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Residues from a Detonation: Are Green and IM Compatible?

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Outline

- Introduction
- Experimental method
- Results
- Discussion
- Solutions
- Conclusions

Introduction

- Exciting new IM formulations
  - IMX-101
  - IMX-104
  - XF compositions from Nexter (TNT/NTO) (XF13333)
  - GUNTOL (TNT/GUDN)
  - …
- Emergence of new molecules
  - GUDN
  - FOX-7
- Re-appearance of old IM (or non-IM) molecules
  - NTO
  - DNAN
  - NQ

Introduction

- IM explosives were designed to withstand external stimuli
- They typically exhibit:
  - Low shock sensitivity
  - Mild response to heat stimuli
  - Large critical diameters

- That implies that they are more difficult to detonate
- It has implications on the destruction of UXO's
- Will IM explosives leave more residues upon detonation?
  - Is that important? (toxicity, environmental fate)
  - Current presentation

Introduction

- Importance of environmental sustainability of operations
  - We have large training ranges and we require their long-term use
  - In the context of thousands of rounds fired at one site in a short period of time
  - Avoid future environmental issues
- There is a better knowledge of current environmental problems related to munitions
  - Molecules that are problematic
    - RDX
    - AP

Water solubility (mg/L)	
RDX	HMX
42	5.0

EPA Lifetime Health Advisory for Drinking Water (µg/L)	
RDX	HMX
2	400

  - Where and why they appear in underground water and surface water
- This work is part of the acquisition of that understanding
- RIGHTTRAC Technology Demonstration Program

RIGHTTRAC Concept

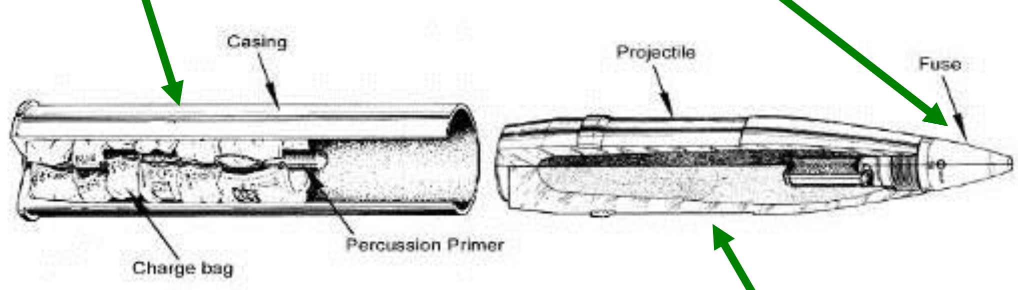
- Test vehicle : 105-mm M1 artillery round
  - Scalable to other weapons

Avoid using toxic and carcinogenic ingredients in gun propellants

Decrease the production of UXOs

Green/IM propellant

More reliable fuzing system with self destruct mechanism



Avoid RDX

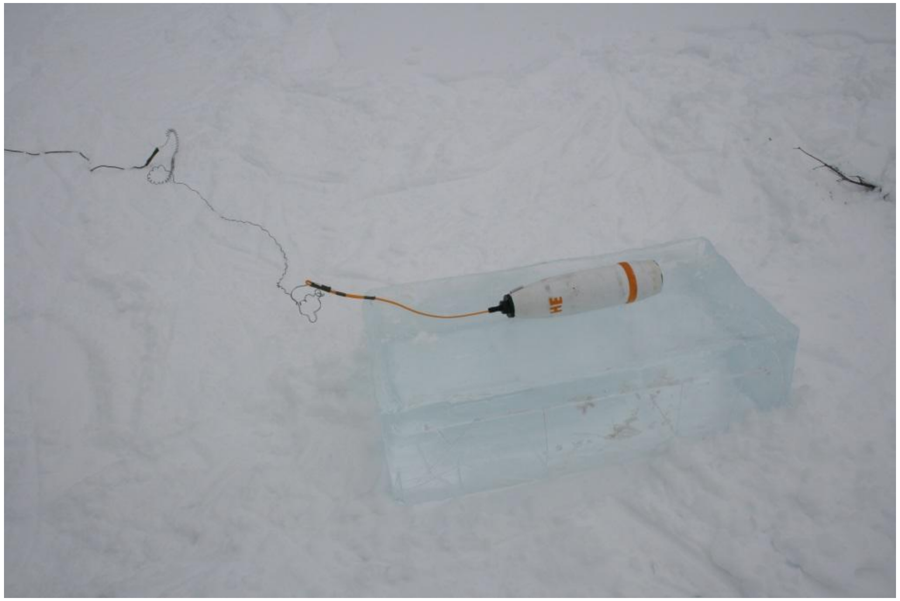
Green/IM explosive

Experimental Method

- Test items
  - Two IM formulations are under study for the replacement of Comp B:
    - A melt-cast formulation named GIM for Green IM explosive
      - GAP based ETPE, TNT and HMX
    - A plastic-bonded explosive (PBX)
      - HTPB/HMX
  - Two explosives that are “greener” but not fully IM compliant
    - LSGT (Comp. B - 216 cards)
      - GIM – 183 cards
      - PBX - 162 cards

Experimental Method

- Detonations made on snow
  - Easier to collect the plume
  - No shortage of it!
  - On a block of ice to limit the crater



