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TECHNICAL NOTE TN-1159

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INVESTIGATION OF BOLT/BOLT CARRIER
CLEARANCES IN THE M16A1 RIFLE

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May 1971

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**DEPARTMENT OF THE ARMY
FRANKFORD ARSENAL
Philadelphia, Pa. 19137**

*U.S. Army Weapons Command, Rock Island, Illinois, 61202

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Ammunition Development and Engineering Laboratories
FRANKFORD ARSENAL
Philadelphia, Pa. 19137

May 1971

*U.S. Army Weapons Command, Rock Island, Illinois 61202

ABSTRACT

A brief series of tests and evaluations was made to provide experimental and analytical data to the U.S. Army Weapons Command in support of the M16A1 Rifle Bolt Dimension Investigation. Both firing tests and mathematical model confirmed that bolts with diameters 0.0075 and 0.010 inch below specification do not give reliable performance because of excessive gas leakage between the outside bolt shaft diameter and its mating diameter in the bolt carrier. Normal rifle function occurred with bolts 0.0004 and 0.0005 inch below specifications.

OBJECTIVE

The objective of this study was to provide experimental and analytical data to the U. S. Army Weapons Command (WECOM) in support of the M16A1 Rifle Bolt Dimension Investigation.¹ In addition, WECOM requested use of an available Frankford Arsenal mathematical model as a vehicle for a theoretical study of bolt diameter versus cyclic rate.

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INTRODUCTION

The M16A1 Rifle operation is obtained by directing cartridge propellant gases through a gas tube into the bolt and bolt carrier assembly, unlocking the bolt and propelling the bolt and bolt carrier rearward. The gas cylinder/piston formed by this assembly fit is designed to form a gas seal and a sliding fit. By the nature of the design, the criticality of these fits is essential to the function of the rifle.

A large quantity of rifles with undersize bolt diameter (0.2503 ± 0.0002 inch dia., undersize 0.0001 to 0.0005 inch) were discovered in the supply system. A request for assistance in preparation of a technical decision to support disposition of this material was received by Frankford Arsenal.

Based on the criticality of the bolt diameter in question, it is possible that all deviated bolts would require replacement as there could be degradation of the reliability of the rifle. However, considering the cost impact (because of the large quantity involved) testing was advisable to make a determination as to the limit of usability of deviated material.¹⁻⁷

This report records data and analytical information obtained in a brief series of tests and evaluations made over a two-day period. WECOM personnel visited Frankford Arsenal in October 1970 to obtain information on the magnitude of the clearance between the bolt shaft and bolt carrier that would produce sufficient gas leakage to cause adverse operation of the M16A1 rifle. Presumably, this would result from excessive clearance between bolt shaft diameter and bolt carrier that could cause a decrease in the propellant gas impulse supplied to the cycling mechanism.

Frankford Arsenal provided two sources of data and information: (1) experimental evaluations consisting of measuring cyclic rate and bolt pressure-time characteristics, and (2) the M16A1 cycling mechanism/ammunition interface model for evaluating small differences in characteristics. Experimentation consisted of functional tests with ball and blank ammunition and bolts having various shaft diameters. Simulation consisted of using the mathematical model to explain failure to function when this occurred in terms of the measured pressure-time data of the bolt. It was also used to evaluate changes in cyclic rate due to small changes in bolt pressure.

Frankford Arsenal fired a total of five hundred and fifty-eight rounds of ball and blank ammunition on 1 October 1970 in two rifles - a standard M16A1 and a modified rifle. The modification consisted of the receiver and carrier being adapted for bolt pressure-time measurements. In both rifles all parts remained unchanged except for the bolt component. Thus, any changes occurring in clearances between bolt shaft and carrier were due to the bolt assembled into the carrier in any given test.

Frankford Arsenal had previously conducted tests on 29 September 1970 in order to determine the extent and type of tests having potential for producing the most fruitful information. Visiting WECOM personnel were supplied with thirty-two bolt pressure-time records for ball ammunition and for blank ammunition on 1 October 1970. In addition, the visitors obtained a complete test schedule and copies of the test results. The mathematical model of the cycling mechanism was operated on the evening of 1 October 1970 and these results were mailed to WECOM on 2 October 1970.

TEST PROCEDURE AND MATERIAL

The improvised test plan called for firing a total of five hundred fifty-eight (558) cartridges selected at random from two different lots of ammunition, three hundred ninety-six (396) M200 Blank Cartridges from Lot TW 18056 and two hundred sixty-two (262) M193 Ball Cartridges from Lot LC 12304. Two 5.56mm Rifles M16A1, serial numbers 694378 and 823793, were used in the test. The bolt carrier and upper receiver assembly of the first rifle had been modified for measuring bolt carrier cavity pressures. During the test this bolt carrier was replaced with a standard bolt carrier whenever the rifle was fired in the automatic firing mode for cyclic rate data. Rifles and ammunition were tested at ambient temperature. Bolt carrier pressure-time measurements were made with a Kistler transducer model 603ASN390. The gauge was seated on a brass gasket using thirty (30) inch-pounds of torque.

The test schedule consisted of three parts as follows:

<u>Part</u>	<u>Date</u>	<u>Test</u>	<u>Tabulation</u>
I	29 Sept. 70	Preliminary test Bolt rings removed	Table I
II	1 Oct. 70	Three different bolts* M200 Blank ammunition	Table II
III	1 Oct. 70	Repeat of II plus std. bolt and M193 Ball ammunition	Table III

*Table IV tabulates bolt and bolt carrier dimensions for the components used in the test: (1) a standard bolt and (2) three bolts having different diameters, supplied by WECOM.

Part I (Table I) consisted of firing sixty-six (66) M193 Ball Cartridges in the 5.56mm Rifle M16A1, SN 694387. Bolt carrier pressure-time measurements were obtained and rifle function was noted for rounds

TABLE I. PART I TEST SCHEDULE:
PRELIMINARY STUDY OF BOLT/BOLT CARRIER CLEARANCE

<u>Test No.</u>	<u>Component Description</u>	<u>Rounds Fired</u>	<u>Firing Mode</u>	<u>Results</u>
1	Bolt carrier w/station, std. bolt	1	single	psi
2	Bolt carrier w/o station, std. bolt	20	auto.	Rd/min
3	Repeat test #1	1	single	psi
4	Bolt carrier w/station, std. bolt w/o rings	1	single	psi
5	Bolt carrier w/o station, std. bolt w/o rings	20	auto.	Rd/min
6	Repeat test #4	1	single	psi
7	Bolt carrier w/station, std. bolt w/o rings w/groove	1	single	psi
8	Bolt carrier w/o station, std. bolt w/o rings w/groove	20	auto.	Rd/min
9	Repeat test #7	1	single	psi

NOTES:

- 5.56mm M193 Ball Cartridge, Lot LC12304.
- 5.56mm Rifle M16A1, SN694387, with upper receiver and bolt carrier modified to obtain bolt carrier cavity pressures.
- Kistler Gauge, Model 603A, SN3090.
- 29 September 1970.

TABLE II. PART II TEST SCHEDULE:
STUDY OF BOLT/BOLT CARRIER CLEARANCE

<u>Test No.</u>	<u>Component</u>	<u>Rounds Fired</u>	<u>Results</u>
1	WECOM Bolt #1	100/5 magazines	Rd/min
2	WECOM Bolt #2	100/5 magazines	Rd/min
3	WECOM Bolt #3	100/5 magazines	Rd/min

NOTES:

Bolts components described in Table IV and Figure 1.
 5.56mm Rifle M16A1, SN823793.
 5.56mm, M200 Blank Cartridge, Lot TW 18056.
 Magazines were Frankford Arsenal improved experimental
 type for firing blank cartridges.
 1 October 1970.

TABLE III. PART III TEST SCHEDULE:
STUDY OF BOLT/BOLT CARRIER CLEARANCE

<u>Test No.</u>	<u>Bolt Assembly</u>	<u>Mode Fire</u>	<u>No. Rds.</u>	<u>Cartridge Type</u>
1	Bolt carrier w/press. station, w/std. bolt	single	2	M193
2	Bolt carrier w/o press. station, w/std. bolt	auto.	20	M193
3	Repeat item #1	single	2	M193
4	Repeat item #1	single	2	M200
5	Repeat item #2	auto.	20	M200
6	Repeat item #4	single	2	M200
7	Bolt carrier w/press. station, w/Bolt #1	single	2	M193
8	Bolt carrier w/o press. station, w/Bolt #1	auto.	20	M193
9	Repeat item #7	single	2	M193
10	Repeat item #9	single	2	M200
11	Repeat item #8	auto.	20	M200
12	Repeat item #9	single	2	M200
13	Bolt carrier w/press. station, w/Bolt #2	single	2	M193
14	Bolt carrier w/o press station, w/Bolt #2	auto.	20	M193
15	Repeat item #13	single	2	M193
16	Repeat item #15	single	2	M200
17	Repeat item #14	auto.	20	M200
18	Repeat item #15	single	2	M200
19	Bolt carrier w/press. station, w/Bolt #3	single	2	M193
20	Bolt carrier w/o press. station, w/Bolt #3	auto.	20	M193
21	Repeat item #19	single	2	M193
22	Repeat item #21	single	2	M200
23	Repeat item #20	auto.	20	M200
24	Repeat item #22	single	2	M200

NOTES:

M16A1 Rifle No. SN694387, having the upper receiver and bolt carrier modified to measure bolt carrier cavity pressures.
Ammunition: 5.56mm M193 Ball, Lot LC 12304, and M200 Blank, Lot TW18056.
Date: 1 October 1970.

TABLE IV. PERTINENT BOLT AND BOLT CARRIER DIMENSIONS

Part Name	Diameters (inch)		Figure 1 Dimensioning
	Specification	Measured	
Bolt Carrier, Modified	0.2523 ± 0.0003 (1)	0.2523 (2)	A
Bolt Carrier, Not Modified	0.2523 ± 0.0003	0.2525	A
Bolt, Standard	0.2503 ± 0.0002	0.2496 (2)	B
Bolt, WECOM #1, Std.	0.2503 ± 0.0002	0.2497 (2)	B
Bolt, WECOM #2, Std.	0.2503 ± 0.0002	0.2425	B
Bolt, WECOM #3, Std.	0.2503 ± 0.0002	0.240	B
Bolt Carrier, Modified	0.500 ± 0.001 (3)		C
Bolt Carrier, Not Modified	0.500 ± 0.001 (3)		C

- (1) Minimum diameter after "H" 0.2514, where "H" is noted on drawing.
 Finish - 1.22 of MIL-Std-D-171: Film Thickness 0.0002/0.0003 inch.
 (2) Dimension out of tolerance.
 (3) Minimum diameter after "H" 0.4984, see note (1).

NOTE: Bolt Carrier: Dwg. No. J61544; Bolt: Dwg. No. J6153.

fired in the single-shot firing mode. Rate of fire was measured and rifle function was noted when the rifle was fired in the automatic firing mode. The bolt sealing rings were removed and the test repeated. It was also planned to machine a groove along the bolt ring diameter to induce greater leakage (clearance) but this test was not necessary (see Test Results, Table V).

Part II (Table II) of the test consisted of firing three hundred (300) M200 Blank Cartridges from Lot TW18056 in the M16A1 Rifle, SN 823793. The standard bolt was replaced by the three bolts supplied by WECOM. Two of the three bolts were modified for this test by having the shaft diameters machined undersize by 0.0075 and 0.010 inch. The bolts are identified as numbers 1, 2, and 3, as indicated in Table IV. The pertinent diameters are identified in Figure 1. The test also made use of a modified experimental magazine for firing blank ammunition. This magazine is described and illustrated in Appendix A.3 The use of this magazine was considered expedient to reduce rifle malfunctions caused by magazine difficulties experienced when firing blank cartridges. Five (5) 20-round magazine loads were fired with each of the three bolts to obtain cyclic rate measurements. For this test the rifle was fired from the Function and Casualty Test Fixture.

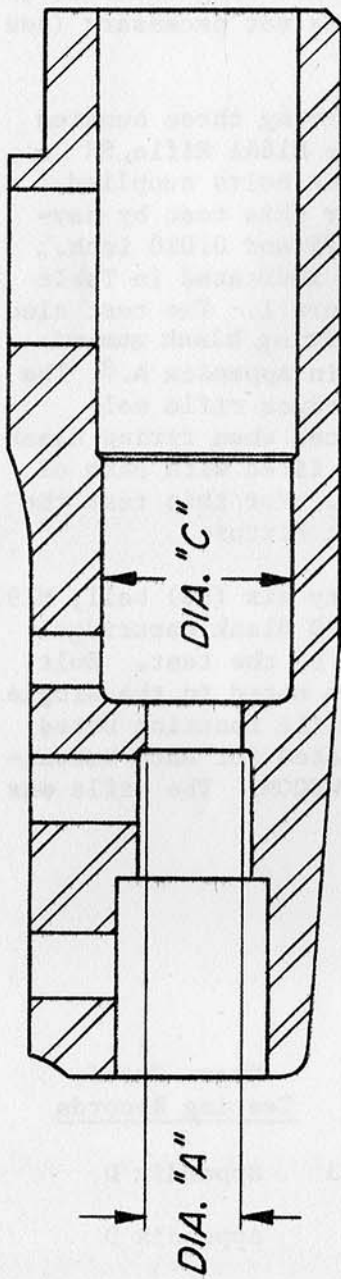
Part III (Table III) consisted of firing ninety six (96) ball, M193 cartridges from Lot LC12304 and ninety six (96) M200 Blank Cartridges from Lot TW18056 in the same rifle used for Part I of the test. Bolt pressure-time data were recorded and rifle function noted in the single shot firing mode. Rate of fire was recorded and rifle function noted in the automatic firing mode. The tests were repeated for each ammunition type and each of the three bolts supplied by WECOM. The rifle was mounted in the Frankford Arsenal Aluminum Mount.

TEST RESULTS

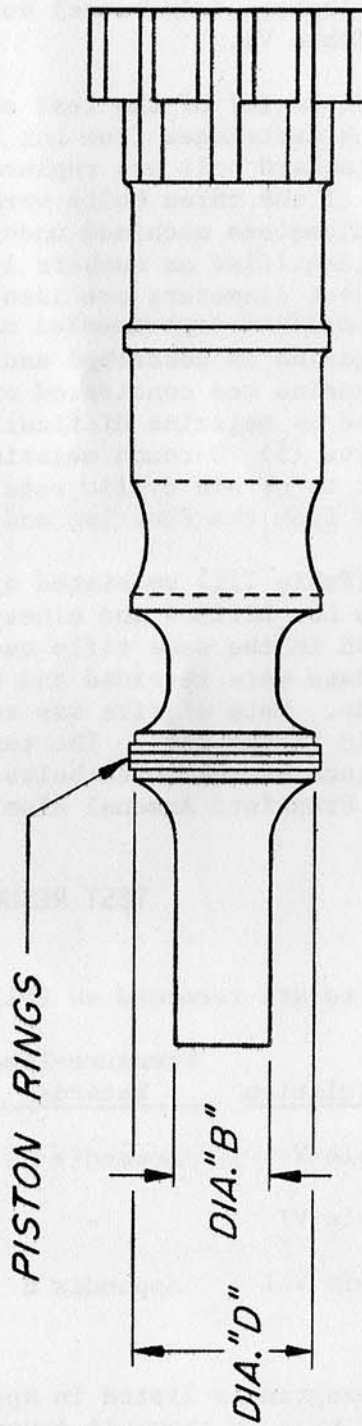
Test results are recorded as follows.

<u>Part</u>	<u>Tabulation</u>	<u>Pressure-Time Records</u>	<u>Computer Analysis*</u>	<u>Engr. Proof Testing Records</u>
I	Table V	Appendix B	Appendix C-3	Appendix D
II	Table VI	-	-	Appendix D
III	Table VII	Appendix B	Appendix C-4	Appendix D

*The computer program is listed in Appendix C-1 and a typical analysis for a standard bolt is shown in Appendix C-2.



BOLT CARRIER



BOLT

Figure 1. Location of Bolt and Bolt Carrier Dimensions in Table IV

The test results of Part I are contained in Table V. In this test a modified bolt was used in the M16A1 Rifle for all firings in the single shot mode. This modified bolt carrier permits the recording of pressure time in the bolt carrier cavity. However, a standard bolt carrier assembly was used for all tests with the rifle in the automatic firing mode when measuring the rate of fire. The rifle malfunction on round no. 3 (failure to eject) was attributed to the high rate of fire (900 rpm). The buffer and buffer spring were replaced to overcome this difficulty prior to continuation of the test.⁴

The bolt sealing rings were then removed and test round no. 6 was fired with the rifle in the single shot firing mode. A maximum bolt carrier cavity pressure of 1600 psi was recorded. At this pressure level, the bolt carrier failed to lock in the open position. The computer simulation analysis of this bolt carrier pressure-time curve (see Appendix C) showed that the bolt carrier traveled only 2.75 inches rearward. To engage the lock, the bolt carrier must travel a minimum of 3.68 ± 0.043 inches.

