Fire to Destruction Test of 5.56mm
M4A1 Carbine and M16A2 Rifle Barrels

Final Report

Prepared by:

Jeff Windham
Small Arms Branch
Engineering Support Directorate
Rock Island Arsenal, Illinois

September 1996
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**REPORT DOCUMENTATION PAGE**

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<th>8. CONTRACT OR GRANT NUMBER(s)</th>
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<tr>
<td>U.S. Army Armament Research, Development and Engineering Center (ARDEC), AMSTA-AR-ESW-S</td>
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<td>Rock Island, IL 61299-7300</td>
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<td>5.56mm Small Arms M4 Carbine Temperature M16A2 Rifle Ruptured</td>
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<table>
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<th>20. ABSTRACT (Continue on reverse side if necessary and identify by block number)</th>
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<td>This test report examines the effects of firing 5.56mm M4A1 Carbine and M16A2 Rifles at a high rate of fire until the weapon is severely overheated and destroyed due to ruptures in the barrel. This test indicated the M4A1 Carbine performs as well as or better than the M16A2 Rifle with respect to barrel ruptures from overheating.</td>
</tr>
</tbody>
</table>
Disclaimer: The findings of this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

ABSTRACT:

This test report examines the effects of firing 5.56mm M4A1 Carbine and M16A2 Rifles at a high rate of fire until the weapon is severely overheated and destroyed due to ruptures in the barrel.

This test indicated the M4A1 Carbine performs as well as or better than the M16A2 Rifle with respect to barrel ruptures from overheating.
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FIRE TO DESTRUCTION TEST OF
5.56mm M4A1 CARBINE AND M16A2 RIFLE BARRELS
16 SEPTEMBER 1996

1.0 BACKGROUND: Reports have been received of 5.56mm M4A1 Carbine barrels rupturing. These incidents have occurred in Special Forces units which have recently been fielded M4A1 Carbines to replace their M16A2 Rifles (see Appendix A). In the past, ruptured barrels have occurred in the M16 Series Rifles when the barrel was grossly overheated due to excessive firing rates. Concern was expressed that the M4A1 Carbine may be more susceptible to the ruptured barrel problem at lower rates of fire. Testing was conducted at Rock Island Arsenal to examine this issue.

2.0 TEST PROCEDURE: A test fixture was constructed which would hold the weapons during firing while protecting the shooter when the barrel ruptured. Provisions were made in this test fixture for both remote firing of the weapon and remote operation of the charging handle. Video cameras were set to show the barrel and ejection port. The barrel was thermocoupled along its length (see Appendix B). Photographs of the test fixture are shown in figures 1, 2, and 3. The M16A2s were modified to fire full automatic by using M16A1 Rifle firing mechanism. The weapons were assembled into the test fixture and fired full automatic in 30 round bursts (magazine changes approximately every 10 seconds).

3.0 TEST RESULTS:

3.1 M16A2 Rifle: The M16A2 was fired continuously using 30 rounds bursts. Shown in table I are the rounds to failure, time to failure and maximum barrel temperature of the barrel. Muzzle flash increased and there was a distinct change in the sound of the weapons firing approximately 30 rounds before the barrel ruptured. There was also noticeable drooping (about 1 inch at the muzzle) of the barrel just prior to the barrel rupture. The barrel ruptured at 491 rounds with an approximately \( \frac{1}{4} \) inch hole in the top of the barrel about 8 inches in front of the chamber. The barrel was bent approximately 5 degrees and bulged in several locations along its length (see figures 4, 5, and 6). A plot of barrel temperature versus time at each thermocouple location is shown in figure 7.

3.2 M4A1 Carbine, Weapon 1: The M4A1 Carbine was fired for
540 rounds. It was thought the M4A1 barrel would rupture well before this point, therefore only 540 rounds were loaded for firing. This weapons barrel was noticeably bent and bulged at the end of the test (see figure 8). A plot of barrel temperature versus time at each thermocouple location is shown in figure 9.

