REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
15-03-2016

2. REPORT TYPE
Final

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
Test Operations Procedure (TOP)
03-2-826A Kinematic Tests of Small Arms

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHORS

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Aberdeen Test Center
Firepower Directorate
400 Colleran Road
Aberdeen Proving Ground, MD 21005-5059

8. PERFORMING ORGANIZATION REPORT NUMBER
TOP 03-2-826A

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Test and Evaluation Command
CSTE-TM (Range Infrastructure Division)
2202 Aberdeen Boulevard
Aberdeen Proving Ground, MD 21005-5001

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
Same as item 8

12. DISTRIBUTION/AVAILABILITY STATEMENT

Distribution Statement A. Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Defense Technical Information Center (DTIC), AD No.:

This TOP supersedes TOP 03-2-826, Kinematic Tests of Small Arms, dated 15 July 1985.

Marginal notations are not used in this revision to identify changes, with respect to the previous issue, due to the extent of the changes.

14. ABSTRACT
This TOP describes methods to determine the dynamic performance of selected weapon components to aid in correcting design problems. This is done by (a) recording the displacement of gun components relative to time and distance through the use of high-speed video (HSV) or other means, and (b) measuring the impulse and recoil of small-caliber weapons by a laser displacement measurement system, HSV, displacement transducers, or other means.

15. SUBJECT TERMS
kinematic, small arms, recoil measurements, laser tracking system

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	B. ABSTRACT	C. THIS PAGE			
Unclassified	Unclassified	Unclassified	SAR	24	19b. TELEPHONE NUMBER *(include area code)*

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18

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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure 03-2-826A — 15 March 2016
DTIC AD No.

KINEMATIC TESTS OF SMALL ARMS

*This TOP supersedes TOP 03-2-826, Kinematic Tests of Small Arms, dated 15 July 1985.

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1. SCOPE.

a. This Test Operations Procedure (TOP) was updated to include new equipment and methods of acquiring displacement data for both subtests because these new equipment and methods have become better solutions as this type of test technology has evolved. Many of the calculations and analysis of the data used remain the same as the previous TOP, as the calculations are based on fundamental physics equations.

b. This TOP describes methods to determine the dynamic performance of selected weapon components to aid in correcting design problems. This is done by (a) recording the displacement of gun components relative to time and distance through the use of high-speed video (HSV) or other means, and (b) measuring the impulse and recoil of small-caliber weapons by a laser displacement measurement system, HSV, displacement transducers, or other means.

c. Kinematics of parts is often conducted in conjunction with recoil measurements. The kinematics study relates the acceleration and speed of a weapon's moving parts to the weapon's receiver or another stationary part. Such a study can clearly identify the effect of weapon modifications; for example, the effect upon bolt carrier displacement and velocity caused by changing the muzzle brake or adding a sound suppressor. A kinematics study is also a diagnostic tool to investigate weapon problems such as poor functioning with certain types of ammunition or high parts breakage rates.

d. Various methods and instrumentation may be used for recording the dynamic characteristics of weapon mechanisms for kinematics of parts testing. The weapon is fired from both a rigid, fixed mount, and a shoulder-fire emulating mount. Typically, HSV in conjunction with software to measure the video data according to a scale, is used to measure the displacement of various gun components with respect to time. Target tracking markers are attached to the various components so it is easier to get a reference of each part's position to make the displacement measurements. A laser system, or any system that can track displacement of the markers or parts with respect to time, could be used in place of HSV.

e. Recoil energy testing is conducted because firing a small arms weapon produces a rearward force that must be absorbed by the shooter or by the weapon mount. Excessive recoil can degrade training, injure the shooter, and damage weapon mounts. Table 1 (from TOP 03-2-504A[**1]) displays the shoulder fire operator safety limitations based on calculated recoil energy.

TABLE 1. RECOIL BASED FIRING LIMITATIONS FOR TEST WEAPONS

CALCULATED RECOIL ENERGY, ft-lbs. (J)	LIMITATION ON ROUNDS
Less than 15 (20.3)	Unlimited firing
15 to 30 (20.3 to 40.7)	200 rounds per day per individual
30 to 45 (40.7 to 61.0)	100 rounds per day per individual
45 to 60 (61.0 to 81.4)	25 rounds per day per individual
Greater than 60 (81.4)	No shoulder firing

** Superscript numbers correspond to Appendix B, References.

f. Various methods and instrumentation may be used for recording the dynamic characteristics of weapon mechanisms for recoil energy. The weapon is fired from a recoil mount, which consists of a weapon cradle mounted on near frictionless linear bearings. Typically, a laser displacement measuring system is used to measure displacement versus time of the entire weapon with respect to time. HSV, displacement transducers, or any other method that can track displacement of the entire weapon with respect to time, could be used in place of a laser displacement measuring system. These methods replace the previous three-wire or five-wire pendulum method.

