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REVISED EDITION

TECHNICAL REPORT NO. 1

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M16 RIFLE SYSTEM RELIABILITY AND QUALITY ASSURANCE EVALUATION

by

O. P. Bruno, ARDC, Chairman
N. C. Krause, AMC
N. J. Miller, MUCOM
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Dr. P. B. Proctor, Consultant
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July 1968

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U.S. ARMY MATERIEL COMMAND
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A B E R D E E N R E S E A R C H A N D D E V E L O P M E N T C E N T E R

TECHNICAL REPORT NO. 1

JULY 1968

(Revised Edition)

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TECHNICAL REPORT NO. 1

M16 RIFLE SYSTEM
RELIABILITY AND QUALITY ASSURANCE
EVALUATION

ABSTRACT

At the direction of the Assistant Secretary of the Army (I&L), a comprehensive study of the reliability of the M16 Rifle has been accomplished. This report contains an extensive analysis of statistical and engineering data

(a) to estimate the reliability characteristics of the M16 Rifle system,

(b) to analyze factors affecting the reliability of the system (propellants, projectiles, ammunition lots, cyclic rate, cycle time, chrome chambering, cleaning, lubricating, mode of fire, magazines and environments), and

(c) to establish a sound technical base for other parts of the study indicated below.

The report also includes an analysis of the pertinent specifications for the rifles, magazines and ammunition, with particular emphasis on the validity of

(a) the parameters,

(b) the tests,

(c) the standards,

(d) the statistical sampling plans,

(e) the criteria and their compatibility with the requirements for a reliable rifle system.

Further, this report presents an evaluation of the Quality Assurance Program including the contractor's in-process quality control practices, materials controls, effectiveness of corrective actions, product improvement studies and statistical techniques for acceptance decisions on materials received from vendors.

In addition, there is an analysis of Department of Defense Quality Assurance policies and procedures and their implementations by the Army and the Defense Contract Administration Service.

As a result of this study, many findings and recommendations are made regarding the aforementioned areas. Some have been acted upon during the period of the study; action is being initiated on others and some will require further research and consideration before implementation.

Basically, the M16 Rifle is a reliable system. Although the M16 Rifle and the M14 Rifle are not comparable in design, weight, ballistic parameters, operating features and effectiveness, their reliability characteristics are approximately similar. The M16 Rifle is more reliable than the M14 Rifle during its initial life but it is slightly more sensitive to environmental effects and maintenance. Although the M16 Rifle currently is reliable the study indicates that there is appreciable potential for improvement.

SUMMARY OF PRINCIPAL FINDINGS AND RECOMMENDATIONS

FINDINGS

Rifle System Reliability

1. The M16 Rifle (with the new buffer) firing ball propellant considering all environments is more reliable than the M14 with respect to the number of rounds fired to the first failure. The M14 is more reliable when considering the number of rounds successfully fired between subsequent failures. (Chap. II, p. 8)

2. The M16 Rifle (with the new buffer) firing IMR propellant considering all environments is less reliable than either the M16 Rifle with ball propellant or the M14 Rifle. (Chap. II, p. 8)

3. The reliability of the M16 Rifle under WSEG-Panama conditions is significantly lower than the reliability which can be inferred from acceptance functioning test results. Gross estimates of reliability obtained from the five sources of available data differ appreciably. The average number of rounds per malfunction is as follows:

Function Firing Acceptance Tests	1922
Endurance Test	3040
Field Tests (troop training)	2293
WSEG - Panama	296
SEA	12400

(Chap. II, pp. 10, 11)

4. There are insufficient data available to estimate precisely the reliability of the latest configuration of the M16 Rifle, i.e., with new buffer, chrome chamber, firing various ratios of ball projectiles/ball propellant and tracer projectiles/IMR propellant in acceptance test or field environments. (Chap. II, p. 8)

5. The reliability of the M16 Rifle cannot be expressed precisely in simple form since the malfunction rate decreases with number of rounds to the next malfunction throughout the normal expected life of the rifle and the probability of failure, therefore, decreases as a function of the number of rounds fired. (Chap. II, p. 8)

6. The reliability of the M16 Rifle is affected significantly by cycle time, the type of propellant used, and the climatic environment. (Chap. II, pp. 28-32, 35-36)

7. Generally, a type of defect, such as "failure to feed," can be immediately clearable in some cases and not immediately clearable in others. With the exception of the WSEG study, data from other tests were normally identified by type of defect only and not according to seriousness; therefore, it was not possible to include seriousness in most of the analyses. (Chap. II, pp. 37-40)

8. The average number of rounds successfully fired to the first malfunction is greater than the average number of rounds successfully fired between the first and second malfunctions and generally the number of successful rounds decreases further between the second and third malfunctions, etc. (Chap. II, pp. 9, 12-24)

9. There is a strong relationship between cyclic rate and malfunction rate. It can be inferred that reliability can be improved significantly through better control and reduction of variation (spread) of cyclic rate. Actually, cycle time or sub-elements of cycle time should be controlled. However, currently, substantial data are available only on cyclic rate and data are not available for a study of cycle time. (Chap. II, pp. 29-32)

10. Both the M16 and M14 Rifles experience significantly higher failure rates while firing the first two rounds from a magazine. Data are not available to establish whether the higher malfunction rate is really related to the number of rounds fired from the magazine or the number of rounds fired in a series. Longer cycle times and related feeding and chambering failures may be the primary factors responsible for the higher failure rates. (Chap. II, pp. 33-34)

11. Available data appear to be insufficient to establish a cleaning schedule which will minimize the number of malfunctions. Cleaning and lubrication increases the cyclic rate significantly by approximately 74 rounds per minute. (Chap. II, pp. 34-35)

12. Firings during troop training at Ft. Polk indicate that about 78% of reported malfunctions were attributable to inadequate cleaning (rifles with non-chrome chambers were used). (Chap. II, p. 35)

13. Preliminary data received from SEA indicate appreciably higher reliability than can be inferred from other sources, but this involves the questionable assumption that all malfunctions are reported in SEA. (Chap. II, p. 11)

Specifications

1. The ammunition and rifle specifications (current and drafts to 23 Apr 68) require revisions which have been addressed in the recommendations contained in this report. (Chap. II, pp. 41-44)

2. The current M16 Rifle specification does not provide definitive reject/accept criteria, thus permitting continuous resubmission of rifles for acceptance. (Chap. II, pp. 41-43)

3. A basis for the assessment of rifle reliability and the related acceptance of rifles using data generated by the function firing test is available, but is not used for this purpose. (Chap. II, p. 42)

4. The proposed mission performance test (in the 23 Apr 68 draft specification) may not be required if data generated from the function firing test are used for purposes of assessing rifle reliability and acceptability of the rifle lot. (Chap. II, p. 42)

5. Acceptance of magazines is based upon requirements established by the contractor which may not be stringent enough to be compatible with Army quality requirements. The statistical sampling plan should be changed to provide better discrimination between acceptable and unacceptable products.

6. The accuracy (dispersion) requirements and criteria for the M16 Rifle are more severe than those for the M14 Rifle. (Chap. II, p. 43)

Quality Assurance Program

1. Currently used Inspection Instruction Sheets, since preparation in 1963, have not been subjected to a thorough review to deter ine proper classification of defects and assignment of Acceptable Quality Levels. (Chap. II, p. 45)

2. The contractor's quality control system requires improvement in light of the high rejection rate and the relatively high amount of Government inspection which is performed. (Chap. II, pp. 46-47)

3. There are no provisions currently for a periodic system test of the M16 rifle/ammunition combination. (Chap. II, p. 48)

QA Policies and Procedures

1. The Army and the DCAS, in principal, are generally complying with DoD quality assurance policies. (Chap. II, p. 51)

2. Techniques and methods for motivation of the contractor to produce better quality are not adequate. (Chap. II, pp. 51-52)

3. Specification MIL-Q-9858 does not provide sufficient or effective motivation. It is also difficult to monitor well enough to assure contractor compliance with specification requirements. (Chap. II, pp. 51-52)

4. Procedures for determining the proper balance between the amount of Government product verification inspection and evaluation of the contractor's quality assurance systems may be desirable. (Chap. II, p. 53-54)

5. The Army may be over specifying Procurement Inspection "Type A" requirements. This may be the result of share responsibility between the Army and DCAS for product quality. (Chap. II, pp. 52-54)

6. The Army's practice of assigning Acceptable Quality Levels and classifying characteristics as to degree of seriousness, major or minor for component parts (repair parts), is not at variance with DoD policy. (Chap. II, pp. 54-56)

RECOMMENDATIONS

Specifications and Contract - Rifle

1. Devise and specify controls over cycle time or sub-elements thereof in addition to cyclic rate. (Chap. II, pp. 31, 41)

2. Examine the effect of ammunition lot on cycle time and effect the specific controls which are necessary. (Chap. II, p. 31, 41)

3. Effect a form of reliability assessment and establish acceptance criteria for rifle lots through the use of large sample information (approximately 30,000 rounds) available from functioning tests. (Chap. II, pp. 42-43)

4. Increase the sample size (number of rifles) of endurance tests and include a test of endurance of magazines. (Chap. II, p. 43)

5. Increase the discriminating power of the sampling plan for acceptance testing of magazines. (Chap. II, p. 43)

6. Consider the utilization of both tracer and ball ammunition in the conduct of rifle acceptance tests. (App. III, p. III-5)

7. Consider a functional test (flow meter) of the gas tubes of the rifle. (App. III, p. III-2)

8. Eliminate the administrative requirements and information (which are properly a part of the contract) from Army specifications (M16 and others) to comply with ASPR and standardization requirements. (App. III, p. III-4)

Specifications - Ammunition

1. Consider a revision of the AQLs for major defectives and their corresponding sampling plans to assure compatibility with the rifle system reliability. (Chap. II, p. 44)

2. Add a provision to control cycle time. (Chap. II, p. 44)

3. Establish specification requirements and tests for cyclic rate. (Chap. II, p. 44)

4. Establish specification requirements for fouling in terms of a measurable characteristic, with appropriate test procedures and methods. (Chap. II, p. 44)

5. Re-examine the propellant specification requirements, such as particle size, chemical composition, burning rate and pressure time relationships, for possible improvement of fouling characteristics. (Chap. II, p. 44)

QA Program

1. Discontinue the practice of applying AQLs and sampling plans to each individual characteristic of an item having multiple characteristics in each of the major and minor defect categories. (Chap. II, p. 45; and App. IV, Sect. XXIII, p. IV-195)

2. Institute more effective in-plant quality control practices. (App. V; Chap. II, pp. 45-46)

3. Review the Inspection Instruction Sheets with respect to correct classification of defects and AQLs. (Chap. II, p. 45)

4. Pursue product improvement recommendations regarding:

a. Reduction of variation in cycle time.

b. Determination of optimum cycle time. (Chap. II, p. 44)

5. Institute a periodic sampling and testing of new and stockpiled rifles/magazines and ammunition to:

a. Assess system performance.

b. Detect the effects of engineering or other changes on performance, and

c. Form a base for prompt corrective actions. (Chap. II, p. 48)

6. Devise and implement a rifle retirement program.

7. Develop methods to protect against a resubmission of rejected products without effective corrective actions. (Chap. II, p. 49)

QA Policy and Practices

1. Explore procedures for the effective implementation of DoD policy toward improvement of the contractor's motivation in developing and maintaining sound quality assurance programs. (Chap. II, pp. 51-52)

2. Develop improved criteria for establishing the proper balance between Government product verification inspection and evaluation of the contractor's quality assurance system. (Chap. II, p. 53-54)

3. Limit the contents of Quality Assurance Letters of Instruction to specific and pertinent mandatory Government product inspection requirements essential to the quality of the product being procured. (Chap. II, p. 52-53)

4. Use DoD Specification MIL-I-45208, "Contractor Inspection System," in lieu of DoD Specification MIL-Q-9858, "Contractor Quality Program," for procurement of the M16 Rifle for subsequent contracts. (Chap. II, p. 51; and App. VII, p. 3)

CONTENTS

CHAPTER I
INTRODUCTION

A. <u>BACKGROUND</u>

1. Initiation of Study

a. The Assistant Secretary of the Army (I&L), conducted a preliminary review of various aspects of the Army quality assurance program for the M16 Rifle. This cursory review indicated shortcomings in the specifications, the general application of statistical techniques, and other parts of the quality assurance program. In a memorandum to Chief of Staff, Army, 8 April 1968, ASA(I&L) recommended that a task force be established to perform the following functions:

(1) Conduct analyses of all available and pertinent test data to provide a good understanding of the current quality of M16 Rifles, ammunition, and magazines.

(2) Prepare a critique of the procedures, specifications, and contractual provisions which constitute the current quality assurance program.

(3) Prepare a set of suggested revisions to the appropriate elements of the quality assurance program.

b. ASA(I&L) further indicated that this project would serve to broaden the application of appropriate statistical analyses and techniques to the Army's Small Arms Program and other programs.

c. DCSLOG on 16 April 1968 requested U. S. Army Materiel Command to establish a task force and on a priority basis accomplish the objectives cited above.

2. Supplemental Information

a. ASD(I&L), in discussion with the Office of the Deputy Undersecretary of the Army (Operations Research) on 8 April 1968, raised certain questions regarding the Army's quality assurance program in general, and as applied to the M16 Rifle program. Specific areas addressed were:

(1) Army implementation of DoD procurement policies outlined in Section XIV of the Armed Services Procurement Regulations (ASPR).

(2) Army application of statistical methodology in development of contract specifications.

(3) Army (AMC)/DCAS system interface.

(4) Relationship between the Quality Assurance Representative (QAR) and Project Manager-Rifles.

b. Memorandum from ASD (I&L) to The Assistant Secretary of the Army (I&L), 23 April 1968, inclosed a list of questions originally developed for an OSD study of the M16 Rifle. An understanding was reached that the Army study, as a minimum, would investigate the elements identified in Phases I and II of the memorandum.

B. STUDY OBJECTIVES

1. The primary objectives of this study are threefold:

a. Analyze available data pertinent to the M16 Rifle program and develop a baseline for the assessment of the current quality and reliability of the rifle/magazine and ammunition.

b. Examine the procedures, specifications and contractual provisions forming part of the quality assurance program and provide a critique as to their effectiveness.

c. Develop a set of suggested revisions to the appropriate elements of the quality assurance program to improve its effectiveness.

2. As an added task the Ad Hoc Study Group addressed specific questions developed by the Assistant Secretary of Defense. These questions were designed to identify improvements that could be made in current contracts and in the Government procurement quality assurance function. The findings of this study are reported in Appendix VI.

C. STUDY CONCEPT.

1. The study concept was developed basically to effect the objective of a comprehensive examination of the most pertinent areas relative to the aforementioned assignment. Specifically, the following areas were addressed:

a. DoD policy.

b. Army, Defense Contract Administration Services, (DCAS), and contractor implementation of policy.

c. Analysis of the Colt contract, specifications and procedures for the rifle/ammunition system.

d. Quality assurance programs.

e. Analysis of data from in-process inspection, acceptance inspections, engineering investigations, functioning tests, quality assurance reports, proving ground tests, user and field tests including the Weapons Systems Evaluation Group Study.

2. Fundamental to the study concept has been the philosophy of strict objectivity and disassociation from assessment of blame or the engendering of recriminations. Rather, the specific purpose has been to assess and constructively identify pertinent areas for improvement.

3. Competent, knowledgeable representation on the committee was obtained from agencies which could contribute prompt, factual information on the many areas which had to be addressed. To counterbalance any possible tendency toward parochialism or departure from objectivity, a chairman was appointed who had no basis for bias. Accordingly, the committee was chaired by a representative of the Army Research and Development Center, with committee representation from the U. S. Army Materiel Command, U. S. Army Weapons Command, U. S. Army Munitions Command, and Defense Contract Administration Services. These individuals, having prior association with the M16 Rifle Program (as one of many other assignments) were in a position to furnish or obtain prompt

information which was required for the study and to discuss in depth various facts and points of view. The matters pertaining to policy, procedure, philosophy, history, and other pertinent matters were given a critical review by the chairman and the committee as a whole. The object of the critical review was not compromise, but rather a search for knowledge and critical scrutiny to ascertain facts and solutions to the pertinent items of the study. The critique of the specifications was accomplished by the committee as a whole with the statistical analysis being conducted by the chairman and personnel of the Surveillance and Reliability Division (S&RD) of the Aberdeen Research and Development Center.

4. The analysis of the reliability and performance of the M16 Rifle/Ammunition System was conducted by the S&RD personnel using data generated from several sources including the Weapons Systems Evaluation Group, U. S. Army Test & Evaluation Command, Frankford Arsenal, Colt Industries, Inc., Twin Cities Ammunition Plant, and Defense Contract Administration Services in Hartford, Connecticut.

5. Throughout the study liaison was maintained with various agencies, committees, and study groups related to the M16 Rifle System. The findings, suggestions, and ideas generated during the study were made accessible to the aforementioned organizations in order that voluntary, prompt action could be taken to use the work of the committee to initiate work or take corrective actions. The latter was effected principally through the representatives of the committee, their liaison with their normal associations, and job assignments.

6. Two consultants, one from industry and one from a university, were engaged to address specific areas of the study and to provide a general review.

7. The contents of the report do not necessarily represent entirely views of each individual member of the committee nor the official position of their parent organization. Although there was general agreement among members on almost all matters, the contents reflect the findings and views of the chairman.

CHAPTER II

PRINCIPAL FINDINGS AND RECOMMENDATIONS

The principal findings and recommendations of this study are summarized under four major headings:

A. STATISTICAL ANALYSIS OF DATA

B. ANALYSIS OF SPECIFICATIONS

C. ANALYSIS OF QUALITY ASSURANCE PROGRAM

D. ANALYSIS OF QUALITY ASSURANCE POLICIES AND PROCEDURES

The intent is to present sufficient information in this chapter for the reader to obtain a good grasp of the principal findings and recommendations with the option of studying the material in the appendices where additional detail is desired.

CHAPTER II

A. STATISTICAL ANALYSES OF DATA

1. Introduction. The object of the statistical analysis was to conduct an independent evaluation of pertinent data to establish a base for:

a. A better understanding of the performance of the M16 rifle/ammunition system and factors which affect its reliability.

b. Analysis of specifications, the parameters which are controlled, and the standards and statistical criteria which are used.

c. Recommendations to improve the quality assurance programs for the M16 rifle/ammunition system and related weapon system programs.

d. Recommendations to improve the reliability of the M16 rifle/ammunition system.

Over the past few years, a large number of firing tests have been conducted using the M16 Rifle. These tests were conducted by various agencies for different purposes and the results were analyzed and reported separately. Generally, these tests were performed with new rifles under controlled environmental conditions with the notable exception of a recent test conducted by the Weapon Systems Evaluation Group (WSEG). The latter test was conducted in Panama during January 1968 under environmental conditions simulating, as closely as possible, those existing in South Vietnam.

The purpose of this study was to re-analyze the data available from each of the tests primarily for the purpose of obtaining additional information. Where it was felt that the testing agency did not use the most efficient statistical tests, did not conduct the analysis in sufficient detail, or omitted areas that should be investigated, further analyses were conducted for this study.

The final and most important objective of this task was to assess the data from each of the above mentioned tests in light of the information obtained from all studies and to produce, for the first time, one overall statistical analysis. The summary of results is given in this chapter. The detailed analyses are given in Appendix IV.

2. Rifle System Reliability Analyses.

a. Field data from the WSEG test.

(1) The reliability of the M16 and M14 weapon systems cannot be expressed in simple form. It was found to be dependent upon numerous factors, such as, propellant type, rifle type, mode of fire, and environment (see Appendix IV, INTRODUCTION). Further, the failure rate is generally not constant, therefore, the probability of failure differs for each round fired in the rifle.

(2) There is not sufficient data to provide reliability functions for each of the conditions given above. Therefore, estimates are provided only for rifle reliability when firing rounds with the two types of propellant, combining data over all other conditions and for each type of propellant at each environment. The estimates based on data segregated by type of propellant are given for the number of rounds to first failure and the number of rounds between subsequent failures, using all corresponding recorded malfunctions (reference Figure II-D through Figure II-F, pp. 12-14, Table II-B through Table II-E, pp. 15-18). The estimates under different environmental conditions are given for the rifle's first experience in a particular environment and because of data limitations, only for the number of rounds to first failure (reference Figure II-J through Figure II-L, pp. 19-21; Table II-G through Table II-I, pp. 22-24). The most significant findings are the following:

(a) The M16 Rifle, with the current buffer, firing ball propellant, over all environments was slightly more reliability than the M14 Rifle with respect to the number of rounds successfully fired to the first failure. However, the M14 Rifle was more reliable when considering the number of rounds successfully fired between subsequent failures.

(b) The M16 Rifle, with the current buffer, firing IMR propellant, over all environments was less reliable than either of the above with respect to both the number of rounds successfully fired to the first failure and the number of rounds successfully fired between subsequent failures.

(c) The reliability function could be considered exponential only for the number of rounds to first failure when firing ball propellant in the M16 Rifle. In all other cases, the distribution took the form of a Weibull distribution with the β parameter being less than one, thus indicating a decreasing failure rate for these cases. A decreasing failure rate implies that the greatest probability of a failure occurs on the first round or the first round after a failure has occurred and that this probability decreases on each succeeding round until another failure occurs. The failure rate when firing IMR propellant in the M16 Rifle decreases much faster than when firing ball propellant in either the M16 or M14 Rifle.

(d) The M16 Rifle, using either type of propellant, was more reliable in the rain forest than in any other test environment (salt water, spray and sand; swamp and mud; upland, dust). The M14 Rifle was less reliable in the rain forest than in any other environment; it was most reliable in the swamp environment.

(e) The M16 Rifle, firing IMR propellant, was less reliable in the swamp environment than in any other environment; and the M16, firing ball ammunition, was less reliable in the beach environment than in any other environment. (It should be recalled that the reliability estimates by environment are based on the time to first failure only.)

b. Endurance acceptance test data.

(1) It appears that the performance of ball and IMR propellant with respect to reliability does not differ during endurance acceptance testing, although a wide difference was noted in the WSEG test. However, an important factor that should be considered when comparing the reliability estimates is the effect of the new buffer. The estimates obtained for ball propellant in the endurance test were for firings of rifles assembled, for the most part, with the new buffer, whereas the estimates for IMR propellant were obtained from firings of rifles assembled predominantly with the old buffer. In the WSEG study, all rifles were assembled with the new buffer.

(2) Under field conditions, such as those in the WSEG study, the reliability of the rifle, based on estimates obtained under the conditions described above, is reduced for both propellant types. The reduction in reliability, when firing rounds assembled with IMR propellant from rifles having the new buffer, is large and immediate, whereas the reduction in reliability, when firing rounds assembled with ball propellant from rifles having the new buffer, is small for the first few hundred rounds and approaches that for IMR propellant after approximately 3,000 rounds (reference Figure VIII-H and Figure VIII-I, Table VIII-B, pp. 25-27).

(3) The reliability, when firing ball cartridges with ball propellant and ball cartridges with IMR propellant, is reduced under field conditions. The reduction in reliability for IMR propellant is large and immediate, whereas that for ball propellant is small for the first few hundred rounds and then approaches that for IMR propellant after approximately 3,000 rounds. These results tend to indicate that current endurance acceptance testing procedures do not produce results that represent the rifle in the field.

c. Gross estimates of reliability.

(1) Function firing tests, endurance tests, field tests, and the WSEG tests provided data from which gross estimates of reliability were obtained. It is emphasized that these estimates are gross estimates since the failure rate for rifles is not constant throughout the life of the weapons.

(2) The estimates from the function firing tests were obtained from data from firings of ball projectiles with ball propellant from accepted and rejected rifles. Estimates obtained from the endurance tests are based on the firing of ball projectiles with ball propellant from rifles which passed the function firing tests and were adjusted by the contractor during the test. The field test estimates were obtained from firings of ball and tracer projectiles with ball and IMR propellant combined in troop training exercises at Fort Polk, Fort Jackson, and Fort McClellan. Estimates from the WSEG tests were

based on the firing of approximately 5,700 rounds, including ball and tracer projectiles with ball and IMR propellants, from each rifle under field type conditions. The followirg table gives estimates of the number of malfunctions per thousand rounds and the average rounds per malfunction, considering all types of malfunctions combined for each source of data.

GROSS ESTIMATES OF RELIABILITY
(ALL TYPES OF MALFUNCTIONS COMBINED)

	NO. MALF/ 1,000 RDS.	AVERAGE* RDS/MALF
Function Firing in Acceptance	.520	1,922[1]
Endurance Test	.329	3,040[1]
Field Tests (Data Collection Program)	.436	2,293[2]
WSEG - Overall	3.383	296[2]
WSEG - Ball Prop.	1.955	512
WSEG - IMR Prop.	4.812	208
SEA	.081	12,400

1 - Ball projectile with ball propellant (tests conducted in 1967 and 1968).

2 - Ball and tracer with ball and IMR propellant combined.

*These are gross estimates since the failure rate is not constant.

<u>Function test</u> results include data on both accepted and rejected rifles combined.

<u>Endurance test</u> results are based on rifles which passed the function test and were adjusted by the contractor during the test.

<u>Field tests</u> - Troop training exercises (Ft. Polk, Ft. Jackson, Ft. McClellan).

<u>WSEG</u> - Approximately 5,700 rounds/rifle.

<u>SEA</u> - It is likely that not all malfunctions were reported.

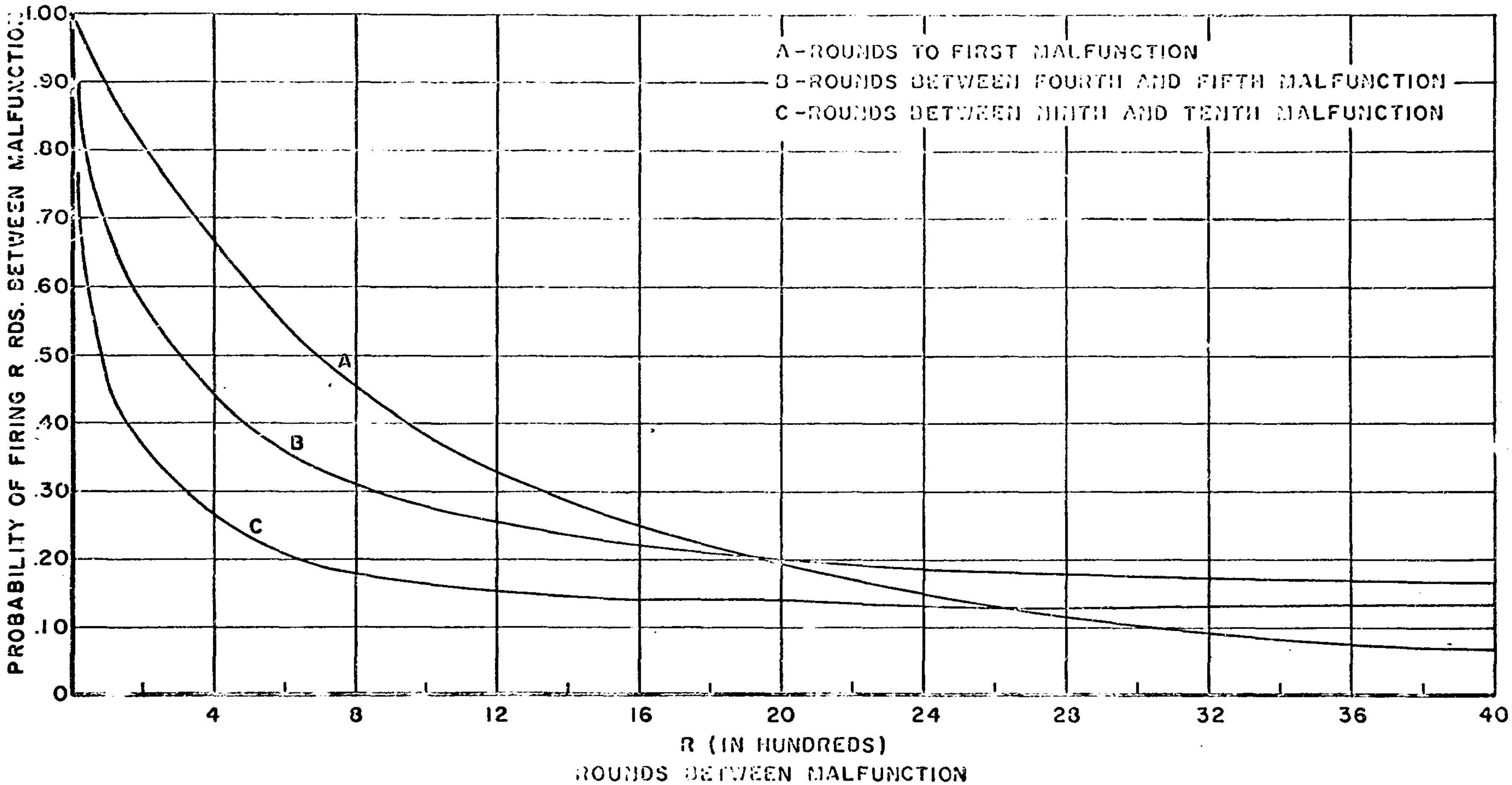

Figure II-D -M16 Rifle Firing Ball and Tracer Rds. w/Ball Prop.
Reliability Estimates of Rounds to or Between Malfunction.

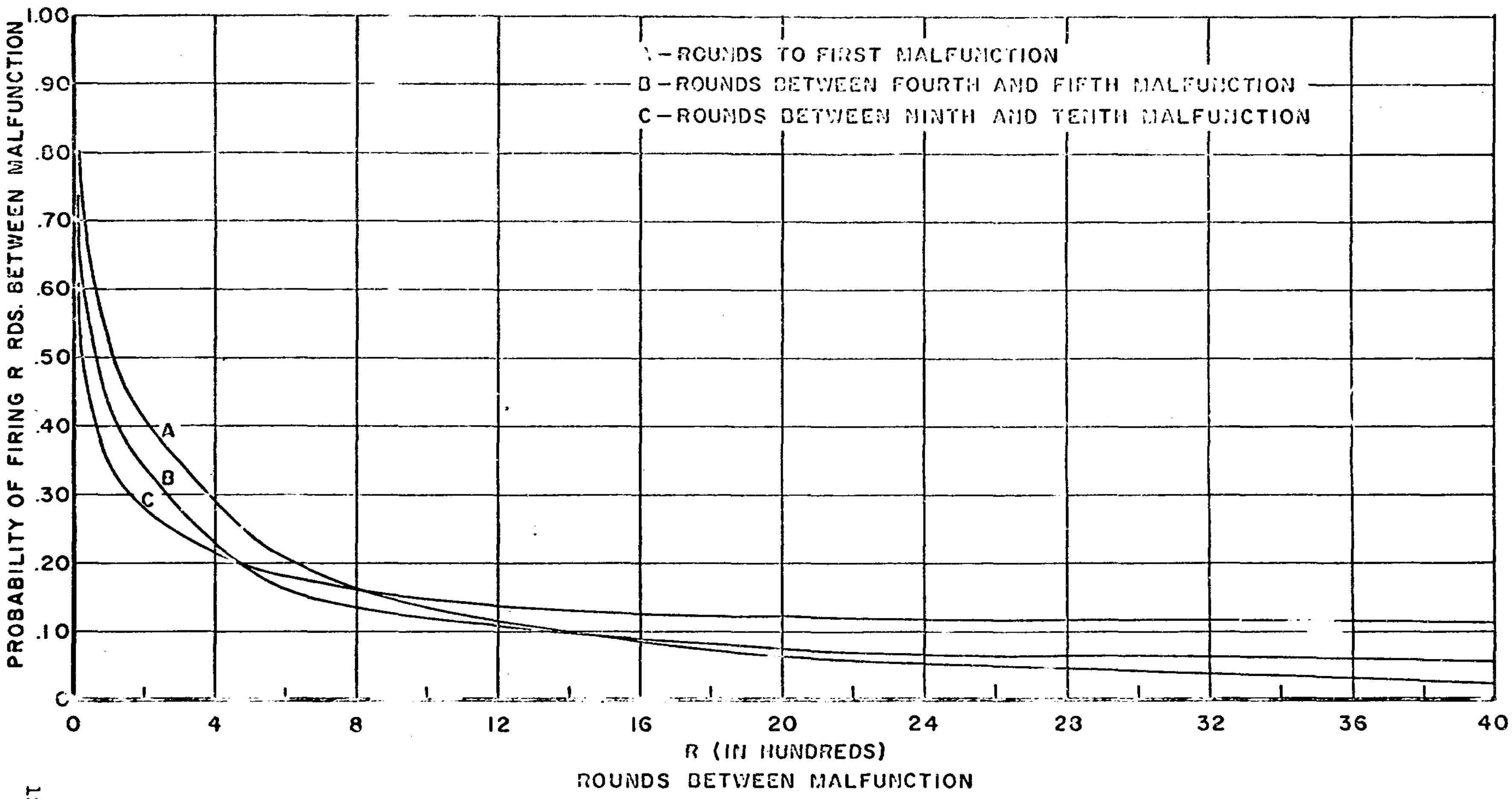

Figure II-E -M16 Rifle Firing Ball and Tracer Rds. w/IMR Prop.
Reliability Estimates of Rounds to or Between Malfunction.

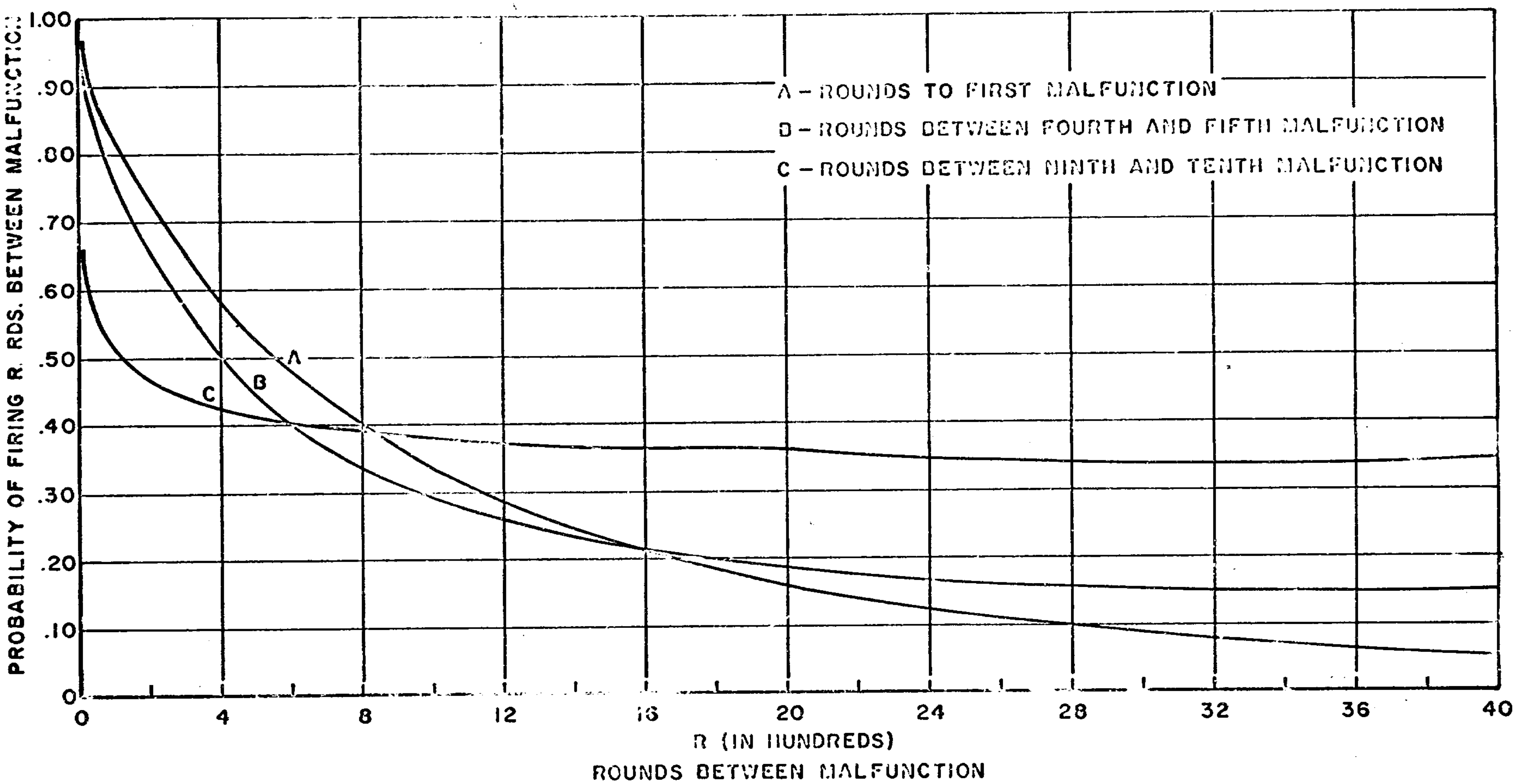

Figure II-F. M14 Rifle Firing Ball and Tracer Rds. w/Ball Prop. Reliability Estimates of R Rounds to or Between Malfunction

TABLE IIB

M16 Rifle Firing Ball and Tracer Rds. w/Ball Prop.
Reliability Estimates of Firing R Rounds
Between Malfunction

Prob. of Firing R Rds.	No. of Rounds					
	1	10	50	100	500	1000
To 1st Malfunction	.9985	.9868	.9422	.8925	.5998	.3778
Between 1st & 2nd Malf.	.9731	.9031	.7740	.6835	.3877	.2483
Between 2nd & 3rd Malf.	.9840	.9290	.8083	.7150	.3864	.2326
Between 3rd & 4th Malf.	.9732	.8943	.7421	.6360	.3201	.2014
Between 4th & 5th Malf.	.9740	.9018	.7669	.6735	.3903	.2769
Between 5th & 6th Malf.	.8641	.7037	.5270	.4388	.2428	.1785
Between 6th & 7th Malf.	.9531	.8384	.6485	.5303	.2306	.1377
Between 7th & 8th Malf.	.9224	.7898	.6103	.5096	.2650	.1826
Between 9th & 10th Malf.	.9203	.7692	.5636	.4536	.2233	.1677
Between 11th &12th Malf	.8363	.6683	.5008	.4235	.2668	.2210
Between 13th & 14th Malf.	.7933	.5964	.4097	.3269	.1671	.1229

TABLE IIC

M16 Rifles Firing Ball and Tracer Rds. w/IMR Prop.
Reliability Estimates of Firing R Rds.
Between Malfunction

Prob. of Firing R Rds.	No. of Rounds					
	1	10	50	100	500	1000
To 1st Malfunction	.9263	.7974	.6167	.5117	.2393	.1994
Between 1st & 2nd Malf.	.8485	.6530	.4393	.3378	.1383	.0863
Between 2nd & 3rd Malf.	.8887	.7167	.5032	.3919	.1485	.0776
Between 3rd & 4th Malf.	.8684	.6815	.4634	.3547	.1288	.0668
Between 4th & 5th Malf.	.9021	.7445	.5425	.4345	.1907	.1167
Between 5th & 6th Malf.	.7945	.5960	.4042	.3174	.1442	.0946
Between 7th & 8th Malf.	.8413	.6510	.4462	.3478	.1447	.0864
Between 9th & 10th Malf.	.7995	.6078	.4263	.3459	.1916	.1496
Between 12th & 13th Malf.	.6822	.4804	.3150	.2453	.1092	.0676
Between 14th & 15th Malf.	.8440	.6604	.4626	.3666	.1638	.1026

TABLE IID

M14 Rifles Firing Ball and Tracer Rds. w/Ball Prop.
Reliability Estimates of Firing R Rds.
Between Malfunctions

Prob. of Firing R Rds.	No. of Rounds					
	1	10	50	100	500	1000
To 1st Malfunction	.9940	.9662	.8911	.8236	.5221	.3360
Between 1st & 2nd Malf.	.9835	.9293	.8137	.7250	.4078	.2506
Between 2nd & 3rd Malf.	.9034	.7740	.6150	.5262	.3081	.2221
Between 3rd & 4th Malf.	.9911	.9616	.8961	.8434	.6306	.5010
Between 4th & 5th Malf.	.9897	.9474	.8433	.7573	.4389	.2910
Between 5th & 6th Malf.	.9922	.9504	.8306	.7253	.3502	.2160
Between 7th & 8th Malf.	.8680	.7326	.5886	.5166	.3486	.2870
Between 9th & 10th Malf.	.7837	.6591	.5562	.5115	.4183	.3864
Between 11th &12th Malf.	.9705	.8651	.6544	.5190	.2368	.1922
Between 12th & 13th Malf.	.9676	.8819	.7296	.6292	.3505	.2529
Between 13th & 14th Malf.	.8674	.7542	.6386	.5803	.4367	.3774
Between 14th & 15th Malf.	.7734	.6000	.4568	.3992	.2990	.2745

TABLE IIE

RIFLES FIRING BALL AND TRACER ROUNDS

COMPARISON OF RELIABILITY ESTIMATES*

Prob. of Firing R Rds.		Number of Rounds 1	10	50	100	500	1000
To 1st Malfunction	M16-BALL	.9985	.9868	.9422	.8925	.5998	.3778
	M16-IMR	.9263	.7974	.6167	.5117	.2393	.1994
	M14	.9940	.9662	.8911	.8236	.5221	.3360
Between 1st & 2nd Malf.	M16-BALL	.9731	.9031	.7740	.6835	.3877	.2483
	M16-IMR	.8485	.6530	.4393	.3378	.1383	.0863
	M14	.9835	.9293	.8137	.7250	.4078	.2506
Between 2nd & 3rd Malf.	M16-BALL	.9840	.9290	.8083	.7150	.3864	.2326
	M16-IMR	.8887	.7167	.5032	.3919	.1485	.0776
	M14	.9034	.7740	.6150	.5282	.3081	.2221
Between 3rd & 4th Malf.	M16-BALL	.9732	.8943	.7421	.6360	.3201	.2014
	M16-IMR	.8684	.6815	.4634	.3547	.1288	.0668
	M14	.9911	.9616	.8961	.8434	.6306	.5010
Between 4th & 5th Malf.	M16-BALL	.9740	.9018	.7669	.6735	.3903	.2769
	M16-IMR	.9021	.7445	.5425	.4345	.1907	.1167
	M14	.9897	.9474	.8433	.7573	.4389	.2910
Between 5th & 6th Malf.	M16-BALL	.8641	.7037	.5270	.4388	.2428	.1785
	M16-IMR	.7945	.5960	.4042	.3174	.1442	.0946
	M14	.9922	.9504	.8306	.7253	.3502	.2160
Between 7th & 8th Malf.	M16-BALL	.9224	.7898	.6103	.5096	.2650	.1826
	M16-IMR	.8413	.6510	.4462	.3478	.1447	.0864
	M14	.8680	.7326	.5886	.5116	.3486	.2870
Between 9th & 10th Malf.	M16-BALL	.9203	.7692	.5636	.4536	.2233	.1677
	M16-IMR	.7995	.6078	.4263	.3459	.1916	.1496
	M14	.7837	.6591	.5562	.5115	.4183	.3864

*These estimates are based on WSEG data.

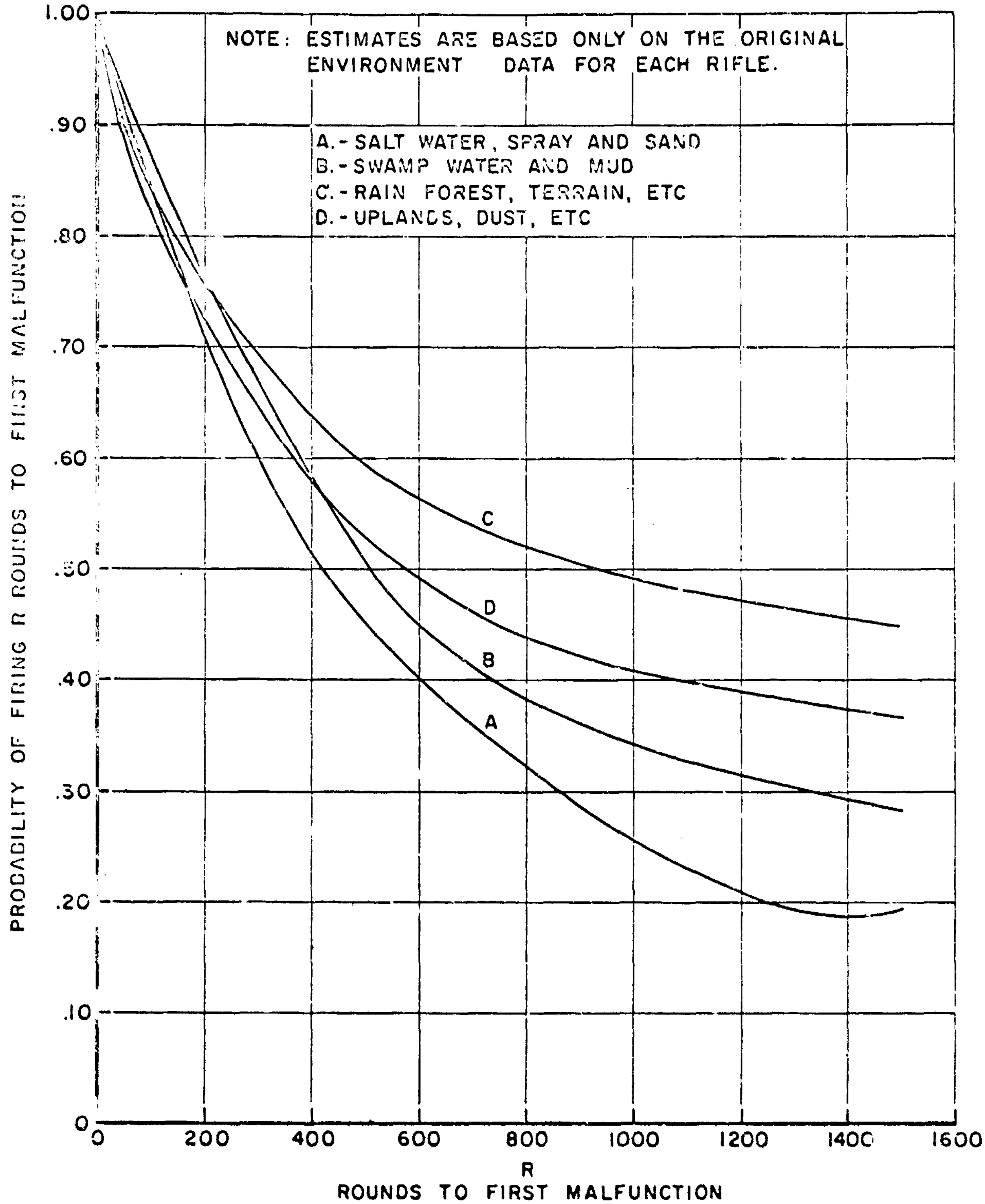

Figure II-J-M16 Rifle Firing Ball and Tracer Rds w/Ball Prop. Reliability Estimates of Firing R Rds to First Malfunction by Environments.

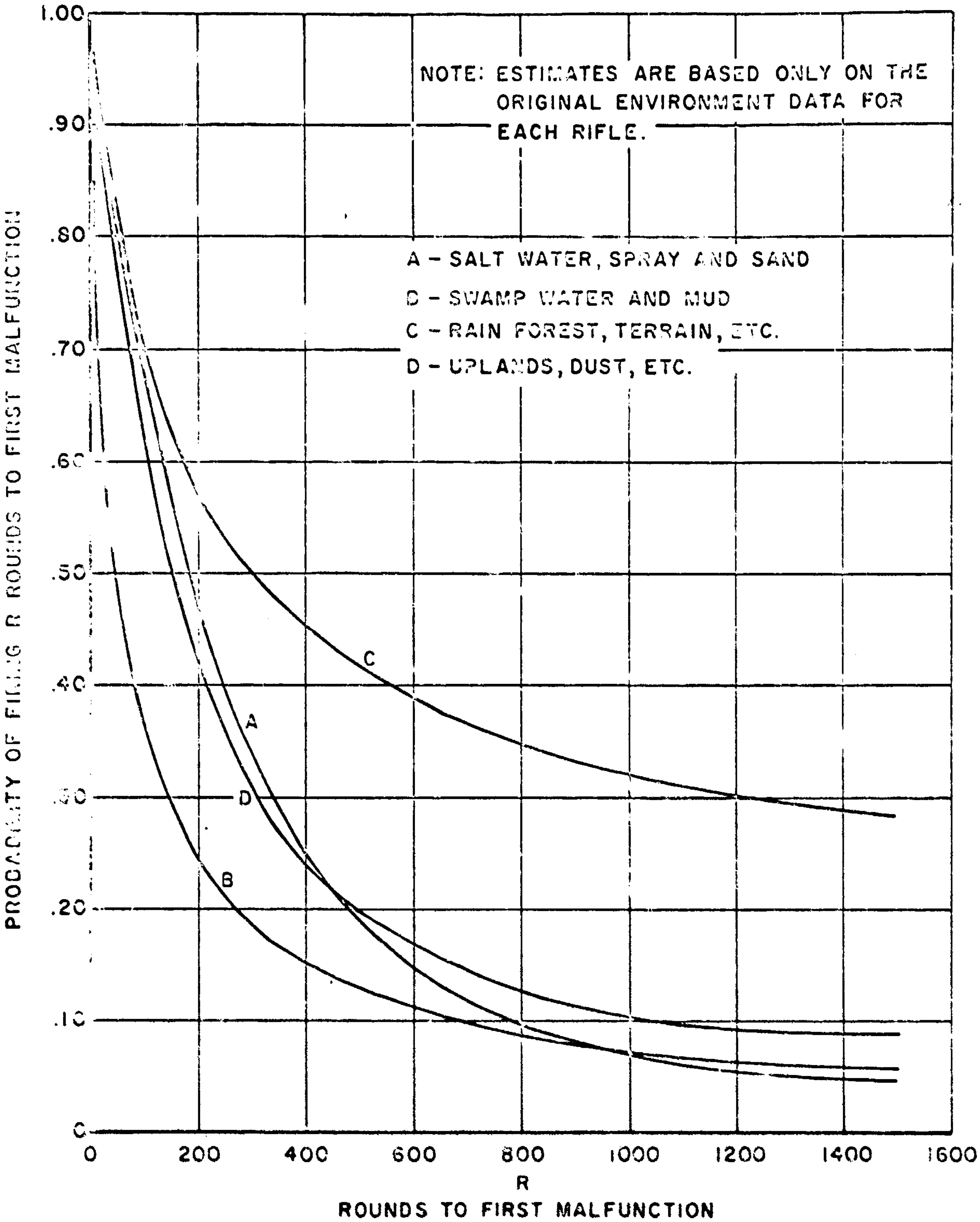

Figure II-K-M16 Rifle Firing Ball and Tracer Rds w/IMR Prop. Reliability Estimates of Firing R Rds. to First Malfunction by Environments.

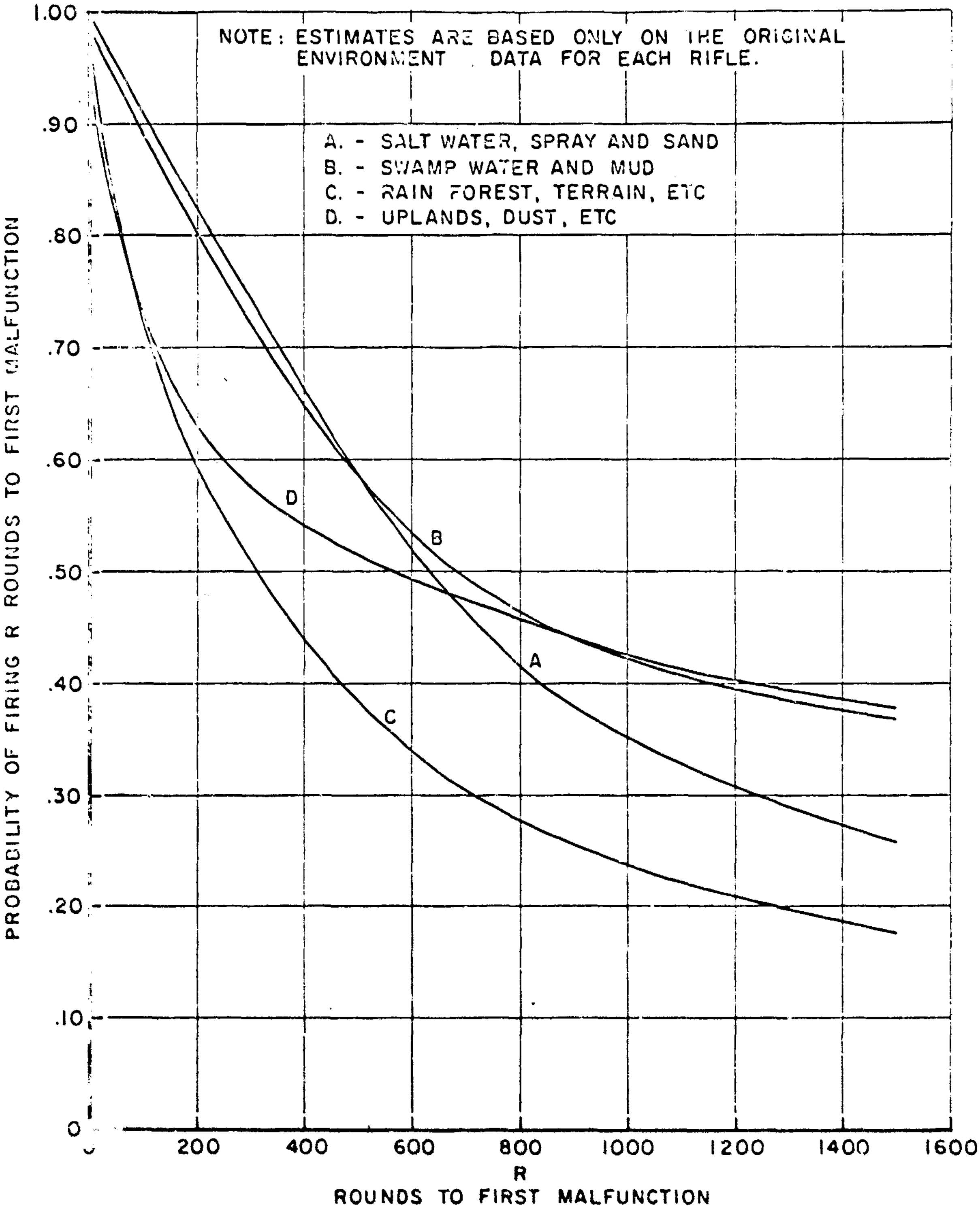

Figure II-L M14 Rifle Firing Ball and Tracer Rds w/Ball Prop. Reliability Estimates of Firing R Rds to First Malfunction by Environments.

TABLE IIG

M14 Rifle Firing Ball and Tracer Rds. w/Ball Prop.
Reliability Estimates to First Malfunction
in Environments

Number of Rounds	Prob. of Firing R Rds. to First Malf.*				
	Over All Environments	Environment I[1]	Environment II[2]	Environment III[3]	Environment IV[4]
1	.9940	.9997	.9989	.9906	.9741
10	.9662	.9946	.9887	.9475	.9119
50	.8911	.9637	.9427	.8338	.8044
100	.8236	.9192	.8881	.7371	.7327
500	.5221	.5865	.5871	.3845	.5155
1000	.3360	.3539	.4239	.2366	.4225

*These probabilities are based on data from firing the rifles in the initial environmental exposure, whereas the "Over All Environments" column includes all other data also.

1 - Salt water, spray and sand.
2 - Swamp water and mud.
3 - Rain forest, terrain, etc.
4 - Uplands, dust, etc.

TABLE IIH

M16 Rifle Firing Ball and Tracer w/Ball Prop.
Reliability Estimates to First Malfunction
in Environments

Number of Rounds	Prob. of Firing R Rds. to First Malf.*				
	Over All Environments	Environment I[1]	Environment II[2]	Environment III[3]	Environment IV[4]
1	.9985	.9988	.9984	.9957	.9955
10	.9868	.9855	.9845	.9725	.9696
50	.9422	.9238	.9252	.9039	.8906
100	.8925	.8494	.8575	.8395	.8173
500	.5998	.4470	.5100	.5953	.5280
1000	.3778	.2532	.3396	.4891	.4073

*These probabilities are based on data from firing the rifles in the initial environmental exposure, whereas the "Over All Environments" column includes all other data also.

1 - Salt water, spray and sand.
2 - Swamp water and mud.
3 - Rain forest, terrain, etc.
4 - Uplands, dust, etc.

TABLE II-I

M16 Rifle Firing Ball and Tracer w/IMR Prop.
Reliability Estimates to First Malfunction
in Environments

Number of Rounds	Prob. of Firing R Rds. to First Malf.*				
	Over All Environments	Environment I[1]	Environment II[2]	Environment III[3]	Environment IV[4]
1	.9263	.9964	.9722	.9836	.9907
10	.7974	.9648	.7184	.9252	.9354
50	.6167	.8372	.4836	.7992	.7691
100	.5117	.7026	.3640	.7059	.6254
500	.2393	.1926	.1276	.4215	.1973
1000	.1994	.0656	.0744	.3210	.1043

*These probabilities are based on data from firing the rifles in the initial environmental exposure, whereas the "Over All Environments" column includes all other data also.

1 - Salt water, spray and sand
2 - Swamp water and mud.
3 - Rain forest, terrain, etc.
4 - Uplands, dust, etc.

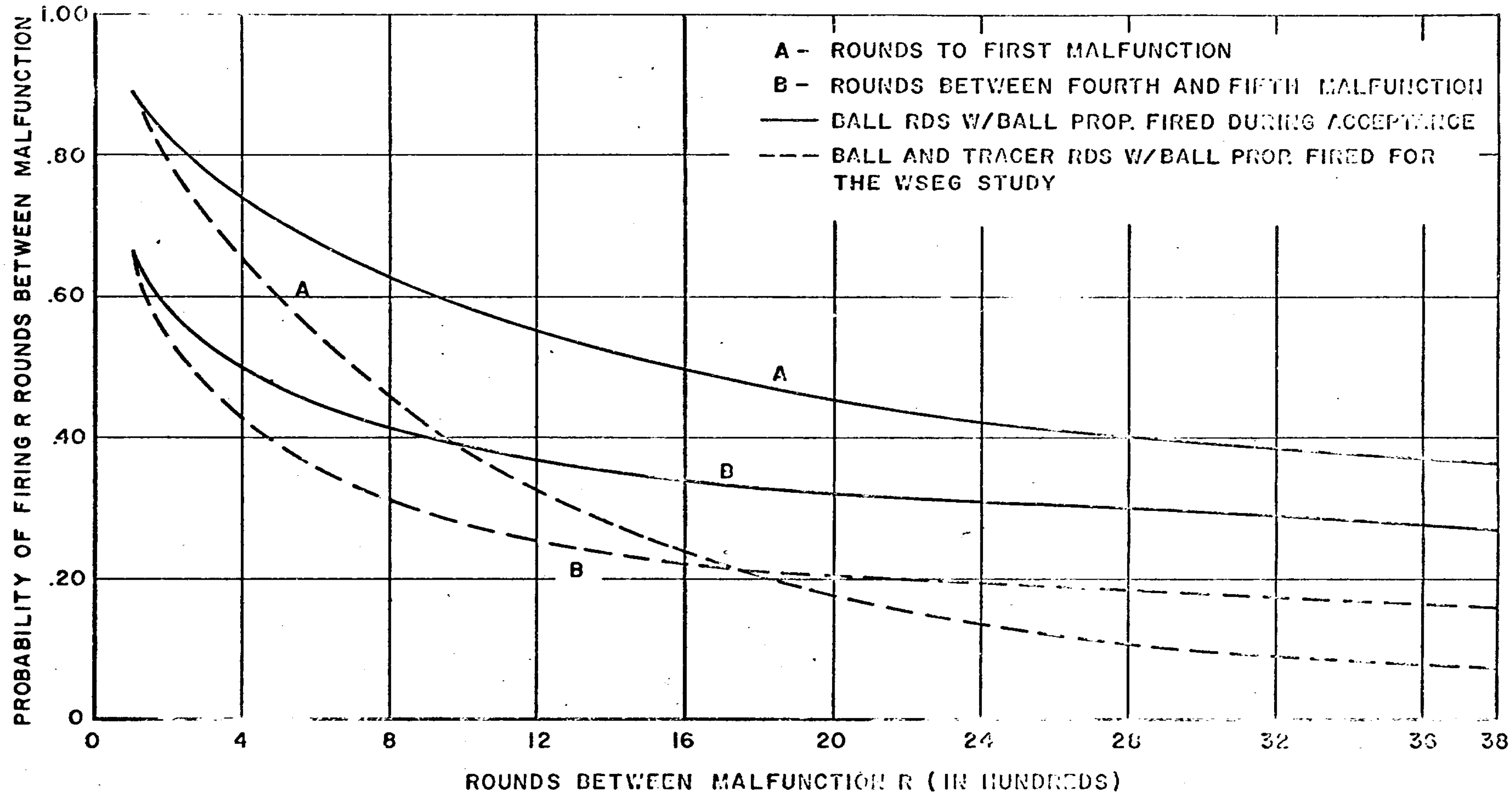

Figure VIII-H. M16 Rifle Firing Rounds Assembled W/Ball Prop.
Reliability Estimates of Rounds to or Between Malfunction

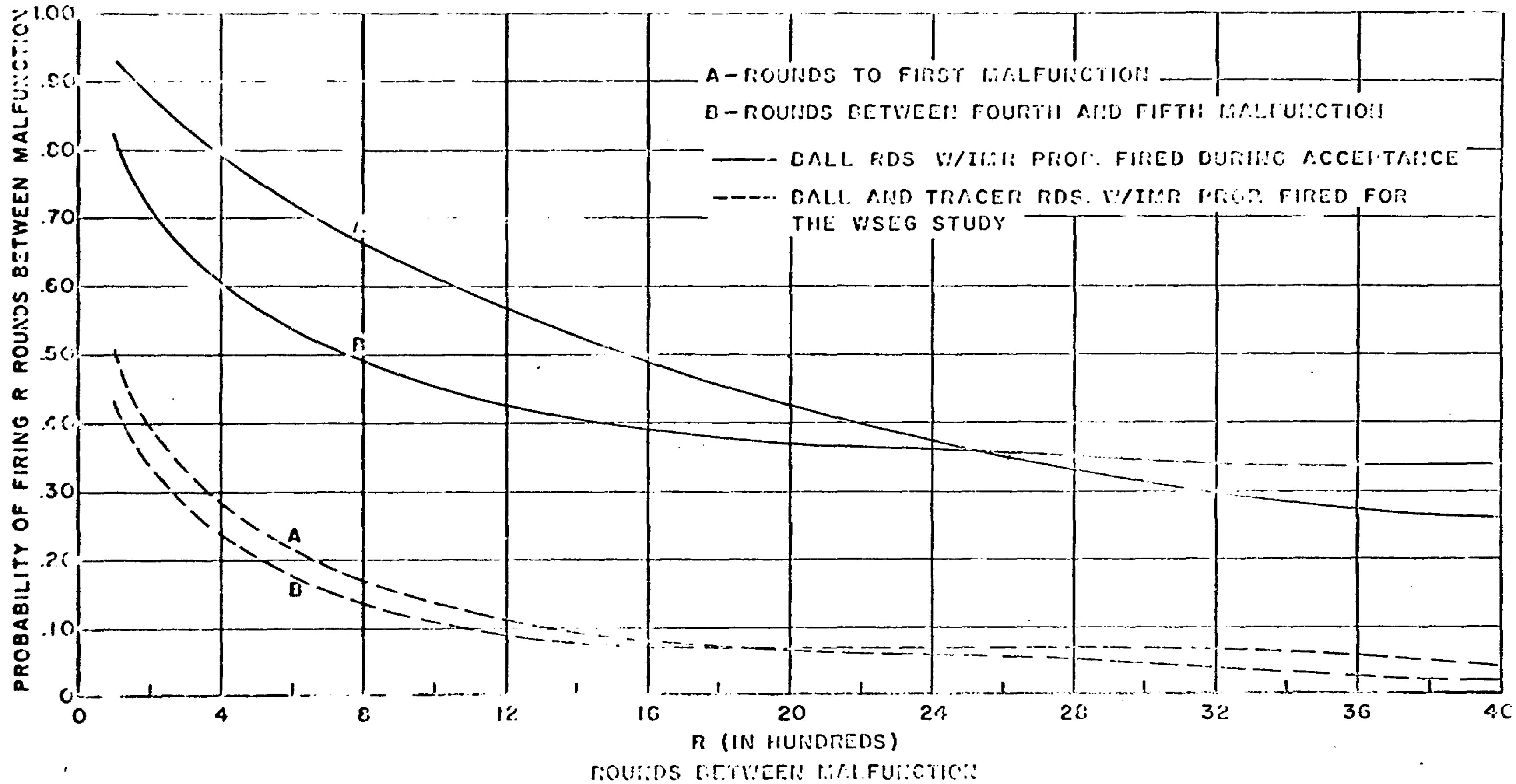

Figure VIII - I. M16 Rifle Firing Rounds Assembled w/IMR Prop.
Reliability Estimates of Rounds to or Between Malfunction

TABLE VIII-B

COMPARISON OF RELIABILITY ESTIMATES*

PROBABILITY OF FIRING R ROUNDS	PROPELLANT TYPE	NUMBER OF ROUNDS (R)					
		1	10	50	100	500	1,000
To First Malfunction	Ball						
	Acceptance	.9964	.9804	.9367	.8971	.7128	.5833
	WSEG	.9985	.9868	.9422	.8925	.5998	.3778
	IMR						
	Acceptance	.9987	.9903	.9620	.9319	.7574	.6107
	WSEG	.9263	.7974	.6167	.5117	.2393	.1994
Between 4th and 5th Malfunction	Ball						
	Acceptance	.9402	.8967	.7304	.6611	.4715	.3906
	WSEG	.9740	.9018	.7669	.6735	.3903	.2769
	IMR						
	Acceptance	.9943	.9673	.8938	.8293	.5732	.4500
	WSEG	.9021	.7445	.5425	.4345	.1907	.1167

* Acceptance estimates are for ball projectiles and WSEG estimates include ball and tracer projectiles.

3. Factors Affecting Reliability.

a. Projectile type.

(1) In the WSEG test, the order of firing ball and tracer projectiles precluded any effective way of separating the results of the two. However, the results of this analysis do not indicate an overall difference in the performance of the two projectiles with respect to their effect on the reliability of the rifle system. Therefore, since there was no strong evidence that ball and tracer projectiles (with the same propellant types) perform differently and because separating them would have been difficult and, for some analyses, impossible, it was assumed for this study that the reliability performance of the two projectiles does not differ.

(2) In examining the results of a special study of high temperature bore fouling of M196 tracer cartridges, it was concluded that the tracer round assembled with ball propellant is unsuitable for use in the M16A1 rifle at temperatures of +95° F and above due to excessive fouling, resulting in yawing, increased dispersions and erratic flights. The gilding metal clad steel bullet jacket with tracer cartridges assembled with ball propellant gave some improvement in performance; i.e., bore fouling and yawing was less and occurred only after firing 480 rounds, but does not eliminate the bore fouling and yawing experienced with the regular gilding metal jackets. Rifles firing tracer rounds assembled with IMR propellant were relatively clean after firing as many as 1,000 rounds; however, significantly more malfunctions, predominantly feeding failures, were experienced.

b. Propellant type.

(1) In the analysis of the WSEG data, the following findings are significant:

(a) The most significant difference noted was in the performance of IMR and ball propellants. For this reason, these types of propellant were analyzed separately throughout this report.

(b) The wide difference in the performance of IMR and ball propellants has been attributed to the wide difference in cycle times (or sub-elements of the cycle time) that are characteristic of each propellant type. An analysis of the cyclic rate information indicated that ball propellant produced significantly higher cyclic rates than IMR propellant (the average difference was 113 rds/min). However, it was also found that the cyclic rates differed significantly among lots having the same type propellant. The cyclic rate for ball propellant loaded by Remington averaged 20 rds/min higher than for ball propellant loaded by Twin City and the cyclic rate for IMR propellant loaded by Twin City averaged 30 rds/min higher than IMR propellant loaded by Lake City.

(c) When considering individual malfunctions, it is apparent that they can be divided into two groups: (A) those associated with a low cyclic rate; and (B) those associated with a high cyclic rate. Feeding failures, chambering failures, and failures of the bolt to remain to the rear are associated with low cyclic rates. Failures to lock, fire, extract, and eject, and double feeds are associated with a high cyclic rate. The remaining failures were too infrequent to permit a suitable statistical analysis.

(d) Figure V-A graphically shows the relationship of cyclic rate to the two groups of malfunctions. The graph shows the average number of failures per rifle versus cyclic rate for the 5,700 rounds per rifle fired in the WSEG test. The relationship of Group (A) malfunctions to cyclic rate produced a decreasing non-linear function, while the relationship of Group (B) malfunctions produced an increasing non-linear function. These results confirm the hypothesis that both a

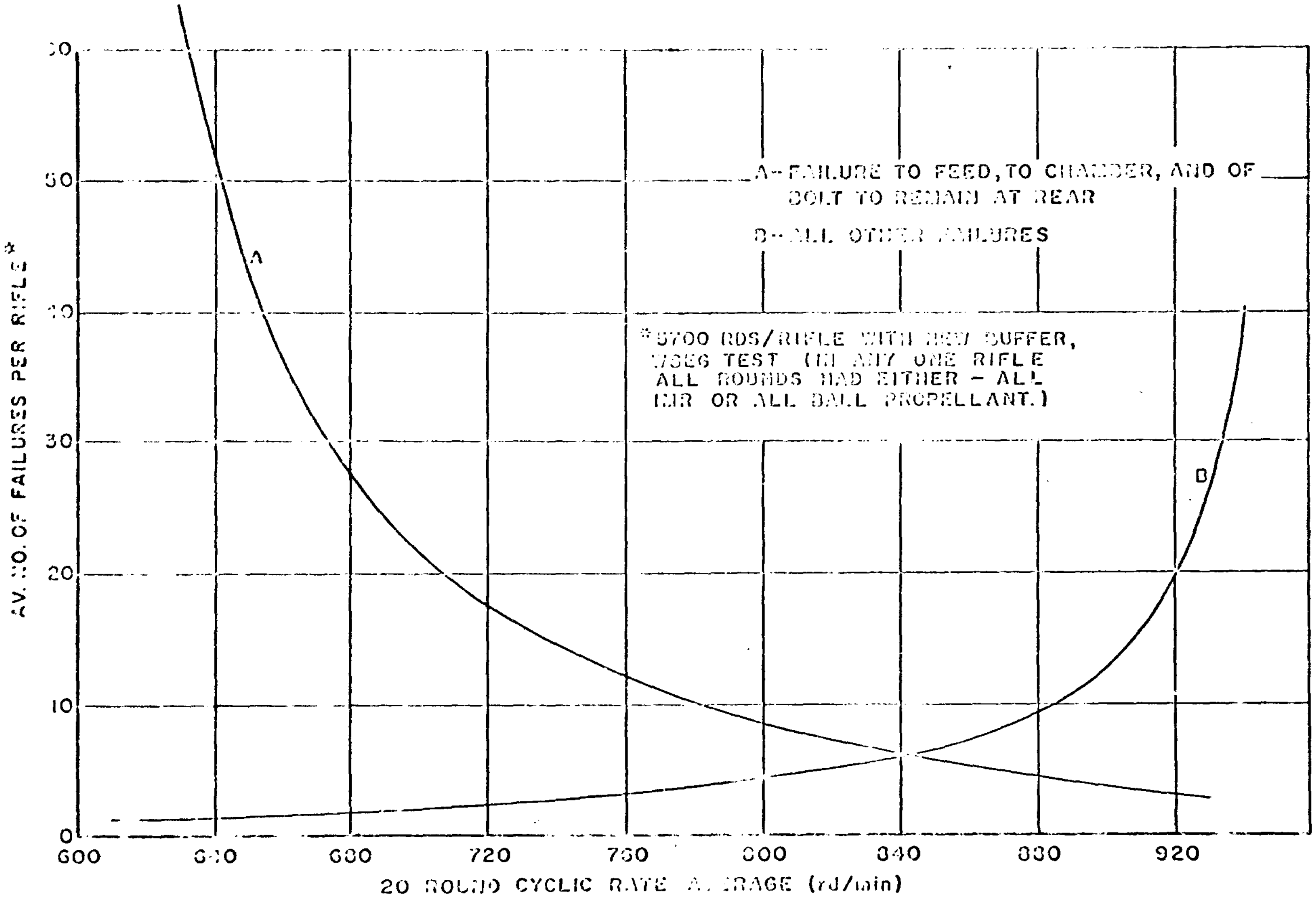

Figure VI-A. Relation Between Failure Rate and Cyclic Rate for Two Classes of Failures.

low and a high cyclic rate (or cycle time) have adverse effects upon malfunction rates. There appears to be an optimum point near the center of the distribution of cyclic rates, and deviations in either direction from this point result in an increased number of malfunctions.

(e) Propellant types (ball and IMR) affected the failure rates for all types of malfunctions. This, again, is attributed to the difference in cycle time. Failures to chamber and failures to eject were also affected by differences between ammunition lots within ammunition types. Chambering failures were affected by IMR lots only, and ejection failures were affected by ball lots only. It has been concluded that these two failures are especially sensitive to cyclic rate (or cycle time) since even the different ammunition lots of the same type produced significantly different results.

(f) It is apparent that the overriding factor affecting the rate of malfunctions is cycle time or cyclic rate. Although the malfunction rate for IMR propellant was higher than for ball propellant, it may be significant that the buffer used in this test was better suited to ball propellant. Since both ball and IMR propellants are to be fired in the M16 Rifle, it would appear most desirable to conduct a study to determine the cycle time which will minimize failure rates while firing combinations of both types. Further, it appears that the cyclic rate and cycle time for this weapon should be controlled more closely to effect high reliability.

(2) Examining data from a product improvement test of the redesigned buffer, the largest differences in the malfunction rates, with regard to propellant types over all environments, were noted in the firings conducted in the automatic mode. There seemed to have been some interaction among projectile types, propellant types, and buffer types in the automatic fire mode, although the statistical tests of significance did not indicate a significant effect. The rate of malfunctions for the combination of ball projectile-ball propellant was higher than that for ball projectile-IMR propellant for firings with the

standard buffer. With the redesigned buffer, the rate for the combination of ball projectile-ball propellant was lower than that for ball projectile-IMR propellant. Using tracer rounds, the rate of malfunction for both ball and IMR, for rifles equipped with the standard buffer, was essentially the same. On the other hand, when firing rifles equipped with the redesigned buffer, the rate of malfunctions for the combination of tracer projectile-ball propellant was higher than that for the combination of tracer projectile-IMR propellant.

Regarding cyclic rates, when firing ball propellant, the ratio of occurrences above 850 to those below 650 was approximately two-to-one, whereas the ratio of trials below 650 to those above 850 for IMR propellant was nearly four-to-one.

(3) Data from combined Fouling Tests of 5.56mm ammunition at Lake City AAP show that the malfunction rate between propellant types over both ball and tracer rounds was essentially the same. Considering the firings of the tracer rounds, the malfunction rate was slightly higher when ball propellant was used.

c. Rifle types.

(1) In examining the relationship of chrome and non-chrome chambers to reliability, field data from the WSEG test indicate that:

(a) There is some evidence that the chrome chambered rifle tends to fire at a faster rate, thus increasing the failure rate for certain types of malfunctions. The incidence of failures to eject are increased through the use of chrome chambers.

(b) Environment appeared to affect the malfunction rate of only the non-chrome plated rifle.

(2) Data from initial production tests of chrome plated chambers for M16A1 rifles indicate that in the dust tests, there was little difference in the malfunction rates regarding Type I (immediately clearable) and Type II (not immediately clearable) malfunctions.

However, examination of the spent cartridge cases revealed rim deformation of cartridges fired from rifles with non-chrome plated chambers, indicating increased extraction forces not observed in the rifles with chrome plated chambers. Rifles with non-chrome plated chambers became pitted after immersion in salt water and stored at high temperatures and high humidity, whereas the rifles equipped with chrome plated chambers resisted the pitting. The chrome plated rifles performed satisfactorily in the 10,000-round endurance test.

(3) Data from Aberdeen Proving Ground Firing Record S-46571, "Comparison Test for Cyclic Rate Comparison of Ball Cartridges in WSEG Weapons" indicated that thirty-three (33) out of the total of fifty-seven (57) malfunctions noted in this test occurred in rifles equipped with chrome plated chambers. Fourteen of these were failures to eject. The most prevalent (11 out of 24) malfunction of the rifles with non-chrome plated chambers was failure of the bolt to remain to the rear after the last round was fired.

d. Magazines and magazine loading.

(1) Analyses of data from the WSEG test indicate that:

(a) Both the M14 and M16 Rifles experienced high failure rates on the first two rounds fired from a magazine.

(b) Feeding and chambering failures are primarily responsible for the large number of failures on the first and second rounds (reference Figure IV-E through Figure IV-L, App. IV, pp. IV-83 through IV-90). The failures appear to be due to the longer cycle time that is characteristic of the first few rounds regardless of the type of propellant or projectile being used.

(c) Firing failures (and to some extent extraction failures) also contributed to the high failure rate associated with the first two rounds and particularly with ball propellant (reference Figure IV-Q, and Figure IV-T, App. IV, pp. IV-95 and IV-98). Significantly, these two failures were the only two to be affected by environment, and the beach environment appeared to be chiefly related to this effect. Two important factors that may contribute to the initial firing failures are: (1) failure to close the bolt with sufficient force, and (2) the presence of foreign matter, such as sand, within the chamber which prevents the bolt from completely closing.

(d) Most malfunctions occurring on the last round in the magazine were failures of the bolt to remain to the rear. An overwhelming majority of these occurred with rounds having IMR propellant because of its longer cycle time. However, for both rounds with ball and IMR propellant, more of these failures occurred with the clips loaded with 18 rounds. Significantly, the last round of the 18-round clip was a tracer, whereas the last round of the 20-round clip was not. It should be pointed out that, within a magazine, tracer projectiles were fired with the same type of propellant as the ball projectiles.

(e) The above conclusion represents the only evidence that tracers may affect the malfunction rate, although the other tracer rounds in the magazine did not differ from ball projectile rounds in their performance with respect to reliability.

e. Cleaning and lubrication.

(1) Analysis of field data from the WSEG test indicates that cleaning cycle appears to affect the number of malfunctions occurring in the non-chrome chambered rifle. In general, frequent cleaning improves the performance of the rifle; however, in some cases where the malfunction rate is associated with a high cyclic rate, cleaning tends to further increase the cyclic rate and thereby increase the malfunction rate.

(2) Cyclic rate determinations were made for the WSEG rifles selected for firing cartridges assembled with ball propellant "as received" at Aberdeen Proving Ground and after cleaning and lubrication. The cyclic rates after cleaning and lubrication were, on the average, 74 rpm higher than those obtained for the "as received" condition.

(3) In firings during troop training exercises at Fort Polk, Louisana, 92 (78%) of the 118 malfunctions noted in the firing of 350,023 rounds were attributed to inadequate cleaning. The rifles used in the training exercises were not of the most recent manufacture and apparently were not equipped with chrome plated chambers.

(4) Unfortunately, there appears to be insufficient data available to establish an optimum cleaning schedule which will minimize malfunctions.

f. Firing mode (automatic versus semi-automatic).

(1) Analysis of data from the WSEG test indicated that all failures associated with low cyclic rate (failures to feed, to chamber and of the bolt to remain at the rear) were affected by firing mode. It appears that the low rate of fire cannot efficiently sustain automatic fire. None of the remaining failure types were affected by firing mode.

(2) In general, the results of a product improvement test of the redesigned buffer indicated that the malfunction rate was higher for firings in the automatic mode than in the semi-automatic mode. However, there were significant interactions between buffer type and mode of fire and projectile type and mode of fire. The overall malfunction rate for rifles equipped with the standard buffer was higher in the automatic mode, whereas the rate for rifles equipped with the redesigned buffer was higher in the semi-automatic mode. Over all conditions, the malfunction rate for ball cartridges (with ball and IMR propellant) was essentially the same for both automatic and semi-automatic fire, but the rate for tracer projectiles (with ball and IMR propellant) was higher in the automatic mode.

g. Environment.

(1) When considering all recorded malfunctions of the M16 rifles fired in the WSEG test, it was found that the environment affected the malfunction rate for both modes of fire. The beach environment was the most severe, followed by the swamp environment. It should be pointed

out that this effect was primarily a result of ammunition fired with IMR propellant. It should be recalled that the environmental effects discussed with respect to reliability functions were based on the time to first failure only. In view of the different results based on all malfunctions, it might be concluded that in a severe environment malfunctions have a tendency to repeat themselves. The M14 rifle was not affected by environment when considering not only malfunction rate to the first failure, but all others as well.

(2) Examination of pertinent data from a product improvement test of the redesigned buffer, analyzed over all environments under which tests were conducted (including high humidity, high temperature, fouling at +20° F, low temperature -65° F, extreme elevation of +80° and depression of -80°, dynamic dust and salt water immersions) indicated that the highest malfunction rate occurred in the salt water immersion test where 13.0% of the rounds malfunctioned. It is pointed out that only rifles equipped with the redesigned buffer were tested in this phase. The highest malfunction rates occurred when firing in the semiautomatic mode. Malfunctions occurred at nearly the same rate for ball and tracer cartridges and for ball and IMR propellants.

An interesting finding in the extreme attitude phase of this test was the high frequency of malfunctions when the rifles were elevated or depressed to ± 80°. Most of the malfunctions were failures to fire in the automatic mode in rifles equipped with the standard buffer. Approximately 62% of the failures to fire occurred when firing one particular lot of ball cartridges assembled with ball propellant.

(3) Analysis of data from the initial test of chrome plated chambers for M16A1 rifles indicated that rifles equipped with chrome plated chambers resist salt water damage and appear to decrease extraction forces in firings under adverse conditions.

4. Seriousness of Malfunctions

a. In the preceding analysis malfunctions were not segregated with respect to seriousness. In this respect, the malfunctions may be categorized into the following three groups as defined by WSEG:

(1) Category I - Malfunctions which were corrected by immediate action on the part of the firer.

(2) Category II - Malfunctions which could not be corrected by Category I action, but were corrected in the field by the shooter using aids normally available to the firer.

(3) Category III - Malfunctions which could not be corrected by Category I or Category II actions, but which were correctable by an armorer with tools and/or parts.

b. Table VII-A, pp. 39-40, shows the number and percentage of malfunctions in each category by type of malfunction.

c. Generally, the number of Category II and Category III malfunctions were small compared to the number of Category I malfunctions. For the eight most prevalent types of failures, the most serious (with respect to the rates of Category I failures to Category II and III failures) was failure to extract while the least serious were double-feed and failure of the bolt to remain to the rear. There is little difference among the remaining five with respect to seriousness.

d. The malfunctions were not considered by category in the preceding analyses of this report for the following reasons:

(1) All malfunctions are potentially serious. The category into which a malfunction is going to fall cannot be predetermined before it occurs. Furthermore, even a Category I malfunction can be serious under certain circumstances.

(2) The percentage of Category I malfunctions was not greatly different for any of the eight most prevalent failures.

(3) The number of Category II and III malfunctions were too few to permit an extensive statistical analysis.

TABLE VII-A

PERCENTAGE OF CATEGORY I, II and III

MALFUNCTIONS BY FAILURE TYPE

BALL AND IMR MALFUNCTIONS COMBINED

TYPE OF MALFUNCTION		CATEGORY I NO.	I %	II NO.	II %	III NO.	III %	TOTAL	% OF TOTAL MALF
FF	1	1,411	81.0	304	17.5	27	1.5	1,742	48.0
FC	2	353	76.7	97	21.1	10	2.2	460	12.7
FL	3	89	76.7	25	21.6	2	1.7	116	3.2
FFR	4	201	76.4	47	17.9	15	5.7	263	7.3
FUL	5	2	25.0	6	75.0	-	-	8	0.2
FX	6	114	66.7	47	27.5	10	5.8	171	4.7
FJ	7	245	82.8	31	10.5	20	6.8	296	8.2
FCK	8	6	66.7	3	33.3	-	-	9	0.2
FLHC	9	-	-	-	-	-	-	-	-
IFR	10	-	-	-	-	-	-	-	-
FMR	11	1	100.0	-	-	-	-	1	0.03
DF	12	63	94.0	3	4.5	1	1.5	67	1.8
FSS	13	-	-	-	-	-	-	-	-
BCE	14	1	100.0	-	-	-	-	1	0.03
FCB	15	3	100.0	-	-	-	-	3	0.08
FML	16	13	86.7	2	13.3	-	-	15	0.4
FTR	17	-	-	-	-	-	-	-	-
FBR	18	368	93.9	23	5.9	1	0.3	392	10.8
FBC	19	4	66.7	2	33.3	-	-	6	0.2
F2R	20	-	-	-	-	-	-	-	-
SSA	21	-	-	-	-	-	-	-	-
CRS	22	-	-	1	100.0	-	-	1	0.03
SLI	23	9	22.0	26	63.4	6	14.6	41	1.1
Other	24	17	48.6	11	31.4	7	20.0	35	1.0
All Types		2,900	80.0	628	17.3	99	2.7	3,627	100

TABLE VII-A (CONTINUED)

1. Failure to feed
2. Failure to chamber
3. Failure to lock
4. Failure to fire
5. Failure to unlock
6. Failure to extract
7. Failure to eject
8. Failure to cock
9. Failure to load by hand changing
10. Firing without trigger being pulled
11. Failure to maintain cyclic rate
12. Double feed
13. Fires with selector on safe
14. Bolt catch engaged bolt carrier instead of bolt
15. Firing on closure of bolt
16. Failure of magazine to lock in rifle
17. Failure of trigger to return to forward position
18. Failure of bolt to remain at rear
19. Failure of bolt to go forward
20. Fired two or more rounds with one trigger pull
21. Single shot (automatic-mode)
22. Cartridge rim shear
23. Selector level inoperative
24. Other

B. ANALYSIS OF SPECIFICATIONS.

1. Purchase Description for Rifle, 5.56mm: M16 and M16A1.

a. Initially the specifications for Rifles, 5.56mm: M16 and M16A1 currently in effect at Colt was under review. Before this review was completed, information was received that SAPD 253B dated 19 April 1966 would be superseded by SAPD 253C (draft dated 1 April 1968). Accordingly, to meet an urgent requirement for the latest draft, comments were prepared on the latter document and transmitted to AMCQA and to the Project Manager/Rifles for their immediate use. Since the emphasis was shifted from the specification which was to be superseded and which was admittedly poor in many respects, effort was directed toward analysis of the latest draft. The latest draft which has been given close scrutiny is SAPD 253C dated 23 April 1968. Detailed information on the critical review is furnished in Appendix III of this report and a summary is given in this section.

b. Cyclic Rate.

(1) The specification imposes a requirement that the cyclic rate should be between 650-850 rounds per minute. It has been established that there is a correlation between cyclic rate and malfunction rate; hence, basically this is an important element of the specification. Although the correlation exists, further analysis indicates that it is really not cyclic rate but rather individual cycle time (or subelements of cycle time) which is of greater importance. Therefore, the specification should probably contain provisions for acceptance or rejection based on individual cycle times.

(2) The test which is conducted currently lacks appropriate controls. The statistical analysis indicates that cyclic rate is highly dependent upon propellant type (ball or IMR) and ammunition lot within each type. In other words, the cyclic rate could vary as much as 100 rounds per minute depending on ammunition lot. Ammunition containing ball propellant is used by the contractor in the test.

Another factor was established during the plant visit upon inquiry into what corrective action is taken when a rifle fails this test. Since the degree of lubrication is not specified, the contractor takes the liberty of either increasing or decreasing the lubrication in order to effect passage of the rifle upon retest. Without adequate controls the rifle can pass the provisions of the specification, but function poorly in the field.

c. Functioning Tests. The specification requires that each rifle pass a functioning test involving firing of 30 rounds without malfunction. This test in iteslf provides little assurance regarding the reliability of the individual rifle. During the plant visit, it was noted that the procedure being used by the contractor further reduces the effectiveness of this test. Apparently the contractor is at liberty to fire 20 rounds in a preliminary firing. If no malfunction is experienced, he has the option of deciding the firing was for record; however, if a failure occurs he ignores the results and subjects the rifle to subsequent tests. Of course, rifles with poor reliability characteristics, say a Mean Time Between Stoppage (MTBS) of 200 rounds, have a rather high probability of passing such a test.

d. Mission Performance.

(1) The addition of the mission performance test is a step in the right direction toward imposing useful criteria for judgement of reliability. However, the statistical analysis of the sampling plan indicates that it is inconsistent with the specification statement that "the mean rounds to malfunction shall be not less than 2400 rounds." The sampling plan which is given actually has a high probability of accepting rifle lots (if submitted) which have a mean round to malfunction of 1200 rounds.

(2) To improve the effectiveness of the specification with respect to the reliability characteristics of the rifles being accepted, it is proposed that a different requirement should be included in the specification in lieu of that given for mission performance. It is proposed that all of the data generated from the function tests (already

required) be accumulated over all 1,000 rifles in the lot and that an appropriate acceptance criterion for reliability be based on the data of approximately 30,000 rounds which will have been fired. To illustrate the effectiveness of this proposal, the operating characteristics (OC) curves or power curves to indicate the discriminating function is given in Appendix III, p. III-12.

e. Endurance Test. The Endurance Test could be a very useful supplement to the reliability criterion since the latter does not provide assurance with regard to the life characteristics of rifles under extended firings, say to 6,000 rounds. It is recognized that it is expensive to conduct extensive endurance tests with many rifles from each lot of 1,000; however, the sample size for the endurance test should be increased to at least four. Further, the test should be conducted in a meaningful way. The plant visit established that the contractor, upon measuring cyclic rate periodically during the test, makes adjustments with respect to cyclic rate, through control of lubrication, in order to increase the probability of obtaining satisfactory results. This practice should not be continued if the endurance test results are to be meaningful.

f. Accuracy. The requirements for accuracy or dispersion have been examined and the statistical analysis of the power of the sampling plan establishes that the criterion for the M16 Rifle is more severe than that for the M14 Rifle. For example, if the true dispersion of the rounds fired from a rifle is 1.5" at 100 yards range the probability of acceptance on the basis of the criterion for the M16 Rifle is only 20% as compared to a probability of acceptance of approximately 80% on the basis of the criterion for the M14 Rifle.

g. Magazines. The specification requirements for functioning tests of magazines involves the firing of 20 rounds from each of 15 magazines drawn from a lot of approximately 35,000. The criterion specifies that there shall be no malfunctions. This sampling plan is rather loose as indicated in the detailed statistical analysis given in Appendix III. It is proposed that the specifications be changed to increase the discriminating power of this characteristic.

2. Military Specification, Cartridge, 5.56mm, Ball, M193 and Tracer, M196

a. Analysis of the specification for 5.56mm ammunition indicates that it is rather comprehensive in a traditional way. However, in relating the specification to the special characteristics of the M16 Rifle it would seem advisable to consider modification of the specifications to add further controls.

b. The statistical analysis has indicated that there are lot-to-lot variations which have a bearing on the cyclic rate and cycle time in firing the M16 Rifle. In view of the current judgement that cyclic rate or cycle time (or sub-elements thereof) has an important bearing on malfunction rate and that further control of these parameters is desirable it may be important to consider the establishment of tests and criteria for these parameters in the ammunition specification.

c. Because of the sensitivity of the M16 Rifle to fouling, consideration should be given to the re-examination of specification requirements and controls for parameters such as particle size, chemical composition, burning rate, and pressure-time relationships for propellants. Consideration should also be given to the establishment of specification requirements for fouling in terms of a measurable characteristic. These requirements should include procedures for the test and measurement of this characteristic.

d. Upon examination of the consistency or compatibility of the AQLs for major defectives and the demands for rifle system reliability, it is believed that the current value of 0.25% may prescribe too loose a sampling plan for the acceptance of ammunition lots. The corresponding plan given in MIL-STD-105 indicates a sample size of 500 and an acceptance number of three defectives. While it is recognized that not all major defectives have a 100% likelihood of causing a malfunction, it is believed that consideration should be given to prescribing a more strict plan.

