Some Aspects Regarding Testing Procedures for 9x19 mm Ammunition System while Evaluating Ballistic and Safety Characteristics During Life Cycle

TRAIAN ROTARIU, DORU GOGA, VIOREL TIGANESCU,
TUDOR CHERECHES, MARIUS CARMACI
Faculty of Integrated Armament Systems
Military Technical Academy
Bucharest, Sector 5, 81-83 G.Cosbuc Bld., 75275
ROMANIA
http://www.mta.ro

Abstract: - Service life of any ammunition system used in operational or training activities and stored in specific conditions is a very important characteristic for the ammunition life cycle. Evaluation of safety and ballistic performances of ammunition system is made in design and development stages as well as during service. This study presents some results of experimental tests made on successive 9x19 mm ammunition lots in order to establish evolution of ballistic characteristics in time and also to emphasis some modifications that have to be made on standard testing procedures in order to improve accuracy of measurements.

Key-Words: - Ammunition, Caliber, Ballistic, Pressure, Velocity, Barrel, Bullet

1 Introduction

Service life of an ammunition system can be defined as the period of time in which the physical, chemical, performance and safety characteristics of the ammunitions are situated inside the boundaries stated by the appropriate authority.

Ammunition producers and also military specialists were always preoccupied by the evolution of all ammunition characteristics in time, by setting acceptable limits and also by finding best way to estimate influence of any parameter over the functional and safety characteristics. Good evaluation of service life allows an efficient operation and reduces demilitarization and disposal cost. Knowing the ammunition behaviour in time also allows preventing accidents or failures in operational missions.

Safety or compatibility in service for any ammunition can be defined as the stage at which no material or component of the ammunition system have suffered degradations that could affect significantly its characteristics.

Periodic evaluation process of ammunition characteristics comprise many stages, and in our opinion most significant among them are:

- establishing initial performance and safety characteristics;
- setting critical performance and safety characteristics;
- setting normal values and acceptable deviations considering associated risks;
- periodical experimental and theoretical determination of critical performance and safety characteristics;
- comparing new values with reception data;
- taking decision regarding future evolution of ammunition system and possible destination.

Periodic evaluation process described above is very laborious and involves great human and material efforts. From this perspective, existence of accessible theoretical/experimental instruments that could indicate tendency of ammunition evolution is indispensable both for producer and beneficiary.

2 Problem Formulation

Ammunitions are normally subjected to a large range of stresses like: extreme temperatures and humidity, vibrations, falling from different heights, shock waves, fire etc.

The study realized in the Explosives and Ammunition Laboratory of Military Technical Academy concerned testing and evaluation of small caliber ammunition: 9x19 mm Parabellum produced by Sadu Gorj SA - Romania. The aim of study was to determine important ballistic and safety parameters of the ammunition in order to evaluate compatibility in service and technical status of the 9x19 mm Parabellum ammunition. It was also the aim of this study to verify consistence of the ammunition with NATO standards for 9 mm caliber.

In this paper we only deal with modifications produced by normal environmental conditions and natural ageing of energetic materials that are contained inside the ammunition system. During long term storage this is the most important process that occurs. We will only present results regarding determination of ballistic characteristics at 21 ^{0}C for 9mm Parabellum ammunition, because these results well express time evolution of performance and safety characteristics and also the complexity of the whole process of evaluating technical status for 9 mm ammunition lots.

Caliber 9x19 mm cartridge is used in caliber 9 mm weapons. It has brass case, lead bullet core and brass bullet jacket and its weight is 7.45 g. Percussion primer is Berdan type, non-corrosive.

Caliber 9x19 mm cartridge components are:

- Brass cartridge case;
- Berdan non-corrosive primer;
    - Alveole;
    - Small round disc;
    - Priming mixture;
- Propellant charge;
    - Simple base propellant, weighing approx. 0.35 g;
- Bullet caliber 9 mm type Parabellum, weighing approx. 7.45g;
    - Brass bullet jacket;
    - Lead bullet core.

Table 1 shows main ballistic characteristics of 9x19 mm ammunition at 21 °C according to NATO specifications [1], [2], [3] and also according to Sadu Gorj SA specifications.

