UMTRI-86-38

STEERING WHEEL ABDOMINAL IMPACT TRAUMA

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Final Technical Report
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16. Abstract

This report outlines the biomechanics impact testing protocol that was developed for simulation of steering wheel assembly abdominal trauma using the unembalmed human cadaver surrogate. A series of non-injurious multiple thoraco-abdominal impacts plus a single injurious abdominal impact to one cadaver utilizing a specially crafted steering wheel assembly, not representative of any manufactured steering wheel assembly, using this protocol is presented. The steering wheel assembly was designed by and obtained from the General Motors Research Laboratories.

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STEERING WHEEL ABDOMINAL IMPACT TRAUMA

MVMA Project No. 6131 - Final Report

Project Director: Guy S. Nusholtz

Overview

Project No. 6131 was a continuation of a project funded in fiscal year 1984-85 concerning abdominal trauma caused by impact with a steering wheel assembly. The precursor project evaluated previous dynamic biomechanics research conducted at UMTRI and elsewhere as part of the task of designing a protocol to conduct simulations of steering wheel assembly impacts using the unembalmed human cadaver as a surrogate for the live response. That data-base included observations made upon six different human surrogates: 1. anesthetized canines, 2. postmortem canines, 3. anesthetized Rhesus, 4. postmortem Rhesus, 5. anesthetized porcine, and 6. the unembalmed repressurized human cadaver (1,2,4)[1]. The detailed methods and results of those research projects and the comparison were reported at the 29th Stapp Car Crash Conference (1,2,4). These data indicated the need to investigate further the kinematic variables involved in steering wheel assembly impact--especially that of victim contact region. This report outlines the impact testing protocol that was developed for simulation of steering wheel assembly abdominal trauma using the unembalmed human cadaver surrogate and a specially crafted steering wheel assembly model designed by and obtained from the General Motors Research Laboratories (GMRL). The specially crafted steering wheel assembly model is a physical one, not directly related to any steering wheel assembly being produced by the automotive industry. In addition, John

[1]Identifies references located at the end of the report.

Horsch and Ian Lau of GMRL were consulted on how best to design the UMTRI impact testing protocol to complement work at GM aimed at improving anthropomorphic test device (i.e. safety dummy) simulation of abdominal response. The protocol that was developed was followed for one unembalmed human cadaver steering wheel assembly thoraco-abdominal impact test, and evaluated. The analysis of the significant kinematic parameters investigated (e.g. subject contact region, repeatability, and pulmonary repressurization) indicated that further dynamic biomechanics laboratory simulations are justified and necessary.

METHODOLOGY

The research program consisted of six series of dynamic thoraco-abdominal impacts to an unembalmed human cadaver. Eighteen impacts (non-destructive) were conducted at 2.6 m/s and a nineteenth (destructive) was conducted at 10 m/s. The test protocol is attached as Appendix A. The kinematic parameters investigated were steering rim force, velocity, subject contact region, repeatability, and pulmonary repressurization. In addition, velocity and displacement at thoracic vertebra T12 were derived from high-speed photogrammetry and digital stringpots.

The impacting device was the UMTRI pneumatic ballistic pendulum. The striker was a steering wheel assembly model crafted by GMRL. Subject instrumentation included a triaxial accelerometer rigidly affixed to thoracic vertebra T12, a stringpot transducer attached to the same location, and a pressure transducer inserted into the pulmonary repressurization tube (within the trachea). Structure instrumentation included a stringpot transducer on the pendulum and a triaxial accelerometer mounted on the steering column.

The subject was suspended from a ceiling hoist by means of a head and parachute harness system. The tests were controlled by an electronic timing device. The gross motion was documented on high-speed film.

The post-test investigation included measurement of the subject's core body temperature. Induced damage was assessed during a gross pathological investigation.

The analytical results are presented in the form of time-histories of the kinematic variables, mechanical transfer impedance, and transfer functions between paired kinematic variables.

Impact Test Matrix - Eighteen low-velocity (2.6 m/s) non-damaging impacts, plus one high-velocity (10 m/s) damaging impact formed the dynamic biomechanics test matrix. The parameters were divided into chronological test groups as follows:

Series A: Abdominal contact region, unrepressurized, low velocity.
Tests: 86M001A-D

Series B: Rib 10 contact region, unrepressurized, low velocity.
Tests: 86M002A-C

Series C: Substernale contact region, unrepressurized, low velocity.
Tests: 86M003A-C

Series D: Substernale contact region, repressurized pulmonary system, low velocity.
Tests: 86M004A-E

Series E: Abdominal contact region, unrepressurized, low velocity.
Tests: 86M005A-C

Series F: Abdominal contact region, unrepressurized, high velocity.
Test: 86M006

Pneumatic Ballistic Pendulum Impact Device - The impact device consisted of a 20 kg ballistic pendulum mechanically coupled to the UMTRI pneumatic impact device (i.e. the cannon), which was used as the energy source. The cannon consisted of an air reservoir and a ground and honed cylinder with a carefully fitted metal-alloy piston. The piston was connected to the ballistic pendulum with a nylon cable. The piston was propelled by compressed air from the air reservoir chamber through the cylinder, accelerating the ballistic pendulum to become a free-traveling impactor. The pendulum striker was fitted with an inertia-compensated load cell, which was rigidly mounted at the base of the specially-crafted steering wheel assembly model column.

GMRL Steering Wheel Assembly Model - The physical model was a mechanical simulation of the lower rim of a steering wheel assembly. It was not directly related to any steering wheel assembly being manufactured by the automotive industry. A triaxial accelerometer was rigidly mounted to the hub of the steering wheel assembly model.

Subject Handling - The unembalmed cadaver used in the dynamic biomechanics testing was obtained from the University of Michigan Department of Anatomy and stored in a cooler at 4°C. The cadaver was x-rayed as a part of the structural screening for existing anomalies, surgical implants, and damage. The subject was then measured using standard anthropometric techniques. Next the cadaver was sanitarily and surgically prepared, dressed in vinyl and cotton clothing, and fitted with the head and parachute harnesses. In the impact laboratory, the accelerometers, pressure transducers, and photo targets were attached. The subject was placed in a seated position on a mobile, adjustable-height table covered with friction-reducing clear plastic sheets, and supported by the head and parachute harnesses via a ceiling hoist. The steering wheel assembly was positioned for the contact-region controlled impact. The subject received multiple impacts, and was examined post-test for damage. The post-test examination included a gross pathological investigation.

Pulmonary Repressurization - A tracheotomy was performed to place a tube in the trachea which was connected to a compressed air reservoir, so that the pulmonary system could be repressurized to 15 mm Hg. An Endevco pressure transducer was inserted into the tracheal tube to measure the dynamic pulmonary pressure at initial repressurization and during the changes in pressure that occurred throughout the impact. The tracheal tube was fitted with a valve so that direct communication between the lungs and the external air was possible just before impact.

Acceleration Measurement - A Kistler triaxial accelerometer, affixed to thoracic vertebra T12, documented the kinematic response of the subject's spine. To surgically implant a rigid support for the triax an incision was made over the thoracic vertebra T12 of the cadaver so that lateral supports for the accelerometer mount were anchored on the lamina bilaterally. Acrylic was applied under and around the mount to ensure rigidity.

Stringpot Measurement - Displacement of the subject was determined by interpreting the linear displacement of a steel cable attached to the thoracic vertebra T12. The cable was connected to a gear that rotated according to the subject's movements during the impact test. The revolutions of the gear were counted by a magnetic probe pickup, and the distance that the subject traveled during the impact was calculated from the probe measurement.

Gross Body Motion - The gross body motion of the subject during impact was recorded on high-speed film at 500 frames per second. The camera was a Hycam, positioned to film a lateral view of the impact.

METHODS OF ANALYSIS

The techniques used to analyze the results are outlined below. Additional information can be found elsewhere (1-3).

Force Time-History Determination - In general the force time-histories were unimodal with a single maximum, smoothly rising, peaking and then falling. Force duration was determined using a boundary defining and least-squares line-fitting technique. This procedure began by determining the peak, or the first peak in the case of a bimodal waveform. Next, the left half of the pulse, defined from the point where the pulse started to rise to the time of peak, was least-squares fitted with a straight line. This rise line intersected the time axis at a point which was taken as the formal beginning of the pulse. A similar procedure was followed for the right half of the pulse, i.e. a least-squares line was fitted to the fall section of the pulse. The fall-section of the pulse was defined from the peak to the point where the pulse minimum occurred. The point where this line intersected the time axis became the formal end of the pulse.

Principal Direction Frame Field - One method of determining the principal direction of motion is constructing the Principal Direction Triad by determining the direction of the acceleration vector in the moving frame of the triaxial accelerometer cluster and then describing the transformation necessary to obtain a new moving frame that would have one of its axes in the principal direction. A single point in time at which the acceleration was a maximum is chosen to define the directional cosines for transforming from the triax frame to a new frame in such a way that the resultant acceleration vector (AR) and the "principal" unit vector (A1) are co-directional. This orthogonal transformation was used to construct a new frame rigidly fixed to the triax, but differing from the original by an initial rotation.

Then, a comparison between the magnitude of the principal direction and the resultant acceleration was performed.

Transfer Function Analysis - For blunt impacts occurring within dynamic biomechanical systems using human surrogates, the relationship between a transducer time-history at a given point and at another given point can be described in the frequency domain through the use of a transfer function. A Fast Fourier Transformation of simultaneously monitored time-histories from any two points in the system can be used to define a frequency response function relating the two points. In a case relating a force to a pressure, a transformation of the form:

$$x(i\omega) = \mathbf{F}[F(t)]/\mathbf{F}[P(t)]$$

can be obtained from the transformed quantities **F**[F(t)] and **F**[P(t)] respectively, the Fourier transforms of the impact force time-history and the pressure time-history, and where ω is the given frequency and i implies the complex domain.

Mechanical Impedance - A special transfer function that relates impact force to the resulting velocity of a point is known as "mechanical transfer impedance." The transfer function is a complex-valued function which will be simply presented in terms of its magnitude and phase angle. This function is defined:

$$Z(i\omega) = (\omega)\mathbf{F}[F(t)/\mathbf{F}[A(t)]$$

where ω is the chosen frequency and **F**[F(t)] and **F**[A(t)] are, respectively, the Fourier transforms of the impact force and acceleration at the point of interest. Mechanical transfer impedance is also defined as the ratio between the simple harmonic driving force and the corresponding velocity at the point of interest (3).

RESULTS

The significant results are presented in summary form. Table 1 includes peak force, force duration, and velocity. The high velocity (10 m/s) steering wheel assembly impact damages were: contusion striping on both lungs, small laceration on superior heart, rib RlR fractured at sternum, ribs fractured twice (R7R, R7L, R8R, R8L, R9R, R9L, R10R, R10L), rupture through superior liver, contused right kidney, and lacerated transverse intestines. Time-histories of selected variables are included in Appendix B.

DISCUSSION

The results cover only one test subject, and entail an extremely limited testing matrix. The goal of the testing was to evaluate the thoraco-abdominal impact test protocol that had been designed. All results of the thoraco-abdominal steering wheel assembly impact testing performed as part of the evaluation of the designed protocol should be considered preliminary, and not necessarily representative of a larger subject population. However, they do indicate areas for future investigation.

The following summarizes the observations from a single test subject:

1. In a limited sense, the impact response in terms of transfer functions between force and pulmonary pressure to a given test subject at a given contact point is potentially repeatable.

2. For the low-velocity impacts, subject contact region is potentially an important aspect of the kinematic response.

3. For impacts in which the rim contact point is the lower sternum, there is a difference in pulmonary pressure response between the repressurized and unrepressurized low-velocity impacts as well as between the low-velocity impacts and the high-velocity impact in which the rim contact point was the abdomen.

4. Comparison of two measures of chest deformation, pulmonary pressure, and differential motion between the sternum and spine showed that pulmonary pressure was to a greater degree affected by repressurization than differential motion.

Table 1. Kinematic Summary

Test No.	Force lbs.	Durations ms	Velocity m/s
86M001A	320	115	2.5
86M001B	310	115	2.5
86M001C	340	115	2.5
86M001D	300	130	2.5
86M002A	360	140	2.5
86M002B	300	150	2.5
86M002C	380	120	2.5
86M003A	430	125	2.5
86M003B	440	120	2.5
86M003C	410	120	2.5
86M004A	300	135	2.5
86M004B	330	100	2.5
86M004C	230	120	2.5
86M004D	290	130	2.5
86M004E	340	130	2.5
86M005A	280	130	2.5
86M005B	250	120	2.5
86M005C	240	120	2.5
86M006	2000	120	10

5. The impact response of the thoraco-abdominal region in terms of differential motion between the abdomen and the spine and pulmonary pressure is potentially velocity dependent.

To illustrate these five trends the following transfer functions are presented in Figures 1-5. Figures 1 and 2 illustrate the transfer function corridors from Test Series A and E for impact force divided by pulmonary pressure and force divided by differential velocity between the sternum and spine. These two series had similar initial conditions for the test subject, but were separated in time by eight hours. It can be seen from the figures that for low frequencies, the relationship between the force and pulmonary pressure and between force and differential velocity were similar. However, although the two transfer functions overlap past 20 Hz, there is a possible difference in this range. It is unknown whether this is an artifact associated with the experimental techniques in this test series or whether the experiments cannot be duplicated. More tests will have to be conducted to determine in a qualitative manner, the degree of repeatability.

