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Marine Corps Liaison Officer
U. S. Army Test & Evaluation Command
Aberdeen Proving Ground, Md. 21005

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WSEG REPORT 124

OPERATIONAL RELIABILITY TEST
M-16A1 RIFLE SYSTEM

February 1968

Return to:

Marine Corps Liaison Officer
U. S. Army Test & Evaluation Command
Aberdeen Proving Ground, Md. 21005

WEAPONS SYSTEMS EVALUATION GROUP
400 ARMY-NAVY DRIVE, ARLINGTON, VA.

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February 1968

WEAPONS SYSTEMS EVALUATION GROUP
400 ARMY-NAVY DRIVE, ARLINGTON, VA.

FOREWORD

This report was produced by the Weapons Systems Evaluation Group in association with the Institute for Defense Analyses, Systems Evaluation Division, as specified in WSEG Task Order No. DAHC15 67 C 0012-T-139.

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ABSTRACT

Title: WSEG Report 124, Operational Reliability Test of the M-16A1 Rifle System

Conducted By: WSEG For: DDR&E

Purpose: To provide a measurement of the operational reliability of the 5.56mm, M-16A1 rifle system as currently employed in South Vietnam.

Methodology: Data were obtained by controlled field testing in the Canal Zone, Panama during the period 9-25 January 1968. To provide weapons exposure similar to South Vietnam, four separate environmental areas were employed, representing (1) salt water and sand, (2) muddy water and swamp, (3) rain forest, and (4) dust, simulated uplands. Marine riflemen conducted realistic combat type maneuvers and rifle firing for three consecutive days in each area, rotating through all four environments.

Rifles and Ammunition: The main test employed three types of rifles: 96 M-16A1 with the new buffer and chromed chamber; 96 M-16A1 with the new buffer but no chrome and a control group of 96 M-14 rifles. All were randomly selected; the M-16's from new and the M-14's from reconditioned stocks. One half of each type of M-16A1 rifles fired ball propellant ammunition throughout the test; the remaining half fired IMR. M-14's fired ball propellant. Firing modes were controlled with one half automatic, the other semiautomatic. One half the magazines were loaded to 20 round capacity, the other to 18 rounds.

Cleaning Schedules: Two cleaning schedules were followed for the main test, each applicable to one half the rifles by type and for the M-16A1 further applicable by type propellant. Schedule C_1 directed cleaning at noon after firing 240 rounds and again at night after an additional 240 rounds. C_2 required cleaning only at noon after a total of 480 rounds.

Findings and Conclusions

- Operational reliability of the M-16A1 with ball propellant approaches but is less than the M-14. Malfunctions per 1000 rounds were: M-16, 1.95; M-14, 1.40.
- Operational reliability of the M-16A1 with IMR is significantly less than the M-14. Malfunction rates are: M-16, 4.81; M-14, 1.40.
- As rifles age in numbers of rounds fired, the spread in reliability between the M-16A1 with ball and with IMR narrows.
- The chromed chamber rifle requires less frequent cleaning. This modification is effective in reducing "failures to extract." However, the effect of the modification on other malfunctions requires study.
- All rifles tested, whether firing IMR or ball propellant, are more prone to malfunction when firing in the automatic mode.
- As a function of environmental exposure, the M-16A1 performance with IMR is characterized by large fluctuations. The M-14 showed least fluctuation, followed closely by the M-16A1 with ball propellant.
- There is no evidence of adverse effect from loading M-16A1 magazines to their design capacity of 20 rounds.
- The types of malfunction most frequently experienced in the M-16A1's with chrome and firing ball propellant are failures to eject (33 percent), fire (21 percent) and feed (13 percent).
- The types of malfunction most frequently experienced in the M-16A1's without chrome and firing ball propellant are failures to eject (18 percent), extract (17 percent), feed (16 percent) and fire (14 percent).
- The type malfunction most frequently experienced in the M-16A1's with chrome and firing IMR is failure to feed (61 percent).
- The type malfunction most frequently experienced in the M-16A1's without chrome and firing IMR is failure to feed (64 percent).
- The types of malfunction most frequently experienced in the M-14's are failure to feed (37 percent) chamber (15 percent) and fire (13 percent).

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I. INTRODUCTION

A. BACKGROUND

For more than a year there have been various reports and allegations directed at the reliability of M-16A1 rifle systems used in South Vietnam. During this time a number of changes in rifle systems themselves and in procedures relating to their use have evolved. However, there have been no large scale controlled tests to measure the operational reliability of the present M-16A1 rifle systems.

In its report of 19 October 1967, the Special Subcommittee on the M-16 Rifle Program of the Committee on Armed Services, House of Representatives, recommended that "the Department of Defense direct and expedite a thorough and objective test by an independent organization of the weapon system consisting of the modified rifle and ammunition in Vietnam, as well as both types of propellant currently being loaded in 5.56mm ammunition."

On 20 November 1967, the Deputy Director of Research and Engineering (DDR&E) designated the Weapons Systems Evaluation Group (WSEG) as the OSD Executive Agent for conduct of an operational reliability test of M-16A1 rifle systems and directed it to establish test conditions and procedures, monitor the test and reduce test data, evaluate test findings and prepare the final report.[1]

The referenced memorandum assigned the Marine Corps responsibility for execution of the test and for obtaining

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[1]DDR&E Memorandum, 20 November 1967, subject: Simulated Combat Test of the M-16 Rifle System, (Enclosure B).

weapons, ammunition, other materiel and personnel. The Department of the Army was directed to furnish materiel, test facilities and other assistance.

The M-16A1 Rifle Systems Test Plan was published by WSEG on 29 December 1967. It provided for conduct of the test in the Canal Zone, Panama within the period 6-26 January 1968.

B. PURPOSE OF THE TEST

The purpose of the test was to measure the operational reliability of the 5.56mm, M-16A1 rifle systems currently used by maneuver battalions in South Vietnam and under environmental conditions simulating as closely as possible those existing in South Vietnam. To serve as a base for this measurement, the 7.62mm, M-14 rifle system was included in the test as a control.

C. OBJECTIVES OF THE TEST

Objectives of the test 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 M-16A1 rifle configured with the new buffer group and chromed chamber.

  Determine the malfunction rates of the M-16A1 rifle configured with the new buffer group.
- Determine the malfunction rate of the M-14 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.

D. CONCEPT OF THE TEST

Data to achieve the test purpose and objectives were obtained by field testing and directed at determining operational reliability of the rifle systems. Weapons systems suitability, accuracy, lethality, efficiency, ruggedness, training and engineering were considered beyond the scope of the test. For this reason, the test is not necessarily a source of detailed design verification or engineering data; information which might better be obtained from instrumented proving ground evaluations. The test did suggest areas in which laboratory and other studies might be conducted and recommendations to this end are being made separately.

The test exposure environments as well as simulated combat maneuvers and combat practices were patterned as closely as possible after those in South Vietnam and were based on information obtained from Headquarters, COMUSMACV and on observations of combat veterans of South Vietnam. For example, the number of rounds expended by each rifleman during each of the 24 firing periods of the test was "that number of rounds an individual in a rifle squad might reasonably be expected to fire over a 24-hour period in an active attack on an enemy position or in defense of his own position." Rifle configurations, ammunition mixes, magazine loadings and cleaning cycles similarly were based on conditions and practices reported as representative of South Vietnam.

Realism in the exposure of weapons and ammunition was achieved by simulation of enemy action at appropriate points in each maneuver thus causing the rifleman to crawl, seek cover and concealment or dig in, with a resultant exposure to water, mud, sand, etc.

II. CONDUCT OF THE TEST

A. TEST DESCRIPTION

Location of Test

The test was conducted within the Fort Sherman Military Reservation, Canal Zone, Panama. Four environmental areas and five firing ranges (see Figure 1) were involved:

- Site E_1, Pina Beach, extending west from the Chagres River for approximately one mile provided exposure to salt air, salt spray and sand. Firing was out to sea from the beach.
- Site E_2, the Mojinga Swamp area contiguous to the Chagres River exposed the weapons to dirty water and mud representing swamps and rice paddies. Firing was at a cleared range within the swamp area.
- Site E_3, two areas of rain forest west and southwest of Fort Sherman provided exposure to terrain and maneuvers associated with combat in this environment. Firing was at the Fort Sherman Known Distance Range.
- Site E_4, the hilly terrain in the southeastern area of the Fort Sherman Reservation provided a simulated upland exposure including dusty roads, steep hills and gullys in fringe jungle areas and dust raised by helicopters. Firing was at two ranges, the Artillery Range in the morning and Familiarization Range in the afternoon and night.

Test Schedule

The test involved four Marine platoons, each containing four squads of nineteen riflemen for a total of 304 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 above. The environmental and firing schedule is indicated by Table 1 which constitutes a "Latin Square." All platoons fired for the same number of days over the same

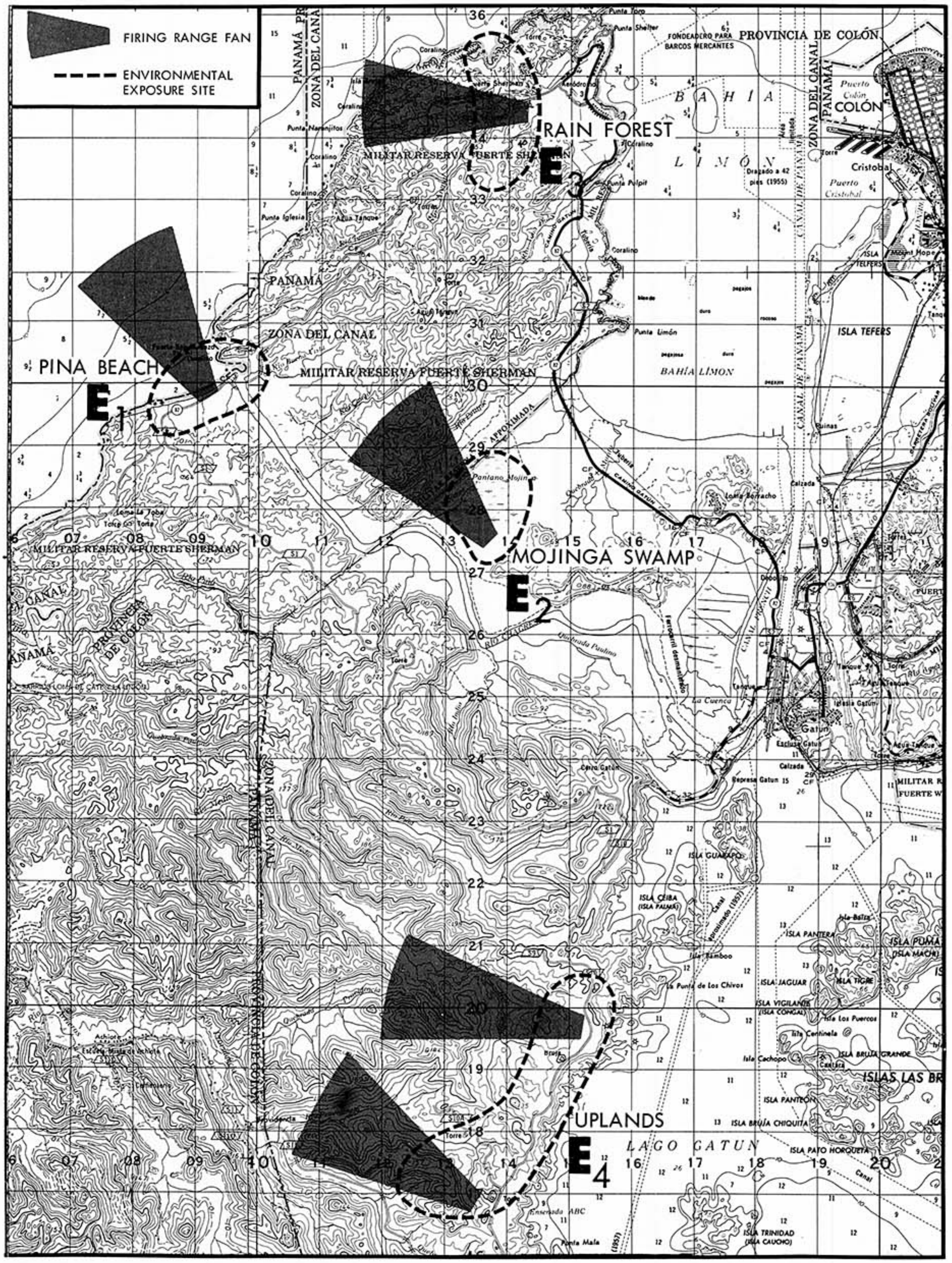

FIGURE 1. The Four Environmental Areas and Five Firing Ranges

areas. Except for the 19th man in each squad (see explanation on page 12), each rifleman fired 480 (468)[1] rounds each calendar day alternating automatic and semiautomatic magazines.

Table 1

Test Days	Phase 1				Phase 2				Phase 3				Phase 4		
	1	2	3		4	5	6		7	8	9		10	11	12
1st Platoon	E_1[a]	E_1[b]	E_1	ONE DAY BREAK	E_3	E_3	E_3	ONE DAY BREAK	E_2	E_2	E_2	ONE DAY BREAK	E_4[a]	E_4[b]	E_4
2nd Platoon	E_2	E_2	E_2		E_4[a]	E_4[b]	E_4		E_3	E_3	E_3		E_1[a]	E_1[b]	E_1
3rd Platoon	E_3	E_3	E_3		E_1[a]	E_1[b]	E_1		E_4[a]	E_4[b]	E_4		E_2	E_2	E_2
4th Platoon	E_4[a]	E_4[b]	E_4		E_2	E_2	E_2		E_1[a]	E_1[b]	E_1		E_3	E_3	E_3

[a] A subtest to determine effects of leaving a round in the chamber with the bolt closed was scheduled for one night of the three at Environmental Site E_1 (Pina Beach) and E_4 (uplands). These two sites represented the salt air, salt spray atmosphere of the beach contrasted to the somewhat different atmosphere of Site E_4 which while not truly upland country, was relatively less moist and less subject to salt atmosphere (see Appendix J, Climatology).

[b] Firing at night was scheduled for one night of the three at Site E_1 (Pina Beach) and Site E_4 (uplands) to determine what effect, if any, darkness might have on the categorization of malfunctions between those immediately clearable by the shooters or the more serious and time consuming variety.

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Rifles

Three hundred and four primary rifles and 143 spares were available for the test. Numbers, types, configurations and test designation of rifles are shown in Table 2.

M-16A1 rifles were selected by random choice from stocks at Marine Corps Supply Activity, Barstow, California; Army Supply Depot, Letterkenny, Pennsylvania and Marine Corps Supply, Camp Pendleton, California. M-14 rifles were selected at random from reconditioned stocks (5900 rifles) stored at the Marine Supply Center at Albany, Georgia. Selector levers were installed giving these rifles an automatic and semiautomatic capability.

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

Table 2

No. of Rifles	Type	Configuration	Test Symbol
150	M-16A1	New buffer and chromed chamber (Oct-Nov 1967 production)	R_1
90	M-16A1	New buffer only - no chrome (Dec 1966-Sept 1967 production)	R_2
67	M-16A1	New buffer field retrofitted - no chrome (prior to Dec 1966 production)	R_3
140	M-14	Reconditioned, with automatic selector lever installed	R_4
447 TOTAL			

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

Each rifle was identified by a three-digit number and issued to a rifleman for his exclusive use. He fired this rifle throughout the test except in a few instances when a substitute rifle was required.

Within each squad of 19 riflemen, 6 R_1, 6 R_2, and 6 R_4 rifles were assigned. In 8 of the total of 16 squads the 19th rifleman fired an R_1 rifle and in the remaining 8 an R_2 rifle. (The 19th rifleman subtest is explained on page 12.)

Ammunition

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 and Co., and with double base ball propellant, WC 846, a proprietary product of Olin Mathieson. M-14 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 3.

Table 3. 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

From Table 3 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. This separation was maintained by color coding and numbering rifle magazines and by separation of ammunition loading areas by type and mix.

All ammunition was selected at random from stocks manufactured between 1 November 1966 and 1 November 1967. In the case of IMR ammunition, only the 8208M was available in sufficient quantity to satisfy test requirements. Acceptance test records of lots selected were checked only after the ammunition had been shipped. These records reflected that all ammunition met acceptance criteria (see Enclosure D).

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 tracers and this load was designated L_1. The number of rounds and use of tracers represents practices reported by units in South Vietnam.

Cleaning Cycles (see Table 4)

The main test provided for two scheduled cleaning cycles, C_1 and C_2. 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 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.

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[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)

Table 4. 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)
M-16A1 new buffer group with chromed chamber, R_1	24	Ball	234/240 rds	234/240 rds	5616/5760
	24	IMR			
	24	Ball	468/480 rds	None	
	24	IMR			
M-16A1 new buffer group without chromed chamber, R_2	24	Ball	234/240 rds	234/240 rds	
	24	IMR			
	24	Ball	468/480 rds	None	
	24	IMR			
M-16A1 new buffer with chromed chamber, R_1	4	Ball	Clean each 3 days--324 rds		1296
	4	IMR	Clean each 6 days--648 rds		
M-16A1 new buffer group without chromed chamber, R_2	4	Ball			
	4	IMR	Clean each 3 days--324 rds		
M-14, R_4	48	Ball	234/240 rds	234/240 rds	5616/5760
	48	Ball	468/480 rds	None	

Scheduled cleaning consisted of unit supervised field stripping and cleaning in accordance with Department of the Army FM 23-9. Materials, lubricants and equipments were standard current issue.

Cleaning cycles were representative of situations in which a rifleman engaged in intensive combat in which he expends 240 (234) rounds was able to field strip and clean his rifle after the cessation of the fire fight. Cleaning cycle C_2 represents the situation in which the rifleman either because of combat demands or darkness, is unable to clean his rifle at the expiration of a days fire fight and reengages the enemy the following morning.

<u>19th Rifleman Schedule</u>

Sixteen M-16A1 riflemen (one per squad and termed the 19th rifleman) were assigned to an extended cleaning period subtest. Their rifles (8 R_1 and 8 R_2) used two additional cleaning cycles C_3 and C_4, corresponding to cleaning intervals of 3 and 6 calendar days, respectively. Ammunition fired by these rifles was the same mix as that of the parent squad; e.g., ball or IMR of the common lots used by the parent squad (see Table 4).

Firing Mode

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 automatic mode and even-numbered magazines in semi-automatic mode. Thus each rifle fired half its total rounds in each mode.

The firing mode (automatic or semi-automatic) existing at the time of occurrence of each rifle malfunction was noted and recorded.

B. PERSONNEL AND TRAINING

Riflemen

Three hundred and twenty-eight riflemen provided by the U.S. Marine Corps participated in the test. Of these, 100 from Camp Pendleton, California, had completed training for the rifleman military occupational specialty (MOS). This group was under 18 years of age and thus not yet subject to overseas duty. The remaining personnel, 25 from Camp Pendleton and 203 from Camp Lejeune, were either awaiting assignment to schools principally in the aviation field or other associated MOSs.

Individuals had completed the following training:

Recruit Training

M-14 Rifle: 10 hours mechanical and 89 hours demonstration, lectures and marksmanship. 250 rounds fired.

Individual Combat Training

Infantry Trainees:

M-1 rifle, 40 hours, 350 rounds fired

Others:

M-1 rifle, 22 hours, 200 rounds fired

Predeployment Training

M-16A1 rifle: 26 hours, 228 rounds fired.

In-Country Training

M-16A1 rifle: 8 hours, 240 rounds fired.

The Marine Corps considered that all riflemen were fully qualified with no disparity in level of training between the M-16A1 and M-14 rifles particularly with respect to handling, field stripping, cleaning, lubricating and ability to clear stoppages.

Armorers

The test employed 40 armorers -- 10 per platoon. Thirty-eight held the military occupational speciality (MOS) of armorer/small arms repairman. The remaining two had qualified through on-the-job training (OJT) but had not been formally awarded the MOS.

All armorers were given 14 hours specialized instructions in the M-16A1 while in Panama. Marine Corps armorers received an additional 11 hours specialized instruction at Camp Lejeune.

The chief armorers of each platoon were Marine Sergeants (E-5). The senior armorer for the test was a Marine Gunnery Sergeant (E-7) who served on the staff of the Test Director.

C. TEST VARIABLES

The test as described in the foregoing permitted the determination and comparison of malfunction rates of the three rifle types or configurations under equivalent conditions of environment, magazine loading, ammunition mixes, cleaning cycles and firing mode. A summary of the controlled variables and number of levels is shown in Table 5.

Dependent variables are the numbers and types of malfunctions observed during the test.

D. DATA COLLECTION AND REDUCTION

Control of malfunction data was the key to success of the test. The details of data collection are contained in Enclosure E, however, the main features of the system as it operated are covered here.

Rifle systems malfunctions were categorized as follows:

Category I - Malfunctions which were corrected by immediate action on the part of the firer. The "immediate action" taken was appropriate to the type weapon and included such actions as manually operating the bolt or withdrawing a spent case with the fingers, but did not include field stripping and did not require the use of tools.

Table 5. 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 = M-14
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 C_2 = after 2 firing periods C_3 = after 6 firing periods C_4 = after 12 firing periods
Firing Mode	2	Automatic Semi-automatic

Category II - Malfunctions which could not be corrected by Category I action, but were corrected in the field by the shooter by field stripping and/or cleaning, lubricating or minor adjustment without the use of tools (other than a cartridge or other aid normally available to the firer). This category did not include second echelon level work, but was intended to include actions which the riflemen could take during a temporary respite in combat.

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

Upon experiencing a malfunction the rifleman did not immediately attempt to clear his weapon but raised his hand to signal the problem. Working as a team, an armorer and a a data collector responded to the malfunction signal. The armorer identified the malfunction and when possible the cause, then instructed the rifleman to clear the stoppage. Using a specially designed form the data collector recorded the nature of the malfunction; the cause, if known, and the time required to clear it. Other pertinent facts such as unusual exposure of the weapon to sand or mud were also recorded.

If the malfunction proved to be Category I or II the rifle was continued in use and completed the normal firing cycle. If the malfunction was Category III the disabled rifle was replaced by a substitute. If and when the original rifle was repaired (generally in time to complete the firing cycle) it was returned to the rifleman who resumed firing it.

