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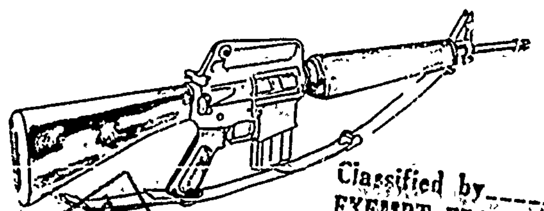
APPENDIX 4

REPORT OF THE M16 RIFLE REVIEW PANEL



1 JUNE 1968

AMMUNITION DEVELOPMENT PROGRAM

[redacted]

DEPARTMENT OF THE ARMY
OFFICE OF THE DEPUTY CHIEF OF STAFF
FOR RESEARCH, DEVELOPMENT, AND ACQUISITION
WASHINGTON, DC 20310

REPLY TO
ATTENTION OF

DAMA-WSW

1 FEB 1994

MEMORANDUM FOR THE RECORD

SUBJECT: Declassification Action - Report of the M16 Rifle Review Panel (C) dated 1 June 1968. [redacted]

1. The Report on the M16 Rifle Review Panel dated 1 June 1968 was prepared for the Office of the Chief of Staff of the Army, by the Office of the Director of Weapons System Analysis. The Ground Combat Systems Division, Office of the Director of Weapons Systems, Office of the Deputy Chief of Staff for Research, Development and Acquisition, is the successor to the originator of the report.

2. This office has completed a review of subject report and appendices 1 through 11 and has determined classification of Confidential is no longer needed. The report is now Unclassified. Selected extracts of the report are at Enclosure 1.

3. Notification of this declassification will be forwarded to all distribution addressees and a declassified copy will be forwarded to the Defense Technical Information Center, Cameron Station, for file.

1 Encl
as

WILLIAM O. COOMER
Colonel, GS
Chief, Ground Combat Systems
Division

[redacted]

APPENDIX 4

AMMUNITION DEVELOPMENT PROGRAM

1 June 1968

[redacted]

[redacted]

APPENDIX 4

AMMUNITION DEVELOPMENT PROGRAM

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Appendix 4

AMMUNITION DEVELOPMENT PROGRAM

A. Introduction

The development of the 5.56mm ammunition system started in 1957 and was essentially derived from the Remington caliber .222 cartridge.[1] In November 1957, the Armalite Division of the Fairchild Aircraft and Engineering Company invited Remington Arms Company, Inc., to cooperate in design and development of a cartridge for use in the Armalite AR15 rifle. The original work was done by Remington Arms in conjunction with Springfield Armory and eventually led to the commercial caliber .222 Remington Magnum. The caliber .222 Remington Magnum was modified and renamed the caliber .223 cartridge as a cooperative effort by Remington Arms Company, Inc., and Mr. E. H. Stoner of Armalite.[2]

The development of caliber .223 ammunition was initiated on ball cartridges, although small quantities of blank, grenade launching, and tracer cartridges were produced. Most of the ammunition produced by Remington until the middle of 1962 was produced commercially for the firm of Cooper-MacDonald (sales

1. Staff Paper, prepared by Remington Arms Company, Inc., undated, sub: Development of Caliber 5.56mm Ammunition.

2. Staff Paper, prepared by Remington Arms Company, Inc., 27 Mar 63, sub: Performance of the .223-AR15 System.

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Technical Coordinating Committee meeting of 10 December 1963,[26] at which a comparison of all tests done by the Army, Air Force, and Colt's Inc. was made, the committee agreed to adopt a modified lighter firing pin, which was used in the cam friction device and was recommended by Colt's as a solution to the problem. The committee also agreed to accept primer sensitivity criterion[27] of none-to-fire limit of 12 inch-ounces and an all-to-fire limit of 48 inch-ounces. The committee recommendation was forwarded through the Army Staff to the Office of the Secretary of Defense and approved 23 December 1963.[28] Thus, two system changes were initiated to correct the primer sensitivity specifications proposed by the joint study in which the Army could not concur.

The Commanding Officer, Frankford Arsenal,[29] suggested to the project manager that further consideration be given to modifying the M16 rifle in order to allow a wider range of primer sensitivity without an increase in the user's risk of either accidental firing or misfire. Rationale for this recommendation was based on

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26. Min, Technical Coordinating Committee Meeting, 10 Dec 63.

27. MIL-C-9963C, 27 September 1963.

28. Ltr, OSD to OSA, 23 Dec 63, sub: AR15 Rifle Ammunition.

29. Ltr, Frankford Arsenal, 31 Mar 65, sub: Primer Sensitivity Limits of 5.56mm Ammunition.

B. Cartridge Case

Initial Military Specifications

The initial military specifications for the 5.56mm cartridge case published by the U.S. Air Force, 24 January 1963,[3] were developed primarily from the commercial specifications prepared by Remington Arms Company, Inc. They provided for control of bullet extraction, water proofing, accuracy, propellant burning time, velocity, and chamber pressure; but did not provide for metallurgical control of cartridge case hardness, although the control of case hardness was mandatory for the 7.62mm North Atlantic Treaty Organization (NATO) cartridge. Military specifications required that no less than 35-pound pressure be necessary to extract the bullet from the cartridge case, and the minimum case wall thickness was specified.

Development

Testing conducted in March 1963 by the U.S. Air Force[4] identified cartridge case defects in the form of blown primers and debulleting (separation of the case from the bullet upon extraction of an unfired cartridge from the chamber). A review of these defects determined that they were the result of a

3. MIL-C-9963, U.S. Air Force, 24 Jan 63.

4. Msg, OOAMA Hill AFB to USAMUCOM (OOYEC 16298), 13 Mar 63.

difference in the chamber configurations of the production rifle and the test barrel. The ammunition had been produced and controlled in a gun chamber developed with Armalite representatives, but this gun chamber differed from that of the Colt's AR15 weapon produced and used in field-testing. The throat angle of the AR15 was steeper and the neck section shorter than in the Remington test weapon. It was also determined that this modification in the Colt chamber had been ordered by Mr. Stoner, the weapon designer, and that Remington and the Project Manager had never been advised of the change.[5/] The production rifle, with a shorter chamber, caused the bullet to be forced into the chamber so tightly that the bullet was actually scored when loaded into the chamber. This chamber incompatibility resulted in the development of higher chamber pressures, which, in turn, caused the blown primers, and also led to the initial requirement of in excess of 35 pounds to extract an unfired cartridge from the chamber. A modification to the chamber corrected this ammunition deficiency. The tests that led to the modification are cited in Appendix II. Remington Arms Company personnel have stated that their inability to acquire a production rifle during early

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5. Rpt, Remington Arms Company, Inc., 27 Mar 63, sub: Performance of the .223 AR15 System.

production (1962-63) was a primary cause of the incompatibility of the rifle and ammunition.

The Twelfth Memorandum Report on the AR15 rifle-ammunition system, prepared by Frankford Arsenal in October 1964,[6] identified the hardness of cartridge cases as a significant factor in functioning and in the occurrence of certain defects that sometimes are observed in the firing of service weapons. For example, too hard or soft case will result in poor obturation. This had been clearly established with 7.62mm ammunition, where extensive engineering tests had disclosed a relationship between case hardness and cartridge performance. No such information was available at that time for 5.56mm ammunition. Frankford Arsenal, anticipating that problems related to cartridge case hardness would arise, initiated action in September 1964 to develop data that would provide a background and basis of comparison for case hardness measurements. The Twelfth Memorandum Report described test procedures used to develop data contained in the report and recommended that these procedures be utilized for making hardness measurements on 5.56mm cartridge cases whenever such measurements were required.

No action to establish metallurgical controls over production was taken, although it was discussed at several Joint Services

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6. Frankford Arsenal Twelfth Memo Rpt, Oct 64, sub: Measurement of Cartridge Case Hardness Patterns.

AR15/M16/M16A1 Technical Coordinating Committee (Technical Coordinating Committee) meetings.[7] The Project Manager, Rifles, informed the Commanding General, United States Army Munitions Command (USAMUCOM), on 2 May 1966, that there had been no apparent need for such controls in view of the absence of cartridge case ruptures with 5.56mm ammunition manufactured to specifications.[8] Although there had been reports of cartridge case ruptures, the Project Manager thought that they were caused by factors such as water in the bore rather than by a deficiency in the cartridge case. This opinion was verified by a message from the 1st Logistics Command,[9] which reported that an investigation in Vietnam had disclosed that no ruptured cartridge cases had been experienced with the M16E1 rifle and that the real problem lay in freezing of the case in the chamber, a failure caused by lack of cleaning. It is interesting to note that a test conducted by Frankford Arsenal during April and May 1966,[10] designed to simulate an extreme climatic and usage condition that could adversely

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7. Min, Technical Coordinating Meetings, 25-26 Jun 63, 24-25 Mar 64, and 12-13 Jan 66.

8. Ltr, Project Manager to CG, USAMUCOM, 2 May 66, sub: Quality Assurance Provisions for 5.56mm Cartridges.

9. Msg, 1st Logistics Command (AVL-GM 00453), 21 Jan 66, sub: Ruptured Cartridge Cases, XM16E1 Rifle.

10. Ltr, Frankford Arsenal to CG, USAMUCOM, 26 May 66, sub: Difficult Extraction in 5.56mm XM16E1 Rifle.

affect cartridge case extraction, failed to identify any noticeable variations in cartridge cases or primers. Frankford Arsenal consequently advised the Commanding General, USAMUCOM, that no changes to 5.56mm cartridge designs or requirements appeared necessary at that time. The Project Manager pointed out to the Commanding General, USAMUCOM, on 2 May 1966, that while there was reason to believe that the metallurgical controls in practice were adequate, these controls were largely the result of voluntary efforts on the part of the producers; and that there was no guarantee of future compliance, particularly if new producers should become involved. With this in mind, the Project Manager requested recommendations from the Commanding General, USAMUCOM, on the minimum metallurgical requirements necessary to insure continued trouble-free performance of 5.56mm ammunition in M16 and M16A1 rifles.[11] He also asked that a survey be conducted to determine the upper and lower limits of the case sidewall hardness gradient common to all lots of ammunition manufactured to the current specifications. Frankford Arsenal started tests on 15 September 1966 to acquire additional data on case sidewall hardness and metallic grain size.

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11. Ltr, Project Manager to CG, USAMUCOM, 2 May 66, sub: Quality Assurance Provisions for 5.56mm Cartridges.

The Project Manager stated to the Commanding General, USAMUCOM, on 13 July 1967,[12] the general concept that unnecessary controls over the ammunition producer must be avoided and that he had hertofore not found sufficient grounds to justify mandatory controls on the hardness or grain configuration of 5.56mm cases. However, as a result of reported difficulties in case extraction with Federal Cartridge Company 5.56mm ammunition, experienced by the Marine Corps in Vietnam and by the United States Combat Developments Command Experimentation Command (USACDCEC), Fort Ord, California, the Project Manager suggested that the requirement now be re-examined on the basis that in those weapons having marginal degrees of chamber deterioration, it was possible that the cartridge case properties might be critical to acceptable functioning.[13] The Frankford Arsenal examination of the Federal cartridges determined that the sidewalls were softer on these cartridges than on known patterns of earlier Federal lots. Federal Cartridge Company was requested to either adopt the new Frankford Arsenal proposed hardness pattern or to revert to its own original pattern. Federal Cartridge Company, with no

12. Ltr, Project Manager to CG, USAMUCOM, 13 Jul 67, sub: Metallurgical Controls for 5.56mm Cartridge Cases.

13. Ltr, Project Manager to CO, Frankford Arsenal, 6 Jun 67, sub: Reported Difficult Case-Extraction With Federal Cartridge Co. 5.56mm Ammunition.

explanation for its change, agreed to revert to its original pattern of hardness, effective with October 1967 production. Federal cartridges have been periodically tested since October and no further evidence of soft cases have been reported.

Frankford Arsenal analyzed all data pertaining to cartridge case metallurgical data over an extended period of time and advised the Commanding General, USAMUCOM, on 24 August 1967 that in order

> ...To minimize the burden on industry and to assure compatibility of recommended hardness patterns with production processes, Frankford Arsenal plans to publish its recommended hardness patterns as a guide to industry. The GOCO plants (Twin Cities and Lake City Army Ammunition Plants) will be required to make the necessary process adjustments and to commence hardness testing of all subsequent ammunition lots. The results of these tests will be studied by Frankford Arsenal and at the end of 6 months, adherence to an established hardness will be made mandatory. In the interim, producers will be aided and guided by Frankford Arsenal in effecting necessary process modifications to meet the recommended hardness profile.[14/]

Additional testing is now being conducted by Frankford Arsenal to determine the effect hard and soft cases have on extraction from Vietnam-conditioned weapon chambers. The report of this test should be available about 14 June 1968.