The trend illustrated by Figure 3 is that for low velocity impacts contact region is an important aspect of the kinematic response. Figure 3 shows the transfer function between force divided by pulmonary pressure for three different initial conditions: 1) abdominal contact region and no repressurized pulmonary system (Test Series A), 2) sternal contact region and no repressurized pulmonary system (Test Series C), and 3) sternal contact region and repressurized pulmonary system (Test Series D). Figure 3 illustrates that the transfer function for the sternal impacts without repressurization and the abdominal impacts below the rib cage without repressurization were similar up to about 6 Hz. Above 6 Hz and below 30 Hz, there was a difference between these signals with the abdominal impact showing greater energy in the frequency range 6 to 25 Hz. Potentially, in this frequency range for

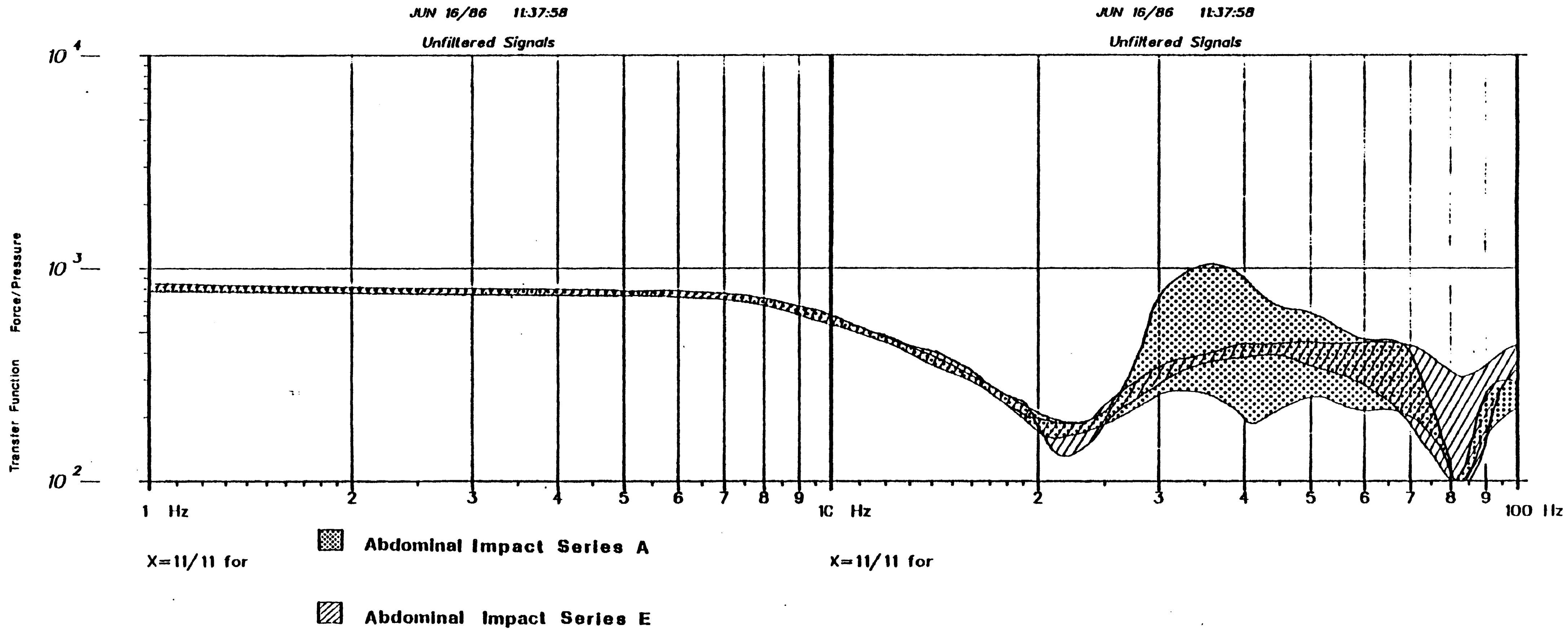

Figure 1. Transfer function for force divided by pressure for two series of impacts with similar initial conditions

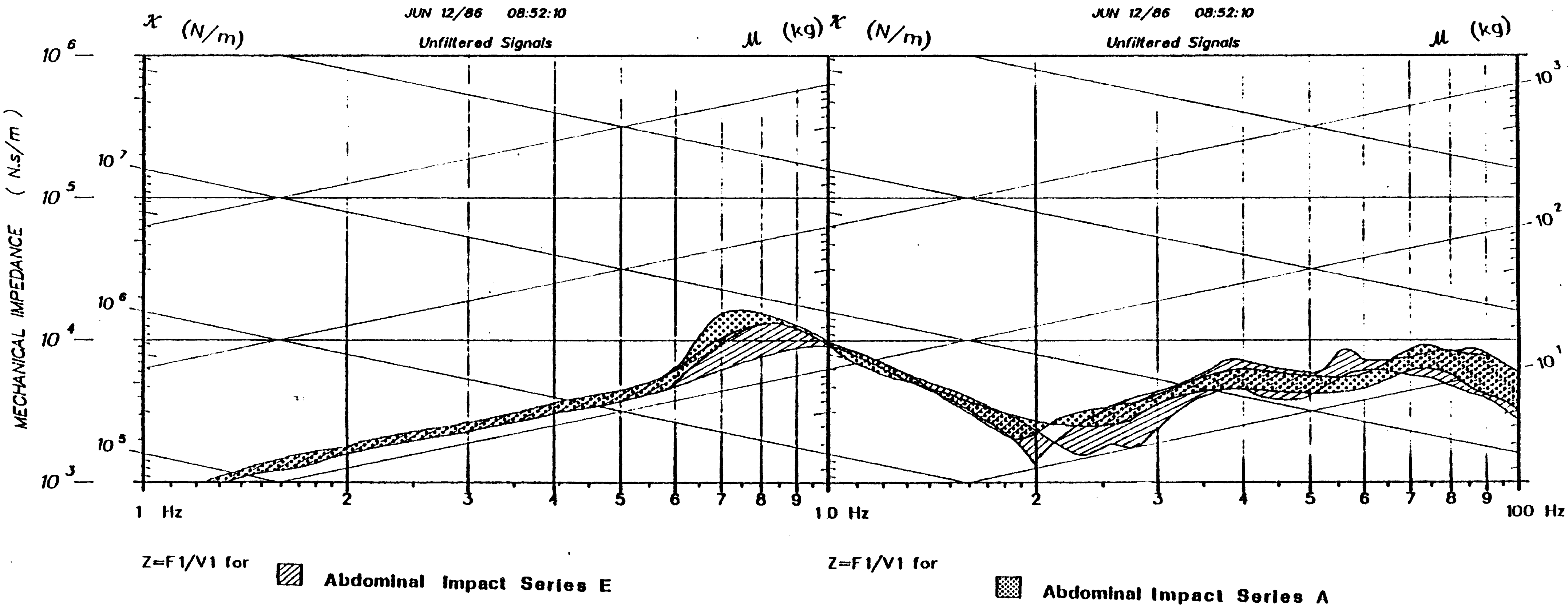

Figure 2. Mechanical impedance for force divided by the differential velocity for the contact point and the spine

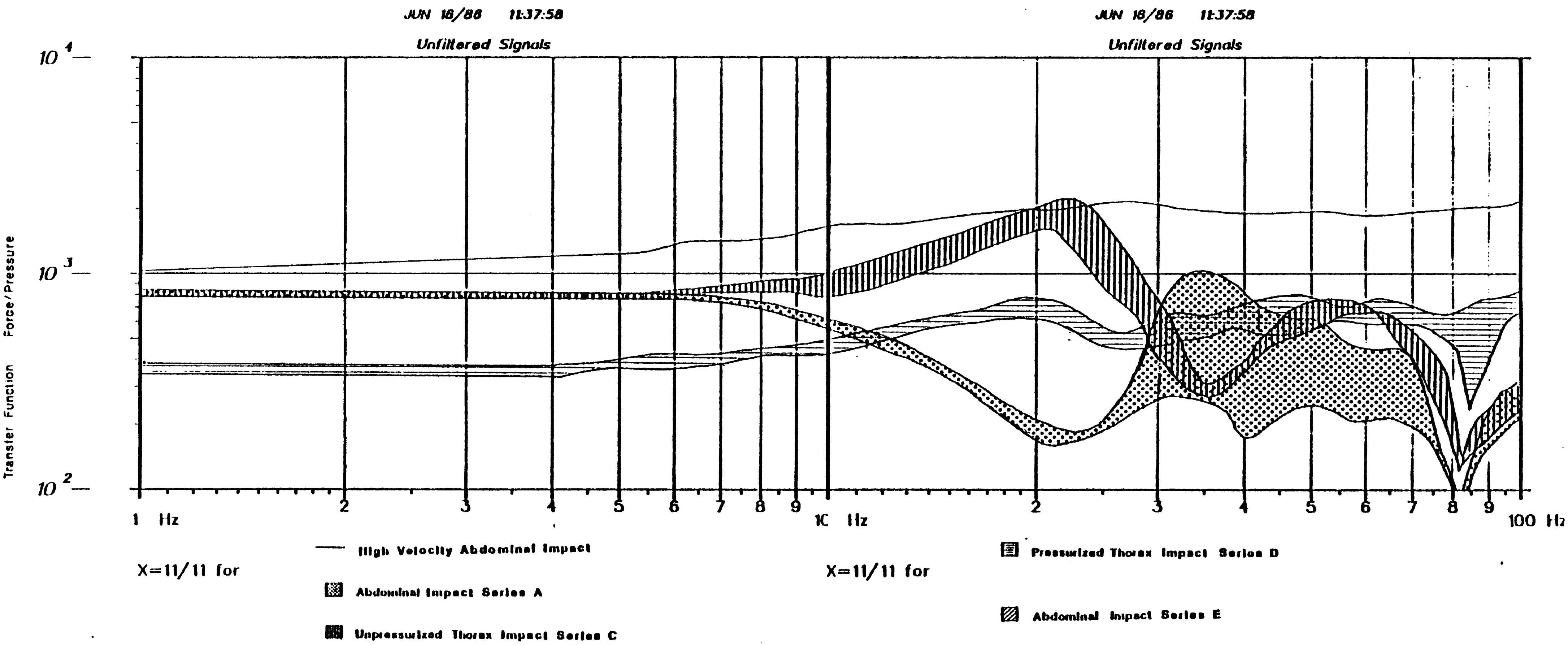

Figure 3. Transfer function for force divided by pressure for different contact points

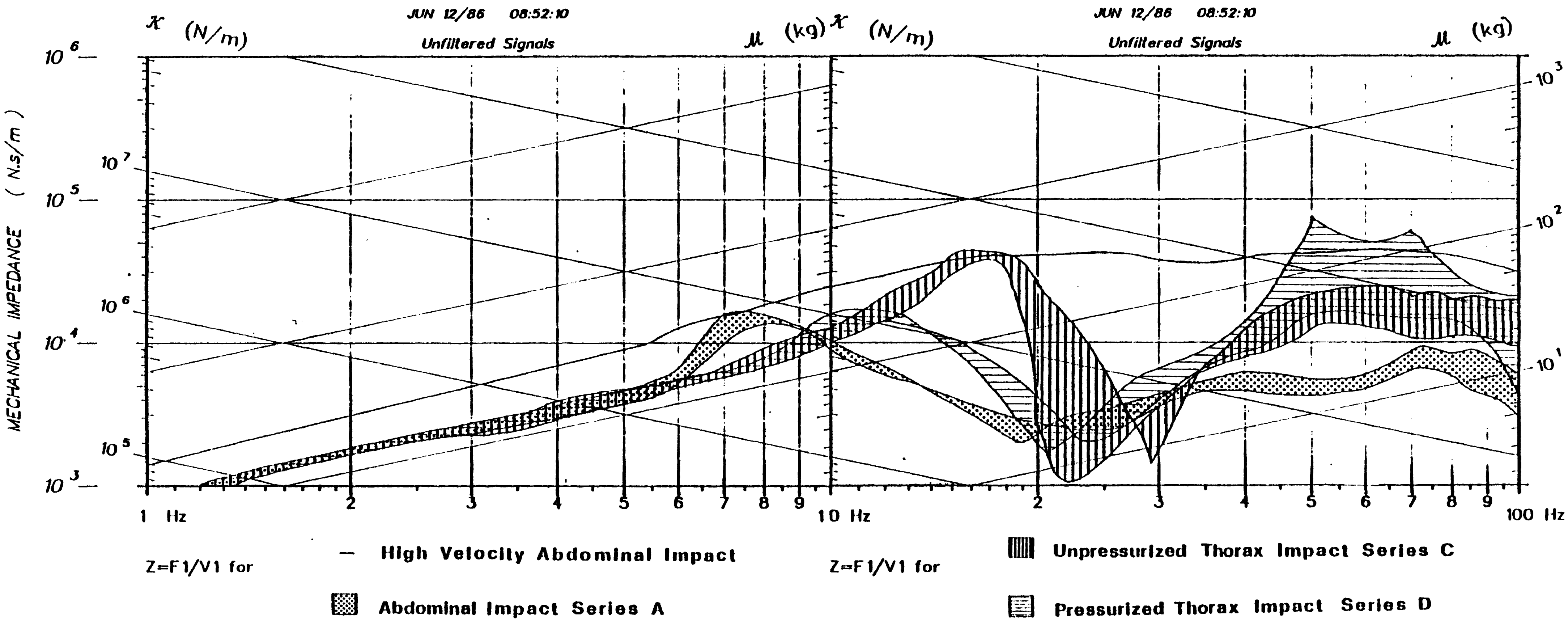

Figure 4. Mechanical impedance for force divided by differential velocity between contact point and spine

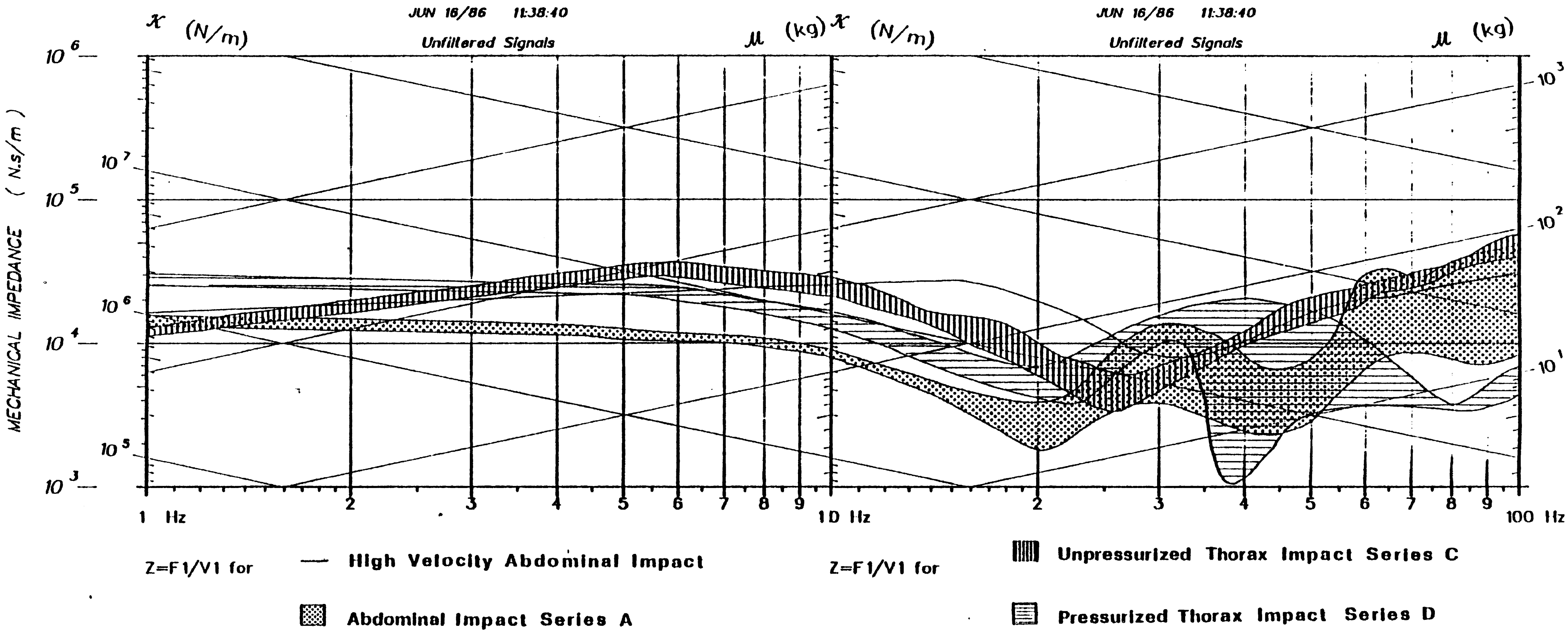

Figure 5. Mechanical impedance for force divided by spinal velocity

this velocity of impact, it is easier to change the lung volume by pushing on the abdomen and forcing material into the thoracic cage than by compressing the thorax directly. The transfer function corridor for the pulmonary repressurized testing (Test Series D) was significantly different at the low frequencies than for the unrepressurized testing (Test Series C) and abdominal contact region testing (Test Series A). This result is believed to be an effect of the increased volume of the lungs. When the rib cage is expanded, as during pulmonary repressurization, the rib positions change and it is easier to compress the thorax and reduce its volume, therefore increasing the pressure during impact as comparison to the unrepressurized testing shows.

