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MEMORANDUM REPORT NO. 2281

ON THE MISUSE OF FIELD ARTILLERY FIRING TABLES

by

Charles H. Lebegern, Jr.

March 1973

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USA BALLISTIC RESEARCH LABORATORIES
ABERDEEN PROVING GROUND, MARYLAND

BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 2281

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ON THE MISUSE OF FIELD ARTILLERY FIRING TABLES

Charles H. Lebegern, Jr.

Exterior Ballistics Laboratory

RDT&E Project No. 1T562603A041

ABERDEEN PROVING GROUND, MARYLAND

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

MEMORANDUM REPORT NO. 2281

CHLebegern/mjm
Aberdeen Proving Ground, Md.
March 1973

ON THE MISUSE OF FIELD ARTILLERY FIRING TABLES

ABSTRACT

This report explains the intimate relationship between firing tables and the techniques of fire used to attack targets. Probable error and accuracy of fire are also explained. The differences between precision probable error and mean point of impact probable error are given and the influence of both of these errors on accuracy of fire is demonstrated.

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I. IMPROPERLY COMPUTED QUADRANT ELEVATIONS TO HIT TARGETS

For many years, field artillery firing tables have contained, in their Introductions, the following statement: "Firing Tables contain the data necessary to arrive at the quadrant elevation and deflection that will produce detonation of the projectile at the target when firing under all conditions of weather and materiel." Until recently, this statement has either been ignored or properly understood by Artillerymen. Today, however, the statement is often quoted and is definitely misunderstood by some Artillerymen.

If the firing table user would continue reading the table Introduction, he would find a description of the gunnery procedures approved by the Artillery Community for the attack of targets. He would also see by reading this Introduction, that the firing table is only one of the required elements necessary to produce detonation of the projectile at the target. The other elements are a function of the particular technique of fire being employed. Today, however, some users have chosen to ignore the approved techniques of fire and invent new techniques of their own. One such technique is called, as we understand, the "should hit-did hit method of fire". This technique is somewhat related to the determination of registration corrections, but it is conducted in a different manner. The "should hit-did hit method of fire" consists of fixing the elevation of the tube, firing several rounds and measuring muzzle velocity, range, deflection and meteorological data. The measured ranges and deflections are then corrected to the ranges and deflections shown in the firing table for the same elevation, muzzle velocity and meteorological data. The difference between the actual and corrected ranges and deflections are, then, attributed to errors in the firing tables.

The most significant difference between this method and a registration is the placing of the blame for the computed differences. In the "should hit-did hit method of fire" the firing table is said to be in error if there are differences. In a registration, however, unknown variations are admitted. The following statements are contained in

FM 6-40, Field Artillery Cannon Gunnery, page 21-3: "Corrections for these unknown variations are included in the corrections determined from a registration. For convenience, the total of the unknown variations are grouped together and termed "velocity error" (VE)."

One of these unknown variations is, of course, firing table error. This error, however, can not be isolated from all of the other errors by conducting either a registration or a firing using the "should hit-did hit method of fire". The firing table error can and has been isolated by analyzing many firings conducted over many years. This analysis can only be performed by the Firing Tables Branch who have access to large amounts of firing data. If firing table errors are discovered by the Firing Tables Branch, new firing tables are issued soon after such a discovery. In general, the firing table error is one of the smallest errors that the Artilleryman must contend with.

II. PROBABLE ERROR AND ACCURACY

Probably the most misunderstood and misused quantity in a field artillery firing table is the probable error. This is so because almost all firing table users feel that probable error is the one quantity that they do understand.

It may be that the Army definition of probable error is poor. The definition does state that probable error is the value that any given error will as likely fall under as exceed; but what it does not do is explain that there are many different kinds of probable error. By different kinds we don't mean the probable errors in time, in range, in deflection, etc. What we do mean is that there are proving ground precision probable errors, pseudo-combat precision probable errors and mean point of impact (MPI) probable errors. To further confuse the issue, MPI probable errors are a function of the delivery technique used to attack a particular target.