2. FACILITIES AND INSTRUMENTATION.

2.1 Kinematics of Parts.

2.1.1 Facilities.

Item	Requirement
Weapon mount	Fixed/rigid and/or shoulder-fire emulating.
Mounting components	To mount weapon in the weapon mount.
Indoor firing facility:	
Standard 120 volt (V) outlet	To run computer and instrumentation.
Local area network (LAN) outlet	To connect computer to network to disperse data.
Weapon firing system	To safely fire weapon for testing.

2.1.2 Instrumentation.

Item	Requirement
Target tracking markers	To mark specific components for measurement.
HSV or laser tracking system	To measure displacement of components.
Universal serial bus (USB)/serial adapters	As needed to connect laser system to computer.
Computer or oscilloscope	To acquire, store, and perform data calculations.
Data acquisition and analytical software	To capture, store, and analyze the data.
Weibel radar	As needed to capture velocity data of projectile.
Other displacement tracking system	As needed in case HSV or laser tracking system not available.

2.2 Recoil Energy.

2.2.1 Facilities.

Item	Requirement
Recoil mount	Near frictionless linear sliding mount.
Adjustable mount weights	To change mount mass to change expected velocity.
Mounting components	To mount weapon in the weapon mount.
Indoor firing facility:	
Standard 120 V outlet	To run computer and instrumentation.
LAN outlet	To connect computer to network to disperse data.
Weapon firing system	To safely fire weapon for testing.

2.2.2 Instrumentation.

The instrumentation required for recoil energy is the same as required for kinematics of parts, shown in paragraph 2.1.2

3. REQUIRED TEST CONDITIONS.

3.1 Kinematics of Parts.

a. Prior to testing, weapon components under study are marked with target tracking markers. These include the moving components that are the purpose of the test along with a fixed position marked on the receiver. Typically, the bolt carrier is the main component under study, but any moving parts that are important to study should be marked as well. The dynamic characteristics of the component with a small marker mounted on it should not adversely affect the performance of the test weapon, nor will the marker prevent the weapon from meeting the specifications of the requirements documents. HSV data with software to measure position versus time are extremely useful for this type of test because it can measure position versus time of multiple targets simultaneously.

b. The HSV or laser tracking system is placed perpendicular to the line of fire in line with the weapon. The view of the measurement system should be placed to capture the entire range of motion of the components under study. A typical system will be able to capture data in both horizontal (x-axis) and vertical (y-axis) planes. A special set-up may be used to also capture positional data in the depth (z-axis) plane. The instrumentation must be able to accurately track the position (x, y, and possibly z) of each marked component with respect to time. The sampling rate and accuracy of the measurement system should be great enough to capture positional data with the necessary resolution for data analysis as determined by the U.S.

Army Test and Evaluation (ATEC) Systems Team (AST). Using these data, the differential of the positional data with respect to time is used to determine the instantaneous velocity of the component versus time.

c. A sample size of three to five firings is typically enough for each firing configuration. This test should be repeated for each type of configuration (attachments, mount, ammunition type, etc.) and for each weapon number. Only the most common configurations would need to be tested. Extra trials may be run as needed if there is a significant variation in the readings from round to round.

3.2 Recoil Energy.

a. Recoil energy is measured based on the initial velocity of the weapon as it recoils along with its mass. Velocity is calculated from the position versus time data acquired by a laser displacement system, HSV, displacement transducer, or some other displacement measuring system. There are more options for obtaining this measurement because the test is only concerned with tracking the position or displacement of one area. The recoil energy of the test weapon may be used to determine if any shoulder-firing limitations are applicable.

b. Aside from using the weapon velocity and mass, the recoil energy can also be estimated based on the projectile mass and velocity, propellant mass and velocity, and weapon mass. Using the conservation of momentum, theoretical weapon velocity can be calculated and the same steps in Section 6. would apply to calculate the recoil energy.

c. A sample size of three to five firings is typically enough for each firing configuration. At a bare minimum, the test would be conducted with the weapon in its most common lightest form. This includes testing the weapon without attachments and only one round. The lightest configuration is the worst-case scenario for the user. This test can be repeated for each type of common configuration (attachments, mount, ammunition type, buffer, etc.) and for each weapon number. Extra trials may be run as needed if there is a significant variation in the readings from round to round.