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14. Ltr, Frankford Arsenal to CG, USAMUCOM, 24 Aug 67, sub: Quality Assurance Provisions for 5.56mm Cartridges.

C. Primers

Primer Sensitivity

Initial Specifications. Ammunition specifications established by the Air Force on 24 January 1963 provided for quality control against cocked, inverted, loose, and nicked primers. The specifications further provided for inspection and test of waterproofing and the crimp of primers. However, the specifications did not provide for specific limitations on primer sensitivity for 5.56mm ammunition.[15]

Development. At the first meeting of the Technical Coordinating Committee on 26 March 1963,[16] the Air Force representatives submitted a list of reported ammunition deficiencies, which included "high primers" and "primers too sensitive". It was agreed that Frankford Arsenal would investigate the matter and recommend corrective action.

One of the malfunctions reported by the Air Force was the premature firing of cartridges that occurred upon initial charging of the M16 rifle with a cartridge from the magazine, or upon single-loading of a cartridge directly into the chamber, or when two rounds were fired at one trigger pull during semiautomatic fire.

15. MIL-C-9963 (USAF), 24 Jan 63.

16. Min, Technical Coordinating Committee, 26 Mar 63.

This malfunction was attributed to "high" or protruding primers, although the tests did not confirm this theory.

However, analysis indicates that if high primers caused the premature firing, the firing should have occurred upon impact of the bolt face with the protruding primer. At this point in the weapon cycle, the bolt head would not have been rotated to the locked position by action of the cam pin and carrier. Had firing occurred with the bolt in the unlocked position, it would have resulted in a blow back and would not have been undetected. No such disruptions were reported. Since premature firing occurred after bolt-locking, it must have coincided in time with the impact of the bolt carrier against the bolt head. At the instant of impact, the "free floating" firing pin is moving at the velocity of the bolt carrier. The kinetic energy of the pin must be dissipated by such frictional forces as it encounters in the forward movement, and, finally, in impact of the firing pin tip with the primer of the chambered cartridge. This premise was confirmed by the visible indentation appearing on cartridges which were chambered by the mechanism and extracted unfired.

Frankford Arsenal identified test procedures for measuring firing pin energy and recommended limits for primer sensitivity.[17]

17. Frankford Arsenal First Memo Rpt on AR15 Rifle-Ammunition System, 4 Apr 63.

These procedures were designed to measure the indent depth of the firing pin upon the primer cup. Tests are conducted by dropping steel balls of known weights from various measured heights upon a device containing a firing pin and a primed case assembly. Using this procedure and measuring the energy in inch-ounces, Frankford Arsenal was able to develop test data upon which to recommend a lower limit of "none-to-fire" and an upper limit of "all-to-fire". It recommended that primers be manufactured so that the none-to-fire limit should be not less than 16 inch-ounces of energy and the all-to-fire limit should be not greater than 64 inch-ounces of energy.

A meeting of the Technical Coordinating Committee was held at Hill Air Force Base 5 June 1963, at which time a difference of opinion arose as to primer sensitivity. The purpose of the meeting was to establish procedures for transfer of the Air Force technical data to Frankford Arsenal for use in the FY 1964 procurement and to insure that there would be no unnecessary duplication of effort in completing the Army technical data package. The Air Force explained at the meeting that it could not release technical data to the Army earlier than 29 May 1963 because it was necessary to withhold data while the Air Force purchase was processed through preprocurement channels.[18/] These data became available to the Army 29 May 1963.

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18. Min, Technical Coordination Committee, 5 Jun 63.

As a result of the 5 June 1963 meeting, the Army Project Manager directed that Frankford Arsenal and Hill Air Force Base take joint action to resolve differences in firing pin energy and primer sensitivity. This joint action included test firing at Lackland Air Force Base during the week of 22 July 1963.[19] Frankford Arsenal presented the results of the joint study to the Technical Coordinating Committee on 13-14 August.[20] The committee agreed to a none-to-fire limit of 12 inch-ounces and an all-to-fire limit of 48 inch-ounces, with an understanding that if tighter limits could be met, consideration would be given to tightening these limits at a later time. The Army Staff representative (from the Assistant Chief of Staff for Force Development) withheld concurrence on these limits pending further evaluation by the Army Staff. On 17 September 1963, the Army Staff informed the Project Manager that the primer sensitivity limits contained in the specifications could not be accepted because of the risk of inadvertent fire.[21] The Commanding General, USAMC, stated that the only practical solution was to modify the weapon. As a result of the Army Staff

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19. Investigation of Firing Pin Energy and Primer Sensitivity on the AR15 Rifle-Ammunition Systems, Frankford Arsenal, 1963.

20. Min, Technical Coordinating Committee Meeting, AR15 Rifle-Ammunition, 13-14 Aug 63.

21. Historical Summary of 5.56mm Cartridge Program From Inception Until 30 September 1963, Frankford Arsenal.

action, USAMUCOM was directed to suspend procurement of one million rounds of 5.56mm M193 ball cartridges for the Army[22] until the problem was resolved. Solicitation of bids for the balance of FY 1964 Army and FY 1964 U.S. Air Force orders were held in abeyance.

In the meantime, on 3 September 1963, the Ammunition Procurement and Supply Agency (APSA) was advised that Olin-Mathieson and Remington, the only two eligible bidders for production of 5.56mm ammunition, had both taken exception to the technical data package.[23] Both companies recommended changes to the primer sensitivity requirements. A meeting was held at Frankford Arsenal on 5 September 1963 with representatives from USAMUCOM, APSA, and the two producers to resolve these disagreements. As a result of this meeting,[24] Frankford Arsenal developed supplementary changes in primer sensitivity requirements in the technical data package. The requirement was established at a minimum of 12 inch-ounces and a maximum of 48 inch-ounces. As previously stated, however, on 17 September 1963, procurement would be suspended until the overall problem could be resolved.

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22. Msg, CG, USAMUCOM to CG, USAWECOM, 18 Sep 63.

23. DF, Chief, National Engineer Branch, Frankford Arsenal, to Chief, Ammunition Engineering Branch, Frankford A.senal, 3 Sep 63.

24. Msg, CO, Frankford Arsenal, to CO, APSA, 6 Sep 63.

Remington Arms Company, on the basis of the information contained in the Frankford Arsenal First Memo Report, undertook the design of a new primer that would be less sensitive and less susceptible to the inadvertent energy delivered to the primer by the free-floating firing pin of the AR15 rifle. Since it is difficult to adjust primer sensitivity by chemical changes, Remington elected to accomplish the "desensitization" by increasing the mechanical strength of the brass primer cup, which must be indented by the firing pin to cause ignition.

As a result of the decision of the Commanding General, USAMC, to modify the rifle, Colt's Inc. developed two designs, a linear spring device and a cam pin friction device, to reduce firing pin energy on bolt closure. These two designs were tested by the Air Force at the U.S. Air Force Marksmanship School.[25] The initial conclusions of this test were that both devices effectively reduced firing pin energy; however, the Air Force recommended against their adoption because they increased the probability of a misfire (although no failures to fire were identified in the test results), added to the cost of the weapon, and adversely affected its reliability. Army tests of these devices indicated that the linear spring friction device was a satisfactory solution; however, at the

25. USAF Marksmanship School Operational Suitability Test (Project 296-63), 6 Dec 63.

Technical Coordinating Committee meeting of 10 December 1963,[26] at which a comparison of all tests done by the Army, Air Force, and Colt's Inc. was made, the committee agreed to adopt a modified lighter firing pin, which was used in the cam friction device and was recommended by Colt's as a solution to the problem. The committee also agreed to accept primer sensitivity criterion[27] of none-to-fire limit of 12 inch-ounces and an all-to-fire limit of 48 inch-ounces. The committee recommendation was forwarded through the Army Staff to the Office of the Secretary of Defense and approved 23 December 1963.[28] Thus, two system changes were initiated to correct the primer sensitivity specifications proposed by the joint study in which the Army could not concur.

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26. Min, Technical Coordinating Committee Meeting, 10 Dec 63.

27. MIL-C-9963C, 27 September 1963.

28. Ltr, OSD to OSA, 23 Dec 63, sub: AR15 Rifle Ammunition.

29. Ltr, Frankford Arsenal, 31 Mar 65, sub: Primer Sensitivity Limits of 5.56mm Ammunition.

production experience with 5.56mm M193 ball ammunition which indicated that specified primer sensitivity limits were difficult to meet. There had been delays in production and deliveries attributable in part to the difficulty of primer manufacture within the prescribed limits. Manufacturers had contended that any appreciable acceleration in production schedules would aggravate this problem. Frankford Arsenal again stated its position, recommending weapon modification.[30]

The Technical Coordinating Committee reviewed the propriety of the primer sensitivity limits on 3 June 1965.[31] Data on about 400 primer lots produced in accordance with the adopted specifications indicated that production difficulty had not been so great as had been predicted by private industry or by Frankford Arsenal. The primer sensitivity limits were about as tight as possible for mass production. A rejection rate of about 3 to 5 percent (depending on the producer) for primer production was indicated, but the rejection rate was not considered excessive for a relatively inexpensive component. The committee noted that no problems with either inadvertent firing or misfire had been experienced or

30. Frankford Arsenal Fourteenth Memo Rpt on AR15 Rifle-Ammunition System - Study of Current Primer Sensitivity for 5.56mm Ammunition, Jun 65.

31. Min, Technical Coordinating Committee Meeting, 3 Jun 65.

reported. The committee did not make any recommendations to change the primer sensitivity limits, but did note that any future weapon designs in 5.56mm caliber must accommodate these limits.

A report by Headquarters, United States Army Combat Developments Command Experimentation Command (USACDCEC), of the field experimentation phase of the Small Arms Weapons System (SAWS) Study, 10 May 1966,[32] identified low primer sensitivity in 5.56mm ammunition as one of the major causes of 5.56mm weapons malfunctions. Analysis by USACDCEC of data accumulated during the experiement indicates that in 1,261,215 rounds fired by the 5.56mm weapons, there were no instances of cartridges firing when the bolt was closed without pulling the trigger and no cases where the primer indentations of misfire cartridges were sufficiently shallow to have caused misfires. Misfires were not due to high primer sensitivity but to low primer sensitivity. They occurred in all five models of 5.56mm weapons being tested. Some of the misfires with the Stoner machine gun were attributed to a lack of sufficient recoil power. The four weapons other than the Stoner machine gun had 829 misfires in 1,008,629 rounds fired, or one per 1,217 rounds.

The analysis of results of SAWS Engineering and Service Tests conducted by the U.S. Army Test and Evaluation Command determined

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32. Report, HQ USACDCEC, Small Arms Weapons Systems (SAWS) Field Experimentation, Part One: Main Text, 10 May 66.

that primer sensitivity of the 5.56mm cartridge was an area requiring further investigation, since failure to fire was the most frequent malfunction with all 5.56mm weapons.[33]

Primer Composition

Initial Specifications. Ammunition specifications established by the Air Force 24 January 1963 did not restrict the chemical composition of primers to be used in 5.56mm ammunition.

Development Efforts. Colt's Inc., first experienced difficulty in 1963 in complying with the 6,000-round endurance test for the Air Force contract.[34] Specifically, the problem was defined by Colt's as an excessive accumulation of fouling on the bolt assembly. This fouling resulted in sluggish operation, which in turn, lead to failures to feed and eject. Frankford Arsenal was assigned the task of investigating the problem and determining to what extent the trouble was attributable to the ammunition used. In the course of the investigation, it was determined that these rifle lots which failed the endurance test were those firing Remington ammunition and using a Remington 72M Primer, which contains lead styphrate, barium nitrate, tetracene, antimony sulfide, and calcium silicide. Those

33. Report, HQ, USATECOM, Jan 66, sub: Analysis of Results of SAWS Engineering and Service Tests.

34. Frankford Arsenal Eighth Memo Rpt, 10 Dec 63, on AR15 Rifle-Ammunition System.

rifle lots that passed the endurance test had fired ammunition using a Remington 92 Primer, which differed from the 72M Primer in that it did not contain antimony sulfide and calcium silicide. In view of the possibility that the primer might have contributed to the excessive fouling problem, and until standardization of a primer-propellant combination could be accomplished, Frankford Arsenal recommended that a satisfactory discriminative fouling test be required as a criterion for 5.56mm cartridge acceptance. An approved change[35/] required that a 1,000-round fouling test be successfully conducted on each pre-production lot of ammunition and on any subsequent change in primer ingredients by the producer as a condition of acceptance. This change was incorporated into the technical data package for the fiscal year 1965 procurement program.

