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REPORT R-1946

ELIMINATION OF GAS TUBE FOULING IN THE M16A1 RIFLE WHEN USING THE M200 BLANK CARTRIDGE

by

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February 1970

U.S. ARMY MUNITIONS COMMAND

DEPARTMENT OF THE ARMY
FRANKFORD ARSENAL
Philadelphia, Pa. 19137

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Ammunition Development & Engineering Laboratories
and
Pitman-Dunn Research Laboratories
FRANKFORD ARSENAL
Philadelphia, Pa. 19137

February 1970

ABSTRACT

Chemical analyses of gas tube fouling residue obtained when firing production lots of 5.56 mm, M200 blank ammunition showed the presence of barium, potassium, titanium, antimony and lead. These were characterized as barium titanate, potassium carbonate, lead sulfide, and antimony metal. The major contributor was found to be barium titanate. The suspected source of the titanium was the white pigment used in the cartridge mouth waterproofing lacquer. Several 10,000-round fouling tests were conducted in order to establish the fouling characteristics of four different mouth waterproofing lacquers. Ammunition mouth waterproofed with white lacquer, pigmented with titanium dioxide, caused gas tube fouling resulting in weapon stoppages. Ammunition mouth waterproofed with clear, dyed and black pigmented nitrocellulose lacquer caused little or no gas tube fouling. The nitrocellulose lacquer containing an organic dye offers the required coloration and minimum fouling characteristic required in the M16A1 rifle.

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INTRODUCTION

Service tests, to determine suitability of the XM15 Blank Firing Attachment (BFA) with M200 blank cartridges in the 5.56 mm M16A1 rifle, were conducted by the United States Army **Infantry** Board (USAIB), Fort Benning, Georgia early in 1968.[1] **During** the durability and reliability phase of the test, it was reported that excessive gas tube and bolt carrier key fouling had occurred in six of the M16A1 rifles being used. USAIB Equipment Performance Reports generated during the test substantiate the gradual increase in malfunction rate as the gas tubes and carrier keys became clogged.

As firing continued, the fouling degree was such that the weapons ceased to function with M200 blank cartridges in either the semiautomatic or automatic firing modes. Reported malfunctions were of the type normally associated with a clogged gas tube.

The number of blank rounds required to achieve gas tube and carrier key clogging in the test rifles varied from 2,760 to 6,890. Cleaned and lubricated rifles continued to malfunction using either M200 blank cartridges or M193 ball cartridges. These same rifles fitted with new gas tubes and carrier keys functioned normally.

The USAIB noted one shortcoming related to the shorter length blank cartridge, compared to the M193 ball cartridge. A high incidence of stoppages resulted from stubbing of the blank rounds on the front lip of the magazine and on the entrance to the chamber.

Subsequent to the USAIB test, Frankford Arsenal included the M200 blank cartridge in the "Gas Tube Clogging Studies" of the M16A1 rifle as authorized by the Project Manager, Rifles, USAWECOM, in letter dated 18 April 1968.

The M200 blank ammunition used for USAIB tests was mouth waterproofed with black cellulose nitrate lacquer. Present production type M200 blank ammunition, obtained for Frankford Arsenal use after the USAIB tests, was mouth waterproofed with a white, cellulose nitrate lacquer. Twin Cities Army Ammunition Plant (TCAAP) initiated the change from black to white pigmented lacquer to simplify

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[1] See REFERENCES

cartridge inspection procedures. No production type M200 blank ammunition with black, mouth waterproofing lacquer was available when studies were initiated; however, a quantity of this type of ammunition was specially prepared for this study. Results obtained in this study using ammunition with black, mouth waterproofing differed from those obtained by the USAIB.[1] Little or no fouling was encountered using the black, mouth waterproofing. This might be attributable to differences in amount of pigment present on each of the rounds. These differences can arise because of the wide latitude provided in the lacquer specifications and can be compounded by solvent loss during the waterproofing process. The cartridges are dipped in an open trough containing the lacquer. As the solvent evaporates from the trough, the lacquer becomes more concentrated resulting in an increase of pigment concentration on each round. In order to counteract this condition, viscosity measurements are made every two hours during a production run. At the end of each two-hour period, the viscosity is adjusted by adding more solvent. However, there can be a wide variation of viscosity during the two-hour periods, thus, resulting in pigment concentration variation within a given lot.

Although the results obtained at Frankford Arsenal did not reproduce the gas tube clogging reported by USAIB with ammunition containing black (carbon black) pigment, the explanation of that fact was not sufficiently important to warrant further delay in the broader investigation, since the use of black pigment had been discontinued for some time. It was considered much more important to investigate the effects of the white pigment (titanium dioxide) which replaced the black pigment. The significant findings pertaining to the present white pigment in particular, and the inferences concerning pigments in general, warrant publication of this report at this time, notwithstanding that the early results with black pigment at USAIB have not been reproduced or positively explained.

CHEMICAL EVALUATION OF FOULING RESIDUE

In order to obtain a fouled M16 gas tube for chemical analysis, a fouling test was conducted using a production lot of 5.56 mm, M200 blank cartridges. A gas tube was obtained from this test which was fouled after 4,820 rounds had been fired through the rifle, using blank ammunition (lot #TW 18055) loaded with HPC-13 propellant (lot #8).

This tube had a flowmeter reading of 1.62 psi at the start of the test and a reading of 3.30 psi when the gun ceased to function. A radiograph taken of the gas tube (see Figure 1) indicated that the deposition was not localized, but was spread over the forward portion of the gas tube. The data obtained from this test are plotted in Figure 2.

In order to subject the gas tube to further studies, transverse sections 1/4-inch thick were taken at 1-inch intervals along the entire length (labeled A through J starting at the port end) of the gas tube. These sections were mounted and metallographically polished. Microscopic examination of the mounted tube sections showed that Section A (just forward of the port hole) was completely clogged, whereas the other sections contained a thin layer of contamination (5 to 25 mils in thickness) around the periphery of the stainless steel gas tube. Photomicrographs of the fouling residue present in Section A, are shown in Figure 3. A random distribution of shiny metallic particles (0.1 to 2 microns in size) can be seen throughout the specimen; the matrix consists of a slate gray phase containing several patches of a darker gray (or black) phase.

A previous study[2] of gas tube fouling in the M16A1 rifle encountered when firing the 5.56 mm, M193 ball cartridge, demonstrated the applicability of the electron microprobe for studying the chemical composition of fouling deposits. It was decided to employ the same technique for studying the chemical composition of the gas tube residue formed when firing the blank M200 cartridge.

Electron microprobe techniques can be used to obtain chemical analysis from a specimen as small as a few cubic microns in volume. A finely focused electron beam is made to impinge onto the specimen area of interest. The electrons diffuse into the specimen a short distance at which point many of them interact with orbital electrons (associated with the atoms of the specimen) and cause ionizations. These ionizations lead to the production of x-rays that are characteristic of elements present in the field of electron diffusion. The depth of electron penetration is dependent primarily on the accelerating voltage of the electron beam and upon the average atomic number of the specimen. At 30 kv, for example, the depth of electron penetration in copper is 2 - 3μ, whereas in carbon it is about 6μ. Characteristic x-rays emitted from the atoms present in the specimen are analyzed by means of dispersive techniques whereby x-rays of a

Figure 1.   Radiograph, Fouled Gas Tube, M16A1 Rifle

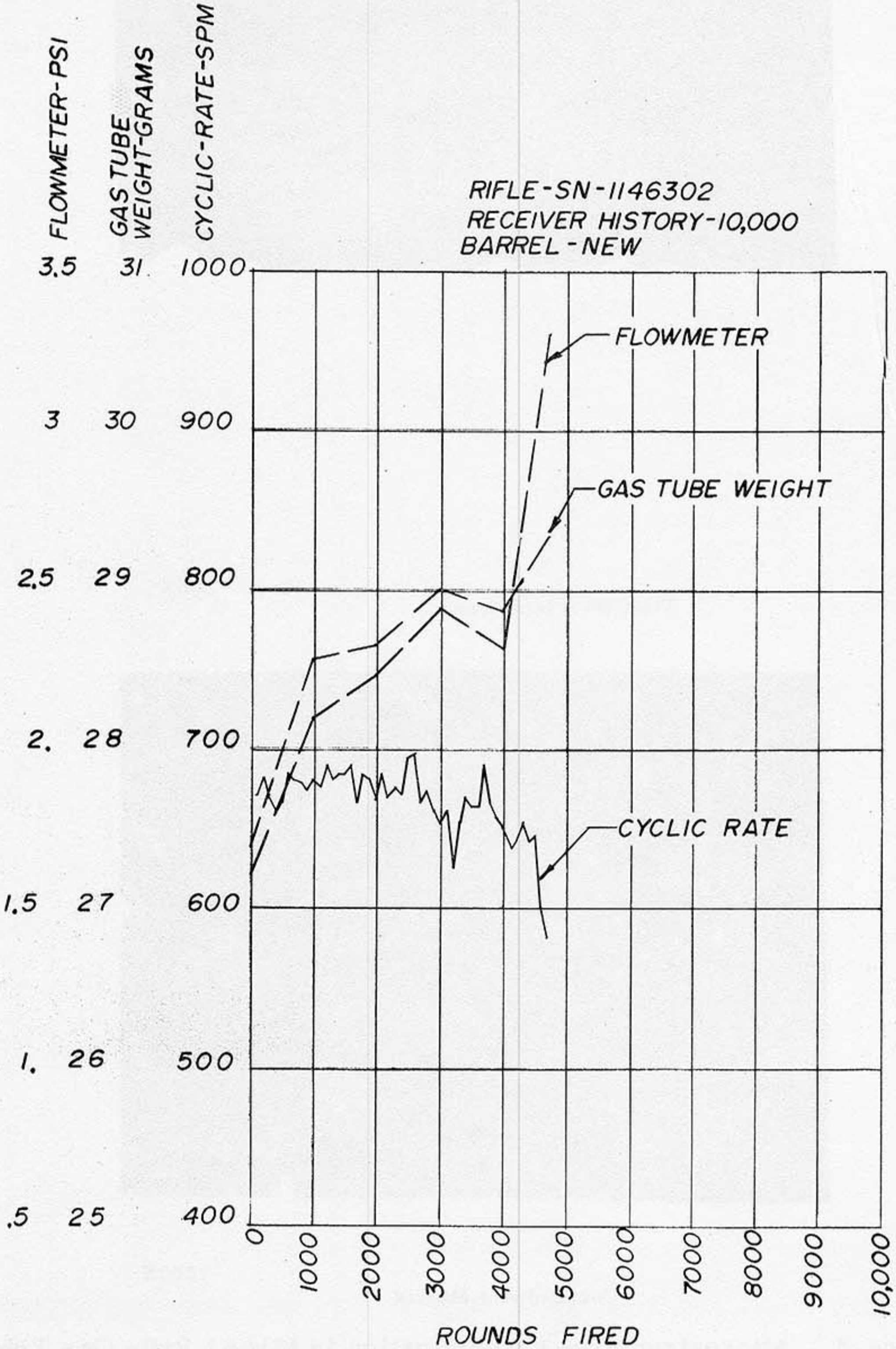
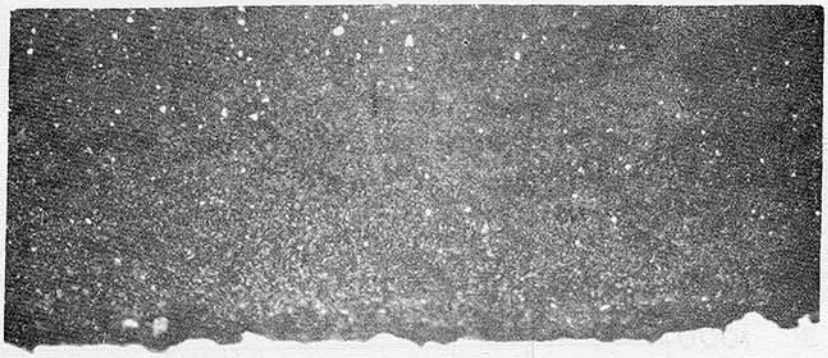
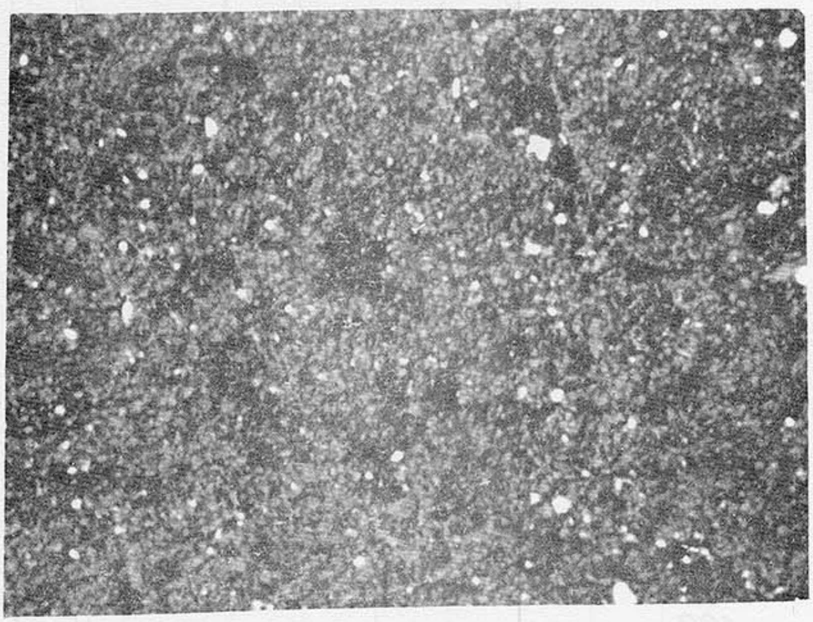


