NAVSEA WARFARE CENTERS CRANE

TEST REPORT
FOR
M4A1/RIS II URG 10.3/M855A1 PERFORMANCE AND ENDURANCE TEST

Crane Division
Naval Surface Warfare Center
Crane, Indiana
47522-5001

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Executive Summary

This test was performed to analyze the functionality, operation, and lifecycle performance of the M4A1 Carbine equipped with the 10.3” Rail Interface System (RIS) II Upper Receiver Group (URG) when firing M855A1 ammunition. The test was performed on eight test weapons. Four of the weapons utilized standard issue tan-follower aluminum bodied 30-round magazines and four utilized P-MAG plastic bodied magazines as manufactured by Magpul Industries. Each weapon was shot to 12,600 rounds.

A very high occurrence of stoppage/misfeed issues occurred when switching from suppressed operation to unsuppressed. Inspection revealed the weapon was very dry as no visible lubrication was present on the bolt/bolt-carrier assembly. This lack of lubrication combined with an extreme build-up of propellant fouling is believed to be the cause of the stoppages. This is an expected result as the suppressor inherently increases the gas pressure to the receiver group which tends to “blow” the lubrication from the bolt and carrier. The increased gas pressure and flow also increases the amount of fouling that passes through the carrier assembly thereby elevating the amount of residue build-up in the system. This lack of lubrication and increased build-up of fouling residue is overcome and/or compensated for by the high gas pressure created by the suppressor. So, the weapon continues to function properly in spite of the lack of lubrication and fouling build-up when suppressed. However, once the suppressor is removed the lower gas pressures are no longer able to overcome the increased friction of the residue build-up. This was confirmed by a liberal application of Cleaner/Lubricant/Protectant (CLP) to the bolt and carrier assembly. In nearly every case, once CLP had been applied the bolt and bolt carrier, the weapon would function reliably unsuppressed.

Bore erosion measurements were taken at 1200 round intervals. The bore gauge used was the M16A2 version which is inserted into the bore through the chamber and a failure mark observed to see if it passes the rear surface of the upper receiver frame. By this gauge it was observed that all eight barrels failed to pass this check at the 6000 round inspection.

Suppressor strikes were anticipated to be numerous and frequent. Our experience was quite the opposite. Five weapons suffered a single suppressor strike and two weapons experienced two suppressor strikes throughout the test. This is in stark contrast to previous testing with M855 (green tip) ammunition where suppressor strikes averaged approximately one strike per 2000 rounds fired. Discussion had taken place, previously, concerning the manufacturing process used to cut and thread the barrels. It was theorized the current process might allow for misalignment of the suppressor to the bore of the barrel. The barrels used in this test were manufactured using the same process used to make the barrels in the previous test. Therefore, it would appear the only difference is in the ammunition itself and the testing indicates that with the current manufacturing process these barrels are capable of being suppressed without causing strikes due to a misalignment issue.

From the onset, testing revealed the suppressors became difficult to remove from the guns due to severe build-up of fouling at the interface of the suppressor and flash hider. After only 120 shots fired, hand tools were required to remove the suppressor from the flash hider. Re-installing the suppressor without thoroughly cleaning the flash hider caused additional build-up to accumulate and increased the force required to remove it. This problem was consistent throughout the testing exercise.

Finally, accuracy appeared to be slightly better when suppressed . Additionally, accuracy was retained well into the lifecycle of the barrels. One notable issue had to do with barrel temperature near the end of the lifecycle. As the barrel temperature would increase during an accuracy firing, the shot-to-shot target precision would degrade drastically with temperature rise.

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1 INTRODUCTION

1.1 Background. Special Operations Command has requested testing of the M4A1 Carbine system in the following special arrangement:

Lower Receiver:	M4A1
Upper Receiver:	Rail Interface System II (RISII) Upper Receiver Group (URG)
Barrel Length:	10.3 inches
Magazine:	Two types: 1) Standard Tan follower 2) PMAG nonmetallic type.
Ammunition:	M855A1
Accessories:	SU-231 Reflex Sight and FMBS-C Suppressor

This request was made due to concerns about how the combination of this particular weapon arrangement and the M855A1 ammunition would perform through an endurance test. The test was performed per test plan TP-JXNLL-F15-0058-C1 Test Plan for Performance of M4A1 with M855A1 Ammunition in 10.3" Upper Receiver Group and FMBS-C Suppressor. Of particular concern was how the two magazine types would deliver ammunition to the barrel breech in the upper receiver and if the delivery of this hard-tipped ammunition into the breech would damage the chamber face or feed ramps in a way that could adversely affect weapon safety and performance throughout its lifecycle.

1.2 Scope. This test report documents the results of the 12,600 round endurance test that was performed on each of eight weapons at the Naval Surface Warfare Center (NSWC) Crane Special Weapons Assessment Facility (SWAF). Accuracy testing was done at each 1,200-round interval for the purpose of documenting the performance of this system and all notable performance/functionality anomalies were recorded throughout the test as a part of this record. Maintenance intervals were modified as needed to maintain functionality and these modifications were also noted. Accuracy and muzzle velocity data have been processed to show performance trends throughout the lifecycle. Pass/Fail criteria are taken from MIL DTL 71186A w/amendment 3 section 3.6.6 for initial firing pre-test and section 3.6.7 for accuracy at 6000 rounds fired. Ammunition characterization testing was performed with the M855A1 ammunition fired from the M4A1 equipped with the RIS II URG 10.3 to document the performance of this new combination of equipment and ammunition. Penetration testing was performed using 8"x8"x18" gelatin blocks at 15ft, 100yds, and 300yds as well as with simulated automobile glass and a simulated automobile door to document the penetration performance of this ammunition when fired from the 10.3 inch barreled RIS II URG.

1.3 Safety. All standard manufacturing, assembly, and test range safety procedures were followed as per NSWC Crane Small Arms Weapons Division Standard Operating Procedures (SOP) requirements.

1.4 Test Data Package. The test data package consists of required test data, pass/fail criteria, and other recorded results. All checks, discrepancies, and corrective actions were recorded on the Test Data Sheets.

1.5 Quality Assurance. The strategy for quality assurance followed the detailed instructions outlined in the Test Procedure section of the test plan. Following the prescribed instructions ensured consistency in the testing for all test articles and allowed comparisons of the data collected to be made. Qualified personnel for explosive operations and small arms testing were the only personnel to perform the tests.

1.6 Risk Assessment. The risk mitigation was done by following all instructions outlined in CR-JXN-SWAF-P-0042, Live Fire SOP.

1.7 Records Management. This test report is assigned a document control number that can be found in the upper right hand corner of each page.

2 REFERENCE DOCUMENTS

- CR-JXN-SWAF-P-0042, Live Fire Standard Operating Procedure (SOP)
- SW370-CC-TRS-010 Rev 1 – Technical Repair Standard for Carbine 5.56MM M4A1
- MIL-DTL-71186A w/Amendment 3 – Detail Specification for Carbine 5.56MM M4A1
- TOP 3-2-045 Test Operation Procedure - Small Arms – Hand and Shoulder Weapons and Machine Guns
- SW300-BC-SAF-010 Rev 2 – Clearing of Live Ammunition From Guns USMC MK 318 MOD 1 & M855A1 EPR TEST REPORT - TR/JXNN/C13/0050
- FBI guidance on penetration testing (Appendix B)
- Test Plan for Performance of M4A1 with M855A1 Ammunition in 10.3” Upper Receiver Group and FMBS-C Suppressor (TP-JXNLL-F15-0058 C1)
- Family of Muzzle Brakes and Suppressors for Rifle and Carbine(FMBS-R/C) Performance Specification 22 September 2010

3 AMMUNITION REQUIREMENTS

- M855A1 (5.56 BALL) (Part # 13020533, NSN 1305-01-568-0755, DODIC AB57) - Lot # LC-10B371-001

4 TEST LOCATION & PERSONNEL

4.1 Test Location. The Operational portion of this test was conducted at Crane Division, Naval Surface Warfare Special Weapon Assessment Facility.

4.2 Test Personnel. The Weapons Systems Engineering Section (Code JXNLL) of the Crane Division, Naval Surface Warfare Center conducted the test with oversight of the range safety officer at the NSWC SWAF.

5 TEST ARTICLES

5.1 Equipment tested. The test items consisted of eight randomly selected M4A1 Lower Receivers (PN 12972690) (A-Condition), eight 10.3” RISII URG’s (PN 408JXN00553-5) as manufactured at NSWC Small Arms Weapons Division, four 30-round “tan-follower” aluminum-bodied magazines per weapon (NSN 1005-01-561-7200) for weapons numbers 1 through 4 and four 30-round black plastic Magpul P-Mag brand magazines (NSN 1005-01-576-5159) for weapon numbers 5 through 8. Also tested was the FMBS-C Suppressor/Flash Hider combination. SU-231 Reflex Sights were installed during all endurance firings to assess their durability and function throughout the test simply to assess whether they would still function properly after after 12,600 rounds fired.

