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REPORT R-2052

THE MECHANISM OF BARREL FOULING AND EROSION IN THE M16A1 RIFLE

by

BRUCE W. BRODMAN
MICHAEL P. DEVINE

September 1972

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Munitions Development & Engineering Directorate
FRANKFORD ARSENAL
Philadelphia, Pa. 19137

September 1972

ABSTRACT

A mechanism is proposed describing the action of calcium carbonate in causing bore fouling and preventing erosion in the M16A1 rifle. Electron microprobe, x-ray diffraction, metallographic examination, and bore gage data are presented which indicate that ball propellant with high calcium carbonate content, when fired through an M16A1 rifle as described in this report, results in heavy bore fouling and little or no erosion. Further, similar firings of propellant with low calcium carbonate content result in little bore fouling, but with erosion, pitting, and cracking of the bore surface.

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INTRODUCTION

Several studies^{1,2} have identified CaCO_3 as the major contributor to gas tube fouling in the M16A1 rifle. It was found that CaCO_3 deposited in the gas tube and acted as a trapping matrix for other debris originating from the propellant, primer, and cartridge components. One of these studies further reported that, in test firings, propellant with low CaCO_3 content produced substantially less barrel fouling than propellant with high CaCO_3 content.

A more recent study³ concerning the effect of propellant additives in reducing fouling and erosion in the M16A1 rifle reported that, with the firing schedule used and with ball propellant of high calcium carbonate level, essentially no erosion occurred at the origin of rifling. Further, propellant having low CaCO_3 levels produced substantially greater erosion at or near the origin of rifling. Since that study was primarily concerned with the effect of nonstandard additives (e.g., tin dioxide) in a WC844 composition on ballistic barrel life, no detailed chemical analysis was conducted of the fouling residue or bore surface. The authors' recommendation, based in part on their study of a high CaCO_3 propellant composition containing SnO_2 , was that further investigation should be conducted to determine the role that CaCO_3 plays in the generally superior barrel erosion characteristics obtained with ball propellant.

This report deals with barrels used to fire two ammunition lots - BAJ45608 and X2842 - one loaded with a low CaCO_3 content propellant and the other, a high CaCO_3 content propellant. Both propellant lots were standard WC844 propellant compositions and, therefore, contained no experimental additives.

¹ Ludwig Stiefel and Bruce Brodman "M16 Rifle Gas Tube Fouling - Composition, Properties and Means of Elimination," Frankford Arsenal Report R-1936, August 1969.

² Edward Hess "Metallurgical Examination of the Fouled Gas Tube and Flash Suppressor From an M16A1 Rifle," Frankford Arsenal Report M70-10-1, February 1970.

³ Ludwig Stiefel and Marvin Levy "Effect of Propellant Additives in Reducing Fouling and Erosion in the M16A1 Rifle," Frankford Arsenal Report R-2028, December 1971.

CHEMICAL AND PHYSICAL STUDIES

Two non-chrome plated M16A1 rifle barrels (obtained from the gas tube fouling study described in Reference 1) were subjected to a detailed chemical and physical study. One barrel (No. 167512) was used to fire 6000 rounds of ammunition loaded with propellant (X2842) having a high calcium carbonate content and the other barrel (No. 859740) was used to fire 6000 rounds of ammunition loaded with propellant (BAJ45608) having a low calcium carbonate content. The firing schedule for these barrels is described in the Firing Tests section of this report and the chemical composition of the propellants is included in Appendix A.

In order to facilitate chemical and physical examination, each barrel was sectioned by taking 1/4 in. thick washer-like sections at one-inch intervals along the length of the barrels. The 1/4 inch sections were labelled A through L, starting at the muzzle end, and the one inch sections were labelled A' through L'. The 1/4 inch washer-like sections were mounted in bakelite and metallographically polished. Each section was subjected to microscopic and chemical examination. Chemical examination was accomplished by means of electron microprobe analysis of the metallographically polished sections and x-ray diffraction analysis.

Since operation of the electron microprobe and its use in investigation of fouling residue is fully described in Reference 1, only a brief description is given here. A beam of accelerated electrons impinges on the specimen area of interest and gives rise to x-rays which are characteristic of the elements present. The intensity of these x-rays is related to the concentration of the elements. By special modification of the electron microprobe, elements from uranium (atomic number 92) to boron (atomic number 5) can be detected. Thus, it is possible to determine carbon and nitrogen.

Two different data collection procedures were employed for this study:

1. Spectral scans - the specimen was held stationary under the electron beam and the spectrometer was scanned over the range of elements.
2. Scanning display - the electron beam was scanned across the area of the specimen by means of orthogonal deflection coils. The monitored

¹ Ludwig Stiefel and Bruce Brodman "M16 Rifle Gas Tube Fouling - Composition, Properties and Means of Elimination," Frankford Arsenal Report R-1936, August 1969.

signal is used to modulate the brightness of a cathode ray tube having a sweep synchronous with the beam. In this manner one can obtain qualitative chemical information about the specimen surface.

A detailed discussion of the chemical and physical findings is given for each barrel.

Barrel No. 167512

Barrel No. 167512 was fired using ammunition loaded with propellant X2842 having a high calcium carbonate content. Physical examination of the metallographically polished sections gave the following results:

1. Sections near the muzzle end contained more fouling than those near the chamber end.
2. The fouling appeared to consist of three phases: a copper or brass colored phase, a gray colored phase, and an intermediate mottled phase which was presumed to be a mixture of the other two.
3. The lands and the grooves appeared to be fouled along the entire length of the barrel. This can be seen in Figure 1, which is a photomicrograph of section L (nearest the chamber end). Figure 2, which is a photomicrograph of section B (nearest the muzzle end), shows heavier fouling of the lands and grooves.
4. Most of the gray phase was found close to the bore surface or in contact with it.
5. The brass phase seemed to form an almost continuous ring, with the gray phase between it and the bore surface.

Chemical analysis of each section was conducted by means of the electron microprobe, and residue was removed from selected sections for x-ray diffraction study. A summary of the electron microprobe spectral scan data for the gray phase and for the brass phase is given in Tables I and II, respectively. X-ray diffraction data from a section near the center of the barrel allowed the identification of brass and the calcite form of calcium carbonate. Generalizations which can be made from this information follow.

1. Copper and zinc (brass), as well as calcium (calcium carbonate), were found in almost all areas.
2. The calcium content was higher in the gray phase and lower in the brass phase.

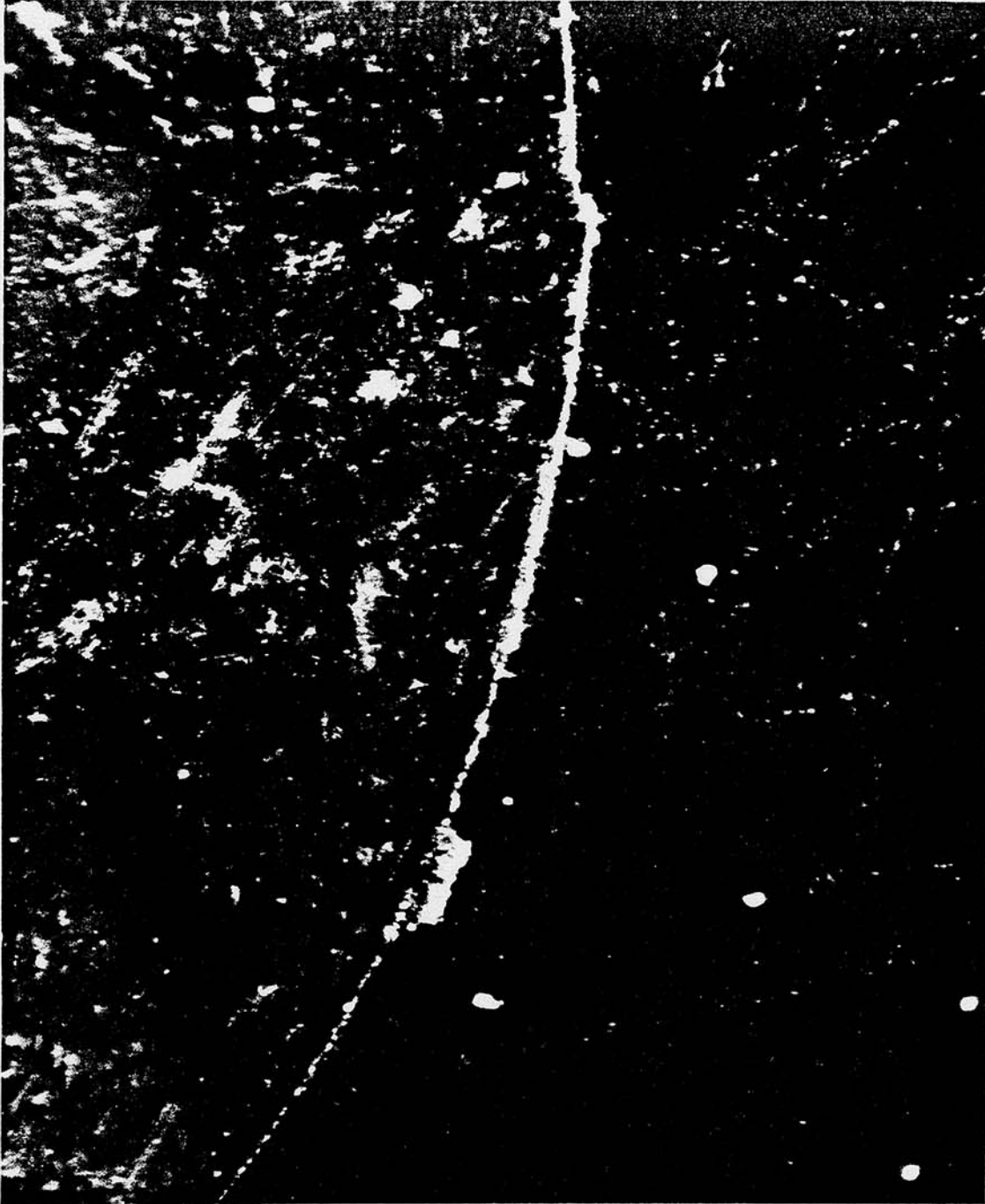


Figure 1. Photomicrograph of Section L (Nearest the Chamber End) of Barrel No. 167512