Additionally, if a given test rifle experienced repeated malfunctions and the shooter was unable to correct the condition, the platoon chief armorer could recommend to the WSEG Site Monitor that the malfunction be classified Category III and the rifle repaired by the armorer. If the recommendation was accepted the Category III procedures outlined above were followed.

If a substitute rifle was introduced within a given firing period, the extent to which it was subjected to the exposure environment was often questionable. For this reason, the policy was adopted in the analysis to disregard those rounds fired and any malfunctions accumulated on the substitute rifle for the remainder of the firing period. However, if a substitute rifle was in use at the outset of any firing period, its treatment in the analysis was identical to that of any other rifle.

Experience indicated that replacement rifles accounted for only a small fraction of total test firing. Throughout the entire main test, data were derived from only 12 different substitute rifles: five type R_1, five type R_2, and two type R_4. Altogether, these 12 rifles accounted for only 1.39 percent of the total test data. The test was initiated with 304 rifles. Of these, 299 finished the test. The five that did not finish were two R_1, two R_2 and one R_4.

Broken parts, bent and defective cartridges, etc., were identified with the malfunction involved, placed in marked envelopes and processed within the data collection system.

Data Reduction

Following the completion of each firing period and after undergoing preliminary checks for consistency and completeness at platoon level and at the Test Direction Center at Fort Sherman, the data records for each test rifle were flown to the Data Collection Center at Albrook AFB for processing and reduction.

The initial data processing operations were to check each Firing Period Recap Form for consistency with the test plan and with its associated Rifle Malfunction Reports and to complete the recap form by entering the total rounds fired for the firing period and the round number corresponding to each malfunction. The completed Firing Period Recap Form was then used as a basis for key punching the data on each test rifle onto standard IBM cards. The data items key punched and verified on the data cards for a given rifle and for a given firing period appear on Form No. 4, Appendix A, Enclosure E.

After key punching and verification the data cards for a given firing period were processed locally at the USAF Data Processing Center at Albrook AFB, Canal Zone, as well as transmitted via AUTODIN to the USAF Command Post in the Pentagon for supplementary processing at IDA.

E. TEST EXECUTION

Firing Rehearsals

The M-16 test was prefaced with a full dress rehearsal of a single firing period[1] (without a maneuver) on 9 and 10 January 1968. The purpose of this rehearsal was to provide familiarization and training for range officers, rifleman, armorers, data collectors, and data reduction and analysis personnel. Additional purposes were to provide for break-in for rifles as well as to simulate reported South Vietnam staging area practices of "shooting in" newly issued rifles. Two hundred and forty rounds were fired through each rifle, including spares. As a consequence, at the start of the test all rifles had been equally preconditioned.

Inspection of the data derived from the pretest rehearsal revealed the existence of a significantly high M-16 malfunction rate which diminished after the expenditure of several magazines. Accordingly, the data (platoons 2 and 4) were preserved

[1] Firing periods: There were two firing periods per calendar day, each firing period representing a combat day. Except for the first morning of each phase, each "firing period" was divided into two firing cycles: A firing cycle before and one after each maneuver in the exposure site.

and form the basis for investigating this effect in the analysis. Data from platoons 1 and 3 showed a similar effect but were of a lower quality and thus not used.

Execution of the Test

General: The M-16 test started on the morning of 11 January 1968. The original date of 10 January was changed in order to allow completion of the firing range in the Mojinga Swamp. Phase I of the test was from 11-13 January; Phase II, 15-17 January; Phase III, 19-21 January and Phase IV, 23-25 January.

Weather: Throughout the test period the weather was generally fair, sunny and warm. Temperatures varied at each of the sites ranging from a low of 63° to a high of 84°. There was very little rainfall. Meteorological stations were established at each site to measure temperature, relative humidity, and precipitation. Measurement of wind velocity and direction was added at the Pina Beach site. Meteorological readings for each site are shown in the appropriate site Appendices in Enclosure K.

Test Site Monitors

Test site monitors, members of the Weapons Systems Evaluation Group in the grade of Colonel/Captain (0-6), were assigned to each of the environmental sites. A lieutenant and NCO from units in the Canal Zone were assigned to each monitor as assistant. Duties of the site monitors included (1) prescribing tactical maneuvers in each exposure area; (2) insuring that weapons and ammunition were exposed to the conditions specified in the test design; (3) insuring that the platoon reacted realistically to the simulated enemy artillery and sniper fire; (4) confirming that cleaning instructions were followed; (5) making certain that data collectors and armorers performed as instructed; and (6) confirming that each squad was issued the ammunition specified by the test design.

The monitors maintained a daily log of all events: reaction of the Marines to the tactical events; routes and maneuvers in the exposure areas; conditions of the environment and any deviation from the test plan which might affect the results of the test. Enclosure E contains a summary of test execution for each site, timing of key activities, meteorological data and a typical daily schedule.

Daily Activities: Three key activities were associated with the daily execution of the test: firing periods, exposure/maneuver periods, and cleaning periods. Schedules for each firing day had to accommodate completion of each of these activities.

Firing Cycles

Three firing cycles were conducted on the first day and four on the second and third day of each phase. With the exception of the first morning of each phase a firing cycle was accomplished before and after each maneuver in the exposure sites.

Firing points at Site E_1, Pina Beach, permitted the entire platoon to fire at one time. At the other sites the firing ranges could accommodate only two squads at one time. Squads were scheduled on the firing line so as to have one squad of riflemen firing ball and one IMR propellant at one time. At two sites on the first night of each phase the test required the chambering of a round overnight, and firing the weapons the next morning. On the second day of each phase the test specified that the fourth firing period would be accomplished at night in lieu of afternoon firing. These two subtests were accomplished at Site E_1 and E_4.

The time required to accomplish each firing period varied depending on the number of rounds to be fired; number and type of malfunctions for the firing period and the time required to identify and record the malfunction data. Of overriding importance, was the need to afford data collectors and armorers sufficient time to correctly identify and record all required information.

Exposure and Maneuver Periods

One or more simple tactical scenarios were prepared for each environmental site. The scenarios depicted an enemy situation and assigned a tactical mission to the maneuver platoon which would require certain actions throughout the exposure site.

Each of the platoons maneuvered through the exposure sites six times in each phase; one maneuver was in the morning and one in the afternoon. The objective of the maneuver was to insure that the weapons were realistically exposed to the elements and environment associated with each of the sites. There was no artificial exposure. During the maneuvers the simulated enemy action directed by the site monitors required action by the platoons according to acceptable tactical doctrine. There was no way to insure that each rifle was subjected to the same conditions within the exposure area; but in the aggregate, exposure of the entire platoon was relatively uniform. Routes and events were varied, squads were rotated within formations and locations of types of tactical events were changed to add realism and variety to the exposure maneuvers. Enemy artillery fire was simulated by the use of "artillery firecracker" simulators and small "Chinese" firecrackers for sniper fire. Figure 2 is a graphic portrayal of the execution of a simulated combat scenario at the Pina Beach environment. Other portrayals are contained in Enclosure F.

Generally the weapons were exposed more on the first day of each phase than on succeeding days. At each site there was an observable increase on the part of the individual rifleman in learning to protect his rifle from the elements.

Cleaning Periods

The test design scheduled supervised cleaning periods for each rifle after a specified number of rounds had been fired and at the expiration of a specified time. The original schedule provided from 20 to 30 minutes for full field stripping and cleaning of the weapon. This time proved to be insufficient and was generally exceeded. For the last three phases of the test one hour was allocated for cleaning.

It was noted that, just as is reported for South Vietnam, riflemen supplemented the standard issue cleaning equipment with small paint brushes and tooth brushes.

The current standard lubricants, MIL-L-46000A (LSA) for the M-16 and PL Special (VV-2-800) for the M-14 were used throughout the test.

Safety

Throughout the planning as well as the execution of the test every effort was made to insure realism and objectivity but within the bounds of rational safety. On the whole it was necessary to sacrifice relatively little.

While it would have been more realistic for troops to fire as they maneuvered through the environment this was not possible and not only for safety reasons, but also because of the need to collect accurate data.

Safety dictated that weapons be loaded with live ammunition only on the approved firing line. For this reason maneuvers were conducted with empty magazines so indicated by being painted white. It is appreciated that when combat is imminent

FIGURE 2. Graphic Portrayal of the Execution of a Simulated Combat Scenario

ENVIRONMENTAL SITE E_1

Exposure: Sand, salt spray, salt water

Location: Pina Beach, Fort Sherman Military Reservation, Panama Canal Zone (9°19'00"N 80°00'30"W)

Exposure: Sand, salt spray, and salt water.

Simulated Combat Scenario: A Marine Platoon, consisting of one officer, 6 NCOs, and 76 riflemen, is assigned the task of seizing a beachhead by an amphibious assault clearing the beach of suspected enemy forces, and securing the mouth of the Chagres River.

(A) An LCM with the assault platoon aboard plows through moderate seas towards the landing beach.

(B) The platoon storms ashore.

(C) Troops along the beach come under simulated enemy small arms fire from the edge of the jungle.

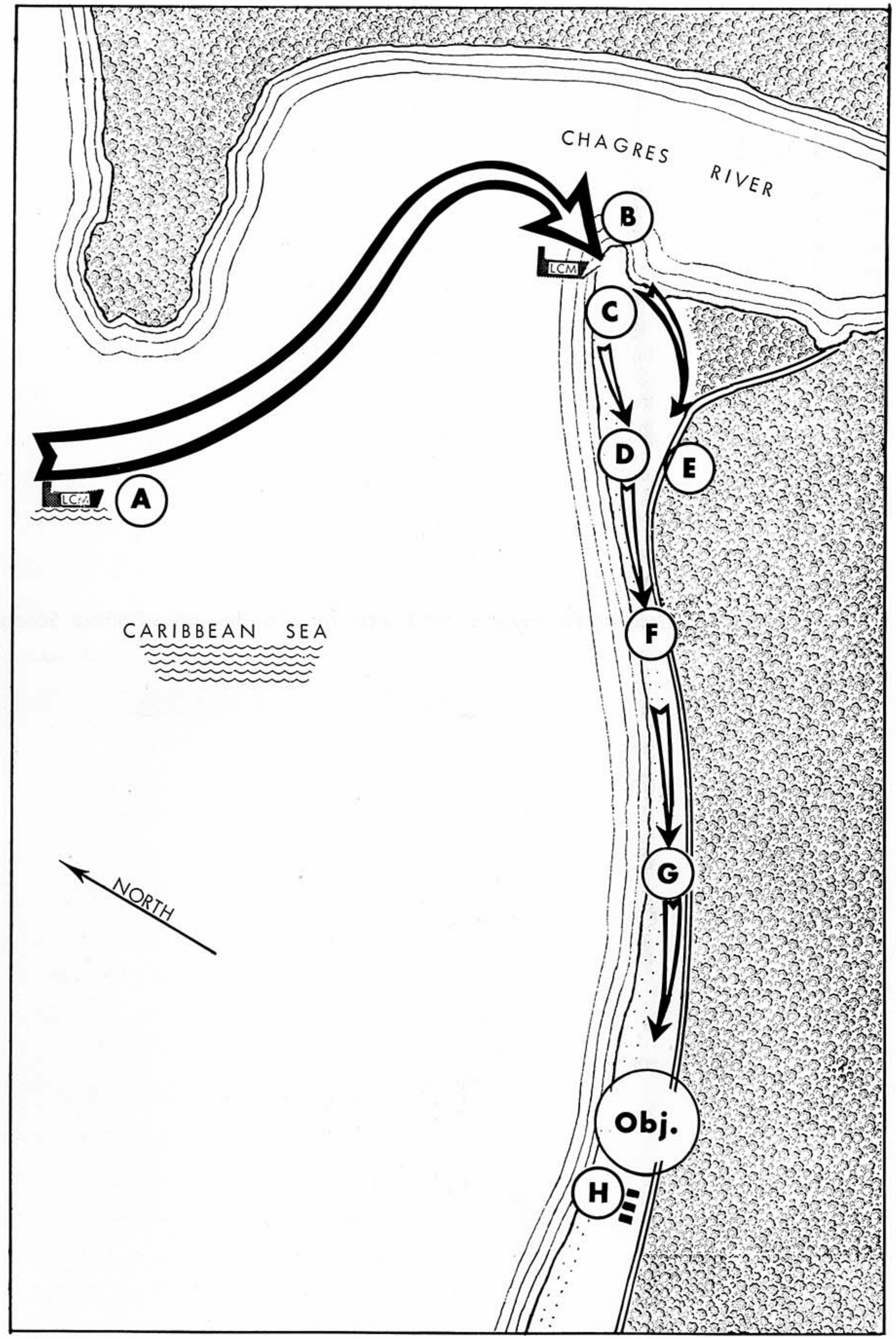
(D) Enemy fire forces troops on the right flank (ocean side) to a base of fire.

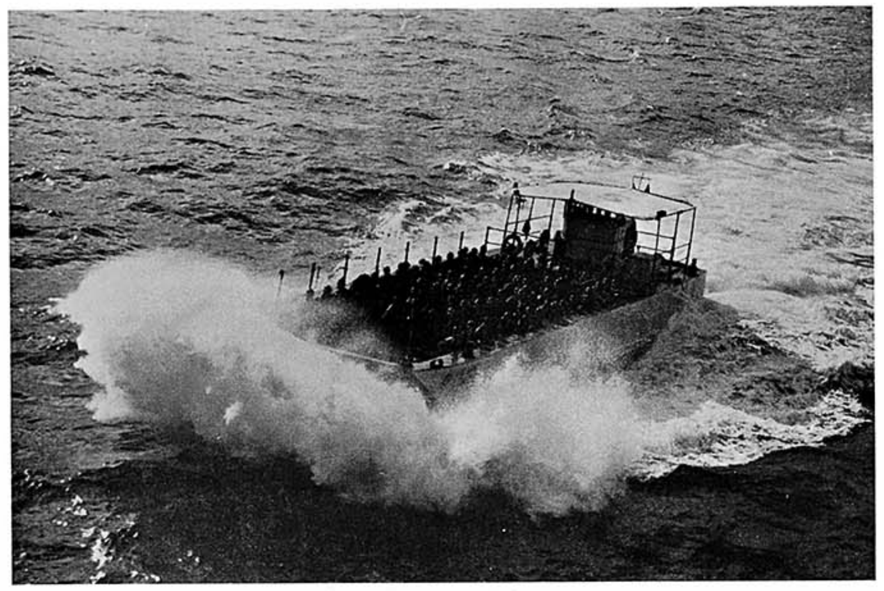
(E) Under cover of the base of fire, troops on the left flank turn the enemy position by fire and movement.

(F) After dislodging hostile resistance, the platoon advances west along the beach in a series of short rushes. While one fire team is advancing, another fire team (background) is in firing position to cover their movement.

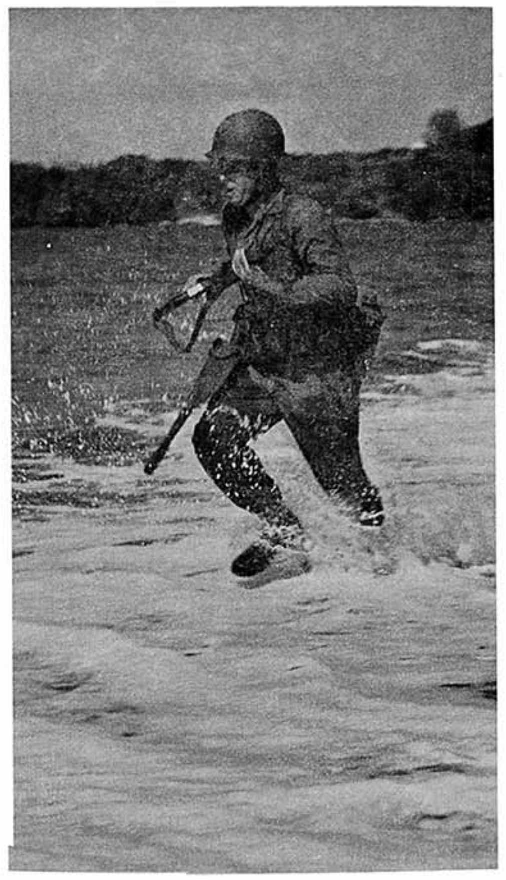
(G) Helicopter arriving for a medical evacuation. Rotor causes sand to blow over platoon.

(H) The final thirty feet before reaching the firing line is accomplished by crawling over the beach. At this point, the firing phase of the test took place from a firing range on the beach.





(A) LCM plows through moderate surf.



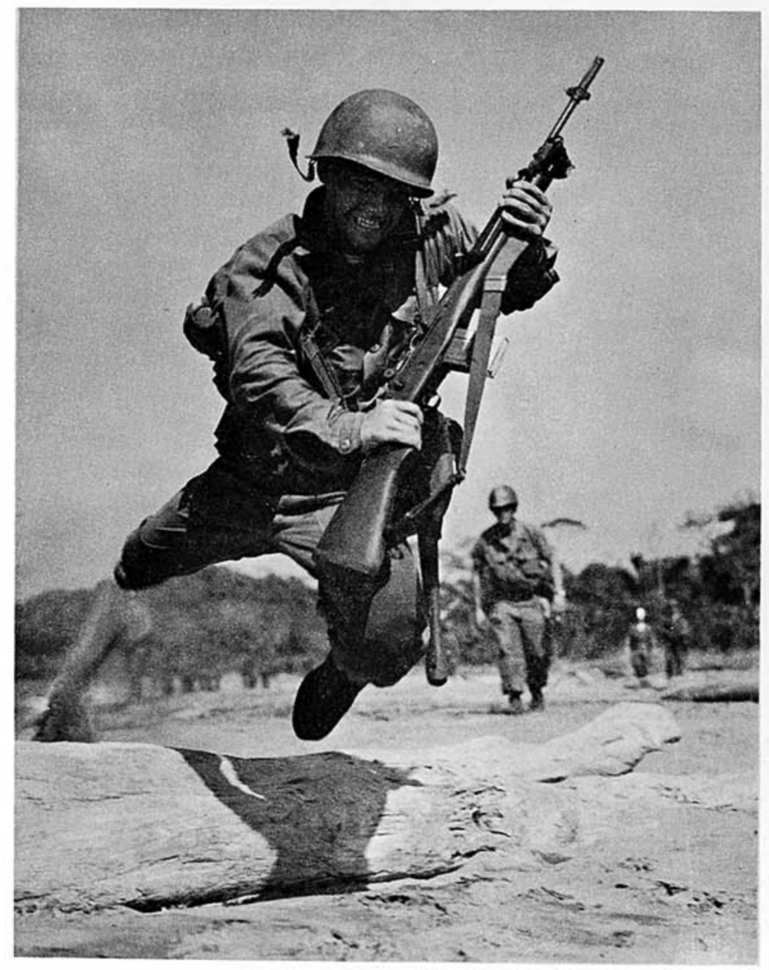
(C) More weapon exposure as right flank moves down beach.

(E) Fire teams move forward by rushes. (Note sand flying near Marine's feet).

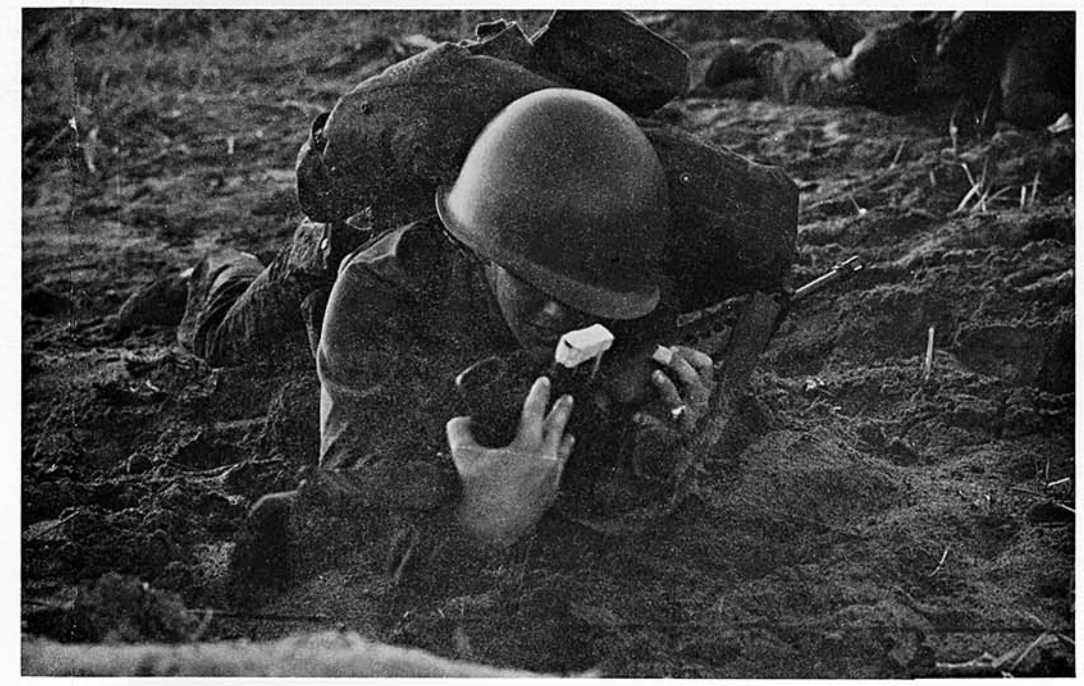
(G) Helicopter medical air evacuation blows sand on weapons.

(A) On board weapons are exposed to salt spray.

(D) Troops establish initial base of fire.



(E) Marine in maneuver element hits the sand.



(H) Crawling to firing line position.

(B) Beach assault exposes weapons to salt and sand.

(D) Sand exposure while digging prone shelters.

(F) Fire team provides cover for advancing element. Exposure to loose sand.

(H) Controlled firing at Pina Beach Range.

the rifleman may have a live round chambered and ready to fire. This might have been simulated by a patch or other means during the maneuver period. However, in the absence of any information as to the prevalence of the practice or any indication of an appreciable effect on malfunctions, it was not considered.