C. ANALYSIS OF THE QUALITY ASSURANCE PROGRAMS

1. Rifle.

a. A plant visit to Colt Industries, Inc. indicated that their quality assurance and quality control practices may depart somewhat from generally accepted concepts.

b. Inquiry with regard to the Inspection Instruction Sheets revealed that the classification of defects (major and minor) was accomplished at Colt in 1963 and since then had not been given a comprehensive review in this regard. It is proposed that action should be taken to determine whether the classification of defects is correct since it is possible that this may have an important bearing both on the amount and cost of inspection and rejection.

c. The system of applying individual sampling plans to each individual characteristic of each component and subassembly (say 1% for each characteristic major defect) is basically unsound and could permit a high percentage of defective materiel, say 20%, to remain in the process without being detected. This method is also applied to incoming inspection of vendor materiel. Unfortunately, this practice is not peculiar to Colt alone, it is being used by the Government rather extensively in the weapons area; however, it is an unsound practice which should be discontinued. An illustration of the effect of this technique and its weakness is illustrated in Section XXIII, Appendix IV. A sound procedure would be to apply a sampling plan to all major characteristics of the component or subassembly rather than to each of the characteristics. The sampling plan should apply to defectives, thereby effecting a control over the fraction of the components in a lot or in a process which are defective.

d. The in-process roving inspections were conducted in a manner which could permit appreciable defective materiel to be produced with a very low probability of being detected on the basis of the weak sampling plans which were being used during the visit.

e. It is believed that the two matters discussed above have a direct bearing on the quality of the in-process materiel. Defective materiel remains in the process undetected and corrective actions, which should be taken with respect to the process, are not exercised.

f. It is also pertinent to observe that the analysis of September 1967 through March 1968 Monthly Summary Reports indicates a rejection rate of approximately 20% of rifles submitted for acceptance. The rejection rate for rifles submitted for the first time is approximately 11% during the functioning tests and 27% for visual and gaging defects. The above statistics pertain to rifles submitted for the first time. The corresponding rejection rate for rifles which are resubmitted for acceptance are 36% and 5% (of those resubmitted), despite the relatively weak sampling plans currently in effect. This is a strong indication that effective corrective actions are not taken. The explanation received was to the effect that there were so many different types of defects at relatively low frequency, say less than 1%, that it would be uneconomical to pursue efforts to reduce them. Another explanation offered was that the defects are mostly visual and cosmetic. This may be partially true. If some of the defects are not important enough for rejection of rifles, a review of the classification of defects may be in order.

g. A discussion of the above matters with a Colt representative gave rise to an expressed philosophy that it is more economical to tolerate such defective materiel in-process and to depend upon inspection, particularly of the final product, to screen out defective materiel. To objectively assess this view would require an appropriate cost analysis which is not currently available. However, intuitively it appears to be questionable on the grounds of customary quality control concepts with respect to mechanical parts and systems, such as the M16 rifle.

h. It is also pertinent that the Government is performing a relatively high (100%) amount of inspection of the final product after the contractor has inspected the rifles 100%. The amount of inspection being performed is probably related to the aforementioned practices, the quality control-quality assurance methods being employed and the rejection rate.

i. Another essential element of a quality assurance program is in the area of product improvement. With a view toward the goal of improving the reliability of the M16 rifle, it is essential to encourage efforts in this direction, particularly in certain obvious or seemingly fruitful areas. For example, methods of reducing the variation in cyclic time through studies of the buffer component may prove fruitful. It was surprising to learn that a relatively simple and apparently desirable correction involving the change in the ramp angle of the barrel extension drawings from 45° to 40° had not been adopted. The 45° angle was apparently an error in the drawings and the change to 40° should tend to reduce the probability of jamming.

j. Other quality and reliability aspects of the rifle also seem to bear further study. For example, it is likely that firing pin indent should be increased to reduce the probability of a misfire occurring as residue and other foreign matter accumulates in the process of firing. Colt indicated that upon firing approximately 2,000 rounds with ball propellant, the deposits cause the firing pin indent to decrease to a point where misfiring can be expected. To increase firing pin indent or hammer blow would involve an increase in the trigger pull by approximately 1/2 pound, which may not be a major price to pay to alleviate this condition.

k. The specification requires a High Pressure Test of barrels and bolts with a Magnaglo inspection for cracks. During the plant visit, it was established that approximately 2% of the barrels were rejected. This rejection rate would tend to indicate that the margin of safety may be too low and that there is a likelihood that barrels could develop cracks should they be subjected to one, two or more additional tests at high pressure (approximately 135% of normal maximum pressure). An explanation furnished by the contractor personnel indicated that cracks are not due to the high pressure test but exist in the barrel slug before they are machined. It seems advisable to examine whether the margin of safety is adequate.

1. It also seems desirable to examine the feasibility of controlling the identity of critical components lot-by-lot in order that rifles issued to the field could be located by serial number and effective corrective actions can be taken when necessary.

2. Rifle/Ammunition System.

a. In examining the rifle/ammunition interface, it is believed that it would be advisable to conduct <u>two types of system tests periodically</u>, at least for awhile, in order to study the rifle/ammunition interface.

b. The program should involve the stratified random selection of <u>new</u> rifles, magazines, and ammunition and firings to obtain:

(1) Estimates of system performance.

(2) The effects of engineering or other changes.

(3) A basis for changes or corrections which may be necessary.

c. This type of test should be also conducted with stratified random samples obtained <u>from the field</u>. The purpose of this test would be to study the effects that the field environment or storage may have on the performance of the system.

d. Addressing the QA practices in general, it would also be advisable for the Government and contractor to conduct <u>periodic analysis</u> and <u>review to determine</u> which <u>inspections and tests may not be serving</u> a sufficiently <u>useful purpose</u> to warrant continuance or perhaps which may be reduced in quantity to be compatible with realistic needs.

3. In further summary:

a. Examination of Monthly Summary Reports (September 1967 through March 1968) indicates: (1) a rejection rate of approximately 27% of the rifles subjected to visual inspection for the first time and approximately 11% subjected to functioning tests for the first time; and (2) rejection rates for resubmitted rifles in excess of reasonable expectation.

b. These two facts indicate that much of the difficulty stems from: (1) ineffective quality control of the vendor's product and Colt's manufactured product; (2) ineffective identification of defects and correction of the product which is resubmitted; and (3) ineffective corrective action with respect to processes which give rise to high rates of defective materiel.

c. To an appreciable extent, the above difficulties may also be traced to the acceptance sampling inspection system, where sampling plans are applied to each individual characteristic of a component rather than to major and minor defectives (which involve the application of the sampling plans to the complete set of characteristics of components falling into the major and minor categories).

d. To identify a further basic problem in this connection, it is pertinent to mention the control of rejected and resubmitted products. Under current practices, the Government does not ascertain in a truly effective way whether, in fact, appropriate corrective action has been taken by the contractor before the product is resubmitted. The high rejection rate in connection with resubmitted products would tend to indicate that either the causes of defects were not identified correctly or that they were identified correctly, but the replacement components were defective or the corrective action was ineffective.

e. Without true and effective corrective actions, and without robust means for Government monitoring, it is entirely possible for defective materiel to be accepted simply on statistical grounds, where the probability of passing is increased by the number of times the product is resubmitted.

4. Overall, it is believed that the quality assurance program applied to the M16 rifle at Colt should be improved. If this is done properly, it should have an effective bearing on the quality and reliability of rifles. It is further believed that the observations and suggestions have application to a broader area of small arms and other weapons programs.

D. ANALYSIS OF QUALITY ASSURANCE POLICIES AND PROCEDURES

1. DoD Policy - Implementation

The Army (AMC) and the Defense Contract Administration Services (DCAS) implementation of DoD procurement quality assurance (QA) policy was examined for adequacy and consistency. This study finds no evidence of basic deviation from DoD policy in AMC and DCAS implementation (Ref. Appendix I).

2. Contractor Responsibility and Motivation

a. The contractor is responsible for controlling product quality and may be required to establish a Quality Program (specification MIL-Q-9858) or an Inspection System (specification MIL-I-45208) when specified in the contract. The Government, accordingly, contracts for a finished product and a QA system as appropriate for a particular procurement.

b. DoD policy in this regard places the burden of proof upon the contractor that the materiel offered to the Government satisfies contract requirements. This study finds, however, that enforcement of the quality program requirement has limitations under other than "peace-time" procurement. When objective evidence is generated that the contractor's quality program is not effectively controlling product quality, penalty measures such as production shut-down are not practical, particularly when materiel is required to meet urgent logistic needs. To maintain the flow of materiel under these conditions, the Government is forced into the position of inspecting the product to assure that outgoing quality is acceptable to the user. Thus, no contractor motivation exists to improve his quality program in the absence of a penalty factor.

c. Several solutions are possible to enhance proper motivation of the contractor. They are:

(1) Require reimbursement from the contractor to compensate for that amount of Government inspection in excess of normal product verification.

(2) Negotiate contracts on a cost plus fixed fee basis for materiel procured under other than "peace-time" conditions. The Government, accordingly, would pay for the contractor's quality program or inspection system and reduce fixed-fee payments proportionately to the inspection costs incurred by the Government.

(3) Accommodate the special conditions associated with Small Business contract awards by providing for requisite Government product inspection at source at the on-set of production.

(4) Develop a set of incentives which would encourage contractors to develop and maintain sound quality control programs.

(5) Modify the criteria for awarding contracts to provide a secure basis for the contracting office to reject bid proposals received from contractors having a continuous history of poor quality.

Reference Appendices II and VII.

3. AMC/DCAS Interface

a. The review of AMC and DCAS implementation of DoD QA policy discloses basic compliance, with no evidence of any significant departure from established policy. The AMC/DCAS interface was examined, accordingly, to bring to light any major problems and, additionally, to determine the need for revision of current DoD QA policy and procedures.

b. DoD procedures and instructions concerned with the delineation of Government quality assurance responsibilities provide specific guidelines relative to the execution of the quality assurance function. Accordingly, the technical activity, the purchasing office, and the contract administration office, within the above framework, have developed specific requirements for their quality assurance programs, respectively. Appendix I provides a general description of the basic elements identified with the AMC and DCAS quality assurance program.

c. The AMC Quality Assurance Letter of Instruction (QALI) furnished to DCAS establishes the mandatory amount of Government product inspection required as a minimum. This requirement originates from many sources (See Appendices I and II). In addition to this product inspection which is required, the QAR may accomplish product inspection for characteristics other than those specified in the QALI. Knowledge regarding implementation of the quality assurance requirements of the contract is further afforded through visits of key inspectors.

d. The DCAS quality assurance program essentially is based upon their evaluation of the effectiveness of the contractor's QA system, his compliance with contract requirements and the amount of product inspection. The latter is established by the QAR (identified as Procurement Inspection Type B) and it may be discontinued or reinstituted depending upon the QAR's evaluation of the quality situation at the facility. In contrast, the mandatory inspections imposed by AMC cannot be discontinued without the expressed approval of the purchasing office.

e. The interface which exists between AMC and DCAS is one of shared responsibility for quality although AMC, in the final analysis, is responsible for the reliability and performance of the product in the field. Ideally, there should be a proper balance between the amount of inspection performed by the Government and their evaluation of the contractors quality assurance system. When the degree of confidence in the effectiveness of the QA system is "high", the amount of Government product inspection can be reduced with minimum risk. Conversely, the amount of Government product inspection must be increased, when confidence in the effectiveness of the contractor's QA system is low.

f. A question arises, then, as to what this balance should be at any given point in time. Some general observations are offered:

(1) The characteristics of the product to be subjected to Government inspection should be directly related to product reliability, safety and functioning (performance).

(2) A formal plan should be established which specifies the minimum amount of Government inspection of the product which is

required to verify the adequacy and effectiveness of the contractor's QA system.

(3) This plan should reflect the combined product inspection requirements of AMC and DCAS for the particular procurement.

(4) A formula should be devised for decreasing Government product inspection as confidence in the contractor's QA system increases.

(5) There should be a penalty clause in the contract which could be exercised when there is evidence that the contractor's QA system is ineffective as evidenced by the amount of Government product inspection which is necessary to insure acceptance of products of requisite quality.

g. In view of the aforementioned observations and recommendations concerning the contractor's responsibility and motivation, consideration should be given to further examination of DoD procedures related to the management of quality assurance.

4. Specifying Quality Assurance Requirements

a. A question has been raised relative to whether the Government places itself in an inconsistent position by specifying in the contract AQLs for anything but the end product. This question has been examined as to whether the specification of AQLs for components contractually imposes both in-process and end-product inspection requirements. DoD policy requires that the Government contract for a finished product and a quality assurance system, i.e., a quality assurance program or an inspection system, as applicable.

b. The AMC position has been that it does not contractually impose in-process inspection requirements when AQLs are specified and defects are classified in accordance with the degree of seriousness (major or minor) for components, which are assembled into the end product. The AMC practice, indicated above, is limited to components procured as repair parts (secondary end items). This practice, as viewed in this study, does not constitute an undue imposition upon the contractor since he is not required to accomplish component inspection as part of the process which is necessary to assure conformance of the end product to specification requirements.

c. Control of the quality of components (repair parts) is considered essential to the effectiveness (reliability, safety, performance) of equipment issued to the field and to the responsiveness of the logistics system. The initial procurement of the end product normally includes a sufficient quantity of repair parts to maintain equipment in the field for a predetermined period of time. Subsequent procurement of repair parts generally involves producers other than the end-product contractor and, more often than not, several producers are involved for a single repair part. To insure interchangeability and proper functioning of the end item using repair parts procured under the above conditions, the Army must specify the quality assurance requirements. The AMC practice, accordingly, is predicated upon the foregoing considerations.

5. Acceptance Quality Levels - Concept

a. Another area which has been addressed is the AQL concept and its application. In accordance with policy established by MIL-STD-105 "Sampling Procedures and Tables for Inspection by Attributes," the pertinent characteristics of a product are classified by degree of seriousness, (critical, major or minor), and corresponding acceptable quality levels (AQLs), (with the exception of critical defects), are assigned. The assignment of an AQL indicates a degree of non-conformance of the product (from prescribed technical requirements), which the Government can tolerate and is willing to accept.

b. MIL-STD-105 defines major and minor defects as follows:

Major defect - One that is likely to result in failure, or to reduce materially the usability of the unit of product for its intended use.

Minor defect - One that is not likely to reduce materially the usability of the unit of product for its intended use, or is a departure from established standards having little bearing on the effective use or operation of the unit.

The key interpretative factors in these definitions are the word "likely" and "not likely." Accordingly, subjective quantitative assessment of the seriousness of a defect is possible.

c. The AQL concept, as a quality indicator, is circumvented in many instances. This is particularly so for products which are rejected for excessive defects in the "departure from established standards having little bearing on the effective use or operation of the unit" category. Often, the rejected materiel are subject to the waiver process and generally the product is accepted, subsequently. Normally, when waivers are granted, the motivation for the contractor to improve his quality assurance system is diminished. There appears to be very little benefit to be derived by the Government in applying the AQL concept to minor defects unless a monetary penalty is imposed, (say 1% of the cost of the item). It is believed that serious consideration should be given to the development of appropriate policies to effect a salutary effect in this connection.

d. As an issue apart from the question which has been raised, it would be well for all contractors doing business with the Government, where military supplies are involved, to establish strict controls over the quality of components assembled into end products. End product reliability and performance is related to component quality. Additionally, the life cycle costs assoicated with military equipment may be correlated with equipment reliability. Contractors faced with the task of improving equipment reliability to reduce life cycle costs, now recognize that success is achieved through improved quality control of components. This suggests that DoD should consider a program emphasizing the importance of component quality control in terms of equipment reliability and costs of maintaining equipment in the field at the desired level of effectiveness.

e. This study finds that the AMC practice of specifying AQLs for components (repair parts) is in principle in consonance with DoD policy and does not necessarily restrict the contractor in developing a QA system (Ref. Appendixes I and VI).

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APPENDIX I

DoD PROCUREMENT QUALITY ASSURANCE POLICY

A. DoD QUALITY ASSURANCE POLICY

1. General.

a. DoD procurement quality assurance policy and general procedures for implementation are prescribed by DoD Instructions and the Armed Services Procurement Regulation (ASPR).[1,2] DoD procurement quality assurance policy is predicated upon the distinct delineation between contractor and government responsibilities for product quality. Prescribed policy and procedures, accordingly, assure that the supplies and services procured by the Department of Defense conform to the quality and quantity set forth in the contract and also assure the proper execution of the acceptance function associated therewith.

b. DoD procurement quality assurance policy, in brief, provides for the following:

(1) The contractor is responsible for:

(a) Controlling the quality of the product and offering to the Government for acceptance only supplies and services that conform to the contract requirements.[3]

(b) Performing the inspection and tests specified in the contract, except for those reserved for sole performance by the Government.[4]

(c) Maintaining an inspection system acceptable to the Government. When referenced in the contract, the contractor, additionally, may be required to comply with the requirements of MIL-I-45208, "Inspection System Requirements," or MIL-Q-9858, "Quality Program Requirements," as applicable.[5]

(2) The Government is responsible for:

(a) Verifying that the contractor has fulfilled contract quality requirements.*[6]

(b) Establishing the inspection and test requirements essential to assure the integrity of products and services.[7]

(c) Determining requirements based upon the particular procurement for standard inspection, inspection system, or quality program and specifying the applicable requirements by insertion of the appropriate quality assurance clauses in the contract.[8]

c. Incumbent upon the Government is the determination of the type and extent of Government procurement quality assurance actions required for the particular procurement. Included in this determination are elements, such as:

(1) Inspection of supplies and services.

(2) Review of the contractor's inspection system, quality program, or of any other means employed by the contractor to control quality and to comply with contract requirements.

(3) Maintenance of Government records to reflect actions, deficiencies, and corrective measures.

(4) Review and evaluation of quality information, including reports from the user, to initiate corrective actions or to adjust Government procurement quality assurance actions.

The foregoing, including the responsibilities cited in para. 1b(2), represent procurement quality assurance policy which determines the basis for Government plans for the execution of the acceptance function.

2. Responsibilities - Government Organizations.

a. ASPR 9 identifies three organizations having responsibility for quality of supplies and services. Specifically, these organizations

*Contract quality requirements as defined by ASPR mean the detailed requisites for quality consisting of: (i) all quality requirements contained in a contract, and (ii) the detailed contractual requirements incumbent upon the contractor to substantiate conformance of products or services to the quality requirements of the contract.

are the activities responsible for technical requirements, the Purchasing Office (PCO), and the Contract Administration Office (CAO). Responsibilities of these organizations, in brief, are as follows:

(1) The Technical Activity:

(a) Preparation of specifications or standards.

(b) Prescribing inspection, testing, or other contract quality requirements.

(c) Preparation of letters of instruction regarding the type and extent of Government inspection and testing requisite to assuring the integrity of products and services.

(d) Approving contractor recommended alternatives to contractually prescribed inspection methods.

(e) Assuring flexible planning and effective utilization of Government quality assurance resources at the facility level through minimum requirements for Government inspection.

(2) Purchasing Office:

(a) Preparing contracts and transmitting to the appropriate CAO.

(b) Conducting, in coordination with the Technical Activity, product-oriented surveys, and evaluation, as required.

(c) Participating with the CAO in pre-award surveys, post-award and pre-production conferences.

(d) Transmitting letters of inspection instructions to the CAO.

(3) Contract Administration Office:

(a) Verifiying the contractor's compliance with contract requirements.

(b) Developing and applying effective and efficient procedures for Government product assurance.

(c) Implementing letters of inspection instructions received from the PCO.

(d) Recommending actions leading to improvements and/or changes to the procurement quality assurance program to the PCO.

Included in this responsibility are recommendations concerning observed deficiencies in design or technical requirements.

b. ASPR Section XIV, Part 4, details the functions of the CAO through statements of policy and general procedures for performance of Government procurement quality assurance by the CAO. The prescribed policy and procedures require that the CAO:

(1) Establish and execute a systematic product-oriented plan for the particular procurement.

(2) Assure appropriate distribution of effort between system and product evaluation.

(3) Maintain adequate Government records which reflect the nature of all Government procurement quality assurance actions, decisions, and distribution of Government procurement quality assurance effort. Additionally, this portion of the ASPR establishes basic actions required of the CAO to determine the contractor's compliance with contract quality requirements.

BIBLIOGRAPHY - APPENDIX I-A

1. DoD Instructions 4155.6, 4155.8, 4155.10, and 4155.11.

2. ASPR Sections I, VII, and XIV.

3. ASPR 14-102.

4. ASPR 14-103.2.

5. ASPR 14-101.

6. ASPR 14-203.

7. ASPR 14-201.

8. ASPR 14-301-302-303, and -304.

9. ASPR Section XIV, Part 2.

B. ARMY (AMC) IMPLEMENTATION

1. General

a. DoD procurement quality assurance policy, briefly described in the preceding discussion, identifies the contractor's and Government's responsibilities for product quality. Additionally, key elements of DoD policy which determine the actions incumbent upon Government organizations having product quality responsibilities in the planning, programming and execution of quality assurance programs appropriate for particular procurements have been identified. This portion of the report examines the Army's(AMC) general implementation of DoD procurement quality assurance policy. AMC's implementation of QA policy as it relates specifically to the M16 Rifle Program is covered in Appendix II "M16 Rifle System QA Program."

b. AMC has a dual role in that it has both technical and procurement responsibilities for assigned materiel. To accomplish its mission, AMC is composed of seven (7) major commodity commands, each of which, has been delegated the design, development and procurement responsibility for its assigned commodities. Certain selected equipment/ systems, in addition, are under Project Manager control. Basic AMC policy delegates to the commodity commands/project managers, the responsibility for the quality of the materiel issued to the user. Inherent in this delegated responsibility is the quality assurance function, which involves the development of appropriate quality assurance requirements and standards for assigned materiel and liaison with contract administration offices.

2. Quality Assurance System

a. As viewed by AMC, three principal elements comprise the quality assurance system. They are: (i) the Technical Data Package, (ii) Contract Quality Assurance Requirements, and (iii) Government (DCAS) Quality Assurance Requirements. The development of a quality assurance system begins in the design/development phase of an end item.

The quality assurance provisions are included in the item specification which becomes part of the technical data package included in the contract. The development of meaningful QA test methods and standards, sampling criteria and acceptance/rejection standards normally requires close liaison between engineering and QA personnel.

b. (1) QA requirements developed for an end item are incorporated in Section 4 of the detailed specification. This specification as well as drawings, standards, and other specifications/reference documents is included in the technical data package. Through the medium of the detailed specification, the contractor's responsibility for inspection and tests is established (Standardization Manual M200 is now a DoD instruction). Where Acceptable Quality Levels (AQLs) are assigned, these AQLs are based upon knowledge of the previous capability (where available) and experience with like items produced under essentially the same conditions. In the absence of the foregoing, engineering judgements are made on an interim basis subject to change as experience is accumulated.

(2) Component AQLs, i.e., secondary items, are established to insure control of component interchangeability in the field and end item interchangeability. The important characteristics affecting the performance, safety and reliability of the end item are identified and the appropriate AQLs assigned. Component control is considered a prerequisite for maintaining the reliability/safety/performance parameters on a continuing basis for the end item. When items are not developed by the Army, the contractor is required to develop appropriate quality requirements and standards based upon this concept or principles he considers unique to the item.

(3) Technical characteristics which are functional in nature are tested to determine conformance or non-conformance with predetermined criteria. In many cases these tests are destructive/costly in nature thus limiting the number of items to be subjected to test. Statistical methodology is applied in establishing sample sizes, confidence

levels and risk factors to demonstrate conformance or non-conformance. This concept is a part of the component end item quality control concept.

3. Contract - QA Requirements.

a. The above efforts beginning with the contractor's responsibility for product quality is in consonance with DoD procurement quality assurance policy. Contract quality assurance requirements apart from the detailed specification are developed in accordance with guidance provided by ASPR Section XIV. The establishment of a contract requirement for a Contractor Inspection System in accordance with MIL-I-45208 or a Quality Program in accordance with MIL-Q-9858 specify the applicable paragraph of ASPR Section VII. Where the requirement for submission of a First Article sample is desired, ASPR clause 1-1900 is utilized.

b. Other quality assurance requirements incorporated in contracts, where applicable, include source inspection, destination inspection, certification and data (ADL-1423) requirements. These are typical but not all inclusive of the contract quality requirements. Specific contract quality requirements are developed by the AMC commodity commands and reflect DoD policy in this respect.

4. AMC - DCAS Interface

a. Quality Assurance Letters of Instruction (QALI)

(1) The intent and purpose of QALI is to provide a vehicle for conveying to the CAO from the PCO specific and/or unique quality assurance information/requirement which relate to a particular procurement and contract. The QALI is a technical document and identifies specific areas which have or may present quality problems to be addressed by the QAR. Typical of the information provided is:

(a) Problem areas encountered during development, engineering, and source tests.

(b) An analysis of past quality history data on the same or similar items.

(c) Requirements for post-award and preproduction conferences.

(d) The quality assurance point of contact for the procurement.

(e) Information feedback from the QAR.

(2) In accordance with DCAS policy, Mandatory A inspection requirements (Government product inspection required by procuring activity) are included in the QALI. Army guidance provides for the judicious selection of those product characteristics to be subjected to Mandatory A inspection by the QAR. Other information provided includes procedures for handling of non-conforming materiel, waiver requests, identification of the PCO quality assurance representative, requirements for first article and special proving ground tests, as applicable.

(3) The QALI is a product oriented document. General administrative or technical requirements which are properly a part of the technical data package are not included.

b. Product Quality - Liaison Representative (key inspector)

(1) The intent and purpose of the PCO quality assurance liaison representative (key inspector) is to provide personal representation to the CAO on all matters affecting contract quality assurance requirements. Through the media of post-award conferences the interface between the key inspector/QAR/contractor is established. This provides a means for obtaining formal interpretation and clarification of QALI requirements and/or other quality assurance requirements contained in the technical data package and other parts of the contract. The product quality liaison representative is selected on the basis of his overall knowledge and familiarity with the commodity, the quality assurance program and the contract.

(2) Apparent inconsistencies between provisions of the technical data package and other parts of the contract are brought to the attention of the PCO by the product quality liaison representative. This provides a basis for the resolution of inconsistencies prior to the initiation of high density production.

C. DCAS IMPLEMENTATION

1. General

Within the Defense Contract Administration Services, the Quality Assurance Representative (QAR) is delegated authority to accept or reject submitted supplies for the Contracting Officer. Within an assigned facility, this authority may be redelegated by the QAR or other quality assurance personnel. Redelegation may be in the form of specific authorizations contained with position descriptions or by a letter of delegation.

2. DCAS Policy

a. Support of Purchasing Offices

(1) Maximum support and cooperation is provided Purchasing Offices. The Purchasing Office may specify requirements for Product Inspection Type (PIT A), which is the direct Government inspection and control of a product or characteristics of a product, and the particular sampling plan that is to be applied by the QAR. Where such requirements are not specified by the Purchasing Office, the QAR selects a method based upon the contract requirements, knowledge of the product and manufacturing process involved, and evidence of control by the contractor. DCAS policy provides for a modular program approach in the application of product inspections or quality assurance system evaluation, depending on contract requirements and the in-plant situation. In the selection of appropriate procedures, the QAR is guided by his knowledge of the product and the plant situation, and may call for staff specialists or higher supervisory personnel assistance.

(2) Direct communication is authorized between the QAR and Purchasing Office and technical activities. Such communications are for the purpose of clarifying requirements and resolving various contract problems.

b. Management Concepts

(1) Upon receipt of new contracts, particularly those involving new contractors, a review by quality assurance personnel is made for the purpose of identifying special or unusual quality requirements. If it is determined that requirements are apparently incorrect, incomplete, or unclear, such discrepancies or omissions are reported to the appropriate Contracting Officer for necessary action in accordance with Section XIV, ASPR. DSA Form 623 is used to report deficiencies or problems involving contracts. Timely and adequate resolution of these problems by purchasing offices is considered an essential element in assuring that supplies and services meet contractual requirements. Also, this review of the individual contract assists the QAR in making a determination as to the advisability of arranging for a post-award orientation conference with the contractor. The essential planning element involves in-plant duty assignments associated with components of the procurement quality assurance program, such as Product Verification Inspection, Procedures Evaluation, Contractor Decision Verification, and other functions.

(2) The individual Military Departments and the Defense Supply Agency have developed and refined a considerable number of techniques that are used by DCAS for specific commodities. The Purchasing Office may make reference to these existing publications at the time the contract is forwarded to the Contract Administration Office.

(3) From a management concept, the Procurement Quality Assurance Program is treated as five major elements. These elements are:

(a) Review of contractor's written procedures
(b) Procedures evaluation (continuing)
(c) Product inspection
(d) Contractor decision verification

(e) Corrective action

These elements, as applicable, are applied to evaluate the effectiveness of a contractor's control of product quality and for determining the acceptability of tendered supplies or services required by contract. All of these elements may not always be applicable to a given contractor or contract.

3. DCAS Procedures

a. General

(1) DSAM 8200.1 is the fundamental document in which procedures for the performance of all in-plant functions of the DCAS Procurement Quality Assurance Program are described. The manual standardizes procedures essential to the effectiveness of the government procurement quality assurance function.

(2) This manual is based on three premises: (1) the Purchasing Office is responsible for establishing contractual quality requirements; (2) the Contractor is responsible for controlling product quality and for offering to the Government only supplies and services that conform to all contractual requirements; and (3) the Contract Administration Services Representative is responsible for assuring that all contractual requirements have been complied with prior to acceptance of the supplies or services.

b. QAR Responsibilities

The DCAS Quality Assurance Representative is responsible for: (1) familiarity with contract quality requirements; (2) verifying that the contractor has complied with all contractual requirements relating to quality; (3) performance of any special inspection actions requested in writing by Purchasing Offices; (4) providing feedback information to Purchasing Offices; and (5) developing and applying an effective and economical quality assurance program.

c. Procurement Quality Assurance Program

(1) The DCAS Procurement Quality Assurance Program is divided into five parts: Procedures Review, Procedures Evaluation, Product Verification Inspection, Contractor Decision Verification, and Corrective Action. The program is viewed as a series of modules or building blocks which may be used separately or all together or in any combination, depending on the particular contract/contractor requirements. Requisite is the requirement that the Procurement Quality Assurance Program be administered both economically and effectively. The Quality Assurance Representative is responsible for selecting the appropriate parts of the program for application in inspection administration of the contract.

(2) Where the contract involves the requirement for a quality program or inspection system, as described in MIL-Q-9858 or MIL-I-45208, the Quality Assurance Representative is responsible for the review and evaluation of the contractor's written procedures. Additionally, other types of contract requirements which require control of processes, such as welding or radiography, must be considered. The Quality Assurance Representative further must plan for performing all requirements imposed by the Purchasing Offices.

(3) PQAP Elements

(a) The first major element of the Procurement Quality Assurance Plan (PQAP) is a review of the contractor's procedures. Normally, H-50, H-51, and H-52 are used as a guide in the review of the procedures. In the event a contractor changes procedures or prepares new procedures, these changes or new procedures are reviewed by the government representative.

(b) The second element is procedures evaluation. The purpose is first to determine that the contractor is, in fact, complying with prepared procedures, and second, the procedures are, in fact, adequate to meet contract requirements. The government representative may establish whatever frequency he deems advisable for such review based on the particular situation.

(c) The third element of the program is product verification inspection. Product verification inspection is identified with three separate categories. The first is product inspection requirements which have been imposed by the purchasing office which DCAS continues to perform until the purchasing office removes the requirement. The second are those inspection requirements that the government representative deems appropriate based on normal contract requirements. The third category is unprogrammed inspection which occurs when the government representative elects to initiate product requirements based on actual quality problems, or those anticipated.

(d) The fourth element is contractor decision verification (CDV). CDV is a technique for evaluating the contractor's compliance with his inspection procedures. It is designed to provide some insight into the contractor's program and is not directly concerned with evaluation of product quality. CDV is a tool designed to move the government into a position where effective audits can be performed to assure the contractor's compliance with quality requirements and is based on the fact that if a constant number of the contractor's inspection decisions are verified at certain time intervals, a process average will be developed which relates to the efficacy of the contractor's program.

(e) The fifth element of PQAP is concerned with corrective action. Methods employed are:

Method A - An on-the-spot, oral conversation with the contractor.

Method B - A standard form is forwarded to the contractor providing written notification of the deficiencies.

Method C - A letter is forwarded by the government representative to the contractor's quality control management personnel requesting immediate correction of the causes of deficiencies.

Method D - The government representative recommends to the ACO that the contractor be advised officially that a serious quality problem exists at his facility and that immediate corrective action must be taken to comply with contract requirements.

Method E - The prime contractor is requested to assure that the subcontractor takes the necessary steps to correct the observed deficiencies.

4. Summary

The DCAS quality program is designed to determine that the contractor (1) has the necessary procedures, (2) is in compliance with those procedures, (3) includes product inspection, (4) has a method for evaluating the contractor inspection decisions, and (5) provides controlled escalating procedures for effective corrective action.

APPENDIX II

M16 RIFLE SYSTEM QA PROGRAM

A. HISTORICAL BACKGROUND

1. The AR-15 rifle, now designated the M16, was developed in the Armalite Division of the Fairchild Engine and Airplane Company without active government participation. Accordingly the rifle was not designed to meet formally established military characteristics and requirements (QMR). This rifle with its production drawings and all rights were subsequently procured by Colt's Inc. (1959).

2. The rifle was made available to the Army in 1958 and testing began as a follow on to earlier investigations of high velocity small caliber weapons systems. 1/

3. The Air Force also became interested in this weapon and about 1960 adopted it (AR-15) for their use.

4. In 1962 the Advanced Research Project Agency (ARPA) looking for a rifle better suited for use by the Vietnamese than the M1 and the carbine selected the AR-15 for troop and combat test in Vietnam. 2/ It was concluded that the AR-15 was a more desirable weapon for use in Vietnam than any of the WWII weapons then being used.

5. In late 1962 and early 1963, the Army undertook a comprehensive evaluation of rifles, conducting engineering and troop test with the AR-15 and comparative tests with the M14. 3/ Based on these tests the AR-15 was adopted by the Army and its procurement for use by airborne, airmobile and Special Forces units was recommended.

6. In early 1963 the Secretary of Defense approved the Army recommendation for procurement of the Rifle and he also designated the Department of the Army the procurement agency for all DOD users. 4/

7. Prior to the initial Army procurement the Air Force in FY 62 and FY 63 had contracts for a total of 27,500 rifles. The initial Army procurement in November 1963 included 85,000 rifles for Army use and 19,000 rifles for the Air Force.

8. As mentioned above there were no formal military characteristics (QMR) approved for this rifle. (The Infantry Board published draft characteristics for such a rifle in 1957 but they were never approved and formalized). Therefore, a task group of personnel of Hq WECOM, Springfield Arsenal, the Air Force, the Navy and the Marine Corps developed performance specifications (SAPD 253) based on conventional type rifle requirements such as headspace, proof testing, firing pin indent, trigger pull, etc. Malfunctions and unserviceable parts permitted during the reliability test outlined in SAPD 253 were generally the same as those specified on the Air Force contract AF-33-(675)-10871. Guidelines provided by the Project Manager (which he received from the Secretary of Defense) were that final acceptance testing for the AR-15 Rifle could be no more stringent than those required for the M14 Rifle. 5/

9. The original SAPD 253 was developed during the week of 15 July 1963. The specifications were concurred in by the four services. Colt's personnel were appraised of the complete document and agreed that the AR-15 rifle would be manufactured in accordance with, and was capable of meeting, the specified requirements.

REFERENCES

1a. "Report of Project NR 2787, Evaluation of Small Caliber High-Velocity Rifles - Armalite (AR-15), (DA Project 502-08-006) (U)," USAIB, 27 May 1958 (AD301918).

b. "Rifle Squad Armed with Lightweight High-Velocity Rifle. (CDOG, CDEC 58T9), Final Report," USACDEC, 30 May 1959.

2. "Report of task #13A Test of Armalite Rifle, AR-15 (U)" R&D Field Unit, ARPA, 31 July 1962.

3. "Rifle Evaluation" ODCSOPS, Hq. DA, October 1962 - January 1963.

4. Memorandum for the Secretary of the Army signed Robert S. McNamara, Subject: AR-15 Ammunition and Rifle (U), 11 March 1963.

5. "AR-15 Conference" held at Springfield, Arsenal 17-18 July 1963.

B. CONTRACT ANALYSIS - QA ASPECTS

1. M16 Rifle

a. Background

The initial Army contract for the procurement of the AR-15 Rifle (Government designation: 5.56mm M16) was awarded to Colt Patent Fire Arms Mfg. Co., Inc (Colt Industries, Inc) Contract No. DA-11-199-AMC-508(Y) on 4 November 1963. The AR-15 rifle was a proprietary item and accordingly the technical data package consisted principally of contractor drawings supplemented by Government drawings which prescribed specific Army requirements; a purchase description (SAPD 253) "Acceptance Testing Specification for Rifle, AR-15 w/Amend 2", and additional Quality Assurance Provisions contained in Section IV of the contract. Subsequently a Letter Contract DAAF03-66-C-0018 was awarded to Colt Industries, Inc in December 1965. All updated Quality Assurance Provisions in effect for Contract DA-11-199-AMC-508(W) as of the date of the Letter Contract were made applicable to Contract DAAF03-66-C-0018.

b. Quality Assurance Provisions

(1) Purchase description. Purchase description SAPD-253 establishes the technical requirements for the AR-15 Rifle and the inspection and test procedures for determining compliance with these requirements. SAPD-253, additionally, places the responsibility upon the contractor for performing all inspection specified therein unless otherwise specified in the contract. (Analysis of the quality assurance requirements of the purchase description is provided in Appendix III, pp. 3, 4.)

(2) Contract.

(a) Additional quality assurance provisions are established in Section IV of the contract. Documents cited therein and pertinent to the quality assurance program were:

1. MIL-Q-9858 "Quality Control System Requirements"
2. MIL-C-45662 "Calibration System Requirements"
3. MIL-I-6868B "Inspection Process - Magnetic Particle"
4. MIL-STD-105 "Sampling Procedures and Tables for Inspection by Attributes"
5. MIL-STD-643 "Evaluation of Contractor Quality Control Systems"

(b) The contractor, in addition to providing the Government with a general quality control plan in accordance with MIL-Q-9858 which included the requirement for a Materiel Review Board (MRB), was also required to provide a detailed quality control plan. The latter consisted of Inspection Instruction Sheets supported by a classification of defects and AQLs for each component, subassembly and assembly of the rifle. The contract, additionally provided a range of AQLs for both major (0.65 - 1.5) and minor (1.5 - 4.0) characteristics which the contractor was to use in setting his AQLs and definitions for classifying characteristics as major or minor.

(c) The contractor was required to provide for all gages and test equipment, both in-process and final, and make available the final inspection equipment to the Government representative for use in his verification procedures.

(d) Four (4) rifles selected at random from first production were required for complete examination and testing. These rifles were identified as Manufacturing Models and intended to serve as "Standards for comparison"; two (2) being retained at Springfield Armory and two (2) at the Contractor's facility. The contract further provided for ten (10) rifles to be selected at random during the course of the contract for Quality Assurance Comparison Testing. The first five (5) rifles were required from the first months production and the remaining five (5) upon request by the Quality Assurance representative.

(e) Packaging and packing requirements including classification of Defects, AQLs and Sampling Instructions are contained in Section IV. AQLs were assigned for each defect rather than for a group of defects. In this respect the contract allowed latitude to be exercised by the contractor in applying AQLs to an individual or group of characteristics in the Inspection Instruction Sheets he was required to develop as part of his detail quality control plan.

(f) Section IV of the contract additionally includes considerable administrative guidance for the contractor. Much of this information is repetitious since it is contained in the documents cited in the contracts such as MIL-Q-9858 and MIL-C-45662.

(g) Detailed reports required of the contractor for submission to the Government included results of final inspection, function firing, targeting and accuracy, reliability and interchangeability tests.

(h) Contractor was advised that his quality control and inspection activities would be subject to Government surveillance and verification at unscheduled intervals.

c. Critique

(1) Section IV of the contract includes material which is superfluous and repetitive since the information repeated is contained in the documents referenced in the contract as indicated

[in para 1.b.(2)(f)] above. This practice is not desirable since the possibility of introducing errors and conflicting requirements is enhanced.

(2) Evaluation of the contractor's quality control system should have been based upon the requirements of DoD Handbook H-110 rather than MIL-STD-643. At this point in time (contract date) MIL-STD-643 had been superseded by DoD Handbook H-110. Although this is not a major point, it is indicative of a failure to employ the latest revision or edition of a referenced document. Unless there are compelling reasons to use an older version the practice is to cite the revision in effect at the time the contract is signed.

(3) The Government in specifying a range of AQLs for major and minor characteristics for component parts imposed a limitation upon the contractor. The preferred approach should have been to require the contractor to submit to the Government his proposed AQLs. The Government, then, could have exercised its option of disapproving the contractor's proposed AQLs if, in its opinion, adequate quality assurance protection was not afforded. Conceivably, the contractor might have selected tighter AQLs for certain major characteristics rather than an AQL of 0.65%. This latitude however was not afforded the contractor under the Quality Assurance Provision - Section IV. The above method would not be applicable when Army develops an end item in-house. Here the AQLs and classification of defects specified for component parts (secondary end items) essential to the logistic support of the end item and maintenance of end item reliability, safety, and performance represent conformance requirements arrived at through engineering analysis.

(4) Although MIL-STD-105 was part of the contract, the Government elected to provide additional guidance regarding the definitions for major and minor characteristics. The definitions provided were at variance with MIL-STD-105 definitions and therefore introduced an additional variable with respect to the development of appropriate quality assurance requirements.

(5) Manufacturing models were established as comparison standards against which other rifles, selected during the course of the contract for purpose of quality evaluation testing, would be compared. It is to be noted there is no provision for new comparison standards in the event major modifications were introduced. Thus updated standards for comparison purpose not being required contractually, permits retention and use of standards which are obsolete and therefore lose their significance as standards.

(6) The provision for a total of ten (10) rifles to be selected for Quality Assurance Comparison Testing throughout the contract affords little assurance that the process is in control. To achieve the objectives of this type of testing, particularly for high density production, comparison testing should be accomplished at frequent intervals. Although additional rifles were selected for endurance testing, as part of a quality audit program instituted when the current difficulty with the M16 Rifle surfaced, future contracts should consider changes to the procedure followed for this and the subsequent contracts which may be awarded to Colt Industries, Inc.

(7) A choice between the use of MIL-Q-9858 and MIL-I-45208 existed at the time the contract was awarded. The use of MIL-Q-9358 generally is for application to complex systems requiring that the contractor maintain a total quality control program. This specification contains requirements in excess of those in specification MIL-I-45208. In considering this procurement and recognizing that a judgement factor was exercised, there is a question as to whether specification MIL-I-45208 would not be more appropriate.

2. 5.56mm Ammunition

a. Background

The commercial version of technical data provided by the manufacturer of .223" ammunition (Remington) did not include the quality assurance requirements considered necessary by the Army to assure conformance of ammunition to technical requirements. These technical data were subsequently revised to reflect the quality assurance requirements associated with the procurement of similar items developed by the Army, e.g., 7.62mm ammunition and used in the procurement of 5.56mm ammunition. The original technical data included the requirement for IMR 4475 propellant; however, ball propellant (WC 846) was introduced as a requirement to provide for minimal performance characteristics, e.g., velocity established for this round. Contracts were placed with Olin-Mathieson, Remington Arms, and Federal Cartridge.

b. Quality Assurance (QA) Provisions

The contract QA requirements consisted of a Technical Data Package List (TDPL) which included MIlitary Specification MIL-C-9963 (See Chapter II, para. B, p. 45) for 5.56mm Ball Ammunition. This list of specifications also included the requirement for a Contractor Inspection System MIL-I-45208A. (This was prior to the development of ASPR Contract clauses for referencing MIL-Q-9858 and MIL-I-45208 in the contract.) The contract also specified submission of an initial production sample to a Government laboratory (Frankford Arsenal) for test and inspection.

c. Critique

(1) The contract established contractor responsibility for conducting all tests and examinations contained in the specification or referenced documentation except as otherwise stated. This is in consonance with a basic principal of DoD policy.

(2) A Military Specification for propellant was also a part of the contract (list of specifications on TDPL). This specification provided for chemical, physical and functional testing of the applicable propellant. The cartridge specification (MIL-C-9963) also included a list of approved Inspection Equipment Designs for the test and examination of the product. This list included mandatory ballistic test equipment which is Government furnished.

(3) The elements of the Quality Assurance System prescribed for contractor action, beginning with the Item Specification through the referenced Quality Assurance Documentation based upon information generated to date appear to have provided a complete system for

determination of contract requirements for product quality of ammunition. Sufficient latitude is afforded contractors to incorporate viable quality control requirements essential to the production of satisfactory ammunition.

C. ARMY QUALITY ASSURANCE PROGRAM

1. M16A1 Rifle Quality Assurance Program.

a. Prior to October 1967, the Quality Assurance Program was essentially managed by the Project Manager, Rifles. During October 1967, the Project Manager requested that USAWECOM Quality Assurance Directorate provide overall quality assurance support with respect to the M16A1 Rifle Program. This represented a basic change since, prior to that time the USAWECOM QA Directorate furnished QA support to the Project Manager only as requested on a case-by-case basis. This Task Group did not conduct an in-depth analysis of the Rifle QA Program for the time period prior to October 1967. However, limited review revealed that elements of a QA Program were instituted. For example, a Quality Assurance Letter of Instruction (QALI) was issued to the Boston Army Procurement District which established procedures for: evaluating the contractor quality control plan; review of contractor's purchase orders; evaluating the contractor's quality and inspection records; evaluating and verifying the contractor's use of "in-process" and "final inspection equipment"; submitting of "Manufacturing Models"; and Government surveillance and product verification. In August 1965, contract administration was transferred to DCASD, Hartford, and requirements established by the QALI were applied to their operations. Various quality verification visits were made. No significant actions, however, were taken as a result of these visits.

b. Since October 1967, the Army QA Program for the M16 rifle includes, but is not limited to, the following:

(1) Quality Assurance Technical Data.

(a) Specification SAPD-253.

1. An analysis of the criteria established for contractor periodic reliability testing (SAPD-235B) of the M16A1 rifle was initiated in October 1967 to determine whether these requirements should be continued or modified to conform to current small arms

knowledge, technology, etc. The study included all aspects of the program to determine numbers and types of allowable malfunctions and unserviceable parts, appropriate sample sizes, and testing procedures. A Task Group was established in February 1968 to review the final examination and performance requirements as specified in SAPD-253B, "Acceptance Testing Specification for Rifles, 5.56mm M16/M16A1", to determine the adequacy of these requirements and revise them, as necessary, to assure that desired performance and quality levels are being met. The reliability analysis and specification review were then conducted concurrently.

2. As a result of the above, revisions were made to SAPD-253B. These revisions were reviewed by the AMC/DCAS QA Committee and were discussed with Colt Industries, Inc., Quality Assurance Representative. These changes included: a revised table of allowable malfunctions and unserviceable parts, improvement to the sampling plan for cyclic rate of fire testing, addition of a mission performance test, addition of an interplant interchangeability test, addition of cleaning and lubrication criteria for testing, addition of inspection and tests for packaging, and revised criteria for inspection lot size. The format was made consistent with standardization procedures for Military Specifications.

(b) Inspection Engineering Documentation. As a result of the monthly quality audit of rifles and a quality verification visit to Colt Industries, Inc., some inadequacies in the inspection equipment designs were noted. As a result, a Task Group of inspection engineering personnel was established in February 1968 and located in-house at Colt Industries, Inc., for the purpose of reviewing inspection equipment designs to determine their adequacy and compatibility with the product drawings. This action was considered essential to correct deficiencies in the criteria for assuring that current hardware conforms to product drawing and to further assure that uniform criteria is furnished to other sources of production. The changes generated by this Task Group review are being implemented into the other sources of production as well as Colt Industries, Inc., contract. Inspection Instruction Sheets are currently being updated, as necessary, for consistency with such changes to the inspection equipment designs determined necessary by the Task Group.

(2) Section IV - Quality Assurance Provisions. The Quality Assurance requirements for contractual documents for Colt's contract and the second source contract were reviewed concurrently with the Purchase Description review indicated in paragraph b(1)(a)1, above, and were subsequently revised to uniformly provide for: additional inspection and test requirements to assure that desired product quality and performance are obtained; extensive quality evaluation of early production items; increased vendor controls by the prime contractor; and increased quality audits by the Government.

(3) Quality Verification Program. A two-week quality verification visit was conducted at Colt Industries, Inc., in December 1967 by a team of two quality assurance specialists to assess the overall adequacy of product inspection, inspection equipment, and the quality assurance program. The quality assurance verification visits are conducted periodically to assure compliance and uniform implementation of quality assurance policies, regulations, approved systems, procedures, and requirements of contracts. DCAS is advised of the results verbally at the time of visit and agreements are confirmed by letter.

(4) Monthly Product Quality Audit of Rifles and Components. As a result of complaints received from the user, a program, which began in November 1967, is being conducted to provide a monthly quality audit of M16A1 rifles and repair parts representative of production on Colt Industries, Inc.,current production contract. Rifles and components are selected monthly from accepted items on the contract and shipped to a Government Arsenal for a quality audit to determine conformance to contract requirements. Results of the audit and subsequent analysis form a part of the monthly product assessment report that is prepared. In addition, DCASD, Hartford and the contractor are provided results

of the quality audit, monthly. As a result of these monthly quality audits, the need for the Task Group review of inspection engineering documentation was identified (see paragraph b(1)(b), above). In addition, the need for selected Product Inspection Type A, in accordance with DCASM 8200.1, was identified and DCASD, Hartford was advised by an amendment to Quality Assurance Letter of Instruction in April 1968.

(5) Quality Assurance Letter of Instruction.

(a) As a result of reports from the user concerning quality of product, a Quality Assurance Letter of Instruction was issued to DCASD, Hartford, on 17 November 1967, requesting the Government representative to perform certain mandatory inspections (PIT A) considered necessary to determine conformance to contract requirements prior to the acceptance of rifles. The letter further requested that periodic reports containing results of contractor's monthly performance testing and final examination of rifles be provided for utilization in the analysis of data and preparation of the monthly M16A1 rifle product assessment report. As a result of the monthly quality audit, additional mandatory inspections were found necessary, and DCASD, Hartford was advised by an amendment to the Quality Assurance Letter of Instruction in April 1968.

(b) In May 1968, Quality Assurance Letters of Instruction were issued to the applicable Defense Contract Administration Services Regions for the new sources of procurement. Post Award QA Conferences have been scheduled for August 1968 with these Regions.

(6) Quality Assurance Test Programs.

(a) Quality Assurance Comparison Tests. A Quality Assurance Comparison Test of M16A1 rifles is currently being conducted by an independent Government test agency in accordance with a coordinated test plan. The Comparison Test started in March 1968. The DCAS element is advised of any quality problems that occur during a Comparison Test. Comparison Tests are conducted to:

1. Determine if the item from continuing production is equal to or better than the item approved by type classification action.

2. Detect any degradation of product quality or reliability during production.

3. Verify that all deficiencies reported as a result of previous tests have been corrected.

4. Evaluate the effect of any product changes on the performance, reliability, and maintainability of the present weapon system.

Additional Quality Assurance Comparison Tests have been scheduled for the M16 rifle during future Colt Industries, Inc. production. In addition, Comparison Tests have been scheduled for periodic evaluation of M16A1 rifles produced by the new sources.

(b) Quality Assurance Initial Production Tests. Initial Production Tests have been scheduled for testing of M16A1 rifles selected from the new sources first month's production. The Initial Production Test is conducted by an independent Government test agency in accordance with a coordinated test plan. The Initial Production Test is conducted to:

1. Verify the complete adequacy and quality of the product when manufactured by the normal production process in accordance with the approved technical data package.

2. Determine if the item from production is equal to or better than the item approved by type classification action, and determine that the user requirements and design intent are being met in the production item.

3. Assure that deficiencies noted and reported in prior and current tests have in fact been corrected in the production item before release.

4. Insure that all appropriate tests and evaluations have been accomplished on the new item prior to initial issue.

5. Provide a basis for the determination of the suitability of this item for issue to the user. (Ref. AMCR 700-34).

(7) Quality Assurance Data Collection and Data Analysis.

(a) Field Data. Equipment Improvement Reports (EIRs) and Unserviceable Materiel Reports (UMRs) are the means by which field data are usually provided.

1. EIRs are provided through maintenance channels and those EIRs which are related to quality are forwarded to quality assurance elements for action. The action which is taken is fed back through maintenance channels. Copies of all EIRs and the actions which are taken are provided to the quality assurance elements for logging and periodic reviews to identify repetitions or trends. It should be noted that the majority of EIRs are not related to quality (i.e., related to design, maintenance, etc.). The frequency of receipt of EIRs (all types) applicable to the M16A1 rifle, is approximately four to five per month.

2. Unserviceable Materiel Reports are documents on materiel received by the field in an unsatisfactory condition (usually at depots). No UMRs have been received since October 1967. UMRs are also evaluated and acted on, as necessary, and are logged and reviewed periodically for reoccurrences or trends.

(b) Gathering Failure Data from Ammunition Test Sites.

1. A feedback channel for transmittal of data generated thru tests of ammunition was established in February 1968 to provide information on parts mortality, performance and durability of slave weapons (M16A1 rifles) and magazines used in ammunition tests. Rifle performance and replacement data, as well as dimensional measurements recorded prior to and after firing tests, will be used by product assessment activities in the development of reliability and performance requirements for acceptance of product on future contracts.

2. A visit was made to an ammunition test site by quality assurance personnel associated with the ammunition and with the rifle in May 1968 to investigate reported magazine failures. This visit resulted in several modifications of test procedures. In addition, reporting procedures were modified to assure that usable data is provided for on rifle QA program.

(c) M16A1 Rifle Quality Assessment Report. A Quality Assessment Report on the M16A1 rifle is prepared monthly to provide an analysis of data gathered from monthly quality audits of rifles, quality verification visits to the contractor's plant, DCAS reporting (as required) by the Quality Assurance Letter of Instruction, contractor inspection reports, Lake City fouling test reports, and user reports from the field. The initial report was prepared in November 1967. This report is provided to various QA elements associated with the rifle program and to DCAS along with results of monthly quality audit of rifles. The data for this report are reviewed to determine the need for additional actions (e.g., in December 1967, action was initiated regarding repetitive contractor responses to DCASD QDR's).

(d) Data Collected at CONUS Training Stations. A program was established in November 1967 for obtaining information concerning malfunctions encountered with the M16A1 rifle during Vietnam-oriented training at CONUS training stations. This was accomplished by visits of a team of quality assurance personnel who gathered data on-site and provided appropriate recommendations relative to utilization of the data. These actions have now been accomplished in connection with the basic infantry training conducted at Fort Polk, Louisana; Fort McClellan, Alabama; and Fort Jackson, South Carolina. Recommendations were made as a result of this program; however, none of these recommendations was directly related to quality assurance activities.

(8) AMC/DCAS M16/M16A1 Rifle Quality Assurance Committee. Representatives of various QA elements familiar with the various quality assurance activities pertinent to M16A1 rifle were appointed in February 1968 to the subject committee to assist in the integrated control over the numerous efforts being made to insure that Colt Industries, Inc. production output meets desired quality levels. As a result, coordination on all quality assurance matters relative to contractor performance will be accomplished with the contractor; DCAS; DCASR, Boston; DCASD, Hartford; USAMUCOM; Project Manager; USAWECOM elements; and USAMC.

(9) Procurement Quality Assurance Pamphlets. A scope of work for preparation of a quality assurance pamphlet has been prepared for inclusion in a contract. The Procurement Quality Assurance Pamphlets contain technical information and general procedures for testing and inspection operation and are used as case examples in training quality assurance personnel (DCAS and contractor) on-site. This pamphlet will be used for training the second and third sources quality assurance personnel.

(10) Quality Assurance Training Program. Planning has been initiated to provide a Quality Assurance Training Program for Government and contractor QA personnel associated with additional sources of M16A1 rifles. This training is essential to provide instruction and guidance in the use of the inspection equipment and test methods with respect to the M16A1 rifle program.

(11) Project Manager Field Offices.

(a) RVN. A field office has been established in RVN to investigate and furnish weekly reports on all malfunctions, supply problems, maintenance, etc., that M16A1 rifle users are having in the field.

(b) Frankford Arsenal. A field office has been established at Frankford Arsenal to provide the Project Manager with on-site representatives associated with ammunition.

(12) Independent Tests. A rifle selected from each inspection lot of rifles produced at Colt's is subjected to a reliability test (SAPD-253B) at a Government test agency to provide an independent evaluation of the reliability performance of rifles currently produced.

(13) Other Actions. In addition to the above, other actions are taken as conditions warrant. For example:

(a) At the request of DCASD, Hartford two QA representatives were stationed at Colt Industries, Inc. on TDY for 30 days to provide technical assistance as to the adequacy of corrective actions taken and to improve communications.

(b) As a result of non-conforming barrel chambers noted at a Government arsenal, a QA representative visited Colt Industries, Inc. to determine the extent of this problem.

(c) A visit to Colt Industries was made by a team of QA representatives to review the DCAS, Colt, and Army plan of inspection. As a result of this visit, the interchangeability control test by DCAS was reinstated and DCAS procedures for approval of the contractor's final inspectors was instituted. The contractor was advised of the area in which he was not complying with the Purchase Description. The monthly data to be forwarded by DCAS for use in preparation of the Product Assessment Report were reviewed with DCAS.

2. Army Quality Program for 5.56mm Ammunition. The quality assurance program for procurement of 5.56mm ammunition consists of three (3) basic elements:

Technical Data Package Requirements (Quality Assurance Provisions of Specification and Reference Documents).

Contract Quality Assurance Requirements (ASPR and Special Clauses).

Government Quality Assurance Efforts PCO and ACO Program.

a. Technical Data Package Requirements. The Quality Program of the Technical Data developed for the procurement of small caliber ammunition includes a coordinated Military Specification for Ball and Tracer cartridges. These documents contain Quality Assurance Provisions of a detailed nature covering end items which require inspection and tests by the contractor. The technical data also include supplemental quality assurance MIL-STD's and Quality Assurance Pamphlets. These documents add to the system, ethods, and procedures for standardization of subjective decisions or other interpretative requirements. Inspection equipment, unique with respect to their function, are also furnished in the Technical Data Quality Program to assist both the contractor and Government.

b. Contract Quality Assurance Requirements.

(1) The quality assurance requirements of the contract include the applicable clauses from ASPR. These requirements include the Inspection System Specification MIL-I-45208A. The contractor is required to establish an inspection system to control the quality of product during manufacture. This system is subject to review and disapproval by the Government.

(2) Where procurement from a new producer or reprocurement from a previous producer is initiated, First Article/Initial Production Samples are required to be submitted to a Government approved laboratory for tests and evaluations prior to the beginning of high density production. This requirements is included in the contract through reference to the appropriate ASPR clauses.

c. Government Quality Assurance Efforts.

(1) The Procurement Contracting Office (PCO) Quality Assurance Program is initiated during the pre-award phase of the contract. Army participation in Pre-Award Surveys with Administrative Contracting Office personnel (DCAS) is a part of the program. Subsequent to awarding the contract, a Quality Assurance Letter of Instruction

(see Incl 1) is prepared by the product quality liaison representative (Key Inspector) to whom the task is assigned. This letter, forwarded to the DCAS office administering the contract, identifies the key inspector to whom the contract is assigned by the PCO. In addition, it identifies specific aspects of the quality program that the DCAS quality assurance representative should be aware of in the development of his plan. Background information as to past quality assurance problems with the item are identified, when available or pertinent. The requirements for Mandatory "A" inspections are also included. Procedures for processing of waivers on non-conforming material and special sampling requirements for Product Specification (Critical Defects) by the Government are other aspects of the Letter of Instruction.

(2) Prior to production, post award visits are made by the PCO key inspector to the DCAS office and the contractor facility. These visits and conferences are scheduled for the purpose of discussing the QA requirements of the technical data and the contract, and to interpret or correct requirements or deficiencies which may be present. During these visits the contractors inspection plan and DCAS verification procedures are reviewed for information purposes. The interface between the key inspector and DCAS QA representative intentionally provides for a catalytic function with respect to the quality assurance program of specific contracts, such as that for the 5.56mm ammunition.

(3) The general aspects of the quality assurance program, through the three basic elements, provide for data feedback and analysis by the quality engineering function of the PCO. Special quality assurance reports are prepared on a quarterly basis and are issued to all elements, i.e., the DCAS, USAMC, Project Manager, etc. These reports indicate the quality of ammunition being produced by the various contractors. These reports also serve to revise, when determined necessary, product and quality assurance requirements of the technical data of the contract.

(4) Special fouling tests have been instituted with samples from each lot of ammunition which is accepted to determine the need for corrective actions by engineering or quality assurance personnel. These tests, conducted at Lake City Army Ammunition Plant, have also served the U. S. Army Weapons Command, relative to data and information on rifle/magazine performance.

Encl. 1.

Q1000 RF
Q5000 RF
Q5200 RF
Q5200 cont file
Q5200 Mr. Edwards
Q5200

Q3000 RF
B1000 RF
P3310 Mr. Foy

Mr. Edwards/mn/3124

29 January 1968

SUBJECT: Quality Assurance Letter of Instructions for Cartridge 5.56MM, Tracer, M196 contract DAAA25-68-C-0162. Olin Mathieson Chem. Corp. Winchester Western Division, East Alton, Ill. 62024

OFFICIAL FILE COPY		
ROUTING	INITIALS	DATE

TO: Director
DCASR, St. Louis
ATTN: Quality Assurance
1136 Washington Avenue
St. Louis, Mo. 63101

1. Reference is made to contract DAAA25-68-C-0162, subject item.

2. The Frankford Arsenal Product Quality Specialist (Key Inspector) assigned to this contract or item is Mr. Thomas C. Edwards, Frankford Arsenal, ATTN: SMUFA Q5200, Phila., Pa. 19137, extension 3124.

3. Inspection of the subject item shall be in accordance with the provisions of the contract, DSAM 8200.1 and the instructions contained herein. Mandatory "A" Inspection is requested as outlined in the inclosure. You are not to reduce this product verification without first obtaining our approval.

4. Request for Waiver on nonconforming supplies shall be processed using AMC Form 1020 and 1020.2. Instructions regarding the procedure to be followed are contained in the inclosure. All Requests for Waiver favorably considered for approval by your office shall be referred to the responsible procuring office, ATTN: SMUFA P1320, for furhter processing and determination regarding disposition of the request.

5. First article approval is required for this contract.

6. Acknowledgment of receipt of these instructions is requested. An indication of the ability of your office to effect compliance is also requested. Should there be any exceptions or suggested modifications to these instructions, this should be brought to our attention at this time.

FOR THE COMMANDER:

OWEN R. CONLIN
Chief, Key Inspection Branch
Quality Assurance Directorate

Copy furnished:
QARIC
c/o Olin Mathieson Chem. Corp.
Winchester Western Division
East Alton, Ill. 62024

Enc. 2-1

MANDATORY "A" GOVERNMENT PRODUCT VERIFICATION

Inspection for Critical Defects, listed in the Classification of Defects will be as follows:

a. Contractor: Sampling inspection by the contractor will never be permitted. The contractor shall inspect on a 100% basis in accordance with the Classification of Defects of applicable specification and additions or deletions of the contract.

b. Government Inspection Representative: The Government Inspection Representative will perform 100% inspection until 2,500 consecutive units of product have passed the acceptance criteria. Witnessing of the performance of the inspection conducted by the contractor will not be permitted unless specifically authorized by this Quality Assurance Element. When 2,500 consecutive units of product have been found acceptable for the characteristic of concern, sampling by the Government Inspection Representative may be instituted as follows:

(1) When MIL-STD-105C is applicable

(a) Single sampling

(b) Normal level

(c) A.Q.L. 0.015%

(d) Ac 0 Re 1

OR

(2) When MIL-STD-105D is applicable

(a) Single sampling

(b) Normal level

(c) A.Q.L. 0.040% in lieu of 0.015%

(d) Ac 0 Re 1

If the Government Inspector finds a Critical Defect in the sample in either of the above arrangements, proceed as follows:

1 Reject the lot

2 Issue a Corrective Action Request

3 Require the contractor to reinspect the lot, 100% for resubmission.

4 Institute and conduct 100% inspection until 2,500 consecutive units of product have again been found to pass the acceptance criteria.

5 Obtain assurance and verify that the contractor has taken appropriate corrective action to preclude the submission of Critical Defects in future production.

No Reduced Sampling Plan or Minimum Verification Inspection is Permitted or Authorized for Critical Defects.

(3) When MIL-STD-1235 is applicable

(a) CSP-1 Plan only

(b) Sampling frequency per Tables II and III, Inspection Level II

(c) A.Q.L. 0.015%

If the Government Inspector finds a Critical Defect in the sample, proceed as follows:

1 Reject and remove the defective unit from the flow of production.

2 Reject all units of product between the contractor's inspection station and the government inspection station.

3 Issue a Corrective Action Request.

4 Require the contractor to reinspect all units of product between the contractor's inspection station and the government's inspection station.

5 Require the contractor to reinspect all available units of product which have passed the government inspection station on a sampling basis. ("All available units of product" is defined as that quantity of affected product remaining in the facility which the Government Inspection Representative can substantiate as being suspect.)

6 Institute and conduct 100% inspection until 2,500 consecutive units of product has again been found to pass the acceptance criteria.

7 Obtain assurance and verify that the contractor has taken appropriate corrective action to preclude the submission of Critical Defects in future production.

No Reduction of the Above Sampling Plan is Permitted or Authorized.

Mandatory "A" Government Product Verification

1. Inspection of all major defect characteristics listed in the classification of defects in the specification and product definition of TDPL, if applicable, will be as follows:

a. The Ratio/Skip Lot Sampling Procedure, Section VI, Part 2 of DSAM 8200.1 may be applied for the inspection of major defect characteristics listed in the classification of defects.

2. Acceptance Tests - Government Verification. During acceptance tests or inspections contained in Section 4 of the detail item specification, other than in the classification of defects, the following procedure will be used:

a. If the test is prescribed to be conducted by the contractor on a sampling basis, witness the testing of all samples tested and make independent determinations and recordings regarding the results obtained.

b. If the test is prescribed to be conducted on a 100% basis by the contractor, the Government Representative may witness the performance of the testing on a sampling basis. Such witnessing will be for the purpose of verifying the proper performance of the test and the adequacy and accuracy of the decisions made by the producer's operators. The sample size for the observations to be made is to be in accordance with MIL-STD-105D, Level II, Tables I and IIA. A day's or shift's scheduled production quantity may be used as the lot size in determining the sample size using MIL-STD-105. In applying the above described arrangement, the Government Representative will:

(1) Assure, on a continuing basis, the adequacy of the material control practices exercised by the producer to preclude the possibility of any quantity of production from being processed beyond the affected testing station without the required test being conducted.

(2) Assure that all defective material revealed by the performance of the required testing is properly identified and segregated from the subsequent flow of material in the production processing.

(3) Assure at appropriate intervals that the test equipment, is in fact, operating at the established limits applicable to the characteristics of concern.

c. In the event any of the above described prerequisites are observed as out of control, or, in the event an incorrect decision is made by the test equipment operator, i.e., a defective piece is passed by the operator, all of the affected product processed since the last satisfactory government verification will be suspect and subject to reinspection. A Request for Corrective Action is to be issued and the cause for the discrepant condition and loss of control is to be identified and eliminated to the satisfaction of the Government Representative.

The foregoing described procedure does not preclude the performance of any of the required testing by the Government Representative if such testing is deemed necessary to verify and assure the quality of the item involved.

NOTE: The term "witness", as used above, requires that the Government Representative witnessing be capable of performing the test independently.

d. The foregoing does not apply to the Government Representative for those samples sent to a Quality Evaluation Laboratory for destructive testing or to a Government Proving Ground for ballistic testing.

SPECIAL INSPECTION EQUIPMENT AND CALIBRATION SERVICES

1. Acceptance inspection equipment is to be in accordance with the design requirements prescribed by Inspection Equipment List (IEL).

2. Where government inspection equipment design is not provided for the required inspection and/or testing equipment, or in instances where the contractor would propose alternate designs of inspection equipment, the contractor's proposed inspection/test equipment designs, and any subsequent changes thereto, shall have been, or shall be submitted to the responsible Engineering Agency, for approval prior to fabrication or procurement of the equipment. The responsible agency is Frankford Arsenal, Philadelphia, Penna. 19137.

3. The contractor shall be required to certify, in writing, as to the conformance of his inspection/test equipment to the government designs as provided, or, to the contractor's design(s), as approved, contractor's certification of conformance must be supported by records which provide:

a. Identification of the Inspection Equipment being certified.

b. Physical location of the certified Inspection Equipment.

c. Identification of the Standards employed to certify the equipment including direct traceability of those Standards to the National Bureau of Standards.

d. Accuracy, stability and range of Standards employed and date of last calibration of those Standards.

e. Physical location of the Standards employed for certification.

4. The Government Representative will verify the validity of the certifications executed by the contractor. Verification will be effected by:

a. Confirming the adequacy and accuracy of the contractor's records with respect to the factors outlined in paragraph 3 above; and

b. Performing actual measurements on the inspection/test equipment utilizing the Standards employed by the contractor. In the event technical assistance would be required to accomplish the actual measurements, a request in that regard should be made to the Engineering Agency identified above.

5. Calibration Services in accordance with SectionX, Part 1, DSAM 8200.1 are required.

INSTRUCTIONS AND PROCEDURES PERTAINING TO NONCONFORMING SUPPLIES GOVERNMENT FURNISHED MATERIAL

1. The following instructions and procedures shall apply with respect to processing Unserviceable New Material Reports, AMC Form 1229, for all material for which Frankford Arsenal has mission responsibility for the procuring and supplying to either Commercial or GOCO Ammunition Plants.

2. Instructions shall be supplied by the QARIC at the Ammunition Plant to the contractor containing the following information:

a. If the contractor's receiving inspection or in-process inspection indicates that GFM does not comply with the requirements of the applicable contract, purchase order, drawing or specification, the contractor shall immediately notify the QARIC or his representative.

b. Under no circumstances shall the contractor make initial contact with the manufacturer of GFM for corrective action. It cannot be over-emphasized that corrective action is not the responsibility of the contractor.

c. Any contact between the contractor and the GFM manufacturer shall be coordinated by the Government, and a Government Representative shall be present at any meeting between the two.

3. Upon notification by the contractor that incoming or in-process GFM is nonconforming, the QARIC shall take the following actions:

a. Ascertain whether the complaint is valid.

b. When found to be valid, instruct the contractor to initiate AMC Form 1229.

c. Upon receipt of UNMR, verify for correctness, sign and distribute in accordance with paragraph 4 below.

d. As soon as possible after ascertaining the validity of the complaint or even if in the QARIC's judgement the material is marginal, notify Frankford Arsenal, Key Inspection Branch, SMUFA-Q5200 by teletype or telephone extension 23225/3124 of the complaint and supply the following information:

(1) Manufacturer of GFM

(2) Item

(3) Contract/P.O. of GFM

(4) Lot number(s)

(5) Inspection results - Type and extent of nonconformance

4. The QARIC will assure that the AMC Form 1229 is prepared and forwarded within five (5) days in accordance with the following distribution:

a. Original and one(1) copy to CO, Frankford Arsenal, ATTN: Quality Management Office (SMUFA-Q2100), Phila., Pa. 19137.

b. Two (2) copies to the DCASR assigned responsibility for inspection and acceptance of the nonconforming material.

c. Other copies as directed by the DCASR responsible for the administration of the contract.

D. Contract Administration Quality Assurance Program - M16/M16A1 Rifle

1. Historical Review of Product Quality Assurance Program (PQAP) Applications and Evolution in Support of M16/M16A1 Rifle Procurement.

It should be noted that the Government quality assurance program was under Army cognizance until August 1965 when DCAS assumed this responsibility.

a. Implementation of Letters of Delegation.

(1) For the Procurement by the Air Force, there was no Letter of Delegation. The contract specified that acceptance would be on the basis of a Certificate of Conformance issued by the contractor and therefore, Government inspection was limited to counting and examining the condition of the end items.

(2) A Quality Assurance Letter of Instruction (QALI), dated 26 December 1963, was issued by the U.S. Army Weapons Command for Contract, DA-11-199-AMC-508-(Y). The letter did not specify a requirement for product inspection although product inspection was expected. Regarding product inspection, the Letter made reference only to AMC Regulation 715-508 (Procurement Inspection Administrative Procedures) and AMCR 715-509 (Procurement Quality Assurance Technical Procedures). It is noted that AMCR 715-509 contains inspection requirements similar to those contained in Defense Supply Agency (DSA) Manual 8200.1, except in different terminology and frequency of application. In general, the letter, which was in effect in August 1965 when DCASR, Boston was inaugurated, required "Surveillance Inspection" by the Government Quality Assurance Representative (QAR).

(3) On 17 November 1967, a new Quality Assurance Letter of Instruction was issued as a result of reports of deficiencies found in examinations of rifles at Camp Foster, Okinawa, and the Marine Corps Depot at Barstow, California. The new letter specified that the authority to accept Class I and Class II nonconforming supplies (see Section V, DSAM 8200.1) was not to be delegated to the Contract Administration Office (CAO).

(4) Change No. 1 to the Quality Assurance Letter of Instruction was issued on 5 April 1968. This change required mandatory inspection of 14 characteristics of each of 10 components, and stated that the contractor's inspection method should not be used unless it was deemed adequate by the Government representative. In addition, the letter required that, once each month, a sample of each of the components be randomly selected from a production lot and inspected by Government representatives for all characteristics on the contractor's Inspection Instruction Sheet. DCASD, Hartford requested a clarification of the requirements regarding the gages specified in the Inspection Instruction Sheets to be used to determine compliance. The intent of the instruction was clarified to indicate that, if a gage was determined to be inadequate, the contractor would be notified accordingly so that an alternate method of inspection, which was acceptable to the Government representative could be requested. If the contractor refused to provide the alternate method, the QAR was to defer acceptance of the component.

b. Product Inspection Type (PIT) "A" Applications.

(1) The 26 December 1963 Quality Assurance Letter of Instruction created problems for DCASD, Hartford in that it was necessary to relate the program, as established under AMCR 715-509 to the quality assurance program in DSAM 8200.1.

(2) The mandatory product inspection requirements contained in the 17 November 1967 Quality Assurance Letter of Instruction resulted in a significant increase in workload. Change No. 1 to this letter, dated 5 April 1968, increased the workload even more.

(3) The following Mandatory A Inspection (Product Inspection Type A - PIT A) requirements were invoked by the Army in November 1967:

1. After completion of all testing and just prior to preservation and packaging, the Government representative will randomly select a sample of 20 rifles from each lot of 100 rifles. The

Government representative will perform examinations listed under paragraph 11.1 of Purchase Description SAPD-253B on each sample rifle.

2. For each month's rifle production, the Government representative will perform the interchangeability control test listed under paragraph 8.3.3 of the Purchase Description SAPD-253B.

3. The Government representative will witness (at the frequency stated below) the following tests listed under Purchase Description SAPD-253B.

a. Paragraphs 8.2 and 8.3.1 Interchangeability. Ten rifles from each inspection lot.

b. Paragraph 8.3.2 Interchangeability. Five parts from each month's production of each concurrent repair part.

c. Paragraphs 9.2.1 and 9.2.2 High Pressure Resistance. One hundred barrel subassemblies per day.

d. Paragraph 9.2.4 Magnetic Particle. One hundred bolts per day.

e. Paragraph 10.1 Targeting and Accuracy. One hundred rifles per day. One hundred barrel assemblies per day.

f. Paragraph 10.2 Functioning. One hundred rifles per day.

g. Paragraph 10.3 Reliability. All reliability tests.

(4) It has been found that with a high concentration of Government product inspection there is an ever present tendency on the part of contractor personnel to pass the decision-making process on to the Government representatives. However, when the contractor's quality system is out of control and/or cannot assure product quality, Government inspection is the only effective means of protecting the Government's interest. Accordingly, a proper balance of Government product inspection in the procurement QA program is essential.

(5) Also, the witnessing of tests conducted by the contractor in lieu of independent testing would seem of little value in light of the results obtained to date. There have been no incorrect or defective observations by the contractor recorded during the witnessing operation. It should be noted that defective observations indicate an improper decision by contractor personnel and not whether the item passed or failed a test. Witnessing is appropriate if the contractor's integrity is in question.

(6) In addition to the PIT A (Mandatory A) inspection requirements imposed by the Weapons Command, the quality assurance representative imposed PIT B (Mandatory B) inspection requirements for selected components. In general, this inspection is removed after the acceptance of five consecutive lots. Since August 1967, there have been a total of 28 PIT B inspection requirements. Many of these have been stopped and then reinstituted. On 30 April 1968, there were 12 components on which PIT B inspection was being performed. PIT B inspection is invoked based upon the results of the Weapons Command's quality audits, contractor decision verifications, customer complaints, end-item inspection results, and any other input indicating the need for closer control of product quality.

c. <u>Responsibilities of the Resident Quality Assurance Representative</u>. The significant areas monitored by QAR are:

(1) Management and Administration
(2) Drawings, Specifications, Instructions and Changes
(3) Measurement and Test Equipment
(4) Control of Purchases
(5) Special Processes
(6) Inspections, Tests and Controls during Manufacture
(7) Inspections, Tests and Controls of Completed Supplies
(8) Control of Contract Items Other than Supplies (Technical and Engineering Data, Reports, etc.)

(9) Handling, Storage, Packaging and Delivery

(10) Statistical Quality Control

(11) Corrective Actions

(12) Non-Conforming Supplies

(13) Government Property

(14) Records

(15) Receiving Inspections

(16) Costs Related to Quality

The significant PQAP applications involved in the M16/M16A1 rifle program at present are:

PIT A and B (Mandatory) Inspection

Requirements: 68

Contractor Decision Verifications: 300/week

Procedure Evaluations: 123 Elements every 90 days

d. Government Plant Quality Assurance Program (PQAP)

(1) The Government (DCAS) Program at Colt is designed to provide overall visibility of the contractor's QA program effectiveness. The DCAS procedures, in accordance with DSAM 8200.1, provide for:

(a) Review of the contractor's written procedures (During Post Award Phase)

(b) Mandatory physical inspections of materiel by the Government (Product Inspection Type A, B or C)

(c) Evaluation of elements of the contractor's documented QA program by continuous audit (Procedures Evaluation - "PE")

(d) Product verification of the contractor's physical inspection decisions on a random and periodic basis (Contractor Decision Verification - "CDV")

(e) Request and review of contractor's corrective actions for deficiencies noted in a, b, c, and d, above (Corrective Action Effort - "CAE")

(2) It is significant to note that achievement of the total Government program objectives hinges on a constant and equitable distribution of effort in each of the program phases listed above. This balance of effort is sensitive to quality history and findings, and additional or required mandatory inspections. These mandatory inspections, directed by the commodity agency (PIT 'A') or selected (PIT B and C) by the Quality Assurance Representative (QAR) have at times caused some slippage in other quality program areas ((a), (c), (d) of para. 1 above). This slippage is unavoidable where prolonged product inspection workload requirements cannot readily be matched by an increase in available manpower resources.

(3) In retrospect, after some fluctuation in program demands, the Government activity at Colt was generally fixed on its program objectives until April 1968, at which time additional mandatory inspections caused some slippage in the management aspects of the DCAS program. This is illustrated in the distribution of effort shown below which has been obtained from recently available data:

PQAP ELEMENTS	MAR	APR	MAY	REMARKS
CDV	141 Hrs	101 Hrs	104 Hrs	
PE	66 "	25 "	23 "	
PIT				
'A'	1,464 Hrs	1,383 Hrs	1,720 Hrs	
'B'	154 "	93 "	121 "	
'C'	82 "	63 "	115 "	
CAE	70 "	116 "	130 "	(Mostly at final
Planning	211 "	69 "	63 "	examination & on
PQAP Spt	145 "	199 "	333 "	vendor material)
Other Spt	79 "	80 "	80 "	

PRODUCT INSPECTION	MAR	APR	MAY	REMARKS
Total OBS	363,888	332,595	347,758	(.46% defective
DEF OBS	221	222	1,609	observations)

CDV APPLICATION		
Total OBS	2,350	(.46% defective observations for
DEF OBS	11	3 month period)

WORK NOT PERFORMED			
CDV NP	12 Hrs	35 Hrs	25 Hrs
PE NP	0	0	30 Hrs

(4) In accommodating the above requirements the addition of two personnel (total force - 17 personnel), and the extremely liberal use of overtime and staff assistance, have not provided the resources to fully realize the total program objectives (see work not performed-CDVNP and PENP in Chart above). The amount, significance and value of the Government product inspection effort is illustrated by the total product observations vs. the total defective observations shown in the above chart, and the application of Contractor Decision Verification, which both uniquely indicate .46% defective (observations) in contractor inspection decisions. The increase in Corrective Action Effort and total defective observations by the Government should be noted also.

(5) In order to support the QAR's evaluation of the contractor's procedures, nineteen (19) Element Evaluation Checklists, representing 151 procedural characteristics, are employed in the Government examination. Twelve (12) of these, representing 98 procedural characteristics, were recently used in a system survey by DCASD Hartford personnel. A total of 1156 observations were involved in this effort which resulted in 47 defective observations covering 6 deficient characteristics. Defective observations referred to are discreet indications of deficiencies in the contractor's procedures to assure appropriate subject coverage and/or timely availability for use, or evidence of the contractor's

non-conformance to his written procedures. The characteristics found defective pertain to the contractor's calibration system and related areas. As a result four (4) Quality Deficiency Reports were initiated by the QAR requiring appropriate corrective action.

(6) The preceding discussion presents a summary of the objectives and recent results of DCAS activities at Colt, and essentially reflects techniques, problems and accomplishments in program implementation.

e. Evaluation of Contractor's Procedures

(1) Army Contract DA-11-199-AMC-508(Y) required that the contractor meet the requirements of MIL-Q-9858, Quality Program Requirements, and specified that he provide the Government with a general and detailed Quality Assurance plan. The contract further specified the areas in MIL-Q-9858 that must be covered by the general plan. The detailed Quality Assurance plan was to contain inspection instruction sheets for each component and subassembly of the rifle through the entire manufacturing process. The detailed plan also specified AQL levels for different characteristics as well as the material certification requirements for raw materials. The contract further stated that failure on the part of the contractor to meet the requirements of MIL-Q-9858 could result in deferring acceptance of the product.

(2) On 7 February 1964, the Contracting Officer's Representative, Boston Procurement District, notified Colt that the general quality control plan and detail written manual satisfy the requirements of specification MIL-Q-9858 as well as other applicable requirements. The manual was reviewed by representatives of the Weapons Command, the Project Manager's Office and the Boston Procurement District.

(3) On 12 February 1964, the Weapons Command notified the Boston Procurement District that in developing their inspection plan, when verification results reflect consistently poor or

inadequate inspection by the contractor, the government representative will not increase product inspection but will take the following action:

Defer acceptance of product.

Immediately notify the Contracting Officer.

Assure corrective action is taken by the contractor before resuming acceptance of product.

(4) Accordingly, in March 1964 that month's shipment of rifles was detained because of inadequacies in the contractor's quality assurance program. Areas requiring corrections were gage calibration, the inspection system and the identification and condition of material in process.

(5) During the remainder of 1964, Weapons Command representatives visited Colt for verification of rifle quality assurance. Deficiencies were noted in such areas as accuracy of gage record cards, contractor replies to corrective action requests, lubrication of working parts prior to firing, housekeeping and material handling, and requesting changes to the quality control manual as remedial action for corrective action reports. On 11 March 1965, the Weapons Command reported to the Boston Procurement District that, based upon a quality verification visit to Colt in February, the contractor was now considered to be in full compliance with the Quality Control provisions of the contract.

(6) In August 1965, DCASD Hartford assumed government contract administration responsibilities at Colt. Despite some confusion on Administrative Procedures after the transition, there appeared to be no deterioration in the contractor's system and, in February 1966, the Weapons Command representative reported that the contractor's Quality Control Program was generally satisfactory at that time. There is nothing significant in the record on the contractor's quality control program throughout the remainder of 1966. During this time, the

QAR implemented a Procurement Quality Assurance Program (PQAP) in accordance with DSAM 8200.1.

(7) In December 1966, the present QAR, Mr. Kantany, was assigned to Colt Inc. At the time of his assignment, he was notified by DCASD Hartford supervisory personnel that the company had a good quality control program and no serious problems were anticipated with Colt in the manufacture and quality control of the M16A1 rifle.

Based on this overall history, it can be concluded that a serious quality problem on the rifle in general was not identified by the government through the end of calendar year 1966.

f. Quality Complaints and Corrective Action

(1) During March and April of 1967, the quality assurance representative imposed Mandatory B inspections in selected areas based upon newspaper reports of troubles with the M16A1 rifles. By August 1967, Mandatory B Inspection had been accelerated based upon adverse publicity. Many of these inspections were performed for a period of time, stopped after good quality history was experienced and then reinstated based upon additional adverse publicity, results of contractor decision verifications or any other input indicating the need for closer control of component quality.

(2) As a result of a message from the Commandant of the U.S. Marine Corps to the U.S. Army Materiel Command in August 1967, critical of the quality of M16A1 rifles, representatives of the U.S. Army Weapons Command, Rock Island Arsenal, HQ DSA CAS and DCASD Hartford conducted an inspection of the rifles located at the USMC Supply Center, Barstow, California during the period 1 through 16 September 1967. Of the 14,676 rifles inspected 326 defects were found in 320 rifles. Thirteen of the defects were classified as

being in the "major" category. In approximately the same time frame representatives of WECOM and Colt proceeded to Camp Forster, Okinawa and reinspected the 172 rifles set aside as defective by the Marine Corps as a result of their inspection of 39,512 rifles. The team concurred with the Marine Corps findings and classified 12 of the defects in the "major" category. Also, an evaluation of rifles representing September 1967 production was conducted at Letterkenny Depot and at Colt by a WECOM/DCAS team. A total of 15,460 rifles were inspected and 281 were found to be defective, 20 of which were in the "major" category.

(3) Subsequently, AMC and DCAS teams conducted a review of the quality program at Colt and various discrepancies were revealed:

(a) Wrong sample size used on 20 lots, upper receivers

(b) Second sample not taken on some lots, upper and lower receivers

(c) Tightened inspection used for certain characteristics over a long period of time without indications that effective corrective action had been taken.

(d) Product audit revealed dimensional and workmanship deficiencies on upper receiver, bolt, bolt carrier and extractor.

(e) Contractor's material handling was poor (reflection on control of non-conforming material)

On 16 January 1968, the Commander, DCASD Hartford, wrote to the President of Colt Inc., relative to the existence of quality control problems at the contractor's facility. Mr. Benke, the President of Colt took exception to many of the deficiencies cited in the letter. However, he did admit that - "the only apparent deficiency in our quality control program appears to be the documentation of our quality investigations and the documentation of the follow-up to insure that corrective action has been implemented. This condition has been discussed with several qualified government quality assurance representatives. It is agreed that improvements can be made by the contractor in this area. At the present time, we are conducting a complete quality audit of all Colt vendors to insure that they are complying with contractual requirements. A report of this audit and the corrective action taken will be submitted to the government by 23 February 1968."

(4) Colt performed a survey of twenty-eight vendors and all were reported to have adequate quality history. Seventeen of them had inadequate inspection records and 18 had inadequate gage control systems. In the latter two categories, 16 vendors had both inadequate inspection records and gage control systems. The deficient vendors were resurveyed in April and all but one were found to be satisfactory. The deficient vendor agreed to improve and will be resurveyed. During February and March 1968, a revised PQAP was developed for the QAR at Colt by an experienced QAR from the Quality Operations Branch, DCASD Hartford.

(5) During February 1968, the AMC-DCAS M16/M16A1 Rifle Quality Assurance Committee was established. At the initial meeting, the Committee recommended that the Colt contract be modified as follows:

"The Colt contract be modified to require that the technical data package purchased from Colt for use in government second source procurement be incorporated into the current Colt contract. This is considered essential to provide a standard base against which to measure the quality of material and assure timely refinement of the package."

"A Government engineer with in depth of small arms experience be stationed at Colt on a full-time basis. This engineer to have delegated authority to act on waivers, approve changes to technical data, establish visual standards, act as Government representative on a Material Review Board and effect the day-by-day coordination essential to the refinement of the technical data package."

Both recommendations were accepted by the Project Manager and were implemented.

(6) Another task assumed by the Committee was the review of quality audit results of the Weapons Command on samples of ten rifles and five repair parts per month from Colt's production. The results of the audit indicated that several components did not meet drawing dimensional requirements.

(7) A Gage Design Review Group was stationed at Colt to review and to recommend changes to gage designs in order to eliminate inconsistencies between physical measurements and present gaging methods. One interesting highlight of the results of this work to date is that they have recommended that many gages be liberalized to avoid rejecting products that meet dimensional tolerances on drawings; in addition there are gages which would accept material which exceed drawing tolerances. Both the resident WECOM engineer and the Gage Design Group are still at Colt.

(8) Also, in February 1968 a representative of the ASD(I&L) visited Colt and, among other things, was critical of the requirements placed upon Colt to perform vendor surveys. This resulted in a study by the AMC-DCAS M16 Committee of the specification and contractual requirements for vendor control. The study revealed that the contractor can use various means for controlling vendor quality under MIL-Q-9858 and, depending upon his selection, vendor inspection records and vendor surveys may or may not be required. Colt indicated that they would supplement their quality plan with regard to measuring and testing equipment at their vendors and would modify the requirements for inspection records by the suppliers. Colt still requires inspection records from selected suppliers. Colt prepared a Quality Control Supplement No. 1 to their Purchase Orders which outlines requirements for raw material specifications, calibration of measuring and test equipment and records of inspection that are required. This

quality control supplement does not apply to all vendors.

(9) One other area of government interface involved establishing a Materiel Review Board (MRB) at Colt. Authority for acceptance of Class II nonconforming material was not delegated by the buying activity. MRB procedures were prepared but, to date, have not been put into effect. The objection of the quality assurance element at Weapons Command is understood to be the principal factor in non-implementation to date. Also, since the proposal would establish the PCO representative as the government member, rather than the CAO representative as envisioned in ASPR, the title of this function has been changed to Material Disposition Board. However, as of 27 May 1968 it is understood that a letter establishing the MDB is before the PCO for approval and signature.

g. Purchase Description

The Purchase Description SAPD-253B with Amendment No. 2 dated 13 December 1967, requires 100% testing of the rifles for function firing, targeting and accuracy, head-space and trigger pull. Each barrel sub-assembly and bolt is subjected to a high-pressure resistance test with subsequent magnetic particle inspection. On a sampling basis, rifles are tested for firing pin indent, interchangeability, cyclic rate and reliability. In addition, each rifle is subjected to a manual and visual examination. This manual and visual examination is highly subjective and may be a source of rejection by the contractor and the government on final inspection. Four manufacturing models of the rifle were submitted on each of the Army contracts to the Springfield Armory for review and approval. Two of the four were returned to Colt. These models are not adequate as standards since they do not represent any range of the visual or manual characteristics. Visual standards are being prepared in an attempt to eliminate differences of opinion.

2. Contractor's Quality Assurance Program

a. Normal or Traditional Commercial System Used

The quality assurance requirements in the commercial manufacture of weapons are based upon functional performance, workmanship and the esthetic or cosmetic appearance of the product. Component inspection is very limited since interchangeability is not considered an important requirement. No special controls are maintained for gages or special processes. It is not uncommon for production assemblers to file to fit a component in order to optimize individual performance and appearance. Final inspection is based upon the salability of the product, and nicks and scratches are tightly controlled. Commercial and military work at Colt is not comingled, however, and separate quality managers are assigned.

b. Colt M16 Rifle Inspection Statistics

A summary of the essential inspection elements follows:

No. of Different Parts, 106

Items made in-house, 10; Items Purchased from Vendors, 96

Characteristics checked

Incoming material from vendors, approx. 1790

Colt's in-process inspections, approx. 1400

Colt's final inspection, approx. 670

Gages: 1090 for in-process, 695 for final inspections

Chip cutters, 543; Inspectors, 122

c. M16 Contract Purchase Description Requirements

As indicated earlier, the contract requires that the contractor maintain a system in accordance with MIL-Q-9858. His detailed quality assurance plan requires individual inspection instructions for each component, listing characteristics and the AQLs that apply to the characteristics. These inspection instructions are similar to the Army-generated Supplementary Quality Assurance Provisions (SQAPs). The contractor depends on suppliers for the major portion of components that make up the rifle. These are 41 machine-type components; 8 forgings, 7 specials (plastic and powdered metals), 5 castings, 16 springs, 2 plating houses and numerous standard hardware items that the contractor purchases for the M16A1 rifle. The philosophy at Colt is to control the quality of these vendors through incoming inspections. Many of the suppliers are small businesses and Colt maintains a very friendly relationship with them in order to insure price and delivery. It is not uncommon for Colt to rework defective components in-house rather than to return them to the supplier. In most instances, the vendor is charged for the service. Universal Industries supplies the magazine assembly for the M16A1 rifle. These are inspected at receiving inspection when shipped to Colt. When magazine assemblies are shipped directly to using activities, the Colt inspector visits Universal Industries to inspect and release the shipment. Colt has not had any serious problem with magazines since 1965 when a problem was discovered with the hard anodizing process.

d. Problems Experienced

For the most part, Colt has been willing to take corrective action when their quality control system is found to be deficient. However, the corrective actions are not always oriented toward the causes and do not normally involve failure analysis of the rifle. They do not believe in reliance upon vendor inspection data but prefer to control the suppliers through incoming inspections. In the area of corrective action on defective rifles, Colt reflects the philosophy that it is more economical to screen defective rifles in final inspections and re-work them rather than depend upon increased in-process inspection. Failure analysis is not conducted unless there is an indication of low yield (high rejection of completed rifles or if component rejection at the final inspection is exceptionally high). Over the past year, the rejection rate has been between 20% and 40%. Approximately 10% of the rifles are rejected on the basis of the functioning tests.

e. Government Actions Influencing Program

(1) Most of these actions are discussed in detail in the paragraph concerning "Procedure Evaluations." The only purchase order

where control of shipments (Government Source Inspection) is required is that from Universal Industries for the magazine assembly. There have been some selective evaluations of other vendors but, for the most part, only on a one-time basis in connection with control of gages.

(2) By agreement between the AMC Project Manager, Rifles, the DCASR Boston, concurred in by CG AMC and DDCAS, an AMC/DCAS M16/M16A1 Rifle Quality Assurance Committee was formed to assist in the resolution of present and future quality assurance problems. Recommendations made by the AMC/DCAS Committee and actions resulting therefrom follow:

(a) Recommended that Colt's contract be amended to include the updated technical package. This was accomplished during the week of 4 March 1968.

(b) Recommended that an engineer with rifle experience be assigned to Colt to approve engineering change proposals, waivers and to assist in establishing visual standards. An engineer was assigned on 4 March 1968.

