Lubricant Evaluation Program Analysis

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ABSTRACT:

Unsubstantiated reports from Operation Iraqi Freedom led to a tasking for the Army Research Laboratory to evaluate and test the small arms lubricants currently in the Army system along with a list of candidates. After reviewing the required lubricant specifications and conducting pilot tests for designing the experiment, testing commenced. The test's goal is to produce qualified candidates meeting laboratory test specifications and performing comparable to currently fielded products, and adding those to the Qualified Product List (QPL). The experiment included simulating a desert environment using a silica flour as a sand surrogate, along with maintaining a constant temperature of 105 degrees Fahrenheit for the duration of the test. The analysis uses a method for recurrence data (recurrences are weapon failures) where the recurrence times may not be statistically independent. Specifically, the method develops a mean cumulative function (MCF), which represents recurrences for a population of systems (weapons). It facilitates simple nonparametric visualizations of the data, nonparametric confidence intervals for the MCF, and the ability to conduct a comparison of two samples of recurrence data.

KEY WORDS: Small Arms, Lubricant, Recurrence Analysis

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1. Background

Due to conflicting reports on lubricant performance in OIF, GEN Kern, Chief AMC, tasked ARL to conduct a test of small arms lubricants. The test involves verifying the current military spec, and testing the currently fielded lubricants (Breakfree and Royal) against the spec. Upon completion of this initial test, 23 candidate lubricants will be compared to those currently in use. The purpose of the test is to find candidates that performed better than the baseline lubricants. These candidates will be added to the Qualified Product List (QPL) for additional testing and consideration for fielding. In addition to firing, lubricants underwent a health hazard assessment and required laboratory tests.

2. Testing

After conducting a pilot test for procedure verification and analysis verification, testing commenced. The test consists of firing seven cycles of 10 new/refurbished M16s per candidate. Each cycle consists of 120 rounds, or 4 full magazines. Prior to firing the weapons, the candidate lubricant was applied per manufacturer's specifications. To simulate the OIF environment, weapons were initially put in a dusting chamber for 30 minutes before firing the first cycle. For each subsequent cycle an identical 30 minute dusting occurred. Weapons were not cleaned nor lubed between cycles, and the temperature for dusting and firing was controlled at 105°F. Magazine to weapon assignment use a randomization scheme to reduce possible bias in results. Photos of the process are provided at the end of this report.

3. Data Collection and Analysis

3a. Collection

Failures were classified by the following:

1. Failure to feed
2. Failure to extract
3. Failure to fire
4. Failure for bolt to remain in the rear position

Failures were annotated by cycle, round count, and magazine for each weapon. In addition each failure was typed Class 1 or 2 failure. A class 1 failure could be corrected by immediate action, class 2 required additional maintenance support. The testing facility compiled the data for each lubricant candidate fired, and provided it in the form of an excel spreadsheet to the analysts. An example of compiled data is provided in figure 1 below.

M16A2 Rifle Wpn. No.	Cycle	Malf.	Mag. No.	Mag. Seq. No.	Mag. Rd. No.	Test Rd.	Remarks
81	2	FFD	26	1	2	122	**Lub. Type X**
		FFD			3	123	
		FFD			29	149	
		FXT	20	4	13	223	
	3	FFD	12	3	1	301	
		FFD	16	4	1	331	
	4	FFD	22	1	14	274	
		FXT	40	2	25	415	
	6	FFD	25	1	4	604	
	7	FFD	18	3	1	781	
		FFD	35	4	1	811	
	Total	9 FFD 2 FXT	Class 1			840	

Figure 1: Compiled Data

3b. Analysis

The method of analysis chosen for the study involved a nonparametric model for recurrence data. This model provides simple nonparametric graphical methods for presenting the recurrence data and drawing conclusions. This method requires only minimal assumptions for implementation. The first assumption required is that there is a population of cumulative functions, in this case one for each weapon in the population. The test conducted draws a sample of systems (weapons) from the population. Defining the cumulative function for each system is a counting process, where recurrences are individual weapon failures. These cumulative functions are discrete step functions, where steps occur at weapon failures. All analysis is conducted using Microsoft Excel.

