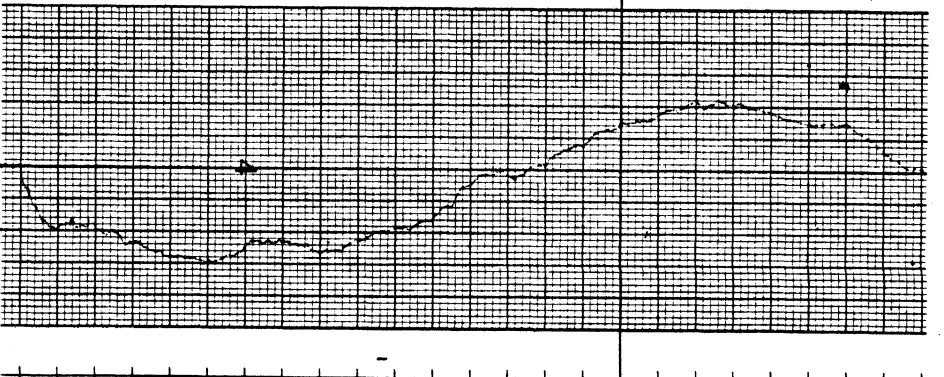
Gould Inc., In

Cleveland, Ohio

LEFT-RIGHT
ACCELERATION

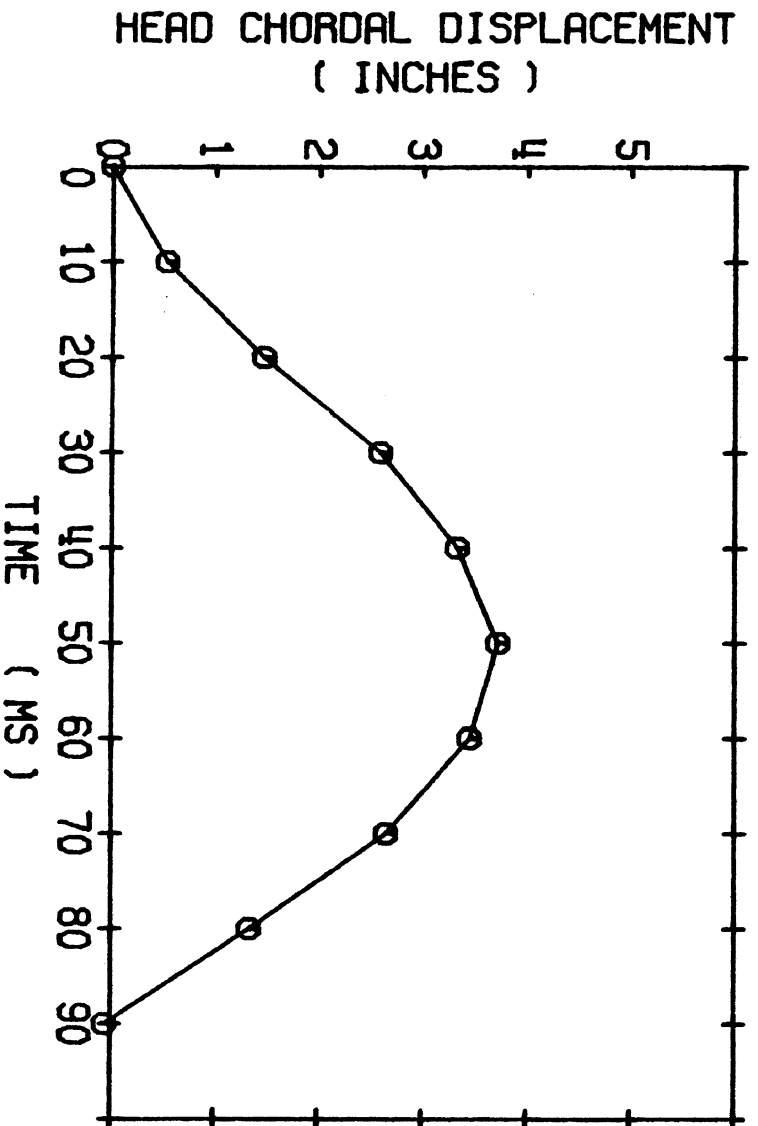
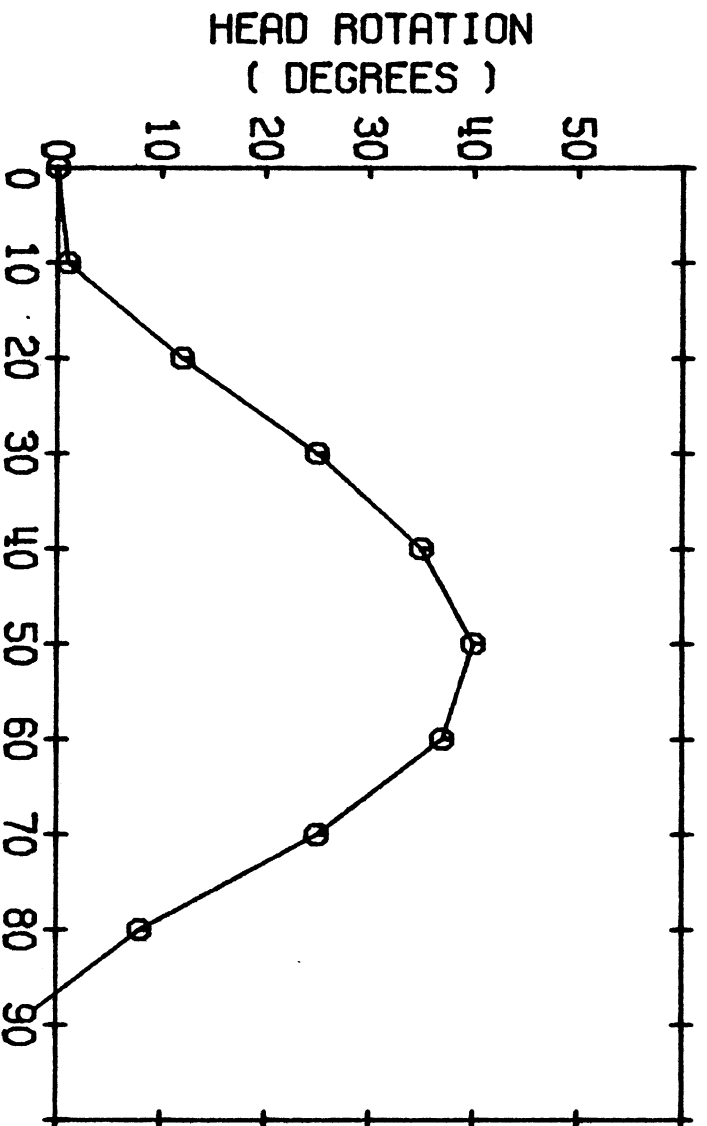
9.6 G =

Filtered Class 1000



LATERAL
13 FPS (NOM.)

76J105

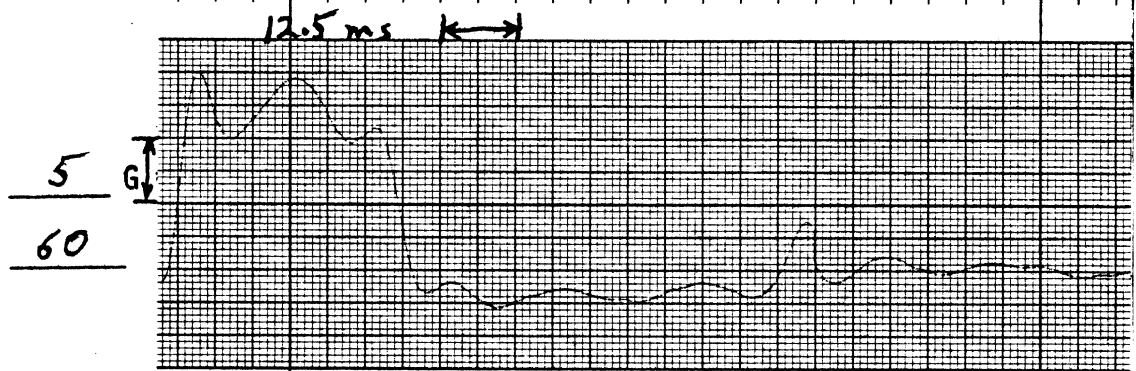


NECK PENDULUM TEST

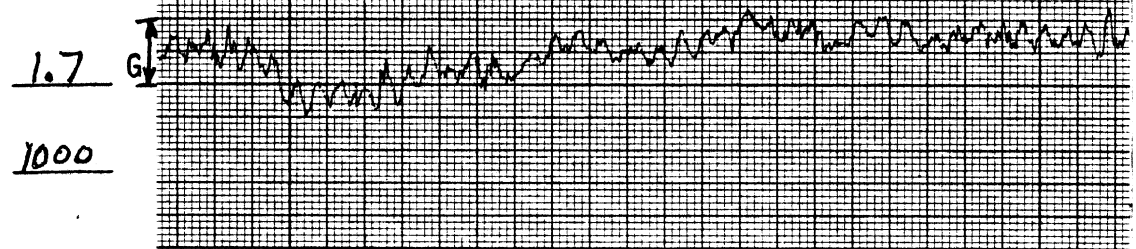
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 106 DUMMY NO. 3 SIDE L BODY REGION HEAD/NECK

