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AEROBALLISTIC TESTING OF THE XM825 PROJECTILE: PHASE IV. VERIFICATION OF FLIGHT STABILITY FOR HIGH MUZZLE VELOCITIES/HIGH QUADRANT ELEVATIONS

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November 1982

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

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

A short series of yawsonde-instrumented tests were conducted for the XM825 white phosphorous/felt wedge projectile at Yuma Proving Ground, AZ, on 3 November 1981. Previous testing had shown that unstable flight behavior can occur for high quadrant elevation and high muzzle velocity launches when the white phosphorous was in a liquid state. Preliminary bounds were established for the unstable behavior at that time. This yawsonde test was aimed at verifying the maximum (Continued)

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20. ABSTRACT (Continued):

allowable quadrant elevations for the M119 and PXR6297 propellant charges. It was found that 1240 and 950 mils were the maximum quadrant elevations for stable flights of liquid XM825 projectiles for the M119 and PXR6297 charges, respectively.

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I. INTRODUCTION

The 155mm XM825 projectile carries a single canister that is loaded with white phosphorous (WP) and felt wedges. Unstable flight behavior was observed for high quadrant elevations and high muzzle velocities when the WP was in a liquid state[1]. A test program was conducted at Yuma Proving Ground (YPG) on 3 November 1981 to determine the maximum allowable quadrant elevation for the M119 and PXR6297 charges. Two six round groups were fired, and all projectiles were instrumented with fuze configured yawsondes[2]. A solid projectile was fired within each group. All other XM825 shell were conditioned to 63 deg C so that the WP would be in a liquid state. Two launch conditions were selected: M119/1240 mils and PXR6297/950 mils. PXR6297 is the proof charge for the M203 charge, while no official proof charge exists for the M119 charge. All rounds were stable. A very small amount of fast mode precession was produced past apogee, but that motion decayed. No other unusual or unwanted behavior was noted in the yawsonde data.

II. BACKGROUND

The XM825 projectile had almost completed DTII, when poor flight behavior was observed for high quadrant elevation and high muzzle velocity conditions. Previous aeroballistic testing had not been conducted under these extreme conditions[3,4]. A large yawsonde program was conducted at YPG with yawsonde-instrumented shell to verify that the flight instabilities were associated only with rounds where the WP was in a liquid state and to provide detailed information as to the yaw and spin behavior under a wide variety of launch conditions. Poor flight behavior with large yaw and rapid despin occurred for the following conditions: PXR6297/1180 mils, PXR6297/1100 mils, M203/1180 mils, and M203/1050 mils. Stable performance was observed for M119/1180 mils. Unstable behavior was not found on any of the solid XM825 shell. Unstable behavior was precipitated shortly after apogee and was always associated with the fast precessional mode. Payload/projectile interactions that produce poor projectile performance normally destablize the fast precessional mode of the yawing motion. The exact nature of the mechanism for the unstable flights is unknown, however.

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1. *W. P. D'Amico and V. Oskay, "Aeroballistic Testing of the XM825 Projectile: Phase III. High Muzzle Velocity and High Quadrant Elevation," BRL Memorandum Report ARBRL-MR-03196, September 1982.*

2. *W. H. Mermagen and W. H. Clay, "The Design of a Second Generation Yawsonde," BRL Memorandum Report 2368, April 1974. AD No. 780064.*

3. *W. P. D'Amico and V. Oskay, "Aeroballistic Testing of the XM825 Projectile: Phase II," BRL Memorandum Report ARBRL-MR-03072, January 1981. AD No. A098036.*

4. *W. P. D'Amico, Jr., "Aeroballistic Testing of the XM825 Projectile: Phase I," BRL Memorandum Report ARBRL-MR-02911, March 1979. AD No. B037680L.*

In order to complete the safety requirements for DTII, the limits for stable performance must be established. For the M203 charge, the proof charge PXR6297 would be utilized. Previous yawsonde tests for M203/1050 mils showed persistent, small amplitude fast precessional motion. However, at these conditions only one out of six XM825 shell were unstable. Based upon these data, stable performance should exist for PXR6297/950 mils. Although no unusual behavior was observed for M119/1180 mils, further testing at the maximum allowable quadrant elevation was required. Modified-point mass trajectories were computed with an 80% standard atmosphere (no winds) for the XM825. Effects of the WP/felt wedge payload when the WP is liquid can not be modeled, so the payload was assumed to be solid. For these conditions, the maximum allowable quadrant elevation at which proper flight performance was predicted for the M119 charge was 1260 mils. An additional 20 mil decrement in quadrant elevation was absorbed as a small safety margin, and a launch condition of M119/1240 mils was selected.

III. TEST MATRIX AND INSTRUMENTATION

Two launch conditions were tested: PXR6297/950 mils and M119/1240 mils. All projectiles were instrumented with yawsondes, and a round-by-round history is provided in Table I. Only eleven XM825 shell were available for the test at YPG, hence, an M483A1 (YPG267, BRL1699) was used to establish baseline data for the PXR6297/950 mils rounds. A solid XM825 (YPG259, BRL1579) provided baseline data for the M119/1240 mils rounds.

Standard range instrumentation was provided by YPG to include a telemetry receiving van and a time-position radar, the DIR. The DIR was located down range. The DIR tracked the M119/1240 mils group, but was unable to track the PXR6297/950 mils group. The MPS-25 radar which had been used on previous XM825 tests was under extensive repairs.

The data obtained by the yawsonde package is in the form of the complementary solar aspect angle (Sigma N) and the spin. Sigma N is the complement of the solar aspect angle, the angle between a vector drawn to the sun and the spin axis of the projectile. Local excursions in Sigma N represent the yawing motion of the projectile about the trajectory. Spin data are in the form of the time-derivative of the Eulerian roll angle (Phi) of the projectile. As long as the spin rate of the shell is substantially faster than the yawing frequencies and the angular motion is small, then Phi Dot is a good measure of spin. Oscillations will be present on the Phi Dot histories, but these oscillations are an artifact of the yawsonde measurement system and are produced by the yaw. The raw yawsonde transmissions were often contaminated by noise. This noise was processed out of the data and results in an intermittent loss of data. The source of this noise is probably the radiation pattern of the transmitting antenna of the yawsonde and cannot be avoided unless a new antenna is utilized. The high spin rates and long times of flight yielded large data arrays. High speed/low resolution plotters were utilized to obtain plots of the data for the entire trajectory. Typically spin plots will contain small ripples, but these are due to the resolution of the graphics system and are not caused by noise within the data. An error in the firing count down for YPG262 caused the gun time zero pulse to be lost. Hence, the zero time for this round may be slightly in error.

Table 1. Round-By-Round Summary of 3 November 1981

YPG Number	BRL Number	Projectile Type*	Muzzle Velocity (m/s)	QE (mils)	Range** (km)	Apogee** (km)
259	1579	XM825/Solid	674.2	1240	12.2	10.6
260	1747	XM825/Liquid	675.4	1240	12.2	10.6
261	1751	XM825/Liquid	675.1	1240	12.2	10.6
262	1752	XM825/Liquid	677.4	1240	N/A	N/A
263	1754	XM825/Liquid	675.7	1240	12.2	10.6
264	1774	XM825/Liquid	673.9	1240	12.2	10.6
267	1699	M483A1	841.5	950	N/A	N/A
268	1750	XM825/Liquid	850.4	950	N/A	N/A
269	1746	XM825/Liquid	850.3	950	N/A	N/A
270	1748	XM825/Liquid	850.8	950	N/A	N/A
271	1749	XM825/Liquid	848.7	950	N/A	N/A
272	1686	XM825/Liquid	849.3	950	N/A	N/A

* XM825/Liquid were conditioned to 63 deg C. XM825/Solid were conditioned to 21 deg C.

** Estimated from plot board of DIR radar.

IV. TEST RESULTS

A. Preliminary Discussion

Spin-stabilized projectiles when launched at high quadrant elevations can experience large angular motions near apogee. Murphy has considered the angular motion of a projectile under such conditions[5]. For high quadrant elevation launches, the nose of the projectile will not follow the trajectory curvature past apogee. During the down leg, the projectile will recover from this condition and may experience large amplitude motions. Normally these angular motions are at the slow precessional frequency. This type of behavior will be expected and is not abnormal. Angular motions at the fast precessional frequency are dangerous and are probably caused by the liquid WP payload. The fast precessional frequency may be as high as 20Hz, while the slow precessional is typically less than 1Hz.

B. M119/1240 mils

Figures 1a and 1b show the yaw and spin behavior of the solid XM825 projectile, YP259. No unusual behavior was observed. Large amplitude motion at the slow precessional frequency occurred subsequent to 60s. This motion was produced by the summital maneuver. A small amplitude, fast precessional component was also observed during this time frame. The yawing motion prior to 15s (a loss in data occurred immediately after this time) also produced a fast precessional mode response. This type of dual-mode or epicyclic motion is common for the M483A1 family at transonic and subsonic Mach numbers. Trajectory analyses indicated subsonic Mach numbers from 15-75s. Figure 1c is an expanded plot of the data between 60-80s, and it indicates that the amplitude of the fast precessional mode k_1 is less than 0.25 deg.

YPG260 was a liquid XM825 and the yawsonde data are shown in Figures 2a and 2b. The character of the yawing motion was similar to the solid round, except a slightly larger amplitude for k_1 occurred ($k_1 \simeq 0.5$ deg as seen in Figure 2c). However, the k_1 mode did damp as shown in Figure 2d. Figures 3a and 3b show the yawsonde data for YPG261. These data are similar to the previous round. Slightly larger k_1 amplitudes were experienced during the 60s time frame (see Figure 3c), but again the k_1 mode damped. Figure 3d shows an expansion of the yaw data to expose the details of the motion. The frequency of k_1 is 17Hz between 60-61s. The yawsonde data for YPG262 are shown in Figures 4a and 4b. Again the data are similar to the previously fired liquid XM825 projectiles. A maximum value of $k_1 = 1$ deg occurred at approximately 72.5s (see Figure 4c). An expanded plot showing the details of the k_1 motion is provided Figure 4d. Figures 5a and 5b show the yawsonde data for YPG263. The data are again of similar character as the previous shell. A maximum value for k_1 of 1 deg occurred during the 60-88s time frame, but the motion

5. *Charles H. Murphy, "Gravity-Induced Angular Motion of a Spinning Missile," Journal of Spacecraft and Rockets, Vol. 8, August 1971, pp. 824-828. (Also BRL Report 1546 dated July 1971. AD No. 730641.)*

was damped (see Figures 5c and 5d). Data from the last round of this group, YPG264, are shown in Figures 6a and 6b. The data are consistent with the other rounds within this group. Expanded plots within Figures 6c and 6d show a maximum k_1 of less than 1 deg and indicate that the motion was damped.

C. PXR6297/950 mils

The first round in this group of shell was an M483A1 (YPG267, BRL1699). Figures 7a and 7b show the yawsonde data. No unusual behavior was noted and the lower quadrant elevation did not produce a large amplitude, slow precessional response as in the previous group of shell. A launch yaw of approximately 3 deg (Figure 7c) was observed, but the yaw quickly damped. Beyond 60s, the epicyclic motion characteristic of the M483A1 family of shell occurred. The k_1 amplitude during this portion of the trajectory was less than 0.25 deg (Figure 7d).

The first XM825 test round in this group was YPG268 (BRL1750). The yawsonde data are shown in Figures 8a and 8b. A small level of fast mode precession was present along most of the trajectory. The k_1 amplitude was approximately 0.5 deg (Figures 8c and 8d). The k_1 motion did damp during the final phases of the flight, however. YPG269 (BRL1746) was the next test round. Yawsonde data are shown in Figures 9a and 9b. As before a small amount of fast mode precession was present, but this amplitude was decreased prior to 60s into the flight. During the 60-80s time frame, the fast precessional mode was less than 0.25 deg (Figures 9c and 9d). The next test round (YPG270, BRL1748) had a very noisy data transmission (Figures 10a and 10b). YPG271 (BRL1749) was similar in nature to the previous test rounds (Figures 11a and 11b). A maximum amplitude for k_1 occurred approximately 60s down range ($k_1 \simeq 1$ deg as shown in Figures 11c and 11d). The last test round in this series was YPG272 (BRL1682), and the data are shown in Figures 12a and 12b. The k_1 amplitude at launch was approximately 1 deg and was less than 0.5 deg at 80s (Figures 12c and 12d).

V. CONCLUSIONS

Two launch conditions were tested for the XM825 when the WP was in a liquid state: PXR6297/950 mils and M119/1240 mils. Baseline data were also obtained at these conditions for solid shell. Liquid XM825 shell at both launch conditions produced very small amplitude fast precessional motion, but these motions always damped and no adverse effects occurred. The conditions that were tested represent the maximum allowable quadrant elevations for the XM825 projectile when the WP is in a liquid state. For the M119 charge, the maximum quadrant elevation for the M483A1 is 1320 mils for standard atmospheric conditions. Recall that the 1240 mils condition was for an 80% standard atmosphere. An 80 mil reduction (less than 5 deg) in the operational capability of the projectile/weapon system should not be serious. For the M203 charge, however, a reduction in quadrant elevation to 950 mils is required. For this charge, the M483A1 has a maximum quadrant elevation of 1260 mils.

VI. ACKNOWLEDGEMENTS

The authors are indebted to Mr.S. Kushubar and Mr. D. Hepner for the reduction and plotting of the yawsonde data. Mr. D. Vasquez and Mr. D. Davis assembled the yawsondes, while Mr. M. Steele was responsible for the calibration of the units. Mr. W. Tenly assisted YPG personnel in the operation of the ground receiving station. Trajectory computations were provided by Mr. R. Lieske and Mr. N. Roberts, Firing Tables Branch, LFD, BRL.

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4. W. P. D'Amico, Jr., "Aeroballistic Testing of the XM825 Projectile: Phase I," BRL Memorandum Report ARBRL-MR-02911, March 1979. AD No. B037680L.

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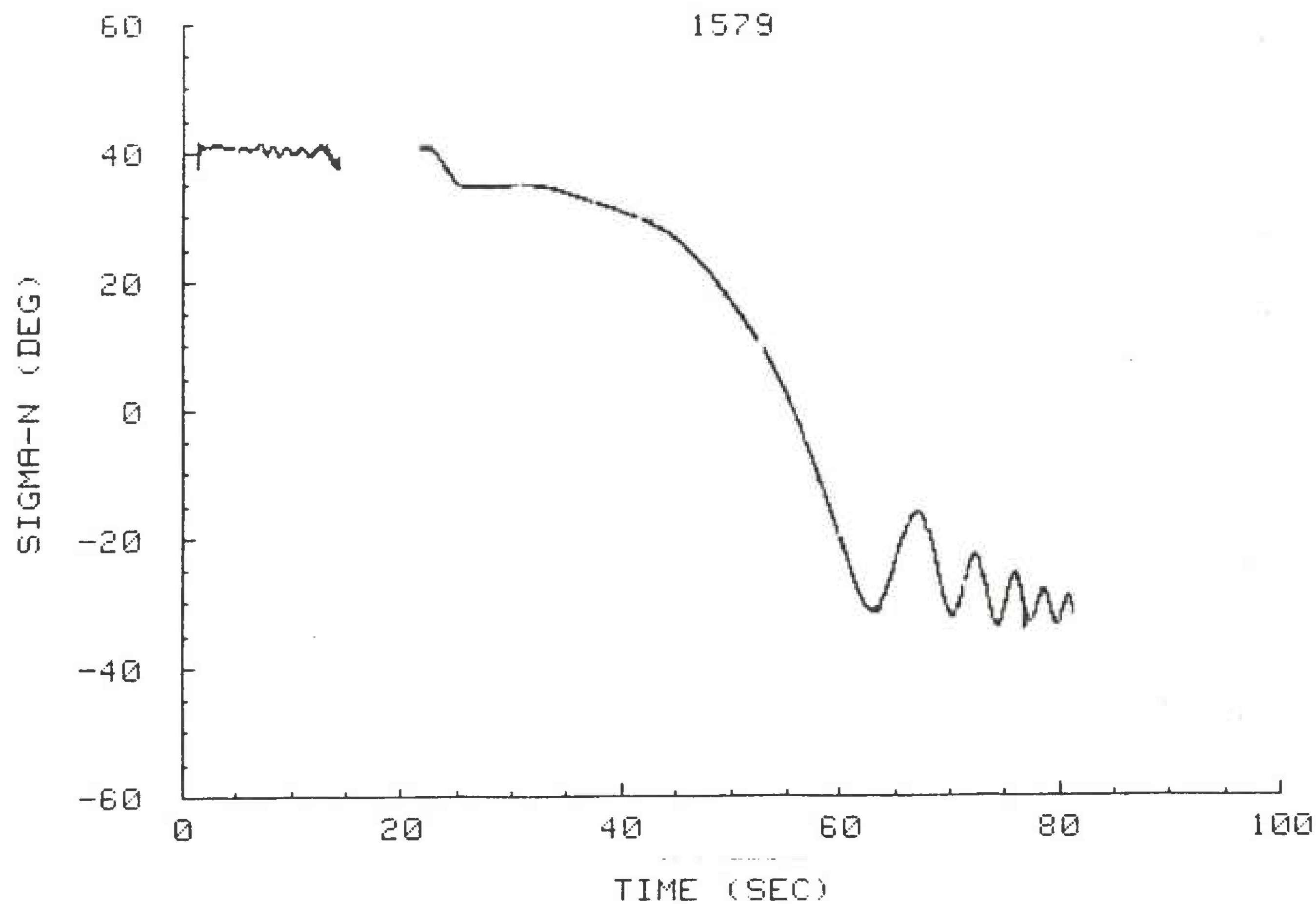


Figure 1a. Sigma-N History - YPG 259, XM825/Solid.

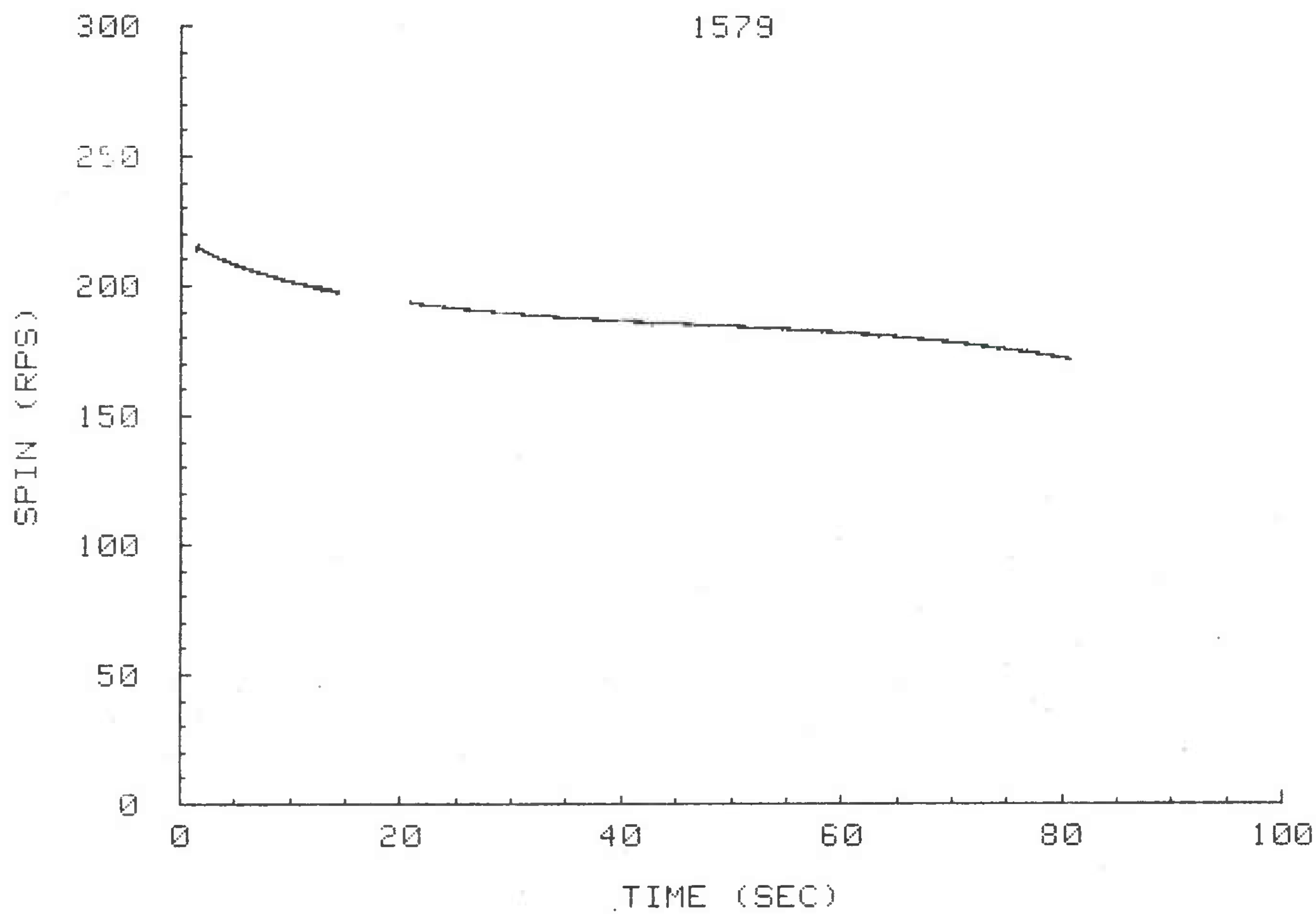


Figure 1b. Spin History - YPG, XM825/Solid.

