# DYNAMIC RESPONSE OF MANGANIN FOIL GAUGES TO 185 KBARS

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## INTRODUCTION

In this report we present results describing the loading and unloading response of manganin foil gauges, oriented parallel to the shock front, to well characterized stress waves in the stress range from 85 to 185 kbars.* These results complement the data reported earlier on the response of manganin foils for matrix stresses to 90 kbars. [1,2] The resistance change profiles from gauges in each of the experiments are presented. The measured values of resistance change at the peak stress, $(\Delta R/R_o)_{peak}$, and the residual resistance change, $(\Delta R/R_o)_{residual}$, are summarized. These data are compared to the values of $(\Delta R/R_o)_{peak}$ and $(\Delta R/R_o)_{residual}$ calculated from the analytical model for the gauge response. [3]

## EXPERIMENTAL TECHNIQUES

Manganin foils (Hamilton Tech., Lancaster, PA.), with a nominal thickness of 33 microns, were obtained from SRI International. The electromechanical constants of these foils have been measured and reported by Chen *et al.* [4] The gauges, for the present experiments, were cut into a four terminal configuration to facilitate resistance measurements. [1,5] The gauges were embedded in a z-cut sapphire matrix in two configurations: (i) in a groove and (ii) on a surface. In the groove configuration the gauge was emplaced in a groove machined in to the surface of one half piece of a 6.35 mm thick sapphire disc that had been cut along the diameter, as shown in Fig. 1. The dimensions of the groove were approximately equal to that of the gauge. A very thin layer of hysol epoxy was used for bonding the gauge in the groove. The surface gauge was placed on the surface of the other half of the sapphire disc and was surrounded by a layer of hysol

* In a parallel study on the piezoresistance of ytterbium gauge, we performed two experiments in which the fused silica targets contained one manganin gauge, to obtain an independent measure of stress, along with one ytterbium gauge. These experiments were performed at matrix stresses of 45 and 50.4 kbars and the measured responses of manganin gauges are included in this report.

epoxy; the thickness of the epoxy layer was equal to that of the gauge. The gauges were covered by a 3.17 mm thick disc of sapphire in such a way that their major surfaces were in the same plane and, therefore, were at the same depth from the target impact surface.

We performed a total of nine experiments (including one in the fused silica) using the 2 1/2" and the 4" gas guns at our laboratory. In five of the eight sapphire experiments the target had only one gauge in the groove configuration. All the experiments were performed using z-cut sapphire impactors. The impactor thickness in each experiment was appropriate to obtain the complete unloading of matrix during the time duration for uniaxial strain in the matrix. The projectile velocity and the resistance change measurements were made following the method described in Refs. 1 and 5.

## RESULTS

The terms resistance change at peak stress, $(\Delta R/R_o)_{peak}$ ,and the residual resistance change, $(\Delta R/R_o)_{residual}$ , are defined in the resistance change profile shown in Fig. 2. The measured resistance change profiles from all the foil gauges are presented in Appendix A. The data on resistance change at peak stress and residual resistance change are summarized in Table I. The peak longitudinal stress in the matrix for all the experiments listed in Table I, were determined from the Hugoniots of z-cut sapphire [6] and fused silica [6] and the measured projectile velocity.

A plot of the measured resistance change at peak stress is shown in Fig. 3. The calculations for the resistance change at peak stress were based on the inclusion model of the gauge. [3] To calculate the response of the gauge in the groove configuration it was considered to be embedded in the sapphire (treated as an isotropic material) or fused silica matrix. The data on mechanical constants for sapphire and fused silica for stresses below their elastic limits were taken from Refs. 6 and 7. In the case of surface gauge configuration the gauge was considered to be embedded in hysol epoxy. To use the

analytical model for the surface gauge, the following procedure was used: the longitudinal stress in the gauge was assumed to be the same as the matrix longitudinal stress; the high stress hysol epoxy response was approximated using the PMMA response reported in the LASL [8] handbook. Because the shear modulus is not known at these stresses, the shear modulus was varied between 0.2 to 20 kbar for a particular longitudinal modulus. The calculated resistance change value was not dependent on the shear modulus chosen for the epoxy. The calculated values of $(\Delta R/R_o)_{peak}$ for gauges in both the configurations are shown in Fig. 3. The calculations for $(\Delta R/R_o)_{residual}$ were performed by following the method described in Ref. 9 and the results are summarized in Table I.

ACKNOWLEDGEMENTS

We thank Jerry Thompson for his technical assistance in building the targets and in performing the experiments. This work was supported by the Defense Nuclear Agency under contract DNA0001-82-C-0148.

## REFERENCES


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**Table I. Summary of the measured and calculated $(\Delta R/R_0)_{peak}$ and $(\Delta R/R_0)_{residual}$.**

| Experiment Number | Peak Longitudinal Matrix Stress (kbars) | Gauge Configur-ation | $(\Delta R/R_0)_{peak}$ | | $(\Delta R/R_0)_{residual}$ | |
|---|---|---|---|---|---|---|
| | | | Measured | Calculated[b] | Measured | Calculated[b] |
| 1a. (85590)[a] | 45.0 | Groove | 0.122 ±0.002 | 0.131 | -- | -- |
| 1b. (86520)[a] | 50.4 | Groove | 0.147 ±0.014 | 0.147 | -- | -- |
| 2. (85559) | 86.0 | Groove | 0.232 ±0.008 | 0.234 | 0.020 ±0.002 | 0.017 |
| 3. (85579) | 111.6 | Groove | 0.282 ±0.020 | 0.302 | 0.019 ±0.003 | 0.019 |
| 4. (85583) | 126.5 | Groove | 0.334 ±0.011 | 0.341 | 0.023 ±0.003 | 0.022 |
| 5. (86001) | 132.0 | Groove | 0.341 ±0.025 | 0.356 | 0.040 ±0.016 | 0.023 |
| | 132.77 (Hamiltonian) | Surface | 0.372 ±0.023 | 0.373 | 0.025 ±0.015 | 0.019 |
| 6. (86003) | 149.0 | Groove | 0.393 | 0.400 | 0.156 ±0.05 | 0.021 |
| | 150.41 (Hamiltonian) | Surface | 0.415 ±0.012 | 0.422 | 0.020 ±0.018 | -- |
| 7. (85587) | 150.0 | Groove | 0.379 | 0.402 | 0.085 ±0.025 | -- |
| 8. (85050) | 183.0 | Groove | 0.442 | 0.489 | 0.238 ±0.112 | -- |
| 9. (86004) | 184.7 | Groove | 0.462 ±0.026 | 0.493 | 0.185 ±0.090 | -- |
| | | Surface | 0.497 ±0.035 | 0.519 | 0.227 ±0.069 | -- |

[a] These experiments were performed in fused silica matrix.
[b] Calculations were carried out by assuming isotropic - elastic response of z-cut sapphire.

7. shows yielding at ~ .25 μs
8. shows immediate yielding

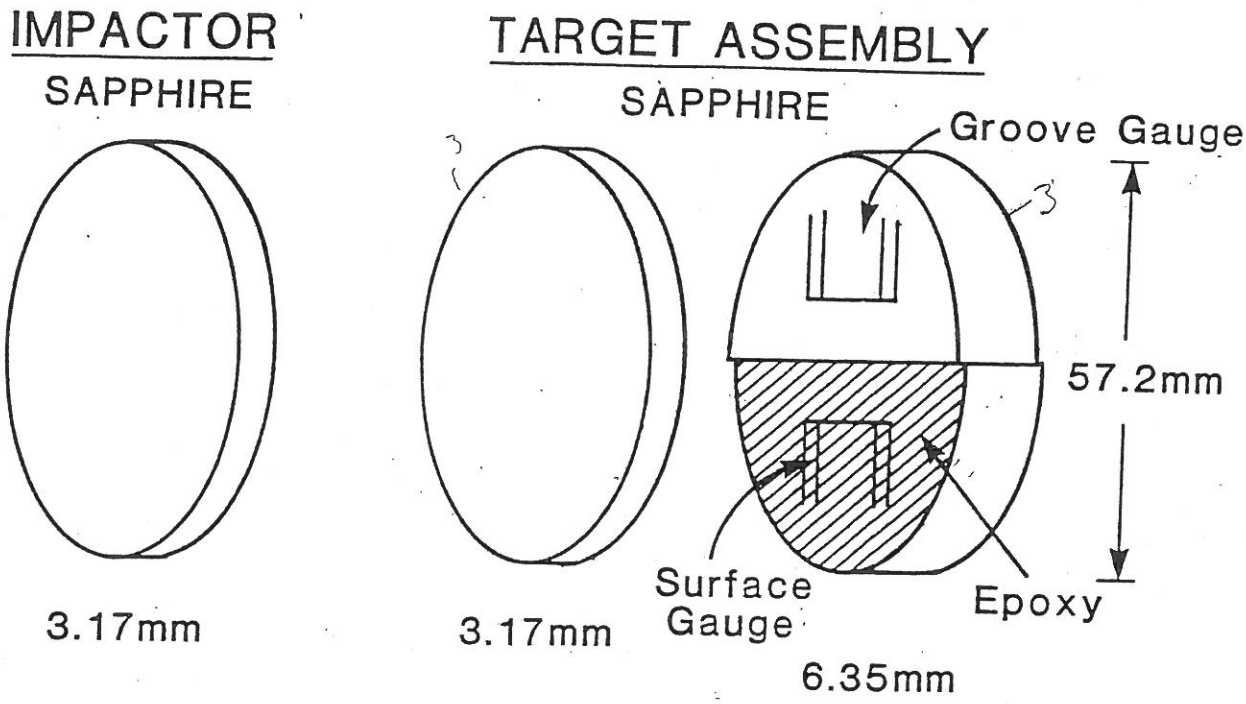



FIG. 1. Schematic view of the impactor and the target assembly. The groove gauge is emplaced in a groove in z-cut sapphire disc. The surface gauge is emplaced on the top of the disc and has a layer of epoxy around it. The thickness of the epoxy layer is equal to that of the gauge.

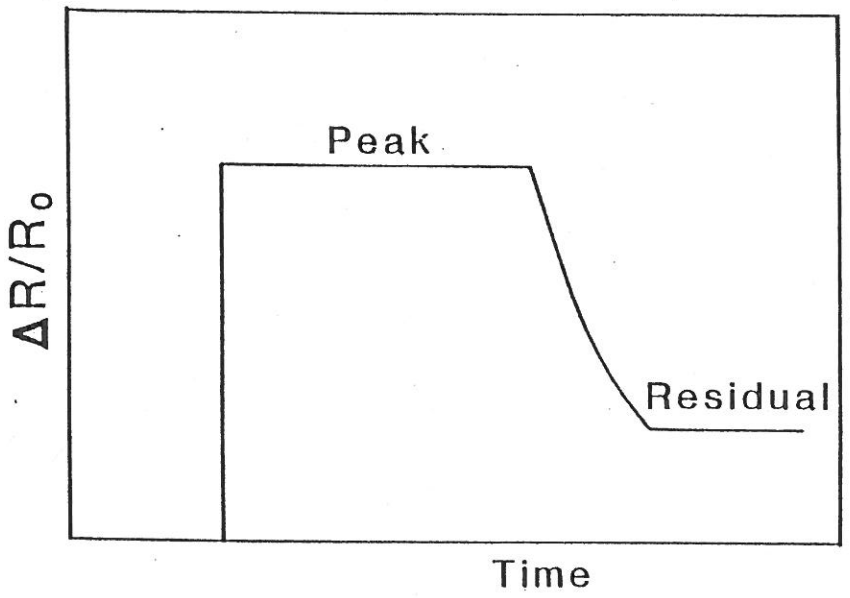



FIG 2. A representative resistance change profile.

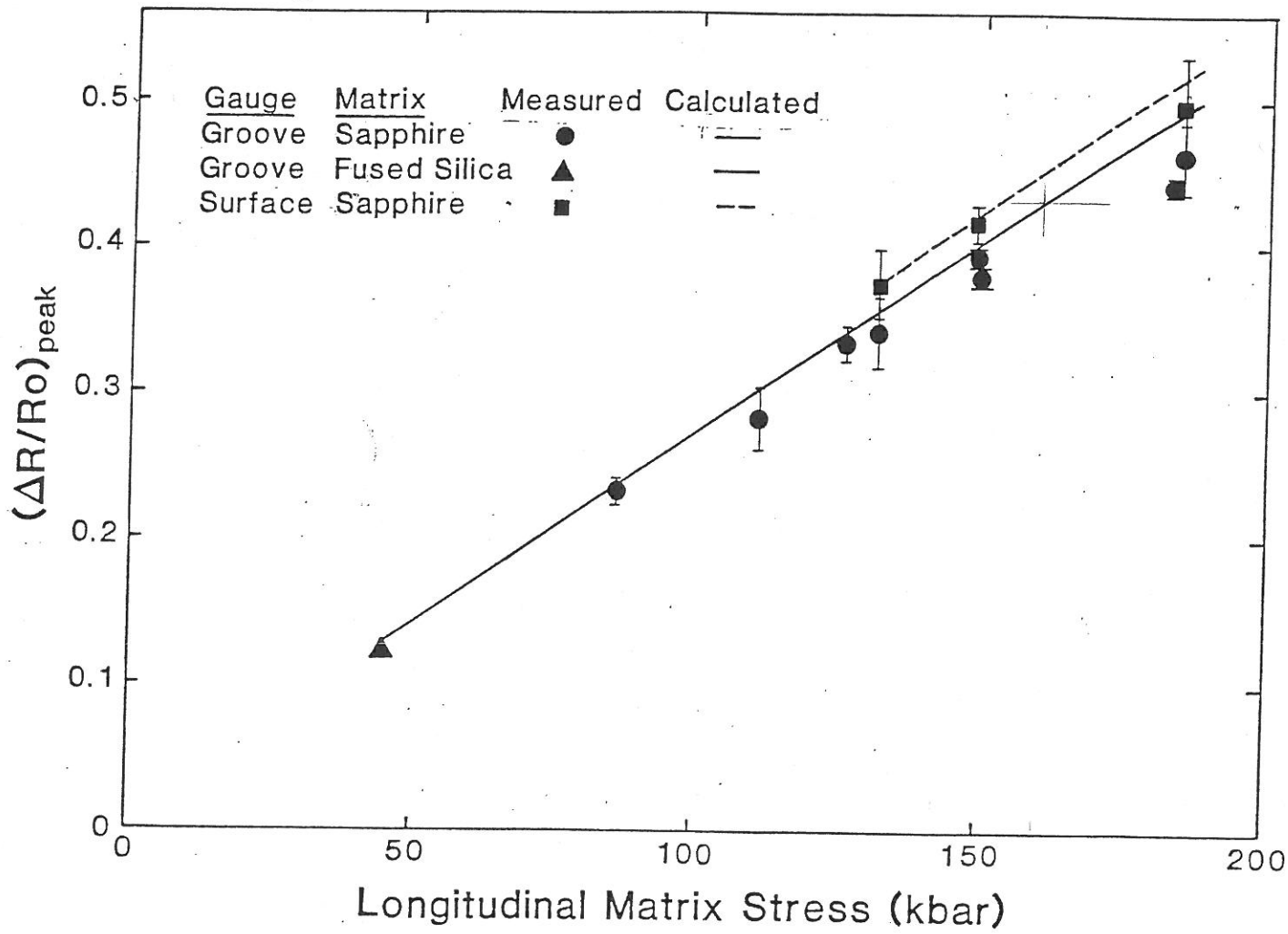
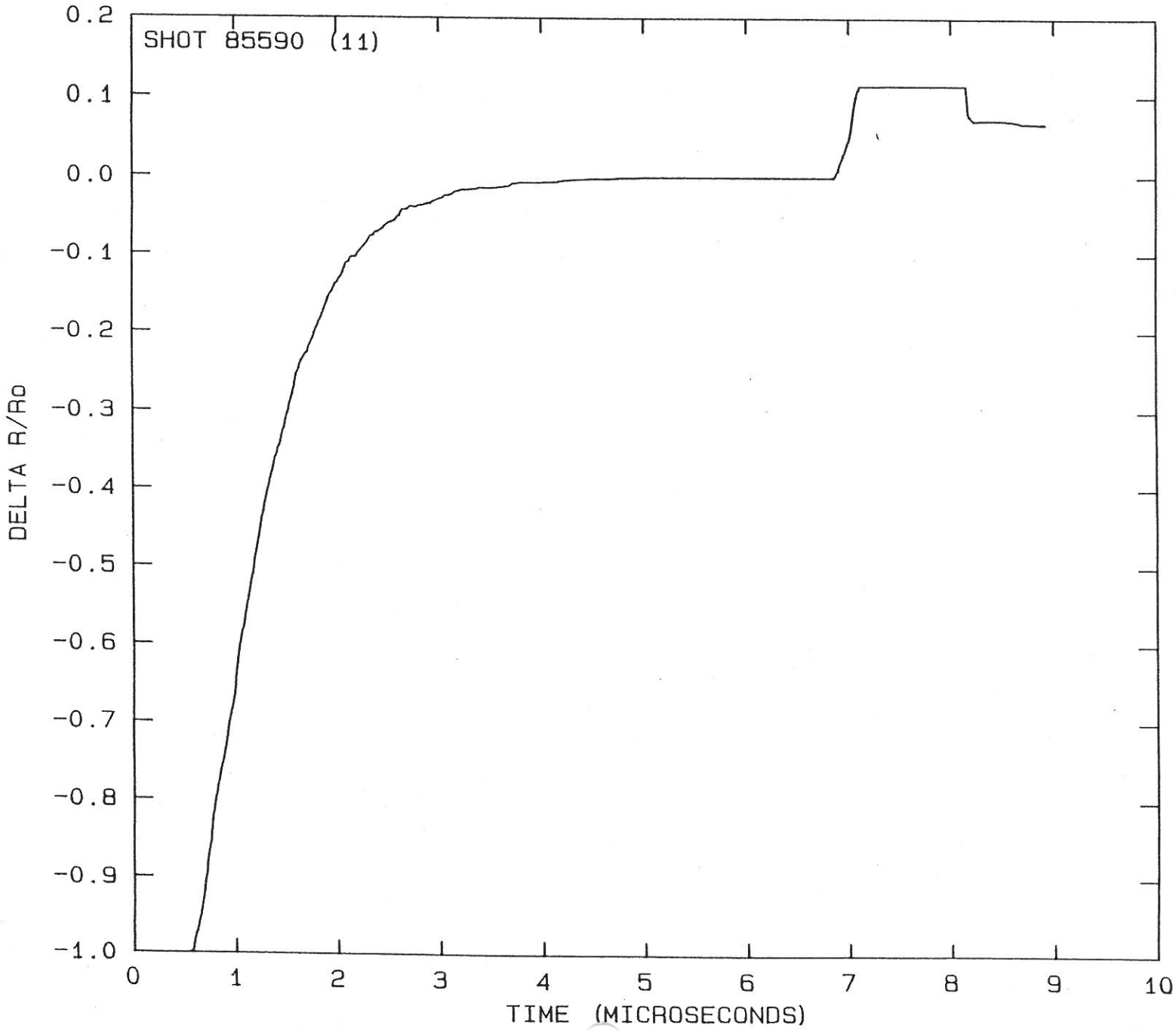


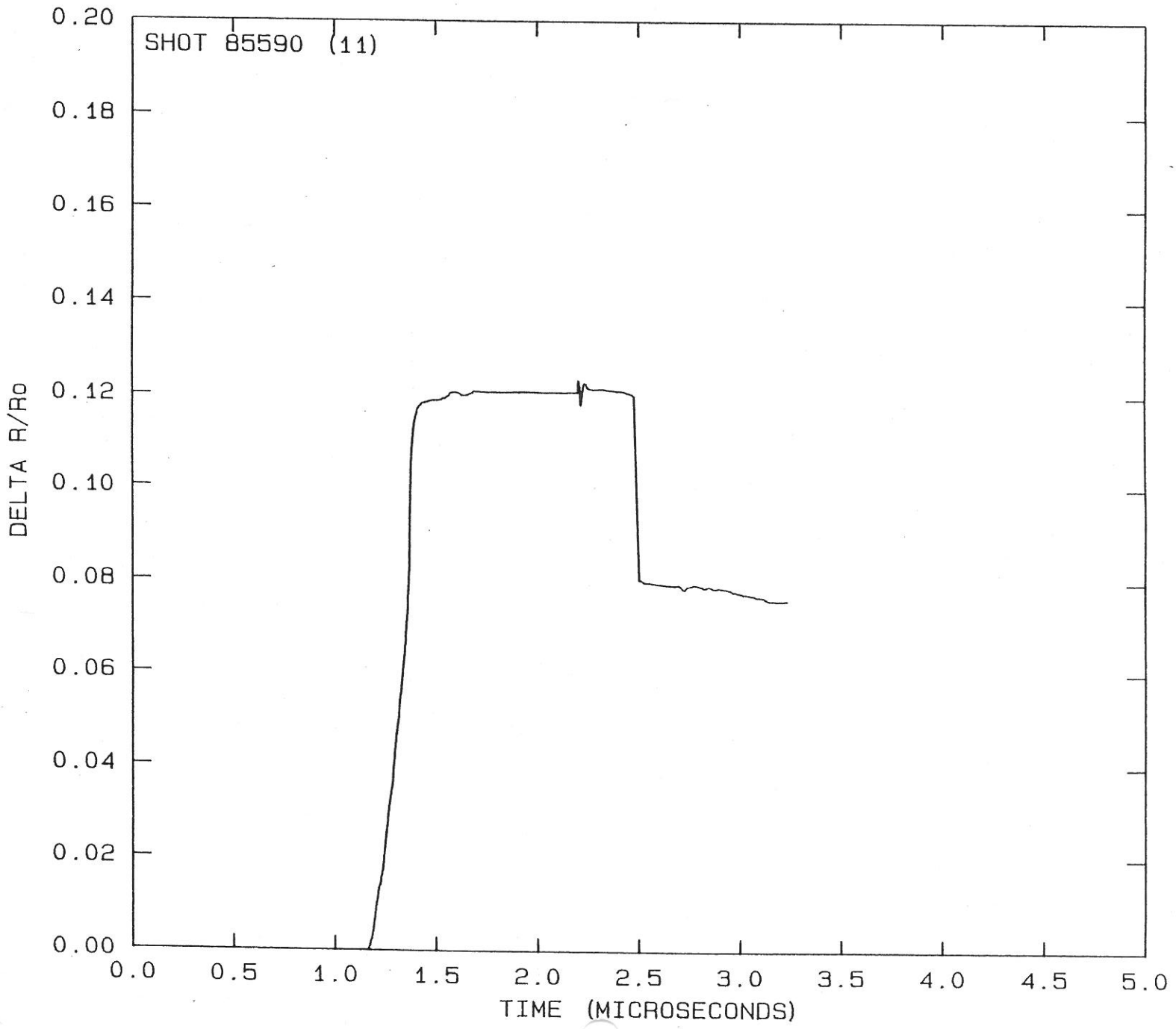

FIG. 3. Calculated and measured values of $(\Delta R/R_o)_{peak}$ as a function of peak longitudinal matrix stress for the groove and the surface gauges.

