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MEMORANDUM REPORT ARBRL-MR-03157

KINEMATIC INVESTIGATION HUGHES  
HELICOPTER 7.62MM CHAIN GUN

R. P. Kaste

February 1982



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

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A kinematic study of the Hughes Helicopter 7.62mm Chain Gun was performed to determine the power required to operate the weapon and loads on the stud roller due to the various components of the weapon. Using a 24-volt battery system the gun drew up to 60 amperes to start and operated on 22 amperes. The stud roller carries a load up to 497 Newtons.		

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## I. INTRODUCTION

The Small Caliber Weapons System Laboratory (SCWSL) of the U. S. Army Armament Research and Development Command (ARRADCOM) contacted the Mechanics and Structures Branch (MGSB) of the Interior Ballistics Division (IBD), Ballistic Research Laboratory (BRL), concerning the Hughes Helicopter 7.62 mm Chain Gun. The BRL agreed to perform a kinetic evaluation of the gun and collect motor characteristic data for their use in completing and evaluating a computer model of the chain gun.

A chain gun, SN EX 008 was received. Testing was begun to determine start-up loads for various initial positions within the firing cycle. Initially a Technipower Model LA 80-25 regulated power supply was used to power the gun. However, throughout the majority of the testing two 12 volt automotive batteries in series were used to more closely simulate the gun's use in a tank. Later, a Hughes Helicopter firing control box was delivered. This box stops the gun in the same position in the gun's firing cycle regardless of where it is when the trigger is released. Therefore, only one start up position is of importance. This position is on the rearward stroke of the bolt carrier just as the striker springs make contact for compression. Figure 1 shows the chain gun and its major components.

## II. TEST PLAN AND SETUP

In order to determine the loads on the motor, the input voltage and current to the motor were monitored. Figure 2 shows a schematic of this setup. Time histories of current and voltage were calibrated and stored using IBD's Ballistic Data Acquisition System (BALDAS). Bolt carrier and hand crank position information were also stored with BALDAS.

Time information from the position data was used to determine the average motor speed over the twelve revolutions it makes per gun cycle. Motor speed was used to determine the work done by the motor from the power information.

Two methods were used to monitor position. An Optron, which is an electro-optical device, was used to track the motion of the bolt carrier. This required that the bolt carrier be exposed. The second method provided position information without exposing the bolt carrier. This method consisted of attaching a one-turn potentiometer to the hand crank shaft which generated a saw tooth curve for each cycle of gun operation. The curve was then calibrated to provide the angular position of the hand crank. Because the moving components of the gun are keyed together, knowing the position of any one component will reveal the position of all the other components. Figures 3 and 4 show bolt-carrier position and hand crank angle with respect to operations of the gun.

By removing various components from the gun and comparing loads on the motor with and without a particular component, the load required to

