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MEMORANDUM REPORT ARBRL-MR-03028
(Supersedes IMR 645)

XM803 YAWSONDE REDUCTION

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W. P. D'Amico

June 1980

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Twelve yawsonde-instrumented XM803 projectiles were tested at Dugway Proving Ground, Utah, on 13 June 1978. All projectiles exhibited stable flights for high subsonic launch conditions when fired from the M198 and M109A1 systems. The XM803 is a member of the 155mm M483A1 family of shell and carries red phosphorous.		

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I. INTRODUCTION

Twelve yawsonde-instrumented XM803 projectiles were tested at Dugway Proving Ground, Utah, on 13 June 1978. All projectiles exhibited stable flights for launch conditions in the vicinity of the critical Mach number of the parent projectile, the M483A1. The red phosphorous (RP) loaded XM803 is under development by the Large Caliber Weapons Systems Laboratory, Dover, New Jersey. The XM803 is currently being tested along with a white phosphorous (WP) impregnated felt wedge projectile, the XM825. One of these shells will be selected for continued development. Both projectiles produce many point sources for smoke generation and should provide increased obscuration.

Two objectives were outlined for this test. First, the stability of the XM803 was to be verified as being similar to that of the M483A1 for a launch Mach number of low gyroscopic stability, a so-called critical Mach number. Little data are available on simultaneous firings of M483A1 type projectiles from both the M109A1 and M198 weapons. Hence, a second objective was to increase this data base. These objectives were only partially met due to poor quality yawsonde data and highly variable winds at the gun site.* All of the yawsonde data did, however, indicate stable flight histories.

II. BACKGROUND

Developmental testing is presently under way for improved smoke concepts for the 155mm M483A1 family of shell. The two candidates are the WP/felt-wedge-loaded XM825 and the RP-loaded XM803. Yawsonde data have been gathered on the XM825 projectile.¹ The XM803, shown in Figure 1, carries 240 RP wedges (apex angle of 60 degrees) within two steel sleeves. Propellant located in the ogive is ignited by a time fuze and pushes a circular plate against the metal sleeves which in turn shear the base threads, and eject the payload. The projectile metal parts of the XM803 are similar to the parent vehicle, and the exterior configurations should be identical for the XM803 and M483A1. However, an error in the overall length of the XM803 shell used in the yawsonde test was discovered. These XM803 projectiles were approximately one centimeter shorter than the M483A1.** The boattail length was in error.

1. W.P. D'Amico, "Aeroballistic Testing of the XM825 Projectile: Phase I," Ballistic Research Laboratory Memorandum Report, ARBRL-MR-02911, March 1979. (AD#B037680L)

* Appendix A provides meteorological data.

** Appendix B provides physical measurements for the XM803 and a comparison to M483A1 physical measurements.

III. TEST PROGRAM

A. Instrumentation

References 2 and 3 provide a complete description of yawsonde techniques and the BRL fuze configured yawsonde, but a short account is given here. The yawsonde measures the motion of the projectile with respect to the sun, and the raw data are displayed in terms of Sigma N, the solar aspect angle, and Phi Dot (Raw), the time rate of change of the Eulerian roll angle. The excursions in Sigma N are related to the yawing motion of the projectile about the trajectory, while for small angular motions the spin of the projectile is well represented by Phi Dot (Raw). Plots within this report that are labeled spin are actually plots of Phi Dot (Raw) versus time. The amplitude modulation on the spin data is produced by the yawing motion of the projectile and the true spin should be regarded as the mean value of the plotted data.⁴

Instrumentation at the German Village range, DPG, was operated by DPG personnel and included a ground receiving station for the yawsonde data, a gun time-zero system, a muzzle chronograph, and a modified Hawk doppler radar. Data from the Hawk radar will not be discussed within this report. A modified muzzle brake of the type used during the XM825 ballistic tests was employed to induce yaw for Charge 4W. Non-standard charge weights were used in an attempt to achieve launch Mach numbers of low gyroscopic stability. The wind conditions were highly variable and as a result the launch Mach numbers were slightly higher than the desired range of 0.90 to 0.92. Table 1 provides a round-by-round summary.

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2. Mermagen, W.H., "Measurements of the Dynamical Behavior of Projectiles Over Long Flight Paths," Journal of Spacecraft and Rockets, Vol. 8, No. 4, April 1971, pp. 310-385.
 3. Clay, W.H., "A Precision Yawsonde Calibration Technique," Ballistic Research Laboratories Memorandum Report No. 2263, January 1973, AD 758158.
 4. Murphy, C.H., "Effect of Large High-Frequency Angular Motion of a Shell on the Analysis of Its Yawsonde Records," Ballistic Research Laboratory Memorandum Report No. 2581, February 1976, AD B0094210.

TABLE 1. XM803 ROUND-BY-ROUND SUMMARY

Charge Weight ¹ (gm)	Muzzle Velocity ² (m/s)	DPG#	BRL#	Weapon	Spin Data	Yaw Data	Comments ⁴	Mach Number ⁵
- 8	307.8	111	1522	M198	Yes	Yes	Stable FMA = 6 degrees	0.89
+ 8	324.9	112	1523	M198	No	No	Stable	0.94
0	318.3	113	1524	M198	Yes	Yes	Stable FMA = 3 degrees	0.92
0	317.5	114	1525	M198	No	No	Stable	0.92
0	332.2	115	1526	M109A1	Yes	Yes	Stable FMA = 4.5 degrees	0.97
-11	323.7	116	1527	M109A1	Yes	Yes	Stable FMA = 5.5 degrees	0.94
-11	322.9	117	1545	M109A1	No	No	Stable	0.95
-14	319.8	118	1529	M109A1 ³	Yes	No	Stable	0.94
-14	320.8	119	1530	M109A1 ³	Yes	No	Stable	0.93
-11	320.8	120	1531	M109A1 ³	Yes	Yes	Stable FMA = 7.5 degrees	0.93
- 8	323.6	121	1532	M109A1 ³	Yes	Yes	Stable FMA = 8 degrees	0.95
- 8	322.1	124	1533	M109A1 ³	No	No	Stable	0.94

1. A decrement or addition to Charge 4W.

2. This velocity has not been adjusted back to the muzzle of the weapon. The measurement of velocity is made approximately 30 metres in front of the gun.

3. Yaw induced by a modified muzzle brake with full side plates (13cm).

4. The first maximum amplitude (FMA) is half of the first recorded peak-to-peak excursion in the solar angle data. This quantity is taken as a measure of the yaw level at launch, but it is not the first maximum angle of yaw. If data are received soon after shot exit, then the FMA may be a good approximation to the first maximum angle of yaw. When stable is not followed by a measurement of FMA, stability is only qualitatively determined from yawsonde data that were not of sufficiently high grade to permit a proper reduction. Hence, the details of the stable behavior are not available.

5. A nominal correction of 3 m/s was applied to the chronograph velocity for all flights. Surface wind corrections were also applied.

B. Yawsonde Results

The poor quality of the yawsonde data for the XM803 program resulted in a loss of data at several test conditions, as seen in Table 1.

Often, the data were intermittent. It is most likely that the poor quality of the data was a result of overdriving the yawsonde transmitter. For the telemetry system employed by the XM803 yawsondes, the output of the optical sensors was fed directly to the transmitter. This type of system produces a direct frequency modulation (FM) of the transmitter. Previously, BRL yawsondes utilized an FM/FM system, where the output of the optical sensors was conditioned, amplified, and fed to a subcarrier oscillator which in turn modulated the transmitter. In an FM system unexpected strong outputs from the optical sensors can over modulate the transmitter and impair the telemetry link. At the present time, an FM/FM telemetry system is preferred over an FM link for P-band transmission (250 MHz).

Four XM803 projectiles were fired from the M198 weapon without yaw induction. The range of launch Mach numbers was between 0.89 and 0.94. Useable data were received only for DPG 111 and 113. Figures 2 and 4 provide the solar angle data, while Figures 3 and 5 give the spin histories. Limit cycle behavior dominated by the slow precessional frequency characterized the yawing motion. Next, three projectiles were launched from the M109A1 without yaw induction, but data are only available for DPG 115 and 116. Solar angle histories are shown in Figures 6 and 8, while spin data are shown in Figures 7 and 9. The yawing motion was again dominated by the slower precessional mode. The final phase of the program consisted of five projectiles launched with induced yaw from the M109A1. Only spin data were obtained from DPG 118 and 119, as shown in Figures 10 and 11. No unusual effects were noted. Figures 12 and 14 give the solar angle data for DPG 120 and 121, while the spin data are in Figures 13 and 15. Both of these projectiles recovered rapidly from the launch disturbances. No data were obtained for DPG 124. Table 2 summarizes the launch conditions and FMA values.