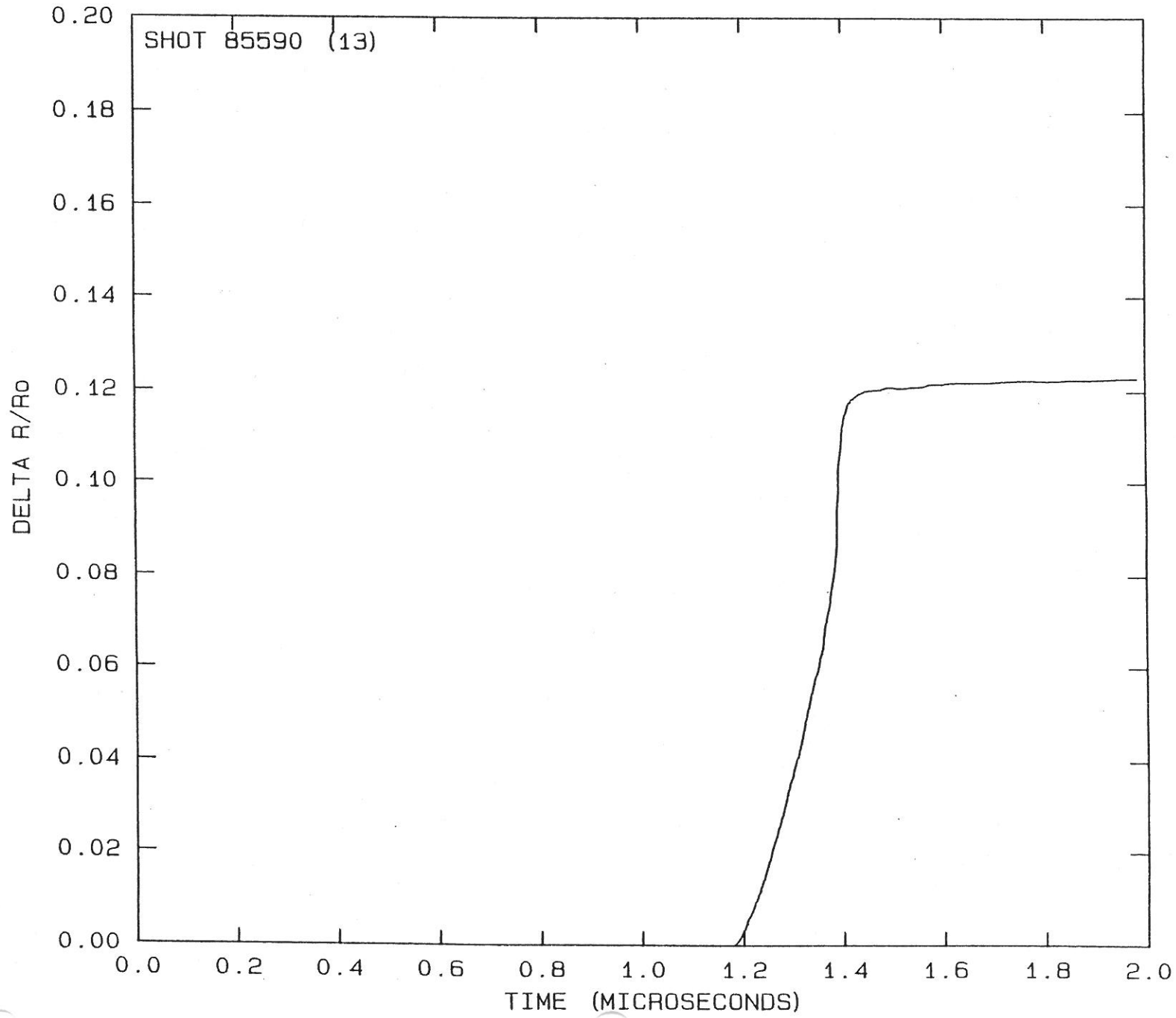
## Shot Number (1a) 85590

| | |
|---|---|
| Longitudinal Stress in the Matrix: | 45.0 kbars |
| Impactor Material: | Z-cut Sapphire |
| Impactor Thickness: | 6.35 mm |
| Projectile Velocity: | 0.49 mms/microseconds |
| Matrix Material: | Fused Silica |
| Depth of Gauges in Matrix: | 6.35 mm |

Remarks: There were two gauges in the target: (i) ytterbium and (ii) manganin. This experiment was performed to study the response of ytterbium gauge at a longitudinal matrix stress around 45 kbars.The manganin gauge was embedded in the target to obtain an independent measure of stress in the matrix. Manganin gauge records are given in this report. The report on the results on ytterbium gauge contains the records obtained from the ytterbium gauge.


SHOT 85590 (11)
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
DELTA R/R0
0
1
2
3
4
5
6
7
8
9
10
TIME (MICROSECONDS)

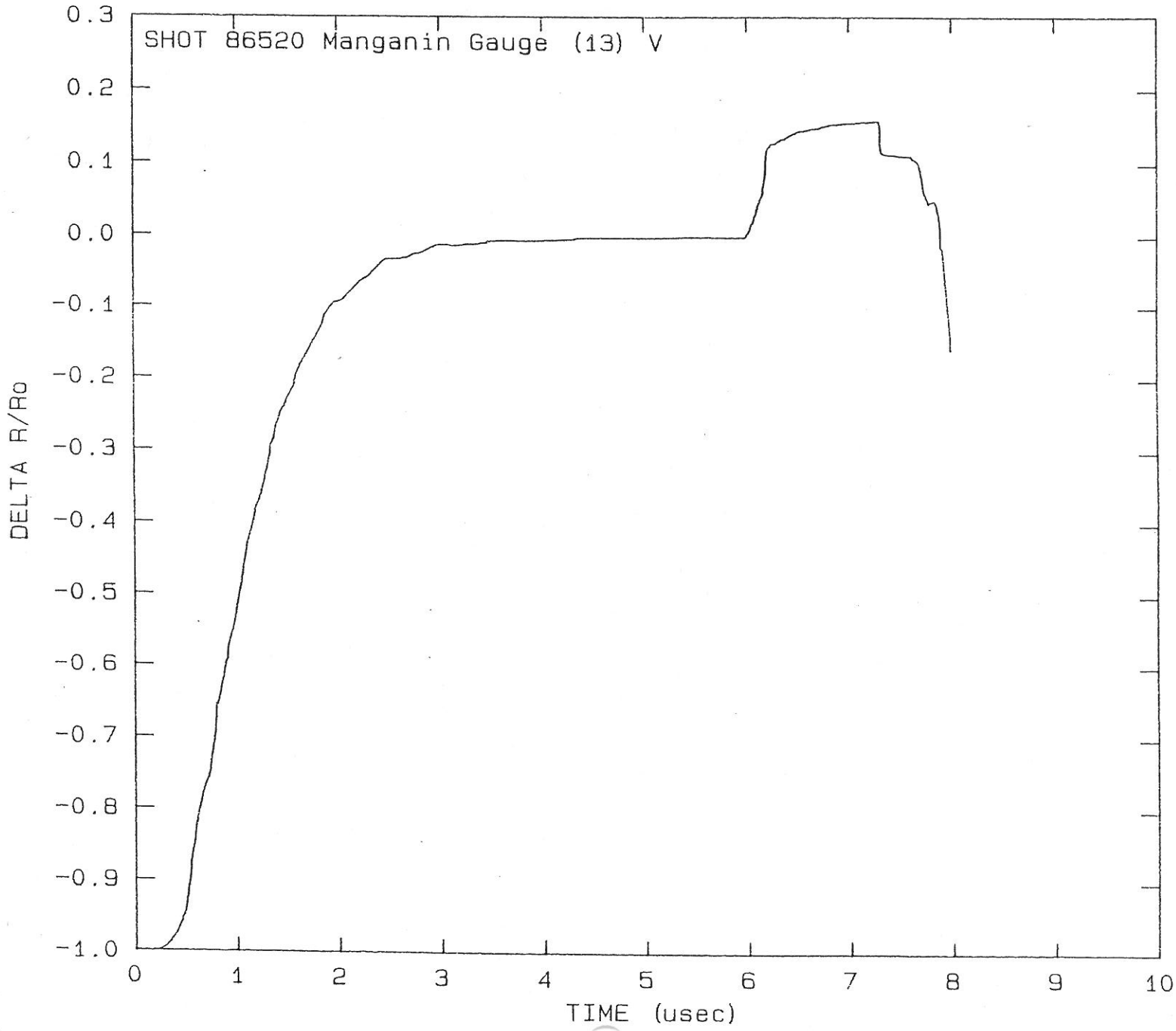

SHOT 85590 (11)
DELTA R/Ro
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
TIME (MICROSECONDS)

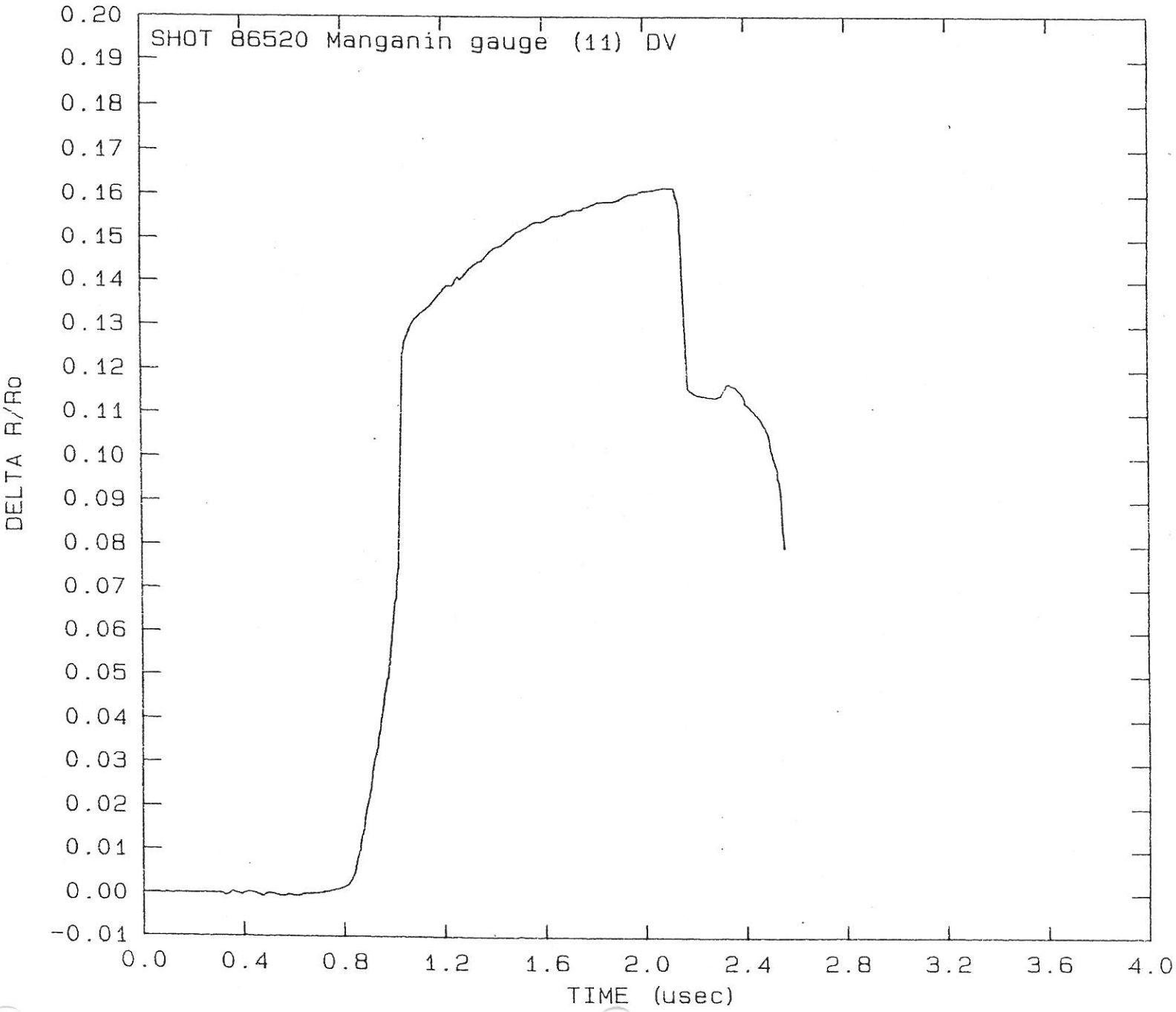

SHOT 85590 (13)
DELTA R/Ro
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
TIME (MICROSECONDS)

## Shot Number (1b) 86520

| | |
|---|---|
| Longitudinal Stress in the Matrix: | 50.4 kbars |
| Impactor Material: | Z-cut Sapphire |
| Impactor Thickness: | 6.35 mm |
| Projectile Velocity: | 0.551 mms/microseconds |
| Matrix Material: | Fused Silica |
| Depth of Gauges in Matrix: | 6.35 mm |

Remarks: There were two gauges in the target: (i) ytterbium and (ii) manganin. This experiment was performed to study the response of ytterbium gauge at a longitudinal matrix stress around 50 kbars.The manganin gauge was embedded in the target to obtain an independent measure of stress in the matrix. Manganin gauge records are given in this report. The report on the results on ytterbium gauge contains the records obtained from the ytterbium gauge.

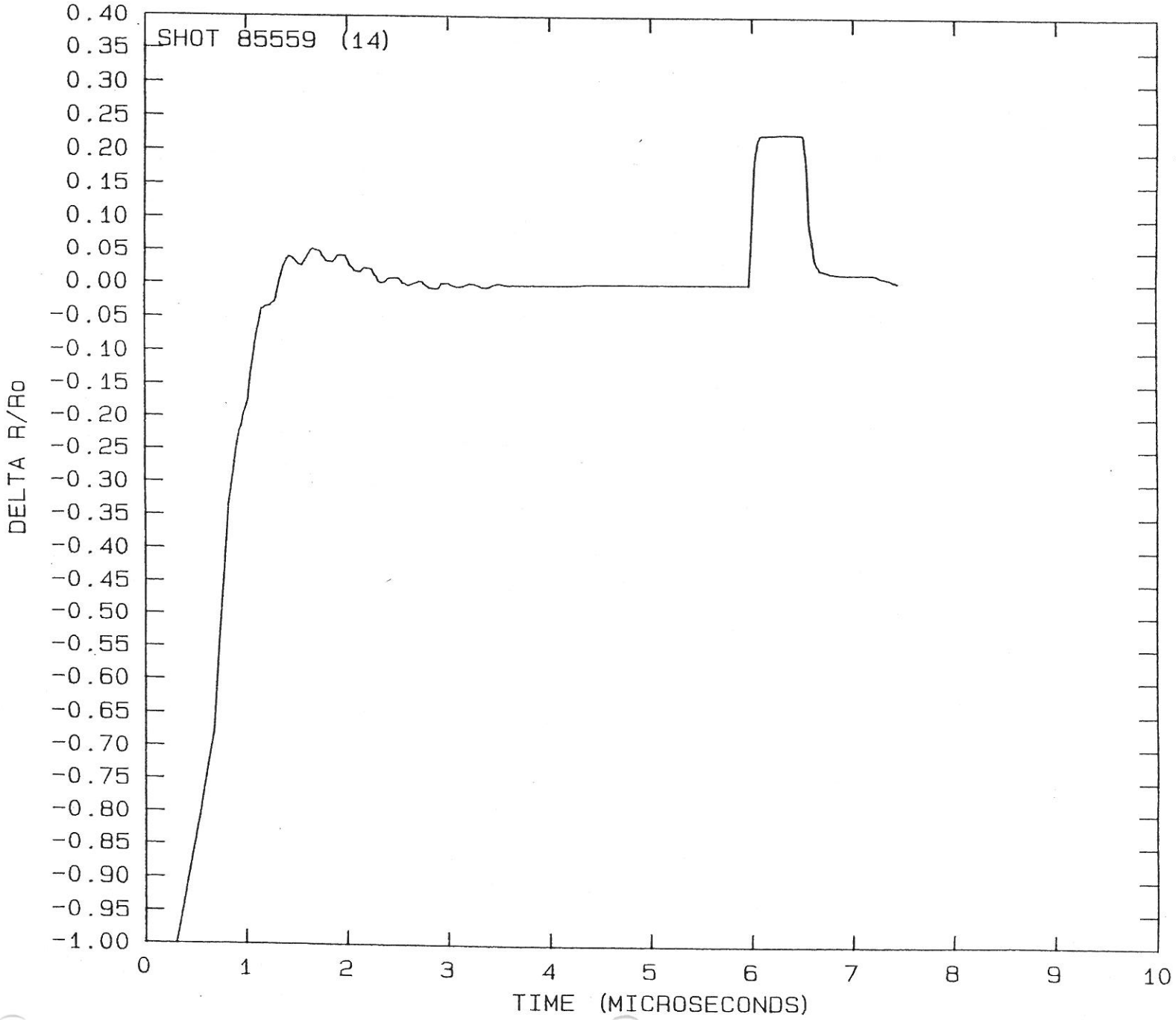

SHOT 86520 Manganin Gauge (13) V
DELTA R/Ro
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
0
1
2
3
4
5
6
7
8
9
10
TIME (usec)

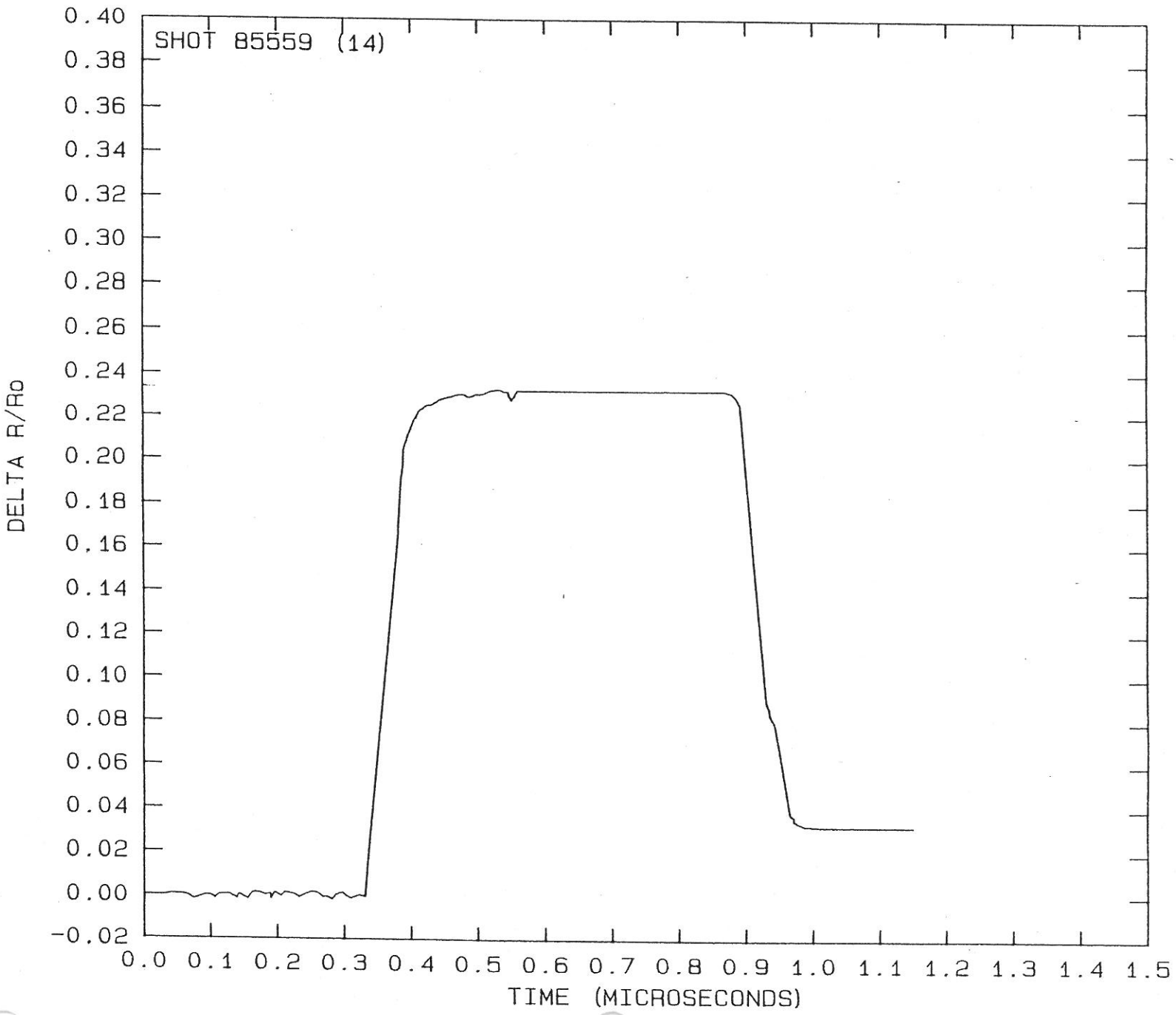

SHOT 86520 Manganin gauge (11) DV
DELTA R/Ro
0.20
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
TIME (usec)