6 WEAPON TEST PROCEDURE

6.1 Initial Visual and Physical Examination

Upon receipt of the test weapons and accessories, all were examined for completeness and inconsistencies. None were noted. Using a digital camera, images were taken of each weapon and accessory type.

6.2 Marking

Upon conclusion of documenting the condition of the test articles, all samples were marked with a unique alphanumeric identifier to include upper and lower receivers, suppressors, and magazines. Throughout testing, markings were reapplied as necessary. Suppressors and magazines bore the same numbers matching their assigned weapons. Magazines were marked as “1-1” through “1-4” for weapon number “1” and “2-1” through “2-4” for weapon number “2” and so on. As replacement magazines were inserted into the test (to replace defective units) they were labeled with alpha suffixes (1-1A, 1-1B, and so on for magazines, 1-1, 1-2, 1-3 and so on for suppressors).

6.3 Reliability

6.3.1 Mean Rounds Between Failures

Per MIL DTL 71186A w/amendment 3, while following the appropriate maintenance and firing schedule, the rifles shall have a maximum Class I, II, and III Mean Rounds Between Failures (MRBF) as listed in Table 1.

Malfunctions 1/	Single Weapon (number permitted in 6000 rounds) 7/	Four Weapons (number permitted in 6000 rounds) 7/
Failure of bolt to lock 2/	2	4
Failure to fire	2	4
Failure to feed (from magazine)	5	10
Failure to eject	3	5
Failure to chamber	3	6
Failure to extract	1	2
Bolts fails/hold rear	2	4
All other malfunctions 4/	1	2
Total – Above malfunctions combined	9	22
Unserviceable Parts 1/	Minimum Life 5/ Rounds	Four Weapons 6/ Combined
Ejector spring	3,000	2
Extractor spring	3,600	4
Bolt ring	1,200	2
Other parts 3/	3,000	2
Total unserviceable parts - (above unserviceable parts combined)		5

Table 1. Mean Rounds Between Failures (MRBF) by Failure Class

6.3.1.1 Table 1 Notes:

1/ All malfunctions and unserviceable parts occurring during the test shall be recorded and properly identified regardless of whether they are chargeable to the weapon. Malfunctions that are traceable to components determined unserviceable after meeting minimum life round requirements may be replaced and charged against the weapon. Once verified that previously recorded malfunctions are attributable to the unserviceable part, they shall not be counted against the weapon provided they occurred within the previous 200 rounds of firing. Malfunctions determined not to be chargeable to the weapon as a result of failure analysis shall be verified and shall not be counted.

2/ In the event of any failure of bolt to lock malfunction, the forward assist assembly shall be operated. Failure of the forward assist assembly to remain engaged with the bolt carrier assembly during manual attempt to lock bolt shall be considered an additional malfunction in the category of "other malfunctions".

3/ Other parts shall be limited to trigger spring, disconnect springs, hammer spring, extractor pin and extractor.

4/ Other malfunctions include, but are not limited to: occurrence of doubling (two shots fired with a single trigger pull) during semi-automatic firings; failure to immediately stop firing when the trigger is released (uncontrolled fire) during automatic firing; and failure of forward bolt assist assembly to remain engaged with bolt carrier assembly during manual attempt to lock the bolt, loosening of the nuts securing the carrying handle assemble to the upper receiver, etc.

5/ Minimum life rounds is defined as the minimum service life of an individual part, whether it is the original part or a replacement part, expressed in the number of weapon rounds fired with the part assembled in the weapon. For example, an extractor spring failing prior to firing 3,600 rounds on a new weapon, has not met the minimum life rounds. The failure shall be recorded and shall be cause for test failure.

6/ The allowable number of serviceable parts shown for 4 weapons combined applies only to parts failing after the minimum life rounds have been fired on the weapon. For example, ejector springs failing at 3,500 rounds on one weapon, and 4,100 rounds on a second weapon, fall within the allowable limits of 2 unserviceable parts on 4 weapons combined however, failure of an ejector spring on a third weapon after firing 3,000 rounds which exceeds the allowance, shall be cause for test failure.

7/ Each individual weapon tested shall not exceed the allowable number for each malfunction in the list or the test shall have failed. When the weapon meets the individual allowable malfunctions and exceeds the cumulative total allowable malfunctions for a weapon, the test shall have failed. The combined four weapons tested shall not exceed the allowable number for each malfunction in the list or the test shall have failed. When the weapons meet the combined four weapons allowable malfunctions in the list and exceed the cumulative total allowable malfunctions for four weapons, the test shall have failed.

Per MIL-DTL-71186A w/amendment 3

6.3.1.2 Malfunction Description

FLK – Failure of Bolt to Lock
FTF – Failure to Fire
FFD – Failure to Feed
FEJ – Failure to Eject
FCH – Failure to Chamber Round
FEX – Failure to Extract
FLR – Failed to Lock bolt to Rear (after firing last round in magazine)

6.3.1.3 Recording of Results

All malfunctions and unserviceable parts occurring during the test were recorded and properly identified. Parts determined to be unserviceable during the scheduled maintenance were replaced and were not scored as a reliability failure. However, for each weapon, more than one change of the same part did result in a failure of the reliability test. When test personnel verified that previously recorded malfunctions were attributable to an unserviceable part (not outside the part replacement parameter of one change), they were not counted against the weapon as long as they occurred within the previous 120 rounds of firing per MIL-DTL-71186A.

6.3.1.4 Test Result

The results of this failure analysis are recorded in the table below:

	M4A1 /URG 10.3 / Tan Follower Magazine				M4A1 / URG 10.3 / P-Mag Magazine			
Malfunction/gun	1	2	3	4	5	6	7	8
FLK	0	0	0	0	0	0	1	0
FTF	0	1	0	0	0	1	0	0
FFD	5	***12***	***7***	***10***	4	5	***21***	1
FEJ	0	0	3	0	0	1	0	0
FCH	5	2	1	***8***	1	0	1	1
FEX	0	0	0	0	1	0	0	0
FLR	0	1	0	0	0	1	0	0
Total	***10***	***16***	***11***	***18***	6	8	***23***	2
Total of 4 guns	***55***				***39***			

Note: numbers in red indicate failures per MIL DTL 71186A Table I (Table 1 above)

Table 2 – Malfunction Tally – 6000 rounds

The results in Table 2 above indicate that weapons 1, 2, 3, 4, and 7 received a score of "fail" individually per the criteria for pass/fail in Table 1 above. Also, each group of weapons (group 1-4 and group 5-8) received a score of "fail" as a group. To document the actual performance, the above table was developed from the test results to show the performance of this combination of equipment and ammunition for the first 6000 round fired. Table 3 below show the results of the same failure analysis after 12,600 rounds fired through each weapon (for information purposes only).

	M4A1 /URG 10.3 / Tan Follower Magazine				M4A1 / URG 10.3 / P-Mag Magazine			
Malfunction/gun	1	2	3	4	5	6	7	8
FLK	0	0	0	0	0	0	0	0
FTF	1	0	0	0	0	4	0	0
FFD	15	8	4	13	5	2	12	3
FEJ	0	0	0	0	0	0	0	0
FCH	29	38	9	26	9	6	13	9
FEX	0	0	0	0	0	0	0	0
FLR	2	6	0	2	7	3	5	5
Total	47	52	13	41	21	15	30	17
Total of 4 guns	153				83			

Table 2A – Malfunction Talley – 12,600 rounds

Feed failures and chambering failures constitute the majority of failures in this test. The exact cause of these failures is not yet determined. However, progression of the test revealed the fact that application of lubrication to the bolt and carrier consistently restored functionality when repeat or back-to-back stoppages began to occur. This phenomenon occurred throughout the test, but repeatedly happened upon removal of the suppressor during accuracy firings as this was the only place in the test sequence where the suppressor was removed and the weapon immediately fired. With high repeatability, the weapons would experience feed failures shot-after-shot when the suppressor was first removed and this problem would continue until lubrication was applied to the bolt and carrier. These feed failures rarely resulted in anything other than a closed bolt with an empty chamber or closed bolt with empty cartridge still in chamber. Due to the schedule impact this feed failure condition was imposing on the test, the procedure was modified to add lubrication of the bolt/carrier assembly upon removal of the suppressor.
Another possible cause of stoppages may be related to the impacting of the ammunition projectile tips with the forcing cone of the breech. Further study into this issue is needed to determine if these impacts are, in any way, connected with the stoppages experienced in this test.

