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KINEMATIC STUDY OF THE M16A1 RIFLE

by

Timothy L. Brosseau

January 1972

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Timothy L. Brosseau

Interior Ballistics Laboratory

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TLBrosseau/ams
Aberdeen Proving Ground, Md.
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KINEMATIC STUDY OF THE M16A1 RIFLE

ABSTRACT

A kinematic study was performed on the M16A1 Rifle under several different mounting and weapon conditions. Displacement versus time, time to projectile exit, recoil impulse, and muzzle velocity were measured. Results showed large round-to-round variations in the rate of fire within a 20-round burst. To determine the cause of these variations, static and dynamic force measurements were taken. Results showed large round-to-round variations in the forces associated with the magazine. To determine the effect of these variations on the rate of fire, tests were performed using a constant force, low-drag magazine. Results showed that the round-to-round variations in the forces associated with the magazine affect the rate of fire for the first three rounds fired from a full 20-round magazine. Results also showed that the coefficient of restitution of the polyurethane buffer button varies for the first three rounds fired in a burst.

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I. INTRODUCTION

The Product Manager, Rifles, at the U.S. Army Weapons Command requested that the Ballistic Research Laboratories perform a kinematic study on the M16A1 Rifle. To further evaluate the kinematics of the weapon, static and dynamic force measurements were also made in the study.

II. FUNCTIONING OF THE M16A1 RIFLE

The functioning components of the M16A1 Rifle are shown in Figure 1.

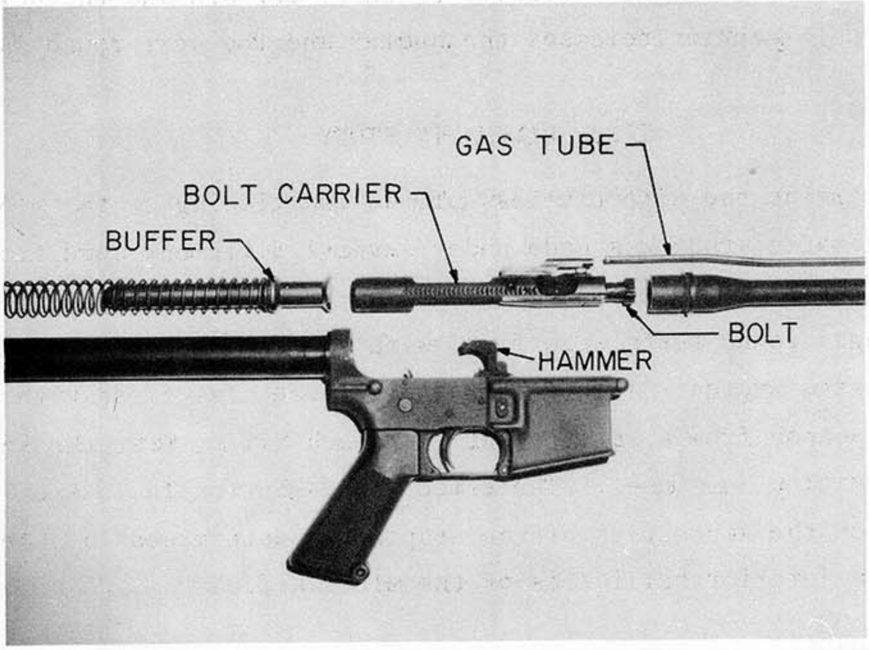

Figure 1. Functioning Components of the M16A1 Rifle

The hammer is released by pulling the trigger and the first round is fired. Propellant gas from the rifle bore passes down the gas tube and pushes forward on the bolt and rearward on the bolt carrier. As the bolt carrier moves rearward it rotates the bolt by means of a cam and pin which unlocks the bolt from the barrel extension. When the bolt carrier has moved a short distance, two vent holes in the bolt carrier are uncovered and the remaining gas in the gas tube is released to the atmosphere. A spring loaded extractor pulls the fired cartridge case from the chamber as the bolt moves rearward after unlocking. A spring loaded plunger in the face of the bolt ejects the cartridge case after extraction. The bolt carrier continues rearward until the polyurethane buffer button, attached to the end of the buffer assembly, contacts the end of the buffer tube. The buffer assembly consists of alternately spaced weights and rubber discs which slide freely in a tube. The bolt carrier then starts forward and the bolt lug strips the next round from the magazine. When the bolt carrier is fully forward and the bolt is locked the bolt carrier releases the hammer and the next round is fired.

III. KINEMATIC STUDY

To determine the effectiveness of the functioning of the M16A1 Rifle a kinematic study was made under several different conditions. The weapon was fired from a rigid mount and from a free recoil pendulum mount. Single round tests were fired with a lubricated weapon and with an unlubricated weapon. Twenty round burst were also fired with a lubricated weapon from a rigid mount. In each firing test the same lot of ammunition was used. The effect of variation in lots of ammunition on the kinematics of the weapon was determined in a separate study on the interior ballistics of the M16A1 Rifle.

A. Measurements

1. Displacement versus Time. The displacements of the bolt carrier and the receiver were recorded with a displacement-time camera[1*] during firing of the test rounds.

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[*] References are listed on page 50 of this report.

2. Recoil Impulse. In the test firings with the weapon constrained in the free recoil pendulum mount, the recoil impulse imparted to the weapon was measured. The recoil impulse was determined by measuring the velocity of the receiver from the displacement-time records.

3. Projectile Exit. The time of the projectile exit was recorded by placing a photocell[2] at the muzzle of the weapon. The photocell sensed the projectile exit and triggered a pulse circuit which placed a light flash on the displacement versus time record.

4. Muzzle Velocity. The muzzle velocity was measured by placing three lumiline screens downrange, 12 feet apart. As the projectile passed through the screens, electronic counters and a printer were actuated which recorded the time of flight between screens for each round fired. The average velocity midway between screens was calculated and then extrapolated back to the muzzle.

B. Test Setup and Procedure

The weapon was constrained in a rigid mount and a free recoil pendulum mount during the firing tests. The test mounts are shown in Figures 2 and 3. The weapon was fired with a solenoid which was controlled, in relation to the shutter opening on the displacement-time camera, by means of an electronic sequence timer. In each single round firing test, one ball round of Lot No. LC12304 was loaded in a magazine on top of one dummy round. The dummy round was used to make the bolt carrier return to battery so that records could be obtained during a complete cycle. In each 20-round burst firing test 20 rounds of Lot No. LC12304 were loaded in a standard magazine.

Displacement versus time records were recorded on photographic paper attached to the rotating drum in the displacement-time camera. Muzzle velocity records were recorded on strip chart paper contained in the printer.

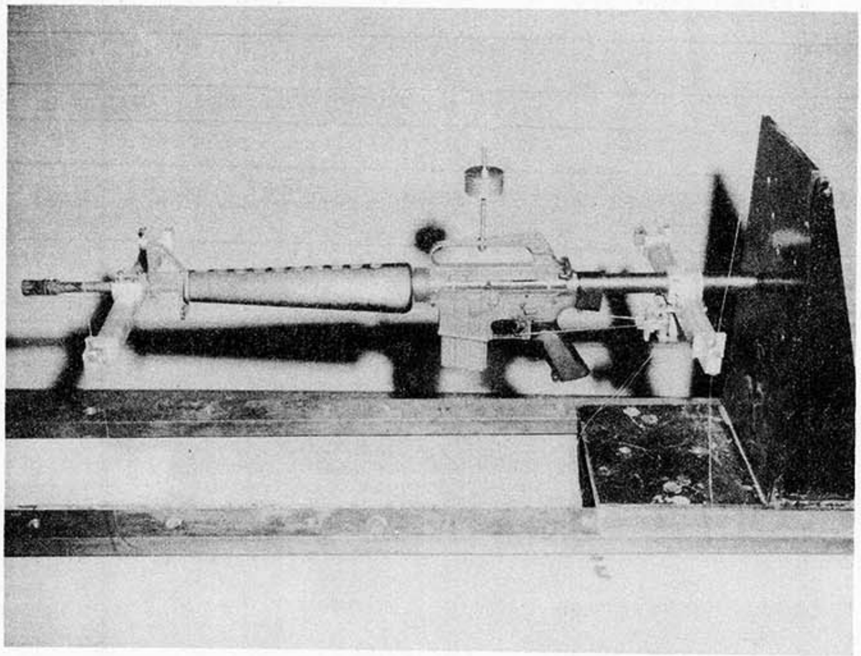

Figure 2. Rigid Mount

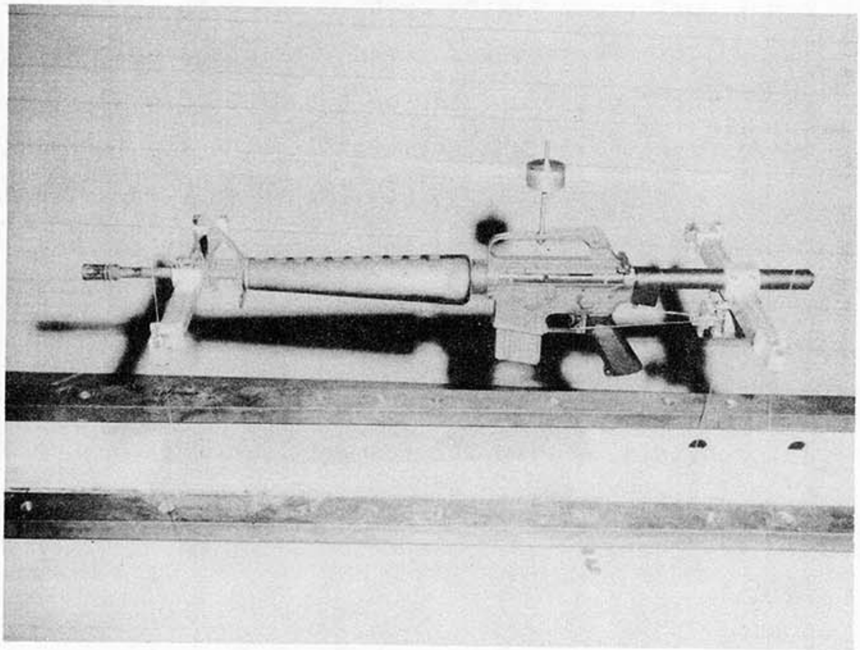

Figure 3. Free Recoil Pendulum Mount

C. Results

The results of the test firings are summarized in Tables I and II. Sample records are shown in Figures 4 and 5.

Table I. Results of Single Round Kinematic Measurements

No. of Rds.	Weapon Condition	Test Mount	Rate of Fire (rds/min)		Muzzle Velocity (ft/sec)		Impulse (lb sec)	
			Av	σ	Av	σ	Av	σ
10	Lubricated	Rigid	845	12	3184	15		
10	Unlubricated	Rigid	745	14	3197	24		
10	Lubricated	Free Recoil Pendulum	862	11	3195	14	1.23	.05
10	Unlubricated	Free Recoil Pendulum	768	16	3189	15	1.25	.02

Table II. Results of 20-Round Burst Kinematic Measurements

No. of Rds.	Position in Burst	Rate of Fire (rds/min)		Muzzle Velocity (ft/sec)	
		Av	σ	Av	σ
10	1st rds	687	19	3166	25
10	2nd rds	739	15	3173	17
10	3rd rds	786	18	3184	11
10	4th rds	828	12	3172	12
10	5th rds	828	11	3185	20
10	6th rds	819	14	3176	14
10	7th rds	839	12	3192	16
10	8th rds	855	12	3184	21
10	9th rds	837	16	3175	12
10	10th rds	857	18	3182	13
10	11th rds	852	12	3171	19
10	12th rds	863	13	3191	16
10	13th rds	863	11	3184	16
10	14th rds	909	10	3171	17
10	15th rds	880	17	3182	16
10	16th rds	923	14	3176	15
10	17th rds	905	10	3184	20
10	18th rds	945	16	3193	17
10	19th rds	949	11	3198	11
10	20th rds			3172	19

Results are for a lubricated weapon constrained in a rigid mount.