Figure 2. Test Data - Lot TW 18055



500X

Tube Wall Interface



1000X

Contaminant Matrix

Figure 3. Microstructure, Contamination in M16A1 Rifle Gas Tube

particular wavelength (λ) are diffracted from a crystalline grating (with a known mean spacing of d) at an angle Θ where $\lambda = 2d \sin \Theta$. Knowing the angle of diffraction and the interplanar spacings, one can determine the wavelength of the x-ray and therefore the elements present. The x-ray line intensities, when appropriately corrected for matrix absorption, secondary fluorescence and various electron effects, can be used to determine quantitative composition.

Man Labs Inc. of Cambridge, Mass., which conducted the electron microprobe measurements, made use of a Phillips AMR/3 Electron Probe Microanalyser. It was equipped with two scanning spectrometers which can simultaneously analyze for any element between sodium (atomic number 11) and uranium (atomic number 92). One of the spectrometers is specially equipped with thin windows and a stearate film overlay on the mica analyzing crystal to extend its analysis range to include the light elements, boron (atomic number 5) to sodium (atomic number 11). Various data collection procedures can be employed as follows:

1. Spectral Scans - The specimen is held stationary under the electron beam and the spectrometers are scanned over a range of 2Θ values to identify the various elements present in the probed sample.

2. Distribution Scans - The spectrometers are set to specific x-ray lines and the specimen is transversed under the beam, presenting a record of x-ray extensity versus distance.

3. Scanning Display - The electron beam is scanned across the area of the specimen by means of orthogonal deflection coils. The monitored signal is used to modulate the brightness of a cathode ray tube having a sweep synchronous with the electron beam. In this manner, one can obtain qualitative chemical information about the specimen surface.

Spectral scans were run on the previously described gas tube section A, D, G, H, and J. A typical scanning display for section D is shown in Figure 4. All scans yielded equivalent data. The elements that were detected in order of highest to lowest intensity were barium, titanium, potassium, antimony, lead, and sulfur. Light element analysis showed the presence of carbon and oxygen. Specific examination of the light metal particles distributed through the fouling matrix showed a large increase in antimony intensity accompanied by a decrease in all other elements. These particles were, therefore, identified as antimony metal.

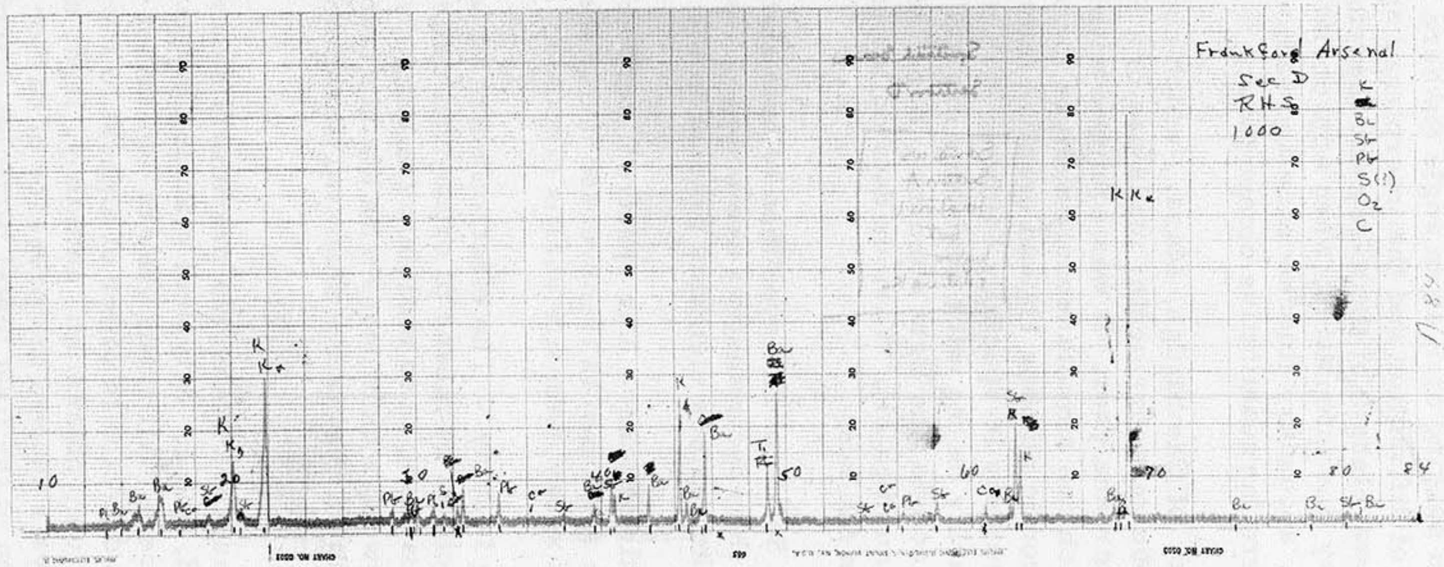


Figure 4. Spectral Scan Gas Tube Section "D"

In order to associate the detected elements with each other, x-ray distribution scans were carried out simultaneously on element pairs (see Figure 5) including lead versus sulfur, titanium versus barium and potassium versus lead. It can be seen in Figure 5 that there is a direct relationship for the first two element pairs (Pb vs S and Ti vs Ba) and an inverse relationship in the case of potassium versus lead; i.e., increase in K intensities are accompanied by a decrease in Pb intensity. These results indicated that titanium and barium as well as lead and sulfur were present as compounds. This was further verified by means of x-ray scanning displays (see Figure 6). Figure 7, a scanning display of K vs Sb, shows no correspondence between these elements. The correspondence between antimony and titanium as well as between lead and sulfur are especially well defined.

In order to characterize the specific compounds present, Debye-Scherrer x-ray diffraction patterns were obtained for residue found in several tube sections. The patterns showed spacings characteristic of lead sulfide and potassium carbonate.

X-ray scanning display photographs and electron microprobe distribution scans showed a good correspondence between barium and titanium. It was concluded that these elements were present as an amorphous compound which would not be identifiable in the x-ray diffraction patterns. The most logical compound that could be postulated was $BaTiO_3$.

Based on electron microprobe and x-ray diffraction data it was estimated that the residue had the following composition:

$BaTiO_3$	60%
PbS	25%
K_2CO_3	10%
Sb	5%

The barium can be traced to the barium nitrate of the primer and the antimony can be traced to the antimony sulfide of the primer. Sulfur could have come from either the antimony sulfide of the primer or the potassium sulfate present in the propellant.

It is interesting to note that in a previous study[2] of 5.56 mm, ball ammunition fouling in the M16A1 rifle, $CaCO_3$ was found to be present in large quantities in the gas tube. The mechanism suggested in that report includes the decomposition of $CaCO_3$, which is present

