CAPT JT Elder, USN
Commanding Officer
NSWC Crane

USSOCOM S&T MK48 MOD1 Machinegun – Sustained Fire Upgrade

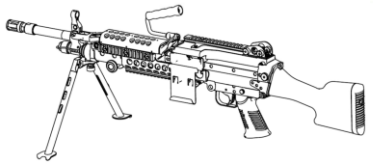
Special Warfare & Expeditionary Systems Department
Small Arms Weapon Systems Division
27 April 2016

Ms. Patricia Herndon
Technical Director (acting)
NSWC Crane

MK48 MOD1 - Sustained Fire Upgrade

Dave Armstrong
Mechanical Engineer
Expeditionary Weapons Branch
Crane Division, Naval Surface Warfare Center
Small Arms Weapon Systems Division
Special Warfare and Expeditionary Systems Department
300 Highway 361
Crane, IN 47522-5001
Ph: 812-854-5731
DSN: 482-5731
Fax: 812-854-1044
Email: david.armstrong@navy.mil

MK48 MOD1 Sustained Fire Upgrade



Project Background –

- ARDEC and ONR have been developing High Performance Alloy Barrels for M240 Series machine guns to avoid the need for spare barrels.
- ATI Flow Formed Cobalt Alloy Lined Nickel Alloy Barrel exceeded 60K rounds of life under standard firing schedule in the M240 series.
- Army agreed to provide USSOCOM S&T Barrels profiled for MK48.
- USSOCOM funded NSWC Crane to Insert Technology to allow Upgrade of MK48 MOD1 **Lightweight** Machine Gun for Sustained Fire Capability.
  - Prove out Sustained Fire Barrel Technology.
    - Increase Sustained Fire Capability and Avoid Spare Barrel.
  - Improve Reliability and Parts Life reducing lifecycle costs.
    - Parts with known lives under 50K rounds:
      - Barrel, Bolt, Extractor, Slide, Cartridge Guides.
    - Unknown parts under high rates of sustained fire.
      - Springs, Feed Pawls, Various Sub-Assembly Parts.
    - Reliability Concerns – Ejector Assy. Life / Gas System Fouling.
  - Heat / Signature Management – Barrel Cooling / Flash Management.

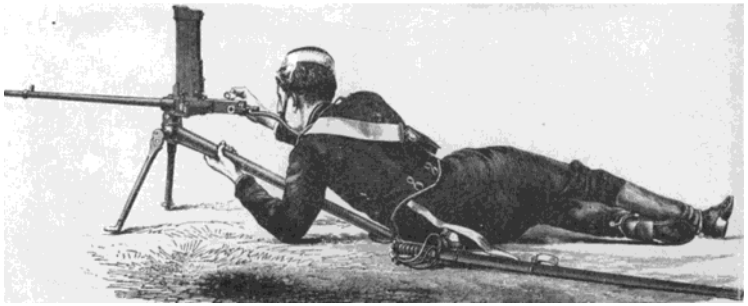
MK48 MOD 1 - Sustained Fire Upgrade

The "Battle of Wanat" Afghanistan showed the potential for current issue weapons, to include M4A1 Carbines and M249 SAW's to overheat to the point of failure during Combat Emergency defensive engagements.

Weight: 18.3 lbs + 5.4 lbs spare barrel + bag
Ammunition: 100 round pack @ 7.3 lbs
ROF: Cyclic 680-780 rpm
ROF: Sustained 100 rpm / Rapid 200 rpm

- While reliable and relatively light for a 7.62mm LMG, the MK48 MOD1 can still be improved to support a higher sustained fire capability and reduce dispersion.
  - Improve component part lives to meet anticipated new barrel life of 50,000+ rounds.
  - Maintain or increase rounds fired to reach Cook-Off conditions / Improve Safety:
    - Look at Active and Passive Cooling Features for Improved Heat Mitigation.
  - Improve Reliability:
    - Through Improvements in Materials, Processing, Design, and Coatings.
  - Reduced Dispersion:
    - Reduce ROF, Rear Monopod, and Non-Quick-Change Barrel Configuration
  - Improve Ergonomics:
    - FN offers partially evaluated MK3 Upgrade Kit – refine as necessary.

Move to "Automatic" Rifles / LMG



1870's Single Barrel Nordenfelt Gun – Manual LMG – 180 rpm @ 13-14 lbs.

M1894 Mondragon (Mexican/Swiss) – Straight Pull Bolt Action with "Automatic" Mode - fires when bolt is manually cycled without trigger contact.

M1908 Mondragon – Straight Pull Manual Mode and Semi-Automatic. Germans bought Mexican leftovers from SIG for use from WWI Aircraft (7X57mm) for a time.

1862 Pat.

Madsen was an Automated Single Shot (Peabody / Martini–Henry Falling Block).

1873 – Bailey MG – First Belt Fed Weapon – fired 100 rounds is 6 sec.

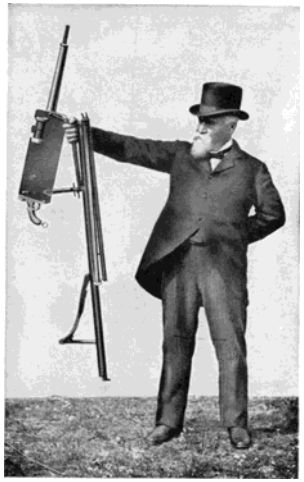
1896 Madsen – Rasmussen Gravity Feed Semi-Auto (45 rpm).

1900 Cei-Rigotti (Italy) @ 10 lbs - auto fire was hard to control.

Rossignol 1901 ENT B1 "Automatic Rifle" @ 21.3 lbs Direct Gas Impingement / Rotating Bolt / Select Fire.

1916 Fedorov Avtomat 6.5mm Jap. (9.7 lbs) First successful select fire of the class.

Move Toward Mobility AR/LMG Concept



1883 Maxim Gun Started out Light @ 26 lbs plus 15 lb tripod.

1902/04 Danish Madsen (20 lbs) First true LMG produced in quantity (later model shown).

M1909 Benèt–Merciè (French Hotchkiss) U.S. LMG entering WW1 @ 30 lbs & 400 rpm cyclic (150 rpm actual) and 6X optic with basic range finding reticle.

1916 Huot Automatic Rifle (Ross Conversion) 33.2 lbs loaded.

1917 – BAR M1918 – Browning Automatic Rifle for “Walking Fire” during assaults @ 16 lbs.

1915 – MG08/15 @ 36-39 lbs (w/ 5 pints water) primary German LMG in WW1 - Adaptation of MG08 Heavy MG – sustained fire capable for up to 6,000 rounds.

Automatic Rifle Model M1915 (Chauchat) 20 lbs “Marching Fire” concept.

M1914 – Lewis Gun (pan feed) Active Air Cooling @ 28 lbs.

Trends & Definitions HMG/MMG/AR/SAW/LMG

- Historical Definitions and their Evolution and Examples:
  - Heavy Machine Gun:
    - MG08 Maxim / M1917 Browning Water Cooled Major Sustain Fire Needed – WWI.
    - Shift away from all day firing to more tactical use / air cool / changeable barrels.
    - Move to M2HB Browning .50 caliber (12.7X99mm) or larger.
    - Fixed firing position, support fire role, defensive or vehicle mobile.
  - Medium Machine Gun:
    - Tripod mounted configuration for General Purpose Machine Gun.
    - Vehicle mounted GPMG which may be used dismounted as LMG if needed.
    - Longer Range Cartridge - .338NM GDOTS – LWMMG with HMG effective range.
  - Automatic Rifle / SAW / LMG – shifted from magazine feed to belt feed:
    - Started as Walking Fire Select Fire Battle Rifle / Shift to Bipod Heavier Automatic.
    - M1918 BAR / Cz ZB26 / FG42 move to Intermediate 7.62X39mm / 5.56X45mm NATO.
    - Squad Support – Highly Mobile – Some desire for heavier caliber now.
    - Viet Nam Era - all squad members carried 200 rounds & or spare barrel for M60.
    - Now – 5.56mm M249 SAW and USMC IAR plus 7.62mm MK48 and M240L.
  - Future – Increase Sustained Fire / Lighter / Longer Range:
    - Versatility – CQB / Suppressed / Sustained Fire Barrel Choices / Cartridge?

US Produced “Modern” 7.62mm LMG’s

				
Model/ Production	MK48 MOD1 FN-America	M240L FN-America	M60E6 U.S. Ordnance	M1919A6 Rock Island Arsenal / GM
Weight / Length	18.3 lbs / 39.8 in.	22.3 lbs / 44.5 in.	20.2 lbs / 42 in.	32.5 lbs / 53 in. (orig. 30-06)
ROF	730 +/-50 rpm	550-650 rpm	550 +/- 50 rpm	400-500 rpm
Pros	Comparably light and reliable	Good reliability	Many improvements over original M60 GPMG @ 23.2 lbs	Filled firepower gap from BAR to M1919A4 in WWII, Korea & Vietnam
Cons	Gas system fouls under sustained fire	Still heavy for LMG Role	Still based on M60 receiver, lighter barrel reduces sustained fire	Very heavy and poor ergonomics for LMG role

Other Modern 7.62mm LMG's

				
Model/ Country	SS-77 Compact / South Africa	NEGEV NG7 / Israel	Pecheneg PKP / Russia (7.62X54R)	HK121 / MG5 A2 Germany
Weight / Length	16.8 lbs / 39.5 in.	16.5 lbs / 36 in.	19.0 lbs / 47 in.	22.0 lbs / 41.7 in.
ROF	600-900 rpm	850-1,150 rpm	650 rpm	640/720/800 rpm
				
Model/ Country	Sig 710-3 / Switzerland	W+F MG 51 / Switzerland	S&T Motiv K12 / South Korea	HK 21E Germany
Weight / Length	21.3 lbs / 45 in.	35.2 lbs / 50 in.	26.0 lbs / 48.6 in.	20.5 lbs / 44.9 in.
ROF	600 rpm	1,000 rpm	650 – 950 rpm	800 rpm

MK48 Sustained Fire Upgrade Plan

- MK48 MOD1 Upgrades:
  - Improve Sustained ROF / Thermal Management.
    - Integrated Army / ONR High Performance Barrel.
    - Improve Parts as necessary to resist heat.
    - Provide for Active and Passive Air Cooling.
    - Increase Reliability / Reduce Lubrication Needed.
      - MK48 required extra CLP lubrication during an Army test.
  - Improve Ergonomics & Reduce Dispersion.
    - Integrate FN MK3 Upgrades and Others.
    - Reduce Barrel to Receiver Interface Tolerances.
    - Reduce ROF and Add Rear Monopod Support.

Sustained and Rapid Rates of Fire - Defined

Excerpts from M60 GPMG Field Manual FM 23-67 Quoted in Army LMG Study

"The sustained rate of fire is 100 rounds per minute in bursts of six to nine rounds at 4- to 5-second intervals (a barrel change is recommended after firing the sustained rate for 10 minutes)." FM 23-67, paragraph 81b.

"The rapid rate of fire is 200 rounds per minute in bursts of six to nine rounds at 2- to 3-second intervals. (A barrel change is recommended after firing the rapid rate for two minutes.)" FM 23-67, paragraph 81b.