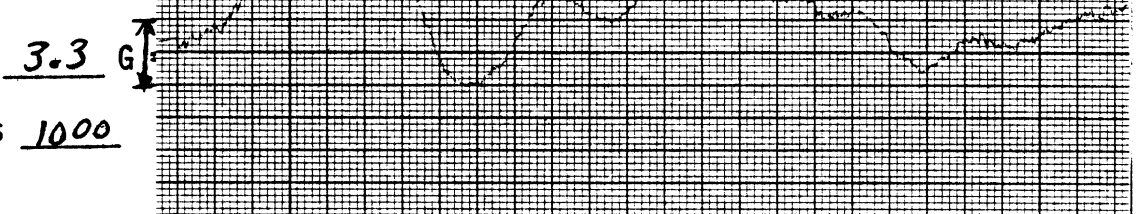
IMPACT MASS
DECELERATION



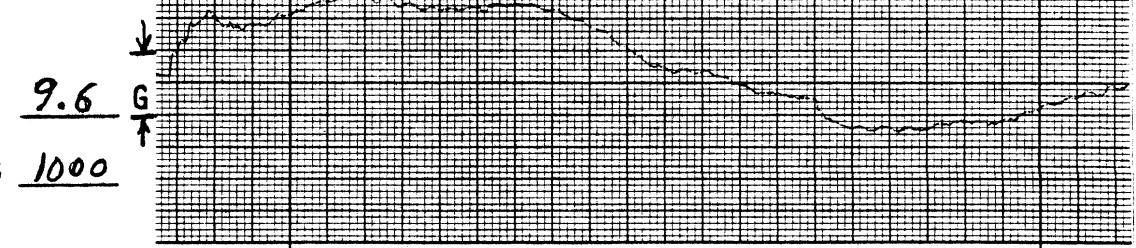
ANTERIOR-POSTERIOR
ACCELERATION



SUPERIOR-INFERIOR
ACCELERATION

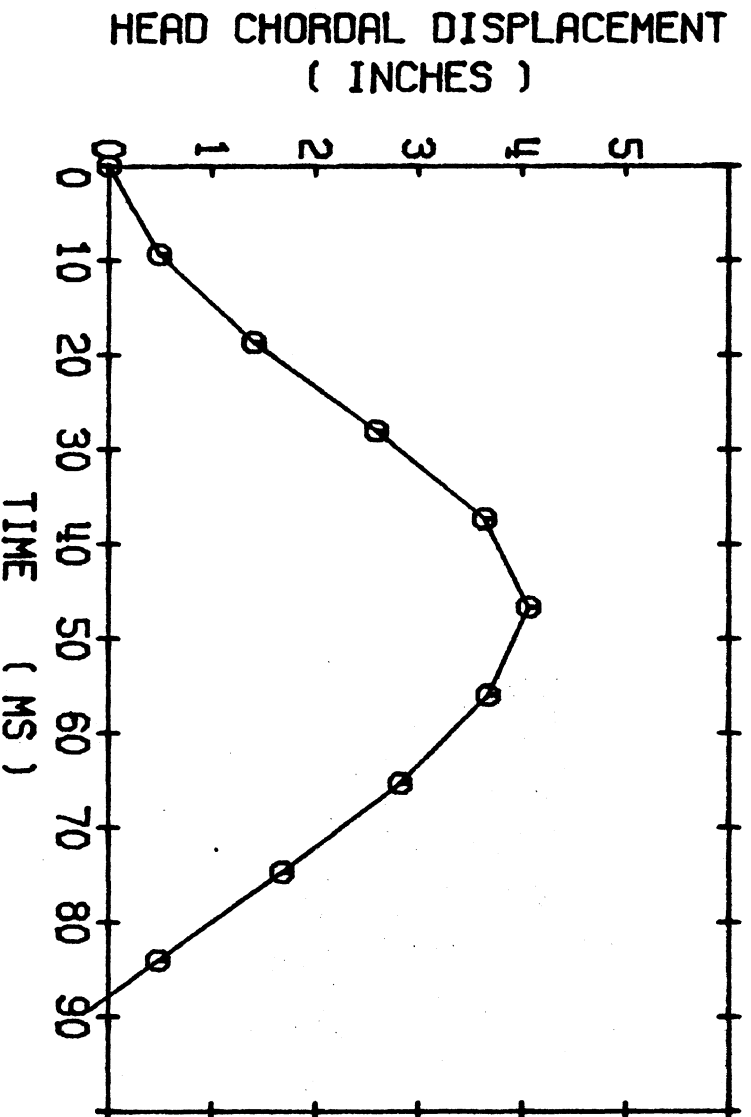
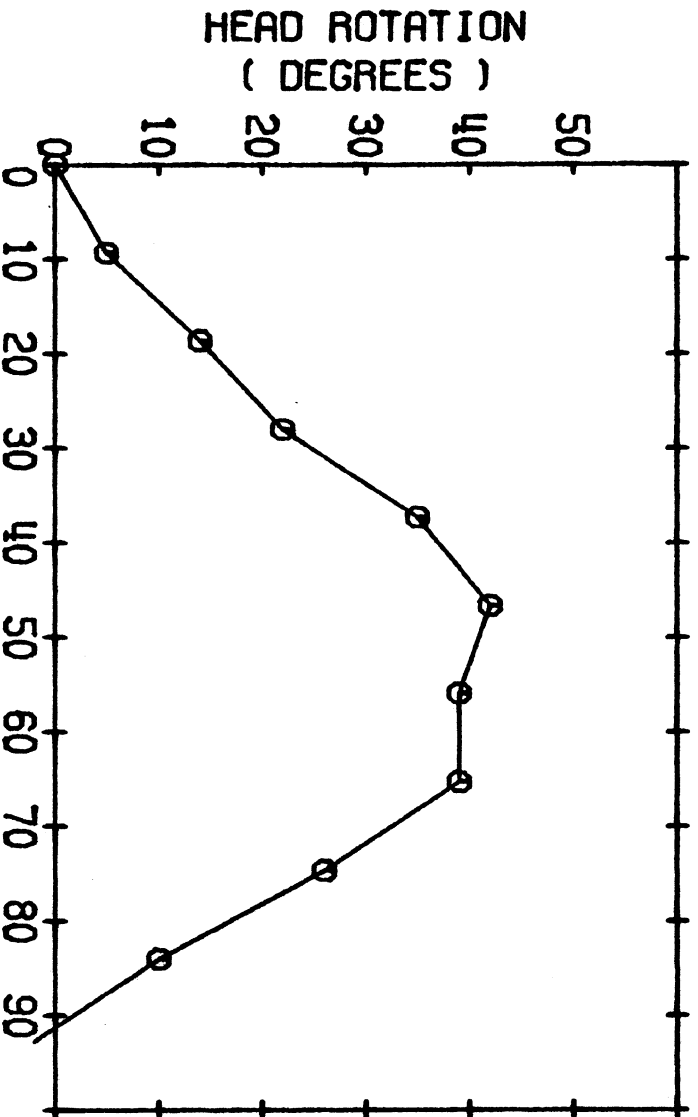


LEFT-RIGHT
ACCELERATION



LATERAL
13 FPS (NOM.)

76J106

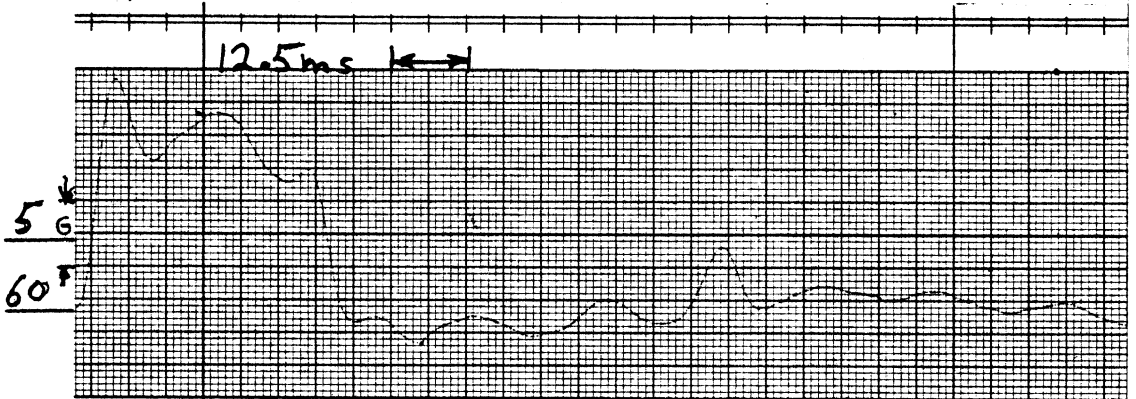


NECK PENDULUM TEST

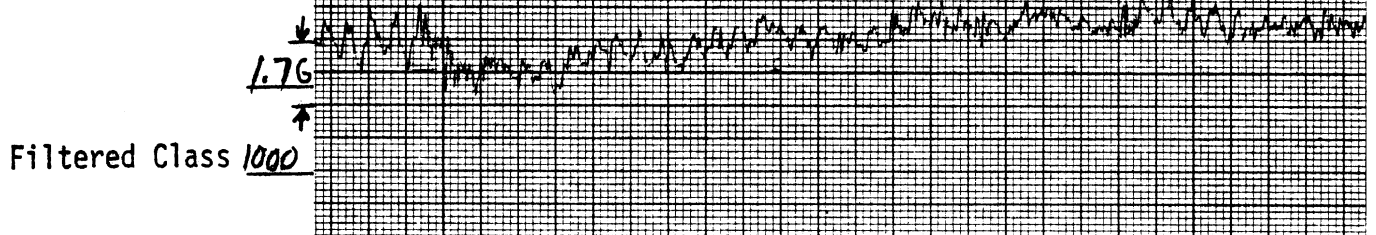
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 107 DUMMY NO. 3 SIDE R BODY REGION HEAD/NECK

