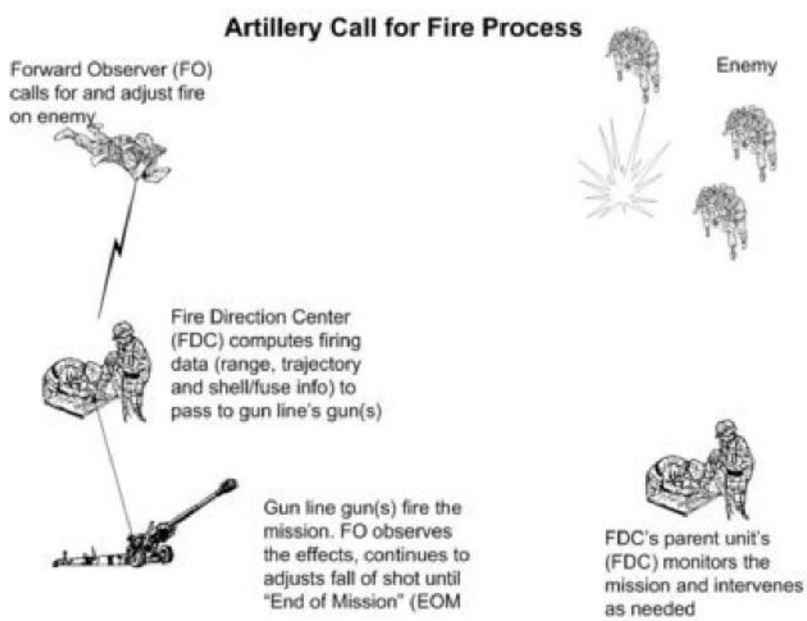
Fire Direction Center Operations in Viet Nam

This is how B Battery, 1st Battalion, 83rd Artillery's Fire Direction Center Operated during March 1968 through March 1969



FDC Operations in Viet Nam

Introduction

I decided to write this paper to explain the operation of a "typical" fire direction center in combat. This paper is written from my perspective while serving as the Section Chief and Chief Computer in the B Battery, 1st Battalion, 83rd Artillery Fire Direction Center (FDC) during 1968 and 1969. I spent about half of my 20 years in the Army working in an FDC, and while that was a long time ago, I think that what I've written is accurate.

I will start off by explaining the major elements of the Field Artillery team followed by the roles and responsibilities of the FDC section members. I will focus on their main responsibilities as it relates to getting firing data to the gun and getting the rounds on target. I will follow that by an example call for fire and explain the interaction of the team. Lastly, I will explain some of the tools and techniques we used in an attempt to shoot accurately. I will make every attempt to not get too bogged down into details; however, to really understand all that we did to get the data to the gun and a round on the target, some detailed discussion is necessary.

Please send any comments, questions, or corrections to Johnnie F. Pearson, Jr., email: johnnie.f.pearson.jr@gmail.com.

The Field Artillery Gunnery Team

The Field Artillery team consists of five major elements, each playing a distinctive and critical role.

The Fire Support Team

For a direct support (DS) artillery unit, the Fire Support Team (FIST) worked at company level in armor, infantry, and air cavalry units and was responsible for developing the fire support plan to support and protect the unit. Forward Observers (FOs) on the ground (FOs) or Aerial Observers (AOs) in the air used radios to call the FDC for fire support and adjusted that fire onto the target. Being an 8-inch battalion assigned to XXIV Corps Artillery with a general support (GS) or general support reinforcement (GSR) mission, most of our fire missions involved AOs. Once the fire mission was completed, the FO or AO would call in an "end-of-mission" and target assessment.

Target Acquisition Team

The radar platoon was responsible for acquiring targets and protecting the force by employing sophisticated target acquisition systems such as radars. The radar sections were the eyes that acquired enemy field artillery rocket and cannon fire and transmitted the coordinates to friendly units for immediate suppressive fires. Radars were also used during FDC "registrations" procedures, which was a set of procedures we used to help compute more accurate firing data. I'll talk about registrations later in this article.

The Fire Direction Center (FDC)

The FDC used a variety of automated and manual procedures to translate the call for artillery fire into the fire commands sent to the guns. A well trained FDC could generally get fire commands to a gun in less than a minute or two after receiving the call for fire. The battery FDC was the control center, or "brains," of the gunnery team. The battery FDC received "fire orders" from the battalion FDC or calls for fire from observers. The battery FDC then processed that information by using technical fire direction procedures.

The battery FDC performed the technical fire direction, while the battalion FDC performed mostly tactical fire direction. The difference you ask? Technical fire direction involved sending accurate fire commands to the gun sections (more on that later in this article). Tactical fire direction involved the planning, coordination, and management of fire missions. It also involved handing off the mission from the AO or FO to the battery FDC and checking the battery's technical solution before it was sent to the guns.

Battalion FDC also provided 'air clearance' to the battery FDC, which gave permission to shoot on a particular azimuth within a certain range of altitudes. It was kind of important that we did not shoot down any friendly aircraft. The battalion FDC also provided ground clearance to the battery FDC, which provide us with the assurance that we were firing at the enemy and not friendly forces. We could not shoot until we had both air and ground clearance and battalion FDC gave us a "data check." This often times delayed us, but we had no other choice.

Survey Section

The Survey section played a very vital role that often times went unnoticed. They provided the FDC with exact battery center locations, down to 100 hundredth of a meter. The FDC used the battery center location as a starting point for all of its technical fire direction calculations. The Survey section also provided grid locations for "registration points" and some targets. Without an accurate battery center location and registration points, it was extremely difficult to shoot with any reasonable sense of accuracy.

The Firing Battery

The firing battery served as the "muscle" of the gunnery team. The firing battery included the battery HQ, the howitzer sections, the ammunition section, and the FDC. The howitzer sections apply the technical firing data sent from FDC to the howitzer and ammunition. All other elements of the FA team: the FIST, radar, survey, and FDC served to enable the firing units to deliver devastating 8-inch artillery fire at the right time and place.

Organization of a Battery Fire Direction Center (FDC)

The battery FDC was organized to facilitate 24-hour operations. As a result we had two 12- hour shifts. We were always short staffed; therefore, some of us performed multiple roles. Having said that, the duties for a fully staffed FDC are described below:

Fire Direction Officer (FDO)

The FDO was responsible for all FDC operations. He was responsible for the training of all FDC personnel, supervising the operation of the FDC, establishing standing operating procedure (SOP), checking target location, announcing the fire order, and ensuring the accuracy of firing data sent to the guns.

Chief Fire Direction Computer

The chief fire direction computer was the technical expert and trainer in the FDC. He ensured that all equipment was on hand and operational, supervised the computation of all data, ensured that all appropriate records were maintained, and kept the FDO out of trouble. He ensured smooth performance of the FDC in 24-hour operations and functioned as the FDO in the FDO's absence. In fact for much of my year in Viet Nam, I ran one of the shifts because we only had one FDO. So I normally wore two hats, as an FDO and Chief Computer. As Chief Computer, I was primarily responsible for computing the firing data and sending fire commands to the gun.

Fire Direction Computer

The fire direction computer operated the Field Artillery Digital Automatic Computer (FADAC), when it was working. When we used FADAC, I independently computed the firing data manually to verify the FADAC computation. When we operated without the FADAC, the fire direction computer became the "check" computer and independently verified that my computations were correct. He also recorded mission-related data and other information as directed. The "check" computer also served as the Horizontal Control Operator (HCO).

Horizontal Control Operator (HCO)

The HCO's primary responsibility was to setup and maintain the horizontal firing chart to determine the range, deflection, and azimuth to a target. To setup the firing chart, the HCO plotted known locations such as our battery center, other firing battery locations, registrations points, "friendly" villages, fire bases, LZs, target locations, no fire zones, and other locations.