In all, the safety record was excellent. There were only a few relatively minor injuries and these were occasioned by the heartwarming enthusiasm of the Marine participants who in their efforts to provide appropriate exposure of their weapons performed with high spirits and in a combat realistic manner.

III. PRINCIPAL FINDINGS

Summarized below are the principal findings of the test. More complete information, including statistical confidence and significance data, appears in the IDA analysis, Enclosure C.

A. GROSS MALFUNCTION RATES

Accumulated overall test conditions, the total number of malfunctions (of all categories) by type/configuration of rifle and the corresponding rate -- malfunctions per 1000 rounds -- is shown below.

Rifle Malfunctions (By Category)	M-16A1 with Chrome Chamber		M-16A1 without Chrome Chamber		M-14		All M-16A1 Rifles	
	Number of Malfunctions	Malfunctions per 1000 rds	Number of Malfunctions	Malfunctions per 1000 rds	Number of Malfunctions	Malf. per 1000 rds	Number of Malfunctions	Malf. per 1000 rds
Category I	1433	2.63	1525	2.80	628	1.15	2958	2.72
Category II	295	0.54	335	0.61	125	0.23	630	0.57
Category III	52	0.10	41	0.08	12	0.02	93	0.09
Total Malfunctions	1780	3.27	1901	3.49	765	1.40	3681	3.38
Rounds Fired	544,048		544,087		545,709		1,088,135	

TOTAL ROUNDS FIRED ALL RIFLES: 1,633,844

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There was no significant difference between the gross malfunction rates of M-16A1 rifles (chromed chambers) R_1 and M-16A1 rifles (without chromed chambers) R_2. Thus, unless otherwise specified, subsequent findings will combine figures for these two configurations.

Within 95 percent confidence limits, the combined R_1, R_2 malfunction rate is 3.38 ± 0.43 and for the M-14 is $1.40 \pm$

0.15. This difference in gross malfunction rates between the M-16 and M-14 is an amount not reasonably attributable to chance, and is considered real.

B. MALFUNCTION RATES OF THE M-16A1 RIFLES AS DEPENDENT UPON AMMUNITION

The table shown below compares the malfunction numbers and rates of the M-16A1 rifle using ball propellant and IMR propellant with the malfunction numbers and rates of the M-14 rifles.

	M-16A1				M-14	
	Type of Propellant					
	Ball		IMR		Ball	
Category of Malfunction	No. of Malfunctions	Rate per 1000 rds	No. of Malfunctions	Rate per 1000 rds	No. of Malfunctions	Rate per 1000 rds
Category I	827	1.52	2131	3.92	628	1.15
Category II	189	0.34	441	0.81	125	0.23
Category III	48	0.09	45	0.08	12	0.02
Total Malfunctions	1064	1.95	2617	4.81	765	1.40
Rounds Fired	544,271		543,864		545,709	

The numbers and rates of malfunctions experienced with the IMR propellant were strikingly higher than with the ball propellant: 4.81 vs. 1.95.

The M-16 ball propellant rate (1.95) approaches but is higher than the M-14 rate (1.40) by an amount (.55) not attributable to chance.

Within 95 percent confidence limits malfunction rates for ball and IMR propellant are:

M-16A1 with ball propellant - 1.95 ± 0.20 per thousand
M-16A1 with IMR propellant - 4.81 ± 0.89 per thousand

Both lots of ball and both lots of IMR propellant ammunition used in the M-16 rifles gave essentially the same results.

C. MALFUNCTION RATES AS DEPENDENT ON ENVIRONMENT

The effects of the different environments on malfunction rates varied during the test and differed among rifles and ammunitions. The sand and salt water of the beach provided the most difficult environment.

The following table shows the total number and rate of malfunctions of M-16A1 and M-14 rifles in each of the four environments.

	M-16A1			M-14		
Environment	No. of Malfunctions	Rate per 1000 Rounds	Rounds Fired	No. of Malfunctions	Rate per 1000 Rounds	Rounds Fired
E_1 (Beach)	1,541	5.68	271,517	264	1.93	136,512
E_2 (Swamp)	848	3.12	272,155	150	1.10	136,512
E_3 (Rain Forest)	597	2.19	272,147	151	1.10	136,463
E_4 (Upland)	695	2.55	272,316	200	1.47	136,222

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The rates of malfunction (all categories) by environment of the M-16A1 rifles firing ball and IMR propellants are below.

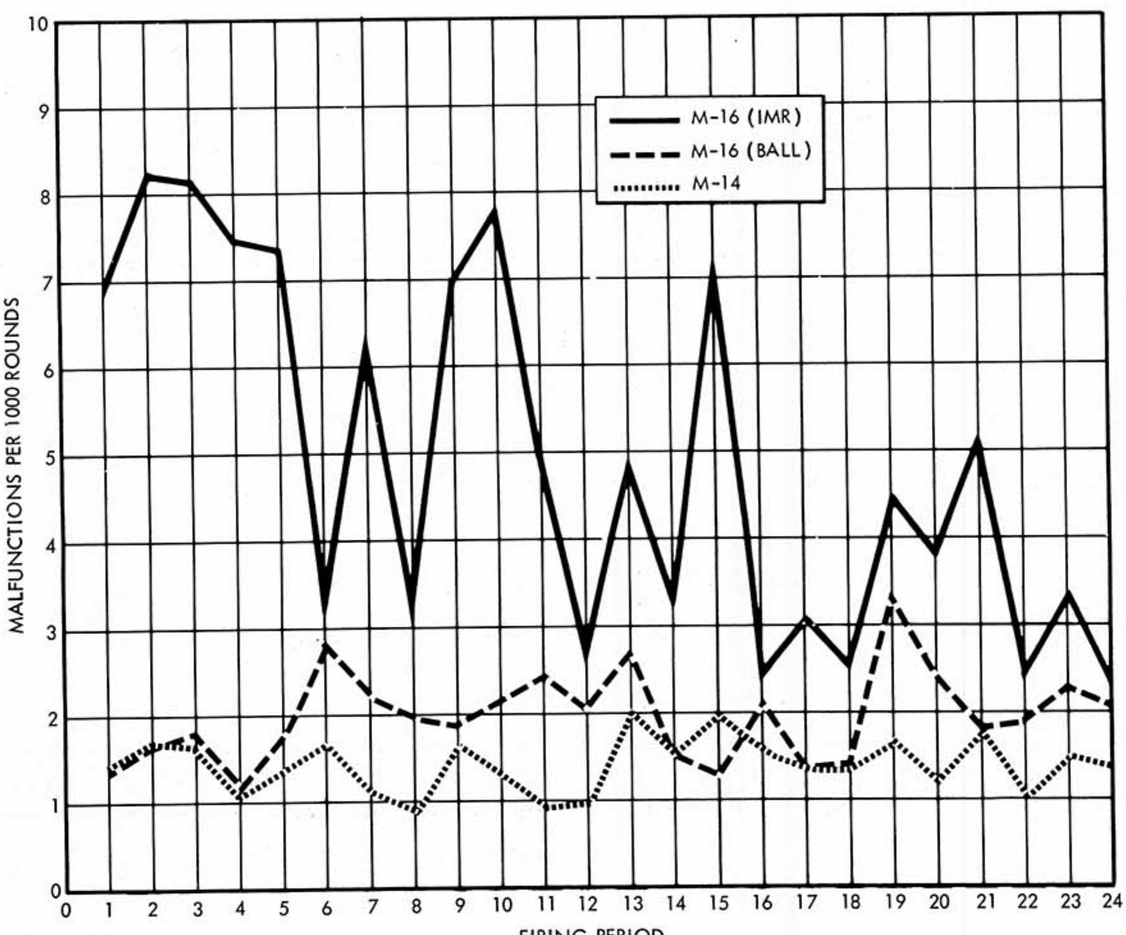
MALFUNCTIONS PER THOUSAND ROUNDS, M-16A1 RIFLES

Environment	Ball Propellant	IMR Propellant
E_1	3.00	8.37
E_2	1.64	4.59
E_3	1.40	2.98
E_4	1.78	3.32

The malfunction rate of the M-14 rifle and of the M-16A1 rifle firing ball propellant ammunition exhibited moderate stability with the changes in environment.

In contrast, the malfunction rate of the M-16A1 rifles firing IMR propellant ammunition was observed to undergo large fluctuations with changes in environmental conditions.

The chart below shows average malfunction rates for all environments by firing period.



Average Malfunction Rates for All Environments by Firing Period

A downward time trend in the malfunction rates of the M-16A-1 rifles firing IMR propellant is apparent. Sharp fluctuations in this rate could generally be attributed to unusual environmental conditions, e.g., high seas and winds at the beach.

D. EFFECTS OF CLEANING SCHEDULES

Malfunction rates for each cleaning doctrine are presented in the following table for each combination of rifle type and ammunition

	Ball Propellant		IMR Propellant		
	R_1	R_2	R_1	R_2	M-14
C_1	2.34	1.37	4.59	4.37	1.53
C_2	1.94	2.17	4.22	6.07	1.25

From these data it can be seen that the malfunction rates of the M-16A1 rifles without chrome-plated chambers, using either ball or IMR propellant, were higher when using the longer term (468/480 round) cleaning interval than when using the more frequent cleaning interval (234/240 rounds).

For the M-14 rifles and for the M-16A1 rifles with chrome-plated chambers -- using either ball or IMR propellant -- the differences in malfunction rates as between the two cleaning cycles are too small to be considered statistically significant.

The Extended Cleaning Cycle subtest involving 3 and 6 day cleaning intervals revealed higher malfunction rates than the main test but the samples were too small to be otherwise significant.

E. EFFECTS OF MAGAZINE LOAD

The test yielded no clear evidence to indicate that magazine loading: 18 rounds vs. 20 rounds per magazine had a significant effect on the reliabilities of any of the rifle systems tested. Because of the test design, however, the effects of loading could have been masked.

F. DEPENDENCE OF MALFUNCTION RATE UPON FIRING MODE

The table below compares the malfunction rates of the M-16A1 and M-14 rifles in the automatic and semiautomatic firing modes.

Firing Mode	M-16A1		M-14
	Ball	IMR	
Automatic	2.11	6.45	1.67
Semiautomatic	1.79	3.04	1.11

For all rifle systems tested, malfunction rates were significantly higher for the automatic mode.

G. PERFORMANCE OF NEW RIFLES

During a pretest rehearsal, new M-16A1 rifles firing IMR propellant exhibited unusually high malfunction rates (at least 18.7 per thousand rounds) during their first 240 rounds. The malfunction rates for these rifles during succeeding firing periods of the actual test reduced dramatically. Neither the M-16 rifles firing ball propellant, nor the M-14 rifles, exhibited unusually high rates in the pretest firing.

H. OTHER FINDINGS

First Two Rounds in the Magazine

Over one-third of all malfunctions occurred during the first two rounds in rifle magazines. This was many more than could be attributed to chance

Chambered Round Subtest

There was no evidence to indicate a detrimental effect from chambering a round overnight. No failures to extract resulted.

Distribution of Malfunctions by Nature

The following tables provide a summary view of the frequency with which malfunctions of all categories occurred, by type of rifle and malfunction.

Nature of Malfunctions	M-16A1 Ball Powder Number of Malfunctions	M-16A1 Ball Powder Percent Total	M-16A1 IMR Powder Number of Malfunctions	M-16A1 IMR Powder Percent of Total	M-14 Number of Malfunctions	M-14 Percent of Total
Failure to Feed	150	14.1	1,641	62.7	282	36.9
Failure to Chamber	91	8.6	360	13.8	113	14.8
Failure of Bolt to Remain at Rear	49	4.6	344	13.1	11	1.4
Failure to Eject	280	26.3	15	.6	16	2.1
Failure to Fire	184	17.3	82	3.1	103	13.5
Failure to Extract	125	11.8	53	2.0	85	11.1
Failure to Lock	78	7.3	38	1.5	86	11.2
Double Feed	45	4.2	25	1.0	3	.4
All others	62	5.8	59	2.2	66	8.6
Totals	1,064		2,617		765	
Rounds Fired	544,271		543,864		545,709	

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When using ammunition with ball powder, the most frequent malfunction of all M-16A1 rifles was a "failure to eject" (i.e., the rifle extracted but did not expel the expended cartridge) which accounted for 26.3 percent of all malfunctions.

When using ammunition with IMR powder, the most frequent malfunction shown on all M-16A1 rifles was a "failure to feed" which accounted for 62.7 percent of all the malfunctions. "failure to chamber" accounted for an additional 13.8 percent of the total. These two malfunctions are closely related and identification was probably not precise. Both malfunctions and "failure of the bolt to remain to the rear" are associated with insufficient rearward travel of the bolt carrier assembly and are consistent with the observation that IMR provides less energy or impulse to the M-16A1 mechanism than does ball propellant.

M-16A1 RIFLE MALFUNCTIONS FOR BALL PROPELLANT

	R_1		R_2	
Nature of Malfunction	Number of Malfunctions	Percent of Total	Number of Malfunctions	Percent of Total
Failure to Feed	73	12.5	77	16.0
Failure to Chamber	45	7.7	46	9.5
Failure to Lock	36	6.2	42	8.7
Failure to Fire	119	20.5	65	13.5
Failure to Extract	43	7.4	82	17.0
Failure to Eject	194	33.3	86	17.8
Double Feed	17	2.9	28	5.8
Failure of Bolt to Remain at Rear	29	5.0	20	4.2
All others	26	4.5	36	7.5
Totals	582		482	

M-16A1 RIFLE MALFUNCTIONS FOR IMR PROPELLANT

Nature of Malfunction	R_1 Number of Malfunctions	R_1 Percent of Total	R_2 Number of Malfunctions	R_2 Percent of Total
Failure to Feed	732 **	61.1	909	64.1
Failure to Chamber	204 **	17.0	156	11.0
Failure to Lock	8 *	.7	30	2.1
Failure to Fire	38 *	3.2	44	3.1
Failure to Extract	10 ***	.8	43	3.0
Failure to Eject	2 **	.2	13	.9
Double Feed	7 **	.6	18	1.3
Failure of Bolt to Remain at Rear	166 *	13.9	178	12.5
All others	31	2.5	28	2.0
Totals	1198		1419	

*** most serious
** next most
* Least

I. FAILURES TO EXTRACT

Of the M-16A1 rifles firing ball propellant ammunition those with the chromed chamber had 48 percent fewer failures to extract (43) than those with the non-chromed chamber (82).

Of the M-16A1 rifles firing IMR propellant ammunition those with the chromed chamber had 88 percent fewer failures to extract (10) than those with the non-chromed chamber (43). In fact, with IMR the overall performance of the chromed chamber rifle was better than the non-chromed.

These differences are not reasonably attributable to chance.

It can be seen, therefore, that the chrome-plated chamber modification of the M-16A1 rifle was effective in reducing the incidence of failure to extract. However, it should be noted that the M-16A1 rifles with the chromed chamber R_1 firing ball ammunition had more malfunctions overall (582), than those with the non-chromed chamber (482). In both cases R_1 and R_2 the dominant malfunction was failure to eject. However, with approximately the same number of rounds fired, R_1 (chromed chamber) had 194 failures to eject while R_2 (without chrome) had only 86. This very strongly supports a need for laboratory determination of the relationship of the chromed chamber modification to failure to eject.

Kinematic effect related to bolt travel rate and holding delay of case?

More detailed data concerning malfunctions are contained in Enclosure C and Enclosure I.

Enclosure I also contains a listing of the rifle parts replaced during the test.

J. TIME TO CLEAR MALFUNCTIONS

A record was made on the Rifle Malfunction Report of the time required by each rifleman to clear each Category I and Category II malfunction. These recorded times revealed that 8-10 seconds was required on the average to clear a Category I malfunction. Actual times to clear Category II malfunctions varied between a few seconds up to a maximum of fifteen minutes, but the recorded average time was approximately two minutes.

K. TIME TO CLEAN RIFLES

Cleaning was accomplished as prescribed in appropriate Field Manuals, and included field stripping, cleaning with solvent, lubrication of operating parts, and reassembly. The time required for riflemen to fully clean their weapons averaged about 45 minutes for the M-14 rifle, and a little more than 50 minutes for the M-16A1 rifle.

IV. CONCLUSIONS

- The operational reliability of the M-16A1 rifle with ball propellant ammunition approaches, but is less than, the operational reliability of the M-14.

- The operational reliability of the M-16A1 rifle with IMR propellant ammunition is markedly less than the M-14.

- As rifles age in terms of numbers of rounds fired, the spread in operational reliabilities between M-16A1's using IMR and those firing ball propellant narrows. However, over the 6000 rounds fired, the malfunction rate of the M-16A1 with the IMR propellant is nearly two and one-half times that of the rifle firing ball propellant.

- The chromed chamber modification to the M-16A1 is effective in reducing malfunctions caused by failures to extract. However, the effect of this modification on other type malfunctions requires study.

- With respect to cleaning, the M-16A1 with chromed chamber and the M-14 are similar in that neither is appreciably sensitive to more frequent or less frequent cleaning, within the limits of the intervals tested.

- M-16A1 rifles without chromed chambers are markedly more sensitive to cleaning intervals than those with chrome.

- Loading M-16A1 rifle magazines to design capacity of 20 rounds produced no evidence of adverse effect on operational reliability.

- Among the type rifles tested, whether firing ball or IMR propellant, all are more prone to malfunction when firing in the automatic mode.

Over a wide range of tropical environmental conditions the operational reliability and stability of the M-16A1 rifle firing ball propellant is markedly greater than that of the M-16A1 firing IMR propellant. The M-14 rifle is least affected by, and shows the least fluctuation in reliability in all these environments.

- M-16A1 rifles with chromed chambers, firing ball propellant are most prone to malfunctions due to failures to eject, fire and feed (66 percent of total).

- M-16A1 rifles without chrome, firing ball propellant, are most prone to malfunctions due to failures to eject, extract, feed and fire (64 percent of total).

- M-16A1 rifles with chromed chambers, firing IMR, are most prone to malfunctions due to failures to feed and chamber (78 percent of total).

- M-16A1 rifles without chrome, firing IMR, are most prone to malfunctions due to failures to feed (64 percent of total).

- M-14 rifles are most prone to malfunctions due to failures to feed, chamber and fire (65 percent of total).

ENCLOSURE A

Enclosure A

LIST OF REFERENCES

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ENCLOSURE B

Enclosure B

AUTHORITIES

COPY

DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING
Washington, D. C. 20301

20 November 1967

MEMORANDUM FOR: SECRETARY OF THE ARMY
COMMANDANT, US MARINE CORPS
DIRECTOR, WEAPONS SYSTEMS EVALUATION GROUP

SUBJECT: Simulated Combat Test of the M-16 Rifle System

The Special Subcommittee on the M-16 Rifle Program of the Committee on Armed Services, House of Representatives, recommended that "the Department of Defense direct and expedite a thorough and objective test by an independent organization of the weapon system consisting of the modified rifle and ammunition in Vietnam, as well as both types of propellant currently being loaded in 5.56mm ammunition."

On 13 November 1967, the Deputy Secretary of Defense requested of the Commandant, Marine Corps that the Marine Corps perform the test of the M-16 Rifle System to comply with the Subcommittee recommendation. The request was made after an understanding was reached with the Subcommittee Chairman Richard A. Ichord that the Marine Corps could be considered a suitable independent organization within the terms of the Subcommittee recommendation.

This memorandum sets forth the responsibilities that have been agreed to in conference since the above action was initiated by the Deputy Secretary of Defense:

The Marine Corps will be responsible for obtaining weapons, ammunition, other materiel, and personnel, will assist the Weapons Systems Evaluation Group in the necessary planning and issuing of test directives, and will be responsible for the execution of the test.

The Weapons Systems Evaluation Group will act as the OSD executive agent, and will monitor the test and test procedures in order to ensure that the test shall meet the intent of the Subcommittee recommendation. The WSEG will be responsible for establishing test conditions and procedures, reduction of the test data, evaluation of the test findings, and preparation of the final report, and will supply such other technical assistance as may be needed.

The Department of the Army will assist by making available as needed materiel, test facilities, and such other assistance as may be requested by the Marine Corps.

Attached is the tentative overall test directive submitted by the Marine Corps.

1 February 1968 is established as the target data for completion of the test and submission of a final test report to the Deputy Secretary of Defense.

Funding support required to support the tests will be arranged by separate action.

The wholehearted and enthusiastic cooperation of the addressees in the performance of this test is requested.

s/ John S. Foster, Jr.

Enclosure

COPY

OFFICE OF THE DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING
Weapons Systems Evaluation Group
Washington, D. C. 20305

29 December 1967

TASK ORDER
No. DAHC15 67 C 0012-T-139

1. In accordance with paragraph C, Article I of Department of Defense Contract No. DAHC15 67 C 0012, this Task Order is for work (study) to be performed by the Institute for Defense Analyses (IDA) under the Weapons Systems Evaluation Group (WSEG) Study Contract.

2. BACKGROUND. The report of the Special Subcommittee on the M-16 Rifle Program of the Committee on Armed Services, House of Representatives, 90th Congress dated October 19, 1967, recommended that "the Department of Defense direct and expedite a thorough and objective test by an independent organization of the weapon system consisting of the modified rifle and ammunition in Vietnam, as well as both types of propellant currently being loaded in 5.56mm ammunition."

a. On 13 November 1967 the Deputy Secretary of Defense requested of the Commandant, Marine Corps, that the Marine Corps perform the test of the M-16 Rifle System. The request was made after an understanding was reached with the Subcommittee Chairman, Richard A. Ichord, that the Marine Corps could be considered a suitable independent organization within the terms of the Subcommittee recommendation.

b. On 20 November 1967, the Director of Defense Research and Engineering in a memorandum addressed to the Secretary of the Army; Commandant, U.S. Marine Corps; and Director, Weapons Systems Evaluation Group, set forth the following responsibilities:

(1) The Weapons Systems Evaluation Group will act as the OSD executive agent and will monitor the test and test procedures in order to ensure that the test shall be carried out in accordance with the test plan. The WSEG will be responsible for establishing test conditions and procedures, reduction of the test data, evaluation of the test findings, and preparation of the final report, and will supply such other technical assistance as may be required.

(2) The Marine Corps will be responsible for obtaining weapons, ammunition, other material, and personnel, will assist the WSEG in the necessary planning and issuing of test directives and will be responsible for the execution of the test.