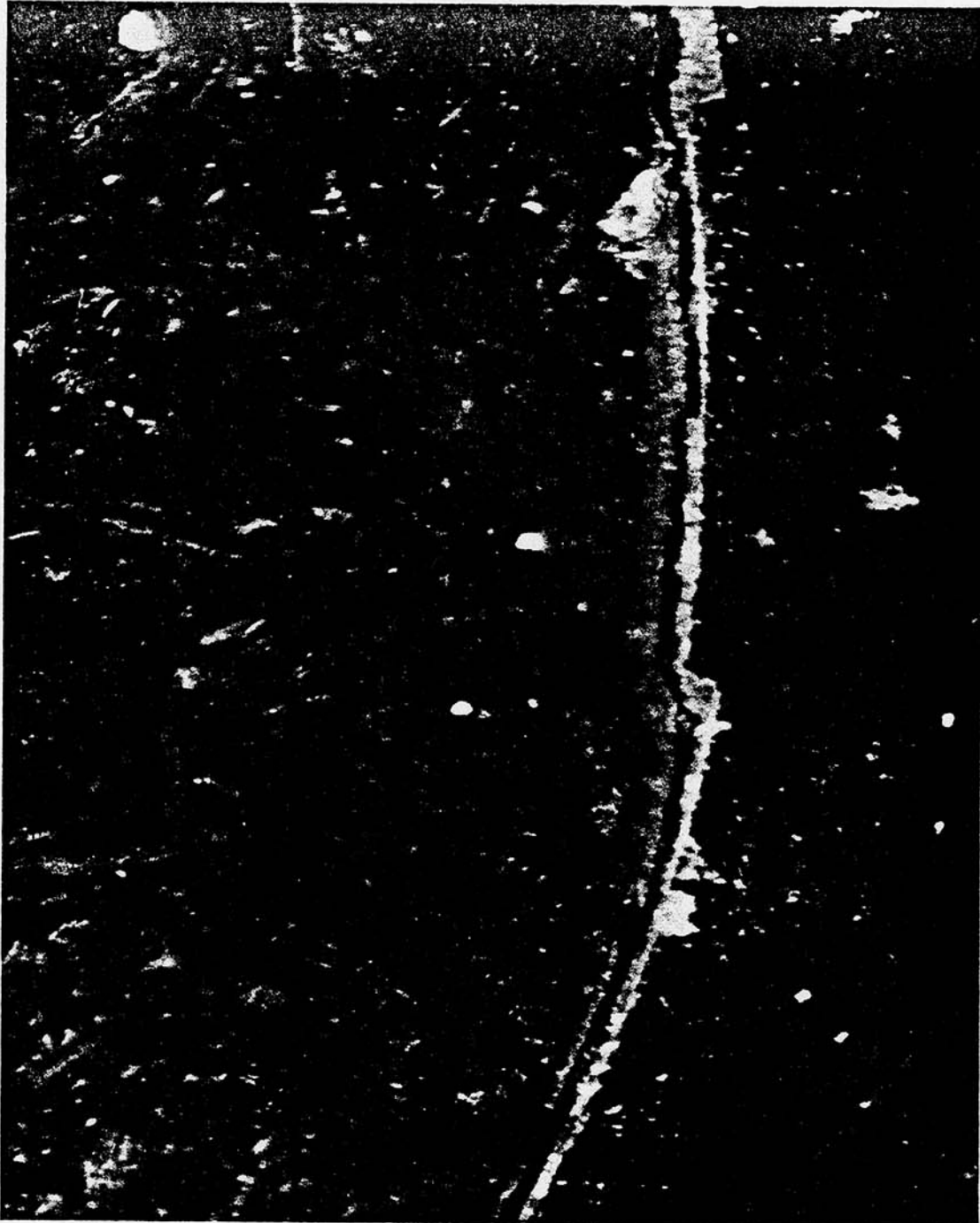


Figure 2. Photomicrograph of Section B (Nearest the Muzzle End) of Barrel No. 167512

3. Iron, chromium, and manganese (which originated from the steel bore) were strongest in the gray phase which was closest to the bore surface.

4. Some small amounts of sulfur were found in the gray phase; the sulfur probably originated from the primer.

5. Small amounts of lead were present in the brass phase; the lead probably originated from the primer or the bullet core.

A series of scanning displays was run in order to better illustrate the elemental distribution of the fouling residue. For this purpose, a section (B) near the muzzle end (shown in Figure 3) was used. Figures 4 through 9 are scanning display results for copper, zinc, calcium, iron, chromium, and manganese, respectively. The following observations can be made by examination of Figures 4 through 9:

1. Copper (Figure 4) - the highest density was in the brass-colored phase, with a high density in the gray phase.

2. Zinc (Figure 5) - results are identical to copper, again indicating the presence of brass.

3. Calcium (Figure 6) - the highest density was in the gray phase, with a high density in the brass-colored phase.

4. Iron (Figure 7) - somewhat more in the gray phase than in the brass phase. As pointed out earlier, the iron originates from the barrel and has collected in the gray phase which is closest to the bore surface.

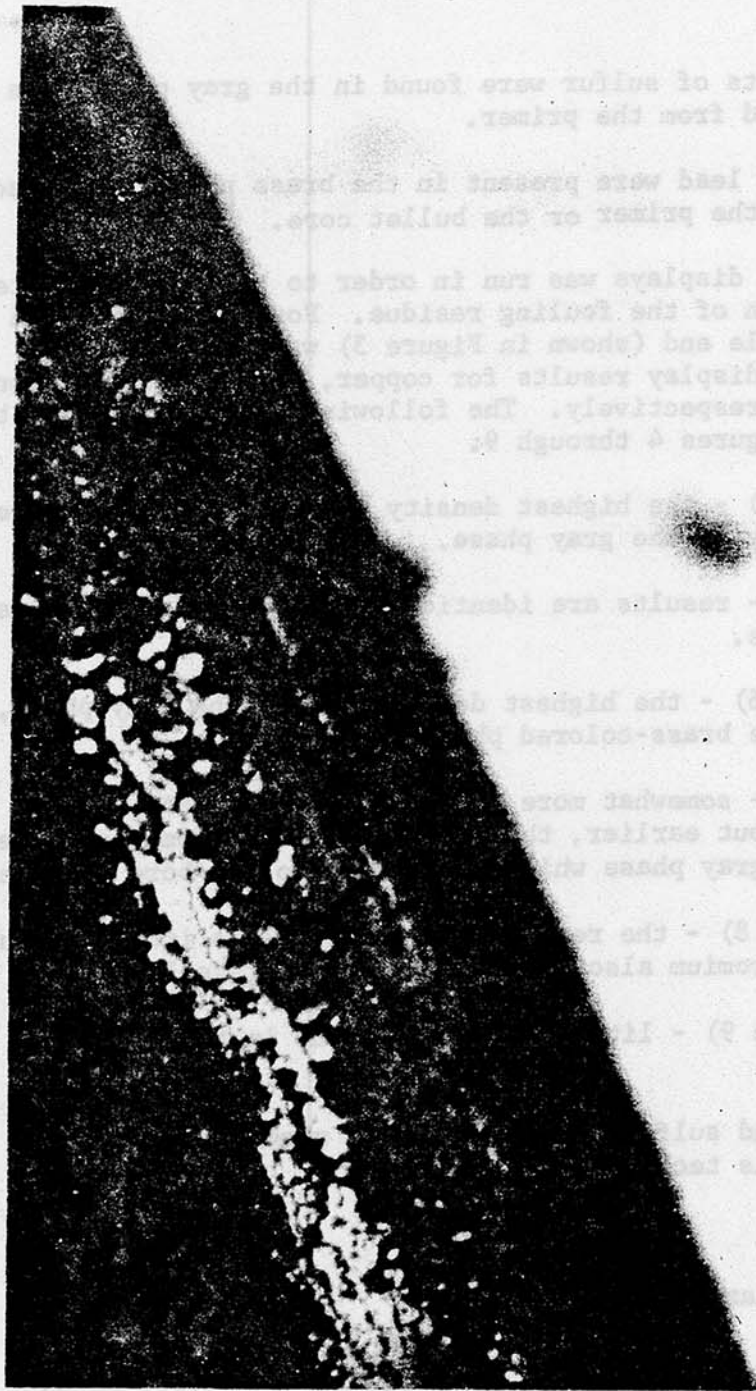
5. Chromium (Figure 8) - the results are identical to iron, as would be expected, since the chromium also originates from the steel bore.

6. Manganese (Figure 9) - little or none present in the fouling residue.

The levels of lead and sulfur present were too minute to yield any significant results by this technique.