Vertical Control Operator (VCO)

The VCO maintain a horizontal firing chart and plotted the target location on a map to determine the target altitude. The VCO checked all chart data announced by the HCO and would use the difference in the battery's altitude and the target's altitude to compute and announce the "site."

The Radiotelephone Operator (RTO)

The RTO manned the radio and received the call for fire from battalion FDC or the fire mission from an observer. The RTO announced and recorded all information received throughout the fire mission. The RTO was normally the operator of the FDC's M577 command track. He also maintained the vehicle and the FDC-associated generators.

The "Adjust" Fire Mission

Battalion FDC or an observer would send us targeting information that consisted of the target location as grid coordinates; type of target (e.g., personnel in the open, personnel in bunkers, wheel vehicles, tanks, and the like); and the 'attitude' to the target in mils. The target attitude was the direction to the target from the observer's perspective. The observer would also provide other information, such as "danger close" if friendly troops were nearby.

Using the targeting information, the FDO would issue a fire order to the FDC. It consisted of the guns to fire; "adjusting" gun (usually the 'base piece') for an AO or FO controlled mission; special instruction, such as 'danger close use gunners quadrant'; the number of rounds to fire in effect (FFE); the projectile in effect; the ammunition lot and charge in effect; fuze in effect; and target number. As soon as the targeting information was received and before the FDO finished the fire order, everyone would have already gone into action because the targeting data provided all of the data needed to start. One of the very first actions was for the chief computer or FDO to announce 'FIRE MISSION' to the XO post and gun sections to get the ball rolling.

In the art and science of computing firing data, every member of the FDC had very specific roles and responsibilities. Everyone also had two jobs – their primary job and the job of checking the data or computations of someone else. Every member of the FDC was responsible for announcing some piece of vital information to rest of the team or for using that information to compute the firing data. Every piece of needed information was announced in a very specific order and in a very specific way so that there was no confusion, and every piece of information was vital and necessary to ensure timely and accurate fire.

If the FADAC were being used, the Fire Direction Computer would enter the targeting information into the FADAC. The FADAC provided the azimuth to target, deflection, quadrant, charge, and, if any, fuze setting; and usually within 30 to 45 seconds. The FADAC was quick and accurate, provided it was setup properly and the targeting information was entered correctly. For the remainder of this article, however, assume the FADAC is NOT being used and all of the firing data is being computed manually.

The HCO immediately plots the targeting information on the Horizontal Chart using a 'grid square'. The HCO would then determine and announce the chart data that consisted of the range to target in meters and the deflection to the target in mils. A good HCO could normally do this in about 15-20 seconds. If necessary, the HCO also determined and announced a new azimuth to target, which would require the guns to re-lay. Any change in azimuth was verified by the FDO. (If a new azimuth was need, the FDO would immediately announce that to the XO post.) The HCO would then place a circular 'target grid' over the target location and orient it along the observer's attitude to the target. This allowed to HCO to plot observer corrections from the view point of the observer.

At the same time, the VCO plotted the target location on his Horizontal Chart to determine his own chart data. When the HCO announced his chart data the VCO would announce "check" if his chart data matched the HCO's chart data within plus or minus 30 meters in range or 3 mils in deflection, or "correction" if either piece did not. The FDO would verify the HCO's plot when the data did not match to resolve the differences. I honestly had an excellent HCO and VCO so it was very, very rare for the data not to match. (Note: For their calculations, both the chief computer and the 'check' computer used the HCO's chart data once 'checked' by the VCO.)

Next the VCO plotted the grid coordinates on the Vertical Chart (map) using a grid square to determine the target altitude. The VCO and FDO would also inspect the target location to see if it was necessary to fire high-angle. In a perfect world, that information would be provided by the observer because they could see the target and the surrounding terrain, but it was up to the VCO and FDO to ensure that our rounds did not land on any intervening terrain, such as a big mountain in the way of our target. If high-angle was needed, the FDO would announce 'USE HIGH ANGLE'.

With the altitude, the VCO then used a 'Graphical Site Table' (which looked much like a slide rule but wasn't) to determine the 'site' in mils. A good VCO could usually do this in about 20 seconds. The site was used to compensate for any differences in the firing battery and target altitude (target height above or below the guns, i.e., plus or minus site respectively). The HCO would then determine the site as a double check.

While the HCO and VCO are doing their thing, the chief computer and 'check' computer are in a ready state waiting for the HCO's announcements of range, deflection, and azimuth, if needed, and the VCO's announcement of "check" on the HCO's chart data. Using the range to target and a Graphical Firing Table (GFT), both computers calculate the elevation to the target and then add or subtract the site (once announced by the VCO) to determine the quadrant. Both computers also used the GFT to determine a fuze setting, if needed. Both computers would also apply a 'deflection correction' to the deflection announced by the HCO to determine the firing deflection. The chief computer would announce the firing data to the entire FDC, for example:

"DEFLECTION 3645, QUADRANT 628"

This triggered several actions:

1. The 'check' computer would compare his firing data and announce check if it matched within plus or minus 3 mils or 'correction' when it did not. Both computers would recheck their data to resolve any differences. While rare, firing data difference did happen from time to time.
2. Once the firing data was 'checked', the RTO would relay that information to the battalion FDC so they could check our initial data. This was the only 'technical' fire direction check performed by battalion FDC.

3. The RTO would establish radio contact with the FO or AO, if not already done. Sometimes the AO or FO would tune to our radio frequency. At other times, battalion FDC would tell us which frequency to use and who to contact on that frequency.
4. The chief computer would send the fire commands to guns, awaiting air and ground clearance, and battalion FDC's data check.

Example:

"BATTERY ADJUST, SHELL H.E., CHARGE 7, FUSE QUICK, DEFLECTION 3645, QUADRANT 628, #2 ONE ROUND, BATTERY 1 ROUND IN EFFECT"

Once we had received all necessary clearances from the battalion FDC, had radio contact with the observer, and the battery reported ready to fire, the chief computer would announce 'FIRE' to the adjusting piece.

When the gun fired, the RTO would announce 'SHOT OVER' to alert the observer. The observer would announce 'SHOT OUT' as an acknowledgement. When the round was approximately 5 seconds from the target, the RTO announced 'SPLASH OVER' to warn the observer. The observer would announce 'SPLASH OUT' as an acknowledgement.

Rarely, did we hit the target on the first shot, or second, or third for that matter for many reasons which I won't go into. It was up to the observer to send corrections to the FDC that would place rounds on the target. Corrections were sent as ADD or DROP and LEFT or RIGHT so many meters. For example, ADD 400, LEFT 200.

The observer announced corrections to the RTO who in term read them back. This triggered basically the same activities used to compute the initial firing data:

1. The HCO and VCO plot the corrections on their respective horizontal charts. The HCO announces the new range and deflection and the VCO 'checks' the data.
2. Both computers recalculate the firing data; the chief computer announces the firing data and the 'check' computer 'checks' the data.
3. The chief computer then sends new fire commands to the gun.
4. The adjust piece reports ready and the chief computer commands '#2 FIRE'
5. The RTO sends 'SHOT' and 'SPLASH' as before.
6. If necessary, the observer sends in more correction
7. Steps 1 through 6 are repeated until the observer requests 'FIRE FOR EFFECT'.
8. The chief computer then commands 'BATTERY 1 ROUND FIRE FOR EFFECT' to instruct the entire battery to shoot the number of rounds specified.
9. Once the battery reports ready to fire, the chief computer announces, "BATTERY, FIRE."
10. The RTO send 'SHOT' and 'SPLASH' as before.
11. When all rounds are expended, the XO or chief of firing battery reports 'ROUNDS COMPLETE' to the FDC. The RTO announces 'ROUNDS COMPLETE' to the observer.
12. The observer then sends 'END OF MISSION (EOM)' or requests additional fire. If EOM, the observer sends in a target assessment, e.g., number of KIAs, bunker destroyed, three trucks burning, and the like.
13. The chief compute announces 'END OF MISSION' to the gun sections.
14. The RTO sends EOM to battalion FDC with the target assessment
15. The 'check' computer does some house keeping things, like update the ammo counts and recording the target assessment.
16. The VCO and HCO update their respective charts by recording the target location and assigning it the target number.