The high-velocity (10 m/s) impact (Series F) transfer function for force divided by pressure is included in Figure 3. The transfer functions for this test (Series F) was different from the other tests (Series A and E) having the same initial conditions. This implies a potential non-linear velocity dependence of the response of the thoracic cage. In addition, the increased magnitude of the transfer function implies that the thoracic abdominal system may be "stiffer" at higher velocities. The same trend seems to be true for differential motion of the abdomen and spine as illustrated in Figure 4. Figure 4 is the impedance between differential velocity and impactor force. However, that trend was not observed for force divided by spinal velocity (Figure 5).

Currently work is being performed to evaluate force-deflection as obtained from stringpot transducers and the impact force. That result is being compared to the impedance between force and differential motion. Theoretically, the results obtained from each analysis should be similar. However, subtle differences in the experimental techniques or in the impact response may produce significant differences.

High Velocity Impact Damages - The injury results indicate that this type of steering wheel assembly is extremely damage-producing in thoraco-abdominal blunt impact. This is believed to be the result of the stiffness of the steering wheel rim, which is consistent with the observations of others (4).

APPENDICES

APPENDIX A - Protocol

MOTOR VEHICLE MANUFACTURERS' ASSOCIATION

"STEERING WHEEL" IMPACT TESTS

86M

performed by

The Biomechanics Department
Biosciences Division
Transportation
Research Institute
The University of Michigan

M Series 86M through 86M

This protocol for the use of cadavers in this test series was approved by the Committee to Review grants for Clinical Research of the University of Michigan Medical Centers and follows guidelines established by the U. S. Public Health Service and those recommended by the National Academy of Science, National Research Council as well as those specifically outlined in the GMRL "Statement of Ethical Practices."

STATEMENT OF ETHICAL PRACTICES

Affirmation Form

The General Motors Research Laboratories require that the following principles be adhered to in any laboratory in which research utilizing cadavers is conducted:

1. The cadavers shall be treated with the greatest respect and handled with dignity.

2. Cadavers shall not be used in tests or experiments which are not essential to research goals.

3. Cadavers shall not be subjected to unnecessary exposure and damage.

4. Individual identities shall not be revealed by name, photographic record, or other means.

5. Cadavers shall be obtained, handled, and disposed of in accordance with the governing legal requirements.

6. It is essential that only cadavers which have been freely donated for medical research be utilized for GM sponsored research, and that unclaimed bodies donated by units of government not be used.

The General Motors Research Laboratories require that all contractors and individual investigators who use cadavers in their research subscribe to the above principles and attest to them by the following form:

> Believing in the essential dignity of man in body and spirit, while recognizing the necessity for the study of human bodies to advance the understanding of human life towards the goal of improving and preserving life, we subscribe to these tenets:
>
> In any laboratory with which we are associated, we shall treat cadavers with the greatest care and respect, never subjecting them to tests that are not essential to our research goals, always maintaining them in a proper condition, avoiding unnecessary exposure and damage, in no case revealing identities, always avoiding any frivolities, and finally returning them for proper burial or disposal.

Signed: ______________________________

____

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TABLE OF CONTENTS

MVMA TEST SERIES OUTLINE

13 HUMAN CADAVER TESTS

Series A: 1 unrepressurized subject (20 kg and low velocity target=abdomen)

Series B: 1 repressurized-lung subject (20 kg and low velocity target=rib 10)

Series C: 1 unrepressurized subject (20 kg and low velocity target=substernale)

Series D: 1 repressurized pulmonary subject (20 kg and low velocity target=substernale)

Series E: 1 unpressurized subject (20 kg and low velocity target=abdomen)

Series F: 1 repressurized pulmonary subject (20 kg high velocity target=abdomen)

TEST NO._______

"STEERING WHEEL" IMPACT WITH PNEUMATIC BALLISTIC PENDULUM
Contact Surface: "Steering Wheel" shape
psi: ___ low velocity=2.5 m/s or high= 10 m/s

15/25/50 kg striker

Camera
Hycam Frame rate_______, lateral view

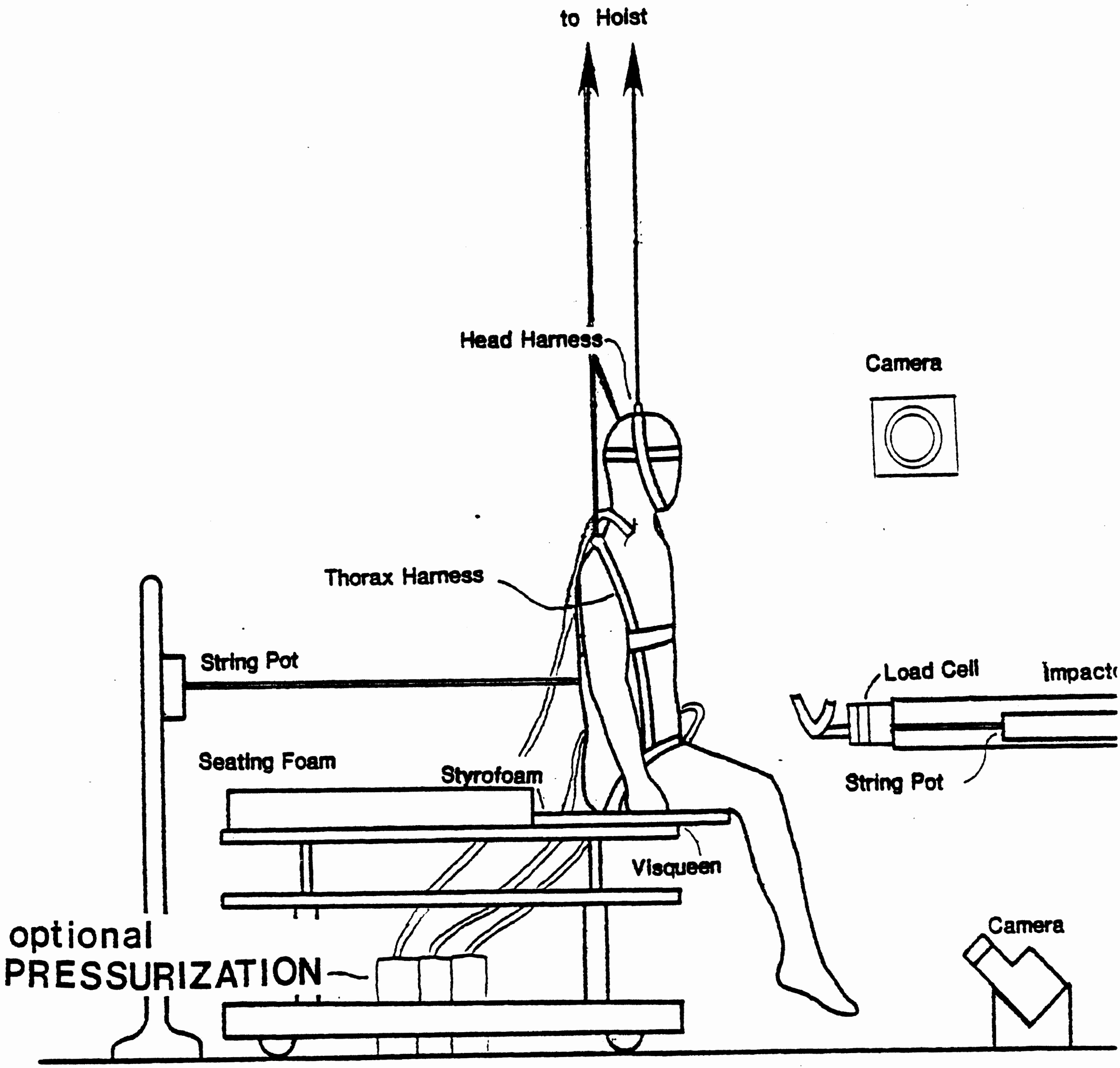
Cadaver Instrumentation
T12 3ax_______
Displacement stringpot at T12 ________
Vascular Pressure - Millar transducer
Pulmonary Pressure - Endevco transducer
Post-test body core temperature

Equipment Instrumentation
Force
Velocity displacement
3ax on "Steering Wheel" column

Subject Position

Supported via head and parachute harnesses, seated on table

MVMA "STEERING WHEEL" IMPACT INITIAL CONDITIONS



"STEERING WHEEL" IMPACT

Anatomical Site	THORACO-ABDOMINAL IMPACT	
	Accs. Trans-ducer*	Targets**
Pulmonary		
T12		
T12		
Femoral/aorta		

*Indicate AXor 3AX.
**Indicate paper target, ball target, or pin target.

HUMAN CADAVER TEST SUMMARY

Cadaver No.________ Sex:_____ Height:_____ Weight:_____

Test No.__________

Test description: Low velocity "Steering Wheel" impact to Thoraco-abdomen/High velocity "Steering Wheel" impact to Thoraco-abdomen. Frontal impact to subject suspended seated on table. Restricting net for high velocity impact.

Type of Impactor: Pneumatic Ballistic Pendulum/______________

Striking Surface: "Steering Wheel" model/______________________

Pressure:_________________ Velocity __________________ m/s

35mm stills:

___ Black and White

___ Color

CAMERAS	FRAME RATE	POSITION
Hycam	__________	__________
Hycam	__________	__________

Notes:____

____

____

CADAVER PRE-SURGERY

TASK	TIME	COMMENTS
Cadaver delivered from U of M Anatomy Dept. and transported to UMTRI Biomedical lab.		
Weigh cadaver and log cadaver information.		
Store cadaver if necessary.		
Sanitary preparation.		
Pretest X-rays: (KV/MA/T) (90/10/1) thorax A-P ___/___/___		
Start film hyping.		
Anthropometry.		

ANTHROPOMETRY

Cadaver Number: __________ Sex: ______ Age ______

Appearance: ______________________________________

Stature: _________________ Weight: _____________

Head Circumference: ______________________________

Head Length: _____________________________________

Head Breadth: ____________________________________

Menton-Vertex: ___________________________________

Menton-Suprasternale: ____________________________

Neck Circumference _______________________________

Acromion Height: _________________________________

Suprasternale Height: ____________________________

Substernale Height: ______________________________

Substernale Circumference: _______________________

Axillary Breadth: ________________________________

Chest Breadth: ___________________________________

Anatomical Anomalies / Clinical Observations

1. Neck:

2. Thorax:

4. Other:

VASCULAR REPRESSURIZATION

TASK	TIME	COMMENTS
Locate right carotid and cut lengthwise.		
Locate right vertebral artery and ligate.		
Loop six pieces of string around carotid artery.		
Insert fabricated Foley catheter (#18) into descending aorta past diaphragm.		
Insert shield into ascending aorta.		
Insert shield into carotid artery.		
Insert arterial pressurization catheters into carotid artery.		
Using syringe, squirt arcrylic into artery. Tie and sew.		
Locate Left carotid, cut, loop strings.		
Locate left vertebral artery and ligate.		

VASCULAR REPRESSURIZATION continued

TASK	TIME	COMMENTS
Insert arterial pressurization catheter (#10) into carotid artery.		
Acrylic, tie and sew.		
Vascular flow check.		
Locate right and left femoral arteries and insert into one a fabricated Foley catheter and tie the other off.		
Seal the artery with the catheter in it.		

CEREBROSPINAL REPRESSURIZATION

TASK	TIME	COMMENTS
Locate L2 by palpation and counting from T12.		
Core a small hole in the lamina with a drill bit.		
Insert Foley catheter (#14) such that balloon is in mid-thorax.		
Insert small screws in lamina and process.		
Seal off hole with acrylic.		
Check for structural integrity of vertebra.		
Check cerebrospinal flow.		

PULMONARY REPRESSURIZATION

TASK	TIME	COMMENTS
Locate trachea and cut lengthwise.		
Loop two tie wraps around trachea.		
Insert polyethelyne tube snugly, tie and sew.		
Calibrate lungs.		
Pulmonary pressure relief valve calibration.		

SPINAL MOUNT

TASK	TIME	COMMENTS
Spinal mount goes on T12.		
Make incisions over T12. Clear muscle and tissue away from process, but do not cut between processes.		
Drill a small hole 1/4" deep in the process.		
Press flanking mount supports to spinous process.		
Screw mount on with wood screw (be sure screw is in process).		
Mold acrylic around and under mount and mount support and allow to dry. Make sure that the accelerometer mounting surface is free of acrylic.		
Make sure accelerometer will be anatomically oriented.		
Spinal geometry if necessary.		

POST-SURGERY PREPARATION

TASK	TIME	COMMENTS
Dress cadaver. (head and body harnesses)		
Store cadaver if necessary.		
Transport cadaver to test area, being care-ful not to damage mount.		

ELECTRONICS CHECK AND PRETEST TRIAL RUN

___ Inspect triaxes for signs of wear
___ Complete wiring
___ Establish and record gains settings
___ Calibrate tape recorder
___ Check pendulum load cell, velocity transducer,
___ Set timerbox
___ Check excitation and balances
___ Gate signal amplifier on
___ Suspend rubber tube 5 inches from ballistic impactor with fiber tape
___ Tape all accelerometers to tube with paper tape
___ RUN TRIAL TEST

___ Examine signals, check wiring if necessary
___ Verify operation of cameras and ropecutter

___ Test Endevco/Millar pressure transducers separately
___ Load Film
Hycam ____________
Hycam ____________

"STEERING WHEEL" IMPACT

Test No. 86M

psi:______ Velocity: 2.5/ m/s

TASK	TIME	COMMENTS
Attach phototargets.		
Attach T12 triax to subject. Attach T12 stringpot to subject. Sew up incisions.		
Attach Millar and Endevco pressure transducers to subject.		
Final positioning of subject in impact field.		
Measure and record head and neck angles Head:___ Neck:___		
Setup photos.		
Hycam check		
Final checklist.		
Run test.		
Take color 35mm final resting position photograph.		

<u>POST-TEST PROCEDURE</u>

TASK	TIME	COMMENTS
AFTER IN-PLACE POST-TEST PHOTOGRAPHS:		
Remove all targets, pressure transducers and accelerometer.		
Store cadaver if necessary.		
Transport cadaver to anatomy lab.		
Remove spinal mount.		