Barrel No. 859740

Barrel No. 859740 was used to fire ammunition loaded with propellant (BAJ45608) having a low calcium carbonate content. Physical examination of the metallographically polished sections gave the following results:



Bakelite
Mount

Brass

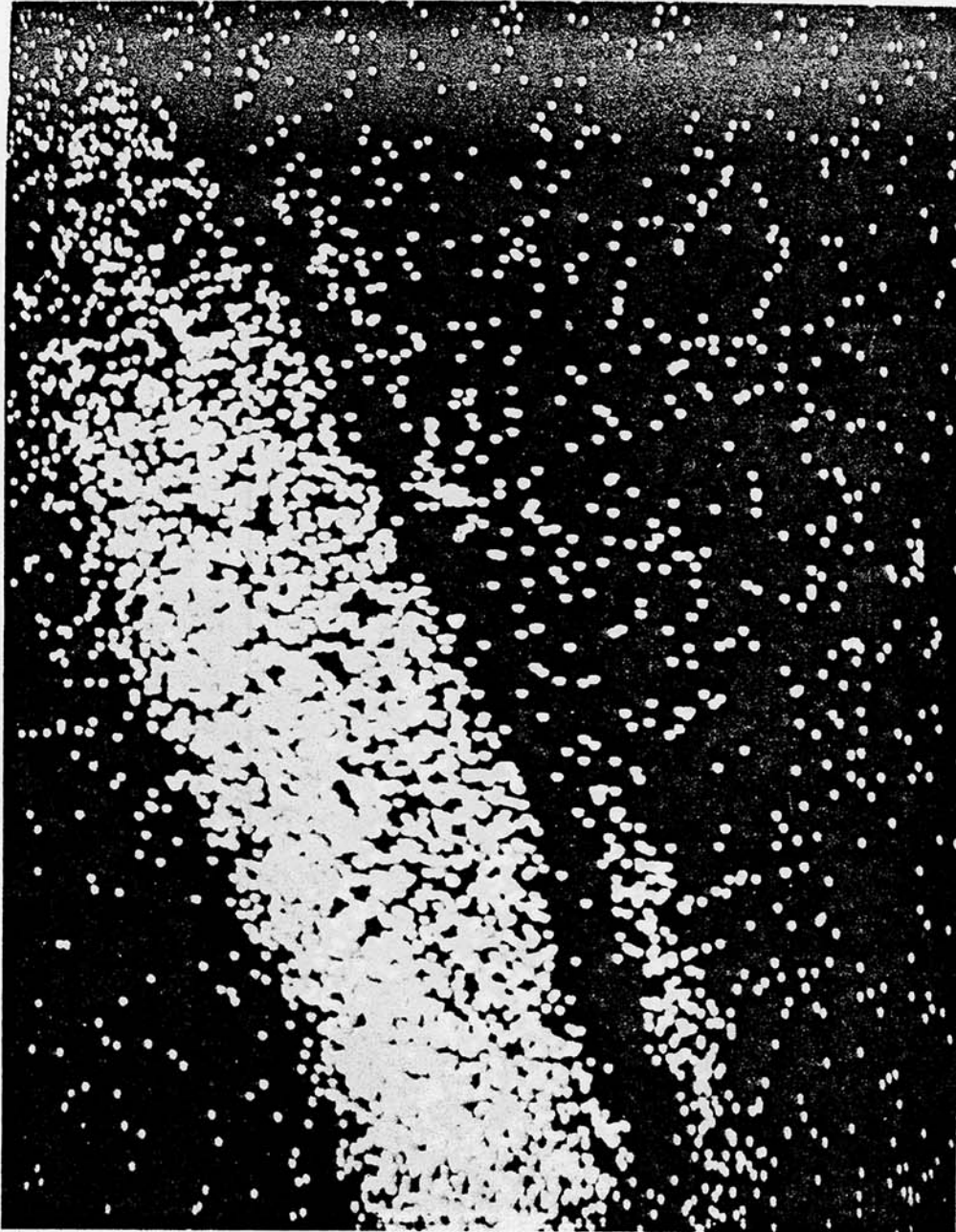
Gray

Void

Steel

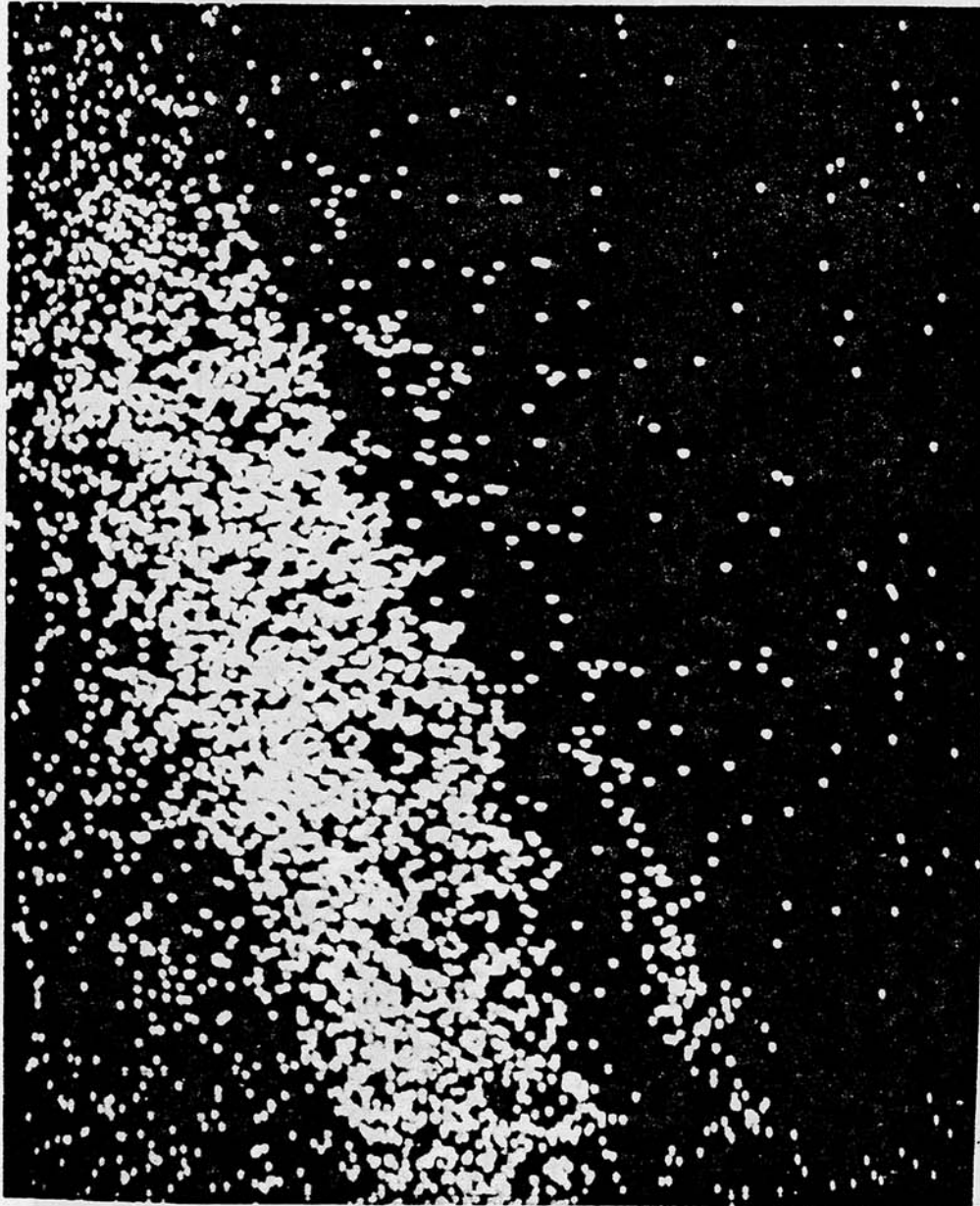
Mag: 400X

Figure 3. Photomicrograph of Section B (Near Muzzle End) of Barrel No. 167512



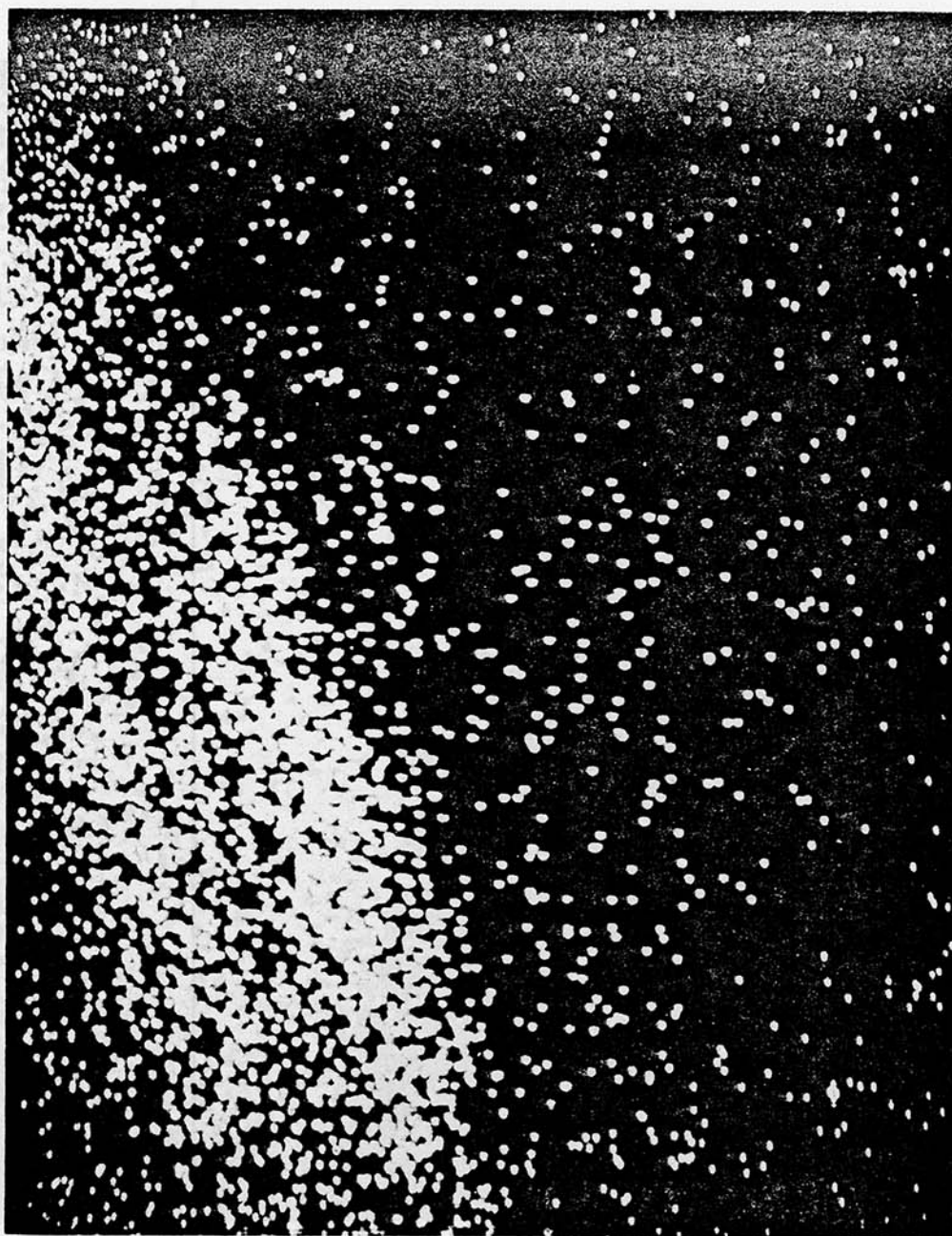
Mag: 400X

Figure 4. Copper Distribution in Section B of Barrel No. 167512



Mag: 400X

Figure 5. Zinc Distribution in Section B of Barrel No. 167512



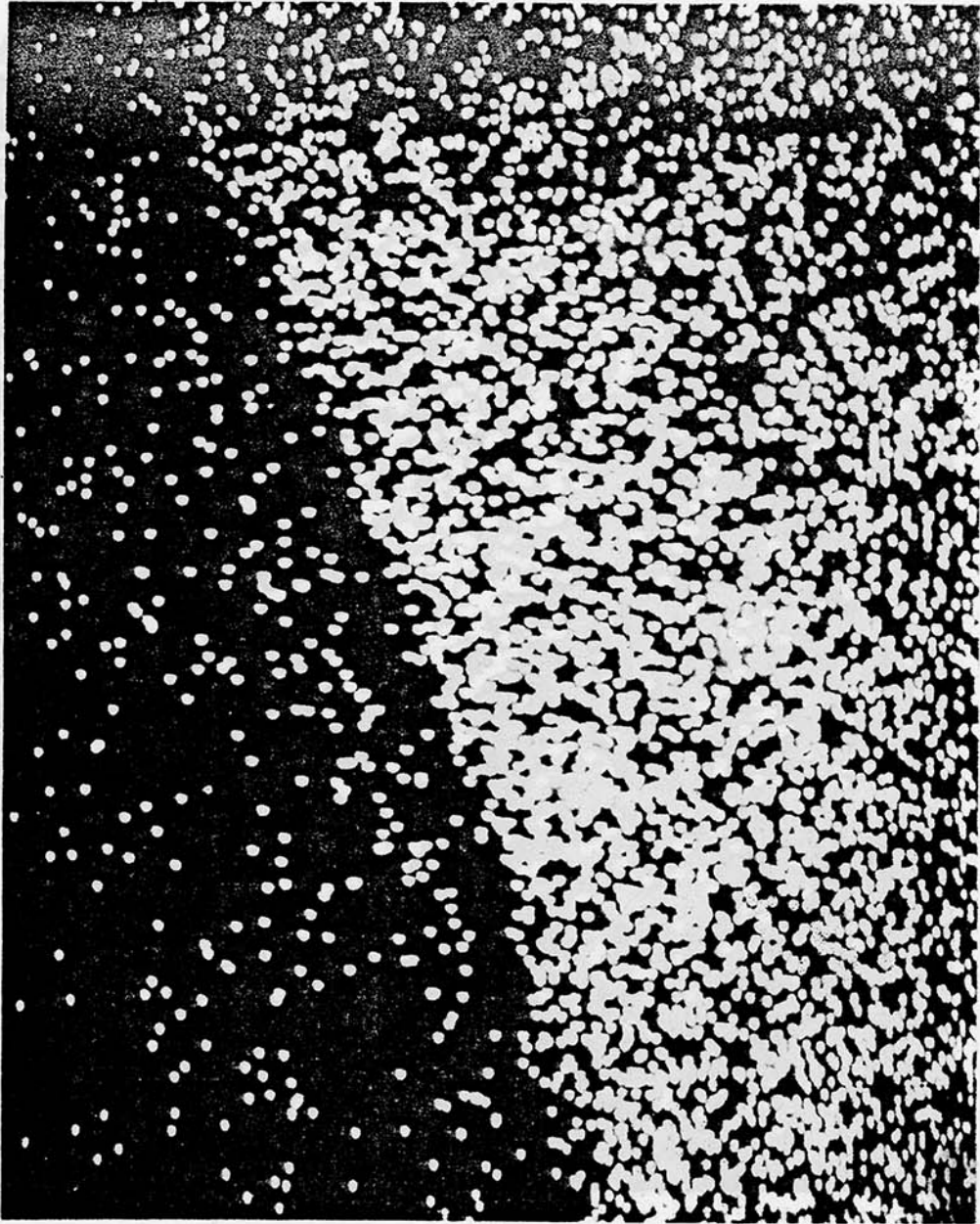
Mag: 400X

Figure 6. Calcium Distribution in Section B of Barrel No. 167512



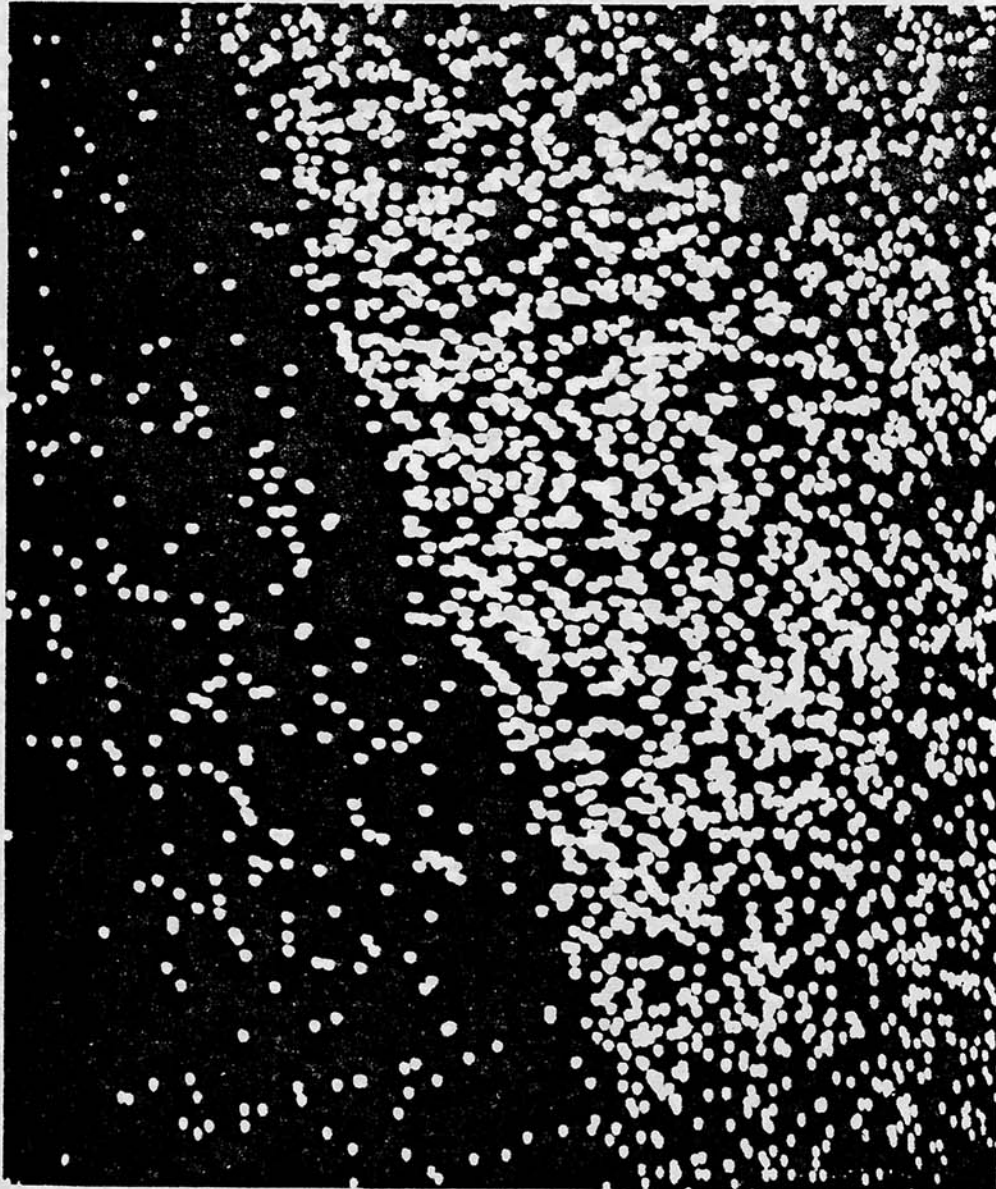
Mag: 400X

Figure 7. Iron Distribution in Section B of Barrel No. 167512



Mag: 400X

Figure 8. Chromium Distribution in Section B of Barrel No. 167512



Mag: 400X

Mag: 400X

Figure 9. Manganese Distribution in Section B of Barrel No. 167512

1. In general, very little fouling was present in this barrel. When present, the fouling appeared in small, isolated areas, and consisted of a brass-colored phase and a dark phase.
2. In general, the three sections near the chamber end of the barrel showed pitting, cracking, and erosion of the bore surface.
3. The cracking effect of the bore surface appeared to stop at about the middle of the barrel. Erosion and pitting were still present near the muzzle end.

Chemical analysis of each section was accomplished by means of the electron microprobe. No x-ray diffraction data was obtained because of the small amount of fouling present. Only a summary of the chemical findings is presented for this barrel because of the limited fouling produced. In general, the barrel appears to contain small, random deposits throughout. These deposits were all similar and were usually composed of copper and zinc (brass) and small amounts of lead (originating from the bullet core or primer) and antimony (which originated from the primer). Varying amounts of calcium, potassium, and sulfur were present. The calcium originated from the propellant, sulfur from the primer, and potassium possibly from a surface coating present on the projectile. Traces of manganese, chromium, and vanadium were present, and small amounts of iron, all originating from the steel barrel surface.

These findings are visually represented in a photomicrograph of Section C (Figure 10) and a series of scanning displays (Figures 11 through 17).