At the 3-4 June 1965 Technical Coordinating Committee Meeting,[36/] the Colt's Inc. representative reported that ammunition recently provided for the endurance test was causing more fouling than the ammunition previously used. The Project Manager directed Frankford Arsenal to conduct a primer chemical analysis to determine whether a producer had made an unauthorized change in primers.

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35. Min, Technical Coordinating Committee, 24-25 Mar 64.

36. Min, Technical Coordinating Committee, 3-4 Jun 65.

Frankford Arsenal reported that its analysis had revealed no change in primer composition and that the primers were acceptable.[37]

Further analysis of the chemical composition of primers by Frankford Arsenal resulted in a change in the military specification on 8 February 1966 to eliminate calcium silicide as an acceptable compound because it was a contributor to excessive fouling. In an attempt to further isolate the cause of fouling, the fouling test was augmented in December 1966 by a monthly fouling test at each plan manufacturing 5.56mm cartridges.[38] The test consisted of 1,000 rounds of each type of cartridge (ball and tracer) for each propellant loaded during the month. The results of these tests indicated that the cause for failure of ammunition lots was something other than ammunition. The Frankford Arsenal Progress Report concluded that:[39]

> The residue accumulating in the working assembly of the 5.56mm rifle is a complex composite of the metal oxide contaminants from the bullet; organic and metal oxide contaminants from the remainder of the round; and the breakdown of the weapon lubricant.

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37. Min, Technical Coordinating Committee, 8 Feb 66.

38. Msg SMUFA103000 CG USAMUCOM to CO, Frankford Arsenal, 12 Dec 66.

39. Frankford Arsenal Progress Rpt of 5.56mm Gun Fouling for Period 1 Apr to 30 Jun 67.

D. Bullet Design

Initial Specifications

The initial military specification for the cartridge, 5.56mm (5.64mm by Air Force designation)[40] stated that the cartridge would comply with the requirements specified on drawing 62C33759.

Development

Bullets of several different shapes had been made by various manufacturers for use in early commercial ammunition for the AR15 rifle. The projectile originally designed for the AR15 was a 55-grain, caliber .223 Remington bullet, with a 9° boattail and a short tangent ogive nose. There had been some question regarding variations in shape, especially as regards bluntness of point, among individual specimens of bullets.

Frankford Arsenal conducted an investigation of bullet configuration in 1963 in order to determine the best design for achieving aerodynamic stability with maximum lethality.[41] It tested the two types of bullets that were then available. The Type A bullets were taken from cartridges manufactured by the Remington Arms Company under government contracts between

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40. Mil-C-9963(USAF), 24 Jan 63.

41. Frankford Arsenal Third Memo Rpt on AR15 Rifle-Ammunition System, 18 Jun 63.

September 1962 and April 1963. The Type B bullets were from a sample provided to Frankford Arsenal by the U.S. Air Force. The Air Force had procured the bullets as separate components (not cartridges) from the firm of Sierra Bullets.

Measurements of the two types of bullets showed marked characteristic differences in their configurations. The ogival curve of the Type A bullets is approximated by a tangent arc of 5.5-caliber radius, whereas the ogival curve of the Type B bullets was approximated by an arc of about 7-caliber radius. The overall length of the Type A bullets was about 3.28 calibers, whereas the length of Type B bullets was about 3.54 calibers.[42] The angle of the boattail was the same for each, but the axial length of the boattail section was approximately .43-caliber for the Type A bullets and approximately .49-caliber for Type B bullets. The Type A bullets generally had blunter points than Type B bullets, which were slightly longer.

During the course of the Frankford Arsenal investigation, particular questions concerning stability and terminal effects arose, of which Frankford Arsenal noted:

> Stability. The results of accuracy firing . . . lead to the qualitative judgment that the stability

42. Example: A Type A bullet of 3.28 calibers in length is one whose length is 3.28 times the diameter of the Type A bullet.

factor of Type B bullets is less than that of Type A bullets, other relevant factors being equal. This also might be expected, since the rather longer ogive and boattail suggest a less favorable ratio of axial to transverse moments of inertia. Perhaps the overturning moment coefficient is also less favorable in consequence of these differences. Although it has been established that the 12-inch twist of rifling is adequate for stability of Type A bullets under all anticipated conditions of use, direct evidence is not known to be available on this point for Type B bullets.

Terminal Effects. Although it seems likely that most terminal effects of Type B bullets would be similar to those of Type A bullets at the same impact velocities, this could not safely be predicted without some evidence. Some terminal effects, notably wounding, cannot be so accurately predicted as are exterior-ballistic phenomena, or at least not without some esoteric knowledge of wound ballistics.

After its investigation, Frankford Arsenal concluded:

1. The Type B bullets evaluated in this test have significantly better exterior-ballistic properties than have the Type A bullets.

2. The use of bullets having more favorable aerodynamic shape (such as Type B instead of Type A) would allow a reduction of 50 fps in muzzle velocity, thereby reducing the probability of interior-ballistic problems which might arise in large-scale loading of .223 ammunition, and still provide higher impact velocities at 100 yards and at all greater ranges.

3. An assessment should be made of the aerodynamic stability and the lethality of Type B bullets when fired from barrels of 12-inch twist under all anticipated conditions of use.[43]

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43. Frankford Arsenal Third Memo Rpt on AR15 Rifle-Ammunition System, 18 Jun 63.

The report was presented by the Frankford Arsenal representative to the Technical Coordinating Committee 25-26 June 1963.[44] At this same meeting, the Ballistics Research Laboratories (BRL) representative reported on the progress of the BRL study of the stability and lethality of the Type A bullet design in 1:12-inch and 1:14 inch twist barrels. The Project Manager asked the BRL representative for an expansion of the study, to include similar experiments with the Type B bullet.

There is little available documented information on this matter for a six-month period following the meeting. It is the recollection of personnel associated with the program at that time, that the studies of stability and lethality for the Type B (Sierra) bullet configuration proceeded on a routine basis.[45] By the June 1963 Technical Coordinating Committee meeting, the Army technical data package had not yet been used in any procurement of ammunition. While Frankford Arsenal suspected, on the basis of engineering knowledge, that the margin of typical chamber pressures below maximum limits might be small, there was no conclusive evidence that the margin would be insufficient to preclude loading cartridges with the IMR 4475 propellant. The Type B (Sierra)

44. Min, Technical Coordinating Committee, 25-26 Jun 63.

45. Hearings before the Special Subcommittee on the M16 Rifle Program, Armed Services Committee, 22 Aug 67, p. 4995.

bullet design was sufficiently promising to warrant further study; however, no immediate action was taken. When it became apparent from comments by industry in late 1963 and early 1964 that the velocity chamber pressure limit, using IMR 4475 propellant was not likely to be compatible, interest was revived in the original Frankford Arsenal observations on the Type B Sierra bullet. (See Appendix 5.)

The Project Manager requested on 26 February 1964 that the Ballistic Research Laboratory prepare a test plan designed to provide sufficient data on which to base a decision on whether to adopt the Type B Sierra bullet for the M16 rifle.[46/] On the basis of the extensive data available at that time on rifle bullets, BRL recommended that further tests to define the performance of the Type B Sierra bullet not be scheduled. BRL provided the following information in its response to the Project Manager:[47/]

> Sierra bullets have been fired from the AR15 rifle with twist rates of 1:12 inch and 1:14 inch in an experiment to determine the stability factor. A table giving comparative stability factors is presented:

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46. Ltr, AMCPM-AR15, sub: Evaluation of Sierra Configuration cal. .223 Bullet.

47. 1st Ind (AMXBR-WO), 20 Mar 64, to Ltr, (AMCPM-AR15), 26 Feb 64, sub: Evaluation of Sierra Configuration cal. .223 Bullet.

Testing at +70°Fahrenheit

Projectile	Twist	Stability Factor	Twist	Stability Factor
.223 Remington	1:12	1.60	1:14	1.20
Sierra	1:12	1.23	1:14	.91
		Testing at -65°Fahrenheit		
.223 Remington	1:12	1.20	1:14	.90
Sierra	1:12	.92	1:14	.68

It appears from these data that the Sierra bullet when launched from a 1:12 inch twist compares quite closely to the .223 Remington when fired from a 1:14 inch twist tube. In order for the Sierra bullet to perform similar to the .223 Remington which fired from a 1:12 inch twist, a twist of 1:9.5 inch is required.

(With reference to velocity, BRL provided the following data:)

The difference in velocity between the Sierra configuration round and the .223 Remington is about 200 feet per second at 500 meters if they are fired with the same initial velocity. Since the matter of most importance is assumed to be wounding power, a comparison of conditional probabilities of incapacitation will provide insight into the extent of improvement which could be expected with the Sierra bullet. These data are:

	.223 Remington		.22 Sierra	
Range (Yards)	Velocity	PHK	Velocity	PHK
0	3,270	.81	3,270	.81
100	2,894	.76	2,944	.77
200	2,540	.68	2,633	.69
300	2,211	.58	2,341	.61
400	1,908	.50	2,068	.54
500	1,627	.41	1,814	.47

BRL further advised that a review of data had indicated that there would be little increase in lethality if the Sierra bullet were chosen.

In a staff study dated 1 April 1964, the Project Manager's Office noted that if the Type B Sierra configuration were adopted it would be necessary to (1) implement an engineering change to change the twist of barrels from 1 turn in 12 inches to 1 turn in 10 inches (or other twist, as testing should establish); (2) replace barrels on hand in Army and Air Force rifles; (3) replace repair barrels in stock of the Army and Air Force; and (4) replace present stocks of M193 ball ammunition.

On the basis of this information and the comments by the Ballistics Research Laboratories, the Project Manager cancelled further tests on 7 April 1964.[48]

In connection with the 1967 study to re-evaluate the decision on the twist for the M16 rifle, the Ballistic Research Laboratories was asked to design a projectile with the same gyroscopic stability, when fired from a 12-inch twist barrel, as that of the production M193 cartridge from a 14-inch twist barrel. Two basic conditions of the design were that the new projectile should have the same weight (55grains) and the same basic construction (gilding metal

48. 2d Ind (AMXBR-WO), 7 Apr 64, to Ltr, AMCPM-AR15, 26 Feb 64, sub: Evaluation of Sierra Configuration cal. .223 Bullet.

jacket and lead-antimony core) as the M193 cartridge. BRL concluded from its study that it was not possible to duplicate the flight of the M193 bullet fired from a barrel with a 14-inch twist by a new projectile fired from a barrel with a 12-inch twist, although several compromises were available.[49] BRL recommended that a few experimental designs of intermediate stability be fabricated to permit further experimental evaluations.

The Ballistic Research Laboratories' report on barrel twist, published December 1967,[50] was based on test data using only the Type A M193 cartridge and rifles with 1:12-inch and 1:14-inch twist. The BRL recommendation was that the "1:12 twist should be maintained for production of M16A1 rifles." BRL is continuing its effort on bullet design, interior, exterior, and terminal ballistics. A flow chart outlining the research and development effort to be accomplished is now being prepared by BRL.[51] To be thorough the final report on this project must examine bullet-barrel interface. At that time additional recommendations may be made about the barrel twist.

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49. Ballistic Research Laboratories Memo Rpt (RDT&E Project 1P523801A287), Jul 67.

50. BRL Memo Rpt, 1886, Dec 67, sub: Effectiveness Comparison of 1:12 and 1:14 Inch Barrel Twist Rates for M16A1 Rifle.

51. Trip Rpt, CSAVCS-W-INF, 14 Mar 68, sub: BRL Activity on 5.56mm Bullet Design.

E. Propellants

There are three major commercial propellant produces in the United States: E. I. Dupont de Nemours and Company, Inc., Hercules Powder Company, and Olin Mathieson Chemical Corporation.