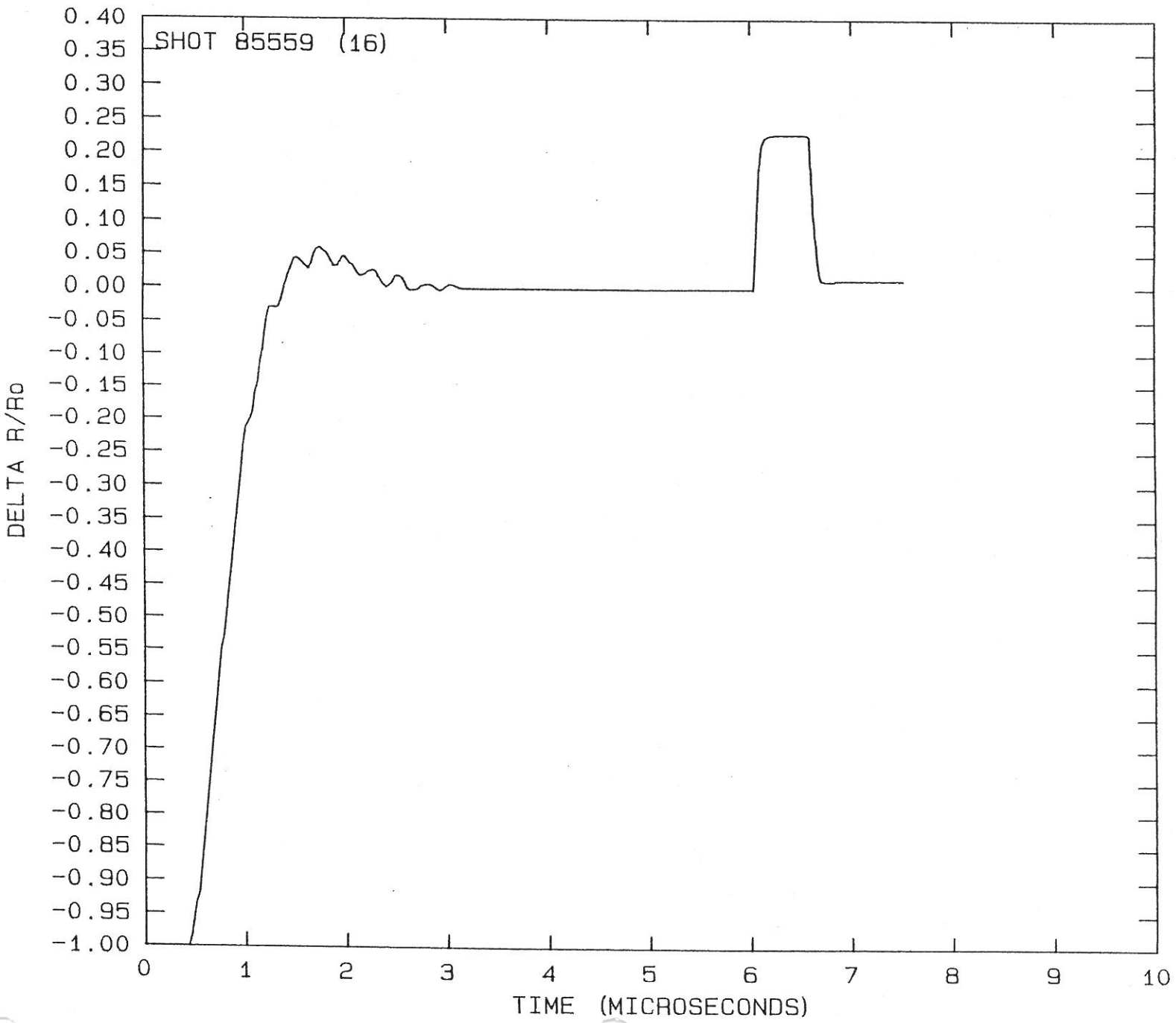
## Shot Number (2) 85559

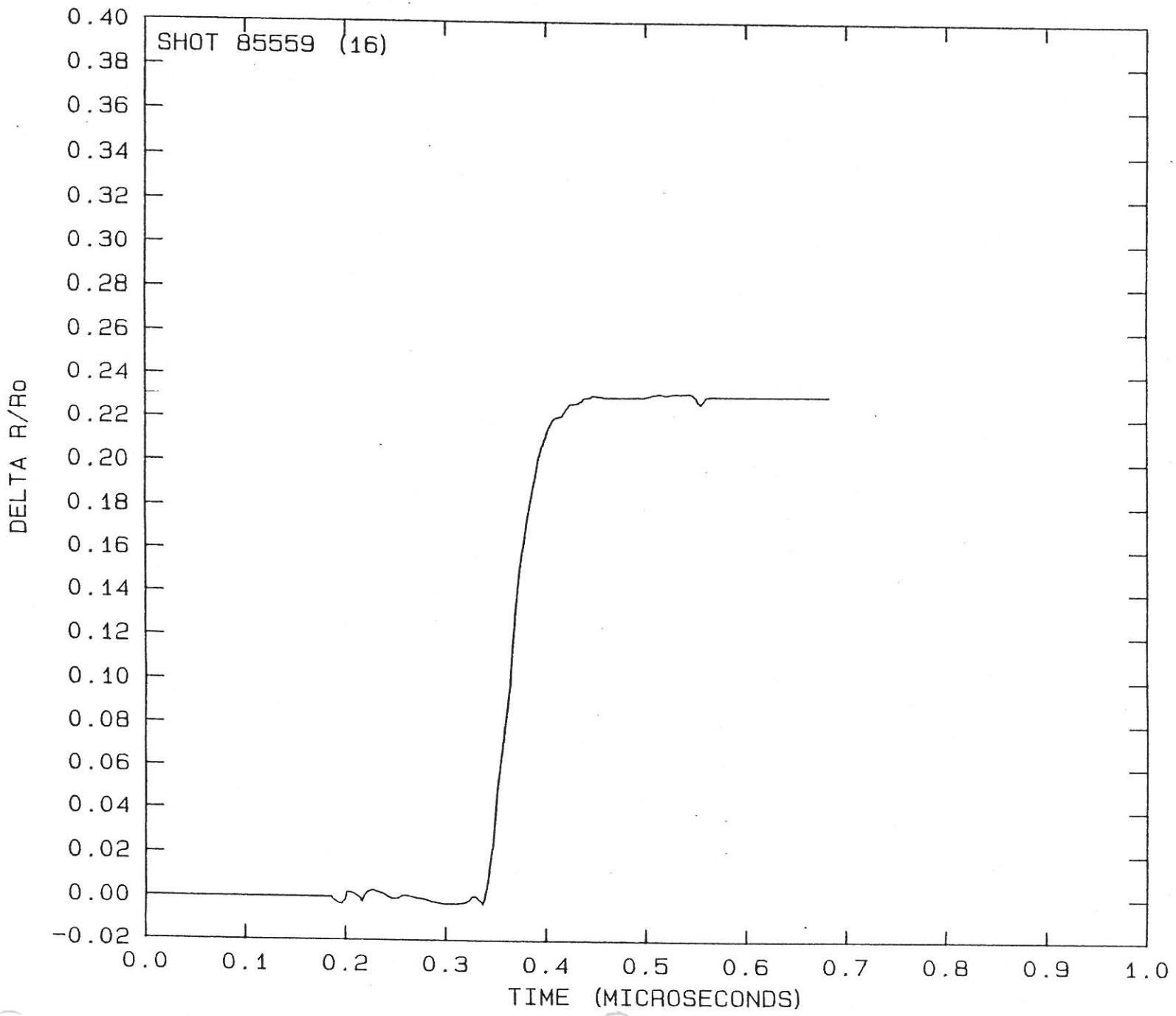
| | |
|---|---|
| Longitudinal Stress in the Matrix: | 86.0 kbars |
| Impactor Material: | Z-cut Sapphire |
| Impactor Thickness: | 3.17 mm |
| Projectile Velocity: | 0.38 mms/microseconds |
| Matrix Material: | Z-cut Sapphire |
| Depth of Gauge in Matrix: | 3.17 mm |

Remarks: The gauge was emplaced in a groove.


SHOT 85559 (14)
DELTA R/Ro
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
-0.40
-0.45
-0.50
-0.55
-0.60
-0.65
-0.70
-0.75
-0.80
-0.85
-0.90
-0.95
-1.00
0
1
2
3
4
5
6
7
8
9
10
TIME (MICROSECONDS)


SHOT 85559 (14)
DELTA R/Ro
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
-0.02
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5
TIME (MICROSECONDS)

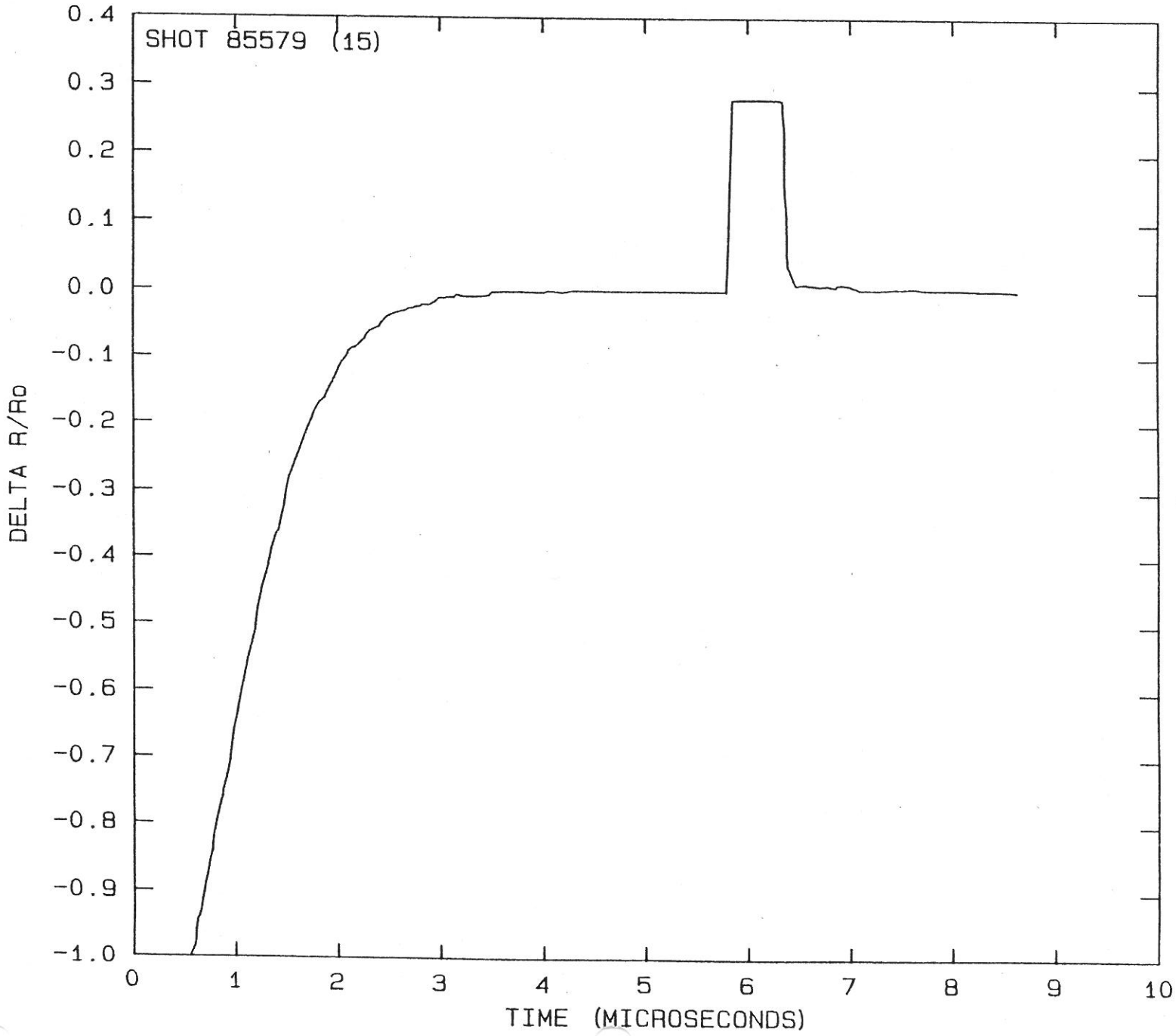

SHOT 85559 (16)
DELTA R/Ro
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
-0.40
-0.45
-0.50
-0.55
-0.60
-0.65
-0.70
-0.75
-0.80
-0.85
-0.90
-0.95
-1.00
0
1
2
3
4
5
6
7
8
9
10
TIME (MICROSECONDS)

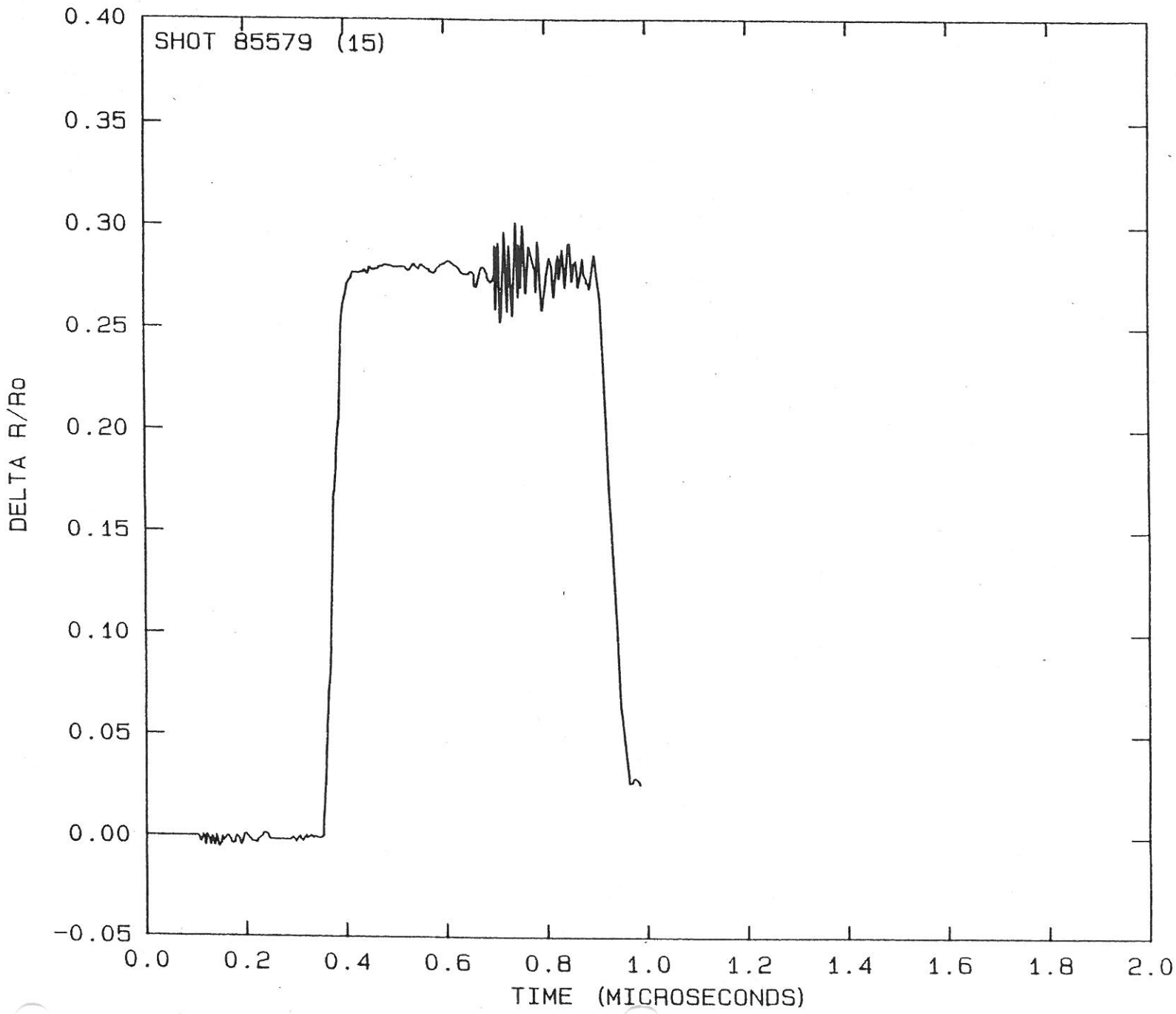

SHOT 85559 (16)
DELTA R/Ro
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
-0.02
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
TIME (MICROSECONDS)

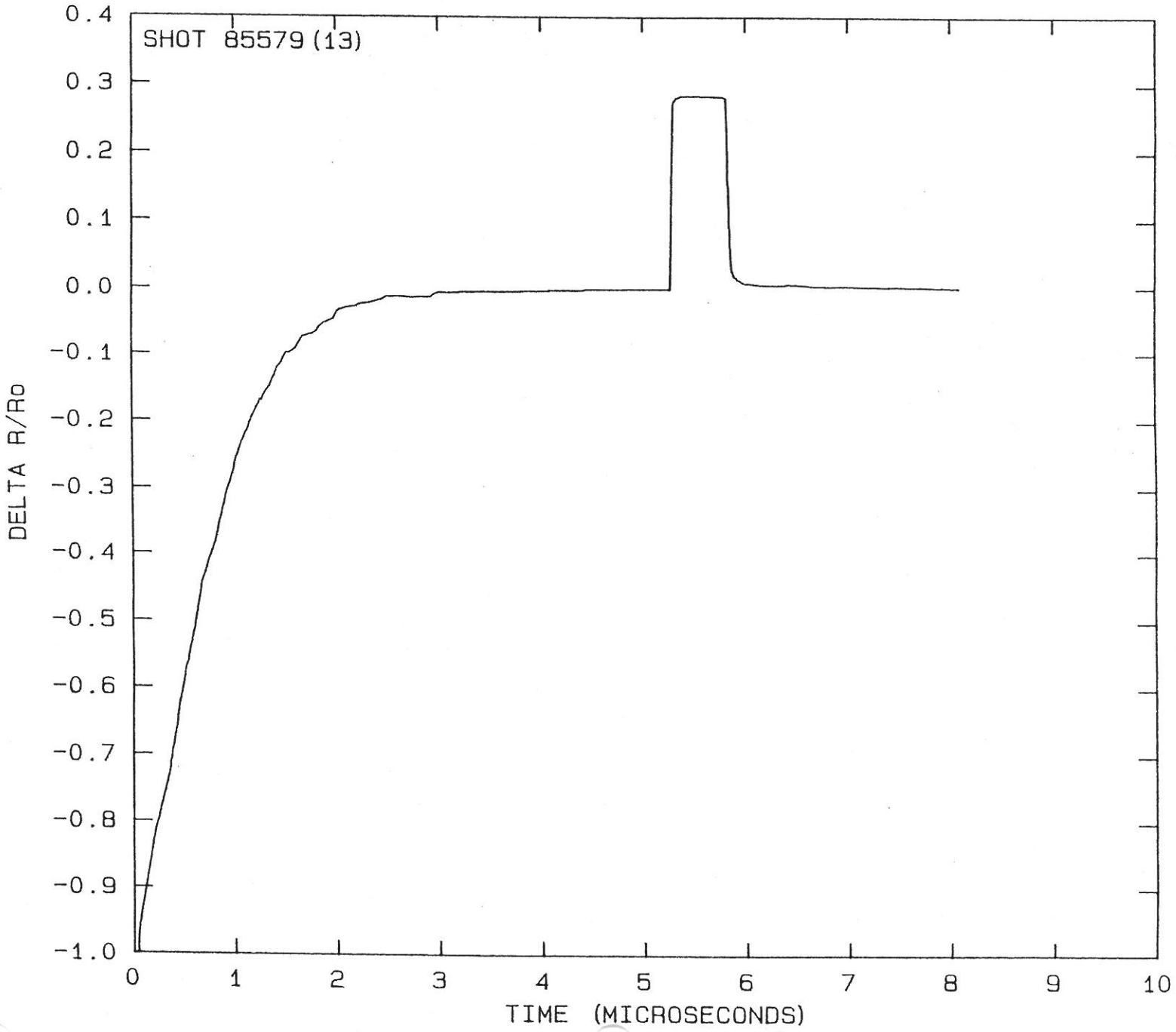
## Shot Number (3) 85579

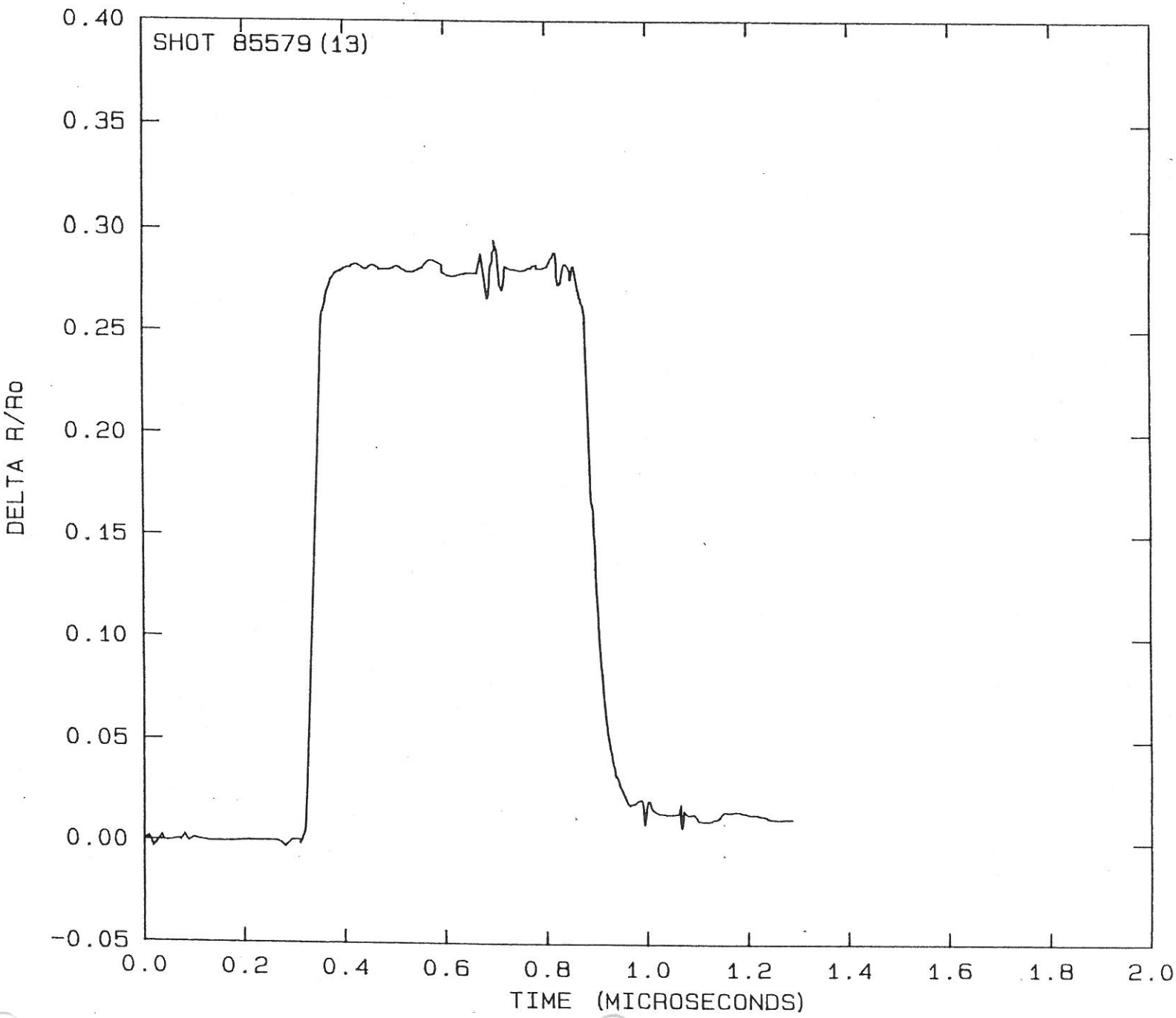
| | |
|---|---|
| Longitudinal Stress in the Matrix: | 111.6 kbars |
| Impactor Material: | Z-cut Sapphire |
| Impactor Thickness: | 3.17 mm |
| Projectile Velocity: | 0.490 mms/microseconds |
| Matrix Material: | Z-cut Sapphire |
| Depth of Gauge in Matrix: | 3.17 mm |

Remarks: The gauge was emplaced in a groove.