Following each pressure test round, an attempt was made to fire a full magazine of twenty (20) cartridges in the full automatic mode. The rifle would not cycle in the automatic firing mode with the bolt sealing rings removed. Successful automatic fire occurs when the bolt carrier travels 3.21 ± 0.042 inches rearward to engage the base of succeeding cartridges in the magazine. The test plan was modified by firing additional cartridges with the bolt sealing rings removed to increase the sample size. It was considered unnecessary to machine a gas leakage groove along the bolt seal ring diameter as dictated by the test plan.

Table VI contains the test results of Part II. The M200 Blank Cartridge was fired with the M16A1 Rifle mounted in the Function and Casualty Mount. To reduce the possibility of magazine malfunctions, the Frankford Arsenal Modified Experimental Magazine for Blanks was used as described and illustrated in Appendix A. Rifle function was normal in the first phase of the test using the Rock Island-supplied bolt #1 (0.0005 inch less than specifications). Test records show a rate of fire increase, normally expected when successive rounds are fired in the automatic firing mode and a minimum of time allowed between reloading. The M16A1 Rifle malfunctioned in tests using WECOM bolts #2 and #3 whose diameters were machined 0.0075 and 0.010 inch, respectively, less than specifications. Firings were repeated with each of the modified bolts to obtain a significant sample size.

Table VII contains the Part III test results. For this test, the M16A1 Rifle was secured in the Frankford Arsenal Aluminum Test Mount. No rifle malfunctions occurred using the standard bolt or the WECOM bolt #1 when firing either M193 Ball or M200 Blank ammunition in the single shot or automatic firing modes. Test round No. 10 (M200 Blank) was fired with a modified bolt carrier and a standard bolt. The bolt carrier pressure-time curve indicated a peak pressure of 900 psi but

TABLE V. PART I TEST RESULTS

Test No.	Bolt Carrier	Bolt	No. Rounds	Firing Mode	Cartridge Type	Maximum Bolt Press (psi)	Velocity (fps) @ 62.5 ft	Rate (rd/min)	Comments
1	with gage	std.	1	single	M193	2300	--	--	cycled (1)
2	w/o gage	"	20	auto.	"	--	--	943	17 rnds BOB
3	"	"	20	"	"	--	--	900	11 rnds (2)
4	"	"	20	"	"	--	--	894	cycled
5	with gage	"	1	single	"	2400	3035	--	cycled
6	"	w/o rings	1	"	"	1600	--	--	bolt did not lock open.
7	w/o gage	"	20	auto.	"	--	--	--	FF (1)
8	"	"	20	"	"	--	--	--	BOB
9	"	"	20	"	"	--	--	--	BOB
10	with gage	"	1	single	"	1400	--	--	FF
11	"	"	1	"	"	1450	--	--	FF
12	"	"	1	"	"	1400	--	--	FF

(1) If the bolt carrier locks in the open position, the rifle has cycled; from test No. 7 the magazine was loaded with 20 cartridges.

(2) Buffer and Buffer spring replaced in an effort to reduce the cyclic rate. Cartridge became impinged between bolt carrier and upper receiver housing.

NOTES:

Rifle M16A1, SN69387, and Kistler gage 603ASN3090 were used in test.
Ammunition was M193 Ball Cartridge, lot LC 12304.

The same rifle components were used in each firing with the exception of the bolt carrier.
Date: 29 October 1970.

TABLE VI. PART II TEST RESULTS

<u>Magazine No.</u>	<u>WECOM Bolt No.</u>	<u>Cyclic Rate (rd/min)</u>	<u>Comments</u>
1	1	549	See notes (1) through (5).
2	1	592	" " " " " "
3	1	683	" " " " " "
4	1	697	" " " " " "
5	1	719	" " " " " "
6	2	-	See notes (6) through (9) - 16 shots were fired in an attempt to cycle the weapon - each stoppage was attributed to a failure to feed.
7	3	-	See notes (10) through (14). 1 round double fired. 2 rounds failure to eject. 16 rounds BOB.

- (1) Headspace, 1.466 inches.
- (2) Firing pin protrusion, 0.033 inch.
- (3) Firing pin indent, 0.021 inch.
- (4) Flow meter reading 5.4.
- (5) The increase in cyclic rate with successive magazines was attributed to the increase in rifle temperature. Time lapse between firings was limited to time required for loading.
- (6) Headspace, 1.499 inches.
- (7) Firing pin protrusion, 0.031 inch.
- (8) Firing pin indent, 0.022 inch.
- (9) Flow meter reading, 3.3.
- (10) Headspace, 1.499 inches.
- (11) Firing pin protrusion, 0.031 inch.
- (12) Firing pin indent, 0.022 inch.
- (13) Flow meter reading, 2.9.
- (14) Date: 1 October 1970.

TABLE VII. PART III TEST RESULTS

Test No.	Bolt Carrier	Bolt Assembly	No. Rounds	Firing Mode	Cartridge Type	Maximum Bolt Press (psi)	Velocity (fps) @ 62.5 ft	Rate (rd/min)	Comments
1	with gage	std.	1	single	M193	2350	3103	--	cycled
2	"	"	1	single	"	2400	3160	--	"
3	w/o gage	"	20	auto.	"	--	3064	891	--
4	with gage	"	1	single	"	2450	3069	--	cycled
5	"	"	1	single	"	2250	3088	--	"
6	"	"	1	"	M200	850	--	--	"
7	"	"	1	"	"	850	--	--	"
8	w/o gage	"	20	auto.	"	--	--	--	--
9	with gage	"	1	single	"	900	--	--	cycled
10	"	"	1	"	"	900	--	--	"
11	with gage	#1	1	single	M193	2600	2968	--	cycled
12	"	"	1	"	"	2350	3142	--	"
13	w/o gage	"	20	auto.	"	--	3093	851	17 rounds
14	"	"	20	"	"	--	3048	873	cycled
15	with gage	"	1	single	"	2550	3103	--	"
16	"	"	1	"	"	2550	3105	--	"
17	"	"	1	"	M200	900	--	--	"
18	"	"	1	"	"	900	--	--	"
19	w/o gage	"	20	auto.	"	--	--	--	"
20	with gage	"	1	single	"	800	--	--	"
21	"	"	1	"	"	900	--	--	"
22	"	#2	1	"	M193	2200	3094	--	"
23	"	"	1	"	"	2100	3072	--	"
24	w/o gage	"	20	auto.	"	--	3089	785	"
25	with gage	"	1	single	"	2150	3132	--	"
26	"	"	1	"	"	2250	3028	--	"
27	"	"	1	"	M200	750	--	--	"
28	"	"	1	"	"	800	--	--	"
29	w/o gage	"	20	auto.	"	--	--	--	"

TABLE VII. PART III TEST RESULTS (Cont'd)

Test No.	Bolt Carrier	Bolt Assembly	No. Rounds	Firing Mode	Cartridge Type	Maximum Bolt Press (psi)	Velocity @ 62.5 ft (psi)	Rate (rd/min)	Comments
30	with gage	#2	1	single	M200	750	--	--	cycled
31	"	"	1	"	"	750	--	--	BOB
32	with gage	#3	1	single	M193	2000	3135	--	cycled
33	"	"	1	"	"	1950	3125	--	"
34	w/o gage	"	20	auto.	"	--	3106	731	"
35	with gage	"	1	single	"	1950	3095	--	"
36	"	"	1	"	"	2000	3125	--	"
37	"	"	1	"	M200	700	--	--	FF
38	"	"	1	"	"	750	--	--	FF
39	"	"	1	"	"	750	--	--	BOB
40	"	"	1	"	"	750	--	--	FF
41	w/o gage	"	20	auto.	"	--	--	--	FF
42	"	"	20	"	"	--	--	--	FF
43	"	"	20	"	"	--	--	--	FF
44	"	"	20	"	"	--	--	--	FF
45	with gage	"	1	single	"	no pict	--	--	BOB
46	"	"	1	"	"	"	--	--	FF
47	"	"	1	"	"	"	--	--	FF
48	"	"	1	"	"	"	--	--	BOB

NOTES:

Rifle M16A1, SN 694387, and Kistler gage model 603ASN3090 were used in test.

All firings for tests 11-21 were with a full magazine.

The bolt diameter at the shaft was 0.2497 inches. The corresponding diameter on the bolt carrier on the modified bolt carrier was 0.2523 inches, and 0.2525 inches on the bolt carrier used in the cyclic rate test.

Cartridge types M193 Ball, lot LC12304, and M200 Blank, lot TW18056.

The Kistler gage was seated with a brass gasket and 30 inch pounds of torque.

The WECOM supplied bolt no. 1 measured 0.2497 inch.

Date: 1 October 1970.

the rifle cycled in an apparent normal manner. Further analysis of this record was made in the simulation computer program (see Appendix C), which showed the bolt carrier traveled 3.55 inches rearward. Minimum required rearward bolt carrier travel for weapon cycling in the full automatic mode is 3.21 inches.

Tests with bolt #2 (0.0075 inch undersize) produced no rifle malfunctions in either the single shot or automatic firing modes when firing ball M193 ammunition. One BOB (bolt over base) malfunction occurred with the blank cartridge in the single shot firing mode. There were no rifle malfunctions in the automatic firing mode.

The WECOM bolt #3, machined 0.010 inch undersize, produced no rifle malfunction when firing ball M193 ammunition. M200 blank ammunition would not cycle the rifle in either the single shot or automatic firing modes.

COMPUTER ANALYSIS OF BOLT CARRIER PRESSURE-TIME CURVE

An abbreviated simulation computer program was used to analyze two bolt pressure-time curves, round nos. 6 and 10, recorded in test Part I, Table V. The computer program is listed in Appendix C-1 and a typical analysis for a standard bolt is shown in Appendix C-2. The analyses of the two rounds are listed in Appendixes C-3 and C-4. Oscillograph histories were recorded using the same pressure transducer, modified M16A1 Rifle, and firing mount. The two rounds differed as follows:

Test Round No. 6. Did not cycle the rifle. Recorded maximum bolt carrier pressure was 1600 psi. The bolt sealing rings were removed.

Test Round No. 10. Cycled the rifle. Recorded maximum bolt carrier pressure was 900 psi.⁵

Table VIII contains a summary of the results of this analysis. The two rounds from this test are compared to each other and to the results of a typical pressure time curve recorded when firing the same modified rifle M193 Ball Ammunition, Lot LC12304.

TABLE VIII. SUMMARY OF RESULTS OF M16A1 SIMULATION ANALYSIS

<u>Rd.</u>	<u>Cartridge Type</u>	<u>Bolt/Bolt Carrier Assembly</u>	<u>Max. (1) Pressure (psi)</u>	<u>Sec. to 0.335 in.</u>	<u>Bolt Carrier Travel Max. in. Rearward</u>	<u>Max. Vel. (fps)</u>	<u>Rifle Operation</u>
6	M193 (2)	Modified bolt carrier sealing rings removed.	1600	0.004	2.75	9.83	Malfunction
10	M200 (3)	Modified bolt carrier standard bolt.	900	0.0045	3.55	11.78	Cycled
Typical	M193 (3)	Modified bolt carrier standard bolt.	2100	0.003	3.82	16.59	Cycled

(1) Bolt pressure-time curve digitized from zero at start to zero at finish, approximately 20 readings.

(2) A rifle malfunction occurred on this round, failure to feed.

(3) The bolt carrier's rearward travel of 3.55 inches would permit the stripping of a cartridge from the magazine. The minimum required is 3.211 - 0.042 inches.

Bolt pressure-time curve obtained with ball cartridge and a standard bolt/bolt carrier assembly.

The travel to a locked open position would require 3.68 ± 0.043 inches of bolt carrier travel.

NOTES:

CONCLUSIONS

Limitations of the tests did not permit significant conclusions and recommendations other than a series of borne-out observations as follow.

Both firing tests and mathematical model computations confirmed that bolts with diameters 0.0075 and 0.010 inch below specification do not perform satisfactorily because of excessive gas leakage between the outside bolt shaft diameter and its mating diameter in the bolt carrier.

Both the modified and unmodified M16A1 Rifles functioned normally with bolts having shaft diameters 0.0004 and 0.0005 inch less than specifications. This was true for both ball and blank ammunition with the rifles mounted in the Frankford Arsenal Test Mount and the Function and Casualty Fixture.

Both the modified and unmodified M16A1 Rifles functioned with bolts having shaft diameters purposely reduced in diameter to 0.0075 and 0.010 inch under specifications and firing Ball M193 ammunition from the Frankford Arsenal Test Mount.

The unmodified M16A1 Rifle failed to function with bolts having their shaft diameters purposely reduced to 0.0075 and 0.010 inch under specifications when fired in the Function and Casualty Mount using M200 blank ammunition.

The modified M16A1 Rifle functioned successfully in three of four tests, one of which was a twenty-round burst with the bolt having a shaft diameter undersize by 0.0075 inch using M200 blank ammunition from the Frankford Arsenal Test Mount.

The modified M16A1 Rifle failed to function in any of the twelve tests (four in the automatic mode of fire) with the bolt having a shaft diameter undersize by 0.010 inch and firing M200 blank ammunition from the Frankford Arsenal Test Mount.

The modified M16A1 Rifle did not function normally when the bolt sealing rings were removed and M193 ball ammunition was fired with the rifle mounted in the Frankford Arsenal Test Mount.

The maximum bolt carrier cavity pressure is not the correct criterion for determining whether the bolt carrier will have sufficient momentum to successfully cycle the rifle. Rather, the total energy under the Bolt-Cavity PT curve should be used. A maximum bolt carrier pressure of 1600 psi obtained with Ball M193 Ammunition (Table V round no. 6) failed to cycle the rifle. A maximum pressure of 900 psi obtained with M200 Blank Ammunition (Table VII round no. 10) did cycle the rifle.²

REFERENCES

1. L. MacMillan, R. Banash and P. Ehle, "M16A1 Rifle Bolt Dimensions (.2503 Dia. + .0002) Investigation," U.S. Army Weapons Command, Rock Island, Ill., Technical Note, 27 October 1970.
2. Martin Horchler, "Experimental Study of the Flow Characteristics in the Gas Tube of the M16A1 Rifle," Frankford Arsenal Technical Note TN-1150, April 1970.
3. Bruce W. Brodman and Andrew J. Grandy, "Elimination of Gas Tube Fouling in the M16A1 Rifle When Using the M200 Blank Cartridge," Frankford Arsenal, Report R-1946, February 1970.
4. Arthur J. Magar, "Investigation of U.K. Extraction Difficulties with 5.56mm Ammunition," Frankford Arsenal Report R-1894, July 1968.
5. Sidney Goldstein, "Qualitative Investigation of the Functioning of 7.62mm Blank Ammunition, Frankford Arsenal Technical Note TN-1141, June 1969.
6. L. MacMillan, "Briefing to General Rasmussen on M16A1 Rifle Dimension Variances Investigation," U.S. Army Weapons Command, Rock Island, Ill., Memorandum for Record, October 1970.
7. Raymond H. Weir, Jr., "Inspection of H&R Bolts P/N 61538," AMSWE-Res. Investigation Plan, September, 1970.

APPENDIX A

FRANKFORD ARSENAL MODIFIED EXPERIMENTAL BLANK CARTRIDGE MAGAZINE

Early experiments with M200 blank ammunition disclosed that it was virtually impossible to maintain the firing continuity that these experiments required.

The M200 blank cartridge is approximately 3/8 inch shorter than the standard M193 ball cartridge. Thus, there can be a random orientation (longitudinal) of the blank cartridges when loaded into the standard magazine. As a result, the bolt will contact the base of the round differently for each chambering action.

If the total blank cartridge load is oriented rearward in normal fashion during the magazine loading process, this will not eliminate the stubbing problem. Forward motion of the bolt during chambering will cause forward motion of the next round beneath the round being chambered. This is caused by the frictional forces existing between rounds in the magazine. When the bolt cycles on the succeeding round, it strikes the base with sufficient energy to misalign it with the chamber. This will either stub the round against the chamber teeth or the magazine, or jam it somewhere within the ejection port.