6.3.2 Firing Schedule

One iteration (firing cycle) consisted of 120 rounds fired as described below:

<u>Accuracy Iteration:</u> Fired from Sliding Rail Fixture with SU-231A Sight removed
10 rounds to zero in pit and to warm & foul post cleaning (Magazine #1) Suppressed
20 rounds fired in 10-shot accuracy groups (Magazine #1) Suppressed
20 rounds fired in 10-shot accuracy groups (Magazine #2) Suppressed
10 rounds fired semi-automatic (6-second intervals) (Magazine #2) Suppressed
30 rounds fired in 10-shot accuracy groups (Magazine #3) Unsuppressed
10 rounds fired in a 10-shot accuracy group (Magazine #4) Unsuppressed
20 rounds fired semi-automatic (2-second intervals) (Magazine #4) Unsuppressed

<u>Suppressed Iteration:</u> Fired from Shoulder with SU-231A Sight - Suppressed
30 rounds fired semi-automatic mode (2 second intervals) (Magazine #1)
30 rounds fired full-auto mode (5-round bursts; 4-5 second intervals) (Magazine #2)
30 rounds fired semi-automatic mode (2-second intervals) (Magazine #3)
30 rounds fired semi-automatic mode (6 second intervals) (Magazine #4)

<u>Rate-of-Fire (ROF) Iteration</u>: Fired from Shoulder with SU-231A Sight
20 rounds fired semi-automatic (2-second intervals) (Magazine #1) - Unsuppressed
10 rounds fired full automatic mode (Magazine #1) – Measure ROF – Unsuppressed
20 shots fired semi-automatic (2-second intervals) (Magazine #2) - Suppressed
10 rounds fired full automatic mode (Magazine #2) – Measure ROF –Suppressed
60 rounds fired in 5-round bursts at 4-5 second intervals(Magazines #3 & #4) – Suppressed

Note: Weapons were lubricated after every 5 firing cycles (600 rounds). Weapons were cleaned, inspected and lubricated after every 10 firing cycles (1,200 rounds). During the firing cycles, several instances of function stoppage were experienced. One possible cause for this was a lack of lubrication on the bolt/carrier assembly. These stoppages were followed by an additional application of lubrication to the bolt and carrier assembly which, subsequently, alleviated most of the stoppage problems during an iteration.

6.3.3 Rounds Fired

Each weapon arrangement was fired a total of 12,600 rounds.

Number of Iterations:
Each weapon arrangement was functioned through a total of 105 iterations consisting of 120 rounds per iteration.

6.4 Dispersion/ Accuracy

Before beginning endurance firing, each endurance test weapon was mounted in the sliding-rail test fixture and fired for dispersion/accuracy measurements. The purpose of this event was to obtain a dispersion/accuracy baseline for each weapon while firing M855A1 ammunition. Dispersion/accuracy results were obtained at every 1,200-round interval and compared to the baseline thereby providing dispersion degradation information at the specified round counts. All dispersion testing consisted of a single ten (10) round warmer / spotter group, followed by four (4) individual 10 round groups (see Table 3). The ten spotter rounds were used to adjust impact on target prior to the firing of the scored groups. Four (4) individual 10 round groups per weapon were scored to provide a total of 56 scored groups for each of the eight (8) weapons being tested.

# Rounds	Fire Type	Comments
100 Yard and 300 Yard – Acoustic Target		
10	Semi	Warmer / Spotters
40	Semi	Four (4) 10-round groups

Table 3. Precision Firing Cycles

The weapon was mounted onto the sliding rail fixture (see Figure 1) and manually fired by the test technician at the 100 yard and 300 yard acoustic targeting system wings (simultaneous measurements). A chronograph was used to measure muzzle velocity for each shot. The acoustic targeting system provided the X and Y coordinates for each shot as well as remaining velocity. Each 10 round group had the following data calculated and recorded:

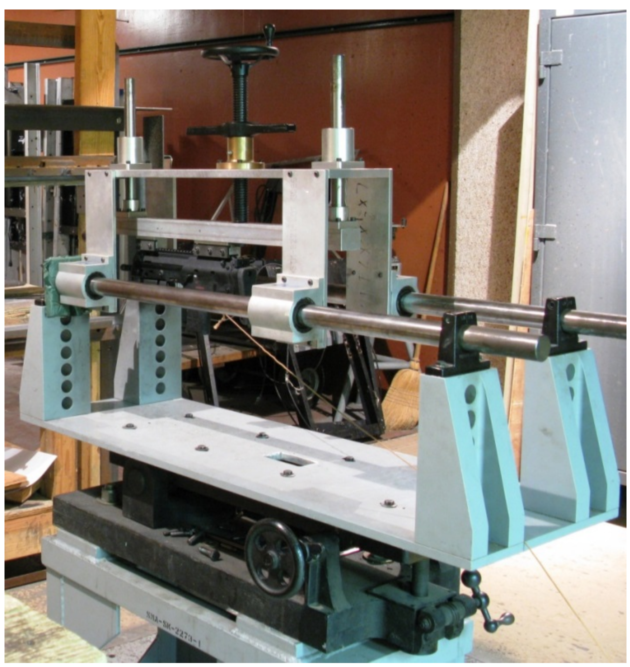


Figure 1: Sliding Rail Mount Fixture

- Average Velocity, Minimum, Maximum, Range and Standard Deviation
- Mean point of impact

- Extreme Spread
- Mean Radius
- Average remaining velocity
- Remaining velocity standard deviation
- COI and Standard Deviation

All dispersion/accuracy testing was fired in the NSWC Crane Code JXN Small Arms Weapons Assessment Facility (SWAF) from an indoor climate controlled firing position. All test ammunition was stored in the original containers in a 70º ± 10º F climate condition. The weapons were progressed through each cycle in sequential order (Weapon 1, 2, …, 8).
Spotter shots were fired to ensure the weapon was properly sighted to adequately pass through an acceptable target wing window and provide simultaneous measurements at 100 and 300 yards.. Adjustments for windage and elevation were made as required to bring the round impact into the acceptable window. No data was collected for the spotter rounds.

Once the desired impact point was achieved from firing the spotter rounds and adjusting, no further adjustment of the weapon or fixture was allowed. The wind speed and direction were monitored at all times. No scored shots were taken if the wind speed exceeded 9 mph full value.

6.4.1 Dispersion/Accuracy Test Method

Procedure as follows (taken from Test Plan TP-JXNLL-F15-0058 C1):

1) Mount cleared weapon in sliding-rail weapon mounting fixture.
2) Install Suppressor
3) Install Magazine #1 loaded with 30-rounds of M855A1 per Data Collection Sheet in Appendix A of the Test Plan, and chamber the first round thereby preparing weapon to be fired.
4) Fire ten (10) rounds to ensure the fixture mounted weapon is correctly sighted on the Acoustic Target System and the weapon is sufficiently fouled and warmed.
5) Two (2) 10-round groups will be fired and recorded at 100 yards and 300 yards simultaneously (using the Acoustic Targeting System). The weapon number, magazine number, suppressor number, and ambient conditions will be noted throughout progression of this step. The X and Y components of each shot will be recorded and the Center of Impact (COI) of each 10-shot group will be calculated and recorded for each sample. In addition the extreme spread, mean radius, and standard deviation from COI for each 10-shot group will be calculated and recorded. M855A1 ammunition will be used. Lot number for ammunition shall be recorded. Muzzle velocity shall be recorded for each round in the data sheets generated by the Computerized Acoustic Targeting System.
6) Clear weapon, remove empty Magazine #1 and install Magazine #2 loaded with 30-rounds of M855A1 per Data Collection Sheet in Appendix A of the Test Plan, and chamber the first round thereby preparing weapon to be fired.
7) Repeat Step 5
8) One (1) 10-round group will be fired from the same fixture with weapon suppressor installed. This group will be fired in semi-automatic mode at six (6) second intervals.
9) Clear weapon, remove empty Magazine #2, remove suppressor, install Magazine #3 loaded with 30-rounds of M855A1 per Data Collection Sheet in Appendix A of the Test Plan, and chamber the first round thereby preparing weapon to be fired.