10P

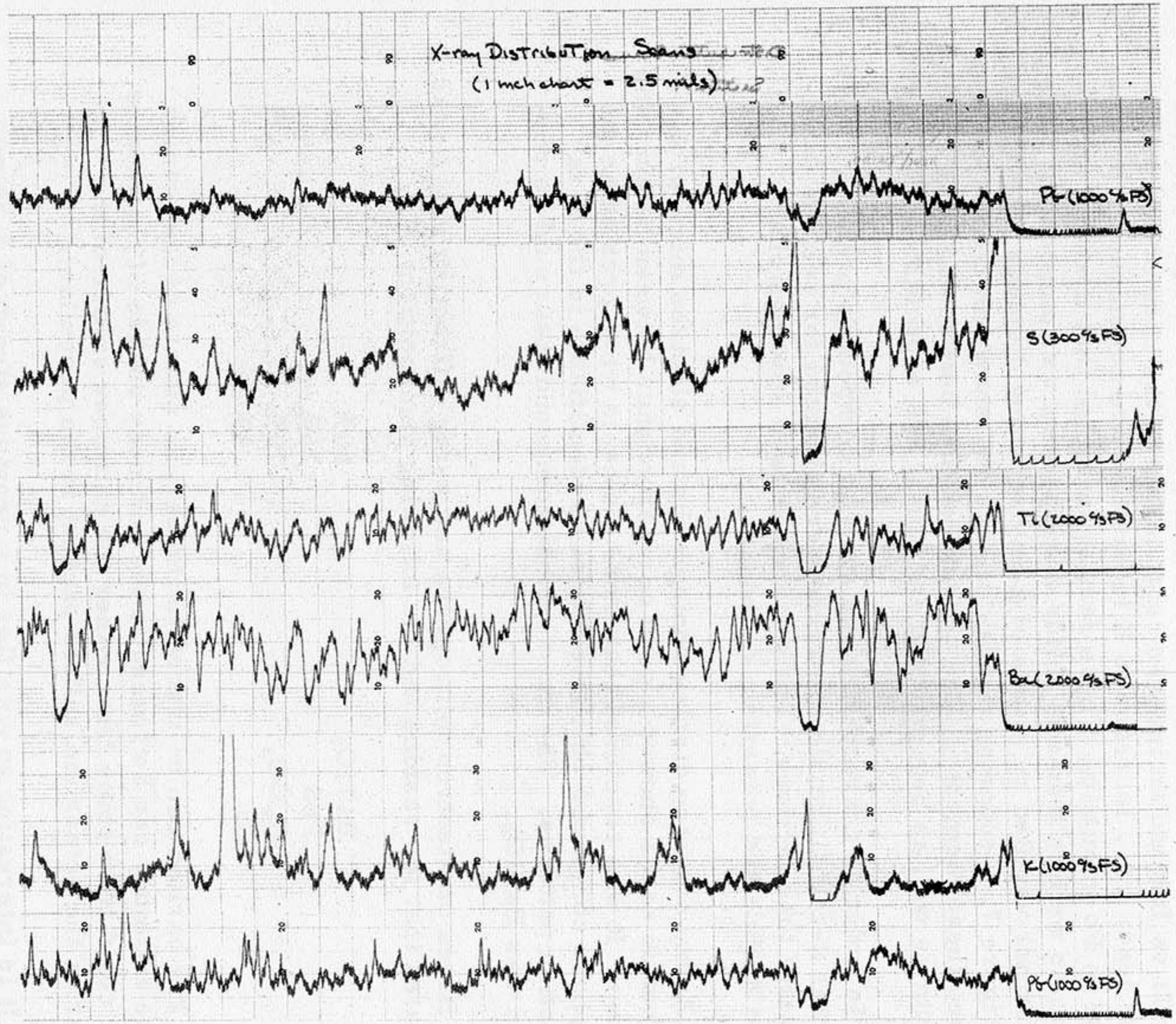


Figure 5. X-ray Distribution Scans (Pb vs S, Ti vs Ba, and K vs Pb)

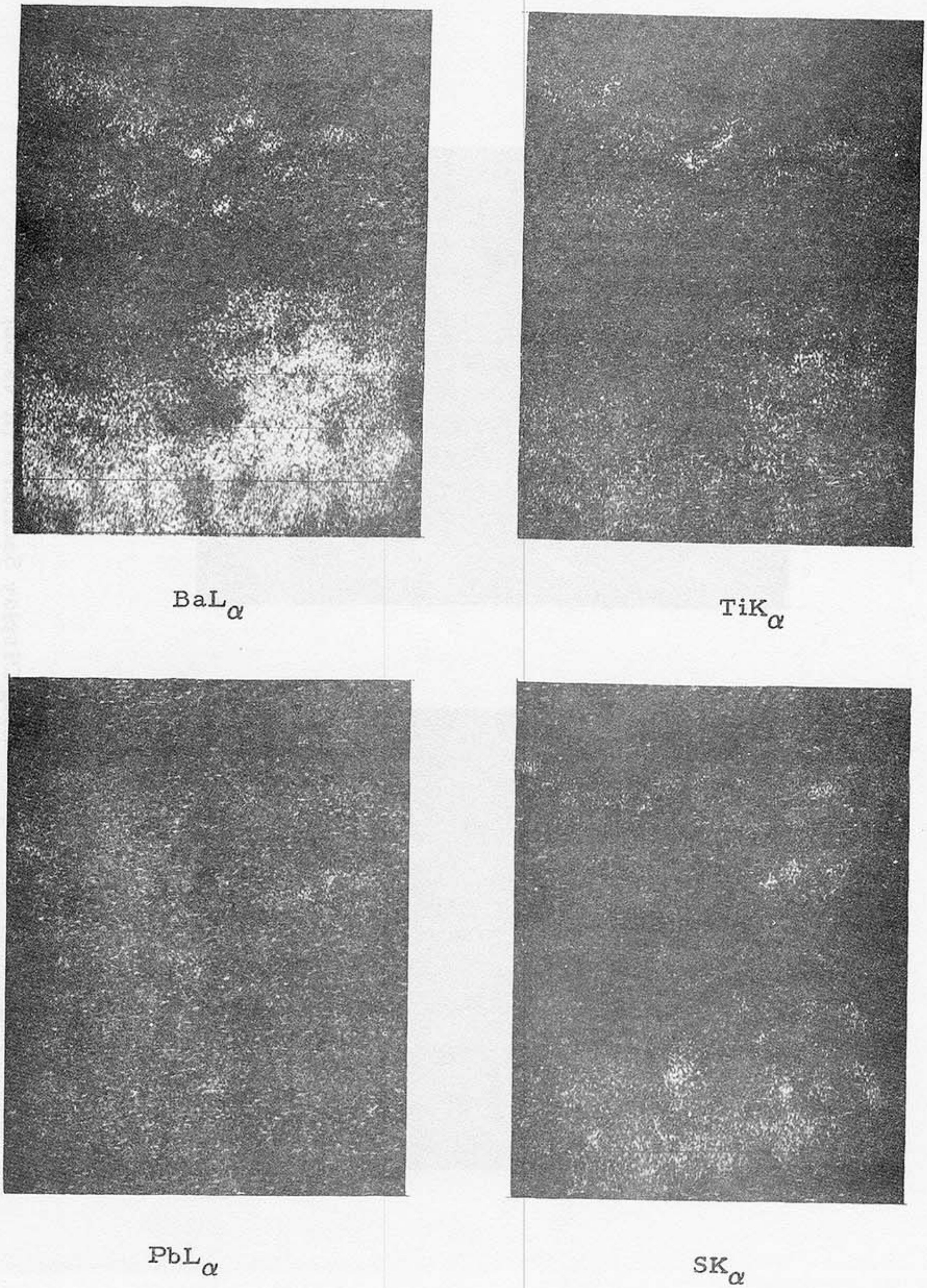
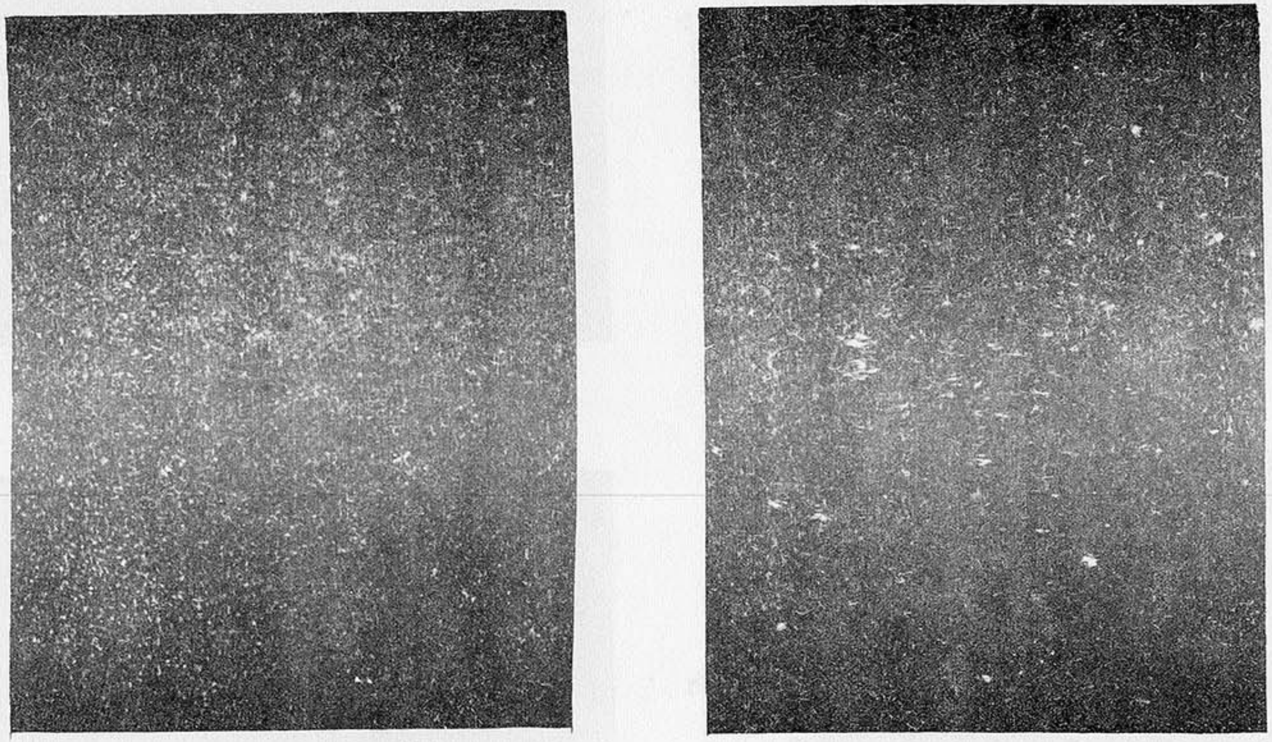


Figure 6. X-ray Scanning Display, Section A (Ba vs Ti and Pb vs S)



K K_{α}

Sb L_{α}

Figure 7. X-ray Scanning Display Section A (K vs Sb)

in the propellant, and its reformation in the gas tube. In this study we have K_2SO_4 present in the propellant and K_2CO_3 (10% of the total residue was K_2CO_3) in the gas tube. This would tend to indicate that the K_2SO_4 decomposes when it passes through the flame zone followed by the formation of K_2CO_3 and its deposition in the gas tube. This information gives further support to the previously proposed mechanism for gas tube fouling with ball ammunition.

The titanium in the residue apparently originated from the titanium dioxide pigment present in the white lacquer applied to the rosette crimp used to seal the mouth of the M200 blank cartridge. A sample of the white lacquer (lot number 16555) was obtained from Twin Cities Army Ammunition Plant (TCAAP). Chemical analysis showed that the lacquer contained 17.6% pigment and that 89.7% of this was TiO_2. There is no other ammunition component containing titanium.

In summary, the residue found in the gas tube of the M16A1 rifle was examined by means of x-ray diffraction and electron microprobe methods. The results indicated that the major contributor to the fouling residue appears to be $BaTiO_3$ (60% of the total residue was $BaTiO_3$) and that the titanium originated from the white lacquer applied to the rosette crimp used to seal the mouth of the M200 blank round.

At this point it was decided to investigate the effect of the lacquer on weapon fouling by means of a 10,000-round test. Four lots of ammunition were produced at TCAAP, all assembled with identical propellant and component lots. One of the lots was mouth waterproofed with a nitrocellulose lacquer, which employed an organic dye rather than an inorganic pigment to obtain coloration. It was reasoned that the organic dye would decompose under gun conditions without leaving a solid residue. The organic dye used for this lacquer was 0.3% methylviolet. This produced a very deep, violet colored, opaque lacquer. Also included in this test were two control waterproofing formulations, one a clear nitrocellulose lacquer and the other a black lacquer using lamp black as the pigment (see Table II).

DESCRIPTION OF FOULING TESTS

Description of Materiel

M16A1 Rifles

Eight standard 5.56 mm M16A1 rifles were used for these tests. The rifle actions were fitted with unused barrel assemblies with chrome plated chambers, new gas tubes, and front sight brackets. Four rifles were used to fire each of the four cartridge lots in a fixed mount. The remaining rifles were used to "shoulder fire" each of the cartridge lots. For rifle identification see Table I.