(c) Recommended personnel be assigned to review inspection equipment designs for adequacy. A task group of six Rock Island Arsenal and WECOM inspection engineering personnel were assigned to Colt the week of 11 March to accomplish this, and to review inspection instruction sheets.

(d) The committee reviewed the results of the Rock Island Arsenal quality audit of five rifles from Colt's January production. The type of action necessary to correct the deficiencies was determined and will be accomplished by Colt and the above mentioned task group.

(e) Additional items for investigation by committee members have been assigned.

f. Responsiveness of Quality Assurance Program to Weapons System Development

(1) Engineering changes of the weapon have been made based upon recommendations of the contractor. These recommendations (particularly

the extractor spring) result from review of product acceptance results. In addition, changes have been incorporated based upon reports and recommendations from Colt's technical personnel working with using activities. However, additional effort on the part of the Government has been required subsequent to the acquisition of the Technical Data Package (TDP) to assure adequacy and control of product quality. Notably, the need for updating gage drawings to conform with component production drawings was identified. A WECOM Gage Review Team undertook the task and to date, 341 gage drawings have been reviewed, and approximately 200 changes have been recommended. Also, the Inspection Engineering Program will be enhanced upon receipt of certain redimensioned drawings presently being processed by Colt.

(2) Revision to the chamber configuration that would eliminate the possibility of a reverse taper in the neck area after chrome plating also was proposed. Frankford Arsenal determined that tests would have to be conducted to determine if there are any conflicts with the ammunition. The AMC/DCAS QA Committee recommended that the change be processed for incorporation into the TDP to allow time for tooling changes, and that Frankford Arsenal expedite the testing to achieve this objective. Representatives from Frankford and WECOM met at Colt on 27 May 1968 to agree upon drawing changes prior to testing. Also, the committee will recommend that the same criteria in the M14 Rifle specification for surface finish in the neck area of the chamber be incorporated in the M16 specification. Evaluations will then be oriented towards marking of the proof round and current problems of visual examination will be eliminated. That is, tool marks which cause the surface finish requirement to be exceeded will be allowed provided that they do not mark the cartridge case of the proof round. Committee recommendations will also reflect the desirability of requiring chamber gaging after chrome plating, rather than before, and of specifying proof firing of each barrel subsequent to chrome plating. This should preclude cartridge case contamination of the chamber prior to plating.

Further, ECPs are being considered by Colt on the lower and upper receivers, bolt, bolt carrier and barrel assembly.

g. Experience Gained Which Should Effect Subsequent Quality Requirements in Contracts

The need for visual standards to be used in connection with final rifle inspection and a more definitive requirement for failure analysis rather than a correction of product seems to be in order. Manufacturing models are not adequate as visual or functional standards. The subjective nature of the problem associated with functional and visual standards is best illustrated by the increase in rejections at final inspection during the peak of adverse publicity in September and October 1967. Also, considerable effort has been exerted by various groups to improve the SAPD 253 series purchase descriptions using essentially the same testing and qualification philosophy. Experience dictates that pre-production tests (first article) should be continued and process control tests should be used, particularly in procurement from new sources of supply. Further evidence substantiates the need for appropriate classifications of defects and, as required, the adoption of a group AQL approach to quality control as opposed to AQLs for individual characteristics when developing Inspection Instruction Sheets for production quality control purposes.

3. Army/DCAS Quality Assurance Management

a. Army/DCAS Interface

(1) Prior to February 1968, when the AMC-DCAS M16A1 Rifle Quality Assurance Committee was established, the interface between the Army and DCAS was generally through the product Quality Assurance Specialist (key inspector) from the Weapons Command and, at times, through the Project Manager's representative. One of the reasons the Committee was established was to improve communications between WECOM and DCAS. The charter has been extended to provide membership for DCAS activities covering rifle sources other than Colt.

(2) The assignment of a Contracting Officer's Representative to the Colt plant with authority for Type I and II non-conformances,

although a departure from normal and prescribed policies in this area, has been accepted by DCAS and AMC in light of the programs's sensitivity. However, such expedients do not obviate the need for sound contractual management. For example, paragraph 14-406 (b)(ii) of ASPR requires that when Type II nonconforming supplies are accepted, the contract be appropriately modified to provide an equitable price reduction or other consideration, except where it is determined that the amount of such reduction is less than the administrative cost of modifying the contract; and the contract file is documented to show the basis of the determination. Under existing arrangements, the Contract Administration Office is uncertain as to whether proper compliance has been taken since the COR signs the AMC Form 1020, Contracting Officer's Notice to the Contractor, and submits a copy of the approved Type II change to the contractor. This matter has been referred to WECOM for proper resolution. Also, it is understood that QALIs are not coordinated with the WECOM PCO for contractual implications and that there is some difference of opinion as to the need for this concurrence on instructions issued to DCAS personnel. This problem has broader implications in terms of Army-wise procurement actions.

b. DCAS Methodology

(1) The DCAS approach to control of quality stresses continued evaluation of the contractor's quality control system, with appropriate amounts of product inspection. The assumption is that if the system is performing satisfactorily, i.e., the procedures are adhered to, that the product quality will be in accordance with contract requirements.

(2) Under MIL-I-45208A and MIL-Q-9858A, Government product verification inspection should not be an end unto itself but rather should be used as a gage to determine the contractor's quality control system effectiveness. It should be noted, however, that DCAS policy requires that every PQAP application include PIT "B" inspections as a minimum to assure product quality prior to Government acceptance.

Also, DCAS implements DOD policy by assuring that all FIT "A" requirements are performed on a mandatory basis as prescribed by the purchasing contracting officer until such time as the requirements are withdrawn.

c. Additional Quality Management Techniques

Many of these have already been discussed. In addition, WECOM draws samples from material that has been accepted by the contractor and DCAS, and critically inspects and tests this material to assure an understanding of the quality requirements and contractual compliance with quality standards. During contract life, samples from accepted material are selected for independent testing by USA Test and Evaluation Command. This independent testing is also performed to assure that there has not been a degradation of quality. The revised purchase description will incorporate changes reflecting the experience since 13 December 1967 when Amendment 2 was issued to SAPD 253B, to correct weaknesses in the inspection program found as a result of Marine Corps complaints, WECOM findings, and DCAS recommendations. Regarding new sources, the PD will require initial qualification testing of weapons and a montly interplant interchangeability test of weapons from all sources. Also, initial weapons from each new source will be field tested in the USA before being released for use overseas.

4. Critique

a. Over the years, one of the problems facing Quality Assurance personnel has been that a user's dissatisfaction with equipment is considered to be indication of poor quality. After correction of the deficiencies, be it through design changes or proper instructions on maintenance and services, the stigma remains that something must have been wrong with the quality control system that produced the product. This appears to be the situation with the M16A1 rifle, irrespective of any actual problems which may exist.

b. In historical perspective, it can be concluded that some problems with the rifle in general were not identified by the Government through the end of calendar year 1966. Some actions were taken in 1967 as the result of adverse publicity and Marine Corps complaints.

c. The findings at Camp Foster, Okinawa; and Barstow, California, indicate the importance of the visual inspection aspects of the weapons in the contractor's quality control system.

d. Also, the small number of unsatisfactory reports covering a small cross section of weapons received by DCASD, Hartford and the contractor raises a question as to whether the feedback system from the field is effective.

e. In the area of corrective action, Colt reflects the philosophy that it is more effective and economical to screen defective rifles during final inspection and rework them rather than depend upon increased in-process controls. Failure analysis is not conducted unless there is an indication of low yield (a high rejection rate at final inspection).

f. A Procurement Quality Assurance Program has been implemented at Colt by DCASD, Hartford which is heavily oriented toward product inspection due to Pit "A" assignments by WECOM. Accordingly, records indicate that some work was not performed on evaluation of procedures and verification of the contractor's decisions due to limitations of resources. It is probable that this situation will continue until objective evidence of the contractor's control of product quality can be established.

APPENDIX III

ANALYSIS OF SPECIFICATION

A. REVIEW OF SPRINGFIELD ARMORY PURCHASE DESCRIPTION, RIFLE, 5.56MM: M16 AND M16A1, SAPD-253C DTD 23 APRIL 1968

1. Introduction

a. This review while specifically addressed to SAPD-253C, dtd 23 April 1968 applies to SAPD-253B which is currently in effect as part of the Colt Industries, Inc. contract. Comments on an earlier review of draft SAPD-C, dtd 1 April 1968 were transmitted 9 April 1968 for early consideration by personnel who were given the task of effecting a thorough examination and review of the purchase description.

b. The current review deals mainly with the following elements:

(1) Clarity of the specification

(2) Duplicative/conflicting requirements

(3) Delineation and identification of the rifle lot submitted for acceptance

(4) Technical characteristics specified

(5) Propriety of tests

(6) Criteria for rifle acceptance/rejection; statistical validity; protection and risks

(7) Supplemental quality assurance documentation, e.g., visual standards

(8) Criteria for acceptance/rejection for components and repair parts.

2. Analysis

a. Technical requirements (Sec 3-SAPD)

(1) Functioning. The cyclic rate limits of 650-850 rounds per minute (RPM) is presumed to represent the limits within which the rifle will perform satsifactorily. The test for cyclic rate is based on firing rounds from one lot of ammunition. Analysis of available data indicates that there are lot to lot variations in ammunition affecting cyclic rate, however, the cyclic rate test is based on firing rounds from

a single lot of ammunition. The standard deviation among lots is 20 RPM. To assure performance within the bounds of 650-850 RPM, the limits may have to be narrowed in order to increase the assurance that upon firing a lot selected at random from the field, the rifle cyclic rate will be within 650-850 RPM. In this connection the question also arises as to the type of ammunition used for determination of cyclic rate; namely tracer with IMR or ball-ball rounds or a combination of the two types. Another aspect relative to functioning of the rifle is the individual cycle time which is not controlled.

(2) Interchangeability. Under this requirement preferential assembly of interchangeable parts is allowed provided all parts are dimensionally acceptable. This provision presumably is based on practices of the small arms weapon industry. It is recommended that the statement (in normal assembly operations .... preferential assembly .... dimensionally acceptable) be deleted.

(3) Endurance. For this test it is recommended that the last sentence be deleted and the following be substituted: "In addition, each measurement of cyclic rate of fire on each rifle shall be within the limits specified in 3.3.5 (650-850 rounds per minute)." Rather than the current requirement permitting acceptability based on average cyclic rate of fire, each test for cyclic rate should be required to fall within the prescribed bounds.

(4) Mission Performance. The sampling plan specified in Sec. 4.0 of the SAPD is not consistent with the requirements of "not less than 2400 rounds" because rifles with a mean round to malfunction of 1200 will be accepted 45% of the time. (This is illustrated in Fig. 1, App. III, p. III-12). Either the sampling plan or this requirement must be modified to eliminate this inconsistency.

It is recommended that the Mission Performance test be eliminated and acceptance of the 1000 rifle lot be based upon the accumulated data generated through the conduct of functioning tests, i.e., 30 rounds per rifle.

The data on the 30,000 rounds should be used in connection with a sampling plan. The sampling plan can be as indicated in Fig. 1, App. III. If a lot is rejected, then data should be analyzed to establish the cause or causes. The lot should be reworked and resubmitted for acceptance where the applicable sampling plan should be tighter than the original.

If this proposal is adopted, the mission performance feature of the specification can be eliminated because it is somewhat duplicative of the reliability evaluation plan. The rounds which would have been expended in this test can be used more effectively by increasing the number of rifles used in the endurance test. It is proposed, additionally, that a total of four rifles be fired for endurance from each week's production.

b. Quality Assurance Provisions (Sec 4-SAPD)

(1) Component Parts and Repair Parts. It is recommended that the Inspection Instruction Sheets for component parts, after critical review for the adequacy of defect classification and propriety of assigned AQLs and appropriate changes thereto, be converted to Supplemental Quality Assurance Provisions (SQAPs).

(2) Firing Pin Indent Testing. The sampling plan appears to be rather loose for so important a characteristic. It is proposed that a more stringent plan be adopted with the provision that the criteria for acceptance of resubmitted lots be tighter than the criteria imposed for first submission acceptance of lots. Consideration should be given to use of a one sided variable sampling plan for greater efficiency.

(3) Endurance Testing. It is recommended that the following requirement be added: "in addition to correcting the process, action will be taken to identify (key serial number) suspect rifles which were previously accepted in order that corrective actions can be taken to assure the quality of rifles issued to the field."

(4) Classification of Defects for Packaging. Individual AQLs are prescribed and hence, there are individual sampling plans for each of 10 characteristics. This practice should be changed to prescribe an AQL for a group of defects of equal seriousness (major and minor) and the sampling plan should pertain to defectives.

3. <u>General Commentary</u>

a. SAPD-253-C contains administrative information which properly belongs in the contract. As an example: the requirement for Quality Assurance Evaluation samples is established under the Quality Assurance Provision (Sec 4-SAPD). This is not in conformance with policy. First articles, initial production samples, etc., requirements are properly handled under ASPR clause 1-1900.

b. The SAPD, as currently written, provides considerable latitude on the part of the contractor regarding the number of resubmissions permitted him after a "first time" rejection has been made. This situation provides little incentive on the part of the contractor to improve his quality control program.

c. For the purpose of clarity and visibility with respect to use of the SAPD, the following suggestions are furnished:

(1) A table should be prepared which will summarize the testing phases, sample sizes and referenced requirement paragraphs. This table would lead to considerable simplification in the presentation of test criteria.

(2) Table I, now contained in Seciton 3, should be a part of the Quality Assurance Provisions.

(3) A table should be prepared which summarizes all of the visual and manual examinations required during final examination of each rifle. Repetitive information now contained in each subparagraph under "<u>Rifles</u>" (Section 4-SAPD) would be eliminated and considerable simplification would result thereby.

d. The rubber stamping of each rifle by the contractor appears to be a questionable practice as a means of denoting acceptability by the Government. Adequate control should be exercised through the serial numbers of rifles posted on the DD250 forms.

e. The utilization of both types of ammunition, tracer and ball, as well as different lots of ammunition should be considered in conducting the rifle functioning test. The argument may be advanced that the purpose of the test is to determine rifle functioning and not ammunition. As a minimum, the use of lots of ammunition representing the extremes of the acceptability range would provide information presently not available regarding the rifle/ammunition interfaces.

f. The revised purchase description should be issued as a Limited Coordinated Specification in consonance with DOD Standardization Policy.

B. REVIEW OF 5.56 AMMUNITION SPECIFICATION FOR BALL AND TRACE

1. Introduction.

A critical review of the quality assurance requirements was made of the existing specifications covering Ball and Trace 5.56mm Ammunition and referenced documents. Emphasis was directed toward the definitiveness of quality assurance requirements; their adequacy, statistical criteria, and clear delineation between contractor and Government responsibilities for product quality.

2. Analysis

a. Section 4 of the detail specification (MIL-C-9963) for 5.56mm ball/cartridge establishes the quality assurance requirements. They are:

(1) Statement of contractor responsibility for inspections.

(2) Classification of defects/acceptable quality levels.

(3) Functional test requirements/sample sizes and accept/reject criteria.

(4) First article (initial production) quality requirements and judgement criteria.

(5) Lotting criteria.

(6) Packaging inspection requirements/AQLs (MIL STD 644).

(7) Visual inspection standards (MIL STD 636).

(8) Ballistic acceptance test procedures - Quality Assurance Pamphlet AMSMU-P-501-FA-1.

(9) Inspection equipment list.

(10) Calibration system MIL-C-45662.

(11) Meaningful parameters which should be subject to control.

b. The contractor is responsible for conducting all tests and examinations contained in the specification or referenced documentation except as otherwise may be stated (DoD QA policy).

c. The acceptable quality levels (AQLs) established for major defects (0.25%) and for minor defects (1.5%) represent a standard of quality which has been acceptable to the Government during recent years of procurement (since 1960) and industry for small caliber ammunition. These AQLs additionally are consistent with the capability of manufacturing processes established for small caliber ammunition.

d. Elements (6) through (10) identified above, specifically support contractor and Government quality assurance efforts relative to uniform interpretation of QA requirements, application of test methods and standards and accept/reject criteria.

e. Testing and inspection requirements for Ball and Trace ammunition cover the following characteristics:

Bullet Extraction
Primer Sensitivity
Residual Stress (Mercurous Nitrate)
Waterproof
Accuracy
Action Time
Velocity
Chamber Pressure
Port Pressure
Function and Casuality Rifle, M16
Stripping
Fouling*

*Initial production sample only.

Statistical methodology has been applied in specifying sample sizes for inspection and testing.

f. The classification of defects (see Incl 1) and MIL-STD-636 establish the seriousness of these defects and provide a basis for accept/reject decisions. Additionally, although this is not a requirement, characteristics 39 to 47 (Incl 1) are inspected 100% by the contractor. This control is necessary to meet the AQL specified for major defects. All producers use this method for process control in addition to hand gaging the required sample sizes after 100% inspection.

g. The following requirements are further prescribed by the specification:

(1) An initial production sample (IPT) is required on all contracts where procurement is the initial buy from a contractor. Characteristics tested are the same as those which are pertinent to subsequent production with the exception of the fouling test.

(2) All samples (production and IPT) are tested at low and high temperature with the exception of bullet extraction, pressure sensitivity, mercuous nitrate, waterproof, and accuracy tests.

(3) All testing is done by the contractor with the exception of the IPT tests which are normally conducted by the Government.

h. The specification has been improved by the following changes:

(1) The one hundred round first article firing test for propellant has been increased to one thousand rounds. (Propellant Specification).

(2) The "no primer vent" defect classification in case, has been classified a critical defect. (Previously major defect).

(3) The "weight" defect classification, in cartridge ball, has been classified a critical defect. (Previously major) (10 grains or less).

(4) The hardness requirement has been added and a hardness test procedure has been included.

(5) There has been an increase in the function and casualty sample size to 1440 rounds from 720.

i. Propellant specification. The test requirements for propellant cover the following characteristics:

Velocity
Pressure
Action Time
Smoke*

Flash*

Fouling*

Extreme Temperature

Chemical and Physical

*First two (2) production lots only.

These characteristics describe the properties which propellant must satisfy to achieve the desired performance of the complete round. All propellant tests, additionally, are conducted with the metal parts furnished by the contractor to whom the propellant will be supplied.

3. Recommendations

a. The listing of defects, although comprehensive, should be re-examined in relationship to M16 Rifle system performance based on the mass of firing data generated to date.

b. Establish a requirement for determining fouling characteristic of propellant and the appropriate acceptability standard. Gas flow measurement can be used as the means for accomplishing this test.

c. Establish a cyclic rate requirement for the M16 Rifle system preferably on a round by round basis. Based on this requirement, cyclic rate conformance of ammunition being tested during the function and casualty test phase could be converted from an information test to an acceptance test.

d. Re-examine AQLs established for major defects associated with functioning and definitely related to M16 rifle malfunctions for compatibility with M16 Rifle system performance requirements.

e. Analyze propellant test requirements in light of variability between propellant lots indicated by study of ammunition test data (e.g., fouling and cyclic rates tests). Process studies and the development of a reliable chemical test method may be required to establish variability limits between and within propellant lots.

f. The current practice of using more than one lot of propellant in a complete round lot should be re-examined particularly with respect to its effect on the results of functiong tests such as velocity, accuracy, maximum pressure, etc., which are based necessarily on sampling.

g. Consideration should be given to establishing better controls of the propellant through measurements of pressure vs. time characteristics since they may have an important bearing on the performance of the M16 Rifle System.

h. Granulation size and burning rates for ball propellant should also be studied as possible parameters which may require controls.

TABLE I

No.	Defect and Method of Inspection	Critical	Major	Minor	Major or Minor
	Visual[1]				
	Cartridge:				
1	Discolored, dirty, oily, smeared			X	
2	Corroded or stained, if etched		X		
	Case:				
4	Round head		X		
5	Dent				X
6	Split case:				
	in K, L or M location	X			
	in I, S or J location		X		
7	Perforated case	X			
8	Draw scratch				X
9	Scratch			X	
10	Beveled underside of head		X		
11	Case mouth not crimped in cannelure		X		
12	Scaly metal				X
13	No chamfer on head (rim)		X		
14	Fold			X	
15	Wrinkle			X	
16	Buckle			X	
17	Bulge			X	
18	Illegible or missing head stamp			X	
19	Defective head			X	
20	Defective mouth			X	
21	No visible evidence of mouth anneal		X		
	Bullet:				
22	Dent			X	
23	Scratch			X	
24	Split bullet jacket		X		
25	Loose bullet		X		
26	Missing cannelure		X		
27	Scaly metal (bullet)				X
28	Upset (crooked) point			X	
30	Blunt point			X	
31	Defective cannelure			X	
	Primer:				
32	No primer	X			
33	Cocked primer	X			
34	Inverted primer	X			
35	Loose primer		X		
36	Nicked or dented primer			X	
37	No waterproofing material (primer pocket joint)				
38	Defective crimp			X	
	Gaging				
39	Total length		X		
40	Cartridge profile failure (requiring more than 10 lbs dead weight to insert in profile and alignment gage)		X		
41	Diameter of extractor groove, max		X		
42	Diameter of extractor groove, min			X	
43	Diameter of head		X		
44	Thickness of head		X		
45	Length to shoulder datum[2]		X		
46	Depth of primer		X		
	Weighing				
47	Weight, min.[3]		X		

Encl. 1.

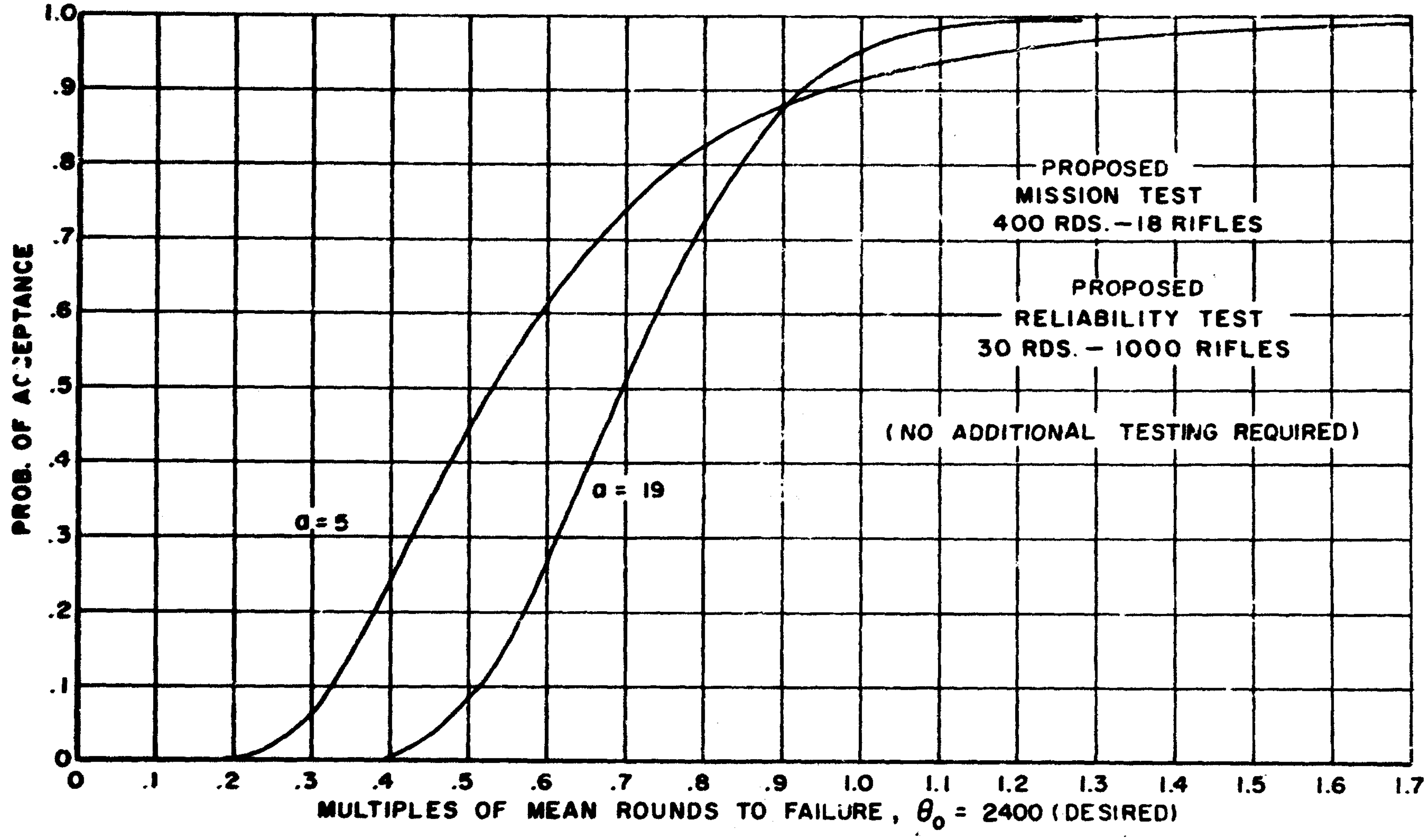
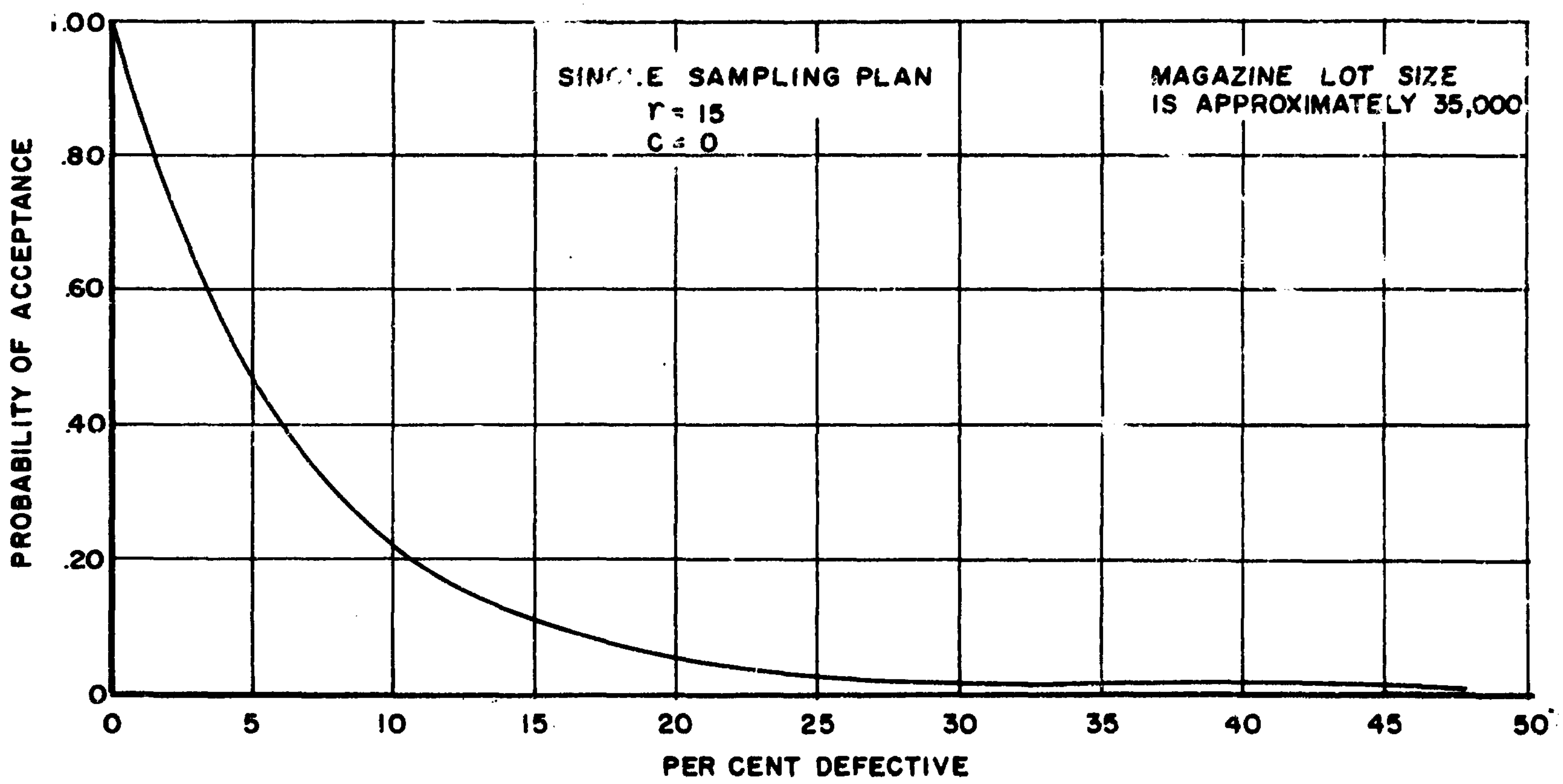


Figure 1 APP III - Analysis of Mission and Reliability Test Plans for M16 Rifle



Assembly, Magazine, M16 Rifle Operating Characteristic Curve For Functional Firing Test
Figure 2 - APP III

APPENDIX IV

DATA ANALYSIS/TECHNICAL EVALUATION

PAGE NO.

APPENDIX IV

DATA ANALYSIS/TECHNICAL EVALUATION

This appendix contains the statistical analyses of data. Sections I thru VII pertain to analyses of data from the WSEG study while Sections VIII thru XXIV pertain to analyses of data from other pertinent sources.

A. <u>WSEG DATA</u>

Introduction.

The test was designed and analyzed by the Weapon Systems Evaluation Group (WSEG) in association with the Institute for Defense Analysis (IDA). For a detailed report of all aspects of the test, including the WSEG analysis and conclusions, the reader is referred to WSEG Report 124, "Operational Reliability Test M16A1 Rifle System," dated February 1968.

The Surveillance and Reliability Division, ARDC, was asked to accomplish a critical review of the above report, and to conduct additional studies where appropriate. In this study, no attempt was made to duplicate or to check the computations of the WSEG Report. Where it was felt that WSEG did not use the most efficient tests, did not investigate in sufficient detail, or omitted areas that should be investigated, further analyses were conducted.

In order that the reader will not be required to consult the WSEG Report, to understand the terminology and to obtain pertinent information regarding the conduct of the test, much of the following information was extracted from the WSEG Report.

Purpose of the Test

The purpose of the test was to measure the operational reliability of the 5.56mm, M16A1 rifle systems currently used by maneuver battalions in South Vietnam under environmental conditions simulating as closely as possible those existing in South Vietnam. To serve as a base for this measurement, the 7.62mm, M14 rifle system was included in the test as a control.

Objectives of the Test

Objectives of the test, as defined by WSEG, were:

Using 5.56mm ammunition of the types now used in South Vietnam, i.e., ball propellant and IMR propellant:

Determine the malfunction rates of the M16A1 rifle configured with the new buffer group and chromed chamber.

Determine the malfunction rates of the M16A1 rifle configured with the new buffer group.

Determine the malfunction rate of the M14 rifle system.

Analyze and compare the preceding malfunction rates.

Identify, for each rifle system and configuration, the types of malfunctions that occur and the environment and conditions under which they occur.

Test Schedule

The test involved four Marine platoons, each containing four squads of nineteen riflemen for a total of 302 riflemen. Each platoon (76 riflemen) fired for one three-day period in each of the four differing environments E_1, E_2, E_3, and E_4, detailed in Table 4. All platoons fired for the same number of days over the same areas. Except for the 19th man in each squad, each rifleman fired 480 (468)[1] rounds each calendar day, alternating automatic and semiautomatic modes of fire.

Three hundred four primary rifles and 143 spares were available for the test. Numbers, types, configurations, and test designation of rifles are shown in Table 1.

Rifles in use in South Vietnam with new buffers but without chromed chambers represent two types: those manufactured and shipped with the new buffer (R_2), and those retrofitted with the new buffer in the field

[1]Rifles firing 18-round magazines expended 468 rounds each calendar day. Those firing 20-round magazines fired 480.

(R_3). Since there was no detectable difference between these rifles, they were treated under one designation, R_2.

The test involved ball and tracer 5.56mm ammunition loaded with the Improved Military Rifle (IMR) single base propellant, 8208M, a proprietary product of E. I. DuPont de Nemours Co., and with double base ball propellant, WC 846, a proprietary product of Olin Mathieson. M14 ammunition, 7.62mm, is loaded only with double base ball propellant, WC 846; and this type propellant was used for all 7.62mm ball and tracer rounds. Type rounds, manufacturer, lot number, propellant and ammunition mixture by squad number are shown in Table 2.

From Table 2 it will be noted that, except for A_5 (7.62mm), each squad fired a distinct and different mix of ammunition. The type and mix fired by any one rifleman was maintained throughout the test. Thus, each rifle is identified with only one type propellant and one mix of ball and tracer ammunition by manufacturer and lot number.

The number of rounds loaded per magazine varied by platoon. Platoons 1 and 3 loaded 20 rounds per magazine with every fifth round (1, 6, 11, and 16) a tracer. This load was designated L_2. Platoons 2 and 4 loaded 18 rounds per magazine with rounds 1, 2, and 18 being tracers and this load was designated L_1. The number of rounds and use of tracers represent practices reported by units in South Vietnam.

The main test provided for two scheduled cleaning cycles, C_1 and C_2 (Table 3). Of the six riflemen in any squad firing one of the three basic types or configurations of rifle, three followed cleaning cycle C_1 (scheduled cleaning after firing 240 (234)[1] rounds) and the remaining three followed C_2 (scheduled cleaning after 480 (468) rounds). C_1

[1] **Rifles firing 18-round magazines (L_1) expended 234 rounds during a firing period as opposed to 240 rounds for 20-round magazines (L_2).**

cleaning took place each day at noon and each evening. C_2 cleaning took place only at noon. Thus, rifles adhering to cleaning cycle C_2 remained dirty overnight and over the one-day break between each environmental phase.

The mode of fire of each of the rifle types R_1, R_2, and R_4 was controlled throughout the test by firing odd-numbered magazines in the automatic mode and even-numbered magazines in the semi-automatic mode. Thus, each rifle fired half its total rounds in each mode.

Table 4 summarizes the test variables used in the analysis. The WSEG notation used to designate the variables and the levels within variables has been maintained throughout this report.

TABLE 1

NO. OF RIFLES	TYPE	CONFIGURATION	TEST SYMBOL
150	M16A1	New buffer and chromed chamber (Oct-Nov 1967 production)	R_1
90	M16A1	New buffer only - no chrome (Dec 1966-Sep 1967 production)	R_2
67	M16A1	New buffer field retrofitted - no chrome (prior to Dec 1966 production)	R_3
140	M14	Reconditioned, with automatic selector lever installed	R_4
447	TOTAL		

TABLE 2

AMMUNITION ALLOCATION

BALL ROUNDS MANUFACTURER/ LOT NO.	TRACER ROUNDS MANUFACTURER/ LOT NO.	PROPEL- LANT	AMMO MIX SYMBOL	FIRED BY SQUAD NO.
Remington Arms RA 5287	Olin Mathieson WCC 6101	Ball WC 846	A_1	1
Lake City LC 12245	Olin Mathieson WCC 6101	Ball WC 846	A_2	2
Twin City TW 18179	Lake City LC 12109	IMR 8208M	A_3	3
Lake City LC 12229	Lake City LC 12109	IMR 8208M	A_4	4
Twin City TW 18103	Lake City LC 12644	Ball WC 846	A_5	All Squads

TABLE 3 - FIRING AND CLEANING SCHEDULE

TYPE/CONFIGURATION/ TEST SYMBOL OF RIFLE	NO. RIFLES	PROPEL- LANT	NOONDAY CLEANING AFTER FIRING	EVENING CLEANING AFTER FIRING	TOTAL ROUNDS PER RIFLE (12 DAYS)
M16A1 new buffer group with chromed chamber, R_1	24 24	Ball IMR	234/240 rds	234/240 rds	5616/5760
	24 24	Ball IMR	468/480 rds	None	
M16A1 group without chromed chamber, R_2	24 24	Ball IMR	234/240 rds	234/240 rds	
	24 24	Ball IMR	468/480 rds	None	
M16A1 new buffer with chromed chamber, R_1	4 4	Ball IMR	Clean each 3 days -- 324 rds		1296
			Clean each 6 days -- 648 rds		
M16A1 group without chromed chamber, R_2	4 4	Ball IMR	Clean each 3 days -- 324 rds		
M14, R_4	48 48	Ball Ball	234/240 rds 468/480 rds	234/240 rds None	5616/5760

TABLE 4

TEST VARIABLES

VARIABLE	NO. OF LEVELS	SYMBOL
Rifle Type	3	R_1 = new buffer group with chromed chamber R_2 = new buffer group without chromed chamber R_4 = M14
Environment	4	E_1 = Salt water, spray, and sand E_2 = Swamp water and mud E_3 = rain forest, terrain, etc. E_4 = uplands, dust, etc.
Magazine Loading	2	L_1 = 18 rounds per magazine L_2 = 20 rounds per magazine
Ammunition Type	5	A_1 = 5.56mm ball propellant (Remington Arms) A_2 = 5.56mm ball propellant (Lake City) A_3 = 5.56mm IMR propellant (Twin City) A_4 = 5.56mm IMR propellant (Lake City) A_5 = 7.62mm ball propellant (Lake City)
Cleaning Cycle	4	C_1 = after each firing period (240 or 234 rds) C_2 = after 2 firing periods (480 or 468 rds) C_3 = after 6 firing periods C_4 = after 12 firing periods
Firing Mode	2	M_1 = Automatic M_2 = Semi-automatic

SECTION I

DISCUSSION OF WSEG ANALYSIS

Basically, the firing program was designed as a Latin Square. The main effects to be analyzed by this design were platoon, phase, and environment. The Latin Square design was arranged in the following manner:

	Phase 1	Phase 2	Phase 3	Phase 4
1st Platoon	E1	E3	E2	E4
2nd Platoon	E2	E4	E3	E1
3rd Platoon	E3	E1	E4	E2
4th Platoon	E4	E2	E1	E3

E1 - Beach environment

E2 - Swamp environment

E3 - Rain forest environment

E4 - Upland environment

A Latin Square design is one of many designs that could have been chosen for this test. The choice of a Latin Square design involves certain limitations that may reduce its effectiveness when analyzed with the data derived from this test. Further, the choice of the particular Latin Square used in this test involves other limitations. Briefly, these limitations are the following: (1) A Latin Square design assumes there is no interaction between the main effects. However, it is not clear that this assumption is valid for this test. (2) Only three main effects can be evaluated by this design, and it is apparent that of the three effects chosen, two of them (platoon and phase) are of secondary importance; and (3) If a different arrangement of the treatments (environment) had been used, the design could have been extended to a Greco-Latin Square and the effect of ammunition could also have been evaluated. (The Latin Square chosen by WSEG has no orthogonal counterpart.)

However, the relative advantages and disadvantages associated with a Latin Square design may be academic at this point since WSEG did not utilize the design in their analysis. Instead, their analysis consisted of numerous statistical tests on the data after sorting the results in many ways. These tests primarily involved the t and χ^2 distribution. There is some uncertainty regarding the validity of these tests since some of the basic assumptions associated with tests of this type have been violated. The statistical tests used in the WSEG report require an assumption that the underlying data be normally distributed. Specifically, the most serious violation of this assumption lies in the fact that the mean and variance of the normal distribution are independent. It is well known that this is not true of Bernoulli variables. However, a transformation is available that will stabilize the variances so that they are independent of the observations, and consequently, of the mean. This transformation is discussed in Section III of this report.

Another area that should be discussed is the confounding of ball and tracer projectiles within the design. This discussion is not intended to be critical of the design on this point, but it is felt that the employment of ball and tracer rounds in the test should be discussed.

It will be recalled from the introduction that each magazine was loaded with several tracer rounds. The number and location of these rounds depended upon whether the magazine was loaded with 18 or 20 rounds.

WSEG, in their analysis, treated tracer and ball projectile rounds as though there were no difference in their respective malfunction rates. This was done primarily because no provisions had been made in reporting the data that would conveniently permit the tracer rounds to be separated.

However, in the present study, a computer program was written that did separate the malfunction rates for each of the two projectile types. This information is summarized in Section IV. It will be seen, from this analysis, that in general there appears to be no evidence that tracer rounds affect the malfunction rates. However, for one specific malfunction type, there is some evidence which suggests that, when the last round in the magazine is a tracer, the malfunction rate may be affected. This evidence, however, is at best weak and the data does not lend itself to a statistical test of significance.

In any event, when estimating reliability, the tracer rounds must be considered with the ball rounds since the reliability functions must be estimated over all rounds fired. Eliminating certain rounds would cause points of discontinuity on the curve and would also bias the estimation of the parameters.

In view of the above discussion, it was decided that for all analyses, except those in Section IV, the results of both ball and tracer projectile ammunition would be combined.

The analyses presented in this report were performed with the data supplied by WSEG. This was essentially the same data that WSEG used in their analysis. Actually, the data used for both analyses were identical except for the fact that substitute rifle data was used for this study and was not used for the WSEG study. The reason for this will become apparent in the following paragraphs.

In the analyses presented in this report, the data was rearranged into a series of factorial designs. A factorial design provides a more powerful test than a Latin Square design if interactions among the main effects are likely or expected. Without confounding, the effects of ammunition type, ammunition lots, rifle type, firing mode, and cleaning cycle were independently evaluated using the factorial model. The interactions among these effects were also independently evaluated. The effects of environment, however, were evaluated from a series of Latin Square designs since this effect could not be easily included in the factorial design. The substitute rifle data was used in this study since it is convenient for each cell within an analysis of variance to have equal weight. The use of substitute rifles was considered too infrequent to cause a significant bias in the data.

In the following analyses, no attempt was made to duplicate or to check the computations of the WSEG report. Where it was felt that WSEG did not use the most efficient tests, did not investigate in sufficient detail, or omitted areas that should be investigated, further analyses were conducted in this study.

Original computer programs were written for the analyses in this study, and all machine computations were performed by the Ballistic Research Laboratories Electronic Scientific Computer (BRLESC).

SECTION II

RELIABILITY ANALYSIS

Method

The reliability of the M16 rifle is dependent upon numerous firing conditions and, for this reason, cannot be represented by a single function. In fact, even with the voluminous results provided by the WSEG test, it is impossible to obtain estimates for all the conditions under which the rifles were fired. For instance, if a reliability function is desired at a specific environment, firing a specific ammunition type in a specific rifle type, the amount of information available would be insufficient. Therefore, the explicitness of the reliability estimates with respect to isolating the main effects will depend upon the amount of data available at each condition. It should be pointed out that although there is sufficient information to yield good estimates of failure rates, it does not follow that there is sufficient information to yield good estimates of a distribution function.

Since the most obvious condition that affects reliability is ammunition type (ball propellant vs. IMR propellant), these were kept separate throughout. Within ammunition type, estimates were given for rifle type over environments and environments over rifle type. It was also anticipated that the reliability would change with the number of failures experienced. Therefore, a different reliability function would be necessary to represent the time to first failure, time from first to second failure, etc.

Because of its versatility and widely used application to life distributions, the Weibull distribution was the first candidate tried to represent the data. The data under each condition was plotted on Weibull distribution paper and in every case it was quite apparent that an excellent fit could be obtained. This was later confirmed for several cases when applying the Kolmogorov-Smirnov goodness-of-fit test. The form of the distribution is as follows:

$$f(R) = \frac{\beta R^{\beta-1}}{\eta^{\beta}} \left[\exp -\left(\frac{R}{\eta}\right)^{\beta}\right]$$

where R = rounds to stoppage

η = characteristic life

β = shape parameter.

When $\beta = 1$ the distribution becomes the exponential with η being the mean rounds to stoppage usually denoted in life testing as θ. If $\beta \neq 1$ the failure rate is not constant, consequently the distribution takes on a form different from the exponential. In this study β in every case was less than one, indicating a decreasing failure rate. In one case β was sufficiently close to one that the exponential distribution could be assumed.

The parameters η and β were estimated from the data. This was accomplished by taking the log (R) and the log [-log(1-F(R))] where

$$F(R) = \int_0^{R_0} f(R)dt.$$

Actually the estimates of F(R) were obtained from the data by summation rather than integration.

Setting

$$y = \log R$$
$$a = \log \eta$$
$$b = 1/\beta$$
$$x = \log [-\log(1-F(R))]$$

it was possible to fit a straight line ($y = a+bx$) to the data by the method of least squares. The corresponding estimates of β and η are

$$\hat{\beta} = 1/\hat{b} \text{ and } \hat{\eta} = e^{\hat{a}}$$

where

$$\hat{b} = \frac{\Sigma(x_i - \bar{x})(y_i - \bar{y})}{\Sigma(x_i - \bar{x})^2} \quad \text{and } \hat{a} = \bar{y} - \hat{b}\,\bar{x}.$$

the failure rate may be represented by $r(R) = \frac{\beta}{\eta^{\beta}} R^{\beta-1}$

The data, as it was collected, presented some difficulty with respect to estimating the reliability function. This occurred for those cases where one or more of the rifles did not malfunction. The distribution functions listed in this text refer to the time to failure on those rifles where failures occurred. Where all or nearly all rifles failed, the function is truely a life distribution. Where a number of rifles did not fail the distribution produces a conservative estimate of reliability. In order to obtain the reliability [R = P (no failure occurs in the first R_o rounds)], the probability (obtained by integrating under the function) that a failure occurs in the first R_o rounds must be multiplied by the probability that a failure will occur before the test is truncated. The reliability (R) is then the compliment of the product of these two probabilities, e.g.,

P(no failure in first R_o rounds)

$$= 1 - [\int_0^{R_o} f(R)dt]\,[P(\text{rifle failed during test})] = 1 - F(R)\,P(r)$$

It was also necessary to multiply the failure rate, r(R), by P(r).

An additional problem presents itself when considering failures subsequent to the first failure. For instance, the rounds from the first to second failure is dependent upon when the first failure occurred. This biases the distribution function to some extent and, for this reason, the distribution functions for rounds to second, third, etc. failure are slightly biased. However, these are the best life distributions that are currently available and should be closely studied, especially to detect changes in the parameters as the number of the failure under consideration increases.

Another problem arises from this same source when the mean rounds between stoppage (MRBS) is computed. The normal method for computing this estimate must be modified in order to compensate for the fact that in subsequent failures the lives begin at different times. If one defines the life to begin after the previous failure, regardless of when it occurs, then the truncation point of the test varies. A modification of the usual method of computing the MRBS has been used in this report and this modification appears to yield reasonable results.

Fitting Distributions By Total Malfunctions

The rounds to the first malfunction and the rounds between each succeeding malfunction were recorded for each individual rifle. Reliability distributions were fitted to these data for three groups: (1) M16 Rifles firing ball and tracer rounds w/ball propellant, (2) M16 Rifles firing ball and tracer rounds w/IMR propellant and (3) M14 Rifles firing ball and tracer rounds w/ball propellant. As previously discussed, the two-parameter Weibull Distribution was fitted to the data. The shape parameter ($\hat{\beta}$) and characteristic life ($\hat{\eta}$) estimates were obtained for the distributions and are shown in Table II-A, which also includes the mean rounds between malfunctions. The estimate of $\hat{\beta}$ for rounds to first malfunction for M16 w/ball propellant indicates that the failure rate is nearly constant (indicative of the exponential distribution), however all other estimates of $\hat{\beta}$ clearly indicate decreasing failure rates for all other rounds to or between malfunction regardless of rifle type or ammunition type. The above observations were later verified by Failure Curves Figure II-G through II-I.

Weibull Distribution, Reliability Estimates, and Failure Rate Curves for: (1) rounds to first malfunction, (2) rounds between fourth and fifth malfunction and (3) rounds between ninth and tenth malfunction, for the three previously defined groups, are shown in Figures II-A through II-I.

The probability of firing R rounds (where R has been calculated for R = 1, 10, 50, 100, 500, and 1000 but may be calculated for any desired value of R) before the first malfunction or between two successive malfunction were calculated and are shown in Tables II-B through II-E. Table II-E, which compares the estimates for the three defined groups, appears to indicate that the estimates for the M16 Rifles w/IMR propellant are significantly lower than the estimates for the M16 Rifles w/ball propellant and M14 Rifles w/ball propellant. However, it should be noted that these lower estimates for M16 Rifles w/IMR propellant appear to have been caused by the excessive number of failures to feed.

The M16 rifle firing ball propellant was slightly more reliable than the M14 rifle with respect to the number of rounds to first failure. However, the M14 rifle was more reliable when considering the number of rounds between subsequent failures.

Fitting Distributions By Environments

The rounds to the first malfunction at the original environment in which each individual rifle was tested were recorded. The two-parameter Weibull Distribution was fitted to these data and estimates of the shape parameter ($\hat{\beta}$), characteristic life ($\hat{\eta}$) and mean rounds to first malfunction were calculated. The mean rounds to first malfunction are shown in Table II-F.

The Reliability Estimate Curves are shown in Figures II-J through II-L. These estimates are also shown in Tables II-G through II-J. These estimates did not reflect the fact that many more malfunctions were observed at the beach environment (Salt Water, Spray and Sand) as had been expected. It should also be noted that the reliability estimates for the M16 Rifles with either type of propellant were higher for the rain forest environment while the M14 Rifles were most reliable when firing in the swamp environment. On the other hand the M16 Rifles w/ball propellant, M16 Rifles w/IMR propellant and M14 Rifles w/ball propellant were least reliable for beach, swamp and rain forest environments respectively.

Fitting Distributions by Nature of Malfunctions

The data by nature of malfunction is presently being analyzed and the findings will be included in a later report.

Fitting Distributions by Number of Rounds to Second, Third, etc. Malfunction

Reliability estimates to the second, third, etc., malfunction are being prepared and will be included in a later report.

TABLE IIA

Rifles Firing Ball and Tracer Rounds
Estimates of Weibull Distribution Parameters

Distribution of Rounds	M 16 - BALL			M 16 - IMR			M 14		
	Shape Parameter $\hat{\beta}$	Characteristic Life $\hat{\eta}$	Mean Rounds	Shape Parameter $\hat{\beta}$	Characteristic Life $\hat{\eta}$	Mean Rounds	Shape Parameter $\hat{\beta}$	Characteristic Life $\hat{\eta}$	Mean Rounds
To 1st Malf.	.9355	1009	1223	.4711	234	521	.7529	869	1122
Between 1st & 2nd Malf.	.5753	515	968	.4170	68	470	.6433	561	892
Between 2nd & 3rd Malf.	.6617	480	916	.4514	111	409	.4044	240	1059
Between 3rd & 4th Malf.	.6171	295	569	.4346	88	324	.6445	1124	1400
Between 4th & 5th Malf.	.5972	333	1259	.4594	127	525	.7207	462	979
Between 5th & 6th Malf.	.3866	111	551	.3551	56	430	.8119	320	629
Between 7th & 8th Malf.	.4693	173	501	.3969	78	375	.3512	147	479
Between 9th & 10th Malf.	.5065	102	339	.3567	47	556	.2684	35	395

TABLE IIB

M16 Rifle Firing Ball and Tracer Rds. w/Ball Prop.
Reliability Estimates of Firing R Rounds
Between Malfunction

Prob. of Firing R Rds.	No. of Rounds					
	1	10	50	100	500	1000
To 1st Malfunction	.9985	.9868	.9422	.8925	.5998	.3778
Between 1st & 2nd Malf.	.9731	.9031	.7740	.6835	.3877	.2483
Between 2nd & 3rd Malf.	.9840	.9290	.8083	.7150	.3864	.2326
Between 3rd & 4th Malf.	.9732	.8943	.7421	.6360	.3201	.2014
Between 4th & 5th Malf.	.9740	.9018	.7669	.6735	.3903	.2769
Between 5th & 6th Malf.	.8641	.7037	.5270	.4388	.2428	.1785
Between 6th & 7th Malf.	.9531	.8384	.6485	.5303	.2306	.1377
Between 7th & 8th Malf.	.9224	.7898	.6103	.5096	.2650	.1826
Between 9th & 10th Malf.	.9203	.7692	.5636	.4536	.2233	.1677
Between 11th &12th Malf	.8363	.6683	.5008	.4235	.2668	.2210
Between 13th & 14th Malf.	.7933	.5964	.4097	.3269	.1671	.1229

TABLE IIC

M16 Rifles Firing Ball and Tracer Rds. w/IMR Prop.
Reliability Estimates of Firing R Rds.
Between Malfunction

Prob. of Firing R Rds.	No. of Rounds					
	1	10	50	100	500	1000
To 1st Malfunction	.9263	.7974	.6167	.5117	.2393	.1994
Between 1st & 2nd Malf.	.8485	.6530	.4393	.3378	.1383	.0863
Between 2nd & 3rd Malf.	.8887	.7167	.5032	.3919	.1485	.0776
Between 3rd & 4th Malf.	.8684	.6815	.4634	.3547	.1288	.0668
Between 4th & 5th Malf.	.9021	.7445	.5425	.4345	.1907	.1167
Between 5th & 6th Malf.	.7945	.5960	.4042	.3174	.1442	.0946
Between 7th & 8th Malf.	.8413	.6510	.4462	.3478	.1447	.0864
Between 9th & 10th Malf.	.7995	.6078	.4263	.3459	.1916	.1496
Between 12th & 13th Malf.	.6822	.4804	.3150	.2453	.1092	.0676
Between 14th & 15th Malf.	.8440	.6604	.4626	.3666	.1638	.1026

TABLE IID

M14 Rifles Firing Ball and Tracer Rds. w/Ball Prop.
Reliability Estimates of Firing R Rds.
Between Malfunctions

Prob. of Firing R Rds.	No. of Rounds					
	1	10	50	100	500	1000
To 1st Malfunction	.9940	.9662	.8911	.8236	.5221	.3360
Between 1st & 2nd Malf.	.9835	.9293	.8137	.7250	.4078	.2506
Between 2nd & 3rd Malf.	.9034	.7740	.6150	.5282	.3081	.2221
Between 3rd & 4th Malf.	.9911	.9616	.8961	.8434	.6306	.5010
Between 4th & 5th Malf.	.9897	.9474	.8433	.7573	.4389	.2910
Between 5th & 6th Malf.	.9922	.9504	.8306	.7253	.3502	.2160
Between 7th & 8th Malf.	.8680	.7326	.5886	.5166	.3486	.2870
Between 9th & 10th Malf.	.7837	.6591	.5562	.5115	.4183	.3864
Between 11th &12th Malf.	.9705	.8651	.6544	.5190	.2368	.1922
Between 12th & 13th Malf.	.9676	.8819	.7296	.6292	.3505	.2529
Between 13th & 14th Malf.	.8674	.7542	.6386	.5803	.4367	.3774
Between 14th & 15th Malf.	.7734	.6000	.4568	.3992	.2990	.2745

TABLE IIE

RIFLES FIRING BALL AND TRACER ROUNDS

COMPARISON OF RELIABILITY ESTIMATES*

Prob. of Firing R Rds.		Number of Rounds 1	10	50	100	500	1000
To 1st Malfunction	M16-BALL	.9985	.9868	.9422	.8925	.5998	.3778
	M16-IMR	.9263	.7974	.6167	.5117	.2393	.1994
	M14	.9940	.9662	.8911	.8236	.5221	.3360
Between 1st & 2nd Malf.	M16-BALL	.9731	.9031	.7740	.6835	.3877	.2483
	M16-IMR	.8485	.6530	.4393	.3378	.1383	.0863
	M14	.9835	.9293	.8137	.7250	.4078	.2506
Between 2nd & 3rd Malf.	M16-BALL	.9840	.9290	.8083	.7150	.3864	.2326
	M16-IMR	.8887	.7167	.5032	.3919	.1485	.0776
	M14	.9034	.7740	.6150	.5282	.3081	.2221
Between 3rd & 4th Malf.	M16-BALL	.9732	.8943	.7421	.6360	.3201	.2014
	M16-IMR	.8684	.6815	.4634	.3547	.1288	.0668
	M14	.9911	.9616	.8961	.8434	.6306	.5010
Between 4th & 5th Malf.	M16-BALL	.9740	.9018	.7669	.6735	.3903	.2769
	M16-IMR	.9021	.7445	.5425	.4345	.1907	.1167
	M14	.9897	.9474	.8433	.7573	.4389	.2910
Between 5th & 6th Malf.	M16-BALL	.8641	.7037	.5270	.4388	.2428	.1785
	M16-IMR	.7945	.5960	.4042	.3174	.1442	.0946
	M14	.9922	.9504	.8306	.7253	.3502	.2160
Between 7th & 8th Malf.	M16-BALL	.9224	.7898	.6103	.5096	.2650	.1826
	M16-IMR	.8413	.6510	.4462	.3478	.1447	.0864
	M14	.8680	.7326	.5886	.5116	.3486	.2870
Between 9th & 10th Malf.	M16-BALL	.9203	.7692	.5636	.4536	.2233	.1677
	M16-IMR	.7995	.6078	.4263	.3459	.1916	.1496
	M14	.7837	.6591	.5562	.5115	.4183	.3864

*These estimates are based on WSEG data.

TABLE IIF

Rifles Firing Ball and Tracer Rounds
Mean Rounds to First Malfunction by Environments

Note: Means are based only on original environment data for each rifle.

Environment	M16*		M16**		M14
	BALL	IMR	BALL	IMR	BALL
I[1]	883	395	850	285	1039
II[2]	1337	190	934	228	1248
III[3]	1204	1629	2160	242	707
IV[4]	1133	494	1330	294	952

* M16 Rifle with New Buffer and Chromed Chamber.
** M16 Rifle with New Buffer only.

1 - Salt water, spray, and sand.
2 - Swamp water and mud.
3 - Rain forest, terrain, etc.
4 - Uplands, dust, etc.

TABLE IIG

M14 Rifle Firing Ball and Tracer Rds. w/Ball Prop.
Reliability Estimates to First Malfunction
in Environments

Number of Rounds	Prob. of Firing R Rds. to First Malf.*				
	Over All Environments	Environment I[1]	Environment II[2]	Environment III[3]	Environment IV[4]
1	.9940	.9997	.9989	.9906	.9741
10	.9662	.9946	.9887	.9475	.9119
50	.8911	.9637	.9427	.8338	.8044
100	.8236	.9192	.8881	.7371	.7327
500	.5221	.5865	.5871	.3845	.5155
1000	.3360	.3539	.4239	.2366	.4225

*These probabilities are based on data from firing the rifles in the initial environmental exposure, whereas the "Over All Environments" column includes all other data also.

1 - Salt water, spray and sand.
2 - Swamp water and mud.
3 - Rain forest, terrain, etc.
4 - Uplands, dust, etc.

TABLE IIH

M16 Rifle Firing Ball and Tracer w/Ball Prop.
Reliability Estimates to First Malfunction
in Environments

Number of Rounds	Prob. of Firing R Rds. to First Malf.*				
	Over All Environments	Environment I[1]	Environment II[2]	Environment III[3]	Environment IV[4]
1	.9985	.9988	.9984	.9957	.9955
10	.9868	.9855	.9845	.9725	.9696
50	.9422	.9238	.9252	.9039	.8906
100	.8925	.8494	.8575	.8395	.8173
500	.5998	.4470	.5100	.5953	.5280
1000	.3778	.2532	.3396	.4891	.4073

*These probabilities are based on data from firing the rifles in the initial environmental exposure, whereas the "Over All Environments" column includes all other data also.

1 - Salt water, spray and sand.
2 - Swamp water and mud.
3 - Rain forest, terrain, etc.
4 - Uplands, dust, etc.

TABLE II-I

M16 Rifle Firing Ball and Tracer w/IMR Prop.
Reliability Estimates to First Malfunction
in Environments

Number of Rounds	Prob. of Firing R Rds. to First Malf.*				
	Over All Environments	Environment I[1]	Environment II[2]	Environment III[3]	Environment IV[4]
1	.9263	.9964	.9722	.9836	.9907
10	.7974	.9648	.7184	.9252	.9354
50	.6167	.8372	.4836	.7992	.7691
100	.5117	.7026	.3640	.7059	.6254
500	.2393	.1926	.1276	.4215	.1973
1000	.1994	.0656	.0744	.3210	.1043

*These probabilities are based on data from firing the rifles in the initial environmental exposure, whereas the "Over All Environments" column includes all other data also.

1 - Salt water, spray and sand
2 - Swamp water and mud.
3 - Rain forest, terrain, etc.
4 - Uplands, dust, etc.

TABLE IIJ

Rifles Firing Ball and Tracer Rounds
Comparison of Reliability Estimates
To First Malfunctions by Environments

Prob. of Firing R Rds. to First Malfunction*		Number of Rounds					
		1	10	50	100	500	1000
Environment I[1]	M16-BALL	.9988	.9855	.9238	.8494	.4470	.2532
	M16-IMR	.9964	.9648	.8372	.7026	.1926	.0656
	M14	.9997	.9946	.9637	.9192	.5865	.3539
Environment II[2]	M16-BALL	.9984	.9845	.9252	.8575	.5100	.4350
	M16-IMR	.9722	.7184	.4836	.3640	.1276	.0744
	M14	.9989	.9887	.9427	.8881	.5871	.4239
Environment III[3]	M16-BALL	.9957	.9725	.9039	.8395	.5953	.4891
	M16-IMR	.9836	.9252	.7992	.7059	.4215	.3210
	M14	.9906	.9475	.8338	.7371	.3845	.2366
Environment IV[4]	M16-BALL	.9955	.9696	.8906	.8173	.5280	.4074
	M16-IMR	.9907	.9354	.7691	.6254	.1973	.1043
	M14	.9741	.9119	.8044	.7327	.5155	.4225

*These probabilities are based only on the original environment data for each rifle.

1 - Salt water, spray and sand.
2 - Swamp water and mud.
3 - Rain forest, terrain, etc.
4 - Uplands, dust, etc.

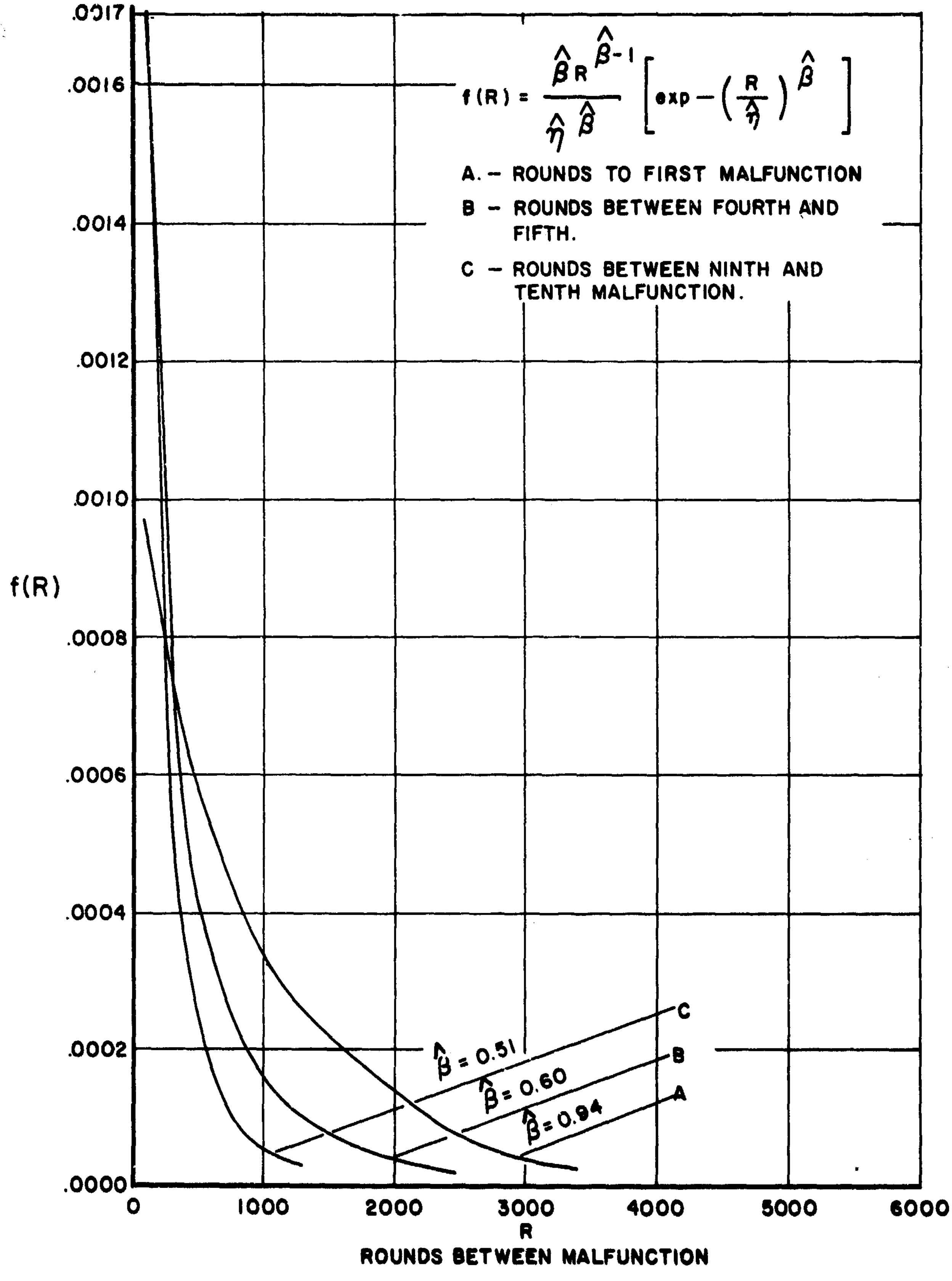


Figure II-A. M16 Rifle Firing Ball and Tracer Rds. W/Ball Prop. Weibull Distribution of Rounds To or Between Malfunction

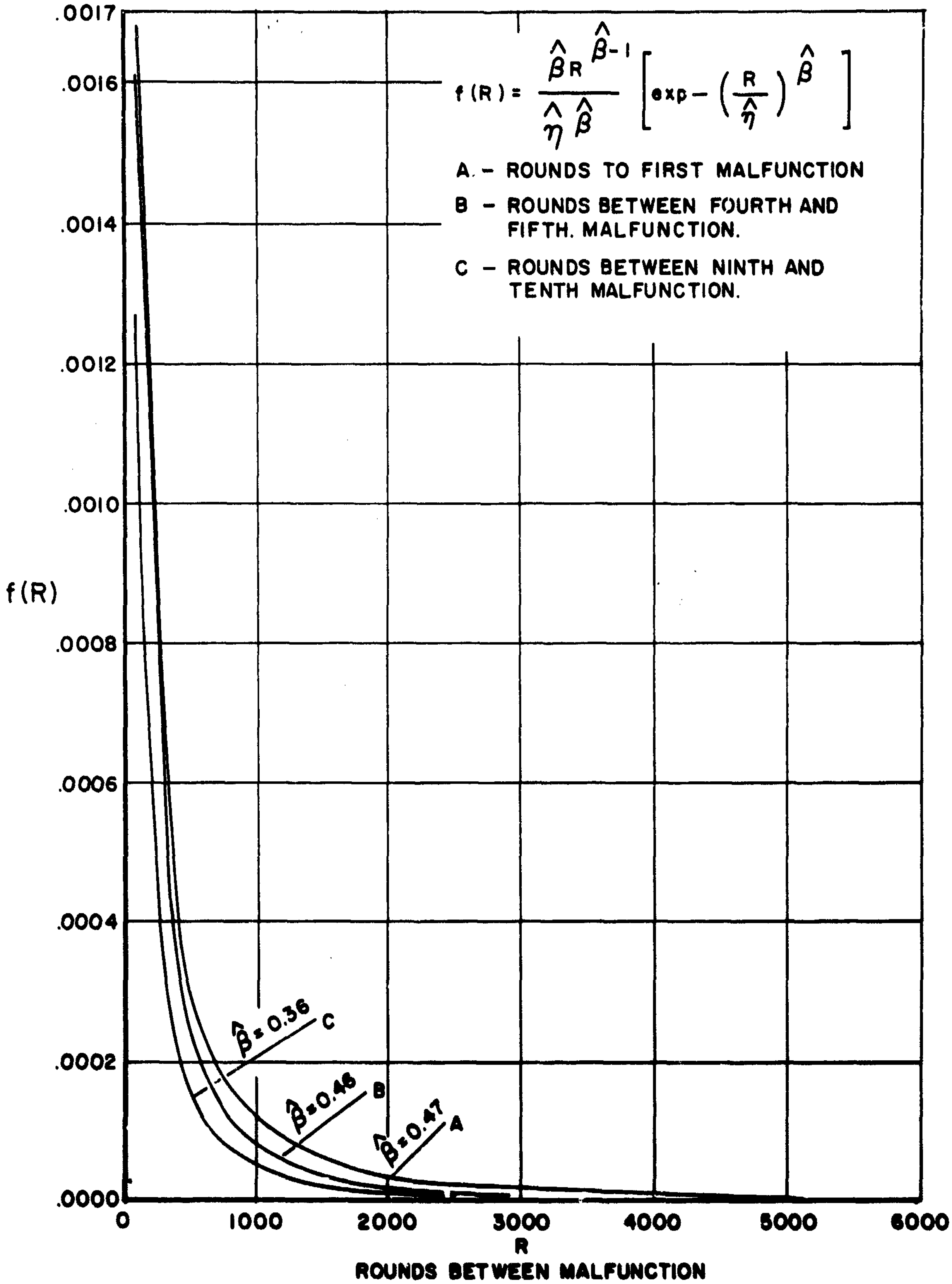


Figure II-B M16 Rifle Firing Ball and Tracer Rds. W/IMR Prop Weibull Distribution of Rounds To or Between Malfunction.

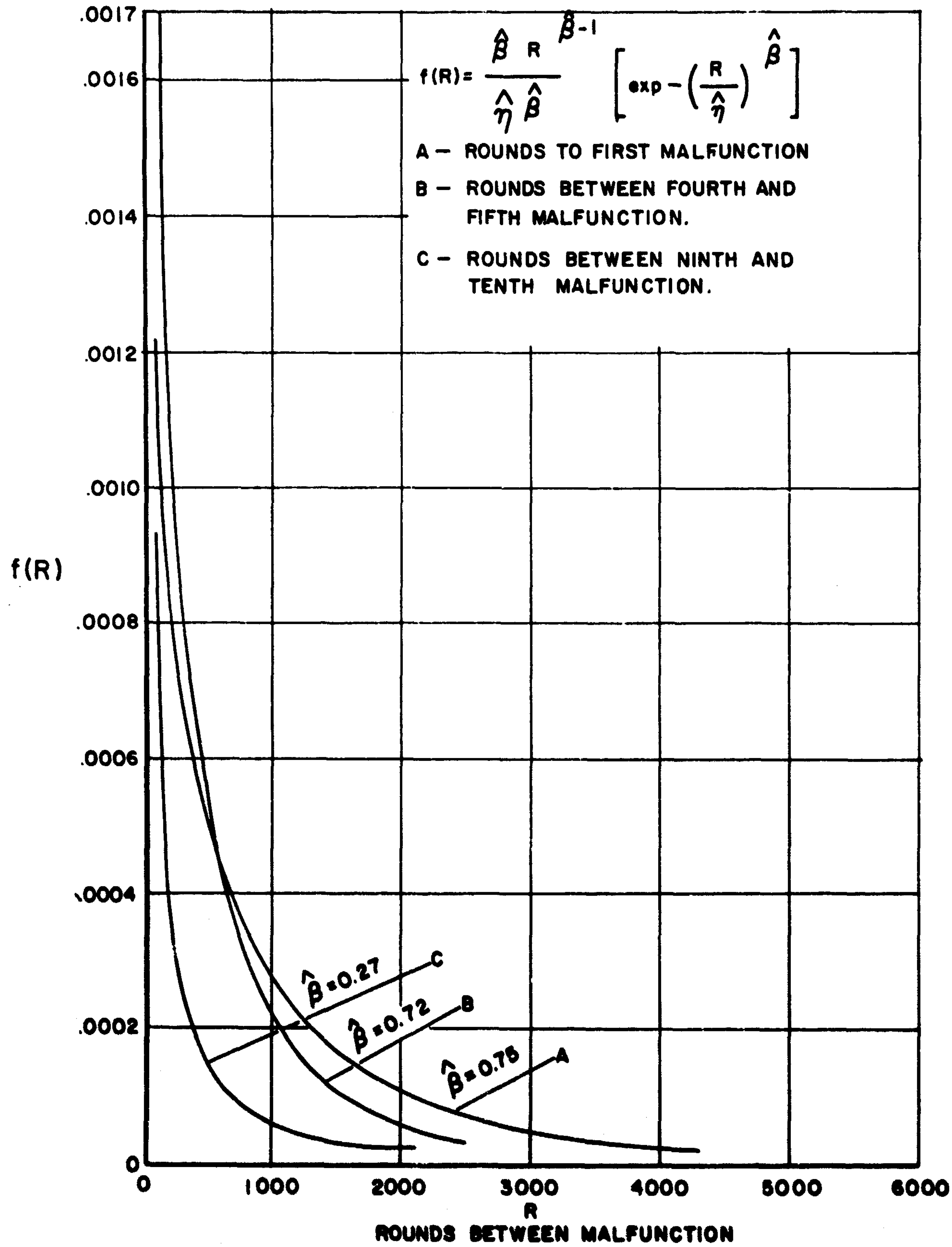


Figure II-C M14 Rifle Firing Ball and Tracer Rds. W/Ball Prop. Weibull Distribution of Rounds To or Between Malfunction

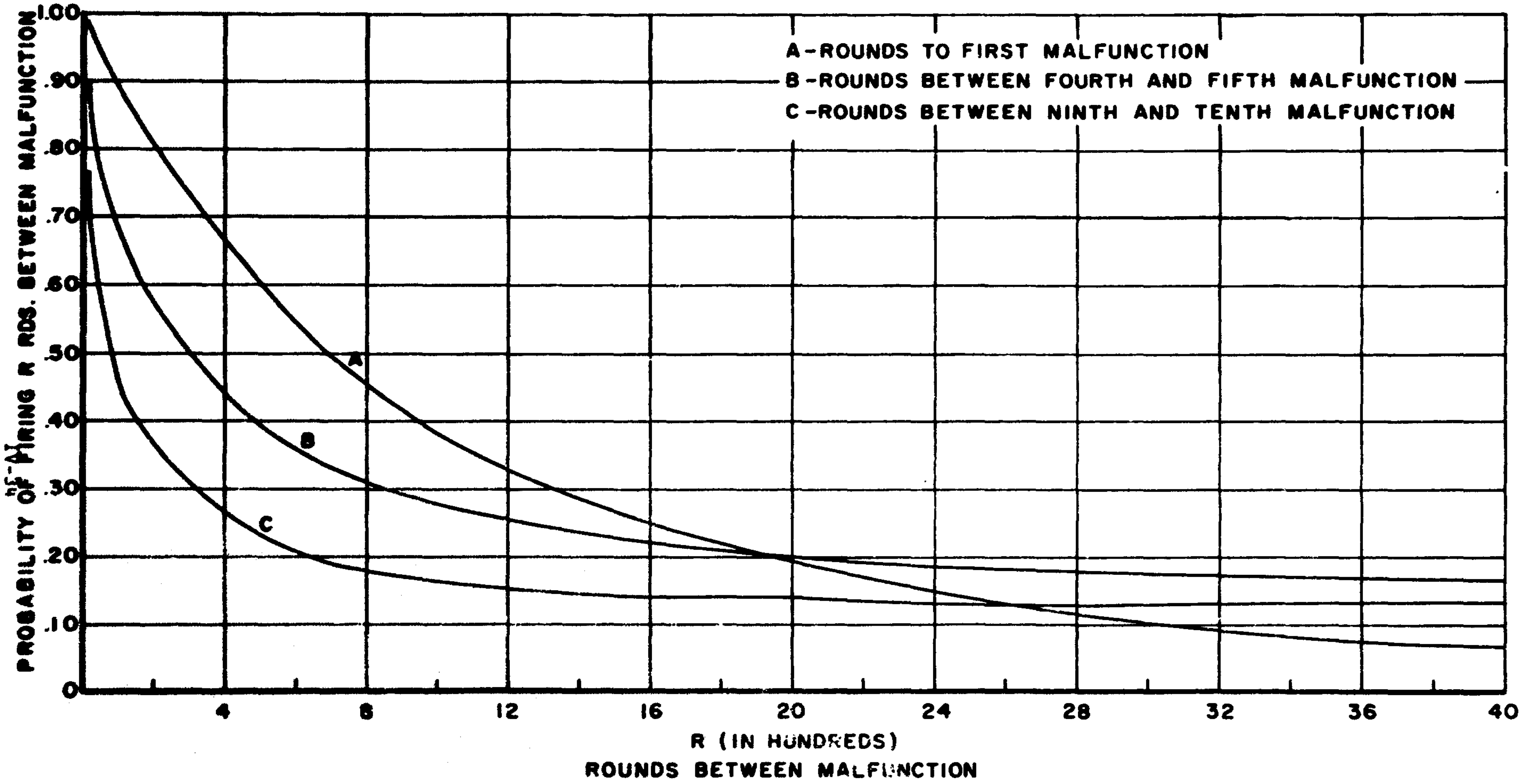


Figure II-D -M16 Rifle Firing Ball and Tracer Rds. w/Ball Prop.
Reliability Estimates of Rounds to or Between Malfunction.

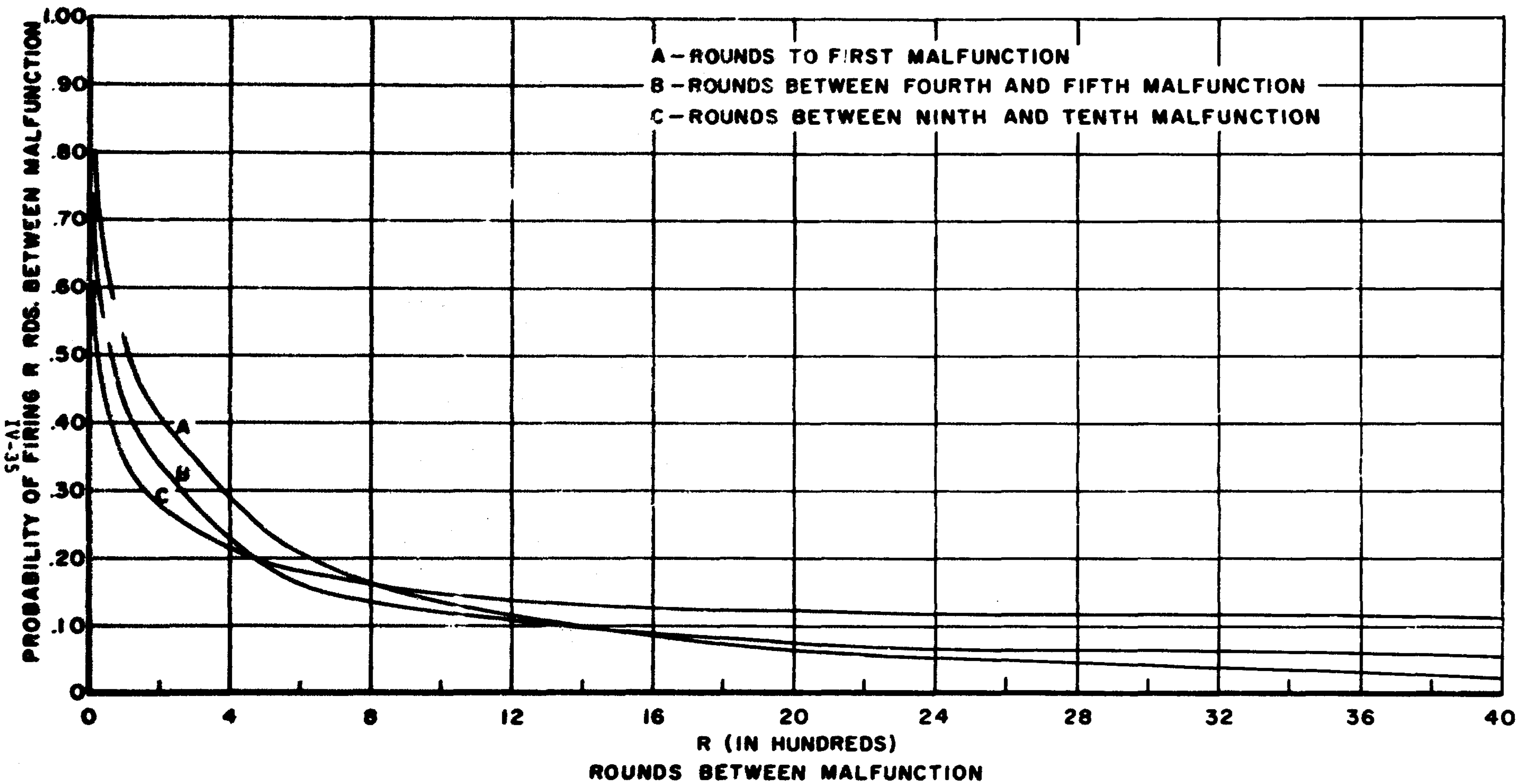


Figure II-E -M16 Rifle Firing Ball and Tracer Rds. w/IMR Prop.
Reliability Estimates of Rounds to or Between Malfunction.

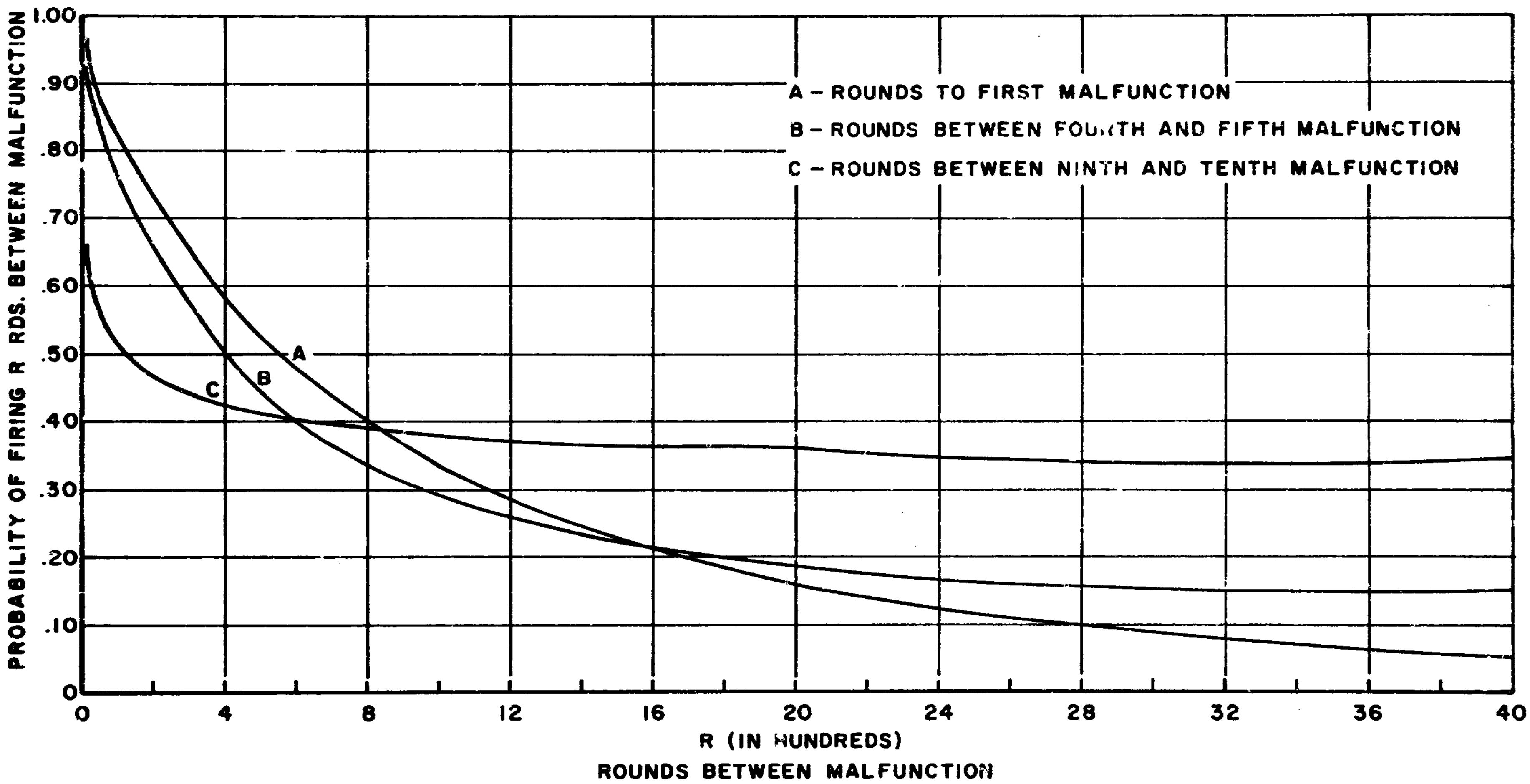


Figure II-F. M14 Rifle Firing Ball and Tracer Rds. w/Ball Prop. Reliability Estimates of R Rounds to or Between Malfunction

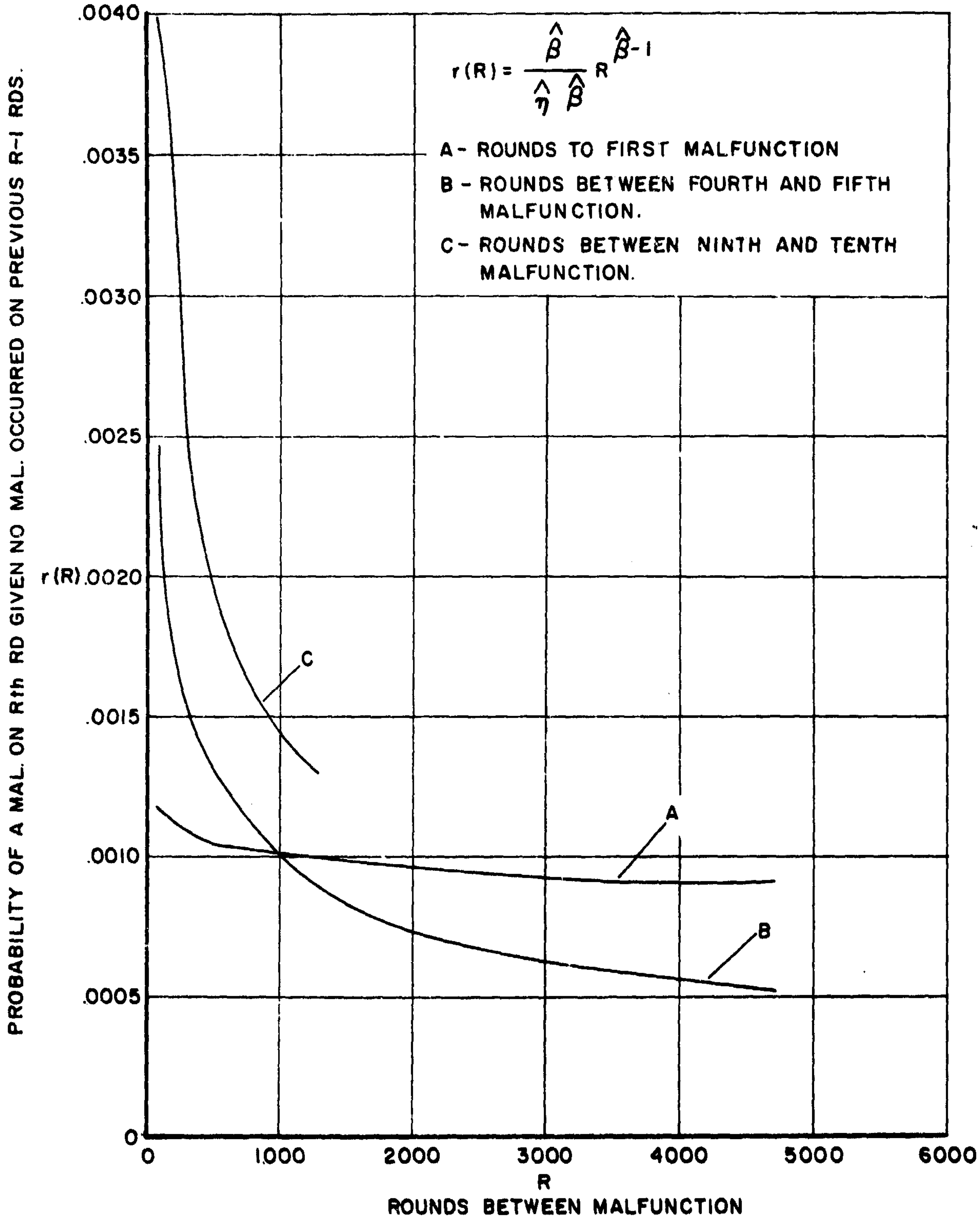


Figure II-G M16 Rifle Firing Ball and Tracer Rds W/ Ball Prop. Weibull Distribution Failure Rates.

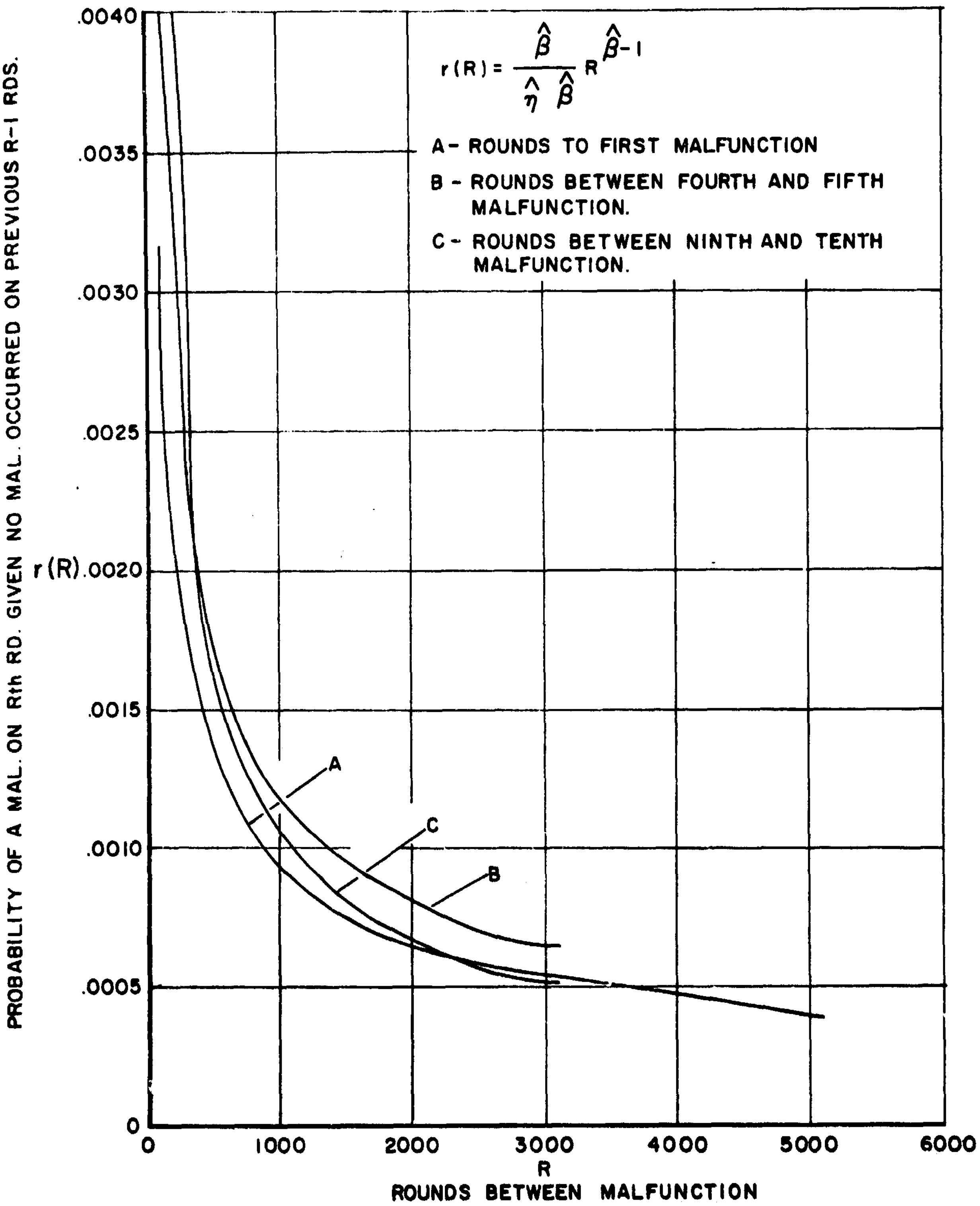


Figure II-H M16 Rifle Firing Ball and Tracer Rds. W/IMR Prop. Weibull Distribution Failure Rates.