A. Proving Ground Precision Probable Errors

Most field artillery firing tables contain columns of range, deflection, height of burst, time to burst and range to burst probable errors.

These probable errors we refer to as proving ground precision probable errors. They are "precision" probable errors because they give the scatter of burst points about the mean point of impact (MPI) of a group of rounds fired from a single weapon on a single occasion. Please note that there is no mention of a "target" in this explanation of precision. This is intentional since there is no attempt, when collecting precision data, to "hit" a target.

The term "proving ground" is contained in the name for these errors because they are, indeed, obtained from artillery range firings conducted at proving grounds. This means that the firings are exceptionally well controlled. Wind conditions are monitored and firings are not conducted when wind speed exceeds predetermined values. The "on carriage" fire control devices are by-passed and more precise external devices are used to insure that the azimuth and elevation of the weapon are maintained during the firing. Human errors are minimized because professional gunners are used and many double checks are made prior to the conduct of the firing. Shell weight is measured for every round and propellant temperature is maintained at a constant value for all rounds fired.

It has been shown [Reference 1] that proving ground precision probable error (in range) can be expressed by the following equation:

$$PE_X^2 = PE_V^2 \left(\frac{\delta X}{\delta V}\right)^2 + PE_C^2 \left(\frac{\delta X}{\delta C}\right)^2 + PE_\phi^2 \left(\frac{\delta X}{\delta \phi}\right)^2$$

where

PE_X = probable error in range

PE_V = probable error in velocity

PE_C = probable error in ballistic coefficient or drag

PE_ϕ = probable error in angle of departure

$\frac{\delta X}{\delta V}$, C or ϕ = first derivative of range with respect to muzzle velocity, ballistic coefficient or angle of departure.

This expression is used to "fit" all of the probable error data collected during proving ground range firings. The "fitted" expression is also used to generate the probable error data shown in the firing table. Please remember that any "fitted" expression does not reproduce the data points used to create the expression exactly and, if the data points are widely scattered, large differences may exist between the data points and the "fitted" expression. This is, in fact, very often the case with probable error data.

B. Pseudo-Combat Precision Probable Errors

By pseudo-combat, we mean that the range firings are conducted by trained artillery units, using their normal procedures in any firing exercise other than actual combat. While an artillery unit is not nearly so interested in the scatter of their shell about the MPI as they are the scatter of their shell about the target, many precision probable errors have been computed from artillery unit firings and compared to firing table values. This comparison sometimes reveals significant differences, and those differences, in turn, cause many users to doubt the validity of their firing tables.

Let us start to list, however, the differences between the proving ground and pseudo-combat precision probable errors:

(1) Propellant temperature is not maintained at a constant value during artillery unit firings. This difference may influence the muzzle velocity contribution to the precision error.

(2) "On carriage" fire control devices are used to maintain the azimuth and elevation of the weapon. This difference may influence the angle of departure contribution to the range probable error and the azimuth contribution to the deflection probable error.

(3) There is a much better chance for human error in artillery unit firings than in proving ground firings due to the care taken during the latter. This difference will also influence the angle of departure contribution to the range probable error.

(4) Wind conditions are not restricted during artillery unit firings and this, too could influence the probable errors obtained.

Looking now at the formula for pseudo-combat precision probable error (in range):

$$PE_X^2 = (PE_V + PE_{V_{PT}})^2 \left(\frac{\delta X}{\delta V}\right)^2 + PE_C^2 \left(\frac{\delta X}{\delta C}\right)^2 + (PE_\phi + PE_{\phi_{HE}} + PE_{\phi_{FC}})^2 \left(\frac{\delta X}{\delta \phi}\right)^2$$

where

$PE_{V_{PT}}$ = probable error in velocity due to propellant temperature

$PE_{\phi_{HE}}$ = probable error in angle of departure due to human error

$PE_{\phi_{FC}}$ = probable error in angle of departure due to "on carriage" fire control

We have not attempted here to isolate all of the individual error sources that contribute to pseudo-combat precision probable error. All that we have tried to do is show that proving ground and pseudo-combat precision probable errors have different contributors. It should be noted, also, that the "longer" formula for pseudo-combat error does not imply a "larger" error than those shown in firing tables.