SHOT 85579 (15)
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
DELTA R/R0
0
1
2
3
4
5
6
7
8
9
10
TIME (MICROSECONDS)


SHOT 85579 (15)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
−0.05
DELTA R/Ro
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
TIME (MICROSECONDS)

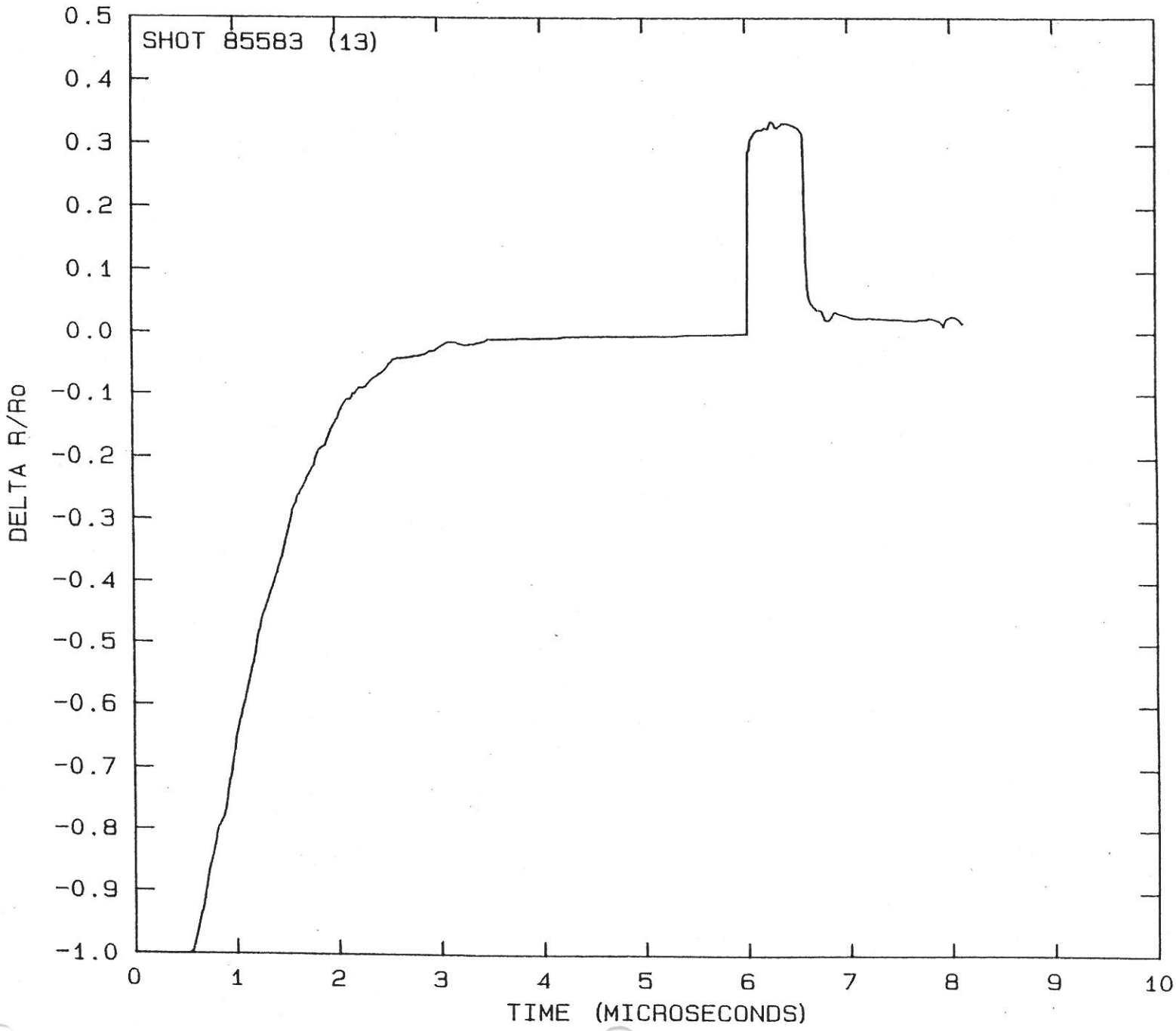

SHOT 85579 (13)
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
DELTA R/Ro
0
1
2
3
4
5
6
7
8
9
10
TIME (MICROSECONDS)

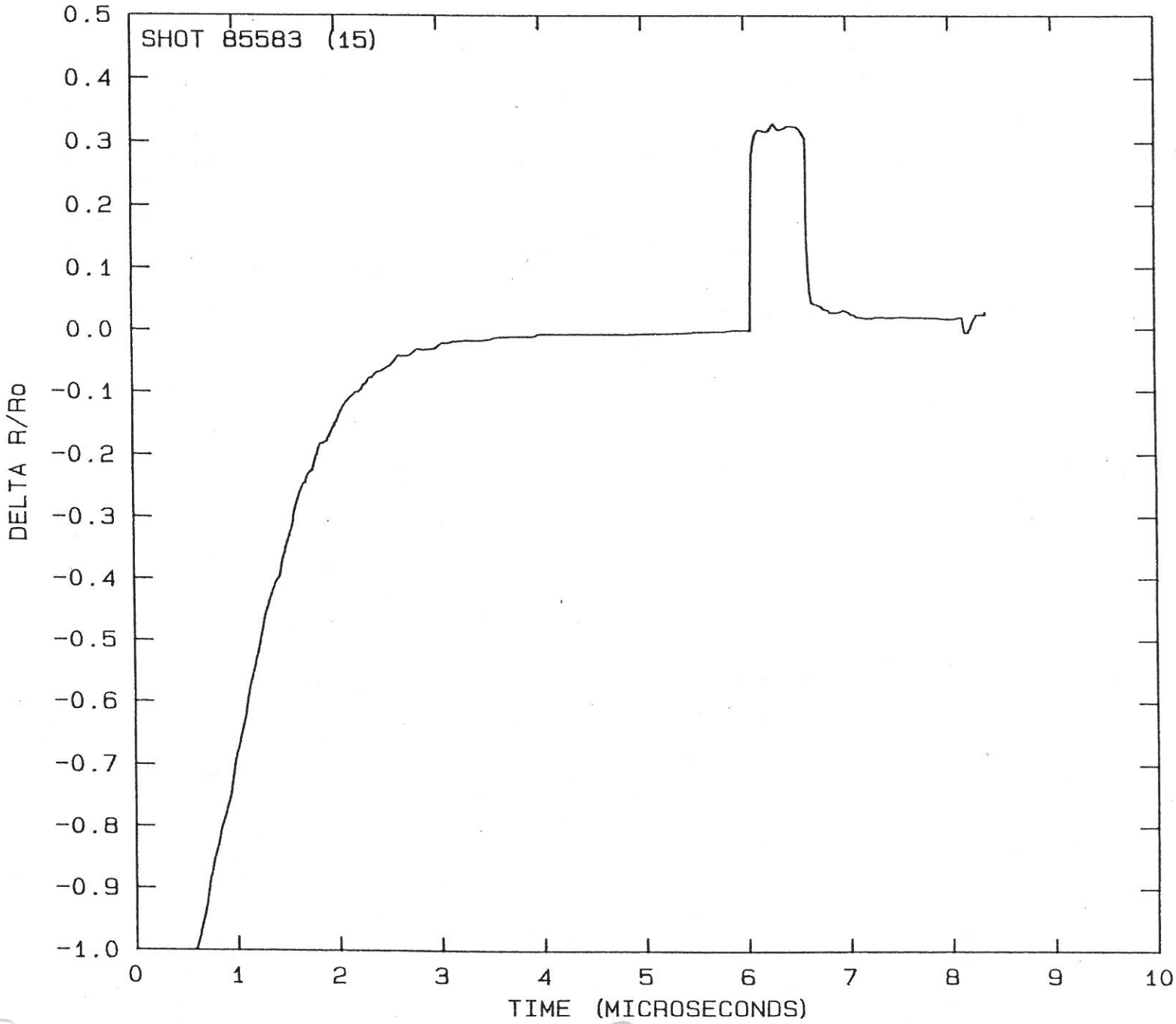

SHOT 85579 (13)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
DELTA R/Ro
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
TIME (MICROSECONDS)

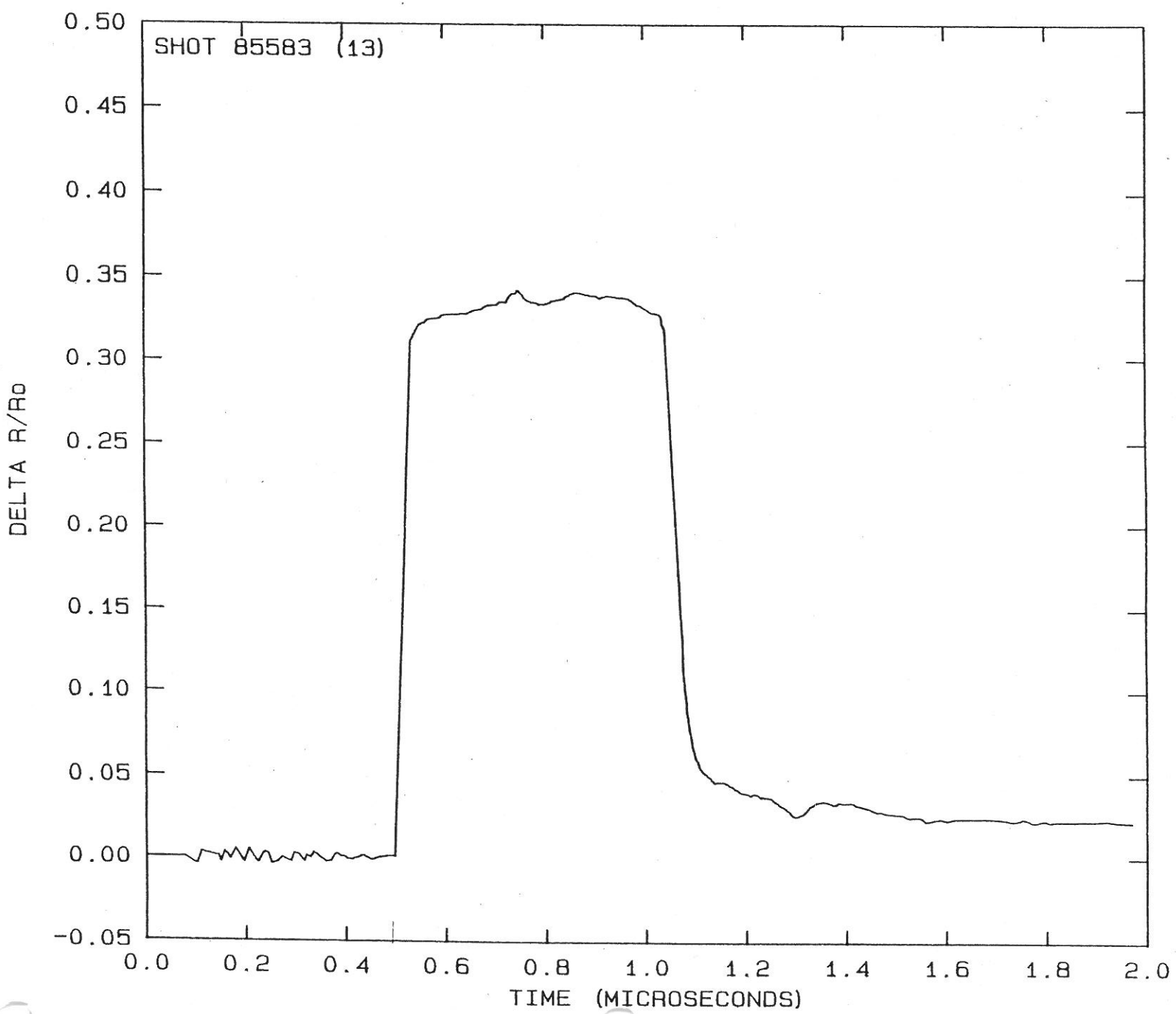
## Shot Number (4) 85583

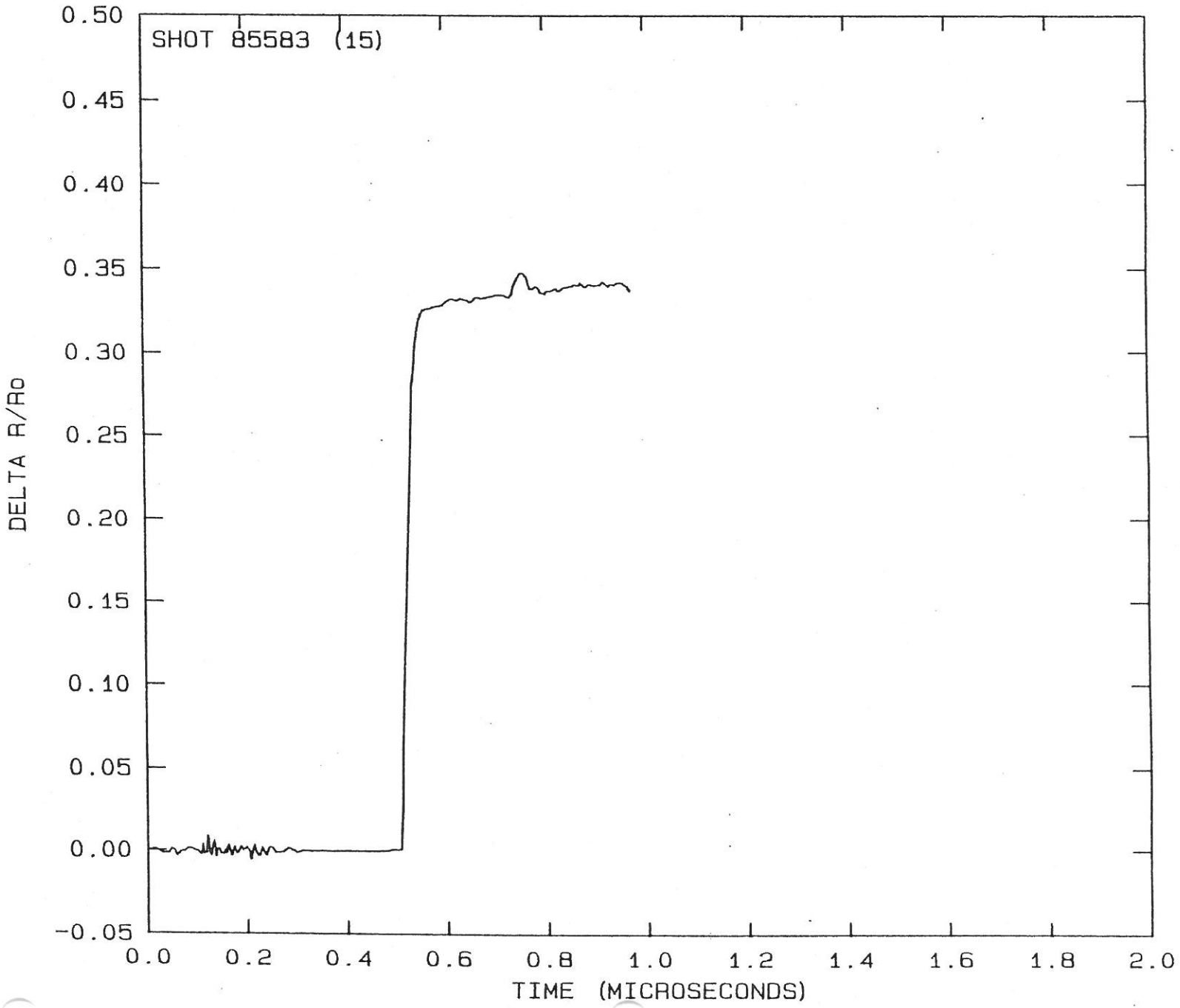
| | |
|---|---|
| Longitudinal Stress in the Matrix: | 126.5 kbars |
| Impactor Material: | Z-cut Sapphire |
| Impactor Thickness: | 3.17 mm |
| Projectile Velocity: | 0.554 mms/microseconds |
| Matrix Material: | Z-cut Sapphire |
| Depth of Gauge in Matrix: | 3.17 mm |

Remarks: The gauge was emplaced in a groove.


SHOT 85583 (13)
DELTA R/R0
TIME (MICROSECONDS)
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
0
1
2
3
4
5
6
7
8
9
10


SHOT 85583 (15)
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
DELTA R/Ro
0
1
2
3
4
5
6
7
8
9
10
TIME (MICROSECONDS)


SHOT 85583 (13)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
DELTA R/Ro
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
TIME (MICROSECONDS)


SHOT 85583 (15)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
DELTA R/Ro
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
TIME (MICROSECONDS)

## Shot Number (5) 86001

Longitudinal Stress in the Matrix: 132.0 kbars

Impactor Material: Z-cut Sapphire

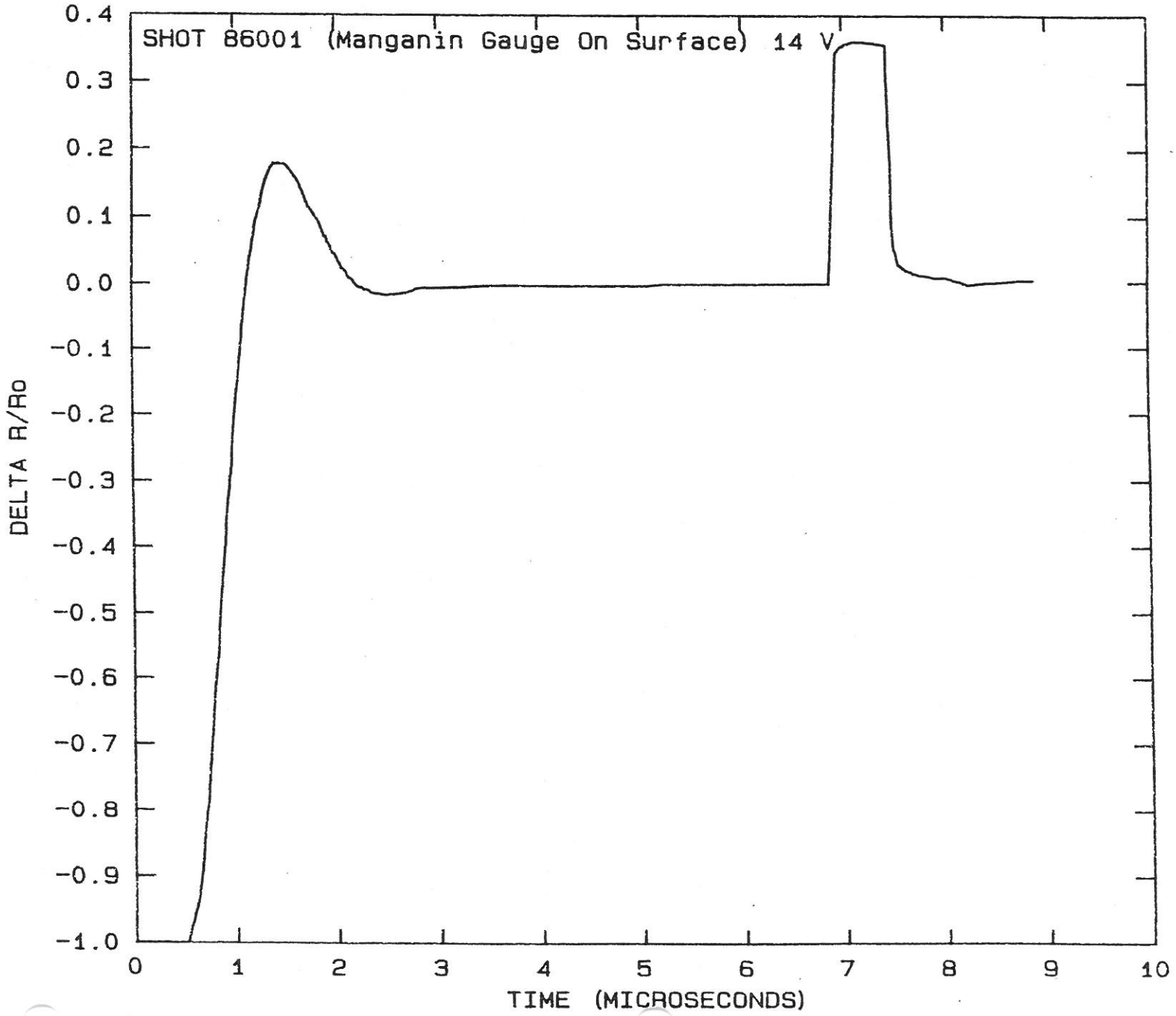
Impactor Thickness: 3.17 mm

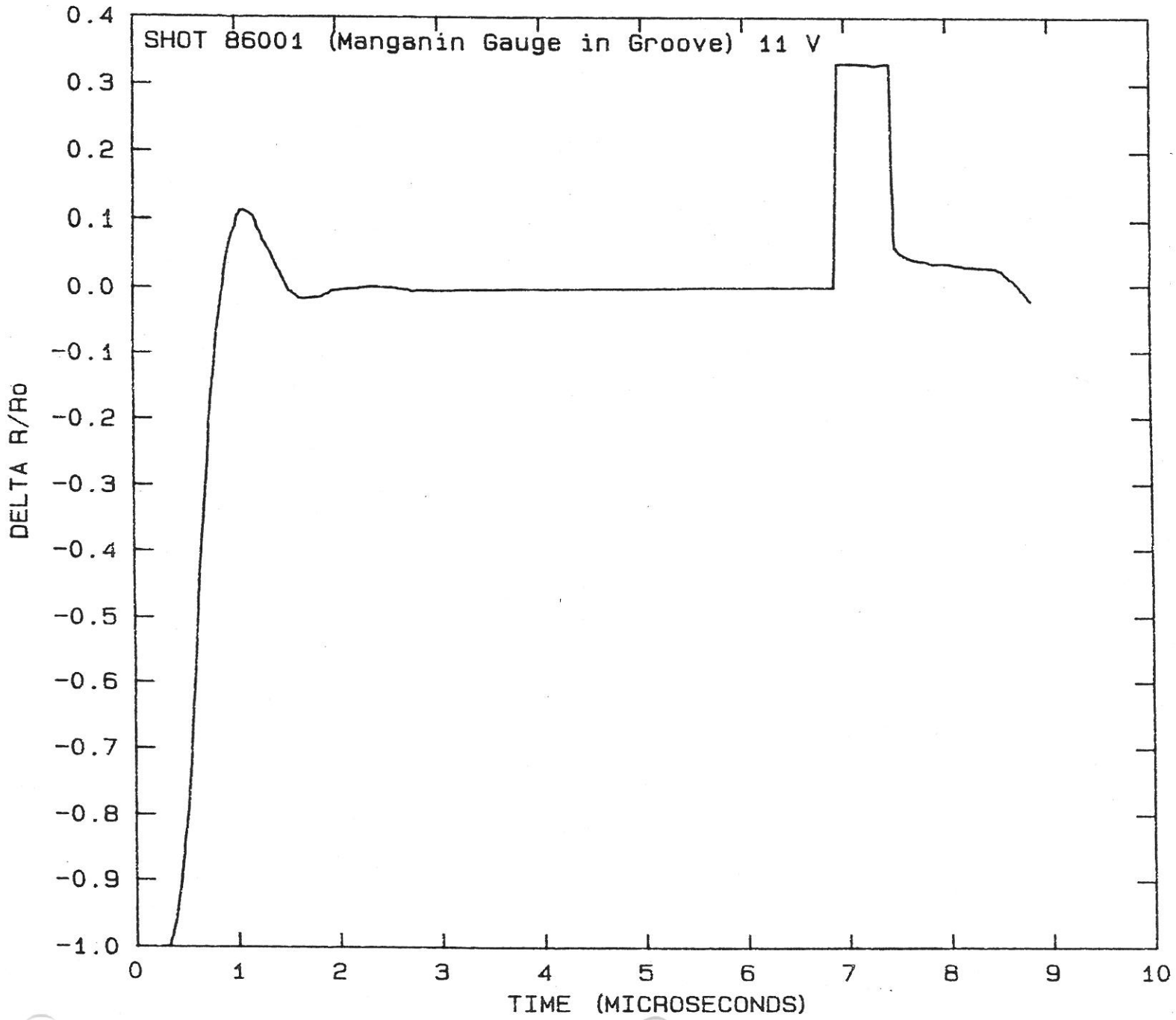
Projectile Velocity: 0.576 mms/microseconds

