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PROJECTILE SPIN RATE MEASUREMENT USING INDUCED
ELECTROMOTIVE FORCE TECHNIQUES

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Frankford Arsenal
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May 1975

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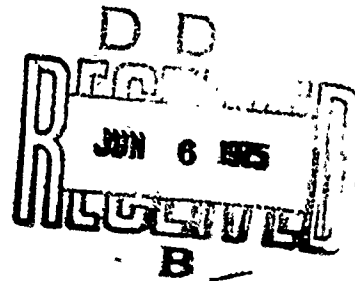
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report deals with the problem of measuring the rotation of a projectile (spin) without altering the center of gravity, exterior surface and true weight of the projectile. Twenty millimeter projectiles were magnetized and fired parallel to a 12 foot long coil. The induced electromotive force (e.m.f.) was amplified and recorded on magnetic tape for playback through an oscillograph recorder. The period of the generated sine wave was then measured to determine (cont'd)		

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the spin ($f=1/T$). Different barrels were used to obtain data over a wide range of twists. It was found that this system provided a reliable and "production line" method for the measurement of spin rate.

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PROJECTILE SPIN RATE MEASUREMENT USING INDUCED ELECTROMOTIVE FORCE TECHNIQUES

Introduction

Measurement of projectile rotation (spin) can be evaluated accurately and economically by means of a laboratory procedure which does not alter the physical and aerodynamic properties of the projectile.

In the past, methods of obtaining spin rate were the following:

a. Microflash photography. This method consists of painting longitudinal lines on the projectile and then taking a series of photographs at measured intervals to determine the rotation of the projectile. This method was abandoned as being costly and time consuming and it presented severe alignment problems.

b. Witness cards. Non-drying paint is placed on the projectiles before firing them through witness cards which are placed perpendicular to the expected line of flight. When fired, the projectile penetrates each witness card leaving a mark of paint on the circumference of the hole in the card. By counting the marks and knowing the velocity of the projectile, it is possible to calculate the approximate spin rate. This same procedure can be used for projectiles fitted with fins. Witness cards are generally unsatisfactory because the method lacks a high degree of precision, and consumes too much time measuring and replacing the witness cards for each projectile.

The principle advantages of measuring the rate of spin using induced e.m.f. techniques are the relatively low cost, extreme accuracy and reliability, and the simplicity of operation and set up which allows a single technician to conduct the test unaided. It should be emphasized that the projectile is not altered in any way. Therefore, the data presented for analysis is a true indication of the projectile's performance.

Test Apparatus

Figure 1 gives an overall view of the coil and fixture. The apparatus is inexpensive and can be fabricated of standard materials in any wood shop. This system was constructed at Frankford Arsenal using 2 x 4 inch lumber with $\frac{1}{2}$ inch dowels.

Thirty-six turns of number 20 wire were used to fabricate the coil.



Figure 1. Test Apparatus

Experimental Set-up

A low-powered laser was used to align the coil so that it would be exactly parallel with respect to the projectile's trajectory. This, of course, results in maximum induction. The coil leads were connected to a Tektronix Model 556 dual beam oscilloscope with Type 1A7A plug-in unit. The amplified signal was also coupled to a Bell and Howell Type VR-3700B Magnetic Tape Recorder/Reproducer. An LDJ Model EM250 electromagnet was used to magnetize the projectiles.

Projectile with Cylindrical Magnetic Inserts

The voltage induced in a multiturn coil linking a changing magnetic field is proportional to the number of turns (N) and to the time rate of change of flux, ϕ ,

or $V=N \frac{d\phi}{dt} = \frac{d\lambda}{dt}$ where λ is the number of flux linkages in weber-turns.

In general, the relation between flux and current is nonlinear; however, linearity can be assumed with negligible error.

In the preliminary stages of this investigation, it was felt that a cylindrical magnet staked into the nose of the projectile would produce a strong magnetic field. A projectile of this type is shown in Figure 2. Although the center of gravity and weight of the projectile were altered in this phase of the experiment, it was beneficial to have a strong signal generated at this time. The only problem experienced in this phase of the experiment was that the magnets occasionally worked themselves loose causing damage to the coil and loss of test results.



Figure 2. Projectile with Magnetic Insert.

Table 1 shows the weights of the rounds before and after insertion of the $\frac{1}{4}$ inch diameter magnets. All rounds were 20MM, TP, M55A2.

