was first mentioned for side impact in Reference 6);

- B = ln maximum ($/F_1/,/F_2/$) where $F_1$ = net velocity change over 10 msec of maximum positive acceleration and $F_2$ = net velocity change over 10 msec of maximum negative acceleration (the B parameter has been described previously by Robbins et al. [1]).

## APPENDIX B

The regression equations to relate number of fractured ribs (NFR) to BLUR and to average power are:

$$NFR = 10.73\ BLUR - 64.1 \qquad R = 0.85$$

$$NFR = .28 \times 10^{-6}\ Ave\ Pow + 2.75 \qquad R = 0.77$$

Where the B parameter is constructed from the left upper rib signal and the average power is constructed from the twelfth thoracic vertebra signal. The same 15 cadaver tests used for the AIS were used here.

## APPENDIX C

The Highway Safety Research Institute cadaver tests numbers 76T034 and 76T039 were set up to be identical. Both were 20 mph sled tests into the Minicars padding (see Reference 1). The results are remarkably dissimilar.

In test 76T034, the left upper rib acceleration is a sharp spike, very similar to the rigid wall test; but in test 76T039, the left upper rib response—as shown in Figure 11—takes on a different wave form. In test 76T034, the cadaver suffered 36 rib fractures (NRF); but in test 76T039, the number of rib fractures is 11. The cadaver in test 76T039 had a weight close to the weight of the Part 572 dummy for which the padding was designed, but the cadaver in test 76T034 was lighter. After examining other factors such as photographs of the padding after the test and travel of the left upper rib toward the wall on which the padding was mounted, the presumption was made that the cadaver in test 76T034 saw a padding which was too stiff.

# A Comparison Between Different Dummies in Car to Car Side Impacts

## ABSTRACT

H. MELLANDER
N. BOHLIN
Volvo Car Corporation

The Part 572 dummy and the APROD and HSRI side impact dummies are tested in identical car to car 90° side impacts. Each dummy is, as the driver in the target car, subjected to tests with different side structure stiffness.

Conventional accelerometer data for the Part 572 dummy, chest deflection measurements in the APROD dummy and data from the 12 accelerometer thorax in the HSRI dummy are given and discussed.

The injury criteria of the side impact dummies are compared.

Car related parameters such as deformation and wall velocity at dummy contact are also given.

## INTRODUCTION

The efforts to develop and build a usable side impact dummy have been substantial since it was concluded that the Part 572 dummy was less suitable as a side impact dummy (9). Today we can see the results of these efforts in the HSRI and APROD dummies. Of necessity the results already presented from the development of these dummies have been related to impactor, sled or drop tests.

This paper will describe the behaviour of these dummies when used in the environment they were intended for, as occupants in cars subjected to side impacts. A comparison is also made with tests using the Part 572 dummy.

Each dummy is tested in target cars with differentiated side structure stiffness in order to examine the capabilities of the dummies to measure the difference in side impact protection.

## Test Methods

The side impacts have been performed with a stationary target car and a bullet car impacting at 35 mph and 90° angle. The centerline of the bullet car has impacted at the seating reference point (SRP) of the front seat in the target car. The passenger dummy was always a Part 572 dummy, and the dummy to be tested was positioned as the driver at the impact side. The driver dummy, when equipped with arms, had its hands on the steering wheel. The seats have been in their rearmost positions. The dummies were wearing three points retractor belts.

Conventional accelerometer signals have been recorded in the cars. High speed cameras have been placed in the target car covering the door wall and the near side dummy in order to achieve the wall velocity at dummy contact.

## Dummy Description

### Part 572 Dummy

The 572 dummy met all the specifications in FMVSS Part 572. No "side impact" calibration was performed on the dummy. The pelvis was instrumented with an accelerometer.

### APROD Dummy

This dummy was equipped with the chest, clavicles and arms in accordance with the APR specification (1). The chest had 55 mm stroke in the pistons with rubber disks of 40 Shore hardness. The aluminum clavicles had 40 mm stroke in y-direction. All other parts were Part 572 dummy parts. The dummy was instrumented as described in Part 572 including the chest. The chest deflection was measured with linear potentiometers connected to the shafts of the pistons. The pelvis was instrumented with an accelerometer.

To check the function of the chest and the potentiometers the dummy was subjected to impactor testing in lateral direction as suggested by HSRI (2). Four tests were performed, two with the arm between the impactor and the chest and two with the arm lifted. The results of these tests are given in figure 1–4. Looking at the results with the arm in a down position it is obvious that the shafts in the deflection device have a tendency to stick causing a large scatter in measured deflections. With the arm lifted the maximum deflections are comparable in the two tests although the shafts jam during the unloading phase resulting in a remaining deflection.

All parts with the exception of the chest were calibrated to conform with Part 572.

### HSRI Dummy

This dummy was the side impact dummy developed by HSRI under contract no DOT-HS-00921. The serial number was 106. The dummy was instrumented with twelve accelerometers in the chest. The head and the pelvis were equipped with triaxial accelerometers.

The same impactor testing in lateral direction (2) used on the APROD dummy was performed with the HSRI dummy. The results are given in figures 5–6. A comparison with published cadaver data (3) for the left upper rib is shown in figure 7.

In figure 8 the lateral chest (centre of gravity) accelerometer readings for the APROD dummy in tests with lifted arm are compared with "first thoracic vertebrae" acceleration for the HSRI dummy.

## Description of Injury Criteria Used in this Report

The conventional HIC criterion has been used to describe the violence to the head.

There exists today no generally accepted chest injury criterion for use in measuring side impact protection. Therefore a selection of proposed criteria has been chosen and used in this paper. Some criteria can only be used with a specific dummy design. In the list of criteria below, each criterion is assigned to the dummies which it could be applied to. The suggested level not to be exceeded is also given for each criterion.

A. The spinal acceleration in lateral direction. ≤40 g 3 ms (4). (Part 572), (APROD) and HSRI dummy.

B. Chest deflection. ≤45 mm. (4). APROD dummy (Maximum average value of deflection in the two chest pistons).

C. AIS = 3.19 + 0,00215 (LURQ) — 43,56 (LSV15) — 68,27 (RURV19) (3). HSRI dummy. An injury predictive function which uses data from the left (near side) upper rib, the lower sternum and the right upper rib. To filter the signals in the reference above a finite impulse response filter with a band pass frequency of 100 Hz was used. In this work the signals of the twelve accelerometers in the HSRI chest are filtered according to channel class 60. The effect of this difference in filtering is not investigated in this report but is considered to be negligible. Following units are used, acceleration in cm/$s^2$, time in sec.

D. AIS = 1,5953 (BLUR)—7,6094 (3). HSRI dummy. An injury predictive function which uses only data from the left upper rib. The units are acceleration in g and time in msec.

E. Maximum velocity change of the upper near side rib ≤9,14 m/s (30 ft/sec) (4). HSRI dummy.

## Filtering

Head signals are filtered according to CFC 1000. As a comparison chest (except for HSRI-dummy) and pelvis accelerations are filtered with both CFC 180 and CFC 60.

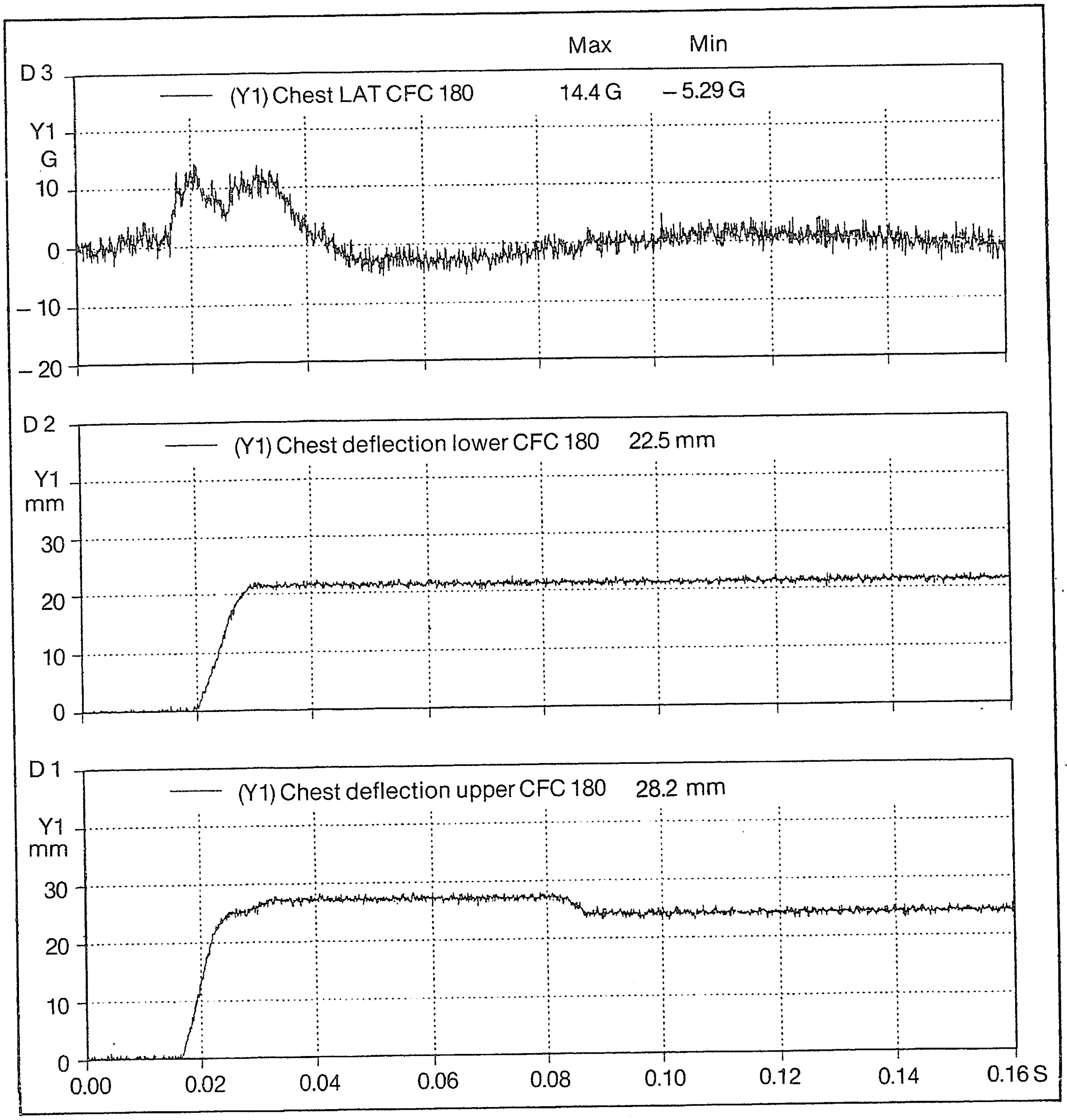

Figure 1 Impactor test (4,25 m/s) with APROD dummy. The arm between impactor and chest.

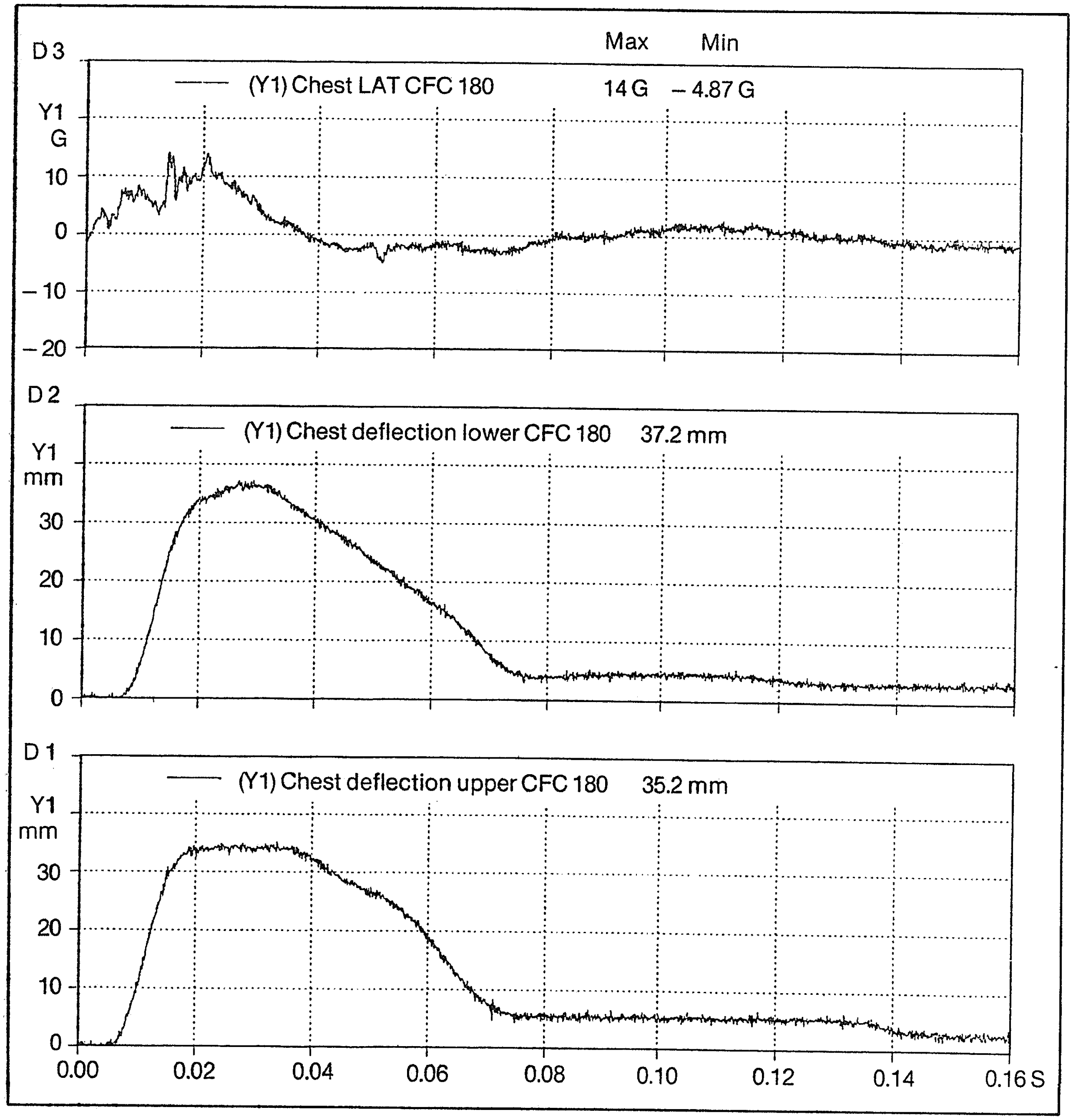

Figure 2. Impactor test (4,25 m/s) with APROD dummy. The arm between impactor and chest.