TABLE 2. SUMMARY

<u>Number of Shell Tested</u>	<u>Weapon</u>	<u>Charge</u>	<u>Launch Condition</u>	<u>Largest FMA in Sample (degrees)</u>
4	M198	4W	Standard	6
3	M109A1	4W	Standard	5.5
5	M109A1	4W	Yaw Induced	8

IV. DISCUSSION AND CONCLUSION

The sample sizes of the test conditions were not sufficiently large to be statistically meaningful. However, the largest natural yaw was achieved for a Mach number of 0.89. Due to the small number of rounds and the Mach number variation, it is not clear that the M198 produces larger launch yaw levels than the M109A1. The yaw levels achieved with the modified muzzle brake were less than 10 degrees, but they were similar to those achieved for the XM802 which is a comparable RP load projectile.⁵ The yawsonde data within this report do not indicate any stability problems for the XM803 for high subsonic launch conditions.

5. A. Mark and W.H. Clay, "Aeroballistic Test of the XM802 RP Smoke Projectile," *Ballistic Research Laboratory Memorandum Report*, ARBRL-MR-02877, November 1978. AD B033753L.



Figure 1. XM803 Red Phosphorous Smoke Projectile, 155mm

DPG #1111
BRL #1522

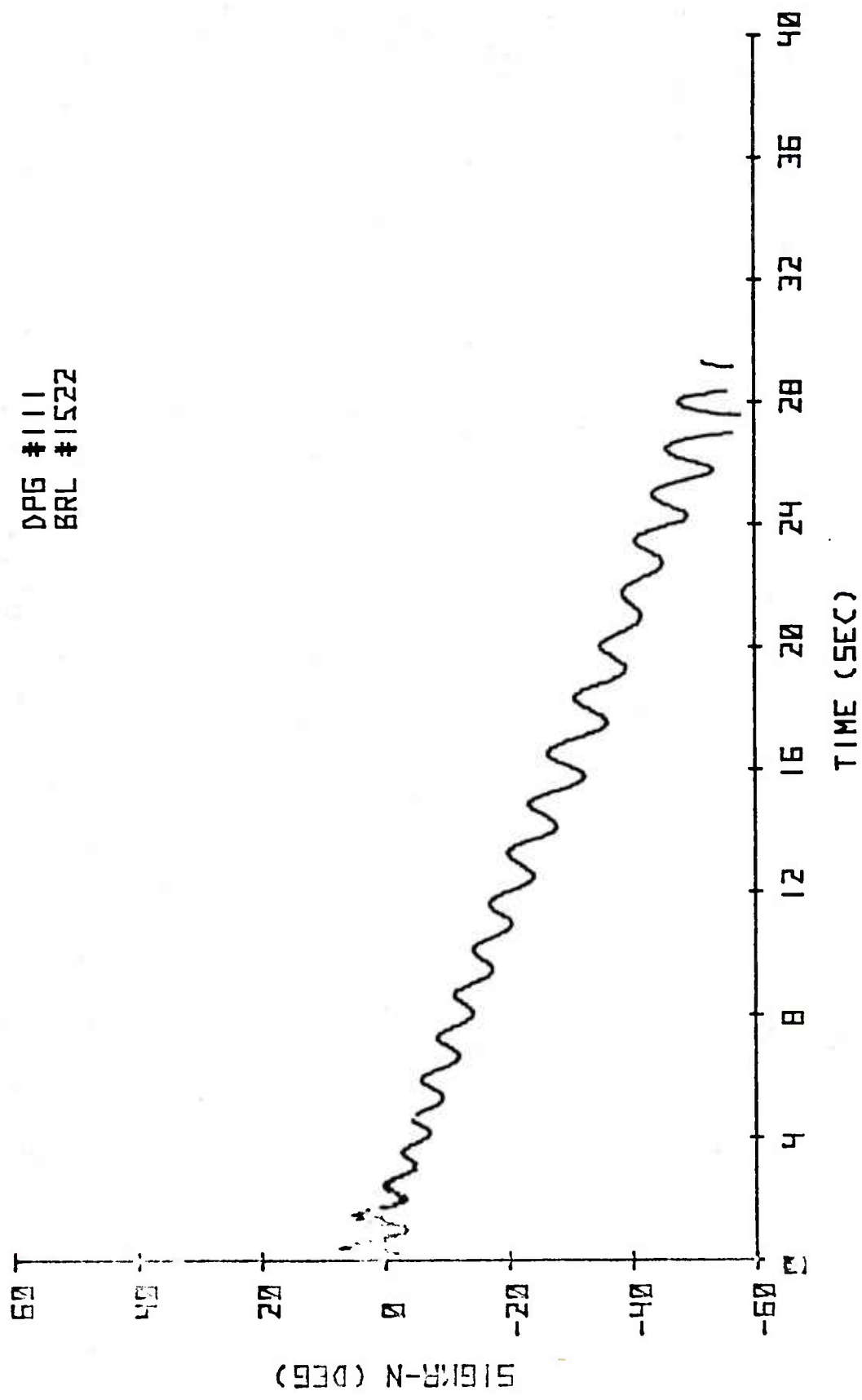


Figure 2. Sigma N Versus Time - Round 1522

DPG #111
BRL #1522

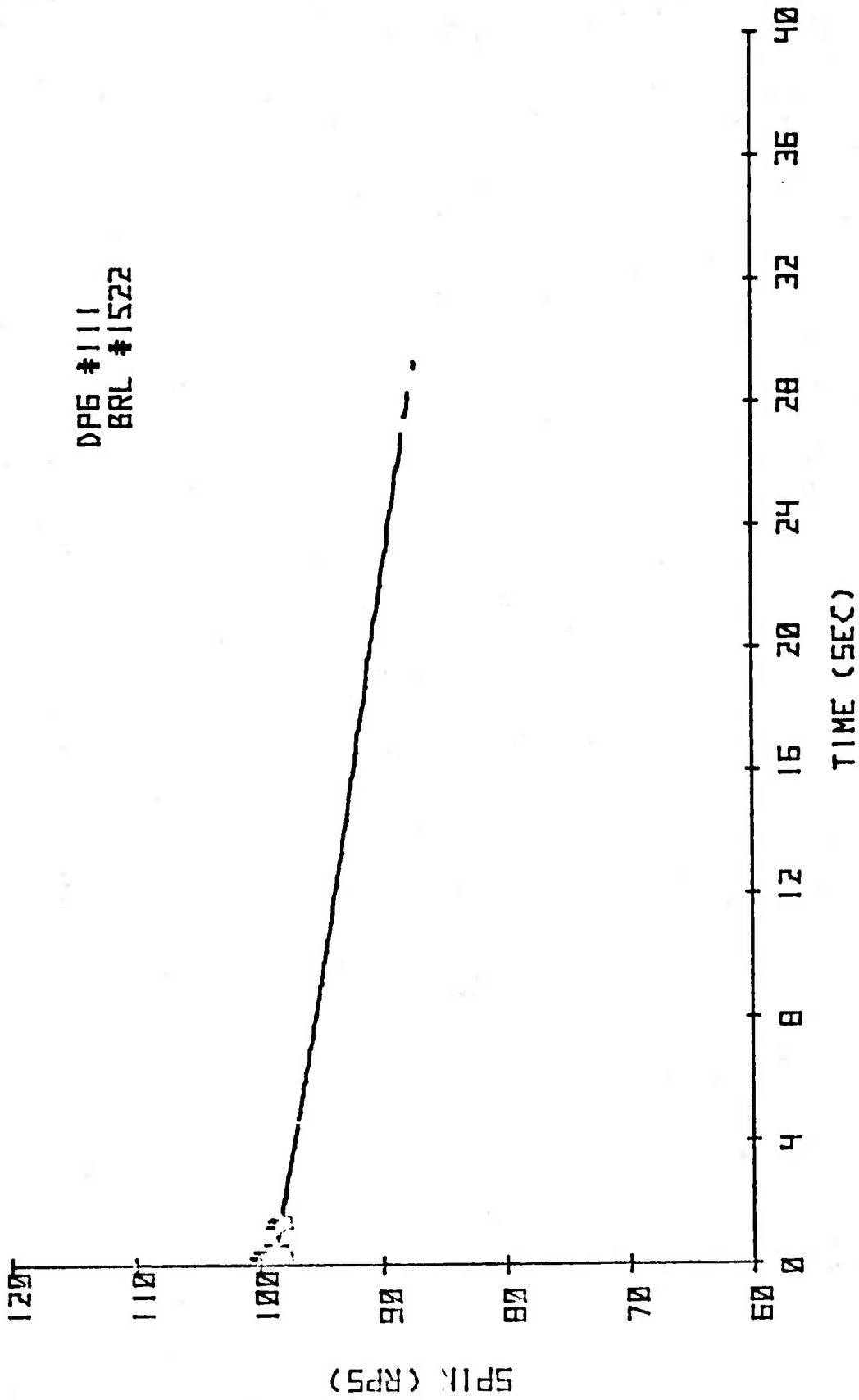


Figure 3. Spin Versus Time - Round 1522

DPG #113
BRL #1524

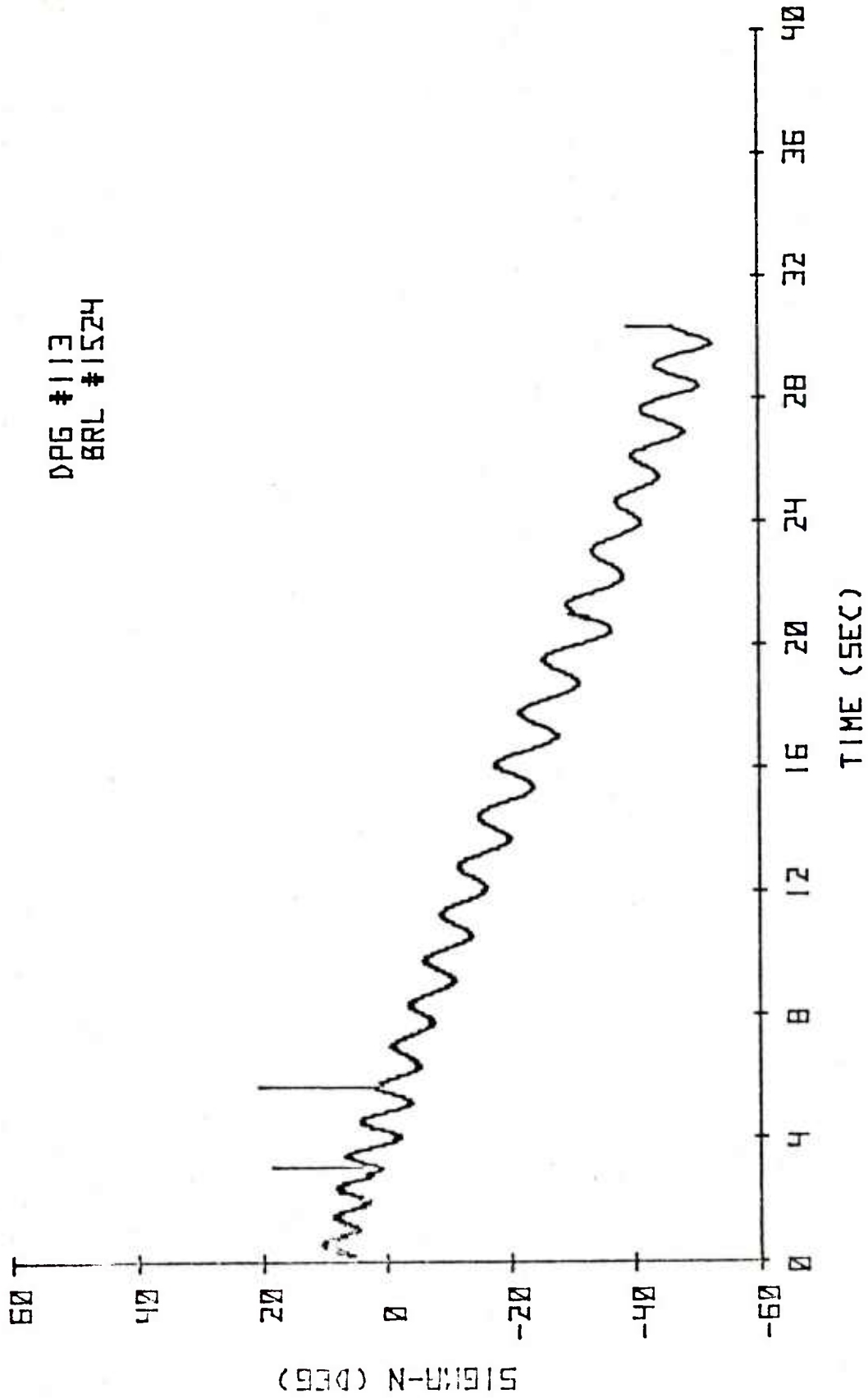


Figure 4. Sigma N Versus Time - Round 1524

DPG # 1113
BRL # 1524

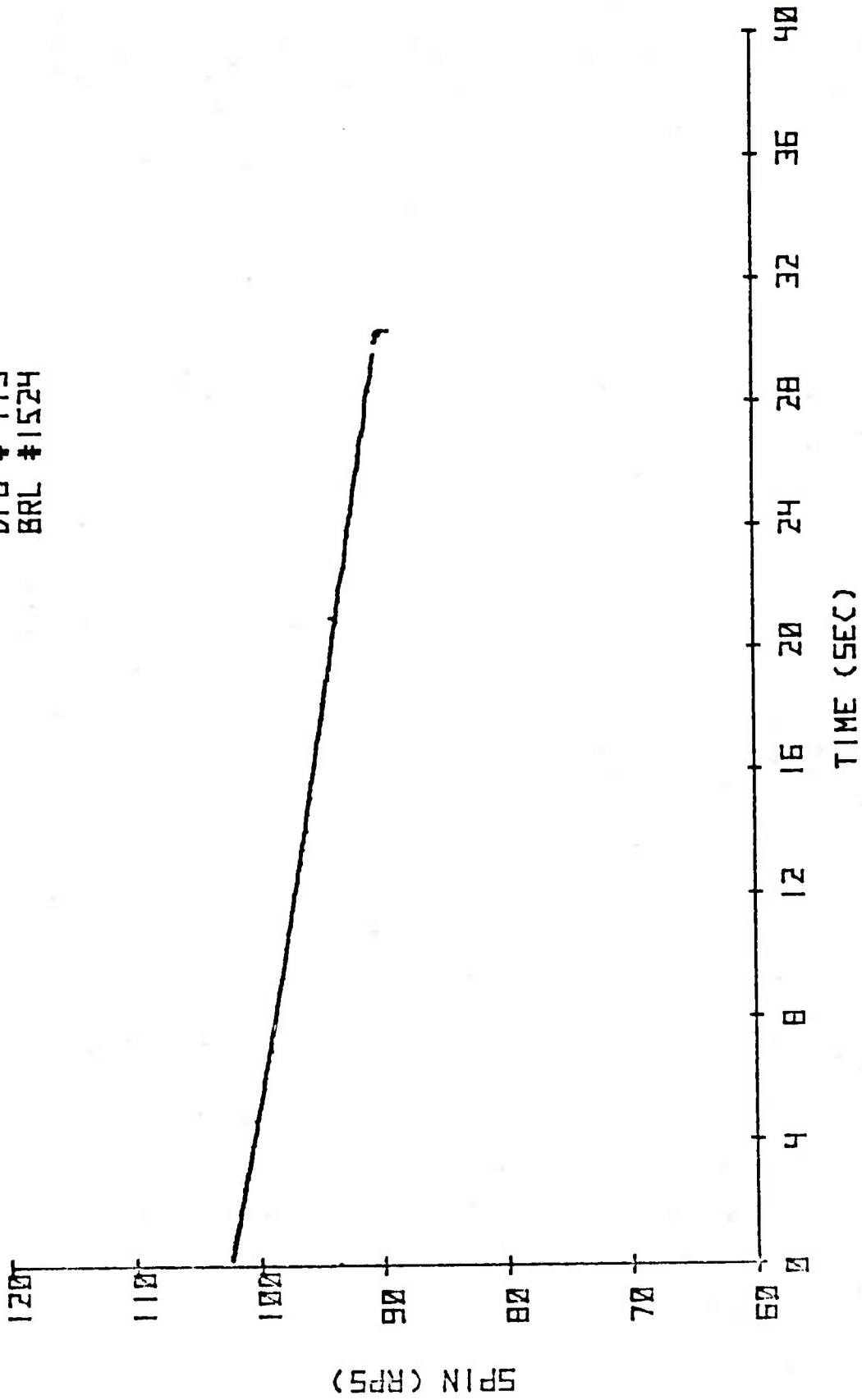


Figure 5. Spin Versus Time - Round 1524

DHG #115
BRL #1526

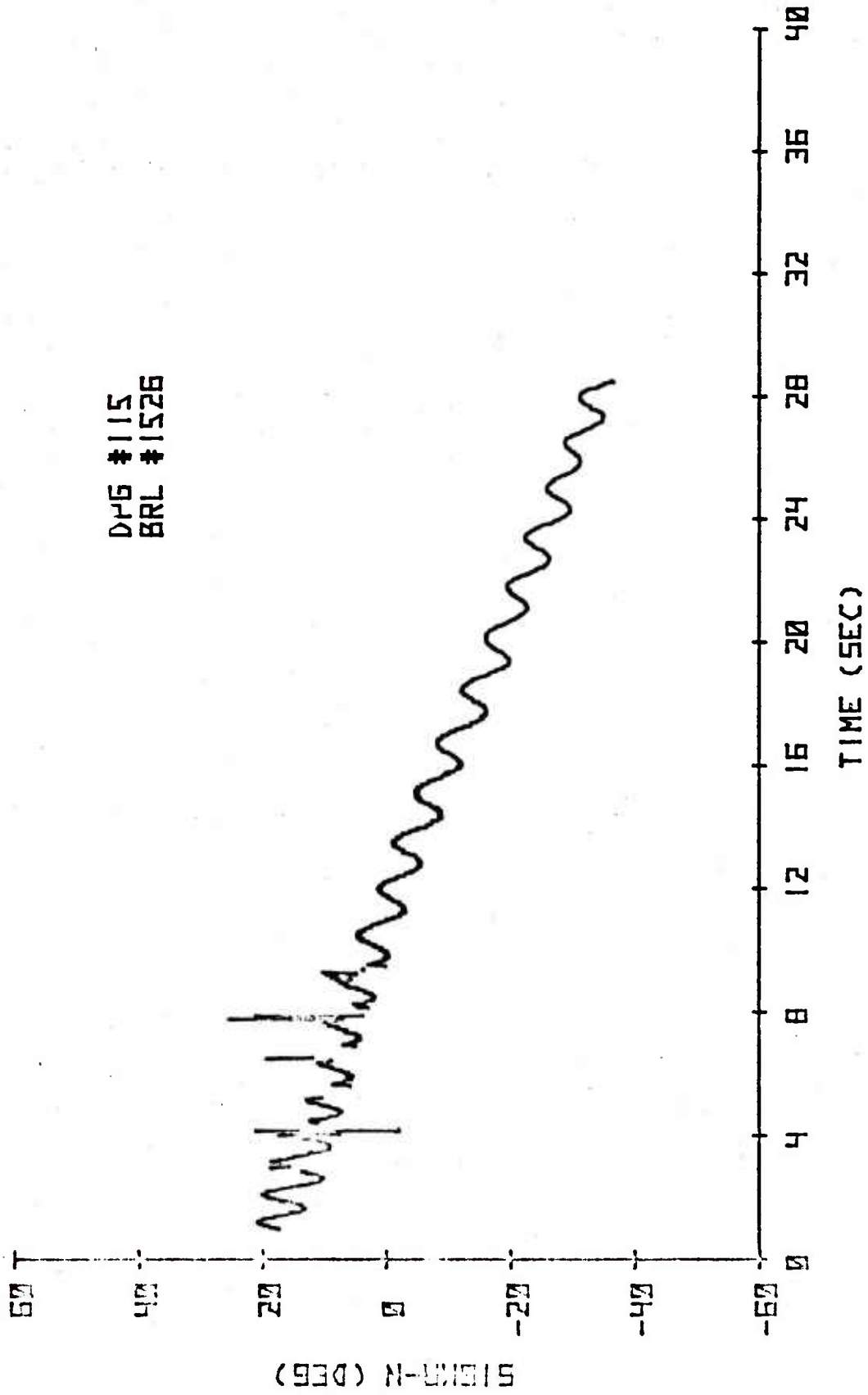


Figure 6. Sigma N Versus Time - Round 1526

DPG#115
BRL#1526

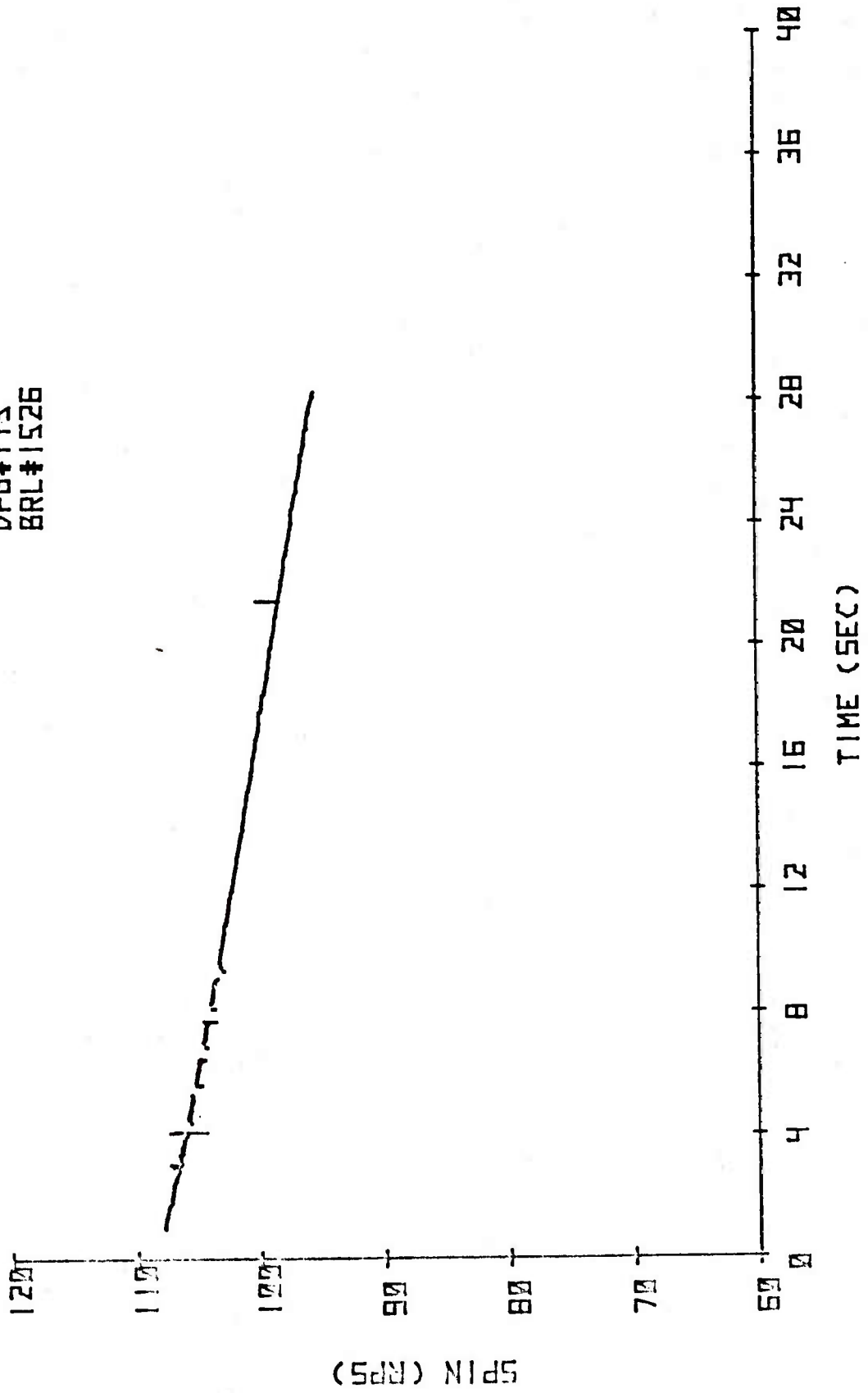


Figure 7. Spin Versus Time - Round 1526

DPG#116
BRL#1527

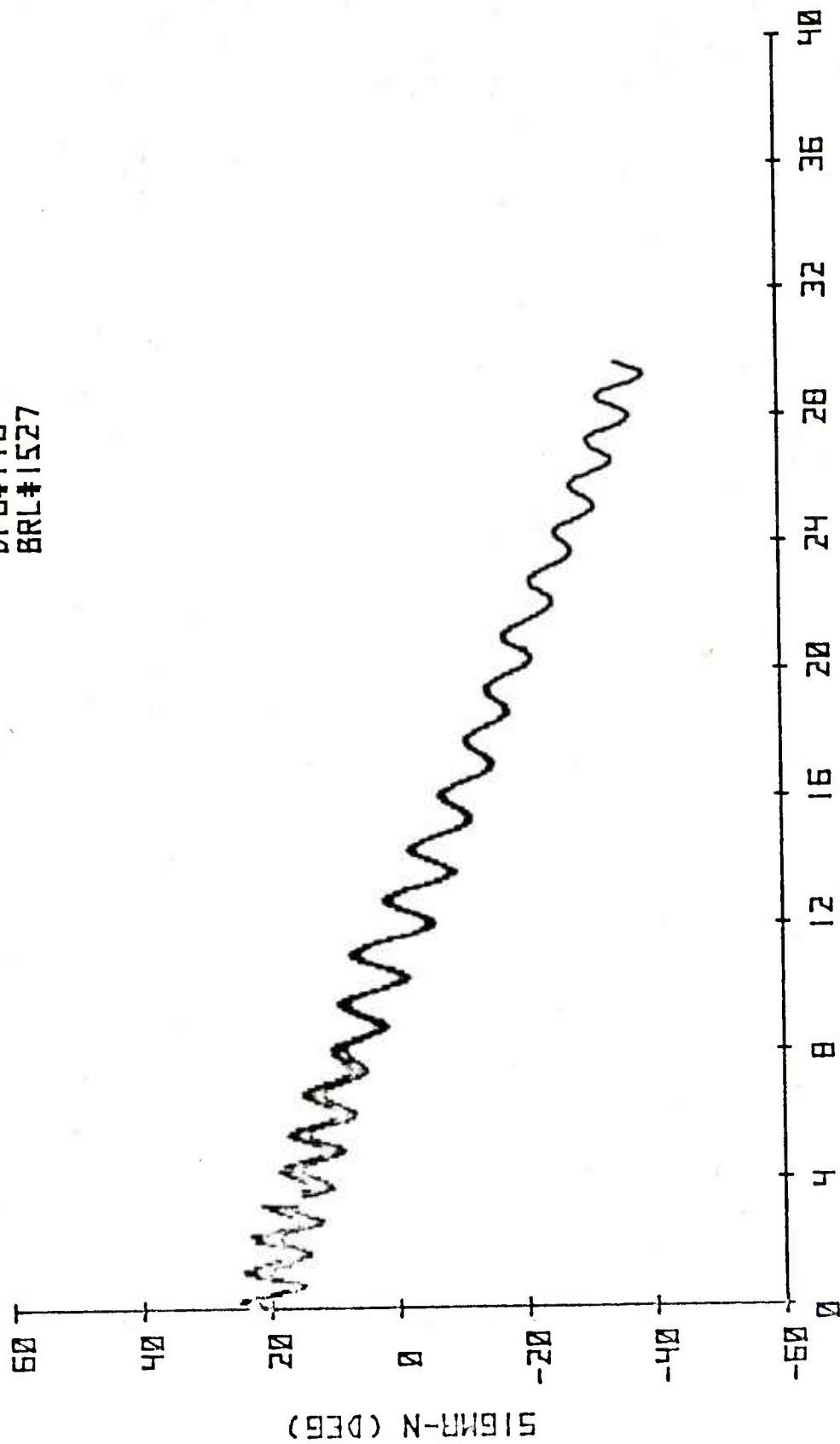


Figure 8. Sigma N Versus Time - Round 1527

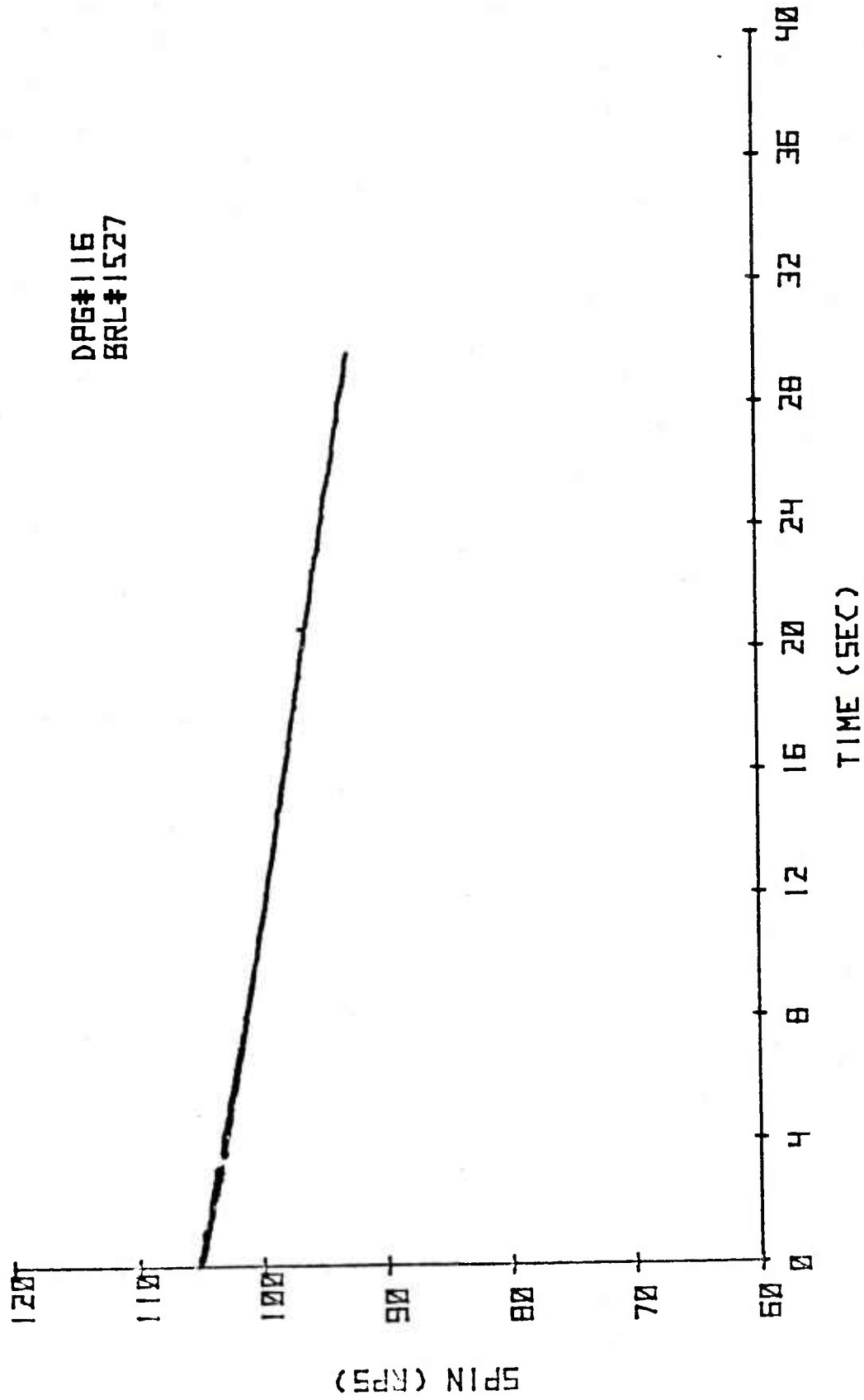


Figure 9. Spin Versus Time - Round 1527

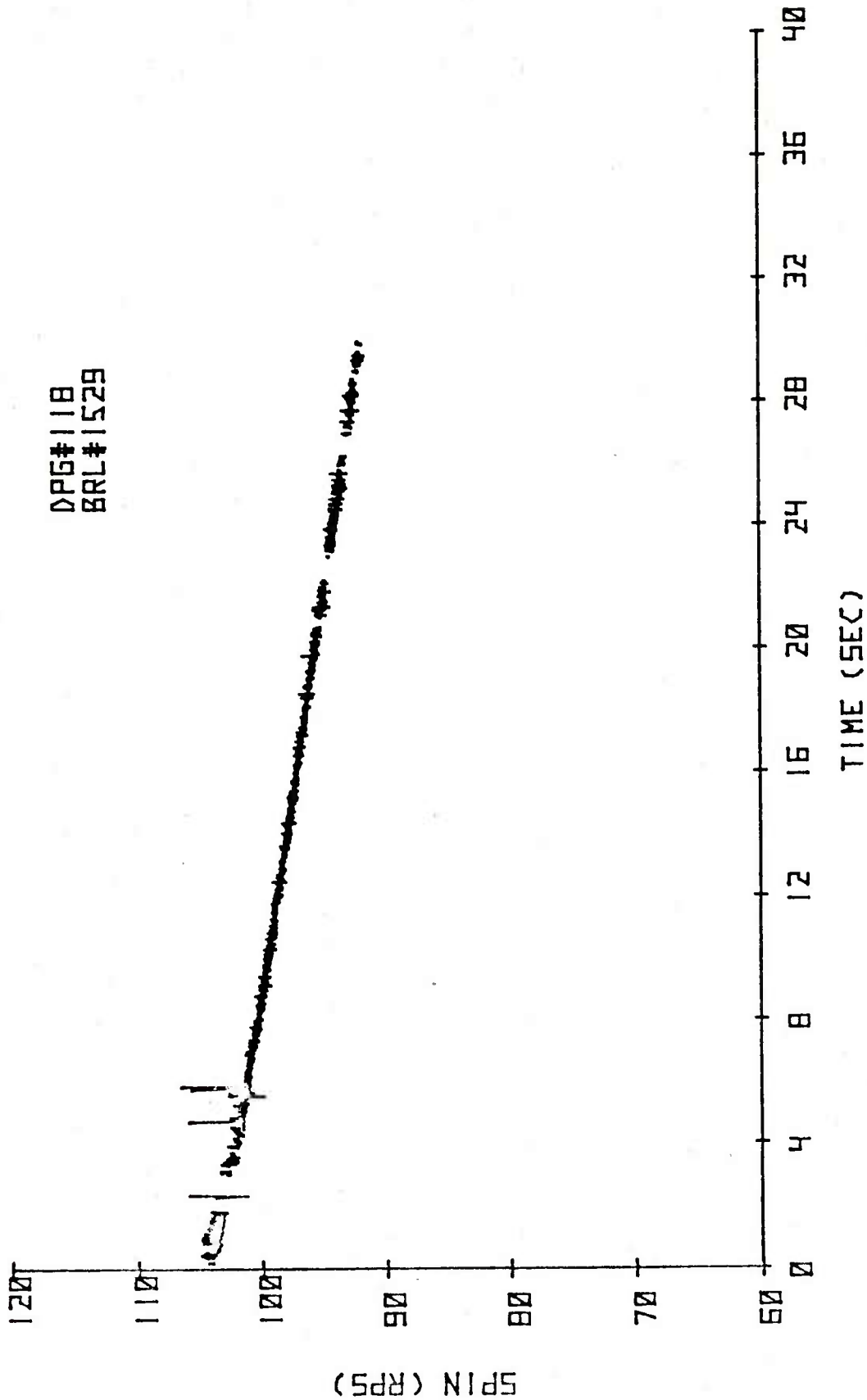


Figure 10. Spin Versus Time - Round 1529

DPG#119
BRL#1530

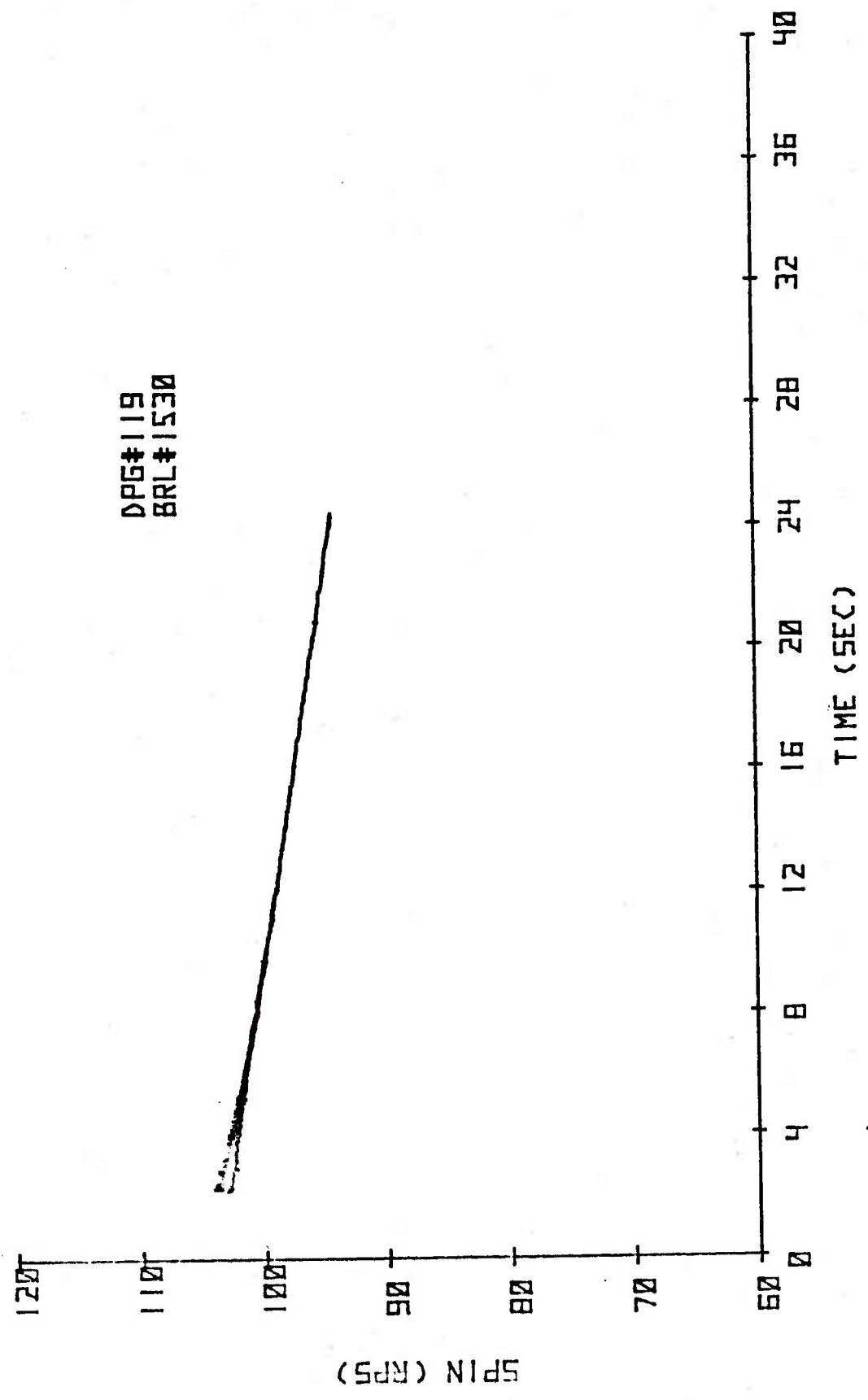


Figure 11. Spin Versus Time - Round 1530

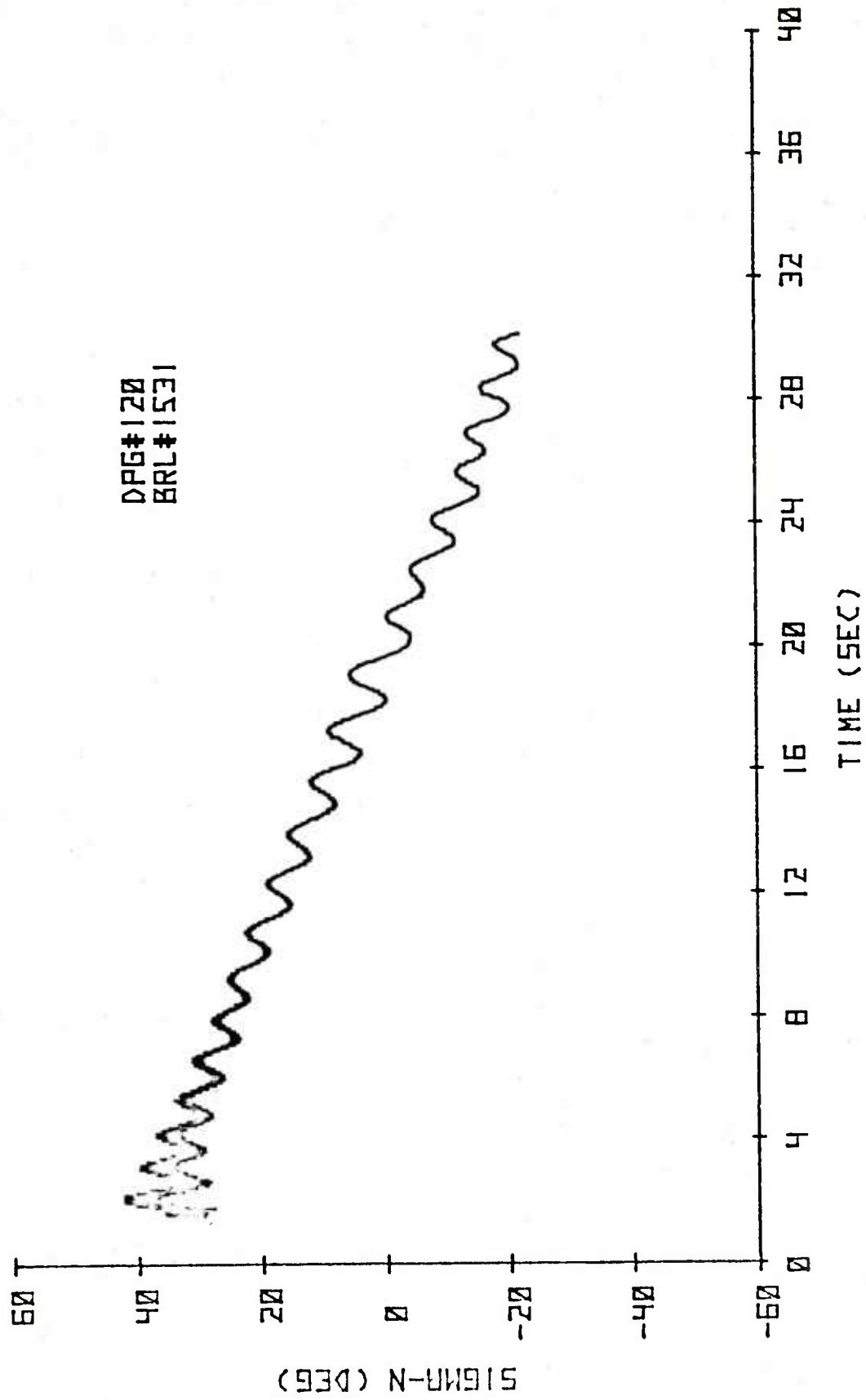


