UM-HSRI-79-4

CALIBRATION AND TEST PROCEDURES FOR 3-YEAR-OLD-CHILD DUMMY

FINAL REPORT

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16. Abstract

Four three year old child dummies, SA 103C models, were tested at HSRI and TRC of Ohio to determine the ranges of responses of these dummies in calibration type tests and to refine testing fixtures and techniques. The dummy head accelerometer mounting was revised to reduce ringing, and the ribcage structure attachment modified to eliminate bottoming. A revised loading fixture was designed to facilitate the lumbar spine calibration. The modified dummies produced consistent calibration response data within the proposed limits of Docket 78-09 at both HSRI and TRC laboratories.

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1.0 FOREWORD

Initial calibration testing of the SA 103-C three-year-old-child dummies at HSRI and TRC of Ohio resulted in significant differences in dummy response characteristics between the two laboratories. It was the intent of this program to investigate and if possible to resolve and eliminate these differences with closely monitored and coordinated testing at each laboratory.

2.0 SUMMARY

Four three-year-old-child dummies underwent preliminary calibration testing and evaluation at HSRI and at the NHTSA Engineering Test Facility at TRC of Ohio. Initial test data resulted in design changes to the dummy head accelerometer mounting and the dummy ribcage attachment to provide a more consistent impact response. The lumbar spine calibration test fixture was also modified to facilitate load applications and thereby improve repeatability. Retesting with these modifications produced calibration response data that fell within the proposed requirements of Docket No. 78-09. General agreement of calibration test results at the HSRI and TRC laboratories was obtained on the four dummies.

3.0 METHODOLOGY

3.1 Objectives

The overall objective of the program was to determine the ranges of responses of the SA 103-C child test dummies in specified calibration testing and to diminish or eliminate the variability of the responses obtained in earlier tests at HSRI and TRC of Ohio. This was pursued in the following manner:

3.2 Procedures

3.2.1 All the dummy test fixtures at HSRI were duplicated from the TRC designs to eliminate this possible source of error. Specific design details of these test fixtures are available in the NHTSA Technical Report DOT-HS-803-530.

3.2.2 All test procedures at HSRI followed TRC practice as closely as possible.

3.2.3 Test fixture design was modified whenever more consistent dummy response could be obtained with the change.

3.2.4 Design changes were incorporated in the dummy whenever inconsistent response was determined to be an inherent result of the dummy's structure.

3.2.5 Test fixture materials such as Teflon sheet and Hexcell aluminum honeycomb were exchanged between the two laboratories whenever such materials were suspect in causing dummy response differences.

3.3 Facilities

The following test equipment was fabricated at HSRI for child dummy calibration testing:

3.3.1 A wire suspended pendulum weighing 10 lbs. 7.5 oz. for conducting head and thorax impact tests.

3.3.2 A seating platform for the dummy for use during head and thorax impact tests.

3.3.3 A platform to which the dummy can be attached to conduct the lumbar spine bending tests.

Already existing equipment used in this project consisted of:

3.3.4 A neck test pendulum

3.3.5 An adjustable height rigid platform to which the dummy seating platform was attached.

Instrumentation consisted of:

3.3.6 Honeywell model 7600 14 channel FM tape recorder.

3.3.7 Honeywell Accudata model 120 bridge balance signal conditioner.

3.3.8 Honeywell Accudata model 105 D.C. amplifier.

3.3.9 Endevco model 2264-2000 accelerometers for the dummy head and thorax.

3.3.10 Photodiode light trap for pendulum velocity measurement.

3.3.11 PDP-11 computer for digitizing, filtering, and processing of data.

4.0 RESULTS

4.1 Head Response

Initial testing indicated excessive vibration in the head impact response. A design change to the accelerometer mounting block was incorporated in the head and the dummies retested. Satisfactory agreement between HSRI and TRC data was obtained, and the ringing adequately reduced. It should be noted that the lateral (R-L) head response in the HSRI data is quite often above the 5G maximum. Very accurate positioning of the dummy and smooth and repeatable loading and release of the pendulum to obtain a perfectly symmetrical impact are required to maintain the lateral head response component within specification.

TABLE 4.1.1

HEAD TEST

DUMMY NO.	TEST NO.	PEAK RESULTANT ACCELERATION(G)	PEAK LATERAL ACCELERATION(G)	TIME ABOVE 50 G LEVEL (MILLISECONDS)
031	78K 128	103.2	14.1	2.0
	78K 129	110.4	17.2	2.1
	78K 130	111.2	18.7	2.1
	78K 131	105.6	18.3	2.1
	78K 132	106.4	15.3	2.1
	78K 133	108.8	16.2	2.2
	AVERAGE	107.6	16.6	2.1
032	78K 134	105.6	3.1	2.3
	78K 135	99.2	3.8	2.2
	78K 136	108.6	4.0	2.2
	78K 137	109.5	3.6	2.1
	78K 138	103.2	4.5	2.2
	78K 139	108.6	4.2	2.1
	AVERAGE	105.8	3.9	2.2
038	78K 122	111.2	7.8	2.3
	78K 123	111.2	6.2	2.4
	78K 124	111.2	4.5	2.4
	AVERAGE	111.2	6.2	2.4
039	78K 125	109.6	19.6	2.3
	78K 126	108.0	15.9	2.0
	78K 127	102.4	14.5	2.1
	AVERAGE	106.7	16.7	2.1
PROPOSED REQUIREMENT		BETWEEN 95 G AND 112 G	LESS THAN 5 G	BETWEEN 2.0 AND 3.0 MILLISECONDS

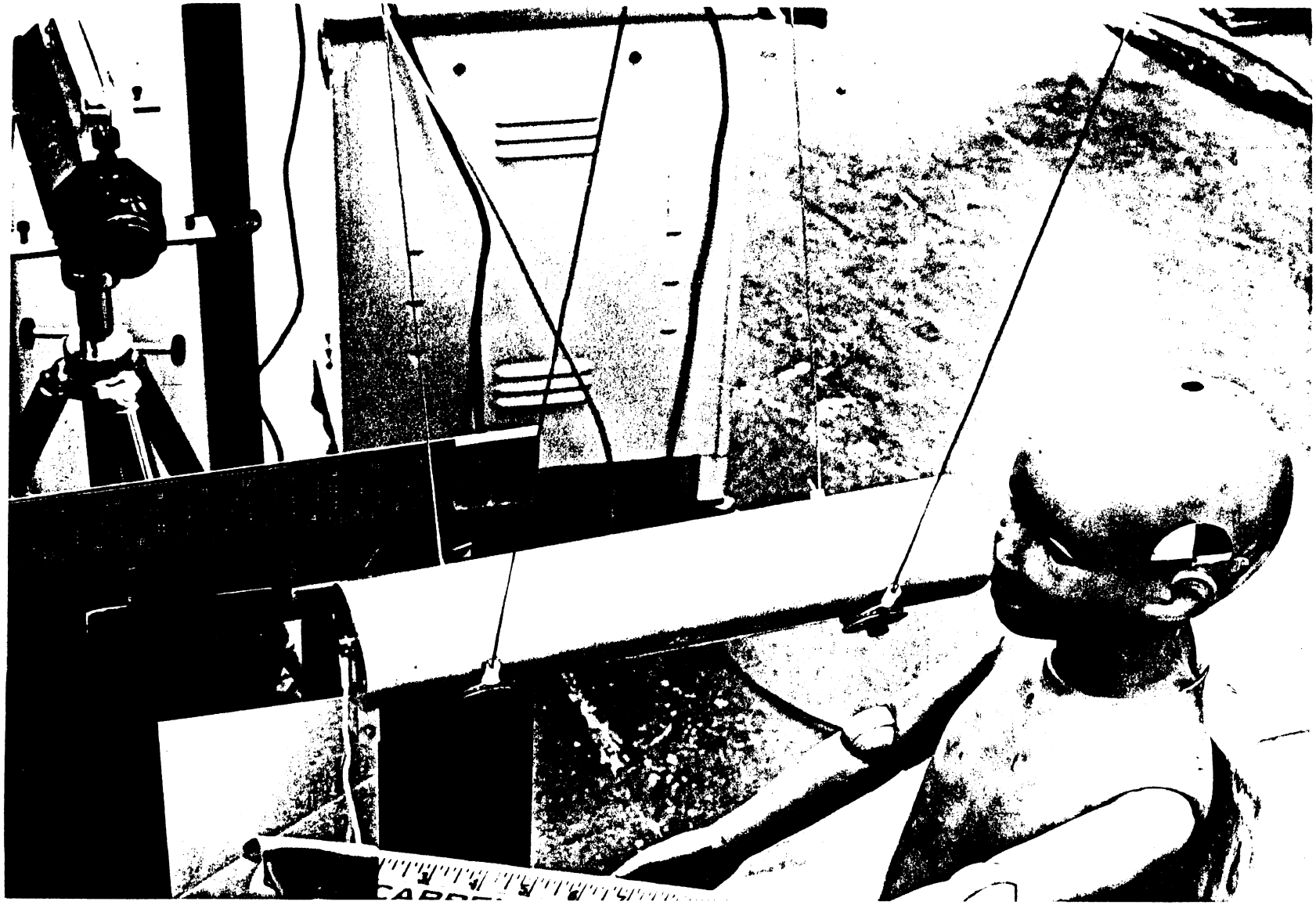

FIGURE 1 - Head Impact Test Setup

4.2 Chest Response

Bottoming of the molded ribcage against the thoracic frame was identified as the cause of inconsistent chest response data and a bimodal waveform of the chest resultant acceleration. A design change was incorporated which fastened the top of the ribcage to the thoracic frame. With this modification, bottoming was eliminated, a unimodal waveform for the chest resultant acceleration was obtained, and the HSRI and TRC chest response data were in essential agreement. However, great care must be taken in dummy positioning to obtain consistent data (See 6.0 Discussion).

TABLE 4.2.1

THORAX TEST

DUMMY NO.	TEST NO.	PEAK RESULTANT ACCELERATION	PEAK LATERAL ACCELERATION	TIME ABOVE 30 G LEVEL
031	78K-248	64.1 G	2.1 G	3.6 MSEC
	78K-249	63.3 G	2.1 G	3.6 MSEC
	78K-250	62.1 G	1.8 G	3.6 MSEC
	AVERAGE	63.2 G	2.0 G	3.6 MSEC
032	78K-240	54.4 G	1.7 G	3.0 MSEC
	78K-241	62.6 G	3.3 G	3.1 MSEC
	78K-242	61.0 G	3.3 G	3.2 MSEC
	AVERAGE	59.3 G	2.8 G	3.1 MSEC
038	78K-198	55.1 G	1.2 G	3.7 MSEC
	78K-199	56.9 G	1.2 G	3.6 MSEC
	78K-200	63.2 G	1.5 G	3.6 MSEC
	AVERAGE	58.4 G	1.3 G	3.6 MSEC
039	78K-204-1	52.9 G	2.3 G	2.9 MSEC
	78K-204-2	57.6 G	3.7 G	3.1 MSEC
	78K-205	61.2 G	1.9 G*	3.4 MSEC
	AVERAGE	57.2 G	2.6 G	3.1 MSEC
PROPOSED REQUIREMENT		BETWEEN 50 G AND 70 G	LESS THAN 5 G	BETWEEN 2.5 AND 4.0 MILLISECONDS

*Lateral Acceleration During Primary Response; a 21 G Lateral Peak Occurred Later During a Secondary Impact of Piston

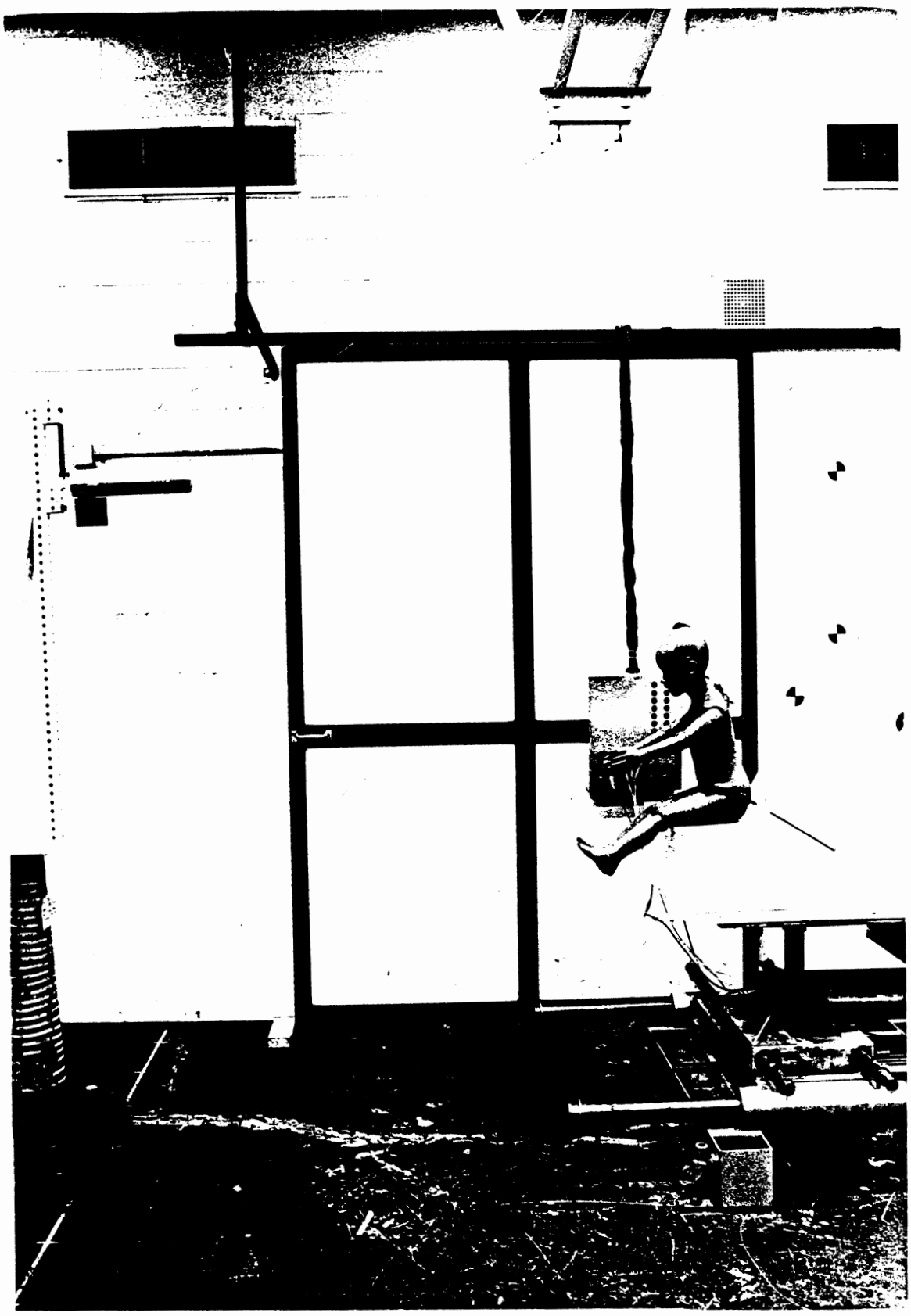

FIGURE 2 - Thoracic Impact Test Setup

4.3 Neck Response

Using the dummy head with the revised accelerometer mounting surface, good agreement with proposed response values was obtained for dummies 031 and 032. An instrumentation malfunction produced a pendulum velocity calibration above specified limits while testing dummies 038 and 039, invalidating the results. However, the head response was also driven above specified limits, indicating the basic sensitivity of the dummy head-neck assembly to this calibration procedure.

TABLE 4.3.1

NECK TEST

HEAD RESULTANT

DUMMY NO.	TEST NO.	HEAD RESULTANT-PEAK ACCELERATION (G)	PROPOSED REQUIREMENT
031	78 K 150	23.8	PEAK HEAD RESULTANT SHALL NOT EXCEED 30 G'S
	78 K 151	24.2	
	78 K 152	24.2	
	AVERAGE	24.1	
032	78 K 147	23.4	
	78 K 148	24.6	
	78 K 149	24.2	
	AVERAGE	24.1	

TABLE 4.3.2

NECK TEST
CHORDAL DISPLACEMENT
FILM ANALYSIS RESULTS

DUMMY NO. 031

HEAD ROTATION	CHORDAL DISPLACEMENT IN INCHES TEST NUMBER 78K150	78K151	78K152	AVERAGE	PROPOSED REQUIREMENT
0°	0.0	0.0	0.0	0.0	-0.8 TO 0.8
30°	2.6	2.5	2.6	2.6	1.4 TO 3.0
60°	4.6	4.5	4.6	4.6	3.5 TO 5.1
MAXIMUM	6.3	6.4	6.5	6.4	5.0 TO 6.6
60°	4.6	4.5	4.5	4.5	3.5 TO 5.1
30°	2.2	2.1	2.2	2.2	1.4 TO 3.0
0°	0.0	0.0	0.0	0.0	-0.8 TO 0.8

DUMMY NO. 032

HEAD ROTATION	CHORDAL DISPLACEMENT IN INCHES TEST NUMBER 78K147	78K148	78K149	AVERAGE	PROPOSED REQUIREMENT
0°	0.0	0.0	0.0	0.0	-0.8 TO 0.8
30°	2.2	2.3	2.5	2.3	1.4 TO 3.0
60°	4.7	4.4	4.5	4.5	3.5 TO 5.1
MAXIMUM	6.4	6.3	6.2	6.3	5.0 TO 6.6
60°	4.7	4.5	4.5	4.6	3.5 TO 5.1
30°	2.6	2.4	2.3	2.4	1.4 TO 3.0
0°	0.0	0.0	0.0	0.0	-0.8 TO 0.8

TABLE 4.3.3

NECK TEST
ROTATION RATE
FILM ANALYSIS RESULTS

DUMMY NO. 031

HEAD ROTATION	TIME IN MILLISECONDS TEST NUMBER 78K150	78K151	78K152	AVERAGE	PROPOSED REQUIREMENT
0°	0.0	0.0	0.0	0.0	-2.0 TO 2.0
30°	22.0	22.2	21.2	21.8	17.3 TO 24.7
60°	32.6	33.9	33.8	33.4	31.1 TO 40.9
MAXIMUM	58.2	63.5	58.2	60.0	55.0 TO 69.0
60°	89.7	93.1	91.9	91.6	81.7 TO 100.3
30°	105.7	108.8	107.1	107.2	97.4 TO 118.6
0°	119.6	120.6	118.5	119.6	111.2 TO 134.8
MAXIMUM HEAD ANGLE	86°	88°	90.2°	88.1°	76° TO 92°

DUMMY NO. 032

HEAD ROTATION	TIME IN MILLISECONDS TEST NUMBER 78K147	78K148	78K149	AVERAGE	PROPOSED REQUIREMENT
0°	0.0	0.0	0.0	0.0	-2.0 TO 2.0
30°	20.6	20.6	21.7	21.0	17.3 TO 24.7
60°	34.8	33.4	34.4	34.2	31.1 TO 40.9
MAXIMUM	61.4	58.2	58.2	59.3	55.0 TO 69.0
60°	89.4	90.0	89.1	89.5	81.7 TO 100.3
30°	104.7	104.7	104.9	104.8	97.4 TO 118.6
0°	118.5	118.5	116.9	118.0	111.2 TO 134.6
MAXIMUM HEAD ANGLE	82.9°	89.5°	84°	85.5°	76° TO 92°

TABLE 4.3.4

NECK TEST

PENDULUM DECELERATION PULSE ANALYSIS

DUMMY NO.	TEST NO.	TIME IN MILLISECONDS $t_2 - t_1$	$t_3 - t_2$	$t_4 - t_3$	AVG. G'S OF PENDULUM IN $t_3 - t_2$
031	78K150	3.3	18.9	3.7	25.9
	78K151	3.1	19.1	3.7	26.7
	78K152	3.3	18.7	3.9	26.3
	AVERAGE	3.2	18.9	3.8	26.3
032	78K147	3.1	18.5	3.1	26.9
	78K148	2.9	18.7	3.3	26.6
	78K149	3.5	19.3	3.5	26.4
	AVERAGE	3.2	18.8	3.3	26.6
PROPOSED REQUIREMENT		LESS THAN 4.0	BETWEEN 18.0 AND 21.0	LESS THAN 4.0	BETWEEN 20 G AND 34 G