TABLE I. Rifle Indentification

Ammunition Lot Number	Fixed Mount Fired	Shoulder Fired
A	SN 143360	SN 1316464
B	SN 142276	SN 141307
C	SN 822138	SN 601869
D	SN 138831	SN 143678

M200 Blank Cartridges

A total of 91,520 blank M200 cartridges were made available (22,880 for each lot). All cartridges were primed with TW 195 primers and loaded with 7.0 grains of HPC 13 propellant, Army Lot No. 19.

TABLE II. Ammunition Identification

Ammunition Lot Number	
A	Mouth waterproofed with current standard white cellulose nitrate lacquer.
B	Mouth waterproofed with clear (no pigment) cellulose nitrate lacquer.
C	Mouth waterproofed with violet colored, cellulose nitrate lacquer.
D	Mouth waterproofed with black, cellulose nitrate lacquer formerly used for production in lots TW 18000 through TW 18024.

Magazines

Excessive malfunctions attributable to the standard magazine were encountered when tests were initiated. Standard endurance schedules were attempted[3] as specified in SAPD-253F,[4] but not maintained. Decision was then made to use a modified version of the magazine which proved effective during preliminary test of M200 blank ammunition.

Standard magazines were fitted with a formed, front filler and a shortened follower to accommodate the M200 blank cartridge which is approximately 3/8 inch shorter than the ball, M193 cartridge. The magazine housing was engraved with the word "BLANK" for identification purposes during testing. An assembled M16A1 rifle with a blank firing attachment (BFA) and a modified magazine is shown in Figure 8. Figure 9 shows the component parts of the standard magazine and modified magazine, as well as a view of each loaded with M200 blank cartridges.

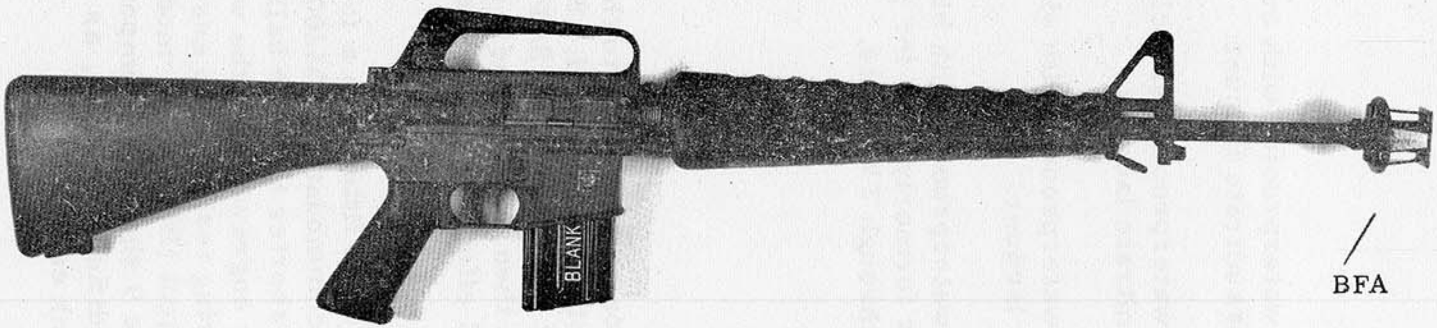


Figure 8. M16A1 Rifle, BFA and Modified Magazine

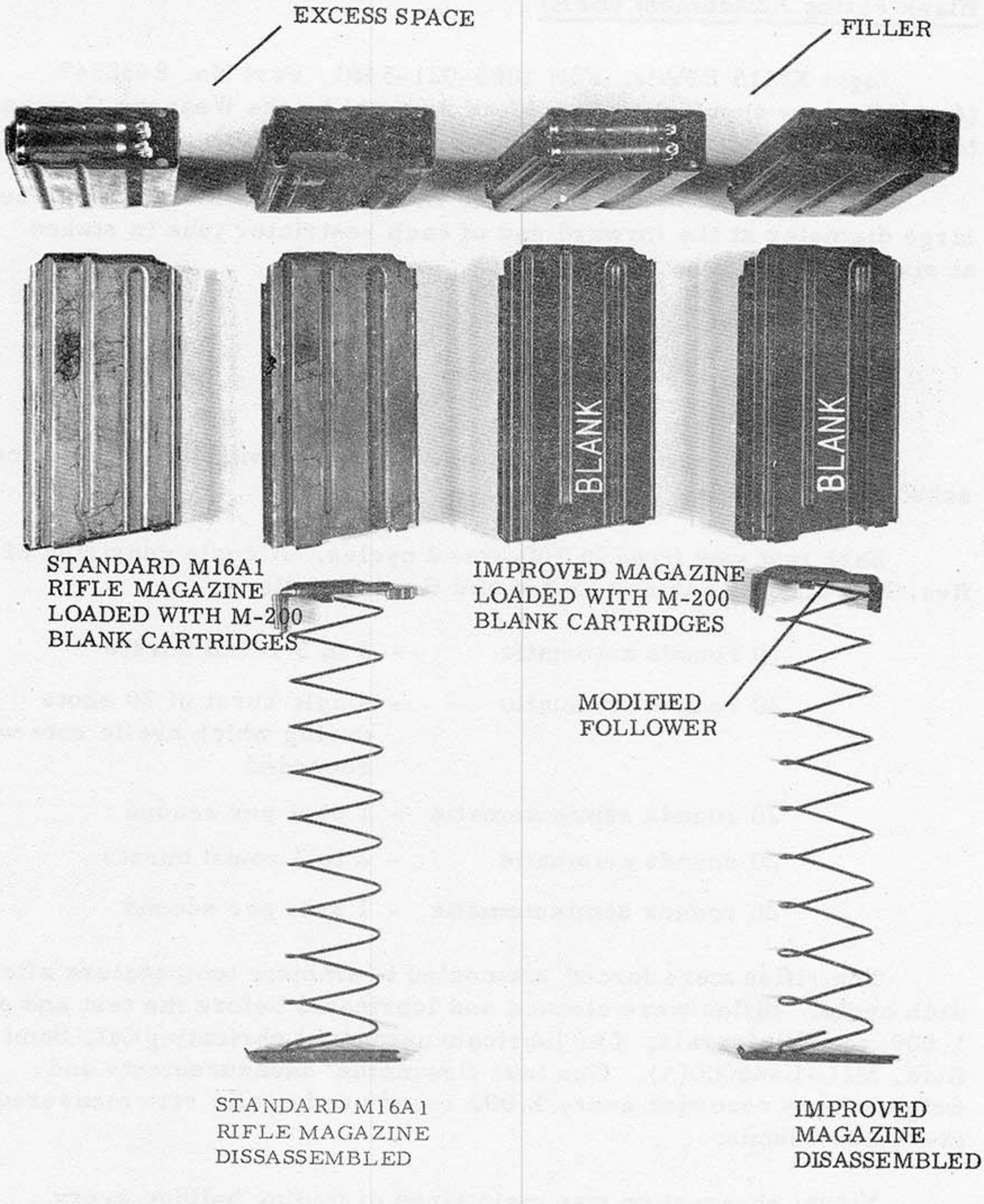


Figure 9. Standard and Modified Magazine, Loaded and Unloaded

Blank Firing Attachment (BFA)

Eight XM15 BFA's, FSN 1005-921-5481, Part No. 8432547 (A-4/69) were supplied to Frankford Arsenal by the Weapons Command to conduct these tests.

Restrictor tubes on each of the BFA's are chrome plated. The large diameter at the forward end of each restrictor tube is staked at six locations to the BFA body.

Test Procedures

Firing sequence was in general accordance with the "endurance" schedule noted in SAPD-253F.[4]

Each test was fired in 100-round cycles. A cycle consisted of five, 20-round magazines loaded and fired as follows:

20 rounds automatic	- 2 to 3 round bursts
20 rounds automatic	- single burst of 20 shots during which cyclic rate was recorded
20 rounds semiautomatic	- 1 shot per second
20 rounds automatic	- 2 to 3 round bursts
20 rounds semiautomatic	- 1 shot per second

The rifles were forced air-cooled to ambient temperature after each cycle. Rifles were cleaned and lubricated before the test and at 1,000-round intervals. The lubricant used was Lubricating Oil, Semi-fluid, MIL-L-46000(A). Gas tube flowmeter* measurements and weights were recorded every 1,000 rounds and cyclic rate measured every 100 rounds.

Visual observation was maintained of fouling buildup every 500 rounds in the weapon bore, chamber, receiver, magazine, and BFA.

All test lots of ammunition were fired both from a fixed mount and from the shoulder in order to observe system function resulting from these two modes of fire.

*Half-bridge type air flow measuring device used to measure the rate of air flow through gas tube.

Test Results

Lot A (Mount Fired), Rifle SN 143360

The weapon began to function erratically after firing 3,200 rounds. The fact that the gas tube was being clogged was indicated by a large increase in flowmeter reading from 1.50 to 3.45 psi and an increase in gas tube weight from 27.2036 to 28.9157 grams. Lowest cyclic rate recorded was 519 shots per minute (spm) and the highest cyclic rate was 651 spm. Plotted data are shown in Figure 10.

A large amount of residue was noted on the outside diameter of the restrictor tube of the BFA and the face of the spring washer after 3,200 rounds (see Figure 11). This abnormal residue accumulation is attributable to the clogging characteristics of ammunition Lot A, mouth waterproofed with white nitrocellulose lacquer. Continued firing attempts after 3,200 rounds yielded malfunctions traceable to the clogged gas tube. The test was discontinued after 3,500 rounds since the rifle would not function in the semiautomatic or automatic firing modes.