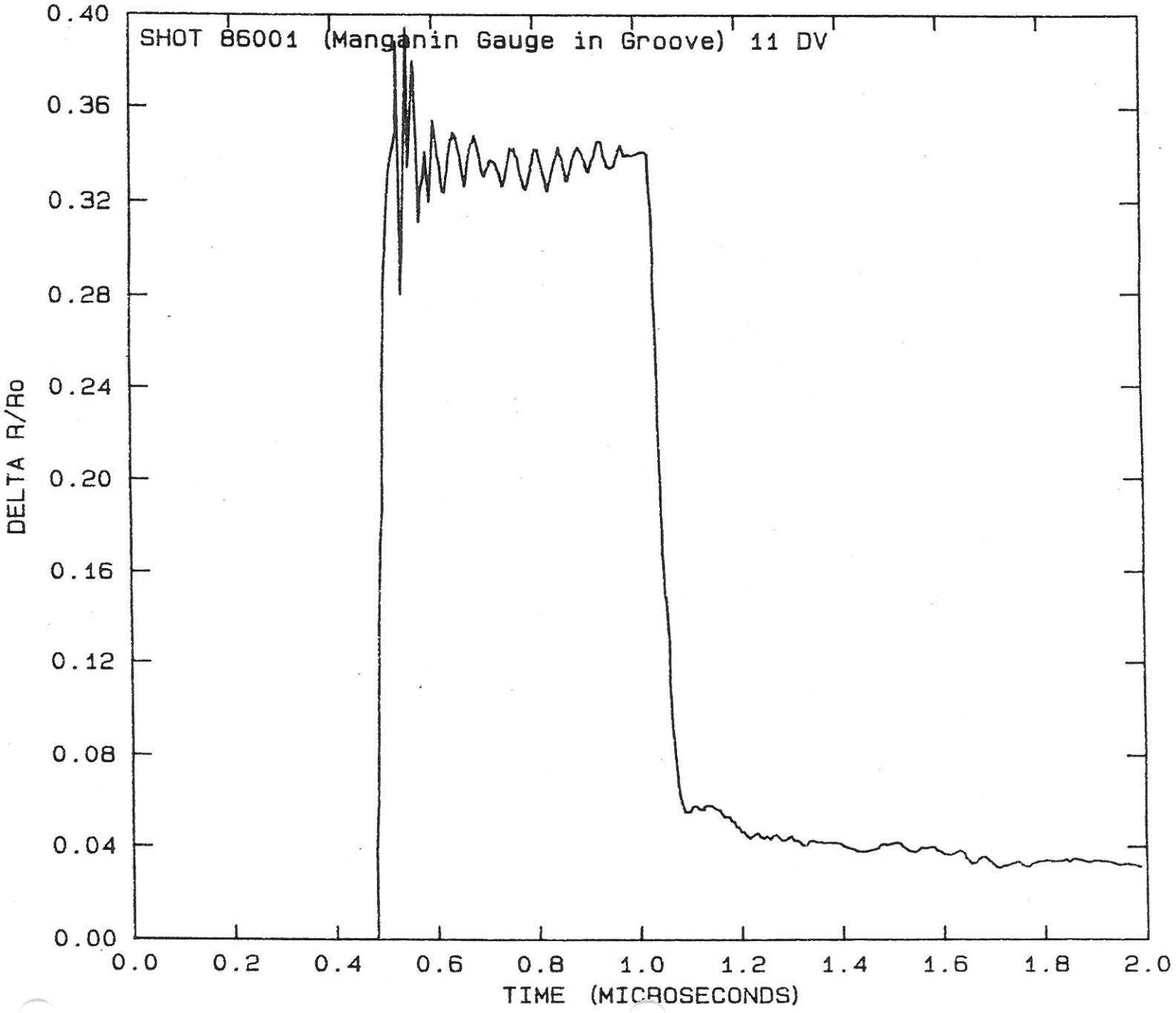
Matrix Material: Z-cut Sapphire

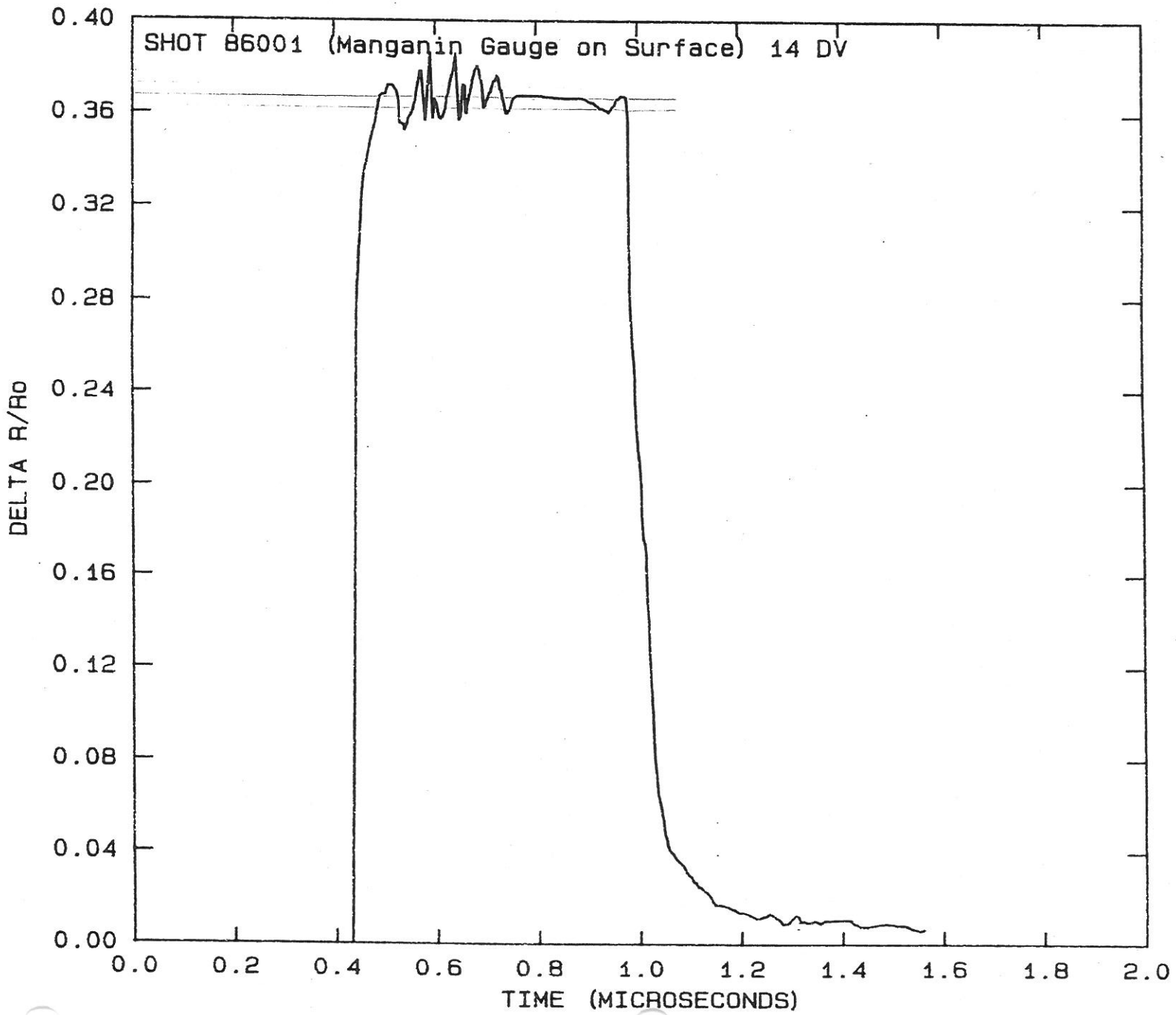
Depth of Gauges in Matrix: 3.17 mm

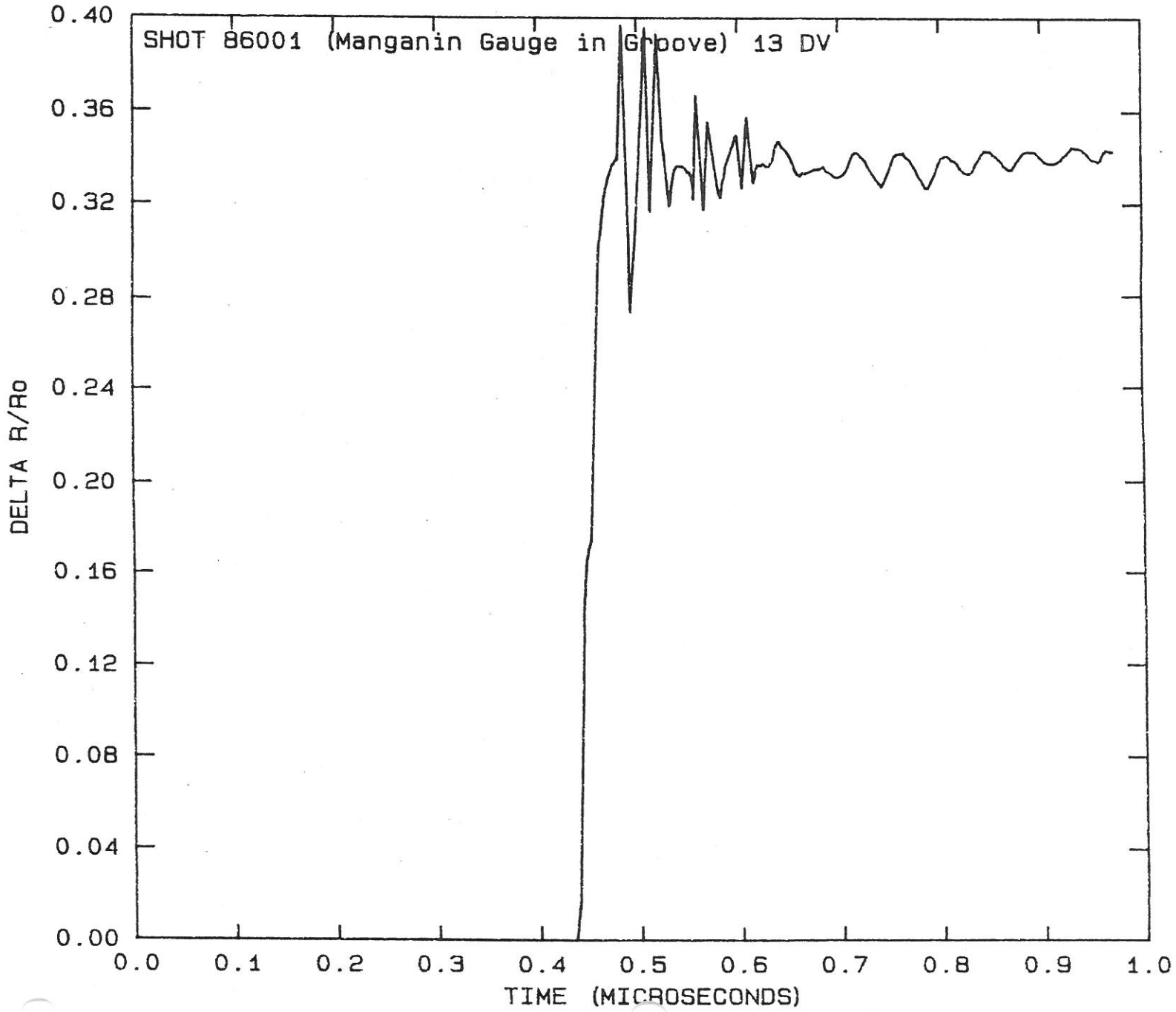
Remarks: There were two gauges in the target: (i) in a groove and (ii) on surface. Both the gauges were at the same depth (3.17 mm) from the target surface. This shot was carried out in the 4" gun. We intended the projectile velocity to be 0.654 mms/usec., but instead obtained a lower value of 0.576 mms/usec.. We suspected the cause to be the projectile being not perfectly round and slightly larger in diameter than the standard value. This shot was repeated as (shot) 86003.

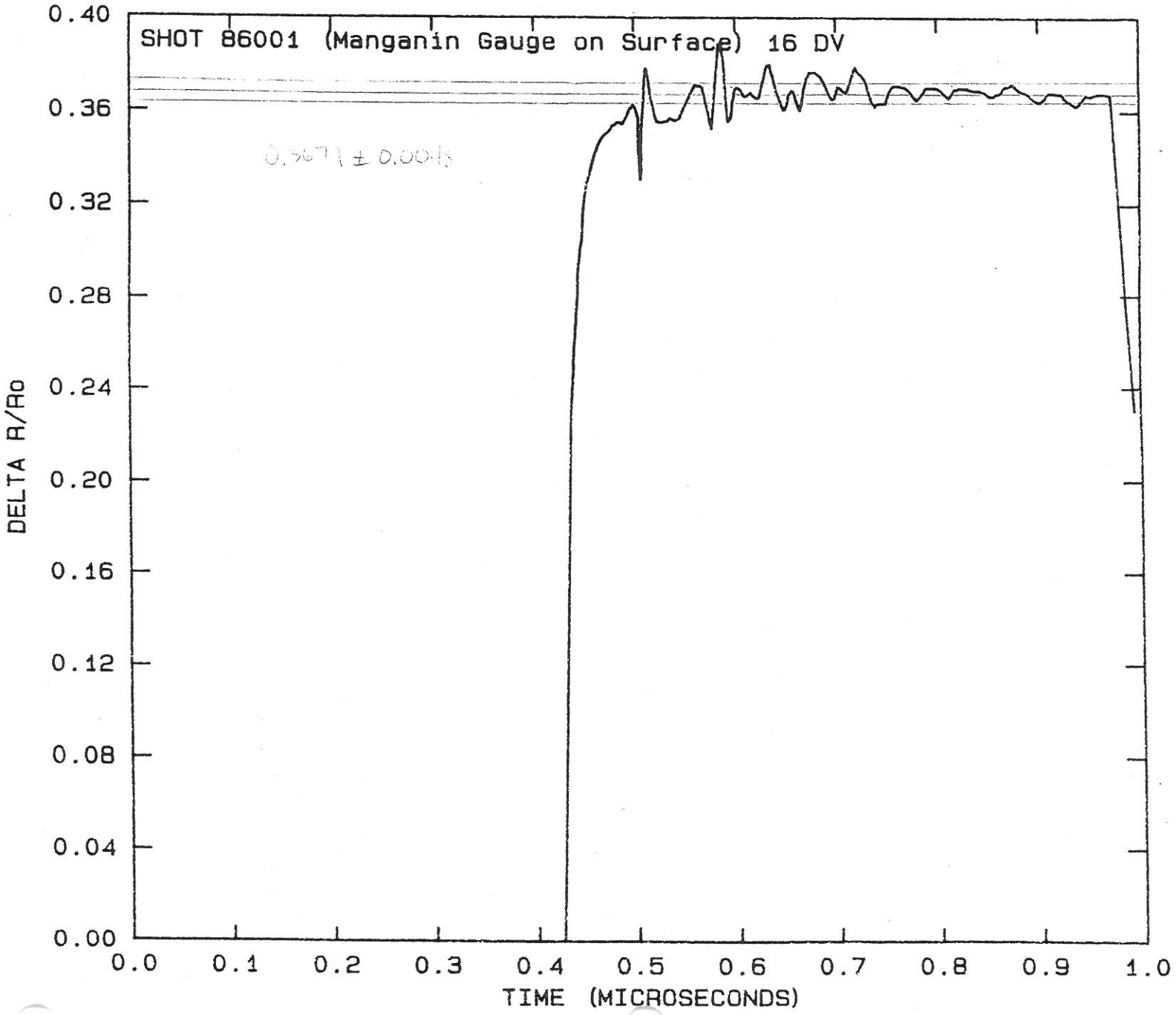

SHOT 86001 (Manganin Gauge On Surface) 14 V
DELTA R/Ro
TIME (MICROSECONDS)
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
0
1
2
3
4
5
6
7
8
9
10


SHOT 86001 (Manganin Gauge in Groove) 11 V
DELTA R/Ro
TIME (MICROSECONDS)
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
0
1
2
3
4
5
6
7
8
9
10


SHOT 86001 (Manganin Gauge in Groove) 11 DV
DELTA R/Ro
0.40
0.36
0.32
0.28
0.24
0.20
0.16
0.12
0.08
0.04
0.00
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
TIME (MICROSECONDS)


SHOT 86001 (Manganin Gauge on Surface) 14 DV
DELTA R/Ro
0.40
0.36
0.32
0.28
0.24
0.20
0.16
0.12
0.08
0.04
0.00
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
TIME (MICROSECONDS)


SHOT 86001 (Manganin Gauge in Groove) 13 DV
DELTA R/Ro
0.40
0.36
0.32
0.28
0.24
0.20
0.16
0.12
0.08
0.04
0.00
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
TIME (MICROSECONDS)


SHOT 86001 (Manganin Gauge on Surface) 16 DV
0.367 ± 0.001
DELTA R/Ro
0.40
0.36
0.32
0.28
0.24
0.20
0.16
0.12
0.08
0.04
0.00
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
TIME (MICROSECONDS)

## Shot Number (6) 86003

Longitudinal Stress in the Matrix: 149.0 kbars

Impactor Material: Z-cut Sapphire

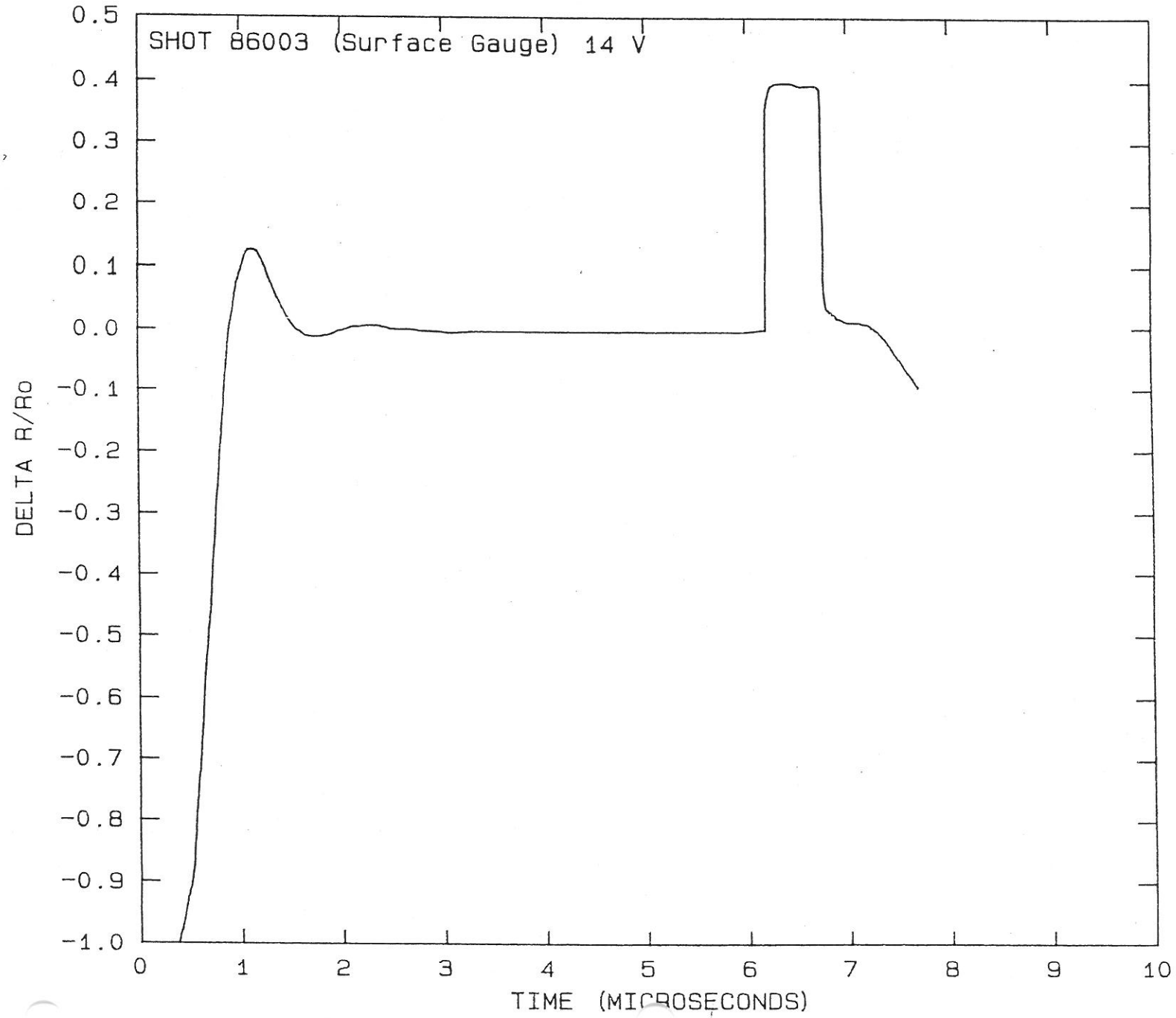
Impactor Thickness: 3.17 mm

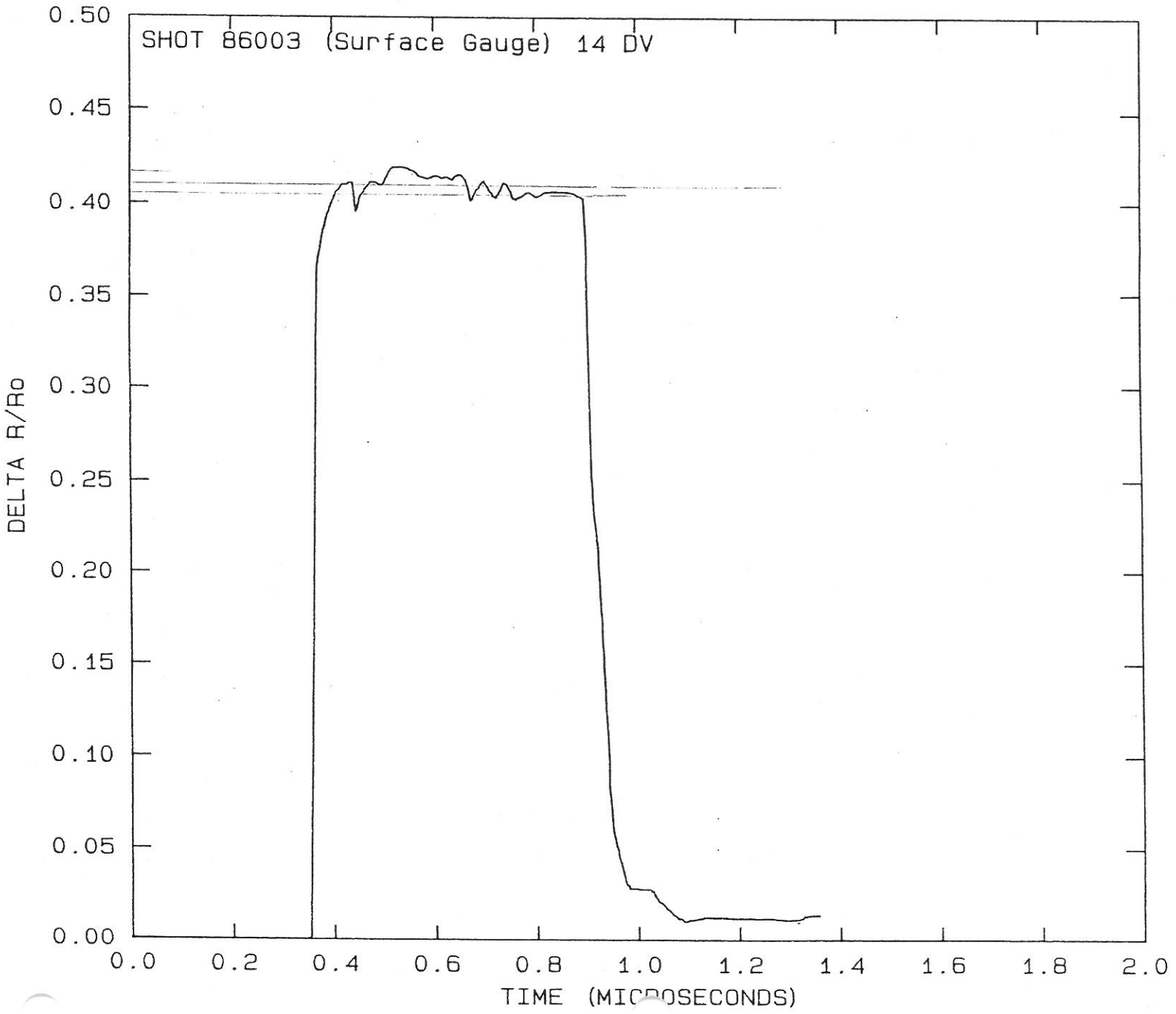
Projectile Velocity: 0.650 mms/microseconds