10) Three (3) 10-round groups will be fired unsuppressed and recorded at 100 yards and 300 yards simultaneously (using the Acoustic Targeting System). The weapon number, magazine number, and ambient conditions will be noted throughout progression of this step. The X and Y components of each shot will be recorded and the Center of Impact (COI) of each 10-shot group will be calculated and recorded for each sample. In addition the extreme spread, mean radius, and standard deviation from COI for each 10-shot group will be calculated and recorded. M855A1 ammunition will be used. Lot number for ammunition shall be recorded. Muzzle velocity shall be recorded for each round.
11) Clear weapon, remove empty Magazine #3, install Magazine #4 loaded with 30-rounds of M855A1 per Data Collection Sheet in Appendix A of the Test Plan, and chamber the first round thereby preparing weapon to be fired.
12) One (1) 10-round group will be fired unsuppressed and recorded at 100 yards and 300 yards simultaneously (using the Acoustic Targeting System). The weapon number, magazine number, and ambient conditions will be noted throughout progression of this step. The X and Y components of each shot will be recorded and the Center of Impact (COI) of each 10-shot group will be calculated and recorded for each sample. In addition the extreme spread, mean radius, and standard deviation from COI for each 10-shot group will be calculated and recorded. M855A1 ammunition will be used. Lot number for ammunition shall be recorded. Muzzle velocity shall be recorded for each round in the data sheets generated by the Computerized Acoustic Targeting System Function-fire 20 rounds at 2 second intervals between shots in semi-automatic mode (no data collection).
13) Ensure all data has been recorded, clear weapon and remove from sliding rail mounting fixture, and allow to cool until no part of the weapon exterior exceeds 120°F as measured with infrared thermometer.

This procedure was performed on each weapon at the beginning of the test and at intervals in accordance with the Data Collection Sheets in Appendix A of Test Plan .

6.4.2 Dispersion/Accuracy Test Result

The following data tables represent the average of all shot groups for a particular iteration. Two target distances and two suppression configurations are represented as labeled. This data indicates the degradation of the weapon shot precision as the barrel aged.

All weapons performed as shown in the tables below for the average value of mean radius for all shot groups of all guns per iteration to illustrate the degradation of precision throughout the life of the barrel. MIL DTL 71186A w/amendment 3 limits extreme spread at 100 yards to 5.6 inches to be acceptable at initial firing and 7.0 inches at 6000 rounds fired. The 7.0 inch extreme spread limit was not exceeded at the 6000 round mark with or without suppressors.

	0	1,200	2,400	3,600	4,800	6,000	7,200	8,400	9,600	10,800	12,000
Suppressed	0.92	1.15	1.75	1.40	1.14	1.27	1.22	1.67	1.81	1.97	2.05
Unsuppressed	0.85	1.05	1.13	1.10	1.54	1.70	1.78	2.48	2.68	2.60	3.02
Note: Each data point represents the average of (32) 10- shot groups comprised of 4 groups for each of 8 guns											

Table 4 - Mean Radius - 100 Yard Range

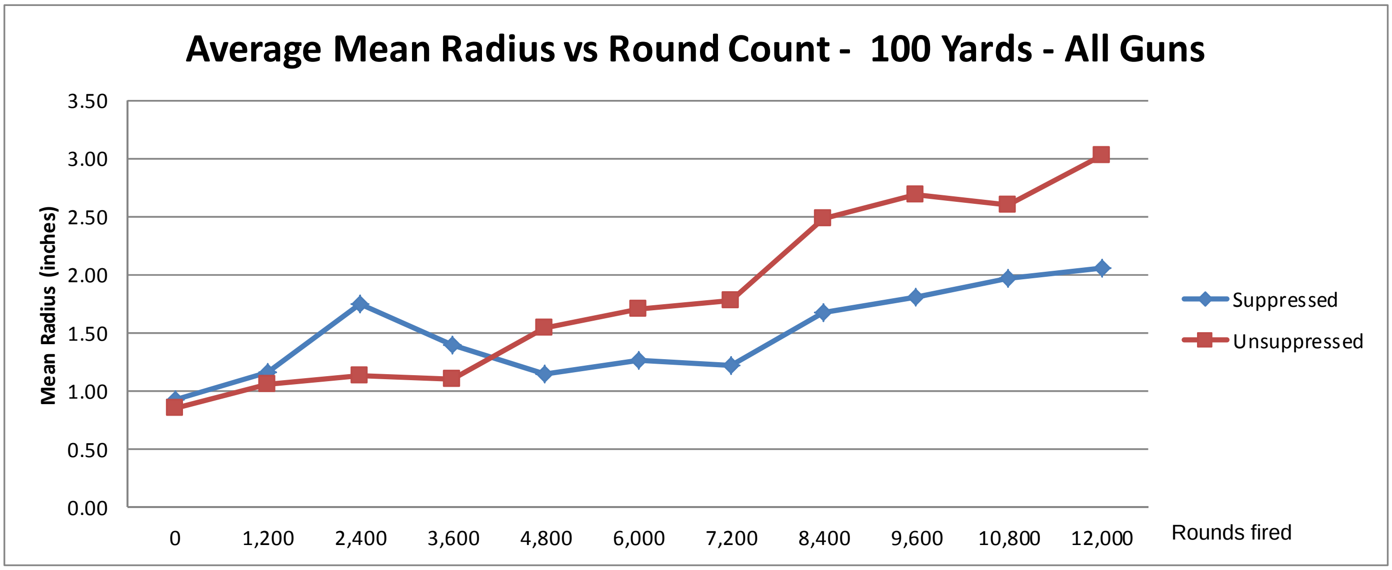


Figure 2 - Mean Radius - 100 Yard Range

Mean Radius (inches)

	0	1,200	2,400	3,600	4,800	6,000	7,200	8,400	9,600	10,800	12,000
Suppressed	2.72	3.33	3.37	4.01	3.51	3.78	3.59	4.82	5.01	5.22	6.23
Unsuppressed	2.53	2.92	3.06	3.35	4.71	4.82	4.88	7.23	7.43	7.39	9.90
Note: Each data point represents the average of (32) 10- shot groups comprised of 4 groups for each of 8 guns											

Table 5 - Mean Radius - 300 Yard Range

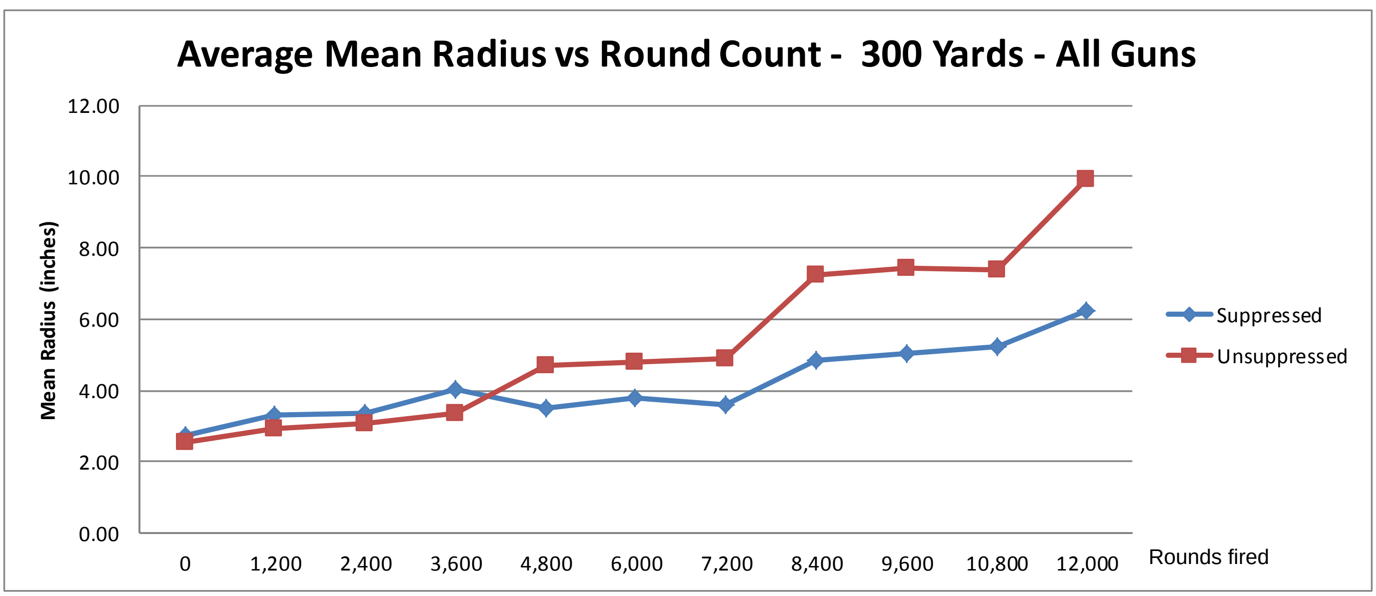


Figure 3 - Mean Radius - 300 Yard Range

Round Count	0	1,200	2,400	3,600	4,800	6,000	7,200	8,400	9,600	10,800	12,000
Suppressed	3.06	3.58	6.38	4.77	4.06	4.65	4.17	5.65	6.08	6.31	6.43
Unsuppressed	2.74	3.21	3.58	3.84	5.84	5.48	6.03	8.56	8.96	8.81	8.80
Note: Each data point represents the average of (32) 10- shot groups comprised of 4 groups for each of 8 guns											