To overcome this unpredictable cartridge position in the magazine, a filler was inserted into the forward part of a standard magazine. This filler was sufficiently long to accommodate the shorter length M200 cartridges. Figure A-1 shows the component parts of the standard magazine and modified magazine, as well as a view of each loaded with M200 cartridges.

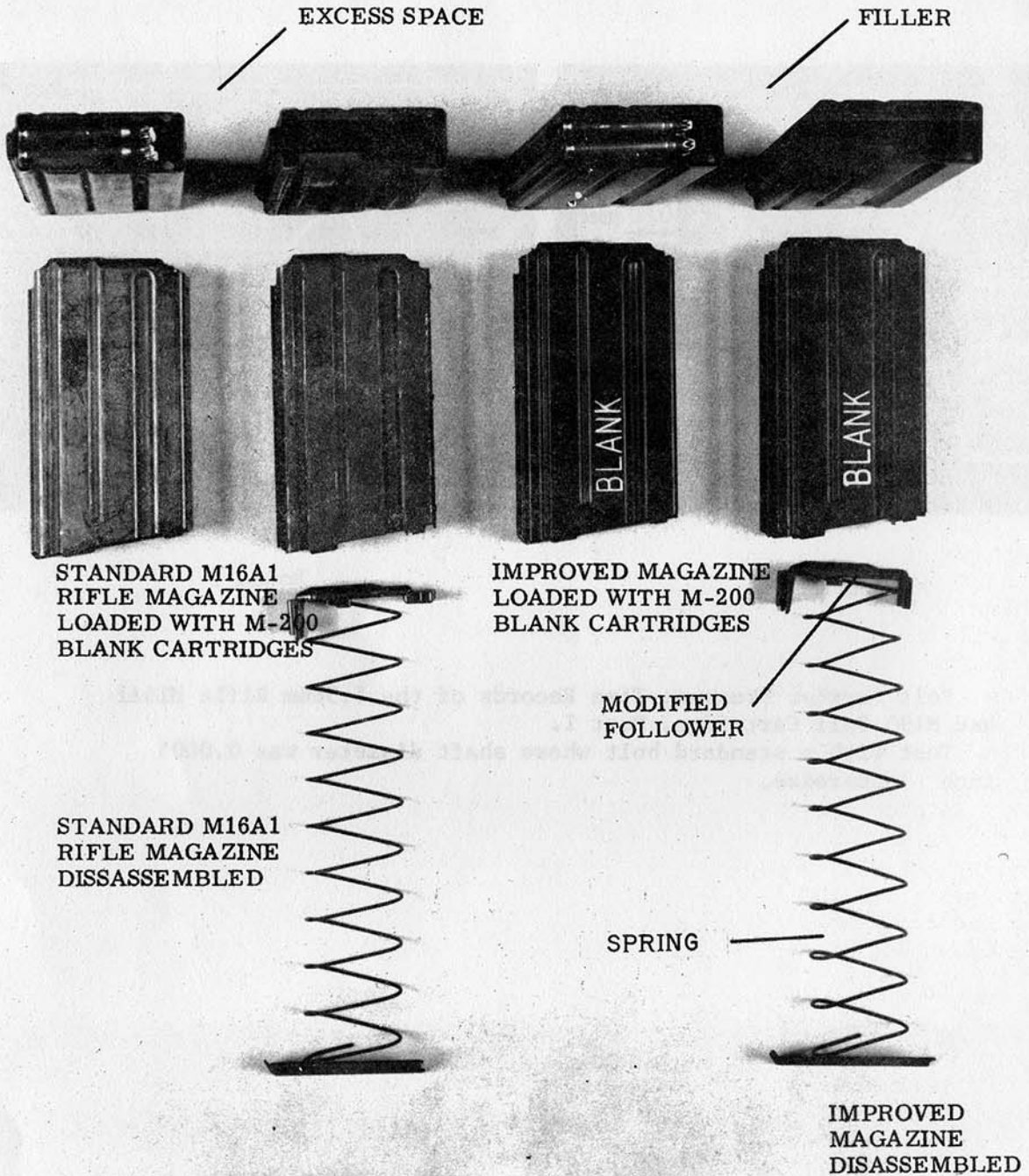
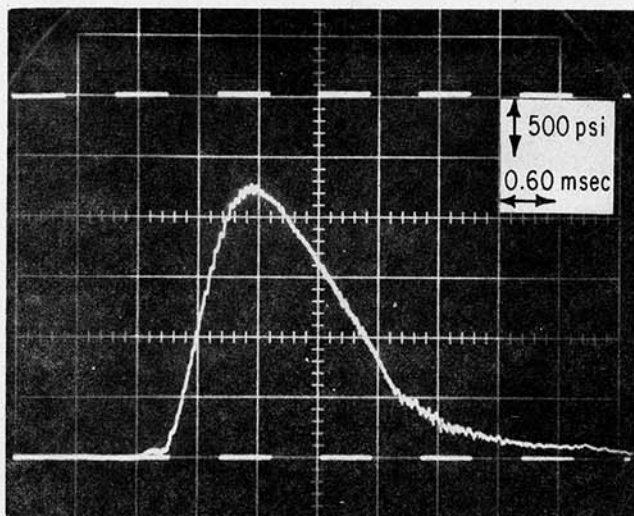
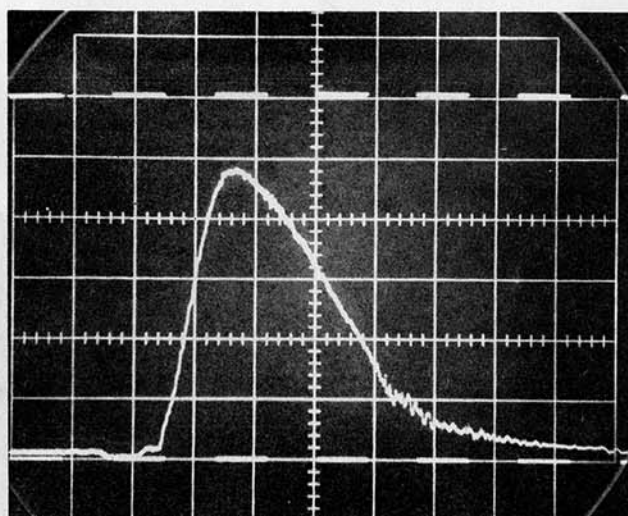


Figure 2. Standard and Improved Magazines with M200 Blank Cartridges for Rifle 5.56mm M16A1

APPENDIX B
PRESSURE-TIME RECORDS



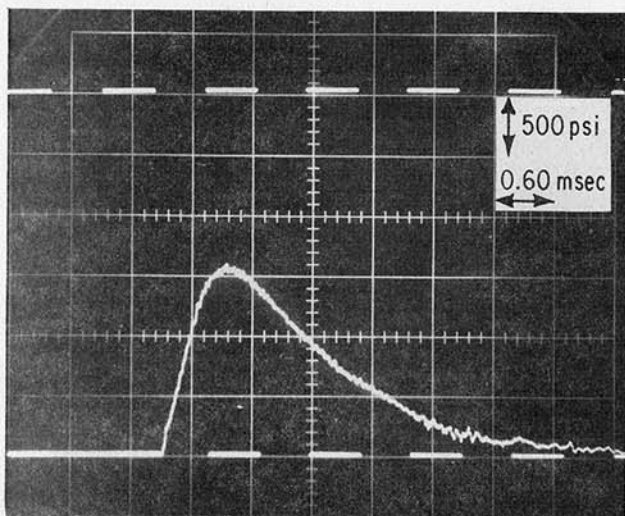
Round 1



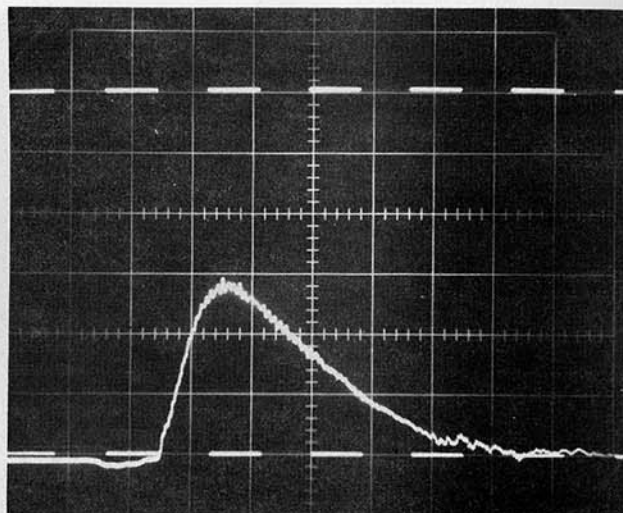
Round 2

Bolt Carrier Pressure-Time Records of the 5.56mm Rifle M16A1
and M193 Ball Cartridge, Part I.

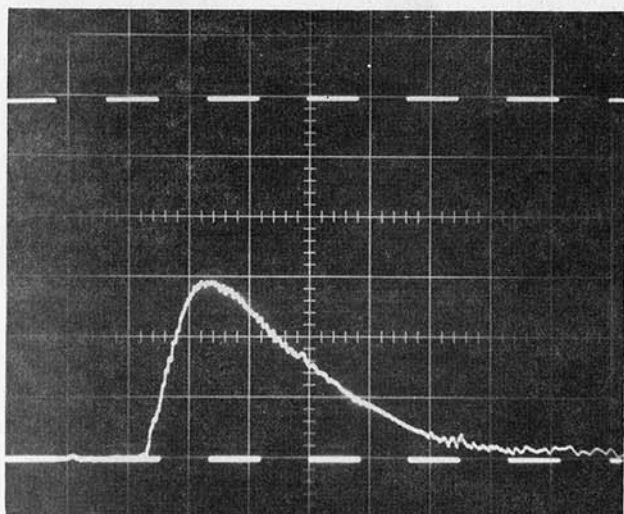
Test with a standard bolt whose shaft diameter was 0.0005
inch. undersize.



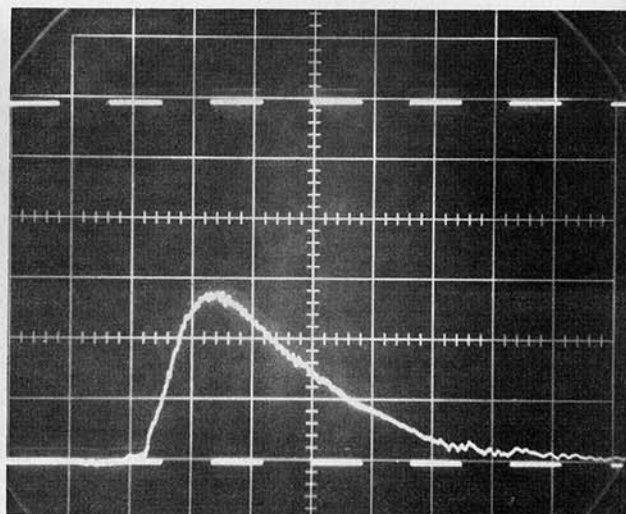
Round 3



Round 4



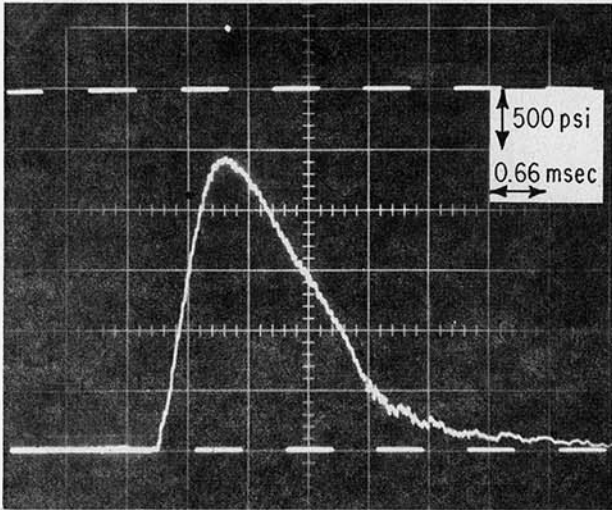
Round 5



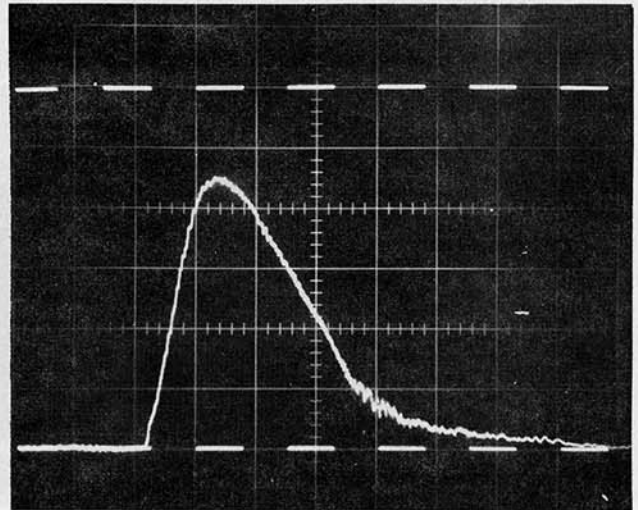
Round 6

Bolt Carrier Pressure Time Records of the 5.56mm Rifle M16A1 and M193 Ball Cartridge, Part I.

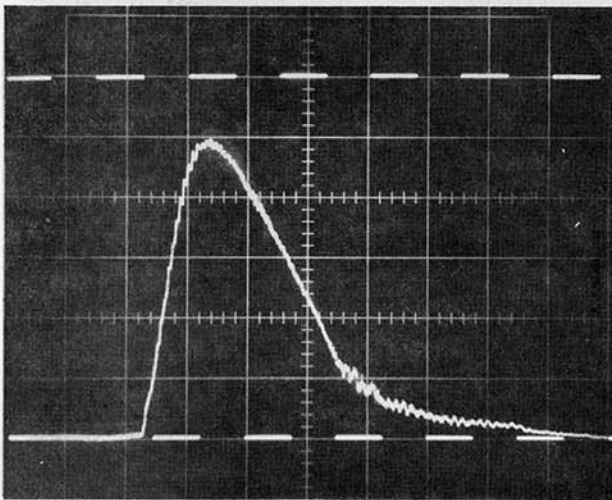
Test with a standard rifle bolt whose shaft diameter was 0.0005 inch undersize and with the bolt rings removed.



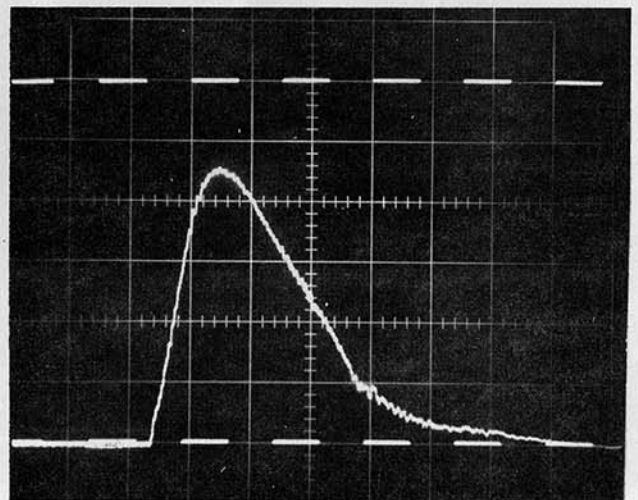
Round 1



Round 2



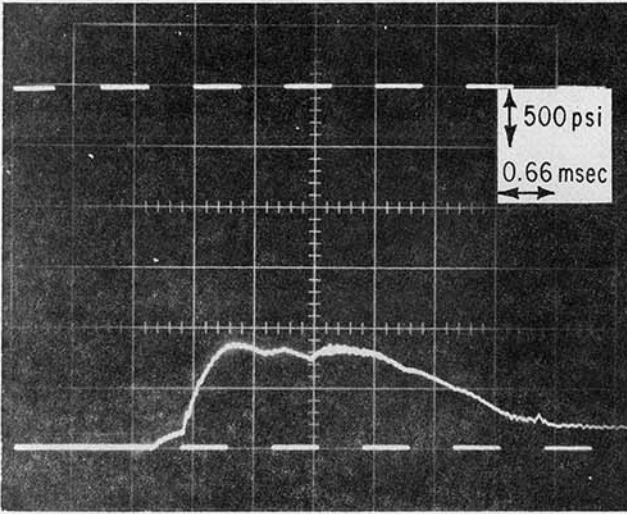
Round 3



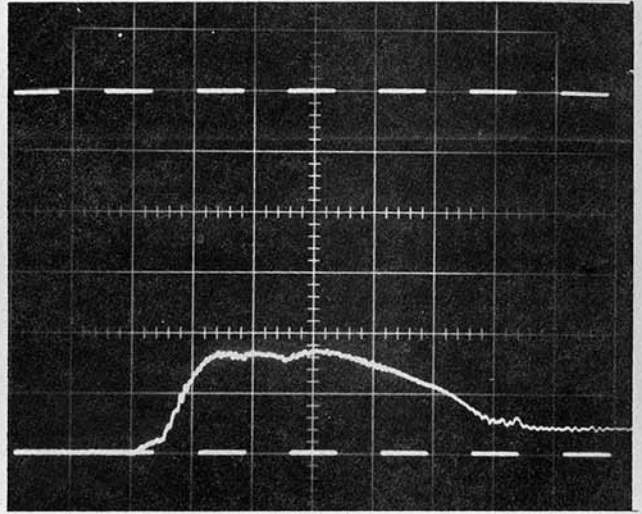
Round 4

Bolt Carrier Pressure-Time Records of the 5.56mm Rifle M16A1 and M193 Ball Cartridge. Part III.