Summary of Chemical Findings

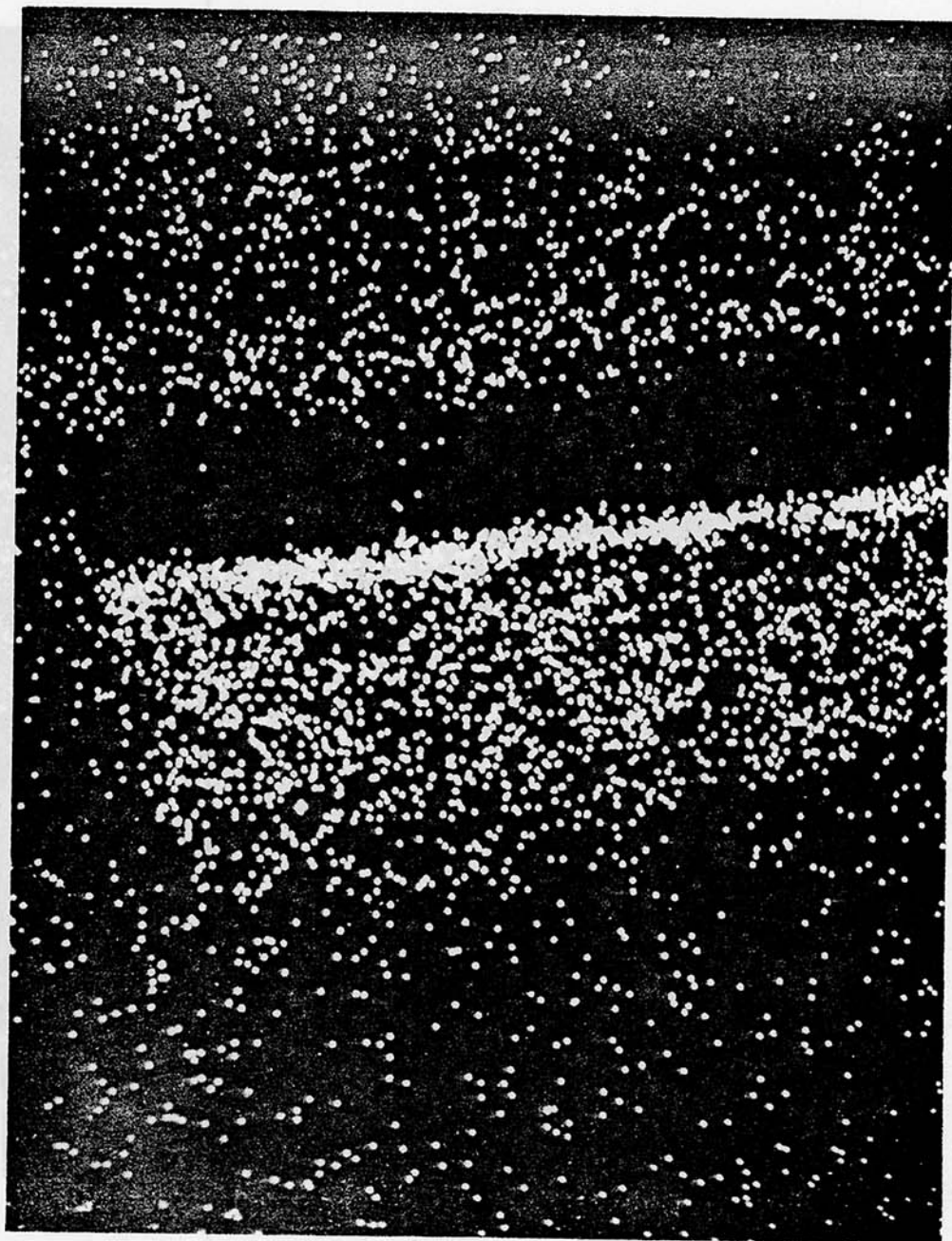
The barrel used to fire ammunition loaded with propellant having a high CaCO_3 content was heavily fouled along its entire length. Microscopic examination of cleaned sections indicated little physical damage to the bore surface and no visible erosion in the chamber end. CaCO_3 appeared to form a matrix which trapped material originating from other cartridge components, and this residue protected the barrel from erosion-producing phenomena.

The barrel used to fire ammunition loaded with propellant having a low CaCO_3 content showed cracking, pitting, and erosion of the bore surface, with very little fouling.