3.3 M4A1 Carbine, Weapon 2: A second M4A1 Carbine was fixtured for testing and fired until barrel rupture. Muzzle flash increased and there was a distinct change in the sound of the weapons firing approximately 30 rounds before the barrel ruptured. There was also noticeable drooping (about \(\frac{3}{4}\) inch at the muzzle) of the barrel just prior to the barrel rupture. The barrel was ruptured at the 12 o'clock position approximately 4 inches in front of the chamber. The rupture was approximately 1\(\frac{1}{4}\) inches long and \(\frac{5}{8}\) inches wide. The barrel around the rupture was bulged out about 30 percent larger than its normal diameter. The barrel was bent at the hole approximately 3 degrees (see figures 10 and 11). A plot of barrel temperature versus time at each thermocouple location is shown in figure 12. There was an approximately 30-second delay in firing of this sequence which can be seen in the temperature plots. This delay allowed additional cooling of the weapon and may have increased the number of rounds to rupture by 30 to 60 rounds.

FIRE TO DESTRUCTION TEST RESULTS

<table>
<thead>
<tr>
<th></th>
<th>M16A2 Rifle</th>
<th>M4 Carbine (Weapon 1)</th>
<th>M4 Carbine (Weapon 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Rounds to Destruction:</td>
<td>491</td>
<td>540*</td>
<td>596</td>
</tr>
<tr>
<td>Time to Destruction: (min:sec)</td>
<td>2:49</td>
<td>3:00*</td>
<td>3:32</td>
</tr>
<tr>
<td>Max Barrel Temperature at Destruction:</td>
<td>1599°F</td>
<td>1712°F*</td>
<td>1639°F</td>
</tr>
</tbody>
</table>

* Gunner ran out of ammunition before weapon's barrel was destroyed.

TABLE I

4.0 Metallurgical Evaluation: The metallurgist report of the ruptured M4A1 Carbine barrel is in Appendix C. The hardness plot of this report shows a change in hardness of the barrel three to
five inches forward of the chamber. This analysis is consistent with the temperature plots in figure 13 which show this area of the barrel reaches the highest temperature during firing. The evaluation shows the chemical content and metallurgical structure of the barrel were acceptable before the rupture.

5.0 ANALYSIS:

5.1 Reviewing the results of Table I, the M16A2 Rifle failed at 491 rounds versus between 540 to 596 for the M4A1 Carbine. This indicates the M4A1 performs better with respect to barrel rupture that the M16A2 (firing full automatic).

5.2 From the rupture, it may appear the bullet exits the side of the barrel, however this test showed no indication of the bullet exiting the side of the barrel on the plywood screens around the barrel. Most likely the bullet exited the end of the barrel and the rupture in the side of the barrel was solely due to the high pressure gases within the barrel.

5.3 The barrels were noticeably bent and bulged upon rupture. This likely occurs just prior to the failure and accounts for the flash increase and sound change just prior to failure as gas blows by the bullet.

6.0 CONCLUSIONS:

6.1 The M4A1 Carbine performs well with respect to the number of rounds and firing schedules required to produce a barrel rupture. The M4A1 Carbine is as good as or better than the M16A2 Rifle (firing full automatic) with respect to number of rounds required to rupture the barrel. It is possible that the 3-round burst mechanism standard in the M16A2 would reduce the probability of a ruptured barrel.

6.2 The ruptured barrels received from the field were visually and metallurgically identical to the ruptured M4A1 Carbine barrel fired during this test. Therefore, it is concluded that the failure mode of the field weapons and the M4A1 Carbine destroyed in this test is the same, i.e., overheating of the barrel due to severe firing schedules.

7.0 OTHER RELATED REPORTS:

a. External Barrel Temperature of the M16A1 Rifle, R-TR-75-045, July 1975, Rodman Laboratory, Rock Island Arsenal, IL.
b. XM4 Carbine Development Program, AD-E401 627, Sept 1987, Colt Firearms, Hartford, CT.
c. External Barrel and Handguard Temperature of the 5.56mm M4 Carbine, SMCAR-ES-94-1, Sept. 1994, Rock Island, IL.
d. ARDEC Evaluation of Blown 5.56mm M4A1 Carbine Barrel,
e. ARDEC Evaluation of Blown 5.56mm M4A1 Carbine Barrel,
31 August 1996.