4. TEST PROCEDURES.

4.1 Kinematics of Parts.

a. Target tracking markers are placed on the moving parts(s) to be studied. Each test is unique. The test weapon may have to be modified so that the needed measurements can be made. If the part is hidden from view within the receiver (basic component), ports may be cut in the receiver to permit the camera to view the marker. Particular care must be taken not to cut the viewing port in such a manner or location that the receiver is weakened or the movement of the part is affected. A typical target tracking marker is presented in Figure 1, but the test is not limited to using this pattern.

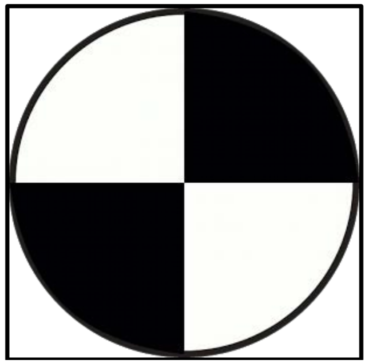

Figure 1. Typical target tracking marker.

b. The weapon normally is fired from a rigid/semi-rigid mount or shoulder-fire emulating mount. The rigid/semi-rigid mount is used to minimize movement of the weapon so that the traces recorded from the reflectors show the exact movements of the part relative to the receiver or stationary component. The shoulder-fire emulating mount is used to better simulate real operation. It is advisable to place a motion marker on the receiver (as well as the part) to record any movement which may result from firing.

c. The view of the HSV or target position tracking system should be placed perpendicular to the line of fire in order to obtain position versus time in the horizontal and vertical planes. The field of view should be zoomed in enough to get a precise reading of the distance, but wide enough to capture the entire range of motion of the part(s) under study. A special set-up of multiple cameras or target tracking systems may be used in case there is significant part movement in three dimensions instead of two dimensions. The HSV or other position tracking system must have a high enough sampling rate and precision to capture the record with a specified resolution. This will help ensure that the signal-to-noise ratio is minimized, which will help produce more precise estimates for the velocity of the moving part(s) with respect to time. The only data needed from the instrumentation for this test are the position versus time during firings for all components under study. Any instrumentation that has this type of output is possibly viable.

d. When analyzing the positional data, before processing, known distances should be put in for certain points of the weapon so distances can be determined from the video data or record of the positional tracking system. This ratio in pixels or other units to real world distances will be used to relate the positional distances.

e. After positional data of the moving part(s) and stationary part have been determined while firing, calculations can be performed to calculate the distance between the moving part(s) and stationary part. Often the moving part of interest is the bolt carrier and the stationary part is the receiver. At time t = 0 s, the distance between the moving part(s) and stationary part should be recorded. This will correspond to a displacement of 0. As distance between these parts changes over time, it can be recorded as displacement. This displacement should be graphed as in Figure 2. The differentiation of these data with respect to time will allow for the velocity to be calculated and graphed as in Figure 3. Using these data, the maximum velocity of the moving part along with cycle time of the part can be found. If this part movement coincides directly with each round fired, the rate of fire (cadence) may also be calculated from the cycle time.

