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22 September 1970

Materiel Test Procedure 4-2-829*
Aberdeen Proving Ground

U. S. ARMY TEST AND EVALUATION COMMAND
COMMON ENGINEERING TEST PROCEDURE

VERTICAL TARGET ACCURACY AND DISPERSION

1. OBJECTIVE

This MTP provides guidance for conducting low-angle test firings against vertical targets to determine accuracy and dispersion of tank gun, recoilless rifle, and artillery projectiles. In so doing, strength of design is observed and usually time-of-flight is measured.

2. BACKGROUND

Though principally associated with direct-fire weapons, such as those that launch antitank projectiles, vertical target accuracy and dispersion firing is also used for artillery weapons to evaluate weapon and ammunition performance.

A target accuracy test is conducted to ascertain the ability of a projectile or a weapon-ammunition system to center projectile impacts on the point of aim. So far as possible, extraneous variables in the test facilities which might affect the impact pattern are eliminated in such tests.

A target dispersion test is conducted to determine the extent to which projectile impacts spread about the center of impact because of round-to-round variations.

Time-of-flight tests provide data for formulating firing tables and for determining the ranges at which armor-piercing projectiles can defeat specified targets. These firings are considered in this MTP since the required data can frequently be obtained in conjunction with accuracy and dispersion tests.

Strength of design tests (formerly called metal parts security tests) are conducted to assure that projectile components are not unintentionally disturbed during projectile launch and flight. Since component failures affect accuracy and dispersion, as well as being a safety hazard, observation of component integrity is often a part of accuracy and dispersion tests. In a strength of design test, all components of the ammunition are tested simultaneously under conditions that usually simulate combat extremes.

Confusion often exists with the terminology associated with the ability of a weapon system to hit a target because the popular concept of the word "accuracy" differs from its definition as used in ballistics. In popular terms, accuracy is the ability of a weapon system, when properly aimed, to repeatedly hit the point of aim. Figure 1 and the definitions below explain accuracy and dispersion as used in weapon system evaluations and in this MTP.

*Supersedes Interim Pamphlet 70-45.

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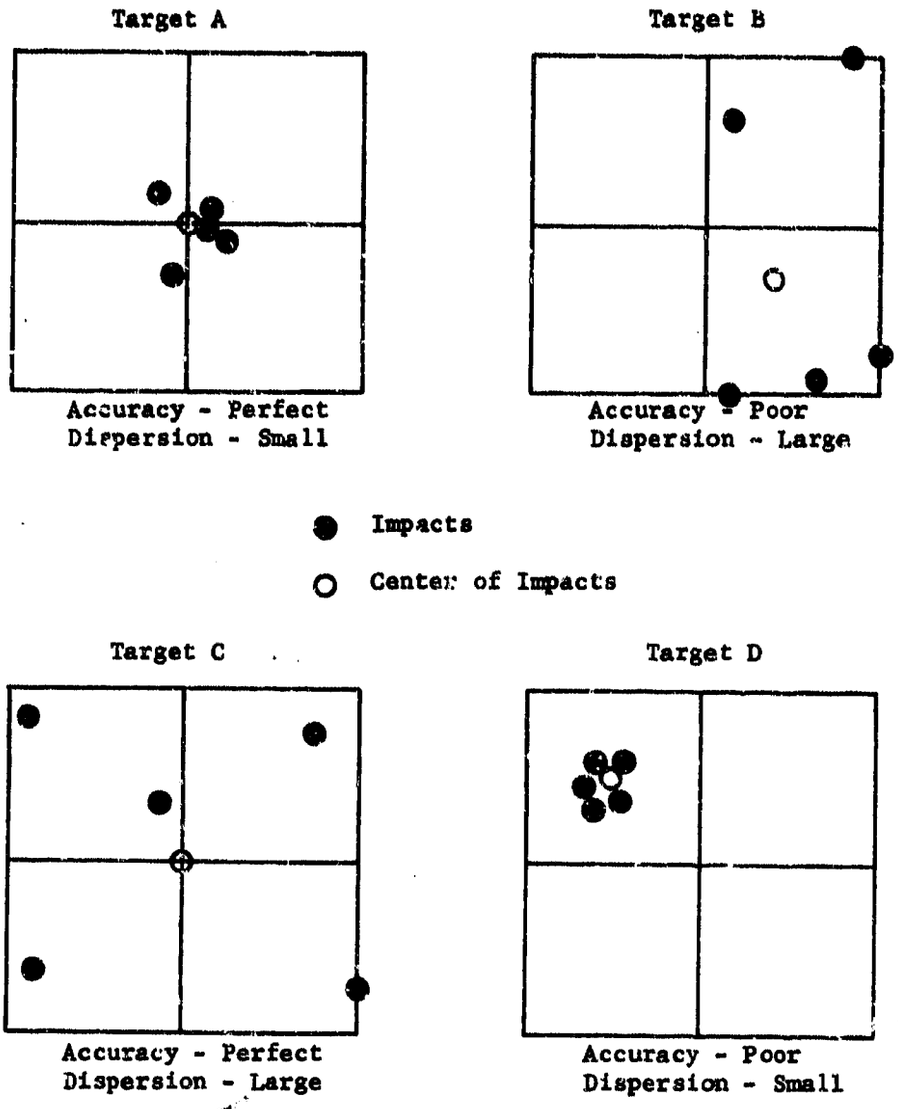

Figure 1. Accuracy and Dispersion Targets

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a. Accuracy - The ultimate in target accuracy is achieved when the mean of the points of impact (center of impact) coincides with the point of aim. (In Figure 1 the aiming point is the center of the target square as shown by the intersecting centerlines.) Targets A and C, Figure 1, indicate perfect target accuracy in that the centers of impact coincide exactly with the aiming point. Poor accuracy is shown in targets B and D, in which the centers of impact fall at some distances from the aiming point. It should be noted that perfect target accuracy does not imply that all rounds must impact on the point of aim; some degree of dispersion in the impact pattern is always to be expected.

b. Dispersion - Small target dispersion is achieved when the projectiles impact closely about the center of impact, i.e., when the distance of every impact from the center of impact is small, regardless of the relationship between the point of aim and the center of impact. In Figure 1, small dispersion is shown in targets A and D; large dispersion in targets B and C. When dispersion is small, a correction in aiming the weapon will bring all impacts close to the point of aim.

3. REQUIRED EQUIPMENT

a. Appropriate Reference Rounds.
b. Appropriate Standard and/or Advanced Development Type Components.
c. Appropriate Weapon for test, including:

1) Cannon
2) Mount
3) Recoil mechanism

d. Sights, as required.
e. Gunner's Quadrant.
f. Target of appropriate size.
g. Time-Of-Flight Measuring Equipment, as specified in MTP 4-1-005, MTP 4-2-805 or MTP 4-2-827.
h. Copper Blast Gages as required (see MTP 3-2-810).
i. Appropriate Test Site.
j. Meteorological Equipment to measure Temperature, Air Density, Pressure, Humidity and Wind Velocity.