Jeff Windham
General Engineer
AMSTA-AR-ESW-S

C:\wpdocs\m4\bln_brl.tst
A0318-SCN-96-08.0174-2069-173
R&D Testing
M16A2 and M4 Carbine Barrel
   Failure Test
Shot on 21 August 1996
Negative 10 of 12
Photographer: Tony Lopez
A0318-SCN-96-08.0174-2069-171
R&D Testing
M16A2 and M4 Carbine Barrel
Failure Test
Shot on 21 August 1996
Negative 8 of 12
Photographer: Tony Lopez
A0318-SCN-96-08.0174-2069-172
R&D Testing
M16A2 and M4 Carbine Barrel
Failure Test
Shot on 21 August 1996
Negative 9 of 12
Photographer: Tony Lopez
A0318-SCN-96-08.0174-2069-165
R&D Testing
M16A2 and M4 Carbine Barrel Failure Test
Shot on 21 August 1996
Negative 2 of 12
Photographer: Tony Lopez
M16A2 Barrel Burst Test
491 rounds 2 min 48 sec

Temperature
°F

0  0.88  1.76  2.64  3.52  4.40  5.28  6.16  7.04  7.92  8.80

Time (minutes)
M4 Carbine Barrel Burst Test #1

540 rds  2 min  49 sec

no failure but barrel badly deformed
M4 Carbine Barrel Burst Test #2
596 rds  3 min 32 sec

FIGURE 12
# M4 and M16A2 Barrel Burst Test

<table>
<thead>
<tr>
<th>Distance</th>
<th>M16 barrel</th>
<th>M16 guard</th>
<th>M4 barrel #1</th>
<th>M4 guard</th>
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<tbody>
<tr>
<td>1.5</td>
<td>259</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1131</td>
<td>1279</td>
<td>1337</td>
<td></td>
<td></td>
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<tr>
<td>2.5</td>
<td>230</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>4</td>
<td>1713</td>
<td>283</td>
<td>1640</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.5</td>
<td>1599</td>
<td>1495</td>
<td>1483</td>
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</tr>
<tr>
<td>6.75</td>
<td>1495</td>
<td>315</td>
<td></td>
<td></td>
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</tr>
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<td>8</td>
<td>1690</td>
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<td></td>
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</tr>
<tr>
<td>11</td>
<td>337</td>
<td>1163</td>
<td>1181</td>
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<tr>
<td>15</td>
<td>1194</td>
<td></td>
<td></td>
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<tr>
<td>18</td>
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</tr>
<tr>
<td>20</td>
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**M4 and M16A2 Temperature Profile**

![Graph showing temperature profile of M4 and M16A2](image)

**FIGURE 13**
RESULTS: The test results are contained in Table I and Figures 1-3.

DISCUSSION: The hardness survey and microstructural analysis of the barrel indicates this barrel failed similar to previously examined barrels, lab reports 95-0879 and 96-1701. Since this barrel is known to have failed at 1700 deg. Fahrenheit it follows that the previously examined barrels would have also reached the same temperature, not the previously reported 1500 deg. F.

Steve Countryman
Metallurgist
SIORI-SEM

<table>
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<tr>
<th>ELEMENT</th>
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<tr>
<td>CARBON</td>
<td>0.41 - 0.49</td>
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</tr>
<tr>
<td>MANGANESE</td>
<td>0.60 - 0.90</td>
<td>0.82</td>
</tr>
<tr>
<td>PHOSPHORUS</td>
<td>0.040 MAX</td>
<td>0.018</td>
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<td>SULFUR</td>
<td>0.040 MAX</td>
<td>0.027</td>
</tr>
<tr>
<td>SILICON</td>
<td>0.20 - 0.35</td>
<td>0.23</td>
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<tr>
<td>CHROMIUM</td>
<td>0.80 - 1.15%</td>
<td>1.06</td>
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<tr>
<td>MOLYBDENUM</td>
<td>0.30 - 0</td>
<td>0.37</td>
</tr>
<tr>
<td>VANADIUM</td>
<td>0.20 - 0</td>
<td>0.26</td>
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* carbon is within test error.

