USAARL Report No. 91-6
Volume II

1

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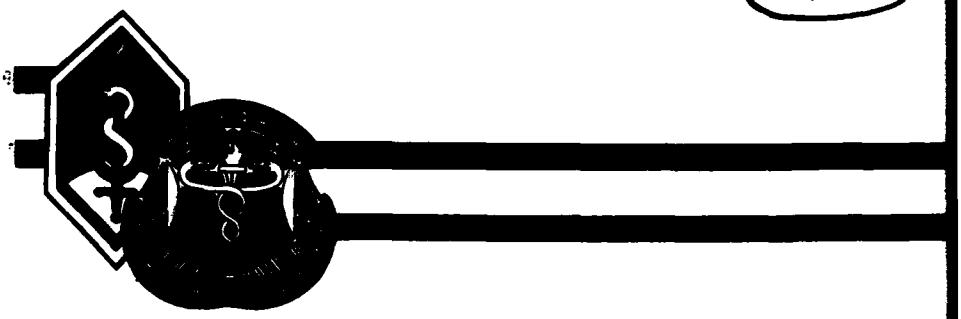

The Airbag as a Supplement to Standard Restraint Systems in the AH-1 and AH-64 Attack Helicopters and Its Role in Reducing Head Strikes of the Copilot/Gunner

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January 1991

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UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release, distribution unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) USAARL Report No. 91-6, Volume II	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Aeromedical Research Laboratory 6b. OFFICE SYMBOL (If applicable) SGRD-UAD-IE	7a. NAME OF MONITORING ORGANIZATION U.S. Army Medical Research and Development Command
6c. ADDRESS (City, State, and ZIP Code) P.O. Box 577 Fort Rucker, AL 36362-5292	7b. ADDRESS (City, State, and ZIP Code) Fort Detrick Frederick, MD 21702-5012
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 0602787A; PROJECT NO. 3M162787A878; TASK NO. AG; WORK UNIT ACCESSION NO. 131

11. TITLE (Include Security Classification)
The airbag as a supplement to standard restraint systems in the AH-1 and AH-64 attack helicopters and its role in reducing head strikes of the copilot/gunner, Volume II

12. PERSONAL AUTHOR(S)
Nabih M. Alem, Dennis F. Shanahan, John V. Barson, and William H. Muzzy, III.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM _____ TO _____	1991 January	159

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Airbag, restraint, head strikes, sled tests, injuries, helicopter, ~~crashes~~

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Accident investigation records of U.S. Army helicopter crashes show injuries of pilots due to striking a structure inside the cockpit outnumber those due to excessive accelerations by a five-to-one ratio. This two-volume report presents the results of a study of the effectiveness of airbags in reducing the severity of contact injury to the gunner when striking the gunsight. Airbag systems were installed on the gunsights in simulated Cobra and Apache cockpits, then sled tested at 7 and 25 g. The tests indicated airbags reduced head accelerations by 65 percent, head injury criteria by 77 percent, and head angular acceleration by 76 percent in the Cobra tests. In the Apache tests, the airbags reduced those same indicators by 68, 52, and 83 percent. An airbag system, the report concludes, is likely to prevent severe or fatal head and chest injuries in an Apache or Cobra crash. Volume 1 of the report describes the tests and discusses the results. Volume 2 consists of Appendixes A, B, and C of the report and contains processed signal graphs of all sled tests.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL Chief, Scientific Information Center	22b. TELEPHONE (Include Area Code) (205) 255-6907 22c. OFFICE SYMBOL SGRD-UAX-Si

DD Form 1473, JUN 86 *Previous editions are obsolete.* SECURITY CLASSIFICATION OF THIS PAGE

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Appendix A

This appendix contains the processed transducer signals from the 11 (Cobra) telescopic sighting unit (TSU) tests with inertia reels and without airbags.

These include eight tests (LX6196 - LX6204) conducted during the first phase of testing and three tests (LX6274 - LX6276) which were run in the second phase.

Figures A-1 thru A-11 show the sled acceleration pulses and computed velocity and jerk signals for the 11 tests.

Figures A-12 thru A-22 display available components and resultants head linear accelerations.

Figures A-23 thru A-33 display the head roll acceleration signals and computed angular velocities and displacements.

Figures A-34 thru A-44 show the head pitch acceleration signals and computed angular velocities and displacements.

Figures A-45 thru A-55 display the amounts of belt extension and the computed velocities and accelerations.

Appendix A

1. LX6196
2. LX6197
3. LX6198
4. LX6199
5. LX6200
6. LX6201
7. LX6203
8. LX6204
9. LX6274
10. LX6275
11. LX6276

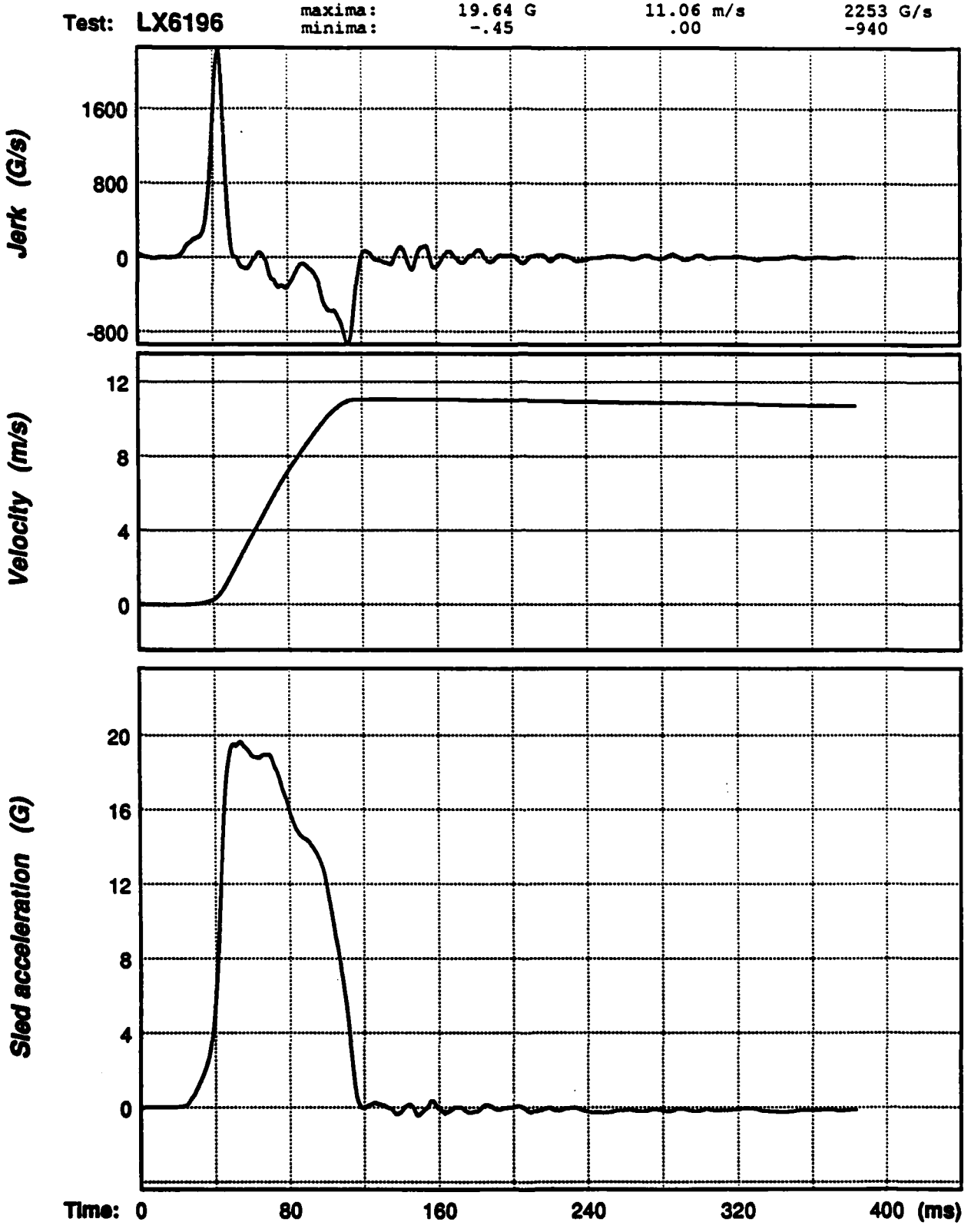

Figure A-1. Sled acceleration signal and its computed velocity and jerk for test LX6196.

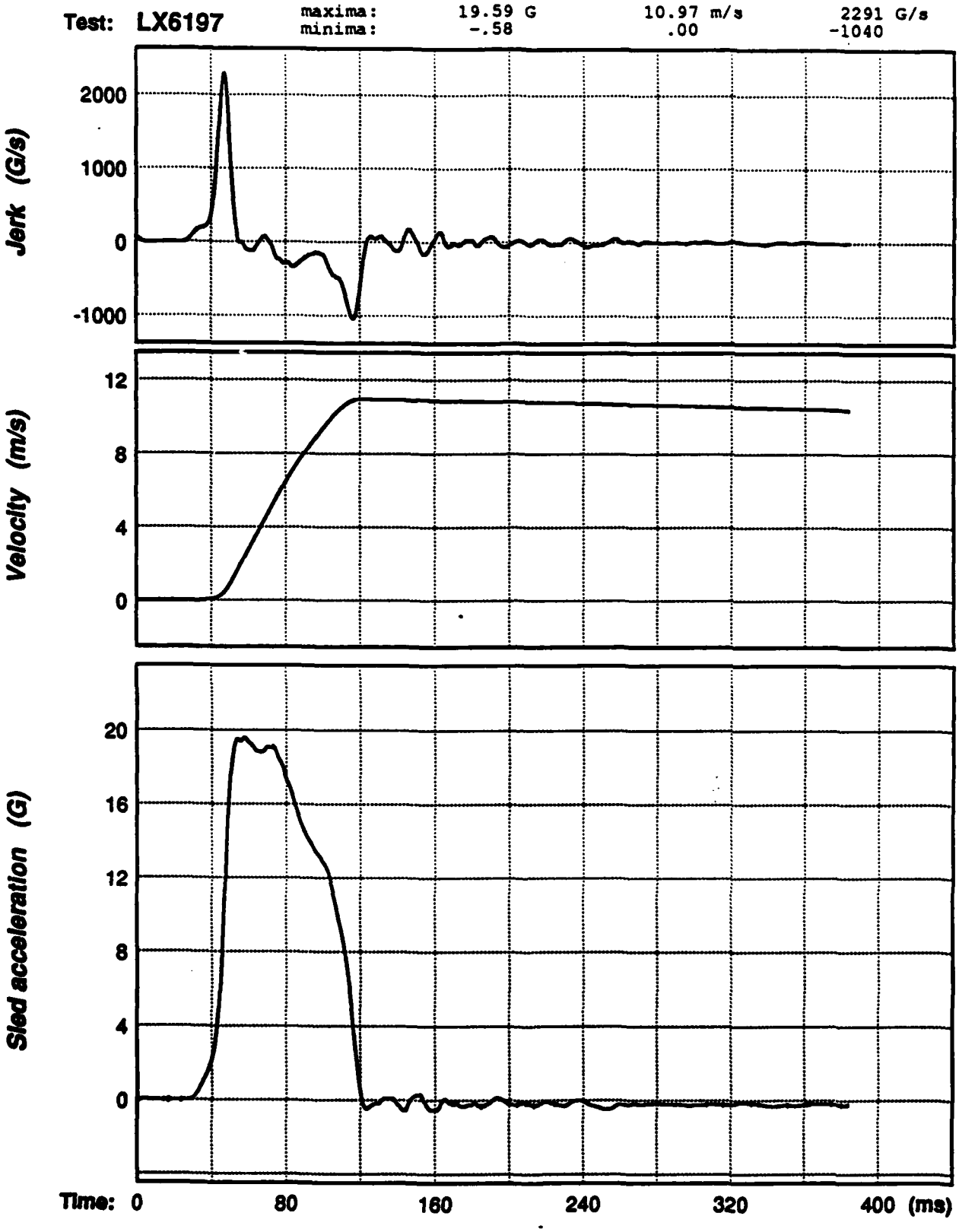

Figure A-2. Sled acceleration signal and its computed velocity and jerk for test LX6197.

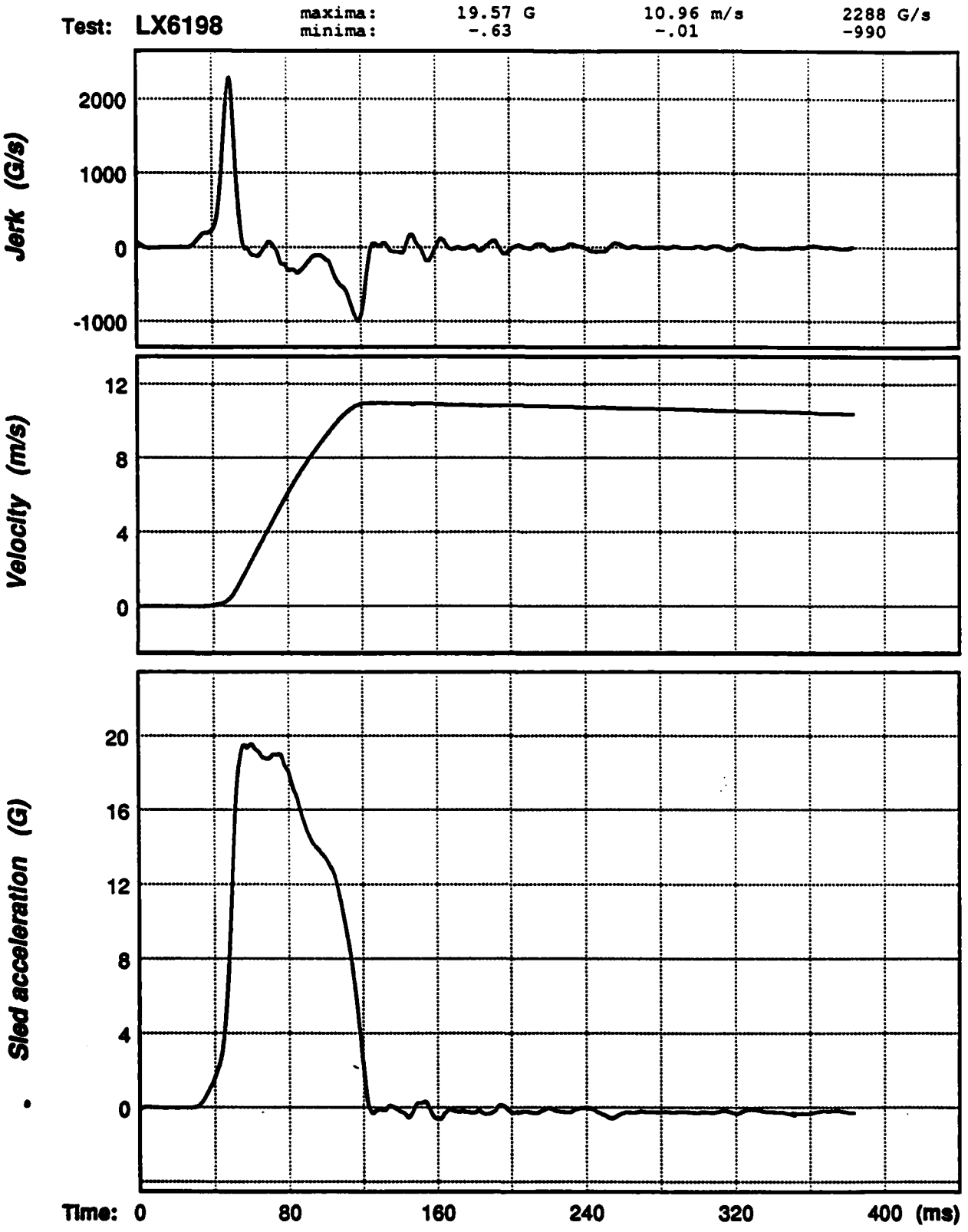

Figure A-3. Sled acceleration signal and its computed velocity and jerk for test LX6198.

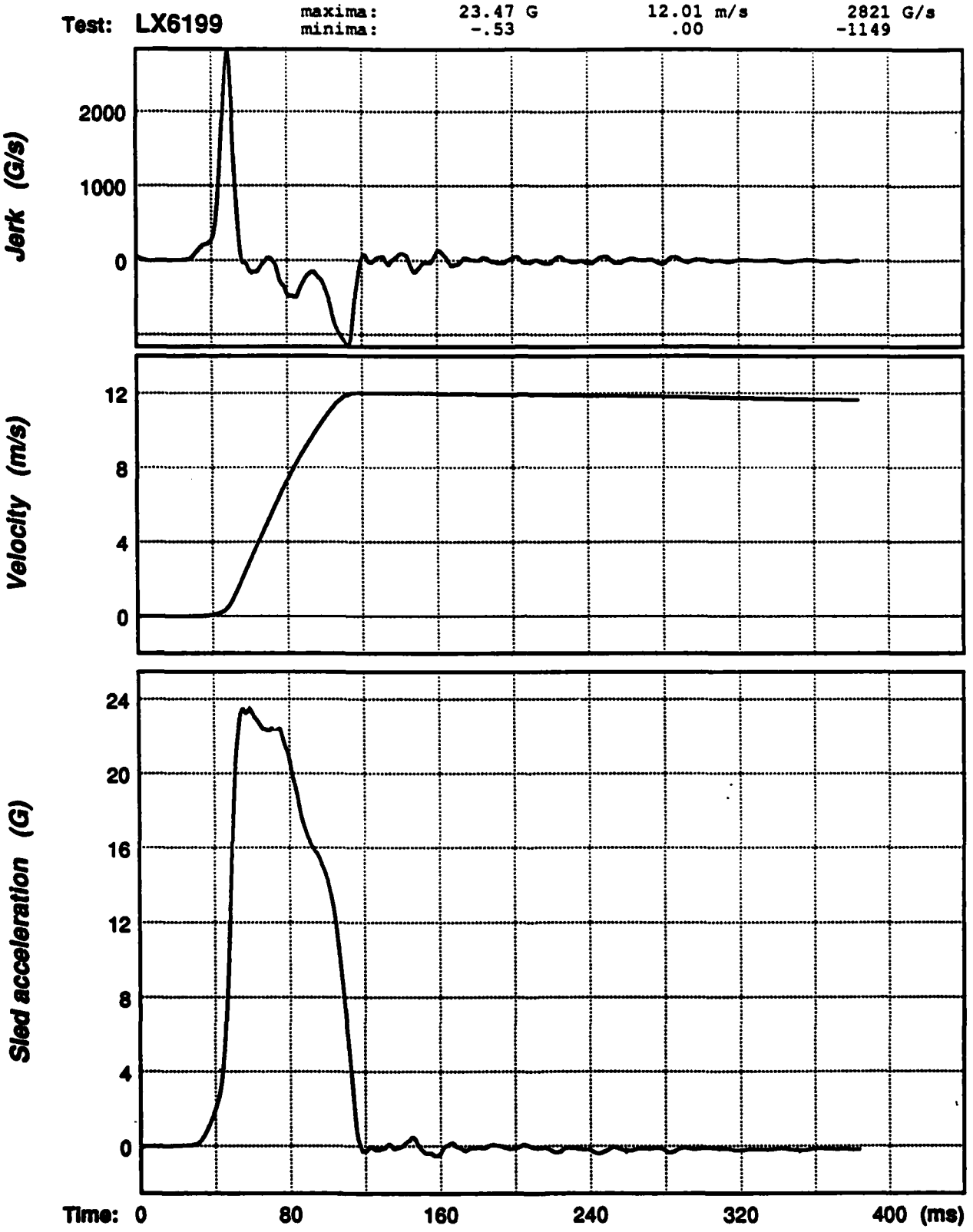

Figure A-4. Sled acceleration signal and its computed velocity and jerk for test LX6199.

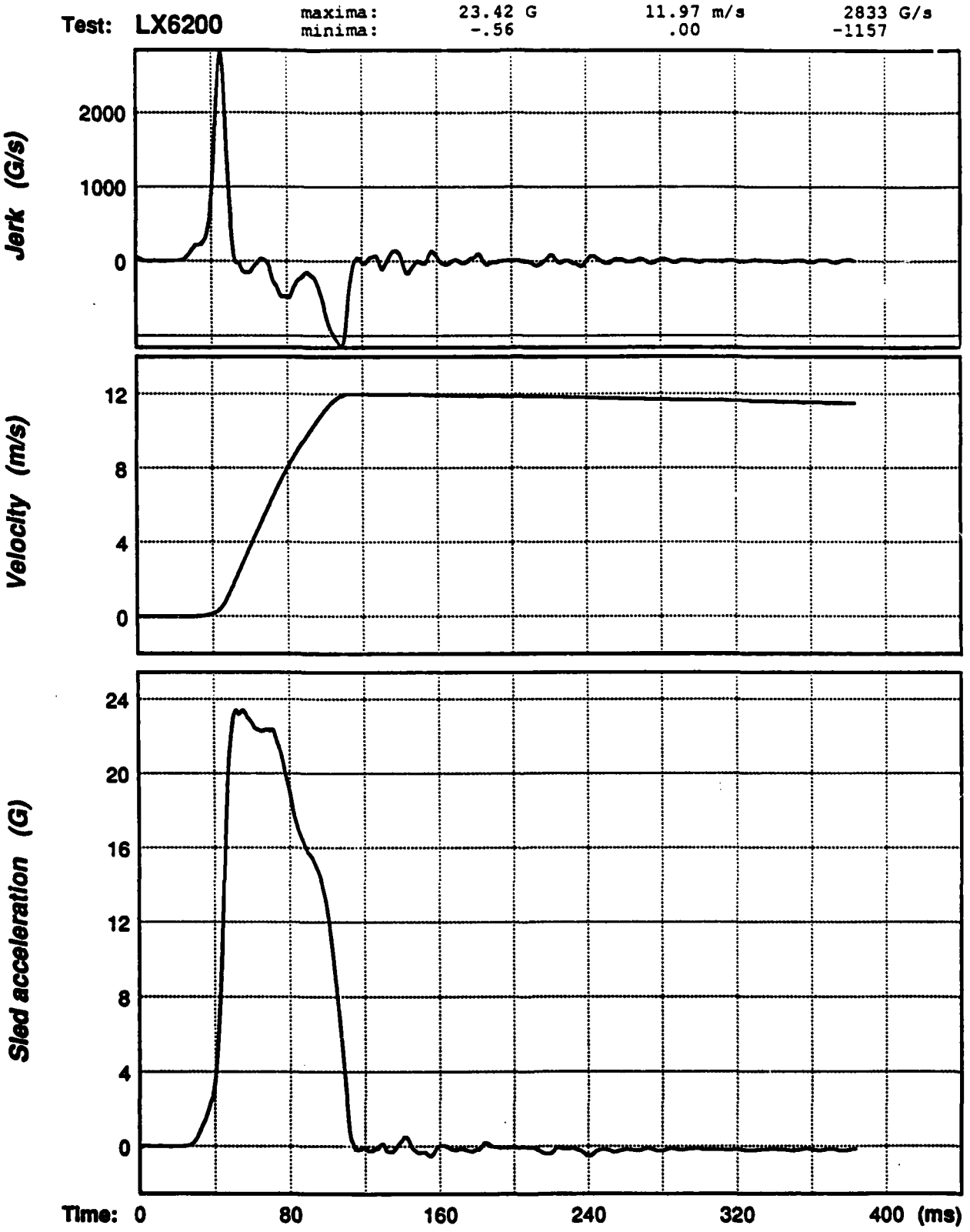

Figure A-5. Sled acceleration signal and its computed velocity and jerk for test LX6200.

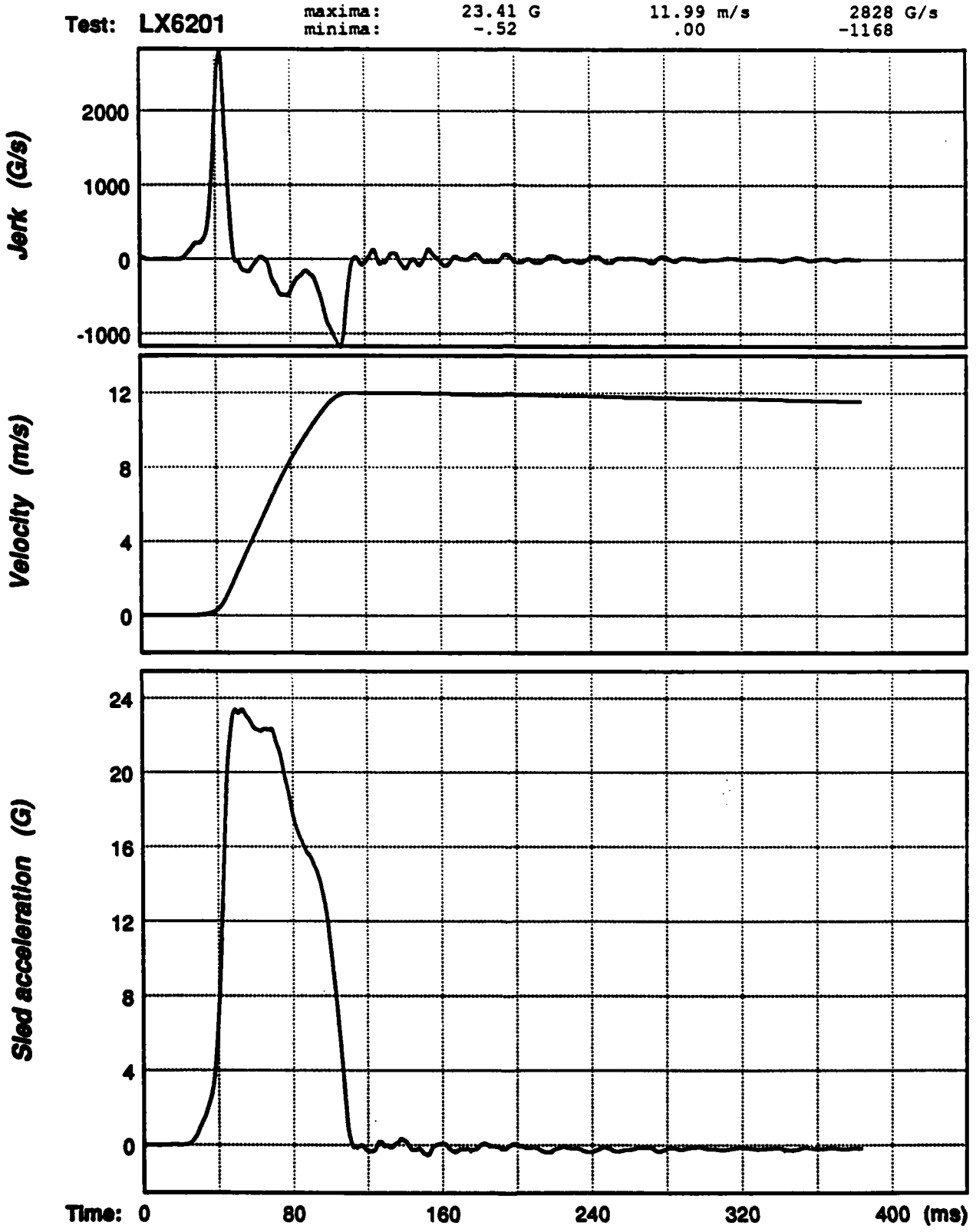

Figure A-6. Sled acceleration signal and its computed velocity and jerk for test LX6201.

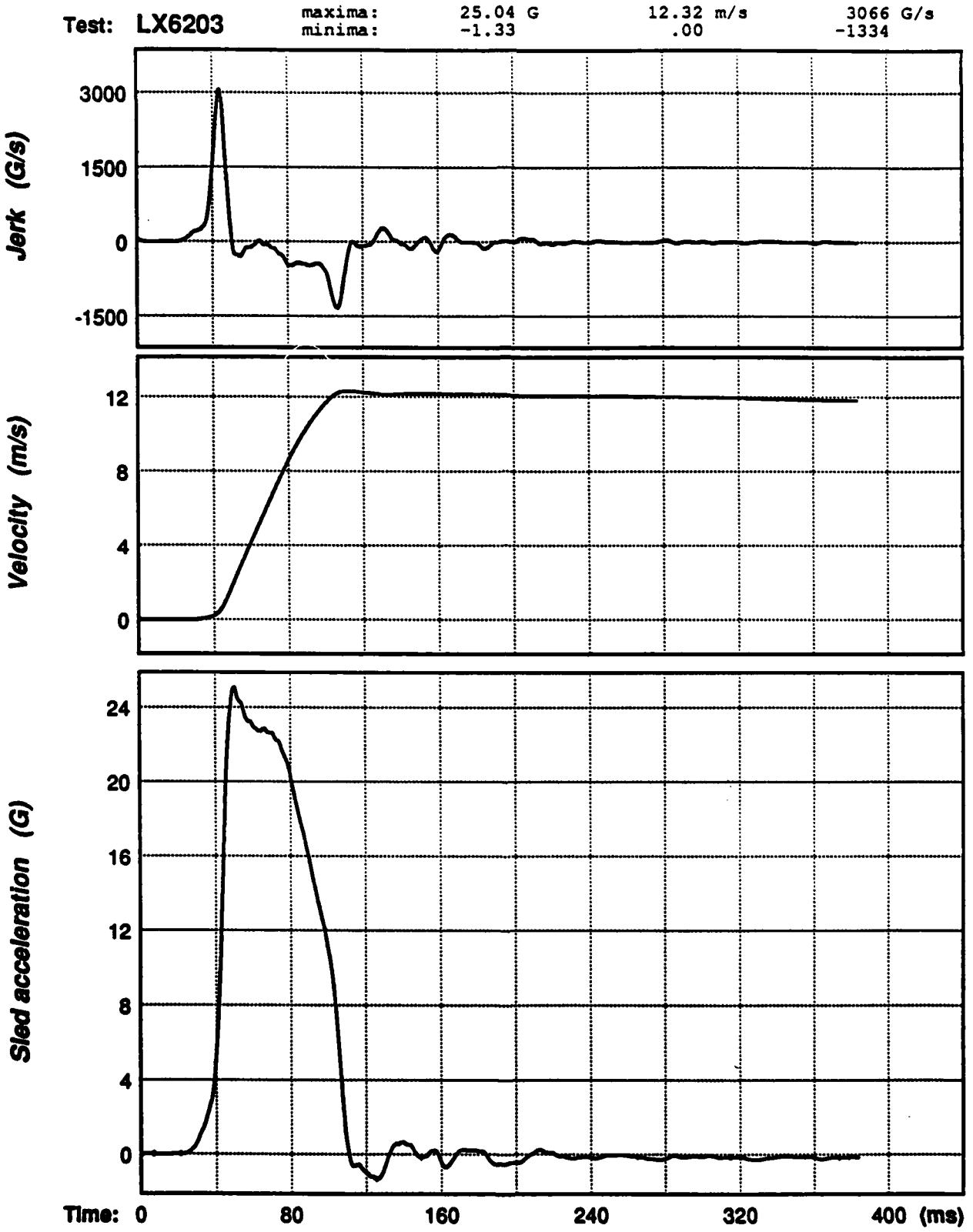

Figure A-7. Sled acceleration signal and its computed velocity and jerk for test LX6203.

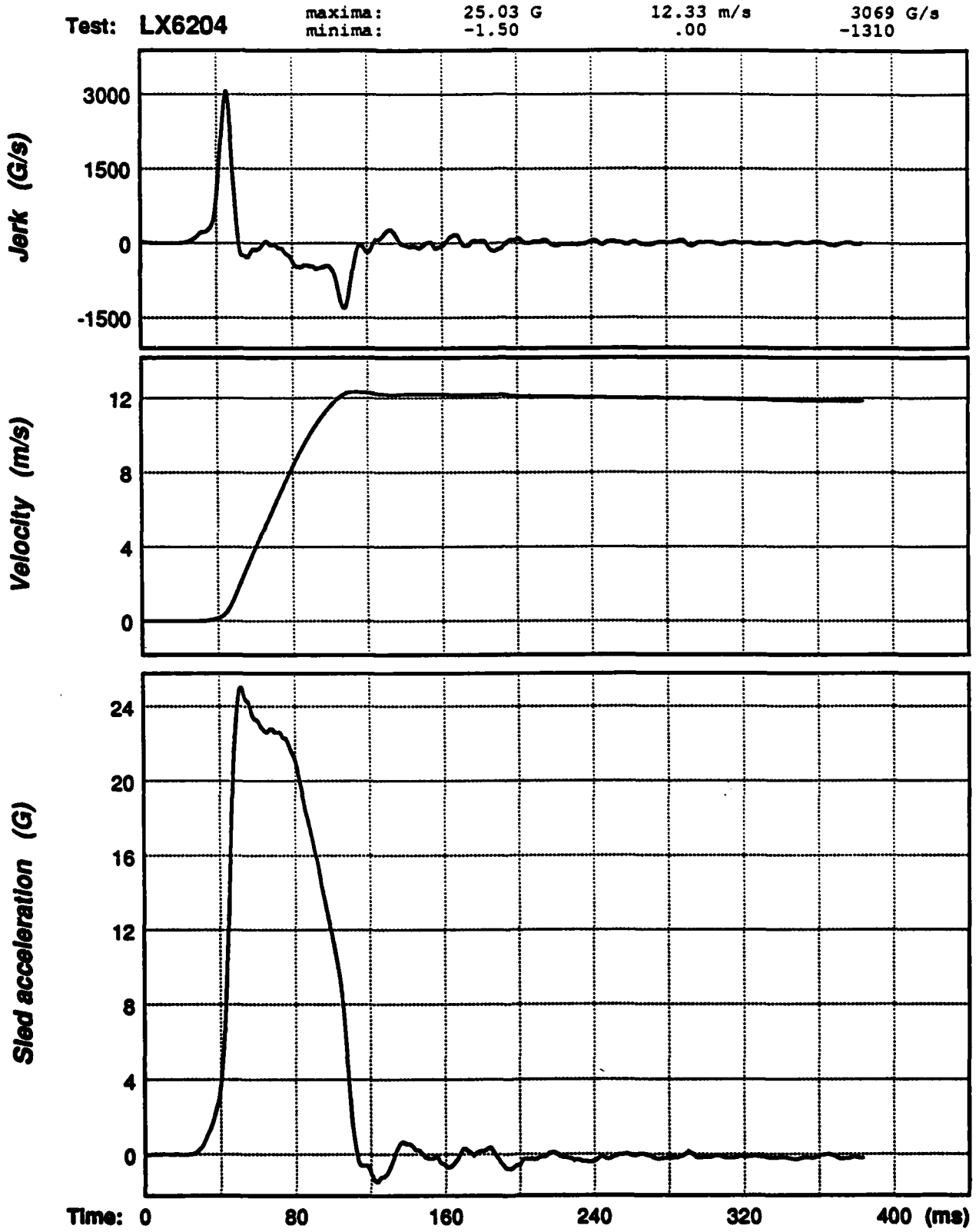

Figure A-8. Sled acceleration signal and its computed velocity and jerk for test LX6204.

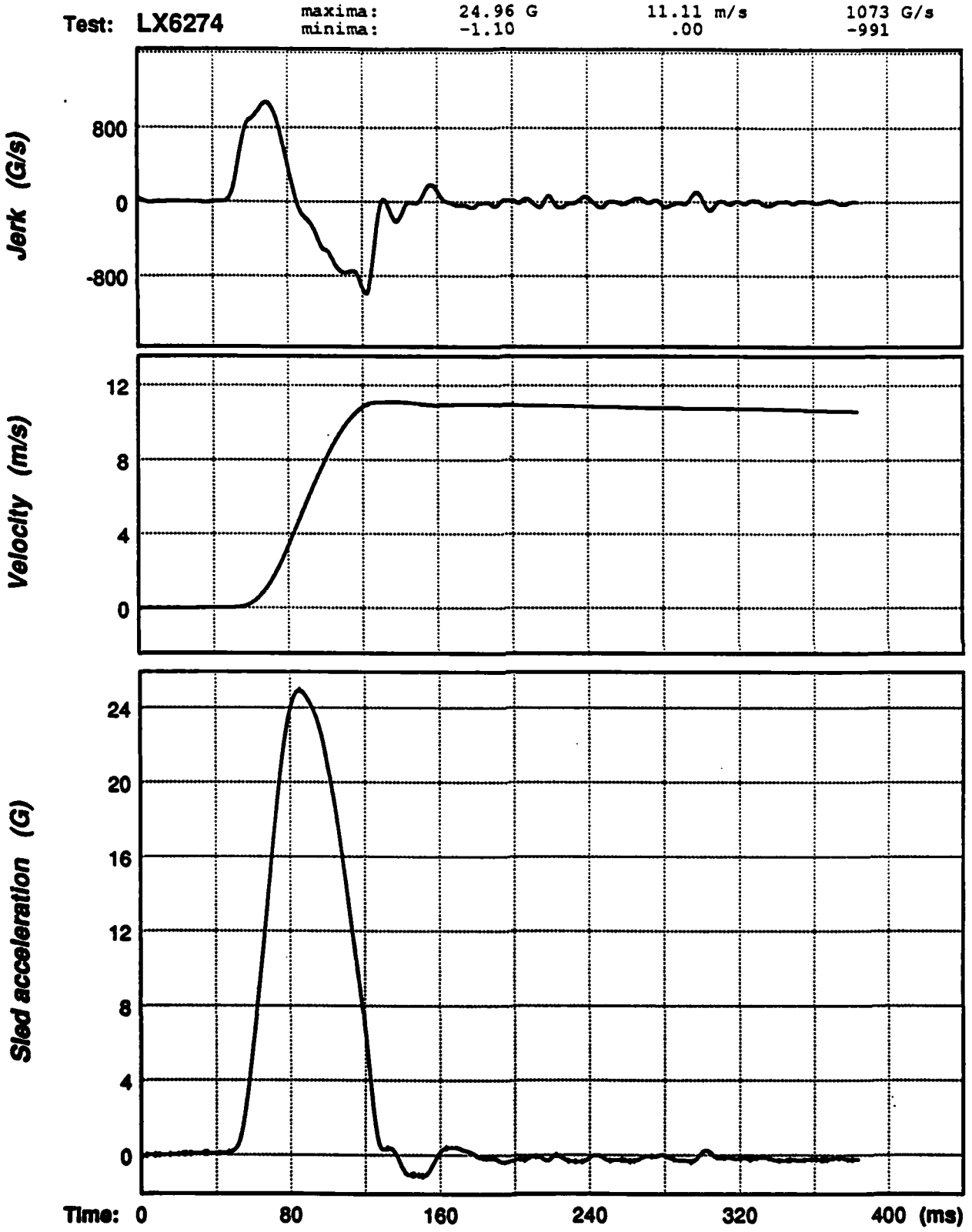

Figure A-9. Sled acceleration signal and its computed velocity and jerk for test LX6274.

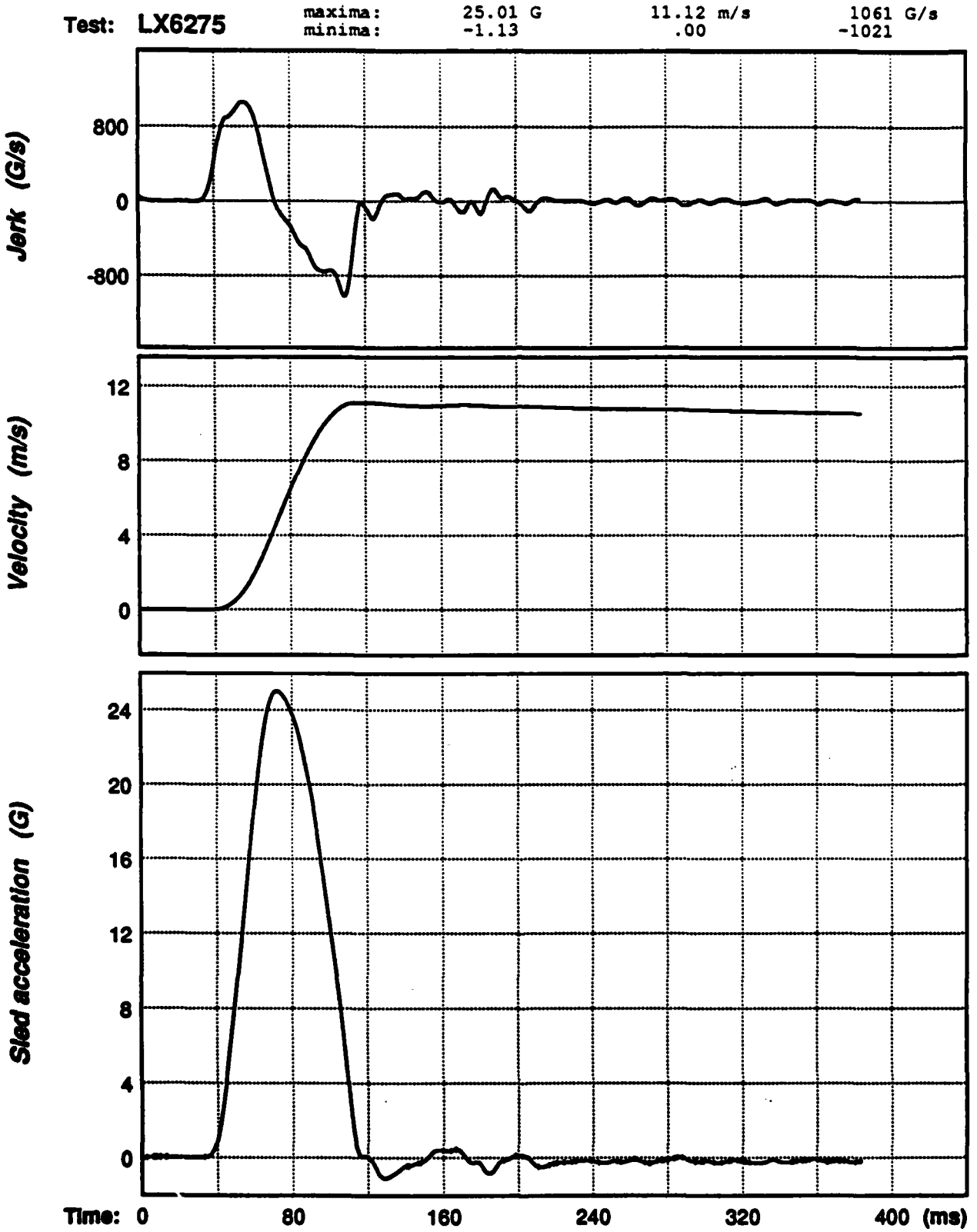

Figure A-10. Sled acceleration signal and its computed velocity and jerk for test LX6275.

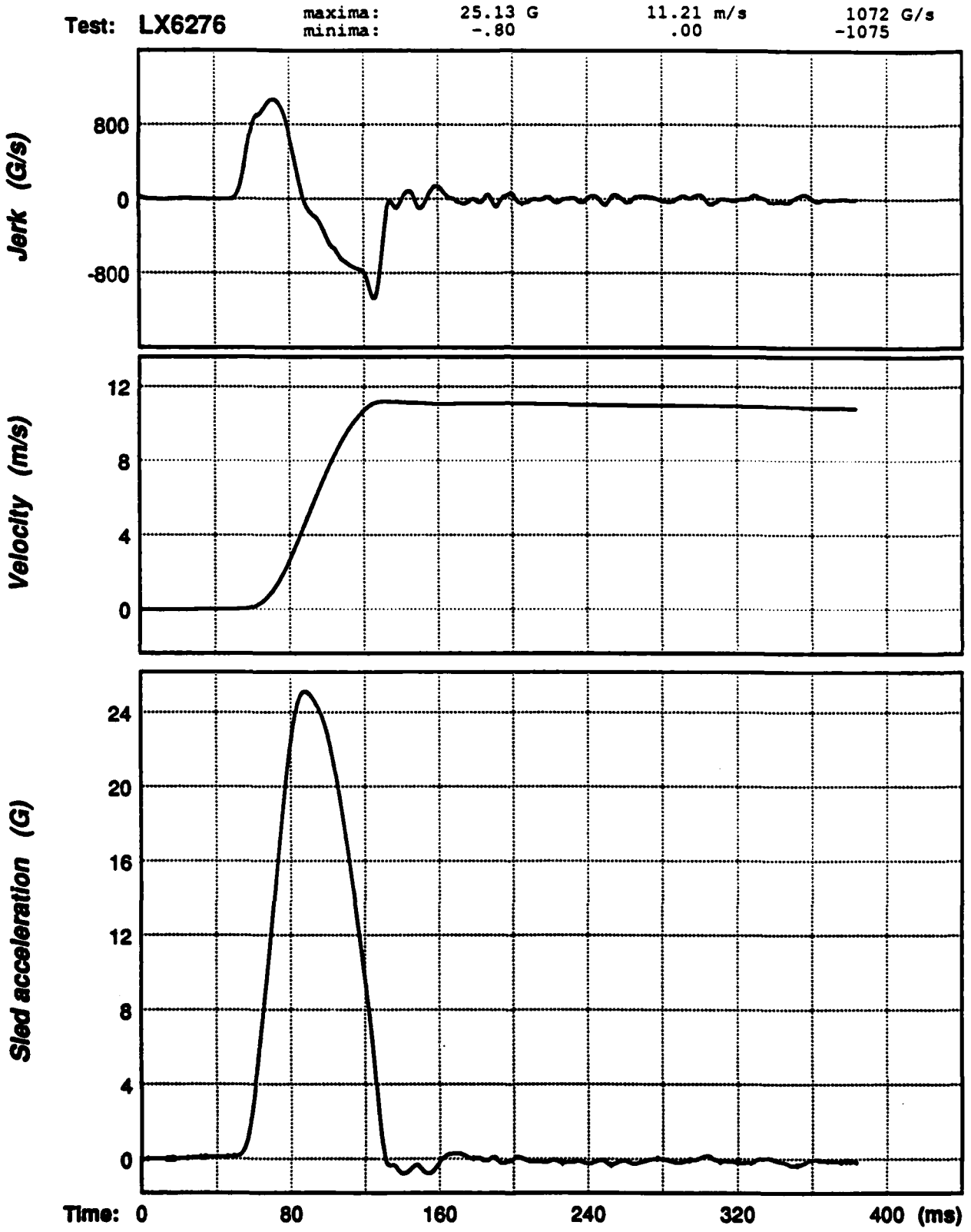

Figure A-11. Sled acceleration signal and its computed velocity and jerk for test LX6276.

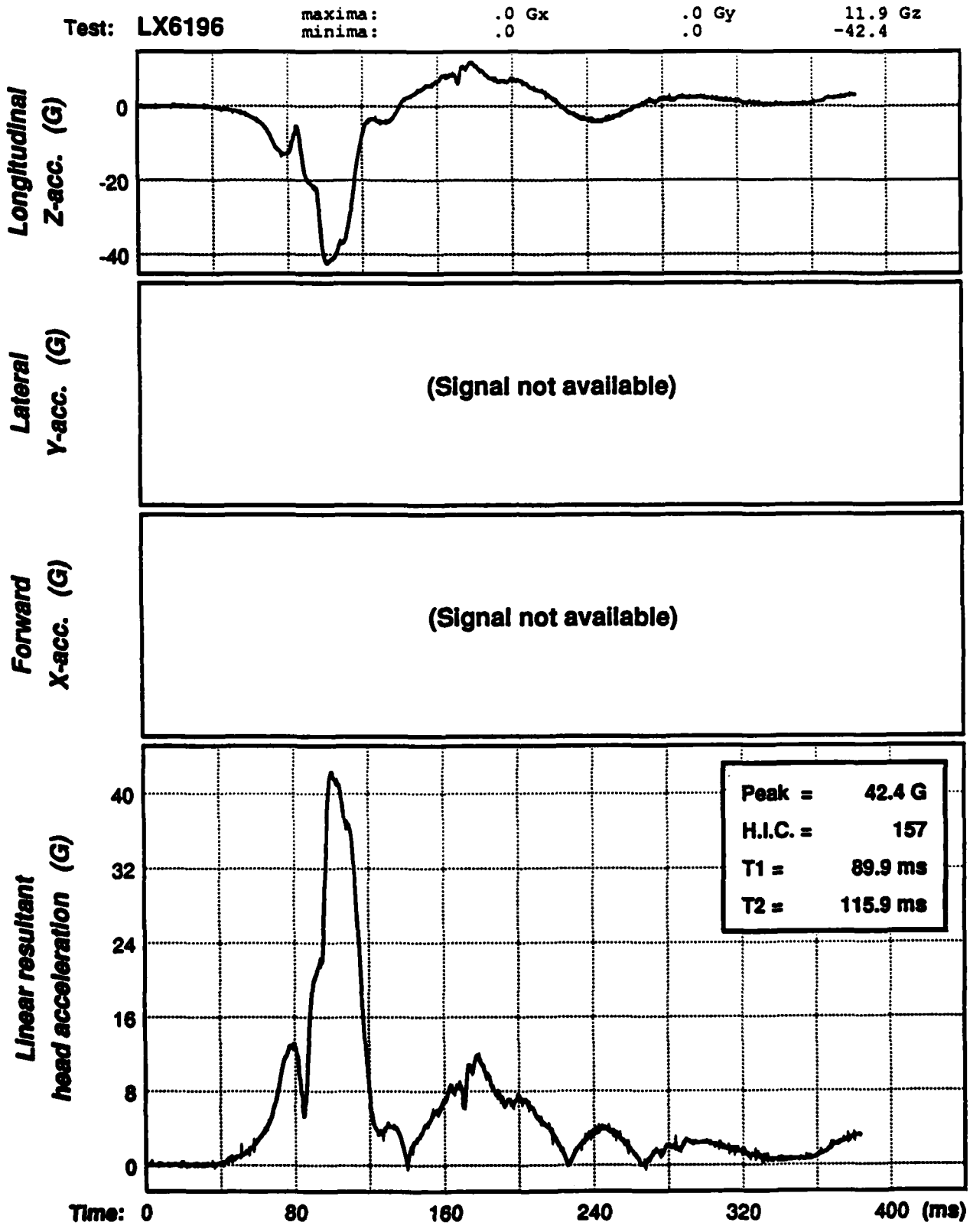

Figure A-12. Three components and resultant of the linear head acceleration for test LX6196.

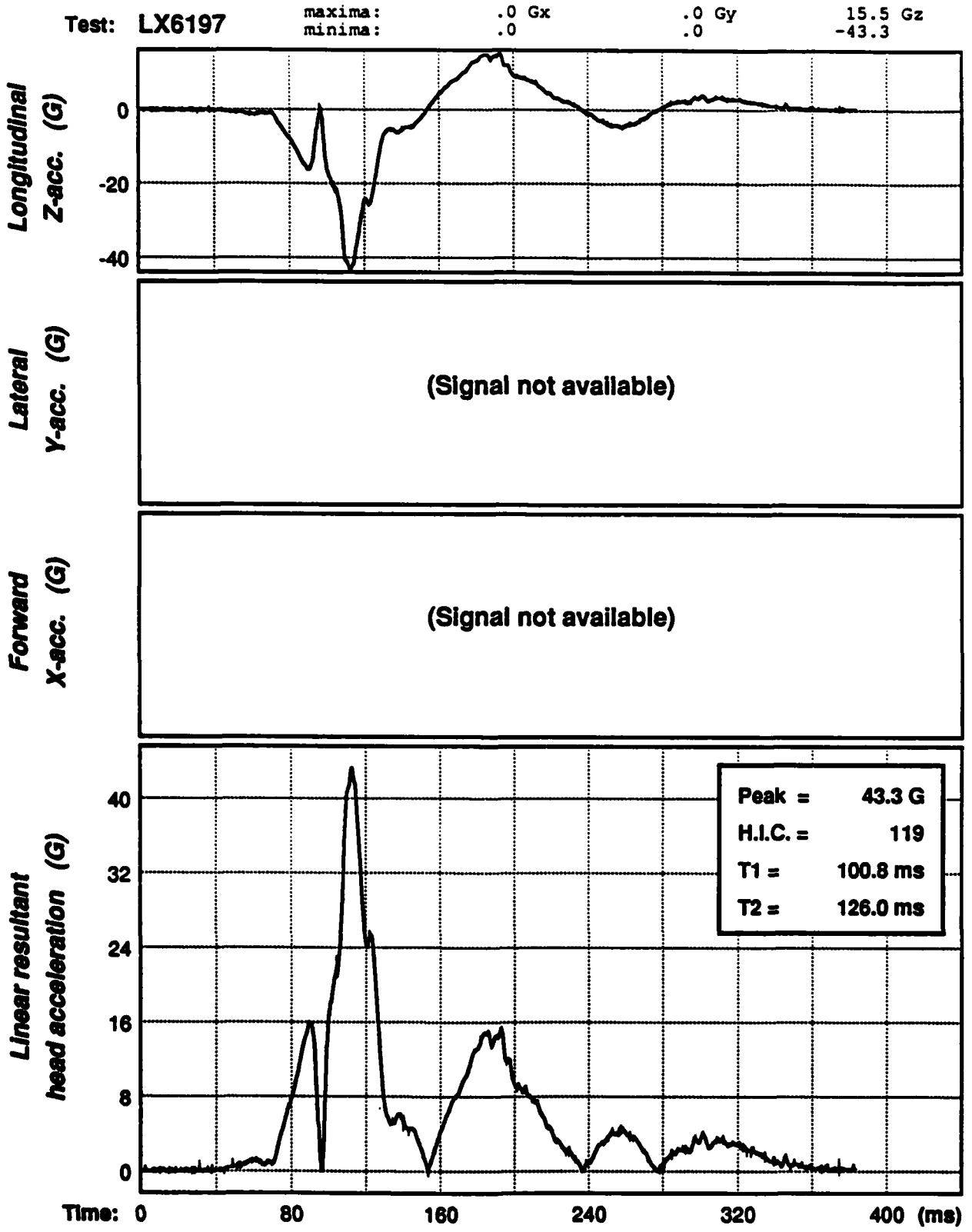

Figure A-13. Three components and resultant of the linear head acceleration for test LX6197.

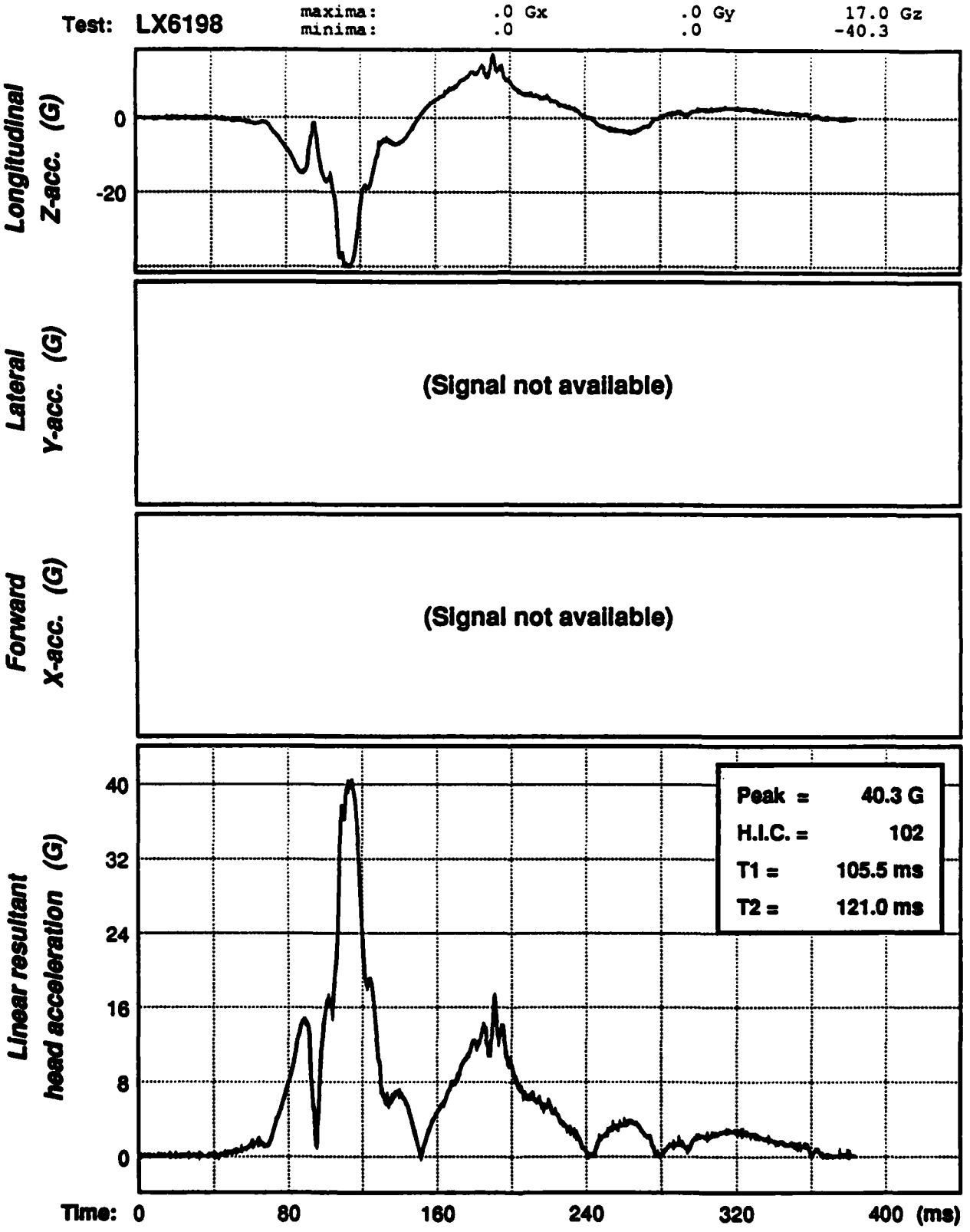

Figure A-14. Three components and resultant of the linear head acceleration for test LX6198.

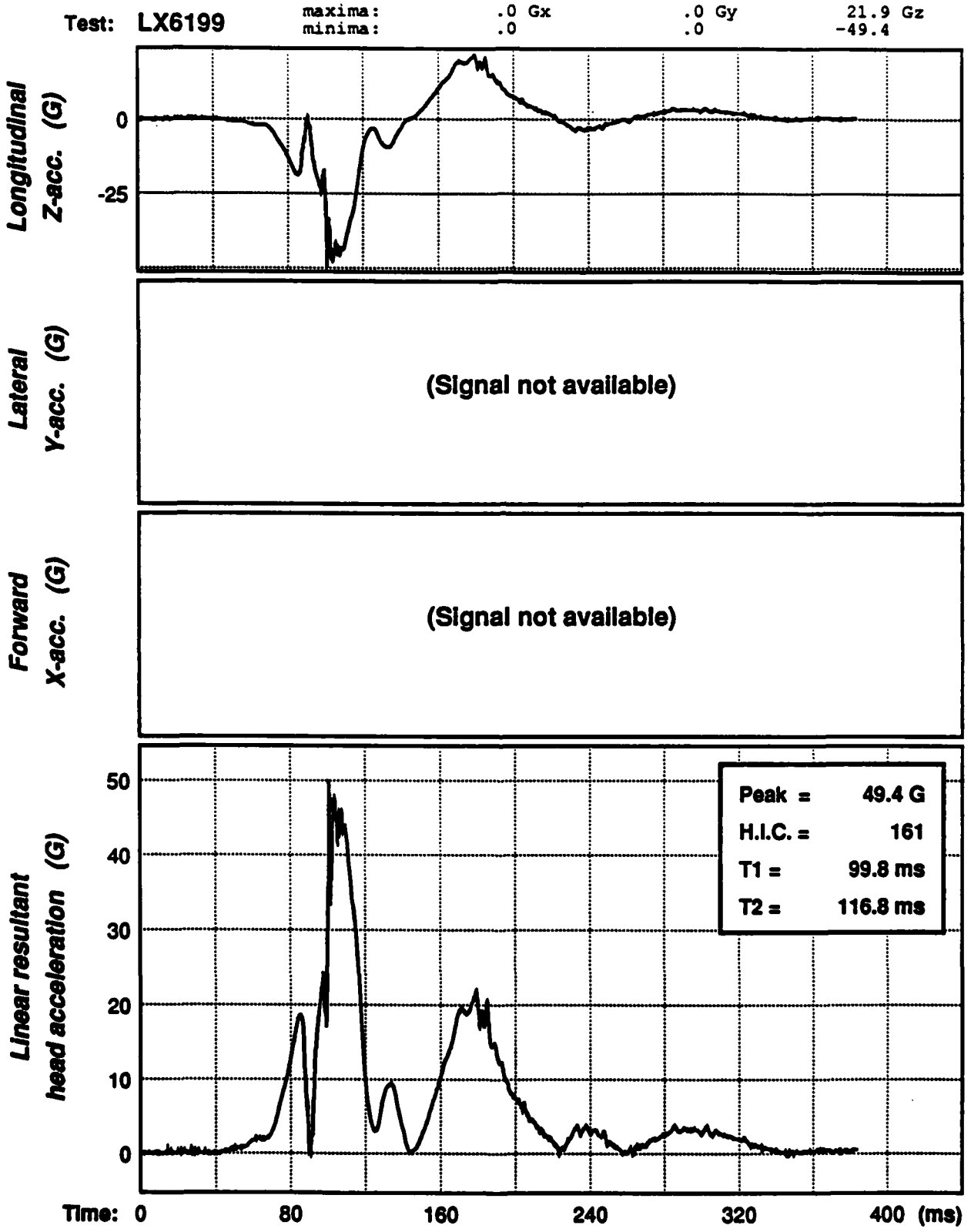

Figure A-15. Three components and resultant of the linear head acceleration for test LX6199.

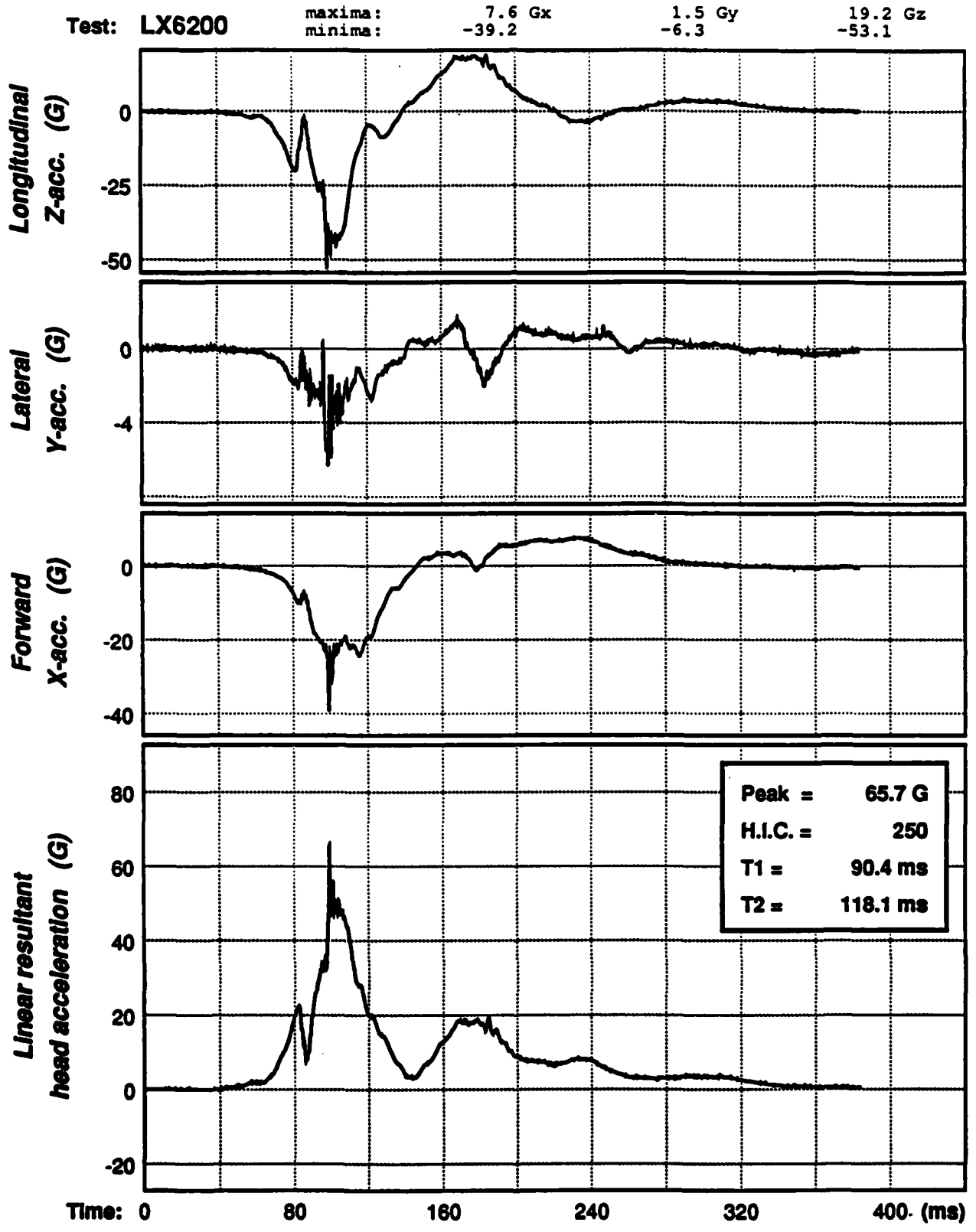

Figure A-16. Three components and resultant of the linear head acceleration for test LX6200.

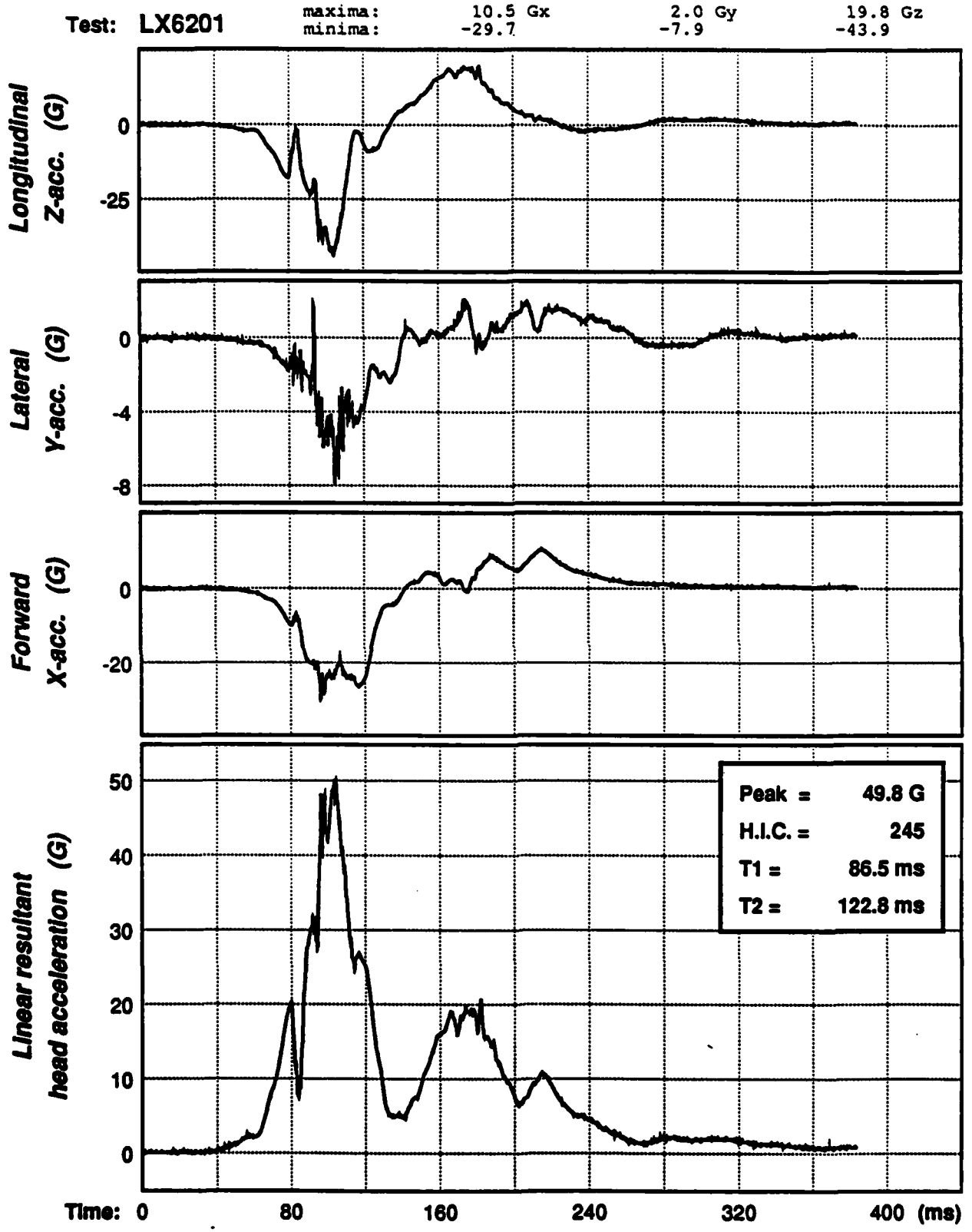

Figure A-17. Three components and resultant of the linear head acceleration for test LX6201.

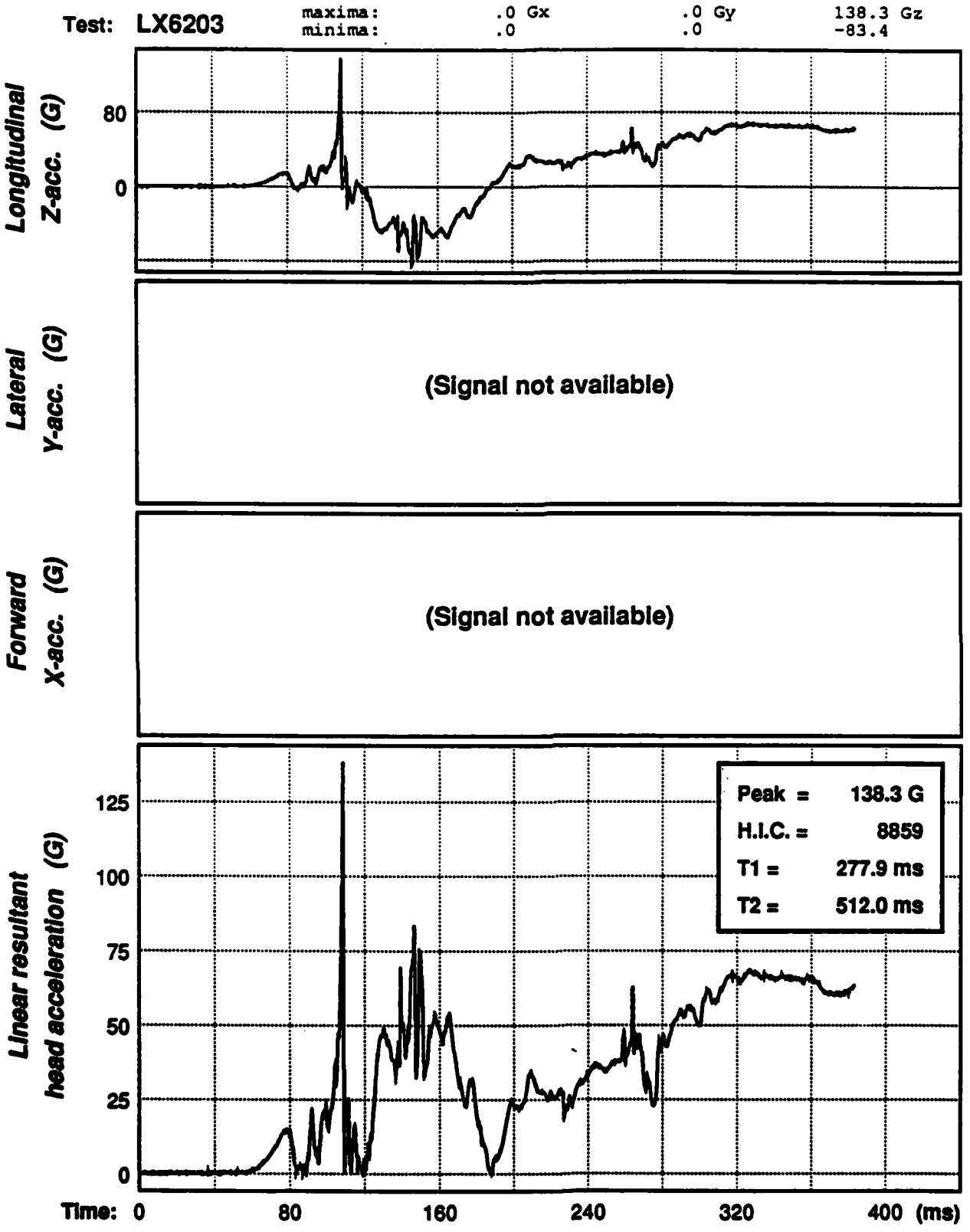

Figure A-18. Three components and resultant of the linear head acceleration for test LX6203.