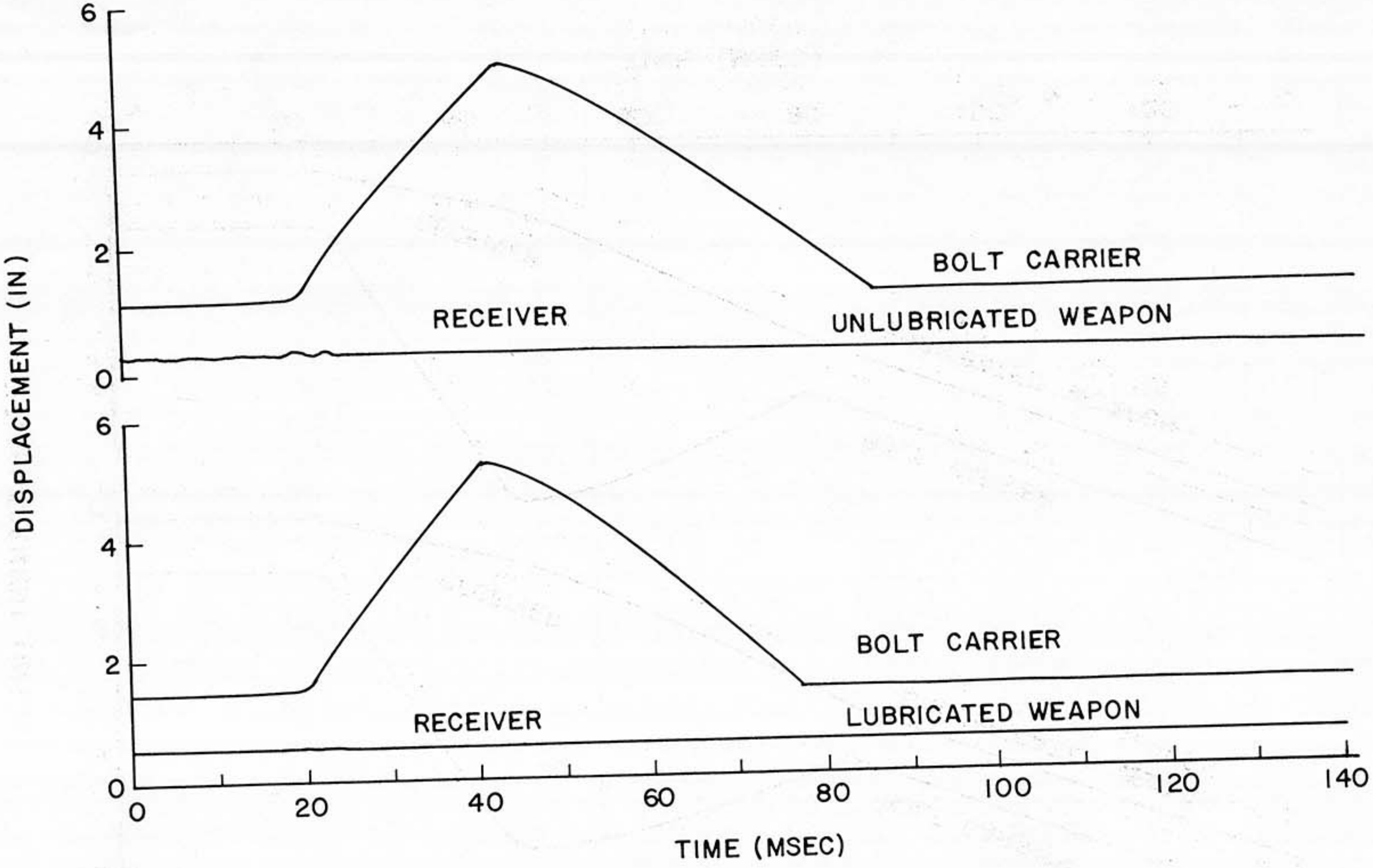

Figure 4. Displacement versus Time with Lubricated and Unlubricated Weapon in Rigid Mount

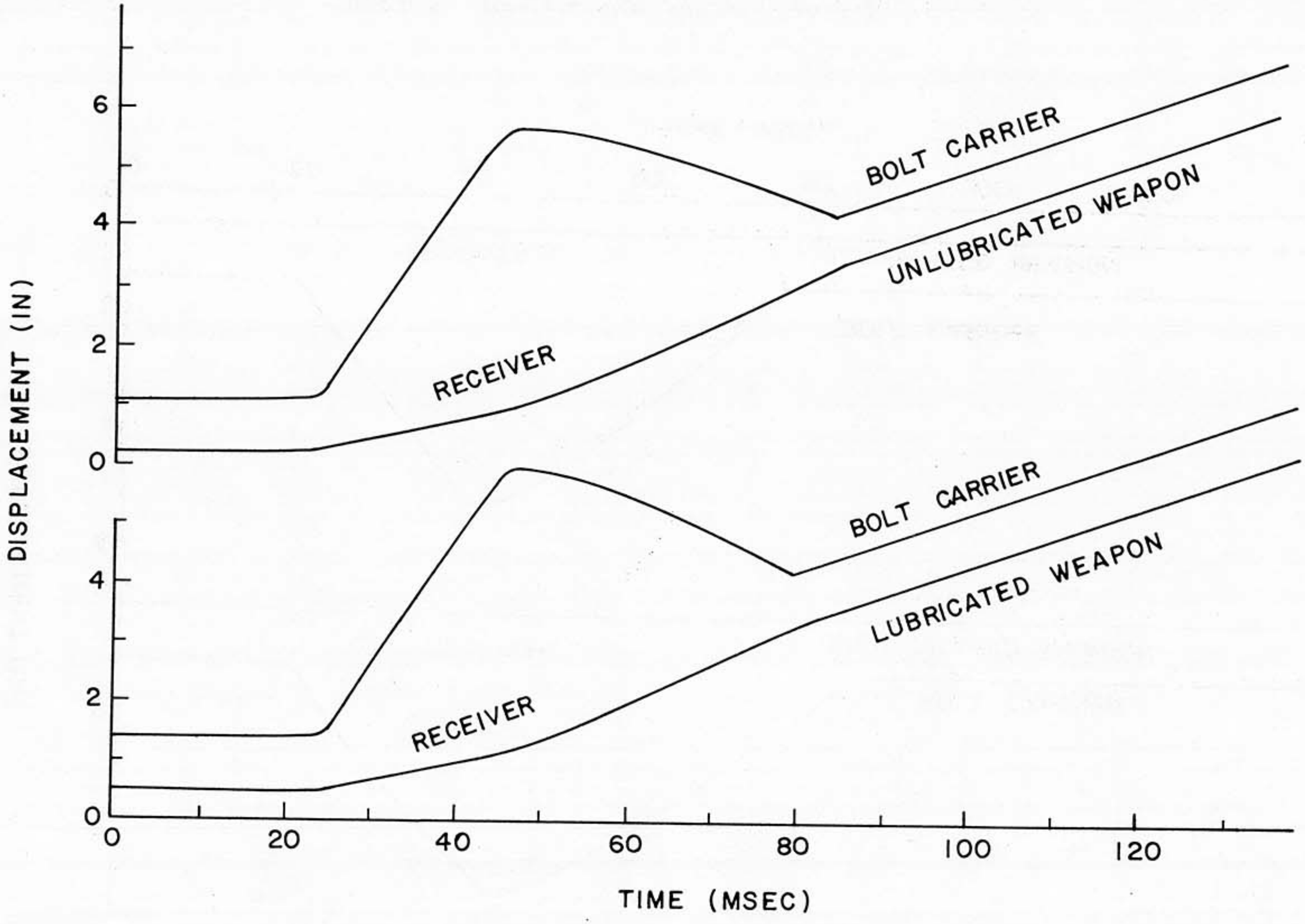

Figure 5. Displacement versus Time With Lubricated and Unlubricated Weapon in Free Recoil Pendulum Mount

D. Conclusions

Based on the results, the following conclusions were made:

1. The rate of fire of the weapon increases 100 rounds per minute when lubricated as compared to unlubricated.

2. The rate of fire of the weapon does not change significantly when fired in a free recoil mount as compared to a rigid mount.

3. The weapon functions satisfactorily in all conditions tested.

4. The rate of fire varies considerably from round-to-round in a 20-round burst, and tends to increase in rate during the firing of the 20-round burst.

IV. FORCES IN THE M16A1 RIFLE

Because of the wide variations in the rate of fire in the 20-round burst tests, a force analysis was performed on the weapon. The driving component in the weapon is the bolt carrier. During a complete cycle the bolt carrier transmits all the forces necessary for the complete functioning of the weapon. The forces associated with each phase of the weapon's functioning can be obtained by measuring the forces acting on the bolt carrier during the cycling of the weapon. The forces acting on the bolt carrier and the duration of these forces with respect to the displacement of the bolt carrier are shown in Figures 6 and 7.

V. SPRING FORCES

The majority of the forces shown in Figures 6 and 7 are the result of springs acting against the bolt carrier during cycling of the weapon. While these forces are different under actual dynamic firing conditions than static conditions, a good comparison of the forces can be made by cycling the weapon with a testing machine to record the forces as functions of bolt carrier displacement. The magnitude and the area under each force-deflection curve can then be compared to show the significance of each force to the operation of the weapon.

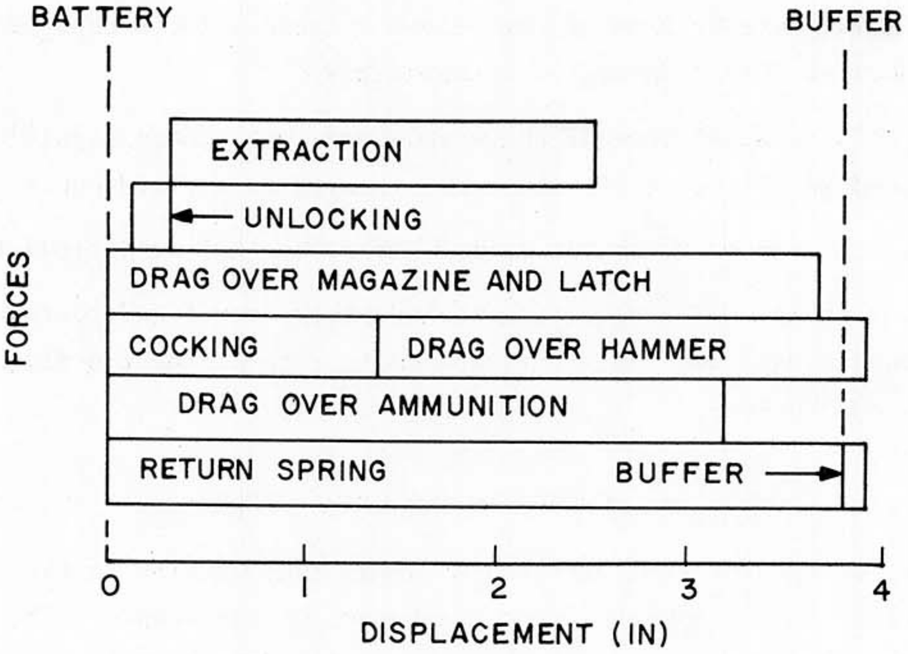

Figure 6. Forces Acting on Bolt Carrier During Rearward Motion

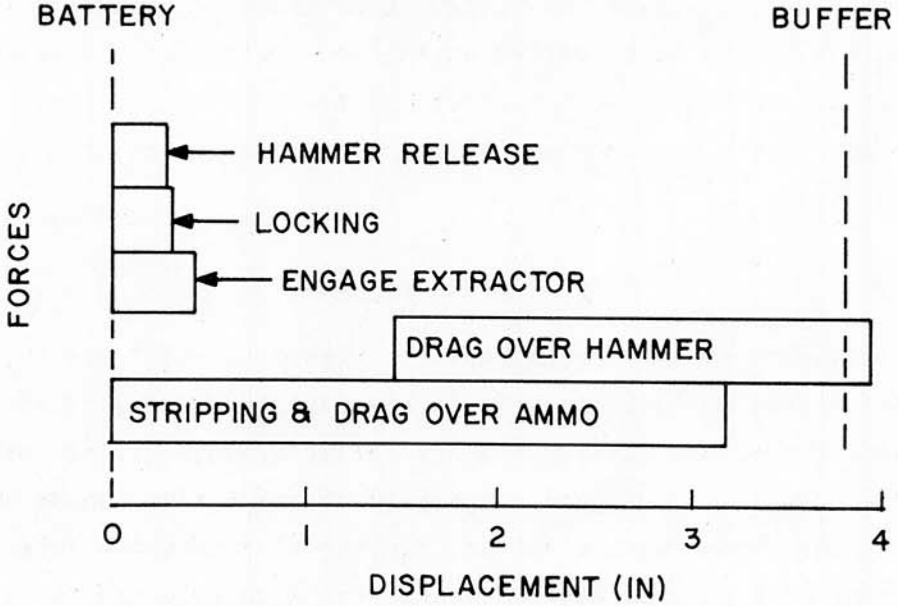

Figure 7. Forces Acting on Bolt Carrier During Forward Motion

A. Forces Measured with Bolt Carrier Moving Rearward

1. Drag Over Ammunition. As the bolt carrier starts to move rearward, it contacts the next round in the magazine and drags across the round which is held in contact with the bolt carrier by the coil spring in the magazine. After the bolt carrier has moved rearward 3.18 inches the bolt clears the end of the round and the drag force diminishes. Since the force exerted by the magazine spring depends on the number of rounds in the magazine, the drag force over the ammunition also depends on the number of rounds in the magazine.