IMPACT MASS
DECELERATION



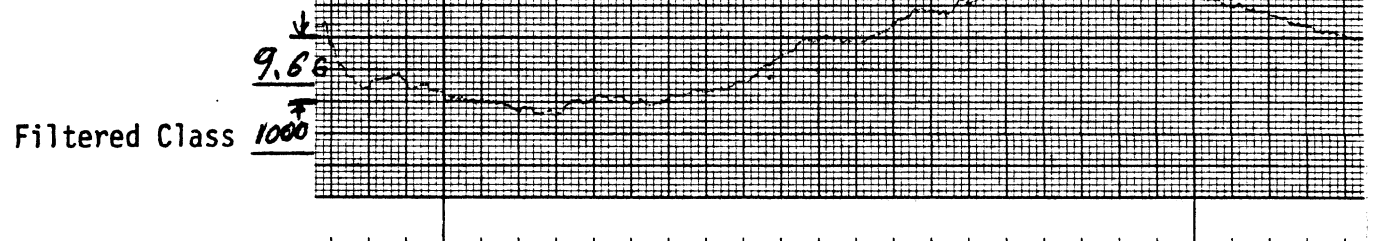
ANTERIOR-POSTERIOR
ACCELERATION



SUPERIOR-INFERIOR
ACCELERATION

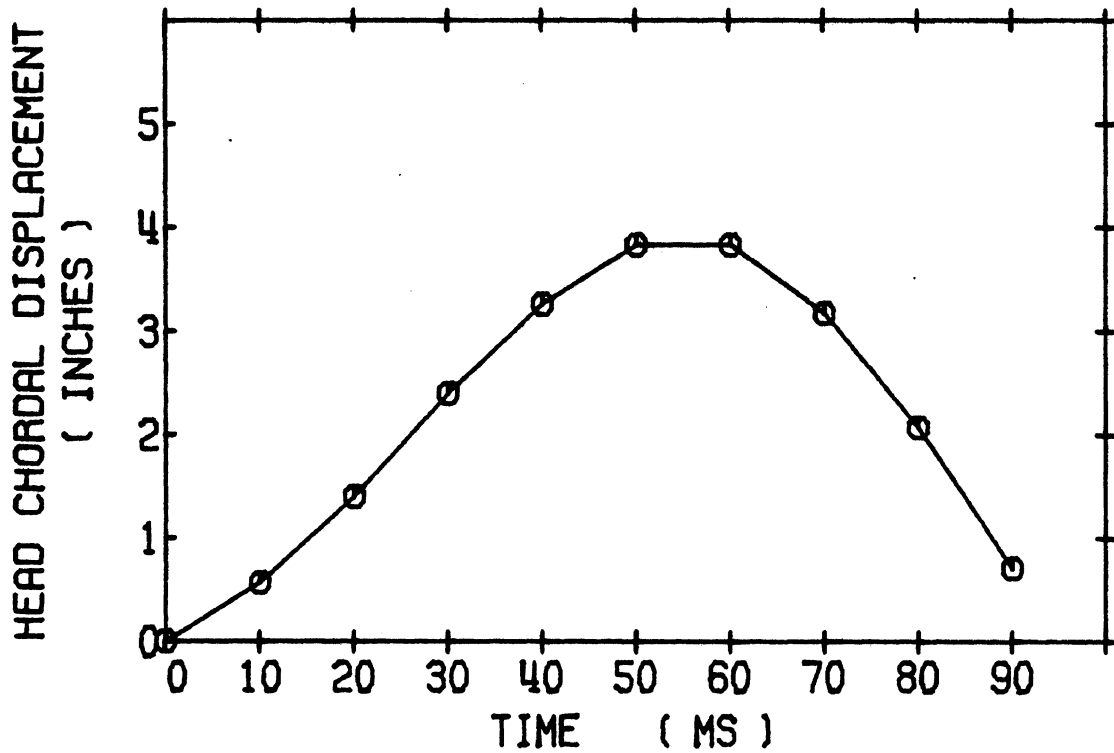
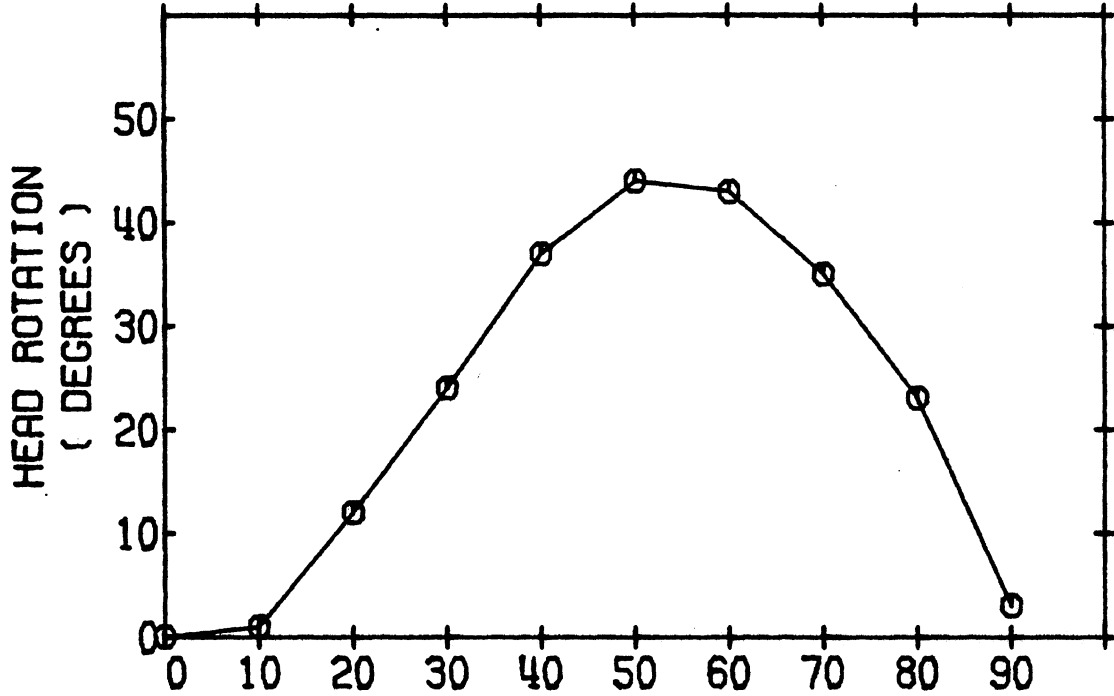


LEFT-RIGHT
ACCELERATION



LATERAL
13 FPS (NOM.)

76J107



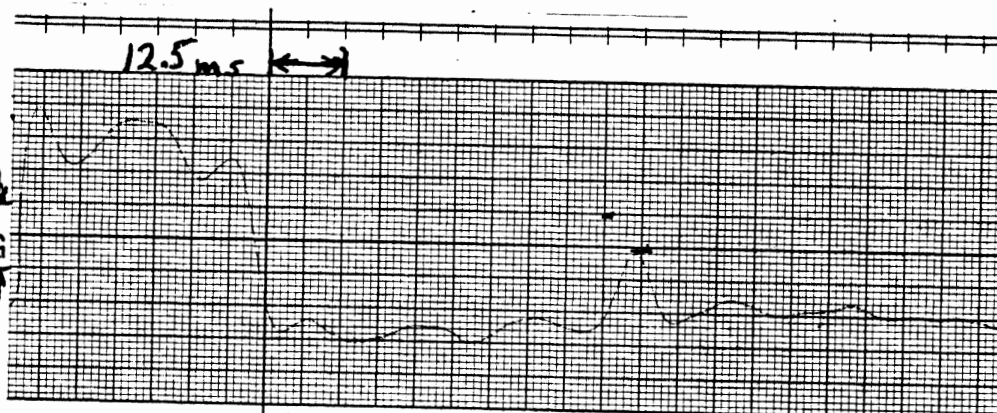
NECK PENDULUM TEST

DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 108 DUMMY NO. 3 SIDE L BODY REGION HEAD/NECK