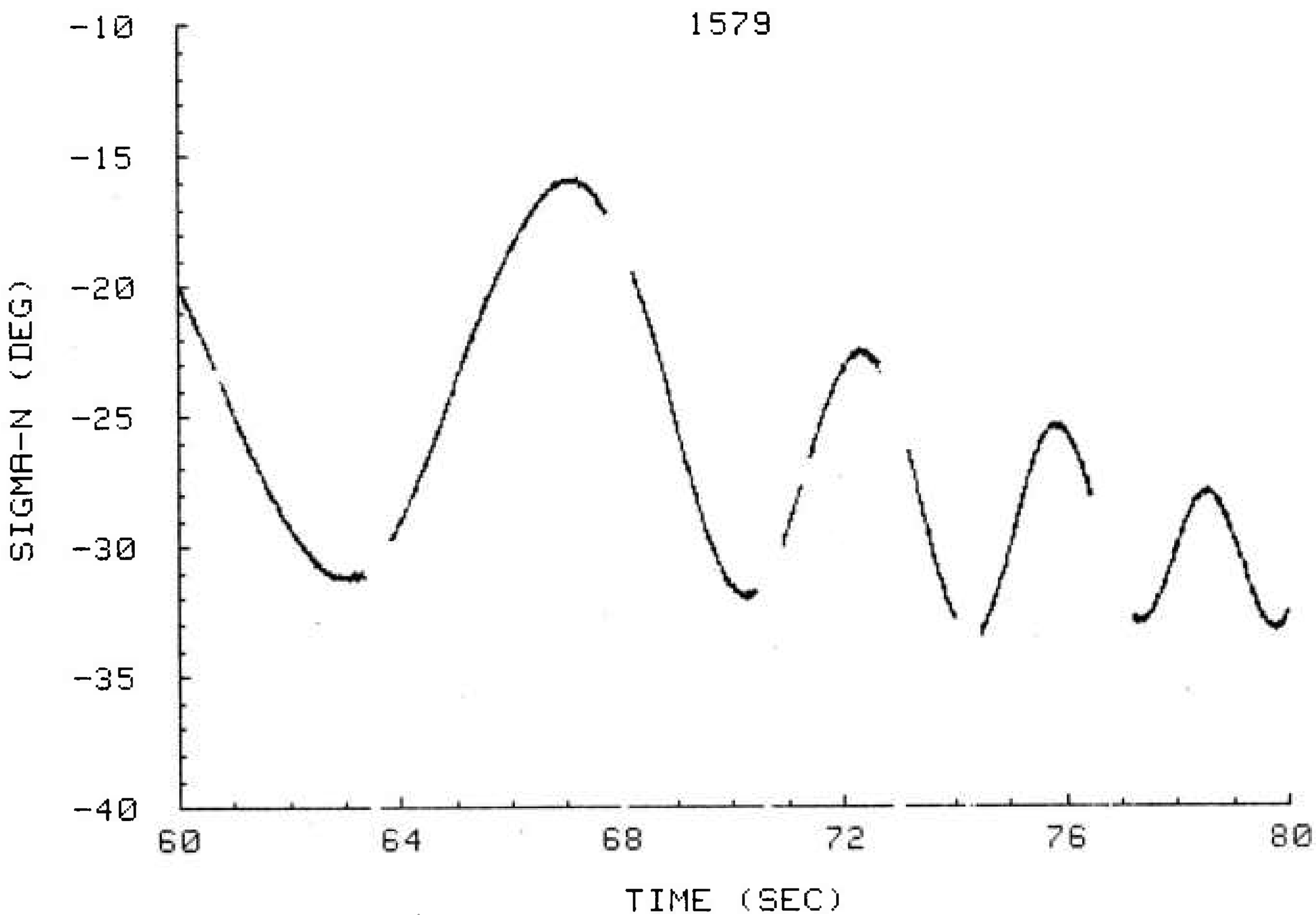
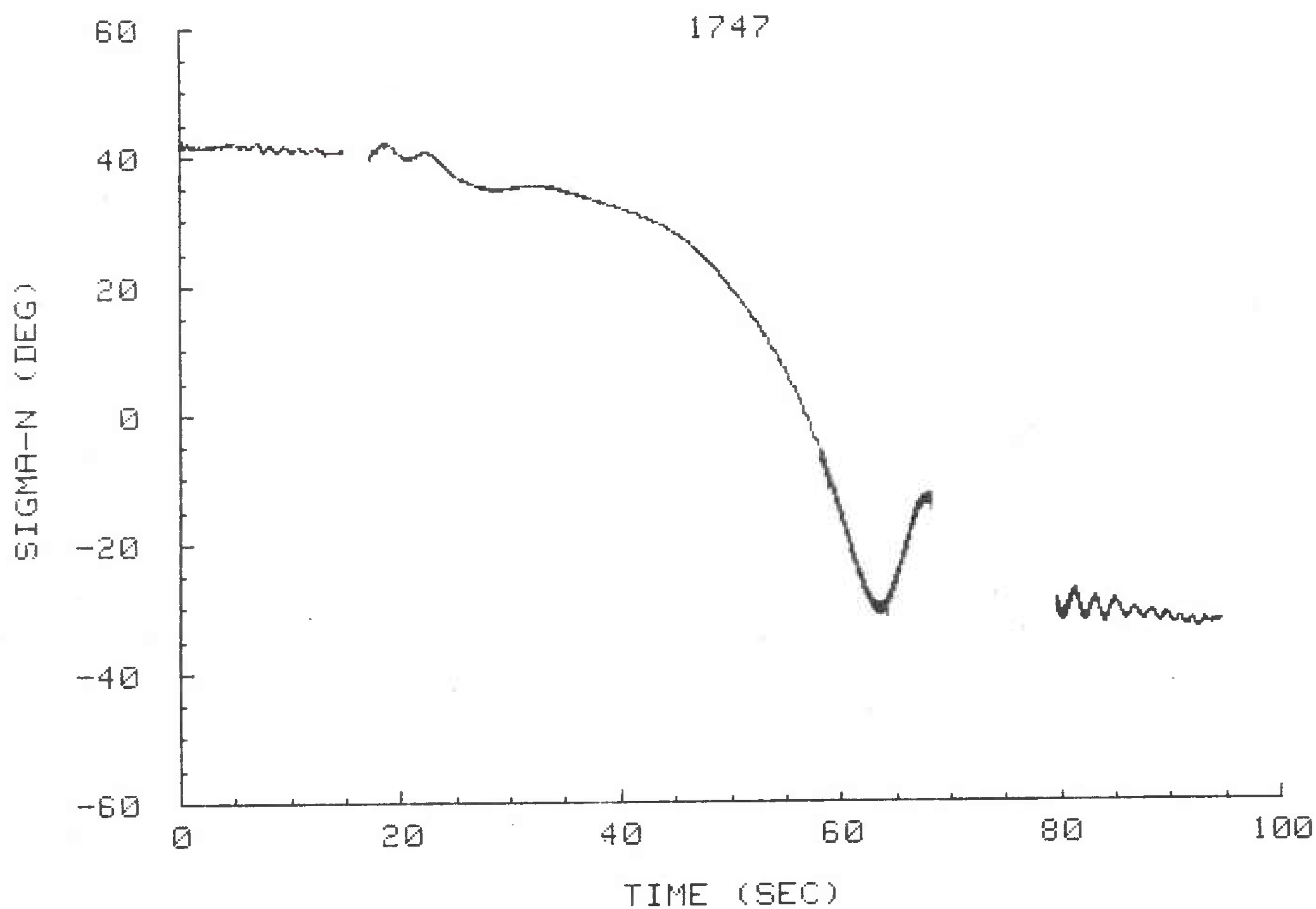


Figure 1c. Expanded Sigma-N History - YPG 259, XM825/Solid.



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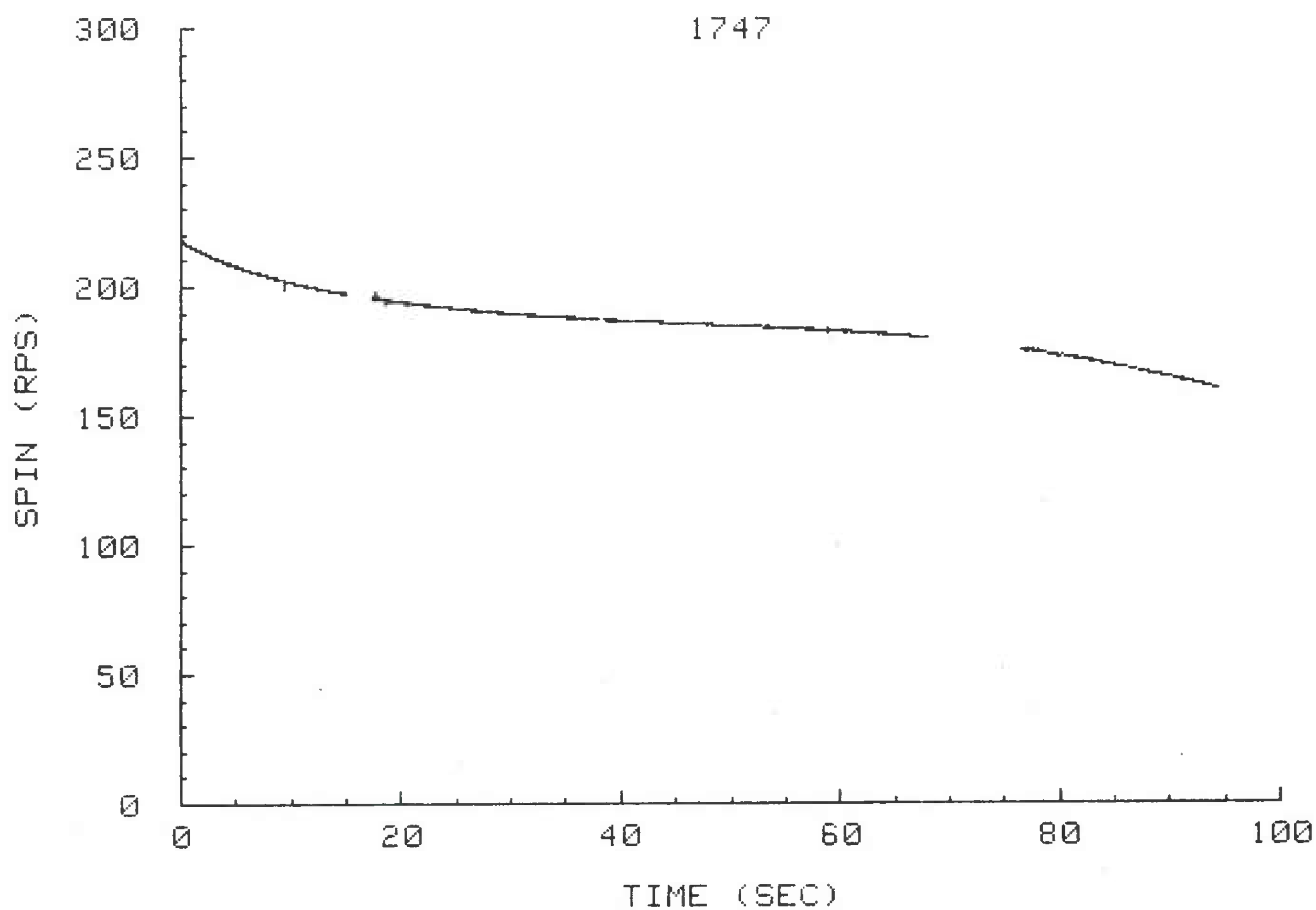

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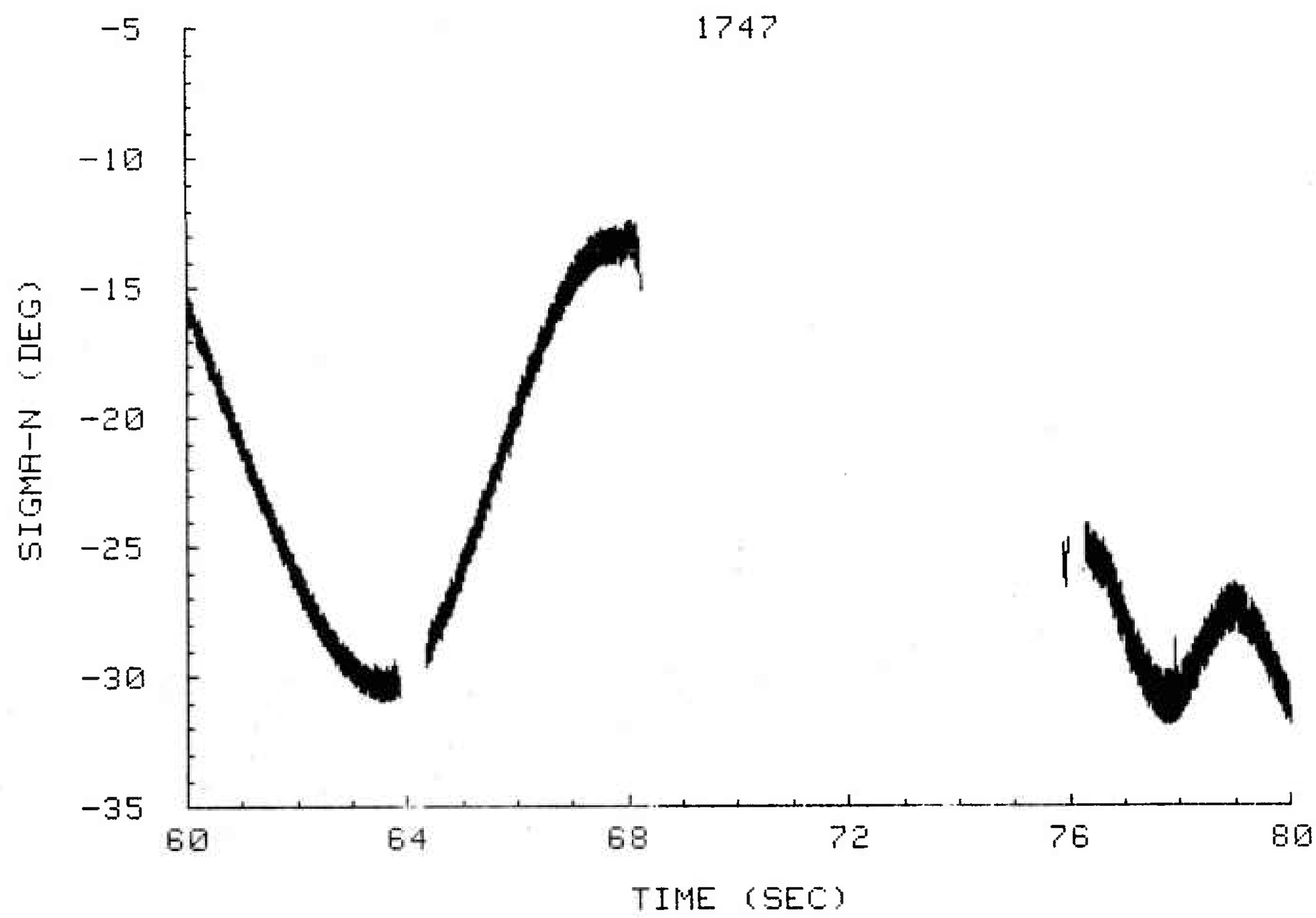

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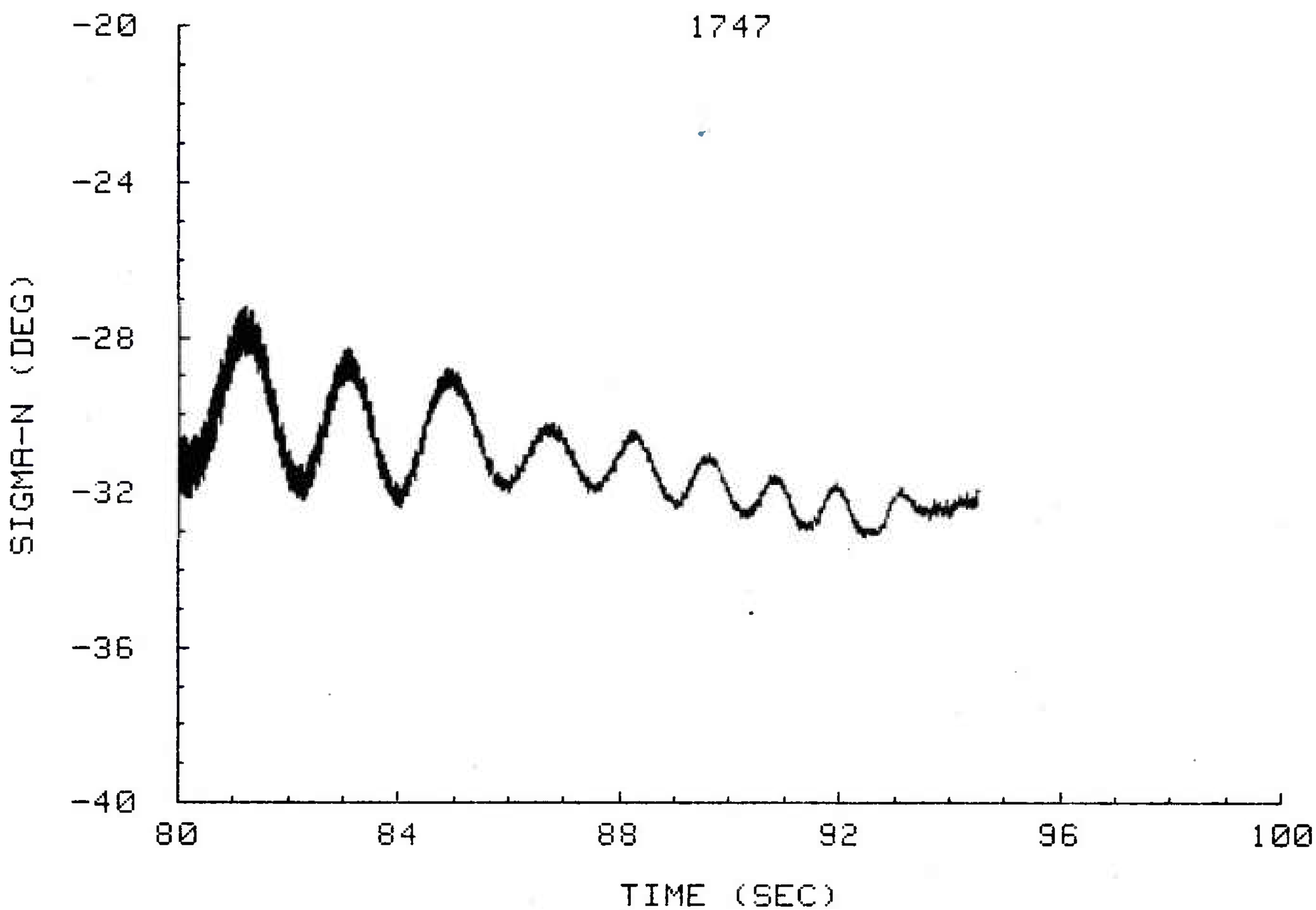
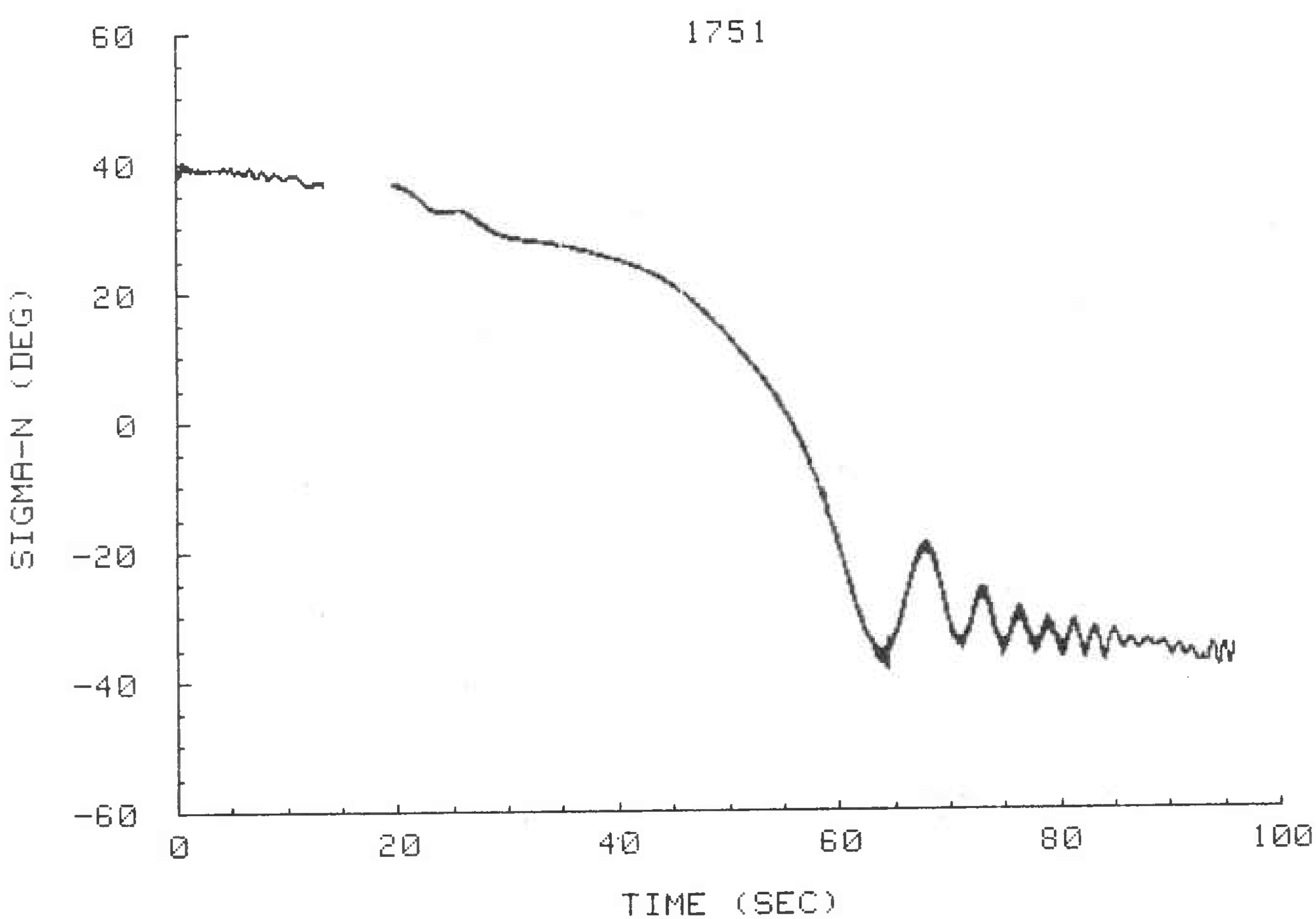


Figure 2d. Expanded Sigma-N History - YPG 260, XM825/Liquid.