AUTOPSY

TASK	TIME	COMMENTS
Autopsy		

Observed Injuries

1. Neck:

2. Thorax:

3. Other:

COMMENTS:

APPENDICES

Timer Box Setup
Preliminary and Final Checklists
Preliminary Impact Lab
Cameras
Subject
Cannon Final Checklist
Final Countdown

"STEERING WHEEL" IMPACT TIMER BOX SETUP

TEST NUMBER 86M psi = ____ velocity 2.5/ m/s

Control	Equipment	Delay		Run
			1	
			2	
			3	
			4	
			5	
			6	
			7	
			8	

SET CANNON SOLENOID SWITCHES TO SYNCHRONIZE TIMING
Cannon fire =
Delay=

PRELIMINARY AND FINAL CHECKLISTS

PRELIMINARY IMPACT LAB CHECKLIST

CAMERAS

_____Light banks positioned, 480-V power on?
_____Cameras set and in position?
_____Newtonian reference?
_____Calibration Target positioned and photographed?
_____Subject positioning completed?
_____TEST ID and phototargets visible?
_____Backdrop positioned?
_____Cables clear of field of view?
_____Pre-Test Photographs

SUBJECT PRELIMINARY CHECKLIST

_____TARGETS visible?
_____Hoist in correct position and locked?
_____Measure and record angles___________
_____GO TO CANNON FINAL CHECKLISTS