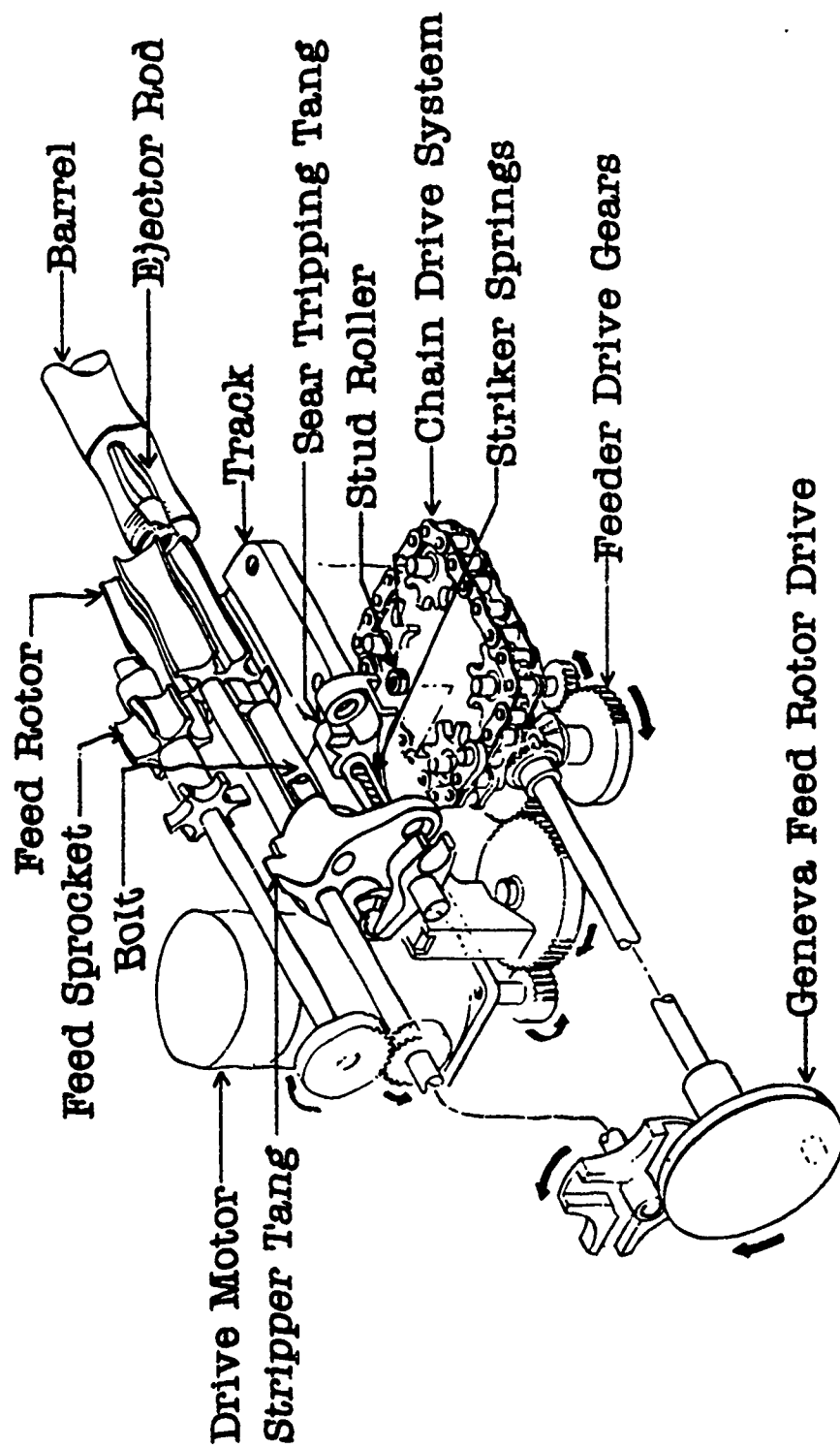


Figure 1. 7.62 mm Chain Gun and Components

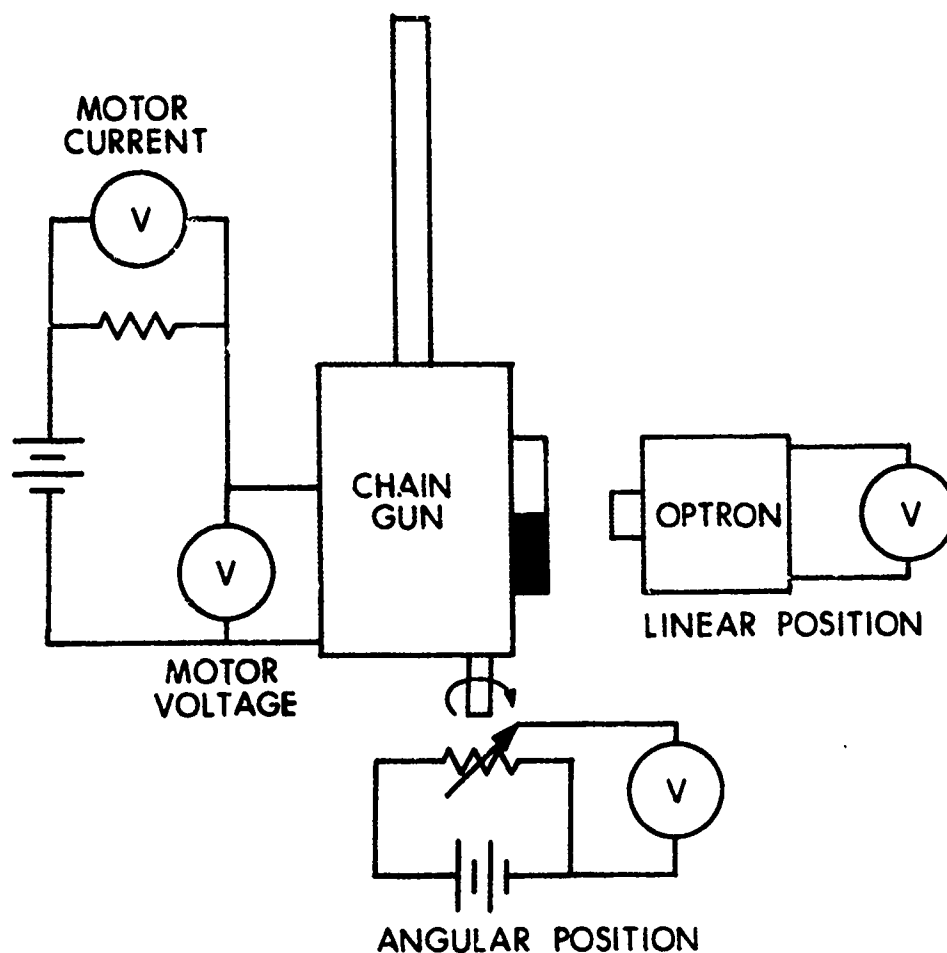


Figure 2. Test Setup Schematic

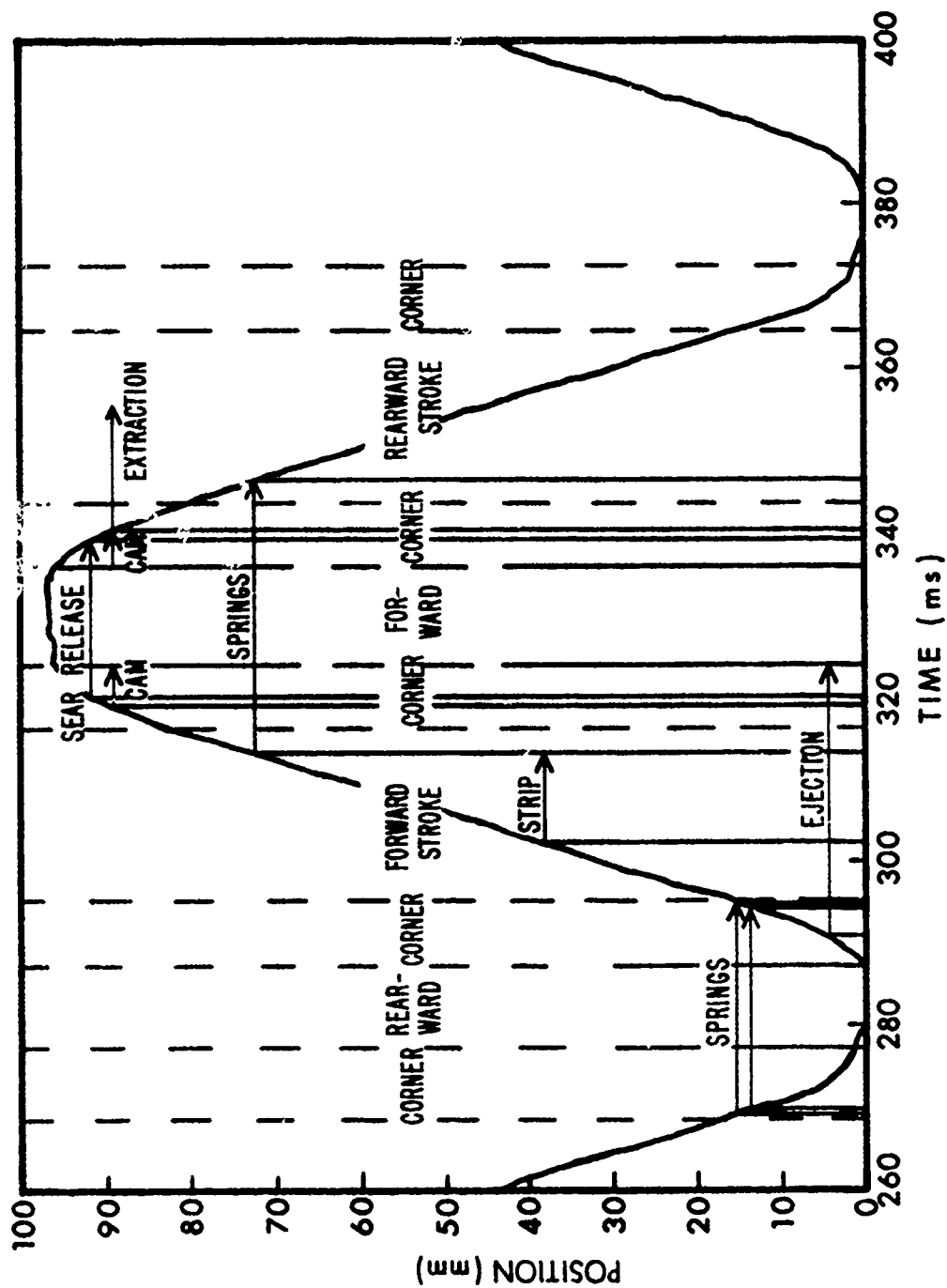


Figure 3. Bolt-carrier Position

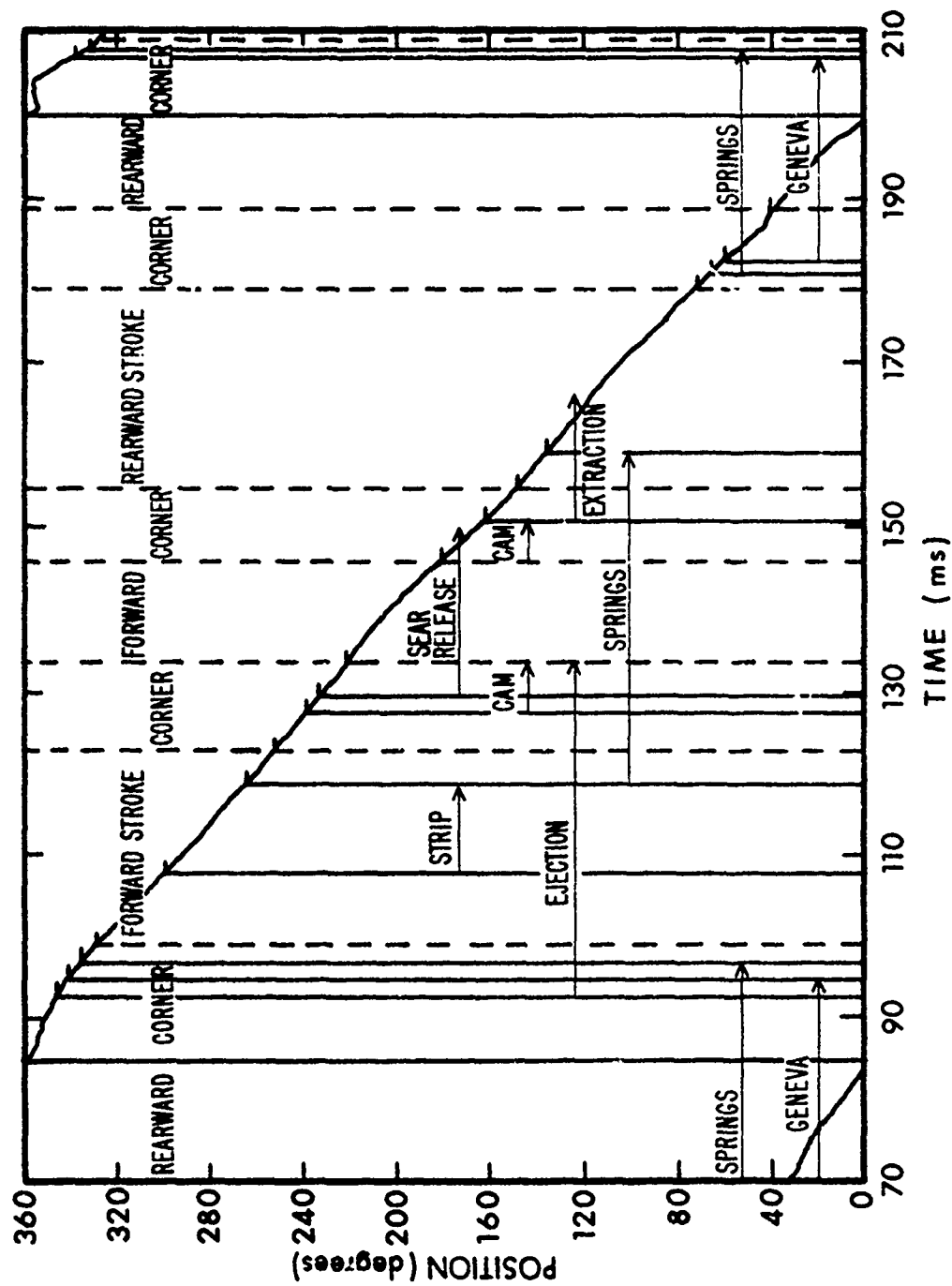


Figure 4. Angular Position of Hand Crank

function that component was determined. The following load components were evaluated:

- Effect of linked rounds;
- Effect of linked dummies;
- Load to release the striker;
- Load of striker springs;
- Effect of bolt-carrier mass;
- Load of feeder operation (geneva, feed sprocket and rotor);
- Load of chain

Additionally, the loads of ejecting, chambering, extracting, and stripping were determined from cycles within the firing data.

Muzzle velocity and dispersion data were also gathered. Muzzle velocity was determined using TSI Universal Counters triggered by five lumiline screens placed at known distances from each other and the muzzle. Muzzle velocity was extrapolated using a least squares fit through the velocities calculated between the screens. Dispersion was determined from a ten-round burst fired down a nominally 18 meter range into a cardboard target.

### III. RESULTS

Initial testing using the regulated power supply and the automotive batteries with 14 gauge wire provided less power than the Hughes control box and cable as shown in Table 1. One attempt to start the gun using the 14 gauge wire and 24 volt battery system failed. The bolt was positioned against the striker spring to provide a maximum start up load. The current reached 28 amperes and the voltage dropped to 11 volts yielding 300 watts which would not turn the motor against the load. Replacing this wire with 12 gauge wire increased the voltage at the motor from 19 volts to 22 volts and the running current from 13 to 16 amperes. At this time a Hughes control box and cable were acquired, eliminating the effect of cabling on the test. The Hughes cable is 10 gauge. The motor running voltage and current were increased to 23 volts and 20 amperes, respectively.

Starting the gun with rounds in the feeder sprocket using the Hughes control box required 1050 watts, with a peak current of 60 amperes. Energy consumption of the individual components are shown in Figure 5. The positions at which these loads are encountered are shown in Figure 6.