Types of Fire Missions

The battalion FDC or observer decided on the type of effect or fire support needed on a particular target. There are three types of fire: destruction, neutralization, and suppression.

Destruction

Destruction is intended to put a target out of action permanently. Direct hits with high-explosive (HE) or concrete-piercing (CP) shells are required to destroy hard materiel targets. Usually, destruction requires large expenditures of ammunition and is not considered economical. We used this type of fire to destroy bunkers - this type of fire was rarely used.

Neutralization

Neutralization is intended to knock a target out of action temporarily. It can be achieved by use of any type of shell-fuze combination suitable for attacking a particular type of target. Neutralization does not require an extensive expenditure of ammunition and is the most practical type of mission. Most of our missions were neutralization fire.

Suppression

Suppression of a target limits the ability of the enemy personnel in the target area to perform their jobs. Firing HE/VT created apprehension and confused the enemy. The effect of suppressive fires usually lasts only as long as the fires are continued. Suppression requires a low expenditure of ammunition; however, since its effects are not lasting, it was unsuitable for most targets.

Categories of Indirect Fire

Indirect fires are divided into two basic categories: observed and unobserved.

Observed Fire

Observed fire is fire for which the points of impact or burst were controlled by an observer. Most of our missions were observed fire were the observer “adjusted” our fire onto the target.

Observed fire usually resulted in the observer sending a target damage assessment (TDA) report to the FDC at end-of-mission.

Unobserved fire

Unobserved fire is fire for which the points of impact or burst were not observed. It involved predicting where targets were, or would be, and shooting at them. The term “H&I” (harassing and interdiction) was used to describe the target packages we received from battalion FDC for our nightly unobserved fire missions.

FDC Tools and Techniques

The FDC used a variety of tools and techniques in our efforts to provide timely and accurate firing data with the goal of hitting the target on the first volley. Our primary tools consisted of instruments and reference books. What follows is a high level overview of their use:

Plotting Scale

The **Plotting Scale** was used by the HCO and VCO to plot or determine grid coordinates. The scale was graduated in meters at scales of 1:25,000 and 1:50,000. Because of our long range guns, we routinely used 1:50,000. Using this instrument, the HCO and VCO could plot coordinates to the nearest 10 meters.

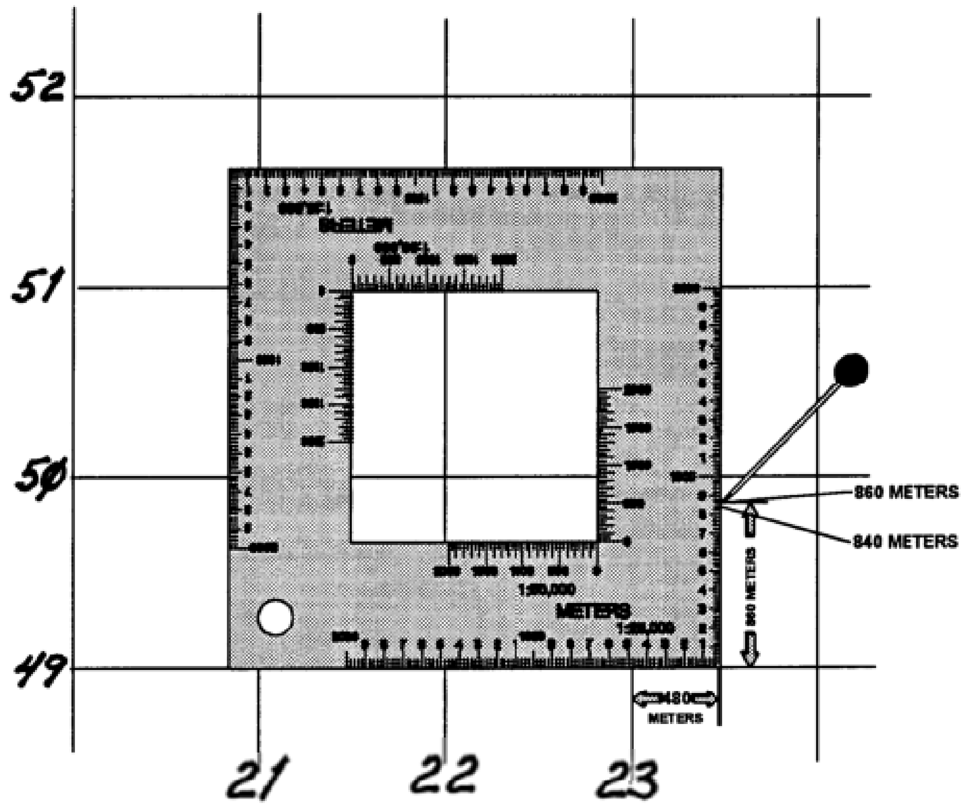


Figure 1: Plotting a Grid Location

As an example, to plot target location **23478 49856** on a firing chart, the plotting scale would be slid to the right of the **23** north-south vertical grid line **480** meters (***see Figure 1: Plotting a*** Grid Location). Note: **23480** is **23478** rounded to the nearest 10 meters.

Next, with the bottom edge of the plotting scale aligned precisely on the **49** east-west horizontal grid line, the plotting pin is set at a **45** degree slant against the plotting scale at the correct distance above the **49** grid line (in this case **860** meters). Once set, the plotting scale was moved to the side, the pin was rotated to a vertical position, and pushed into the firing chart to anchor the location. Next, on a firing chart, the pin hole was then converted to a "tick mark."

Tick Marks

The **Tick Mark** was the symbol used to mark and identify the location of a point plotted on a firing chart. The HCO and VCO constructed a tick mark in the form of a cross with each arm beginning 40 meters from the pinhole on the chart and extending 160 meters in length. Tick marks were drawn in black with a 4H pencil, except for targets located by firing, which were drawn in red.

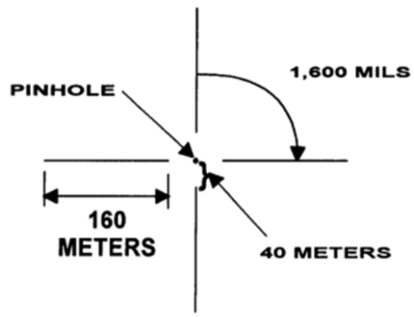


Figure 2: Tick Mark Dimensions

Firing Battery and Radar: Firing battery and radar tick mark locations were drawn in black with a 4H pencil. Firing battery unit designations (A, B, or C) or the radar symbol were drawn in upper right-hand quadrant and were color coded as follows:

- **A**lpha Battery in **Red**
- **B**ravo Batter in **Black**
- **C**harlie Battery in **Blue**
- Radar symbol was drawn in **Green**

Observation Posts: Observation posts (Ops) were represented by tick mark using (1) the military symbol for an OP (a triangle with a dot in the middle) and the short call sign for the observer, or (2) a tick mark labeled with the observer's assigned number (e.g., O1, O2, etc.) We normally used the assigned number.

Known Points: Known points were identified in the upper right-hand quadrant with the number assigned to it (e.g., KN PT 1). We would also record the altitude in the lower left quadrant. Known points were sometimes "special" targets, such as "registration points."

Targets: Like known points, targets were also identified in the upper right-hand quadrant with their assigned target number (e.g., AJ1001). We would also record its altitude in the lower left quadrant. Other information was also recorded for targets. For example, the Charge and, if used, High Angle were recorded in the upper-left quadrant, in the lower-right quadrant the fuze used if other than fuze quick (e.g., VT for variable time fuze or TI for a time fuze).