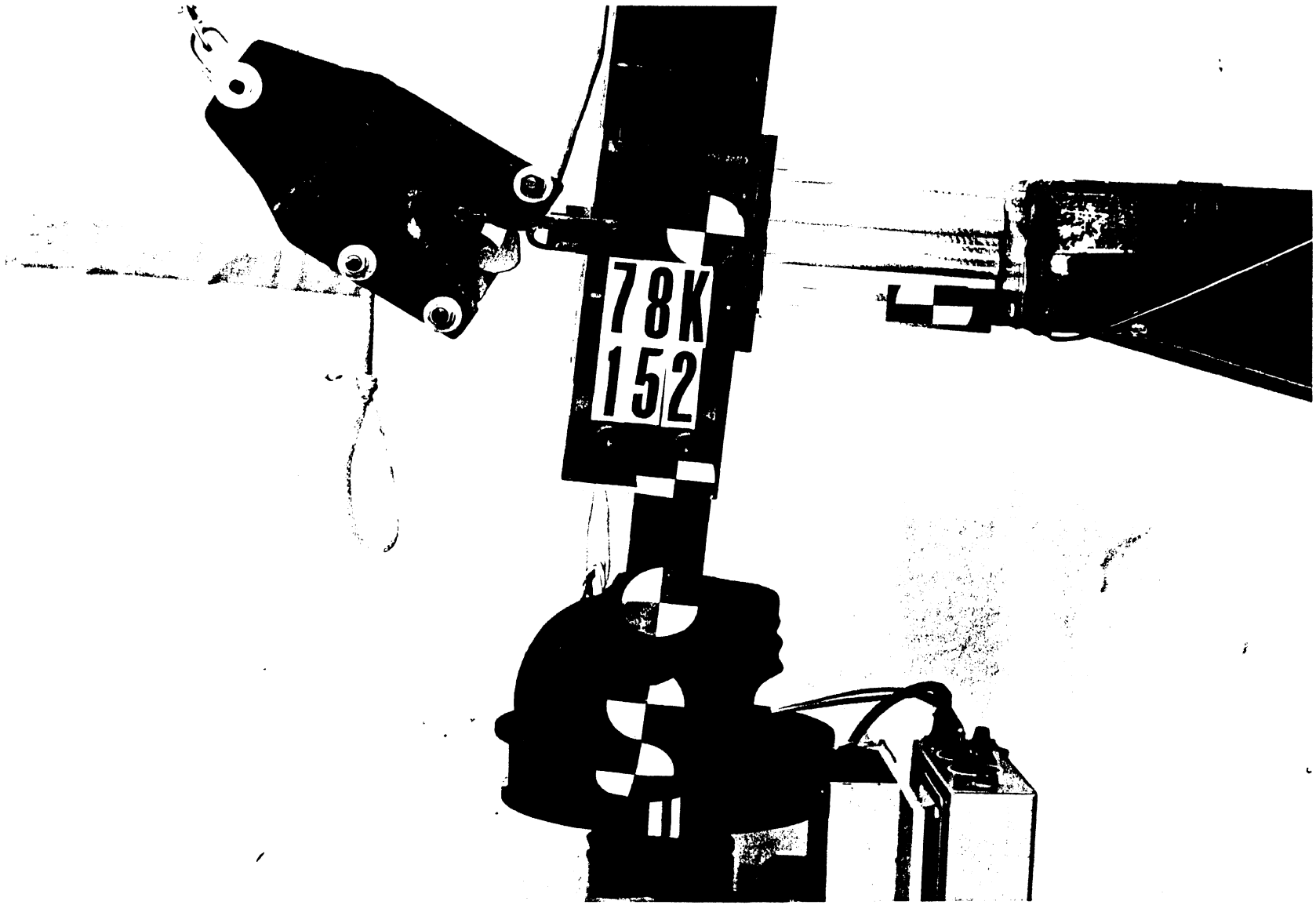

FIGURE 3 - Neck Response Test Setup

4.4 Lumbar Spine Response

The initial method of manually loading the dummy from behind to measure the lumbar spine response proved to be awkward and inconsistent. A revised loading method was devised which substituted a forward tension at a specified angle. A simple cable winch provided the operator with mechanical advantage and the ability to closely control the rate of loading. Angular deflection was obtained from a rotary potentiometer, and a GSE seat belt load cell used to measure the load on the dummy. Each dummy provided remarkably consistent lumbar spine response data, all four dummies were within specification, and HSRI and TRC data were in essential agreement.

TABLE 4.4.1

STATIC LUMBAR SPINE FLEXION
LOAD IN POUNDS

DUMMY NO.	TRIAL NO.	DUMMY THORACIC SPINE ROTATION 0°	10°	20°	30°	40°	UNLOADED NECK ROTATION
031	1	0	16.0	24.0	32.0	35.0	0°
	2	0	16.0	23.2	30.0	36.8	0°
	3	0	15.6	24.0	30.4	36.4	0°
	AVG.	0	15.9	23.7	30.8	36.1	
032	1	0	16.0	25.6	31.0	37.6	0°
	2	0	15.0	23.8	30.0	36.0	1°
	3	0	15.0	23.0	30.0	36.0	0°
	AVG.	0	15.3	24.1	30.3	36.5	
038	1	0	16.0	25.0	32.0	41.0	0°
	2	0	15.5	25.5	32.5	41.5	0°
	3	0	17.0	25.0	32.5	41.0	0°
	4	0	15.5	24.5	32.5	41.0	0°
	5	0	16.0	24.0	31.5	41.5	0°
	6	0	15.0	24.0	31.0	40.0	0°
	AVG.	0	15.8	24.7	32.0	41.0	
039	1	0	18.0	29.0	37.5	46.0	0°
	2	0	19.0	28.5	37.0	46.5	0°
	3	0	19.0	28.5	37.0	46.0	0°
	4	0	19.0	28.5	37.5	46.5	0°
	5	0	18.5	27.5	36.5	46.0	0°
	6	0	19.0	28.0	35.5	45.5	0°
	AVG.	0	18.8	28.3	36.8	46.1	
PROPOSED REQUIREMENT		-	-	-	-	34 TO 47 LBS	WITHIN 5° OF INITAL POSITION

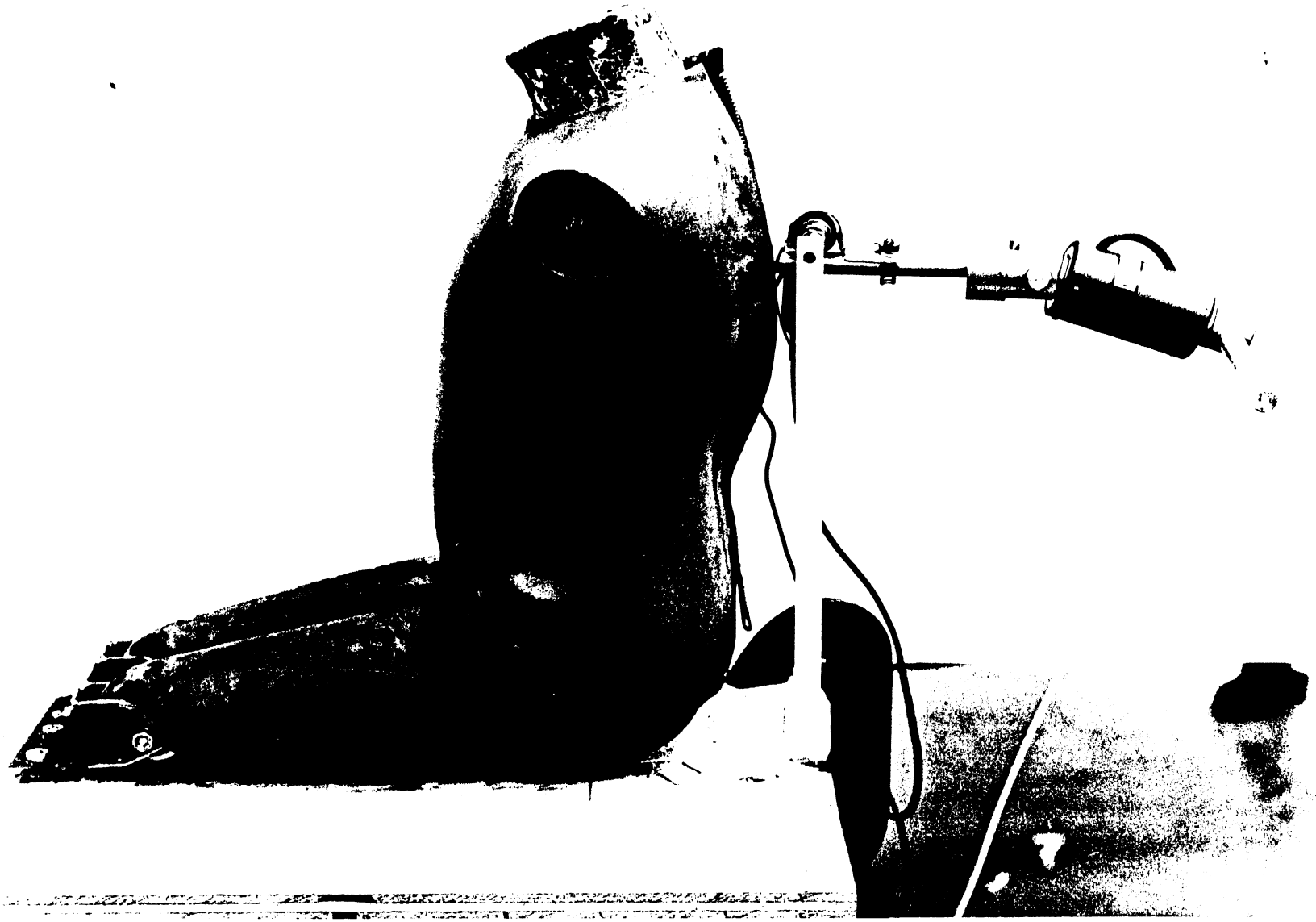

FIGURE 4 - Original Rear Loading Lumbar Spine Test Setup

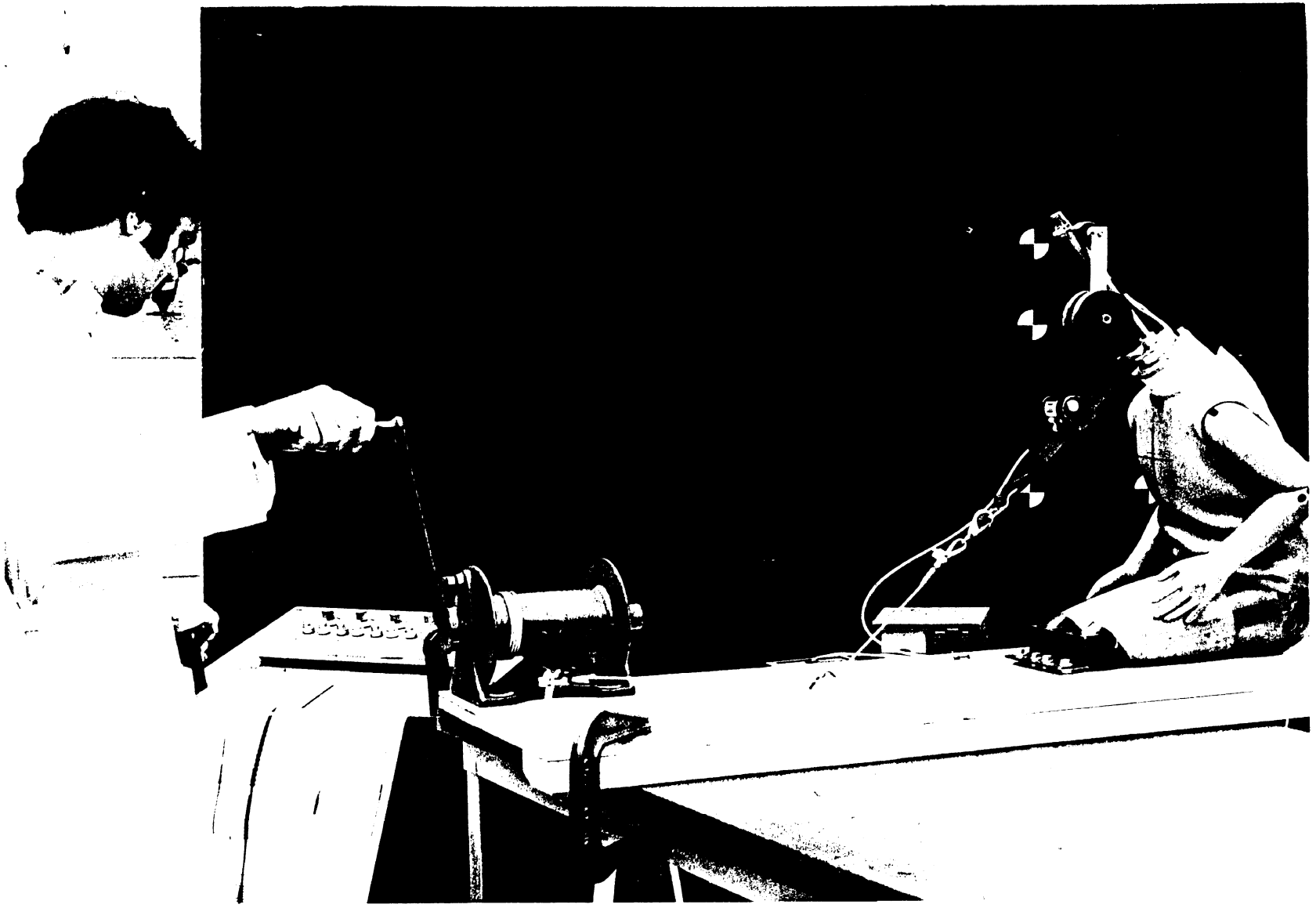

FIGURE 5 - Improved Forward Loading Lumbar Spine Test Setup

5.0 Conclusions

1. The SA 103C 3-year-old-child dummy, as modified, will provide consistent calibration response data within the proposed limits specified in Docket 78-09.

2. Accurate positioning of the dummy is very critical to maintain the lateral response component for both head and chest impacts below the proposed 5G limit.

3. Molded surface irregularities of the chest skin contribute to inconsistencies in the lateral component of chest calibration data by providing off-center interaction with the impact piston.

4. The attachment of the front upper edge of the dummy ribcage to the thoracic frame results in consistent, unimodal calibration response data by eliminating ribcage bottoming, but increases the response sensitivity to the height of the impact on the chest.

6.0 DISCUSSION

While the three-year-old dummy, with a revised head accelerometer mounting and ribcage attachment modifications, meets the requirements of proposed Docket No. 78-09, the head and chest impact responses are both sufficiently dependent upon the test technique that further comment is required. It is the opinion at HSRI that several common factors contribute to this sensitivity of the head and chest regions. They are:

1. Irregularities in the molded skin surface can contribute to initial off-center loading of the impact piston. This is especially a problem in the chest region, which is nearly planar, and therefore more susceptible to this condition.

2. The four wire suspension system provides inadequate control of the impact piston trajectory.

The chest region also has additional factors contributing to impact response inconsistencies:

3. The attachment of the upper front of the ribcage to the thoracic frame to eliminate bottoming of the ribcage and reduce ringing of the response data introduced a marked sensitivity to the vertical impact point of the piston on the chest.

4. The molded skin of the dummy chest tends to shift slightly between impacts, moving the target point stenciled on its surface for piston alignment relative to the ribcage. The resulting vertical change in impact point, coupled with the sensitivity problem mentioned above, can drive the chest response data outside the specified limits.

7.0 RECOMMENDATIONS

It is the opinion at HSRI that the following procedures would reduce the level of dependency on technique in the calibration of the three-year-old child dummy:

1. The impact point on the chest should be remeasured and remarked on the chest skin before each impact to obtain consistent response data.

2. An improved suspension system for the impact piston should be investigated which would provide better trajectory control.

3. Consideration should be given to a slightly spherical rather than planar face on the impact piston to reduce the effects of off-center impacts due to the irregularities of the molded dummy skin.

8.0 ACKNOWLEDGEMENTS

The authors wish to acknowledge the close coordination efforts and technical assistance of the contract manager, Mr. Vladislav Radovich, and the cooperation extended by the NHTSA Engineering Test Facility at TRC of Ohio. We also wish to express our appreciation to the Sled Lab staff at HSRI for their contributions to this program. In particular, we wish to recognize Donald Erb, Instrument Maker, Thomas Tann, Research Assistant, and Stan Schneider and Gil VanDeventer, Engineering work-study students, for their vital role in test equipment fabrication which permitted the project to proceed on schedule.

9.0 APPENDIX

9.1 HEAD RESPONSE TEST DATA PLOTS

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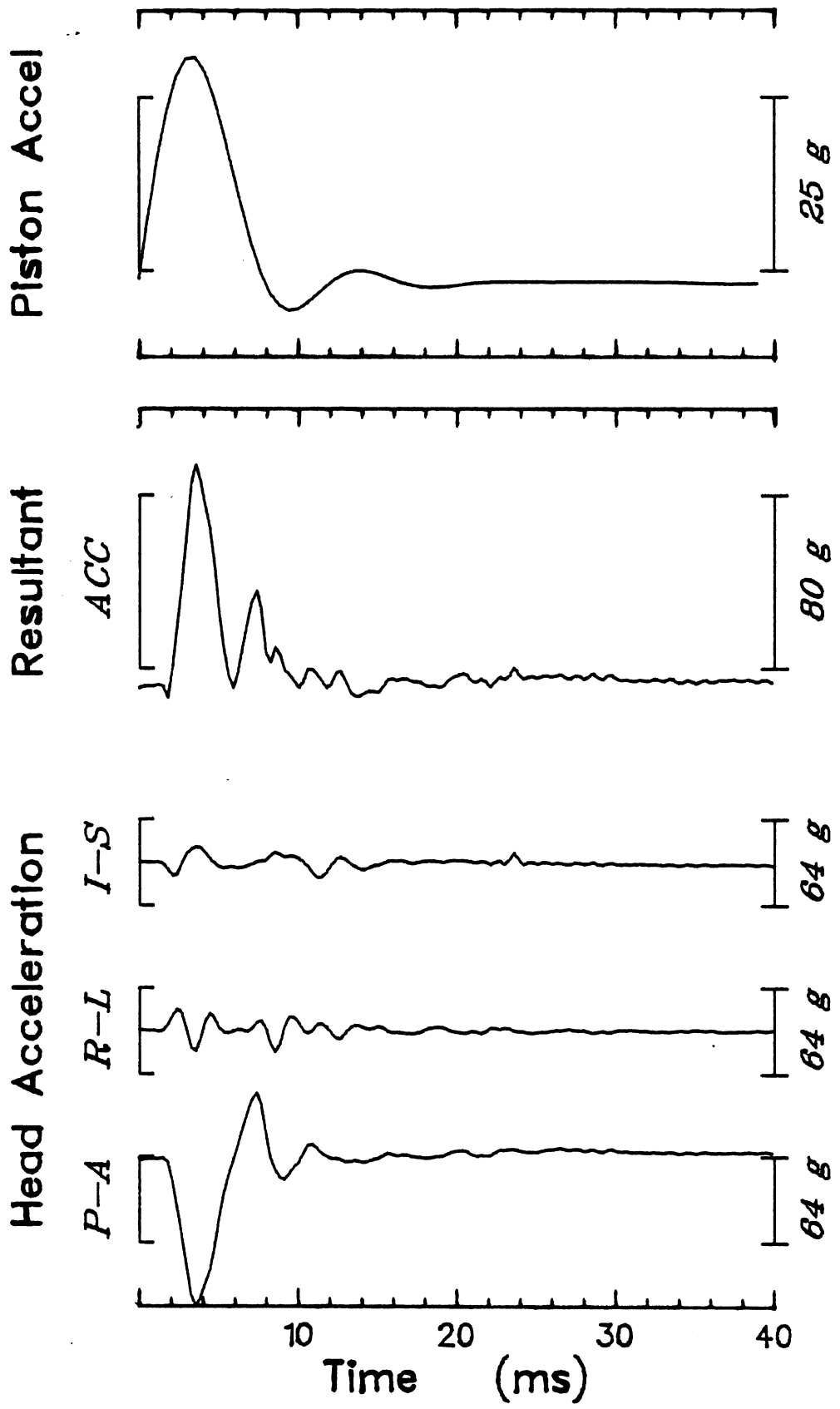