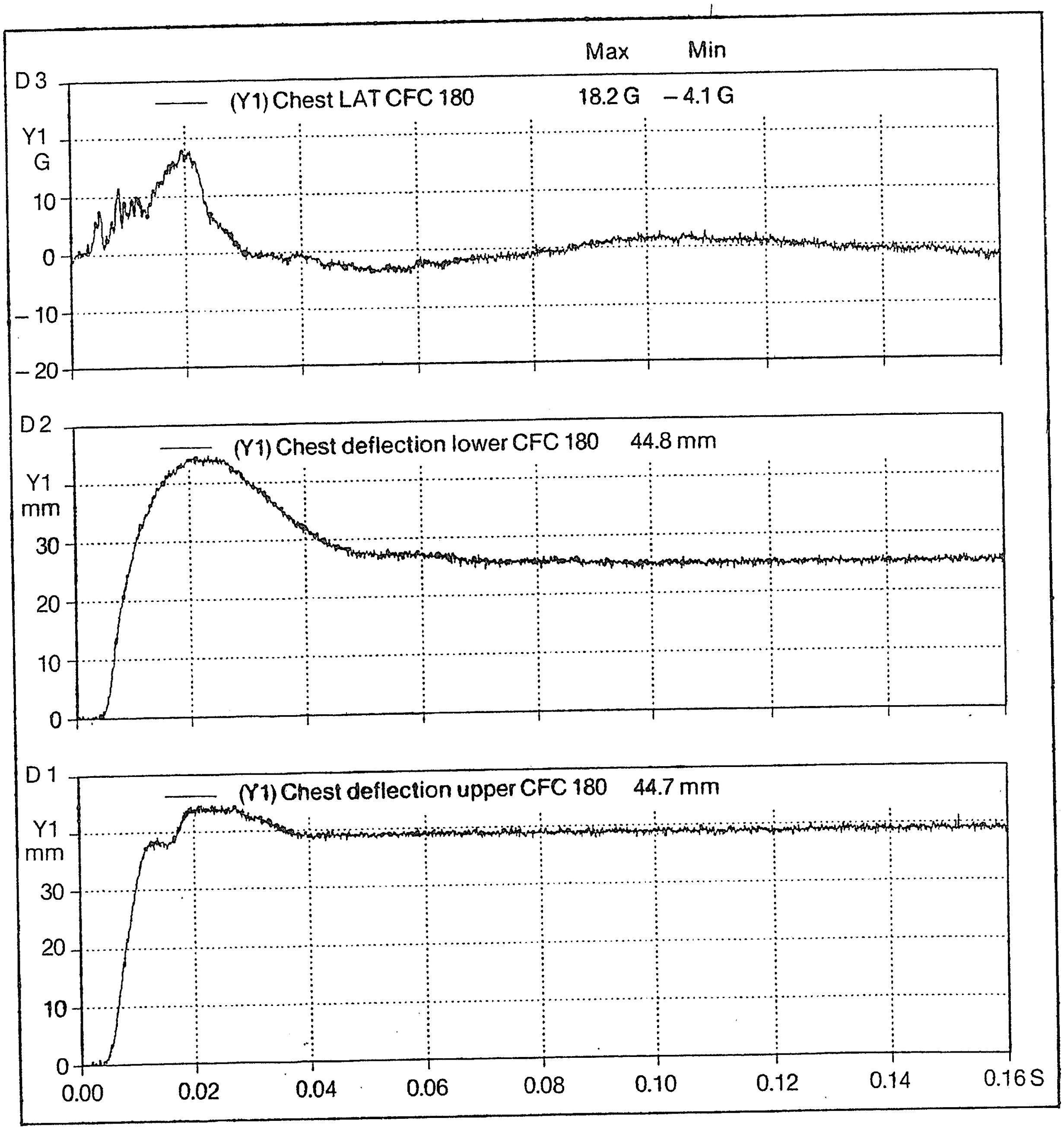

Figure 3. Impactor test (4,25 m/s) with APROD dummy. Arm lifted.

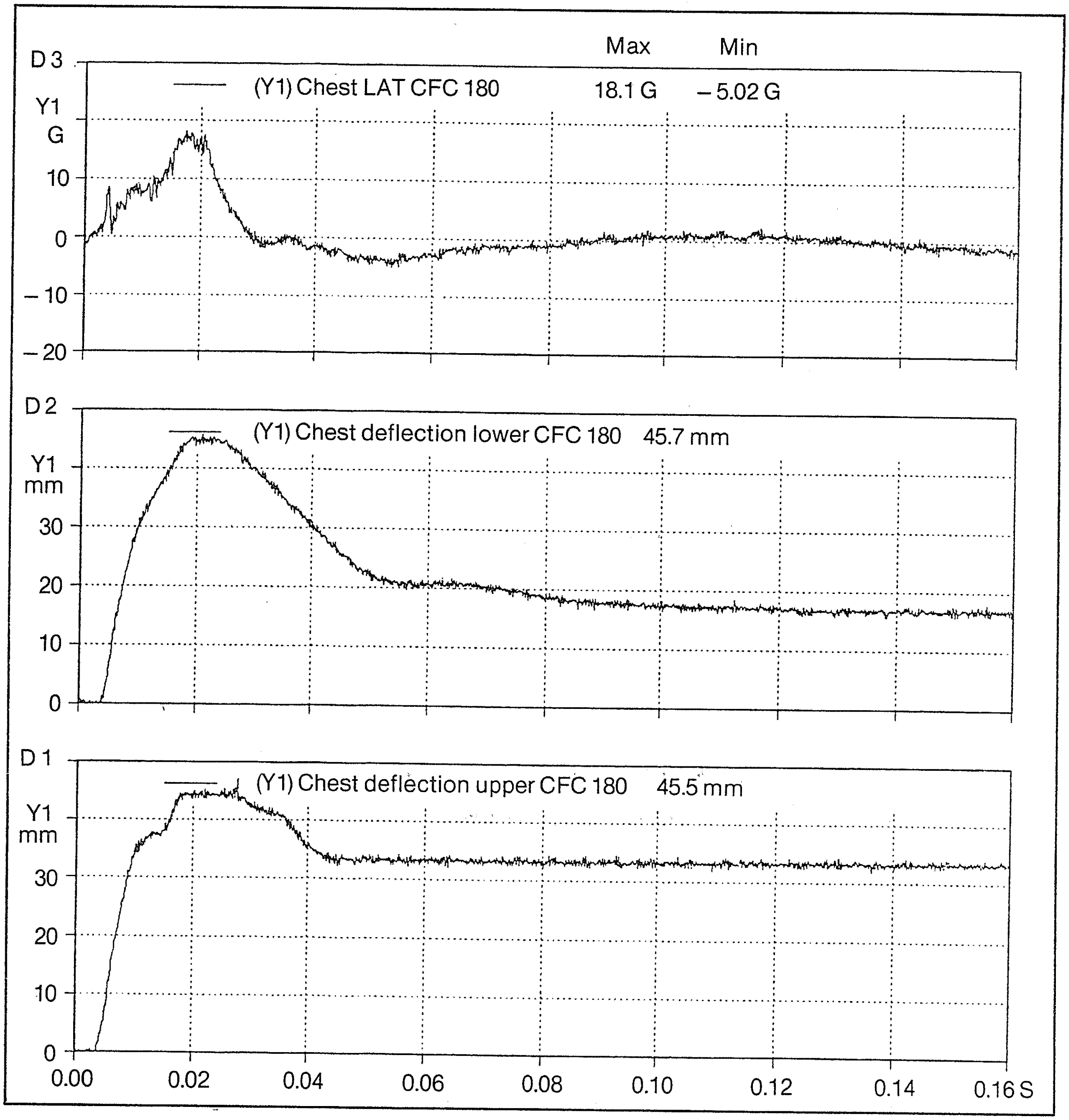

Figure 4. Impactor test (4,25 m/s) with APROD dummy. Arm lifted.

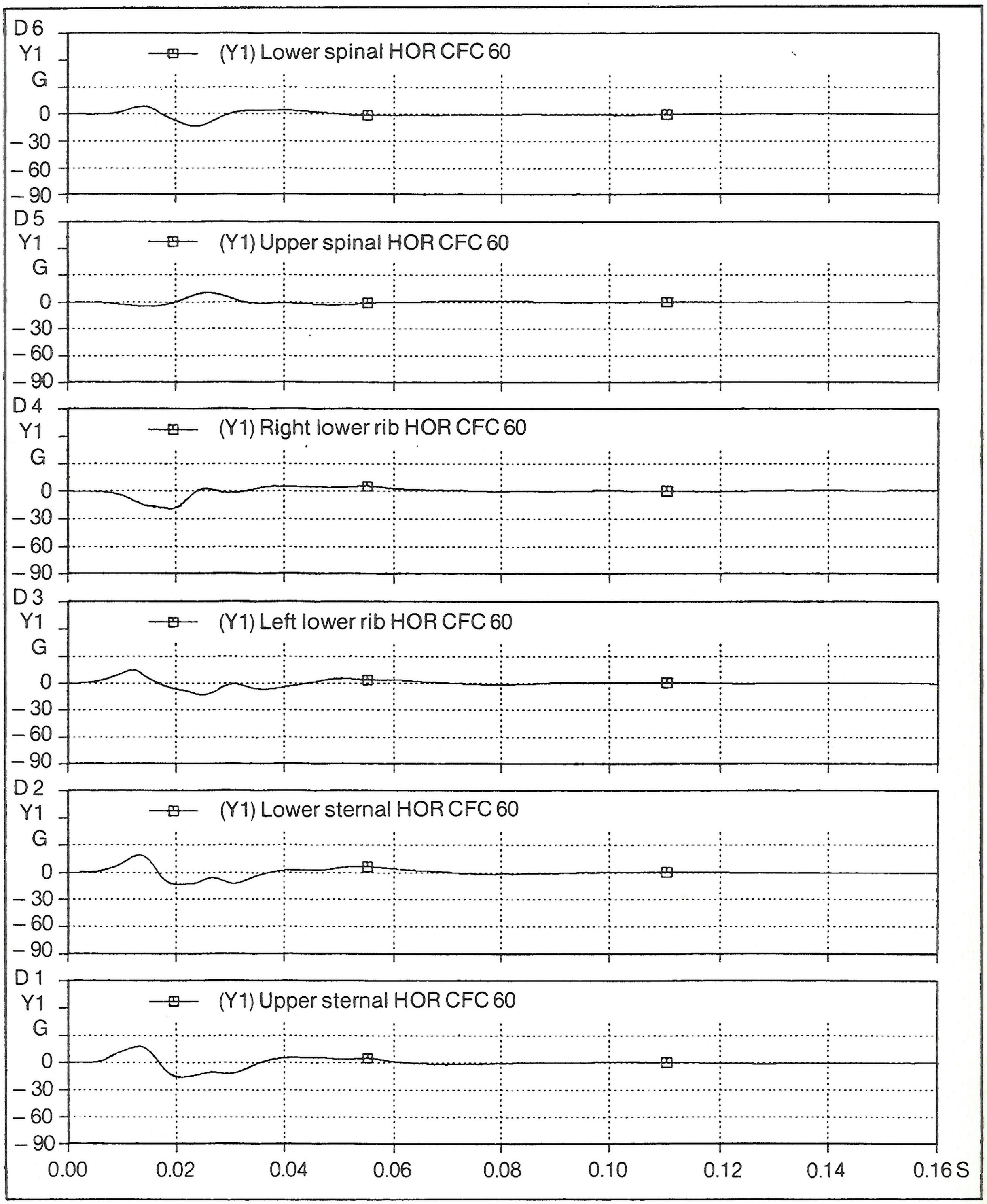

Figure 5. Chest signals from impactor test (4,25 m/s) with HSRI dummy. CFC 60.

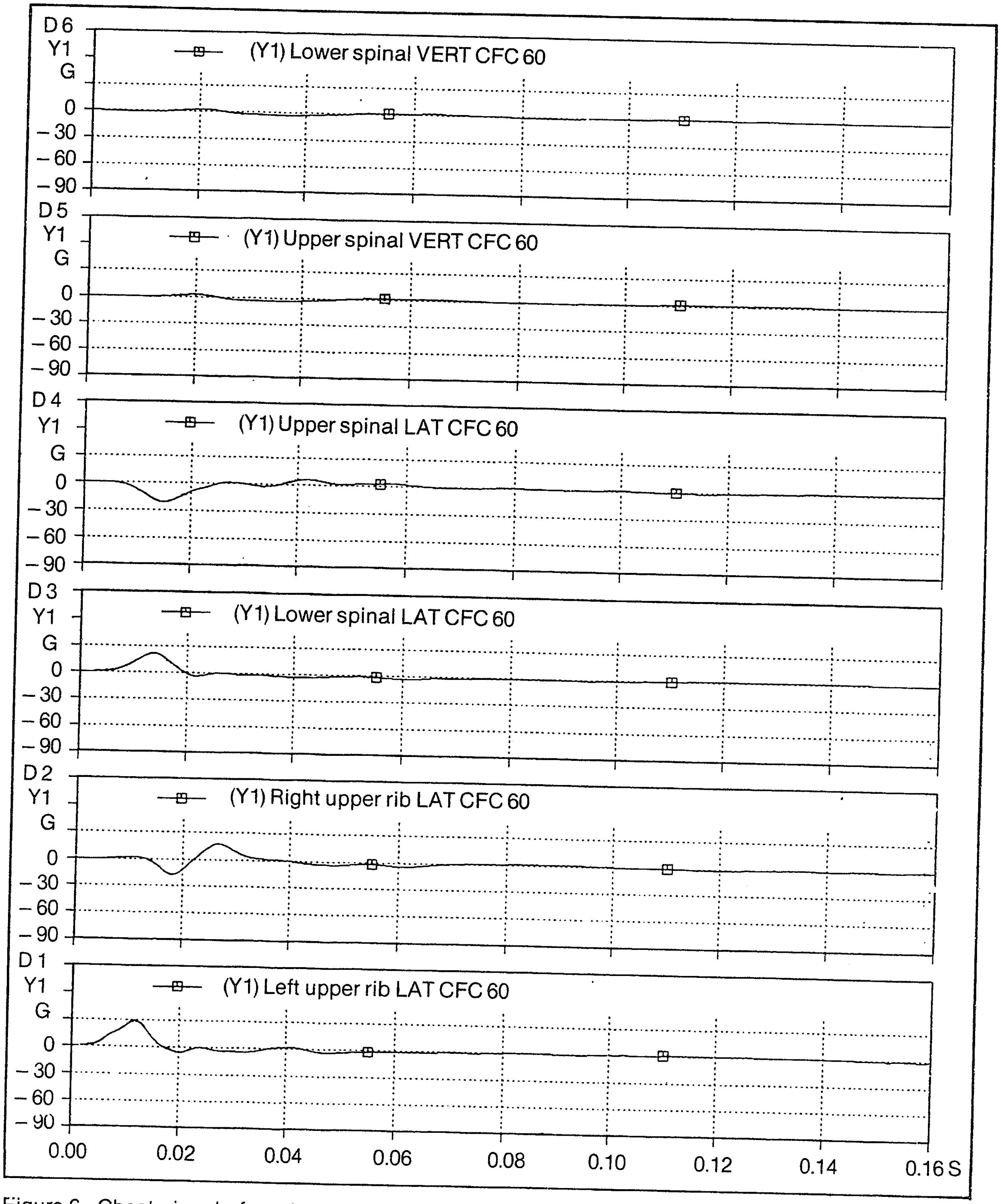

Figure 6. Chest signals from impactor test (4,25 m/s) with HSRI dummy. CFC 60.

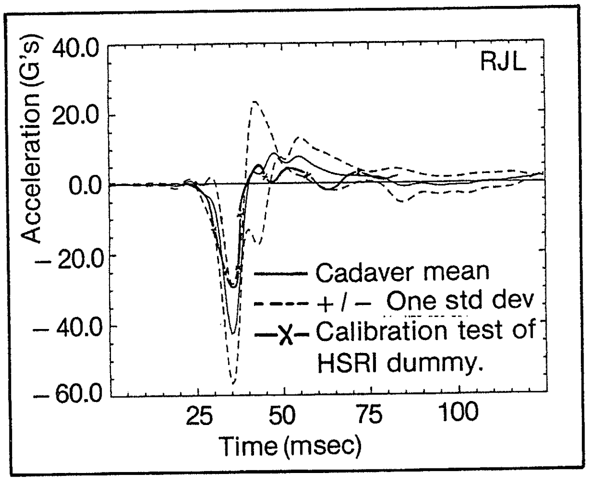

Figure 7. Comparison of mean and +/– one std. dev. for left upper rib in cadaver tests (3) and the calibration test of the HSRI dummy.

## Test Matrix

Table 1.

| Test no. | Driver dummy | Target car Side structure stiffness | Velocity (mph) |
|---|---|---|---|
| 76236 | Part 572 | Level I | 35 |
| 79229 | " | Level II | 35 |
| 80241 | APROD | Level I | 35 |
| 80231 | " | Level II | 35 |
| 80221 | HSRI | Level I* | 35 |
| 80220 | " | Level II | 35 |

*steering wheel on the right side

## Test Results

### Comparison Vehicle Data

The intention of this test series was to test dummies in car to car side impacts. The only parameter to be varied except for the dummies was the target car side stiffness. Every effort was made to keep the other test parameters constant.