D. Assd.
FIGURE 1

Burst Barrel

Barrel before sectioning for examination

SPECIMEN NO.: MY  MAGNIFICATION: 0.25 X  

STCK: 1
Figure 2

Microstructure of Steel at Burst

A mixed microstructure is present. Slow cooling from 1700 °F could result in this microstructure.

Specimen No.: M4
Magnification: 500x
Etch: N41
HARDNESS SURVEY OF RUPTURED BARREL

HARDNESS, ROCKWELL "C" (HRC)

DISTANCE FROM BREACH, INCHES

Figure 3
M-4A1 CARBINE ACCIDENTS/COOK-OFF INCIDENTS

**APPENDIX C**

* THIS IS ALL THE INFORMATION AVAILABLE AT THE MOMENT. WE ARE TRACKING ANY AVAILABLE SOURCE FOR INFORMATION. OUR DCSLOG IS AWARE OF THE SITUATION. WE WILL BRIEF THE USASFC CoS.

* June 1995: The 10 SFG(A) reported two incidents of "cook-off's" with the M-4; no injuries.

* September 1995: The 1/1st SFG(A) reported problems with "cook-off's" and various durability problems during a training mission in the Republic of Korea. Quality Deficiency Report's (QDR) submitted thru channels by unit.

* May 1996: The 7th SFG(A) reported malfunction (weapon exploding) during training at Ft. Bragg, NC.

* August 1996: The 3rd SFG(A) reported a problem associated with rounds lodging in weapon causing destruction of weapon during a training mission in Africa. One soldier injured by shrapnel from exploding weapon. Unit imposed a cease-fire until USAEUR personnel could investigate. The findings of the investigation are unknown, however, the incident and continuation of the unit's self-imposed cease-fire caused an excess of ammunition to be left over at the end of the mission.


* August 1996: (most recent incident) 5th SFG(A) reported an M-4A1 damaged by a cook-off during a live fire exercise at Ft. Bliss, Texas. The soldier attempted to clear the malfunction when the cook-off occurred. The cook-off damaged the upper receiver and jammed the bolt carrier to the rear. The report received mentioned a second weapon damaged in a separate incident (the range commander suspended any further firing of ammo [lot # LC92J103004]).

USASOC Safety Office submitted a message to the field reference dated 20 May 96 (201327Z May 96) subject: Reporting Requirements Associated with Weapons or Munitions Malfunctions, Misfires, or Hangfires to facilitate capturing any M-4A1 carbine incident.
We understand that Rock Island Arsenal is studying the problem and we are trying to contact them to capture any initial findings.
SERIOUS INCIDENT REPORT

1. DATE TIME GROUP: 19910Z AUG 96
2. LOCATION: DONA ANA RANGE COMPLEX, FT. BLISS TX - RANGE 52
3. PERSONNEL AND EQUIPMENT INVOLVED: M4 RIFLE AND SSG EDWARD C. BAKER
5. CLASSIFICATION OF ACCIDENT AND TOTAL COST: NOT KNOWN.
6. PERSONNEL INVOLVED/INJURED: NO INJURIES.

<table>
<thead>
<tr>
<th>NAME</th>
<th>RANK</th>
</tr>
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<tbody>
<tr>
<td>EDWARD C. BAKER</td>
<td>SSG</td>
</tr>
<tr>
<td>STEVEN L. SCHMIDT</td>
<td>WO1</td>
</tr>
<tr>
<td>RICHARD D. STEPHENSON</td>
<td>MSG (UI OF RANGE 52)</td>
</tr>
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7. ON OR OFF DUTY: ON DUTY.
8. WAS ACCIDENT DUE TO TRAINING: YES, IT OCCURRED DURING THE CONDUCT OF A M4 CARBINE RANGE.
10. EXTENT OF INJURIES OR PROPERTY DAMAGE: THERE WERE NO INJURIES. ONE M4 CARBINE, IN WO1/MB, HAS BARK, HAND GUARDS, AND GAS TUBE DAMAGED BEYOND REPAIR.