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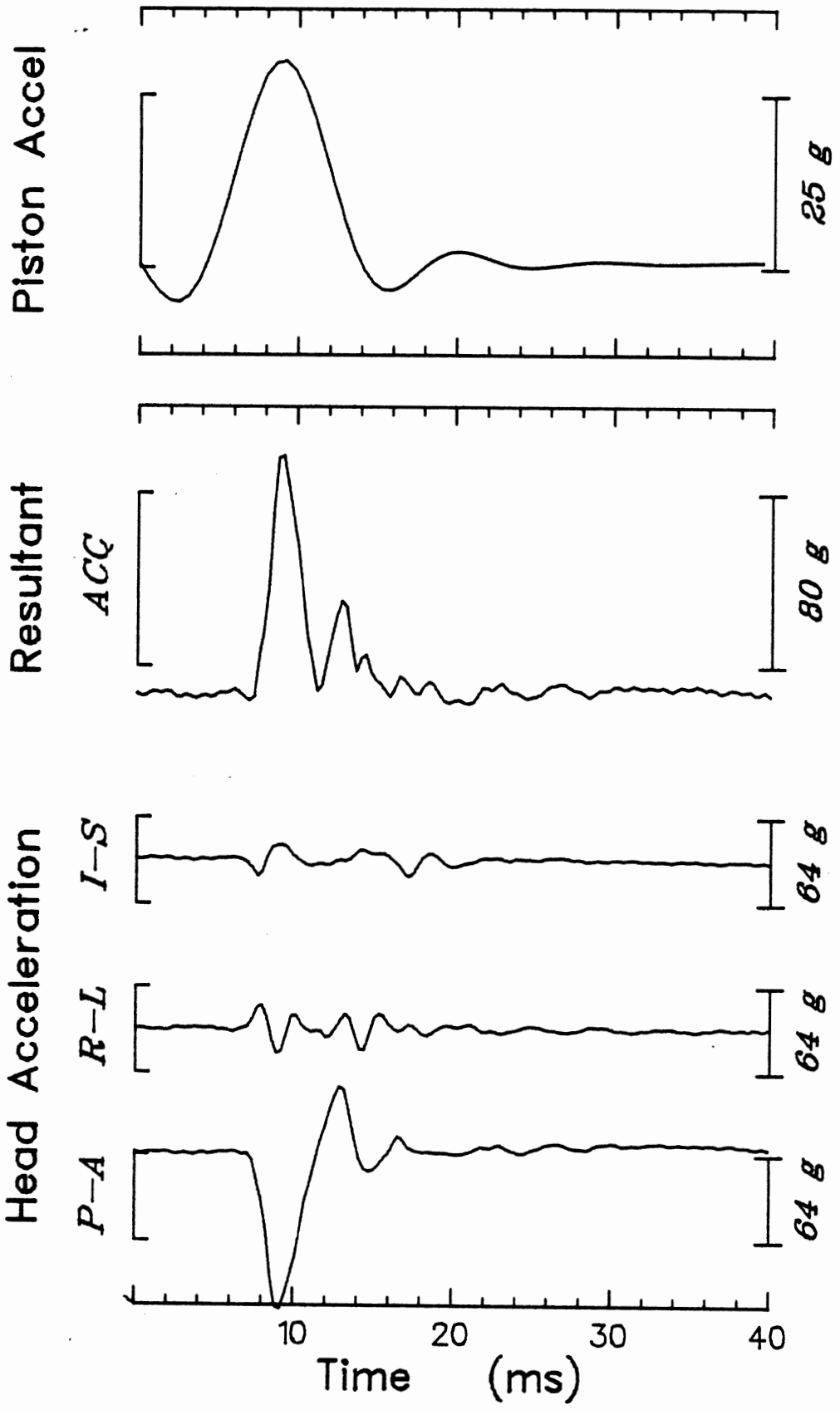

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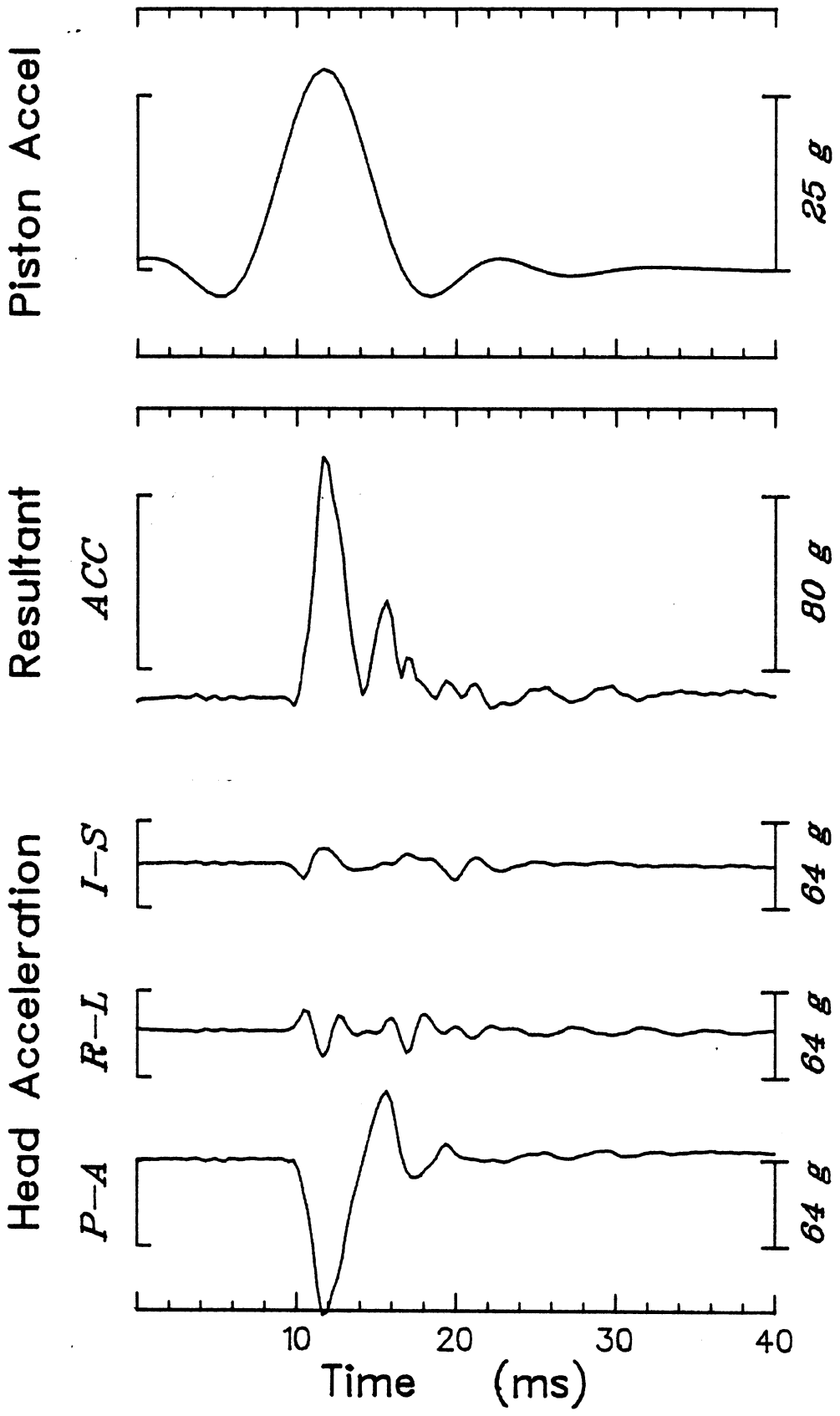

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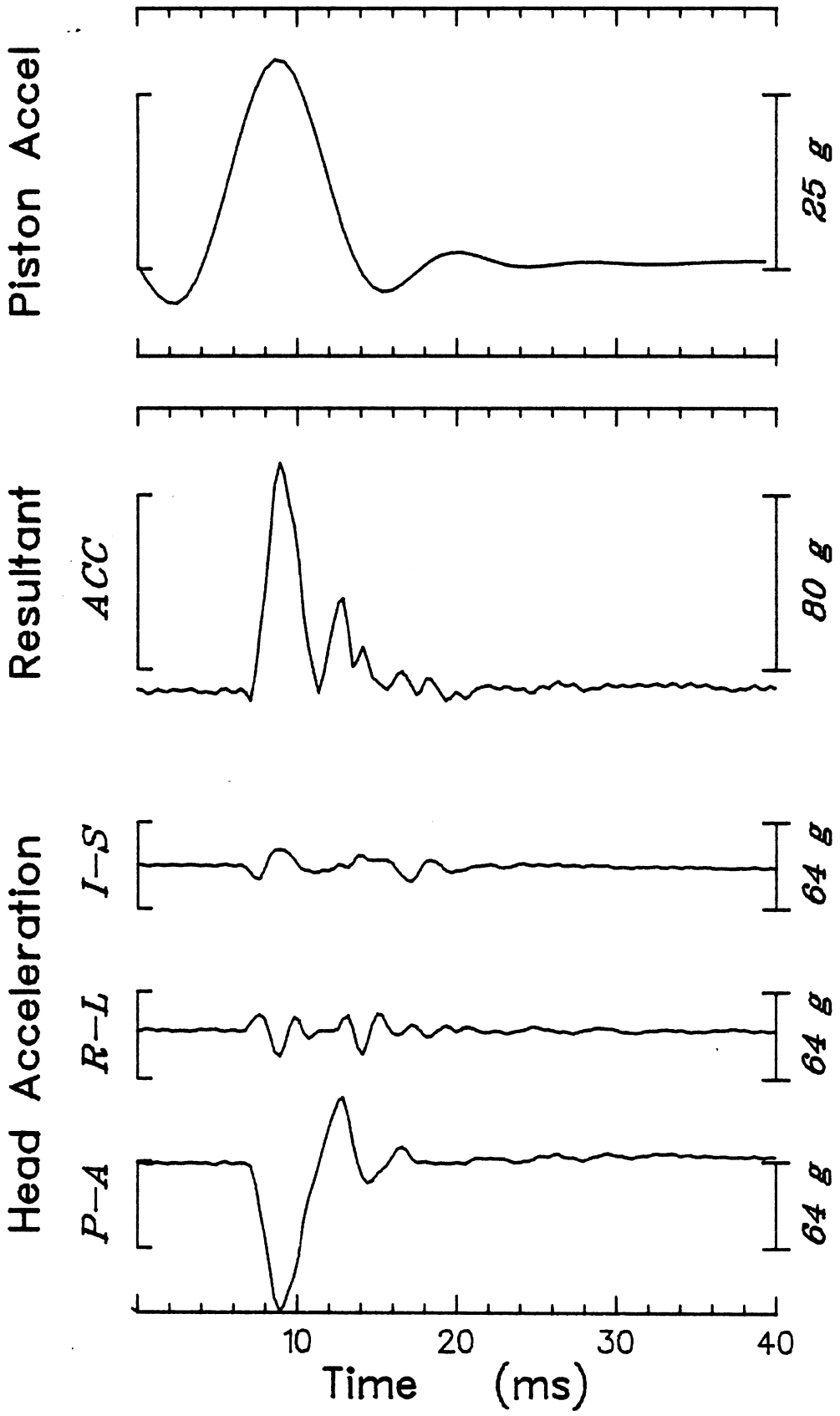

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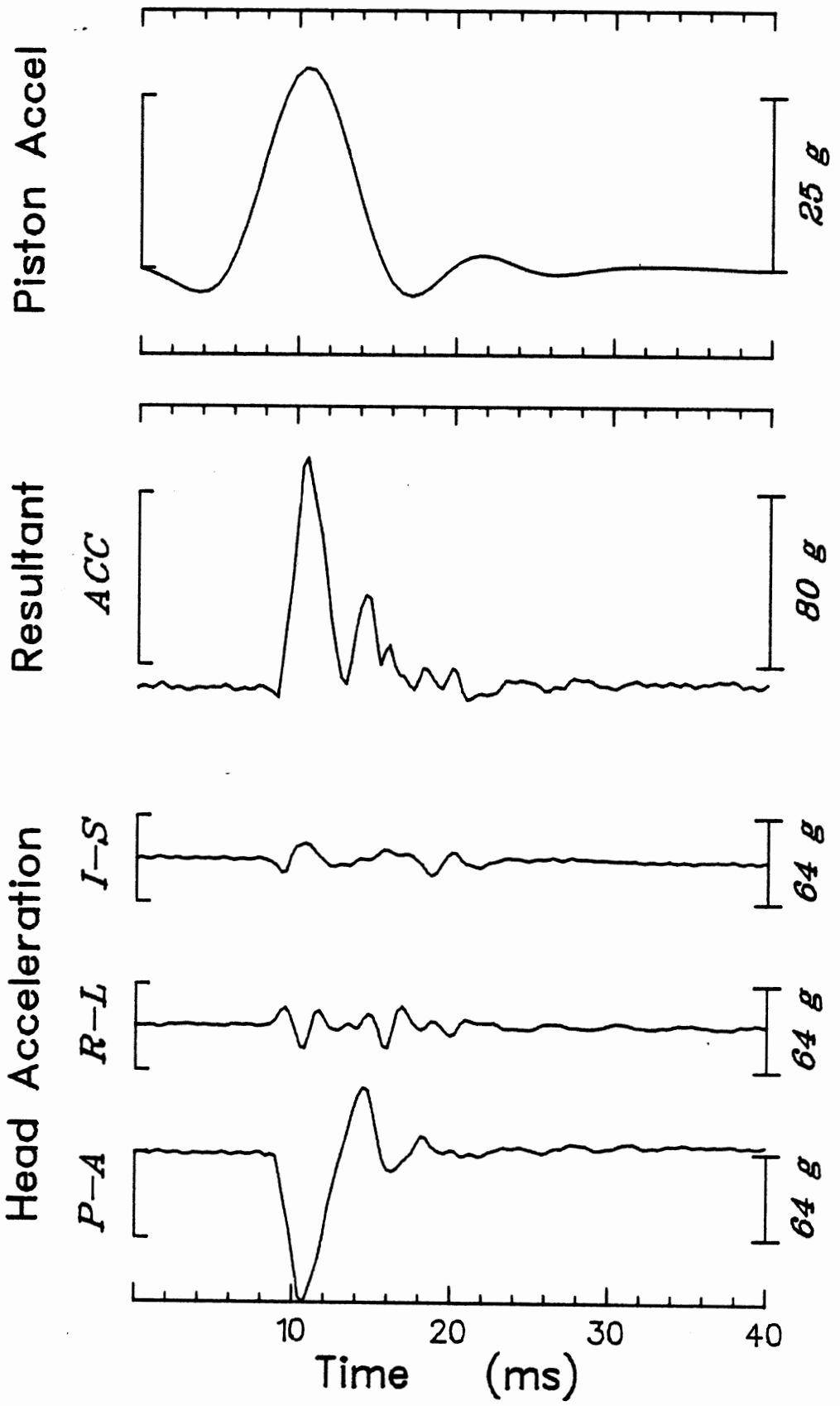

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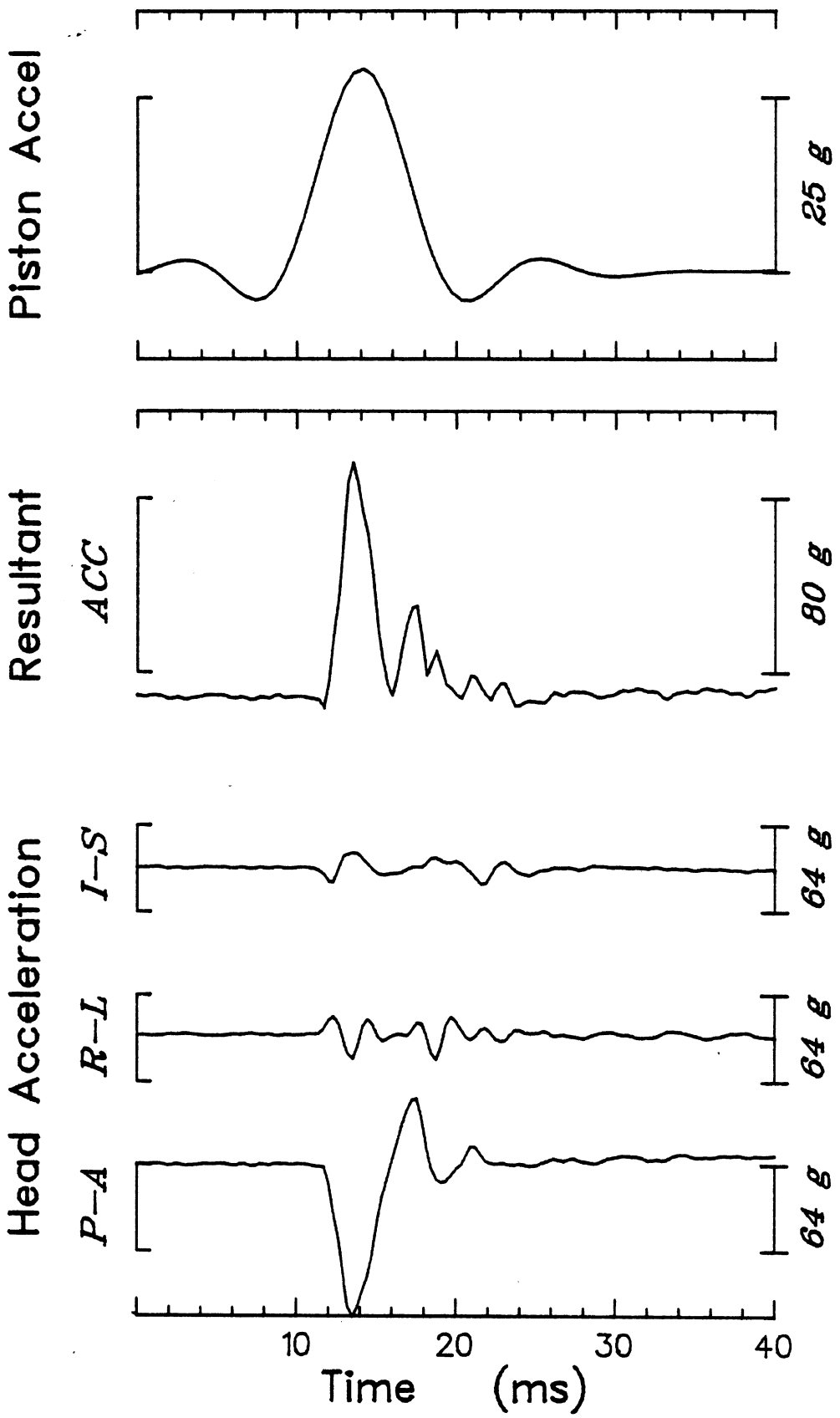

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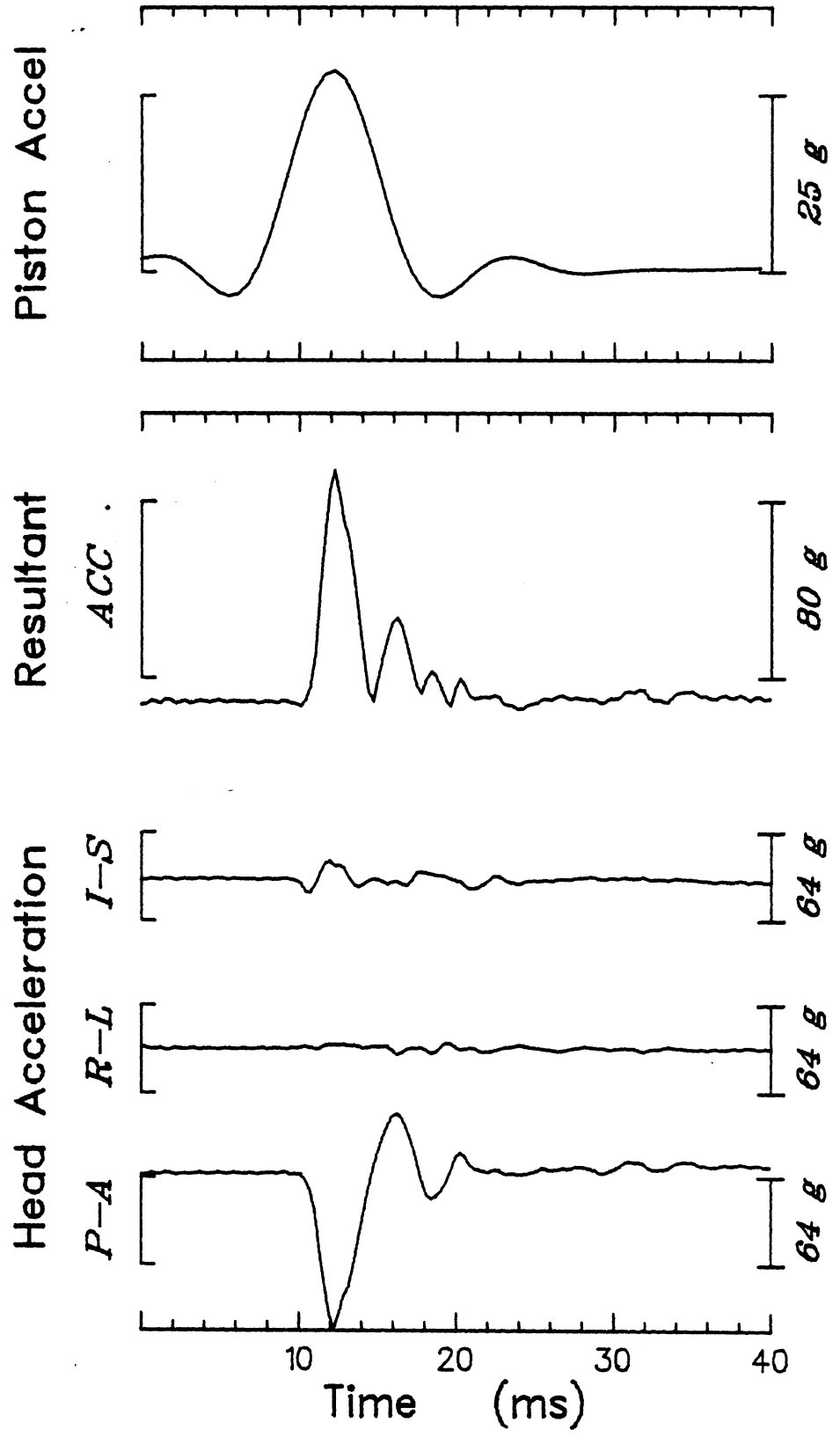

