MEMORANDUM REPORT ARBRL-MR-03122

MEASUREMENT AND ANALYSIS OF THE RECOIL REACTION FORCES OF THE ADMAG 75mm GUN SYSTEM ON A HARD MOUNT

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US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

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REACTION MOMENTS
TORSIONAL IMPULSE

20. ABSTRACT (Continue on reverse side if necessary and identify by block number) jmk

The ADMAG system was instrumented to characterize the dynamic response of the gun needed to validate system simulations being developed for MC-AAAC as a part of the HSTVL program. This report deals with the measurement and analysis of recoil reaction forces at the trunnions. The resulting data are presented for use as input to the gun dynamics simulations.

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I. INTRODUCTION

The Ballistic Research Laboratory (BRL) became involved in the Medium Caliber Anti-Armor Automatic Cannon (MC-AAAC) program by proposing a method of measuring the motion of the 75 mm Advanced Design Mobility and Agility (ADMAG) gun system during firing. This gun, developed by Aries, Inc., Port Clinton, OH., is the main armament for the High Survivability Test Vehicle-Light (HSTV-L).

Large Caliber Weapons Systems Laboratory (LCWSL), Army Research and Development Command (ARRADCOM) requested that BRL measure the ballistic parameters necessary for their computer simulation of the gun system.

This report deals with the measurement of recoil reaction forces at the gun trunnions. Subsequent reports will contain further data and analysis as it is completed.

II. PROCEDURE

Scaling up of existing techniques developed for small arms dynamic testing seemed the most feasible method of measuring the gun trunnion reaction forces. Calculated reaction forces for the gun system fell within the load limits of existing force gages produced by the Interior Ballistics Division (IBD) in the past. To determine the reaction forces in the six degrees of freedom between the mount and the ADMAG gun system, the receiver was attached to the rigid mount by means of six force gages in an assembly shown in Figure 1. A seventh gage was created by placing strain patches on the elevation link that was attached to the receiver from the gun mount. Figure 2 shows the positive orientation of the reaction forces as measured by the gages. The gun trunnion mounts were designed at IBD and manufactured by Aircraft Armaments Inc., (AAI). Initially, firing tests for recording reaction forces were scheduled for Aberdeen Proving Ground (APG), but program delays were encountered in the delivery of the ADMAG. In order to avoid further delays, the reaction force measurements were incorporated into the hardstand test firing at Yuma Proving Ground (YPG).

On arrival at YPG, the gun trunnion mount was assembled and the gun positioned for firing. Due to aiming requirements, the axis of the trunnion mounts was not coincidental with the gun axis nor with the ground. Off-axis deviation was recorded prior to firing and the deviations required a 7.77° shift in the force vector as shown in Figure 2. The gun instrumentation included the six trunnion force gages, the instrumented elevation link, twelve accelerometers mounted on the gun barrel, and pressure gages in the chamber and recoil pistons. A muzzle velocity measurement device developed at IBD[1] was attached at the muzzle. Static measurements were made of tube droop and muzzle orientation prior to

[1] *J.Q. Schmidt, A Radio Frequency Oscillator for Measuring Projectile Muzzle Velocity, BRL Technical Report ARBRL-TR-02158, April 1979.*

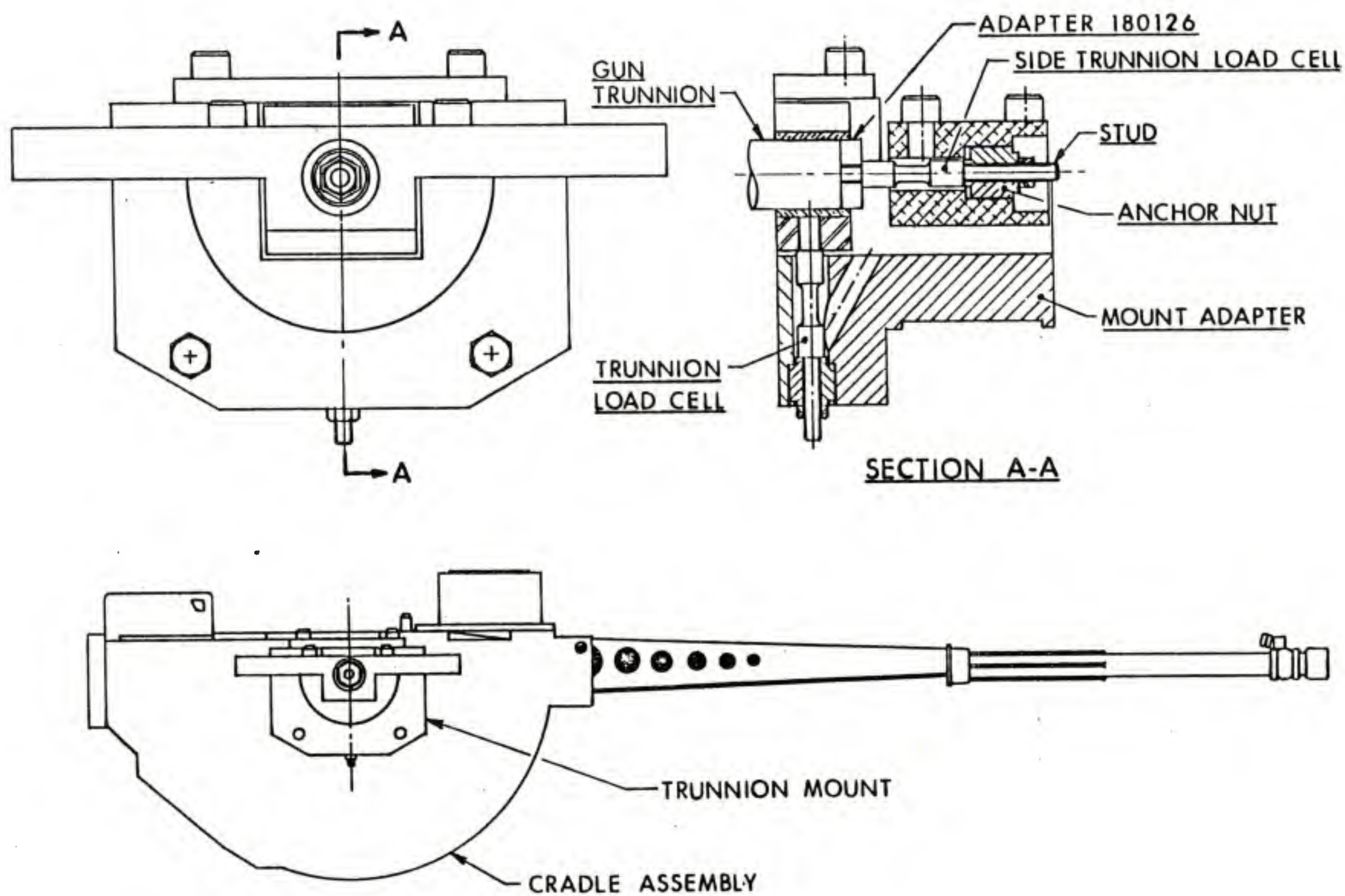
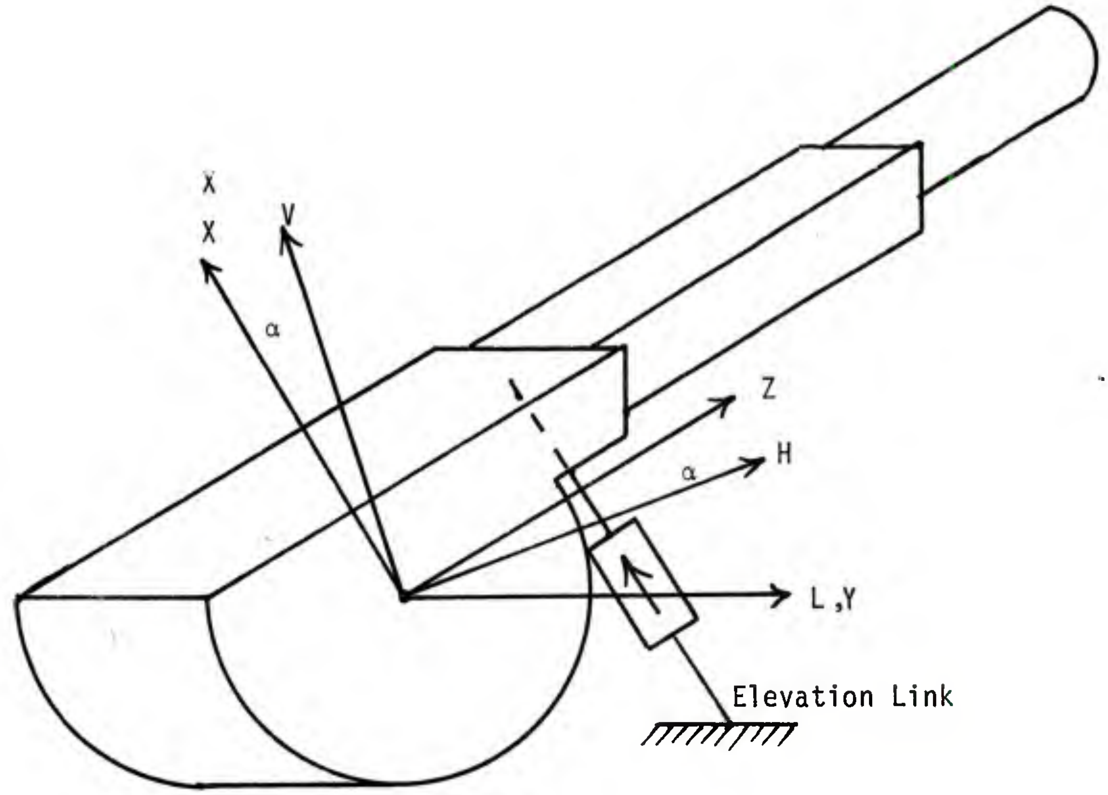


Figure 1. Trunnion Mount Assembly



V,L,H - Positive Orientation of Recoil Reaction Forces, Trunnion Axes

X ,Y ,Z - Positive Orientation of Recoil Reaction Forces, Gun Axes

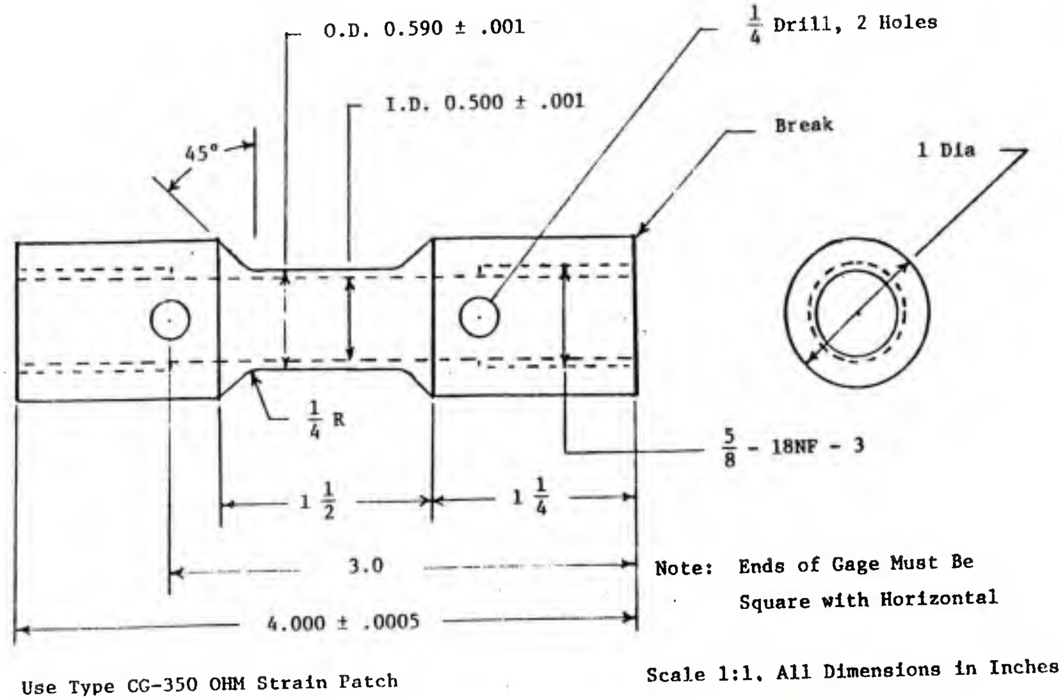
α - 7.77° ∢ between trunnion and gun axes

Figure 2. Positive Orientation of Recoil Reaction Forces

commencing the firing program.

III. DESCRIPTION

A trunnion reaction force gage, shown in Figure 3, is a cylindrical section of high strength steel. The active section is the thin-walled center which provides high support strength but allows elastic deformation for the gage sensitivity. The wall thickness determines the range and



Note: All measurements have been retained in English units because the original drawing is dimensioned in inches and there is no metric equivalent for the designated thread.

Figure 3. Gage, Trunnion Reaction 10,000 lbs.

sensitivity of the gage, while the uniform cylindrical section provides for a linear deformation of the two resistive strain patches mounted on the center section. These patches are positioned to measure longitudinal strain and are mounted opposite each other to compensate for bending moments. Care must be taken in mounting these gages that the fragile center section is not exposed to a damaging torque. Loading the unit in tension or compression produces a resistive change proportional to the applied load.

IV. REDUCTION AND ANALYSIS OF FORCE DATA

Figures 4 thru 10 show the characteristic reaction forces at each trunnion gage and the reaction moment about the trunnion axis as measured by the elevation link for one round. These plots are the result of low pass filtering the data at 160 Hz, and then digitizing and converting the data to engineering units. By the use of the spectrum analyzer it was determined that a 10 Hz high pass filter would remove the first vibrational mode as well as the higher modes. With this in mind, the data was digitally high pass filtered at 10 Hz and the results subtracted from the original data leaving only the recoil reaction forces. Figures 11 thru 16 show the results of this operation.