12. ACTIONS TAKEN BY THE REPORTING UNIT: COMMANDER NOTIFIED 2/5TH SFG(A) AND DONA ANA RANGE CONTROL.

13. INDIVIDUAL TO BE CONTACTED FOR FURTHER INFORMATION:

CPT DAVID M. Witty  DONA ANA RANGE  B CO. 2/5TH SFG(A)  DSN 979-0353
SGM CLINTON L. QUEEN  DONA ANA RANGE  B CO. 2/5TH SFG(A)  DSN 979-0353
MSG KEN W. BARRIEER  DONA ANA RANGE  B CO. 2/5TH SFG(A)  DSN 979-0353

14. ADDITIONAL INFORMATION/REMARKS: THE COMMANDER BELIEVES THIS INCIDENT OCCURRED BECAUSE OF DEFECTIVE AMMUNITION OR A DEFECTIVE BARREL. WEAPON WILL REDPLOY TO FT. CAMPBELL FOR FURTHER INSPECTION.

ORIGINATOR: KENNETH W. BALLINGER, MSG, USA, CPOE NCO
RELEASED BY: DAVID M. Witty, CPT, BF, COMMANDING

200806Z Aug 96
**USASFC(A) STAFF ACTION SUMMARY SHEET**

**SUBJECT:** M-4 RIFLE EXPLODED IN BOTSWANA DURING FLINTLOCK II B

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<td>80</td>
<td>12 Aug</td>
<td></td>
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<tr>
<td>2. C, OPS</td>
<td>7</td>
<td>12 Aug</td>
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<td>3. DG3</td>
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<td>4. G3</td>
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<tr>
<td>5. SAFETY</td>
<td>9</td>
<td>12 Aug</td>
<td>Will coord/lnk des loc.</td>
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</table>

**DATE:** 12 AUG 96

**POC. OFFICE, TEL #:**
- CPT Daniels, 2-6107
- AOSO-GCO-A
- RETURN TO: G3

**TASKER?** YES/NO

**CONTROL #**

**DATE RECEIVED BY SGS:**

**LOGGED IN:**

**DATE OUT FROM SGS:**

**LOGGED**

---

1. **PURPOSE:** To update the initial oprep-3 report on the 3rd SFG(A) M-4 explosion incident during Flintlock II B in Botswana.

2. **DISCUSSION:** MAJ DEGNON IMPOSED A CEASE FIRE ON ALL M-4's UNTIL FURTHER INSTRUCTIONS ARE RECEIVED. THERE ARE 17000 RDS OF 5.56 REMAINING FOR TRAINING. MAJ DEGNON BELIEVES A ROUND WAS LODGED IN THE CHAMBER WHEN THE SECOND ROUND WAS FIRED CAUSING THE EXPLOSION.

Tab A: Initial Oprep-3, 082200Z AUG96, Subject: Explosion/destroyment of a M-4 Rifle, EXER//Flintlock II B/

Tab B: Follow-up Oprep-3, 121350Z AUG96, Subject: Statement For Record, 3rd SFG(A) to USASFC(A), EXER//Flintlock II B/

Tab A: Follow-up Oprep-3, 121500Z AUG96, Subject: Statement For Record, USASFC(A) to USASOC, EXER//Flintlock II B/