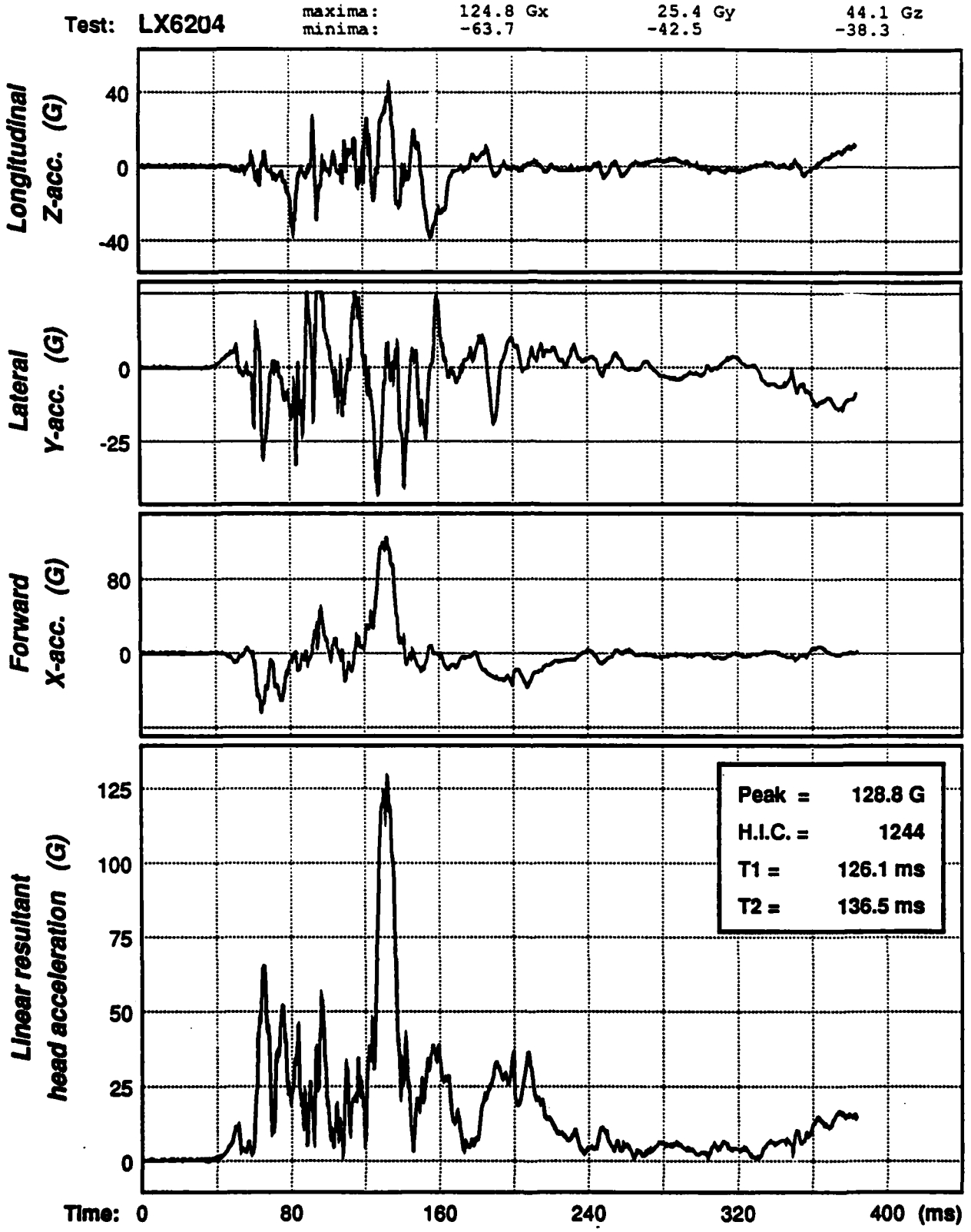

Figure A-19. Three components and resultant of the linear head acceleration for test LX6204.

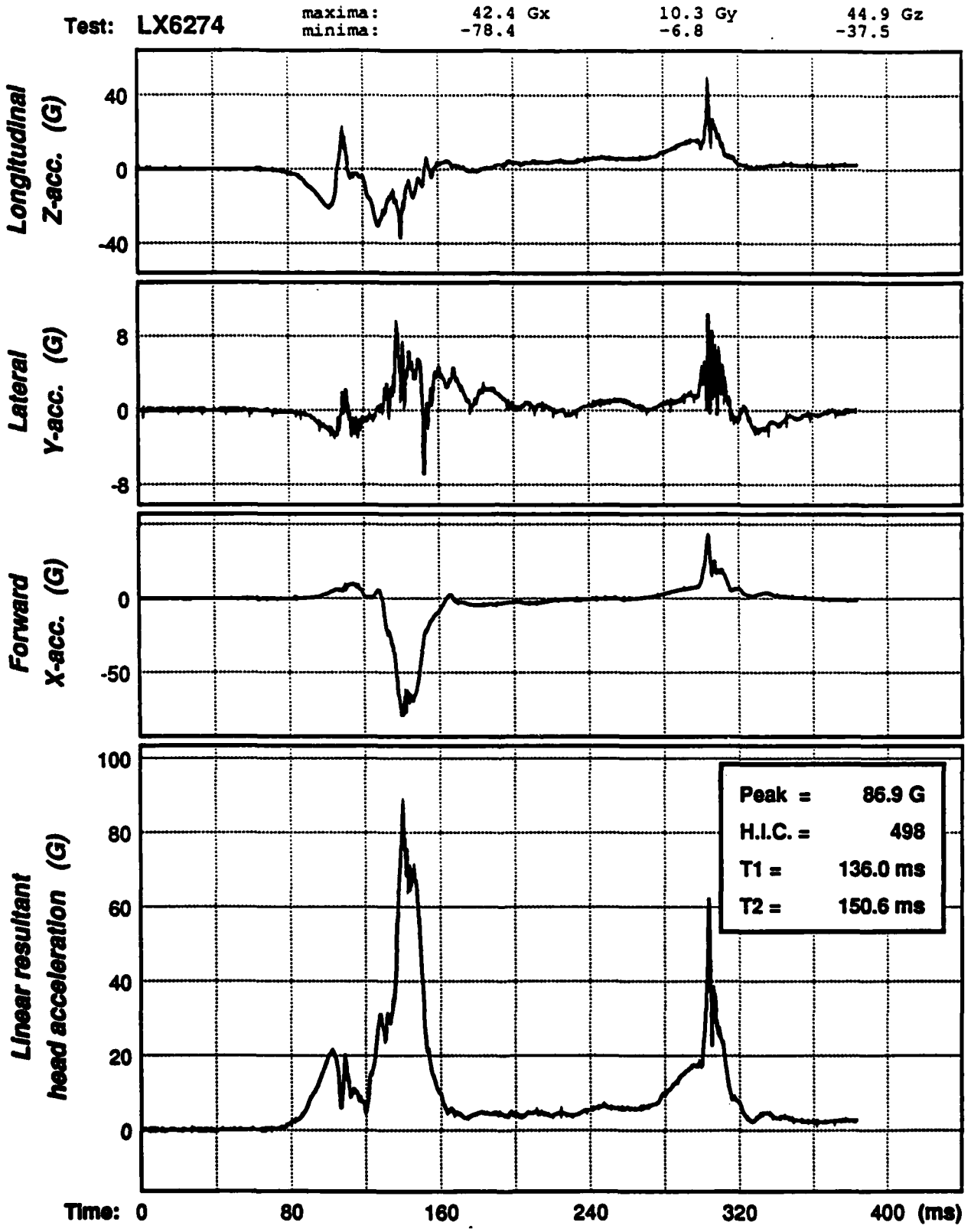

Figure A-20. Three components and resultant of the linear head acceleration for test LX6274.

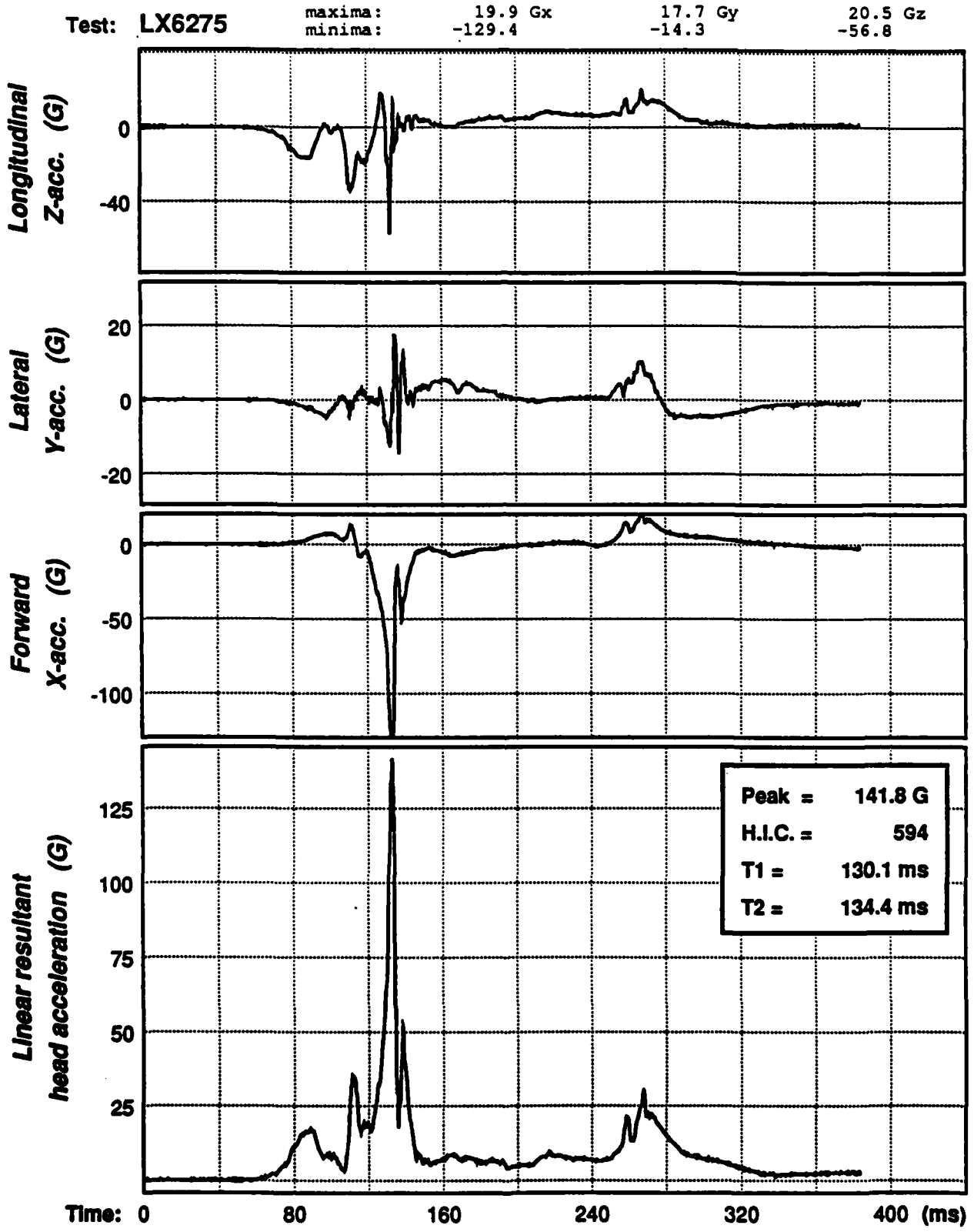

Figure A-21. Three components and resultant of the linear head acceleration for test LX6275.

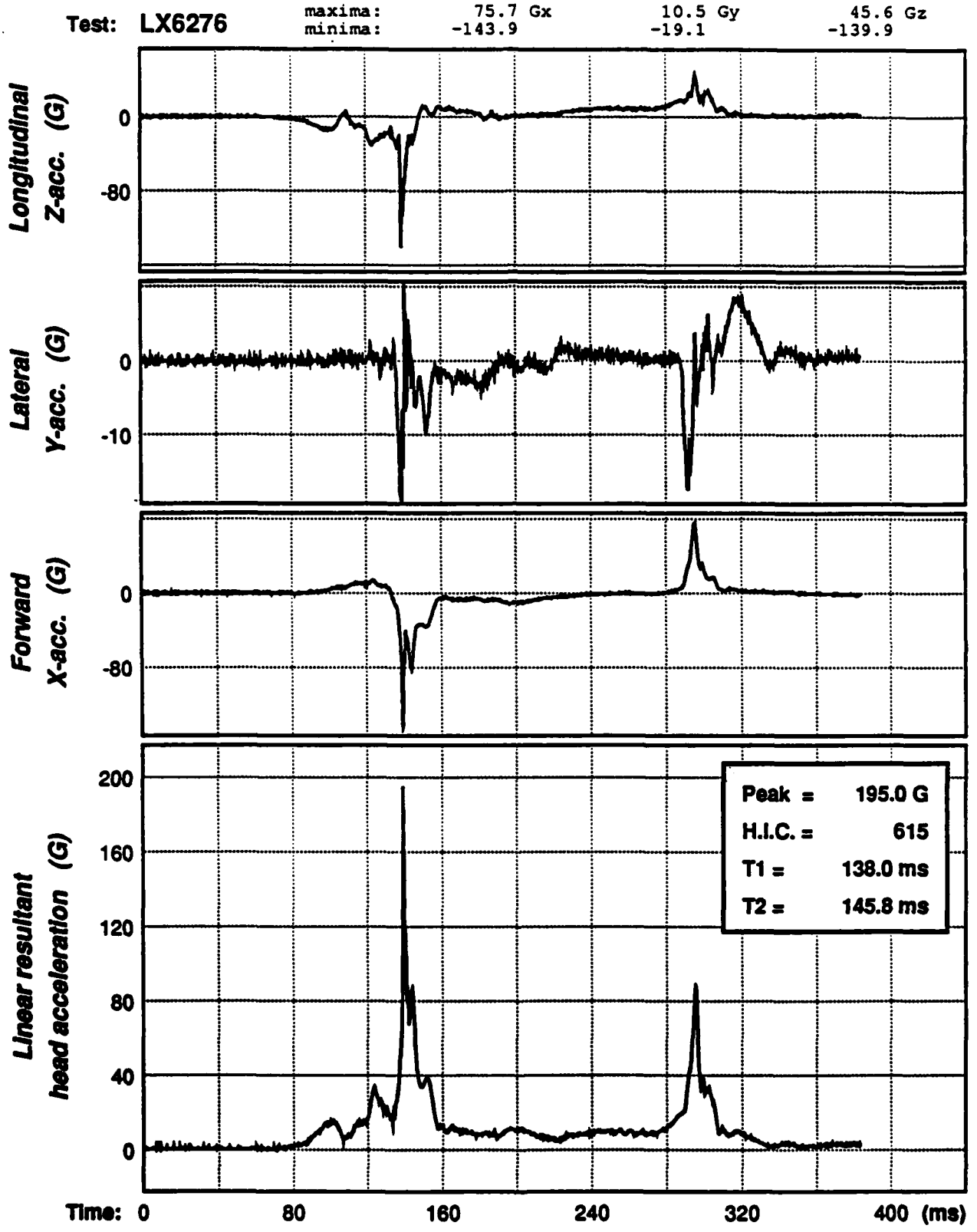

Figure A-22. Three components and resultant of the linear head acceleration for test LX6276.

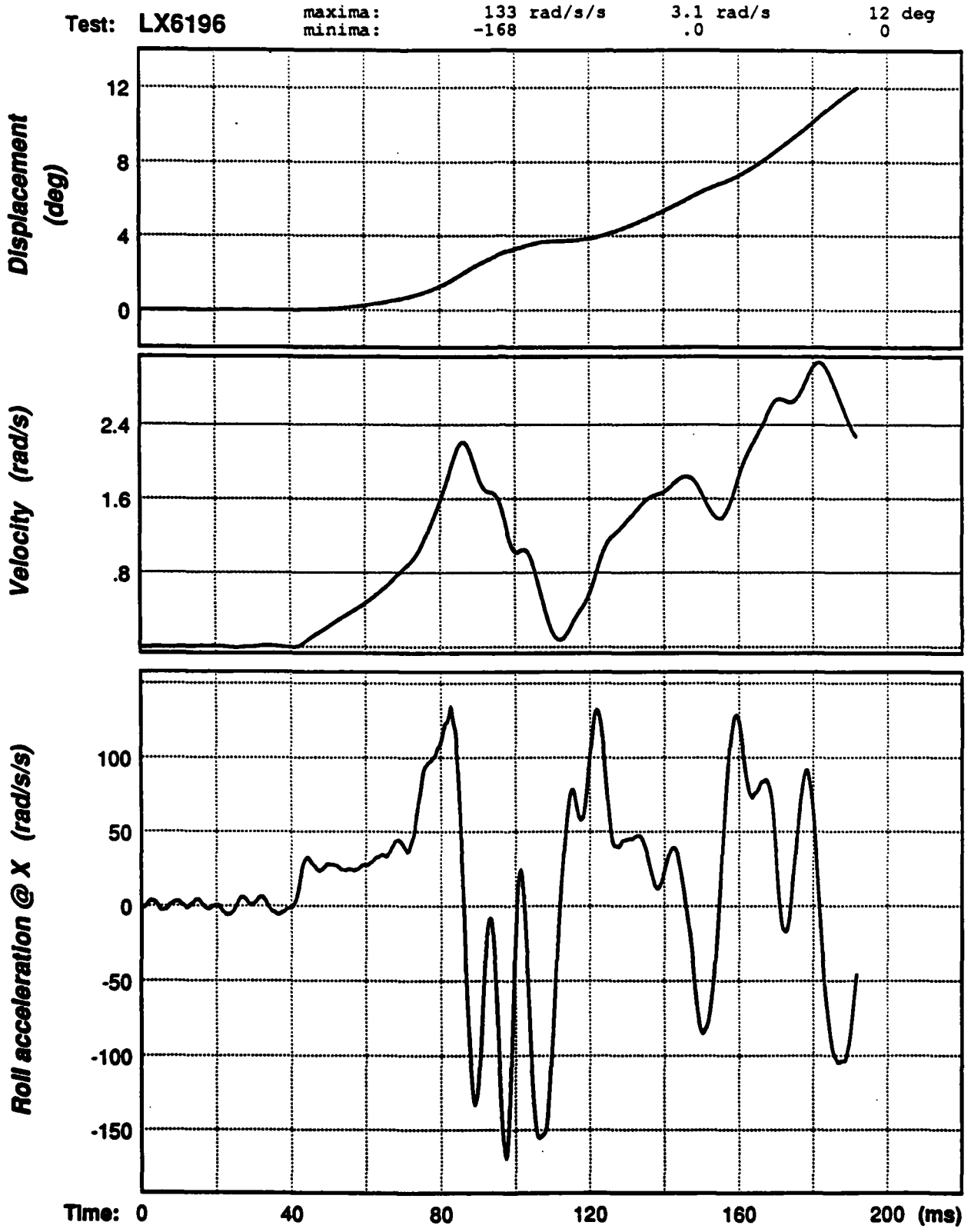

Figure A-23. Head roll angular acceleration, velocity, and displacement signals for test LX6196.

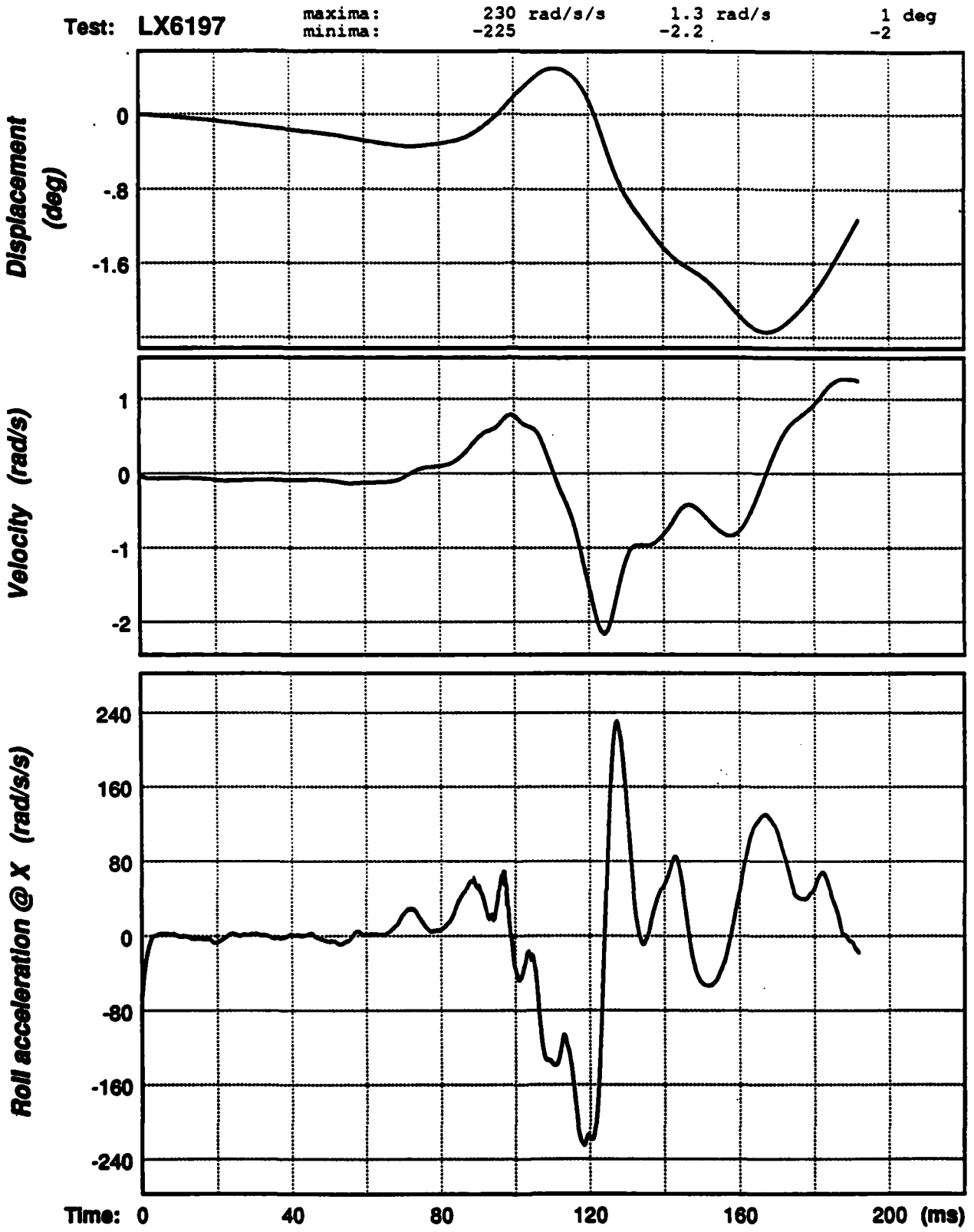

Figure A-24. Head roll angular acceleration, velocity, and displacement signals for test LX6197.

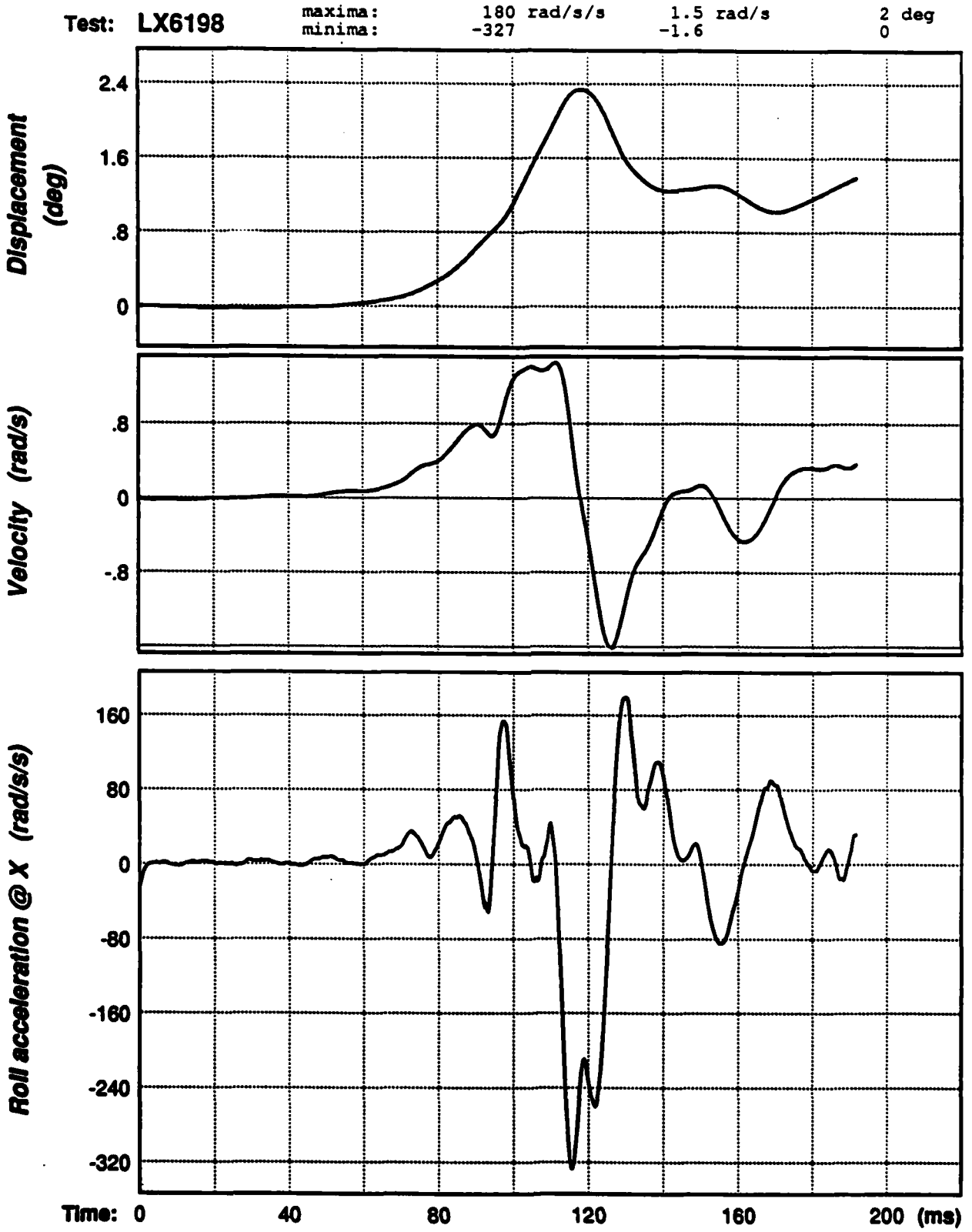

Figure A-25. Head roll angular acceleration, velocity, and displacement signals for test LX6198.

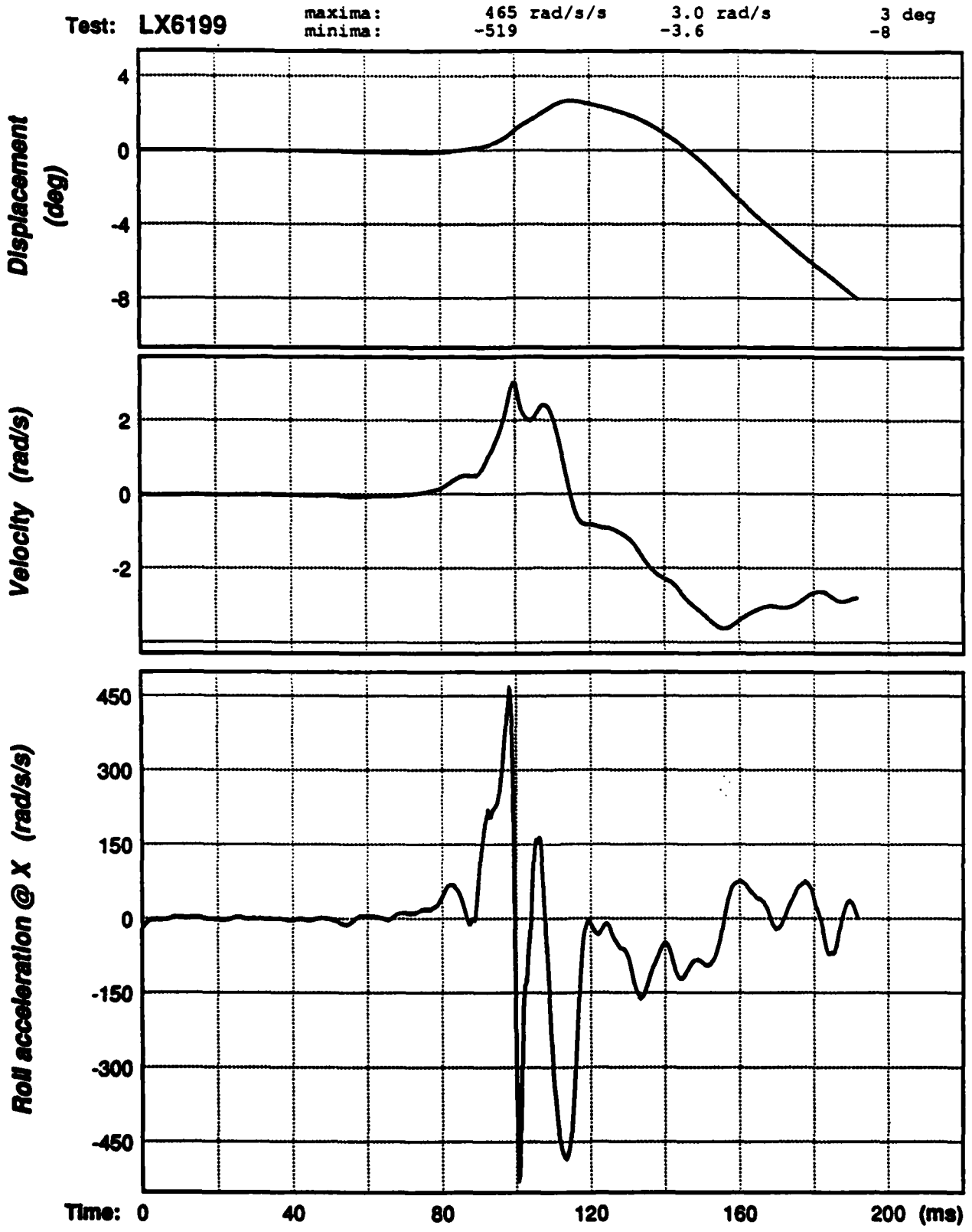

Figure A-26. Head roll angular acceleration, velocity, and displacement signals for test LX6199.

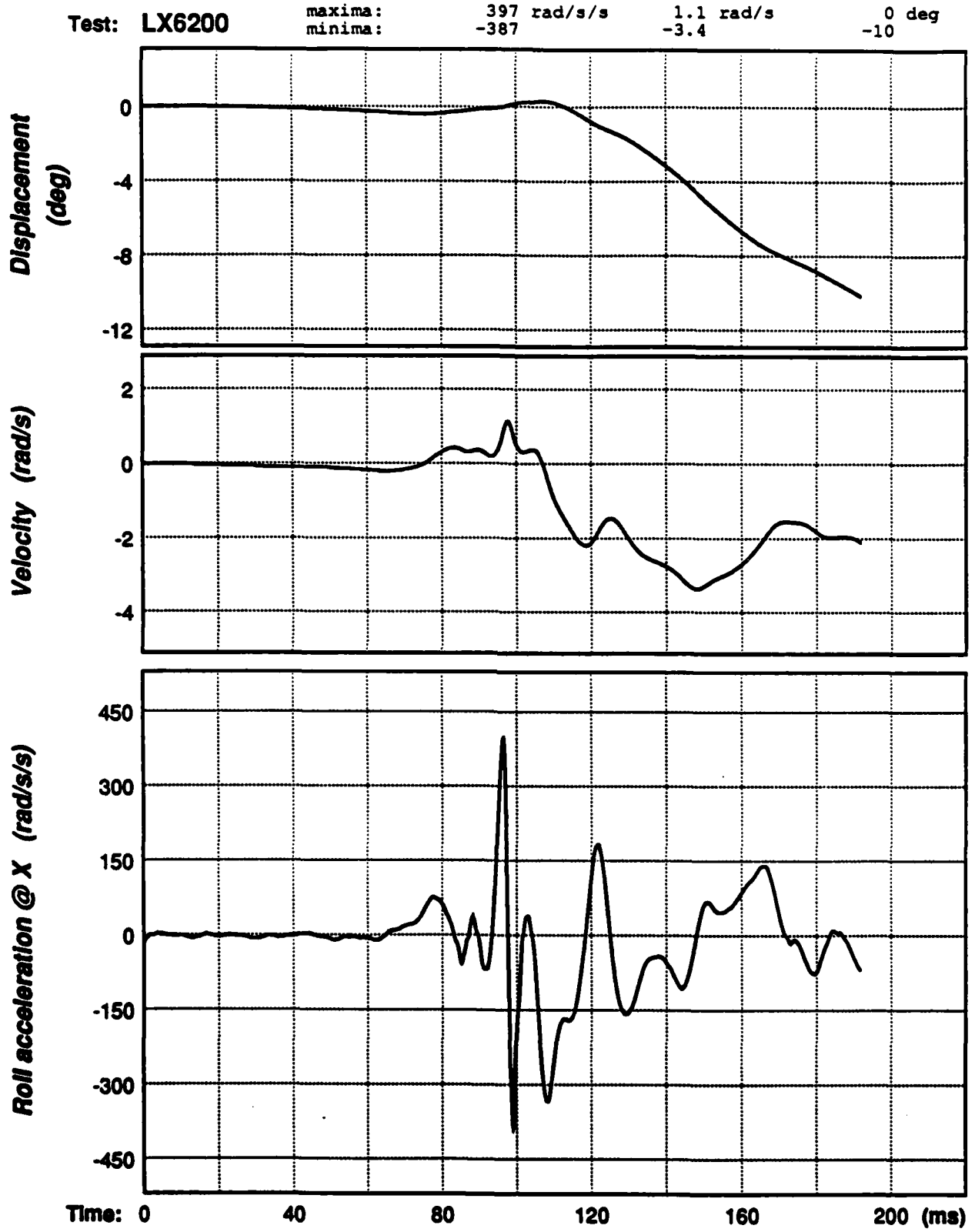

Figure A-27. Head roll angular acceleration, velocity, and displacement signals for test LX6200.

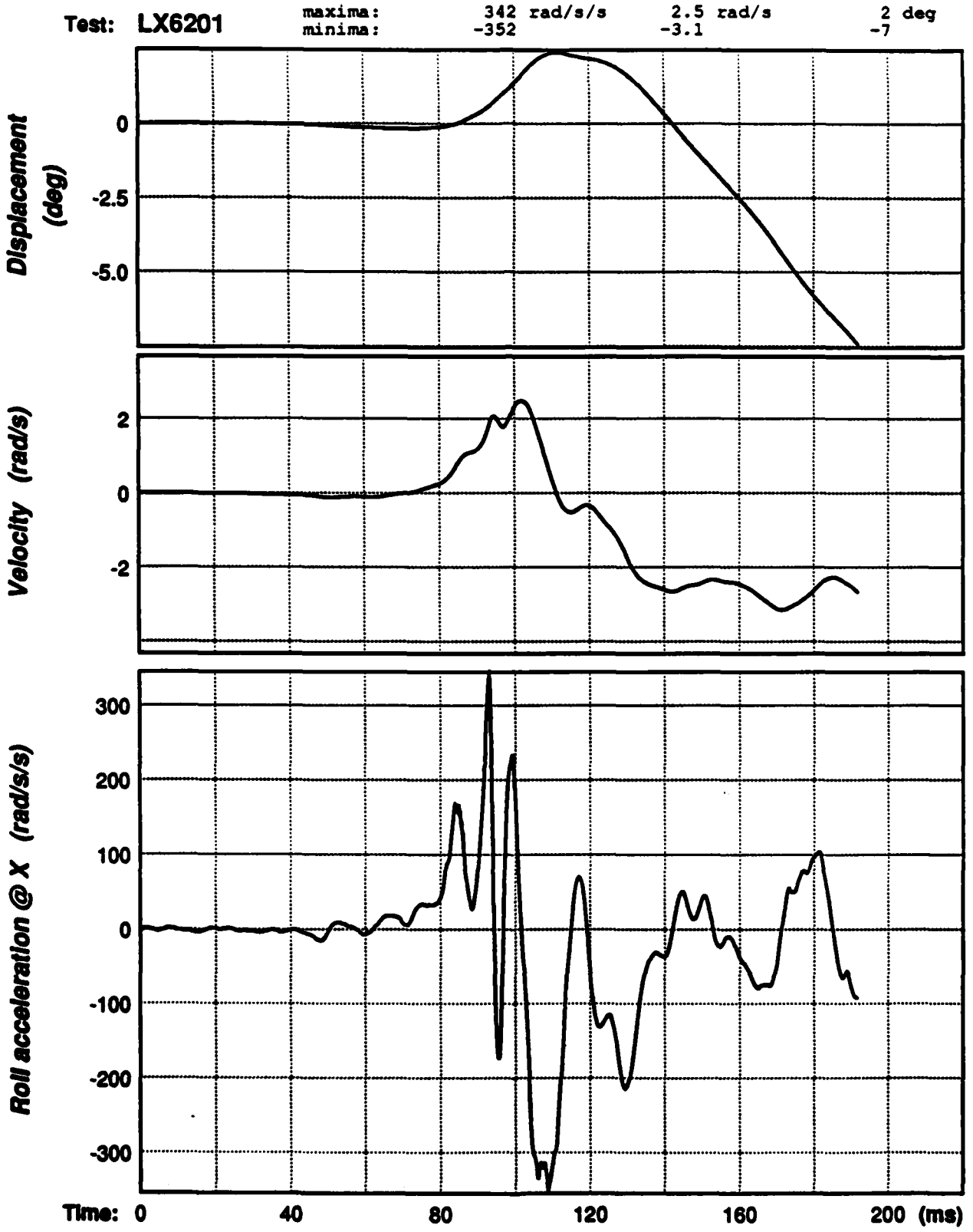

Figure A-28. Head roll angular acceleration, velocity, and displacement signals for test LX6201.

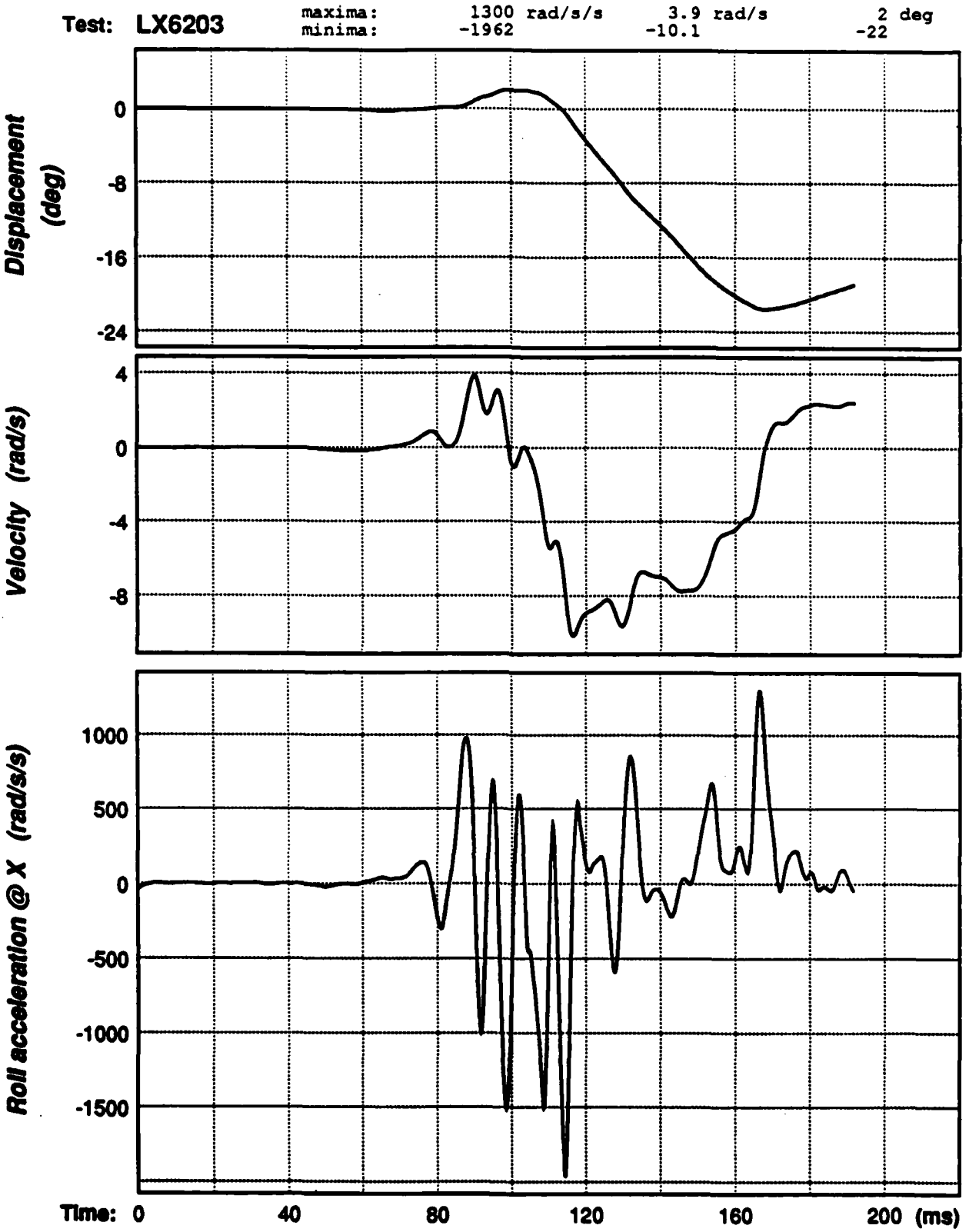

Figure A-29. Head roll angular acceleration, velocity, and displacement signals for test LX6203.

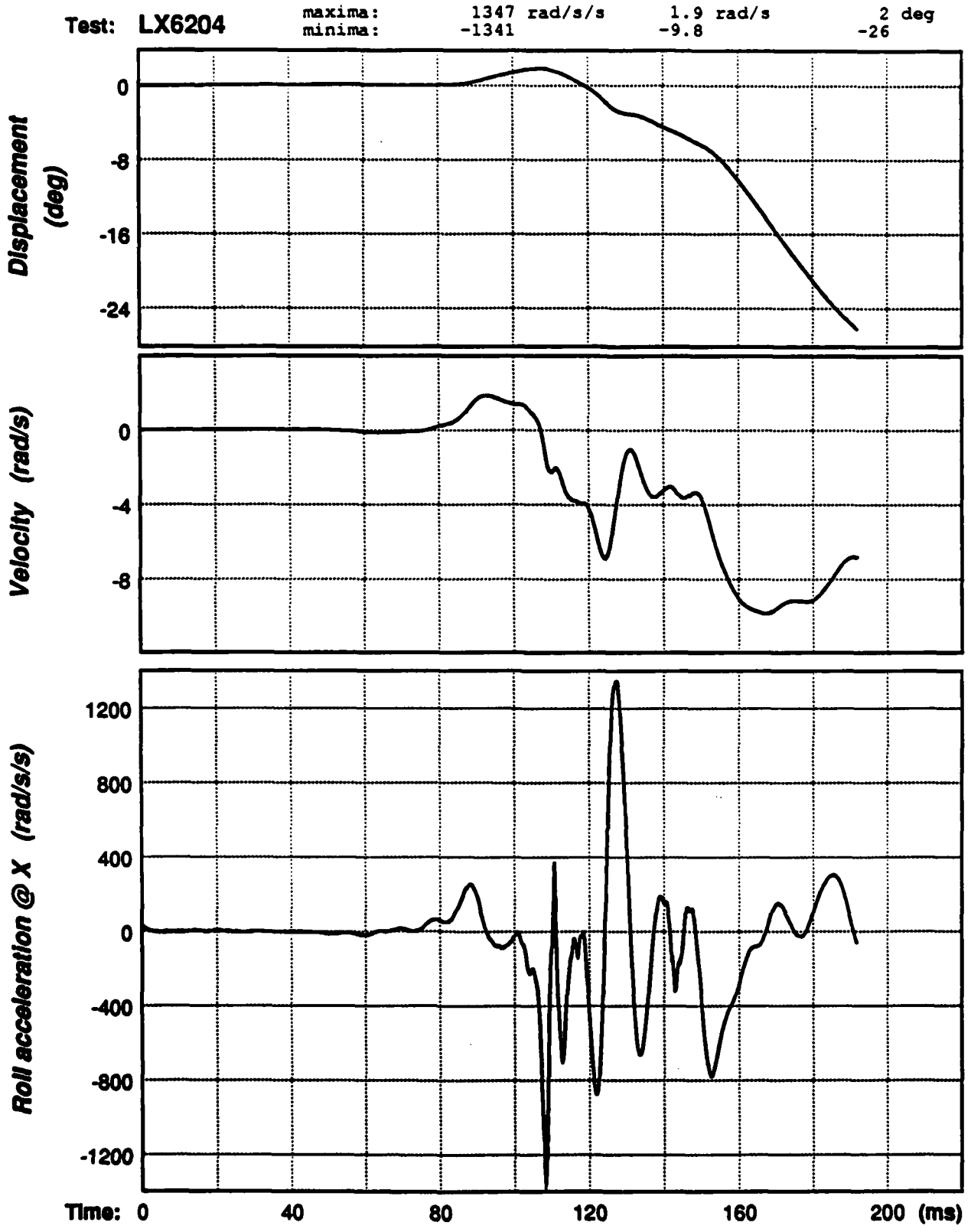

Figure A-30. Head roll angular acceleration, velocity, and displacement signals for test LX6204.

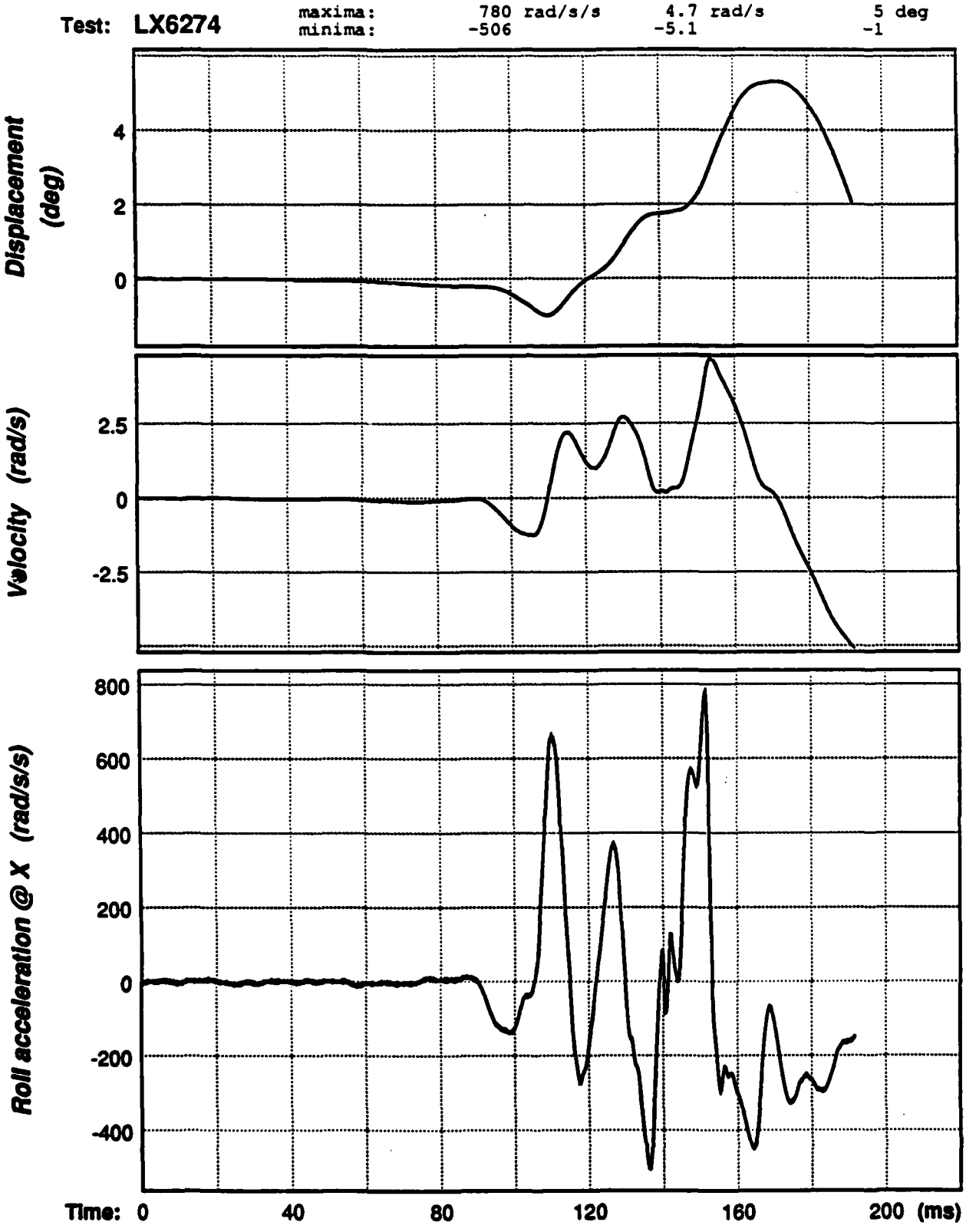

Figure A-31. Head roll angular acceleration, velocity, and displacement signals for test LX6274.

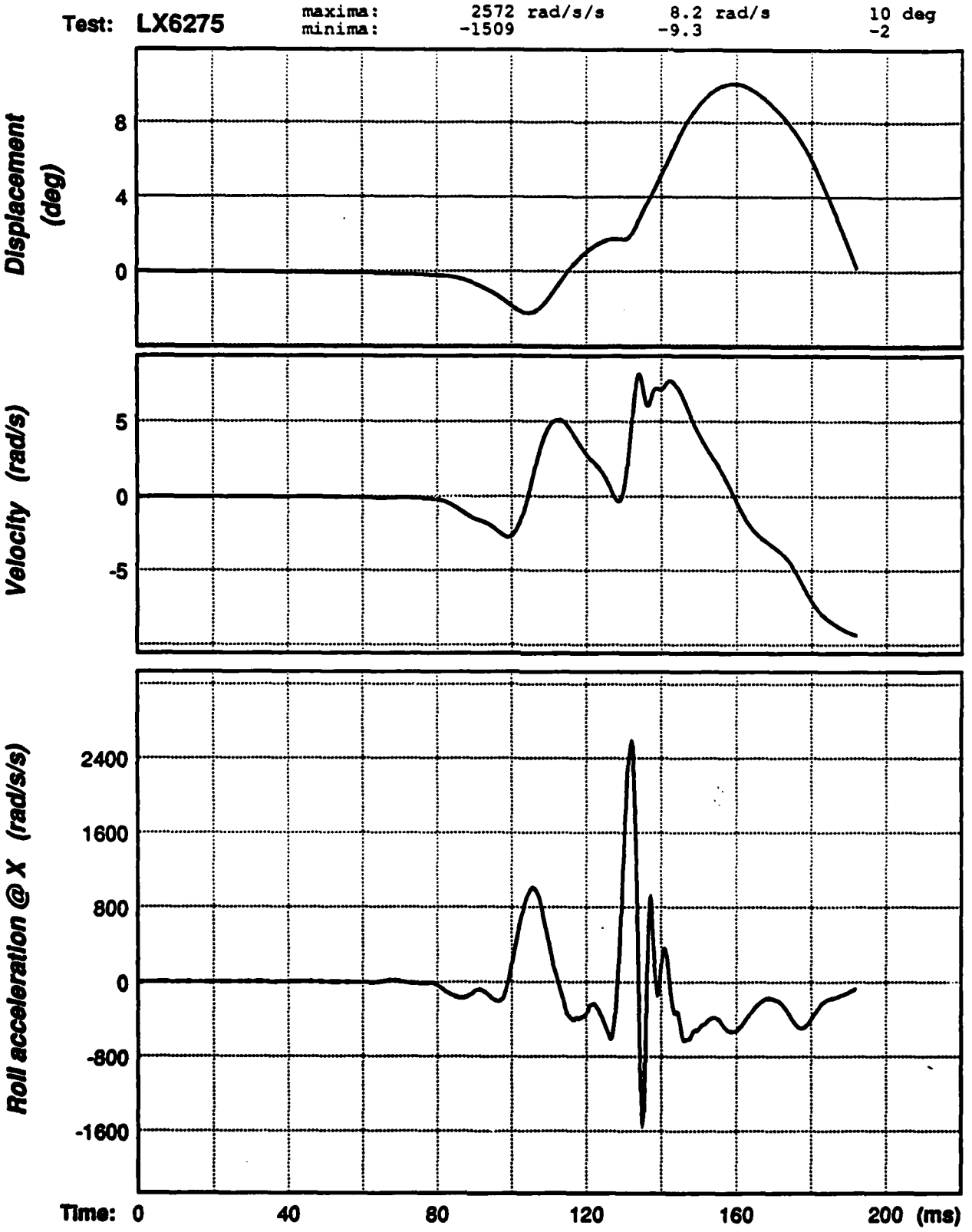

Figure A-32. Head roll angular acceleration, velocity, and displacement signals for test LX6275.

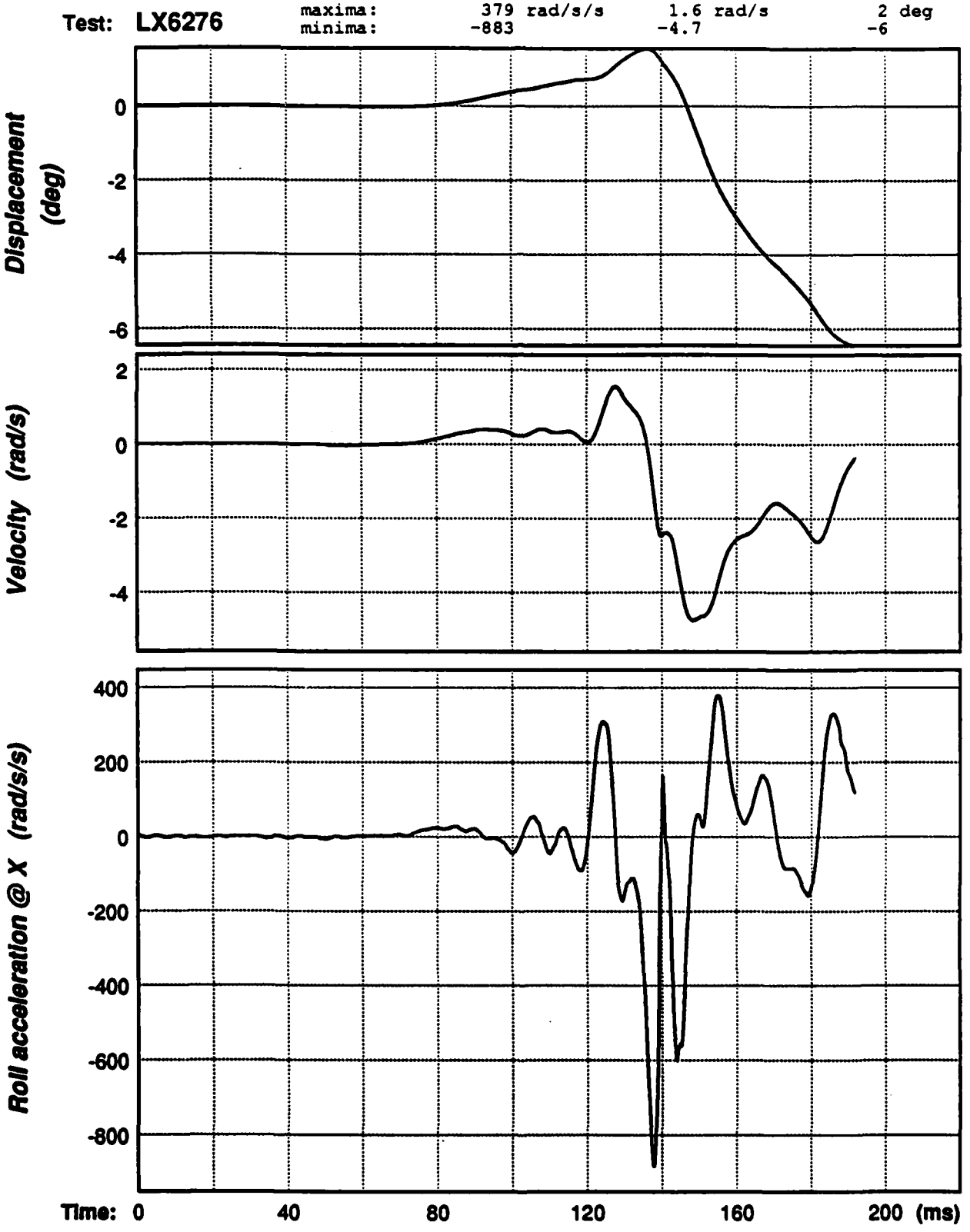

Figure A-33. Head roll angular acceleration, velocity, and displacement signals for test LX6276.

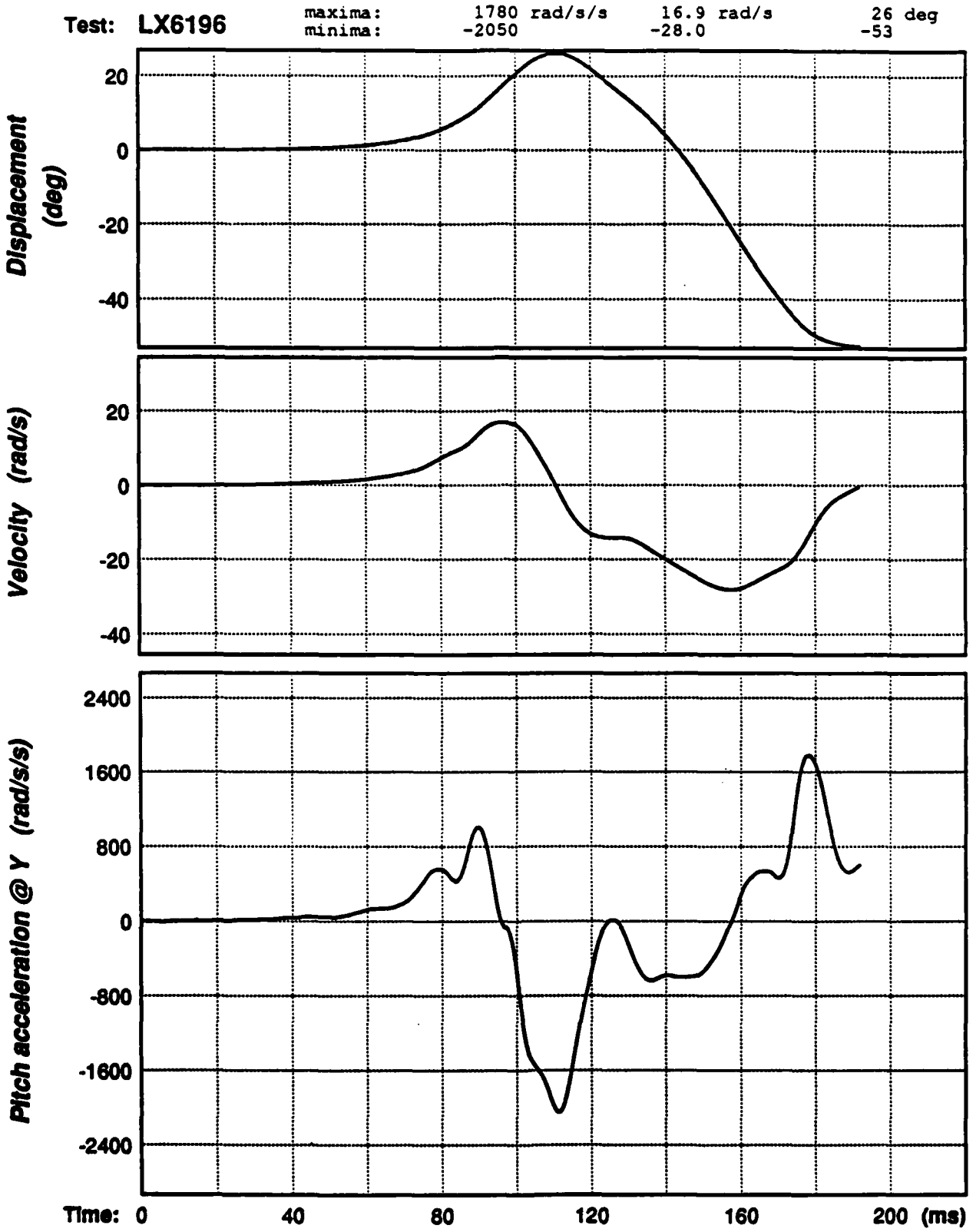

Figure A-34. Head pitch angular acceleration, velocity, and displacement signals for test LX6196.

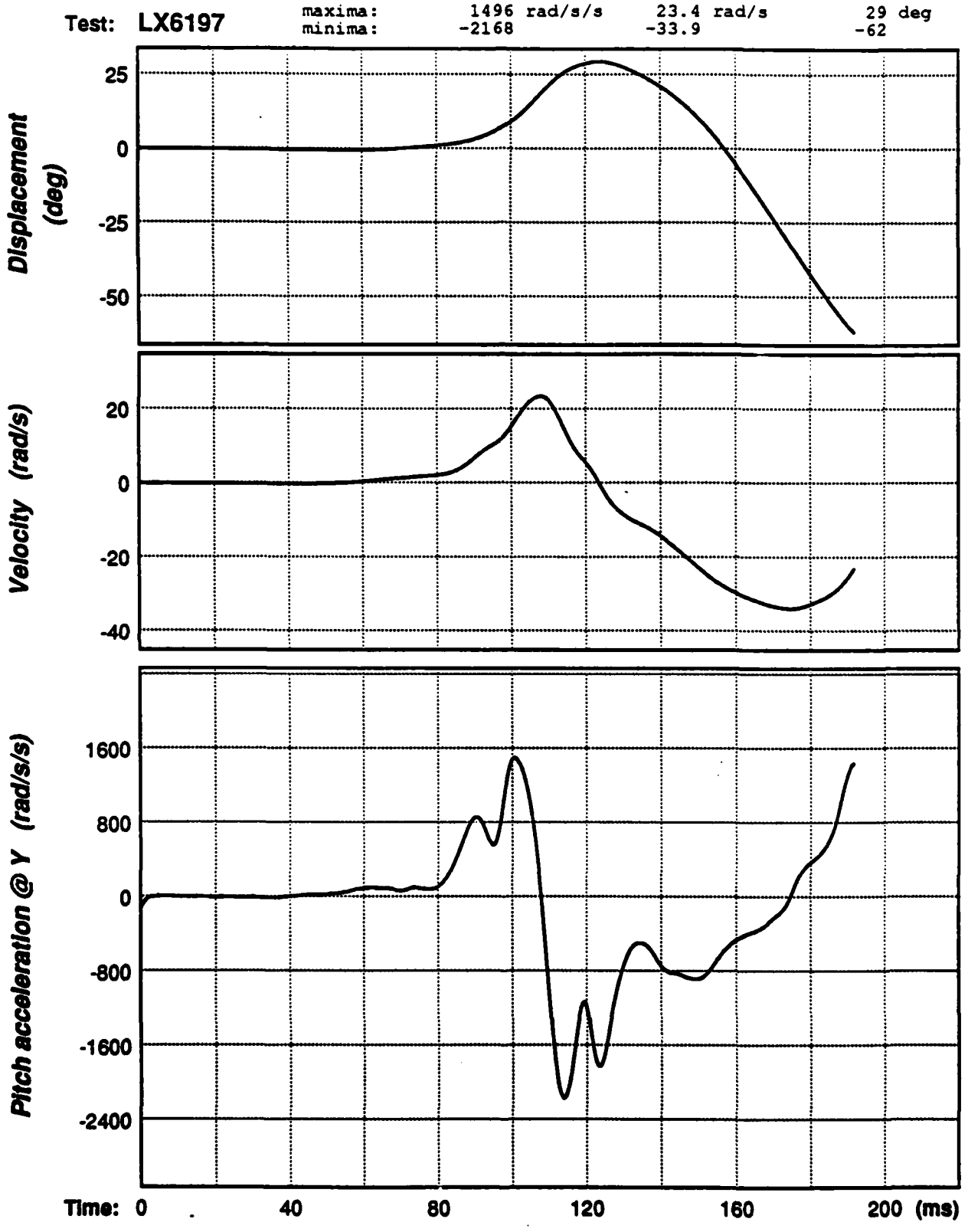

Figure A-35. Head pitch angular acceleration, velocity, and displacement signals for test LX6197.

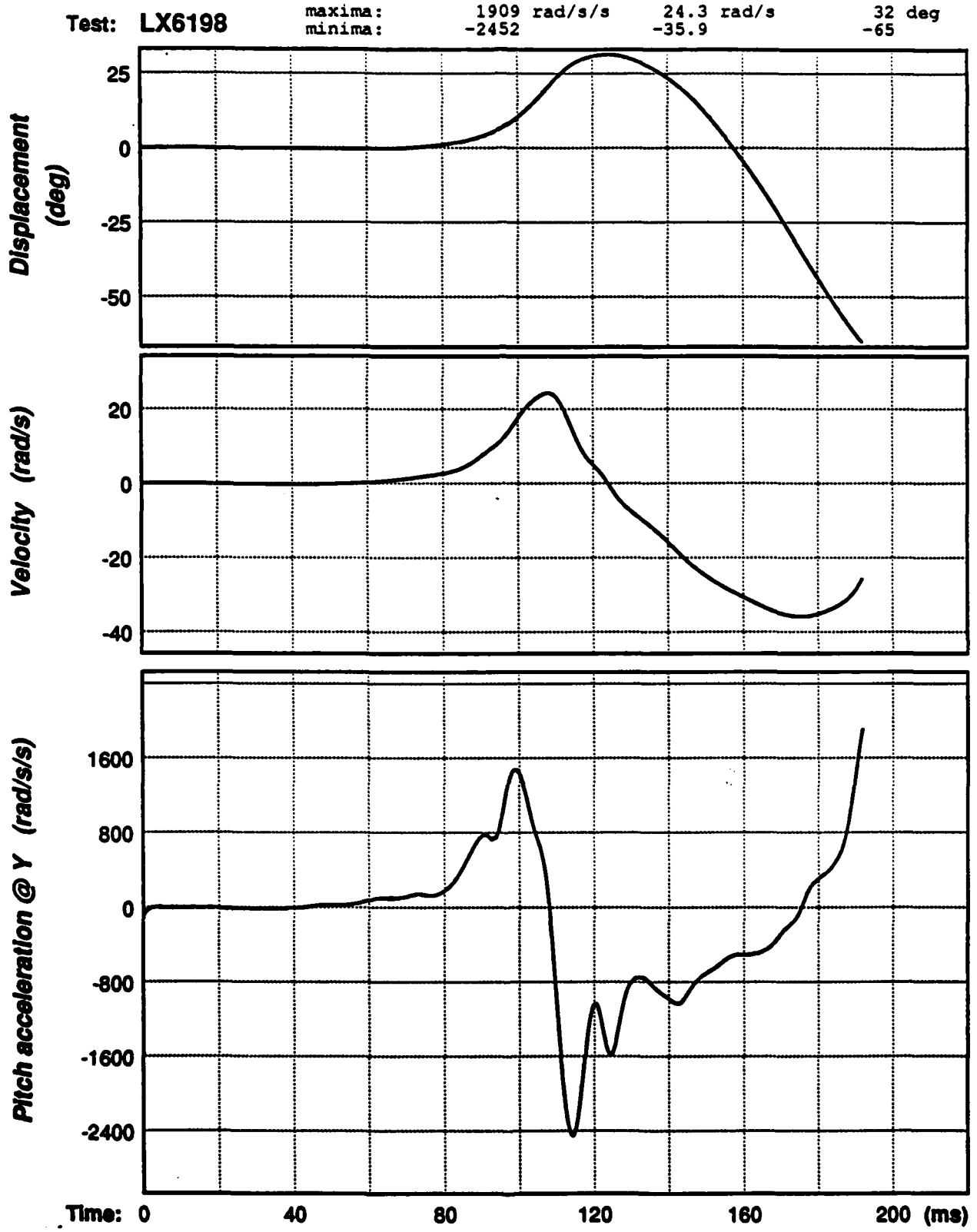

Figure A-36. Head pitch angular acceleration, velocity, and displacement signals for test LX6198.

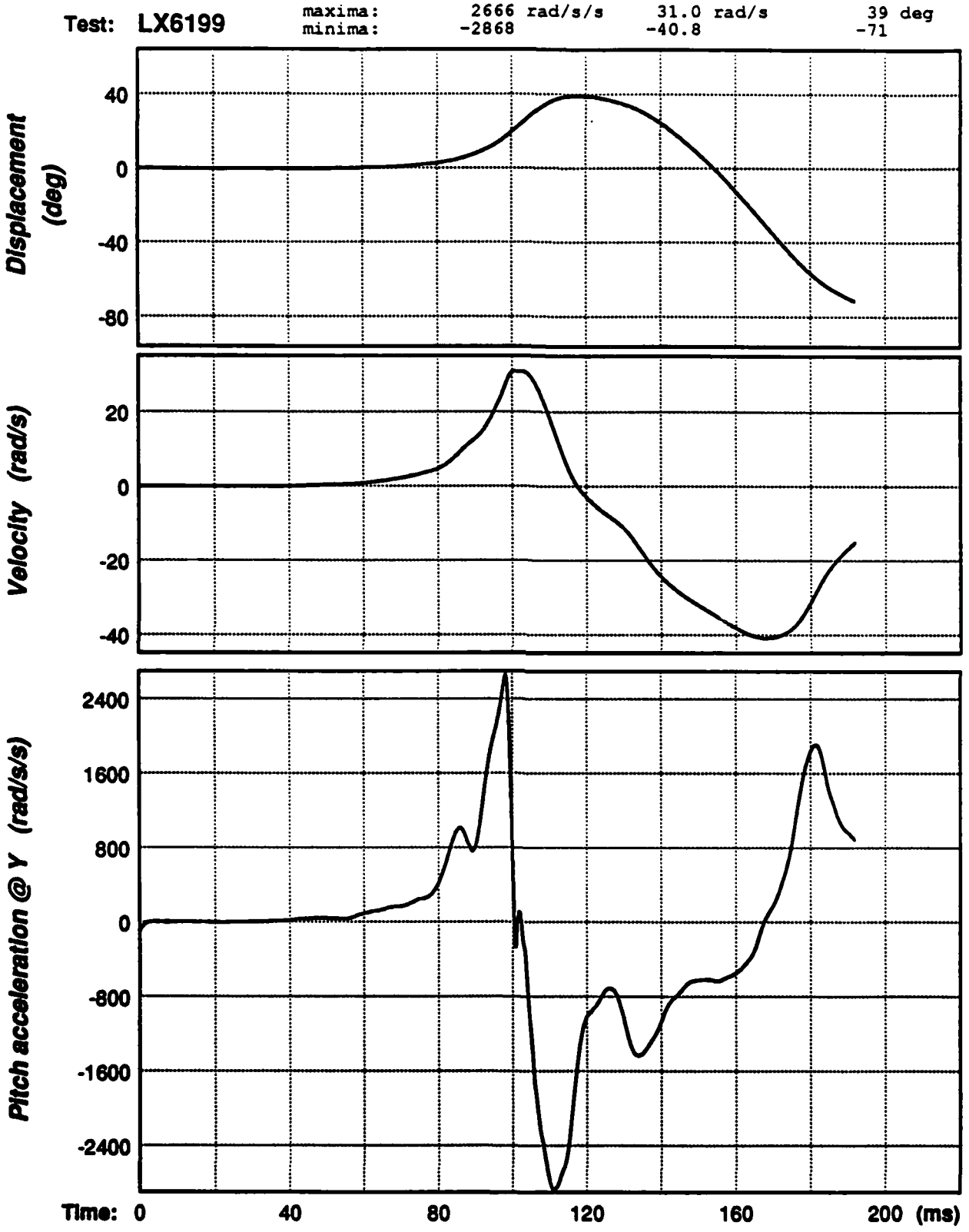

Figure A-37. Head pitch angular acceleration, velocity, and displacement signals for test LX6199.