The malfunction legends are as follows:

FF	Failure to feed
BOB	Bolt overrode base of round in feeding from magazine
SR	Short recoil
FX	Failure to extract
FF-SR	Failure to feed, short recoil
FJ	Failure to eject

Lot A (Shoulder Fired), Rifle SN 1316464

A total of 1,820 rounds were fired in this test. After 300 rounds, numerous malfunctions occurred. These were of the FF-SR and FF type and were traced to a loose carrier key. The key was tightened

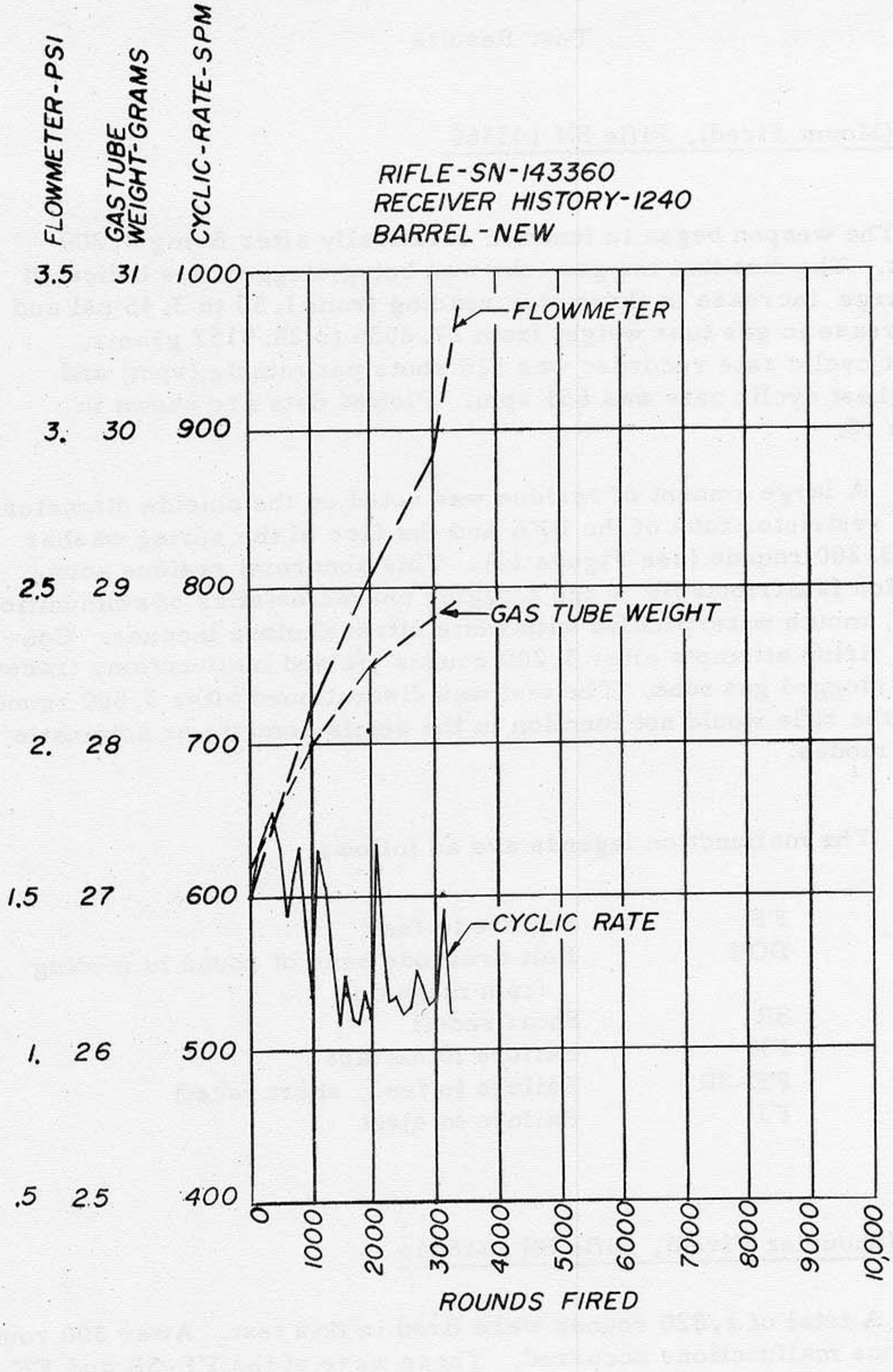


Figure 10. Test Data, Lot A, Mount Fired

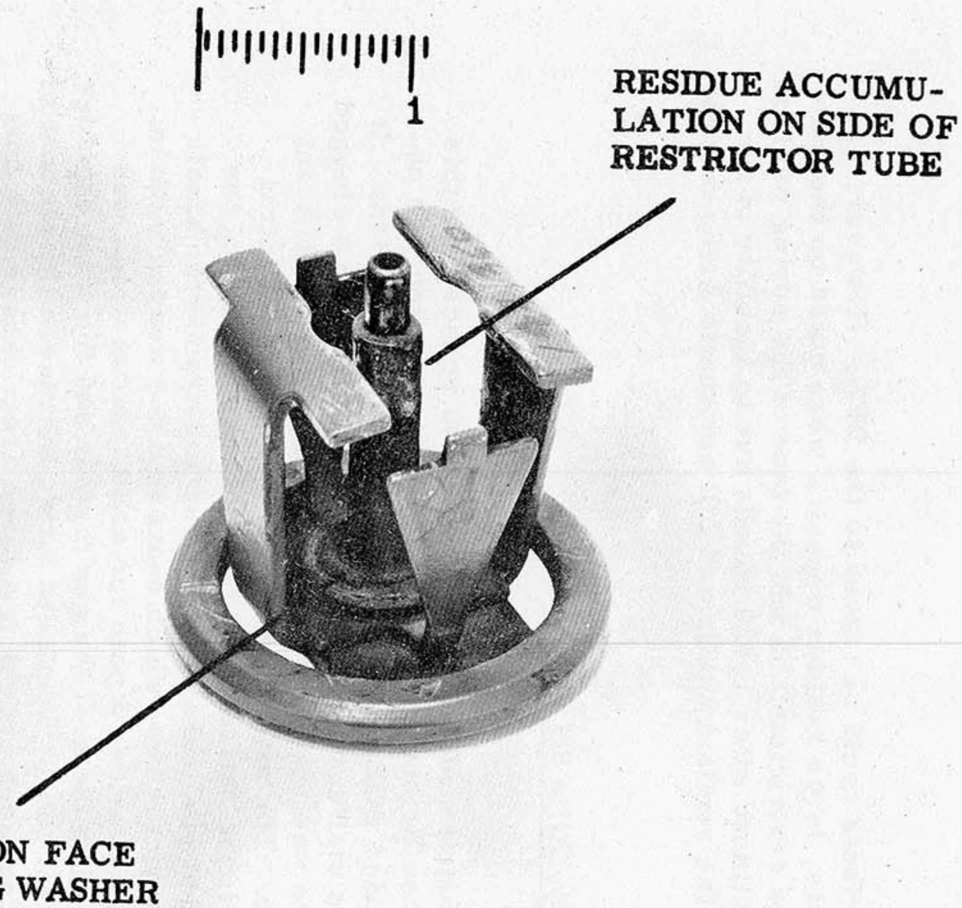


Figure 11. BFA, from Rifle SN 143360

and normal operation was restored up to 1,700 rounds. At this point the weapon could not be cycled in the automatic mode. Increase in flowmeter reading from 1.45 to 2.70 psi and increase in gas tube weight from 26.6696 to 28.1620 grams verified the existence of a clogged gas tube. Plotted data are shown in Figure 12. Lowest cyclic rate recorded was 562 spm and the highest cyclic rate recorded was 653 spm.

No adverse effects could be traced to the BFA. However, as noted in earlier tests, large residue deposits were noted on the outside diameter of the restrictor tube and the face of the spring washer. The test was discontinued after 1,820 rounds due to inability of the rifle to function in the semiautomatic and full automatic firing modes.

Lot B (Fixed Mount), Rifle SN 142276

The weapon functioned normally up to 8,640 rounds. At this point evidence of insufficient gas energy for bolt operation was observed. This included BOB, FX, and FF-SR type malfunctions. It was evident that the malfunctions could not be attributed to a clogged gas tube since there was no appreciable weight gain or significant flowmeter increase. The magazine was transposed to a control weapon and it functioned satisfactorily. Upon examination of the BFA it was found that gas leakage was occurring around the small diameter of the restrictor tube which seats into the weapon muzzle. Progressive leakage provided a path for solid residue which was deposited on the mating faces of the gun muzzle and the first shoulder on the BFA restrictor tube. Continued firing increased the amount of deposit on the mating faces providing a large area leakage path due to the buildup. This resulted in a progressively lower cyclic rate until 8,640 rounds were fired. At this point the energy loss was sufficient to induce rifle malfunctions. Replacement of the BFA after 8,640 rounds resulted in trouble-free operation of the system. Plotted data are shown in Figure 13. Highest cyclic rate recorded was 689 spm and the lowest cyclic rate was 516 spm.