(3) The Department of the Army will assist by making available as needed, material, test facilities, and such other assistance as may be requested by the Marine Corps.

3. TEST PURPOSES AND OBJECTIVES.

a. Purpose. The purpose of the test is to measure the operational reliability of the M-16 rifle systems presently used by maneuver battalions in combat, and under conditions simulating as closely as possible those being experienced by these units in South Vietnam. System configurations presently in use in South Vietnam and to be tested are:

(1) Fully modified M-16 A1 rifle using both IMR and ball propellant;

(2) Partially modified M-16 A1 rifle (without chromed chamber) using both IMR and ball propellant.

b. Objectives. Using the M-14 rifle system as a control:

(1) Determine the malfunction rate of the fully modified M-16 A1 rifle (new buffer group and chromed chamber) when using ball propellant and when using IMR;

(2) Determine the malfunction rate of the partially modified M-16 A1 rifle (new buffer group but without chromed chamber) when using ball propellant and when using IMR;

(3) Identify for each rifle configuration and for each propellant the types of malfunctions and conditions under which they occur.

4. SCOPE. The test is restricted in scope to the measurement of rifle system reliability. It is beyond the scope of this test to evaluate the combat effectiveness of the rifle systems represented.

5. TASK ASSIGNMENTS.

a. This Task Order assigns to the Institute for Defense Analyses responsibility for the following items in support of WSEG's prosecution of the test.

(1) The development of the technical design of the test;

(2) The reduction analysis and evaluation of the test data; and

(3) Submission to WSEG of a report containing the analysis and the evaluation of test results.

b. WSEG will support IDA in fulfilling the above responsibilities by releasing required data and reports from the Services and by providing necessary military personnel.

c. WSEG is responsible for the preparation of the detailed test plan, for data collection, and for the control and monitoring of the test to ensure that it is conducted in accordance with the test plan.

d. WSEG is also responsible for the necessary liaison and support activities with all military elements concerned with the test or support thereof.

e. IDA analysts assigned to the project will provide technical assistance and guidance to WSEG in carrying out these responsibilities.

6. LEVEL OF EFFORT. The expenditure of approximately one professional staff man year is authorized for this task. This level of effort will not be exceeded without approval of the Director, WSEG.

7. MILITARY PARTICIPATION. Major General A. J. Beck, USAF, is the Test Director for the Weapons Systems Evaluation Group. Other military members will be assigned by the Director, WSEG, in accordance with the needs of the project.

8. SPECIFIC INSTRUCTIONS AND LIMITATIONS.

a. The Target Date for completion of the test and submission of the test report to the Deputy Secretary of Defense is 10 February 1968.

b. IDA will complete analysis and evaluation of test data so as to permit WSEG submission of the test report to the Deputy Secretary of Defense not later than the target date of 10 February 1968 established in a. above.

c. The actual firing test will be conducted in Panama during the period from about 9 January - 25 January 1968.

9. <u>TITLE.</u> This shall be known as the M-16 Study.

s/ K. S. MASTERSON
Vice Admiral, USN
Director

ACCEPTED (signed)
MAXWELL D. TAYLOR
President, Institute for Defense Analyses

DATE 28 Dec 1967

ENCLOSURE C

Enclosure C

PRELIMINARY ANALYSIS OF THE M-16 RIFLE SYSTEM TEST

(Prepared by the Institute for Defense Analyses: Complete IDA Report R-135 is not included since it contains a description of the conduct of the test which can be found in greater detail on pages 5-18 of the basic WSEG Report.)

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I. INTRODUCTION

This report provides analytical backup to the Weapons Systems Evaluation Group (WSEG) report, Operational Reliability Test of the M-16 Rifle System. It responds to Task Order No. DAHC15 67 C 0012-T-139 from the Director of WSEG to the Institute for Defense Analyses (IDA). This task order assigned to IDA the responsibility for the following tasks in connection with the prosecution of the M-16 rifle system test:

- The development of the technical design of the test;
- The reduction, analysis, and evaluation of the test data; and
- The submission to WSEG of a report containing the analysis and evaluation of the test results.

The test, which was conducted in Panama from 10 January to 26 January 1968 had the purpose of measuring the operational reliability of the M-16 rifle systems being used by maneuver battalions in combat, and under conditions simulating as closely as possible those being experienced in South Vietnam. The rifle systems represented in the test included:

- The fully modified M-16A1 rifle using both IMR and ball propellant.
- The partially modified M-16A1 rifle (without chromed chamber) using both ball and IMR propellant.
- The M-14 rifle using standard 7.62mm ammunition.

Using the M-14 rifle as a control, the test had the following specific objectives:

- To determine the malfunction rate of the fully modified M-16A1 rifle (new buffer group and chromed chamber) when using ball propellant and when using IMR;

- To determine the malfunction rate of the partially modified M-16A1 rifle (new buffer group but without chromed chamber) when using ball propellant and when using IMR;
- To identify for each rifle configuration and for each propellant the types of malfunctions and the conditions under which they occur.

The test was restricted in scope to the measurement of rifle system reliability. In particular, it was beyond the scope of the test to yield data suitable for evaluating the combat effectiveness of the rifle systems represented. Additionally the design of the test was oriented toward providing data having operational significance in contrast to detailed engineering data. For this reason, the test is not necessarily a source of detailed design or design verification data which might better be obtained from a more highly controlled and instrumented proving ground test.

For description of the following, see the main paper of the WSEG Report:

- Background
- Purpose
- Objective
- Concept
- Test Description
- Personnel and Training
- Data Collection and Reduction

II. STATISTICAL TEST DESIGN

A basic objective of the initial test design was to achieve a balanced design which would permit a valid comparison and separation of the effects of the principal test variables on rifle system reliability. To this end the main test was configured to insure that each applicable variable combination ($R_iA_jC_k$) of rifle type (R_i; i=1,2,4), ammunition type (A_j; j=1,2,3,4,5), and cleaning cycle (C_k; k=1,2) was tested at the same time and under exactly the same environmental condition (E) and magazine loading (L). In the interest of simplifying test administration, test rifles and riflemen were paired at the outset of the test and not interchanged (i.e., randomized) thereafter. Consequently the assumption is implicit in comparisons that each rifleman assigned to a given rifle-type/ammunition/cleaning cycle combination in any squad is, on the average, equivalent in ability to his counterpart assigned to any other combination of the same variables in the same or any other squad. A similar assumption applies to the average uniformity of the quality of the test rifles used. To aid in satisfying the first assumption, participating USMC riflemen were to be given essentially equivalent training and indoctrination in the M-14 and M-16 rifle prior to the test and were to be assigned to squads in a manner designed to achieve uniformity in pertinent ability and background.

The test design fails to provide simultaneous comparisons between magazine loadings L_1 and L_2 for a given $R_iA_jC_k$ combination under the same environmental condition (E). Instead L_1 and L_2 can be compared at a given test site only at different times separated by at least two test phases (12 firing periods).

Since the environmental condition at a given site fluctuates with meteorological conditions, prior usage by other platoons, etc., such comparisons between magazine loadings L_1 and L_2 are weak, being confounded with temporal and other changes in the environment.

The design of the main test assures that a given rifleman fires his assigned rifle type (R_i) using his assigned ammunition (A_j), cleaning cycle (C_k), and magazine loading (L_m) at each of the four test sites (E_1, E_2, E_3 and E_4) for six consecutive firing periods. Each of Figures C1 through C4 depicts the interrelationships between the various controlled test variables (factors) for one of the four 6-firing-period phases comprising the test. Referring to the figures, the first two numbers in each cell indicate, respectively, the platoon number and squad number assigned to a particular set of test variables during the indicated test phase. The encircled number indicates the number of riflemen assigned during that test phase to a given combination of test variables.

PHASE 1, FIRING PERIODS: 1 THROUGH 6			R_1				R_2					R_4			
			L_1		L_2		L_1		L_2			L_1		L_2	
			C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2		C_1	C_2	C_1	C_2
E_1	BALL	A_1			1 - 1 -③	1 - 1 -③			1 - 1 -③	1 - 1 -③	A_5			1 - 1 -③	1 - 1 -③
		A_2			1 - 2 -③	1 - 2 -③			1 - 2 -③	1 - 2 -③				1 - 2 -③	1 - 2 -③
	IMR	A_3			1 - 3 -③	1 - 3 -③			1 - 3 -③	1 - 3 -③				1 - 3 -③	1 - 3 -③
		A_4			1 - 4 -③	1 - 4 -③			1 - 4 -③	1 - 4 -③				1 - 4 -③	1 - 4 -③
E_2	BALL	A_1	2 - 1 -③	2 - 1 -③			2 - 1 -③	2 - 1 -③			A_5	2 - 1 -③	2 - 1 -③		
		A_2	2 - 2 -③	2 - 2 -③			2 - 2 -③	2 - 2 -③				2 - 2 -③	2 - 2 -③		
	IMR	A_3	2 - 3 -③	2 - 3 -③			2 - 3 -③	2 - 3 -③				2 - 3 -③	2 - 3 -③		
		A_4	2 - 4 -③	2 - 4 -③			2 - 4 -③	2 - 4 -③				2 - 4 -③	2 - 4 -③		
E_3	BALL	A_1			3 - 1 -③	3 - 1 -③			3 - 1 -③	3 - 1 -③	A_5			3 - 1 -③	3 - 1 -③
		A_2			3 - 2 -③	3 - 2 -③			3 - 2 -③	3 - 2 -③				3 - 2 -③	3 - 2 -③
	IMR	A_3			3 - 3 -③	3 - 3 -③			3 - 3 -③	3 - 3 -③				3 - 3 -③	3 - 3 -③
		A_4			3 - 4 -③	3 - 4 -③			3 - 4 -③	3 - 4 -③				3 - 4 -③	3 - 4 -③
E_4	BALL	A_1	4 - 1 -③	4 - 1 -③			4 - 1 -③	4 - 1 -③			A_5	4 - 1 -③	4 - 1 -③		
		A_2	4 - 2 -③	4 - 2 -③			4 - 2 -③	4 - 2 -③				4 - 2 -③	4 - 2 -③		
	IMR	A_3	4 - 3 -③	4 - 3 -③			4 - 3 -③	4 - 3 -③				4 - 3 -③	4 - 3 -③		
		A_4	4 - 4 -③	4 - 4 -③			4 - 4 -③	4 - 4 -③				4 - 4 -③	4 - 4 -③		

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FIGURE C1. Main Test Design for Phase 1

PHASE 2, FIRING PERIODS: 7 THROUGH 12			R_1				R_2					R_4			
			L_1		L_2		L_1		L_2			L_1		L_2	
			C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2		C_1	C_2	C_1	C_2
E_1	BALL	A_1			3 - 1 - ③	3 - 1 - ③			3 - 1 - ③	3 - 1 - ③	A_5			3 - 1 - ③	3 - 1 - ③
		A_2			3 - 2 - ③	3 - 2 - ③			3 - 2 - ③	3 - 2 - ③				3 - 2 - ③	3 - 2 - ③
	IMR	A_3			3 - 3 - ③	3 - 3 - ③			3 - 3 - ③	3 - 3 - ③				3 - 3 - ③	3 - 3 - ③
		A_4			3 - 4 - ③	3 - 4 - ③			3 - 4 - ③	3 - 4 - ③				3 - 4 - ③	3 - 4 - ③
E_2	BALL	A_1	4 - 1 - ③	4 - 1 - ③			4 - 1 - ③	4 - 1 - ③			A_5	4 - 1 - ③	4 - 1 - ③		
		A_2	4 - 2 - ③	4 - 2 - ③			4 - 2 - ③	4 - 2 - ③				4 - 2 - ③	4 - 2 - ③		
	IMR	A_3	4 - 3 - ③	4 - 3 - ③			4 - 3 - ③	4 - 3 - ③				4 - 3 - ③	4 - 3 - ③		
		A_4	4 - 4 - ③	4 - 4 - ③			4 - 4 - ③	4 - 4 - ③				4 - 4 - ③	4 - 4 - ③		
E_3	BALL	A_1			1 - 1 - ③	1 - 1 - ③			1 - 1 - ③	1 - 1 - ③	A_5			1 - 1 - ③	1 - 1 - ③
		A_2			1 - 2 - ③	1 - 2 - ③			1 - 2 - ③	1 - 2 - ③				1 - 2 - ③	1 - 2 - ③
	IMR	A_3			1 - 3 - ③	1 - 3 - ③			1 - 3 - ③	1 - 3 - ③				1 - 3 - ③	1 - 3 - ③
		A_4			1 - 4 - ③	1 - 4 - ③			1 - 4 - ③	1 - 4 - ③				1 - 4 - ③	1 - 4 - ③
E_4	BALL	A_1	2 - 1 - ③	2 - 1 - ③			2 - 1 - ③	2 - 1 - ③			A_5	2 - 1 - ③	2 - 1 - ③		
		A_2	2 - 2 - ③	2 - 2 - ③			2 - 2 - ③	2 - 2 - ③				2 - 2 - ③	2 - 2 - ③		
	IMR	A_3	2 - 3 - ③	2 - 3 - ③			2 - 3 - ③	2 - 3 - ③				2 - 3 - ③	2 - 3 - ③		
		A_4	2 - 4 - ③	2 - 4 - ③			2 - 4 - ③	2 - 4 - ③				2 - 4 - ③	2 - 4 - ③		

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FIGURE C2. Main Test Design for Phase 2

PHASE 3, FIRING PERIODS: 13 THROUGH 18			R_1				R_2					R_4			
			L_1		L_2		L_1		L_2			L_1		L_2	
			C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2		C_1	C_2	C_1	C_2
E_1	BALL	A_1	4 - 1 - ③	4 - 1 - ③			4 - 1 - ③	4 - 1 - ③			A_5	4 - 1 - ③	4 - 1 - ③		
		A_2	4 - 2 - ③	4 - 2 - ③			4 - 2 - ③	4 - 2 - ③				4 - 2 - ③	4 - 2 - ③		
	IMR	A_3	4 - 3 - ③	4 - 3 - ③			4 - 3 - ③	4 - 3 - ③				4 - 3 - ③	4 - 3 - ③		
		A_4	4 - 4 - ③	4 - 4 - ③			4 - 4 - ③	4 - 4 - ③				4 - 4 - ③	4 - 4 - ③		
E_2	BALL	A_1			1 - 1 - ③	1 - 1 - ③			1 - 1 - ③	1 - 1 - ③	A_5			1 - 1 - ③	1 - 1 - ③
		A_2			1 - 2 - ③	1 - 2 - ③			1 - 2 - ③	1 - 2 - ③				1 - 2 - ③	1 - 2 - ③
	IMR	A_3			1 - 3 - ③	1 - 3 - ③			1 - 3 - ③	1 - 3 - ③				1 - 3 - ③	1 - 3 - ③
		A_4			1 - 4 - ③	1 - 4 - ③			1 - 4 - ③	1 - 4 - ③				1 - 4 - ③	1 - 4 - ③
E_3	BALL	A_1	2 - 1 - ③	2 - 1 - ③			2 - 1 - ③	2 - 1 - ③			A_5	2 - 1 - ③	2 - 1 - ③		
		A_2	2 - 2 - ③	2 - 2 - ③			2 - 2 - ③	2 - 2 - ③				2 - 2 - ③	2 - 2 - ③		
	IMR	A_3	2 - 3 - ③	2 - 3 - ③			2 - 3 - ③	2 - 3 - ③				2 - 3 - ③	2 - 3 - ③		
		A_4	2 - 4 - ③	2 - 4 - ③			2 - 4 - ③	2 - 4 - ③				2 - 4 - ③	2 - 4 - ③		
E_4	BALL	A_1			3 - 1 - ③	3 - 1 - ③			3 - 1 - ③	3 - 1 - ③	A_5			3 - 1 - ③	3 - 1 - ③
		A_2			3 - 2 - ③	3 - 2 - ③			3 - 2 - ③	3 - 2 - ③				3 - 2 - ③	3 - 2 - ③
	IMR	A_3			3 - 3 - ③	3 - 3 - ③			3 - 3 - ③	3 - 3 - ③				3 - 3 - ③	3 - 3 - ③
		A_4			3 - 4 - ③	3 - 4 - ③			3 - 4 - ③	3 - 4 - ③				3 - 4 - ③	3 - 4 - ③

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FIGURE C3. Main Test Design for Phase 3

PHASE 4, FIRING PERIODS: 19 THROUGH 24			R_1				R_2					R_4			
			L_1		L_2		L_1		L_2			L_1		L_2	
			C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2		C_1	C_2	C_1	C_2
E_1	BALL	A_1	2 - 1 - ③	2 - 1 - ③			2 - 1 - ③	2 - 1 - ③			A_5	2 - 1 - ③	2 - 1 - ③		
		A_2	2 - 2 - ③	2 - 2 - ③			2 - 2 - ③	2 - 2 - ③				2 - 2 - ③	2 - 2 - ③		
	IMR	A_3	2 - 3 - ③	2 - 3 - ③			2 - 3 - ③	2 - 3 - ③				2 - 3 - ③	2 - 3 - ③		
		A_4	2 - 4 - ③	2 - 4 - ③			2 - 4 - ③	2 - 4 - ③				2 - 4 - ③	2 - 4 - ③		
E_2	BALL	A_1			3 - 1 - ③	3 - 1 - ③			3 - 1 - ③	3 - 1 - ③	A_5			3 - 1 - ③	3 - 1 - ③
		A_2			3 - 2 - ③	3 - 2 - ③			3 - 2 - ③	3 - 2 - ③				3 - 2 - ③	3 - 2 - ③
	IMR	A_3			3 - 3 - ③	3 - 3 - ③			3 - 3 - ③	3 - 3 - ③				3 - 3 - ③	3 - 3 - ③
		A_4			3 - 4 - ③	3 - 4 - ③			3 - 4 - ③	3 - 4 - ③				3 - 4 - ③	3 - 4 - ③
E_3	BALL	A_1	4 - 1 - ③	4 - 1 - ③			4 - 1 - ③	4 - 1 - ③			A_5	4 - 1 - ③	4 - 1 - ③		
		A_2	4 - 2 - ③	4 - 2 - ③			4 - 2 - ③	4 - 2 - ③				4 - 2 - ③	4 - 2 - ③		
	IMR	A_3	4 - 3 - ③	4 - 3 - ③			4 - 3 - ③	4 - 3 - ③				4 - 3 - ③	4 - 3 - ③		
		A_4	4 - 4 - ③	4 - 4 - ③			4 - 4 - ③	4 - 4 - ③				4 - 4 - ③	4 - 4 - ③		
E_4	BALL	A_1			1 - 1 - ③	1 - 1 - ③			1 - 1 - ③	1 - 1 - ③	A_5			1 - 1 - ③	1 - 1 - ③
		A_2			1 - 2 - ③	1 - 2 - ③			1 - 2 - ③	1 - 2 - ③				1 - 2 - ③	1 - 2 - ③
	IMR	A_3			1 - 3 - ③	1 - 3 - ③			1 - 3 - ③	1 - 3 - ③				1 - 3 - ③	1 - 3 - ③
		A_4			1 - 4 - ③	1 - 4 - ③			1 - 4 - ③	1 - 4 - ③				1 - 4 - ③	1 - 4 - ③

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FIGURE C4. Main Test Design for Phase 4

III. ANALYSIS AND RESULTS

A. PRINCIPAL FINDINGS

The following are the principal findings of the test:

- Averaged over all conditions of the test, the malfunction rate of the modified M-16A1 rifles (with modified buffers, with or without chrome-plated chambers) firing ammunition with ball propellant was 1.95 malfunctions of all categories per thousand rounds fired, with 95 percent confidence limits of 1.75 and 2.15 per thousand. This rate was comparable to, but slightly higher than, the rate for the M-14 rifles.
- Under the same conditions, the malfunction rate of the M-14 rifles, firing standard ammunition (with ball propellant) was 1.40 malfunctions of all categories per thousand rounds fired, with 95 percent confidence limits of 1.25 and 1.55 per thousand. The difference between the M-14 rate, and the M-16 rate with ball propellant, although small, is believed to be real.
- Averaged over all conditions of the test, the malfunction rate of the modified M-16 rifles (with modified buffers, with or without chrome-plate chambers) firing ammunition with IMR propellant was 4.81 malfunctions of all categories per thousand rounds fired, with 95 percent confidence limits of 3.92 and 5.70 per thousand. The difference between this rate, nearly two and one-half times as high as the rate with ball propellant, and the rate with ball propellant is undoubtedly real. The difference is believed possibly to arise from a smaller impulse imparted to the actuating mechanism of the M-16 rifle by IMR than by ball propellant, the smaller impulse being sometimes inadequate to overcome frictional forces arising from dust, dirt, and fouling, particularly in rifles in which clearances (through slight manufacturing variations) may be unusually tight.
- During a "rehearsal" in advance of the planned test, unusually high malfunction rates were noticed among the M-16 rifles, all new, employing IMR propellant. Among 9500 rounds fired, the rate was at least 18.7 per thousand. This "new rifle" effect had practically disappeared

by the beginning of the planned test. The effect was not observed among the M-16 rifles, also new, firing ball propellant, where the rate of malfunctions during the rehearsal was 1.2 per thousand among 11,232 rounds. The effect was also not observed in the pre-test M-14 rifles which exhibited a malfunction rate of 2.2 per thousand. The preceding findings, and others of less importance, are discussed in the following sections of this report.

B. GROSS MALFUNCTION RATES

Accumulated over all test conditions, the total numbers of malfunctions observed in each of the three categories and the total numbers of malfunctions of all categories are listed in successive rows of Table C1 for the M-16 rifles of type R_1 (completely modified) in the first column, for M-16 rifles of type R_2 (modified buffers, but without chrome-plated chambers) in the second column, and for M-14 rifles (R_4) in the third column. The numbers of rounds that were fired from each type of rifle are shown below the respective columns, and the total number of rounds (1,633,844) at the bottom right.