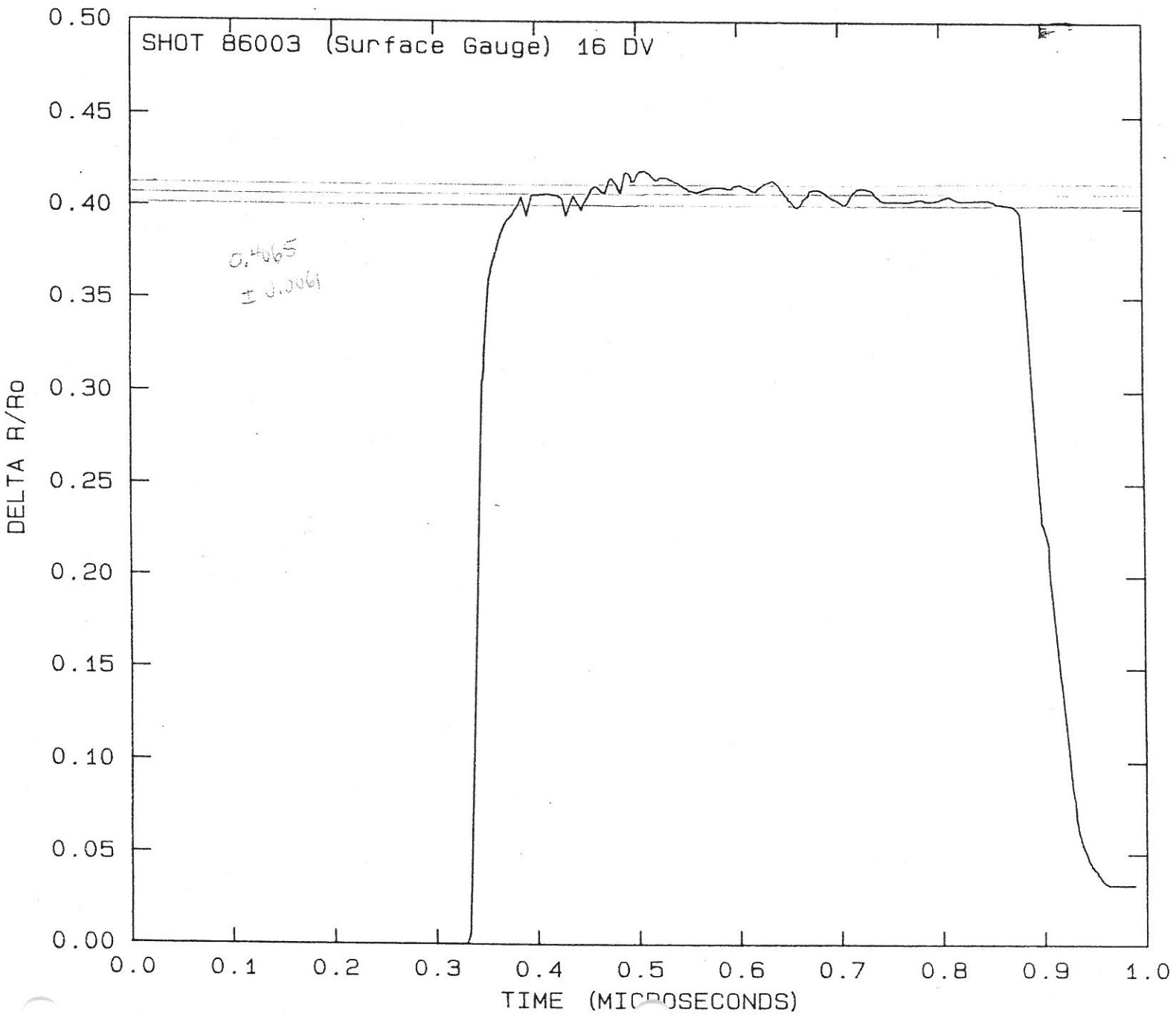
Matrix Material: Z-cut Sapphire

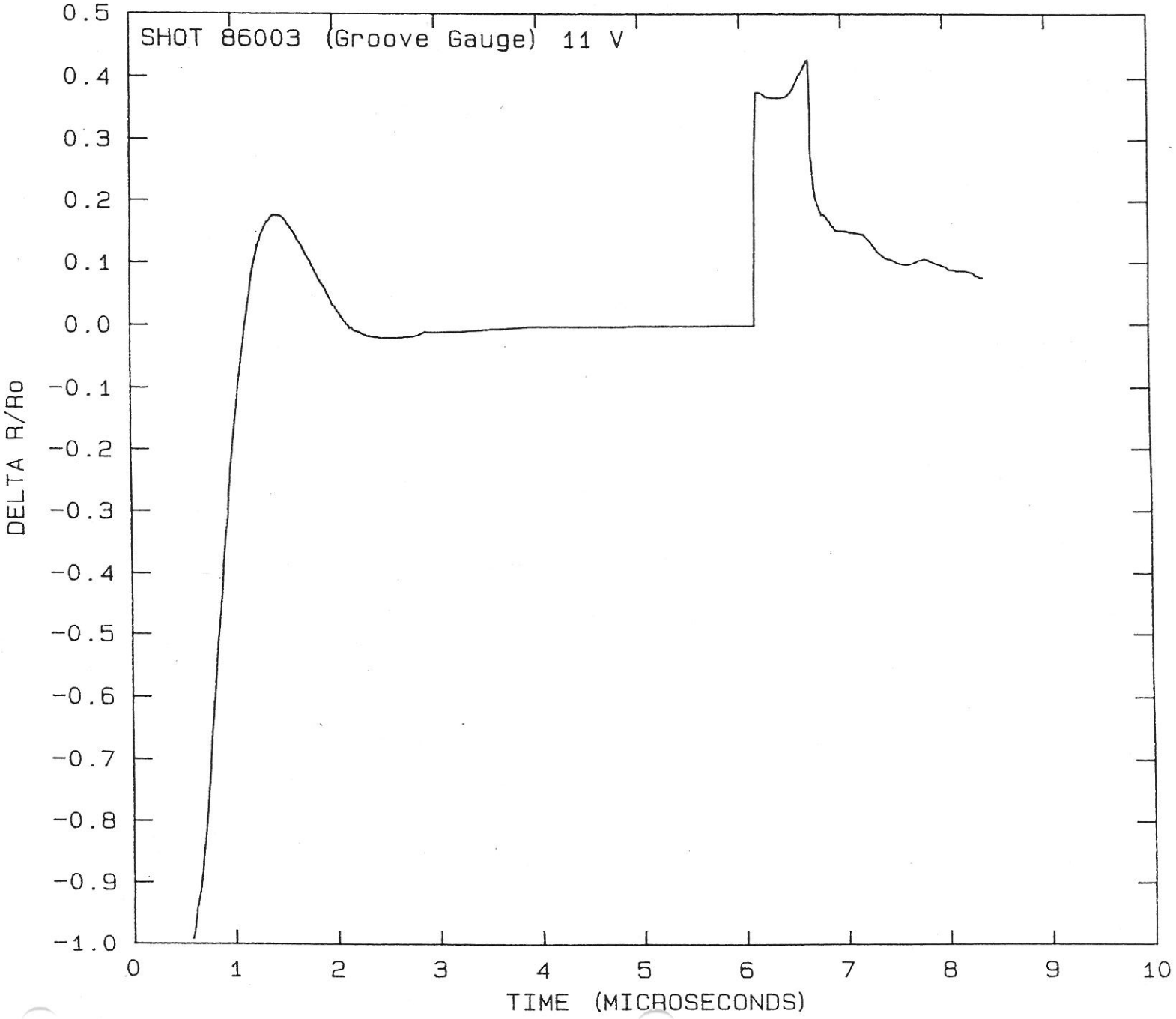
Depth of Gauges in Matrix: 3.17 mm

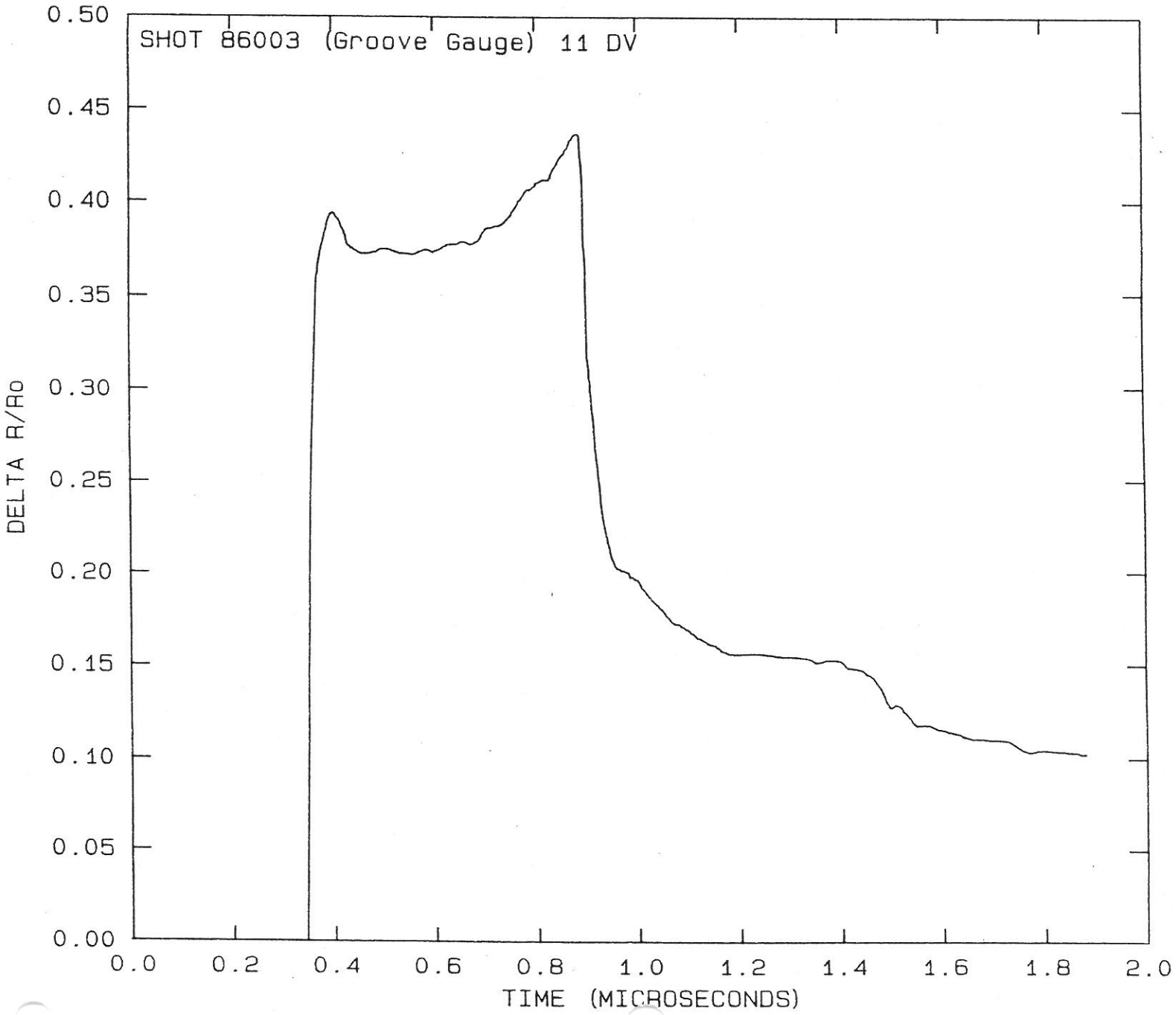
Remarks: There were two gauges in the target: (i) in a groove and (ii) on surface. Both the gauges were at the same depth (3.17 mm) from the target surface. This shot was carried out in the 4" gun.

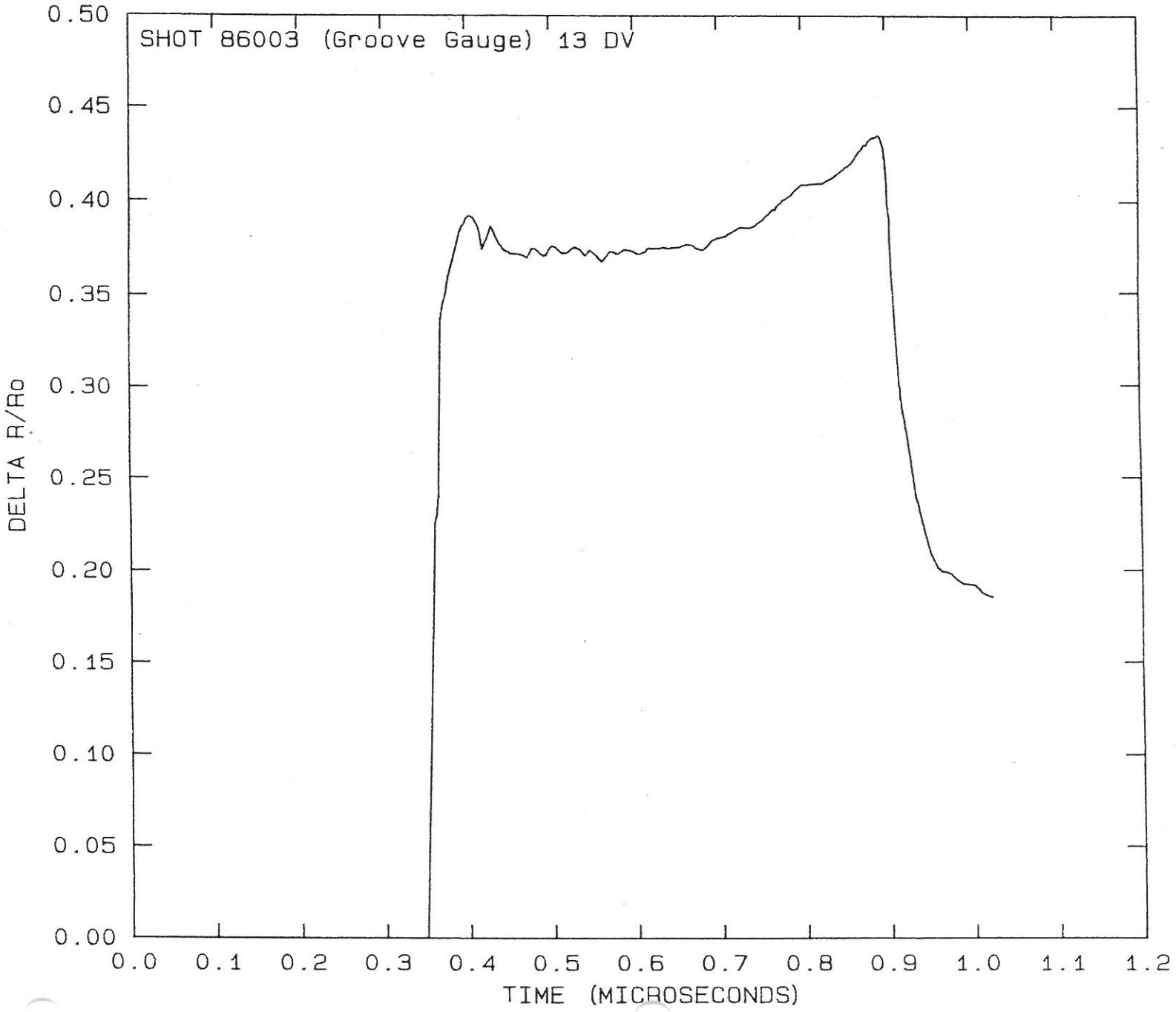

SHOT 86003 (Surface Gauge) 14 V
DELTA R/Ro
TIME (MICROSECONDS)
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
0
1
2
3
4
5
6
7
8
9
10


SHOT 86003 (Surface Gauge) 14 DV
DELTA R/Ro
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
TIME (MICROSECONDS)


SHOT 86003 (Surface Gauge) 16 DV
0.4065
± 0.0001
DELTA R/Ro
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
TIME (MICROSECONDS)


SHOT 86003 (Groove Gauge) 11 V
DELTA R/Ro
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
0
1
2
3
4
5
6
7
8
9
10
TIME (MICROSECONDS)

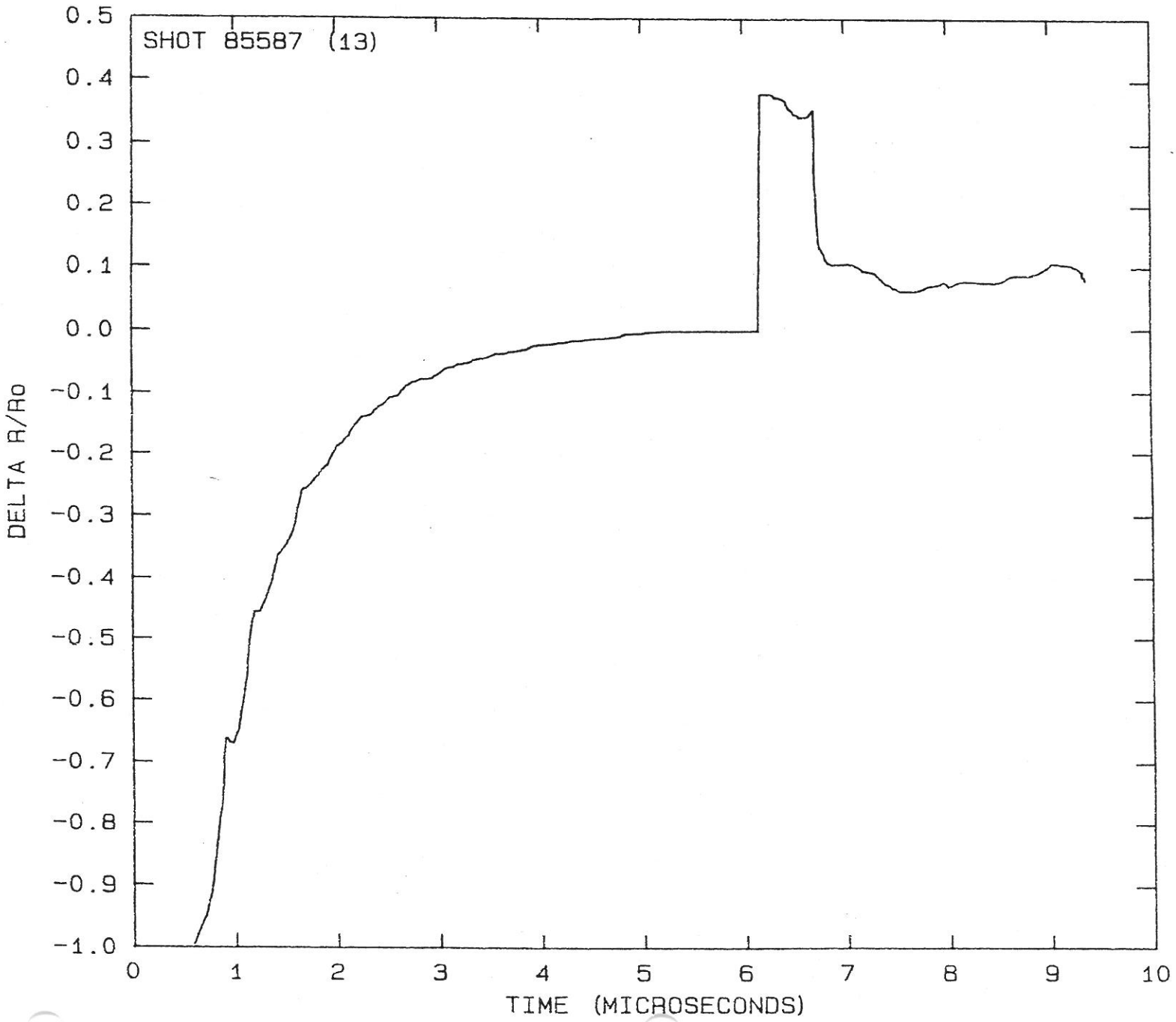

SHOT 86003 (Groove Gauge) 11 DV
DELTA R/Ro
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
TIME (MICROSECONDS)

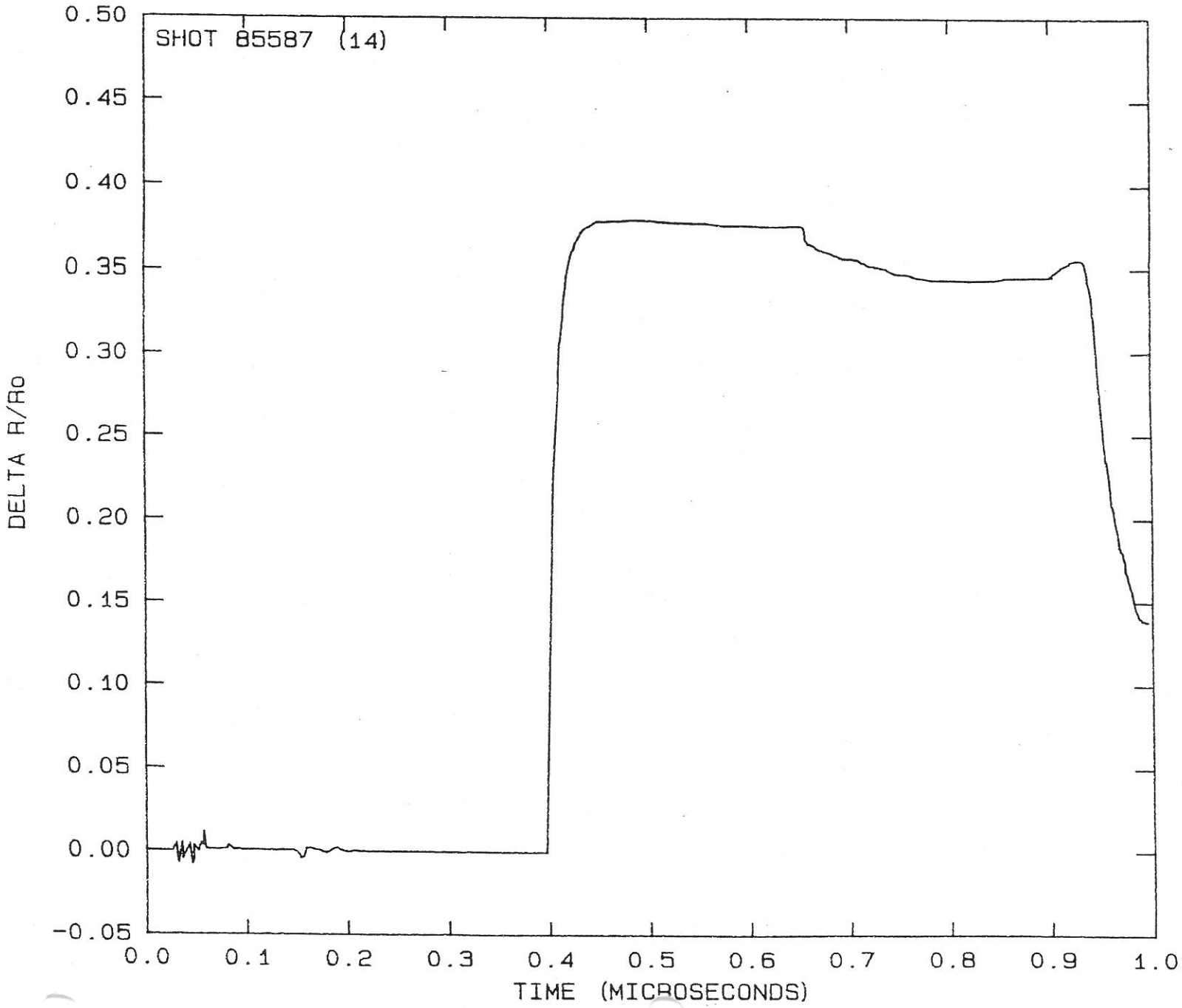

SHOT 86003 (Groove Gauge) 13 DV
DELTA R/Ro
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
TIME (MICROSECONDS)