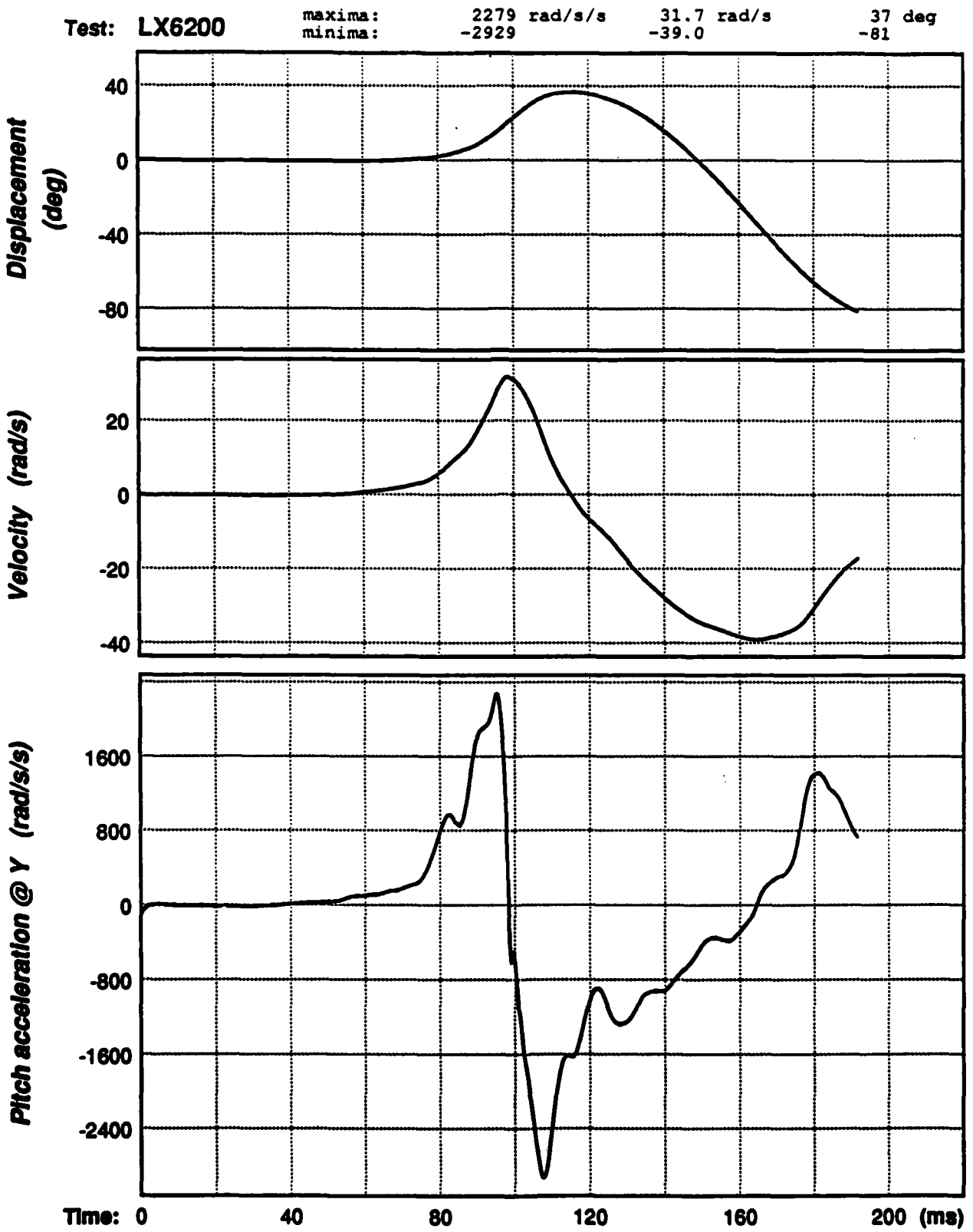

Figure A-38. Head pitch angular acceleration, velocity, and displacement signals for test LX6200.

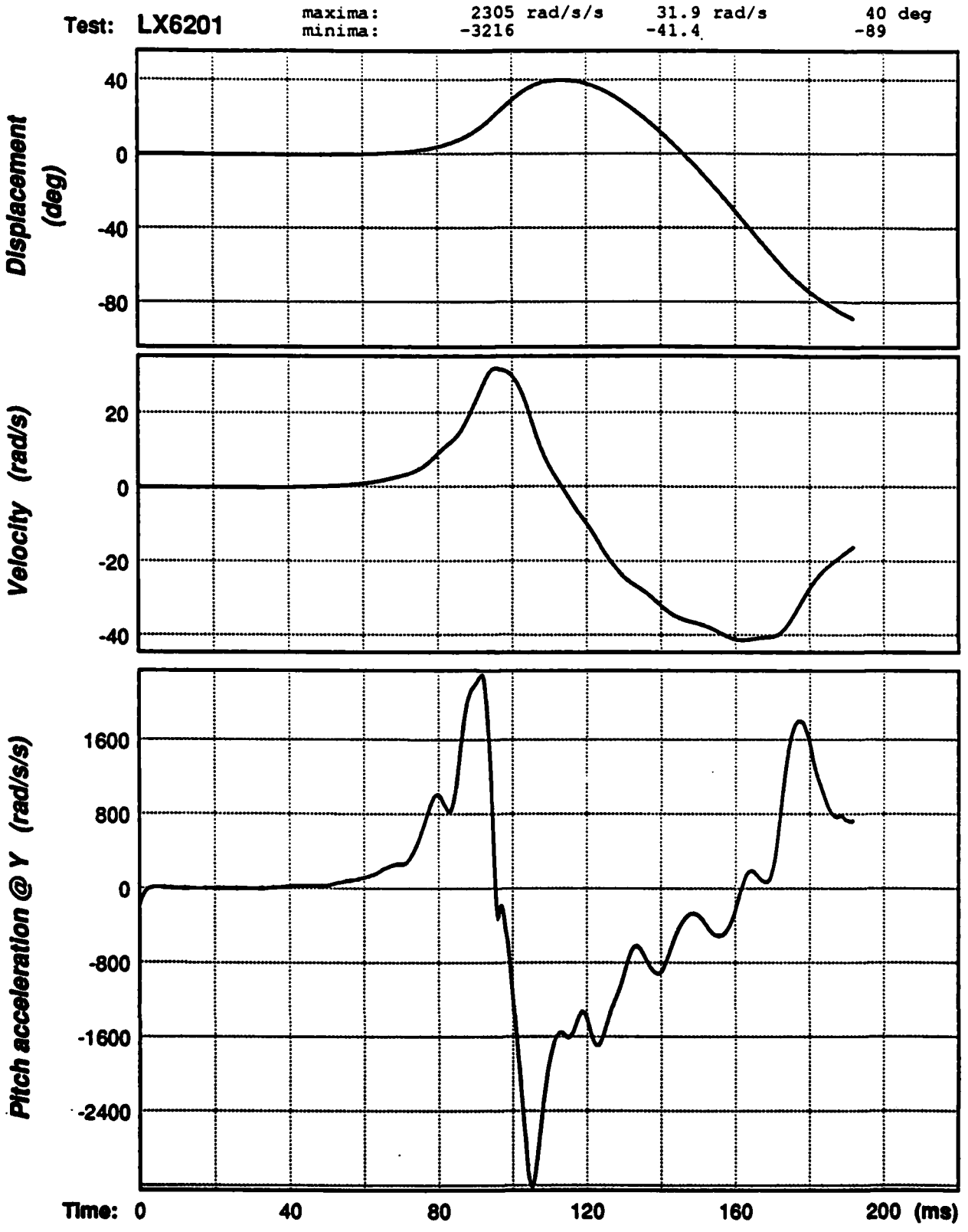

Figure A-39. Head pitch angular acceleration, velocity, and displacement signals for test LX6201.

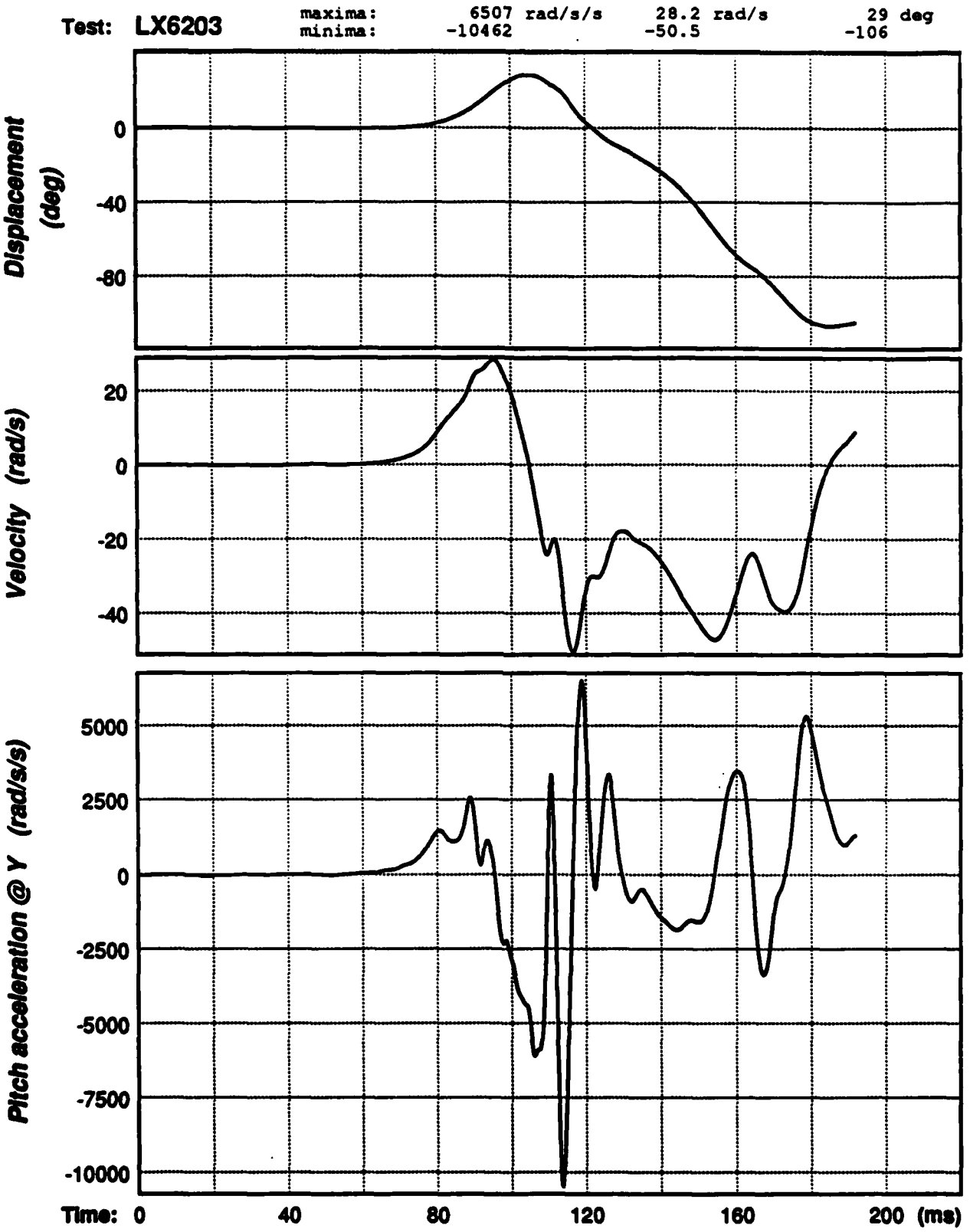

Figure A-40. Head pitch angular acceleration, velocity, and displacement signals for test LX6203.

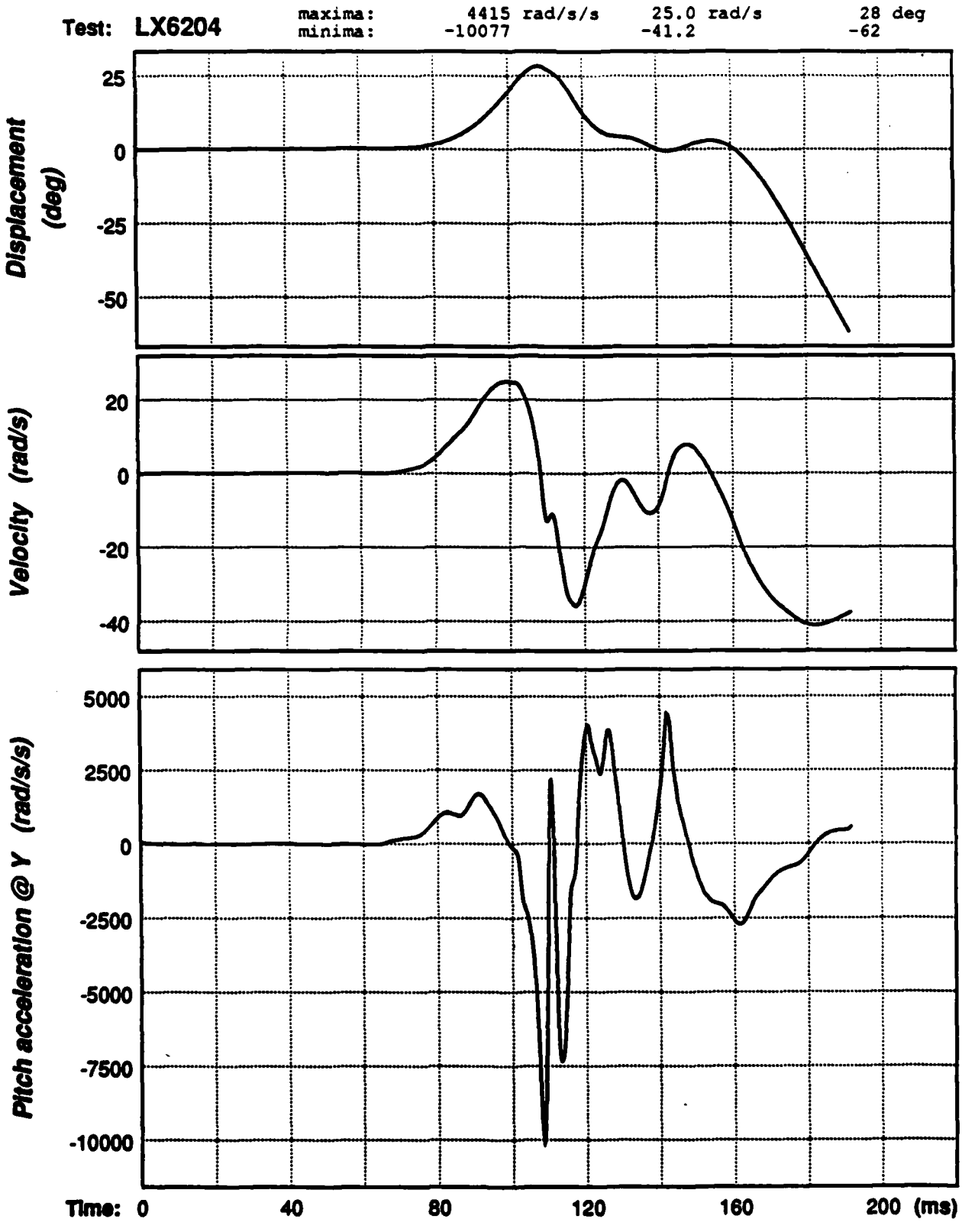

Figure A-41. Head pitch angular acceleration, velocity, and displacement signals for test LX6204.

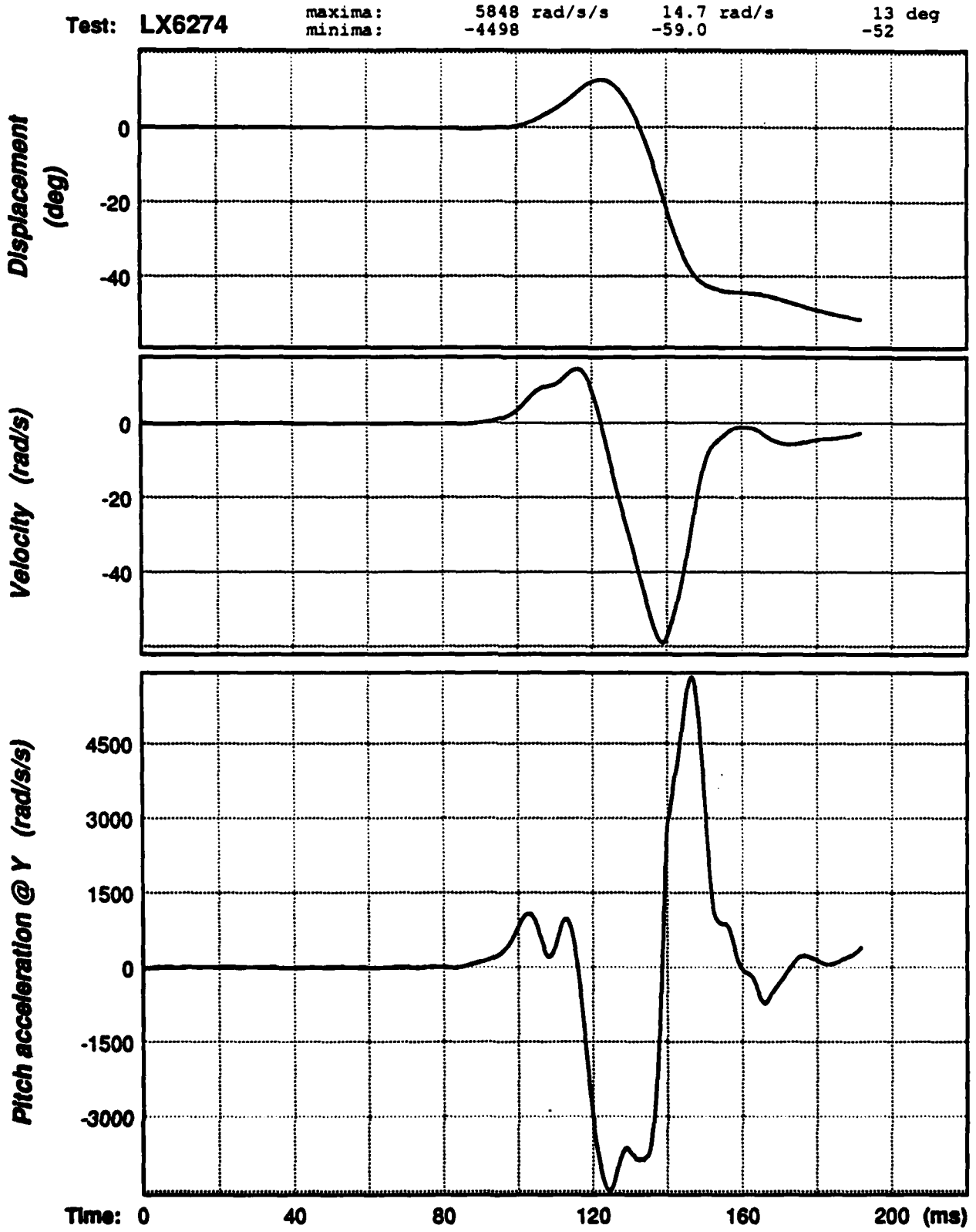

Figure A-42. Head pitch angular acceleration, velocity, and displacement signals for test LX6274.

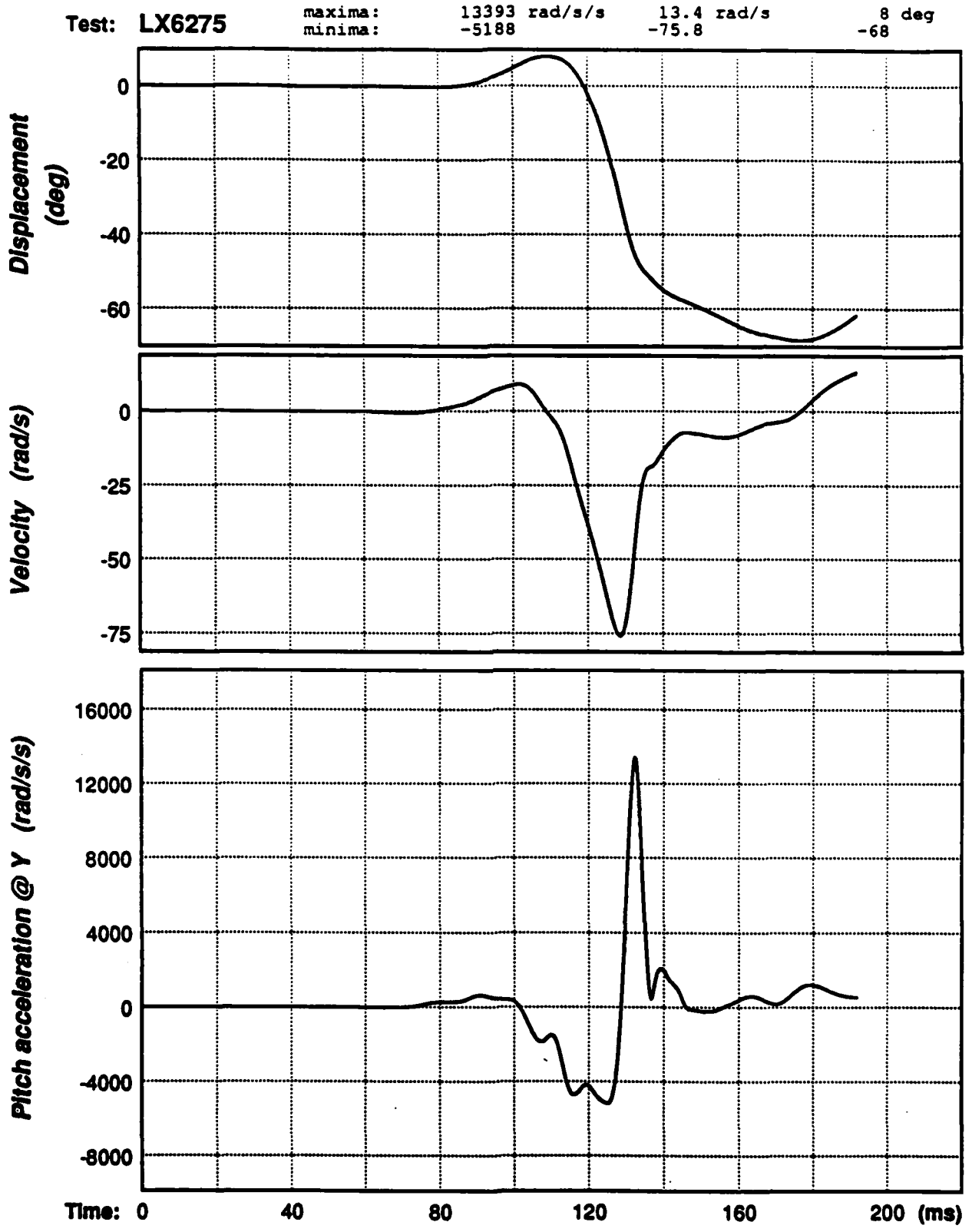

Figure A-43. Head pitch angular acceleration, velocity, and displacement signals for test LX6275.

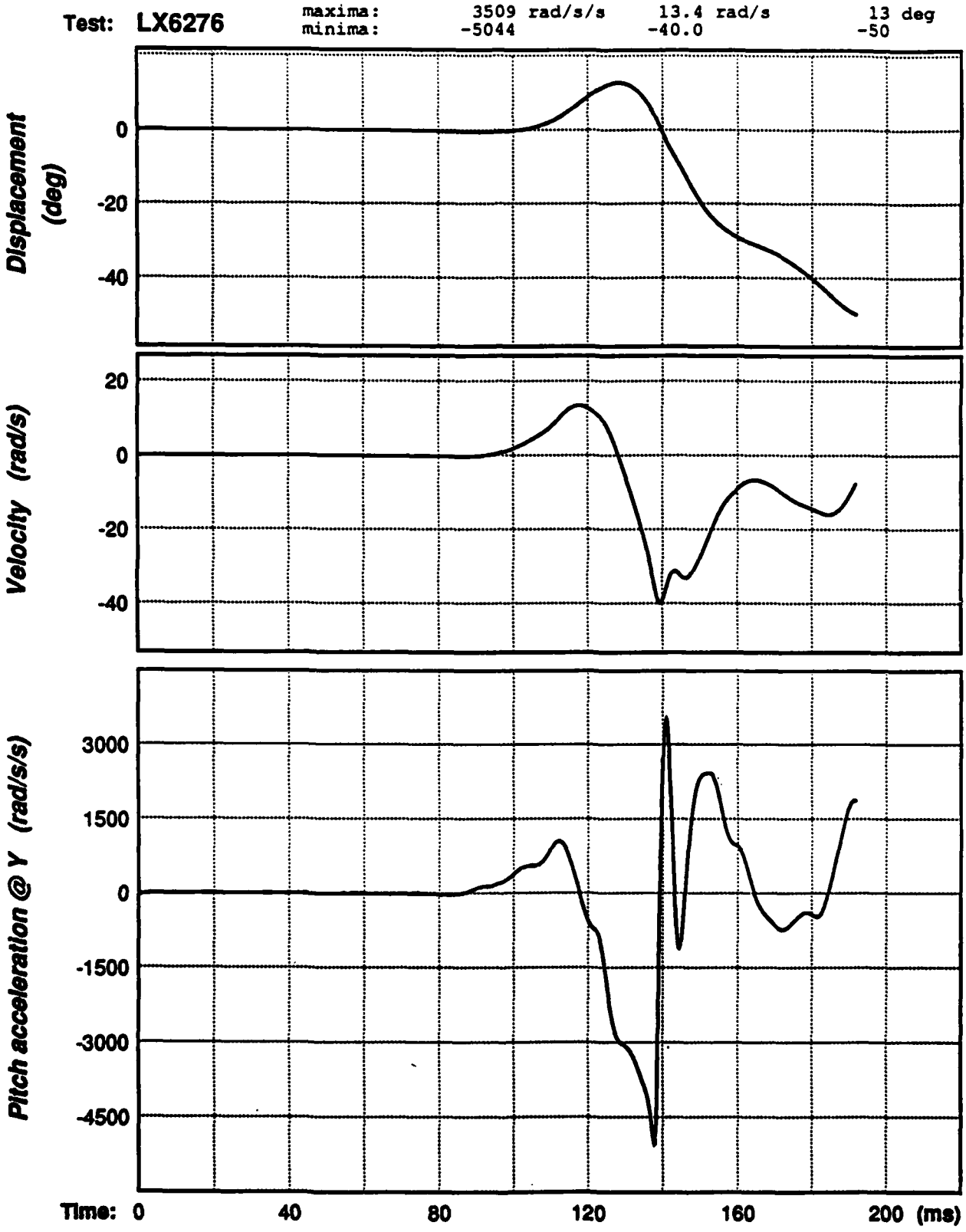

Figure A-44. Head pitch angular acceleration, velocity, and displacement signals for test LX6276.

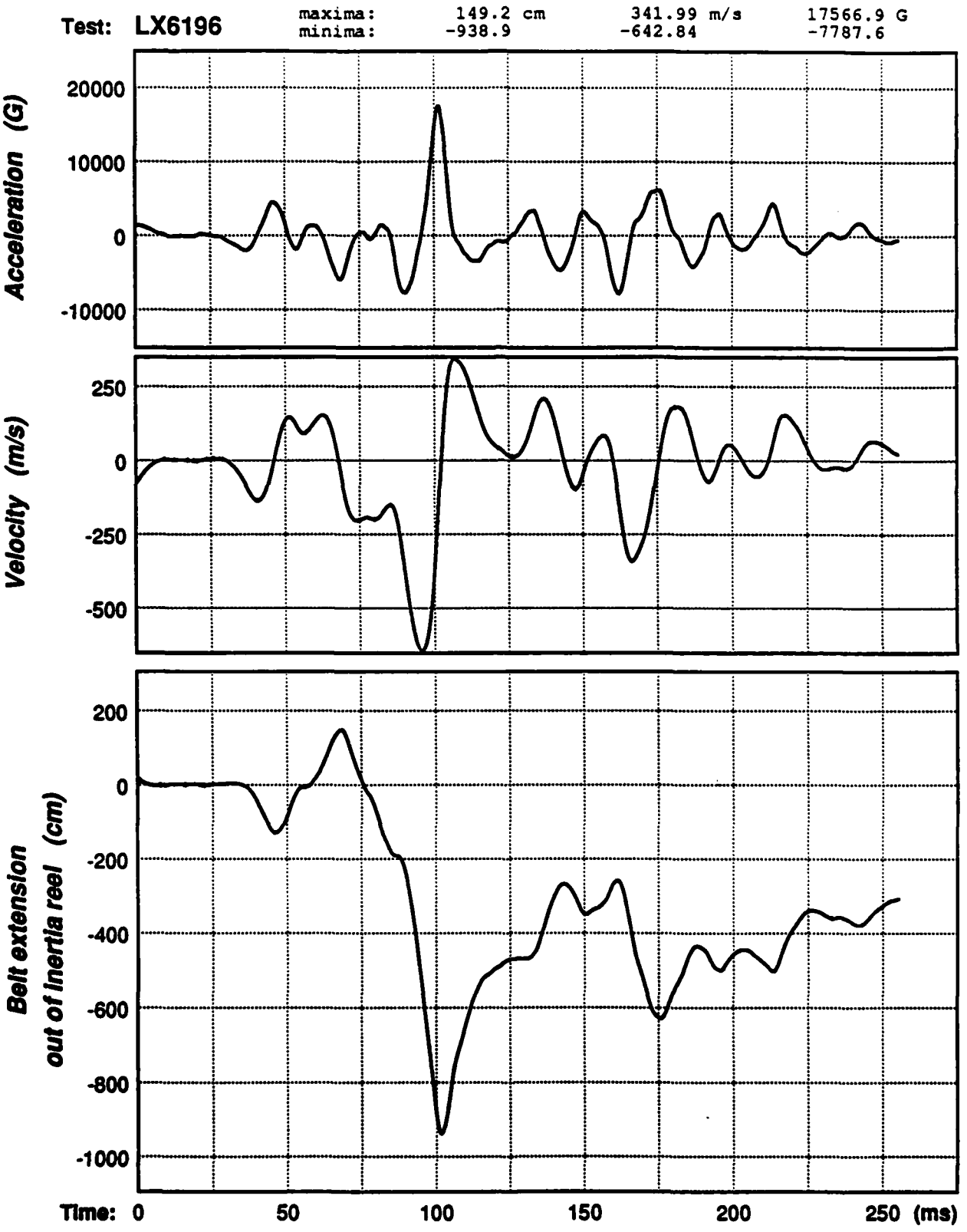

Figure A-45. Amount of belt extension and the velocity and acceleration of extension for test LX6196.

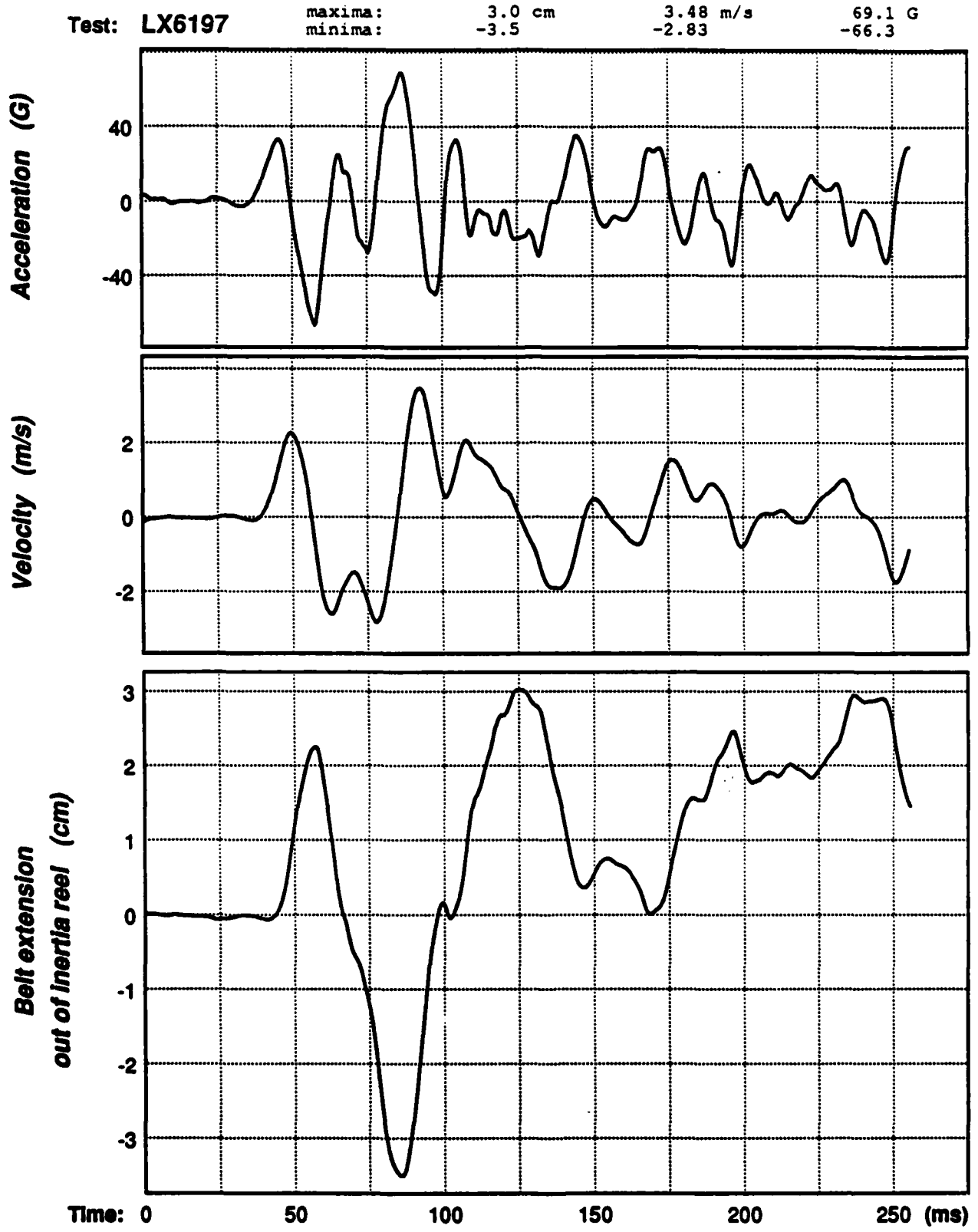

Figure A-46. Amount of belt extension and the velocity and acceleration of extension for test LX6197.

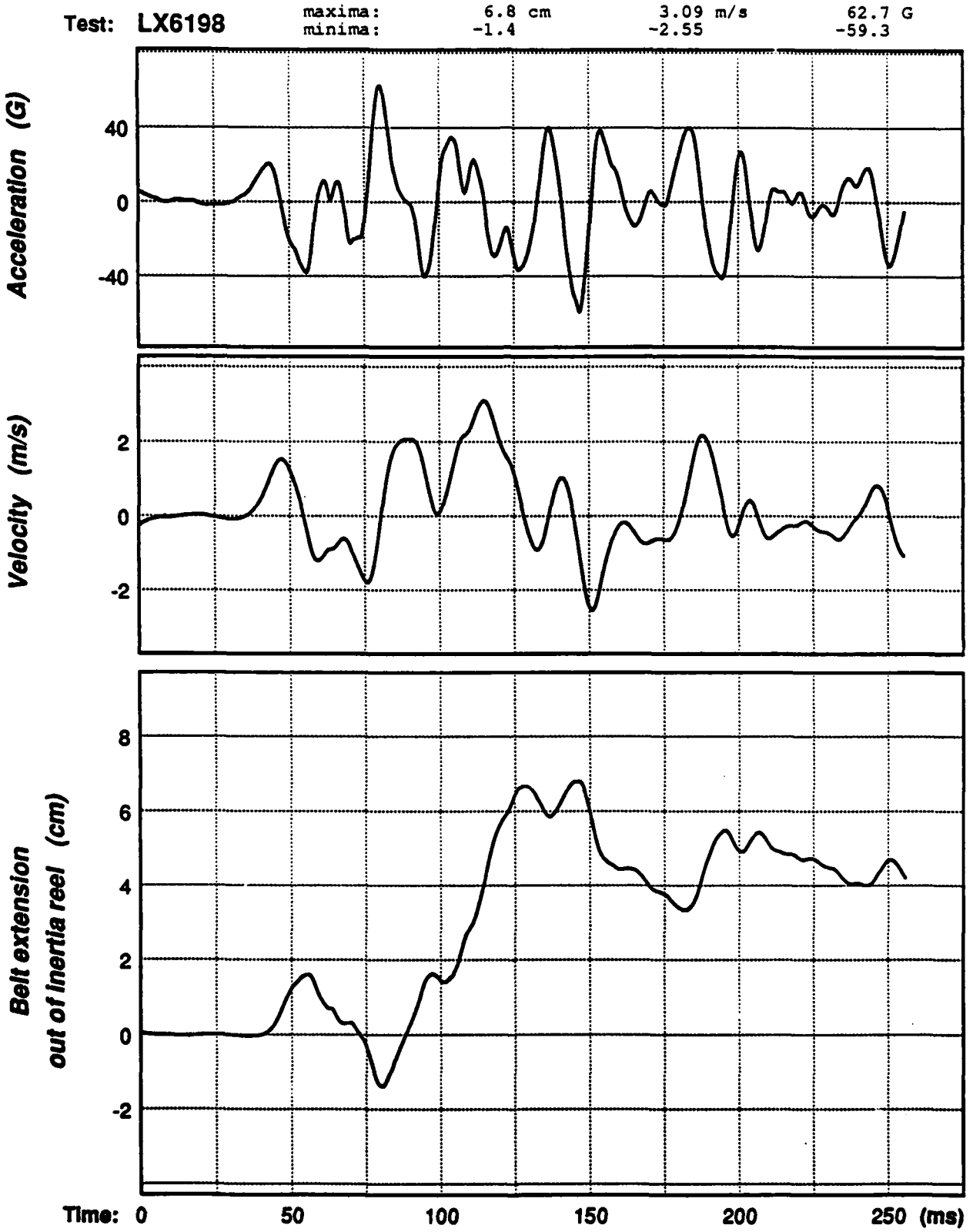

Figure A-47. Amount of belt extension and the velocity and acceleration of extension for test LX6198.

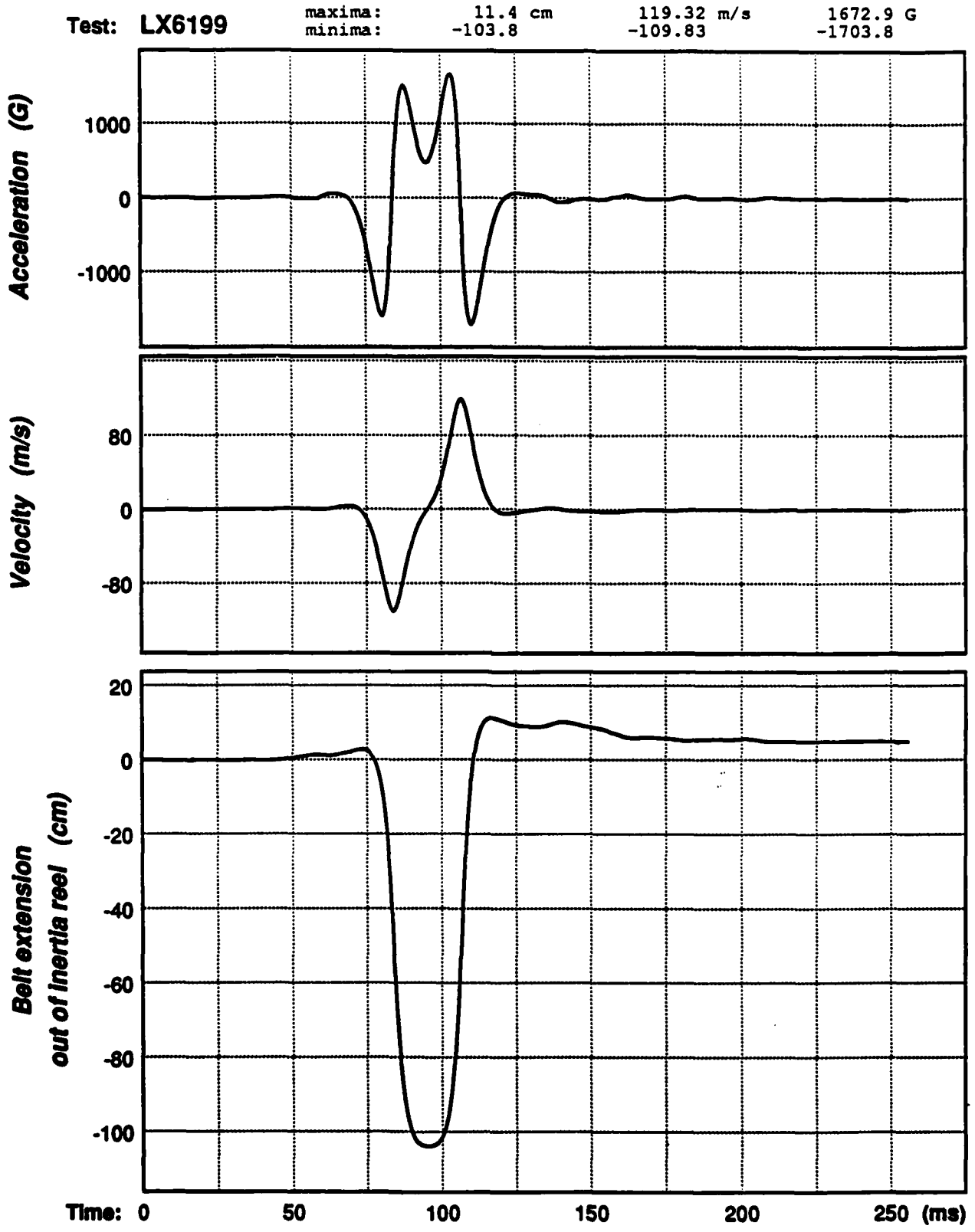

Figure A-48. Amount of belt extension and the velocity and acceleration of extension for test LX6199.

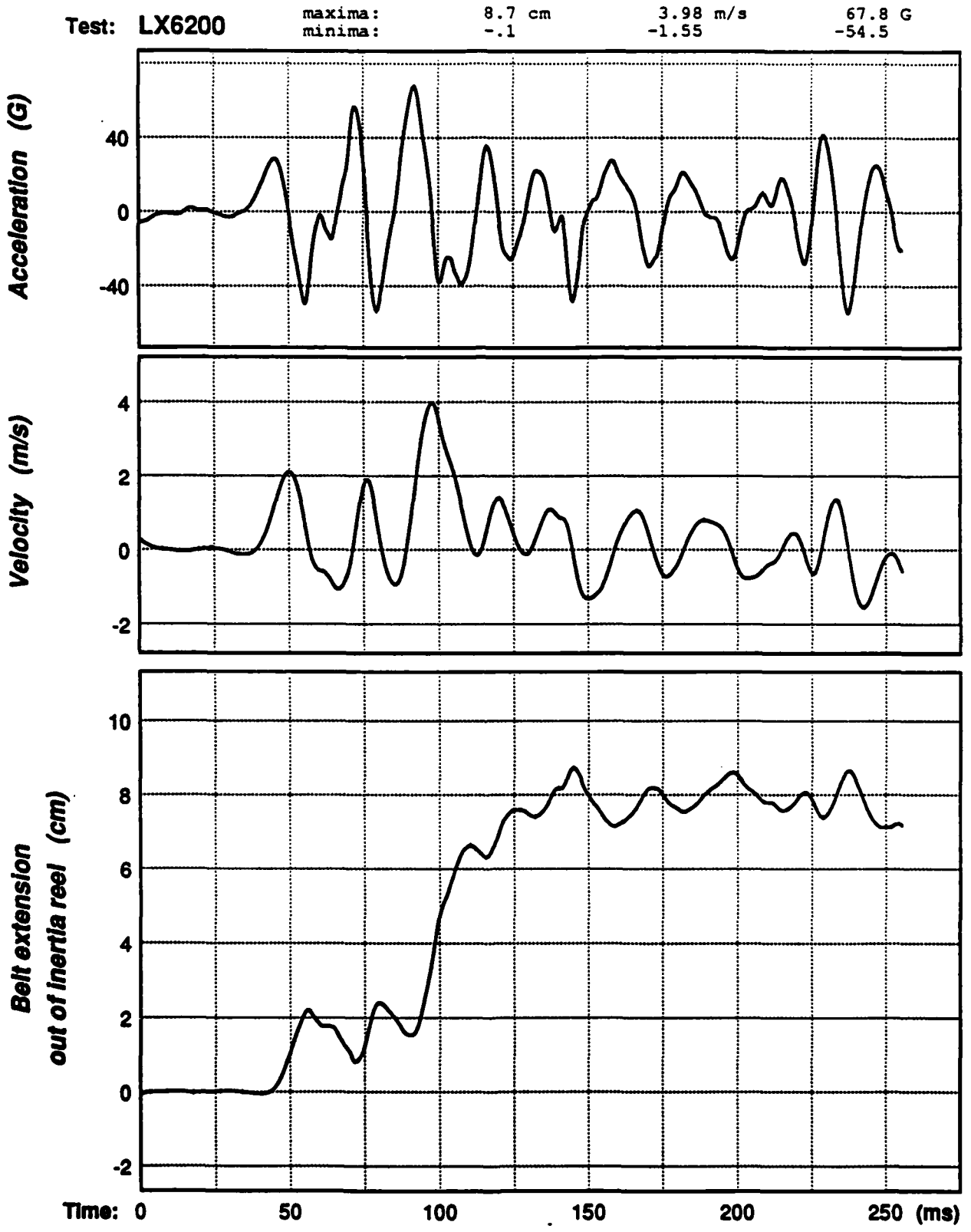

Figure A-49. Amount of belt extension and the velocity and acceleration of extension for test LX6200.

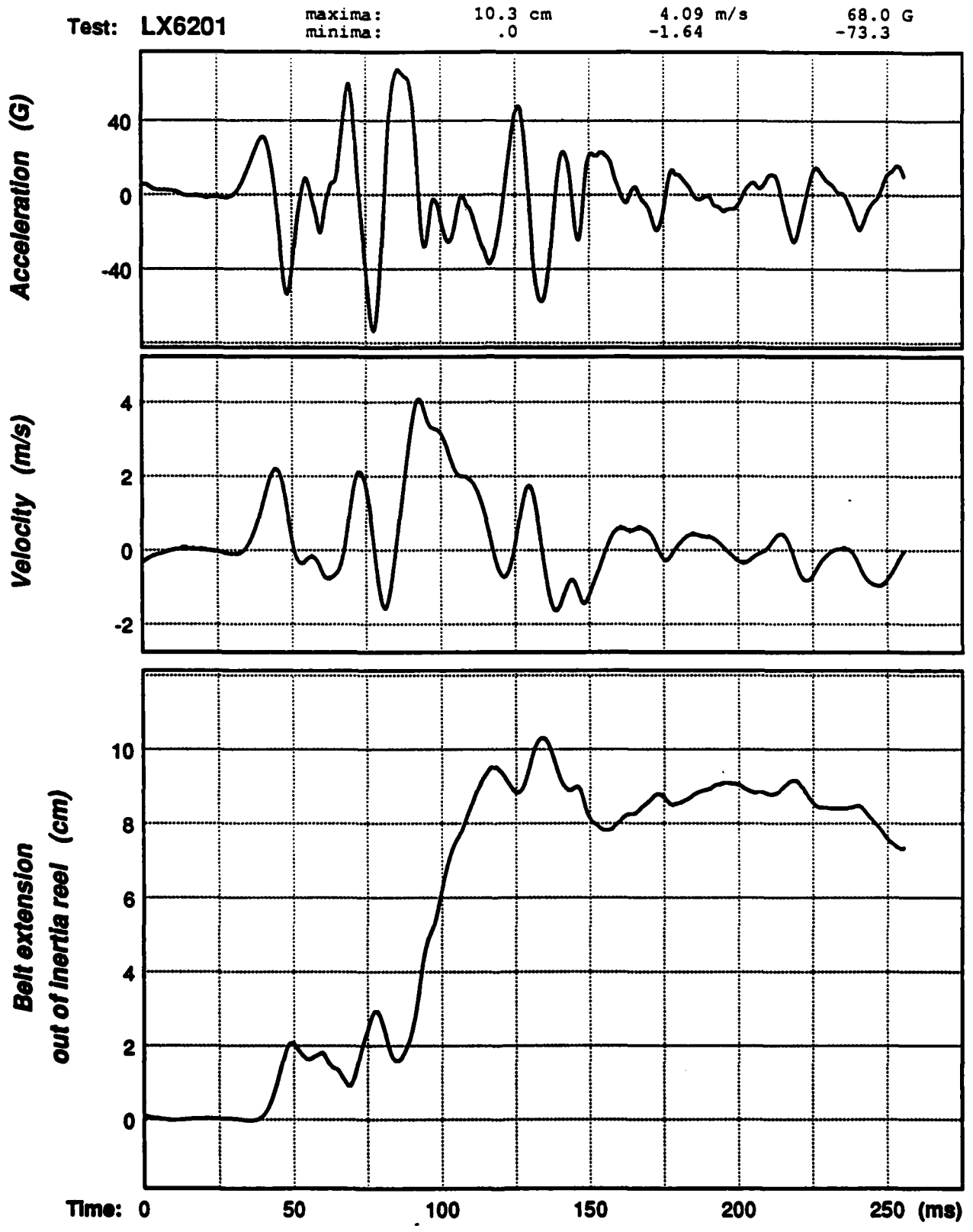

Figure A-50. Amount of belt extension and the velocity and acceleration of extension for test LX6201.

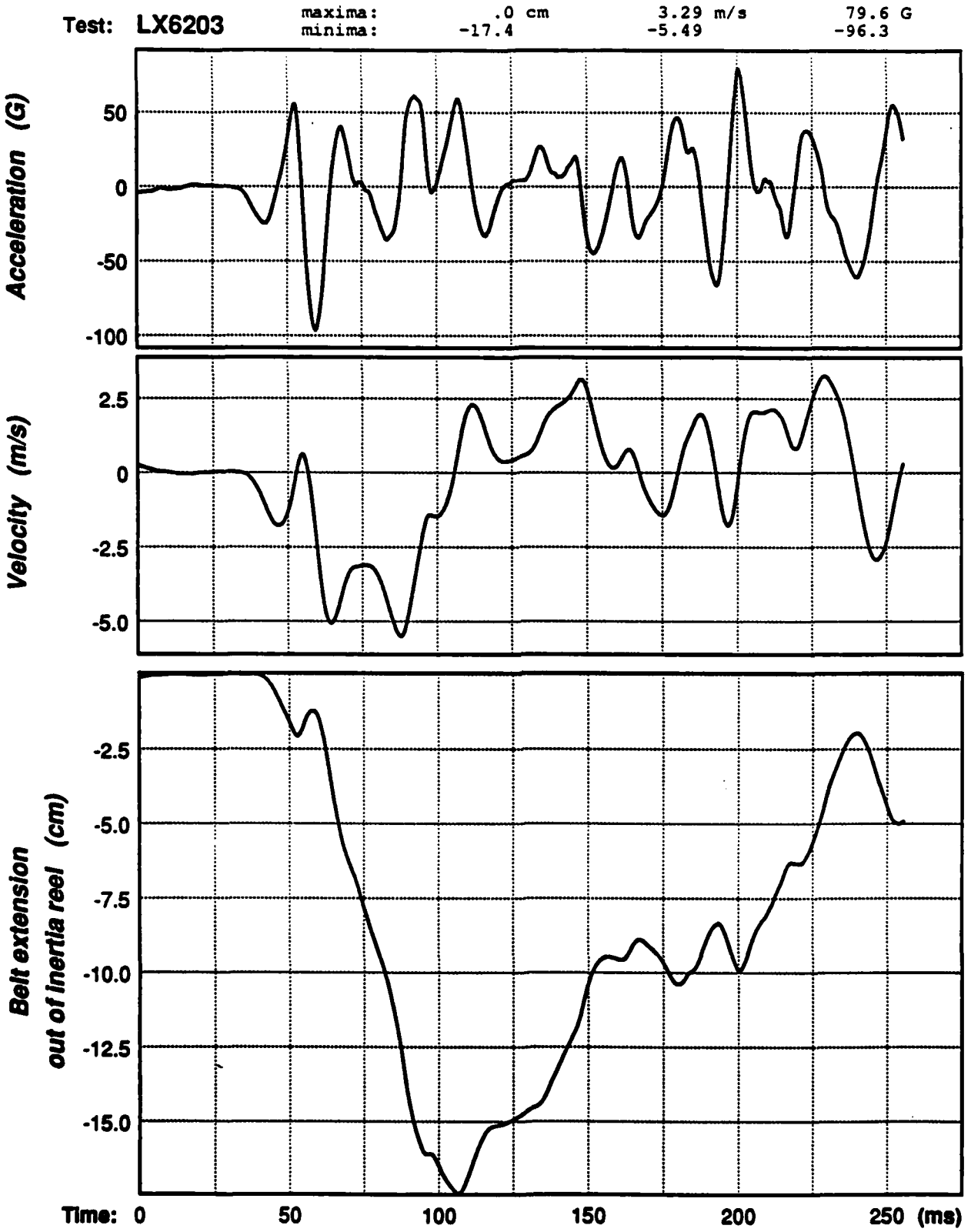

Figure A-51. Amount of belt extension and the velocity and acceleration of extension for test LX6203.

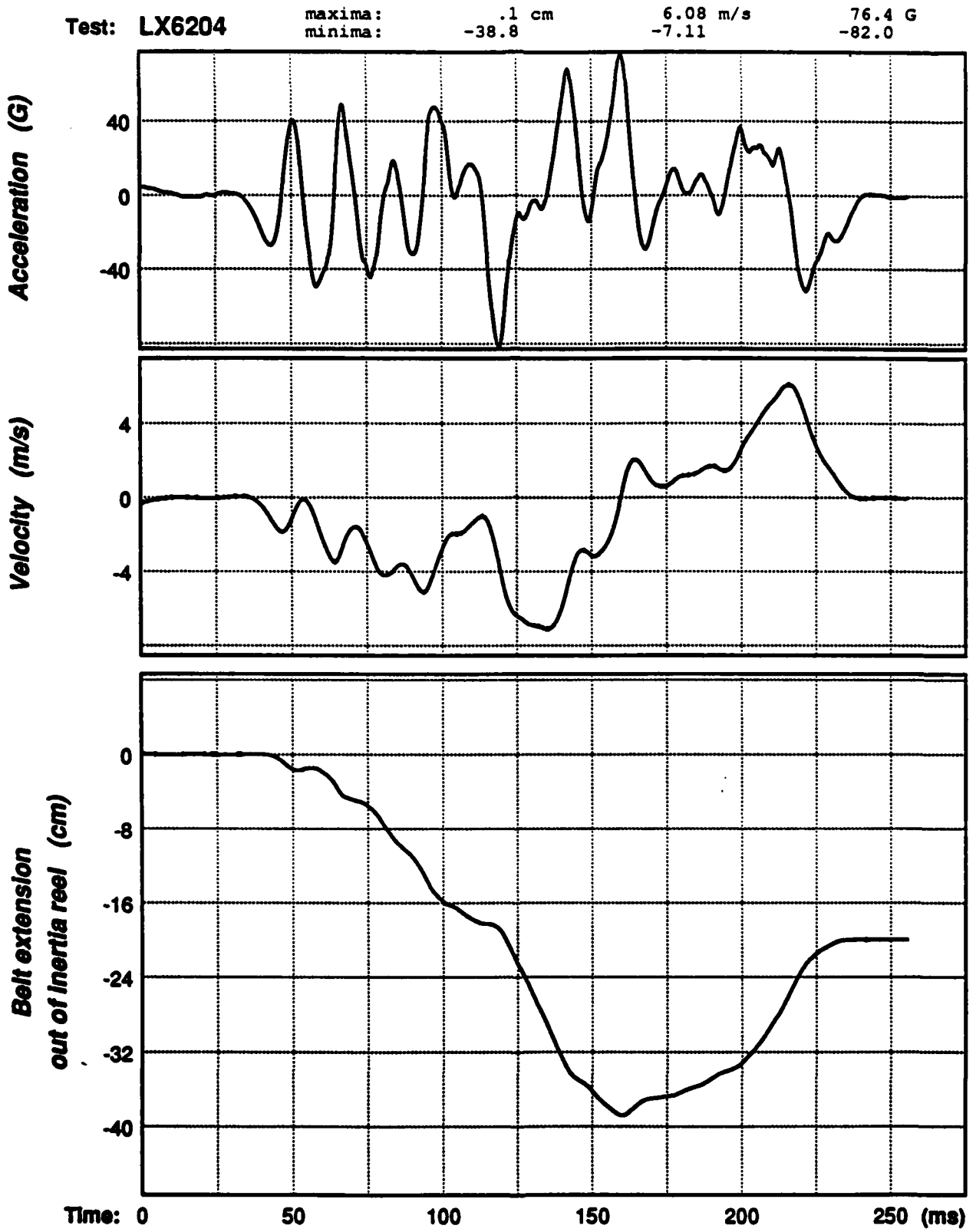

Figure A-52. Amount of belt extension and the velocity and acceleration of extension for test LX6204.

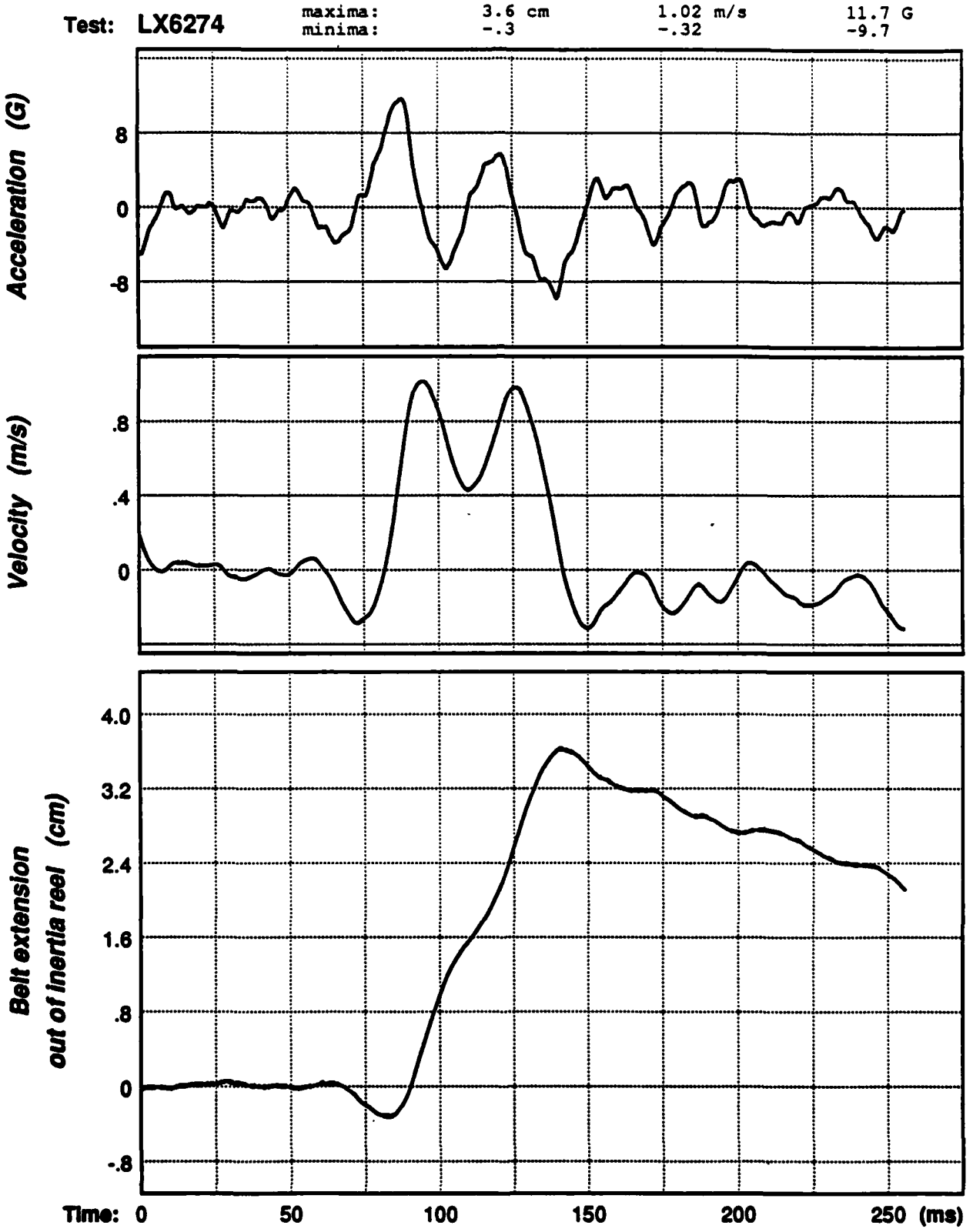

Figure A-53. Amount of belt extension and the velocity and acceleration of extension for test LX6274.

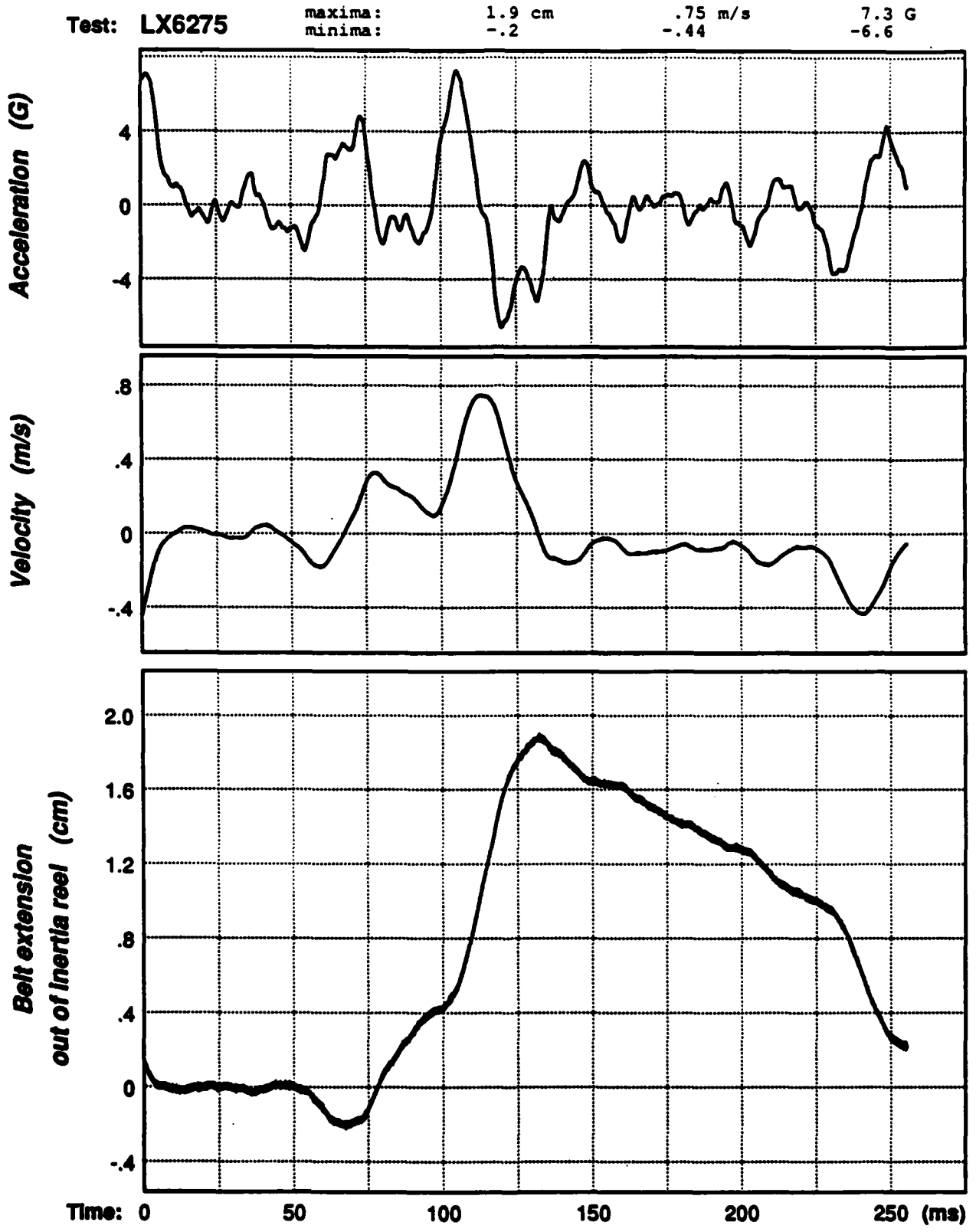

Figure A-54. Amount of belt extension and the velocity and acceleration of extension for test LX6275.

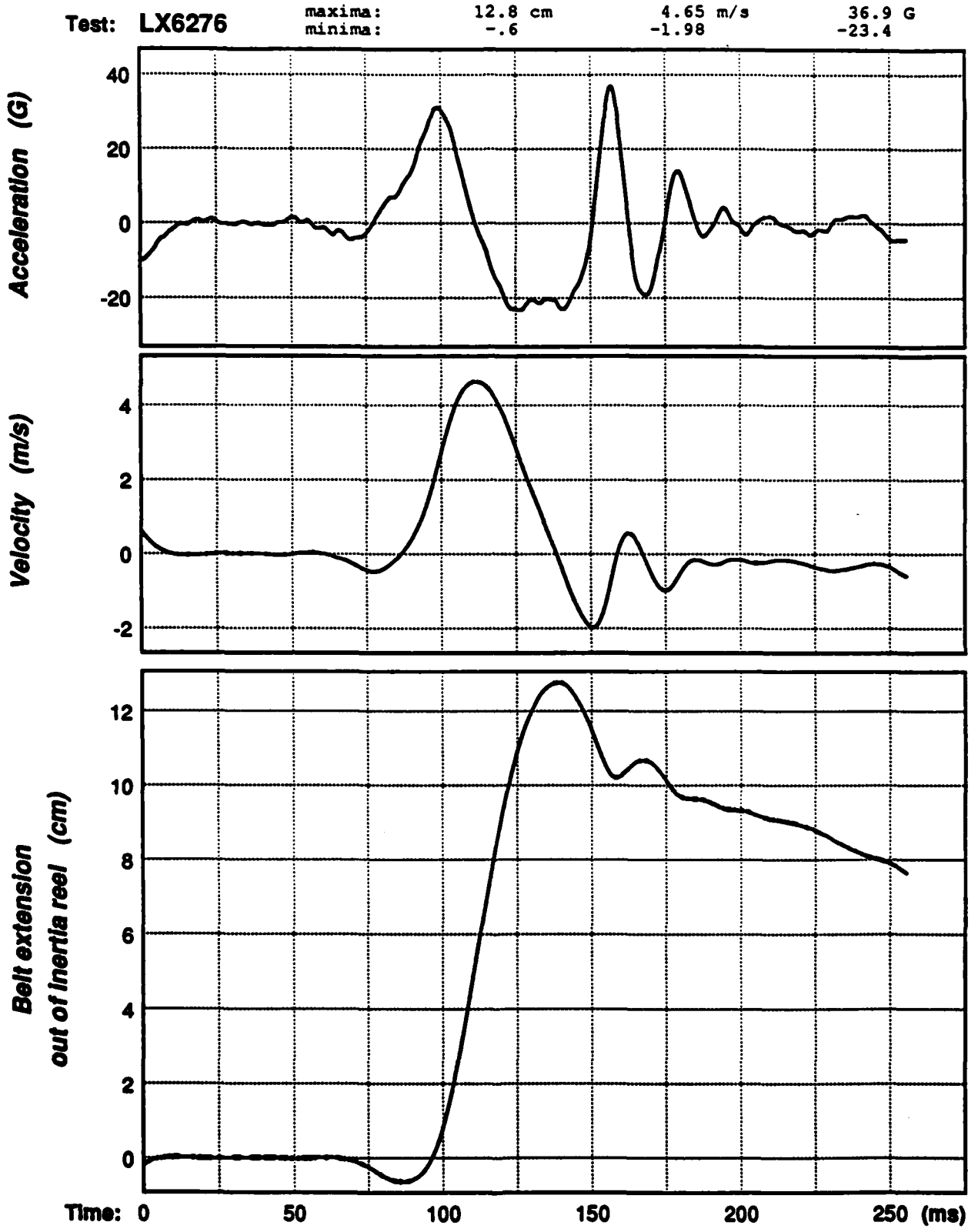

Figure A-55. Amount of belt extension and the velocity and acceleration of extension for test LX6276.

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Appendix B

This appendix contains the processed transducer signals from the 11 AH-64 (Apache) optical relay tube (ORT) tests with inertia reels and without airbags.

These include 10 tests (LX6208 - LX6217) conducted during the first phase of testing and one test (LX6277) which were run in the second phase.

Figures B-1 thru B-11 show the sled acceleration pulses and computed velocity and jerk signals for the 11 tests.

Figures B-12 thru B-22 display components and resultants head linear accelerations.

Figures B-23 thru B-33 display the head roll acceleration signals and computed angular velocities and displacements.

Figures B-34 thru B-44 show the head pitch acceleration signals and computed angular velocities and displacements.

No belt extension signals were available for these tests.

Appendix B

1. LX6208
2. LX6209
3. LX6210
4. LX6211
5. LX6212
6. LX6213
7. LX6214
8. LX6215
9. LX6216
10. LX6217
11. LX6277

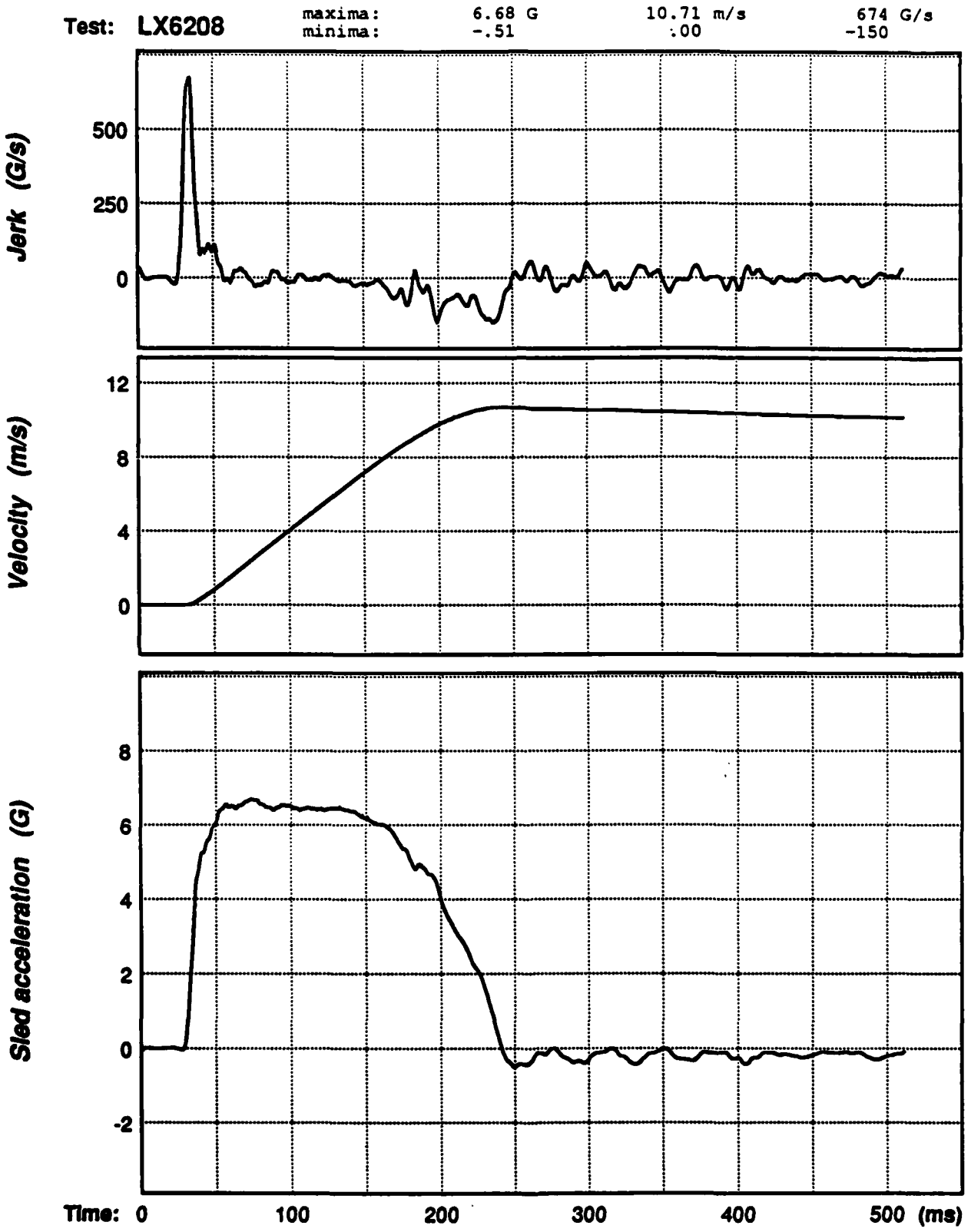

Figure B-1. Sled acceleration signal and its computed velocity and jerk for test LX6208.