SW370-CH-OPI-010 MK 48 Operator's Manual

Rate of Fire	
Cyclic	730 ± 50 rds / min
Sustained	100 rds / min
(3-5 burst, 4-5 seconds between bursts)	
Rapid	200 rds / min
(8-10 rd burst, 2-3 seconds between bursts)	

NOTE
RECOMMEND BARREL CHANGE AFTER FIRING 200 ROUNDS OF CONTINUOUS FIRING TO ENSURE MAXIMUM BARREL LIFE

Requirement Comparison

M240B Reliability Requirement is 7,500 MRBS and MRBF 25,000 rounds compared to the MK48 Requirement of 4,000 MRBS (T) / 8,000 MRBS (O) over the same 50,000 round minimum receiver life. TR/4081/C03/1308 reported the Avg. MRBS in DT was 11,512 and in Op. Assessment Avg. MRBS was 8,288.

Standard 7.62mm MG belt pull requirement is 9.9 lbs. Strive for most uniform ROF under most varied conditions -dry, well lubricated, hot, and cold conditions, as well as for hard, soft, and dis-mounted (shoulder) firing. The MK48 requirement had a goal of no grease or lubricants required. M240 ROF required is 500-650 rpm.

Goal of up to 50,000 round high performance barrel life depending on firing rates. Original MK48 Barrel Life Requirement Below –

3.4.7.1 Requirement: The MK48 shall have a quick-change barrel with a minimum service life of 10,000 rounds. The objective is a barrel service life of 25,000 rounds. Barrel service life is determined by four standards, 1) velocity drops more than sixty-one meters per second, 2) 20% of a burst exhibits keyhole on a paper target, 3) barrel fails gauging: headspace, barrel straightness, and or bore erosion, 4) or barrel develops cracks.

Typical Army Barrel Life testing involves 100 rpm ROF with cooling every 200 rounds fired, lubrication every 2,000 rounds and complete clean and lube every 4,000 rounds.

MK48 MOD1 Firing Schedules

Prior MK48 Evaluation TR/4081/C03/1308

3.4.6.3 While performing the receiver service life and the endurance/reliability test, the MK48s were fired in accordance with the schedule shown below in Table XI. The MK48s were allowed to cool between every 1,000 round schedule and lubricated every 2,000 rounds. The MK48's were thoroughly cleaned and visually inspected at 4,000 rounds intervals

Table XI 1000 Round Firing Schedule

Schedule	Description
1	One 25 round burst
2	100 rounds fired at the 100 rpm (sustained rate of fire)
3	10 seconds of cooling
4	100 rounds fired at 200 rpm (Rapid Rate)
5	3-5 round burst for a total of 25 rounds
6	2 minutes cooling
*	Repeat schedule 1 thru 6 three more times

Note: This firing schedule caused copper buildup on flash suppressor requiring scraping every 6,000 rounds to avoid radical loss of accuracy.

- All MK48 barrels exceeded the 25,000 round objective life goal.
- Need to establish firing schedule(s) based on High / Low Goals.
  - Perhaps 150 rpm for 3,000 rounds (20 min.) and Objective Sustained Fire Capability of 250 rpm for 5,000 rounds (20 min.) - or base upon maximum expected combat ammunition load (fire team or squad based with gunner carrying 1,200 rounds and each team or squad member carrying up to 300 rounds each in support of the LMG for 2,100 to 3,300 rounds available.

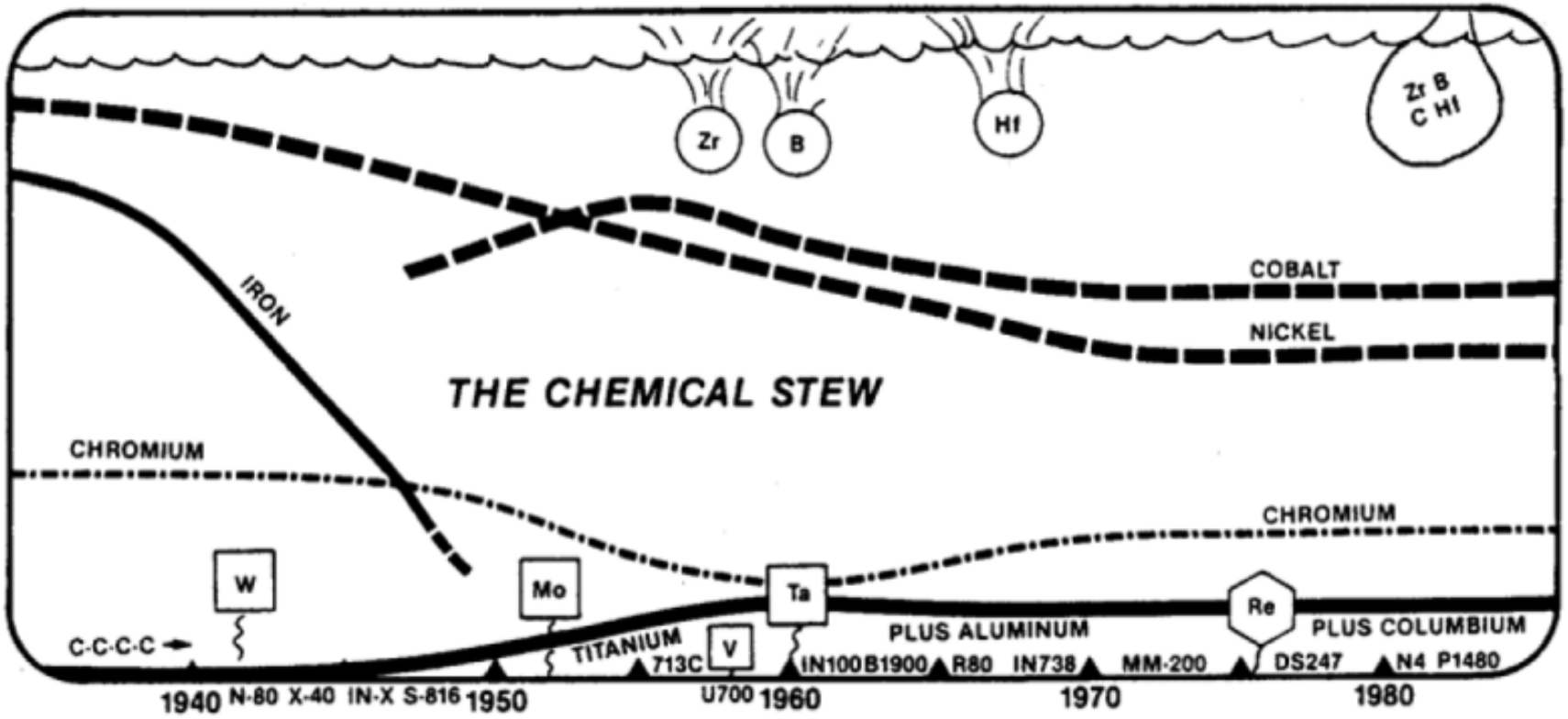
PKP - Most Recent Version of PK LMG

Cooling Ribs and Ducting/ Heat Deflecting Handle/ Air Passage/ Flutes Gas Block to Muzzle.

Controlled Convection behind gas block and Air Passages along barrel under shroud in front. Barrel bore is hard chrome plated and possibly hardened (Induction / Resistance Hardening?).

- Pecheneg PKP (6P41) reportedly can withstand 600 rounds of continuous sustained fire without barrel damage and has a 250 rpm practical rate of sustained fire (for how long?). It can have a 30,000 round barrel life while firing 1,000 rounds per hour (average of 17 rpm).
- The M240 with High Performance Barrel was able to withstand over 20,000 rounds of severe firing including a 1 minute burst at cyclic rate (then cooled) alternated with 1,400 rounds of defensive fire (then cooled).

High Performance Barrel Materials



- Nickel & Cobalt Based Superalloys are fully developed.
- Colt Work from Flow Forming improves Barrel Liner properties.
- Bore Surface Treatments.
  - B4C (Boron Carbide) Diffusion Bore Treatment.
  - Micro-machining Process Bore Polishing.

Prior MG Barrel Material Efforts (70's)

EROSION ANALYSIS AND CONTROL STUDIES
AT ROCK ISLAND ARSENAL - A REVIEW

W. T. Ebihara
Materials and Manufacturing Technology Division
Small Caliber Weapon System Laboratory
U. S. Army Armament Research and Development Command
Dover, New Jersey 07801

Prior to 1969, the materials generally used for small caliber were primarily limited to medium alloy steels either unplated or chromium plated and with or without cast cobalt alloy Stellite 21 breech insert liners. The physical limitations of shrink fitting liners precluded full length lined gun tubes. However, with materials and fabrication technology developed for aerospace and nuclear industrial needs, new heat-resistant materials were now possible for gun tube application.

<M60 MG Liner (1st few inches)

(a) (500-round burst at 4000 spm rate with a 10-second cooling interval) repeated 4 times before complete cooling and then repeated to failure. (Schedule for six barrel complement).

333 rpm per barrel for 1 minute (M134)

(b) (125 round burst at 650 spm rate with a 10-second cooling interval) performed 6 times prior to complete cooling; this schedule was repeated to failure.

375 rpm per barrel for 2 minutes (M60)

All ammunition used in these tests was the standard 7.62mm M80 NATO ammunition containing WC 846 propellant. Projectile yaw, loss of velocity or loss of accuracy constituted the criteria for gun tube failure.

- The effect of mass distribution in gun tubes was also investigated and mass near the throat proved valuable (relates to heat sink effect).

Prior MG Barrel Material Efforts (70's)

- Need to maintain a good combination of two materials that are synergistic – autofrettage effect throughout heating cycle is optimal.

The test firing results for multi-layered gun tubes is graphically illustrated in Figure 3. Several observations can be made from this graph. The service life the full length lined gun tubes is not necessarily dictated by the melting point of the liner material. The molybdenum alloy TZM- and columbium alloy WC103-lined gun tubes exhibit lower wear life than the cobalt alloy HS-21 breech lined Cr-plated steel M134 gun barrel. Also, the HS-25 (L605) lined gun tube shows nearly the equivalent service life as the tantalum alloy T-222 lined 4150 steel gun barrel. Also, the material performance in multi-layered structures appear to be significantly different from monolythic forms. The cobalt alloy HS-25 exhibits significantly better wear life when backed with a 4150 steel jacket than alone in a monolythic gun tube. The differential in thermal expansion between the steel and HS-25 may be important in inhibiting enlargement of the bore. An important aspect of erosion or wear in most small caliber gun tubes is that surface melting does not appear important in the deterioration of the gun tube material.

Prior MG Barrel Material Efforts (70's)

Data from 1977, HS-25 and Tantalum T222 (Ta-10W-10Hf-0.01C) showed promise when lining a steel barrel.