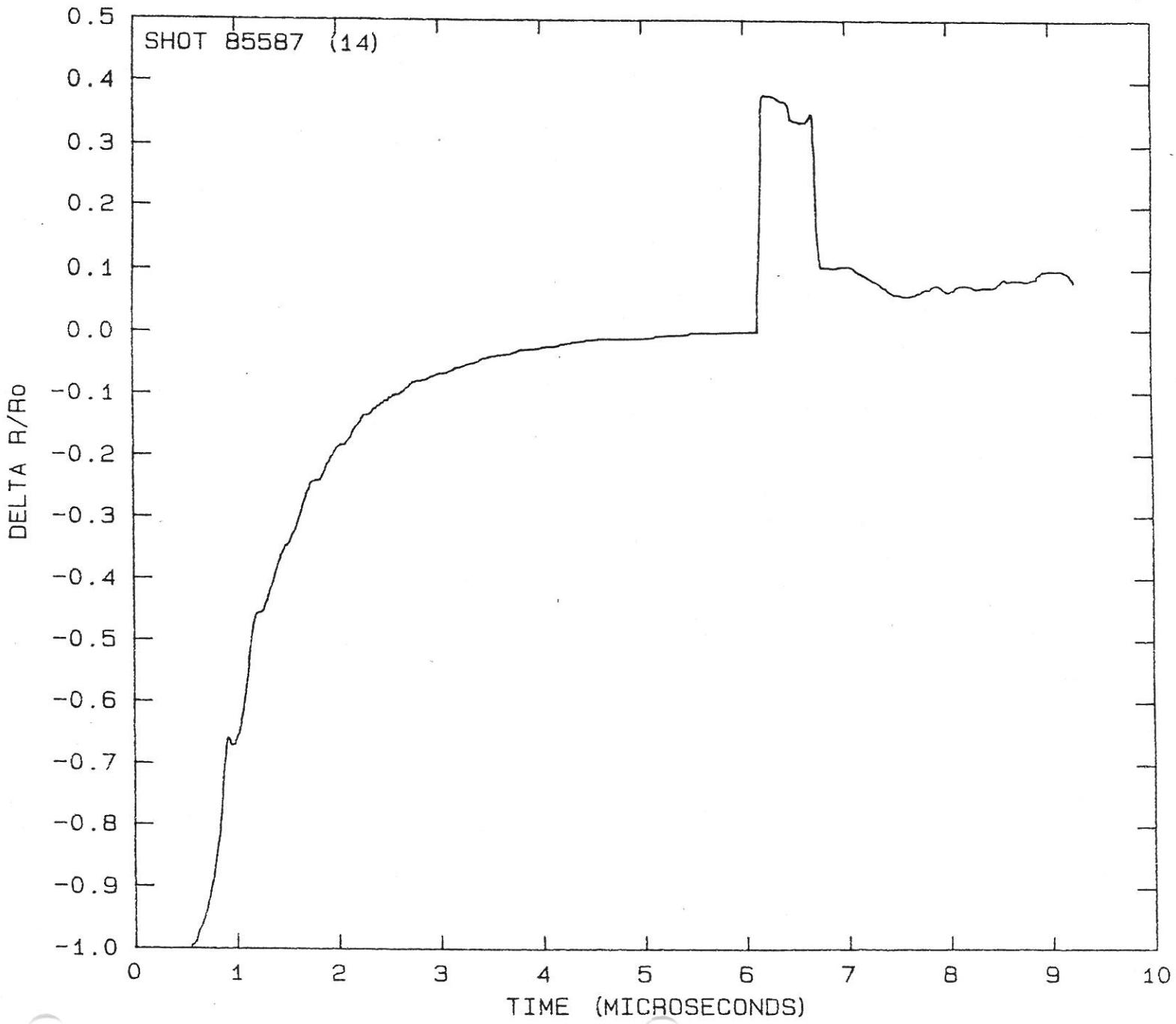
## Shot Number (7) 85587

| | |
|---|---|
| Longitudinal Stress in the Matrix: | 150.0 kbars |
| Impactor Material: | Z-cut Sapphire |
| Impactor Thickness: | 3.17 mm |
| Projectile Velocity: | 0.653 mms/microseconds |
| Matrix Material: | Z-cut Sapphire |
| Depth of Gauge in Matrix: | 3.17 mm |

Remarks: The gauge was emplaced in a groove.


SHOT 85587 (13)
DELTA R/Ro
TIME (MICROSECONDS)
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
0
1
2
3
4
5
6
7
8
9
10


SHOT 85587 (14)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
DELTA R/Ro
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
TIME (MICROSECONDS)


SHOT 85587 (14)
DELTA R/Ro
TIME (MICROSECONDS)
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
0
1
2
3
4
5
6
7
8
9
10

## Shot Number (8) 85050

Longitudinal Stress in the Matrix: 183.0 kbars

Impactor Material: Z-cut Sapphire

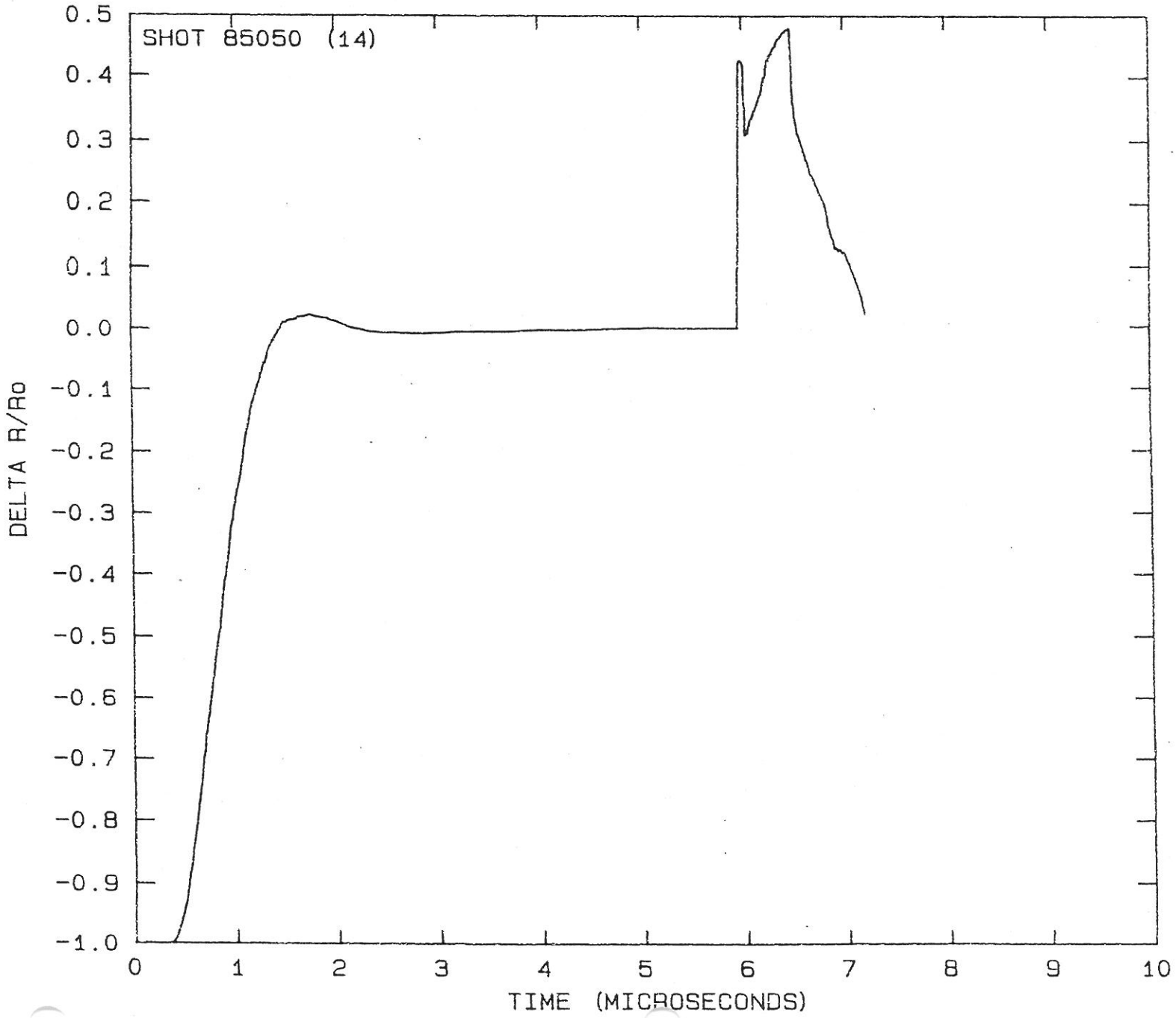
Impactor Thickness: 3.17 mm

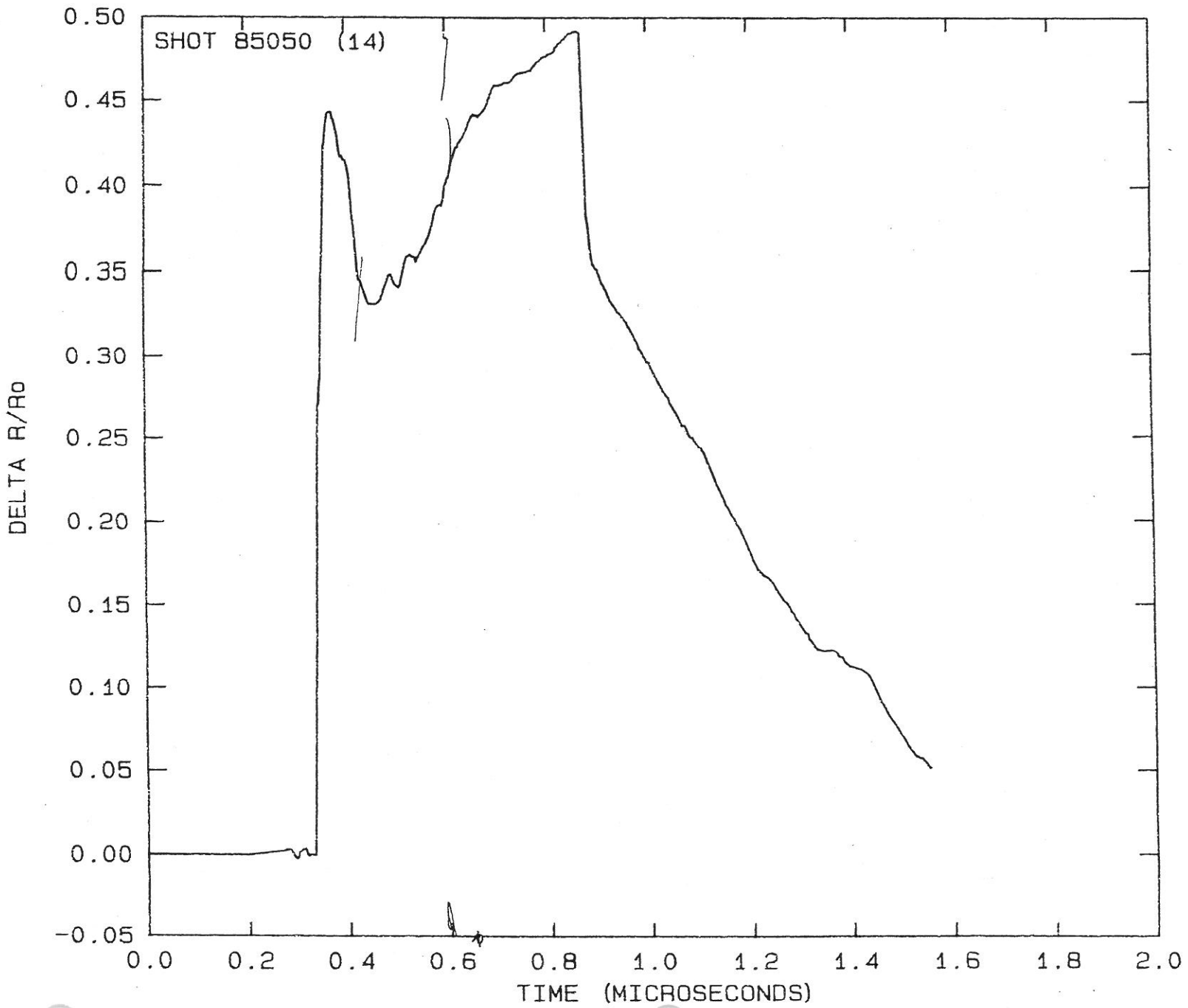
Projectile Velocity: 0.793 mms/microseconds

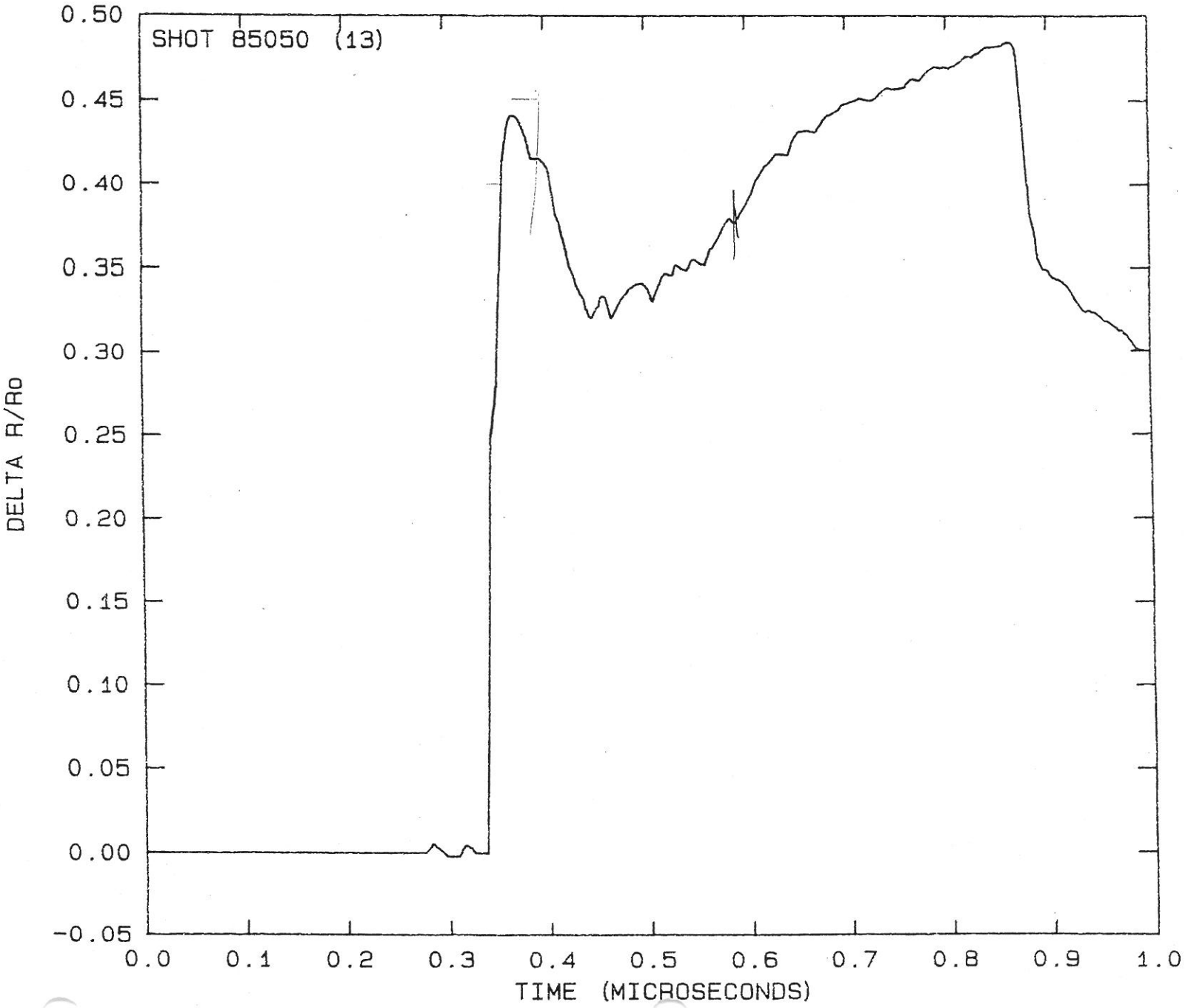
Matrix Material: Z-cut Sapphire

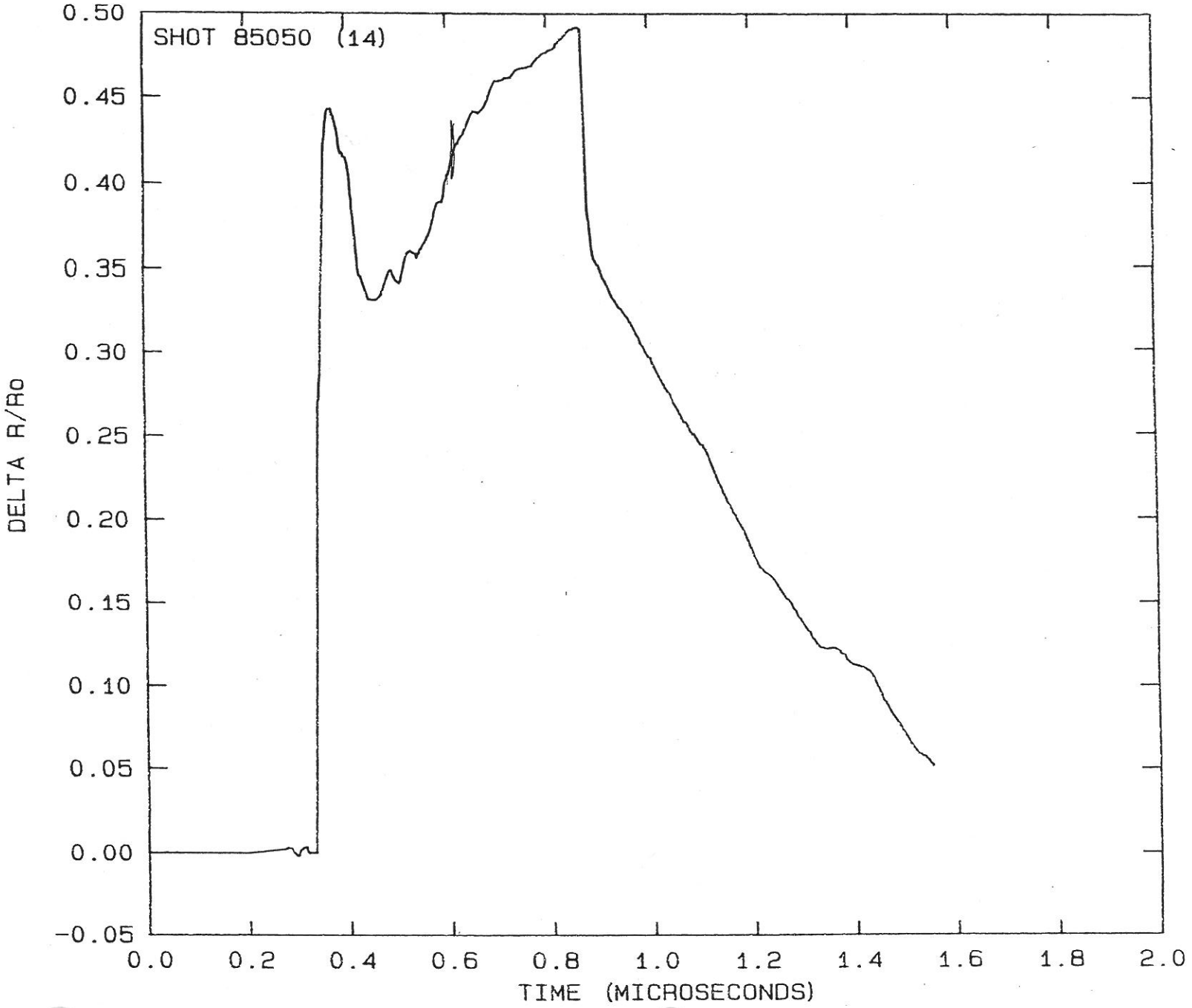
Depth of Gauge in Matrix: 3.17 mm

Remarks: The gauge was emplaced in a groove. This shot was carried out in the 4" gun.