Experimental Method

- High-order detonations
  - Booster charge in the fuze cavity

- Blow-in-place of UXO's
  - Block of C-4 on the shell

Results

- Larger plumes were observed with nose ignition of GIM
- In most cases TNT was not detected except for Blow-in-place of GIM (0.0005-0.011%)
- Generally, High-order deposits less than blow-in-place

GIM

PBX

Results

- GIM (melt-cast):
  - High-order detonation residues: 0.0002 - 0.0004 % of the original HMX
  - Blow-in-place residues: 0.002 - 0.14 % of the HMX (higher variability)
- PBX:
  - High-order detonation residues: 0.0003 - 0.0008 % of the original HMX
  - Blow-in-place residues: 0.02 % of the HMX

- For comparison – Comp. B
  - High-order detonation residues: 7.3 x 10^{-6} % of the original RDX
  - Blow-in-place residues: 0.0028 % of the RDX/HMX

- Two orders of magnitude more for IM rounds, but still very low
  - 10-20 mg HMX residues per high-order round, 0.4 g residues per BIP

Results - Literature

- Walsh et al, PEP 38 (3), June 2013
  - PAX-21 in 60-mm mortar
  - Normal detonation residues: 0.006 % of the original RDX/DNAN (16 mg)
    - Reference: Comp. B - 0.00002 % of the original TNT/RDX/HMX
  - Blow-in-place residues: 0.2 % of the original RDX/DNAN (1600 g)
    - Reference: Comp. B – 0.03% of the original TNT/RDX/HMX
- PAX-21 is reported to have a LSGT of 155 cards (NDIA IMEMTS 2007)

- More recent unpublished work seems to indicate that the numbers will go up for more insensitive products and molecules.

Discussion

- The values for our two candidates were deemed satisfactory
- It appears that IM explosives spread more residues upon detonation than conventional explosives.
- It appears that better IM explosives will produce more residues.
- If we keep on developing even less sensitive explosives, we will reach a threshold where the normal detonation of thousands of round on some sites will represent an environmental risk.

Solutions

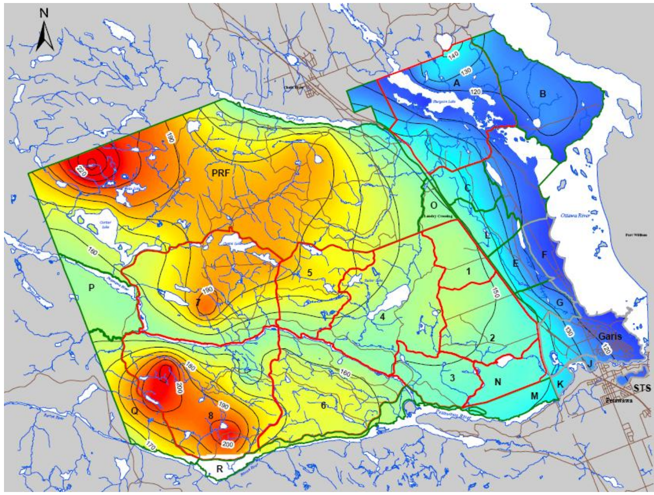
- Reach an equilibrium between insensitivity and environmental impacts
  - Stay with IM explosives that have decent properties and produce little residues
    - We may have to give up passing some IM tests
      - Shaped charge jet – especially the large SC
        - Large critical diameters
      - Fragment impact – high velocity
        - Super low shock sensitivity
      - French system MURAT 2* or MURAT 1*

Solutions

- Develop new efficient destruction methods for IM UneXploded Ordnances
  - The traditional application of C-4 may not work well enough
    - We may need to use more
    - We may need to place it differently
    - We have to know that the round is IM when we go to destroy it
  - We are currently running experiments with shaped charges for the destruction of UXO's
    - "There is always a big enough shaped charge"

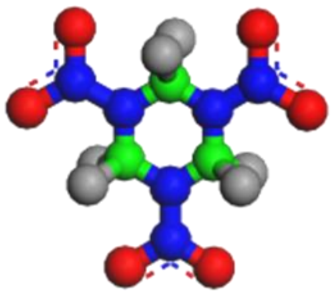
Solutions

- Manage the use of IM explosives
  - Know if your range is susceptible to contamination
    - Where is the underground water?
  - Try to predict if the training area can absorb the effect
    - Where is the underground water flowing to?
    - Train at specific places
  - Ensure that UXO's are not produced
    - Additional fuzing
  - … or know if they are
    - And where they are
    - Get rid of them quickly and efficiently



Solutions

- Select your molecules carefully
  - Some molecules are known to cause environmental problems
    - RDX
    - AP
  - Other molecules are almost never found in underground water (transport and fate, bioavailability)
  - Some molecules are less toxic



- Use other means to reach IM properties
  - New work on molecules
    - Nanoparticles
  - New explosives that have small critical diameters but low shock sensitivity
  - Packaging, venting, etc…

Solutions

- Add ingredients that will raise the reaction temperature
  - Burn the potential residues when a reaction occurs
  - Metals (ex: Al powder) added to current IM explosives
  - Larger fireball, longer fireball duration, higher temperature, better combustion
  - Al can have beneficial effects for thermal IM tests
  - We may not need a lot of it
  - We will test that solution

Conclusions

- The generation of detonation residues of two new IM explosives was measured.
- Our two candidates did not generate large amounts of residues.
- IM explosives produce more residues upon detonation.
- Destruction of UXO's create more residues than normal functioning of the shell.
- IM explosives may become an environmental risk on training ranges if they generate too much residues.
- There are potential solutions to this problem.