TABLE 1. Weight Variations

<u>Round</u>	<u>Weight - grns (without magnets)</u>	<u>Weight - grns (with magnet)</u>	<u>Weight Increase (Percent)</u>
1	1519.03	1535.02	1.05
2	1516.01	1531.14	0.99
3	1516.02	1531.19	1.00
4	1520.07	1534.08	0.92
5	1525.03	1540.01	0.98

Magnetized Projectiles

Figure 3 shows an M55A2, projectile in the fixture being cross magnetized. The projectile is then loaded into the weapon and fired. Printed circuit paper is used at the beginning of the event to start a thyatron which, in turn, triggers the scope, causing it to sweep. This signal also starts a velocity counter. Upon exit from the coil, the projectile breaks the printed circuit paper which stops the velocity counter and produces a spike on the scope trace to indicate the end of the event.

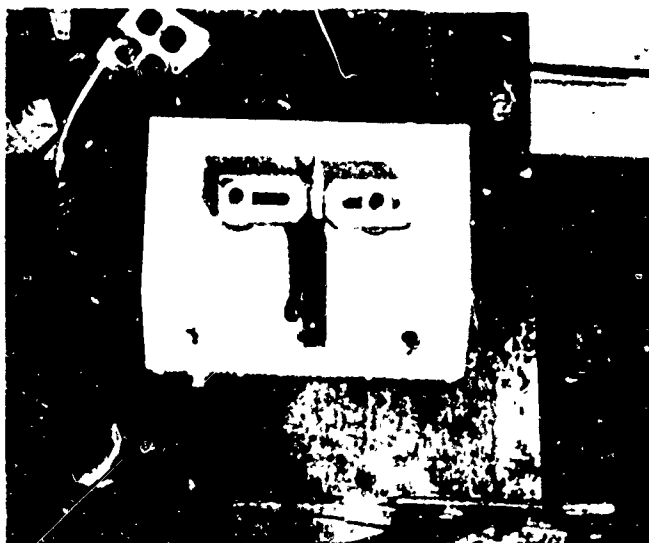


Figure 3. Projectile being Magnetized

Figure 4(a) shows the spin of a 20MM projectile which has been magnetized and fired from a 1 revolution/20 inch barrel. The theoretical calculation is as follows:

$$\text{twist (revolution/feet)} \times \text{velocity (feet/sec)} = \text{rev/sec}$$

$$\frac{1 \text{ rev}}{20 \text{ in.}} \times \frac{12 \text{ in.}}{1 \text{ ft.}} \times 3,419 \text{ feet/sec.} = 2,051 \text{ rev/sec}$$

The measured spin is the reciprocal of the period ($f = 1/T$) which in this case is $1/0.495$ msec which equal 2,020 rev/sec. (1.5% error).

Figure 4(b) shows the results of an unmagnetized round fired under identical conditions. The reason for firing an unmagnetized round was to measure the amount of noise present in the test range. It also detected any shift in ground level.

Figures 5(a) and 5(b) show the results of magnetized and unmagnetized rounds respectively fired from a 1 rev/12 inch barrel. Theoretical calculation of spin is determined to be 3,365 rev/sec using a velocity of 3,365 ft/sec. Actual measured spin is 3,333 rev/sec using a period of 300 micro sec. Sweep speed and amplitude settings were unchanged. Tables 2 and 3 indicate the results for all 20MM rounds fired.

TABLE 2. 1 revolution/20 inch barrel

<u>Round No.</u>	<u>Spin theoretical (rev/sec)</u>	<u>Spin actual (rev/sec)</u>	<u>Velocity (ft/sec)</u>	<u>Percentage Error</u>
1	2,048	2,045	3,400	0.15
2	2,051	2,020	3,419	1.53
3	2,050	2,014	3,417	1.79
4	2,053	2,069	3,422	0.78
5	2,025	2,027	3,376	0.09

TABLE 3. 1 revolution/12 inch barrel

<u>Round No.</u>	<u>Spin theoretical (rev/sec)</u>	<u>Spin actual (rev/sec)</u>	<u>Velocity (ft/sec)</u>	<u>Percentage Error</u>
1	3,365	3,333	3,365	0.96
2	3,295	3,308	3,295	0.40
3	3,326	3,320	3,326	0.18
4	3,306	3,320	3,306	0.42
5	3,294	3,312	3,294	0.55