FINAL CHECKLISTS

<CANNON FINAL CHECKLIST

_____Solenoid Switches set to synchronize timer box?

_____Timer Box times correct?

_____Timer Box firing channels correct?

_____Cannon cocked?

_____Piston status GREEN, GREEN, GREEN?

_____Record launch rope angle________

_____Head noose check

_____All cables clear and strain relieved?

_____Gate set?

_____PRESSURIZE CANNON

_____Ratchet and turn handle off brake winch?

_____Force cal set in cannon room?

_____Amps cal set in cannon room?

_____Begin INSTRUMENTATION ROOM COUNTDOWN

<INSTRUMENTATION ROOM FINAL COUNTDOWN

_____Earphone contact?

_____Necessary rewiring accomplished?

_____Amplifier gains set?

_____Amplifer excitation set?

_____Amplifers zeroed? [balance]

_____Tape recorders set at 30 ips?

_____Volume of tape recorders off?

_____Tapes positioned?

_____TEST NUMBER VERIFIED?

_____Cannon Timer Box Armed?

_____RUN TEST

SETUP CHECKLISTS

Anatomy Room Setup
Testing Area Setup
Cart Setup
Autopsy Setup
Timer Box Setup

MEASUREMENT

___ Anthropometer

___ Metric measuring tape

PAPER AND PLASTICS

___ Visqueen on autopsy table

___ Blue pads on table

___ Gauze

TAPES AND STRINGS

___ Silver tape

___ white tape

___ Flat waxed string

SCALPELS

___ 2 medium (#4) handles

___ 2 small (#3) handles

___ 5 #22 blades

___ 2 #15 blades

___ 2 #12 blades

FORCEPS

___ 2 hooked

___ 2 large plain

___ 2 small plain

HEMOSTATS

___ needle

___ small straight

___ large straight

___ large curved

SCISSORS

___ 2 medium

SPREADERS

___ 1 large

___ 1 medium

NEEDLES

___ 2 double curved

___ 2 5cc sringes

CLOTHING

___ Tampons

___ Thermoknit longjohns and top

___ Cotton socks

___ Blue vinyl pants and top

___ Head and body harnesses

BOLTS AND SCREWS

___ 3 lengths of wood screws

MOUNT

___ Spine(1)

___ Dental acrylic

TOOLS

___ Electric hair clippers

___ Electric drill w/key

___ Drill bits (No. 7, approx. 1/16", etc.)

___ large screwdriver

MISCELLANEOUS

___ calculator

___ bone wax

____ TEST ID LABELS

TAPES