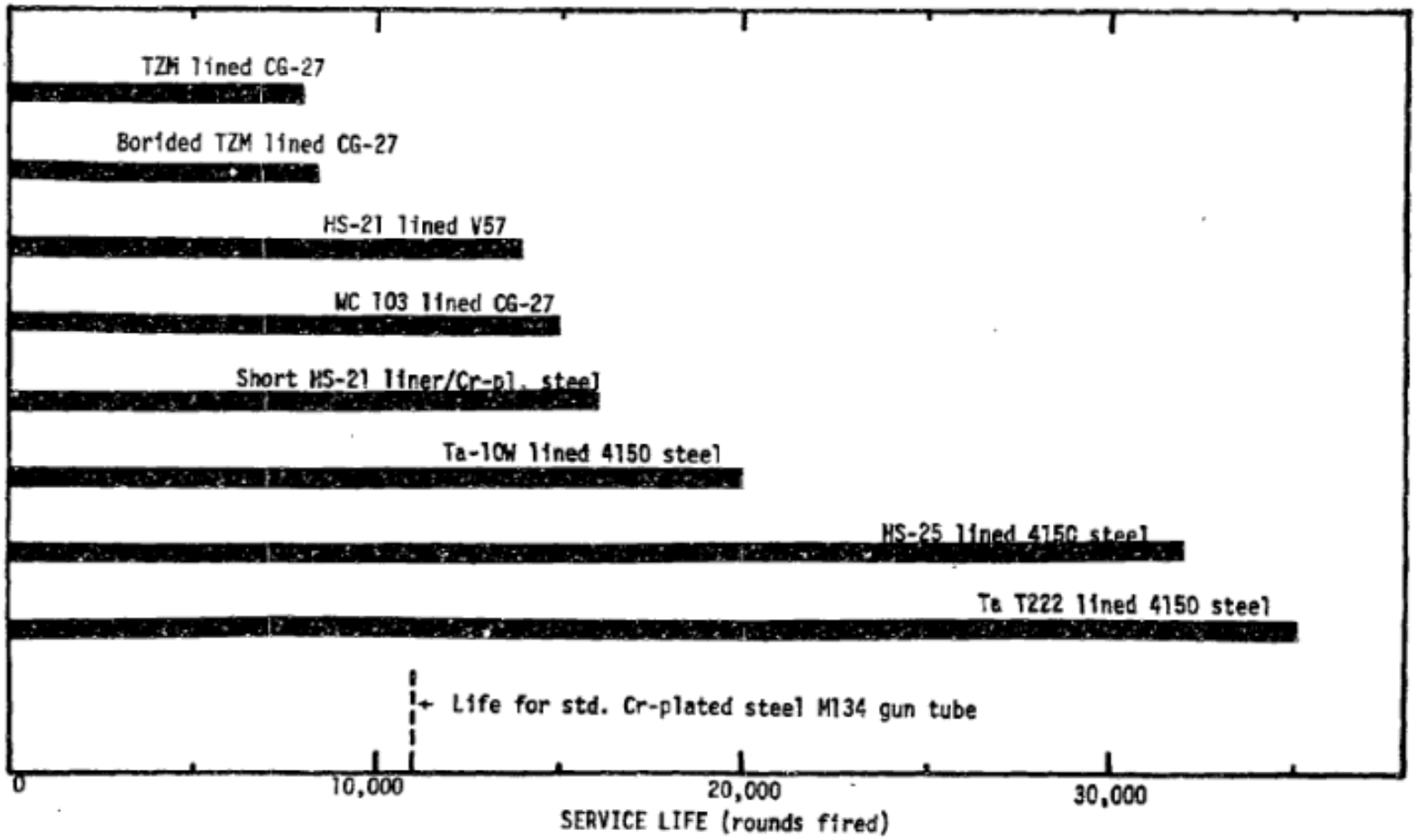


FIGURE 3. Effect of Liner/Substrate Material System on Service Life of 7.62mm M134 Gun Tubes

V-589

(Minigun)

Material Options for Strength / Fatigue Life

Figure 3. Toughness Index vs. Specific Strength

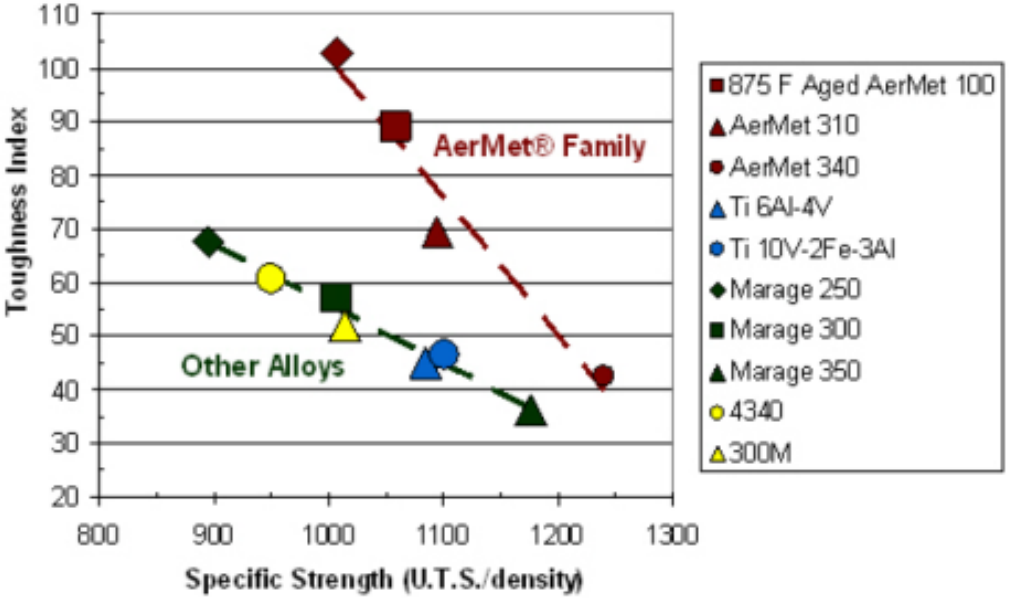
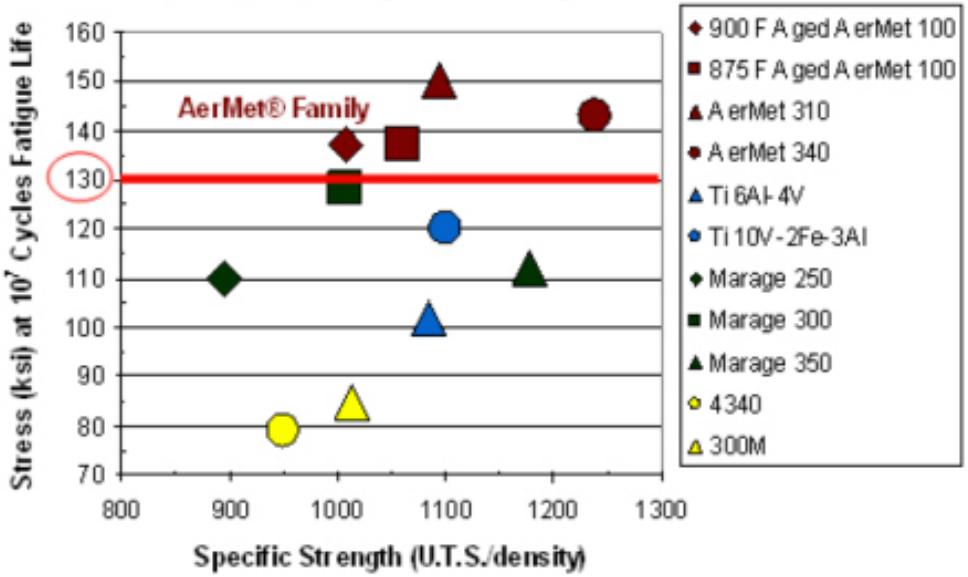


Figure 4. Rotating Bending (R = -1, Kt = 1) Fatigue Stress at Run-Out (10^7 Cycles) vs. Specific Strength



The Toughness Index and Specific Strength values allow the strength, toughness, and fatigue life of ten alloys to be compared with only two graphs. In fact, it may even be possible to compare these values in one three-dimensional graph. For example, the Goodman Diagram in **Figure 1** might be modified to include the Toughness Index on a Z-axis. (However, that may end up being overly complicated.)

Figure 1. Alternating vs. Mean Stress Diagram Example (Goodman Diagram) for Axial or Bending Loads

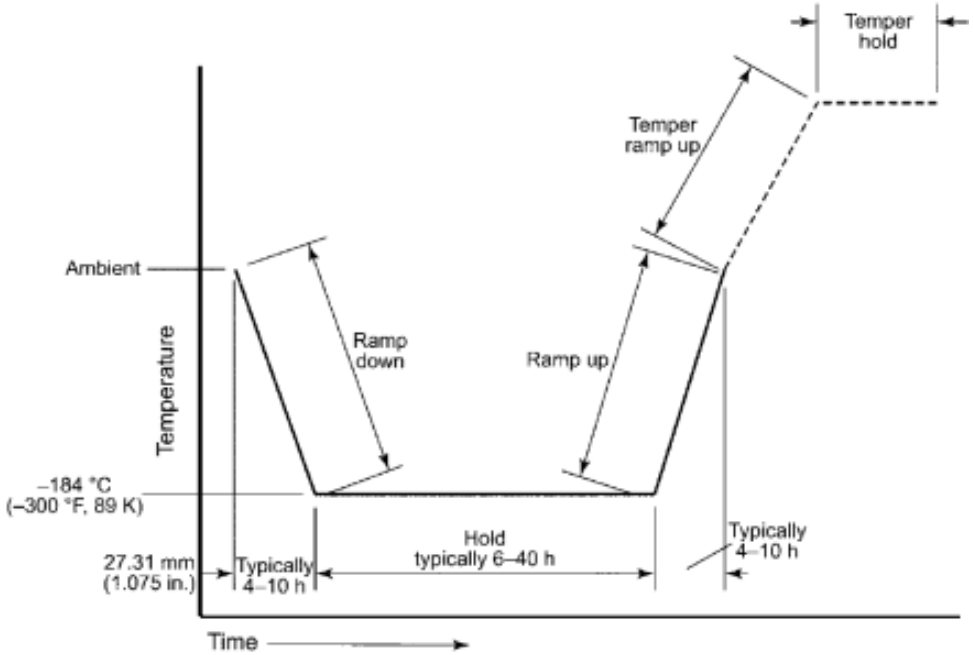
- AerMet® 100 is still a solid choice for toughness and fatigue life and is off patent (unlike 310/340). ATI also recommends their 13-8 Supertough® PH Stainless Steel.

Springs and Low Cycle Fatigue

- Springs.
  - Benefits of Twisted Wire Springs (already in use).
    - Surge/Wave Damping - Energy Absorbing (inter-wire friction).
  - Nickel and/or Cobalt Based Alloy Options.
    - Elgiloy® type Cobalt-chromium-nickel-molybdenum-iron alloy.
      - Vacuum Induction Melting (VIM), Electro Slag Re-melt (ESR).
  - "Super Clean Wire" / Shot Peen / Nitride / Micropolish.
- Other Part Treatments for Improved Fatigue Life.
  - Avoid Coating / Plating that reduces fatigue life.
  - Shot Peening / Low Plasticity Burnishing / Laser Peening.
  - Cryogenic Treatment.