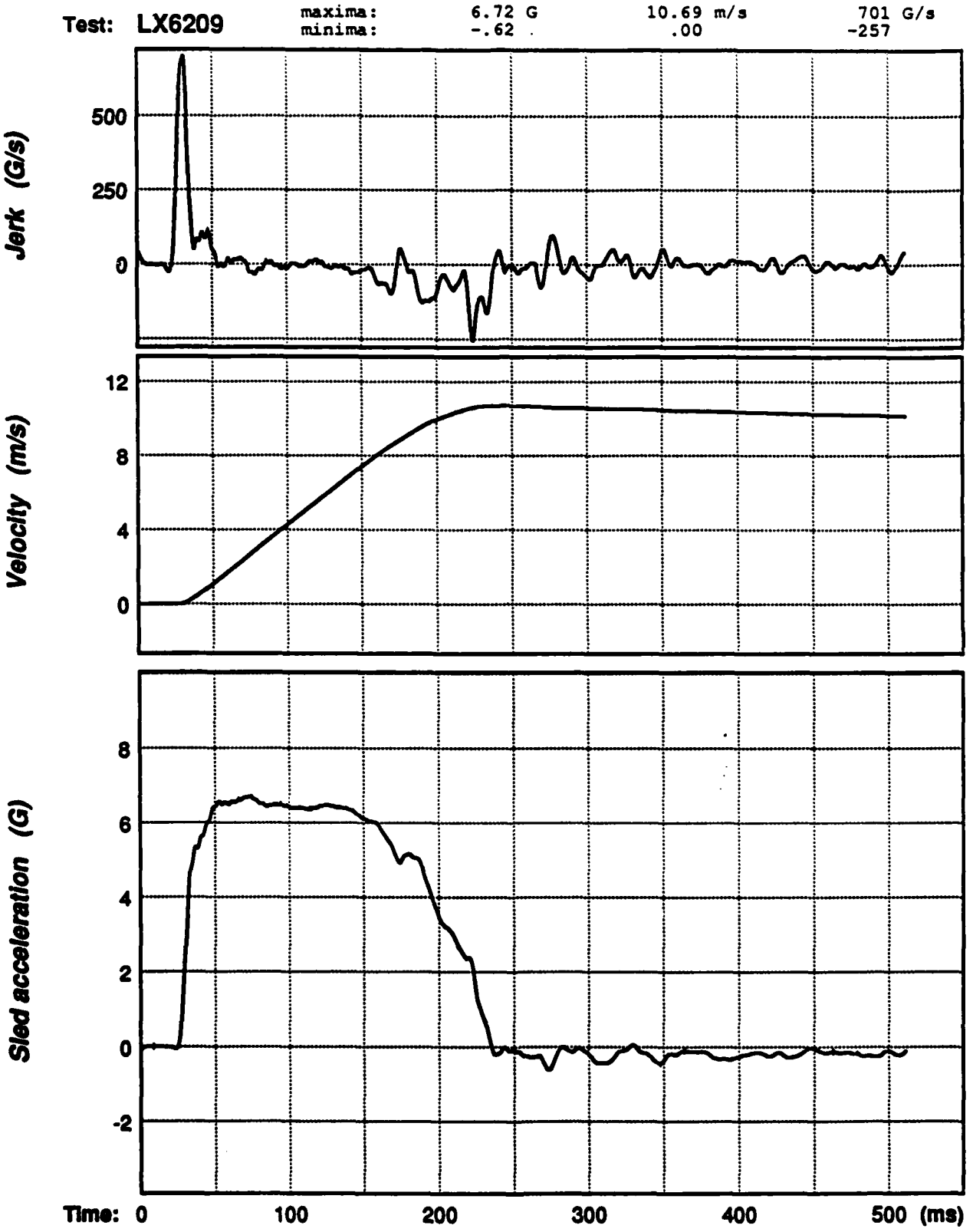

Figure B-2. Sled acceleration signal and its computed velocity and jerk for test LX6209.

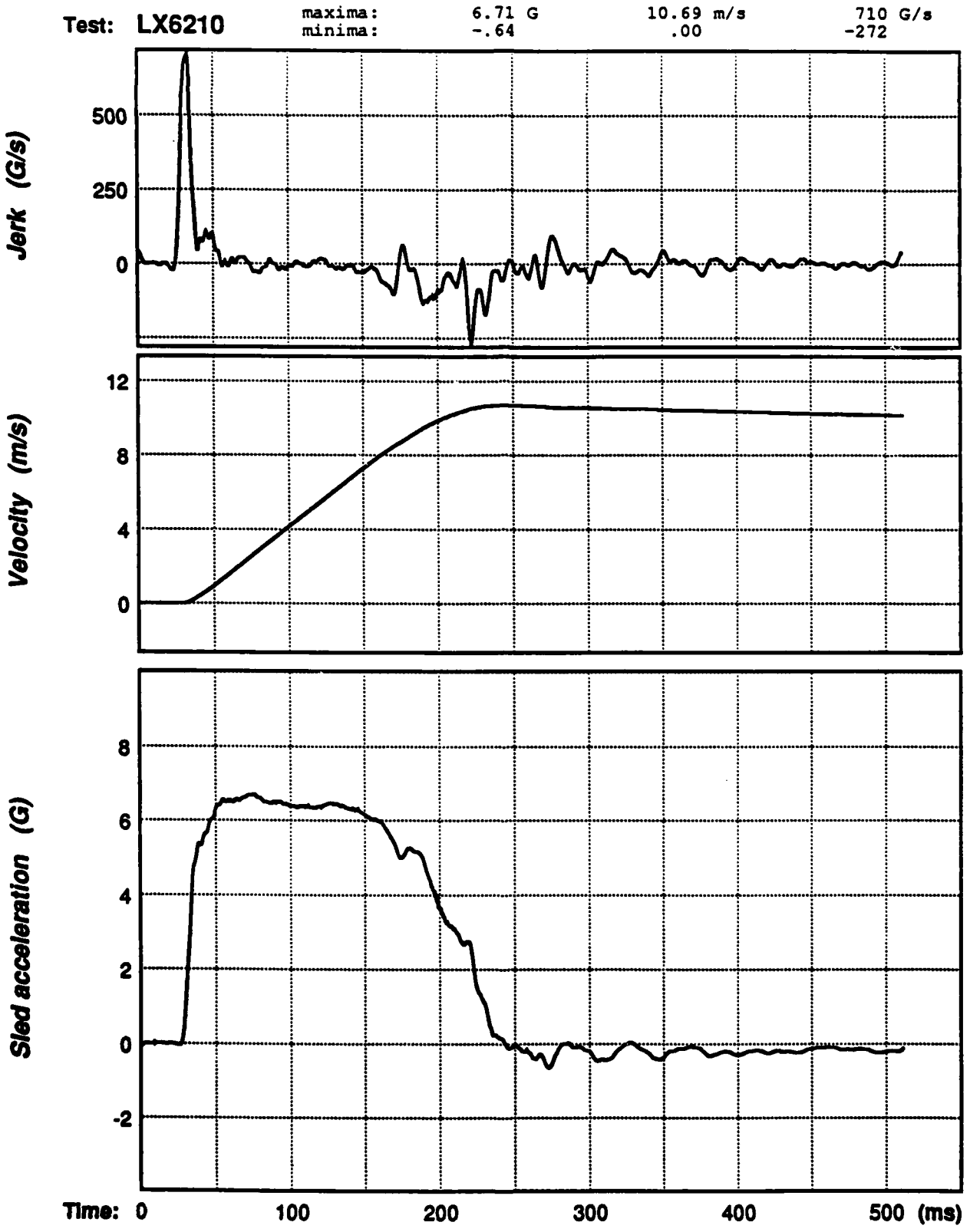

Figure B-3. Sled acceleration signal and its computed velocity and jerk for test LX6210.

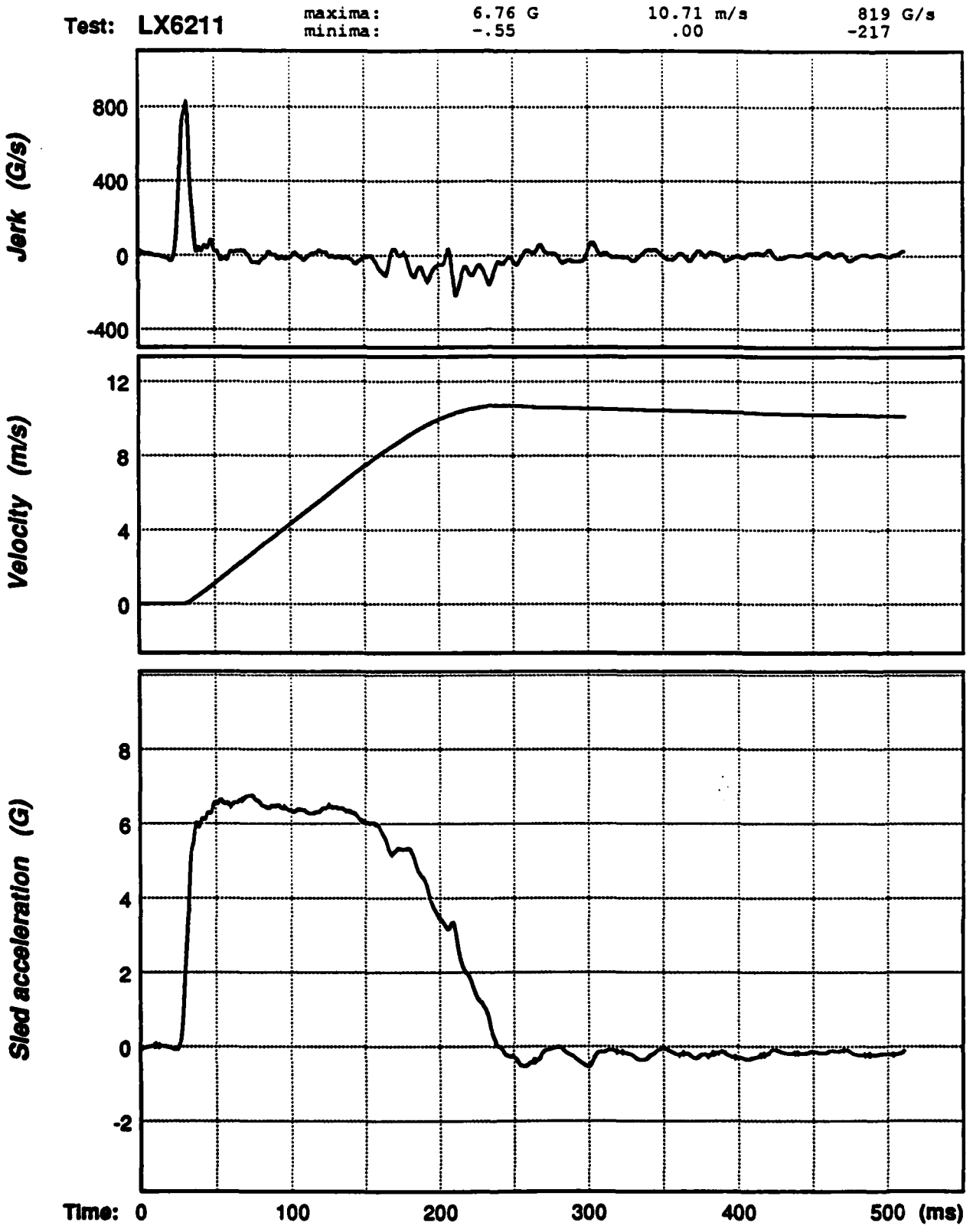

Figure B-4. Sled acceleration signal and its computed velocity and jerk for test LX6211.

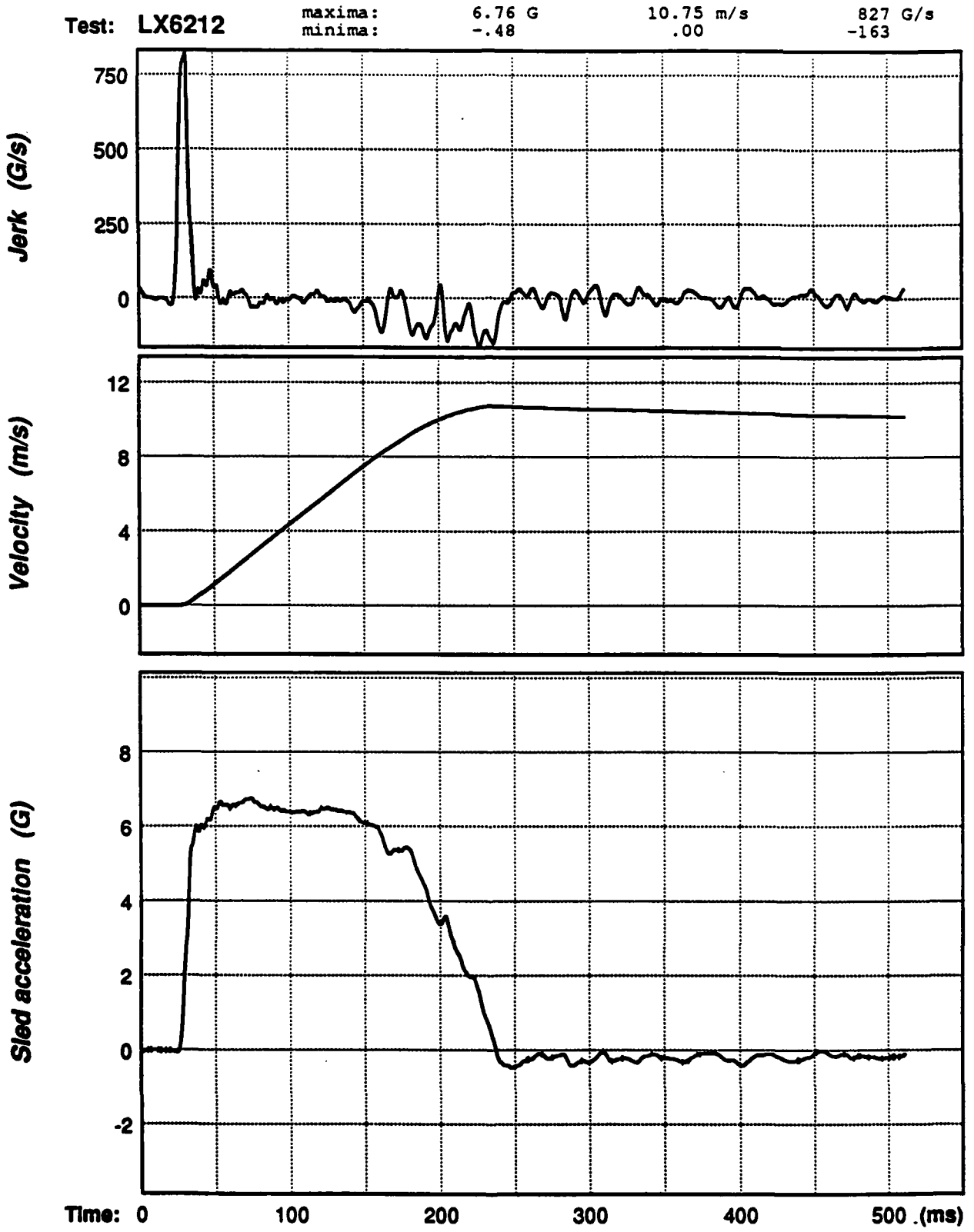

Figure B-5. Sled acceleration signal and its computed velocity and jerk for test LX6212.

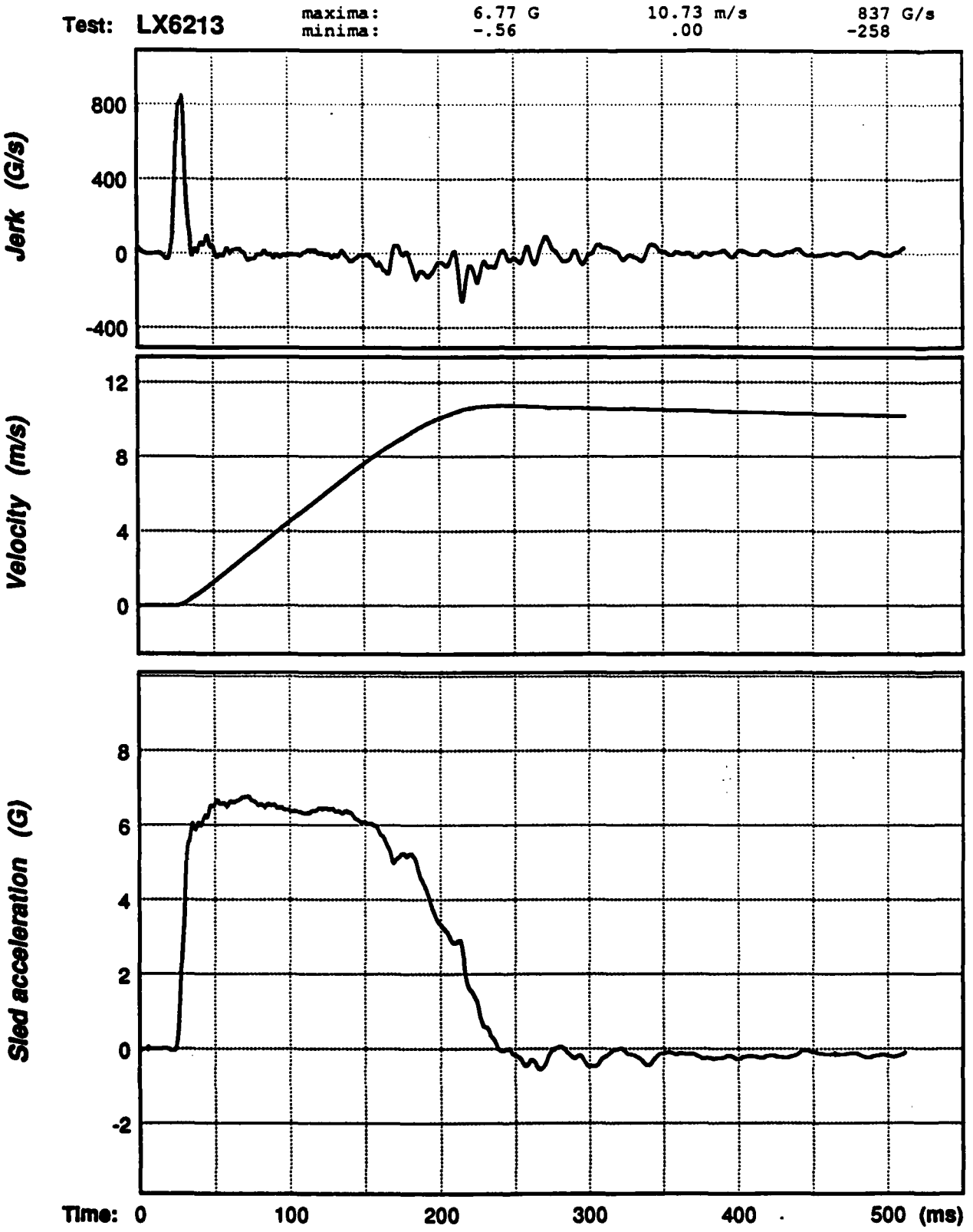

Figure B-6. Sled acceleration signal and its computed velocity and jerk for test LX6213.

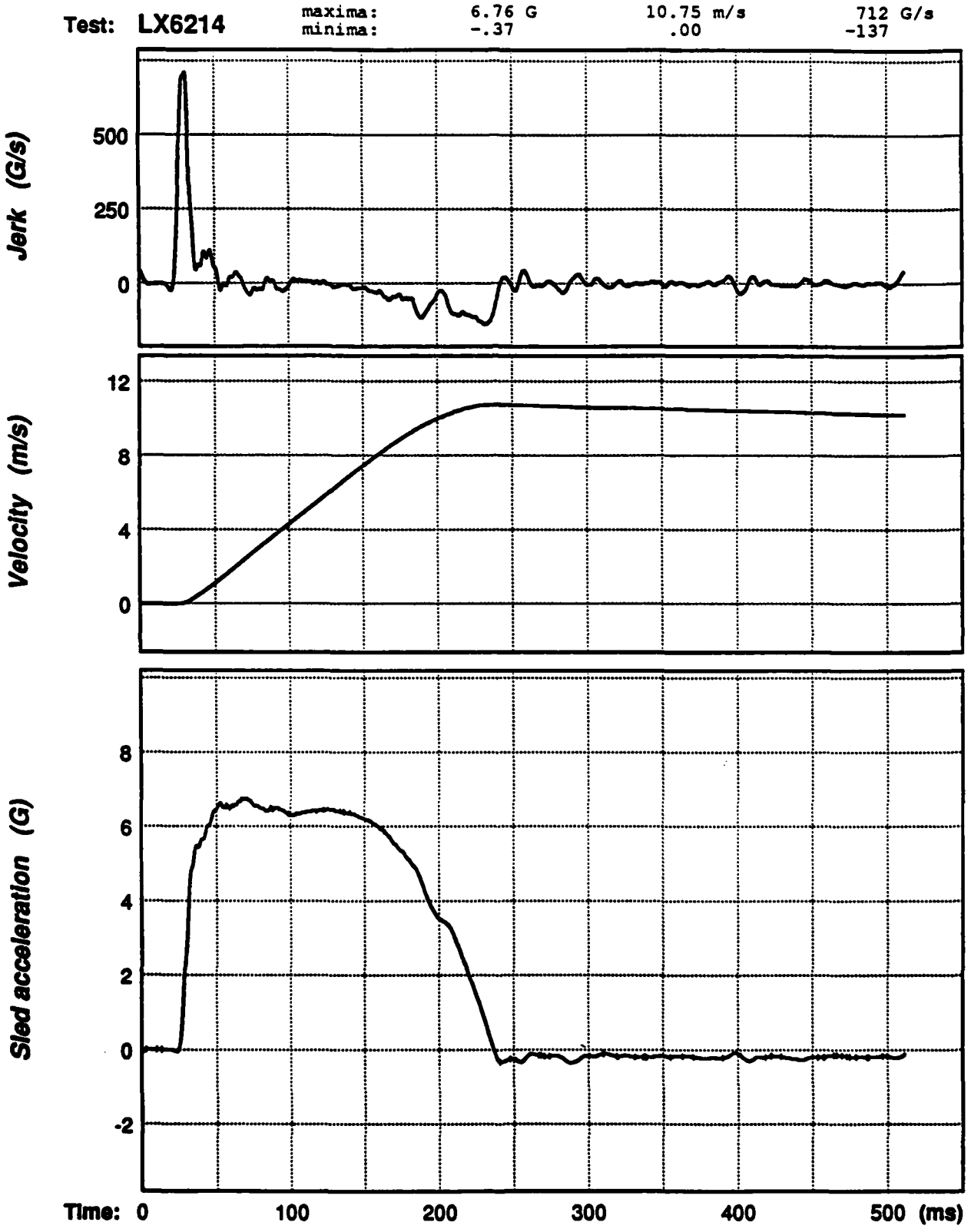

Figure B-7. Sled acceleration signal and its computed velocity and jerk for test LX6214.

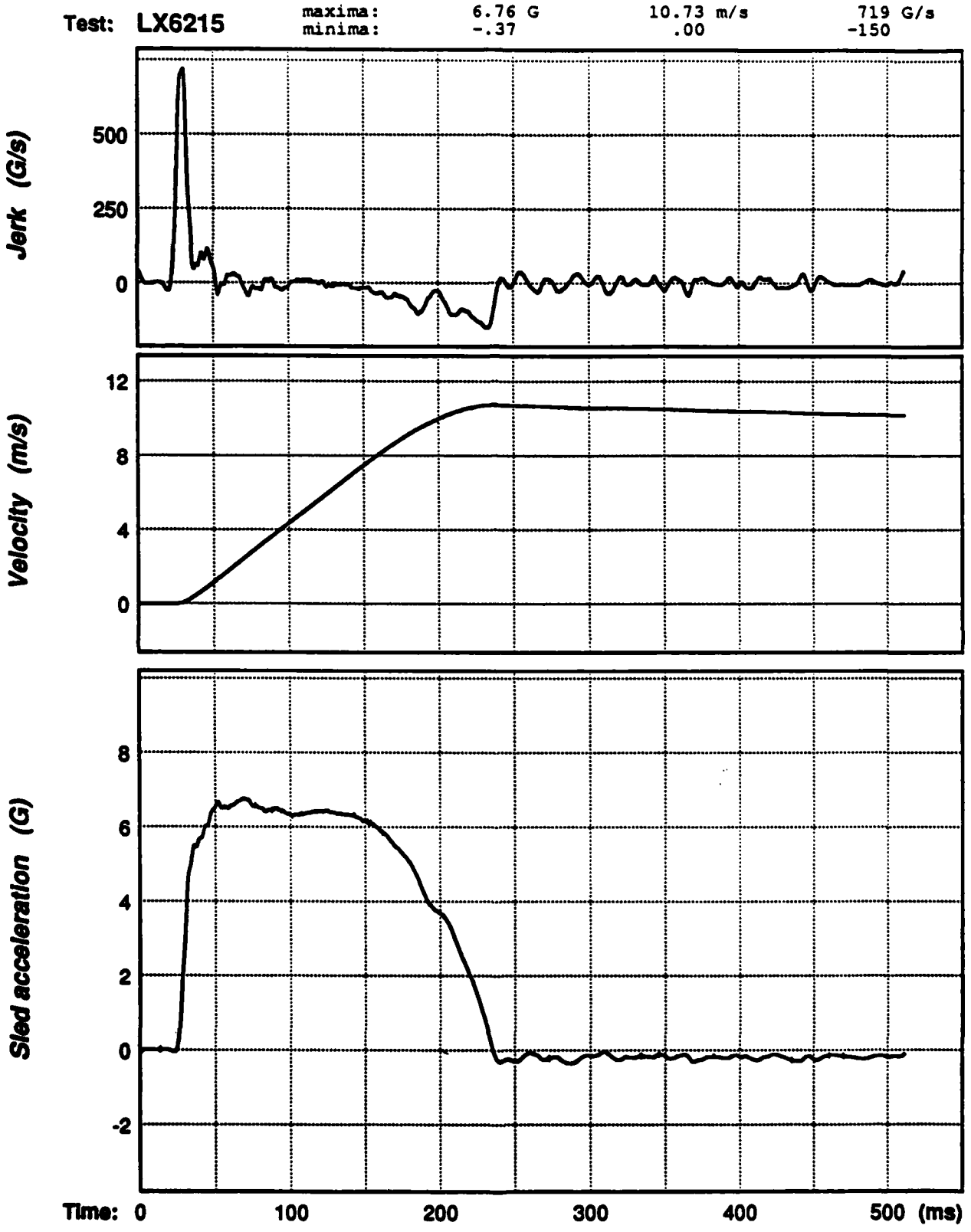

Figure B-8. Sled acceleration signal and its computed velocity and jerk for test LX6215.

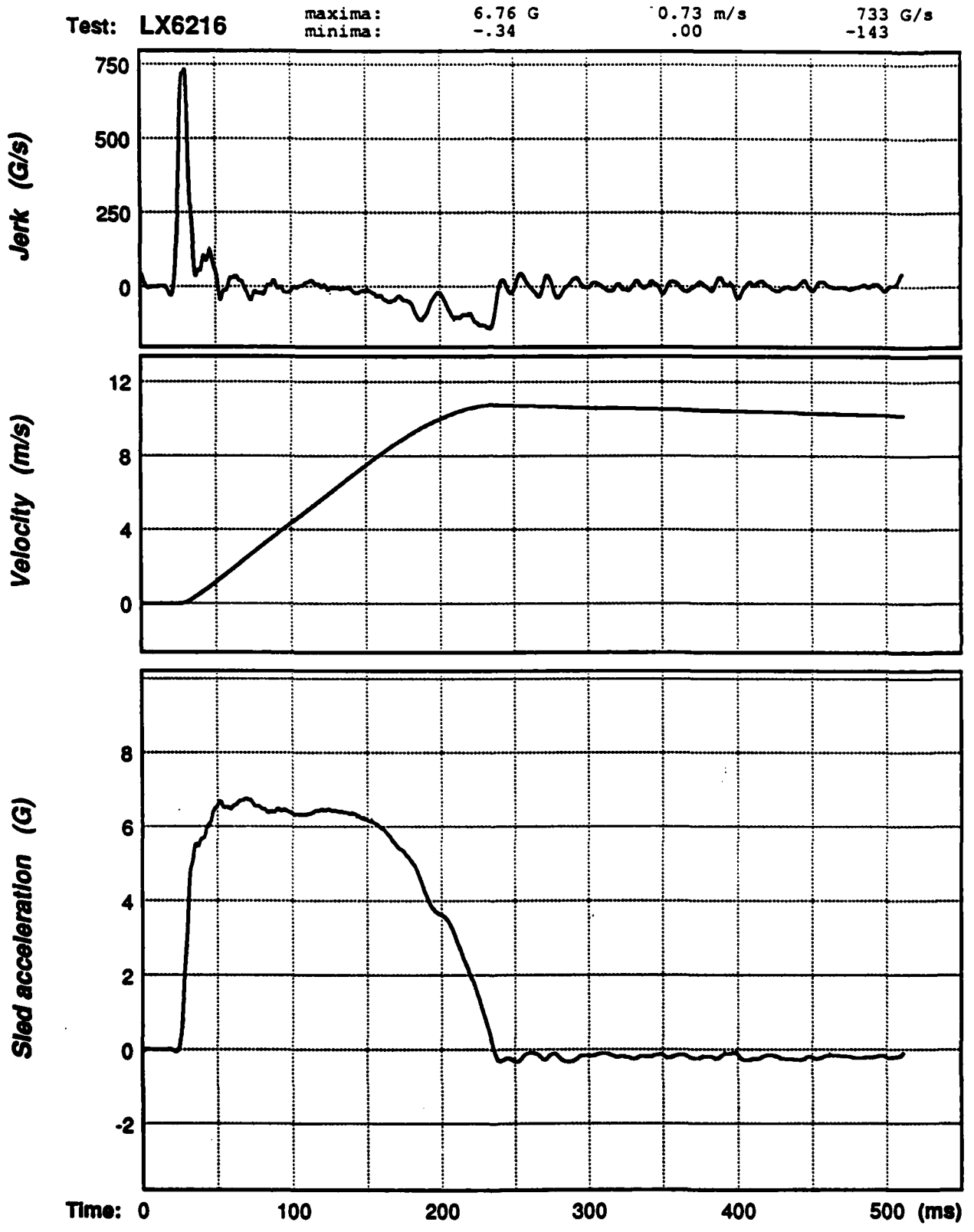

Figure B-9. Sled acceleration signal and its computed velocity and jerk for test LX6216.

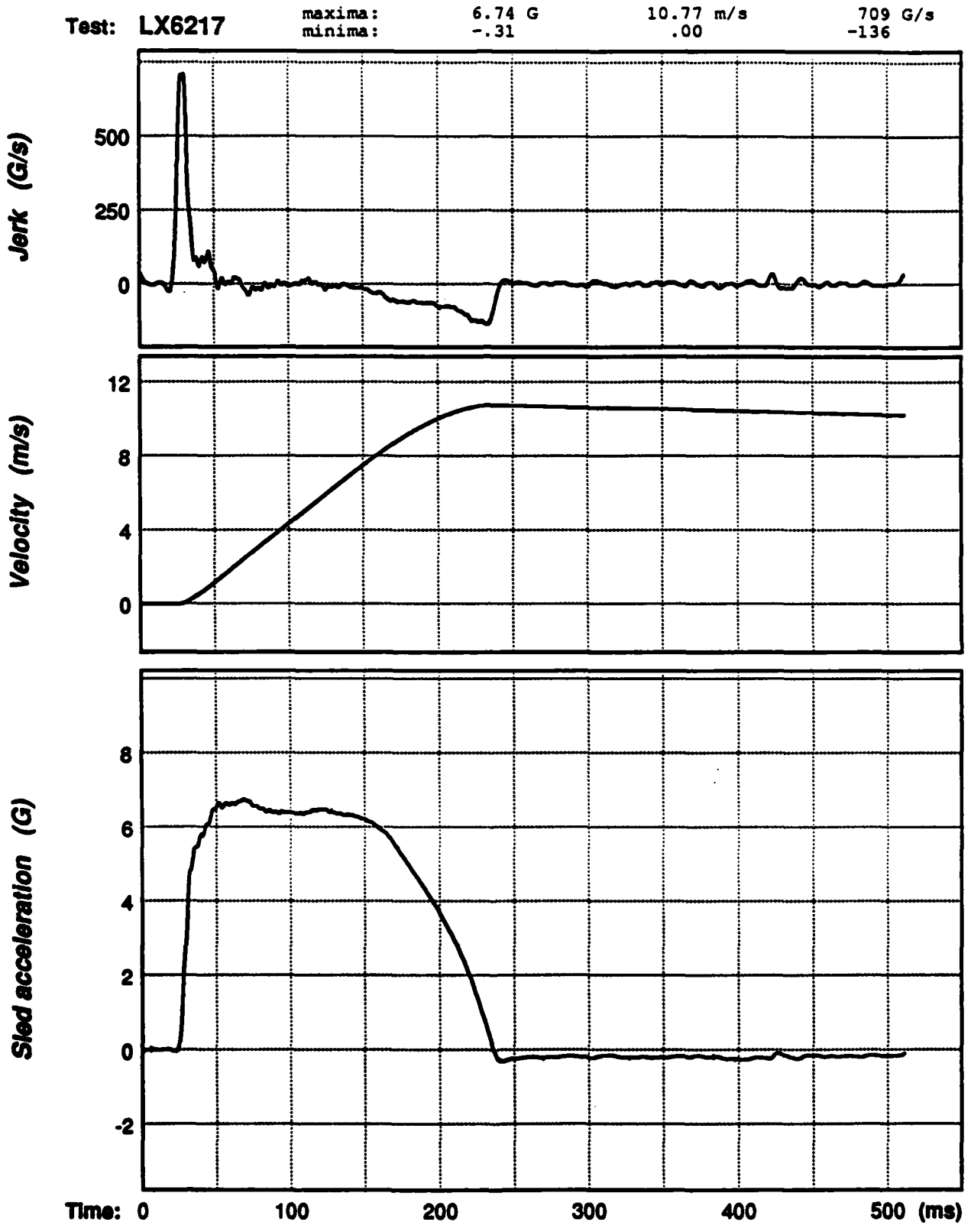

Figure B-10. Sled acceleration signal and its computed velocity and jerk for test LX6217.

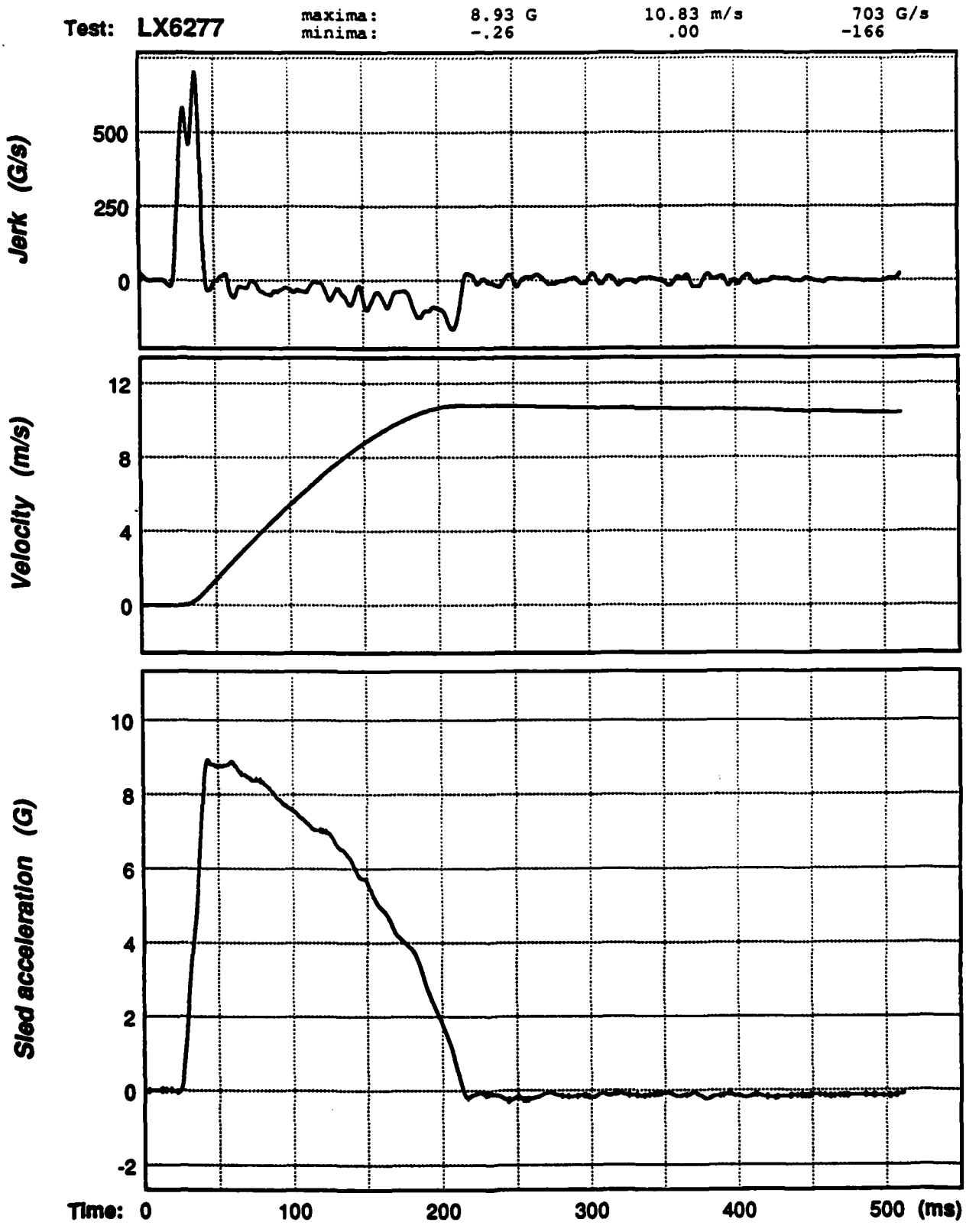

Figure B-11. Sled acceleration signal and its computed velocity and jerk for test LX6277.

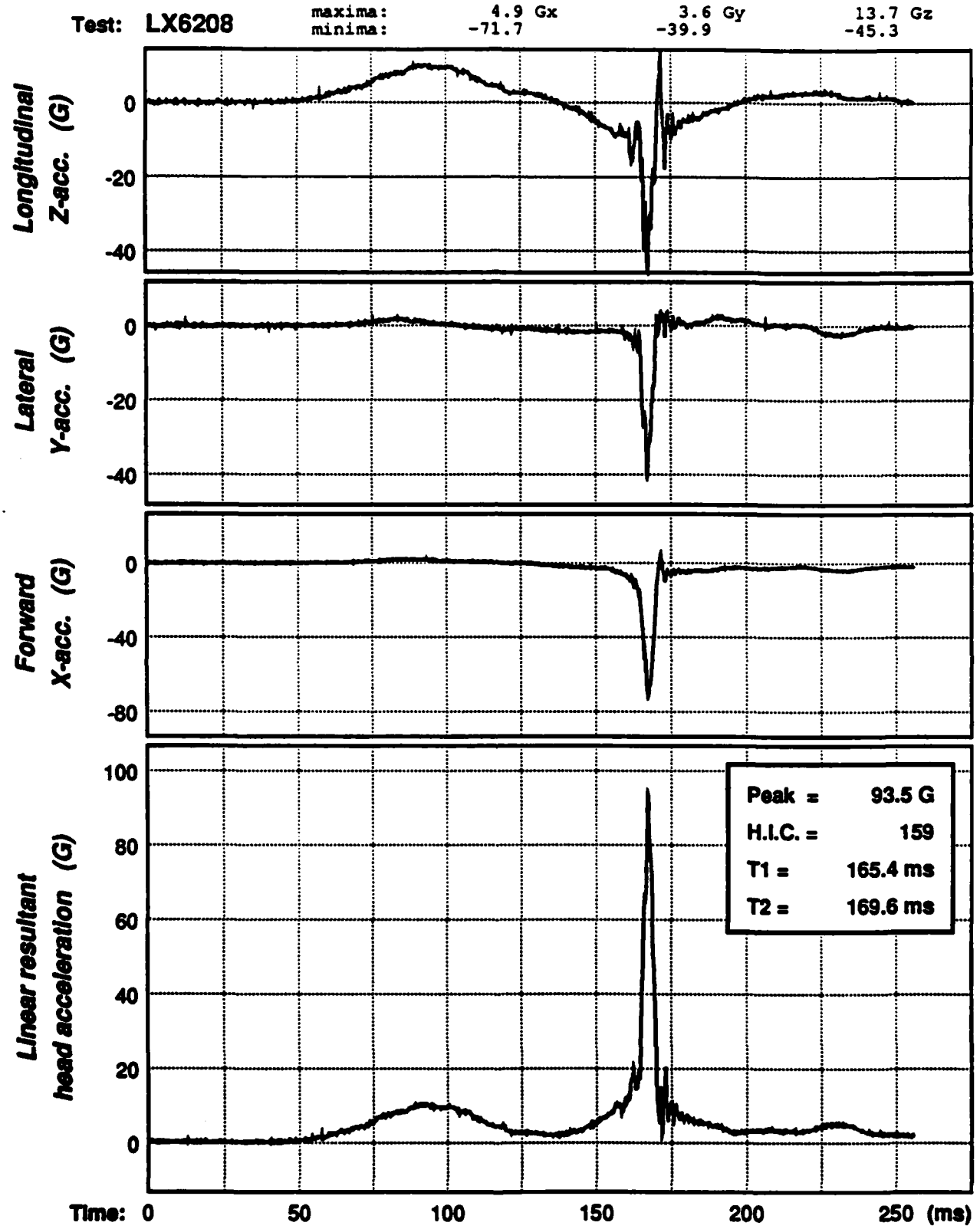

Figure B-12. Three components and resultant of the linear head acceleration for test LX6208.

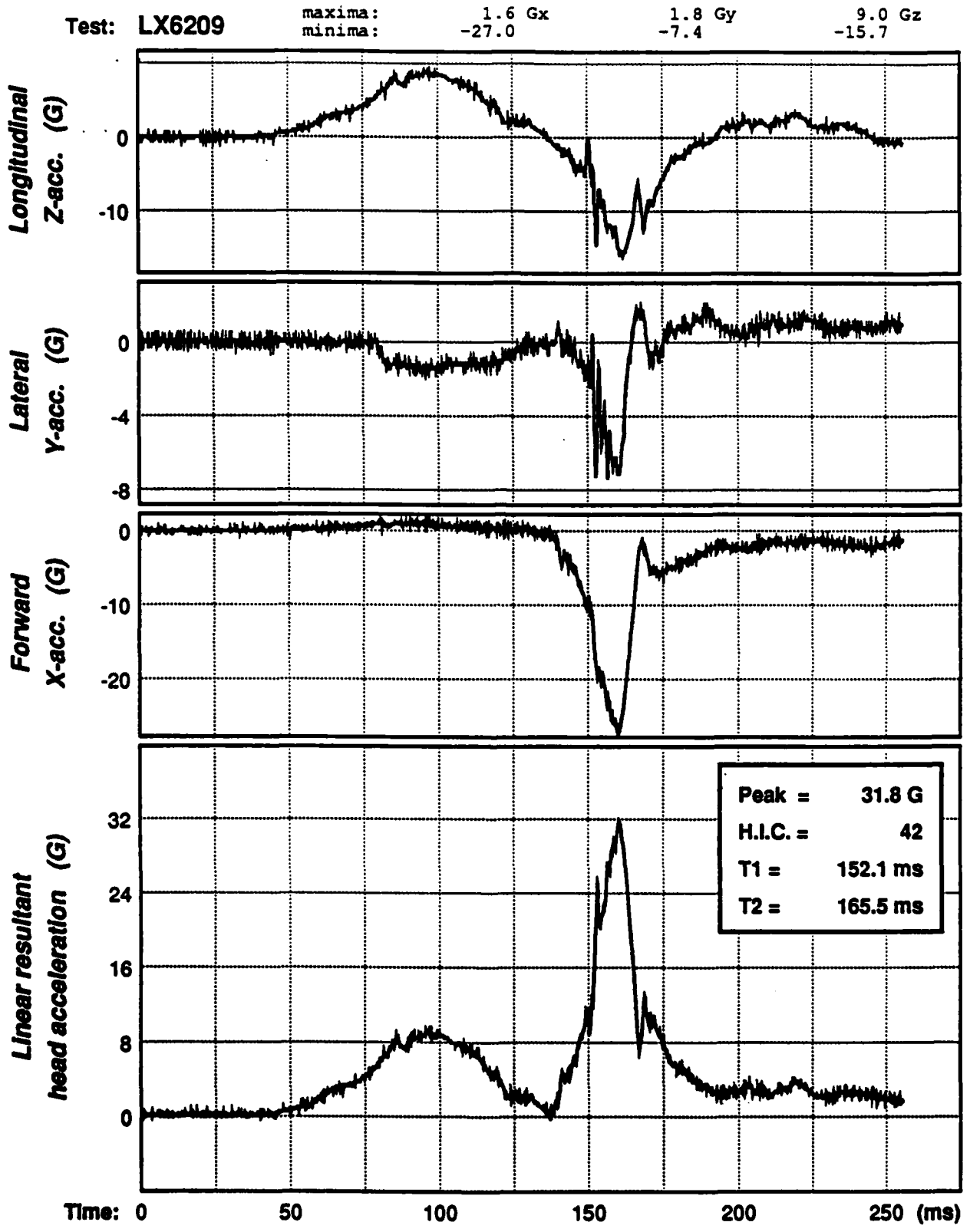

Figure B-13. Three components and resultant of the linear head acceleration for test LX6209.

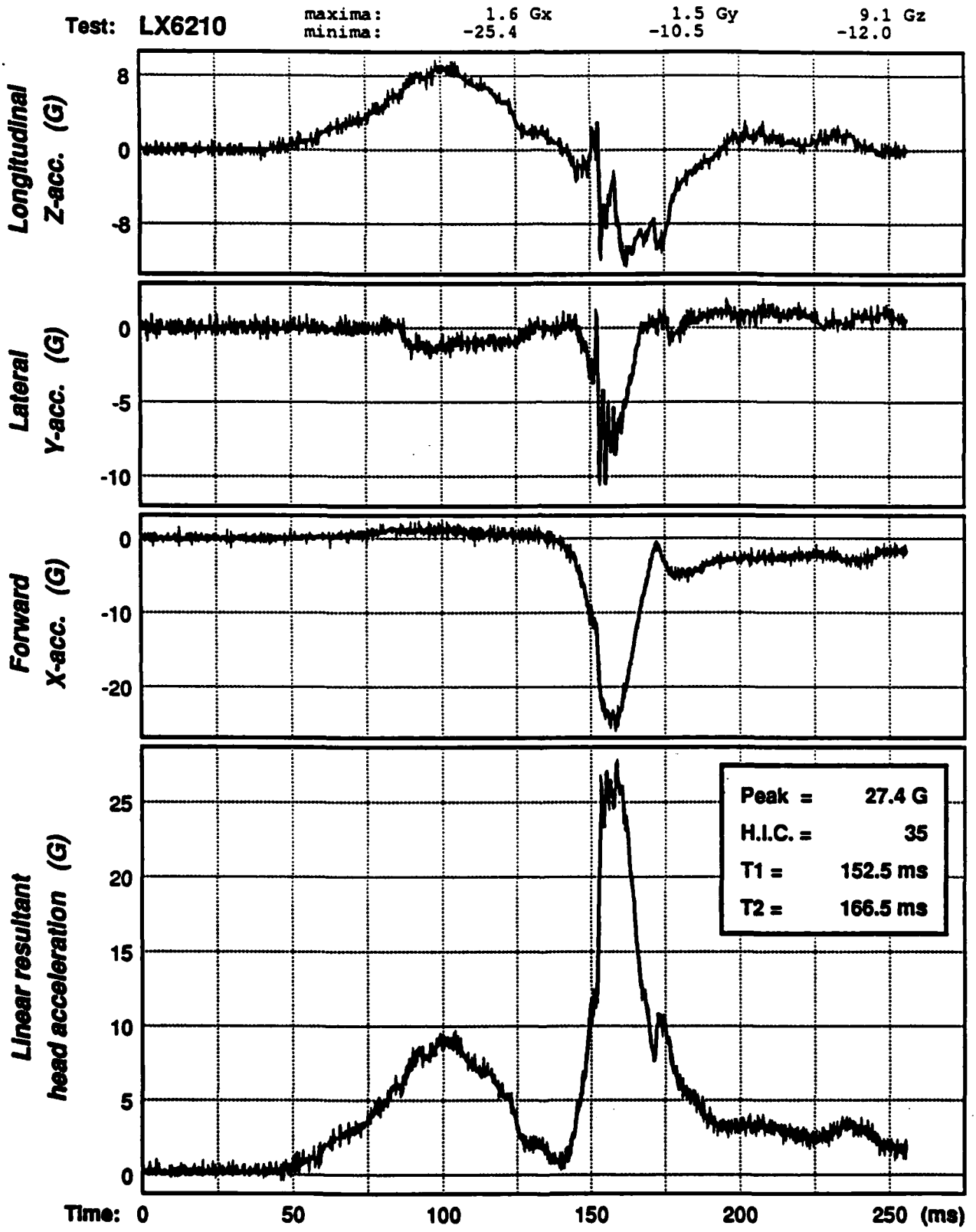

Figure B-14. Three components and resultant of the linear head acceleration for test LX6210.

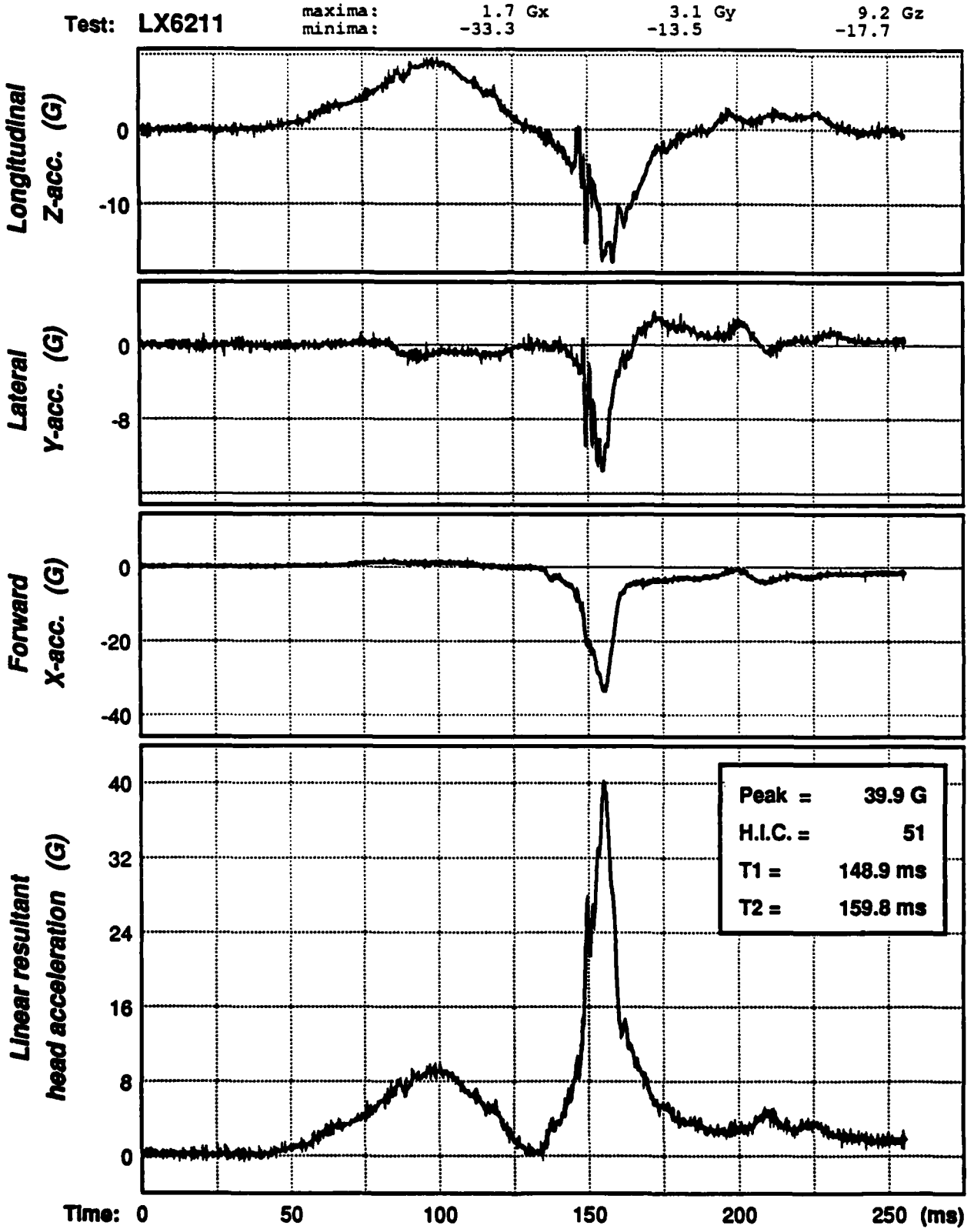

Figure B-15. Three components and resultant of the linear head acceleration for test LX6211.

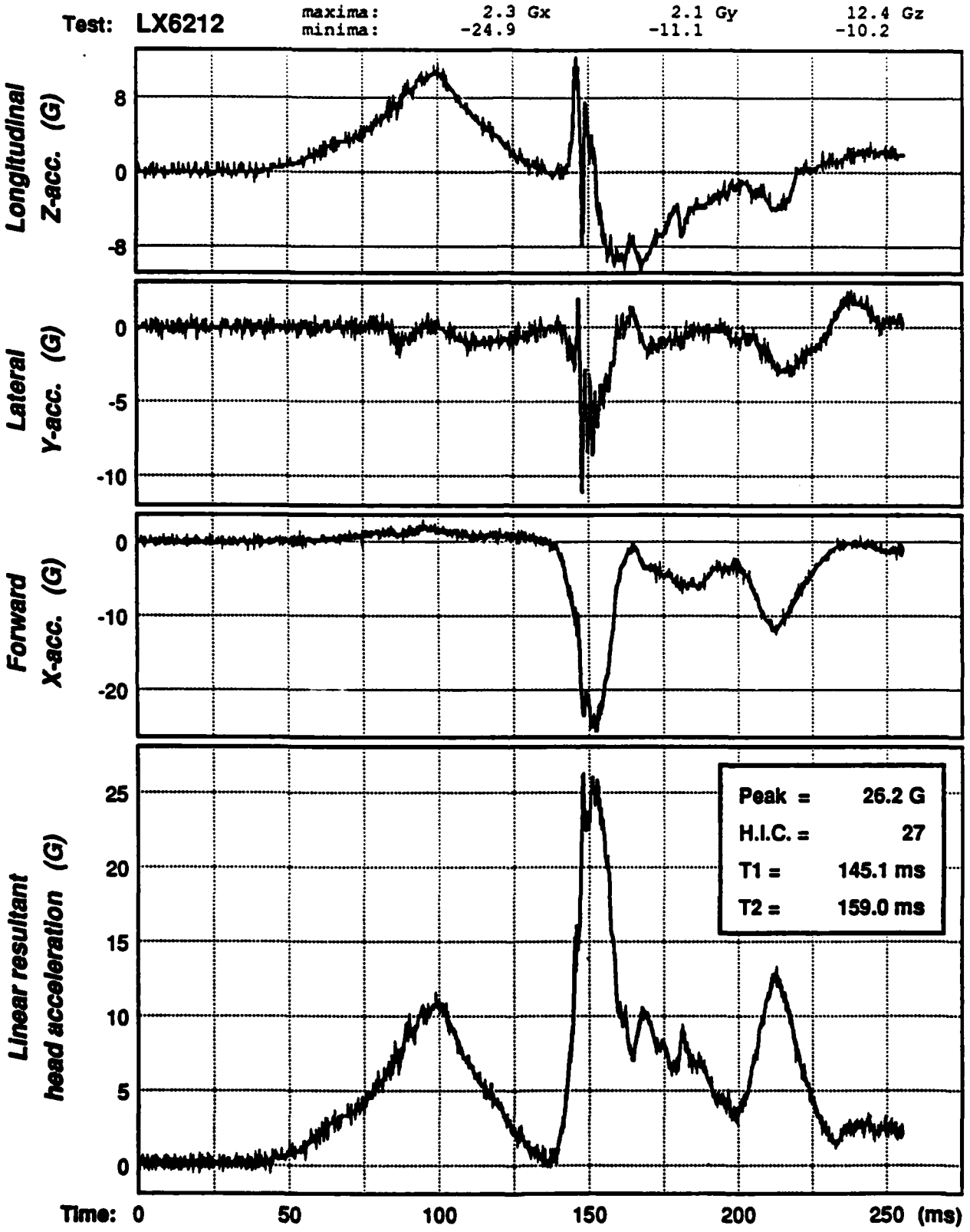

Figure B-16. Three components and resultant of the linear head acceleration for test LX6212.

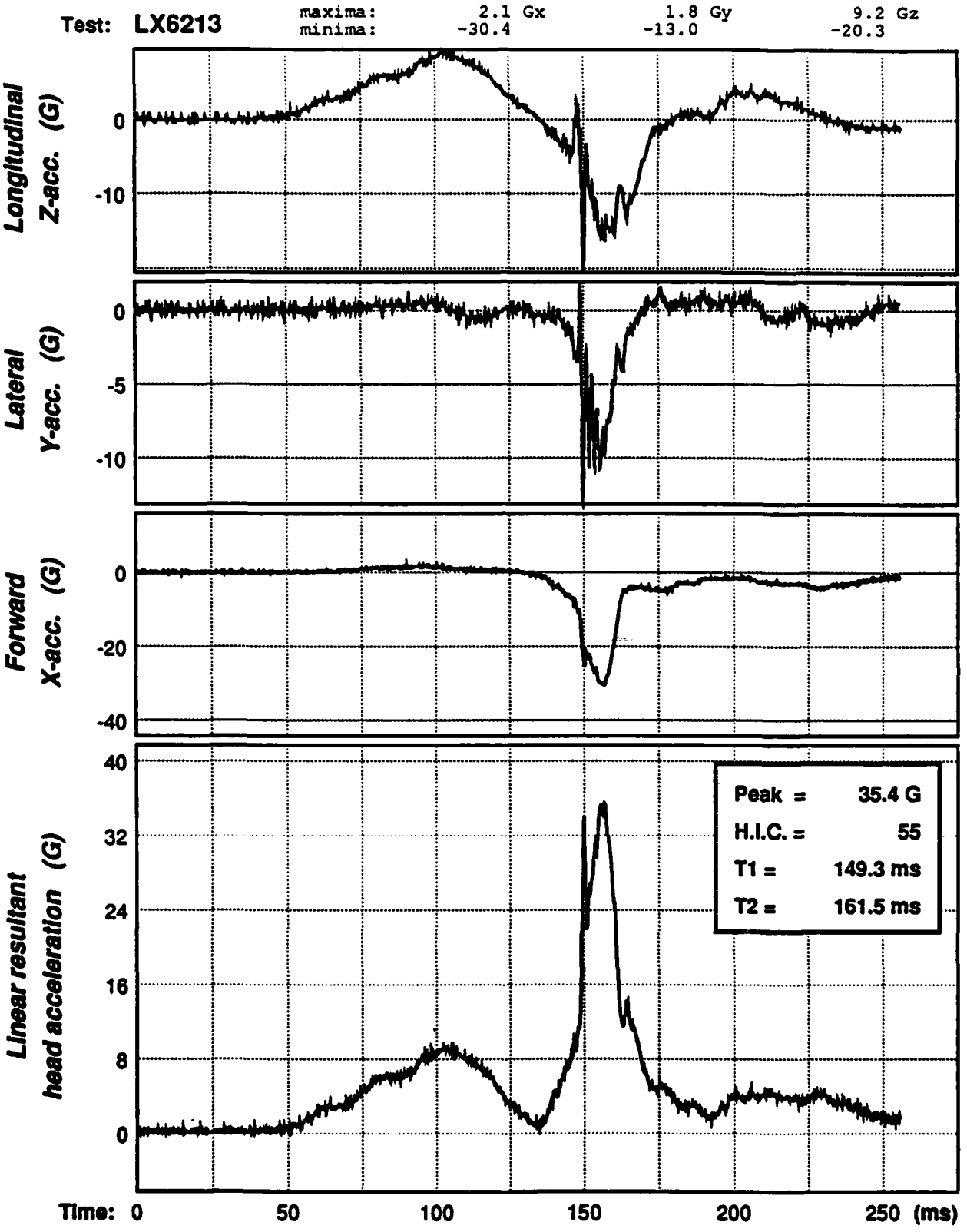

Figure B-17. Three components and resultant of the linear head acceleration for test LX6213.

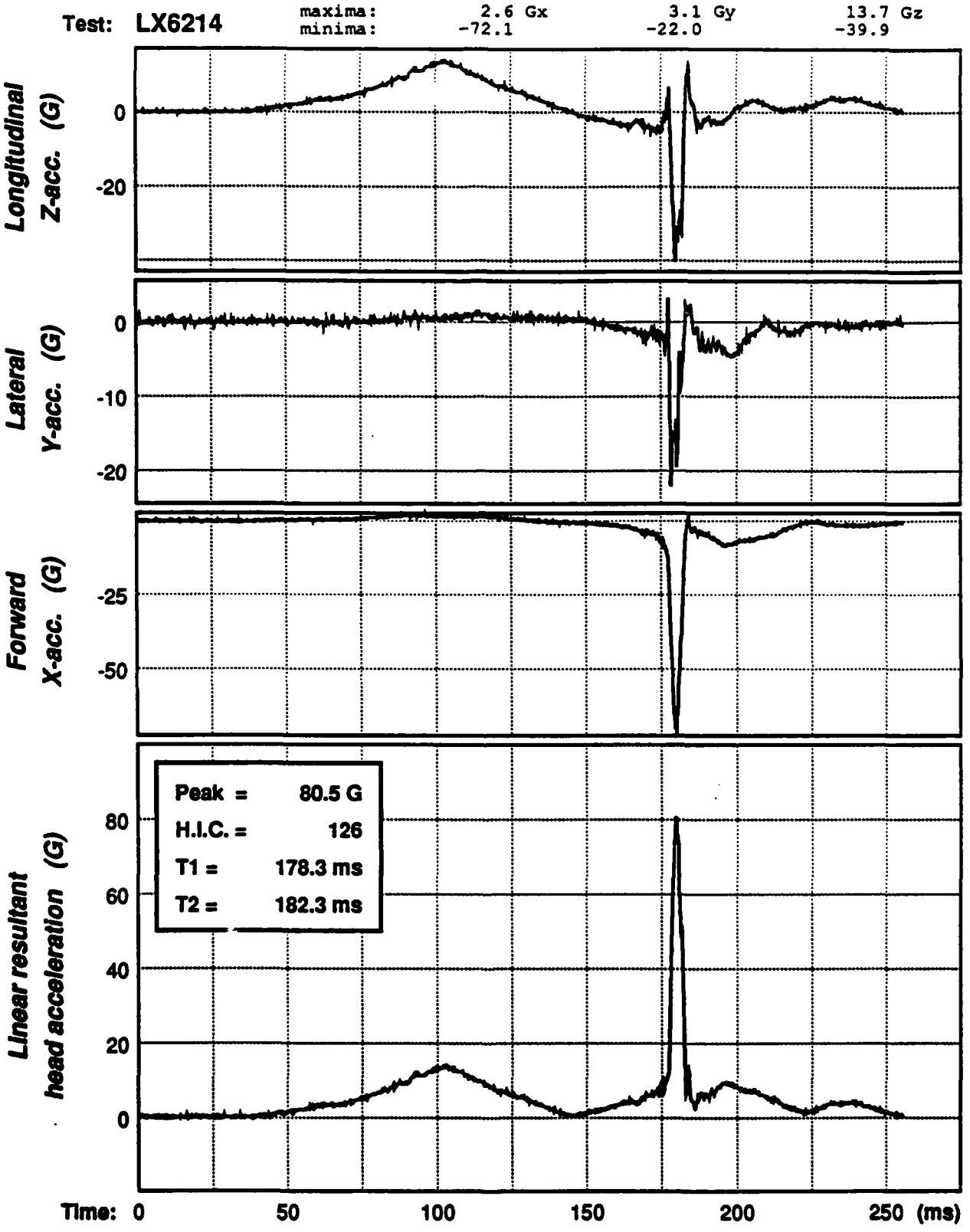

Figure B-18. Three components and resultant of the linear head acceleration for test LX6214.

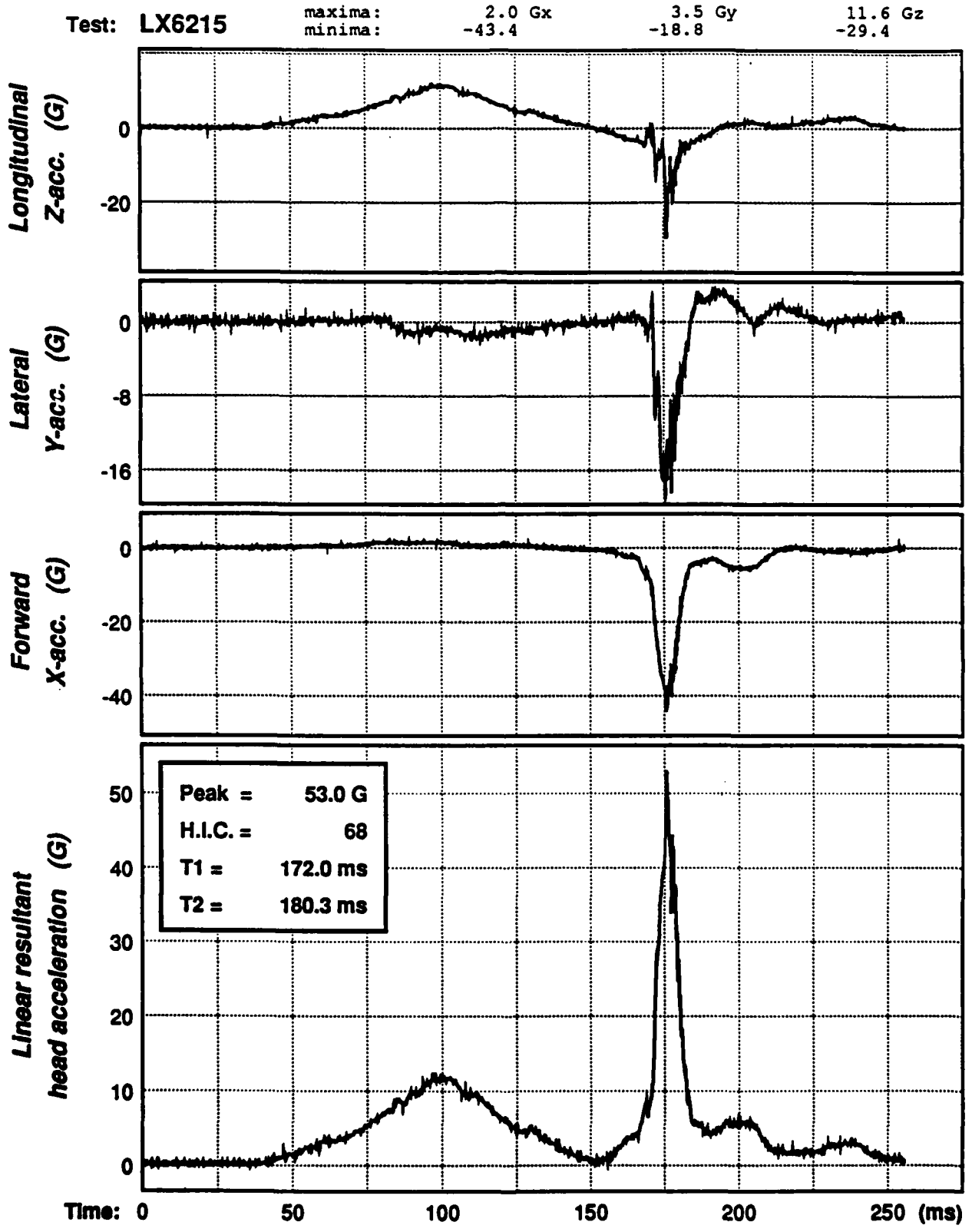

Figure B-19. Three components and resultant of the linear head acceleration for test LX6215.