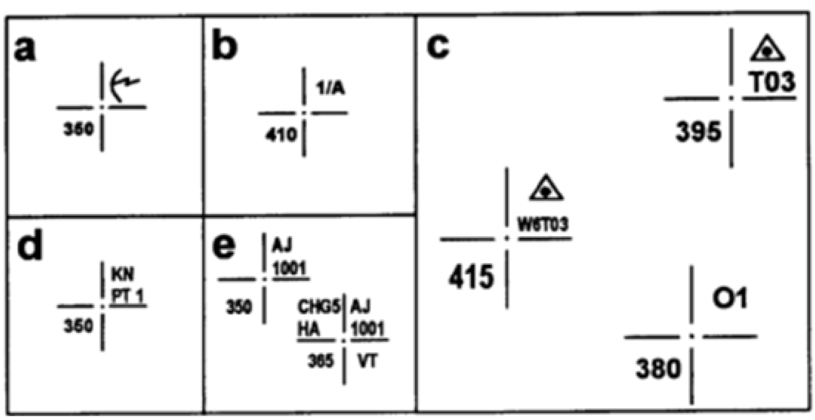


Figure 3: Examples of Different Tick Marks

Range-Deflection Protractor (RDP)

The **Range-Deflection Protractor (RDP)** was used by the HCO and VCO to measure angles in mils and ranges (or distances) in meters. The range and deflection were measured from the "battery center" to a target.

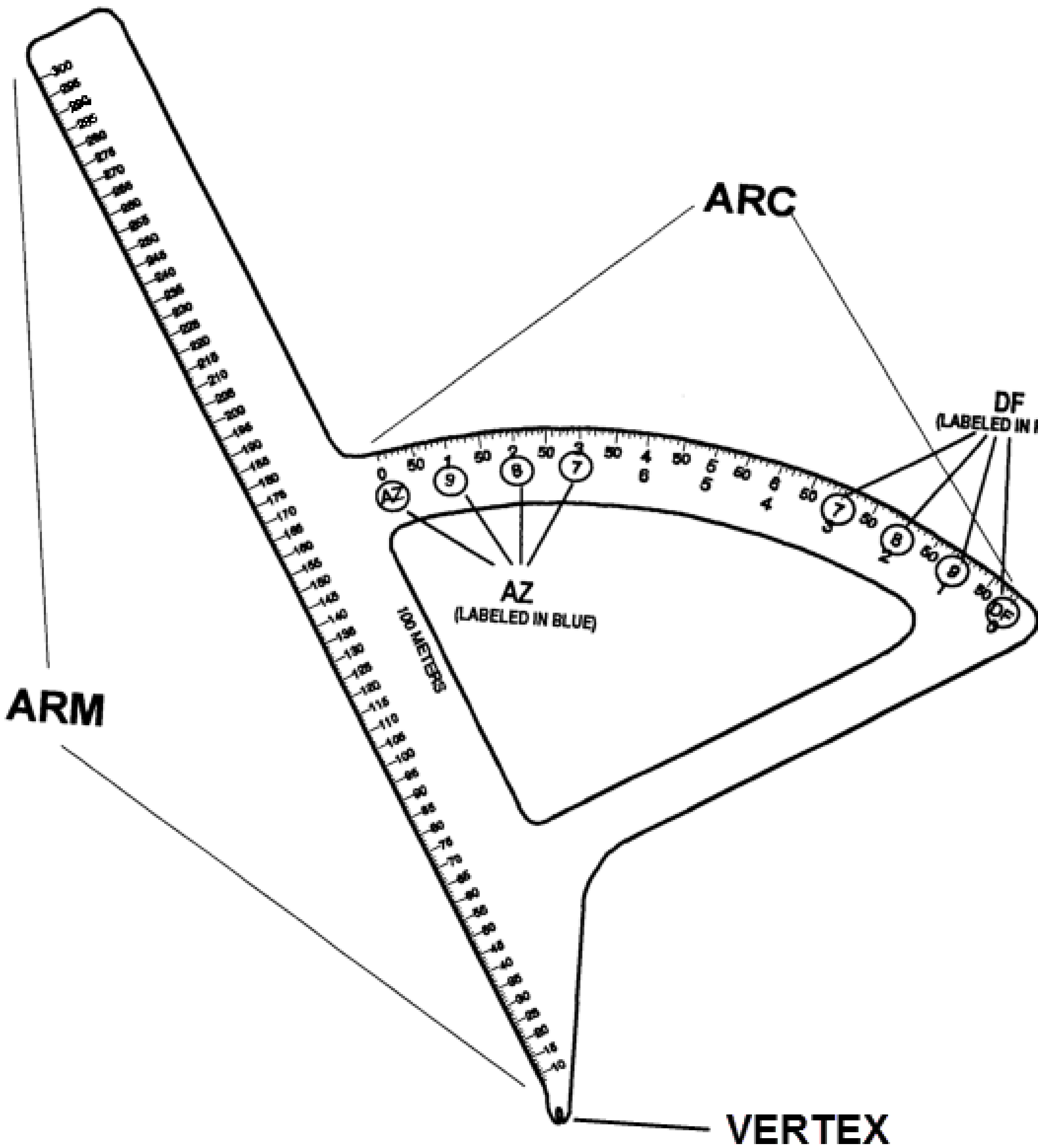


Figure 4: Range-Deflection Protractor

- The **VERTEX** (the slotted portion of the RDP) was set at the battery center “plotting pin” to properly position the RDP for determining data.
- The **ARM** of the instrument was used to measure range or distance. It was graduated in 50-meter increments and labeled every 500 meters on a scale of 1:25,000 or 1:50,000. Ranges and distances were visually interpolated to an accuracy of 10 meters.
- The **ARC** spanned 1,000-mils, graduated in 5-mil increments. The 50-mil increments were indicated by longer graduations and were permanently numbered. The **ARC** was visually interpolated to an accuracy of 1 mil.

Target Grid

The Target Grid was a circular paper device with grid lines. The grid lines matched the scale of the firing chart, dividing a 1,000-meter grid square into 100-meter squares. An azimuth scale was printed around the outer edge of the target grid that was graduated in 10-mil increments and numbered every 100 mils. An arrow extended across the center of the target grid; it was used to orient the target grid along the observer-target line so that any adjustments sent by the observer were plotted from their point of view. Needless to say, this was EXTREMELY important.

