MUZZLE VELOCITY MANAGEMENT

CPT M.W. Heimer

"CHECK FIRING, CHECK FIRING, CHECK FIRING! To the rear of the Piece, fall in. Everyone vacate the FDC: except for the FDO to maintain communications only. NOBODY TOUCH ANYTHING! Someone will arrive at your position shortly."

That short conversation or a similar variation of it is enough to strike fear in the hearts of every artilleryman. The entire intricate system of secondary independent checks, certification, policies, SOPs, supervision, command climate, and unit competence can all be subject to scrutiny, until the cause of the incident can be determined.

Imagine now for a minute that you draw an un-calibrated lot of propellant during your next field exercise. Your weapon's last pullover gage measurement occurred when it was at the depot as a new tube, and you're the third or fourth FDO in a row to estimate shooting strengths on EFC's alone. Next imagine that there isn't a propellant efficiency reference in existence for your weapon system other than what has already been calibrated in your MVV log book. If you're an M119A2/A3 FDO you don't have to imagine very hard. You probably know this scenario very well. Most 155mm FDC's do not have nearly as complicated a situation for managing muzzle velocities, but more on that later. However, I'm sure that 155mm FDC's have taken notice that their locally calibrated propellant efficiencies can vary significantly from the published propellant efficiencies.

Firing incidents often occur during calibrations and training exercises when FDC's do not adhere to proper MVV management. If your unit SOP rightly requires an immediate investigation of any round over 400 meters off target, maybe you have been subject to the conversation in the first paragraph.

As Field Artillerymen we know that muzzle velocity is the single most influential factor, outside of gravity and the atmosphere that affects the achieved range of a projectile at a given quadrant in cannon artillery. It is the sum of all 14 factors that affect interior ballistics. Of those 14 factors outlined in chapter 3 of the FM 6-40 we know that most are impractical to measure or impossible to account for, though there are measures to mitigate their effects. Purely from a technical fire direction stand point, we focus on the factors that have the greatest influence on muzzle velocity that we can affect; propellant temperature, projectile square weight, tube wear, and ammunition lots.

We concern ourselves with Muzzle Velocity in terms of the stated standard muzzle velocity listed for the specified weapon system in the appropriate TFT and in terms of measured muzzle velocities. The difference between the two is our Muzzle Velocity Variations (MVVs). MVVs are of the most use to us, they allow us to determine a range correction and adjusted aim point. We define Muzzle Velocity Variations with the equation MVVs = Shooting Strength + Ammunition Efficiency + Round to Round variations. Round to round variations are impractical to predict so we average out their effect on MVVs by obtaining six useable rounds after two

warm up rounds during a calibration. Ammunition Efficiency is the sum of Projectile Efficiency and Propellant Efficiency. Projectile efficiency is primarily concerned with the shape, mass, finish and moment of inertia of a projectile. We simplify those factors through the use of projectile families and square weights. We're left with the equation MVVs = Shooting Strength + Propellant Efficiency.

This equation is familiar to every field artillery officer as our equation for predictive muzzle velocity variations. We also know that it is third in our order of preference for applying MVVs. First is a full calibration of every howitzer utilizing our Muzzle Velocity Systems. Second being a subsequent lot inferred calibration. Third, MVVs = Shooting Strength + Propellant Efficiency. Fourth (only to be used in emergencies) is Shooting Strength alone. We know that shooting strength is unique to each howitzer and is interpolated between the sum of our last pullover gage reading and equivalent service rounds. Propellant Efficiencies are provided to us or computed following a calibration.

Here is where we leave the idealizations of doctrine and our doctrinal tactical techniques and procedures. Quite often the real world problems we face, whether we understand their source or not require on the spot solutions. The purpose of what follows is to provide real solutions to those problems bringing us back into doctrinal tolerance.

Pullover Gaging

Unfortunately, we've reached a point in many light units where the 105mm Pullover gage is a thing of myth and legend. It does exist (see Figure 1-1). We've reached this point because *TM 9-1000-202-14, Evaluation of Cannon Tubes,* does not require pullover gaging for the M20A1 tube on the M119A2/A3 because it has no condemnation criteria based upon wear.

Purely from a maintenance standpoint there is nothing to gain from taking a pullover gage reading. So it simply isn't performed. It's hard to find anyone in the force that has ever seen it done on a M119A2/A3. This is why the myth originated that the pullover gage for the 105mm howitzers doesn't exist or is a depot level task. However, in the unlikely event your unit is obtaining regular pullover gage measurements on your M119A2/A3's is that *TM 9-1000-202-14* does not indicate where to set the pullover gages' stop assembly. Ensuring the measurement is taken at the correct location within the tube. It does provide this information for the M776 and M284 tubes. We find the measurement information for the M20A1 in the Tabular Firing Tables. 16 inches forward of the breech end of the tube. You may need to provide a copy of the TFT to your maintenance personnel.