2. Return Spring and Polyurethane Buffer Button. As the bolt carrier starts rearward, it contacts the buffer assembly which is held against the bolt carrier by the return spring. After the bolt carrier has moved rearward 3.80 inches, the polyurethane button on the end of the buffer assembly contacts the end of the buffer tube and starts to compress.

3. Cocking of Hammer and Drag Over Cocked Hammer. As the bolt carrier starts to move rearward, it contacts the hammer and forces it down against the resistance of a torsion spring. The hammer is caught by the sear after the bolt carrier has moved rearward 1.54 inches, but the bolt carrier continues to drag over the cocked hammer for the duration of the rearward travel of the bolt carrier.

4. Drag Over Empty Magazine and Bolt Latch . As the bolt carrier starts rearward, after firing the last round in the magazine, it contacts the feed tray and the bolt latch. The bolt carrier drags across the feed tray and the bolt latch until the bolt clears the bolt latch, which occurs after the bolt carrier has moved rearward 3.67 inches. The bolt latch then springs up in front of the bolt and the bolt carrier is locked to the rear. Both the feed tray and the bolt latch are held in contact with the bolt carrier by the coil spring in the magazine.

B. Forces Measured with Bolt Carrier Moving Forward

1. Drag Over Cocked Hammer. As the bolt carrier starts forward off the polyurethane buffer button, the bolt carrier is in contact with the cocked hammer. The bolt carrier drags over the cocked hammer until the bolt carrier is 1.38 inches from battery. Forward of this position the cocked hammer no longer touches the bolt carrier and the force diminishes.

2. Stripping and Drag Over Ammunition. After the bolt carrier has moved forward to 3.11 inches from battery, the bolt lug contacts the base of the next round in the magazine and stripping begins. When the bolt carrier has moved forward to 2.11 inches from battery, the round is free from the magazine, but the bolt carrier continues to drag over the next round in the magazine until the bolt carrier is in battery. The stripping force and the drag force are caused by the magazine spring and therefore depend on the number of rounds in the magazine.

3. Hammer Release in Automatic Mode. After the bolt carrier has moved forward to 0.23 inch from battery, the bolt carrier contacts the hammer release when the selector lever is in the automatic position. The hammer release is resisted by the action of the torsion spring on the hammer which is only functional in the automatic mode.

4. Engagement of Extractor. After the bolt carrier has moved forward to 0.35 inch from battery the round is fully chambered and the extractor starts to engage over the rim of the case. The extractor engagement is resisted by a coil spring which holds the extractor in the groove at the rim of the cartridge case.

5. Locking of Bolt. After the bolt carrier has moved forward 0.22 inch from battery, the bolt starts to rotate through the action of a cam contained in the bolt carrier.

C. Test Setup and Procedure

The force measurements were made using an Instron Testing Machine to force the bolt carrier through a complete cycle. Measurements were taken with individual components removed, so that each force could be measured separately without any other force acting on the bolt carrier. During measurements that are dependent on compression of the magazine spring, forces were measured using a magazine containing two rounds, ten rounds, and nineteen rounds. In all test measurements the crosshead speed of the testing machine was five inches per minute. The test setups for measuring the forces are shown in Figures 8 and 9.

The force measurements were recorded with respect to the displacement of the bolt carrier on the paper-pen recorder incorporated with the Instron Testing Machine.

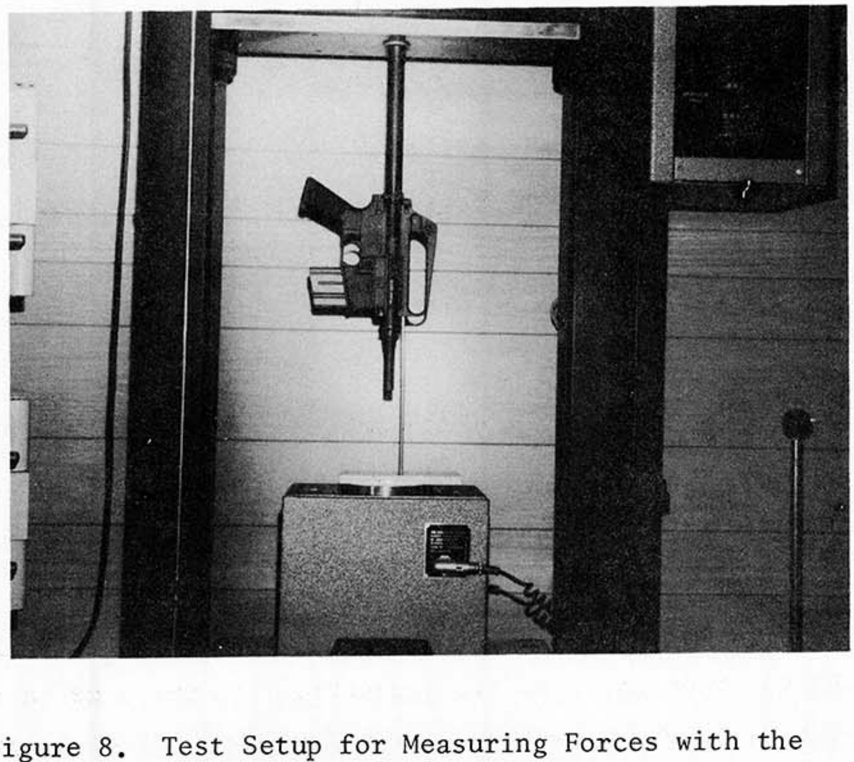

Figure 8. Test Setup for Measuring Forces with the Bolt Carrier Moving Rearward

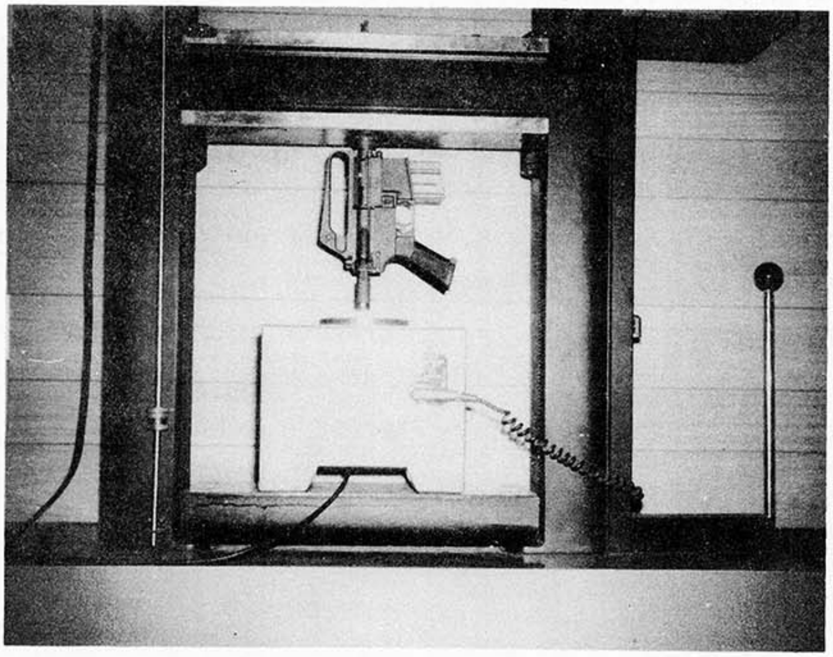

Figure 9. Test Setup for Measuring Forces with the Bolt Carrier Moving Forward

D. Results

The results are summarized in Table III. Sample records are shown in Figures 10 and 11.

E. Conclusions

Based on the results, the following conclusions were drawn.

1. The force and energy associated with the rearward drag of the bolt carrier over the ammunition are slightly larger with nineteen rounds in the magazine than with one round in the magazine.

2. The force and energy associated with stripping and the forward drag of the bolt carrier over the ammunition are twice as large with nineteen rounds in the magazine as with one round in the magazine.

Table III. Results of Spring Force Measurements

Measurement	Motion of Bolt Carrier	No. of Rds in Magazine	Maximum Force (lb)		Integral (in.lb)		Spring Rate (lb/in.)	
			Av	σ	Av	σ	Av	σ
Drag over ammunition	Rearward	2	2.5	.10	5.5	.04		
		10	3.1	.15	7.1	.20		
		19	3.3	.05	8.1	.13		
Return spring	Rearward		12.8	.05	36.2	.10	1.6 (7.5 preload)	.02
Buffer button	Rearward						5000.	200.
Cocking hammer and drag over cocked hammer	Rearward		6.6	.05	14.0	.14		
Drag over empty magazine & bolt latch	Rearward		3.6	.05	4.6	.10		
Drag over cocked hammer	Forward		2.4	.05	3.0	.02		
Stripping and drag over ammunition	Forward	2	3.9	.05	3.2	.29		
		10	6.1	.35	6.3	.25		
		19	8.1	.05	7.4	.09		
Hammer release in automatic mode	Forward		4.4	.10	0.4	.01		
Engagement of extractor	Forward		10.0	.50	0.7	.09		
Locking of Bolt	Forward		4.4	.53	0.5	.13		
Magazine spring							.9 (2.5 preload)	.01

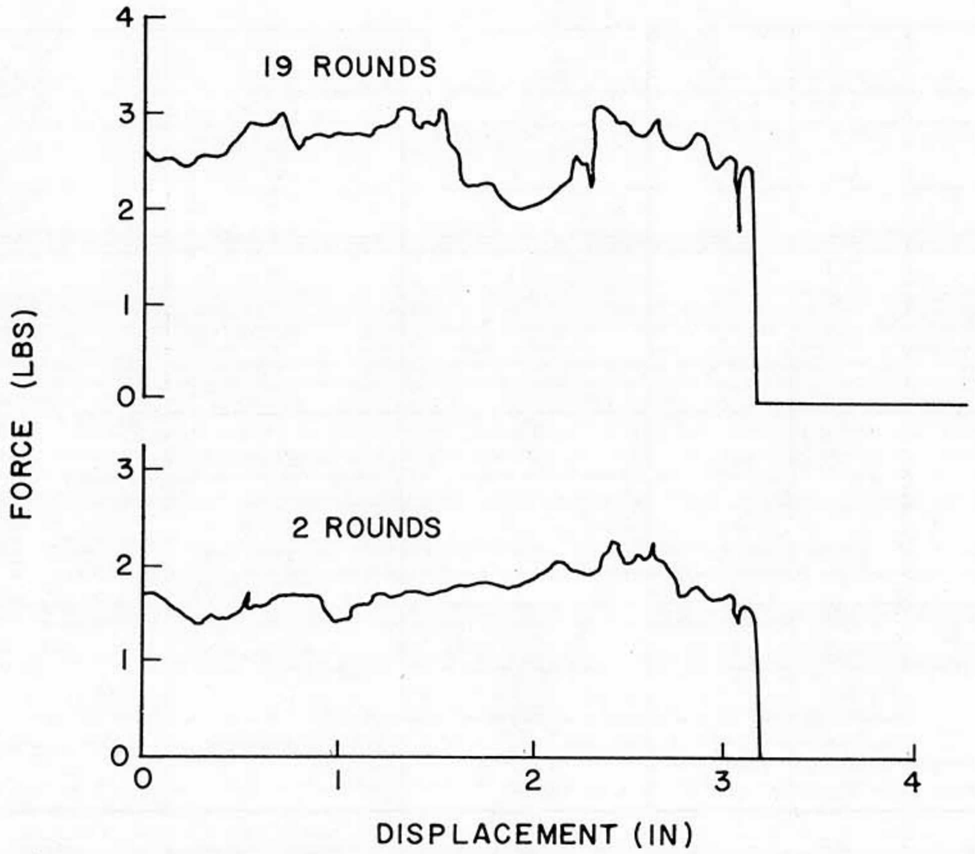

Figure 10. Rearward Drag of Bolt Carrier Over Ammunition with Nineteen and Two Rounds in a Standard Magazine