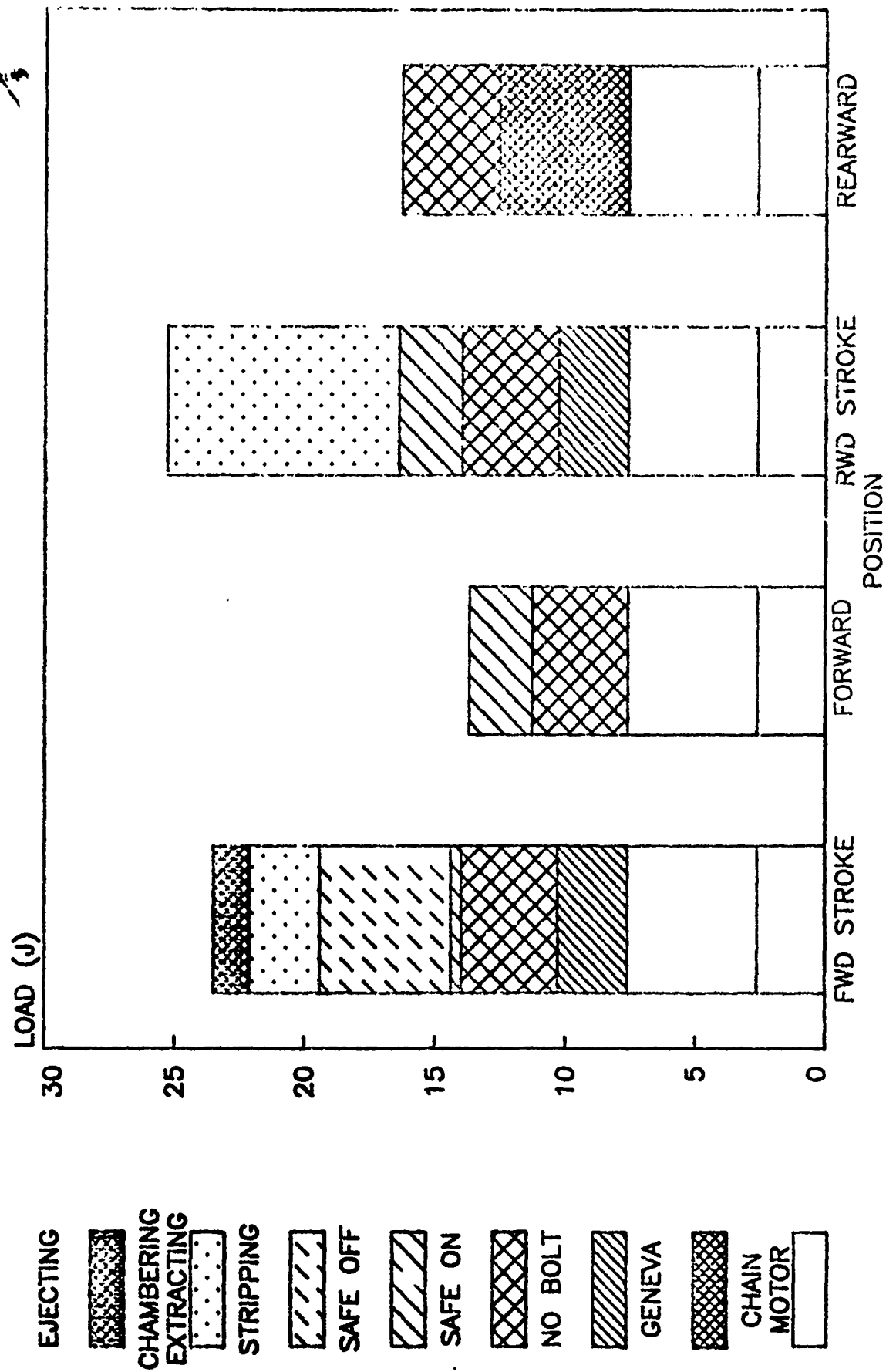
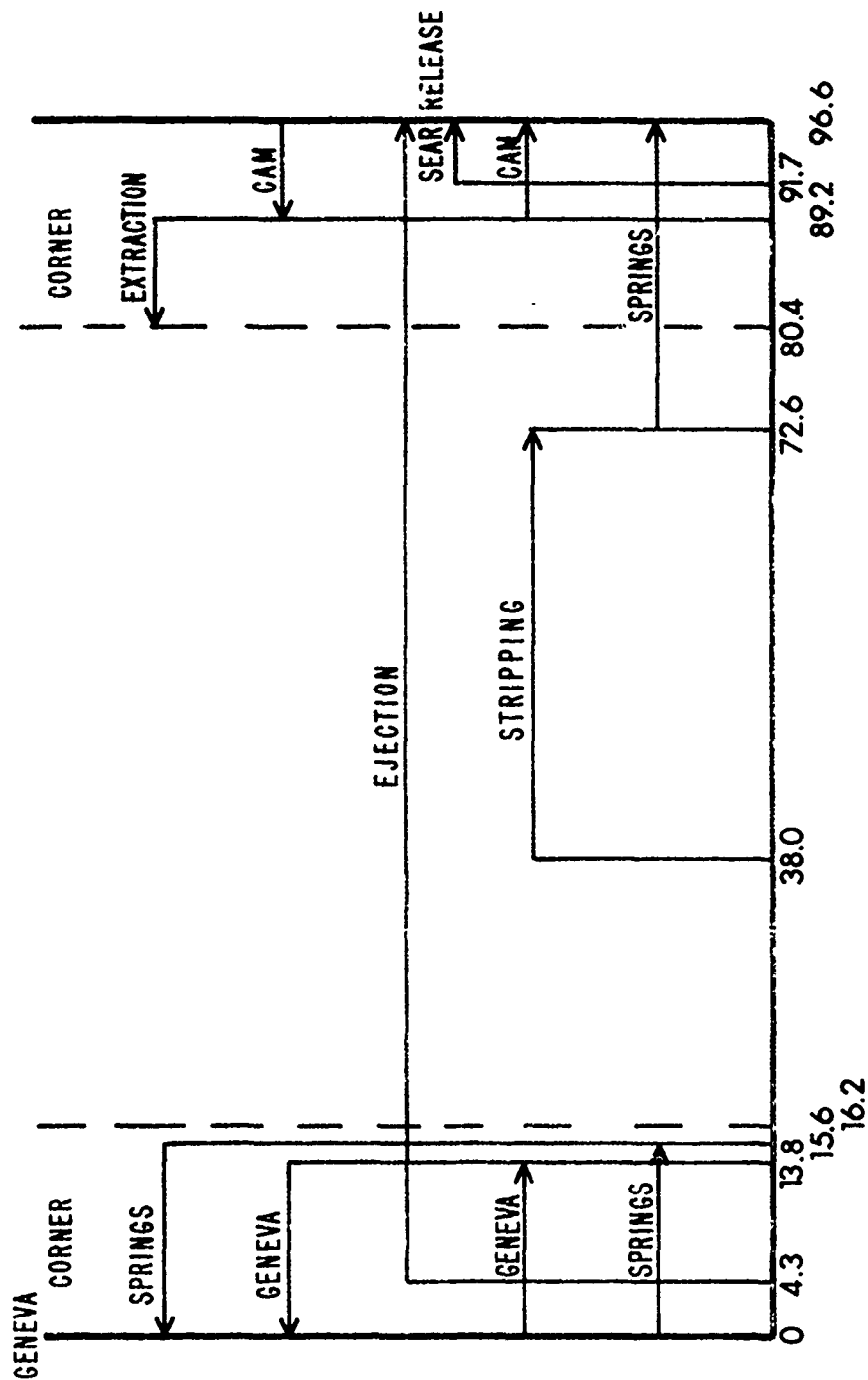


Figure 5. Component Loading of Chain Gun



BOLT CARRIER POSITION FROM REARWARD (mm)

Figure 6. Bolt-carrier Position of Loads

TABLE 1. EFFECTS OF CABLING

CONDITION	P <sub>peak</sub> (WATTS)	C <sub>peak</sub> (AMPS)	C <sub>running</sub> (AMPS)	V (VOLTS)	N (RPM)
14 Gauge Wire Power Supply	300	26	11	18	5760
14 Gauge Wire Batteries	290	24	12	19	5900
12 Gauge Wire Batteries	640	43	17	22	6860
Hughes Cable (10 Gauge) Batteries	1050	60	19	24	7580

Typical data output is shown in Figures 7 through 13. Figure 7 shows the voltage drop as the motor starts and the running voltage for steady state operation. Motor current is shown in Figure 8. Current peaks as the motor begins to turn and then drops to normal operating levels. Power and position, shown in Figure 9, give the required information to determine work done by the motor. Figures 10 and 11, safe on and safe off, are used to determine the power required to operate the sear safety assembly. The 165 Hz filter level used to simplify data reduction was determined experimentally to reduce noise in the steady state operation of the gun with little effect on the magnitude of current or voltage values. This filtration does effect the magnitude of start up peak loading and therefore was not used when determining these values. In cycle data, stripping and chambering is shown in Figures 12 and 13. Figure 13, Chambering includes the effects of extraction.

Loads on the stud roller were determined from the difference between the applied torque and the torque required to drive the chain and geneva gear. Because the roller cannot support a load in the "Y" direction, as shown in Figure 14, torque drops off when the bolt-carrier is in the rearward or forward positions. Torque, when the bolt-carrier is in these positions, is governed by the relationship of  $T = \mu rL$  where T equals torque, r is the moment arm, L is the load applied against the roller, and  $\mu$  is a friction coefficient. When the stud roller is in the forward or rearward strokes the friction coefficient,  $\mu$ , is omitted. The loads on the roller are shown in Figure 15. Calculations of these loads are presented in Appendix B.

The striker spring assembly was calibrated using an Instron testing machine. The spring constant for the assembly is 1629 N/m. The