Cryogenic Treatment of Materials

- Cryogenic Treatment Benefits:
  - Relief of any residual stresses.
  - Reduced retained austenite in steels.
  - Increases in all of the following:
    - Wear Resistance.
    - Fatigue Life.
    - Hardness.
    - Dimensional Stability.
    - Thermal Conductivity.
    - Corrosion Resistance.
- Use Vacuum Insulated Processing

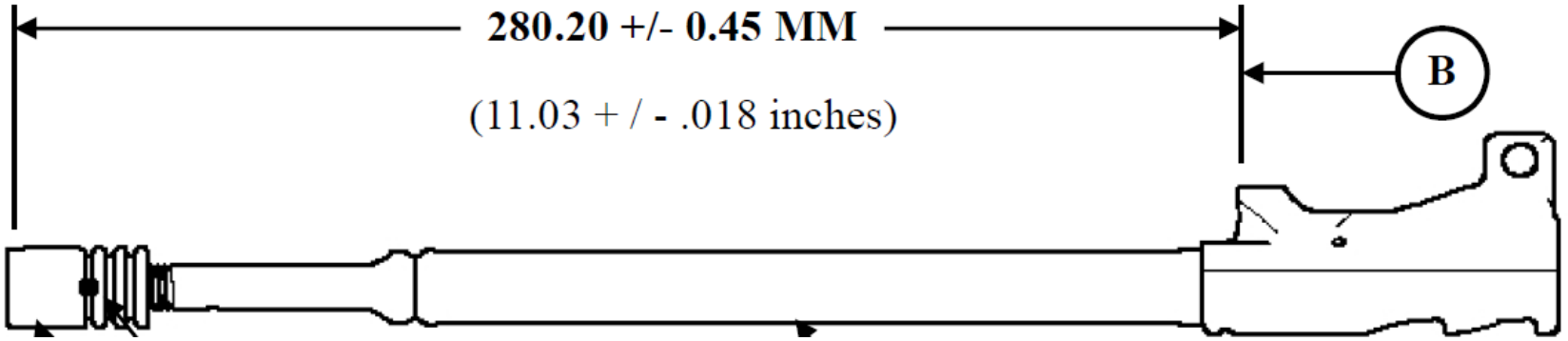


ASM Handbook, Volume 4A, *Steel Heat Treating Fundamentals and Processes*
J. Dossett and G.E. Totten, editors

MK48 Tolerance / Sensitivity

NOTE

Dimensional compliance of Piston (3) to the Tower Surface (B) must be maintain, if not it can result in short recoil and failure to chamber.



- The above requirement shows that the gas system has little “tolerance” for pressure loss.
- Try to increase “tolerance” while reducing rate.
- Could add a captured / spring loaded piston in the gas block to push rearward while venting out of gas block.

MK48 MOD1 Gas System Upgrade

STEP 2. Insufficient gas pressure.

(a) CORRECTIVE ACTION

Check for caked carbon in grooves (1) and inside diameter of gas piston (2) and in internal grooves of gas cylinder assembly. Clean as required.

Figure 2-41. MOD 0/1 Piston Assembly.

STEP 3. Check for gas leakage (white deposit) between gas cylinder and knurled head of gas cylinder assembly (Figure 2-42).

(a) CORRECTIVE ACTION

If evidence of gas leakage is present, replace gas cylinder assembly (see page 2-38).

Figure 2-42. MOD 0/1 Gas Cylinder.

Add self cleaning features to piston

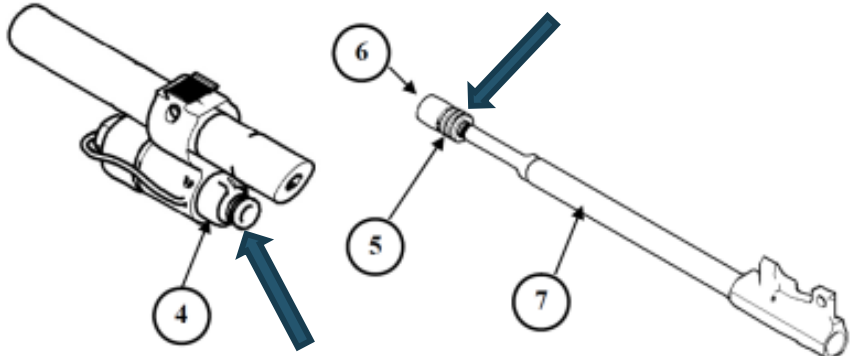
Add self cleaning features to gas block

- MK48 Gas System currently fouls to the point of causing stoppages after 1,200-1,300 rounds of a heavy firing schedule.
- Currently the barrel would be switched out at 1,200 rounds if in sustained combat to maintain reliable function.
- After 2,400 rounds (2 barrels X 1,200 each), the gas system requires maintenance action (scraping of jacket material and carbon buildup).

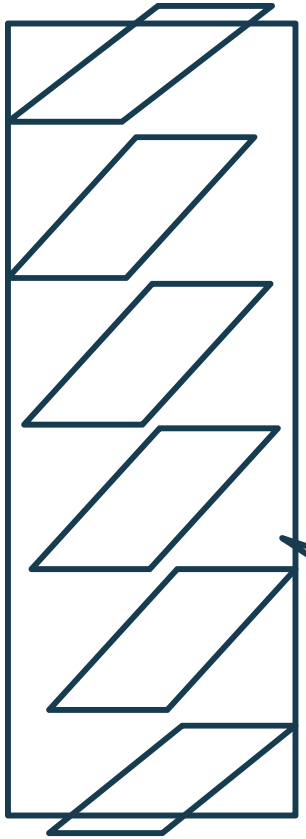
MK48 MOD1 Gas System Upgrade

FAILURE TO EJECT. (cont.)

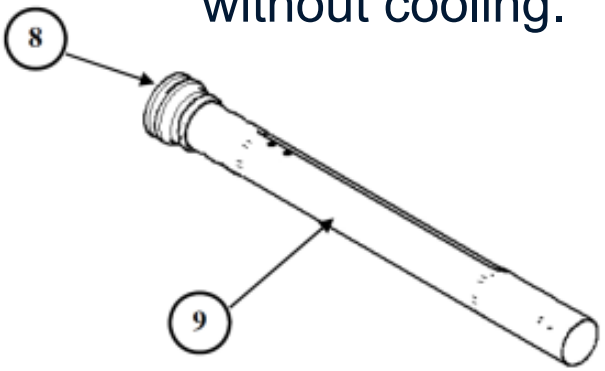
Step 3. Insufficient gas pressure. Check for caked carbon in Gas Block (4), Piston Cup (6), 3 Grooves (5) of Piston, and internal Grooves (8) of Gas Cylinder Assembly (9).
Clean and lubricate, as required (See SW370-CH-OPI-010).



Not necessarily insufficient pressure, but excessive interference due to copper fouling build up - based on failures to cycle (short stroke) after 1,200+ rounds without cooling.



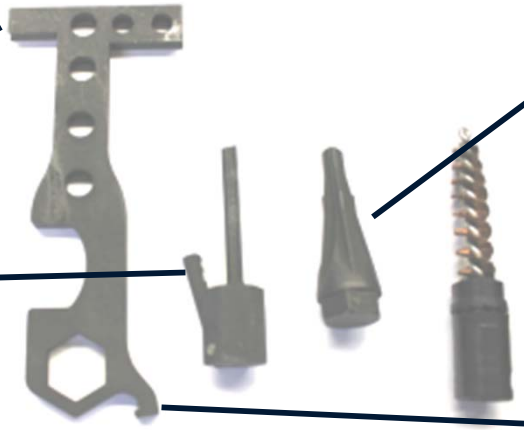
Add Cleaning Feature Rings at Arrows – larger diameter than Sealing Rings



- Self Cleaning Feature Concepts.
- Alternative would be convert to short stroke gas piston (similar to ULTIMAX 100).
- HBN on projectiles can reduce bore fouling.

NOTE
DO NOT lubricate chrome area of Gas Block (4), Piston (6), and internal grooves (8) of Gas Cylinder Assembly.

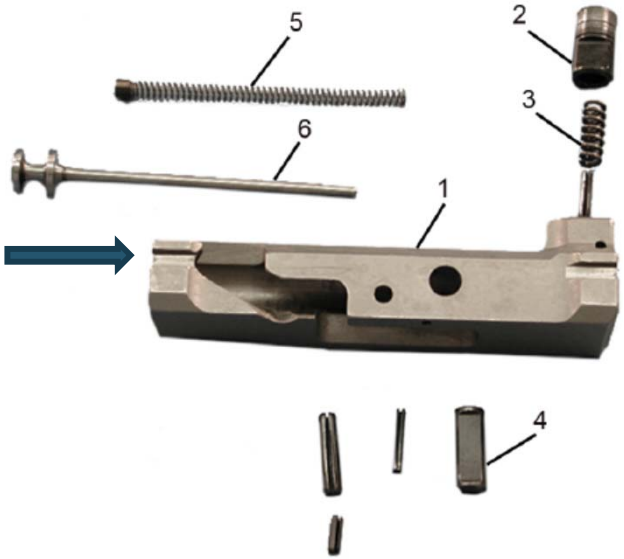
Minimize Need for Special Tools



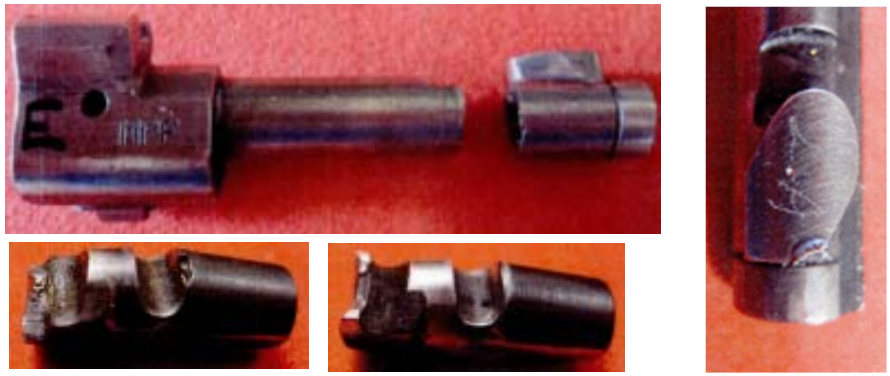
- Attempt to reduce need for scraping by design
  - Gas System / Muzzle Device.
- Gas system scraping every 1,200 rounds/barrel.
- Flash suppressor scraping every 6,000 rounds.
- Remain aware of any design change impacts to cleaning tool configurations.

MK48 MOD1 Parts Replacement

Cartridge Guides replaced at **45K** rounds



Slide Assembly replaced at **30K** rounds (to avoid breaking cam lug stop tab – see arrow) Nested Spring Pins fail on occasion before 30K rounds (similar issue with piston retaining pins).



Bolt Assembly replaced at **15K** rounds to avoid breaking in front of cam lug.

Consider Design / Material / Process Changes.

MK48 MOD1 Ejector Issues

CAUTION

Tip of cartridge ejector must be well defined to ensure proper ejection. Cleaning rods can easily damage cartridge ejector tips when they are used to ensure weapons are cleared.

STEP 1. Check for chipped, distorted or rounded tip on cartridge ejector (1), bent, broken or missing cartridge ejector spring (2), or damaged or missing cartridge ejector pin (3).

(a) CORRECTIVE ACTION

Replace unserviceable or missing parts (see page 2-45).