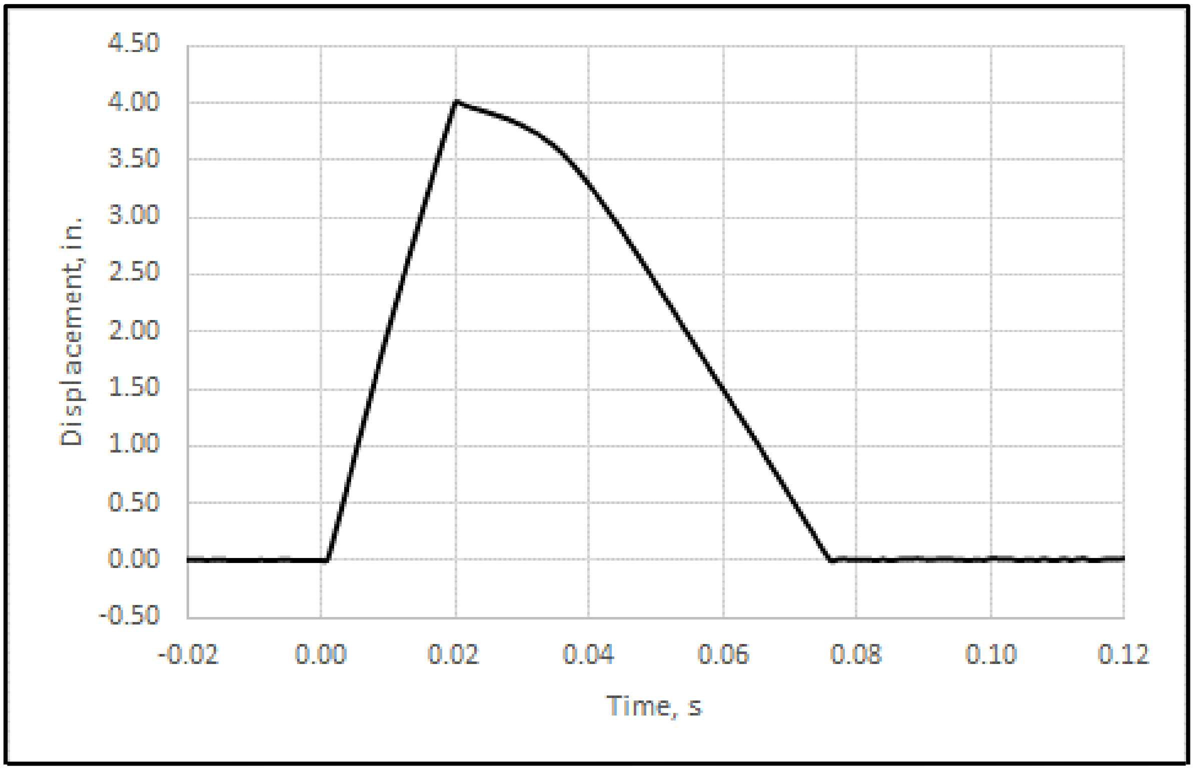

Figure 2. Sample graph of displacement versus time of moving part compared to stationary part.

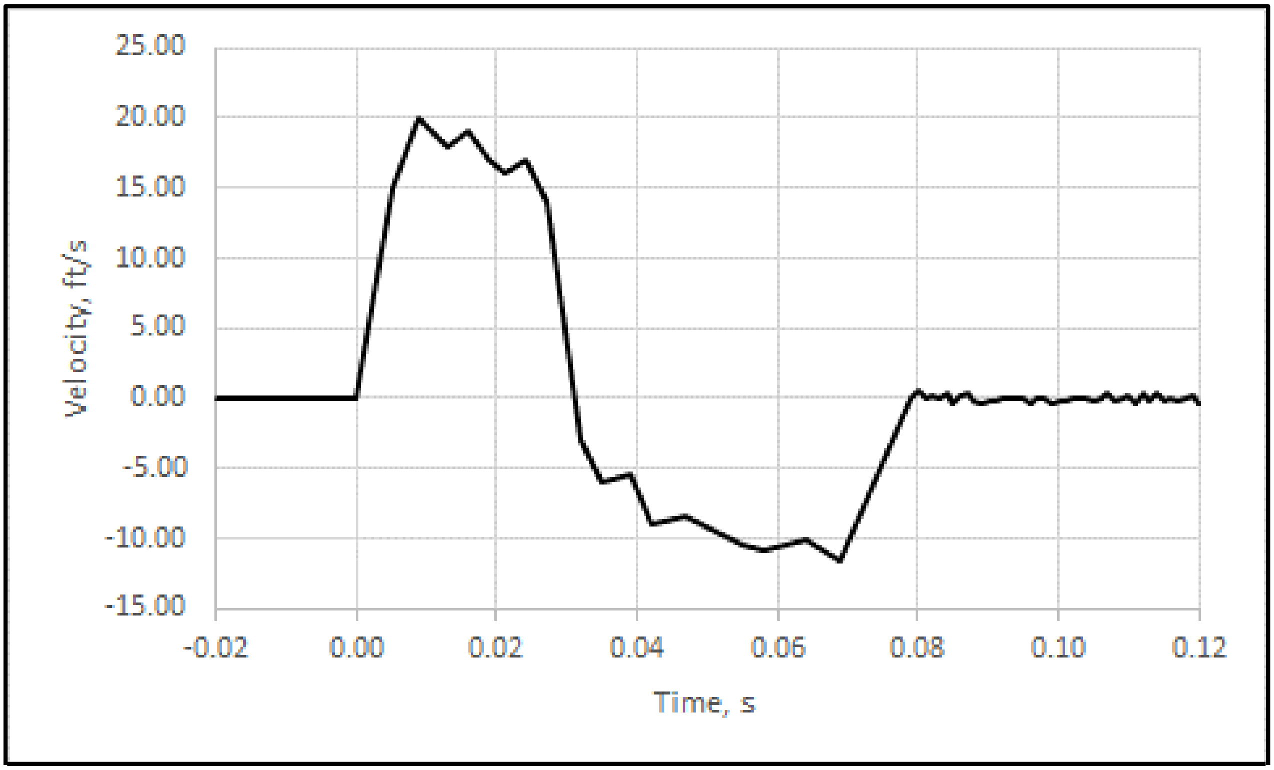

Figure 3. Sample graph of velocity versus time of moving part compared to stationary part that was calculated from differentiation of displacement with respect to time.