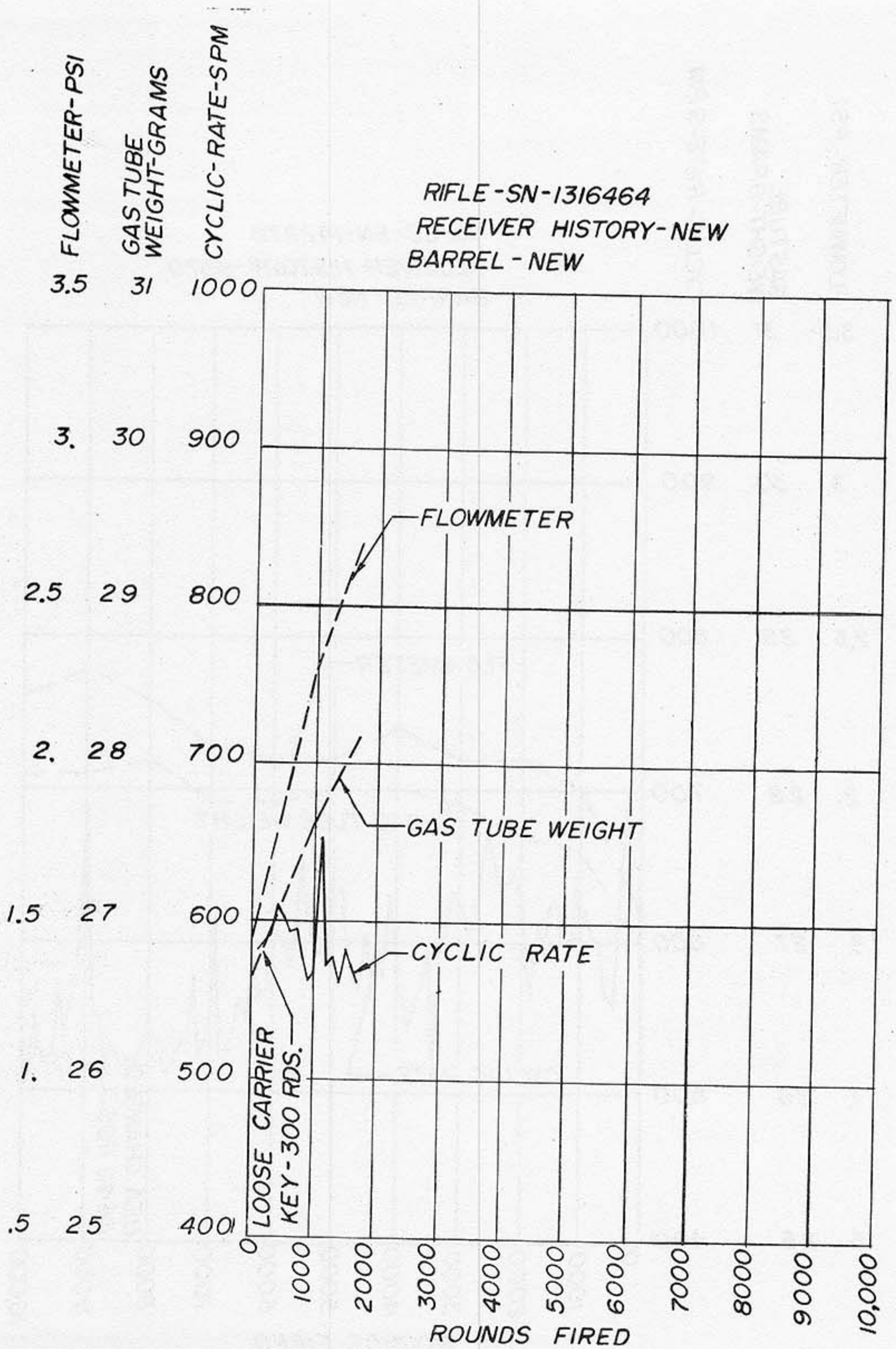


Figure 12. Test Data, Lot A, Shoulder Fired

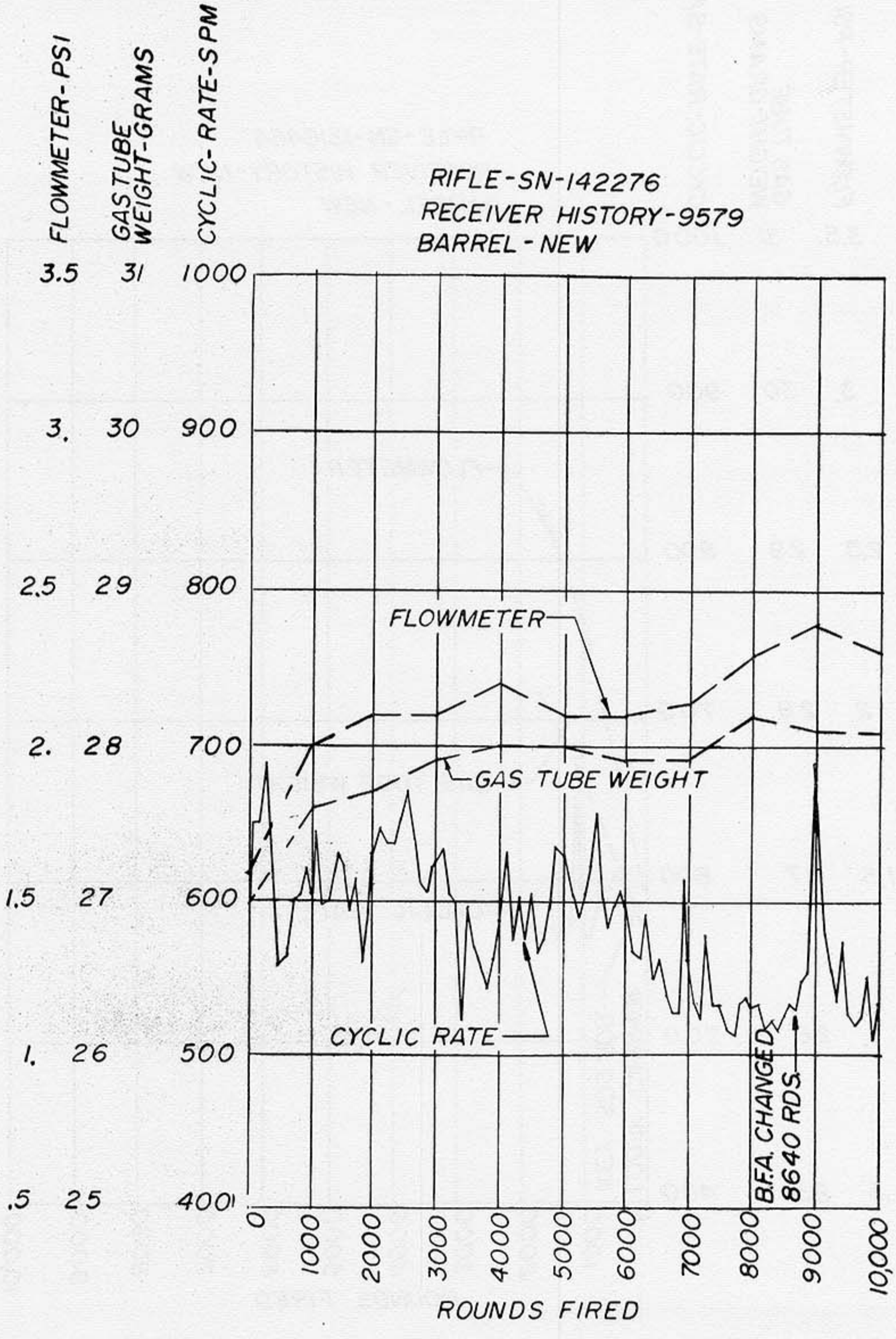


Figure 13. Test Data, Lot B, Mount Fired

Lot B (Shoulder Fired), Rifle SN 141307

A total of 10,000 rounds was fired in this test. Lowest cyclic rate recorded was 534 spm and the highest cyclic rate recorded was 683 spm. An increase in gas tube weight was experienced up to 2,000 rounds. After 2,000 rounds the tube weight decreased and remained level until completion of the test. There was also a steady rise in the flowmeter readings up to 5,000 rounds. This decreased gradually to 8,000 rounds. Plotted data are shown in Figure 14. No malfunctions occurred during these rises up to 7,800 rounds. At that point, FF and FF-SR malfunctions were experienced. Small increases in gas tube weight and flowmeter readings indicated that the energy loss was due to a leak from the BFA rather than a clogged gas tube. Large residue deposits were noticed on the restrictor tube and the spring washer. In addition, the BFA had become extremely loose. The BFA was replaced at 7,800 rounds and the test was concluded at 10,000 rounds.

Lot C (Mount Fired), Rifle SN 822138

A total of 10,000 rounds was fired in this test. Lowest cyclic rate recorded was 540 spm, and the highest cyclic rate recorded was 741 spm. No abnormal increases which could lead to malfunctions were noted in gas tube weight or flowmeter readings. Plotted data are shown in Figure 15. One misfire occurred at 7,000 rounds. Examination of the misfired round showed that it was caused by a faulty primer.

Lot C (Shoulder Fired), Rifle SN 601869

A total of 10,000 rounds was fired in this test. Lowest cyclic rate recorded was 548 spm and highest cyclic rate recorded was 719 spm. No abnormal increases which could lead to malfunctions were noted in gas tube weight. A slight increase in the flowmeter readings was noticeable after 4,000 rounds which accounts for a gradual decrease in cyclic rate. However, no malfunctions were encountered. Plotted data are shown in Figure 16. The test was concluded at 10,000 rounds.