Figure 12. Sigma N Versus Time - Round 1531

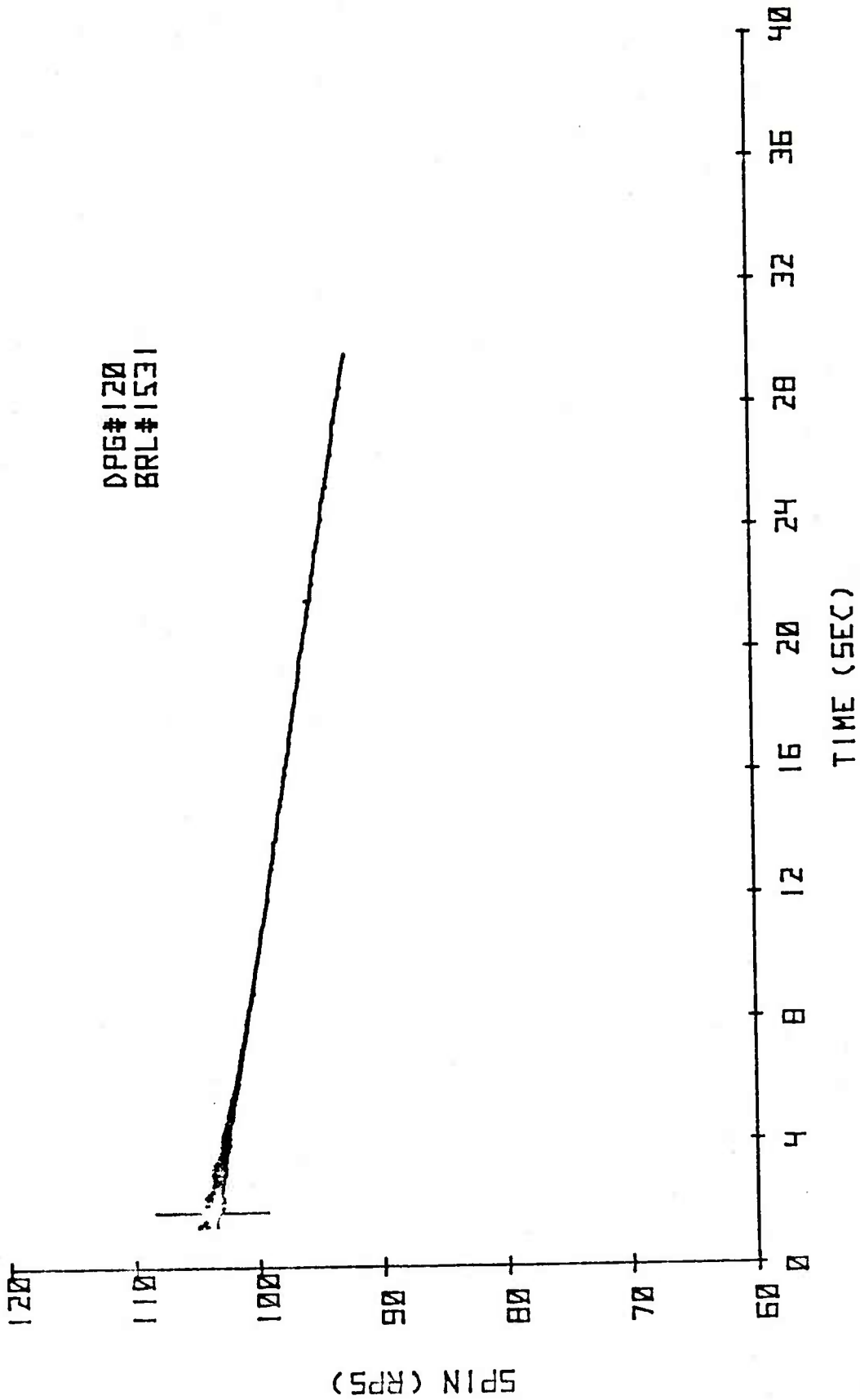


Figure 13. Spin Versus Time - Round 1531

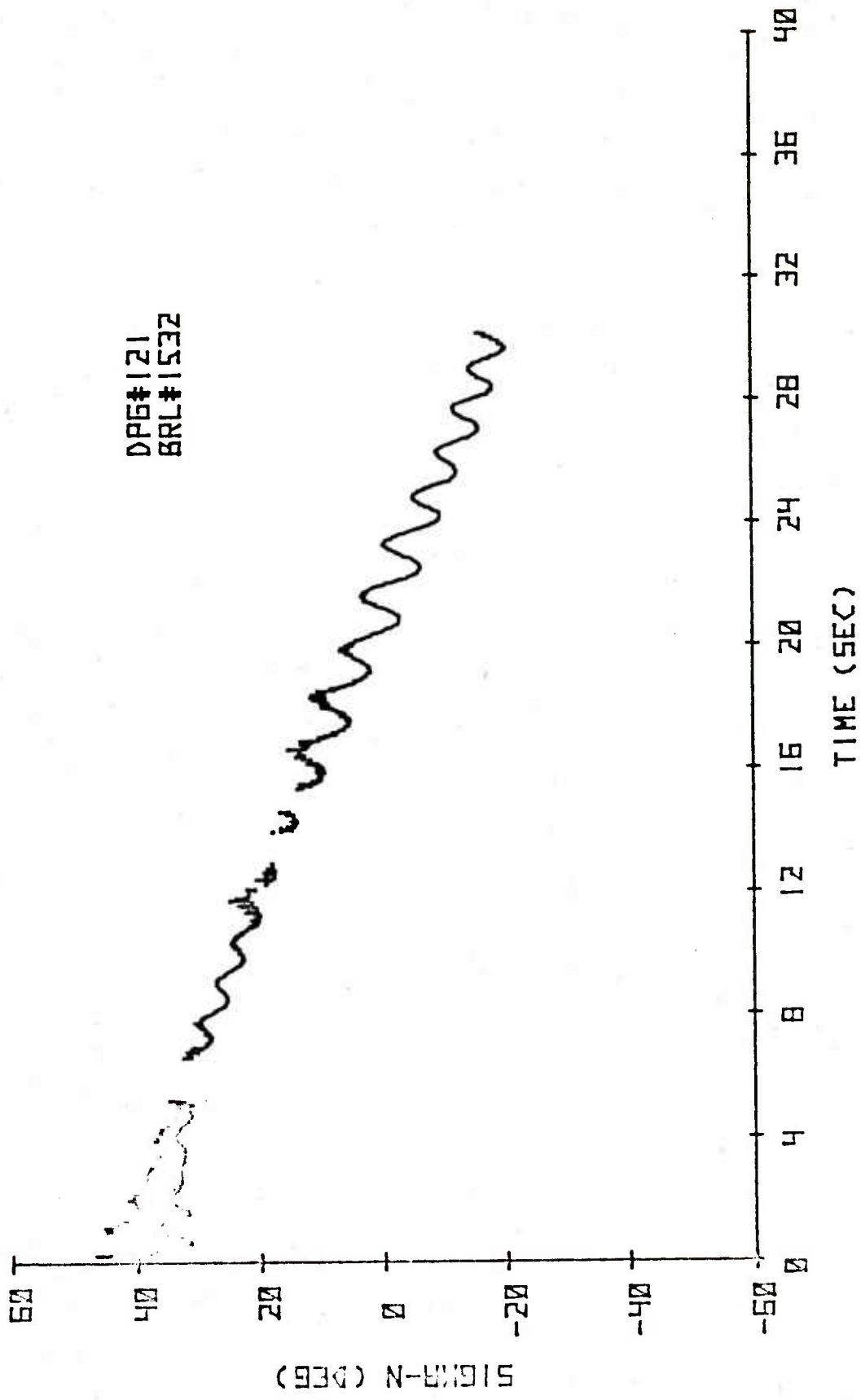


Figure 14. Sigma N Versus Time - Round 1532

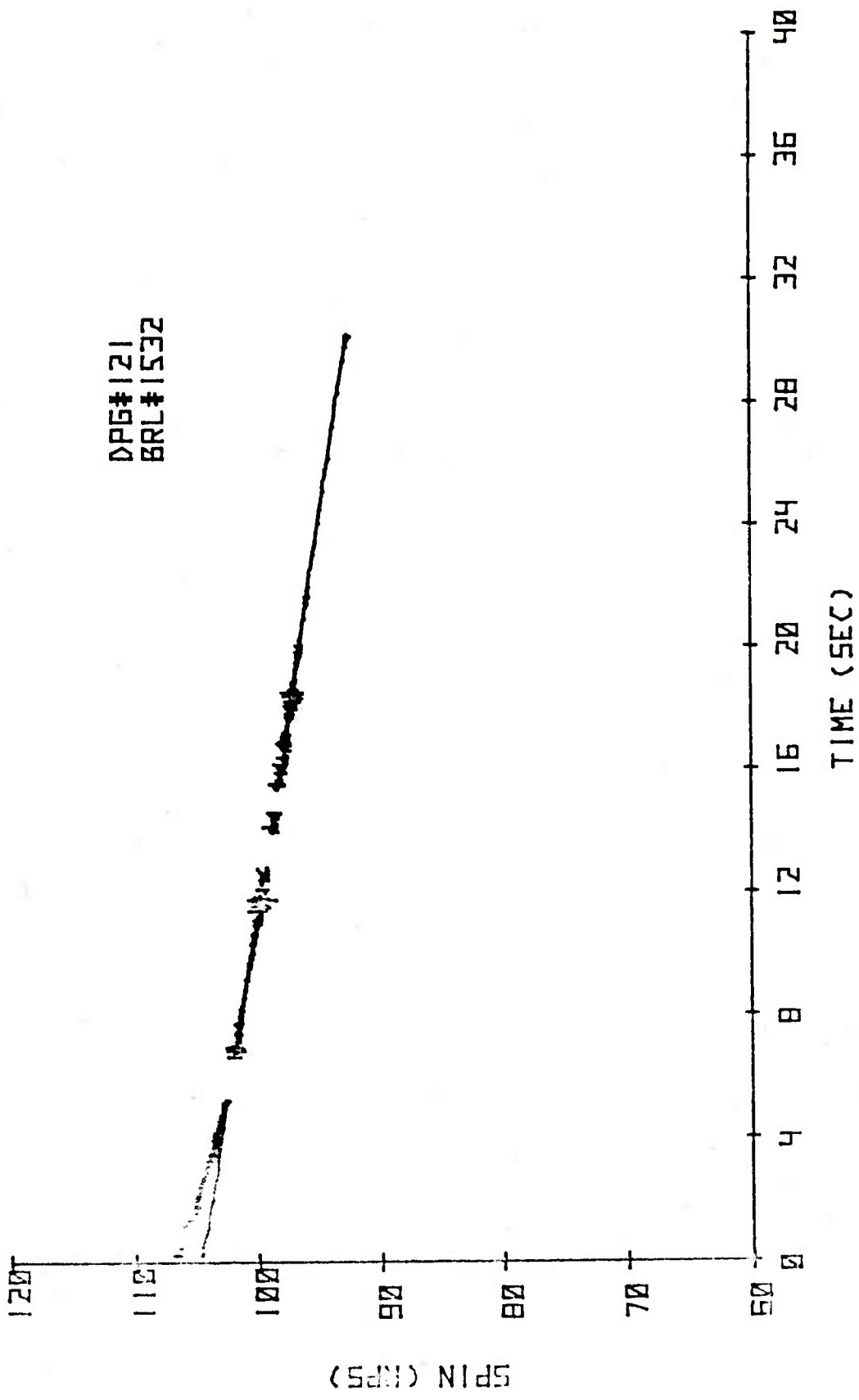


Figure 15. Spin Versus Time - Round 1532

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1. W.P. D'Amico, "Aeroballistic Testing of the XM825 Projectile: Phase I," Ballistic Research Laboratory Memorandum Report, ARBRL-MR-02911, March 1979. (AD#B037680L)
2. Mermagen, W.H., "Measurements of the Dynamical Behavior of Projectiles Over Long Flight Paths," Journal of Spacecraft and Rockets, Vol. 8, No. 4, April 1971, pp. 310-385.
3. Clay, W.H., "A Precision Yawsonde Calibration Technique," Ballistic Research Laboratories Memorandum Report No. 2263, January 1973, AD 758158.
4. Murphy, C.H., "Effect of Large High-Frequency Angular Motion of a Shell on the Analysis of Its Yawsonde Records," Ballistic Research Laboratory Memorandum Report No. 2581, February 1976, AD B0094210.