f. In order to make these calculations, software that allows frame-by-frame measurements along with tracking the markers over time is required. Additionally, the software should be able to output these positional values over time into a common format, such as a comma delimited file or an Excel spreadsheet file. It should allow for the data to be sent to others over the network for further calculations. Table 2 shows an example of positional output for two points. This would be expanded for as many points as needed. Additionally, a set-up could allow for the recording of data in three axes instead of just two.

TABLE 2. SAMPLE POSITIONAL OUTPUT FOR KINEMATICS OF PARTS

TIME, (second)	POINT 1 X, (inch)	POINT 1 Y, (inch)	POINT 2 X, (inch)	POINT 2 Y, (inch)
0.000	35.056	45.038	29.019	39.502
0.001	35.014	45.001	29.026	39.515
0.002	35.005	45.029	29.032	39.531
0.003	35.005	45.031	29.036	39.530
0.004	35.003	45.046	29.053	39.555
0.005	35.045	45.027	29.068	39.557
0.006	35.079	45.013	29.080	39.561
0.007	35.029	45.010	29.072	39.579
0.008	35.069	45.001	29.095	39.586
0.009	35.003	45.038	29.107	39.590
0.010	35.042	45.032	29.117	39.619
0.011	35.052	45.018	29.123	39.617
0.012	35.016	45.028	29.129	39.634
0.013	35.054	45.016	29.147	39.638
0.014	35.064	45.033	29.143	39.642
0.015	35.063	45.039	29.158	39.663

4.2 Recoil Energy.

a. Similar to the kinematics of parts test, the outcome of this test is to measure position versus time. The difference is that the recoil test is interested in the motion of the entire weapon while on a near frictionless, linear mount. A laser distance measuring system is used to measure the position of the entire weapon versus time, which is used to calculate displacement and velocity of the entire weapon. In case HSV is used instead, target tracking markers are placed on a fixed weapon part. Other displacement sensors, such as a displacement transducer, may be used. The only data needed for this test are the displacement versus time values of the weapon and mount during firings. Any instrumentation that has this output is viable.

b. The test weapon should be in the lightest configuration in which it is likely to be employed. Magazine fed weapons should be tested with an empty magazine (other than the single round to be fired). The weapon should be tested both with and without muzzle devices, such as flash suppressors and muzzle compensators, if the items are designed to be operator removable. Use the ammunition that will give the greatest recoil; if there is any doubt in findings, repeat the test with other possible cartridge types.

c. Each weapon is fired from a near-frictionless recoil mount. The mount consists of 4 linear roller bearings mounted into 2 aluminum carriers that slide freely over 2 one-inch-diameter shafts. The total rearward motion allowed by the mount is 3.5 inches.

d. After positional data of the mounted weapon have been determined while firing, calculations can be performed to calculate displacement versus time. The displacement data will then be differentiated with respect to time to obtain velocity versus time of the recoil mount and weapon combination. Using this velocity along with the masses of the weapon and mount, the velocity of the weapon alone would be obtained using the conservation of momentum. Using this velocity of the weapon with its mass, the free recoil energy of the weapon can then be calculated. The equations for these calculations are described in paragraph 6.2.

e. As additional supporting evidence, the free recoil energy can also be estimated from the muzzle velocities and masses of the projectile and propellant gasses. Using these data along with the weapon mass and the conservation of momentum, the velocity of the weapon alone is obtained. The free recoil energy is then calculated using the method in paragraph 6.2.

f. Some special considerations must be considered when collecting the data. Variable mass can be added to the mount for firings. This will limit the velocity window of the weapon and mount combination during firing. The mount and weapon should be fast enough that the signal-to-noise ratio is minimized. It should also not move too fast as it could possibly damage the mount. A typical range is one to two feet per second. The required mass for the mount can be based off of the methods described in paragraphs 4.2.c and 4.2.d, and calculations in paragraph 6.2. Additionally, when collecting data and determining an initial velocity estimate, at least 100 milliseconds (ms) must be used to obtain a value. This is because anything lower would include the moving parts (i.e., cycle of bolt carrier) of the weapon that might cause it to speed up or slow down slightly right in the beginning of firing. Lastly, buffers may be used in the end of the mount to protect the weapon, mount, and instrumentation as needed. Each test is unique. The test weapon may have to be modified so that the needed measurements can be made.

g. In order to make these calculations, software should be able to output these positional values over time into a common format, such as a comma delimited file or an Excel spreadsheet file. It should allow for the data to be sent to others over the network and for use in calculations.