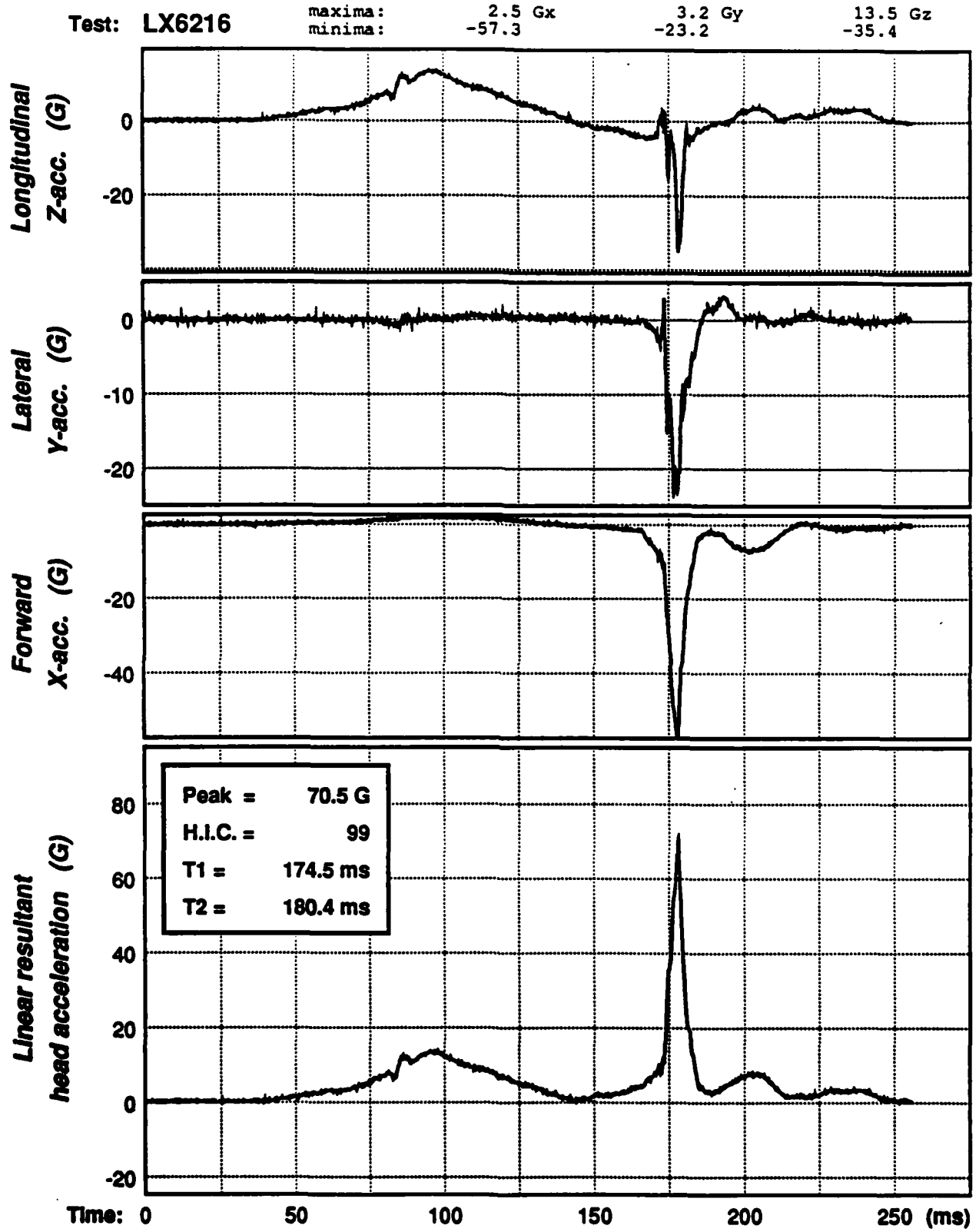

Figure B-20. Three components and resultant of the linear head acceleration for test LX6216.

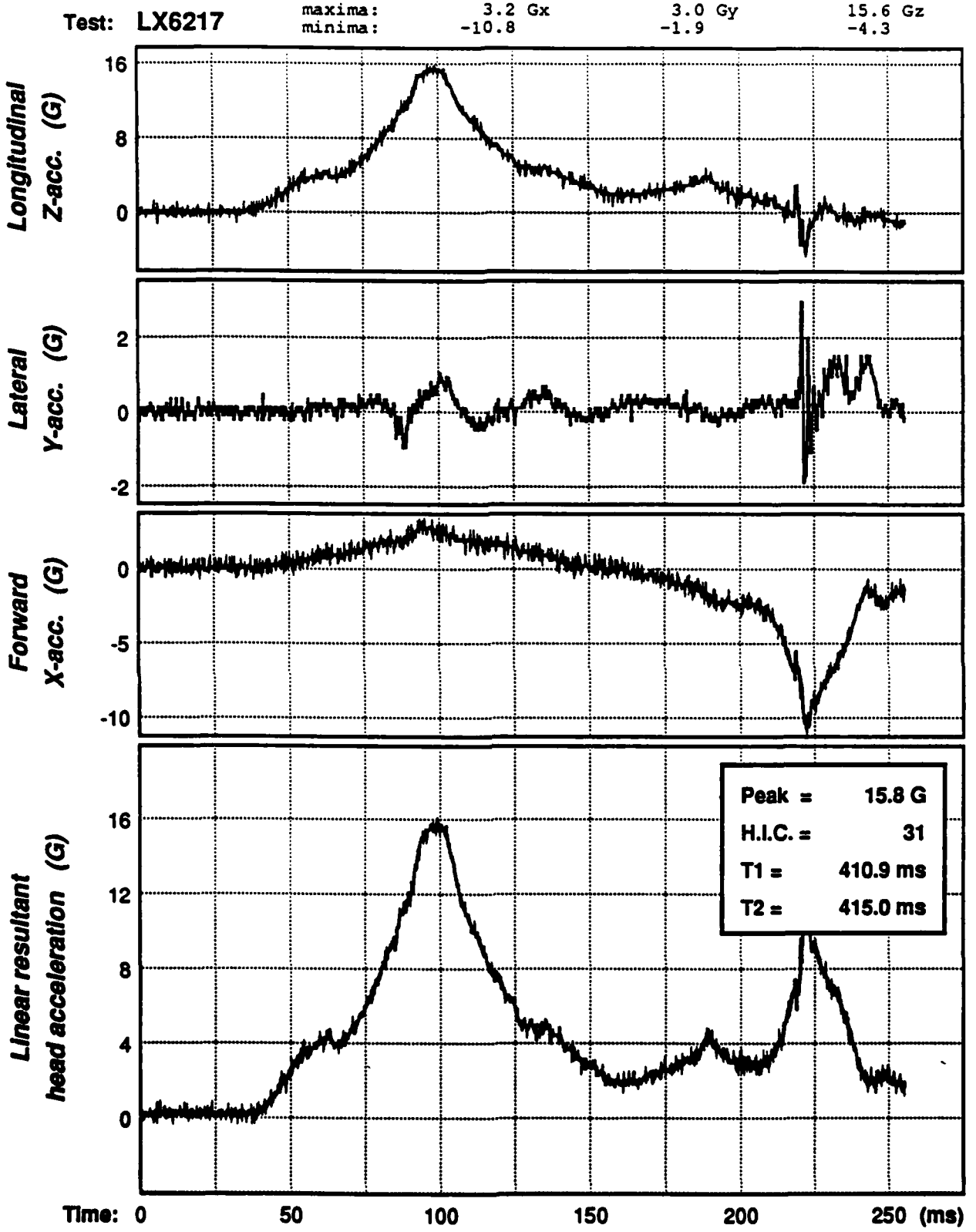

Figure B-21. Three components and resultant of the linear head acceleration for test LX6217.

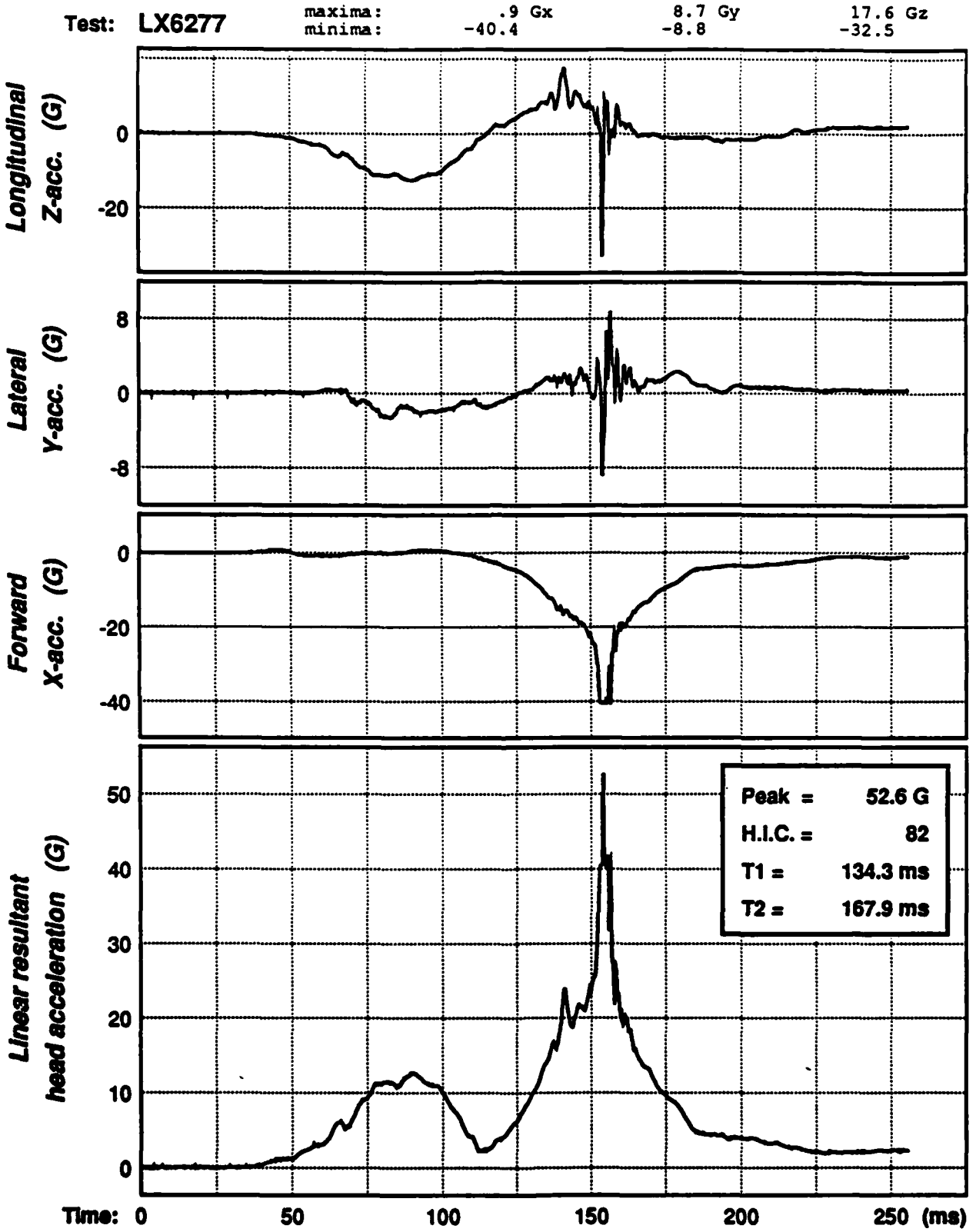

Figure B-22. Three components and resultant of the linear head acceleration for test LX6277.

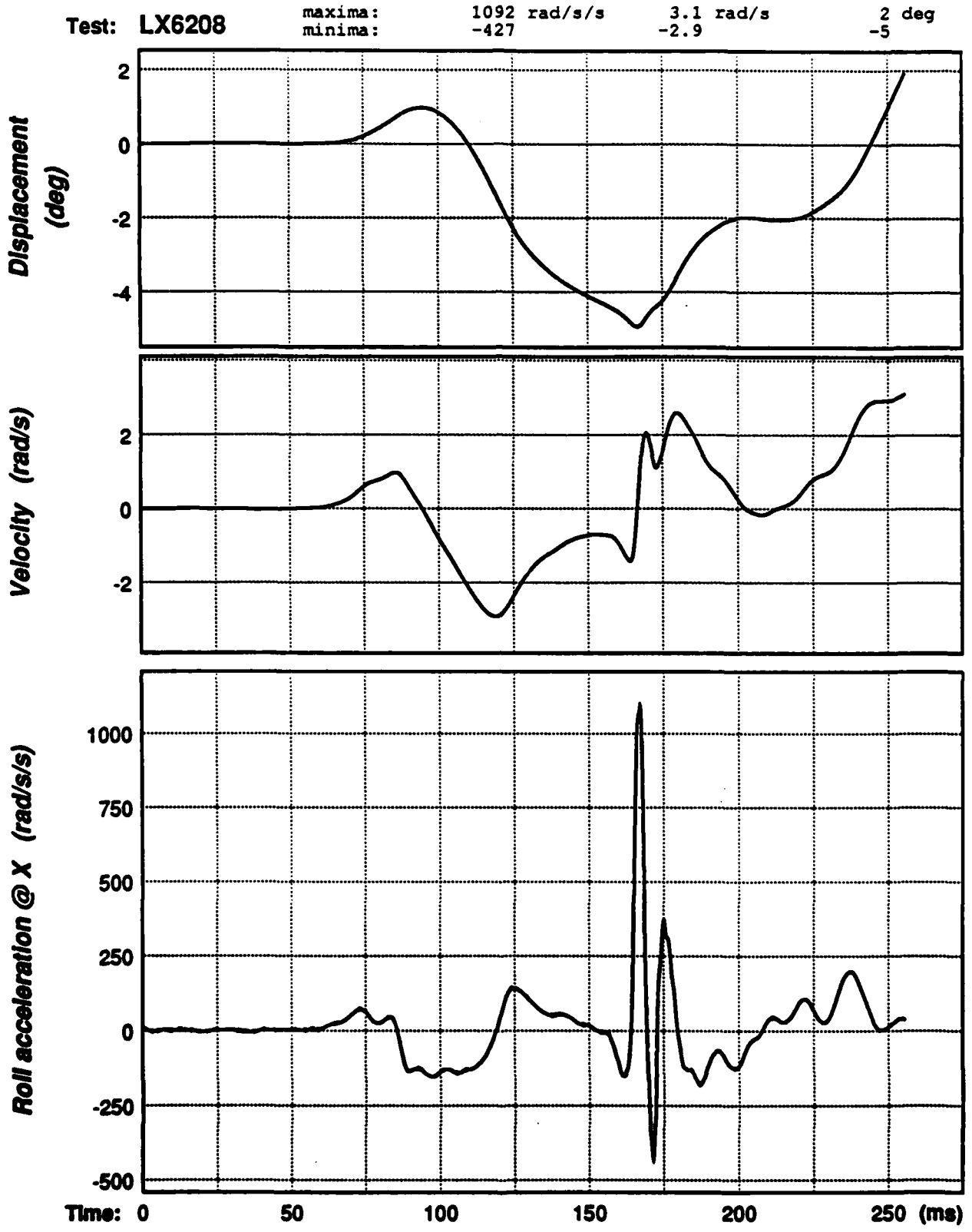

Figure B-23. Head roll angular acceleration, velocity, and displacement signals for test LX6208.

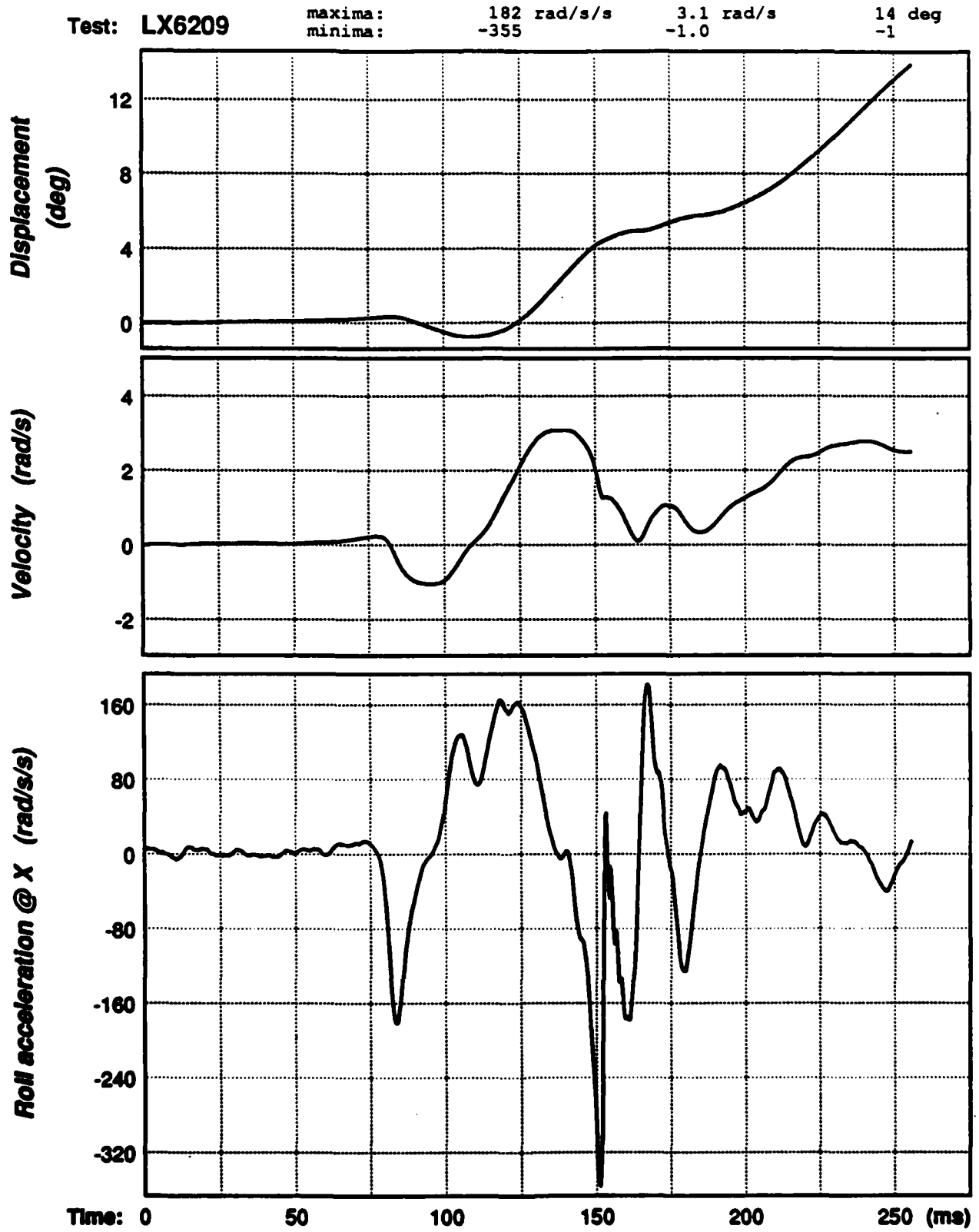

Figure B-24. Head roll angular acceleration, velocity, and displacement signals for test LX6209.

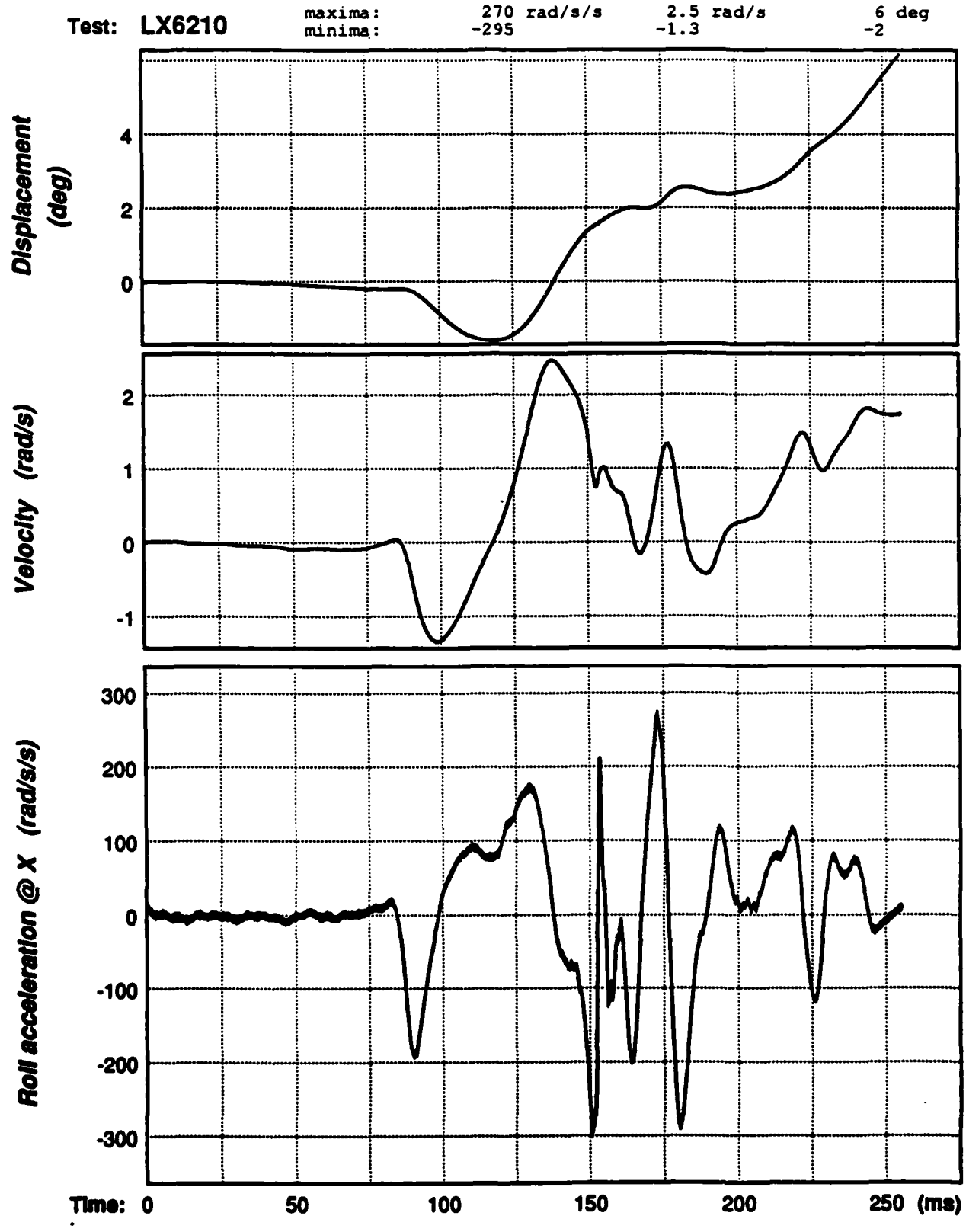

Figure B-25. Head roll angular acceleration, velocity, and displacement signals for test LX6210.

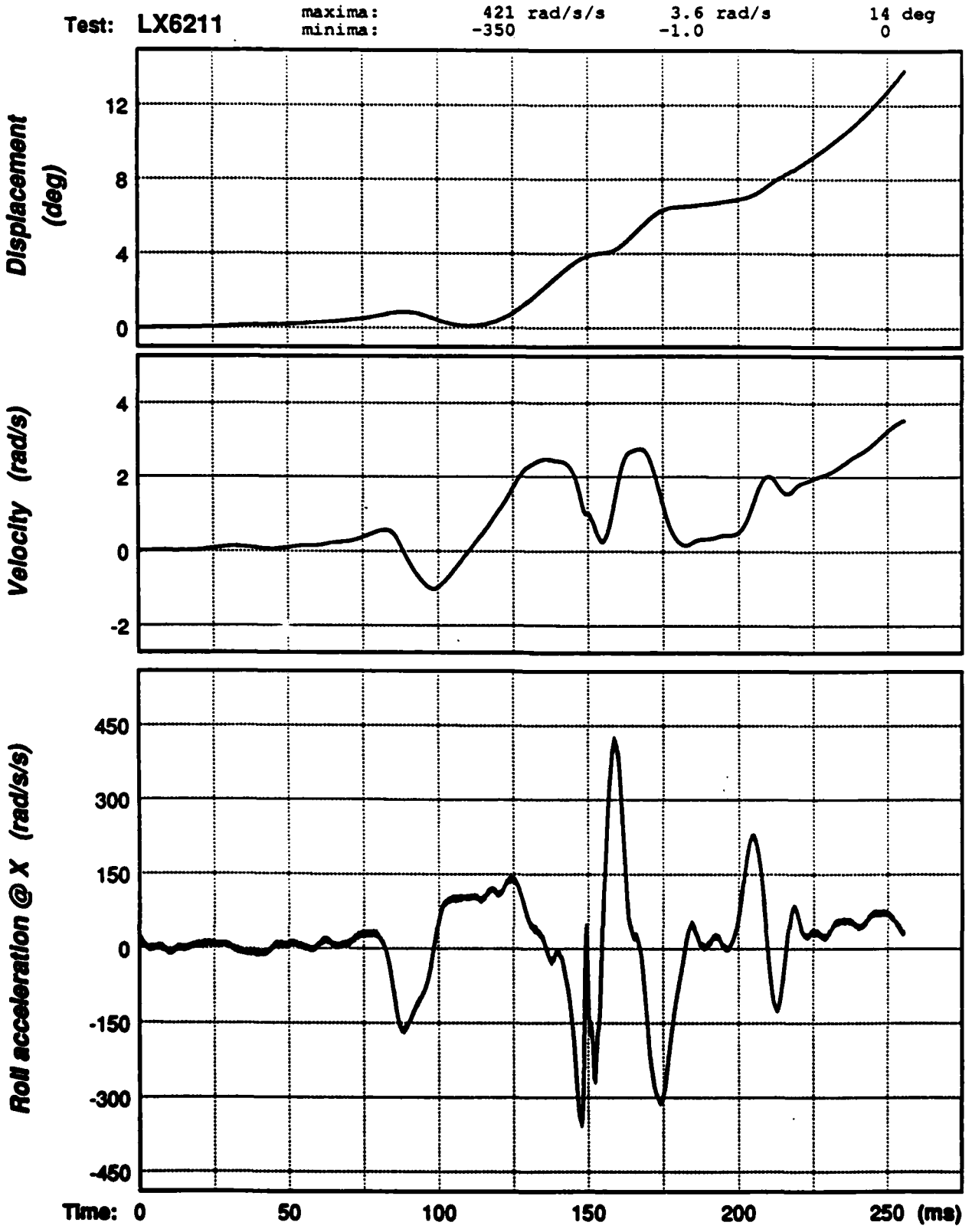

Figure B-26. Head roll angular acceleration, velocity, and displacement signals for test LX6211.

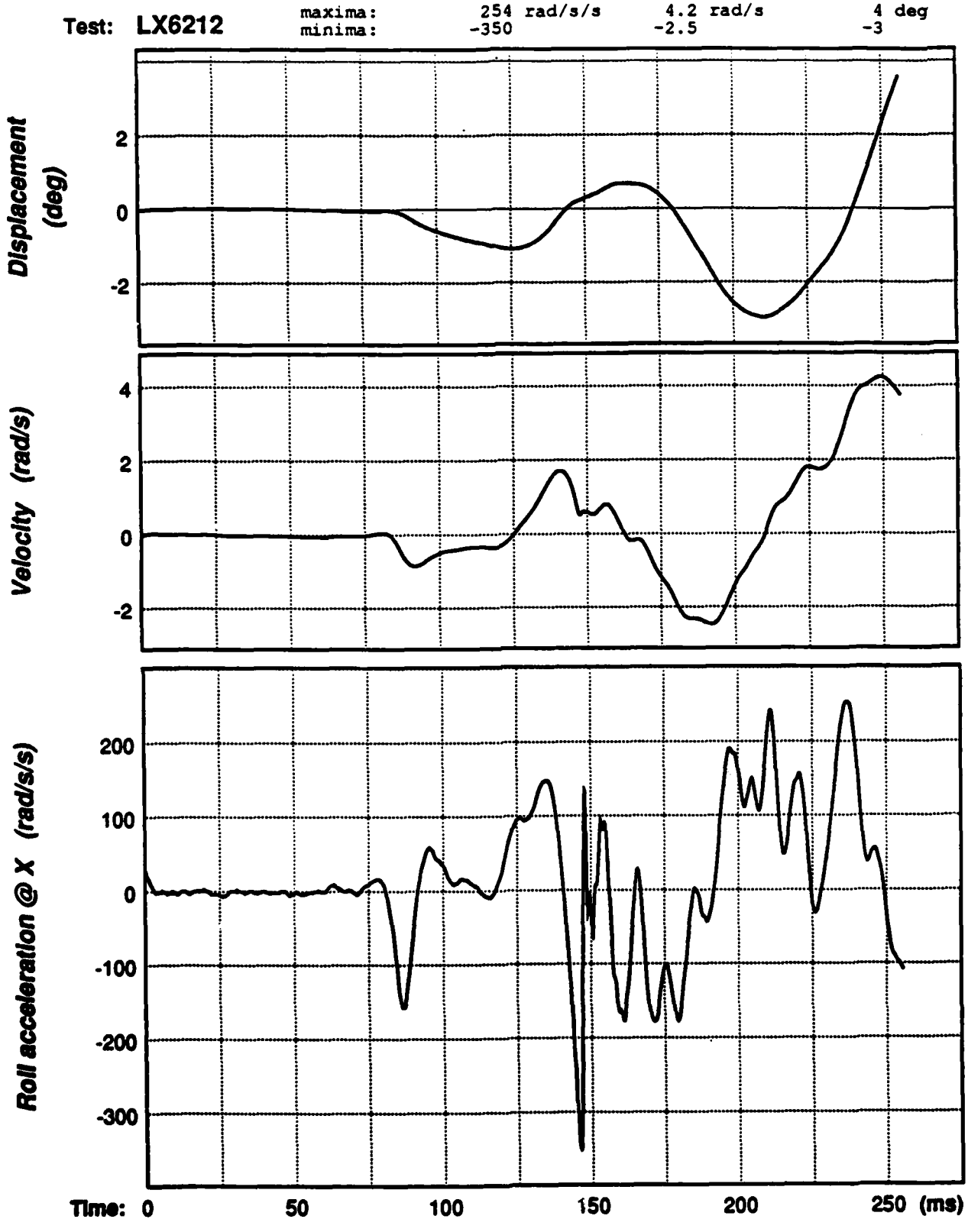

Figure B-27. Head roll angular acceleration, velocity, and displacement signals for test LX6212.

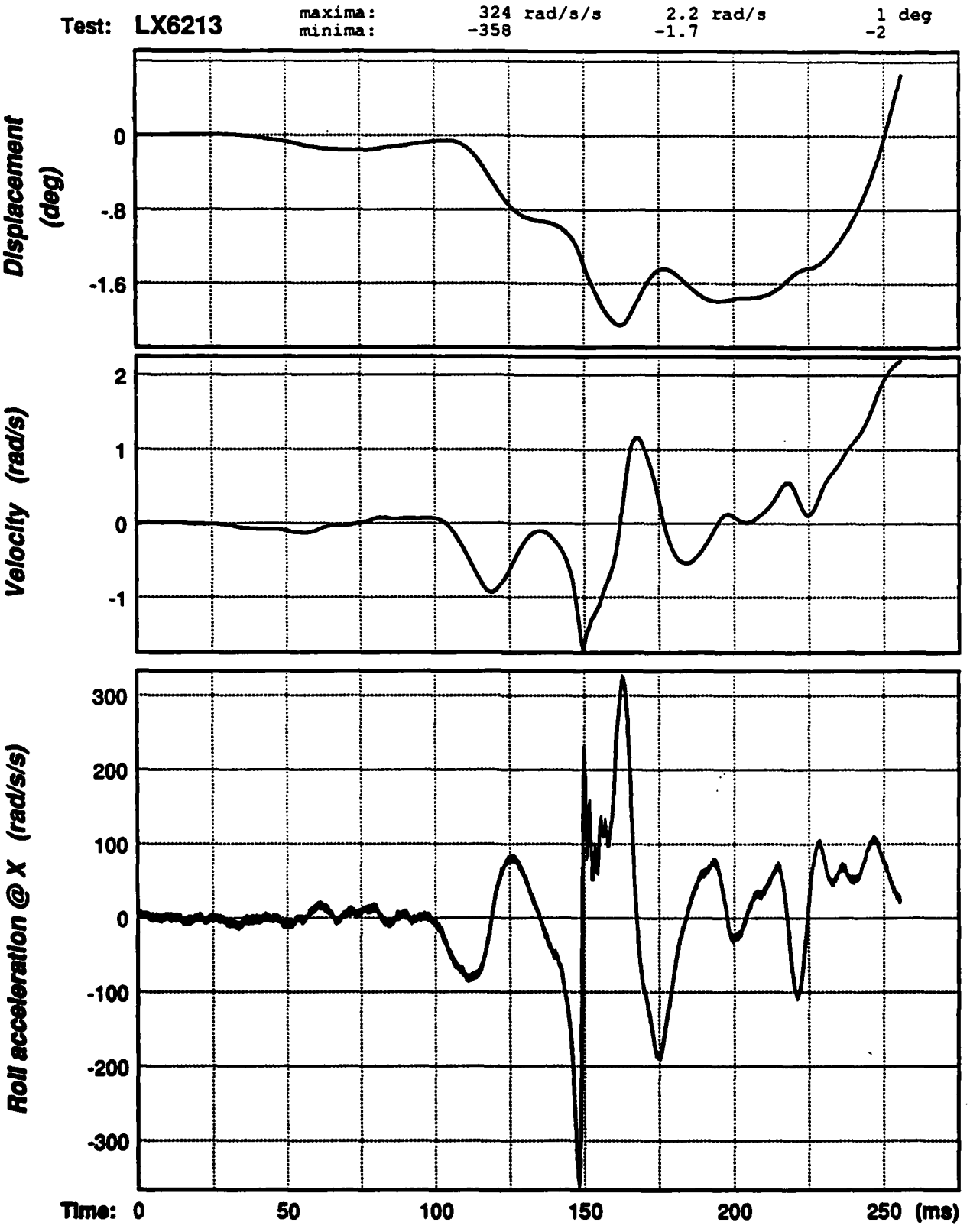

Figure B-28. Head roll angular acceleration, velocity, and displacement signals for test LX6213.

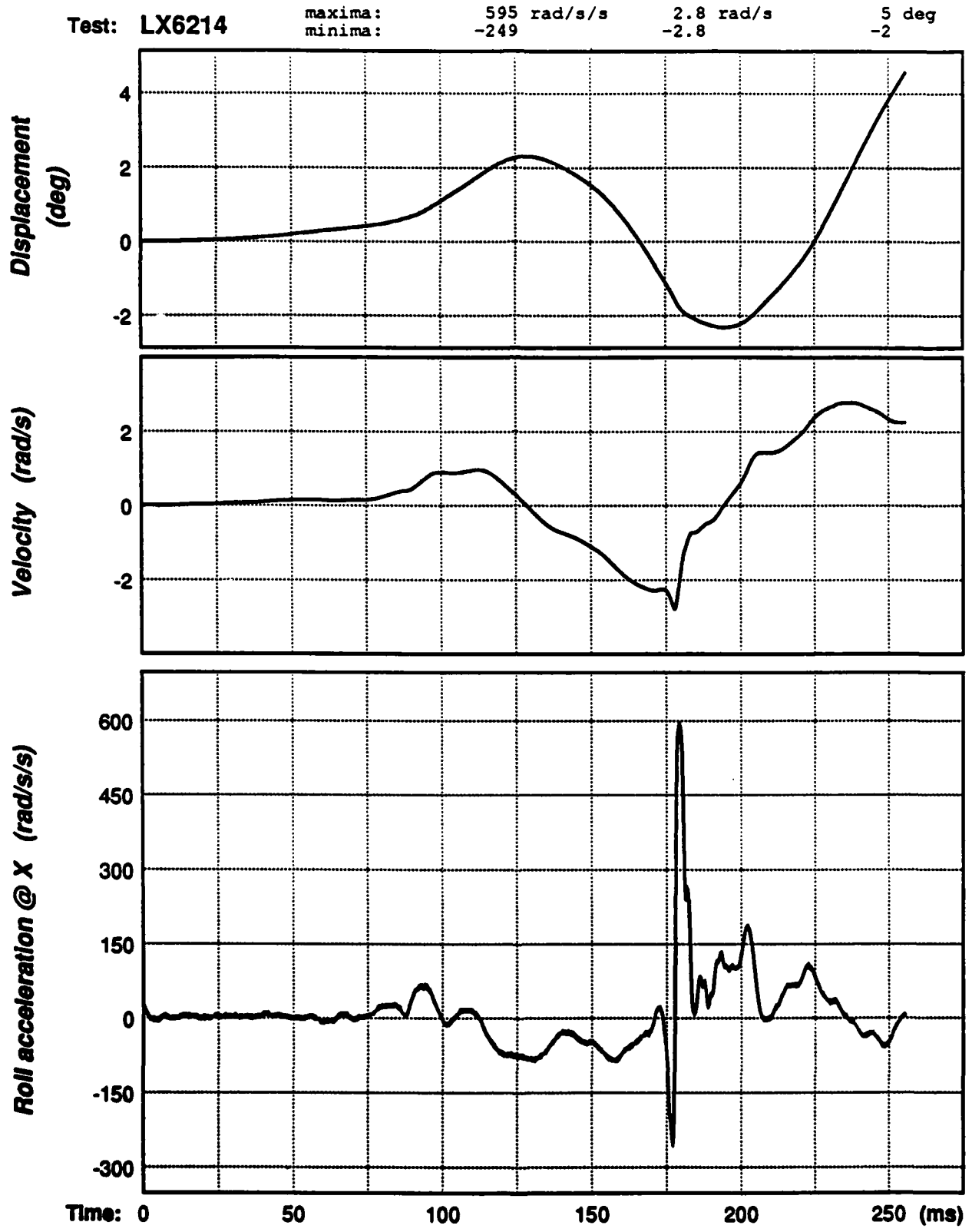

Figure B-29. Head roll angular acceleration, velocity, and displacement signals for test LX6214.

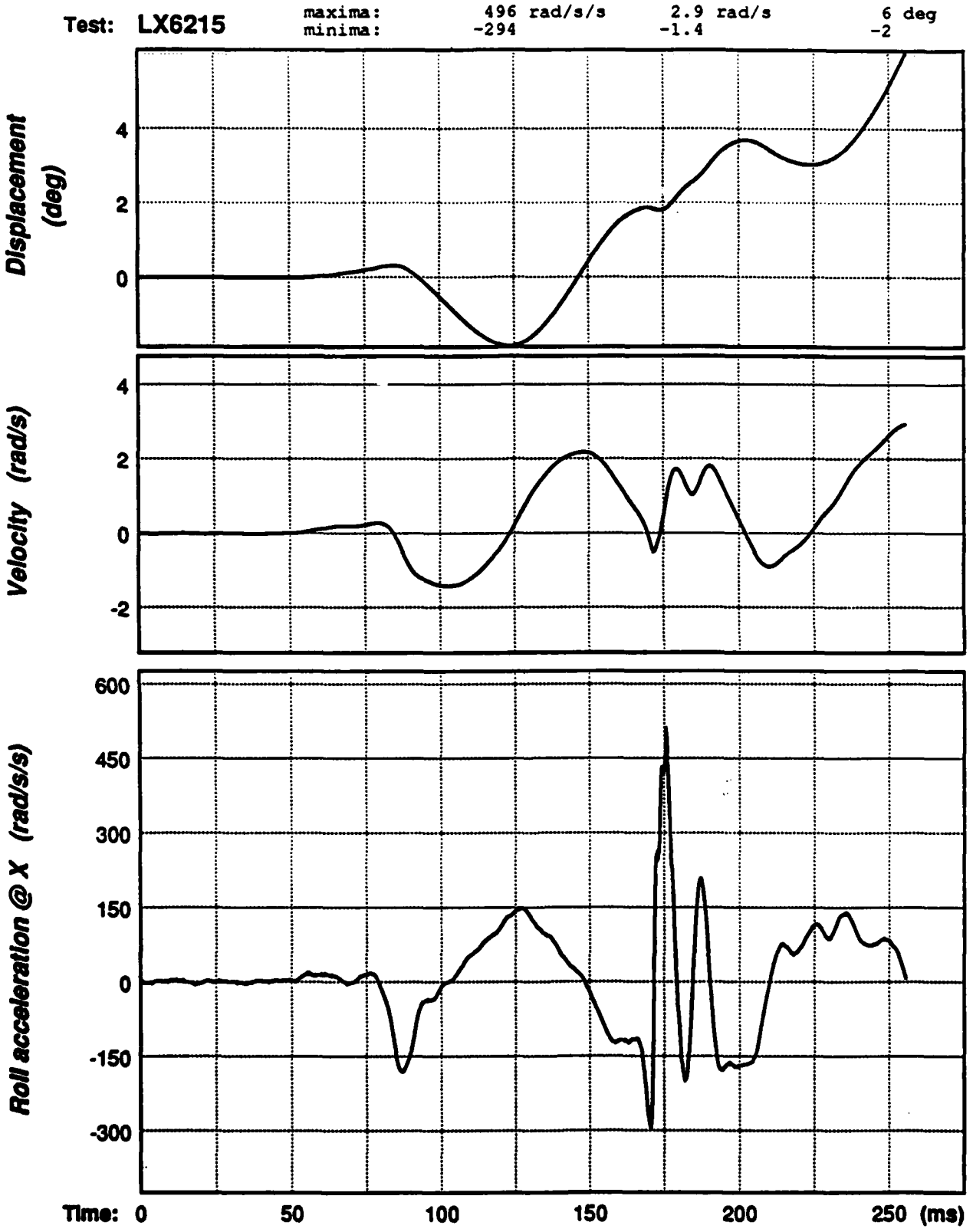

Figure B-30. Head roll angular acceleration, velocity, and displacement signals for test LX6215.

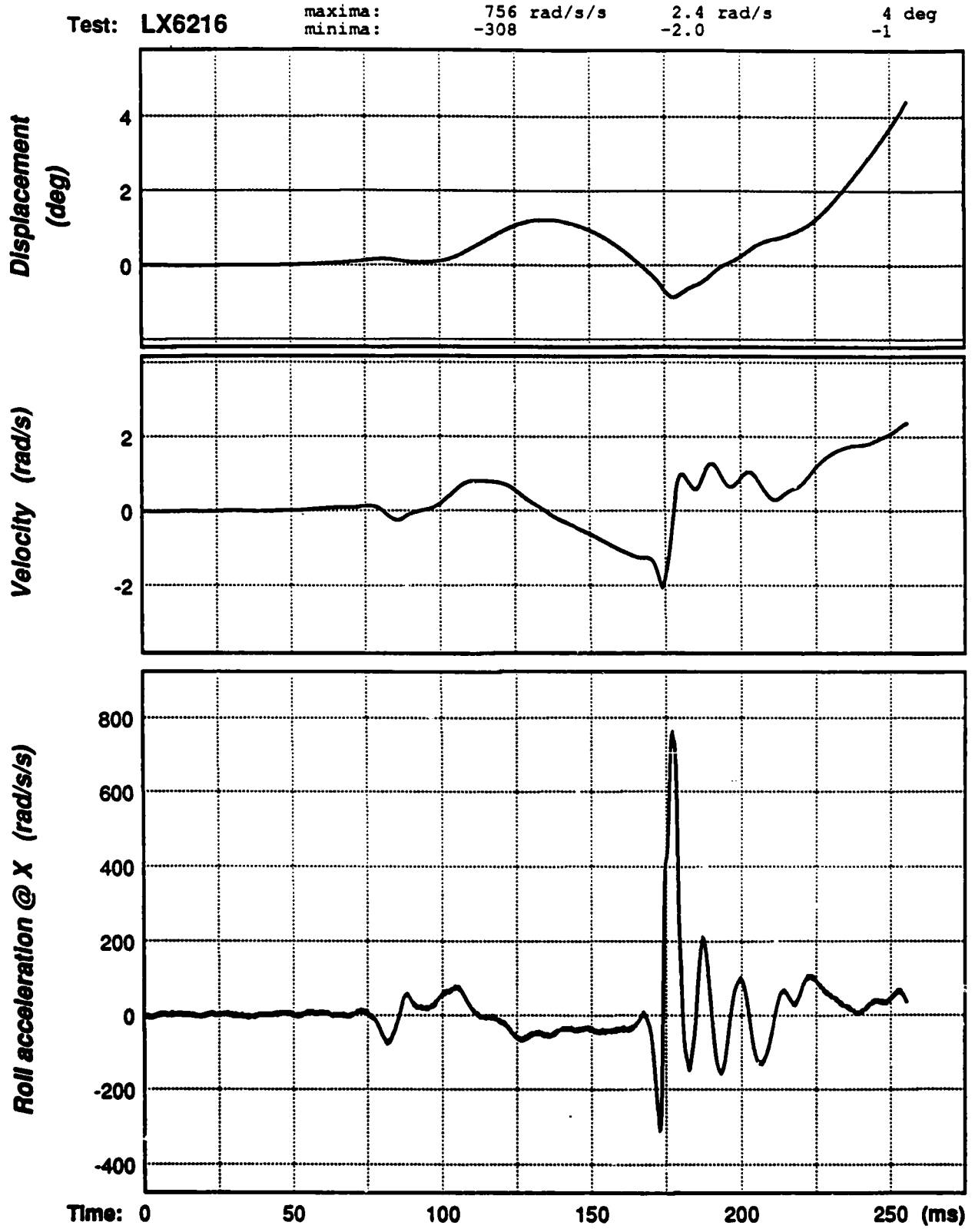

Figure B-31. Head roll angular acceleration, velocity, and displacement signals for test LX6216.

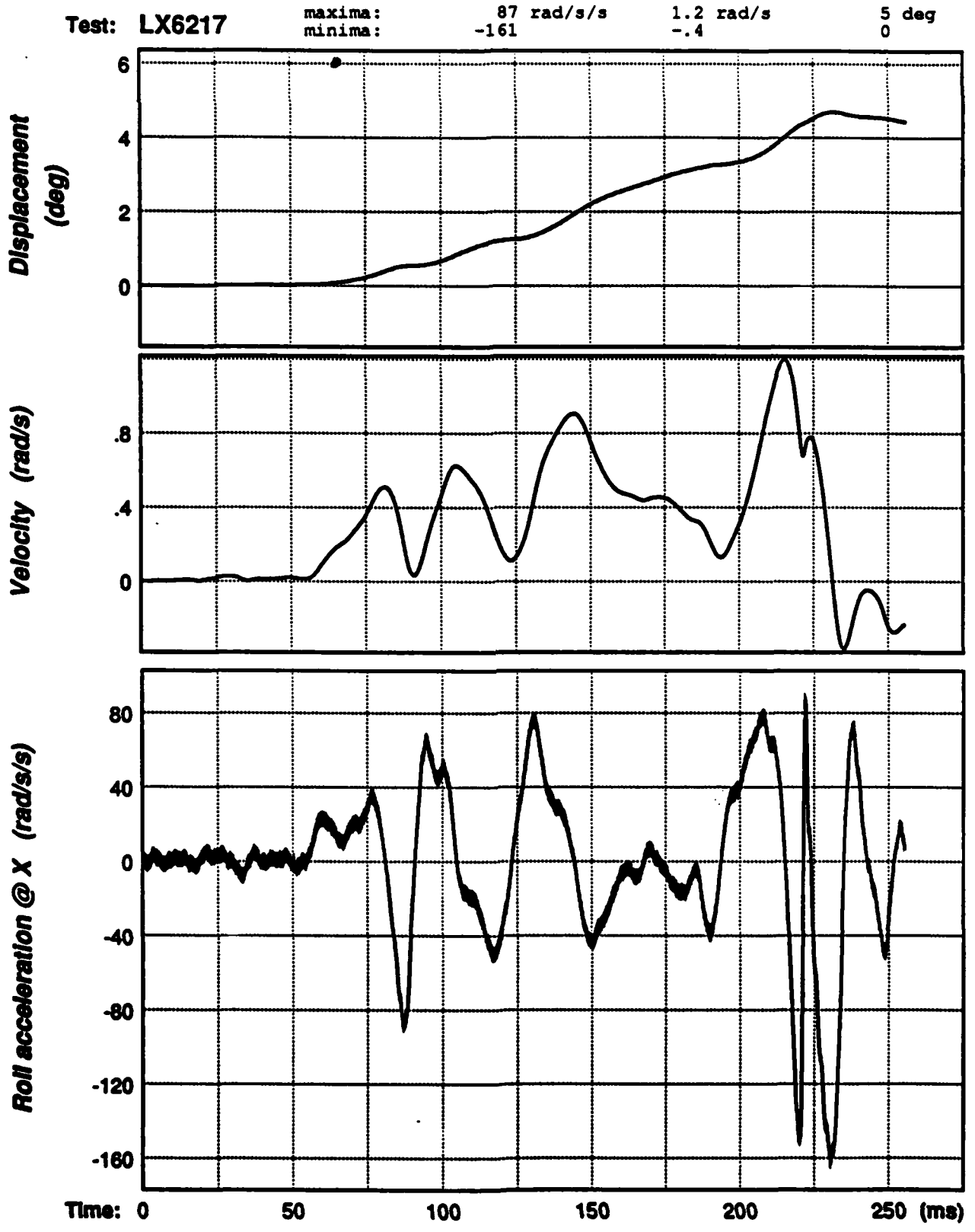

Figure B-32. Head roll angular acceleration, velocity, and displacement signals for test LX6217.

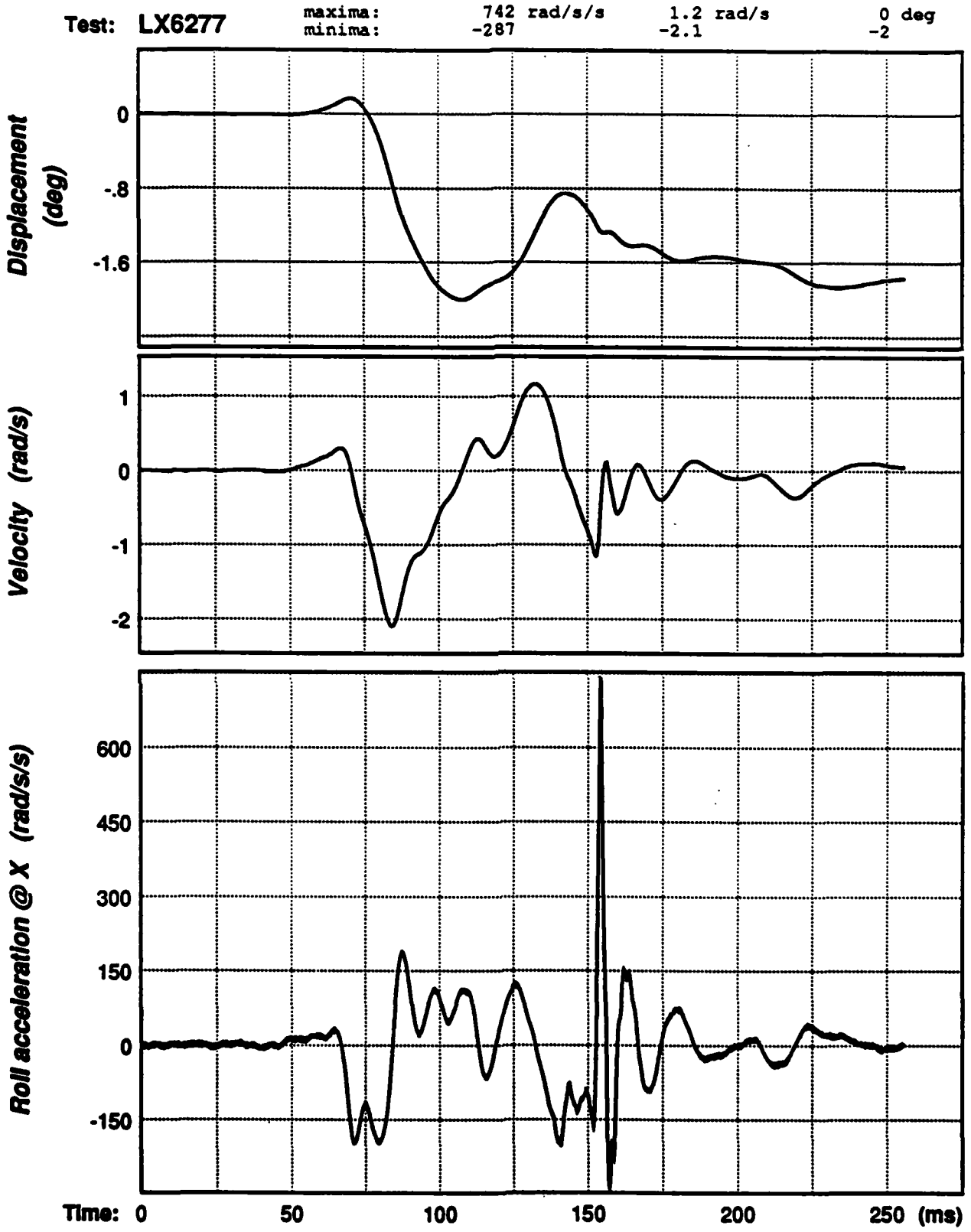

Figure B-33. Head roll angular acceleration, velocity, and displacement signals for test LX6277.

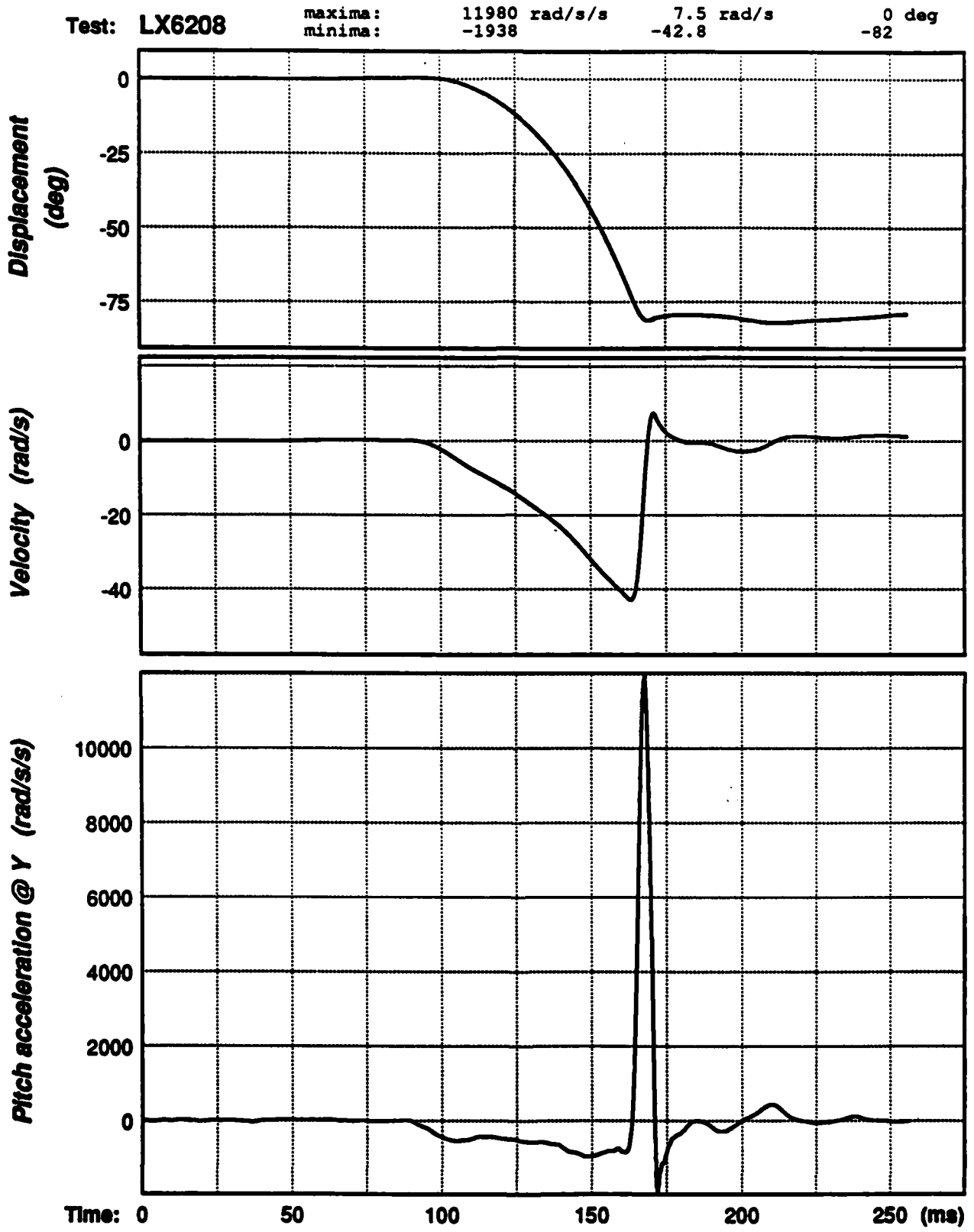

Figure B-34. Head pitch angular acceleration, velocity, and displacement signals for test LX6208.

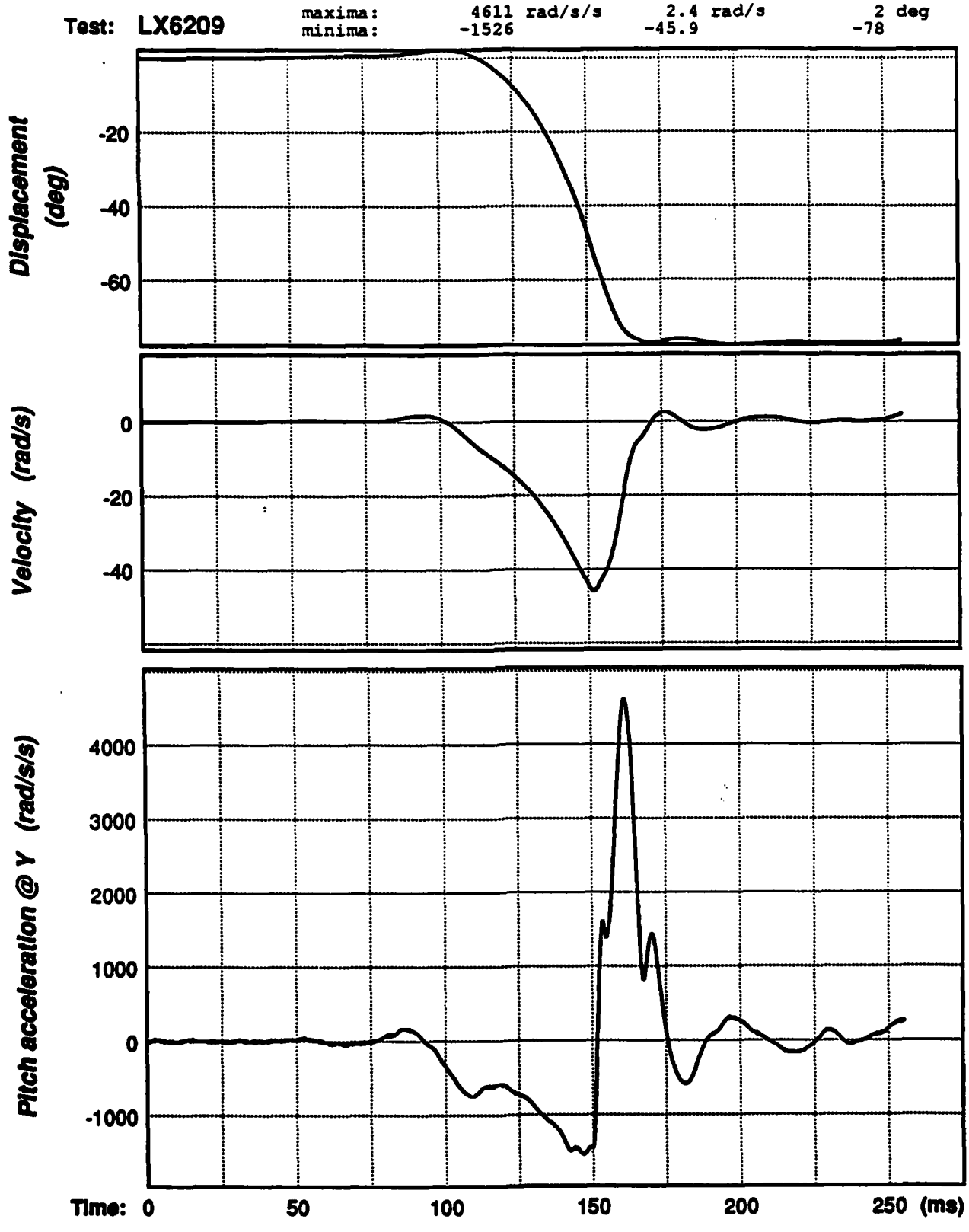

Figure B-35. Head pitch angular acceleration, velocity, and displacement signals for test LX6209.

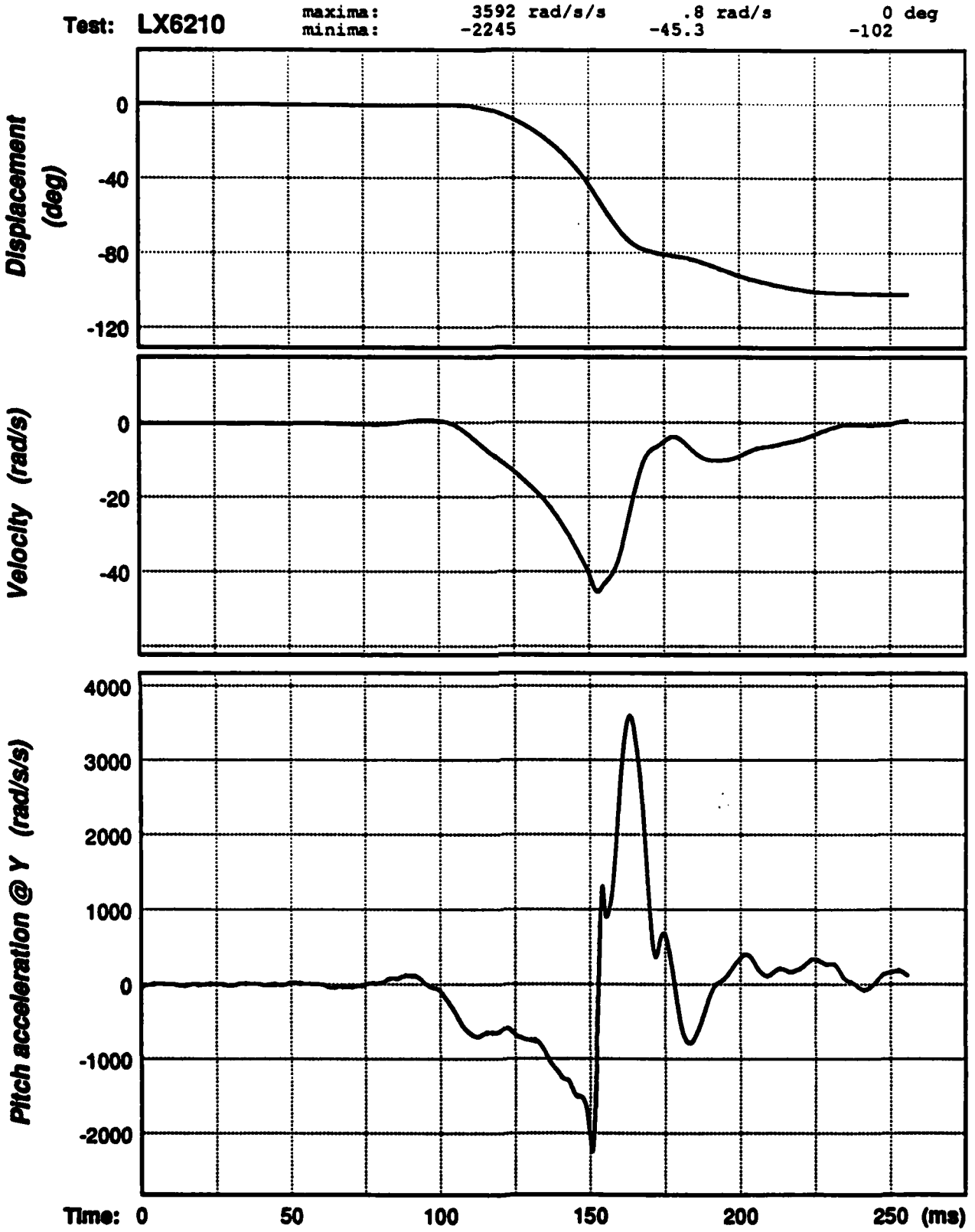

Figure B-36. Head pitch angular acceleration, velocity, and displacement signals for test LX6210.

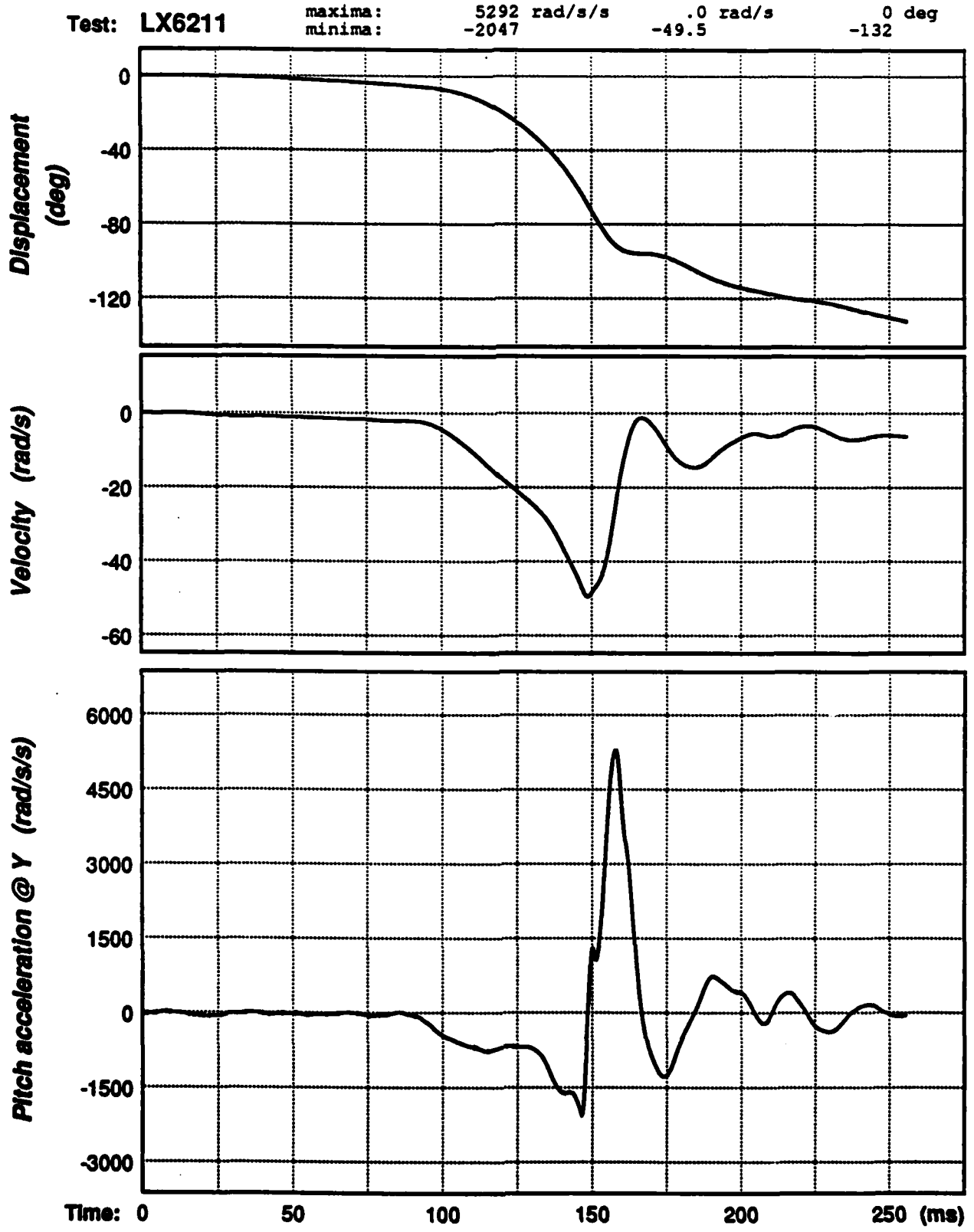

Figure B-37. Head pitch angular acceleration, velocity, and displacement signals for test LX6211.

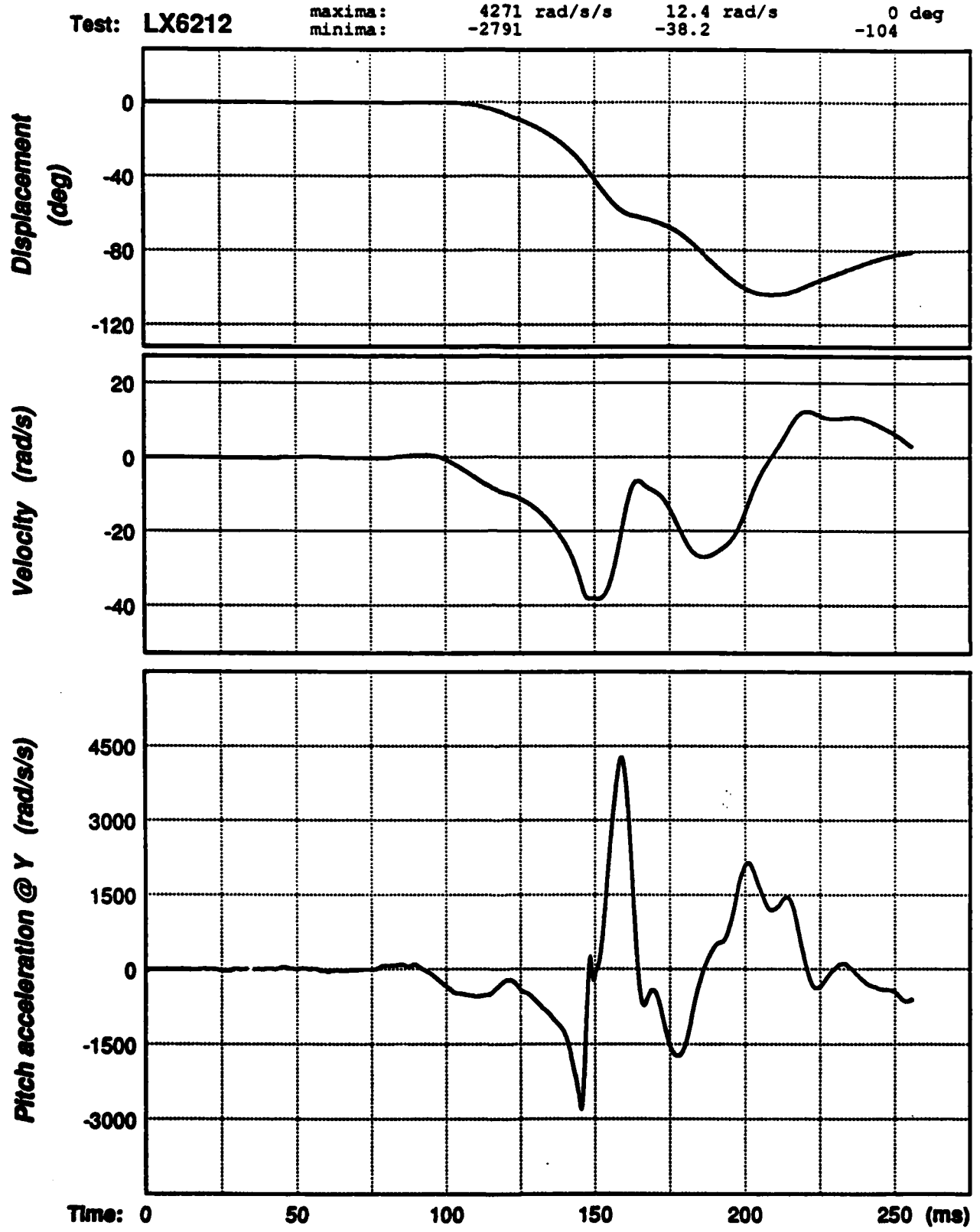

Figure B-38. Head pitch angular acceleration, velocity, and displacement signals for test LX6212.