To describe the violence in side impacts there exist a number of methods. The most commonly used is to give the wall velocity at dummy contact. Such a value may however have a low accuracy or relevance as it is difficult to measure and is not properly defined. Nevertheless, by high speed film analysis we have measured the wall intrusion relative the car as a function of time at chest and pelvis level. The results are shown in figure 9. In spite of the scatter it is possible to see two families of curves in each diagram. The curves with the smaller deformation belong to the cars with stiff side structure, Level I. The wall velocity at dummy contact can be estimated by taking the slope of the curves of the displacement relative the ground at time of contact. These figures are shown in table 2.

Another method is to compare the remaining deformations in the target cars. The deformations at bumper height 200 mm behind the B-pillar are shown in table 3.

### Tests with the Part 572 Dummy

The resultant head accelerations in the two tests are shown in figure 10. There were no head impacts at the B-pillar and the HIC values are consequently low, 134 in the Level I test and 276 in the Level II test. The peaks seen later in the event (~120 ms) show the interaction between the driver and the passenger dummy. The time period for the computer to search for maximum HIC value was set not to include interaction.

The Part 572 dummy was capable of measuring a difference in side impact protection offered by the two cars even if the measurements in absolute

Table 2. Estimated wall velocity relative ground at time of dummy contact.

| Test no. | | Chest level m/s | Pelvis level m/s |
|---|---|---|---|
| 76236 | Level I | 5 | 6 |
| 80241 | | 7.5 | 7 |
| 80221 | | 7.5 | 8 |
| 79229 | Level II | 10 | 10.5 |
| 80231 | | 11 | 11.5 |
| 80220 | | 8.5 | 11.5 |

Table 3. Deformation at bumper height.

| Test no. | | (cm) |
|---|---|---|
| 76236 | Level I | 25 |
| 80241 | | 23 |
| 80221 | | 25 |
| 79229 | Level II | 40 |
| 80231 | | 51 |
| 80220 | | 45 |

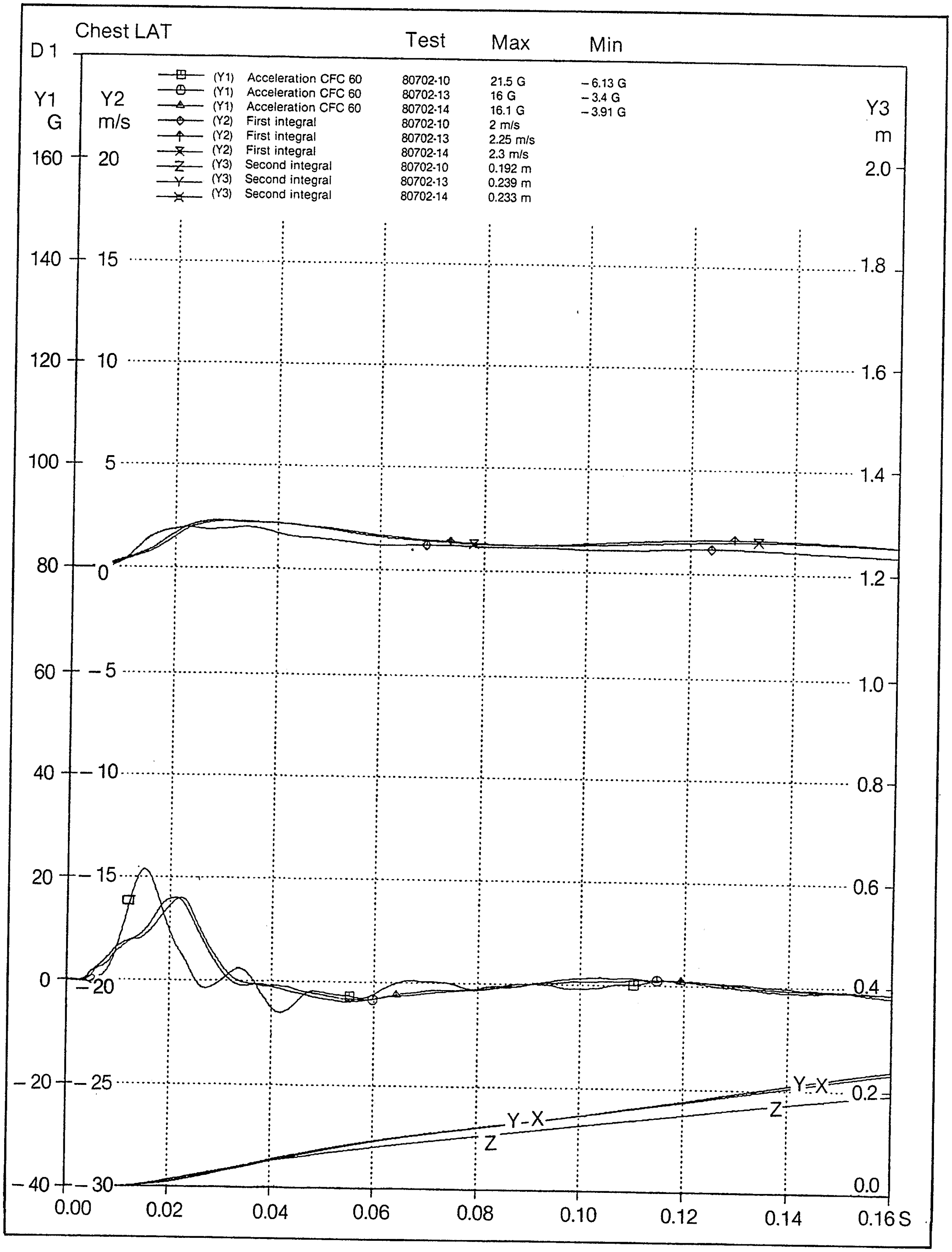

Figure 8. Comparison of lateral acceleration in "first thoracic vertebrae" HSRI dummy (Test No 80702-10) and lateral chest (center of gravity) acceleration APROD dummy (Test No. 80702-13,14) impactor speed (4,25 m/s).

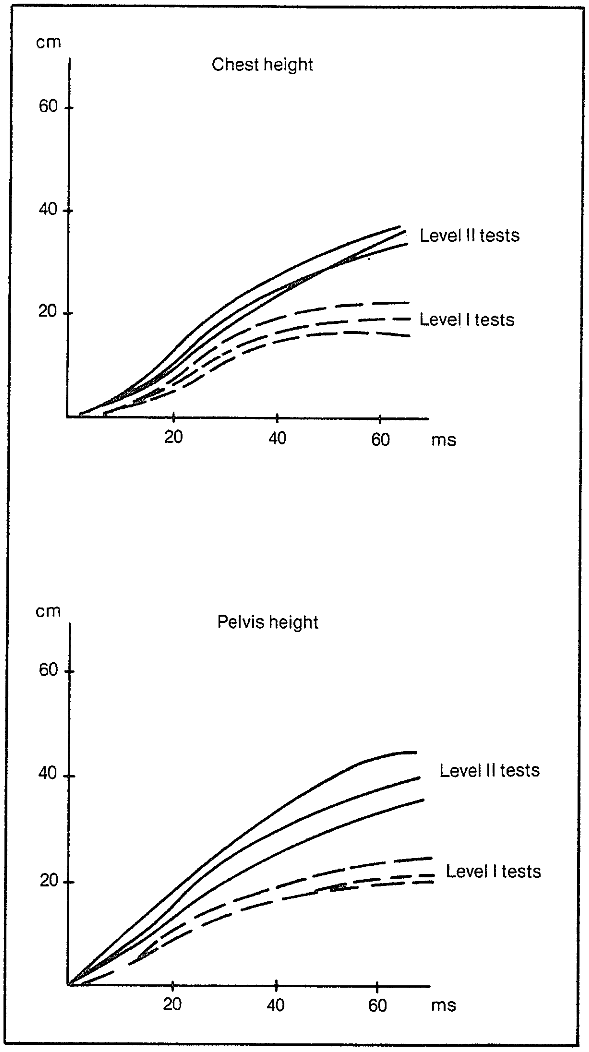

Figure 9. Wall intrusion relative to the car as a function of time. Evaluation made by high speed film analysis.

figures may not be "biomechanically" correct due to unrealistic head trajectories (9).

The chest accelerations in lateral direction are shown in figures 11–12. The maximum value (CFC 180) for Level I test is 62 g compared with 139 g in the Level II test. The 40 g criterion is exceeded in both tests but the dummy distinguish between the two levels of violence.

Pelvis lateral accelerations are shown in figures 13–14. The difference between the two tests is obvious both in acceleration and velocity change.

### Test with APROD Dummy

The resultant head accelerations are shown in figure 15. In the Level I test the HIC value is 98 and in the Level II test 149. Nor in these tests were there any head impacts with the B-pillar but a head to head impact later in the event in one test. This part is excluded from the HIC calculation.

In spite of an improved chest and an improved arm and clavicula attachment this dummy does not impact any structure with its head. It is impossible to say if this is unrealistic without being able to compare with the trajectories of cadavers in similar test conditions. However it is possible that the dummy head trajectories could be improved with a more human-like neck. Still the difference in side impact protection was indicated by this dummy too.

The lateral chest accelerations are shown in figures 16–17. The test with the stiff structure, Level 1, has a lower peak value (CFC 180) 74 g compared with 92 g for the other test, Level 2. The 40 g criterion is exceeded in both tests. Although there is a difference, this difference will almost disappear if one compares the 100 Hz filtered curves in figure 17. In peak values the maximum spinal acceleration in this dummy does not indicate the difference in side structure stiffness.

This dummy is however built to measure chest deflection and the results from these measurements are shown in figure 18. Unfortunately the signal for the upper segment in the Level I test was lost but the shaft stuck in what is believed to be the innermost position. This position was therefore measured after the test giving 32 mm deflection. Looking at the curves in figure 18 it is quite obvious that the friction in the bearing-bushings of the shafts is too high or uncontrolled causing permanent compression or step wise expansion. The question is also to what degree this friction has affected the compression phase and the maximum deflection.

The average deflection in the Level I test is 25 mm, compared with 37 mm for the Level II test. The suggested criterion of 45 mm is not exceeded in any of the two tests.

Assuming that the shaft friction did not affect the maximum values of the chest deflection the dummy indicates the difference in side impact protection.

The pelvic accelerations in lateral direction are shown in figures 19–20. The evident difference in peak acceleration is also reflected in a higher maximum velocity change for the Level II test as shown by the curve for the first integral.

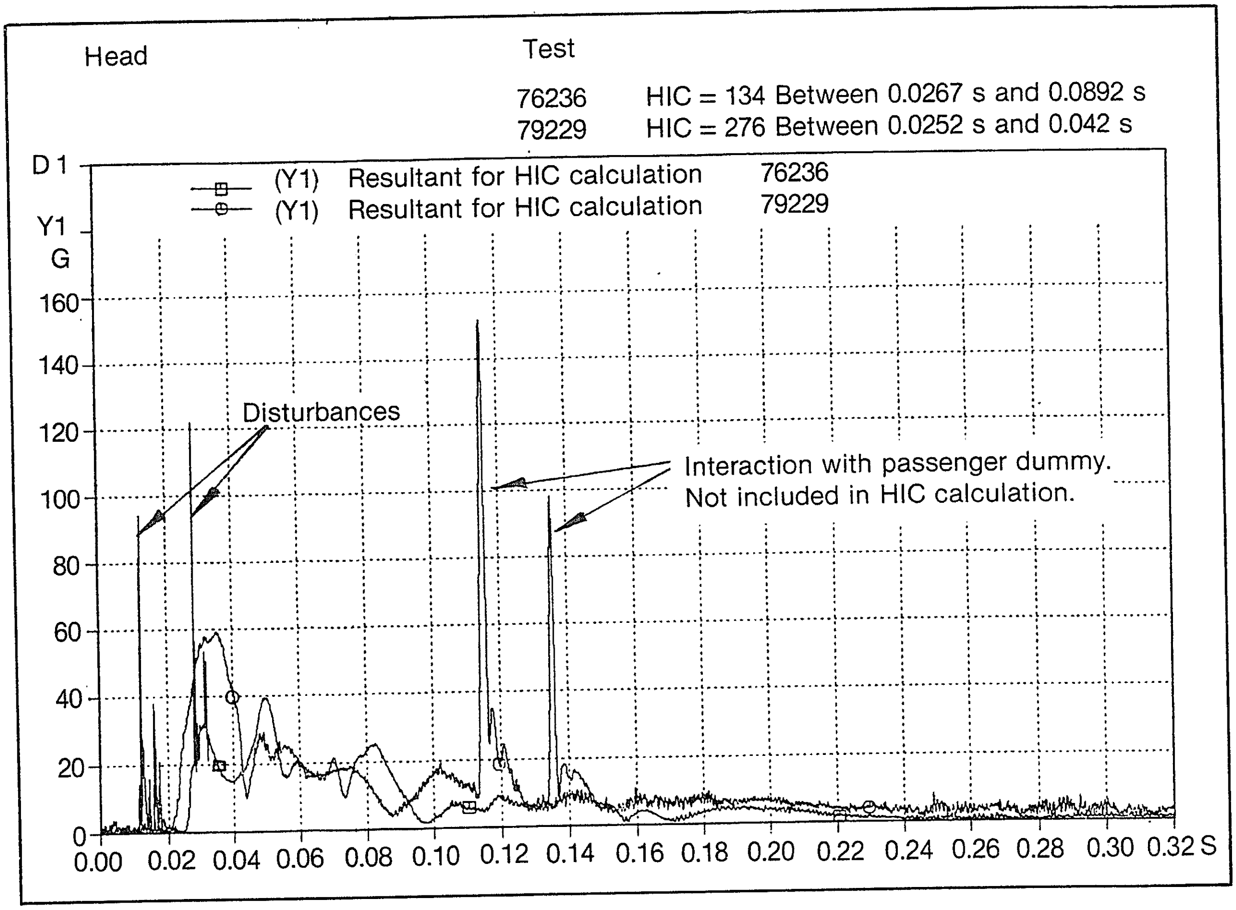

Figure 10. Comparison of head resultant acceleration in tests with part 572 dummy.

### Test with HSRI Dummy

In both tests there were head impacts at B-pillar. These impacts occur as prominent peaks in the head resultant acceleration as depicted in figure 21. The maximum HIC values have been found during this impact phase, giving in the Level I test 226 and the Level II test 509. This dummy has obviously the capability of simulating head impacts and even to differentiate between the severity of such impacts.

The data from the twelve accelerometers in the chest are all given in figures 22–25. Please observe that the target car in test 80221 had the steering wheel on its right side. Consequently the impact direction was from the right and the dummy was changed to be tested at the right side. For instance, to compare test 80220 with test 80221 data from the left side of the chest have to be compared with data from the right side.

The peak values for the lateral acceleration of the "first thoracic vertebrae" were (CFC 180) 47 g for the Level I test and 62 g for the Level II test. The 40 g criterion is exceeded in both tests.

The accelerations and velocity changes of the near side rib are shown in figure 26. In the Level I test the maximum velocity change is 7.4 m/s compared with 9.6 m/s in the Level II test. The proposed criterion of 9.14 m/s is slightly exceeded in the Level II test.