5. A. Mark, and W.H. Clay, "Aeroballistic Test of the XM802 RP Smoke Projectile," Ballistic Research Laboratory Memorandum Report, ARBRL-MR-02877, November 1978, AD B033753L.

APPENDIX A

TABLE A1. SURFACE METEOROLOGICAL DATA

Date: 13 June 1978

Round Number	Time	Wind Speed		Wind Direction (az from N)	Ambient Temp (°C)	Relative Humidity (pct)
		(m/s)				
		<u>avg</u>	<u>gusts</u>			
111	1053	6.3	8.7	170	26.7	26
112	1111	5.3	7.6	195	26.7	26
113	1120	5.1	7.8	186	27.0	26
114	1131	5.6	8.0	189	27.2	26
115	1210	6.1	8.3	234	28.8	22
116	1222	6.3	8.9	212	28.8	22
117	1235	8.5	11.2	233	28.8	22
118	1250	7.4	9.4	236	28.8	22
119	1332	5.6	7.4	225	29.9	24
120	1340	7.2	9.6	214	29.9	24
121	1347	8.0	11.6	223	29.9	24
124	1354	8.0	12.1	232	29.9	24

TABLE A2. METEOROLOGICAL DATA ALOFT

Date: 13 June 1978 Time: 1105 MDT Azimuth: 243.23

Altitude (m)	Temperature (°C)	Virtual Temperature (°K)	Density (kg/m ³)	Range Wind (m/s)	Crosswind (m/s)
0	28.8	303.1	1.001	- 6.2	0.3
300	23.8	297.5	0.986	- 3.3	2.9
600	21.0	294.7	0.961	- 4.7	5.1
900	18.5	292.2	0.936	- 5.4	6.0
1200	15.9	289.5	0.912	- 6.0	5.7