Table 1: Comparison of performance and safety characteristics presented in reference documents

Parameter	**MU**	**Values according to MOPI 9 mm**	**Producer Specification**
1	2	3	4
Average initial velocity $V_{16\,med+21}$	[m/s]	-	380±15 at 25 m)
Initial kinetic energy for 7.45 ± 0.13 g bullet	[J]	542 - 814	-
Initial velocity standard deviation sd_v	[m/s]	-	$\Delta V_{25} \leq 40$ m/s
Average maximum pressure (EPVAT) P_{maxmed}	[MPa]	≤ 230	≤ 220 (crushing cylinder)
1	2	3	4
Maximum maximum pressure (EPVAT) P_{maxmax}	[MPa]	≤ 265	≤ 250 (crushing cylinder)
Action time ta	[ms]	≤ 3	-
Propellant type		Simple or double base propellant	Simple base propellant
Propellant weight (informative)	[g]	-	0,35

Comparing parameters presented in product documentary with those mentioned in [3], can be observed there are some characteristics that have to be evaluated and examined, especially pressure and velocity parameters.

3 Problem Solution

Pressure measurement was carried out using two piezoelectric transducers and a ballistic barrel P-142 realized at Sadu Gorj SA and fulfiling NATO specifications (figure 1).

The ballistic barrel has multiple apertures for gas capture and pressure measuring. One of these apertures is located exactly at the muzzle of cartridge case (according to NATO specifications) and one is located inside the cartridge chamber (back from the bullet). This second aperture allows measuring rising pressure from the start, before the bullet leaves the cartridge, thing that is not possible according to NATO procedure (using only first aperture described).

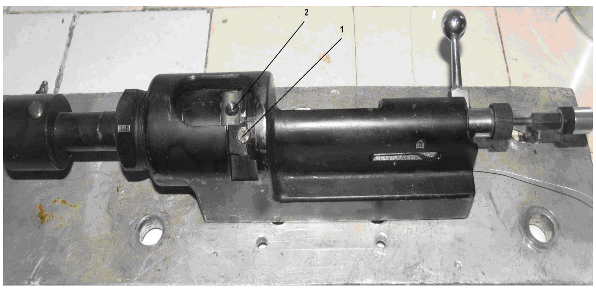


Figure 1: Caliber 9 mm ballistic barrel
1. Transducer aperture inside cartridge case
2. Transducer aperture at cartridge case muzzle

Electric signals from transducers were amplified using a NEXUS electric charge amplifier having amplification factor 1000 bar/V.

Bullet initial velocity was measured at 5 m in front of the barrel muzzle using photo-detectors and

OEHLER velocity measuring installation. Photo-detectors were positioned at 4, 5 and 6 meters in front of the weapon muzzle (figure 2).

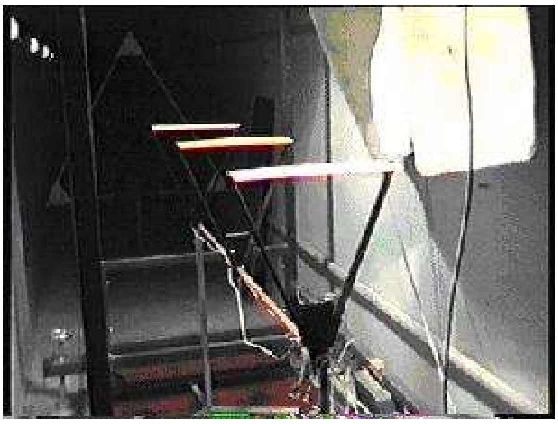


Fig. 2: Photo-detectors for bullet velocity measurement

Triggering was realized using a signal generator and signal acquisition was made using a Tektronix memory oscilloscope.

