RIGHTTRAC Technology Demonstration Program: Preliminary IM Tests

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ABSTRACT

RIGHTTRAC (Revolutionary Insensitive, Green and Healthier Training Technology with Reduced Adverse Contamination) is a five-year technology demonstration project aiming to show that “green” and insensitive munitions have better properties than current munitions, and that it is feasible to implement safer weapon solutions that would ease the environmental pressure on ranges and training areas (RTA’s), and decrease the health hazards for the users. The vehicle selected for the project is the 105-mm M1 artillery round, although the project is made to be applicable to other calibres. As part of the project, the booster explosive is to be replaced by a new HMX-based pressed composition. The main charge explosive, currently Composition B, is also to be replaced. The two candidates for the main charge are a melt-cast and a cast-cured HMX-based composition. A down-selection based on their performance is to be made during the next year. Three gun propellants are currently being evaluated to replace the M1 propellant, and only one will be selected for the rest of the demonstration. While the primary objective is to replace the explosives and the propellants by “greener”, non-RDX containing compositions, a strong secondary objective is to improve the IM response of the round. To reach that goal, a number of preliminary full-scale and small-scale IM tests were performed on the selected candidates, namely shaped-charge jet attack, bullet impact, slow cook-off and sympathetic reaction. Variable confinement cook-off tests were also run on the explosives. The results of those tests will be presented as well as some performance tests such as the plate dent, velocity of detonation and closed bomb tests.

INTRODUCTION

The main objective of the technology demonstration project (TDP) RIGHTTRAC is to minimize the adverse environmental impacts of weapons by designing greener munitions that will have better environmental properties than current munitions. This will ease the environmental pressure on operational Canadian Forces RTAs and decrease the health hazards for the users. The test vehicle selected for the study is the 105-mm M1 artillery ammunition. As shown in Figure 1, the project intends to work on three main components: the fuze, to add a self-destruct capacity to existing fuzes in order to significantly reduce or eliminate the unexploded ordnances (UXOs); the gun propellant, to replace toxic or carcinogenic ingredients, and add Insensitive Munitions (IM) characteristics to the propellant; and the explosives to replace the RDX in the main charge and to obtain an IM explosive.