5. DATA REQUIRED.

The following data are required for the Kinematics of Parts and Recoil Energy subtests:

a. Specific facility used.

b. Firing procedure.

c. Weapon configuration and mass.

d. Type of ammunition fired.

e. Calculated displacement and velocity versus time.

f. Projectile velocity as needed.

g. Cyclic rate as needed.

h. Mount mass.

i. Position or displacement versus time measurements.

j. Projectile and propellant mass.

6. ANALYTICAL PLAN.

6.1 Kinematics of Parts.

a. Beginning with the position versus time data, the distance between the moving part(s) and the base part is calculated using distance formulas. The following distance formulas are applicable for these data in one axis, two axes, and three axes:

$$\text{(One axis) Distance} = x_2 - x_1 \qquad \text{(Equation 1)}$$

$$\text{(Two axes) Distance} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \qquad \text{(Equation 2)}$$

$$\text{(Three axes) Distance} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2} \qquad \text{(Equation 3)}$$

Where:

x_2, y_2, and z_2 denote the position of the moving part (i.e., bolt carrier)
x_1, y_1, and z_1 denote the position of the stationary part (i.e., receiver).

b. Once the distances at each time have been calculated, the distance at time t = 0 s should be noted. This value should be subtracted from all of the other distance measurements for this part to give the displacement versus time. Plotting these data will result in a graph similar to Figure 2. The shape of the graph will not always have this type of appearance as the parts move differently for each weapon.

c. This displacement data versus time can then be differentiated with respect to time to find the velocity versus time. Plotting these data will result in a graph similar to Figure 3. The shape of the graph will not always have this type of appearance as the parts move differently for each weapon. Care must be chosen in how many points before and after are used to calculate velocity at each point. Using more points before and after results in a smoother result, but is less responsive to time changes. Using less points makes the data more responsive to changes, but can result in erroneous noise spikes. The following equation represents the calculation for velocity versus time at data point i.

$$v_i = \frac{\Delta d}{\Delta t} = \frac{\left(d_{i+j} - d_{i-j}\right)}{\left(t_{i+j} - t_{i-j}\right)} \qquad \text{Equation 4}$$

Where:

d is distance
t is time
j represents the number of data points before and after data point i used to calculate velocity at data point i.

d. The maximum and minimum displacements for each velocity can be calculated. The time required for the displacement to return to 0 (i.e., complete a cycle) after firing can be calculated too. If the part motion coincides with each round fired, the cyclic rate can be found from how long it takes for the moving part to complete a cycle.

e. After data are calculated for each round, the data for multiple rounds can be analyzed together using descriptive statistics to determine such values such as mean and standard deviation of the maximum velocity. If different round types or weapon configurations are fired, these data can be used to describe if any significant differences in the part velocity, displacement range, cyclic rate, etc. are present. A comparison of means, analysis of variance (ANOVA), or design of experiments (DOE) may be used if there are multiple factors under study for parts kinematics.

6.2 Recoil Energy.

a. Beginning with the position versus time data, the displacement can be calculated by subtracting the position at time t = 0. Since motion is only in one axis and the position is measured from the sensor, there is no need to use the distance formula. This is the displacement of the weapon and mount during firing.

b. The displacement data versus time can then be differentiated with respect to time to find the velocity versus time. Care must be chosen in how many points before and after are used to calculate velocity at each point. Using more points before and after results in a smoother result, but is less responsive to time changes. Using less points makes the data more responsive to changes, but can result in erroneous noise spikes. Use Equation 4 to calculate velocity versus time at data point i.

c. Using these velocity data, the velocity of the weapon and mount as it is fired is found. The velocity between 0 and 100 ms should be ignored because it also includes momentum from the moving parts. After an appropriate velocity is selected for weapon and mount, conservation of momentum is used to find the velocity of the weapon alone. The following equation will give the velocity of the weapon alone:

$$\text{velocity}_{weapon} = \frac{\left(\text{mass}_{weapon+mount} \times \text{velocity}_{weapon+mount}\right)}{\text{mass}_{weapon}} \qquad \text{Equation 5}$$

d. Using the velocity of the weapon, the free recoil energy is obtained based on the equation for kinetic energy. The free recoil energy is given by the following equation:

$$\mathrm{FRE}_{weapon} = \frac{1}{2} \times \mathrm{mass}_{weapon} \times (\mathrm{velocity}_{weapon})^2 \times \frac{1}{g} \qquad \text{Equation 6}$$

Where:

g is the standard gravity

(1) To express the free recoil energy in foot pounds (ft-lbs), the unit for mass should be in pounds (lbs) and velocity in feet per second (ft/s) with the standard gravity of 32.1740 ft/s^2.