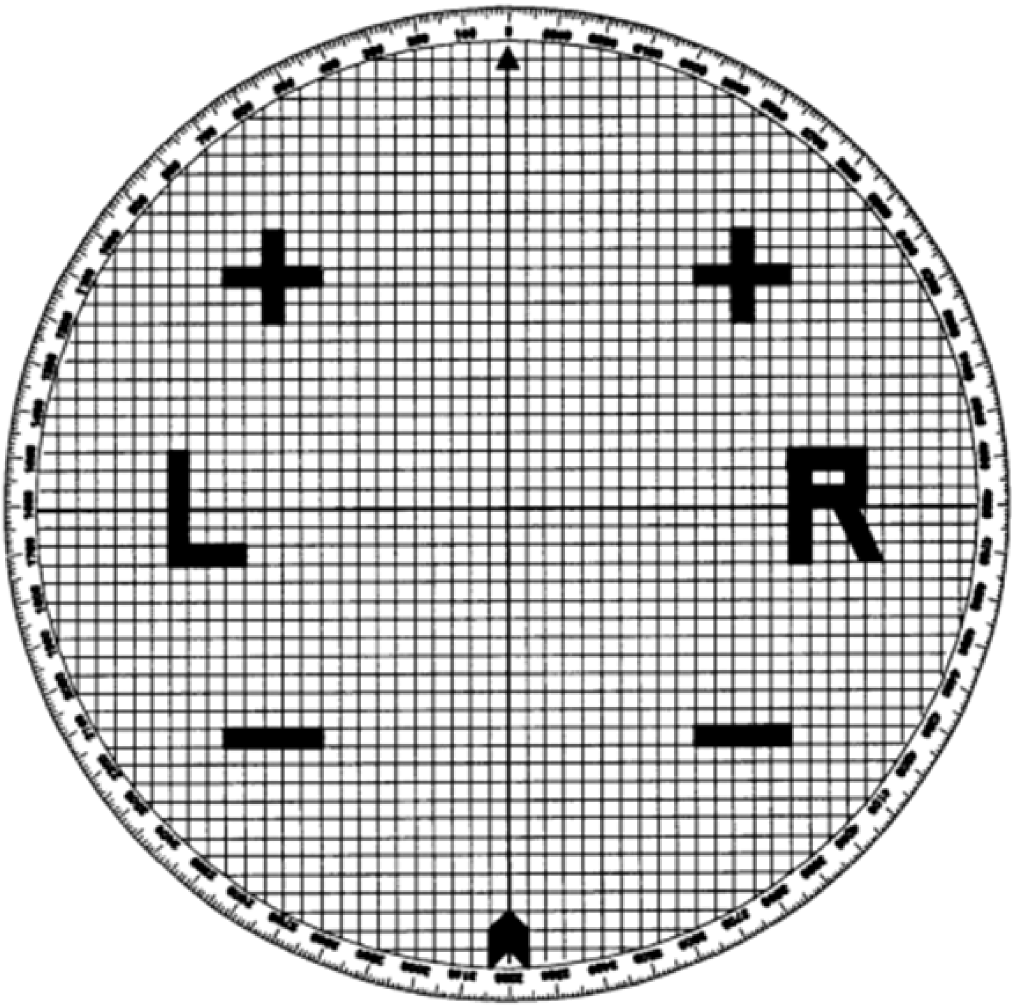


Figure 5: Target Grid

The target grid was be labeled as shown above. (**The L and - were written in blue pencil; the R and +, in red.)** Masking tape was applied to the reverse side of the target grid to prevent the center hole from becoming enlarged. The target grid is used for three distinct operations:

- Plotting the position of targets located by a shift from a known point.
- Plotting observer subsequent corrections.
- Determining “angle T.”

In the interest of maintaining everyone’s sanity, I will not try to explain any of the above bullets. Rather, the next figure illustrates an RDP, Target Grid, Battery Center Pin, and Target Pin sitting on a firing chart. Hopefully, this will help your understanding. Needless to say, there was A LOT to this stuff, and I’m only scratching the surface.

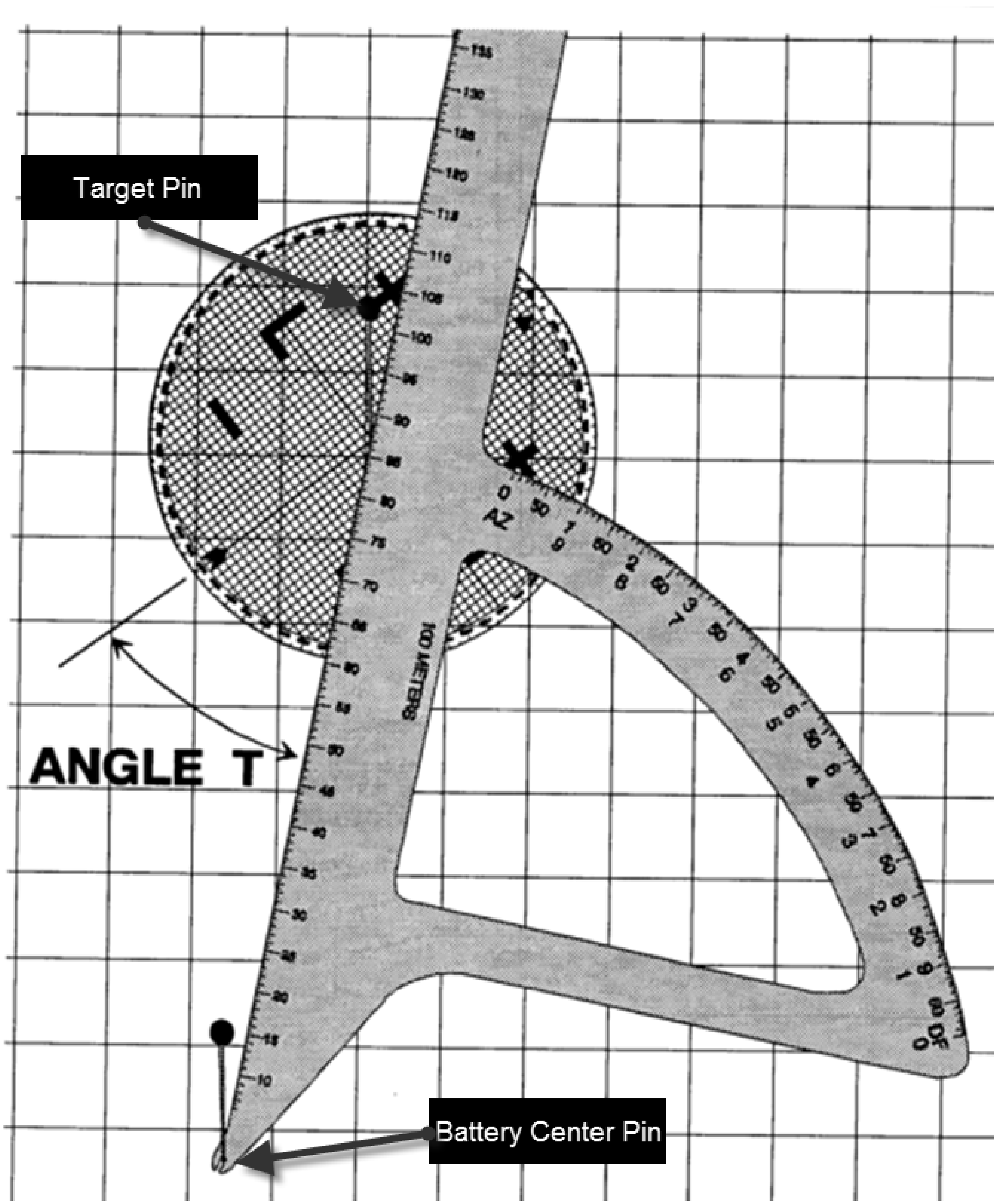


Figure 6: Sample Firing Chart and Tools Used

To explain the significance of correctly orienting the Target Grid, image an observer is sending corrections using the sample firing chart above. From the FDC perspective, a ground observer is always looking at the target somewhere along the line that extends from the rear of the arrow through the Target Pin towards the arrow head. Since a ground observer is not looking EXACTLY down the gun-target line (like and aerial observer), we used the Target Grid to correct for that situation.

For example, if the observer commanded DROP 400, the HCO and VCO would reset the Target Pin 400 meters in a straight line (along the arrow) down towards the observer. To drop 400, the RDP would actually be moved to the LEFT (against the Target Pin) AND the range would decrease, but not exactly 400 meters. If the observer was looking down the gun-target line, the RDP would not move to the LEFT, but the range would be decreased EXACTLY 400 meters.

Standard and Nonstandard Conditions

We determined firing data using various firing tables and equipment. The tables contained fire control information (FCI) for "standard conditions" and data that allowed us to correct for "nonstandard conditions." These tables and equipment include the tabular firing tables (TFT), graphical firing tables (GFT), and graphical site tables (GST).

- The tabular firing tables were the basic source of firing data and presented fire control information in a tabular format. The data listed in the TFTs were based on standard conditions.
- The GFTs and GSTs were the graphical representations of the tabular firing tables.