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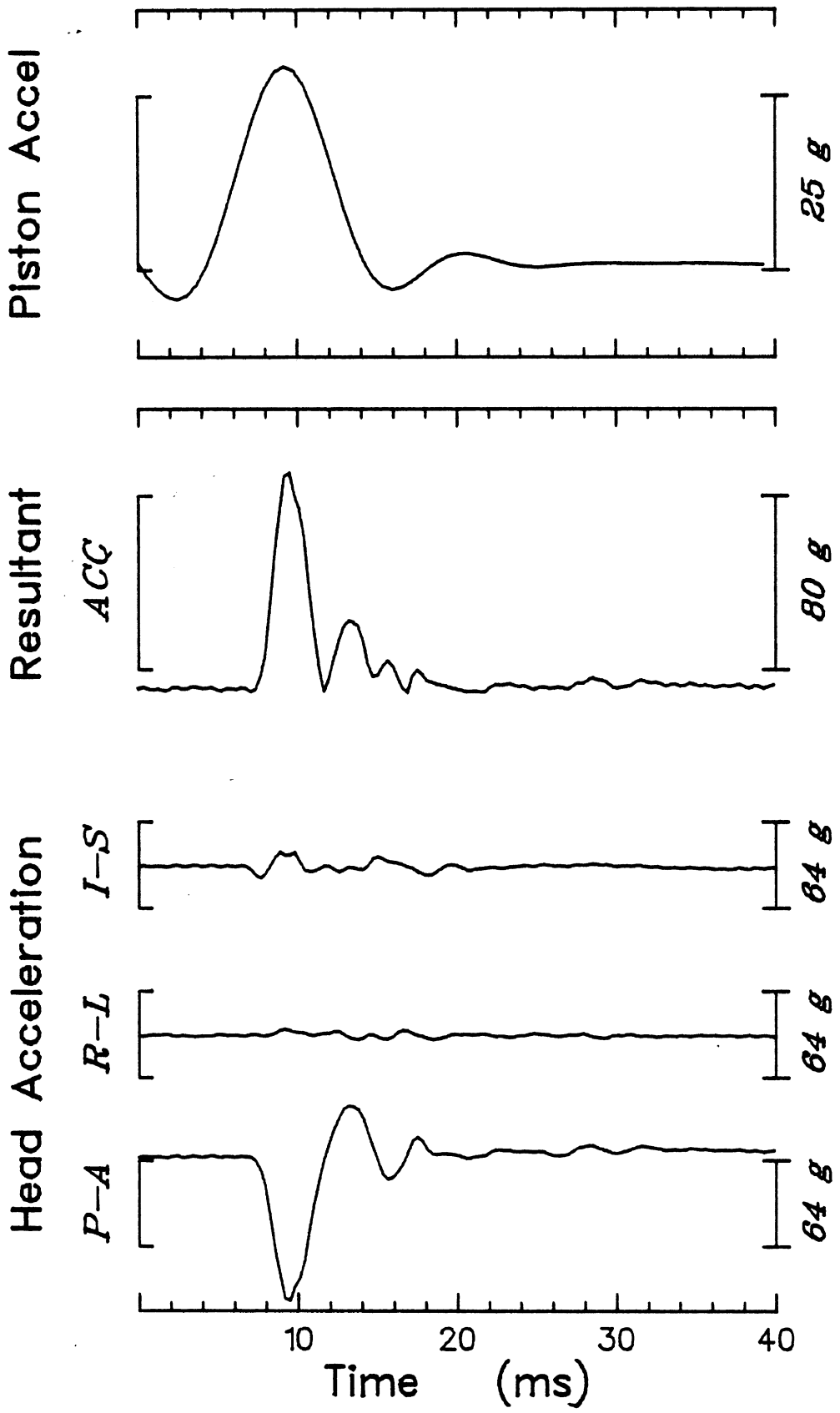

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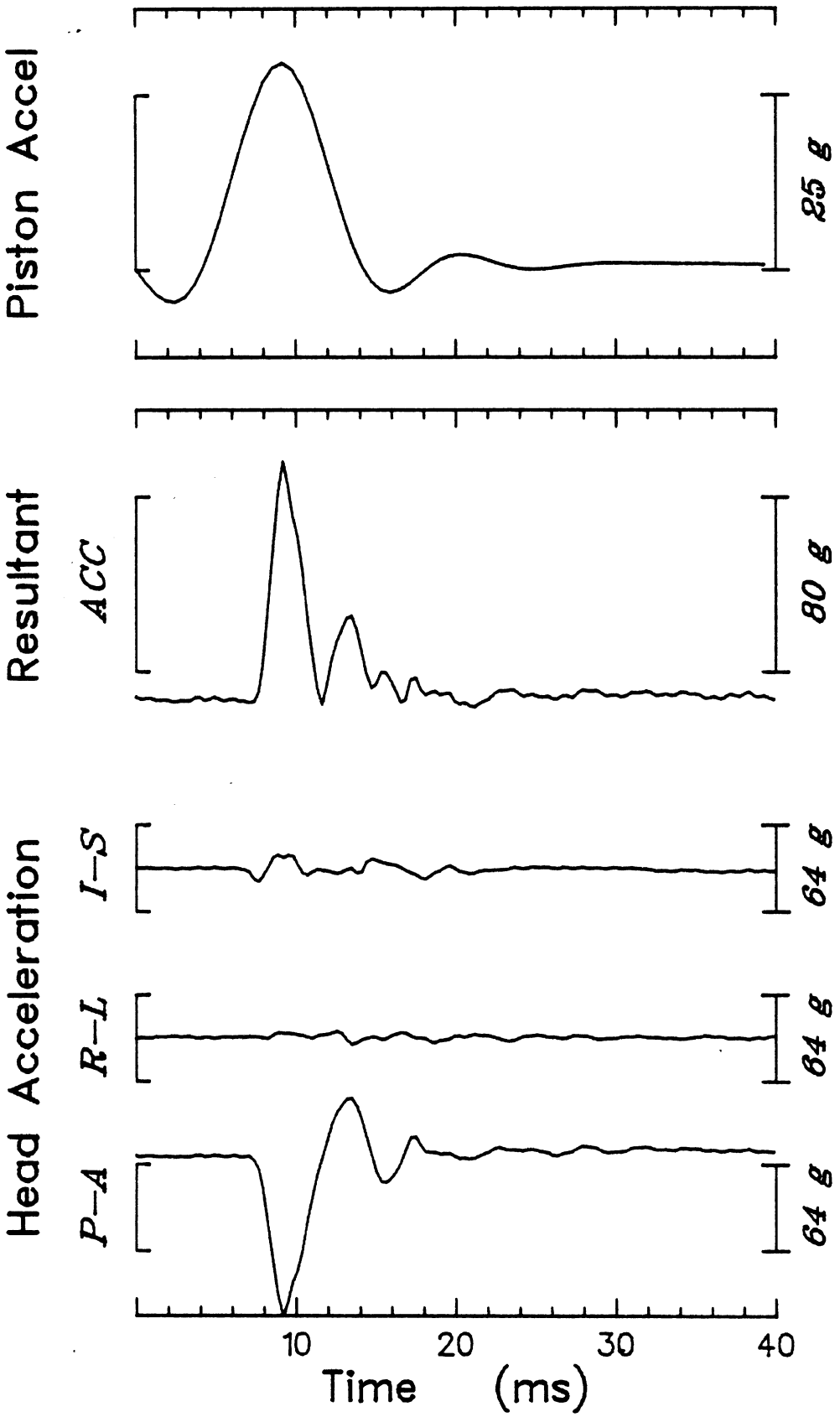

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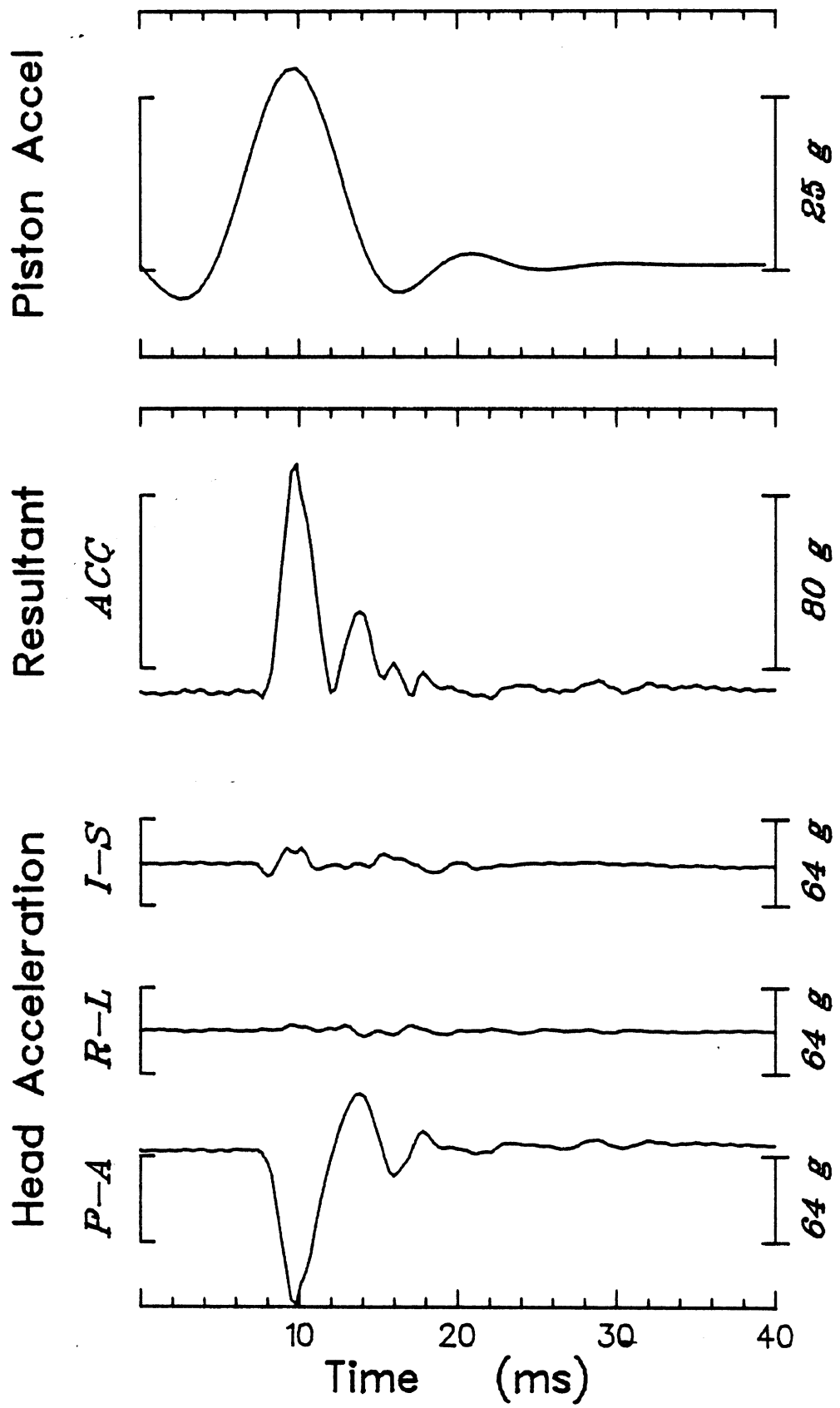

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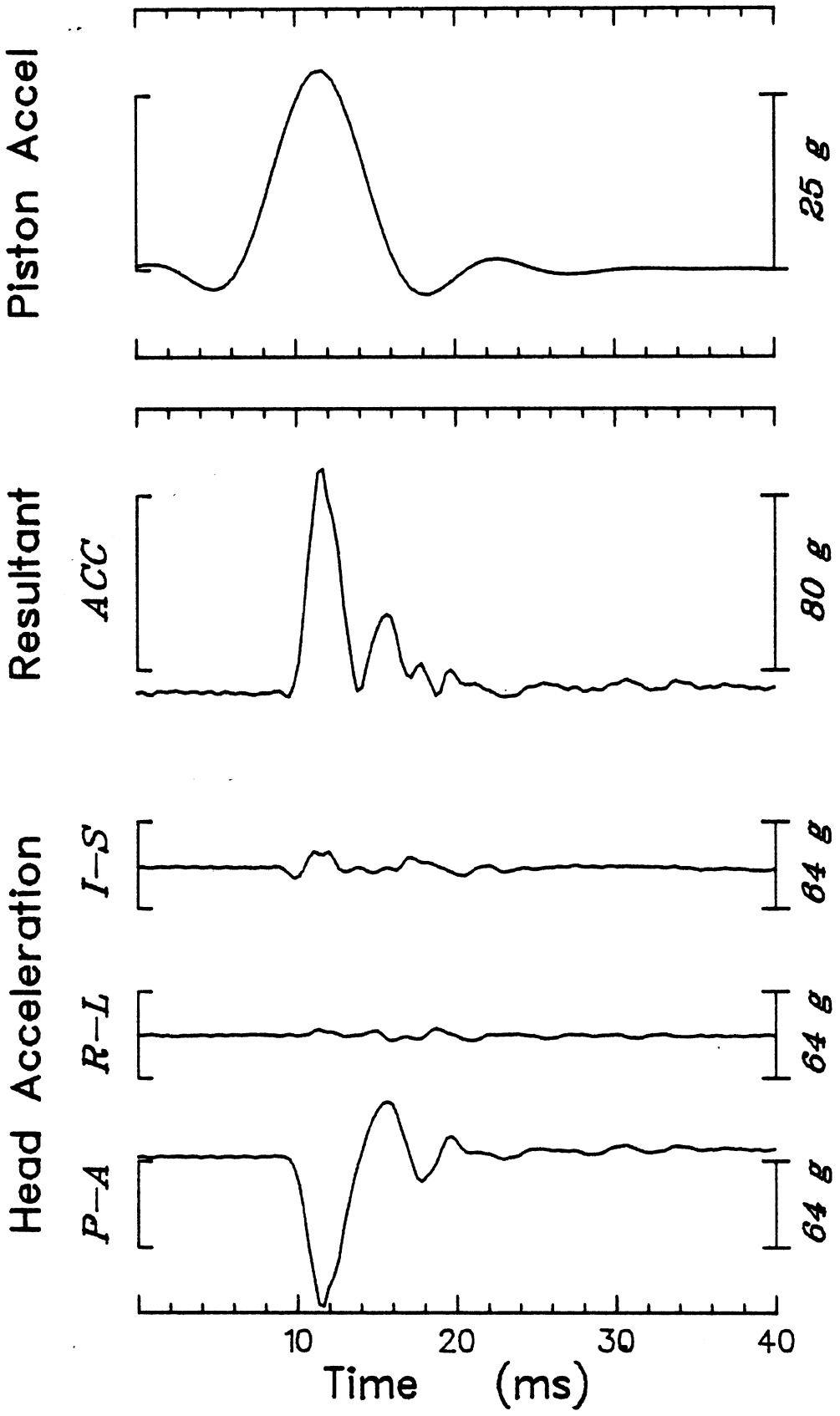

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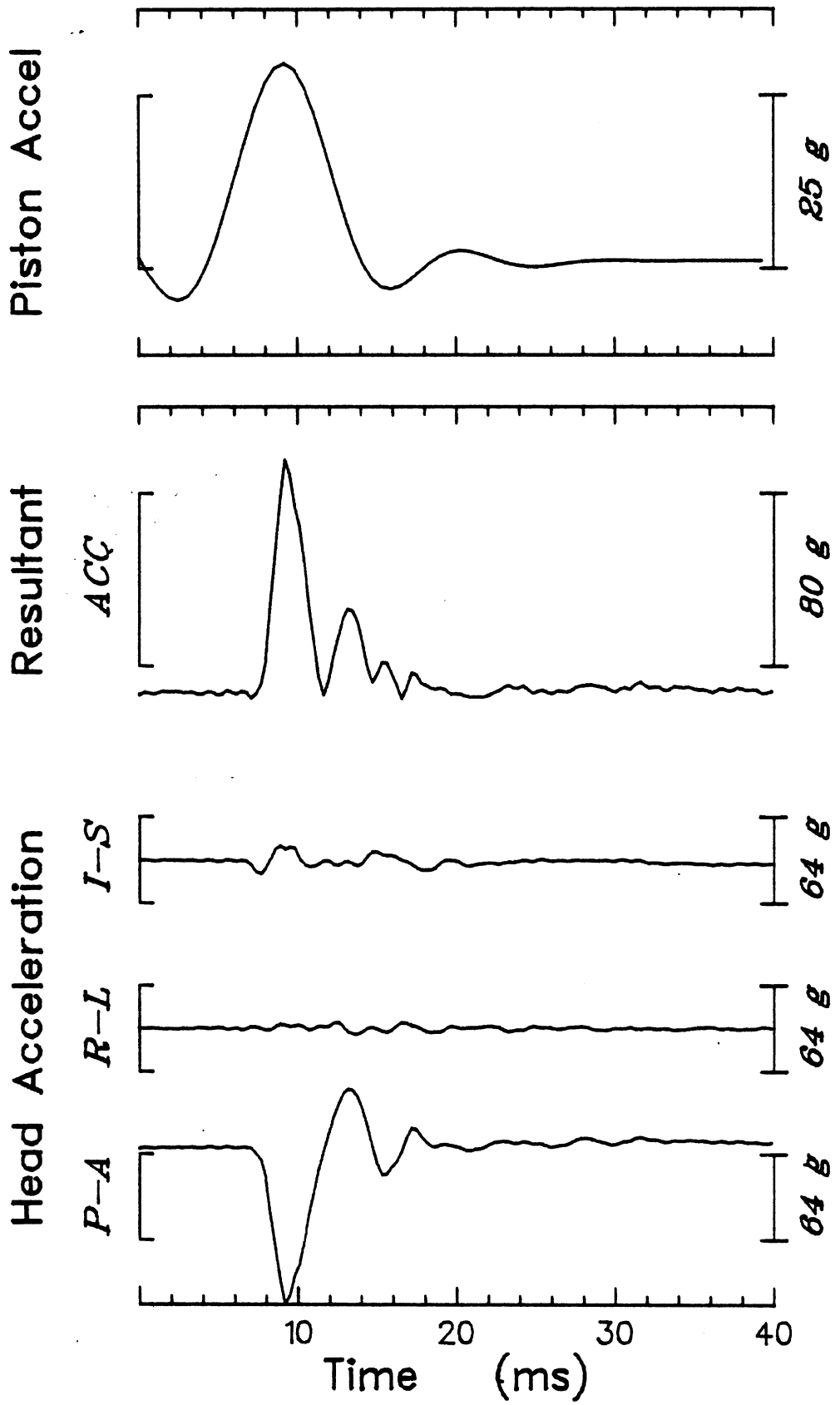
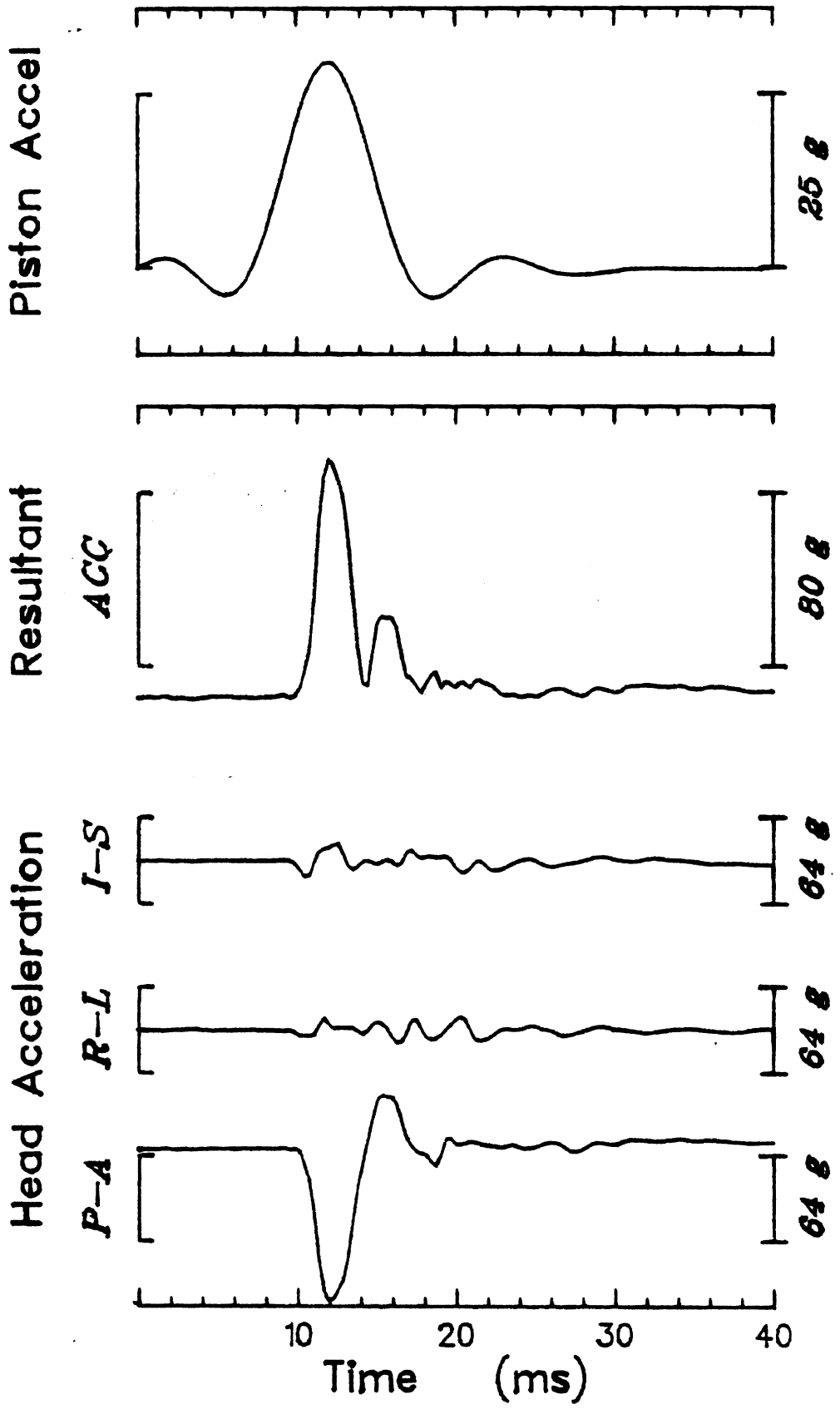
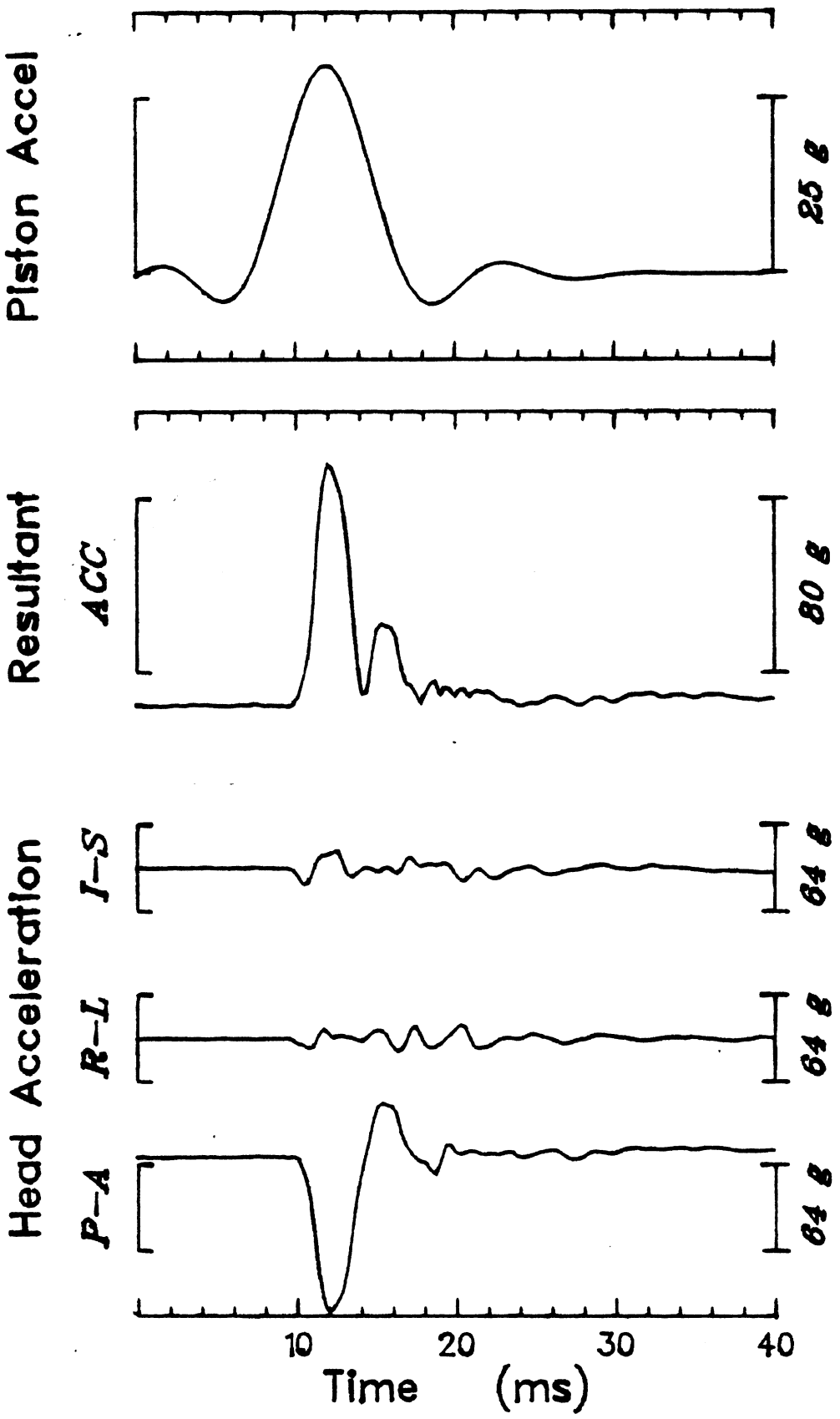