C. Mean Point of Impact Probable Error

MPI probable error is defined as the scatter of MPI's about an aimpoint (target). This is the first of our definitions that make mention of the target, and since certain procedures or techniques are used when we attack a target, this probable error is a function of those procedures or techniques, therefore, we have MPI probable errors for observer adjusted fire, MET + VE fire, K-transfer fire, etc.

When the observer adjusted technique is being used against an area target, the bracket and halving method of adjustment is normally employed until a 100 meter bracket is achieved. This bracket is then split and fire for effect is entered. Since the rounds are not "aimed" at the center of the target, it is clear that an extra error is introduced over and above the precision errors discussed earlier.

When the MET + VE technique is being used, a prior registration (with it's associated error) is conducted and fire for effect is entered at a later time when met space and time variability, propellant temperature, etc. will introduce extra errors.

Mathematical formulae for these MPI errors have been developed and published widely, and they will, therefore, not be reproduced here.

D. Accuracy of Fire

Very frequently, in answer to the question of how "accurate" are certain weapons, individuals will look at the probable error value listed in the firing table and quote this figure as representative of the accuracy of the weapon. Nothing could be further from the truth. Accuracy consists of both precision and MPI errors. Therefore, when quoting figures for the accuracy of a weapon/shell combination, one should first state the technique of fire used and then give either the precision and MPI errors separately or the RMS (Root Mean Square) of these two values. As an example of the difference between these values, the following table is given:

Weapon: 155mm Howitzer M109
Projectile: 155mm Projectile M107
Technique of Fire: Observer Adjusted
Charge: 7
Radius of Target Adjusted Upon: 25 meters

Range meters	Probable Error - Meters		
	Precision	MPI	Accuracy (RMS)
2,000	10	43	44
6,000	19	47	51
10,000	29	51	59
14,000	42	57	71

This table illustrates the reasons why some Artillerymen fail the Artillery Training Tests (ATT) conducted by artillery units who have completed their schooling. The criterion for passing these tests is the placement of rounds from several different fire missions in a "box" eight range probable errors long and eight deflection probable errors wide. This certainly sounds like a very generous sized box, but the fact is that the box is constructed using precision probable errors rather than accuracy probable errors. In our example above, for instance, the box would be 152 meters long for a target at 6,000 meters range, but, in fact, it should be 408 meters long if an eight probable error box is desired.

III. FUTURE FIRING TABLE IMPROVEMENTS

When today's field artillery firing tables are used with today's approved delivery techniques [as described in FM 6-40], accurate fire can be brought to bear on targets.

Such a statement can only be made because today's approved delivery techniques recognize that many errors (both precision and bias errors) exist and those techniques are designed to minimize these errors. The techniques are not designed to produce first round hits, nor does the statement above infer that such hits can be achieved.

Since today's approved delivery techniques are designed to discover and eliminate "bias" type errors, the Firing Tables Branch could, in good conscience, relax in the expectation that any errors it introduces will be eliminated in the field. Such relaxation, unfortunately, is not warranted by the facts.

We sympathize with the Artilleryman's desire for "first round" hits and we have several efforts underway which are designed to bring the Artilleryman closer to this goal. Not only do we conduct studies on the design of a better firing table range firing experiment so that bias errors will be minimized, but we also monitor the latest developments in hardware for field use (lasers, muzzle velocity chronographs, etc.) in an effort to study the impact of these devices on field artillery delivery techniques.

In summary, then, if the Artilleryman uses approved delivery techniques and understands the probable errors given in firing tables, he should not find it difficult to bring fire to bear on targets. And further, if the Artilleryman could participate in the current studies being conducted by the Firing Tables Branch, even more accurate fire would certainly result.

REFERENCES

1. C. Odom, "The Derivation of Range Dispersion Parameters from Range Firing Data," Ballistic Research Laboratories Memorandum Report Number 1169, September 1958. AD 205124

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