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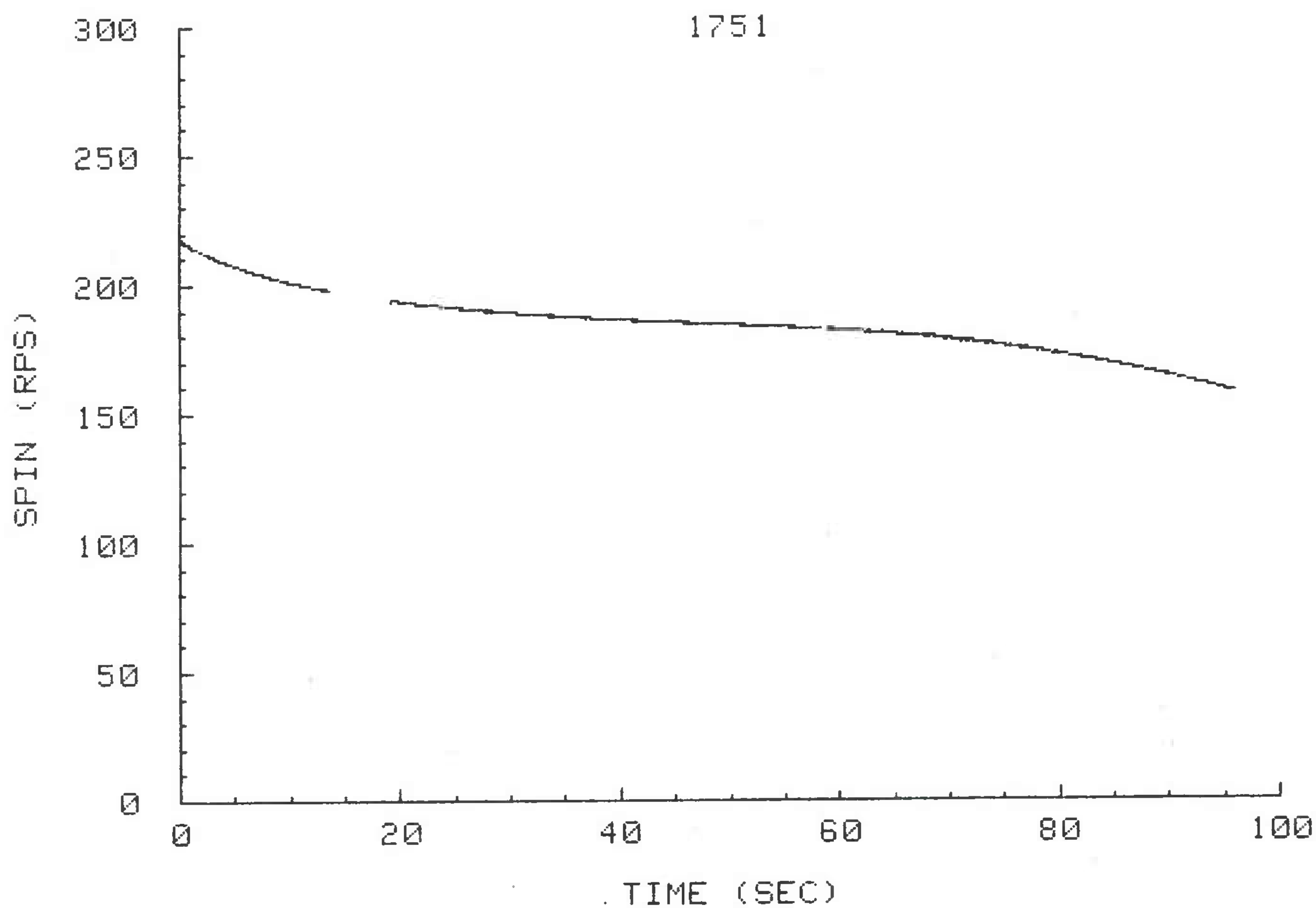

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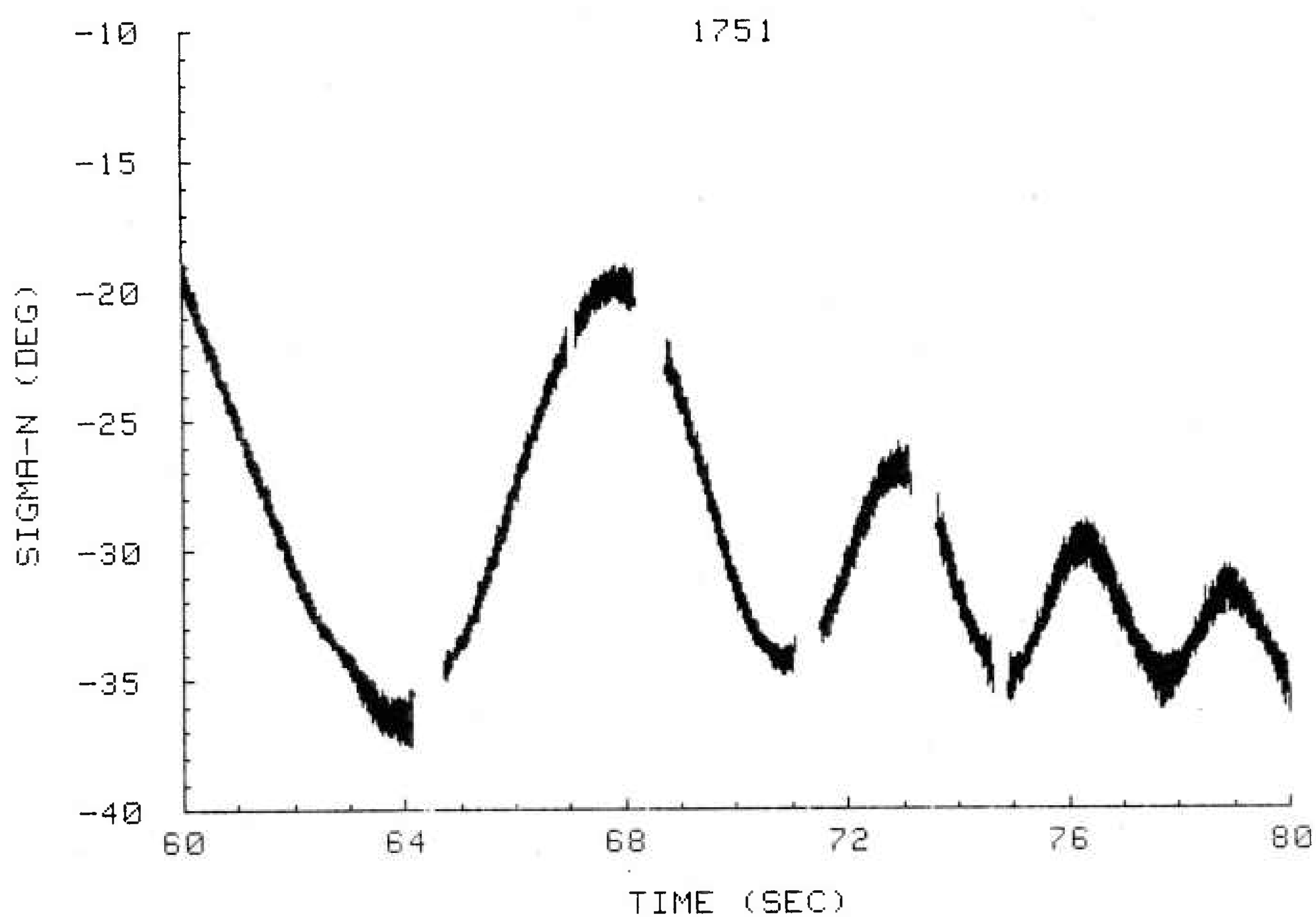

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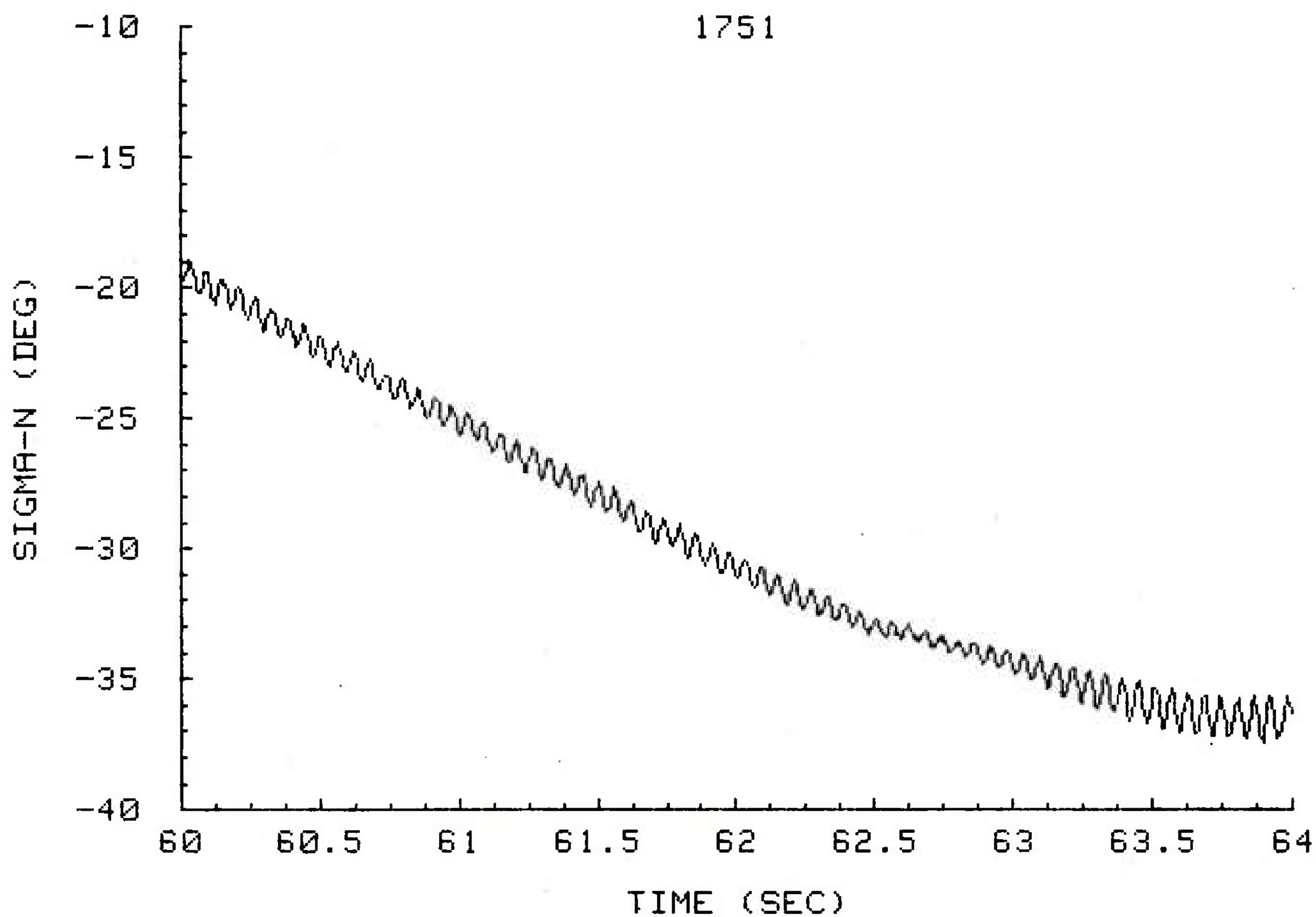

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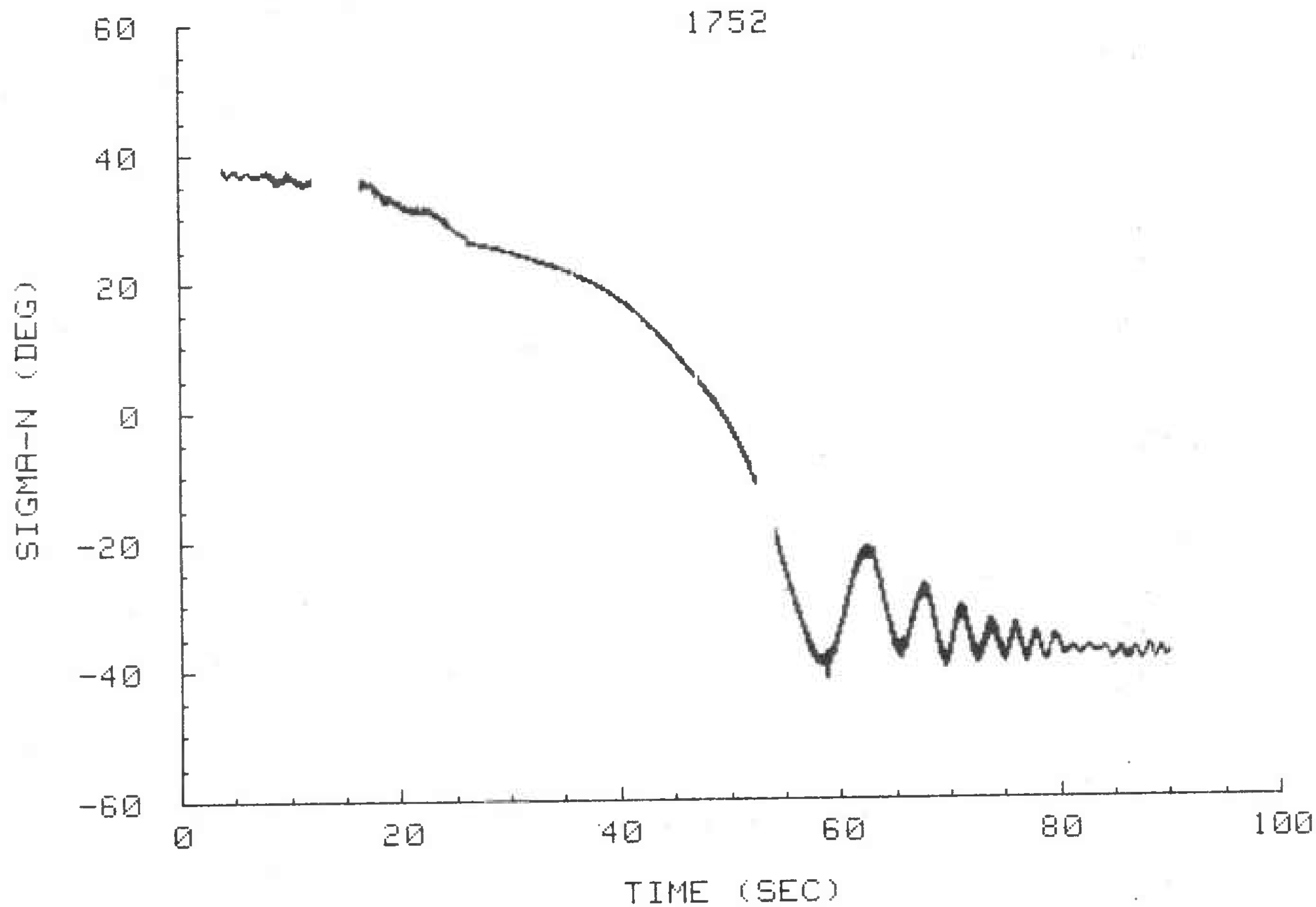

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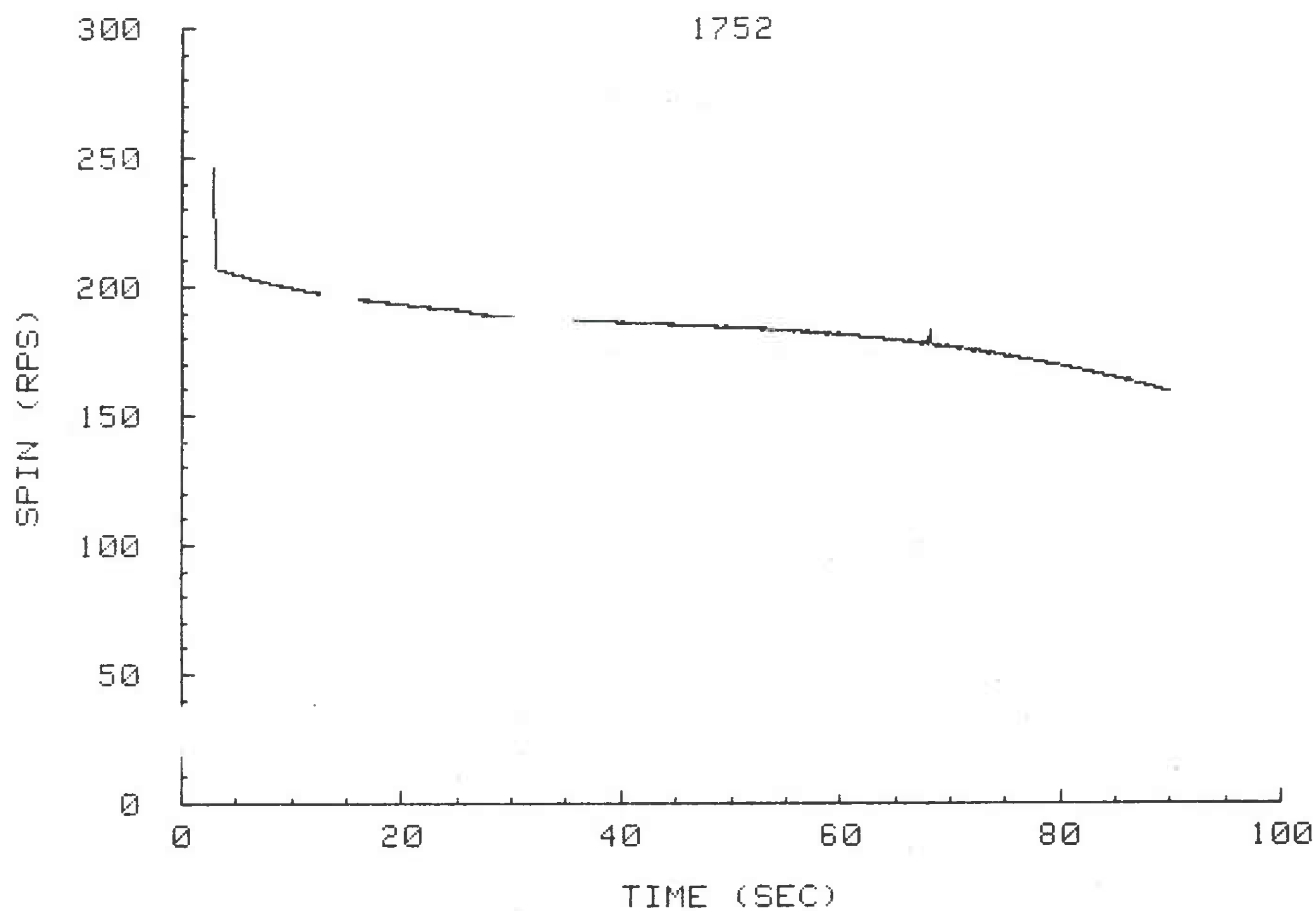

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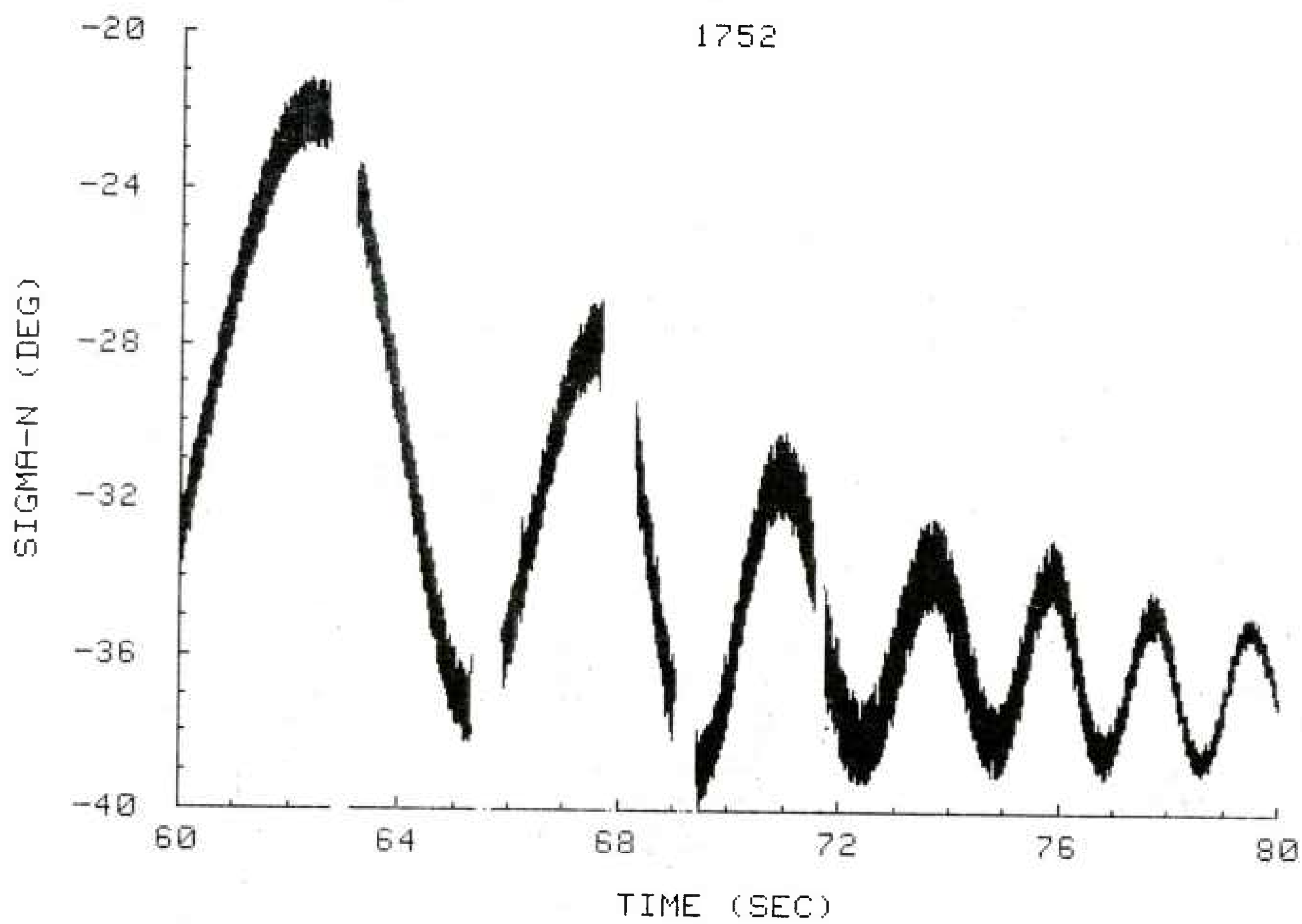

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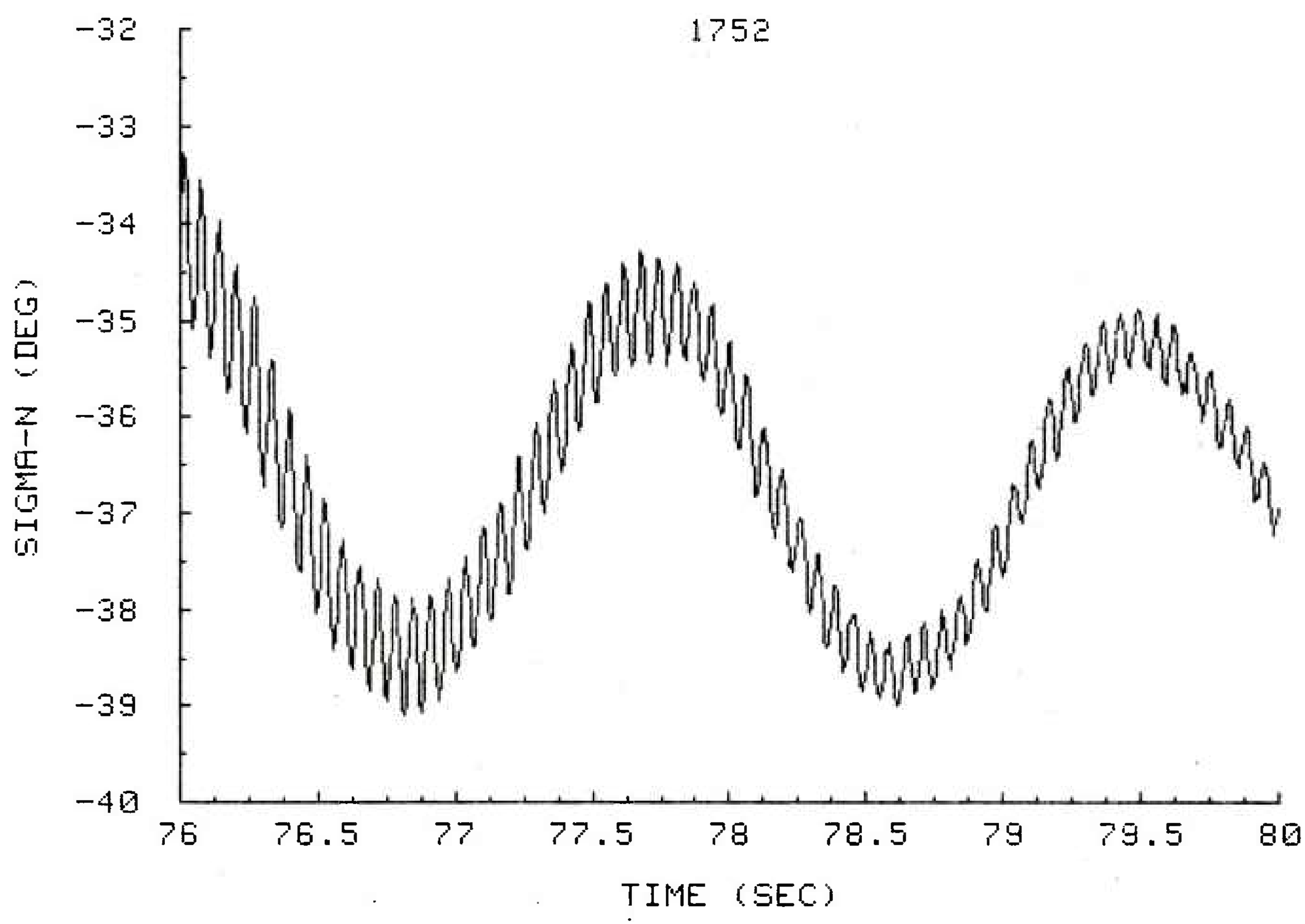