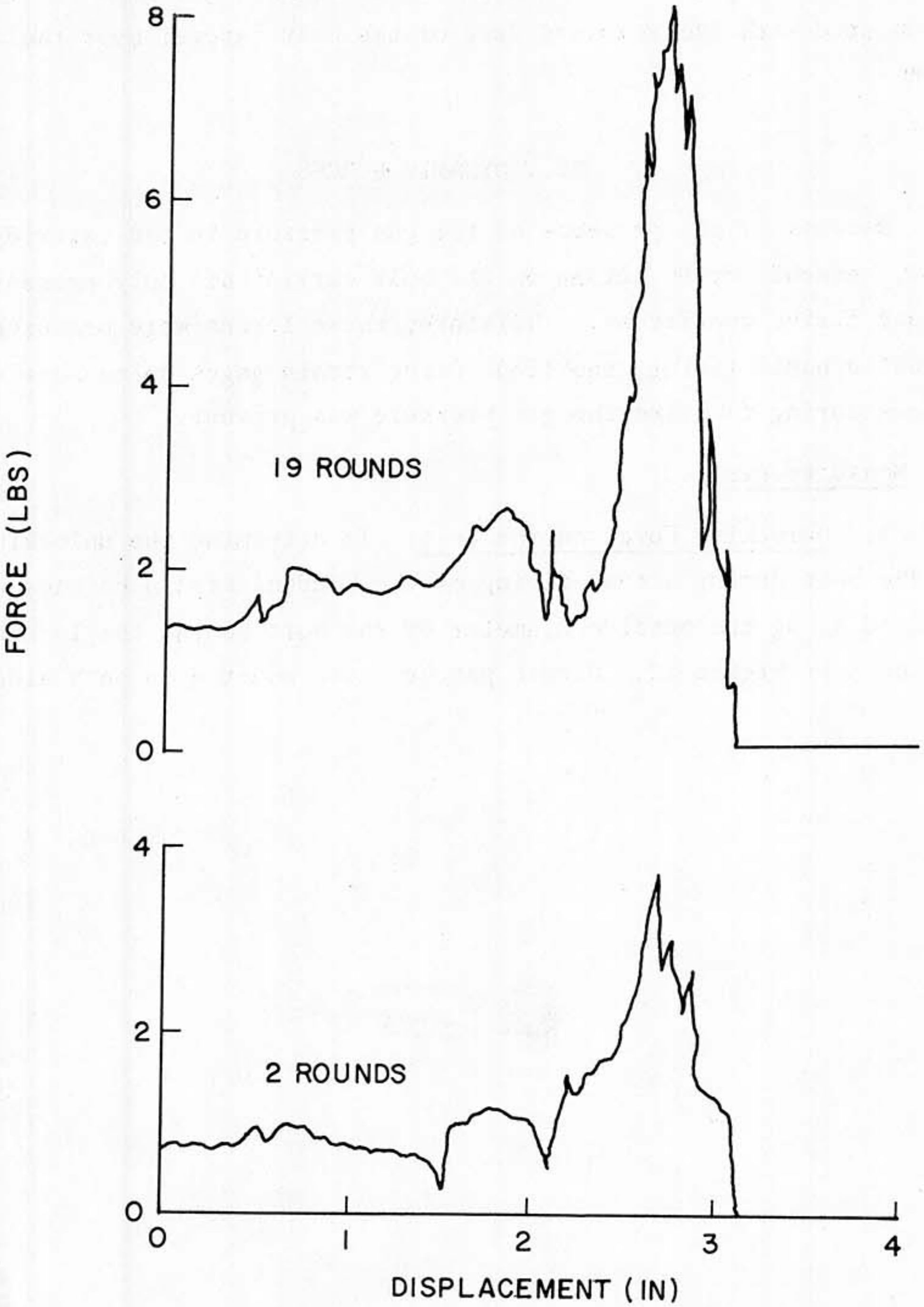

Figure 11. Stripping and Forward Drag of Bolt Carrier Over Ammunition with Nineteen and Two Rounds in a Standard Magazine

3. The forces associated with stripping and the forward drag of the bolt carrier over the ammunition are much larger than the force associated with the rearward drag of the bolt carrier over the ammunition

VI. DYNAMIC FORCES

Because of the presence of the gas pressure in the cartridge case, several forces acting on the bolt carrier are only present under actual firing conditions. Therefore, these forces were measured under actual dynamic firing conditions using strain gages to measure the forces during the time the gas pressure was present.

A. Measurements

1. Unlocking Force on the Bolt. To determine the unlocking force on the bolt during actual firing of the weapon, strain patches were mounted along the outside diameter of the bolt behind the locking lugs, as shown in Figure 12. Strain patches were mounted on both sides of

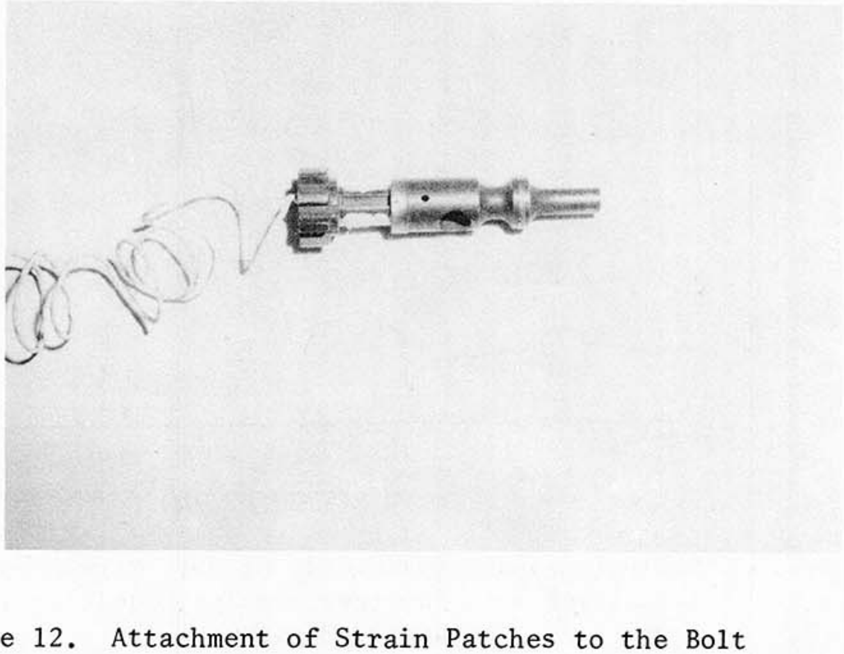

Figure 12. Attachment of Strain Patches to the Bolt

the bolt to cancel out bending moments. The outside diameter of the bolt was turned down to 0.37 inch to increase the sensitivity.

2. Cavity Pressure. To determine the force exerted by the propellant gas on the bolt and the bolt carrier, a Kistler 601H pressure gage was mounted in the bolt carrier as shown in Figure 13. The weight of the bolt carrier was reduced to compensate for the weight of the gage by grinding material from the bolt carrier.

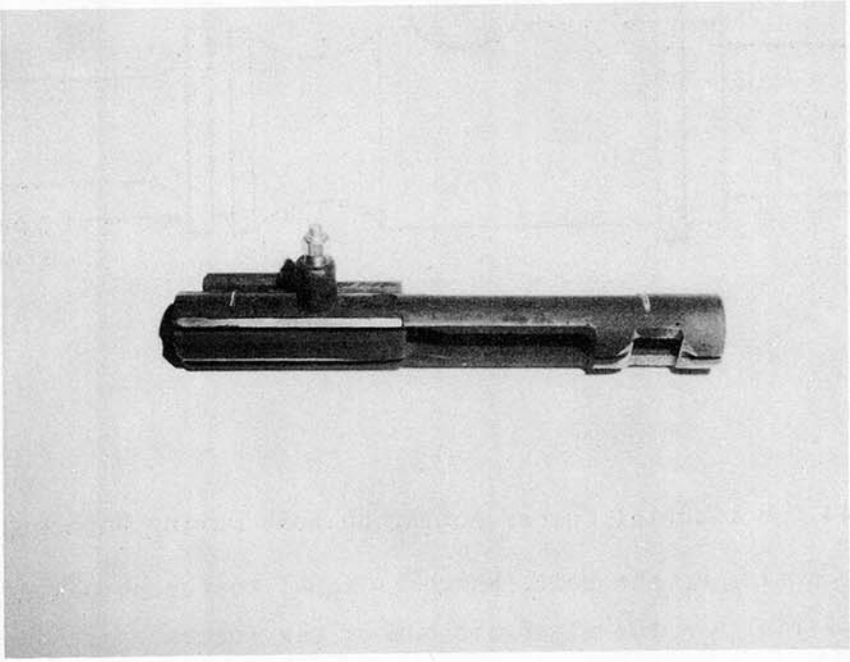

Figure 13. Installation of Pressure Gage in Bolt Carrier

3. Unlocking Force on the Bolt Carrier. The bolt and the bolt carrier interact through the cam in the bolt carrier during unlocking. The unlocking force on the bolt carrier is not the same as the unlocking force on the bolt. Because the bolt has no linear motion during unlocking, the horizontal forces acting on the bolt can be summed to determine the unlocking force on the bolt carrier. The horizontal forces acting on the bolt during unlocking are shown in Figure 14.

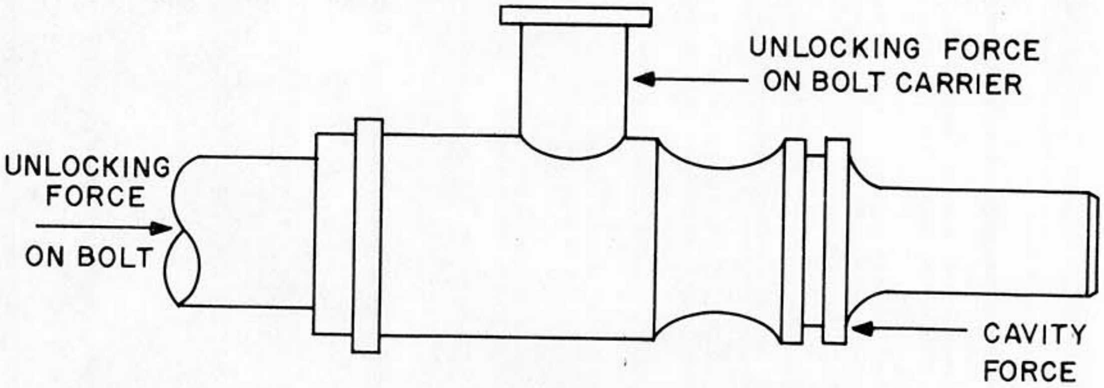

Figure 14. Horizontal Forces Acting on Bolt During Unlocking

The cam force acting on the bolt, which is equal to the unlocking force on the bolt carrier, is the algebraic sum of the forces exerted on the bolt by the gas pressure and the unlocking force on the bolt as measured by the strain gages on the bolt.

4. Extraction Force. To determine the extraction force on the bolt and the bolt carrier during firing of the weapon, a strain patch was mounted on the extractor as shown in Figure 15. The bolt and the bolt carrier are moving together as one component during extraction. Therefore, the extraction force on the bolt is the same as the extraction force on the bolt carrier.