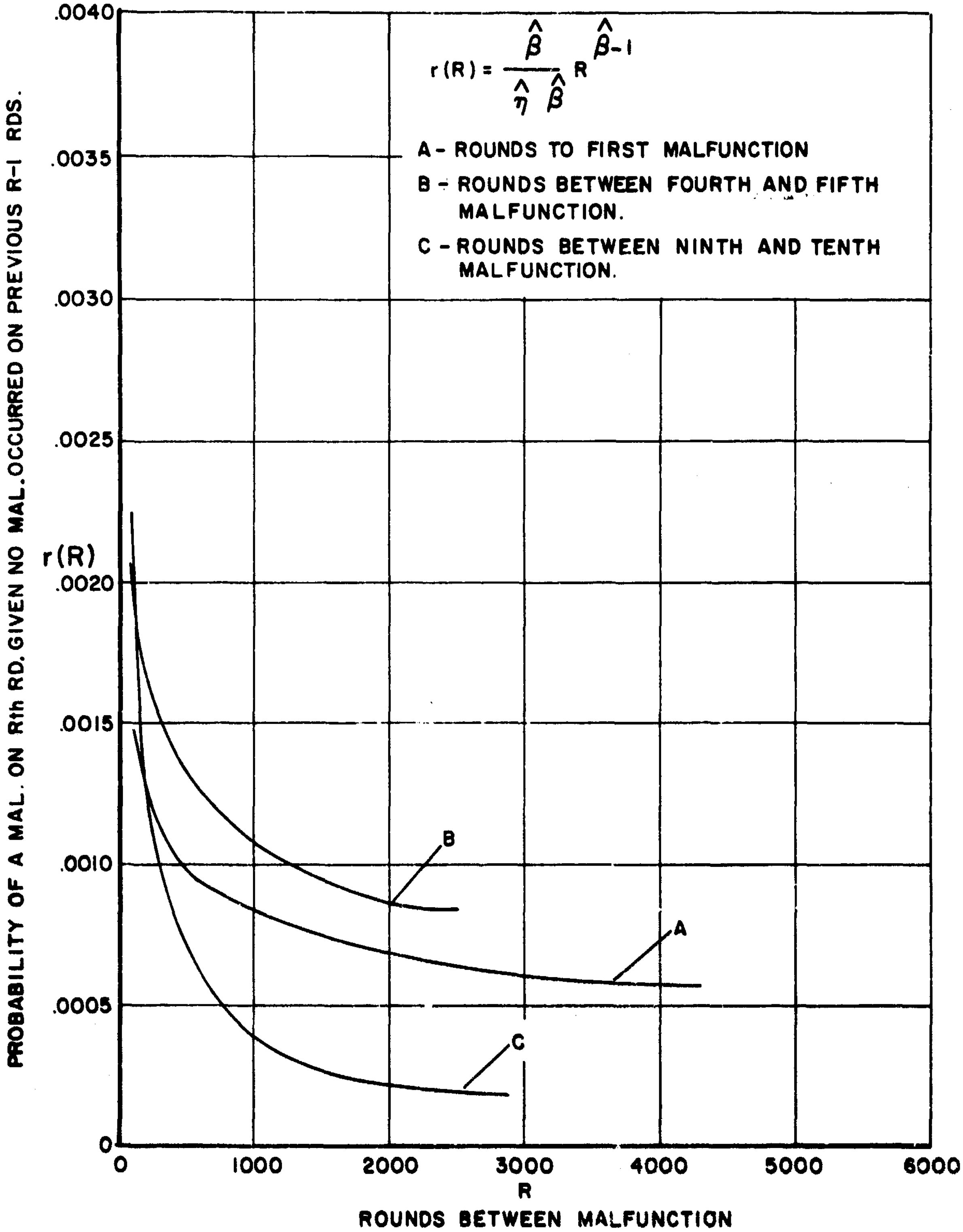


Figure II-1 M14 Rifle Firing Ball and Tracer Rds W/Ball Prop. Weibull Distribution Failure Rates.

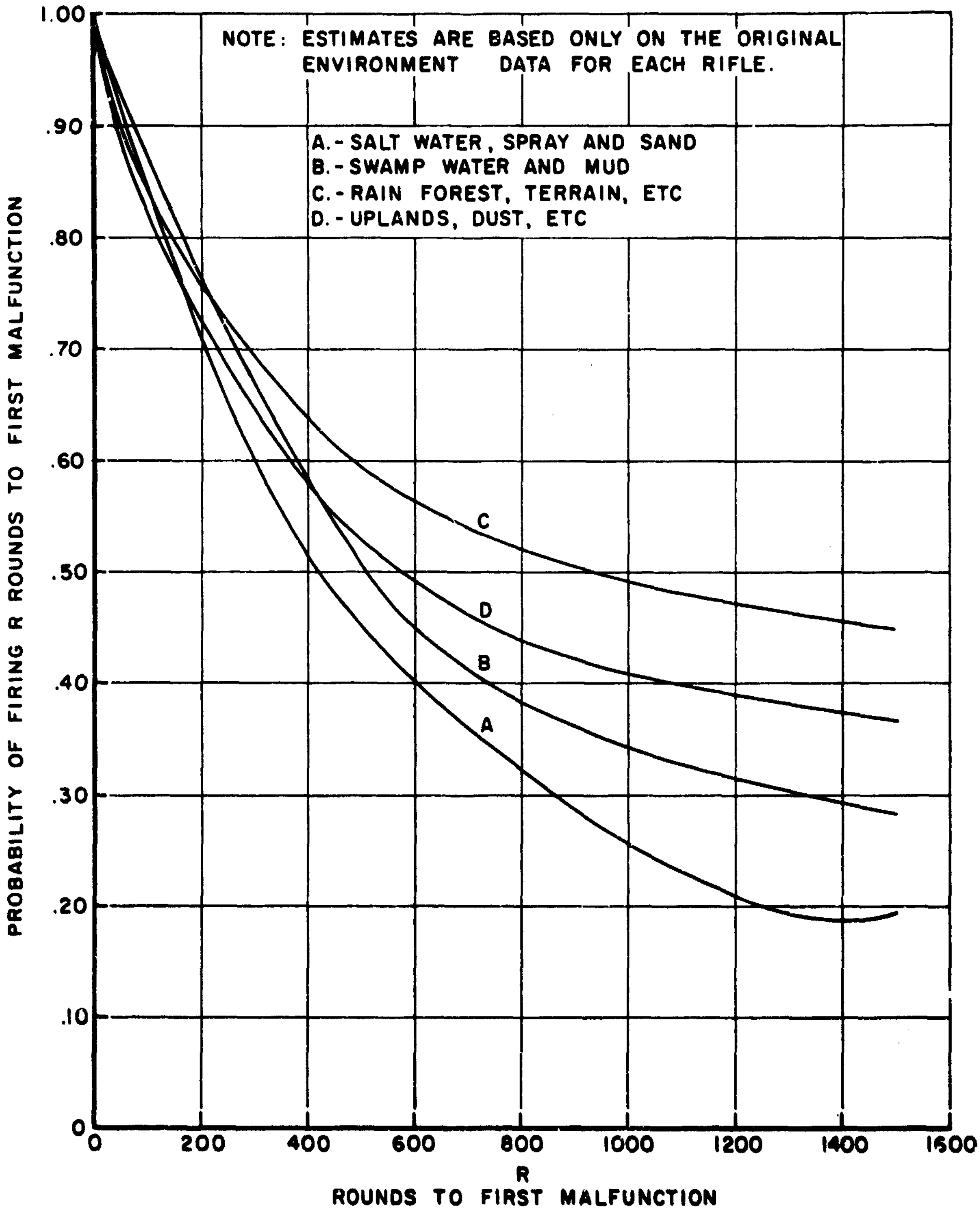


Figure II-J-M16 Rifle Firing Ball and Tracer Rds w/Ball Prop. Reliability Estimates of Firing R Rds to First Malfunction by Environments.

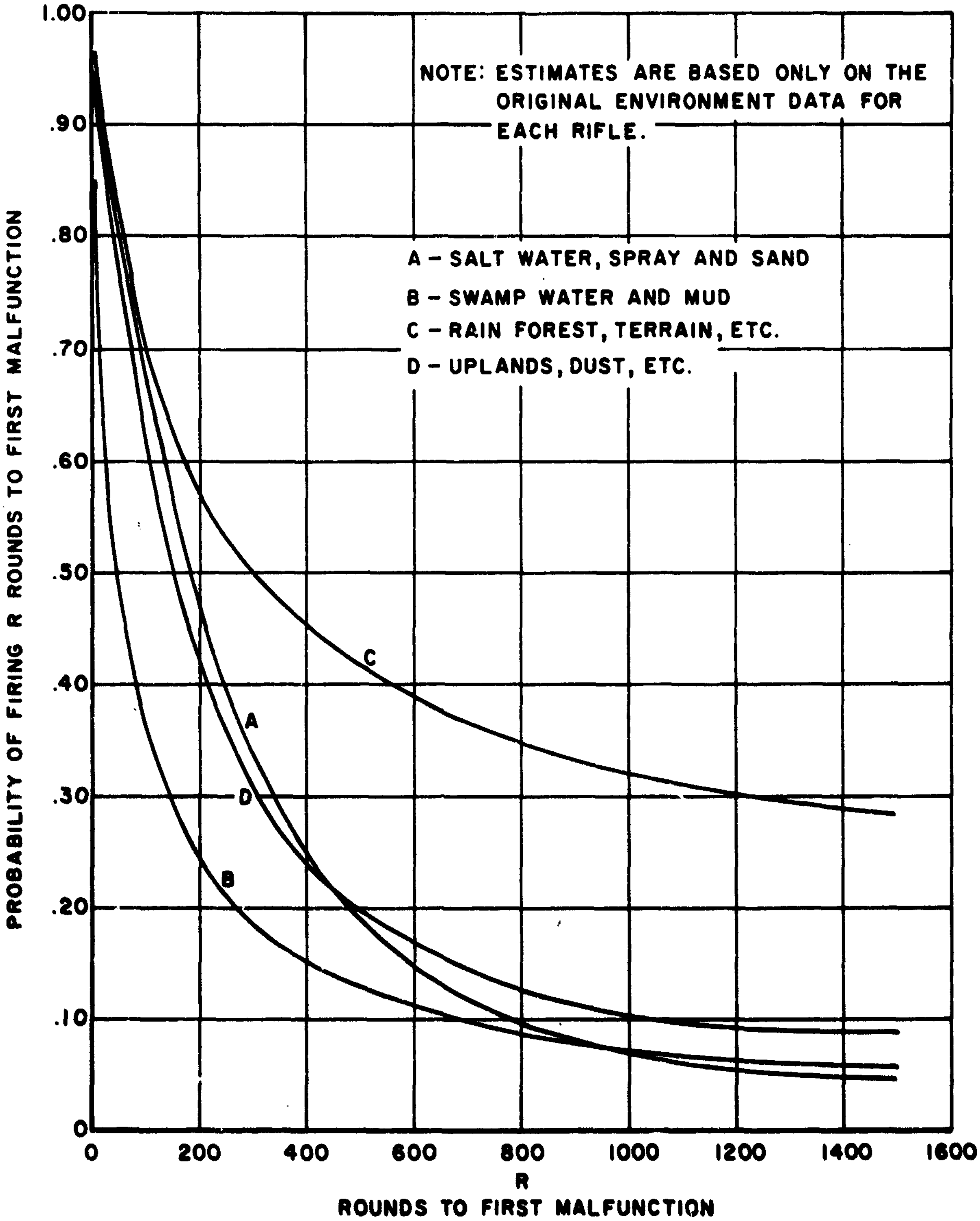


Figure II-K-M16 Rifle Firing Ball and Tracer Rds w/IMR Prop. Reliability Estimates of Firing R Rds. to First Malfunction by Environments.

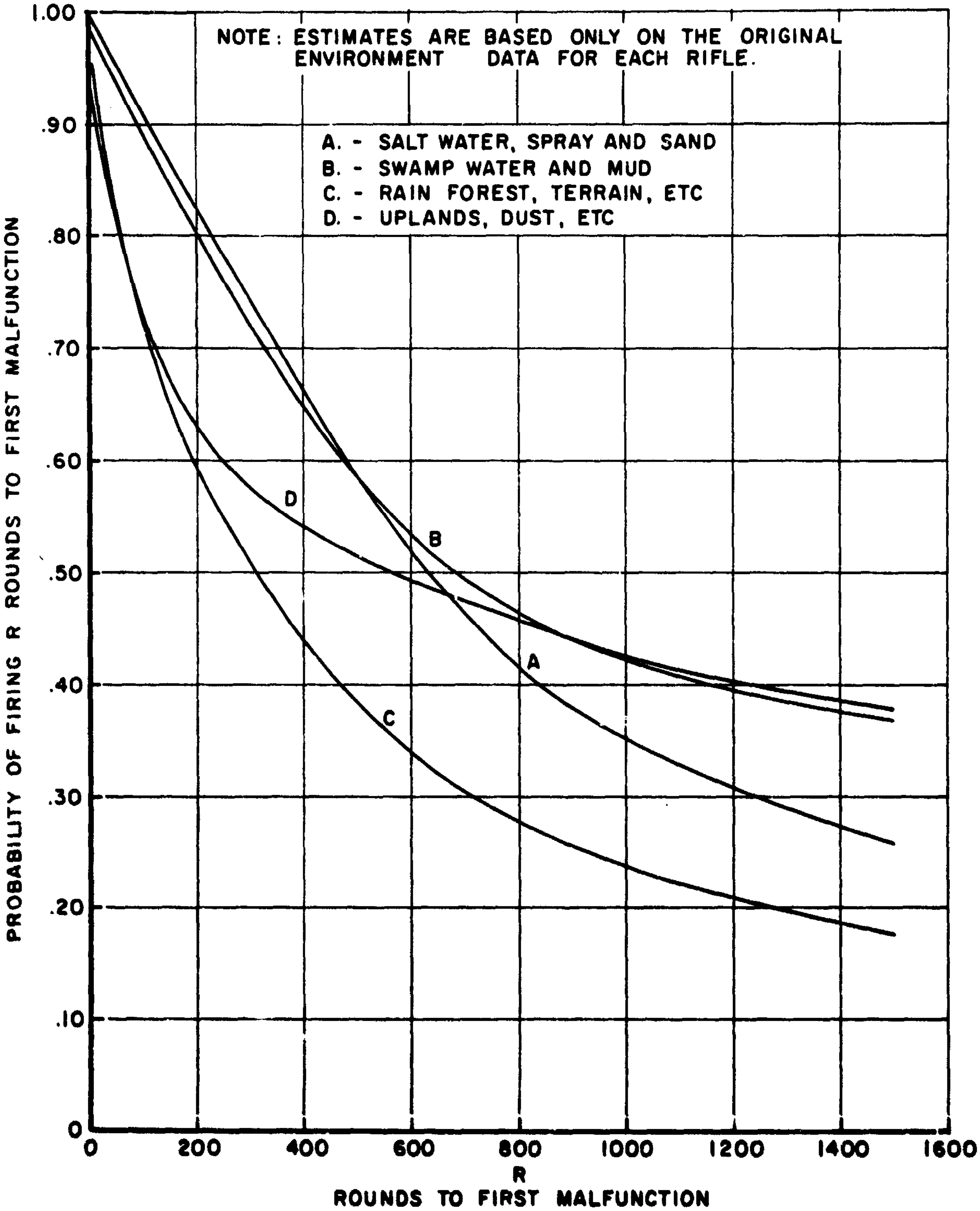


Figure II-L M14 Rifle Firing Ball and Tracer Rds w/Ball Prop. Reliability Estimates of Firing R Rds to First Malfunction by Environments.

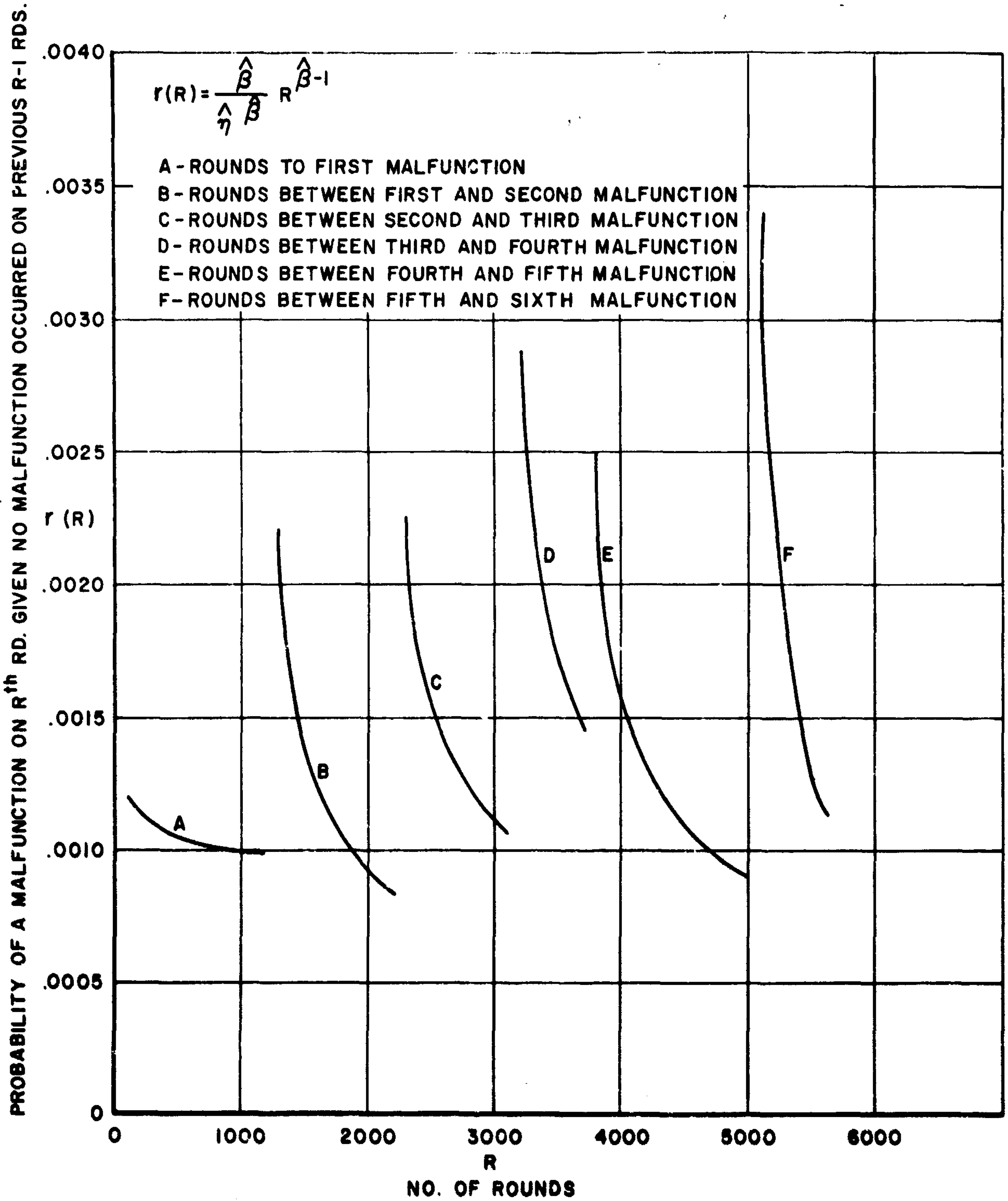


Figure II-M. M16 Rifle Firing Ball and Tracer W/Ball Prop. Weibull Distribution Failure Rates to Mean Rds. Between Malfunction

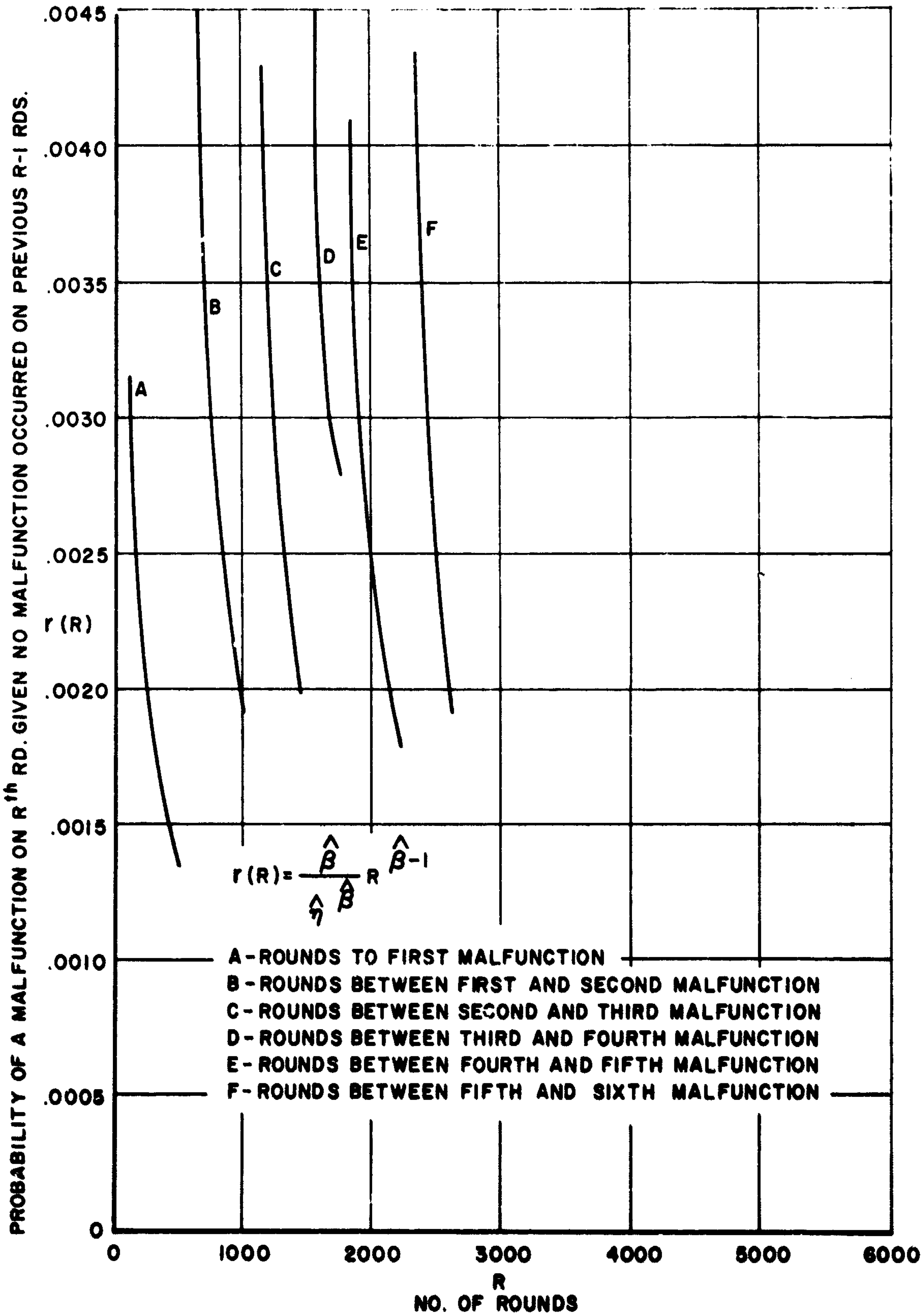


Figure II-N. M16 Rifle Firing Ball and Tracer W/IMR Prop. Weibull Distribution Failure Rates to Mean Rds. Between Malfunction

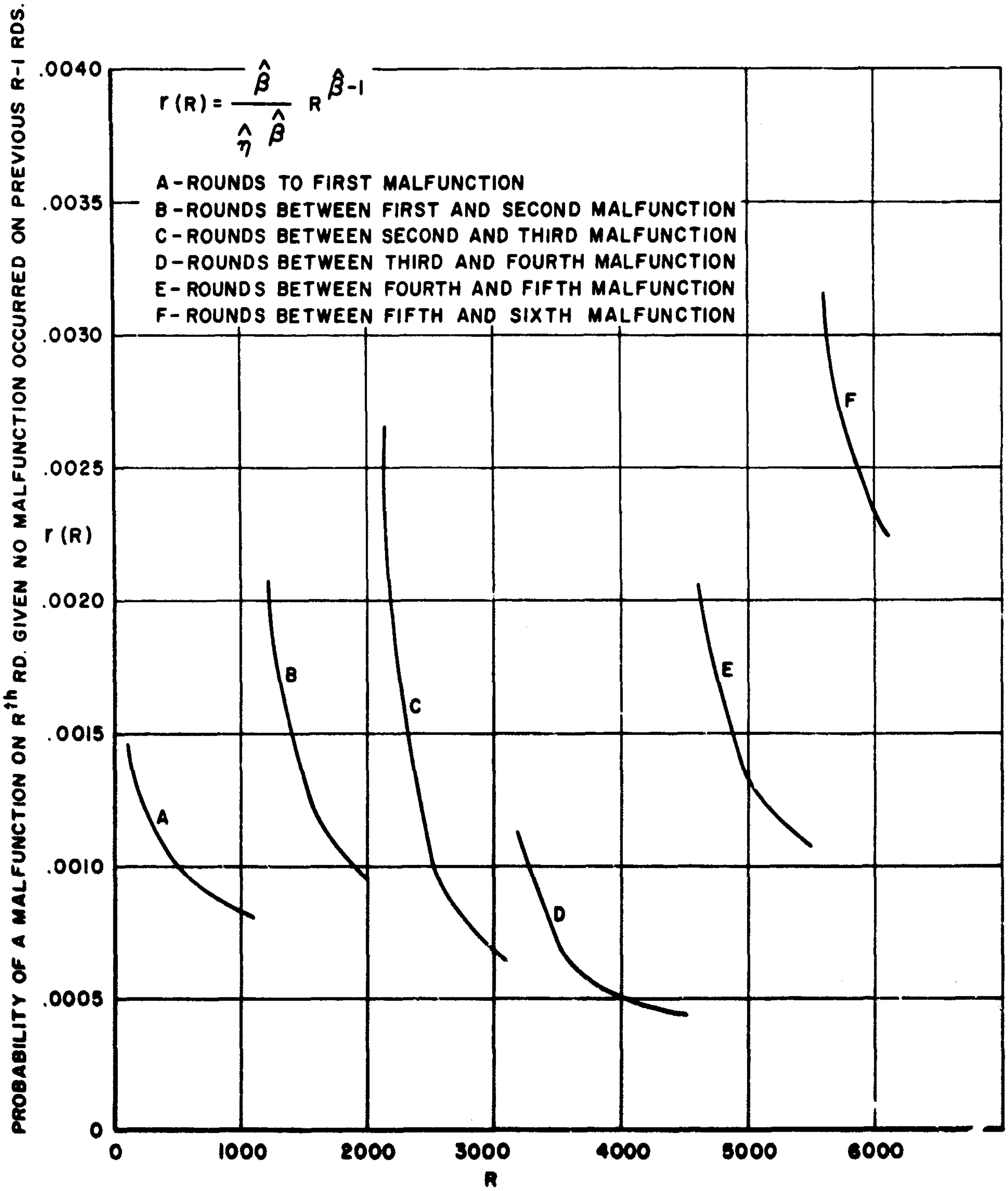


Figure II-O. M14 Rifle Firing Ball and Tracer W/Ball Prop. Weibull Distribution Failure Rates to Mean Rds. Between Malfunction

SECTION III

ANALYSES OF VARIANCE

"The validity of the analysis of variance as a method of separating the total variation in a set of observations into components from different sources does not depend upon any assumption of normality. It requires only that the observations are independent and arise from the usual type of additive model. If in addition all observations have equal error variance, the error mean square in the analysis gives an unbiased estimate of this. Normality of the distribution of random error is required only for strict validity of the usual test of significance and of calculations of fiducial limits to estimates; the Central Limit Theorem will presumably operate to prevent moderate departures from normality disturbing these unduly."[1]

The data used in the analyses of variance conducted for this report are failure rates. Since they are each based upon a large number of firings, it is assumed that the Central Limit Theorem will apply in this case. The only violation of the assumptions given above is that of an equal error variance for each observation. It is well known that the variance of Bernoulli variables is dependent upon the point estimate; therefore, unless the point estimates are equal the variances would not be equal.

However, the variables may be transformed so that the variances will be a function of n only and since n is nearly equal in all cases the variances are then stabilized. Thus, the variable used in the analysis was

$$\phi = 2 \text{ arc sin } \sqrt{p}$$

1 Finney, D. J., The Theory of Experimental Design. The University of Chicago Press, 1960.

Where p is the failure rate.[2]

Using Φ as the variable, a Latin Square analysis was performed on the M16 results and the M14 results where the data was separated (within rifle sets) only by mode of fire. The main effects to be measured by this analysis were that of platoon, phase, and environment.

The M16 analysis indicated that the only significant effect was due to environment. This hypothesis can be accepted with 90% confidence for semiautomatic mode of fire and with 95% confidence for the automatic mode of fire. The malfunctions per thousand for each environment are as follows:

	Automatic	Semiautomatic
E1 (Beach)	7.5	3.7
E2 (Swamp)	3.7	2.4
E3 (Rain Forest)	2.8	1.6
E4 (Uplands)	3.1	1.9

The beach environment (E1) appears to be the most severe followed by the swamp and mud (E2) environment.

None of the main factors showed any significant effect on the M14 rifle.

It may be noted that the above differences appear to be more pronounced than was indicated by the Reliability Section of this report. It should be recalled that the reliability estimates for environment were for times to first failure in the first environment that the rifle experienced. The above data includes all failures. Apparently subsequent failures occur more frequently in a severe environment.

2 Eisenhart, Hastay, and Wallis; Selected Techniques of Statistical Analysis, McGraw-Hill Book Co., Inc., New York and London, 1947.

Further Latin Square analyses were carried out as explicitly as possible with respect to the main effects of the test. Therefore, in order to prevent confounding of the remaining and more important effects, a Latin Square analysis was conducted for each combination of levels of these remaining effects. These effects were: two rifle types (R_1 and R_2), two cleaning cycles (C_1 and C_2), two firing modes (M_1 and M_2), and four ammunition types (A_1,A_2,A_3,A_4). A total of 32 Latin Squares were analyzed over all malfunctions plus an additional eight analyzed for each of the eight most prevalent types of malfunctions.

The result of these analyses are summarized in Tables III-A, III-B, and III-C. These tables show the F-ratios obtained in each analysis and an asterisk indicates significance at the .95 level of confidence. The left hand column of Table III-A shows the level of the rifle, ammunition, and cleaning effect for which the design was analyzed.

Looking first at Table III-A, although the significant effects appear to be lightly scattered throughout, it is important to note that the environmental effect was significant only when the R_2 (non-chrome chambered) rifle was fired. It would appear, from this analysis, that the chrome chambered rifle is more adaptable to adverse environmental conditions. In fact, in these tests environment appears to have had no effect upon the chrome chambered rifle.

Differences in platoons appear to be prevalent throughout the analyses. However, there appears to be nothing about the location of the significant platoon effect that would indicate that they are related to any of the specific levels of the four conditions. In order to determine whether the failure rates for any of the platoons were consistently different the failure rates by platoon are summarized in Table III-C. These overall results indicate that the failure rates among platoons do not differ.

There was no indication of a statistically significant effect due to phases, where a phase is defined to be one of four three day intervals of the 12 day test. Although, in the event that a trend in failure rate over phases is present, it is possible that this test would not be powerful enough to detect it.

In connection with the power of the test, it should be pointed out that a Latin Square design (which was the plan for the WSEG test) assumes no interaction among the main effects. Should one or more interactions actually exist, the effect of these interactions would be confounded with the residual error and would have the effect of inflating the error so that it would appear to be larger than it actually is. Since the main effects are tested against the residual error, it would then be possible that existing effects might not be detected.

Table III-B, which summarizes the Latin Square analysis by type of defect, indicates that only failures to fire and to extract are sensitive to environment in the automatic mode of fire. None of the failures were significantly affected by environment in the semi-automatic mode of fire.

It was fortunate that the test was designed in such a manner that the remaining effects could be arranged into a more powerful factorial design. By arranging the transformed grand mean failure rate taken from each Latin Square design into a factorial design, it was possible to analyze the data first as a set of 2^4 factorials.

The first factorial design was analyzed using only ammunition with ball propellant and the second using only IMR propellant. For these two designs a significant ammunition effect would indicate a lot-to-lot difference in the ammunition within types. If no lot-to-lot differences were detected, the data was combined so that in the combined analysis a significant ammunition effect would indicate a difference in ammunition type (ball vs. IMR). This was done over all malfunctions and for eight of the individual malfunction types that comprised a large majority of the total. The results of the analysis in terms of F ratios is summarized in Table III-D. These tables represent some very important findings; therefore, each column of Table III-D will be discussed separately. The actual failure rates for each type of failure are summarized in Table III-E through III-I and the significant differences in these ratios are summarized in Table III-J.

Analysis of over-all failures
Ref: Tables III-D, III-E, and III-J

All main effects were highly significant except rifle type (chrome vs. non-chrome). Three interaction effects (Firing mode-ammunition, ammunition-rifle, and cleaning cycle-rifle) were also highly significant. One interesting aspect of this analysis is that the results left very little doubt as to which effects are significant. The significant effects can be accepted with a very high degree of confidence, while the remaining effects do not indicate even weak evidence that they may be significant.

The analysis indicates that the malfunction rate is highly dependent upon firing mode, ammunition type, and cleaning cycle. In this preliminary analysis, there was no indication of any lot differences within ammunition types.

It is interesting to note that although an over-all effect due to rifle type does not exist, there is an effect of rifle type when combined with certain ammunition types and cleaning cycles (A R and C R interactions). The chrome chambered rifle, R_1, appeared to perform better with I M R ammunition while the non-chrome chambered rifle (R_2) did slightly better with ball ammunition (Table III-J). The reason for this will become apparent when discussing the individual failure types.

The cleaning-cycle-rifle type interaction confirms what the Latin Square analysis has already shown. This implicitly indicates that the failure rate for the non-chromed rifle can be reduced by frequent cleaning (Table III-J).

The significance of the firing mode-ammunition type interaction can be understood when reviewing the results of Table III-J. It is clear that the increased failure rate associated with the automatic mode of fire is almost entirely due to IMR propellant. The low cyclic rate associated with IMR ammunition is apparently not sufficient to efficiently sustain automatic fire. It is interesting to note in Table III-D that the only types of failures where the firing mode (M) and firing mode-ammunition (MA) interaction were significant were failure to feed, failure to chamber, and failure of the bolt to remain to the rear. These three failures comprised most of the IMR failures. Similarly, these three failures can be associated with insufficient energy produced by the propellant. Furthermore, it will be seen in Section IV that both feeding and chambering malfunctions tend to occur on the first and second round in the magazine where the cyclic rate is the lowest.

Failure to Feed

Ref: Tables III-D, III-F, and III-J

It is interesting to note that the failure to feed analysis yielded results identical to the over-all failure analysis as far as the significant effects are concerned. The very large F-ratio associated with ammunition type reflects the fact that an overwhelming majority of the feeding failures occurred with the IMR propellant.

The comments regarding significant effects given above under "Over-all failures" also apply to failures to feed.

Failure to Chamber

Ref: Tables III-D, III-F, and III-J

It is important to note that for the first time there is a significant effect due to lots within ammunition types. This effect, however, was significant only for IMR ammunition.

Ammunition A_4 (Lake City) produced significantly more malfunctions than A_3 (Twin City) ammunition. It will also be seen in Section V that A_4 ammunition produced significantly lower cyclic rates than A_3 ammunition.

Failure to Lock

Ref: Tables III-D, III-G, and III-J

Firing mode and cleaning cycle appear to have no effect upon this type of failure. However, an interaction between cleaning cycle and rifle type indicates that infrequent cleaning has more of an adverse effect upon the non-chrome chambered rifle.

The other effects may be interpreted in a manner similar to the interpretation given for the overall failures.

Failure to Fire

Ref: Tables III-D, III-G, and III-J

Firing mode, cleaning cycle, and rifle type were not significant for this type of failure. However, interactions between ammunition type and rifle type and between cleaning cycle and rifle type were significant.

The ammunition type-rifle type interaction indicates that ball propellant performs better with the non-chrome rifle. However, the cleaning cycle-rifle interaction indicates that frequent cleaning tends to increase the failure rate when firing IMR propellant in the chrome chambered rifle.

Although the above results may, at first glance, appear to have no physical explanation; if one considers the fact that this failure, to some extent, appears to be associated with high cyclic rate, the reason for these results becomes apparent. The IMR propellant with its inherently low cyclic rate will perform better. The chrome chambered rifle will tend to increase the cyclic rate and thereby adversely affect the performance of the rifle. Similarly, frequent cleaning will also tend to increase the cyclic rate and also adversely affect the performance of the rifle.

This failure will be discussed in greater detail in Section IV where it was found that most of the firing failures associated with ball propellant occurred on the first and second round in the magazine. The remaining failures were uniformly distributed over the remaining rounds. All the IMR failures appeared to be uniformly distributed over the entire magazine but with a lower frequency than the uniformly distributed failures associated with ball propellant. The difference in the uniformly distributed failures (third through last round in magazine) was probably due to cyclic rate. However, another factor, possibly independent of cyclic rate, is causing failures of the first and second round, especially when firing ball propellant ammunition.

Failure to Eject

Ref: Tables III-D, III-H, and III-J

The ejection failures associated with IMR propellant ammunition were too infrequent to permit an analysis; therefore, only the data obtained from ball propellant ammunition were analyzed. The only significant effect (and it was highly significant) was the effect of ammunition lots.

The Remington Lot of ball propellant produced significantly more ejection failures than the Lake City lot. It will be seen in Section V that this same Remington lot also produced a significantly higher cyclic rate than the Lake City lot. These results, coupled with the fact that the IMR propellant produced a negligible number of ejection failures, clearly indicate that this failure type is highly dependent upon cyclic rate.

The WSEG analysis indicated that significantly more of these failures occurred with the chrome chambered rifle. The results of this analysis weakly indicates that this may be true, although with less than 95% confidence. In the event that rifles do affect the number of ejection failures, it is highly probable that again the slightly higher cyclic rate associated with the chrome chambered rifle is responsible.

Failure to Extract

Ref: Tables III-D, III-H, and III-J

Ammunition type, cleaning cycle, and rifle type significantly affected the failure rate for this malfunction. Firing mode did not. Ammunition-rifle cleaning cycle and rifle cleaning cycle-rifle type interactions were also significant.

Frequent cleaning of the rifle appeared to improve the performance of the ball propellant ammunition but had little effect upon the IMR ammunition. Frequent cleaning of the rifles also improved the performance of the chrome chambered rifle when firing ball ammunition, but increased the failure rate when firing IMR propellant in the non-chromed rifle.

Even though this failure is also associated with a high cyclic rate,cleaning appears to reduce the number of extraction failures. This is probably due to the fact that the round will extract easier from a clean, lubricated rifle and this tends to more than compensate for the adverse effect due to the increased cyclic rate.

Double Feed

Ref: Tables III-D, III-I, and III-J

Ammunition type was the only significant factor affecting this failure type. This malfunction appears to be affected in the same manner and by the same factors as the ejection failures. Briefly, it appears again that cyclic rate is the dominant factor affecting this type of malfunction.

Failure of the Bolt to Remain to the Rear

This malfunction appears to be associated with low cyclic rates and is similar to feeding and chambering failures.

Firing mode was again significant as it has been with all failures associated with low cyclic rate. The MA interaction indicates that firing mode is only a significant factor for IMR ammunition.

Frequent cleaning appeared to reduce failures in the non-chrome plated rifles firing IMR propellant.

Conclusions

1. It is apparent that the overriding factor affecting the number of malfunctions is cyclic rate which is, of course, dependent upon the energy output of the propellant. In general, it may be concluded that IMR propellant imparts too little energy to the bolt and that ball propellant imparts too much energy to the bolt. It may be significant that the buffer used in this test was better suited for ball propellant. Perhaps a buffer designed to better suit IMR propellant could increase the cyclic rate to the extent that it would eliminate most of the failures due to low cyclic rate without increasing the rate to the point where it increases the number of failures due to a high cyclic rate. In any event, it appears that the cyclic rate for this weapon must be closely controlled.

2. Environment appeared to affect the malfunction rate of only the non-chrome plated rifle. Environment was also found to affect the number of firing and extraction failures.

3. The malfunctions can be divided into two groups: (1) those that are associated with a low cyclic rate,and (2) those that are associated with a high cyclic rate. Feeding failures, chambering failures, and failure of the bolt to remain to the rear are associated with low cyclic rates. Failures to lock, fire, extract, and eject, and double feeds are associated with a high cyclic rate. The remaining failures were too infrequent for the sample size to permit a suitable statistical analysis.

4. All the failures associated with a low cyclic rate were affected by firing mode. It appears that a low rate of fire cannot efficiently sustain automatic fire. None of the remaining failures were affected by firing mode.

5. Ammunition types (ball vs. IMR) affected the failure rates for all failure types. This again is attributed to the difference

in cyclic rate. Rates of failures to chamber and failures to eject were also affected by differences in lots within ammunition types. Only the IMR lots performed differently for chambering failures, whereas, only the ball lots performed differently for ejection failures. It has been concluded that these two failures are especially sensitive to cyclic rate since even the different ammunition lots appeared to produce significantly different results. It will be noted in Section V that a lot to lot difference in cyclic rate does exist within an ammunition type.

6. Cleaning cycle appears to affect the number of malfunctions occurring in the non-chrome chambered rifle. In general, frequent cleaning improves the performance of the rifle; however, in some cases where the malfunction rate is associated with a high cyclic rate, cleaning tends to further increase the cyclic rate and thereby increase the malfunction rate.

7. There is some evidence that the chrome chambered rifle also tends to fire at a faster rate, thus increasing the failure rate for certain malfunctions and decreasing the rate for other malfunctions.

8. Finally, as a result of the above analysis, it is suggested that both the rifle and ammunition design be examined in order to effect better control over cyclic rate.

Table III-A

F - Ratios From Latin Square Analyses

	Automatic Fire			Semiautomatic Fire		
	Phases	Platoons	Environment	Phases	Platoons	Environment
R1A1C1	0.88	4.10	0.80	0.42	1.23	0.45
R1A1C2	1.32	2.23	1.40	0.82	8.31*	2.40
R1A2C1	1.36	4.93*	2.72	0.08	7.43*	3.53
R1A2C2	7.12*	4.72	1.08	0.62	1.42	1.38
R1A3C1	0.88	6.05*	0.96	0.95	0.99	1.92
R1A3C2	0.51	26.24*	3.75	2.05	11.74*	3.29
R1A4C1	2.65	3.69	2.27	1.02	2.15	1.19
R1A4C2	0.38	0.93	2.54	0.12	2.21	4.05
R2A1C1	0.44	0.17	1.21	5.43*	1.05	4.40
R2A1C2	2.81	4.21	1.72	1.25	7.79*	1.70
R2A2C1	0.39	0.31	2.50	0.61	1.98	5.51*
R2A2C2	0.57	3.10	8.52*	0.16	2.38	2.38
R2A3C1	4.53	C.37	11.97*	0.39	0.60	0.72
R2A3C2	0.35	1.45	0.79	0.15	0.28	1.07
R2A4C1	1.02	4.04	2.27	2.03	6.47*	8.43*
R2A4C2	2.80	6.43*	5.92*	1.38	0.90	0.98
R4A5C1	0.25	0.17	1.04	4.44	2.71	1.62
R4A5C2	0.48	0.28	2.01	0.14	0.92	0.44

*Significant at .05 Level

Table III-B

F Ratios From Latin Square Analyses
M16 Over Rifle Type, Ammo Type and Cleaning Cycle by Nature of Failure

Nature of Defect	Automatic Fire			Semiautomatic Fire		
	Phases	Platoons	Environment	Phases	Platoons	Environment
Failure to Feed	1.09	.87	3.82	1.35	.74	2.22
Failure to Chamber	.90	2.67	2.58	1.26	2.17	3.48
Failure to Lock	.76	4.91*	2.02	2.43	13.38*	1.92
Failure to Fire	6.16*	3.11	8.52*	.27	.45	.90
Failure to Extract	.10	3.04	7.50*	.04	2.08	2.18
Failure to Eject	3.92	.83	1.82	2.07	1.83	1.80
Double Feed	.22	1.61	1.59	.72	1.62	1.30
Failure of Bolt to Remain at Rear	2.19	18.29*	3.97	.60	5.08*	.99
Other	.20	3.89	4.86*	.39	.10	3.43
All	1.09	.83	5.54*	1.03	.24	3.80

*Significant at .05 Level

Table III-C

Overall Failures Per 1000 Rounds
by Platoon, Firing Mode, Rifle Type, Ammunition Type
and Cleaning Cycle

	Automatic Fire				Semiautomatic Fire			
	Platoon				Platoon			
	1	2	3	4	1	2	3	4
R1A1C1	2.6	7.8	0.7	2.0	3.2	5.1	0.8	2.6
R1A1C2	1.6	1.8	1.0	3.1	2.0	0.1	1.2	4.0
R1A2C1	0.2	1.8	2.2	1.9	0.2	0.9	3.0	1.7
R1A2C2	2.1	1.0	2.9	2.3	3.2	2.2	1.5	0.9
R1A3C1	1.5	13.1	4.9	1.0	1.4	4.8	2.8	0.5
R1A3C2	0.3	12.6	2.7	5.8	0.3	8.4	1.7	1.9
R1A4C1	14.6	3.5	5.2	8.8	3.0	2.1	3.7	1.2
R1A4C2	5.1	7.5	4.5	7.9	2.5	0.8	1.5	2.6
R2A1C1	1.6	2.6	1.0	2.1	1.4	0.6	0.5	1.9
R2A1C2	3.0	1.7	2.0	4.4	3.8	0.6	0.7	1.7
R2A2C1	0.6	1.7	2.3	0.8	0.9	0.8	1.9	1.0
R2A2C2	1.7	1.2	3.0	2.1	0.9	1.4	2.5	3.6
R2A3C1	7.3	3.6	6.5	4.1	3.5	1.8	3.9	1.8
R2A3C2	4.7	5.2	7.1	11.7	5.0	4.1	7.3	3.9
R2A4C1	0.7	4.8	16.9	3.7	0.9	1.8	5.9	2.7
R2A4C2	2.8	10.4	11.2	6.6	2.2	4.9	5.1	3.3
Total C1	3.6	4.9	5.0	3.0	1.8	2.2	2.8	1.7
Total C2	2.7	5.2	4.3	5.5	2.5	2.8	2.7	2.7
Total	3.2	5.0	4.6	4.3	2.2	2.5	2.8	2.2
R4A5C1	3.1	3.0	3.9	4.0	3.4	1.7	2.5	2.8
R4A5C2	2.7	3.1	3.9	3.0	2.0	1.2	2.4	1.4
Total	2.9	3.0	3.9	3.5	2.7	1.4	2.8	2.1

Table III-D

F Ratios from Factorial Analysis

		Failure to Feed	Failure to Chamber	Failure to Lock	Failure to Fire	Failure to Extract	Failure to Eject***	Double Feed	Failure of Bolt to Remain at Rear	All Failures
Firing Mode	M	50.1*	4.7*	.8	.0	3.6	1.3	1.9	56.8*	55.6*
Ammo Type	AT	511.6*	24.4*	5.7*	20.4*	26.4*		7.1*	92.5*	136.1*
Ammo Lot	AL		30.2**				19.1*			
Cleaning	C	7.1*	.2	2.6	.0	4.4*	.1	.9	4.0	11.3*
Rifle Type	R	4.0	.1	5.9*	1.2	28.0*	4.2	4.3	.3	2.2
Interaction	MA	22.2*	4.5*	.1	1.1	.0	.1	.3	38.2*	26.3*
Interaction	MC	.0	.1	.2	.9	.4	.1	.1	.0	.0
Interaction	MR	3.8	.0	.6	.5	3.0	1.0	.1	1.0	1.4
Interaction	AC	2.0	.1	.0	2.0	17.1*	3.8	.7	5.2*	.0
Interaction	AR	6.5*	.3	.7	4.4*	.4	.0	.0	.9	10.3*
Interaction	CR	7.6*	3.4	5.0*	7.5*	7.6*	.1	.0	14.3*	18.7*

*Significant at .95 level of confidence
**For IMR lots only
***Considered only ball propellant ammo since the number of failures for IMR propellant ammo was negligible

Table III-E

All Malfunctions
Failure Rates (per 1000 rds)

Ammo Type		Rifle 1				Rifle 2			
		Cleaning 1		Cleaning 2		Cleaning 1		Cleaning 2	
		Auto	Semi	Auto	Semi	Auto	Semi	Auto	Semi
Ball	1	3.292	2.942	1.878	1.810	1.850	1.106	2.760	1.707
	2	1.517	1.453	2.071	1.958	1.330	1.145	2.013	2.122
IMR	3	5.119	2.360	5.354	3.093	5.372	2.752	7.168	5.060
	4	8.034	2.482	6.260	1.849	6.548	2.832	7.745	3.881

Table III-F

Failure to Feed

Failures per 1000 rounds

Ammo Type	Rifle 1				Rifle 2			
	Cleaning 1		Cleaning 2		Cleaning 1		Cleaning 2	
	Auto	Semi	Auto	Semi	Auto	Semi	Auto	Semi
Ball 1	.390	.219	.342	.180	.222	.093	.282	.209
Ball 2	.225	.302	.369	.093	.371	.212	.368	.482
IMR 3	3.294	1.707	3.540	2.514	3.660	1.800	3.972	3.508
IMR 4	4.231	1.222	3.768	.907	4.635	1.762	4.762	2.450

Failure to Chamber

Failures per 1000 rounds

Ammo Type	Rifle 1				Rifle 2			
	Cleaning 1		Cleaning 2		Cleaning 1		Cleaning 2	
	Auto	Semi	Auto	Semi	Auto	Semi	Auto	Semi
Ball 1	.331	.519	.055	.486	.056	.280	.197	.427
Ball 2	.084	.434	.194	.517	.169	.519	.174	.754
IMR 3	.456	3.526	.284	3.655	.478	3.962	.973	4.426
IMR 4	2.166	4.964	1.319	4.338	.504	4.921	1.082	5.170

Table III-G

Failure to Lock
Failures per 1000 rounds

Ammo Type	Rifle 1				Rifle 2			
	Cleaning 1		Cleaning 2		Cleaning 1		Cleaning 2	
	Auto	Semi	Auto	Semi	Auto	Semi	Auto	Semi
Ball 1	.084	.331	.084	.084	.167	.118	.251	.348
Ball 2	.389	.325	.084	.316	.000	.256	.141	.556
IMR 3	.000	.485	.055	.316	.056	.597	.165	1.005
IMR 4	.029	2.166	.083	1.319	.055	.565	.194	1.268

Failure to Fire
Failures per 1000 rounds

Ammo Type	Rifle 1				Rifle 2			
	Cleaning 1		Cleaning 2		Cleaning 1		Cleaning 2	
	Auto	Semi	Auto	Semi	Auto	Semi	Auto	Semi
Ball 1	.577	.936	.201	.402	.227	.282	.422	.502
Ball 2	.306	.662	.365	.685	.141	.264	.343	.266
IMR 3	.116	.180	.084	.116	.028	.372	.113	.316
IMR 4	.255	.344	.055	.141	.112	.200	.143	.522

Table III-H

Failure to Extract
Failures per 1000 rounds

Ammo Type	Rifle 1				Rifle 2			
	Cleaning 1		Cleaning 2		Cleaning 1		Cleaning 2	
	Auto	Semi	Auto	Semi	Auto	Semi	Auto	Semi
Ball 1	.000	.577	.276	.426	.307	.414	.391	.717
Ball 2	.058	.396	.229	.748	.252	.391	.478	.568
IMR 3	.058	.145	.029	.116	.254	.121	.028	.242
IMR 4	.028	.284	.056	.087	.343	.259	.141	.269

Failure to Eject
Failures per 1000 rounds

Ammo Type	Rifle 1				Rifle 2			
	Cleaning 1		Cleaning 2		Cleaning 1		Cleaning 2	
	Auto	Semi	Auto	Semi	Auto	Semi	Auto	Semi
Ball 1	1.354	1.559	.581	1.070	.561	.680	.712	.861
Ball 2	.174	.174	.631	.663	.142	.281	.143	.536
IMR 3	.000	.058	.000	.029	.056	.254	.028	.056
IMR 4	.000	.028	.000	.121	.058	.526	.029	.141

Table III-I

Double Feed

Failures per 1000 rounds

Ammo Type	Rifle 1				Rifle 2			
	Cleaning 1		Cleaning 2		Cleaning 1		Cleaning 2	
	Auto	Semi	Auto	Semi	Auto	Semi	Auto	Semi
1	.112	1.416	.113	.643	.083	.686	.114	.773
Ball								
2	.056	.174	.000	.721	.085	.171	.112	.359
3	.029	.000	.056	.090	.172	.118	.083	.028
4	.028	.000	.000	.000	.028	.119	.113	.029

Failure of Bolt to Remain to the Rear

Failures per 1000 rounds

Ammo Type	Rifle 1				Rifle 2			
	Cleaning 1		Cleaning 2		Cleaning 1		Cleaning 2	
	Auto	Semi	Auto	Semi	Auto	Semi	Auto	Semi
1	.389	.144	.084	.142	.000	.115	.196	.147
Ball								
2	.083	.185	.056	.029	.084	.147	.056	.237
3	1.080	.093	1.076	.185	.583	.172	1.722	.578
IMR								
4	1.157	.182	.864	.158	.641	.214	1.141	.431

Table III-J

Mean Differences in Failure Rates
Defects Per 1000 rounds

	Failure to Feed	Failure to Chamber	Failure to Lock	Failure to Fire	Failure to Extract	Failure to Eject	Double Feed	Failure of Bolt to Remain at Rear	All Failures
Firing Modes (A-S)	1.048	-1.898						.378	1.871
for Ball Ammo	.097	- .334						-.025	.309
IMR	1.999	-3.462						.781	3.411
Ammo Types (IMR-Ball)	2.711	2.314	.302	-.218	- [illegible]		-.295	.511	2.810
for Automatic Fire	3.662	.750						.914	4.361
Semi-Automatic Fire	1.760	3.878						.108	1.258
for Cleaning Cycle 1					-.113			.372	
Cleaning Cycle 2					-.358			.651	
for Rifle 1	2.383			-.355					
Rifle 2	3.039			-.080					
IMR Lots (4 - 3)		.838							
Ball Lots (1 - 2)						.579			
Cleaning Cycles (1 - 2)	- .213				-.057				
for Rifle 1	- .054		.184	.166	-.053			.090	
Rifle 2	- .410		-.264	-.125	-.062			-.319	-1.177
for Ball					-.180			.025	- .768*
IMR					.066			-.254	-1.588*
Rifle Types (1 - 2)			.026		-.104				
for Ball	- .015			.211					.361
IMR	- .671			-.064					- .644
for Cleaning Cycle 1	- .146		.249	.219	-.099			.170	.533
Cleaning Cycle 2	- .540		-.198	-.072	-.108			-.239	- .816

***For Rifle 2, cleaning cycle not statistically significant for Rifle 1**
Note: Only significant differences are given above.

Table III-K

Total Failures By Nature, Rifle and Ammunition Type

	Failure to Feed	Failure to Chamber	Failure to Lock	Failure to Fire	Failure to Extract	Failure to Eject	Double Feed	Failure of Bolt to Remain at Rear	All Failures
R_1A_1	40	23	7	67	17	145	12	19	342
R_1A_2	34	22	29	52	26	47	5	11	239
R_1A_3	379	38	4	15	5		6	84	550
R_1A_4	350	166	4	23	5	2	1	80	643
$R_1A_1A_2$	74	45	36	119	43	192	17	30	581
$R_1A_3A_4$	729	204	8	38	10	2	7	164	1193
$R_1A_1A_2A_3A_4$	803	249	44	157	53	194	24	194	1774
R_2A_1	28	16	21	35	41	73	13	9	[illegible]56
R_2A_2	49	30	20	30	41	13	15	11	225
R_2A_3	446	77	13	20	17	4	11	98	703
R_2A_4	462	79	17	24	26	9	7	80	716
$R_2A_1A_2$	77	46	41	65	82	86	28	20	481
$R_2A_3A_4$	908	156	30	44	43	13	18	178	1419
$R_2A_1A_2A_3A_4$	985	202	71	109	125	99	46	198	1900

Table III-K (Continued)

Total Failures By Nature, Rifle and Ammunition Type

	Failure to Feed	Failure to Chamber	Failure to Lock	Failure to Fire	Failure to Extract	Failure to Eject	Double Feed	Failure of Bolt to Remain at Rear	All Failures
$R_1R_2A_1A_2$	151	91	77	184	125	278	45	50	1062
$R_1R_2A_3A_4$	1637	360	38	82	53	15	25	342	2612
$R_1R_2A_1A_2A_3A_4$	1788	451	115	266	178	293	70	392	3674

SECTION IV

ANALYSES OF FAILURE RATES BY ROUND NUMBER IN MAGAZINE

The malfunctions were sorted according to the type of failure and according to the round within the magazine on which the malfunction occurred. The total failures and the eight failure types that were most prevalent are shown on Figures IV-A through IV-TT according to the round number within the magazine and the mode in which the round was being fired. It is apparent from these graphs that most of the failures occurred on rounds one and two. This is particularly true for the failures to feed and failures to chamber. These type failures are related to the lower cyclic rate that is present in the first rounds of a clip.

Although failures associated with a low cyclic rate tended to occur on the first few rounds in the magazine, failures to fire appeared to be an exception. As mentioned in Section III, firing failures tend to increase with cyclic rate. However, for ball propellant, most of these failures occurred on the first two rounds in the magazine. In fact, 56% of the failures associated with ball propellant occurred on either the first or second round, and 34% of the failures associated with IMR propellant occurred on either the first or second round.

Recently, it has been demonstrated (as part of the current study) that it is possible for the rifleman to cause a firing failure by not closing the bolt with sufficient force. It is, therefore, likely that a proportion of these failures were caused by the rifleman. However, this does not explain why ball propellant was associated with significantly more firing failures on the first round than was the IMR propellant. It also does not explain the large number of failures on the second round.

It should be recalled, from Section III, that failures to fire and failures to extract were the only failures that were significantly affected by environment (in the automatic mode of fire only). It is significant that these two malfunctions were the only two (not associated with a low cyclic rate) that tended to occur on the first several rounds within the magazine. The most logical explanation of this would be that sand, mud, or other foreign matter within the chamber caused these malfunctions, and that after firing a few rounds the foreign matter was eliminated through usage. Tables IV-C and IV-D indicate that these failures tend to occur more frequently at the beach environment, indicating that the presence of sand in the chamber is a likely suspect.

Therefore, it appears that firing failures (and, to some extent, extraction failures) on the first few rounds could be a result of a combination of factors. Two of these factors could be the failure of the rifleman to close the bolt with sufficient force and the presence of foreign matter within the chamber.

In Table IV-A, the percent of failures by round number is given for each round in the eighteen and twenty-round magazines according to the ammunition fired and the total over all ammunition for the M16 and M14 rifles.

It should be noted that over all ammunition, the M14 produced a higher percentage of the failures on rounds one and two than the M16 rifle (42% to 38%). The percentage was also higher for rounds one, two, and three for the M14 than for corresponding rounds of the M16 (53% to 47%). Thus, it appears that the tendency to malfunction on the first few rounds in a magazine is not restricted to the M16 rifle.

The tracer cartridges (rounds 1, 6, 11, 16 in the twenty-round magazines, and 1, 2, 18 on the eighteen-round magazines) frequency of malfunction did not differ significantly from the ball cartridge with the possible exception of the eighteenth round tracer. The eighteenth round of the eighteen-round magazine malfunctioned significantly more often than either the eighteenth or the twentieth round of the twenty-round magazine. Whether this is due primarily to the tracer or to a combination of factors is not clear.

The main source of malfunctions on the last round of a magazine is the failure of the bolt to remain at the rear which, of course, can only happen on the last round. These malfunctions are summarized in Table IV-B. The mode of fire, type of propellant, and either the number of rounds in a magazine or the fact that in the eighteen-round magazine the eighteenth round is a tracer cartridge, all appear to affect the malfunction rate. The automatic fire using IMR propellant with an eighteen-round magazine had the most malfunctions.

However, the malfunction rate of the tracer cartridges, other than the last round in the eighteen-round magazine, did not appear to differ from the ball cartridge rounds. Since round one in all magazines was a tracer, there is nothing with which to compare this round. However, in the twenty-round magazine, round two was not a tracer; yet the malfunction rate was approximately the same as round two in the eighteen-round magazine, which was a tracer. Rounds 6, 11, and 16 in the twenty-round magazine did not differ with the corresponding rounds (non-tracer) in the eighteen-round magazine or with the ball cartridge rounds in the same magazine. In general, therefore, there is very little evidence to infer that the malfunction rate for the tracer rounds is different from that for ball cartridge rounds.

CONCLUSIONS

1. Feeding and chambering failures are primarily responsible for the large number of failures on the first and second round. This is due to the lower cyclic rate that is characteristic of the first few rounds whether they are fired with ball or IMR propellant.

2. Firing failures (and, to some extent, extraction failures) also contributed to the high failure rate associated with the first two rounds and particularly with ball propellant. However, these failures are not considered to be associated with a low cyclic rate. Two important factors that may contribute to these initial failures are: (a) failure of the rifleman to close the bolt with sufficient force; and, (b) the presence of foreign matter (especially sand) within the chamber.

3. Both the M14 and M16 rifles experienced high failure rates on the first two rounds.

4. Most malfunctions occurring on the last round in the magazine were failures of the bolt to remain to the rear. An overwhelming majority of these occurred with IMR propellant because of its lower cyclic rate. However, for both ball and IMR propellant, significantly more of these failures occurred on the clips loaded with 18 rounds. Significantly, the last round of the eighteen-round clip was a tracer, whereas the last round of the twenty-round clip was not.

5. Conclusion 4 represents the only evidence that tracers affect malfunctions. However, since this evidence does exist, it may be further hypothesized that a portion of the first round failures (in all clips) and second round failures (in the eighteen-round clip) were a result of tracer ammunition. The degree of this effect, if it does exist, cannot be estimated.

TABLE IV-A

PERCENT DEFECTIVE BY ROUND NUMBER

ROUND NO.	R1R2 20 ROUND MAG	A1A2 18 ROUND MAG	R1R2 20 ROUND MAG	A3A4 18 ROUND MAG	R4A5 20 ROUND MAG	18 ROUND MAG	R1R2A1A2 20 ROUND MAG	A3A4 18 ROUND MAG
	%	%	%	%	%	%	%	%
1	24	23	12	13	17	18	16	16
2	18	13	25	27	23	28	22	23
3	5	6	7	14	11	10	6	11
4	5	4	4	6	9	8	5	5
5	4	3	8	3	6	6	7	3
6	2	2	6	3	6	5	5	3
7	3	2	4	2	3	3	4	2
8	2	3	5	2	3	2	4	2
9	3	3	3	1	2	2	3	2
10	4	4	5	2	3	3	5	3
11	2	3	1	1	2	1	1	1
12	4	3	3	1	1	4	3	2
13	3	3	1	1	1	2	1	1
14	3	3	1	1	1	1	2	2
15	2	4	2	1	2	3	2	2
16	3	5	2	2	2	1	3	3
17	3	4	2	1	2	2	2	2
18	3	11	2	21	2	3	2	18
19	5		1		1		2	
20	6		7		2		6	

Percent defective on round one and two = 39% for M16 Rifle

Percent defective on round one and two = 42% for M14 Rifle

TABLE IV-B

FAILURE OF BOLT TO REMAIN AT REAR

BY PROPELLANT, MODE AND NUMBER OF ROUNDS IN MAGAZINE

NUMBER OF FAILURES

BALL PROPELLANT				IMR PROPELLANT			
20-ROUND MAGAZINE		18-ROUND MAGAZINE		20-ROUND MAGAZINE		18-ROUND MAGAZINE	
SEMI AUTO	AUTO	SEMI AUTO	AUTO	SEMI AUTO	AUTO	SEMI AUTO	AUTO
4	8	11	26	12	58	36	236

TABLE IV-C

FAILURE TO FIRE BY ENVIRONMENT AND ROUND NUMBER
IN MAGAZINE FOR M16 RIFLE USING BALL PROPELLANT

NUMBER OF FAILURES

	20-ROUND MAGAZINE					18-ROUND MAGAZINE			
ENVIRONMENT	E1	E2	E3	E4		E1	E2	E3	E4
RD NO					RD NO				
1	20	7	5	6	1	5	8	4	4
2	11	6		2	2	10	6	3	6
3	3	1	1	1	3	4	1	1	2
4	1	1	1	1	4				1
5	4	1	2	2	5	1			1
6	1		1	2	6	1			
7	3			1	7			1	
8	1		1	2	8				1
9	1			3	9				1
10	1		3		10		1		1
11	1			2	11				
12	2		2		12			1	
13					13				
14	1		2		14	1			
15				1	15	1		1	
16	1		1		16	1			
17		1			17			1	
18	1				18	1			2
19									
20	1								
TOTALS	**53**	**17**	**19**	**23**		**25**	**16**	**12**	**18**

TABLE IV-D

FAILURE TO FIRE BY ENVIRONMENT AND ROUND NUMBER
IN MAGAZINE FOR M16 RIFLE USING IMR PROPELLANT
NUMBER OF FAILURES

	20-ROUND MAGAZINE					18-ROUND MAGAZINE			
ENVIRONMENT	E1	E2	E3	E4		E1	E2	E3	E4
RD NO					RD NO				
1	5	2	3	1	1	3	1	2	
2		2	1		2	2		3	3
3	2	3	1		3	1	2		1
4	2	1			4	2		1	1
5		1			5		1		2
6	1	1			6				1
7		1		1	7				1
8	1	1			8	1			
9	2				9		1		2
10	1	1			10	1			
11					11				
12			1	1	12				1
13					13				1
14					14				
15		2			15				
16					16				
17	1				17			1	
18	1	1			18	—	—	1	2
19									
20	—	1	—	1					
TOTALS	**16**	**17**	**6**	**4**		**10**	**5**	**8**	**15**

TABLE IV-E

FAILURE TO EXTRACT BY ENVIRONMENT AND ROUND NUMBER
IN MAGAZINE FOR M16 RIFLE USING BALL PROPELLANT
NUMBER OF FAILURES

	20-ROUND MAGAZINE					18-ROUND MAGAZINE			
ENVIRONMENT	E1	E2	E3	E4		E1	E2	E3	E4
RD NO					RD NO				
1	2		1		1	21	2	3	8
2	2				2	8	1	1	
3	1		1		3	1		1	2
4	2		3		4			2	
5					5		1		1
6			2	1	6	3		2	
7	1		1		7	2	1		
8					8	3			
9		1			9	2			
10	1	2			10	1	1		
11	1			1	11	3			
12	1	2	1	1	12	1			1
13	1		1		13				1
14	1		2		14				1
15				1	15				
16		2			16	1			
17			3		17				
18	1	1	1		18				
19	1	1	3						
20	1		1						
TOTALS	16	9	20	4		46	6	9	14

TABLE IV-F

FAILURE TO EXTRACT BY ENVIRONMENT AND ROUND NUMBER IN MAGAZINE FOR M16 RIFLE USING IMR PROPELLANT

NUMBER OF FAILURES

	20-ROUND MAGAZINE					18-ROUND MAGAZINE			
ENVIRONMENT	E1	E2	E3	E4		E1	E2	E3	E4
RD NO					RD NO				
1	2			1	1	5		1	
2	7		1		2	4			
3			1		3	1			
4				1	4			1	
5	2		1		5			2	
6			1		6	1	1	1	
7			2		7				
8	1		1		8			1	
9	1				9				
10	1				10				
11					11				
12	1		1		12				
13					13			1	
14					14			3	
15					15				
16					16		1	1	
17					17				
18					18			2	
19									
20	1								
TOTALS	16		8	2		11	2	13	

TABLE IV-G

FAILURE TO FIRE BY ENVIRONMENT AND ROUND NUMBER
IN MAGAZINE FOR M14 RIFLE
NUMBER OF FAILURES

	20-ROUND MAGAZINE					18-ROUND MAGAZINE			
ENVIRONMENT	E1	E2	E3	E4		E1	E2	E3	E4
RD NO					RD NO				
1	2	3	4		1	5	1		
2	4	5	4	4	2	5	1		2
3		2	1	2	3	1			
4	3	3	1		4			1	
5		2	1	1	5				1
6	1		3	2	6				
7		1			7				
8	1	1		2	8				
9		1	1	1	9				
10	1		2		10				
11		1	1	1	11	1	1		
12	1				12	1			
13		1		2	13				
14		1			14				
15				2	15	1		1	
16	1	1			16				
17	2	1		1	17				
18		1			18				
19			1	1					
20		1	1						
TOTALS	16	25	20	19		14	3	2	3

TABLE IV-H

FAILURE TO EXTRACT BY ENVIRONMENT AND ROUND NUMBER

IN MAGAZINE FOR M14 RIFLE

NUMBER OF FAILURES

	20-ROUND MAGAZINE					18-ROUND MAGAZINE			
ENVIRONMENT	E1	E2	E3	E4		E1	E2	E3	E4
RD NO					RD NO				
1	1	2	4	1	1	7		1	1
2	4	2	4	2	2	8	1	3	2
3	4		2	1	3	2			1
4	1	1	1		4	2			1
5	3		1		5	1			1
6		1			6	2			1
7	1				7				
8		1			8			1	1
9	2	1	1		9				
10	1		2		10				
11	1		1		11				
12					12				
13					13				
14	1				14				
15	1	1			15				
16					16				
17	1				17	1			
18		1			18				
19			1						
20									
TOTALS	21	10	17	4		23	1	5	8

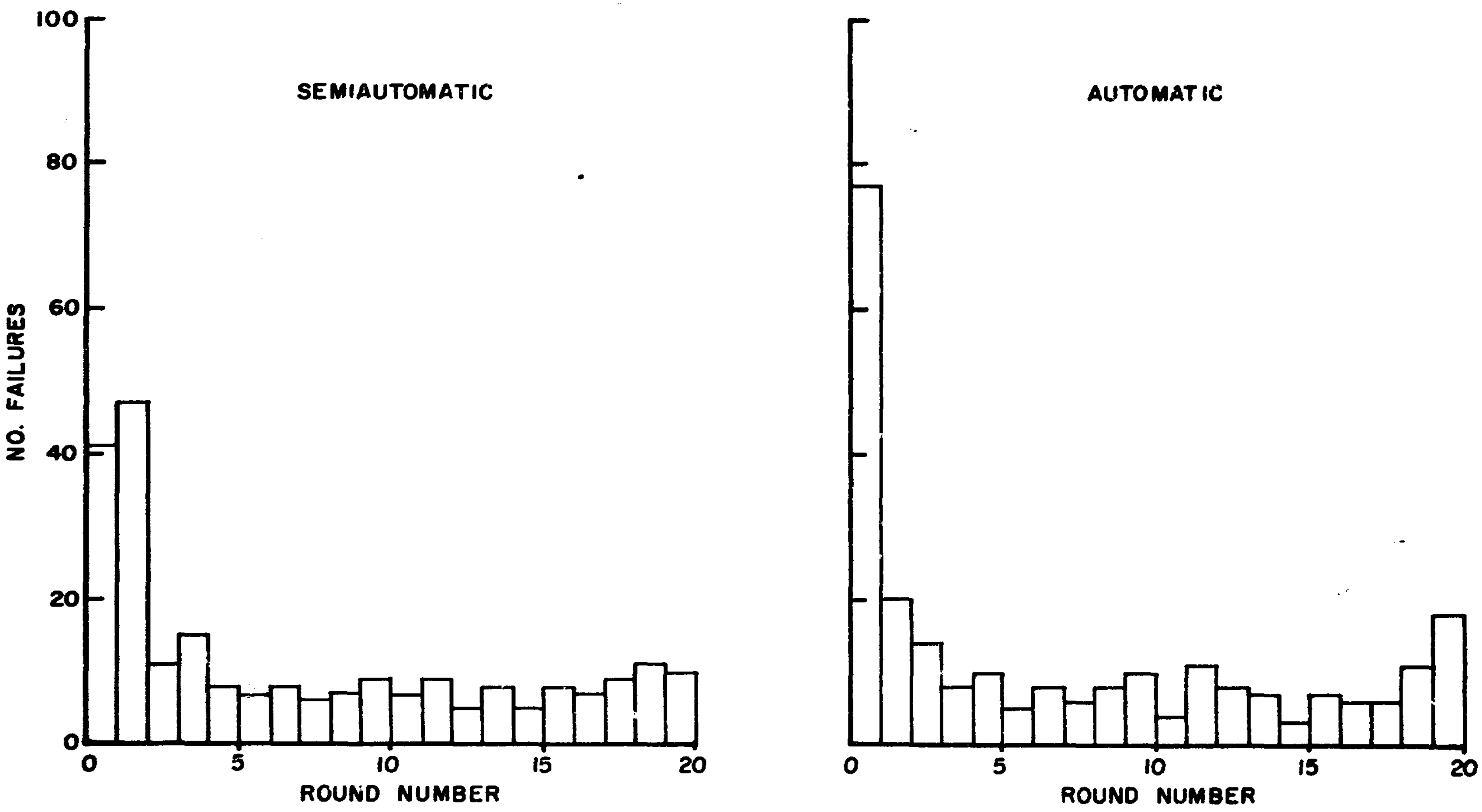


Figure IV-A. Ball(M16) - Twenty Round Magazine - Total Over All Type Failures

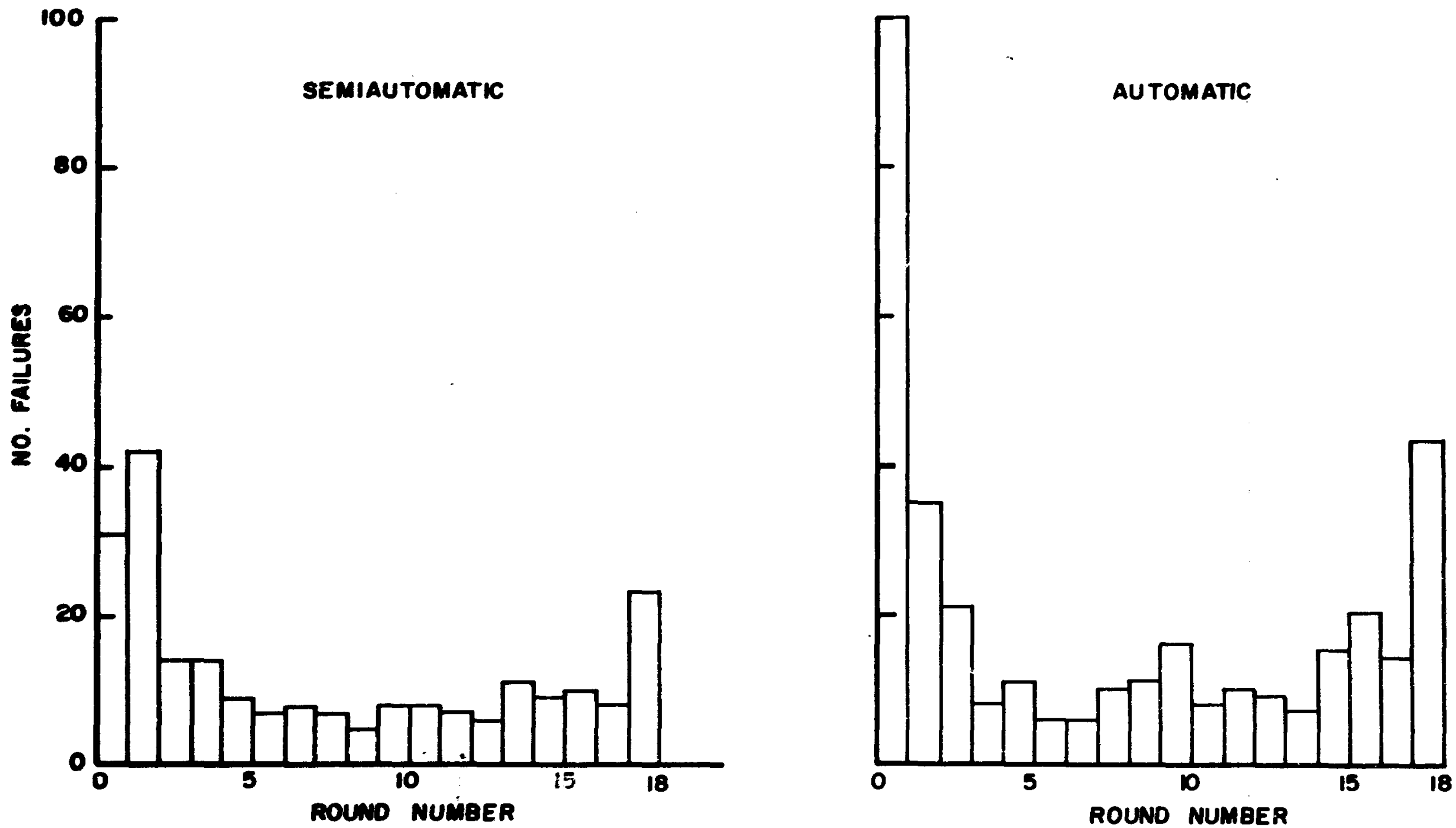


Figure IV-8. Ball(M16)—Eighteen Round Magazine—Total Over All Types Failures

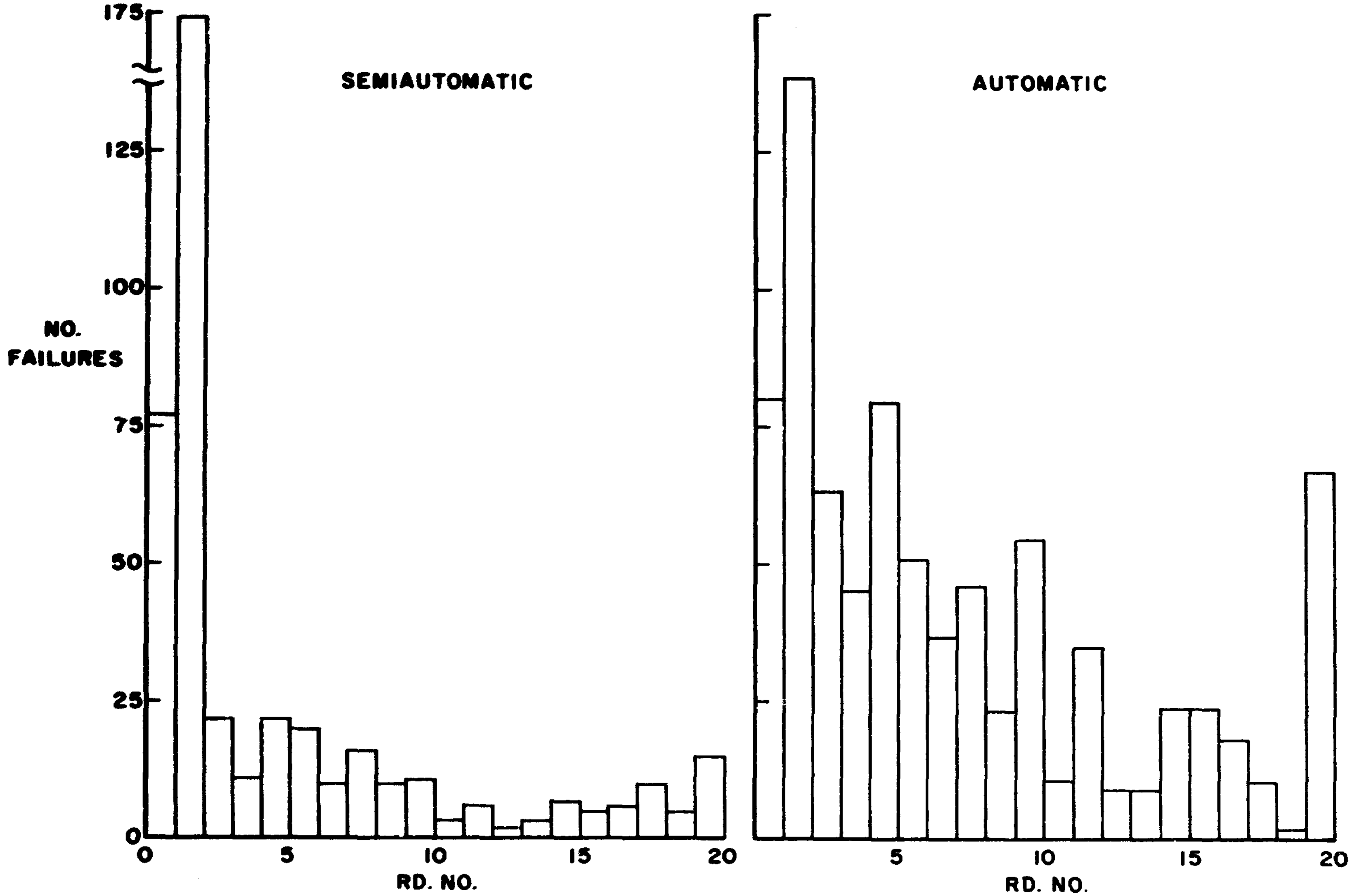


Figure IV-C. IMR (M16)-Twenty Round Magazine-Total Over All Types of Failures.

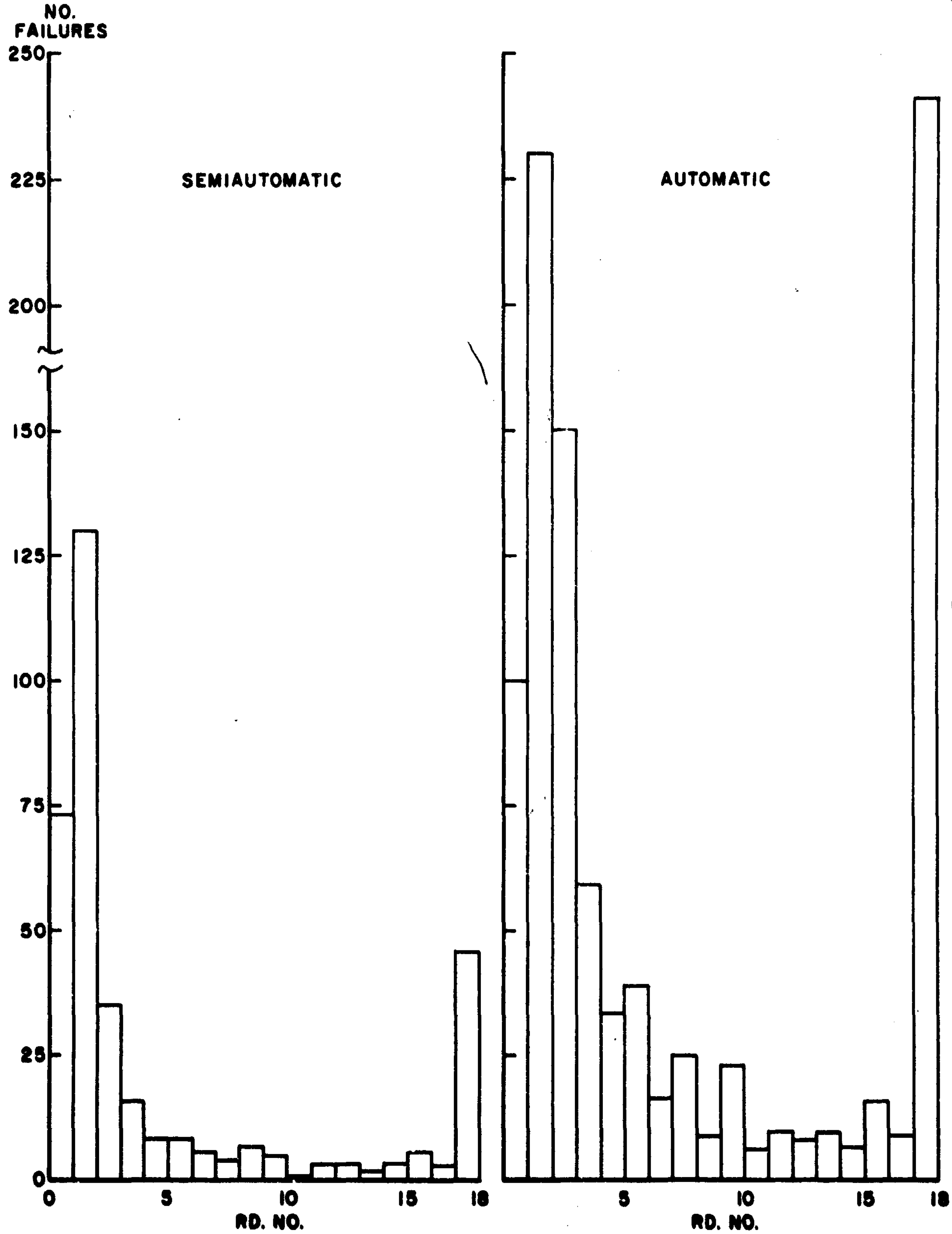


Figure IV-D. IMR (M16)-Eighteen Round Magazine-Total Over All Types of Failures.