Table 6 - Average Extreme Spread vs Rounds Fired - 100 Yards

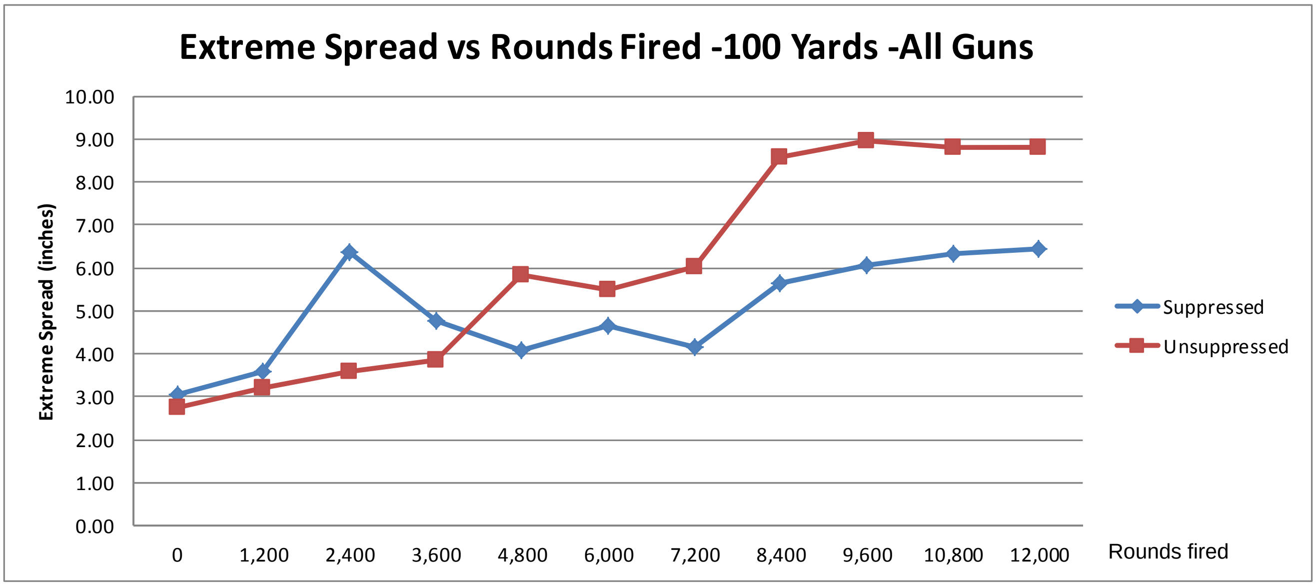


Figure 4 - Average Extreme Spread vs Rounds Fired - 100 Yards

Round Count	0	1,200	2,400	3,600	4,800	6,000	7,200	8,400	9,600	10,800	12,000
Suppressed	9.01	9.68	10.35	14.29	11.77	13.57	11.82	16.43	16.58	17.81	18.67
Unsuppressed	7.94	8.67	8.79	11.89	16.44	15.91	16.69	25.12	26.81	26.54	27.44
Note: Each data point represents the average of (32) 10- shot groups comprised of 4 groups for each of 8 guns											

Table 7 - Average Extreme Spread vs Rounds Fired - 300 yards

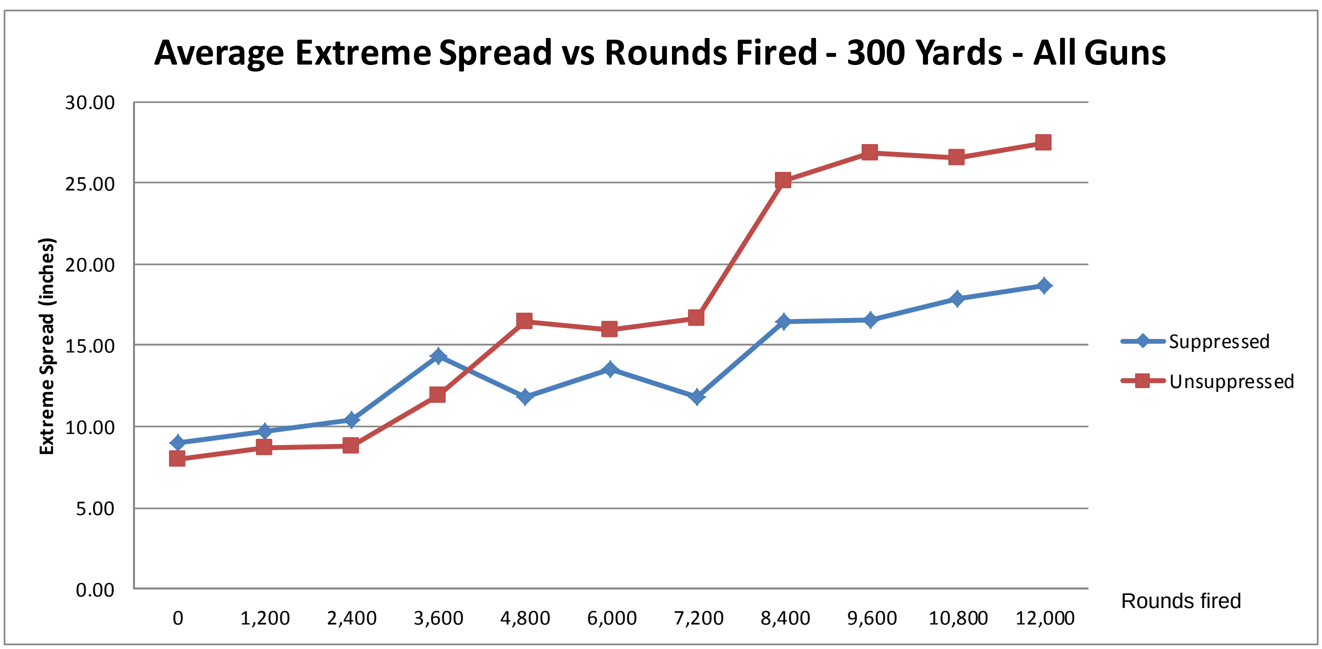


Figure 5 - Average Extreme Spread vs Rounds Fired - 300 Yards

6.5 Endurance

6.5.1 Endurance Test Method

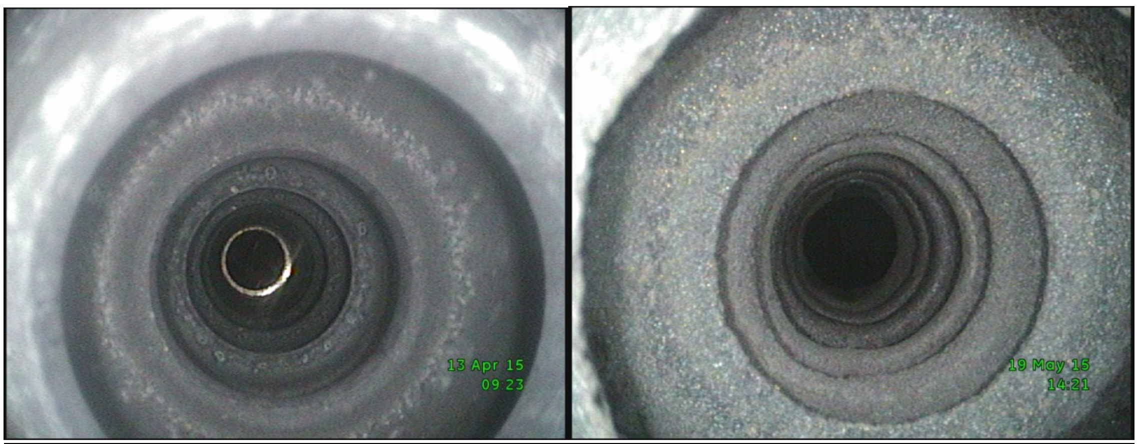
Weapons were shoulder fired utilizing 120 round iterations consisting of four 30-round magazines fired in succession according to the firing schedule as listed in 6.3.2 and per the data collection sheets in Appendix A of the test plan. Application of the suppressor was per the data collection sheet schedule (Appendix A of the test plan). Upon completion of each 120 round iteration, the weapons were allowed to cool in ambient air until no part of the weapon assembly exterior had a surface temperature exceeding 120°F as measured by infrared thermometer.

The test utilized eight M4A1 Carbines equipped with 10.3 inch RIS II URG’s and all ancillary equipment for each weapon including magazines. Two types of magazines were tested in conjunction with this endurance/reliability test. Sixteen magazines of each type were entered in testing. If a magazine failure occurred, or a magazine was suspected of causing multiple stoppages, the magazine was replaced with a new magazine from the spares provided. The replacement magazine was marked the same as the magazine it replaced with the addition of a sequential alphabetic suffix starting with A behind the marking (for example, 1-4A, next magazine failure 1-4B, etc.).

