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TITLE: An Analysis of the 120mm M829 Screening in Operation Desert Storm

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ABSTRACT:

The screening results for the 120mm M829 APFSDS round fired from one tank battalion deployed to Southwest Asia from Germany are presented and analyzed in an effort to explain the deviation from expected accuracy. A background history of the ammunition prior to the screening is presented as well as a detailed description of the screening process, measurements of hits on the screening panels, a statistical analysis of the target impacts, and an exterior ballistic analysis to determine the loss of muzzle velocity needed to account for the low hits observed. It was found that a loss of about 170m/s muzzle velocity was necessary to cause the low hits. A mean point of impact was computed for the battalion and compared to the Computer Correction Factor for the M829.

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AN ANALYSIS OF THE 120mm M829 SCREENING IN OPERATION DESERT STORM

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INTRODUCTION

During Operation Desert Storm it became necessary to Screen the M1A1 tanks prior to entering combat. This paper describes the screening process followed by one battalion and the efforts taken to correct for the unacceptable accuracy obtained from the fleet Computer Correction Factor (CCF) for the M829 round for this occasion.

During the screening in Saudi Arabia about 20 tanks in the battalion failed to hit the screening panel. There were 10 other tanks who hit the screening panel but failed to satisfy the screening criterion [1:A-20]. This was a drastic change from past gunnery experiences where this battalion had to proof fire four out of 58 tanks at worst. Now there were 30 out of 58 tanks that failed to screen. The screening failures were analyzed by the battalion master gunner, the brigade master gunner, the company commander, the brigade operations officer, and the battalion commander. Most of the shots were observed to be low. The mean point of impact of the battalion across the board was likewise observed to be low.

BACKGROUND

Wet Ammunition

There is some history of poor performance of 120mm training ammunition used in Germany. This same battalion, while at annual tank gunnery qualification in Grafenwoehr in March 1988 was issued training ammunition that had been exposed to the weather for a prolonged period. The soldiers in the battalion had to chip ice off the casing of their M831 and M865 training rounds with screwdrivers in order to get them to fit inside the ammunition ready racks. This all occurred despite published guidance on how to store the 120mm ammunition. During this gunnery rotation the battalion consistently fired low on targets beyond 1700 meters range. At the time it was theorized by the battalion master gunner the water content of the ammunition was to blame for the low shots at long range. The battalion also drew water damaged ammunition in 1989 and some rounds could not be chambered due to excessive swelling of the cartridge case. The rotation in March 1990 saw mostly new ammunition issued and no problems were encountered with water soaked ammunition.

The battalion had finished off cycle gunnery two months prior to notification of deployment to SWA and had not encountered any mechanical difficulties with the their fire control systems nor were any problems reported with the M865 and M831 ammunition. The battalion had just received its M1A1 (Heavy) tanks in July 1990 and all were in excellent mechanical condition. The battalion had been uploaded since February of 1987 until the fall of 1988 when the ammunition was placed in subterranean bunkers. During the time the battalion was up-loaded, the ammunition was subjected to the constant rain and high humidity of the north German weather. To exacerbate this problem, the environmental cover at the rear of the turret bustle allowed water to leak into the ammunition compartment. This, along with any scratches or gouges on the cartridge case, created a condition allowing the ammunition to absorb water. This was known by PM, TMAS and the ammunition units in Germany[7,8]. In November 1989, one ammunition surveillance team from PM, TMAS found ammunition that had been submerged in water, had soft casings, rusty primers and rusty stub cases. Some turret bustle ammunition compartments had standing water along with condensation droplets forming on the inside walls [7]. One quality control inspection by an ammunition unit to the battalion studied in this report showed such findings as: soft cartridge cases, 63% of the ammunition inspected had corrosion on the base and primer, and 100% with scrapes and scratches on the combustible cartridge case [8].