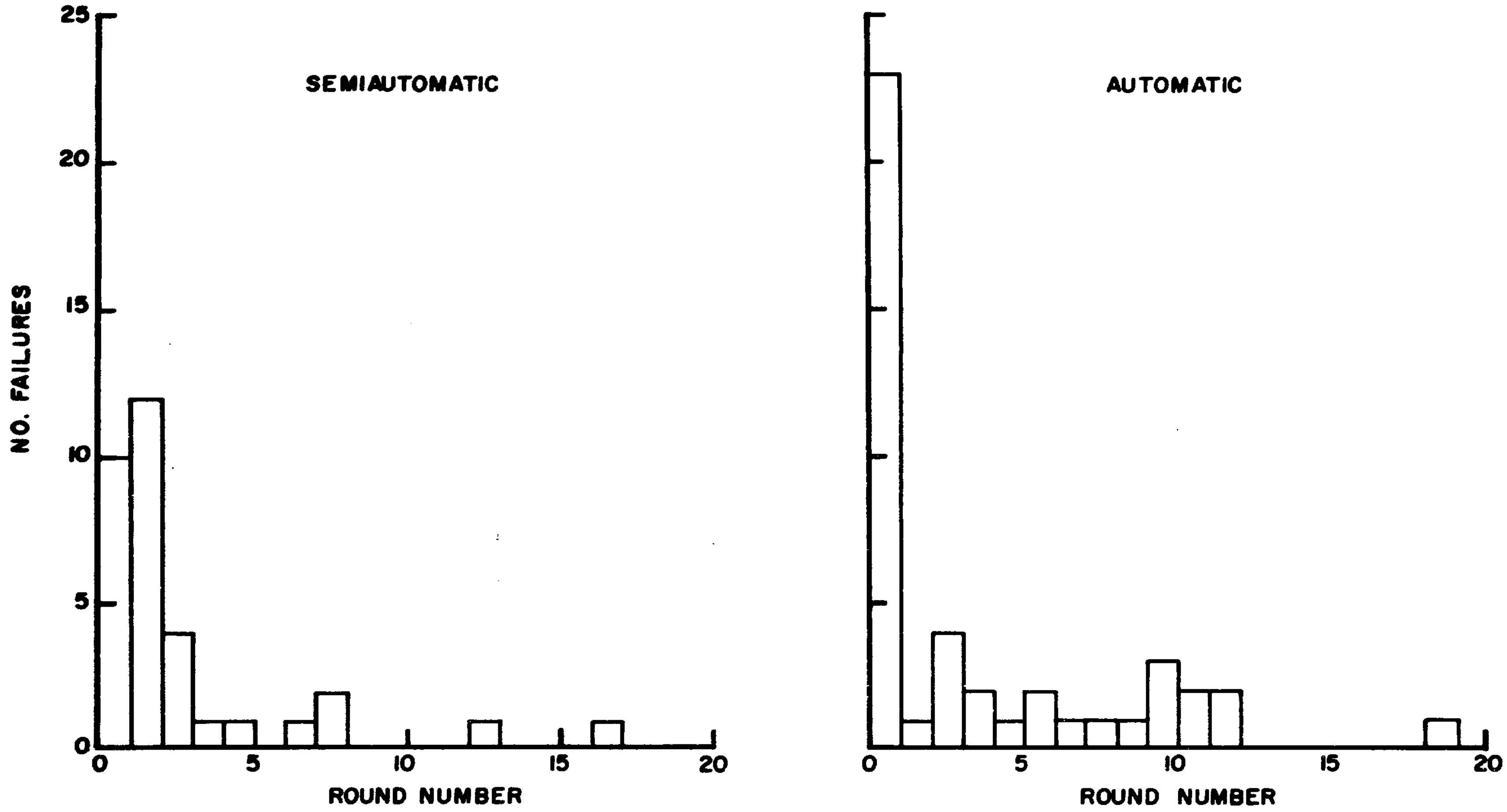


Figure IV-E. Ball (M16) – Twenty Round Magazine – Failure to Feed

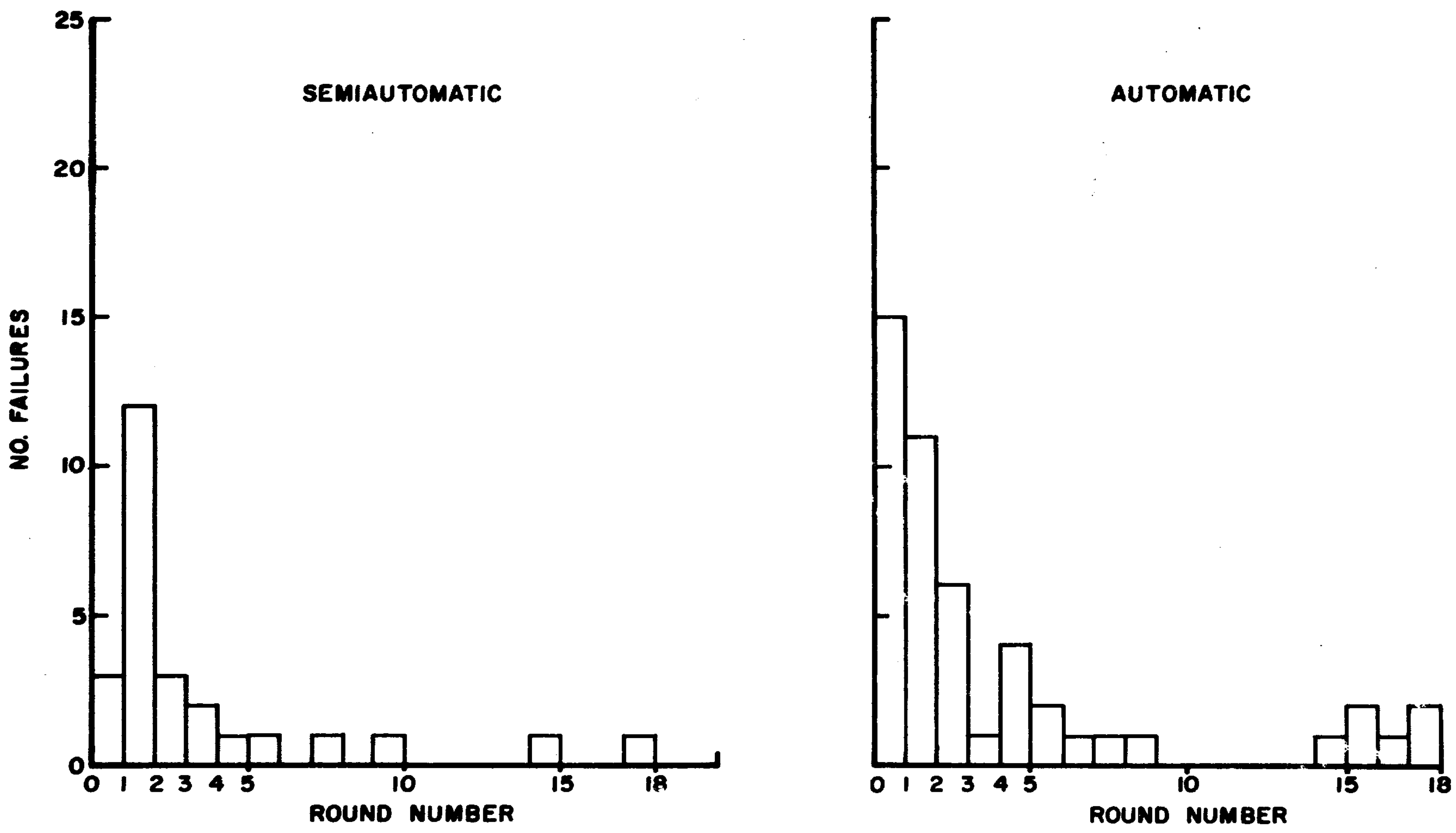


Figure IV-F. Ball (M16)-Eighteen Round Magazine-Failure to Feed

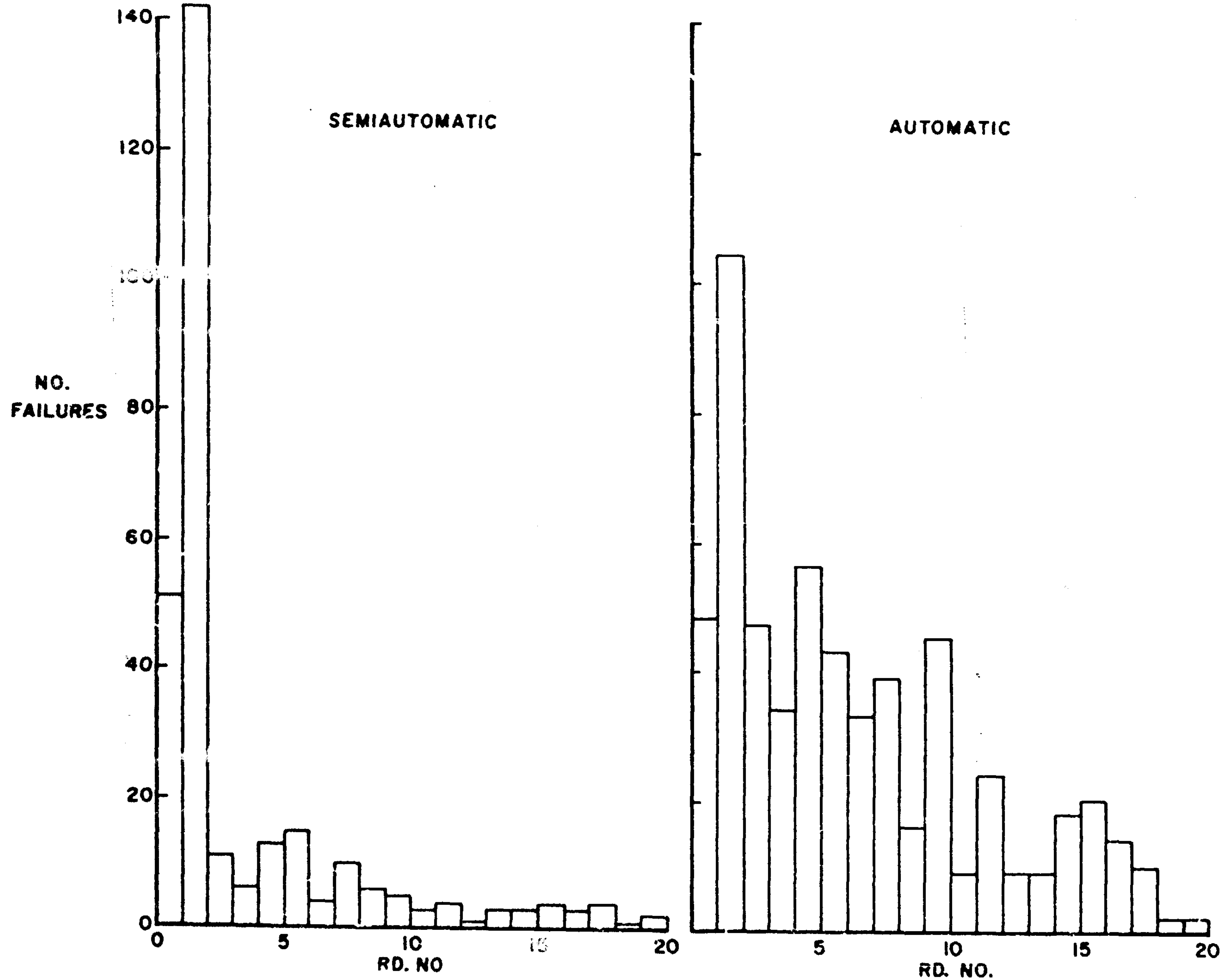


Figure IV-G. IMR (M16)-Twenty Round Magazine-Failure to Feed

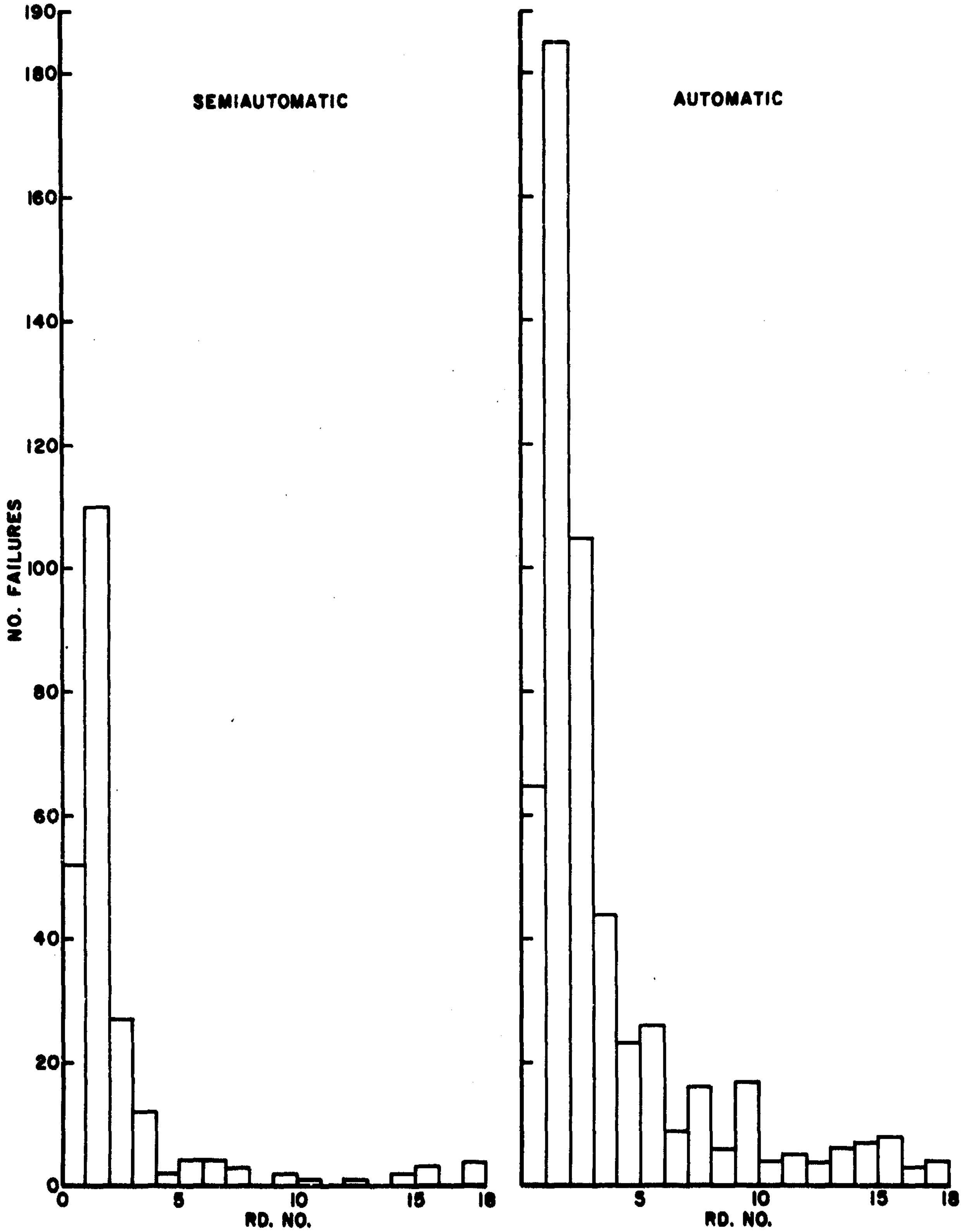


Figure IV-H. IMR (M16)-Eighteen Round Magazine-Failure to Feed

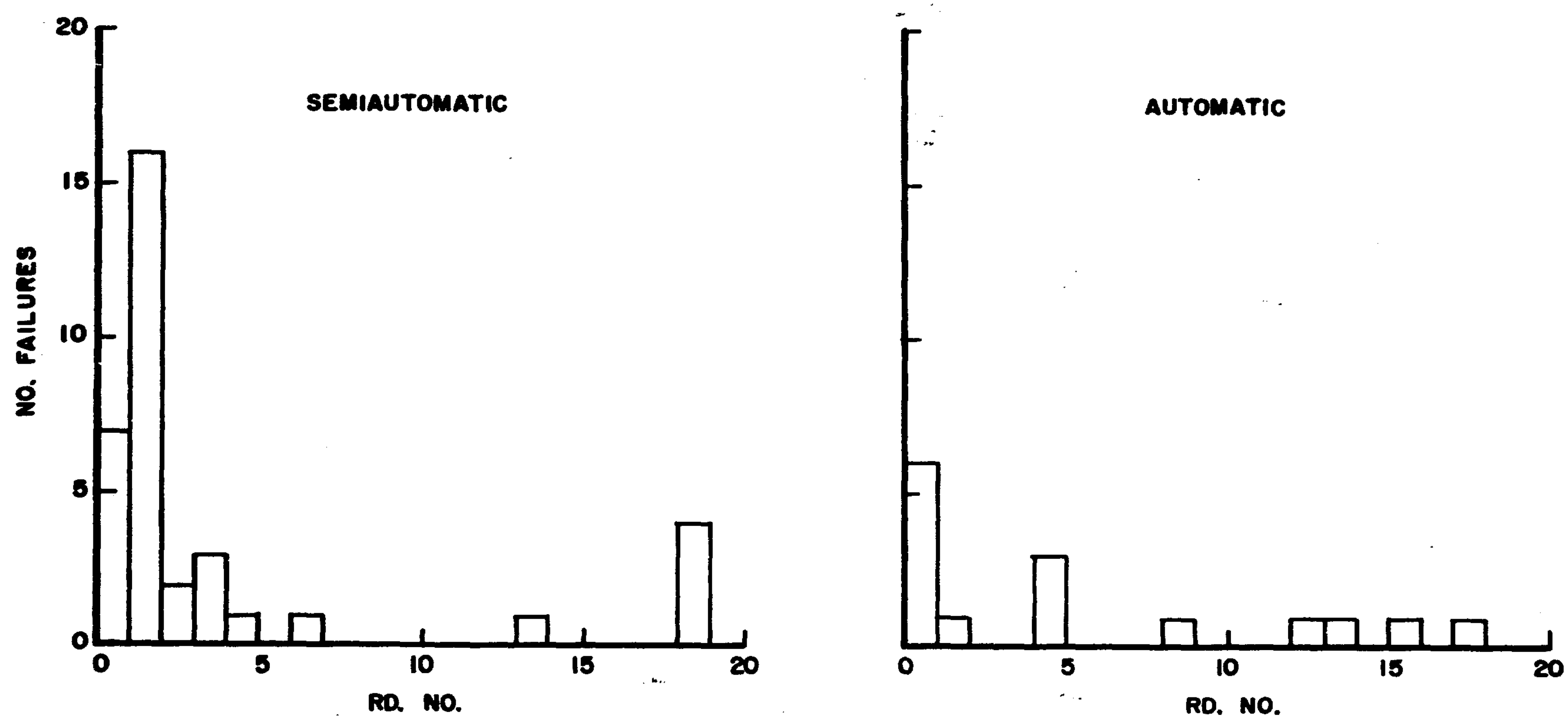


Figure IV-I. Ball (M16) - Twenty Round Magazine - Failure to Chamber

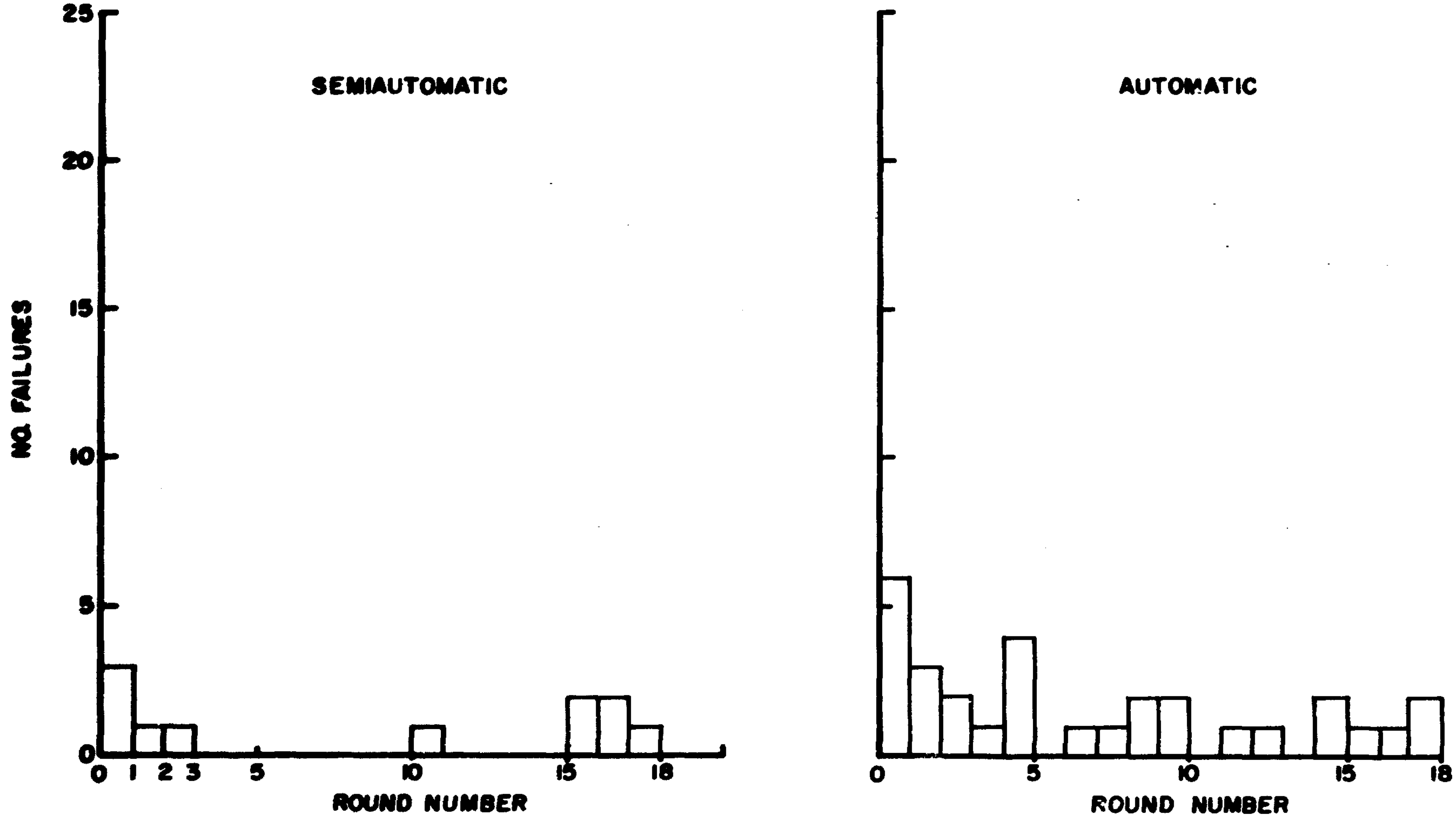


Figure IV-J. Ball (M16)- Eighteen Round Magazine—Failure to Chamber

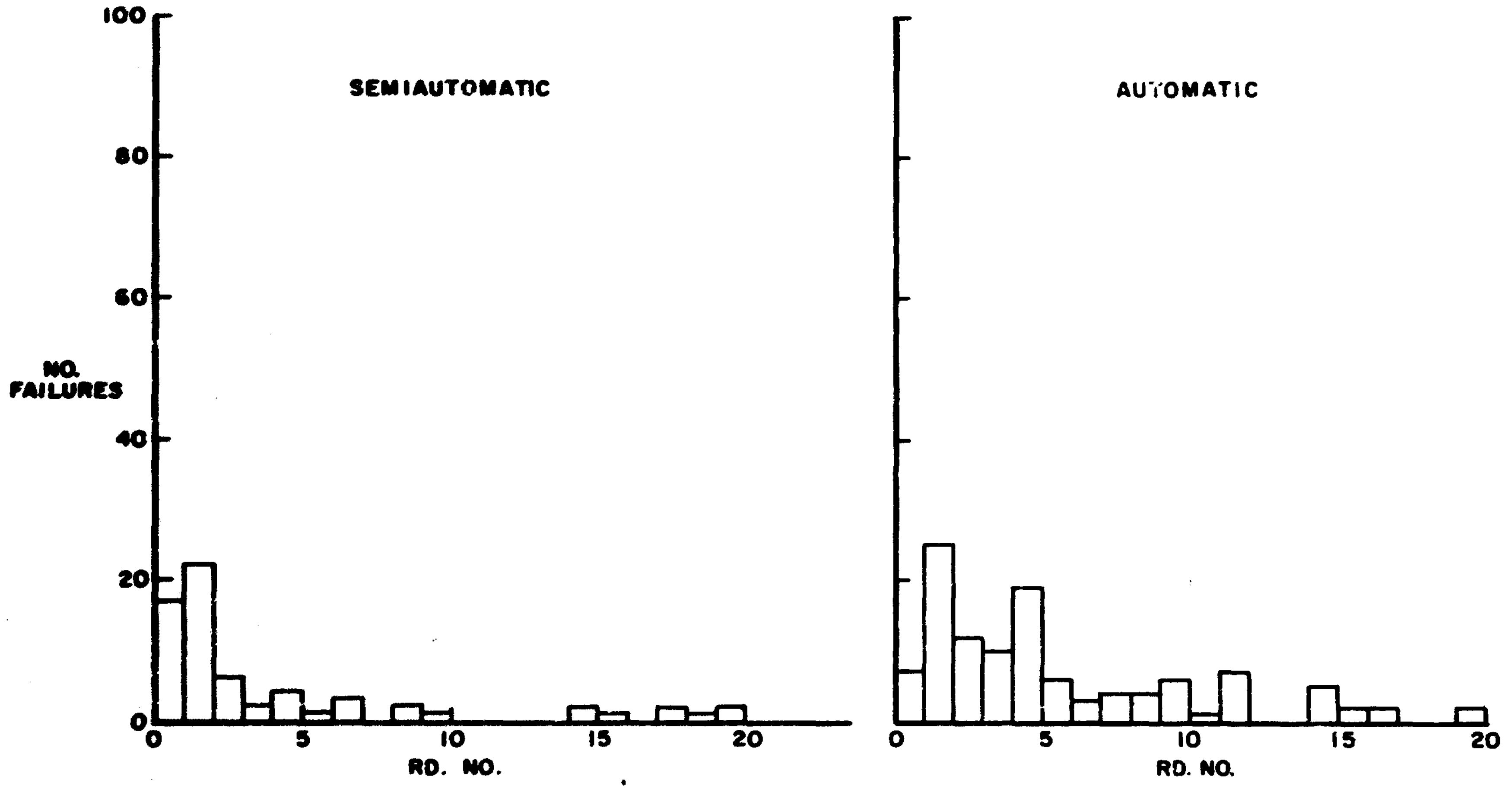


Figure IV-K. IMR (M16) - Twenty Round Magazine - Failure to Chamber

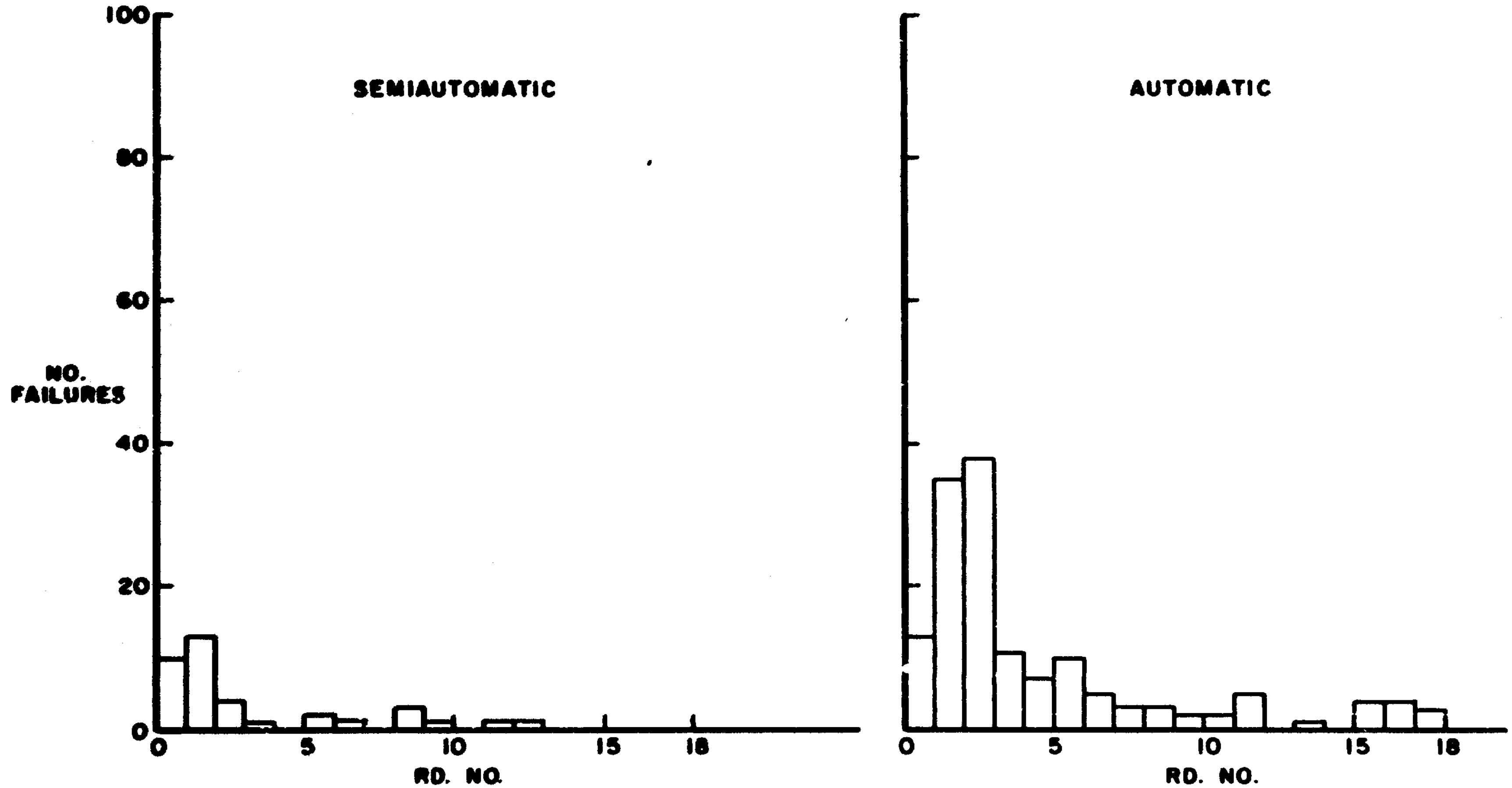


Figure IV-L. IMR (M16) - Eighteen Round Magazine - Failure to Chamber

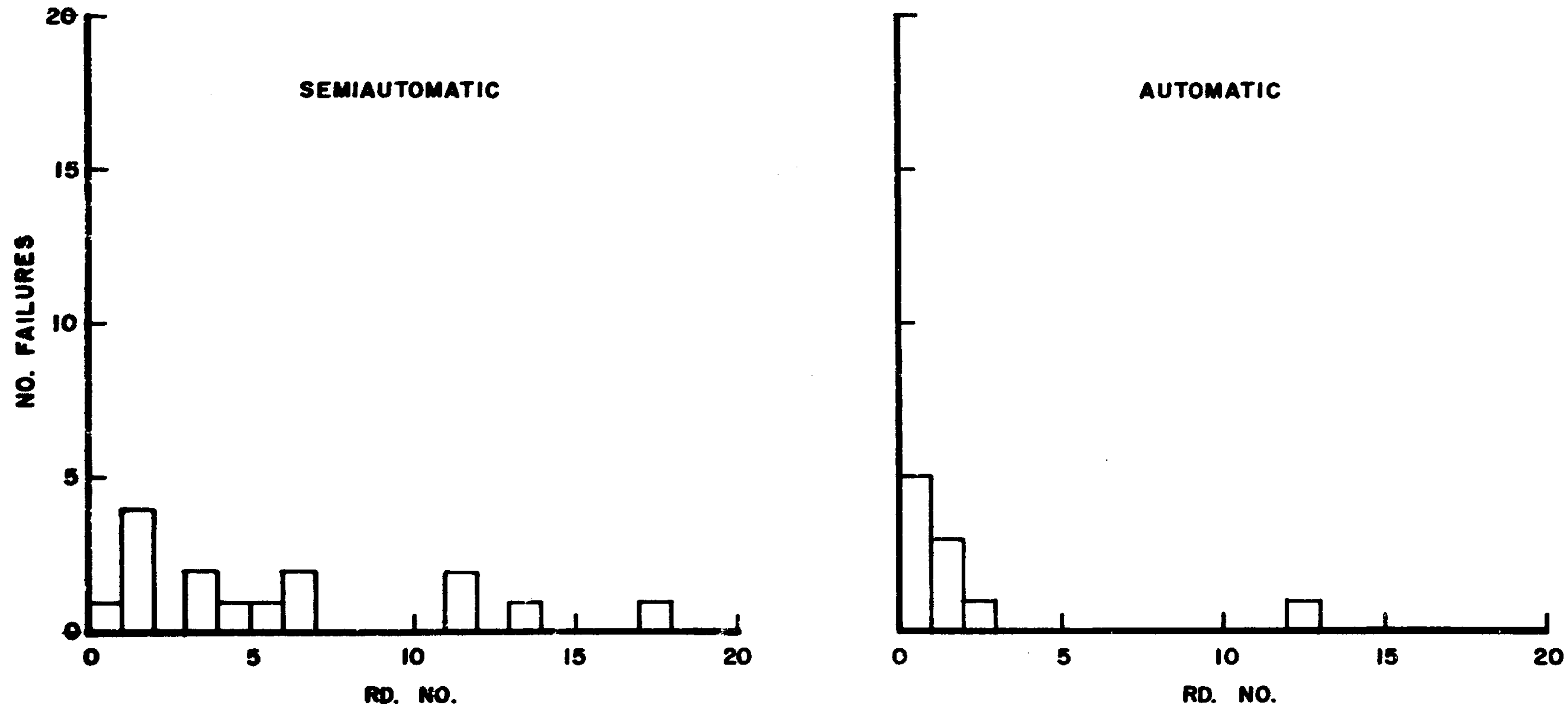


Figure IV-M. Bail (M16)-Twenty Round Magazine - Failure to Lock

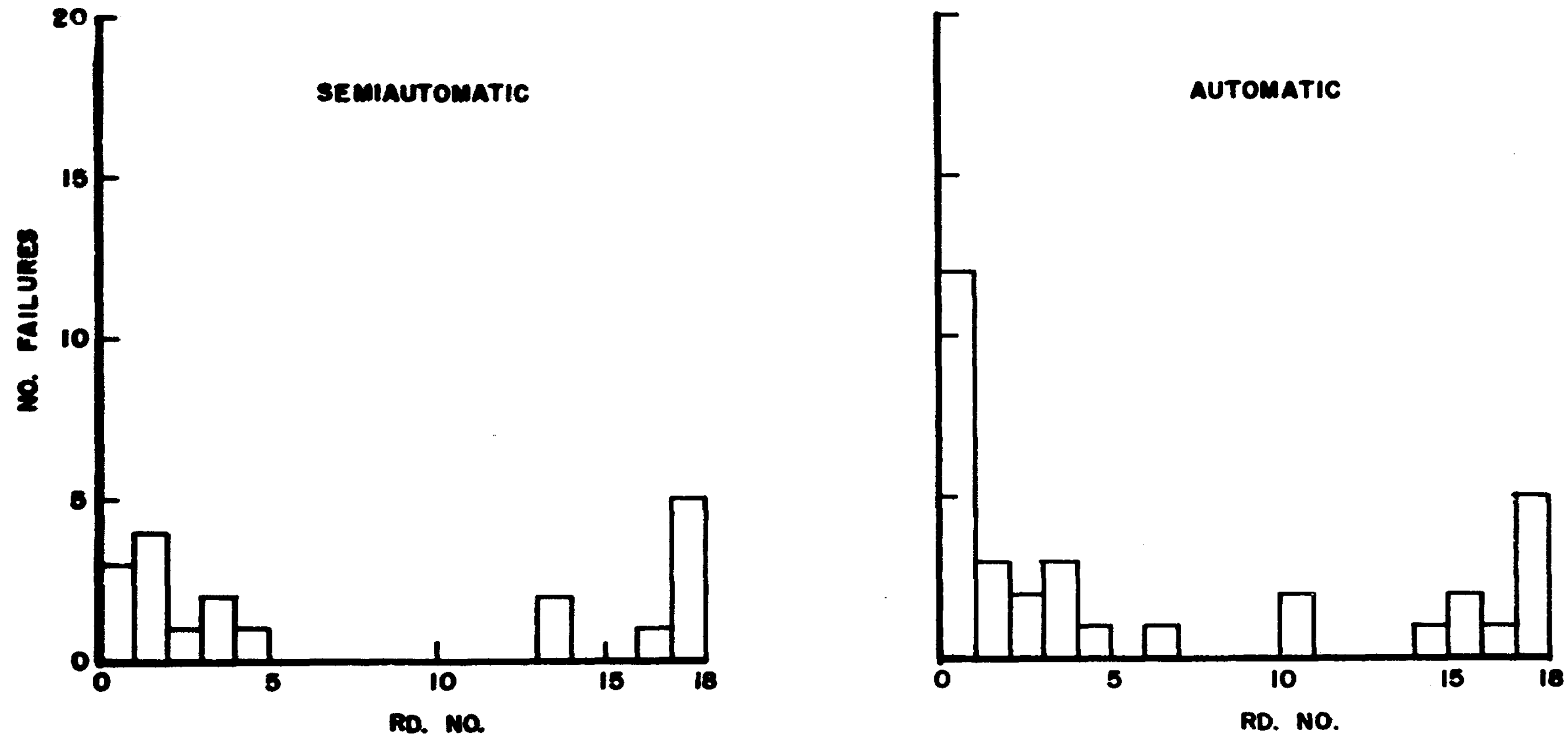


Figure IV-N. Ball (M16) - Eighteen Round Magazine - Failure to Lock.

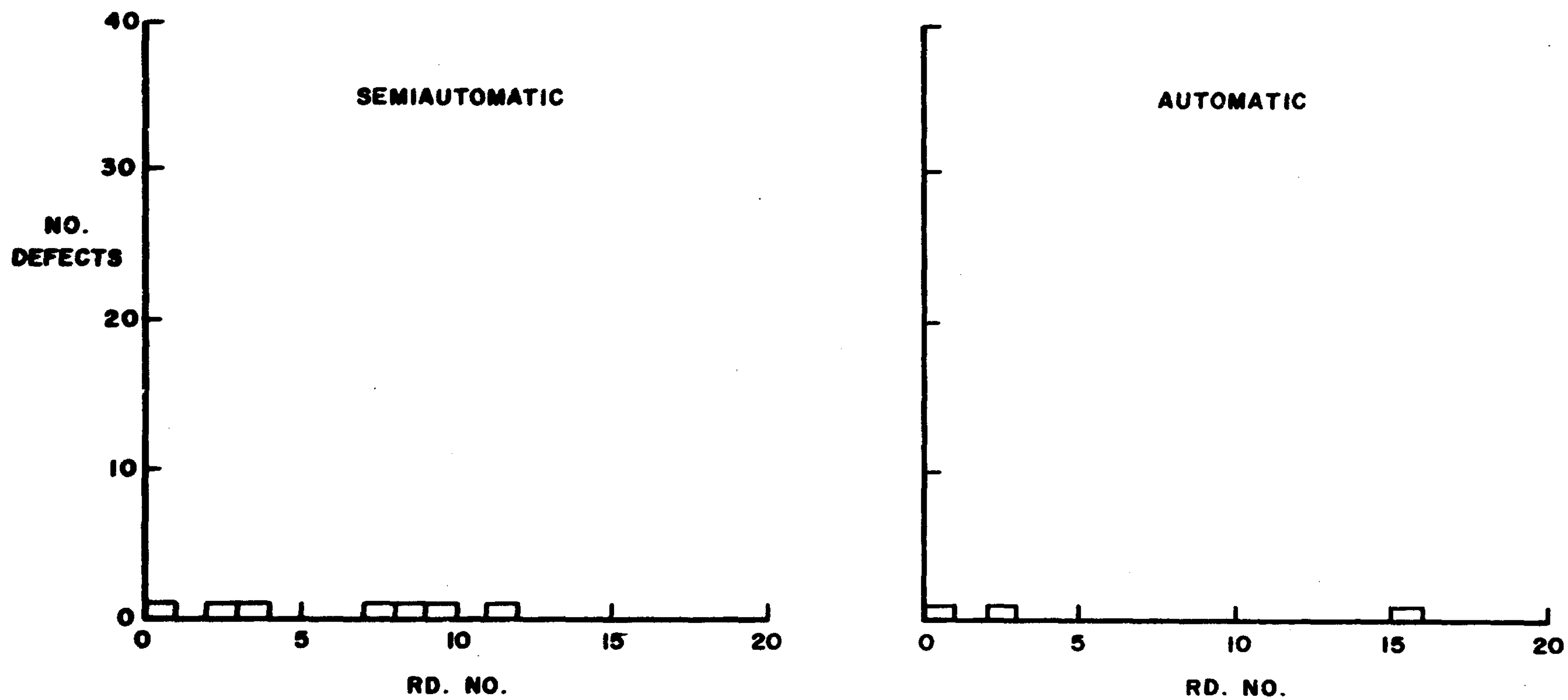


Figure IV-O. IMR (M16) Twenty Round Clip – Failure to Lock

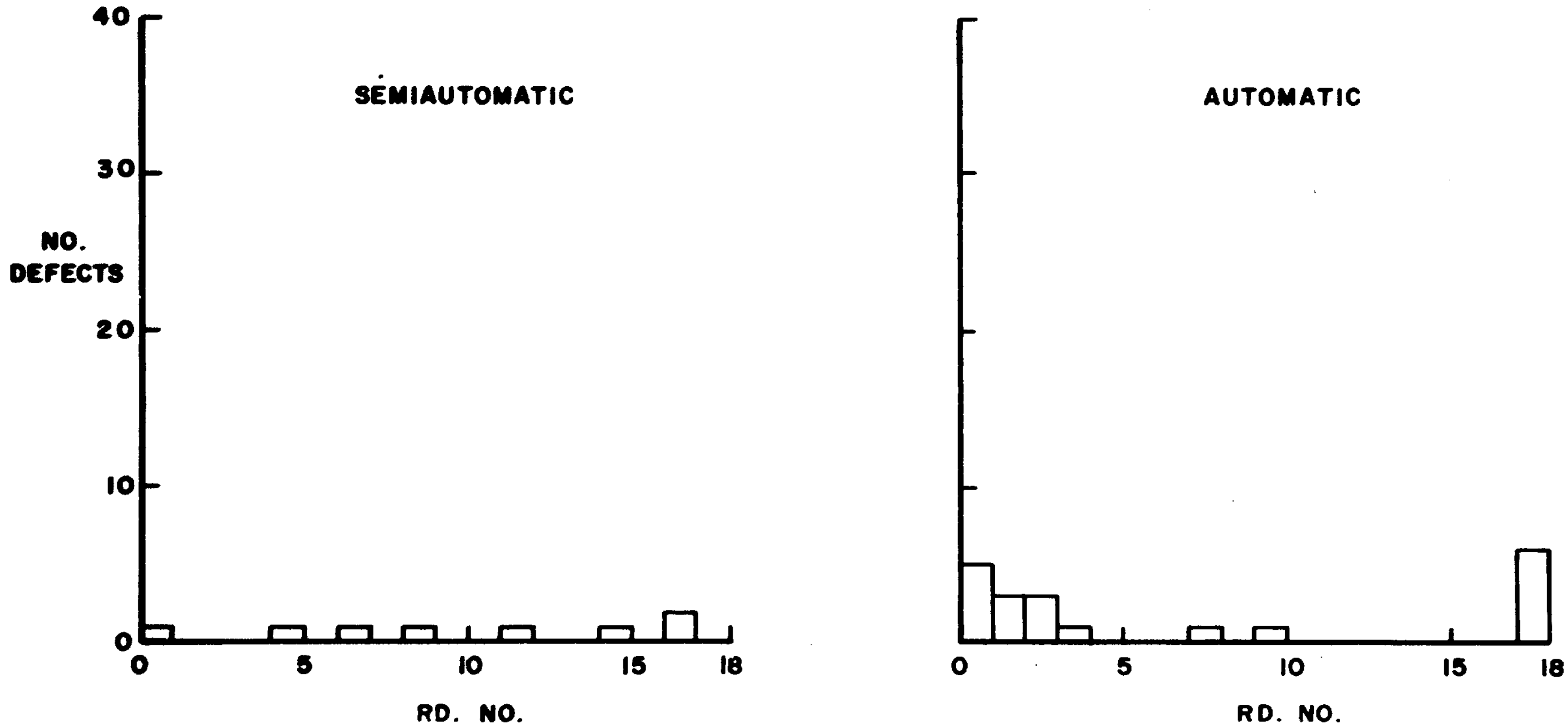


Figure IV-P. IMR (M16) - Eighteen Round Clip — Failure to Lock

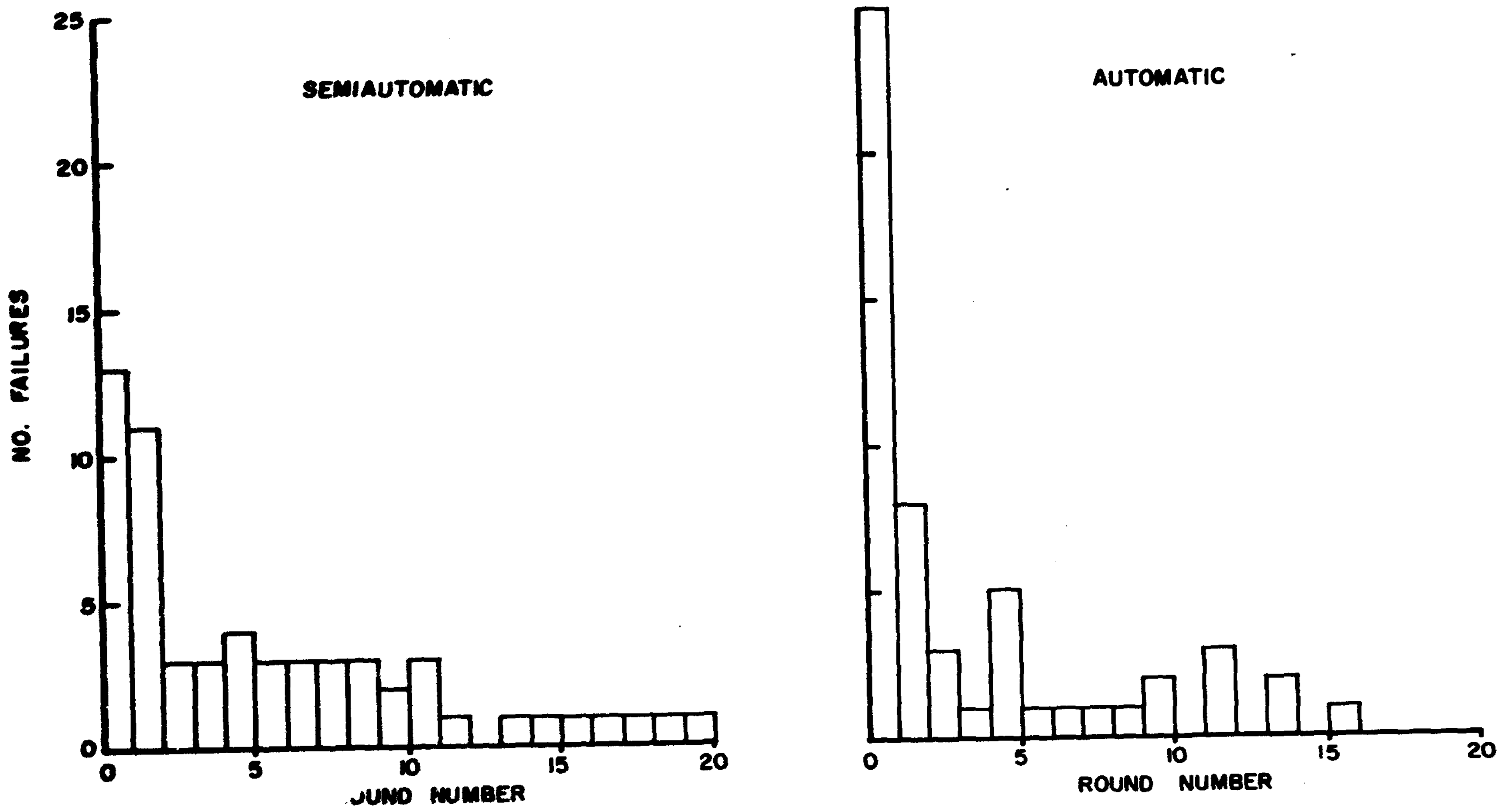


Figure IV-Q. Ball (M16) – Twenty Round Magazine – Failure to Fire

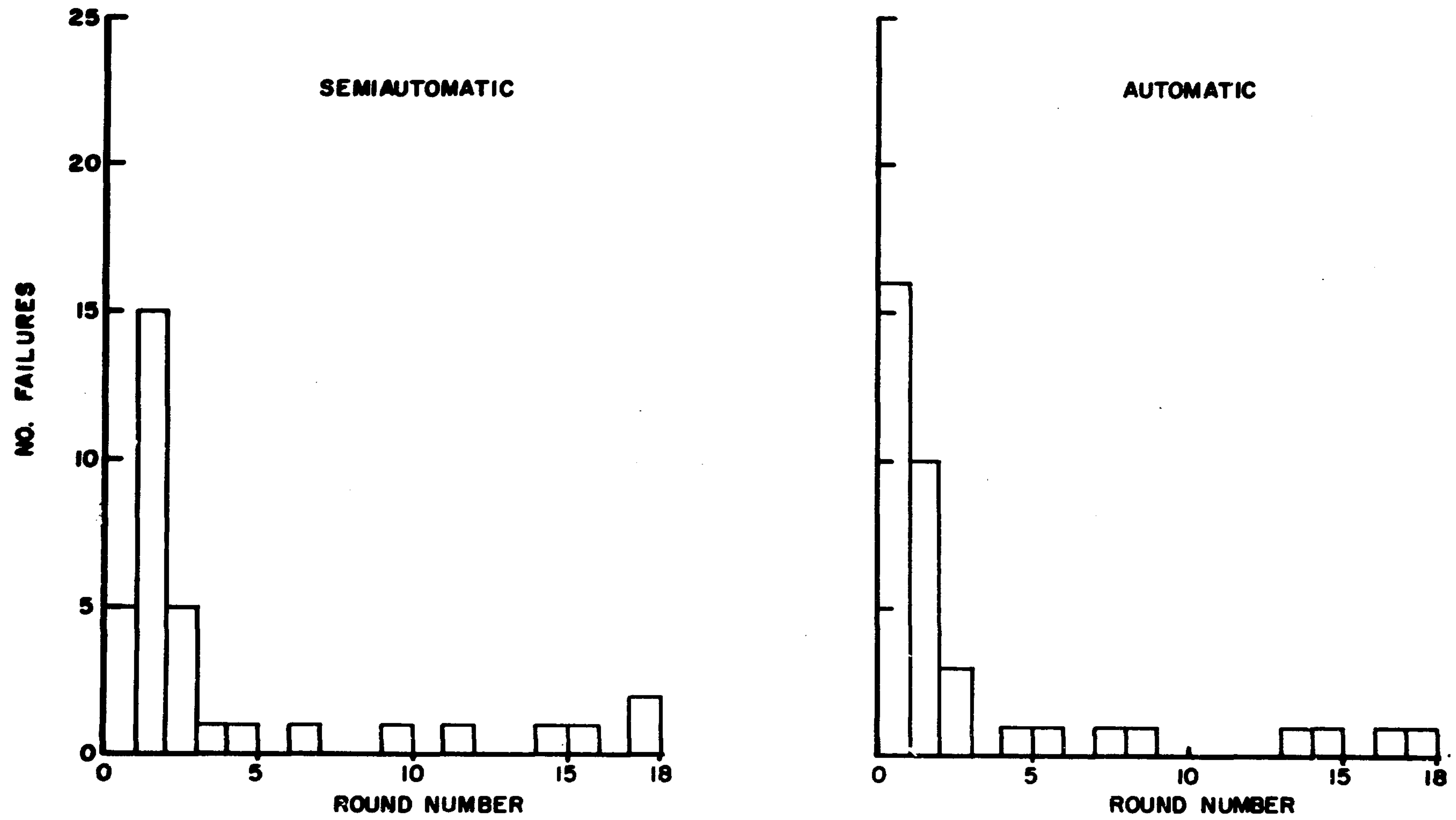


Figure IV-R. Ball (M16) - Eighteen Round Magazine — Failure to Fire

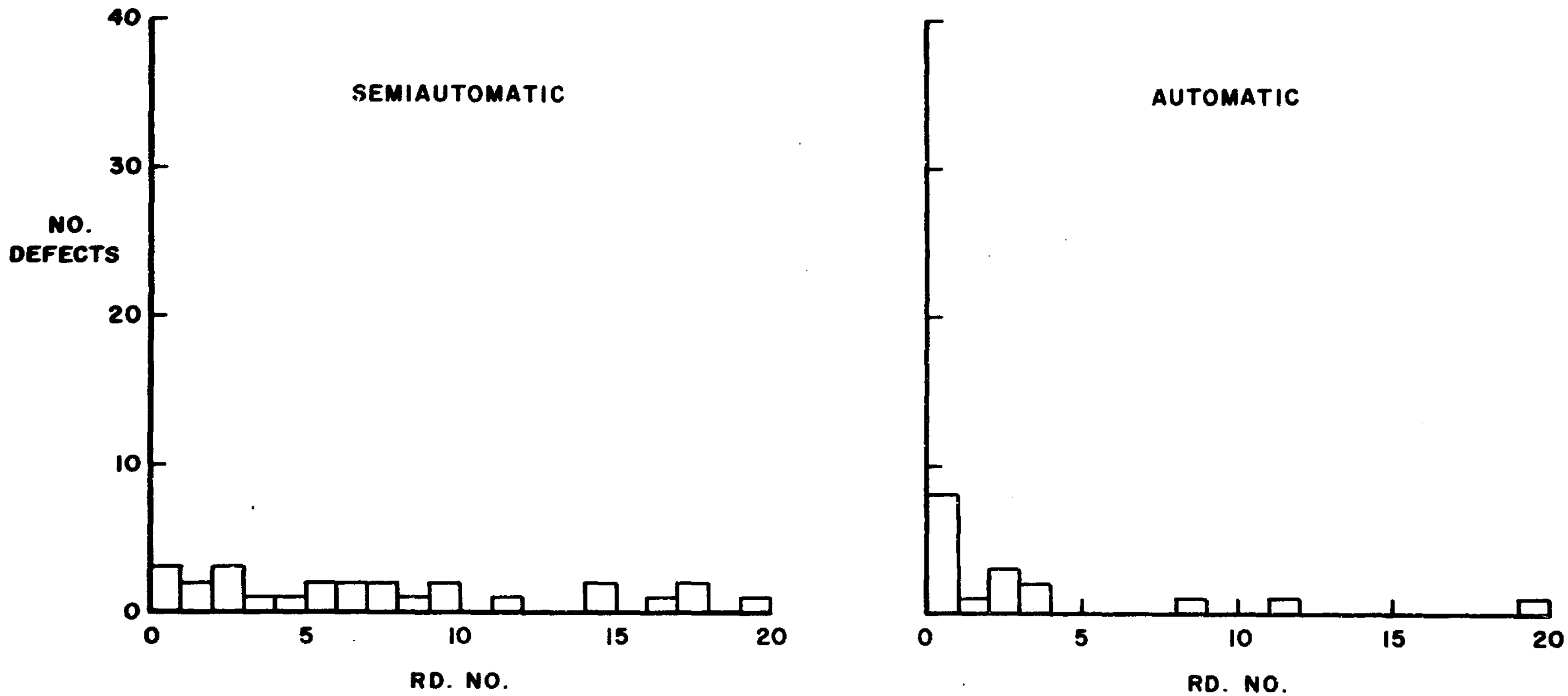


Figure IV-S. IMR (M16)-Twenty Round Clip - Failure to Fire

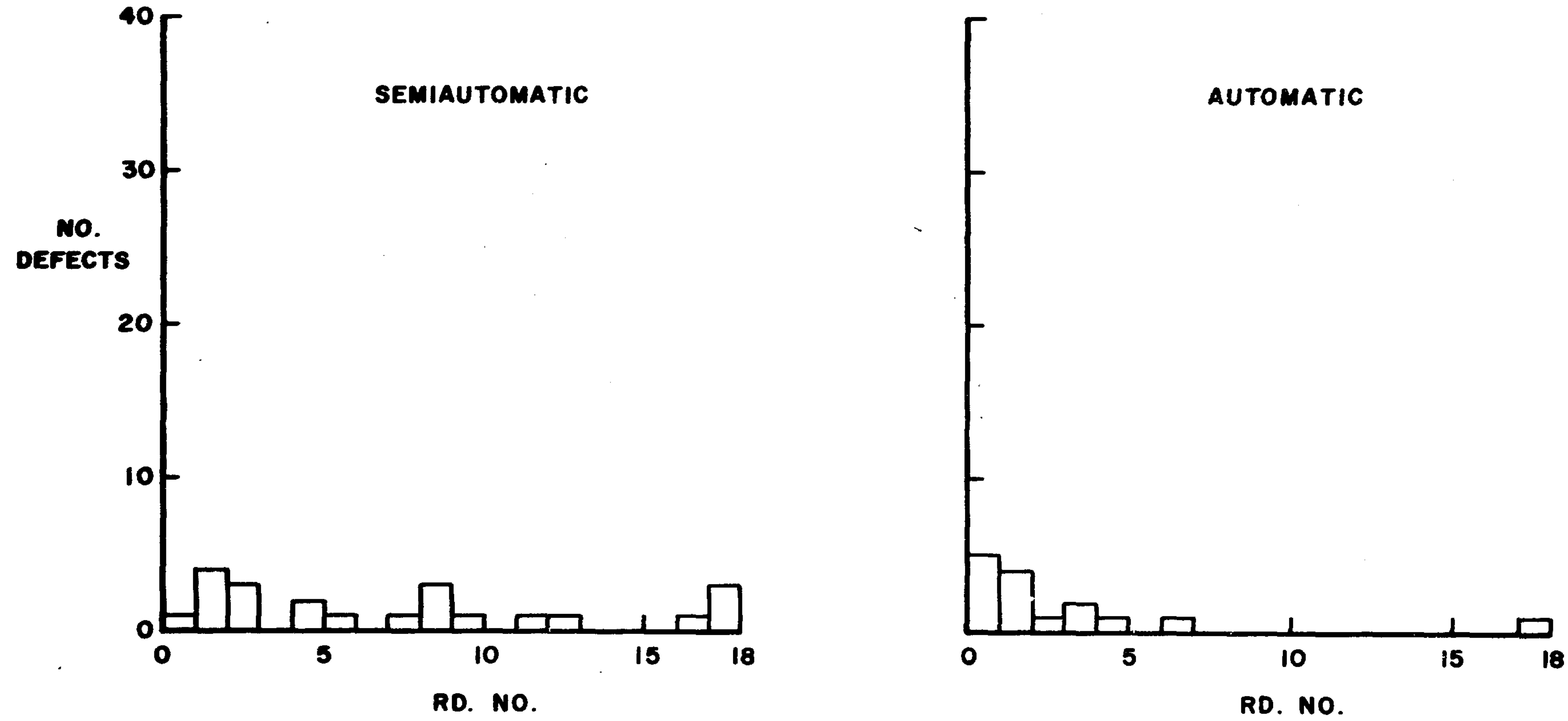


Figure IV-T. IMR (M16) Eighteen Round Clip - Failure to Fire

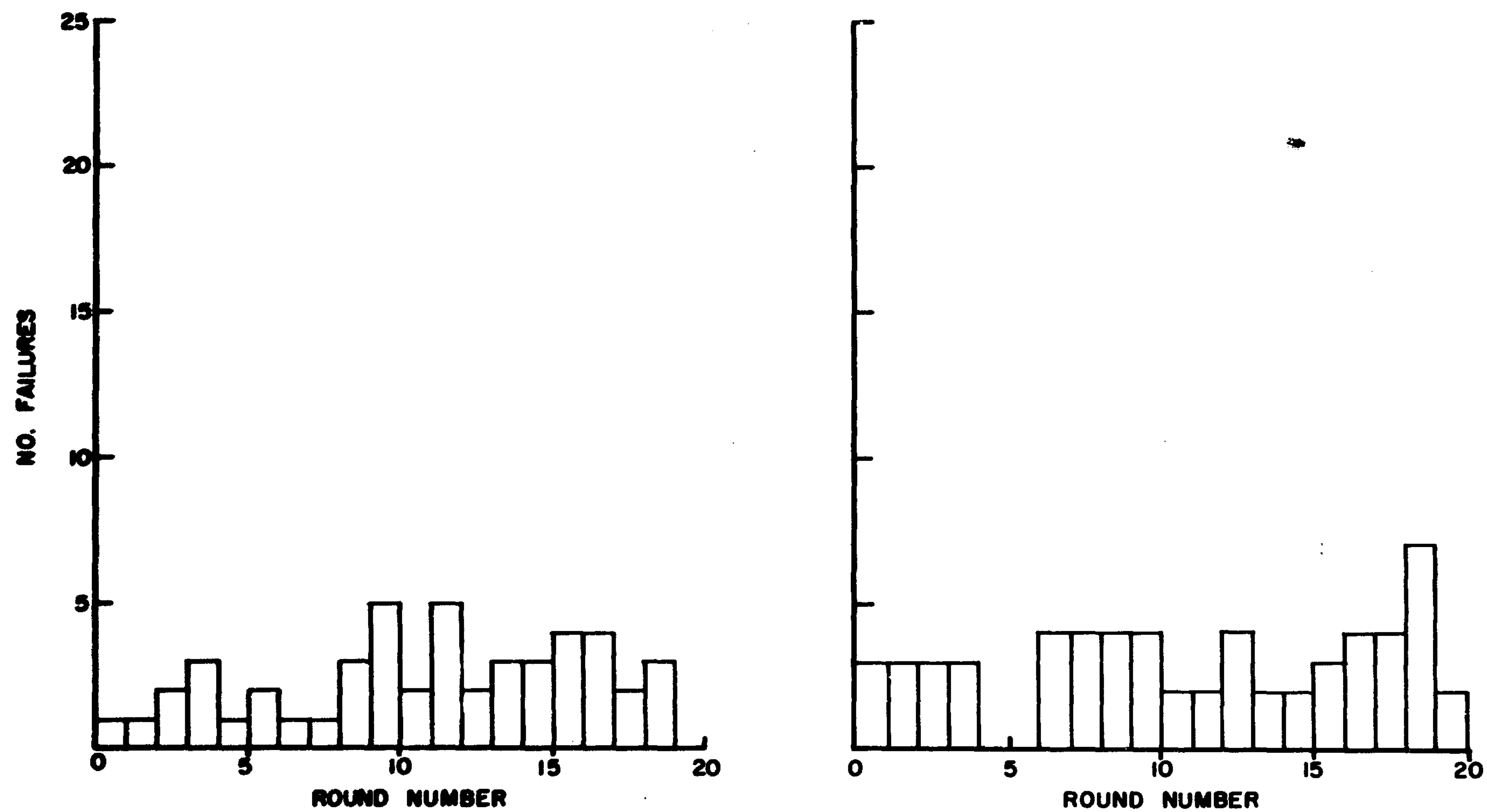


Figure IV-U. Ball (M16) — Twenty Round Magazine — Failure to Eject

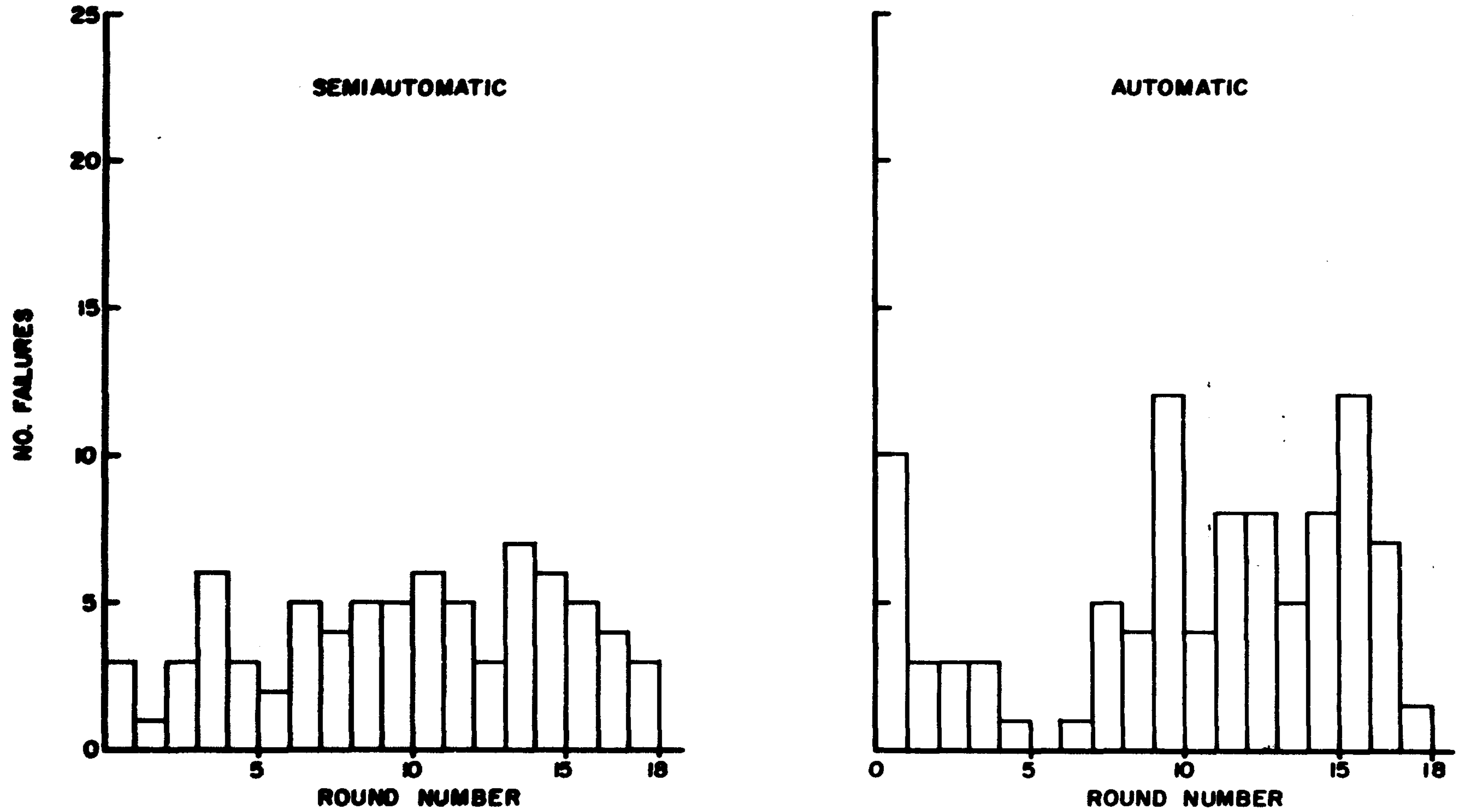


Figure IV-V. Ball (M16)—Eighteen Round Magazine—Failure to Eject

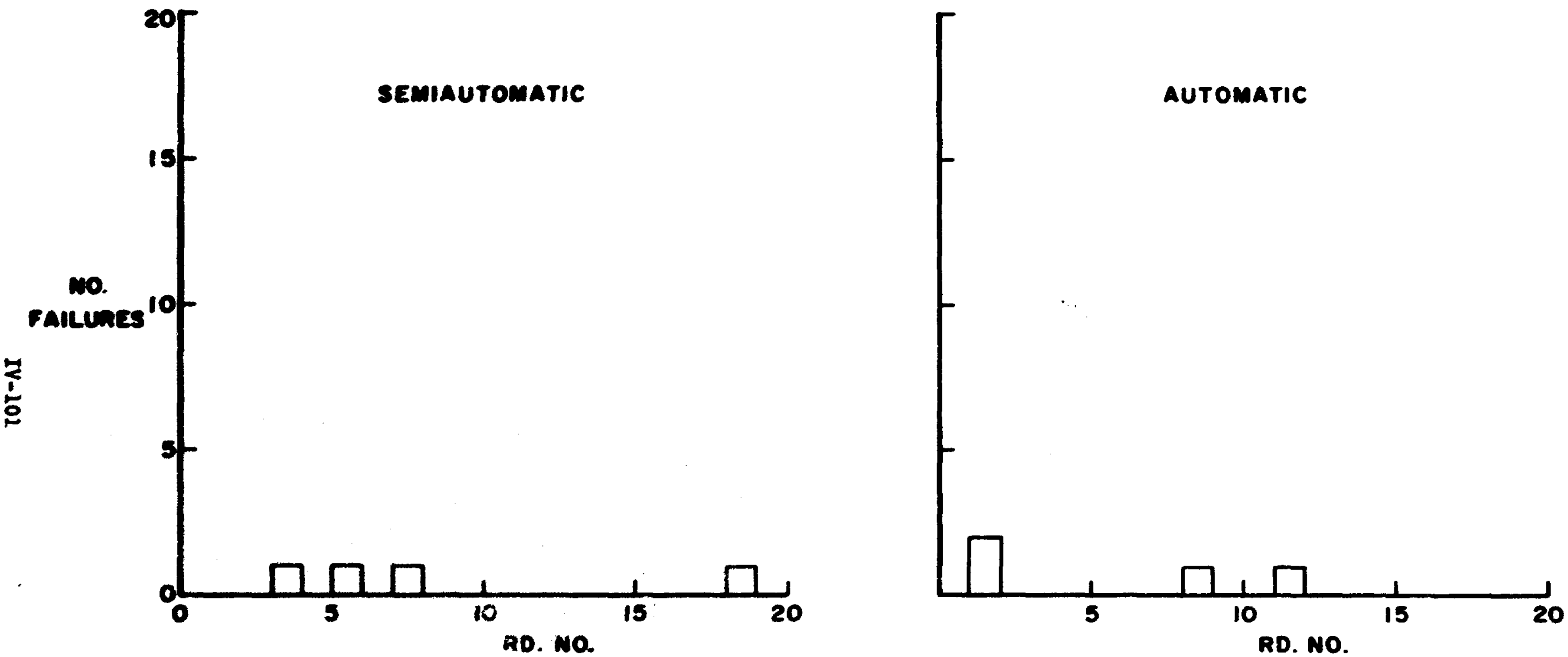


Figure IV-W. IMR (M16) - Twenty Round Magazine - Failure to Eject

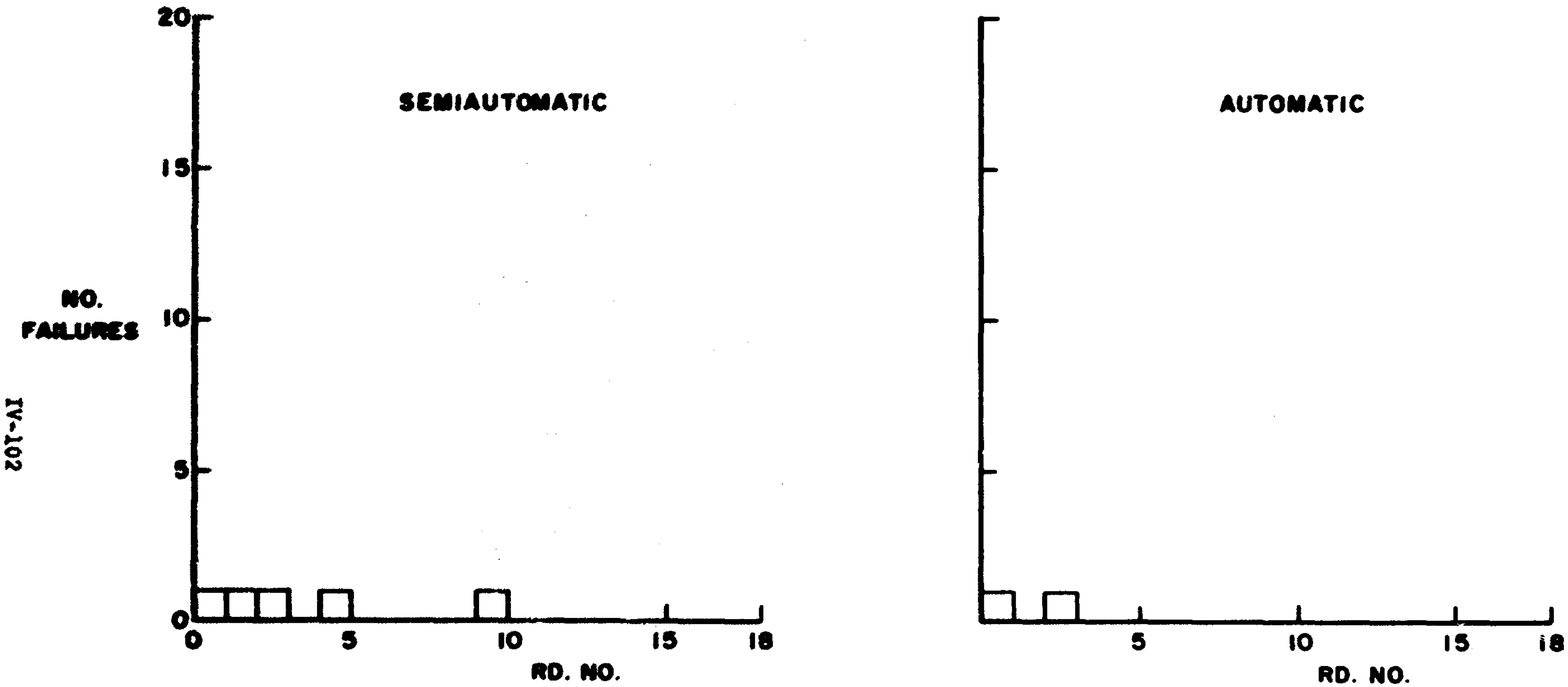


Figure IV-X. IMR (M16) -Eighteen Round Magazine- Failure to Eject

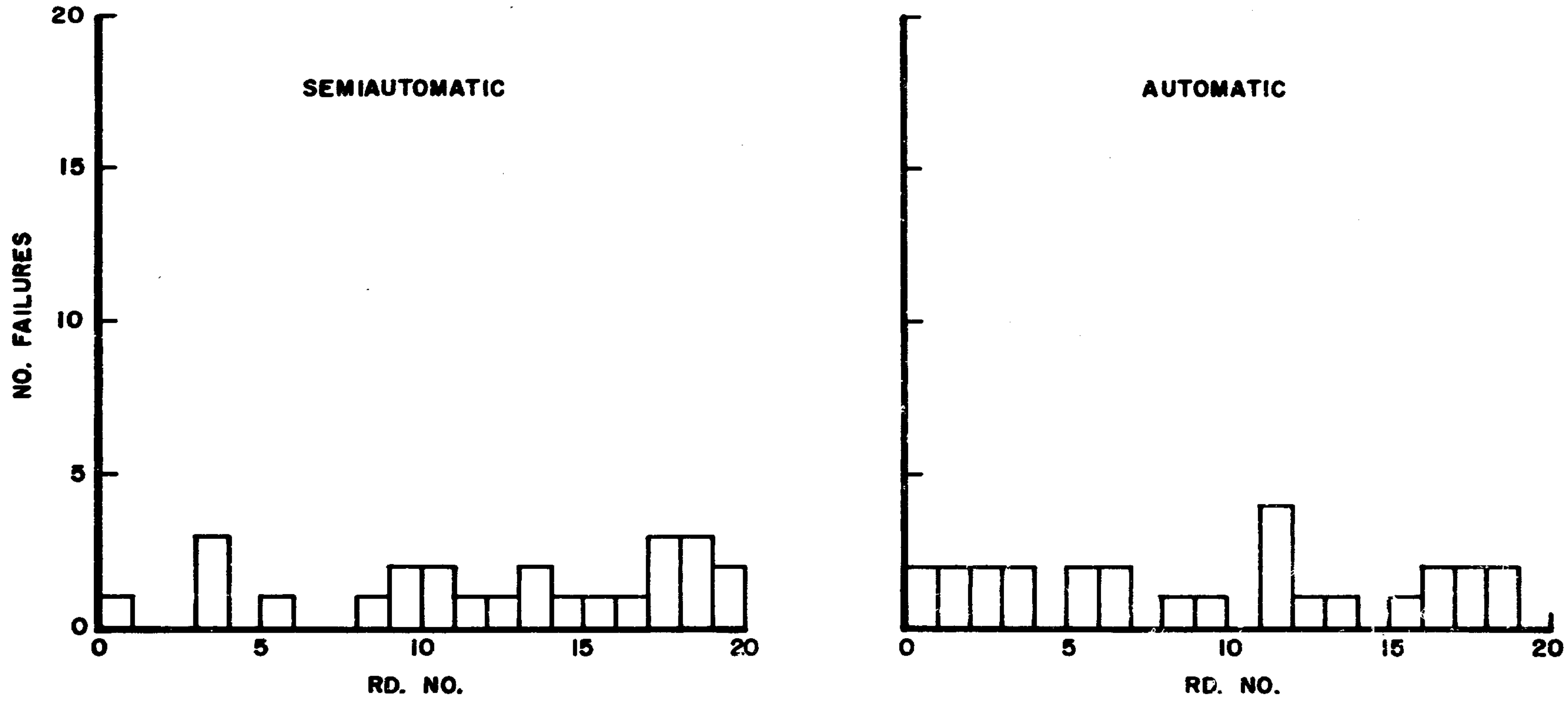


Figure IV-Y. Ball (M16) - Twenty Round Magazine - Failure to Extract

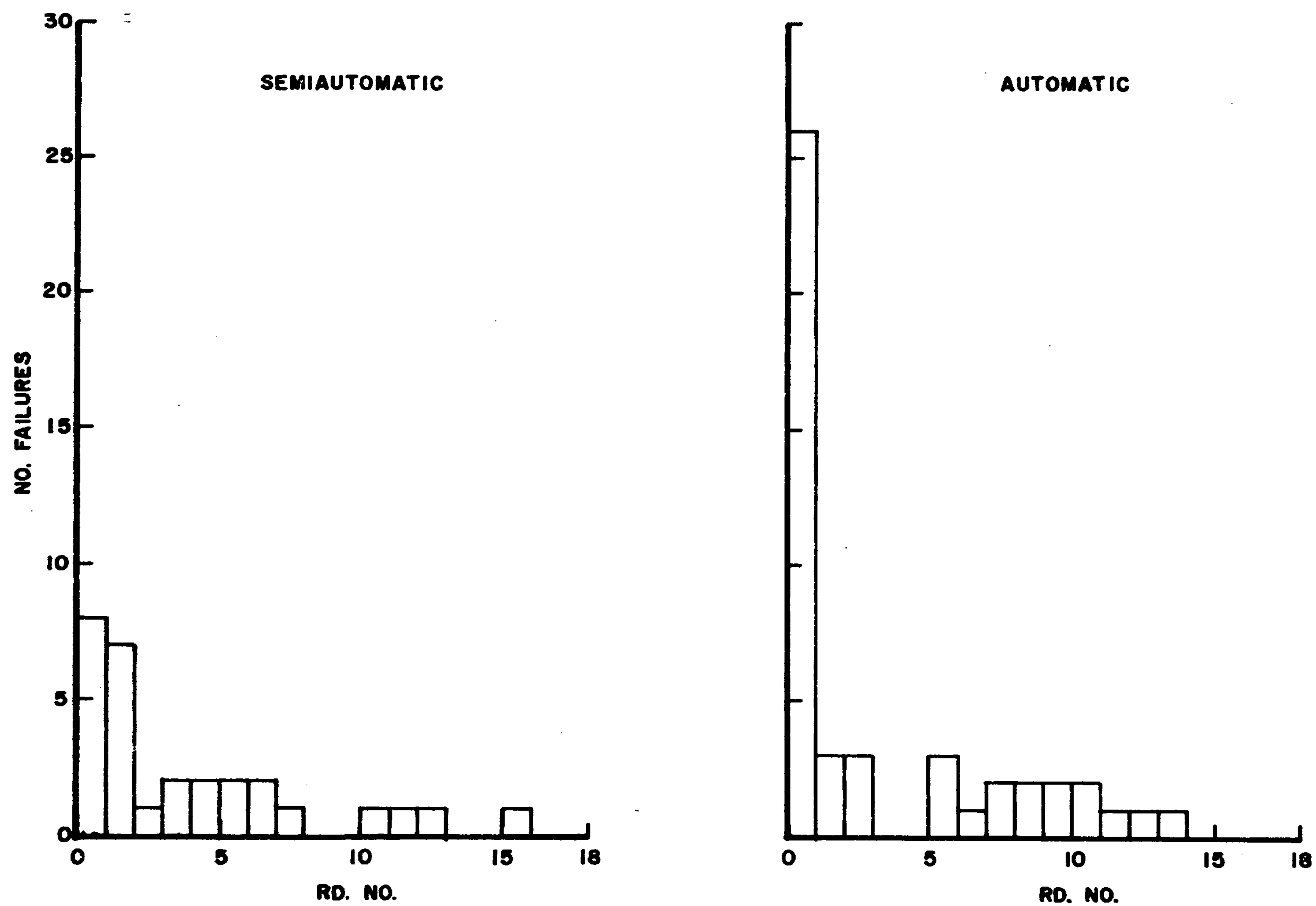


Figure IV-Z. Ball (M16) - Eighteen Round Magazine - Failure to Extract

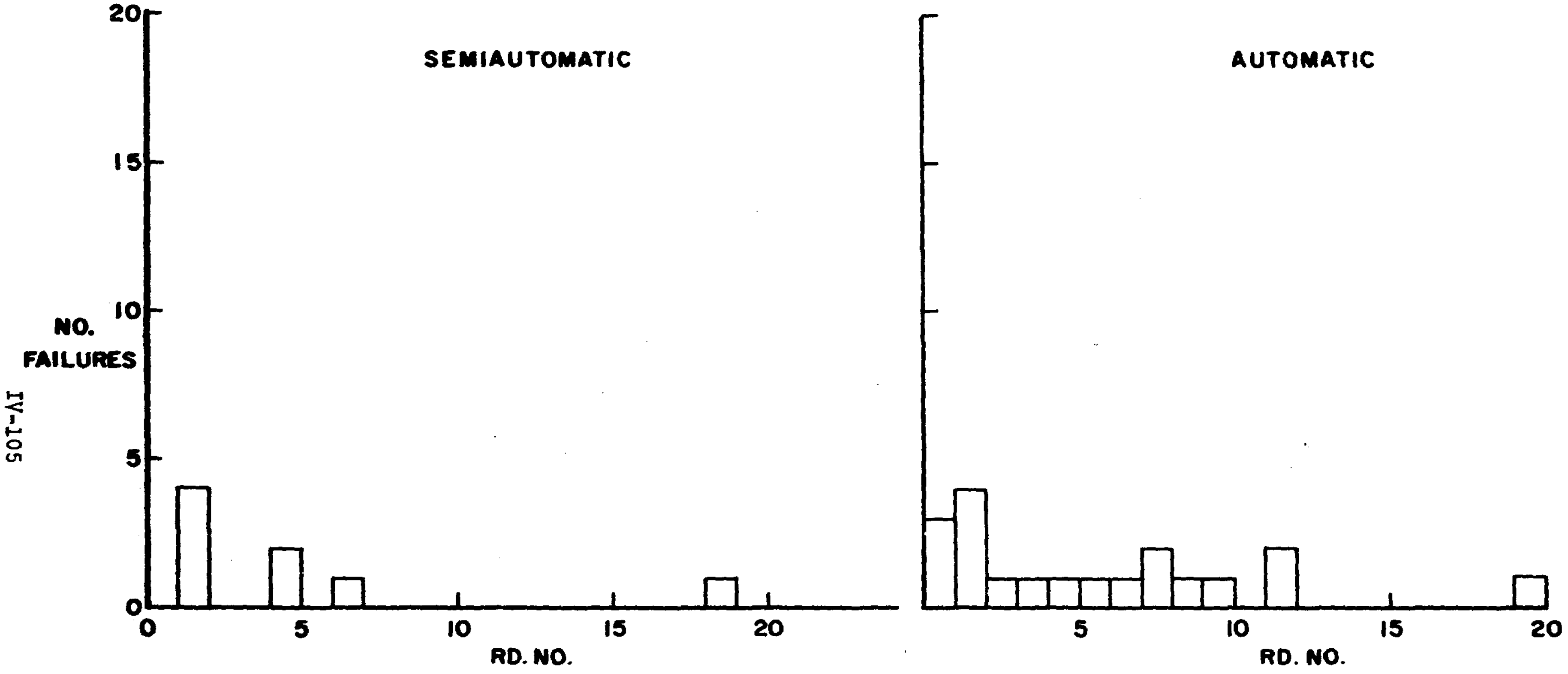


Figure IV-AA. IMR (M16) -Twenty Round Magazine-Failure to Extract

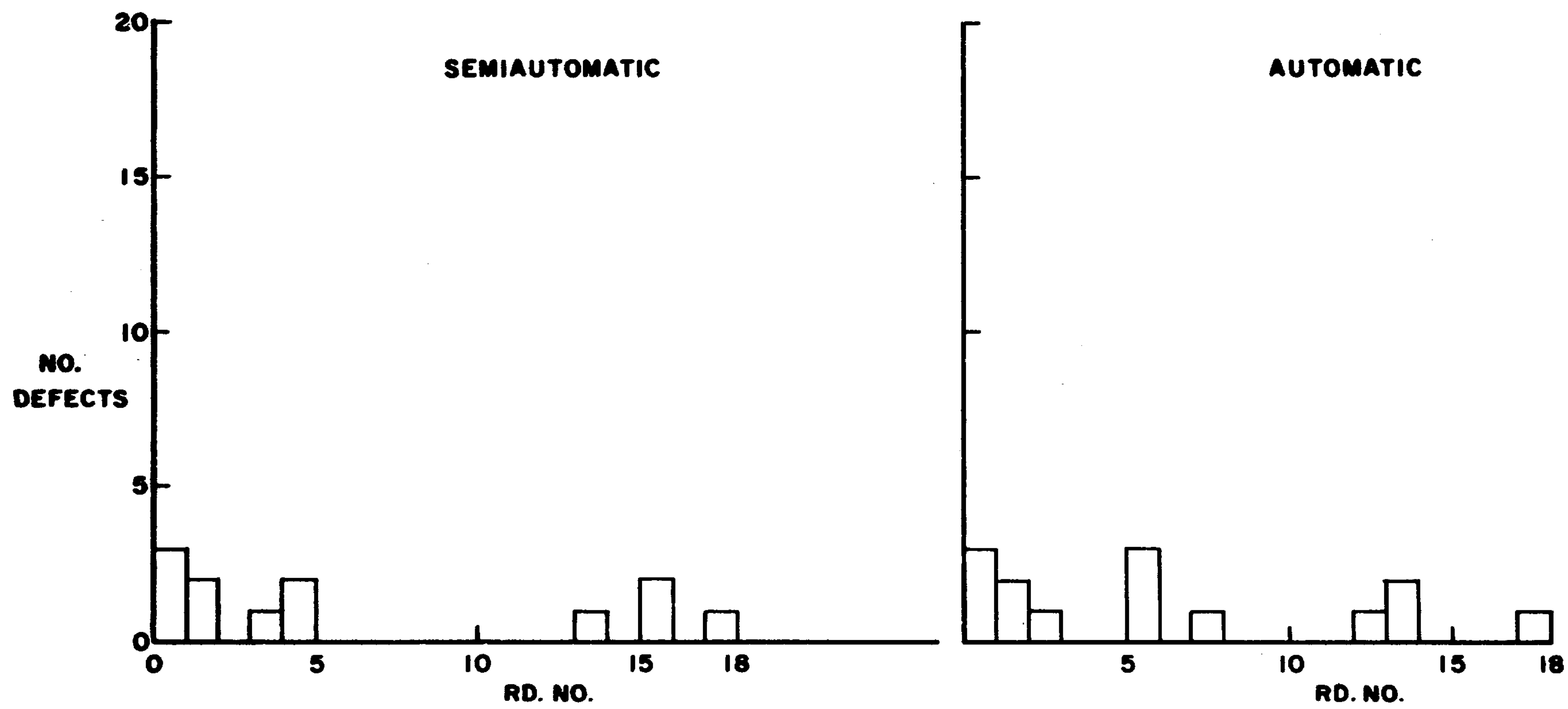


Figure IV-BB. IMR (M16)-Eighteen Round Clip-Failure to Extract

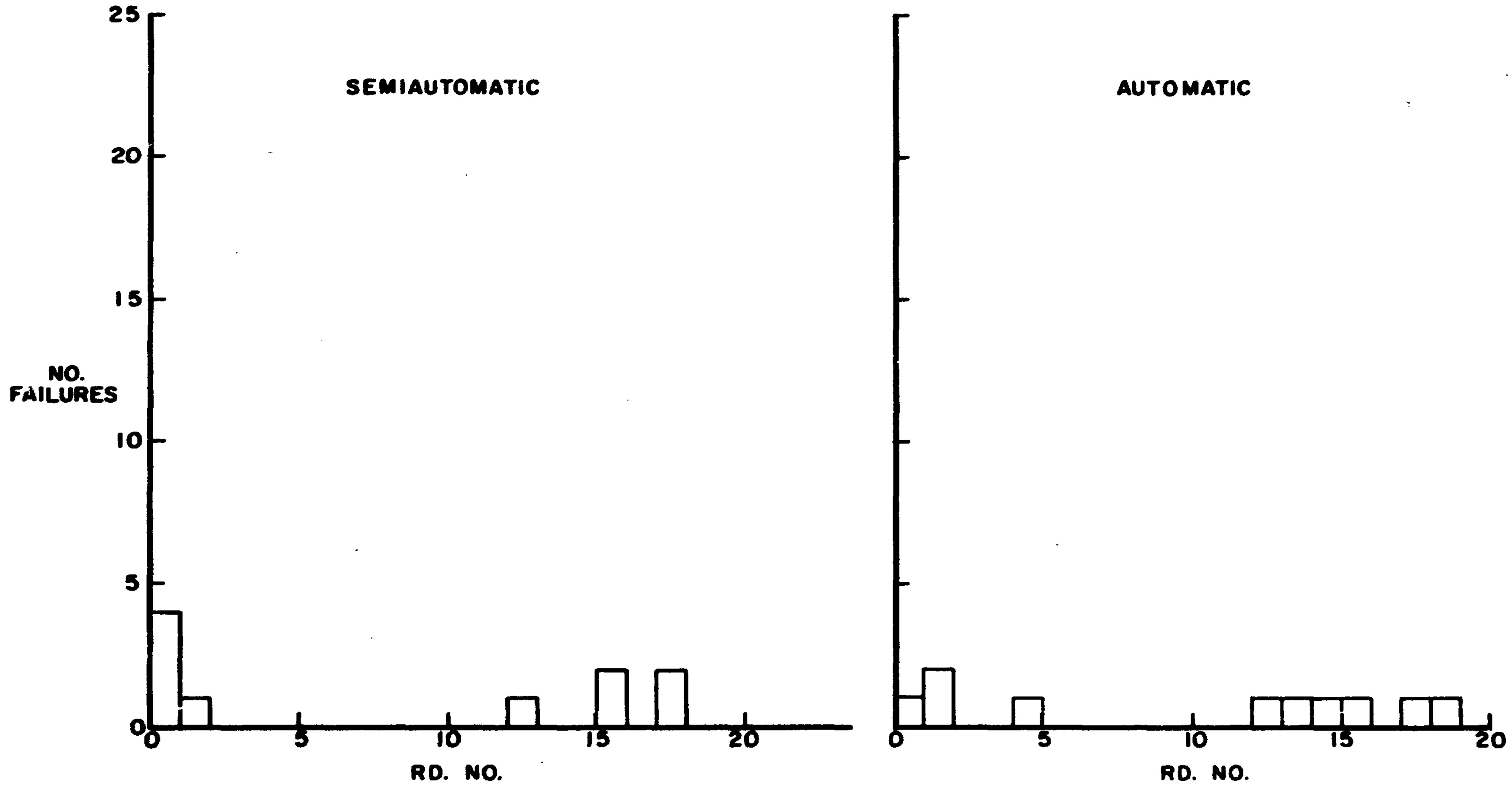


Figure IV-CC. Ball (M16) - Twenty Round Magazine - Two Rounds Fed from Magazine at Once

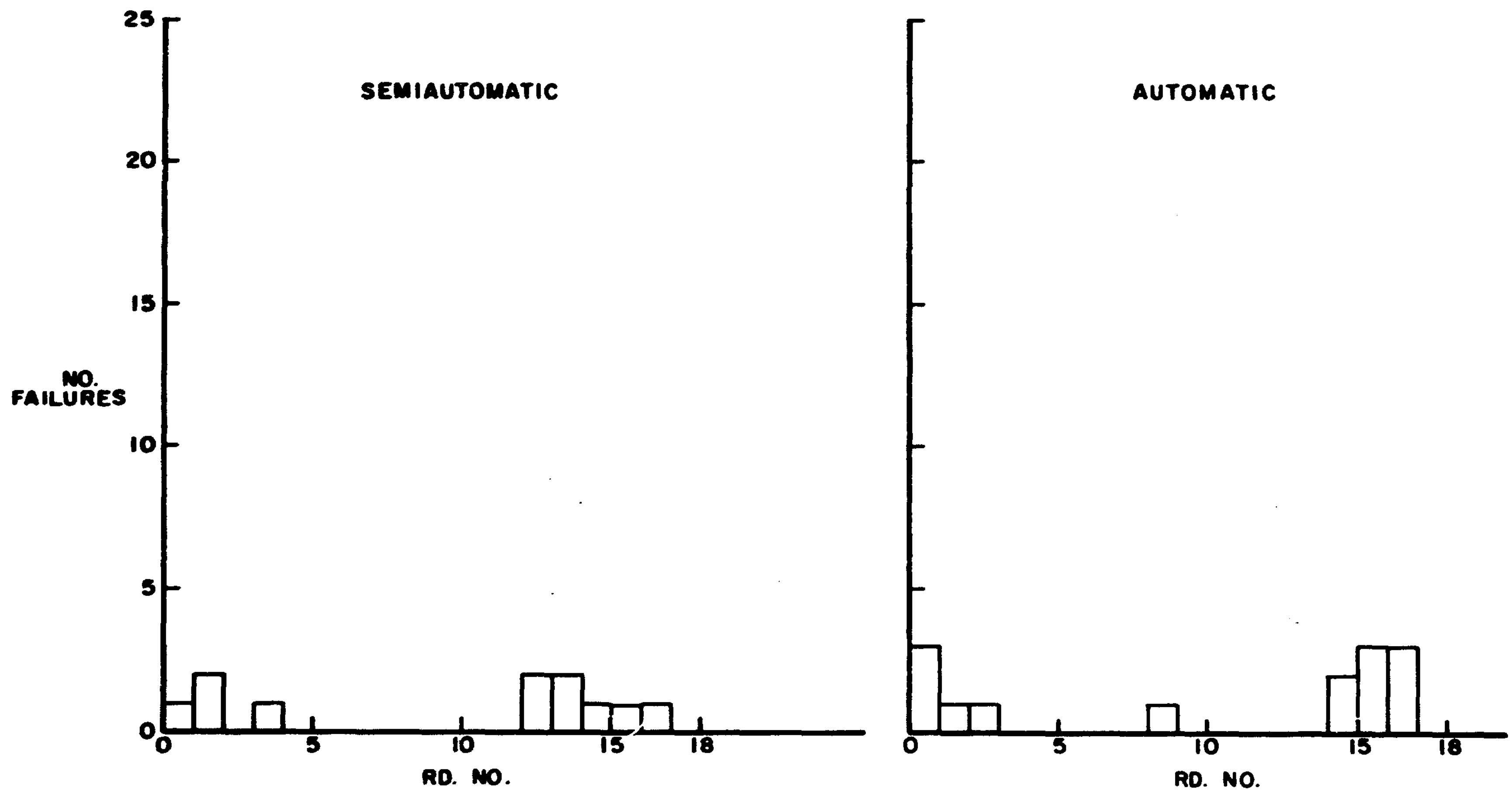


Figure IV-DD. Ball (M16) - Eighteen Round Magazine - Two Rounds Fed from Magazine at Once

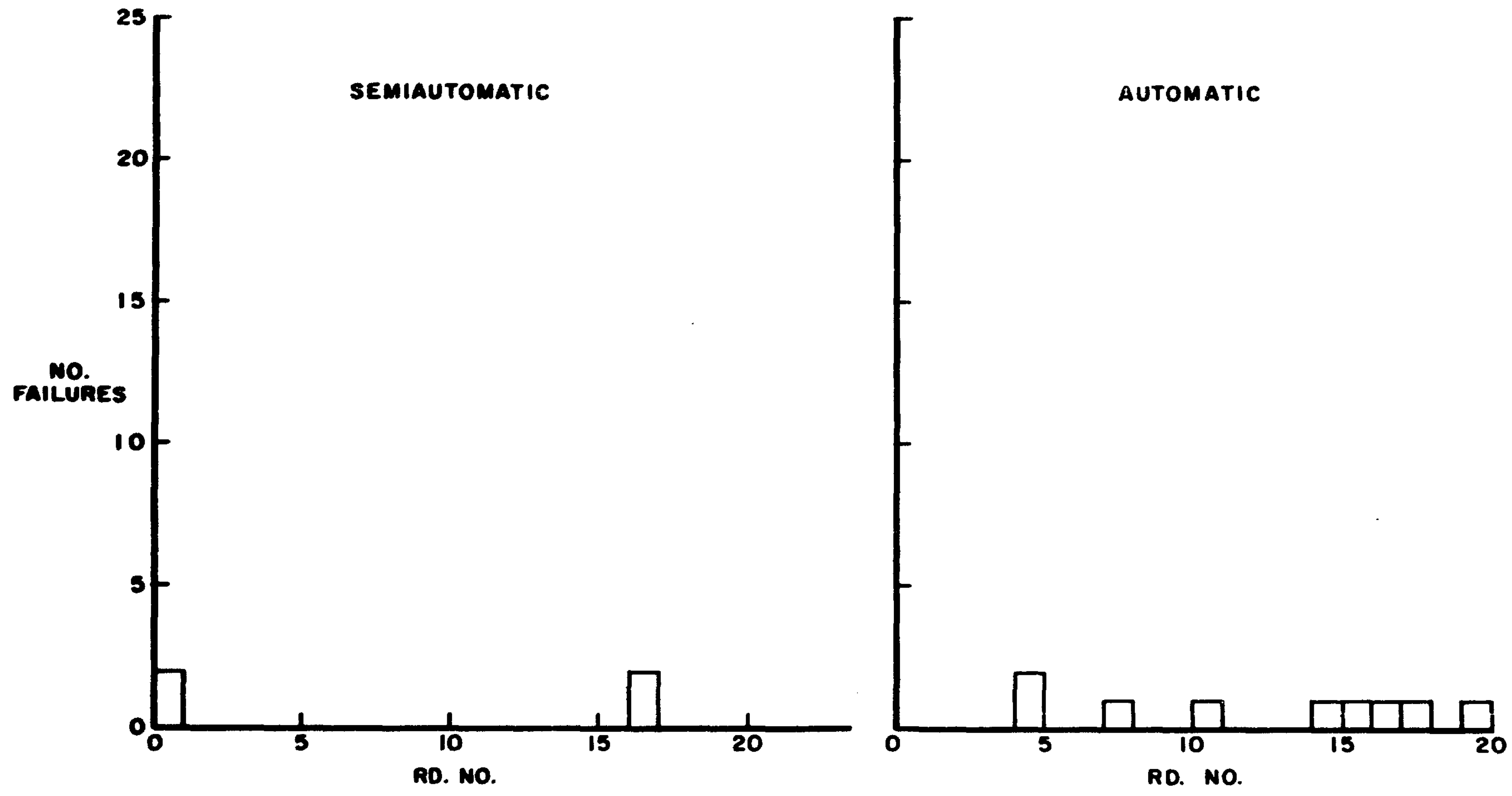


Figure IV-EE. IMR (M16) - Twenty Round Magazine - Two Rounds Fed from Magazine at Once

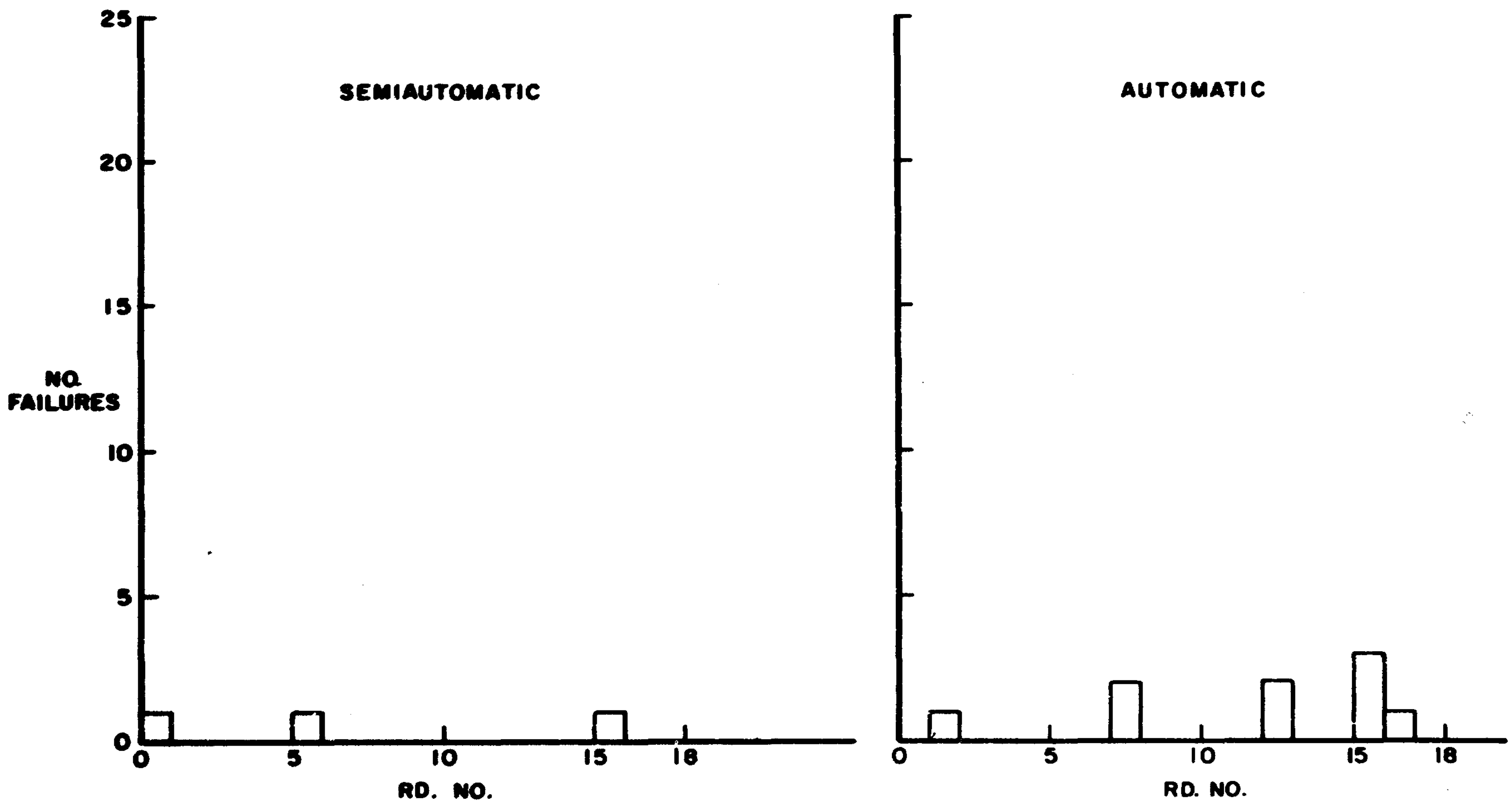


Figure IV-FF. IMR (M16) - Eighteen Round Magazine - Two Rounds Fed from Magazine at Once