1500	13.3	286.9	0.888	- 7.9	5.5
1800	10.8	284.3	0.865	- 9.3	5.1
2100	8.4	281.9	0.841	- 9.4	5.0
2400	5.8	279.2	0.819	- 9.6	5.3
2700	3.2	276.6	0.797	-11.5	5.3
3000	1.6	274.9	0.772	-13.6	5.2
3300	-0.3	273.0	0.749	-15.2	5.0
3600	-2.7	270.6	0.727	-15.7	5.2
3900	-5.1	268.2	0.706	-16.1	5.8
4200	-7.5	265.8	0.686	-16.4	6.3
4500	-9.8	263.4	0.666	-16.2	5.9
4800	-12.2	261.0	0.647	-15.8	4.8

TABLE A3. METEOROLOGICAL DATA ALOFT

Date: 13 June 1978 Time: 1300 MDT Azimuth: 243.23

Altitude (m)	Temperature (°C)	Virtual Temperature (°K)	Density (kg/m ³)	Range Wind (m/s)	Crosswind (m/s)
0	30.0	304.0	0.997	6.5	5.8
300	25.4	299.2	0.979	- 4.6	5.5
600	22.7	296.4	0.955	- 4.2	5.5
900	19.9	293.5	0.931	- 4.5	6.3
1200	17.1	290.7	0.907	- 4.2	5.5
1500	14.3	287.9	0.885	- 4.1	5.9
1800	11.6	285.1	0.862	- 4.1	5.3
2100	8.9	282.3	0.840	- 4.3	4.6
2400	6.0	279.5	0.818	- 5.8	5.9
2700	3.2	276.6	0.796	- 8.1	6.8
3000	1.2	274.5	0.773	-10.7	6.9
3300	- 1.1	272.2	0.751	-12.8	6.6
3600	- 2.6	270.7	0.727	-15.4	5.6
3900	- 4.9	268.4	0.706	-15.8	5.9
4200	- 7.2	266.1	0.685	-16.9	6.6