4. REFERENCES

A. MTP 3-1-002, Confidence Intervals and Sample Size.
B. MTP 3-2-810, Weapon Pressure Measurement.
C. MTP 3-2-828, Statistical Aids.
D. MTP 4-1-005, The Doppler Velocimeter.
E. MTP 4-2-501, Projectiles.
F. MTP 4-2-805, Projectile Velocity Measurements.
G. MTP 4-2-827, Time of Flight and Ballistic Coefficient.

5. SCOPE

5.1 SUMMARY

This MTP outlines principles, methods, and techniques for conducting direct fire accuracy and dispersion tests suitable for evaluating the weapon and ammunition of tank guns, artillery, and recoilless rifles. It also covers current observations that are made for time-of-flight and strength of design.

5.2 LIMITATIONS

Techniques for measuring time-of-flight are discussed in MTP 4-2-827. Tests for strength of design are covered by MTP 4-2-501. Accuracy and dispersion tests of small arms are covered in separate MTP's.

6. PROCEDURES

6.1 PREPARATION FOR TEST

6.1.1 General

a. After reviewing the test directive, the test director considers the following points in developing a test plan that will provide optimum results from an engineering, statistical, and economic viewpoint:

1) The test should incorporate the use of control or reference rounds. The type, quantity, and order in which these rounds are fired depend upon the nature of the test. Through the use of reference rounds it is possible to check the test setup, detect extraneous variables, and relate the results of the test to standard conditions.
2) The number of rounds fired should be the minimum required to secure results with acceptable statistical reliability.
3) The order of firing (alternated individual rounds or groups, or other means for controlling test conditions) is determined by the time allotted for firing, target measurement, and replacement of targets; time lapse between test and reference firings; and possible interaction between propellants.
4) The requirements for instrumentation and measurements should be carefully determined.
5) If the test is skillfully designed, it may be possible to eliminate by data analysis the effect of extraneous variables in the test rounds, even though these variables cannot be measured directly.

b. The test directive should allow the test director to alter the program or to cease firing if warranted by the early results in order to obtain the most information from a particular firing and to permit economical operation. The test director should evaluate the target concurrently with the firing using Figure 2. In Figure 2 vertical and horizontal dispersions are treated separately to obtain approximate vertical and horizontal standard deviations, respectively.

6.1.2 Ammunition Requirements

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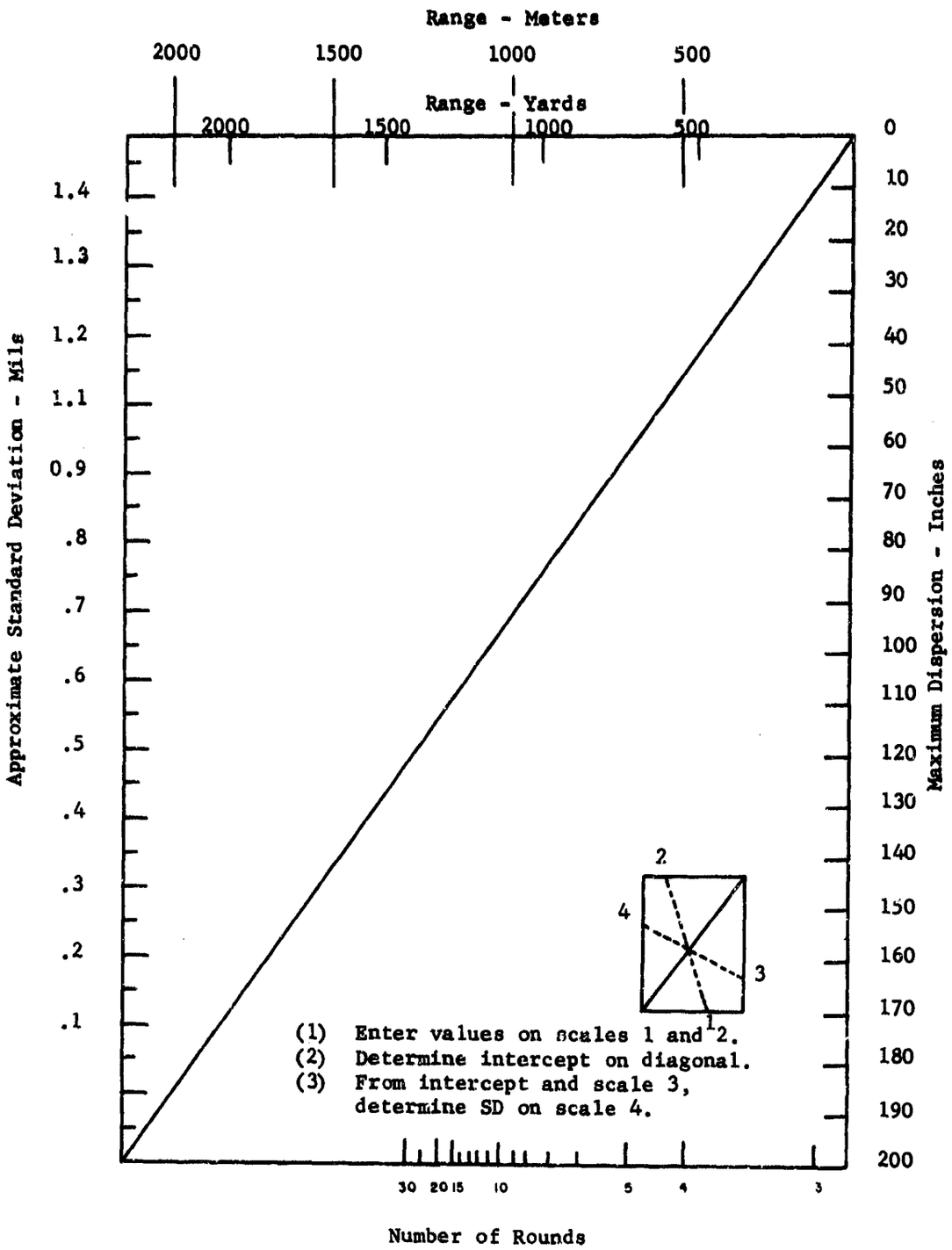


Figure 2. Target Standard Deviation From Maximum Dispersion.

6.1.2.1 Reference Rounds

In accuracy and dispersion tests a standard round is fired for reference purposes. Only in rare instances, as with new types of guns using new families of ammunition, will it be impossible to fire some sort of reference round. A reference round establishes the best comparison and control for the test series. From the results of the reference firing the test director can judge whether the test facilities, as assembled, are performing satisfactorily. If the accuracy or dispersion is unsatisfactory after five to 10 reference rounds, the test should be stopped until the cause of the difficulty can be isolated. The trouble usually can be traced to the gun, gunner, mount, or sight, either singly or in combination.