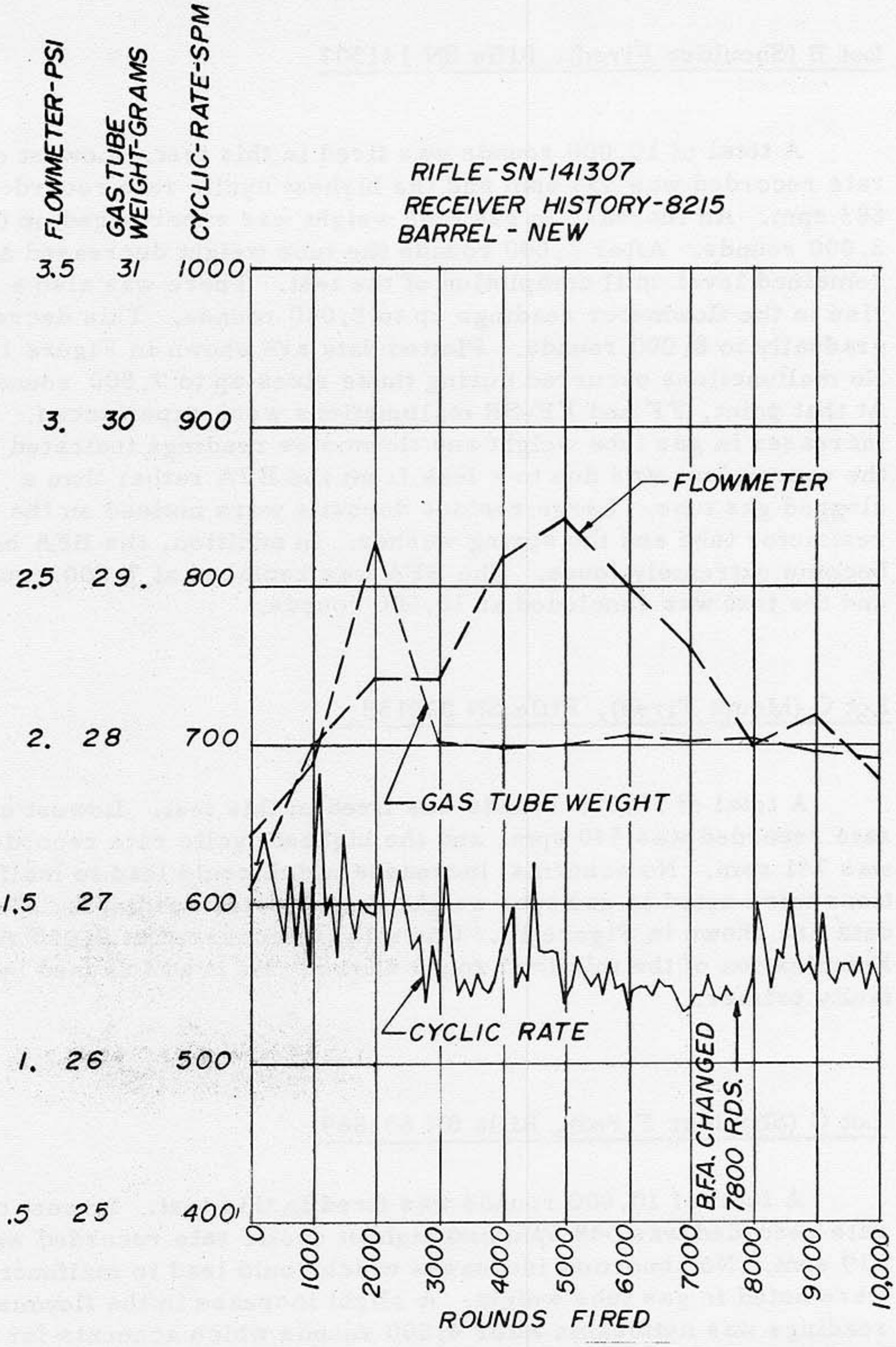


Figure 14. Test Data, Lot B, Shoulder Fired

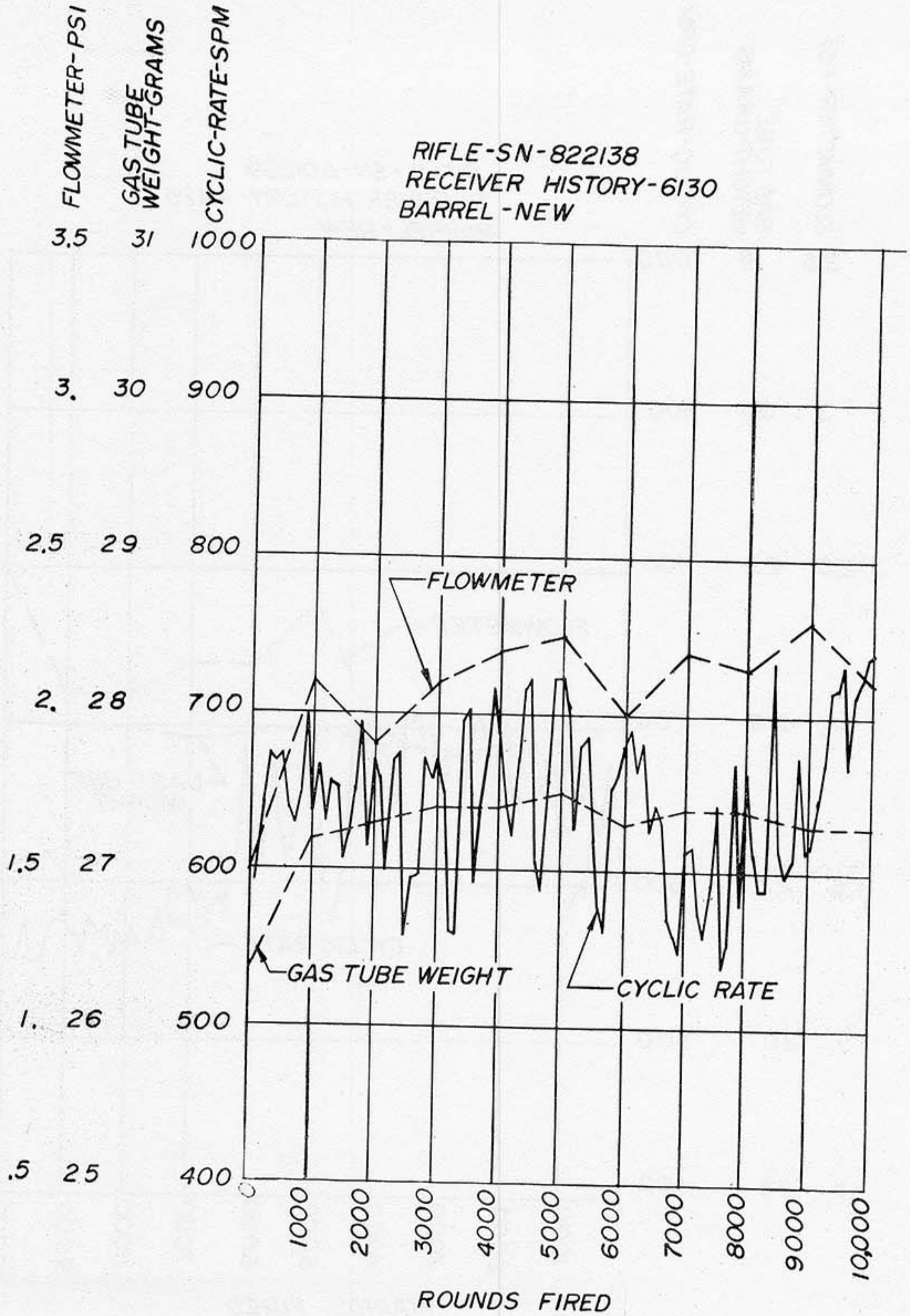


Figure 15. Test Data, Lot C, Mount Fired

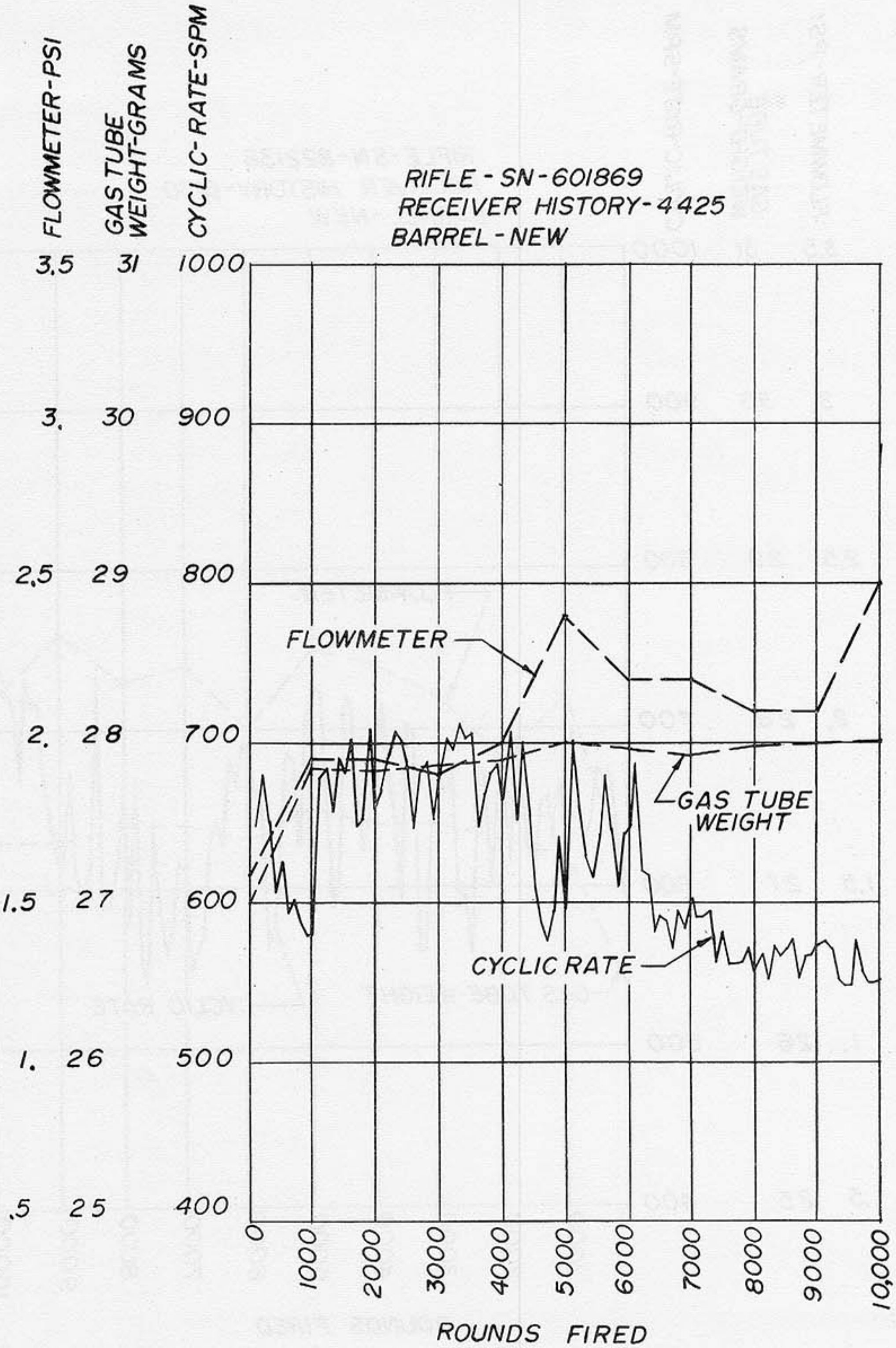


Figure 16. Test Data, Lot C, Shoulder Fired

Lot D (Mount Fired), Rifle SN 138831

A total of 10,000 rounds was fired in this test. Lowest cyclic rate recorded was 519 spm and the highest cyclic rate recorded was 786 spm. No abnormal increases which would lead to malfunctions were noted in gas tube weight or flowmeter readings. Plotted data are shown in Figure 17.

A steady decrease was noted in the cyclic rate after 4,000 rounds. This could not be attributed to a clogged gas tube since no abnormal increases could be noted in flowmeter readings or gas tube weight. Examination of the BFA disclosed that it had become extremely loose and a large amount of residue was deposited on the exterior of the restrictor tube and spring washer. This indicated an abnormal leakage path at the muzzle thus reducing energy level through the gas tube. The cyclic rate decreased steadily to 5,600 rounds where numerous malfunctions began to occur; i.e., BOB, FF, and FF-SR. After replacement with a new BFA at 5,600 rounds the system returned to normal and the test was completed at 10,000 rounds.

Two misfires occurred, one at 5,180 rounds and the other at 7,560 rounds. These were both caused by faulty primers.

Lot D (Shoulder Fired), Rifle SN 143678

A total of 10,000 rounds was fired in this test. Lowest cyclic rate recorded was 534 spm and the highest cyclic rate recorded was 719 spm. No abnormal increases which would lead to malfunction were noted in gas tube weight or flowmeter readings. Plotted data are shown in Figure 18.

A steady decrease in cyclic rate noted after 4,000 rounds was traced to gas leakage on the BFA. Examination disclosed that a large amount of residue had collected on the face of the restrictor tube which mates with the muzzle face of the rifle. Figure 19 is an enlarged view of the BFA from rifle SN 143678 showing the degree of deposit. Note that the gas paths are provided by clearances in the rifling groove diameter of the barrel. Clearly defined is the residue at each groove termination on the restrictor tube face.