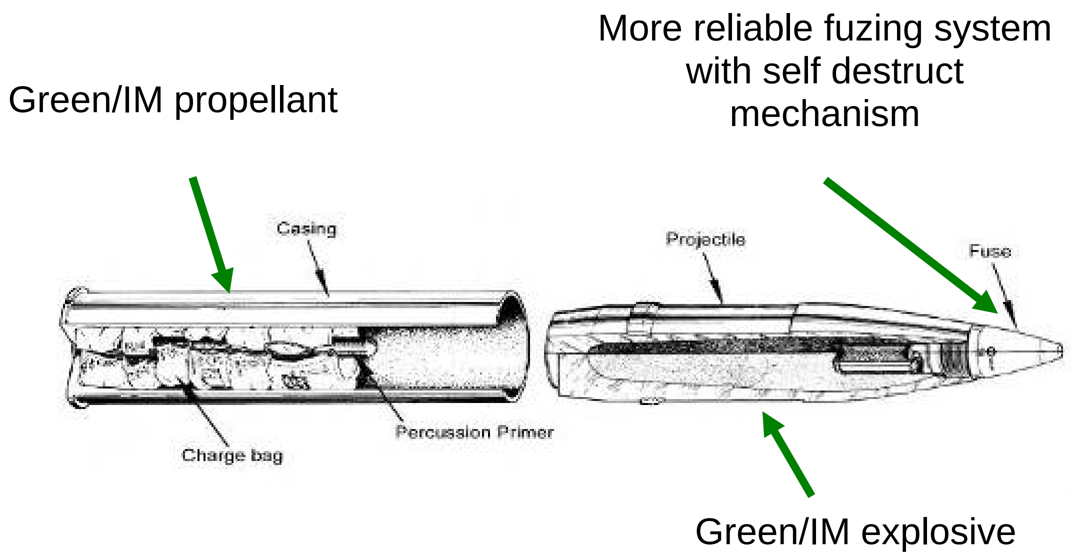

Figure 1: RIGHTTRAC concept

The formulations for the green/IM explosive and the green/IM gun propellant have been short-listed for a selection later this year. One important criterion is the environmental properties of the new compositions. This will carry a lot of weight on the final choice of the energetic materials. The results of the environmental tests carried out so far were presented earlier this year at the ICT International Annual Conference (ref. 1). This paper is focussed on the IM properties of the new formulations. In order to allow a ranking of the IM properties of the formulations, a number of preliminary small-scale and full-scale IM tests were run on them. The performance will be a factor as well, but it will not be discussed in detail in this paper. The objective of this paper is to present the IM properties of the explosive and gun propellant candidates for the program RIGHTTRAC.

EXPERIMENTAL

Compositions

Main Charge Explosive

For the main charge, two candidates were selected, one melt-cast and one cast-cured. The ingredients are summarized in Table I. The IM melt-cast explosives are rather popular in North America because of the large industrial base for the processing of such formulations. The choice for the melt-cast is a formulation developed at DRDC Valcartier called Green IM explosive or GIM (ref 2). It is very similar to another formulation discussed in past papers and called XRT (for eXperimental Rubbery TNT, refs 3-4). The formulation under study is a mix of TNT, HMX and the DRDC GAP-based ETPE. HMX is used as a replacement for RDX, because of the environmental problems related to RDX. Recently, low sensitivity HMX that has a very low RDX content was also procured in order to optimize the advantages of HMX. One may argue that TNT is not green and is rather toxic. However, it was found over the years that while it is toxic and that the EPA Drinking Water advisory is low, it is often not found in underground water because it decomposes rapidly to amino derivatives that bind to the organic material on the top soil and does not move to the underground water table. The cast-cured explosive is an HTPB/HMX plastic-bonded explosive (PBX). It has the advantage of being a good IM choice but it does not melt and therefore its recycling is more cumbersome.

Table I: Ingredients for the two explosive candidates

Composition name	Ingredients
GIM	HMX TNT ETPE
PBX (CX-85)	HMX HTPB DOA IPDI Surface agents Curing catalyst

Gun Propellant

Three gun propellant formulations were selected for analysis. They were suggested after a preliminary project in collaboration with General Dynamics, Ordnance and Tactical Systems – Canada, Valleyfield. The candidates are presented in Table II.

Table II: Composition of the three selected gun propellants.

Composition name	Ingredients
Green M1 (GM1)	Nitrocellulose (NC) Inert plasticizer Stabilizer
Modified Triple-Base (MTB)	Nitrocellulose (NC) TEGDN Nitroguanidine (NQ) Stabilizer
HELOVA	HMX Nitrocellulose (NC) ETPE TEGDN Cellulose acetate butyrate (CAB) Stabilizer

Performance Measurements

The performance of the explosives was measured using a modified plate dent test. Cylinders of explosives of 4.10 cm diameter by 25.4 cm long were cast and detonated on plates of 1018 steel. The indentation was measured for each shot and is reported as the plate dent. Three samples were fired for each composition. The cylinders were initiated with a small RDX/wax pellet. The velocity of detonation was measured at the bottom of the cylinder using three ionisation pins separated by 2.54 cm each, giving two measurements of the velocity. The two measurements are averaged to give the reported velocity, unless the difference in the velocity is too large, indicating a problem in the measurements. The performance of the gun propellants was evaluated through standard closed vessel firings at GD-OTS in Valleyfield.