The reference rounds should be as nearly identical to the test rounds in form and weight as possible. If a reference round similar to the test round is not available, any standard projectile with good accuracy characteristics is selected as a reference and fired at its own service charge. Both groups should be fired at the same temperature, velocity and pressure levels. Other reference components, such as the propellant, cartridge case, and primer, are chosen from one lot, when practicable.

Record the type of round used and its propellant weight, composition, web size and lot number.

6.1.2.2 Test Rounds

The test directive usually specifies the type and model of test projectile to be fired; in many cases the directing agency actually supplies the test projectile. Other components used to complete the round should be standard. If standard components are not available advanced development types designed specifically for the projectile may be used.

Record the following for complete test projectiles:

a. Identification of individual components by model and lot number
b. Assembly arrangement
c. Propellant weight, composition, web size, and lot number

6.1.2.3 Ammunition Component Effects

In selecting ammunition components for accuracy and dispersion firings, the following factors must be considered because they may affect results:

a. Projectile - Differences between lots and individual projectiles due to variation in physical characteristics may affect test results and should be noted. These variations may occur in the rotating band seating, rotating band and bourrelet diameters, projectile finish, projectile filler, center of gravity, eccentricity, axial and transverse moments of inertia, weight and fit of components designed to discard in flight.

b. Propellant - The propellant-ignition system may affect accuracy in that large variations in muzzle velocity will increase vertical target dis-

persion while muzzle blast may influence initial launching. Certain propellant compositions may erode metal parts of the projectile during passage through the gun bore.

c. Cartridge case - The case may affect dispersion by introducing an eccentric projectile assembly that could result in balloting of the projectile and subsequent engraving. If crimping is too severe, portions of the cartridge case or related assembly may become detached and remain with the projectile in flight.

6.1.3 Test Facilities and Equipment

6.1.3.1 Site

The optimum site for a vertical target dispersion test is one that affords unrestricted view of, and access to, the target.

6.1.3.2 Cannon

The cannon consists of two basic assemblies, the tube and the breech ring. The models of tube and breech ring to be used are determined by the ammunition to be fired or by the test directive. In recoilless weapons, the venturi nozzle replaces, or is part of, the breech assembly.

Before firing, measure and record the condition of the tube in terms of wear measurements and accuracy life remaining based on both visual examination and the latest available pullover gage readings. Record the model and serial numbers of the weapon and tube, and the method of firing, i.e., electric or lanyard.

The tube remaining life must be satisfactory for the entire firing program. Assurance will be based upon previous experience with tube wear and the type of projectile being fired.

6.1.3.3 Mount

The mount is chosen primarily on the basis of its stability, sighting brackets, and telescope mount. The tube should fit the mount securely, and the mount is best anchored in a permanent concrete pedestal (unless the cannon is to be fired from the service mount). When unlocked, the mount should traverse and the cradle elevate freely and smoothly. Both traversing and elevating mechanisms should be capable of mounting a direct-fire sight, should operate freely and smoothly with a minimum of gear slack, and should be capable of adjustment and secure locking.

Record the mount model and serial number.

6.1.3.4 Recoil Mechanism

This facility depends upon the cannon to be fired. It must be in satisfactory operating condition.

Record the recoil mechanism model and serial number.

6.1.3.5 Sights

A telescopic sight of about six-power magnification with a reticle is suitable for on-carriage fire control. The sights used for accuracy and dispersion tests (except fire control equipment supplied for test) should be marked "Special for Accuracy and Dispersion Tests Only," stored and handled with particular care, inspected regularly, and kept in excellent operating condition. An optical boresight, for aligning the carriage sight with the bore, is desirable but not mandatory.

Record the model and serial numbers of the sighting equipment used.

6.1.3.6 Quadrant

A gunner's quadrant, M1 or M1A1, should be employed for superelevation only. The quadrant should be calibrated before use, stored and handled carefully, and kept in excellent operating condition. On extended tests, the quadrant should be recalibrated at prescribed intervals.

Record the quadrant model and serial number.

6.1.3.7 Target

The primary target should be large enough to register all the anticipated impact for any particular weapon-ammunition combination, with a 100-percent "safety" factor in maximum dispersion. For example, if the maximum spread of the impacts is expected to be within a 4-foot square, the minimum target size should be 8 by 8 feet. The maximum target size is usually 20 by 20 feet. The target frame should be of minimum weight consistent with the requirements for strength and rigidity. The target material, either chipboard, plywood, or cloth, should be securely attached to the frame. The aiming point is shown on the target by a cross, the legs of which extend to the edges of the target or the target pattern. The legs have the narrowest width capable of being seen from the gun. An additional pattern of cross hatching at 3-foot intervals will aid in locating impacts. The target should be erected vertically and braced to withstand projectile impact and wind pressure. Braces should be kept to the side of the target in order to avoid damage from the projectile.

The optimum primary target is one that can be seen from the weapon position and on which the gunner can thus directly align his telescopic line of sight. If the primary sight is obscured by intervening knolls or bushes, etc., the gunner's telescopic line of sight can be directed at a secondary aiming target, of any convenient size, sufficiently displaced in azimuth from the primary target to avoid being accidentally hit.

Record the size and shape of the target used and its distance from the weapon.

6.1.3.8 Time-of-Flight Measurement Equipment

Time-of-flight data are required whenever a determination of form factor or ballistic coefficient is needed as described in MTP 4-2-827. Time-of-flight data are usually obtained in conjunction with vertical target accuracy and dispersion tests. There are three methods of measuring time-of-flight as follows:

a. Doppler velocimeter (MTP 4-1-005)
b. Sky screens (MTP 4-2-805)
c. Wire mesh screen (MTP 4-2-827)

Record the method used and, as applicable, the model and serial number of the equipment used.

6.1 3.9 Strength-of-Design Determination

The need for concurrently evaluating strength of design (which includes metal parts security) and the complexity of the instrumentation and observation techniques used depend upon the past performance of the projectile, the comprehensiveness of the test program, and other factors. Techniques for studying metal parts security are described in MTP 4-2-501.

6.1.3.10 Observation Point

Depending upon the range used, the point for observing target impacts should be located about 25 yards uprange from the primary target and adjacent to (but not on) the line of fire. The observation point should be heavily protected on the weapon side and open toward the target. It should be equipped for communication with the gun position. Observations may also be made for the gun position by use of battery commanders' telescope to check the forward observers.

6.1.3.11 Velocity Measurements

Set up equipment to measure projectile velocity as indicated in MTP 4-2-805 and record the following:

a. Velocity recording devices by type and model number.
b. Distance from muzzle of gun to first coil and between coils measured to 0.01 foot.

NOTE: The distance between the coils will be the average of four measurements: inside-to-inside and outside-to-outside, both top and bottom of coils.

6.1.3.12 Chamber Pressure Measurements

Prepare gages for measuring chamber pressure described in MTP 3-2-810 and record the model and copper lot number and number of each gage used.