(2) To express the free recoil energy in kilograms per meter (kg-m), the unit for mass should be in kilograms (kg) and velocity in meters per second (m/s) with the standard gravity of 9.80665 m/s^2.

e. As an alternative means, the free recoil energy can be estimated from projectile and propellant gas masses and velocities. The first step is to obtain the velocity of the weapon using the conservation of momentum and then apply Equation 7. The velocity is found by the following equation:

$$\mathrm{velocity}_{weapon} = \frac{(\mathrm{mass}_{projectile} \times \mathrm{velocity}_{projectile} + \mathrm{mass}_{propellant} \times \mathrm{velocity}_{propellant})}{\mathrm{mass}_{weapon}} \qquad \text{Equation 7}$$

(1) The projectile velocity is found from the muzzle velocity given by the Weibel radar system. The masses of the projectile and propellant should be measured prior to shooting for custom rounds or are given as a standard based on the design of the round. This equation is set up so that all measurements are in the same units. Masses should be in kg or lbs. and velocities should be in m/s or ft/s. The velocity of the projectile gas is hard to measure and can be estimated by the following factors:

(a) $\mathrm{velocity}_{propellant} = \mathrm{velocity}_{projectile} \times 1.75$ for high powered rifles.

(b) $\mathrm{velocity}_{propellant} = \mathrm{velocity}_{projectile} \times 1.50$ for shotguns (average length), pistols, and revolvers.

(c) $\mathrm{velocity}_{propellant} = \mathrm{velocity}_{projectile} \times 1.25$ for shotguns (long barrel).

(2) Even if the propellant velocity is off by a factor, it will likely not play a huge role in the calculation of free recoil energy because the propellant mass is usually very small compared to the projectile mass.

f. After data are calculated for each round, the data for multiple rounds can be analyzed together using descriptive statistics to determine such values such as mean and standard deviation of the free recoil energy. If different round types or weapon configurations are fired, these data can be used to describe if any significant differences in free recoil energy or moment are present. A comparison of means, ANOVA, or DOE may be used if there are multiple factors under study for parts kinematics.

7. PRESENTATION OF DATA.

7.1 Kinematics of Parts.

For each round fired and each moving part under study, graphs similar to Figures 2 and 3 can be generated. Data can also be presented for each round and each part in terms of max velocity, time to complete a displacement cycle, and cyclic rate. After enough samples have been fired for each scenario, simple descriptive statistics (mean, standard deviation, maximum, minimum, etc.) can be used to describe the resulting measurements. A test of sample means, ANOVA, or DOE could be used as comparison tools between different configurations.

7.2 Recoil Energy.

a. Acquisition and analysis software can be developed using programs such as Laboratory Virtual Instrument Engineering Workbench (LabVIEW)*** for the recoil energy test. This allows the user to input test information along with specific masses and velocities collected during the test. The software reads data from the sensor and calculates a velocity for the weapon and mass combined. Using the other data inputted, free recoil energy is then calculated. Figure 4 shows the typical output from firing a single round. Many of the boxes that are covered in white or gray would be filled in for the test or calculated from the data collected.

*** The use of brand names does not constitute endorsement by the Army or any other agency of the Federal Government, nor does it imply that it is best suited for its intended application.

Figure 4. Free recoil energy test output for a single round from a LabVIEW program.

b. After enough samples have been fired for each scenario, simple descriptive statistics (mean, standard deviation, maximum, minimum, etc.) can be used to describe the resulting measurements. A test of sample means, ANOVA, or DOE could be used as comparison tools between different configurations. In safety considerations, resulting values would be compared to those in Table 1 to determine any shoulder-fire limitations.