The injury predictive models give the following result:

Table 4. Results of injury predictive models.

| Test no. | LURQ AIS | BLUR AIS |
|---|---|---|
| 80221 Level I | 2.42 | 2.42 |
| 80220 Level II | 3.78 | 3.10 |

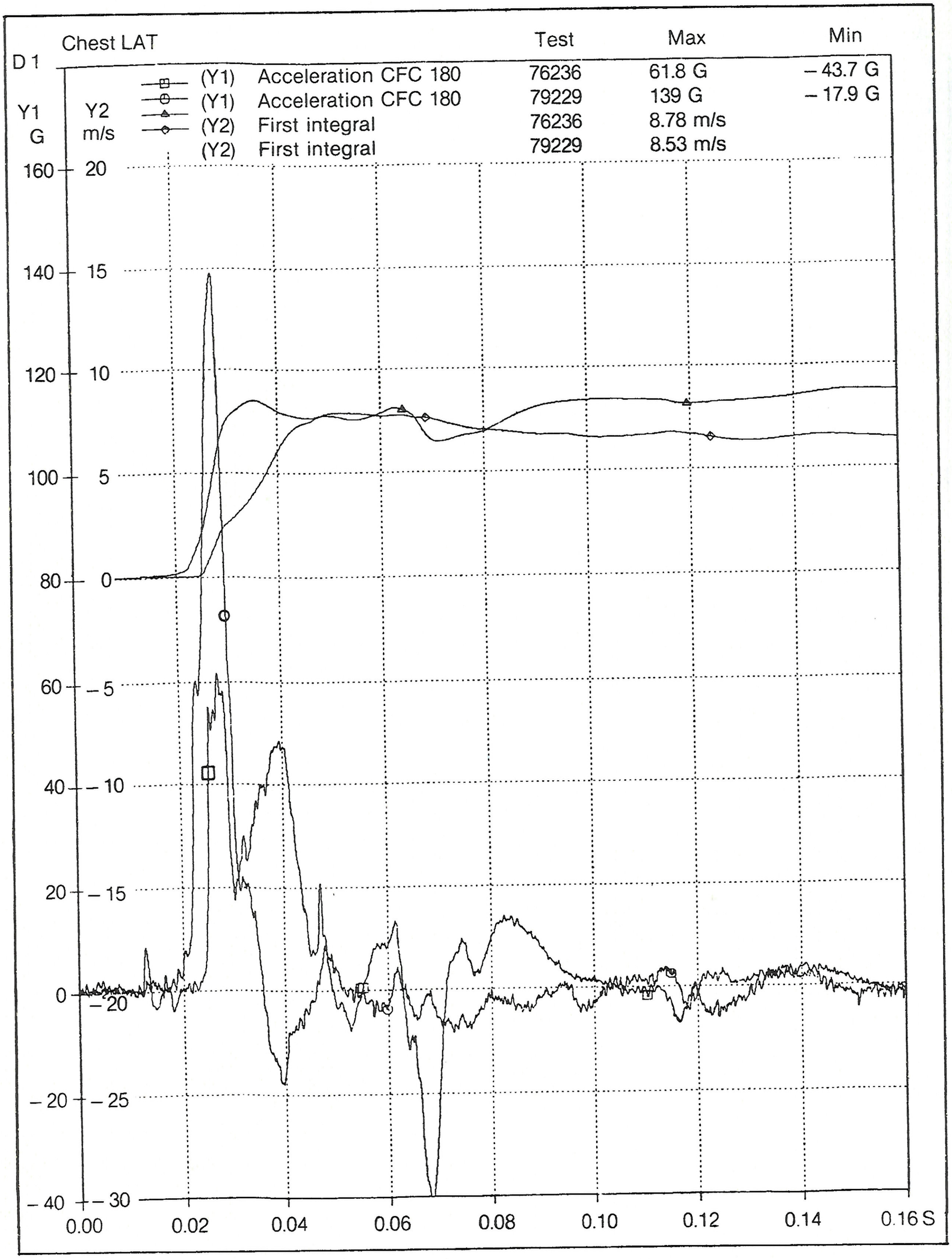

Figure 11. Comparison of lateral chest acceleration in tests with part 572 dummy. CFC 180.

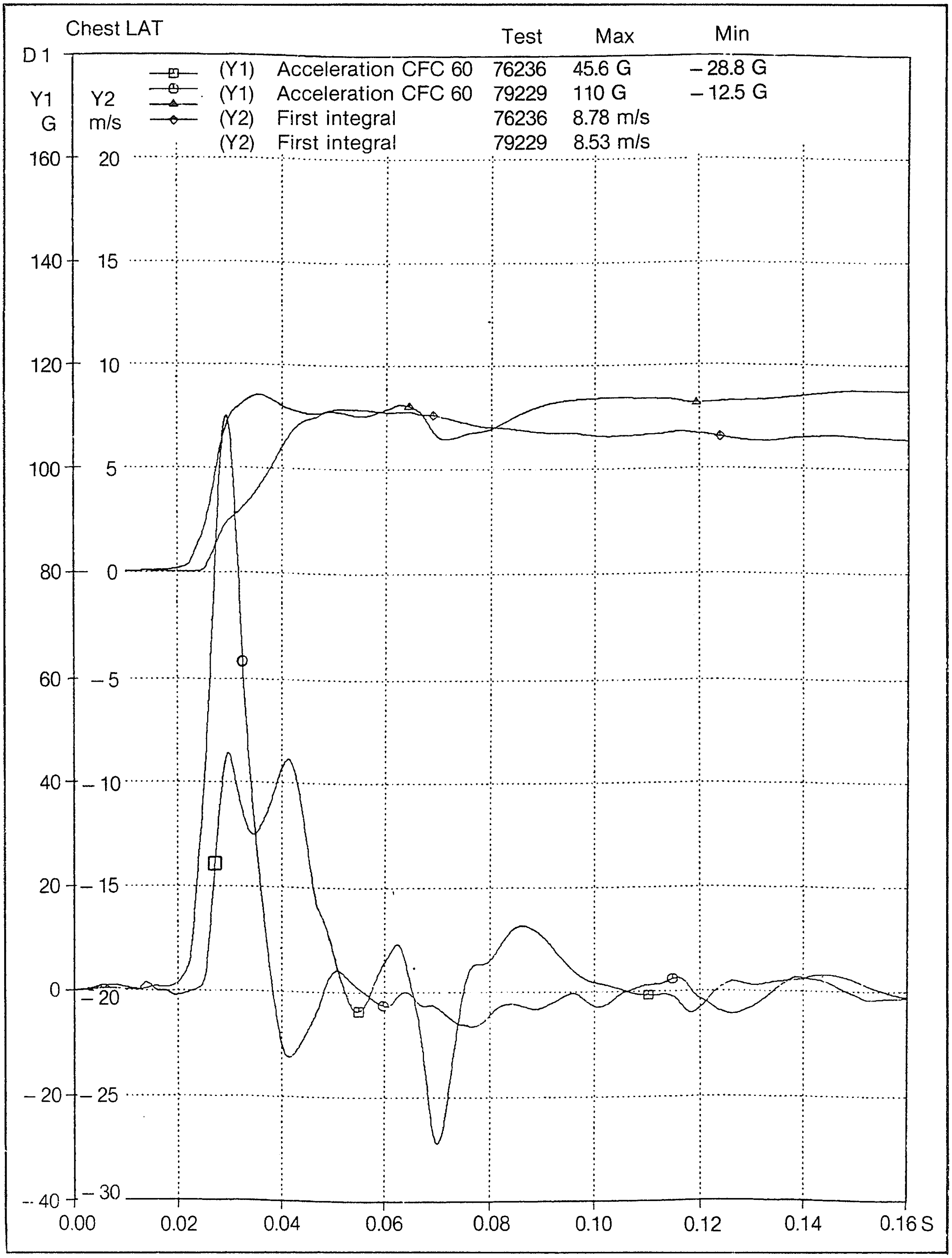

Figure 12. Comparison of lateral chest acceleration in test with part 572 dummy. CFC 60.

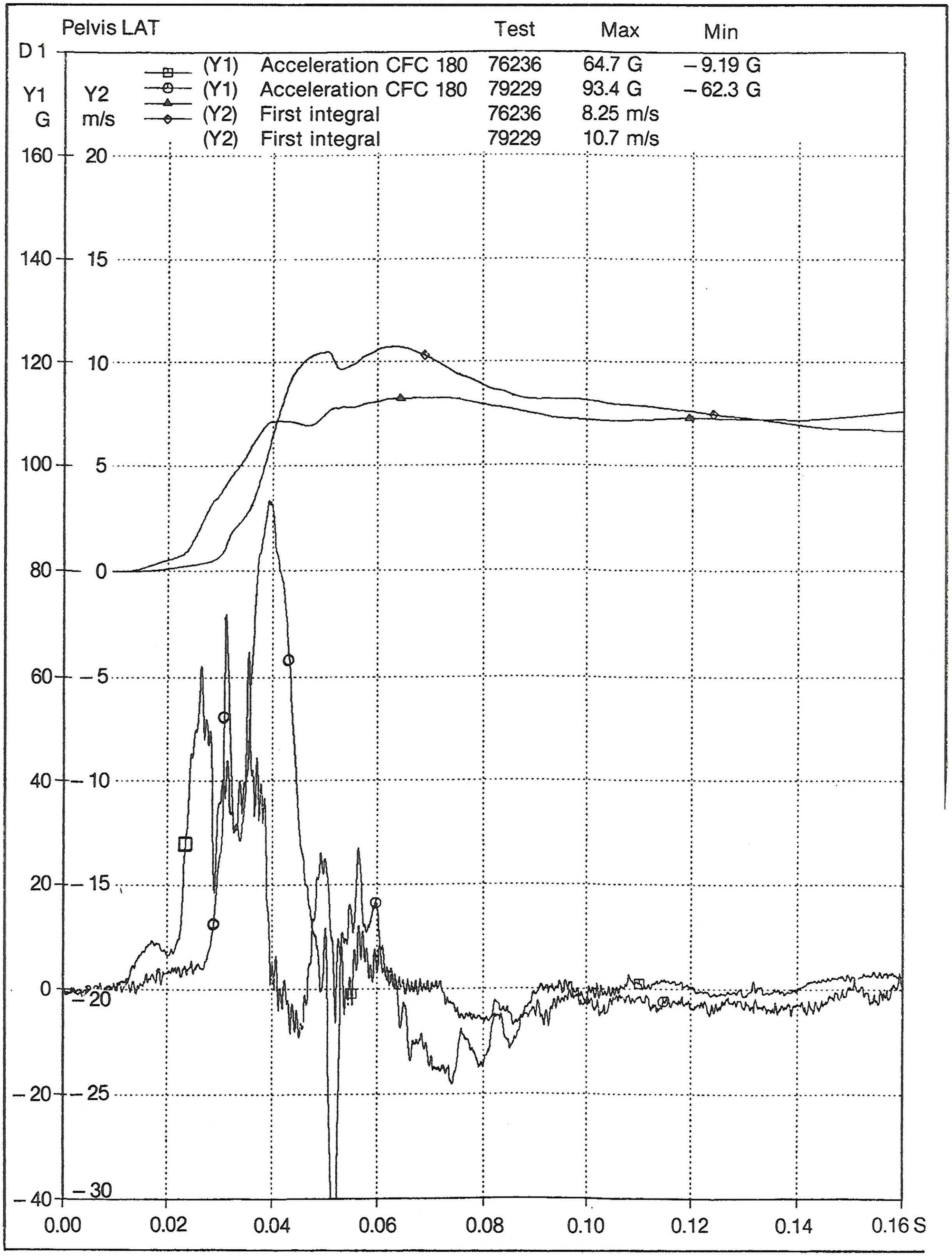

Figure 13. Comparison of pelvis lateral acceleration in test with part 572 dummy. CFC 180.

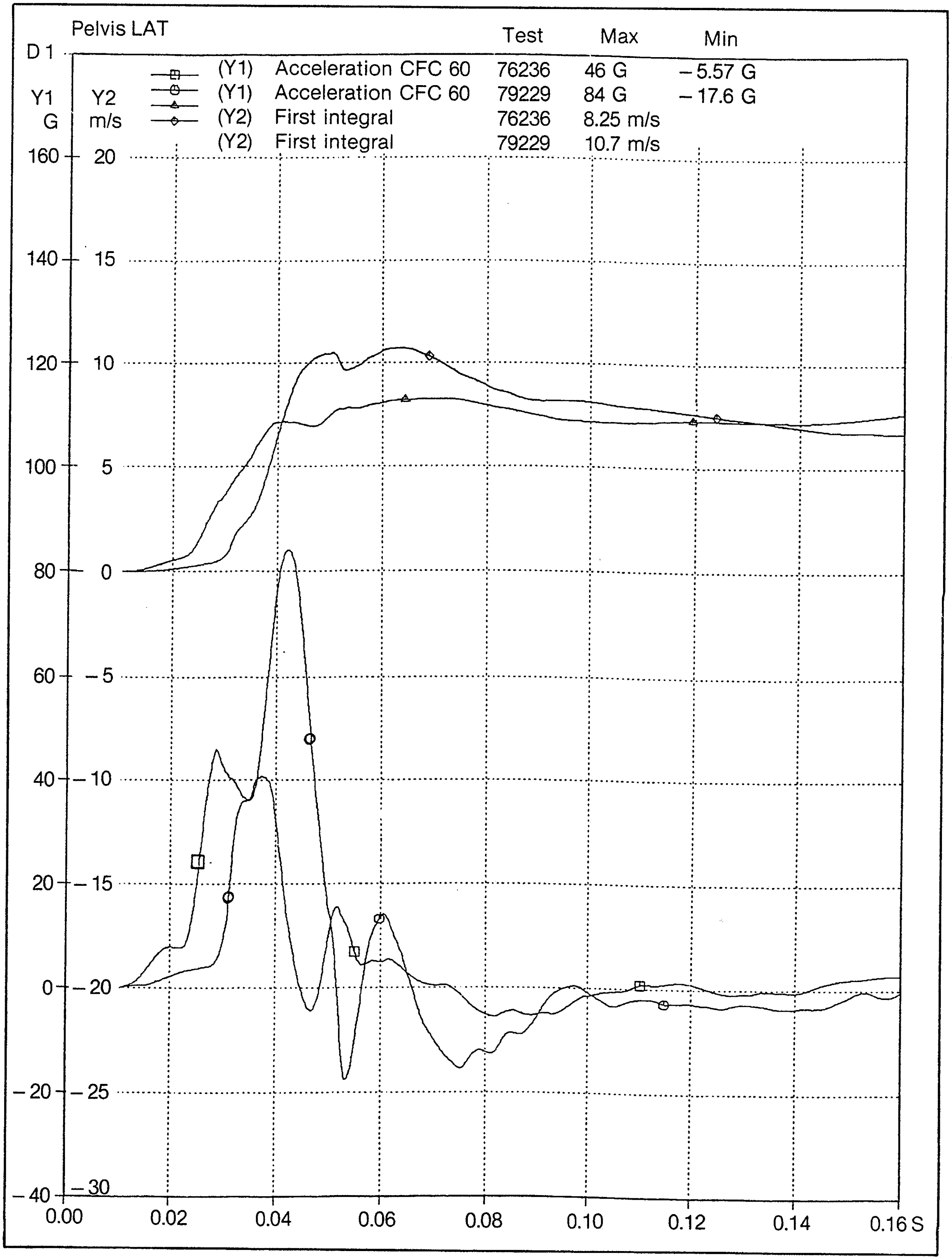

Figure 14. Comparison of pelvis lateral acceleration in test with part 572 dummy. CFC 60.