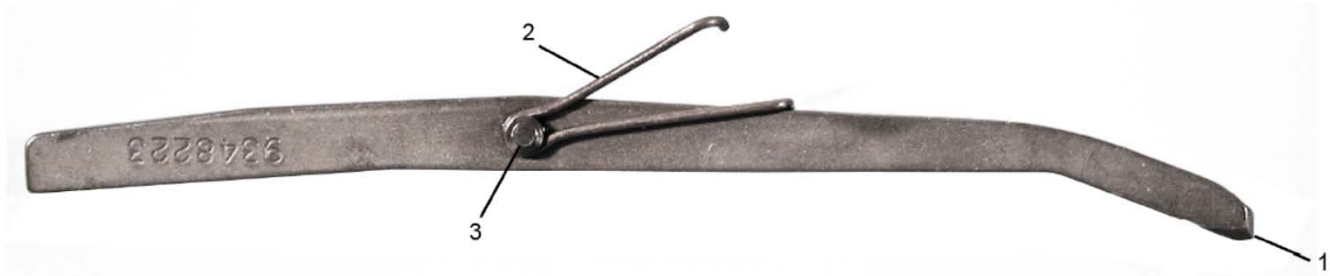


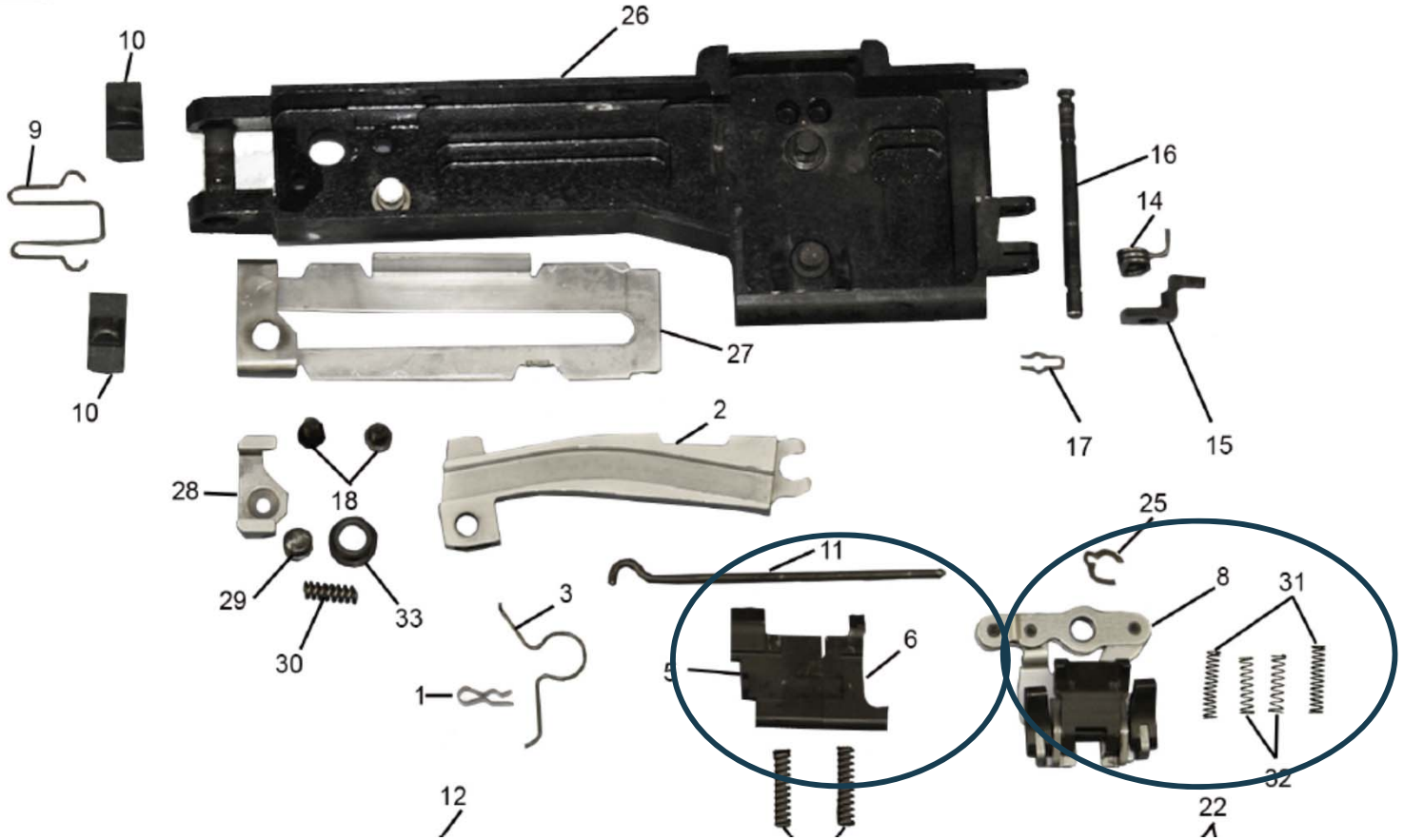
Figure 2-40. MOD 0/1 Cartridge Ejector Spring and Pin.

NOTE

Do not lubricate chrome area of piston or inside of gas cylinder assembly.

- Ejector Pins are known to fail.
- FN determined failures can be linked to deformation of ejector tip causing increased shear stress in pin.
- Materials / Process changes may be needed.

MK48 MOD1 Feed Cover Assembly

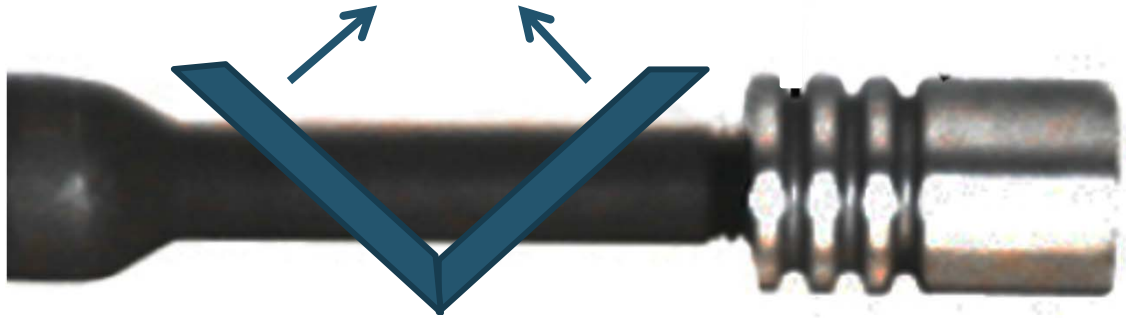


- Inspection of cartridge guides and feed pawls as well as their springs during life testing under harsh firing schedule is important (image missing rear sight assy.).

Active Cooling Fan Concept

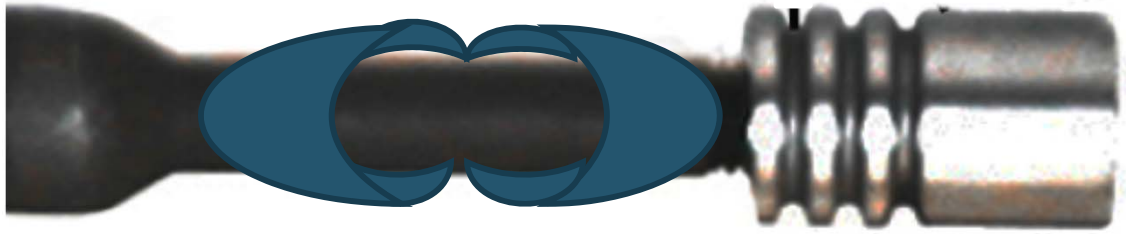
Active Cooling Concept – Reciprocating Fan
– Combine with Cooling Fins on Barrel.

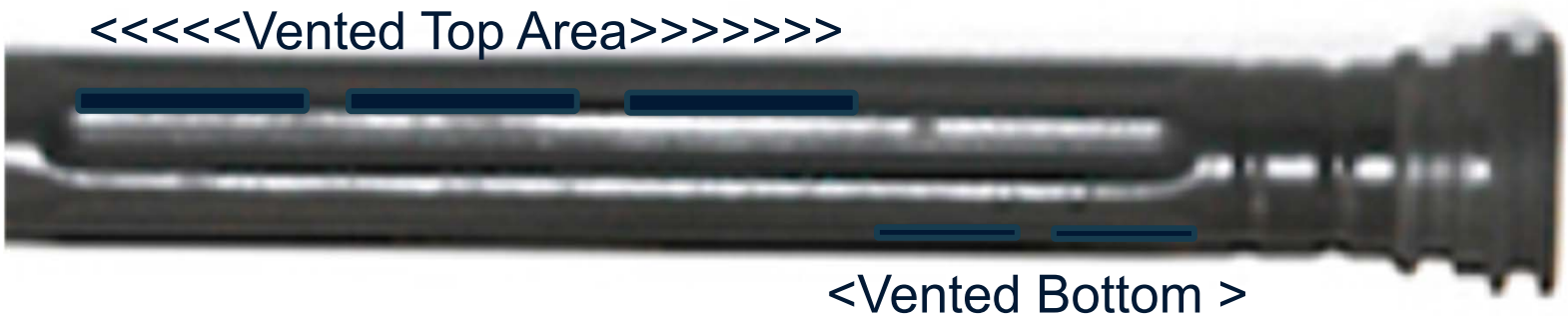
Side



Air pulses directed up toward barrel during each back and forth cycle of the gas piston assembly.

Top





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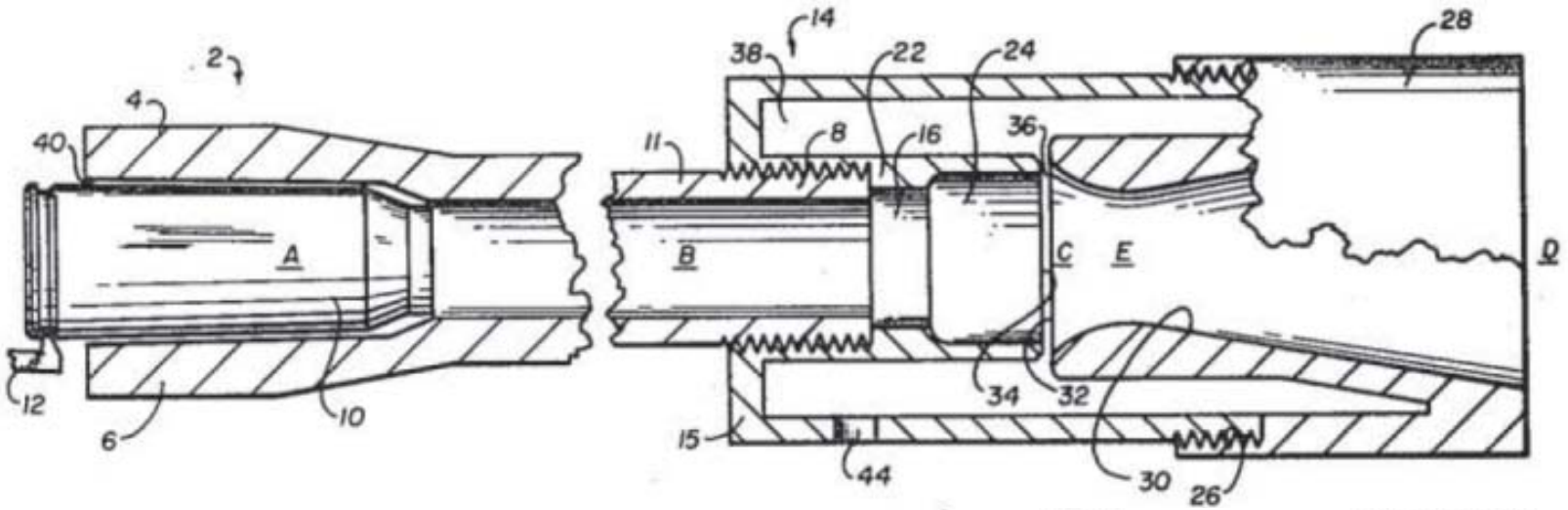
Active Cooling Muzzle Device



[54] **BORE GAS EVACUATION DEVICE FOR CANNONS AND GUNS**

[75] Inventor: **Conrad Elmer Heiderer**, Huntington Woods, Mich.