___ fiber

___ silver

___ masking

___ black

___ double stick

PAPER AND PLASTIC

___ blue pads

___ gauze

___ gloves

___ plastic garbage bags

STRING

___ flat waxed string

TOOLS

___ 2 small (2-56) screwdrivers

___ large screwdriver

___ 2-56 screws

AUTOPSY SETUP

PAPER AND PLASTICS

___ Visqueen on autopsy table

___ blue pads

___ gauze

TAPE

___ silver tape

___ masking tape

___ fiber tape

SCALPELS

___ 2 large (#8) handles

___ 2 medium (#4) handles

___ 2 small (#3) handles

___ 2 #60 blades

___ 10 #22 blades

___ 5 #15 blades

___ 2 #12 blades

FORCEPS

___ 2 hooked

___ 2 large plain

___ 2 small plain

HEMOSTATS

___ needle

___ small straight

___ small curved

___ large straight

___ large curved

SCISSORS

___ 2 small

___ 2 medium

___ 2 large

SPREADERS

___ 1 medium

___ 1 large

MISCELLANEOUS

___ Stryker saw and blade

___ bone shears

___ wedge

___ rib cutters

___ body bag

___ Test ID Autopsy Photo Labels

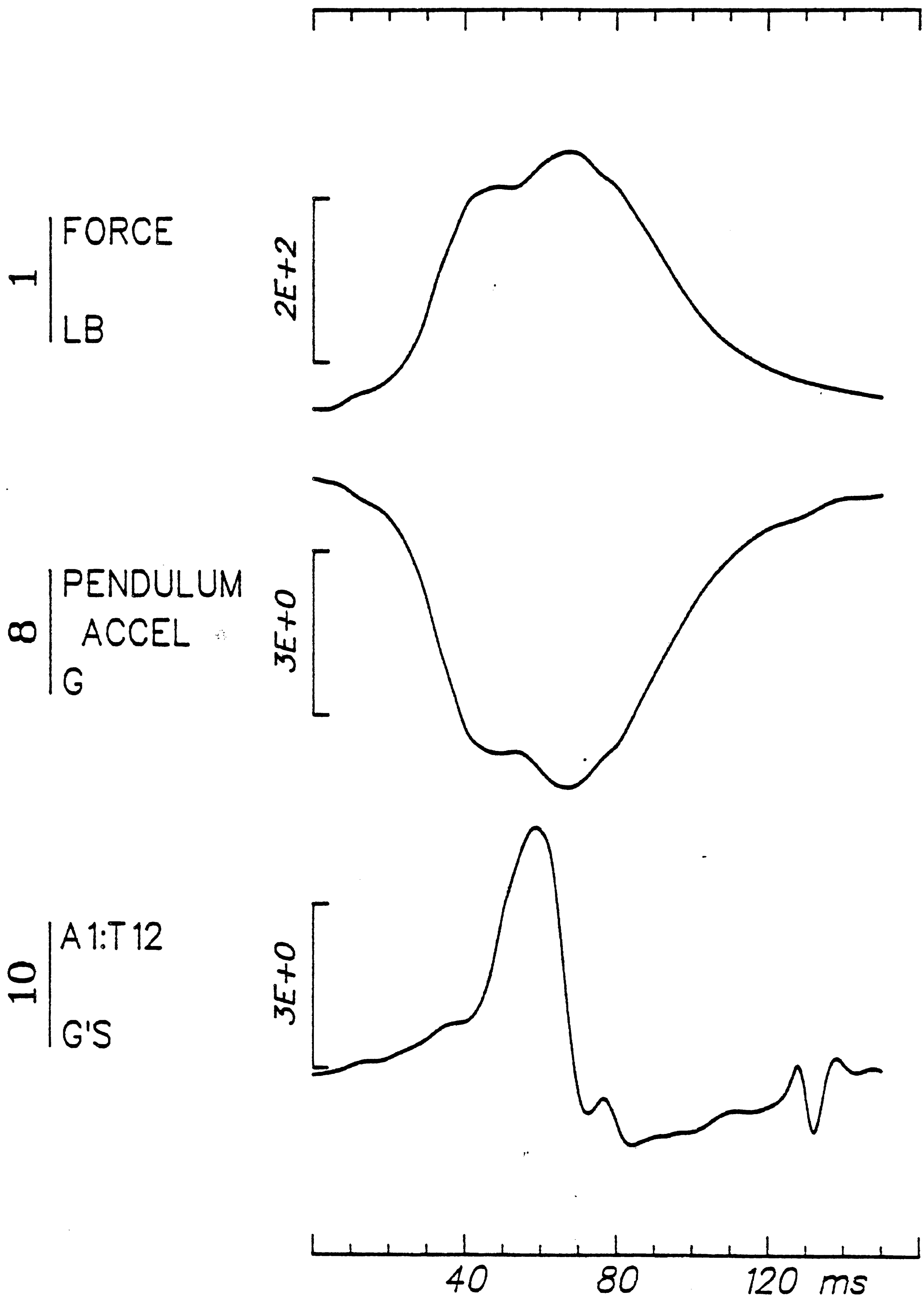
___ 35 mm cameras

___ 2 bounce flash

___ bounce flash shield

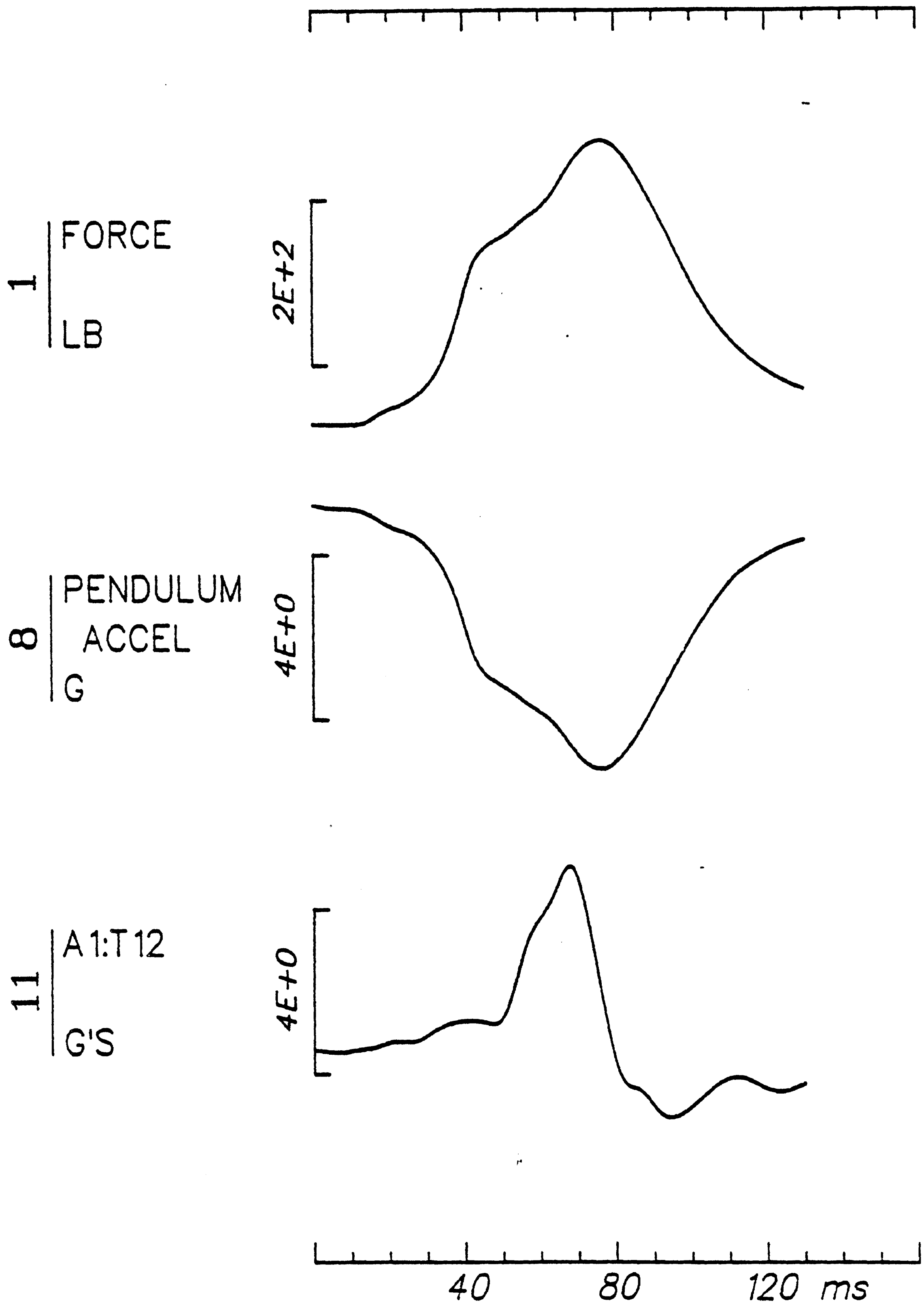
APPENDIX B - Selected Time-Histories

Run ID: 86M001B AB *Filter: 100*4C Smooth:*



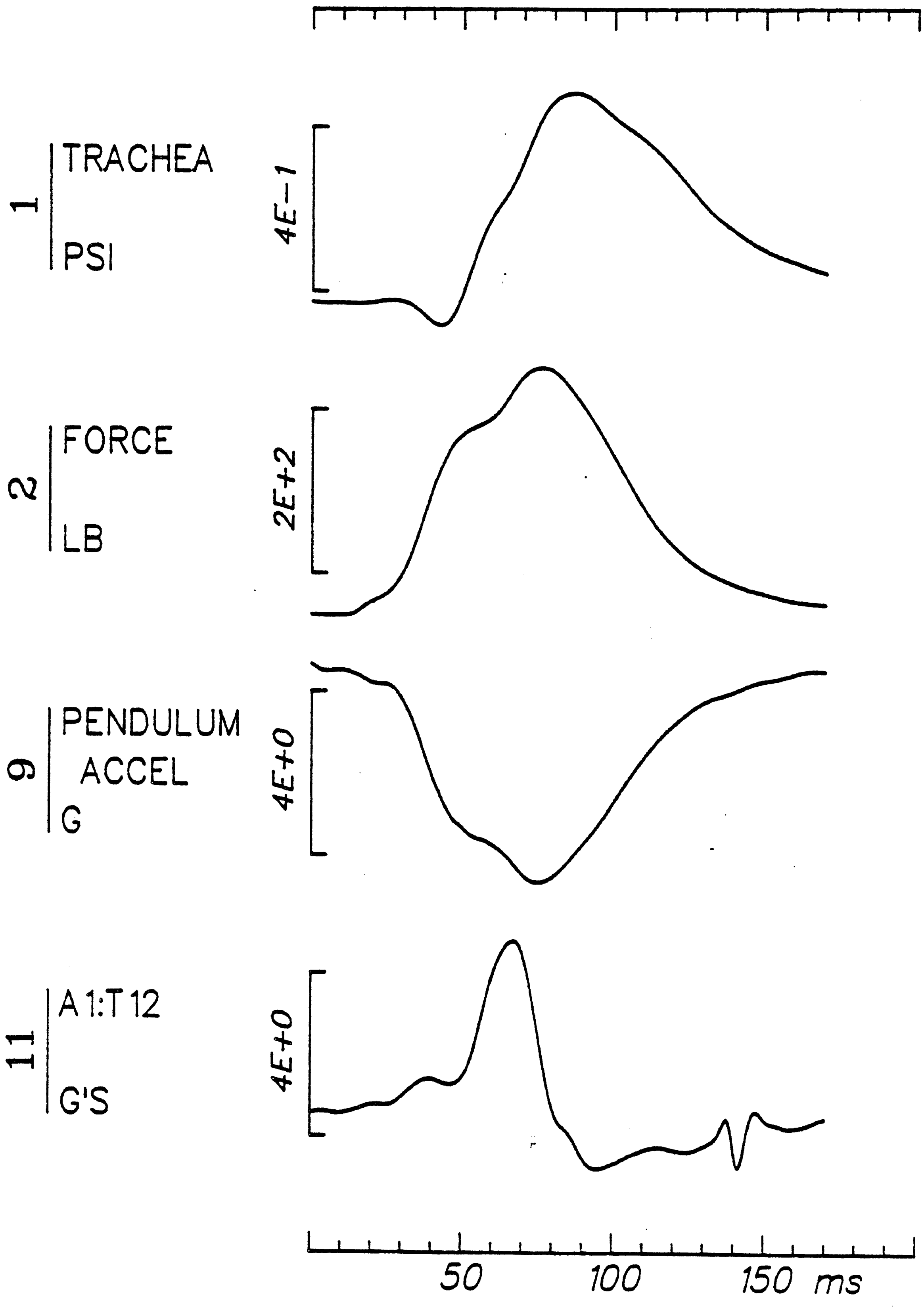
Impact to Abdomen

Run ID: 86M001C AB *Filter: 100*4C Smooth:*



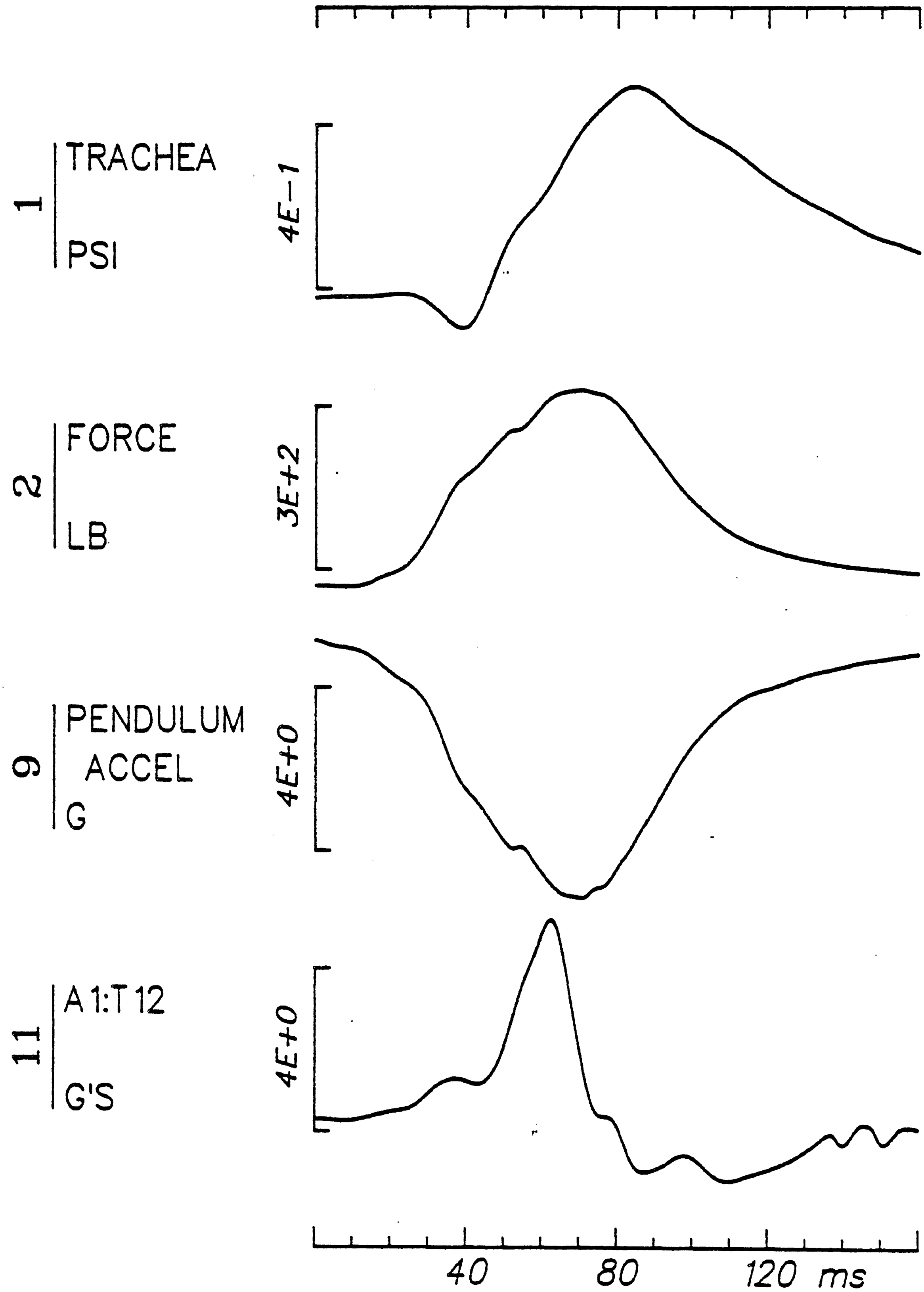
Impact to Abdomen

Run ID: 86M001D AB *Filter: 100*4C Smooth:*



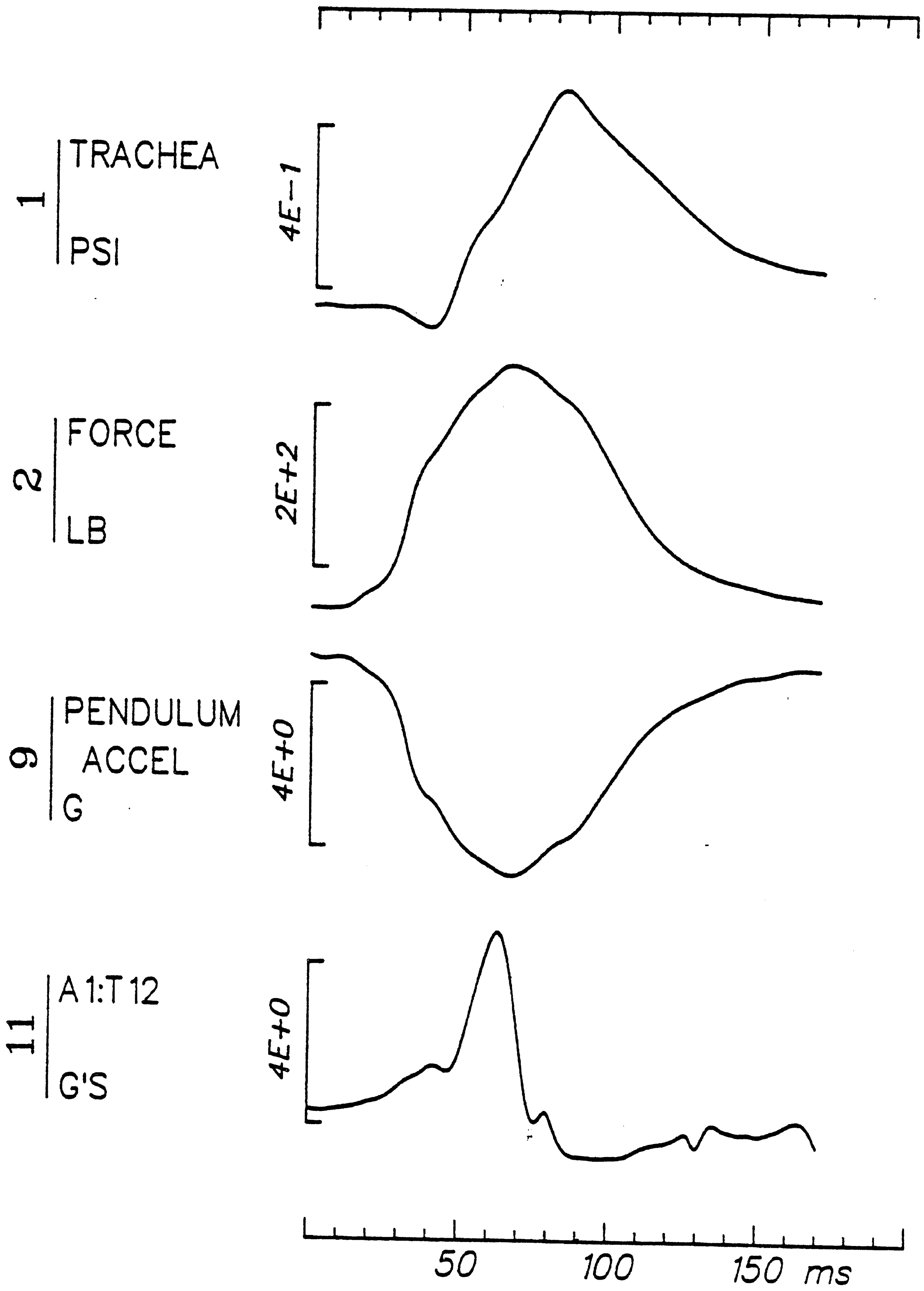
Impact to Abdomen

Run ID: 86M002A AB *Filter: 100*4C Smooth:*



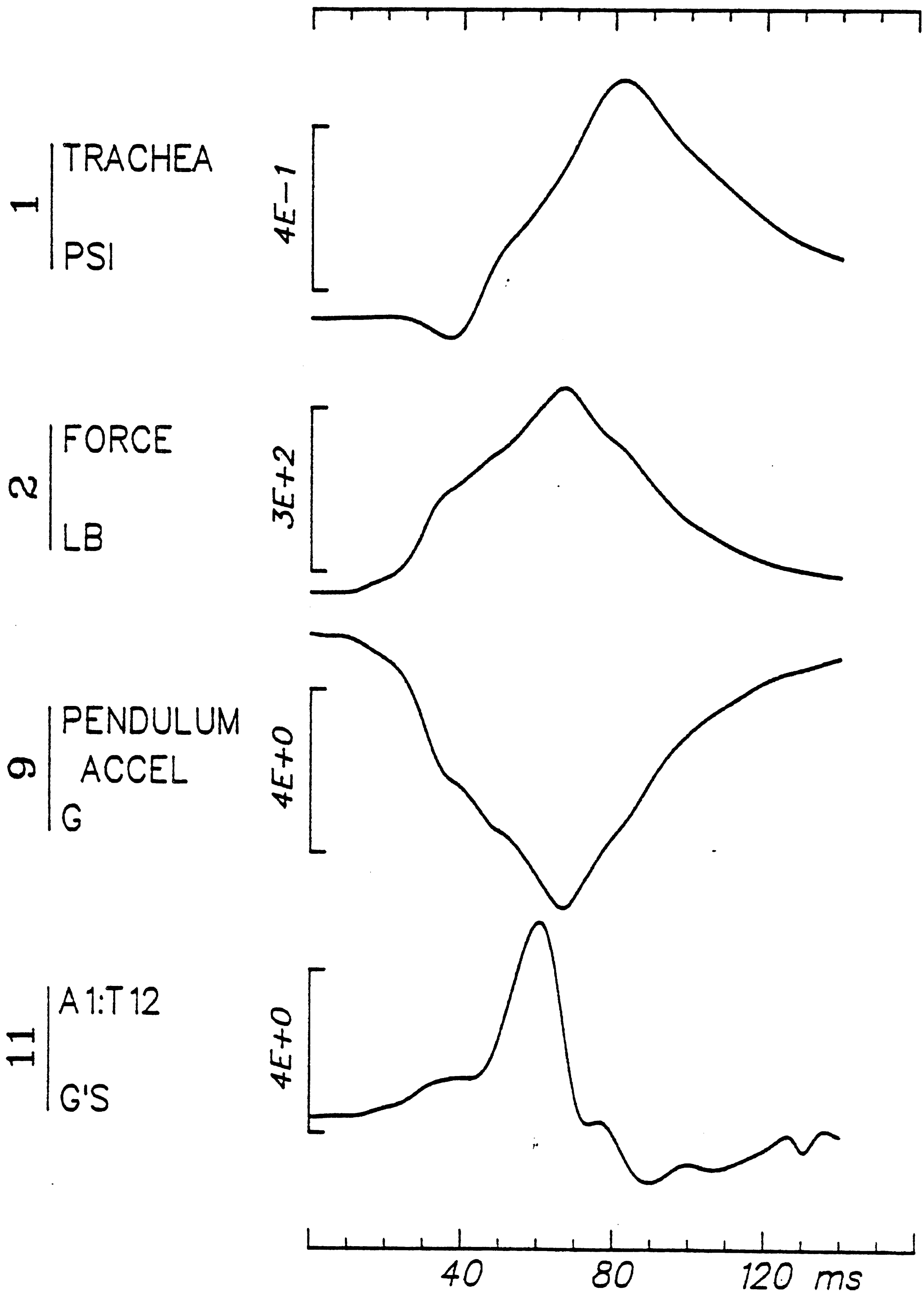
Impact at 10th Rib - Lower Rib Cage

Run ID: 86M002B AB *Filter: 100*4C Smooth:*



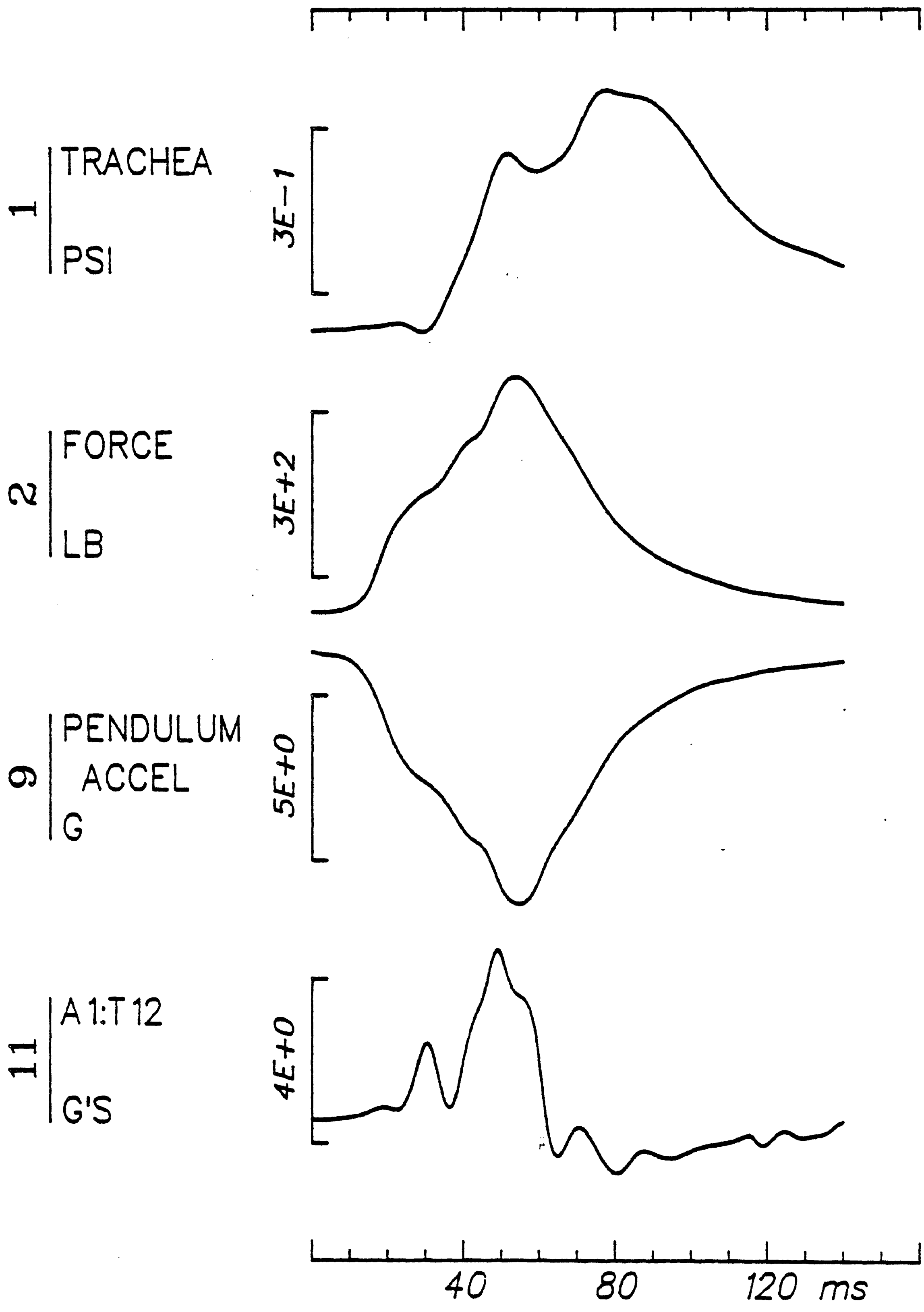
Impact at 10th Rib - Lower Rib Cage

Run ID: 86M002C AB *Filter: 100*4C Smooth:*



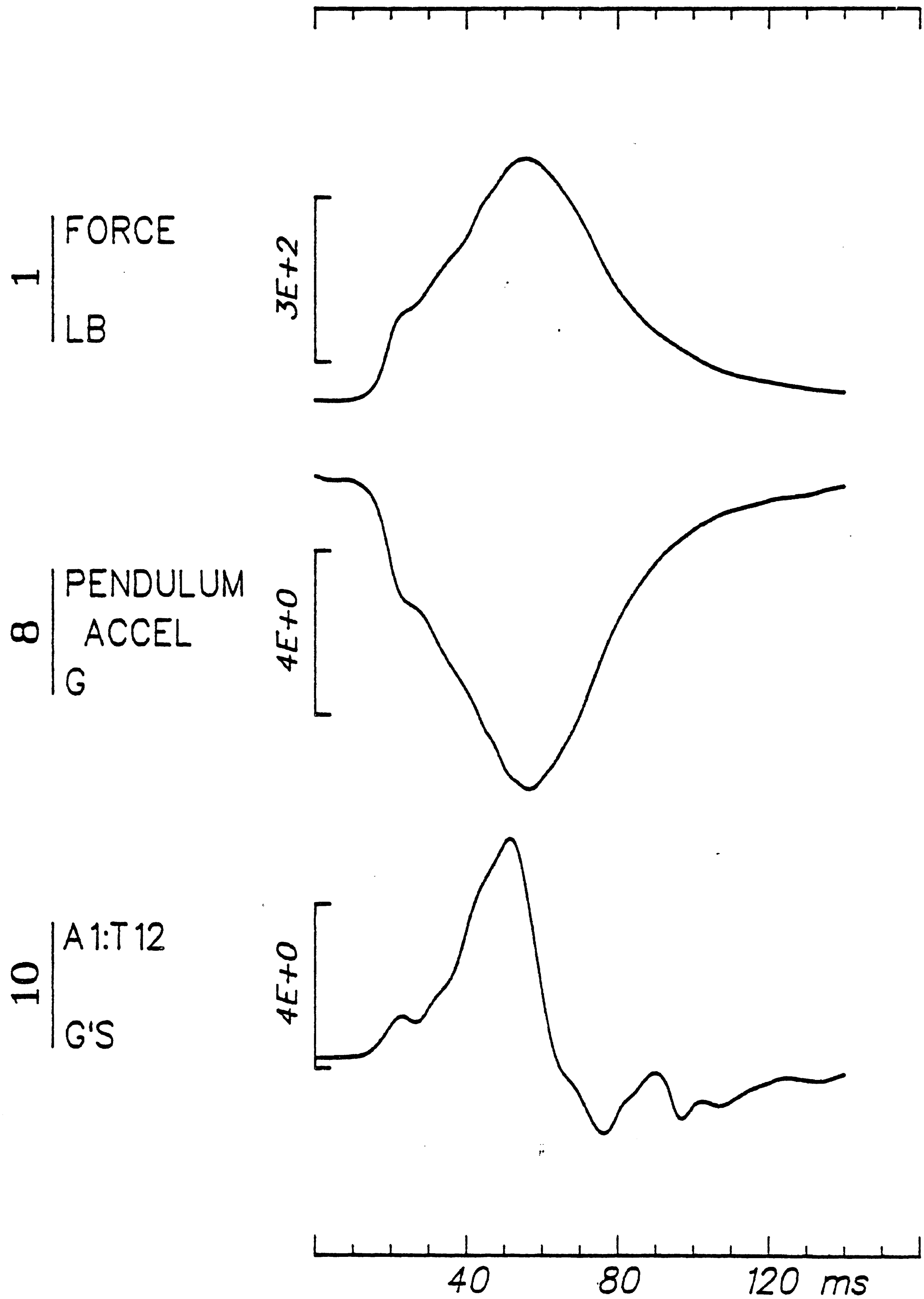
Impact at 10th Rib - Lower Rib Cage

Run ID: 86M003A AB *Filter: 100*4C Smooth:*



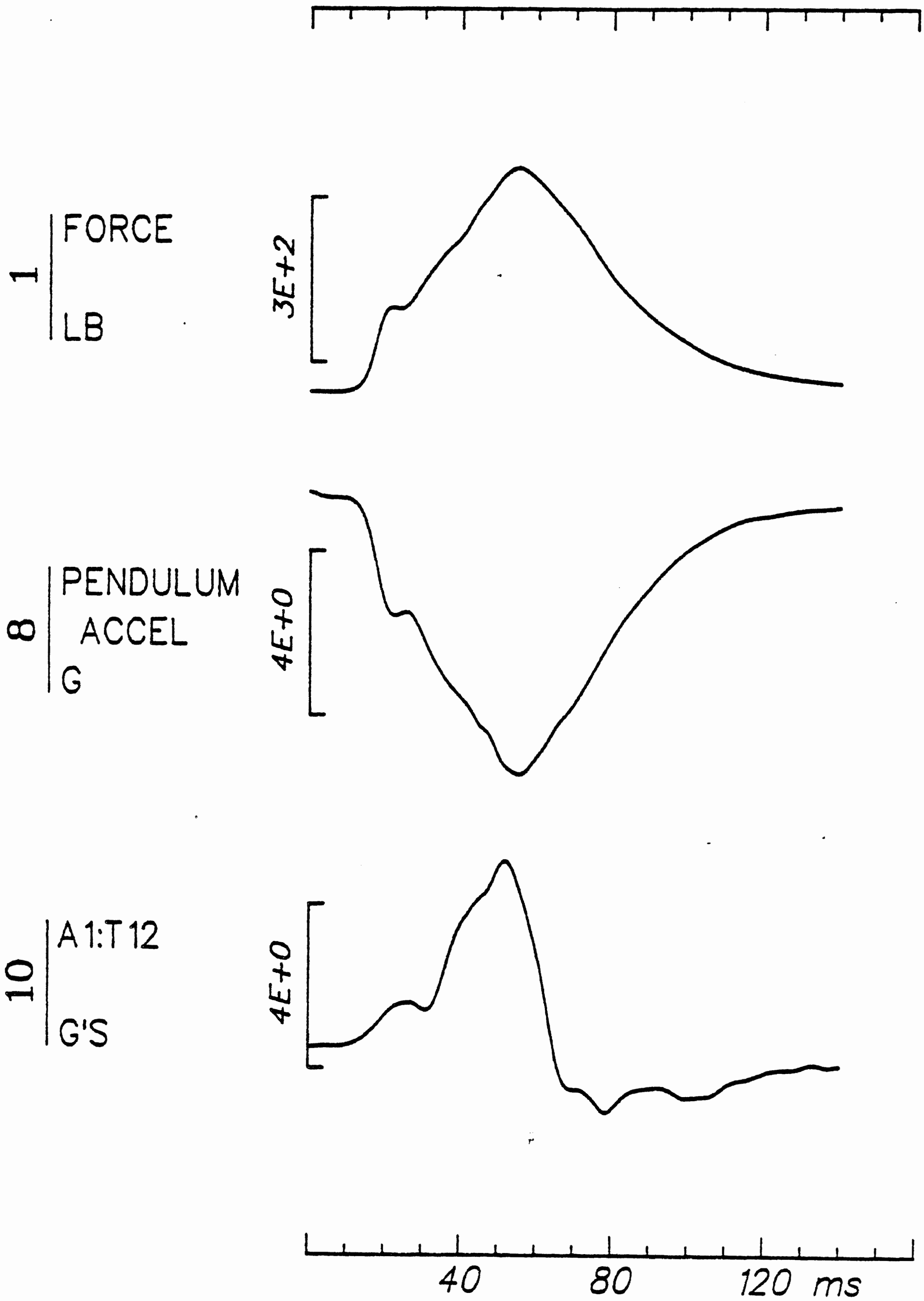
Impact to Lower Sternum - Unrepressurized

Run ID: 86M003B AB *Filter: 100*4C Smooth:*



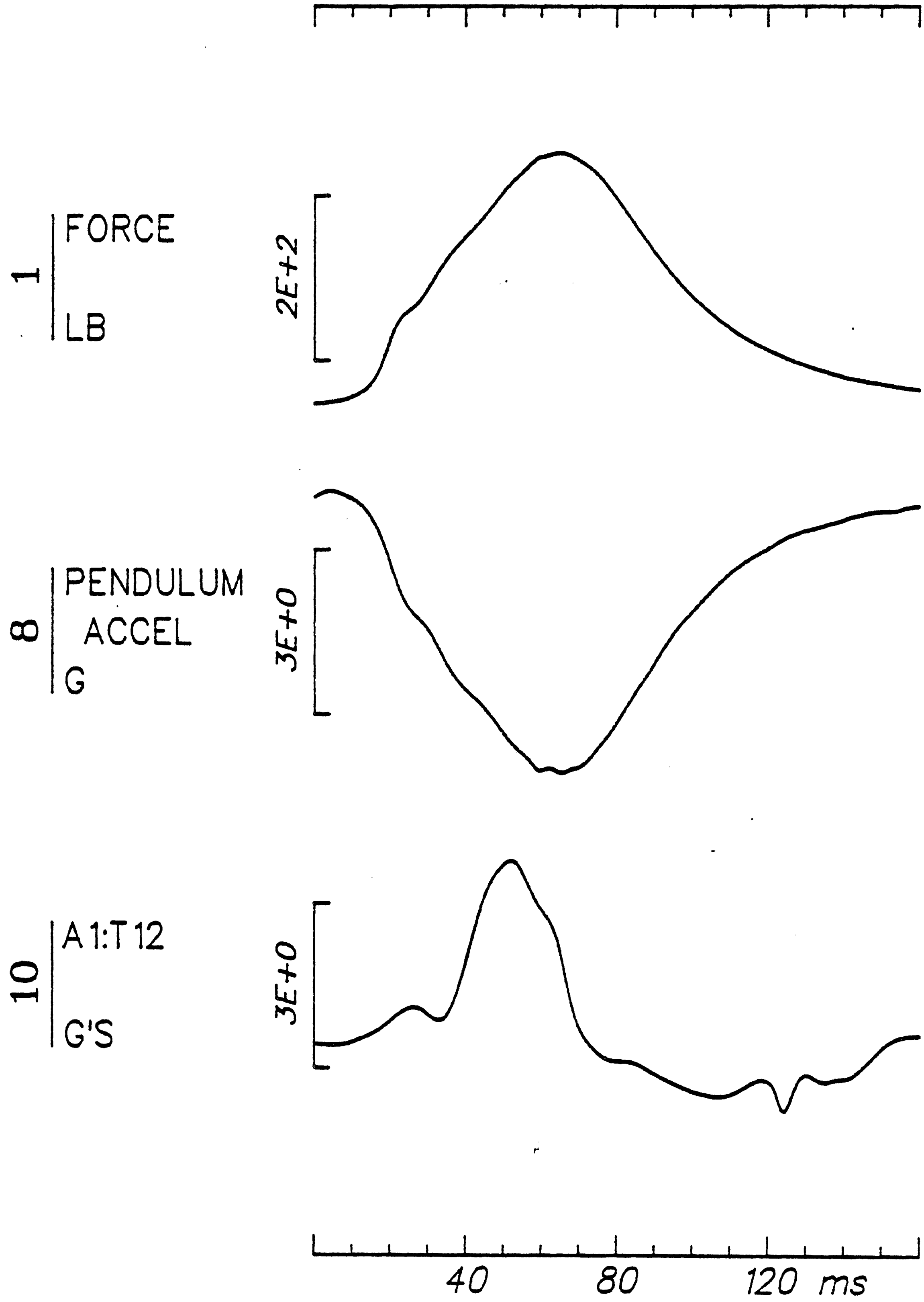
Impact to Lower Sternum - Unrepressurized