Tabular firing tables were based on test firings and computer simulations of a weapon (e.g., 8-Inch, 155mm) and its ammunition, correlated to a set of conditions that were defined and accepted as "standard." These "standard conditions" were as follows:

Table 1: Standard Conditions

STANDARD CONDITIONS	
WEATHER	
1	AIR TEMPERATURE 100 PERCENT (59 Degrees Fahrenheit)
2	AIR DENSITY 100 PERCENT (1,225 gm/m^3
3	NO WIND
GUN/HOWITZER/TARGET POSITION	
1	GUN, TARGET, AND MEAN-DATA-PLAIN AT SAME ALTITUDE
2	ACCURATE RANGE
3	NO ROTATION OF THE EARTH
MATERIAL	
1	STANDARD WEAPON, PROJECTIVE, AND FUZE
2	PROPELLANT TEMPERATURE (70 Degrees Fahrenheit)
3	LEVEL TRUNNIONS AND PRECISION SETTINGS
4	FIRING TABLE MUZZLE VELOCITY
5	NO DRIVE
Legend	gm/m^3 – grams per cubic meter

Since these standard conditions never existed at once in the real world, we used TFT, GFT, and GST corrections to compensate for the variables in the weather-weapon-ammunition combination. All of the things we did to correct for "nonstandard conditions," are beyond the scope of this article. Plus it is really complicated and hard to explain. I will, however, explain the purposes for the TFT, GFT, and GST, without going into too much boring detail (you're welcome!).

Tabular Firing Tables

The main purpose of the TFT was to provide the data to bring effective fire on a target under any set of conditions. Firing tables were based on actual firings of a gun or howitzer and its ammunition, correlated to the set of standard conditions (**see Table 1: Standard Conditions**). Actual firing conditions, however, will never really equate to these standard conditions.

Deviations from standard conditions then, if not corrected for when computing firing data, would cause the projectile to impact at a point other than the desired location. Thus, corrections for nonstandard conditions were made to improve accuracy. Some of the deviations from standard conditions affected the shooting range; others affected the shooting deflection. See the following table for the list of nonstandard conditions the FDC corrected for:

Table 2: Standard Conditions

CORRECTIONS FOR NONSTANDARD CONDITIONS	
RANGE EFFECTS	
1	Muzzle Velocity
2	Projectile Weight
3	Wind Speed
4	Air Temperature
5	Air Density
6	Rotation of the Earth
DEFLECTION EFFECTS	
1	Drift (caused by the spinning projectile)
2	Crosswind
3	Rotation of the Earth

The TFT provided a lot of information. Some we used every four hours, when we had to recalculate our "met messages" to account for weather changes. Some we used during and after a "registration" to account for inaccuracies in survey data, wear and tear on the gun, and other factors. Some we only used when we changed firing battery locations. Other's we simply used for reference and remainders, below is such a table:

RANGE METERS	CHARGE 1G	2G	3G	4G	5G	3W	4W	5W	6W	7W	8
1000	10	7	6	5	6	9	7	8	9	12	17
2000	20	14	11	8	8	16	10	11	10	11	17
3000	29	21	17	11	9	23	13	14	12	12	17
4000		29	23	14	11	31	16	16	14	13	18
5000			29	18	13	39	20	19	17	14	20
6000			36	23	15	47	24	21	19	17	22
7000				28	18	56	28	23	21	19	24
8000				34	21		34	26	23	21	27
9000					24			29	25	24	30
10000								33	27	26	33
11000									29	27	35
12000									32	29	38
13000										32	40
14000										34	42
15000											44
16000											46
17000											49
18000											52

Figure 7: Charge Selection Table

This reference table provided guidance to the FDO on the selection of the charge to fire based on range and "probable error." At the intersection of the range to target and charge, was the probable error. The gray shaded area shows those charges with the lowest probable error in range and thereby the charge that should be selected given no other considerations. Note: the lower the probably error, the closer our rounds should land near the target.

The TFT was divided into Tables **A** through **J**. It is beyond the scope of this article to delve into each table. However, each table did provide some "tidbit" of information that allowed us to correct for nonstandard conditions. I'll show two more examples, before moving on to my next topic:

TABLE E

PROPELLANT TEMPERATURE

EFFECTS ON MUZZLE VELOCITY DUE TO PROPELLANT TEMPERATURE

TEMPERATURE OF PROPELLANT DEGREES F	EFFECT ON VELOCITY M/S	TEMPERATURE OF PROPELLANT DEGREES C
-40	-6.4	-40.0
-30	-5.6	-34.4
-20	-4.8	-28.9
-10	-4.2	-23.3
0	-3.5	-17.8
10	-2.9	-12.2
20	-2.4	-6.7
30	-1.8	-1.1
40	-1.3	4.4
50	-0.9	10.0
60	-0.4	15.6
70	0.0	21.1
80	0.4	26.7
90	0.8	32.2
100	1.2	37.8
110	1.7	43.3
120	2.1	48.9
130	2.5	54.4

Figure 8: Propellant Temperature

Table E was used when calculating met messages to arrive at a correction to the muzzle velocity speed based on the powder temperature. Note a couple of things. First, no correction was applied if the power temperature was 70 degrees Fahrenheit (the "standard" condition). Below 70 degrees, the air gets heavier with a decrease in muzzle velocity and a shorter achievable range. Conversely, above 70 degrees, the air gets lighter with an increase in muzzle velocity and increased range. This why the FDC bugged the XO post for a powder temperature reading every 4 hours (or more) so that we could correct for muzzle velocity variations caused by temperature variations.

Table F was comprised of 19 columns. Columns 2 through 7 provide information for the computation of basic firing data and are based on a set of standard conditions. The remaining columns provide corrections to range and deflection for nonstandard conditions.

These complicated looking tables were actually very easy to use as reference material. We entered them using two parameters, the Charge and the Range to target. It was then a simple matter of reading across to derive the values we needed in our calculations. Knowing when and how to use the data was a bit complicated, but since we had to recalculate new “met” data every 4 hours, it became second nature.

CHARGE 4G — TABLE F — BASIC DATA — FT 155-AM-2 — PROJ, HE, M107 FUZE, PD, M557

1	2	3	4	5	6	7	8	9
RANGE	ELEV	FS FOR GRAZE BURST FUZE M564	DFS PER 10 M DEC HOB	DR PER 1 MIL D ELEV	FORK	TIME OF FLIGHT	AZIMUTH CORRECTIONS	
							DRIFT (CORR TO L)	CW OF 1 KNOT
M	MIL			M	MIL	SEC	MIL	MIL
0	0.0			20	1	0.0	0.0	0.00
100	5.1			20	1	0.3	0.0	0.01
200	10.1			20	1	0.6	0.0	0.01
300	15.2			20	1	1.0	0.1	0.01
400	20.3			20	1	1.3	0.1	0.02
500	25.4			19	1	1.6	0.2	0.02
600	30.6	1.9	1.06	19	1	1.9	0.3	0.03
700	35.8	2.2	0.91	19	1	2.3	0.4	0.03
800	41.1	2.5	0.79	19	1	2.6	0.5	0.04
900	46.4	2.8	0.71	19	1	2.9	0.6	0.04
1000	51.7	3.2	0.63	19	1	3.2	0.7	0.04
1100	57.1	3.5	0.57	19	1	3.6	0.8	0.05
1200	62.5	3.8	0.53	18	1	3.9	0.8	0.05
1300	67.9	4.2	0.48	18	1	4.3	0.9	0.05
1400	73.4	4.5	0.45	18	1	4.6	1.0	0.06
1500	78.9	4.9	0.42	18	1	4.9	1.1	0.06
1600	84.4	5.2	0.39	18	2	5.3	1.2	0.07
1700	90.0	5.5	0.37	18	2	5.6	1.3	0.07
1800	95.6	5.9	0.35	18	2	6.0	1.4	0.07
1900	101.3	6.2	0.33	18	2	6.3	1.6	0.08
2000	107.0	6.6	0.31	17	2	6.7	1.7	0.08
2100	112.8	6.9	0.30	17	2	7.0	1.8	0.08
2200	118.6	7.3	0.28	17	2	7.4	1.9	0.09
2300	124.4	7.6	0.27	17	2	7.7	2.0	0.09
2400	130.3	8.0	0.26	17	2	8.1	2.1	0.09
2500	136.2	8.3	0.25	17	2	8.4	2.2	0.10
2600	142.2	8.7	0.24	17	2	8.8	2.3	0.10
2700	148.2	9.1	0.23	17	2	9.2	2.5	0.10
2800	154.3	9.4	0.22	16	2	9.5	2.6	0.11
2900	160.4	9.8	0.21	16	3	9.9	2.7	0.11
3000	166.6	10.2	0.20	16	3	10.3	2.9	0.12
3100	172.9	10.6	0.20	16	3	10.6	3.0	0.12
3200	179.2	10.9	0.19	16	3	11.0	3.1	0.12
3300	185.5	11.3	0.18	16	3	11.4	3.2	0.13
3400	191.9	11.7	0.18	16	3	11.8	3.4	0.13
3500	198.4	12.0	0.17	15	3	12.2	3.5	0.13