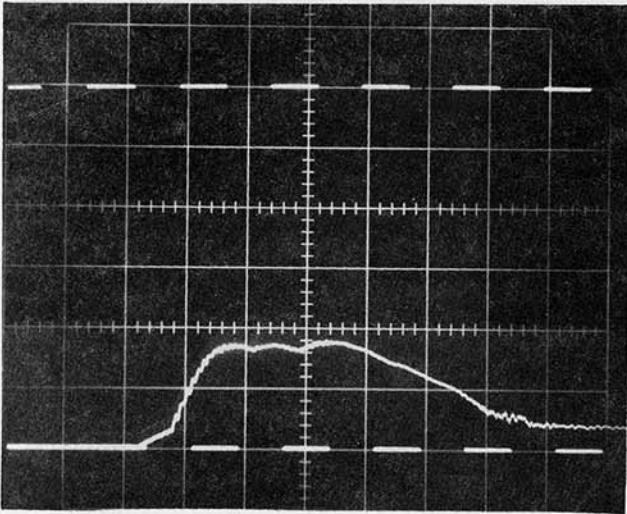
Test with the undersized bolt shaft diameter, 0.2503 ± 0.0002 versus 0.2496 inch.



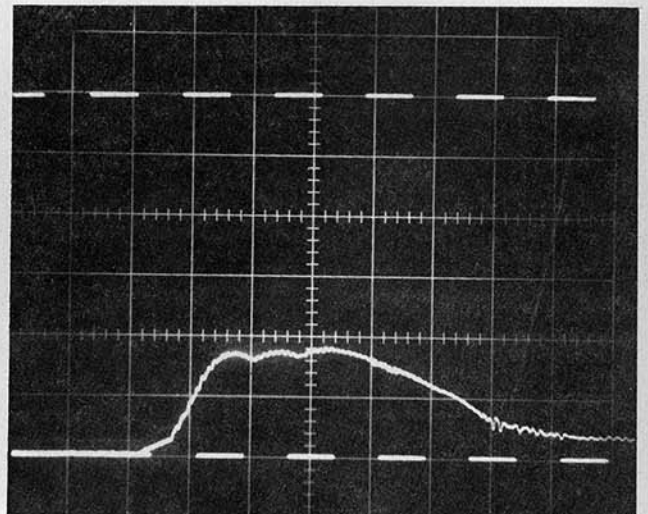
Round 5



Round 6



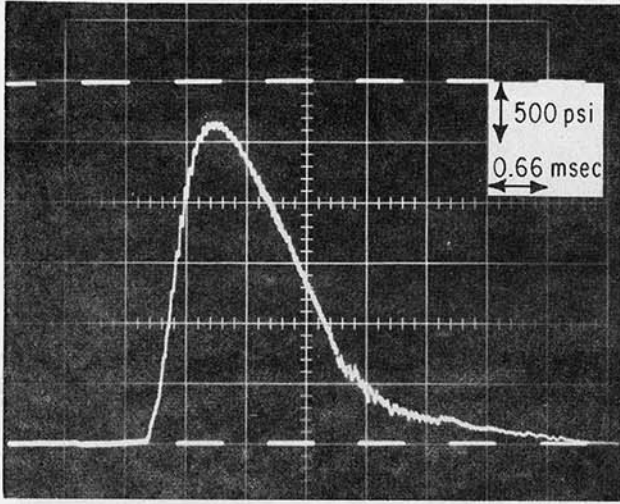
Round 7



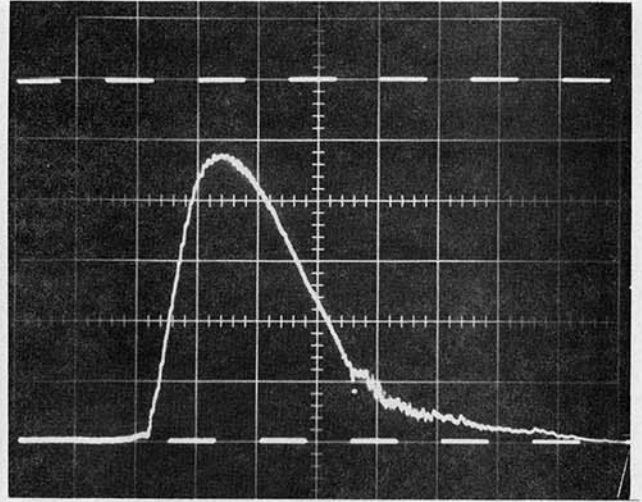
Round 8

Bolt Carrier Pressure-Time Records of the 5.56mm Rifle M16A1 and M200 Blank Cartridge. Part III.

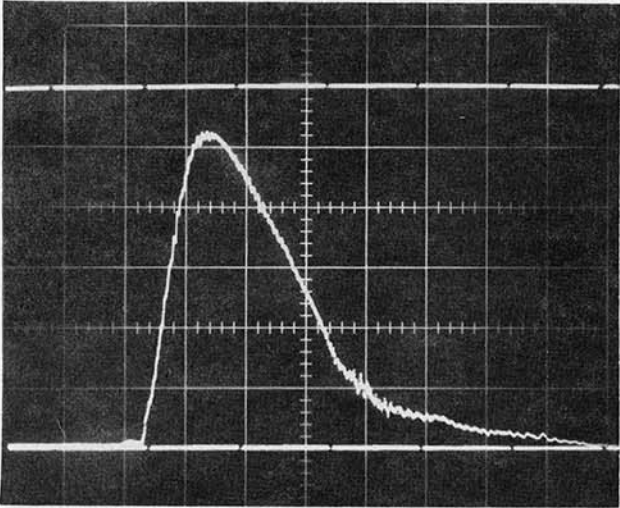
Test with the undersized bolt shaft diameter, 0.2503 ± 0.0002 versus 0.2496 inch.



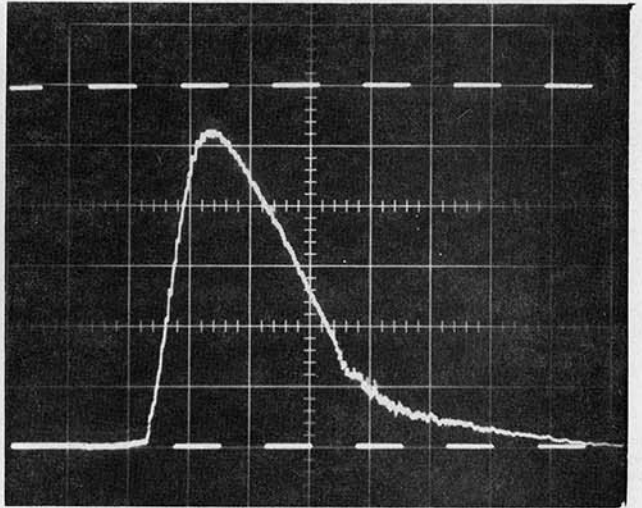
Round 9



Round 10



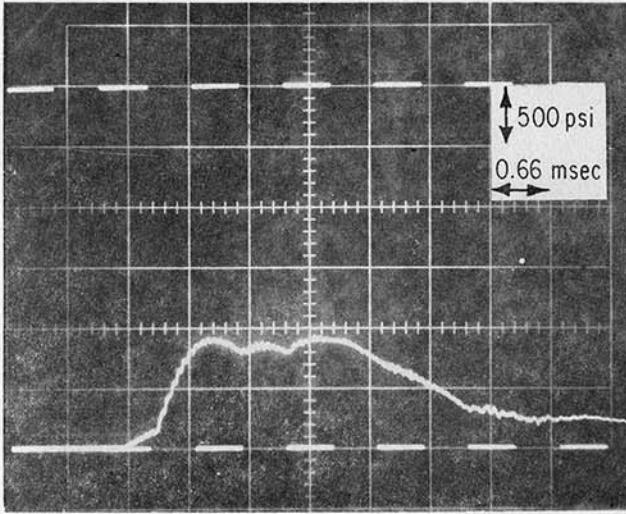
Round 11



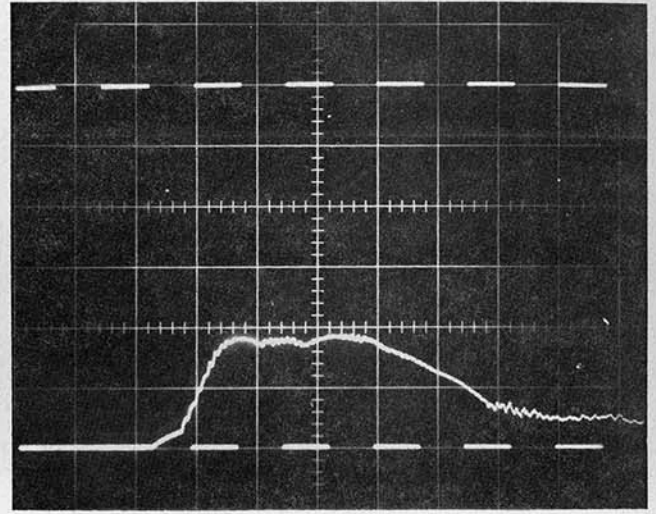
Round 12

Bolt Carrier Pressure-Time Records of the 5.56mm Rifle M16A1 and M193 Ball Cartridge. Part III.

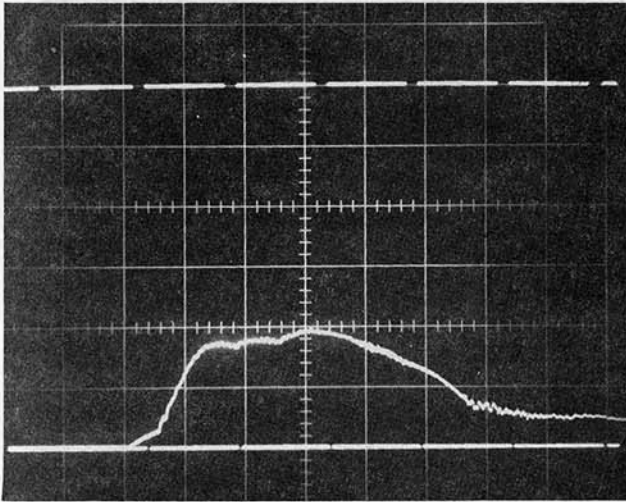
Test with the undersized bolt shaft diameter, 0.2503 ± 0.0002 versus 0.2497 inch.



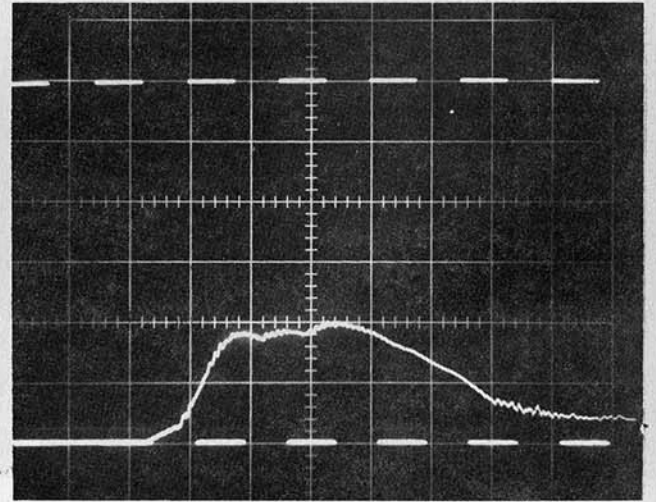
Round 13



Round 14



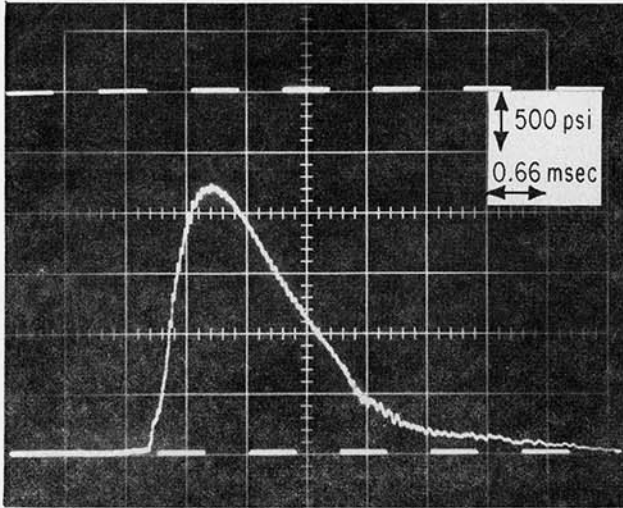
Round 15



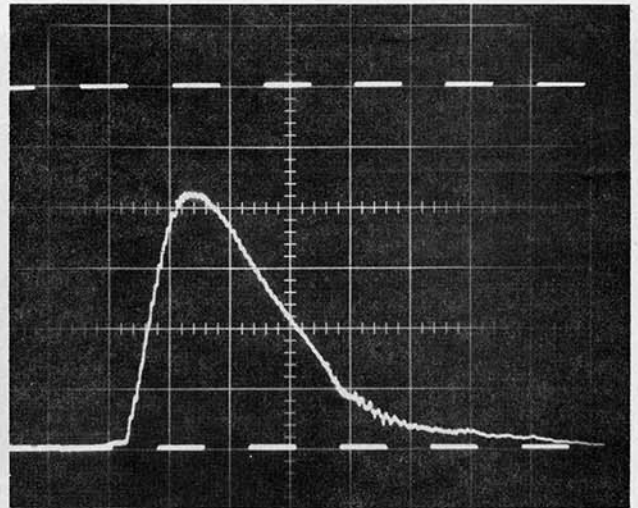
Round 16

Bolt Carrier Pressure-Time Records of the 5.56mm Rifle M16A1 and M200 Blank Cartridge, Part III.

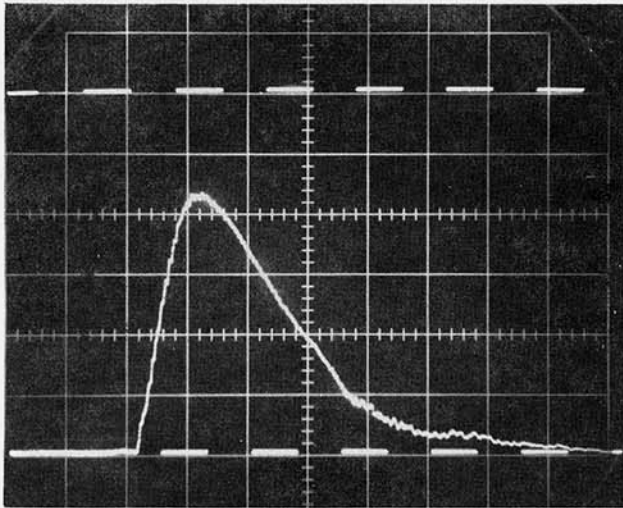
Test with the undersized bolt shaft diameter, 0.2503 ± 0.0002 versus 0.2497 inch.