The Gunnery Department investigated this issue. The M119's fired at BOLC receive regular pullover gaging. All 2LT's receive real 2408-4's during gunnery live fire exercises with recent pullover gage readings on them, followed by rounds fired to determine equivalent service rounds and shooting strength. Ft. Sill DLA Artillery Maintenance service the USAFAS howitzers for tube wear, their internal SOP mandates this requirement. They have provided the part numbers and NSN's of the equipment required to perform this task.

(FIGURE 1-1)

The 105mm pullover gage pictured in Figure 1-1 has an NSN of 5210-01-259-9104, part number 7247996. It comes as part of NSN 4933-01-577-2086, LIN T24523, SHOP EQUIPMENT ARTILLERY: FIELD MAINT SET N LESS PWR, it is part of your direct support maintenance battery MTOE. The reference is SC 4933-95-A15.

In technical fire direction we know the importance of tracking the shooting strength for every howitzer. Equivalent service rounds, is only an estimation of fatigue and erosion effects, based on equivalent full charges, EFC-wear and EFC-fatigue. For technical fire direction purposes we utilize EFC-wear as a temporary means of updating shooting strength between pullover gage readings. In determining shooting strength it is un-acceptable to utilize the initial pullover gage reading from a new tube plus the hundreds if not thousands of equivalent service rounds that the tube has fired since.

While maintenance purposes and publications do not require pullover gaging for the M20A1, technical fire direction does. A poor estimation of tube erosion will result in a poor estimation of shooting strength, making predictive MVV techniques potentially dangerous. It will also result in the computation of inaccurate propellant efficiencies following a calibration. A

unit level policy memorandum requiring pullover gaging as part of quarterly services or after every 500 rounds fired, which ever comes first will help mitigate MVV related problems.

Propellant Efficiencies

Accurate propellant efficiencies are extremely valuable to us as Field Artillerymen. Not only do they allow us to transfer MVVs between units following a calibration but on the receiving end they allow us to apply MVVs for un-calibrated lots during a calibration. Additionally, on a lot by lot basis they show whether or not we can transfer MVVs between charges. Remember our restricted charges are restricted because it is more accurate to use the equation MVVs = Shooting Strength + Propellant Efficiency than to transfer MVVs between these charges.

Locally calibrated propellant efficiencies are more accurate than the published propellant efficiencies. Local propellants are more likely to be subject to the same set of conditions that degrade the chemicals in the propellant over time (temperature changes, etc.). Additionally, MACS charges are only propellant efficiencies currently published. There are no Propellant Efficiency references readily available for M67 propellant.

Furthermore units such as 2ND Bn. 10TH Marines at Camp Lejuene are discovering inaccuracies between the published data and their calibrated propellant efficiencies that exceed the 400m correction, warranting a firing incident investigation by unit SOP.

The gunnery department regularly computes calibrated propellant efficiencies for canister lots of M1DC that exceed negative 30 meters per second. Translate that into charge 4 at a range of 5,000 meters and if you're only using shooting strength alone to predict your MVVs for a calibration you will certainly be subject to the conversation in the 1st paragraph of this article. The resulting adjusted aim point should be 900 meters over the target.

To solve this problem the gunnery department has established an AKO website with a link to a propellant efficiencies folder. Inside that folder are two files. One is a master file intended to compile and publish your locally calibrated propellant efficiencies. The other file is for you to input your locally calibrated propellant efficiencies to send to the gunnery department.

These files are very basic right now but over time, and with the field artillery community's participation, they will become a valuable resource in technical fire direction. For example, your unit is heading to another post to conduct training. With enough data built up, you can filter unit locations and your weapon systems propellants to have propellant efficiencies on hand for that area if you draw an un-calibrated lot of propellant.

Eventually, with enough data we will be able to determine how well our rules governing the transfer of MVVs between the charges in a charge group are holding up with the lots in circulation. Additionally, an extensive amount of data will allow for an easy comparative calibration search. This could potentially help provide early identification of problems like, deficiencies in ammunition storage, or potential problems with a howitzer's tube.

As a disclaimer, the Gunnery Department will not be able to verify the accuracy of the computational procedures utilized during the computation of the propellant efficiencies. This comes through unit training, supervision, and certification. However, as we compile more data per lot and location, trends will emerge and outliers identified. The use of the data in applying MVVs during a calibration while not perfect, is better than what we have now. With active participation by units submitting their calibrated propellant efficiencies hopefully we can prevent MVV related firing incidents during calibrations.

Standardizing Muzzle Velocity Management

In order for us to obtain accurate propellant efficiencies, we need accurate shooting strengths. In order to obtain accurate shooting strengths we need to conduct regular pullover gaging. In order to track our propellant efficiencies we need to standardize how we manage our MVVs in our MVV logbooks. This section is primarily concerned with M119A2/A3 units.

Every single M119A2/A3 unit in the Army is managing Muzzle Velocity incorrectly identified in the two methods stated below. Refer to the pictures in **Figures 1-2** and **1-3**. How is your unit tracking their MVVs?

(Figure 1-2)

(Figure 1-3)

We have encountered two methods that units are utilizing to manage their 105mm MVVs. The first occurs when units track them by the lot found on the crate, fiber, and projectile (canister lot). The second method is driven by units assuming that the lot on the crate, fiber, and projectile is the projectile lot so they pull out charge 7 and track MVVs by the propellant lot.