SHOT 85050 (14)
DELTA R/Ro
TIME (MICROSECONDS)
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
0
1
2
3
4
5
6
7
8
9
10


SHOT 85050 (14)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
DELTA R/Ro
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
TIME (MICROSECONDS)

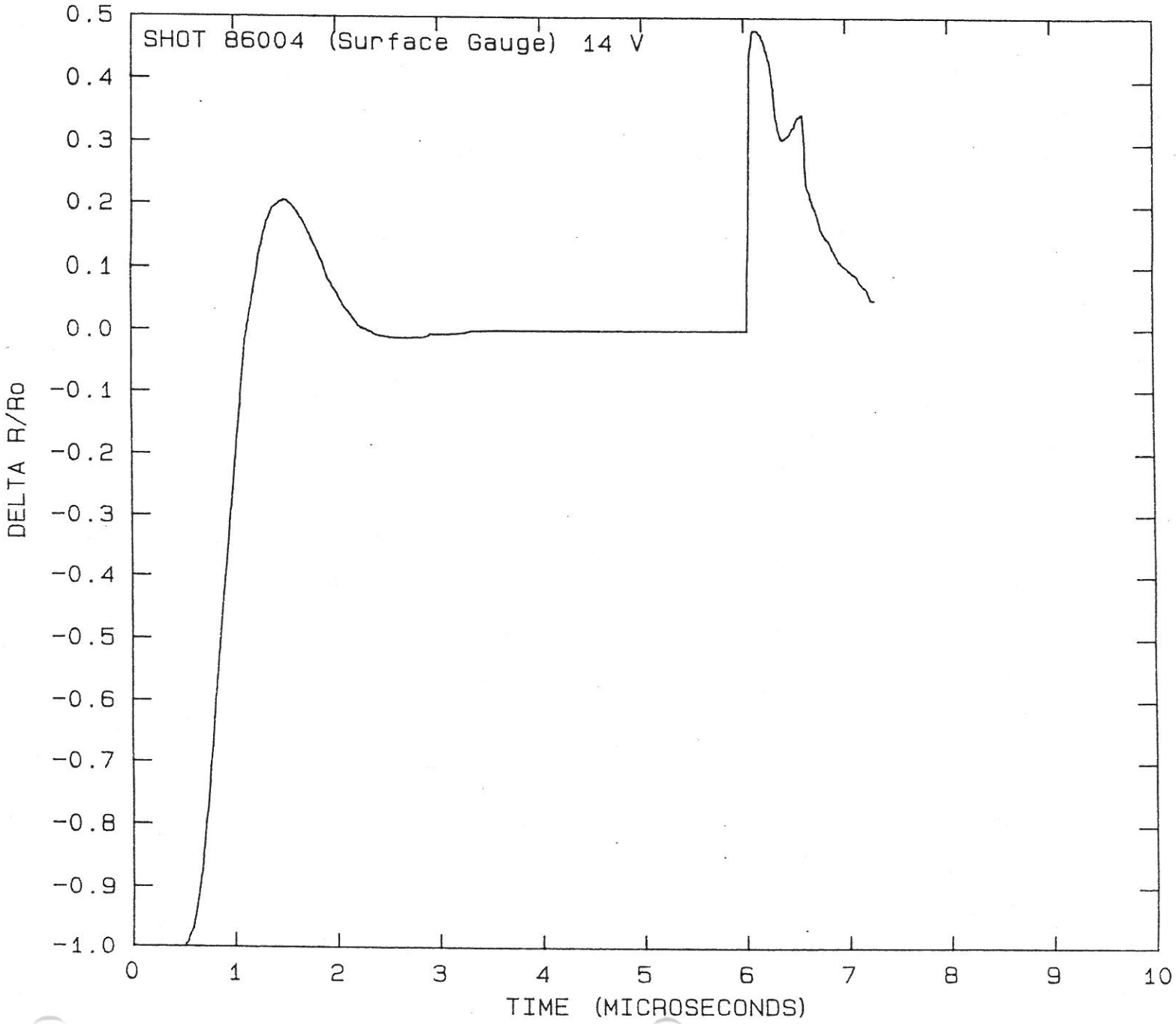

SHOT 85050 (13)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
DELTA R/Ro
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
TIME (MICROSECONDS)

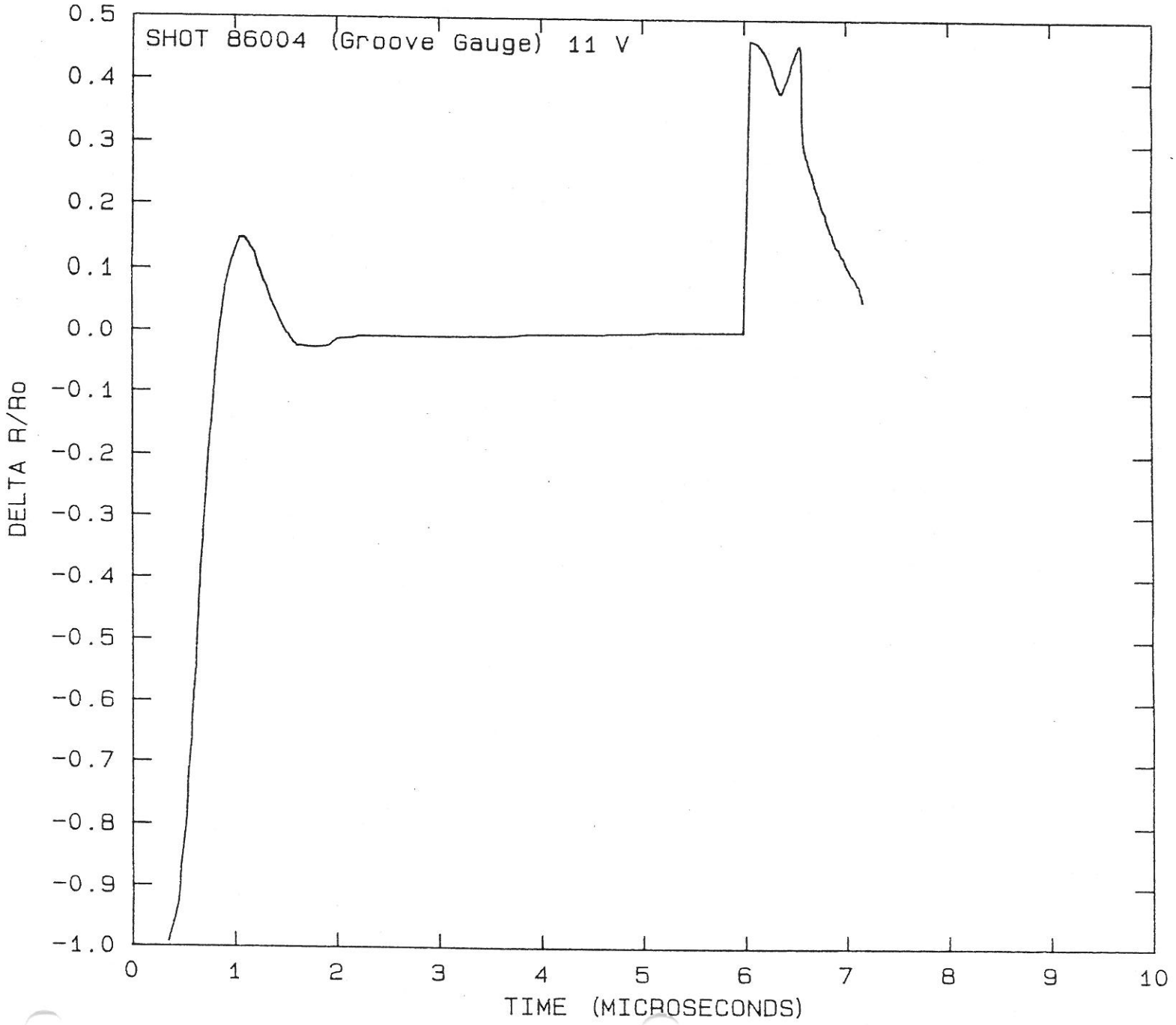

SHOT 85050 (14)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
DELTA R/Ro
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
TIME (MICROSECONDS)

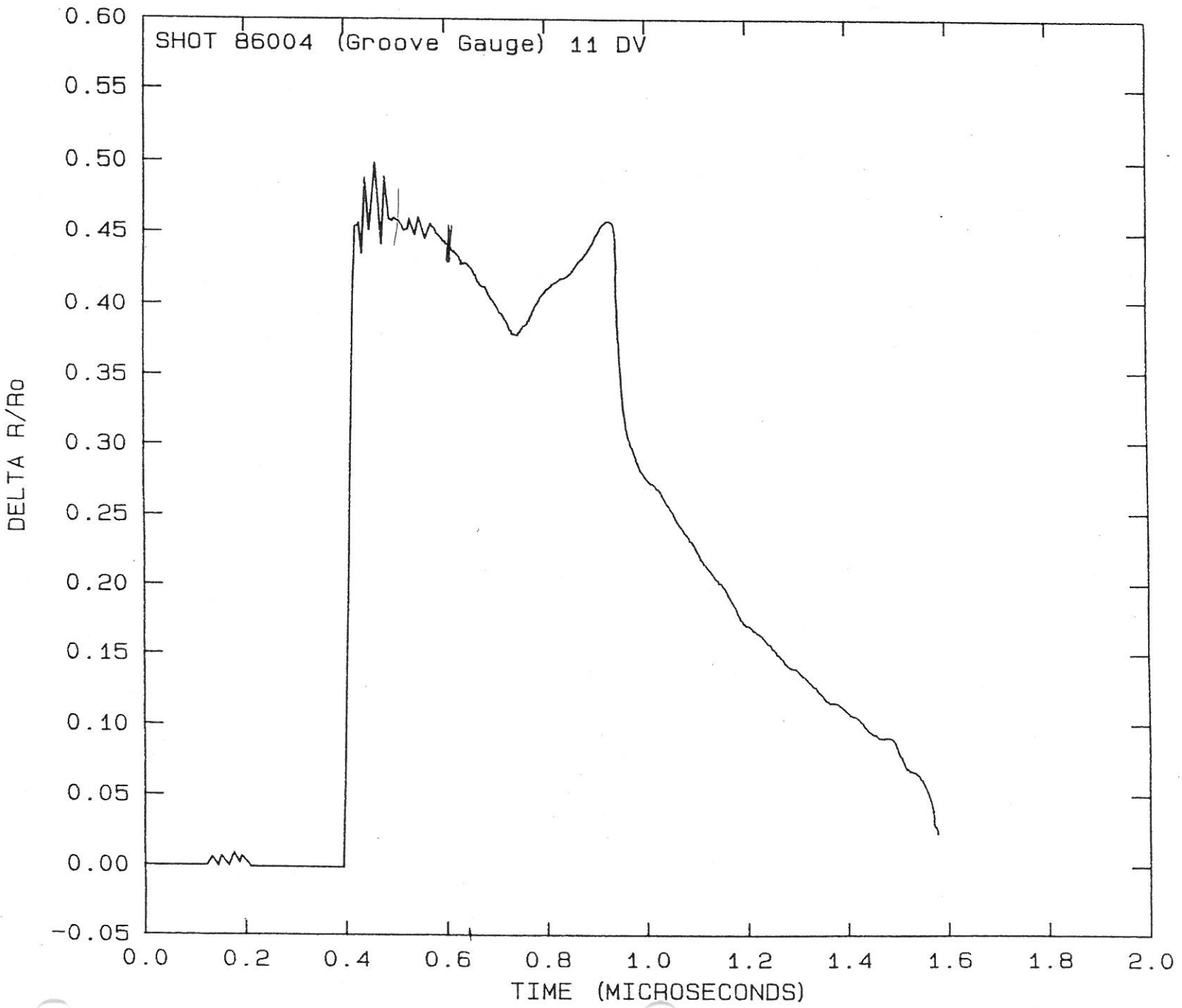
## Shot Number (9) 86004

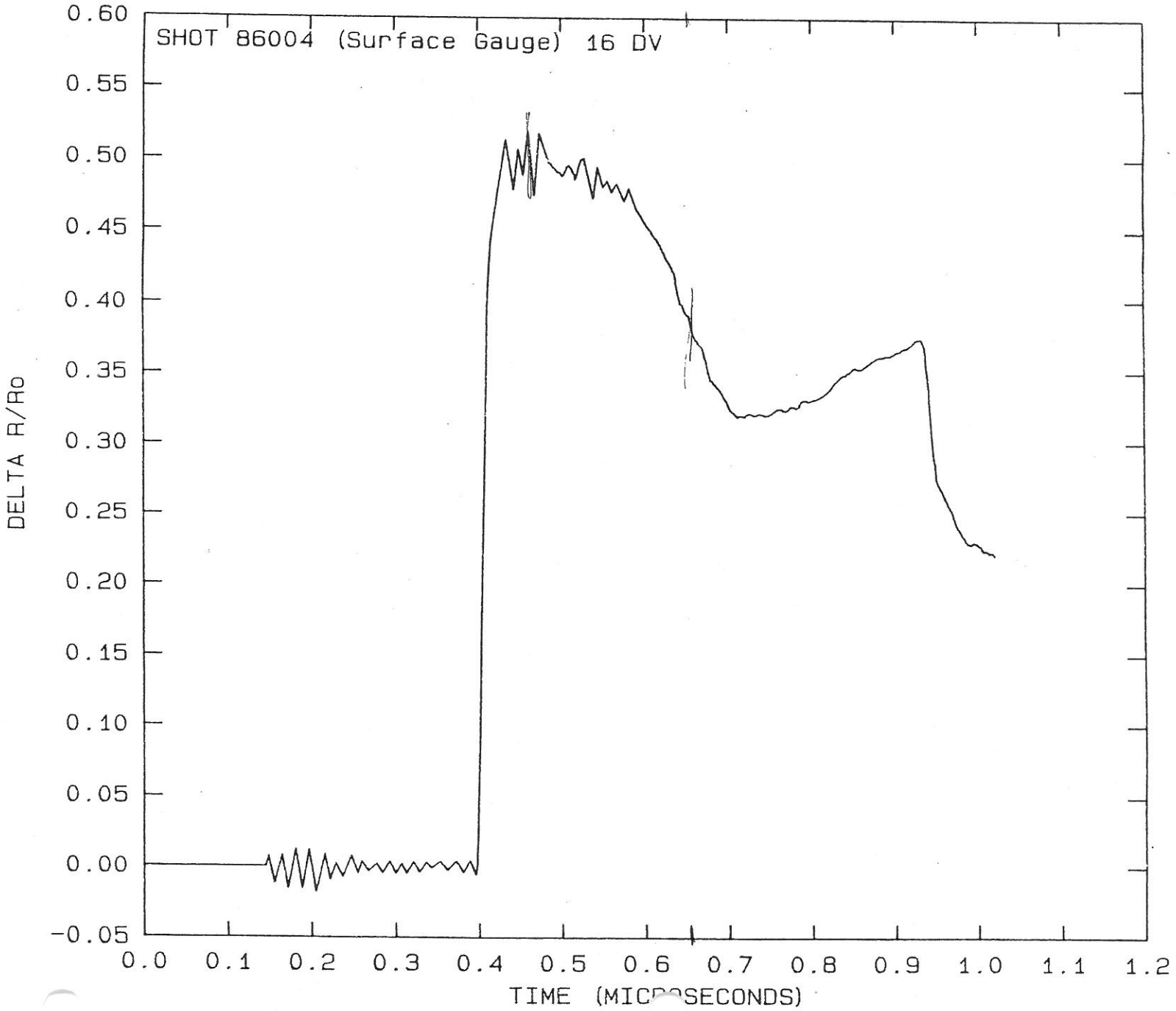
| | |
|---|---|
| Longitudinal Stress in the Matrix: | 184.7 kbars ~~~ 158 plasR |
| Impactor Material: | Z-cut Sapphire |
| Impactor Thickness: | 3.17 mm |
| Projectile Velocity: | 0.80 mms/microseconds |
| Matrix Material: | Z-cut Sapphire |
| Depth of Gauges in Matrix: | 3.17 mm |

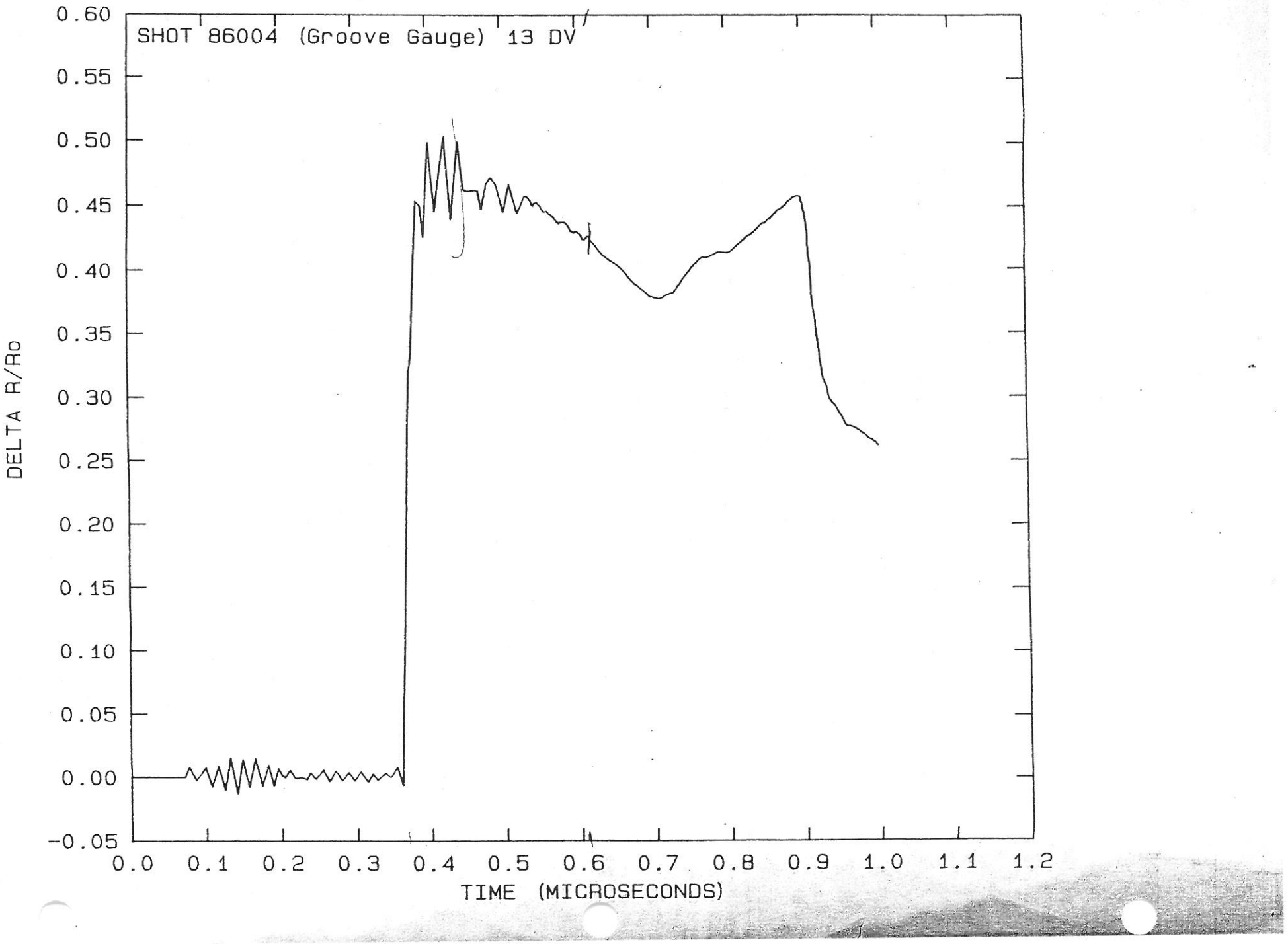
Remarks: There were two gauges in the target: (i) in a groove and (ii) on surface. Both the gauges were at the same depth (3.17 mm) from the target surface. This shot was carried out in the 4" gun.

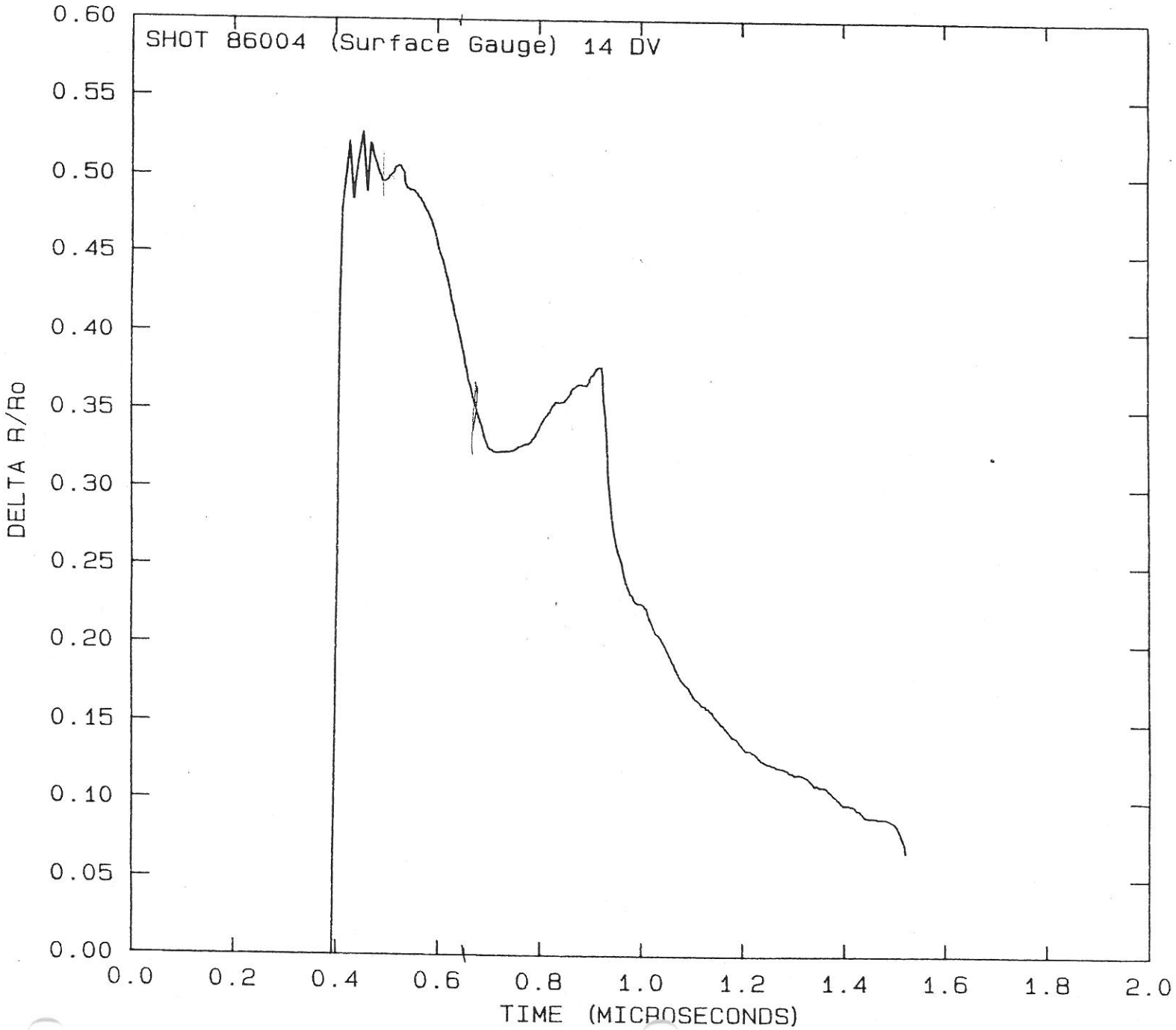

SHOT 86004 (Surface Gauge) 14 V
DELTA R/Ro
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
0
1
2
3
4
5
6
7
8
9
10
TIME (MICROSECONDS)


SHOT 86004 (Groove Gauge) 11 V
DELTA R/Ro
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
0
1
2
3
4
5
6
7
8
9
10
TIME (MICROSECONDS)


SHOT 86004 (Groove Gauge) 11 DV
DELTA R/Ro
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
TIME (MICROSECONDS)


SHOT 86004 (Surface Gauge) 16 DV
DELTA R/Ro
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
TIME (MICROSECONDS)


SHOT 86004 (Groove Gauge) 13 DV
DELTA R/Ro
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
TIME (MICROSECONDS)


SHOT 86004 (Surface Gauge) 14 DV
DELTA R/Ro
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
TIME (MICROSECONDS)