4,024,790

May 24, 1977

[57] **ABSTRACT**

A bore gas evacuation system for large and small caliber guns, especially when used in combat vehicles, and employing apparatus carried by the gun barrel and constructed to utilize the Coanda effect to enhance flow of ambient air through the barrel.

that required with prior art systems. Holes need not be drilled in the gun barrel. Component requirements are reduced to a minimum. The operation of the system of the present invention is independent of the time cycling of the recoiling components of the gun. Adaption of the apparatus to existing weapon systems, including automatic weapons, is relatively simple and easy to apply. In this regard, the existing design of the breech or receiver components is unaffected. In addition, the apparatus of the present invention performs a gas flash suppression function by minimizing gas buildup adjacent the muzzle of the gun.

- Bore Evacuation Muzzle Device (Inconel) would add cooling and reduce flash – especially from sustained fire.
- There is also a Patent for a Bore Evacuating Sound Suppressor.

Potential Use of DSL and Polymers

Consider Army Durable Solid Lubricant (DSL):

- Provisional Patent - Diamond Like Carbon (DLC)
- Applied by Plasma Vapor Deposition Process
- Promising Results from M4 Evaluations
- Should withstand up to 800 deg. F
- Must be applied to base metal
- Army is doing M240L and more M4 Testing

Alternative - Tungsten Carbon Carbide (WCC)

DSL15,000 rounds fired dry compared to CLP lubricated Manganese Phosphate Carrier

Energy Absorbing Material may be integrated into transfer mechanism to reduce ROF and system "Wear and Tear", improving reliability and parts life. Note: MK46 / M249 and MK48 all use same hydraulic buffer.

Bolt Cam Lug to Slide Stop Lug - could integrate energy absorbing material at contact / interface to reduce peak force / stress levels during unlocking event.

MK48 Upgrade Developmental Testing

Tests Included in Test Plan – MK48 Sustained Fire Upgrade -

- Dispersion – single fire and burst (100, 600, 1,000 yards).
  - Test for Dispersion/ POI Shift with Barrel Cold and Hot.
- Muzzle Velocity – check to correlate with barrel wear rates.
- Rate of Fire / Belt Pull – document effects of any design changes.
- Cook-off / Barrel Temperature – cooling feature benefits check.
- Endurance at two firing rates High (300 rpm?) and Low (150 rpm?) for how many rounds / minutes until cooling/ (10 min. at High would be 3,000 rounds and 20 min. at Low would also be 3,000 rounds).
  - Track Reliability MRBS / MRBF.
  - Check all characteristics at Baseline and then every 5-6K rounds.
    - Headspace, Spring Lengths and Rates, Dispersion, ROF, Reliability (at all times)
    - Perform Laser Bore Mapping Examination every 5-6K rounds
- Thermal / IR / Visible Signature / Flash
  - Check Barrel Temperatures and Rounds to Cook-Off Conditions
    - Goal to reduce steady state barrel temperature during sustained fire
  - Confirm Fore-grip is safe to hold for duration of sustained firing.

MK48 MOD1 FN MK3 Upgrades

MINIMI® MK3 Upgrade Kit

MK3 Kit Upgrades: Double Bent Sear - improves safety aspects, Lower cost / stronger bipod, ergonomic charging handle, larger trigger guard, adjustable buttstock, improved feed cover retaining latch, and handguard/rail upgrade.

MK48 MOD1 - FN MK3 Upgrades

NAVSPECWARCOM MK3 Kit Feedback -

- Improved MK48/46 MK3 Bipod -apparent durability issue.
  - Need improvement for feet (non-sinking).
  - Retention in stowed position needs improvement.
- Double Bent Sear – Untested – Need Safety Release.
- Improved Feed Tray Latch & Spring – Untested.
- Improved Buttstock – Good (not tested for durability).
- Improved Charging Handle – Good (could use more roughness).
- Improved Trigger Guard – Good.
- Naval Special Warfare Command will support MK48 MOD1 Upgrade future User Assessments (Camp Billy Machen, CA).

NTW-20 foot

MK48 Dispersion Evaluations

e. Dispersion. The extreme spread of a ten-round burst fired from the machine gun shall not exceed 30 cm at 100 meters. This is required for both the assigned and spare barrels (MIL-M-63314D/and 4, para 3.4.3.2.2).

d. The three MK48 machineguns as tested passed the requirements of having an extreme spread of less than 30 cm (12 in.) as shown in Table 2.1-6. Data for the M240E6 machineguns were unavailable and could not be assessed.

Test MK48 Upgrade from firing fixture as well as from bipod with alternate rear supports.

Navy MK48 MOD0 Fixture Mounted Dispersion Test Configuration.

TABLE 2.1-6. EXTREME SPREAD RESULTS FOR THE MK48 MACHINEGUNS

Gun No.	Barrel, cm	
	A	B
1	15.6	19.5
2	16.0	22.3
3	21.0	23.7
Average	17.5	21.8

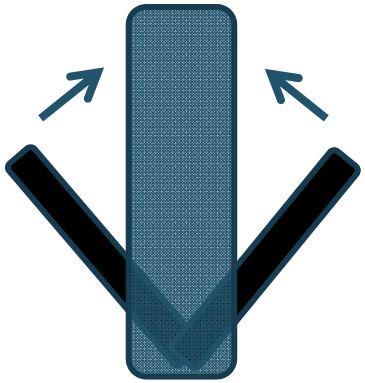
(Army Test Results)

Dispersion Reduction

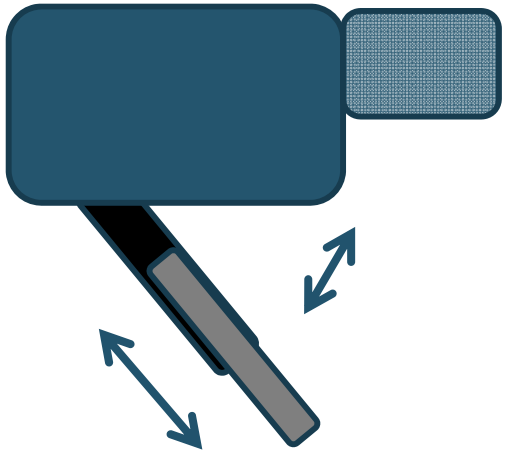
- Considerations for Dispersion Reduction and Evaluation.
  - Consider Tightening Barrel to Receiver / Gas Cylinder Fit.
    - reduced dispersion potential.
  - Consider Adding “Swing Capable” Rear Monopod.
    - Improved stability and control.
  - Reduce ROF.
    - Improved control / reduced rate of heat input to barrel.
- Compare Baseline to Upgraded MK48.
  - Fire single shots, and 5 and 10 shot bursts - or 6 and 9 round bursts which have been found optimal in the past for LMG’s.
    - From Test Fixture.
    - From Shoulder Prone with Bipod.
      - Rear Supports – Hand, Monopod, Firm Sandbag.

Rear Monopod to Support Reduced Dispersion

Polish UKM-2000/2013 7.62mm NATO with Folding Rear Monopod/Grip – Major adaptation of basic PKM design to use push through M13 links – Reliable.



Rake Target Area Keeping Set Elevation



Accu-Shot Monopod – Mil-Std 1913 Rail Mounted

NTW-20 rear monopod

Consider Folding Monopod Concept with added telescope and swivel capability for Removable or Integral Option for Telescoping MK48 Stock.

1970's LMG Study Results

A Study of Operational Testing applying results of Improved SA Test Procedures and Expansion of Test Facilities

INFANTRY WEAPONS TEST METHODOLOGY STUDY

FINAL REPORT

VOLUME III

LIGHT MACHINE GUN TEST METHODOLOGY
UNITED STATES ARMY INFANTRY BOARD
FORT BENNING, GEORGIA 31905

LMG practical max. 100 rpm and MMG 250 rpm

Excerpt from MMG Definition Page A-1-2

"Even when several interchangeable barrels are available, a gas-operated medium machine gun is seldom capable of sustained fire of more than 6,000 rounds per hour actually delivered. The water-cooled varieties on the other hand have been known to fire up to 15,000 rounds per hour, because of their more efficient but far bulkier and heavier cooling systems.

Excerpt from LMG Definition Page A-1-1

"The light machine gun is capable of use by a single man under emergency conditions. Normally, however, it is operated by at least a two-man crew, the gunner and an ammunition carrier who feeds the weapon. Furthermore, it must be recognized that this form of weapon uses ammunition at such a high rate under combat conditions that it really requires additional support in the form of reserve ammunition carriers or providers.

LMG Study - Measures of Effectiveness (MOE's)

From page G-2-5 of Annex G / FR Vol. III LMG TM

- Fire Support Element - Measures of Effectiveness (MOE's)
  - (most have multiple elements – only most important listed)
  - Accuracy – Hit Probability Per Trigger Pull
  - Responsiveness – Time to Shift Fire
  - Sustainability – Hits per Pound as % of Basic Load
  - Reliability – Number of Rounds Between Malfunctions/Stoppages
  - Portability & Compatibility
  - Signature Effects
  - Stability

MG evaluations must be oriented toward combat tasks and actions required of system on battlefield.

Of the 3 rates of fire (cyclic, rapid, & sustained) rapid is preferred and must be maintained at least until fire superiority is achieved 6-9 round burst every 1-2 seconds. Pg. A-3-2.

A good optic and closed bolt semi-auto capability combined with solid bipod and rear monopod could significantly improve LMG performance against several MOE's.

MK48 Upgrade User Assessment

- **Operational / User Assessment – MK48 Upgrade.**
  - Prior Lessons Learned.
    - 6-9 round bursts - optimal for bipod fire.
    - Test Accuracy with individual shots also.
  - Test with and without rear monopod support.
  - Realistic Scenarios / Targets near to far.
    - Use of Optics (1 or 1.5X near and 4 or 6X far).

- Dispersion – single fire and burst (100, 600, 1000 yards?).
- “Break Contact” Drills and other practical exercises.
- Sustained Fire Actions (Check Times and Temperatures).
- Consider using MK48 MOD1 as Baseline (future M240L comparison?).
- Get M80A1 ammunition to include in both UA and DT.

MK48 Upgrade Summary

- Summary: MK48 MG Sustained Fire Upgrade.
  - Receive Improved MK48 Barrels from Army.
  - Test barrels along with associated upgraded parts and cooling modifications (DT).
  - Refine changes as necessary to optimize.
  - Provide optimized prototype for User Assessment.
  - Use DT/UA results to guide additional efforts
  - Get a Safety Release and quantity of MK48's upgraded for sustained fire & further evaluations.

