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Surveillance Tests of a new LOVA Gun Propellant

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Abstract

A novel nitramine gun propellant, designated CLP-15, was developed and tested for 120 mm gun ammunitions. The new propellant exhibits improved ballistic and safety properties compared to those of conventional double-base propellants such as M-26 & JA 2. This propellant is the second in the CLP's family after CLP-26 for APFSDS-T 105 mm gun that was presented at the 2004 IM symposium at San Francisco.[1]

The current paper will present results of various stability tests as stabilizer depletion, of accelerated aging storage of the new propellant and ammunition. Microscope FTIR investigation of stabilizer and filler migration has shown good stability of the new propellant matrix. Firing tests of ammunitions after aging has shown small deviation of the ballistic and good stability of the propellant.

The new propellant was designated to assist IM test. Therefore some IM tests results will be presented as well. The propellant was subjected to Fast Cook Off, Bullet attack, and large scale gap test. The results have shown good behavior of the propellants. The new gun propellant was proven to have good chemical and ballistic stability and has shown satisfactory IM characteristics.

This work is part of an unofficial IM program that is conducted and procured by the IMOD to the defense industries in Israel [2].

Introduction

Tremendous efforts have been made in order to increase the performance of medium gun ammunition by improving the ballistics. However, little attention was paid to research in the field of high energetic propellants for large calibers.

The most common energetic material to serve as high energetic filler is an energetic nitramine crystalline such as RDX[3]. Several attempts to use RDX as an additive to double-base propellant formulations have been investigated. The most recognized formulation known, is JAX[4], although, several questions at this attempt remained unsolved especially the stability and RDX migration from the matrices.

IMI developed the CLP propellants family where the main objective is to increase the specific energy of the composition without affecting the flame temperature and barrel life cycle due to erosion. In order to achieve the above goal, compositions based on a novel plasticizer and RDX as the Nitramine filler were investigated.
The CLP-15 propellant was design for the 120 mm kinetic rounds and demonstrated a tremendous improvement in ballistic performances and a good safety characterization. In order to forecast how those features will be affected during the product shelf-life an extensive accelerated ageing was performed.

Surveillance Test and Methodology

Ammunition contains components and substances which are subjected to ageing. Ageing effects have the potential of decreasing the safety and reliability of ammunition. In order to detect and counteract the undesirable effects of ageing in-service, ammunition is subjected to regular surveillance tests.

The aim of ammunition surveillance is to ensure user safety and functional reliability during the entire in-service phase of the ammunition life cycle, and to predict the residual life time of ammunition (e/g propellant) at any point in time of its service life.

Ammunition components containing energetic materials are the most critical parts of surveillance and stability testing, since they are subject to ageing due to natural chemical degradation processes which can affect the impact on the safety and reliability of the whole ammunition.

Surveillance testing of propellant / Energetic materials at IMI in general include:

- Inspection of the entire ammunition
- Electrical tests (if applicable).
- Non-destructive testing (X-raying, ultrasonic testing)
- Destructive testing.
- Chemical analyses and stabilizer depletion.
- HFC – Heat Flow calorimeter
- Physical testing such as MicFTIR.
- Interruption bomb tests
- Environmental testing (at low, ambient, high temperature)
- Firing & functional testing

The new IMI LOVA propellant CLP- 15 was subjected to different surveillance tests in order to evaluate the service life of the entire ammunition. Those tests are presented in this current paper.

The propellant was tested under an accelerated ageing program in packed inside sealed conventional kinetic rounds. The rounds were stored in a controlled oven at 65^{o}C for up to 120 days (Fig. 1), during this period of time sample were taking for lab and firing test. Although, the conventional period of time for accelerated ageing tests at 65^{o}C is 60 days, in order to increase the reliability and the safety margins the test in this case was extend up to 120 days.

Fig. 1 - Accelerated ageing oven storage

(Stabilizer) Depletion

The new LOVA-propellant has been subjected to numerous conventional stability tests during development, qualification and production, e.g. to the 90°C weight loss test,

105°C Dutch test, and 115°C Bergmann-Junk test. All test requirements have been fulfilled.