6.1.3.13 Fire Control Equipment

Fire control equipment and its operation are carefully checked and adjusted to avoid introducing systematic errors into the firing program. Sight mounts and brackets should fit snugly and be free of play.

6.1.3.14 Treatment of Instrumentation

Observation and recording instrumentation (including meteorological) are carefully installed. Necessary calibration measurements are made and verified.

Record the following:

a. Photographic equipment used by type and model.
b. New or unusual equipment used by type, model number, and a brief description.

6.1.4 Gunner and Gun Crew

A highly skilled gunner is designated for an accuracy and dispersion program. The variables inherent in human performance are minimized if the weapon is laid and fired each time by the same gunner using the same step-by-step procedures.

The procedures for accomplishing the program are discussed with the gun crew in advance of the firing. A mutual understanding of the problems and the operation of the program helps to avoid misunderstandings and serious errors at critical moments.

6.2 TEST CONDUCT

NOTE: Tests for accuracy and dispersion and strength-of-design may be run simultaneously or through separate firings.

6.2.1 Sighting

6.2.1.1 Alignment of Optical Sight With Boresight

a. Provide breech and boresight references as follows:

1) Mount a breech boresight in the weapon chamber with a muzzle insert (a cross hair either of fine wire or the cross taken from an optical instrument and mounted to fit the muzzle).
2) If a suitable muzzle insert is not available, a cross hair is constructed with two pieces of fine string pulled taut across the boresight lines on the muzzle face.

NOTE: Since the boresight lines may not be truly horizontal and vertical, the intersection of the cross hairs furnishes a suitable reference point.

3) If a suitable breech boresight is not available, insert a boresight case (a cartridge case with a 1/16-inch hole in the center) into the breech.

NOTE: The case should be inserted in the same manner each time: a reference mark on the case is made to coincide with a similar reference mark on the breech of the weapon.

b. Align the weapon so that the optical line formed by the muzzle and breech references intersect a distant reference point, preferably a corner of the target.

NOTE: Any effect caused by movement of the eye must be considered and compensation made.

c. Finally, adjust the optical sight on the gun carriage to intersect the same point, thus aligning it with the boresight.

NOTE: There is a natural error of one-third of a mil in boresighting since this value is the limit of the angular resolution of the eye.

6.2.1.2 Acquisition of the Target

a. Proceed as follows after the optical carriage sight has been aligned with the boresight:

1) Aim the weapon at the center of the target, using the optical sight and record the azimuth.
2) Check the elevation at boresight with the gunner's quadrant and record the reading.
3) Add the estimated superelevation obtained using the techniques described in Appendix A to the boresight reading and elevate the piece accordingly.
4) View the target again through the optical sight to ensure that the weapon did not move in azimuth when it was raised in superelevation.

NOTE: It is considered prudent to match, if possible, a fixed reference on the target (such as the top edge) with one of the horizontal grid lines on the sight reticle, for comparison with subsequent quadrant readings.

5) Load a reference round of ammunition into the weapon and recheck the quadrant and the sight so that any movement of the piece inherent in the loading operation can be detected and corrected

b. If in firing low-velocity weapons to fairly long ranges, the situation arises when the optical sight will not intersect any point on the target after the weapon is raised in superelevation, proceed as follows:

1) Depress the optical sight from the boresight line to some reference point on the target or, if clearance does not permit, traverse the sight to a secondary target placed as close to the main target as possible, at boresight elevation.
2) Confirm the adjustment of step b.1 above, with the sight at superelevation.

NOTE: It is apparent that the more the movement of the optical sight away from the boresight, the greater the possibility of error due to cant or parallax. Such movements should be kept to the minimum and care should be taken to record the exact azimuth and elevation changes. Thus, a check of the optical sight against the boresight can still be made at intervals throughout the test.

6.2.2 Firing

Record the following for all firing exercises:

a. Date of test.
b. Meteorological data covering the time interval of firing, including:

1) Wind speed to the nearest meter per second.
2) Wind direction to the nearest 5 degrees.
3) Statement as to whether wind was shifting or gusty.
4) Air temperature read to the nearest degree centigrade at one-half-hour intervals while firing.
5) Barometric pressure and humidity recorded every hour.
6) Air temperature, barometric pressure, and humidity recorded for every round if results are required to greatest possible accuracy.

6.2.2.1 Registration

a. Fire a round, observing it in flight, if possible, and locate its point of impact, using the technique of paragraph 6.2.2.4, and, if it does not exhibit any undue behaviour (excessive yawing, tumbling, loss of components, etc.), and if it is not a first conditioning round, assume it to represent characteristic performance and proceed as follows:

1) If the projectile falls short or over, and the amount of miss can be estimated, correct the elevation of the weapon by changing the elevation by the number of mils it would take to put the impact on the center of target.

NOTE: For small angles, a mil is equal to 1 meter at 1,000 meters, or any proportional amount for other ranges.

2) Repeat the process until a target hit is registered. Not more than three practice rounds should be required to hit a vertical

target at ranges up to 2,000 meters, provided that the impacts are observed each time.

3) Once a good hit has been registered, fire two additional rounds at the same azimuth and elevation to obtain an estimate of the center of impact.
4) If the dispersion of step c is large compared to target size, or if many rounds are to be fired, indicating a probably increase in dispersion, realign the center of impact closer to the center of the target.
5) Record the following for each round fired:

   a) Tube round number.
   b) Firing time.
   c) Projectile weight to nearest 0.01 pound for projectiles larger than 20 millimeters.
   d) Superelevation after loading to nearest 0.1 mil.
   e) Traverse setting (right or left of target center).
   f) Muzzle velocity and chamber pressure.
   g) Location of target impact (indicate probable flight - high over, low under, right, left, etc., for rounds that miss) determined as described in paragraph 6.2.3, below.

b. Fire a reference group, the number of rounds being at least equal to the number in a test series, at the rate indicated in paragraph 6.2.2.3 below while controlling the gun movement as indicated in paragraph 6.2.2.2 below, and record the data of step a.5 above, for each round and the individual reference round number.

NOTE: If the accuracy or dispersion is unsatisfactory after 5-to-10 reference rounds, the test should be stopped until the cause of the difficulty is determined.

c. Fire test rounds immediately following the reference group, unless statistical techniques, based upon the number of test series and number of rounds within each series, dictate a different firing order, using the following guidelines:

1) The firing rate shall be as indicated in paragraph 6.2.2.3 b below.
2) Gun movement control shall be as indicated in paragraph 6.2.2.2 below.
3) Delays between reference and test firings are to be held to a minimum to avoid differences in meteorological conditions.
4) A 10-round series generally is of optimum acceptable value for a dispersion measurement although small calibers may require 20 rounds and large calibers only five rounds depending upon the availability of ammunition and knowledge of prior performance.
5) Two separate 10-round groups are considered better than one 20-round group due to possible fatigue effects and cumulative

round-to-round errors.