Future LMG Thoughts with a View to the Past

- *Past & Future? Light Machine Gun Features.*
  - *Closed Bolt Semi-Auto and Open Bolt Auto-Fire Operation.*
    - *Improved Precision Potential Semi-Auto, Rifle Level Performance.*
    - *Optimized Cyclic Rate of Fire (Adjustable w/o change to op. sys.).*
  - *High Sustained Fire Barrel (consider adding phase-change material).*
    - *Alternate Barrel Configurations – Weight/ Length/ Suppressed.*
  - *Highly Ergonomic / Versatile.*
    - *Suitable for Optics / Accessory Compatible.*
  - *High Reliability, not dependent on Wet Lubrication.*
    - *High Tolerance for Sand / Mud / Salt Water / Rough Handling.*
  - *Optimized Bipod and Rear Monopod Features.*
  - *Belt Feed (from 50/100/150/200 round semi/soft packs).*
- ***QUESTIONS ? and / or we get into more U.S. & MG History…***

Turn of the Century Firearms and Tactics

MODERN IMPROVEMENTS

IN FIRE ARMS AND THEIR TACTICAL EFFECTS.

BY

Captain J. T. Dickman, 8th Cavalry.

Instructor, Department of Tactics.

SEPTEMBER 26, 1902.

Of the two hundred and fifty thousand soldiers assembled at various camps in the United States within a few months after the outbreak of the *Spanish-American War*, all but the regulars and one regiment of volunteer cavalry were armed with the Springfield rifle, caliber 45, single loader, and firing black powder.

The history of portable fire arms shows a continuous reduction of caliber, from over three quarters of an inch in 1630 to one quarter of an inch in the most modern rifles. For various reasons it is believed that the limit of reduction has been reached with rifles of 6.5 mm. caliber, (about one quar-

While the benefits of smokeless powder, small caliber / high velocity, and magazine feed rifles were beginning to be obvious, it took longer still for the U.S. to establish that automatic machineguns were highly advantageous in battle.

Turn of the Century Firearms and Tactics

A TACTICAL EVOLUTCON.

Lecture and Demonstration before the Faculty and Students, General Service & Staff College, September 26, 1903.

—BY—

CAPTAIN JOHN H. PARKER, 28th INFANTRY, U. S. A.

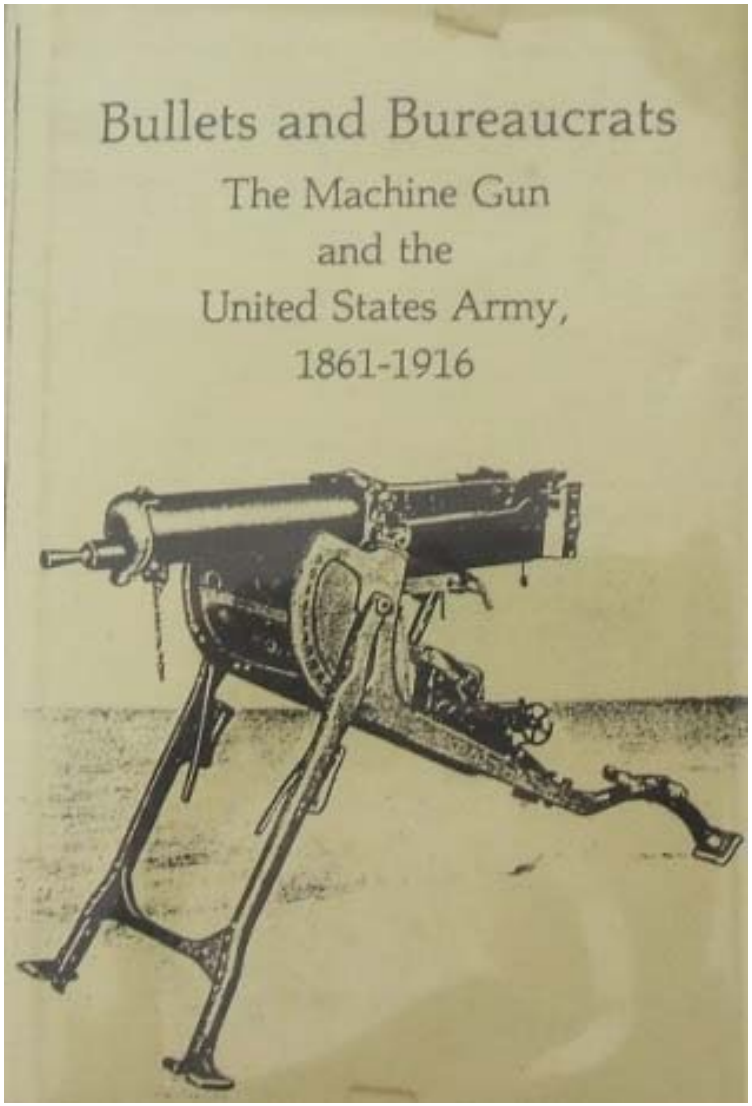
Gentlemen:—

The subject we are to consider today is a proposed system to meet two pressing tactical problems of the Infantry service. These problems are;—

1. Ammunition supply for the firing line in battle.
2. Fire concentration.

Captain Parker goes on to propose that if enough ammunition can be made available within the zone of rifle fire, that a machinegun can be worth it's weight in ammunition. He mentions that the Maxim, Gatling, and Colt Automatics have all proven reliable, accurate, and effective. The War Dept. determined that a squad could perform ammunition supply and machinegun service for an infantry battalion (executive order as legal authority). This would include 3 pack mules and a cart with one gun and 7,500 rounds.

The MG and U.S. Army 1861 - 1916



An interesting book written by David A. Armstrong, published in 1982.

"Like the airplane, the machine gun was, in its final form, a novel weapon, but particularly in its early versions, it was not markedly different from conventional artillery pieces"

"the machine gun became a sort of military oddity – a weapon that had considerable power, but did not fit established tactical and organizational concepts." (pg. xiv)

With the above quotes in mind then it is not hard to see how artillerymen came to view the MG as an inferior artillery piece instead of a superior rifle.

The Franco-Prussian War showed that the MG could not be effectively used as an artillery piece (2,000+ yards).

The Spanish-American War was a wake up call for U.S. modernization. The MG best supports infantry!

Page 197 Provisional MG Firing Manual 1917

There is nothing so harmless as a disabled machine gun.

C. SUMMARY.

204. *Powers.*	*Limitations.*
Smaller sheaf fire more accurate than Infantry and more easily controlled. The ballistic properties are the same as those of the rifle.	Small sheaf demands precise adjustment of fire and can be directed at but one point at a time.
Each gun represents an instantly available reserve of fire power equal to from 30 to 60 rifles. This permits fire to be delivered from a restricted front at a high rate.	Can not be used continuously in a prolonged fire fight. Ten to fifteen minutes' continuous firing is about the limit of its opportunity or capability at any time.
With ammunition at hand, the fire power is undiminished so long as there remains a man unwounded who can operate the gun.	The mechanism of the piece is delicate and is readily disabled by hostile fire or by a lack of a suitable supply of cleaning and lubricating material.
Its mobility is such that it can operate over any terrain accessible to Infantry or to Cavalry.	Heavy losses of personnel destroy mobility in battle; those of pack animals, mobility in march or maneuver.
The moral power of the gun lies in its prestige, in the sound of its fire, in its surprise action, and in its ability to produce many casualties in a short space of time.	The gun is limited to fire action. There is lacking the threat of the bayonet. A disabled gun is at once an encouragement to the enemy and a discouragement to our own troops.

Progress Toward Cartridge / Automation

1854 Treeby (British) – continuous chain feed progress toward belt feed concept -Lever rotated to seal percussion chamber to barrel

1855 Colt Revolving Rifle – Hazardous - may have stunted U.S Military Adoption of multi-shot and rapid-fire individual arms. (per Col. Chinn)

1848 Walter Hunt develops first self contained cartridge “Rocket Ball” and Volition Repeating Rifle lever gun to fire it at 56 ft-lbs KE. Still required percussian cap

Hunt’s Toggle Action in Henry and future Winchesters (‘66,’73,’76)

1860 Spencer - .56-56 Rimfire – Reasonable Muzzle Energy – 7 shot Lever Action Rolling Block.

1855 Volcanic Repeating Arms Company formed to improve ammunition (added “primer”) and further develop the action – Smith & Wesson and Winchester form from Volcanic.

1857 Horace Smith creates copper case .22 Rimfire (Short) Cartridge – Derivative of French Flowbert .22 BB Cap.

1860 Henry – 16 Shot .44 Rimfire – Marginal Muzzle Energy 216 grain bullet over 25 grains black powder.

Manual MG move toward HMG Concept

1851 Mitrailleuse -Belgium (service 1866 France)– "Grapeshot Shooter" (multi-bore barrel) 1858 French Rifled field guns not good for Shot.

1870's Nordenfelt (Sweden)– linear multi-barrel / toggle feed.

1861 Agar – "Union Repeating Gun" / "Old Coffee Mill".

1874 Gardner Gun – Pratt and Whitney (1885 water cooled 2 barrel shown).

German Maxim MG08 – Cooled with recirculated water.

Browning / Colt 1895 – Air Cooled 5K round Barrel.

1862 (Pat.) Gatling – Rotary, Single Feed, 1 bolt per barrel.

Hotchkiss Air Cooled – Heat Sink / Radiator.

M1917 Browning – Water Cooling provided excellent sustained fire capability -design available from 1910 (considered a Heavy MG at time).

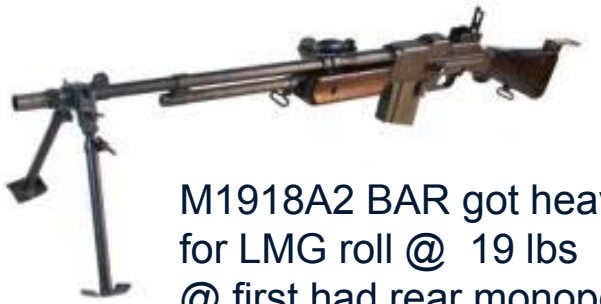
Post WW I into WW II Light Machine Guns

1922 6.5mm Japanese Type 11 (Nambu) Hopper Feed @ 22.5 lbs.

1928 - Russian DP28 Pan Feed @ 20.1 lbs.

1926 Cz Zb 26 @ 21.3 lbs – Quick Change Barrel.

MG13 1930 (air cooled version of Dreyse 1918 MG) 26.4 lbs 750 rpm (100 rpm sustained) top of trigger allows for semi-auto firing.



M1918A2 BAR got heavier for LMG roll @ 19 lbs @ first had rear monopod - ROF selectable.

1938 BREN .303 British @ 22.8 lbs (Cz ZGB 33).

Furrer M25 7.5X55mm Swiss @ 19 lbs 450 rpm.

Select Fire 250-950 rpm

1946 Dror “Liberty” (Israel) @ 22 lbs Pattern 2 8mm, last version of 1941 Johnson LMG.

WW2 Era to 1957 LMG's

1934 – MG-34 Primary German GPMG entering WW2 and first true GPMG (used in Lafette Mount for Medium MG Role) Select Fire by finger position on trigger @ 26.7 lbs.

RP-46 Belt fed version of DP @ 25.6 lbs.

MG-42 7.92X57mm @ 25.5 lbs
1,200-1,500 rpm -Very Suppressive.

1937 Japanese Type 99
Quick Change Barrel
7.7X58mm Arisaka.

Cz Vz 52 LMG – Rear grip slides forward and back to charge 7.62X45mm & 7.62X39mm Mag. or Belt feed.