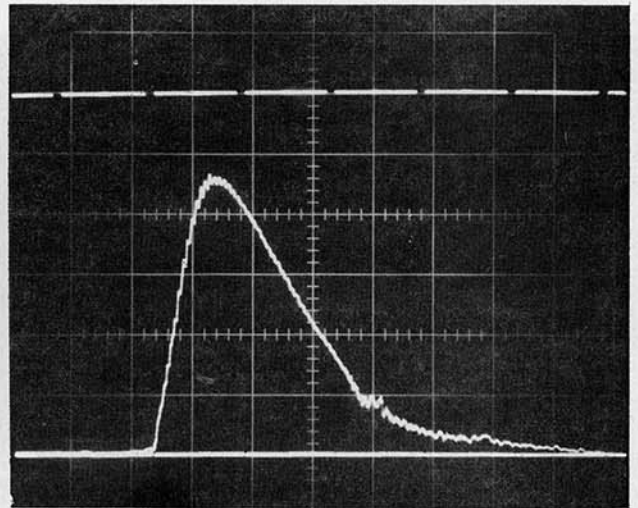
Round 17



Round 18



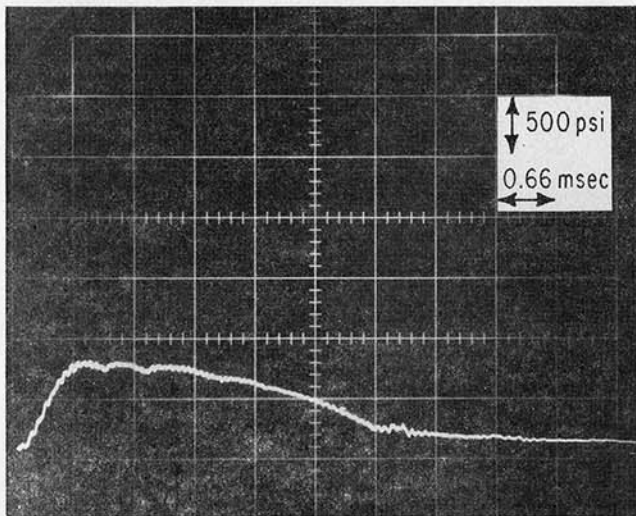
Round 19



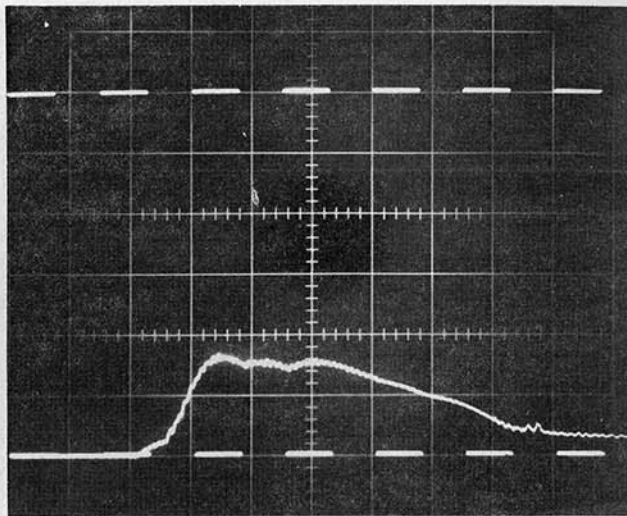
Round 20

Bolt Carrier Pressure-Time Records of the 5.56mm Rifle M16A1 and M200 Ball Cartridge, Part III.

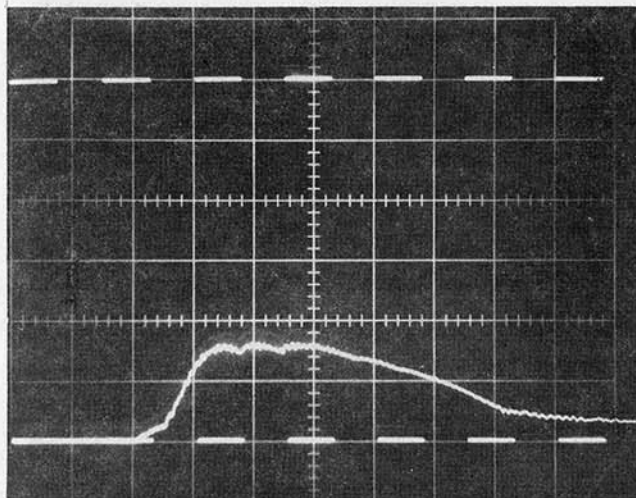
Test with the undersized bolt shaft diameter, 0.2503 ± 0.0002 vs. 0.2425 inch.



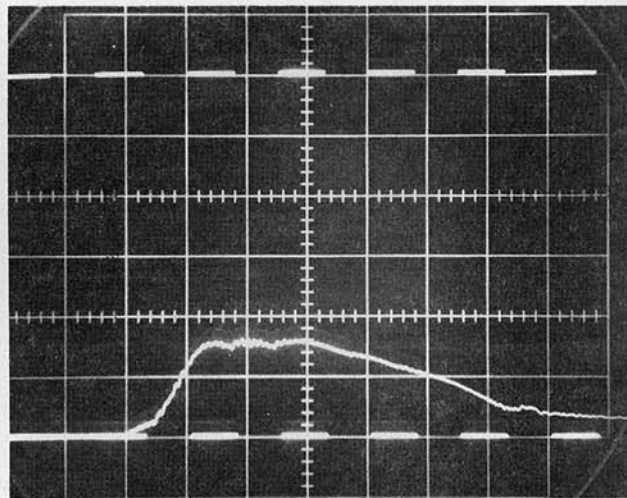
Round 21



Round 22



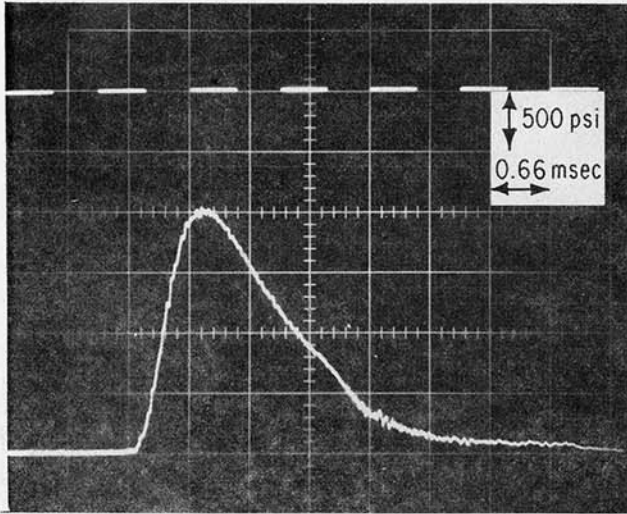
Round 23



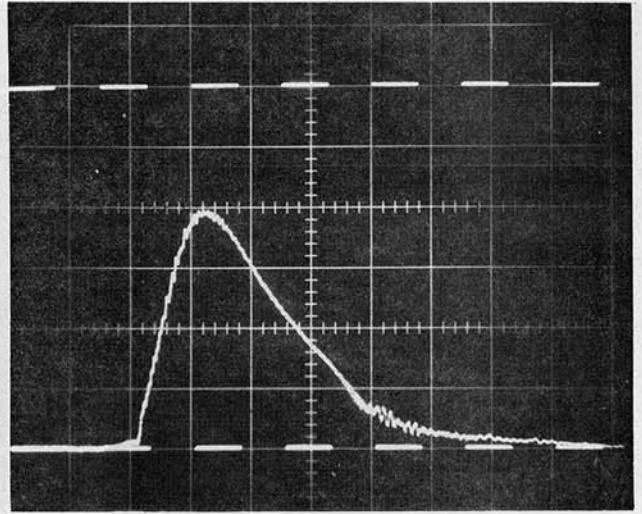
Round 24

Bolt Carrier Pressure-Time Records of the 5.56mm Rifle M16A1 and M193 Ball Cartridge, Part III.

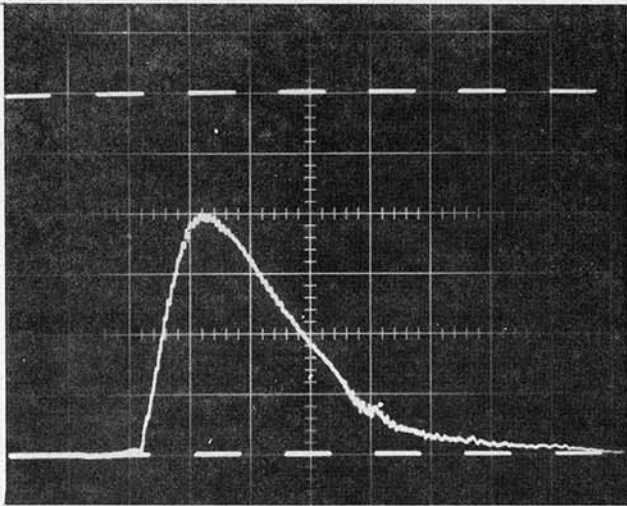
Test with the undersized bolt shaft diameter, 0.2503 ± 0.0002 versus 0.2425 inch.



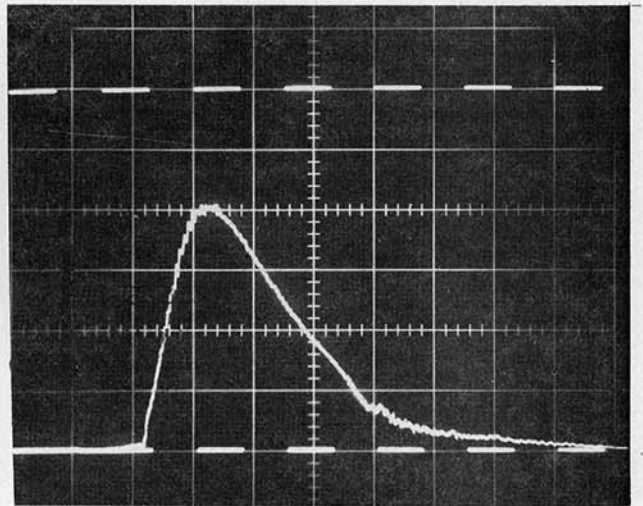
Round 25



Round 26



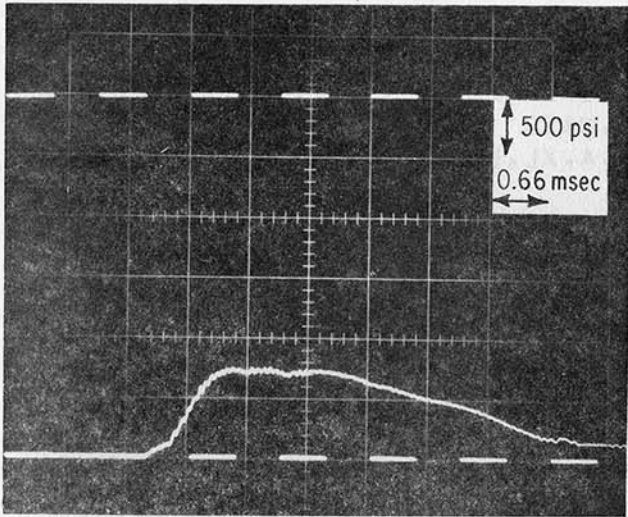
Round 27



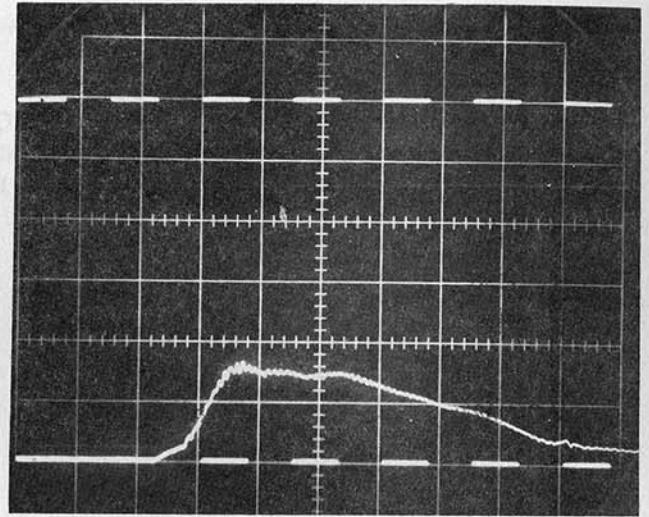
Round 28

Bolt Carrier Pressure-Time Records of the 5.56mm Rifle M16A1 and M193 Ball Cartridge, Part III.

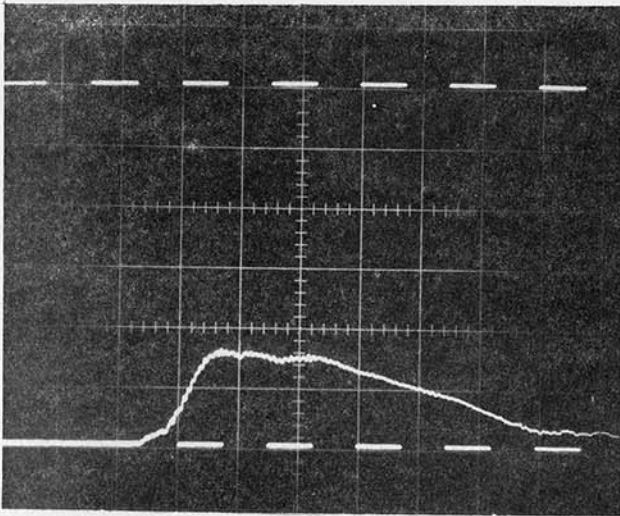
Test with the undersized bolt shaft diameter, 0.2503 ± 0.0002 versus 0.2400 inch.



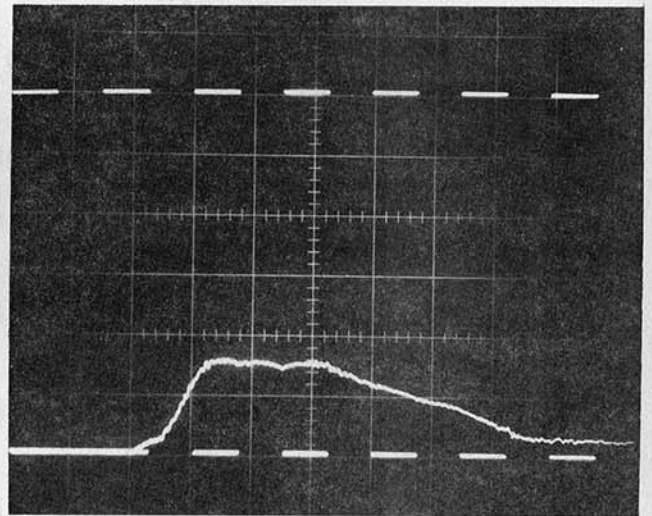
Round 29



Round 30



Round 31



Round 32

Bolt Carrier Pressure-Time Records of the 5.56mm Rifle M16A1 and M200 Blank Cartridge, Part III.

Test with the undersized bolt shaft diameter, 0.2503 ± 0.0002 versus 0.0002 inch.