Table C1

Category or Malfunction	Type of Rifle				
	R_1	R_2	R_4	(R_1+R_2)	
I	1,433	1,525	628	2,958	
II	295	335	125	630	
III	52	41	12	93	
All Types	1,780	1,901	765	3,681	
Rounds Fired	544,048	544,087	545,709	1,088,135	(1,633,844)

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Both types of M-16 rifles showed more malfunctions than the M-14 rifles. While the R_2 rifles had somewhat more malfunctions than the R_1 rifles, a t-test of statistical significance[1] (involving the numbers of malfunctions observed

[1] A discussion of the application of such tests appears in the Enclosure.

separately in each of the 24 firing periods) shows that if rifles of types R_1 and R_2 had the same inherent rates of failure, a difference between the total numbers of their malfunctions at least as great as the difference (121 malfunctions) that was observed would have occurred by chance in 19 percent of such comparisons. The difference is therefore judged to be of no significance and it is concluded that there is no evidence for a difference between the inherent gross malfunction rates of the two types of M-16 rifles.

The significance of the difference observed between the malfunction rates of the R_1 and R_2 rifles was tested in a second way. Table C2 shows the number of instances in which for each type of M-16 rifle, individual rifles experienced $\underline{i}$ malfunctions in a firing period. The two rows in Table C2 were tested by a chi-square test[1] to determine the probability that if the frequencies of $\underline{i}$ failures in the two rows were random samples from a single parent population, the same for both rifle types, then the two sets of frequencies would differ

Table C2. NUMBER OF INSTANCES IN WHICH INDIVIDUAL M-16 RIFLES EXPERIENCED $\underline{i}$ MALFUNCTIONS IN A FIRING PERIOD

Rifle Type	i=0	1	2	3	4	5	6	7	8	9	10	11	12 or more
R_1	1564	358	162	80	46	30	22	13	7	10	3	2	7
R_2	1495	410	178	89	52	27	14	8	7	4	5	1	14

2-3-68-2

from each other by as much as, or more than, the two observed rows did. The probability was found to be 18 percent, again suggesting no inherent differences between the malfunction rates of the two types of M-16 rifles. Since instances of 12

[1] A discussion of the application of such tests appears in the Enclosure.

or more malfunctions were pooled in this second test, it is less sensitive than the earlier test to "stragglers;" that is, to those individual rifles with unusually large numbers of malfunctions in single firing period. The effect of these "stragglers" on the gross malfunction rates is further discussed in Section C below.

Since there is no evidence for a difference between the malfunction rates of rifles R_1 and R_2, it is proper henceforth to combine the results for rifles R_1 and R_2 and such combined results are shown in the column headed R_1+R_2 in Table C1. Unless otherwise specified, all subsequently reported results for the M-16 rifle system will be so combined.

The gross malfunction rates (the numbers of malfunctions of all types divided by the numbers of rounds fired) of the M-16 and M-14 rifles, during the test, were as follows:

M-16 3.38 ± 0.43 per thousand
M-14 1.40 ± 0.15 per thousand

where the quantities following the $\pm$ signs are the 95 percent confidence limits as estimated (by use of the t-distribution with 23 degrees of freedom) from the variance of the numbers of malfunctions that occurred during the 24 separate firing periods. The difference observed between the gross malfunction rates of the M-16 and M-14 rifles, during the test, is much too large to have occurred by chance. For, if the two rifle systems had inherently equal rates, so large a difference would have been observed by chance less frequently than once in a hundred thousand such comparisons, as shown by both "t" and chi-square tests by which the difference was examined. The observed difference between the gross malfunction rates of the M-16 and M-14 rifle systems is therefore judged to be real.

The "95 percent confidence limits" demand explanation. The values of such limits given in this report relate to imagined repetitions (replications) of the present test, under similar conditions and policies relating to environmental exposure, full cleaning (scheduled), partial cleanings (discretionary), etc., with the same degrees of exposure to swamp mud, beach sand and spray, etc., and with riflemen and armorers having the same degree of proficiency as those in the test. Although determined attempts have been made to achieve realism with respect to many or all of the preceding conditions, the confidence limits obtained by analysis of the test results necessarily cannot reflect or allow for the effects of variations from the test conditions that would probably occur within a wide range of field conditions. The confidence limits of this report must therefore be understood to relate only to rates of malfunction that might be observed during conceivable repetitions of the present test under its conditions and procedures, and not to rates of malfunction that may be obtained under different conditions.

The malfunction rates here reported are intended to be as realistic as possible, but the confidence limits attached to them in this report are recognized to be applicable only to replications of the present M-16 test. As well as can be judged from this test, the probability that the true population mean in this test lies between the cited limits is 95 percent.

Table C3 presents some of the same data as in Table C1, but in the form of malfunctions per thousand rounds.

Table C3. MALFUNCTIONS PER THOUSAND ROUNDS FIRED

Category of Malfunction	Type of Rifle	
	M-16	M-14
I	2.72 ± 0.40	1.15 ± 0.11
II	0.57 ± 0.11	0.23 ± 0.06
III	0.09 ± 0.02	0.02 ± 0.01
All	3.38 ± 0.43[a]	1.40 ± 0.15[a]

[a]The ± intervals are explained in the text.

C. MALFUNCTION RATES OF THE M-16 RIFLES AS DEPENDENT ON AMMUNITION

Ammunitions A_1 and A_2 had ball propellant, ammunitions A_3 and A_4 had IMR propellant. Table C4 exhibits the numbers of malfunctions of the various types and the total numbers of malfunctions for M-16 rifles (both types, R_1 and R_2, pooled) using ball propellant (A_1 and A_2 pooled) and IMR propellant (A_3 and A_4 pooled).

Table C4. M-16 RIFLES

Category of Malfunction	Type of Propellant	
	Ball	IMR
I	827	2,131
II	189	441
III	48	45
All Types	1,064	2,617
Rounds Fired	544,271	543,864

The numbers of malfunctions experienced with the IMR propellant was strikingly higher than with the ball propellant. A statistical test (the t-test) involving a comparison of the total malfunctions in each of the 24 separate firing periods, with both ball and IMR ammunitions separately, showed that if both rates were really the same so large a difference could have occurred by chance less frequently than once in 100,000 comparisons. The difference is therefore judged to be real.

The same conclusion can be reached by the other method from a tabulation (Table C5) of the numbers of instances in which i malfunctions were experienced in a firing period. A chi-square test applied to the rows, with pooling of all i's greater than 11 (rendering the test relatively insensitive to IMR "stragglers" evident in Table C5) again showed that if the malfunction rates, for the ball and IMR ammunitions, were

Table C5. NUMBER OF INSTANCES IN WHICH INDIVIDUAL M-16 RIFLES EXPERIENCED *i* MALFUNCTIONS IN A FIRING PERIOD

Propellant	i=0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	19	20	22	23	31
Ball	1721	368	111	48	24	10	8	5	1	4	2	0	0	0	0	1	0	0	0	1	0	0
IMR	1338	400	229	121	74	47	28	16	13	10	6	3	7	2	3	1	1	1	1	1	1	1

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inherently the same then the probability would be less than one in 100,000 that random samples would differ from each other by as much as, or more than, the two rows in Table C5. Both tests thus very strongly suggest that the malfunction rates of M-16 rifles, firing ammunition with ball and IMR propellants, are inherently different.

The total malfunction rates inferred from the data in Table C4, with the 95 percent confidence limits inferred from the dispersion of the results in the 24 separate firing periods, are

M-16 with ball propellant 1.95 ± 0.20 per thousand
M-16 with IMR propellant 4.81 ± 0.89 per thousand

The malfunction rate of the M-16 rifles using ball propellant is considerably lower than the gross M-16 malfunction rate pooled over ball and IMR ammunition, and approaches the M-14 rate previously determined. A comparison is shown in Table C6.

Table C6. MALFUNCTIONS PER THOUSAND ROUNDS FIRED

Category of Malfunction	Type of Rifle	
	M-16 Using Ball Propellant	M-14
I	1.52 ± 0.16	1.15 ± 0.11
II	0.34 ± 0.08	0.23 ± 0.06
III	0.09 ± 0.04	0.02 ± 0.01
All Types	1.95 ± 0.20	1.40 ± 0.15

Table C7. NUMBER OF INSTANCES IN WHICH INDIVIDUAL M-16 RIFLES, WITH BALL PROPELLANT, AND M-14 RIFLES EXPERIENCED i MALFUNCTIONS IN A FIRING PERIOD

Rifle	i=0	1	2	3	4	5	6	7 or more
M-16, Ball Propellant	1721	368	111	48	24	10	8	14
M-14	1796	358	97	24	17	4	5	3

The M-16 malfunction rate with ball propellant is higher, however, than the M-14 malfunction rate by an amount 0.55 malfunctions per thousand which, although small, appears to be statistically significant, beyond the 0.0004 level, by the t-test. This is confirmed by the chi-square test, applied to the values in Table C7.

If the malfunction rates of the M-16 rifle with ball propellant and of the M-14 rifle were inherently the same, then the probability would be about one in one thousand that the frequencies in the two rows would have differed from each other by at least as much as they do. It is concluded that the M-16 rifles employed in the test, when firing ammunition with ball propellant, had malfunction rates that were inherently higher than those of the M-14 rifles.

Figure C5 presents cumulative distribution curves showing the percentage of all test rifles of a given type that sustained individually at most a given number N of malfunctions throughout the entire test. It is evident from the figure that most of the "stragglers," or rifles having an unusually large number of malfunctions, belong to the M-16 IMR class. For example, from Figure C5, none of the M-14 test rifles nor the M-16 rifles firing ball propellant ammunition sustained in excess of 50 malfunctions of all categories throughout the entire test. In contrast, about 14 percent of the M-16 rifles

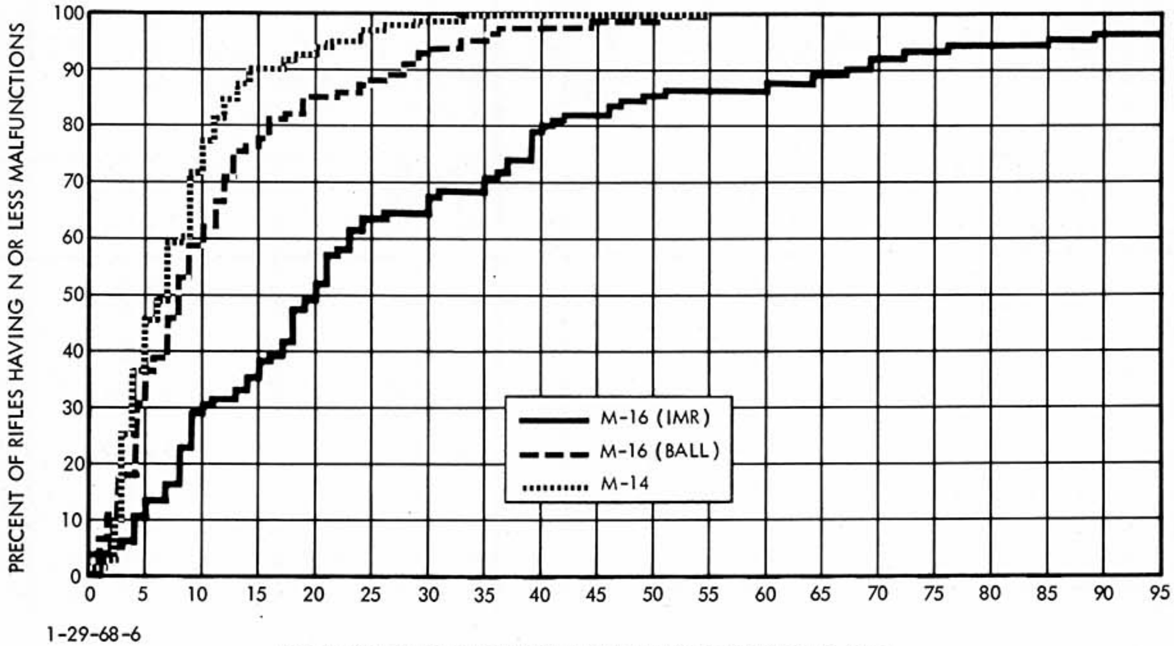

FIGURE C5. Distribution of Malfunctions Among Individual Rifles

firing IMR propellant had in excess of 50 malfunctions in the test.

The values cited previously for gross malfunction rates as well as those applying to the M-16 rifle using either IMR or ball propellant ammunition were evaluated simply by taking the ratio of the total number of malfunctions to the total number of rounds fired. It is conceivable that a relatively small number of rifles with many malfunctions could have a much greater effect on these rates than a large number of rifles with few or no malfunctions. One method for examining the effect on the malfunction rates of such "stragglers" is to set an arbitrary limit on the maximum number (N) of malfunctions that will be accepted from any rifle in one firing period. Table C8 shows the effect of this procedure on the malfunction rates of the M-16 (with ball propellant, with IMR propellant, and the overall combination of both propellants) and of the M-14 rifle systems.

Table C8. MALFUNCTION RATES PER THOUSAND ROUNDS AS A FUNCTION OF N, THE LIMITING NUMBER OF MALFUNCTIONS FOR ANY RIFLE IN ONE FIRING PERIOD

N	Ball	M-16 IMR	Ball and IMR	M-14
4	1.760	3.834	2.797	1.356
6	1.859	4.269	3.064	1.393
8	1.902	4.486	3.194	1.400
10	1.924	4.608	3.265	1.402
12	1.931	4.683	3.307	1.402
∞	1.955	4.812	3.383	1.402

In this table the variable N is the maximum number of malfunctions counted for a rifle in a firing period, and under this hypothetical test policy any rifle sustaining more than N malfunctions in a period would be removed from the firing line and replaced. It is seen from the table that even for a value of N as low as 4 (i.e., an average of 1 malfunction in about 60 rounds) none of the previously presented rates change by more than 21 percent. Thus, the effect of "stragglers" on the malfunction rate is relatively minor.

The variation of malfunction rate with elapsed time or firing period throughout the test is shown in Figure C6 for the M-16 rifle using both ball and IMR propellant ammunition and for the M-14 rifle. Each plotted point corresponds to the total number of malfunctions of all three categories sustained during the indicated firing period divided by the corresponding number of rounds fired in that period. In the figure, the plotted points have been connected by straight line segments only for ease of reading and following time trends; the basic process is, of course, discrete with only a single value of malfunction rate for each firing period. Since very little (1.4 percent) of the total test data were derived from substitute rifles, and

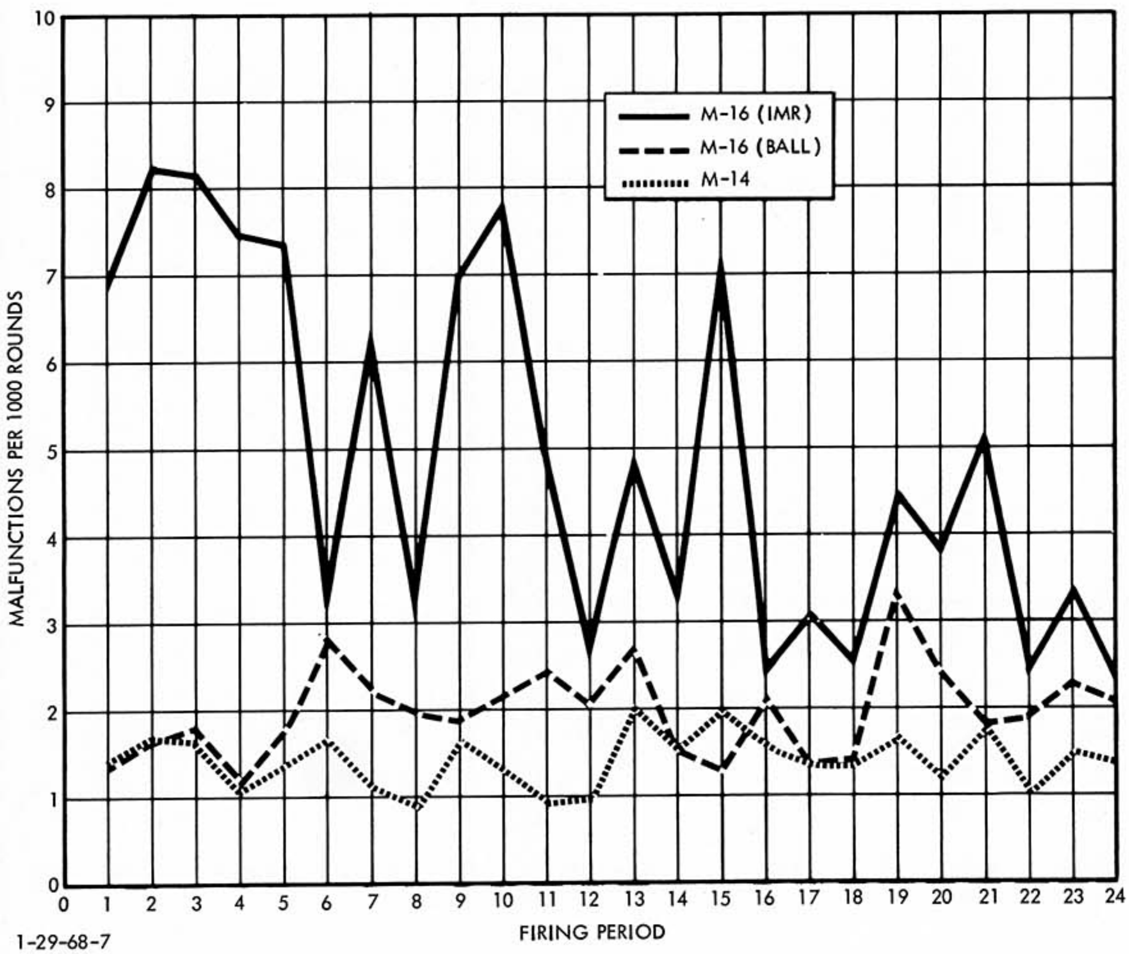

FIGURE C6. Average Malfunction Rates for All Environments by Firing Period

further since each test rifle fired very nearly 240 rounds per firing period, the horizontal scale in Figure C6 can be regarded as being nearly proportional to number of rounds fired.

Several features pertaining to test rifle system reliability performance are evident from an inspection of Figure C6:

- The malfunction rate of the M-14 rifle appears to exhibit the greatest stability with no discernible upward or downward time trend. In addition, its fluctuation (variance) about the mean performance is smaller than that of either of the indicated M-16 curves.
- The variation with time of the malfunction rate of the M-16 rifle employing ball propellant ammunition appears

to be comparable to that of the M-14 rifle. However, the M-16 rate appears to exhibit a slightly increasing rate with time. In addition, its fluctuation (variance) is slightly greater than that of the M-14.

- The variation with time (or rounds fired) of the malfunction rate of the M-16 rifle employing IMR propellant ammunition is characterized by large fluctuations about the mean performance. In addition the mean rate shows a decreasing trend as the rifles age.

Some of the peaks shown on the M-16 IMR curve in Figure C6 have been correlated with environmental conditions at certain of the test sites and will be discussed later in Section D, Malfunction Rates as Dependent on Environment.

The higher malfunction rate with the IMR propellant can possibly be understood in terms of a lower impulse, imparted to the M-16's actuating mechanisms, by IMR than by ball propellant.

The smaller operating impulse with IMR propellant should be expected to render the M-16 rifles more sensitive, when firing that propellant than when firing ball propellant, to influences of dust, dirt, and fouling that tend to increase frictional forces, particularly in rifles in which clearances (through slight manufacturing variations) may be unusually tight.

Malfunction Rates of M-16 Rifles as Dependent on Chrome Plating and Propellant

The R_1 and R_2 rifles experienced the following numbers of malfunctions of all types when firing ball and IMR propellants:

	Ball	IMR
R_1	582	1198
R_2	482	1419

The malfunction rates per thousand rounds were

	Ball	IMR
R_1	2.14	4.40
R_2	1.77	5.22

The differences, although small, between the malfunction rates of rifles R_1 and R_2 with each propellant turned out to be of strongly suggested statistical significance when the separate differences in the 24 firing periods were examined by the t-test. If R_1 and R_2 had had the same intrinsic malfunction rates with ball propellant, the probability that so large a difference would have arisen in the test by chance would have been only 0.014. With IMR propellant the probability would have been only 0.013. It is concluded that the population value of the malfunction rate of the R_1 rifles exceed that of the R_2 rifles with ball propellant, and is less than that of the R_2 rifles with IMR propellant. These conclusions will be further discussed in Section I.

It was noted that the preceding differences between the performances of the R_1 and R_2 rifles arose almost entirely from their behavior during firing periods 1 through 12, and that the differences were considerably smaller in firing periods 13 through 24. In firing periods 1 through 12 the rates were

	Ball	IMR
R_1	2.29	5.25
R_2	1.57	6.54

while in periods 13 through 24 they were

	Ball	IMR
R_1	1.99	3.56
R_2	1.97	3.90

With equal inherent rates during periods 1 through 12, with ball propellant, the chance probability was 0.005 and with IMR propellant 0.028. Thus, the differences are of strongly suggested statistical significance. However, during firing periods 13 through 24 the chance probabilities were 0.88 with ball propellant and 0.27 with IMR propellant. Hence, there is no evidence that the effects present during the earlier firing periods continued to exist through the later ones.

Malfunction Rates of the M-16 Rifles as Dependent on Manufacturing Lots

Ammunitions A_1 and A_2 both employed ball propellant, but the former involved cartridges made by Remington Arms while the latter involved cartridges made by Lake City. Similarly, A_3 and A_4 both employed IMR propellant, but the former involved cartridges made by Twin Cities while the latter involved cartridges made by Lake City. The test data were examined for possible differences between the malfunction rates of rifles firing A_1 and A_2 ammunition, and between the rates of rifles firing A_3 and A_4. The numbers of malfunctions are shown in Table C9, classified according to the four ammunition types A_1, A_2, A_3, and A_4. Interest will concentrate upon comparisons of A_1 with A_2 and A_3 with A_4, since it has already been established that the malfunction rate is highly dependent upon whether ball or IMR propellant is used.