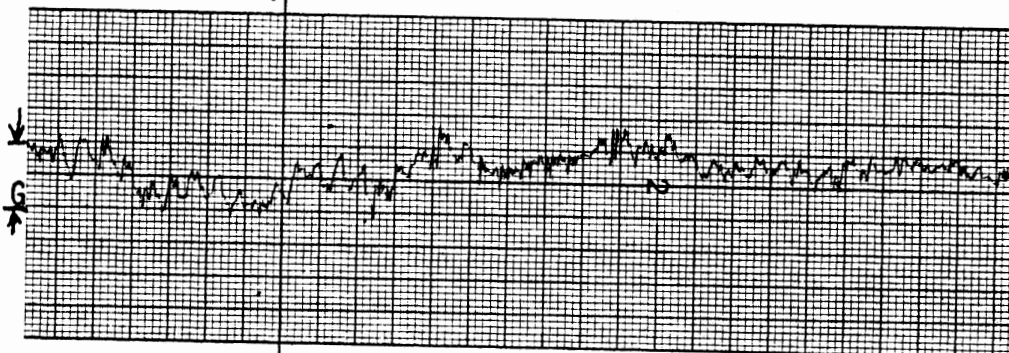
IMPACT MASS
DECELERATION

5
G
Filtered Class 60



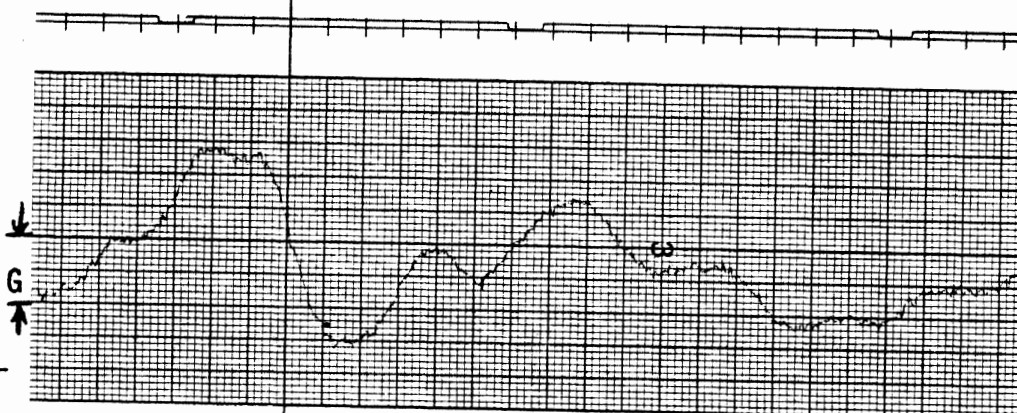
ANTERIOR-POSTERIOR
ACCELERATION

1.7
G
Filtered Class 1000



SUPERIOR-INFERIOR
ACCELERATION

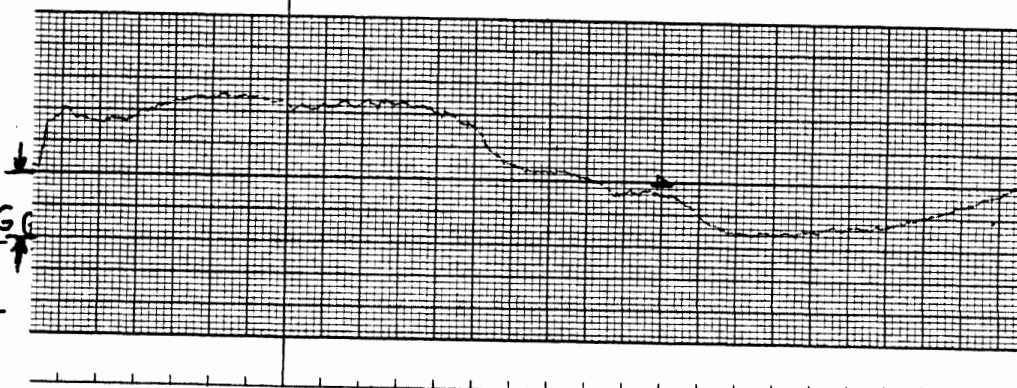
3.3
G
Filtered Class 1000



BRUSH ACCUCHART

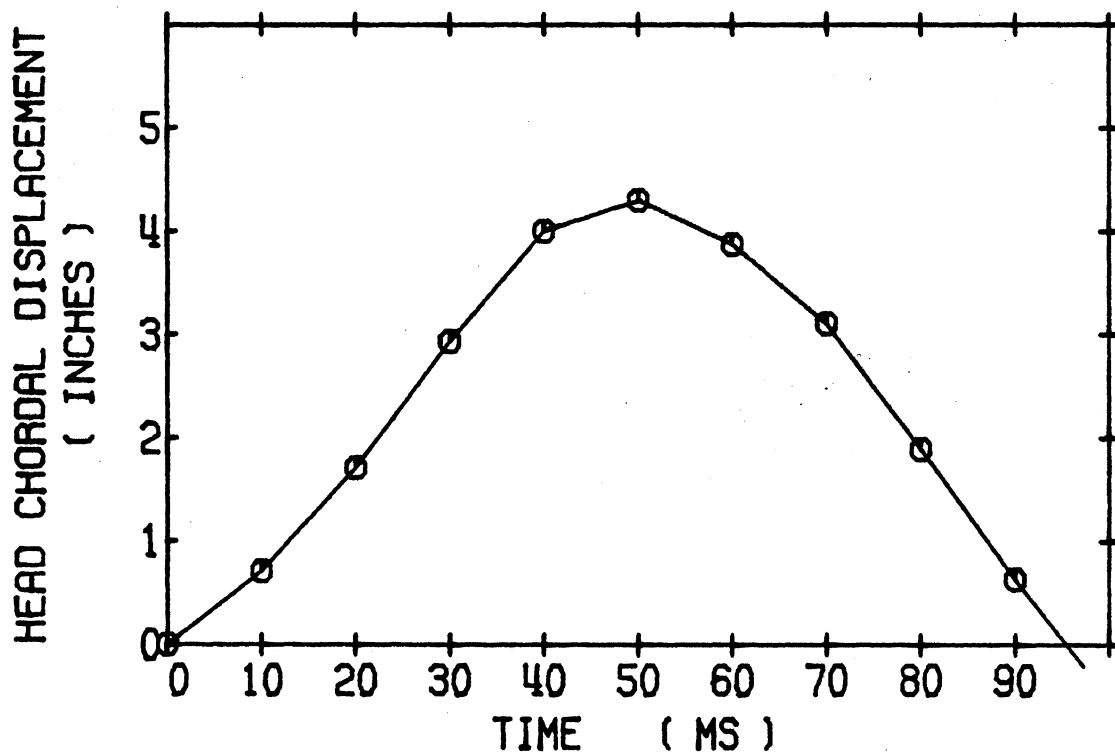
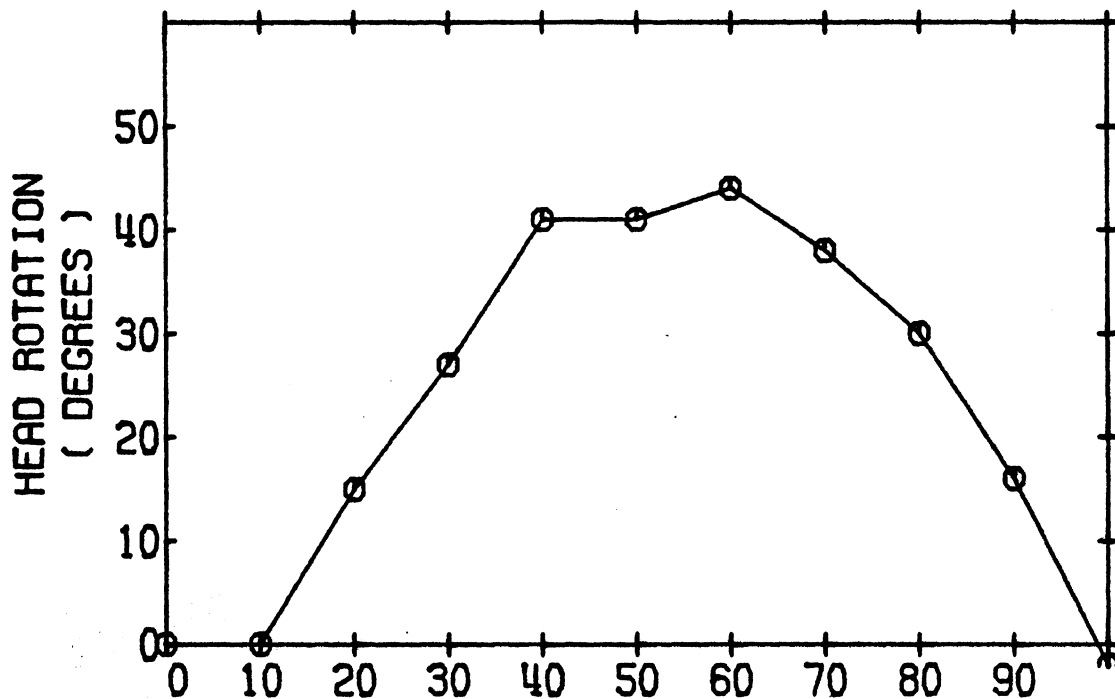
LEFT-RIGHT
ACCELERATION

9.6
G
Filtered Class 1000



LATERAL
13 FPS (NOM.)

76J108

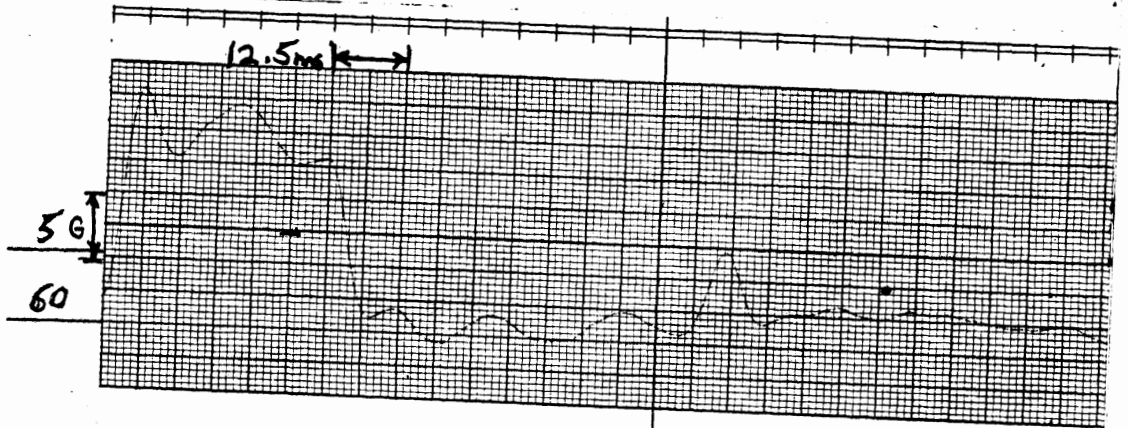


NECK PENDULUM TEST

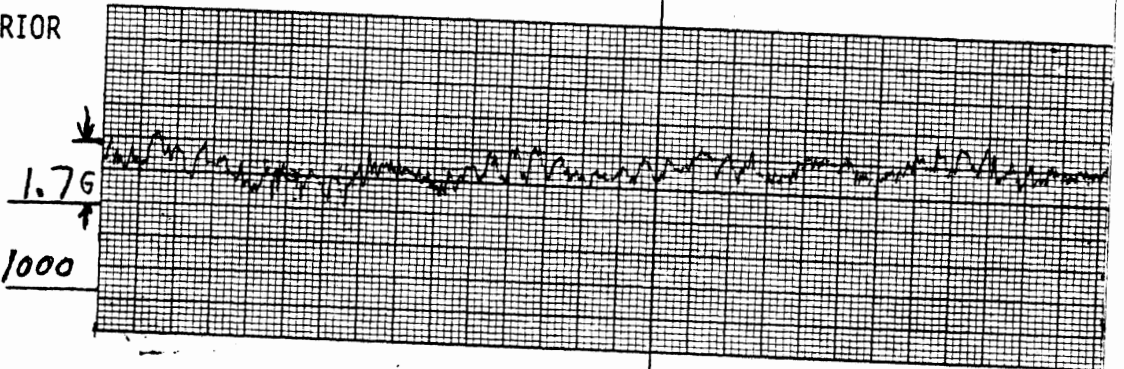
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 109 DUMMY NO. 3 SIDE R BODY REGION HEAD/NECK