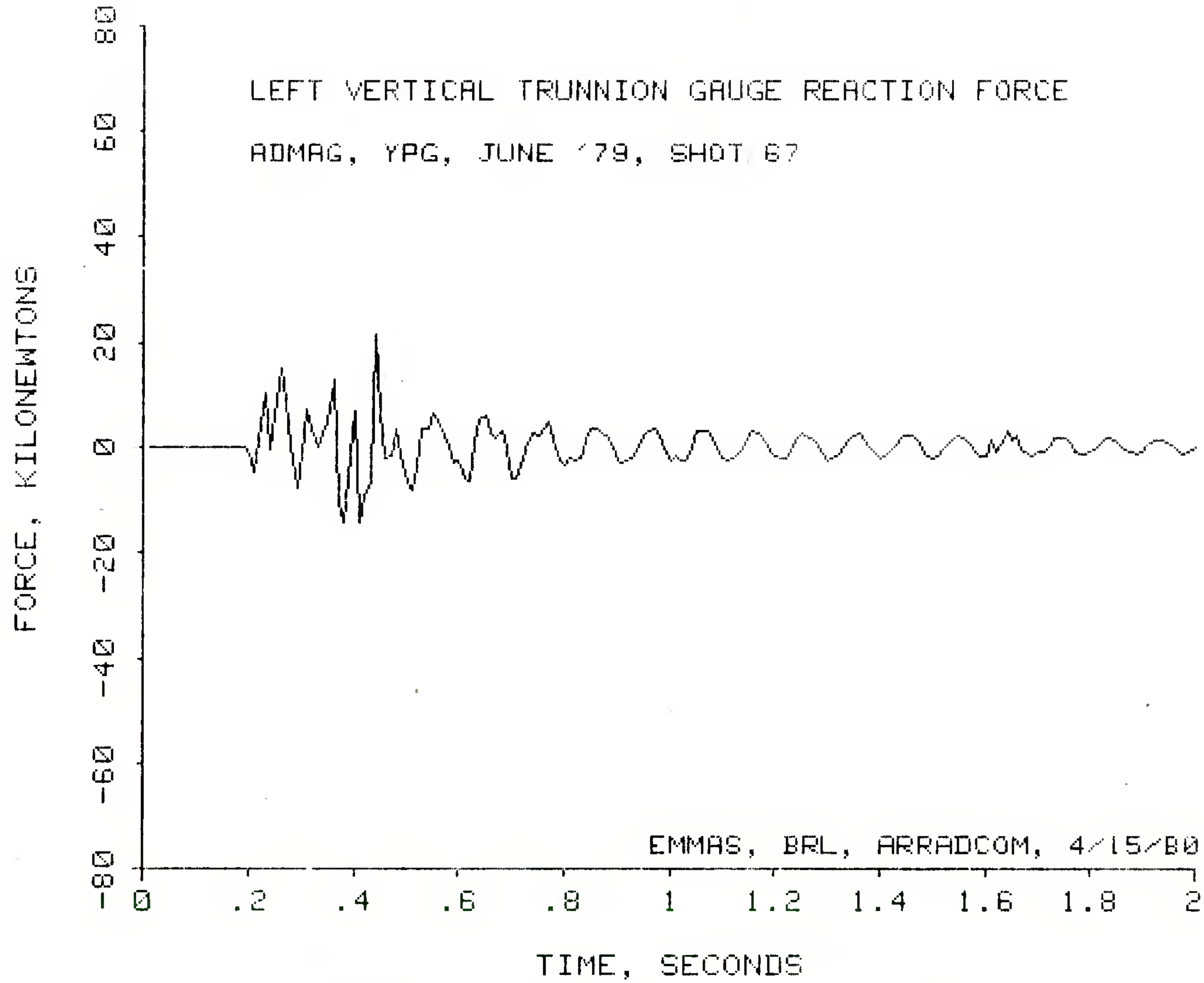


Figure 4. Left Vertical Trunnion Gauge Reaction Force

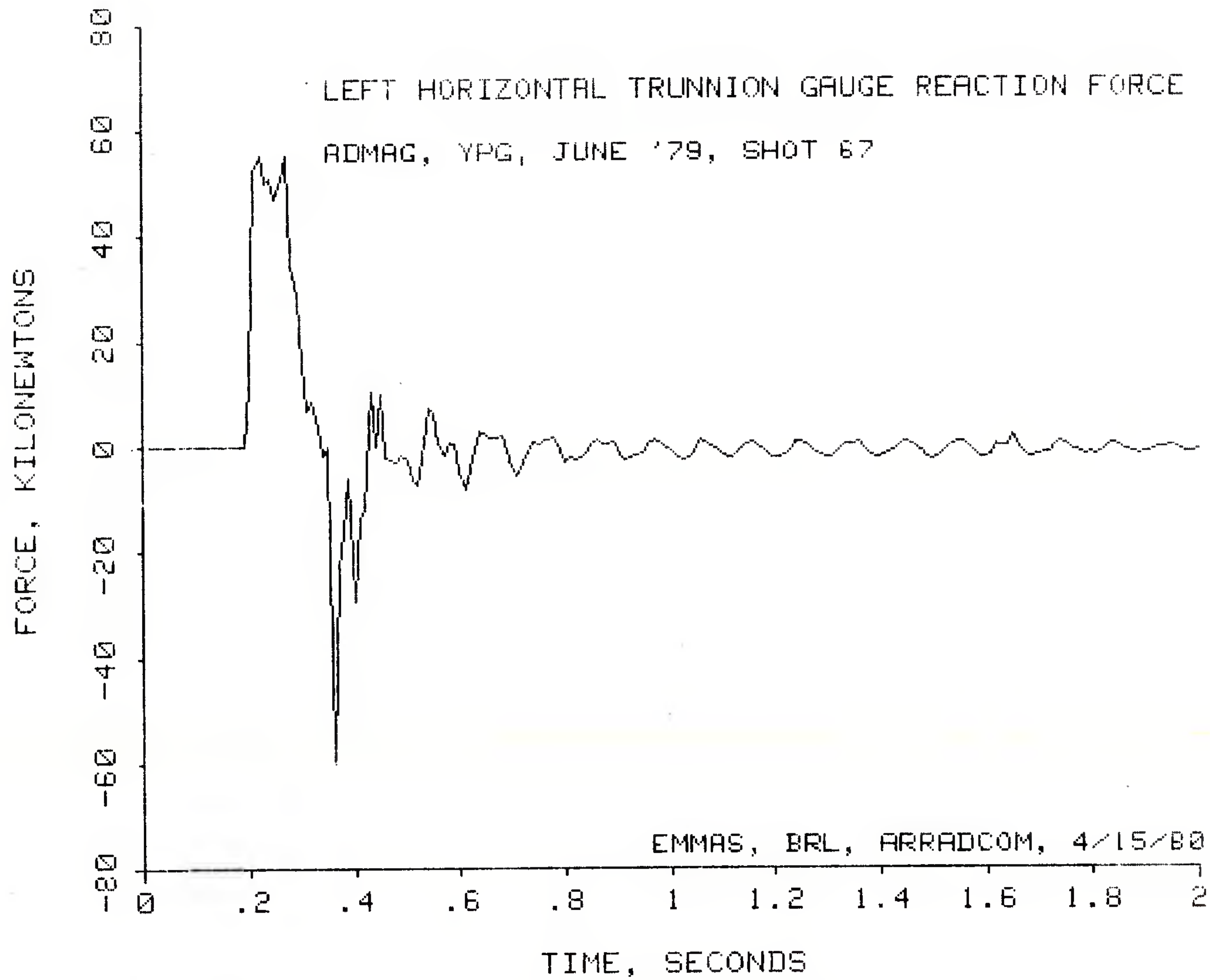


Figure 5. Left Horizontal Trunnion Gauge Reaction Force

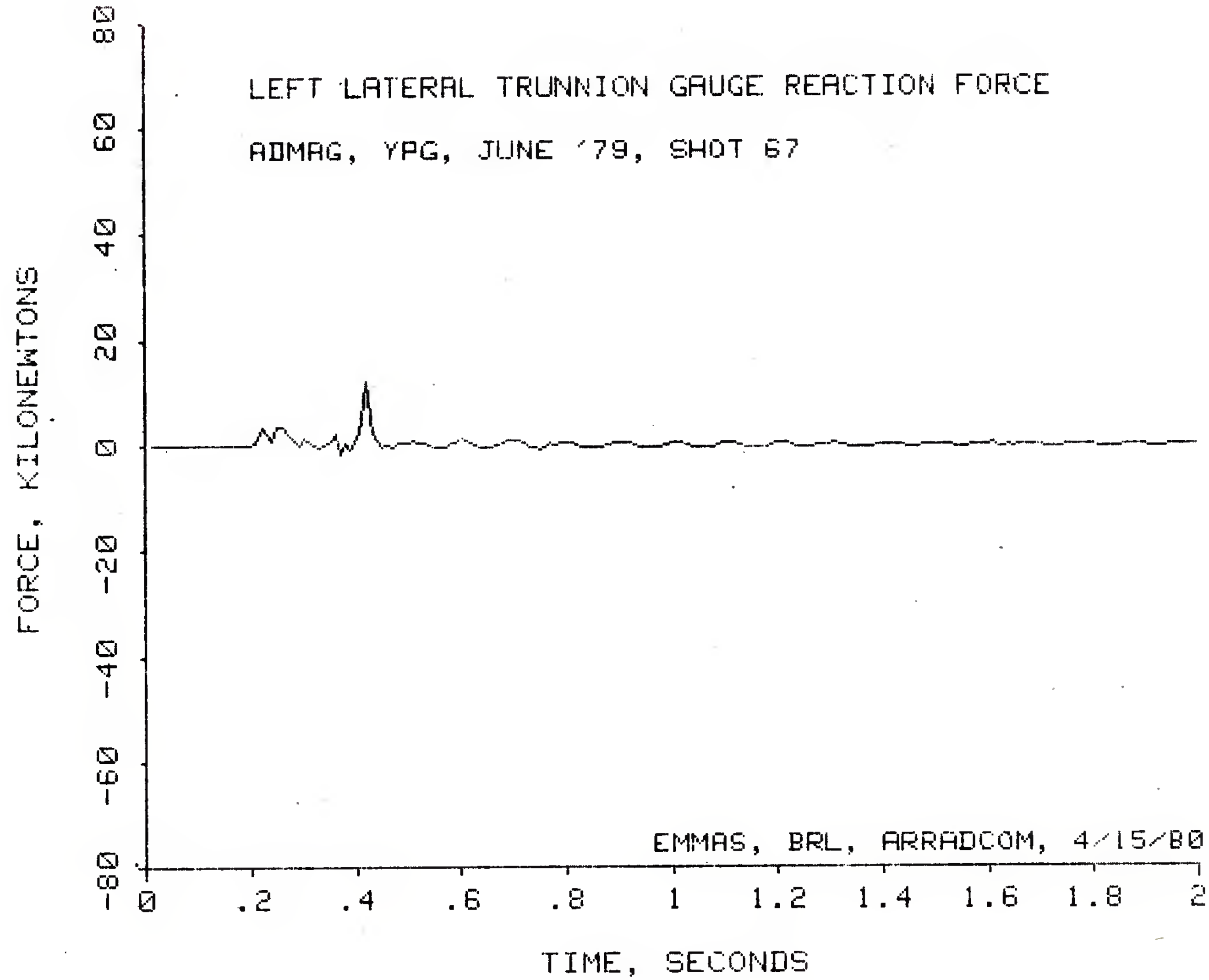


Figure 6. Left Lateral Trunnion Gauge Reaction Force

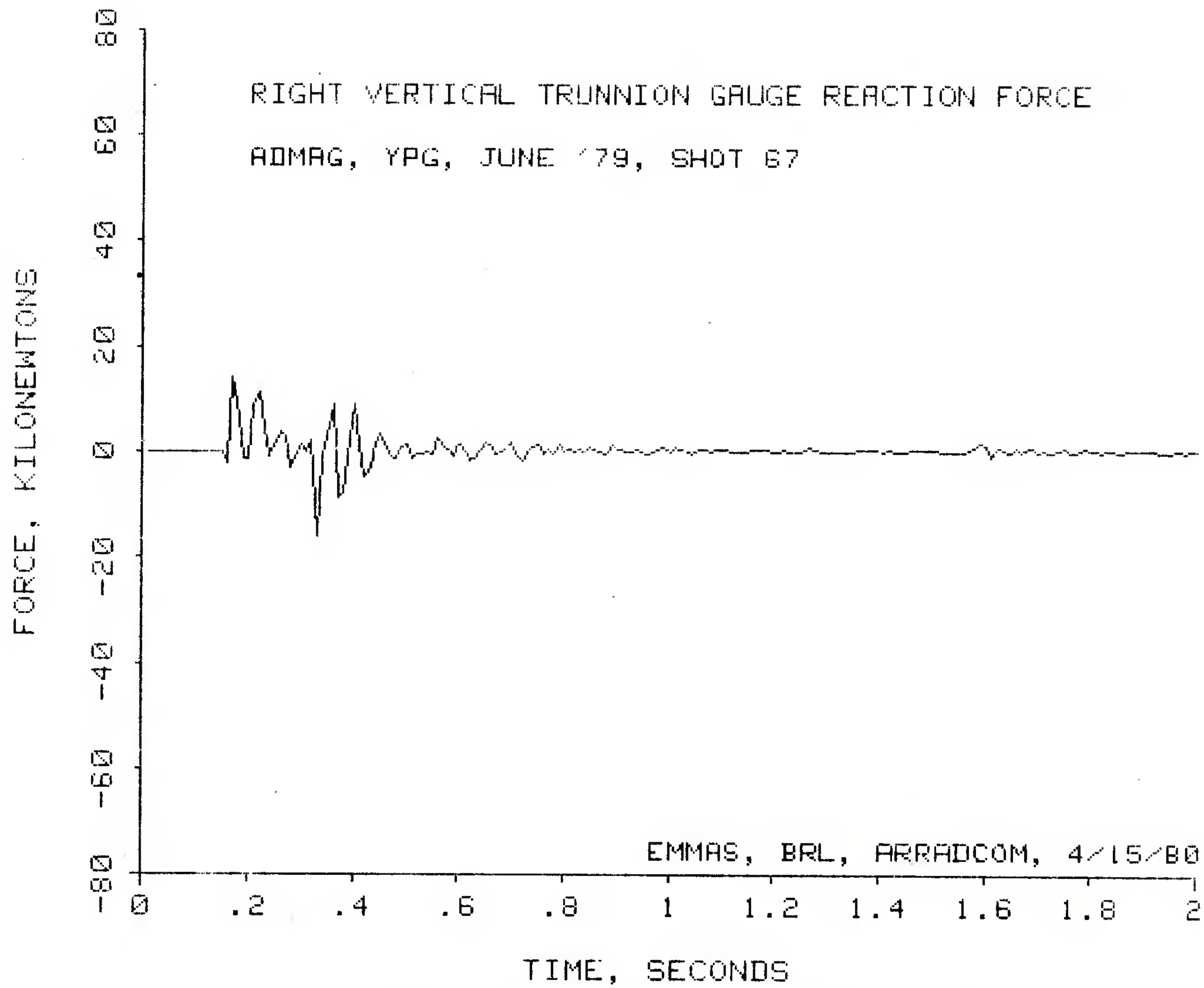


Figure 7. Right Vertical Trunnion Gauge Reaction Force

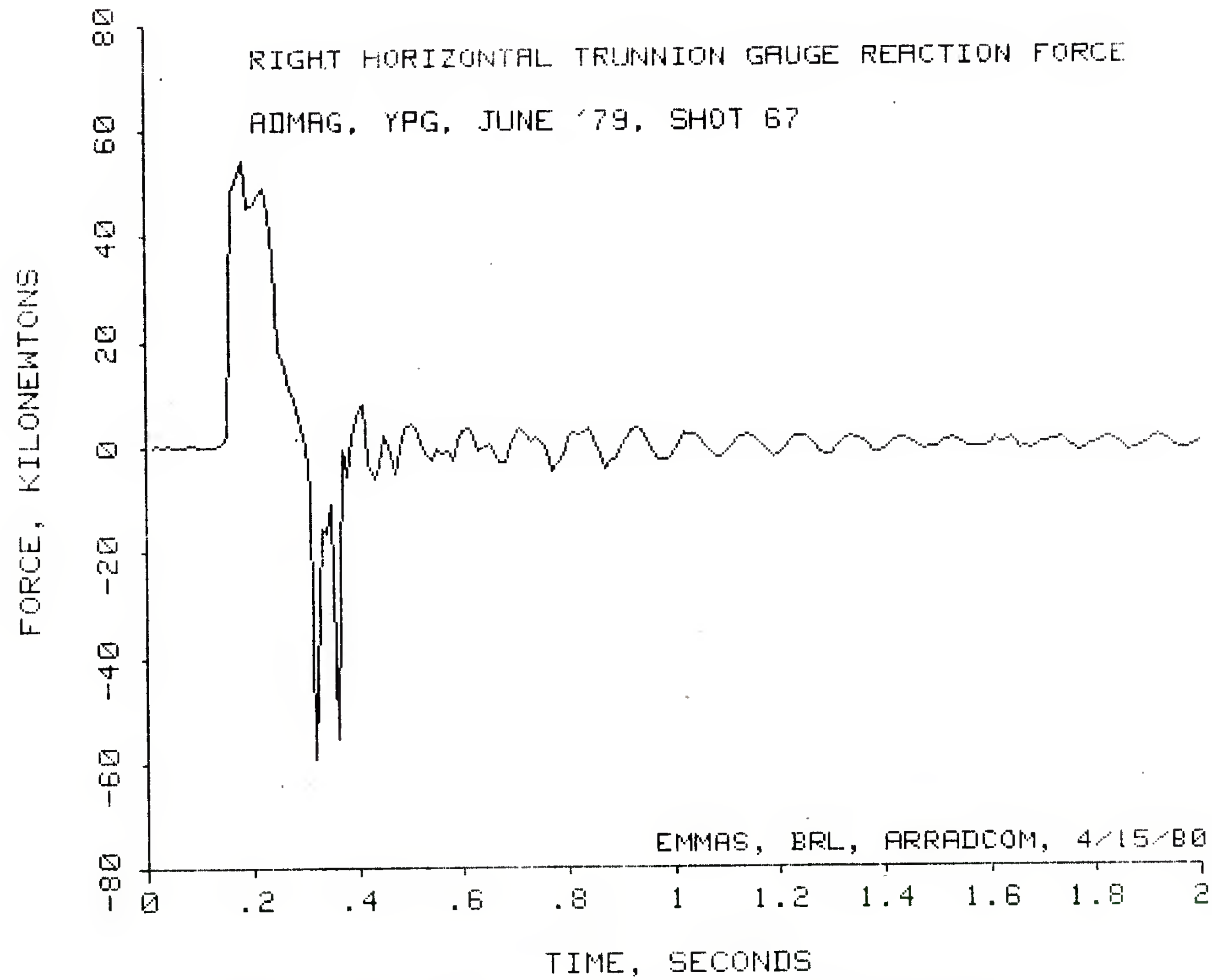


Figure 8. Right Horizontal Trunnion Gauge Reaction Force

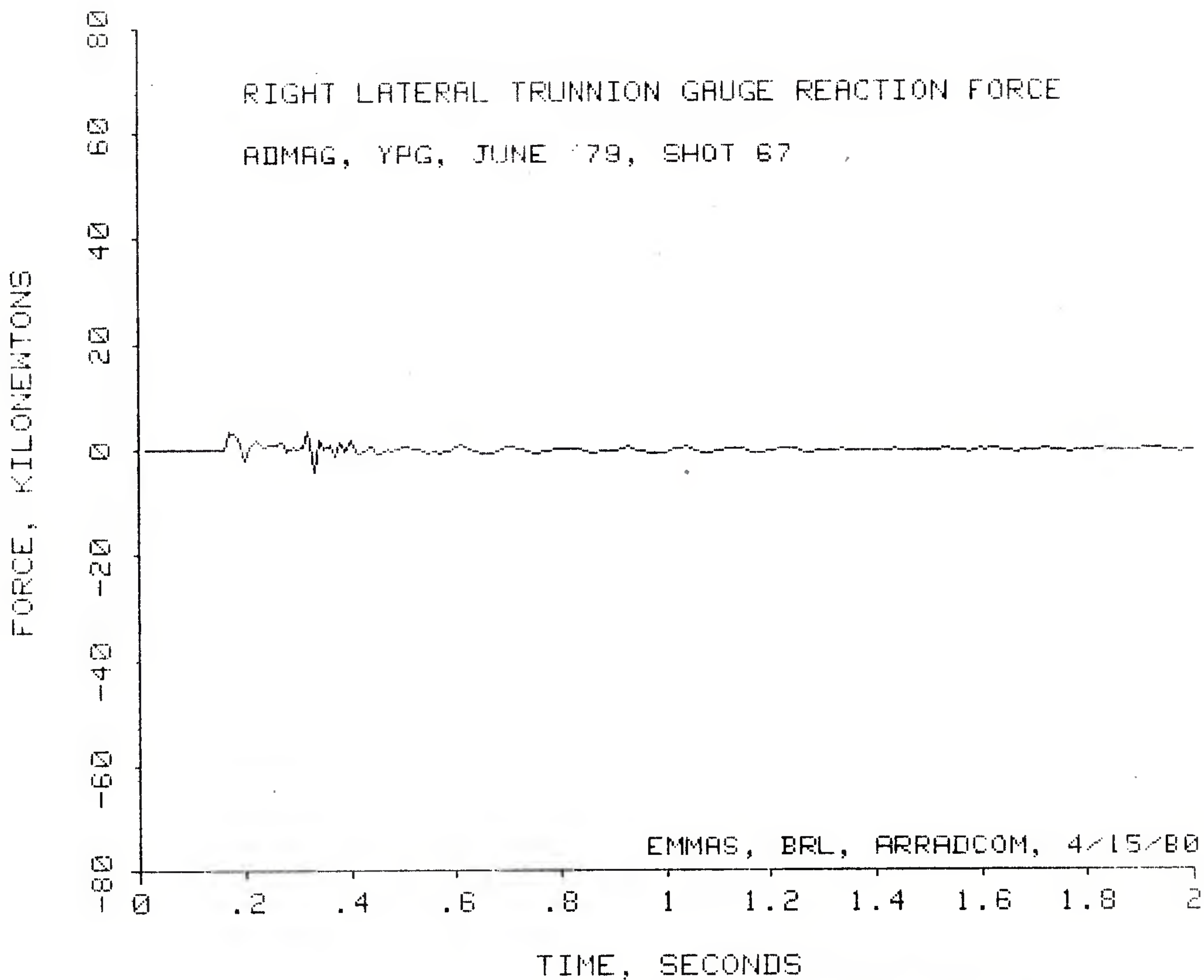


Figure 9. Right Lateral Trunnion Gauge Reaction Force

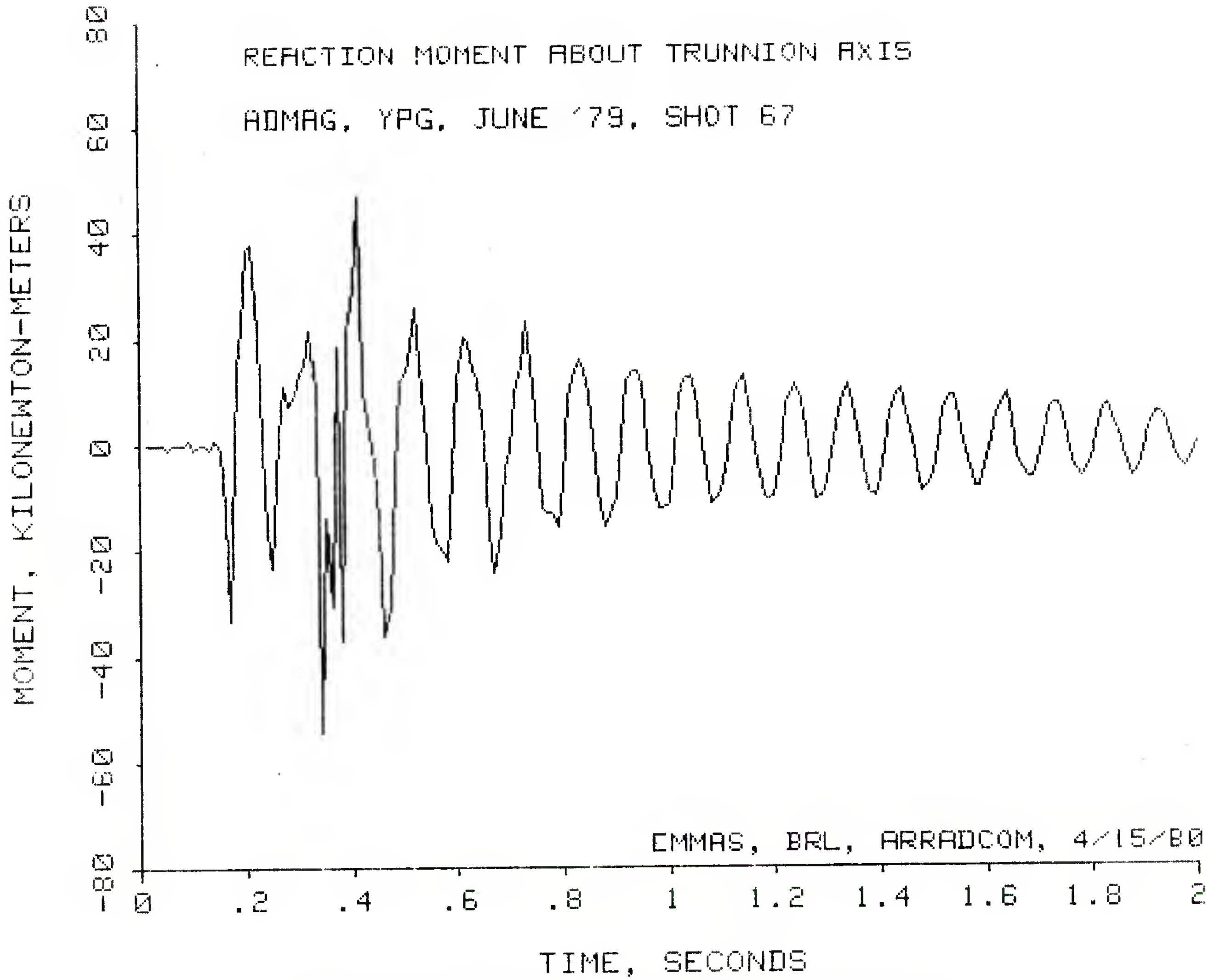


Figure 10. Reaction Moment About Trunnion Axis

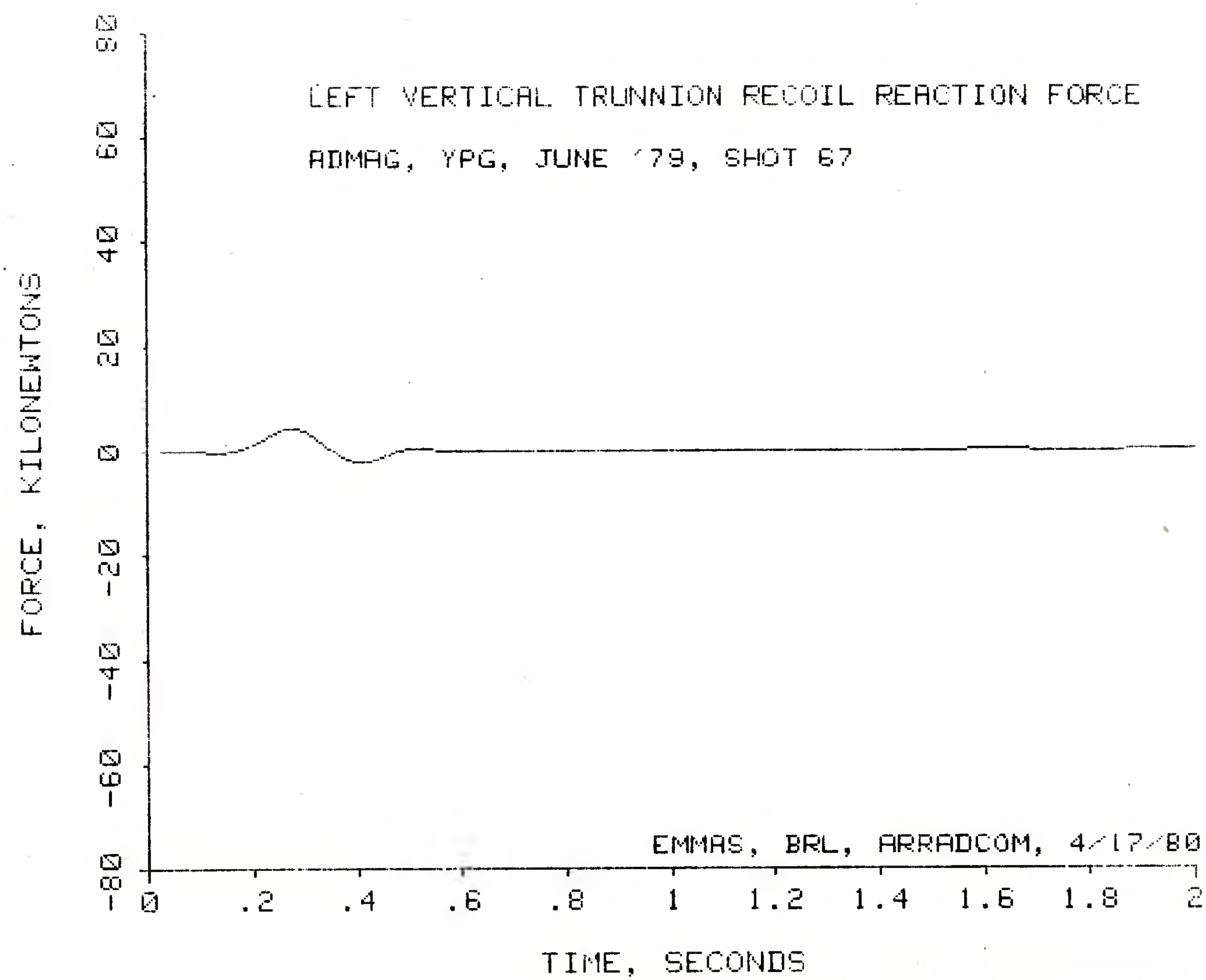


Figure 11. Left Vertical Trunnion Gauge Recoil Reaction Force

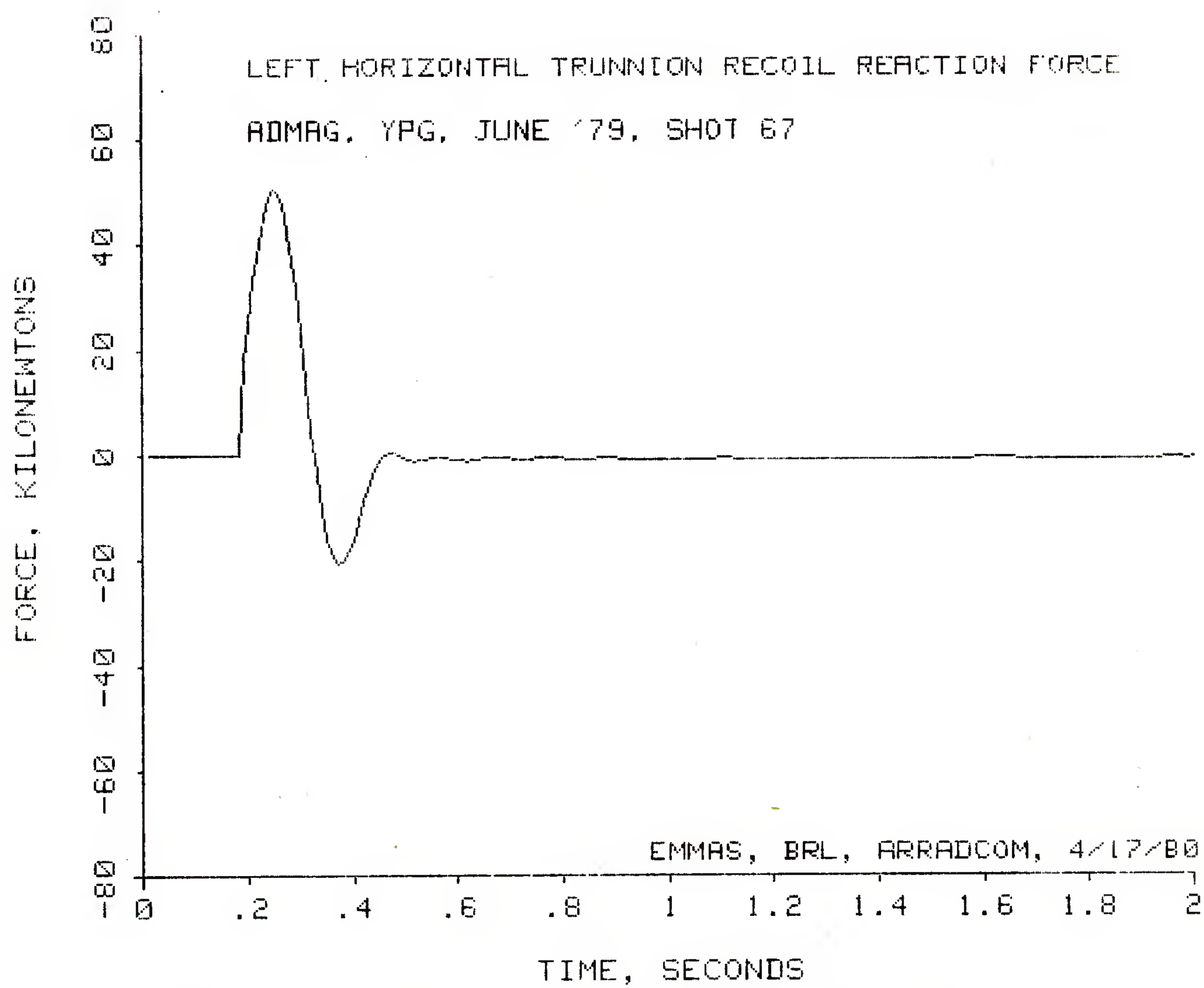


Figure 12. Left Horizontal Trunnion Gauge Recoil Reaction Force

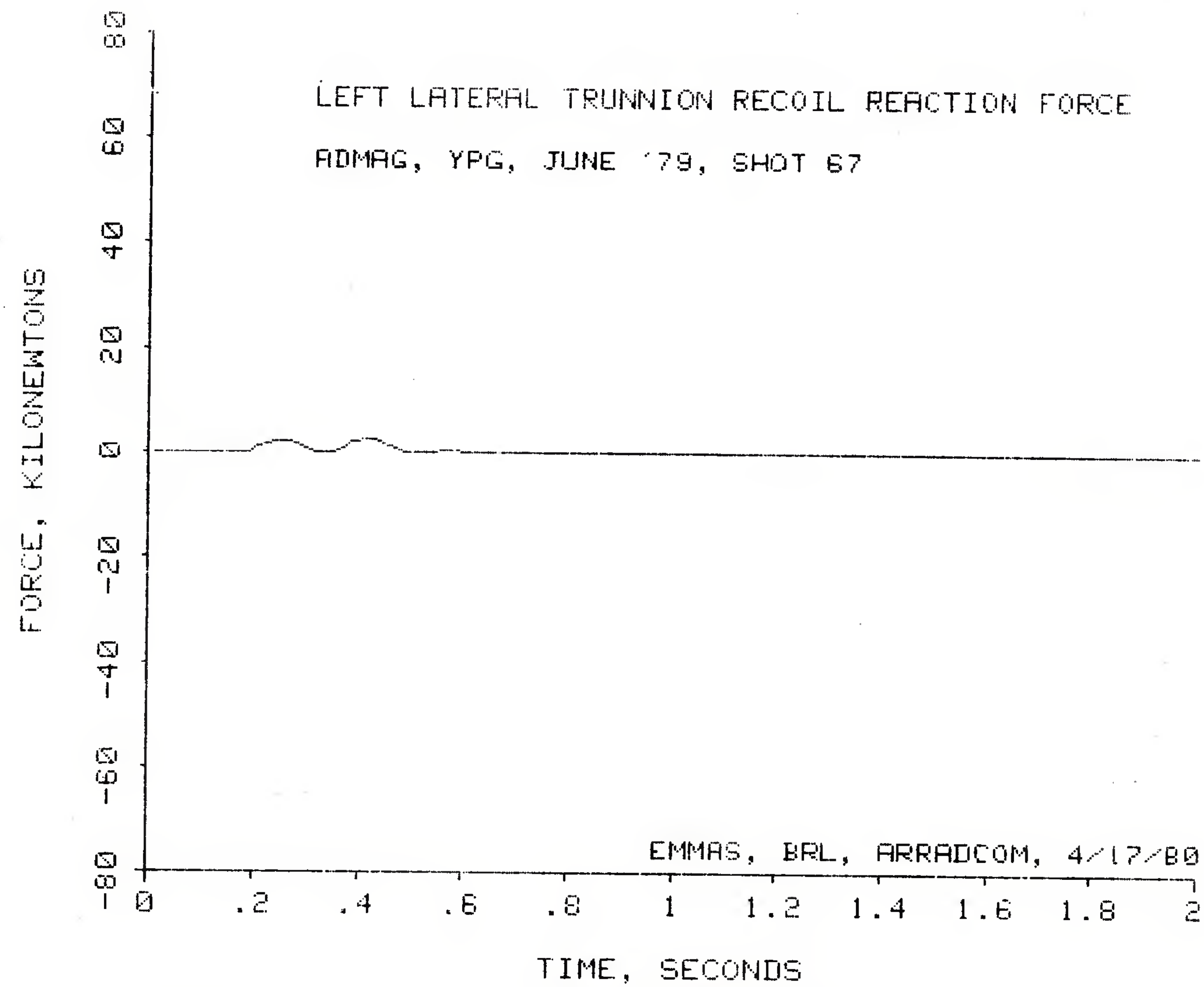


Figure 13. Left Lateral Trunnion Gauge Recoil Reaction Force

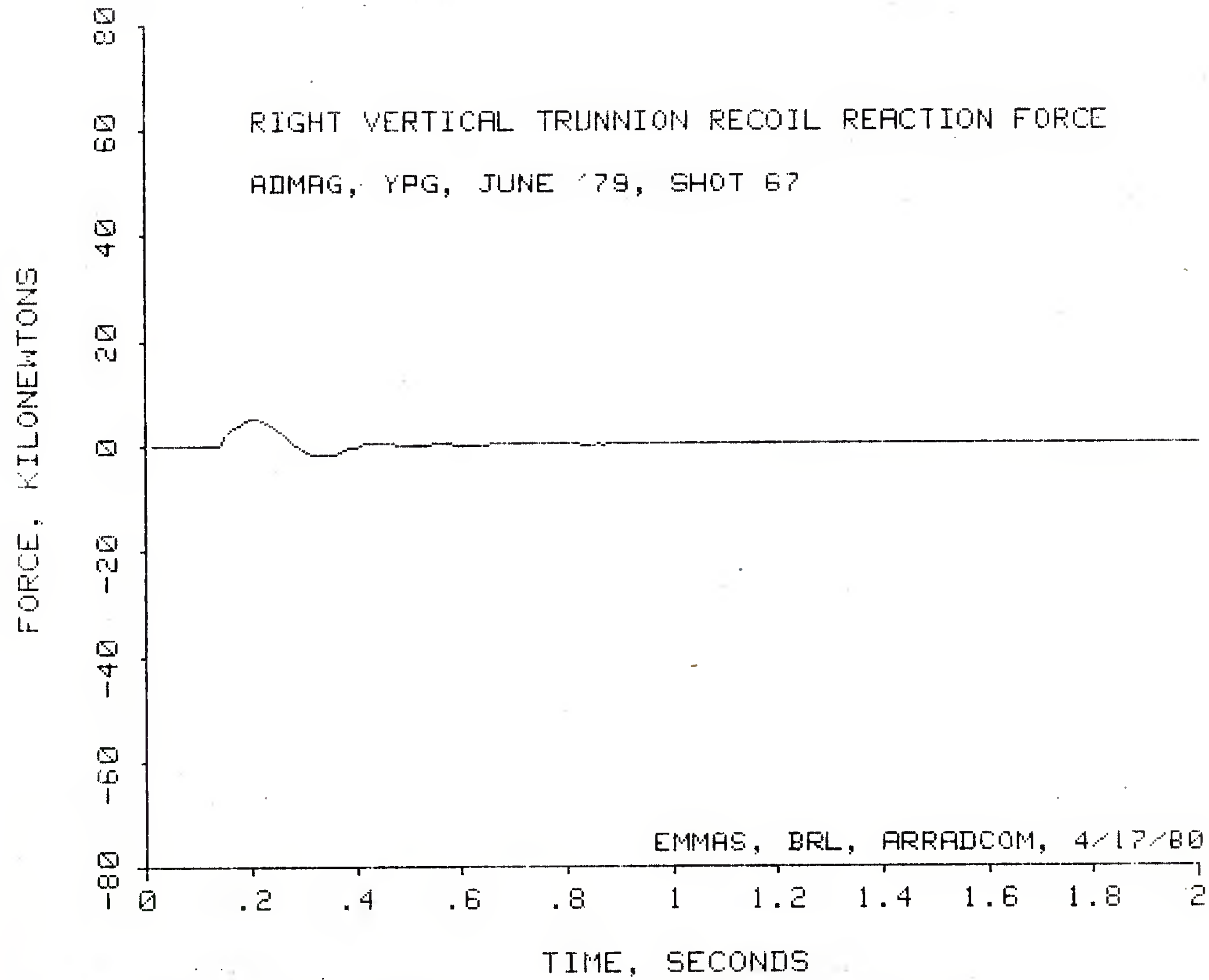


Figure 14. Right Vertical Trunnion Gauge Recoil Reaction Force

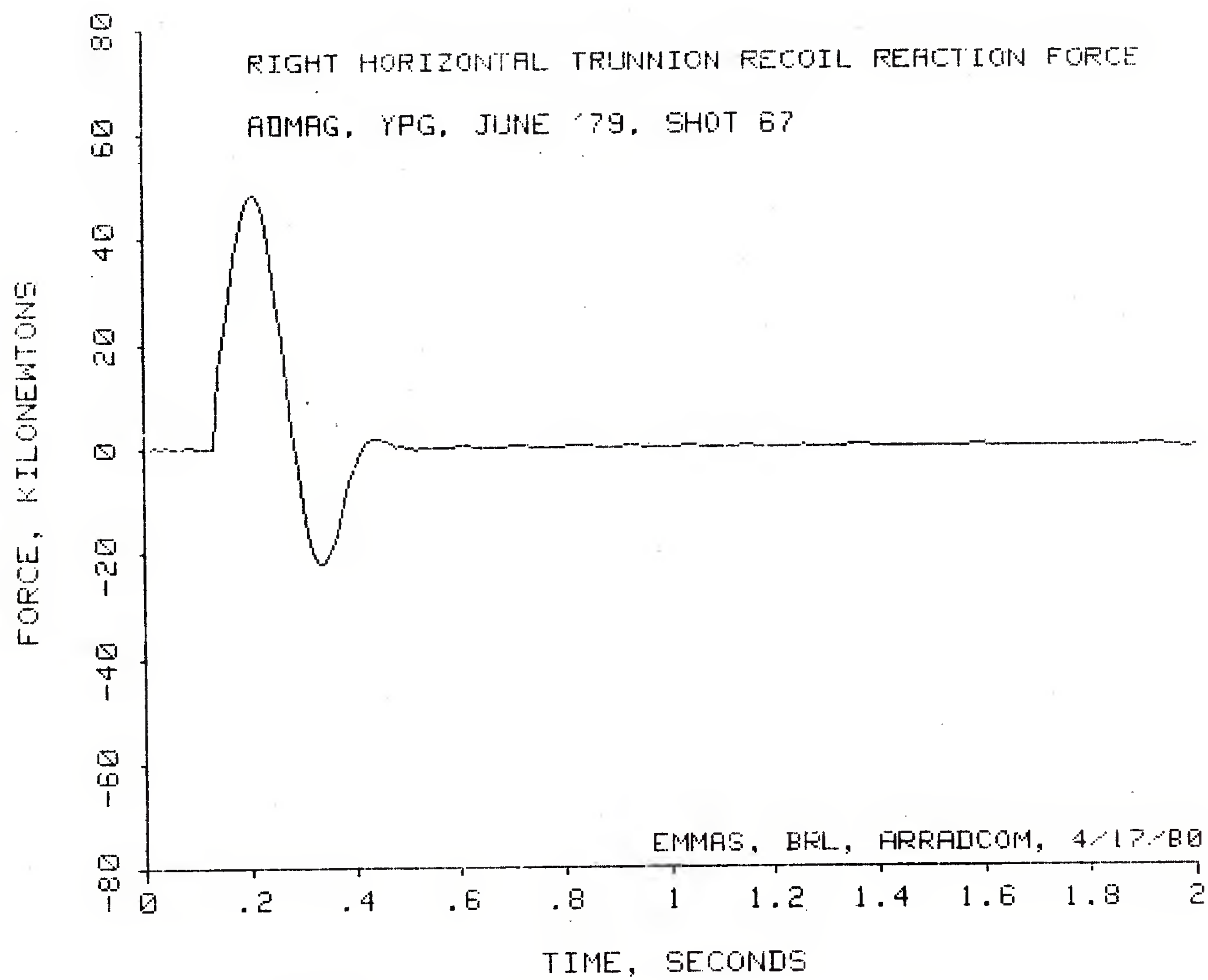


Figure 15. Right Horizontal Trunnion Gauge Recoil Reaction Force

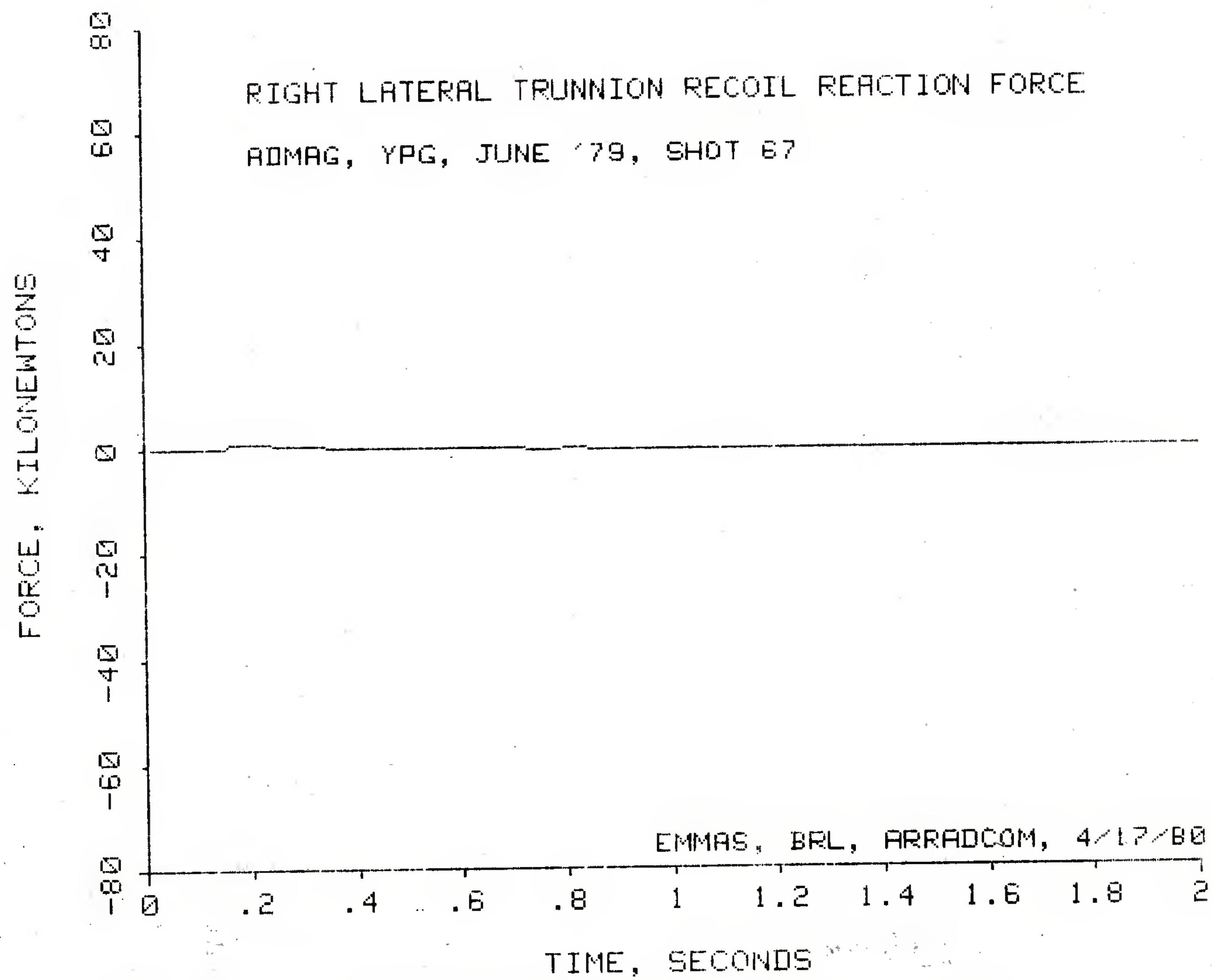


Figure 16. Right Lateral Trunnion Gauge Recoil Reaction Force