All firing conducted for the endurance/reliability test was with the weapon supported by the shoulder of the shooter - with the shooter having the option of using a forward rest. All weapons were fired for endurance/reliability with an SU-231A (EOTech) sight installed on the upper receiver 12 o’clock rail. During accuracy/dispersion testing the SU-231A was removed and the weapon was mounted onto the Sliding Rail Weapon Mounting Fixture (Figure 3) using the 12 O’clock rail position as the interface to the fixture.

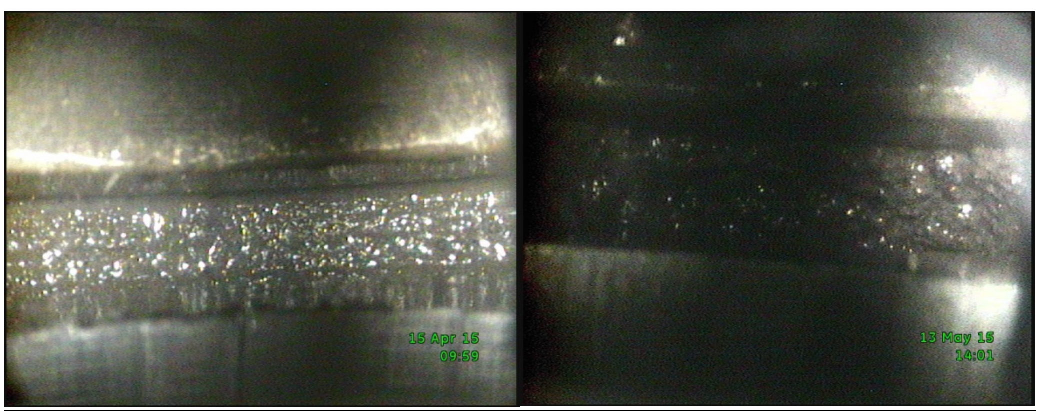
Pictures of the bore of each weapon and suppressor were taken by bore scope at the zero round count for baseline then at 1,200 round intervals thereafter in accordance with the Data Collection Sheets in Appendix A. The areas of the bore that were photographed are as follows:

- Suppressor
- M4A1 Muzzle Crown – compensator gap
- Gas port
- 2 inches forward of the chamber
- Feed ramps



Pre-test **Post-test (12,600 rounds)**

Figure 6 – Suppressor Bore Photos

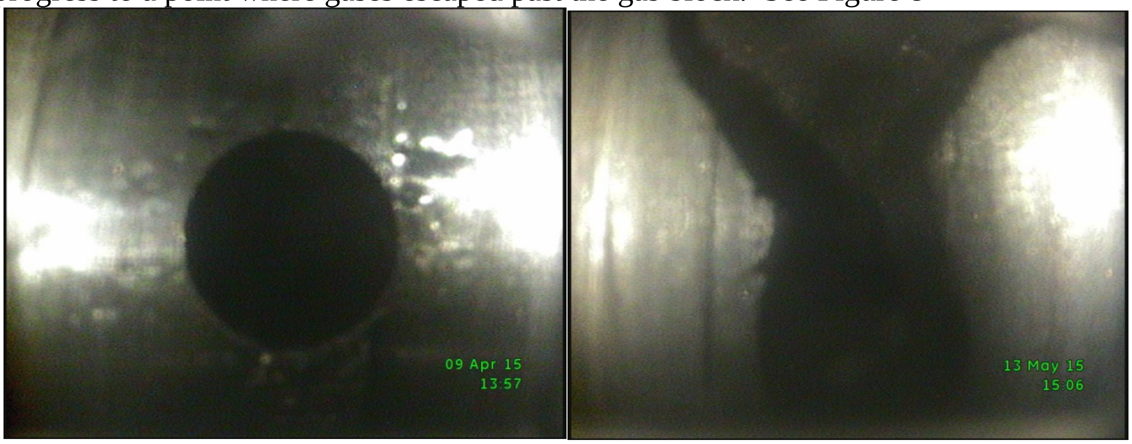


Pre-test Post-test (12,600 rounds fired)

Figure 7 – Muzzle Gap (typical)

6.5.2 Endurance Test Results

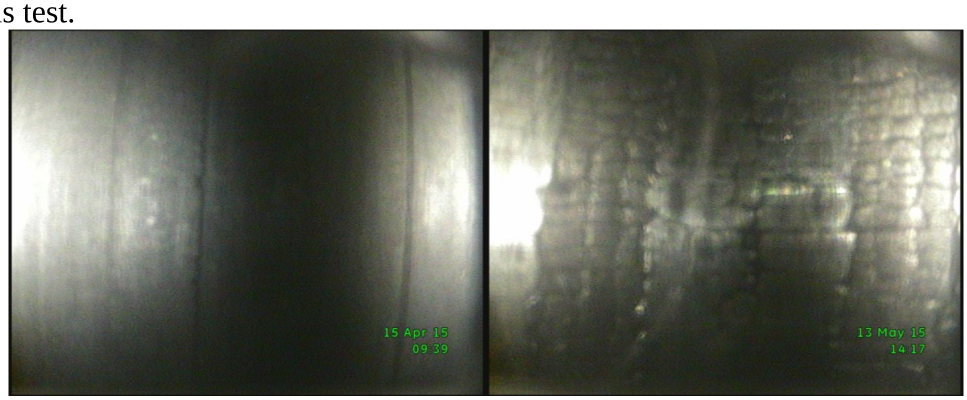
Suppressors exceed expectation based on performance observed in previous M855 testing. Internals of the suppressors showed signs of blast scarring in certain non-functional areas but were not adversely affected. Compensator gaps stayed much cleaner with M855A1 than with the M855 ammunition used in previous testing. However, at later stages of this test the gaps did begin to acquire buildup of residue and copper fouling. In one instance, accuracy was severely affected by residue buildup in the gap. The flash hider was removed and replaced with new. Accuracy of the weapon was restored as a result of this action. Gas port cutting was severe, but did not progress to a point where gases escaped past the gas block. See Figure 8



Pre-test Post-test

Figure 8 – Gas Port Cutting (Typical)

The area of the bore two inches forward of the chamber suffered extensive wear (see Figure 9) throughout the test. But weapon performance did not seem to be affected in any major way as a result. Feed ramps were not affected during this test.



Pre-test Post-test

Figure 9 – Bore Surface 2 inches from Chamber

However, the forcing cone area of the breech on each weapon developed an indentation as a result of the hardened projectile tips impacting the cone area during the chambering portion of the weapon's automatic loading function. (see circled area in Figure 10)

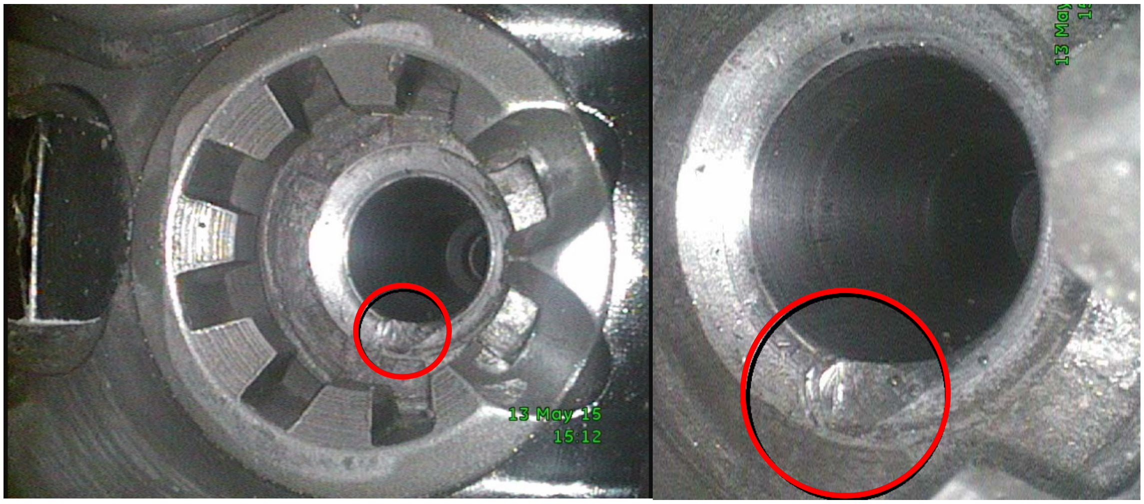


Figure 10 – Forcing Cone Damage

This indentation is indicated in the above photographs. This indication of projectile impact could be related to the frequency of the feeding and chambering failure weapon stoppages that were experienced. This indentation was present on weapons with utilizing both tan-follower aluminum type and P-mag type magazines.