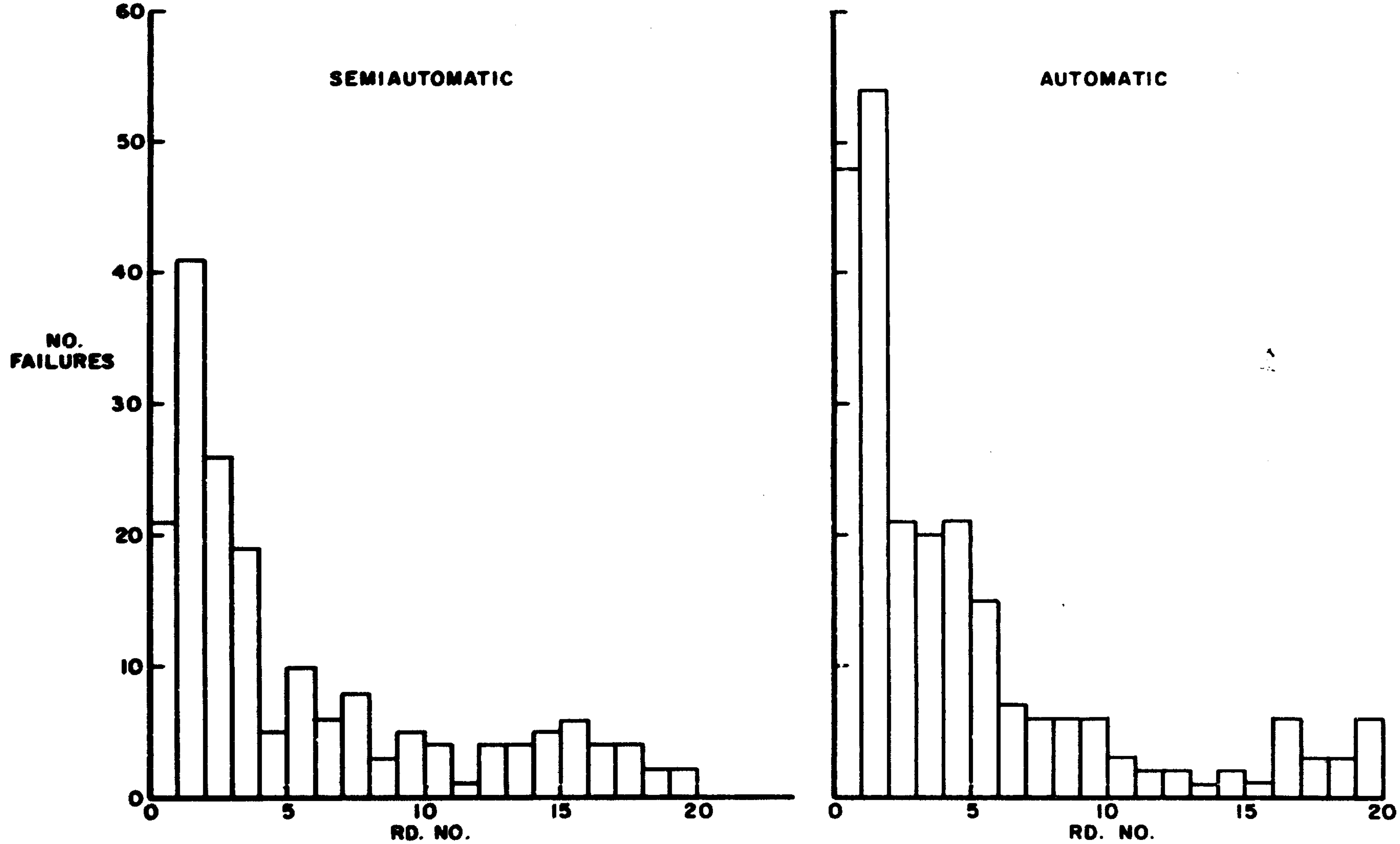


Figure IV-GG. M14-Twenty Round Magazine - Total Over All Type Failures

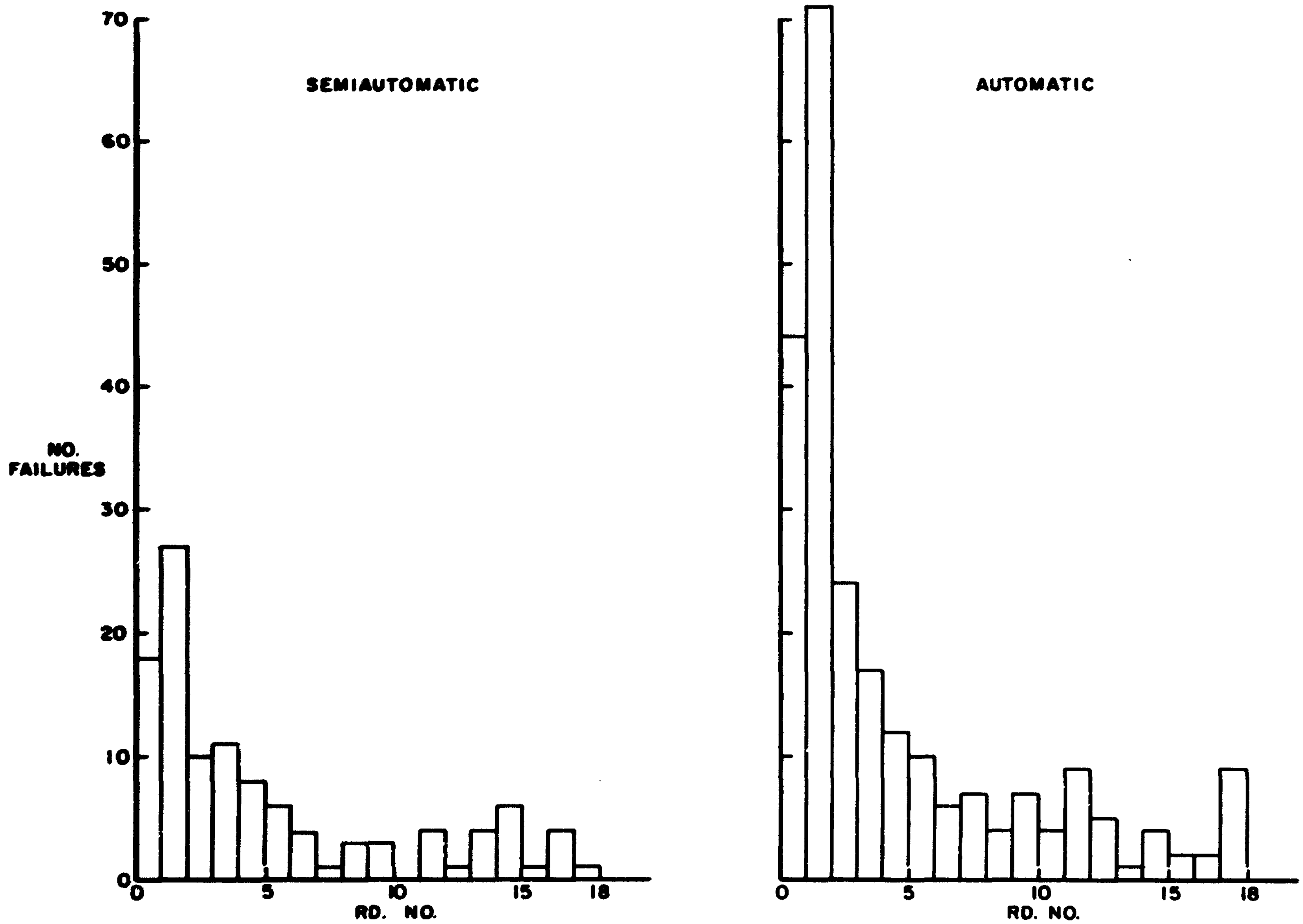


Figure IV-HH. M14-Eighteen Round Magazine - Total Over All Type Failures

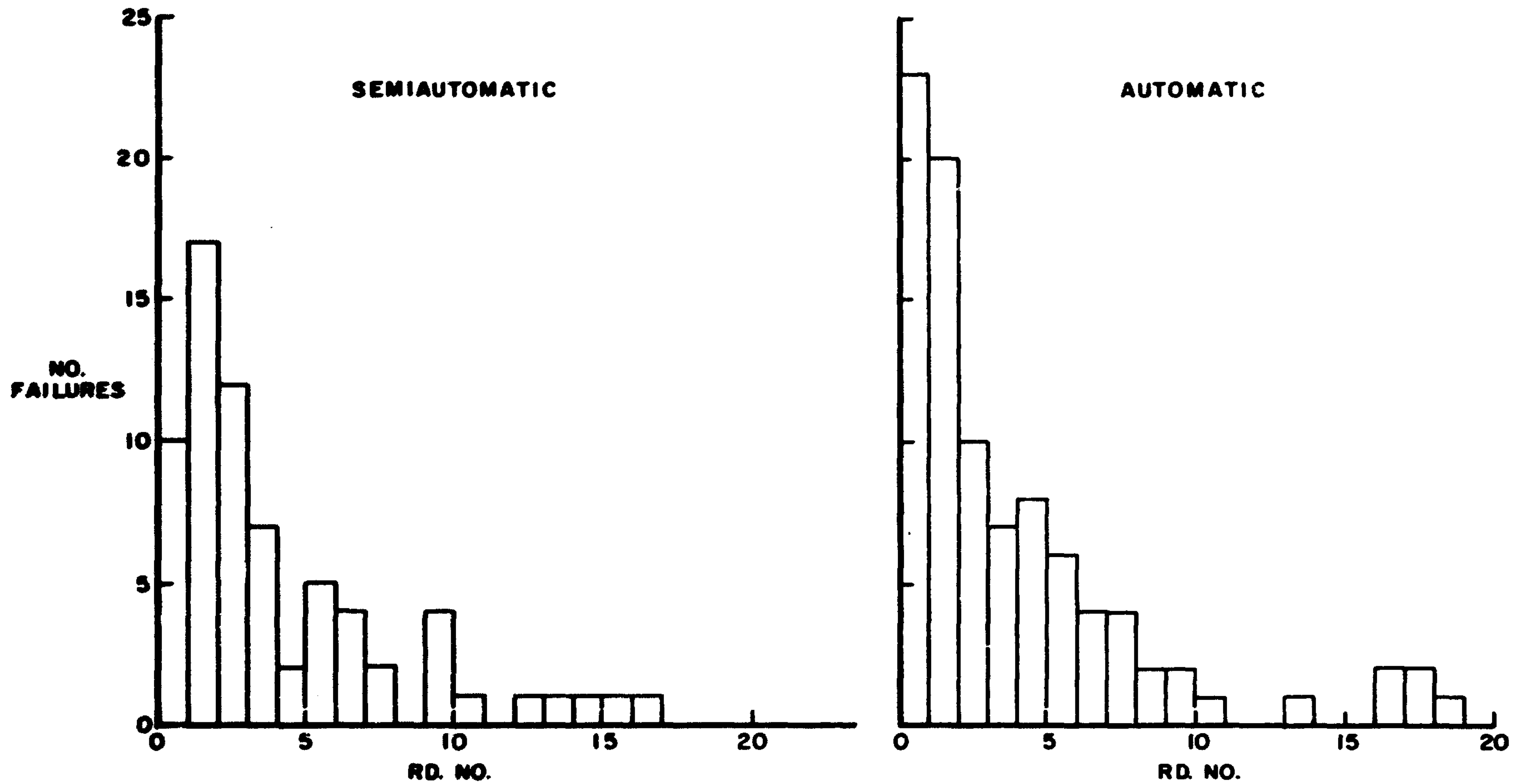


Figure IV-II. M14-Twenty Round Magazine - Failure to Feed

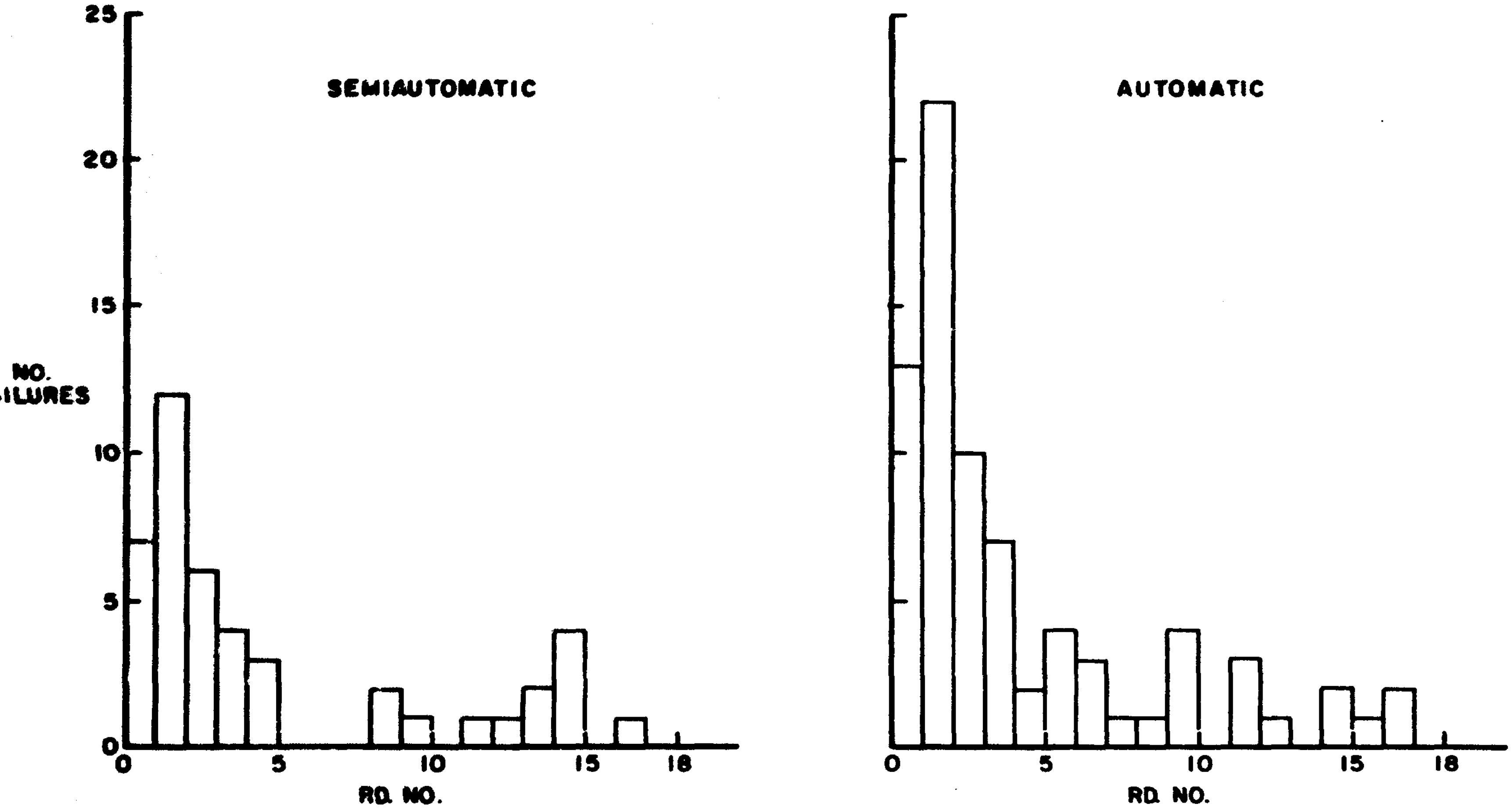


Figure IV-JJ. M14-Eighteen Round Magazine - Failure to Feed

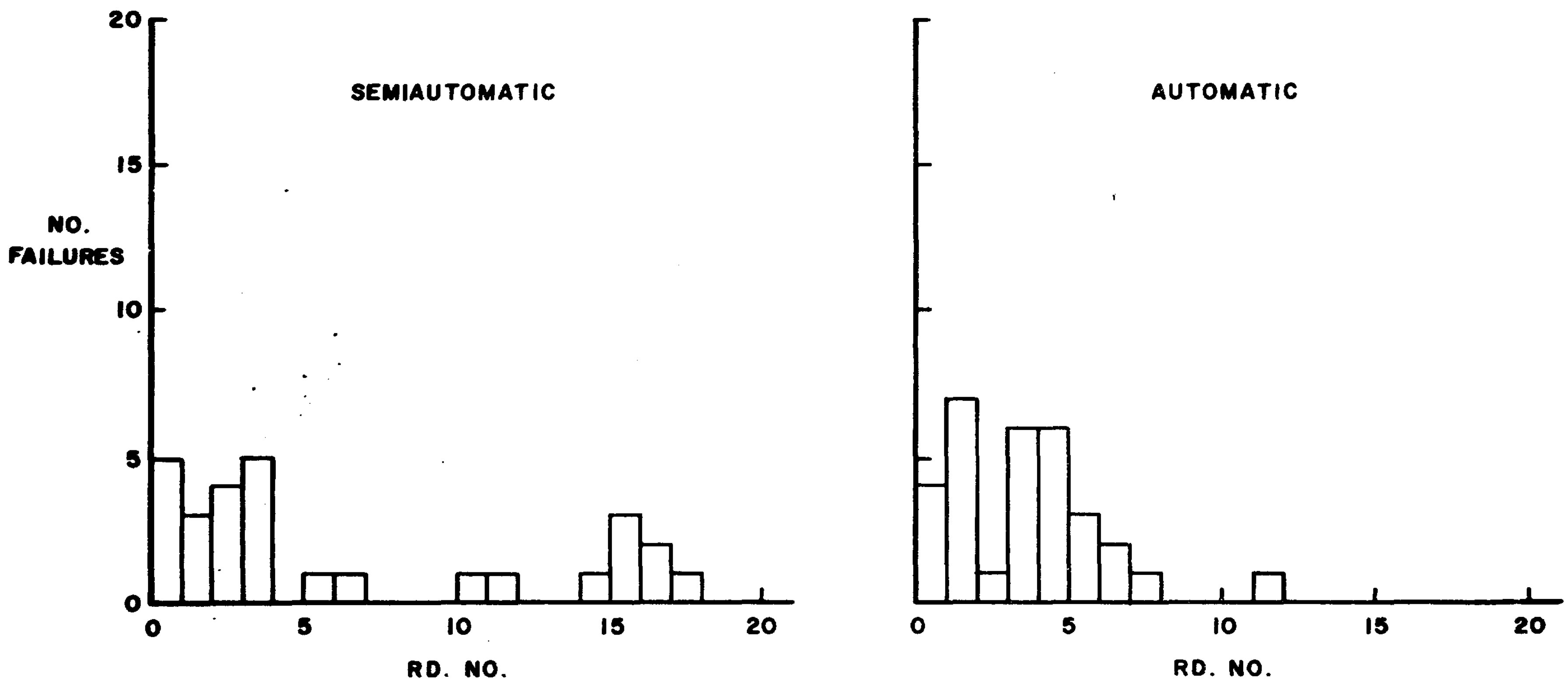


Figure IV-KK. M14 Twenty Round Magazine - Failure to Chamber

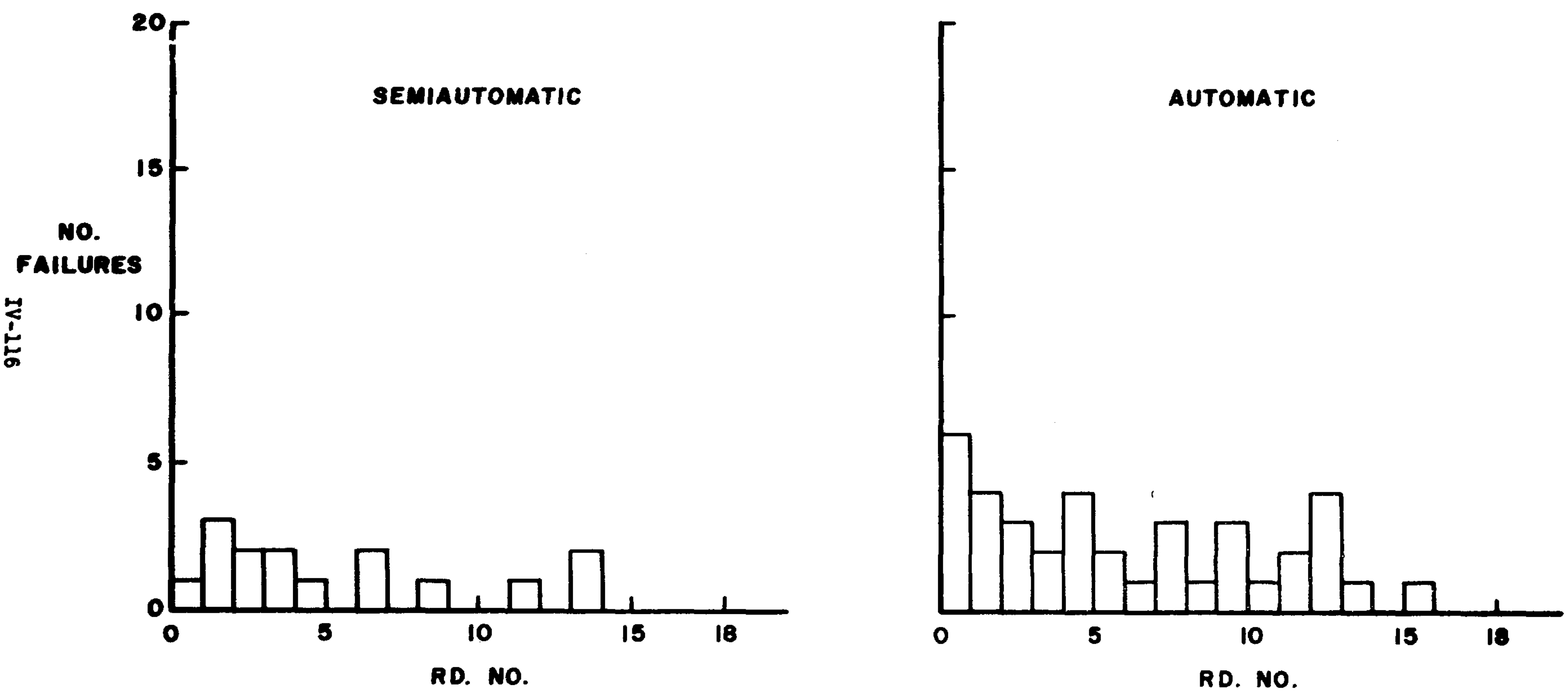


Figure IV-LL. M14 Eighteen Round Magazine - Failure to Chamber

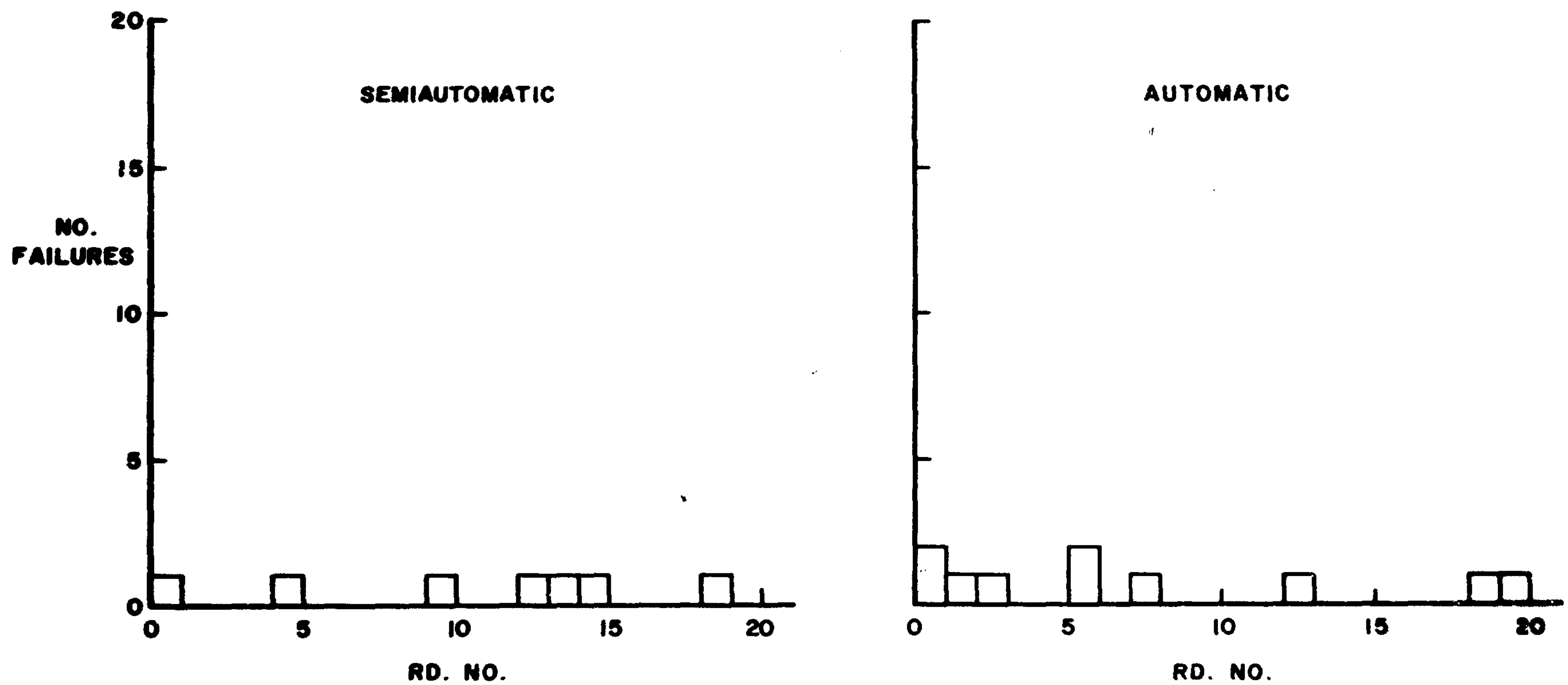


Figure IV-MM. M14 Twenty Round Magazine – Failure to Lock

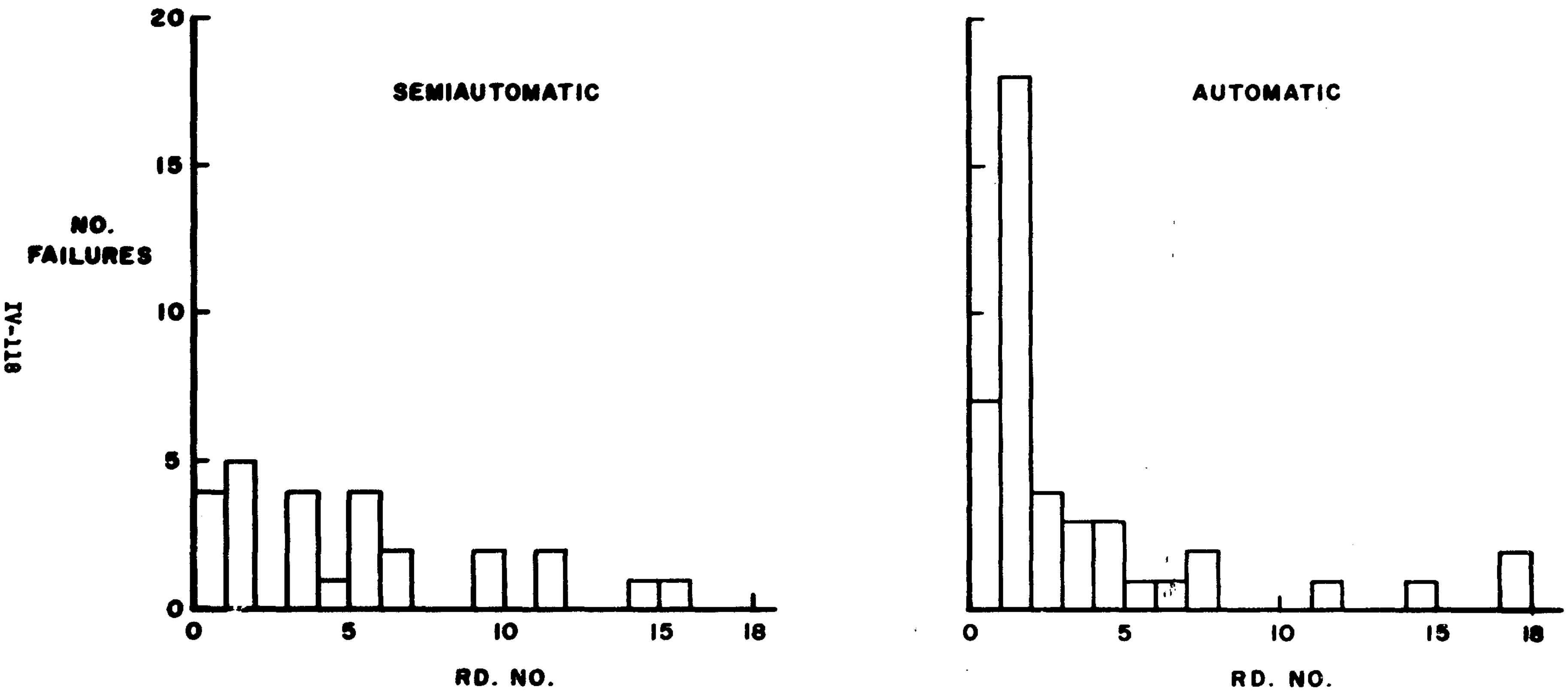


Figure IV-NN. M14 Eighteen Round Magazine – Failure to Lock

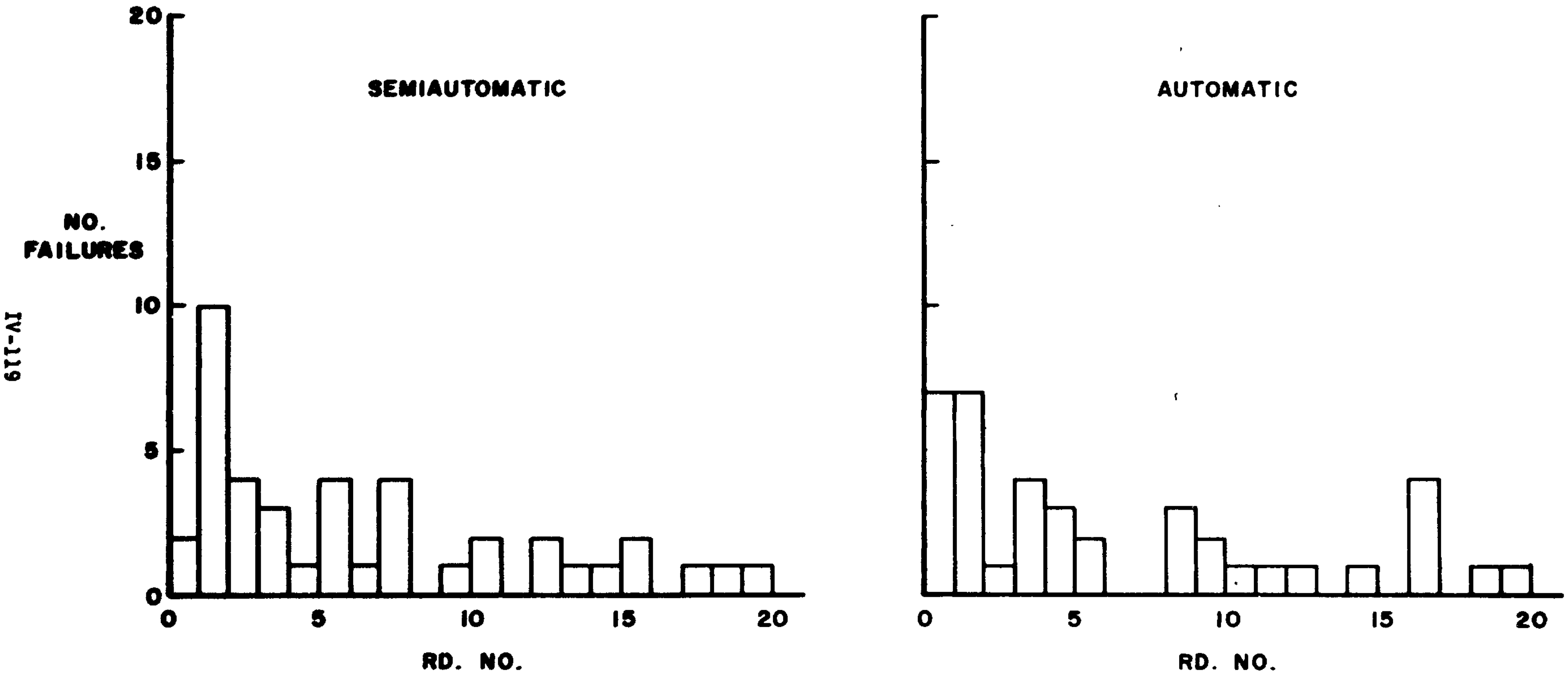


Figure IV-00. M14 Twenty Round Magazine – Failure to Fire

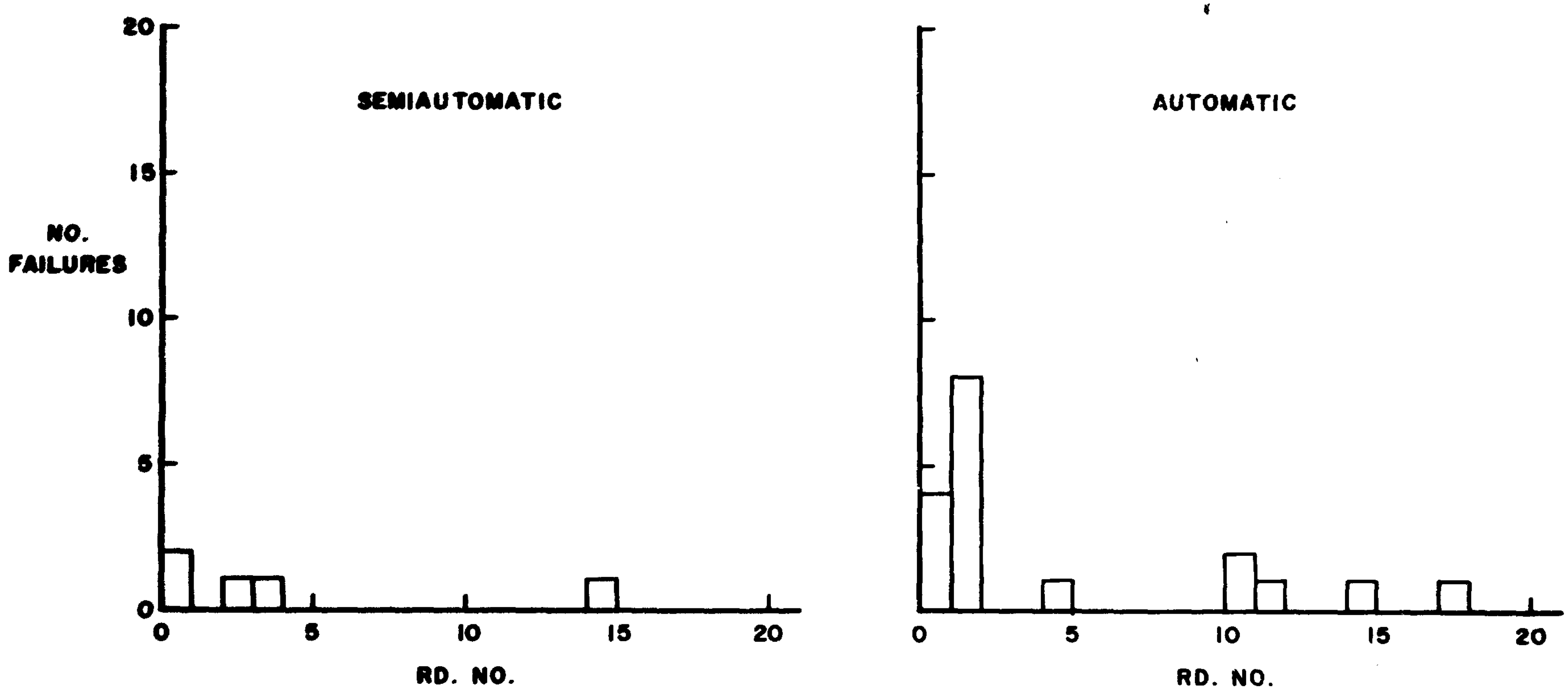


Figure IV-PP. M14 Eighteen Round Magazine - Failure to Fire

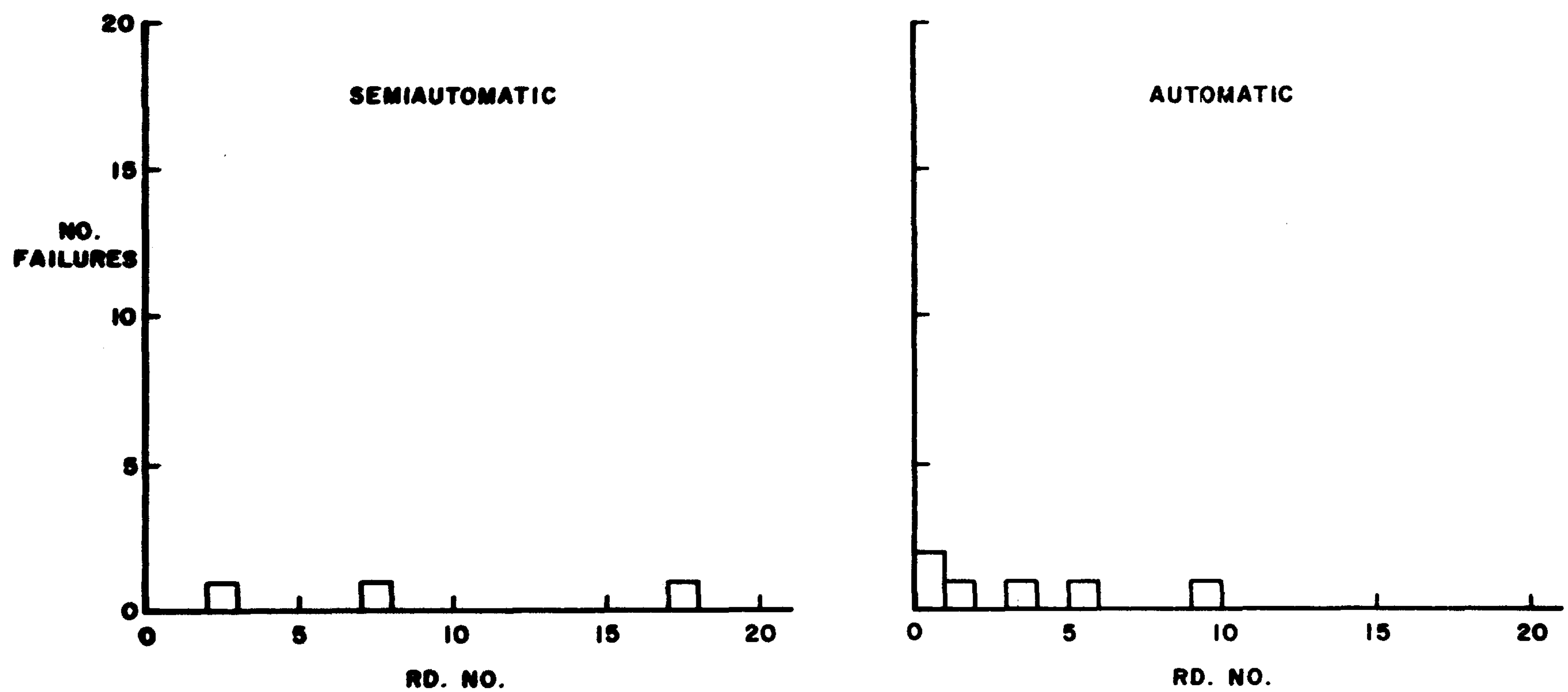


Figure IV-QQ. M14 Twenty Round Magazine - Failure to Eject

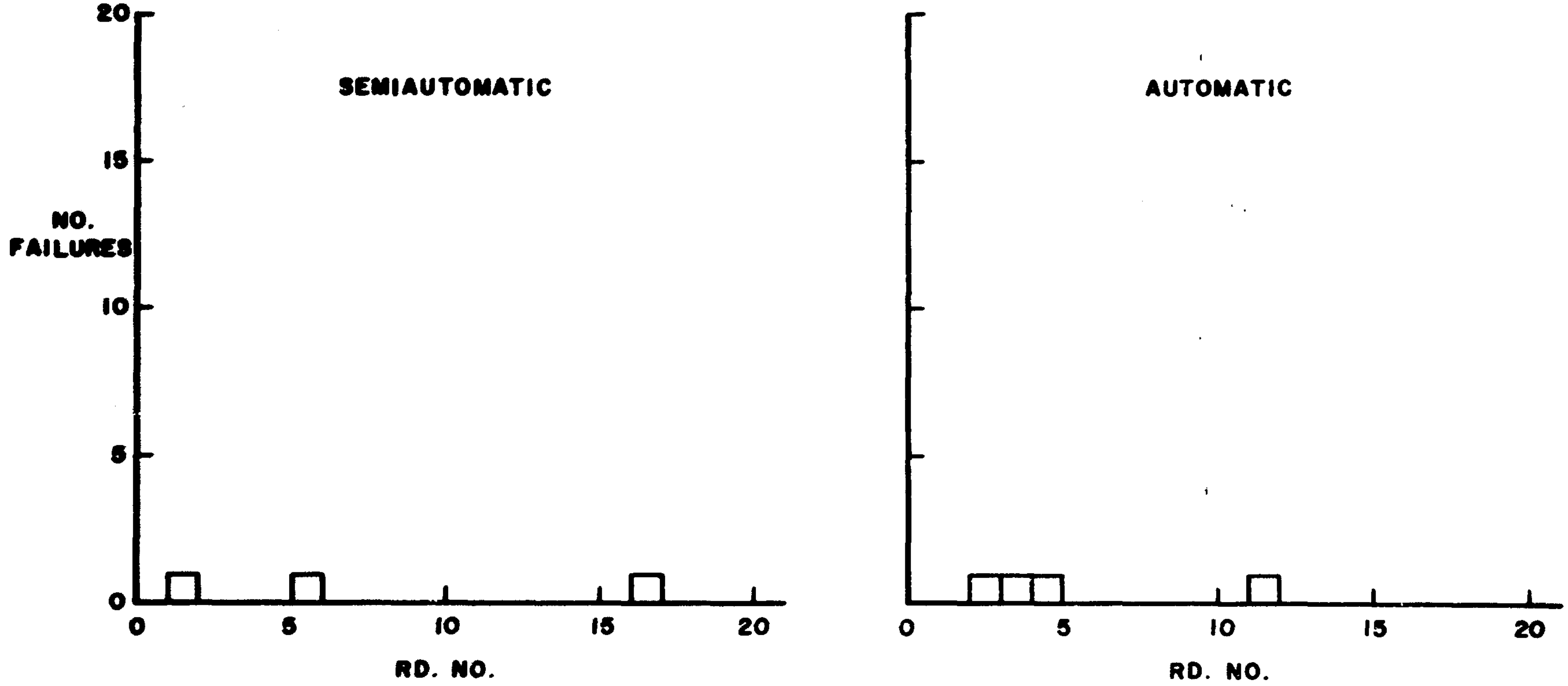


Figure IV-RR. M14 Eighteen Round Magazine - Failure to Eject

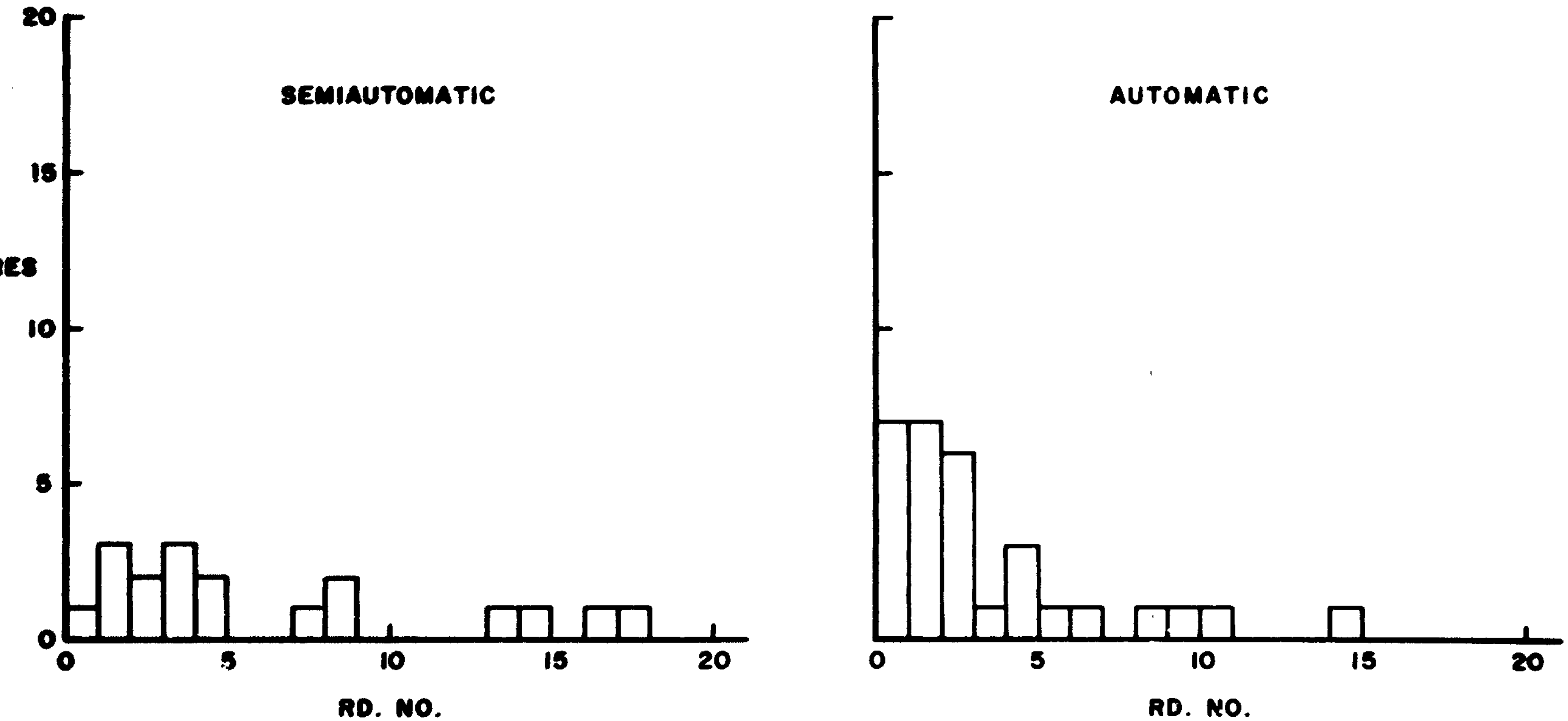


Figure IV-SS. M14 Twenty Round Magazine – Failure to Extract

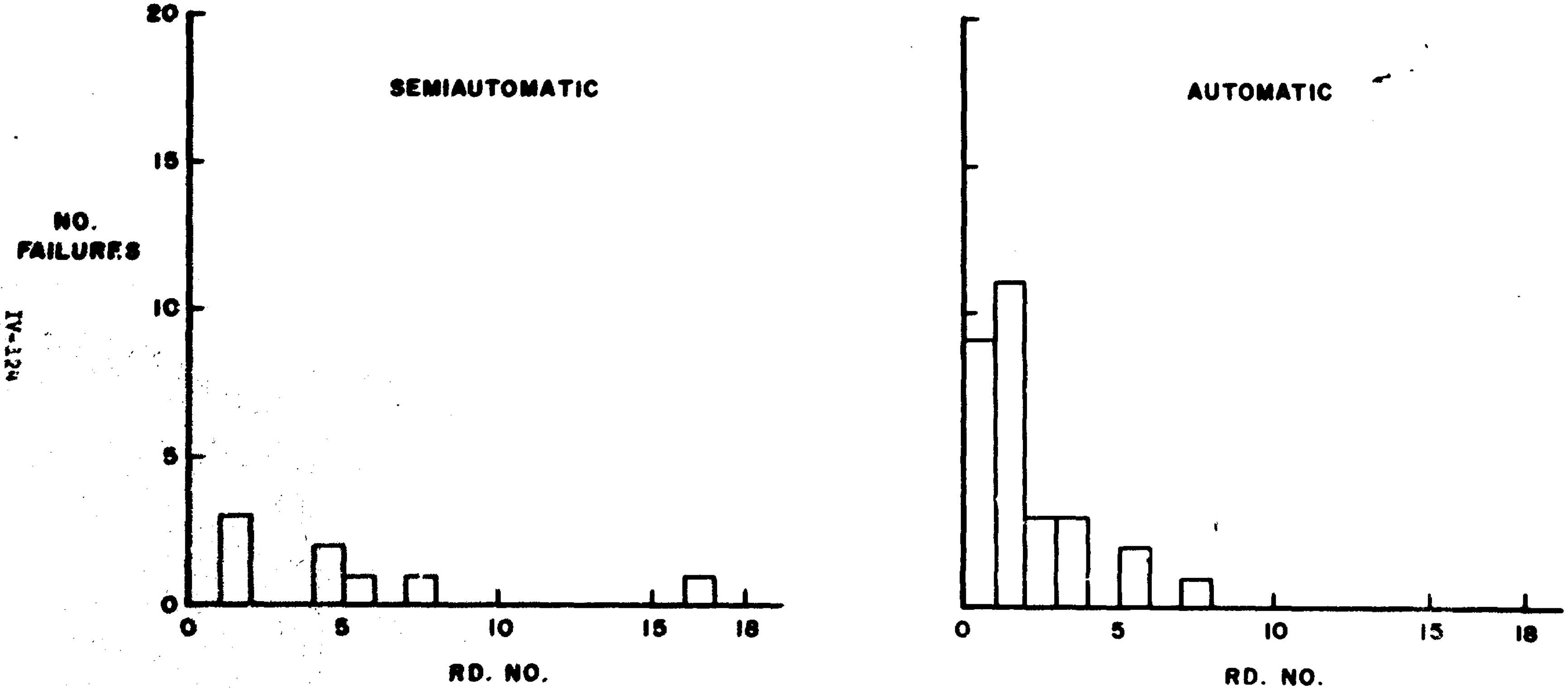


Figure IV-TT. M14 Eighteen Round Magazine - Failure to Extract

SECTION V

CYCLIC RATE ANALYSIS

Effect of Cyclic Rate on Number of Malfunctions

After the WSEG test was completed, the rifles were shipped to Aberdeen Proving Ground, where each weapon was cleaned, lubricated, and fired to measure cyclic rate. Three twenty-round bursts were fired and the cyclic rate for each burst was measured.

Since the cyclic rate was measured, after approximately 6,000 rounds had been fired from each rifle, it is probably true that the characteristics of each rifle had changed appreciably from the time that it was first fired. It is also probably true that the rate of change due to wear for each characteristic of the rifle varied greatly from rifle to rifle. Therefore, if malfunctions that occurred at different times in the life of the rifle are related to cyclic rates that were measured at a later time in the life of the rifle, it is clearly possible that, although a true relationship exists, the results may not indicate this relationship because of the additional error due to variable changes in rifle characteristics. However, in the event that the data, in spite of the additional error, indicates that the malfunction rate is a function of cyclic rate; the results may be accepted with a high degree of confidence.

When considering all malfunctions, it was found that the malfunction rate was not a function of cyclic rate. However, since it appeared that feeding and chambering failures and failure of the bolt to remain to the rear were, to a large extent, a function of low cyclic rates; an analysis was made of the cyclic rates associated with these malfunction types. Figure V-A graphically shows this relationship and the results indicate a non-linear decreasing function. When comparing the cyclic rates with the remaining malfunctions, it can be seen from Figure V-A that another non-linear relationship exists, but in the opposite direction. These results indicate that both a low and a high cyclic rate have adverse effects upon malfunction rates. There appears to be an optimum point near the center of the distribution of cyclic rates, and deviations in either direction from this point result in an increased number of malfunctions.

The actual cyclic rates recorded here should not be used to determine the optimum rate since they do not represent the rate at the time of malfunction. In fact, it is known that the cyclic rate is dependent upon numerous factors, such as lubrication, temperature, propellant, age of weapon, and many others. For this reason, the rates recorded for this test should be viewed with respect to their relative position under the conditions of the test. The validity of this comparison is dependent upon the assumption that a rifle with an inherently high cyclic rate will tend to function at a higher rate at any age or under all conditions. This would also apply to rifles firing with a low cyclic rate, etc. Those whose rates tend to be near the average should produce the fewest malfunctions.

The method used in fitting these curves was developed by Willoughby.[3]

[3]Willoughby, W. F., Estimation of Time Fuze Characteristics by Nonlinear Regression Methods, Ballistic Research Laboratories, Memo Report No. 1819, 1967.

Cyclic Rate by Propellant Lots and Propellant Types

An analysis of the cyclic rates indicates, as expected, that the ball propellant produced significantly higher cyclic rates than IMR propellant. (The average difference was 113 rds/min.) However, it was also found that the cyclic rates differed significantly between lots within propellant types. The cyclic rate for A_1 (Remington-ball) propellant averaged 20 rds/min higher than A_2 (Lake City-ball) propellant, and the cyclic rate for A_3 (Twin City-IMR) propellant averaged 30 rds/min higher than A_4 (Lake City-IMR) propellant. These differences are probably primarily responsible for the lot differences noted in certain defect rates found in Section III.

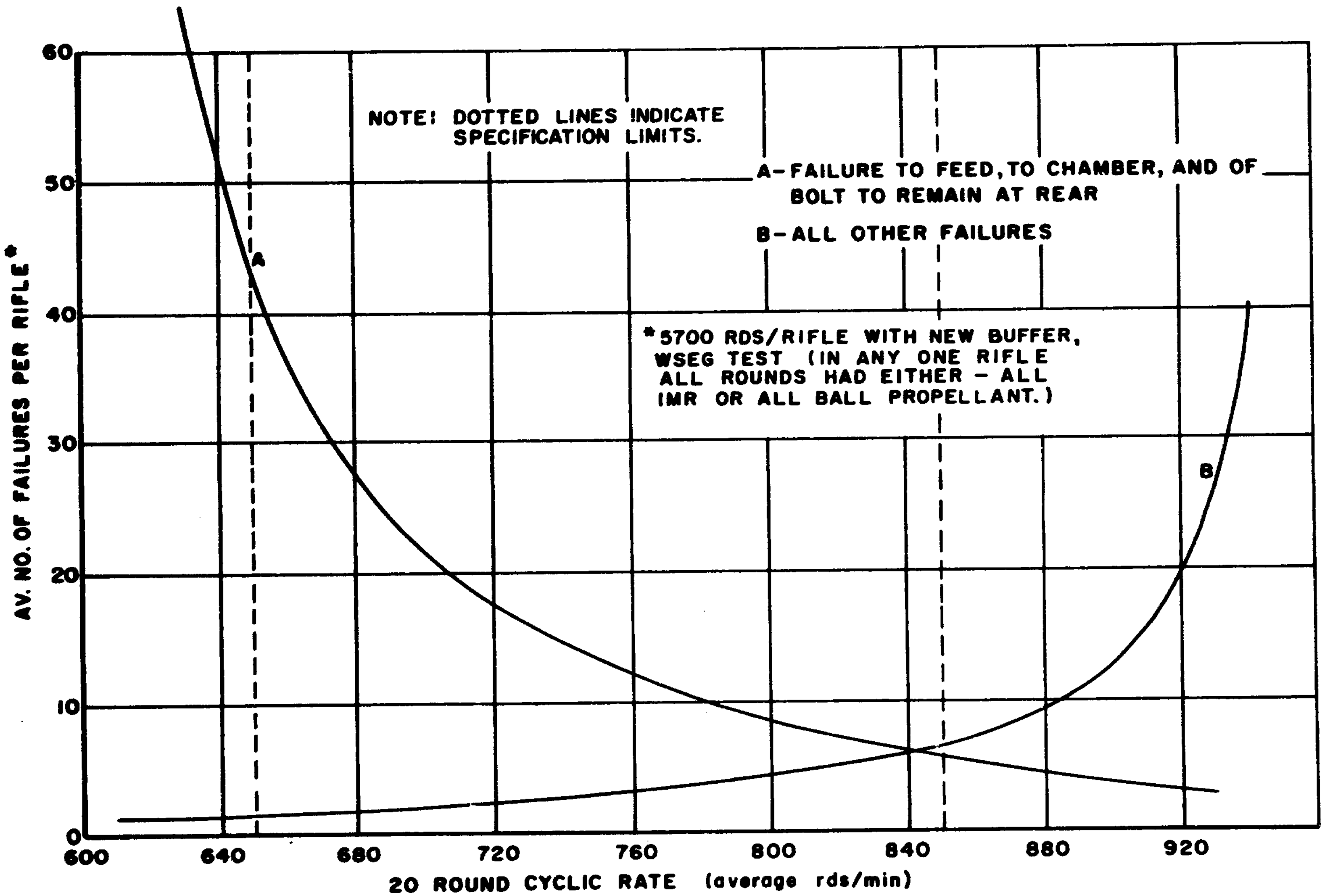


Figure V-A. Relation Between Failure Rate and Cyclic Rate for Two Classes of Failures.

SECTION VI

AVERAGE NUMBER OF ROUNDS BETWEEN

(i-1) st AND i th FAILURE

This study was based on the mean rounds between failures computed in the manner described in Section II of this report. The average number of rounds between the 0th failure and the first failure is defined to designate the mean rounds to first failure. The rounds between subsequent failures is self-explanatory.

Figures VI-A through VI-H graphically portray this information for the eight most common failures. The graphs are truncated at the point where either no more failures occurred or where the number of failures were too infrequent to provide meaningful estimates. However, in any event, all graphs were truncated after 16 malfunctions.

A downward trend of a curve indicates that the mean rounds to stoppage is decreasing with each succeeding failure which indicates that the mean rounds to stoppage are dependent upon the number of previous failures. A relatively constant curve indicates that the mean rounds to stoppage are independent of preceding failures. This, however, does not indicate a constant failure rate. For instance, the fact that the means of two distributions are equal has no bearing on the nature of the failure rates associated with those distributions.

The interpretation of these graphs are otherwise obvious, and generally support what has already been concluded in preceding sections.

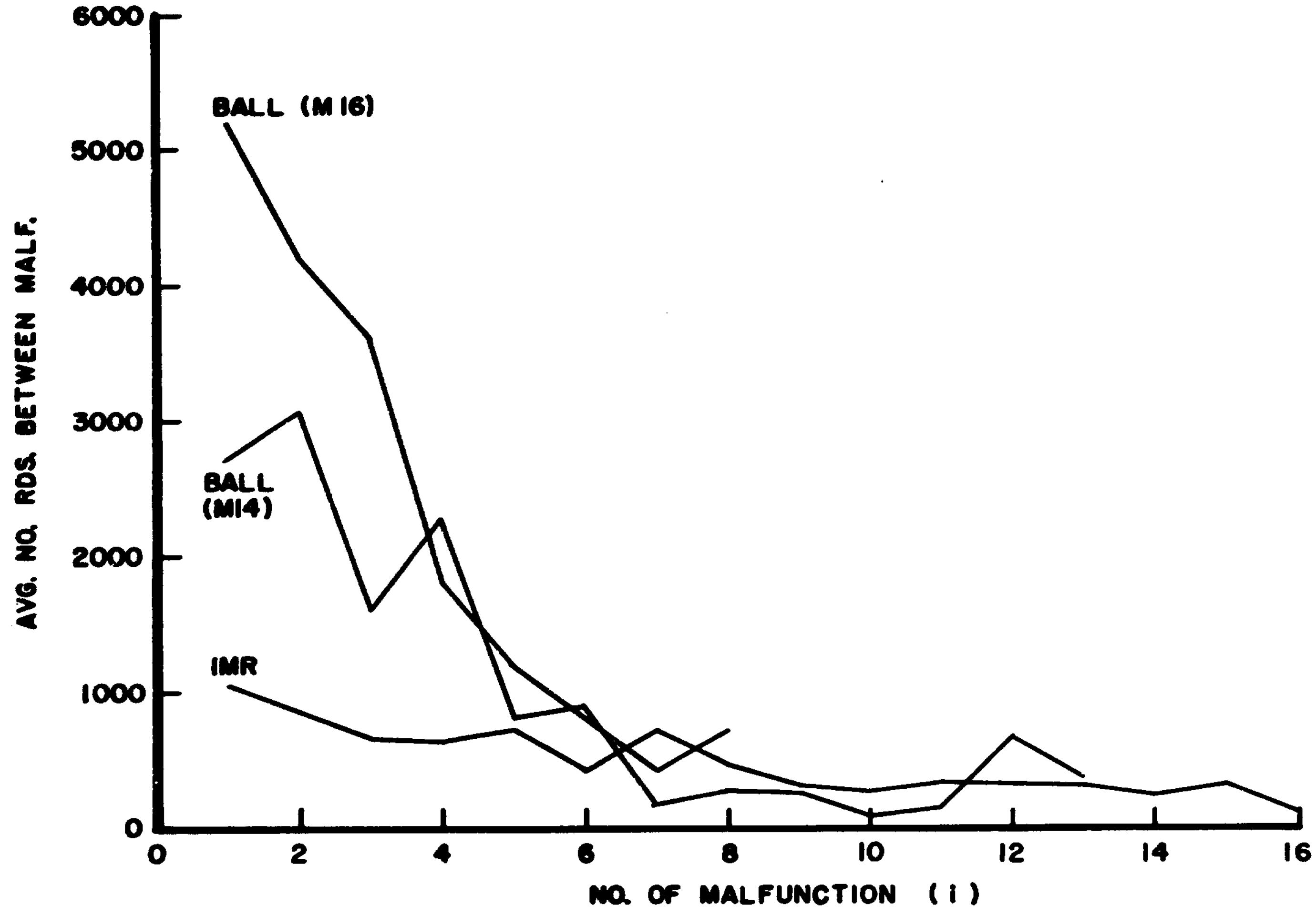


Figure VI-A. Avg. No. of Rounds between (i-1)st and ith Failure to Feed.

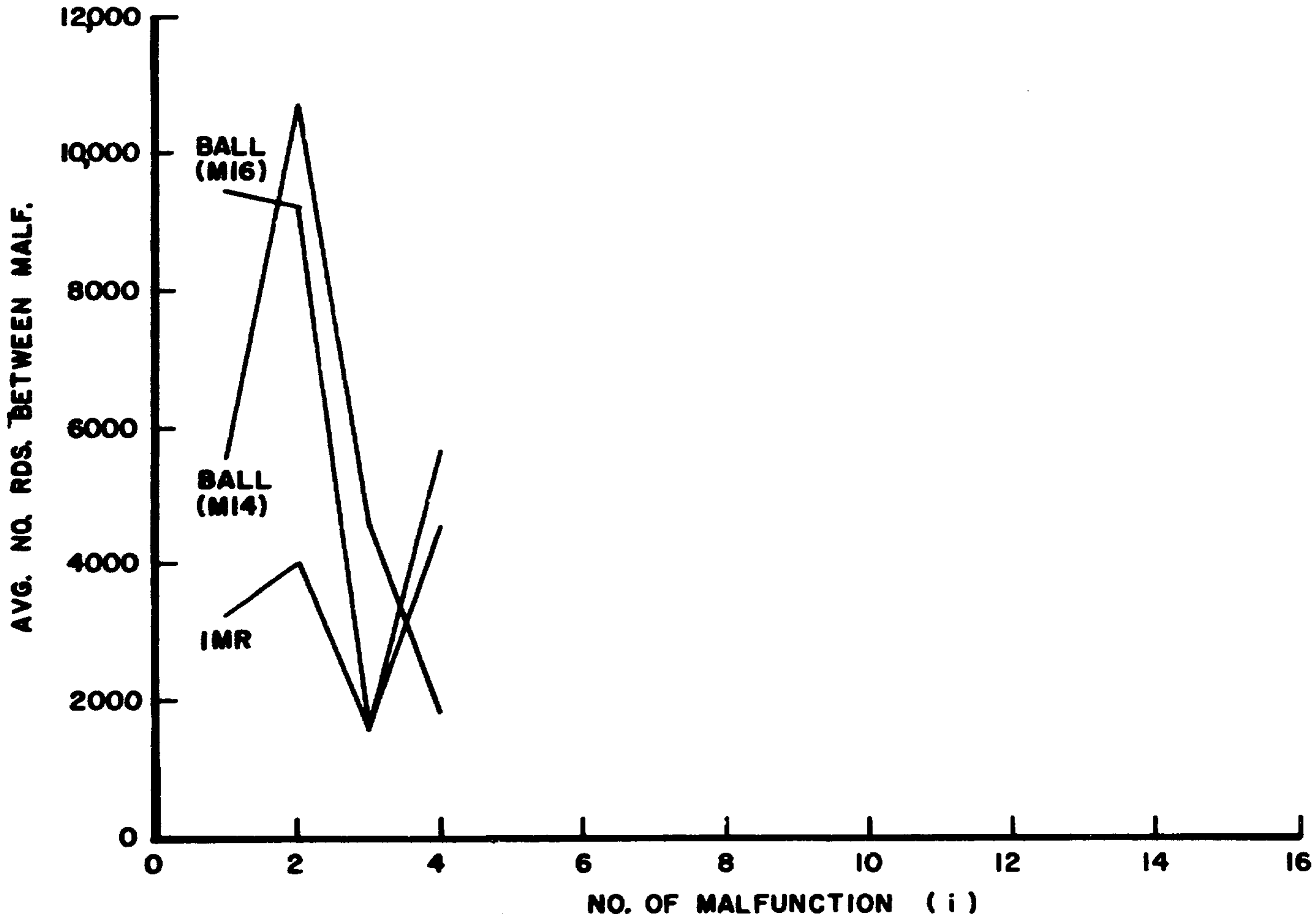


Figure VI-B. Avg. No. of Rounds between (i-1)st and ith Failure to Chamber.

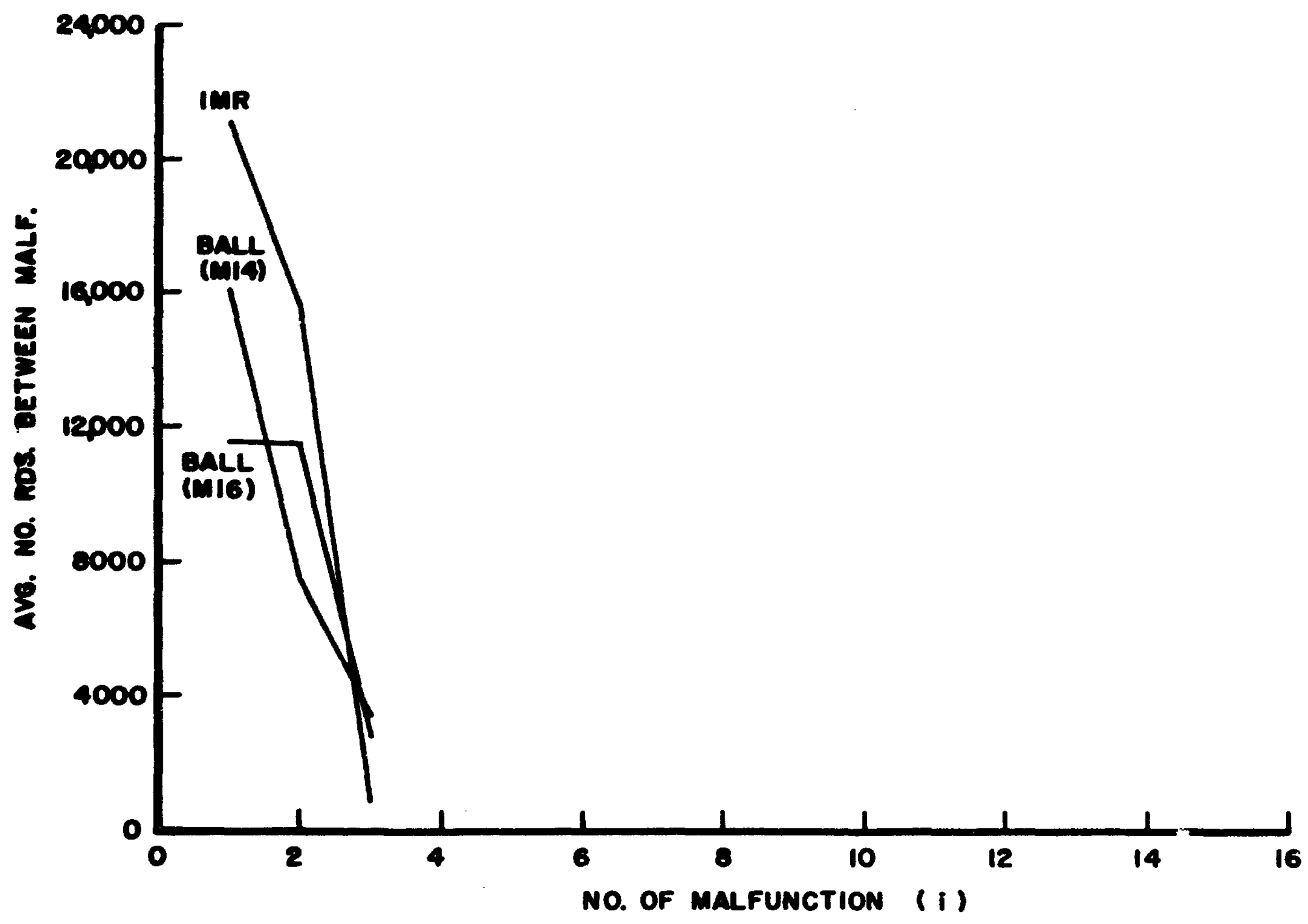


Figure VI-C. Avg. No. of Rounds between (i-1)st and ith Failure to Lock.

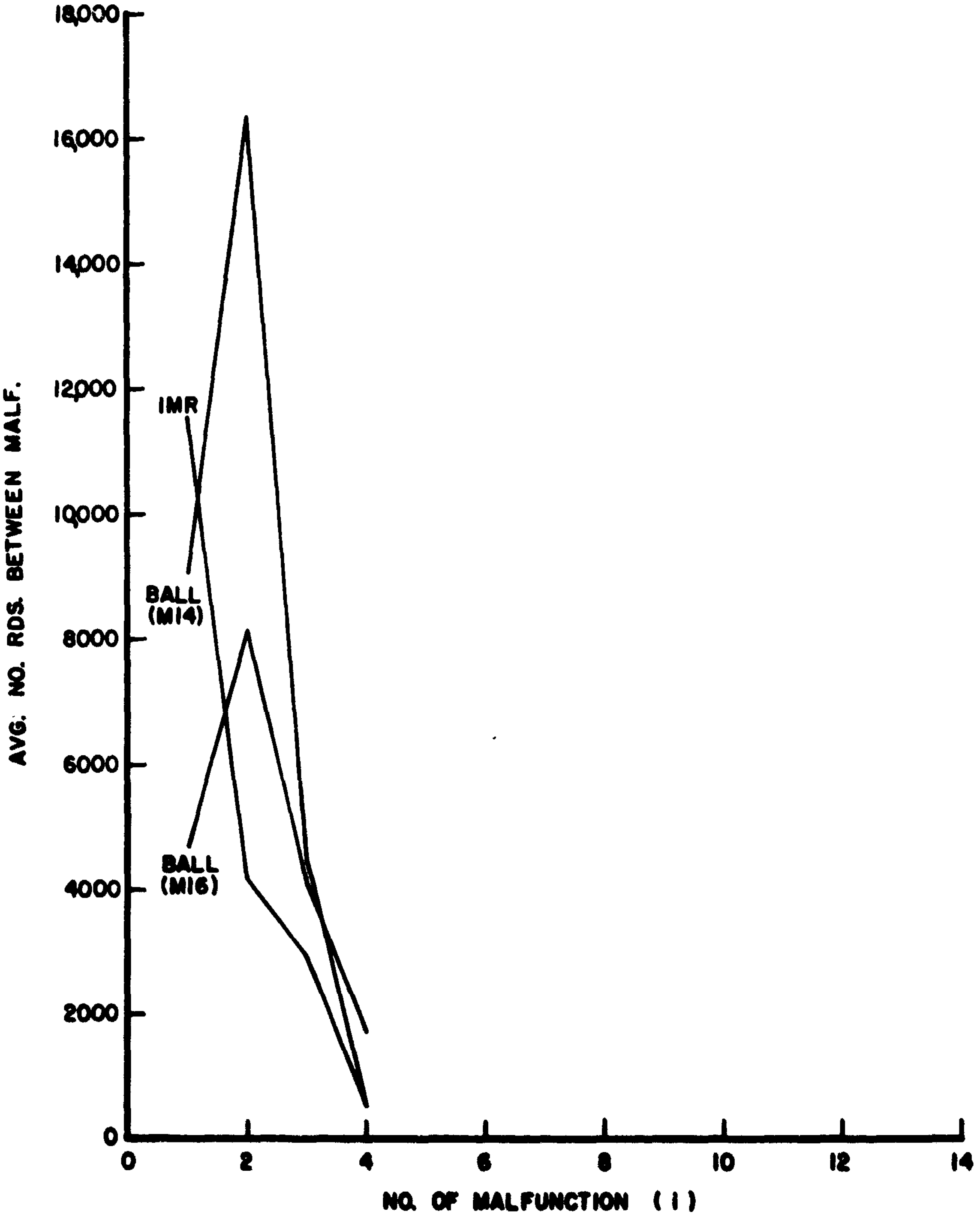


Figure VI-D. Avg. No. of Rounds between (i-1)st and ith Failure to Fire.

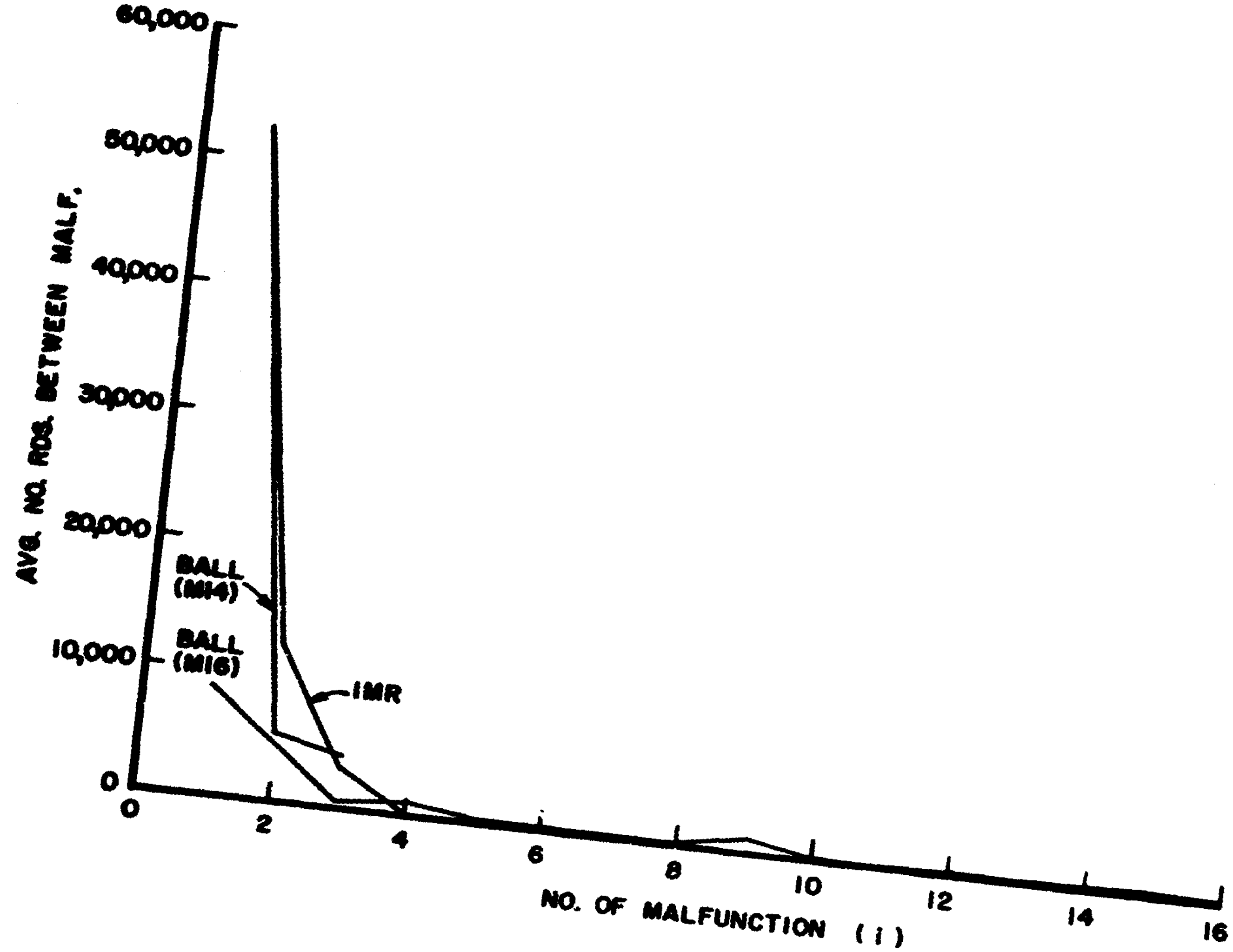


Figure VI-E. Avg. No. of Rounds between $(i-1)^{st}$ and i^{th} Failure to Eject.

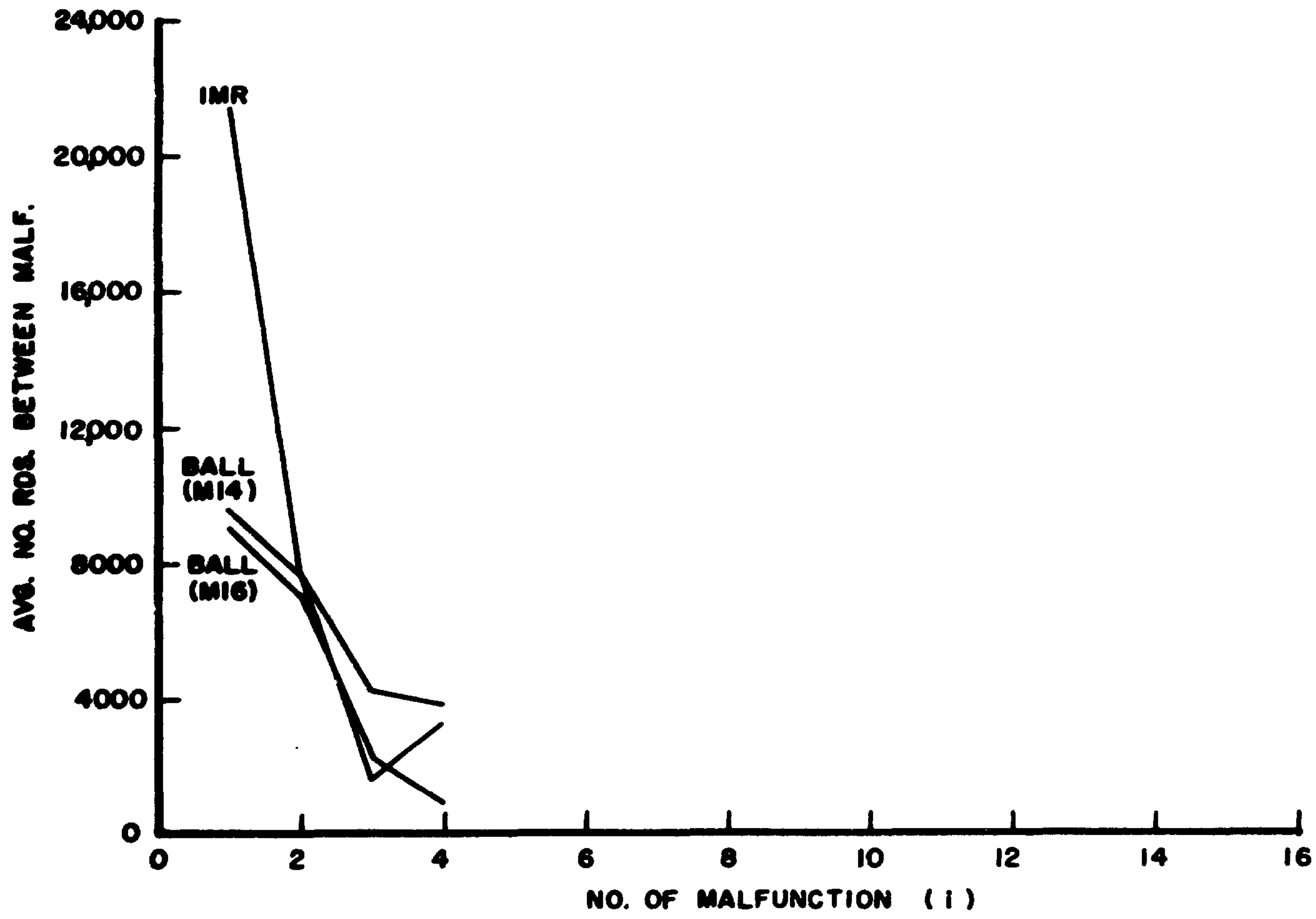


Figure VI-F. Avg. No. of Rounds between (i-1)st and ith Failure to Extract.

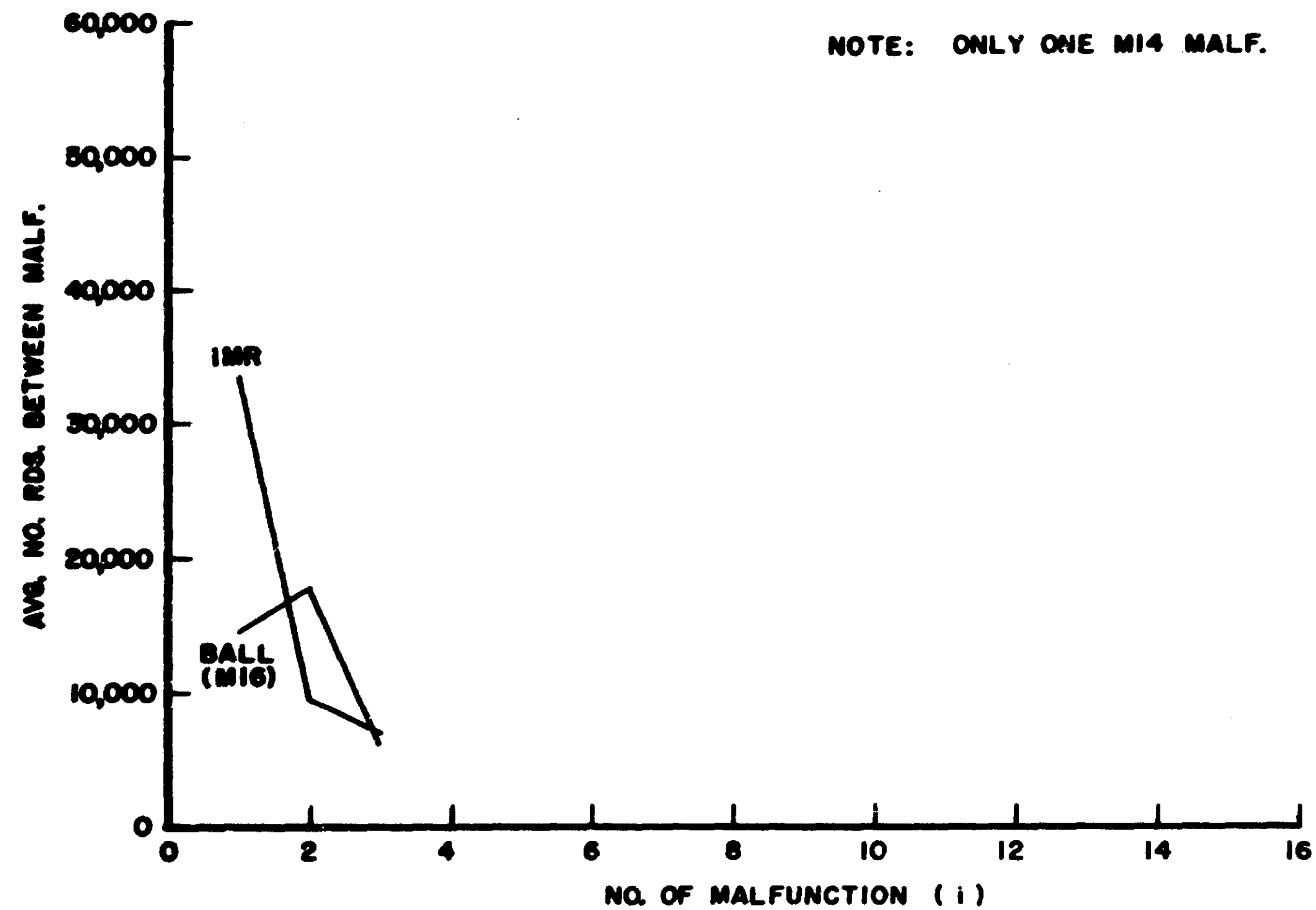


Figure VI-G. Avg. No. of Rounds between (i-1)st and ith Double Feed.

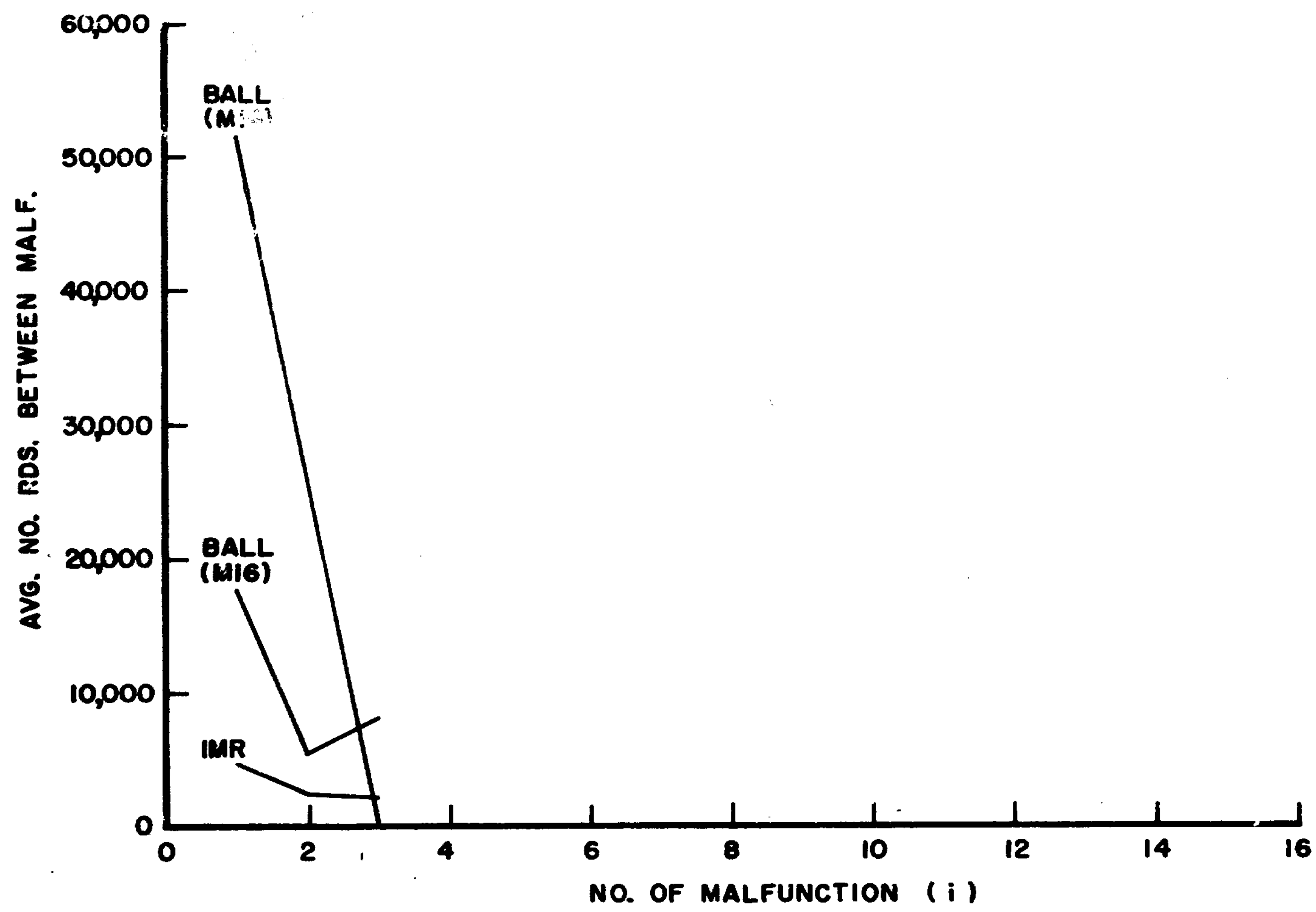


Figure VI-H. Avg. No. of Rounds between (i-1)st and ith Failure of Bolt to Remain at Rear after Last Round.

SECTION VII

SERIOUSNESS OF FAILURES

During the preceding analysis, the seriousness of each defect type was not considered. In this respect, the malfunctions may be categorized into the following three groups as defined by WSEG:

Category I - Malfunctions which were corrected by immediate action on the part of the firer.

Category II - Malfunctions which could not be corrected by Category I action, but were corrected in the field by the shooter using aids normally available to the firer.

Category III - Malfunctions which could not be corrected by Category I or Category II actions, but which were correctable by an armorer with tools and/or parts.

The following table shows the number and percentage of malfunctions in each category by type of malfunction.

Generally, the number of Category II and Category III malfunctions were small compared to the number of Category I malfunctions. For the eight most prevalent types of failures, the most serious (with respect to the ratio of Category I failures to Category II and III failures) was failure to extract while the least serious were double-feed and failure of the bolt to remain to the rear. There is little difference among the remaining five with respect to seriousness.

The malfunctions were not considered by category in the preceding analyses of this report for the following reasons:

1. All malfunctions are potentially serious. The category into which a malfunction is going to fall cannot be predetermined before it occurs. Furthermore, even a Category I malfunction can be serious under certain circumstances.

2. The percentage of Category I malfunctions was not greatly different for any of the eight most prevalent failures.

3. The number of Category II and III malfunctions were too few to permit an extensive statistical analysis.

TABLE VII-A

PERCENTAGE OF CATEGORY I, II AND III
MALFUNCTIONS BY FAILURE TYPE

BALL AND IMR MALFUNCTIONS COMBINED

TYPE OF MALFUNCTION		CATEGORY I NO.	I %	II NO.	II %	III NO.	III %	TOTAL	% OF TOTAL MALF
FF	1	1,411	81.0	304	17.5	27	1.5	1,742	48.0
FC	2	353	76.7	97	21.1	10	2.2	460	12.7
FL	3	89	76.7	25	21.6	2	1.7	116	3.2
FFR	4	201	76.4	47	17.9	15	5.7	263	7.3
FUL	5	2	25.0	6	75.0	-	-	8	0.2
FX	6	114	66.7	47	27.5	10	5.8	171	4.7
FJ	7	245	82.8	31	10.5	20	6.8	296	8.2
FCK	8	6	66.7	3	33.3	-	-	9	0.2
FLHC	9	-	-	-	-	-	-	-	-
IFR	10	-	-	-	-	-	-	-	-
FMR	11	1	100.0	-	-	-	-	1	0.03
DF	12	63	94.0	3	4.5	1	1.5	67	1.8
FSS	13	-	-	-	-	-	-	-	-
BCE	14	1	100.0	-	-	-	-	1	0.03
FCB	15	3	100.0	-	-	-	-	3	0.08
FML	16	13	86.7	2	13.3	-	-	15	0.4
FTR	17	-	-	-	-	-	-	-	-
FBR	18	368	93.9	23	5.9	1	0.3	392	10.8
FBC	19	4	66.7	2	33.3	-	-	6	0.2
F2R	20	-	-	-	-	-	-	-	-
SSA	21	-	-	-	-	-	-	-	-
CRS	22	-	-	1	100.0	-	-	1	0.03
SLI	23	9	22.0	26	63.4	6	14.6	41	1.1
Other	24	17	48.6	11	31.4	7	20.0	35	1.0
All Types		2,900	80.0	628	17.3	99	2.7	3,627	100

TABLE VII-A (CONTINUED)

1. Failure to feed
2. Failure to chamber
3. Failure to lock
4. Failure to fire
5. Failure to unlock
6. Failure to extract
7. Failure to eject
8. Failure to cock
9. Failure to load by hand changing
10. Firing without trigger being pulled
11. Failure to maintain cyclic rate
12. Double feed
13. Fires with selector on safe
14. Bolt catch engaged bolt carrier instead of bolt
15. Firing on closure of bolt
16. Failure of magazine to lock in rifle
17. Failure of trigger to return to forward position
18. Failure of bolt to remain at rear
19. Failure of bolt to go forward
20. Fired two or more rounds with one trigger pull
21. Single shot (automatic-mode)
22. Cartridge rim shear
23. Selector level inoperative
24. Other

B. REVIEW AND ANALYSIS OF DATA OF PERTINENT REPORTS

Introduction.