7.62 MM CHAIN GUN

ROUND: 44 PLOT: 1

CONTROL BOX TEST

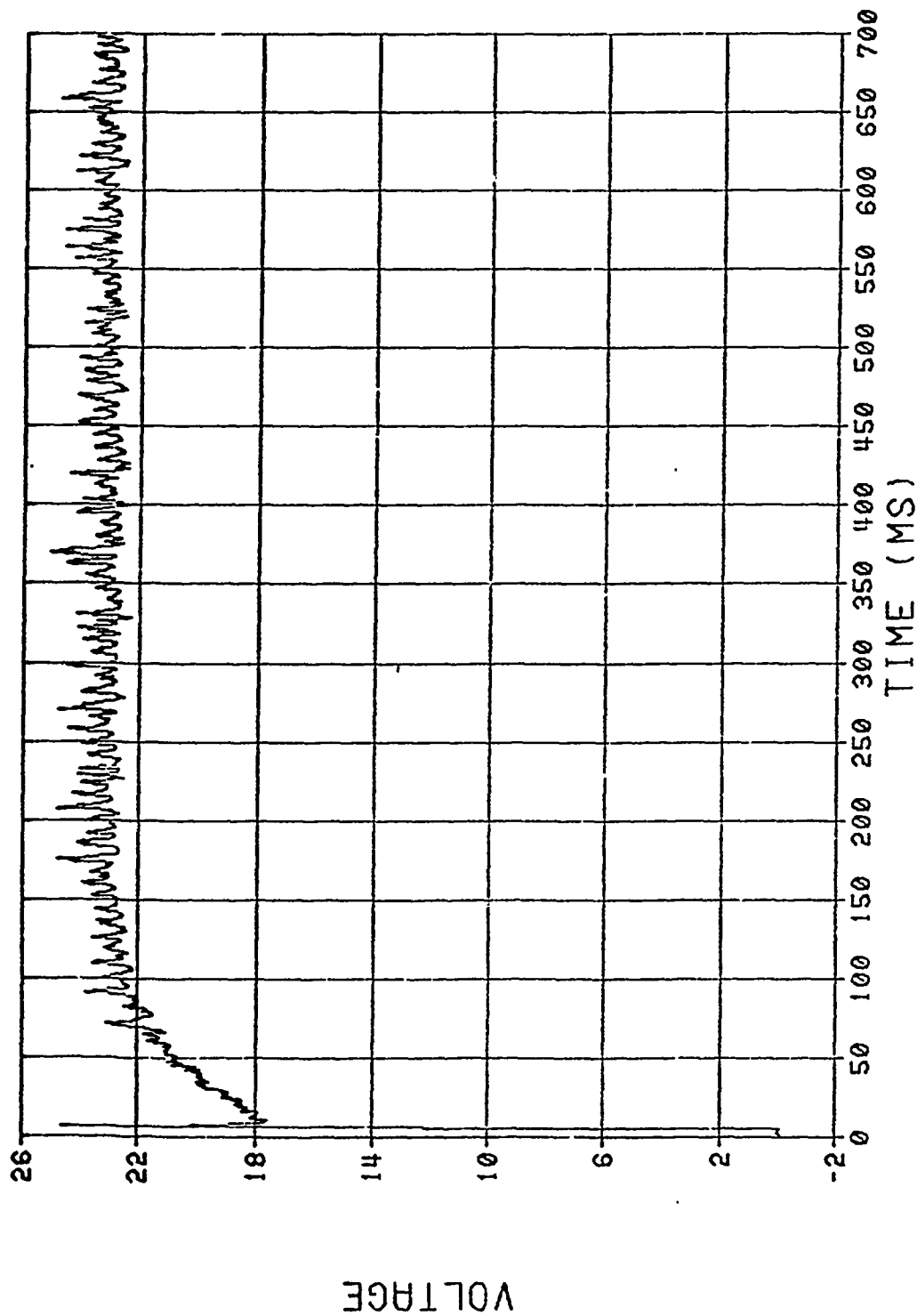


Figure 7. Motor Voltage

7.62 MM CHAIN GUN

ROUND: 44 PLOT: 2

CONTROL BOX TEST

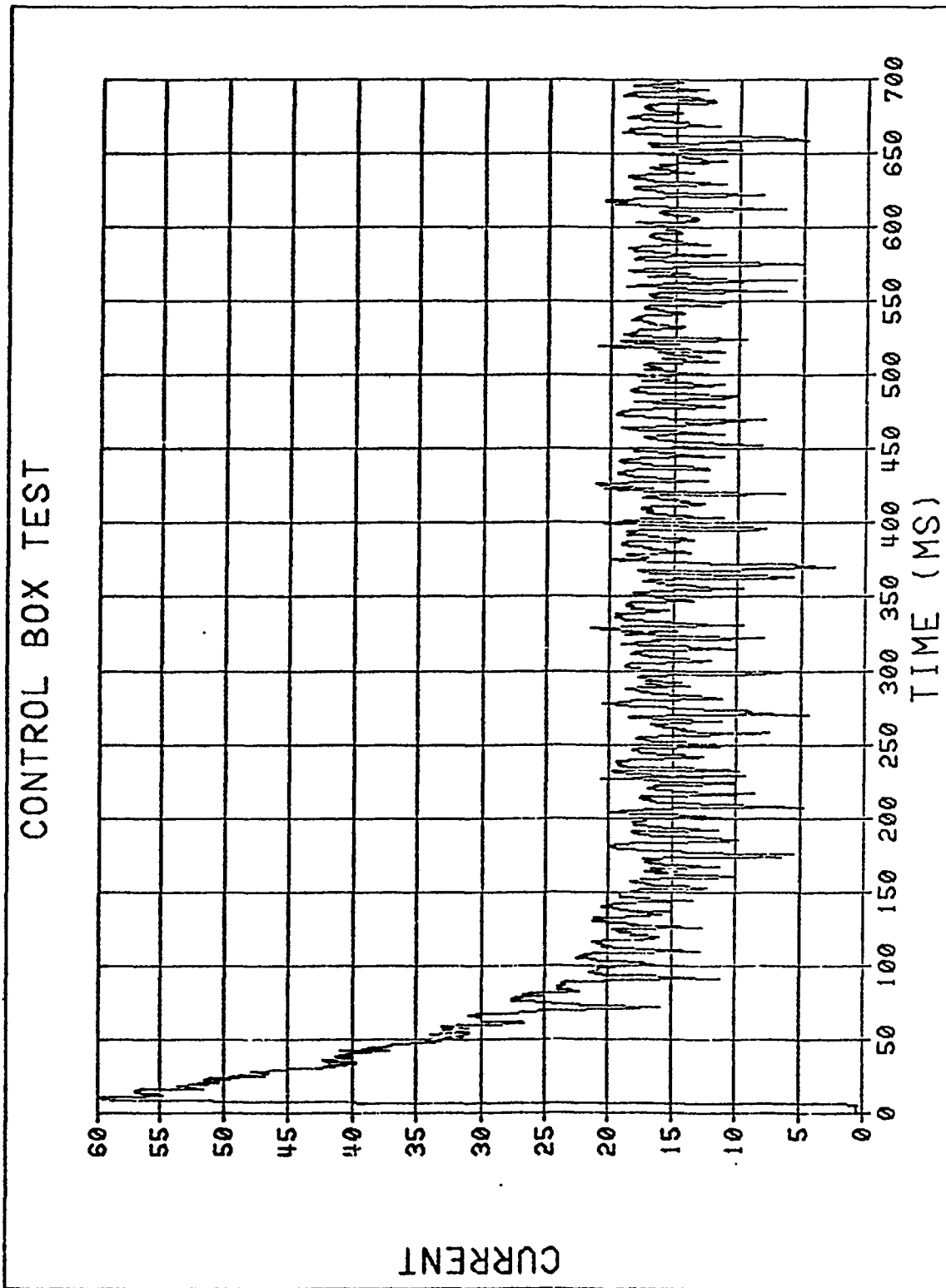


Figure 8. Motor Current

7.62 MM CHAIN GUN

SAFE OFF, NO ROUNDS

ROUND: 67 PLOT: 1

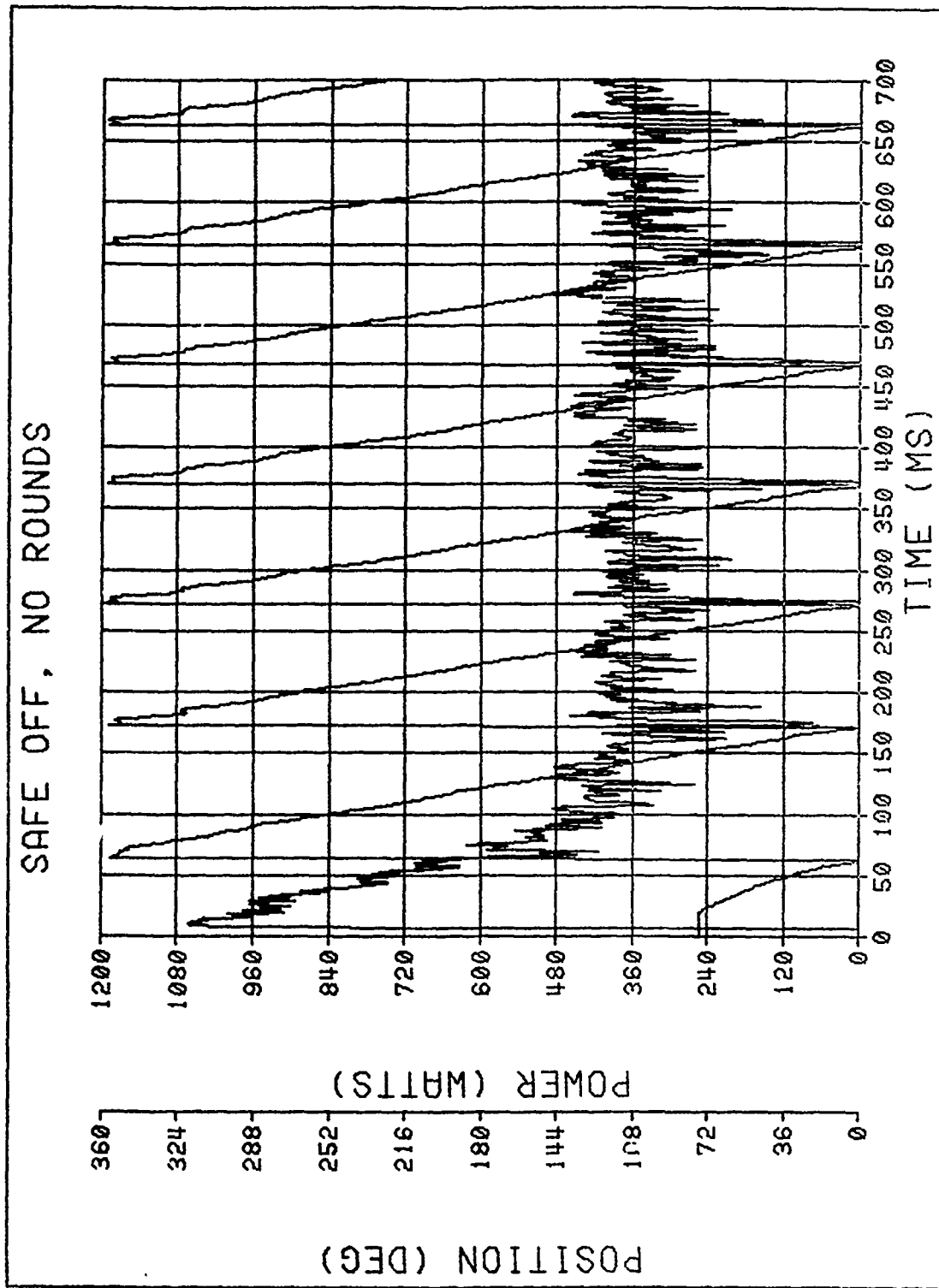


Figure 9. Power and Position

7.62 MM CHAIN GUN

ROUND: 47

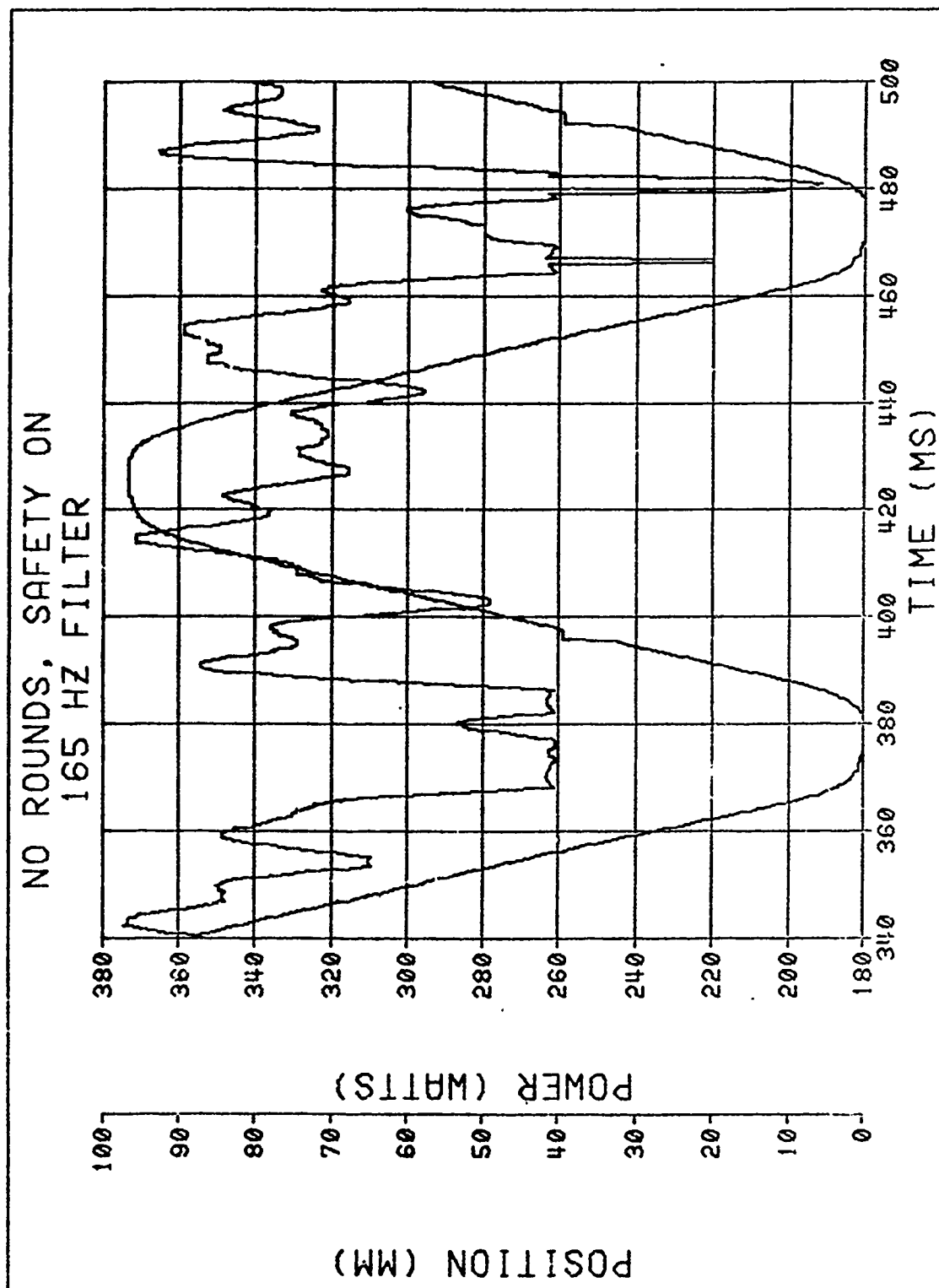