Figure 9: Table F Basic Data

FT 155-AM-2

PROJ, HE, M107
FUZE, PD, M557

TABLE F

CORRECTION FACTORS

CHARGE 4G

1	10	11	12	13	14	15	16	17	18	19
RANGE	RANGE CORRECTIONS FOR									
	MUZZLE VELOCITY 1 M/S		RANGE WIND 1 KNOT		AIR TEMP 1 PCT		AIR DENSITY 1 PCT		PROJ WT OF 1 SQ (4 SQ STD)	
	DEC	INC	HEAD	TAIL	DEC	INC	DEC	INC	DEC	INC
M	M	M	M	M	M	M	M	M	M	M
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
100	0.6	-0.6	0.0	0.0	0.0	0.0	0.0	0.0	-1	1
200	1.3	-1.2	0.0	0.0	0.1	-0.1	0.0	0.0	-2	2
300	1.9	-1.7	0.1	0.0	0.2	-0.1	0.0	0.0	-3	3
400	2.5	-2.2	0.1	-0.1	0.3	-0.2	-0.1	0.1	-4	4
500	3.1	-2.7	0.2	-0.1	0.5	-0.2	-0.1	0.1	-5	5
600	3.6	-3.2	0.3	-0.1	0.6	-0.3	-0.1	0.1	-6	6
700	4.2	-3.7	0.4	-0.2	0.9	-0.4	-0.2	0.2	-7	7
800	4.7	-4.1	0.5	-0.2	1.1	-0.5	-0.2	0.2	-7	8
900	5.3	-4.5	0.6	-0.2	1.4	-0.6	-0.3	0.3	-8	8
1000	5.8	-5.0	0.7	-0.3	1.7	-0.8	-0.3	0.3	-9	9
1100	6.3	-5.4	0.8	-0.3	2.0	-0.9	-0.4	0.4	-10	10
1200	6.8	-5.8	0.9	-0.4	2.3	-1.0	-0.4	0.4	-10	11
1300	7.3	-6.2	1.1	-0.4	2.6	-1.1	-0.5	0.5	-11	11
1400	7.9	-6.6	1.2	-0.5	2.9	-1.3	-0.6	0.5	-12	12
1500	8.4	-7.0	1.4	-0.5	3.3	-1.4	-0.7	0.6	-13	13
1600	8.8	-7.3	1.5	-0.6	3.6	-1.6	-0.7	0.7	-13	14
1700	9.3	-7.7	1.7	-0.6	4.0	-1.7	-0.8	0.8	-14	14
1800	9.8	-8.1	1.8	-0.7	4.4	-1.8	-0.9	0.9	-14	15
1900	10.3	-8.4	2.0	-0.8	4.7	-2.0	-1.0	1.0	-15	16
2000	10.8	-8.8	2.2	-0.8	5.1	-2.1	-1.1	1.1	-16	16
2100	11.3	-9.2	2.3	-0.8	0.0	0.0	-1.2	1.2	-16	17
2200	11.7	-9.5	2.5	-1.0	0.1	-0.1	-1.3	1.3	-17	17
2300	12.2	-9.9	2.7	-1.0	0.2	-0.1	-1.4	1.4	-17	18
2400	12.7	-10.2	2.8	-1.1	0.3	-0.2	-1.5	1.5	-18	19
2500	13.1	-10.6	3.0	-1.2	0.0	0.0	-1.7	1.6	-19	19
2600	0.6	-0.6	0.0	0.0	0.0	0.0	-1.8	1.8	-19	20
2700	1.3	-1.2	0.0	0.0	0.1	-0.1	-1.9	1.9	-20	20
2800	1.9	-1.7	0.1	0.0	0.2	-0.1	-2.0	2.0	-20	21
2900	2.5	-2.2	0.1	-0.1	0.3	-0.2	-2.2	2.2	-21	22
3000	0.0	0.0	0.0	0.0	0.0	0.0	-2.3	2.3	-21	22
3100	0.6	-0.6	0.0	0.0	0.0	0.0	-2.5	2.4	-22	23
3200	1.3	-1.2	0.0	0.0	0.1	-0.1	-2.6	2.6	-22	24
3300	1.9	-1.7	0.1	0.0	0.2	-0.1	-2.7	2.7	-23	24
3400	2.5	-2.2	0.1	-0.1	0.3	-0.2	-2.9	2.9	-23	25
3500	0.0	0.0	0.1	-0.1	0.3	-0.2	-3.1	3.1	-24	25

Figure 10: Table F Correction Factors

Ok, I can't help myself. I want to talk about just one more table – Table H, because I thought it was kind of neat. Table H was used to extract a correction to the range in meters for the rotation of the earth. Imagine correcting for the rotation of the earth mind you – how neat is that.

Table H was entered along the left side with the range expressed to the nearest 500 meters and along the top or bottom with the exact azimuth (to the nearest mil) to the target (direction of fire) expressed to the nearest listed value. For example, if the azimuth to the target is 1,499 mils, we would enter Table H with 1400.

FT 155-AM-2 | TABLE H | CHARGE 4G

PROJ, HE, M107
FUZE, PD, M577

ROTATION - RANGE

CORRECTIONS TO RANGE, IN METERS, TO COMPENSATE FOR THE ROTATION OF THE EARTH

RANGE METERS	AZIMUTH OF TARGET - MILS								
	0 3200	200 3000	400 2800	600 2600	800 2400	1000 2200	1200 2000	1400 1800	1600 1600
500	0	0	-1+	-1+	-2+	-2+	-2+	-2+	-2+
1000	0	-1+	-2+	-2+	-3+	-4+	-4+	-4+	-4+
1500	0	-1+	-3+	-4+	-5+	-6+	-6+	-6+	-7+
2000	0	-2+	-3+	-5+	-6+	-7+	-8+	-8+	-9+
2500	0	-2+	-4+	-6+	-7+	-9+	-10+	-10+	-10+
3000	0	-2+	-5+	-7+	-9+	-10+	-11+	-12+	-12+
3500	0	-3+	-5+	-8+	-10+	-12+	-13+	-14+	-14+
4000	0	-3+	-6+	-9+	-11+	-13+	-14+	-15+	-15+
4500	0	-3+	-6+	-9+	-12+	-14+	-16+	-16+	-17+
5000	0	-4+	-7+	-10+	-13+	-15+	-17+	-18+	-18+
5500	0	-4+	-7+	-11+	-14+	-16+	-18+	-19+	-19+
6000	0	-4+	-8+	-11+	-14+	-17+	-18+	-20+	-20+
6500	0	-4+	-8+	-11+	-14+	-17+	-19+	-20+	-20+
7000	0	-4+	-8+	-11+	-15+	-17+	-19+	-20+	-21+
7500	0	-4+	-8+	-11+	-14+	-17+	-18+	-20+	-20+
8000	0	-3+	-7+	-10+	-13+	-15+	-16+	-17+	-18+
********	********	********	********	********	********	********	********	********	********
8000	0	-2+	-3+	-5+	-6+	-7+	-8+	-9+	-9+
7500	0	-1+	-1+	-1+	-2+	-2+	-2+	-3+	-3+
7000	0	0	+1-	+1-	+1-	+1-	+2-	+2-	+2-
6500	0	+1-	+2-	+3-	+4-	+5-	+6-	+5-	+6-
6000	0	+2-	+3-	+5-	+6-	+7-	+8-	+9-	+9-
5500	0	+2-	+5-	+7-	+9-	+10-	+11-	+12-	+12-
5000	0	+3-	+6-	+9-	+12-	+14-	+15-	+16-	+16-
4500	0	+4-	+8-	+12-	+16-	+18-	+20-	+21-	+22-
	3200 6400	3400 6200	3600 6000	3800 5800	4000 5600	4200 5400	4400 5200	4600 5000	4800 4800
	AZIMUTH OF TARGET - MILS								