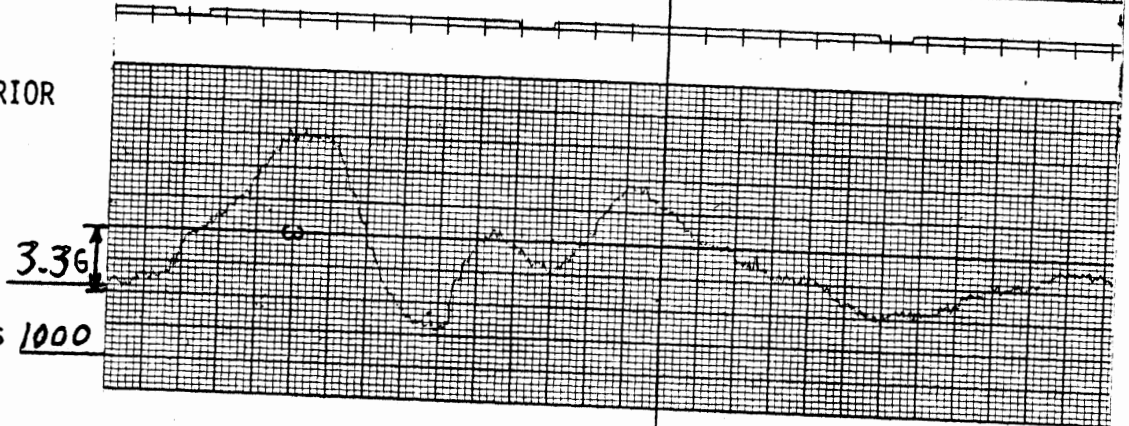
IMPACT MASS
DECELERATION



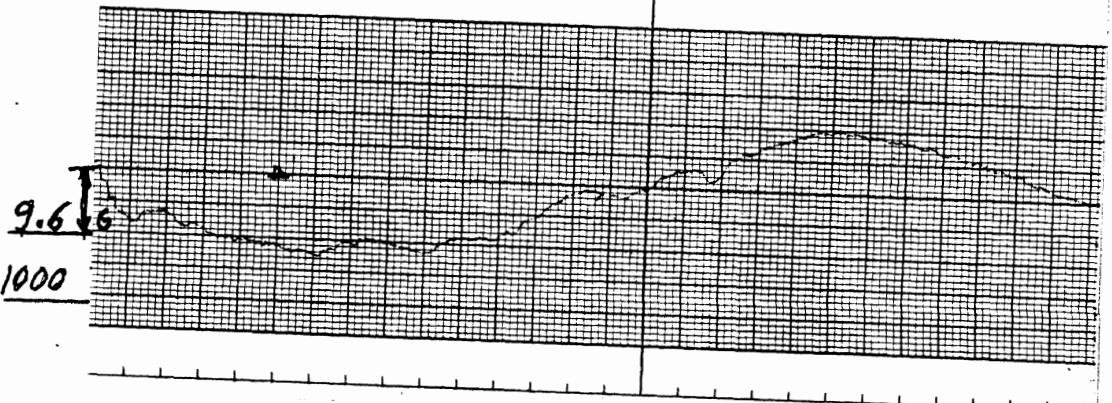
ANTERIOR-POSTERIOR
ACCELERATION



SUPERIOR-INFERIOR
ACCELERATION

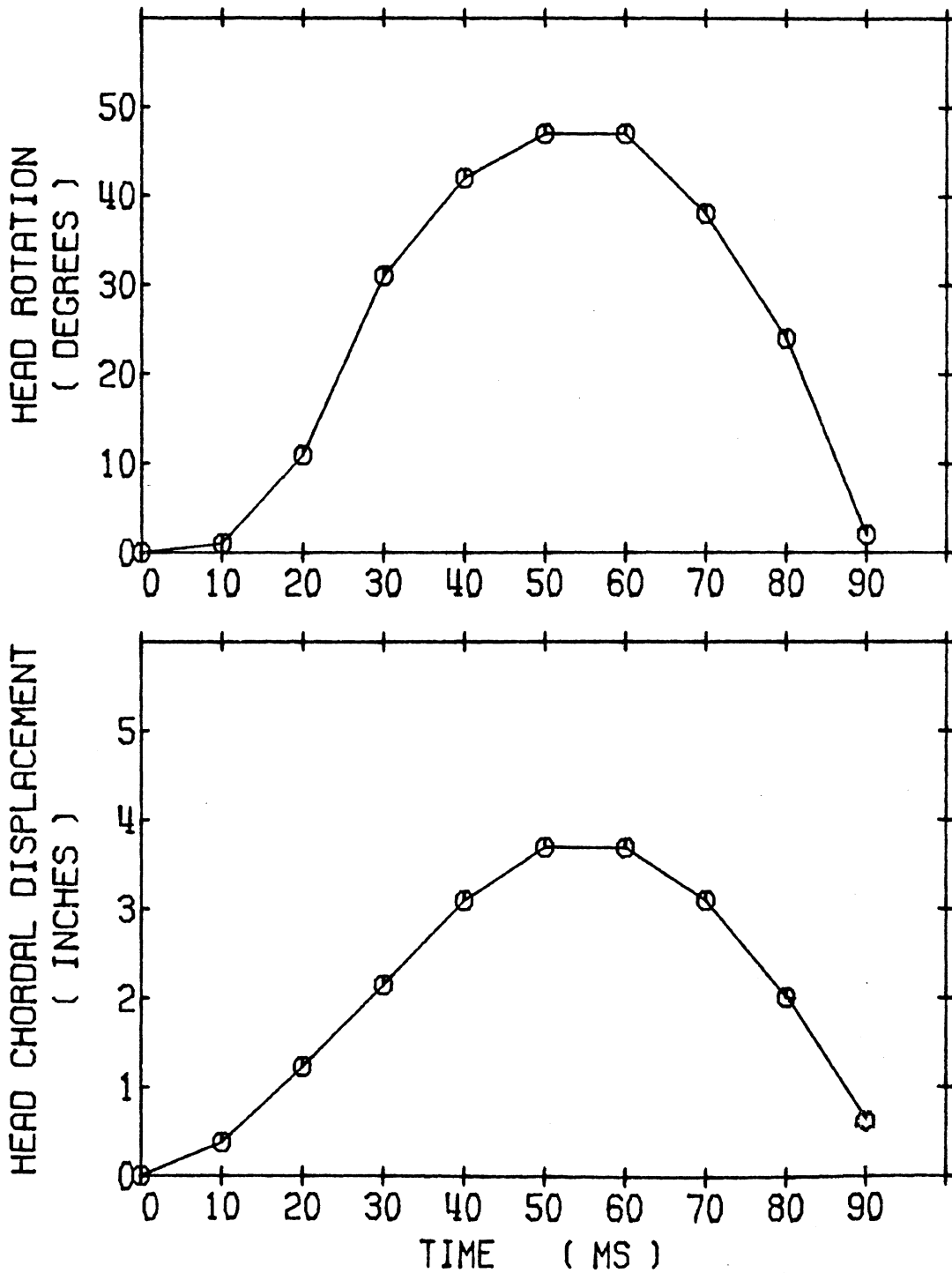


LEFT-RIGHT
ACCELERATION



LATERAL
13 FPS (NOM.)