3. **RESOURCE IMPACT:** N/A

4. **RECOMMENDATION:** For your signature, Sir
STATEMENT FOR RECORD

I SSG AUBREY R. HAWKINS WAS AT THE RANGE FIRING MY M-4 AT APPROXIMATELY 1430-1445 7 AUG 96. SSG MORGAN AND MYSELF WERE FIRING AT VARIOUS TARGETS AND CYCLIC RATES. I FIRED THE FIRST MAGAZINE ON SEMI AUTOMATIC THAN CHANGED MAGAZINES AND FIRED THE SECOND MAGAZINE ON AUTOMATIC. WHEN I COMPLETED FIRING THE SECOND MAGAZINE, I LOADED A THIRD MAGAZINE AND PLACED THE WEAPON ON SEMI AND AIMED. I HEARD THE ROUND FIRE BUT I DID NOT THINK THAT THE ROUND EXITED FROM THE BARREL. I LOWERED THE WEAPON TO PERFORM IMMEDIATE ACTION WHEN THE WEAPON EXPLODED IN MY HANDS AND SENT HANDGUARD FRAGMENTS INTO MY FACE AND HEAD. NO INJURIES WERE SUSTAINED WHEN THE WEAPON EXPLODED. I THEN PULLED IMMEDIATE ACTION ON THE WEAPON AND CLEARED IT AND PUT THE WEAPON ON SAFE. I CALLED A CEASE FIRE AND MOVED BACK TO THE TENT AREA.

WEAPON SERIAL NO. 306033
NO. OF ROUNDS FIRED BEFORE 60
WHEN THE WEAPON WAS LAST FIRED THE DAY PRIOR
WHEN WAS THE WPN LAST CLEANED THE NIGHT PRIOR
RATE OF FIRE SEMI
LOT NO. OF AMMO LC-941-006 606/M193 BALL
CAUSE IF KNOWN ROUND LODGED IN THE BARREL

FOR THE ACOFS, G3:

WERNER C. KRUEGER
LTC, GS
Chief, Operations Division
MEMORANDUM FOR RECORD.

13 MAY 1996

SUBJECT: MALFUNCTION REPORT.

MALFUNCTION REPORTED BY: Bill Bowden, TACOM-ARMAMENT LAR.

A. LOCATION OF MALFUNCTION: Range 66F, Ft. Bragg, NC.

B. IDENTIFICATION OF UNIT: C Co, 2d Bn, 3d SFG, USASOC, ft. Bragg, NC.

C. DATE AND TIME OF MALFUNCTION: 06 May 96, 1830 Hrs.

D. IDENTIFICATION OF WEAPON/AMMUNITION:

WEAPON: Carbine, 5.56mm M4A1, NSN: 1005-01-382-0953, SN: W305902
AMMUNITION: DODAAC #: A066, 5.56mm Ball, LOT NUMBER: LC95C0005-612.

E. NUMBER OF FATALITIES/INJURIES: None.

F. PROPERTY DAMAGE: Barrel Assy, PN: 9390009
   Guard Hand, 2ea NSN: 1005-01-234-2297
   Gas Tube, 1 ea, NSN: 4710-01-233-8637

G. DESCRIPTION OF MALFUNCTION: The operator had been firing at a sustained rates of more then 300 rounds per minute. He was firing on his 4th 30 round magazine when a round blew out the left side of the barrel, approximately 4 3.4 inch forward of the breech.

H. OTHER INFORMATION CONSIDERED PERTINENT: Inspection of the weapon by this LAR, show excessive heat to the point that the phosphate coating was discolored. The barrel was bent to the right about 5 to 10 degrees. The hole in the barrel was approximately 1 ½ inches long and 1 inches wide. The gas tube was bent upward and to the right. The top hand guard was broken in two places at the rupture point. The bottom handguard inner and outer liners was deformed.

1. WAS ANY RADIATION DEVICES INVOLVED? No.

2. NAME OF ITEM: N/A

3. IF SO WAS THE SOURCE DAMAGED? N/A

4. IF DAMAGED WAS A WIPE TEST PERFORMED? N/A
I. DATE AND TIME OF REPORT PREPARATION: N: 15, May 1996, 1700 EDT.

J. SOURCE OF INFORMATION FOR THIS REPORT: Maj. Meddaugh, The Operator, SFC. Jones, C, Co, 2d Bn, 3d SFG, Mr. Al Whittlekiend, USASOC Safety, Mr. Rock Roberton, USASOC DCSLOG.

Bill Bowden, TACOM-ARMAMENT LAR, 1ST COSCOM FT. BRAGG, NC, DSN: 236-0395, E-MAIL BBOWDEN.