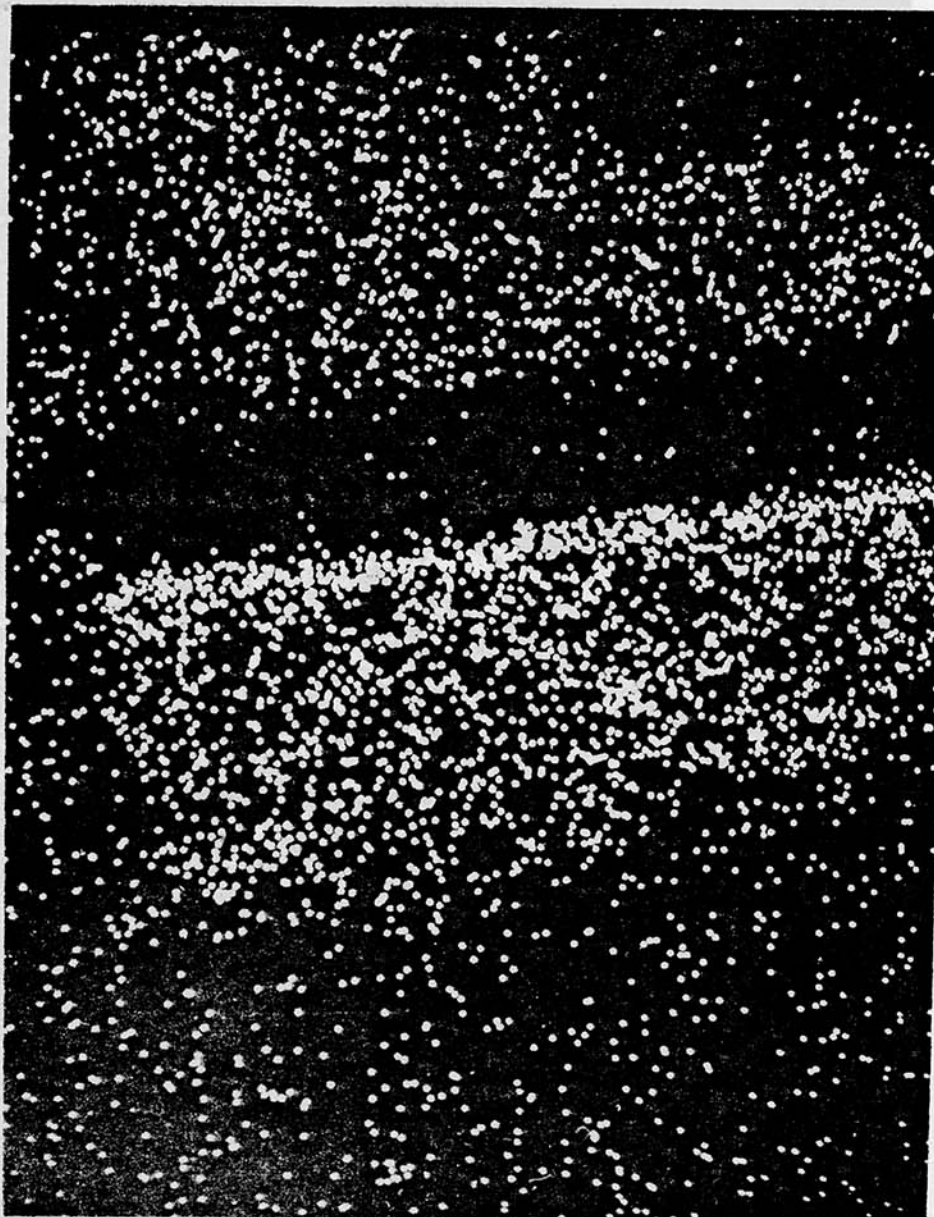


Mag: 500X

Figure 10, Photomicrograph of Section C of Barrel No. 859740

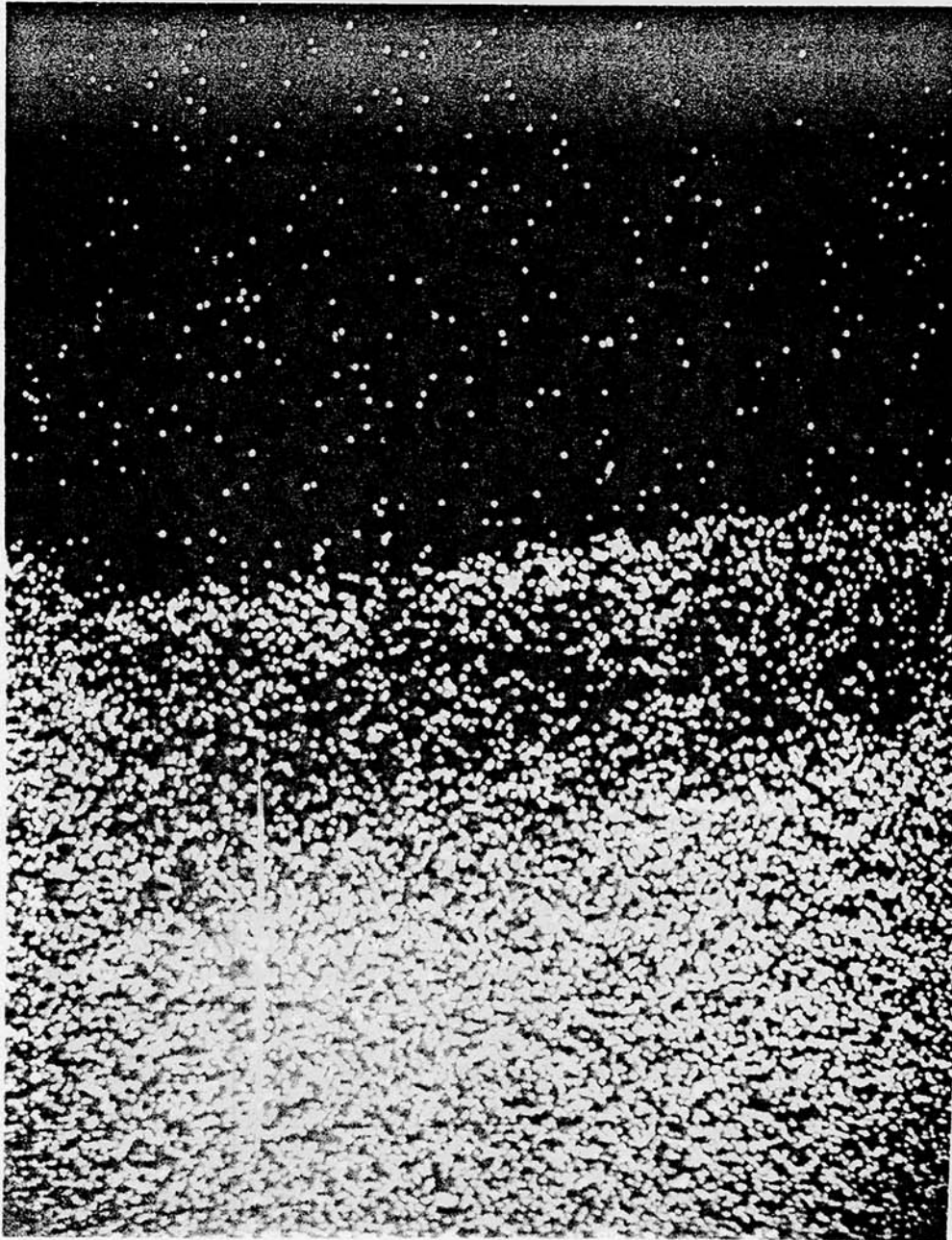


Mag: 400X
Figure 11. Calcium Distribution in Section C of Barrel No. 859740



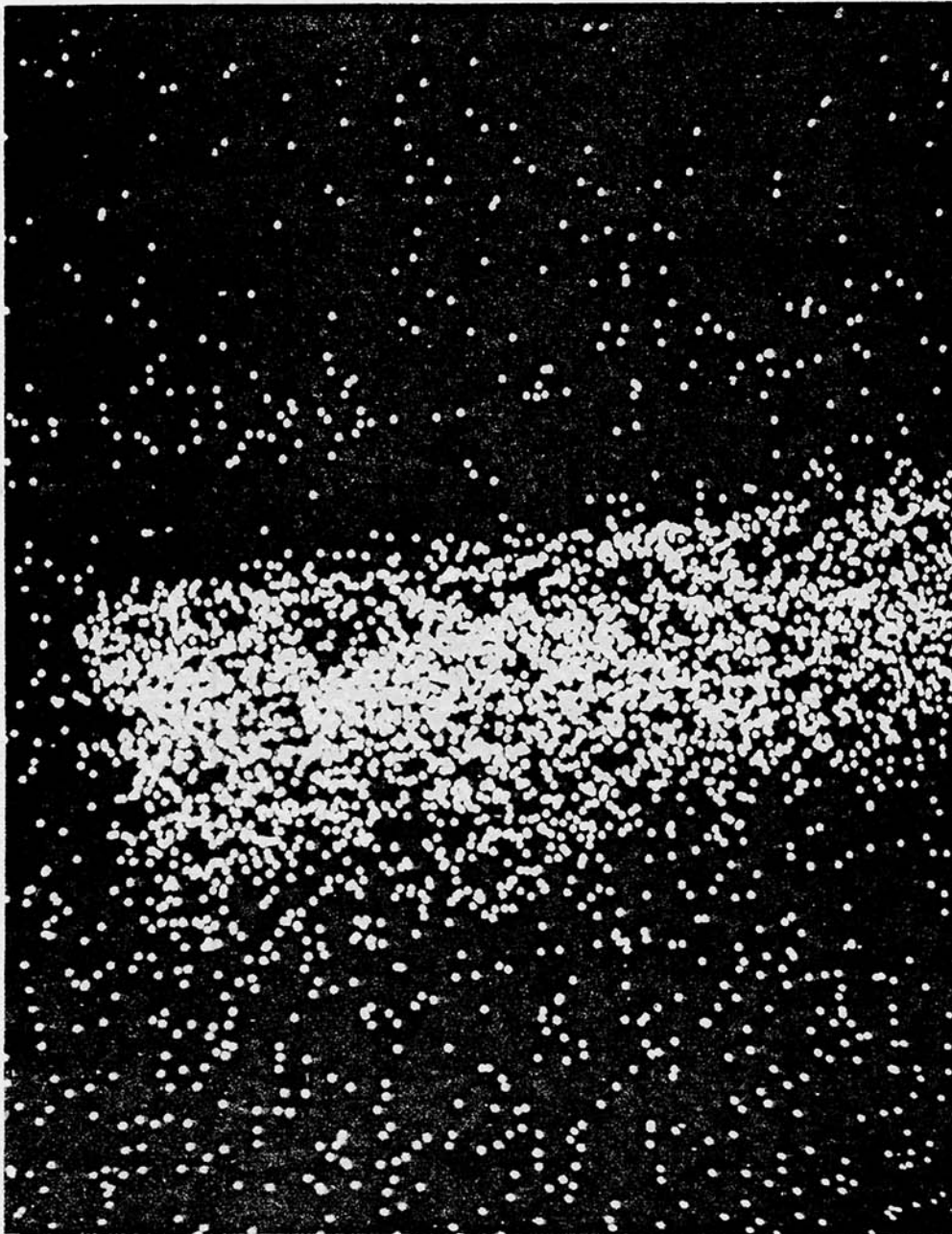
Mag: 400X

Figure 12. Sulfur Distribution in Section C of Barrel No. 859740



Mag: 400X

Figure 13. Iron Distribution in Section C of Barrel No. 859740

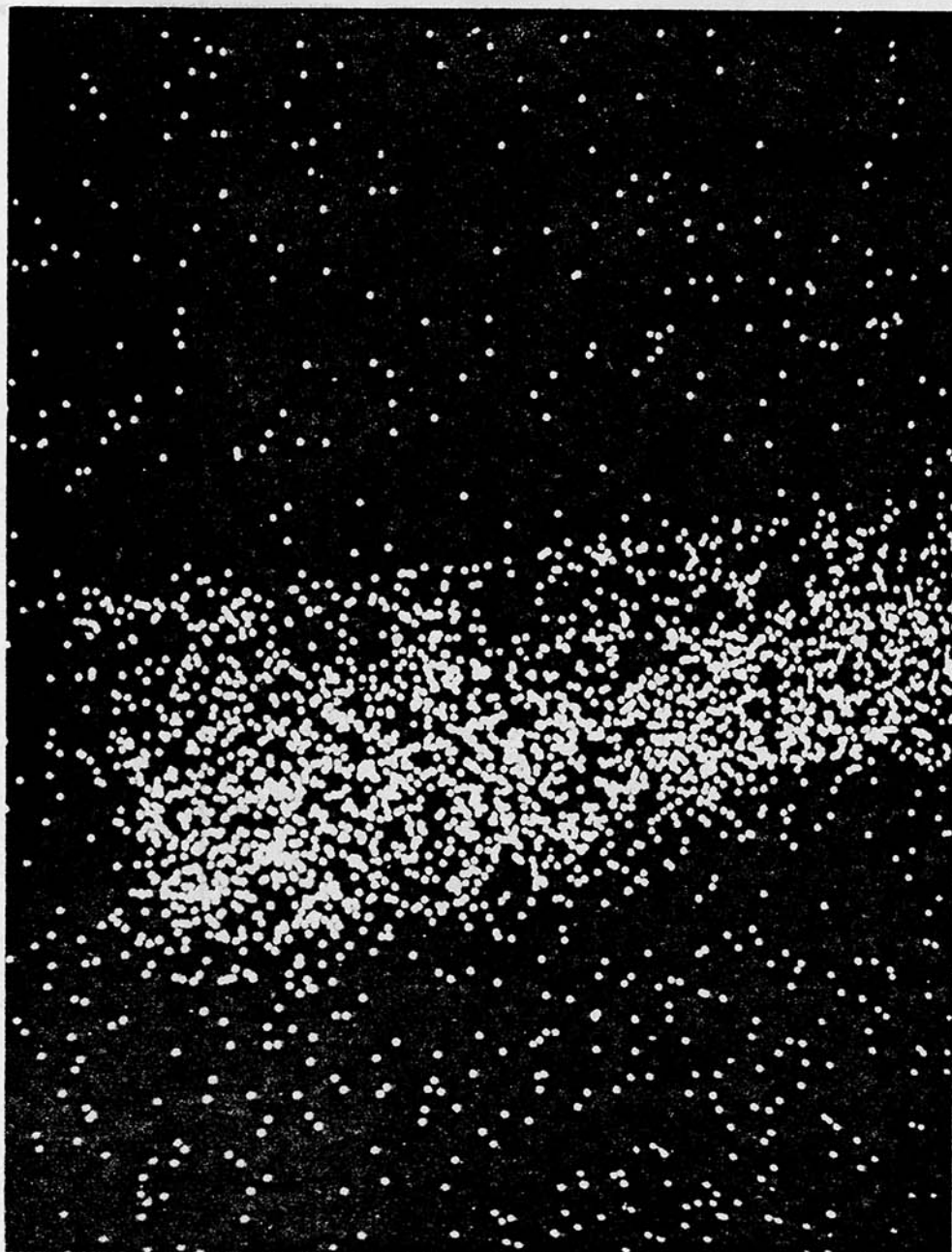


X004 :25M
Mag: 400X
Figure 14. Copper Distribution in Section C of Barrel No. 859740