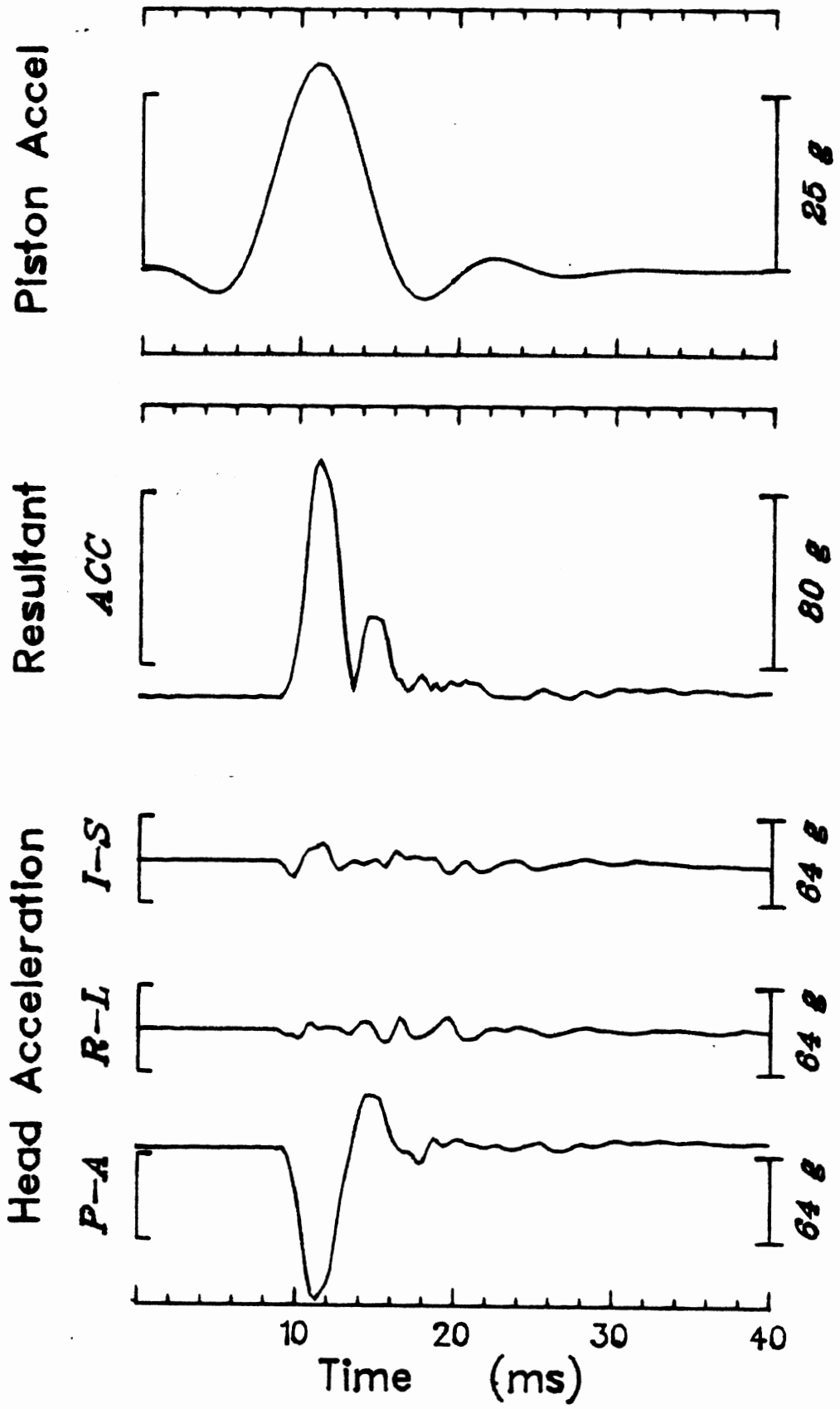
Test No. 78K122 H38



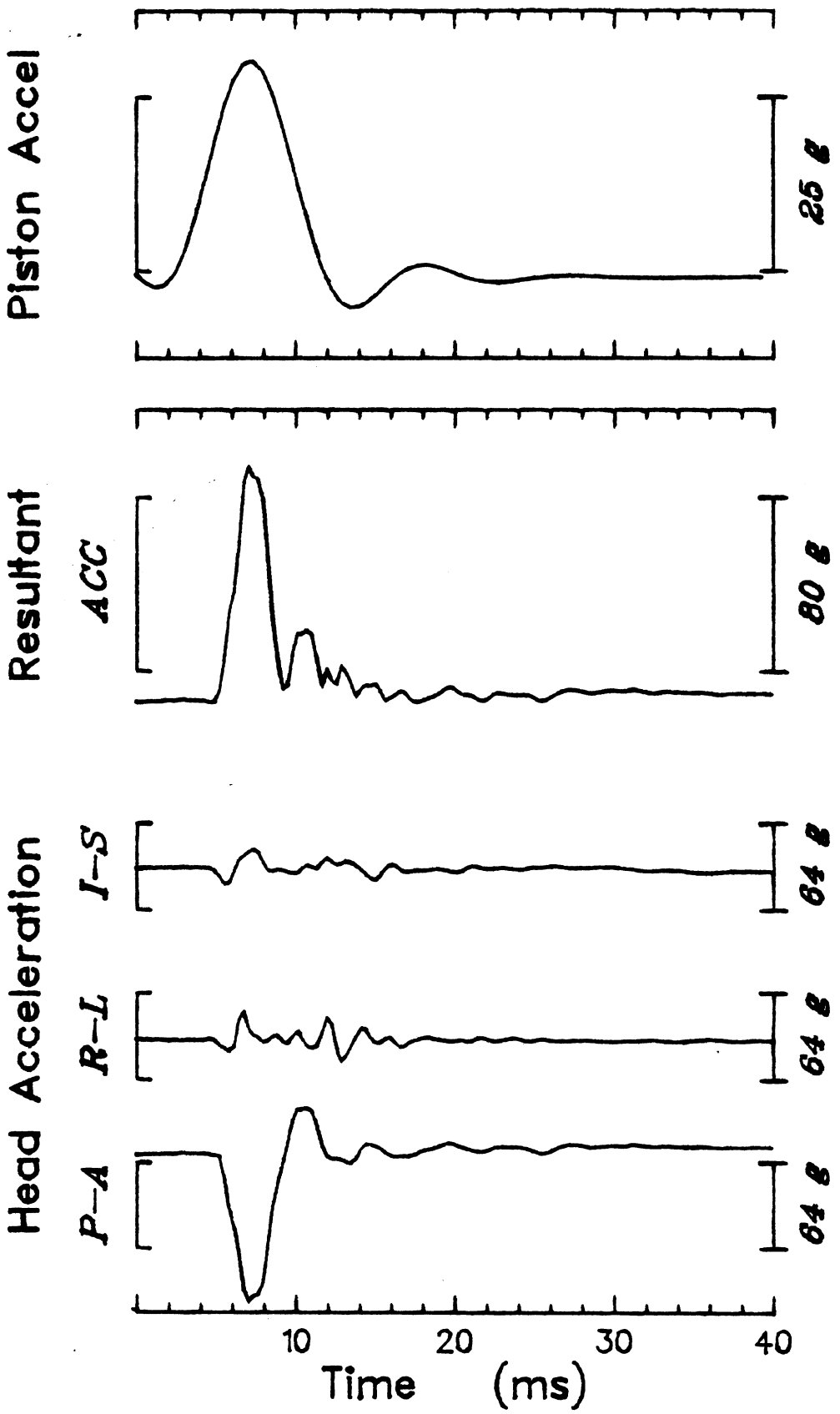
Test No. 78K123 H38



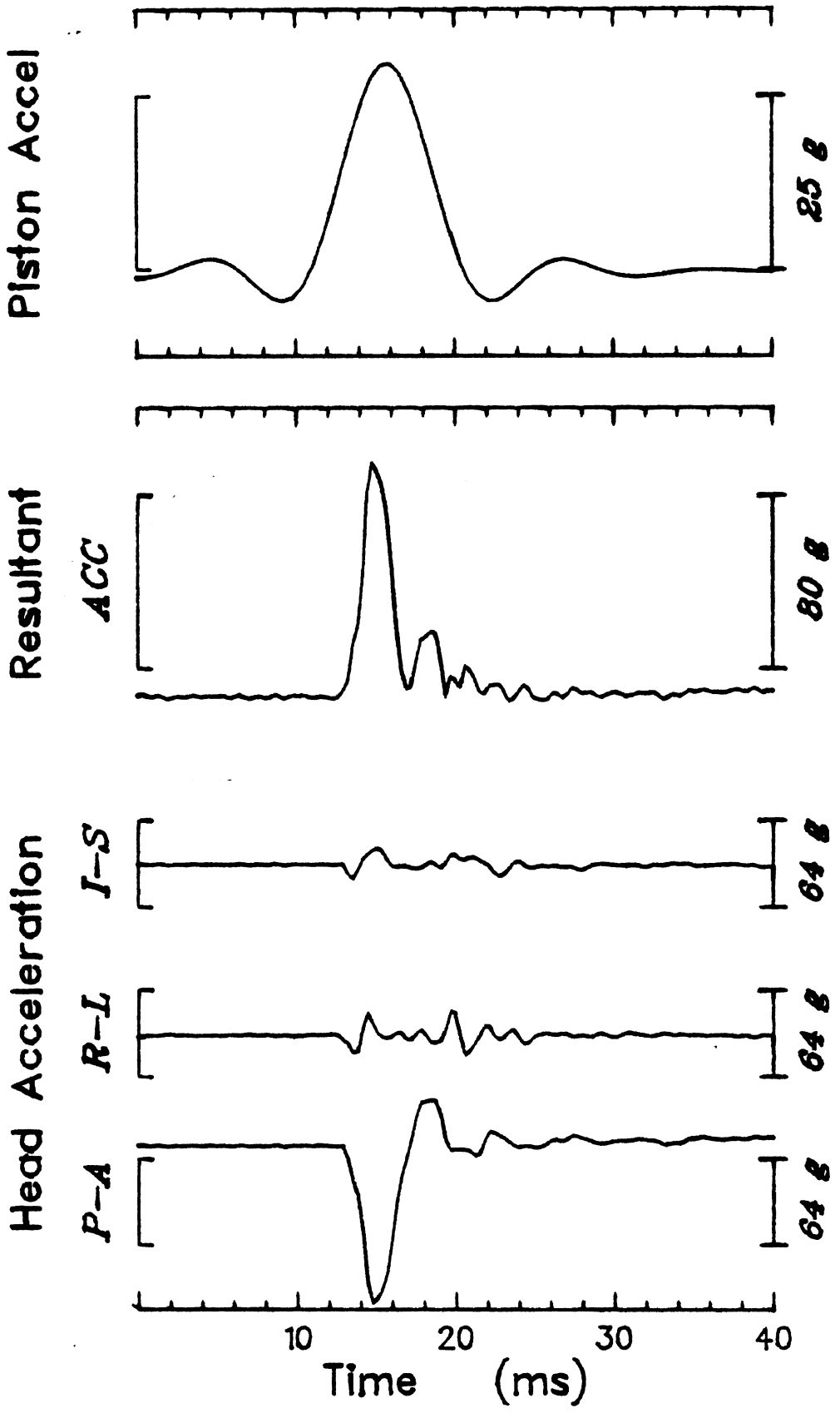
Test No. 78K124 H38



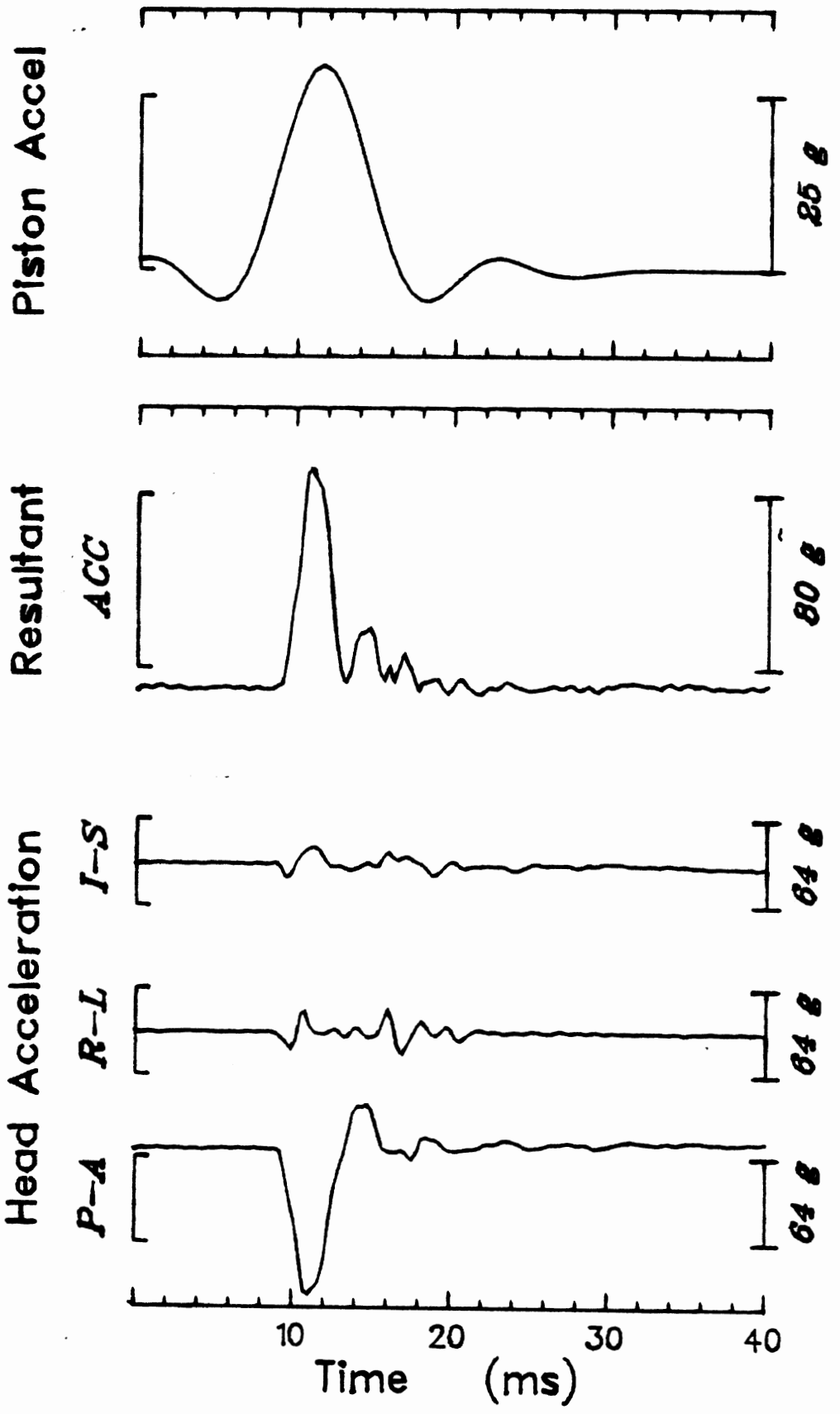
Test No. 78K125 H39



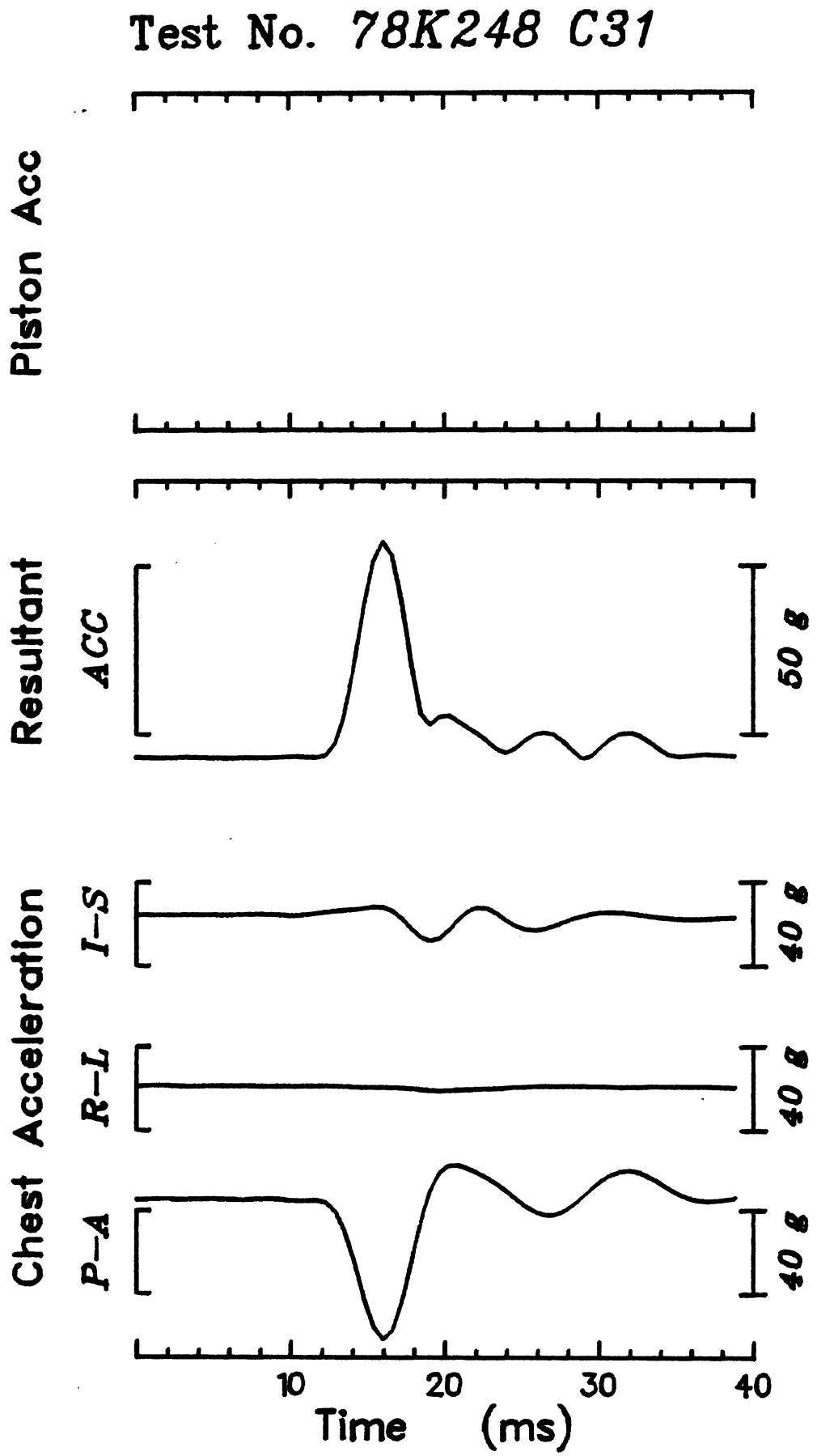
Test No. 78K126 H39



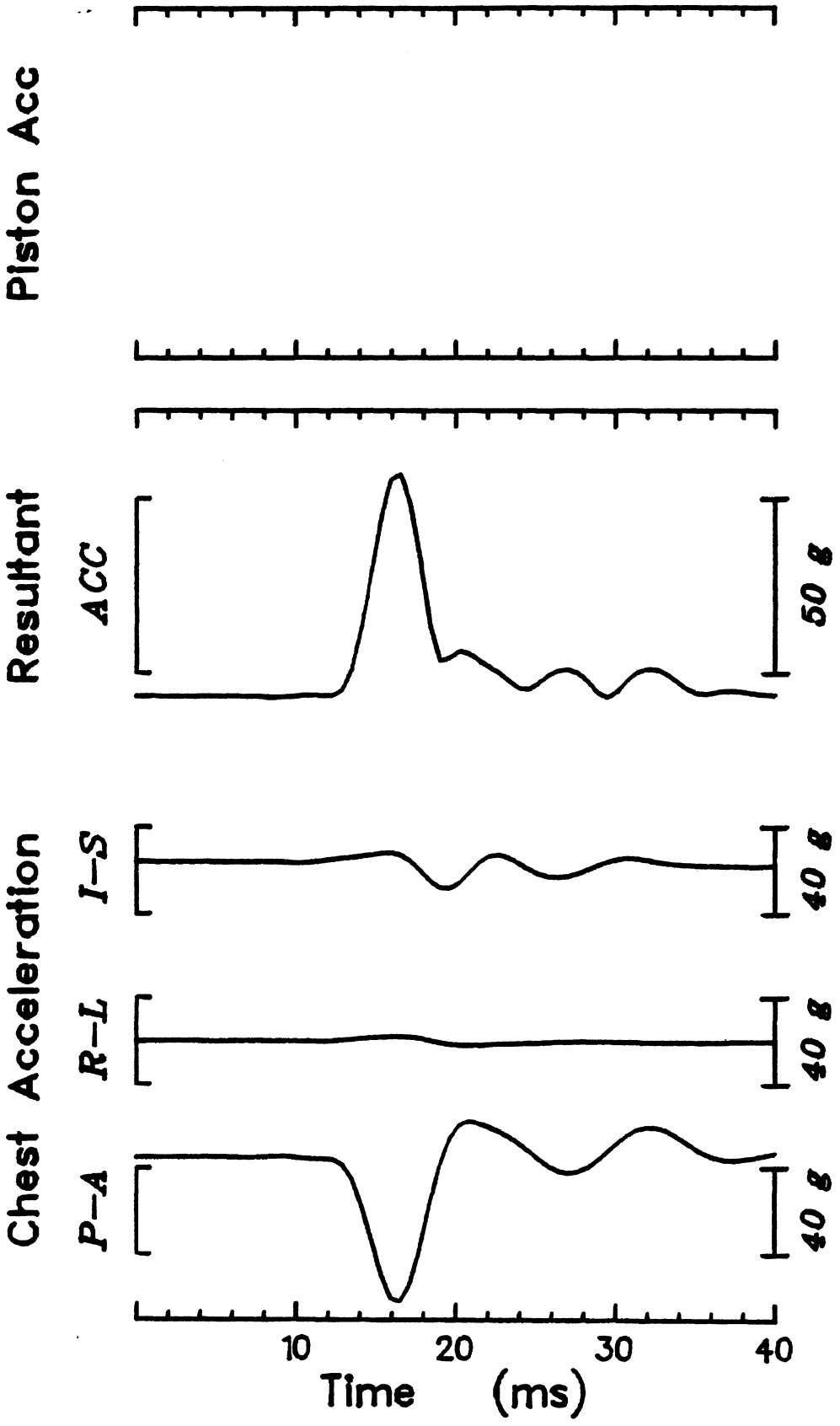
Test No. 78K127 H39



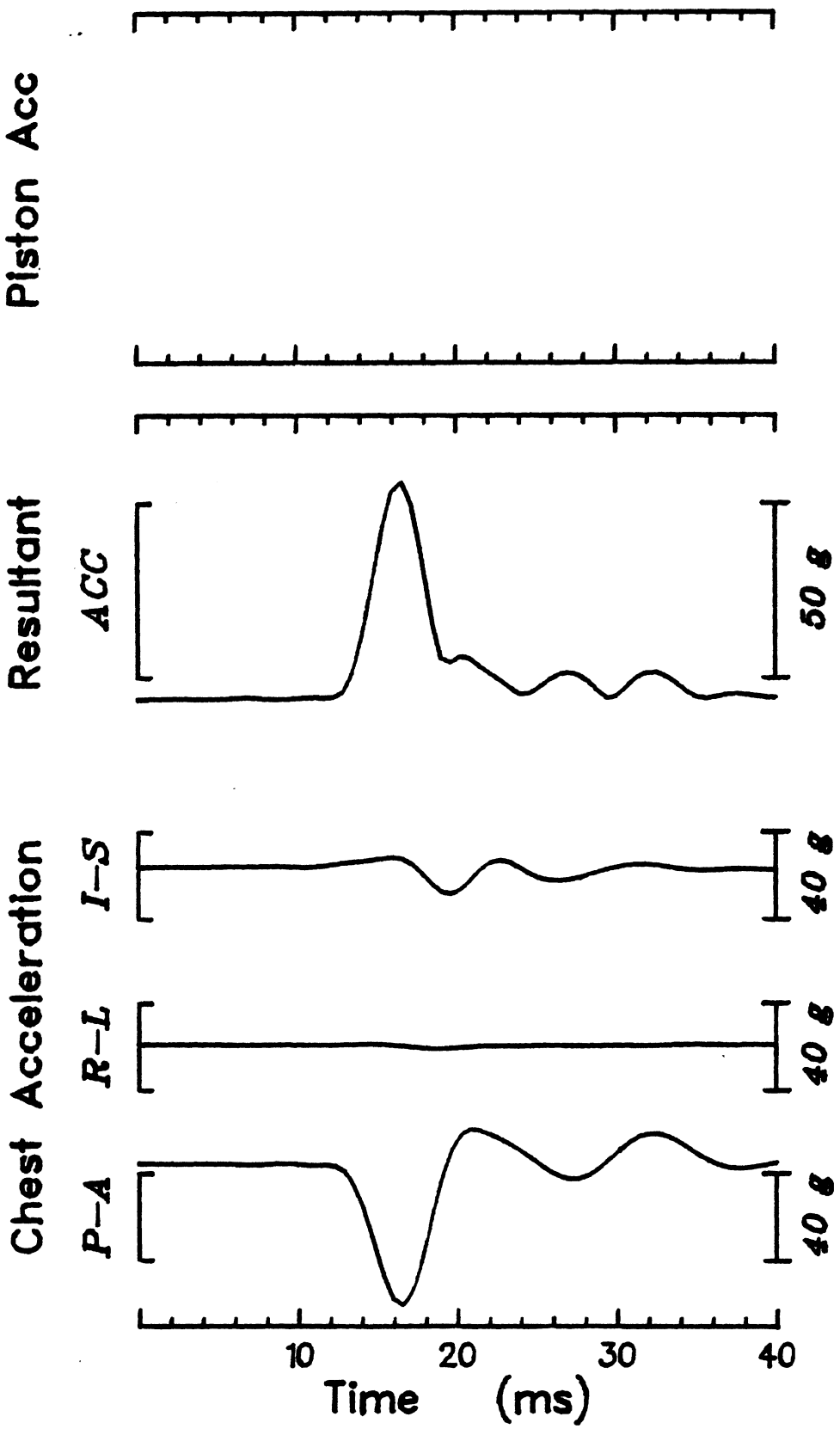