The IMR (improved military rifle) propellants are single-base (continaing no nitroglycerin), extruded (as spaghetti is extruded), hollow tubes, which are chopped to lengths suitable for measuring and loading into cartridges. These IMR propellants have been in use for more than 30 years and are proprietary developments of Dupont.

The double-base extruded propellants are similar in shape of grain to the IMR propellants, but differ from these in that they contain nitroglycerin as a supplementary source of energy. They are proprietary developments of Hercules Powder Company, from which the designation HPC is derived. Propellants of this type have been in use for more than fifty years.

The ball propellants are generally similar in chemical composition to extruded double-base propellants, but the form of the grain is roughly spherical, hence the name ball propellant. Ball propellants are proprietary developments of Olin Mathieson, and have been used for about 25 years. They have the designation WC for Western Cartridge, an Olin Mathieson subsidiary. The Olin Mathieson process for manufacture of ball propellant allows for the use of reclaimed nitrocellulose. Thus, obsolete propellant can be reprocessed rather than discarded.

The principal difference among Dupont (IMR) propellants is in the chemical coating which is applied to the surfaces of the propellant to control the initial burning rate of the individual propellant grains; the chemical coating to control initial burning is also the key attribute that distinguishes individual Olin Mathieson and Hercules propellants as well. Thus, a given plant can easily make several propellants of a similar type, but the manufacture of certain propellants -- notably the double-base ones -- requires special facilities, such as a nitroglycerin processing capability.[52]

The commercial specification for the caliber .223 cartridge, which was developed by Remington Arms Company and was the forerunner of the present 5.56mm round, stipulated: "The cartridge shall be loaded with single base rifle power suitable to ballistic requirements of this cartridge."[53] The same commercial specification required an average velocity of 3,245 ± 40 feet per second and maximum average chamber pressure of 52,000 pounds per square inch. The ammunition manufactured by Remington Arms and used by

52. Memo, Chief of Staff for Secretary of the Army, 27 Sep 67, sub: M16 Rifle Testing.

53. Commercial Specification, Remington Arms Company, Inc., 13 Jul 61.

Cooper-MacDonald Company for demonstration and testing of the AR15 rifle was loaded with IMR 4475 propellant.[54]

During the joint development phase of the military technical data package by the Air Force and the Army in 1962 and early 1963, the question of chamber pressure specifications was discussed. At a meeting at Lake City Ordnance Plant on 9-10 January 1963, representatives of the two services discussed whether the maximum average chamber pressure of 52,000 pounds p.s.i. could be maintained or whether an increase of two to three thousand pounds per square inch might be required.[55]

At a meeting held in the Pentagon on 26 February 1963 attended by representatives of Office Secretary of Defense (OSD), Advanced Research Projects Agency (ARPA), the U.S. Air Force, the U.S. Army and Remington Arms Company, the question of excessive chamber pressure in the M16 rifle above 52,000 pounds per square inch (as high as 56,000 pounds p.s.i.) was discussed.[56] It was decided that the cause of excessive chamber pressure in the M16 was probably incompatability in the cartridge design and the rifle

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54. Memo, Remington Arms Company, Inc., 28 Jul 67, sub: Development of Caliber 5.56mm Ammunition.

55. MFR, HQ USAMUCOM, 21 Jan 63, sub: USAF Meeting on Technical Data for 5.64mm Ammunition.

56. Trip Report, Frankford Arsenal, 26 Feb 63.

chamber. The discussion did not include any reference to the possibility of a propellant problem.

The Air Force technical data package required the use of IMR 4475, and specified the velocity of 3250 ± 40 feet per second, and the chamber pressure of 52,000 pounds per square inch (the commercail specifications). These requirements were also contained in the 16 August 1963 proposal for procurement of one million rounds of M193 ball cartridges. Both Olin Mathieson and Remington Arms, the two eligible bidders, took exception to provisions of the technical data package, but at the time, had no objection to the use of IMR 4475 propellant.[57]

A visit to Frankford Arsenal on 16 September 1963 by the Project Manager resulted in a further discussion of propellants. The Project Manager agreed with the Frankford Arsenal representative that some other propellant would probably be necessary for loading in special types of ammunition, but thought that an alternate propellant should not be developed at the expense of other tasks which he felt were more urgent.[58]

A Frankford Arsenal memorandum of 11 July 1962 noted that the three propellant manufacturers had shown a desire to do a limited

57. Memo, USAMUCOM, 3 Sep 63, sub: TDP for 5.56mm Cartridges.

58. Ltr, Frankford Arsenal, 27 Sep 63, sub: Engineering Program for 5.56mm (AR15) Ammunition.

amount of developmental work and to supply samples of propellants to Frankford Arsenal for evaluation.[59/] The memorandum added that the propellant manufacturers were seriously handicapped in developmental work by their lack of test equipment, weapons, and cartridge components. If Frankford Arsenal provided the manufacturers with the equipment they needed, the development or improvement of small arms propellants would be facilitated. The government would gain considerable savings because Frankford Arsenal would have to do less testing. As a consequence of the above memorandum, USAMUCOM in late 1963 and early 1964 negotiated identical "No Cost" or "Dollar" contracts with Dupont[60/], Olin Mathieson,[61/], and Hercules[62/], in turn.

Under the contract terms, propellant manufacturers would provide engineering service to perform ballistic tests and screen newly developed or improved propellants for small arms; Frankford Arsenal would supply all necessary test equipment and cartridge components, such as primer cases and bullets. These contracts have been renewed annually without significant change in their provisions, and are now effective through 1968. They provide for the general

59. Frankford Arsenal, DF, ORDBA-6152, 11 Jul 62, sub: Proposed Contracts with Propellant Manufacturers.

60. Contract: DA-36-038-AMC-923(A), 29 Jan 64.

61. Contract: DA-36-038-AMC-922(A), 20 Apr 64.

62. Contract: DA-36-038-AMC-921(A), 24 Dec 63.

development of all types of small arms propellants, not merely propellants specifically for 5.56mm ammunition. Frankford Arsenal representatives report that up to this time no propellant samples for 5.56mm ammunition have been submitted solely in response to the contracts. However, in response to specific letter requests from Frankford Arsenal, the three propellant manufacturers did submit alternate propellant candidates to Frankford Arasenal in 1964.

In telephone conversation on 27 December 1963, representatives of the Air Force and the Army decided to include WC 846 as an alternate propellant for the Air Force FY 1963 procurement.[63/]

A meeting was held on 20 January 1964 to resolve manufacturers' further objections to the technical data package. At this meeting, it was agreed to permit the maximum chamber pressure to be increased from 52,000 p.s.i. to 53,000 p.s.i. on the one million rounds.[64/] This agreement was confirmed by the Army to the manufacturer on 21 January 1964.[65/]

Also, on 21 January 1964, Olin Mathieson proposed that WC 846 ball propellant be adopted by the Army as an alternate propellant and stated that the Company was prepared to guarantee WC 846

63. Msg, CO APSA to CO Hill AF Base, 28 Dec 63.

64. MFR, HQ USAMUCOM, 20 Jan 64, sub: Meeting on Procurement of One Million Cartridges, 5.56mm.

65. Msg, APB 630, CO APSA, 21 Jan 64.

compliance with applicable ballistic, physical, and chemical specifications without waivers.[66] The Commanding Officer, APSA, replied to Olin Mathieson that the Army had no objection to further testing of the alternate propellant; however, it would not change the existing contract for one million rounds.[67] This contract authorized an increase of the maximum allowable chamber pressure to 53,000 pounds per square inch.

The Air Force did not concur in increasing the chamber pressure and held to its previous position of using WC 846, if necessary, for its procurement of ammunition.

The Project Manager advised the Commanding General, AMC on 30 January 1964, of the difficulty the Army was having in obtaining responsive bids for the manufacture of the initial one million rounds of the total 150 million rounds required in FY 1964.[68] The Project Manager stated that the elements of the technical data package under question were those specified by Remington Arms Company as part of a procurement package purchased by the Army in conjunction with the 600,000-round purchase of ammunition in mid-1963. Remington had declared that the specifications were correct

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66. Ltr, Olin Mathieson to USAMUCOM, 21 Jan 64.

67. Msg, CO APSA, to Olin Mathieson, 23 Jan 64.

68. Memo, Project Manager, 30 Jan 64, sub: FY 64 Ammunition Procurement Program -- XM16E1 Rifle.

at the time of the 600,000-round purchase; however, Dupont now claimed it could not meet the pressure-velocity requirements of the specification for the propellant. The Project Manager further stated:

> It is my opinion that in the 1963 buy, the best propellant was selected from several lots so that the proper pressure-velocity relationship could be maintained. This presented no problem on a minor purchase such as the 600,000 round buy; however, for a large volume procurement such as 150 million rounds, an inordinate number of high quality lots of propellant would be required.

During the same period (early 1964) when the Army was attempting to develop a new propellant for the 5.56mm cartridge, effort was also being devoted to the development of a new propellant for the 7.62mm NATO cartridge. The basis for this development was:

> The 1964 version of the 7.62mm NATO M80 ball cartridge cannot be consistently loaded with IMR 4475 propellant to a velocity of 2750 fps without exceeding the limit on average chamber pressure (50,000 p.s.i.). Some lots of IMR will meet the ballistic requirement. Many lots, however, will not.[69]

USAMUCOM further advised the Commanding General, AMC, that "a production engineering program had been initiated to thoroughly evaluate a new Dupont propellant having a different type coating and designated Experimental (EX) 8138. Testing of this new propellant in 7.62mm ammunition proved encouraging."

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69. 1st Ind, HQ USAMUCOM to CG AMC, 3 Feb 64, sub: Small Arms Ammunition Propellants.

Meanwhile, testing of the three candidate propellants -- WC 846 by Olin Mathieson; IMR 4475-5.56 and Cool Rifle (CR) 8136 by Dupont; and HPC-10 by Hercules -- continued.70/ At the same time (March 1964) the cartridge manufacturers were pressing the Army for a decision in order to meet contract commitments. Olin Mathieson stated that the Company would not be able to meet its production schedule if the Dupont propellant was selected because Dupont required an eight-week production lead time. Olin Mathieson also said that the Company could begin loading immediately with WC 846 if the Army approved that propellant.71/ Remington Arms Company and Federal Cartridge Company, the other two cartridge manufacturers, also informed the Army that if WC 846 was approved by 30 March 1964, that they, too, could meet their production schedules.72/ The date for approval was later extended to 30 April 1964.73/

The results of the testing of alternate propellants by USAMUCOM determined that the Olin Mathieson propellant, WC 846, and Dupont's

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70. For an analysis of the evaluation criteria, see Incl 4-1.

71. MFR, HQ USAMUCOM, 23 Mar 64.

72. MFR, HQ USAMUCOM, 30 Mar 64, sub: AR15-M193 Ball Cartridge Procurement.

73. DF, HQ USAMUCOM, 10 Apr 64, sub: Test and Evaluation of Alternate Propellants for Cartridge, 5.56mm, M193.

Cool Rifle (CR), 8136 were both suitable for loading in the 5.56mm M193 cartridge. Dupon IMR 4475 was continued as acceptable for existing contracts. The cartridge producers loaded ammunition as indicated below.[74]

Propellant Loading

Producer	Contract	Propellant
Olin Mathieson	DA-11-173-AMC-181	WC 846
	DA-11-173-AMC-168	IMR 4475
Remington Arms	DA-11-173-AMC-169	IMR 4475
	DA-11-173-AMC-182	CR 8136
Federal Cartridge	DA-11-173-AMC-180	WC 846

The Army continued the development effort in 1965 by asking the three propellant producers to submit other candidate propellants for evaluation. Olin Mathieson responded that it did not desire to change the chemical composition of WC 846 at that time.[75] Remington Arms submitted a propellant designated Experimental (EX) 8208, which was an IMR base grain composition coated with the same polymer type deterrent as IMR 8138-M propellant used in 7.62mm M80 cartridge loading.[76] Hercules recommended its propellant HPC-11.

Tests of the experimental propellants conducted by Colt's Inc. provided the following information:

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74. MFR, Frankford Arsenal, 11 Dec 64, sub: Cartridge 5.56mm.
75. Ltr, Olin Mathieson Corporation, 7 Jun 65.
76. Ltr, Dupont Company, 6 Apr 65.