8. FUTURE CONSIDERATIONS.

a. This TOP covers several general methods for kinematics of parts (displacement versus time measurements) and free recoil energy. The current measurement methods for kinematics of parts include HSV or a laser measurement system. The current measurement methods for free recoil energy include a laser measurement system, HSV, or some form of a displacement transducer. In both of these tests, the key is to collect position versus time data to calculate displacement versus time and velocity versus time.

b. For both tests, it is possible that some form of accelerometers may be used. If accelerometers are small enough, they could be attached to moving parts for the kinematics of parts test. Larger accelerometers could be used for the free recoil energy test. These transducers would give acceleration versus time. This would give an idea of the shock response of firing a weapon. Additionally, instead of differentiating the data, the data could be integrated with respect to time, to give velocity versus time and position versus time. Many of the similar equations could be used for the different calculations. There is also the opportunity that more information may be gained from using these types of gauges.

c. For the recoil test, it is possible that a type of shoulder emulating mount with force sensors may be used. This might give a more accurate representation of the force and energy that the shoulder actually experiences when firing the weapon. The shoulder could even be modified to represent different percentiles of the population to get a better understanding of how it might affect people of different sizes differently. For example, one could add more mass in the shoulder to represent a 95th percentile male, but remove mass to represent a 5th percentile female.

APPENDIX A. ABBREVIATIONS.

ANOVA	analysis of variance
AST	ATEC Systems Team
ATC	U.S. Army Aberdeen Test Center
ATEC	U.S. Army Test and Evaluation Command
d	distance
DOE	Design of Experiment
FRE	free recoil energy
ft	foot or feet
ft-lbs	foot pounds
ft/s	feet per second
g	standard gravity
HSV	high speed video
J	joules
kg	kilogram
LabView	Laboratory Virtual Instrument Engineering Workbench
LAN	local area network
lbs	pounds
m/s	meters per second
ms	millisecond
s	second
t	time
TOP	Test Operations Procedure
USB	universal serial bus
v	velocity
V	volt
x	horizontal distance
y	vertical distance
z	depth distance

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APPENDIX B. REFERENCES.

1. TOP 03-2-504A, Safety Evaluation of Small Arms and Medium Caliber Weapons, 29 May 2013.

For information only (related publications).

a. Saami Technical Data Sheet. Technical Correspondent's Handbook. Gun Recoil - Technical. 5/1/1976. Pages 1.0402A - 1.0402D.

b. Michlin, Alex E. & Brosseau, Timothy L. ARL-TN-0644: Recoil Impulse and Time Displacement for the M14EBR Rifle, M110 Rifle, M240B Machine Gun, M240H Machine Gun, and the M240L Machine Gun while Firing M80A1, M80, M62A1, and M62 Ammunition from a Rigid and a Simulated Shoulder Mount. November 2014.

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APPENDIX C. APPROVAL AUTHORITY.

CSTE-TM 15 March 2016

MEMORANDUM FOR

Commanders, All Test Centers
Technical Directors, All Test Centers
Directors, U.S. Army Evaluation Center
Commander, U.S. Army Operational Test Command

SUBJECT: Test Operations Procedure (TOP) 03-2-826A Kinematic Tests of Small Arms, Approved for Publication

1. TOP 103-2-826A Kinematic Tests of Small Arms, has been reviewed by the U.S. Army Test and Evaluation Command (ATEC) Test Centers, the U.S. Army Operational Test Command, and the U.S. Army Evaluation Center. All comments received during the formal coordination period have been adjudicated by the preparing agency. The scope of the document is as follows:

This TOP describes methods to determine the dynamic performance of selected weapon components to aid in correcting design problems. This is done by (a) recording the displacement of gun components relative to time and distance through the use of high-speed video (HSV) or other means, and (b) measuring the impulse and recoil of small-caliber weapons by a laser displacement measurement system, HSV, displacement transducers, or other means.

2. This document is approved for publication and will be posted to the Reference Library of the ATEC Vision Digital Library System (VDLS). The VDLS website can be accessed at https://vdls.atc.army.mil/.

3. Comments, suggestions, or questions on this document should be addressed to U.S. Army Test and Evaluation Command (CSTE-TM), 2202 Aberdeen Boulevard-Third Floor, Aberdeen Proving Ground, MD 21005-5001; or e-mailed to usarmy.apg.atec.mbx.atec-standards@mail.mil.

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JENNIFER P. CHEW
Associate Director, Test Management Directorate (G9)

FOR

RAYMOND G. FONTAINE
Director, Test Management Directorate (G9)

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Forward comments, recommended changes, or any pertinent data which may be of use in improving this publication to the following address: Range Infrastructure Division (CSTE-TM), U.S. Army Test and Evaluation Command, 2202 Aberdeen Boulevard, Aberdeen Proving Ground, Maryland 21005-5001. Technical information may be obtained from the preparing activity: Firepower Directorate, U.S. Army Aberdeen Test Center, 400 Colleran Road, Aberdeen Proving Ground, Maryland, 21005-5059. Additional copies can be requested through the following website: http://www.atec.army.mil/publications/topsindex.aspx, or through the Defense Technical Information Center, 8725 John J. Kingman Rd., STE 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.