76J109

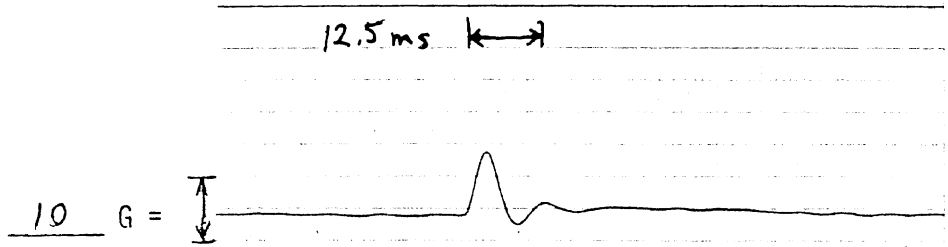


NECK PENDULUM TEST

DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

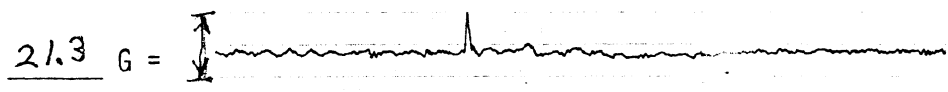
TEST NO. 76J 114 DUMMY NO. 1 SIDE R BODY REGION HEAD

IMPACT MASS
DECELERATION



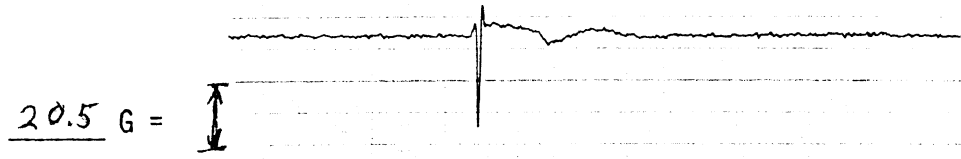
Filtered Class 60

ANTERIOR-POSTERIOR
ACCELERATION



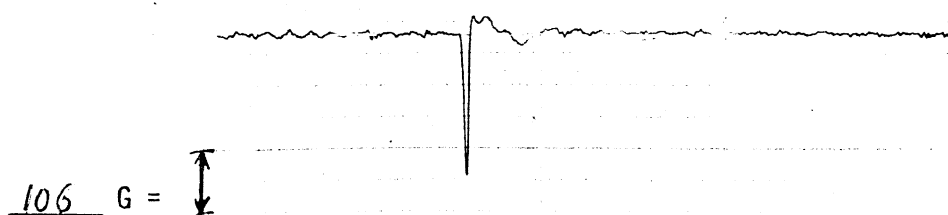
Filtered Class 1000

SUPERIOR-INFERIOR
ACCELERATION



Filtered Class 1000

LEFT-RIGHT
ACCELERATION



Filtered Class 1000

DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

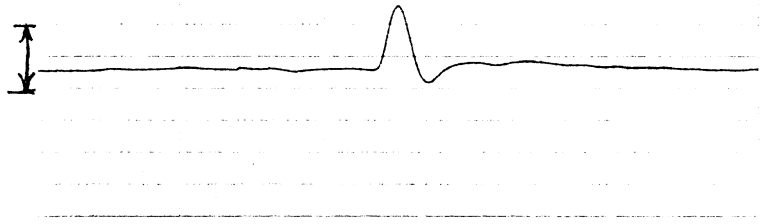
TEST NO. 76J115 DUMMY NO. 1 SIDE R BODY REGION HEAD

IMPACT MASS
DECELERATION

12.5ms \longleftrightarrow

10 G = \updownarrow

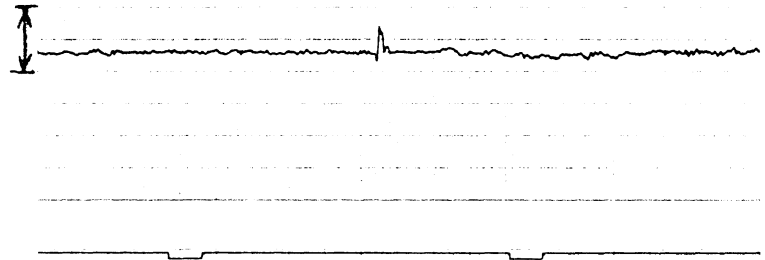
Filtered Class 60



ANTERIOR-POSTERIOR
ACCELERATION

21.3 G = \updownarrow

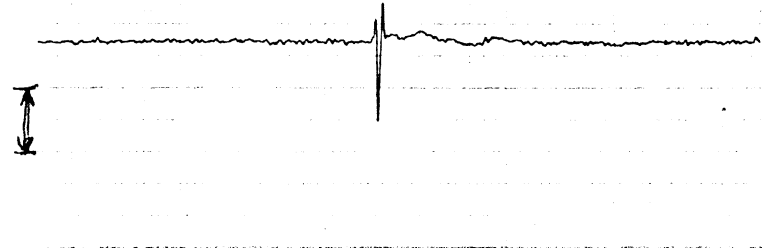
Filtered Class 1000



SUPERIOR-INFERIOR
ACCELERATION

20.5 G = \updownarrow

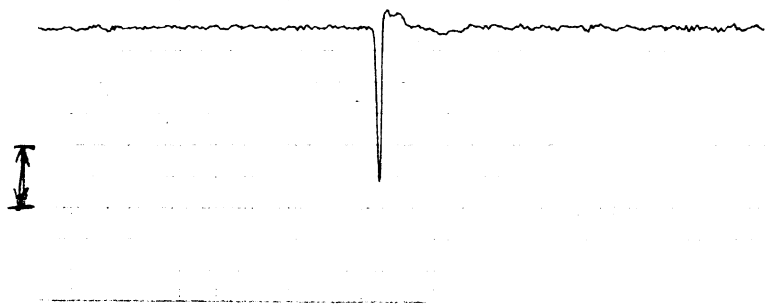
Filtered Class 1000



LEFT-RIGHT
ACCELERATION

106 G = \updownarrow

Filtered Class 1000

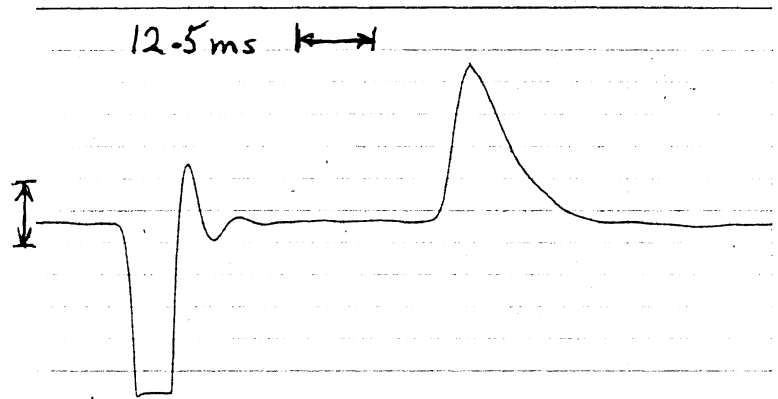


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J116 DUMMY NO. 1 SIDE R BODY REGION THORAX

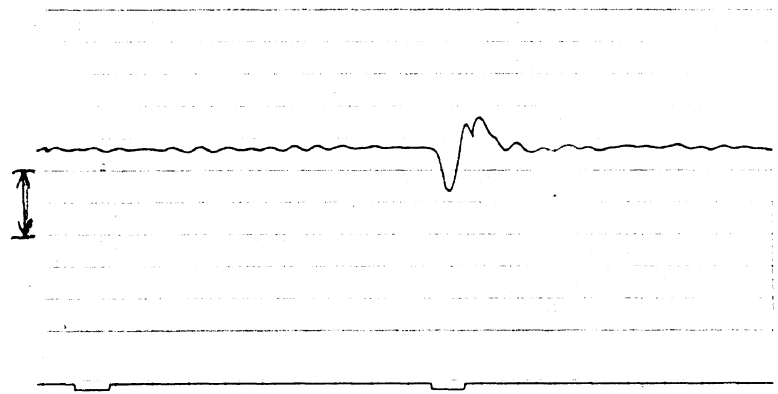
IMPACT MASS
DECELERATION

10 G =
Filtered Class 60



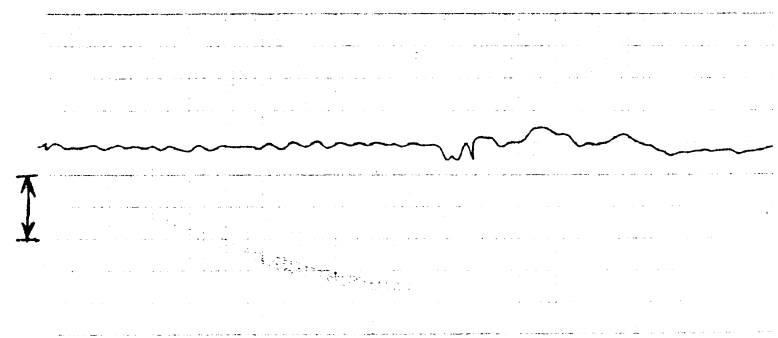
ANTERIOR-POSTERIOR
ACCELERATION

21.3 G =
Filtered Class 180



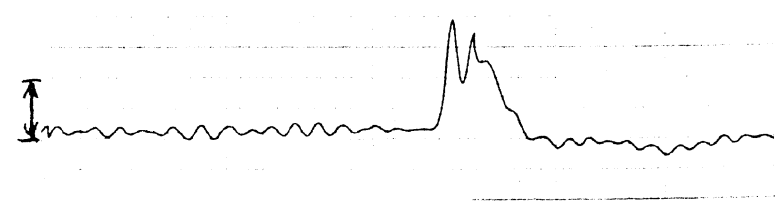
SUPERIOR-INFERIOR
ACCELERATION

8.2 G =
Filtered Class 180



LEFT-RIGHT
ACCELERATION

17 G =
Filtered Class 180



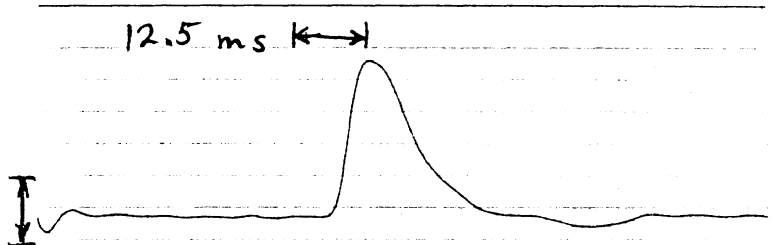
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 117 DUMMY NO. 1 SIDE R BODY REGION THORAX