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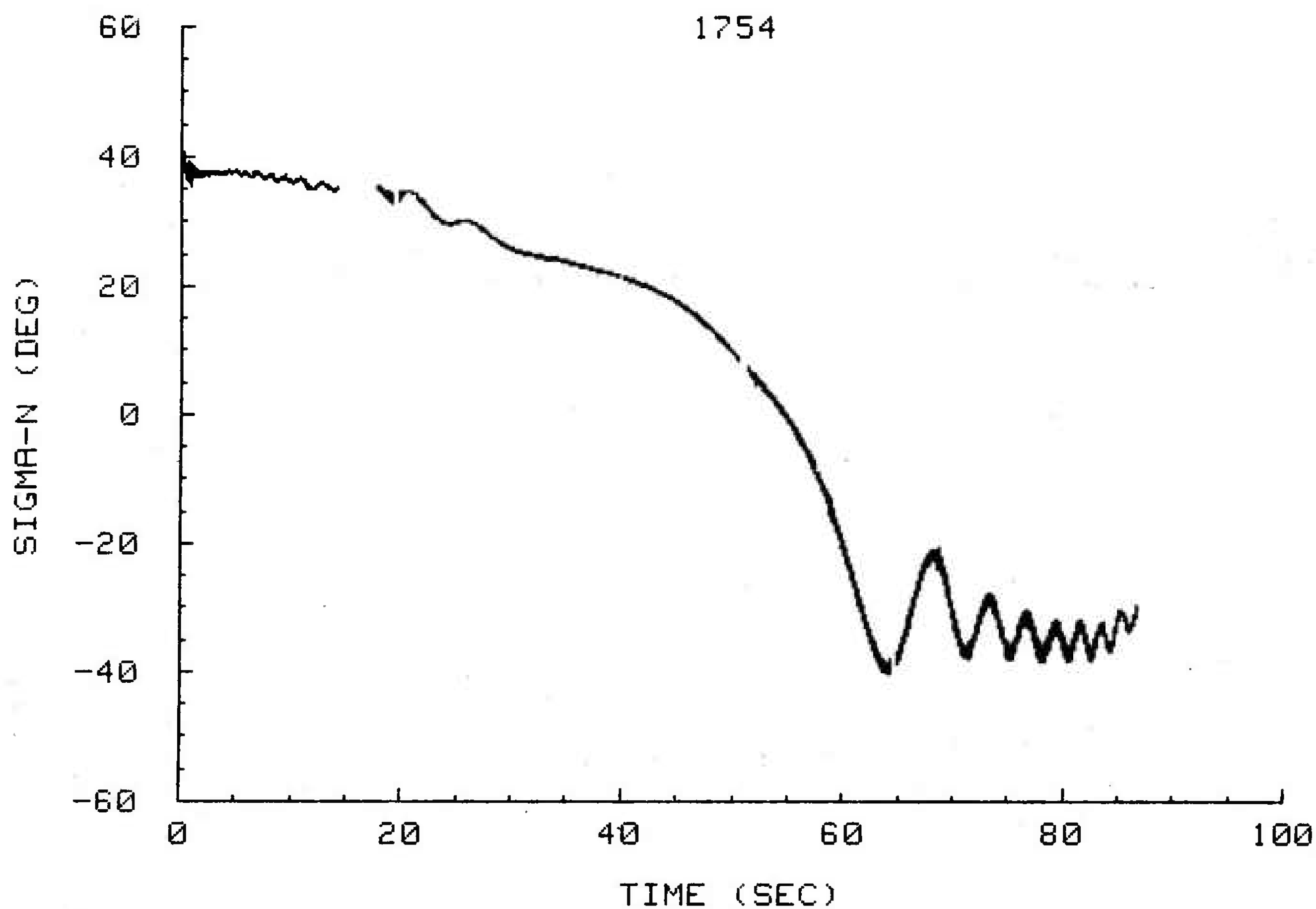

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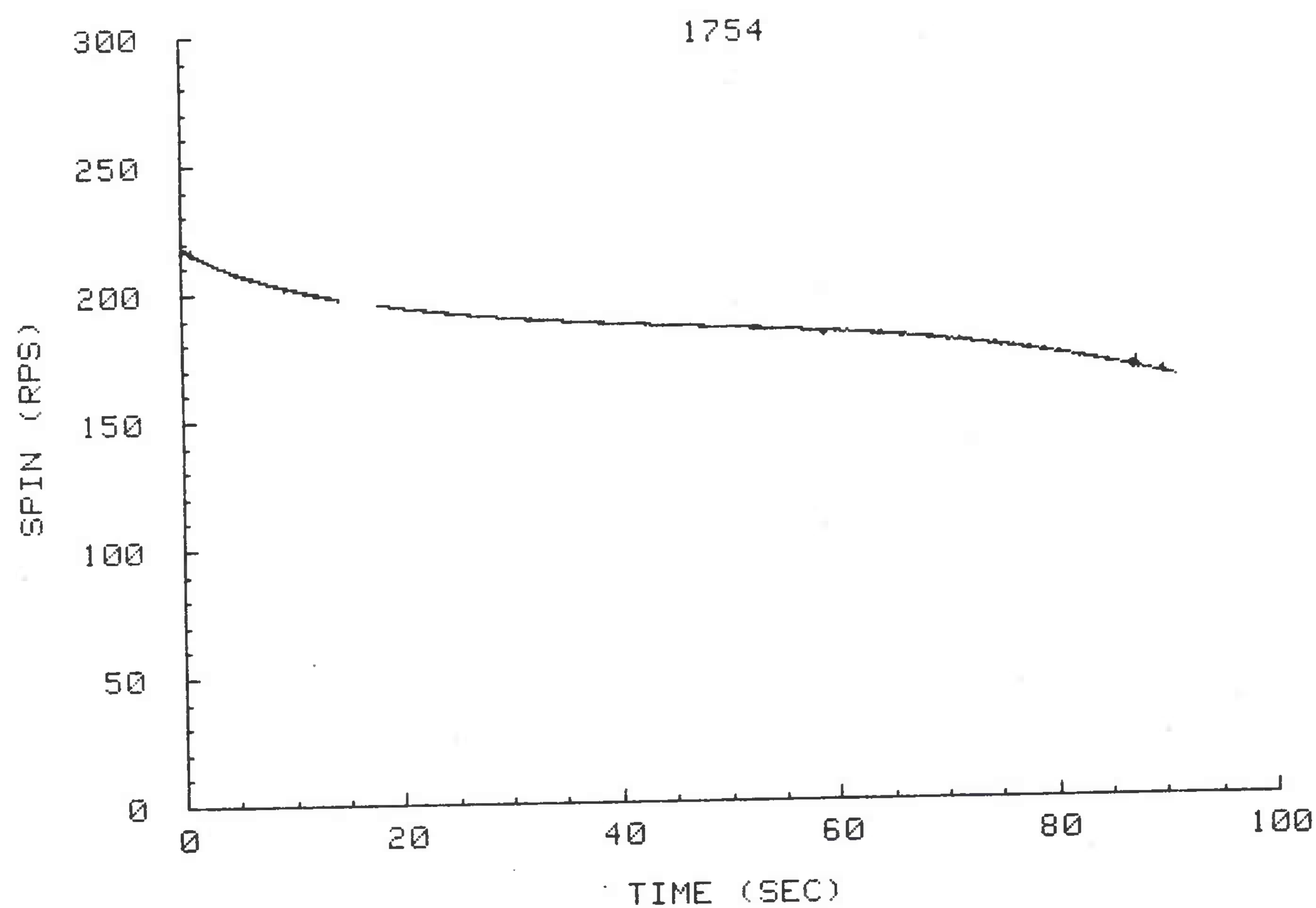

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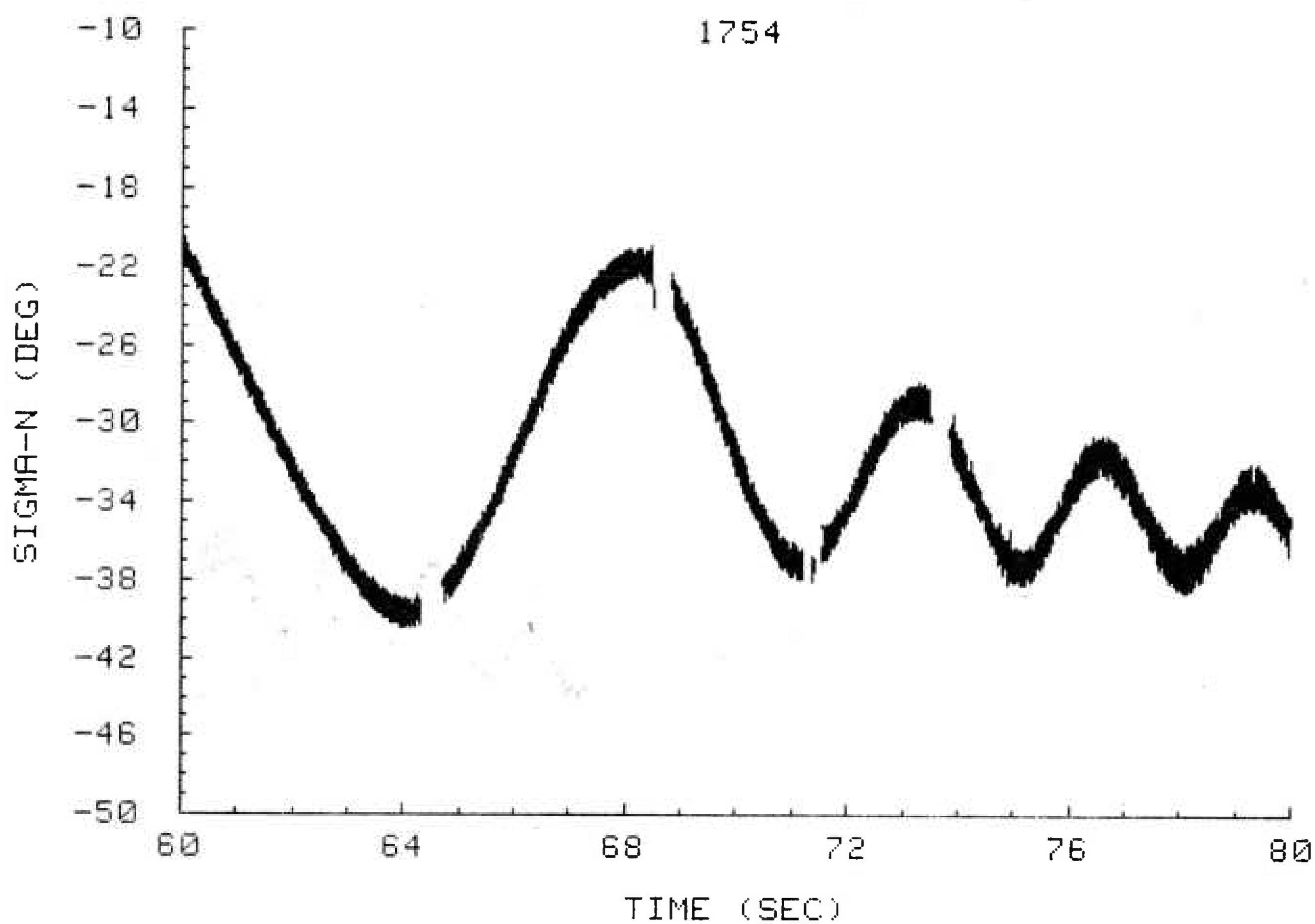

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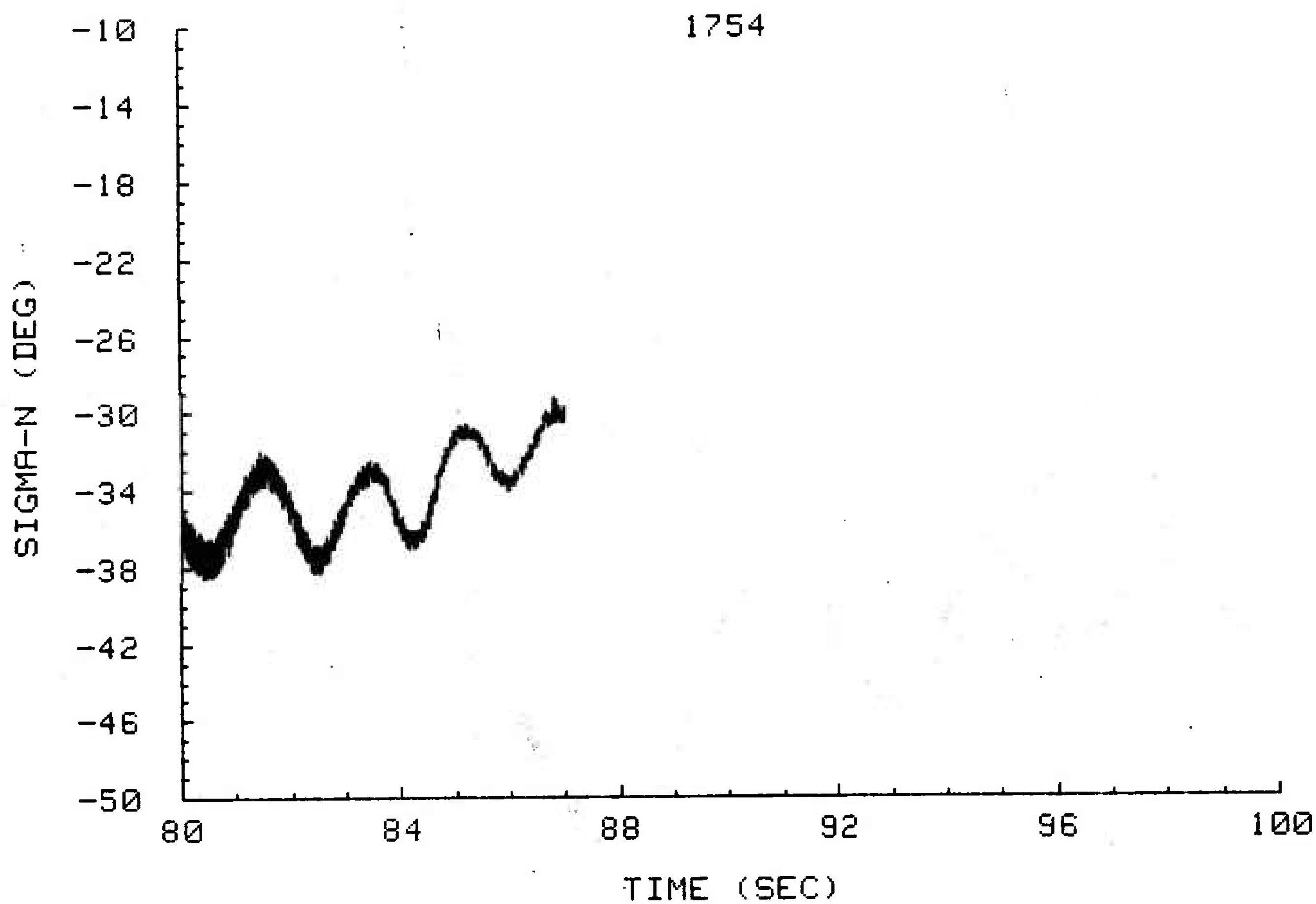

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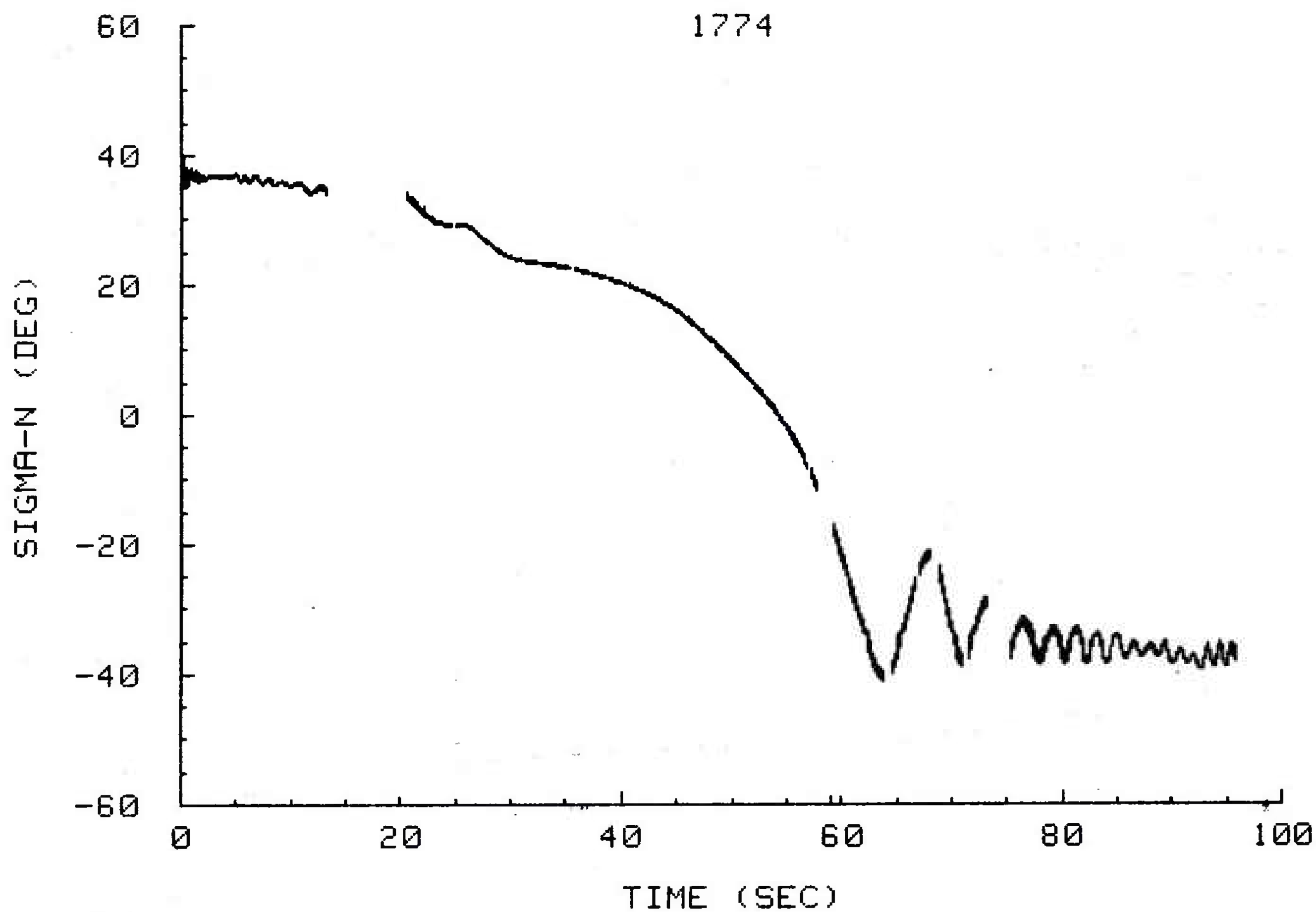