To arrive at the total recoil reaction forces along the gun axes, the forces at each gage were rotated through 7.77° about the trunnion mount. The total recoil reaction forces along each axis are plotted in Figures 17 thru 20. The moments about each trunnion axis, computed from the recoil reaction forces, are shown in Figures 21 thru 23.

The chamber pressure was measured by external strain gages. Knowing the wall thickness at the gage location, and knowing the gage factor, the magnitude of the chamber pressure was calculated. Since the positioning of the strain gages on the chamber was not precise due to the configuration of the gun system, the amplitude of the chamber pressure may be biased. The peak pressure appears to be within 10% of previous measurements made on this gun system. The chamber pressure is plotted in Figure 24 to help correlate the timing of the firing cycle with the trunnion records. The time scale is the same for all the plots so that the pressure plot may be used to establish the firing time, an initiation point from which to determine the action time of the gun system.

Integrating the force curves yields the impulse, or momentum due to the recoil. The forces were integrated and the resulting translational and rotational recoil reaction impulses are plotted in Figures 25 thru 31.

V. RESULTS

By the use of digital spectral analysis and selective filtering, the recoil reaction was readily separated from the vibrating response of the gun system. Separated in this manner, three forces, three moments, and their corresponding impulse are established and therefore can be used as input to gun dynamics simulations. A subsequent step in the analysis of this data deals with vibration analysis, establishing structural damping ratios and response frequencies.

VI. CONCLUSION

Trunnion force gages have been used extensively on small caliber gun systems at BRL. This program demonstrated that the trunnion force gages could be used effectively to measure trunnion forces on large caliber gun systems as well.

The use of spectral analysis techniques and selective digital filtering allows the analyst to readily separate the different components of the data. The recoil impulse was readily separated from the vibrating response of the gun system using these techniques.

The combination of the trunnion force gages and the digital signal processing techniques was highly successful in providing critical input data for gun system simulation efforts in the program. Currently the data is being used by S&D Dynamics Inc., under contract with BRL to verify gun simulations. In addition to the trunnion reaction forces discussed in this report, principal modes of vibration and effective damping of those have been determined.