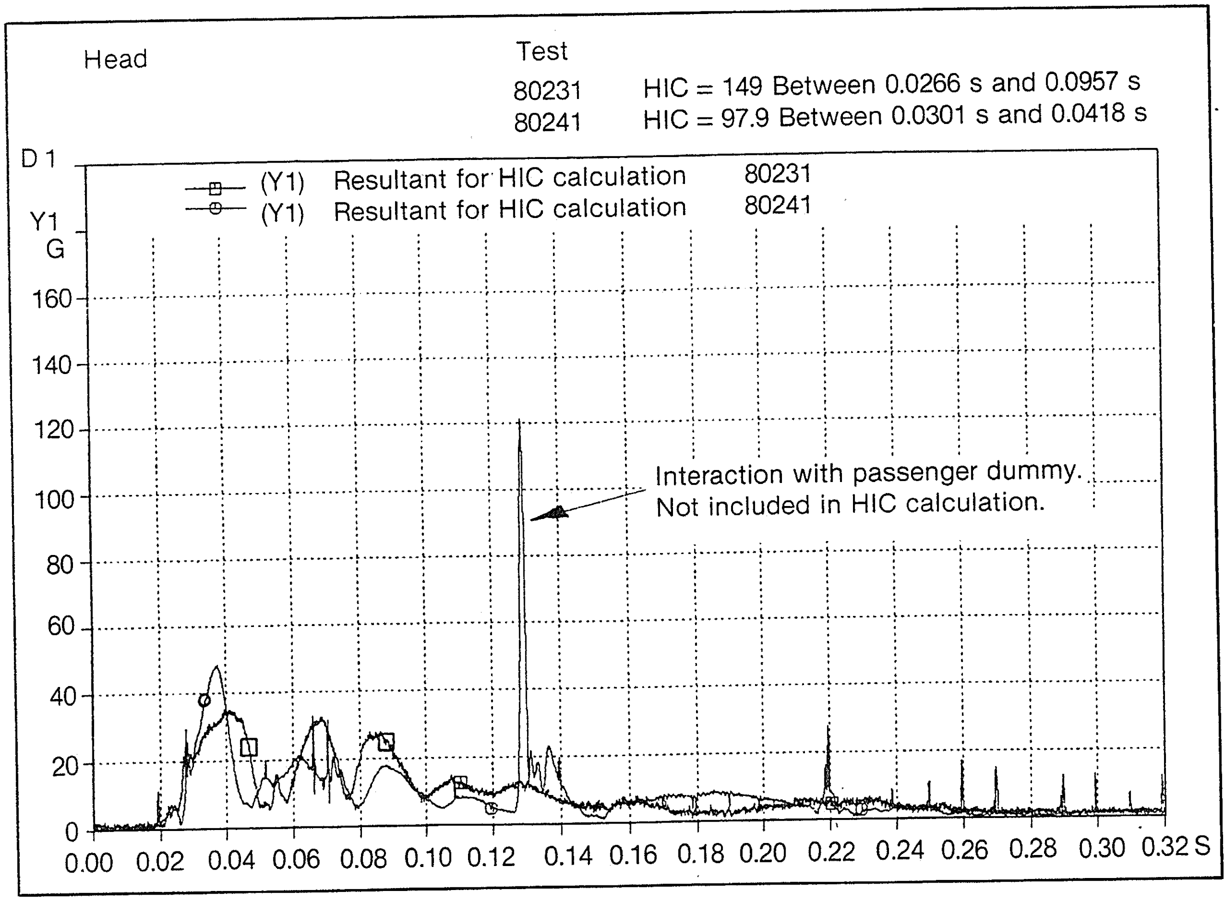

Figure 15. Comparison of resultant head acceleration in tests with APROD dummy.

It is evident that the thorax in this dummy distinguish the difference in side impact protection with all the proposed criteria.

The pelvic lateral accelerations are shown in figures 27–28. Also for this dummy there is a difference both in the peak accelerations and the maximum velocity changes.

## Summary

### Head Results

A summary of all the head results is shown in table 5.

### Chest Results

A summary of the chest (spinal) data is shown in table 6. In the HSRI dummy the data of the "first thoracic vertebrae" accelerometer have been used.

Table 5. Head results. Resultant acceleration. Interaction with passenger dummy excluded.

| Test no. | Dummy | HIC |
|---|---|---|
| 76236 Level I<br>79229 Level II | Part 572<br>" | 134<br>276 |
| 80241 Level I<br>80231 Level II | APROD<br>" | 98<br>149 |
| 80221 Level I<br>80220 Level II | HSRI<br>" | 226*<br>509* |

*Head impact B-pillar

### Pelvis Results

The pelvis acceleration in lateral direction is summarized in table 7.

The chest injury criteria results are summarized in table 8.

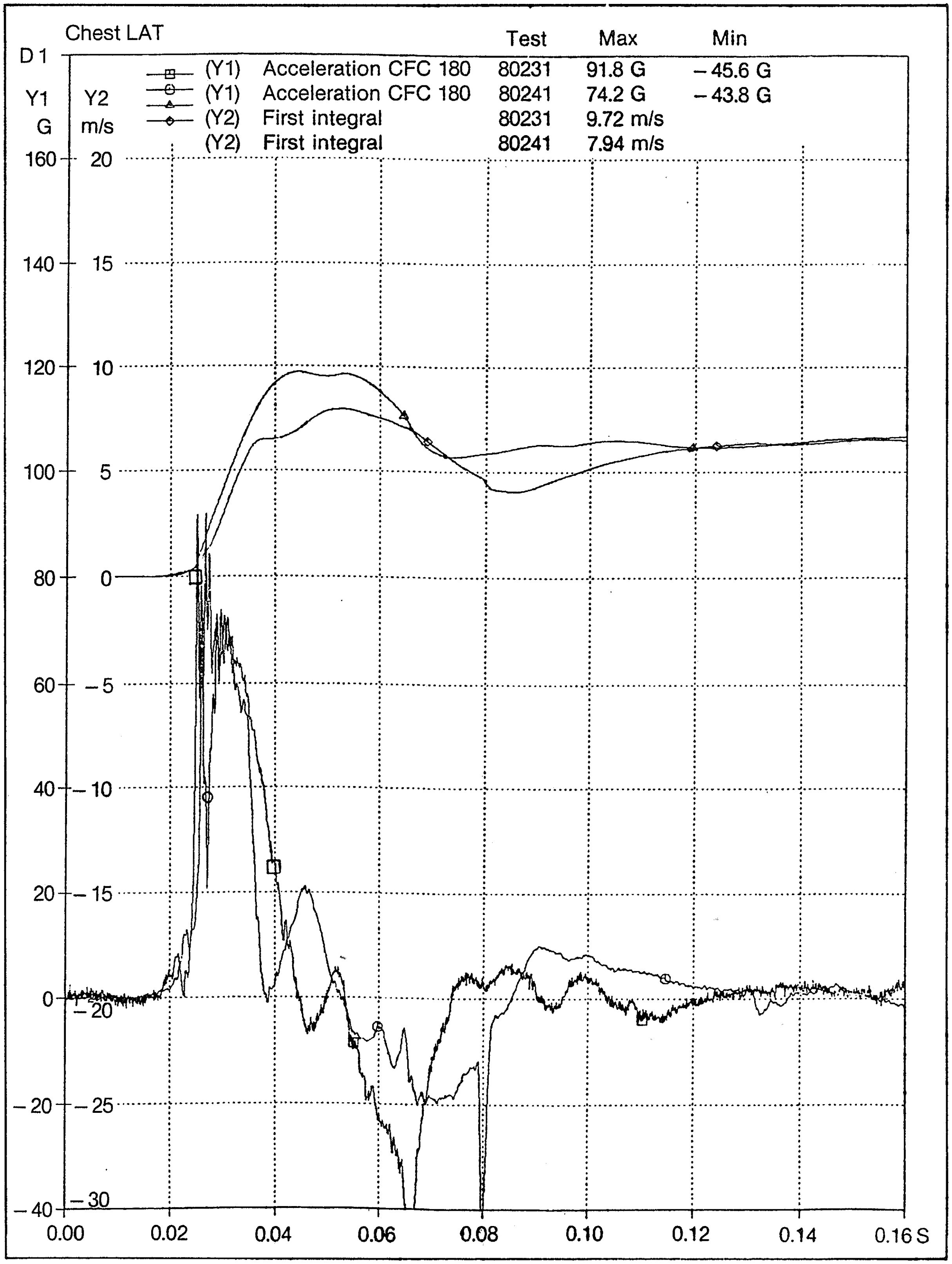

Figure 16 Comparison of lateral chest acceleration in test with APROD dummy. CFC 180.

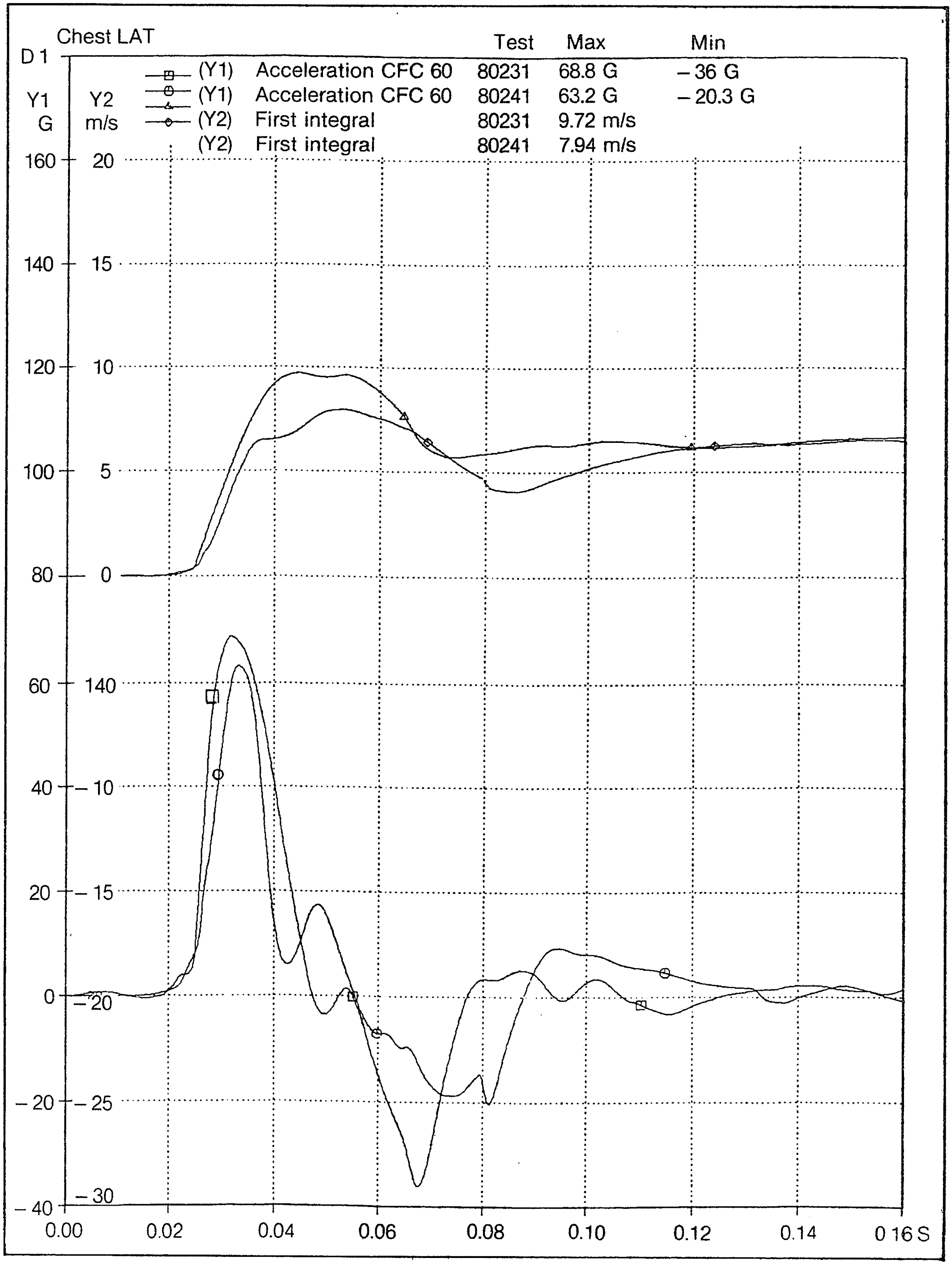

Figure 17. Comparison of lateral chest acceleration in tests with APROD dummy. CFC 60.

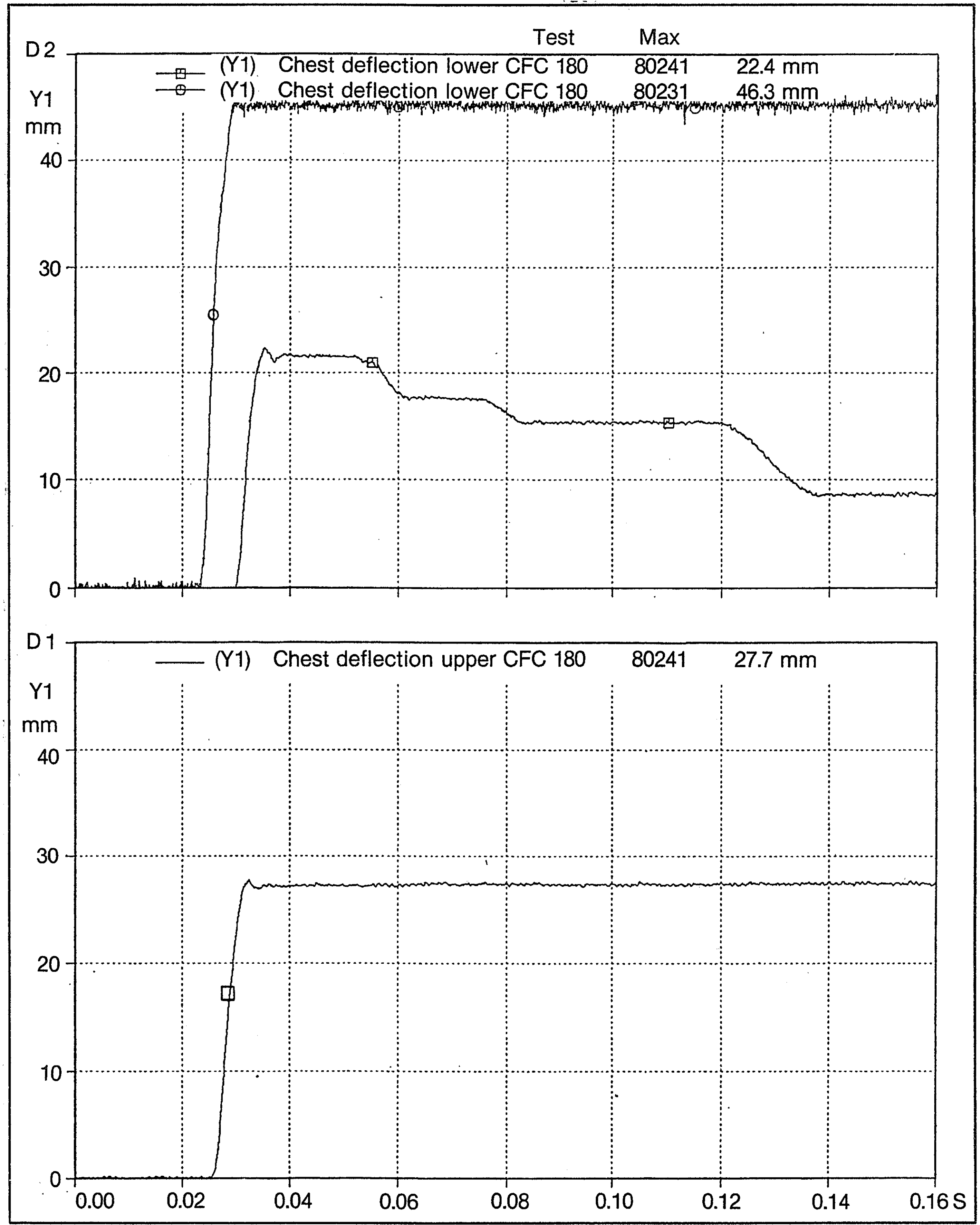

Figure 18. Comparison of chest deflections in tests with APROD dummy.