Screening Doctrine

The current doctrine, as put forth by the Armor School, states that tanks will not be zeroed but rather calibrated by boresight, then screened using a fleet CCF for each type of main gun ammunition [1:A-17]. There has been debate in the armor community for several years on the necessity of zeroing. The Armor School maintains that zeroing is good for only a specific occasion and despite the increase in accuracy for this occasion, the costs [of the ammunition] for zeroing make this practice "irresponsible" [6]. This argument unfortunately does not quantify the costs of destroyed tanks and incinerated solders as a result of not zeroing. The tank manufacturer, however, states that to get the maximum accuracy from the tank it must be zeroed [2:2-276]. The manufacturer also states that zeroing will only need to be done once and unless the gun tube, mount, or recoil spring are removed there is no need to re-zero the tank [2:2-76]. To further complicate the issue, FM 17-12-1 does not give any instructions for screening prior to combat. The only references to screening are made when referring to a training situation and not combat.

As the last of the old M60 tankers leave the army so does the institutional memory on zeroing. Since the M1 and M1A1 tankers have only screened during gunnery and few have proof fired their tanks, there is little experience save for the master gunner in zeroing. When a tank does not pass screen and has to be proofed, the master gunner usually supervises the crew.

GENERAL APPROACH

Research

A literature search of the Defense Technical Information Center discovered some problems with accuracy during tests of early production M1A1 tanks [3:1]. However, there was no consistent pattern of low hits mentioned in the literature.

Reduction of Raw Firing Data

All the tanks in the battalion fired M829 at screening panels placed at 1500 meters. Figure 1 shows the 1500 meter screening panel. Initially, each tank was boresighted and applied the fleet CCF for the M829 round and attempted to fire for confirmation. Each hit was measured and the distance from the center of the panel to the hit was recorded. Figure 2 shows the mean point of impact (MPI) of the shots fired from the fleet CCF. Not shown on the figure are the locations of all the hits nor the 17 shots that missed the target short, one that missed to the right and three that flew over the target.

At this point we decided to correct for the poor hit distribution observed in the M829 rounds brought from Germany. We computed a modified CCF for those tanks missing the panel or hitting low. Based on the distribution of hits the modified CCF was L0.13, U0.30. This is in comparison to the published CCF for the M829 of L0.13, U0.65. Figure 2 shows the MPI of those shots fired from tanks using the modified CCF. As a result of this correction, the MPI was brought closer to the aim point.

After a closer look at the strike of all the rounds a more precise computation of the MPI was computed. From these data a corrected CCF was found to be L0.01, U0.34. This would be the CCF for these rounds fired for this screening occasion. Compared to our field estimate CCF of L0.13, U0.30 we came close to the true mean point of impact for the vertical jump be since we ignored horizontal jump we were off roughly one tenth of a mil. Table 1 compares the fleet CCF with the modified CCF computed at the range and the corrected CCF computed in this report. The MPI based on the corrected CCF is also shown on figure two and the proximity of the MPI with the aim point is evident. As an added comment, the crews whose shot hit close to the center were very comfortable with the screening process. However, those crews whose shot hit 80 cm from their aim point had considerably less confidence in their ability to hit a hostile target even though reference 1 said they were "properly screened".

Table 1 Comparison of Fleet with Modified CCFs

CCF	Horizontal (mils)	Vertical (mils)
Fleet	Left 0.13	Up 0.65
Modified at Range (Dillon)	Left 0.13	Up 0.30
Modified in Report (Dillon)	Left 0.01	Up 0.34

Discussion

At the firing range, figure 3, our immediate concern was to find the cause of the poor accuracy of some of the M829 rounds. One source of error we considered was optical path bending. The high temperatures in the desert and the convex curvature of the range from the firing line to the target area caused considerable heat striations distorting the image of the targets. If the gunners were aiming at the apparent center of the target, this could explain the poor accuracy. We tested this hypothesis by firing some available M865 rounds from tanks that failed the M829 screening. All these tanks hit very close to the aim point with M865. This narrowed our alternatives to two possible causes: 1) the M829 CCF was not correct, 2) the M829 ammunition was faulty. To narrow our alternatives down we reasoned that the CCF was for the M829 was correct and our history of wet rounds gave us some insight into the cause of the low hits. Based on this experience and after some lengthy discussion at the range we assumed one or two things were happening. One was some of the M829 ammunition had absorbed enough water to slow the round down to the point that the lost muzzle velocity would cause the round to hit low. The other was the lower muzzle velocity would cause the slower round to arrive at the muzzle late which would cause the projectile to exit the tube with different horizontal and vertical velocities and displacements due to gun dynamics. We thought this could have a very large and random effect on dispersion. We were not in a position to do anything about narrowing down the source of error(s) but we did have to come up with a solution and fast. The time and ammunition constraints we faced prohibited us from zeroing 30 tanks. Our modified CCF was our interim solution. Our modified CCF allowed all tanks in the battalion to pass screen except two which had to be zeroed.