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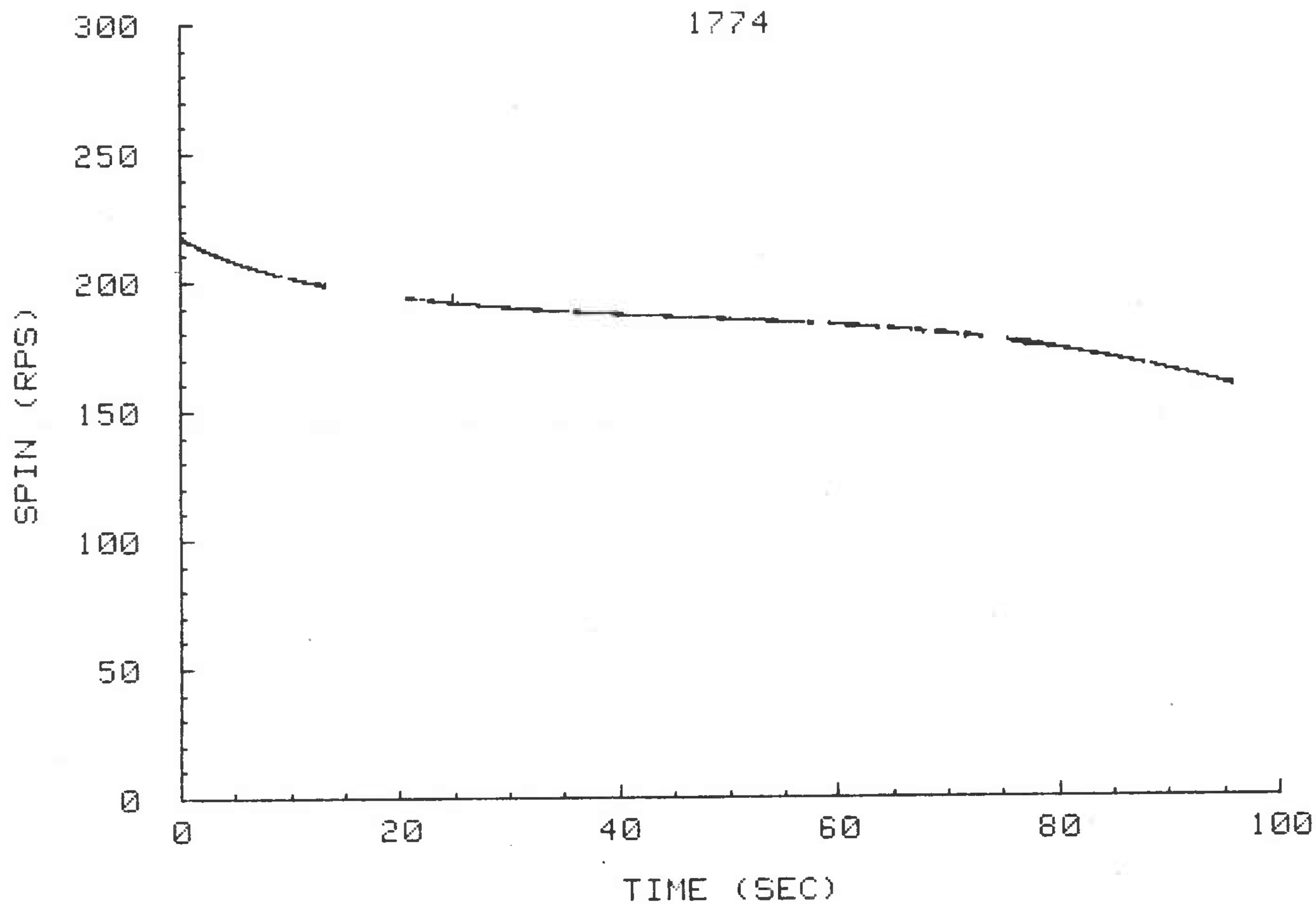
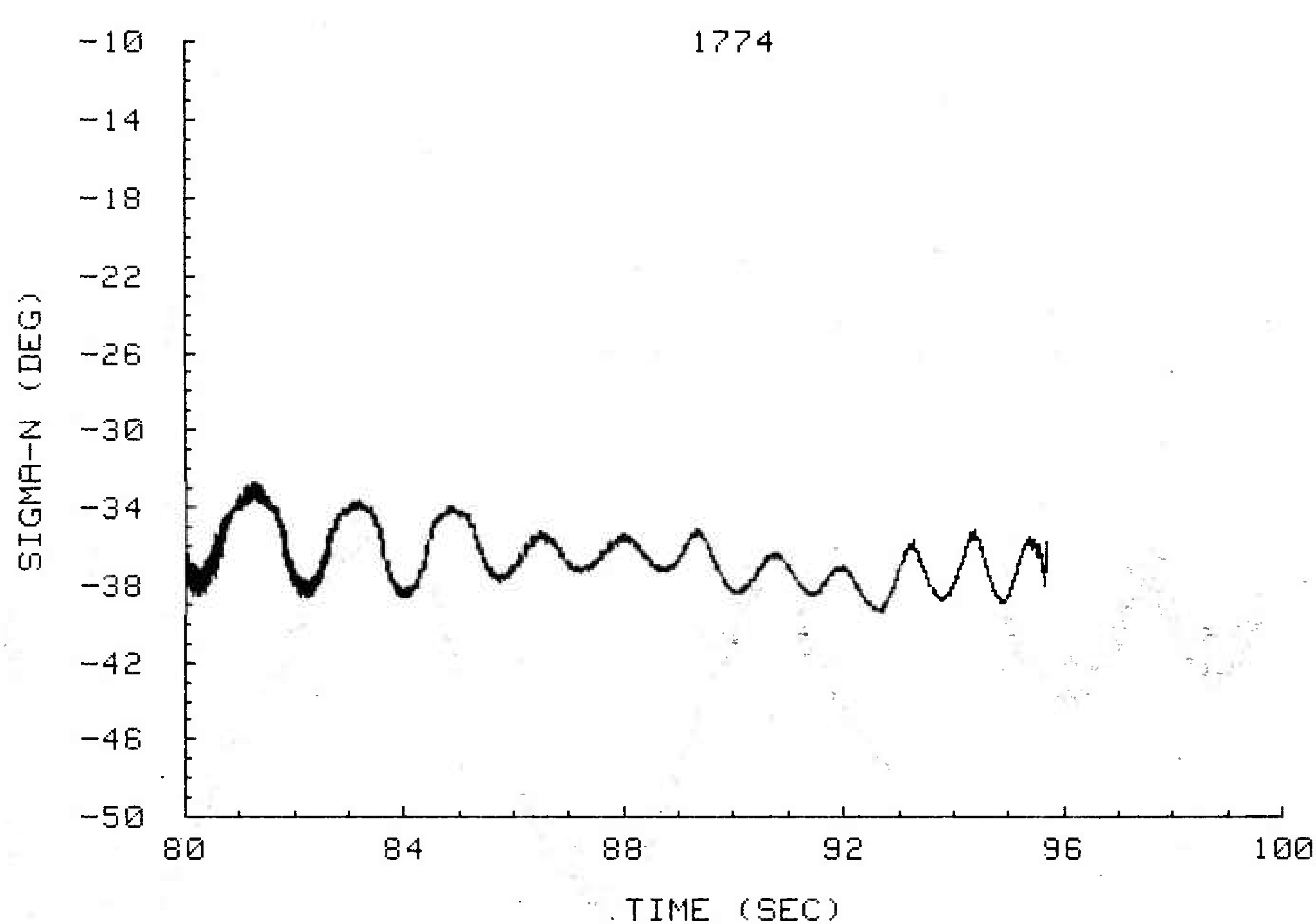


Figure 6b. Spin History - YPG 264, XM825/Liquid.



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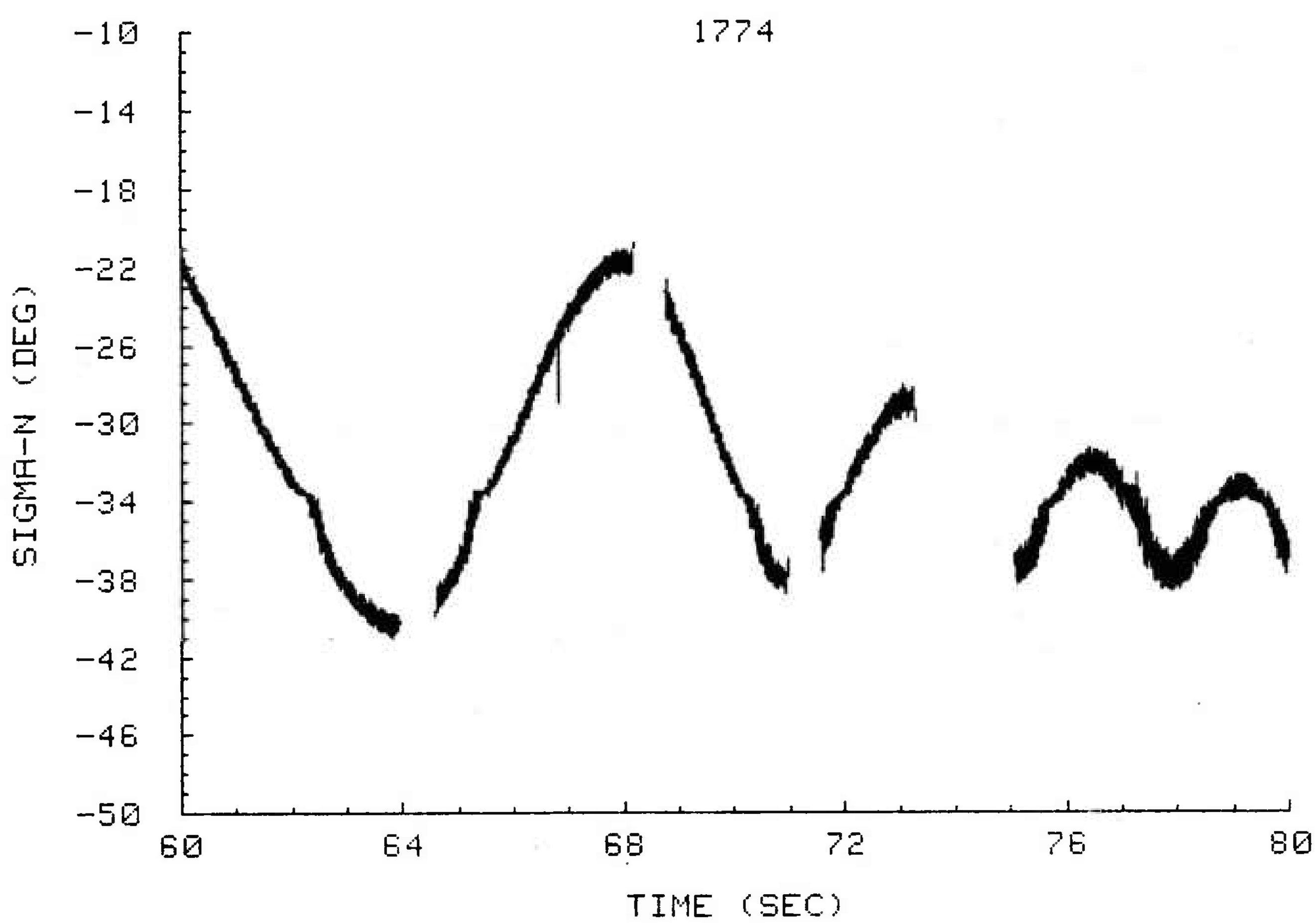

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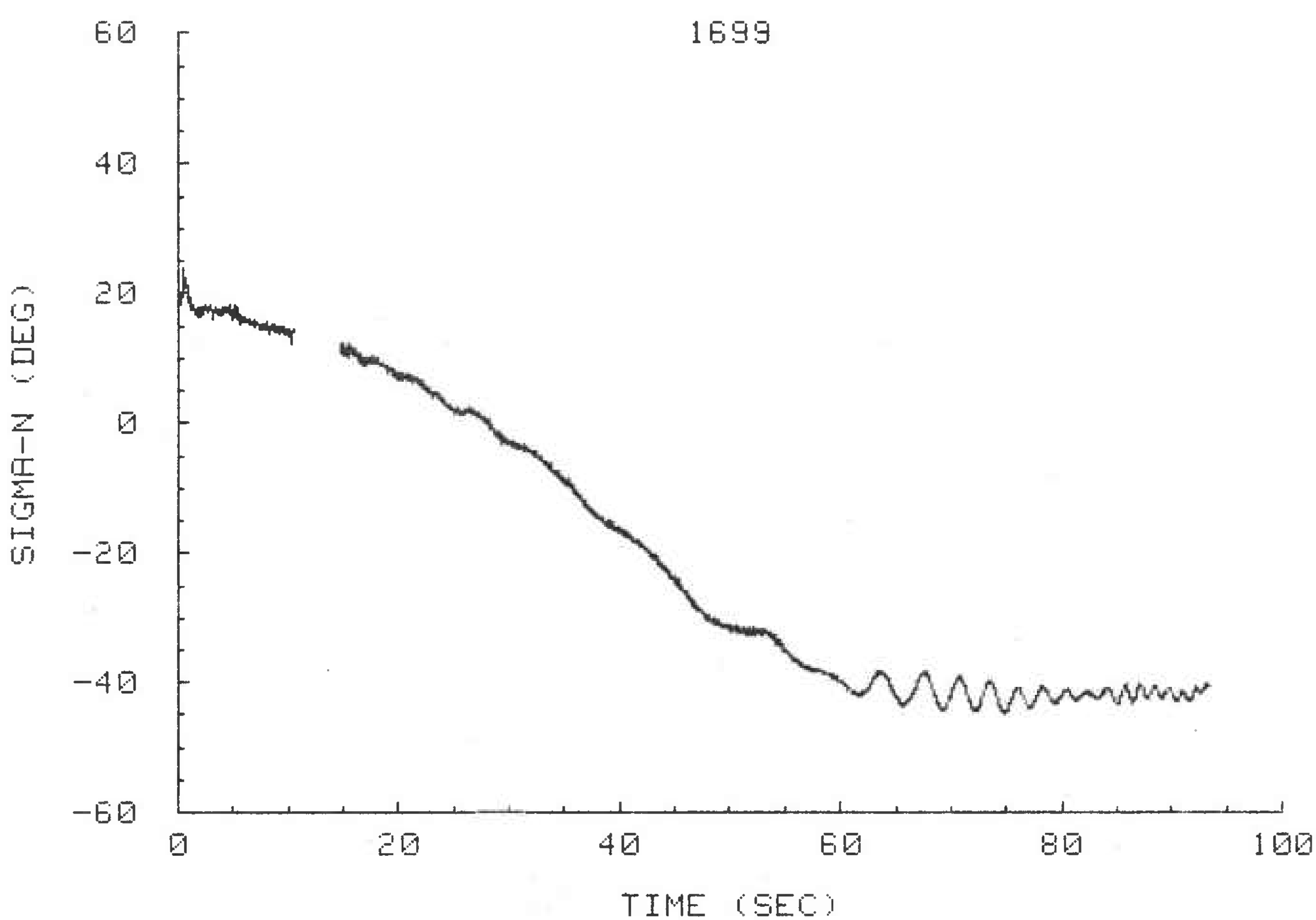

Figure 7a. Sigma-N History - YPG 267, M483A1.

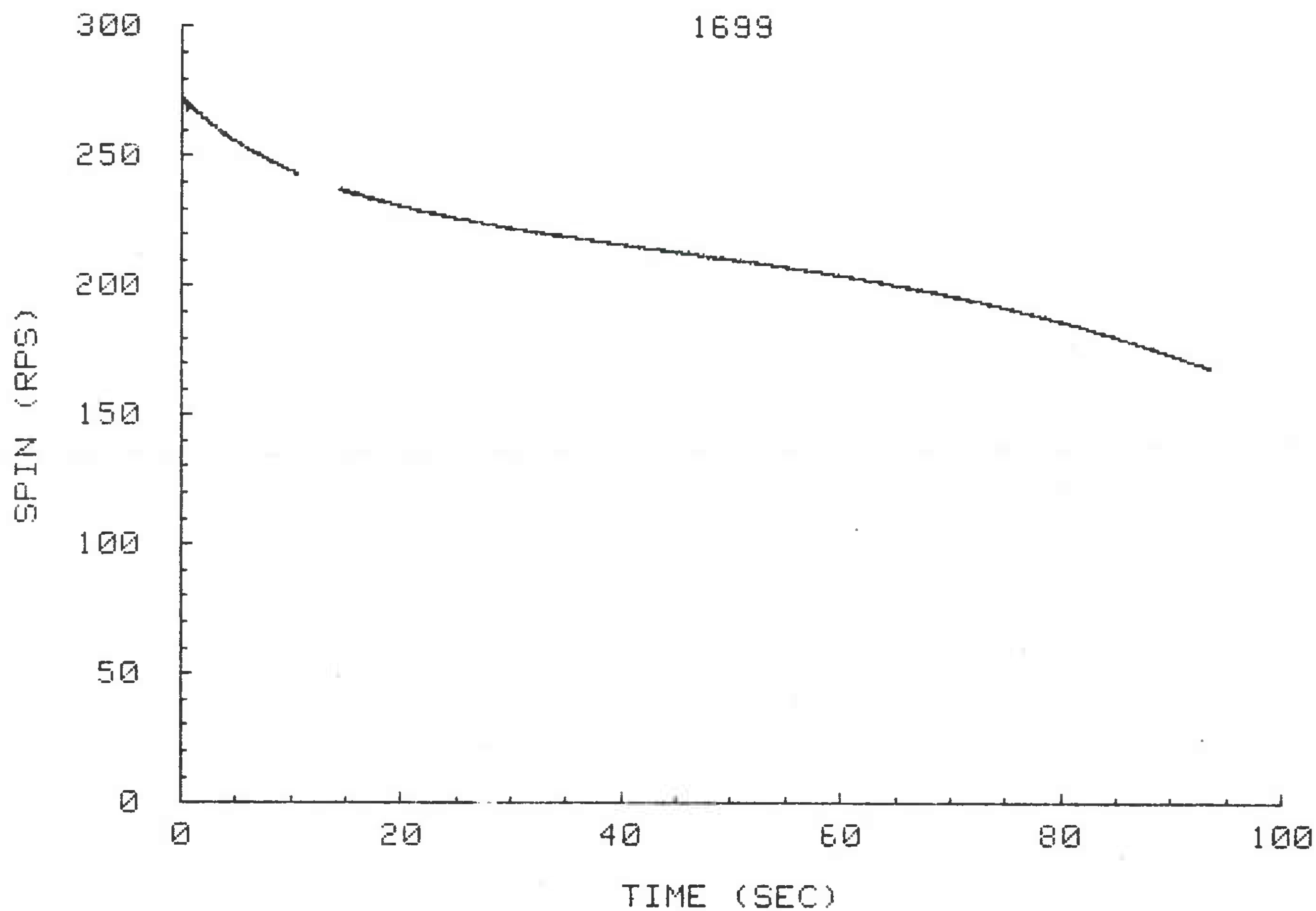

Figure 7b. Spin History - YPG 267, M483A1.

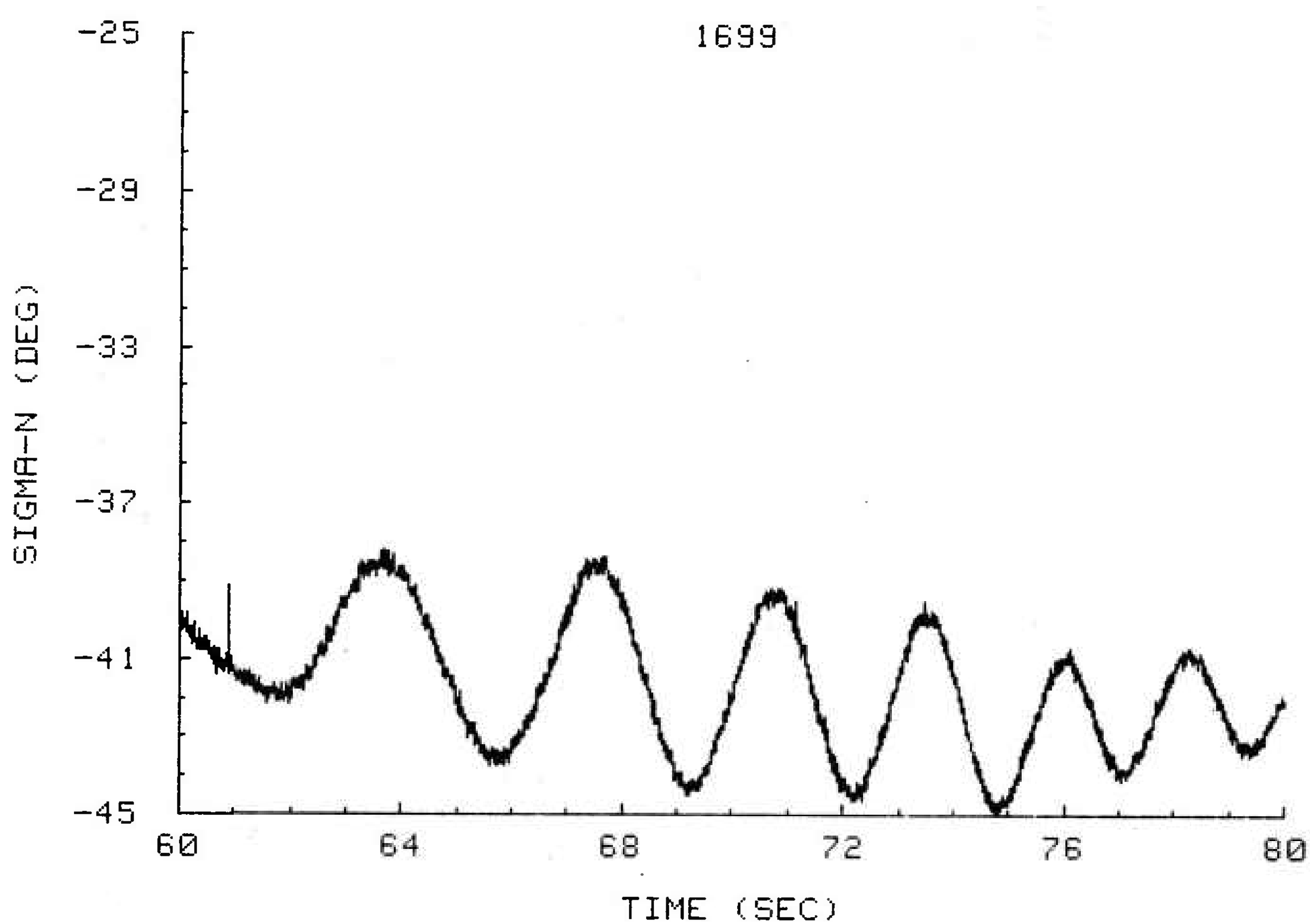

Figure 7c. Expanded Sigma-N History - YPG 267, M483A1.

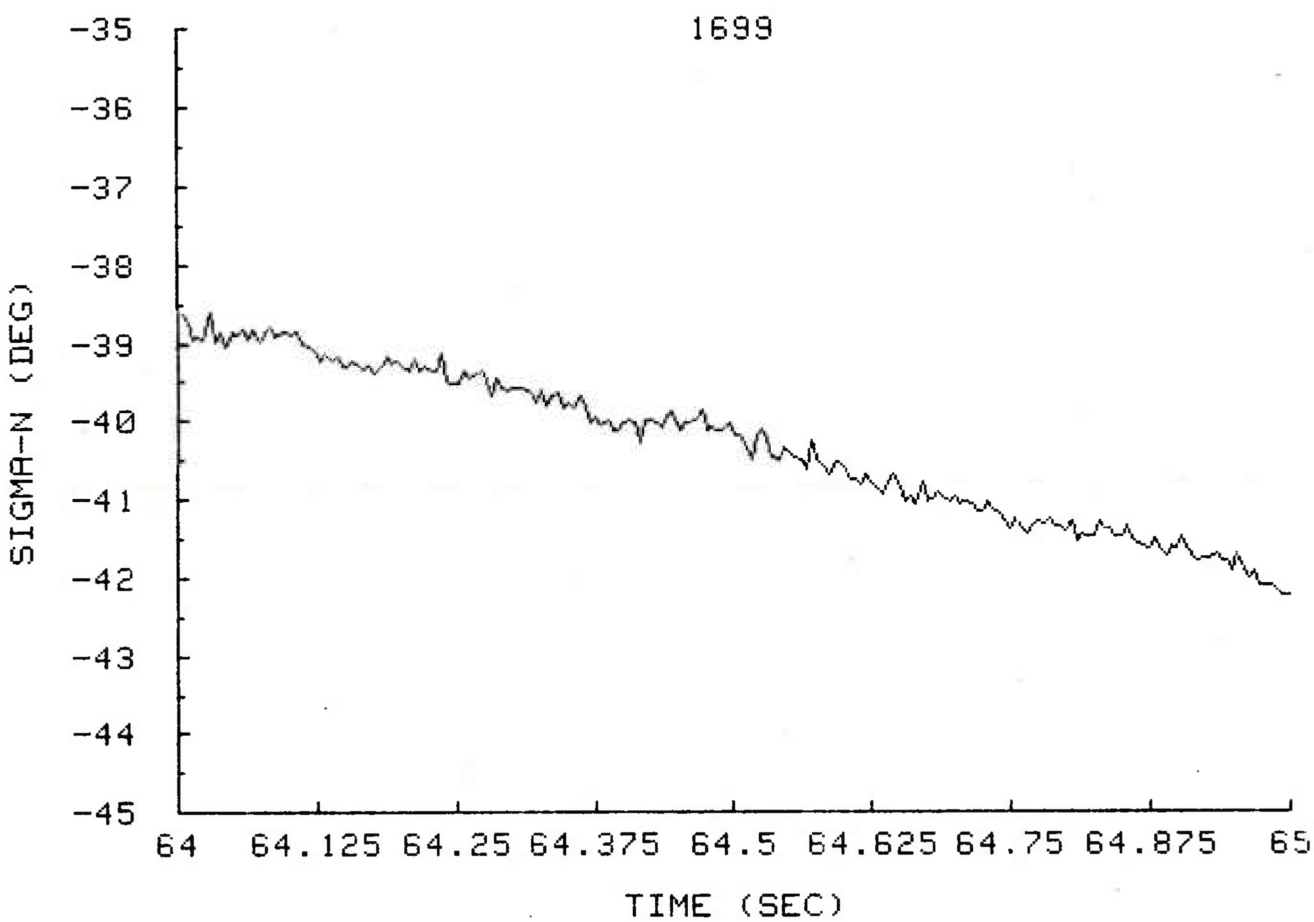

Figure 7d. Expanded Sigma-N History - YPG 267, M483A1.