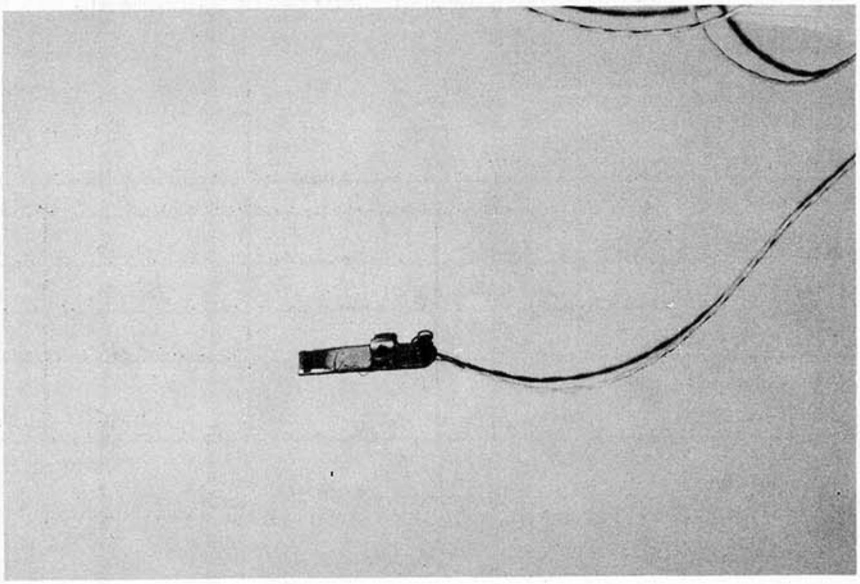

Figure 15. Attachment of Strain Gage to Extractor

5. Supporting Measurements. To show the force measurements as a function of bolt carrier displacement, instead of time, displacement versus time records were taken. To correlate the force versus time records with the displacement versus time records, a photocell was mounted at the muzzle.

B. Test Setup and Procedure

The same test setup and procedures were used as in the previous rigid mount firings. The force versus time measurements were recorded on a Honeywell Electromagnetic Tape Recorder.

C. Results

The results are summarized in Table IV. Sample records are shown in Figures 16 and 17.

Table IV. Results of Dynamic Force Measurements

No. of Rds	Measurement	Maximum Force (lb)		Integral (in. lb)	
		Av	σ	Av	σ
10	Extraction	+220	32	4.6	0.1
10	Cavity	-330	40	49.2	0.5
10	Unlocking on bolt	-335	36	29.6	0.3
10	Unlocking on bolt carrier	+210	37	19.6	0.2

Results are for a lubricated weapon constrained in a rigid mount.

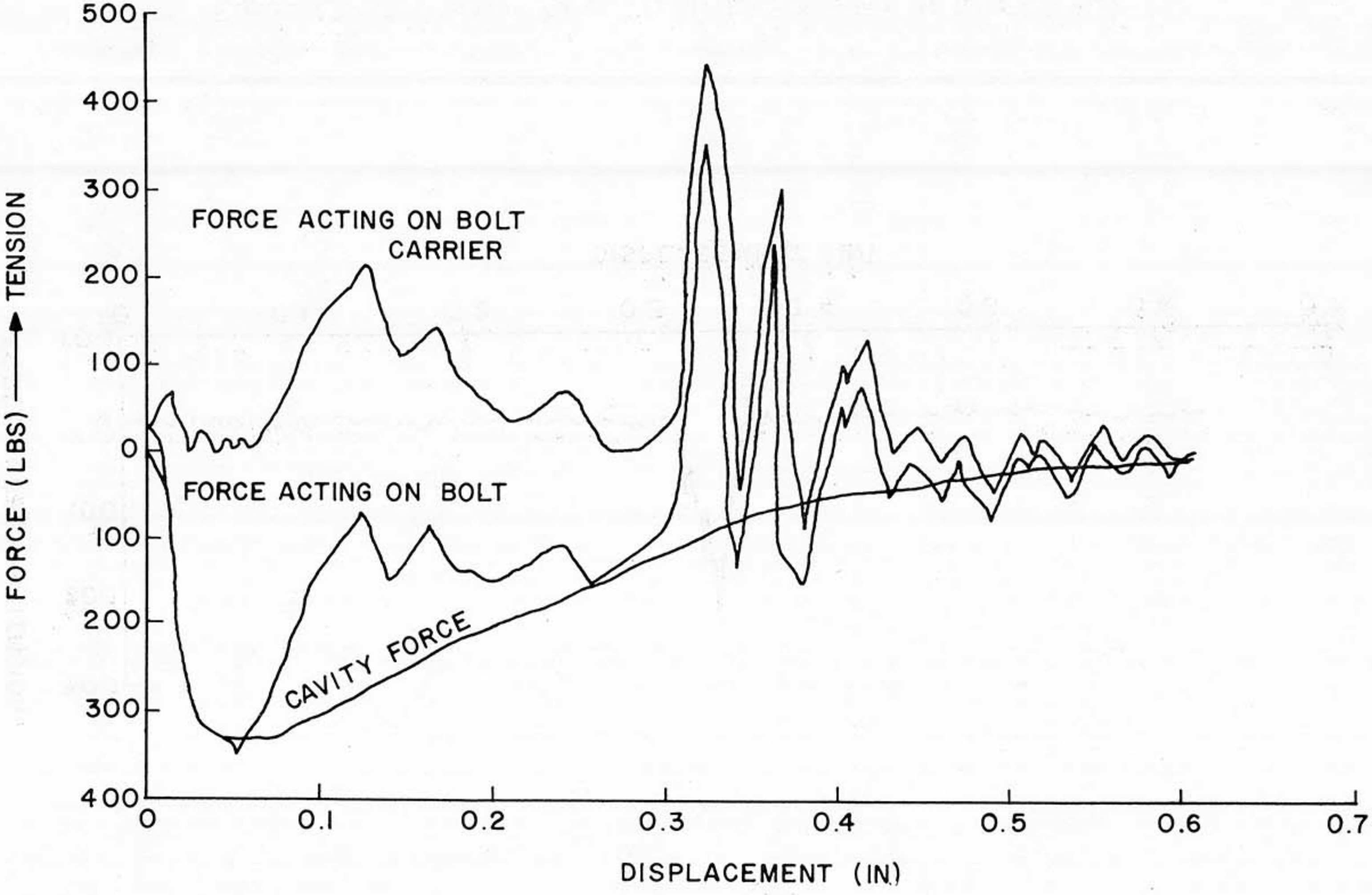

Figure 16. Unlocking Forces Versus Displacement of Bolt Carrier

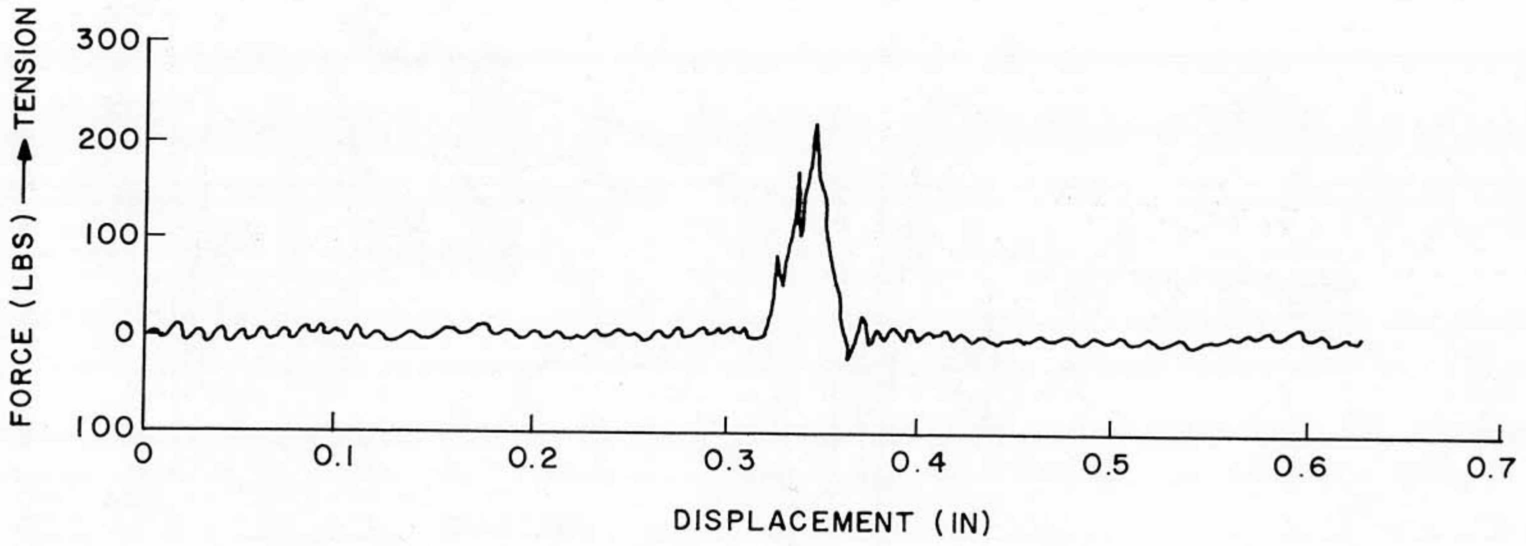

Figure 17. Extraction Force Versus Displacement of Bolt Carrier

D. Conclusions

Based on the results, the following conclusions were drawn.

1. The energies associated with the unlocking force and the extraction force are small because of the short time duration.

2. The energy associated with the unlocking force on the bolt carrier is four times larger than the energy associated with the extraction force.

VII. EFFECT OF VARIATIONS IN SPRING AND FRICTION FORCES ON THE KINEMATICS OF THE WEAPON

Because of the variations in the forces associated with the magazine spring, 20-round burst firing tests were conducted to determine if these variations had any effect on the kinematics of the weapon. The varying forces associated with the magazine spring are the rearward drag of the bolt carrier over the ammunition, and the stripping and forward drag of the bolt carrier over the ammunition. The 20-round burst tests were fired using a constant force, low-drag magazine. The constant force, low-drag magazine was made by replacing the coil spring in the standard magazine with two constant force negator springs as shown in Figure 18.

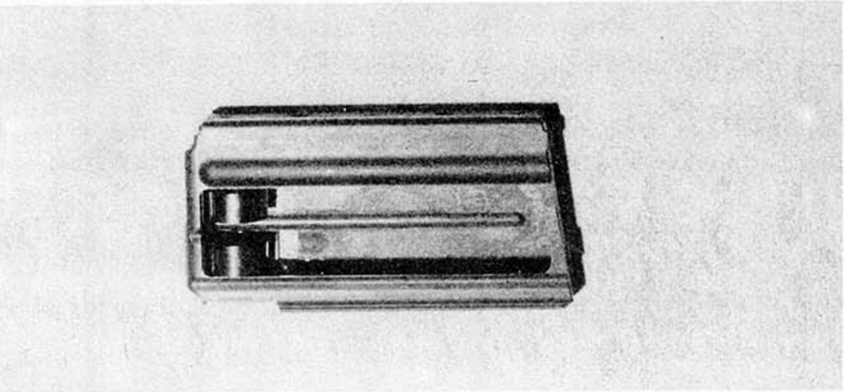

Figure 18. Constant Force, Low-Drag Magazine

The variation in force due to the changing weight of ammunition, from one round to 20 rounds, was eliminated by firing the weapon on its side.

A. Measurements

1. Recoil Time. The time required for the bolt carrier to move from battery to the position where the polyurethane buffer button contacts the end of the buffer tube was measured to show the effect of variations in the rearward drag of the bolt carrier over the ammunition on the kinematics of the weapon.

2. Cycle Time. The time required for the bolt carrier to move rearward from battery and return to battery was measured to show the effect of variations in stripping and forward drag of the bolt carrier over the ammunition on the kinematics of the weapon.

3. Rearward Drag of Bolt Carrier over Ammunition Using Constant Force, Low-Drag Magazine. The force associated with the rearward drag of the bolt carrier over the ammunition using the constant force, low-drag magazine was measured to compare with the same force measured previously using the standard magazine.