Each weapon was fired as described above and stoppages/issues were noted. Due to the frequency of these stoppages, the results are presented in an overall narrative fashion. Throughout the test, there were multiple stoppages resulting from failures-to-feed, bolt-over-base, and double feed issues. These stoppages occurred, in most cases, directly following the removal of the suppressor during accuracy firings. Multiple successive stoppages occurred in these cases until lubrication was applied to the bolt and carrier. In most cases, the application of a liberal amount of lubrication would alleviate the stoppage issue. This was, likely, due to the prolonged high gas pressure resulting from the restriction of the suppressor forcing gasses through the upper receiver system in a way that removed the lubricant layer from the sliding components. These prolonged gas pressures also forced the upper receiver to function dry in spite of fouling and the lack of lubricant. When the suppressor was removed, the gas pressure dwell was reduced and could no longer overcome the increased sliding friction of the dry components. Once lubricated the components would again function properly and would retain their lubrication throughout unsuppressed operation. This same issue was also noticed with both the plastic P-mag magazines and the aluminum bodied “tan-follower” magazines. These magazines became very dirty internally as a result of suppressed weapon operation. Cleaning of the magazines was required at approximately 600 round intervals in order for them to function reliably. If not cleaned and lubricated at these intervals, they would begin to show signs of increasing action friction and not feed the rounds into the upper receiver resulting in stoppages of the weapon. This problem seemed to be fairly equal between the two types of magazines. The P-mag magazines did display an issue not common in the aluminum bodied ‘tan-follower” magazines in that they would occasionally fail to lock the bolt to the rear after the last round was fired.
Each weapon suffered breakage of one bolt during the test progression (see Table 8 below). All bolt breakages were similar as one or both of the bolt lugs adjacent to the extractor broke. In most cases the broken parts caused a stoppage of the weapon. No safety related incidents occurred as a result of these breakages. See Figure 11 below.

Broken Bolt				
Gun	Iteration	Mag	Rd	Total rds fired
1	67			7890
2	74	4	27	8877
3	84	4	10	10060
4	68	2	15	8085
5	100	1	1	11881
6	92	1	20	10940
7	94	4	28	11278
8	67	3	10	7990
Average Bolt Life (rounds fired)				9625

Table 8 - Broken Bolt Data

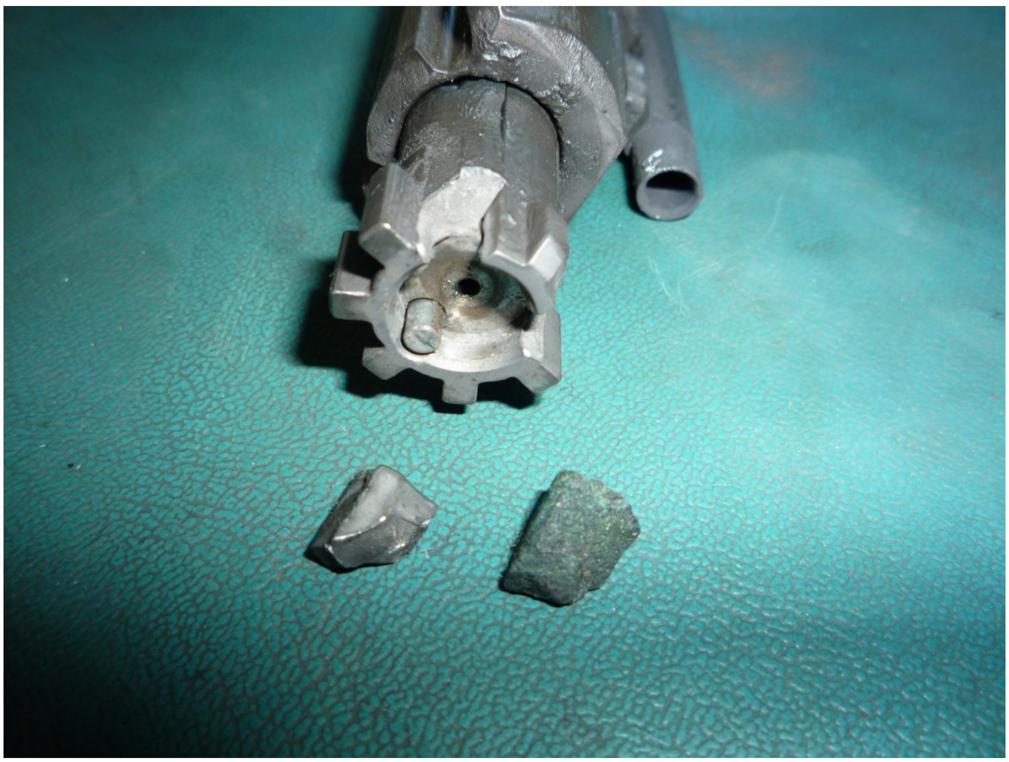


Figure 11 – Broken Bolt Lugs

6.6 Barrel Erosion

6.6.1 Test Method Per SW370-BU-MMI-010

Clean weapon thoroughly. Install key and bolt carrier in assembly with bolt assembly and firing pin removed. Hold weapon in vertical position with receiver up. Insert barrel erosion gage PN 8448496 (30 in Figure 12 below) into rear of upper receiver assembly. The M16A2 reject mark must be read at rear edge of upper receiver assembly. Measurements shall be noted on test data sheet (Appendix A of the test plan). Gage shall be measured for its actual embedment depth and this depth measurement shall be noted along with final round count data for the barrel. Measurements shall be taken from the rejectM16A2 reject mark to the rear edge of the upper receiver assembly. In the event the reject mark should fall below the plane of the rear edge of the upper receiver, then measurements shall be recorded as negative numbers to indicate the gauge insertion has surpassed the reject mark

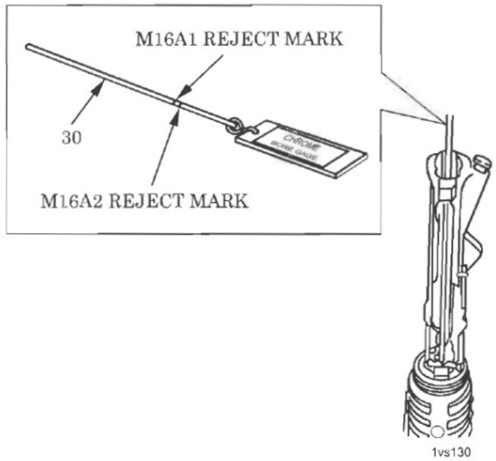


Figure 12: Erosion Gage

6.6.2 Test Result

Table 9 below contains the data for measurements taken on each gun at 1200 round intervals.

Rounds Fired		0	1200	2400	3600	4800	6000	7200	8400	9600	10800	12000	12600
Gun	1	0.441	0.445	0.271	0.079	-0.060	-0.228	-0.381	-0.473	-0.664	-0.934	-1.117	-1.196
	2	0.447	0.479	0.340	0.219	0.091	-0.033	-0.153	-0.187	-0.319	-0.438	-0.639	-0.710
	3	0.464	0.436	0.234	0.000	-0.185	-0.318	-0.506	-0.664	-0.947	-1.099	-1.359	-1.474
	4	0.440	0.423	0.278	0.074	-0.105	-0.275	-0.456	-0.577	-0.799	-0.904	-1.146	-1.232
	5	0.431	0.401	0.174	-0.167	-0.426	-0.640	-0.731	-1.021	-1.466	-1.760	-1.983	-2.133
	6	0.429	0.425	0.228	0.010	-0.252	-0.364	-0.587	-0.839	-1.023	-1.190	-1.658	-1.758
	7	0.426	0.400	0.271	0.097	-0.086	-0.313	-0.352	-0.534	-0.798	-1.011	-1.230	-1.539
	8	0.424	0.423	0.256	0.043	-0.113	-0.335	-0.401	-0.524	-0.706	-0.826	-1.054	-1.090
Barrel erosion measured from the failure mark on the gage to the rear of the upper receiver receiver. Negative values indicate gage has inserted past the rear of the receiver.													

Table 9 – Barrel Erosion (inches)

The values in the table represent the distance (in inches) from the rear surface of the upper receiver to the reject mark on the bore erosion gauge. Negative numbers indicate the distance the gauge has surpassed the reject mark indicating the barrel should be replaced. The data indicates the barrel on gun #5 failed this test after 3600 rounds fired. Guns 1, 4, 6, 7, and 8 failed after 4800 rounds fired and guns 2 and 3 failed after 6000 rounds fired.

6.7 Ammunition Characterization

6.7.1 Ammunition

AB57, M855A1 Lot Number LC 10B 371-001

6.7.2 EPVAT Test

Chamber, Port Pressure, and Muzzle Velocity (EPVAT) Testing: The ammunition was conditioned a minimum of two hours prior to test. A total of twenty (20) rounds per temperature condition were fired with the ammunition conditioned at the following temperatures; -65° + 5° F; -20° + 5° F; 70° +/- 5° F; +125° - 5° F; +140° - 5° F; +165° - 5° F. The results for this test are in Appendix C.