Figure 10. Power with Safe On

7.62 MM CHAIN GUN

ROUND: 46

NO ROUNDS, SAFETY OFF  
165 HZ FILTER

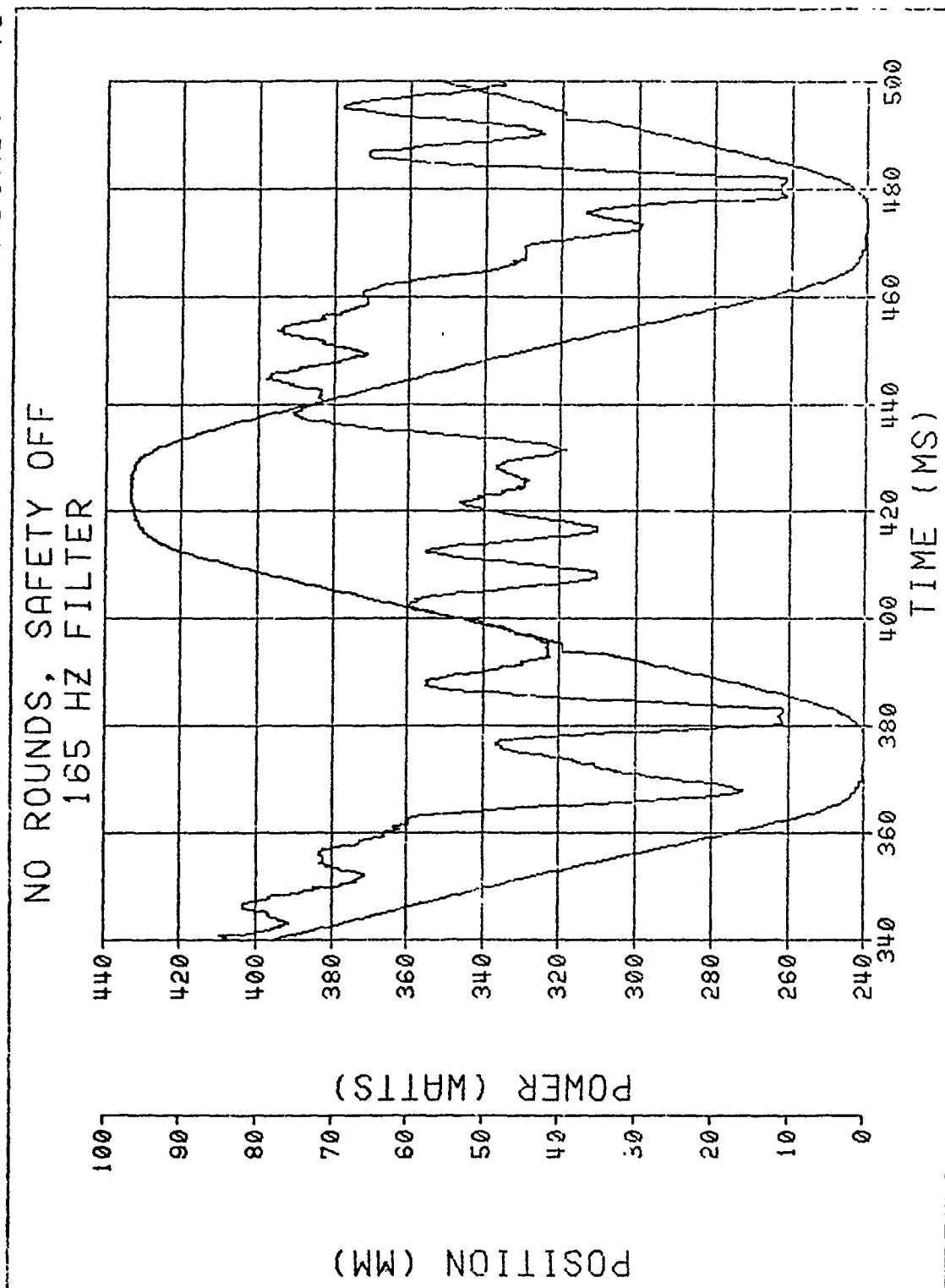


Figure 11. Power with Safe Off

7.62 MM CHAIN GUN

ROUND: 54

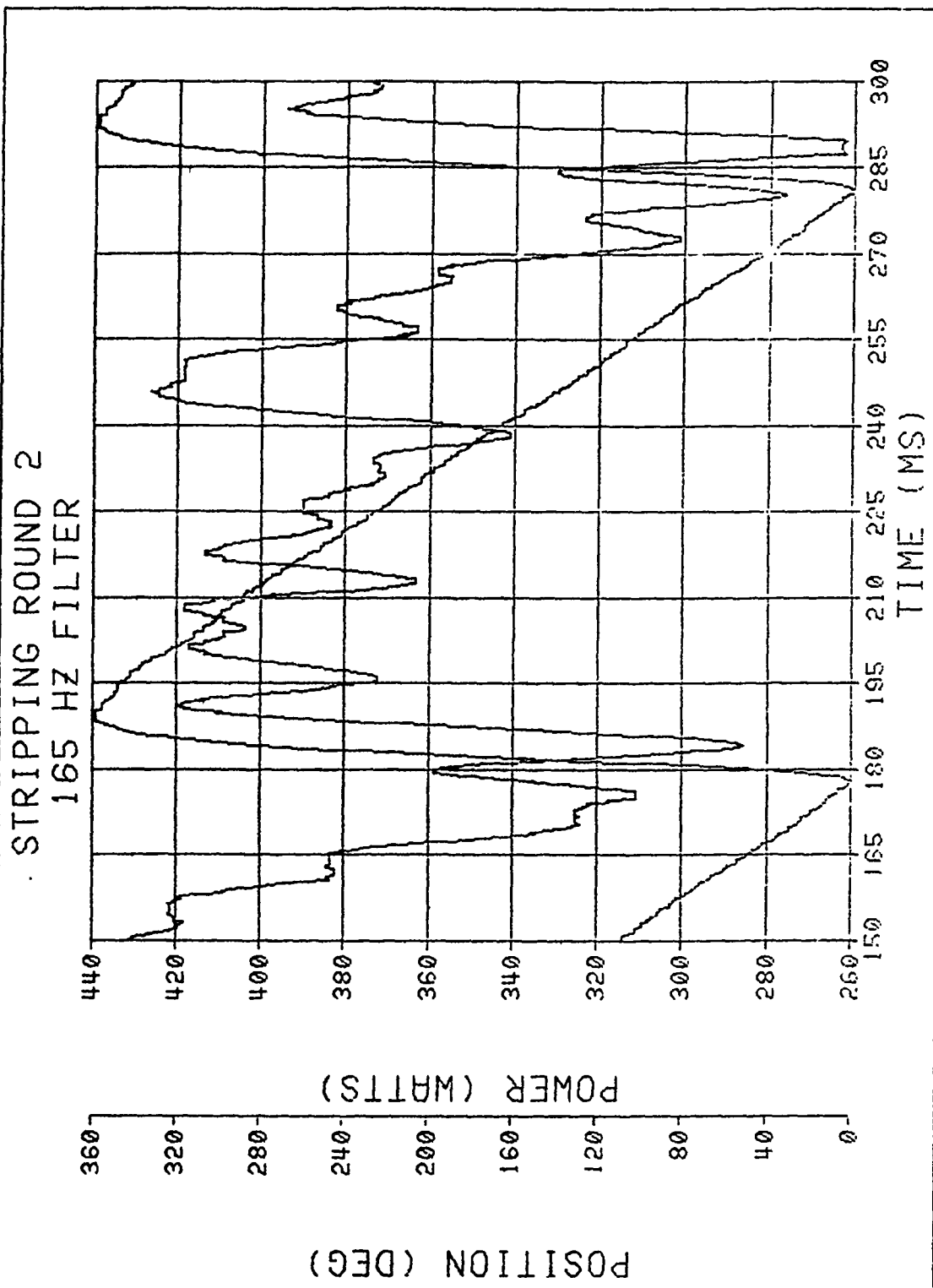


Figure 12. Power Stripping

7.62 MM CHAIN GUN

ROUND: 54

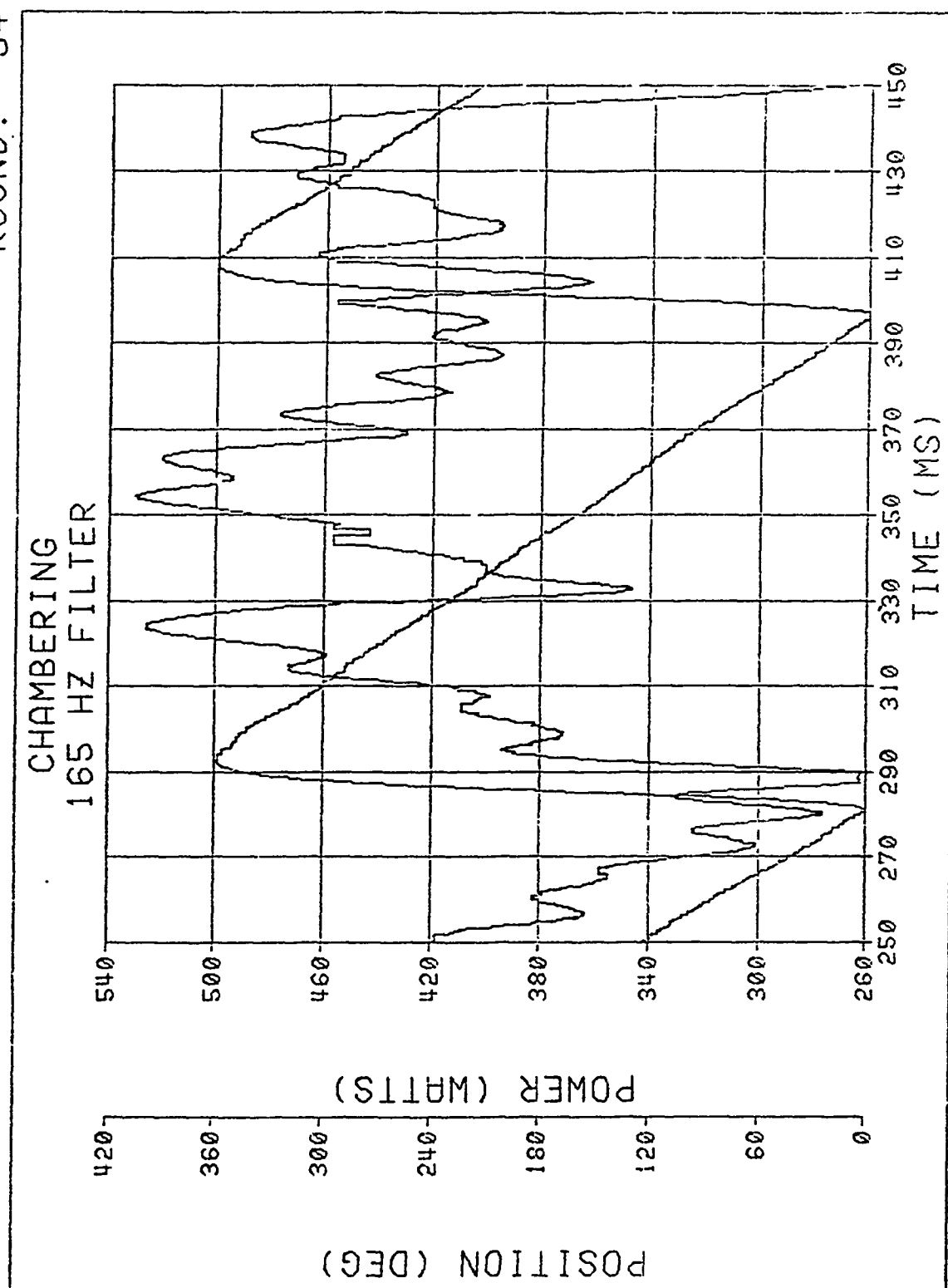
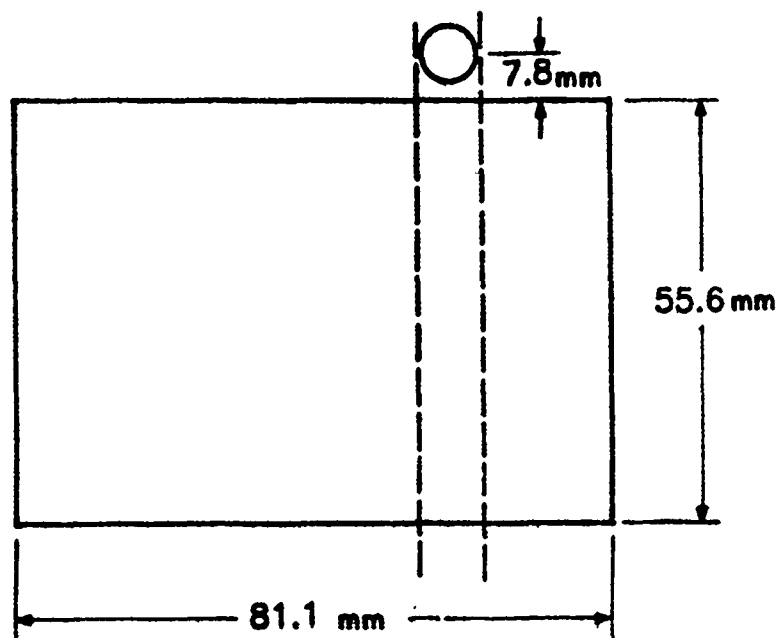
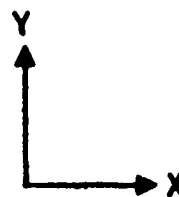