Bullet Impact Tests

The bullet impact tests were performed according to STANAG 4241, with a few modifications. The tests were a single shot of 0.5 cal AP M2 bullets, on 105mm shells or cartridges that were standing vertically. The velocity was 850 m/s at the target. For the explosives, the shells were fitted with the transport plastic plug, not a fuze, since this is how they are stored and transported. Walls were placed around the item, and a metal roof was even added during the tests in order to minimize the environmental impact of the tests (spread of material during a low order reaction). This affects the pressure measurements, causing multiple reflections, and it also complicates the evaluation of the reaction level when items are ejected, since it is difficult to assess if any part would travel more than 15 meters. The tests were performed on the two explosives candidates, as well as on Composition B, and the three gun propellants, as well as on the standard M1 propellant. The shells were filled with explosives (2.3 kg). The 105mm brass cartridges were used as the containers for the gun propellant tests. However, due to the availability of the propellant, only 500 g of propellant was used. Wooden plates were placed under and above the propellant, which was placed loose in the cartridge. The igniter and the igniter tube were removed. Consequently, only the sensitivity of the propellant was evaluated.

Shaped Charge Jet Tests

The tests were performed according to STANAG 4526, with a number of modifications. The shaped charge was taken from a dismantled 84mm Carl Gustav weapon. The shaped charge was found to be representative of the rocket-propelled grenade (RPG) threat in our current military context. It was known in advance that this was a very severe threat, but it was expected that different levels of reactions would be found. The stand-off distance was 45 cm and a conditioning plate was placed at 24 cm from the item to be tested. A 2.54-cm witness plate was placed at the back and underneath the items. A thin aluminum witness plate was placed on the side of the item. Thick metal plates were placed behind the set-up to stop the jet. The whole set-up was contained by concrete blocks in an effort to reduce the environmental impact of the tests (spread of energetic materials). A picture of the set-up is shown in Figure 2. Again, the tests were performed on the two explosives candidates, as well as on Composition B, and the three gun propellants, as well as on the standard M1 propellant. The shells were filled with explosives (2.3 kg). The 105mm brass cartridges were used as the containers for the gun propellant tests. As for the bullet impact tests, only 500 g of propellant was used. Wooden plates were placed under and above the propellant, which was placed loose in the cartridge. The igniter and the igniter tube were removed. Consequently, only the sensitivity of the propellant was evaluated.

Figure 2: Set-up of the shaped charge jet tests

Sympathetic Reaction Tests

The tests were performed according to STANAG 4396, with a number of modifications. Only the explosives were tested for sympathetic reaction, both experimental candidates and Composition B. Only one donor and one acceptor were used. The acceptor was in a diagonal position, at the bottom (see Figure 3). The other two rounds were inert. The standard transport and storage containers were used and stacked as described in the standard military procedures. In this arrangement, in theory, brass cartridges with gun propellant would have been in the place of the inert shells. It was assumed (and also tested) that an adjacent shell placed in the reverse position (warhead on the opposite side) would receive very little fragments and a much lower pressure. It was decided to only have one acceptor in this configuration since two acceptors would have meant a 3 x 3 configuration which would have cost more for this preliminary test. The final tests should be done with two receivers. Confinement around the set-up consisted in wooden plates made of 4 x 4 beams. No sand was used as confinement to avoid having to decontaminate it.

Slow Cook-off Tests

The slow cook-off tests were run according to STANAG 4382 with significant modifications. They were run only on the gun propellant candidates so far. The tests on the explosives are planned for later this year. Since less fragmentation was expected, they were run in a detonics bay. The gun propellants (full amount, 1.25 kg) were placed in the brass cartridge, with a confinement plate on top (representative in weight of a 105mm M1 shell). This was then placed in a vertical ceramic oven. The heating rate was selected as 25 °C/h, instead of the standard 3.3 °C/h. This was judged more realistic in a threat hazard assessment for the typical storage conditions. The oven was heated to 100 °C in 15 minutes, and then left at 100 °C for 105 minutes to stabilize. The oven was then heated at 25 °C/hr until a reaction occurred. Four thermocouples were placed on the set-up: the control thermocouple was in the oven at mid-height. There was also one at the top of the oven, one in the propellant, and one on the brass cartridge. This latter temperature was reported as the reaction temperature. A reaction was generally observed within 5-6 hours from the beginning of the tests, which is ideal for preliminary tests. The igniter and the igniter tube were removed for these tests, making them evaluate solely the reaction of the propellant.