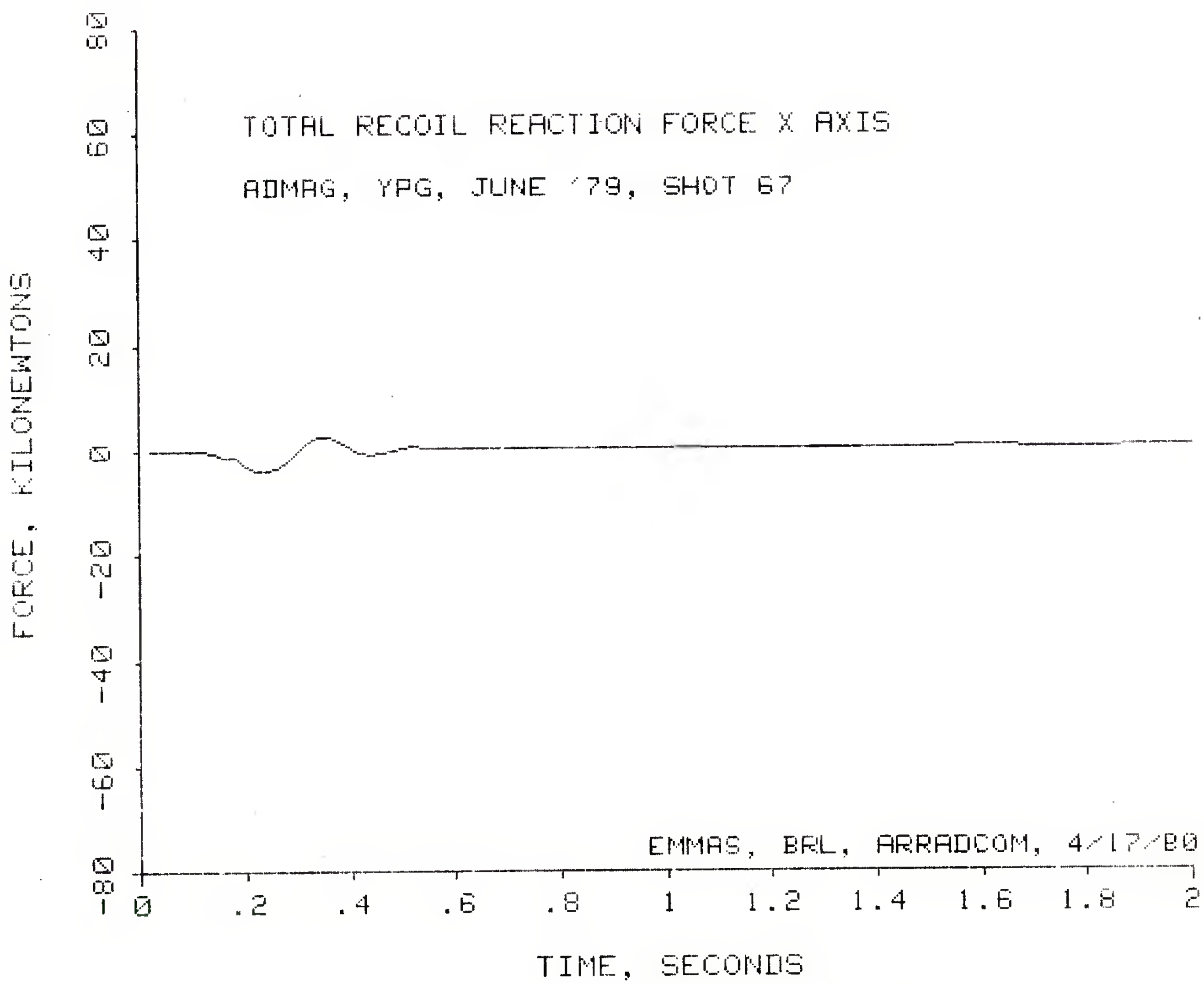


Figure 17. Total Recoil Reaction Force Along X-Axis

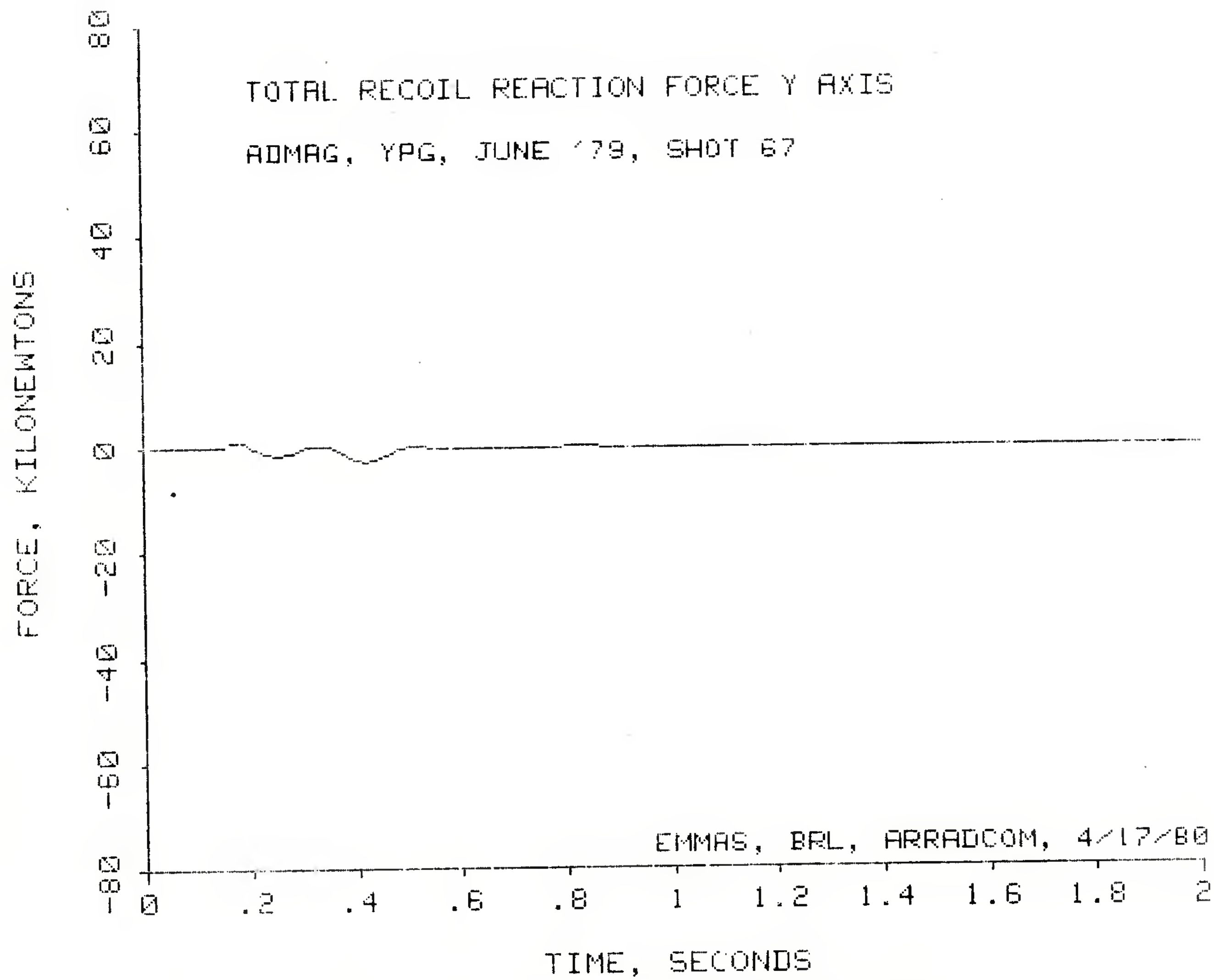


Figure 18. Total Recoil Reaction Force Along Y-Axis

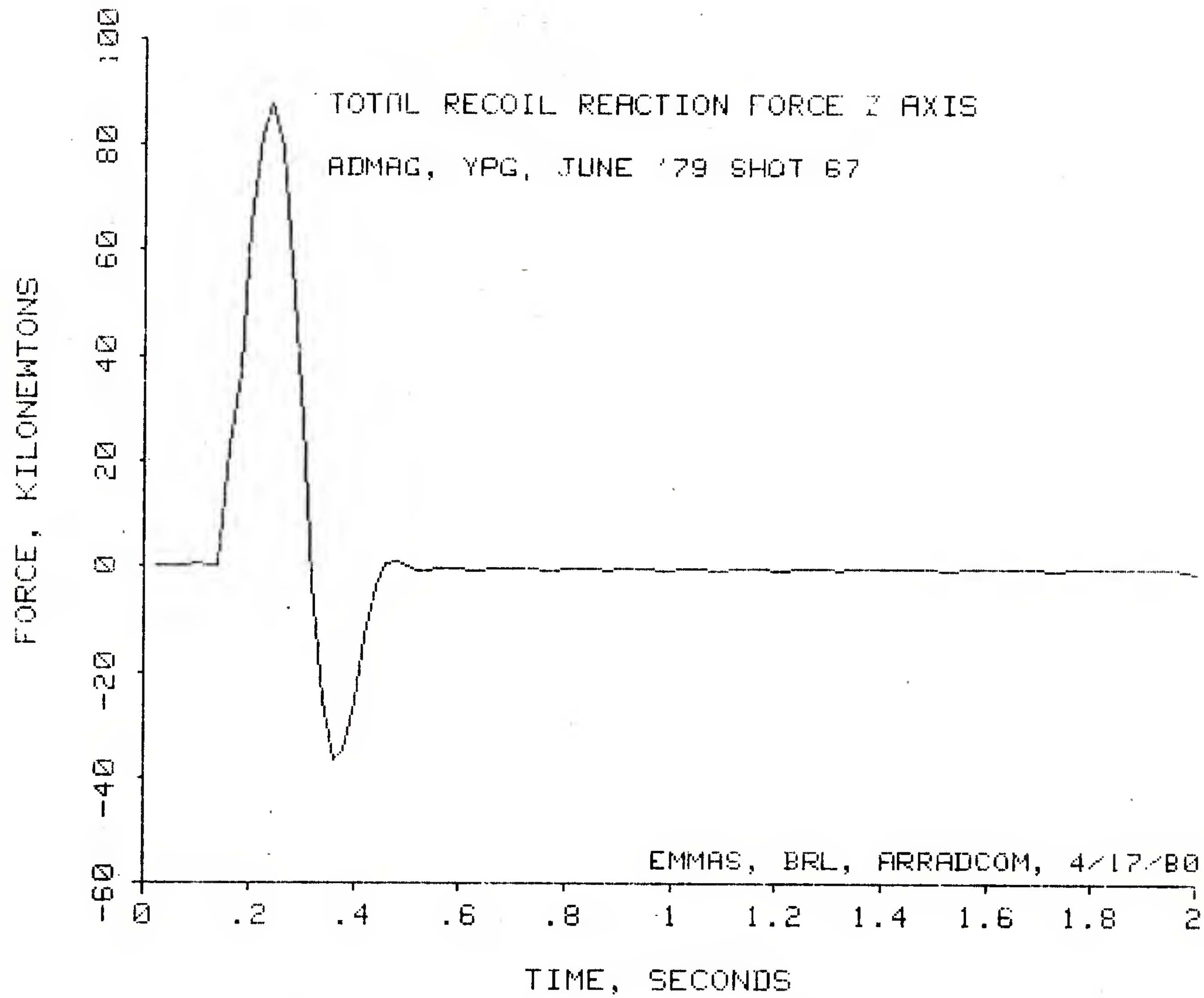


Figure 19. Total Recoil Reaction Force Along Z-Axis

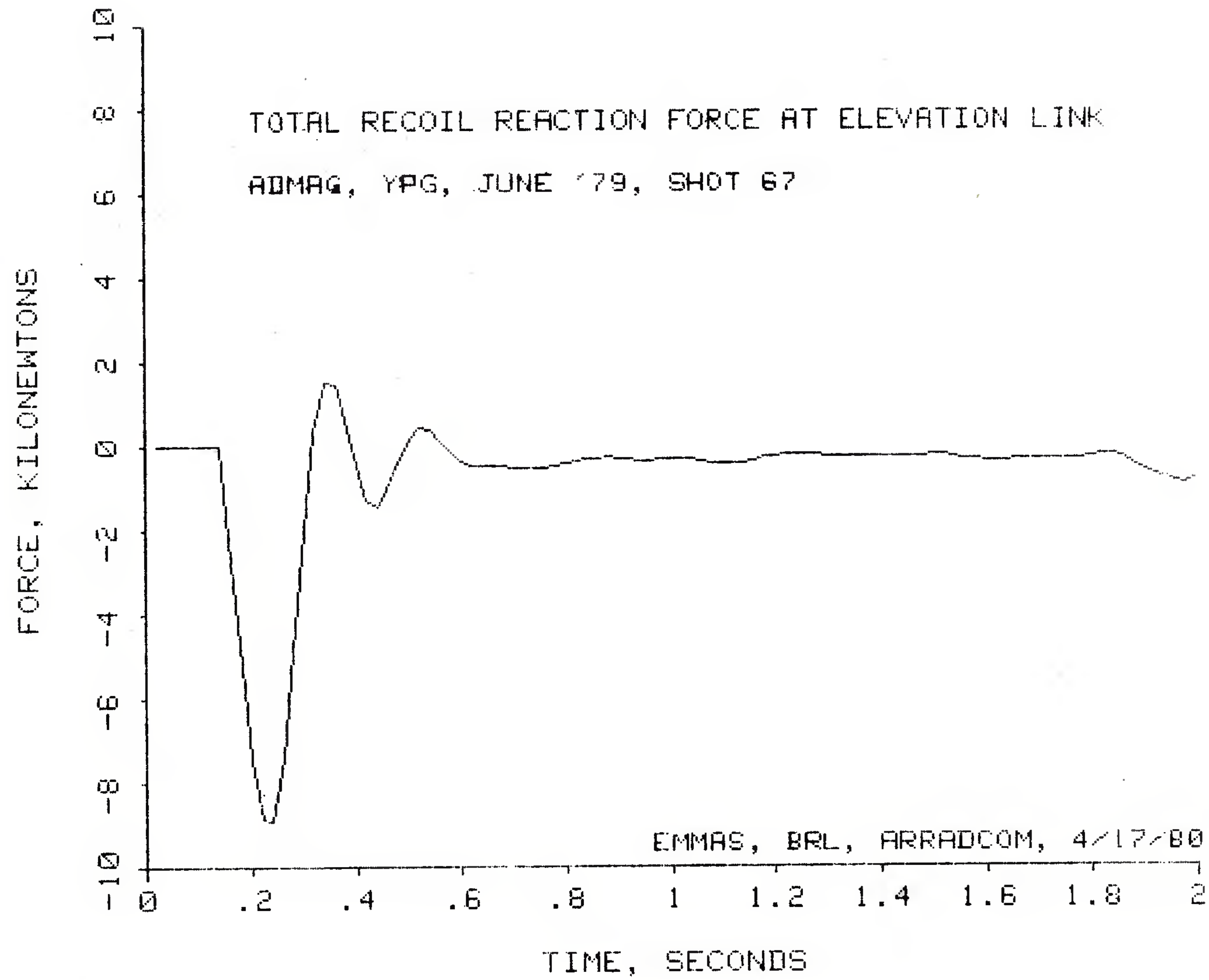


Figure 20. Total Recoil Reaction Force at Elevation Link