One of simple ways to detect the depletion of the stabilizer is by laboratory accelerated tests of propellant samples. Generally, the chemical propellant shelf life is based on the remaining stabilizer. The remaining stabiliser contents were assayed quantitatively for the unaged propellantas well as for all artificially aged samples by high performance liquid chromatography (HPLC).

The performance of the propellant is not affected until the stabilizer has been depleted. The catalytic decomposition of propellants occurs when NOx species remain inside the propellant grain. The species react with the energetic materials and cause further decomposition. This is an exothermic process and unless the heat is removed at a sufficient rate to keep the grain temperature constant, the temperature of the grain will rise.

This in turn will speed up the decomposition process. Eventually the propellant will heat up to its explosion temperature and self-ignite. This is the purpose of adding stabilizers to propellant. The stabilizers are added to prevent the auto-ignition phenomenon. The level of stabilizer that has characteristically been chosen as the "safe" level for propellants is about 2 % by weight. Table 1 indicates that after exposing propellant samples at 65C for 120days, the EC depletion was 46% from the origin. This means that the EC remained is above 1% which is considered as a very good chemical stability.

Table 1: CLP-15 Stabilizer Depletion

Time Ageing	**Stability @ 120^{o}C [min]**	**% Weight loss**	**% Stabilizer content decrease**
0 day	100	-	origin
45 days	-	-	21
60 days	-	0.3	27
75 days	-	-	32
90 days	-	0.5	35
105 days	-	-	41
120 days	90	0.7	46

Fig 2. Summaries and compares the stabilizer depletion data of accelerated aging for two CLP propellants referred to a typical double base propellant.

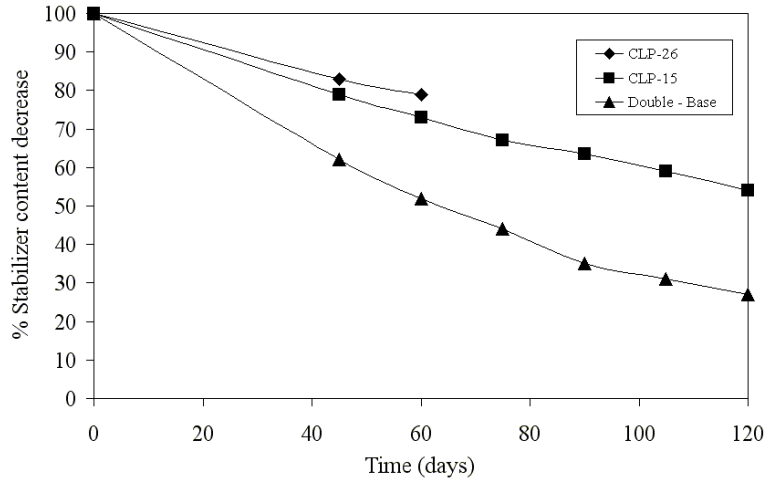

Fig. 2 – Accelerated ageing - Stabilizer depletion of Nitramine compared to DB propellants.

Microscope FTIR investigation

The main drawback of the JAX propellant [4] was the phenomena of RDX migration to the grain surface during aging. This phenomenon is considered as a hazard that can lead to sensitivity increase of the propellant affecting the ballistic shelf life.

The diffusion of the nitramine ingredient in the LOVA propellant matrices during accelerated ageing was investigated using Fourier transform infrared (FTIR) micro spectroscopy.

The concentration profiles that were determined by the FTIR were used to detect the migration of the nitramine from the edge of a single grain towards the central web as seen in figure 3. The MicFTIR scanned the area to detect any shift of the nitramine concentration. The investigation was performed on the surface of the LOVA grain propellant, a 7 hole perforated cylinder as shown in the picture below.