Sections VIII through XXIV contain the results of reviews and reanalyses of data obtained from reports of tests and evaluations of various characteristics of the M16 Rifle System. These reports generally summarize the results of tests conducted in the acceptance of rifles and ammunition lots, product improvement and engineering design tests, quality assurance and reviews, special tests, and experience from the field. The results contained in these reports were, therefore, considered to be representative of characteristics of the rifle system when newly manufactured, under field conditions, and under controlled conditions at proving grounds. For each report, a critical review was made and data was analyzed to determine if the conclusions arrived at were well founded and what, if any, additional conclusions could be drawn from further analysis.

In order to compute estimates of the reliability of the M16 system at the time of acceptance, data obtained in reliability tests conducted by the manufacturer were used to derive the distribution of rounds to or between failures. In these tests, 1000 rounds were fired from each of three rifles from each lot of rifles or until the number of failures of specific types exceeded the specified maximum allowed in the first 6,000 rounds. Weibull and failure rate distributions were derived using the procedures described in Section II of this appendix. From the distributions, estimates of reliability, expressed as the probability of firing a specified number of rounds to or between failures, were obtained and are given in graphical representation. For comparison, the Weibull distributions, failure rates and reliability curves based on acceptance data and those based on the WSEG data are given, where applicable, on the same figures.

Gross estimates of the reliability of the rifle/ammunition system, expressed as the average number of rounds per malfunction also are given. It is emphasized, however, that these are gross estimates since the rate of occurrence of failures is not constant throughout the usable life of a rifle.

SECTION VIII

RELIABILITY ANALYSIS OF ACCEPTANCE DATA

In the endurance tests, 10,000 rounds are fired from each of three rifles which are selected periodically according to a prescribed schedule. Malfunctions and unserviceable parts are noted along with the round number on which failure occurs. The rifle is satisfactory or unsatisfactory on the basis of the number of unserviceable parts and malfunctions occurring in the first 6,000 rounds. The number of allowable failures is specified in the rifle Purchase Description.

Data accumulated in endurance tests of 135 rifles during the period February 1964 through February 1968 were used to estimate the distribuiton of rounds to and between failure (i.e., rounds to first failure, from first to second, etc.) using methods described in the Appendix IV discussion of the analysis of the WSEG data. These data included firings of M16 and M16A1 rifles equipped with the standard and redesigned buffers, chrome and non-chrome plated chambers, and firing ball cartridges assembled with ball and IMR propellant. The redesigned buffer was assembled into new rifles at approximately the same point in time that predominantly ball propellant was used in acceptance testing of rifles. Although many factors, such as propellant type, buffer type, and chamber type, affect the reliability of the rifle, estimates of the distributions of rounds to and between failures were obtained only considering propellant types. β and η of the two-parameter Weibull distributions were estimated from the combined data and from the data for ball and IMR propellants separately. Due to the scarcity of data, no efforts were made to isolate the distributions for other factors.

In order to compare the estimates from acceptance test data with those obtained in WSEG analysis, malfunctions attributed to unserviceable parts were included in spite of the fact that such malfunctions were not counted against the rifle in the acceptance tests. Another factor considered in comparison with the WSEG data was the firing of only ball projectiles in acceptance tests and a mixture of ball and tracer projectiles in the WSEG firings.

Estimates of the shape parameters and characteristic life were obtained for the distribution of rounds to the first malfunction and rounds between succeeding malfunctions through the fifth malfunction. Some of these are given in Table VIII-A, which also gives estimates obtained from the WSEG analysis for the M16 rifle firing ball and tracer projectiles with ball and IMR propellant.

Figures VIII-A through VIII-C give curves of the Weibull distributions of rounds to the first malfunction and between the fourth and fifth malfunction. Figures VIII-D through VIII-I give the failure rate curves and reliability curves expressing the probability of firing specific numbers of rounds to and between malfunctions. Included in these figures and Table VIII-B are estimates from the WSEG analysis for comparison purposes.

It appears that the performances of ball and IMR propellant with respect to reliability do not differ during endurance acceptance testing, although a wide difference was noted in the WSEG test. However, an important factor that should be considered when comparing the reliability estimates is the effect of the new buffer. The estimates obtained for ball propellant in the endurance test were for firings of rifles assembled, for the most part, with the new buffer, whereas the estimates for IMR propellant were obtained from firing of rifles assembled predominantly with the old buffer. In the WSEG study, all rifles were assembled with the new buffer.

Under field conditions, such as those in the WSEG study, the reliability of the rifle, based on estimates obtained under the conditions described above, is reduced for both propellant types. The reduction in reliability, when firing rounds assembled with IMR propellant from rifles having the new buffer, is large and immediate, whereas the reduction in reliability, when firing rounds assembled with ball propellant from rifles having the new buffer, is small for the first few hundred rounds and approaches that for IMR propellant after approximately 3,000 rounds.

It should also be noted that the reliability, when firing ball propellant, is much less between the fourth and fifth malfunction than it was before the first malfunction. The reliability, when firing IMR propellant, appears to change only slightly over the same number of malfunctions.

These results indicate that current acceptance testing procedures do not produce results that represent the rifle reliability in the field.

TABLE VIII-A

ESTIMATES OF WEIBULL DISTRIBUTION PARAMETERS

DISTRIBUTION OF ROUNDS	M16 - BALL PROPELLANT				M16 - IMR PROPELLANT			
	SHAPE PARAMETER $\hat{\beta}$		CHARACTERISTIC LIFE $\hat{\eta}$		SHAPE PARAMETER $\hat{\beta}$		CHARACTERISTIC LIFE $\hat{\eta}$	
	ACCEPT	WSEG	ACCEPT	WSEG	ACCEPT	WSEG	ACCEPT	WSEG
To 1st Malf.	.7475	.9355	1,152	1,009	.8649	.4711	1,776	234
Between								
1st and 2nd Malf.	.7136	.5753	763	515	.6971	.4170	808	68
4th and 5th Malf.	.4272	.5972	369	333	.7702	.4594	486	127

TABLE VIII-B

COMPARISON OF RELIABILITY ESTIMATES*

PROBABILITY OF FIRING R ROUNDS	PROPELLANT TYPE	NUMBER OF ROUNDS (R)					
		1	10	50	100	500	1,000
To First Malfunction	**Ball**						
	Acceptance	.9964	.9804	.9367	.8971	.7128	.5893
	WSEG	.9985	.9868	.9422	.8925	.5998	.3778
	IMR						
	Acceptance	.9987	.9903	.9620	.9319	.7574	.6107
	WSEG	.9263	.7974	.6167	.5117	.2393	.1994
Between 4th and 5th Malfunction	**Ball**						
	Acceptance	.9402	.8967	.7304	.6611	.4715	.3906
	WSEG	.9740	.9018	.7669	.6735	.3903	.2769
	IMR						
	Acceptance	.9943	.9673	.8938	.8293	.5732	.4500
	WSEG	.9021	.7445	.5425	.4345	.1907	.1167

* Acceptance estimates are for ball projectiles and WSEG estimates include ball and tracer projectiles.

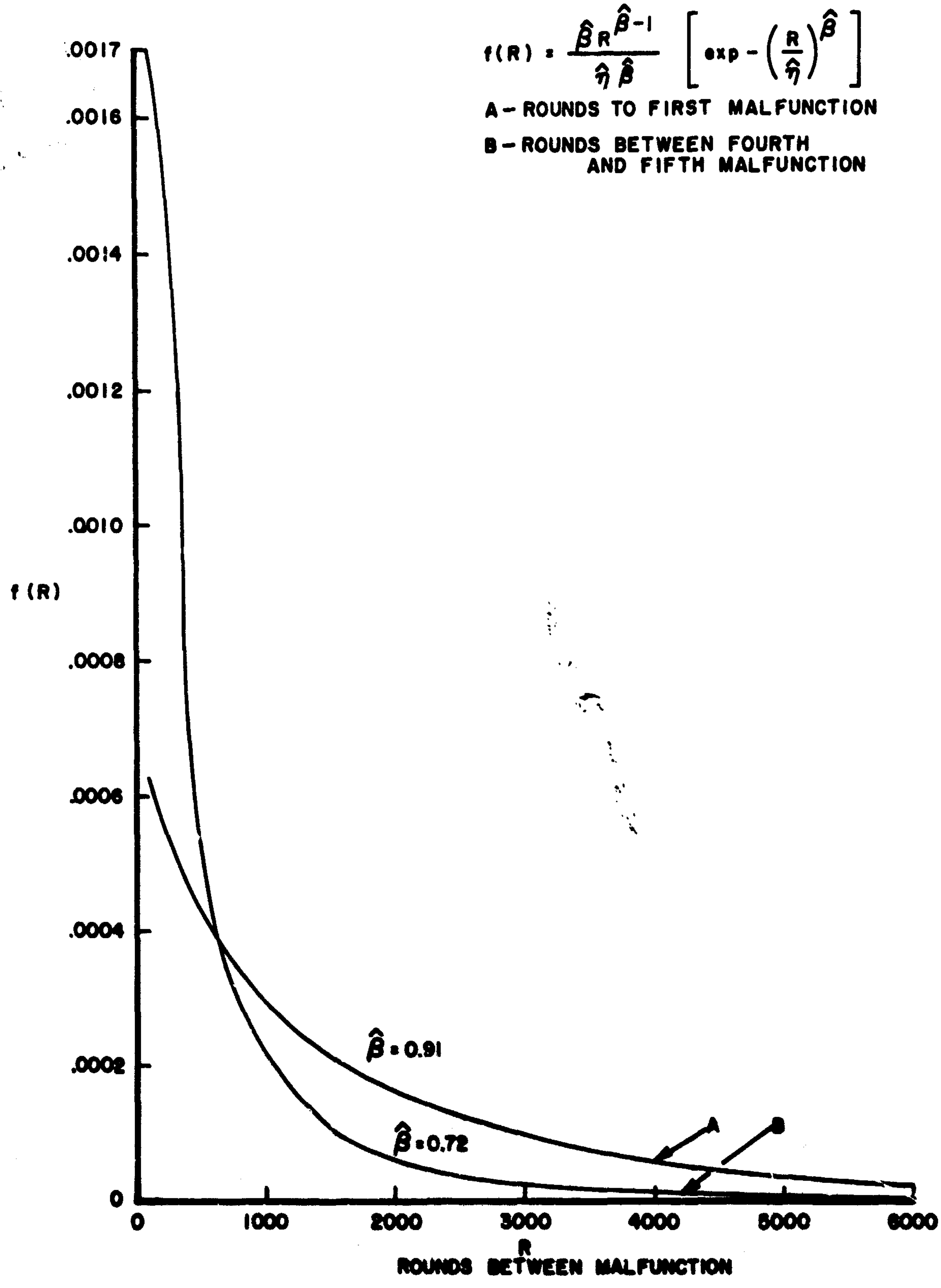


Figure VIII-A. M16 Rifle Firing Ball Rds. w/Ball and IMR Prop. Weibull Distribution of Rounds to or between Malfunction

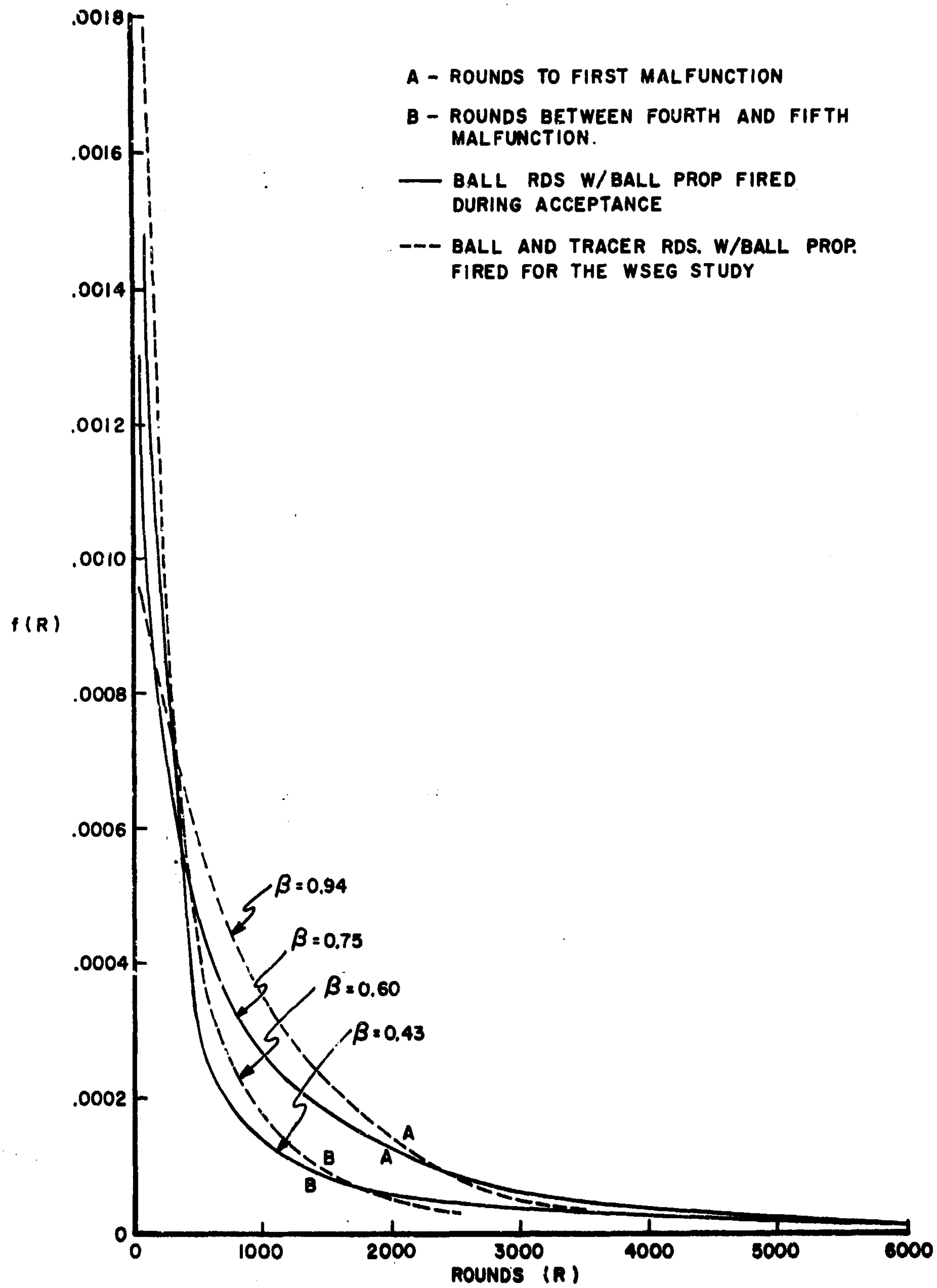


Figure VIII-B. M16 Rifle Firing Ball Propellant.
Weibull Distribution of Rounds To or Between Malfunctions.

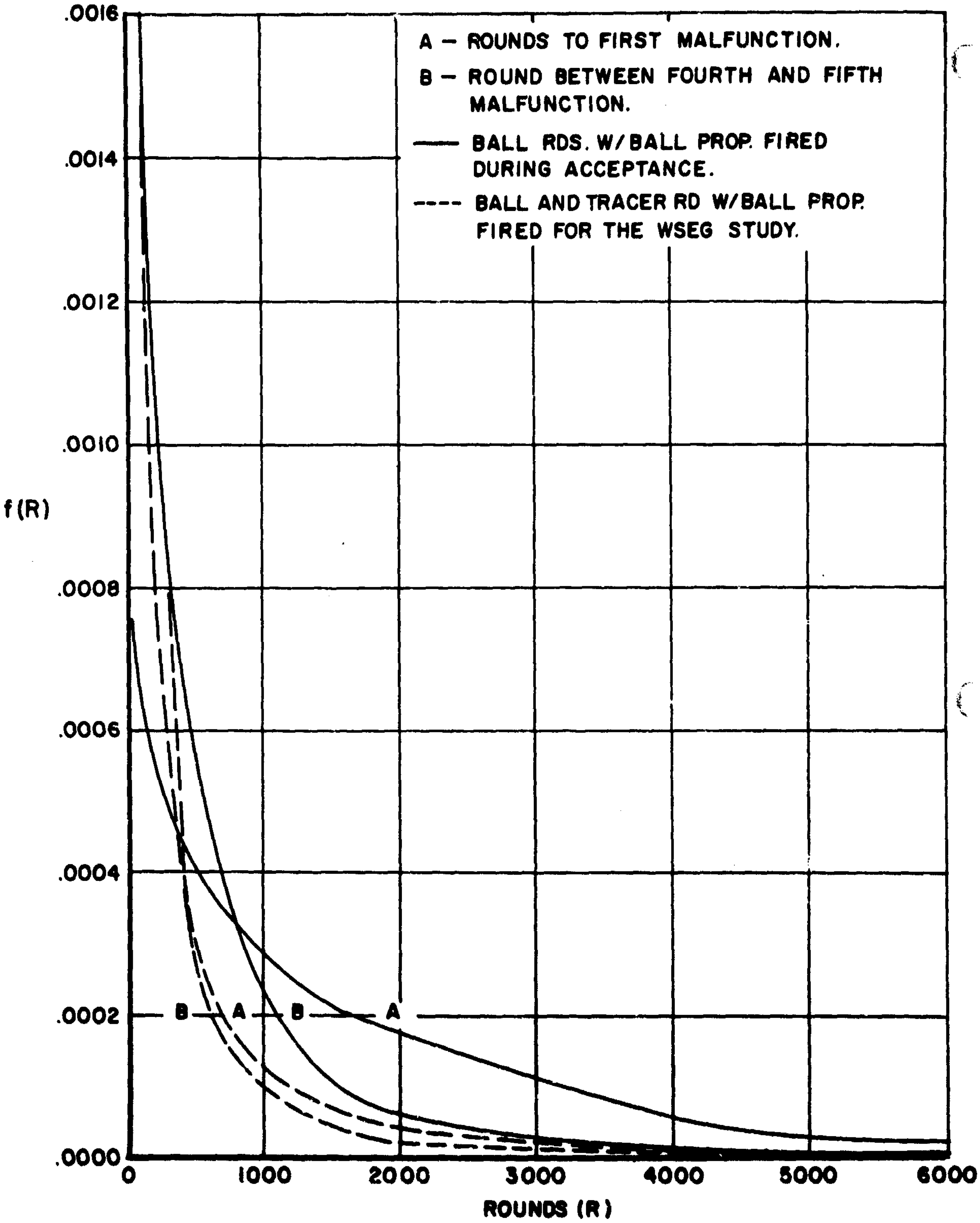


Figure VIII-C. M16 Rifle Firing IMR Propellant
Weibull Distribution of Rounds To or Between Malfunctions

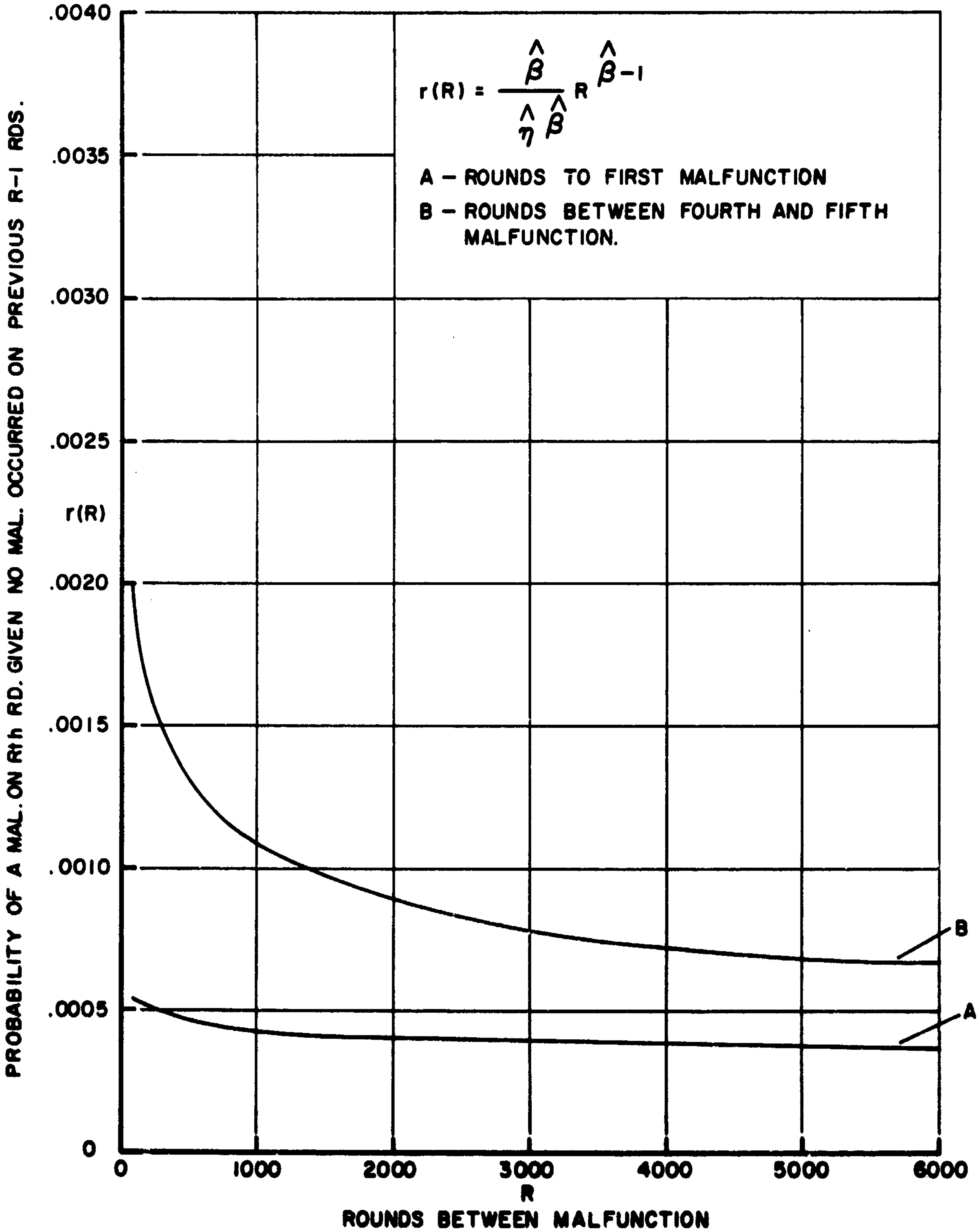


Figure VIII-D. M16 Rifle Firing Ball Rds w/Ball & IMR Prop. Weibull Distribution Failure Rates for Acceptance

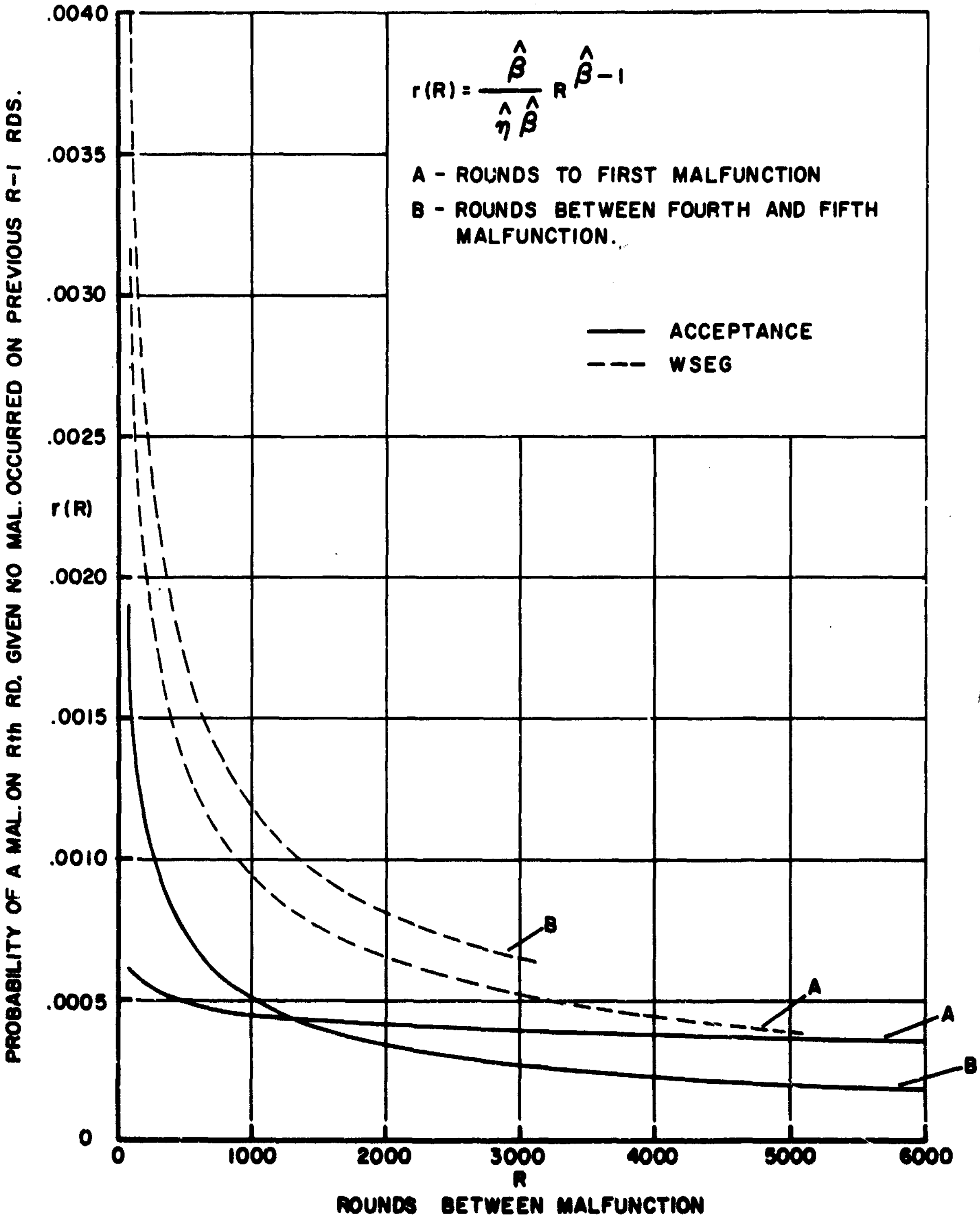


Figure VIII-E. M16 Rifle Firing Ball Rds (Acceptance) and Ball and Tracer Rds (WSEG) with IMR Prop. Weibull Distribution Failure Rates

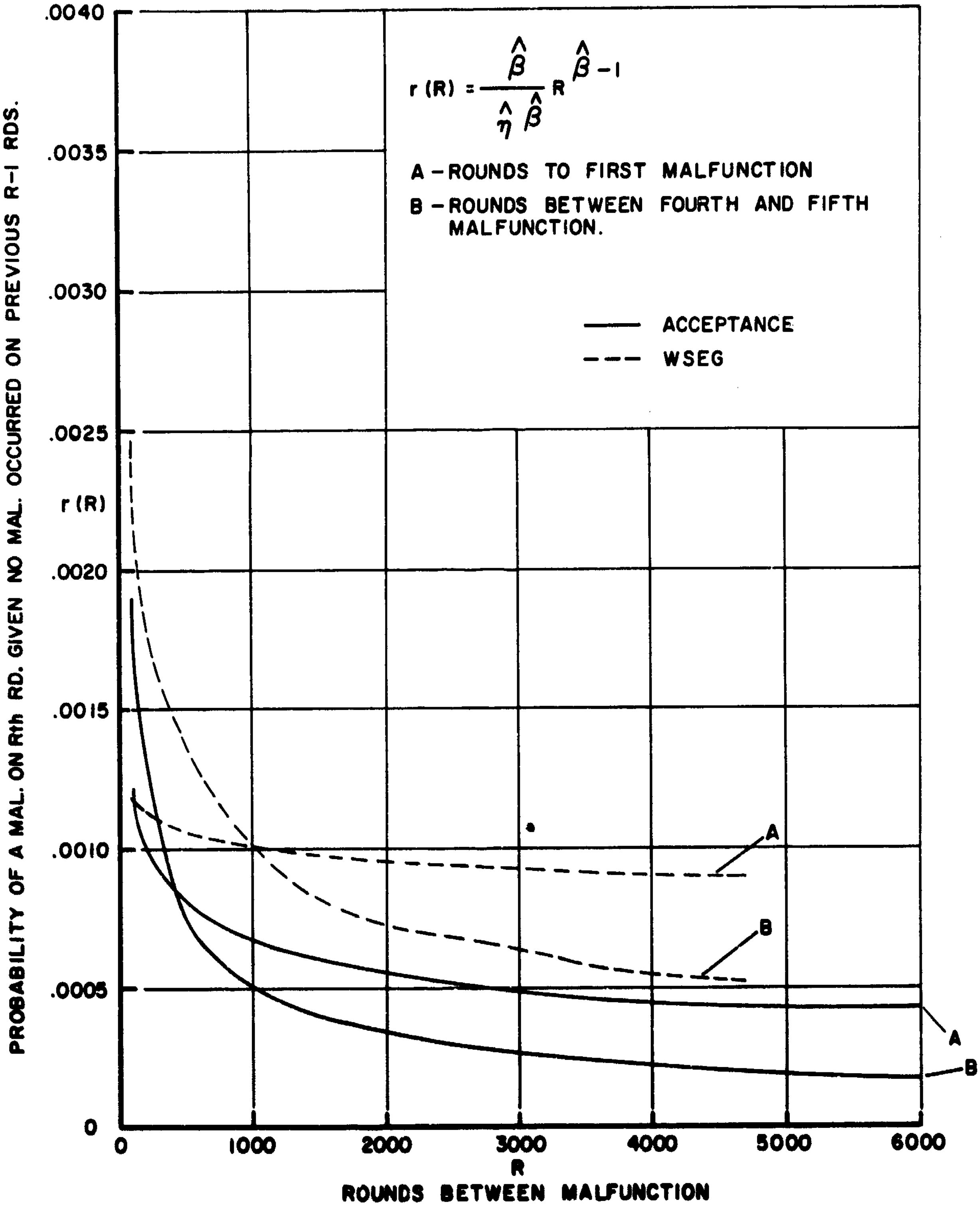


Figure VIII - F. M16 Rifle Firing Ball Rds (Acceptance) and Ball and Tracer Rds (WSEG) with Ball Prop. Weibull Distribution Failure Rates

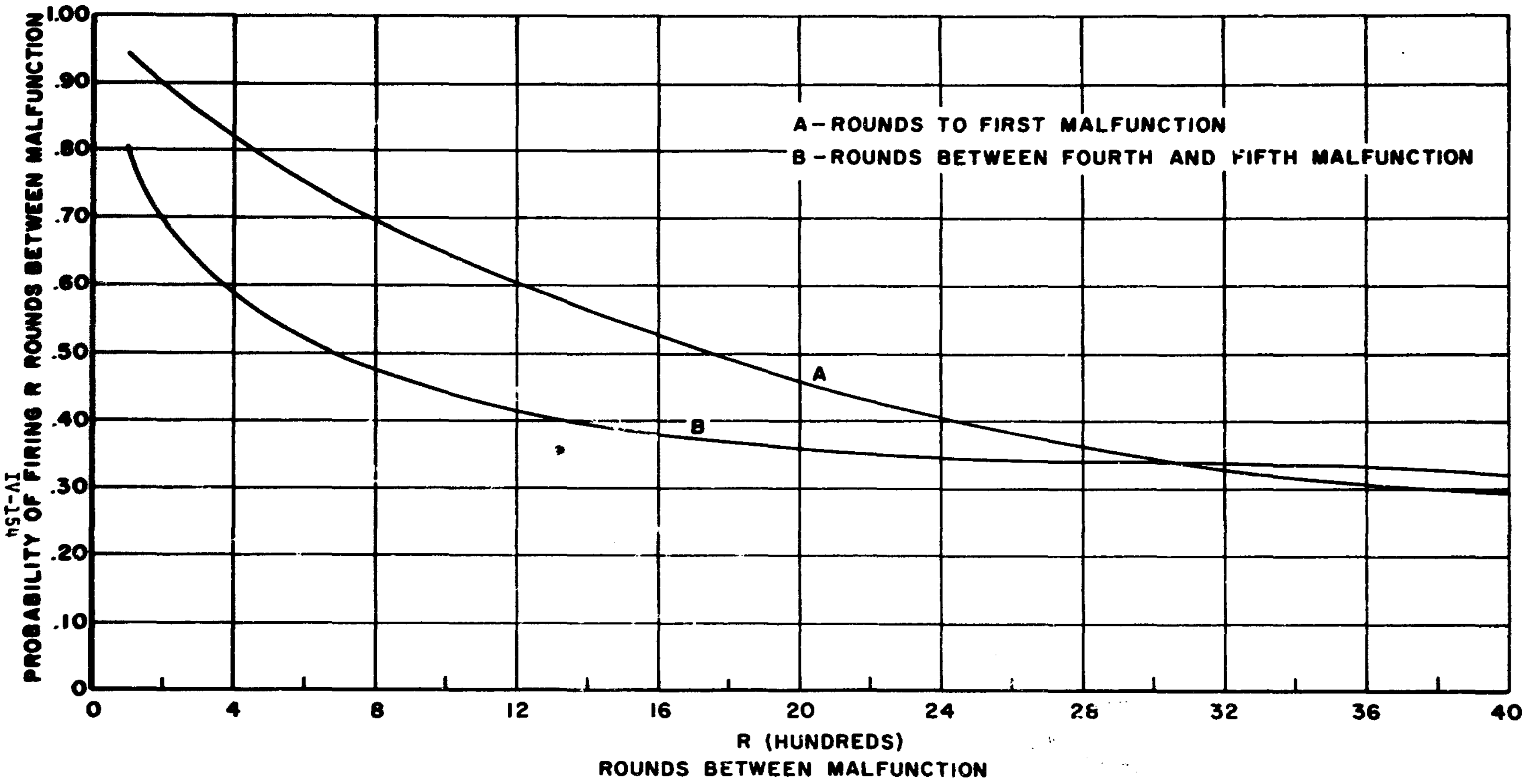


Figure VIII - G. M16 Rifle Firing Ball Rds. w/Ball and IMR Prop. Reliability Estimates of Rds. to or Between Malfunction in Acceptance.

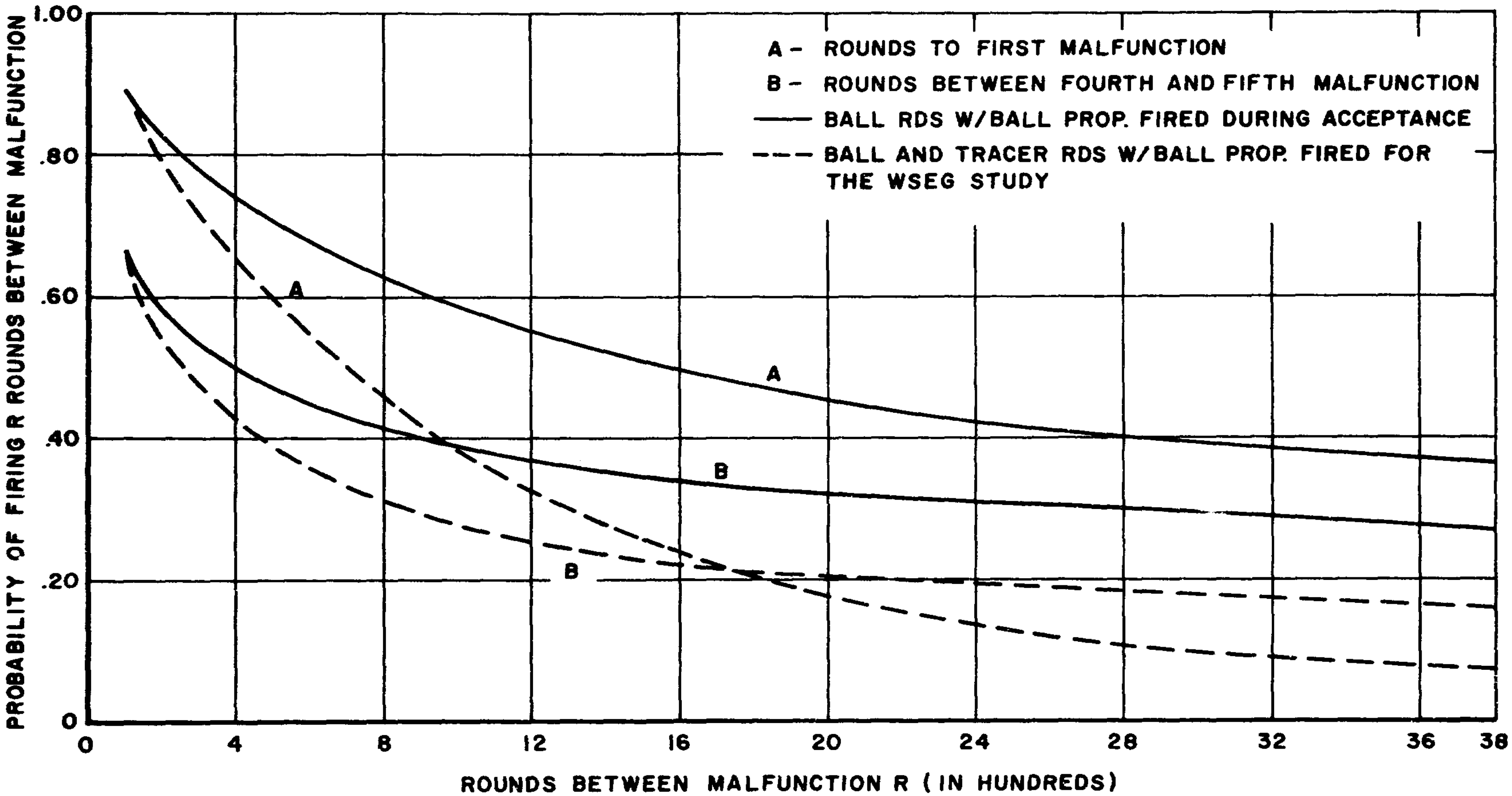


Figure VIII-H. M16 Rifle Firing Rounds Assembled W/Ball Prop.
Reliability Estimates of Rounds to or Between Malfunction

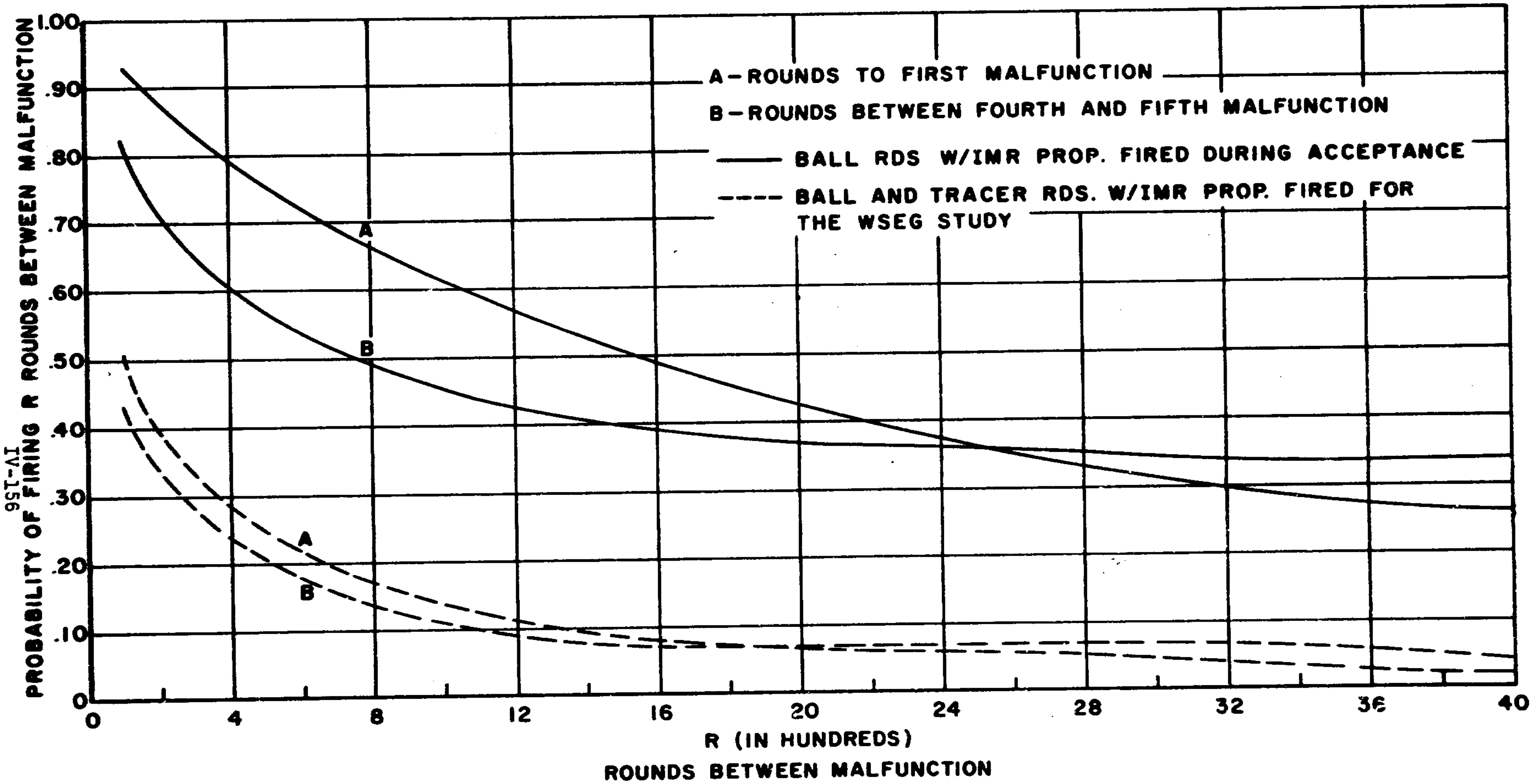


Figure VIII - I. M16 Rifle Firing Rounds Assembled w/IMR Prop. Reliability Estimates of Rounds to or Between Malfunction

SECTION IX

FINAL INSPECTION REPORTS IN ACCEPTANCE

OF M16 AND M16A1 RIFLES

Data from function firing, target inspection, accuracy inspection and final inspection of rifles produced at Colt's during the period September 1967 through March 1968 have been summarized. During this period, 186,118 new rifles were tested for acceptance. Of these, 3,934 (2.1%) were rejected in the function firing tests, 9,805 (5.3%) were rejected in the targeting test, 7,256 (3.9%) were rejected in the accuracy test, and 45,778 (24.6%) were rejected in the final inspection. Two hundred seventy-nine (7.1%) of those rejected in the function firing tests were rejected for failure to meet the cyclic rate requirements. The table below gives a summary of the rifles rejected in the acceptance testing of new and repaired rifles during the period.

FINAL TEST AND INSPECTION RESULTS

SEP 1967 - MAR 1968 AT COLT

TYPE OF TEST	NUMBER OF RIFLES FIRED		NUMBER OF RIFLES REJECTED	PERCENT OF RIFLES REJECTED
Function Firing	New	186,118	3,934	2.1
	Repaired	4,696	762	16.2
	Total	190,814	4,696	2.5
Targeting Test	New	186,118	9,805	5.3
	Repaired	10,997	1,192	10.8
	Total	197,115	10,997	5.6
Accuracy Test	New	186,118	7,256	3.9
	Repaired	8,196	940	11.5
	Total	194,314	8,196	4.2
Final Inspection	New	186,118	45,778	24.6
	Repaired	48,192	2,414	5.0
	Total	234,310	48,192	20.6

FOOTNOTE: All tests conducted with ball rounds.

The frequency of malfunctions of new rifles fired in the function firing tests over the entire period is given in the following table.

SUMMARY OF FUNCTION FIRING TESTS OF NEW RIFLES
(SEP 1967 - MAR 1968)

TYPE OF MALFUNCTION	NO. OBSERVED IN APPROX 7,559,892 RDS	RATE OF OCCURRENCE PER 1,000 RDS	ESTIMATED AVG RDS PER FAILURE
Failure to feed	826	0.109	9,152
Failure to extract	235	0.031	32,170
Failure to eject	219	0.029	34,520
Failure to stay open on last round	274	0.036	27,591
Failure to close on charging	289	0.038	26,159
Failure to fire	64	0.008	118,123
Failure to fire automatically	139	0.018	54,388
Failure to fire semi-automatically	36	0.005	209,997
Failure to pull off on automatic	96	0.013	78,749
Fires automatic on semi-automatic	1	0.0001	7,559,892
Erratic fire	139	0.018	54,388
Selector binds	269	0.036	28,104
Bolt binds	165	0.022	45,818
Magazine release binds	108	0.014	69,999
Loss of power	306	0.040	24,706
High cyclic rate	110	0.015	68,726
Low cyclic rate	169	0.022	44,733
Miscellaneous	489	0.065	15,460
TOTAL	3,934	0.520	1,922

By far, the most frequent malfunction was failure to feed, occurring at the rate of 0.109 per 1,000 rounds. The overall rate of malfunctions was 0.520 per 1,000 rounds. This is equivalent to an average of approximately 1,922 rounds per malfunction.

Final Inspection Report of Acceptance of M16 Rifles Reported by Colt (Form C-1180).

SECTION X

MONTHLY PRODUCT QUALITY AUDIT OF M16A1

RIFLES AND COMPONENT SPARE PARTS (WECOM)

The results of three monthly product quality audits on five M16A1 rifles and selected spare parts were summarized. In each of the months, five rifles were disassembled and dimensional inspections were performed on various components. Similar inspections were performed on the spare parts. Defects of individual components were classified in accordance with Inspection Instruction Sheets as either major or minor. The number of major and minor defects was summarized for each component for the reports covering November 1967, December 1967, and January 1968. It was necessary to estimate the number of major and minor characteristics inspected in the November and December reports since this information was not given in the WECOM reports for the two months.

The following table gives a summary of the defects which were found upon inspection of 27 characteristics of each of five rifles and one characteristic of each of 12 spare parts. The overall percent of major and minor defects for the types of rifle components and spare parts are shown in Figure X-A and Figure X-B.

The high rate of defects would lead one to question the quality control and inspections of the manufacturer when five rifles picked at random from those having passed inspection are found to have dimensions outside specified limits with such a high frequency.

Monthly Product Quality Audit of M16A1 Rifles and Component Spare Parts (WECOM)

TABLE X

ITEMS INSPECTED	TYPE OF CHARACTERISTIC INSPECTED	NOV 1967			DEC 1967			JAN 1968		
		NO OBS CONS	NO. DEFECTS	% OF DEFECTS	NO OBS CONS	NO. DEFECTS	% OF DEFECTS	NO OBS CONS	NO DEFECTS	% OF DEFECTS
Main Components of 5 Rifles	Major	800*	183	22.9	800*	219	27.4	800	73	9.1
	Minor	440*	38	8.6	445*	54	12.1	450	30	6.7
12 Spare Parts	Major	600*	104	17.3	600*	134	22.3	600	40	6.7
	Minor	455*	22	4.8	455*	25	5.5	460	24	5.2

* Estimated

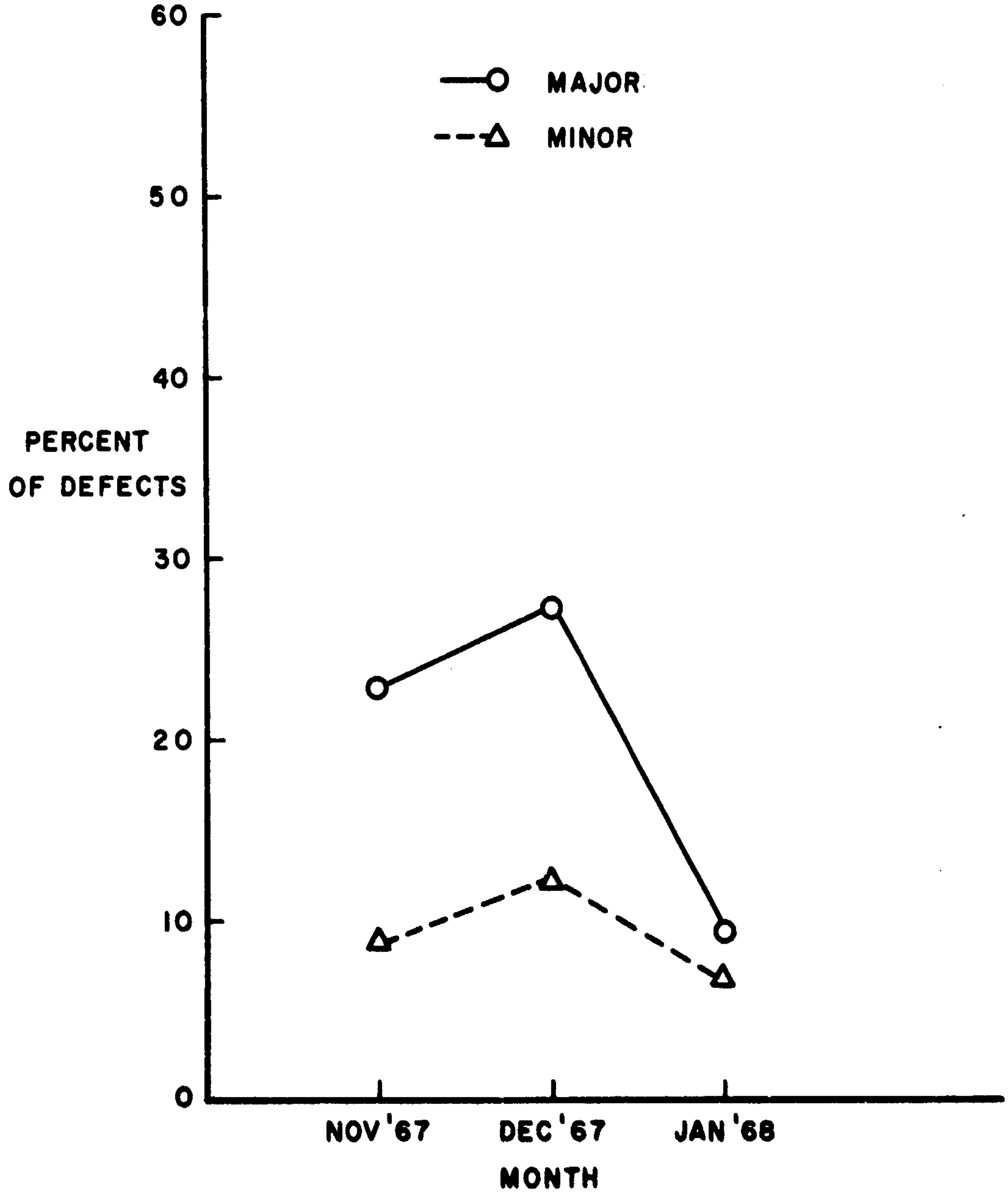


Figure X-A. Percent of Defects Observed In Dimensional Inspection of Rifle Components

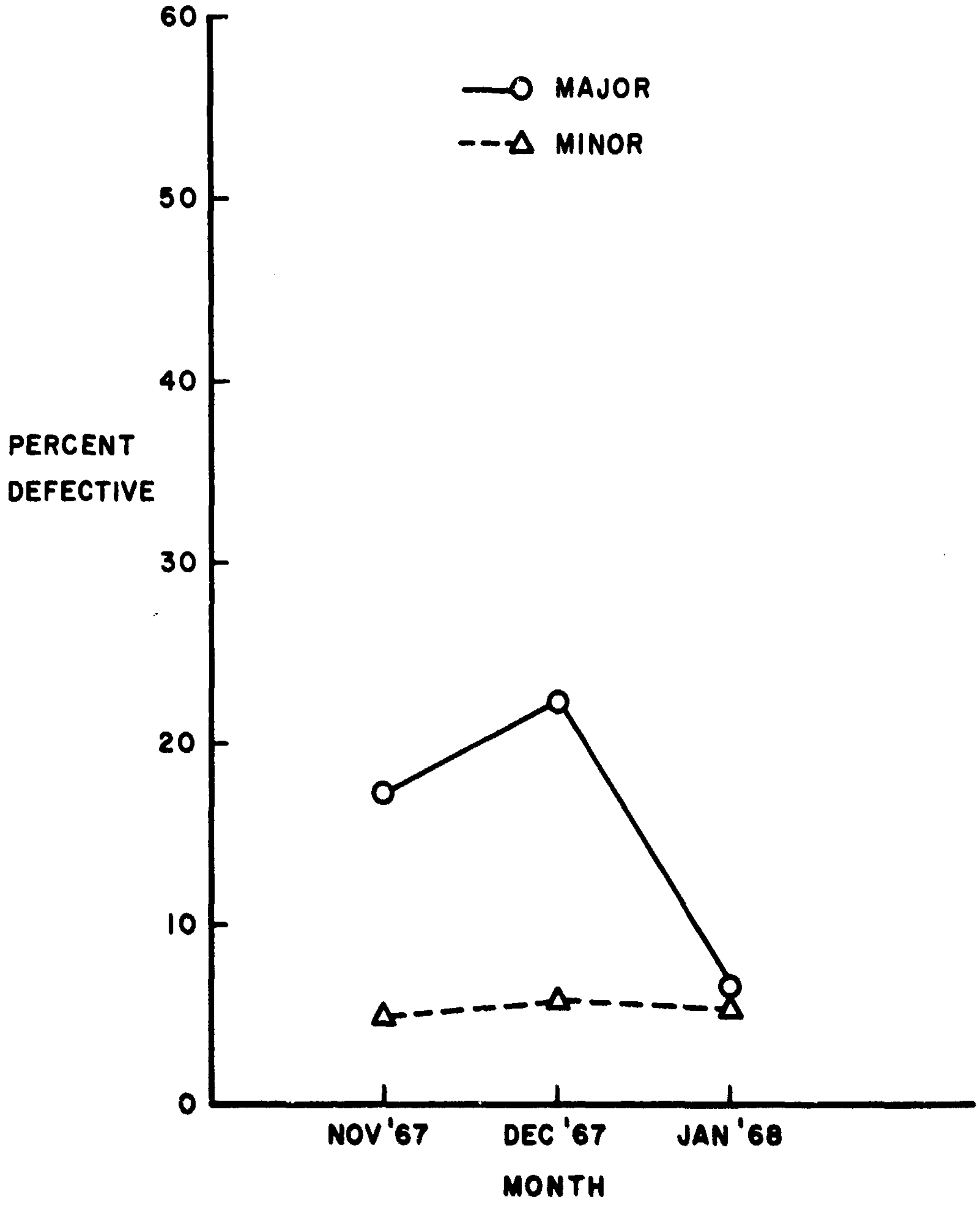


Figure X-B. Percent Defective Observed in Dimensional Inspection of Spare Parts

SECTION XI

QUALITY ASSURANCE REVIEW OF 5.56mm

M193 BALL AMMUNITION (23 OCT 1967)

This report gives a review of the quality of M193 Ball ammunition produced in FY 67 and the first quarter of FY 68. A total of 660 lots of cartridge, 5.56mm: Ball, M193 was produced in the period covered by the report. These lots represented approximately 909 million cartridges. Of the 660 lots produced, only five were rejected. Forty-seven lots were accepted on retest, six lots were accepted on waiver due to defects in packaging, and six lots were accepted on waiver for CONUS use only due to accuracy characteristics which did not meet specification requirements. The remaining 596 lots met all specification requirements and were accepted on first test.

Included in the report is a summary of reported malfunctions of 5.56mm ball ammunition. A total of 18 malfunctions, involving 18 different lots, were reported, 13 of which had been investigated at the time of the report. The malfunctions included one blown primer, eight ruptured cases, two misfires, four bullets in bore, one problem with extraction, two blown rifles, and one case of excessive pressure. Six lots involved in the malfunctions were retested and found to meet specification requirements. Two incidents indicated evidence of on-site tampering. The lots involved were tested and found to meet specification requirements. Dirt and sand were found in the weapon involved in one malfunction. The lot involved was released for use. In retests of three lots, defects (split cases) noted in initial production were observed. These lots were accepted originally on waivers due to urgent delivery requirements. In retests at Frankford Arsenal, these lots were rejected.

Quality Assurance Review of 5.56mm, M193 Ball Ammunition published by Frankford Arsenal, Oct 1967.

SECTION XII

M16A1 RIFLE QUALITY ASSESSMENT REPORTS

RCS AMCQA-111

JAN AND FEB 1968

PREPARED BY AMSWE-QA

The two quality assessment reports, in general, gave evaluations of the quality of rifles produced by the contractor in the period January through February 1968. Included in the reports were: (1) composite monthly rejection rate charts, (2) Monthly Reliability Charts, (3) Equipment Improvement Recommendations (EIR's), (4) results of final inspection of rifles, (5) cyclic rates of rifles in the function firing tests, (6) summaries of 5.56mm cartridge lots produced in the period, and (7) other comments concerning the quality of the rifles production program.

The composite monthly rejection rate charts were checked against data given in the Final Inspection Report (Form C-1180). The comparisons of data from the two sources indicate that some of the inferences concerning the stability or improvement in quality of certain rifle characteristics from month to month were slightly in error. However, this is not serious and from an overall standpoint, there is a general trend toward a decrease in the number of rifles rejected in the final examination, function firing, and targeting and accuracy tests.

The distribution of cyclic rates observed in the function firing tests of 392 rifles from the January and February 1968 production, when firing cartridges assembled with ball propellant, is shown in the accompanying figure. The statistical distribution appears to be fairly normal, although slightly skewed toward the left, i.e., toward lower cyclic rates.

If the behavior (tendency to decrease for the first 6-8 thousand rounds and then increase) of cyclic rates observed in the initial production test of chrome-plated chambers for M16A1 rifles is characteristic of all M16A1 rifles, then a shift toward lower cyclic rates can be expected for these rifles.

Based on the results obtained in the reliability tests during the period December 1966 through January 1968, a total of 82 malfunctions occurred in the firing of 249,313 rounds. This would indicate an average of approximately 3,040 rounds per malfunction. These malfunctions do not include those attributable to the magazine. Two incidents of failure of the bolt to lock, 33 failures to eject, 43 failures to feed (33 cartridges visible and 10 cartridges not visible), 2 light blows and one failure to extract were noted. The table below gives a summary of the malfunctions of the type given above per 1,000 rounds fired in the reliability tests and in the function firing tests during the period September 1967 through March 1968.

	RELIABILITY TESTS		FUNCTION FIRING TESTS	
TYPE OF MALFUNCTION	NO. OBSERVED	NO./ 1,000 RDS	NO. OBSERVED	NO./ 1,000 RDS
Bolt fails to lock	2	0.008	289*	0.038*
Failure to eject	33	0.132	219	0.029
Failure to feed	43	0.172	826	0.109
Light blow	2	0.008	-	-
Failure to extract	1	0.004	235	0.031
All malfunctions	82***	0.329	3,934**	0.520**

* Number of failures of bolt to close on charging in Function Firing Tests

** Includes failures during Cyclic Rate Tests

*** One malfunction undetermined

The malfunctions per 1,000 rounds given in the table above for Function Firing Tests are based on an estimated 7,559,892 rounds fired from 186,118 rifles over the seven-month period. It can be seen from the table above that, from an overall standpoint, the number of malfunctions per thousand rounds fired in the Reliability Tests was significantly lower than that in the Function Firing Tests. This may be due to the fact that Endurance or Reliability Tests are conducted only with rifles which were previously tested and accepted.

M16A1 Rifle Quality Assessment Report, RCS AMCQA-111, January 1968, Prepared by AMSWE-QA.

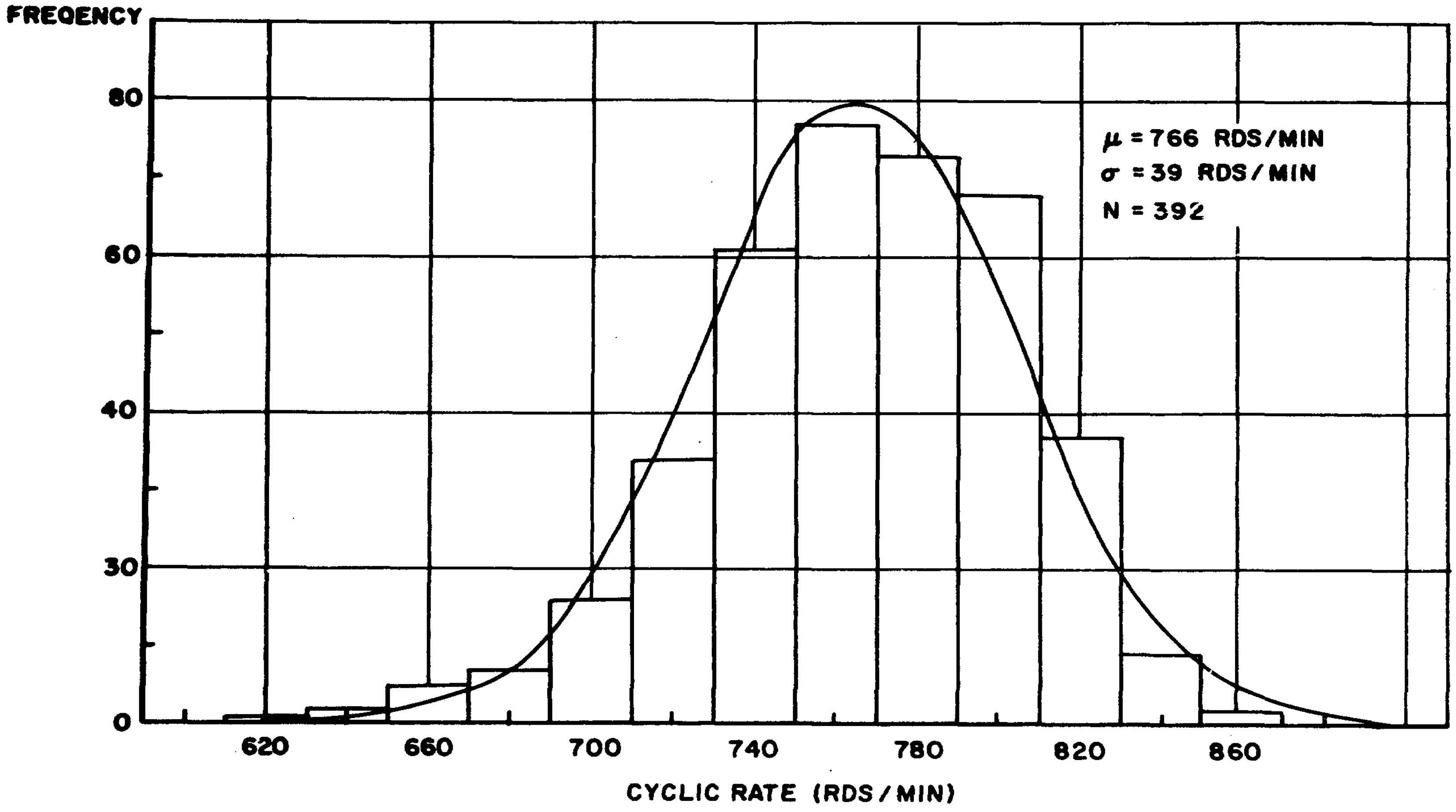


Figure XII-Distribution of Cyclic Rates in Function Firing Test of January and February, 1968 Production of M16A1 Rifles Firing Ball Propellant.

SECTION XIII

QUALITY REPORT FOR SMALL CALIBER AMMUNITION AND PROPELLANT ACTUATED DEVICES

(1ST, 2ND AND 3RD QUARTERS FY 1968)

These reports give summaries of data pertinent to the quality of small caliber ammunition produced during the first three quarters of FY 1968. A total of 602 lots of 5.56mm cartridges, including ball, tracer, blank, and high pressure test cartridges, were produced in the period. Of these lots, 593 containing 933,464,740 rounds were accepted, five of which were accepted on waivers. Nine lots, containing 10,360,560 rounds were rejected. Eight of the rejected lots were tracer lots assembled with ball propellant (WC 846). Because of defects, such as bursting bullets, fragmentation, key holing, yawing and failures to feed, these lots were scrapped.

As well as could be determined from the data given, considering 472,955 rounds tested in the 2nd and 3rd quarters, four (.0008%) misfires, three (.0006%) case ruptures and one (.0002%) major/critical primer defects were noted. Based on these data, a gross estimate of the mean rounds to malfunction is 59,119.

Regarding the accuracy characteristics of 402 lots submitted, the overall mean radius of the ball M193 cartridge, when fired from a bench rest, was estimated to be 1.3 inch at 200 yards with a standard deviation of 0.24 inch. If the impact points of the rounds on the target are assumed to have a bivariate normal distribution, then the mean radii will have the Chi distribution (square root of a Chi square variable). However, based on the histograms given in the reports, the distribution of mean radii can apparently be satisfactorily approximated by a normal distribution with the parameters given above. Based on the quarterly reports, the overall mean radii have been: 1.32" (1st quarter), 1.43" (2nd quarter), and 1.25" (3rd quarter). The variability in mean radii has remained relatively constant.

Quality Reports for Small Caliber Ammunition and Propellant Actuated Devices, published by Frankford Arsenal, Jan and Mar 1968, for the 1st, 2nd, and 3rd Quarters FY 1968.

SECTION XIV

INTERIM QUALITY ASSURANCE REPORT OF 5.56mm FOULING TEST CONDUCTED AT LAKE CITY ARMY AMMUNITION PLANT (FEB AND APR 68)

These reports summarize the malfunctions observed in fouling tests conducted in acceptance tests of cartridge lots at Lake City. Summaries have been made, when possible, by individual malfunction types, by projectile type, and by propellant type. In these tests, 1,000 rounds were fired from each cartridge lot. Malfunctions and degree of fouling were summarized. Possible causes of malfunctions were designated in the tests, i.e., malfunctions due to the weapon, ammunition or magazine.

The rates for projectiles (ball and tracer) loaded with IMR propellant were essentially the same as those for projectiles (ball and tracer) loaded with ball propellant. In general, the malfunction rate for tracer cartridges (with either propellant) was higher than that for ball cartridges (with either propellant). In assigning possible cause of malfunctions, 16.9% were attributed to fouling, 64.6% were attributed to the magazine, 12.7% were attributed to the weapon and the cause of 5.9% of the malfunctions was unknown. The greatest degree of fouling was noted in cartridges assembled with ball propellant. Considering individual types of malfunctions, failures to feed and incidents of the bolt overriding the base of the round were most prevalent. The overall malfunction rate was 1.545 per 1,000 rounds, which is equivalent to approximately 647 rounds per malfunction.

Interim Quality Assurance Report of 5.56 Fouling Test conducted at Lake City Army Ammunition Plant published by Frankford Arsenal, February 1968.

TABLE XIV-A

COMBINED FOULING TESTS

PROJ. TYPE	PROP. TYPE	NO. LOTS	NO. RDS	NO. MALF.	NO. MALF/ 1,000 RDS
M193 (Ball)	Ball	90	90,000	115	1.278
	IMR	21	21,000	39	1.857
		111	111,000	154	1.387
M196 (Tracer)	Ball	12	12,000	41	3.417
	IMR	31	31,000	41	1.323
		43	43,000	82	1.907
	Ball	102	102,000	156	1.529
	IMR	52	52,000	80	1.538

TABLE XIV-B

SUMMARY OF COMBINED FOULING TESTS

TYPE OF MALFUNCTION	NO. OBSERVED IN 154,000 RDS	RATE OF OCCURENCE PER 1,000 RDS	ESTIMATED AVERAGE RDS PER FAILURE
Broken extractor spring	1	.006	154,000
Bolt overrode base of round	103	.669	1,495
Double feed	11	.074	14,000
Failure of bolt to close	1	.006	154,000
Failure to feed	75	.487	2,053
Failure to fire	5	.032	30,800
Failure to eject	9	.058	17,111
Failure to extract	2	.013	77,000
Short recoil	31	.201	4,968
TOTAL	238*	1.545	647

* Not in agreement with combined fouling tests total (236) due to inconsistency of data.

SECTION XV

QUALITY ASSURANCE INTERCHANGEABILITY REPORT

This report presented the results obtained in the Interchangeability Test of 16 lots of M16A1 rifles. A sample of ten rifles from each of the 16 lots were selected. For each sample of ten, headspace, firing pin indent, trigger pull, targeting and accuracy, and functioning determinations were made before and after interchanging parts.

Analyses have been performed with the data obtained in the firing pin indent with the hammer released and with the hammer not released and the cyclic rate determinations. Data from these tests are summarized in the following table.

CHARACTERISTIC MEASURED	BEFORE INTERCHANGE		AFTER INTERCHANGE	
	AVERAGE	STD DEV	AVERAGE	STD DEV
Firing Pin Indent				
Hammer Released	0.0221 in.	0.00103 in.	0.0218 in.	0.00093 in.
Hammer Not Released	0.0057 in.	0.00092 in.	0.0060 in.	0.00079 in.
Cyclic Rate	773 rds/min	37 rds/min	774 rds/min	37 rds/min

Only one rifle failed to meet the requirements of the firing pin indent test. This rifle gave an indent of 0.017 inch with the hammer released as compared to the minimum specified indent of 0.02 inch. The firing pin in this rifle was replaced and 40 more weapons from the lot were selected for testing. In the retests, the lot from which the failing rifle was selected was finally passed.

An analysis of the variation in firing pin indent before and after interchange of parts indicated that there were no significant differences at the 0.05 level in the indents from lot to lot or those obtained before and after interchange of parts with the hammer not released. However, there was a significant interaction effect between lots and interchangeability (i.e., there were sizable differences in indents before and after interchange of parts for some rifle lots). In the firing pin indents with the hammer released, there were significant differences among rifle lots and there was also a significant interaction between lots and interchangeability.

Regarding the cyclic rates observed in the interchangeability tests, no significant differences were noted among lots or before and after interchange of parts. However, there were significant interaction effects between lots and interchangeability just as there were in the firing pin indent test.

It is of interest to note that none of the cyclic rates were outside the specified limits of 650-850 rounds per minute; however, examination of the frequency distribution indicates that the reported data may have been truncated at 850 rds/min. At least, it appears that a small portion of the distribution should have extended beyond 850 rds/min. In fact, since the cyclic rates appear to be normally distributed with a mean of approximately 773 rds/min and a standard deviation of 37 rds/min, 1.9% of the cyclic rates should have been 850 rds/min or greater.

Obviously, the distribution is affected by the practice, observed during a plant visit, of oiling or wiping dry the rifles which fail the cyclic rate test before retesting for this characteristic, and deleting the original test results.

Colt's Quality Assurance Interchangeability Report from September 1967 through March 1968.

SECTION XVI

FIRING RECORD (S-46571) OF COMPARISON TEST

FOR CYCLIC RATE OF BALL CARTRIDGES IN THE WSEG WEAPONS

Firing record, S-46571, contains data from tests conducted to determine the cyclic rates of the M16A1 rifles used in the WSEG Study when firing ball cartridges assembled with ball propellant and with IMR propellant. A total of 307 of these rifles were shipped to Aberdeen Proving Ground for testing, along with 29,000 cartridges from the four lots of M193 Ball Cartridges used in the WSEG study. One hundred fifty-six magazines used in the Study were also shipped to APG; however, they were not used in the cyclic rate determinations due to the condition of the packaging when received.

The cyclic rates of the rifles, when fired as received, have been summarized by rifle type (i.e., chrome and non-chrome chambers with new buffers installed in the factory and non-chrome chambers with new buffers installed in the field), by cartridge lot, and by magazine (i.e., first, second, and third magazines). Only the rifles selected to fire the two lots of cartridges assembled with ball propellant were fired as received. Because of the poor condition of the rifles as received at APG, the rifles were cleaned and lubricated and new cyclic rates were determined. The data obtained for the old rifles (with approximately 5,700 rounds fired) and the spare rifles (with approximately 240 rounds fired), after cleaning and lubrication, have been summarized by rifle type, cartridge lot, and by magazine number.

Analysis of variance methods were used to obtain estimates of the variation of cyclic rates among rifles, magazines, ammunition lots within propellant types, chamber types, within rifles and the interactions of these factors.

Malfunctions observed in the tests were summarized by chamber type and round number within a magazine. The latter summaries were made to obtain information concerning the frequency of malfunctions by round number of magazines in which the first round was a ball cartridge for comparison with the results in the WSEG Study in which the first one or two rounds were tracer cartridges.

In general, the analysis indicated significant variations in cyclic rates among rifles, magazines, propellant types, and lots within propellant types. There appeared to be an increase in cyclic rate from one magazine to the next of the order of 7 rpm for the lots assembled with ball propellant and 27 rpm for lots assembled with IMR propellant (cyclic rates were determined for three magazines on each rifle); however, this increase may have been due to the conditioning of the rifle. The cyclic rates also increased after maintenance (cleaning and lubrication) by approximately 74 rpm. As expected, the rates for lots assembled with IMR propellant were lower (by 86 rpm for the spare rifles and by 113 rpm for the old weapons after maintenance) than those for lots assembled with ball propellant. Within propellant types, the standard deviation in cyclic rate from lot to lot was approximately 20 rpm.

Regarding the malfunctions which occurred in the tests, 33 out of the total of 57 occurred in the rifles with chrome chambers, 14 of which were failures to eject. For the rifles with non-chrome chambers, the most prevalent malfunction was failure of the bolt to remain to the rear after the last round was fired. Eleven of the 24 malfunctions occurring in the rifles with non-chrome chambers were of this type. Regarding the malfunctions by round number, 8 (14.0%) occurred on the first round, and 21 (36.8%) occurred on the last (20th) round of the magazine.

Firing Record No. S-46571, Comparison Test for Cyclic Rate Comparison of Ball Cartridges in WSEG Weapons.

SECTION XVII

FINAL REPORT ON SPECIAL STUDY OF HIGH TEMPERATURE BORE FOULING OF 5.56mm, M196 TRACER CARTRIDGE IN M16A1 RIFLE

(REPORT NO. DPS-2664)

This report summarizes the results of a special test conducted to investigate bore fouling when firing the M196 tracer cartridge at high temperature environments. Seventeen lots of cartridges from two assembly plants (Lake City and Twin City) assembled with both ball and IMR propellant and with experimental gilding metal clad steel (GMCS) bullet jackets and standard gilding metal (GM) bullet jackets were fired. Tests were conducted in: (a) 20 weapons with both the weapons and ammunition conditioned at +155° F, (b) one weapon conditioned at +155° F and ammunition conditioned at +44° F, (c) one weapon conditioned at 44° F and ammunition conditioned at +155° F, (d) four weapons with both the weapons and ammunition conditioned at +95° F, (e) one weapon reconditioned from +155° F to 44° F, and (f) three weapons reconditioned from +155° F to 95° F.

Under each condition, the bores of the weapons in which ball propellant was fired were fouled, in some instances, after as few as 80 rounds fired and as many as 1,000 rounds fired. The bores of the weapons firing cartridges loaded with IMR propellant were clean after firing as many as 1,000 rounds. In most of the cases where the bores were fouled, yawing was observed, dispersions increased, erratic flights were noted and evidence of bullet breakup was indicated. The excessive bore fouling after firing ball propellant was generally localized in the area forward of the gas port. The remainder of the barrel was relatively clean.

The number of malfunctions (stoppages) has been summarized by magazine round number, propellant type and mode of fire. The table below gives a summary of the frequency of all types of malfunctions combined for the semi-automatic (SA) and automatic (A) modes of fire using ball and IMR propellants.

	BALL PROPELLANT			IMR PROPELLANT		
	SA	A	TOTAL	SA	A	TOTAL
No. rounds cons.	2,517	2,520	5,037	6,478	6,500	12,978
No. malfunctions	2	0	2	37	18	55
Malfunction rate	0.08	-	0.04	0.26	0.28	0.42

As can be seen from the table above, most of the malfunctions occurred when firing IMR propellant. Forty-five (81.8%) of the malfunctions observed when firing cartridges assembled with IMR propellant were failures to feed. The two malfunctions which occurred when firing ball propellant were failures to extract. The rifles used in this test apparently had non-chrome plated chambers. The tests did not include the determination of cyclic rates.

It was concluded, based on the results of the test, that the M196 tracer cartridge assembled with ball propellant (WC 846) is unsuitable for use in the M16A1 rifle at temperatures of +95^{o} and above due to excessive fouling resulting in yawing of bullets, increased dispersions, and erratic flights. Use of the gilding metal clad steel bullet jackets with the tracer round loaded with ball propellant give some improvement in performance, but did not eliminate the bore fouling and yawing problem experienced with the regular gilding metal jackets. Although the rifles which fired rounds assembled with IMR propellant were not fouled as were those which fired rounds assembled with ball propellant, significantly more malfunctions, predominantly feeding failures, occurred when firing IMR propellant. Regarding malfunctions by magazine round number, nothing concrete could be concluded since no indication of magazine round number was given for 21 of the malfunctions noted.

Report No. DPS-2664, Final Report on Special Study of High Temperature Bore Fouling of 5.56mm, M196 Tracer Cartridge in M16A1 Rifle, by A. R. Hankins, February 1968.

SECTION XVIII

ANALYSIS OF FINAL REPORT ON PRODUCT IMPROVEMENT TEST OF REDESIGNED BUFFER FOR M16A1 RIFLE

A test was conducted by D&PS to compare the functioning characteristics of rifles assembled with the redesigned buffer and those assembled with the standard buffer. Four combinations of projectiles and propellant types were fired under several adverse environmental conditions.

Malfunctions observed in the tests have been summarized considering test environment, mode of fire (automatic or semi-automatic), buffer type, projectile type, propellant type, and nature of malfunction (serious or non-serious). The cyclic rate of fire of twenty rounds from magazines have been summarized according to the classifications given above. The frequencies of cyclic rates falling outside the limits of 750 $\pm$ 100 rds/min have also been summarized.

Twelve M16A1 rifles with non-chrome plated chambers were used in the test. Four lots of ammunition were fired. These lots contained combinations of ball and tracer projectiles and ball and IMR propellants.

The new buffer was designed with the objective of reducing the cyclic rate of fire and to reduce the incidence of failures to fire.

The results of the tests indicate that the cyclic rate was reduced by the redesigned buffer; however, the number of trials falling below the lower limit of 650 rounds per minute was increased. The number of failures to fire was also reduced, but there was an increase in the number of failures to feed.

An analysis of variance of total malfunction rates (after use of the arcsine transformation to remove the dependency of the variance on the mean) indicated that over all environments tested, the malfunction rate for rounds fired with the redesigned buffer was significantly higher than that for the standard buffer. There were also significant interactions between buffer types and modes of fire and also projectile types and modes of fire. The malfunction rate for the standard buffer was higher for automatic fire, whereas the rate for the redesigned buffer was higher for semi-automatic fire. The rate for ball projectiles was essentially the same for both modes of fire, whereas the rate for tracer projectiles was higher for automatic fire.

Report No. DPS-2662, Final Report on Product Improvement Test of Redesigned Buffer for M16A1 Rifle, by Lloyd Staley, January 1968.

TABLE XVIII

SUMMARY OF MALFUNCTIONS OVER ALL ENVIRONMENTS

MODE OF FIRE		STANDARD				REDESIGNED			
		BALL		TRACER		BALL		TRACER	
		BALL	IMR	BALL	IMR	BALL	IMR	BALL	IMR
Semi-Auto	No. rds fired	3,835	3,595	3,403	3,643	3,930	3,850	3,943	3,943
	No. malf	29	38	33	17	90	134	145	139
	Malf/1,000 rds	7.562	10.570	9.697	4.666	22.901	34.805	36.774	35.252
Auto	No. rds fired	8,379	8,200	7,903	8,230	8,830	8,597	8,883	8,815
	No. malf	253	142	208	209	83	174	214	176
	Malf/1,000 rds	30.195	17.317	26.319	25.395	9.400	20.240	24.091	19.966

SECTION XIX

FINAL REPORT ON INITIAL PRODUCTION TEST OF CHROME-PLATED CHAMBERS FOR 5.56MM, M16A1 RIFLES

This investigation was conducted in order to evaluate the effects of chrome-plated chambers on the performance of the M16A1 rifle assembled with the new buffer. Five rifles with chrome-plated chambers, two rifles with non-plated chambers, and 56 magazines were employed.* The test was divided into four subtests; three environmental and one endurance test. Malfunctions were noted as Type I (those immediately clearable by use of the bolt-closure-assist device or retraction of the charging handle), or Type II (those not immediately clearable), as well as by individual types.

In the first environmental subtest (Static Dust Test), 20 magazines were used. Five hundred rounds were fired from each of four M16A1 rifles (two with chrome-plated chambers and two with non-plated ones). Five magazines, having 20 rounds each, were used with each rifle. Each magazine was subjected to five cycles of loading, conditioning periods in 140-mesh silica flour dust, firing in one of the rifles, and cleaning. The rifles were not conditioned. There was little difference between the two types of rifles with respect to Type I malfunctions, and there were no Type II malfunctions. However, examination of the spent cartridges revealed rim deformations among those fired with rifles with non-plated chambers, indicating increased extractive forces not present among those fired from chrome-plated chambers.

The second environmental subtest was the Dynamic Dust Test. The same 20 magazines (plus an additional one) and the same four rifles were used. In this test, the rifles were subjected to dust conditioning. As in the previous test, nothing was observed to associate Type I malfunctions with chrome-plating or the lack of it; however, two failures to extract and various rim deformations indicate that relatively high extractive forces were produced while firing the rifles with non-plated chambers. In addition to evaluating the rifles, it was also desirable to

* The ammunition used was 5.56mm ball, M193, loaded with ball propellant.

ascertain the severity of 140-mesh silica flour as a medium for use in dust tests. For this purpose, soil from three distinct areas in Vietnam were included in the test. In this connection, 103 or the 115 rounds which malfunctioned during this test had been conditioned with silica flour.

The last environmental test was a salt water immersion, high temperature and humidity test. Twenty new, fully loaded magazines were immersed for 60 seconds in a 20% salt water solution. Upon removal, 100 rounds loaded in five magazines were fired from each of the four rifles previously tested. The magazines were then reloaded, reimmersed, as before, and stored in an environmental chamber with a controlled temperature of 105° F and a relative humidity of 90 to 95%. The upper receiver assemblies of the four rifles were also stored in the environmental chamber. Twenty rounds were fired from each rifle after the first, third, sixth, and tenth day of storage. Examination of the rifles on the tenth day revealed light spot pitting of the chrome-plated chambers, while the non-plated chambers exhibited heavy corrosion and deterioration of the chamber head spacing shoulder. One weapon with a non-plated chamber was completely inoperable on the tenth day.

Three new rifles with chrome-plated chambers and 15 new magazines were used in the endurance test. Each magazine was loaded 100 times and 10,000 rounds were fired from each rifle using all modes of fire (full automatic, semi-automatic, and 3-to-5 round bursts). The weapons were cooled after each 100 rounds and maintenance was performed after each 1,000 rounds fired. Cyclic rates were measured for each magazine fired in full automatic mode. It was found that the cyclic rate increased during each 100 round cycle, but the average cyclic rate for each 100 round cycle decreased for the first six to eight thousand rounds and then began to increase. The majority of the Type I malfunctions encountered while firing in full automatic mode occurred during periods of relatively low cyclic rate, while most of the Type II malfunctions could be associated with high cyclic rates. The overall malfunction rate was less than .2%.

It was concluded that:

a. Chrome-plated chambers appear to decrease extractive forces, at least while firing under extreme conditions.

b. Chrome-plated chambers resist salt water damage.

c. Rifles with chrome-plated chambers perform satisfactorily for 10,000 rounds under normal usage and normal maintenance.

In addition, analysis of the data indicates that dust tests using 140-mesh silica flour appear to produce conditions at least as rigorous as those produced using dust from various areas in Vietnam.

Report No. DPS-2675, Final Report on Initial Production Test of Chrome-Plated Chambers for 5.56mm, M16A1 Rifles, by Franklin H. Miller, February 1968)

SECTION XX

FINAL ENGINEERING DESIGN TEST - MAGAZINE 20-ROUND, DISPOSABLE FOR M16A1 (XM16E1) RIFLE DPS-2536

A requirement for a reliable low-cost magazine for the M16A1 (M16E1) rifle was established because of the high consumption of the standard metal magazine in combat areas. Seven different types of disposable plastic magazines were submitted to APG for an Engineering Design Test; one type from the US Army Limited War Lab (LWL), one from Rock Island Arsenal (RIA), three from a manufacturer designated "Code A," and two from yet another manufacturer designated "Code B." These magazines were tested under various types of extreme conditions in order to evaluate their suitability for use in combat. Standard issue metal magazines were tested simultaneously for comparison. The two types of magazines from LWL and RIA were selected as the most promising ones, and these two sources resubmitted improved versions for a second Engineering Test. Standard magazines were again used as controls.

Although the order of firing was not clear, the test method and design appeared to be satisfactory. Evaluation, however, was made on the basis of defects (some of which were overlapping) rather than defectives. For example, non-firing defects were counted for: (1) a cracked magazine body, (2) a magazine which ejected rounds, (3) difficulty in inserting, and (4) difficulty in extracting the magazine. However, it is possible to find all of these defects in one magazine, and all four defects could conceivably have been caused by the cracked magazine.

The rate of occurrence of non-firing defects and drop test defects, computed with widely varying bases, were summed numerically with malfunction rates per 100 rounds fired, to produce an "over-all evaluation figure" which was presumably used as a basis for choosing the most promising magazine type.

The above procedures can badly distort the evaluation and may result in questionable decisions. In this case, one of the types produced by Code B appears to have been at least as promising as the RIA type chosen. However, the LWL product was so superior that the unorthodox procedures mentioned above probably did not affect the final choice.

Data from the control magazines tested were also analyzed. The malfunction rate over all tests was 1.87%. The Mud Test appeared to produce the highest malfunction rate (6%), and the most prevalent defect was failure of the bolt to remain to the rear (53% of all observed malfunctions). The next highest defect rate was failure to chamber (24% of observed malfunctions). Drop Test defects were the most common non-firing defects (98% of all observed) of which 41 out of 47 were magazines which ejected rounds. The combined overall defect and malfunction rate was 20%.

Over all tests, the control (standard) magazine was superior to all test models. The LWL type 1-A, which was the best of the test models, was comparable to the standard magazine except under adverse conditions.

Report No. DPS-2536, Final Report on Engineer Design Test of Magazine, 20-Round, Disposable, For M16A1 (XM16E1) Rifle, by Franklin H. Miller, October 1967.

SECTION XXI

M16A1 RIFLE DATA COLLECTION PROGRAM

In the period between December 1967 and February 1968, three teams, including representatives from AMC and WECOM, visited Fort Polk, Louisana, Fort McClellan, Alabama, and Fort Jackson, South Carolina as part of the M16A1 Rifle Data Collection Program. During the visits, the representatives observed the following types of troop training:

(a) Familiarization

(b) Introduction to Automatic Fire

(c) Qualification

(d) Technique of Fire

(e) Squad Tactics

At each of the training centers, data was collected on the malfunctions of the M16A1 rifle system. The data was summarized and published in three reports.

At Fort Polk, 4,500 rifles were fired a total of 350,023 rounds. One hundred eighteen malfunctions were noted, 46 (39.0%) of which were failures to fire automatic and 35 (29.7%) of which were failures to extract. Ninety-two (78.0%) of the malfunctions at Fort Polk were attributed to inadequate cleaning, 17 (14.4%) were attributed to improper assembly and 9 (7.6%) were attributed to unserviceable parts. The rifles at Fort Polk were not of recent manufacture; however, some of them were assembled with the new buffer. No determination of malfunctions by ammunition type could be made from the data in the report.

At Fort McClellan, 106,867 rounds (23,384 tracer rounds and 83,483 ball rounds) were fired from 1,308 rifles. Sixty-one malfunctions occurred, 21 (34.4%) of which were double feeds, and 10 (16.4%) of which were failures to fire automatic. Twenty-nine (47.5%) of the malfunctions were attributed to failure of the feed cycle, 9 (14.8%) to inadequate cleaning, 7 (11.5%) to unserviceable parts, 6 (9.8%) to improper assembly, 2 (3.3%) to defective ammunition, and 8 (13.1%)

could not be assigned a cause. The rifles at Fort McClellan did not have chromed chambers. Considering malfunctions by ammunition type, 8 occurred when firing tracer rounds and the remaining 53 occurred when firing ball rounds. The distribution of malfunctions by propellant type was not given.

A total of 95,629 rounds (24,716 tracer rounds and 70,913 ball rounds) were fired from 1,224 rifles at Fort Jackson. Sixty-two malfunctions occurred, 15 (24.2%) of which were failures to fire automatic, and 18 (29.0%) of which were double feeds. Twenty-five (40.3%) of the malfunctions were attributed to failure of the feed cycle, 9 (14.5%) each to inadequate cleaning and unserviceable parts, 6 (9.7%) to improper assembly and 13 (21.0%) could not be assigned a probable cause. The rifles at Fort Jackson were assembled with the new buffer and had a mix of chromed and non-chromed chambers. Thirty-seven of the malfunctions occurred when firing ball rounds and 25 when firing tracer rounds.

From an overall standpoint, the most frequent malfunctions among the total of 241 noted were failures which occurred during the feeding cycle (40 double feeds and 20 failures to feed), failures to extract (41), and failures to fire automatic (71). Thirty-five (85.3%) of the failures to extract occurred in the firings at Fort Polk where the rifles apparently did not have chromed chambers. It is of interest to note that 92 (78.0%) of the malfunctions occurring at Fort Polk were attributed to inadequate cleaning. This, in addition to the fact that the rifles did not have chromed chambers may account for the higher frequency of failures to extract.

M16A1 Rifle Data Collection Program; Ft. Polk, Louisana, 4-15 December 1967; Ft. McClellan, Alabama, 8-19 January 1968; Fort Jackson, South Carolina, 22 January-2 February 1968.

TABLE XXI-A

	FT. JACKSON S.C.	FT. McCLELLAN ALA.	FT. POLK LA.	TOTAL
No. Rifles Fired	1,224	1,308	4,500	7,032
No. Rounds Fired	95,629	106,867	350,023	552,519
Type of Rifle Chamber	Chrome and Non-Chrome	Non-Chrome	Non-Chrome	
Type of Buffer	New	Unknown	New and Old	
TYPE OF MALFUNCTION				
Failure to Feed (CNV)	-	4	-	4
Failure to Feed (CV)	7	4	5	16
Failure to Extract	2	4	35	41
Failure to Eject	1	3	5	9
Double Feed	18	21	1	40
Failure to Fire Automatic	15	10	46	71
Failure to Fire Semi-Automatic	3	7	11	21
Failure of Bolt to Lock	8	2	-	10
Failure of Bolt Stop to Hold Bolt Open	7	3	-	10
Failure of Forward Assist	1	-	-	1
Light Blow	-	3	13	16
Selector Binds	-	-	2	2
ASSIGNABLE CAUSES OF MALFUNCTIONS				
Inadequate Cleaning	9	9	92	110
Improper Assembly	6	6	17	29
Unserviceable Parts	9	7	9	25
Failure of Feed Cycle	25	29	-	54
Defective Ammo	-	2	-	2
Unknown	13	8	-	21
TOTAL MALFUNCTIONS	62	61	118	241
Number Malfunctions/1,000 Rds	0.648	0.571	0.337	0.436
***Estimated Average Rds Per Malf**	1,542	1,752	2,966	2,293

*** These are gross estimates since the failure rate is not constant.**

TABLE XXI-B

	FT. JACKSON, S.C.	FT. McCLELLAN, ALA.	FT. POLK, LA.	TOTAL
No. Rifles Fired	1,224	1,308	4,500	7,032
No. Rounds Fired	95,629	106,867	350,023	552,519
Type of Rifle Chamber	Chrome and Non-Chrome	Non-Chrome	Non-Chrome	
Type of Buffer	New	Unknown	New and Old	
UNSERVICEABLE PARTS				
Magazine Assembly	9	5		14
Disconnect (Burrs)		1		1
Rear Sight Detent (Burrs)		1		1
Extractor Spring			15	15
Extractor Pin			12	12
Action Spring			7	7
Gas Tube			5	5
Ejector Spring			1	1
TOTAL NO.	9	7	40	56

Section XXII

Comparison of Operating Characteristics for the Accuracy Requirements of Rifle, 7.62mm: M14 and Rifle, 5.56mm: M16

A study was carried out to compare the operating characteristics of acceptance specifications for the accuracy requirements of the M14 and M16 rifle systems. For this study it was assumed that the distribution of the coordinates of impact points for both rifles was circular normally distributed; i.e., horizontal and vertical dispersions (standard deviations) are equal.