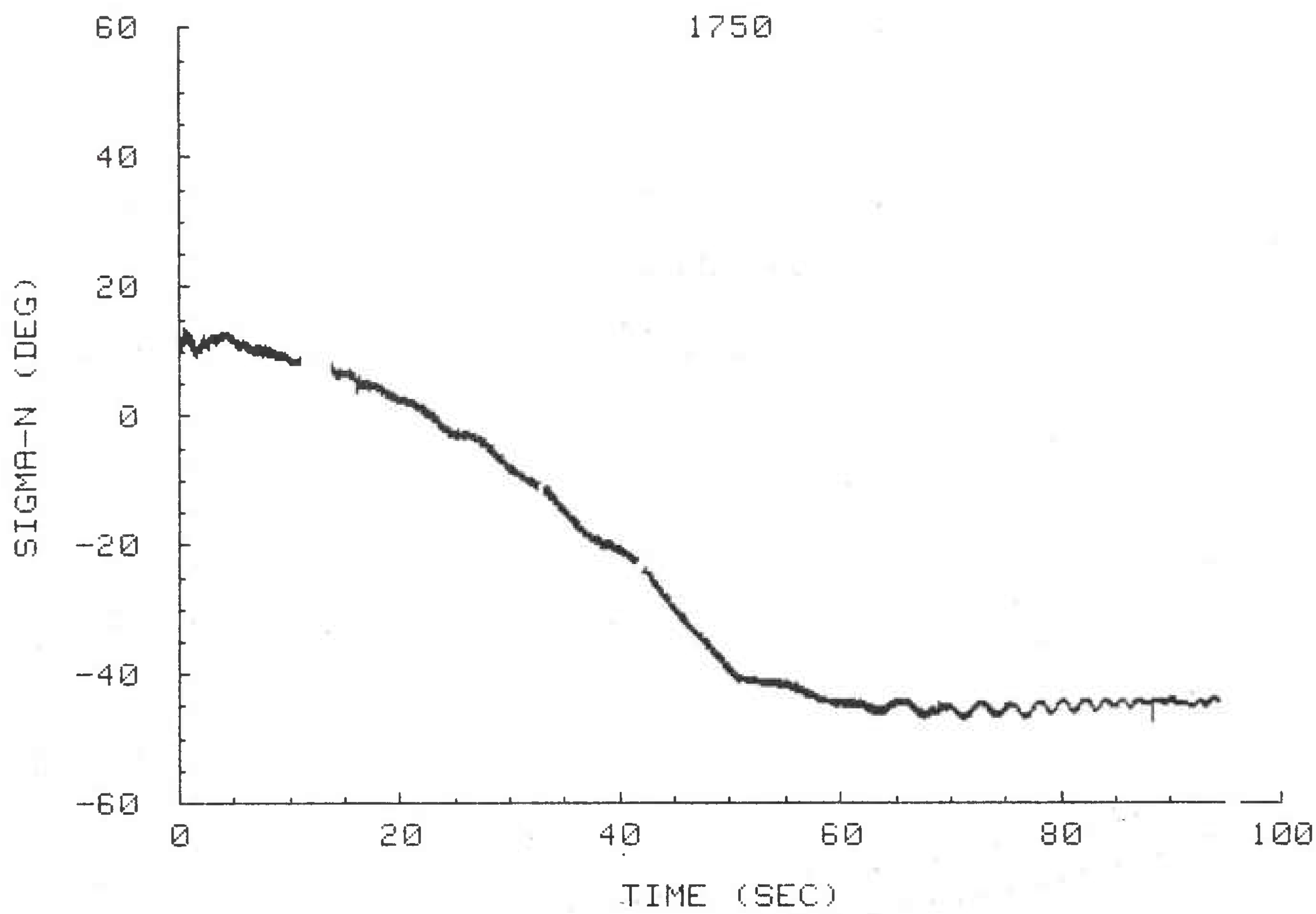

Figure 8a. Sigma-N History - YPG 268, XM825/Liquid.

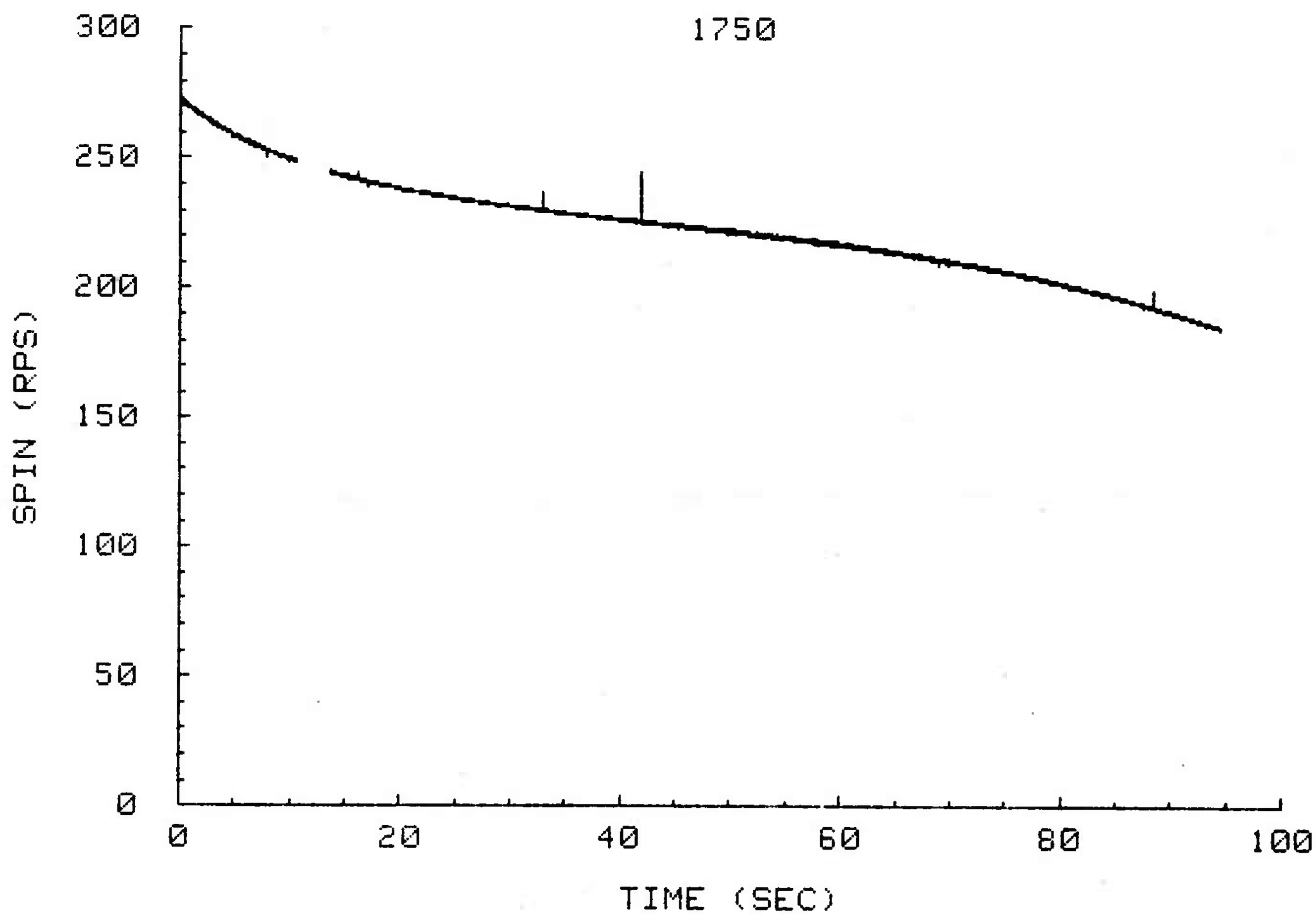

Figure 8b. Spin History - YPG 268, XM825/Liquid.

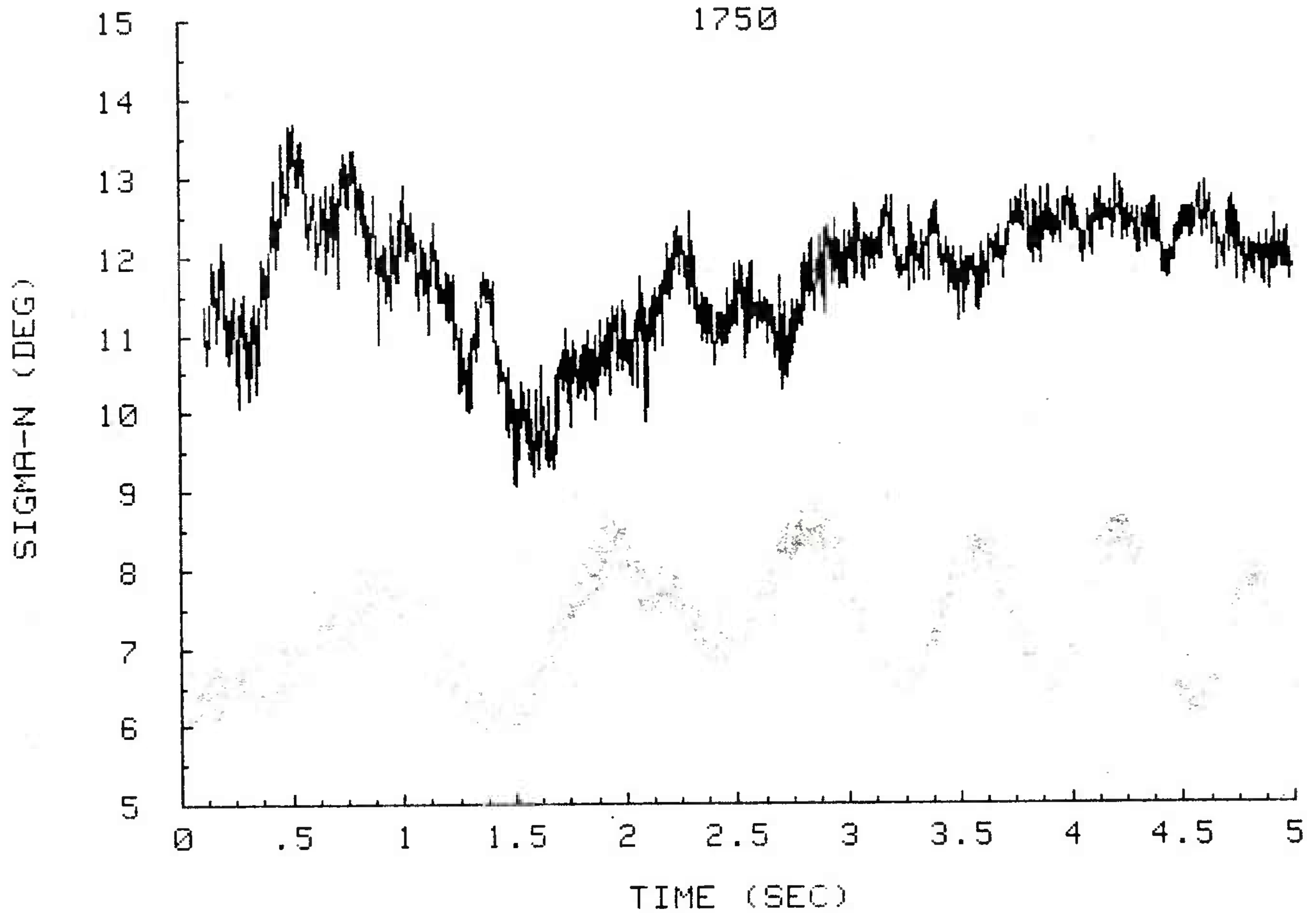

Figure 8c. Expanded Sigma-N History - YPG 268, XM825/Liquid.

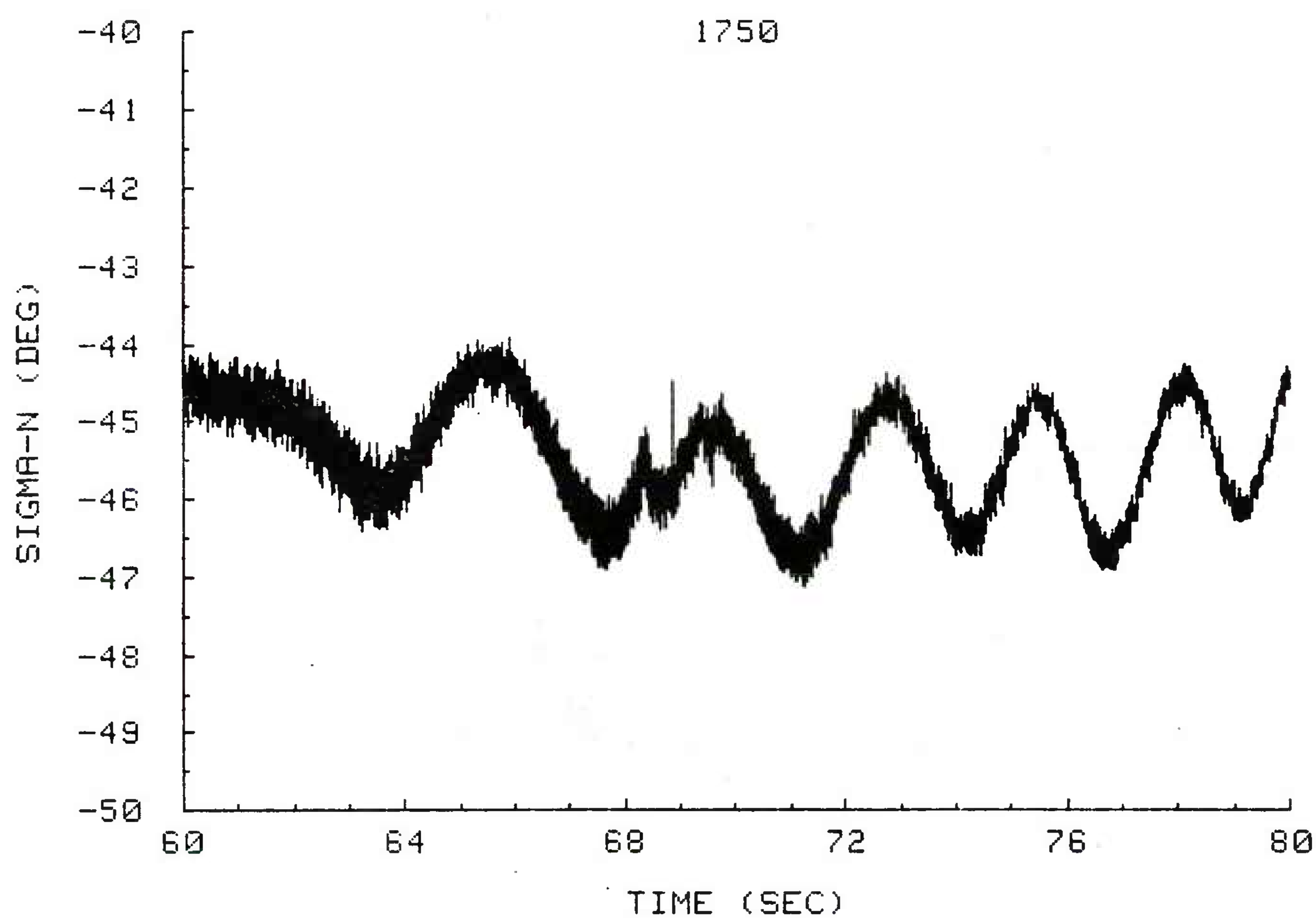

Figure 8d. Expanded Sigma-N History - YPG 268, XM825/Liquid.

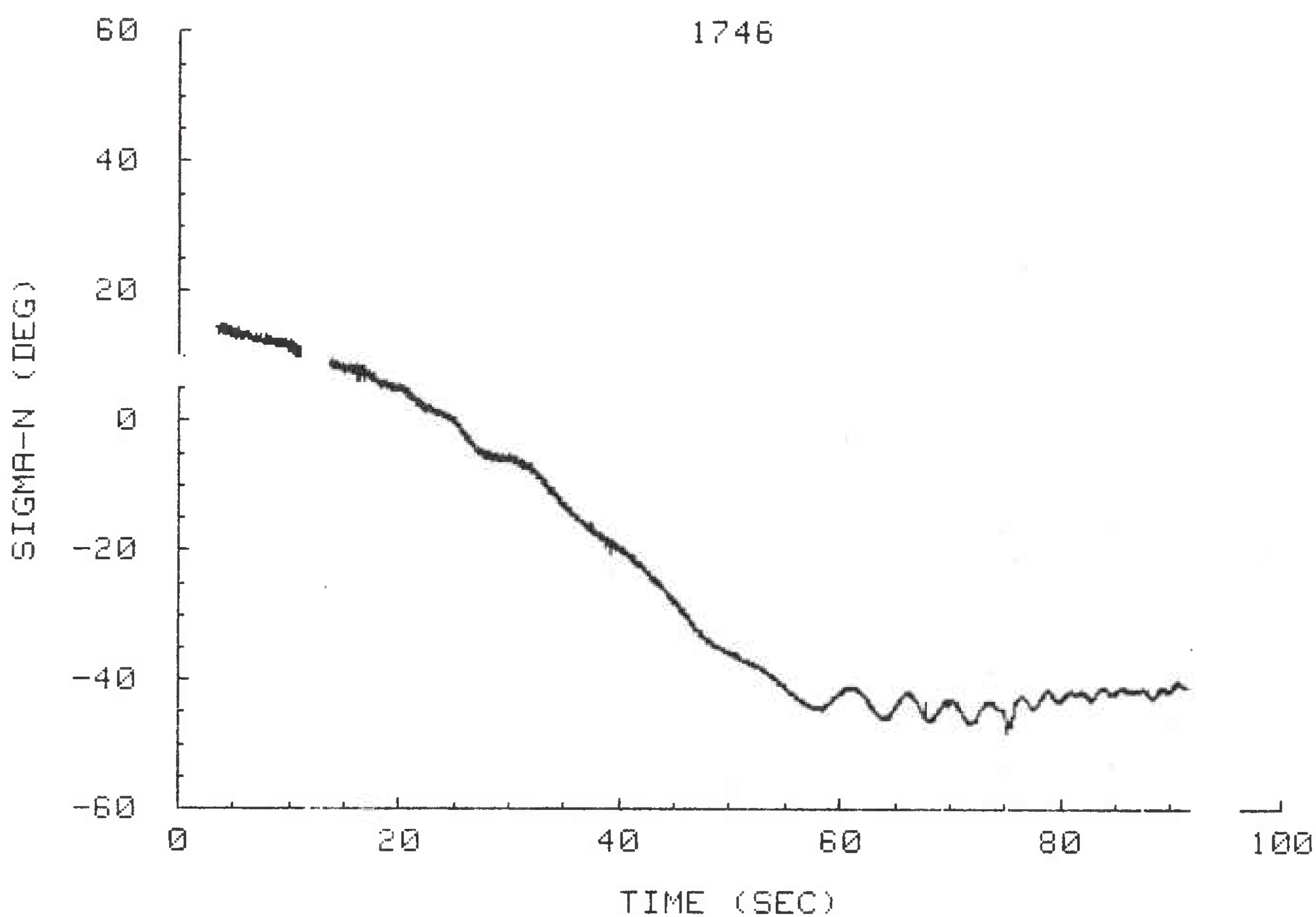

Figure 9a. Sigma-N History - YPG 269, XM825/Liquid.

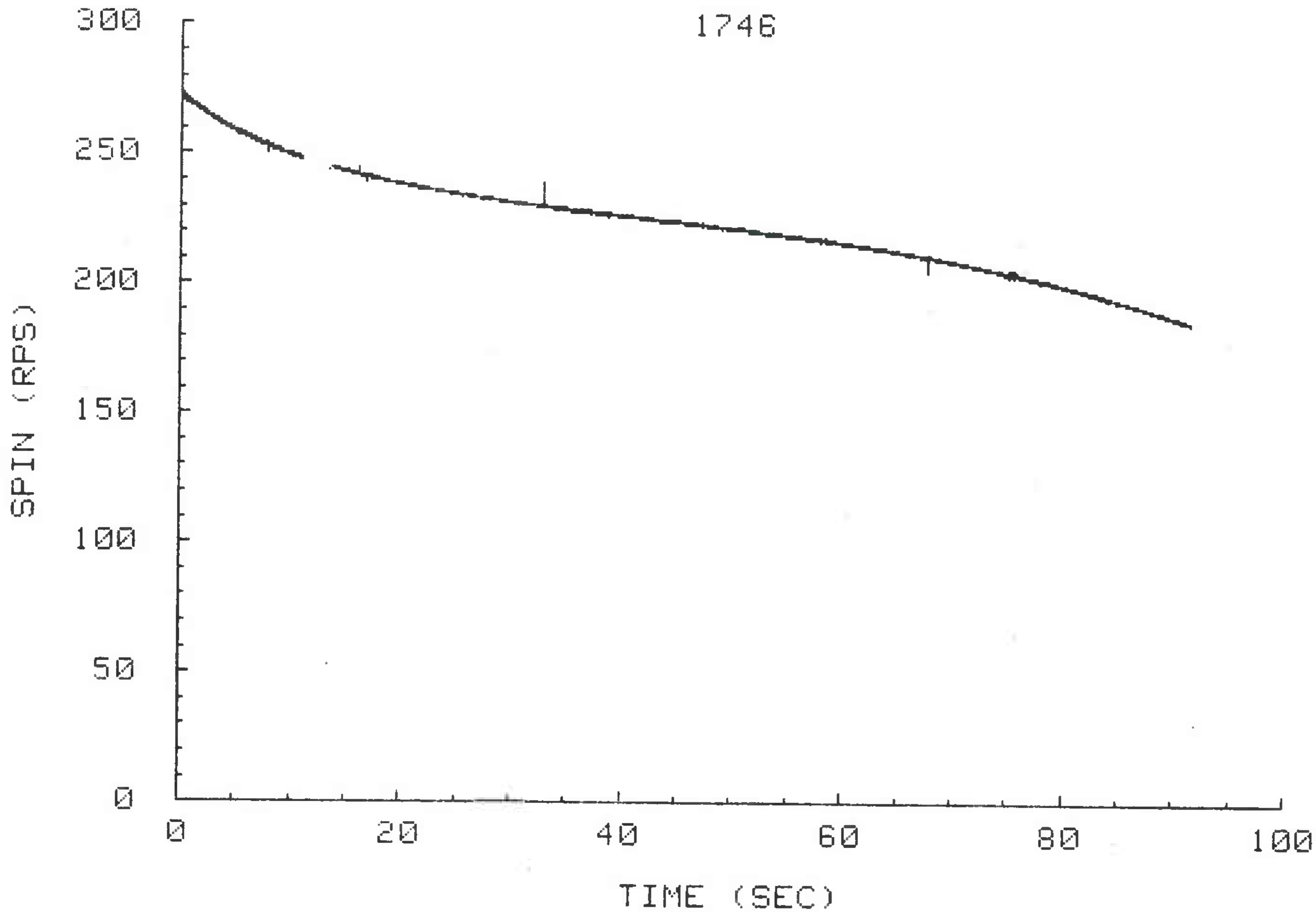

Figure 9b. Spin History - YPG 269, XM825/Liquid.