Figure 3: Set-up of the sympathetic reaction tests

Variable Confinement Cook-Off Tests (VCCT)

The tests were performed according to STANAG 4491 with significant modifications. Two thicknesses of the steel tubes were used (T45 and T155). In order to increase the confinement and prevent leaks, especially of melting compositions (such as the GIM), special connectors were added where the thermocouples are inserted, and the top and bottom metal plates were machined to insert o-rings between the aluminum cylinder and the steel. Figure 4 presents the set-up. This created a much better seal, but gas leaks were still observed at times. The two candidate explosives were tested, as well as Composition B. However, there were very small differences in the compositions and the tests will have to be performed again on the final choices. They are still presented here because the ingredients are all the same and the percentages are within a few percent.

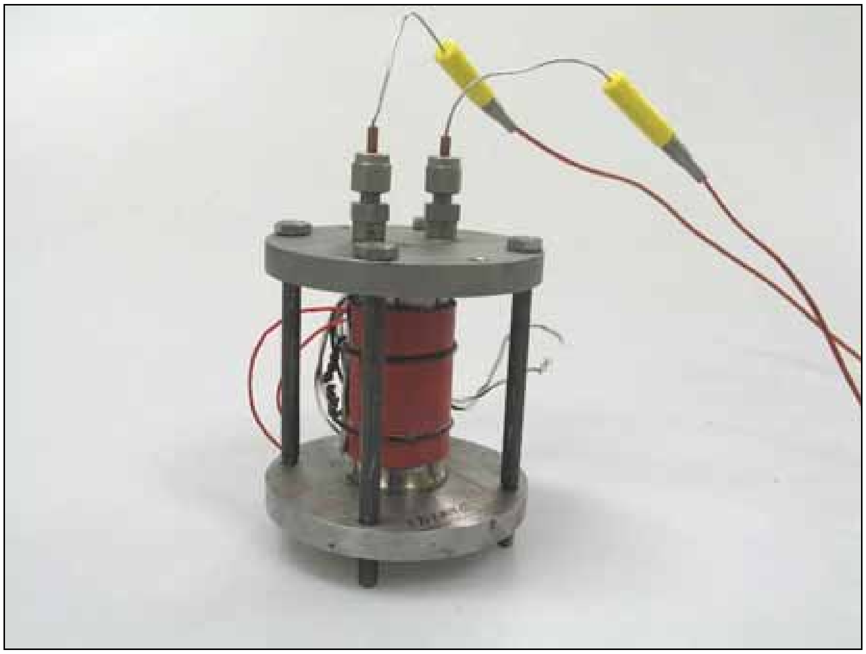

Figure 4 : Set-up of the VCCT

RESULTS AND DISCUSSION

Performance

The measured velocity of detonation and the measured plate dent of the two explosives as well as Composition B are presented in Table III. The table also presents the calculated detonation pressure (1/4 ρ D^2) of the candidates. In theory, the plate dent should correlate well with the detonation pressure. The candidates were selected to have a detonation velocity and a detonation pressure as good as Composition B. One of the observations is that the PBX underperforms relative to the predicted values. The measured value of the plate dent is ten percent below that of Composition B. The assumption is that a thin layer of polymer may form at the bottom and this may affect the plate dent. The tests will be repeated.

For the propellants, the performance was presented before (ref. 2) and is shown in Table IV. The latest version of the Green M1 has a lower force but should have excellent “green” properties. The other two perform better than M1.