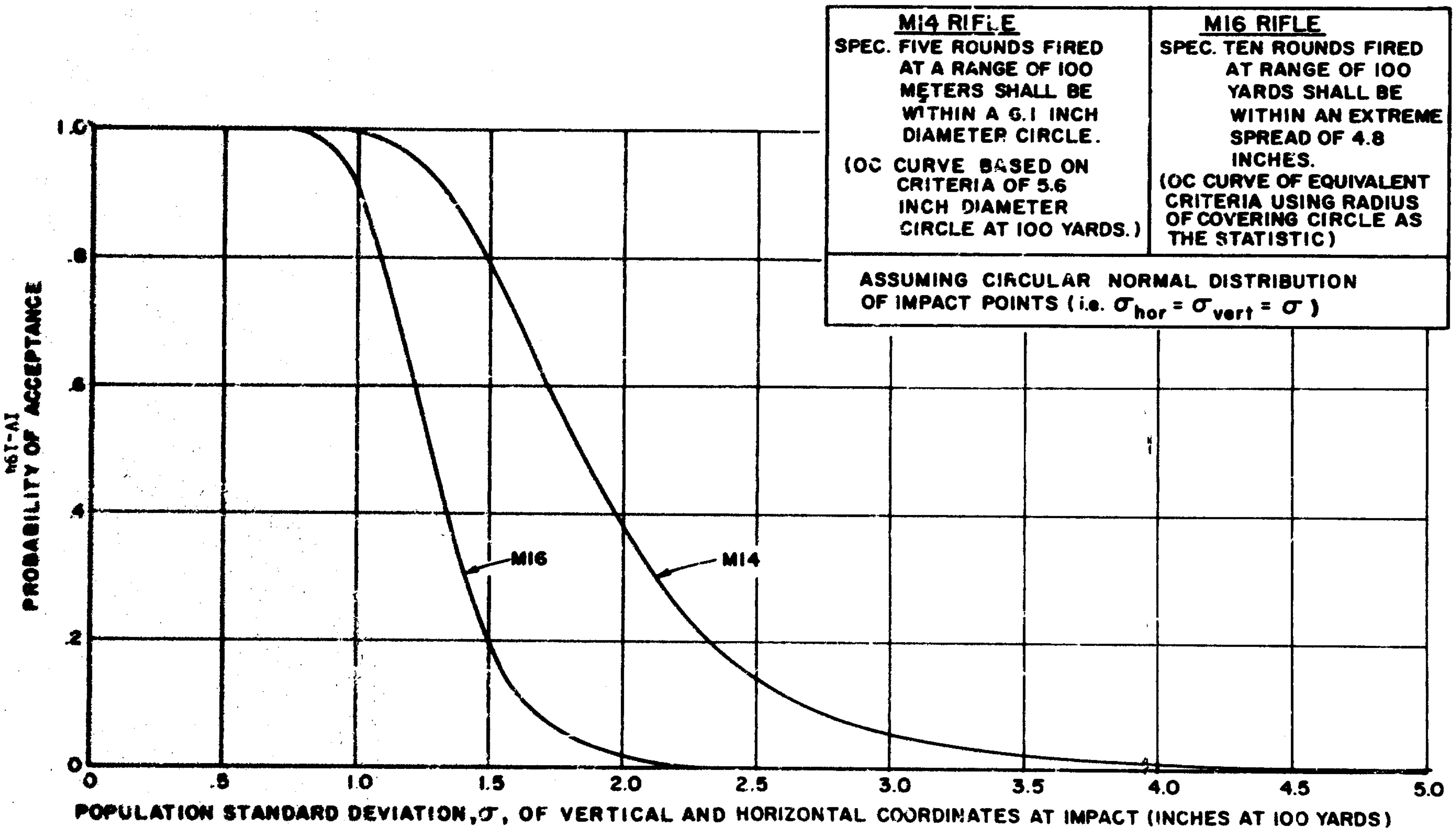
For the M16 rifle the accuracy requirement as specified in Purchase Description SAPD-253C is that the extreme spread (bivariate range) of the impact points for 10 rounds fired at a range of 100 yards shall not exceed 4.8 inches. Extreme spread is defined as the maximum of the distances.

$$\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad i \neq j \quad i,j = 1,2,3,\cdots 10$$

where (x_i, y_i) denotes the coordinates of a general point of impact. Since the distribution of the extreme spread for any general sample size has not been worked out, an approximate operating characteristics curve of equivalent criteria was computed using the radius of the covering circle as the statistic since the distributions of the extreme spread and radius of the covering circle are closely related. The covering circle is defined as the smallest circle on the target which contains all the sample impact points.

For the M14 Rifle the accuracy requirement as specified in Military Specification MIL-R-45012B is that five rounds fired at a range of 100 meters shall be within a 6.1 inch diameter circle, i.e., within a radius of covering circle of 3.05 inches. However, for comparison purposes the operating characteristics were based on a radius of covering circle criteria of 2.8 inches for a range of 100 yards, the range used for the M16 Rifle accuracy requirements.

The results of this study, as shown on the accompanying graph, indicate that the operating characteristics for the accuracy requirements of the M16 Rifle are more discriminating than that for the M14 Rifle. For example, for a population or true standard deviation of 1.5 inches at 100 yards range the probability of acceptance for a M16 Rifle is .20 as compared to a probability of acceptance of approximately .80 for the M14 Rifle.



Comparison of Operating Characteristics for Accuracy Requirements of Rifle, 7.62 MM: M14 and Rifle, 5.56 MM: M16

FIGURE XXII

SECTION XXIII

An Analysis of the Effect of Applying Sampling Inspection Plans to Individual Characteristics of Components

In the quality assurance system for the M16 rifle, the inspection results for attribute type inspections are evaluated using a separate sampling plan for each possible type of defect rather than grouping the inspection results for a number of different defects and evaluating these inspection results on the basis of the number of defective items in the sample. A defective item is an item that contains one or more defects. Also the Acceptable Quality Levels (AQLs) used in selecting the sampling plans for individual defects reflect the defect rate required for the entire rifle rather than a much lower figure needed to insure satisfactory rifle performance if the test results are to be evaluated using a number of separate acceptance criteria.

For example, the magazine assembly of the M16 rifle is inspected for 21 different major defects and an individual sampling plan using an AQL of 1% is applied for each type of defect. For a lot size of 35,000, the resulting double sampling plan using MIL-STD-105D is given on Figure 1. If a lot of magazine assemblies is submitted to this sampling plan which is 1% defective with respect to a given type of major defect, the probability that the lot would be accepted for that type of defect would be .982 which might be considered satisfactory if this were the only type of defect occurring in this lot. However, suppose that the lot was 1% defective with respect to each of the 21 different types of major defects that could occur with the magazine assembly. Then the probability of acceptance of the lot would be $P(A)=(.982)^{21}=.685$ while the total percent defective magazine assemblies in the lot would be $P_T=[1-(.99)^{21}]\ 100\%=19\%$. Thus these individual sampling plans for each defect would accept lots of magazine assemblies which are 19% major defective 68.5 percent of the time which certainly can not be considered satisfactory. However, had the lot subjected to the acceptance procedure been 19% defective but with all the defects of a single type, then this acceptance procedure would have almost certainly rejected the lot.

Thus for the procedure used for the M16 rifle, the probability of acceptance of a lot depends not only on the total percent defective items in the lot, but also on how that total percent defective is divided among the various possible types of defects for the item. For a fixed percent defective items in the lot, the probability of acceptance of the lot will be a maximum if there is an equal number of each type of defect in the lot. On the other hand, if all the defects are of one type, then the probability of acceptance of the lot will be a minimum for a fixed percent defective in the lot. For any other distribution of defects among the possible types of defects, the probability of acceptance will lie between these two limiting cases. On Figure 1 the probability of acceptance for these limiting cases are plotted as a function of the total percent defective in the submitted lot. It may be noted from Figure 1 that there is considerable uncertainty as to the probability of acceptance of a lot with a given total percent major defective which is subjected to this acceptance procedure for the magazine assembly for the M16 rifle. For example, a lot which is 8% defective would almost certainly be rejected if all the defects in the lot were of a single type; however, if all 21 types of defects were equally likely, then the lot would be almost certain to be accepted.

To remove the above uncertainty as to the probability of acceptance of a lot of a given total percent defective and to preclude the acceptance of lots containing a high total percent defective which is distributed among a number of different types of defects, a sampling plan based on the number of defectives in the sample should be used rather than individual sampling plans for each type of defect. Thus if the magazine assembly is inspected for 21 different major defects, the results of all these inspections should be combined in determining the acceptability of the lot. The number of defective items in the sample should be determined and this number would be used in determining the acceptability of the lot. Thus we would have a single sampling plan for this component (magazine assembly) and the probability of acceptance would be constant regardless of whether all the defects were of one type or an equal number of each of the 21 types of defects were present.

Ideally, from an evaluation standpoint, all possible defects of the rifle should be inspected in a single sample and then the acceptability of the lot of rifles could be evaluated on the basis of the total number of defective rifles in this sample. However, in-process inspections are desirable to minimize the likelihood that defective parts will be assembled to other parts thus making a whole assembly defective. Hence, inspections of the components of the rifle are necessary; but, these inspections should be carried out on the basis of the number of defectives in the sample and generally, separate acceptance criteria should not be applied to each type of defect. Also, in selecting the AQLs for these sampling plans for components, it should be remembered that these AQLs for components must be lower than the AQL required for the entire rifle to insure that the components passing these plans may be assembled into rifle lots that are of acceptable quality.

Thus the principle is to use as few separate sampling plans as possible consistent with the requirement of maintaining effective in-process control of the product and to evaluate the results of each sampling plan on the basis of the total number of defective items in the sample rather than by having separate acceptance criteria for each type of defect.

These same points are basic to acceptance inspection of vendor furnished components. It is highly likely that the current practices have had a direct bearing on the large percentage of rifles which have been rejected during (100%) final functioning tests and visual inspections as indicated on summary reports for the periods September 1967 thru March 1968.

TABLE I

Lower Limit on Probability of Acceptance of
Magazine Assemblies for M16 Rifle *

Corresponds to case where all defects in lot are of one type

Double Sampling MIL-STD-105D

Normal Inspection

Sample Size Code Letter M

AQL 1%

n1=200	Ac=3	Re=7
n2=200	Ac=8	Re=9

Percent of Lot Having a Given Type Defect	Probability of Acceptance of Lot if Submitted To Above Sampling Plan
$100\ p_i$	P(A)
0.2%	1.0000⁻
0.5%	.9997
1.0%	.9822
1.2%	.9536
1.5%	.8720
2.0%	.6483
3.0%	.2183
4.0%	.0499
5.0%	.0100

* Also corresponds to operating characteristic curve of individual sampling plan for each type of major defect for magazine assembly for M16 Rifle.

TABLE II

Upper Limit on Probability of Acceptance of Magazine Assemblies for M16 Rifle

Corresponds to case where the lot contains an equal number of each of the 21 types of defects

Percent of Lot Having Each Type of Major Defect	Total Percent Defective of Lot	Probability of Acceptance of Lot
100 p_i	$p_t=[1-(1-p_i)^{21}]$ 100%	$[P(A)]^{21}$
0.2%	4.1%	1.0000⁻
0.5%	10.0%	.9947
0.8%	15.5%	.9028
1.0%	19.0%	.6854
1.2%	22.4%	.3687
1.5%	27.2%	.0563
2.0%	34.6%	.0001
3.0%	47.2%	.0000

P(A) = probability of acceptance from Table I corresponding to p_i.

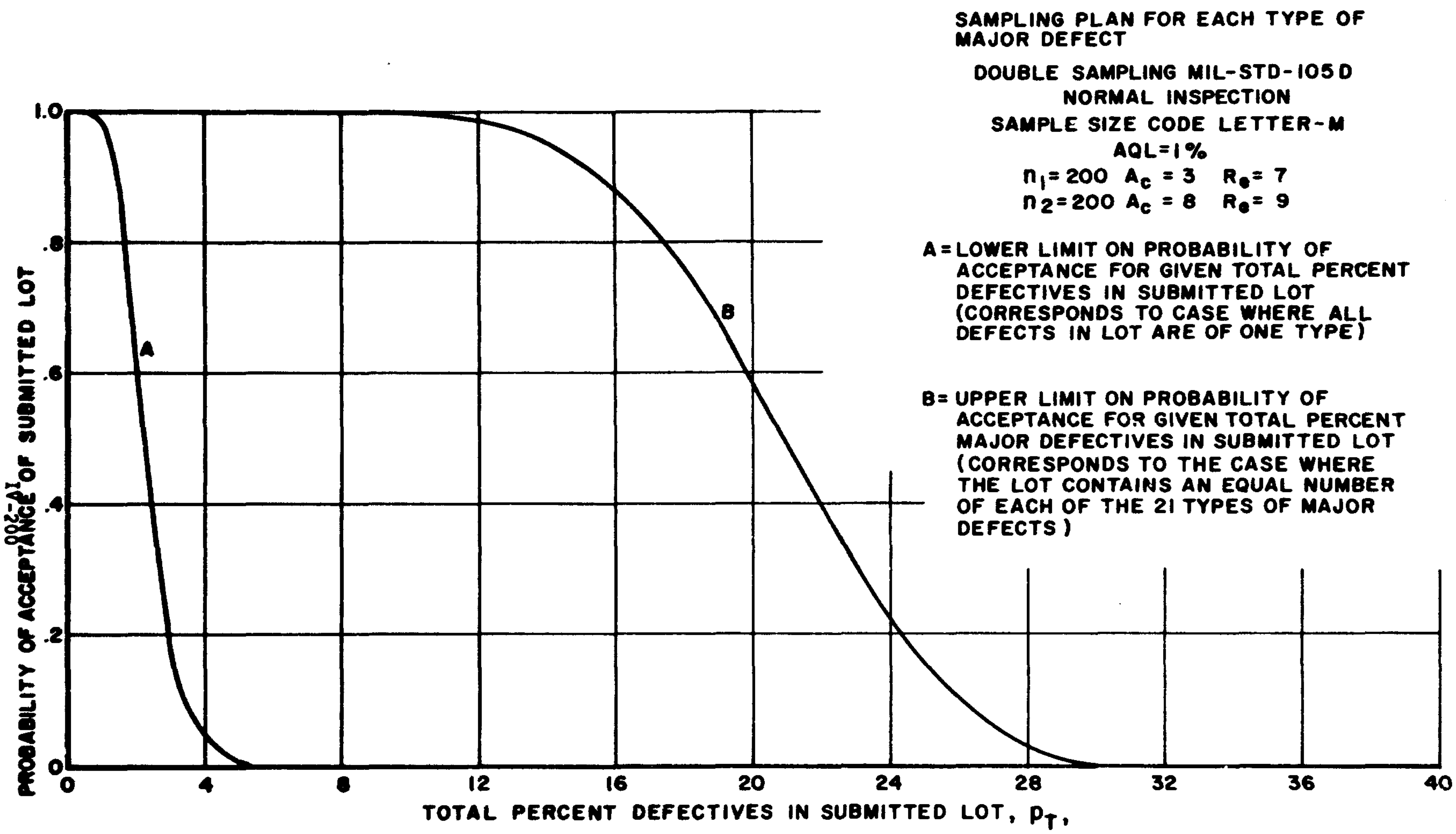


Figure XXIII - Upper and Lower Limits for Operating Characteristics of Acceptance Procedure For Magazine Assembly for M16 Rifle.

21 TYPES OF MAJOR DEFECTS

APPENDIX V

NOTES ON VISIT OF 15-16 MAY 1968 TO

DCAS, Hartford
Colt Industries, Inc.
Remington-Bridgeport
Universal Corporation

in connection with the M16 Rifle System

The visit to Colt revealed several significant matters which are pertinent to the quality and reliability of the M16 Rifle System.

Colt produces approximately 10 of the 116 or so major components of the system. There are approximately 40 vendors supplying parts to Colt.

The plant visit indicated that the quality assurance and quality control practices may depart somewhat from generally accepted concepts. As examples, the in-process roving inspections were conducted in a manner which could permit appreciable defective material to be produced with very low probability of being detected. At many work stations there was a Form C-1158 in use. This form indicated that a roving inspector would draw 5 pieces at least every two hours for inspection. Depending on the operation, the acceptance number varied. The data on inspection of the 5 piece samples were treated cumulatively, where for example, the acceptance number for 80 parts is 9. In other words, in this process 10% defective material is accepted a high percentage of the time and the probability of say, 20% defective material being accepted is also high. It would appear that this system is not designed to detect defective material promptly nor will it motivate personnel to take immediate corrective action. Rather, the defective material could remain in the system through subsequent operations without being detected. This point was brought up in discussions with the Chief of Quality Assurance and he indicated that they were changing this procedure.

The Chief of Quality Assurance, Mr. D. Grove, expressed their philosophy to the effect that it is more economical to tolerate such defective material in-process and to depend upon inspection, particularly of the final product, to screen out defective material. To objectively assess this view would require an appropriate cost analysis which is not currently available. However, intuitively it appears to be questionable.

It is also pertinent to observe that there was little evidence shown of any appreciable effort to take positive corrective actions to improve quality, e.g., the monthly summary reports on final inspection of rifles indicates rejection of the order of 20-30% of rifles submitted for acceptance and of 3% for headspace, an admittedly important characteristic. Although Mr. Grove said something was being done about it and corrective action had been taken, the statistics do not support this conclusion. Mr. Grove did indicate that there were so many different types of defects at relatively low frequency, say less than 1%, that it would be uneconomical to pursue efforts to reduce them. Another explanation offered was that the defects are mostly "visual and cosmetic." This may be partly true. If some of the defects are not important enough for rejection, a review of this matter is in order. Serious consideration should be given to further requiring the contractor to inform the Government of specific actions which are taken to effect improvements. There should also be follow-up and factual information required to establish that this is being done.

Another basic problem stems from a practice, throughout the plant, of applying AQLs and corresponding sampling plans to individual characteristics of a component or subassembly. Unfortunately this practice (which has been reviewed and not disapproved by the Government) is used by some Government agencies. It can be shown mathematically that under this procedure of applying, say an AQL of 1%, to each of 10 characteristics could permit defective material substantially in excess of 1% to be accepted a high percentage of the time. Accordingly, the cumulative effect permitted by such practices gives rise to a high likelihood of defects culminating in an end product in which 20-30% of defective material can be found in the final inspection. The proper methodology is to properly classify defects with respect to individual characteristics into groups of major, minor, or incidental categories. The sampling plans can be applied to these categories rather than the individual characteristics. This methodology would be stricter but sound and in keeping with the objective of ending up with a product which would have a required low percentage of defectives. In this connection, examination of inspection instruction sheets indicated substantial liklihood that many individual characteristic defects are over classified, i.e., many defects are classified as major when in fact the incidence of such a defect is not in keeping with the standard definitions and the impact of such a defect. This was discussed with Mr. Grove, QA Engineer, and he indicated that he and his staff had prepared classification of defects and much of it was done hurriedly and without appreciable study. However, this is important and costly.

The lower receiver, one of the major components, involves 137 inspection characteristics and on each of these there is an individual sampling plan. This would make it highly likely that if defective material is submitted for acceptance it could pass a high percentage of the time. In this connection, during the plant visit, DCAS Government Inspectors conducting inspections (which are performed, on a once a month basis, at the direction of WECOM) found a large number of defects. As a matter of fact two operations were completely-not performed- indicating that either the inspection performed by the Company was not particularly dependable and/or that material controls leave something to be desired. Further, Mr. Grove of Colt indicated that there are problems with the lower receiver which are attributable to dimensioning on the drawings. These are Colt drawings where dimensioning tolerances between surfaces and holes must under go further study.

Colt receives components from approximately 40 vendors. The incoming product is inspected on the basis of inspection plans where the methodology is similar to that discussed and criticized previously, i.e., materials inspected on the basis of AQLs pertaining to individual characteristics. Such practices do not provide effective controls over incoming products. Mr. Grove indicated that he was satisfied that the incoming product was satisfactory because the contractor's product was within AQLs.

It was also surprising to receive answers to engineering questions which would indicate that certain other matters should be examined, e.g., firing pin protrusion, and firing pin indent. In connection with the latter, it was developed that firing pin indent probably should be increased in order to reduce the probability of misfires occurring as residue and other foreign matter accumulates in the process of firing. Mr. Grove indicated that upon firing approximately 2,000 rounds the deposit caused the firing pin indent to decrease to a point where misfires can be expected. To increase firing pin indent or hammer blow would involve an increase in the trigger pull (approximately 1/2 pound), but this is not considered a major price to pay to alleviate this condition. It would be desirable to obtain information relating firing pin indent to number of rounds fired from a weapon under various schedules for cleaning. This may lead to the type of information which may be needed to effect improvements in the reliability of this system.

Endurance tests which are conducted at Colt are not particularly representative of endurance characteristics which may be experienced in the field, since the former are performed under somewhat non-representative conditions, e.g., the cyclic rate is monitored during endurance test and corrective action is taken with respect to lubricating and cleaning.

Observation of the high pressure tests of barrels and bolts in the Magna-Glo Inspection indicated that approximately 2% of the material is rejected. This seems to be a rather high rate of rejection due to cracks and raises a question regarding the quality of the material which is accepted even though 100% inspection is involved. The 2% rejection rate would tend to indicate that there may not be much margin of safety and the likelihood that other barrels could develop cracks should they be subjected to 1, 2, or more additional tests at high pressure. Presumably the high pressure tests impose a level of stress which is not completely beyond that which may occur in the field occasionally due to environmental conditions and product variations.

Examination of the operations of twist of rifling indicated several matters which could be pertinent. The method of cutting the twist of rifling is such that one could expect a non-uniform twist. Further, the method of gaging is questionable in assuring that the requirements for twist are met. The cutting is done with a "button" tool where the cutting edges are at an angle. A power rod is used to push the button through the barrel and cause the twist to be inscribed. This method would appear to be subject to non-uniform cutting due to bore diameter and metal variations and due to the non-uniform linear movement of the ram, particularly near the ends of the barrel. In the gaging operation the twist of only 12 inches of the barrel (in 20 inches of the barrel) is examined and the measurement made only establishes whether, over the total of 12 inches, the twist is one, but this does not assure either a uniform twist throughout the barrel or the rate of twist near the muzzle of the barrel.

Product improvement appears to be another important area currently lacking in emphasis. As an example, in discussing defects, their causes and seriousness with Mr. D. Grove, it developed that through some unexplainable reason the ramp angle of the barrel extension drawings is indicated as 45° although it is believed that a 40° angle is to be preferred and should reduce the possibility of jamming. Yet specific action to effect such a change is lacking.

In discussing technical aspects of cyclic rate, Mr. Grove agreed that probably it would be more important to control individual cyclic times although the current practice is to specify cyclic rate. In this connection it was indicated that cyclic rate specifications were chosen arbitrarily and were not based on engineering studies. He also agreed it would be advisable to institute a study to determine the optimum cyclic rate which will minimize the probability of malfunctions. This study should include consideration of several important pertinent factors such as type of ammunition to be used with the system, the effect of ammunition lot on cyclic rate and individual cyclic times, lubrication, cleaning, angle of fire, and environment.

In reviewing with Mr. Grove the question of types of defects and their seriousness, he is of the opinion that there is only one serious type of defect, i.e., failure to extract and it is a rather rare event. However, this may be a rare event in the test environment at Colt, but is probably not so rare an event in the field environment where pitted chambers, dirt, etc., are not uncommon. Mr. Grove indicated that chrome chambers are not a complete solution in itself because the surface is porous and will eventually corrode. In his opinion, the chrome plated chamber is an improvement only in so far as it will permit longer periods between cleanings by the rifleman. In his opinion, failure to feed, failure of the bolt to stay open, and failure to eject are not serious defects. Certain defects in the category of failure to fire may also be important depending on the cause. Incorrect headspace causes split cartridge cases or case separations which are serious defects. Mr. Grove indicated that in Colt's experience in reliability tests since 1964, the failure rate has been 2.2 malfunctions of all types for each 6,000 rounds fired.

In discussing magazines, Mr. Grove indicated that Colt has very little fault to find in this connection, however, it is clear that in the field magazines could be a major source of trouble due to lack of cleanliness or possible distortions attributable to dropping, wear, and tear. The characteristics of the lips of the magazine are carefully controlled at the manufacturers plant but the deformation due to dropping, wear, or tear could give rise to malfunctions.

In raising a question regarding action which is taken in connection with rifles which fail the cyclic rate test, it was found that corrective action is mainly limited to cleaning or oiling to effect a change in cyclic rate. This is somewhat questionable with respect to truly corrective action.

After the functioning test, the rifles undergo a disassembly and cleaning operation. This is done on all rifles by workers who are on a wage incentive plan. After the cleaning operation all rifles undergo a disassembly and final inspection process where approximately 80 characteristics are examined visually. This operation takes approximately 4-1/2 minutes. The records indicate that more than 20% of the rifles are rejected during this inspection. After this is completed, 20% of the rifles undergo a similar disassembly inspection and reassembly by DCAS personnel. The 20 rifles per 100 inspected have an acceptance number of zero. The lot of 100 rifles is further inspected through an additional sample of 32 rifles if the lot fails in the first 20. Examination of recent records indicate that 45 defects were found in a total of 5500 rifles inspected by DCAS personnel.

The visit to Universal Corporation was made. Discussions were held with Mr. Edward O'Kay, Plant Manager. The operations and material controls appeared to be in good order. A substantial amount of inspection is conducted but there do not appear to be very costly or undesirable operations. The record keeping on inspection results appears to be minimal or nonexistent. However, this does not appear to be a serious matter. Examination of data obtained from WECOM indicates that 15 magazines out of a lot of approximately 35,000 undergo tests where the acceptance number is zero. This appears to be a relatively loose acceptance sampling plan.

The visit to Remington-Bridgeport involved discussions with Mr. Joe Collins, QAR, and a brief visit with Mr. Pierce, Plant Manager. The QAR performs no in-process inspections and restricts his activities to only final product inspection although all in-process inspection results are available to the Government. The QAR witnesses every test of primer sensitivity.

Examination of the automatic machine inspection operations indicates a rejection rate of approximately 1.5% of the rounds. Following this operation, the rejected rounds are subjected to further gaging both by machines and manually and the rejection rate is reduced to 0.5%.

Examination of the rejected rounds indicated the main cause to be bruises. Discussion of this matter indicated that the 5.56MM round tends to deform and bruise more than other rounds because the cartridge case is thinner. This may have an important bearing on the malfunction rate experience in the field and possibly may involve deformation of rounds during magazine loading operations in the field.

In accordance with MIL-C-9963B, the functioning and casualty test of each lot of ammunition involves the firing of 240 rounds at each of ambient, cold, and hot temperatures where the firings are done in M16 Rifles both in the semi-automatic and automatic mode. It may be significant that the rifles are kept very clean and probably are not particularly representative of a condition in the field. The more serious types of defects which could have a bearing on rifle malfunction are attributable to blown primers which could cause weapons to fail to fire and pierced primers which may or may not cause a weapon to fail to fire. It may be significant to observe that inquiry revealed no particular evidence that Remington voluntarily or otherwise examines engineering questions relating to interface problems between the rifle and ammunition. It may be fruitful to encourage attempts to study ways and means of reducing the likelihood of malfunctions under various rifle/ammunition conditions which may pertain to the field.

Mr. Collins will furnish the committee with lot acceptance results including functioning and visual inspections. Data which were examined at the plant indicated that average port pressure for the lots being produced at Remington are fairly consistent. This type information will be examined later. Information available at Remington on headspace as a function of round number fired from a gun may prove valuable and Mr. Collins was asked to provide the committee with this type of data. It may lead to information pertinent to control of rifles in the field.

APPENDIX VI

A REVIEW OF QUALITY ASSURANCE RELATED TO THE PRODUCTION OF M16 RIFLE, MAGAZINE AND AMMUNITION

1. REFERENCE. Memorandum to Assistant Secretary of the Army (I&L) from Assistant Secretary of Defense (I&L), subject: Review of Production Quality Control of M16 Rifle, dated 23 April 1968.

2. BACKGROUND.

a. The reference cited, lists a number of questions regarding the quality assurance provisions and practices related to the procurement of the M16 Rifle/Magazine and Ammunition. These questions were developed for the primary purpose of identifying areas wherein improvements might be effected in current contracts and in the Government procurement quality assurance function.

b. The questions attached have been addressed by the M16 Rifle System Reliability Evaluation Task Force as part of the Army Study of the M16 Rifle Quality Assurance Program. The latter was requested by the Deputy Chief of Staff for Logistics in response to a request made by the Assistant Secretary of the Army. The subject matters related to the questions served as a baseline for emphasis placed by the Task Force in its analysis of the many elements comprising the M16 Rifle Quality Assurance Program.

c. Detailed answers to many of the questions are contained in the Appendices to the main Task Force report. Where excessive repetition would be involved in answering the questions, reference has been made to the Appendix in which the detailed information can be found.

PHASE I: OPERATIONAL REQUIREMENTS

1. QUESTION:

Have military operating requirements for this equipment been developed?

RESPONSE:

No QMR has been developed. The purpose (and preparation) of a QMR appears pertinent before a system is adopted by the Army, although the usefulness of preparing one for the M16 rifle at this late date is questionable. The reasons no QMR was prepared will be found in Appendix II. Reference should also be made to this Appendix and Appendix III for answers to the remaining questions in Phase I.

2. QUESTION:

If so, in what documents are the operating requirements for the M16 Rifle, Magazine, and Ammunition stated (e.g., QMR)?

RESPONSE:

See answer to Question 1.

3. QUESTION:

What are the operating requirements? If none exist, why not?

RESPONSE:

See answer to Question 1.

4. QUESTION:

If formal operating requirements exist, have they been meaningfully translated into specifications, i.e., were specific performance requirements accompanied by the necessary QA demonstration provision, incorporated into the specifications? Were new specifications developed to meet the special needs dictated by the operating requirements, or were existing specifications used?

RESPONSE:

See answer to Question 1.

PHASE II: CONTRACTUAL QUALITY ASSURANCE PROVISIONS

1. Contracts:

a. QUESTION:

Is procurement and production of the M16 accomplished along "system" lines, or is this weapon procured by separate contracts for the rifle, magazine, and ammunition? If separate contracts are used by the Government, is there clear evidence that the contracts and the associated production and contract changes are properly integrated to insure satisfactory functioning of the procured items as a "weapon system"?

RESPONSE:

(1) Separate contracts are executed by the Government for the procurement and production of the M16 rifle/ magazine, and ammunition. Present procedures include one M16 rifle producer and six ammunition suppliers.

(2) The M16 rifle program is directed by the Project Manager, Rifles, who has overall management responsibility for the program. Contracts and associated production and contract changes are integrated since all contracts and changes thereto are processed through the Project Manager's office and must be approved before being implemented. The Project Manager, Rifles, is responsible for assuring that all changes affecting the functioning and performance of the rifle system undergo thorough examination and analysis prior to effecting a change.

(3) Although the M16 Rifle Program is project managed, the Task Group finds no provision for testing the subsystems, i.e., rifle, magazine, and ammunition as a "weapon system". The Task Group considers a "weapon system" test necessary to:

(a) Insure continuing compatibility of interfacing subsystems.

(b) Provide a basis for current evaluation of system performance characteristics, such as reliability, accuracy, and effectiveness.

(c) Input for product improvement and/or corrective actions, as may be required.

To accomplish the foregoing, the Task Group recommends that an independent test be conducted at intervals utilizing the Test and Evaluation Command for this purpose. The test samples should be composed of rifles, magazines, and ammunition randomly selected from field and depot stocks, thus affording the opportunity to examine the interfacing subsystems as a system and determine the interaction effects upon system reliability and performance.

b. QUESTION:

Who (what organization) is responsible for initiating the purchase requests?

RESPONSE:

(1) Rifle - The US Army Weapons Command is responsible for initiating purchase requests for the rifle.

(2) Ammunition - The US Army Munitions Command is responsible for initiating purchase requests for ammunition for the M16 rifle.

c. QUESTION:

What organization writes the contracts?

RESPONSE:

(1) Rifle - The Procurement and Production Directorate, US Army Weapons Command, writes the contracts for the rifle.

(2) Ammunition - The Procurement and Production Directorate of Frankford Arsenal, which is part of the US Army Munitions Command, writes the contracts for ammunition used with the M16 rifle.

d. QUESTION:

Who negotiates the contract(s), i.e., performs the PCO function?

RESPONSE:

Rifle and ammunition - The Procurement and Production Directorates of the organizations indicated in the preceding question perform the Procurement Contract Office (PCO) function.

NOTE: In response to 1b, c, and d, above, it should be noted that it is Army policy for commodity commands to initiate proposals, write, and negotiate contracts and perform the PCO functions for the commodities over which they have cognizance. This is not undesirable per se, but it can contribute to interface problems.

e. QUESTION:

Does the contract(s) comply with the ASPR (e.g., use standard format and standard inspection/quality control clauses)?

RESPONSE:

Rifle and ammunition - Contracts are prepared in accordance with the guidance contained in ASPR. Contracts contain the appropriate quality assurance clauses and requirements in effect at the time contracts were prepared. Newly developed ASPR clauses pertaining to quality assurance are utilized. Failure of the contractor to fully implement these requirements contributed to M16 quality problems.

f. QUESTION:

What, if any, superfluous/duplicative/or contradictory QA requirements do the contracts contain?

RESPONSE:

(1) Rifle - Basically, there were no serious superfluous/duplicative QA requirements in the contract, although some of the detailed requirements of MIL-Q-9858 and MIL-C-45662 were restated in the contract. No contradictory QA requirements were noted.

(2) Ammunition - No superfluous/duplicative or contradictory QA requirements were noted in the review of the ammunition contracts.

g. QUESTION:

How does the contract define the contractor's responsibility for quality and reliability?

RESPONSE:

(1) Rifle - Contractor responsibility for control of quality was delineated in the contract through incoroporation of MIL-Q-9858 in the contract. Additionally, paragraph 1 of the initial purchase description (SAPD-253-B) cites the contractor's responsibility for inspection and tests through incorporation of the standard paragraph (M-200 Standardization Manual). Again, this is not a question of whether or not the requirements were adequately defined; lack of full implementation by the contractor caused many of the quality problems under discussion.

(2) Ammunition - Contractor responsibility for inspection is established through incorporation of MIL-I-45208 in the contract which requires the contractor to comply with the inspection system requirements specified therein. Additionally, specifications covering ammunition delineate contractor responsibility for inspection and test through utilization of the standard paragraph as prescribed by Standardization Manual M-200.

h. Does the contract:

(1) QUESTION:

Clearly define the contractor's responsibility for the quality of vendor-furnished material (i.e., components fabricated by sub-contractors)?

RESPONSE:

Rifle and ammunition - The contracts covering rifles and ammunition cite specifications MIL-Q-9858 and MIL-I-45208, respectively. Paragraphs 5 and 3.12 of these specifications, respectively, provide for control of vendor-furnished material by the prime contractor. The contractor's responsibility, accordingly, is clearly defined in the contracts.

(2) QUESTION:

Limit in any way the contractor's responsibility for the quality of vendor-furnished material?

RESPONSE:

(a) Rifle - Contractor was required by contract to develop Inspection Instruction Sheets for parts and components produced either by the prime contractor or by his sub-contractors. Preparation of the Inspection Instruction Sheets is predicated upon requirements established by the contractor's drawings for the applicable parts and components. Contractor's responsibility for quality of vendor-furnished material may have been limited by the fact that the contract specified the range of acceptable quality levels (0.65 to 1.5) for major characteristics and (1.5 to 4.0) for minor characteristics, including definitions for major and minor characteristics, notwithstanding the fact that MIL-STD-105 was part of the contract. The preferred method would have been to require the contractor to furnish to the Government the AQL ranges which he proposed, allowing the Government the option to disapprove his proposed AQLs if they were not acceptable.

(b) Ammunition - No limitations were imposed upon the contractor since the Government did not specify defect classification and AQLs for component parts making up the complete ammunition round, except for furnishing visual standards to cover defects, such as metal defects, splits, dents, and cracks. The contractor, accordingly, was responsible for exercising all necessary in-process controls and providing to the Government ammunition which complied with the end item specifications.

(3) QUESTION:

Specify the quality levels for vendor-furnished material? Are these levels adequate? Compatible with required end item reliability requirements/objectives?

RESPONSE:

Rifle and ammunition - The contract for rifles can be considered to specify quality levels for vendor-furnished material, as indicated in the preceding discussion since a range of AQLs were provided in the contract for contractor use. The Colt's QA Manager indicated that the AQLs were established hurriedly and arbitrarily. The compatibility among quality levels is questionable. Further, a question must be raised as to the concept of specifying separate AQLs and applying sampling plans independently for each separate characteristic. It can be shown mathematically that there will be a high probability of accepting defective material under this system, i.e., the power curve or operating characteristic of the overall sampling plan is weak. No definitive answer can be provided regarding the compatibility of the AQLs selected by the contractor with end item reliability requirements/objectives. As indicated in Phase I of this Questionnaire, firm reliability requirements/objectives for the rifle system were not established by Government agencies.

(4) QUESTION:

Include specific interchangeability requirements? If so, are these compromised by any other contractual provisions?

RESPONSE:

Rifle - SAPD-253-B and changes thereto establish specific interchangeability requirements. It is believed that these requirements may be compromised by permissive use of "preferential assembly" and "hand refinement". Even though the use of selective fits is limited by a requirement that the parts must comply with drawing requirements, it is obvious that such practices may compromise interchangeability. Reports of tolerance incompatibilities also suggest the possibility of interchangeability problems.

(5) QUESTION:

Require the contractor (prime and/or sub) to identify and take action to remove defect-causing conditions?

RESPONSE:

Rifle and ammunition - Both specifications, MIL-Q-9858A and MIL-I-45208, paragraphs 5 and 3.23, respectively, which are part of the rifle and ammunition contracts, require that the contractor take corrective action to identify and remove assignable causes of defects, but as noted in answers to previous questions, all evidence points to unsatisfactory performance by the rifle contractor in this area.

(6) QUESTION:

Require 100% post-firing disassembly inspection, analysis of failures, and reassembly? If so, is this provision conducive to obtaining satisfactory quality and reliability of the delivered item?

RESPONSE:

Rifle and ammunition - The requirement for 100% function firing and post-fire disassembly and inspection are a part of SAPD-253-B, end-item specification and the contract. Analysis of data derived from these inspections disclose the presence of a high percentage of defective materiel and suggests that this operation serves as a screening inspection. Recently, additional control has been imposed by the

Government requiring the further inspection of 20 rifles from each lot of 100 rifles after contractor acceptance. It appears that inadequacies and/or absence of process controls throughout the production cycle, i.e., manufacturing, assembly, testing, and reassembly, contribute to the presence of numerous defects in the rifles at final inspection and would prevent the application of sampling inspection. The alternative of stopping production until comprehensive corrective actions could be taken (to correct in-process deficiencies) has serious disadvantages at this time with respect to urgent schedules. In other words, because of extensive shortcomings in quality control during the manufacture of the M16 rifle, 100% final acceptance inspection is an absolute necessity. This would not be necessary (nor economically desirable) if the manufacturing processes were under adequate quality control.

2. Drawings:

a. QUESTION:

Have applicable drawings been subjected to tolerance review by the Government? By the contractor?

RESPONSE:

Drawings covering the configuration of the rifle were contractor drawings and are proprietary. The Government, accordingly, did not subject the contractor's drawings to detailed tolerance reviews since drawing requirements and materiel requirements for component parts were established by the contractor. The extent of the contractor's engineering review of his drawings cannot be specified, except that after-the-fact information indicates some tolerance conflicts are present. (See answer to Question 1h(4).)

b. QUESTION:

Is there any tolerance interference that would contribute to the failure of the end item?

RESPONSE:

As indicated in the preceding paragraph, tolerance interference may exist. Whether this interference, when present, contributes to the failure of the end item is not known. Gaging problems do exist and the Project Manager, Rifles, has an AMC Working Group engaged, in coordination with the contractor, in analyzing this problem. Additionally, an engineering study for determining the "tolerance" condition has been initiated.

c. QUESTION:

Have the applicable drawings been made available to the contractor?

RESPONSE:

As previously indicated, essentially all of the drawings covering the rifle are the property of the contractor. For the new procurements, the Government has purchased the manufacturing rights. Government drawings applicable to the rifle were made available to the contractor and these were cited in the contract.

3. Specifications:

a. QUESTION:

Are there specifications for the end item, components, magazine, ammunition (including the powder and ammunition components)?

RESPONSE:

There are specifications for the M16 rifle and ammunition, including propellant and ammunition components. The magazine, as part of the rifle, is described by drawings and the Inspection Instruction Sheets. As discussed in Appendix III, inadequacies exist in these specifications and suggested improvements have been recommended.

b. QUESTION:

Do these clearly define the contractor's responsibility for performing the inspections/tests contained therein?

RESPONSE:

Specifications clearly define the contractor's responsibility for performing the inspections and tests specified therein.

c. QUESTION:

Is there any overlap or duplication?

RESPONSE:

No overlap or duplication of contractor/Government inspection responsibilities is evident.

d. QUESTION:

Are there any conflicting or contradictory requirements?

RESPONSE:

No conflicting or contradictory requirements are contained in the specification for the M16 rifle and specifications for ammunition, including propellant and ammunition components.

e. QUESTION:

If AQLs (acceptable quality levels) are included, are they proper, i.e., afford adequate protection? Too tight? Too loose?

RESPONSE:

(1) Rifle - The M16 rifle specification (SAPD-253-B) does not contain stated AQLs. An AQL for the firing pin indent test, for example, may be inferred by examining the sample plan specified and the acceptance number. The AQLs for the M16 rifle parts and components are specified by the Inspection Instruction Sheets developed by the contractor. Due to the manner of applying the specified AQLs to individual characteristics, the sampling plans are very likely to be too loose.

(2) Ammunition - AQLs are included in the ammunition military specification for ball and trace 5.56mm ammunition. The AQLs established at .25% for Majors and 1.5% for Minors (class basis), represent a standard of quality which has been accepted by the Government and industry. AQLs are consistent with the process capabilities of small caliber ammunition manufacturers. While the listing of defects is comprehensive, these should be re-examined in relationship to the M16 rifle system to determine whether changes are appropriate in light of the firing data generated to date.

f. QUESTION:

Are specified AQLs compatible with each other? With 100% inspection requirements for the end item?

RESPONSE:

The AQLs for the M16 rifle component inspection were established on the basis of the contractor's proprietary drawings. The AQLs have a range of 0.65 to 1.5% for Major characteristics and 1.5 to 4.0% for Minor characteristics. (In actual practice, AQLs of 1.0% and 2.5%, respectively, are applied across the board.) It is not known if these AQLs are compatible with each other. However, these AQLs combined with inadequate contractor process controls, result in high rejection rates during 100% inspection of the end item. (Refer to Chapter II B). The AQLs specified for ammunition apply only to the end item and not to components. No inconsistencies exist between the 100% inspection for the critical characteristics of ammunition, e.g., gage and weigh requirements, and the AQLs specified for Major and Minor inspection characteristics for acceptance.

g. QUESTION:

Is the contractor required to maintain records of all specification tests and inspections?

RESPONSE:

Contractors are required to maintain records of all specification tests and inspections, as specified by specifications MIL-Q-9858 and MIL-I-45208. Cursory examination of the contractor's inspection and test records indicates that further investigation of this subject is in order.

h. QUESTION:

Is there any possibility for misunderstanding of the respective role of the contractor vs the Government for test requirements contained in the applicable specifications?

RESPONSE:

No misunderstanding of the respective roles of the contractor vs the Government for test requirements prescribed in applicable specifications exists.

i. QUESTION:

Are all test requirements meaningful to the end item?

RESPONSE:

All requirements are pertinent to and meaningful with respect to providing information on the end item. However, some accept/reject criteria, as stated in current specifications, may not be meaningful in clearly differentiating between good and poor products. (See Chapter II for discussion.)

j. QUESTION:

Are specification technical requirements (provisions contained in Sec. 3) covered by appropriate demonstration provisions (i.e., inspections/tests) contained in Sec. 4?

RESPONSE:

All specification technical requirements both for the rifle and ammunition are supported by demonstration requirements; i.e., quality assurance requirements. Although SAPD-253-B was not prepared in specification format, each technical requirement is supported by a quality assurance requirement and inspection and/or test method. Improvements in demonstration provisions are being recommended. For example, there is a need for establishing visual standards to assist in making subjective determinations, such as the "cosmetic defects" on rifle parts. For ammunition, the technical requirements specified in Section 3 of military specifications are supported by appropriate quality assurance provisions in Section 4.

4. Quality Control of Production:

a. QUESTION:

Is the contractor required to control manufacturing processes (e.g., as required in MIL-Q-9858A)?

RESPONSE:

(1) Rifle - Specification MIL-Q-9858 is part of the contract awarded to Colt, Inc. The contractor, accordingly, is required to control manufacturing processes as specified in the referenced specifications.

(2) Ammunition - The contracts for 5.56mm ammunition specify MIL-I-45208. Contractor control of manufacturing processes is required to the extent required by the end item specifications. All ammunition producers, however, have quality control procedures which are an inherent part of their process control.

b. QUESTION:

If MIL-Q-9858 is required, is it in fact implemented by the contractor, e.g., does the contractor segregate and maintain positive control over non-conforming items; provide adequate work instructions; maintain calibration over gages and test equipment (traceable to NBS); maintain records of all inspections?

RESPONSE:

The contractor segregates and maintains control over non-conforming items by identifying and routing non-conforming materiel to segregation areas for determination as to rework, waiver, or scrap. He provides work instructions in the form of component inspection instruction sheets, test procedure sheets, in-process inspection instructions and final weapon inspection procedures. The contractor maintains calibration over gages and test equipment on a time-recall basis by direct utilization of his atmospherically controlled laboratory and traceable standards. He maintains records on component and final weapon inspections and tests, although, as previously noted, there appears to be a need for improvement in this area. Further, high rejection rates during final inspection and test, and observations made during plant visits, indicate that the contractor's entire quality assurance system is in need of improvement. (Refer to Chapter II-C)

c. QUESTION:

Does the contractor require similar controls to be exercised by subcontractors? How does he insure performance?

RESPONSE:

No. However, the contractor does require all vendors to have, or depend upon, a calibration system which controls the accuracy of measuring and test equipment. A recent change was made in the contractor's purchase order requirements to more clearly define this requirement. Component inspection records must be maintained only by manufacturers of certain components, as specified in the purchase order. To assure conformance to quality requirements, the contractor performs standard lot sampling of all vendor material at the receiving inspection. Vendors are contacted as conditions or history warrant. Additionally, the contractor recently completed a survey of all vendors.

The magazine receives special attention. A sample of 15 is selected from each lot of approximately 35,000 for assembleability and functional testing. The magazines also receive considerable testing as part of the rifle functioning test (one magazine per rifle), but this is not part of a formal acceptance/rejection requirement or criteria. It is considered that the sample size of 15, with acceptance of zero, constitutes a relatively loose sampling plan.

d. QUESTION:

For calibration and control of the accuracy of tools and gages (including production tooling used as a media of inspection), is MIL-C-45662 required? Is it properly used?

RESPONSE:

(1) Rifle - Both specifications, MIL-Q-9858 and MIL-I-45208, reference MIL-C-45662. Accordingly, implementation of the requirements of MIL-C-45662 is required of the contractors.

(2) Ammunition - The contractor has a calibration system which satisfies MIL-C-45662, including an environmentally controlled metrology laboratory. There are record keeping, recall, and control procedures for issuing and storing gages. These procedures are followed in-house.

e. QUESTION:

If sampling inspection is used, how are rejected lots controlled (for in-house production as well as for subcontractor-furnished material)? Is corrective action (e.g., remedial action to correct the cause) taken to change the manufacturing process? To require appropriate corrective action by subcontractors?

RESPONSE:

(1) Rifle - Rejected lots are identified and controlled. After screening or correction of defects, an alpha suffix is added to the lot number to identify the resubmission. The lot is reinspected for the

characteristic(s) which caused rejection. Additionally, the process control department is notified of the rejection on in-house produced items. Action taken may be increased process sampling or frequency of sampling or action to correct the manufacturing process if, in the opinion of the contractor, the frequency or seriousness of the deficiency dictates this course of action. When a purchased item is rejected, the vendor is notified immediately so that he may take the necessary corrective action in his current production. Lots which had been returned to the vendor for correction are identified by adding an alpha suffix to the lot number. Upon their return to the contractor, these resubmitted lots, since they were not under the control of the contractor, are reinspected for all characteristics when they are returned from the vendor. Analysis of inspection summary reports (Sep 1967 through Mar 1968) indicate that whatever corrective action was taken may not have been fully effective.

(2) Ammunition - Hold areas have been established for materiel rejected as a result of sampling inspection. A review of sampling inspection data covering ammunition indicates that a high quality level exists for ammunition producers. This high quality level is attributed to the maintenance of quality control procedures, such as control charts by the producers which provide timely information regarding changes occurring in the processes. The prime contractors require corrective action by their subcontractors whenever there is evidence of unsatisfactory vendor supplied materiel.

f. QUESTION:

Are rejected sample inspected lots subject to reinspection/test after screening/correction of defective items? Is tightened sampling inspection used to retest rejected lots? Or instituted for subsequent lots?

RESPONSE:

(1) Rifle - Where sampling inspection is applicable, rejected lots are subjected to reinspection. The decision to use tightened sampling inspection to retest or reinspect rejected lots is dependent upon the quality history of the materiel in question. Since MIL-STD-105 forms a part of the contract, the criteria covering normal, tightened, or reduced inspection apply. Normally, tightened inspection is used to retest rejected lots and subsequent lots. When a lot is rejected, a determination is made if defects are to be submitted for waiver consideration. If so, the lot is set aside and retained until a waiver has been processed. The lot is released if a waiver is granted. If any part of the waiver request is disapproved, the lot will be screened for unsatisfactory conditions.

(2) Ammunition - Lots of ammunition which have not met the criteria established in the specification are rejected subject to repair and/or reinspection prior to resubmission for acceptance. Repair and/or reinspection procedures are subject to the approval of the Government representative. Where retests are permitted, double sample sizes are required.

g. QUESTION:

In the event sample inspected lots are rejected, what action is taken when investigation indicates that similar defects may exist in items already delivered? Is the procuring activity (ACO or PCO) notified by the contractor? What action is taken to correct completed items awaiting shipment?

RESPONSE:

(1) Rifle - The use of sampling inspection for the M16 rifle (end item) is minimal since the majority of tests required by the specification are conducted on a 100% basis. During testing and final 100% inspection, all defective parts found are removed and replaced by

acceptable parts. In the event the investigation of a defective condition leads to the conclusion that similar defectives may exist in items already shipped, the PCO is immediately notified. Items awaiting shipment are screened whenever deemed necessary. For example, a bell-mouth condition was found in the chamber of the barrel. The ACO and PCO were made aware of this condition. A large sample of barrels was checked to determine the extent of this defect. The defect was also noted in finished weapons. The PCO was then notified of the inspection results which were found in the evaluation of the defect. The PCO then notified the ACO that the condition was waiverable. The ACO notified the QAR and the weapons were released. The contractor then followed-up with a formal waiver action. The Task Force, in considering the possible need for identifying and locating shipped items containing or suspected of containing defects, concluded that the establishment of a lot identification requirement would be highly desirable. It is recognized that the increased configuration control disciplines required to make lot control effective would be costly, but there should be no compromise with quality in the case of a rifle upon which a soldier may depend on for his life. Accordingly, the Task Force recommends the establishment of a study to determine the feasibility of requiring lot identification and control of all rifles.

(2) Ammunition - Ammunition is identified by lot number, type, caliber, model, supplier identification, and a federal stock number. When sampling inspection or tests reveal that items in production or awaiting shipment may contain serious defects, all suspect material can be identified and held for necessary investigations pending the outcome of corrective action. With this lot identification, any lot can be removed from the supply system if investigation indicates that similar defects may exist in items already delivered.

h. QUESTION:

Does the contractor maintain positive control over scrap and unauthorized (for use) non-conforming material to prevent it from getting back into the production process? Are stocks of manufactured parts and vendor items used to fill orders for delivery as spare parts subject to special control (e.g., as bonded stock)?

RESPONSE:

The contractor maintains control over scrap and non-conforming material. Rejected material is moved to a segregated area for disposition, except vendor items which are returned to vendor or screened by the contractor. Scrap material is sold as scrap. Upper and lower receivers to be scrapped are mutilated and barrel extensions are removed from the barrels. Components acceptable for the end item are the same as those shipped out as spares. The same controls are used for both, but special controls, e.g., bonded stock, are not used. Increased quality control is employed, however, when quality history indicates a deterioration of quality. Mandatory Government inspection (PIT A or B) is normally employed until the contractor's control is re-established as evidenced by Government evaluation. The use of bonded stock techniques would better protect Government interests and is recommended.

i. QUESTION:

Does the contractor maintain complete/accurate records of all inspections/tests performed? Defects found? Corrective action taken? What level of contractor management reviews these?

RESPONSE:

The contractor maintains records of all inspections/tests performed, defects found, percent defective, and corrective action taken (rework, screen). First line supervisors are responsible for this review. The extent of corrective action by the contractor is indicated by his evaluation of the frequency and cause as related to cost. Studies of defect patterns, conducted by DCAS, have given direction to the contractor's corrective actions (e.g., visual standards for clarifying arbitrary criteria for acceptance or rejection). All levels of management from Chief Inspector to the Vice President of Manufacture are involved in the reviews. As indicated elsewhere in this report, the Task Force has reservations regarding the effectiveness of these reviews and of corrective action, in general.

j. QUESTION:

Are contractor work instructions adequate/complete/available/ compatible to contract requirements?

RESPONSE:

Inspection Instruction Sheets for component parts contain a listing of the characteristic to be inspected, applicable AQL, method of inspection, sampling plan, etc. But, as previously discussed, objections have been raised by the Task Force concerning the component Inspection Instructions, AQLs, and process control procedures. As of mid-May 1968, the Inspection Instruction Sheets, which were prepared in 1963, had not been reviewed or revised with respect to classification of defects and the application of AQLs. The impression has been given that Colt prepared these instructions hurriedly in 1963 to meet urgent deadlines. Testing and final Inspection Instruction Sheets are compatible with the rifle specification. These Inspection Instruction Sheets are available for use by contractor inspectors and as required by the Government representative.

k. QUESTION:

Are records of rejections/scrap/rework analyzed and reviewed by company management? What level of management?

RESPONSE:

The contractor claims that inspection, test, and scrap records are reviewed for problems dictating action by various levels of company management based on the impact of data. Previous comments on in-process inspection deficiencies, which result in high rejection rates during 100% final inspection, suggest that management has not analyzed the cost effectiveness trade-offs between poor process control and high 100% final inspection costs, or the probability that a defective product will be shipped as a result of the difficulty of detecting all defects when the defective incidence is so large at the time of final inspection.

5. Drawing and Configuration Control:

a. QUESTION:

Is there a requirement that the contractor establish a procedure for maintaining strict control over drawings and drawing changes?

RESPONSE:

Both specifications, MIL-Q-9858 and MIL-I-45208, established the requirement that the contractor establish a procedure for maintaining strict control over drawings and drawing changes.

b. QUESTION:

Does the contractor's program provide for the control of drawings include release, change approval, removal, and designate the time and point of effectivity for new, or changes to drawings?

RESPONSE:

(1) Rifle - In the contractor's present program, the Engineering Department is responsible for the control of drawings and changes thereto. Proposed changes are first circulated to affected departments and vendors for comment. After this coordination, the ECP's are submitted

to AWC for approval and implemented by normal contract change procedures. Contractors in-house distribution is controlled by the Engineering Department and return of obsolete drawings is required. The program calls for incorporation of changes at specified effective points.

(2) Ammunition - The control of the technical data package in the case of the ammunition is with the Army Design Agency and all engineering changes to drawings, specification, and other technical data are accomplished through the Engineering Change System, which provides for control of the basic configuration. The Engineering Change System also provides for consideration of any effect of changes on production schedules, costs and mandatory effectivity dates. The contractual control of changes is effected by the Procurement Contracting Office in conjunction with the Administrative Contracting Office.

c. QUESTION:

Are the contractor's drawing and configuration control procedures adequate? Followed?

RESPONSE:

(1) Rifle - The contractor's drawing and configuration control procedures are followed. However, the implementation of proposed and approved engineering changes, updating of Inspection Instruction Sheets and the revision of gage drawings is in need of improvement. Known deficiencies which could be readily corrected by engineering change have been extremely slow in being implemented. Examples are the change of the ramp angle from 45° to 40°, the dimensioning of the lower receiver and the correction of known tolerance incompatibilities and improvements in gage designs.

(2) Ammunition - Same as 5b(2), above.

d. QUESTION:

Does the contractor's control extend to drawings and changes applicable to subcontractors/vendors?

RESPONSE:

(1) Rifle - The contractor's controls extend to drawings and changes applicable to subcontractors. However, since approximately 90% of the components are supplied by vendors, the preceding comments are pertinent here.

(2) Ammunition - If the engineering change affects vendor items, the contractors control extends to his vendors.

6. Deficiency Data:

a. QUESTION:

Does the contractor receive deficiency reports initiated by Government field activities?

RESPONSE:

(1) Rifle - The contractor receives Unsatisfactory Material Reports through Government channels. Customer Complaints and UMR's, which should normally comprise the more critical user feedback of problems and which, in turn, might be related to the effectiveness of the quality program, have not been of the density that would reflect significant quality problems from the user point of view. This official feedback (approximately ten UMR's since January 1967) has covered a small number of weapons and provided only limited visibility. Other feedback data from rifle tests conducted by the user, technical agencies, and TECOM have not in all cases found their way back to the quality elements of DCAS, or where appropriate, to the contractor. It is considered essential that user problems, or problems found in tests, be properly defined and reported, and that this feedback be provided the Contract Administration Office, and the contractor as applicable, in order that any necessary corrective action might be taken.

NOTE: The foregoing does not reference the Marine Corps complaint and the investigations which followed. The results of the investigations were used to effect design changes and corrective action in quality control procedures.

(2) Ammunition - When there are field malfunctions, contractors are notified and brought into the investigation depending on the preliminary investigation which might imply a hardware deficiency.

b. QUESTION:

Does he evaluate and analyze these deficiency reports to identify conditions requiring changes in the production process to prevent defect recurrence?

RESPONSE:

(1) Rifle - He evaluates and analyzes all deficiency reports received, as indicated in the answer to 6a(1), above. It is of interest to note, however, that UMR's received to date have not been sufficiently complete or specific to cause the contractor to make any significant changes in his production processes.

(2) Ammunition - The deficiency reports are analyzed by a joint team of contractor/Government representatives and recommendations are based on their findings.

c. QUESTION:

Does he incorporate or make timely changes in the manufacturing process to prevent such recurrence?

RESPONSE:

(1) Rifle - He does, if the discrepancy warrants a change. (See answer to 6a(1) and 6b(1).)

(2) Ammunition - If the recommendations require such changes, they are implemented into the manufacturing process through the Engineering Change System.

d. QUESTION:

Is action taken by the contractor to insure that such deficiencies are corrected on items awaiting shipment?

RESPONSE:

(1) Rifle - Yes, if the deficiencies exist in items awaiting shipment.

(2) Ammunition - When actions are required on materiel suspected of containing deficiencies, the items are placed into a suspended status pending corrective action.

e. QUESTION:

Does the contractor have an internal (within plant) deficiency data feedback system, i.e., one that advises management of production quality control deficiencies?

RESPONSE:

(1) Rifle - The contractor utilizes a series of quality reports to keep management informed of production quality control deficiencies. Feedback related to floor level deficiencies are transmitted by QA to appropriate supervisory personnel.

(2) Ammunition - The contractor's processes are controlled by quality control techniques which provide for data feedback relative to the quality of the items.

f. QUESTION:

Does management take timely and effective action to correct the conditions responsible for these deficiencies?

RESPONSE:

(1) Rifle - Particular deficiencies have received timely and effective action to correct the conditions responsible for them. However, it is the conclusion of the Task Force that the contractor's philosophy

of screening defects at 100% final inspection, rather than correcting manufacturing and process deficiencies, is inimical to good quality management.

(2) Ammunition - Analysis of acceptance data and rejection rate indicates that management takes timely and effective action to assure the production of materiel in conformance with contractual requirements. Formal complaints received from the field relative to ammunition deficiencies are such as to indicate that required process controls and corrective actions are in effect, timely, and responsive.

7. Project Management (Program Management Office):

a. QUESTION:

Is the M16 managed and procured as an integrated system (e.g., one contract for the complete system, or separate contracts for each major component, i.e., rifle, magazine, ammunition)? If procured by separate contracts, how are these managed to insure effective integration as a "weapon system"?

RESPONSE:

As previously indicated, the M16 is not procured as an integrated system since separate contracts have been awarded - ammunition and rifles/ magazine, including repair parts. Although the above listed components of the M16 Rifle System are procured by separate contracts, the Project Manager, Rifles, is responsible for their management as a weapon system.

b. QUESTION:

Does the M16 Rifle Program Management Office write (negotiate) the contract?

RESPONSE:

The Procurement and Production Directorate of the respective commodity commands writes and may negotiate contracts.

c. QUESTION:

If the Program Management Office does not write the contract, does it review the purchase request or contract for adequacy of the quality assurance (QA) provisions?

RESPONSE:

Contracts prepared by the commodity commands for the Program Management Office are reviewed by his staff for the adequacy of QA provisions. Recently, the Program Manager assigned personnel to Frankford Arsenal to effect liaison with interfacing organizations.

d. QUESTION:

Does it have an organic capability for insuring and/or providing continuing review of QA during production? What skills exist (e.g., are there GS-1900 series class-act civilian personnel assigned)? If not, who provides this capability?

RESPONSE:

The Project Manager's Office, in addition to having a quality assurance element, is supported by the QA elements of the commodity commands. The QA elements of the commands provide to the Project Manager both quality engineering and GS-1900 series personnel and their particular services.

e. Does the Program Management Office:

(1) QUESTION:

Review and initiate action to correct QA deficiencies/ conflictions in the contract?

RESPONSE:

The Project Management Office reviews and monitors the QA activities of performing agencies and may initiate action to correct deficiencies, when considered necessary. At the present time, the Project Manager, Rifles, has an AMC/DCAS committee investigating QA deficiencies, gaging problems, specification requirements, and other related matters for the purpose of improving the QA program.

(2) QUESTION:

Review field deficiency reports? Monitor correction action? How?

RESPONSE:

Field deficiency reports received by the Project Manager's Office are reviewed and requests for corrective action initiated. These requests are processed through the Contract Administration Office with follow-on visits either by personnel of the PMO and/or commodity command key inspectors.

(3) QUESTION:

Review contractor production quality control?

RESPONSE:

PMO review of contract control is exercised through quality reports provided by the commodity commands.

(4) QUESTION:

Establish mandatory inspections/tests to be performed by the Government QA representative at the contractor's plant?

RESPONSE:

Mandatory inspection tests are established through the medium of the QA Instruction Letters prepared by the PCO/QA activity.

(5) QUESTION:

Does this direction emphasize independent Government inspection (to verify the effectiveness of the contractor's inspection), or does it require only a witnessing of contractor performed inspection/tests?

RESPONSE:

This direction requires witnessing of contractor performed inspections/tests and independent Government product verification inspection.

(6) QUESTION:

Require independent quality audit to be performed by outside inspection agencies on contractor produced/furnished items? If so, what action is taken to insure that identical inspection criteria is followed (i.e., same inspection performed as is contractually required of the contractor)?

RESPONSE:

In light of the difficulties experienced with the M16 rifle, the Project Manager, Rifles, and the commodity commands have established a procedure for the independent quality audit of contractor produced/furnished items. This audit is accomplished by an outside inspection agency and deficiencies disclosed by the audit are furnished to the contractor through the DCAS/QA element.

APPENDIX VII

MOTIVATION OF CONTRACTORS FOR QUALITY

Prepared by Dr. Phimister B. Proctor

The procurement policy of the Department of Defense is based on holding the contractor responsible for quality. This is accomplished by contracting for a quality system, as well as for a product which meets specified quality requirements. Under this policy, the Government inspects a minimal amount of hardware (both in process and final inspection) to assure that the contractor's system is capable of producing products of acceptable quality. The Government also monitors the Contractor's quality system to assure that he is, in fact, putting it into practice.

The vast majority of American contractors honestly try to meet their contractual requirements. A good contract is the best basis for a good understanding between the Government and a contractor. To be a good contract, it must clearly define the product or system under procurement. It must also define all supporting tasks related to accomplishment of the contract. A quality assurance system is one of these "software" tasks.

MIL-Q-9858A is an excellent quality system specification. It (and its predecessors) served a useful purpose in defining contractors quality responsibilities, particularly a few years back when most contractors lacked formal quality programs. Systems specifications of this type, however, have the weakness of being subject to variable interpretation; the contractor striving for leniency, the Government representative tending toward extensive enforcement.

With the advent of the fixed price environment and the increase in competitive bidding there is a need for more clearly defining quality tasks so that contractors who are competing for a procurement can be assured that they are pricing the same requirements. (This approach is equally important to the Government to avoid over-specifying costly quality requirements.)

It is the opinion of the undersigned that the best way to "Motivate" contractors to better quality is to negotiate a sensible and firm quality program plan, which becomes a part of the contract, effective as soon as the work begins, i.e., MIL-Q-9858A can still serve as the "shopping list" for a full-scale quality program plan for a complex system, scaling down the requirements for less complex products, commensurate with their end use.

Both the Aerospace Industries Association and the National Security Industrial Association have recommended the above procedure to the DoD, and a committee of which the writer was chairman made a similar recommendation to the NASA. The principal deterrent to its accomplishment is the shortage of quality assurance personnel in Government to prepare the quality program plans required for each procurement. At the least, however, quality program requirements should be a part of every bid package for any weapons system that is large enough or important enough to have a Project Manager - and there should be a quality specialist to monitor the quality program after the contract is let.

Industry is demanding a clearer definition of quality requirements; more definitive than can be conveyed by the mere reference of MIL-Q-9858 in the contract. There is a new industry saying that, "you can't price motherhood."

In this connection there are those who believe that recent improvements in reliability, resulting from reliability performance incentives, have stemmed more from the establishment of reliability goals and measurement criteria than from the cash incentives alone. On the other hand, no acceptable formula has yet been found to apply incentives to quality control performance. Indirect measurements, such as meeting performance specifications, reliability and maintainability goals, prices and schedules, are all indications of low defective and scrap rates and good quality control in general. There is logic in applying incentives and penalties to such parameters but it is difficult to see how the Government can pay a contractor for meeting a specification which, presumably, he is already being paid to meet.

Carrying out the theme that a good contract is the best way to get a good product, it is believed that MIL-Q-9858, which establishes quality system requirements for complex items, is not the proper quality specification for the M16 Rifle procurement. A small arm is an assembly of precision-machined parts; it is a precise product, but not a complex one. The important quality control elements for such a product are: (1) precision manufacturing to carefully selected and integrated tolerances, and (2) accurate gages, properly calibrated, to assure conformance to specified tolerance limits; backed up by rigid materials control, fully effective control of special processes (heat treat, surface finishes, etc.) and strict manufacturing controls attained through in-process and piece part inspection - followed, of course, by final acceptance inspection which is based on meaningful accept/reject criteria.

An inspection system designed to satisfy the foregoing standards need not include all of the system control requirements inherent in a quality program for a complex item. It would not, therefore, be unreasonable to substitute MIL-I-45208 for MIL-Q-9858 in M16 Rifle contracts, with no reduction in cost (because the contractor is not non-complying with the latter specification). The contractor should then be required to develop an effective quality program plan (subject to Army disapproval) to satisfy MIL-I-45208, and be required to adhere to it without waiver.

Inherent in the above plan is the necessity of convincing the contractor that he must review his specifications and drawings related to tolerances, and for tightening his quality controls over parts manufacture, special processes, etc., as discussed above. It would no doubt also be necessary to provide assistance to the contractor in the preparation of the quality plan. There is little doubt that the Government would find it necessary to engage in above-normal direct inspection of piece parts in order to demonstrate the need for the reevaluation of tolerances and better inspection practices.

It is believed that the contractor will respond (be motivated to better quality) to the proposed change to a quality specification that is more closely related to the conventional operating practices of the industry of which he is a part, and to the product he is manufacturing.

The weakest link in virtually all quality systems is Corrective Action. While Corrective Action cannot be classed as a "Motivation" method, improvement in this area can do more for quality than any single action the quality profession has ever experienced.

There is a lesson to be learned from the space business that could be applied to Corrective Action. The lesson was born of necessity because of the unattended-nofix-nature of spacecraft. Because of this, every production and test failure on a spacecraft must be traced to a satisfactory conclusion. To assure that this is done, Failure Review Boards are established to maintain strict controls and accountability of failure reports, provide for competent failure analysis, and assign responsibility for problem solution and effective corrective action. The Failure Review Board on Surveyor spacecraft was made up of Vice Presidents, Division Managers and Chief Scientists - and they reviewed the disposition of every single failure report.

Corrective action need not be quite that stringent for average manufacturing operations, but the establishment of Corrective Action Review Boards, at appropriate levels, with authority to fix responsibility for corrective action and to review the results would have a salutary effect on quality. The present routine of sending corrective action requests to Production and Engineering - and waiting for a "snow job" has never worked.

Past history indicates that split responsibility for the management of weapons system contracts often results in uncoordinated changes, buck-passing and unsatisfactory overall performance. Conversely, full weapons system responsibility vested in a single contractor is a strong motivation for good quality performance. It is recognized that this may be difficult to accomplish under the fragmented responsibilities of the several Commodity Commands. A possible solution would be to give overall authority to a Project Manager, whose staff would consist of personnel assigned from the Commands and reporting directly to him for the tenure of the assignment. This would motivate both the Contractor and the Army to produce a product of high quality.

APPENDIX VIII

FAILURE ANALYSIS

A. INVESTIGATION OF AMMUNITION AND COMPONENT PARTS CAUSING OR RESULTING IN MALFUNCTIONS OF THE M16A1 RIFLES.

1. For the purpose of this study ammunition and component parts returned for the WSEG study in Panama were analyzed in the laboratory. Two hundred eighty-six rounds and components of 5.56mm and sixty-three of 7.62mm were received for study. Each round, cartridge case or projectile was checked to determine, as accurately as possible, the cause of the malfunction. Firing pin indents on the primers of the rounds which failed to fire were measured for depth and position of the strike. Cartridge cases were examined, under magnification, to determine what may have occurred to cause the malfunction. All cartridge cases involved in a failure to fire, failure of the bolt to lock or a failure to extract were measured for roundness. Projectiles were checked for any deformities.

2. The majority of the malfunctions for the M16A1 were failures to fire and/or failure of bolt to lock (116) and failure to chamber (78). Seven of the "failures to fire" can be attributed definitely to the ammunition because the depth of the firing pin indent on the primer ranged from 0.015 inch to 0.020 inch. Four of these rounds were tracers from the WCC lot. Most of the rounds from the WCC lot had a concave condition of the primer surface toward the actual firing pin indent. This could have been a contributing cause of "failure to fire" for rounds from this particular lot of ammunition. The remaining firing pin indentations ranged from less than 0.001 inch to 0.0145 inch and these may be attributable to the rifle.

3. There are two likely causes for a light firing pin indentation. The primer can be struck by the firing pin upon full chambering and bolt locking (before activation of the trigger). This occurrence will give an indentation of 0.001 inch to 0.010 inch without firing a round. The primer can also be struck by the firing pin when the bolt is not fully locked and the trigger is activated. The hammer can be released by a pull of the trigger when the bolt still has 3/4 of an

inch of travel left before locking. Of course, dirt in the chamber can prevent full locking of the bolt. Dirt and grime in the bolt carrier group can also cause a light blow on the primer by the firing pin. Also, if the bolt carrier group does not carry all of the way to the rear on recoil the bolt may not have sufficient energy to lock the bolt on the return forward. Many rounds which were identified as having "failed to fire" had not been fully locked in the chamber. The rounds had slight dents on the cases which only could have been caused by foreign deposits in the chambers. Some of the rounds had a ring of carbon around the neck of the cartridge case indicating that the chamber may have had a residue of carbon.

4. Conjectures of the reasons for so many "failures to fire" on the first round from a magazine are that the rifleman may not have charged the rifle properly; that is, did not let the bolt slam home but followed it in with the charger handle; or did not hit the bolt assist; or the chambers were dirty and would not allow the bolt to lock. Dirt and dust in the bolt carrier group could also prevent proper closure of the bolt.

5. It cannot be determined, at this time, if any of the "failures to fire" (other than the seven mentioned previously) were caused by faulty primers. An attempt would have to be made to fire the round to determine this.

6. The "failures to fire" occurred more frequently with the chromed chambered rifles than with the non-chrome chambered rifles. Automatic and semi-automatic modes of firing had approximately equal numbers of "failure to fire" and/or "failure of bolt to lock."

7. An additional six rounds were found to have manufacturing defects. Three cartridge cases had "blind primer holes" (i.e. no hole for the primer to flash through to ignite the propellant) and three rounds had been loaded with primers but no propellant. The first three rounds mentioned caused "failures to extract" because the case swelled in the chamber or blew out the primer cup. The three rounds with primers but no propellant forced the projectile into the barrel

and caused a "jam" as the next round was chambered.

8. "Failures to feed" and "failures to chamber" should be considered together since both are almost always caused by an insufficient amount of gas impulse. In the instances of "failures to chamber" the scratches and nicks on the rounds indicated that the bolt did not clear the base and rim of the cartridge cases on recoil. This allows the bolt lugs to catch in the extractor groove or on the case itself and drive the round from the magazine only to have the bolt override the case and jam it into the chamber guides, thereby resulting in a "failure to chamber." Some of the cartridge cases which had been involved in "failures to feed" had the same type of scratches and groove marks as the cases identified as "failure to chambers." Other cases had a long groove up the side to the neck of the cartridge case. This was caused by the overriding of the bolt. Whether the bolt failed to strip the rounds from the magazine or "jumped" over the rim of the case on return and thereby jammed the round against the front edge of the magazine cannot be determined.

9. A few of the rounds involved in "failures to chamber" had minor nicks and scratches and some of the projectiles appeared to have been "crimped" with pliers. Whether this happened during loading of magazines, handling by the rifleman or inspection by other investigating personnel is not known. Marks on five of the cartridge cases indicated that several attempts had been made to chamber them.

10. The malfunctions, "failure to feed" and "failure to chamber," occurred more frequently with the IMR rounds and when the rifles were firing "automatic."

11. Spread magazine lips were mentioned as causes of malfunctions. However, upon using some of the magazines which had spread lips, malfunctions could not be duplicated in the laboratory. "Double feeding," which occurs when two rounds are stripped from the magazine together, could not be duplicated and may have been a defect caused by the rifleman.

12. Another possible cause of "failure to feed" and "failure to chamber" is "loose magazine latch" or "tight magazine latch." Using a rifle that had had the magazine catch loosened so that the spring had very little tension, attempts were made to determine if the loaded magazine could cause a malfunction. Even with the rifle set "automatic" the magazine stayed in position and properly fed the rounds.

13. Failures to extract were more prevalent in the non-chrome chambered rifles when firing the IMR rounds. Most of the rounds examined had pits and scratches which indicated that the chambers were very dirty with sand and carbon deposits. One fired cartridge case had "layer" metal on the rim which peeled away when the extractor pulled on it.

B. INVESTIGATION OF DEFECTIVE PARTS.

1. Of seventy defective parts analyzed most were of the bolt and bolt carrier group. The most common part to wear out or break was the bolt gas ring. It appeared that the ring became worn and then broke off. The majority of the broken gas rings occurred in the twenty-third firing period (approximately 5300 rounds). One bolt assembly was found to have an excessive head spacing when gaged. This condition could cause a failure to eject, (as was stated on the parts envelope), but it more then likely could cause a light firing pin strike of the primer. Another bolt assembly was replaced because it failed to function properly but it appeared to be extremely dirty. There were some grains of dirt under the extractor.

2. The extractor springs and ejector springs were the causes of malfunction at least eleven times. All of the springs which were examined were worn or had been broken. An extractor spring could break if it is not assembled properly. The ejector springs cannot be improperly assembled unless the retaining pin is left out during assembly.

3. There were two instances of firing pin failures. Both were caused by improper assembly of the firing pin. In one case the rifleman had not replaced the firing pin retaining pin. This allows the firing pin to "float free" and could cause a jam of the hammer. The other firing pin had been inserted after the returning pin had jammed upon being struck by the hammer.

4. The next most prevalent defective parts were the buffer and buffer spring. Two of the springs which were examined had the same number of coils as a spring from a new rifle but they were 3/4 of an inch shorter. This condition could be an effect of extensive firing. The "head" or surface that makes contact with the bolt carrier assembly of the buffer had uneven wear in most of the defective buffers which were returned. This could have been caused if the buffer and bolt carrier group were not in proper alignment and would be a defect in manufacturing. However, most of the malfunctions attributed to the

buffer and/or buffer spring could have been caused by insufficient gas impulse and/or dirt and grime in other parts of the rifle.

5. Two sear assemblies were replaced. One sear was reported to have a worn sear spring. How this condition was determined in the field is unknown. The sear spring and automatic sear group did not differ noticeably from the assembly of another satisfactory rifle at the laboratory. Another automatic sear assembly was replaced because of damage to the spring sleeve. It appeared to have been damaged during assembly of the rifle.

6. Foreign material, a small peice of brass, prevented the selector lever of a rifle to be set in the safe position. The brass piece measured .09 inch in diameter and .06 inch in height. Its origin is unknown.

7. A gas rod was replaced but it did not appear to be defective. However, it may not have been in satisfactory assembly with the gas part of the bolt carrier group. This could cause a loss of gas and result in a failure to feed and/or chamber.

8. Dust covers, hand guards and butt stocks were damaged during the tactical manuvers.

9. Seven magazines were rejected because they had spread lips. New magazines were gaged and found to have a spread of 0.450 inch. The magazines which where rejected had measurements from 0.460 to 0.492 inch. This condition could cause malfunctions although none could be reproduced in the laboratory when using the rejected magazines. One magazine had been damaged to the extent that it had to be forced into and out of the rifle. The damage could have been caused during loading of the magazine.

APPENDIX IX

Authorities

DEPARTMENT OF THE ARMY
HEADQUARTERS UNITED STATES ARMY MATERIEL COMMAND
WASHINGTON, D.C. 20315

IN REPLY REFER TO

AMCQA

[illegible] APR 1968

SUBJECT: Establishment - M16 Rifle System Reliability Evaluation Task Force

Commanding Officer
U.S. Army Ballistic Research Laboratories
Aberdeen Proving Ground, Maryland 21005

1. AMC has been directed by the Deputy Chief of Staff for Logistics to establish a Task Force on a priority basis to evaluate the M16 Rifle Quality Assurance Program. The charter of the Task Force is to:

a. Conduct analyses of all available and pertinent test data to provide a good understanding of all current quality of M16 rifles, ammunition, and magazines.

b. Prepare a critique of the procedures, specifications, and contractual provisions which constitute the current quality assurance program.

c. Prepare a set of suggested revisions to the appropriate elements of the quality assurance program.

The target date for completion of this study is 15 June 1968.

2. The effort of the Task Force under the charter cited above is not considered limited solely to the quality assurance aspects of the M16 rifle system. The effort should take into consideration all technical elements comprising the system with particular emphasis upon system evaluation in terms of user needs and development of a capability to assist the system at any given point in time. In accomplishing this study, the Task Force should interface with other study groups/committees, such as the Quality Assurance Committee. It is anticipated that the recommendations resulting from this study will lead to improvement in present practices and procedures and have application to the Army Small Arms Program.

AMCQA
SUBJECT: Establishment - M16 Rifle System Reliability Evaluation Task Force

3. Mr. O. P. Bruno of your activity has been selected to chair this Task Force. This selection has been made in light of the fact that Mr. Bruno has no specific commodity orientation and has much experience in the effective application of good statistical techniques. The latter being an essential element to be considered in this study. The present composition of the Task Force includes representation from DSA/CAS, WECOM, MUCOM, and AMC. It may be desirable to have legal and procurement representation additionally. This Headquarters will provide all necessary support to the chairman, as required. Point of contact for this purpose is Mr. N. C. Krause.

4. Additional information concerning this study is provided in Incl 1.

FOR THE COMMANDER:

S. J. LORBER
Director of Quality Assurance

1 Incl
as

DEPARTMENT OF THE ARMY
OFFICE OF THE DEPUTY CHIEF OF STAFF FOR LOGISTICS
WASHINGTON, D.C. 20310

ADCSLOG(P&B)-M16

1 0 APR 1968

SUBJECT: M16 Rifle Quality Assurance Program

Commanding General
U. S. Army Materiel Command
Washington, D. C. 20315

1. In accordance with the attached memorandum from the Assistant Secretary of the Army (I&L), AMC is requested to establish a task force and on a priority basis to:

a. Conduct analyses of all available and pertinent test data to provide a good understanding of the current quality of M16 rifles, ammunition, and magazines.

b. Prepare a critique of the procedures, specifications, and contractual provisions which constitute the current quality assurance program.

c. Prepare a set of suggested revisions to the appropriate elements of the quality assurance program.

2. The DA Staff Monitor for M16 Rifle Matters, COL W. P. Cumbie, is designated the Army Staff contact for this study. The AMC task force chairman will insure that all instructions received direct for the USA(OR) are provided the DA Staff contact.

3. A report of the findings, conclusions, and recommendations will be provided to DCSLOG(P&B) for forwarding to USA(OR).

FOR THE DEPUTY CHIEF OF STAFF FOR LOGISTICS:

1 Incl
as

H. A. Miley, Jr.
HENRY A. MILEY, Jr.
Major General, GS
Acting Assistant Deputy Chief
of Staff for Logistics

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
WASHINGTON, D.C. 20310

6 APR 1968

MEMORANDUM FOR THE CHIEF OF STAFF

SUBJECT: M16 Rifle Quality Assurance Program

In response to a memorandum from the Office of OASD(I&L)(Inclosure 1), a preliminary review was conducted of various aspects of our quality assurance program for the M16 rifle. This review, though cursory, revealed shortcomings in the specifications, the general application of statistical techniques, and other parts of the QA program. The issues were discussed by Mr. A. Golub with Mr. S. Lorber, Director of Quality Assurance, AMC, and he agreed generally with our findings. Mr. Lorber emphasized, however, that efforts are underway in AMC to correct the situation.

To help focus our efforts, and in response to the ASD(I&L) suggestion that appropriate revisions in the QA program be developed and implemented as soon as possible, I recommend that a task force be established immediately in AMC to perform the following functions:

1. Conduct analyses of all available and pertinent test data to provide a good understanding of the current quality of M16 rifles, ammunition, and magazines.

2. Prepare a critique of the procedures, specifications, and contractual provisions which constitute the current quality assurance program.

3. Prepare a set of suggested revisions to the appropriate elements of the quality assurance program.

I believe that the task force should be headed by someone who has no specific commodity orientation and who possesses long experience in the effective application of good statistical techniques. Accordingly, I would like to suggest Mr. O. P. Bruno of the Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland, as the task force chairman. This has been discussed with Mr. Lorber and he has fully endorsed Mr. Bruno for the position.

Incl 1

The task force chairman should maintain direct contact with Mr. A. Golub, Acting Assistant Deputy Under Secretary of the Army (Operations Research) who will coordinate these matters.

In view of the pressing need for an effective M16 rifle QA program, this project should be completed by 15 June 1968.

I am interested in this effort not only as a means for responding to ASD(I&L), but also because it will broaden the application of appropriate statistical analyses and techniques to the Army's Small Arms Program.

1 Incl
as

Robert A. Brooks
Assistant Secretary of the Army
(Installations and Logistics)

ASSISTANT SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

INSTALLATIONS AND LOGISTICS

MEMORANDUM FOR The Assistant Secretary of the Army(I&L)

SUBJECT: Review of Production Quality Control of M16 Rifle

Your memorandum of April 17 suggested that the scope of the review of production quality control on the M16 rifle by the Office of the Secretary of Defense be limited pending the results of the Department of the Army task force study. I am willing to delimit the scope of the OSD study temporarily as proposed.

This arrangement is subject to an understanding that the Department of the Army will:

a. Incorporate into the task force study -- as a minimum -- issues identified in the enclosure.

b. Make available to my staff (Major General A. T. Stanwix-Hay and Mr. John J. Riordan) a copy of the task force study plan and schedule.

c. Forward a final report of the findings and corrective actions to this office.

We will proceed with examination of government quality assurance practices (as distinct from requirements) on the M16 rifle. Mr. Riordan will also, on request, brief your study group regarding technical problems that merit consideration.

In view of the above it will not be necessary for the Department of the Army to assign two quality assurance specialists to the OSD review as previously requested. Please advise Mr. Abraham Golub to contact Mr. Riordan directly regarding further arrangements.

Your memorandum refers to specific actions the Department of the Army has already taken to improve its quality assurance practices. I would appreciate information regarding the specifics of these actions.

Tom Morris

THOMAS D. MORRIS
Assistant Secretary of Defense
(Installations and Logistics)

Enclosure
Review Criteria

A REVIEW OF QUALITY ASSURANCE RELATED TO THE PRODUCTION OF THE M16 RIFLE, MAGAZINE AND AMMUNITION

At the direction of the Deputy Secretary of Defense, a study of the quality assurance provisions and practices relating to the production of the M16 Rifle, Magazine and Ammunition has been initiated. The primary purpose of this study is to identify improvements that can be made in current contracts and in the Government procurement quality assurance function. As a result of this effort, it is also anticipated that specific improvements will be identified which will have applicability to other DoD programs.

To achieve the objectives of this study, data required to assess the current program follows. It is currently planned that Department of the Army will - as a minimum - investigate the elements identified in Phases I and II. The DoD review group established by OSD will limit its review to the elements comprising Phase III pending completion of the Army study.

The questions which follow were drafted for guidance of the OSD review, but are equally pertinent to the Army review.

PHASE I: OPERATIONAL REQUIREMENTS

1. Have military operating requirements for this equipment been developed?

2. If so, in what documents are the operating requirements for the M16 Rifle, Magazine and Ammunition stated (e.g., QMR)?

3. What are the operating requirements? If none exists, why not?

4. If formal operating requirements exist, have they been meaningfully translated into specifications, i.e. were specific performance requirements, accompanied by the necessary QA demonstration provisions, incorporated into the specifications? Were new specifications developed to meet the special needs dictated by the operating requirements, or were existing specifications used?

PHASE II: CONTRACTUAL QUALITY ASSURANCE PROVISIONS

1. Contracts

   a. Is procurement and production of the M16 accomplished along "system" lines, or is this weapon procured by separate contracts for the rifle, magazine and ammunition? If separate contracts are used by the Government, is there clear evidence that the contracts and the associated production and contract changes are properly integrated to insure satisfactory functioning of the procured items as a "weapon system"?

b. Who (what organization) is responsible for initiating the purchase requests?

c. What organization writes the contracts?

d. Who negotiates the contract(s), i.e., performs the PCO function?

e. Does the contract(s) comply with the ASPR (e.g., use standard format and standard inspection/quality control clauses)?

f. What, if any, superfluous/duplicative/or contradictory QA requirements does the contract contain?

g. How does the contract define the contractor's responsibility for quality and reliability?

h. Does the contract:

(1) Clearly define the contractor's responsibility for the quality of vendor furnished material (i.e., components fabricated by sub-contractors)?

(2) Limit in any way, the contractor's responsibility for the quality of vendor furnished material?

(3) Specify the quality levels for vendor furnished material? Are these levels adequate? Compatible with required end item reliability requirements/objectives?

(4) Include specific interchangeability requirements? If so, are these compromised by any other contractual provisions?

(5) Require the contractor (prime and/or sub) to identify and take action to remove defect causing conditions?

(6) Require 100% post firing disassembly inspection, analysis of failures, and reassembly? If so, is this provision conducive to obtaining satisfactory quality and reliability of the delivered item?

2. **Drawings**

a. Have applicable drawings been subjected to tolerance review by the Government? By the contractor?

b. Is there any tolerance interference that would contribute to the failure of the end item?

c. Have the applicable drawings been made available to the contractor?

3. Specifications

   a. Are there specifications for the end item, components, magazine, ammunition (including the powder and ammunition components)?

   b. Do these clearly define the contractor's responsibility for performing the inspections/tests contained therein?

   c. Is there any overlap or duplication?

   d. Are there any conflicting or contradictory requirements?

   e. If AQL's (acceptable quality levels) are included, are they proper, i.e. afford adequate protection? Too tight? Too loose?

   f. Are specified AQL's compatible with each other? With 100% inspection requirements for the end item?

   g. Is the contractor required to maintain records of all specification tests and inspections?

   h. Is there any possibility for misunderstanding of the respective role of the contractor vs. the Government for test requirements contained in the applicable specifications?

   i. Are all test requirements meaningful to the end item?

   j. Are specification technical requirements (provisions contained in Sec. 3) covered by appropriate demonstration provisions (i.e., inspections/tests) contained in Sec. 4?

4. Quality Control of Production

   a. Is the contractor required to control manufacturing processes (e.g., as required by MIL-Q-9858A)?

   b. If MIL-Q-9858 is required, is it in fact implemented by the contractor, e.g., does the contractor segregate and maintain positive control over non-conforming items; provide adequate work instructions; maintain calibration over gages and test equipment (traceable to NBS); maintain records of all inspections?

   c. Does the contractor require similar controls to be exercised by subcontractors? How does he insure performance?

   d. For calibration and control of the accuracy of tools and gages (including production tooling used as a media of inspection), is MIL-C-45662 required? Is it properly used?

e. If sampling inspection is used, how are rejected lots controlled (for in-house production as well as for subcontractor furnished material)? Is corrective action (e.g., remedial action to correct the cause) taken to change the manufacturing process? To require appropriate corrective action by subcontractors?

f. Are rejected sample inspected lots subject to reinspection/test after screening/correction of defective items? Is tightened sampling inspection used to retest rejected lots? Or instituted for subsequent lots?

g. In the event sample inspected lots are rejected, what action is taken when investigation indicates that similar defects may exist in items already delivered? Is the procuring activity (ACO or PCO) notified by the contractor? What action is taken to correct completed items awaiting shipment?

h. Does the contractor maintain positive control over scrap and unauthorized (for use) non-conforming material to prevent it from getting back into the production process. Are stocks of manufacturered parts and vendor items used to fill orders for delivery as spare parts subject to special control (e.g., as bonded stock)?

i. Does the contractor maintain complete/accurate records of all inspections/tests performed? Defects found? Corrective action taken? What level of contractor management reviews these?

j. Are contractor work instructions adequate/complete/available/ compatible to contract requirements?

k. Are records of rejections/scrap/rework analyzed and reviewed by company management? What level of management?

5. Drawing and Configuration Control

a. Is there a requirement that the contractor establish a procedure for maintaining strict control over drawings and drawing changes?

b. Does the contractor's program provide for the control of drawings include release, change approval, removal, and designate the time and point of effectivity for new, or changes to drawings?

c. Are the contractor's drawing and configuration control procedures adequate? Followed?

d. Does the contractor's control extend to drawings and changes applicable to subcontractors/vendors?

6. Deficiency Data

   a. Does the contractor receive deficiency reports initiated by Government field activities?

   b. Does he evaluate and analyze these deficiency reports to identify conditions requiring changes in the production process to prevent defect recurrence?

   c. Does he incorporate or make timely changes in the manufacturing process to prevent such recurrence?

   d. Is action taken by the contractor to insure that such deficiencies are corrected on items awaiting shipment?

   e. Does the contractor have an internal (within plant) deficiency data feedback system, i.e. one that advises management of production quality control deficiencies?

   f. Does management take timely and effective action to correct the conditions responsible for these deficiencies?

7. Project Management (Program Management Office)

   a. Is the M16 managed and procured as an integrated system (e.g., one contract for the complete system, or separate contracts for each major component, i.e., rifle, magazine, ammunition)? If procured by separate contracts, how are these managed to insure effective integration as a "weapon system"?

   b. Does the M16 Rifle program management office write (negotiate) the contract?

   c. If the program management office does not write the contract, does it review the purchase request or contract for adequacy of the quality assurance (QA) provisions?

   d. Does it have an organic capability for insuring and/or providing continuing review of QA during production? What skills exist (e.g. are there GS-1900 series class-act civilian personnel assigned)? If not, who provides this capability?

   e. Does the program management office:

      (1) Review and initiate action to correct QA deficiencies/conflictions in the contract?

      (2) Review field deficiency reports? Monitor corrective action? How?

(3) Review contractor production quality control?

(4) Establish mandatory inspections/tests to be performed by the Government QA representative at the contractor's plant?

(5) Does this direction emphasize independent Government inspection (to verify the effectiveness of the contractor's inspection), or does it require only a witnessing of contractor performed inspections/tests?

(6) Require independent quality audits to be performed by outside inspection agencies on contractor produced/furnished items? If so, what action is taken to insure that identical inspection criteria is followed (i.e., same inspection performed as is contractually required of the contractor)?

PHASE III: CONTRACT QUALITY ASSURANCE ADMINISTRATION

The following topics will be incorporated in this phase of the review.

1. Contract knowledge
2. Skills/Capability
3. Government surveillance actions
4. Corrective action
5. Controls over vendor furnished material (subcontracts)
6. Compliance with applicable Government directives, manuals, publications, handbooks

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13. ABSTRACT

At the direction of the Assistant Secretary of the Army (I&L), a comprehensive study of the reliability of the M16 Rifle has been accomplished. This report contains an extensive analysis of statistical and engineering data (a) to estimate the reliability characteristics of the M16 Rifle system, (b) analyze factors affecting the reliability of the system (propellants, projectiles, ammunition lots, cyclic rate, cycle time, chrome chambering, cleaning, lubricating, mode of fire, magazines and environments), and (c) to establish a sound technical base for other parts of the study indicated below.

The report also includes an analysis of the pertinent specifications for the rifles, magazines and ammunition, with particular emphasis on the validity of (a) the parameters, (b) the tests, (c) the standards, (d) the statistical sampling plans, (e) the criteria and their compatibility with the requirements for a reliable rifle system.

Further, this report presents an evaluation of the Quality Assurance Program including the contractor's in-process quality control practices, materials controls, effectiveness of corrective actions, product improvement studies and statistical techniques for acceptance decisions on materials received from vendors.

In addition, there is an analysis of Department of Defense Quality Assurance policies and procedures and their implementations by the Army and the Defense Contract Administration Service.

As a result of this study, many findings and recommendations are made regarding the aforementioned areas. Some have been acted upon during the period of the study.

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
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QUALITY ASSURANCE						
STATISTICAL ANALYSIS						

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13. Abstract

action is being initiated on others and some will require further research and consideration before implementation.

Basically, the M16 Rifle is a reliable system. Although the M16 Rifle and the M14 Rifle are not comparable in design, weight, ballistic parameters, operating features and effectiveness, their reliability characteristics are approximately similar. The M16 Rifle is more reliable than the M14 Rifle during its initial life but it is slightly more sensitive to environmental effects and maintenance. Although the M16 Rifle currently is reliable the study indicates that there is appreciable potential for improvement.