Table C9

Category of Malfunction	Ball Propellant		IMR Propellant	
	A_1	A_2	A_3	A_4
I	485	342	1,037	1,094
II	87	102	198	243
III	27	21	20	25
All	599	465	1,255	1,362
Rounds Fired	272,049	272,222	272,019	271,845

The numbers of malfunctions, as expected, are considerably lower in the ball propellant class than in the IMR propellant class; within such classes, the differences are seen to be small compared to the differences between the propellant classes. The difference of 134 rounds between the A_1 and A_2 malfunctions has been tested for significance by the t-test applied to the 24 differences, in the separate firing periods, between the numbers of malfunctions of rifles firing the A_1 and A_2 ammunitions. If the inherent malfunction rates with both ammunitions were the same, the probability that so large a difference as 134 or a larger one would be obtained is 0.037. There is thus some evidence that the malfunction rates inherently differ. A study was also made of the malfunctions experienced separately by each of the 48 rifles firing each type of ammunition in each of the 24 firing periods. A comparison was made of the number of instances in which, with each ammunition, individual rifles experienced i malfunctions in a period. The numbers of instances shown in Table C10 occurred:

Table C10. NUMBER OF INSTANCES IN WHICH INDIVIDUAL M-16 RIFLES EXPERIENCED i MALFUNCTIONS IN A FIRING PERIOD

Ammunition	i=0	1	2	3	4	5	6 or more
A_1	842	187	60	30	13	6	14
A_2	879	181	51	18	11	4	8

If the failure rates of both ammunitions were inherently the same, the probability that the two rows of the table would differ from each other by at least as much as they do is 24 percent by the chi-square test. This test is less affected by "stragglers" than the t-test. On the whole, it is concluded that the M-16 test provides weak evidence that the malfunction rates with A_1 and A_2 ammunition inherently differ.

The number of malfunctions with ammunition A_3 differs by 107 from the number of malfunctions with ammunition A_4. A test of significance using the corresponding differences during the 24 separate firing periods indicated that differences as large as 107 or larger would occur by chance in 26 percent of such comparisons even with inherently equal malfunction rates for the A_3 and A_4 ammunitions.

A chi-square comparison of the number of instances in which M-16 rifles experienced i malfunctions, individually, in a firing period indicated that were the malfunction rates with IMR ammunitions A_3 and A_4 the same, differences as large as those observed between ammunitions would occur in 10 percent of such comparisons. No evidence has thus been obtained of differences between the inherent malfunction rates of M-16 rifles firing ammunitions A_3 and A_4.

D. MALFUNCTION RATES AS DEPENDENT ON ENVIRONMENT

In Table C11 are shown the numbers of malfunctions of the various types (and the total numbers) of M-16 rifles and M-14 rifles in each of the four environments E_1 (beach), E_2 (swamp), E_3 (rain forest) and E_4 (upland).

Table C11

Category of Malfunction	M-16 Rifles				M-14 Rifles			
	E_1	E_2	E_3	E_4	E_1	E_2	E_3	E_4
I	1,190	692	501	575	203	127	133	165
II	322	130	79	99	60	23	14	28
III	29	26	17	21	1	0	4	7
All	1,541	848	597	695	264	150	151	200
Rounds Fired	271,517	272,155	272,147	272,316	136,512	136,512	136,463	136,222

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The same data are also presented in Table C12 in the form of rates of malfunction per thousand rounds fired. Confidence limits have not been calculated, since the environmental effects were included in the test largely to simulate combat conditions in a generally representative manner, and to obtain rough indications, only, of the magnitude of the effects. Within any single environmental condition, such as a beach landing, the precise results obtained on any particular occasion must be dependent on conditions of surf, sand or rock, wind, etc., to such an extent that a confidence interval would have little meaning.

The high malfunction rates with the M-16 rifles in Tables C11 and C12 are a consequence of the high rates indicated in

Table C12. MALFUNCTIONS PER THOUSAND ROUNDS FIRED

Category of Malfunction	M-16 Environment				M-14 Environment			
	E_1	E_2	E_3	E_4	E_1	E_2	E_3	E_4
I	4.38	2.54	1.84	2.11	1.48	0.93	0.97	1.21
II	1.19	0.48	0.29	0.36	0.44	0.17	0.10	0.21
III	0.11	0.10	0.06	0.08	0.01	0.00	0.03	0.05
All	5.68	3.12	2.19	2.55	1.93	1.10	1.10	1.47

Table C1 and C3, involving malfunctions pooled over all conditions. The sums over environments of the malfunctions exhibited in Table C11 must clearly equal the malfunctions reported in Table C1. For the same reasons, the rates of malfunction of the M-16 rifle firing ball propellant in the various environments must be lower than those exhibited in Tables C11 and C12. The rates of malfunction (all categories) per thousand rounds of the M-16 rifles firing ball and IMR propellants are exhibited in Table C13.

Table C13. MALFUNCTIONS PER THOUSAND ROUNDS, M-16 RIFLES

Environment	Ball Propellant	IMR Propellant
E_1	3.00	8.37
E_2	1.64	4.59
E_3	1.40	2.98
E_4	1.78	3.32

Time Trends Within Environments

The effects of the different environments on malfunction rates varied during the test and differed among rifles and ammunitions. Figures C7 through C10 present malfunction rates as a function of elapsed time in each of the four environments for the M-16 with ball propellant, the M-16 with IMR propellant, and the M-14.

Malfunction rates of the M-16 with ball propellant and of the M-14 exhibited no substantial time trend in any

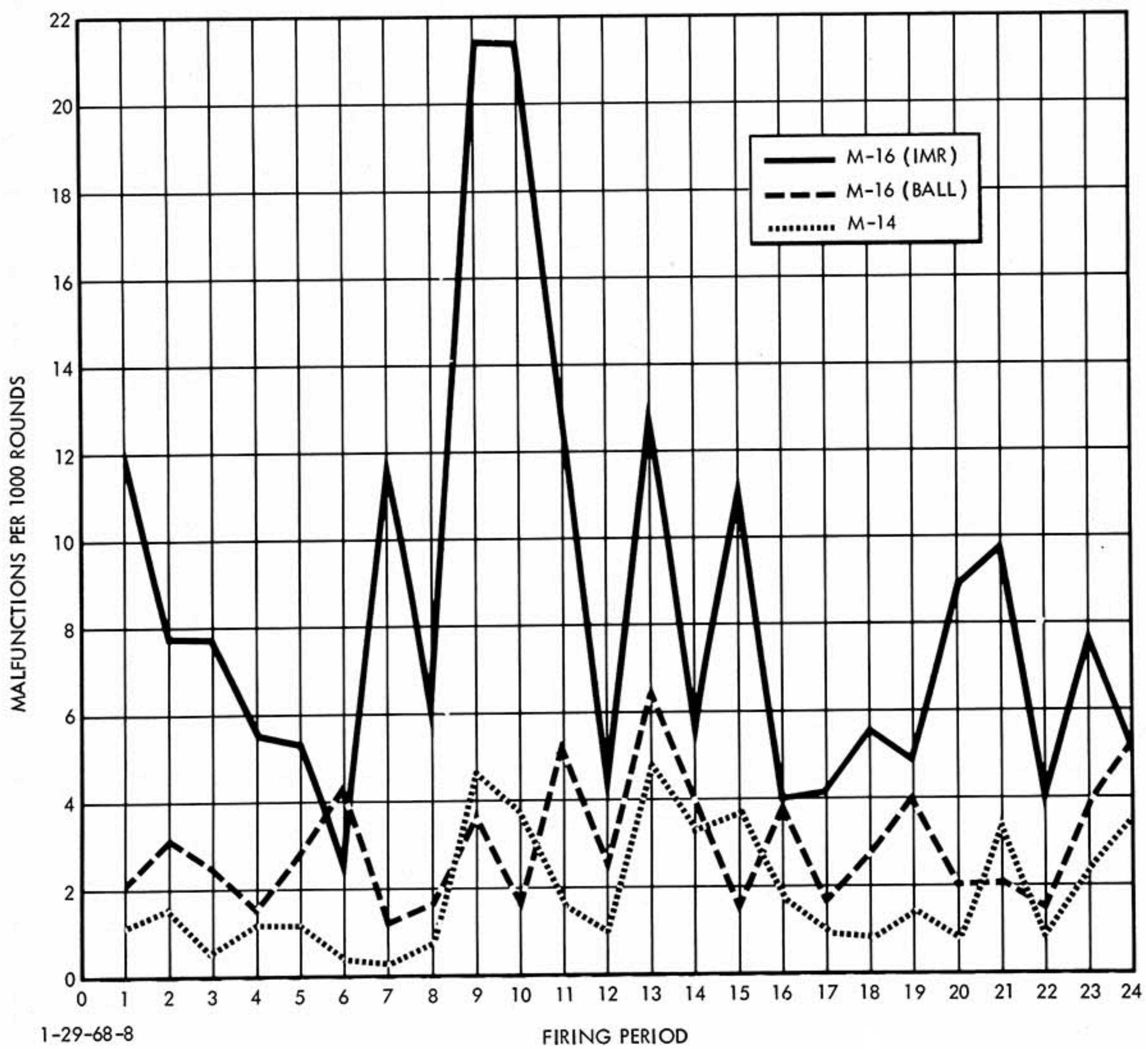

FIGURE C7. Malfunction Rates at Beach (E_1) by Firing Period

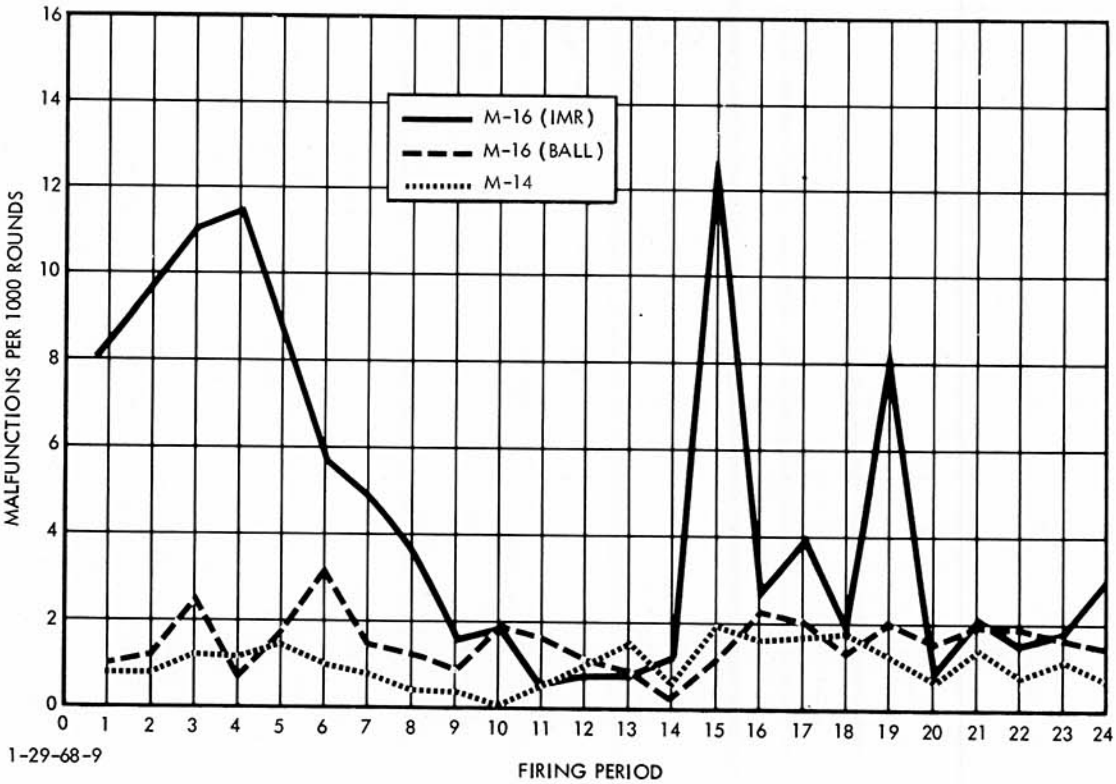

FIGURE C8. Malfunction Rates at Swamp (E_2) by Firing Period

environment and remained relatively stable throughout the test. A downward time trend in malfunction rates of the M-16 with IMR propellant was apparent in each environment although these rates remained highly variable throughout the test.

This variability was most pronounced at the beach, as evidenced in Figure C7, but was also present in the other environments. The occurrence of exceptionally high malfunction rates is correlated with the presence of inclement weather conditions. At the beach, for example, rain and choppy seas were present during firing period 9 and heavy rains occurred during period 10. A heavy salt spray was observed during period 13. At the swamp (Figure C8), fifteen-minute rains occurred during periods 15 and 19, both of which exhibited unusually high malfunction rates for the M-16 with IMR propellant.

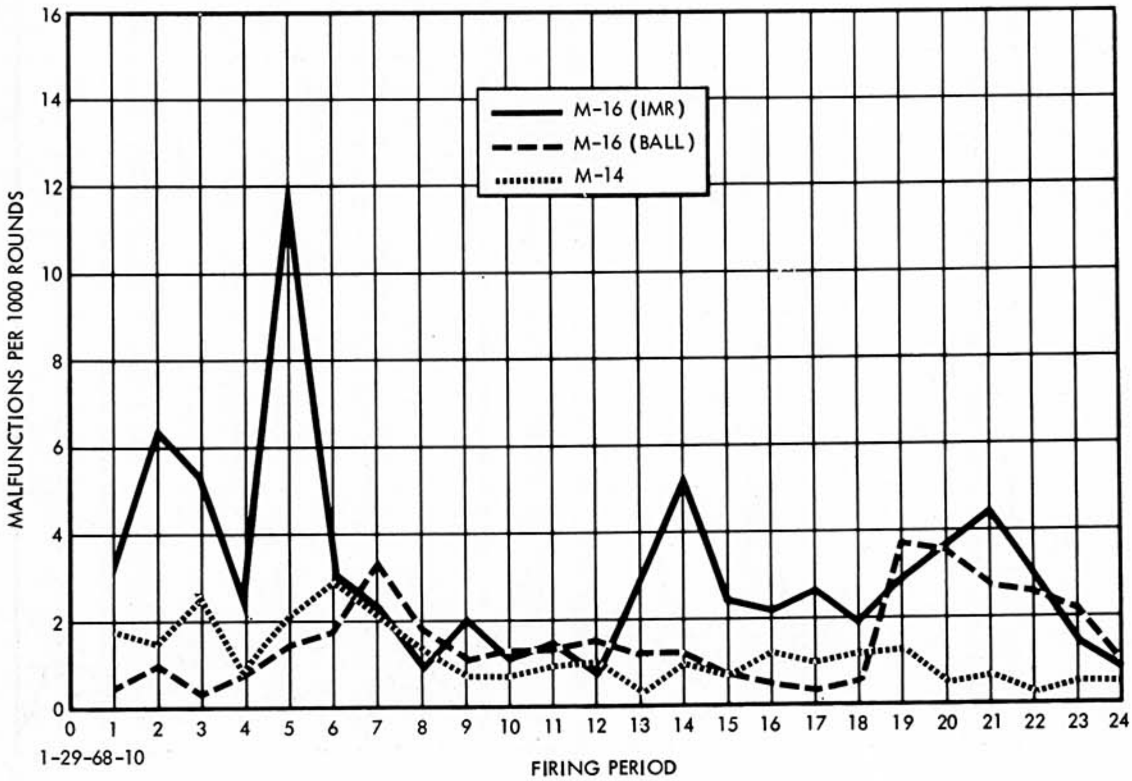

FIGURE C9. Malfunction Rates at Rain Forest (E_3) by Firing Period

The high rates sometimes observed during the first firing period of each test phase (periods 1, 7, 13, and 19) might be partially accounted for by the fact it was during these periods that the riflemen first encountered a new environment and may not have known all the techniques for protecting their rifles during the exposure period.

Certainly not all of the variations observed can be explained in terms of inclement weather and intense exposure. Nevertheless, two important factors are evident in the data. Firstly, the performance of the M-16 with IMR propellant appears to be sensitive to environmental conditions. Secondly, the performances of the M-16 with ball propellant and of the M-14 appear to be much less affected by these same conditions.

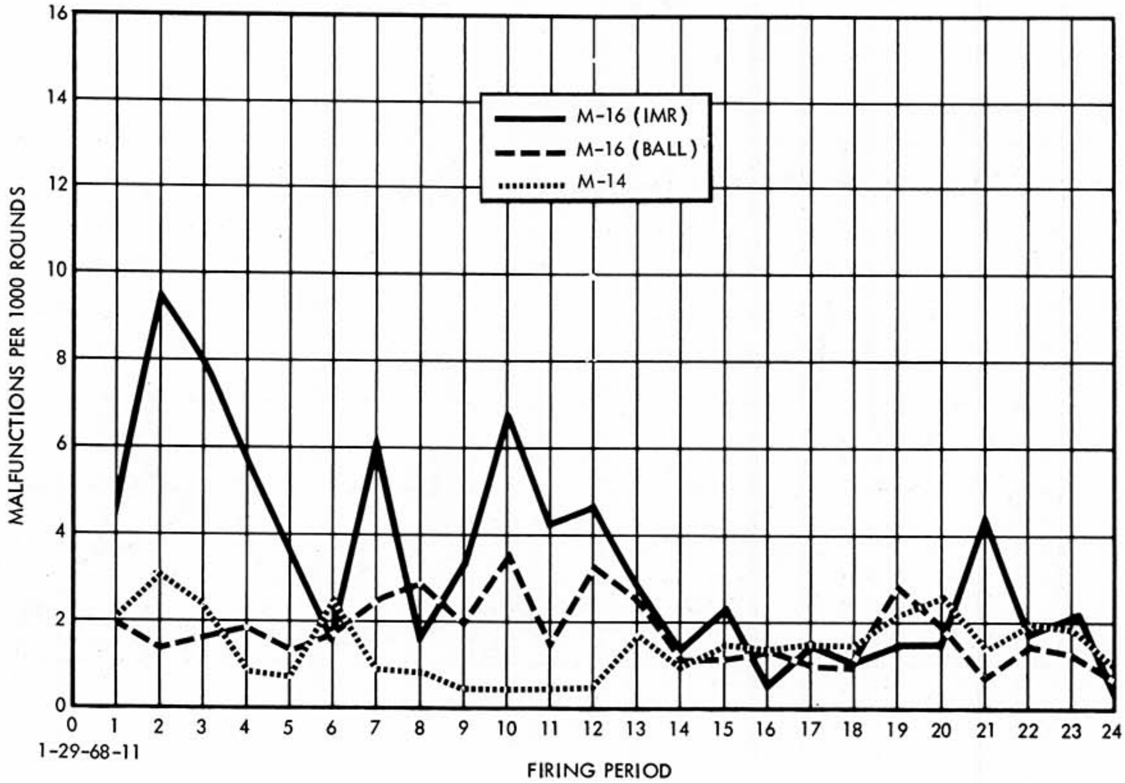

FIGURE C10. Malfunction Rates in Uplands (E_4) by Firing Period

E. EFFECTS OF CLEANING SCHEDULES

In Table C14 are shown the malfunctions experienced by M-16 and M-14 rifles subjected to cleaning schedules C_1 and C_2. The t-test, applied to the total numbers of malfunctions of M-16 rifles in each of the 24 firing periods, suggests although not very strongly that the number of malfunctions of rifles cleaned according to cleaning schedule 2 exceeds the number with cleaning schedule 1. With inherently equal rates of malfunction, differences as large as, or larger than, those observed would have been obtained in 2.5 percent of such comparisons. However, a more detailed examination by the chi-squared method, of the number of instances in which individual rifles experienced i malfunctions in a firing period, showed that cleaning schedule 1 yielded significantly fewer malfunc-

Table C14

Rifles	M-16		M-14	
Cleaning Schedules	1	2	1	2
Category of Malfunction				
I	1,422	1,536	353	275
II	263	367	62	63
III	38	55	6	6
All	1,723	1,958	421	344
Rounds Fired	543,717	544,418	272,734	272,975

malfunctions except among rifles that experienced five or more malfunctions in single firing periods -- in other words, schedule 1 yielded fewer malfunctions for all rifles that were not "stragglers" with unusually high numbers of malfunctions. These differences were of very strongly suggested statistical significance, and could have arisen by chance in fewer than about 0.0001 of such comparisons had the malfunction rates been inherently the same under both cleaning schedules.

There is thus good evidence that cleaning schedule 1 led to fewer malfunctions than schedule 2, among M-16 rifles.

The t-test applied to the M-14 rifles suggested although not very strongly that cleaning schedule 1 caused more malfunctions than schedule 2. With equal rates, differences as large as those observed or larger would have occurred in 2.2 percent of such comparisons. The chi-square test, however, applied to the number of instances of $\underline{i}$ malfunctions of a rifle in a firing period

Schedule	i=0	1	2	3	4 or more
1	874	196	53	14	15
2	922	162	44	10	14

disclosed no evidence for a difference. With inherently equal rates, the probability that the two rows would differ by at least as much as they do is 20 percent. On the whole, it is concluded that there is no good evidence from this test of a dependence of the M-14 malfunction rate upon cleaning schedule.

Effects of Cleaning Schedules and Chrome Plating

Among the M-16 rifles, the dependence of malfunction rate upon cleaning schedule has also been examined separately for rifle types R_1 and R_2 of which the former differs from the latter in having chrome-plated chambers. Among rifles R_1 the t-test, applied to the total numbers of malfunctions of R_1 rifles in each of the 24 firing periods does not suggest that the number of malfunctions of rifles cleaned according to cleaning schedule 1 differs from the number with cleaning schedule 2. With inherently equal malfunction rates, differences as large as, or larger than, those observed would have been obtained in 17 percent of such comparisons. A more detailed examination, by the chi-square method, of the number of instances in which individual R_1 rifles experienced $\underline{i}$ malfunctions in a firing period showed that cleaning schedule 1 yielded significantly fewer malfunctions among rifles that

Schedule	i=0	1	2	3	4	5	6	7-8	9 or more
1	795	166	79	28	24	14	15	17	14
2	769	192	83	52	22	16	7	3	8

experienced five or fewer malfunctions in a single firing period and significantly more malfunctions among rifles that experienced six or more malfunctions in a single firing period. These differences were of very strongly suggested statistical significance, and could have arisen by chance in fewer than about 0.002 of such comparisons had the two rows of the table been random samples from some single population. However, although there is thus very strong evidence for variations not attributable to chance, there is no good evidence that such variations depend upon cleaning schedule. It is thus concluded that there is no good evidence for a dependence of the malfunction rate of rifles R_1 upon cleaning schedule.

