John Fildes, Ph.D.
Spotlight Business Consulting LLC
www.SpotlightBC.com
jfildes@SpotlightBC.com
(630) 248-0836

Background

Dr. Fildes has devised a unique small arms testing methodology that uses bench-scale testing to identify the key technical issues in a failure of intellectual property dispute followed by a limited amount of full-scale weapons testing and electrochemical corrosion assessment. Full scale testing of small arms is extremely time-consuming because thousands of rounds may have to be fired. Full scale testing is also affected by numerous uncontrolled variables such as the firing rate and the weapon has many components that move. All of the surfaces are involved in the full-scale test, which requires that each failure be examined to determine the cause. This more than anything makes full scale testing very time-consuming.

This methodology is based on pioneering R&D Dr. Fildes conducted under Army funding at the non-profit Institute of Tribology and Coatings that Dr. Fildes co-founded and led. Dr. Fildes developed a new and highly effective 3-gall on disc test method and test equipment to measure the friction and abrasive and adhesive wear resistance of coatings, the description and results of which were published in the leading tribology journal *Wear*. The approach described in this paper was used to identify a coating that has been highly effective in extensive testing by the Army for improving the abrasive wear resistance and life of small arms.

Dr. Fildes' approach uses modified ASTM methods with standard bench-scale test equipment that simulate a specific aspect of a weapon. A weapon has many moving components and many types of motion such as sliding, rolling, engagement/disengagement, reciprocation, oscillation, etc. A unique systematic framework for categorizing the motion and interaction of surfaces and for selecting bench scale test as is provided by the tribological aspect number, which is a four-digit code in which each of the four digits represent a key parameter. The first (most significant) digit indicates the type of motion, the next digit indicates the contact geometry, the next indicates the contact pressure, and the final (least significant) digit indicates entry angle. We developed the following table to identify an appropriate test framework for virtually any aspect of small arms.

Weapon Component	Type of Wear	TAN	Bench Test	ASTM Standard
Bolt				
Engagement Teeth	Sliding	1531	Unidirectional 3 Pad on Disk	Modified G99
Gas Rings	Sliding	2211	Oscillating Piston Ring Test	Modified G133
Side Walls	Sliding	2511	Oscillating 3 Pad on Disk Conformal Block on Ring	Modified G99 Modified G77
Extractor	Sliding	2211	Oscillating Piston Ring Test Block on Ring	Modified G133 Modified G77
Cam Pin	Sliding	2414/2514	Oscillating Cylinder on Flat Oscillating cylinder on Ring	Modified G133 Modified G77
Firing pin	Sliding	2518	Oscillating Cylinder on Flat Oscillating Block on Ring	Modified G133 Modified G77
Bolt Carrier				
Slides	Sliding	2514	Oscillating 3 Pad on Disk Oscillating Linear Area Contact Test	Modified G99 Modified G133
Inner Diameter	Sliding	2518	Conformal Block on Ring	Modified G77
Hammer				
Flats	Sliding	2514	Oscillating 3 Pad on Disk Oscillating Linear Area Contact Test	Modified G99 Modified G133
Trigger				
Flats	Sliding	2528	Oscillating Block on ring	Modified G77
Barrel				
Inner Diameter	Sliding	1516	3 Pad on Disk	Modified G99
Receiver				
Inner Diameter	Sliding	2514	Oscillating 3 Pad on Disk Oscillating Cylinder on Flat	Modified G99 Modified G133

This approach uses the extensive knowledge base that exists for the various ASTM methods, utilizes equipment that is proven, and allows others to replicate the testing and results. This approach allows the key issues in a litigation or intellectual property dispute to be quickly determined for early resolution and limits and focuses any full-scale testing may be needed.

Abrasion resistance is tested using aggressive testing in a dust chamber that was specifically designed to provide repeatable and consistent dust conditions. The dust chamber is configured as a once-through open system. Ambient air is injected via a ¾ hp blower motor and exhausted through a dust capture bag. This permits the air to be circulated around the weapon at such a velocity that the dust particles remain in suspension but allows for the escape of air to prevent pressurization of the chamber. The dust capture bag also ensures that that dust particles remain in the chamber as the air is exhausted. Each test contains the same amount and distribution of dust particles.