9.2 THORAX RESPONSE TEST DATA PLOTS

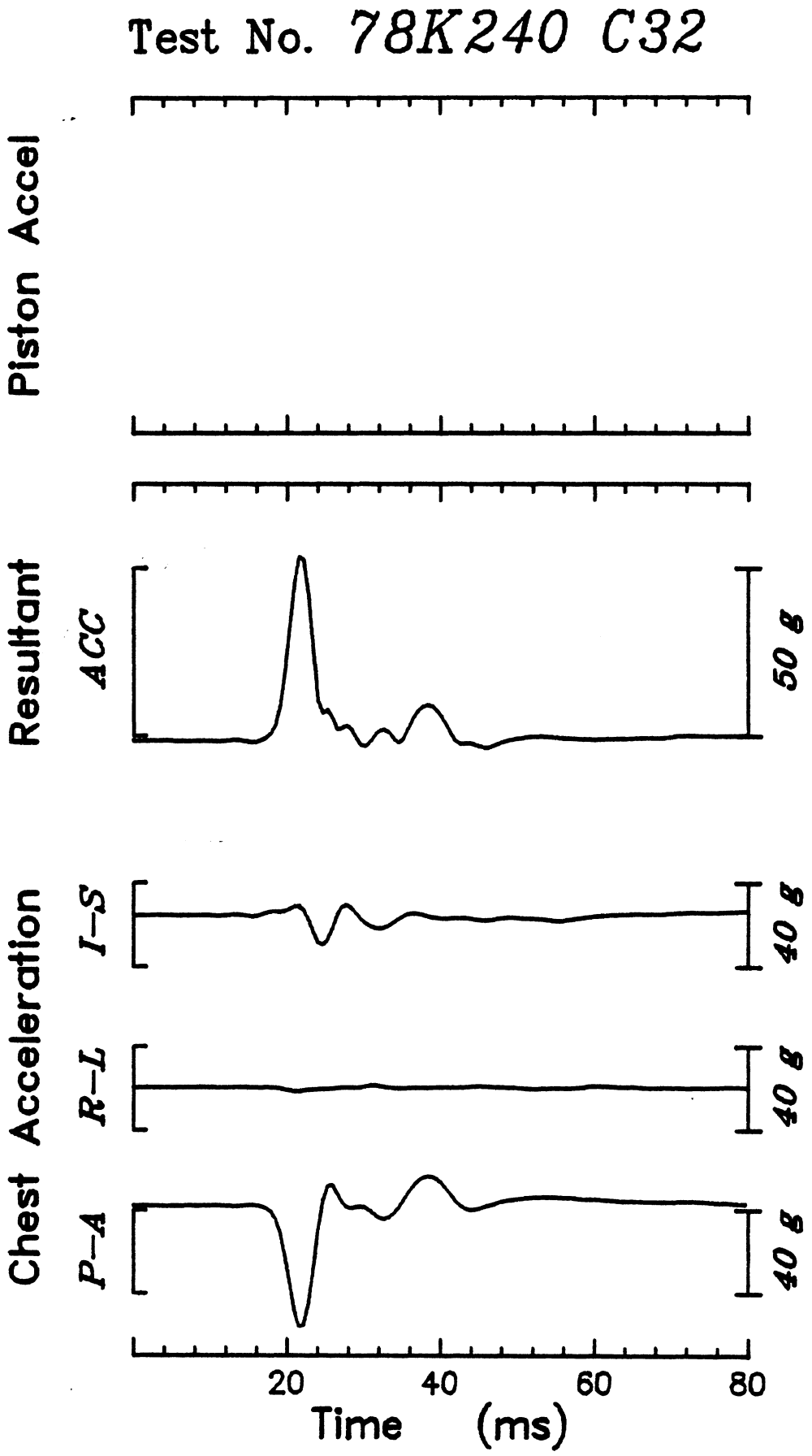

Test No. 78K248 C31
Piston Acc
Resultant
ACC
50 g
Chest Acceleration
I-S
40 g
R-L
40 g
P-A
40 g
10
20
30
40
Time (ms)

Test No. 78K249 C31

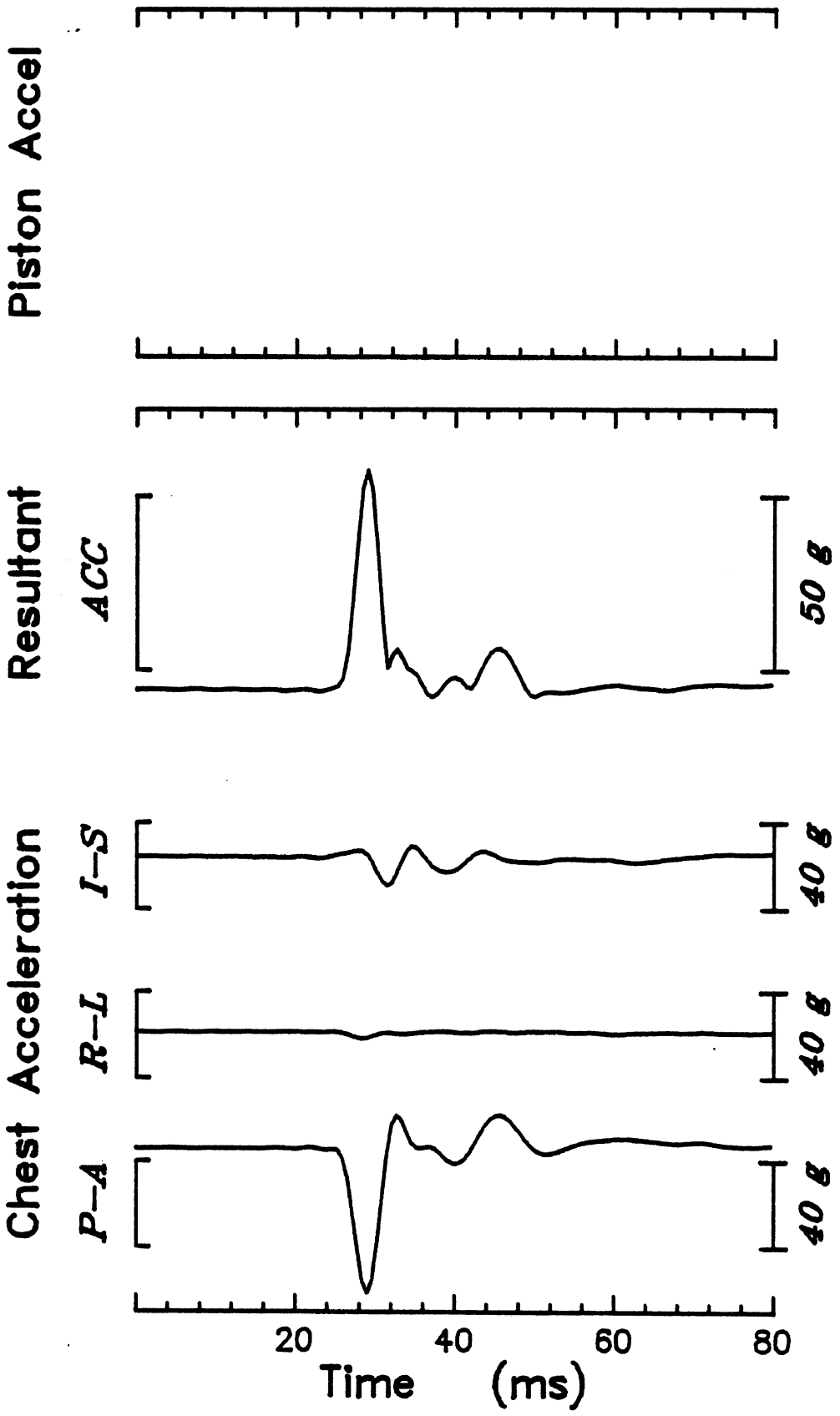


Test No. 78K250 C31

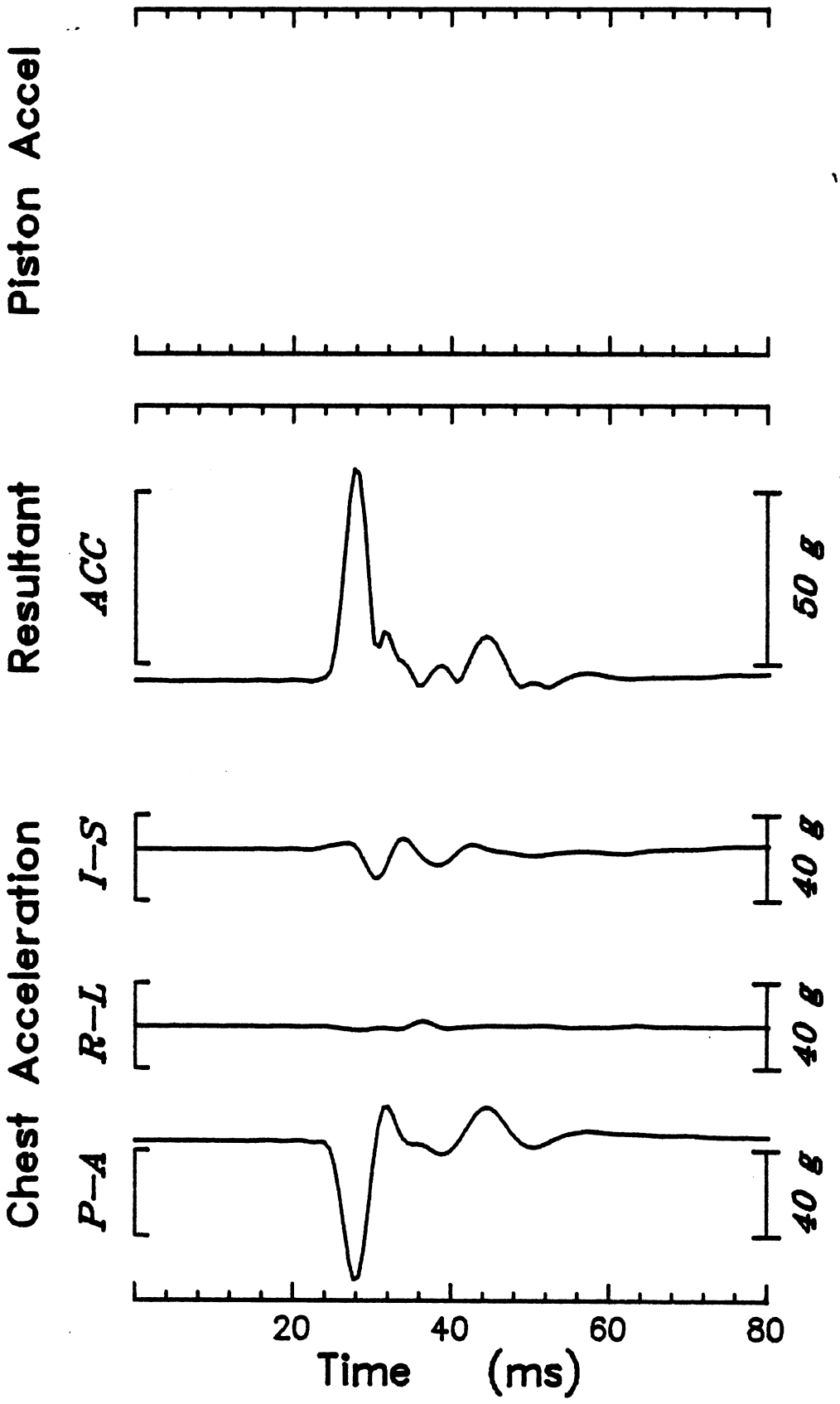



Test No. 78K240 C32
Piston Accel
Resultant
ACC
50 g
Chest Acceleration
I-S
40 g
R-L
40 g
P-A
40 g
20
40
60
80
Time (ms)