APPENDIX C
M16A1 SIMULATION PROGRAM AND ANALYSIS OF BOLT CARRIER PRESSURES

1. Program Listing

```
EXTERNALACCELL  
REALKO,K1,K3,IMPACT,MASS  
COMMONMASS,KO,K1,K3,A,XL,L,C  
00110 FORMAT(4(4X,E14.8))  
00120 FORMAT(1H1)  
      KO:6.  
      K1:1.5  
      A:.137  
      MASS:.0029  
      XL:3.75  
      K3:9380.  
      D3:1.6556  
      D:0.0  
      DELTA:.00005  
00400 WRITE(3,120)  
      TIME:0.0  
      X:0.0  
      XDOT:0.0  
      X2DOT:0.0  
      OUTDEL:0.0  
      PRDEL:20.*DELTA  
00001 IF(TIME-OUTDEL)2,3,3  
00003 WRITE(3,110)TIME,X,XDOT,X2DOT  
      OUTDEL:OUTDEL+PRDEL  
00002 CALLTWORK(ACCELL,DELTA,TIME,X2DOT,XDOT,X)  
      IF(XDOT)201,206,206  
00201 IF(X-.33)203,204,204  
00203 MASS:.002496  
      GOTO300  
00204 IF(X-2.6)205,206,206  
00205 MASS:.002931  
      GOTO300  
00206 IF(X-.33)207,208,208  
00207 MASS:.002496  
      GOTO300  
00208 IF(X-2.6)209,209,210  
00209 MASS:.002901  
      GOTO300  
00210 MASS:.002836  
00300 CONTINUE  
      IF(TIME-.001)1,6,6  
00006 IF(TIME-.1)5,4,4  
00005 IF(X)4,1,1  
00004 CONTINUE  
      STOP  
      END
```

Program Continued

```

FUNCTIONACCELL(TIME,XDOT,X)
REALKO,K1,K3,IMPACT,MASS
COMMONMASS,KO,K1,K3,A,XL,L,C
HAMSPR:0.0
IF(TIME-.005)1,2,2
00001 IF(X-.33)3,2,2
00003 CALLPRESFT(TIME,PRESS)
PA:PRESS*A
GOTO4
00002 PA:0.0
IF(X-XL)4,4,5
00004 IMPACT:0.0
GOTO6
00005 IMPACT:K3*(X-XL)
00006 ACCELL:(PA-KO-K1*X-D*XDOT-IMPACT-HAMSPR)/MASS
RETURN
END

SUBROUTINEPRESFT(TIME,PRES)
REALKO,K1,K3,IMPACT,MASS
DIMENSIONTT(50),PP(50),D(50),ZZ(50,50),AA(50),TP(100)
COMMONMASS,KO,K1,K3,A,XL,L,C
00001 FORMAT(2F6.2)
IF(TIME)103,103,104
00103 M:23
MN:M-1
DO17I:1,M
DO16J:1,MM
00016 ZZ(I,J):0.0
00017 READ(1,1)TT(I),PP(I)
DO10I:1,MN
00101 D(I):TT(I+1)-TT(I)
ZZ(1,1):-1.
ZZ(1,2):1./D(1)+1./D(2)
ZZ(1,3):-1.
ZZ(M,M-2):-1./D(M-2)
ZZ(M,M-1):1./D(M-2)+1./D(M-1)
ZZ(M,M):-1./D(M-1)
DO110I:2,MN
ZZ(I,I-1):D(I-1)/6.
ZZ(I,I):(D(I-1)+D(I))/3.
ZZ(I,I+1):D(I)/6.
00110 ZZ(I,M+1):((PP(I+1)-PP(I))/D(K))-(PP(I)-PP(I-1))/D(I-1)
DO102I:1,M
00102 AA(I):ZZ(I,MM)
CALLSIMQ(ZZ,AA,M,KS)
00104 CONTINUE
CALLINTPRL(TT,PP,D,AA,M,TIME,PRES)
RETURN
END

```

Program Continued

```

SUBROUTINE NETWORK(ACCEL,DELTA,TTT,AAA,VVV,XXX)
AAA:ACCEL(TTT,VVV,XXX)
C1:DELTA*AAA
TT1:TTT+DELTA/2.
VV1:VVV+C1/2.
XX1:XXX+DELTA*VVV/2.+DELTA*C1/8.
C2:DELTA*ACCEL(TT1,VV1,XX1)
TT2:TT1
VV2:VVV+C2/2.
XX2:XX1
C3:DELTA*ACCEL(TT2,VV2,XX2)
TT3:TTT+DELTA
VV3:VVV+C3
XX3:XXX+DELTA*VVV+DELTA*C3/2.
C4:DELTA*ACCEL(TT3,VV3,XX3)
TTT:TT3
XXX:XXX+DELTA*(VVV+(C1+C2+C3)/6.)
VVV:VVV+(C1+2.*C2+2.*C3+C4)/6.
RETURN
END

```

```

SUBROUTINE INTPRL(XX,YY,D,AA,M,XIN,Y)
DIMENSION XX(50),YY(50),D(50),AA(50)
C:6.
K:1
IF(XX(K)-XIN)1,2,3
00001 IF(XX(M)-XIN)3,2,4
00004 IF(XX(K+1)-XIN)5,8,6
00005 K:K+1
GOTO4
00006 Y:AA(K)*(XX(K+1)-XIN)**3/(C*D(K))
      +AA(K+1)*(XIN-XX(K))**3/(C*D(K))
      +(XX(K+1)-XIN)*(YY(K)/D(K)-AA(K)*D(K)/C)
      +(XIN-XX(K))*(YY(K+1)/D(K)-AA(K+1)*D(K)/C)
GOTO7
00002 Y:YY(K)
GOTO7
00008 Y:YY(K+1)
GOTO7
00003 Y:0.0
00007 CONTINUE
RETURN
END

```

2. M16A1 Simulation Computer Program, Typical Standard Bolt

M193 Ball Cartridge, Lot LC12304, with:

- (a) A modified bolt carrier - pressure station at pressure cavity;
- (b) Standard bolt component.

Time (sec)	Travel (inch)	Velocity (in/sec)	Acceleration (in/sec ²)
.0000000E-99	.0000000E-99	.0000000E-99	.0000000E-99
.5000000E-03	.34138493E-02	.21476448E 02	.81350745E 05
.1000000E-02	.27107570E-01	.74892865E 02	.11161156E 06
.1500000E-02	.77820633E-01	.12640643E 03	.95088541E 05
.2000000E-02	.15145077E-00	.16562000E 03	.65762976E 05
.2500000E-02	.24058263E-00	.18840395E 03	.34053469E 05
.3000000E-02	.33799635E-00	.19908250E 03	.16637080E 05
.3500000E-02	.43725504E-00	.19794820E 03	-.22892216E 04
.4000000E-02	.53594019E-00	.19678830E 03	-.23402780E 04
.4500000E-02	.63403902E-00	.19560298E 03	-.23910319E 04
.5000000E-02	.73153885E-00	.19439237E 03	-.24414768E 04
.5500000E-02	.82842706E-00	.19315662E 03	-.24916060E 04
.6000000E-02	.92469116E-00	.19189591E 03	-.25414132E 04
.6500000E-02	.10203186E 01	.19061039E 03	-.25908918E 04
.7000000E-02	.11152968E 01	.18930024E 03	-.26400354E 04
.7500000E-02	.12096137E 01	.18796562E 03	-.26888376E 04
.8000000E-02	.13032574E 01	.18660670E 03	-.27372924E 04
.8500000E-02	.13962159E 01	.18522368E 03	-.27853934E 04
.9000000E-02	.14884760E 01	.18381671E 03	-.28331342E 04
.9500000E-02	.15800271E 01	.18238596E 03	-.28805088E 04
.1000000E-01	.16708569E 01	.18093164E 03	-.29275112E 04
.1050000E-01	.17609537E 01	.17945392E 03	-.29741350E 04
.1100000E-01	.18503059E 01	.17795301E 03	-.30203745E 04
.1150000E-01	.19389019E 01	.17642910E 03	-.30662237E 04
.1200000E-01	.20267303E 01	.17488238E 03	-.31116764E 04
.1250000E-01	.21137797E 01	.17331307E 03	-.31567270E 04
.1300000E-01	.22000387E 01	.17172136E 03	-.32013695E 04
.1350000E-01	.22854963E 01	.17010746E 03	-.32455981E 04
.1400000E-01	.23701416E 01	.16847157E 03	-.32894074E 04
.1450000E-01	.24539634E 01	.16681389E 03	-.33327914E 04
.1500000E-01	.25369510E 01	.16513464E 03	-.33757446E 04
.1550000E-01	.26190930E 01	.16342621E 03	-.34186065E 04
.1600000E-01	.27003662E 01	.16166502E 03	-.34609392E 04
.1650000E-01	.27807535E 01	.15988246E 03	-.35022045E 04
.1700000E-01	.28602441E 01	.15807875E 03	-.3542958E 04
.1750000E-01	.29388278E 01	.15625416E 03	-.35829079E 04
.1800000E-01	.30164940E 01	.15440891E 03	-.3622455E 04
.1850000E-01	.30932325E 01	.15254323E 03	-.36616731E 04
.1900000E-01	.31690329E 01	.15065737E 03	-.37005145E 04
.1950000E-01	.32438855E 01	.14875161E 03	-.37388145E 04
.2000000E-01	.33177803E 01	.14682617E 03	-.377665906E 04
.2050000E-01	.33907074E 01	.14488131E 03	-.381409072E 04
.2100000E-01	.34626573E 01	.14291728E 03	-.3851140E 04
.2150000E-01	.35336204E 01	.14093438E 03	-.38877927E 04
.2200000E-01	.36035873E 01	.13893283E 03	-.392409072E 04
.2250000E-01	.36725490E 01	.13691291E 03	-.39599906E 04
.2300000E-01	.37404963E 01	.13487491E 03	-.4004869E 04
.2350000E-01	.38017459E 01	.13281200E 02	-.4048827E 04
.2400000E-01	.38220902E 01	-.18309761E 02	-.4090869E 04
.2450000E-01	.37858576E 01	-.11649405E 03	-.41359562E 06
.2500000E-01	.37202160E 01	-.13548826E 03	-.41845039E 06
.2550000E-01	.36519634E 01	-.13752086E 03	-.423559100E 04
.2600000E-01	.35826990E 01	-.13953530E 03	-.428908642E 04
.2650000E-01	.35124322E 01	-.14153128E 03	-.43452827E 04
.2700000E-01	.34411720E 01	-.14350855E 03	-.44042827E 04
.2750000E-01	.33689279E 01	-.14546685E 03	-.446613703E 04
.2800000E-01	.32957095E 01	-.14740591E 03	-.45309703E 04
.2850000E-01	.32215264E 01	-.14932548E 03	-.45988691E 04
.2900000E-01	.31463883E 01	-.15122530E 03	-.46700123E 04
.2950000E-01	.30703055E 01	-.15310513E 03	-.47445212E 04
.3000000E-01	.29932876E 01	-.15496470E 03	-.4822428E 04
.3050000E-01	.29153451E 01	-.15680378E 03	-.49037669E 04
.3100000E-01	.28364882E 01	-.15862213E 03	-.498861064E 04
.3150000E-01	.27567274E 01	-.16041952E 03	-.50770672E 04
.3200000E-01	.26760733E 01	-.16219569E 03	-.51692350E 04
.3250000E-01	.25945364E 01	-.16395042E 03	-.52652758E 04
.3300000E-01	.25121417E 01	-.16562727E 03	-.53652994E 04
.3350000E-01	.24289138E 01	-.16728296E 03	-.54694082E 04
.3400000E-01	.23448634E 01	-.16891724E 03	-.557764356E 04
.3450000E-01	.22600012E 01	-.17052991E 03	-.56900468E 04
.3500000E-01	.21743383E 01	-.17212077E 03	-.58066478E 04

Print-Out 2 Continued

Time (sec)	Travel (inch)	Velocity (in/sec)	Acceleration (in/sec ²)
.35500000E-01	.20878854E 01	-.17368961E 03	-.31200439E 04
.36000000E-01	.20006536E 01	-.17523622E 03	-.30754408E 04
.36500000E-01	.19126540E 01	-.17676041E 03	-.30304443E 04
.37000000E-01	.18238979E 01	-.17826198E 03	-.29850599E 04
.37500000E-01	.17343967E 01	-.17974073E 03	-.29392937E 04
.38000000E-01	.16441618E 01	-.18119648E 03	-.28931514E 04
.38500000E-01	.15532049E 01	-.18262908E 03	-.28466390E 04
.39000000E-01	.14615375E 01	-.18403829E 03	-.27997624E 04
.39500000E-01	.13691716E 01	-.18542396E 03	-.27525277E 04
.40000000E-01	.12761188E 01	-.18678591E 03	-.27049409E 04
.40500000E-01	.11823908E 01	-.18812399E 03	-.26570079E 04
.41000000E-01	.10879997E 01	-.18943796E 03	-.26087350E 04
.41500000E-01	.99295780E 00	-.19072771E 03	-.25601283E 04
.42000000E-01	.89727664E 00	-.19199306E 03	-.25111940E 04
.42500000E-01	.80096895E 00	-.19323385E 03	-.24619383E 04
.43000000E-01	.70404702E 00	-.19444991E 03	-.24123676E 04
.43500000E-01	.60652328E 00	-.19564106E 03	-.23624883E 04
.44000000E-01	.50841022E 00	-.19680720E 03	-.23123068E 04
.44500000E-01	.40972037E 00	-.19794817E 03	-.22618295E 04
.45000000E-01	.31046588E 00	-.19908307E 03	-.22119402E 04
.45500000E-01	.21060309E 00	-.20036327E 03	-.21626291E 04
.46000000E-01	.11010773E 00	-.20161333E 03	-.21138728E 04
.46500000E-01	.89948620E-02	-.20283310E 03	-.20656446E 04

3. M16A1 Simulation Computer Program, Round Number 6

M193 Ball Cartridge, Lot LC12304, with:

- (a) A modified bolt carrier - pressure station at pressure cavity;
- (b) Standard bolt component with the sealing rings removed.

Time (sec)	Travel (inch)	Velocity (in/sec)	Acceleration (in/sec ²)
.00000000E-99	.00000000E-99	.00000000E-99	.00000000E-99
.50000000E-03	.38695051E-02	.22508329E 02	.73058794E 05
.10000000E-02	.24237024E-01	.57666656E 02	.63627572E 05
.15000000E-02	.60016782E-01	.83928266E 02	.45313285E 05
.20000000E-02	.10672025E-00	.10148205E 03	.28232163E 05
.25000000E-02	.16048222E-00	.11249751E 03	.16262161E 05
.30000000E-02	.21813402E-00	.11747506E 03	.69686426E 04
.35000000E-02	.27735626E-00	.11889356E 03	.50252355E 03
.40000000E-02	.33661387E-00	.11793733E 03	-.22392524E 04
.45000000E-02	.39530096E-00	.11630863E 03	-.22696265E 04
.50000000E-02	.45341990E-00	.11566482E 03	-.22997072E 04
.55000000E-02	.51096319E-00	.11450608E 03	-.23294906E 04
.60000000E-02	.56792341E-00	.11333253E 03	-.23589730E 04
.65000000E-02	.62429320E-00	.11214433E 03	-.23881504E 04
.70000000E-02	.68006526E-00	.11094164E 03	-.24170192E 04
.75000000E-02	.73523235E-00	.10972461E 03	-.24455755E 04
.80000000E-02	.78978738E-00	.10849339E 03	-.24738157E 04
.85000000E-02	.84372329E-00	.10724813E 03	-.25017361E 04
.90000000E-02	.89703311E-00	.10598902E 03	-.25293332E 04
.95000000E-02	.94970994E-00	.10471621E 03	-.25566033E 04
.10000000E-01	.10017469E 01	.10342986E 03	-.25835430E 04
.10500000E-01	.10531370E 01	.10213014E 03	-.26101485E 04
.11000000E-01	.11038740E 01	.10081722E 03	-.26364166E 04
.11500000E-01	.11539511E 01	.99491264E 02	-.26623439E 04
.12000000E-01	.12033622E 01	.98152410E 02	-.26879272E 04
.12500000E-01	.12521005E 01	.96800868E 02	-.27131629E 04
.13000000E-01	.13001600E 01	.95436814E 02	-.27380479E 04
.13500000E-01	.13475342E 01	.94060422E 02	-.27625790E 04
.14000000E-01	.13942173E 01	.92671871E 02	-.27867529E 04
.14500000E-01	.14402032E 01	.91271341E 02	-.28105668E 04
.15000000E-01	.14854858E 01	.89859012E 02	-.28340172E 04
.15500000E-01	.15300594E 01	.88435068E 02	-.28571013E 04
.16000000E-01	.15739179E 01	.86999693E 02	-.28798161E 04
.16500000E-01	.16170560E 01	.85553073E 02	-.29021586E 04
.17000000E-01	.16594682E 01	.84095394E 02	-.29241260E 04
.17500000E-01	.17011487E 01	.82626843E 02	-.29457154E 04
.18000000E-01	.17420924E 01	.81147612E 02	-.29669241E 04
.18500000E-01	.17822938E 01	.79657892E 02	-.29877493E 04
.19000000E-01	.18217477E 01	.78157878E 02	-.30081882E 04
.19500000E-01	.18604490E 01	.76647758E 02	-.30282382E 04
.20000000E-01	.18983928E 01	.75127731E 02	-.30478969E 04
.20500000E-01	.19355742E 01	.73597992E 02	-.30671615E 04
.21000000E-01	.19719884E 01	.72058740E 02	-.30860298E 04
.21500000E-01	.20076305E 01	.70510174E 02	-.31044990E 04
.22000000E-01	.20424962E 01	.68952494E 02	-.31225670E 04