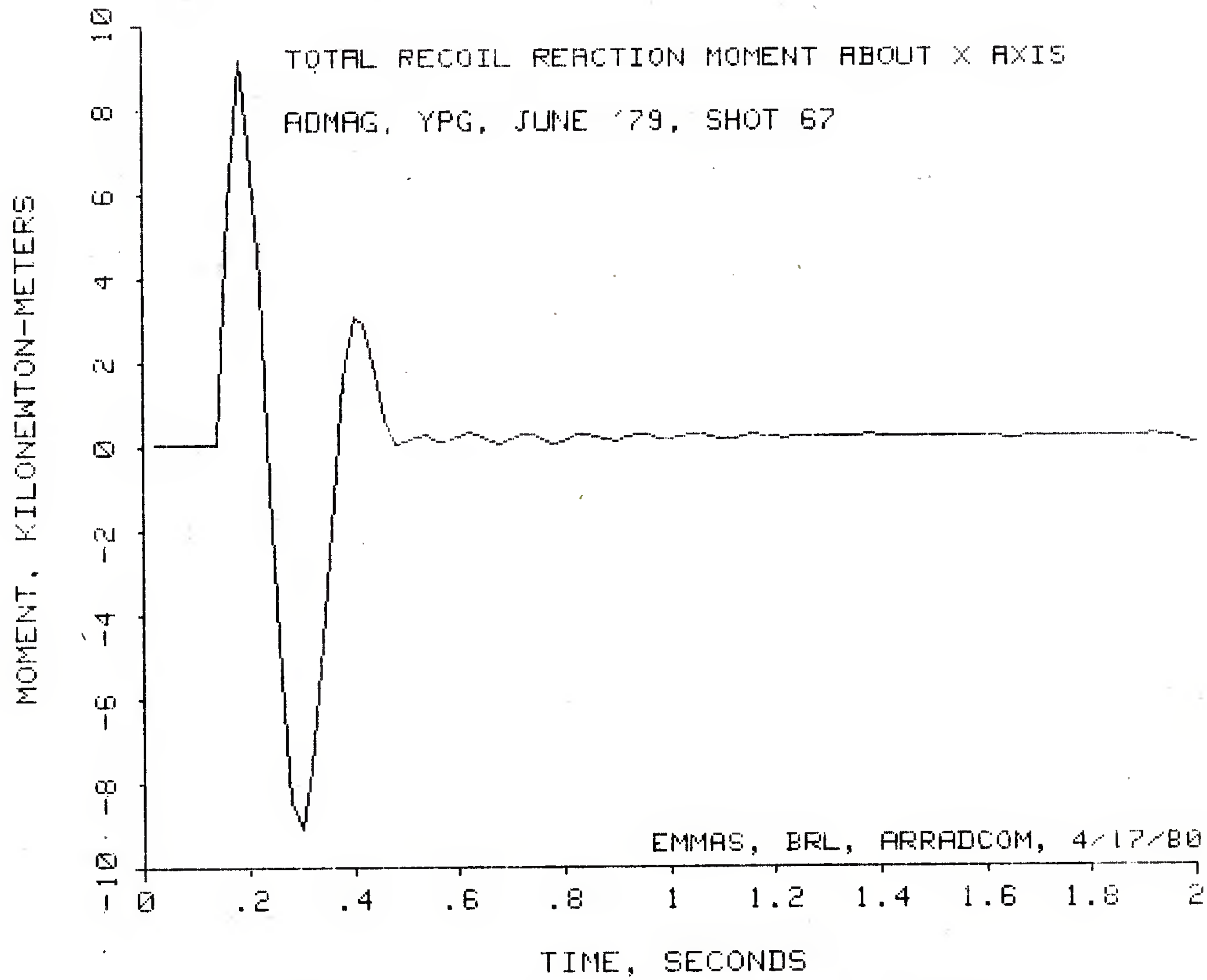


Figure 21. Total Recoil Reaction Moment About X-Axis

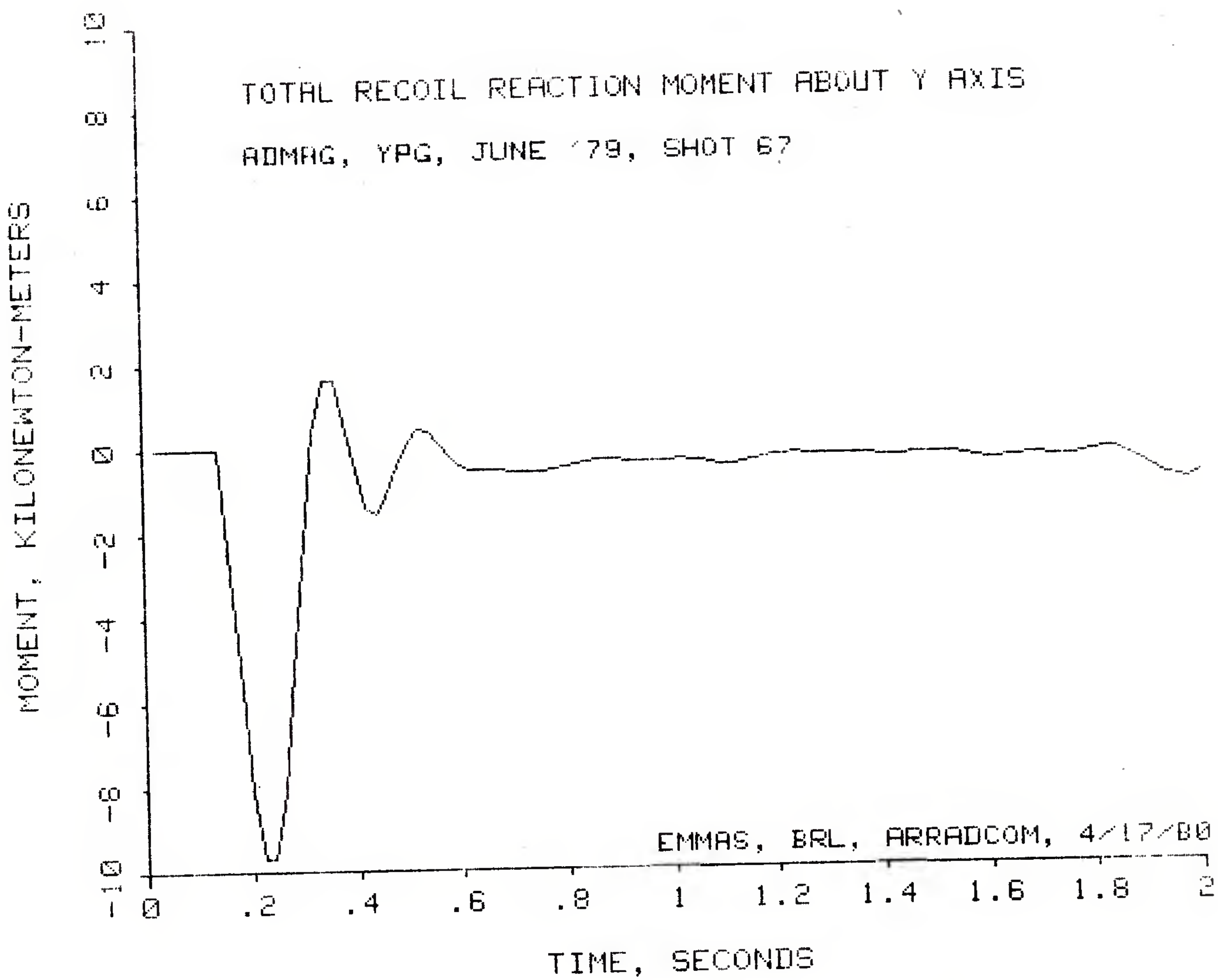


Figure 22. Total Recoil Reaction Moment About Y-Axis

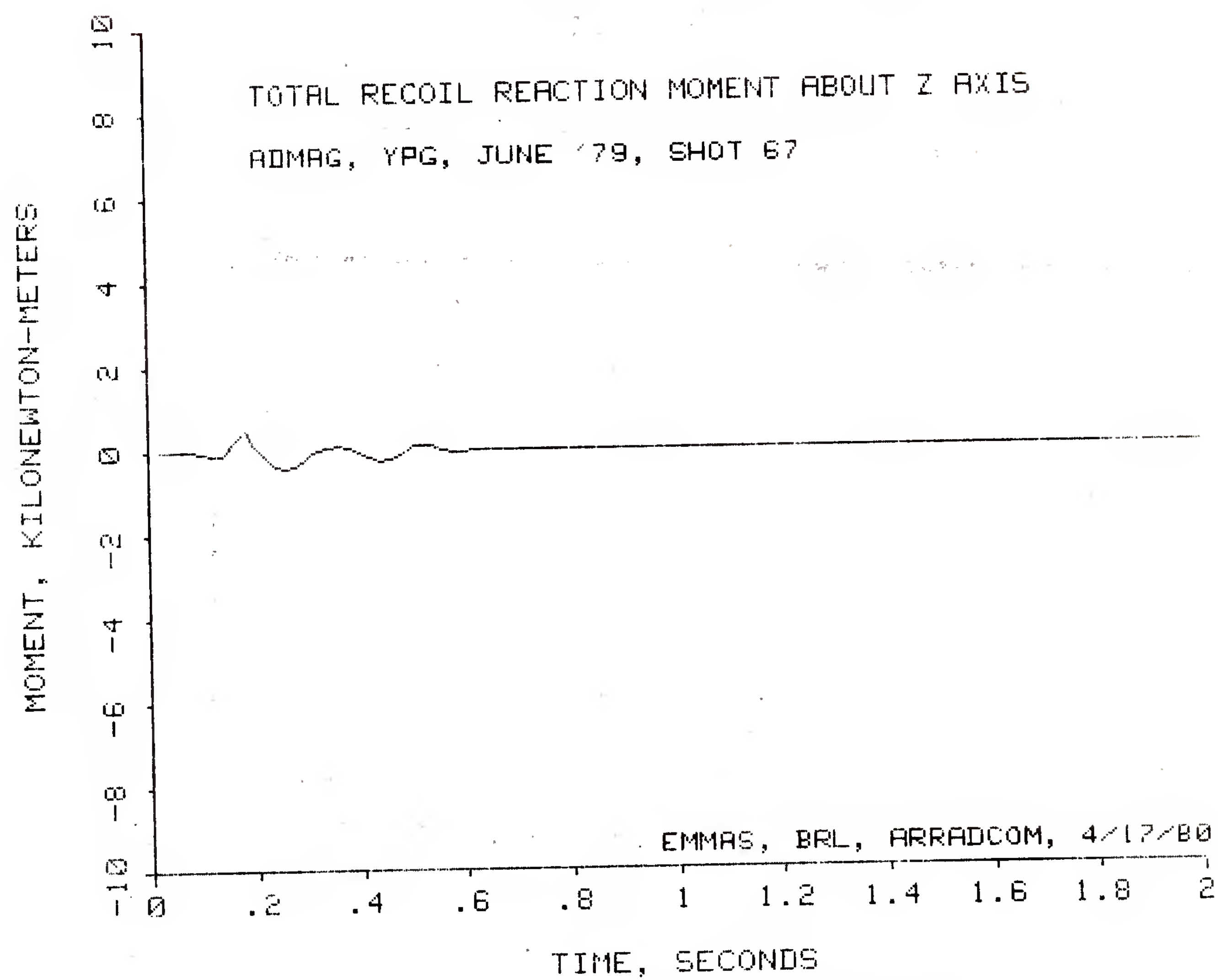


Figure 23. Total Recoil Reaction Moment About Z-Axis

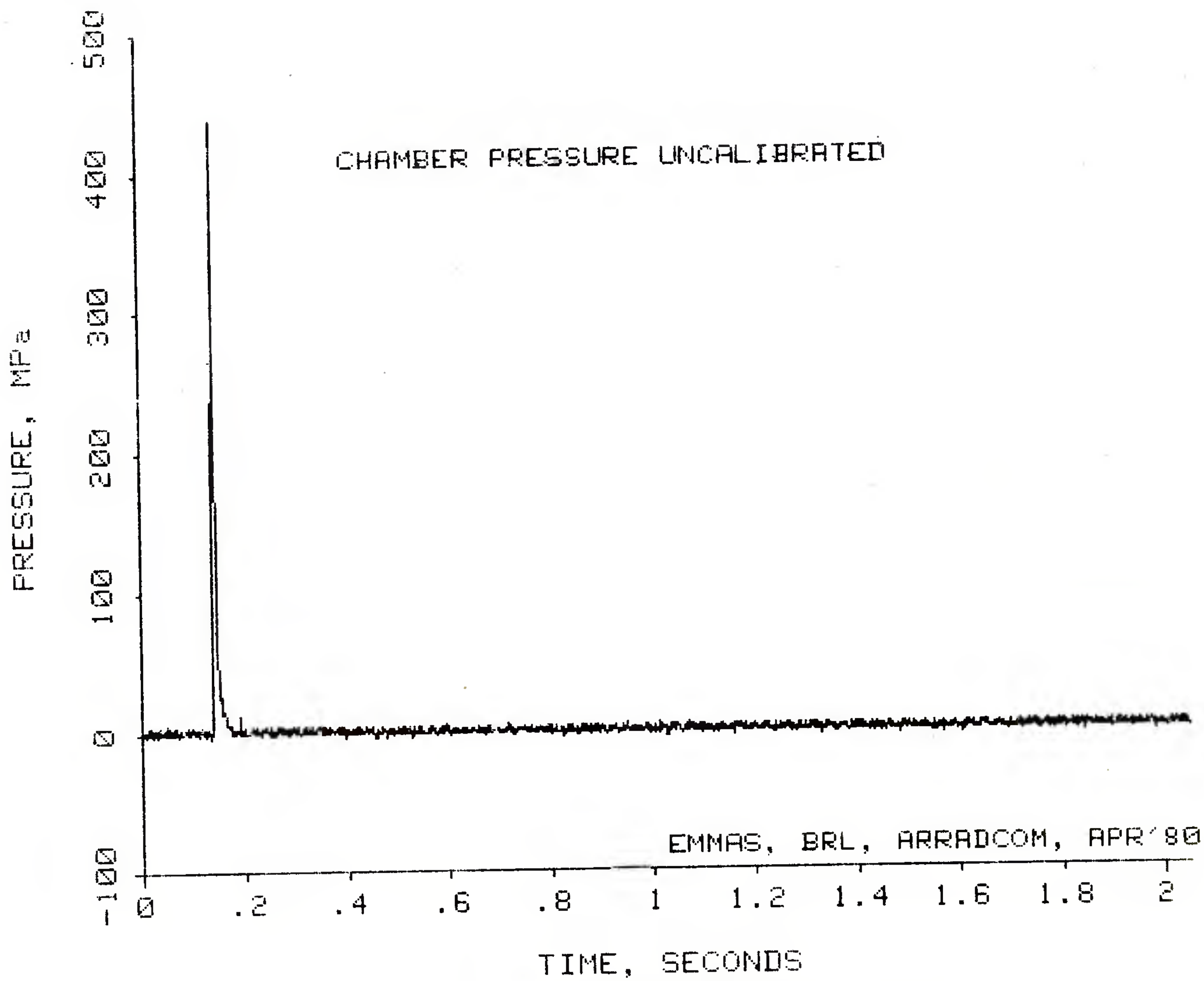