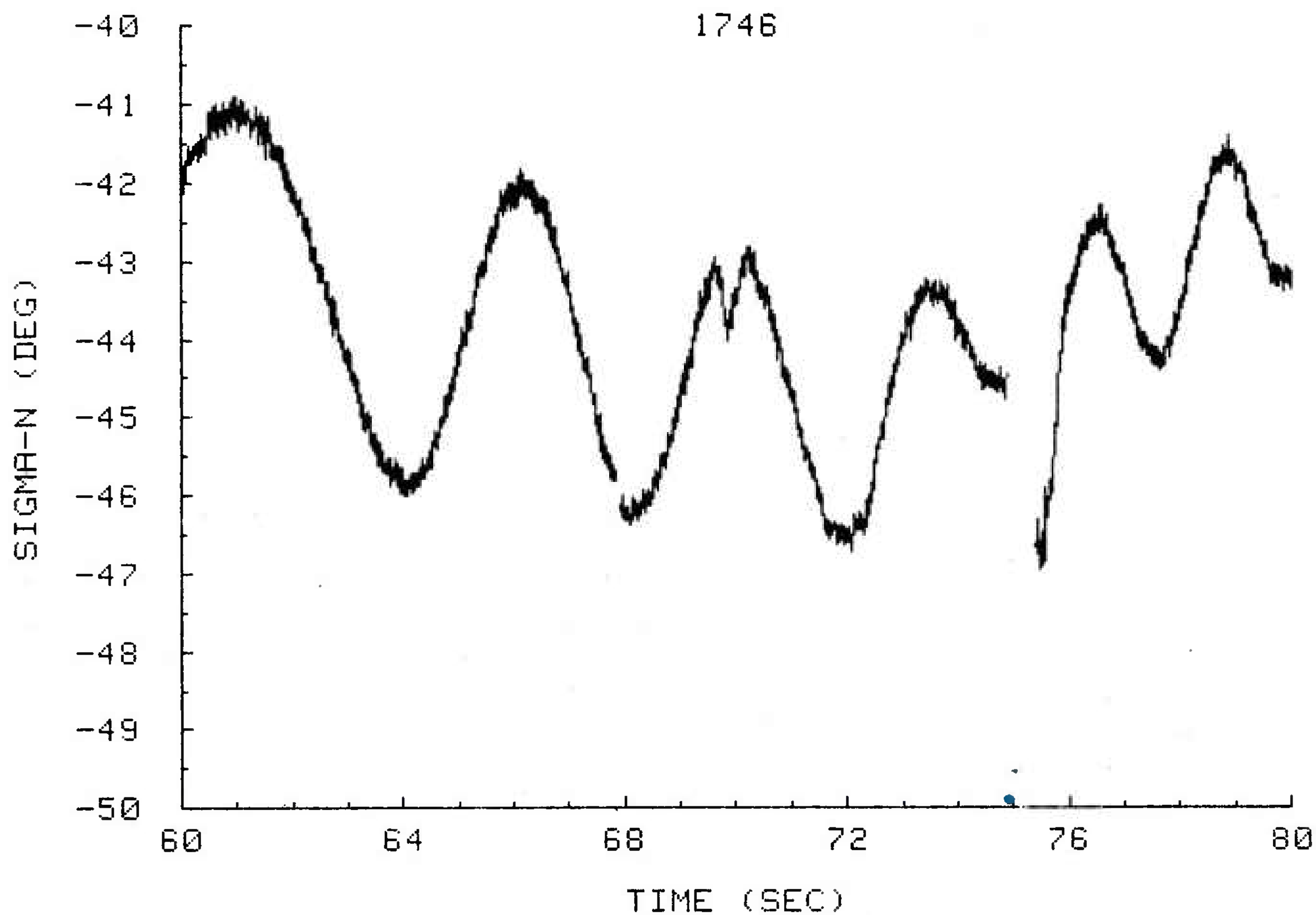

Figure 9c. Expanded Sigma-N History - YPG 269, XM825/Liquid.

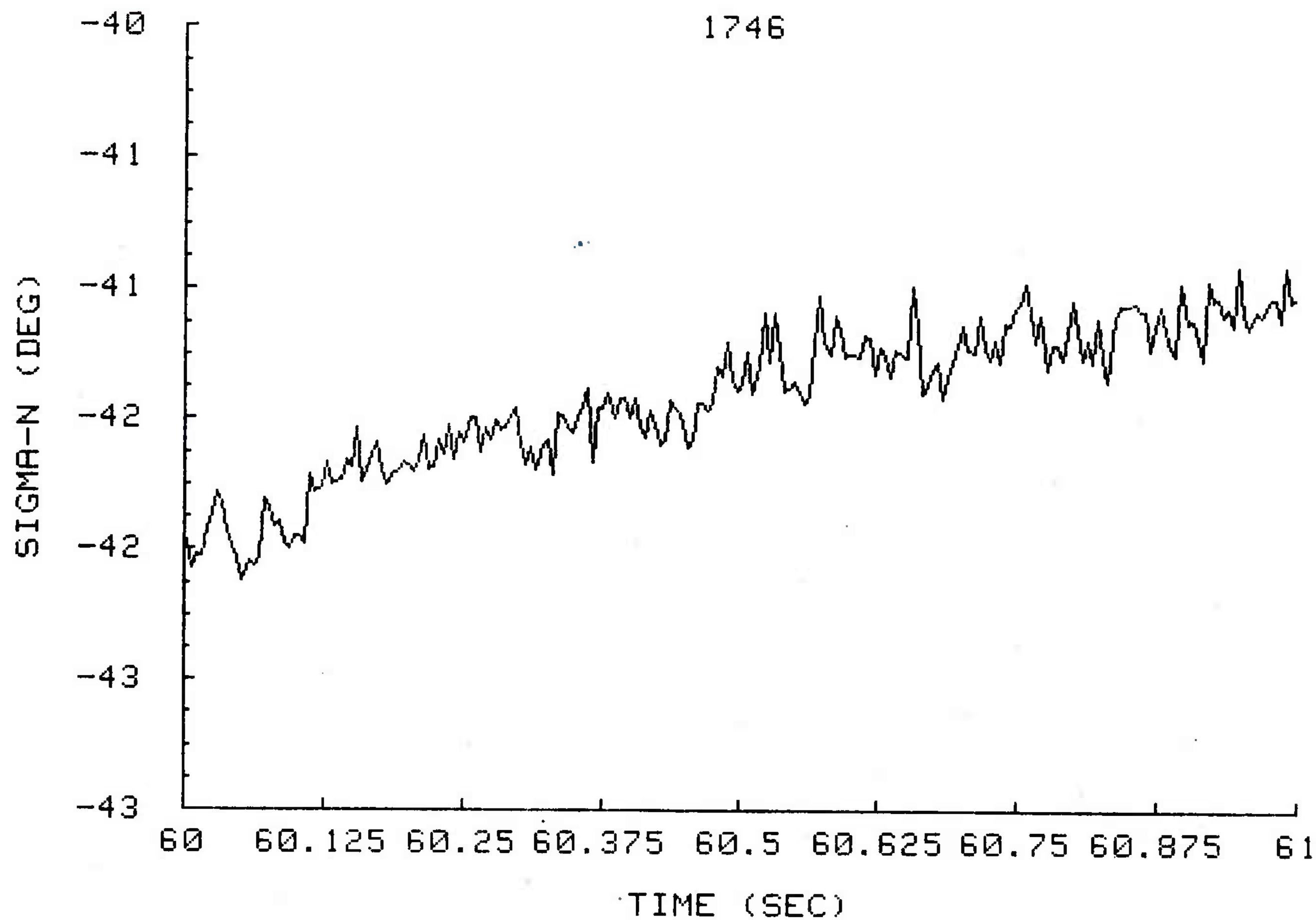

Figure 9d. Expanded Sigma-N History - YPG 269, XM825/Liquid.

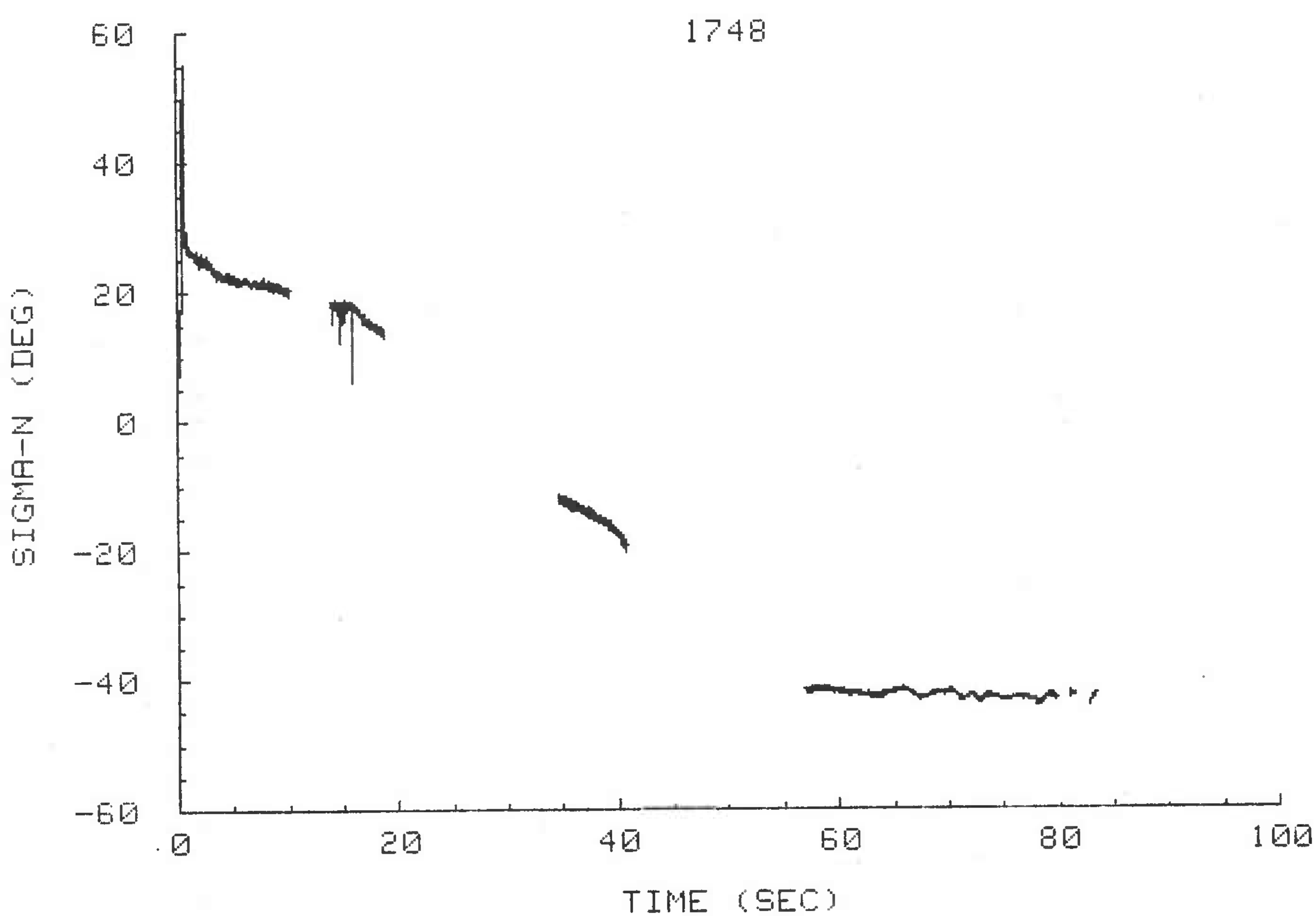

Figure 10a. Sigma-N History - YPG 270, XM825/Liquid.

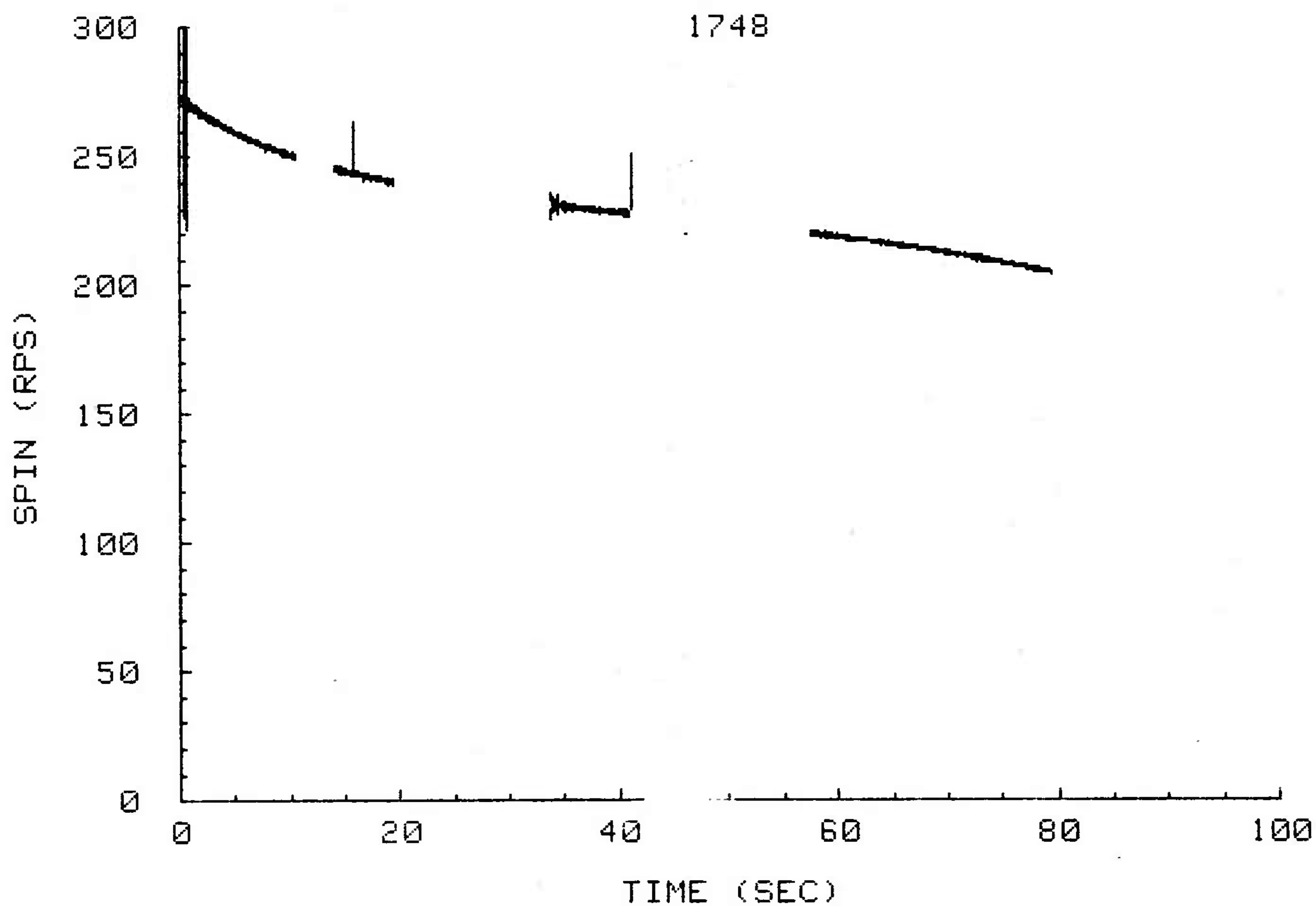

Figure 10b. Spin History - YPG 270, XM825/Liquid.

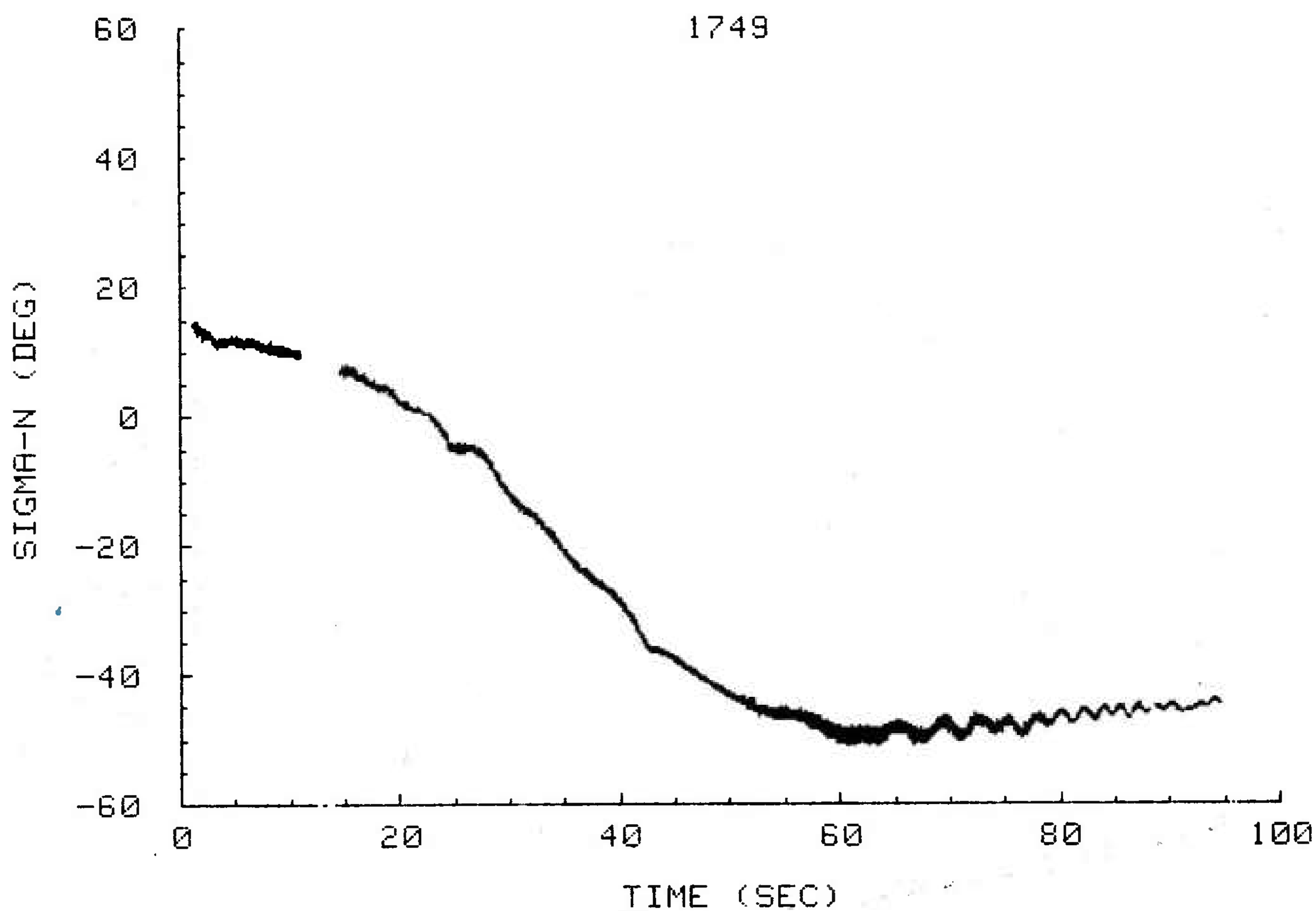

Figure 11a. Sigma-N History - YPG 271, XM825/Liquid.

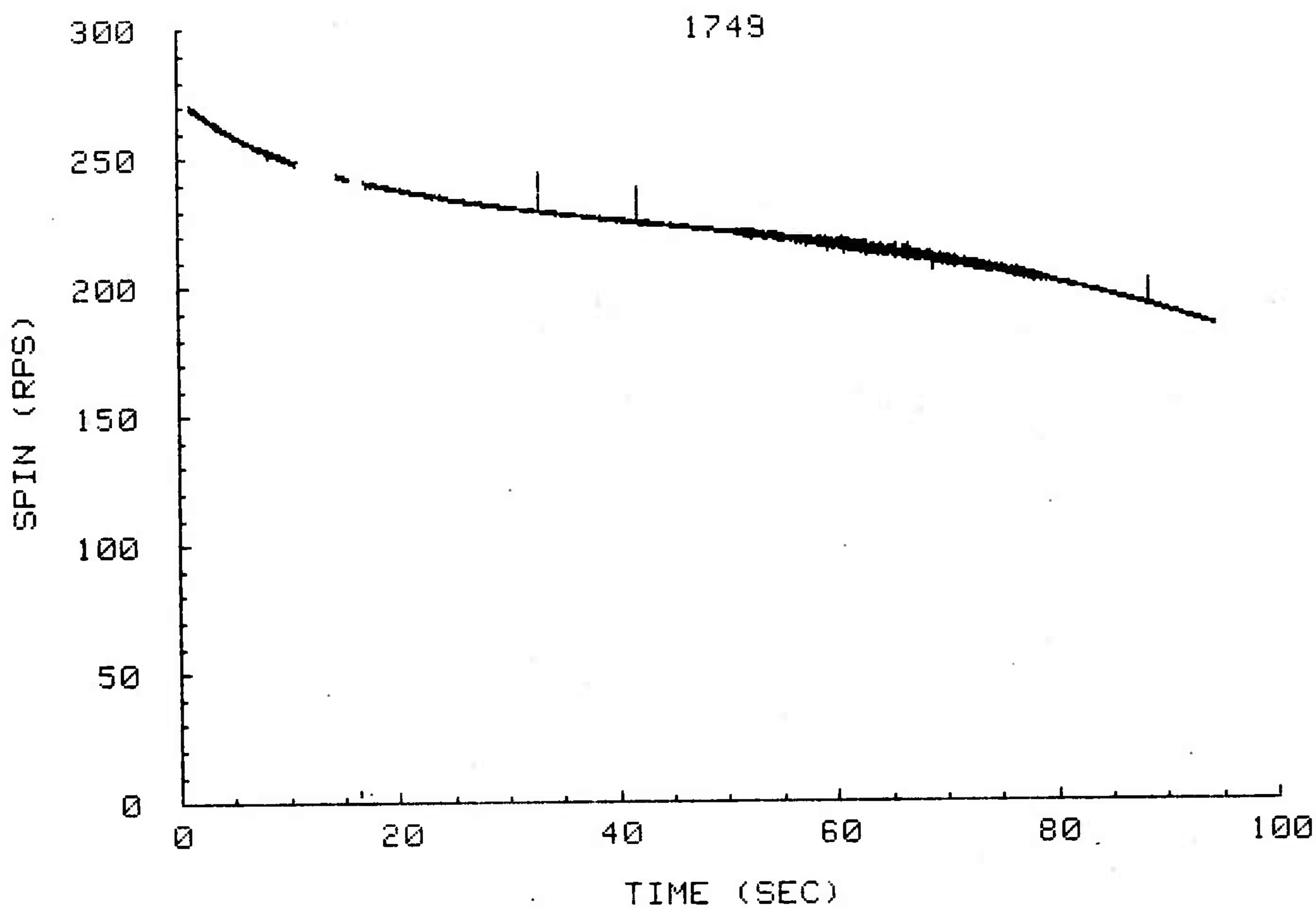

Figure 11b. Spin History - YPG 271, XM825/Liquid.