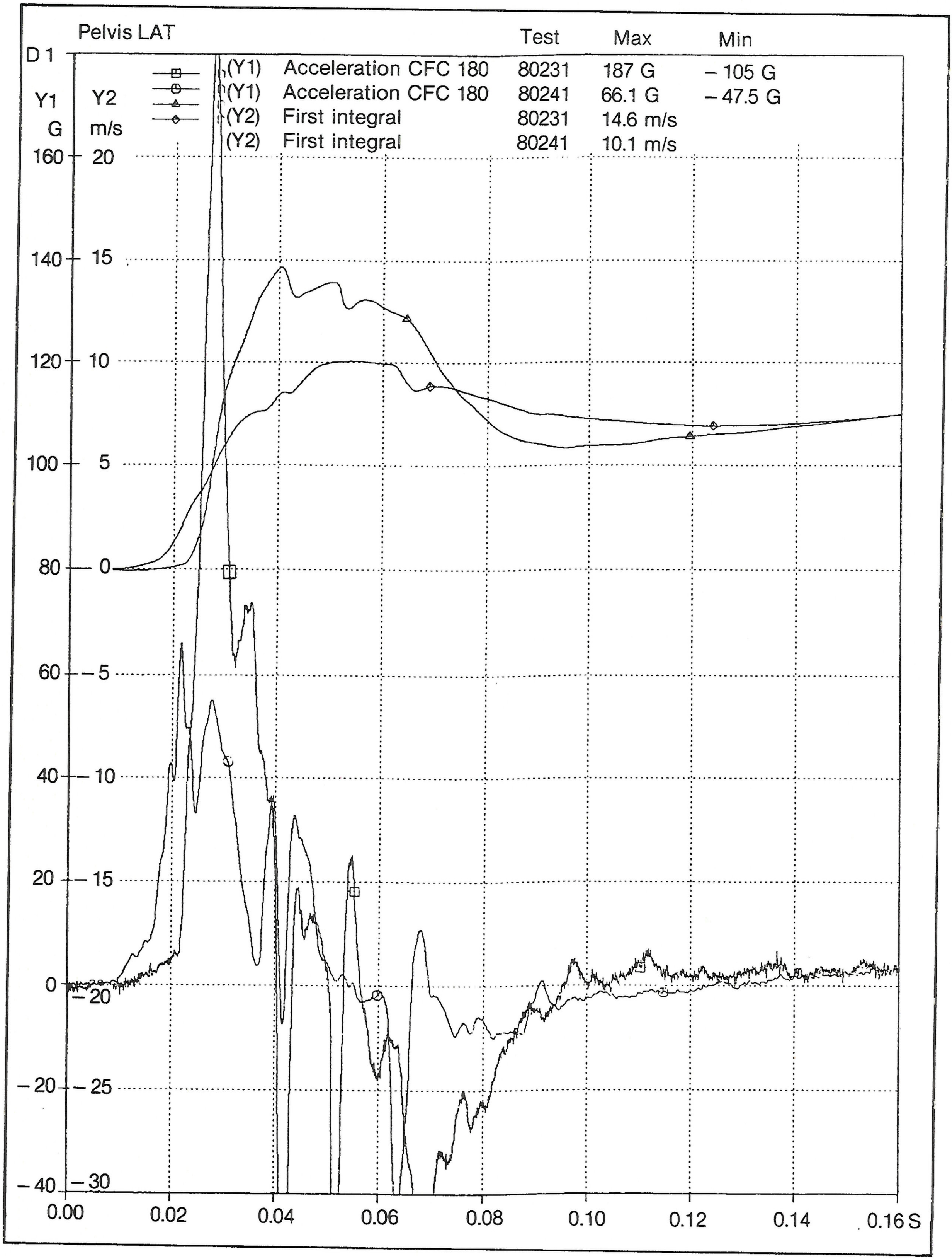

Figure 19. Comparison of lateral pelvis acceleration in tests with APROD dummy. CFC 180.

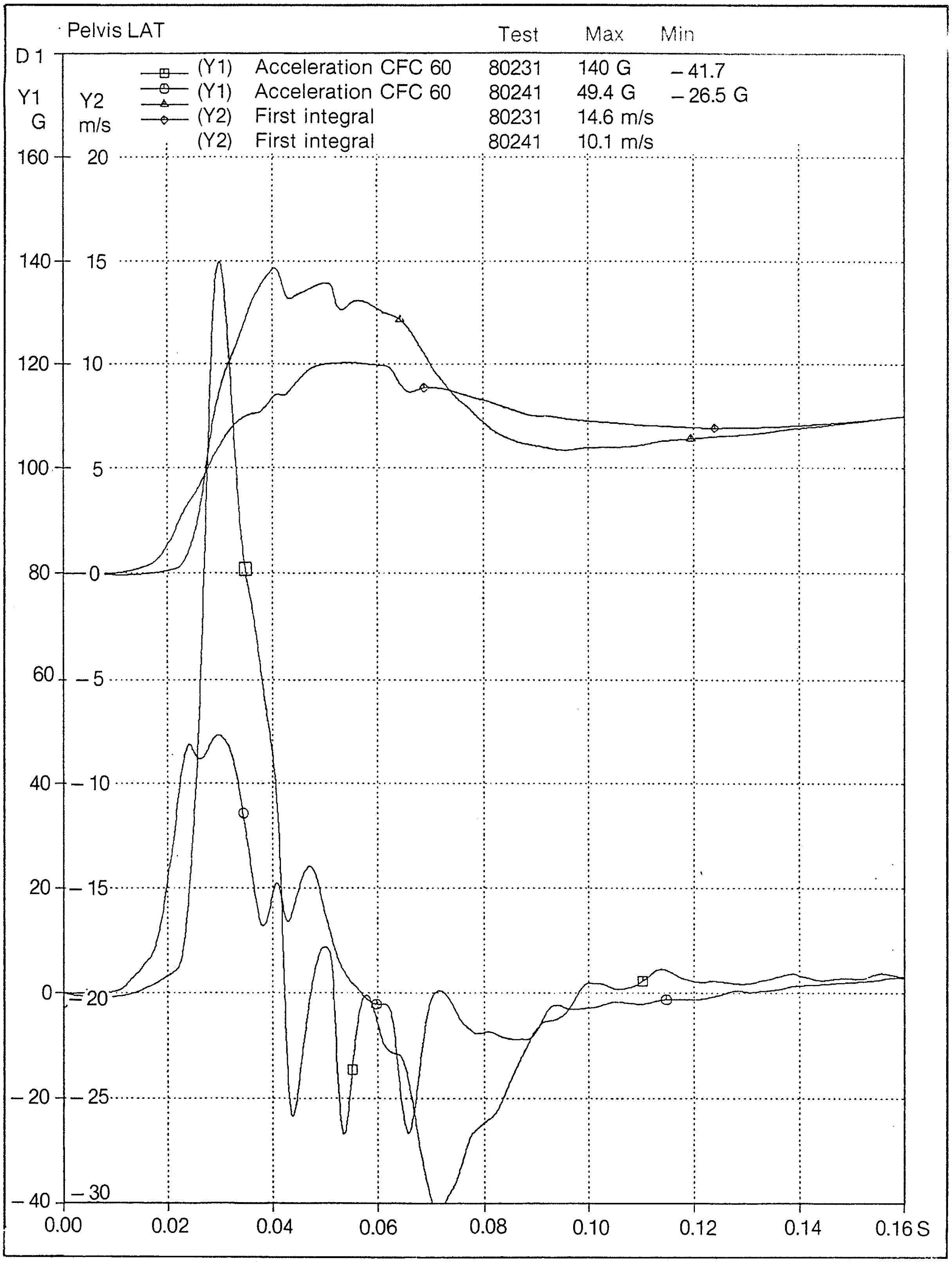

Figure 20. Comparison of lateral pelvis acceleration in tests with APROD dummy. CFC 60.

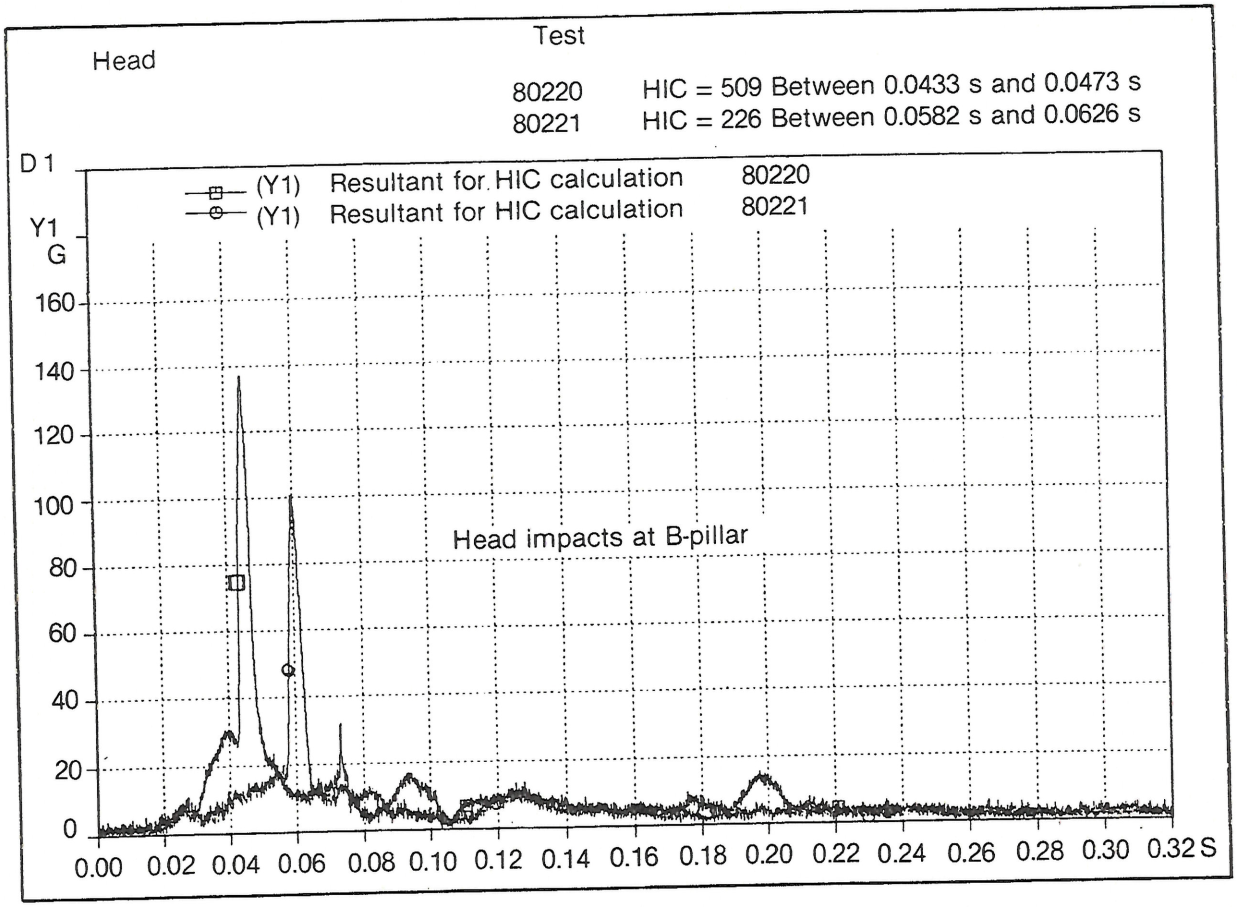

Figure 21. Comparison of resultant head acceleration in tests with HSRI dummy.

Table 6. Chest lateral acceleration.

| Test no. | Dummy | Max acceleration (CFC 180) (g) |
|---|---|---|
| 76236 Level I<br>79229 Level II | Part 572<br>" | 62<br>139 |
| 80241 Level I<br>80231 Level II | APROD<br>" | 74<br>92 |
| 80221 Level I<br>80220 Level II | HSRI<br>" | 47<br>62 |

Table 7. Pelvis lateral acceleration.

| Test no. | Dummy | Max acceleration (g) (CFC 180) |
|---|---|---|
| 76236 Level I<br>79229 Level II | Part 572<br>" | 65<br>93 |
| 80241 Level I<br>80231 Level II | APROD<br>" | 66<br>187 |
| 80221 Level I<br>80220 Level II | HSRI<br>" | 81<br>176 |

## DISCUSSION

It is a known fact that a complex crash testing method like the one used in this work does create a large scatter in measured data, even if one tries to hold input parameters constant. Therefore any deeper analysis, trying to correlate the results between the different dummies, cannot be justified.

However, there are trends in the results which are interesting. First, the evaluation of the trajectories of the dummies shows that the HSRI dummy has the most compliant chest including arm simulations. This effect makes the dummy head to impact the inner structure of the car.

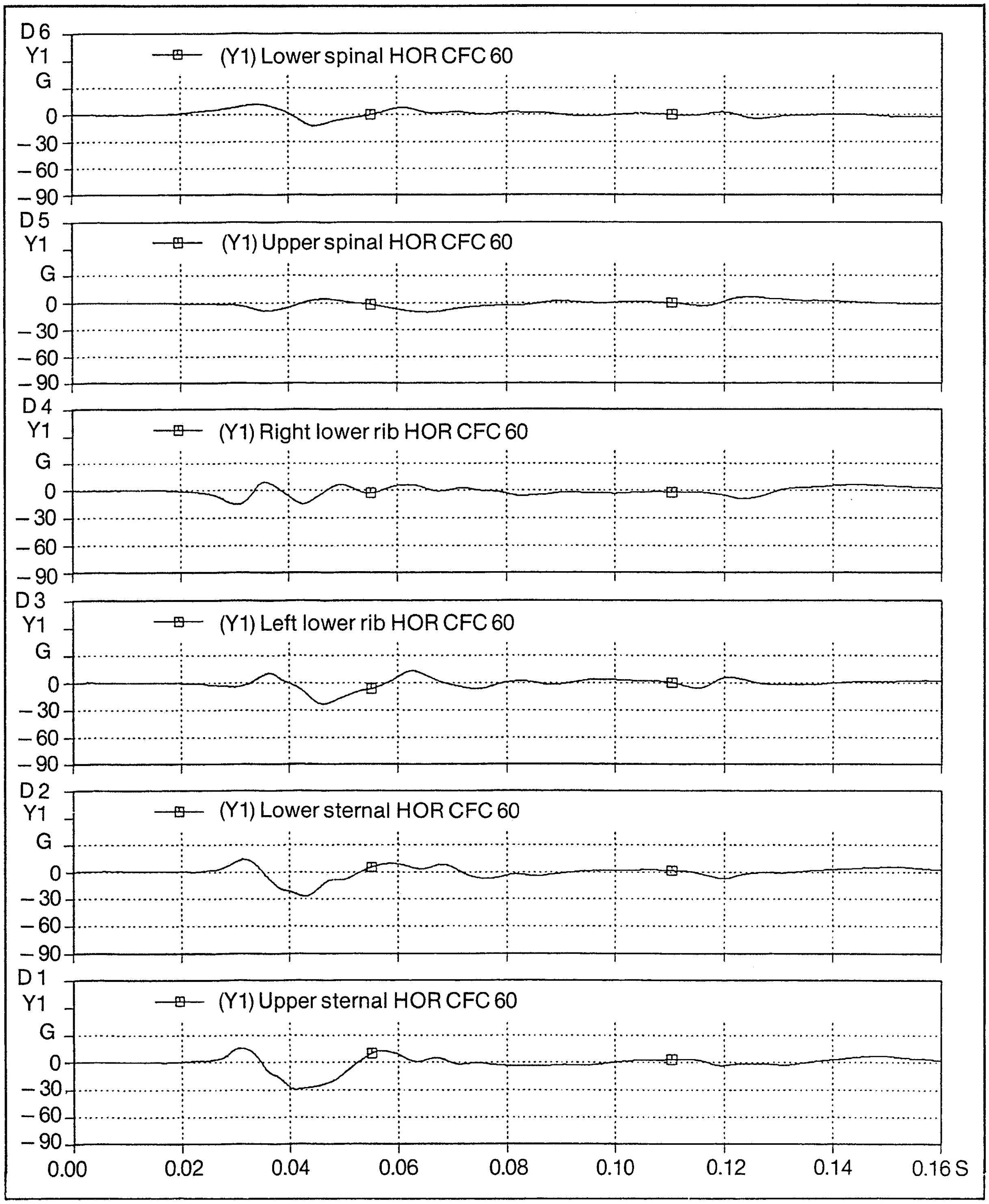

Figure 22. Chest signals from test 80221, level I, with HSRI dummy. CFC 60.