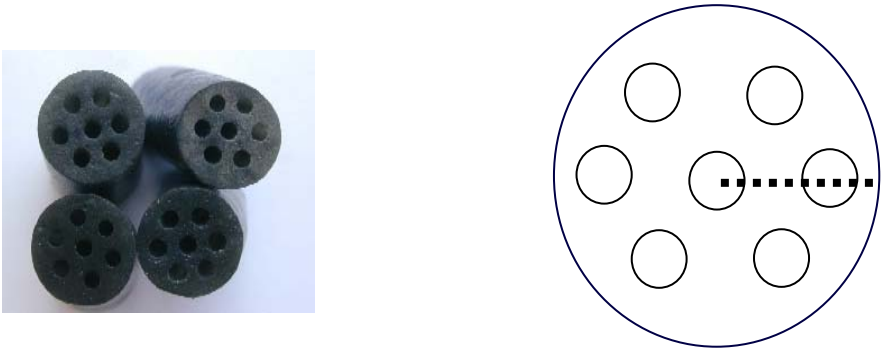

Fig 3: Cross section of the Mic-FTIR scan

Radial slice of propellant (5 micron) were cut and prepared for the tests. The transmission spectrum of the IR was sampled in predefine points along constant axe (usually from the grain edge toward the one of the holes). The focus of every sampling point was 50μm X 50μm. For every run data in 3-dimensions were collected, 1) the distance from the grain edge, 2) the wave length, 3) the transmission measured intensity (Fig.4).

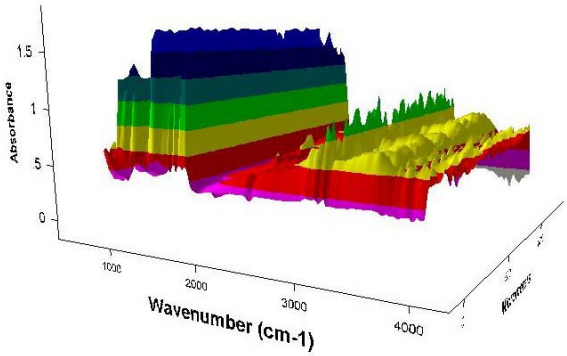

Fig 4: Nitramine FTIR imaging along the LOVA grain

In order to isolates the RDX contribution we had to focus on wavelength which is individual for RDX and does not been affected be the other ingredient in the matrix. By examining the pure ingredients spectrums and compare them to the propellant spectrum, wavelength of 3075 cm^{-1} was found to be most suitable for the investigation propose.

In the frame of the FTIR tests the RDX concentration profile was measured in propellant samples before and after accelerated ageing, additional measurements were performed in different scanning resolutions and different total length from the grain edge.

The overall FTIR test results indicate that the RDX concentration seems to be homogenous to high degree both in propellant samples before and after accelerated aging.

Fig. 5 shows the RDX concentration profile that was measured in a single grain after 120 days of ageing. The graph describes the concentration profile from the grain edge (the origin axes) towards the side of the first hole (about 1300 μm). The concentration is almost constant without any irregularity near the grain walls. The small fluctuations are mostly due to little changes in the samples thickness and the beam resolution, nevertheless that can not contradict the main conclusion about the RDX concentration homogeneity.