Run ID: 86M003C AB *Filter: 100*4C Smooth:*



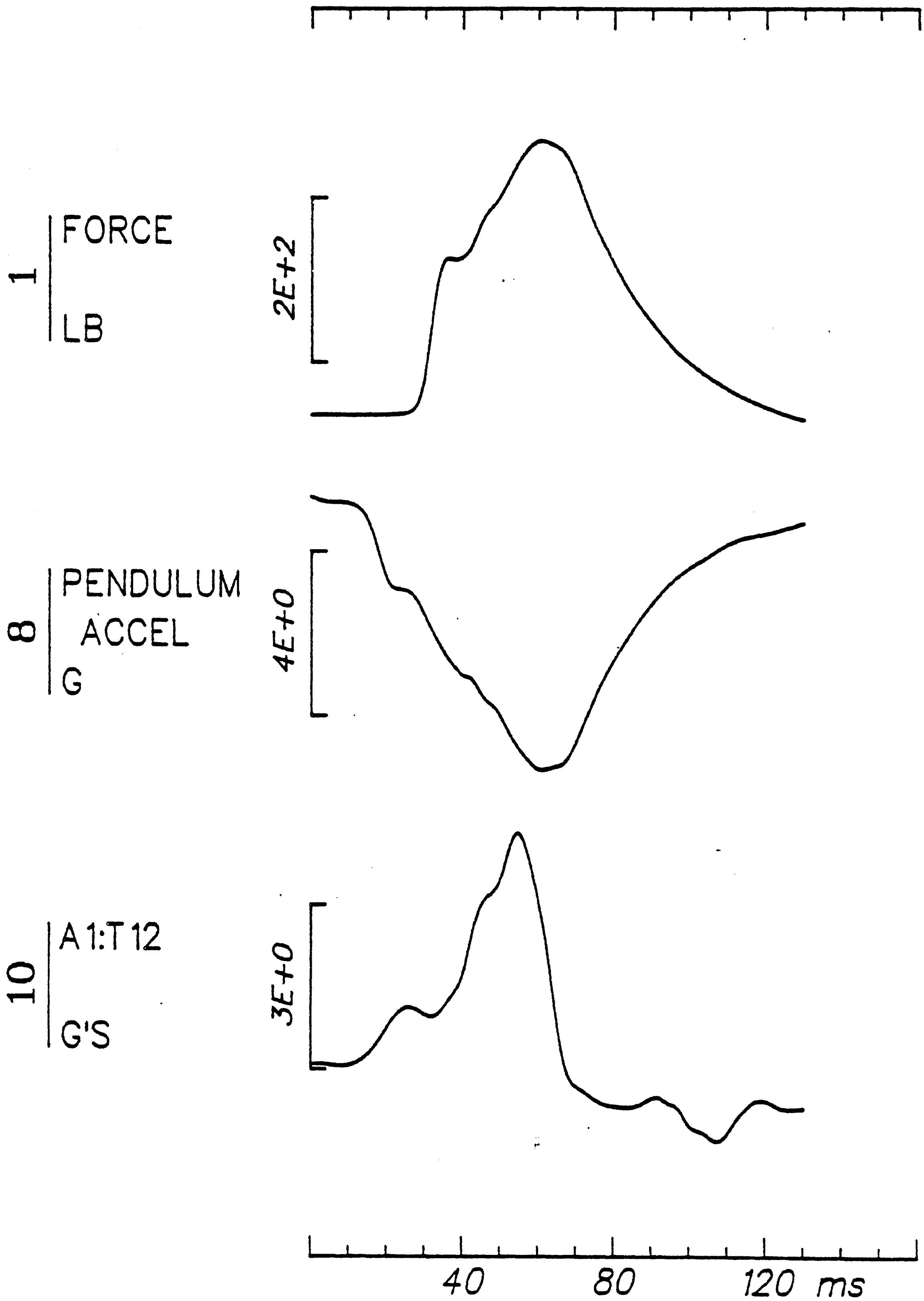
Impact to Lower Sternum - Unrepressurized