4. Stripping and Forward Drag of Bolt Carrier over Ammunition Using Constant Force, Low-Drag Magazine. The force associated with stripping and forward drag of the bolt carrier over the ammunition using the constant force, low-drag magazine was measured to compare with the same force measured previously using the standard magazine.

B. Test Setup and Procedure

The same test setup and procedures were used as in the previous rigid mount firings.

C. Results

The results are summarized in Tables V and VI. Sample records are shown in Figures 19 thru 23. The measurements in Table V and Figures 21 and 22 using the standard magazine are from the 20-round burst measurements made in the previous tests on the kinematic measurements.

Table V. Results of Kinematic Tests Using Constant Force, Low-Drag Magazine

No. of Rds	Position in Burst	Recoil Time Modified Magazine (msec)		Recoil Time Standard Magazine (msec)		Cycle Time Modified Magazine (msec)		Cycle Time Standard Magazine (msec)	
		Av	σ	Av	σ	Av	σ	Av	σ
10	1st rds	23.9	0.6	24.8	1.0	62.8	1.2	77.3	1.9
10	2nd rds	23.5	0.5	23.8	0.8	62.4	1.0	71.2	1.5
10	3rd rds	24.1	0.8	22.8	0.9	63.8	1.9	66.3	1.8
10	4th rds	23.3	0.7	22.9	0.6	60.7	1.5	62.5	1.2
10	5th rds	22.7	1.0	23.0	0.6	60.1	1.3	62.5	1.1
10	6th rds	22.5	0.7	22.9	0.7	58.7	1.1	63.3	1.4
10	7th rds	21.9	0.4	22.4	0.6	57.1	1.4	61.5	1.2
10	8th rds	22.5	0.9	21.6	0.6	59.3	1.6	60.2	1.2
10	9th rds	22.5	0.6	22.9	0.8	58.5	1.7	61.7	1.6
10	10th rds	22.5	0.8	22.0	0.9	58.5	1.3	60.0	1.8
10	11th rds	22.9	0.5	21.9	0.6	59.5	1.6	60.4	1.2
10	12th rds	22.5	0.8	21.9	0.7	58.3	1.8	59.5	1.3
10	13th rds	22.1	0.7	22.2	0.6	57.4	1.6	59.5	1.1
10	14th rds	21.7	0.5	22.2	0.5	57.0	1.2	56.0	1.0
10	15th rds	21.3	0.8	21.8	0.9	55.2	1.7	58.2	1.7
10	16th rds	20.9	0.7	20.4	0.7	54.4	1.3	55.0	1.4
10	17th rds	21.5	1.0	21.1	0.5	55.9	1.6	56.3	1.0
10	18th rds	20.3	0.4	20.0	0.8	53.4	1.7	53.5	1.6
10	19th rds	21.5	0.6	20.2	0.6	54.9	1.9	53.2	1.1
10	20th rds	20.9	0.9	20.0	0.8				

Results are for a lubricated weapon constrained in a rigid mount.

Table VI. Results of Spring Force Measurements Using Constant Force, Low-Drag Magazine

Measurements	Motion of Bolt Carrier	No. of Rds in Magazine	Maximum Force (lb)		Integral (in. lb)		Spring Rate (lb/in.)	
			Av	σ	Av	σ	Av	σ
Drag over ammunition	Rearward	2	1.1	.05	3.1	.03		
		10	1.2	.05	3.2	.06		
		19	1.1	.05	3.0	.07		
Stripping and drag over ammunition	Forward	2	0.7	.10	0.8	.05		
		10	0.9	.06	1.0	.10		
		19	0.9	.10	1.0	.20		
Modified magazine spring			0.5	.03			0 (constant force)	

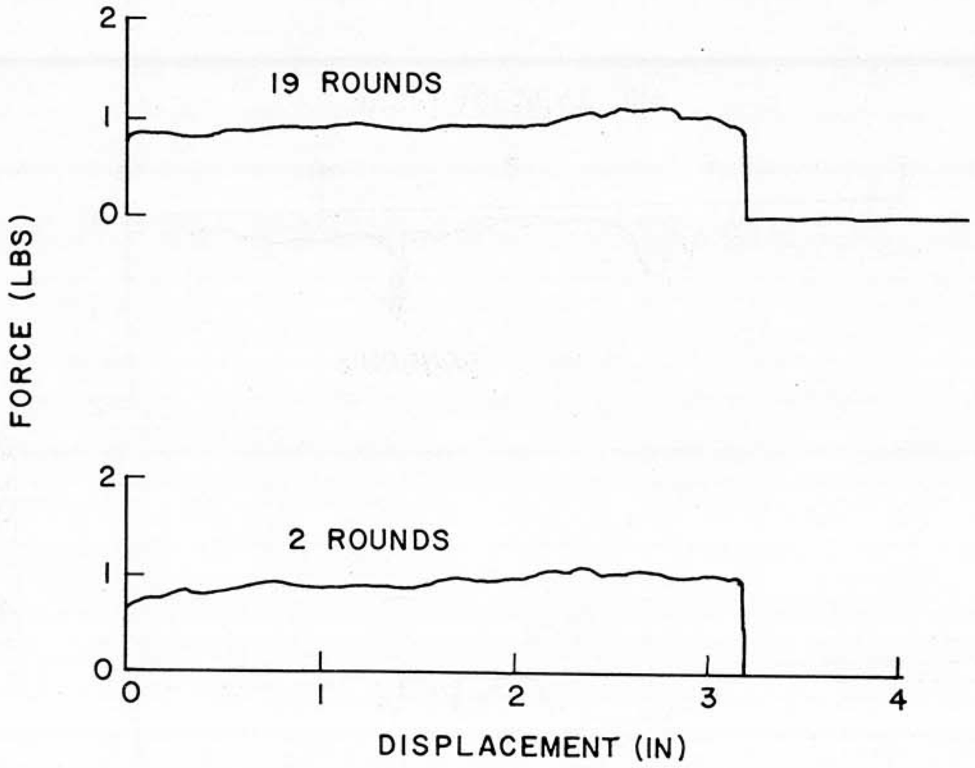

Figure 19. Rearward Drag of Bolt Carrier Over Ammunition With Nineteen and Two Rounds in a Constant Force, Low-Drag Magazine

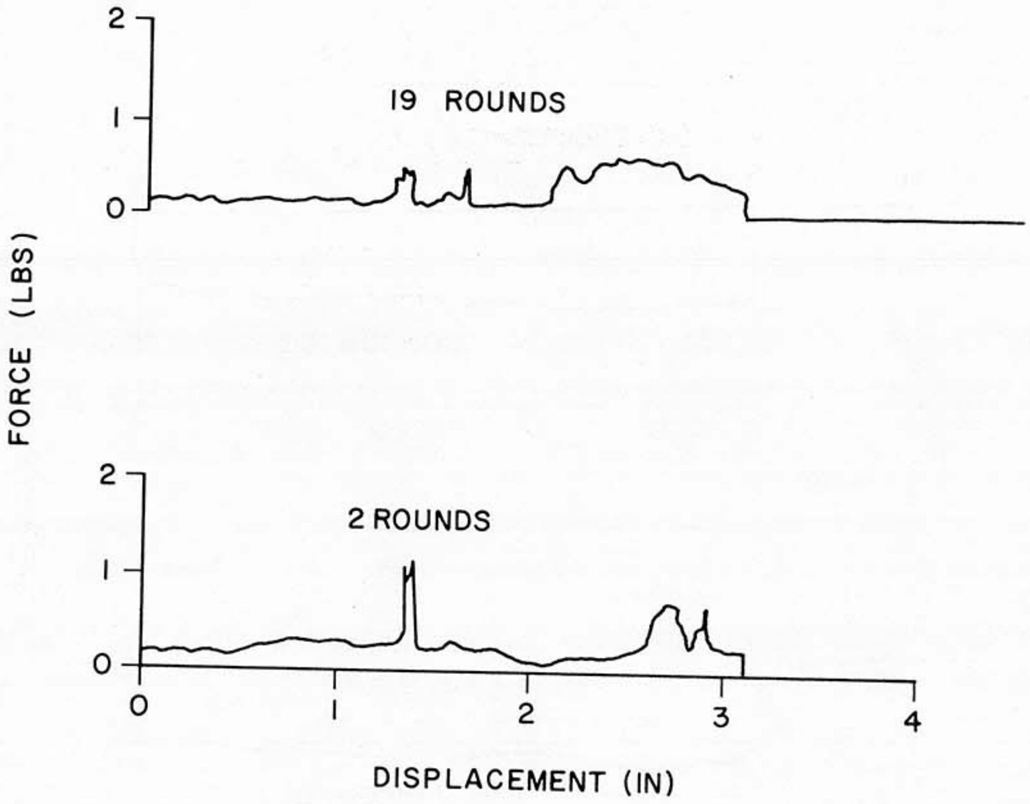

Figure 20. Stripping and Forward Drag of Bolt Carrier Over Ammunition with Nineteen and Two Rounds in a Constant Force, Low-Drag Magazine

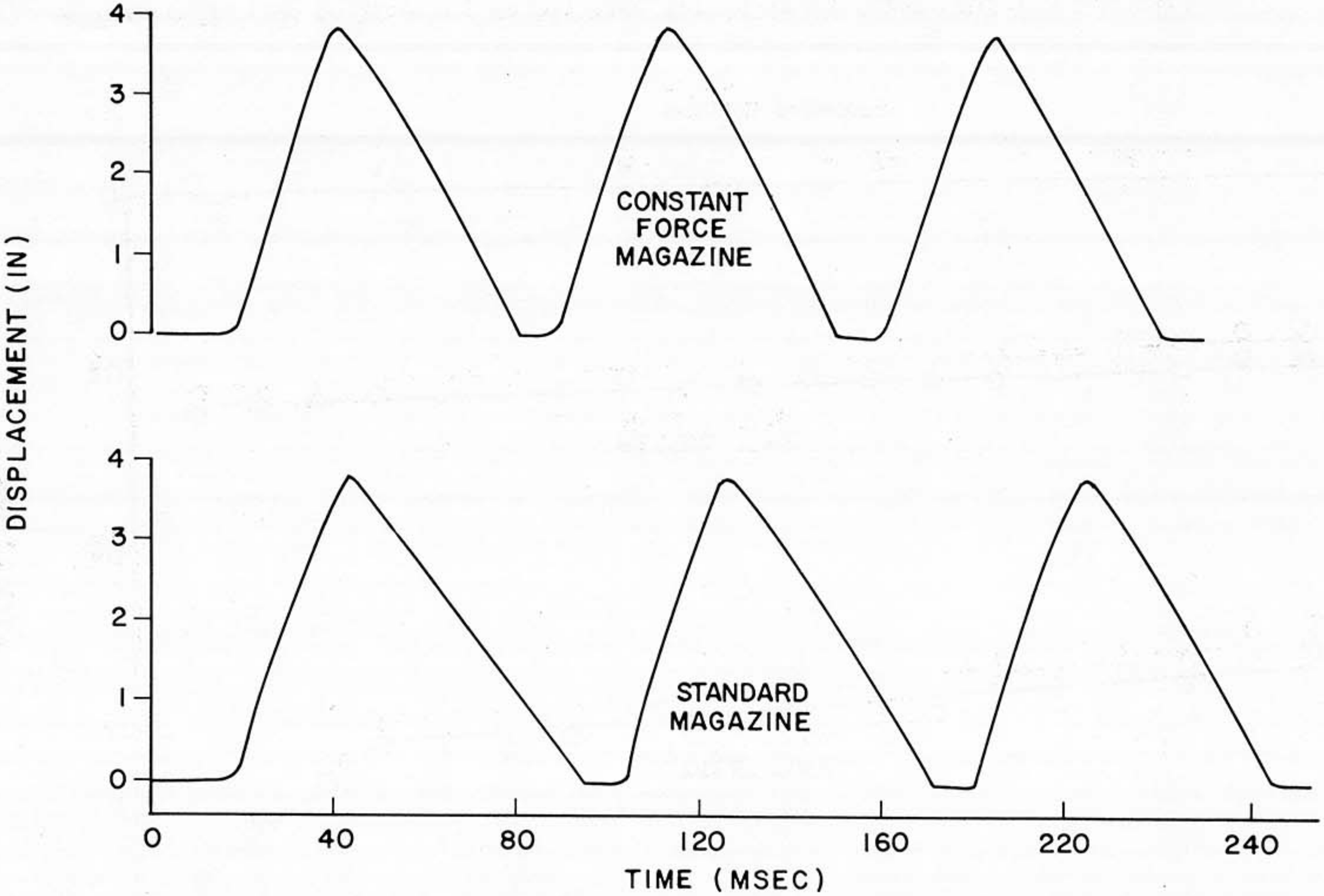

Figure 21. Displacement versus Time for the First Three Rounds in a 20-Round Burst Using a Constant Force, Low-Drag Magazine and a Standard Magazine