Among rifles R_2, the t-test suggests very strongly that the number of malfunctions of rifles cleaned according to cleaning schedule 2 exceeds the number with cleaning schedule 1. With inherently equal malfunction rates, differences as large as those observed or larger would have been obtained in fewer than 0.0001 of such comparisons. A more detailed examination, by the chi-square method, of the number of instances in which individual rifles R_2 experienced $\underline{i}$ malfunctions in a firing period showed that cleaning schedule 1 yielded systematically fewer malfunctions in the $\underline{i}$ classes. Had the malfunction rates been inherently the same,

Schedule	i=0	1	2	3	4	5	6-9	10 or more
1	811	185	69	36	20	13	11	7
2	684	225	109	53	32	14	22	13

differences as large as those observed or larger would have arisen by chance less often than once in 100,000 such comparisons. It is concluded that the malfunction rate of the rifles R_2 is inherently lower with cleaning schedule 1 than with cleaning schedule 2.

Cleaning schedule 1 involved full cleanings every 240 or 234 rounds, while cleaning schedule 2 involved full cleanings every 480 or 468 rounds. The preceding conclusions indicate that with steel chambers, not chrome-plated, the malfunction rate depends markedly upon the frequency of full cleanings. With the less frequent cleaning, the gross malfunction rate was 4.12 malfunctions of all categories per thousand rounds, while with the more frequent cleanings, the gross malfunction rate was 2.87 malfunctions of all categories per thousand rounds. Among rifles with chrome-plated chambers, the M-16 test was unable to establish that there was any real difference between the rates of malfunction with the two cleaning schedules, the combined rates being 3.27 per thousand rounds.

The dependence of malfunction rate upon cleaning schedule has also been examined separately among rifles R_1 employing ball propellant and employing IMR propellant, and among rifles R_2 employing ball propellant and employing IMR propellant. This more detailed examination on the basis of type of propellant provided no new information, nor any reasons for modifying the earlier conclusions as to the effects of chrome-plating and cleaning schedules upon malfunction rate. Among R_1 rifles firing either ball propellant or IMR propellant, considered separately, the t-tests indicated no significant dependence of malfunction rate on cleaning schedule. The probabilities of obtaining greater differences by chance were 20 percent and 29 percent, respectively, in the two cases. The chi-square tests furnished corresponding probabilities of 10 percent in both cases, but in neither case did the i table show that even such small differences, as there were, depended systematically upon cleaning schedule. Among R_2 rifles firing either ball propellant or IMR propellant, considered separately, the t-tests in each case suggested very strongly (0.0003 and 0.0006, respectively) that the malfunction rates were inherently greater under cleaning schedule 2 than under cleaning schedule 1. The chi-square tests furnished similar conclusions, the chance probabilities being 0.0008 and 0.002, respectively, and both i tables showing a systematic dependence, throughout, upon cleaning schedule.

F. EFFECTS OF MAGAZINE LOAD

In Table C15 are shown the malfunctions experienced by M-16 and M-14 rifles firing magazines loaded with 18 (L_1) and 20 (L_2) rounds:

Table C15

Category of Malfunction	Rounds per Magazine			
	M-16		M-14	
	18	20	18	20
I	1,520	1,438	280	348
II	354	276	64	61
III	62	31	7	5
All	1,936	1,745	351	414
Rounds Fired	536,938	551,197	269,264	276,445

The 20-round magazines yielded 191 fewer malfunctions in the M-16 rifles than did the 18-round magazines. A t-test of the 24 differences during the 24 separate firing periods indicated that with inherently equal malfunction rates for both loadings, differences as large or larger would occur by chance in 41 percent of such comparisons. A comparison by the chi-square method of the number of instances in which individual rifles with the two loadings experienced <u>i</u> malfunctions in a firing period indicated that with inherently equal rates for both loadings, differences as large as those observed or larger could occur by chance in only about 0.1 percent of such comparisons. However, there is some inconsistency in the pattern of differences; and although there is strong evidence for variations not attributable to chance, there is no good evidence that such variations depend on magazine loading. In the test design, effects of environment and aging tend to mask those of loading. The validity of the evidence for a dependence of malfunction rate, among the M-16 rifles, upon the number of rounds in a magazine is on the whole doubted.

Among M-14 rifles, a t-test of the 24 differences during the 24 separate firing periods indicated that if the inherent malfunction rates with both loadings were the same, differences as large as those observed or larger would occur by chance in 21 percent of such comparisons. A chi-square comparison of the numbers of instances in which individual rifles with the two loadings experienced $\underline{i}$ malfunctions in a firing period indicated that if the malfunction rates were inherently the same with both loadings, differences as large as those observed or larger could occur by chance in fewer than 4.5 percent of such comparisons. There is thus some evidence that M-14 rifles experience more malfunctions with 20-round magazine loads than with 18-round magazine loads, but its validity is doubted for reasons given in connection with the M-16.

Effects of Propellant Type and Magazine Loading

Among the M-16 rifles, the dependence of malfunction rate upon magazine loading has also been examined separately within propellant types ball and IMR. The t-test suggested, but very weakly, that with ball propellant there were more malfunctions with 18-round magazine loadings. With inherently equal rates, the observed differences or larger ones would have occurred by chance with a probability of 10 percent. The chi-square test, applied to an $\underline{i}$ table, indicated that differences as large as those between its rows, or larger, would have occurred by chance in 29 percent of such comparisons even if the malfunction rates were inherently the same. Thus there is no good evidence, from the M-16 test, for any dependence of malfunction rate upon magazine loading when ball propellant is used.

The t-test, applied to the numbers of malfunctions observed in separate firing periods, suggested no dependence of malfunction rate upon magazine loading when IMR propellant was used. With equal inherent rates of malfunction, the observed difference or a larger one between the numbers of malfunctions with the different loadings would have occurred by chance in 62 percent of such comparisons. The chi-square test, applied to an i table, indicated that differences as large as those between the cell-frequencies in its two rows, or larger differences, could have occurred by chance with a probability of only 0.0006 among such comparisons if both rows had been random samples from some single population. In the i table, however, there is inconsistency in the pattern of differences. There were more instances of malfunctions with the 18-round loading than with the 20-round loading among rifles with four or fewer malfunctions in a firing period, but there were fewer instances among rifles with five or more malfunctions in a firing period. However, although there is thus very strong evidence for variations not attributable to chance, there is no good evidence that such variations depend upon magazine loading. Although there is some evidence for a dependence of the malfunction rate of M-16 rifles, using IMR propellant, upon magazine loading its validity is on the whole doubted.

Loading	i=0	1	2	3	4	5	6-7	8-10	11 or more
1	623	211	132	78	44	22	21	12	9
2	715	189	97	43	30	25	23	17	13

As has been indicated earlier in this Report, the effects of environment and of aging tend to mask those of magazine loading because of the nature of the test design.

G. DEPENDENCE OF MALFUNCTION RATE UPON FIRING MODE

In Table C16 are shown the observed rates of malfunction of M-16 and M-14 rifles per thousand rounds when firing in the automatic and semiautomatic modes:

Table C16

Firing Mode	Rifle	
	M-16	M-14
Automatic	4.28	1.67
Semiautomatic	2.41	1.11

A t-test employing the 24 differences between the rates of malfunction of M-16 rifles in the two firing modes during individual firing periods indicates that if the rates of malfunction in the two modes were inherently equal then the observed difference, or a larger one, could have occurred by chance with a probability of less than one in a million. A similar test applied to the M-14 rifle indicates that with inherently equal rates in the two modes, the observed difference or a larger one could have occurred by chance with a probability of only 0.0009. It is concluded that both M-16 and M-14 rifles have intrinsically higher rates of malfunction when firing in their automatic, than when firing in their semiautomatic, modes.

In the case of the M-16 rifles, the rates of malfunction in the two modes have been further examined separately according to whether the rifles employ ball or IMR propellant. The comparison is shown in Table C17.

A t-test indicates that if the rates of malfunction of M-16 rifles firing ball propellant in the automatic and

Table C17

Firing Mode	M-16 Rifles	
	Firing Ball Propellant	Firing IMR Propellant
Automatic	2.11	6.45
Semiautomatic	1.79	3.04

semiautomatic modes were inherently equal, a difference as large as that observed or larger could have occurred by chance with a probability of only 0.025. This suggests that the difference, although small, is real. For M-16 rifles firing IMR propellant in the automatic and semiautomatic modes, the corresponding probability is less than one in one million suggesting very strongly that the difference is in this case real.

It is generally concluded that the M-14 and M-16 rifles have higher rates of malfunction when firing in their automatic than when firing in their semiautomatic modes regardless (in the case of the M-16) of whether the ammunition contains ball or IMR propellant.

H. PERFORMANCE OF NEW RIFLES

Before the start of the actual test, all rifles were new and subjected to a pretest firing period without environmental exposure. This was done both to simulate new-rifle staging area break-in as presently carried out in South Vietnam and to familiarize the riflemen, data collectors, armorers, and other personnel with the test procedures. It was not intended that any data obtained from this pretest would actually be used in the evaluation of the rifle systems, and indeed a combination of unexpected difficulties resulted in the loss of a large portion of the data. Nevertheless, fairly reliable results were obtained from platoons 2 and 4. These are shown graphically in Figures C11 through C14 in which the M-16 data for these two platoons for the pretest firing period are compared with those for the first firing period of the actual test (firing period 1).

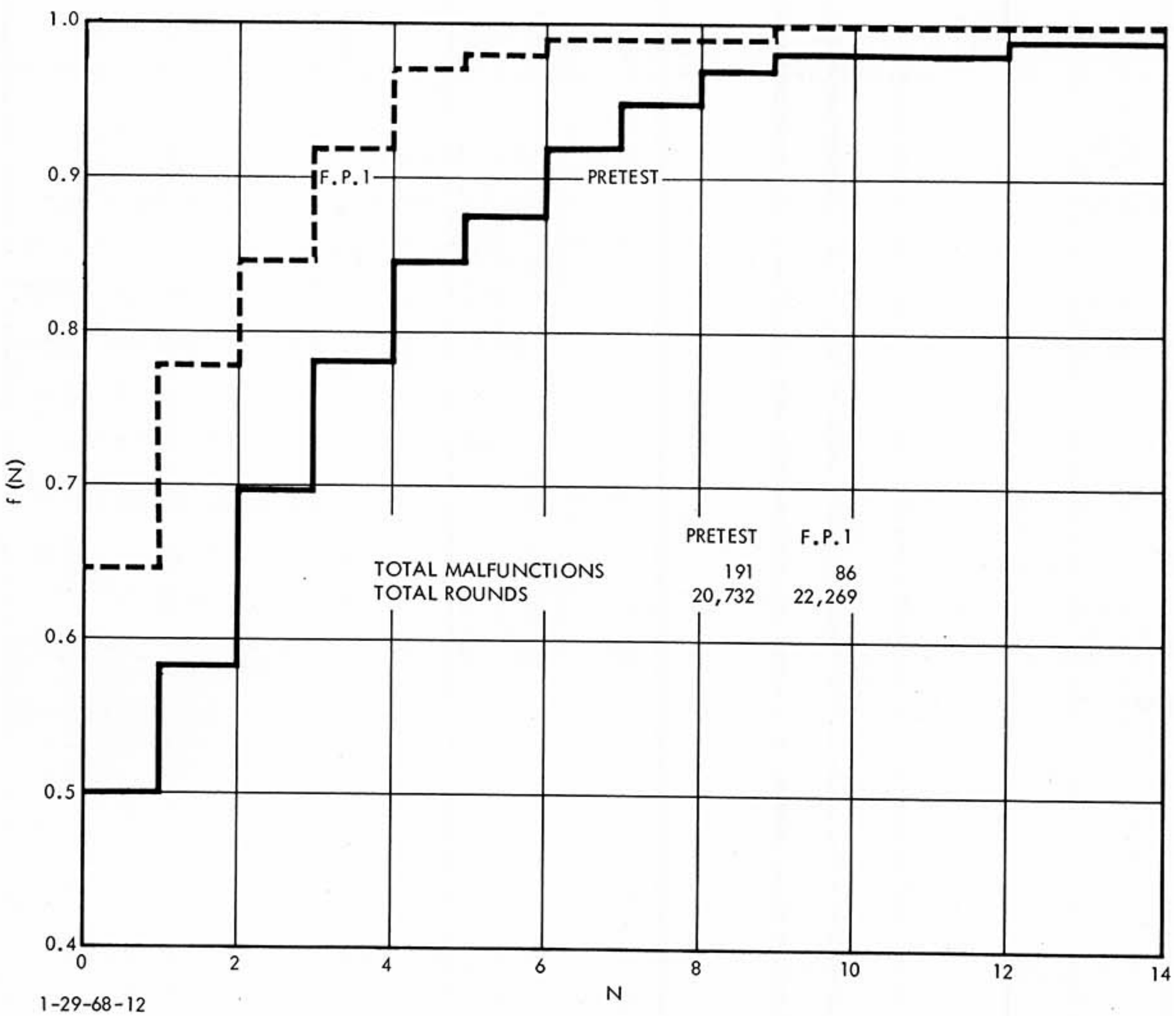

FIGURE C11. Fraction of Rifles With N Or Less Malfunctions
Platoons 2 and 4 - All M-16 Rifles

Figure C11 shows that the individual rifles tended to sustain more malfunctions in the pretest firing period than in

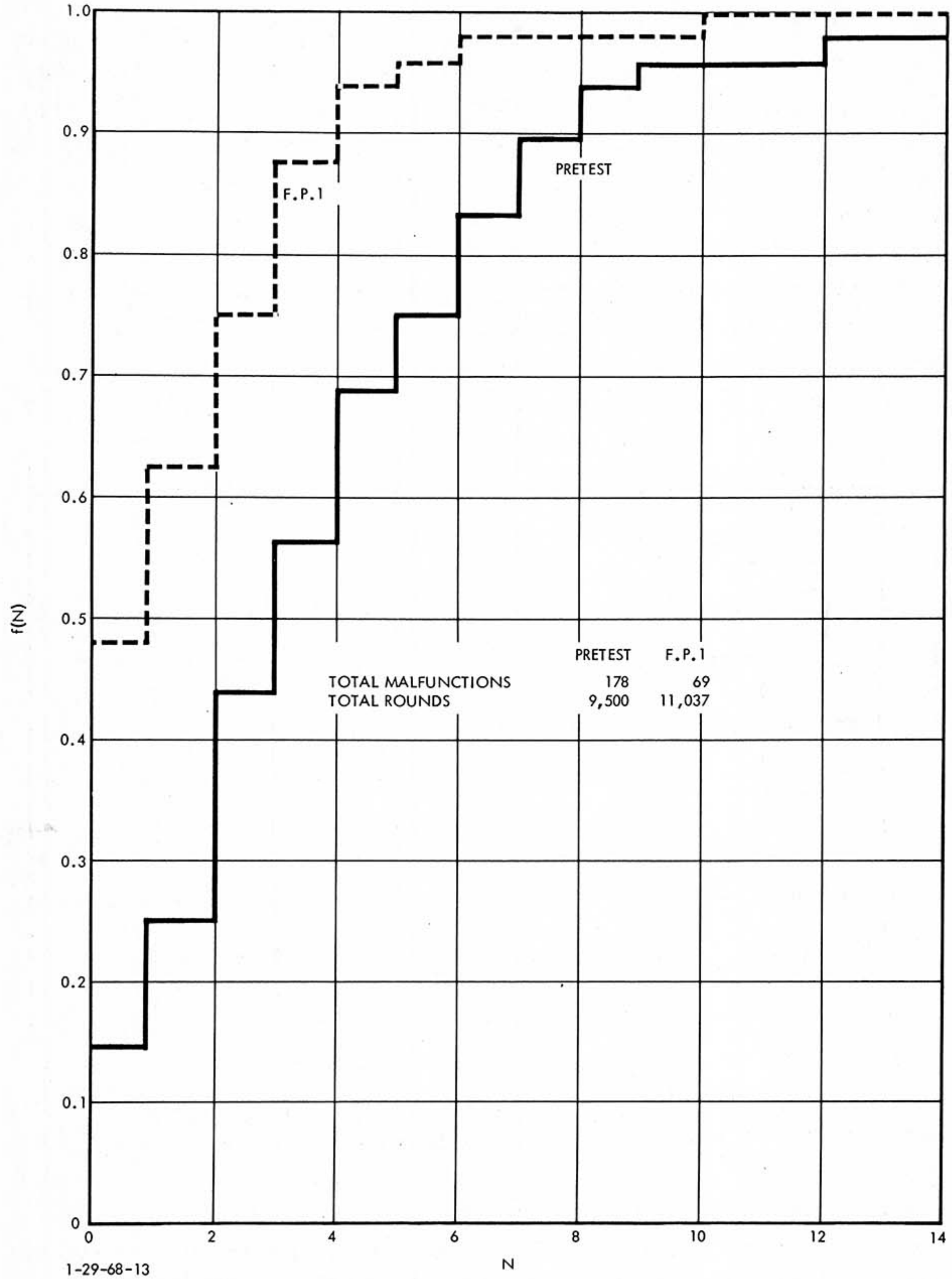

FIGURE C12. Fraction of M-16 Rifles With N Or Less Malfunctions
Platoons 2 and 4 - IMR Propellant

the first firing period of the test. The total number of malfunctions for the two platoons in firing period 1 in fact was only 86 while the number reported -- known to be less than the number which actually occurred -- for the pretest firing period was 191, over twice as large. Figures C12 and C13 show that this difference between the two periods was entirely due to a corresponding difference in performance of the rifles using IMR propellant. Indeed, the number of malfunctions occurring in the pretest and first firing periods with rifles using ball propellant -- 13 and 17, respectively -- was negligible. The corresponding numbers for the M-14 system were 25 and 16.

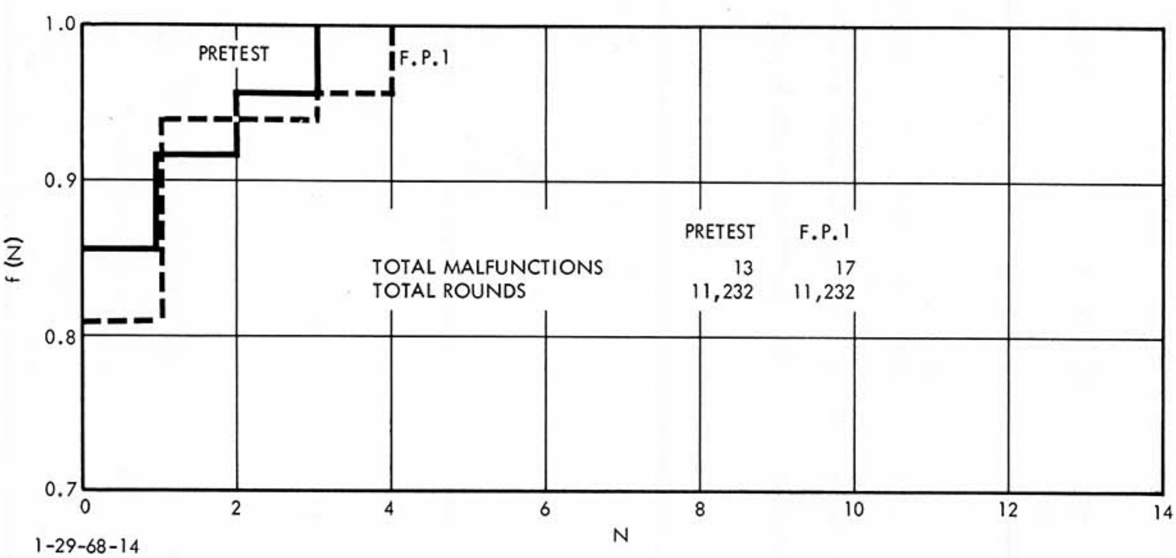

FIGURE C13. Fraction of M-16 Rifles with N Or less Malfunctions
Platoons 2 and 4 - Ball Propellant

In Figure C14 the dependence of malfunctions on magazine number is displayed. (In every period, firing commenced with magazine no. 1 and continued in order through magazine no. 13.) Two trends are quite evident from the graph. First, there was a marked tendency for malfunctions to occur during the early magazines, especially the first; and second, more malfunctions tended to occur with the automatic firing mode (the odd-numbered

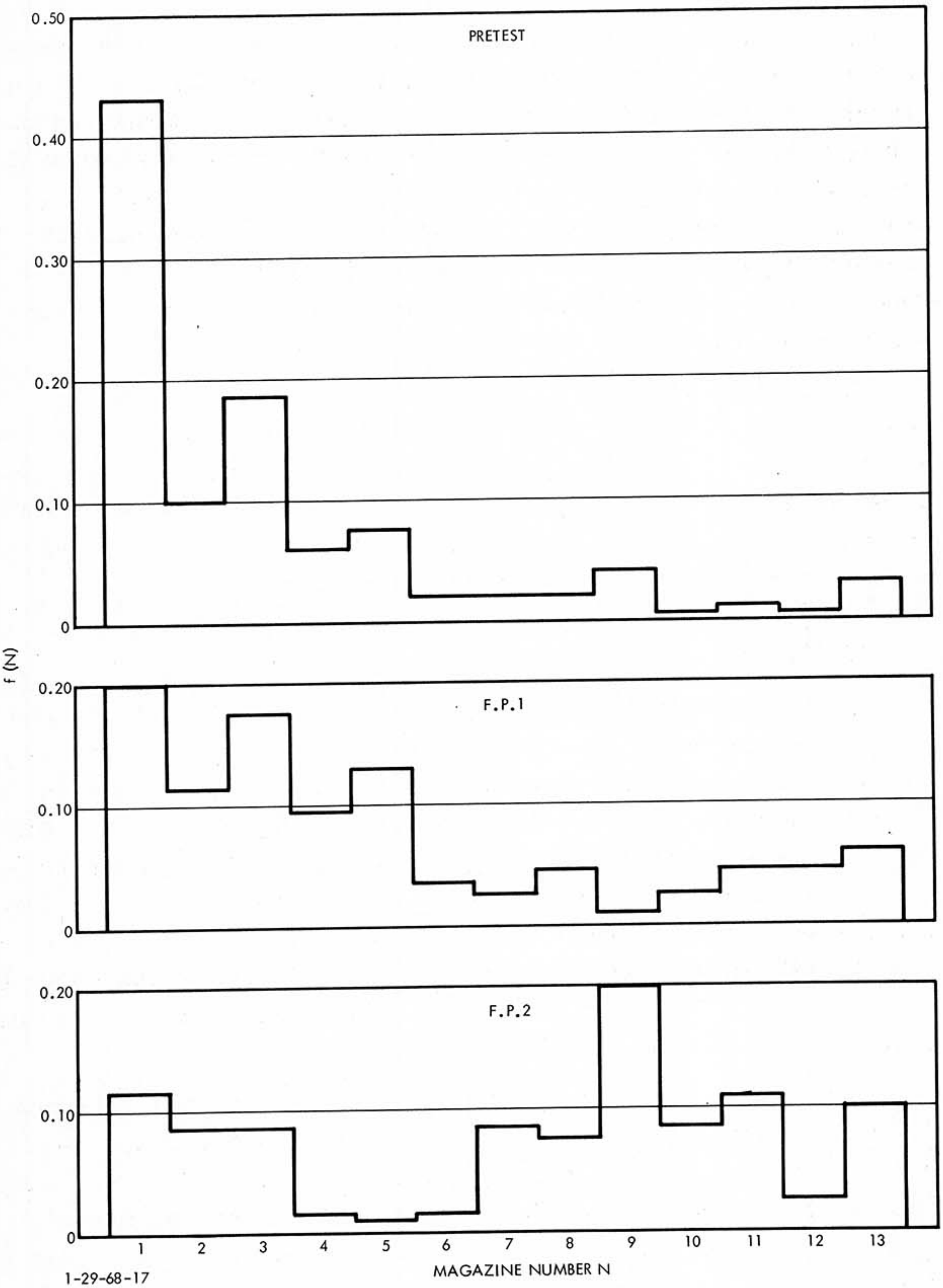

FIGURE C14. Fraction of Malfunctions Occurring on Magazine N
Platoons 2 and 4 - All M-16 Rifles

magazines) than with the semiautomatic firing mode (the even-numbered ones). These trends are seen to have continued to a lesser extent through firing period 1 and even somewhat through firing period 2. It should be noted that for firing period 2 the environmental exposure occurred just before magazine 8, whereas for firing period 1 it occurred just before magazine 1. Thus in each case the magazine associated with the most malfunctions was the first automatic-mode magazine after the environmental exposure.