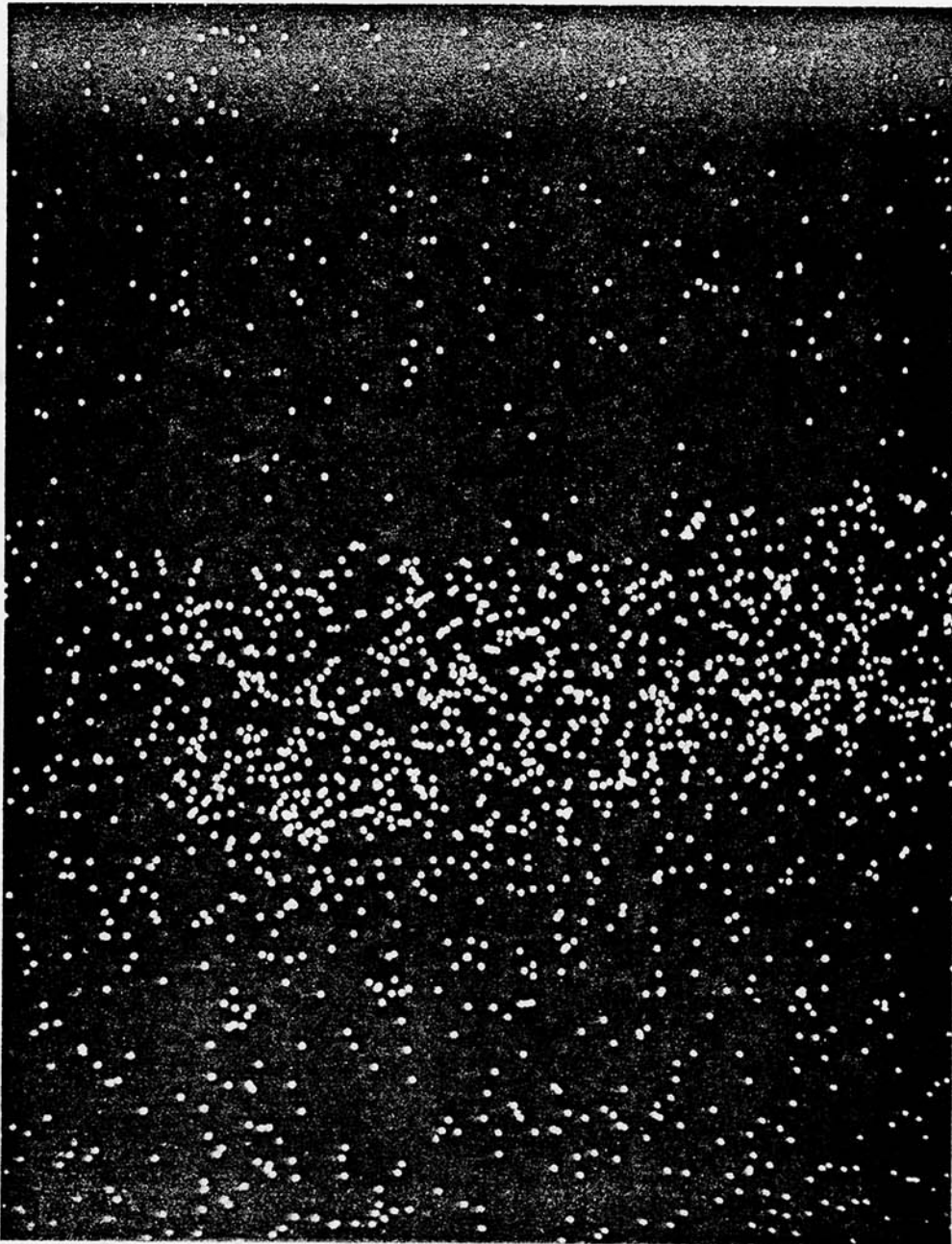
Mag: 400X

Figure 15. Zinc Distribution in Section C of Barrel No. 859740



Mag: 400X

Figure 16. Lead Distribution in Section C of Barrel No. 859740



Mag: 400X

Figure 17. Antimony Distribution in Section C of Barrel No. 859740

FIRING TESTS

The erosion data for the two M16A1 rifle barrels is presented in this section. The firing schedule to which these barrels were subjected was:

1. Twenty rounds, automatic, in bursts of approximately five rounds each.
2. Twenty rounds, automatic, in one burst.
3. Twenty rounds, semiautomatic, at a rate of 10 to 30 rounds per minute.
4. Twenty rounds, automatic, in bursts of approximately five rounds each.
5. Twenty rounds, semiautomatic, at a rate of 10 to 30 rounds per minute.

The cyclic rate was recorded during the fully automatic burst. The barrel was allowed to cool to the touch after each 100 rounds. This schedule was repeated until 1000 rounds were fired, at which time the barrel was bore-gaged. This sequence was then repeated until 6000 rounds had been fired.

As mentioned earlier, both barrels were sectioned for electron microprobe analysis. Barrel 859740 (low CaCO_3 content propellant) was bore-gaged prior to sectioning, but barrel 167512 (high CaCO_3 content propellant) was so heavily fouled that the bore gage would not enter. (This data was presented in Reference 1 and is included in Appendix B).

Attempts were made to clean all the sections of barrel 167512 in the hope of obtaining bore-gage data to compare with the original dimensions of the barrel, which would show the extent to which any erosion of the metal surface had occurred. Because of the difficulty involved in getting the sections sufficiently clean, only the two nearest the chamber were used. Section L' begins near the origin of rifling and extends three inches into the barrel; section J' begins approximately 1-1/2 inches later, and is one inch in length. The intervening space was taken up by two 1/4 inch microprobe sections and the one inch section K', which was ~~unavailable~~.

¹Ludwig Stiefel and Bruce Brodman "M16 Rifle Gas Tube Fouling - Composition, Properties and Means of Elimination," Frankford Arsenal Report R-1936, August 1969.

It is felt that sections J' and L' are sufficient to characterize the erosion that has taken place because all other studies of fouling and erosion have shown that the most severe erosion always occurred within the first few inches of the barrel. These sections were measured, using a Precisionaire gage, and the results are shown in Appendix B.

The readings at the end of the test were taken at three points whenever possible, but this could not be done for the lands of section L' because "rolling" of the lands had occurred. When a land "rolls" (or protrudes into the adjacent groove), the groove-measuring guide of the Precisionaire gage will pass while the land guide will not, thus preventing land measurements during the testing.

Following the 6000-round test, barrel No. 859740 was quite free of fouling and most of the bore was measured (Appendix B). Note, however, that the probe would not enter portions of this barrel at the start of the test. For this reason the barrel cannot strictly be used for bore-gage data. However, the fact that the probe did not enter before the test, coupled with the large groove diameter readings after the test, indicates that significant erosion has taken place near the chamber end.

Because barrel No. 859740 did not give significant bore-gage data, a third barrel (No. 3300668) was introduced into the testing to provide this data for low calcium carbonate propellant rounds. This barrel was subjected to the same 6000-round schedule as the other two, using rounds loaded with low calcium carbonate propellant (BAJ46892). The chemical composition of this propellant is included in Appendix A; Appendix B gives the bore-gage data for this barrel as taken after each 1000 rounds.

After 4000 rounds, the land guide would not pass the point 12.5 inches from the muzzle. Inspection with a borescope revealed that this barrel was very lightly fouled and that rolling of the lands occurred frequently in the region between the chamber and the 12.5 inch point.

RESULTS

Overall observation of the bore gage data for the two low CaCO_3 propellant barrels indicated that significant wear was confined to a region near the origin of rifling. Beyond 1-1/2 inches from this point (toward the muzzle), the variations are of the order of experimental errors associated with the Precisionaire gage.

Inspection of the data in Appendix B shows clearly that there was little or no erosion present in the barrel which fired high CaCO_3 content rounds. The data for the low CaCO_3 firings (barrel 3300668) is quite different. Beginning with the 3000-round measurements, both the

lands and grooves were eroded (i.e., diameters were increasing). This erosion was evident in the 1-1/2 inches nearest the chamber, and groove erosion continued steadily to the end of the test. This same trend was evident for the lands up to the point where the gage would not enter, and it is reasonable to expect that it continued throughout the firings.

In summary, the data presented above indicate that a barrel firing rounds having propellant with high CaCO_3 content will become more heavily fouled and will erode much less than a barrel in which rounds containing a lesser amount of CaCO_3 had been fired.

It should be noted that all the above information concerns steel M16A1 rifle bores. Product improvement tests of chrome-plated barrel bores for the M16A1 rifle⁴, recently conducted by U.S. Army Test and Evaluation Command (TECOM), compared steel and chrome-plated barrel bores. The background section of the TECOM report points out that the required life of the standard non-chromed bore is 6000 rounds and the desired life is 10,000 rounds. Further, this report states that the standard non-chromed bores have been meeting these requirements under rifle endurance test conditions at Aberdeen Proving Ground.

Product improvement of the rifle by chrome plating was undertaken because of corrosion problems experienced in southeast Asia (SEA). It is interesting to note that chrome-plated bores outlasted the standard bores during this test. The purpose of presenting this information is to show that there was no erosion problem in either the standard steel bores or in the chrome-plated bores. The present data has indicated that CaCO_3 can foul the bore of the M16A1 rifle and act to prevent erosion. However, it should be kept in mind that erosion is not a problem in this system and that any increase in CaCO_3 content of the propellant could result in serious gas tube fouling. Therefore, it is neither implied nor recommended that the CaCO_3 content of ball propellant be increased.

CONCLUSIONS

1. It appears that ball propellant with a high CaCO_3 content results in heavy bore fouling when fired through an M16A1 rifle under conditions described in this report. Further, in the case where the bore was heavily fouled, little or no erosion was found to occur.

⁴ Eric Keele "Product Improvement Test of Chrome-Plated Barrel Bores for the M16A1 Rifle," USA TECOM Report APG-MT-3948, October 1971.

2. It appears that ball propellant with a low CaCO_3 content results in very light bore fouling when fired through an M16A1 rifle under conditions described in this report. In the case where little bore fouling occurs, erosion, pitting, and cracking of the interior bore surface was found.

3. The major contributors to the fouling residue produced by high CaCO_3 content propellant were found to be CaCO_3 and gilding metal (copper-zinc alloy, used as the bullet jacket). The portion of the residue in contact with the bore surface was largely CaCO_3 . The outer region was composed of significant quantities of gilding metal and CaCO_3 .