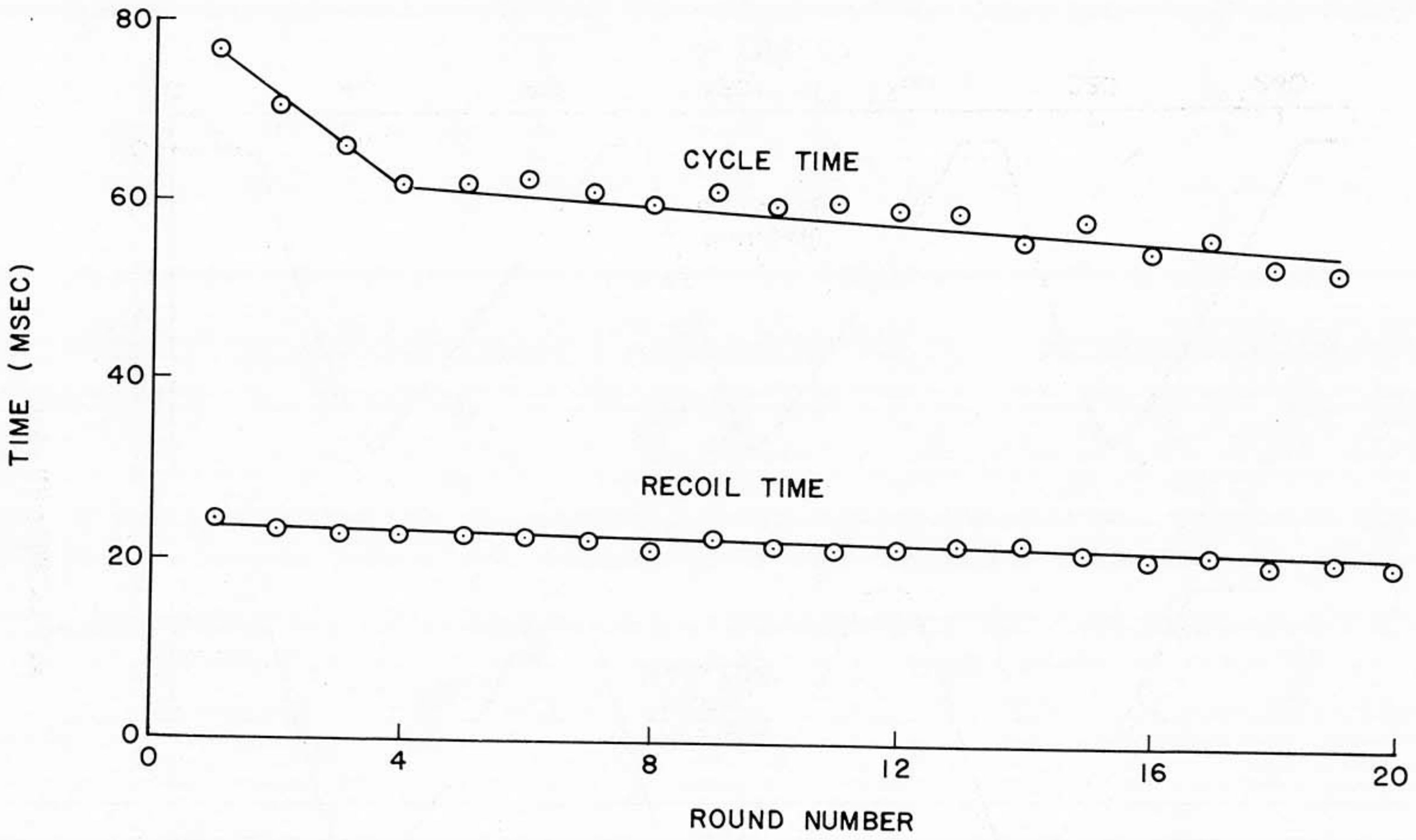

Figure 22. Cycle Time and Recoil Time for 20-Round Bursts Using a Standard Magazine

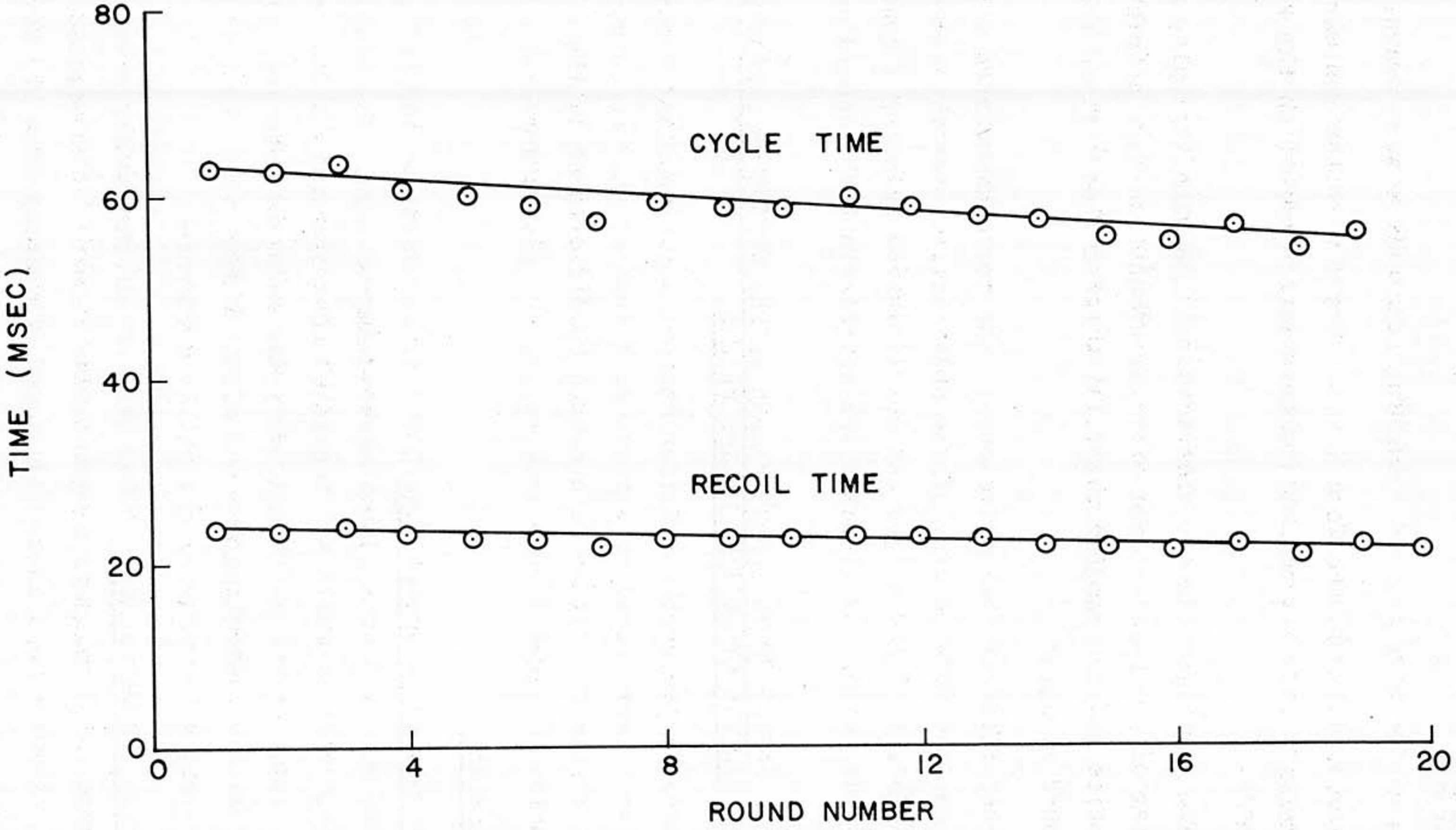

Figure 23. Cycle Time and Recoil Time for 20-Round Bursts Using a Constant Force, Low-Drag Magazine

D. Conclusions

Based on the results, the following conclusions were drawn.

1. The variations in the force associated with the rearward drag of the bolt carrier over the ammunition have little effect on the kinematics of the weapon.

2. The variations in the forces associated with stripping and the forward drag of the bolt carrier over the ammunition have an effect on the kinematics of the weapon for the first three rounds fired from a full 20-round magazine.

3. The effect of the variations in the force associated with stripping and the forward drag of the bolt carrier over the ammunition on the kinematics of the weapon can be eliminated by using a constant force magazine, or by lowering the spring rate in the standard magazine.

VIII. EFFECT OF THE POLYURETHANE BUFFER BUTTON ON VARIATIONS IN THE CYCLE TIME OF THE WEAPON.

Because the polyurethane buffer button is a viscoelastic material, 20-round bursts were fired to determine if some of the round-to-round variations in the cycle time were caused by differences in the coefficient of restitution obtained during a series of successive impacts.

A. Measurements

1. Displacement versus Time. The displacement of the buffer assembly was measured with a displacement-time camera. The displacement of the buffer assembly was magnified four times the actual movement. The displacement of the buffer assembly was recorded from just prior to the buffer button contacting the end of the buffer tube, to just after the buffer button leaving the end of the buffer tube.

2. Velocity versus Time. The velocity of the buffer assembly was measured from the displacement versus time records. The velocities of the buffer assembly upon contact with and separation from the buffer tube were measured for each round in the burst. A ratio was then made by

dividing the exit velocity by the impact velocity to give an indication of how the coefficient of restitution for the polyurethane buffer button changes from round-to-round.

B. Test Setup and Procedure

The same test setup and procedures were used as in the previous rigid mount firings.

C. Results

The results are summarized in Table VII. Sample records are shown in Figures 24 thru 26.

D. Conclusions

Based on the results, the following conclusions were drawn.

1. The coefficient of restitution of the polyurethane buffer button increases during the firing of the first three rounds and then stays constant for the remaining rounds.

2. The polyurethane buffer button, therefore, accounts for some of the large variations in the cycle times of the first three rounds fired.

Table VII. Results of Kinematic Tests on Polyurethane Buffer Button

No. of Rounds	Position in Burst	Exit Velocity / Impact Velocity	
		Av	σ
10	1st rds	.40	.02
10	2nd rds	.50	.04
10	3rd rds	.54	.01
10	4th rds	.56	.05
10	5th rds	.55	.02
10	6th rds	.56	.03
10	7th rds	.55	.04
10	8th rds	.55	.01
10	9th rds	.55	.01
10	10th rds	.55	.03
10	11th rds	.54	.05
10	12th rds	.55	.01
10	13th rds	.55	.02
10	14th rds	.56	.04
10	15th rds	.55	.01
10	16th rds	.55	.05
10	17th rds	.55	.03
10	18th rds	.56	.03
10	19th rds	.56	.02
10	20th rds	.56	.05

Results are for a lubricated weapon constrained in a rigid mount.