Figure 24. Chamber Pressure - Uncalibrated

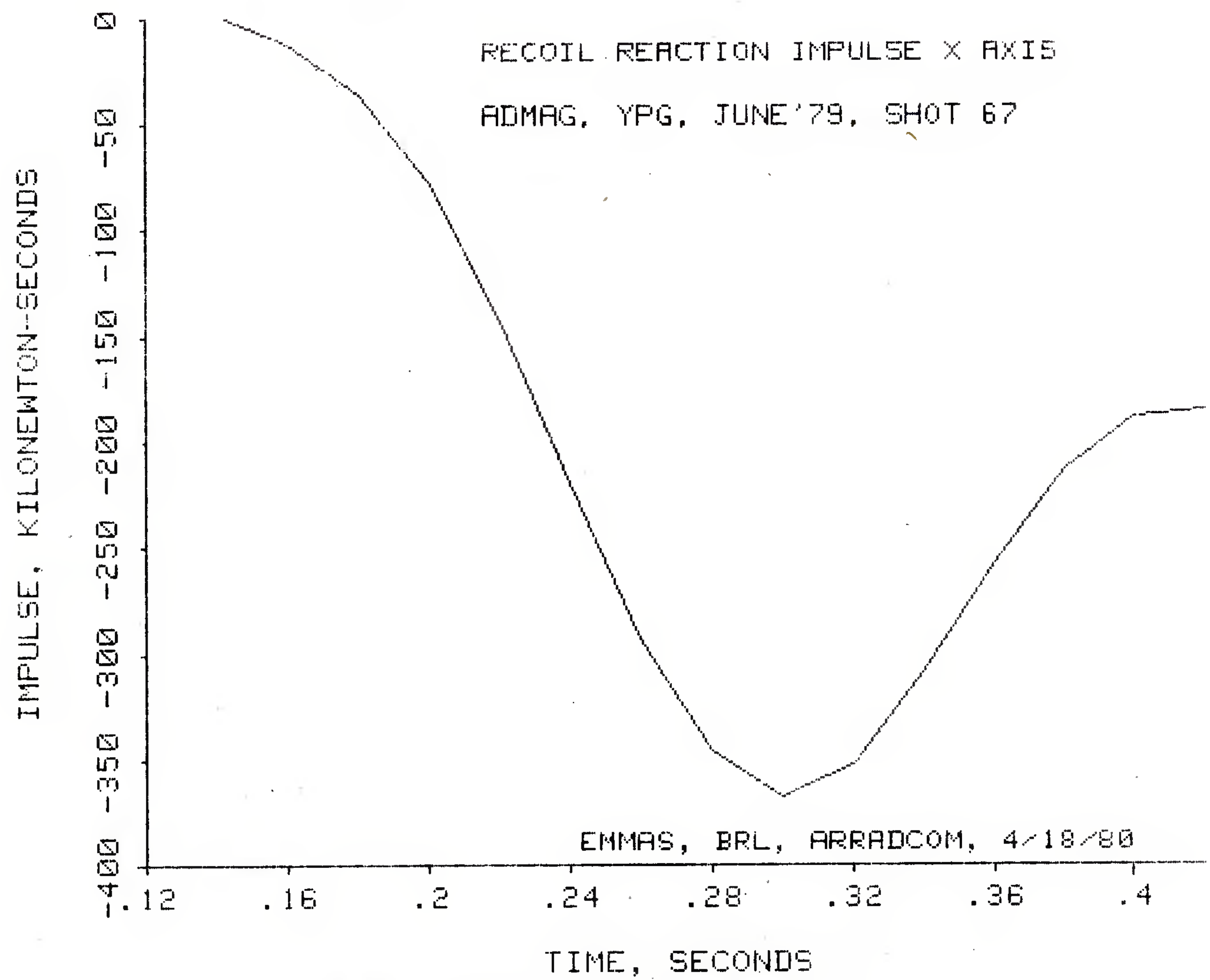


Figure 25. Recoil Reaction Impulse X-Axis

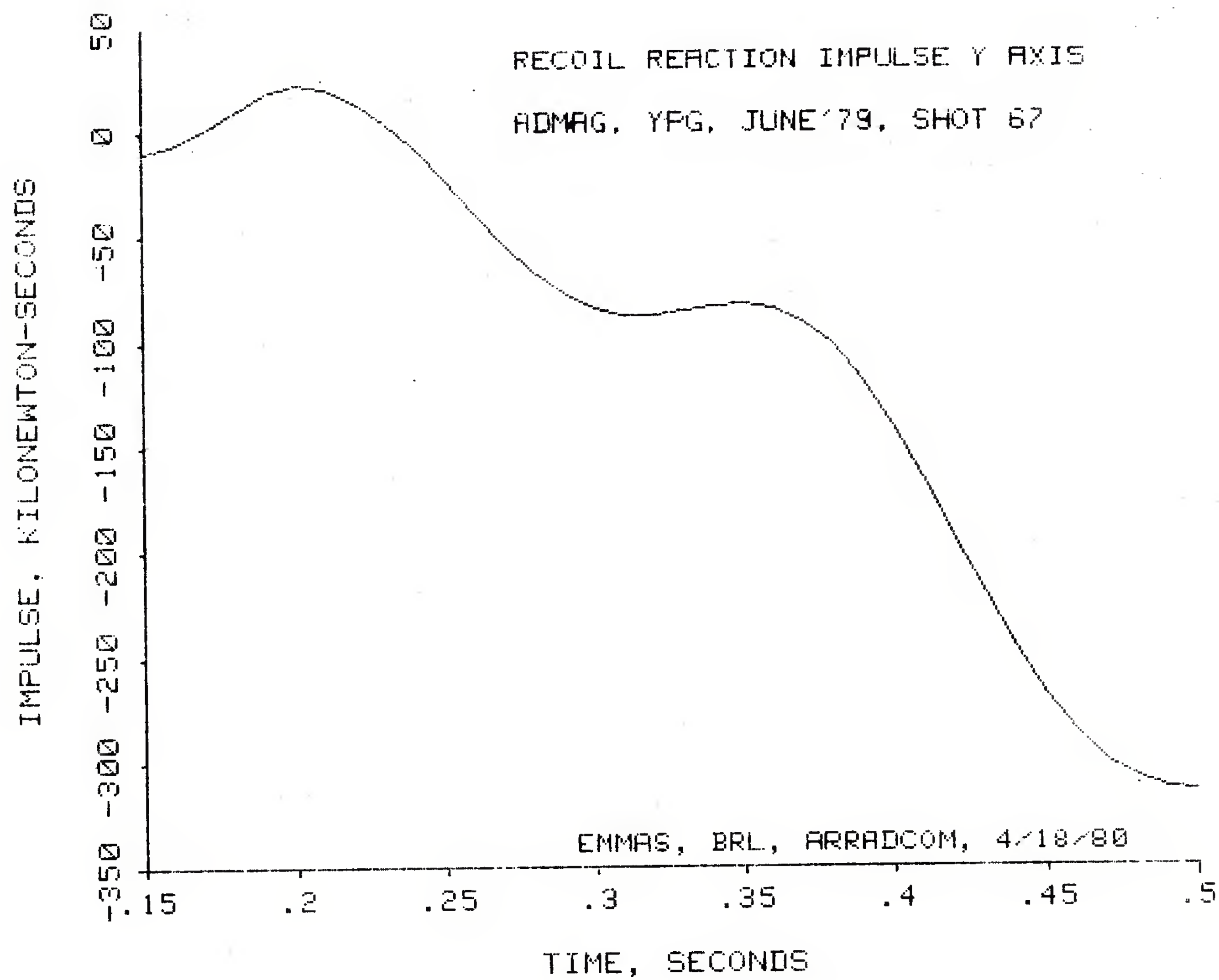


Figure 26. Recoil Reaction Impulse Y-Axis

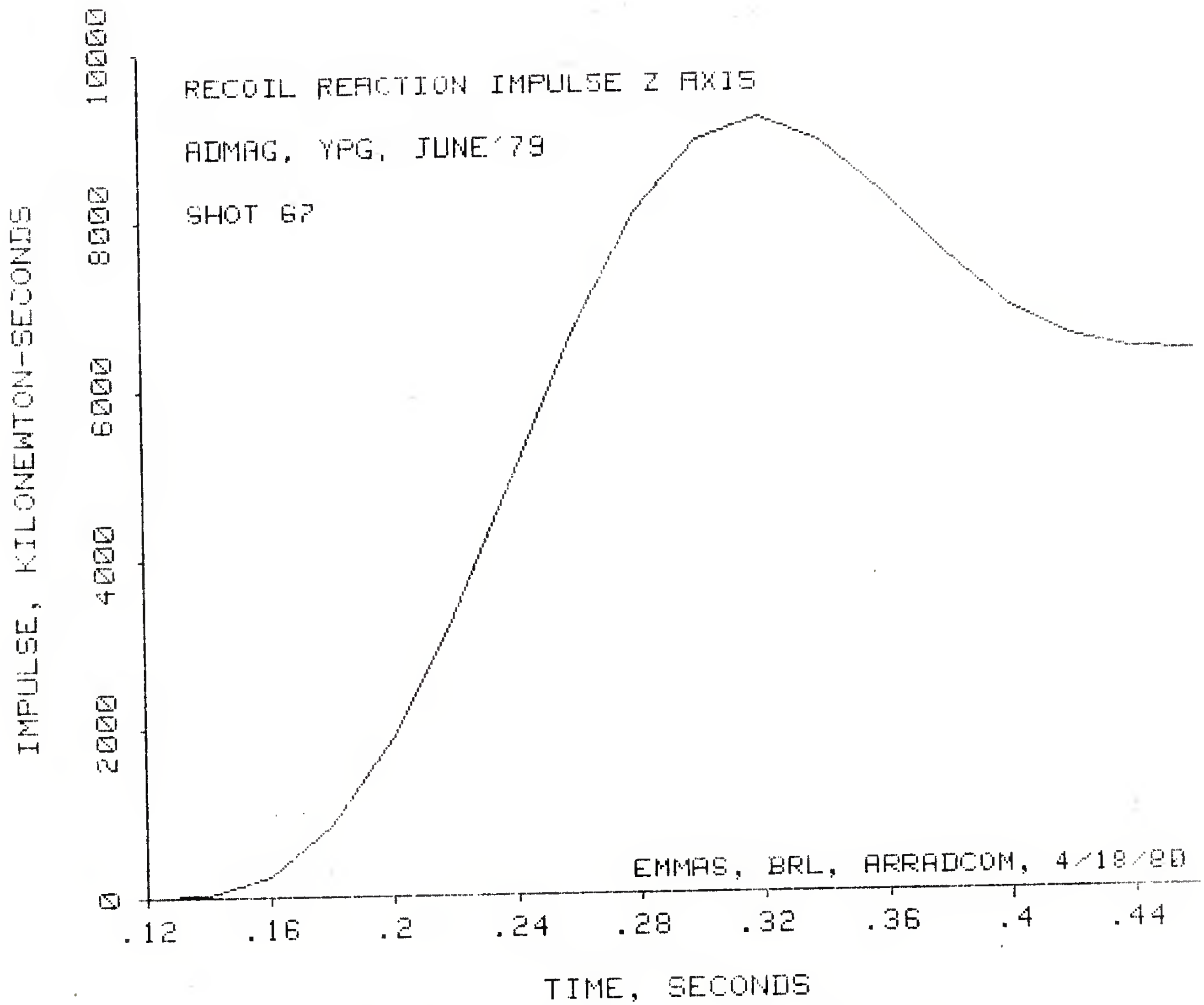


Figure 27. Recoil Reaction Impulse Z-Axis

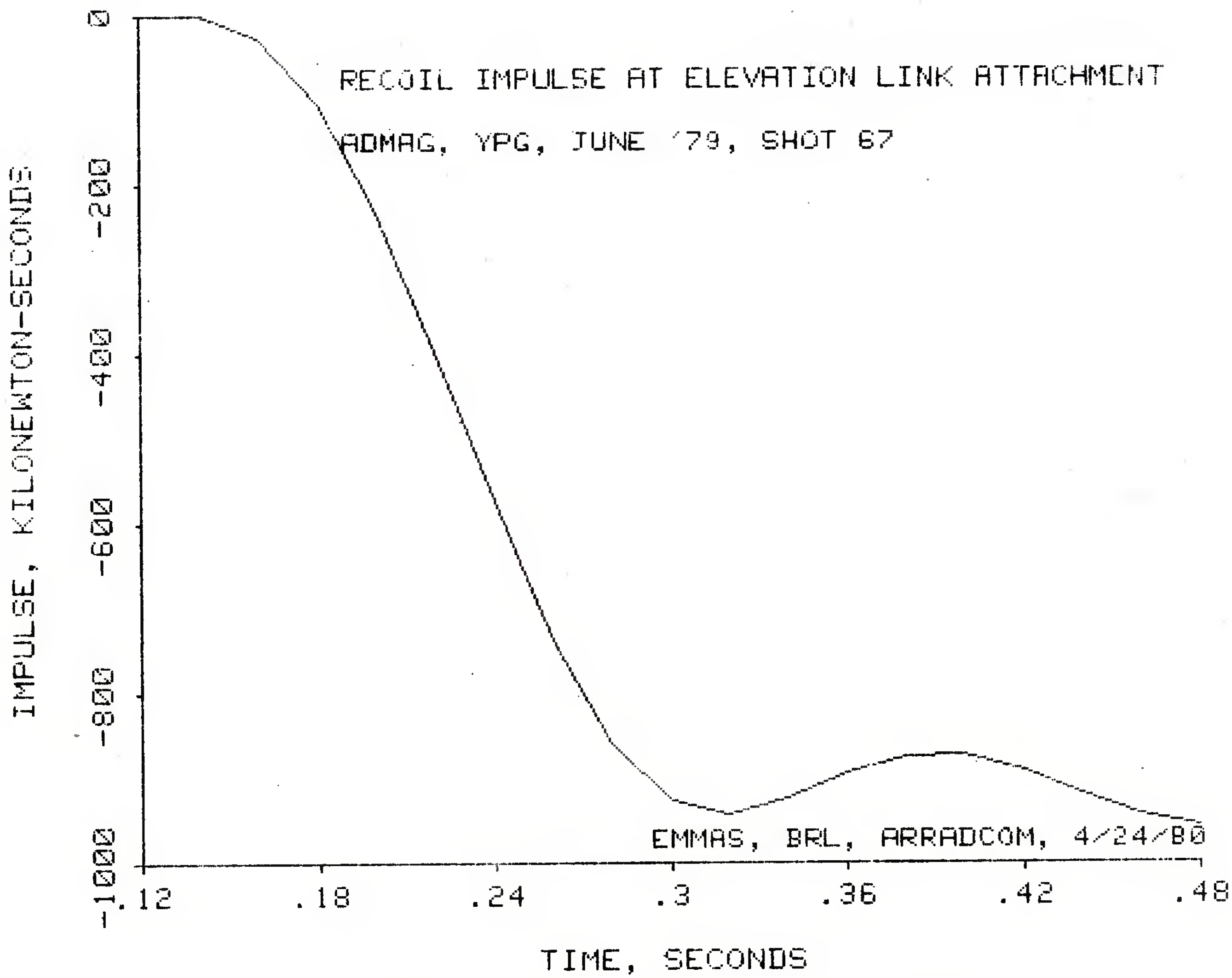