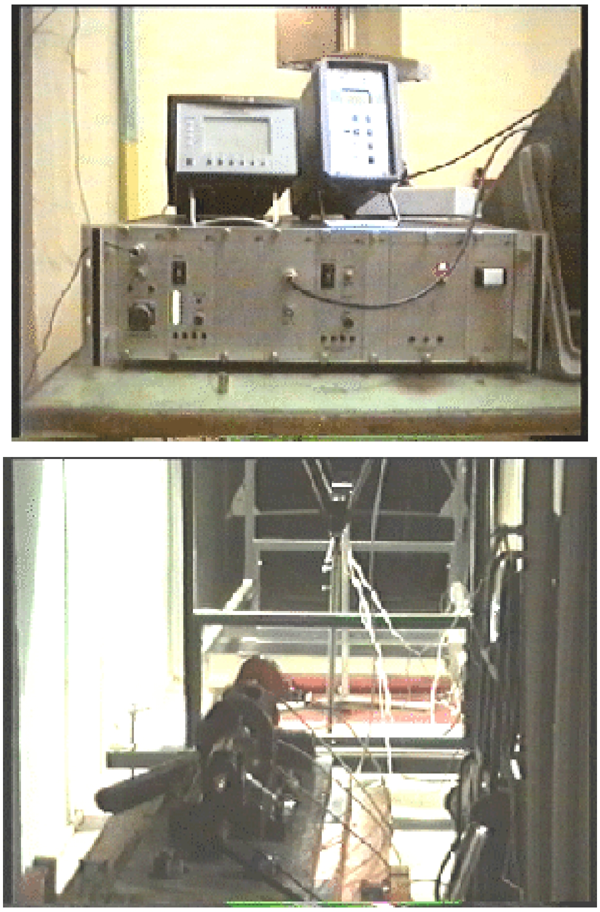
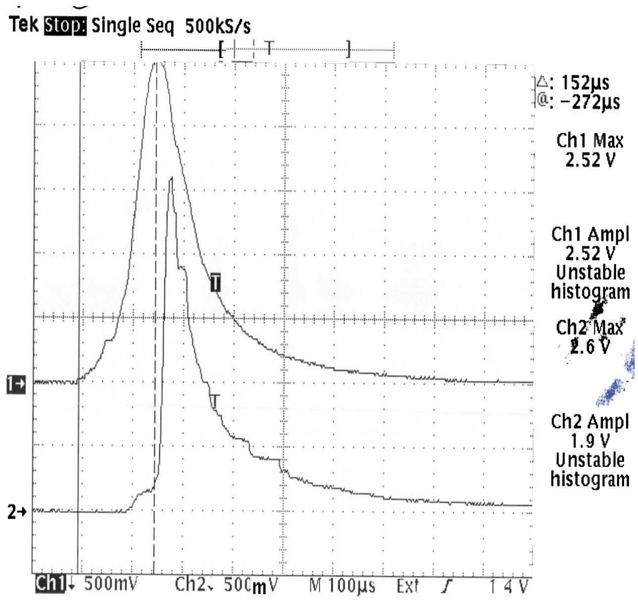


Fig. 3: Experimental setup

Fifty measurements were done using five different lots of Parabellum ammunition.

Pressure vs. time curves were recorded on two channels using transducers positioned inside the cartridge case and at its muzzle. Typical pressure diagrams are presented in figure 4.

As the amplification factor is 1000 bar/V, pressure (in bar) is determined multiplying the voltage by 1000. Two channels measurement allowed us to determine differences between pressure values inside the cartridge case and at the muzzle of cartridge case.



Lot M06-96

Fig. 4 Typically pressure vs. time diagram

On channel 1 was recorded pressure P_{max1} (measured in the cartridge case) and on channel 2 was recorded pressure P_{max2} (measured at the muzzle of the cartridge case). For the great majority of the propellants, P_{max2} values are higher than P_{max1} but in some cases, especially when porous simple base propellants are used, it was observed that P_{max2} values are smaller than p_{max1} values. This can be put on the high deflagration velocity of porous propellants (compared to other propellants like ball powders) which causes burning of almost entire energetic material before the bullet passes aperture number 2.

Final average results of the measurements are centralized in Table 2.

Table 2: Average ballistic characteristics of ammunition lots

Lot	Value/ Characteristic	P_{max} (bar)	V_5 (m/s)	E_5 (m/s^2)
M02-95	Med	2844,2	366,7	501,3
M03-96	Med	3047	373,7	522,5
M06-96	Med	3059,5	373,7	519,7
M09-96	Med	2950	376,5	525,3
M03-97	Med	3009	382,2	545,3

Reception tests results for the ammunition lots according to their passport forms supplied by the producer are presented for comparison below in table 3 (pressure measurement was realized using crushing cylinder apparatus disposed at the muzzle of the cartridge case).