1. The test sample containing EX 8208 propellant gave generally satisfactory performance in M16 rifles, both with the present standard buffer and with the experimental buffer being evaluated for use in the M16-XM16E1. With the standard buffer, however, the upper limit of 850 rounds per minute was occasionally exceeded.

2. The test sample containing HPC-11 propellant gave evidence of producing insufficient operating energy for reliable gun functioning. In all other respects, its performance was very satisfactory.

3. The control sample containing WC 846 gave excessively high cyclic rates of fire when the standard buffer was used. With the experimental buffer assembly, the cyclic rates of fire were satisfactory.[77]

Further problems involving the 5.56mm ammunition propellants were identified by Headquarters, USAMUCOM, on 24 March. "In addition to rifle cyclic rate variations with type of propellant, we are concerned with questions of whether ball propellant causes excessive fouling and whether muzzle velocity in the test barrel is meaningful in terms of velocity in the M16 rifle."[78] A test barrel of a given size, such as 5.56mm, will not duplicate all ballistic characteristics of each weapon of that size.

The USAMUCOM propellant evaluation conducted by Frankford Arsenal was concluded on 5 May 1966 with a recommendation that the Dupont propellant EX 8208 (soon to be identified as IMR 8208M) be

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77. Test Rpt, Colt's Inc., 23 Mar 66, sub: Test of Experimental Propellants for 5.56mm M193 Ball Ammunition in M16 Rifles.

78. Ltr and MFR, HQ USAMUCOM, 24 Mar 64, sub: Propellants for 5.56mm M193 Ball and M196 Tracer Cartridges.

approved for use in 5.56mm ball M193 and tracer M196 cartridges. The Frankford Arsenal proposal was approved by the Project Manager 17 May 1966.[79]

The Project Manager briefed the Commanding General, USAMC, and representatives from ODCSLOG 8 December 1966 on the detailed analysis of the ammunition development program for the M16 rifle. The ODCSLOG representative forwarded a memorandum to the Chief of Staff, Army, which summarized key subjects of the briefing.[80]

> . . . The original technical data, procured from Remington, for the ammunition specified a mean velocity of 3,250 f.p.s. and a mean chamber pressure not to exceed 52,000 pounds p.s.i. The problem, which developed when the Army attempted to procure ammunition in volume, was that IMR powder could not consistently develop the 3,250 ± 40 f.p.s. without exceeding the chamber pressure limitation. In June 1963, the AR15 Technical Coordinating Committee took this matter under consideration but rejected, unanimously, any reduction of the 3,250 f.p.s. requirement. . . . Dupont has developed a new IMR type of power and, after testing, the Army has procured one million pounds. First shipments (to cartridge producers) were made in October. Initial reports suggest the same old problem, and waivers of 50 f.p.s. have had to be granted in two lots.

At the conclusion of the discussion, CG, USAMC directed that the Project Manager take the following action:

> Come to grips at an early date with the 3,250 f.p.s. requirement.

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79. Ltr, Frankford Arsenal, 5 May 66, sub: Request for Concurrence with 1st Ind, Project Manager, 17 May 66.

80. Memo, ODCSLOG, 12 Dec 66, sub: M16E1 Rifle Ammunition.

Introduce the new buffer (to reduce the cyclic rate) into production as soon as possible.

Develop a plan to procure the necessary new buffers and retrofit all rifles in the hands of troops.

The ODCSLOG was required to provide the Chief of Staff a monthly progress report.

The Project Manager wrote the U.S. Army Ballistics Research Laboratories (BRL).[81]

1. Since the inception of military interest in the 5.56mm (cal .223) cartridge, the velocity requirement for the ball cartridge has been 3,250 ± 40 f.p.s. instrumental at 15 feet from the muzzle when fired from an ammunition test barrel. This requirement and the related requirement that the average peak chamber pressure not exceed 52,000 p.s.i. has created a near sole-source situation for propellant supply, although repeated attempts have been made to utilize propellant from other sources.

2. This Office is considering a reduction in the velocity requirement for 5.56mm ammunition as a means of expanding the procurement base for propellant. It is anticipated at this time that a velocity reduction on the order of 50 to 100 f.p.s. would be required, although the exact magnitude of the reduction depends on a number of factors and has not yet been established.

3. On being advised recently of this contemplated action, the Commanding General, AMC, expressed some concern about the possible adverse effect of the proposed change on the exterior- and terminal-ballistic performance. In particular, he questioned the effect of such a change on accuracy and lethality. We have

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81. Ltr, Project Manager Rifles to USABRL, 14 Dec 66, sub: Velocity for 5.56mm Ball Ammunition.

assured him that there is o reason to expect any degradation in accuracy from a velocity change of the anticipated magnitude, either from test data available on this particular cartridge or from related experience with similar ammunition. Since the velocity retardation of the M193 bullet near the muzzle is about 4 f.p.s. per yard of range, a reduction in muzzle velocity of 50 f.p.s. would shorten the range for equivalent terminal effect by about 13 yards, i.e., whatever its terminal effects are now at a range of, say, 400 yards, those same effects could be expected at approximately 387 yards if the muzzle velocity were reduced 50 f.p.s. In response to another question, he was advised that no appreciable effect on aerodynamic stability would be expected in consequence of a velocity reduction of the contemplated magnitude.

4. Your comments on the validity of the conclusions described in para 3, above, or on any other possible adverse effect of the proposed velocity reduction on exterior- and terminal-ballistic performance are requested, at your earliest convenience.

On 4 January 1967, the Project Manager, Rifles, submitted the First Report on Proposed Product Improvements for the XM16E1 rifle and 5.56mm ammunition. He reported:

As soon as BRL's comments have been received, the Joint Services Technical Committee will be briefed on the problems in propellant supply created by the current interior-ballistic requirements for 5.56mm ammunition and the changes in performance which would result from a permanent velocity reduction. The advanced concurrence of all four services in a velocity reduction will be requested in the event such a reduction proves to be the only alternative to a sole-source propellant supply situation.

In event a permanent reduction in the velocity requirements for 5.56mm ammunition may become necessary, the U.S. Army Ballistics Research Laboratories have been requested to assess the effects on exterior- and terminal-ballistic performance. This report is expected to be forwarded to AMC by 15 January 1967.

The Ballistics Research Laboratories responsed on 10 January 1967[82]. . . "Conclusions in paragraph three of referenced letter are valid and are applicable to dispersion, stability, and terminal effectiveness against personnel and hard targets."

A review of the records available indicates no further reporting or action on this matter until 19 October 1967, when the Commanding General, AMC, again brought up the 50 f.p.s. reduction in muzzle velocity in his report to the Chief of Staff.

The Office of the Project Manager, Rifles, was queried by the M16 Rifle Review Panel to determine the status of this matter in March 1968, fifteen months after the original question was raised. The matter is now considered by the Project Manager to be terminated since incorporation of the new buffer precludes the use of IMR 8208M powder with ball ammunition.

The two government-owned commercially-operated (GOCO) ammunition loading plants at Lake City (LCAAP) and Twin Cities (TCAAP) began loading with IMR propellant 8208M during late 1966 and early 1967. The initial nineteen propellant lots supplied by Dupont showed little improvement over previous IMR propellant, insofar as meeting the velocity-chamber pressure specifications. In addition, certain propellant lots failed to pass the 1,000-round fouling test

82. UNCLAS Msg, APG 0420 for AMCPM, Rifles, 101508Z Jan 67, sub: Velocity for 5.56mm Ball Ammunition.

when loaded in cartridges. Dupont initiated a modification in its propellant process with lot number 20, which proved to be successful in meeting the velocity-chamber pressure requirements.[83] By 21 July 1967, the loadings of IMR 8208M at the GOCO plants were as follows:

Plant	Cartridge	Total Quantity (millions)
LCAAP	M193	19.0
LCAAP	M196	57.5
TCAAP	M193	130.2
TCAAP	M193	11.3

As a result of test and field reports of excessive fouling with 5.56mm ammunition, an additional fouling test was directed on 21 November 1967 by the Commanding General, AMC. The test plan required a 1,000-round fouling test on each lot of cartridges with all testing to be conducted at Lake City Army Ammunition Plant.[84]

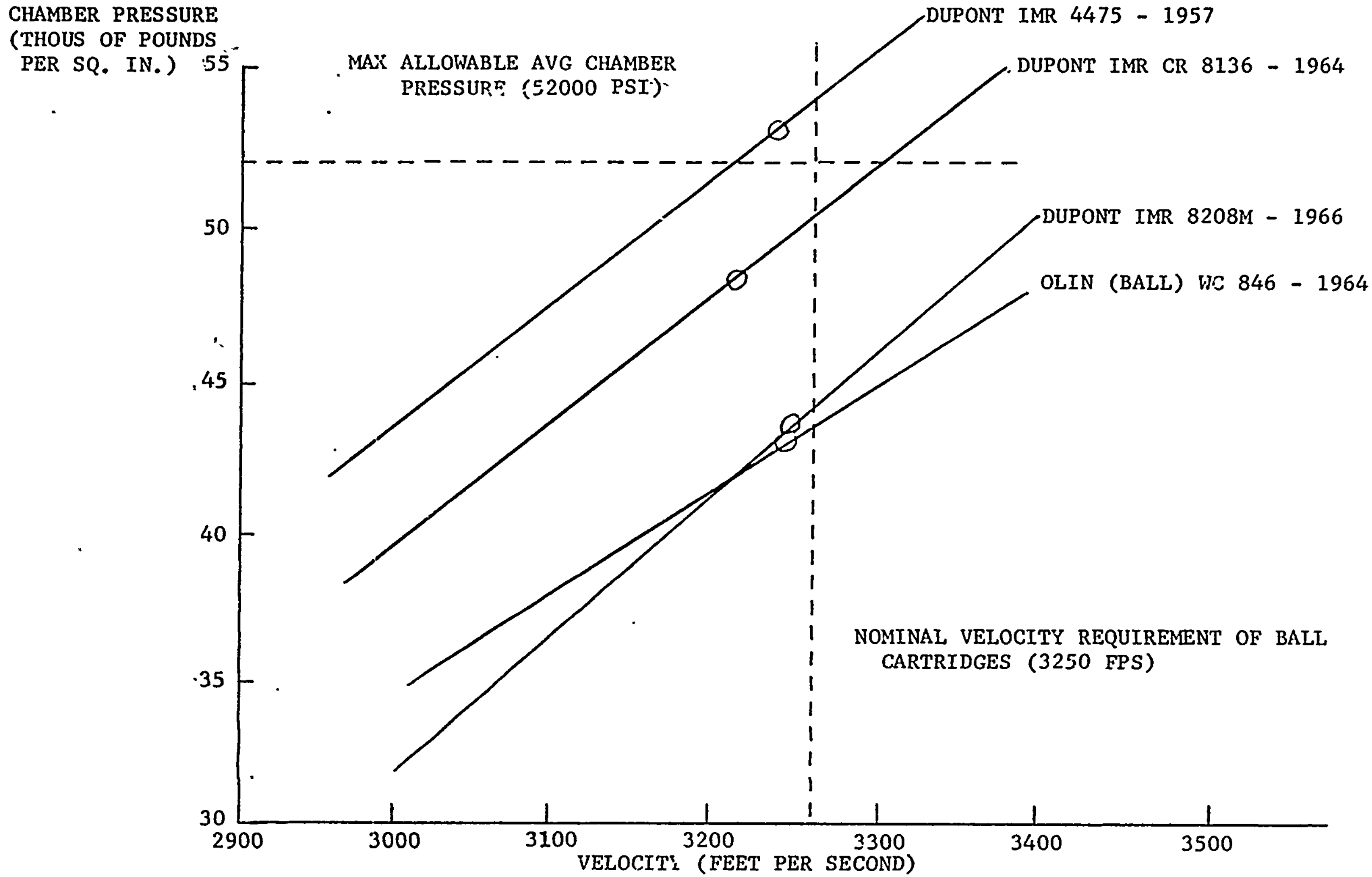
An evaluation of the Dupont propellants, illustrating the velocity-chamber pressure relationship of the three Dupont propellants and Olin Mathieson WC 846 ball propellant are shown graphically on Figure 4-1. Note that the velocity/pressure relationship of the Dupont propellants is approaching that of ball

83. Memo, ODCSLOG, 22 Mar 67, sub: M16A1 Rifle Ammunition.

84. DF, HQ USAMUCOM, 22 Nov 67, sub: 1,000-Round Fouling Tests.

Figure 4-1

VELOCITY - CHAMBER PRESSURE RELATIONSHIP WITH VARIOUS PROPELLANTS IN M193 BALL CARTRIDGE



MAJOR SOURCE: PM Briefing to Under-Secretary of the Army, 17 March 1967 propellant through this evolution. The points plotted on the velocity-chamber pressure curves represent the actual velocity and pressure levels of machine-loaded ammunition samples, purchased from Remington Arms, for the purpose of evaluating the respective propellants. The lines through these points represent the velocity/pressure gradient for each of the propellants, which is determined by hand loading cartridges with carefully weighed charges of each propellant type, and measuring the velocities and pressures produced by each hand loaded sample.