Figure 28. Recoil Reaction Impulse at Elevation Link

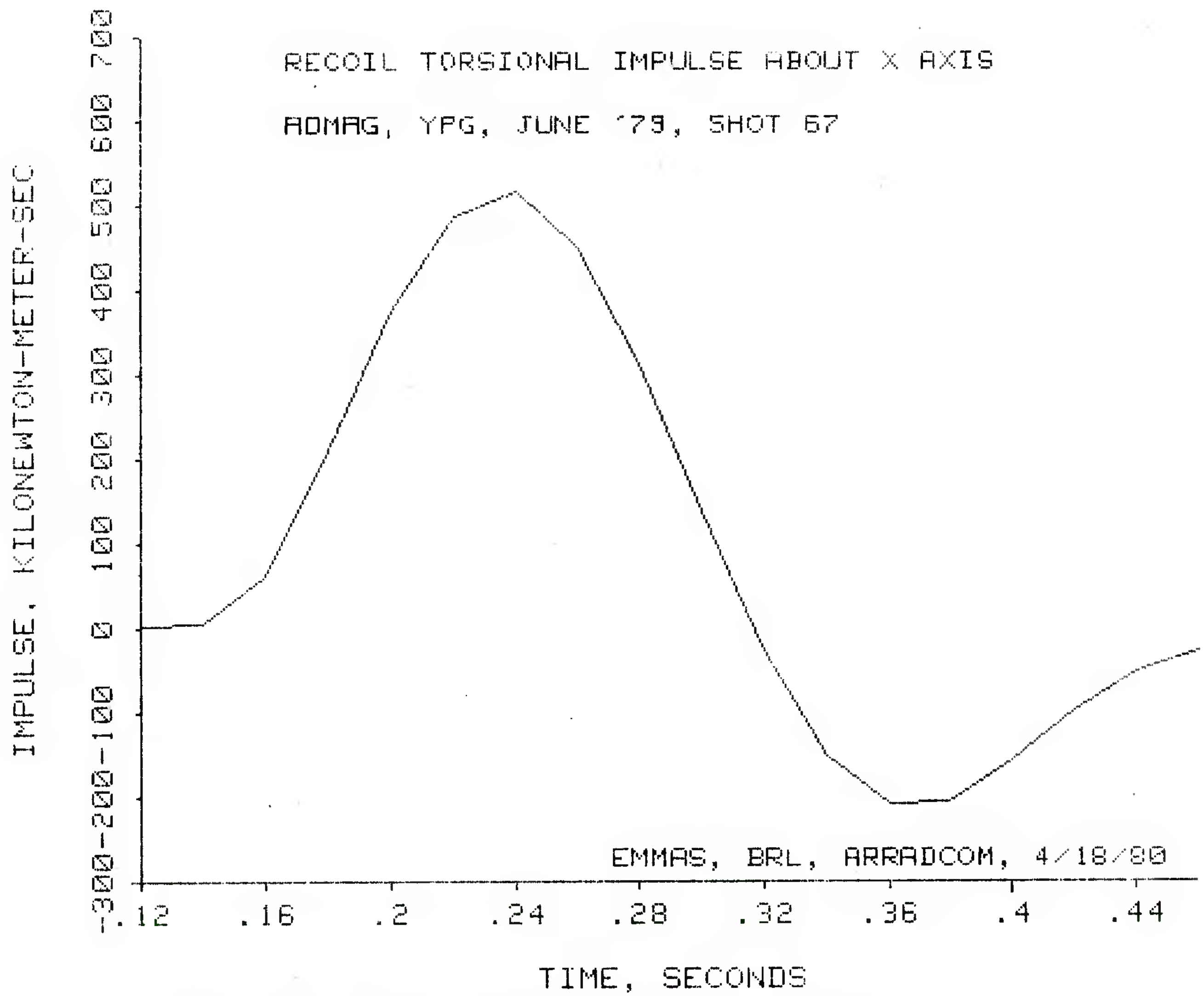


Figure 29. Recoil Torsional Impulse About X-Axis

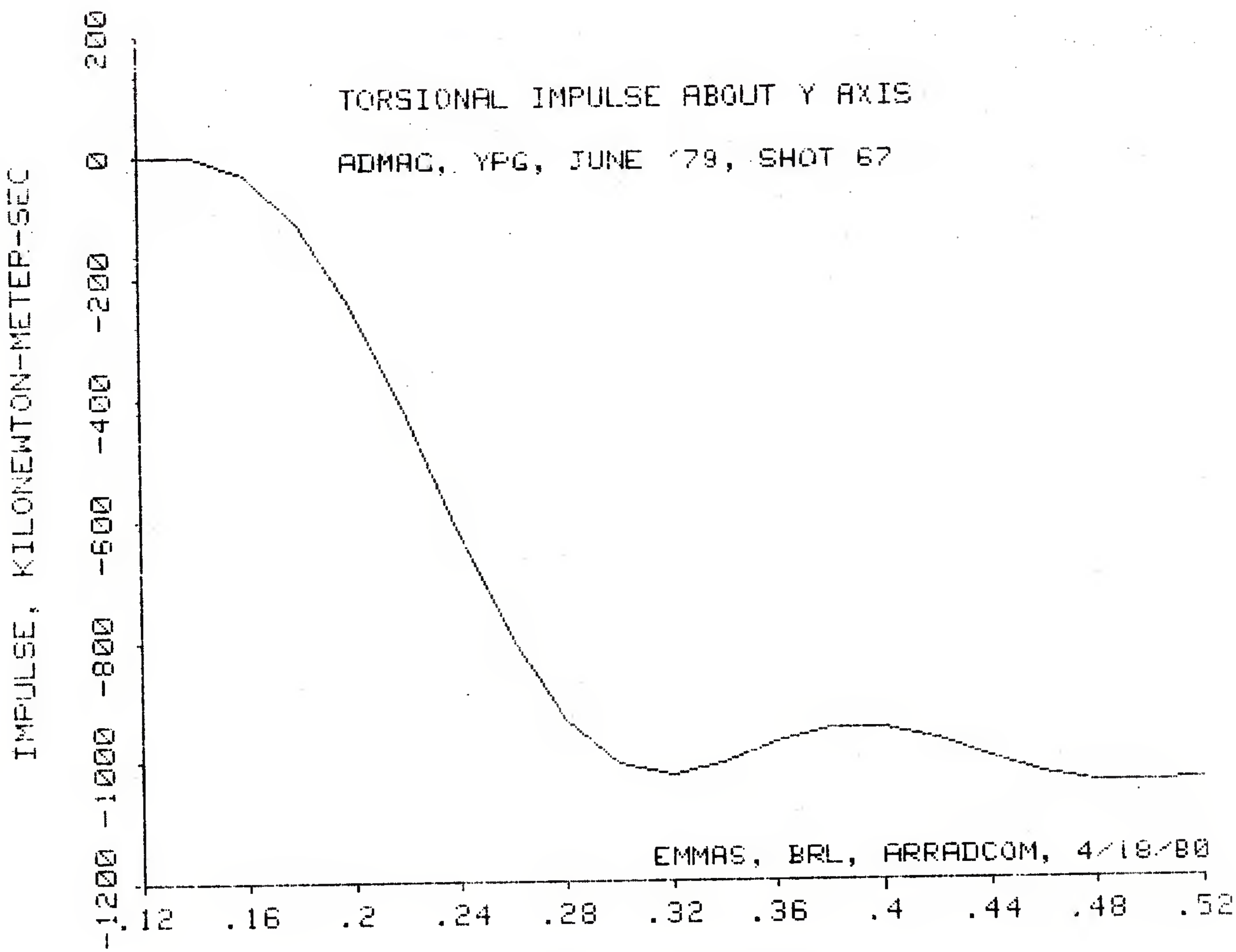


Figure 30. Recoil Torsional Impulse About Y-Axis

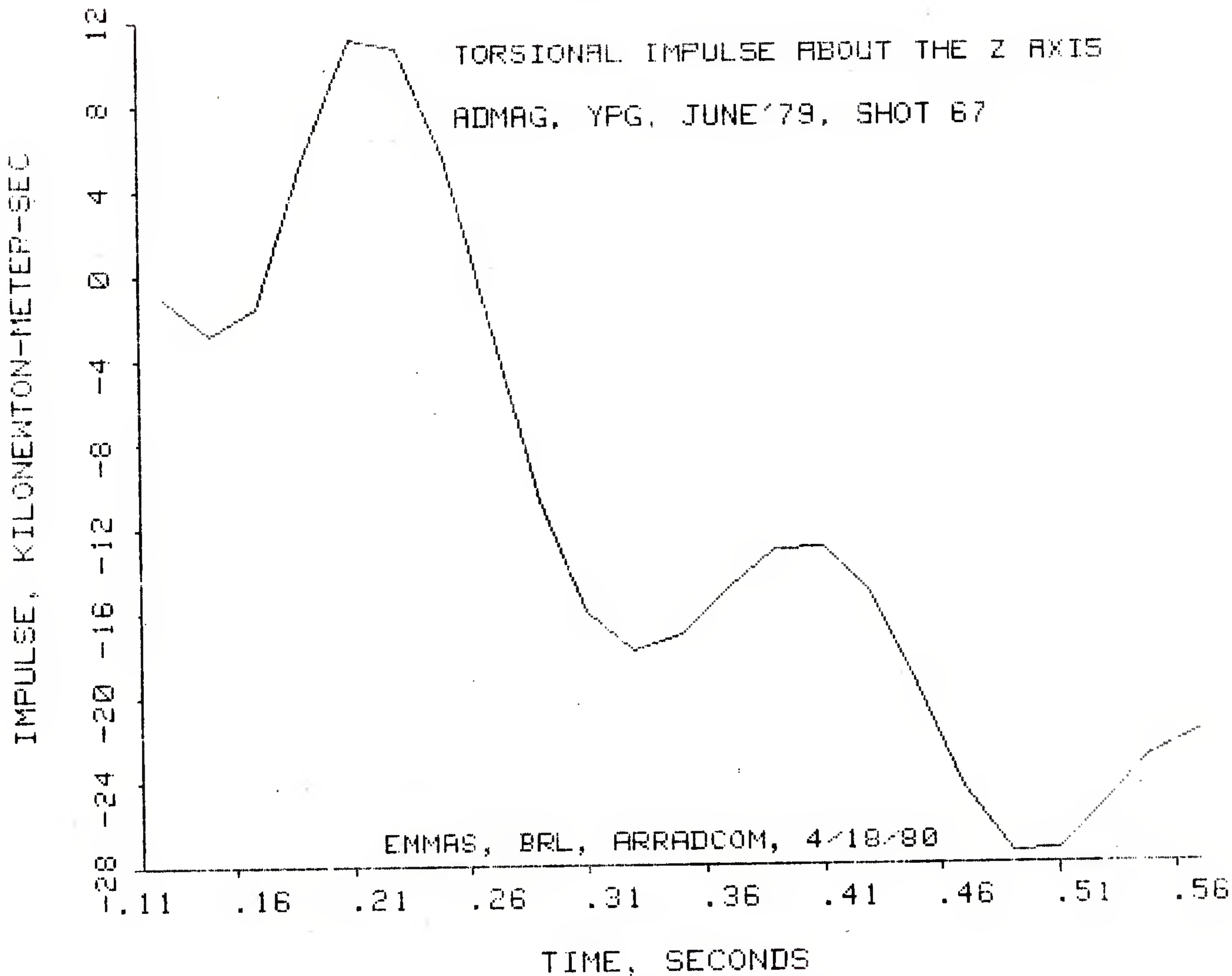


Figure 31. Recoil Torsional Impulse About Z-Axis

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