Bullet Impact Tests

Table V summarizes the results of the bullet impact tests. It was known that the GIM and the PBX reacted well to the bullet impact test and this was also presented earlier (ref. 2). The gun propellants did not produce the violent reactions that were expected. This may be due to the reduced amount of propellant or to the absence of an igniter tube that would have reacted more violently. It is also difficult to determine which candidates are better. They all demonstrated some reduction of the violence of the reaction compared to the type IV of the current M1.

Table III: Plate dent test results of the explosive candidates

	Density (g/cm^3)	VoD (m/s)	Relative VoD (% Comp B)	Detonation Pressure (calc) (GPa)	Relative P_{CJ} (% Comp B)	Plate dent (cm)	Relative perf. (% Comp B)
PBX	1.61	8159	103	26.8	102	0.71 ± 0.01	90
GIM	1.67	7726	97	24.9	94	0.76 ± 0.01	96
Comp B	1.68	7931	100	26.4	100	0.79 ± 0.01	100

Table IV: Gun propellant performance

	Relative Force
Current M1 gun propellant	100
"Green" M1 propellant	81
Modified triple-base propellant	109
Modified HELOVA (HMX-based propellant with ETPE)	138

Table V: Bullet impact test results

Composition	Reaction Type
Explosives	
Composition B	I
GIM	V and NR
PBX (CX-85)	V and V
Gun Propellants	
Current M1	IV and NR
Modified M1	V and V
Modified Triple Base	NR and V
Modified HELOVA	NR and V

Shaped Charge Jet Tests

All the explosives produced type I reactions and all the propellants produced what were evaluated as type II reactions. The violent reactions were expected for the explosives but were somewhat surprising for the gun propellants. The threat was definitely severe and full-scale tests may not be repeated unless a different shaped charge is selected.

Sympathetic Reaction Tests

The results of the Sympathetic Reaction tests are given in Table VI. Composition B passed the test in this configuration. The melt-cast explosive did not produce an improvement but also passed the test. The PBX passed the test with no reactions. The projectiles were simply crushed and some of the PBX was ejected out of the shell.

Table VI: Sympathetic reaction test results

Composition	Reaction Type
Composition B	III and III
GIM	III and III
PBX (CX-85)	NR and NR

Slow Cook-off Tests

The results are presented in Table VII. All the propellants produced non-violent reactions. The exact reaction level was difficult to evaluate because propellant was always ejected and stopped by the walls of the detonics bay. The throw away distance was impossible to evaluate exactly. They all produced violent burnings, often pushing out the mass at the top of the cartridge. The temperatures were similar for all propellants, with the HELOVA potentially able to withstand a few more degrees.

Table VII: Results of the slow cook-off test

	Reaction Temperature (oven, °C)	Reaction Temperature (cartridge, °C)	Reaction Level
M1	179.4 173.7	150.4 149.0	IV-V IV-V
Modified M1	183.1 175.9	151.3 149.2	IV-V IV-V
Modified Triple Base	179.6 173.3	149.6 149.6	IV-V IV-V
HELOVA	185.4 180.6	153.5 153.0	IV-V IV-V

Variable Confinement Cook-Off Tests (VCCT)

The explosives reacted quite differently in the VCCT. There was a strong advantage for the PBX, which always reacted in type V, at both confinements. The melt-cast GIM was only a little better than Composition B, which did not react violently either.

Table VIII: Results of the VCCT's

	Confinement Cylinder	Reaction Temperature (°C)	Reaction Level
Comp. B	T45 T155	195 195	Severe III IV
GIM	T45 T155	183 183	Light III V
PBX (CX-85)	T45 T155	207 203	V V

CONCLUSIONS

Preliminary IM tests and small-scale tests were performed on two explosive candidates and three gun propellants candidates, as well as on the standard energetic materials in the 105mm M1 munitions. All the candidates present an IM signature better than the current products. However, they do not always pass the IM tests with the NATO required level, such as for the shaped charge jet test, where all the compositions failed. For the explosives, there seems to be a small advantage to the PBX for the IM tests. For the gun propellant, the HELOVA behaves just slightly better than the other ones in IM tests and has a much better performance.

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