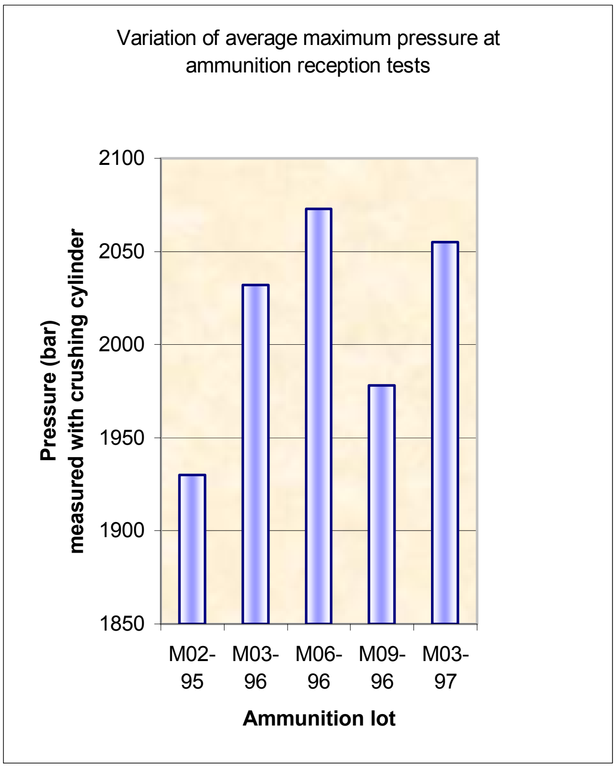
Table 3: Initial ballistic characteristics (average values) for Parabellum ammunition lots

Lot	P_{med}	P_{max}	P_{min}	V_{25}
M02-95		2014	1876	386,3
M03-96	2032	2116	1950	387,2
M06-96	2073	2126	1927	384
M09-96	1978	2174	1842	384,4
M03-97	2055	2195	1915	381,6

On can see that P_{max} values measured with crushing cylinders are significantly lower than those obtained with piezoelectric transducers, but it can be explained by the lower accuracy of the first method.

Graphic expression of ballistic characteristics and their evolution are presented in figures 5 and 6. Same allure of variations can be observed in case of pressure measurements (figure 5) when compare reception tests with nowadays tests. It indicates that maximum pressure is not relevant when looking for ageing effect on ammunition performances.

On the other hand figure 6 shows important decrease of initial velocity nowadays compared with reception data. Having in mind that velocity measurements present good accuracy, it suggests a significant decrease of nitrogen content inside the propellant and subsequent decrease of energy supplied by the energetic material. This is a good indicator for ammunition specialists showing that further investigations for nitrogen content would be necessary to complete evaluation.