6) When several test series are fired on the same day, a reference group (step b, above) at the beginning and at the end of the firing is considered prudent.
7) Should any test series exhibit unusually poor performance for no apparent reason, a reference group (steb b, above) should be fired immediately to determine whether any factor in the test setup has changed.
8) Record the data of step a.5 above, for each test round fired and the individual test round number.

d. At the completion of firing of each test series of rounds return the weapon to the original boresight to detect any relative movement or loss of alignment between the optical sight and the bore.

6.2.2.2 Control of Gun Movement During Firing

a. Round-to-round control can be accomplished by using the optical sight for azimuth and elevation, checking the elevation with a quadrant, and observing the following guidelines:

1) The gunner shall check the physical looseness of the sight on the mount at each sighting.
2) Care shall be taken in laying the weapon to traverse and elevate in the same direction for each round and against the backlash of the gearing in all cases.
3) Final adjustments are made after the round has been loaded and the breech closed.
4) Any tendency of the lanyard to move the gun from its setting shall be checked, particularly if the mount is not rigid.

NOTE: The best indication of the rigidity of the system is found when the sight setting does not change after firing each round. This is a desirable but not an essential condition.

b. For weapons which do not have quadrant seats, which are usually provided on the gun for placing the quadrant when making elevation measurements, an accurate mount can be provided with machined quadrant seats and the weapon affixed parallel to these surfaces as follows:

1) Place a V-block on the tube to simulate a quadrant seat.
2) The feet of the quadrant should always be placed on the seats identically each time to guard against possible nonparallelism of the seats.

NOTE: Good round-to-round control is thus maintained, even though the absolute elevation may be in error.

c. Exercise care to detect and correct any pronounced cant using the following guidelines:

NOTE: Cant exists when the gun does not move in an exact horizontal plane in azimuth or perpendicular plane in elevation.

1) If the sight has been cross-leveled at the boresight elevation and cant exists, the leveling bubbles will not remain fixed as the gun is elevated or traversed.
2) Once the sight has been aligned with the gun bore, both will remain parallel, regardless of cant. If any sight adjustments are made at superelevation, however, parallelism may be lost and the exact magnitude of change will not be known.
3) Adjustment of the sight should always be made at boresight elevation and never at superelevation.
4) When neither the gun nor the sight is provided with leveling bubbles, cant can be detected by using the horizontal and vertical edges of the target, or the target cross, as a reference. If the weapon is without cant, the boresight will remain parallel to the horizontal adge of the target when the weapon is traversed and parallel to the vertical edge when it is elevated.

6.2.2.3 Rate of Fire

The rate of fire should be as uniform as possible, approximately one round every 2 minutes. Cooling and heating of the tube cause dimensional changes as well as velocity variations, which affect accuracy.

6.2.2.4 Spotting and Recording Hits on Target While Firing

As each target impact occurs, the approximate location of the impact is recorded by observers, both at the gun and at the target, if possible. A gridded target with corresponding coordinate paper is convenient for this purpose. General observations pertaining to the nature of the projectile flight are important and may explain outlying impacts.

6.2.2.5 Time-of-Flight Measurements

Time-of-flight measurements, as appropriate, are made in accordance with MTP 4-2-827.

6.2.2.6 Strength of Design

Observations of strength of design are made in accordance with MTP 4-2-501.

6.2.3 Measuring for Coordinates of Impact

The location of impacts on the target is required for each round. These locations should be determined by specifying a horizontal and vertical distance from some fixed reference point. This reference point is somewhat

arbitrary and may be the center of the target, a corner of the target, the aiming point, or any other fixed point on the target. Once the reference point is selected and located, the horizontal and vertical distances of each impact are measured. These measurements, to the nearest one inch, will be made to the center of each impact hole. If a point other than the aiming point is used as a reference for these measurements, then the coordinates of the aiming point should also be measured relative to the established reference point.

a. If the azimuth, the elevation, or both are changed at any time during the dispersion series, the following procedure will be applied:

1) Determine by quadrant and sight the exact distance the gun was traversed or elevated. These changes are noted in the round-by-round data in the firing record.
2) Measure the impact coordinates from the same point as on the previous rounds. These measurements are corrected in the firing record for the sighting changes.

b. One should be alert to the possibility of a projectile missing the target so that every effort can be made to determine the direction of miss. This information should be concise but reliable enough to establish trend patterns if they exist. Therefore, the miss information may be stated as "high and right," "high," "low," "low and left," etc.

6.3 TEST DATA

6.3.1 Preparation for Test

6.3.1.1 Ammunition Requirements

Record the following:

a. For reference rounds:

1) Type round used
2) Propellant weight, composition, web size, and lot number

b. For test rounds:

1) Individual components by model and lot number
2) Assembly arrangement
3) Propellant weight, composition, web size and lot number

6.3.1.2 Test Facilities and Equipment

Record the following:

a. Location of test site
b. For the weapon:

1) Model and serial number

2) For the tube:

a) Tube model and serial number
b) Visual observation commentary on tube condition
c) Latest available pullover gage readings
d) Firing mechanism (electric, lanyard)

3) Mount model and serial number
4) Recoil mechanism model and serial number

c. For sighting equipment:

1) Type used (telescope, borescope)
2) Model and serial number of each item used

d. Quadrant model and serial number
e. For target:

1) Size and shape
2) Distance from weapon to nearest 0.1 meter

f. For time-of-flight measurements:

1) Method used (doppler velocimeter, sky screen, wire mesh screen).
2) Description, model and serial number of all equipment used.

g. For velocity measurements:

1) Type and serial number of velocity recording devices used
2) Distance to nearest 0.01 foot from:

a) Gun muzzle to first coil
b) First coil to second coil

h. For chamber pressure measurements:

1) Model and copper lot number of types used
2) Number of gages used

i. For instrumentation:

1) Type and model number of photographic equipment.
2) Type, model number and brief description of new or unusual equipment used.

6.3.2 <u>Test Conduct</u>

6.3.2.1 Sighting

6.3.2.1.1 Alignment of Optical Sight with Boresight -

Record boresighting reading to nearest 0.1 mil.

6.3.2.1.2 Acquisition of the Target -

Record the following:

a. Quadrant elevation with boresight on center of target to the nearest 0.1 mil.
b. Azimuth of line of fire to nearest degree.

6.3.2.2 Firing

a. Record the following during the interval of firing:

1) Date of test in day, month and year
2) Meteorological data covering the time interval of firing, including:

a) Wind velocity to the nearest meter per second.
b) Wind direction to the nearest 5 degrees.
c) Statement as to whether wind was shifting or gusty.
d) Air temperature read to the nearest degree centigrade at one-half-hour intervals while firing.
e) Barometric pressure and humidity recorded every hour.
f) Air temperture, barometric pressure, and humidity recorded for every round if results are required to greatest possible accuracy.

b. Record the following for each round fired, as applicable:

1) Time of firing in hour and minute.
2) Type of round (conditioning, spatter, reference, test).
3) Tube round number.
4) Test round number.
5) Projectile weight to nearest 0.01 pound.
6) Elevation over boresighting (superelevation) after loading to nearest 0.1 mil.
7) Traverse setting (right or left of target center) in inches.
8) Muzzle velocity in fps.
9) Chamber pressure in psi.
10) Location of target impact for rounds hitting target.
11) Probable flight (high over, low under, left, right, etc.) for rounds missing target.
12) Time-of-flight data collected as described in MTP 4-2-827.
13) Observations on strength of design made in accordance with MTP 4-2-501.