In order to present a possible cause of the low hits by some of the M829 rounds an exterior ballistic analysis was conducted to determine how much muzzle velocity would have to be lost to cause an M829 round fired from the fleet CCF to miss a screening panel 1500 meters away. Following the exterior ballistic analysis an initial interior ballistic analysis was conducted to attempt to quantify how much muzzle velocity could be lost from a wet casing.

Exterior Ballistic Analysis

An exterior ballistic analysis was conducted on the M829 ammunition in an effort to determine how much muzzle velocity would have to be lost to miss a screening panel 1500 meters away. From the size of our panel, the round would have to pass 0.67 mils below the aim point to miss the panel.

A solution to this can be calculated by modeling the trajectory of the M829 round in two dimensions. The differential equations of motion in the x and y directions are:

$$x'' = -(1/m)K_d d^2 x' \quad (1)$$

$$y'' = -(1/m)K_d d^2 y' - g \quad (2)$$

where m is the projectile mass, K_d is the ballistic drag coefficient, d is the projectile body diameter, and g is the acceleration due to gravity. The values for the drag coefficient were obtained from reference 9 and are a function of the flight Mach number.

These equations were integrated for several initial conditions of muzzle velocity to determine how much loss would cause the round to fall 0.67 mils at 1500 meters. Table 2 shows the results of this. In order for a round to miss the panel the muzzle velocity would have to be below about 1500 m/s which is a loss of about 170 m/s at the muzzle. A cursory interior ballistic analysis was done to explore the feasibility of the wet ammo theory.

Table 2 Projectile Strike vs Muzzle Velocity

Muzzle Velocity (m/s)	Strike at 1500 m (cm below baseline)	Change in Vmuz (m/s)
1670	0.0	0.0
1570	-40.5	-100
1500	-100.5	-170

This analysis was done assuming the low hits were a result of low muzzle velocity only. In actuality, it is presumed the gun dynamics would be different with a loss of 170 m/s of muzzle velocity. With this lower velocity and time of arrival at the muzzle, we theorize the projectile would experience a different jump due to the lateral and vertical displacement and velocity of the muzzle at the time of shot ejection. So, in addition to the greater fall from low muzzle velocity, the projectile would have a different jump due to different gun dynamics during launch.

Interior Ballistic Analysis

In order to study the possibility of wet ammo causing a loss of muzzle velocity sufficient to cause a round to miss the panel, a simple interior ballistic parametric study was done using IBCODE [4:--]. To establish a baseline from which to compare, the interior ballistic solution for the M829 was calculated.

Since there was no way of determining how much water permeation existed in the rounds already fired we decided to remove the combustible cartridge case from the initial conditions of the calculation. Although very crude this allowed us to see how much the cartridge case contributed to the interior ballistic solution [5:--]. By removing the cartridge case from the input deck an 8.3% loss of muzzle velocity resulted. This corresponds to 137 m/s in the M829. If the cartridge case was water soaked, the water would act as an energy sink and presumably reduce the muzzle velocity even further. As a result of the interior ballistic analysis, wet ammo theory could cause the low shots seen in the screening.

CONCLUSIONS

The M829 fleet CCF was not acceptable for all tanks during Operation Desert Storm.

The field modified CCF provided an interim solution for the M829 rounds during the ground campaign in Operation Desert Storm.

Wet ammunition is suspected as the major cause of poor accuracy with the fleet CCF.

RECOMMENDATIONS

A more precise analysis of the interior ballistics of the M829 ammunition be conducted to determine the effect of moisture in the propellant on the performance of this ammunition.