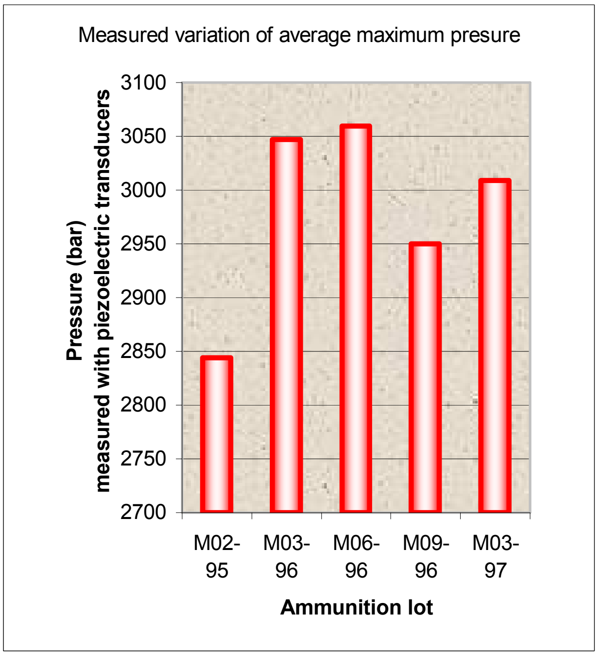


Fig. 5: Comparison between average maximum pressure at reception and nowadays

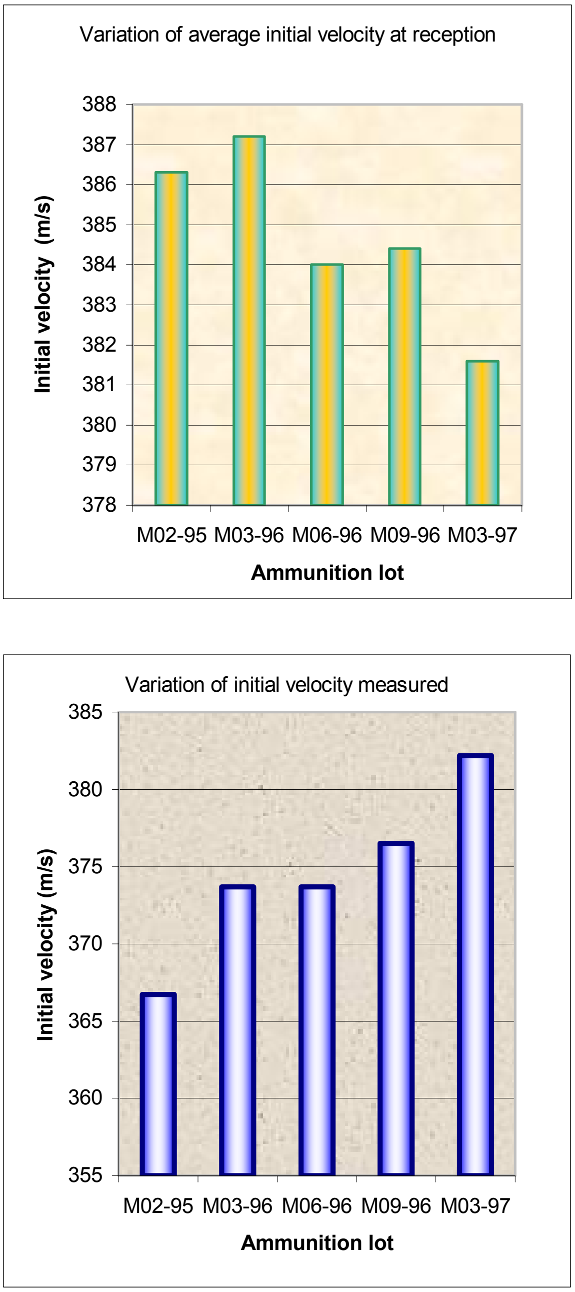


Fig. 6: Comparison between initial velocity at reception and nowadays

4 Conclusion

Analysis of pressure results from reception tests and nowadays tests shows similar tendency regarding average maximum pressure. Absolute values are different due to measuring techniques used and also due to chemical modification of the propellant charge. Only this similarity in tendency does not allow us to draw any conclusion regarding any modification that could occur. But analysis of caliber 9 mm Parabellum lots allowed us to draw other important conclusions:

a. if maximum pressure P_{max1} (measured in the cartridge case) was not reached until bullet gets in front of aperture number 2, then $P_{max2} > P_{max1}$;

b. if maximum pressure (measured in the cartridge case) was reached until the bullet gets in front of the aperture number 2, then $P_{max2} < P_{max1}$; in this situation typical procedure indicated in NATO standards for pressure measurements will not indicate the true maximum pressure value;

c. situation presented at b) is common to porous single base propellants, having high deflagration velocities.

As maximum pressure is a very important parameter especially for the safety of any armament system it is very important to setup procedures that allow measuring it with maximum accuracy insuring that standard limitations are not exceeded.

Significant modifications regarding the propellant charge and its deflagration velocity are indicated by the evolution of average initial velocity. Natural ageing of propellant causes important decrease of initial velocity, best observed for older lots, especially M02-95 which came very close to the lower limit for initial velocity.

References:

[1] ***, *Manuel d'essais OTAN des armes et munition de petit calibre*, NATO, D14, 2001;

[2] ***, *STANAG 4090, Edition 2- Small Arms ammunition (9 mm Parabellum)*, NATO, 1982;

[3] ***, *Manual of Proof and Inspection Procedure (MOPI) for NATO 9 mm Ammunition*, NATO, 1981.