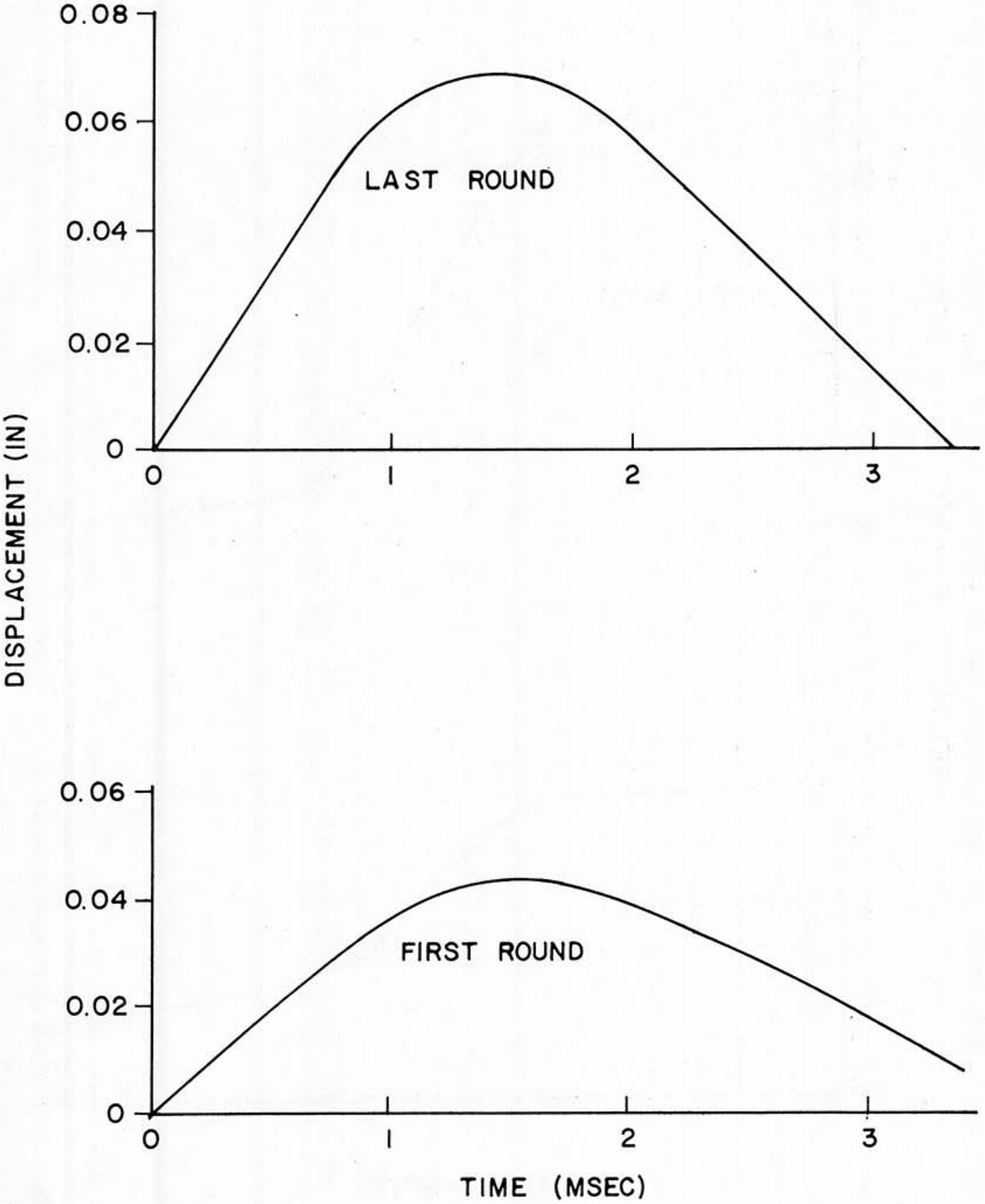

Figure 24. Displacement versus Time of Buffer Assembly for Last Round and First Round in a 20-Round Burst Using a Standard Magazine

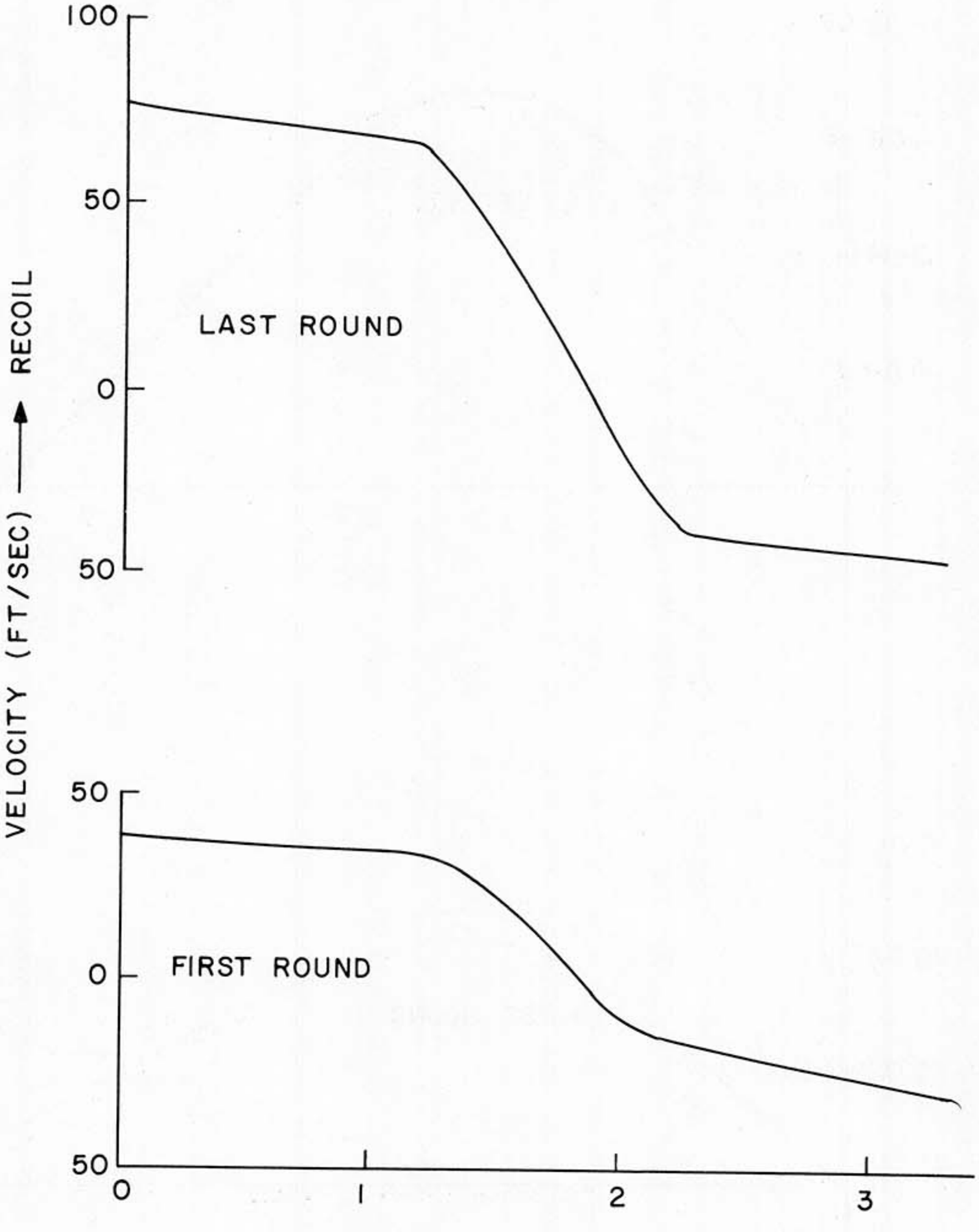

Figure 25. Velocity versus Time of Buffer Assembly for Last Round and First Round in a 20-Round Burst Using a Standard Magazine

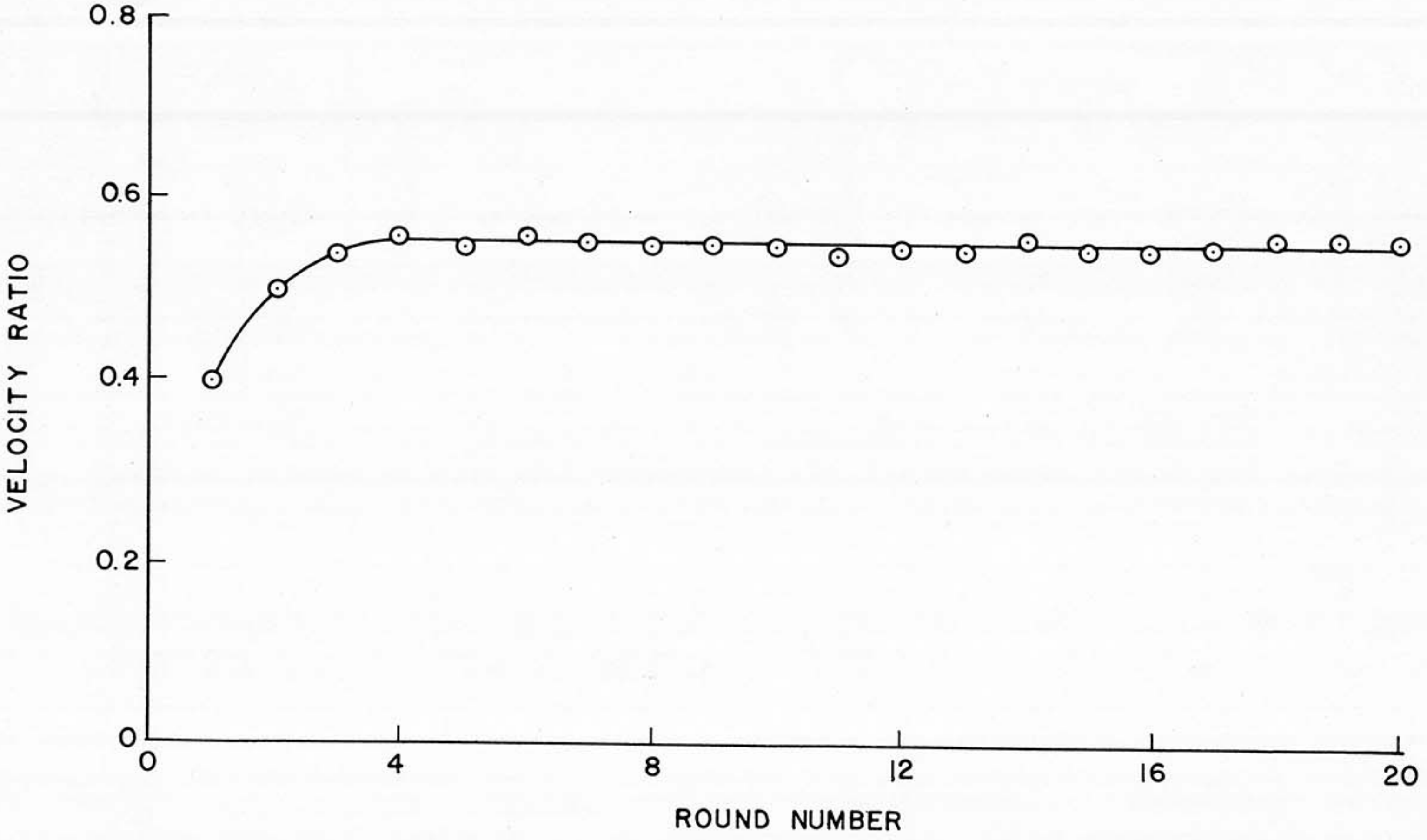

Figure 26. Exit Velocity of Buffer Assembly Divided by Impact Velocity of Buffer Assembly for 20-Round Bursts

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2. Richard D. Kirkendall, "A Photo-Duo-Diode for Measuring the Time of Shot Ejection," Ballistic Research Laboratories Memorandum Report No. 1859, July 1967.

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13. ABSTRACT

A kinematic study was performed on the M16A1 Rifle under several different mounting and weapon conditions. Displacement versus time, time to projectile exit, recoil impulse, and muzzle velocity were measured. Results showed large round-to-round variations in the rate of fire within a 20-round burst. To determine the cause of these variations, static and dynamic force measurements were taken. Results showed large round-to-round variations in the forces associated with the magazine. To determine the effect of these variations on the rate of fire, tests were performed using a constant force, low-drag magazine. Results showed that the round-to-round variations in the forces associated with the magazine affect the rate of fire for the first three rounds fired from a full 20-round magazine. Results also showed that the coefficient of restitution of the polyurethane buffer button varies for the first three rounds fired in a burst.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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Rigid Mount						
Free Recoil Pendulum Mount						
Displacement Versus Time						
Recoil Impulse						
Muzzle Velocity						
Static Forces						
Dynamic Forces						
Constant Force, Low-Drag Magazine						
Cycle Time						
Recoil Time						
Rate of Fire						
Polyurethane Buffer Button						