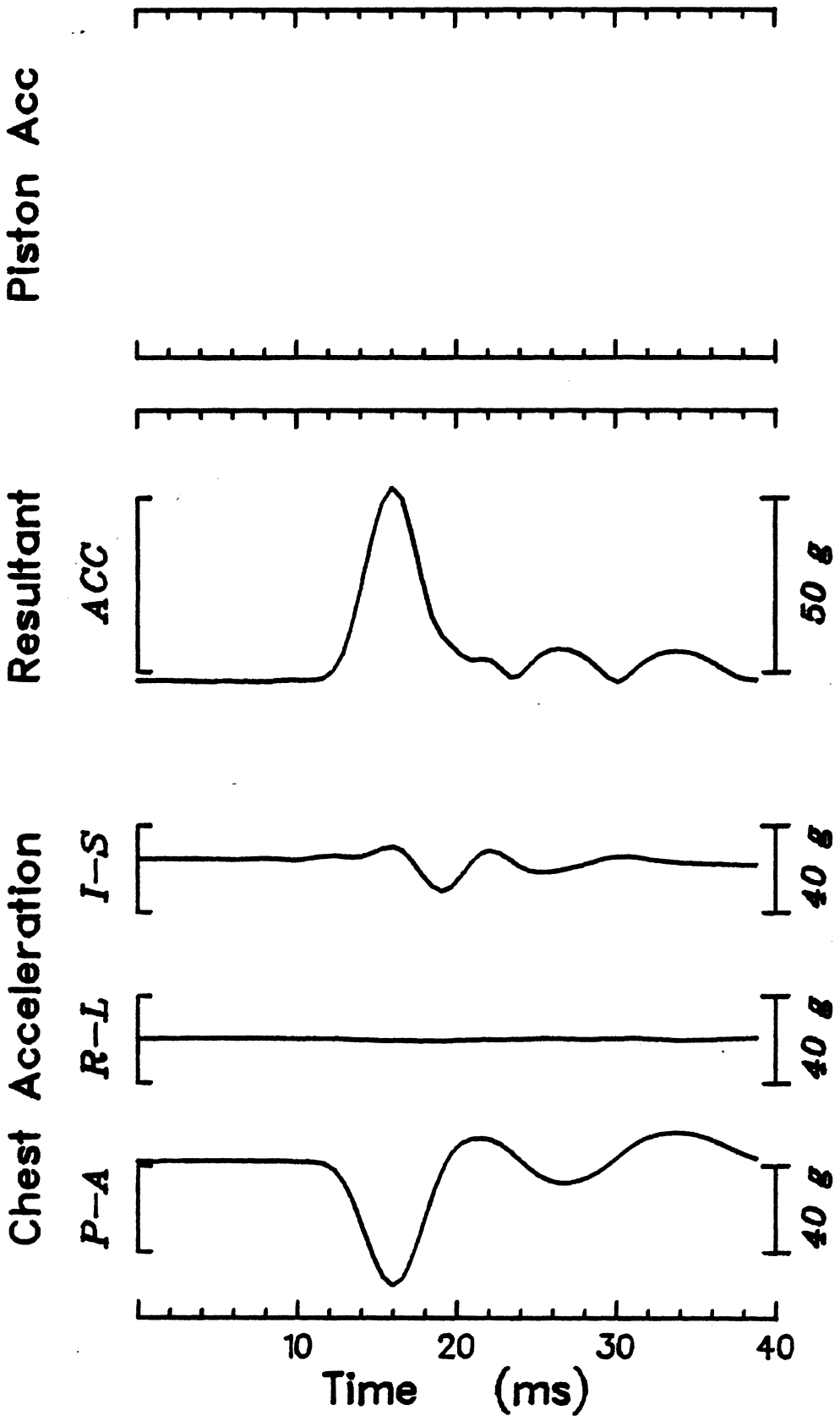
Test No. 78K241 C32



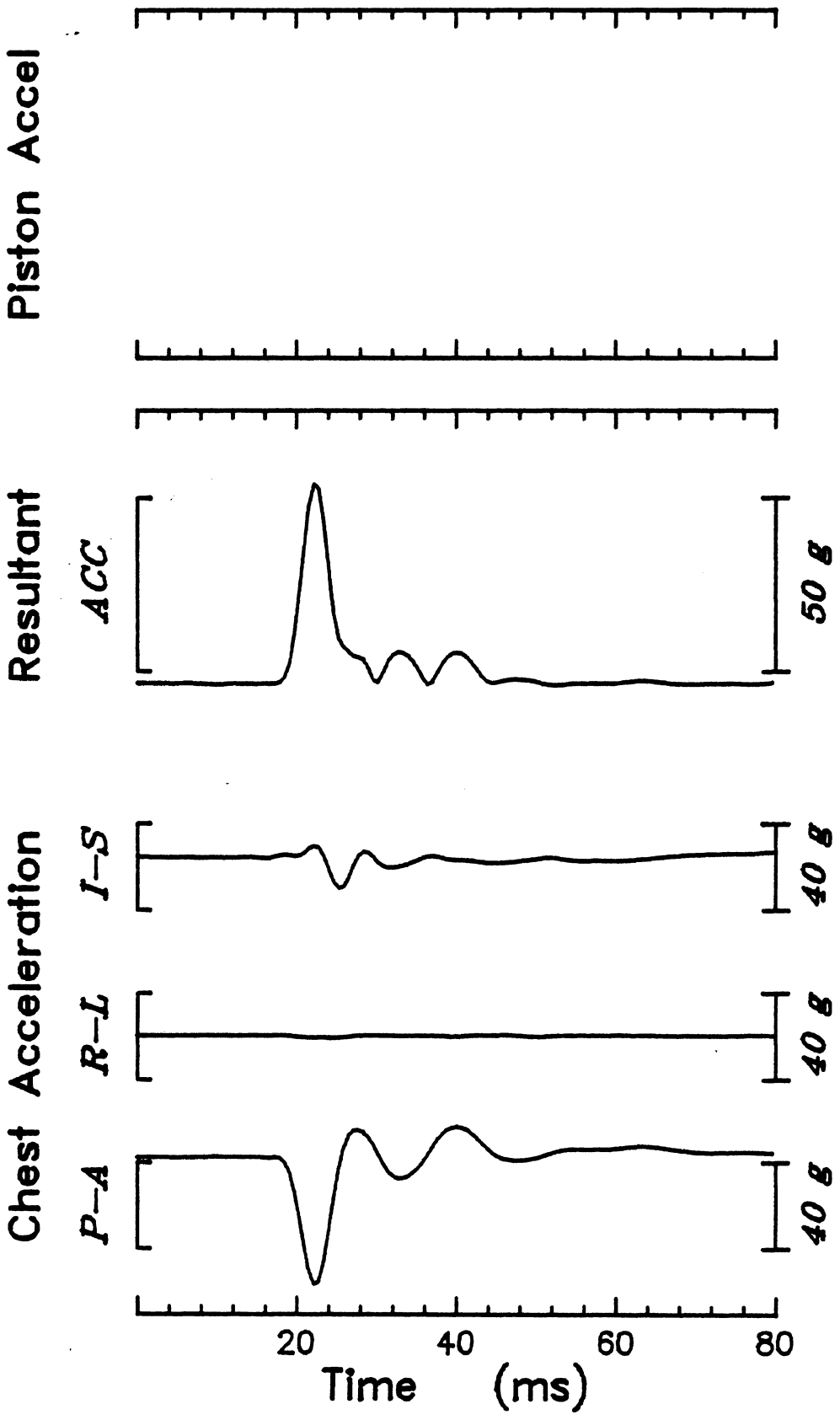
Test No. 78K242 C32



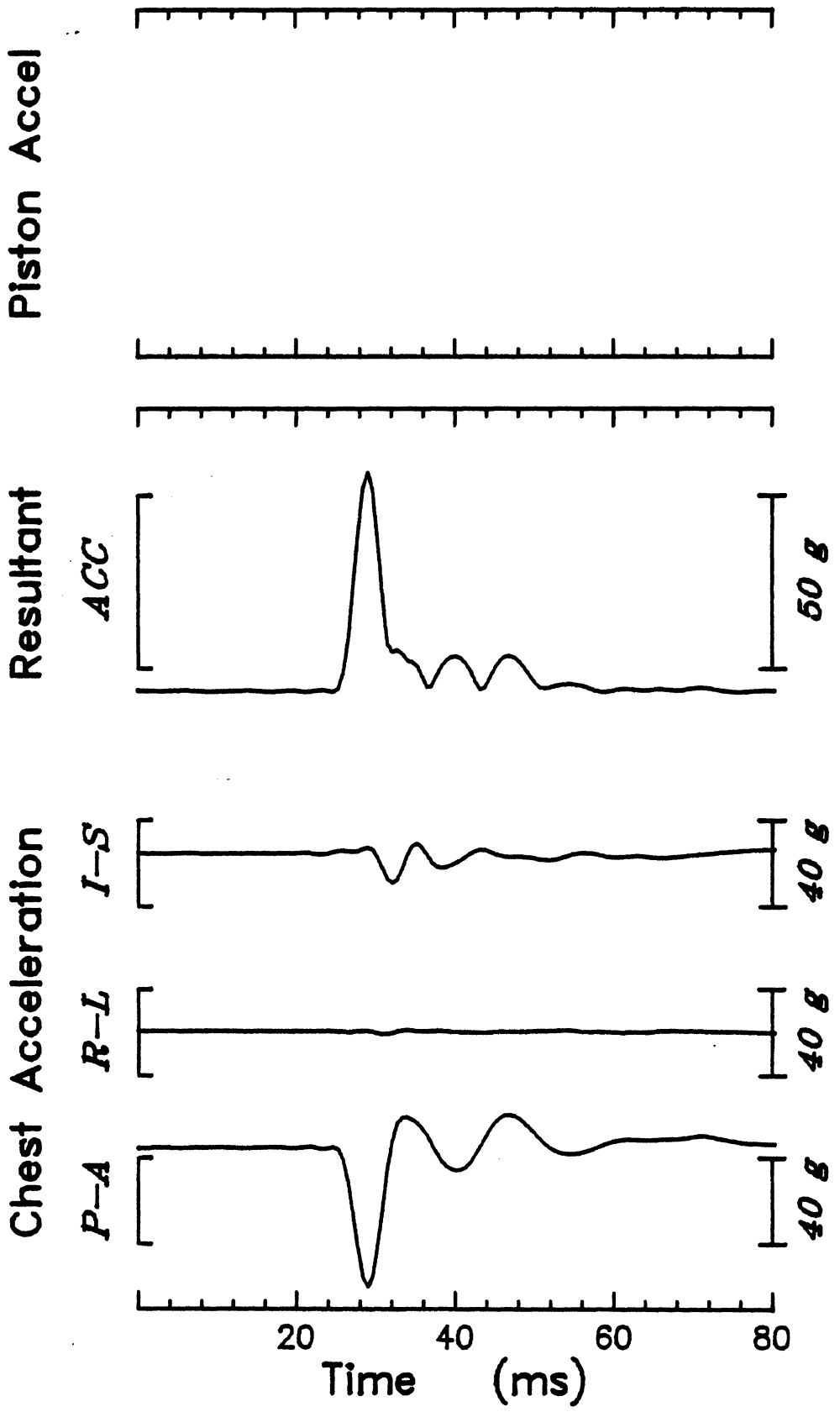
Test No. 78K198 C38



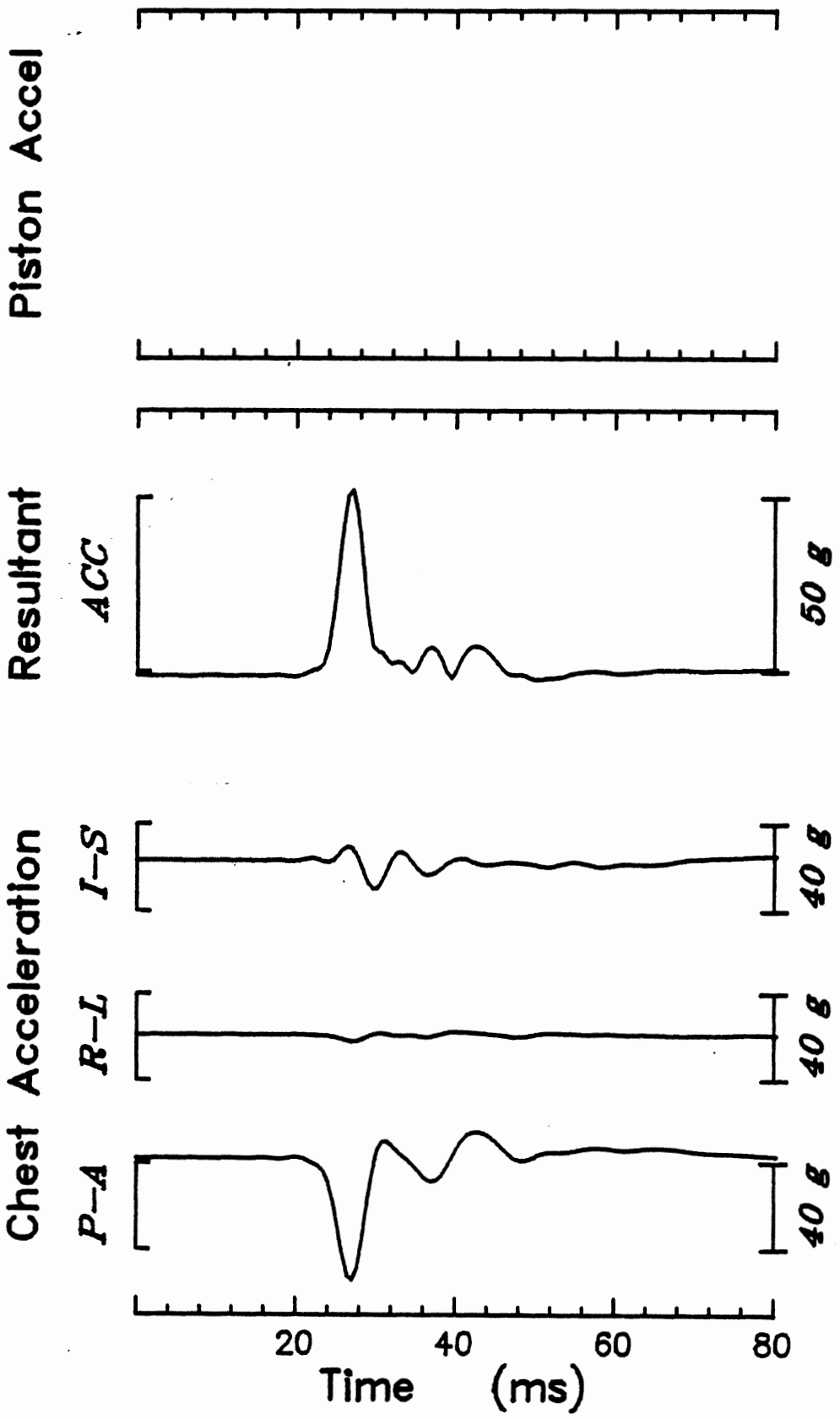
Test No. 78K199 C38



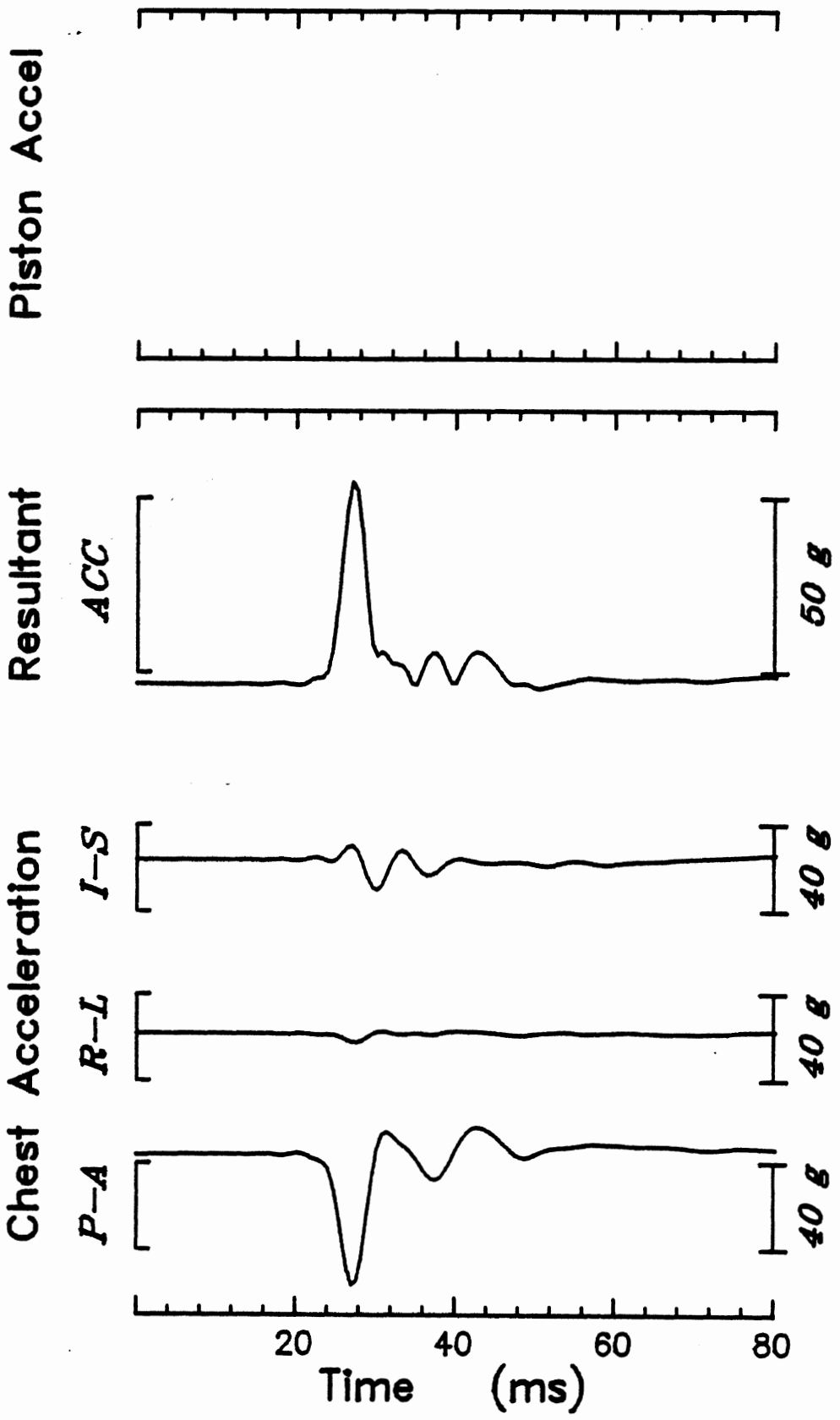
Test No. 78K200 C38



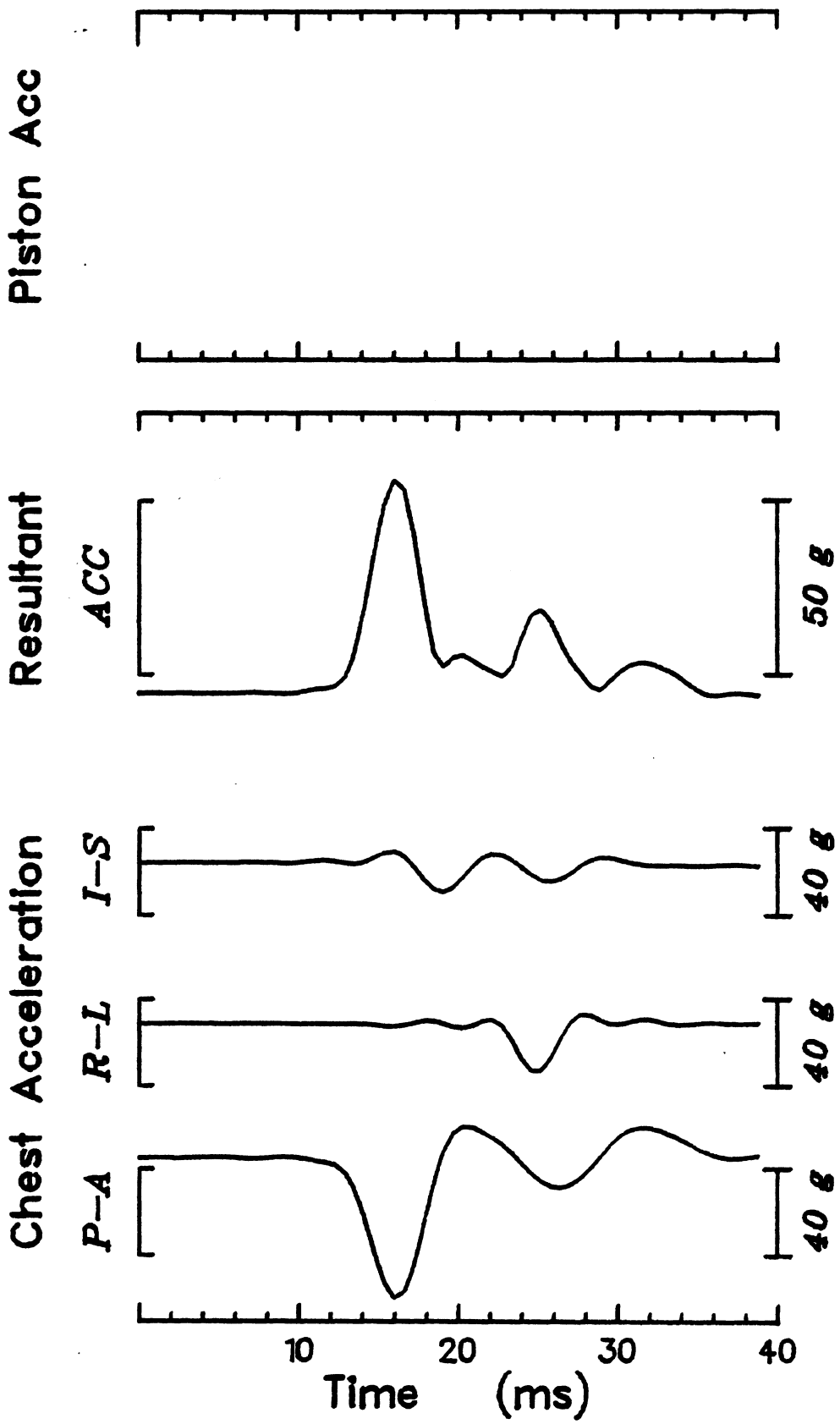
Test No. 78K204 1 C39



Test No. 78K204 2 C39