Figure 13. Power Chambering

BOLT CARRIER SLOT TRANSMITS  
ONLY LOADS IN THE "X"  
DIRECTION TO STUD



Figur. 14. Stud Roller/Bolt-carrier Interface

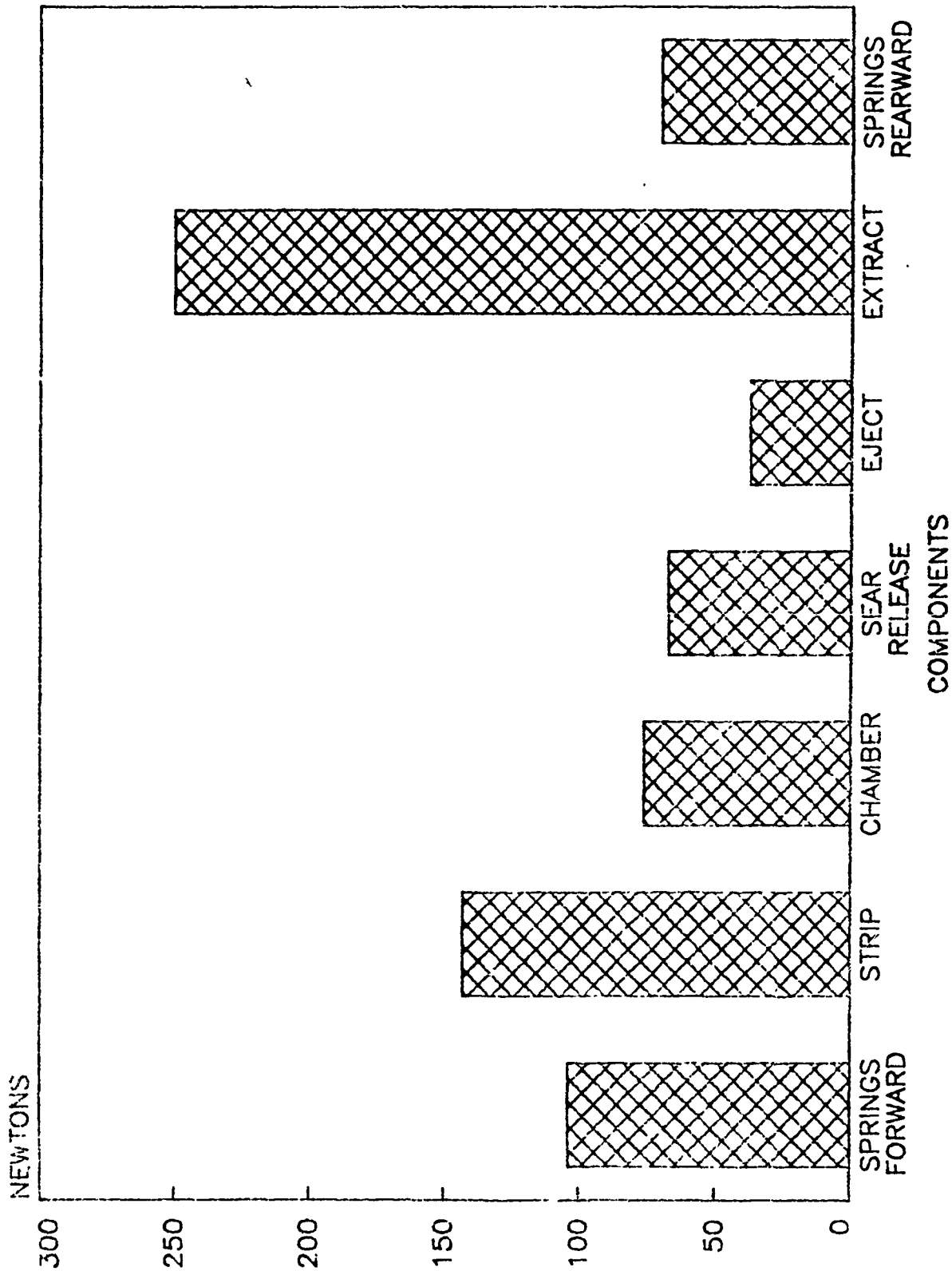


Figure 15. Stud Roller Loads

assembly has a preload of 53.4 N. In the forward position the springs are compressed to provide a load of 96.5 N. This corresponds well with the 104 N load on the roller found experimentally. The 104 N load also includes the effects of the extra mass of the bolt, locking and unlocking, interaction with the sear cam, and frictional losses as well as experimental error.

A newer version of the chain gun with a shunt field motor, rather than a permanent magnet motor as in the former version, required more power. The gun, when used with automotive batteries, used 2300 watts to start, drawing 101 amperes. Firing rounds, it drew 102 amperes to start and peaked at 25 amperes running as shown in Figure 16. It fired at a rate of 600 shots per minute (SPM). Firing with the new Hughes firing control box and power supply, which has a current limiting feature, the gun drew 47 amperes at start up which required 560 watts. It ran with a peak current of 19 amperes at a rate of 510 SPM as shown in Figure 17.

Firing a ten-round burst of ball ammunition at a target 19.0 m away yielded a maximum spread of 28.6 mm. This dispersion, shown in Figure 18, is 1.5 mil,  $\sigma_H$  is 5.17 mm and  $\sigma_V$  is 4.60 mm.

Muzzle velocity firing ball ammunition was found to be 890 m/sec as shown in Figure 19.  $\sigma$  was equal to 4.83 m/sec.

#### IV. CONCLUSIONS

The effect of the cable is of considerable importance because of the large current drawn at start up. Losses through the cable should be minimized by using large gauge cabling and reducing the cable length where possible.

Start up requires the greatest amount of power, drawing up to 60 amperes. The gun operating at 24 volts draws 22 amperes.

The stud roller carries loads of up to 497 Newtons.

The gun with the control box stops within 100 msec of trigger release, after extracting the fired case. Without the control box, the gun stops in a minimum of 150 msec and may take about 300 msec to stop. The gun will stop on either the forward or rearward stroke.

The new shunt wound motor draws 102 amperes from an automotive battery power supply and runs at 600 SPM. Operating with the Hughes power supply, starting current is 49 amperes and the gun operates at 510 SPM.

7.62 MM CHAIN GUN

ROUND: 61 PLOT: 3

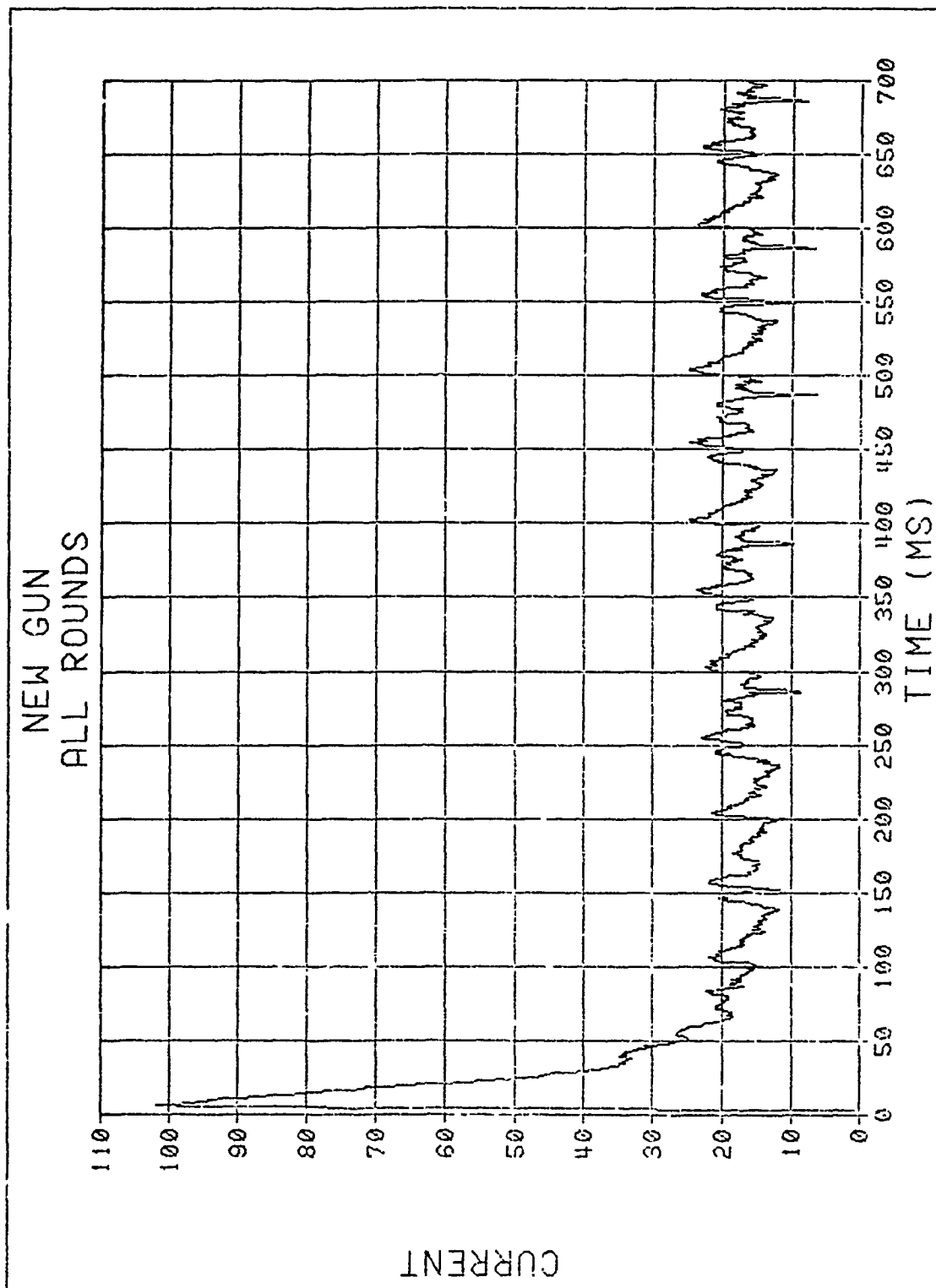


Figure 16. New Gun Current (Shunt Wound Motor)