In October 1967, testing of the XM177E2 (CAR-15) submachine gun and later the M16 rifle, revealed that the use of WC 846 ball propellant in tracer M196 cartridges was responsible for bullet breakup. Consequently, on 6 December 1967, Frankford Arsenal directed that propellant WC 846 no longer be loaded in the tracer M196 cartridge.[85/]

During the WSEG test of the M16 rifle, conducted in Panama in January 1968, it was determined that the use of IMR 8208M propellant in ball ammunition contributed to increased malfunctions. A temporary suspension of loading ball cartridges with IMR 8208M propellant was therefore directed by the Department of Defense. (This test is discussed in Appendix 6.) History of changes to specifications of 5.56mm ball cartridge is at inclosure 4-2.

85. Msg, Co Frankford Arsenal, 6 Dec 67, sub: Cartridge, Tracer, M196, 5.56mm.

Improvement Efforts

The Army Chief of Staff announced guidance pertaining to the Army Small Arms Program by memorandum on 8 March 1967.[86] The purpose was to reorient the Army Small Arms Program to a more deliberate approach in concurrent areas of investigation and development. Two such areas listed in the memorandum were:

> Improvement in design and performance of the Army's current (M16 rifle-M14 rifle) small arms system, within existing technology, to increase effectiveness.
>
> The program should relate to more than one time frame and include efforts to improve existing standard systems (M16 rifle-M14 rifle) . . . .

Consequently, USAMUCOM and Frankford Arsenal reoriented and expanded the ammunition program in their Research and Technology Resume. This resume, submitted to the Chief Research and Development on 15 October 1967,[87] provided for effort in three areas:

1. Research in common studies applied to systems analysis, interior, exterior wound and terminal ballistics, simulation, materiel, tracer, and instrumentation.

2. Concept feasibility studies to evaluate concepts prior to initiation of exploratory development.

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86. CSM 67-96, 8 Mar 67.

87. Research and Technology Resume, USAMUCOM-Frankford Arsenal, 15 Oct 67, sub: Ammunition, Explosives and Pyrotechnics, Ballistics, Armor.

3. Exploratory development of rifle, pistol, machine gun, and shotgun ammunition.

Further, the Research and Technology Resume outlined a series of tasks to be undertaken through FY 1970. In part, these are:

Definition of optimum values of weapon and ammunition variables.

Study of propellants, primers, erosion, flash, smoke, and primer-propellant interface problems, to include:

Interior ballistic theory

Propellant development for increased velocity

New propellant ingredients

Temperature coefficients

Improvement in existing instrumentation and development of new instrumentation techniques. This includes the development of reliable gages to measure chamber pressure-time curves within 1 percent.

Initiation of a general study to simulate the behavior of complex weapon and ammunition systems by computer methods in an attempt to isolate the physical basis for some of the current interface problems. This study is expected to provide data on the behavior of the cartridge case, primer, propellant, bolt, and gas system.

The Commanding General, USAMC, informed the Chief of Staff, Army, of the formation of a USAMC Executive Committee.[88] This committee will provide the framework for an integrated weapon system approach to the remaining M16 rifle problems. The Project Manager is Chairman, and the committee includes a representative of USAWECOM, USAMUCOM, Frankford Arsenal, USATECOM, and the Ballistic Research Laboratories. Major tasks have been assigned by the Project Manager, Rifles, to members of the executive committee. (See Figure 4-2.) Members are presently developing a time-phased, costed program for the accomplishment of each of the major tasks.

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88. Ltr, CG USAMC to CofSA, 27 Feb 68.

Figure 4-2 -- INTEGRATED APPROACH TO M16 WEAPON SYSTEM PROBLEMS: TASK ASSIGNMENTS BY THE M16 EXECUTIVE COMMITTEE

Task	Agency with Principal Responsibility
Compatibility investigation of 4 ball-1 tracer ammunition mix fired in current rifle.	USATECOM
Analysis of existing test and acceptance inspection data	BRL
Review of specifications	BRL
Development of improved instrumentation-techniques for engineering-type tests and acceptance tests	Frankford Arsenal
Interior ballistic-kinematic studies	BRL
Development of mathematic model to simulate internal functioning of the weapon system	Frankford Arsenal
Investigation of design approaches to reduce sensitivity of weapons to ammunition variability	USAWECOM
Investigation of design approach to minimize ammunition variability	Frankford Arsenal
Establishment of system operational reliability goals	USATECOM

F. History of Special Ammunition

Tracer Ammunition, M196

The initial Army specification for the tracer cartridge, 5.56mm, M196 was dated 17 March 1964. Significant changes in requirements from the ball cartridge, 5.56mm, M193, were the relaxation of accuracy from 2 inches at 200 yards to 5 inches at 200 yards and the reduction of velocity from 3,250 ± 40 feet per second to 3,200 ± 40 feet per second. The reduction of velocity was determined by Frankford Arsenal to provide the best exterior ballistics match with the ball M193 cartridge. The requirement for visible tracer was established to be over a range of 75 to 500 yards.[89]

Small amounts of tracer ammunition were produced by Remington Arms Company in 1962 for use by Cooper-MacDonald in tests and demonstrations. No specification was available for this ammunition and the design which Remington followed was generally patterned after the design for the 7.62mm and caliber .30 tracer ammunition. Frankford Arsenal reported that limited tests, which were run on the experimental 5.64mm (5.56mm) tracer cartridge, proved that the experimental bullet used the same tracer and igniter mixes as those used in the 7.62mm M62 tracer cartridge, but the proportion of tracer igniter weight to total bullet weight was significantly

89. MIL-C-6011(MU), Cartridges 5.56mm, Tracer, M196, 17 Mar 64.

lower than that of the M62 cartridge.[90] Accuracy of the experimental bullet appeared to be superior to that of the M62; however, USATECOM believed that the experimental cartridge might not have had enough tracer mix to provide satisfactory visibility under all conditions. On 18 July 1963, Frankford Arsenal requested test samples of tracer ammunition for which it could develop specifications.

In conjunction with the development of the specifications, the Commanding General, USACDC, expressed a desire that the tracer be comparable to the M62 7.62mm cartridge in order that the 5.56mm tracer might be used to designate targets for machine gunners to the maximum effective range to which the machine gun fire could be accurately controlled under conditions of low visibility.[91] The minimum requirements, however, were stated as a tracer visible to the naked eye to a range of 400 meters. No requirement for dim and bright tracers, or for color and brightness, were established by USACDC. The Air Force submitted a stated requirement that the tracer ammunition should trace to 500 yards, with a minimum ballistic mismatch.[92]

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90. Memo for Record, USAMUCOM, 22 Jan 63, sub: Meeting at U.S.A. Test and Evaluation Command on Small Caliber Rifle Test Results, 16 January 1963.

91. Msg, CG USACDC to CG USAWECOM (CDCMR-W-S-289), 23 Aug 63.

92. Ltr, Hill AF Base to CG USAMUCOM, 13 Sep 63, sub: Air Force Military Characteristics for AR15 Rifle Ammunition.

Frankford Arsenal, with the cooperation of technical representatives from Remington Arms Company, Inc., and Colt's Inc., developed a technical data package and military specifications. The cartridge underwent a service test during the period May 1964 through 23 March 1965[93] and was classified as Standard A for temperate (intermediate climate) use in January 1965. The Arctic winter testing (15 October 1964 to 23 March 1965) was in progress at the time of type classification action but in this test it was found that although the functioning and ballistic properties of the cartridge were satisfactory, the reliability of tracer ignition decreased markedly at 32° Fahrenheit and below.

Corrective action was undertaken by Frankford Arsenal and in December 1965 a sample of cartridges was forwarded to the U.S. Army Arctic Test Center for a check test. Tests were conducted during the winter of 1965-66 to determine whether the previously reported unreliable ignition had been corrected and to confirm other performance characteristics, including the effect of Arctic winter temperatures on accuracy, dispersion, and weapon functioning.[94] As a result of these tests it was determined that the previously

93. Service Plan of Test of Cartridge, Tracer, 5.56mm, XM196, U.S. Army Infantry Board (USAIB Project 3068), Jan 65.

94. Ltr, USATECOM, 12 Apr 66, sub: Final Report of Check Test of Cartridge, Tracer, 5.56mm, XM196, Under Arctic Conditions, USATECOM Project 8-4-0210-09.

experienced unreliable tracer ignition had been satisfactorily corrected, and that the test cartridge was satisfactory with respect to accuracy, reliability, and its effect upon weapon functioning.

During the course of the Small Arms Weapon Study, there were reports that riflemen firing both the 7.62mm and 5.56mm tracers in daylight could not see their own tracers, although their tracers were visible to observes stationed nearby on either flank.[95] The Project Manager suggested to the Commanding Officer, U.S. Army Human Engineering Laboratories (HEL), that two circumstances might account for the reported observations:

> If the weapon is being aimed with the sights at the time of firing, the reaction of the man/weapon to recoil forces may temporarily interpose the weapon in the gunner's line of sight, causing him to lose sight of the tracer in daylight conditions.
>
> To the gunner, tracer light output possibly appears to originate more nearly from a point source, whereas it may appear as a streak when viewed from an angle.

HEL replied that the above hypotheses might be correct, but insufficient data were available to give a positive answer.[96]

Early in 1967, the Project Manager received several reports from the field stating that the bores of M16 and M16A1 rifles were

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95. SAWS Test Report, 1966.

96. Ltr, U.S. Army Human Engineering Laboratories, 7 Mar 67, sub: Visibility of 7.62mm and 5.56mm Tracers.

unusually difficult or even impossible to clean after tracer ammunition had been fired.[97/] The Commanding General, USAMUCOM, requested Frankford Arsenal to include a comparative evaluation of bore fouling from both ball and tracer ammunition to the 5.56mm propellant monthly fouling program. Frankford Arsenal advised USAMUCOM on 20 June 1967 that bore fouling observations had been incorporated into the monthly fouling test.[98/] Frankford Arsenal asked USATECOM and all plants producing ball and tracer ammunition to report their observations on bore fouling produced by these two types of ammunition. It was the general opinion, based on limited observation, that no noticeable increase in bore fouling was evident during production control testing; it was generally felt, however, that tracer ammunition exhibited a greater degree of fouling in the bolt assembly area.

The Project Manager also received reports of a high buildup of gilding metal in the barrel of the M16 Rifle when tracer ammunition was being used.[99/] When a great deal of tracer ammunition is used, especially in a hot barrel, bullet-jacket material (metal fouling) forms in the rifling grooves of the barrel. The Project Manager

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97. Ltr, Project Manager, Rifles to CG USAMUCOM, 3 May 67, sub: 5.56mm M196 Tracer Ammunition.

98. Incl 2, to Ltr, Project Manager, Rifles, to CF USAMUCOM, 3 May 67, sub: 5.56mm M196 Tracer Ammunition

99. Ltr, Project Manager, Rifles, to CG, Fort Polk, 5 Jul 67, sub: Tracer Ammunition.

pointed out that small arms tracer ammunition was intended as a special purpose round to make a pyrotechnic display for marking targets by rifle fire and for observing the trajectory in order to adjust the fire of automatic weapons. In these roles, the Project Manager added, tracer was ordinarily fired only occasionally in rifles and heretofore had caused no problems in the maintenance of rifles. The primary method for preventing the buildup of gilding metal in the bore of the rifle was to restrict the use of tracer ammunition and to clean the bore thoroughly after firing. Lack of cleaning of the bore would cause the bore to pit and would accelerate the builup of gilding metal. As a result of the problem of metal fouling, the Project Manager requested the Commanding General, USAMUCOM,[100] to test and evaluate, as part of an existing program, the comparative effect of gilding metal clad-steel (GMCS) bullet jackets on the rate of copper accumulation in the bore. Frankford Arsenal, after preliminary testing, reported that there were no significant effects of the GMCS jacket upon barrel erosion or metal fouling.[101]

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100. Ltr, Project Manager, Rifles, to CG, USAMUCOM, 16 Aug 67, sub: Gilding Metal Fouling in M16-M16A1 Rifle Barrels.