6.4 DATA REDUCTION AND PRESENTATION

Proper analysis of the test data requires a knowledge by the analyst of all factors that might influence the weapon system performance and thus

affect the test results. Once the performance of the test item can be defined, it is then a question of how this performance compares with requirements for target accuracy and dispersion. These comparisons will involve statistical analysis of the data, but it is not unusual for experience and engineering judgment to play important parts in these comparisons. Results of the data reduction and analysis should be carefully examined for clues that would suggest faulty or inadequate data collection. A reanalysis might be necessary or even additional firing. Metal parts separation or deformation could be an unfair influencing factor.

6.4.1 Target Accuracy and Dispersion Data

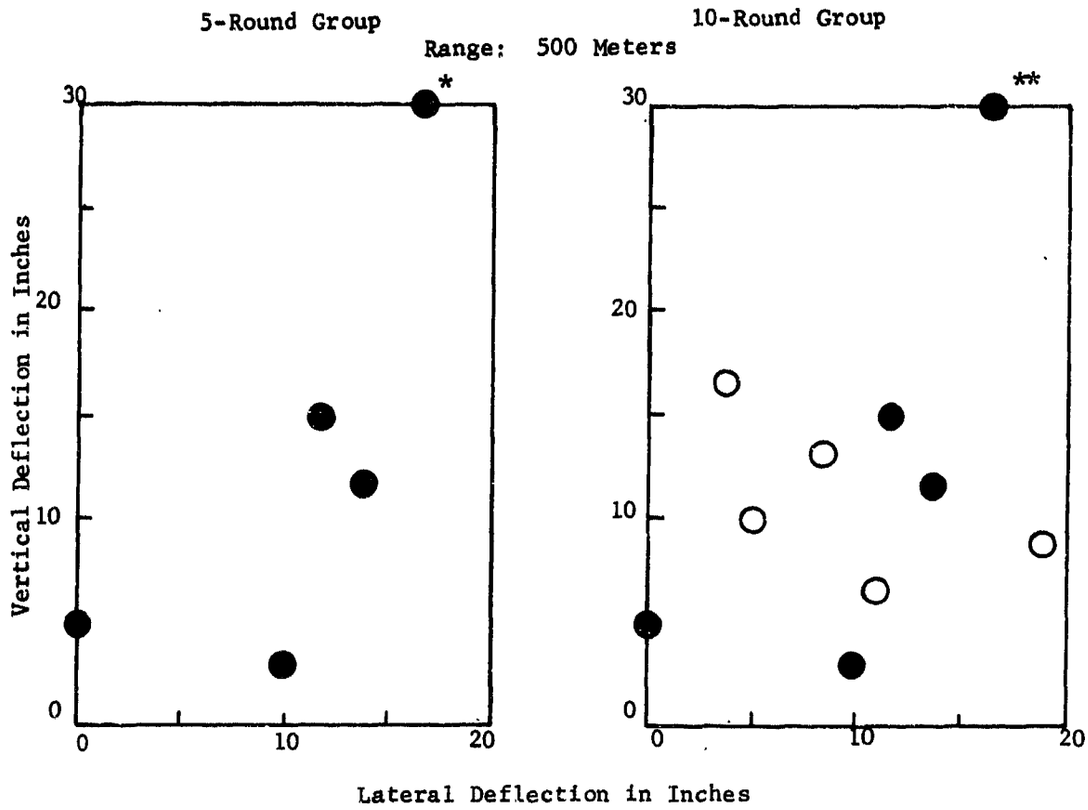
Reduction of the basic impact data should be performed with corrections applied only for changes in elevation or azimuth of the weapon. These calculations will include the center of impact (CI) or the particular group of rounds as well as the dispersion. The dispersion will be expressed as maximum dispersion (MD) and standard deviation (SD). These calculations will be shown first in the units of actual measurement, generally inches, and then converted to mils. Additional details on performing these calculations are in MTP 3-2-828.

Refinements of these basic data are performed on a round-by-round basis to account for the influence of projectile weight and velocity on impact. In addition, the data and firing procedure are studied carefully to detect outliers, trends, or shifts in level of performance. Plots illustrating some of these problems and their effects on the data are shown in Figures 3 to 6. When the test firing includes both a control and test round fired alternately, care must be taken to treat both types of rounds alike when correcting for trends or shifts. When a bracketing technique is used in the order of fire, the treatment of trends or shifts may become considerably more complicated but also more important.

A summary of the accuracy and dispersion data will be prepared showing results for the basic data and the final corrected or refined data. A detailed accounting of these corrections will be shown. If the performance of a test round is to be compared with that of a control round or with a stated level of performance, statistical statements should be made in accordance with procedures shown in MTP 3-1-002 and MTP 3-2-828.

6.4.2 Time-of-Flight Data

Time-of-flight data should be prepared for each round fired. Depending on the instrumentation used, this may be only the flight time as is the case with the wire mesh screens. When using sky screens the data will include velocity and flight time to several positions, while with the doppler velocimeter a continuous velocity-time profile is obtained. It is essential in the reduction of data for all these methods that the projectile characteristics be known and that the location and orientation of all instruments be known. Following a careful review of the round-by-round data, it may be possible to select representative rounds for reduction of ballistic data. The procedures for computing the projectile form factor and ballistic coefficient from these data are described in MTP 4-2-827.



Vertical SD: 0.41 mils

Vertical SD: 0.29 mils
0.18 mils (omitting **)

*This round is not a statistically significant outlier in the five-round group.
**This round is a statistically significant outlier in the ten-round group.

Figure 3. Vertical Target Dispersion. (Illustrating the influence of sample size on the estimation of dispersion in groups with a maverick round.)