The first method is the better of the two. The lot on the crate, fiber, and painted on the projectile is the canister lot. This indicates that all propellants within that canister lot will be the same. There are other similarities indicated such as projectile square weight, primer lots, etc. This method of managing MVVs will provide you with safe and accurate data. However, there are thousands of canister lots and your unit may never see the same one twice. M119A2/A3 units are authorized one muzzle velocity system per platoon by MTOE. One muzzle velocity system per platoon requires a lot of mission interrupting calibrations. With shooting strength alone applied as the MVV. It also makes lot management extremely challenging when you constantly have 5-7 un-calibrated lots on the firing point.

The second method of managing MVVs certainly reduces the complexity of managing so many un-calibrated lots. However, if you are using this method to track and apply MVVs CEASE AND DESIST IMMEDIATELY! Discard all of your MVV data contained in your logbook that has been tracked by the propellant lot. M67 propellant consists of the single perforated powder

grains found in charges 1 & 2, as well as the multi-perforated powder grains in charges 3-7. Each has their own lot number and one is not indicative of the other. Not only is this method inaccurate, but potentially unsafe and you are unknowingly transferring MVVs between lots.

The correct method of managing 105mm MVVs is to utilize the "propellant charge lot number". This is the lot number assigned to the specific pairing of the two lots of propellant in charges 1-2 and 3-7. This method provides safe and accurate data. It also vastly expands the number of "canister lots" that you can apply historic MVV data too.

Herein lies the problem. The propellant charge lot number cannot be found anywhere on the canister, fiber, or crate. It's found through the Munitions History Program website: https://mhp.redstone.army.mil

This is not a practical resource for FDOs to utilize on the firing point. However, the Gunnery Department has spent a considerable amount of time data mining the website to compile a canister lot to propellant charge lot master key. It is also posted on the Gunnery Department's AKO webpage in the Muzzle Velocity Management Folder. It should be saved to the desktop of every M119A2/A3 AFATDS for easy reference on the firing point.

As mentioned earlier Muzzle Velocity Management as it is currently implemented is exceptionally difficult for M119A2/A3 units. The reason for this is the majority of our 105mm ammunition was originally manufactured during the Vietnam War. Canister lots were originally manufactured in much larger quantities than what we have in circulation right now. An example is canister lot KN-818-30B. The original manufacture date is 1975 under canister lot KN-818-30. The original quantity of KN-818-30 was 40,611. What remains of KN-818-30 has been refurbished at multiple intervals of varying quantities into 7 new canister lots. On 19 October 2006 thirty canisters of what originally was KN-818-30 became KN-818-30B after receiving propellant charge lot SDP05J012-001.

During the Vietnam War and the period immediately following, it was practical to track MVVs by canister lot numbers. The problem is we have whittled away in training and conflict at what remains of the originally massive quantities of individual canister lots manufactured during the Vietnam War. We've also multiplied those original canister lots into numerous canister lots of much smaller quantity. Quite often the canister lots we draw and fire are all that remains of that lot.

We have no option other than adjusting our Muzzle Velocity Management TTPs to tracking our MVVs by propellant charge lot numbers. This is the only way possible that we can effectively manage Muzzle Velocity in M119A2/A3 units.

The canister lot to propellant charge lot master key on the Gunnery Departments website will greatly assist in your transition to this method of managing your MVVs. However, this is a dynamic document as it will need continual updating as new lots are being created. This will require unit participation. As units encounter canister lots they cannot reference through the key they should email the workbook manager hyperlinked on the spreadsheet and he will add it in.

If you encounter a canister lot that cannot be found on the key through the find function (CTRL-F), then you must calibrate that lot and track it by canister lot until the propellant charge lot is determined.

Keep in mind that the DFCS on M119A3 makes MVV management slightly more complicated than it already is. The howitzer sections build their ammo database, and digitally send it to the FDC in their piece status. If they do not input the long lot designator correctly, AFATDS will not apply the MVVs from the MVV log book to the firing solution. Upon physical receipt of ammunition on the firing point you must translate the canister lots into propellant charge lots. You have two options from here. You can immediately update and distribute your parameter cards outlining what you want built into the database or you can change your MVV long lot designator inside AFATDS to apply to what the guns send you.

Conclusion

With time and technology the intricacies of running an FDC have increased dramatically. The technical fire direction skill set is larger in both scope and depth than it has ever been in the past. Our FDC's are much faster and more accurate but at the same time have many more potential points of failure. Technology, while adding complexity has unquestionably assisted the capabilities of our branch. We still have to fight for every mil of accuracy that we can get. Muzzle Velocity Management is always a good place to start when going after those mils.

The gunnery department still exists not only to create new FDOs but also to solve problems encountered in the Force and Fleet. The problems we face in technical fire direction today are much more unpredictable and elusively defined than they were in the past. If ever you encounter a problem in fire direction and cannot determine the solution, do not hesitate to contact a gunnery instructor through the contact information listed on the gunnery department's AKO webpage at https://www.us.army.mil/suite/page/668036

.