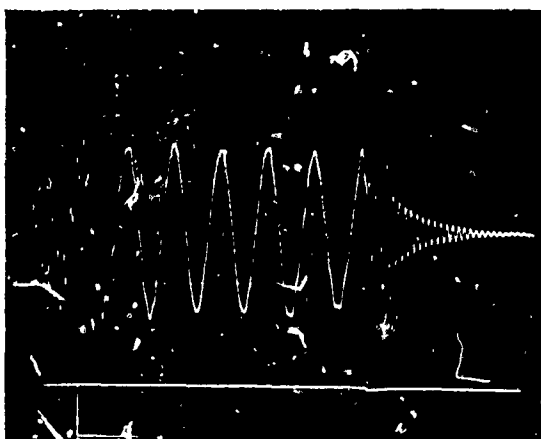


Figure 4(a). Magnetized Round
Fired From 1 Rev/20 Inch
Barrel.

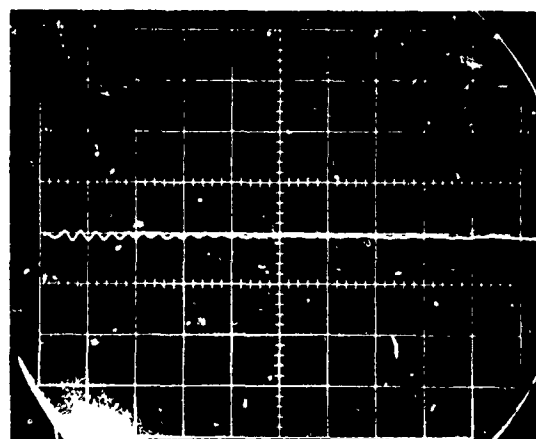


Figure 4(b). Unmagnetized Round
Fired From 1 Rev/20 Inch
Barrel.

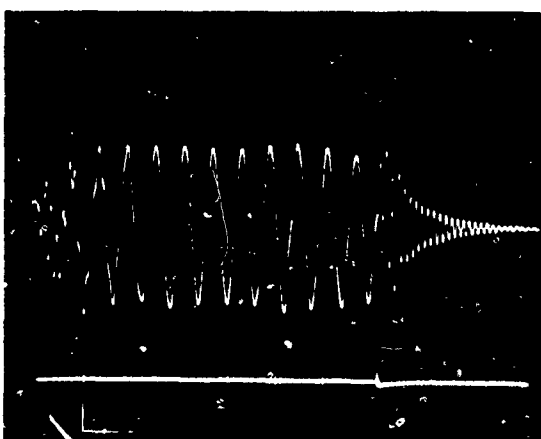


Figure 5(a). Magnetized Round
Fired From 1 Rev/12 Inch
Barrel.

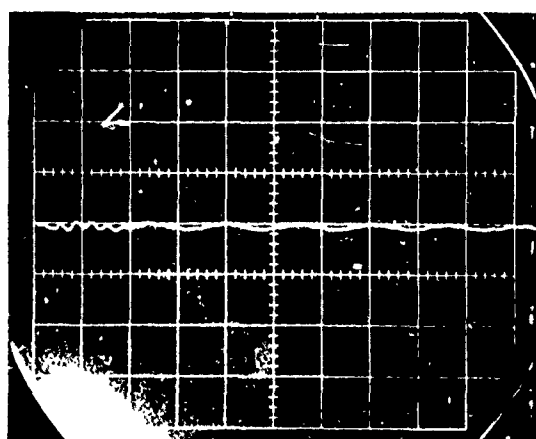


Figure 5(b). Unmagnetized Round
Fired From 1 Rev/12 Inch
Barrel.

CONCLUSION

Sound principles of measurement engineering are as important as sound design of the equipment itself. This report has shown in detail the method used to measure projectile rotation. Although the techniques discussed in the foregoing sections worked satisfactorily, there are however, two limitations. They are:

1. Projectiles must contain sufficient material for magnetization.
2. Appropriate filtering techniques must be employed if the test area is not noise free.

Future work will include the firing of smaller caliber projectiles and projectiles composed of different materials. A study will also be conducted into the feasibility of measuring pitch and yaw of multiple flechette projectiles.

From the compiled data, it is believed that the study outlined above represents the most logical and efficient approach to the investigation of this important field.