7.62 MM CHAIN GUN                      ROUND: 63   PLOT: 4

NEW GUN WITH POWER SUPPLY  
ALL ROUNDS

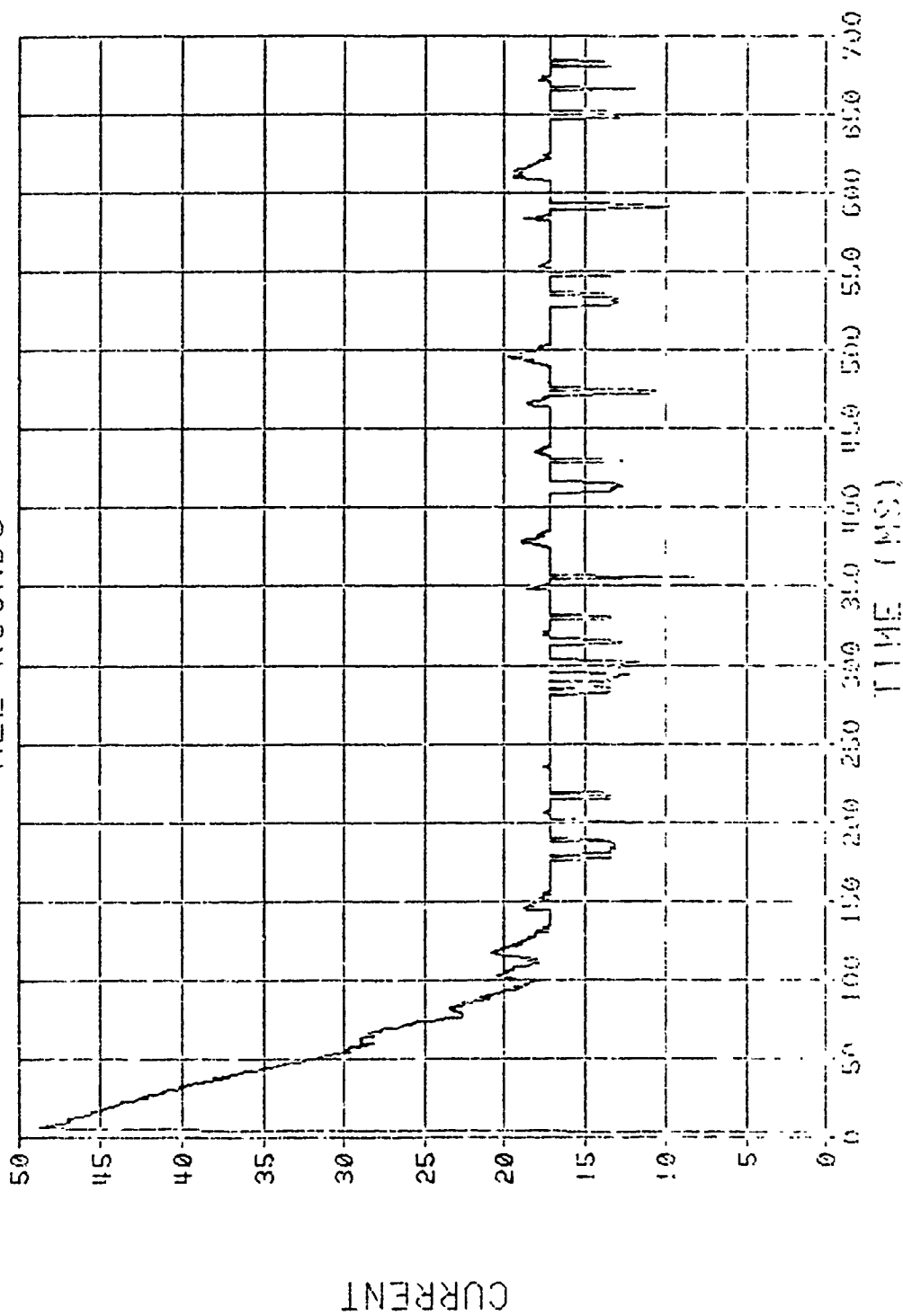


Figure 17. New Gun with Power Supply Current (Shunt Wound Motor)

10 ROUNDS (BALL)  
MUZZLE TO TARGET 19.04 m

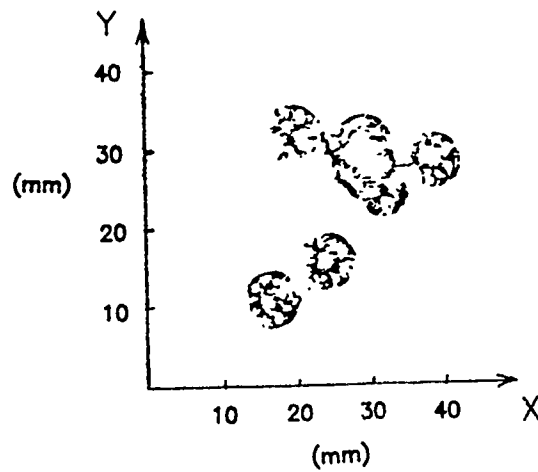


Figure 18. Dispersion

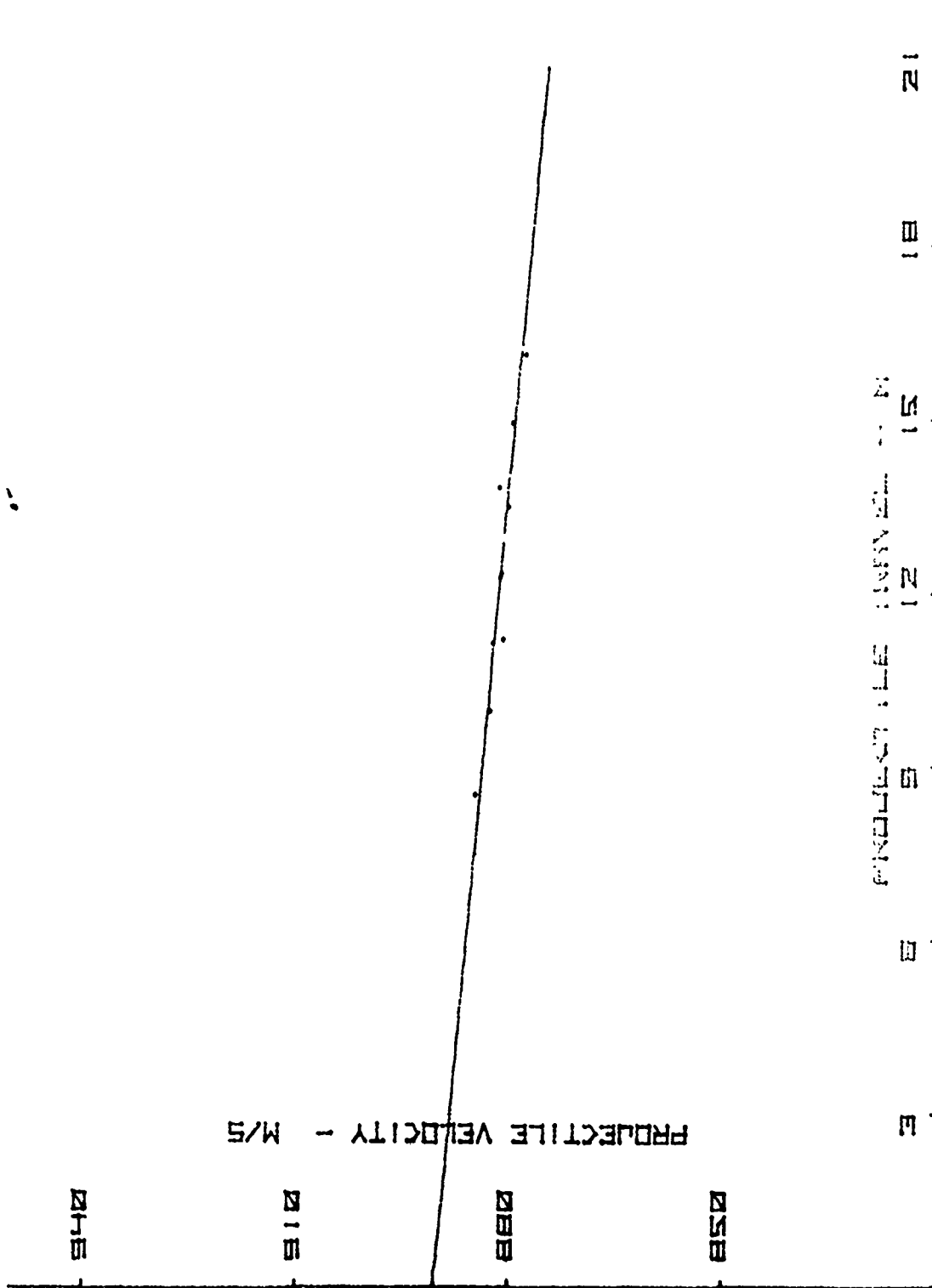


Figure 19. Muzzle Velocity

APPENDIX A  
MANIPULATED DATA

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APPENDIX A  
MANIPULATED DATA

12 Gauge Wire

CONDITION	P (Watts)	t (msec)	E' (J/min)	$t_1$ (r/min)	$\lambda$ (')
CHAIN AND GENEVA	210	87	12600	1317	9 6
SAFE ON	320	102	19240	1123	17 1
SAFE OFF	350	105	21000	1091	19 3

P - Power of operation

t - Period of one cycle

E' - Power

$t_1$  = Speed of Motor (radians/min).