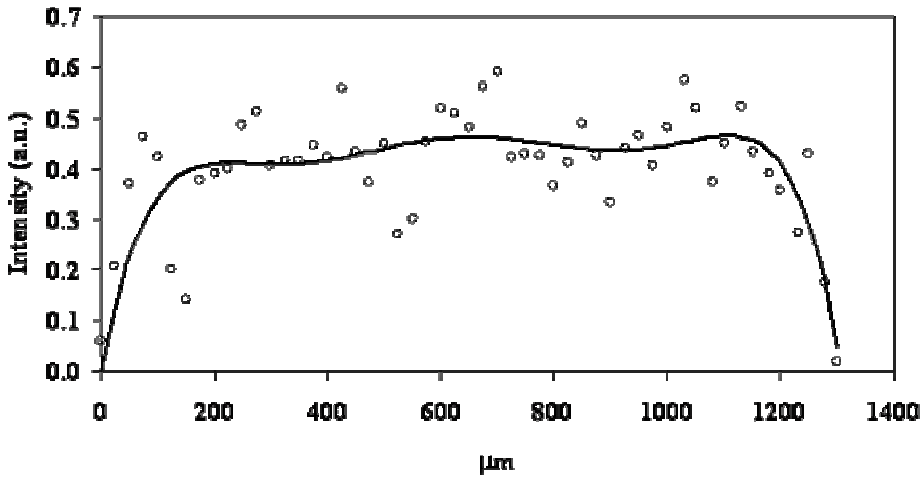

Fig 5: Nitramine FTIR distribution across the web size grain

Performance Stability

In order to insure sufficient ballistic shelf life, the phenomena that might contribute to the changes in the interior ballistic behavior have to be kept to an acceptable level. For LOVA propellants, the main factors are molecular weight reduction of the nitrocellulose and the diffusion of the plastisizer into the propellant grain. Both Processes have been investigated.

A Ballistic shelf life plan was determined using a test plan of 120 days at temperatures of 65°C before being tested in the weapon at various firing temperatures.
This test has been performed in a full scale firing test of APFSDS-T ammunition using a large gun system. Over the entire range of firing temperatures (usually -40°C to +52°C), only marginal changes in peak pressure and muzzle velocity were introduced by artificial ageing periods.

Fig 6 shows the relative performance after accelerated ageing compares to the original performances of the propellant.

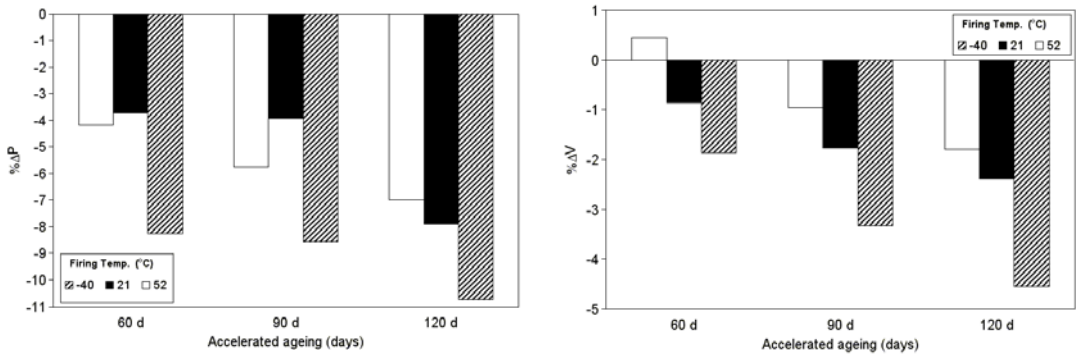

Fig 6 – Ballistic Performances after accelerated ageing

It can be seen that there is a minor muzzle velocity changes after 60 days, respectively less than 1% increase at +52 , and less than 1% decrease at +21. For example, by performing the same test for conventional double-base propellant a rapid pressure rise was recorded. Therefore the new LOVA CLP is considered more stable and safer for a very long period time.

Those results are equivalent to at least 15 years storage at 21°C by using an ageing factor of 3.0 which is known to be a conservative estimation. In particular, no dangerous rises in peak pressure appeared, and the sensitivity and safety of the LOVA-propellant was proven. In the contrary, the peak pressure was fall down in an insignificant manner that assures the safety of the ammunition for long time storage

Summary

The development of novel and improved gun propellant was achieved by combing nitramine energetic filler, and a new energetic plastisizer. Due to the enhanced thermo-chemical properties, the new formulation yielded a good ballistic performance. The safety features as opposed to the conventional double-base propellant were superior. The new LOVA propulsion has shown a significant performance gain under system-compatible conditions for large caliber applications. The base grain, and a diffusion-stable surface were kept both chemical and physico-mechanical were proven for more than 15 years. Those excellent results enable the ammunition a safe chemical and ballistic shelf life, therefore this, attainable with new generation of LOVA propellants for large caliber ammunitions applications.

Future Work

In the near future work task plan our new LOVA propellant will bee tested and investigated by using the extremely sensitive heat flow calorimeter - HFC. We hope to report the results at the next IM conference.

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