Lest too much be read into these results, it should be emphasized that the data for the pretest firing period are incomplete. In particular it is known that a number of malfunctions which occurred during the late magazines were not recorded. Thus, any conclusions drawn from these results should be of a qualitative and not a quantitative nature.

I. THE FREQUENCIES OF MALFUNCTION TYPES

Each malfunction observed in the test was identified and classified by one of the platoon armorers into one of 24 natures of failure; for example: failure to feed, failure to chamber, failure to lock, failure to extract, etc. Table C18 ranks these natures of malfunction in the order of their frequency of occurrence for the M-16 rifle systems. The tabulated results represent averages accumulated over all test conditions and the percentages apply to the sum of all three categories of malfunctions. Table C19 gives a similar breakdown for the malfunctions sustained by the M-14 test rifles.

Comparison of Tables C18 and C19 shows that the observed dominant class of malfunction for both the M-16 and the M-14 rifle systems, when accumulated over all test conditions, was failure to feed; that is, failure to deliver the top magazine round in line with the face of the retracted bolt. The next most prevalent class of malfunction for both rifles was failure

Table C18. RANKING OF M-16 RIFLE SYSTEM MALFUNCTIONS BY FREQUENCY OF OCCURRENCE

(Total Malfunctions: 3,681; Total Rounds Fired: 1,088,135)

Nature of Malfunction	Percent of Total
Failure to feed	48.6
Failure to chamber	12.2
Failure of bolt to remain at rear after last round	10.6
Failure to eject	8.0
Failure to fire	7.2
Failure to extract	4.8
Failure to lock	3.2
Double feed	1.9
All others	3.5

Table C19. RANKING OF M-14 RIFLE SYSTEM MALFUNCTIONS BY FREQUENCY OF OCCURRENCE

(Total Malfunctions: 765; Total Rounds Fired: 545,709)

Nature of Malfunction	Percent of Total
Failure to feed	36.9
Failure to chamber	14.8
Failure to fire	13.5
Failure to lock	11.2
Failure to extract	11.1
Failure to unlock	2.5
Failure of magazine to lock in rifle	2.3
Failure to eject	2.1
Failure of bolt to remain at rear after last round	1.4
All others	4.2

to chamber; that is, given that a round is fed from the magazine, the failure to properly insert the round into the rifle chamber.

If for the M-16 rifle Category I and Category II malfunctions are each considered separately, the most prevalent type of malfunction remains failure to feed followed by failure to chamber. This order was also maintained for the Category I failures sustained by the M-14 rifle. However, the most prevalent class of Category II malfunction observed for the M-14 rifle was failure to eject (29.6 percent; i.e., failure to eject a spent cartridge from the rifle) followed by failure to feed (24.8 percent).

Tables C20 and C21 show a breakdown for the M-16 rifle of the distribution of failure modes in Table C18 into those that occurred with IMR propellant and those with ball propellant ammunition. It is evident from Tables C20 and C21 that the patterns of failure modes for the two propellants are strikingly different. With IMR propellant ammunition in the M-16 rifle, 62.7 percent of all observed malfunctions were attributed to failures to feed with essentially negligible (0.57 percent or 15 failures) observations of failures to eject. On the other hand, with the use of ball propellant ammunition the dominant observed mode of failure was failure to eject (26.3 percent or 280 failures) with failure to feed relegated to third place (14.1 percent).

The observed larger incidence of failures to feed in M-16 rifles using IMR propellant is consistent with the statement made in Section C relating to the response of the M-16 bolt-assembly mechanism to the two types of propellant. That is, if the gas-port impulse imparted to the bolt assembly is marginal in the case of IMR, then the correspondingly reduced backward travel of the bolt may be insufficient to permit the top round to be fed from the magazine. Further evidence

Table C20. RANKING OF M-16 RIFLE SYSTEM MALFUNCTIONS FOR IMR PROPELLANT AMMUNITION

(Total Malfunctions: 2,617; Total Rounds Fired: 543,864)

Nature of Malfunction	Percent of Total
Failure to feed	62.7
Failure to chamber	13.8
Failure of bolt to remain at rear after last round	13.1
Failure to fire	3.1
Failure to extract	2.0
Failure to lock	1.5
All others	3.8

Table C21. RANKING OF M-16 RIFLE SYSTEM MALFUNCTIONS FOR BALL PROPELLANT AMMUNITION

(Total Malfunctions: 1,064; Total Rounds Fired: 544,271)

Nature of Malfunction	Percent of Total
Failure to eject	26.3
Failure to fire	17.3
Failure to feed	14.1
Failure to extract	11.7
Failure to chamber	8.5
Failure to lock	7.3
Failure of bolt to remain at rear after last round	4.6
Double feed	4.2
Selector lever inoperative	1.8
All others	4.2

that the port-impulse is probably marginal with IMR propellant is provided by the higher incidence of failures of the bolt to remain at the rear after the last round with IMR (13.1 percent or 344 failures) than with ball propellant (3.6 percent or 49 failures).

It is believed that the explanation for the observed higher incidence of failures to eject for the M-16 rifle with ball propellant ammunition may also be due to the higher impulse imparted to the bolt by the ball propellant. That is, for a given stiffness of the ejector spring, the increased backward velocity component of the bolt at ejection causes the trajectory of the spent cartridge to make a smaller angle, with respect to the rearward extension of the longitudinal axis of the rifle, with ball propellant than with IMR. If this angle is sufficiently small, the spent cartridge would strike the rear edge of the ejector port, and might rebound back into the path of the returning bolt possibly to become lodged between the bolt and the rear of the upper receiver. This process is illustrated in Figure C15 for actual cases of M-16 rifles firing ball propellant during the test.

One of the purposes for adding the chrome-plated chamber to the M-16 rifle was to increase its resistance to chamber pitting, thereby reducing the incidence of failures to extract. A notion as to the efficacy of this rifle modification might therefore result from a comparison of the numbers of extraction failures sustained separately by the R_1 and R_2 test rifles. This comparison is set forth in Table C22. Application of the chi square test to Table C22 reveals that the increased number of extraction failures of the R_2 rifle over the R_1 is highly significant in a statistical sense. It therefore appears that the chrome-plated chamber of the R_1 rifle was effective in reducing extraction failures in the test.

FIGURE C15a. Spent Cartridge Reentering Upper Receiver After Rebounding from Rear Edge of Ejection Port

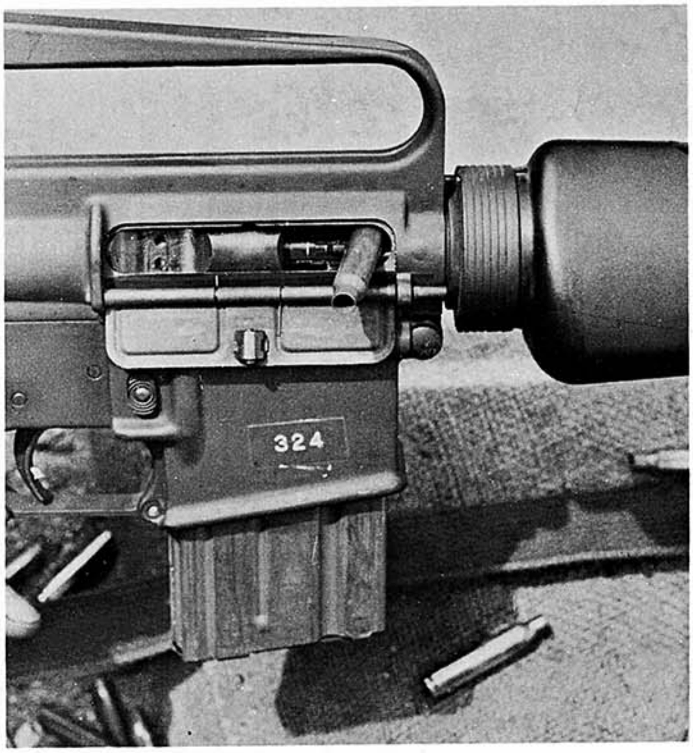

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FIGURE C15b. Spent Cartridge Lodged Between Face of Bolt and Rear of Barrel Extension

Table C22. INCIDENCE OF EXTRACTION FAILURES FOR M-16 TEST RIFLES

Rifle	Total Rounds Fired	Total Malfunctions of all Kinds	Number of Extraction Failures	Percent of Total Malfunctions
R_1	544,048	1780	53	3.0
R_2	544,087	1901	125	6.7

As mentioned in Section C, with IMR propellant the M-16 rifle R_1 (with the chrome-plated chamber) exhibited a significantly lower overall malfunction rate 4.40 per thousand) than the R_2 (nonchromed) rifle (5.22 per thousand). Tables C23 and C24 show the ranking of the observed malfunctions for these two rifles using IMR propellant ammunition. Comparison of the two tables shows that the relative distribution of failure modes is comparable for both rifles. Considering only the dominant mode of failure in each case, the tables show that for roughly the same number of rounds fired, the R_2 rifle sustained 177 more failures to feed than did R_1; however, this difference is not statistically significant. Application of the chi-square test shows that if the R_1 and R_2 rifles had inherently the same propensity for failures to feed, a difference at least as large as that observed would have occurred by chance in 12 percent of such comparisons.

In the case of using ball propellant in the R_1 and R_2 M-16 rifles, the reverse effect was observed from the test. That is, R_2 exhibited fewer (482) total malfunctions than did R_1 (582). In both cases the dominant mode of failure was failure to eject as it was for R_1 and R_2 combined (see Table C21). However, with roughly the same number of rounds fired, it was observed that R_1 (chromed chamber) sustained 194 failures

Table C23. RANKING OF R_1 (CHROME CHAMBER) M-16 RIFLE SYSTEM MALFUNCTIONS FOR IMR PROPELLANT AMMUNITION (Total Malfunctions: 1,198; Total Rounds Fired: 272,125)

Nature of Malfunction	No. of Failures	Percent of Total
Failure to feed	732	61.1
Failure to chamber	204	17.0
Failure of bolt to remain at rear after last round	166	13.9
Failure to fire	38	3.2
Selector lever inoperative	13	1.1
Failure to extract	10	0.8
Failure to lock	8	0.7
All others	27	2.2

Table C24. RANKING OF R_2 (NONCHROMED CHAMBER) M-16 RIFLE SYSTEM MALFUNCTIONS FOR IMR PROPELLANT AMMUNITION (Total Malfunctions: 1,419; Total Rounds Fired: 271,739)

Nature of Malfunction	No. of Failures	Percent of Total
Failure to feed	909	64.1
Failure of bolt to remain at rear after last round	178	12.5
Failure to chamber	156	11.0
Failure to fire	44	3.1
Failure to extract	43	3.0
Failure to lock	30	2.1
Double feed	18	1.3
All others	41	2.9

to eject while R_2 (nonchromed) sustained only 86. This result which is highly significant in a statistical sense is consistent with the expectation that the fraction force during extration for R_1 should be less than that for R_2. That is, the reduced friction during extraction for R_1 should result in increased bolt kinetic energy (i.e., rearward velocity) at ejection with an attendant increase in the likelihood that the spent cartridge will strike the rear edge of the ejection port.

J. MISCELLANEOUS RESULTS

The following miscellaneous observations derived from the analysis of the test may be of correlative interest in connection with rifle system reliability.

Distribution of Malfunctions by Magazine Round Numbers

For each malfunction that occurred, a record was made of whether it occurred on the first or second round fired from the magazine. Table C25 presents for different test conditions the percentages of malfunctions that occurred on the first and second rounds and the average percent for each remaining round in the magazine.

Table C25. PERCENT OF MALFUNCTIONS BY MAGAZINE ROUND NUMBER

	M-16		M-16		M-14	
	Ball Propellant		IMR Propellant			
Round	L_1	L_2	L_1	L_2	L_1	L_2
First	22.6	24.0	12.8	12.7	18.0	16.4
Second	13.4	13.7	27.0	24.8	28.2	23.2
Other[a]	4.0	3.5	3.8	3.5	3.8	3.4

[a] Average percent of malfunctions for each remaining round in mazagine (16 such rounds with L_1, 18 with L_2).

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1-2-18 T 1-6-11-16 T

The data provide no evidence that magazine loading has an effect on the distribution of malfunctions over magazine round number. The data do indicate that over a third of all malfunctions occurred on the first two magazine rounds for each combination of rifle type, propellant, and magazine loading.

Time Required to Clear Malfunctions

A record was made of the time used by each rifleman to clear each Category I and Category II malfunction in the test. Table C26 summarizes the resultant mean time interval required to clear each category of malfunction for each type of test rifle. It is known that many of the original time entries were estimates often recorded to the nearest five seconds. For this reason the differences shown in the tabulated results between the different rifle types are not considered to be significant.

Table C26. MEAN TIME REQUIRED TO CLEAR MALFUNCTIONS

Rifle Type	Category I Malfunction (sec)	Category II Malfunction (sec)
R_1	7.55	121
R_2	9.17	104
R_4	8.19	102

Time Required to Completely Clean a Test Rifle

Each rifleman participating in the main test completely cleaned and lubricated his rifle in accordance with one of the cleaning schedules C_1 or C_2 described previously. Records were kept by platoon and squadleaders of the time used by individual riflemen to carry out each of these periodic cleaning operations. The resultant mean cleaning times for each type of test rifle are summarized in Table C27.

Table C27. MEAN TIME REQUIRED FOR COMPLETELY CLEANING A TEST RIFLE

Rifle Type	Mean Time (minutes)
M-14	45.4
M-16	52.1

K. SUBTESTS

Three different subtests were carried out concurrently with the main test. These were the "extended cleaning cycle subtest," the "chambered round subtest," and the "night firing subtest." The first two of these were carried out separately from the main test, although the night firing subtest formed an integral part of it. Each of these three subtests was designed to investigate only gross effects and hence the small amount of data associated with them is insufficient to reveal more subtle differences between rifle classes.

Extended Cleaning Cycle Subtest

The nineteenth man of each squad used special firing and cleaning doctrines. Each such rifleman fired only 54 rounds per firing period (three magazines) although he used the same type of ammunition as the rest of the M-16 riflemen in his squad. Half of these nineteenth men used M-16 rifles with chrome-plated chambers and half used rifles without them. Within each of these two groups, half of the riflemen cleaned their weapons at three-day (six firing periods) intervals and half cleaned them at six-day (12 firing periods) intervals.

The malfunction rates for the weapons using ammunition with ball propellant and for those using ammunition with IMR propellant are presented in the tabulation below. They were evaluated in exactly the same manner as those for the rifles in the main test, and the values for the main test are also given.

	Ball	IMR
Extended Cleaning Cycle Subtest	4.34 ± 1.83	15.00 ± 4.38
Main Test	1.95 ± 0.20	4.81 ± 0.89

The malfunction rates observed in the nineteenth man subtest thus differ significantly at the 95 percent confidence level from those observed in the main test.

Comparisons using the chi square test yielded no significant difference between rifle types or cleaning schedules for weapons using ammunition with ball propellant. For weapons using ammunition with IMR propellant no significant difference within rifle type was observed but the weapons using the six-day cleaning interval performed significantly (at the 0.02 percent level) better than those using the three-day interval. It is believed that this was due to effects resulting from variability of environment rather than difference in cleaning schedule, since no significant time trends were observed. The small number of rifles used in the test and the extreme variability may also have led to this unexpected result. The total number of malfunctions for each of the 16 rifles used in the test was in increasing order: 1, 2, 3, 3, 4, 4, 5, 5, 5, 6, 7, 8, 16, 28, 43, 65. The four stragglers (16, 28, 43, 65) did not possess any common quality such as rifle type, cleaning schedule, or ammunition type.

The Chambered Round Subtest

Each rifleman fired a round chambered overnight at the beach environment and at the upland environment. This was done to investigate gross effects leading to "failure to extract" category malfunctions possibly resulting from chambering rounds overnight. Although a total of five malfunctions were observed (all at the beach environment), none of these was of a "failure to extract" category. Thus, no evidence was found of a gross detrimental effect resulting from chambering a round overnight.

Night Firing Subtest

Night firing occurred during one-half period of each six-period cycle at both the beach and upland environments. No gross increase or decrease in malfunction rates due to night firing was observed at either environment. Subtle changes, however, may have been present as the test was too limited to be sensitive to them.

IV. OBSERVATIONS

Summarized below are some of the observations made from the analysis. More complete information concerning each item, including statistical confidence and significance data, where applicable, is to be found in the indicated part of Section III.

- Averaged over all the conditions of the test, there was no difference that could not reasonably be attributed to chance between the malfunction rates of completely modified M-16 rifles (new buffers, chromed chambers) R_1 and of partially modified M-16 rifles (new buffers) R_2. The gross malfunction rate of all M-16 rifles was 3.38 malfunctions of all categories per thousand rounds. The gross malfunction rate of the M-14 rifle under the same conditions was 1.40 per thousand rounds, lower by an amount not reasonably attributable to chance. Section III, Subsection B.
- The malfunction rate of all M-16 rifles firing ball propellant was lower than the malfunction rate of M-16 rifles firing IMR propellant, the averages over all the test conditions being 1.95 per thousand rounds with ball propellant and 4.81 per thousand with IMR. The rate 1.95 is higher than the 1.40 rate of the M-14 rifles by an amount not attributable to chance. The dependence of the M-16 malfunction rate upon propellant may be caused by differences, in the inpulses imparted to the actuating system of the rifle.
- Both lots of ball propellant ammunition used in the M-16 rifles gave nearly the same results. Both lots of IMR propellant ammunition used in the M-16 rifles gave nearly the same results. Section III, Subsection C.
- Averaged over all the test conditions and firing ball propellant ammunition, the R_1 rifles exhibited a higher malfunction rate than the R_2 rifles. However, when firing IMR propellant, the R_1 rifles exhibited a lower malfunction rate than the R_2 rifles. These responses of the two rifles

appear to be consistent with the differing impulses imparted to the rifle actuating mechanism by the two propellants. The preceding effects were most noticeable during the first half of the test and essentially absent during the second half. This time trend is possibly due to a "loosening up" of all rifles with an attendant decrease in friction forces. The reduced friction would partially offset the marginal impulse from the IMR propellant. Section III, Subsections C and I.

- Malfunction rates of the M-16 rifles with ball propellant and of the M-14 rifles showed no substantial time-trend when averaged over all test conditions, nor in any of the four environments separately and remained relatively stable throughout the test. A downward time-trend in the malfunction rate of the M-16 rifles firing IMR propellant was apparent in the test generally as well as in each environment separately, and such malfunction rates remained highly variable throughout the test. Section III, Subsection D.

- The malfunction rate of the M-14 rifle and that of the M-16 when firing ball propellant ammunition exhibited moderate stability with changes in environment. In contrast the malfunction rate of the M-16 rifles firing IMR propellant ammunition was observed to undergo large fluctuations with changes in environmental conditions. This sensitivity to environment is believed to result from a marginal impulse imparted to the rifle actuating mechanism by the IMR propellant in combination with fluctuations in friction forces induced by dust, water, and other random environmental factors. Section III, Subsection D.

- Malfunction rates of the M-16 rifles without chrome-plated chambers, using either ball or IMR propellant, were higher when fully cleaned every 468 or 480 rounds than when fully cleaned every 234 or 240 rounds. Malfunction rates of the M-14 rifles and of the M-16 rifles with chrome-plated chambers, using either ball or IMR propellant did not differ appreciably between cleaning doctrines. Section III, Subsection E.

- There was no evidence for a difference between the reliabilities of any of the rifle systems arising from the employment of magazines loaded with 18 rounds instead of 20 rounds. On the other hand, owing to the confounding effects of aging and environment, the test design provided only a marginal capability for detecting such a difference. Section III, Subsection F.

- Averaged over all test conditions, the M-16 rifles exhibited a malfunction rate of 4.28 per thousand in the