Chatellerault M1924/29 – fire 400 rounds & cool.

AR10 LMG – 1957 7.62mm.

First U.S. Government Design GPMG

FG-42 @ 10.3 lbs Automatic Rifle Select Fire - Fallschirmjager Gewehr – Semi Auto Closed Bolt / Full Auto Open Bolt.

USA T44 - 14 lbs @ 500 rpm – FG-42 Action and MG-42 Belt Feed Evolved into M60 GPMG.

MG-42 as MMG – not suited to aimed offhand fire as LMG.

1957 M60 GPMG @ 23.2 lbs.

MK43 MOD0 @ 20.8 lbs.

Intent for M60 - replace BAR & M1919A6 in SAW role and M1919A4 in MMG role. It could be shoulder fired from standing unlike the M1919A6, but was still not optimal as a SAW and the MINIMI® / M249 eventually replaced it there, with M240 Series later filling the GPMG role.

Progression Toward Intermediate Caliber - LMG

Furrer Model 1921 (Swiss) ”pistol-rifle” 7.65X35mm select fire, toggle action.

Ribeyrolle AR M1918 - 8X35mm @ 11.2 lbs (blow back 400m range) France - .351 Win. based cartridge.

Stg / MP44 – 7.92X33mm @ 10 lbs.

Weibel M32 7X44mm (Denmark).

AK47- 1947 7.62X39mm @ 11 lbs.

AR15/M16 – 5.56X45mm @ 6.8 lbs.

AKM – 7.62X39mm @ lbs

RPD – 1946 7.62X39mm @ 16.3 lbs.

Army BRL XM106 – only mag fed SAW contender. (1979 trials +FN,HK, & Ford).

1945 British goal of 600 yards – study determined .280/30 (7X43mm) 140gr. @ 2415 fps would be good.

U.S. 6X45mm SAW 1970’s

Modern 5.56mm LMG/SAW Comparison

Stoner 63A / MK23 @ 11.7 lbs
U.S.A. First Modular MG.

1967 Colt CMG-2

Orig. 1984 @ 16.5 lbs

Para
+ MK46 belt fed only

M249 SAW /LMG Belgium / U.S. made.

KAC Stoner LMG/SAW
550 rpm @ 10 lbs.

Vektor Mini- SS 1994
conversion from SS-77
South Africa @ 18.2 lbs.

ULTIMAX 100 MK4 / Singapore – "Constant Recoil" MK4 @ 11.7 lbs.

– MK8 IAR Contender

FN IAR/HAMR

M27 IAR - Infantry Automatic Rifle USMC @ 8 lbs.

ARES-16™ AMG-2
Mag/Belt Feed @ 7.5 lbs.

Galil ARM replaced in 1997 by NEGEV LMG Israel
(overheated easily)

Colt M16 LMG / LSW
5.56X45mm @ 12.7 lbs
Open Bolt / Full-Auto only.

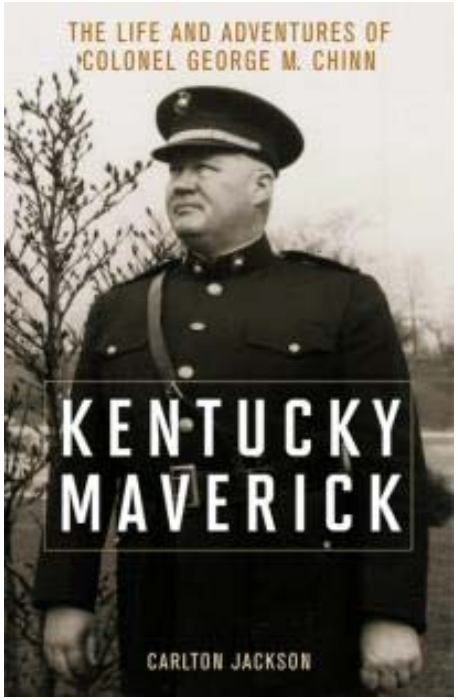
Modern Upgrade>> 6.5 Grendel

CETME Ameli MG82
850-1,200 rpm @ 11.7 lbs.

HK MG4

Colt IAR™/6940 @ 9.5 lbs.

1951 Contributions of Colonel Chinn



1962 Honeywell HMGL, Navy MK 18 MOD 0 – the last hand powered machinegun?…

The Machine Gun
History, Evolution, and Development of Manual, Automatic, and Airborne Repeating Weapons
by
George M. Chinn
Lieutenant Colonel, USMC
VOLUME I OF FIVE VOLUMES

Preface

With the belief that the next best thing to actual knowledge is knowing where to find it, this research has been compiled by the Bureau of Ordnance, Department of the Navy, in order to place in the hands of those rightfully interested in the art of automatic weapon design, the world's recorded progress in this field of endeavor.

So great a period has been covered on a vast and controversial subject, with practically no precedent to use as a guide, that the sum total of this effort must be regarded somewhat in the nature of an experiment.

While nothing is claimed for this volume except that it is the result of tedious and laborious research, it is believed that in some manner it will help point the way to a better understanding of past development. In so doing, it should help to reduce pitfalls that beset the designer traveling an otherwise dimly lighted path.

Beardmore-Farquhar 1924 British MG's – Bad Timing / Great Advertising

SPECIAL FEATURES.

It is the lightest Machine Gun.

It is the cheapest to manufacture.

It is the cheapest to use. Owing to the Spring system there is less strain on the working parts, and there are, therefore, fewer breakages and fewer spares are required, than with any other Machine Gun.

It cannot jamb. If any sort of failure occurs, due to defective ammunition or other cause, it can be cleared without dismounting any part of the gun.

It has perfect breech locking, and cannot be fired until the breech is locked.

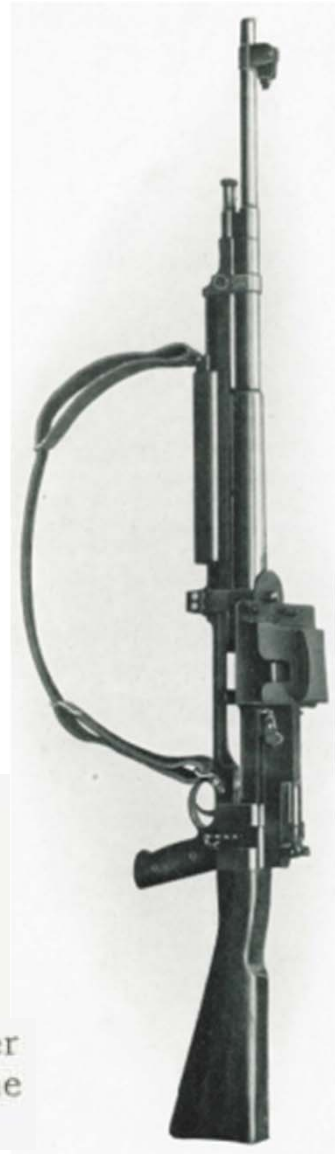
It is well protected against the entrance of dust and mud.

It can be used without any oil, and is, therefore, not liable to go out of action through freezing at very low temperatures or high altitudes.

The Automatic Mechanism is never lubricated. It is not affected by the heat of the barrel, and will continue to function even though the barrel be kept red hot by continuous rapid firing.

Weight of Gun complete with mounting ...	15½ lbs.
Length of Gun	47⅝ inches
Length of Barrel	26 inches
Weight of Barrel without attachments ...	3½ lbs.

The normal rate of automatic fire is about 450 shots per minute. This rate can be increased to over 1,000 by increasing the strength of the main spring and bolt-closing spring.



1924 Beardmore-Farquhar Bonus Configuration

The "BEARDMORE-FARQUHAR" is a one-man machine gun, just as a rifle is a one-man weapon. The magazines, magazine catch, and other controls are designed and arranged for the convenience of the firer and not of an assistant whose position, as in practice with other light machine guns, is dangerously conspicuous.

Novel Mechanism uses gas piston to compress spring which is then released to cycle action – easily adjusted for whatever ROF desired.

BEARDMORE-FARQUHAR ·5-inch MACHINE GUN.

READY FOR ACTION.
MAGAZINE CAPACITY
29 CARTRIDGES.

.5 Vickers - 12.7X81mm (left vs. BMG)

The butt-stock is of steel tubing screwed into the body cap. It has a steel shoulder piece and an arrangement for absorbing the shock of recoil.

Weight of the .5in. Gun complete with field mounting 37¾ lbs.

Length, with 35in. barrel, complete with field mounting 61 inches.

Future LMG Ammunition & Mechanism

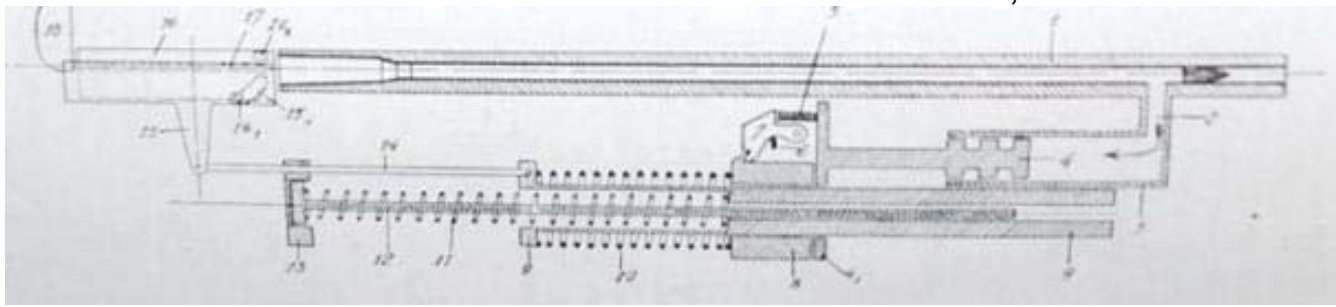
- *6.5mm (.260 Rem. or 6.5 Creedmoor @ 1,200m + or .264 USA @ 1000m).*
  - *Polymer Case or Case-Telescoped Options, Polymer Coated Projectile (or Polymer Driving Band) –Cooler & No Copper Fouling.*
- *300m Optimized Belt Fed – 10 in. barrel – 5.56 MARS / .300 AAC Blackout (Whisper).*
- *Optimize Cartridge - Propellant Additives / Ablative Cooling.*

High Pressure- 6mm "Unified" ~80 grains @ 3,700+ fps, 1500m Accuracy claimed.

Russian "Unified" LMG – integrated Optic 6X49mm.

Army LSAT LMG @ 10 lbs w/ Case-Telescoped Ammunition @ 20.4 lbs **less** than M249 - both with 1,000 rounds.

30mm GAU-8 Plastic Driving Bands – should consider for small arms rounds to increase barrel life/ reduce heat & fouling.



"Nyclad" type pistol rounds work well.

Beardmore-Farquhar: Next best thing to "Constant Recoil"? Could work with multiple springs to ramp up rate near end of travel / shorten length of travel for 7.62mm NATO energy.

MK48 MOD1 - Sustained Fire Upgrade

Dave Armstrong
Mechanical Engineer
Expeditionary Weapons Branch
Crane Division, Naval Surface Warfare Center
Small Arms Weapon Systems Division
Special Warfare and Expeditionary Systems Department
300 Highway 361
Crane, IN 47522-5001
Ph: 812-854-5731
DSN: 482-5731
Fax: 812-854-1044
Email: david.armstrong@navy.mil