Run ID: 86M004A AB *Filter: 100*4C Smooth:*



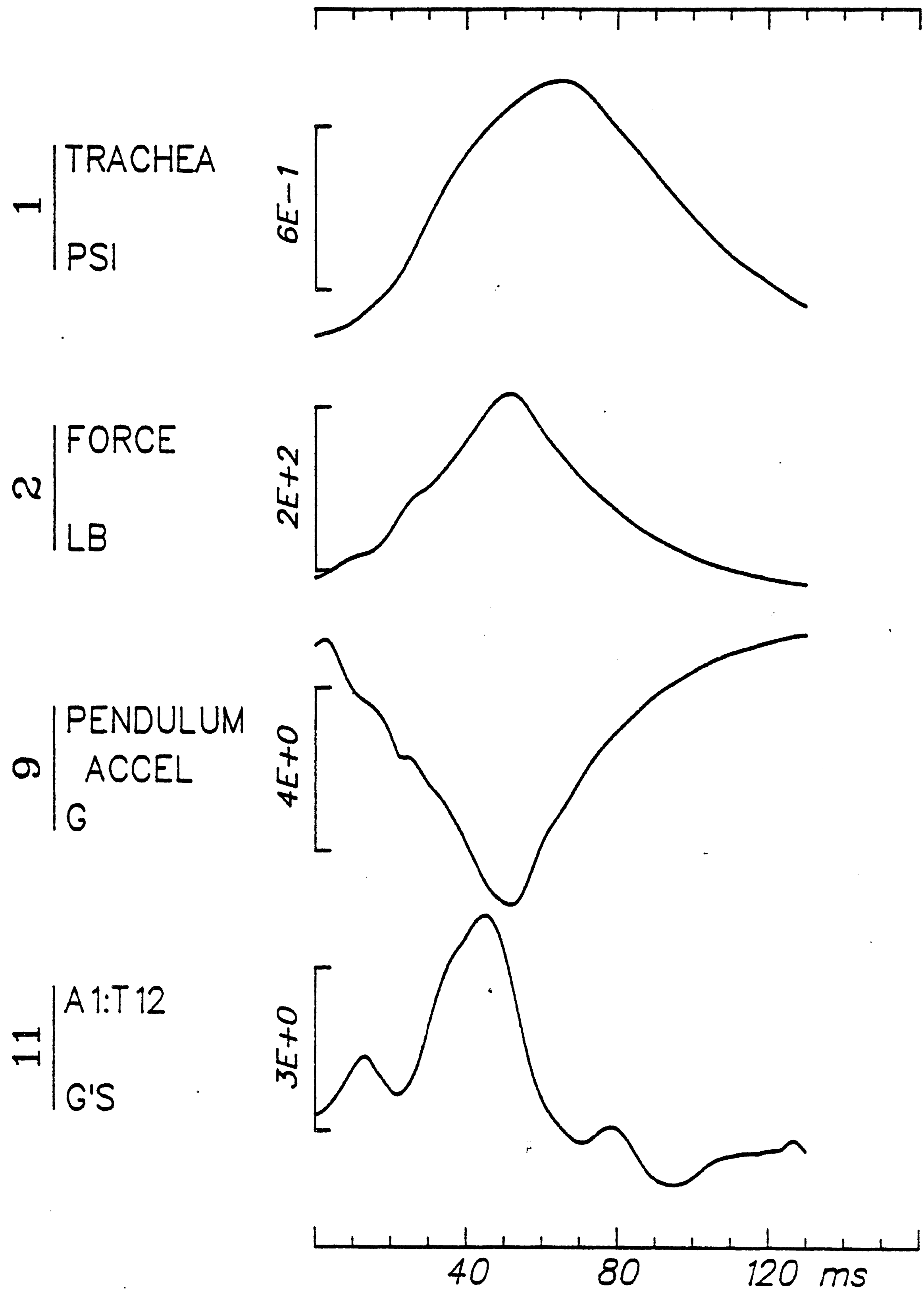
Impact to Lower Sternum - Repressurized

Run ID: 86M004B AB *Filter: 100*4C Smooth:*



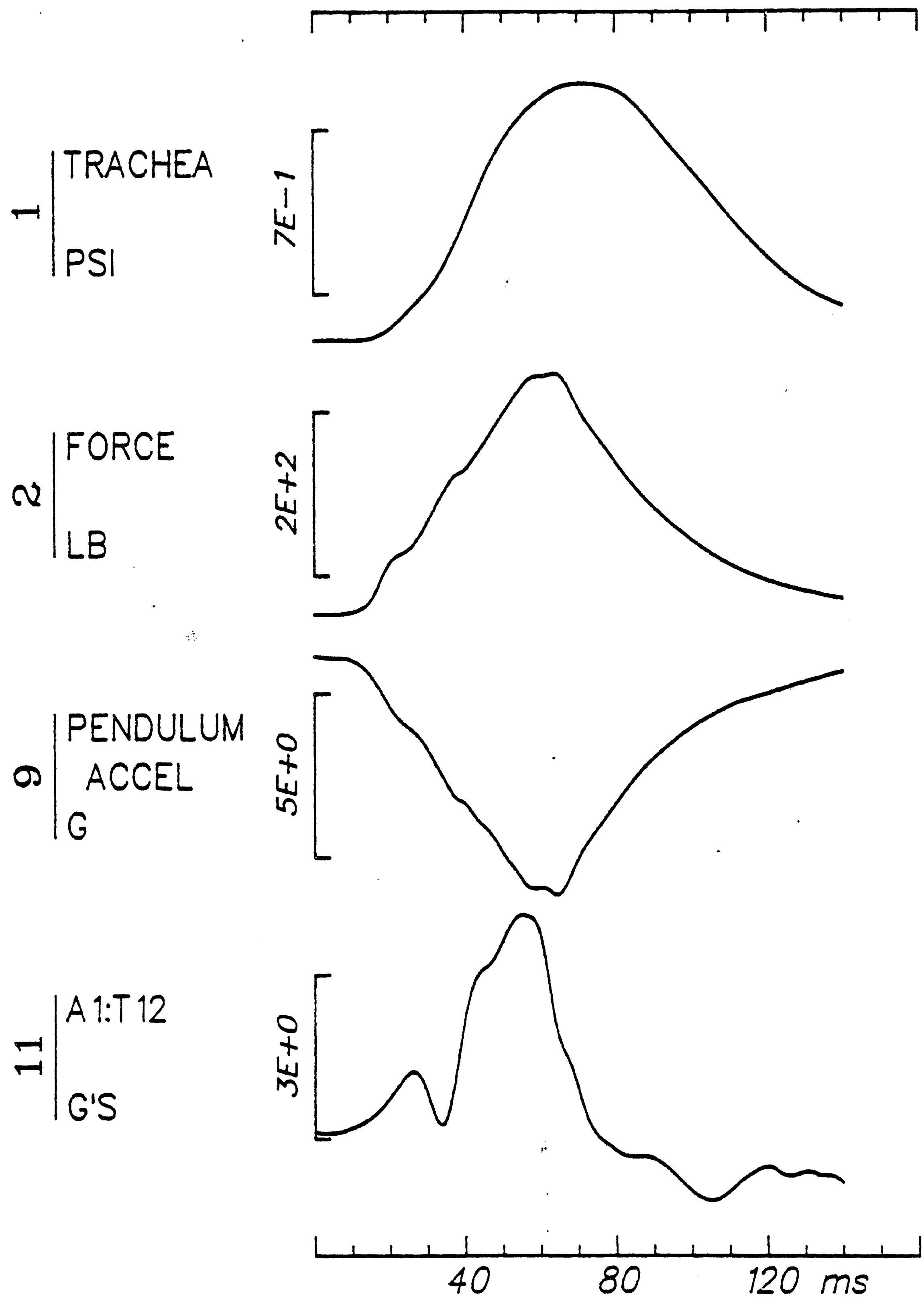
Impact to Lower Sternum - Repressurized

Run ID: 86M004C AB *Filter: 100*4C Smooth:*



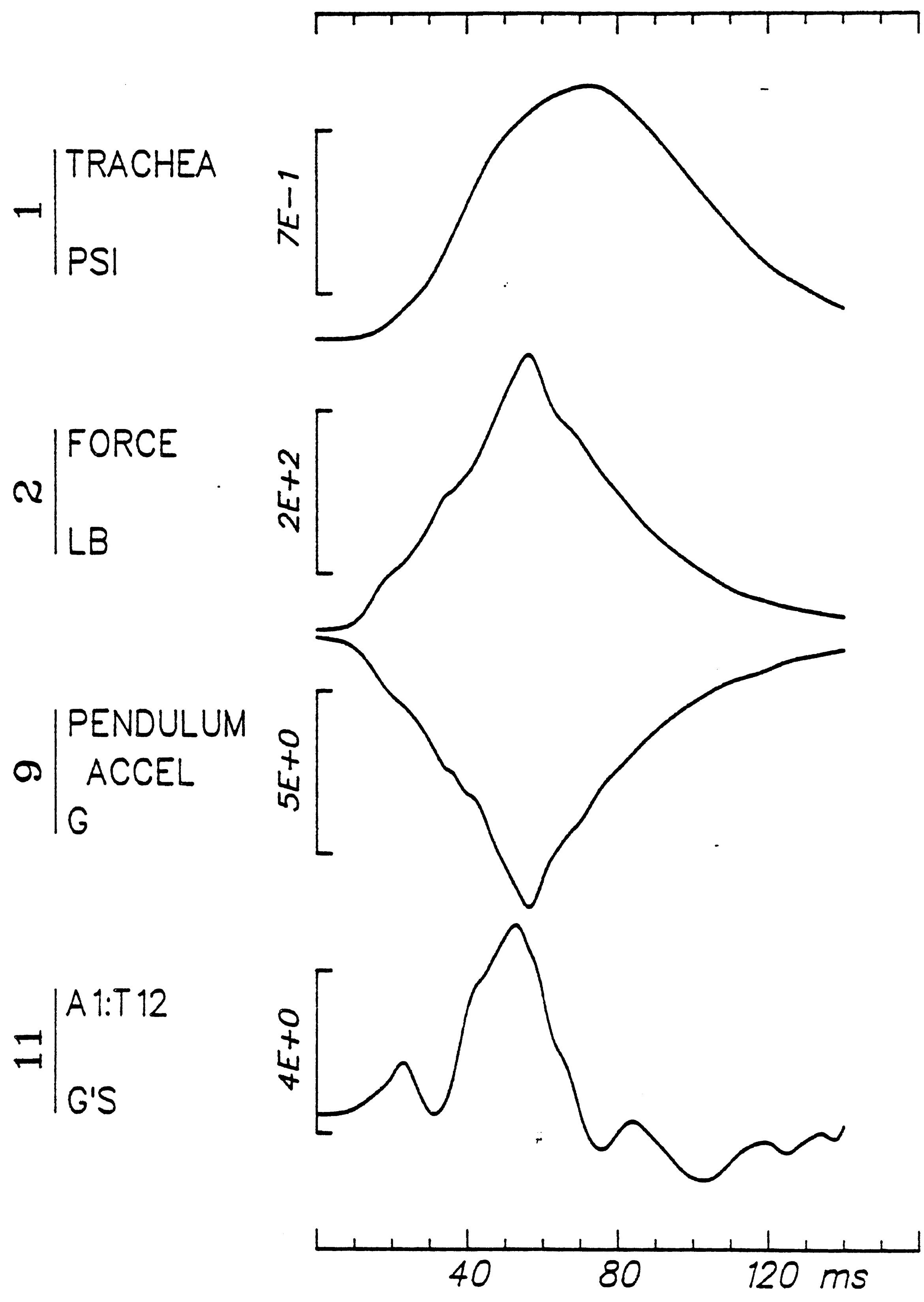
Impact to Lower Sternum - Repressurized

Run ID: 86M004D AB *Filter: 100*4C Smooth:*



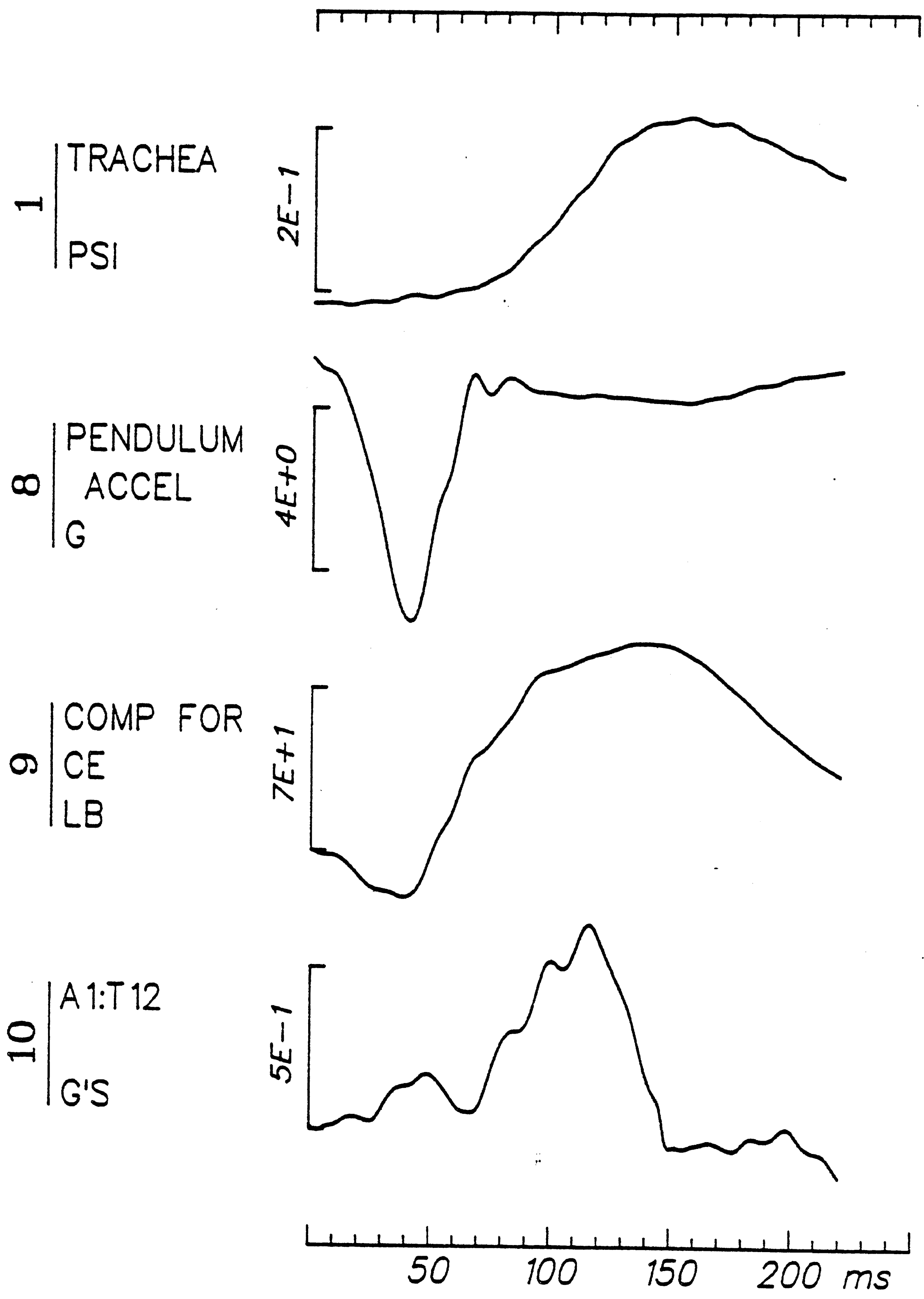
Impact to Lower Sternum - Repressurized

Run ID: 86M004E AB *Filter: 100*4C Smooth:*



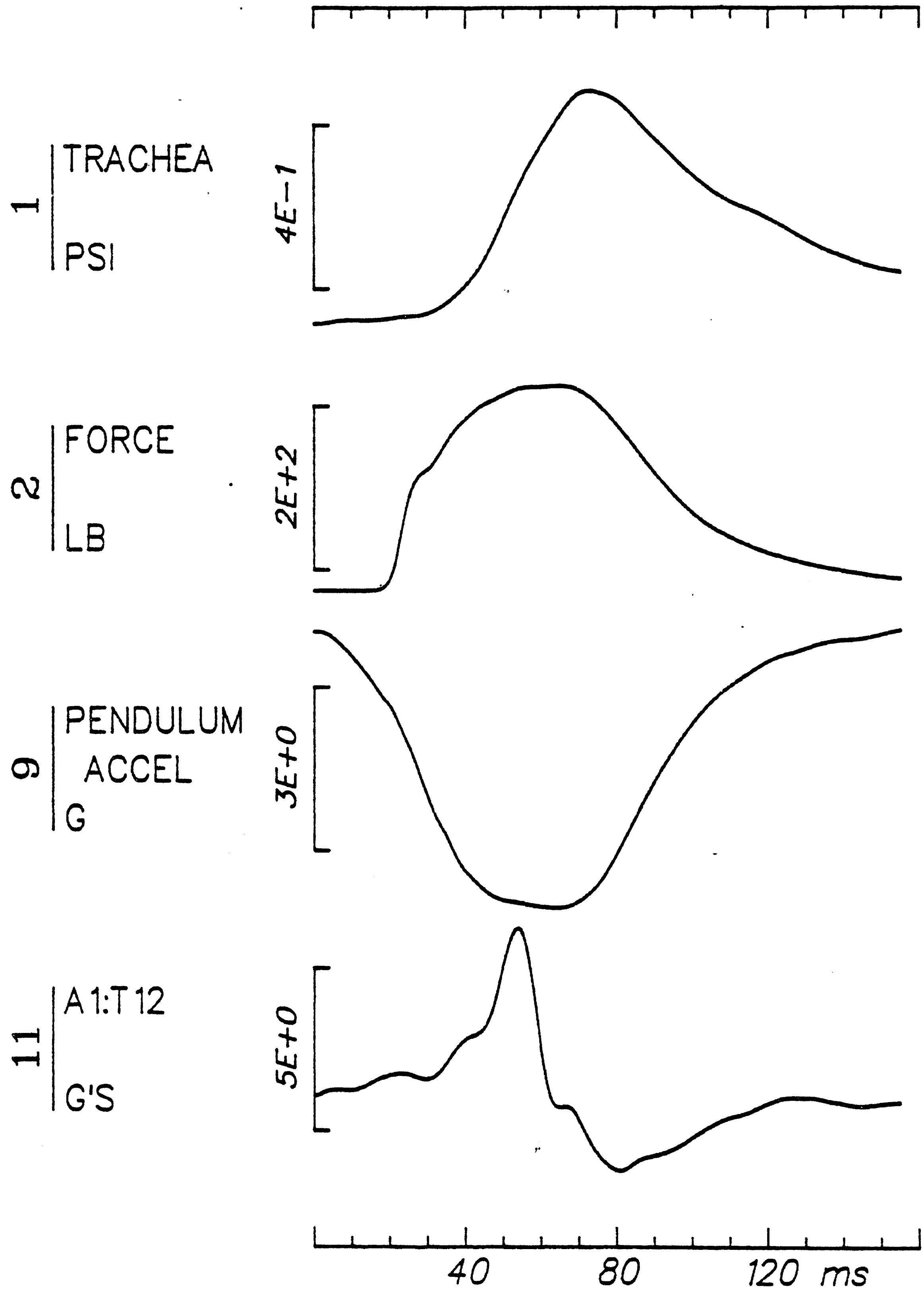
Impact to Lower Sternum - Repressurized

Run ID: 86M005A AB *Filter: 100*4C Smooth:*



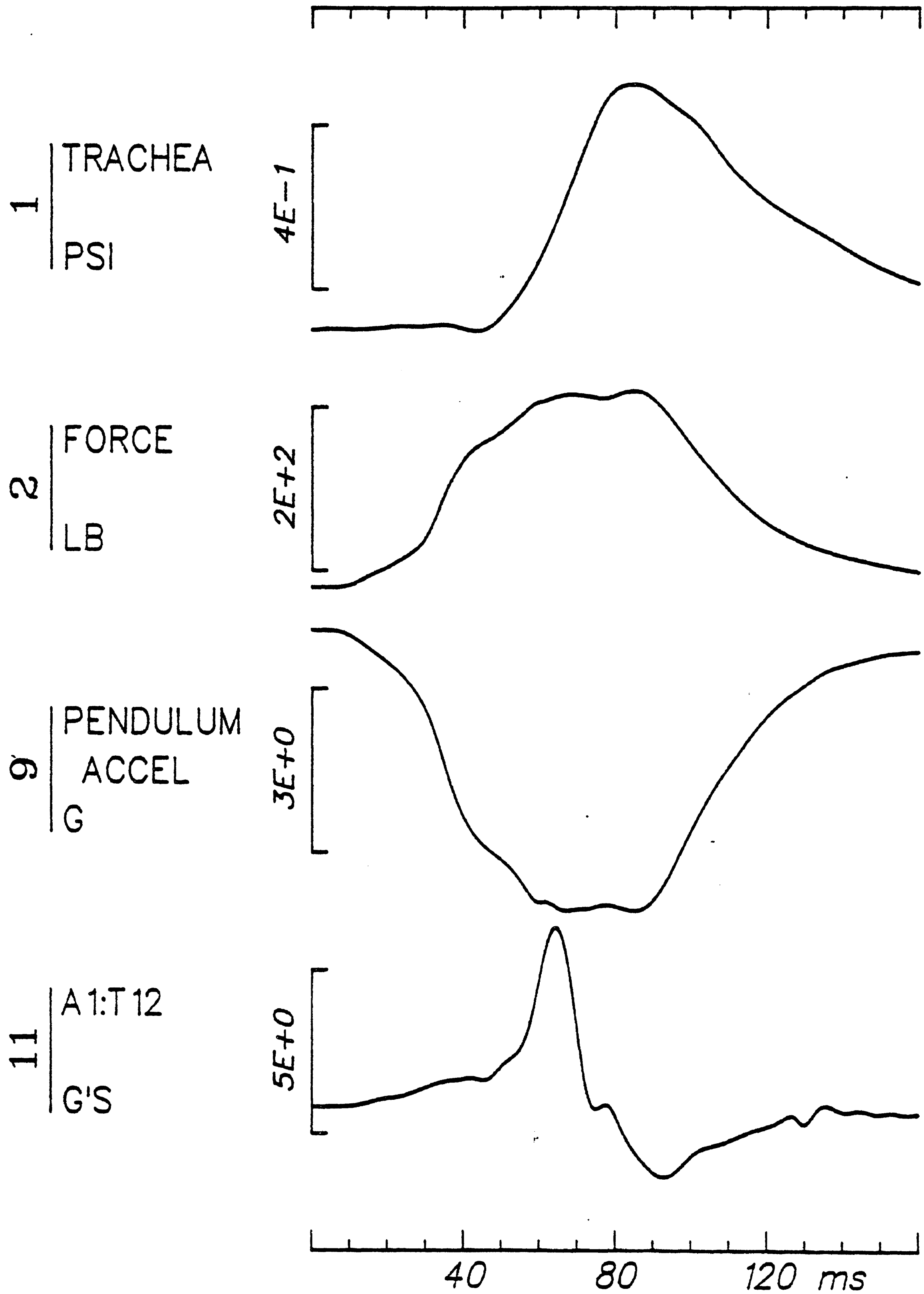
Impact to Abdomen

Run ID: 86M005B AB *Filter: 100*4C Smooth:*



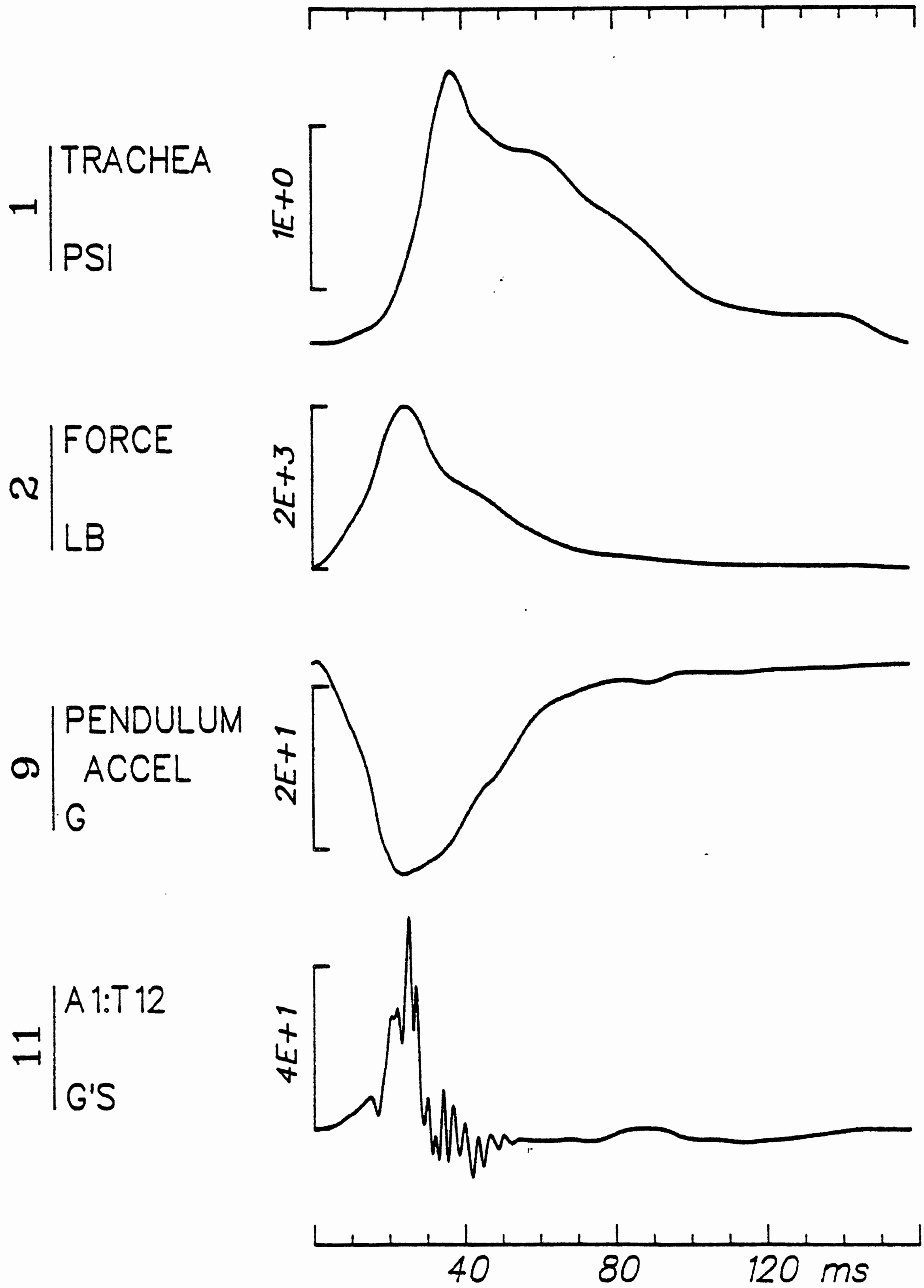
Impact to Abdomen

Run ID: 86M005C AB *Filter: 100*4C Smooth:*



Impact to Abdomen

Run ID: 86M006 AB *Filter: 400*4C Smooth:*



High Velocity Impact 10-m/s