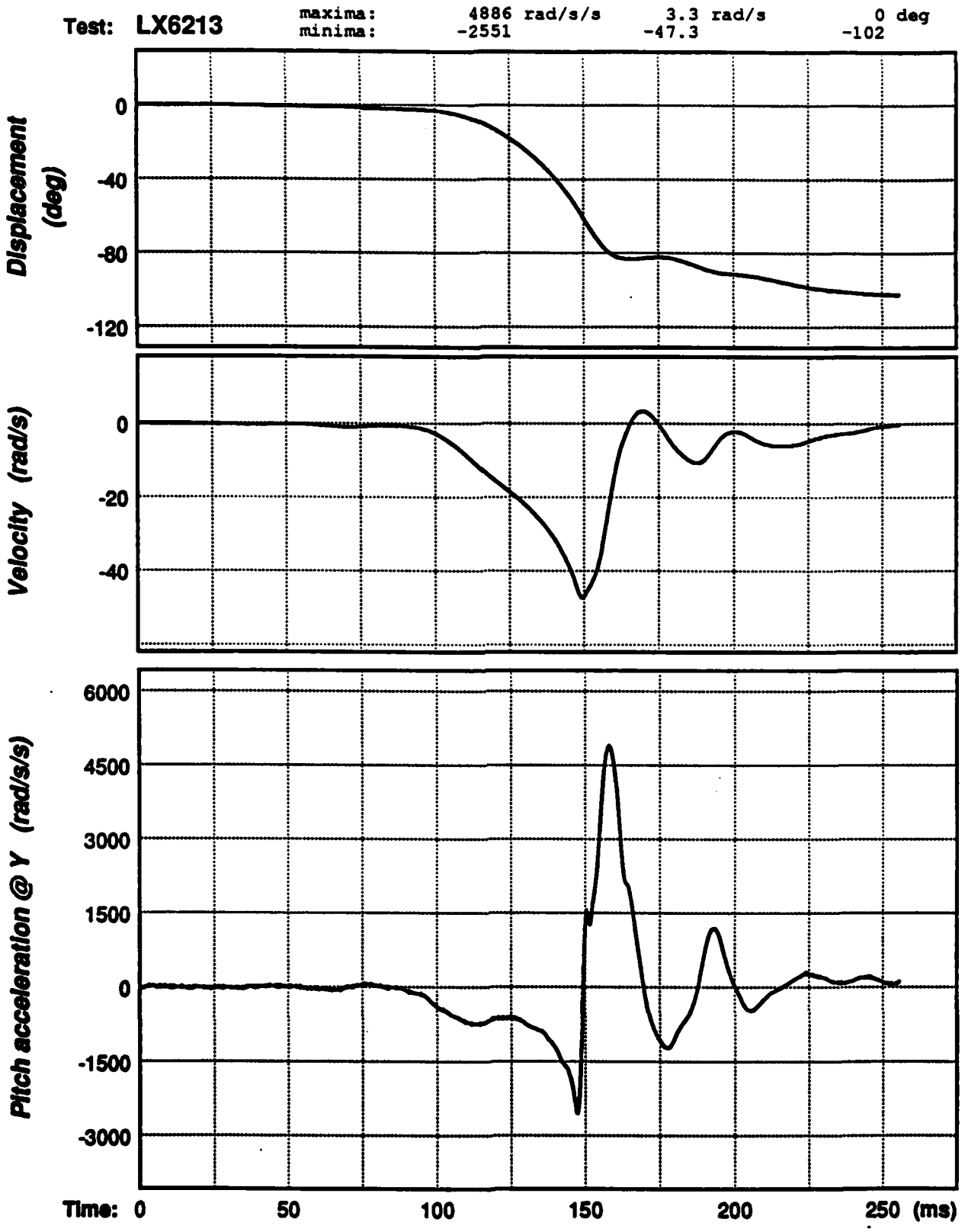

Figure B-39. Head pitch angular acceleration, velocity, and displacement signals for test LX6213.

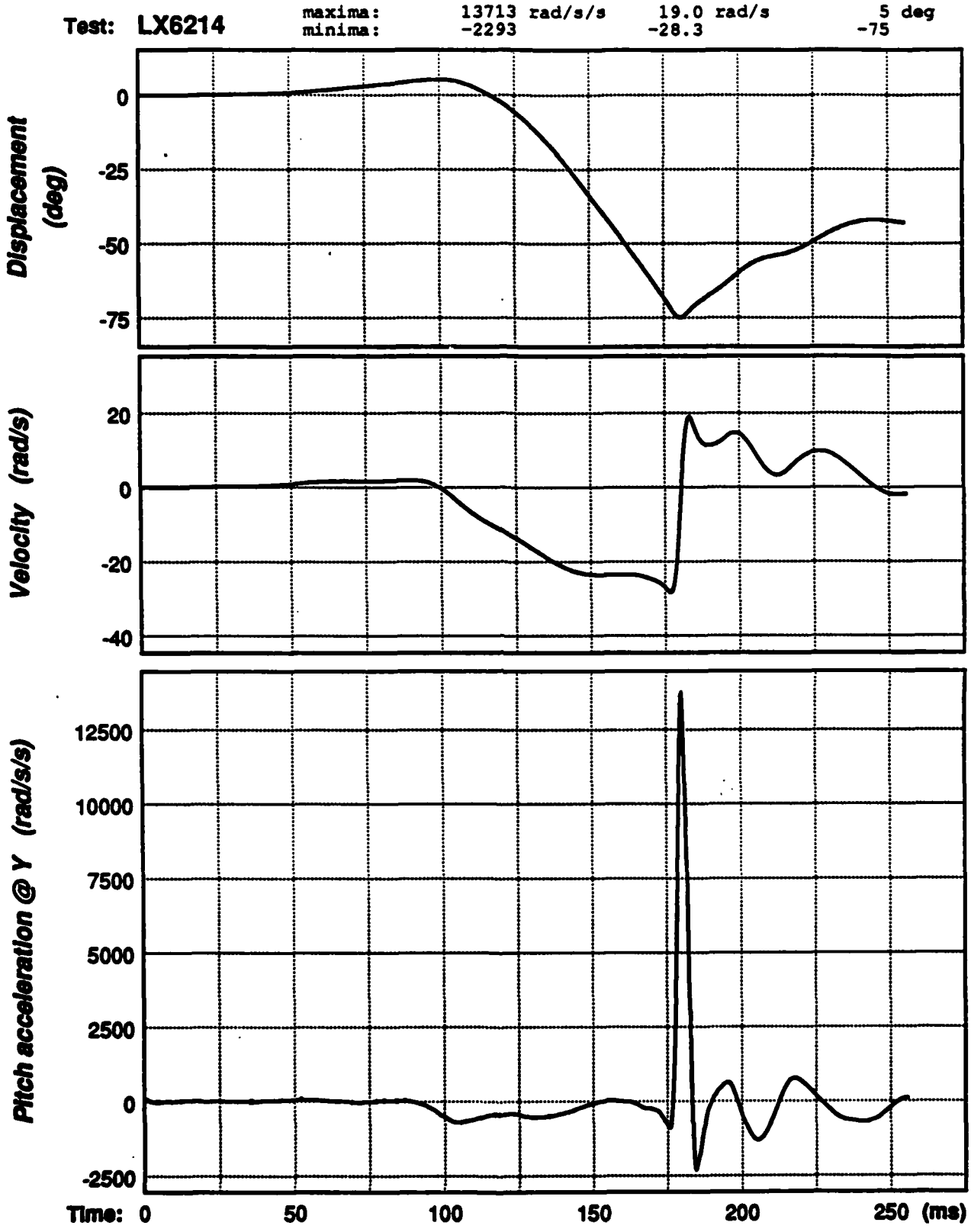

Figure B-40. Head pitch angular acceleration, velocity, and displacement signals for test LX6214.

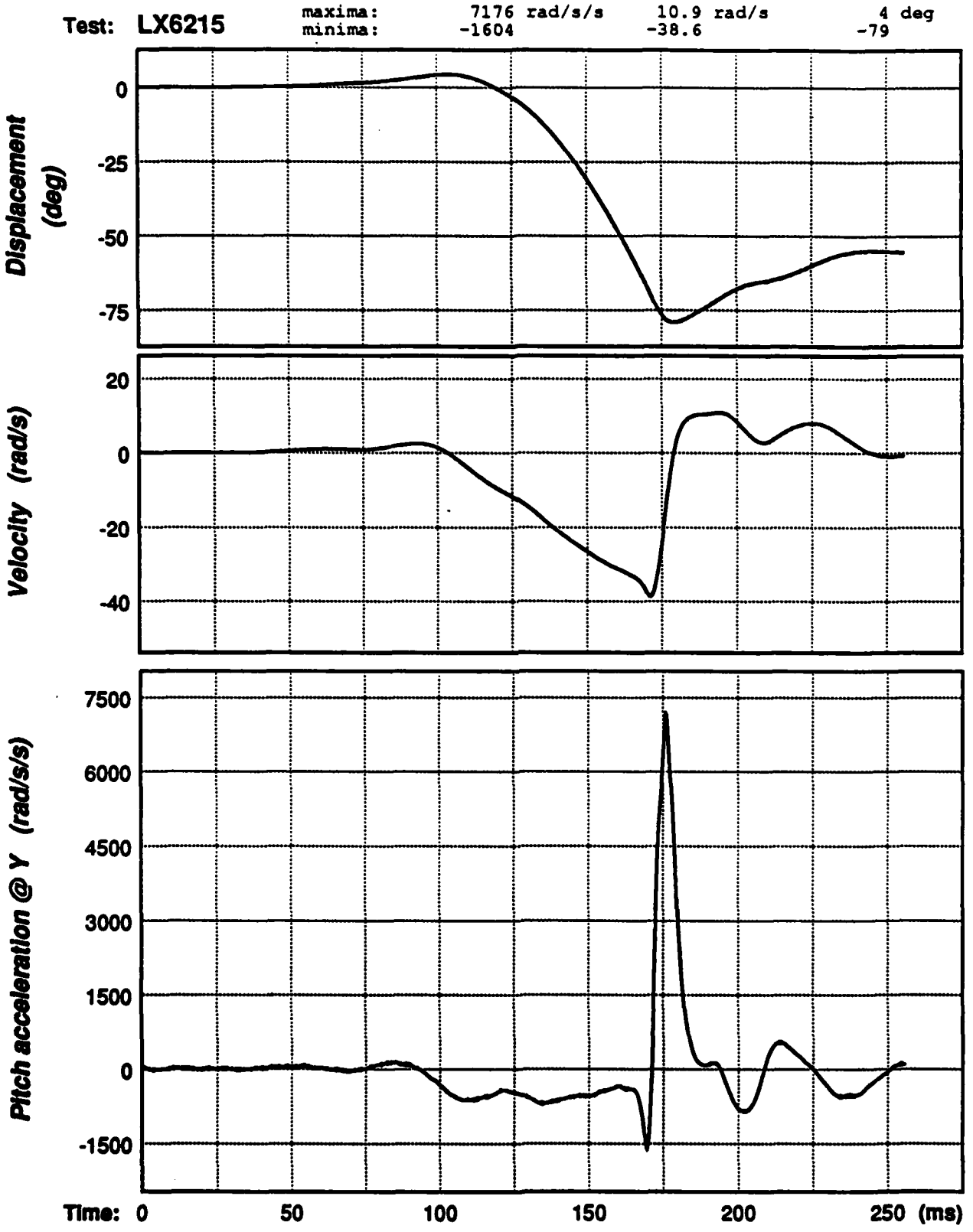

Figure B-41. Head pitch angular acceleration, velocity, and displacement signals for test LX6215.

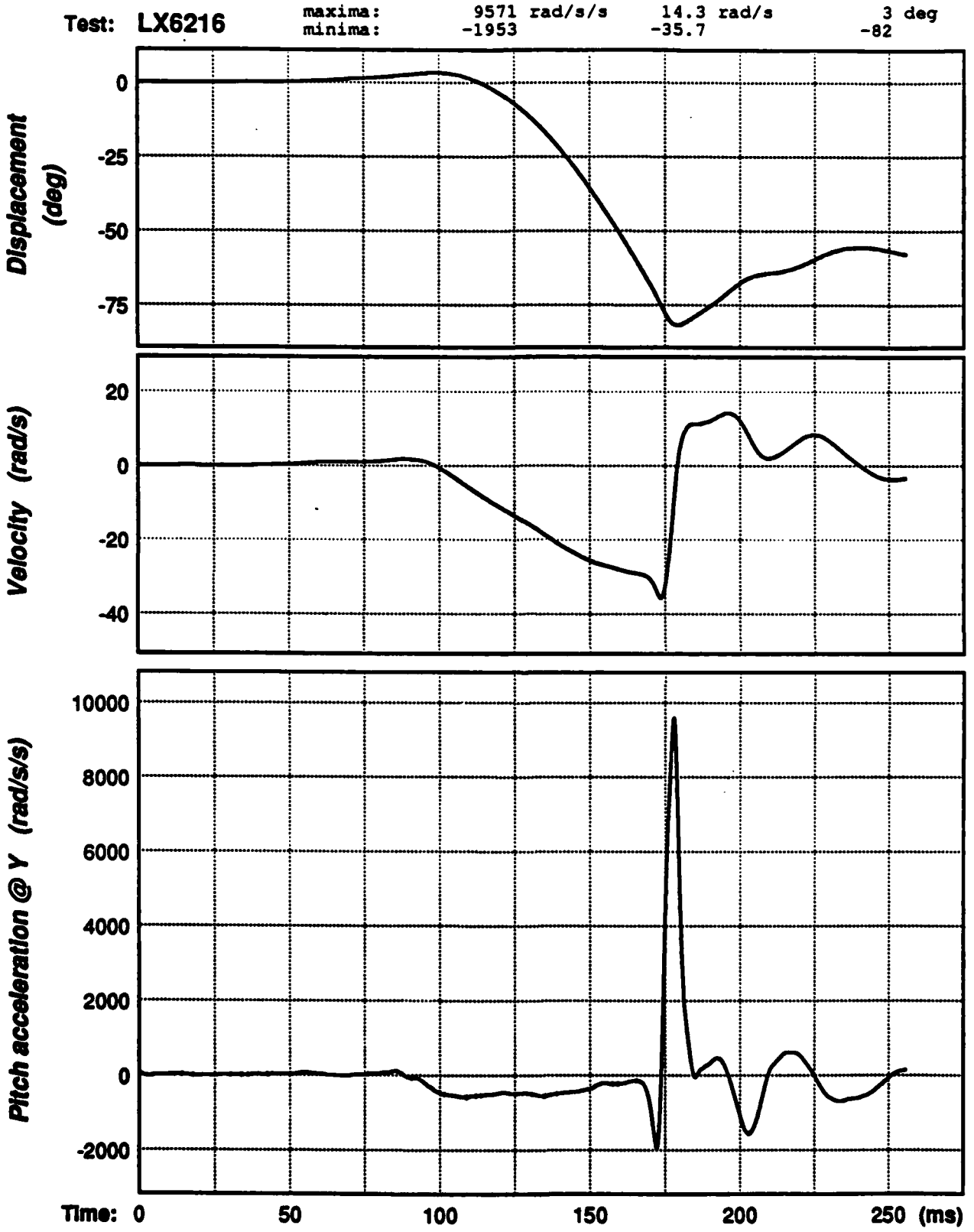

Figure B-42. Head pitch angular acceleration, velocity, and displacement signals for test LX6216.

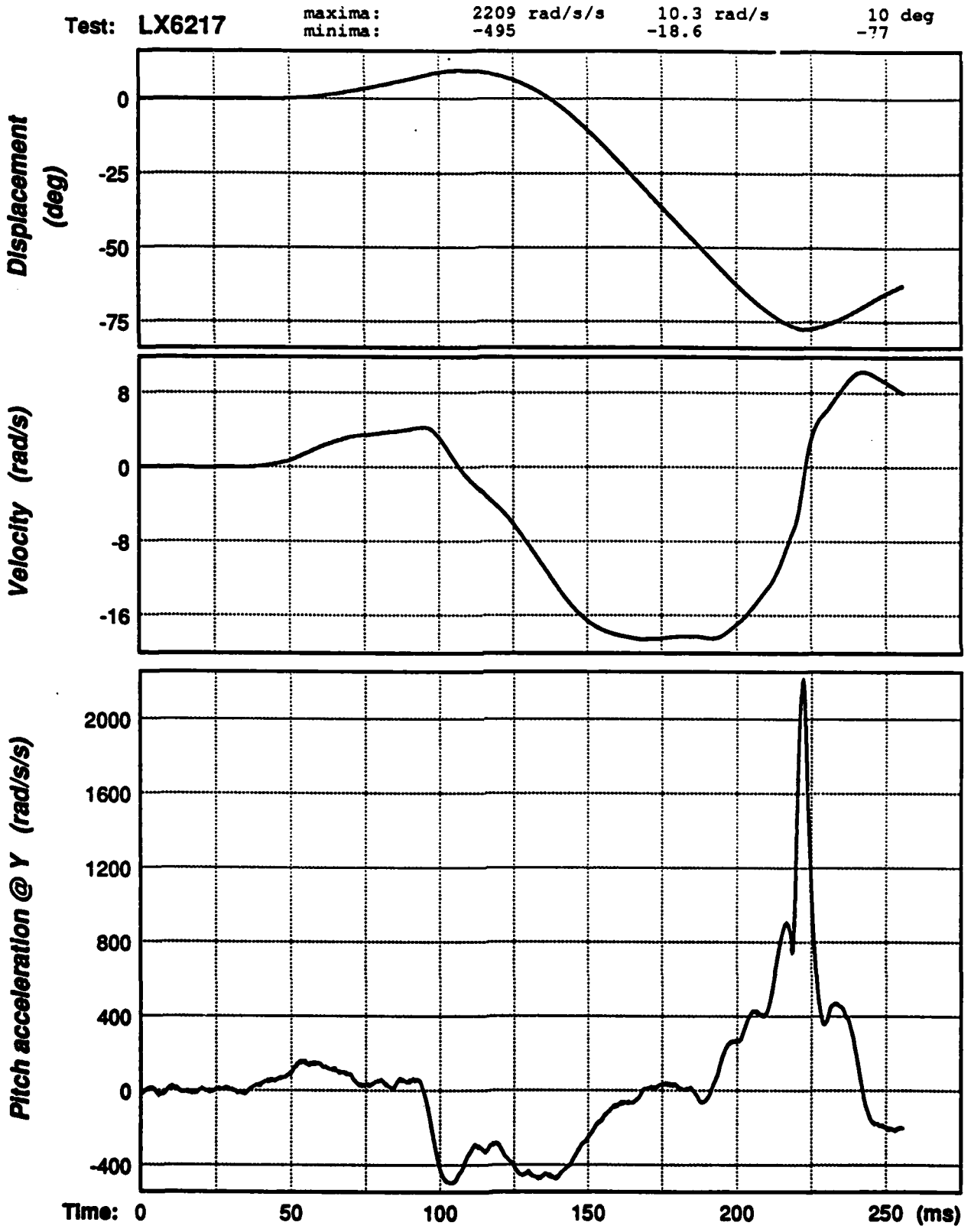

Figure B-43. Head pitch angular acceleration, velocity, and displacement signals for test LX6217.

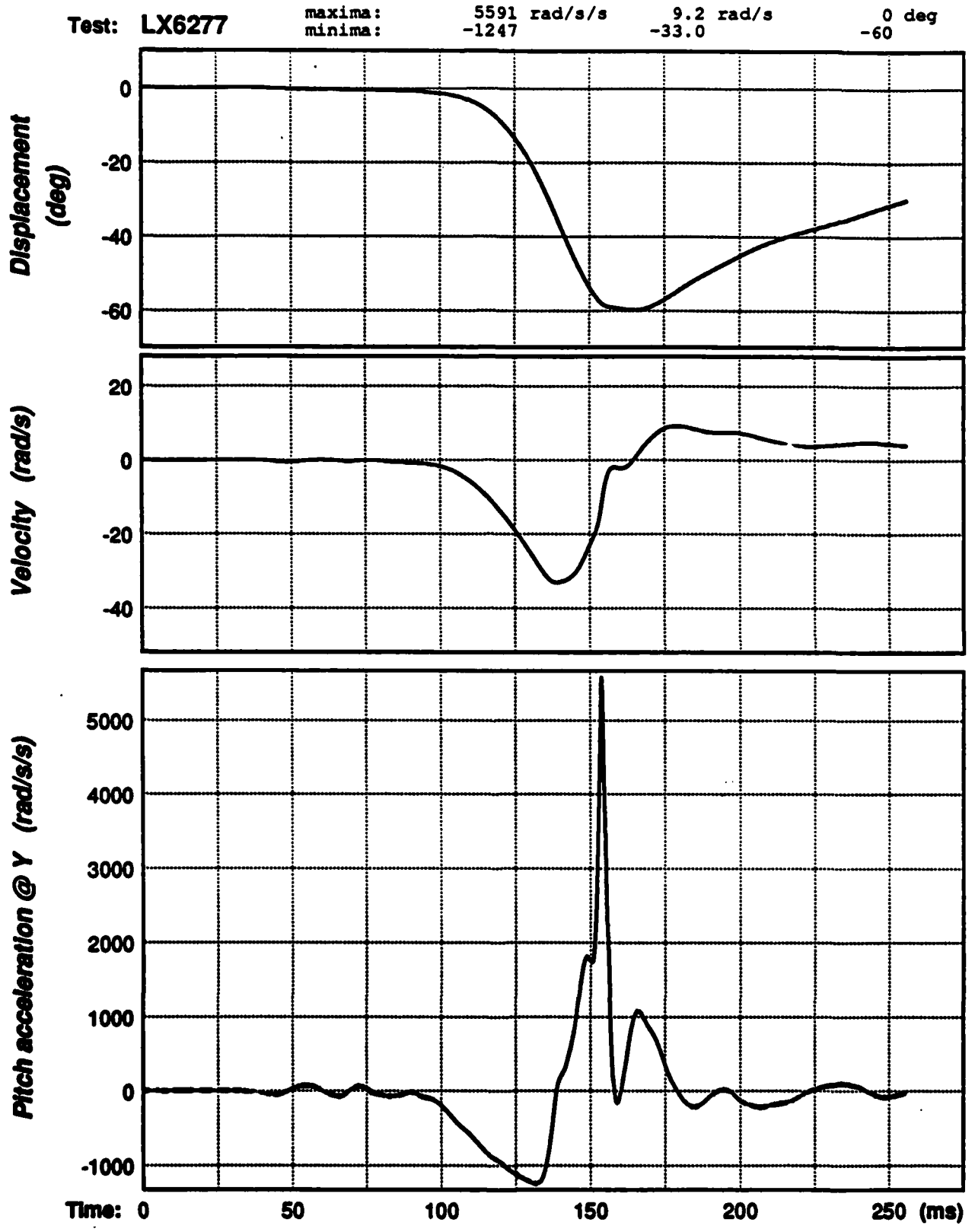

Figure B-44. Head pitch angular acceleration, velocity, and displacement signals for test LX6277.

Appendix C

This appendix contains processed transducer signals from 11 tests where an airbag was mounted below the gunsight to supplement the standard restraint system in the Cobra and Apache.

These include five Cobra tests (LX6269 thru LX6273) and six Apache tests (LX6278 thru LX6283) which were all conducted in the second phase of testing.

Figures C-1 thru C-11 show the sled acceleration pulses and computed velocity and jerk signals for the 11 tests. Note for test LX6269, the sled pulse was the only transducer signal that was available for processing.

Figures C-12 thru C-21 display components and resultant head linear accelerations.

Figures C-22 thru C-31 display the head roll acceleration signals and computed angular velocities and displacements.

Figures C-32 thru C-41 show the head pitch acceleration signals and computed angular velocities and displacements.

Figures B-42 thru A-51 display the amounts of belt extension and the computed velocities and accelerations.

Appendix C

1. LX6269
2. LX6270
3. LX6271
4. LX6272
5. LX6273
6. LX6278
7. LX6279
8. LX6280
9. LX6281
10. LX6282
11. LX6283

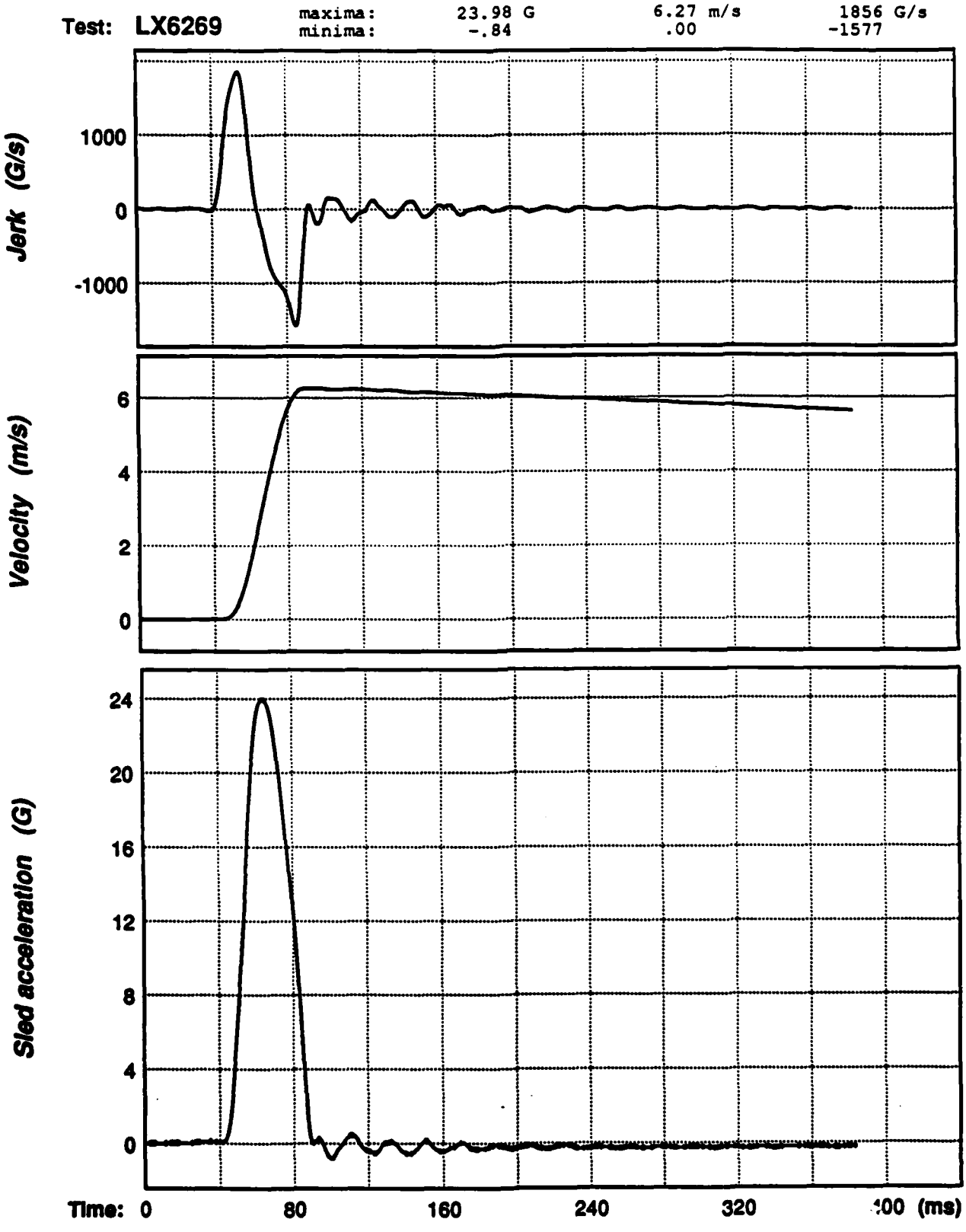

Figure C-1. Sled acceleration signal and its computed velocity and jerk for test LX6269.

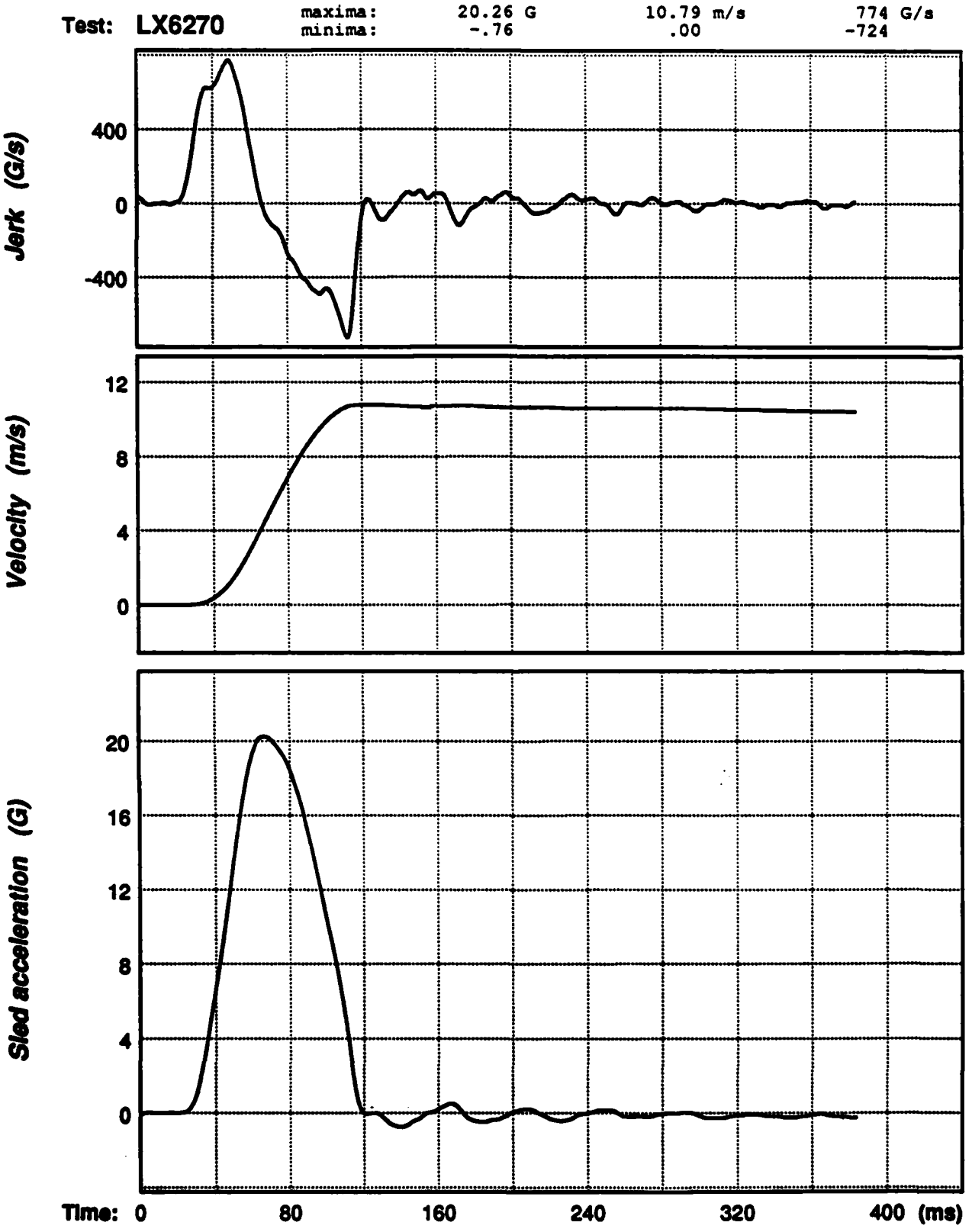

Figure C-2. Sled acceleration signal and its computed velocity and jerk for test LX6270.

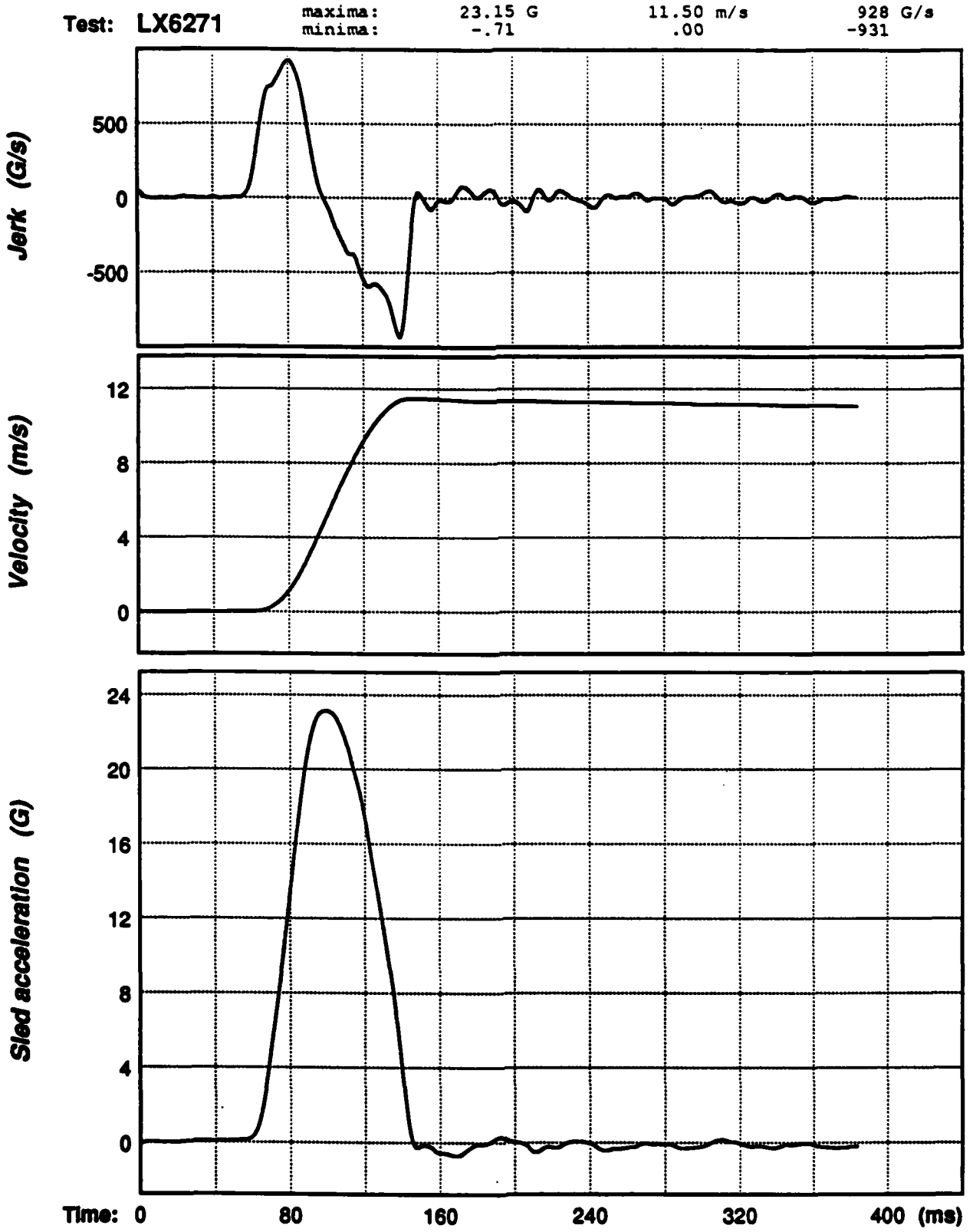

Figure C-3. Sled acceleration signal and its computed velocity and jerk for test LX6271.

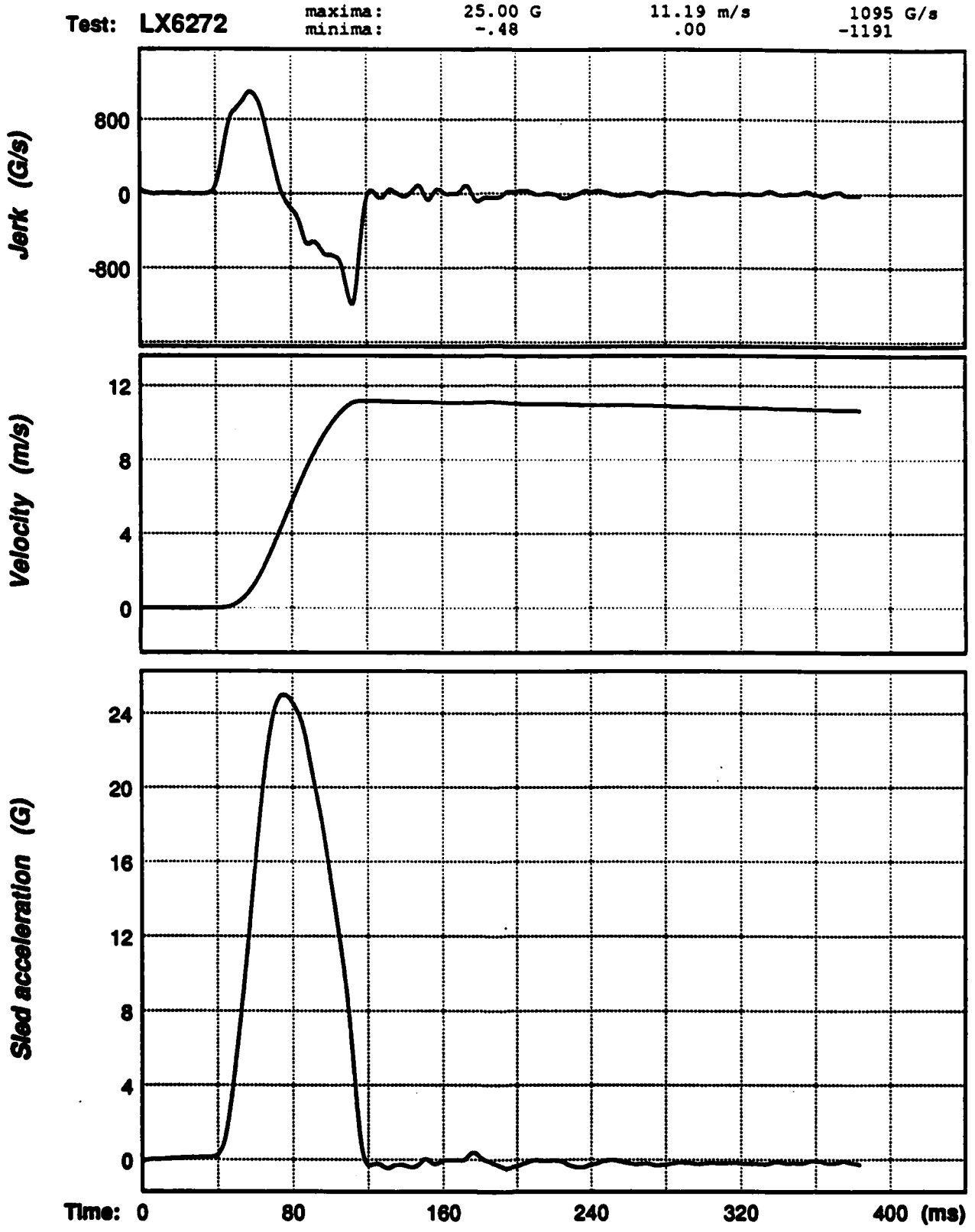

Figure C-4. Sled acceleration signal and its computed velocity and jerk for test LX6272.

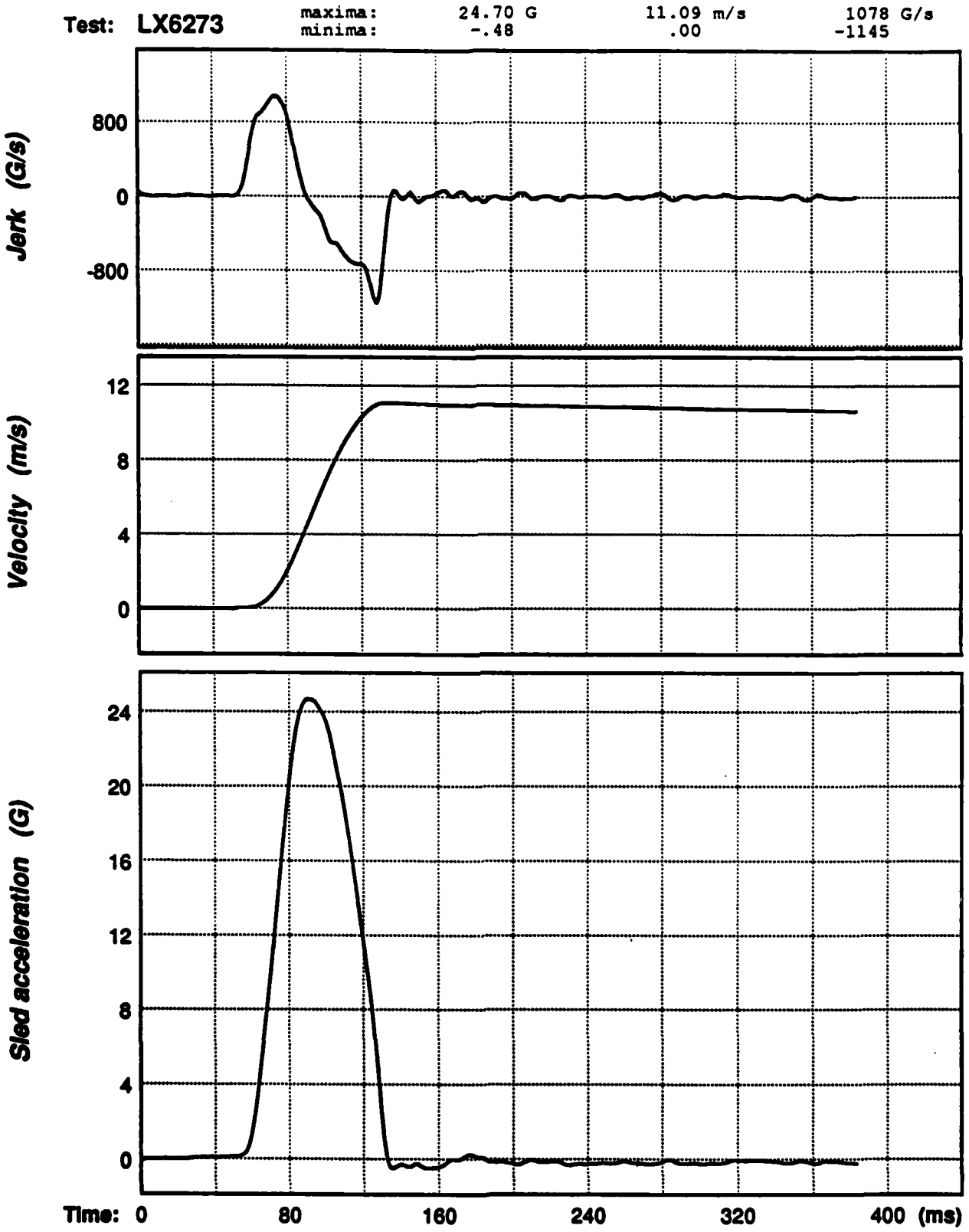

Figure C-5. Sled acceleration signal and its computed velocity and jerk for test LX6273.

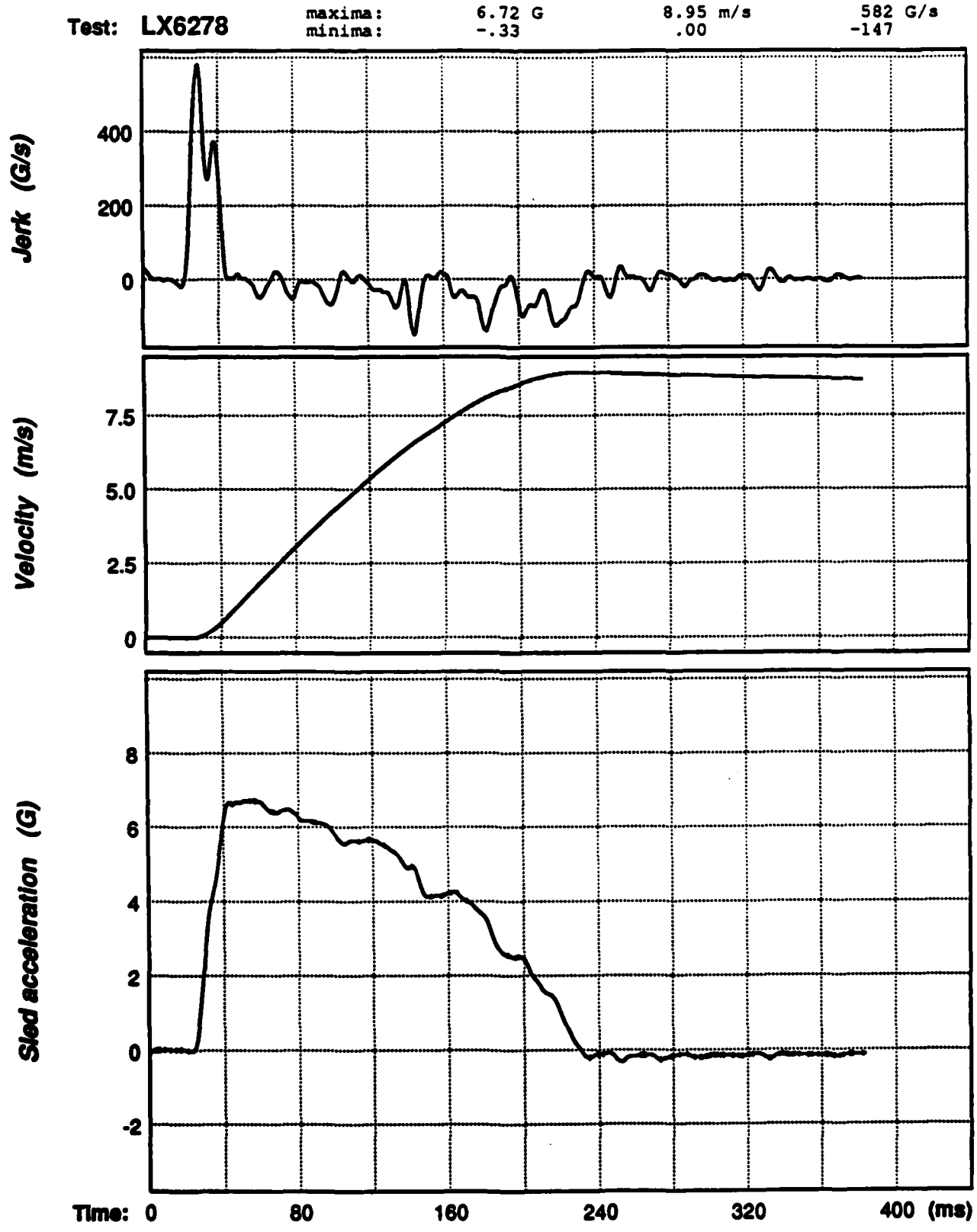

Figure C-6. Sled acceleration signal and its computed velocity and jerk for test LX6278.

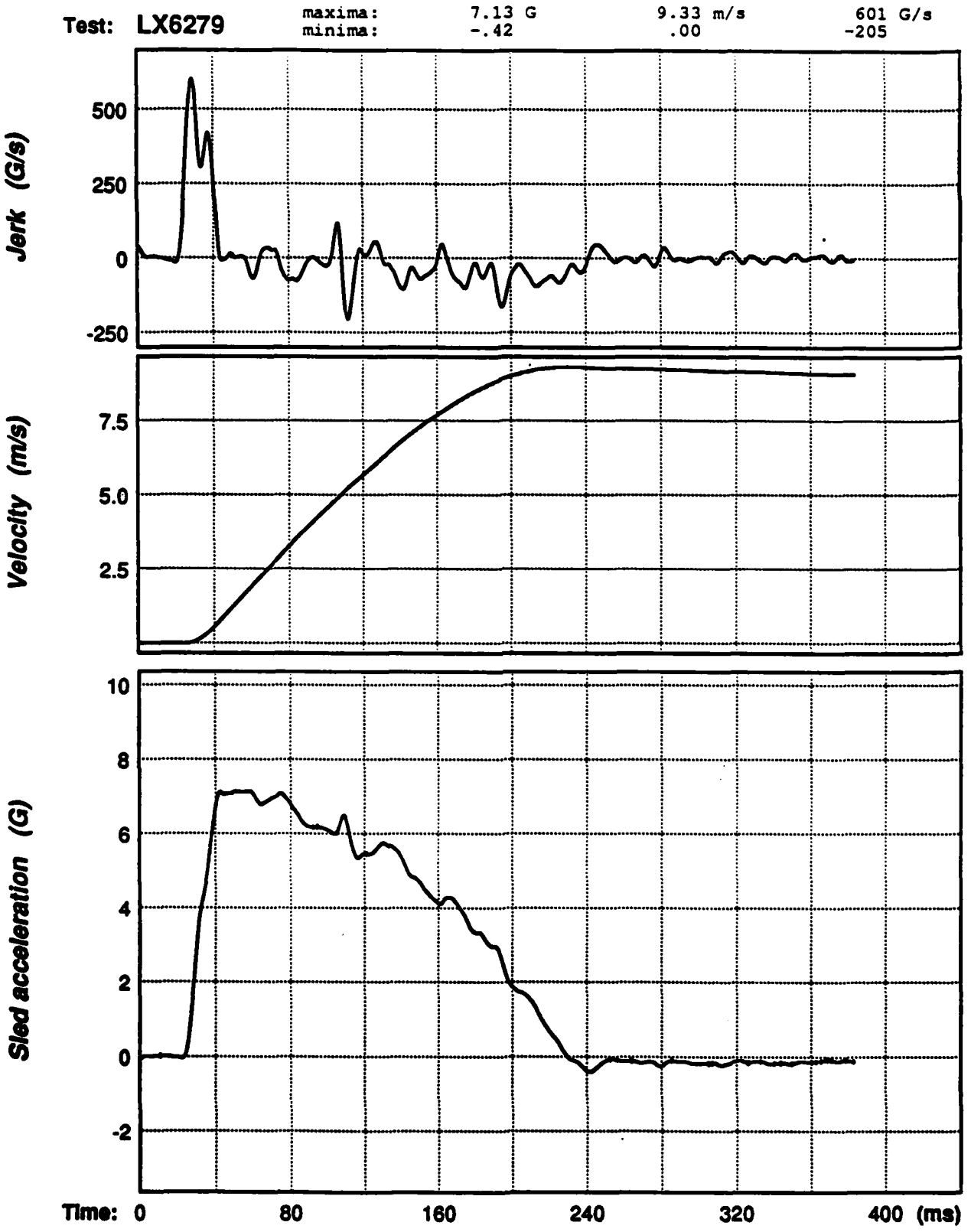

Figure C-7. Sled acceleration signal and its computed velocity and jerk for test LX6279.

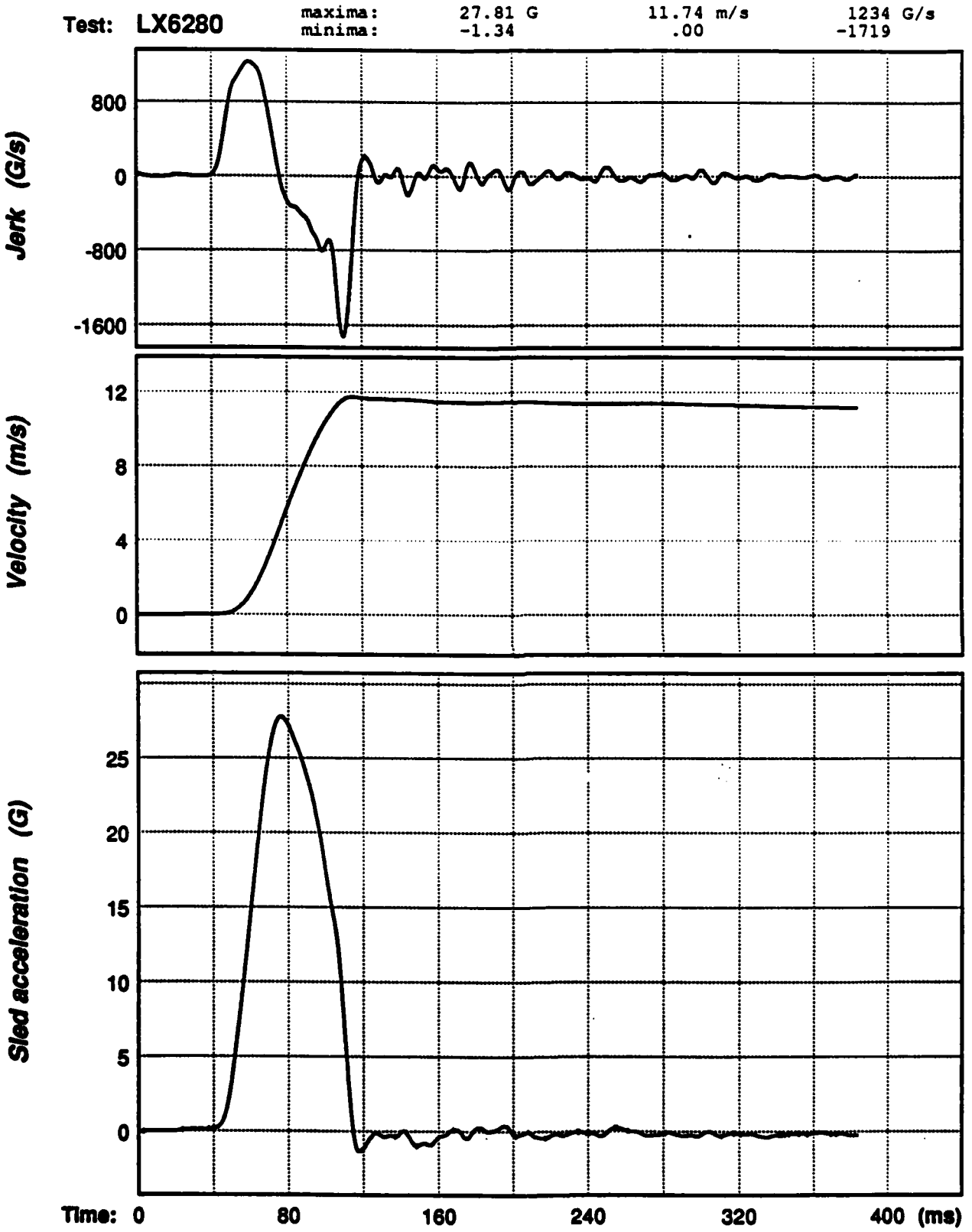

Figure C-8. Sled acceleration signal and its computed velocity and jerk for test LX6280.

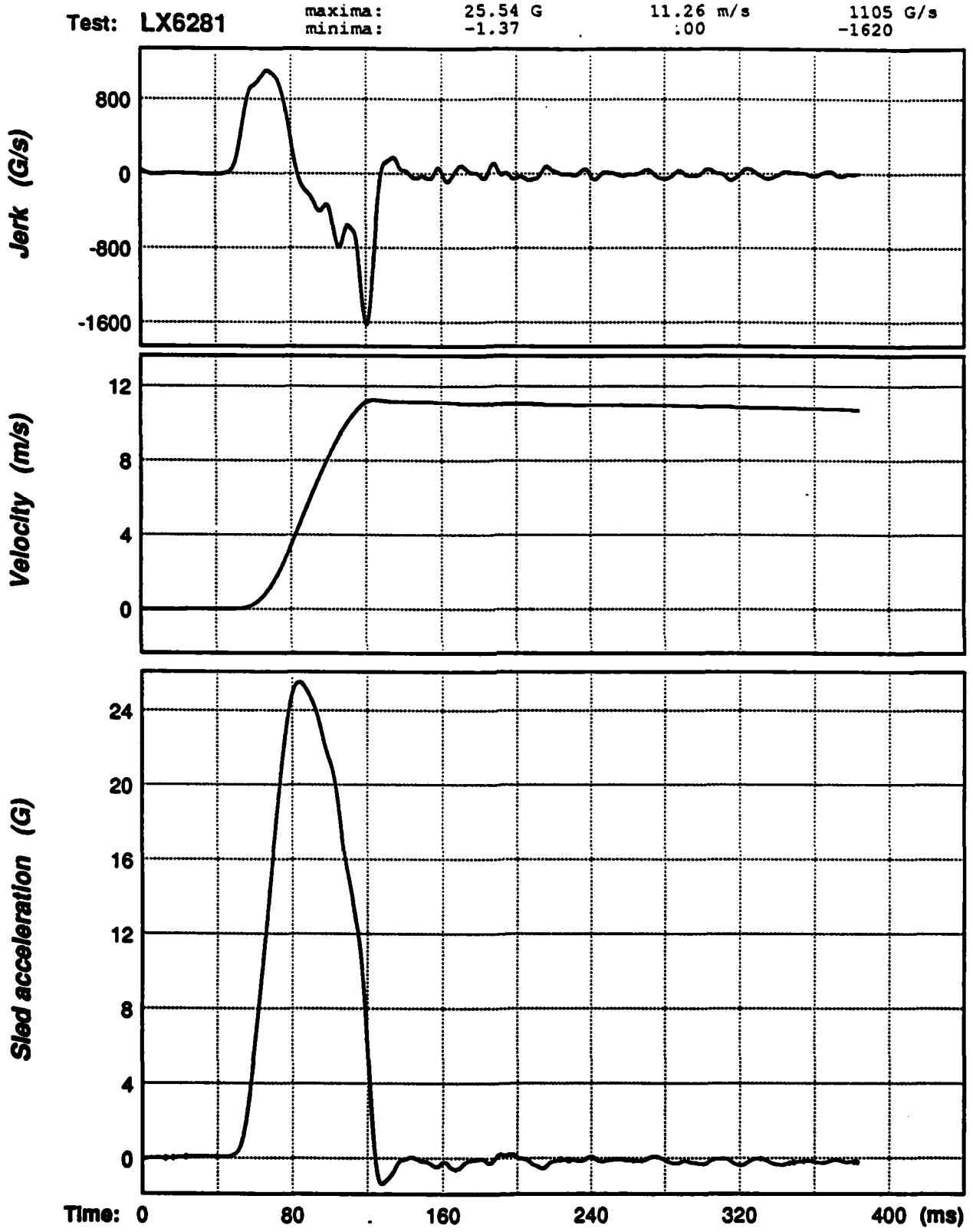

Figure C-9. Sled acceleration signal and its computed velocity and jerk for test LX6281.

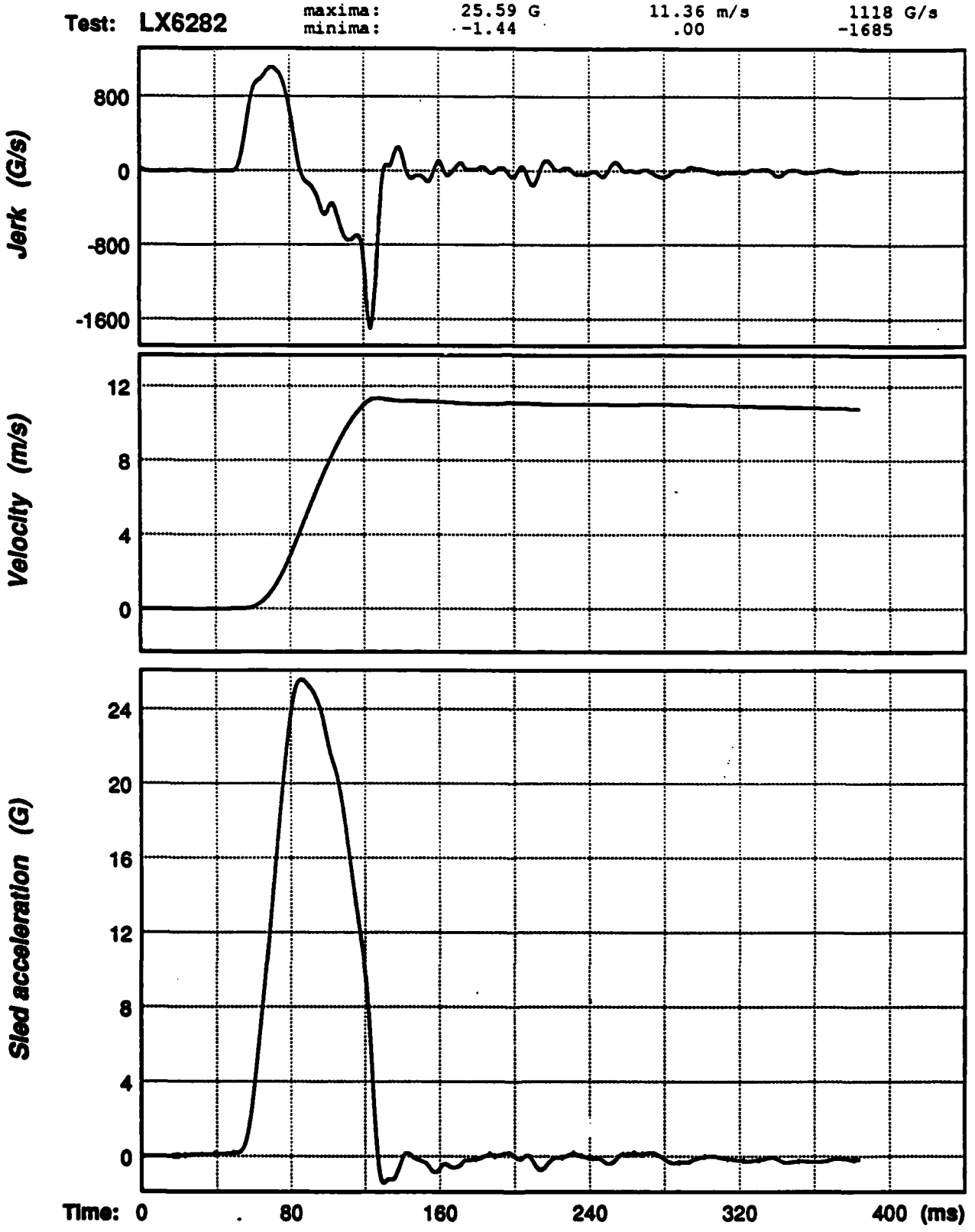

Figure C-10. Sled acceleration signal and its computed velocity and jerk for test LX6282.

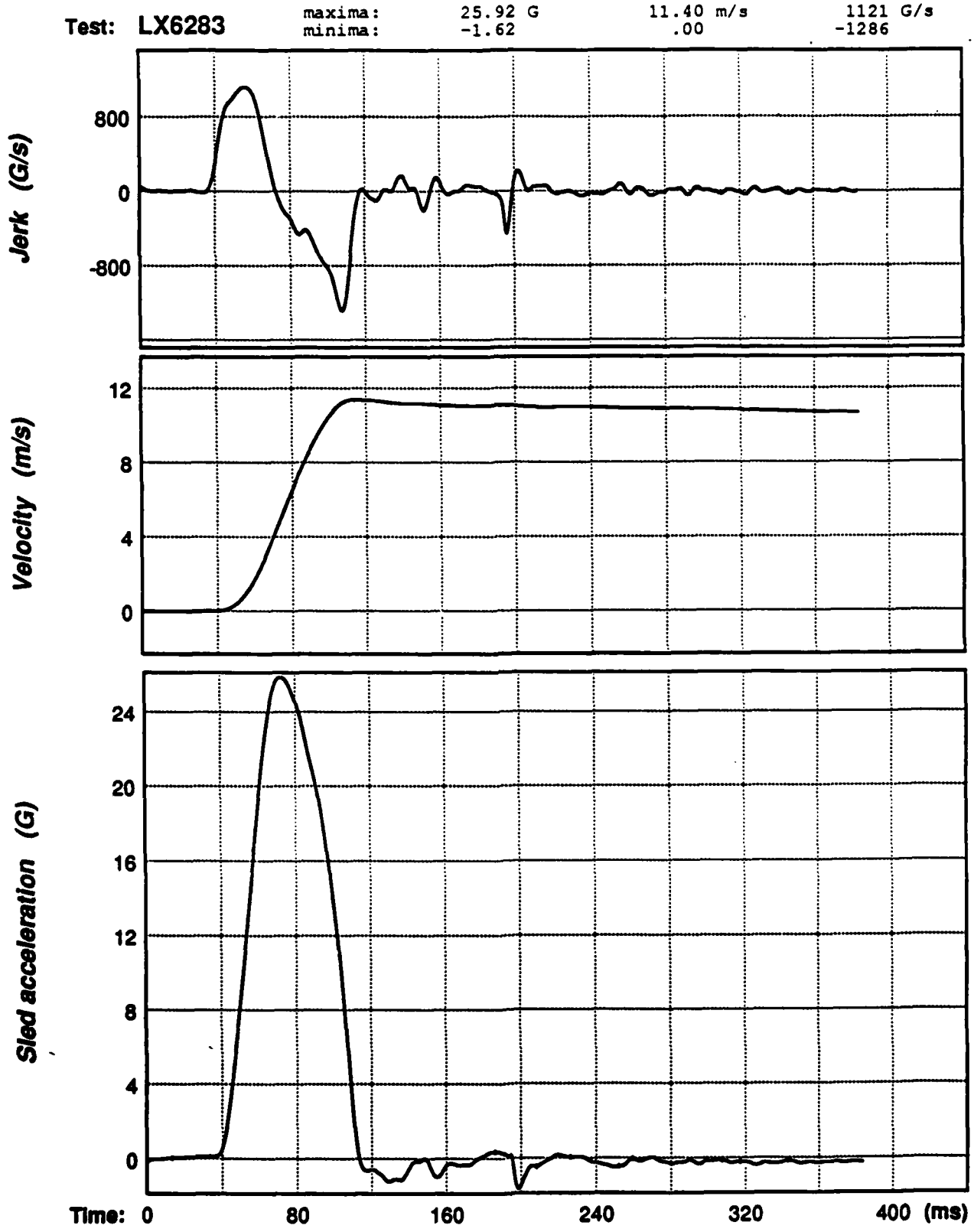

Figure C-11. Sled acceleration signal and its computed velocity and jerk for test LX6283.

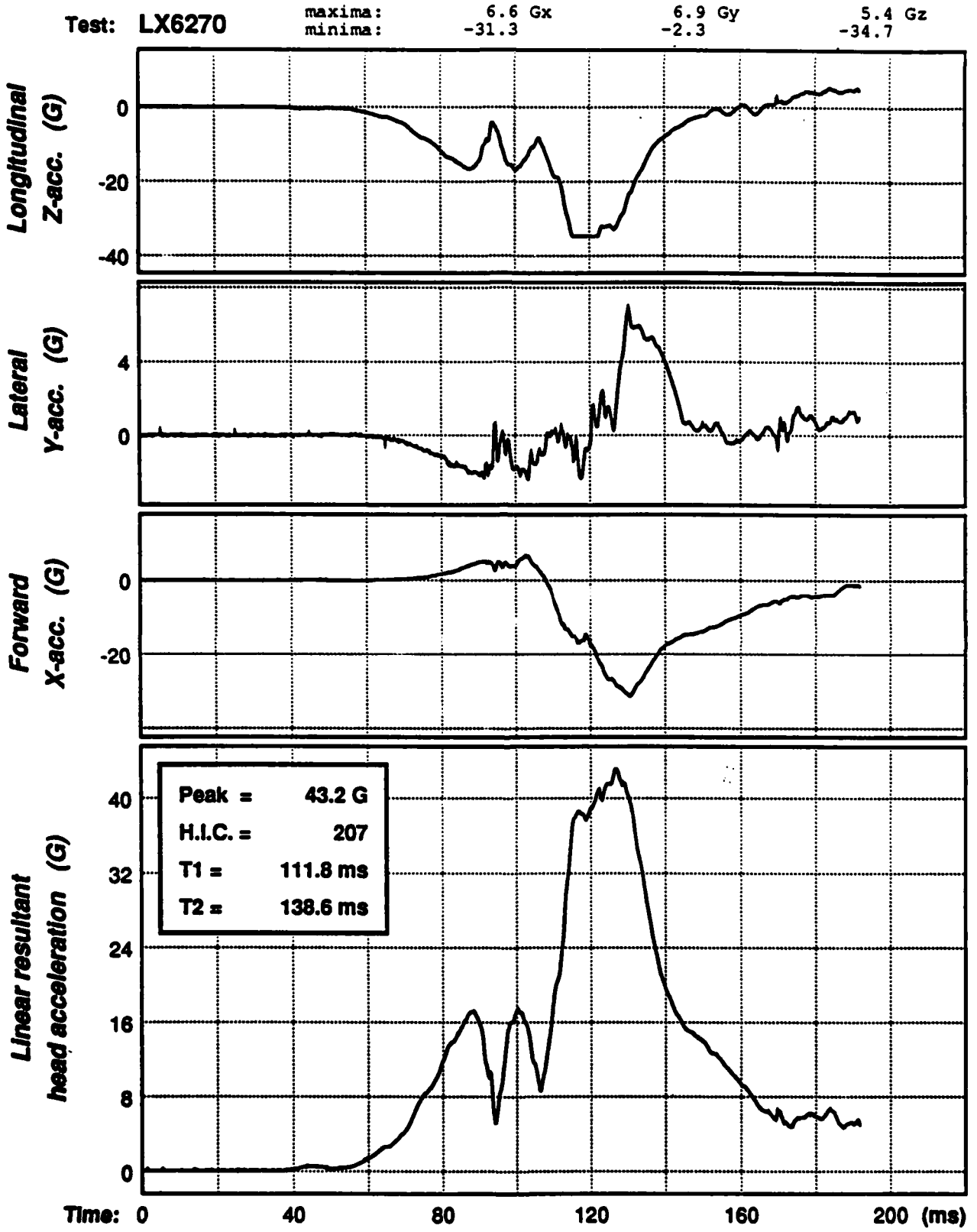

Figure C-12. Three components and resultant of the linear head acceleration for test LX6270.

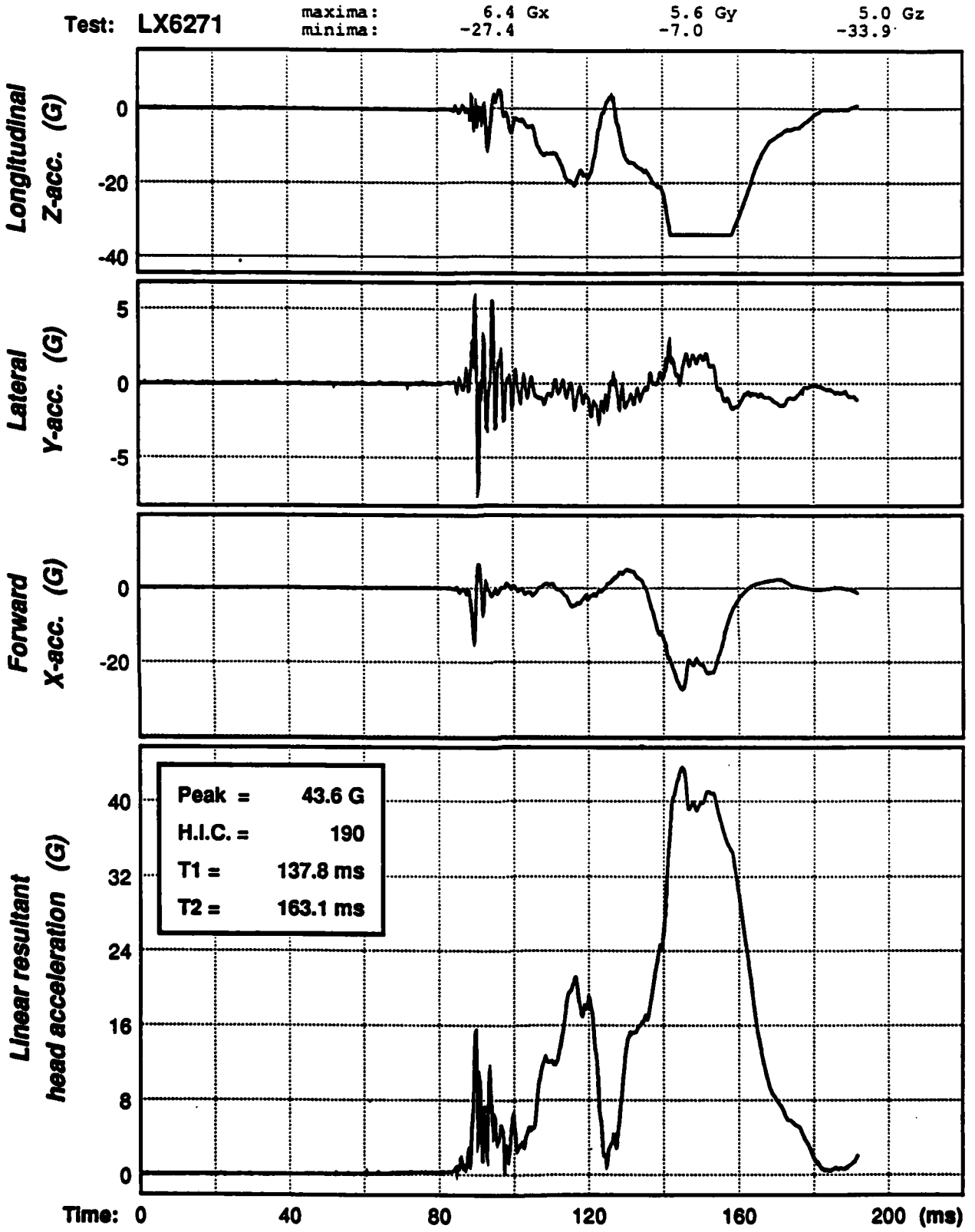

Figure C-13. Three components and resultant of the linear head acceleration for test LX6271.