IMPACT MASS
DECELERATION

10 G =

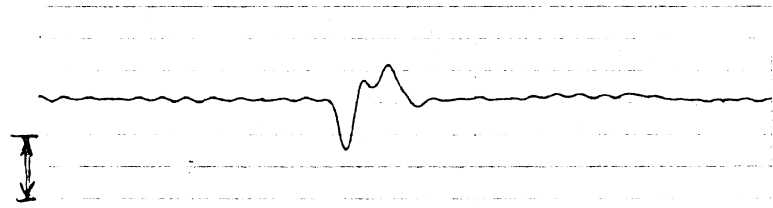
Filtered Class 60



ANTERIOR-POSTERIOR
ACCELERATION

21.3 G =

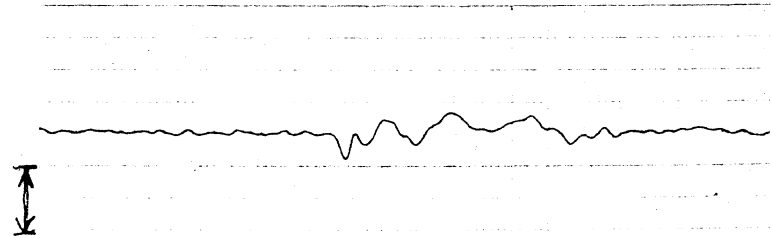
Filtered Class 180



SUPERIOR-INFERIOR
ACCELERATION

8.2 G =

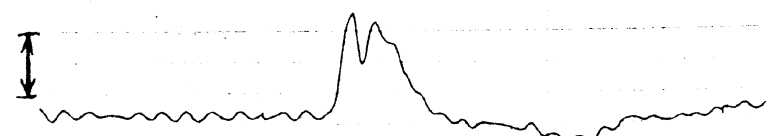
Filtered Class 180



LEFT-RIGHT
ACCELERATION

17 G =

Filtered Class 180

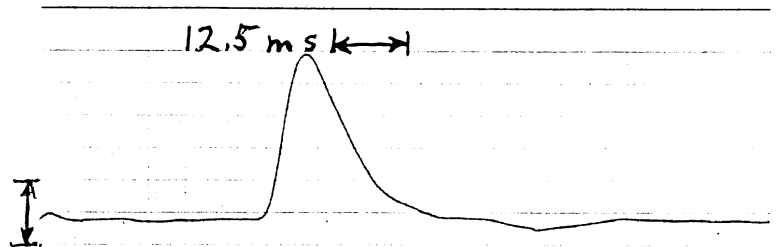


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 118 DUMMY NO. 1 SIDE R BODY REGION THORAX

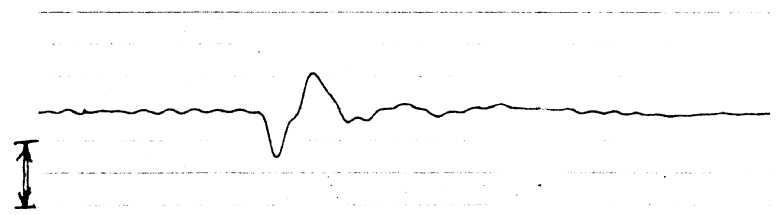
IMPACT MASS
DECELERATION

10 G =
Filtered Class 60



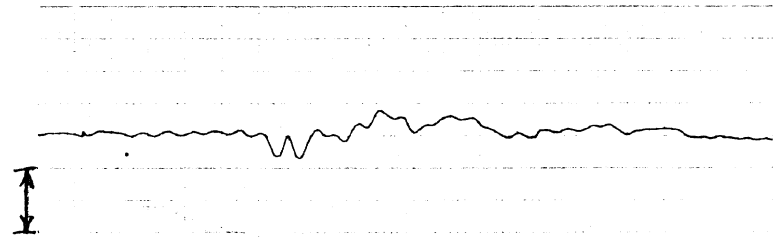
ANTERIOR-POSTERIOR
ACCELERATION

21.3 G =
Filtered Class 180



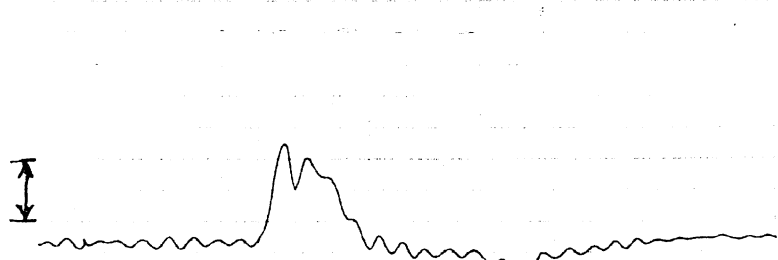
SUPERIOR-INFERIOR
ACCELERATION

8.2 G =
Filtered Class 180



LEFT-RIGHT
ACCELERATION

17 G =
Filtered Class 180

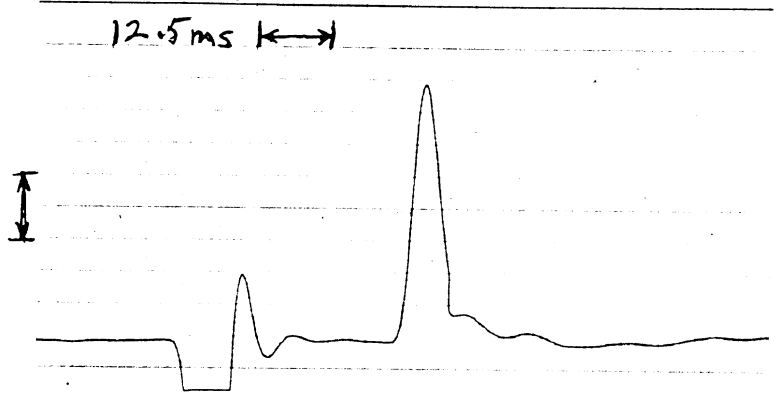


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 119 DUMMY NO. 1 SIDE R BODY REGION SHLDR

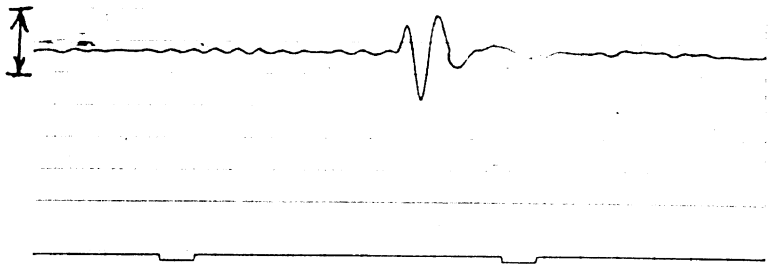
IMPACT MASS
DECELERATION

10 G =
Filtered Class 60



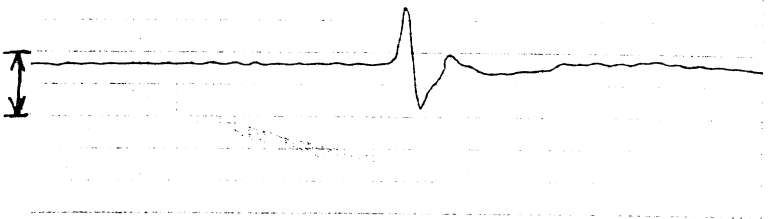
ANTERIOR-POSTERIOR
ACCELERATION

21.3 G =
Filtered Class 180



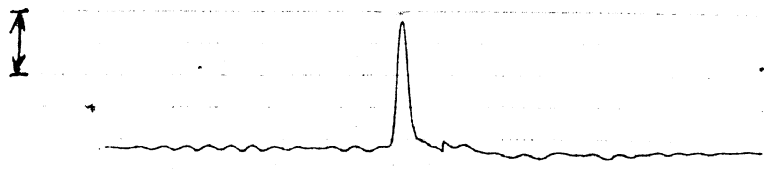
SUPERIOR-INFERIOR
ACCELERATION

20.5 G =
Filtered Class 180



LEFT-RIGHT
ACCELERATION


42.5 G =
Filtered Class 180

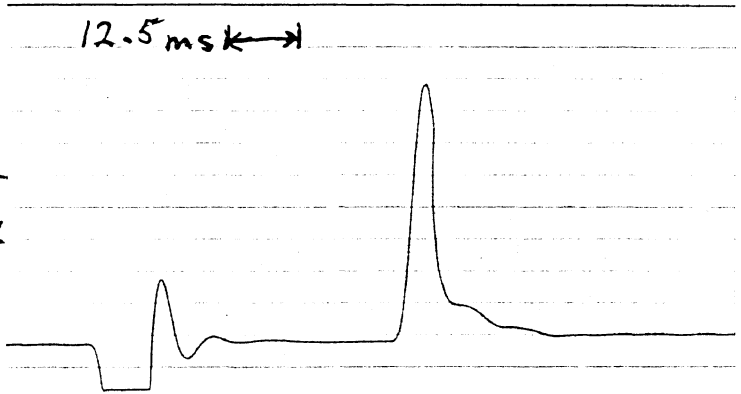


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J 121 DUMMY NO. 1 SIDE R BODY REGION SHLDR