4. It appears that CaCO_3 , when present in high concentrations in the propellant, deposits in the bore and acts to trap various elements originating from cartridge components. Factors such as chemical and mechanical attack, as well as propellant flame temperature, have been identified as being associated with barrel erosion. Thus, it appears that this fouling residue reduces barrel wear by shielding the surface from these degradative effects.

RECOMMENDATIONS

It is recommended that

1. A comprehensive test be run to establish the role that CaCO_3 plays in barrel fouling and erosion in a high cyclic rate weapon system which is currently experiencing barrel life problems.

2. A test be designed to establish if addition of a small amount of CaCO_3 (equivalent to the amount present in current production lots of ball propellant) to extruded propellant compositions results in any increase in barrel life.

APPENDIX A

CHEMICAL COMPOSITION OF
PROPELLANT LOTS X2842, BAJ45608, AND BAJ46892

	<u>Percentage of Component in Propellant Lots</u>		
	<u>X2842</u>	<u>BAJ45608</u>	<u>BAJ46892</u>
	<u>(Barrel 167512)</u>	<u>(Barrel 859740)</u>	<u>(Barrel 3300668)</u>
Nitrogen in ^{NC} WC	13.16	13.16	13.15
Nitroglycerine	9.11	10.52	10.66
Dinitrotoluene	0.66	0.06	-
Diphenylamine	0.94	0.98	0.99
Dibutylphthalate	4.89	5.68	4.87
Total volatiles	1.21	1.23	1.02
Moisture	0.83	-	-
Residual solvent	0.38	0.60	0.52
Moisture and volatiles	0.87	1.06	0.96
Calcium carbonate	{ 1.02 ^a	{ 0.13 ^a	{ 0.04 ^a
	{ 1.15 ^b	{ 0.19 ^b	
Sodium sulfate	{ 0.28 ^a	{ 0.09 ^a	{ 0.05 ^a
	{ 0.055 ^b	{ 0.027 ^b	
Graphite	0.21	0.12	0.16
Nitrocellulose (by difference)	81.68	81.19	83.23

^a
By Specification (morpholine) method.

^b
By atomic absorption spectrometry.

APPENDIX B
BORE GAGE DATA

Bore Gaging Records for Barrels 859740 and 167512

Distance from Muzzle (in.)	Bore Diameter (in.)							
	Barrel No. 859740				Barrel No. 167512			
	Start of Test Land	Start of Test Groove	End of Test Land	End of Test Groove	Start of Test Land	Start of Test Groove	End of Test Land	End of Test Groove
0.5	0.2196	0.2238	0.2195	0.2238	0.2195	0.2238	0.2195	0.2238
1	0.2196	0.2238	0.2195	0.2237	0.2195	0.2238	0.2195	0.2238
2	0.2196	0.2238	0.2195	0.2237	0.2195	0.2240	0.2195	0.2240
3	0.2195	0.2238	0.2195	0.2237	0.2195	0.2237	0.2195	0.2237
4	0.2193	0.2238	0.2195	0.2237	0.2195	0.2237	0.2195	0.2237
5	0.2195	0.2238	0.2195	0.2237	0.2195	0.2237	0.2195	0.2237
6	0.2193	0.2237	0.2195	0.2237	0.2194	0.2237	0.2194	0.2237
7	0.2192	0.2237	0.2193	0.2237	0.2195	0.2237	0.2195	0.2237
8	0.2191	0.2237	0.2193	0.2237	0.2195	0.2237	0.2195	0.2237
9	0.2191	0.2238	0.2194	0.2238	0.2194	0.2237	0.2194	0.2237
10	0.2191	0.2238	0.2192	0.2238	0.2195	0.2237	0.2195	0.2237
11	0.2190	0.2238	0.2192	0.2238	0.2195	0.2237	0.2195	0.2237
12	0.2191	0.2238	0.2191	0.2238	0.2195	0.2238	0.2195	0.2238
13	0.2191	0.2238	0.2191	0.2238	0.2195	0.2238	0.2195	0.2238
14	0.2191	0.2238	0.2192	0.2238	0.2195	0.2238	0.2195	0.2238
15	b	b	0.2197	0.2238	0.2195	0.2237	0.2195	0.2237
16	b	b	c	0.2238	0.2194	0.2237	0.2194	0.2237
17	b	b	c	0.2243	0.2194	0.2237	0.2194	0.2237
17.5	b	b	c	0.2248	0.2194	0.2237	0.2194	0.2237

a Excessive fouling on lands and grooves would not allow entry of Precisionaire gage spindles from muzzle end; fouling visible from gas port to muzzle of rifle.
 b Probe would not enter.
 c Over maximum calibration of 0.2200 inch.

Bore Gaging Record for Barrel No. 3300668

(Taken at 1000-rd Intervals)

Distance from Muzzle (in.)	Diameter (in.) after Firing						
	0 rd	1033 rd	2066 rd	3099 rd	4132 rd	5165 rd	6198 rd
0.5	0.2193	0.2191	0.2192	0.2194	0.2192	0.2193	0.2193
1	0.2194	0.2190	0.2191	0.2194	0.2193	0.2192	0.2193
2	0.2193	0.2190	0.2190	0.2190	0.2190	0.2192	0.2192
3	0.2193	0.2190	0.2192	0.2190	0.2190	0.2192	0.2191
4	0.2192	0.2190	0.2192	0.2190	0.2190	0.2192	0.2190
5	0.2193	0.2191	0.2192	0.2190	0.2190	0.2192	0.2191
6	0.2193	0.2191	0.2191	0.2192	0.2190	0.2192	0.2192
7	0.2192	0.2190	0.2192	0.2193	0.2190	0.2192	0.2191
8	0.2193	0.2190	0.2192	0.2191	0.2190	0.2192	0.2191
9	0.2193	0.2190	0.2192	0.2191	0.2190	0.2192	0.2191
10	0.2193	0.2190	0.2192	0.2191	0.2190	0.2191	0.2190
11	0.2193	0.2190	0.2192	0.2192	0.2190	0.2191	0.2191
12	0.2193	0.2191	0.2192	0.2192	0.2190	0.2191	0.2190
13	0.2193	0.2190	0.2193	0.2192	0.2191	0.2191	0.2191
14	0.2193	0.2190	0.2193	0.2193	(12.5 in.) (12.5 in.) (12.5 in.)	d	d
15	0.2193	0.2190	0.2193	0.2193	d	d	d
16	0.2192	0.2190	0.2193	0.2194	d	d	d
17	0.2193	0.2190	0.2193	0.2198	d	d	d
17.5	0.2193	0.2190	0.2193	0.2198	d	d	d

Precisionaire gage would not pass 12.5 inch point due to rolling of the lands.

Bore Gaging Record for Barrel No. 3300668 (Cont'd)

	Groove Diameter									
0.5	0.2240	0.2240	0.2240	0.2240	0.2240	0.2240	0.2240	0.2240	0.2240	0.2240
1	0.2240	0.2239	0.2240	0.2240	0.2240	0.2241	0.2240	0.2240	0.2240	0.2240
2	0.2240	0.2239	0.2239	0.2240	0.2240	0.2241	0.2240	0.2240	0.2240	0.2241
3	0.2240	0.2239	0.2239	0.2240	0.2240	0.2240	0.2240	0.2240	0.2240	0.2240
4	0.2240	0.2239	0.2239	0.2240	0.2240	0.2240	0.2240	0.2240	0.2240	0.2240
5	0.2240	0.2239	0.2239	0.2240	0.2240	0.2240	0.2240	0.2240	0.2240	0.2240
6	0.2239	0.2239	0.2239	0.2240	0.2240	0.2240	0.2240	0.2240	0.2240	0.2241
7	0.2239	0.2239	0.2239	0.2240	0.2240	0.2240	0.2240	0.2240	0.2240	0.2241
8	0.2239	0.2239	0.2239	0.2240	0.2240	0.2240	0.2240	0.2240	0.2240	0.2241
9	0.2239	0.2239	0.2239	0.2240	0.2240	0.2240	0.2240	0.2240	0.2240	0.2240
10	0.2239	0.2239	0.2239	0.2240	0.2240	0.2240	0.2240	0.2240	0.2240	0.2240
11	0.2239	0.2239	0.2239	0.2240	0.2240	0.2239	0.2239	0.2239	0.2240	0.2240
12	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239	0.2240
13	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239
14	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239
15	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239
16	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239	0.2239	0.2240	0.2240
17	0.2239	0.2239	0.2239	0.2239	0.2240	0.2241	0.2241	0.2241	0.2242	0.2242
17.5	0.2239	0.2240	0.2240	0.2240	0.2240	0.2241	0.2241	0.2242	0.2244	0.2244
				0.2240	0.2240	0.2241	0.2241	0.2244	0.2246	0.2246

Bore Gaging Records for Section J' and L' of Barrel No. 167512

Section J'		Bore Diameter (in.)		Section L'	
Start of Test	End of Test	Start of Test	End of Test	Start of Test	End of Test
Land	Groove	Land	Groove	Land	Groove
0.2195	0.2238	0.2194	0.2238	0.2194	0.2237
0.2195	0.2238	0.2194	0.2238	0.2193	0.2238
0.2194	0.2238	0.2194	0.2238	0.2193	0.2238

Note: Section L' was nearest the chamber.

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Bore Gaging Record for Barrel No. 167512 (cont.)

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13. ABSTRACT A mechanism is proposed describing the action of calcium carbonate in causing bore fouling and preventing erosion in the M16A1 rifle. Electron microprobe, x-ray diffraction, metallographic examination, and bore gage data are presented which indicate that ball propellant with high calcium carbonate content, when fired through an M16A1 rifle as described in this report, results in heavy bore fouling and little or no erosion. Further, similar firings of propellant with low calcium carbonate content result in little bore fouling, but with erosion, pitting, and cracking of the bore surface.			

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	Barrel Fouling and Erosion Propellant Additives Calcium Carbonate M16A1 Rifle Small Arms Propellant						

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