101. 2d Ind, 14 Sep 67, to Ltr, Project Manager, Rifles, to CG, USAMUCOM, 16 Aug 67, sub: Gilding Metal Fouling in M16-M16A1 Rifle Barrels.

Interior Ballistic Mismatch. The Project Manager, Rifles, was aware of an interior ballistic mismatch problem on 5.56mm ammunition issued prior to 21 December 1965. His memorandum of 22 December stated: "It has been established also that the functioning differences induced by one of the approved propellant types are directly related to an increased number of weapon malfunctions."[102/] This problem came up again during the USACDCEC SAWS experiment and appeared in SAWS' final report.

In response to the Chief of Staff,[103/] DCSLOG requested the comments of USAMC on the "mismatch between ball cartridges (loaded with ball powder) and tracer cartridges (loaded with a different powder) with respect to effect on weapon cyclic rate and reliable weapon functioning in the M16E1 rifle and developmental 5.56mm machine gun."[104/] DCSLOG also asked for the planned corrective action "if indicated."

The Project Manager's response to DCSLOG's request identified the differences in internal ballistic parameters of 5.56mm ammunition and compared these differences with 7.62mm and caliber .30

102. Memo, Project Manager, 22 Dec 65, sub: Feeder Submission for Letter to USAMUCOM.

103. Chief of Staff Memorandum (CSM) 66-485.

104. Ltr, DCSLOG, 29 Nov 66, sub: 5.56mm Ammunition.

ammunition.[105] The mismatch was greatest in caliber .30, somewhat less in 7.62mm, and least of all in 5.56mm ammunition. These comments referred to tracer ammunition loaded with IMR powder as compared with ball ammunition loaded with ball powder. The Project Manager also identified test procedures where by at least 720 rounds of tracer from each lot are test fired. No ammunition-induced gun stoppage is allowed. Based on these data the Project Manager recommended that no change be made in the present 5.56mm ammunition to reduce ballistic mismatch.

In November 1967, a special test was conducted on 5.56mm tracer ammunition loaded with ball propellant. This test confirmed projectile breakup and verified that firing pure tracer results in gilding metal deposits in the bore of the weapon. These tests resulted in the suspension of all lots of tracer ammunition loaded with ball propellant.

In December 1967, the M16 Rifle Review Panel requested a recapitulation of all 5.56mm tracer ammunition by propellant type produced in 1966-67. The response showed that during the year preceding the Project Manager's report, 39 million rounds of tracer ammunition were produced with ball propellant. This amounted to 57.4 percent of the 1966 production. During the 22-month period

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105. Rpt, Project Manager, 31 Jan 67, sub: A Review of Differences in Interior Ballistics Between Ball and Tracer Cartridges.

preceding the decision to suspend tracer ammunition loaded with ball propellant, 74.6 million rounds were produced.[106]

Tracer Lethality. The question of the comparative lethality of the M193 ball cartridge and the M196 tracer cartridge was first raised by the Commanding General, United States Army, Vietnam (USARV), to the Commanding General, USAMUCOM, on 3 August 1967.[107] The USAMUCOM response to USARV stated:

> No tests of lethality have been conducted on the 5.56mm M196 tracer cartridge, nor have lethality tests been conducted on other standard tracers such as the 7.62mm M62. The best estimate available from wound ballistics experts is that the 5.56mm tracer bullet should be essentially as lethal as the 5.56mm ball bullet for all rifle ranges (400 meters or less). A program has been initiated to obtain acutual test data to validate the estimate.[108]

The Commanding General, USAMUCOM, stated to USARV:

> Preliminary results of the program to obtain actual wound ballistics data for (M16 tracer ammunition) evaluation have been received. These data indicate an average of 27 percent reduction in the probability of incapacitation (P_{h_k}) with the M196 tracer cartridge than of the M193 ball cartridge.[109]

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106. Rpt, Special Asst to ODCSLOG (P&B) for M16 Rifle Matters, 11 Jan 68.

107. Ltr, 3d Bn, 39th Inf, 9th Inf Div, with 3d Ind, CG, USARV, 3 Aug 67, sub: Evaluation of M16 Tracer Ammunition.

108. 4th Ind to Ltr, 3d Bn, 39th Inf, 9th Inf Div, with 3d Ind CG, USARV, 3 Aug 67, sub: Evaluation of M16 Tracer Ammunition.

109. Msg, CG, USAMUCOM (AMSMU-RE-M 11-1071), 15 Nov 67, sub: Evaluation of M16 Tracer Ammunition.

Frankford Arsenal and the Ballistics Research Laboratories are now conducting further testing and evaluation for the purpose of confirming the data provided to the Commanding General, USARV.

Bullet Breakup. The first report to make reference to bullet breakup, or bullet jacket separation, was made on 29 April 1966 during the Small Arms Weapon Study test and involved a Stoner machine gun and 5.56mm M196 tracer ammunition. The Project Manager forwarded this report, with photographs, to the Commanding Officer, Frankford Arsenal, requesting comments on the probable weapon and ammunition design characteristics that could be causing or contributing to bullet breakup.[110/]

The Frankford Arsenal reply on 16 May 1966 indicated that the most probable cause, based on previous experiences, was the use of excessively worn barrels.[111/] Other possible causes were: inadequate or improper consolidation of tracer mix; breakage of tracer column during bullet resizing; or discrepancies in the bullet jacket.

Frankford Arsenal advised the Project Manager that further findings or evaluations of this malfunction would be provided.

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110. Ltr, Project Manager, 29 Apr 66, sub: SAWS Program/5.56mm Tracer Cartridge.

111. 1st Ind to Ltr, Project Manager, 29 Apr 66, sub: SAWS Program 5.56mm Tracer Cartridge.

There were apparently no further reports of bullet breakup until USATECOM tested the XM177E2 (CAR15) submachine gun in October and November 1967, when this malfunction was again observed in the firing of tracer ammunition loaded with WC 846 ball propellant.[112/] Confirmation of these data resulted in the decision by Frankford Arsenal to discontinue loading M196 cartridges with the ball (WC 846) propellant.

Armor-Piercing Cartridges

A requirement for developing a 5.56mm Armor-Piercing cartridge was proposed by the Commanding General, USAMUCOM, to the Commanding Officer, Frankford Arsenal, 12 October 1964.[113/] USAMUCOM pointed out that the inferior penetration performance of 5.56mm M193 ball cartridges at ranges exceeding 400 meters suggested that a 5.56mm armor-piercing cartridge might offer significant tactical advantages over the M193, particulary in weapons filling the squad automatic rifle and general machine gun roles. On the basis of MUCOM recommendation, Frankford Arsenal conducted a preliminary investigation of the feasibility of developing an armor-piercing cartridge for the M16 rifle. Advising USAMUCOM of the difficulty

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112. Msg (R131803), Project Manager, Rifles, 22 Dec 57, sub: Special Study of High Temperature Bore Fouling with Tracer Ammunition-USATECOM.

113. Ltr, Hq, USAMUCOM to CO, Frankford Arsenal, 12 Oct 64, sub: Investigation of 5.56mm Armor-Piercing Cartridges.

of meeting both lethality and penetration requirements at the same time, Frankford Arsenal submitted a plan to develop both an armor-piercing and a multipurpose cartridge. The U.S. Army Combat Developments Command Infantry Agency supported the need for an armor-piercing cartridge but requested further information concerning the proposed multipurpose cartridge. As a result of USACDC interest in the armor-piercing ammunition, the Commanding General, USAMUCOM, on 14 December 1965, directed the Commanding Officer, Frankford Arsenal, to prepare a draft Small Development Requirement (SDR) for a 5.56mm armor-piercing cartride for the M16 rifle,[114/] which was forwarded to USAMUCOM on 1 February 1966.[115/] USAMUCOM reviewed the proposal and, on the basis of the reduced lethality that would result from the armor-piercing round, terminated the SDR.

Grenade Cartridge, XM195

Rifle grenades were satisfactorily fired from the AR15 during 1959 through 1962 testing and demonstrations, using a grenade cartridge developed by Remington Arms Company. Drawings of the

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114. 1st Ind, HQ USAMUCOM to CO, Frankford Arsenal, 14 Dec 65, to Ltr, Project Manager, Rifles, 1 Nov 65, sub: Investigation of 5.56mm Armor-Piercing Cartridges.

115. 2d Ind, HQ Frankford Arsenal, 1 Feb 66, to Ltr, Project Manager, Rifles, 1 Nov 65, sub: Investigation of 5.56mm Armor-Piercing Cartridges.

grenade cartridge were furnished to Frankford Arsenal 7 August 1962, along with the statement that a substantial amount of additional development and test work would be required.

The Army did not establish initially a requirement for a grenade cartridge,[116] but Frankford Arsenal developed a plan in October 1963 to test the existing commercial caliber .223 grenade cartridge. The proposed characteristics specified that the cartridge propel the M28 rifle grenade to a range of at least 150 yeards and that the cartridge be suitable for launching rifle signals and flares.

Frankford Arsenal commented on these characteristics:

> It is estimated that a maximum range between 130 and 150 yards can be attained within the limiting parameter of the propellant capacity of the cartridge case. The effect of the gas pressure on the recoiling parts of the weapon might impose lower values from the viewpoint of weapon durability.[117]

The Project Manager at first wished to develop one cartridge that would serve as both a blank and a grenade cartridge.[118] Frankford Arsenal, however, pointed out, that because the characteristics of the two cartridges were different, some compromise would

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116. Msg TT00152, CG, USAWECOM, to CG, USAMUCOM, 3 Sep 63.

117. Ltr, Frankford Arsenal, 8 Aug 63, sub: Estimated Schedules for Preparation of Test Quantities of 5.56mm Special-Purpose Ammunition.

118. Ltr, Frankford Arsenal, 27 Sep 63, sub: Engineering Program for 5.56mm (AR15) Ammunition.

be necessary in the performance of each role of such a dual-purpose cartridge. The Project Manager agreed with Frankford Arsenal and work on separate cartridges proceeded.

Because of the developmental work on Colt's XM148 Grenade Launcher, which fired the 40mm grenade, the Army did not establish a requirement for a grenade launching round, although Frankford Arsenal did continue with developmental work. A limited quantity of grenade cartridges were procured for test purposes during the period 1963-66.

The Air Force requested USAMUCOM in January 1966 to prepare a technical data package for a grenade cartridge so that the Air Force could competitively procure a quantity to meet its requirements for launching all types of grenades from the M16 rifle.[119] USAMUCOM provided the data that it had developed.

During the Technical Coordinating Meeting in March 1967, representatives from the Department of the Army and Combat Developments Command were asked if there was any forecast on future requirements for the rifle grenade cartridge XM195.[120] The Army responded that the present Vietnam requirement was a limited

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119. Min, Rifle Technical Coordinating Committee Meeting, 12-13 Jan 66.

120. Min, Technical Coordinating Committee Meeting, 2 Mar 67.

one, based only on the use of rifle-launched pyrotechnic flares and signals as temporary expedients, and that there was no need to develop further the XM195 cartridge with a view toward standardization at that time. The Army reaffirmed this opinion at the 17 November 1967 meeting.

Limited quantities of XM195 grenade cartridges (500,000 rounds) have been procured to meet the requirements in Vietnam under the military specification MIL-C-60537(MU) dated 23 August 1967.

Two additional special types of cartridges have been developed for the M16 rifle - the blank cartridge and the reference cartridge. The history of the development and the distribution of the blank cartridge is contained in inclosure 4-3. Because the reference cartridge is used only in the production and acceptance phase of the rifle, its development and distribution history is not included here.

G. Conclusions

The technical data package for 5.56mm ammunition has never specified metallurgical requirements for the brass cartridge cases as was done for 7.62mm NATO ammunition. Although Army agencies, primarily Frankford Arsenal, have accumulated data over the years on which to provide a basis for the measurement and testing of cartridge case hardness, the establishment of mandatory controls over the producers was not considered necessary by the Project Manager.

The evaluation of cartridges produced by the Federal Cartridge Company was added evidence that compulsory specifications are needed.