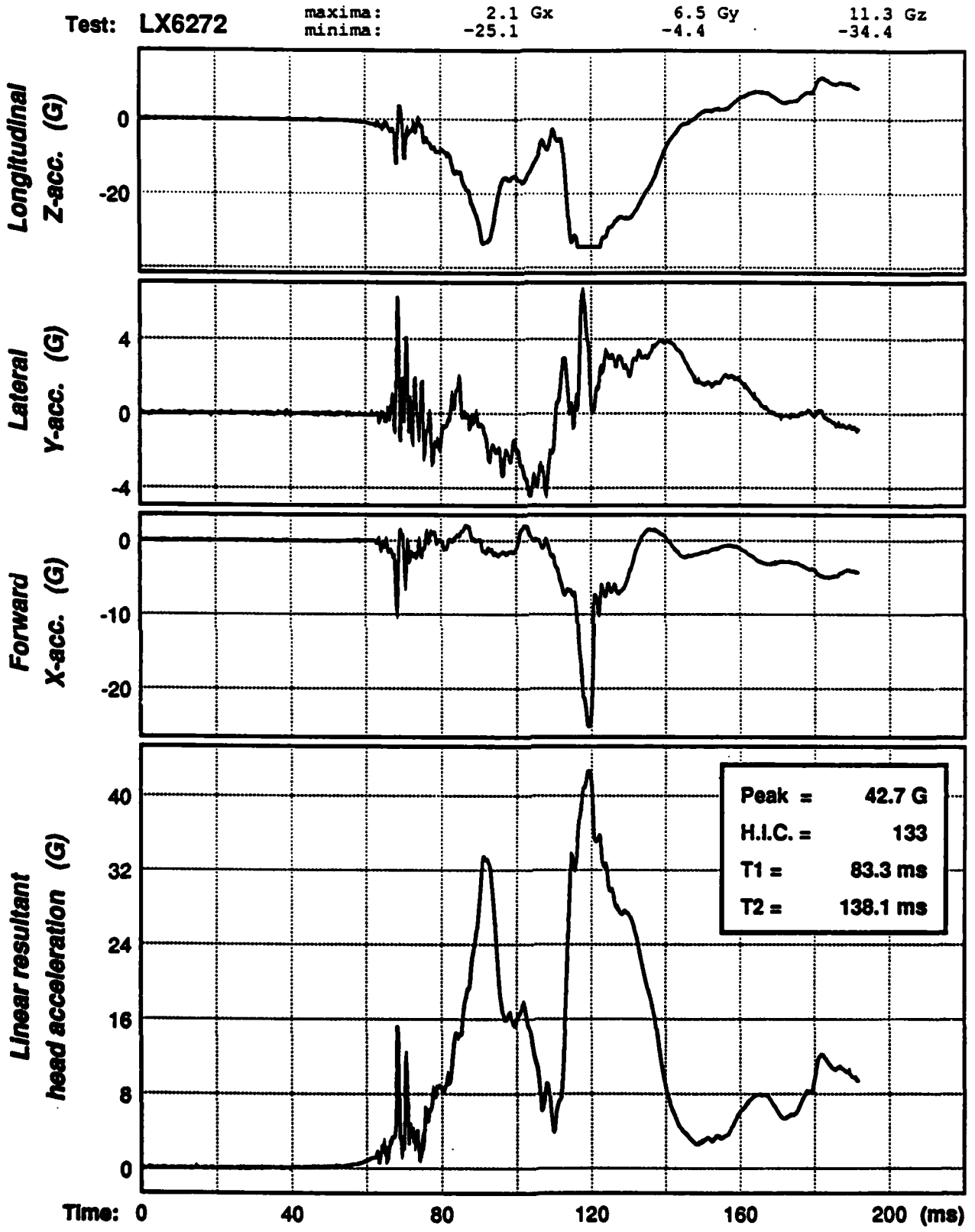

Figure C-14. Three components and resultant of the linear head acceleration for test LX6272.

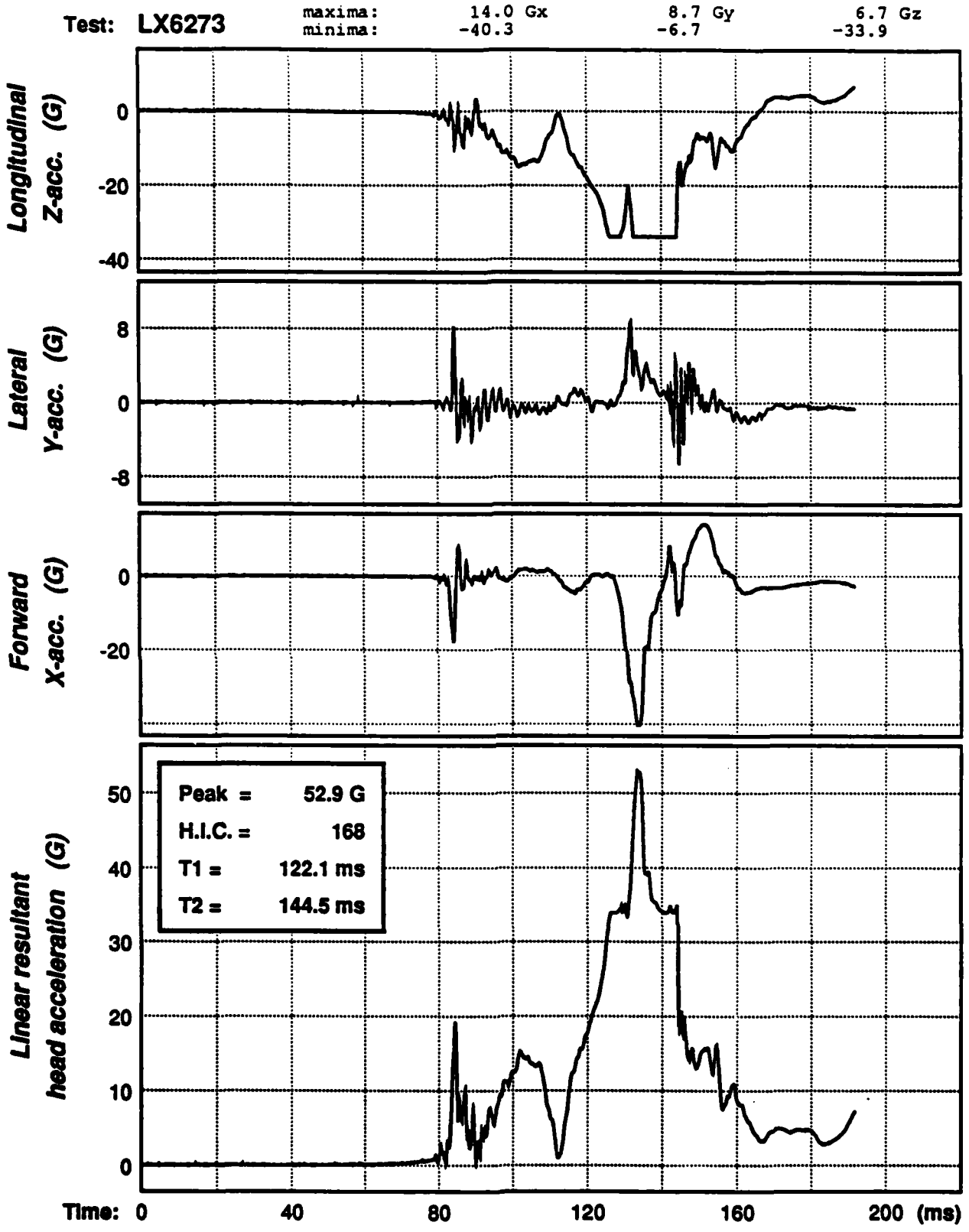

Figure C-15. Three components and resultant of the linear head acceleration for test LX6273.

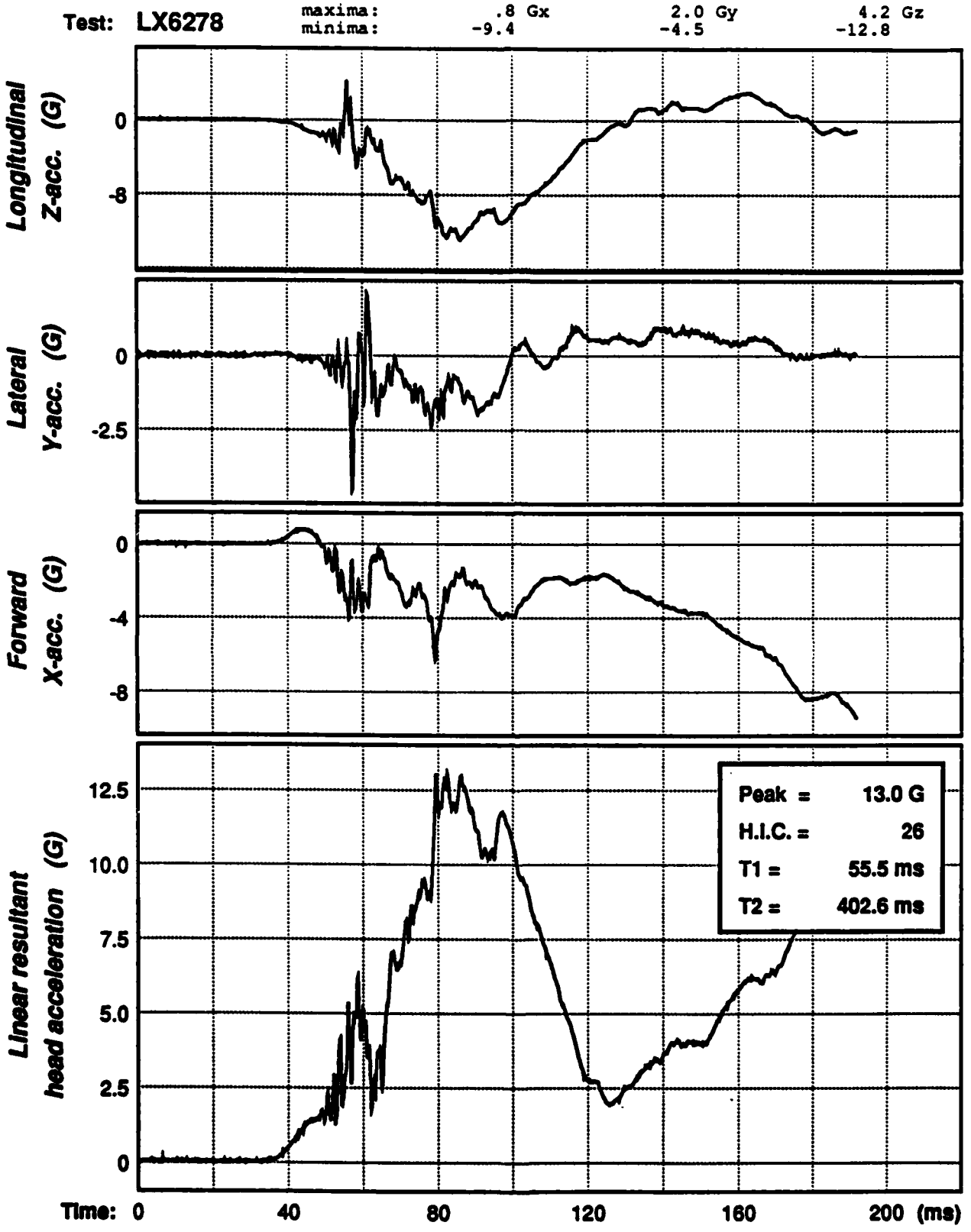

Figure C-16. Three components and resultant of the linear head acceleration for test LX6278.

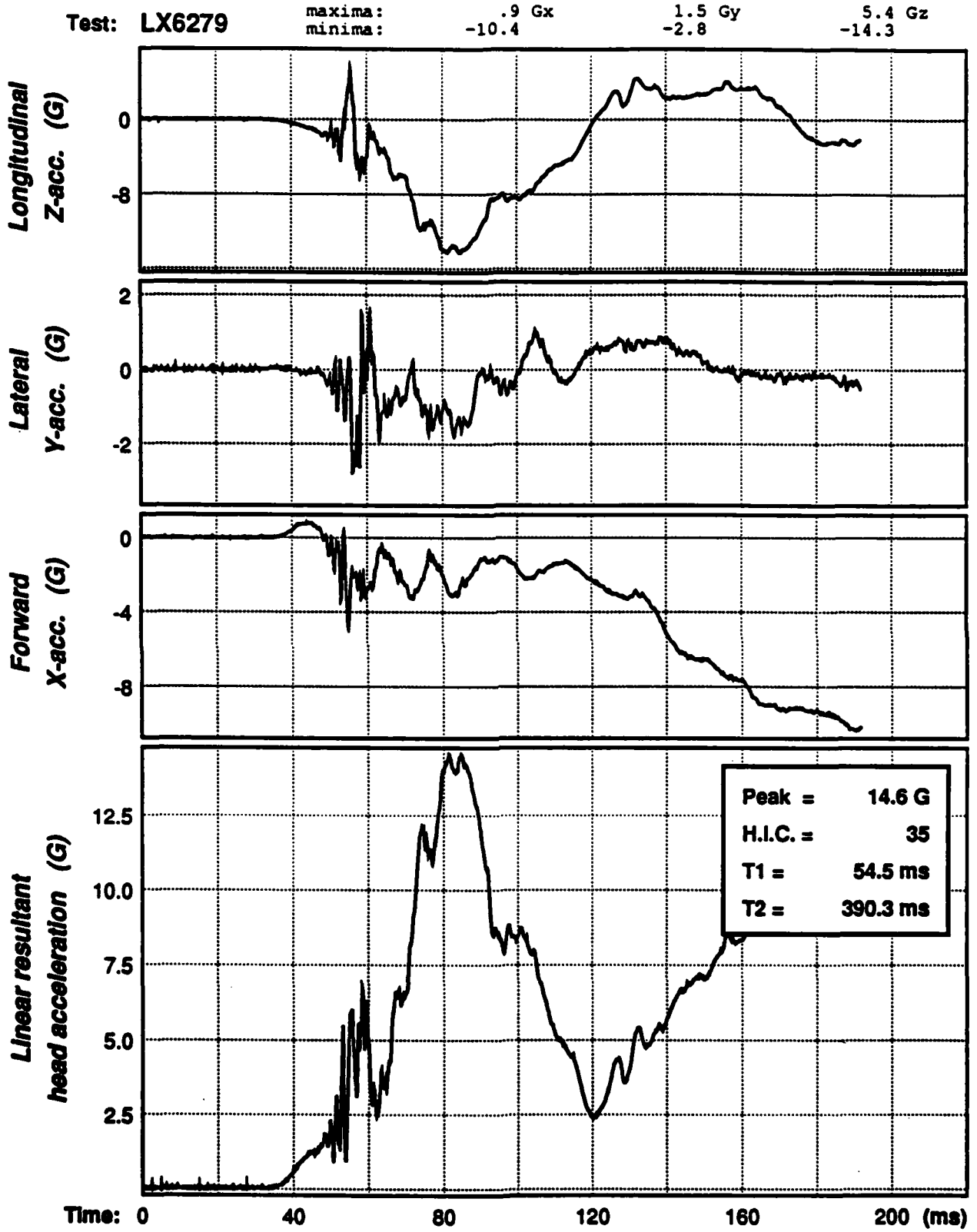

Figure C-17. Three components and resultant of the linear head acceleration for test LX6279.

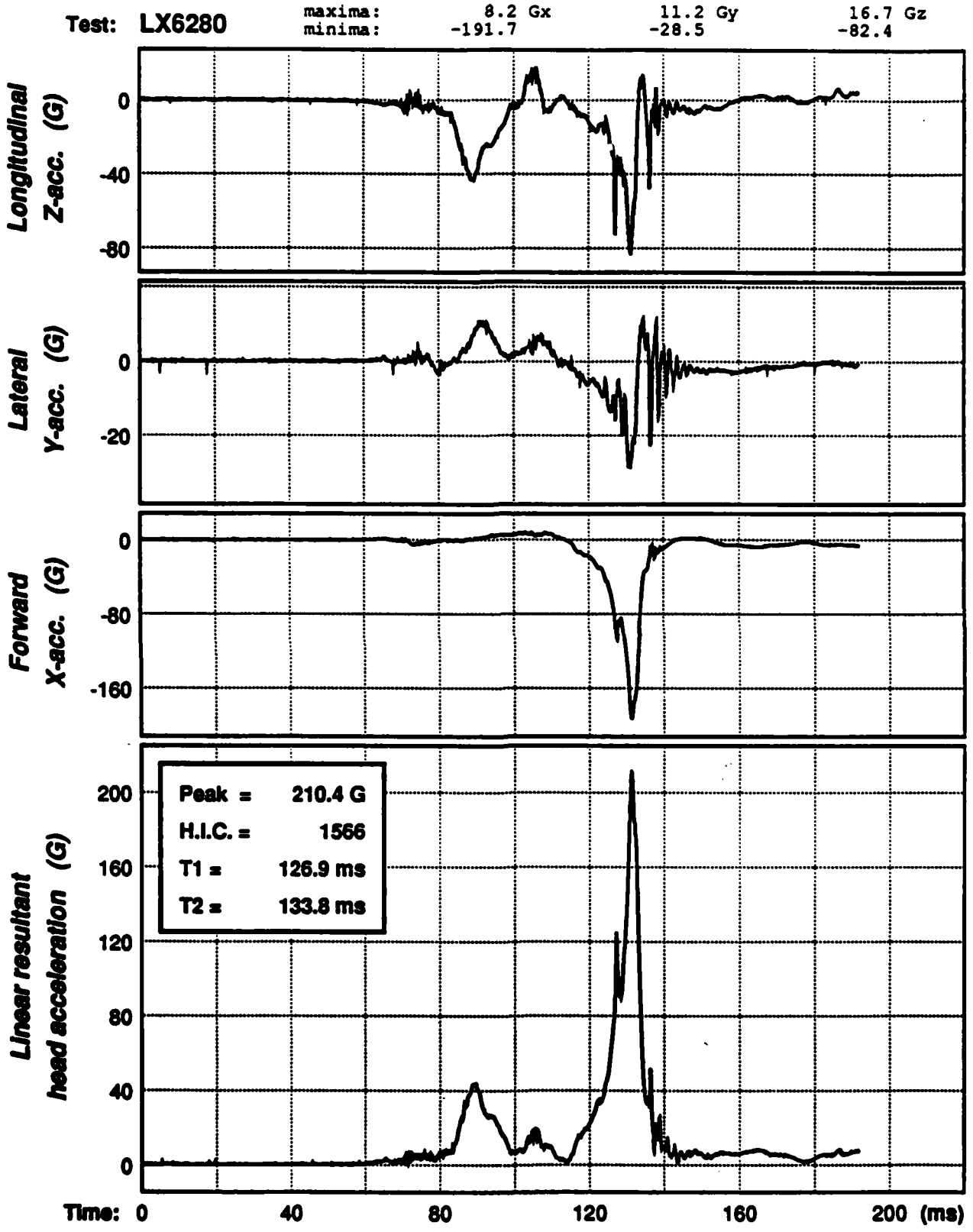

Figure C-18. Three components and resultant of the linear head acceleration for test LX6280.

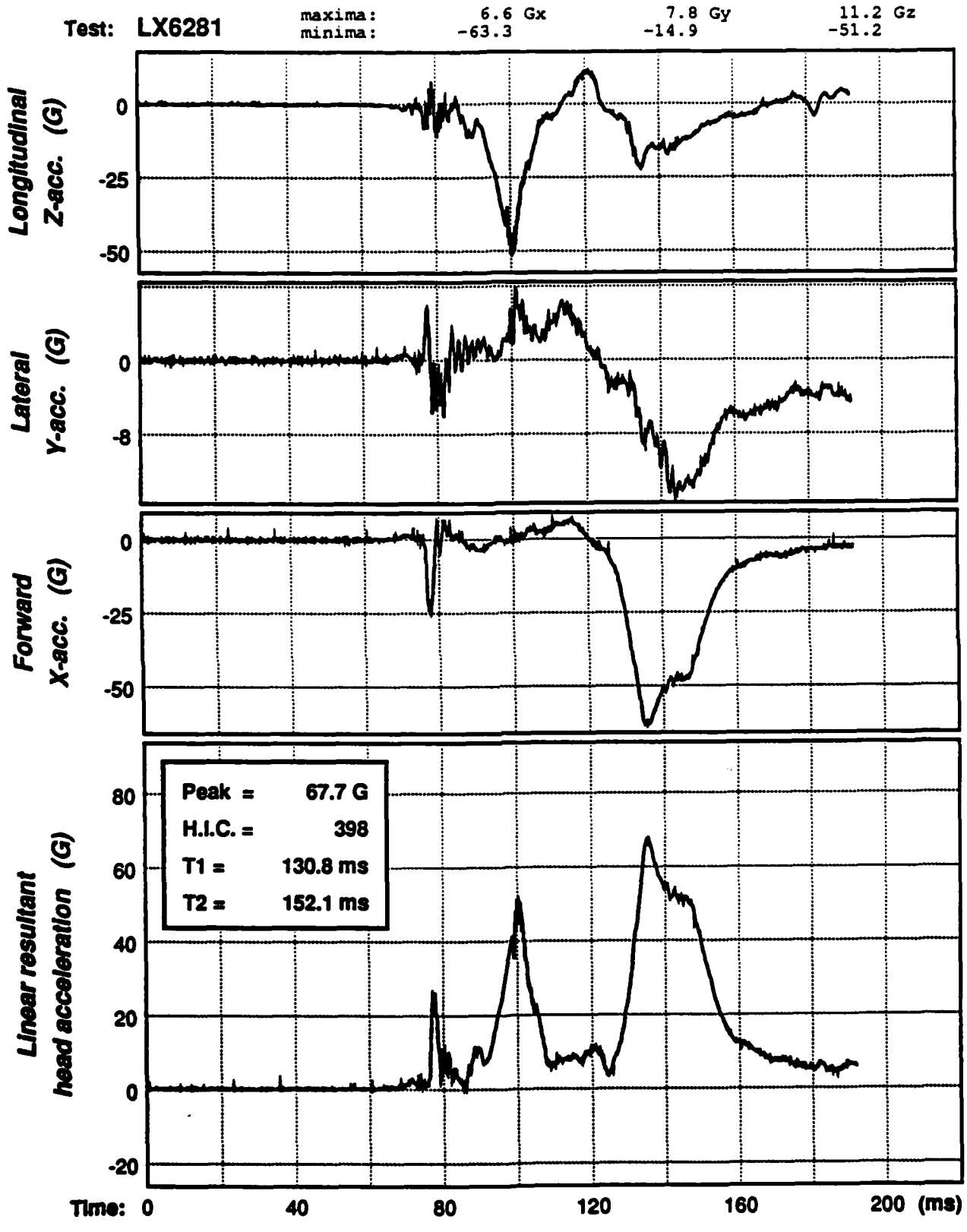

Figure C-19. Three components and resultant of the linear head acceleration for test LX6281.

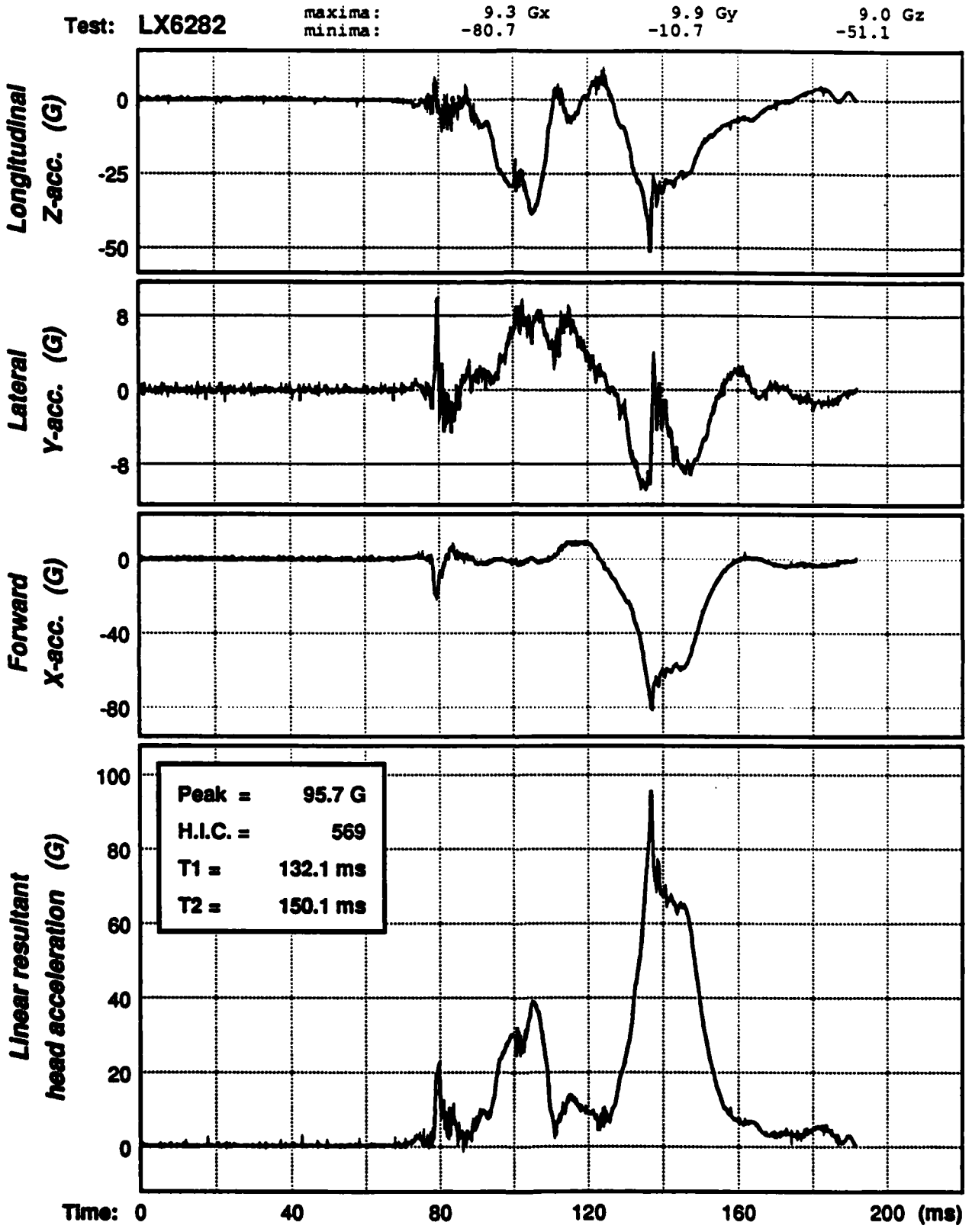

Figure C-20. Three components and resultant of the linear head acceleration for test LX6282.

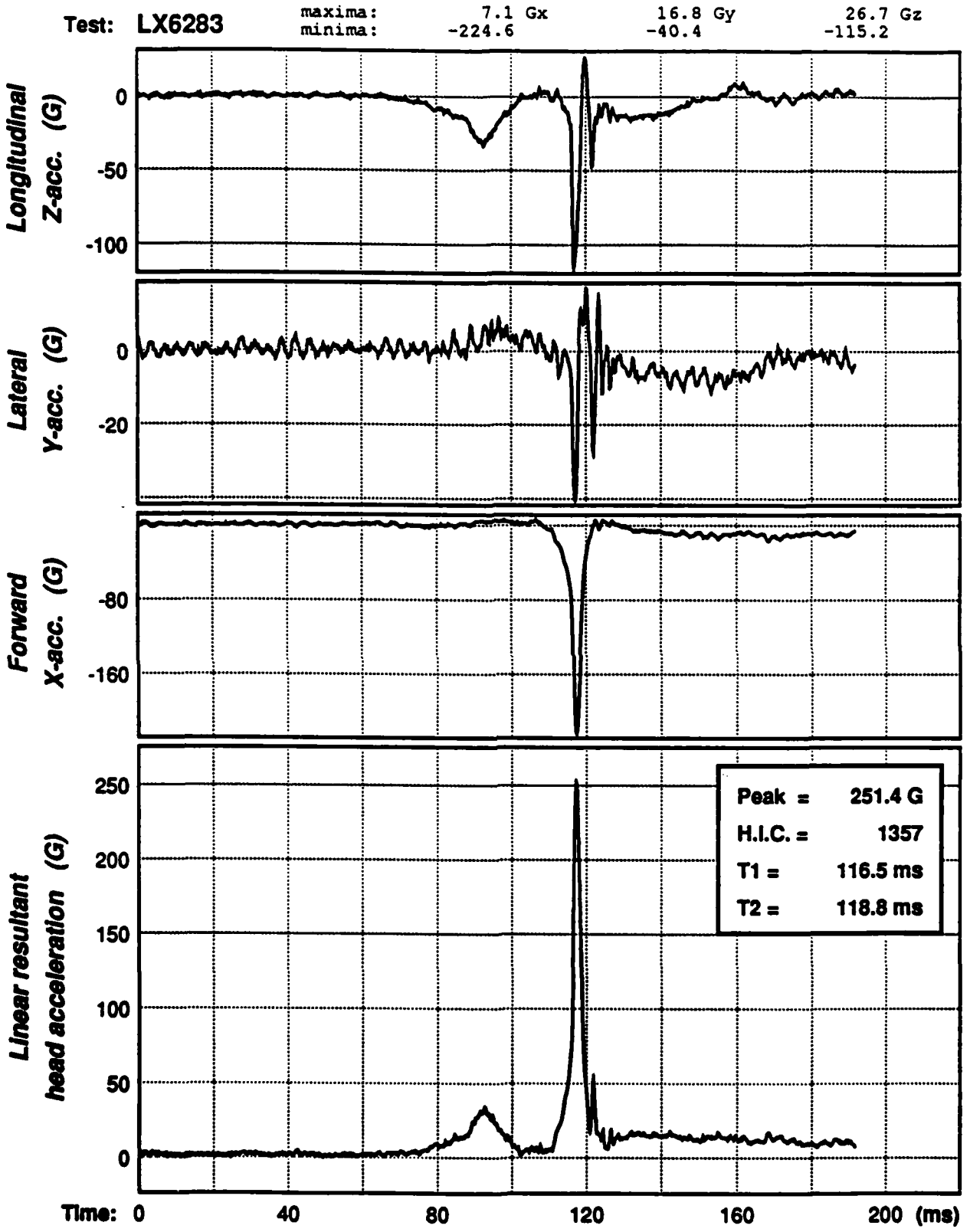

Figure C-21. Three components and resultant of the linear head acceleration for test LX6283.

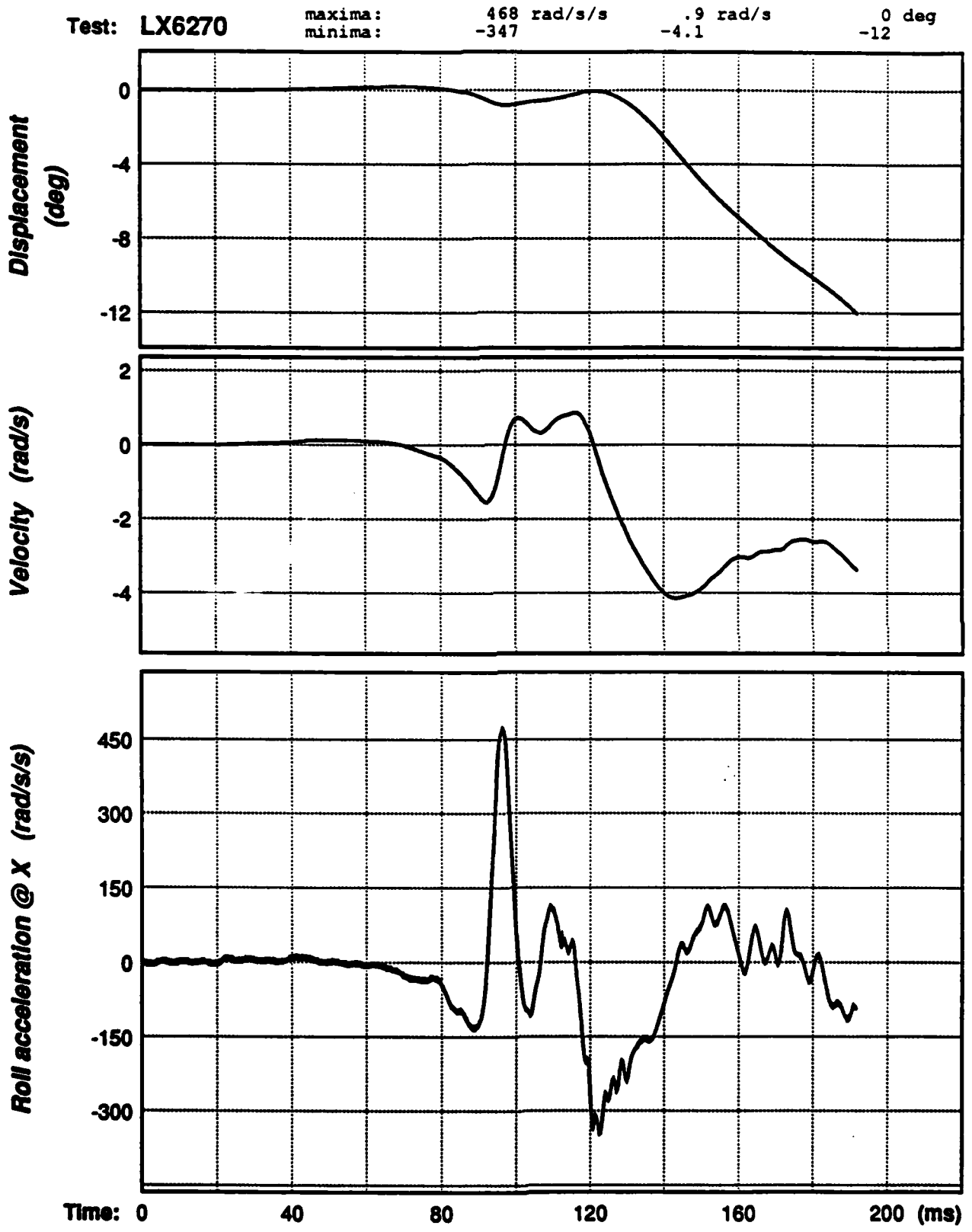

Figure C-22. Head roll angular acceleration, velocity, and displacement signals for test LX6270.

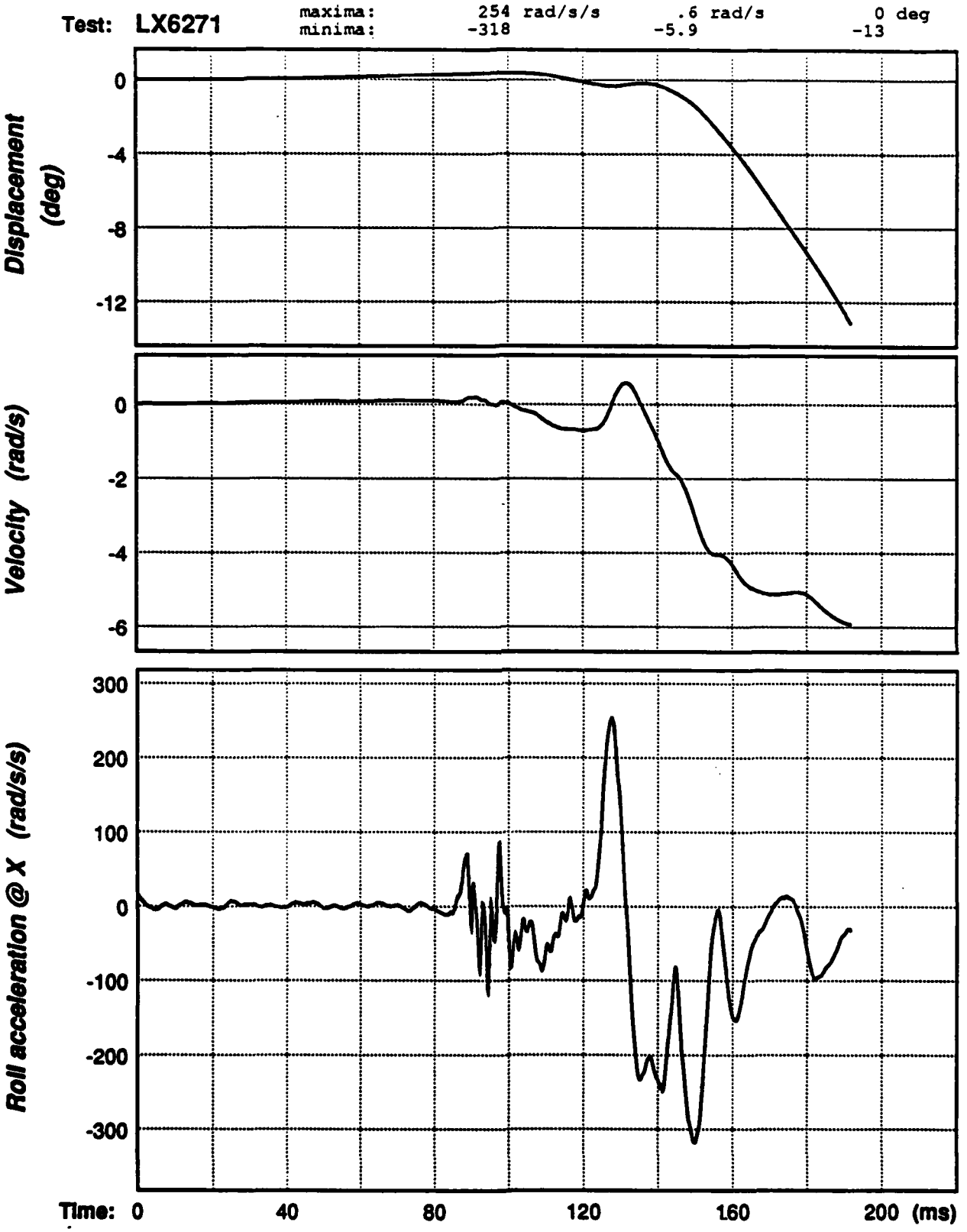

Figure C-23. Head roll angular acceleration, velocity, and displacement signals for test LX6271.

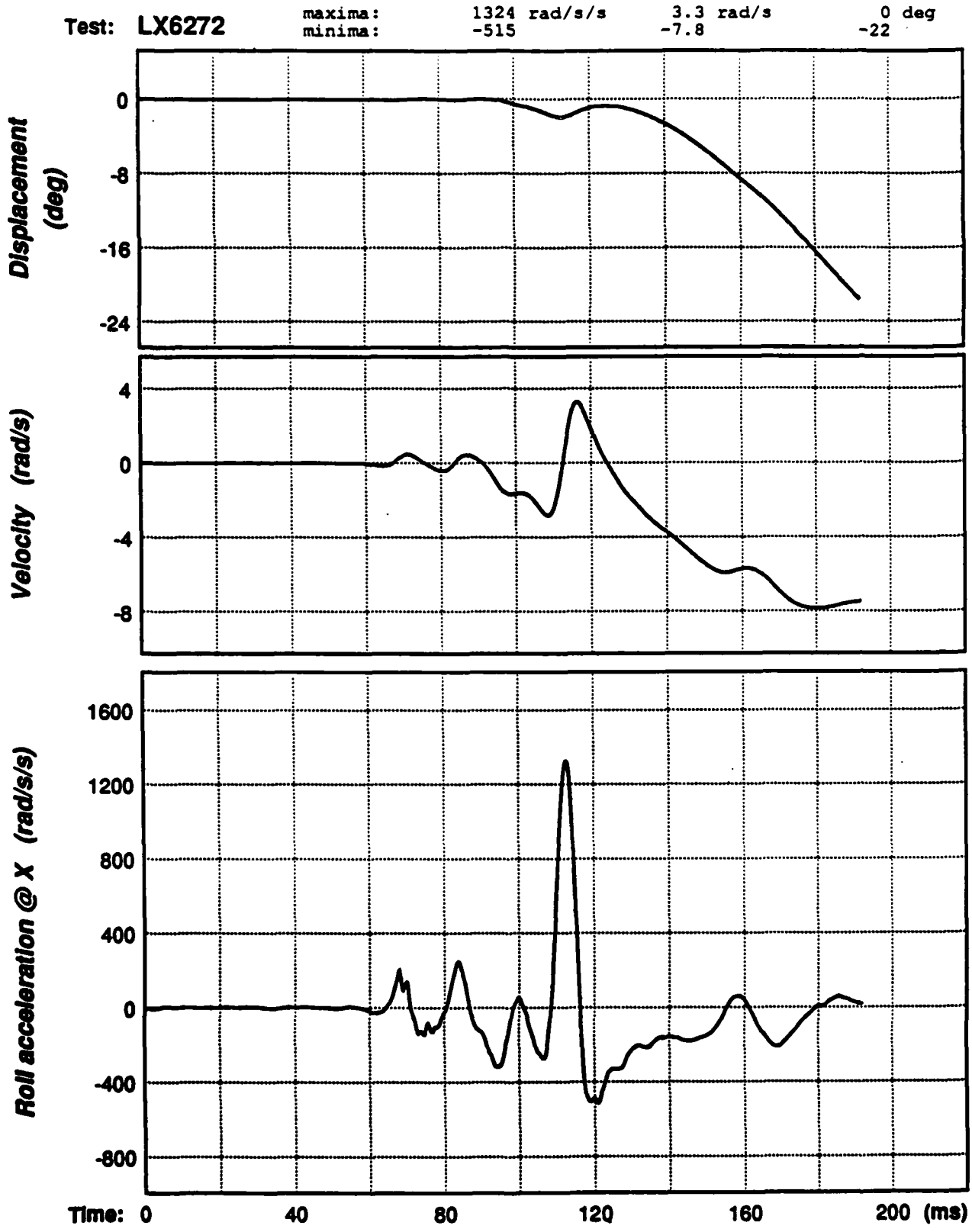

Figure C-24. Head roll angular acceleration, velocity, and displacement signals for test LX6272.

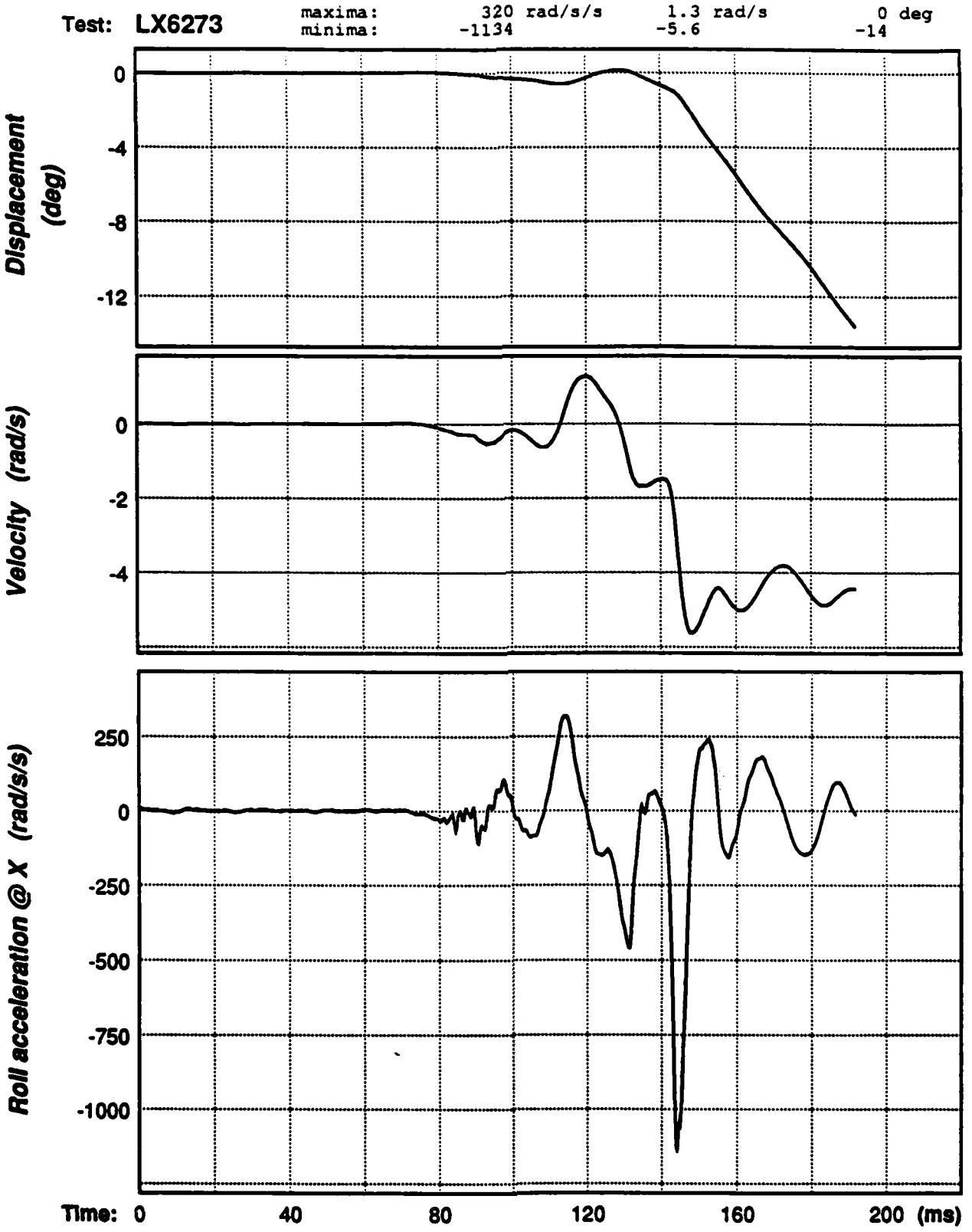

Figure C-25. Head roll angular acceleration, velocity, and displacement signals for test LX6273.

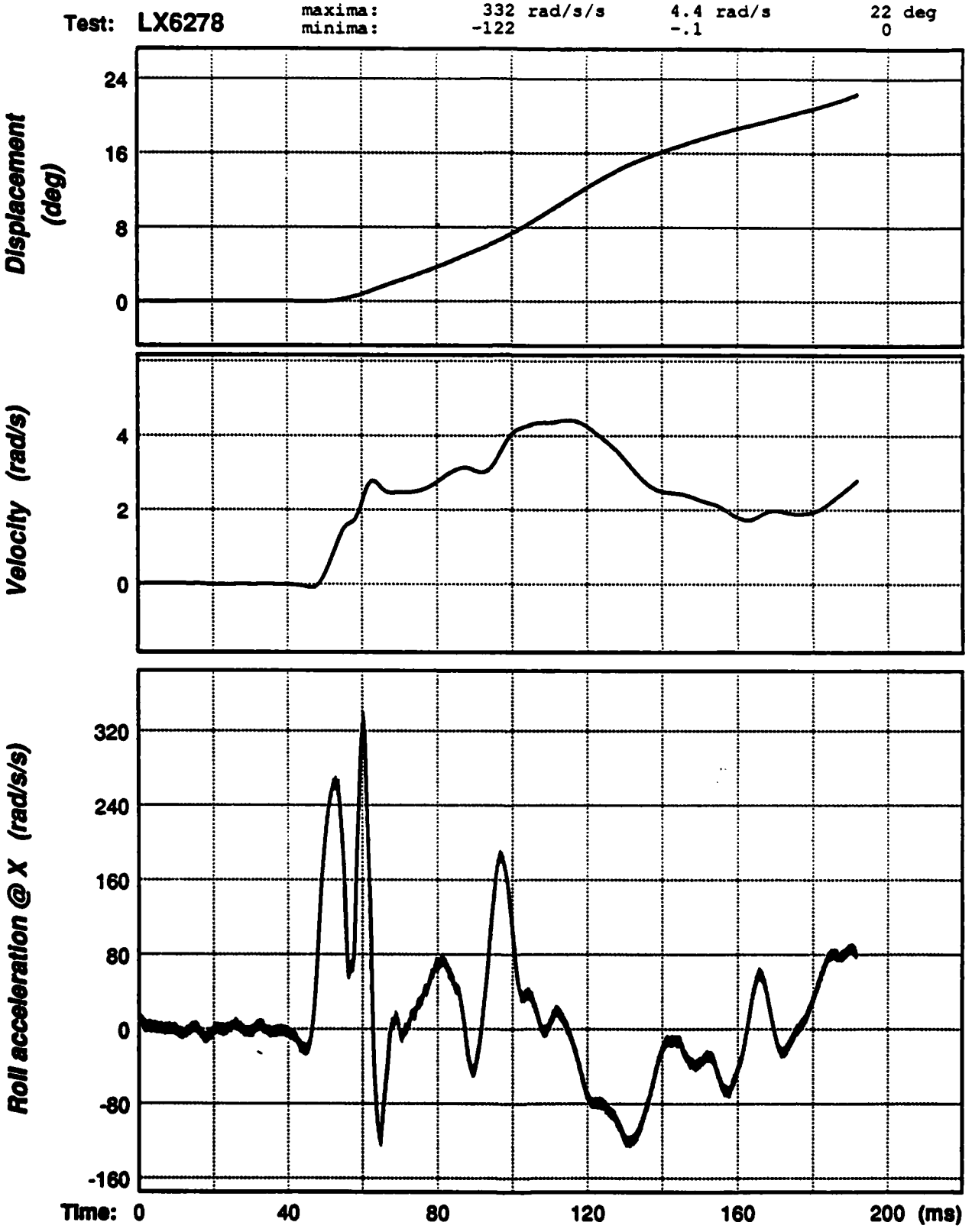

Figure C-26. Head roll angular acceleration, velocity, and displacement signals for test LX6278.

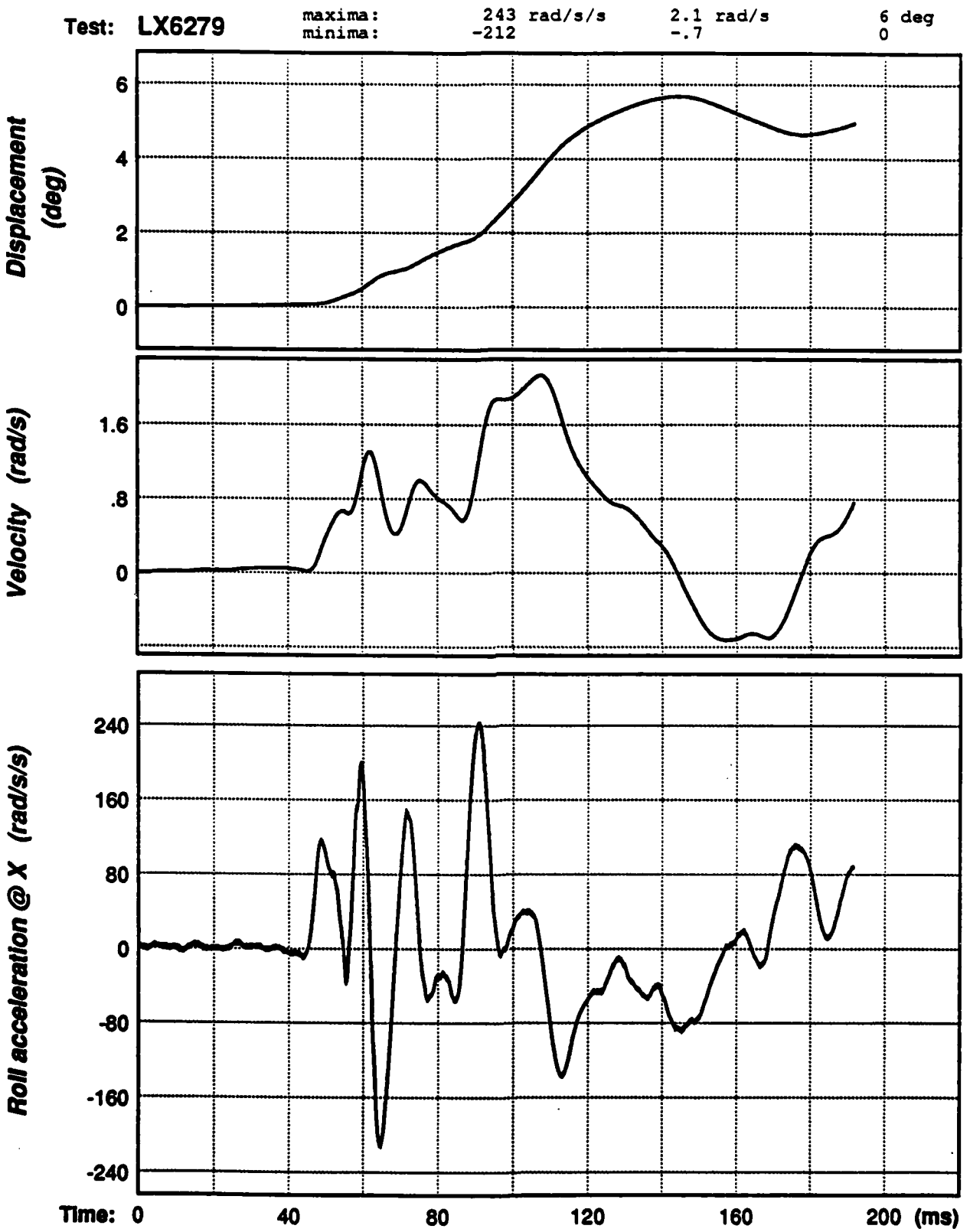

Figure C-27. Head roll angular acceleration, velocity, and displacement signals for test LX6279.

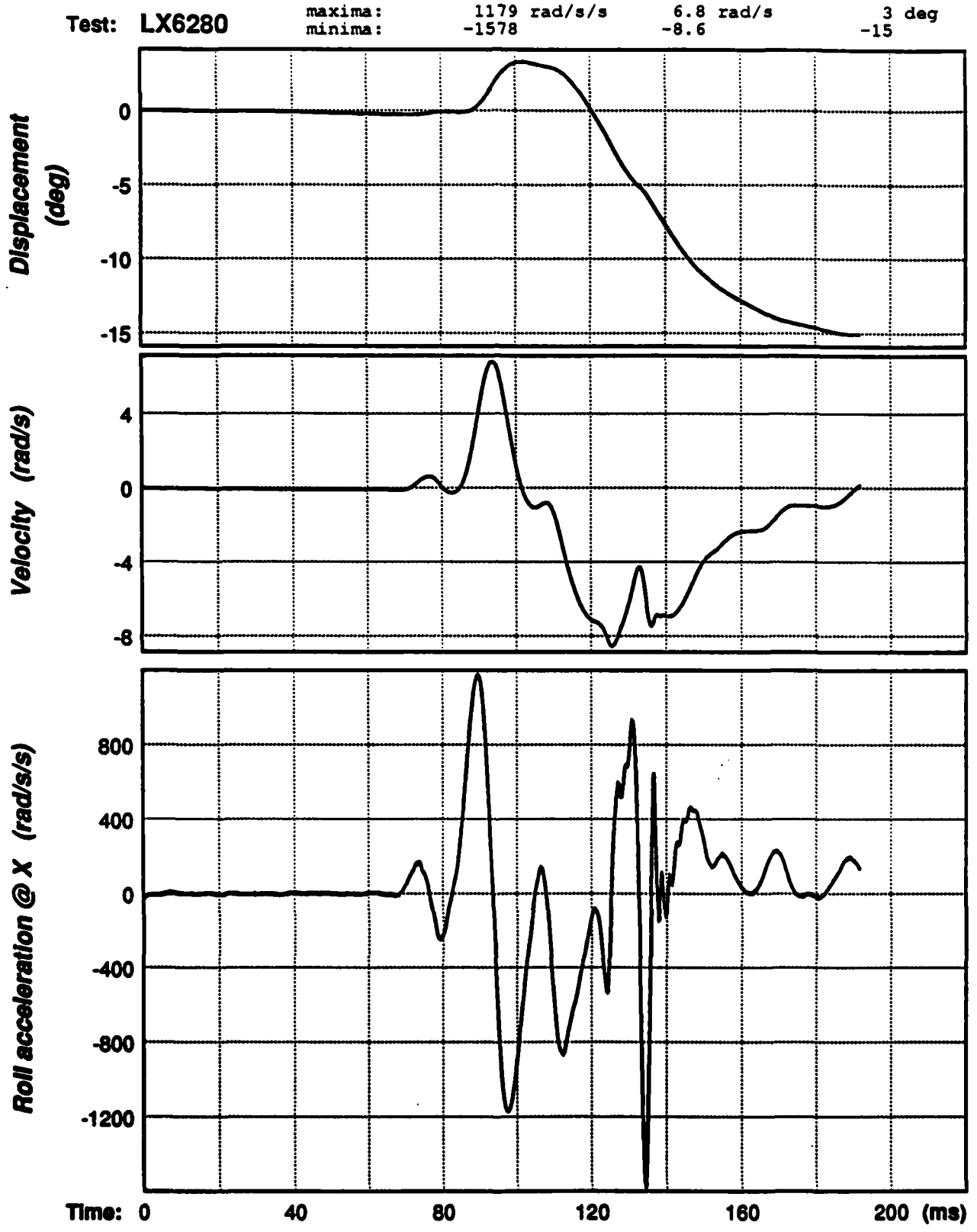

Figure C-28. Head roll angular acceleration, velocity, and displacement signals for test LX6280.

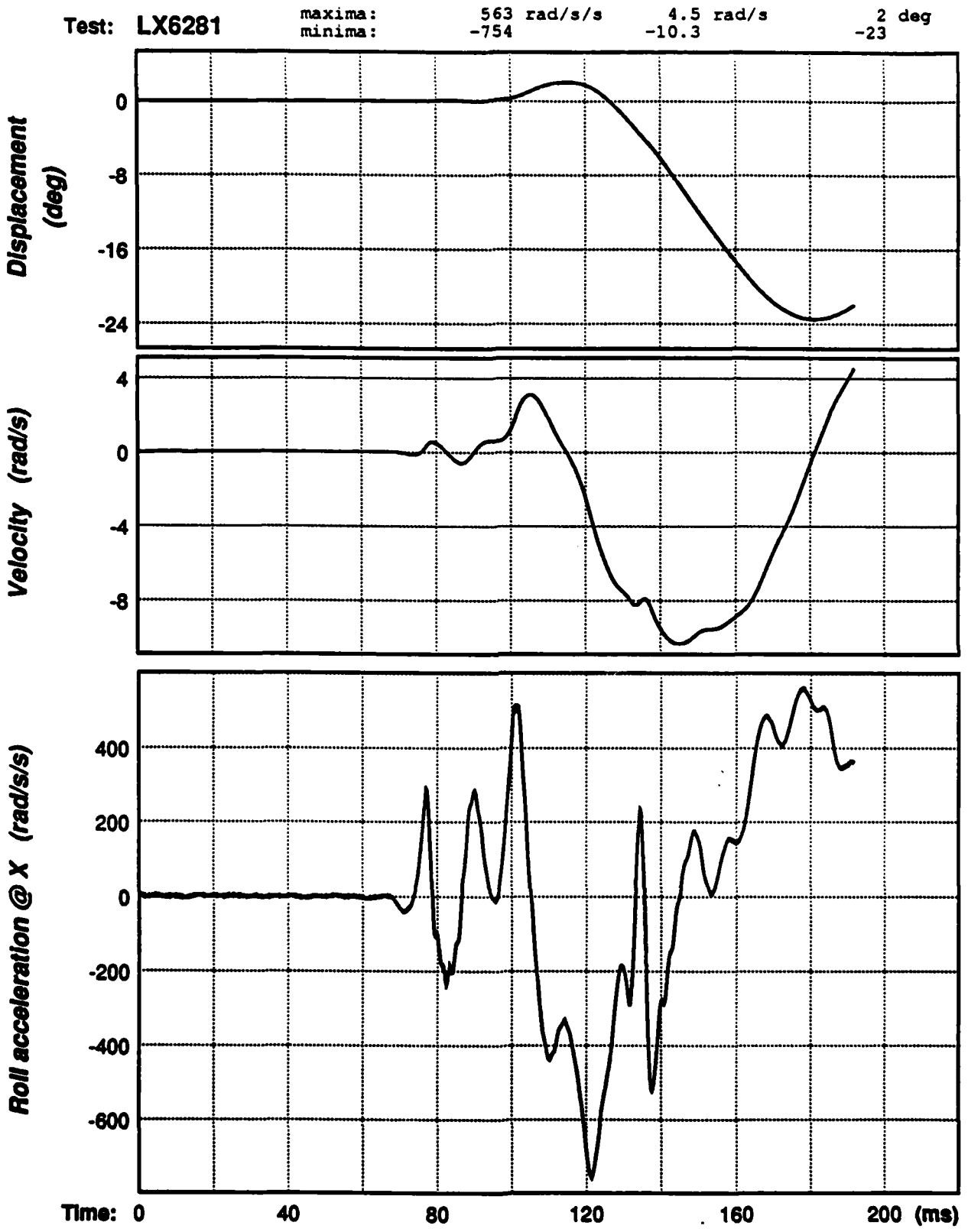

Figure C-29. Head roll angular acceleration, velocity, and displacement signals for test LX6281.

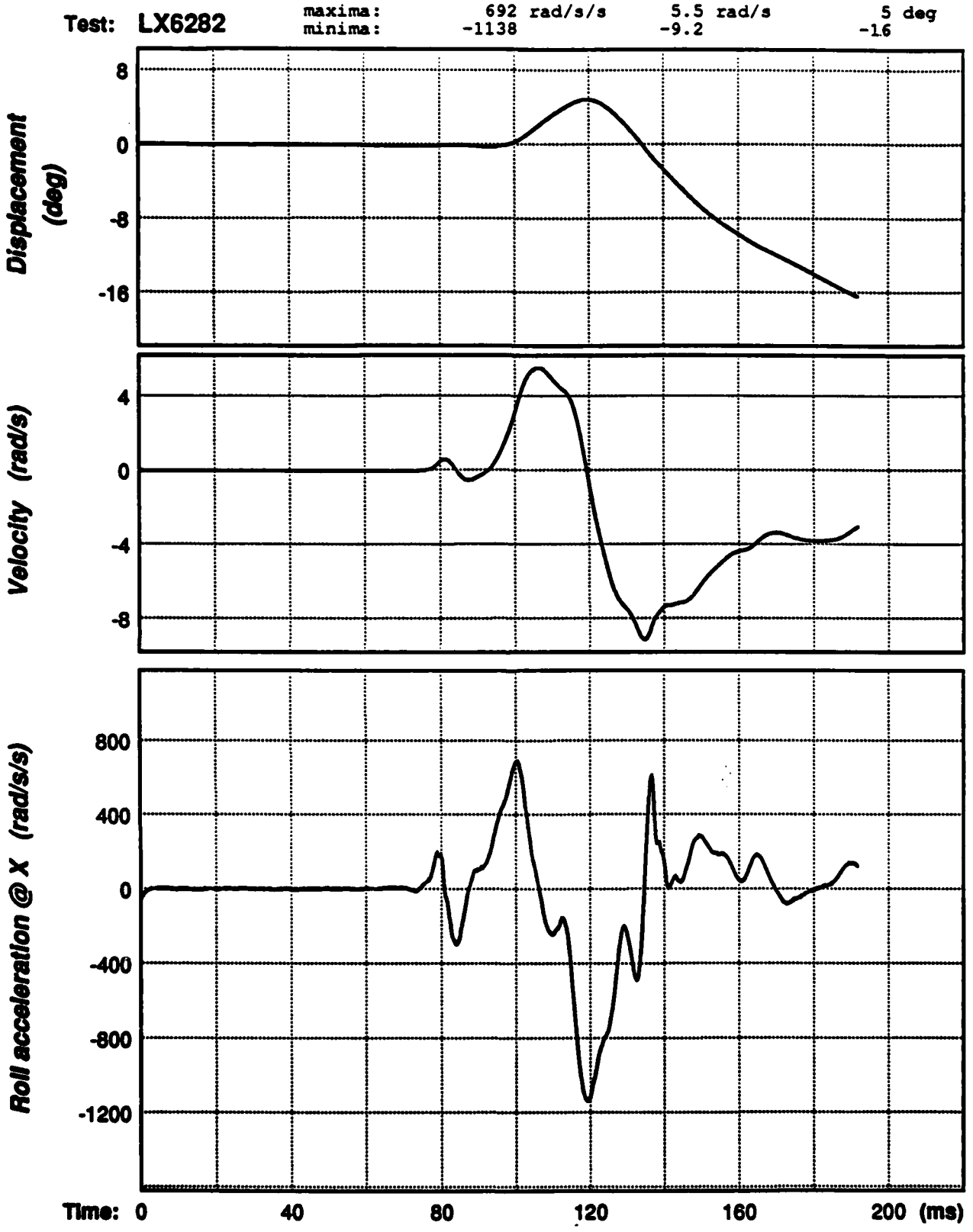

Figure C-30. Head roll angular acceleration, velocity, and displacement signals for test LX6282.

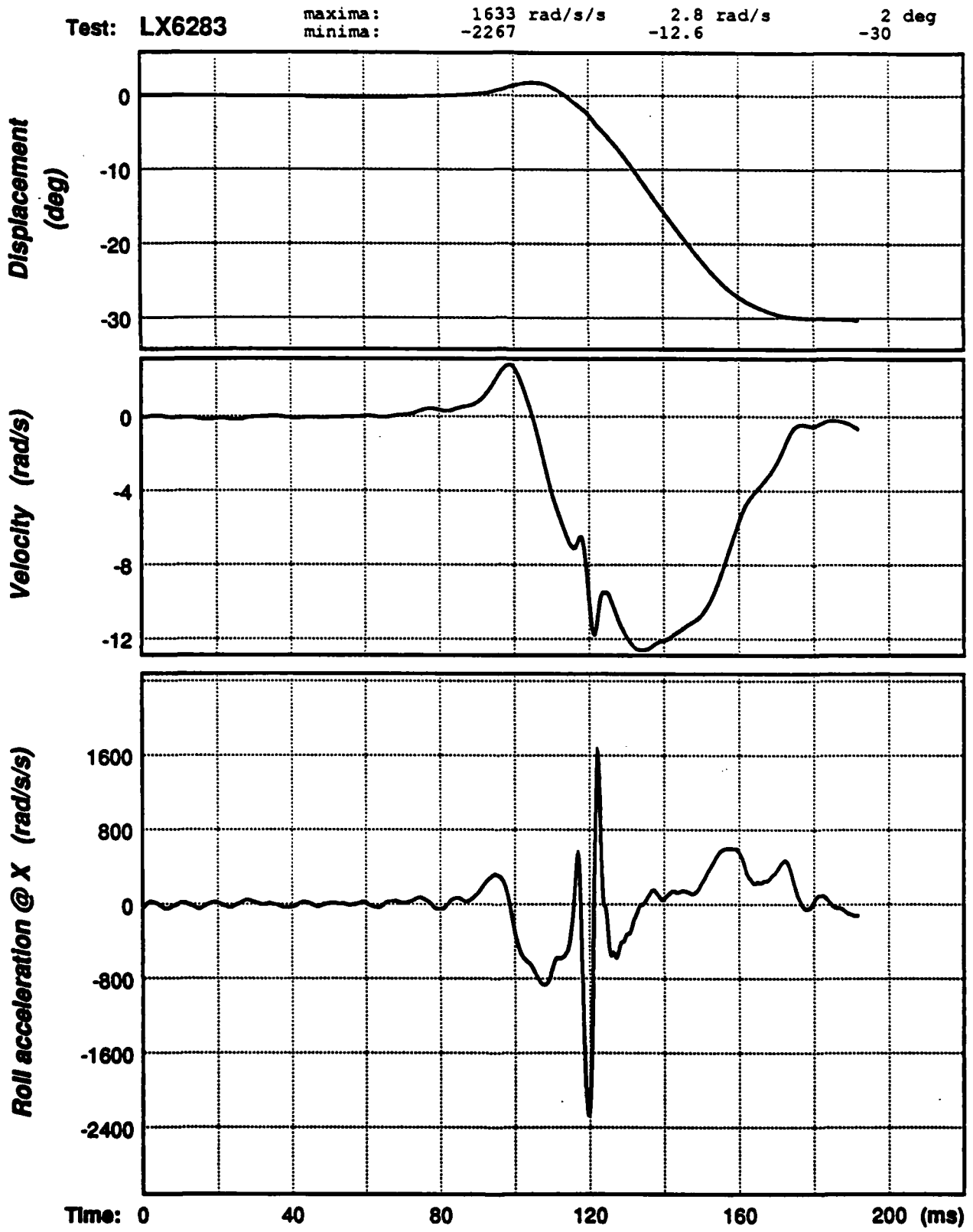

Figure C-31. Head roll angular acceleration, velocity, and displacement signals for test LX6283.

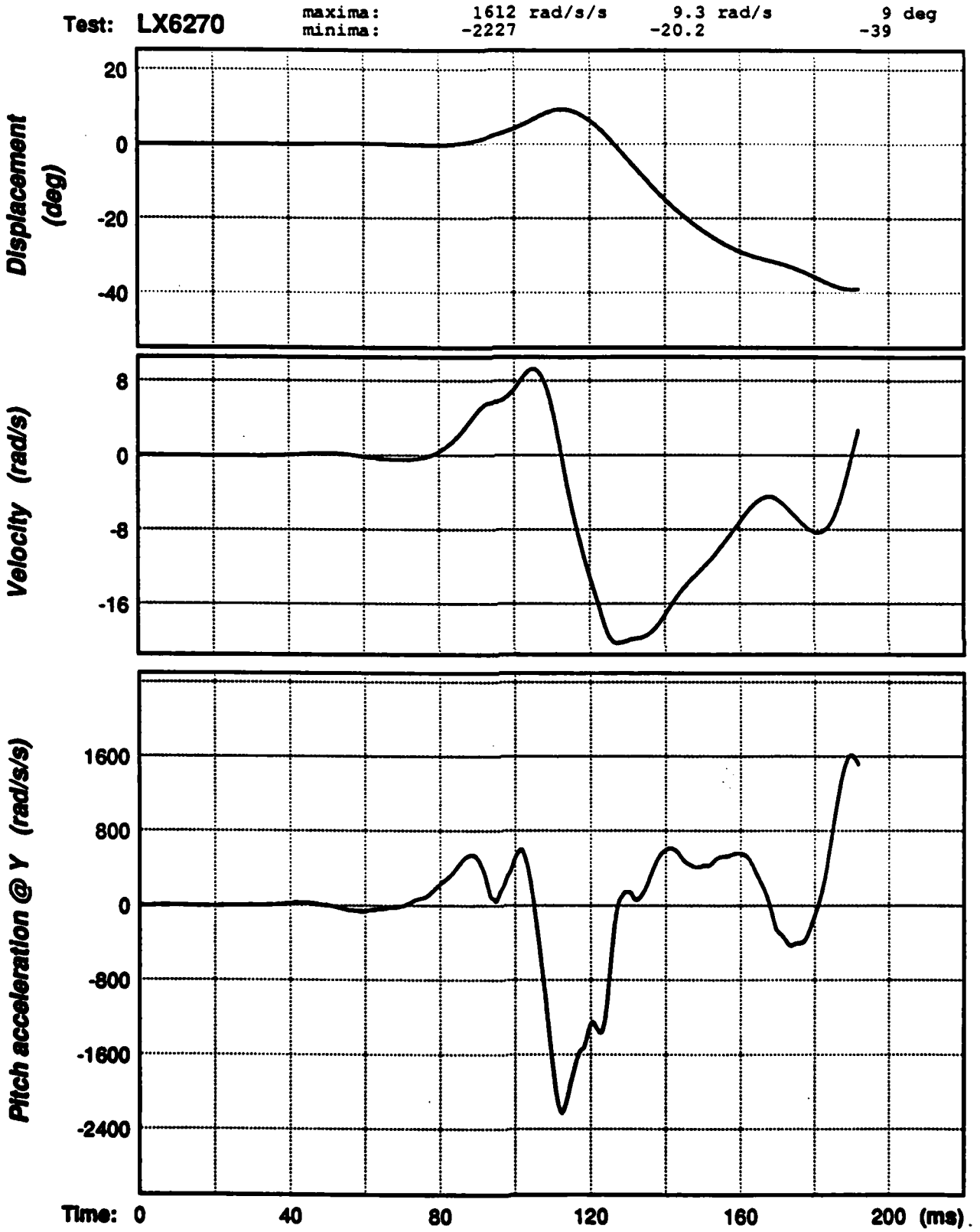

Figure C-32. Head pitch angular acceleration, velocity, and displacement signals for test LX6270.