NOTES - 1. WHEN ENTERING FROM THE TOP USE THE SIGN BEFORE THE NUMBER.
2. WHEN ENTERING FROM THE BOTTOM USE THE SIGN AFTER THE NUMBER.
3. AZIMUTH IS MEASURED CLOCKWISE FROM NORTH.
4. CORRECTIONS ARE FOR 0 DEGRESS LATITUDE. FOR OTHER LATITUDES MULTIPLY CORRECTIONS BY THE FACTOR GIVEN BELOW.

LATITUDE (DEG)	10	20	30	40	50	60	70
MULTIPLY BY	.98	.94	.87	.77	.64	.50	.34

Figure 11: Table H Rotation – Range

Graphical Firing Tables

The Graphical Firing Table (GFT) was used to eliminate the difficulties in trying to compute firing data through the interpolation of TFT data. The GFT provided all the information needed to compute firing data in a slide rule form. We FDC "computers" used the GFT on every fire mission. The GFT was made in two parts. The rule is a rectangular wooden base on which is printed one or more sets of scales. With a few exceptions, GFTs are printed on both sides. The second part of the GFT is the cursor, which is a transparent plastic square that slide on the rule. Engraved in the plastic of the cursor is a manufacturer's hairline used to determine values from the scales.

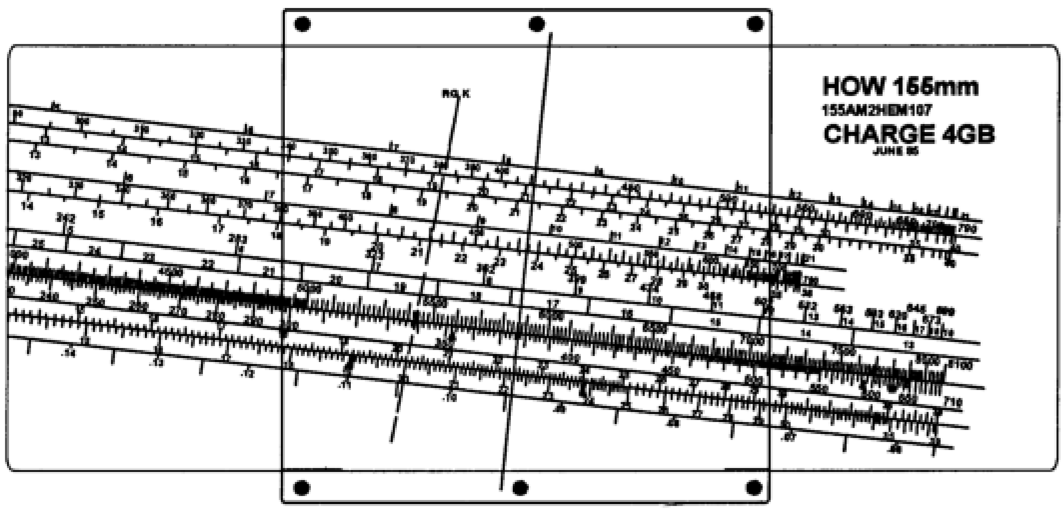


Figure 12: Graphical Firing Table

Graphical Site Tables

The Graphical Site Table (GST) was used to provide a quick and accurate computation of vertical angle, angle of site, and site. It could be used to convert yards to meters or meters to yards and to multiply and divide. Each GST was designed for a particular weapon and projectile family, and the computations were valid only for the weapon specified on the GST. The GST consists of three parts: a base, a slide, and a cursor with a manufacturer's hairline

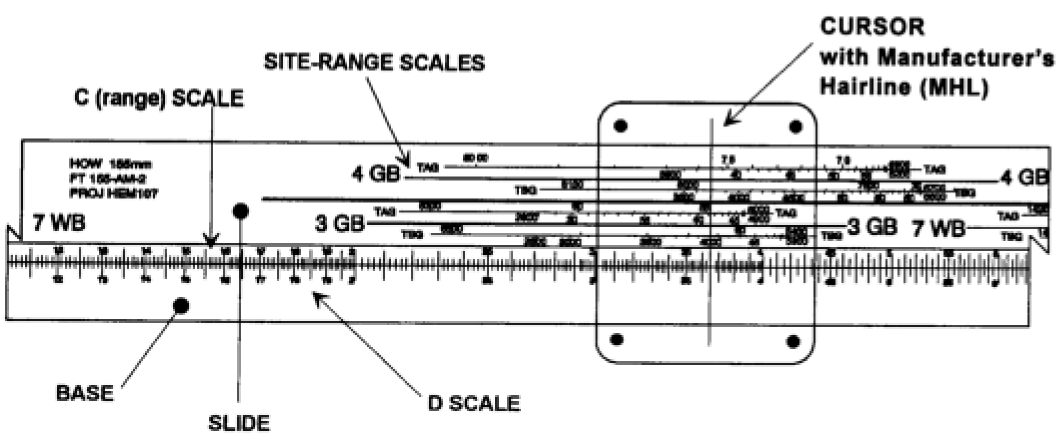


Figure 13: Graphical Site Table

Registrations

From an FDC perspective, I saved the best for last – that being "Registrations." A registration was the means by which we determined "cumulative errors" and the corrections for those errors. If all conditions of weather, position, and material were standard, a cannon firing at a particular elevation and deflection would cause the projectile to travel the range shown in the TFT or GFT corresponding to that elevation and charge. Since all standard conditions will never exist at the same time, firing table data must be corrected. Thus, the purpose of a registration was to determine firing data corrections that would correct for the cumulative effects of all nonstandard conditions.

Because many of these nonstandard conditions were position dependent, one of the first things we did when moving to a new fire base was to shoot one or more registrations. If I remember correctly, we would always register Charge 5 green bag and Charge 7 white bag because we used them the most. With these corrections applied to firing data, the FDC and firing battery could rapidly and successfully engage any accurately located target within the range.

In Viet Nam, we used two types of registrations: precision registration and radar registration. Other type include: high-burst and/or mean-point-of-impact (HB/MPI) registration and abbreviated registration.

- **Precision registration.** The precision registration was a technique for determining, by adjustment, firing data that placed the mean-point-of-impact (MPI) of a group of rounds on a point of known location. The point of known location was called a registration point.
- **Radar-observed registration**. The radar-observed registration determined the mean burst location of a group of rounds fired with a single set of firing data. When the mean burst location (or MPI) had been determined, the chart data (should hit data) were determined and compared to the data that were fired (adjusted-data [did hit data]) to arrive at the corrections needed.

The final step in every registration was the determination and application of registration corrections. Registration corrections consisted of total range, total fuze, and total deflection corrections. The total corrections were determined by comparing the chart data (that is the data the HCO said should hit the target) to the adjusted data (that is the data that did hit the target). The total corrections were then used as the basis for our GFT settings. With the GFT setting properly applied, it was possible to fire for effect without an adjustment phase on accurately located targets.

Conclusion

I hope that you enjoyed reading this as much as I enjoyed writing it. I have a lot of fond memories of my FDC crew in Viet Nam. We shared a lot of good times, and very few bad ones, which is a blessing in of itself. Best regards, Johnnie Pearson.