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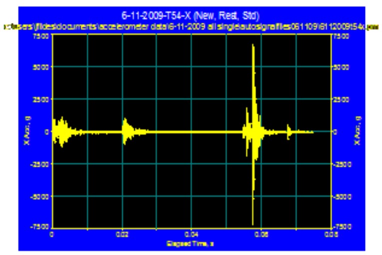
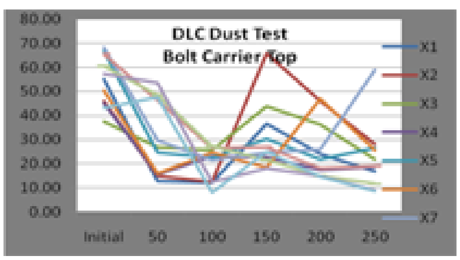
The dust chamber is capable of handling a wide variety of sand/dust types. We have utilized Silica Flour #140 and Silica Sand #35-50 which are materials that meet the specifications of MIL-STD-810F for sand, and rounded quartz grain sand as typified by AFS 50/70 Test Sand that meets ASTM 65-04 Standard Test Method for Measuring Abrasion Using the Dry Sand/Rubber Wheel Apparatus. Inside the dust chamber weapons are mounted to a weapon specific (M4 or M9) firing rack that has nitrogen filled gas shock tubes and a pneumatic trigger pull mechanism. This mounting system ensures repeatable recoil reaction and controlled firing sequences.



During full scale testing, the weapon is monitored with a sensor suite that includes a PCB 3 axis accelerometer (model 350B50) that provides a range of +/- 10,000 g's with a frequency response of 10,000 Hz for +/- 1 db and 20,000 Hz for -3 db and a micro-electromechanical (MEMs) acoustic sensor. Data collection is via a data acquisition system with 4 channels, each sampling at up to 51,200 samples per second with 24 bits. The accelerometer provides 0.524 mv/g and the 24 bit data converter is able to read down to 176 nv, providing a detection range of slightly less than +/- 0.5 g's to +/- 10,000 g's. The MEMs acoustic sensor provides 40 Hz to 20 KHz frequency response. Advanced wavelet joint time-frequency analysis and neural network signature recognition are used with statistical methods and short time Foruier transform analysis.



The effectiveness of materials and coatings in full scale testing is measured by several methods. The failures to fire are examined and categorized according to criteria used by the Army, and this data is plotted to provide graphical records of the weapon's performance. The wear of the weapon's components are also measured quantitatively using profilometric methods and microscopic examination. Bench-scale test data provides further insight for the full-scale performance of the weapon.

John Fildes, Ph.D. is uniquely qualified through experience and training to provide insight on the role of science and engineering in litigation. In addition to conducting highly successful technical investigations for high-stakes litigation involving a wide spectrum of metals and materials, chemical processes, and sensors and controls, he also organized and conducted over $27.5 million in funded projects including research, development, and collaborations involving Government labs, large companies, and leading universities. John was instrumental in establishing and served as Director of the 501(c)3 Institute of tribology and Coatings federally funded Small Arms Tribology and Materials Characterization Project, which was a was a highly successful collaboration involving University staff and professors, the Army's Benet Weapons Laboratory, the Joint Services Small Arms Program Office at Picatinny Arsenal, several small arms manufacturers, and small companies. He is a doctoral-level scientist who has 50 published papers, reports and presentations, and has 3 patents. John's credits involve:

- *John served as the principal investigator for a multi-million-dollar, multi-year project funded by the U.S. Army to analyze the failures of weapons due to abrasive wear and to evaluate coatings and lubricants and develop new friction and wear test methods for improving the functioning of weapons.*
- *Conducts failure analysis and diagnostics of the underlying basis for materials related performance issues with machinery and weapons systems.*