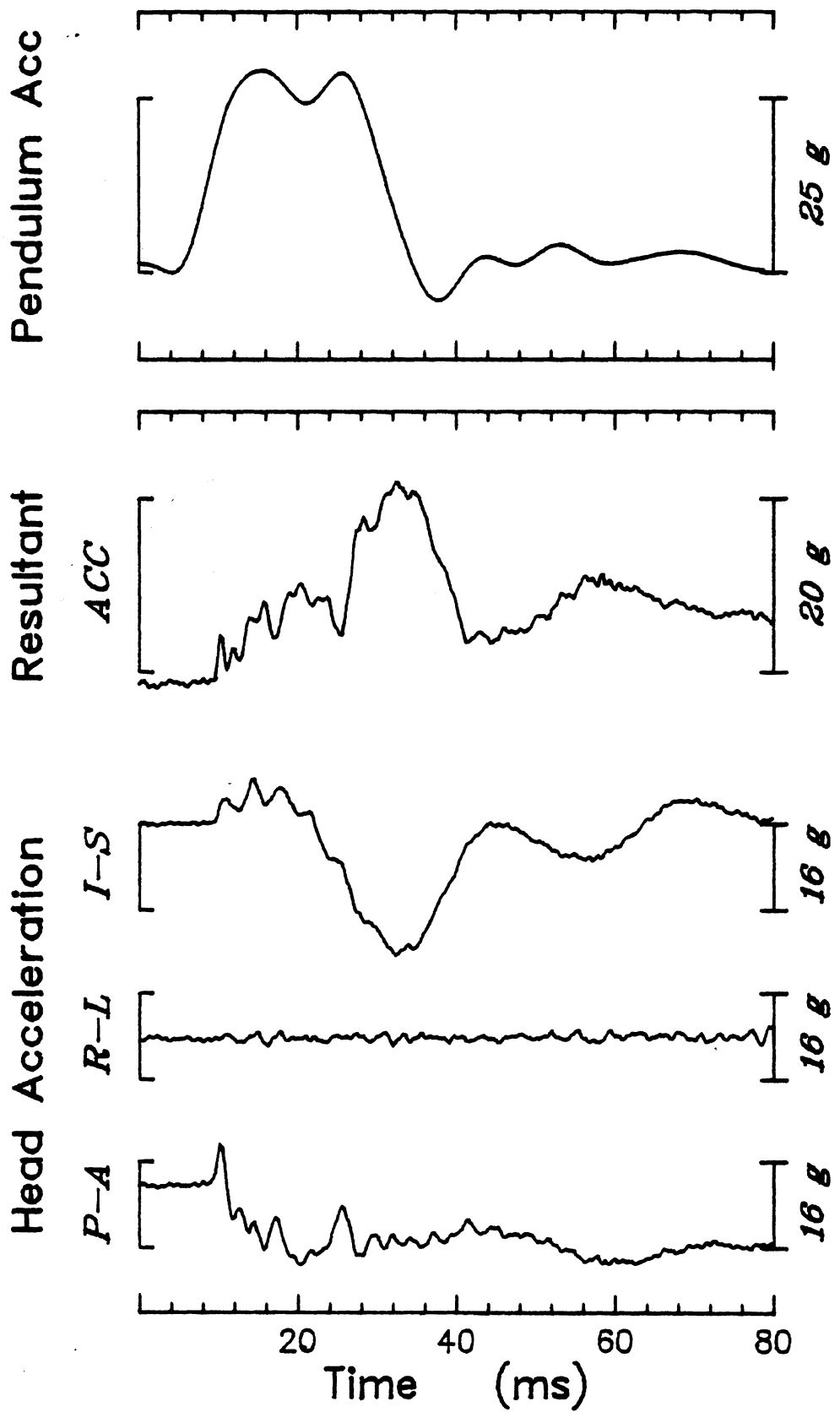


Test No. 78K205 C39

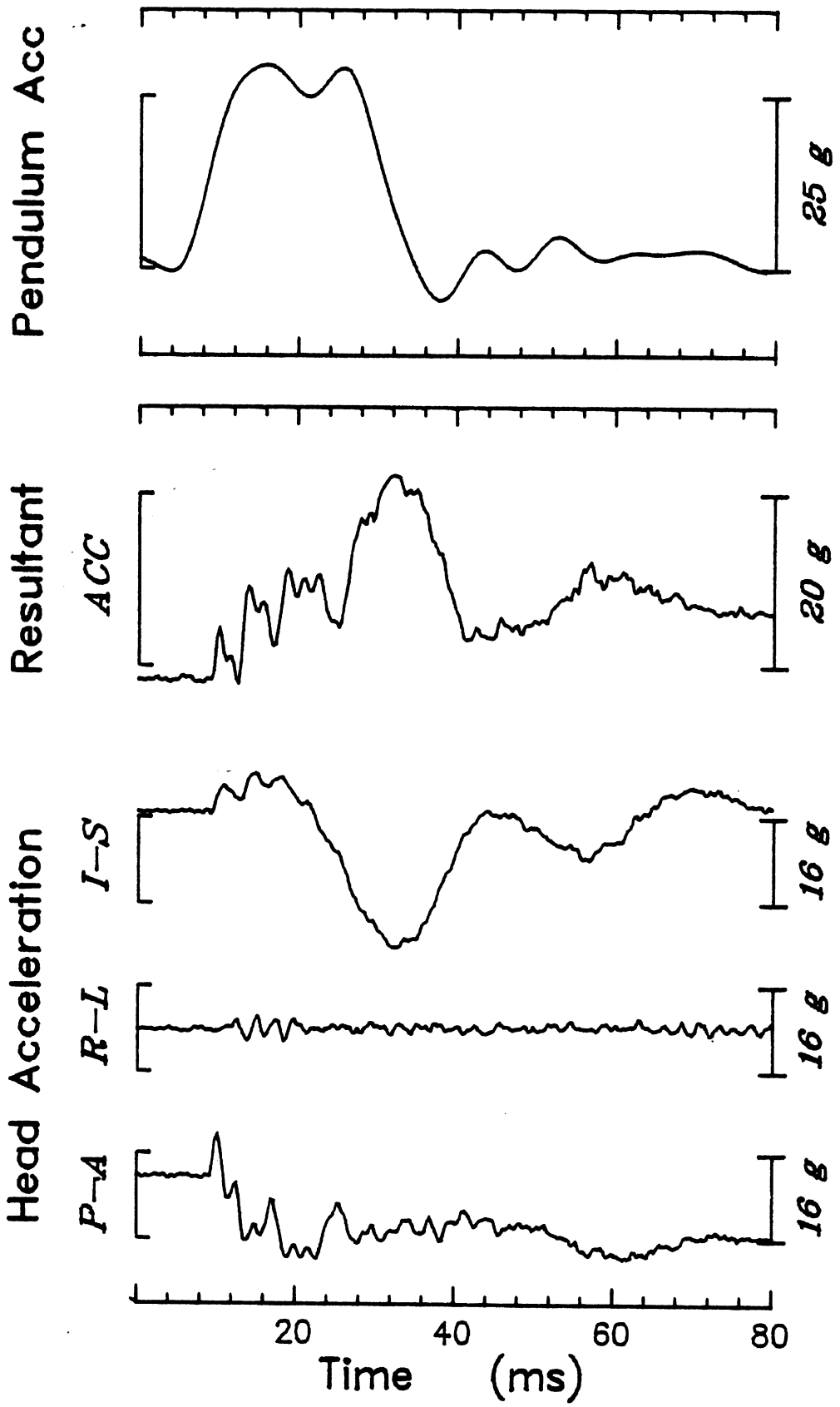


9.3 NECK RESPONSE TEST DATA PLOTS

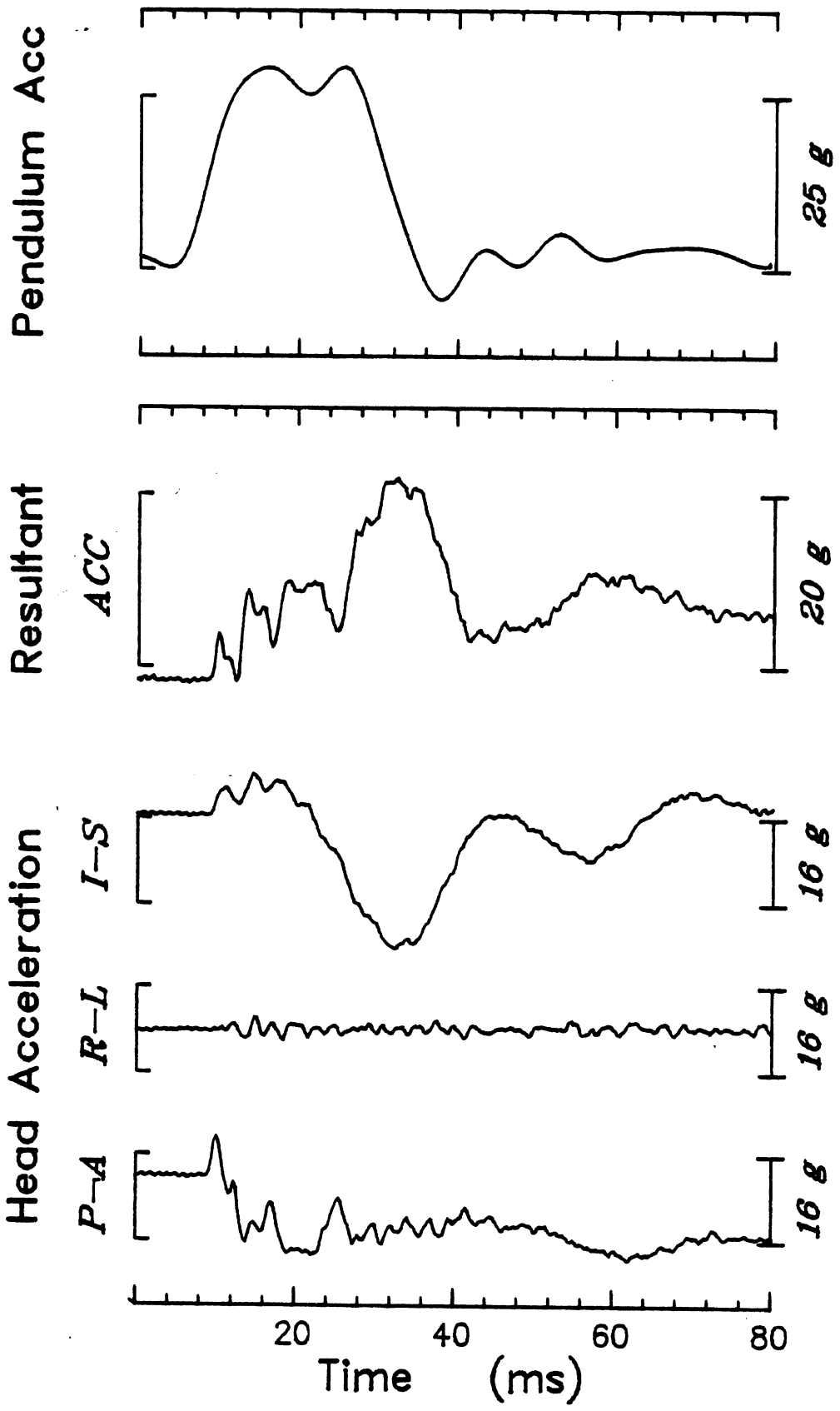
Test No. 78K150 N31



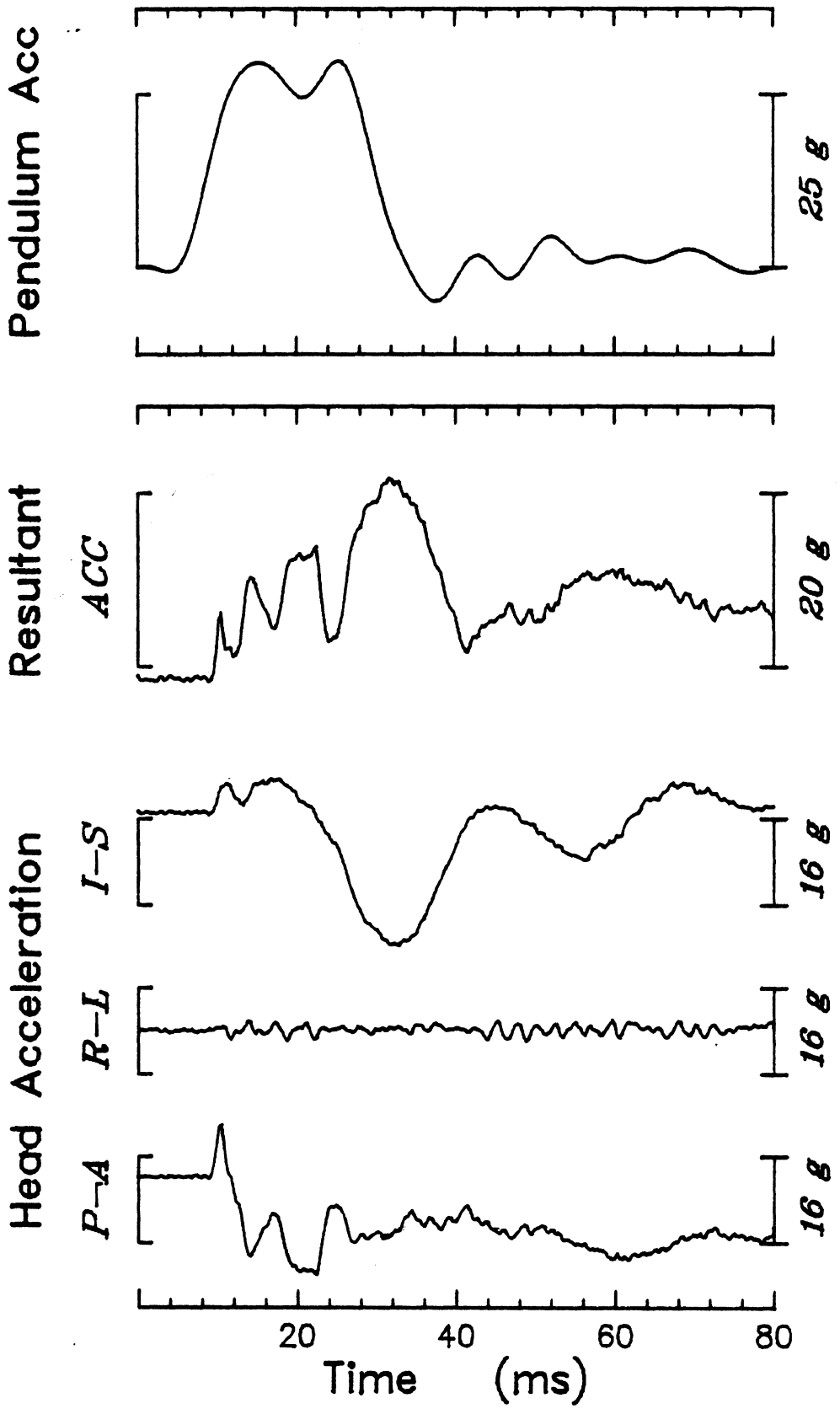
Test No. 78K151 N31



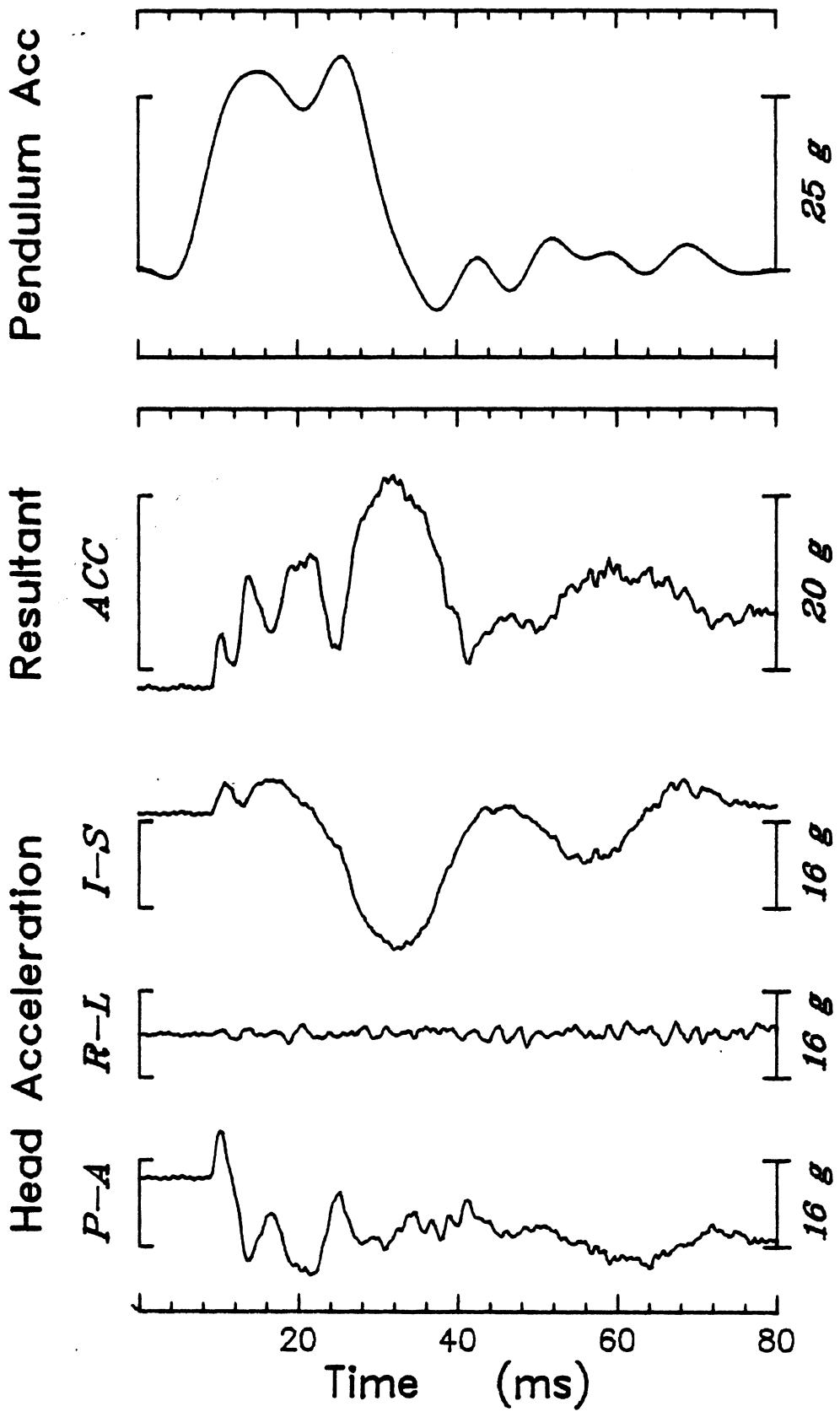
Test No. 78K152 N31



Test No. 78K147 N32



Test No. 78K148 N32



Test No. 78K149 N32