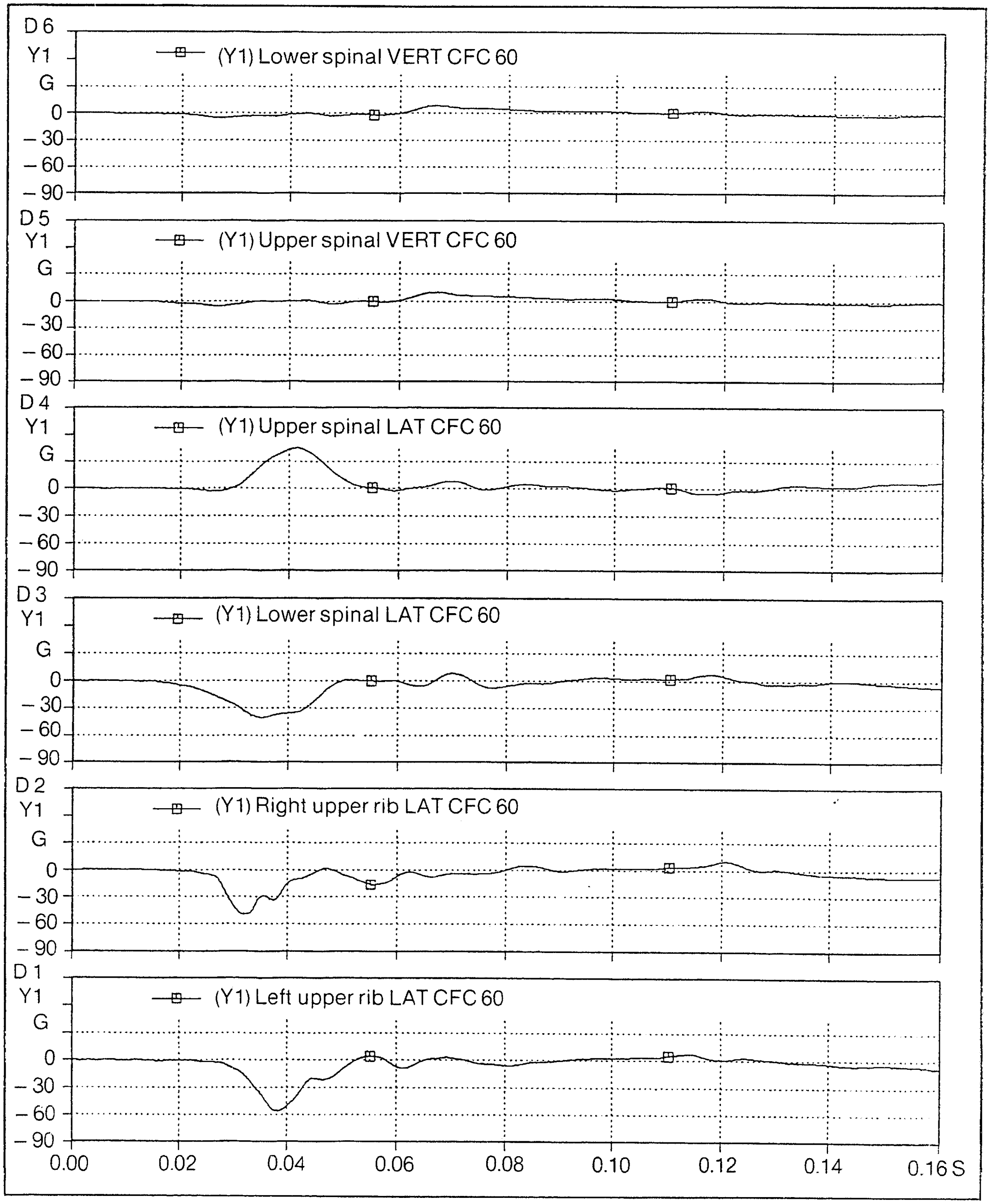

Figure 23. Chest signals from test 80221, level I, with HSRI dummy. CFC 60.

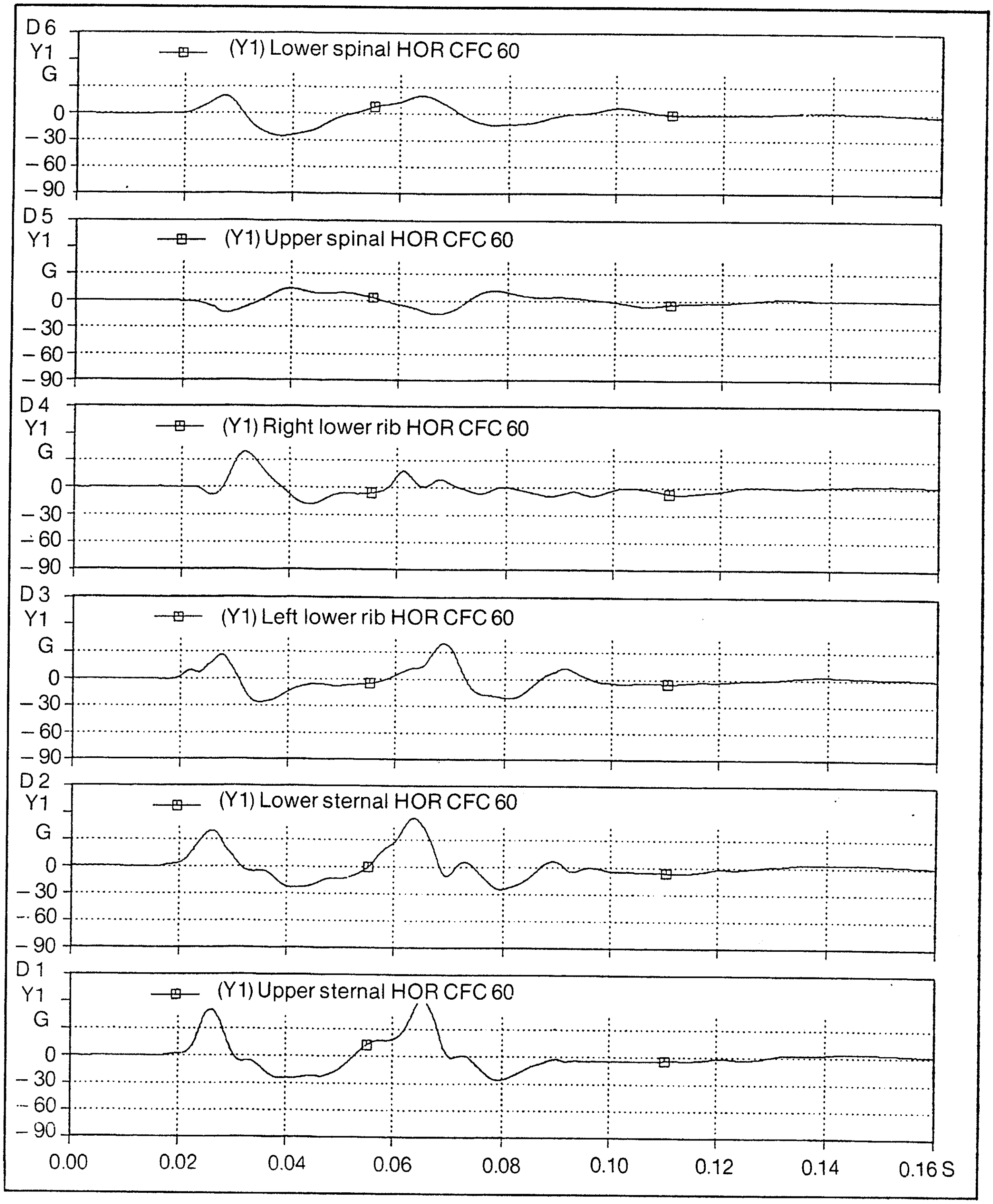

Figure 24. Chest signals from test 80220, level II, with HSRI dummy. CFC 60.

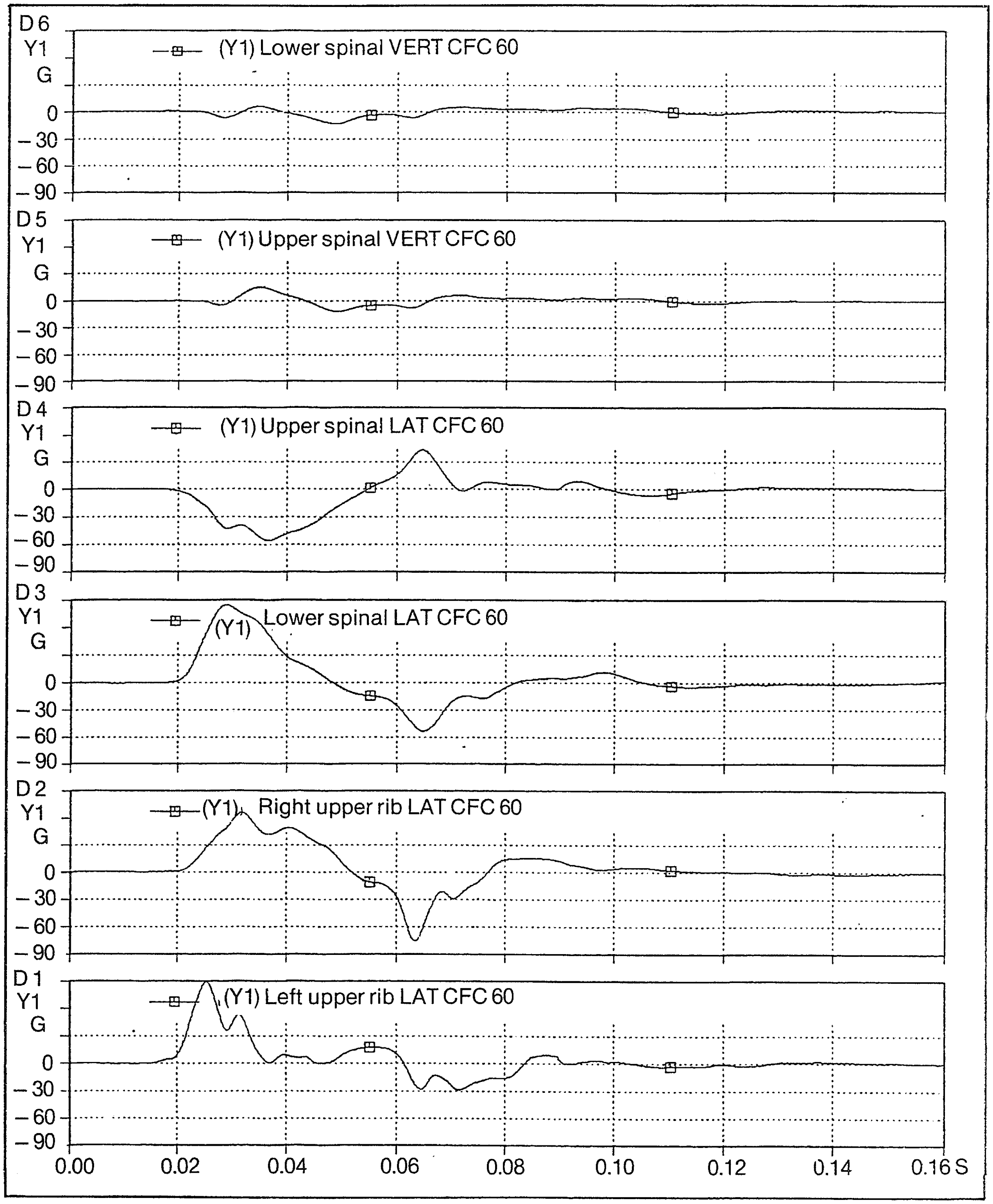

Figure 25. Chest signals from test 80220, level II, with HSRI dummy. CFC 60.

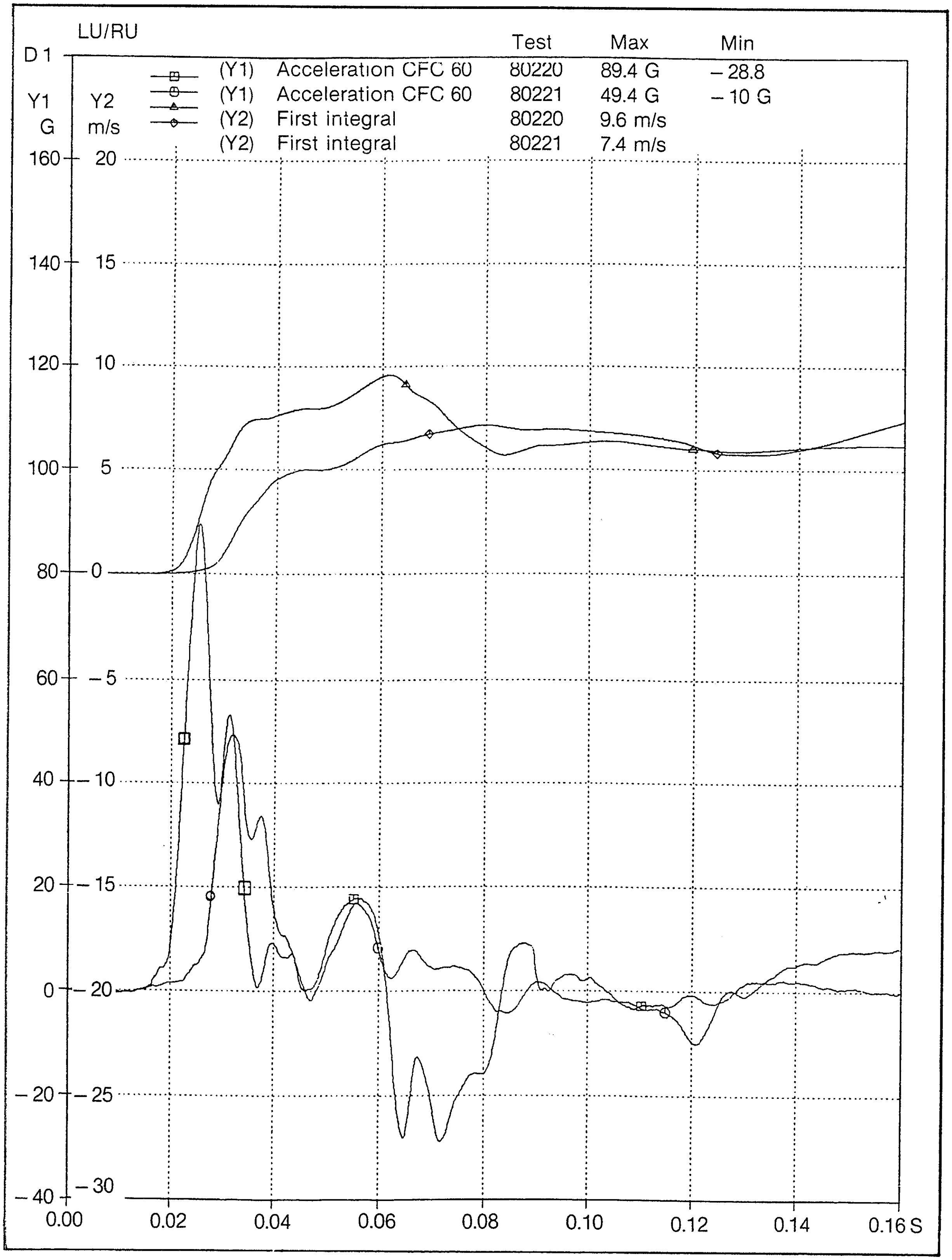

Figure 26. Comparison of data for near side upper rib in tests with HSRI dummy.