A full scale firing test be conducted using water soaked ammunition to provide an insight on the applicability of the fleet CCF for water soaked ammunition.

A study is recommended to investigate the effect of gun dynamics on the accuracy of the M829 round with lower than nominal muzzle velocities.

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FIGURES

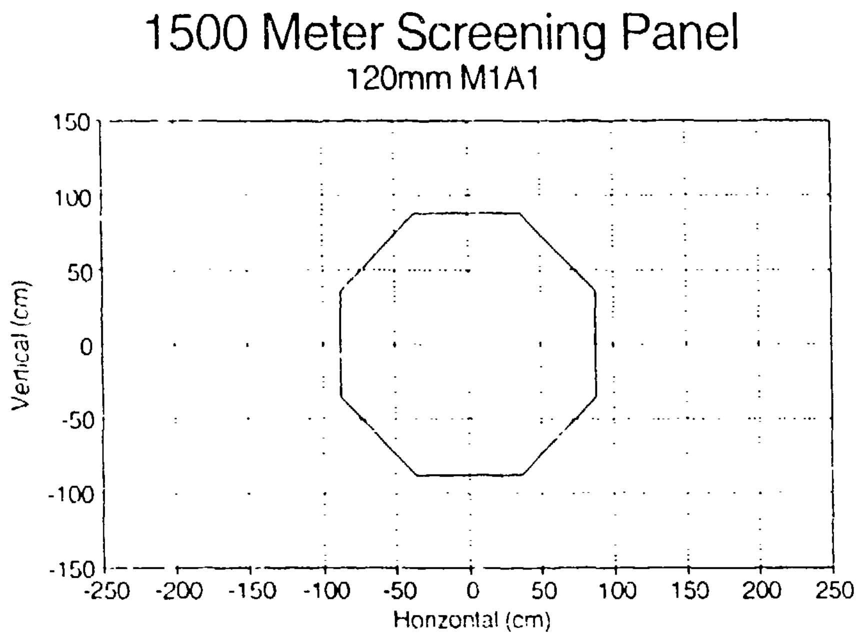

Figure 1. 120mm 1500 meter screening panel.

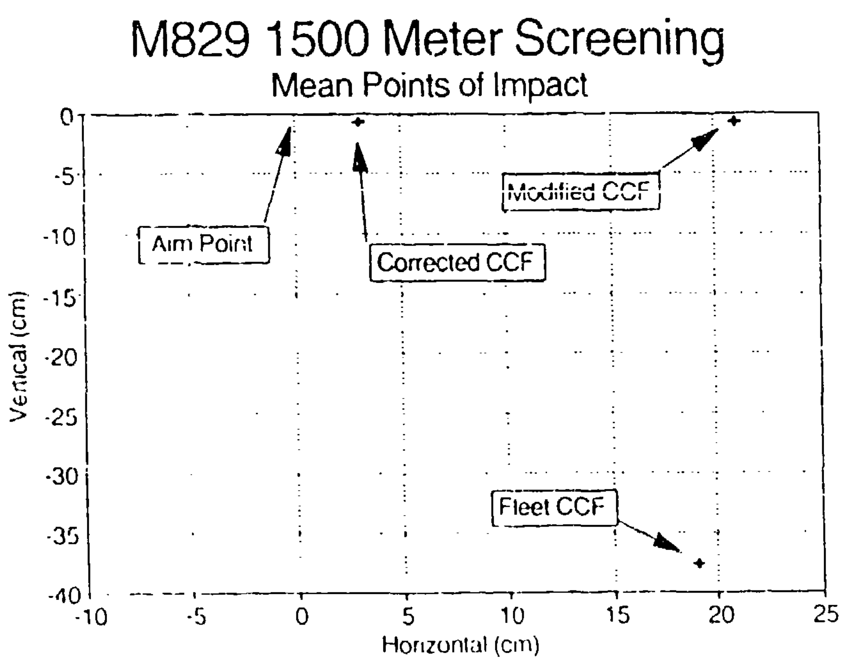

Figure 2. Mean Points of Impact.

Figure 3. Tanks at the Screening Range