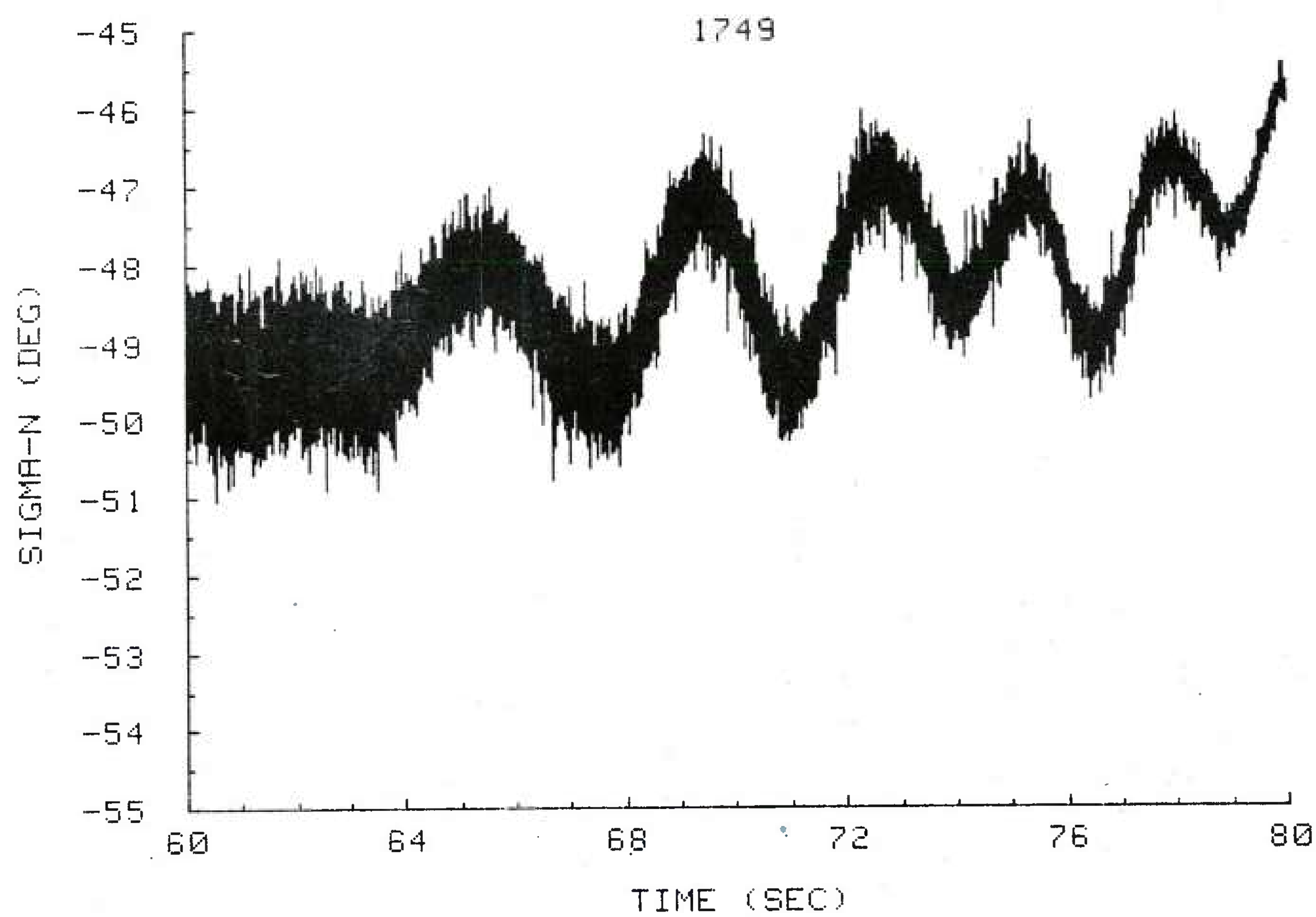

Figure 11c. Expanded Sigma-N History - YPG 271, XM825/Liquid.

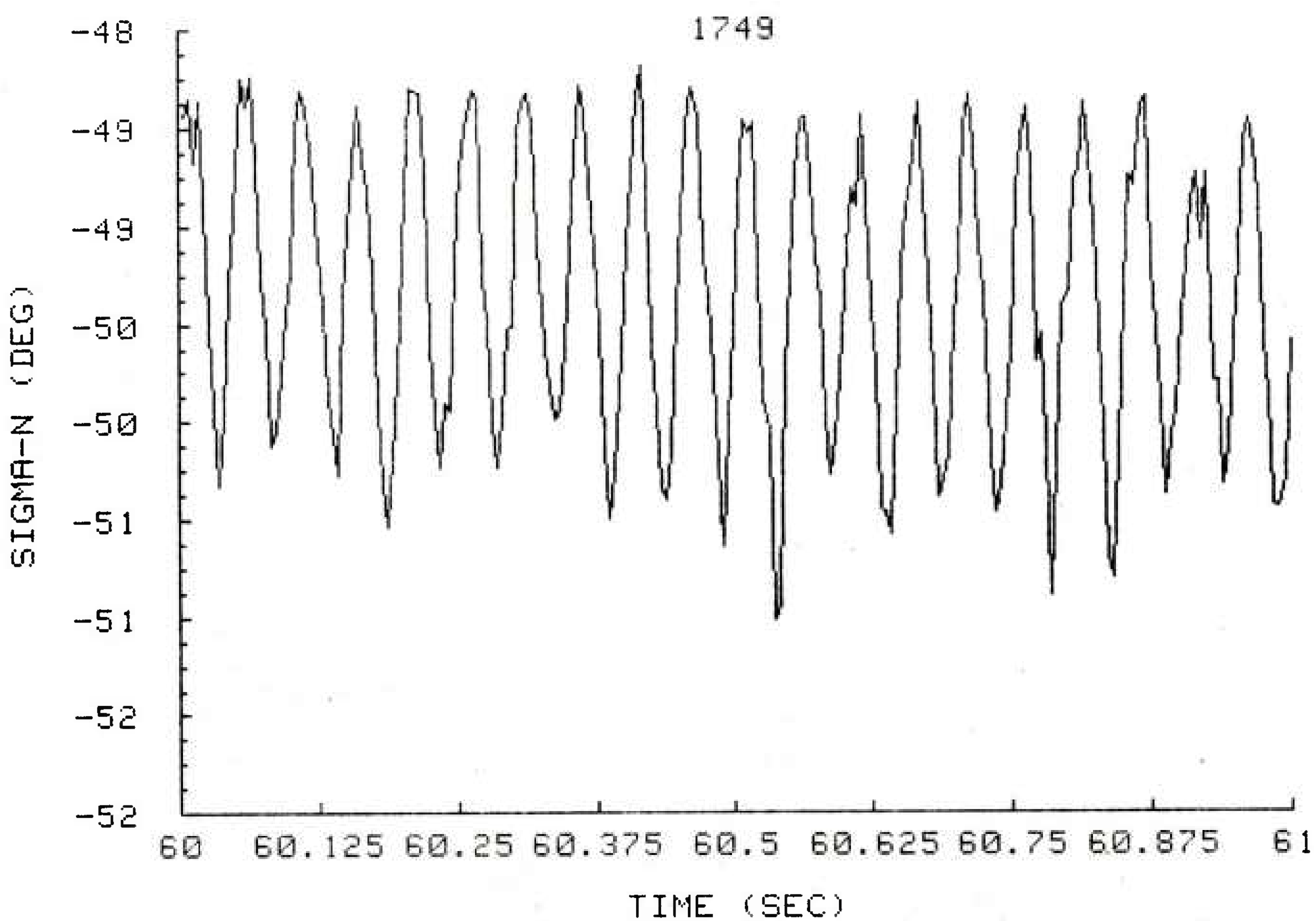

Figure 11d. Expanded Sigma-N History - YPG 271, XM825/Liquid.

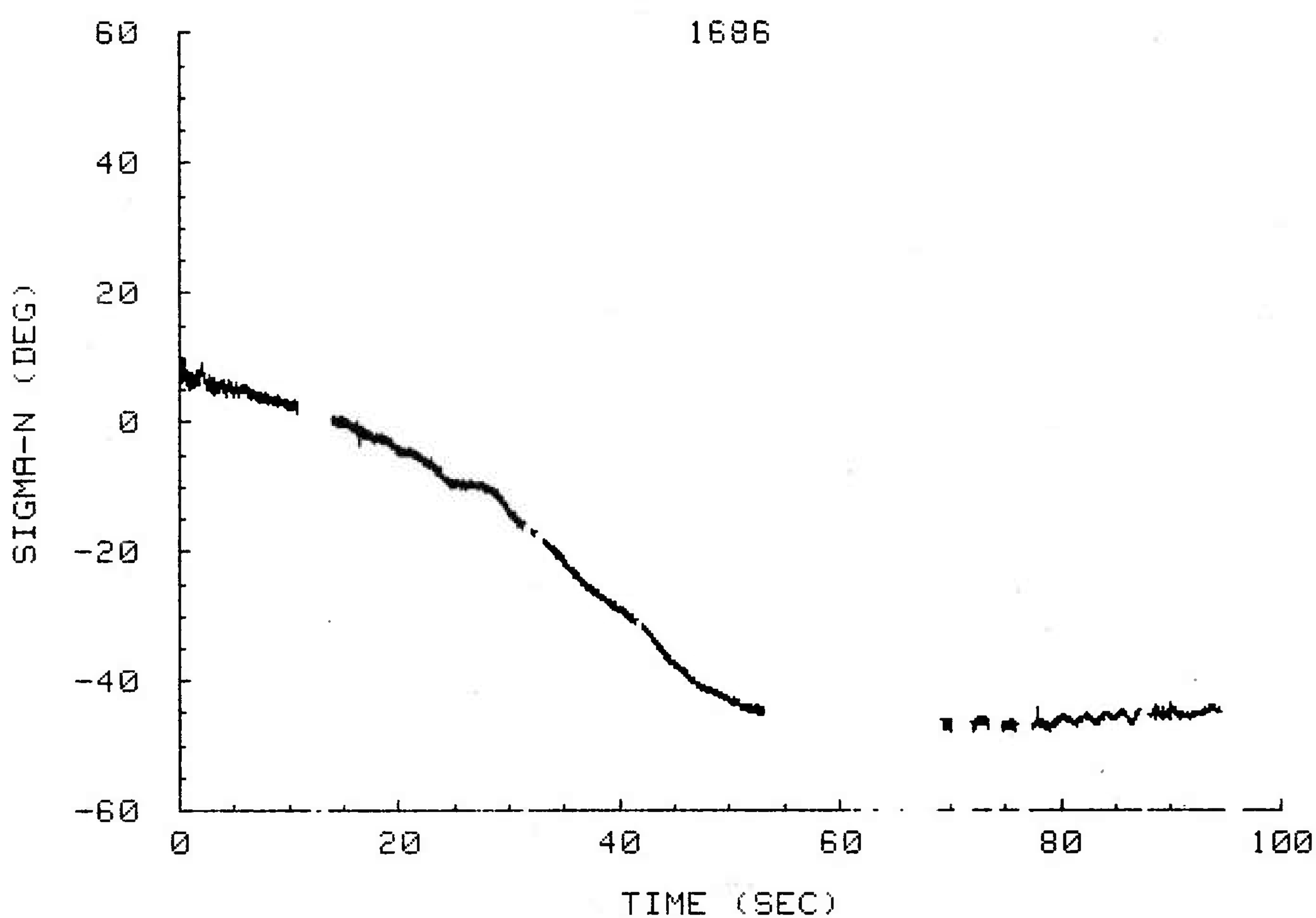

Figure 12a. Sigma-N History - YPG 272, XM825/Liquid.

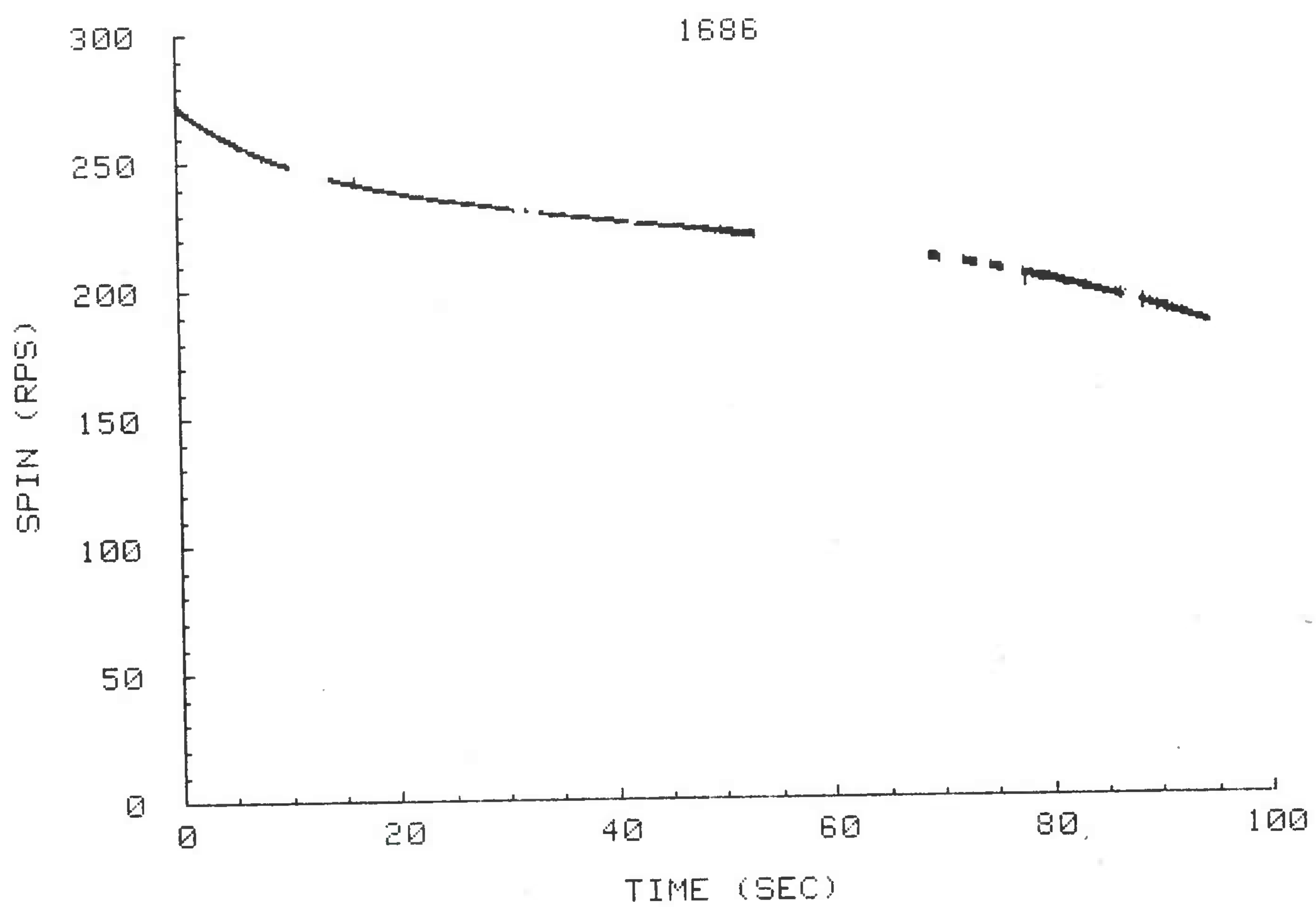

Figure 12b. Spin History - YPG 272, XM825/Liquid.

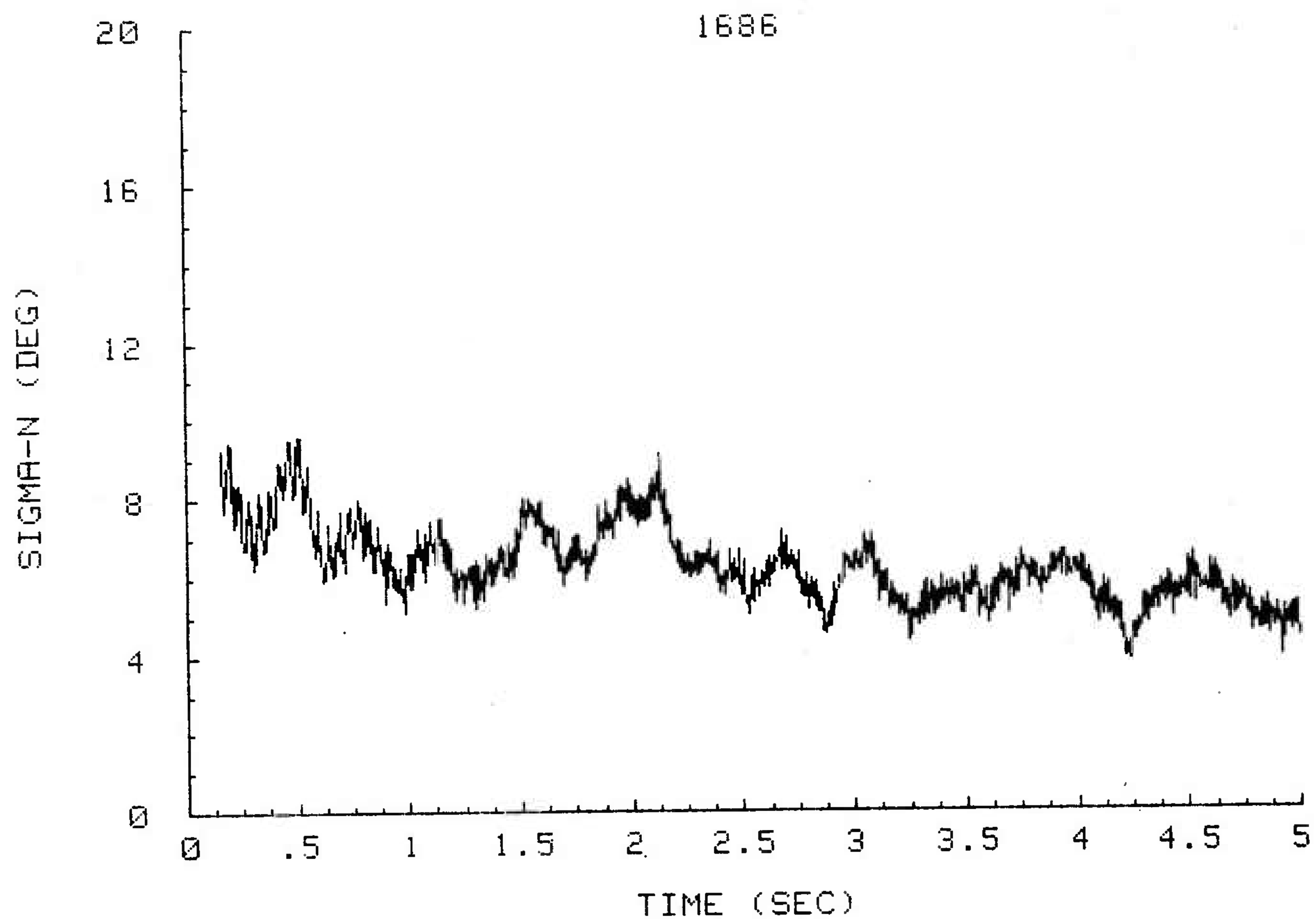

Figure 12c. Expanded Sigma-N History - YPG 272, XM825/Liquid.

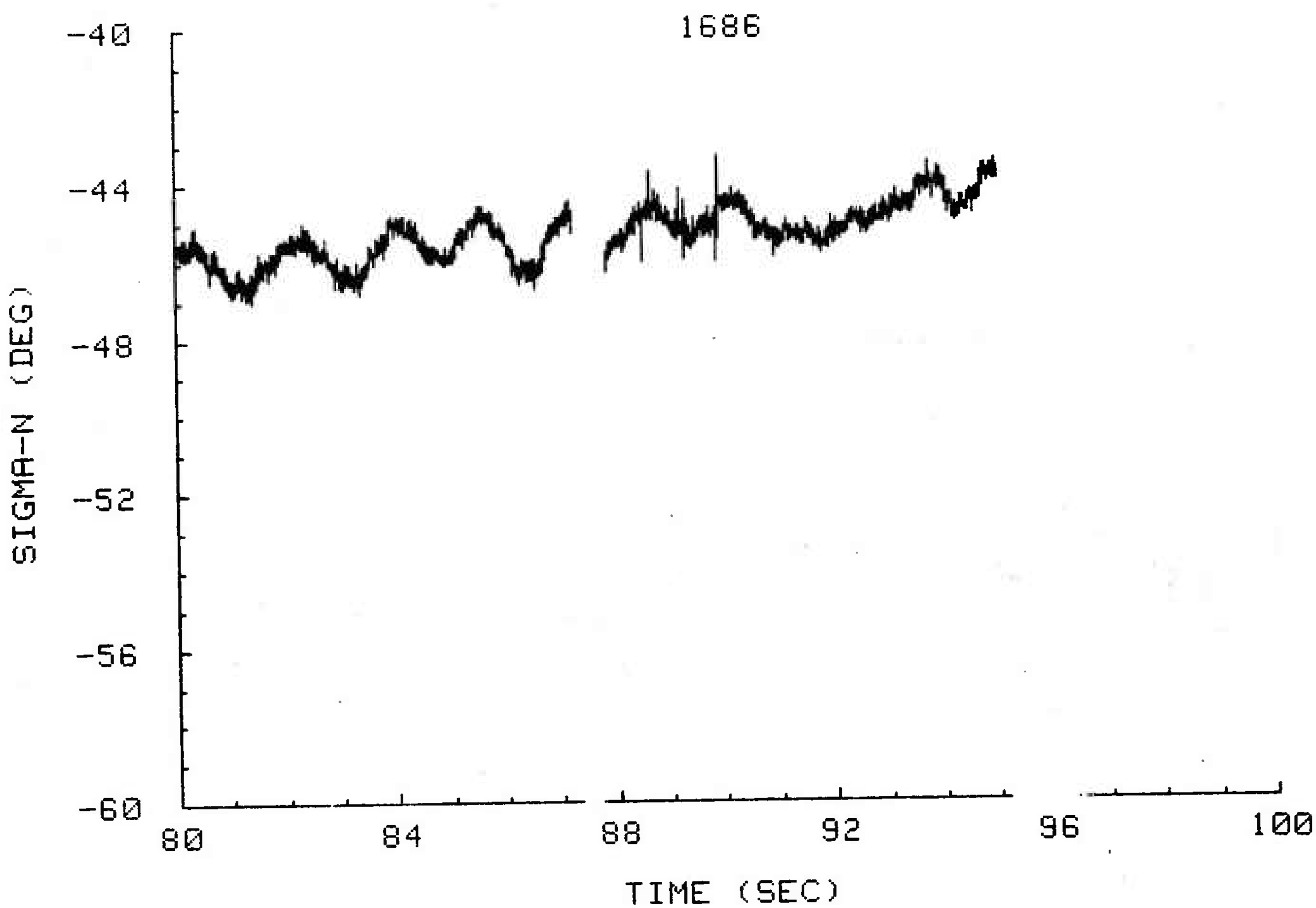

Figure 12d. Expanded Sigma-N History - YPG 272, XM825/Liquid.

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