4500	- 9.4	263.8	0.665	-18.4	8.5
4800	-11.8	261.4	0.646	-18.6	7.0

TABLE A4. SURFACE METEOROLOGICAL DATA

Date: 14 June 1978

Round Number	Time	Wind Speed		Wind Direction (az from N)	Ambient Temp (°C)	Relative Humidity (pct)
		(m/s)				
		<u>avg</u>	<u>gusts</u>			
318	1206	6.7	9.8	225	29.9	30
319	1212	6.5	9.2	235	30.0	30
322	1219	7.2	9.7	245	30.1	30
323	1223	7.4	10.7	245	30.2	30
320	1240	7.4	11.0	235	30.3	31
301	1246	8.0	12.7	235	30.4	31
302	1251	8.9	11.2	206	30.5	31
311	1257	6.3	9.4	220	30.6	31

TABLE A5. METEOROLOGICAL DATA ALOFT

Date: 14 June 1978 Time: 1325 MDT Azimuth: 243.23

Altitude (m)	Temperature (°C)	Virtual Temperature (°K)	Density (kg/m ³)	Range Wind (m/s)	Crosswind (m/s)
0	30.6	304.9	0.989	- 7.7	6.1
300	26.4	300.2	0.971	- 7.7	7.7
600	23.7	297.4	0.947	- 8.5	7.1
900	20.7	294.4	0.924	- 9.4	7.2
1200	17.8	291.5	0.901	- 9.5	7.8
1500	15.0	288.6	0.878	- 8.7	8.9
1800	12.2	285.8	0.856	- 8.2	10.8
2100	9.5	283.1	0.834	- 8.9	9.4
2400	6.6	280.1	0.812	- 9.4	7.8
2700	3.7	277.2	0.791	-10.5	7.4
3000	1.0	274.4	0.770	-11.6	7.2
3300	- 1.5	271.9	0.749	-12.6	6.0