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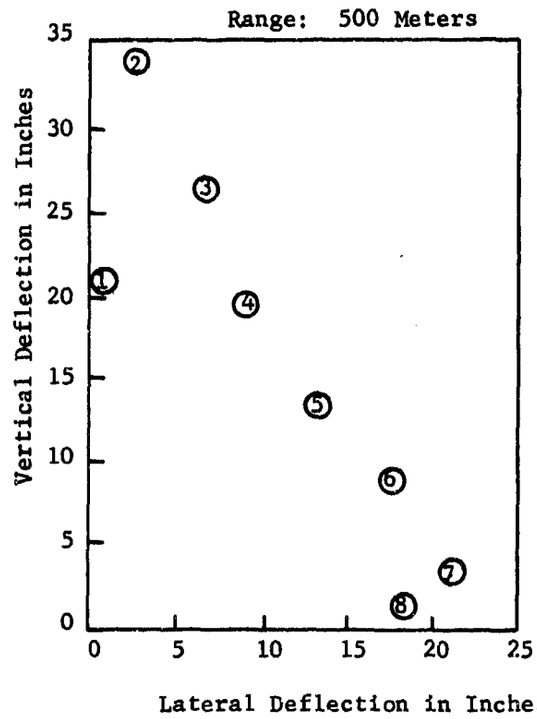
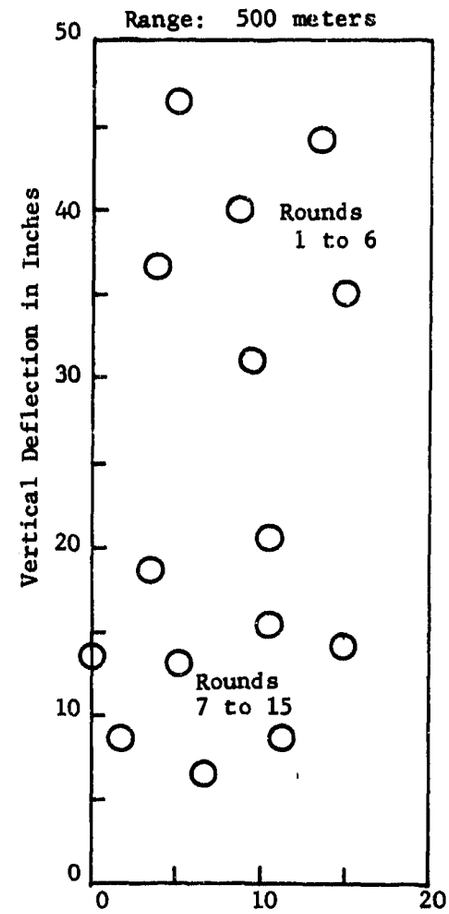
Illustrating Presence of Shift in Centers of Impact

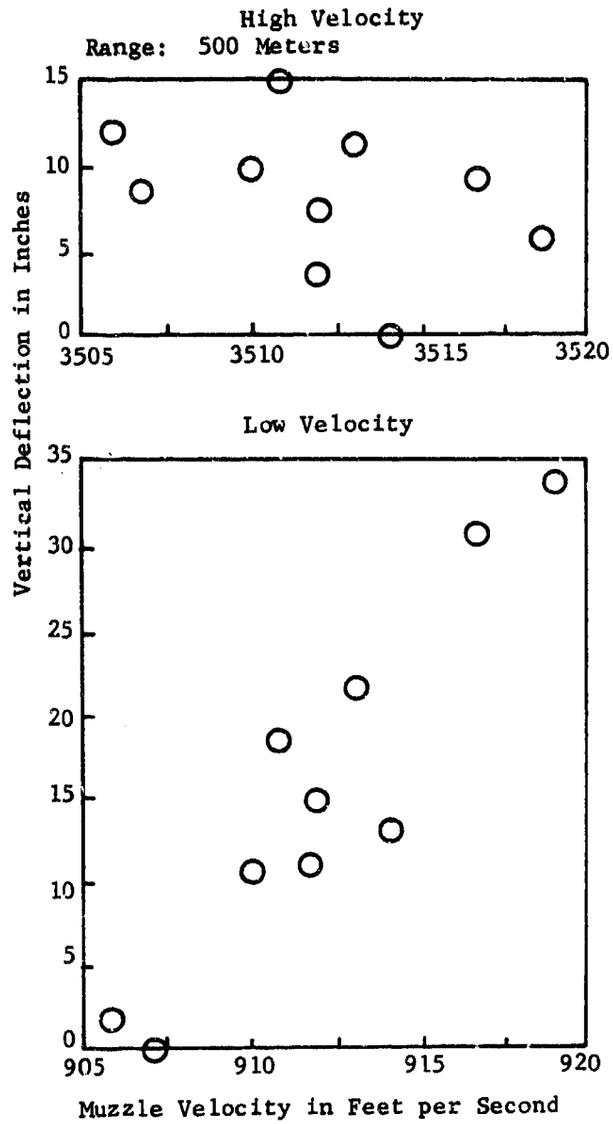


Coordinate	Standard Deviation (mils) By Root Mean Square	By Successive Differences
Vertical	0.43	0.20
Lateral	0.30	0.09



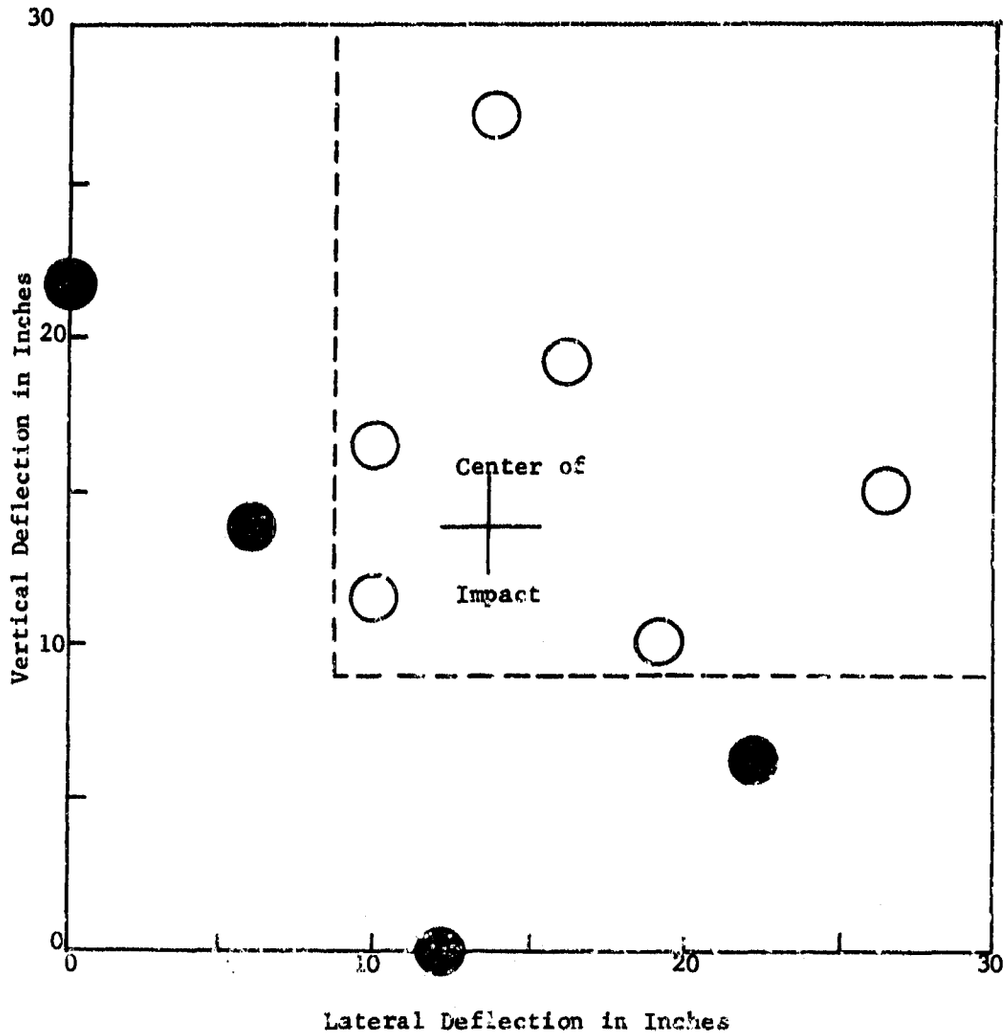
	Vertical SD (mils)
All 15 rounds	0.53
Pooling the results for rounds 1-6 and 7-15	0.19

Figure 4. Vertical Target Dispersion.