Print-Out 3 Continued

Time (sec)	Travel (inch)	Velocity (in/sec)	Acceleration (in/sec ²)
.22500000E-01	.24518158E 01	.90495038E 02	-.33336540E 04
.23000000E-01	.24966448E 01	.88821232E 02	-.33568767E 04
.23500000E-01	.25406341E 01	.87135945E 02	-.33796654E 04
.24000000E-01	.25837780E 01	.85439395E 02	-.34020174E 04
.24500000E-01	.26260672E 01	.83708289E 02	-.35024034E 04
.25000000E-01	.26674819E 01	.81950490E 02	-.35243547E 04
.25500000E-01	.27080149E 01	.80181853E 02	-.35458399E 04
.26000000E-01	.27476611E 01	.78402616E 02	-.35668561E 04
.26500000E-01	.27864150E 01	.76613011E 02	-.35874009E 04
.27000000E-01	.28242716E 01	.74813276E 02	-.36074714E 04
.27500000E-01	.28612258E 01	.73003648E 02	-.36270648E 04
.28000000E-01	.28972727E 01	.71184366E 02	-.36461787E 04
.28500000E-01	.29324076E 01	.69355672E 02	-.36648102E 04
.29000000E-01	.29666258E 01	.67517808E 02	-.36829576E 04
.29500000E-01	.29999228E 01	.65671018E 02	-.37006177E 04
.30000000E-01	.30322943E 01	.63815542E 02	-.37177884E 04
.30500000E-01	.30637360E 01	.61951628E 02	-.37344675E 04
.31000000E-01	.30942437E 01	.60079524E 02	-.37506530E 04
.31500000E-01	.31238134E 01	.58199475E 02	-.37663427E 04
.32000000E-01	.31524411E 01	.56311731E 02	-.37815342E 04
.32500000E-01	.31801229E 01	.54416542E 02	-.37962256E 04
.33000000E-01	.32068552E 01	.52514159E 02	-.38104150E 04
.33500000E-01	.32326347E 01	.50604831E 02	-.38241004E 04
.34000000E-01	.32574579E 01	.48688812E 02	-.38372806E 04
.34500000E-01	.32813215E 01	.46766356E 02	-.38499531E 04
.35000000E-01	.33042224E 01	.44837714E 02	-.38621167E 04
.35500000E-01	.33261573E 01	.42903146E 02	-.38737693E 04
.36000000E-01	.33471238E 01	.40962903E 02	-.38849104E 04
.36500000E-01	.33671186E 01	.39017247E 02	-.38955373E 04
.37000000E-01	.33861393E 01	.37066429E 02	-.39056491E 04
.37500000E-01	.34041833E 01	.35110711E 02	-.39152447E 04
.38000000E-01	.34212483E 01	.33150348E 02	-.39243222E 04
.38500000E-01	.34373319E 01	.31185605E 02	-.39328811E 04
.39000000E-01	.34524322E 01	.29216738E 02	-.39409199E 04
.39500000E-01	.34665471E 01	.27244007E 02	-.39484379E 04
.40000000E-01	.34796747E 01	.25267674E 02	-.39554333E 04
.40500000E-01	.34918132E 01	.23288002E 02	-.39619058E 04
.41000000E-01	.35029612E 01	.21305249E 02	-.39678547E 04
.41500000E-01	.35131171E 01	.19319680E 02	-.39732789E 04
.42000000E-01	.35222795E 01	.17331555E 02	-.39781777E 04
.42500000E-01	.35304474E 01	.15341139E 02	-.39825504E 04
.43000000E-01	.35376194E 01	.13348694E 02	-.39863963E 04
.43500000E-01	.35437948E 01	.11354485E 02	-.39897154E 04
.44000000E-01	.35489727E 01	.93587735E 01	-.39925066E 04
.44500000E-01	.35531523E 01	.73618210E 01	-.39947700E 04
.45000000E-01	.35563332E 01	.53638951E 01	-.39965056E 04
.45500000E-01	.35585151E 01	.33652602E 01	-.39977122E 04

Print-Out 3 Continued

Time (sec)	Travel (inch)	Velocity (in/sec)	Acceleration (in/sec ²)
.46000000E-01	.35596973E 01	.13661803E 01	-.39983906E 04
.46500000E-01	.35598806E 01	-.63308038E 00	-.39985401E 04
.47000000E-01	.35590646E 01	-.26322570E 01	-.39981614E 04
.47500000E-01	.35572493E 01	-.46310858E 01	-.39972542E 04
.48000000E-01	.35544346E 01	-.66293024E 01	-.39958184E 04
.48500000E-01	.35506211E 01	-.86266425E 01	-.39938543E 04
.49000000E-01	.35458092E 01	-.10622840E 02	-.39913617E 04
.49500000E-01	.35399995E 01	-.12617631E 02	-.39883416E 04
.50000000E-01	.35331928E 01	-.14610753E 02	-.39847944E 04
.50500000E-01	.35253900E 01	-.16601944E 02	-.39807200E 04
.51000000E-01	.35165922E 01	-.18590939E 02	-.39761195E 04
.51500000E-01	.35068005E 01	-.20577478E 02	-.39709929E 04
.52000000E-01	.34960162E 01	-.22561294E 02	-.39653413E 04
.52500000E-01	.34842407E 01	-.24542128E 02	-.39591657E 04
.53000000E-01	.34714756E 01	-.26519716E 02	-.39524661E 04
.53500000E-01	.34577226E 01	-.28493797E 02	-.39452443E 04
.54000000E-01	.34429836E 01	-.30464111E 02	-.39375007E 04
.54500000E-01	.34272602E 01	-.32430398E 02	-.39292366E 04
.55000000E-01	.34105547E 01	-.34392397E 02	-.39204527E 04
.55500000E-01	.33928693E 01	-.36349848E 02	-.39111502E 04
.56000000E-01	.33742066E 01	-.38302492E 02	-.39013311E 04
.56500000E-01	.33545688E 01	-.40250072E 02	-.38909957E 04
.57000000E-01	.33339585E 01	-.42192331E 02	-.38801459E 04
.57500000E-01	.33123784E 01	-.44129010E 02	-.38687834E 04
.58000000E-01	.32898315E 01	-.46059856E 02	-.38569090E 04
.58500000E-01	.32663205E 01	-.47984610E 02	-.38445246E 04
.59000000E-01	.32418487E 01	-.49903020E 02	-.38316318E 04
.59500000E-01	.32164194E 01	-.51814830E 02	-.38182323E 04
.60000000E-01	.31900359E 01	-.53719789E 02	-.38043282E 04
.60500000E-01	.31627017E 01	-.55617646E 02	-.37899210E 04
.61000000E-01	.31344204E 01	-.57508149E 02	-.37750126E 04
.61500000E-01	.31051957E 01	-.59391048E 02	-.37596050E 04
.62000000E-01	.30750315E 01	-.61266093E 02	-.37437006E 04
.62500000E-01	.30439320E 01	-.63133038E 02	-.37273007E 04
.63000000E-01	.30119008E 01	-.64991634E 02	-.37104083E 04
.63500000E-01	.29789426E 01	-.66841638E 02	-.36930253E 04
.64000000E-01	.29450617E 01	-.68682804E 02	-.36751537E 04
.64500000E-01	.29102624E 01	-.70514888E 02	-.36567965E 04
.65000000E-01	.28745493E 01	-.72337648E 02	-.36379555E 04
.65500000E-01	.28379272E 01	-.74150843E 02	-.36186336E 04
.66000000E-01	.28004010E 01	-.75954233E 02	-.35988332E 04
.66500000E-01	.27619756E 01	-.77747581E 02	-.35785567E 04
.67000000E-01	.27226563E 01	-.79530647E 02	-.35578074E 04
.67500000E-01	.26824479E 01	-.81303197E 02	-.35365874E 04
.68000000E-01	.26413560E 01	-.83064999E 02	-.35149002E 04
.68500000E-01	.25993858E 01	-.84815817E 02	-.34927479E 04
.69000000E-01	.25565571E 01	-.86499036E 02	-.33576651E 04

Print-Out 3 Continued

Time (sec)	Travel (inch)	Velocity (in/sec)	Acceleration (in/sec ²)
.69500000E-01	.25128895E 01	-.88171189E 02	-.33353601E 04
.70000000E-01	.24683888E 01	-.89832061E 02	-.33126285E 04
.70500000E-01	.24230604E 01	-.91481442E 02	-.32894730E 04
.71000000E-01	.23769105E 01	-.93119116E 02	-.32658967E 04
.71500000E-01	.23299446E 01	-.94744877E 02	-.32419025E 04
.72000000E-01	.22821688E 01	-.96358518E 02	-.32174936E 04
.72500000E-01	.22335890E 01	-.97959830E 02	-.31926729E 04
.73000000E-01	.21842119E 01	-.99548609E 02	-.31674438E 04
.73500000E-01	.21340437E 01	-.10112461E 03	-.31418096E 04
.74000000E-01	.20830906E 01	-.10268766E 03	-.31157732E 04
.74500000E-01	.20313593E 01	-.10423759E 03	-.30893384E 04
.75000000E-01	.19788563E 01	-.10577417E 03	-.30625082E 04
.75500000E-01	.19255885E 01	-.10729722E 03	-.30352863E 04
.76000000E-01	.18715625E 01	-.10880655E 03	-.30076760E 04
.76500000E-01	.18167854E 01	-.11030195E 03	-.29796809E 04
.77000000E-01	.17612639E 01	-.11178324E 03	-.29513046E 04
.77500000E-01	.17050054E 01	-.11325023E 03	-.29225507E 04
.78000000E-01	.16480170E 01	-.11470273E 03	-.28934229E 04
.78500000E-01	.15903062E 01	-.11614056E 03	-.28639250E 04
.79000000E-01	.15318800E 01	-.11756351E 03	-.28340606E 04
.79500000E-01	.14727462E 01	-.11897143E 03	-.28038337E 04
.80000000E-01	.14129121E 01	-.12036413E 03	-.27732481E 04
.80500000E-01	.13523858E 01	-.12174143E 03	-.27423077E 04
.81000000E-01	.12911745E 01	-.12310316E 03	-.27110164E 04
.81500000E-01	.12292861E 01	-.12444913E 03	-.26793783E 04
.82000000E-01	.11667288E 01	-.12577922E 03	-.26473973E 04
.82500000E-01	.11035106E 01	-.12709318E 03	-.26150777E 04
.83000000E-01	.10396394E 01	-.12839089E 03	-.25824235E 04
.83500000E-01	.97512336E 00	-.12967218E 03	-.25494389E 04
.84000000E-01	.90997044E 00	-.13093688E 03	-.25161280E 04
.84500000E-01	.84418936E 00	-.13218481E 03	-.24824951E 04
.85000000E-01	.77778854E 00	-.13341586E 03	-.24485446E 04
.85500000E-01	.71077645E 00	-.13462982E 03	-.24142808E 04
.86000000E-01	.64316168E 00	-.13582655E 03	-.23797082E 04
.86500000E-01	.57495289E 00	-.13700590E 03	-.23448312E 04
.87000000E-01	.50615880E 00	-.13816772E 03	-.23096541E 04
.87500000E-01	.43678822E 00	-.13931187E 03	-.22741816E 04
.88000000E-01	.36685001E 00	-.14043820E 03	-.22384181E 04
.88500000E-01	.29634541E 00	-.14162347E 03	-.22024191E 04
.89000000E-01	.22521276E 00	-.14290372E 03	-.21661244E 04
.89500000E-01	.15344535E 00	-.14416250E 03	-.21295848E 04
.90000000E-01	.81053946E-01	-.14539962E 03	-.20927492E 04
.90500000E-01	.80494080E-02	-.14661490E 03	-.20556786E 04

4. M16A1 Simulation Computer Program, Round Number 10

M300 Blank Cartridge, Lot LC18056, with:

- (a) A modified bolt carrier - pressure station at pressure cavity;
 (b) Standard bolt component.

Time (sec)	Travel (inch)	Velocity (in/sec)	Acceleration (in/sec ²)
.00000000E-99	.00000000E-99	.00000000E-99	.00000000E-99
.50000000E-03	.61875104E-03	.42961447E 01	.17355824E 05
.10000000E-02	.63542171E-02	.20932434E 02	.44248149E 05
.15000000E-02	.22694267E-01	.44427240E 02	.46986362E 05
.20000000E-02	.50780269E-01	.67915085E 02	.46967135E 05
.25000000E-02	.90493110E-01	.90705609E 02	.44473513E 05
.30000000E-02	.14102615E-00	.11073804E 03	.36759356E 05
.35000000E-02	.20042783E-00	.12595111E 03	.26020913E 05
.40000000E-02	.26582519E-00	.13491718E 03	.15592172E 05
.45000000E-02	.33510275E-00	.14140394E 03	.13438669E 05
.50000000E-02	.40552297E-00	.14027411E 03	-.22743052E 04
.55000000E-02	.47537373E-00	.13912614E 03	-.23104521E 04
.60000000E-02	.54464601E-00	.13796019E 03	-.23463004E 04
.65000000E-02	.61333086E-00	.13677641E 03	-.23818453E 04
.70000000E-02	.68141938E-00	.13557495E 03	-.24170825E 04
.75000000E-02	.74890279E-00	.13435597E 03	-.24520071E 04
.80000000E-02	.81577236E-00	.13311962E 03	-.24866149E 04
.85000000E-02	.88201945E-00	.13186607E 03	-.25209012E 04
.90000000E-02	.94763548E-00	.13059545E 03	-.25548616E 04
.95000000E-02	.10126119E 01	.12930797E 03	-.25884918E 04
.10000000E-01	.10769400E 01	.12800377E 03	-.26217872E 04
.10500000E-01	.11406119E 01	.12668303E 03	-.26547437E 04
.11000000E-01	.12036192E 01	.12534592E 03	-.26873570E 04
.11500000E-01	.12659541E 01	.12399259E 03	-.27196230E 04
.12000000E-01	.13276083E 01	.12262323E 03	-.27515375E 04
.12500000E-01	.13885738E 01	.12123803E 03	-.27830964E 04
.13000000E-01	.14488427E 01	.11983716E 03	-.28142954E 04
.13500000E-01	.15084074E 01	.11842080E 03	-.28451307E 04
.14000000E-01	.15672600E 01	.11698913E 03	-.28755982E 04
.14500000E-01	.16253930E 01	.11554235E 03	-.29056940E 04
.15000000E-01	.16827990E 01	.11408063E 03	-.29354143E 04
.15500000E-01	.17394705E 01	.11260416E 03	-.29647552E 04
.16000000E-01	.17953998E 01	.11111313E 03	-.29937127E 04
.16500000E-01	.18505802E 01	.10960773E 03	-.30222833E 04
.17000000E-01	.19050042E 01	.10808816E 03	-.30504632E 04
.17500000E-01	.19586649E 01	.10655462E 03	-.30782489E 04
.18000000E-01	.20115555E 01	.10500732E 03	-.31056366E 04
.18500000E-01	.20636691E 01	.10344643E 03	-.31326229E 04
.19000000E-01	.21149989E 01	.10187218E 03	-.31592044E 04
.19500000E-01	.21655382E 01	.10028475E 03	-.31853774E 04
.20000000E-01	.22152805E 01	.98684326E 02	-.32111387E 04
.20500000E-01	.22642193E 01	.97071141E 02	-.32364848E 04
.21000000E-01	.23123485E 01	.95445410E 02	-.32614127E 04
.21500000E-01	.23596615E 01	.93807341E 02	-.32859188E 04
.22000000E-01	.24061526E 01	.92157147E 02	-.33100003E 04