NOTE: Weapon used for all ordnance gelatin testing was a 10.3 inch URG, with FMBS-C suppressor, mounted on an M4A1 (or M16 series) lower receiver.

6.7.3 15' Bare Gelatin Test

Five (5) valid shots each. Target was bare 8"x8"x18" 10% Ordnance Gelatin located 15' from the muzzle of the test weapon. Impact velocity was measured as close to gelatin block as possible.

6.7.4 100 Yd. Bare Gelatin Test

Five (5) valid shots each. Target was bare 8"x8"x18" 10% Ordnance Gelatin located 100 yards from the muzzle of the test weapon. Impact velocity was measured as close to gelatin block as possible.

6.7.5 100 Yd. Simulated Automobile Glass / Gelatin Test

Five (5) valid shots each. Target is simulated auto windshield glass panel and with bare 8"x8"x18" 10% Ordnance Gelatin block placed 18" behind the center of the glass panel. Test protocol is standard FBI which requires the glass panel to be fixed at a 45º / 15 º angles. Impact velocity will be measured as close to gelatin block as possible.

6.7.6 300 Yd. Bare Gelatin Test

Five (5) valid shots each. Target is bare 8"x8"x18" 10% Ordnance Gelatin located 300 yards from the muzzle of the test weapon. Impact velocity will be measured as close to gelatin block as possible.

6.7.7 100 Yd. Simulated Automobile Door / Gelatin Test

Five (5) valid shots each. Target is simulated automobile door steel panels and with bare 8"x8"x18" 10% Ordnance Gelatin block placed 18" behind the center of the steel panels. Test protocol is standard FBI which requires the steel panels to be 20 gauge galvanized sheet metal. Two panels will be placed perpendicular to the path of bullet travel and 3 inches apart to create two impact surfaces to be penetrated by the projectile after which the projectile will travel an additional 18 inches to strike the entry surface (8" x 8" square surface) of the gelatin block. Impact velocity will be measured as close to gelatin block as possible.

6.7.8 Ammunition Characterization Results

Test results for this information-gathering test are available upon request as this test was performed to establish a base-line for the purpose of separating failures due to weapon issues from failures occurring due to ammunition issues. This data can also be used for performance comparison to M855 ammunition.

6.8 Suppressor Assessment

6.8.1 Failure Assessment

Suppressors are required to perform per the Performance Specification for Family of Muzzle Brakes and Suppressors for Rifles and Carbines (FMBS-R/C) part 3.3.1. Suppressor was considered unsafe to fire when significant contact of a projectile with the internal components of the suppressor can be seen through bore scope observation or external visual evidence of contact can be seen. Inspection to make this determination took place during lubrication cycles for internal inspection and between firing iterations for external observation. If the operator suspected the suppressor had been struck by a projectile by either feel or audible indication, then firing of the weapon ceased and an external inspection took place. When inspection revealed that significant contact had been made between a projectile and the suppressor, then the suppressor was removed from the test, marked as damaged, retained for analysis, and a replacement suppressor (labeled accordingly) installed to allow for continuation of the test.

6.8.2 Results

See Table 10 below. Weapons 1, 3, 4, 5, and 6 suffered one suppressor strike. Weapons 2 and 7 suffered two suppressor strikes. Weapon 8 had no strikes. Unfortunately, suppressor number 8-1 was inadvertently installed on weapon number 7 during and iteration and suffered a strike during that iteration. Therefore, weapon 8 received a replacement suppressor due to this unfortunate circumstance.

Iteration	Round count	Gun	Suppressor	Failure Mode
27	3240	7	7-1	Internal Strike (graze)
35	4200	1	1-1	Internal Strike (graze)
50	6000	4	4-1	Internal Strike (graze)
57	6840	3	3-1	Internal Strike (graze)
69	8280	5	5-1	Internal Strike (graze)
84	10080	2	2-1	Internal Strike (graze)
92	11040	6	6-1	Internal Strike (graze)
97	1571*	2	2-2	Internal Strike (graze)
97	11640	7	8-1	Internal Strike (graze)
* This value represents rounds fired on this replacement suppressor				

Table 10 – Suppressor Failures

Based on this data the average life of a suppressor in this test was 6986 rounds with three of the nine failed suppressors lasting in excess of 10,000 rounds. All failed suppressors suffered only minor internal damage. No catastrophic failures occurred. However, there was one unexplained occurrence where, during Iteration #3, suppressor #7-1 on gun #7, which had been checked for proper installation by the operator and two team leads, came loose and was propelled down range approximately 75 feet where it came to rest in the grass. This suppressor was inspected thoroughly and found to be in good working order with no damage incurred. It was immediately put back into service and the test continued. As can be seen in the above table (Table 10) this suppressor was the first to fail during iteration #27 when it suffered a minor projectile strike.

The suppressors produced an unexpected result as they quickly became difficult to remove from the flash-hiders. This problem occurred repeatedly after only 120 rounds (4 magazines) had been fired since a cleaning cycle. The suppressor removal exercise required the use of pry-tools. Our experience throughout the test revealed the suppressors were much less resistant to removal if removed when hot. As the suppressor would cool and shrink they would become extremely difficult to remove. Two technicians/operators and the use of a large pry-tool were required to remove the suppressors. Copper fouling buildup on the flash hider/suppressor interface surfaces seemed to be the source of this problem (See Figure 13).

Figure 13 – Flash Hider Deposits and Cleaning

Notice the photo on the upper left of Figure 13 shows the flash hider as it appeared after 120 rounds fired. The photo on the upper right shows the same flash hider after very light wire wheel buffing to illustrate the presence of copper deposits. The photo on the lower left shows the process used to clean these copper deposits from the flash hiders. This exercise was performed after each iteration. The photo on the lower right shows the cleaned flash hider ready for re-installation of the suppressor.

At the onset of testing, 480 rounds were fired before the suppressors were removed. Removal of the suppressors after 480 rounds fired took approximately 30 minutes to avoid damaging the weapon system. Therefore it was decided to remove them after each iteration (each 120 rounds) and clean the flash hiders with a wire wheel to remove the fouling/copper deposits. This modification to our test procedure enabled the team to continue testing without damaging the weapon system. We believe this will be a serious problem for an operator who needs to remove the suppressor during a mission. The weapons also suffered bolt breakages as listed in Table 8 on page 15.

7.1 Conclusion

The eight weapons were functioned for a total of 12,600 rounds and all functioned with no major malfunctions or safety issues. Weapon #8 suffered a partial obstruction issue in the flash hider resulting from a build-up of copper projectile jacket material that could not be removed with normal cleaning. This obstruction only affected accuracy and rendered the weapon unreliable so far as its ability to place projectiles in an acceptable target area. After replacement of the affected flash hider on this weapon its accuracy was improved to an acceptable level for testing purposes. The M855A1 ammunition produced large amounts of residue in the weapon action. This residue in conjunction with a lack of proper lubrication inherent with suppressed operation caused many stoppages of the weapons during testing. In virtually all instances of repeating stoppages (shot after shot stoppages), a liberal application of lubrication to the bolt and carrier assembly restored the operability and reliability of the weapon. The three major findings we gleaned from this test were:

1) When firing this particular weapon system arrangement with the M855A1 ammunition, the suppressors become bonded to the flash hider after only 120 rounds fired. This bonding is caused by the combination of propellant fouling and residual copper jacket particles building up in the clearance gaps between the flash hider and suppressor interface. This results in the need for hand tools to remove the suppressor from the flash hider which can be difficult for the soldier in the field.

2) After firing 60 rounds suppressed, removal of the suppressor and subsequent firing of the weapon unsuppressed consistently resulted in chronic (repeated) weapon stoppages. Application of lubricant to the bolt/carrier group restored operability in all of these cases. This problem seems to be the result of prolonged high gas pressures during suppressed operation forcing lubricant out of the bolt/carrier group and the accelerated build-up of propellant residue in the bolt/carrier group resulting from these prolonged gas pressures. The suppressed operation gas pressures forced the weapon to function in spite of the residue and lack of lubrication. However, once the suppressor was removed, the gas pressure duration was reduced and the weapon could no longer function reliably until additional lubrication was applied to the bolt/carrier assembly.

3) Use of the M855A1 ammunition in this weapon with the two magazine types tested resulted in minor damage to the forcing cone area of the breech. No feed ramp damage was visible. Both magazine types appear to be acceptable for use with M855A1. However, the P-mag magazines produced better reliability of operation compared to the standard issue tan-follower aluminum bodied type.

Finally, in spite of the functionality issues observed, there were no safety related issues or problems noted with this particular equipment and ammunition combination.