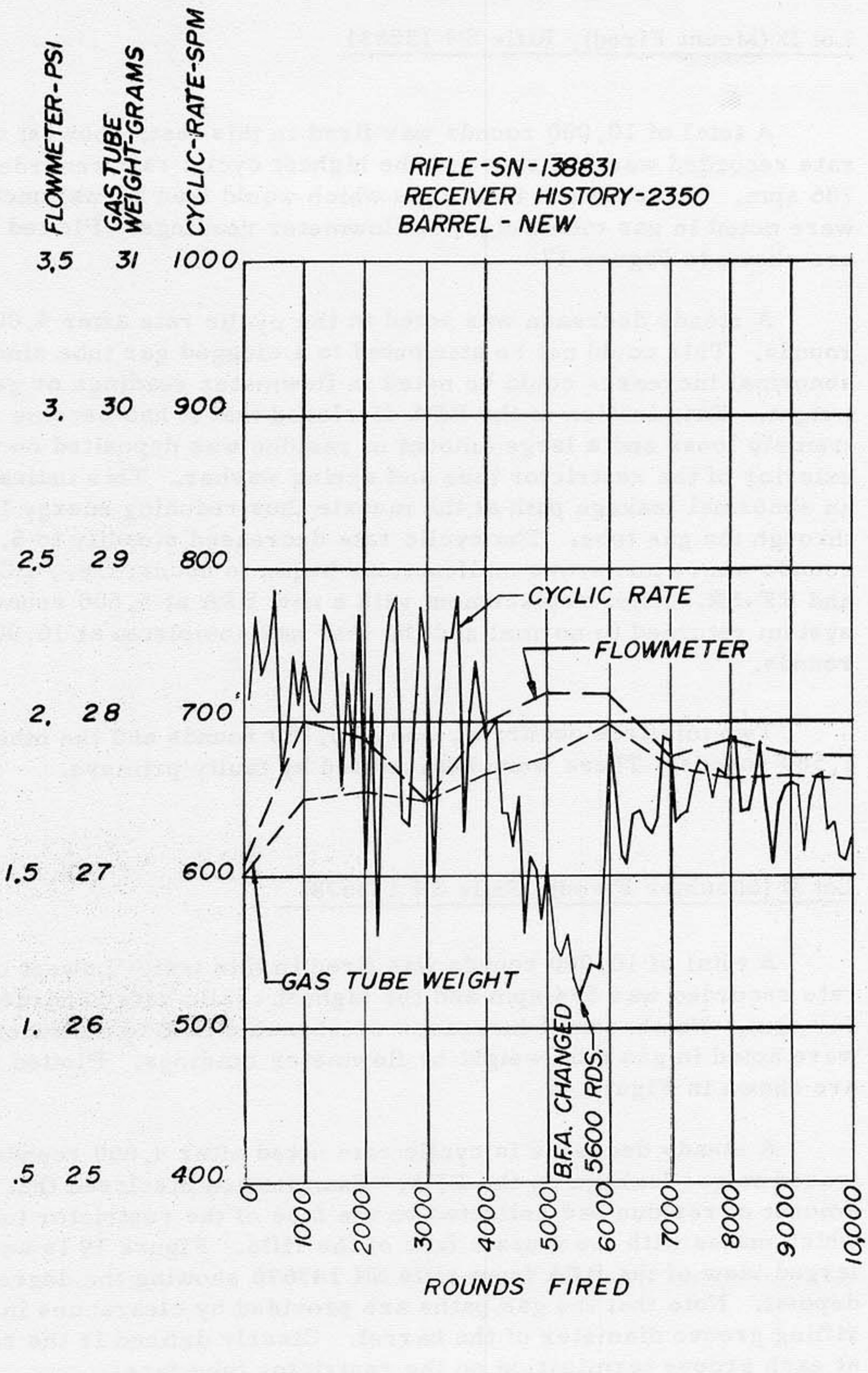


Figure 17. Test Data, Lot D, Mount Fired

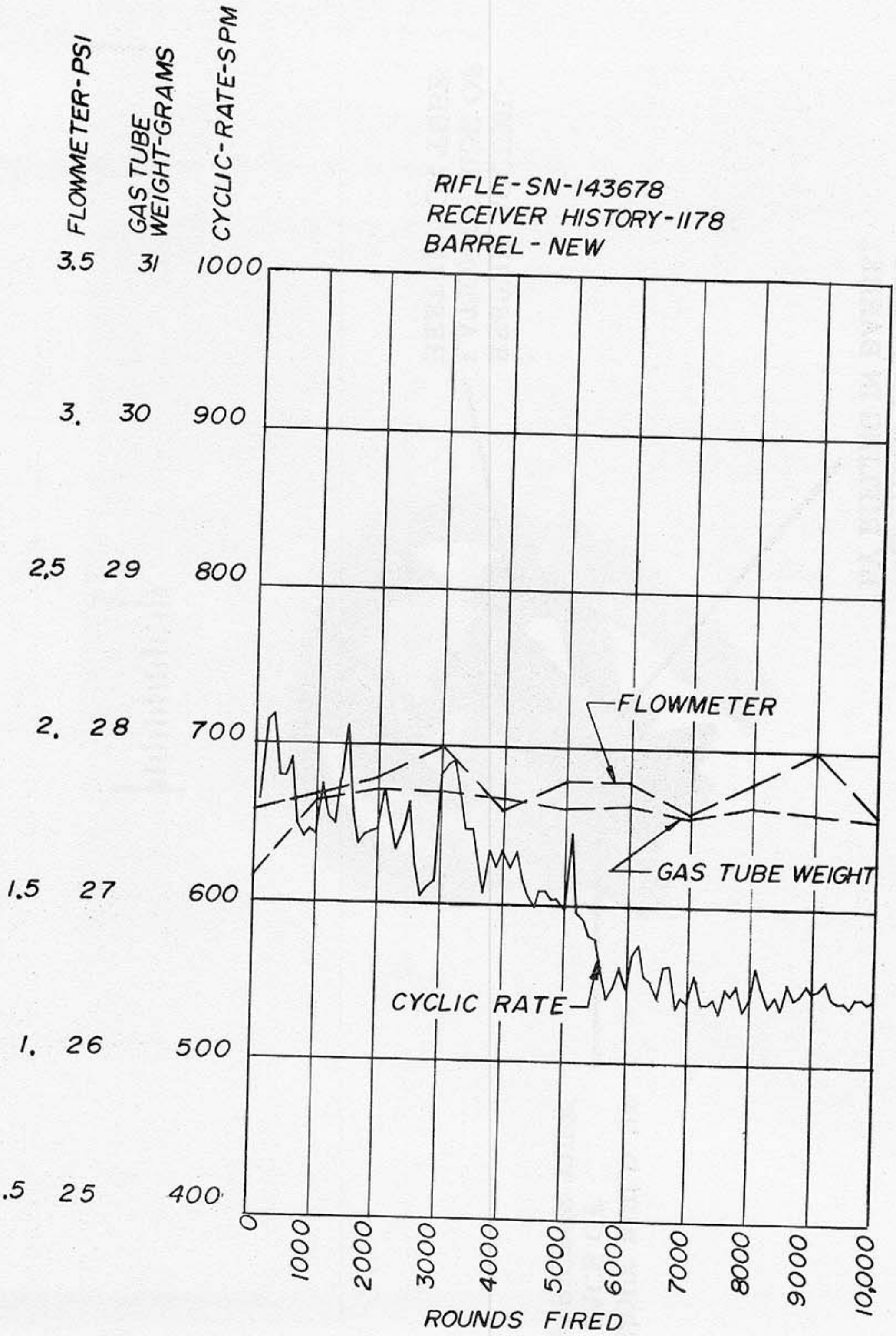


Figure 18. Test Data, Lot D, Shoulder Fired

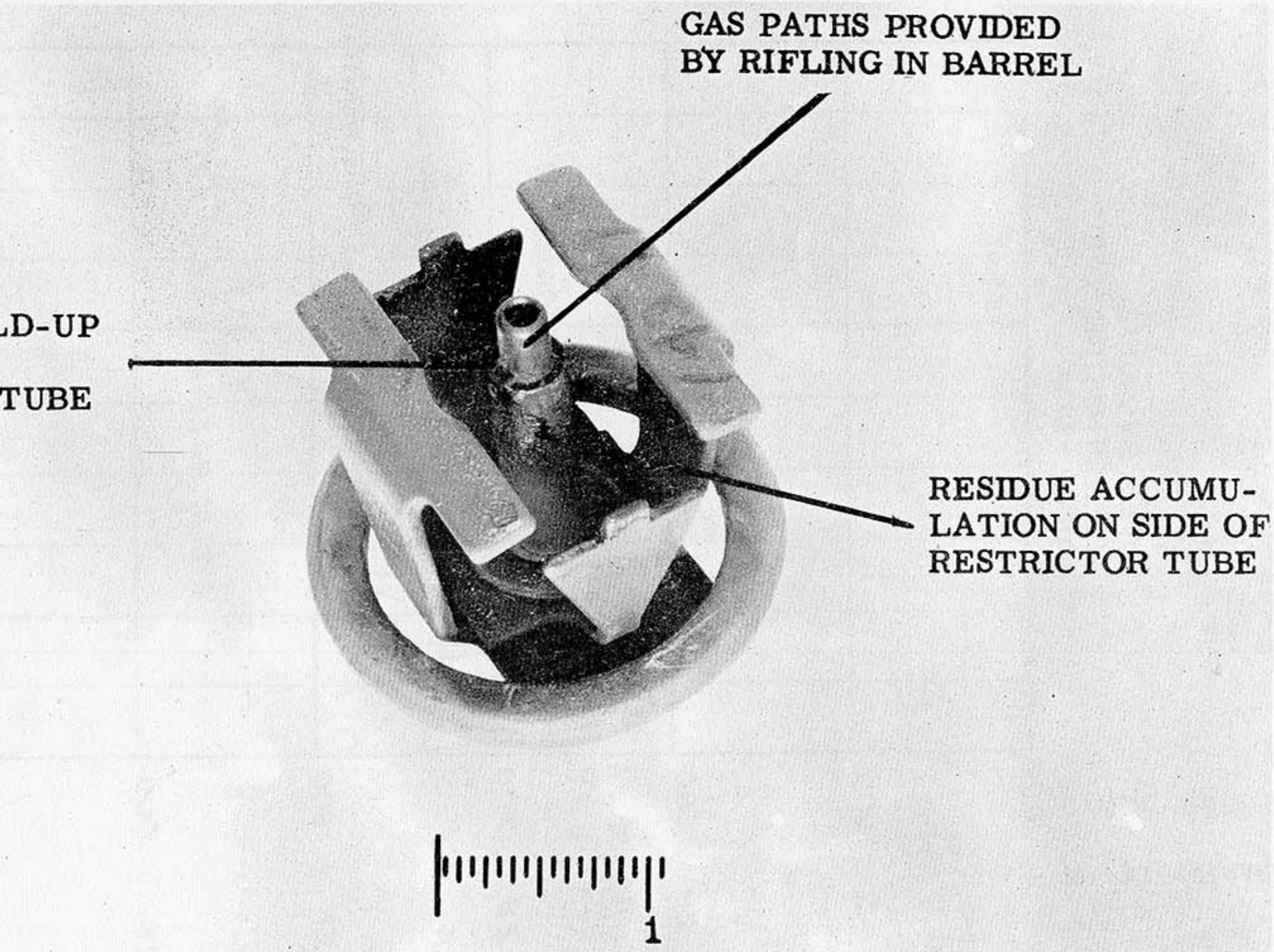


Figure 19. BFA from Rifle SN 143678

Residue buildup on the restrictor tube face ranged from 0.040 to 0.060 inch. Thus, as firing proceeded, the restrictor tube face became positioned progressively further from the muzzle face of the barrel. This allowed a progressive gas leakage with resultant loss of gas energy supplied through the gas tube. No malfunctions were encountered even at the low cyclic rate level. Testing was concluded at 10,000 rounds.

General Comments on Test Firings

1. No differences were noted in gun performance between mount and shoulder fired weapons for a given ammunition lot.

2. No malfunctions could be attributed to the modified test magazine.

3. Ammunition Lot A, mouth waterproofed with the white nitrocellulose lacquer caused gas tube fouling in both of the firing modes. Weapon stoppages resulted in both cases.

CONCLUSIONS

1. Primary cause of gas tube fouling in the 5.56 mm, M16A1 rifle when using 5.56 mm, M200 blank ammunition is the titanium present as the pigment in the white nitrocellulose lacquer applied to the rosette crimp on the round.

2. A violet colored nitrocellulose lacquer using an organic dye for the required coloration caused no gas tube fouling in the 10,000 round tests conducted in this study.

3. Significant amounts of lead sulfide and potassium carbonate were detected in the gas tube, but did not contribute to gas tube clogging when using violet colored nitrocellulose lacquer. Formation of both of these compounds may be associated with the potassium sulfate incorporated in the HPC 13 propellant.

RECOMMENDATIONS

It is recommendated that:

1. The use of the present TiO_2 pigmented lacquer be discontinued and that it be replaced by clear or organically dyed lacquer.

2. Studies be conducted to determine effect of potassium sulfate on the formation of fouling residue in weapon systems where this compound is present in the propellant.

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13. ABSTRACT

Chemical analyses of gas tube fouling residue obtained when firing production lots of 5.56 mm, M200 blank ammunition showed the presence of barium, potassium, titanium. antimony and lead. These were characterized as barium titanate, potassium carbonate, lead sulfide, and antimony metal. The major contributor was found to be barium titanate. The suspected source of the titanium was the white pigment used in the cartridge mouth waterproofing lacquer. Several 10,000-round fouling tests were conducted in order to establish the fouling characteristics of four different mouth waterproofing lacquers. Ammunition mouth waterproofed with white lacquer, pigmented with titanium dioxide, caused gas tube fouling resulting in weapon stoppages. Ammunition mouth waterproofed with clear, dyed and black pigmented nitrocellulose lacquer caused little or no gas tube fouling. The nitrocellulose lacquer containing an organic dye offers the required coloration and minimum fouling characteristic required in the M16A1 rifle.

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Blank ammunition						
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