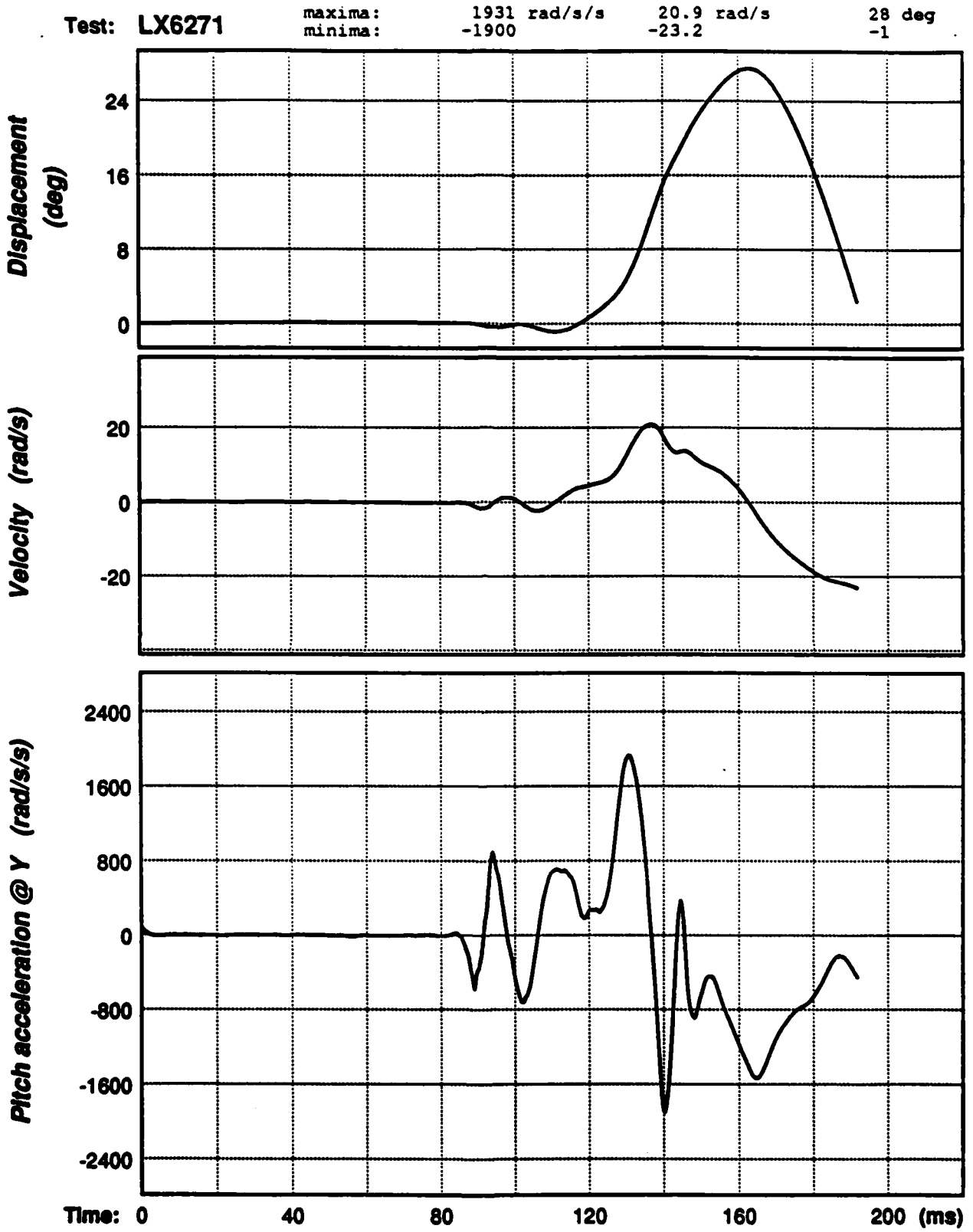

Figure C-33. Head pitch angular acceleration, velocity, and displacement signals for test LX6271.

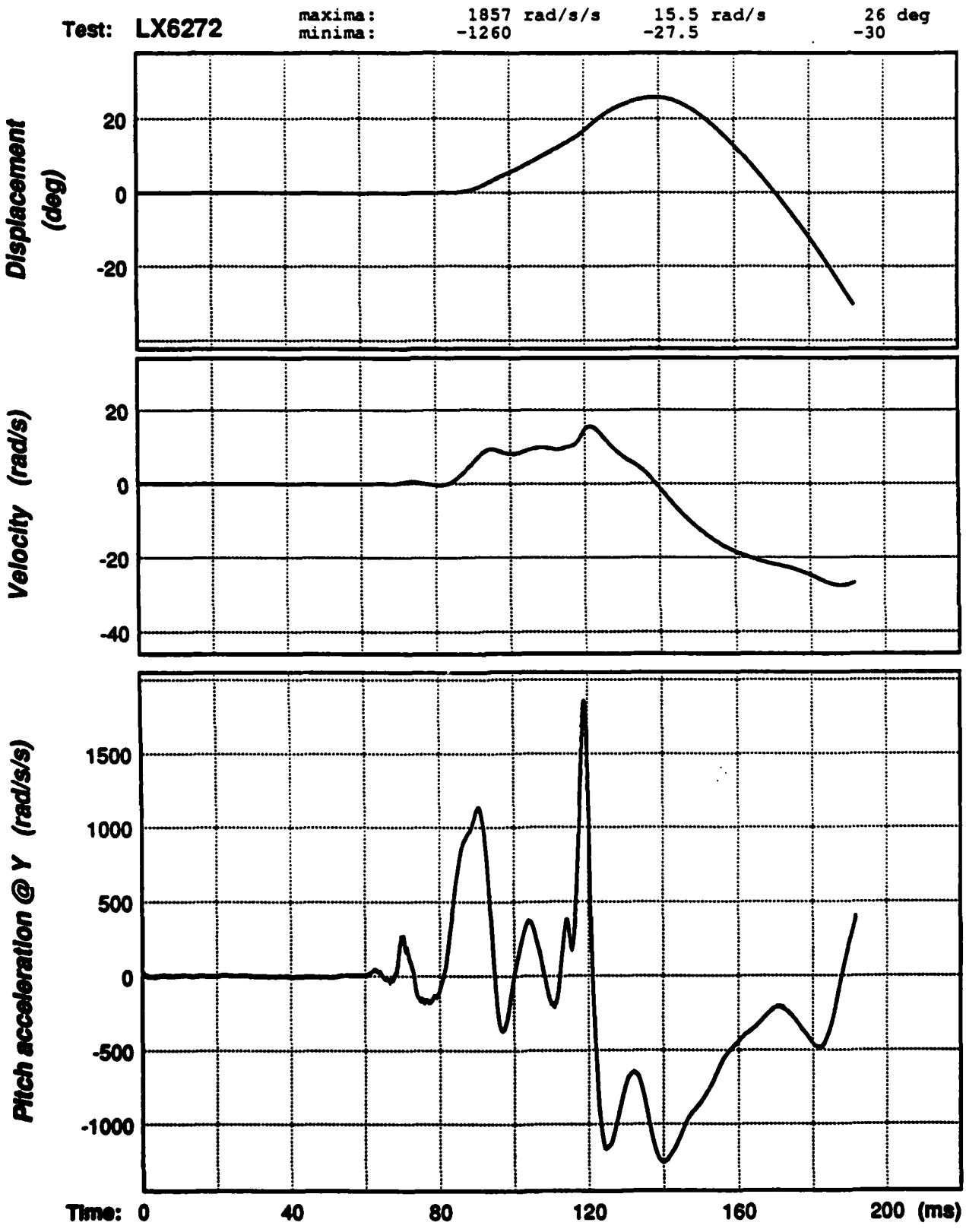

Figure C-34. Head pitch angular acceleration, velocity, and displacement signals for test LX6272.

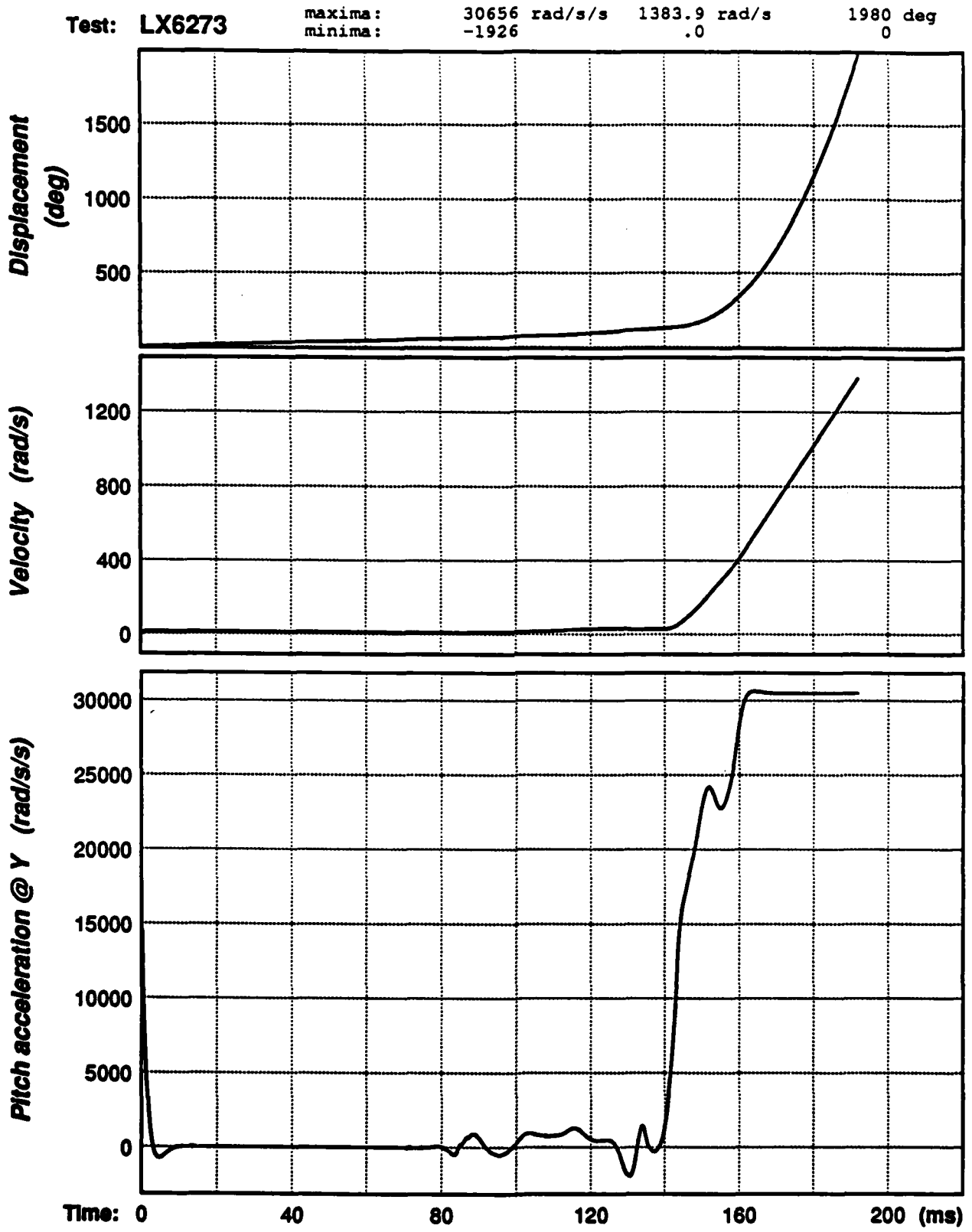

Figure C-35. Head pitch angular acceleration, velocity, and displacement signals for test LX6273.

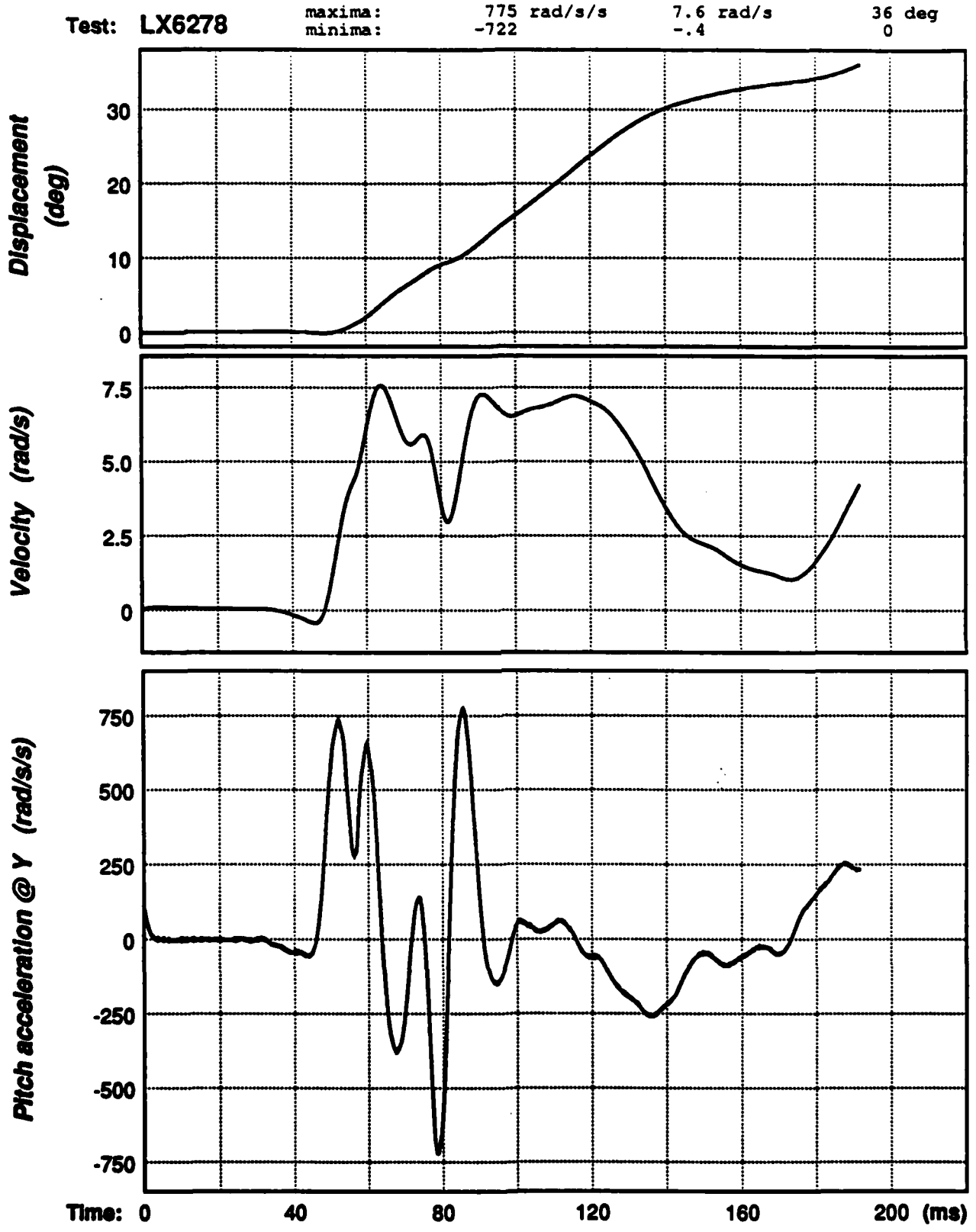

Figure C-36. Head pitch angular acceleration, velocity, and displacement signals for test LX6278.

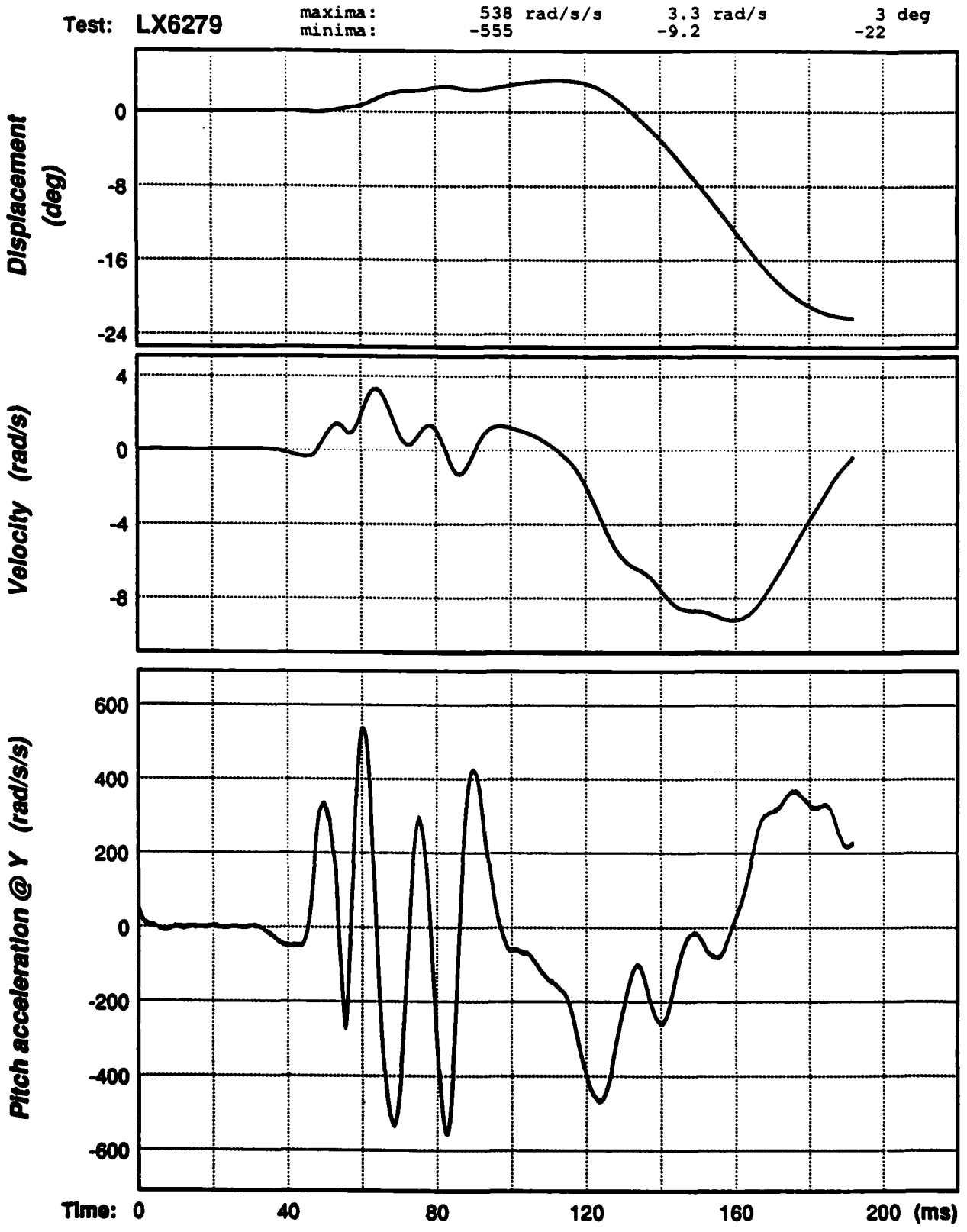

Figure C-37. Head pitch angular acceleration, velocity, and displacement signals for test LX6279.

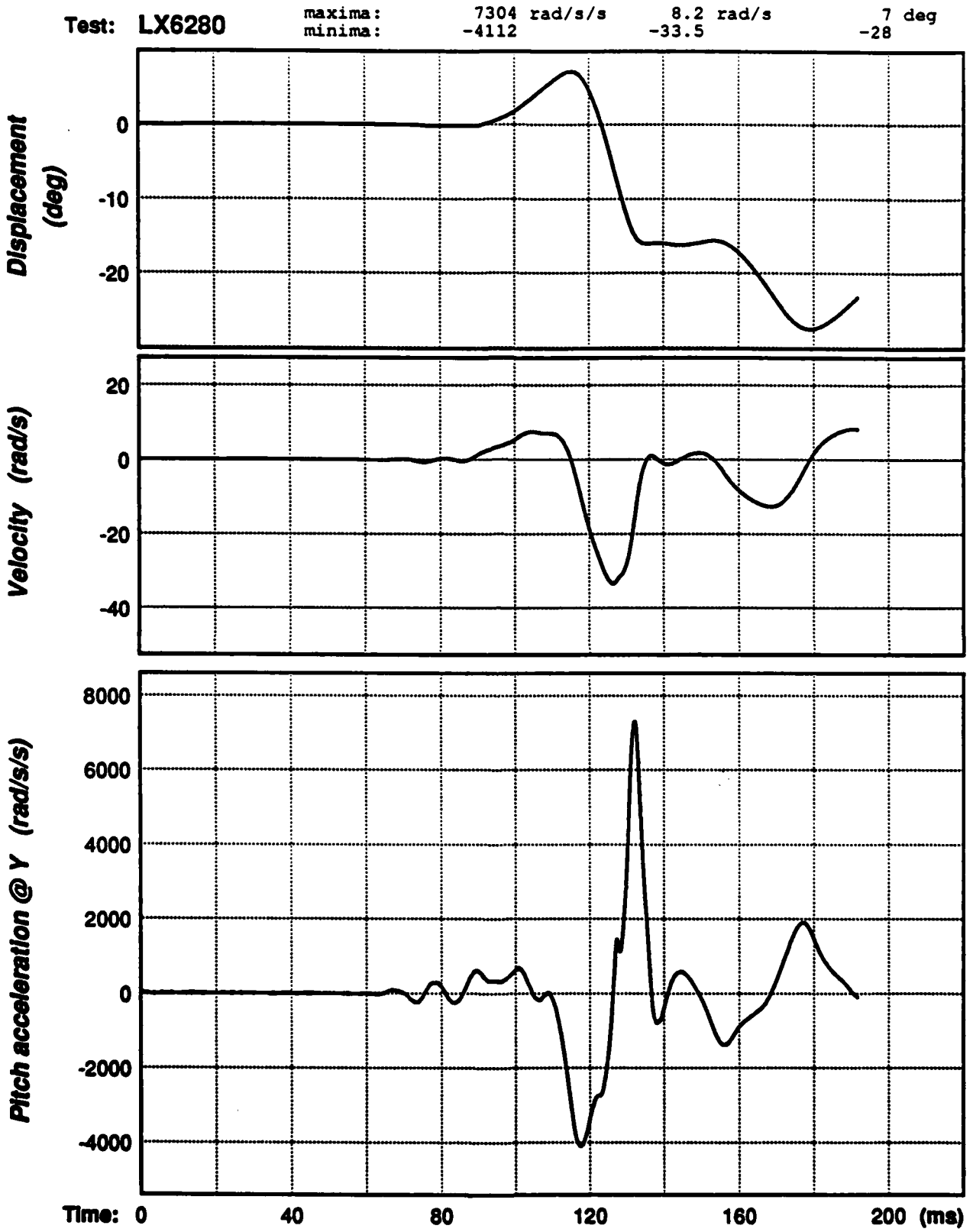

Figure C-38. Head pitch angular acceleration, velocity, and displacement signals for test LX6280.

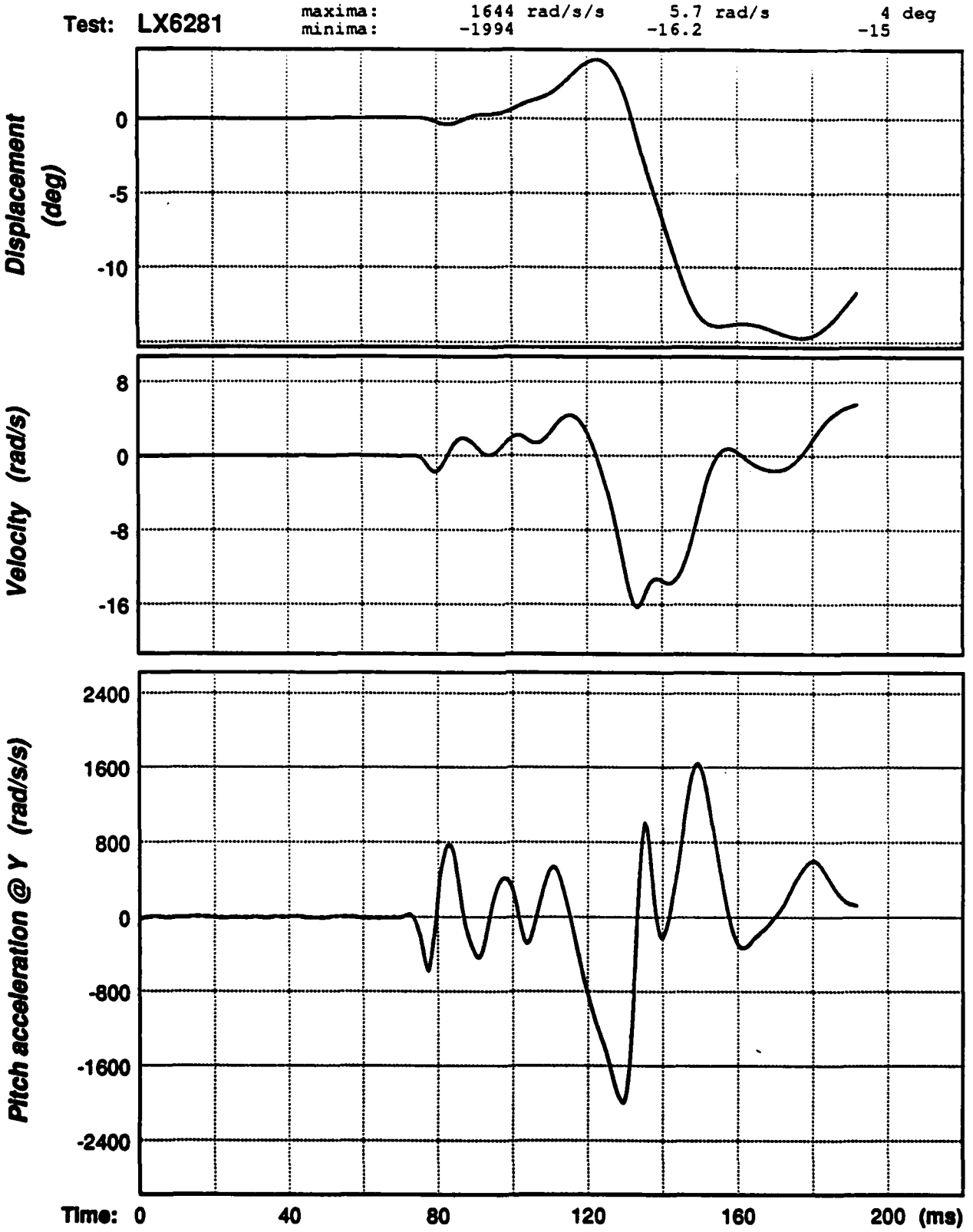

Figure C-39. Head pitch angular acceleration, velocity, and displacement signals for test LX6281.

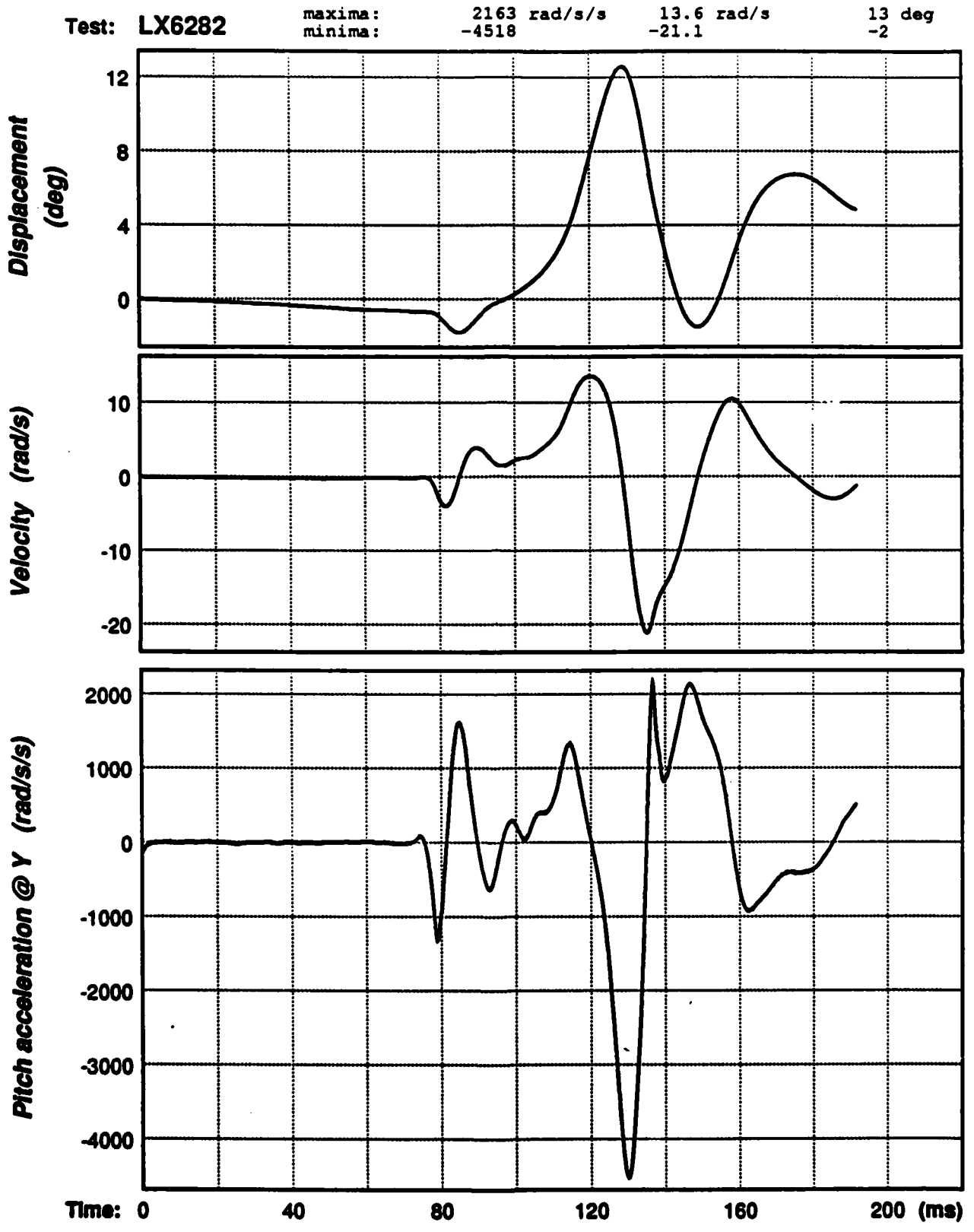

Figure C-40. Head pitch angular acceleration, velocity, and displacement signals for test LX6282.

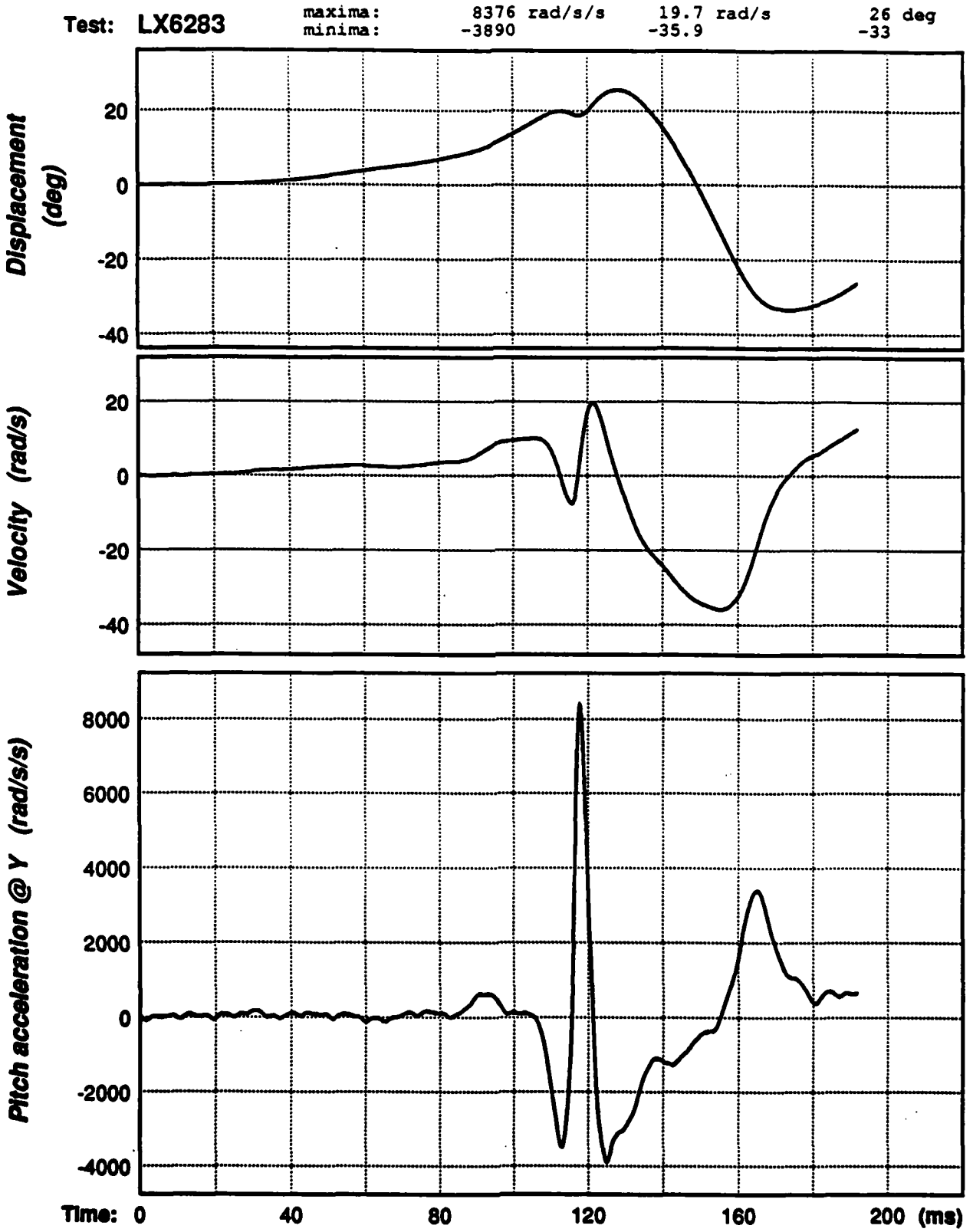

Figure C-41. Head pitch angular acceleration, velocity, and displacement signals for test LX6283.

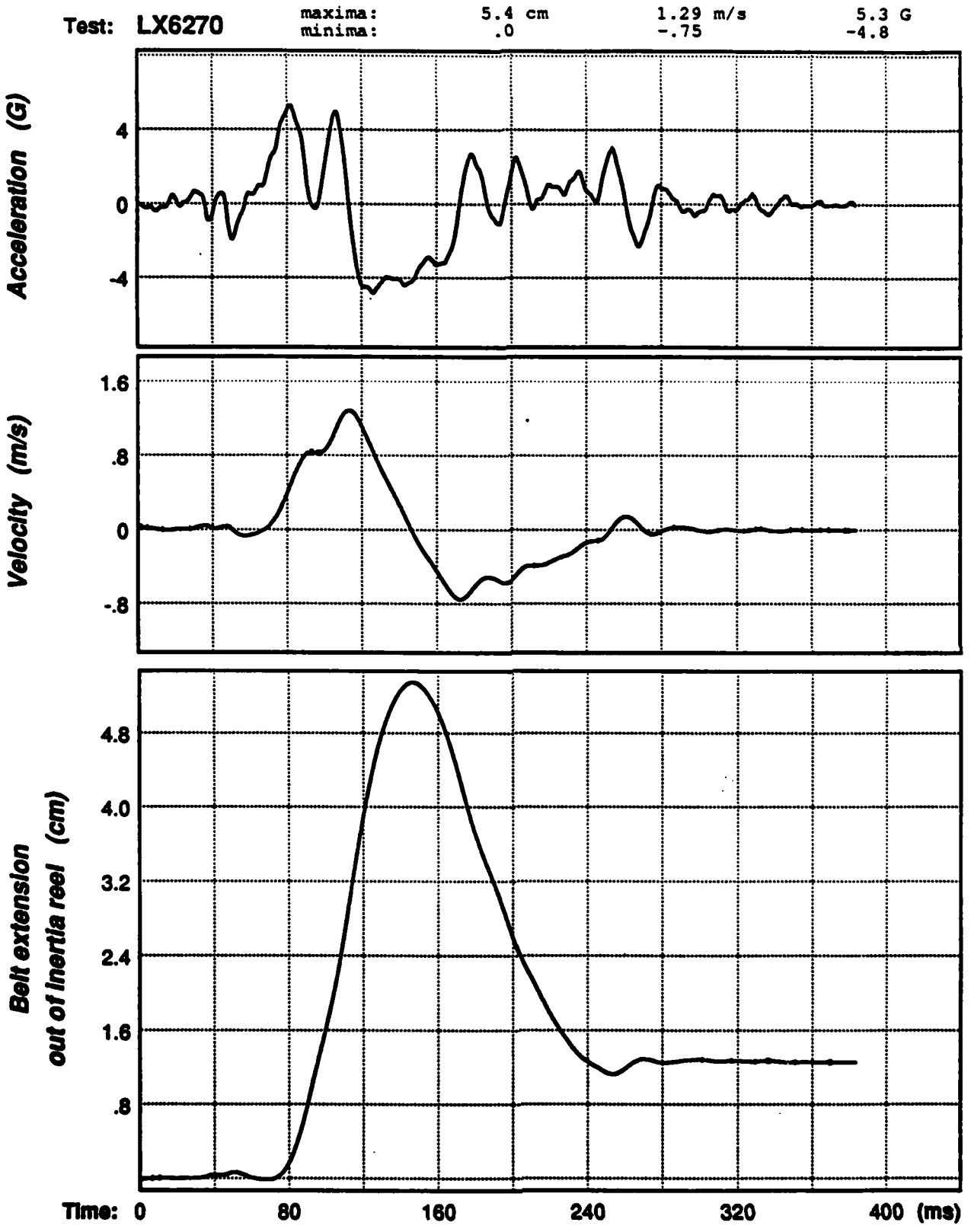

Figure C-42. Amount of belt extension and the velocity and acceleration of extension for test LX6270.

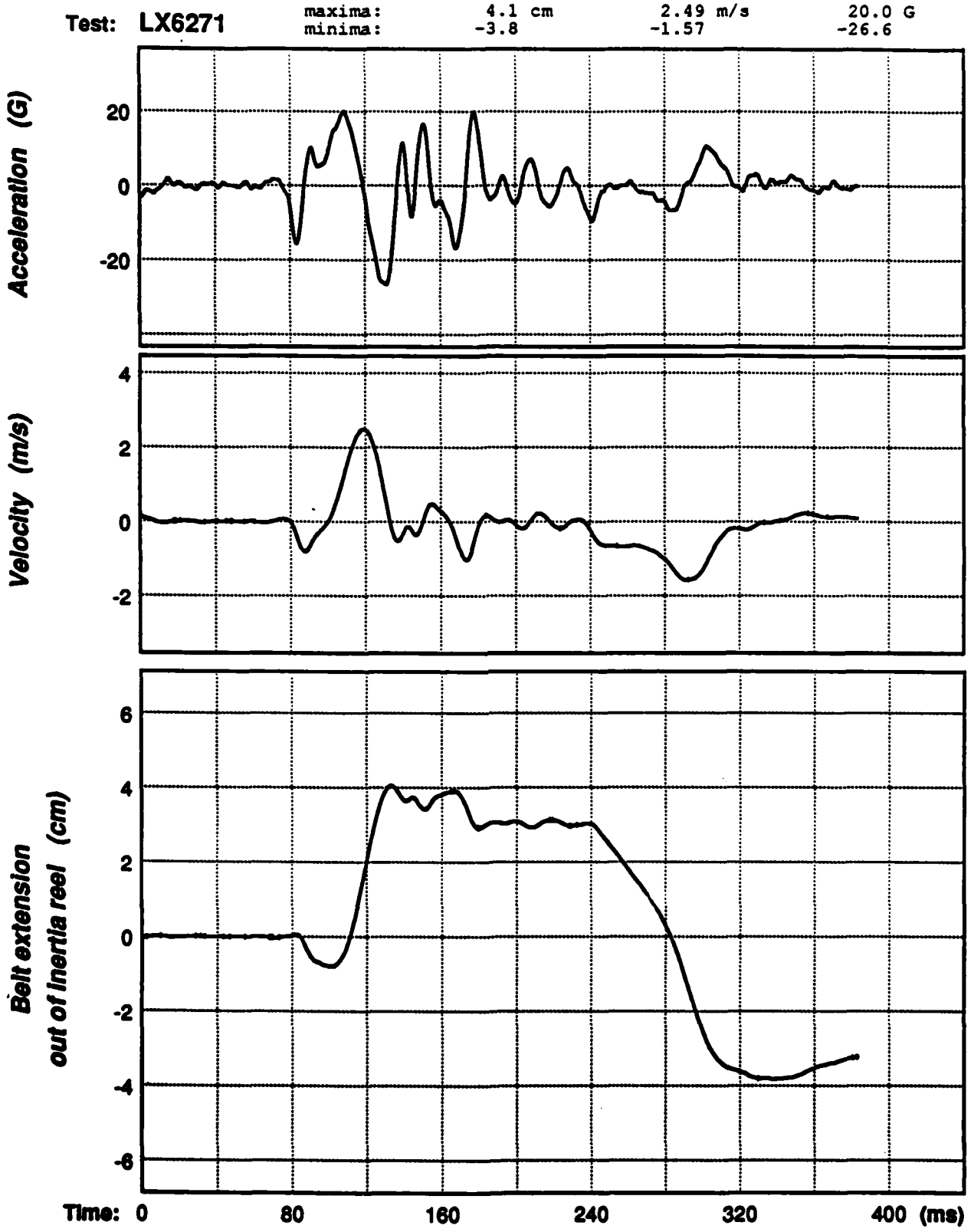

Figure C-43. Amount of belt extension and the velocity and acceleration of extension for test LX6271.

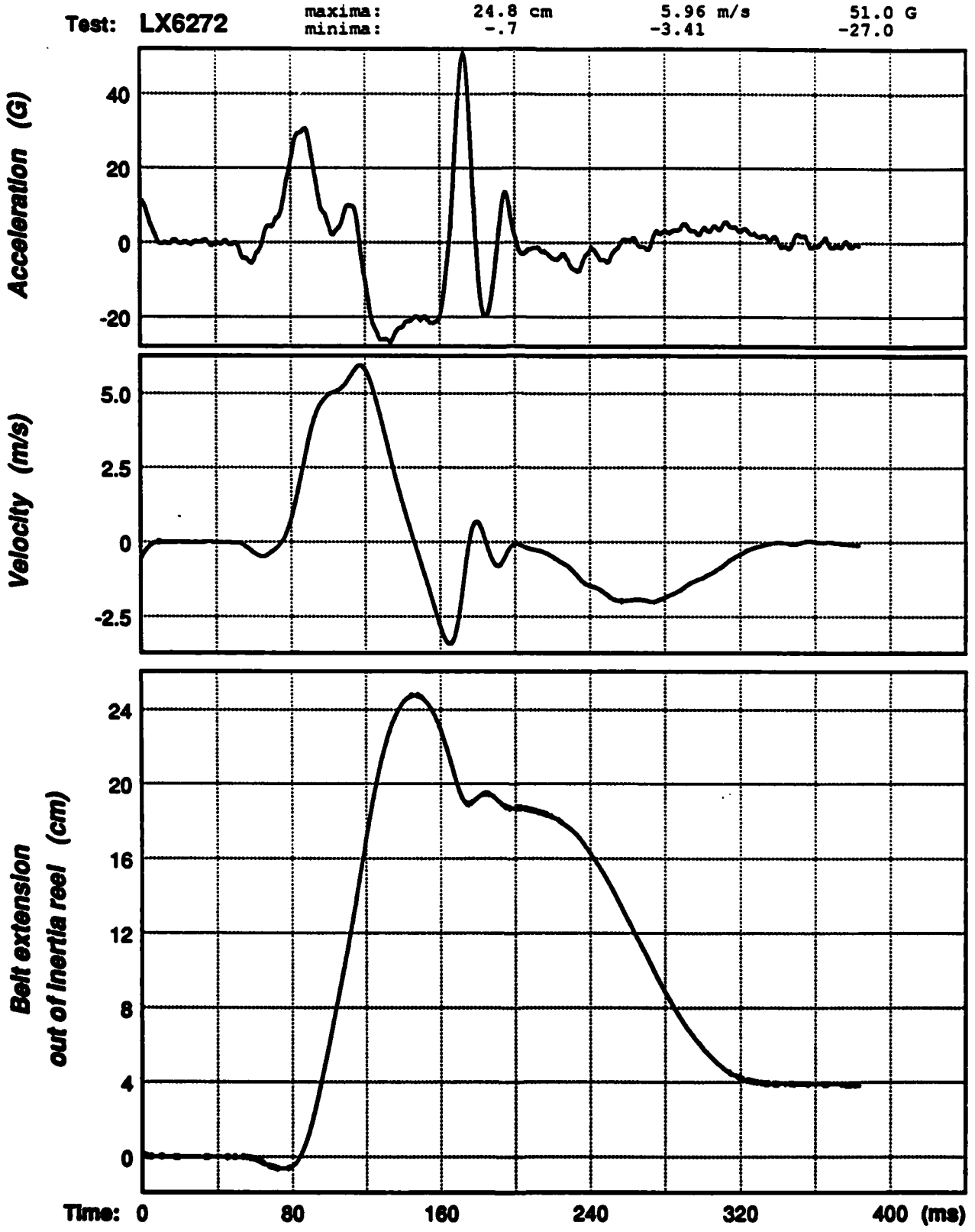

Figure C-44. Amount of belt extension and the velocity and acceleration of extension for test LX6272.

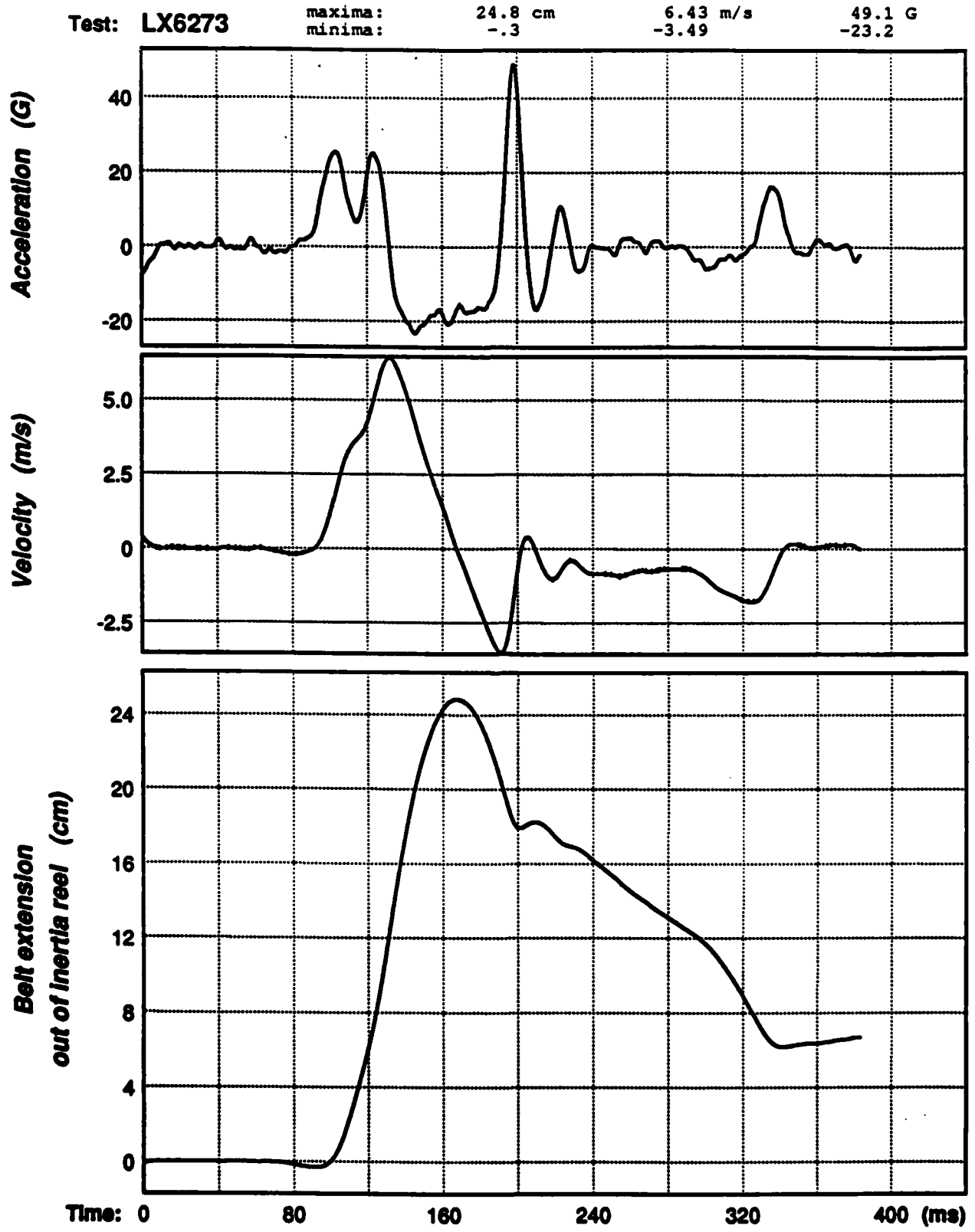

Figure C-45. Amount of belt extension and the velocity and acceleration of extension for test LX6273.

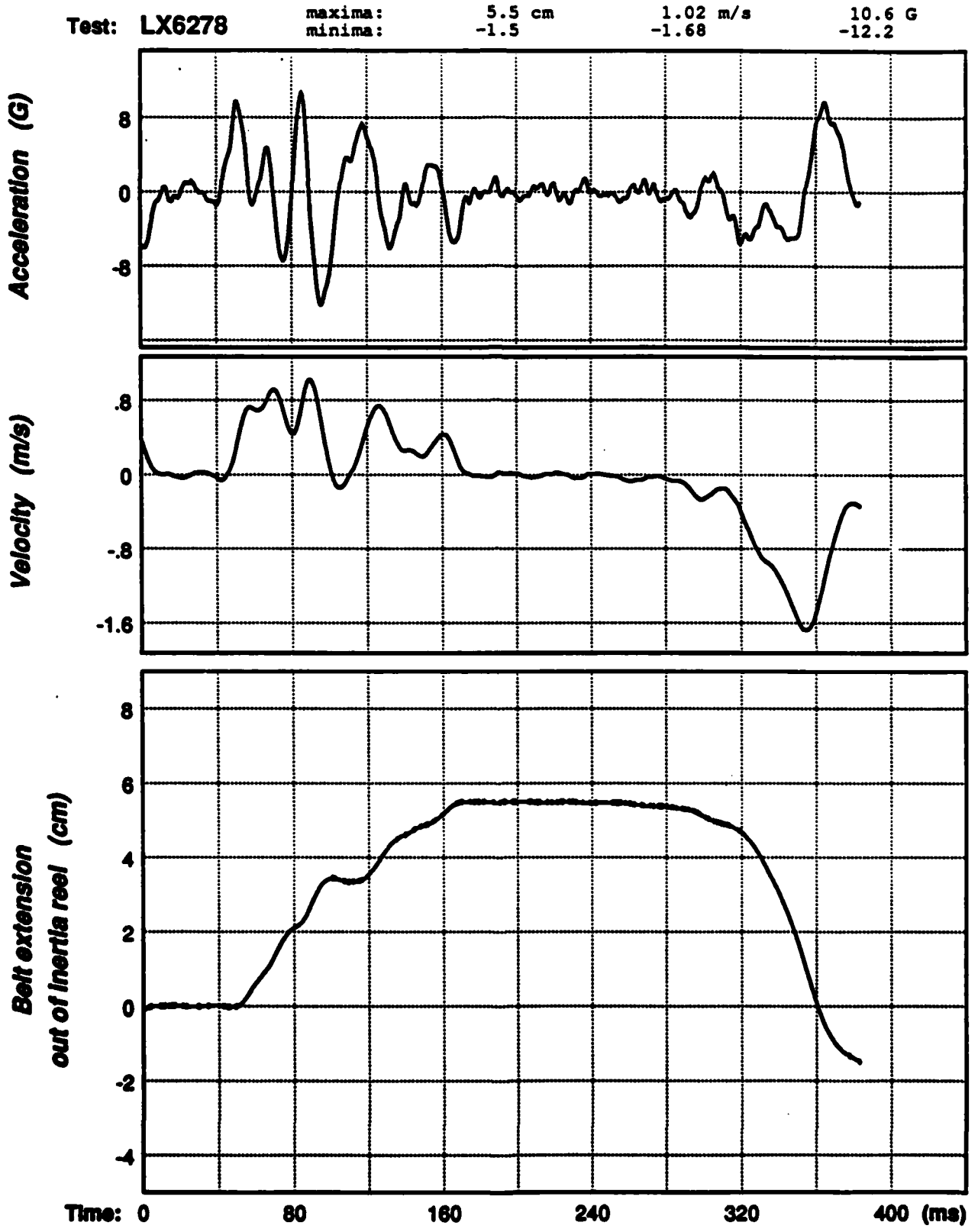

Figure C-46. Amount of belt extension and the velocity and acceleration of extension for test LX6278.

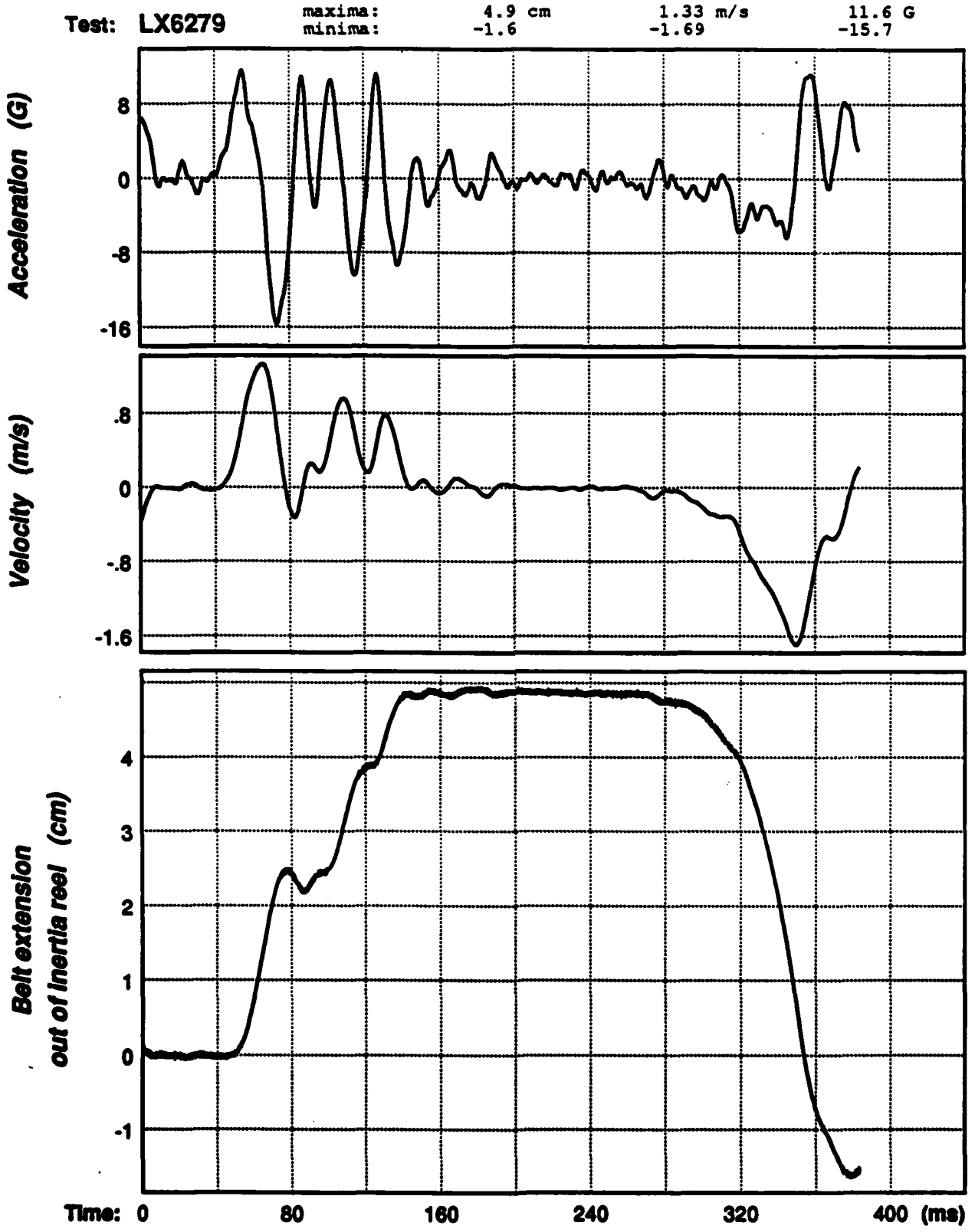

Figure C-47. Amount of belt extension and the velocity and acceleration of extension for test LX6279.

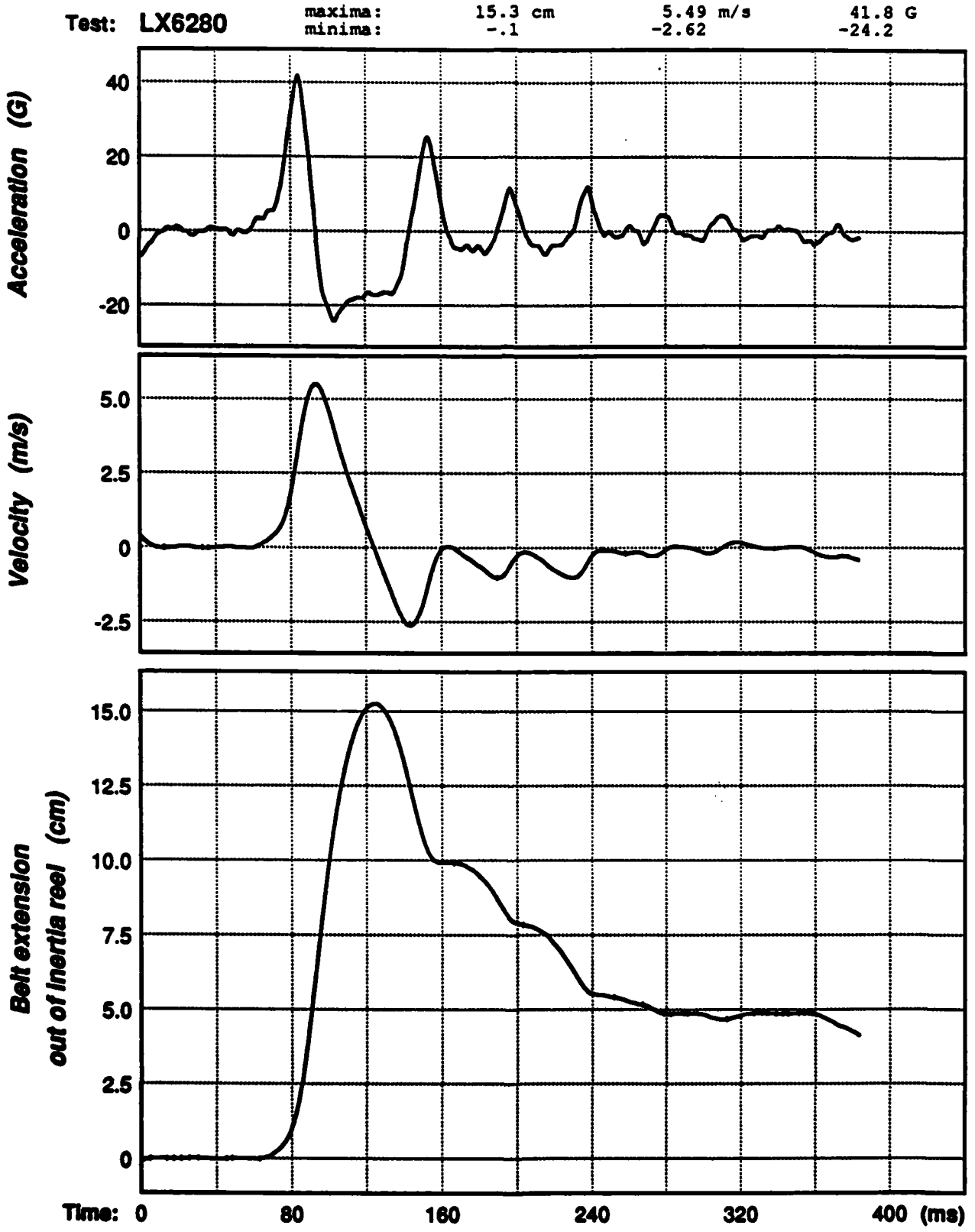

Figure C-48. Amount of belt extension and the velocity and acceleration of extension for test LX6280.

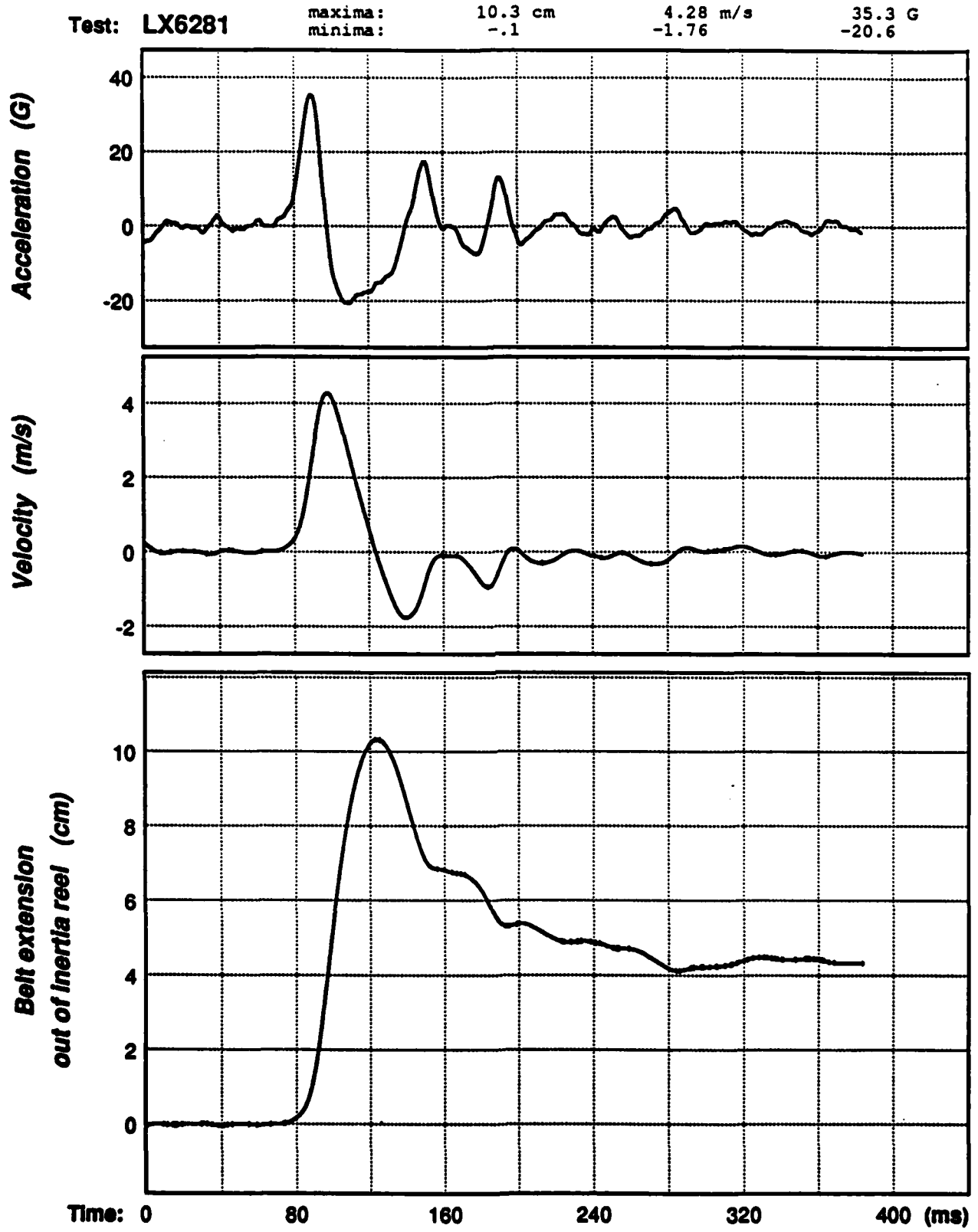

Figure C-49. Amount of belt extension and the velocity and acceleration of extension for test LX6281.

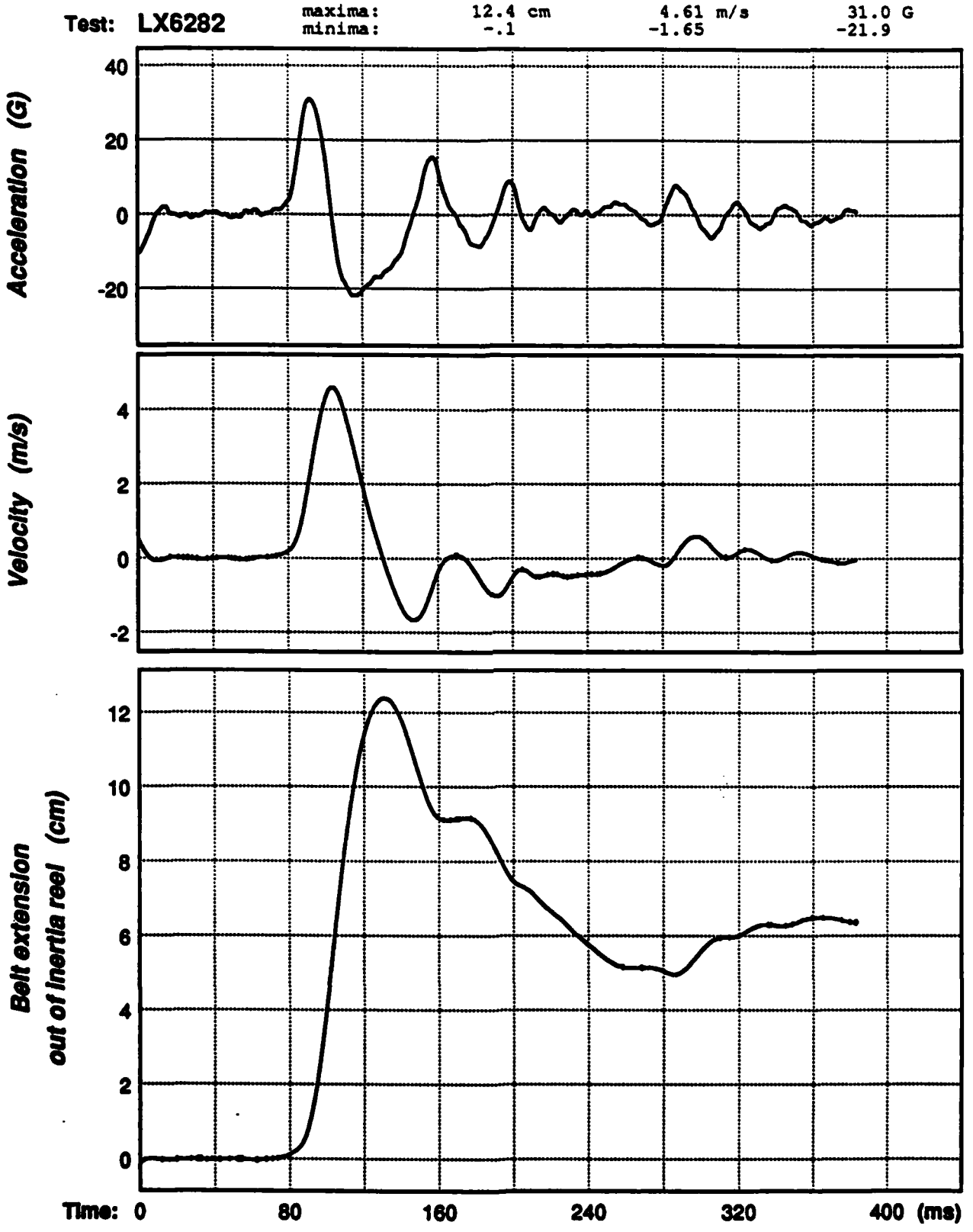

Figure C-50. Amount of belt extension and the velocity and acceleration of extension for test LX6282.

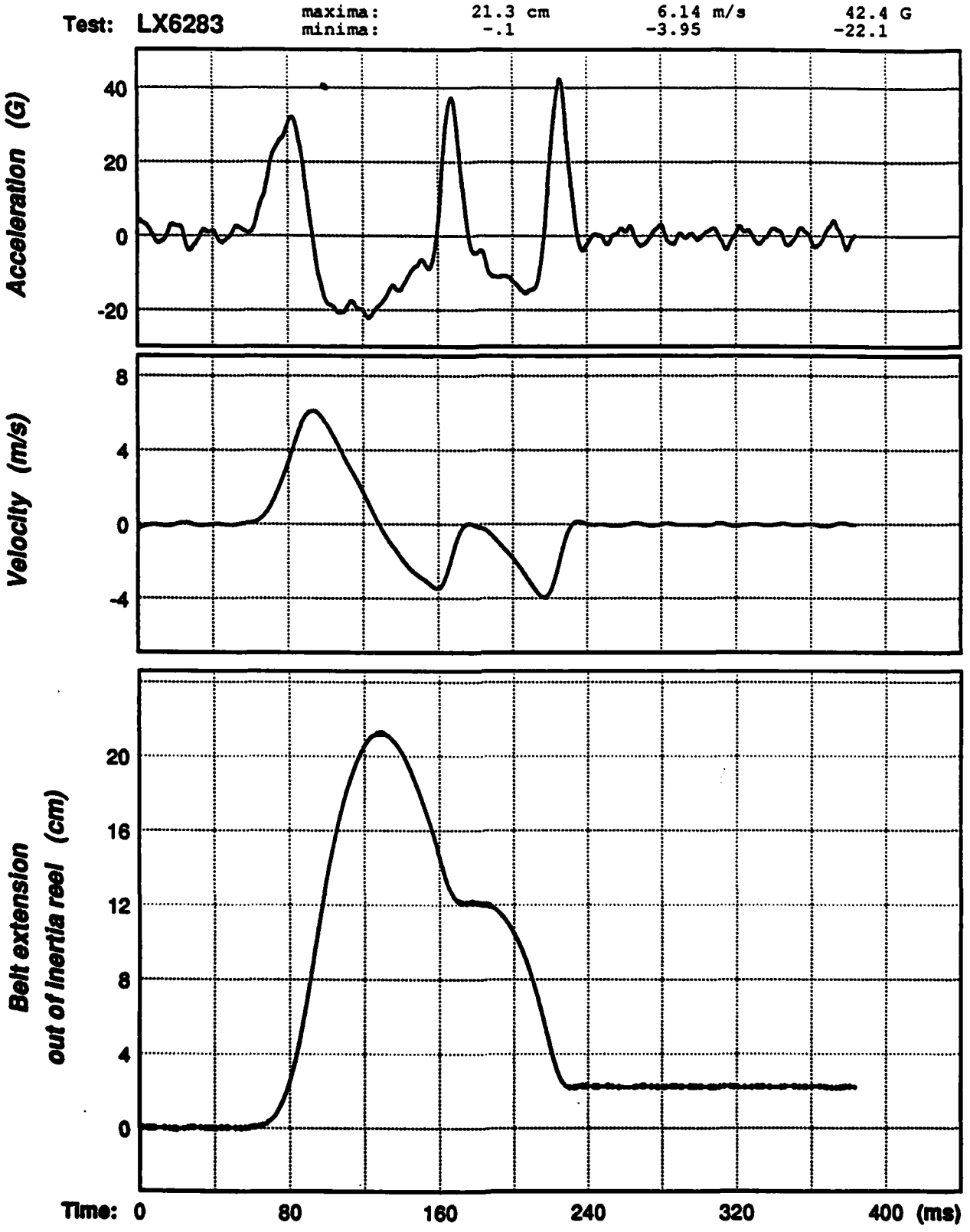

Figure C-51. Amount of belt extension and the velocity and acceleration of extension for test LX6283.