Although the action taken by Frankford Arsenal and the Project Manager to remedy the deficiency in case hardness was correct, it was not timely. The fact that the manufacturers could not maintain case hardness standards was detected after tacical units had experienced malfunctions. In retrospect, the decision by the Project Manager to exercise minimum control over the ammunition producer was not wise; it has been determined since that combat capability suffered as a consequence. A visit by members of the M16 Review Panel to Remington Arms Company, Inc., and Twin Cities GOCO plants on 11-12 March 1968 has indicated a need for further implementing instructions for these controls. The Project Manager is taking appropriate action.

The bullet configuration of the M193 ball cartridge was a compromise between the several different designs available during the early period of Air Force and Army procurement 1961-64. The influence of Remington Arms in the decision is apparent in that as the initial producer of the commerical round, Remington Arms had a broader experience with small caliber ammunition than did the military services. It is understandable that Remington Arms adopted a bullet of its own design.

After completion of the Frankford Arsenal report the Project Manager in 1963 requested BRL to provide a solution to the bullet design problem. This problem has not yet been solved. It would appear, in retrospect, that all concerned discounted the possibility of redesign of a bullet which could permit a reduction of minimum muzzle velocity. However, until December 1966 there was never any real doubt expressed that the new IMR propellant could not be loaded in cartridges to meet the prescribed chamber pressure and velocity.

The development of the current specifications for primer sensitivity has been a gradual but deliberate process in which joint service testing of technical factors has played a major role. Experience to date, including that in Southeast Asia, supports the contention that the primer sensitivity limits that were established continue to be the most efficient available for compatibility between the M16 rifle and 5.56mm ammunition.

The overall primer development has failed, however, to standardize the basic design of the primer. Contrary to the requirements for 7.62mm ammunition, which specifies that the FA34 Primer is mandatory, no attempt has been made to standardize one type of primer for 5.56mm ammunition. At least three primers are being used in 1968 which could be responsible, in part, for inconsistencies in performance of ammunition from differenct producers and could contribute to the excessive fouling problem.

After production of the rifle and ammunition had commenced in quantity, any decision for a major change of either bullet design or barrel twist would have a major impact on logistics. If development and testing should establish a need to change the barrel twist, a barrel retrofit program would be required. A change in the ammunition could be accomplished by a phase-out of existing ammunition stocks by attrition and replenishment with ammunition of an improved bullet design.

Significant production of tracer ammunition loaded with ball propellant was allowed to continue when information was available in the Office of the Project Manager, Rifles which indicated that tracer ammunition loaded with IMR propellant provided the best interior ballistic match with ball cartridges.

A review of propellant history indicates that the availability of a suitable propellant and the willingness of cartridge producers to load with an approved propellant have influenced the Army's decision as to which propellant to accept rather than which propellant would make the weapon function properly.

The Project Manager, Rifles, has to date not complied with a December 1966 directive from the Commanding General, USAMC to "come to grips at an early date with the 3,250 f.p.s. velocity requirement" when the necessary information became available to him.

Since many tests have been conducted to determine the compatability of the M16 rifle and associated 5.56mm ammunition loaded with both propellants, it appears unusual to have recent tests conducted fr October 1967 through January 1968 prove finally that tracer ammunition must be loaded only with IMR propellant and that ball ammunition must be loaded with ball propellant.

Analysis of the Propellant Evaluation Criteria

A new propellant necessitates a wider variety of tests than are run for lot-by-lot acceptance of a propellant which has already been approved. All of the criteria which apply to lot-by-lot acceptance must be met also by any new propellant. In addition, certain characteristics of a propellant which are not tested for a lot-by-lot acceptance are studied in some detail when a new propellant is being considered for qualification. The first qualification tests always include extensive testing of smoke, flash, and barrel-erosion, all of which may vary among propellants of different compositions, but none of which vary much among lots of the same type. Generally included in the first tests also are recording and analysis of pressure-time records, taken at the chamber and at the gas port position, and long-term storage tests. This procedure is complicated and lengthy, and is not performed for lot-by-lot acceptance of an approved propellant.

The principal interior ballistic measurements included in lot-by-lot acceptance of approved propellants are chamber pressure, gas port pressure, and muzzle velocity. The chamber pressure is specified in terms of the maximum allowable average for the peak pressure (as determined by a copper-crusher gage) measured on a sample of 20 rounds. For a temperature of +70°F, this average must not exceed 52,000 pounds per square inch, according to the propellant specification for 5.56mm ammunition.[121] There is also a limit of 58,000 pounds per square inch on the mean observed chamber pressure; it serves to limit the variation in chamber pressure and thus guards against excessively high pressures from individual rounds of any given ammunition lot. The gas port peak pressure, measured by a copper-crusher gage, must be within the range of 15,000 pounds per square inch plus or minus 2,000 pounds, for the average of a 20-round ballistic sample. The muzzle velocity is controlled by specifying an instrumental velocity at a point 15 feet from the muzzle because accurate measurement of velocity exactly at the muzzle is very difficult. The specified instrumental velocity 15 feet from the muzzle is 3,250 plus or minus 20 feet per second,[122] at a temperature of 70°F for propellant used in 5.56mm M193 ball ammunition, and 3,200 plus or minus 20 feet per second for M196 tracer ammunition. Pressures and velocities are also specified for high and low temperatures of firing.

Although pressure time records are not taken for lot-by-lot acceptance of propellant, several factors implicitly control the variation in the pressure time curves of any lot which passes the

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121. Military specification, MIL-P-3984D, 31 May 67, with Amendment 1, 4 Oct 67, sub: Propellants for Small Arms Ammunition.

122. Not to be confused with the cartridge specification, which is 3,250 plus or minus 40 feet per second.

specified acceptance criteria. These controls include the following:

Maximum ordinate of the pressure time curve is limited by the chamber pressure criteria of the specification. (Maximum is 52,000 pounds per square inch by copper-crusher gage.)

Ordinate of the pressure time curve at the gas port position is controlled by the port pressure requirement of the specification. (Range is 15,000 plus or minus 2,000 pounds per square inch by copper-crusher gage.)

The area under the pressure time curve is closely limited (about plus or minus 1 percent) by the velocity requirement of 3,250 plus or minus 20 feet per second.

The base-line (total width) of the pressure time curve is accurately fixed by the length of the barrel. (Bullet travel is about 18 inches.)

The volume of the chamber (and the capacity for propellant) is limited by the design of the weapon and the cartridge case.

The expansion ratio (a measure of the change in volume occupied by the propellant as the projectile travels to the muzzle) is established by the chamber volume and the volume of the bore.

Within these parameters, which are controlled by a combination of specification requirements and fixed dimensions of the weapon and the cartridge, it is not possible for gross differences in the pressure time or pressure travel curves to exist among propellants.

It has been observed, however, that there are differences in performance of ammunition lots in the M16 even though gross differences do not exist in pressure time or pressure travel curves.[123] Investigations now in progress call for closer examination of pressure time records and of the movements of gun parts during the operating cycle of the weapon. (See Figure 4-2.) One object of these investigations is to establish the correlation between the pressure time curve and the operating characteristics of the gun, in order to define more accurately the factors that are involved in weapon-ammunition compatibility.

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123. Memo, AMCPM-RS, 22 Dec 65, sub: Feeder Submission for Letter to USAMUCOM; Memo, ACCSLOG (P&B)-M16, 7 Feb 68, sub: Meeting with Weapons System Evaluation Group.

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HISTORY OF CHANGES TO SPECIFICATIONS FOR 5.56MM BALL CARTRIDGES

	ORIGINAL, 1961 1/	1962 2/	1963 3/	MIL-C-9963 (USAF) 24 Jan 63 4/	MIL-C-9963A (USAF) 14 Apr 63 5/	MIL-C-9963C 27 Sep 63	Amendment 25 Mar 64	MIL-C-9963D 1 Jun 64 6/	Amendment 8 Feb 66	Amendment Dec 66
Cartridge	Made in accordance with drawing EX21492, 29 Jun 61 and suitable for use in AR15	Update drawing	Update drawing	Reference drawing 62C33759 (Ctg 5.64mm)				Reference drawing D10523632		
Case	Made of cartridge brass, nominal composition 70 percent copper, 30 percent zinc. Identified by standard commercial type head marking per drawing EX21491, 29 Jun 61.	Update drawing	Update drawing							
Bullet	Made in accordance with drawing EX21490, 29 Jun 61, with lead core and copper alloy jacket. Nominal weight is 55 grains.	Lead cored, 99.25 percent lead, 0.75 percent antimony, 38 grains; guilding jacket, 90 percent copper, 10 percent zinc, 17 grains; Reference to drawing EX25321, 27 Jun 62.	Update drawing							
Primer	Remington 44M(5067) primer		Update drawing	Not specified		Primer sensitivity established. No fire, 12 inch-ounces. All fire, 48 inch-ounces.	Requirement for 1,000-Round Fouling test for each preproduction lot of ammunition.		Calcium silicide eliminated as an acceptable chemical in primer composition	Additional requirement for 1,000-Round Fouling test each month.

1/ Remington Arms Specification for Cartridge, Cal .223, With 55-Grain Taper Heel Metal Case Bullet, 13 Jul 61.
2/ Remington Arms Specification for Cal .223, With 55-Grain Taper Heel Metal Case Cartridge, 1962.
3/ Remington Arms Specification for Cartridge, Cal .223, With 55-Grain Taper Heel Metal Case Ball, 1963.
4/ MIL-C-9963 (USAF), 24 Jan 63.
5/ MIL-C-9963A (USAF), 17 Apr 63.
6/ MIL-C-9963D, 1 Jun 64, With Amendment, 3, 2 Nov 66

Inclosure 4-2

History of Blank Ammunition

The history of the 5.56mm blank round began with the award of a contract to Remington Army, Inc., for production of a prototype round (XM200) on 24 November 1964. The chronological history of the blank round is shown below.

24 November 1964	Contract was awarded to Remington for prototype XM200.
26 February 1965	12,000 roudns were delivered to Springfield Armory for tests (first sample).
April 1965	First sample was rejected.
22 November 1965	Draft limited procurement action was submitted to USAMC.
14 February 1966	58,000 rounds (second sample) were delivered to Springfield Armory.
March 1966	Test was suspended pending design and testing of new buffer and closed-end flash suppressor. The results of substituting the new buffer and the closed-end flash suppressor had to be determined before proceeeding with the blank round.
2 May 1966	Limited procurement approval was received for 4,060,000 rounds.
1 July 1966	Design evaluation test was completed at Springfield Armory.
14 September 1966	Springfield Armory function test was completed.
23 September 1966	Springfield Armory shipped ammunition to U.S. Army Test and Evaluation Command (USATECOM) for Engineering Test and Service Test (ET/ST).

3 October 1966	Frankford Arsenal began preparation of technical data package.
11 October 1966	Work directive was issued to Frankford Arsenal for 4,060,000 rounds.
18 October 1966	Project Manager, Rifles, suspended blank ET/ST because of higher priority requirements.
2 November 1966	Frankford Arsenal completed technical data package.
13 January 1967	USAWECOM received increased approval of 2,000,000 rounds.
14 January 1967	Blank (without blank firing adaptor) safety test was initiated.
23 January 1967	Frankford Arsenal awarded contract to Twin Cities Army Ammunition Plant (TCAAP) for 4,060,000 rounds.
30 January 1967	Blank safety test completed.
24 March 1967	Project Manager, Rifles, requested ACSFOR to establish priority of issue for blank round.
11 April 1967	USAWECOM received increased limited procurement approval for 500,000 rounds.
26 April 1967	Request for 60.0 million rounds 5.56mm blank XM200 was submitted by USAWECOM to ACSFOR (this in addition to the 6.560 million rounds).
11 July 1967	ACSFOR approved 11.9 million for limited procurement and requested USAMC to type classify the round as Standard A subject to single shot mode.
July 1967	TCAAP began production of blank round.
1 August 1967	Frankford Arsenal submitted draft Standard A type classification action to USAMC.

9 August 1967	Strike halted production of blank round at TCAAP.
13 September 1967	Initial distribution of blank round made to USARPAC, USATECOM, and USA Combat Developments Command Experimentation Command (USACDCEC).
22 Deptember 1967	Program authority in amount of $2.9 million was received by USAWECOM to procure 55.7 million blank rounds.
30 September 1967	800,000 rounds were produced.
31 October 1967	700,000 rounds were produced.

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