Group	SD of Vel (fps)	SD of Vertical Impacts (mils) Uncorrected	Corrected for Velocity
High Velocity	2.7	0.16	0.16
Low Velocity	2.7	0.42	0.16

Figure 5. Vertical Impacts Versus Muzzle Velocity. (Illustrating the effect of velocity dispersion at different velocity levels on drop of vertical impacts.)



Group	Standard Deviation (mils) Vertical	Lateral
All Rounds	0.29	0.29
Omitting ●	0.23	0.22

● Assuming dotted line is the edge of the target, these rounds would have missed.

Figure 6. Vertical Target Dispersion. (Illustrating the effect of the relation between centers of impact and the edge of the target in estimating standard deviation.)

APPENDIX A

ESTIMATION OF SUPERELEVATION

Except at very close ranges, a hit cannot be obtained on a target merely by boresighting. When a projectile leaves a weapon, it is affected by gravity so that its path is curved downward. To insure a hit, it is necessary to elevate the weapon above the boresighted position by a given amount, depending on the type of projectile, the muzzle velocity, and the target range. The elevation above boresight required to hit the target is called superelevation. Firing tables provide the best source for this information. In some instances, however, these tables may not be available for experimental weapon and ammunition, while in other cases the loss of muzzle velocity due to weapon erosion might preclude the accurate application of firing table data. In this event, the nomograph shown in Figure A-1 can be used to make the initial prediction of a superelevation provided that either the muzzle velocity or the time of flight is known or can be estimated. The nomograph is designed primarily for spin-stabilized projectiles in the 75- to 120-millimeter-caliber range, having a long conical or ogival nose, a cylindrical body, a flat or boattailed base, and a cross-sectional density of about 2.0 pounds per square inch. This method is not generally recommended for use with blunt-nose projectiles, test slugs, or fin-stabilized projectiles. For such projectiles, the nomograph values of superelevation are generally too low.

The scales of Figure A-1 are designed so that if two variables are known, the remaining two variables may be determined. To solve for an unknown, proceed as follows: Locate the position of the two known variables on their respective scales and connect these positions with a straightedge. The value of the unknown will be found at the intersection of the straightedge with the particular scale of the unknown.

> <u>Sample Problem</u>: For a projectile having a muzzle velocity of 2400 fps, find the superelevation required to hit a target at 1000 meters. First, locate 2400 on the velocity scale and 1000 meters on the range scale. Then place a straightedge along those two points and read the superelevation, 9.7 mils, at the intersection of the straightedge and the superelevation scale. Although not required for the problem, the intersection of the straightedge and the time-of-flight scale will also yield the correct time-of-flight, which is 1.45 seconds.

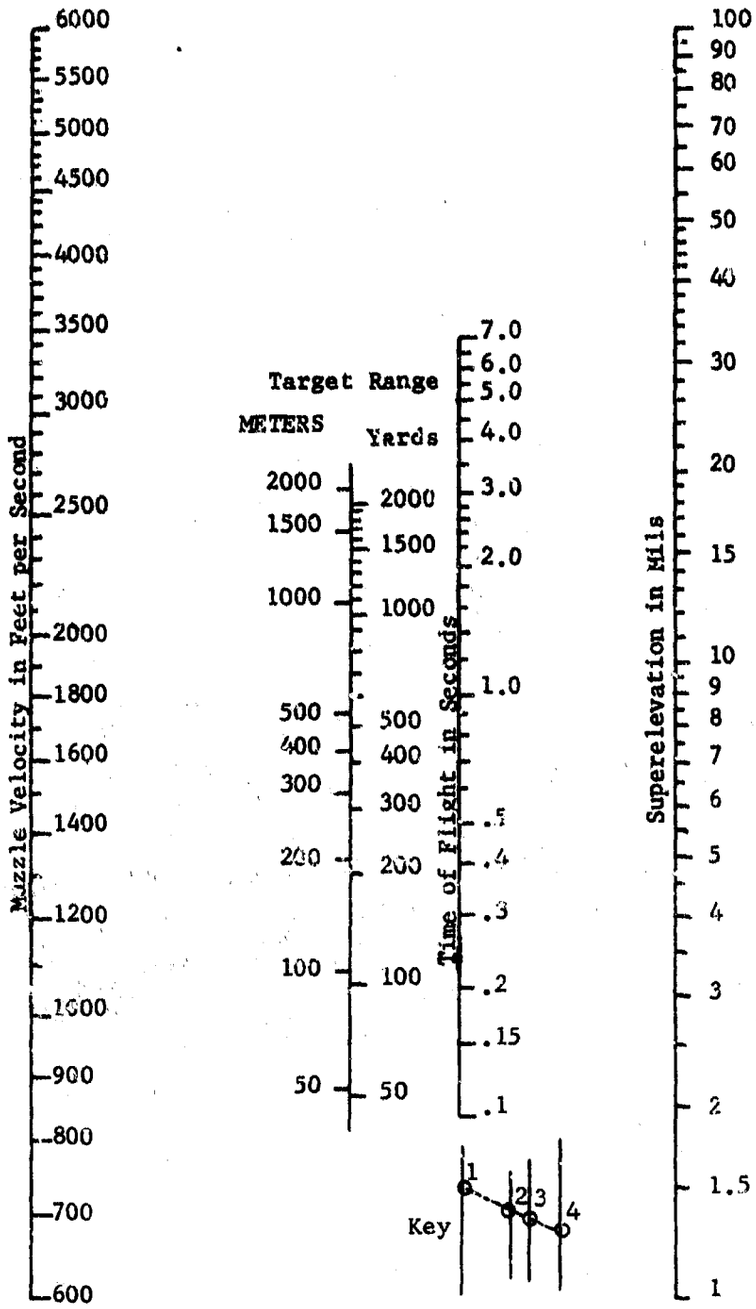


Figure A-1. Approximate Superelevation and Time of Flight Required to Hit Targets at Various Ranges.