E - Energy Required

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# GUN WITH HUGHES CONTROL BOX

CONDITION	P (Watts)	t (msec)	E' (J/min)	t <sub>1</sub> (r/min)	E (J)	*E <sub>Comp</sub> (J)
MOTOR	75	---	4500	1719	2.6	2.6
CHAIN	180	80	10800	1432	7.6	5.0
GENEVA	265	86	15900	1332	11.9	4.3
NO BOLT	310	90	18600	1273	14.6	2.7
SAFE ON	360	97	21600	1181	18.3	3.7
SAFE OFF	360	99	21600	1157	18.7	0.4
FORWARD						
REARWARD	400	99	24000	1157	20.7	2.4
DUMMIES						
CHAMBERING						
AND STRIPPING	430	107	25800	1071	24.1	5.4
EXTRACTING	420	107	25200	1071	23.6	2.9
DUMMIES	420	104	25200	1102	22.9	4.2
CHAMBERING						
AND STRIPPING						
EXTRACTING	430	104	25800	1102	23.5	2.8
ROUNDS	430	105	26600	1091	24.4	5.7
STRIPPING						
CHAMBERING	460	109	27600	1051	26.3	1.9
EXTRACTING	470	109	28200	1051	26.8	6.1
EXTRACTING	510	112	30600	1023	30.0	9.2
EJECTING	450	112	27000	1023	26.4	0.1
STRIPPING	430	103	26600	1113	23.2	4.5
CHAMBERING	450	108	27000	1061	25.5	2.3
EXTRACTING	460	108	27600	1061	26.0	5.3
EXTRACTING	540	112	32400	1023	31.7	11.0
EJECTING	500	112	30000	1023	29.3	3.8
STRIPPING	440	103	26400	1113	23.7	5.0
CHAMBERING	480	110	28800	1042	27.7	3.9
EXTRACTING	530	110	31800	1042	30.5	9.8
EXTRACTING	550	113	33000	1014	32.5	11.8
EJECTING	470	113	28200	1014	27.8	0.1

\*E<sub>Comp</sub> - Energy required to operate that component.

# NEW GUN (SHUNT WOUND MOTOR)

Condition	P (Watts)	t (msec)	L (J/min)	t <sub>l</sub> (r/min)	E (J)
CHAIN	165	88.5	8615	1295	6.6
SAFE ON	500	94.5	26100	1213	21.6
SAFE OFF	530	95	27670	1206	22.9
DUMMIES STRIPPING	530	99	29760	1158	23.9
DUMMIES "FIRING"	570	99	29880	1158	25.8
ROUNDS STRIPPING	590	100.5	30800	1140	27.0
ROUND FIRING	600	100.5	31320	1140	27.5
W/POWER SUPPLY 350 SAFE ON		97.5	18270	1175	15.6
W/POWER SUPPLY 360 ROUNDS		118.5	18790	967	19.4
W/POWER SUPPLY 165 CHAIN		88.5	8610	1295	6.6

APPENDIX B  
STUD ROLLER LOAD CALCULATIONS

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## APPENDIX B

### STUD ROLLER LOAD CALCULATIONS

$L = T/\Gamma$ ,  $L$  = Load on Roller,  $T$  = Torque,

$\Gamma$  = moment arm

$\Gamma = 55.6/2 + 7.8$  mm, Roller on side of sprocket support

$\Gamma = .0356$  m

#### LOAD OF SPRINGS (FORWARD) (SAFE ON - NO BOLT)

$L = (18.3 - 14.6)/.0356$

$L = 104$  N

#### LOAD OF STRIKER REARWARD)

(SPRINGS: 290 w @ 97 msec, NO BOLT 260 w @ 90 msec)

$L = (14.7 - 12.2)/.0356$

$L = 70$  N

#### LOAD OF STRIKER RELEASE (SAFE OFF - SAFE ON)

$L = (20.7 - 18.3)/.0356$

$L = 67$  N

#### LOAD OF STRIPPING (STRIPPING - SAFE OFF)

$L = (23.8 - 18.7)/.0356$

$L = 143$  N

#### LOAD OF CHAMBERING (CHAMBERING - STRIPPING)

$L = (26.5 - 23.8)/.0356$

$L = 76$  N

#### LOAD OF EXTRACTION (EXTRACTION - SAFE OFF REARWARD)

$L = (29.6 - 20.7)/.0356$

$L = 250$  N

#### LOAD OF EJECTION (EJECTION - CHAMBERING)

$L = (27.8 - 26.5)/.0356$

$L = 37$  N

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TOTAL LOADS ON ROLLER

$$\text{LOAD} = (\text{WORK DONE TOTAL} - \text{WORK NOT DONE THROUGH ROLLER}) / .0356$$

FORWARD STROKE

$$L = (23.5 - 7.6) / .0356$$

$$L = 447 \text{ N}$$

REARWARD STROKE

$$L = (25.3 - 7.6) / .0355$$

$$L = 497 \text{ N}$$

APPENDIX C  
STRIKER SPRING ASSEMBLY CALIBRATION

## APPENDIX C

### STRIKER SPRING ASSEMBLY CALIBRATION

0 COMPRESSION 12.0 LB (53.4 N)

.805 Inch (20.4 mm) COMPRESSION 19.5 LB (86.7 N)

SPRING RATE 9.3 LBS/IN + 12.0 LBS  
(1628.7 N/in + 53.4 N)

#### IN USE PRELOAD

.12 Inch (3.0 mm) COMPRESSION  
Yields 13.1 LB (58.3 N)

#### FOREWARD

1.04 Inch (26.4 mm) COMPRESSION  
Yields 21.7 LB (96.5 N)

#### REARWARD

.56 Inch (14.2 mm) COMPRESSION  
Yields 18.6 LB (82.6 N)

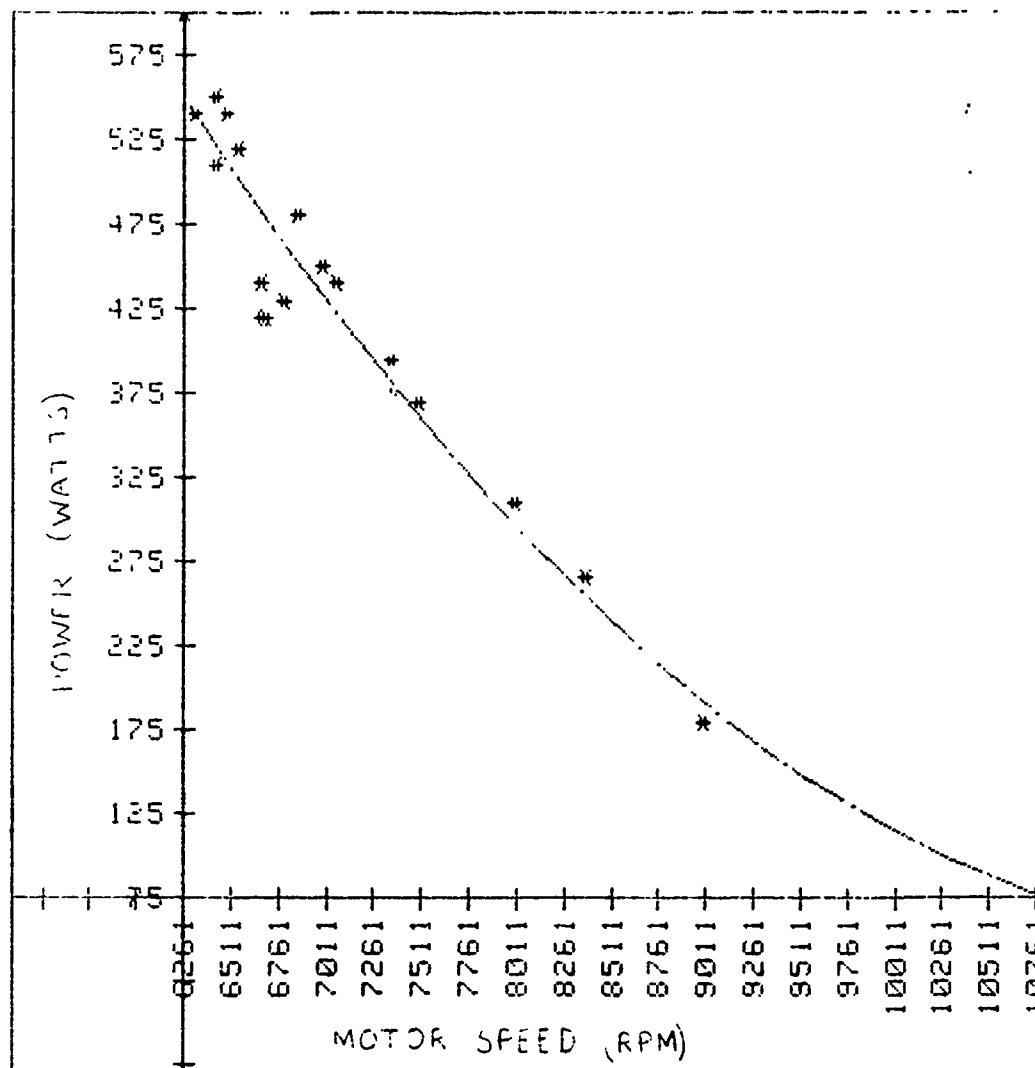
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APPENDIX D  
MOTOR DATA AND SPECIFICATIONS

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**APPENDIX D**  
**MOTOR DATA AND SPECIFICATIONS**

POLYNOMIAL



TACHTRONIC INSTRUMENTS DC MOTOR PART NO. 25DCMI 313

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# DATA

Point #1:	X=9000	Y=180
Point #2:	X=8372	Y=265
Point #3:	X=8000	Y=310
Point #4:	X=7500	Y=370
Point #5:	X=7347	Y=395
Point #6:	X=6667	Y=420
Point #7:	X=6667	Y=440
Point #8:	X=6990	Y=450
Point #9:	X=6429	Y=550
Point #10:	X=6690	Y=420
Point #11:	X=6316	Y=540
Point #12:	X=6857	Y=480
Point #13:	X=6792	Y=430
Point #14:	X=6429	Y=510
Point #15:	X=6261	Y=600
Point #16:	X=7059	Y=440
Point #17:	X=6545	Y=520
Point #18:	X=6486	Y=540
Point #19:	X=10800	Y=75

POLYNOMIAL MODEL:  $Y=A(M)X^M+A(M-1)X^{(M-1)}+...+A(1)X+A(0)$

Coefficients:

$A(0)=2193.665511$

$A(1)=-.354012359$

$A(2)=1.46219658000E-05$

Source	Df	SS	MS	F
Regression	2	300435.535	150217.767	141.942
Residual	16	16932.886	1058.305	
Total	18	317368.421		

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APPENDIX E  
DEFINITION OF TERMS

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## APPENDIX E

### DEFINITION OF TERMS

- MOTOR - Motor and drive sprocket are the only components in operation.
- CHAIN - In addition to motor the chain and sprocket support are operational.
- GENEVA - In addition to chain the Geneva mechanism and feeder sprocket and rotor are included.
- NO BOLT - In addition to geneva the bolt-carrier without the bolt and striker assembly is included.
- SAFE ON - In addition to no bolt the bolt and striker assembly are included. The safety knob is in the "SAFE" position.
- SAFE OFF - ARC components, safety knob is in the "FIRE" position.
- FORWARD STROKE - Bolt-carrier is in motor towards front of gun; includes corners of chain operation.
- FORWARD - Bolt-carrier is in stationary forward most position.
- REARWARD STROKE - Bolt-carrier is in motion towards rear of gun. Includes corners of chain operation.
- REARWARD - Bolt carrier is stationary in rearward most position.

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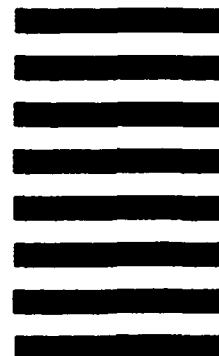


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