3600	- 3.6	269.7	0.727	-14.1	4.7
3900	- 5.6	267.7	0.705	-15.8	4.1
4200	- 8.0	265.3	0.684	-18.1	4.6
4500	-10.1	263.2	0.664	-18.9	5.5
4800	-12.2	261.1	0.643	-16.5	5.9
5100	-14.4	258.8	0.624	-17.2	6.3
5400	-16.9	256.3	0.605	-18.0	6.2

APPENDIX B

APPENDIX B. PHYSICAL CHARACTERISTICS¹

DPG#	Weight (kg)	Length (m)	CG ² (m)	Moments of Inertia	
				Axial (kg·m ²)	Transverse (kg·m ²)
111	45.96	0.887	0.322	0.18	1.67
112	46.20	0.887	0.321	0.18	1.67
113	46.18	0.887	0.321	0.18	1.67
114	46.25	0.887	0.321	0.18	1.67
115	46.17	0.886	0.320	0.18	1.67
116	46.04	0.887	0.321	0.18	1.67
117	46.15	0.887	0.321	0.18	1.67
118	45.98	0.886	0.321	0.18	1.67
119	45.86	0.886	0.321	0.18	1.67
120	45.93	0.886	0.321	0.18	1.67
121	45.91	0.886	0.321	0.18	1.66
124	46.35	0.885	0.321	0.18	1.68

-
1. Average values of M483A1 projectiles from data by V. Oskay are:
weight - 46.83 kg, center of gravity (from base) - 0.333m,
moments of inertia - 0.158 kg·m² (axial) and 1.69 kg·m² (transverse),
length - 0.8973 m.
 2. Center of gravity is measured from the base.

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