Using a random sample of *n* weapons, a Mean Cumulative Function (MCF) is created to represent the population of systems. This MCF is plotted, allowing a simple comparison between candidate and baseline data. For development of the MCF and the variance of the MCF, see Meeker and Escobar, 1998. Computation of these MCFs allows a simple test as to whether the difference is statistically significant. Additionally, confidence intervals can be created for each MCF as well as the difference of the MCFs. Figures 2 and 3 below provide examples of an MCF comparison and the difference between 2 MCFs. Note in Figure 3, for the difference $MCF_{Baseline}$ - $MCF_{Candidate}$, a pointwise approximate 95% confidence interval is also provided. Figure 3 demonstrates statistical significance over the entire round count. Similar comparisons are made for each candidate.

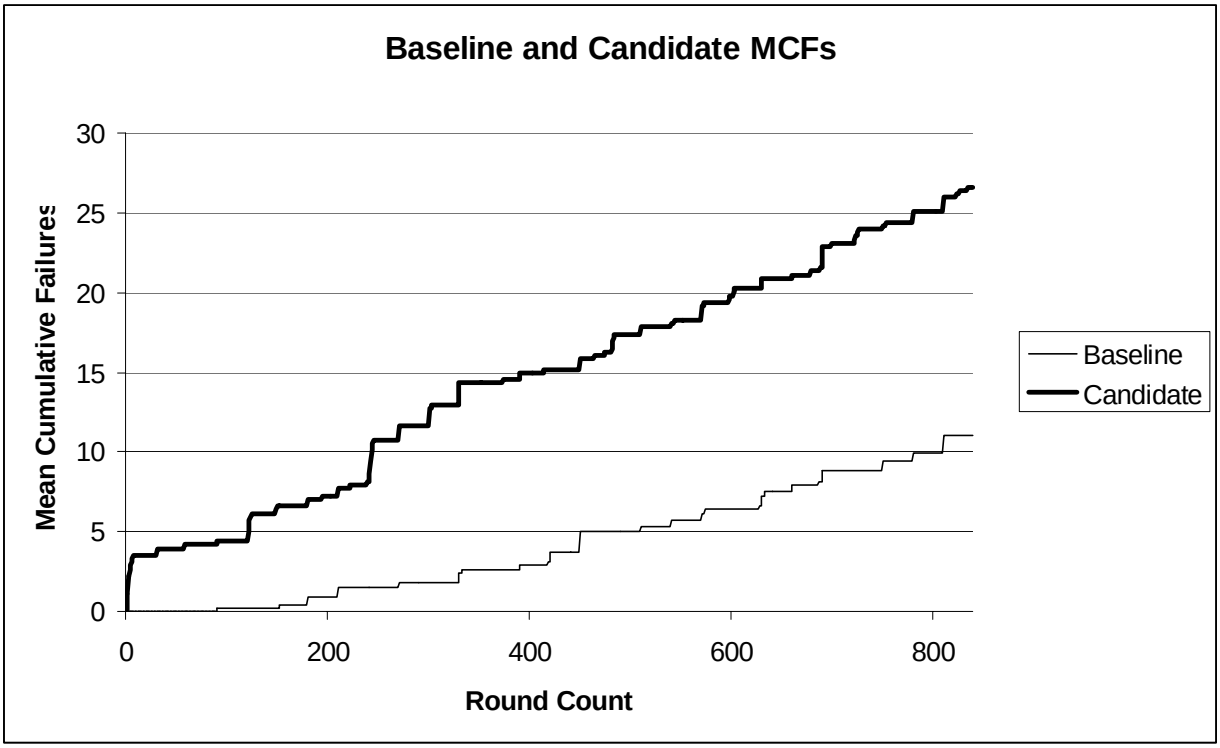

Figure 2: MCF Comparison for Baseline and Candidate

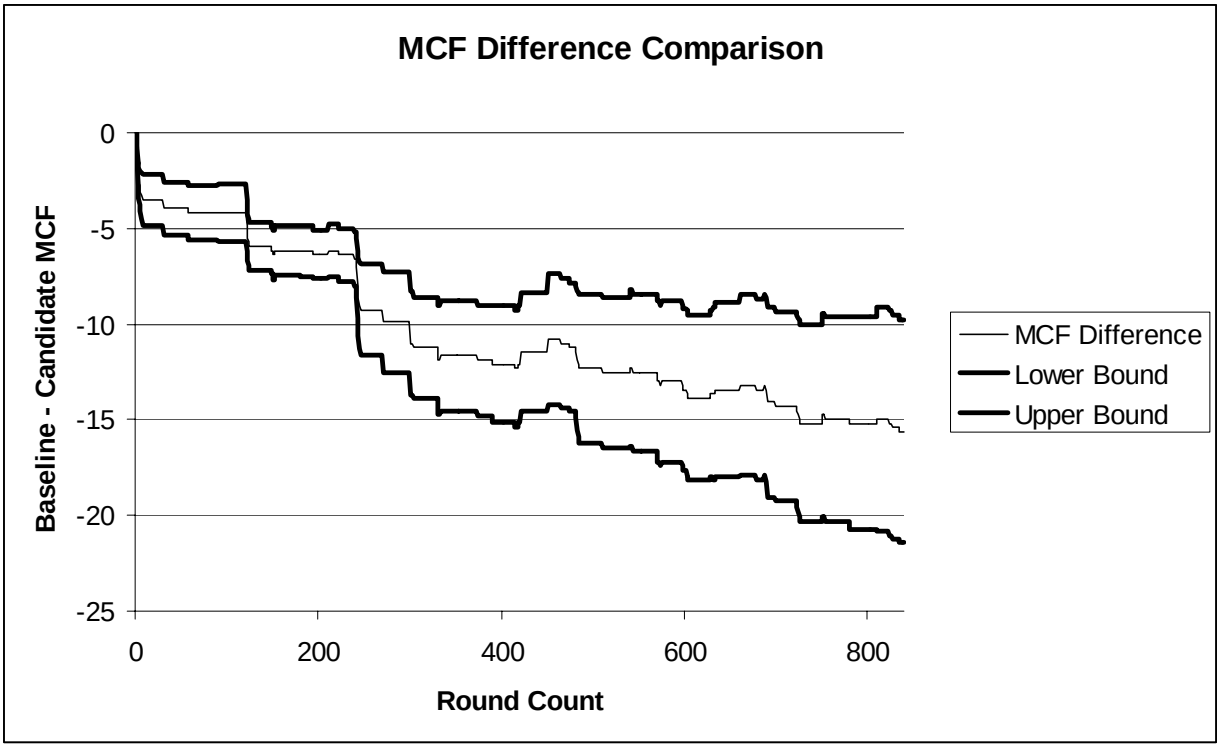

Figure 3: MCF Difference and Confidence Interval, alpha = .05

During the firing phase, early analysis occurred to determine whether a candidate test should terminate early. For a specified alpha, we calculated the MCF value at 480, 600, and 720 rounds. Using the baseline MCF, stopping rules were established for testing. The stopping rules consisted of a conservative upper bound indicating with high confidence that the candidate performs worse than the baseline.

3c. Current Progress

The program is ongoing as of the date of this report. Upon completion of firing, candidates meeting necessary criteria will undergo further testing with several other weapons. Similar analysis is anticipated for other weapon types. Due to weapons availability only candidates selected following the M16 firing will move forward for more testing.

REFERENCES

Meeker, William Q., and Luis A. Escobar, *Statistical Methods for Reliability Data*, Wiley Interscience, pp 393 - 406, 1998.

Photo #1: Weapon & magazine placement in dust chamber

Photo #3: First 10sec of dust cycle

Photo #2: Silica Flour loaded into hopper of dust blower

Photo #4: Post-dust firing from standard test mount