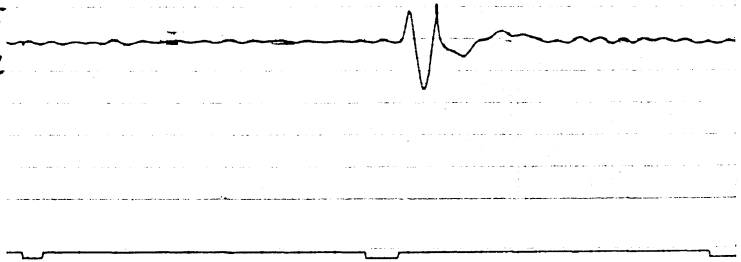
IMPACT MASS
DECELERATION

10 G = 
Filtered Class 60




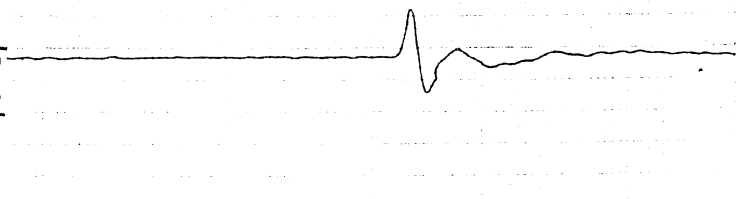
ANTERIOR-POSTERIOR
ACCELERATION

2.13 G = 
Filtered Class 180




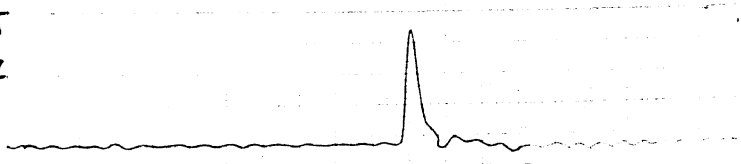
SUPERIOR-INFERIOR
ACCELERATION

20.5 G = 
Filtered Class 180



LEFT-RIGHT
ACCELERATION

42.5 G = 
Filtered Class 180



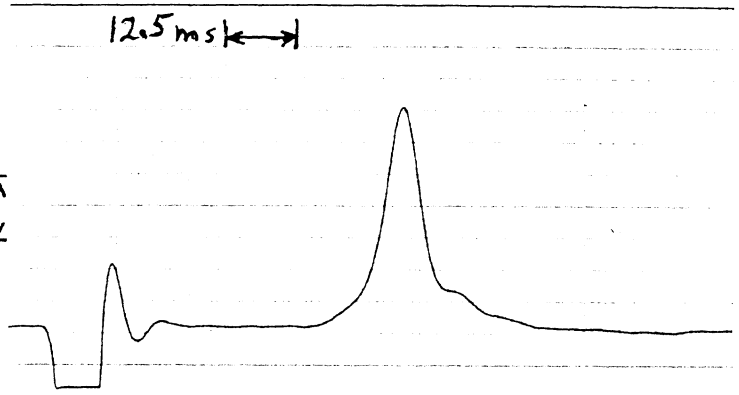
DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM

TEST NO. 76J 122 DUMMY NO. 1 SIDE R BODY REGION PELVIS

IMPACT MASS
DECELERATION

10 G =

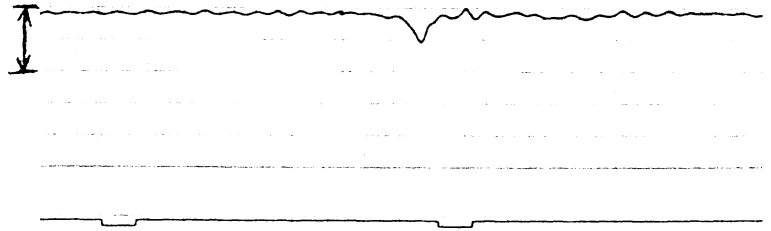
Filtered Class 60



ANTERIOR-POSTERIOR
ACCELERATION

21.3 G =

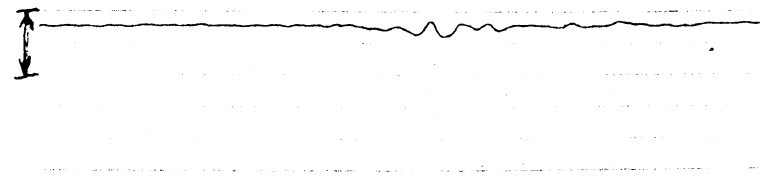
Filtered Class 180



SUPERIOR-INFERIOR
ACCELERATION

20.5 G =

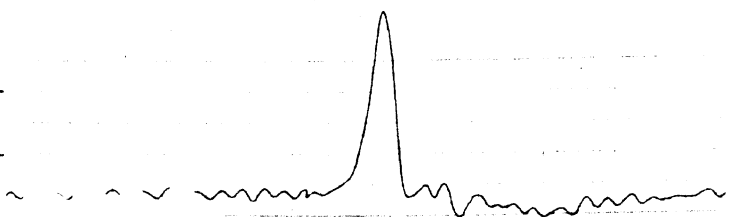
Filtered Class 180



LEFT-RIGHT
ACCELERATION

17 G =


Filtered Class 180

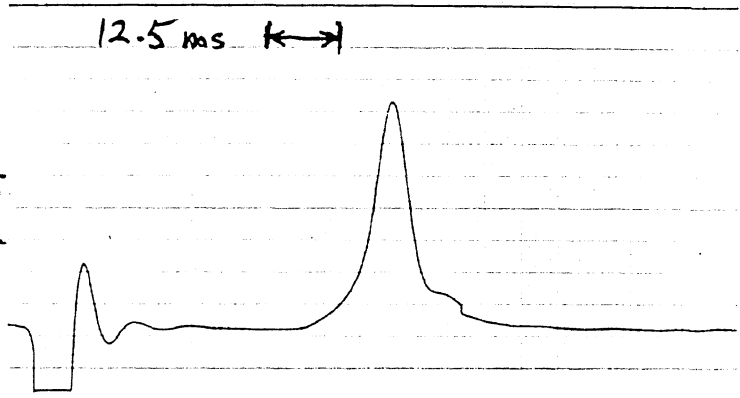


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J 123 DUMMY NO. 1 SIDE R BODY REGION PELVIS

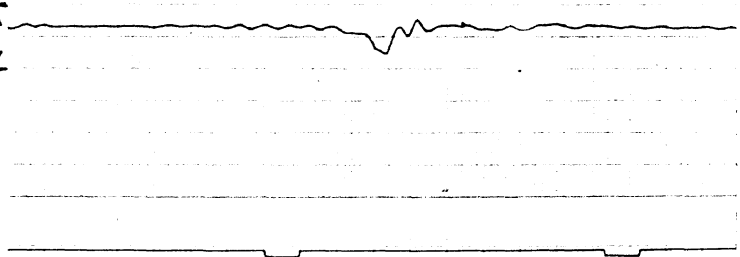
IMPACT MASS
DECELERATION

10 G = 
Filtered Class 60




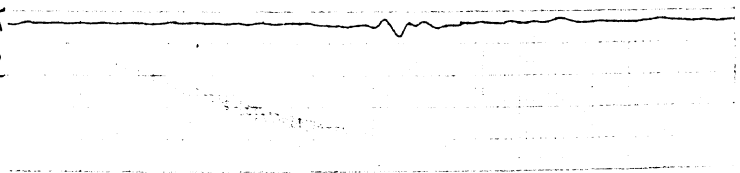
ANTERIOR-POSTERIOR
ACCELERATION

21.3 G = 
Filtered Class 180




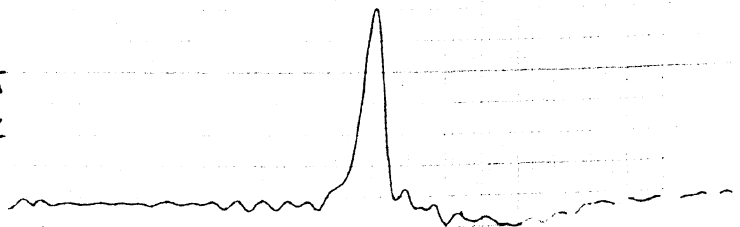
SUPERIOR-INFERIOR
ACCELERATION

20.5 G = 
Filtered Class 180



LEFT-RIGHT
ACCELERATION


17 G = 
Filtered Class 180

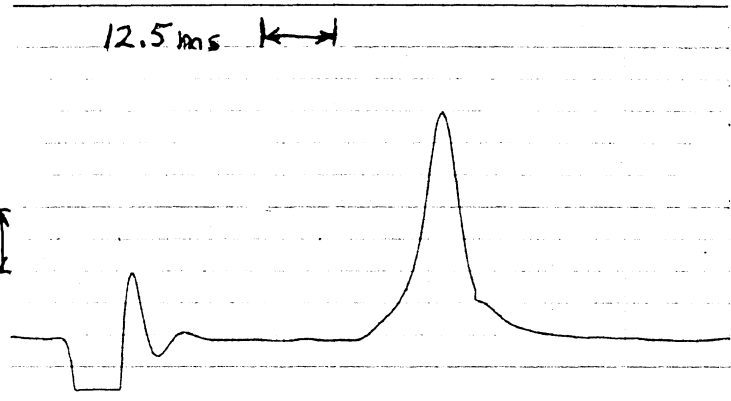


DUMMY SIDE IMPACT CALIBRATION PROCEDURE PROGRAM


TEST NO. 76J 124 DUMMY NO. 1 SIDE R BODY REGION PELVIS

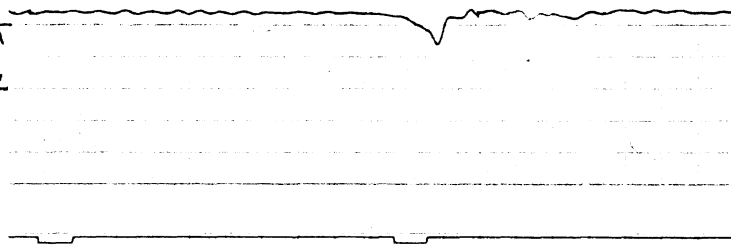
IMPACT MASS
DECELERATION

10 G = 
Filtered Class 60




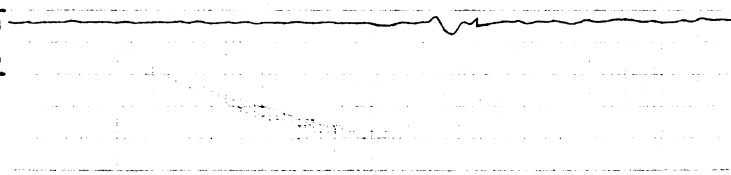
ANTERIOR-POSTERIOR
ACCELERATION

21.3 G = 
Filtered Class 180




SUPERIOR-INFERIOR
ACCELERATION

20.5 G = 
Filtered Class 180



LEFT-RIGHT
ACCELERATION

17 G = 
Filtered Class 180