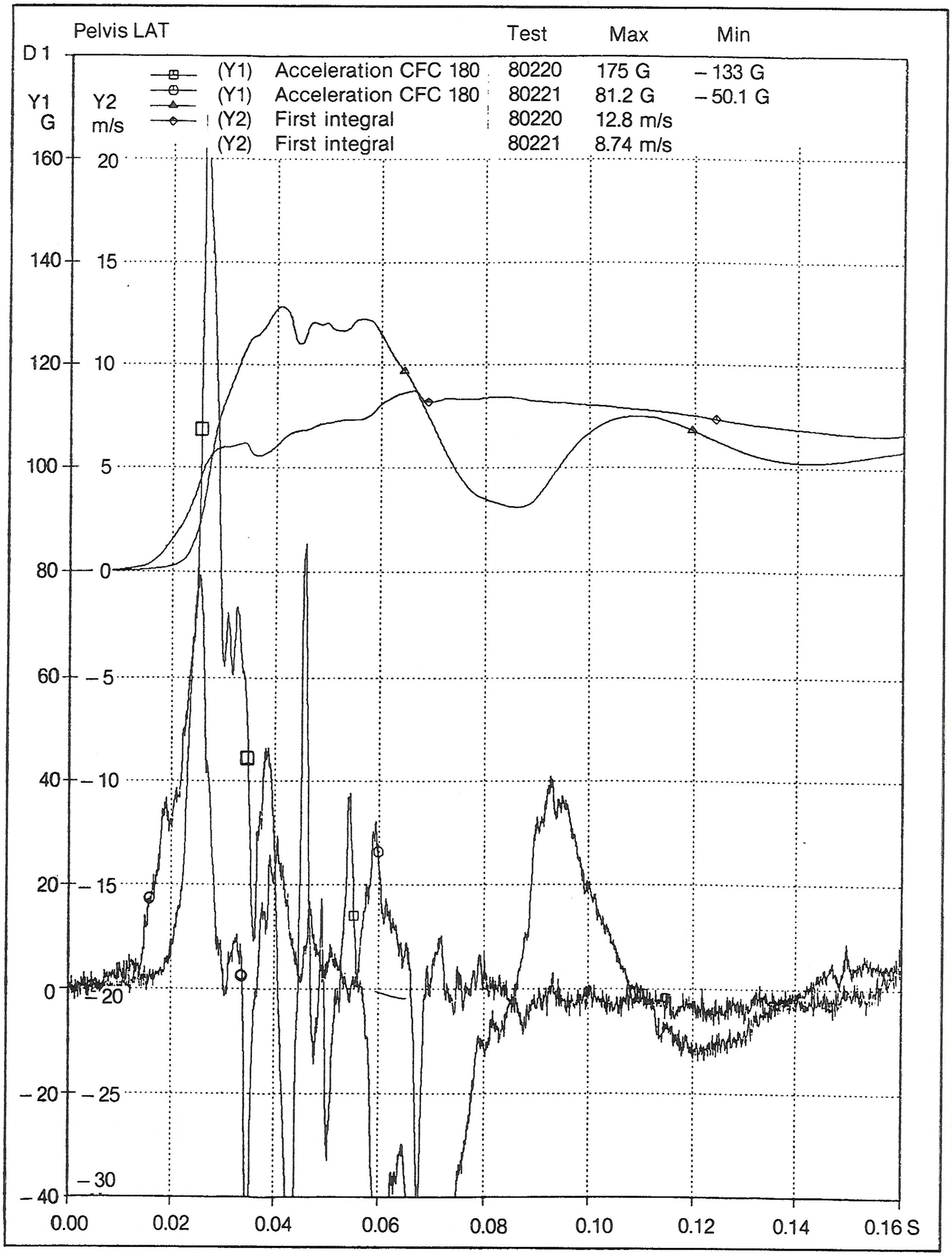

Figure 27. A comparison of lateral pelvis acceleration in tests with HSRI dummy. CFC 180.

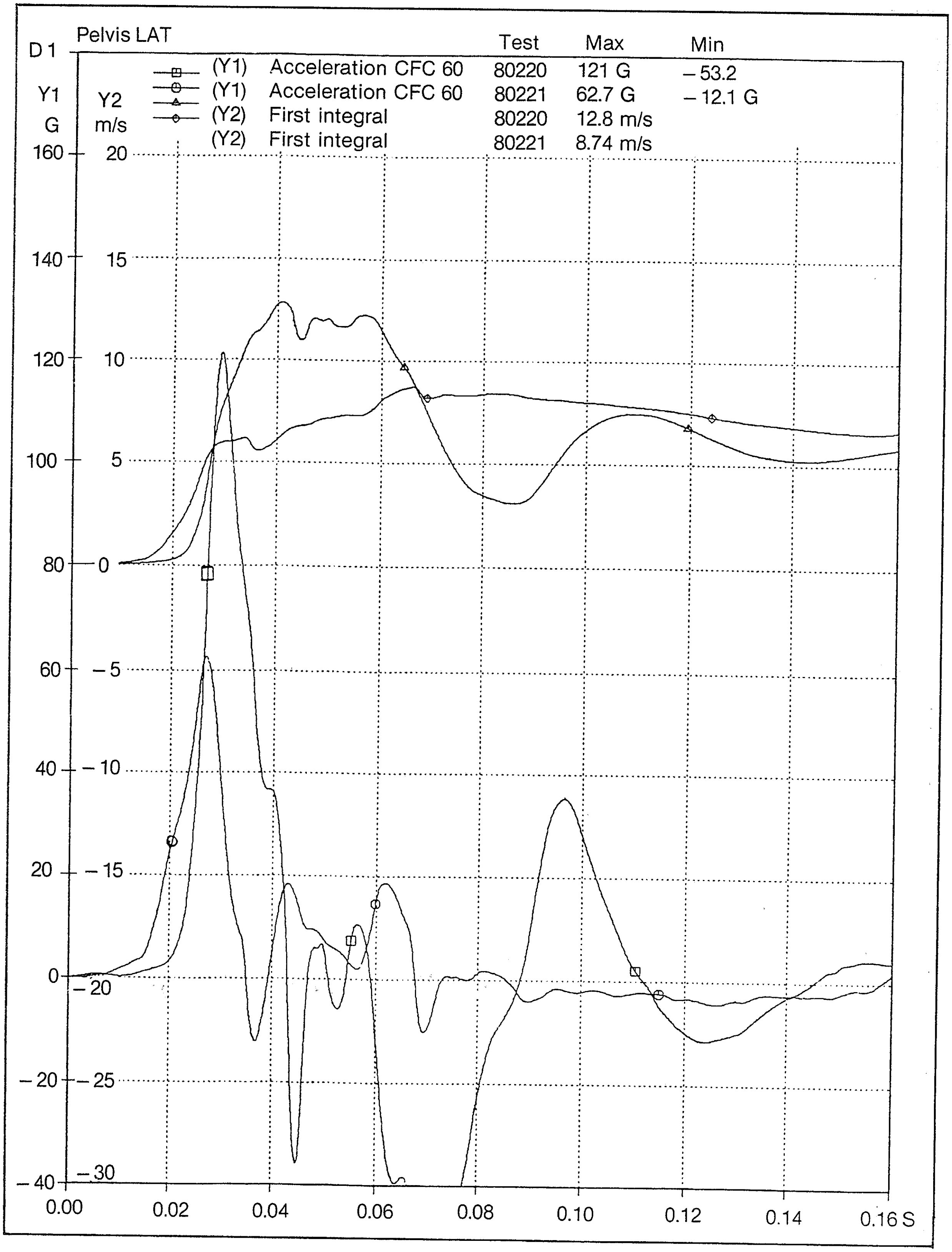

Figure 28. Comparison of lateral pelvis acceleration in tests with HSRI dummy. CFC 60.

Table 8. Chest injury criteria.

| Test no. | Dummy | Max spinal acc ≤40g 3 ms | Average chest defl ≤45mm | AIS LURQ | AIS BLUR | Max vel near side rib ≤9,14 ms |
|---|---|---|---|---|---|---|
| 76236 Level I | Part 572 | Exceeded | — | — | — | — |
| 79229 Level II | " | " | — | — | — | — |
| 80241 Level I | APROD | " | 25 | — | — | — |
| 80231 Level II | " | " | 37* | — | — | — |
| 80221 Level I | HSRI | " | — | 2,4 | 2,4 | 7,4 |
| 80220 Level II | " | " | — | 3,8 | 3,8 | Exceeded 9,6 |

*One channel was lost. See under results.

Presumably this response is close to the cadaver response but this has to be proven by further research. The APROD dummy did not produce any head impacts. Probably this dummy might be improved with a more humanlike neck. Assuming that the dummies could reproduce a realistic head impact there still remains the question whether the Part 572 head is suitable for measuring impacts to the side of the head.

Second, the peak spinal acceleration criterion (≤40 g) is in complete disagreement with the other criteria for the APROD and HSRI dummy. However a cautious comparison between the deflection results for the APROD dummy and the AIS predictions and the near side rib velocity criterion for the HSRI dummy (see table 8) reveals a rather good resemblance in predictions.

The deflection criterion for the APROD dummy used in this report has been an average value of the measurements of the two segments. A better solution could probably be to have a deflection criterion for each segment. Such a solution would better measure the effect of localised trauma to the thorax, for instance caused by an armrest or the intruding body structure.

The application of the HSRI criteria approach has given rather consistent results in this work. However, as the upper near side rib seems to be the main governing contributor and as the accelerometer on the lower near side rib has the sensitivity axle in A-P direction the question could be raised what the response will be if the impact is local at a low point of the thorax. The twelve accelerometer method has been used by researchers to describe cadaver response and to check the response of the potential side impact dummies. For some specific impact conditions it has been shown that injury predictive models are able to perform well using data only from a few of the twelve accelerometers (3,5,6). It has to be carefully evaluated if this is true for all the impact situations which could be experienced in side impacts.

## Considerations of Dummy Design

The work with the APROD chest has given useful insight in the "engineering aspect" of such a design. As said earlier in this report the shafts had a tendency to jam. After a test "scares" were found on the shafts suggesting that the material in the shafts is too soft. It was also found that by compressing only one segment a bending is produced in the rib cage which affects the friction in the other shaft. Furthermore it must be realized that a deflection criteria puts some special demands on this type of design. First, the pistons unloaded positions must be carefully adjusted to avoid any play. Otherwise it is possible to "lose" some millimeters in deflection before the force will rise. Secondly, the friction in the bushings must be sufficiently low to ensure that the pistons are in their utmost extended position before testing.

Although the chest deflections measured in these tests were well below the suggested criterion of 45 mm it is our opinion that the available stroke has to be increased above the recent 55 mm in order to enable measuring of high violence. It was also found that the rear ends of the ribs might interact with the spine box before the 55 mm stroke is completed, under special loading conditions.

The shaft in the clavicula of the APROD dummy seemed to suffer of the same problems as the deflection shafts.

The response of the HSRI dummy is greatly depending on the performance of the damper in the chest. It has been found that small air bubbles in the silicon oil in this damper drastically affect the signal in the upper rib. Therefore the cylinder has to be carefully bleeded and the oil checked for air bubbles.

This could be done by removing the cover of the oil reservoir and visually inspect the oil. However, it can be seen that air can enter through a swirl in the oil in the reservoir if the damper is pulled out. This effect only shows up when the pull-out speed reaches a certain value. It might also be that air could enter between the shaft and the bushing.

Once the oil is free from air, the cylinder shall be in its utmost position and a foam insert shall be placed in the reservoir to compensate for volume change. The cover shall be screwed down with the bleeding screw open. Superfluous oil shall be allowed to come out and after that the bleeding screw should be tightened. The damper should now be able to be compressed and the foam will decrease in volume as the oil is pressed up in the reservoir. However, it was found that the foam could not compensate the volume change for the whole stroke without a pressure being built up in the cylinder. It could also be seen that the foam contained a lot of small air bubbles which were very difficult to get rid of. Considering this we decided to leave the foam out in our tests and instead make a hole for air passage in the cover. With the right amount of oil in the system the damper can be compressed and only air will escape through this vent hole. Once the damper with no air bubbles in the oil has been mounted it is terribly important not to pull the damper in and out during dummy handling. Otherwise the damper will suck air again.

Although the procedures described above could be used in a limited number of tests, they cannot be accepted in ordinary testing. The damper must therefore be improved, for instance, by adding a diaphragm in the reservoir and adding a seal at the bushing.

To assure that the whole stroke of the damper is available at a test this dummy has to be reset before testing. This could be rather difficult to check once the jacket is put on the dummy.

Another practical aspect on this dummy is that the twelve accelerometers occupy a lot of measuring channels. Hopefully future research will point out the accelerometers needed to measure the violence in side impacts and leave us with a reduced number.

## CONCLUSIONS AND RECOMMENDATIONS

All the three tested dummies could distinguish between the difference in side impact protection offered by the cars.

Only the HSRI dummy produced head impacts.

In spite of some shortcomings in the deflection device the APROD dummy gave chest deflection measurements in rather good agreement with the injury predictions of the HSRI dummy.

With a carefully bleeded and vented damper the HSRI dummy chest performed satisfactorily and the injury predictive models produced reasonable results.

The peak spinal acceleration criterion (≤40 g) was not in agreement with the result of the other proposed criteria for the APROD and HSRI dummy.

Both the APROD dummy and the HSRI dummy used in this work have to be mechanically improved.

The objective of this work has been to contribute to the evaluation process of side impact dummies. The results have shown that there still remain problems to be solved. However, it is important that in the future the amount of oncoming tests will be increased considerably before any firm conclusions are made.

## REFERENCES

1. Presentation of a frontal impact and side impact dummy defined from human data and realized from a "Part 572" basis. A. Fayon, Y.C. Leung, R.L. Stalnaker, G. Walfish, M. Balthazard, C. Tarriere. ESV 1979.

2. Calibration procedures of test dummies for side impact testing. John W. Melvin, Joseph B. Benson, Highway Safety Research Institute.
3. Prediction of thoracic injuries as a function of occupant kinematics. D.H. Robbins, R.S. Lehman. HSRI. ESV 1979.
4. DOT. NHTSA. 49 CFR Part 571. (Docket No. 79–0.4. Notice 1).
5. Development of a promising universal thoracic trauma prediction methodology. Rolf H. Eppinger, Kennth Augustyn, D. Hurtey Robbins, 22nd Stapp Car Crash Conference.
6. The prediction of thoracic impact injuries. D.H. Robbins, J.W. Melvin, R.L. Stalnaker. 20th Stapp Car Crash Cenference.
7. Contribution to defining the human tolerance to perpendicular side impacts. C. Got. A. Pate, A. Fayon, C. Tarriere. G. Walfish. 1977 Ircobi.
8. Modification of Part 572 dummy for lateral impact according to biomechanical data. R.L. Stalnaker, C. Tarriere, A. Fayon, G. Walfish, M. Balthazard, J. Masset, C. Got, A. Patel. 23rd Stapp Car Crash Conference.
9. Side impact response and injury. J.W. Melwin, D.H. Robbins and R.L. Stalnaker. ESV 1976.

# Pre-Test Osteologic Studies for Determining Cadaver Skeletal Quality

MICHAEL J. WALSH
BARBARA J. KELLEHER
Calspan Corporation

## ABSTRACT

A non-invasive pre-test method for determining human cadaver skeletal quality without affecting a cadaver's usability in an experimental program is presented in conjunction with the standard post-test "rib bending" skeletal analysis.

Osteoporosis (porous bone) is detectable, in varying degrees, to a trained orthopedist or radiologist in the lumbar spine or pelvic girdle region of a given subject. Such expertise is not always available to the researcher at the time cadaver selection must be made. Thus, a rapid and accurate engineering analysis of skeletal quality has been developed wherein the technique for determining the percent cortical area (PCA) of a long bone (the second metacarpal), delineated according to age and sex, is extrapolated to determine the PCA using a pre-selection radiograph of the mid shaft view of a commonly x-rayed long bone (femur).

These femur PCA's are presented and discussed for approximately twenty cadaveric subjects utilized in both car crash and pedestrian impact tests.

A further pre-test skeletal quality determination technique in which a section of an easily excisable long bone is removed (mid-shaft radius) and the PCA accurately measured is presented for comparison of results.

## INTRODUCTION

A major concern in evaluating results of automobile tests with cadavers is that of comparability or relative quality of the subjects. Therefore, in addition to the obvious parameters used for definition in cadaver research (such as age, height, weight, cause of death, etc.) there is a need for additional specificity with regard to strength characteristics of bones. The criterion most commonly used by researchers in measuring quality is skeletal strength, as determined by a "beam bending" test of one of the subject's ribs.

A common malady in the aged or those confined to bed for long durations is osteoporosis (porous bone). Since most cadavers available for research are of advanced age, or have been confined to bed, the question of the level of osteoporosis in a given subject must be one of the primary considerations in cadaver selection. Osteoporosis, early in its development, is most notable in the lumbar vertebrae, and a trained orthopedist or radiologist can, to some degree, detect and define the level of bone deterioration from x-rays taken prior to selection. Unfortunately, such expertise or equipment is not always available to researchers at the time selection must