Print-Out 4 Continued

Time (sec)	Travel (inch)	Velocity (in/sec)	Acceleration (in/sec ²)
.22500000E-01	.20765807E 01	.67385900E 02	-.31402313E 04
.23000000E-01	.21098797E 01	.65810596E 02	-.31574897E 04
.23500000E-01	.21423889E 01	.64226784E 02	-.31743400E 04
.24000000E-01	.21741042E 01	.62634670E 02	-.31907799E 04
.24500000E-01	.22050212E 01	.61034461E 02	-.32068073E 04
.25000000E-01	.22351363E 01	.59426362E 02	-.32224203E 04
.25500000E-01	.22644453E 01	.57810581E 02	-.32376167E 04
.26000000E-01	.22929445E 01	.56187329E 02	-.32523945E 04
.26500000E-01	.23206303E 01	.54556812E 02	-.32667520E 04
.27000000E-01	.23474991E 01	.52919244E 02	-.32806872E 04
.27500000E-01	.23735474E 01	.51274835E 02	-.32941983E 04
.28000000E-01	.23987718E 01	.49623799E 02	-.33072835E 04
.28500000E-01	.24231691E 01	.47966349E 02	-.33199413E 04
.29000000E-01	.24467362E 01	.46302698E 02	-.33321700E 04
.29500000E-01	.24694699E 01	.44633062E 02	-.33439679E 04
.30000000E-01	.24913673E 01	.42957657E 02	-.33553336E 04
.30500000E-01	.25124253E 01	.41276698E 02	-.33662653E 04
.31000000E-01	.25326418E 01	.39590405E 02	-.33767621E 04
.31500000E-01	.25520138E 01	.37898994E 02	-.33868224E 04
.32000000E-01	.25705389E 01	.36202683E 02	-.33964449E 04
.32500000E-01	.25882144E 01	.34501694E 02	-.34056282E 04
.33000000E-01	.26050377E 01	.32784508E 02	-.34142273E 04
.33500000E-01	.26209925E 01	.31035636E 02	-.34222300E 04
.34000000E-01	.26360717E 01	.29282659E 02	-.34296362E 04
.34500000E-01	.26502734E 01	.27525812E 02	-.34364458E 04
.35000000E-01	.26635957E 01	.25765324E 02	-.34426588E 04
.35500000E-01	.26760370E 01	.24001430E 02	-.34482750E 04
.36000000E-01	.26875955E 01	.22234363E 02	-.34532942E 04
.36500000E-01	.26982699E 01	.20464356E 02	-.34577154E 04
.37000000E-01	.27080585E 01	.18691645E 02	-.34616386E 04
.37500000E-01	.27169602E 01	.16916460E 02	-.34650638E 04
.38000000E-01	.27249735E 01	.15139040E 02	-.34680000E 04
.38500000E-01	.27320980E 01	.13359616E 02	-.34705472E 04
.39000000E-01	.27383322E 01	.11578427E 02	-.34727054E 04
.39500000E-01	.27436753E 01	.97957054E 01	-.34744746E 04
.40000000E-01	.27481267E 01	.80116858E 01	-.34758548E 04
.40500000E-01	.27516858E 01	.62266069E 01	-.34768460E 04
.41000000E-01	.27543522E 01	.44407048E 01	-.34774482E 04
.41500000E-01	.27561255E 01	.26542156E 01	-.34776714E 04
.42000000E-01	.27570055E 01	.86737560E 00	-.34775156E 04
.42500000E-01	.27569924E 01	-.91957939E 00	-.34769808E 04
.43000000E-01	.27560864E 01	-.27064124E 01	-.34761670E 04
.43500000E-01	.27542871E 01	-.44928878E 01	-.34750842E 04
.44000000E-01	.27515946E 01	-.62787692E 01	-.34737424E 04
.44500000E-01	.27480093E 01	-.80638205E 01	-.34721516E 04
.45000000E-01	.27435319E 01	-.98478058E 01	-.34703218E 04
.45500000E-01	.27381628E 01	-.11630486E 02	-.34682530E 04

Print-Out 4 Continued

Time (sec)	Travel (inch)	Velocity (in/sec)	Acceleration (in/sec ²)
.46000000E-01	.27319026E 01	-.13411628E 02	-.35609495E 04
.46500000E-01	.27247521E 01	-.15190994E 02	-.35572143E 04
.47000000E-01	.27167128E 01	-.16968353E 02	-.35530095E 04
.47500000E-01	.27077853E 01	-.18743469E 02	-.35483346E 04
.48000000E-01	.26979708E 01	-.20516107E 02	-.35431904E 04
.48500000E-01	.26872708E 01	-.22286032E 02	-.35375775E 04
.49000000E-01	.26756863E 01	-.24053010E 02	-.35314971E 04
.49500000E-01	.26632192E 01	-.25816808E 02	-.35249500E 04
.50000000E-01	.26498712E 01	-.27577192E 02	-.35179366E 04
.50500000E-01	.26356437E 01	-.29333931E 02	-.35104580E 04
.51000000E-01	.26205389E 01	-.31086791E 02	-.35025152E 04
.51500000E-01	.26045586E 01	-.32835540E 02	-.34941093E 04
.52000000E-01	.25877119E 01	-.34540383E 02	-.33722797E 04
.52500000E-01	.25700212E 01	-.36223831E 02	-.33632692E 04
.53000000E-01	.25514902E 01	-.37902646E 02	-.33538285E 04
.53500000E-01	.25321207E 01	-.39576612E 02	-.33439586E 04
.54000000E-01	.25119154E 01	-.41245514E 02	-.33336609E 04
.54500000E-01	.24908771E 01	-.42909137E 02	-.33229367E 04
.55000000E-01	.24690082E 01	-.44567271E 02	-.33117873E 04
.55500000E-01	.24463116E 01	-.46219704E 02	-.33002141E 04
.56000000E-01	.24227903E 01	-.47866225E 02	-.32882187E 04
.56500000E-01	.23984473E 01	-.49506622E 02	-.32758026E 04
.57000000E-01	.23732857E 01	-.51140682E 02	-.32629675E 04
.57500000E-01	.23473087E 01	-.52768202E 02	-.32497149E 04
.58000000E-01	.23205194E 01	-.54388969E 02	-.32360464E 04
.58500000E-01	.22929217E 01	-.56002780E 02	-.32219640E 04
.59000000E-01	.22645189E 01	-.57609424E 02	-.32074694E 04
.59500000E-01	.22353147E 01	-.59208698E 02	-.31925645E 04
.60000000E-01	.22053126E 01	-.60800396E 02	-.31772510E 04
.60500000E-01	.21745166E 01	-.62384314E 02	-.31615311E 04
.61000000E-01	.21429306E 01	-.63960252E 02	-.31454066E 04
.61500000E-01	.21105588E 01	-.65528008E 02	-.31288798E 04
.62000000E-01	.20774049E 01	-.67087381E 02	-.31119525E 04
.62500000E-01	.20434736E 01	-.68638169E 02	-.30946272E 04
.63000000E-01	.20087692E 01	-.70180177E 02	-.30769059E 04
.63500000E-01	.19732960E 01	-.71713205E 02	-.30587910E 04
.64000000E-01	.19370585E 01	-.73237059E 02	-.30402847E 04
.64500000E-01	.19000614E 01	-.74751543E 02	-.30213895E 04
.65000000E-01	.18623096E 01	-.76256466E 02	-.30021077E 04
.65500000E-01	.18238077E 01	-.77751630E 02	-.29824418E 04
.66000000E-01	.17845606E 01	-.79236848E 02	-.29623944E 04
.66500000E-01	.17445734E 01	-.80711926E 02	-.29419678E 04
.67000000E-01	.17038514E 01	-.82176679E 02	-.29211650E 04
.67500000E-01	.16623996E 01	-.83630918E 02	-.28999884E 04
.68000000E-01	.16202232E 01	-.85074457E 02	-.28784407E 04
.68500000E-01	.15773279E 01	-.86507110E 02	-.28565248E 04
.69000000E-01	.15337189E 01	-.87928698E 02	-.28342434E 04

Print-Out 4 Continued

Time (sec)	Travel (inch)	Velocity (in/sec)	Acceleration (in/sec ²)
.69500000E-01	.14894020E 01	-.89339034E 02	-.28115994E 04
.70000000E-01	.14443830E 01	-.90737942E 02	-.27885959E 04
.70500000E-01	.13986673E 01	-.92125240E 02	-.27652354E 04
.71000000E-01	.13522607E 01	-.93500753E 02	-.27415211E 04
.71500000E-01	.13051693E 01	-.94864302E 02	-.27174560E 04
.72000000E-01	.12573993E 01	-.96215714E 02	-.26930433E 04
.72500000E-01	.12089568E 01	-.97554817E 02	-.26682861E 04
.73000000E-01	.11598477E 01	-.98881440E 02	-.26431875E 04
.73500000E-01	.11100784E 01	-.10019540E 03	-.26177506E 04
.74000000E-01	.10596553E 01	-.10149651E 03	-.25919789E 04
.74500000E-01	.10085850E 01	-.10278464E 03	-.25658756E 04
.75000000E-01	.95687349E 00	-.10405961E 03	-.25394438E 04
.75500000E-01	.90452775E 00	-.10532127E 03	-.25126871E 04
.76000000E-01	.85155456E 00	-.10656946E 03	-.24856089E 04
.76500000E-01	.79796068E 00	-.10780400E 03	-.24582127E 04
.77000000E-01	.74375296E 00	-.10902476E 03	-.24305021E 04
.77500000E-01	.68893835E 00	-.11023156E 03	-.24024804E 04
.78000000E-01	.63352384E 00	-.11142426E 03	-.23741515E 04
.78500000E-01	.57751655E 00	-.11260271E 03	-.23455187E 04
.79000000E-01	.52092363E 00	-.11376675E 03	-.23165860E 04
.79500000E-01	.46375233E 00	-.11491624E 03	-.22873568E 04
.80000000E-01	.40600996E 00	-.11605103E 03	-.22578350E 04
.80500000E-01	.34770389E 00	-.11717097E 03	-.22280243E 04
.81000000E-01	.28882426E 00	-.11839113E 03	-.21979738E 04
.81500000E-01	.22930806E 00	-.11967087E 03	-.21672454E 04
.82000000E-01	.16915648E 00	-.12093263E 03	-.21359345E 04
.82500000E-01	.10837854E 00	-.12217623E 03	-.21042667E 04
.83000000E-01	.46983367E-01	-.12340146E 03	-.20723578E 04

APPENDIX D
FRANKFORD ARSENAL

PROPELLANT	Engineering Proof Testing Record		AMMUNITION
TYPE	TEST Velocity, Piezo Pressure and Function		LOT LC-12304
ARMY LOT			TYPE M-193
CHARGE	SPEC/AUTH	Part I	CALIBER 5,56 mm
			BULLET Ball
	OBJECT Investigate gas leakage in bolt carrier		CASE Brass
REC/UNIV NO	BRL NO	TRFD	STORED °F
REC/UNIV NO 694387	BRL NO 1	TRFD 456	PERIOD
REC/UNIV NO	BRL NO	TRFD	FIRE AT °F
REC/UNIV NO	BRL NO	TRFD	

SHOT NO	Bolt Carrier	Bolt	No. Rds.	Function	Bolt Pressure	Cyclic Rate
1	With Pres. Sta.	Std.	1	Sat.	2300	
2	W/o Pres. Sta.	Std.	17	BOB		943
3	W/o Pres. Sta.	Std.	11	A	Replaced old buffer & buffer spring with new ones to reduce cyclic rates	
4						
5						
6	W/o Pres. Sta.	Std.	20	Sat.		894
7	With Pres. Sta.	Std.	1	Sat.	2400	
8	With Pres. Sta.	W/o rings	1	Sat.	1600	Bolt did not remain in rearward position
9						
10	W/o Pres. Sta.	W/o rings	20	FF		
11	W/o Pres. Sta.	W/o rings		BOB		
12	W/o Pres. Sta.	W/o rings		BOB		
13	With Pres. Sta.	W/o rings	1	FF	1500	Very weak ejection
14	With Pres. Sta.	W/o rings	1	FF	1450	Replaced new buffer & buffer spring with old ones
15						
16						
17	With Pres. Sta.	W/o rings	1	FF	1400	
18						
19						
20						
TOTAL						
MEAN						
CF						
COR'D						
EX VAR						
STD DEV						

Kistler Gage Model 603A SN 3090

CASUALTIES	REF RD DATA
REMARKS BOB = Bolt overrode base of next cartridge	AUTH
A-Bolt caught case in process of ejecting	CASE LOT
FF = Failure to feed next round in magazine.	BULLET LOT
Silver paper covered styrofoam screens placed 50 ft. and 75 ft. from muzzle	PROPELLANT
PROOF TECHNICIANS McGuinn & Gardner	JAR CHG
FOREMAN X.O. 03810-06-005	VEL VAL
	CP VAL
	PP VAL

DATE 29 Sept. 1970

CHIEF BALLISTICIAN

SMUFA-U Form 10, 28 Mar 66
(Formerly SMUFA Form 951)

FRANKFORD ARSENAL
Engineering Proof Testing Record

PROPELLANT

AMMUNITION

TYPE	TEST Cyclic Rate & Function	LOT TW-18056
ARMY LOT		TYPE XM200
CHARGE	SPEC/AUTH Part II	CALIBER 5.56 mm
		BULLET --
	OBJECT Investigate gas leakage in bolt carrier	CASE Brass
REC/UNIV NO	BRL NO	TRFD
REC/UNIV NO	BRL NO	TRFD
REC/UNIV NO	BRL NO	TRFD
REC/UNIV NO	BRL NO	TRFD
		STORED °F
		PERIOD
		FIRE AT °F

SHOT NO	Rock Island		Cyclic Rate		Comments
	Bolt No.		Rds/min		
1	1		549	HS 1.466 inches	--
2	1		592	FPP 0.033 inch	--
3	1		683	FPI 0.021 inch	--
4	1		697	FMR 5.4	--
5	1		719		--
6					
7	2		-	HS 1.499 inches	Failure to feed
8				FPP .031 inch	16 shots were fired
9				FPI .022 inch	in an attempt to cycle the
10				FMR 3.3	rifle
11	3		-	HS 1.499 inches	Double feed
12			-	FPP .031 inch	2 rounds failed to eject
13			-	FPI .022 inch	16 rounds BOB
14				FMR 2.9	
15					
16					
17					
18					
19					
20					

TOTAL					
MEAN					
CF					
COR'D					
EX VAR					
STD DEV					

FF = Failure to feed next round in magazine	REF RD DATA
CASUALTIES BOB = Bolt override base of next cartridge in magazine	
REMARKS Double feed - two cartridges from magazine	AUTH
	CASE LOT
	BULLET LOT
	PROPELLANT
	JAR CHG
PROOF TECHNICIANS Reynolds	VEL VAL
	CP VAL
FOREMAN X.O. 03810-06-005	PP VAL

DATE 1 Oct 1970 CHIEF BALLISTICIAN

SMUFA-U Form 10, 28 Mar 66
(Formerly SMUFA Form 931)

FRANKFORD ARSENAL
Engineering Proof Testing Record

PROPELLANT

AMMUNITION

TYPE	TEST Velocity, Pressure & Function	LOT
APMY LOT		TYPE
CHARGE	SPEC/AUTH Part III (cont'd)	CALIBER
		BULLET
	OBJECT Gas leakage in bolt carrier	CASE

REC/UNIV NO	BRL NO	TRFD	STORED °F
REC/UNIV NO 694387	BRL NO 1	TRFD 522	PERIOD
REC/UNIV NO	BRL NO	TRFD	FIRE AT °F
REC/UNIV NO	BRL NO	TRFD	

SHOT NO	Bolt Carrier	Bolt	Type Ammo.	No. Rds.	Function	Bolt Pres.	Velocity f/s	Cyclic Rate
21	1 With Pres. Sta.	2	M-200	1	Sat.			
22	2 With Pres. Sta.	2	M-200	1	Sat.			
	3 W/o Pres. Sta.	2	M-200	20	Sat.			
23	4 With Pres. Sta.	2	M-200	1	Sat.			
24	5 With Pres. Sta.	2	M-200	1	BOB			
25	6 With Pres. Sta.	3	M-193	1	Sat.		3135	
26	7 With Pres. Sta.	3	M-193	1	Sat.		3125	
27	8 W/o Pres. Sta.	3	M-193	20	Sat.		3106*	731
28	9 With Pres. Sta.	3	M-193	1	Sat.		3095	
29	10 With Pres. Sta.	3	M-193		Sat.		3125	
30	11 With Pres. Sta.	3	M-200	1	FF			
31	12 With Pres. Sta.	3	M-200	1	FF			
32	13 With Pres. Sta.	3	M-200	1	BOB			
33	14 With Pres. Sta.	3	M-200	1	FF			
	15 W/o Pres. Sta.	3	M-200	1	FF			
	16 W/o Pres. Sta.	3	M-200	1	FF			
	17 W/o Pres. Sta.	3	M-200	1	FF			
	18 W/o Pres. Sta.	3	M-200	1	BOB			
1	19 With Pres. Sta.	3	M-200	1	FF	Miss		
2	20 With Pres. Sta.	3	M-200	1	FF	Miss		
3	With Pres. Sta.	3	M-200	1	BOB			
4	With Pres. Sta.	3	M-200	1	BOB			
TOTAL								
MEAN								
CF								
COR'D								
EX VAR								
STD DEV								

CASUALTIES

REF RD DATA

REMARKS BOB = Bolt override base of cartridge
FF = Failure to feed next round from magazine
* = Avg velocity of burst.

AUTH
CASE LOT
BULLET LOT
PROPELLANT

PROOF TECHNICIANS

JAR CHG
VEL VAL
CP VAL
PP VAL

FOREMAN

X.O.

DATE

CHIEF BALLISTICIAN

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13. ABSTRACT			
A brief series of tests and evaluations was made to provide experimental and analytical data to the U.S. Army Weapons Command in support of the M16A1 Rifle Bolt Dimension Investigation. Both firing tests and a mathematical model confirmed that bolts with diameters 0.0075 and 0.010 inch below specification do not give reliable performance because of excessive gas leakage between the outside bolt shaft diameter and its mating diameter in the bolt carrier. Normal rifle function occurred with bolts 0.0004 and 0.0005 inch below specifications.			

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