Recent Developments in Composition C-4: Towards an Alternate Binder and Reduced Sensitivity

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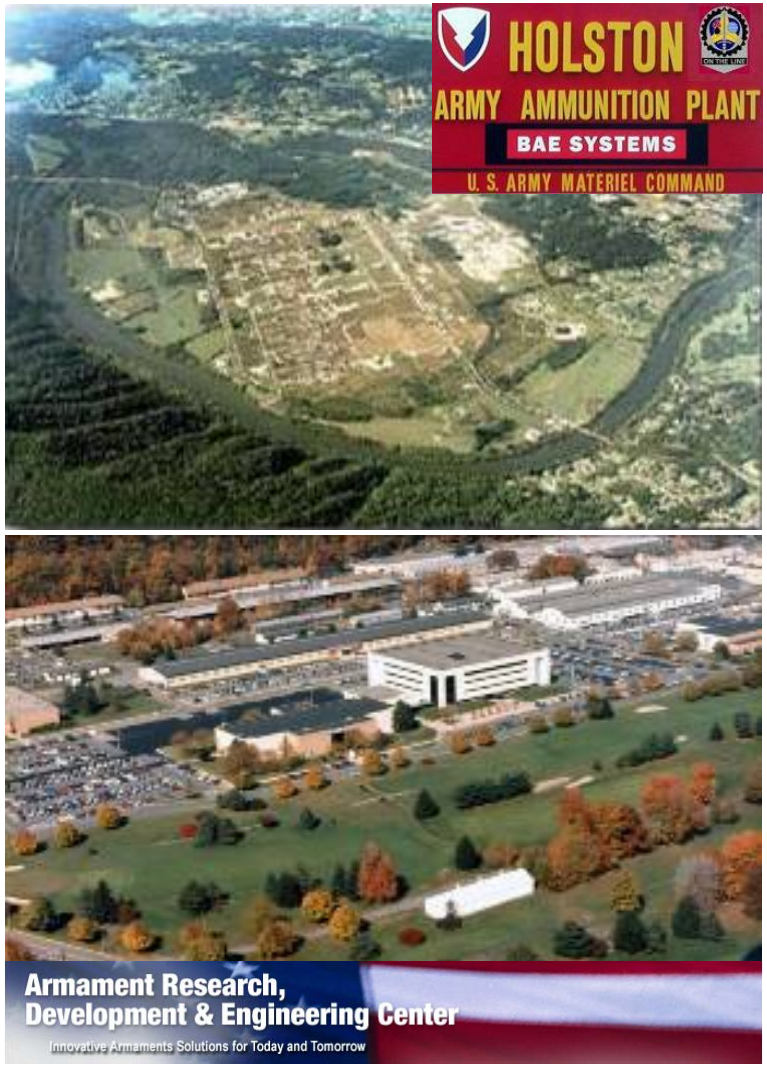


OSX-REMIX – Program Objectives

- Composition C-4 already fares well in the arena of insensitivity, due to relatively large amount of binder.
  - Passes Bullet Impact and Fragment Impact (Army) sensitivity tests at ambient temperature.
  - Fails shock stimulus – Sympathetic Detonation and Shaped Charge Jet.
- BAE's task – to develop an alternate extrudable formulation with similar physical and energy output characteristics, while enhancing its insensitivity.
  - Maintain current binder configuration for comparison to standard C-4.
  - Identify modifications to process or alternate input energetics.
  - Formulate and evaluate physical and energetic properties.

OSX-REMIX – Technical Approach

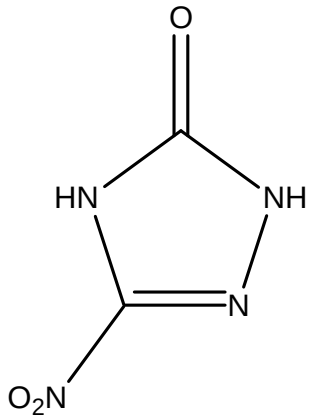
- Modification to manufacturing process.
  - Maintain aqueous slurry-coating process.
  - Premixing RDX with fluid portion of binder (DOA/Oil).
    - Reduced sensitivity in Melt Cast applications.
- Modification of traditional formulation.
  - Manipulation of Coarse : Fine.
    - Finer particle nitramine has shown decreased shock sensitivity.
  - Manipulation of nitramine energetic input.
    - FEM RDX.
    - HMX may prove lower shock sensitivity.


LAB PROCESSING STILL

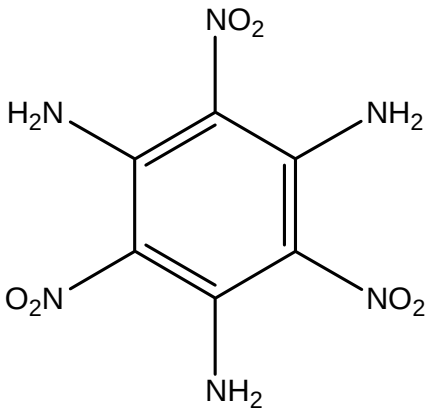

PRODUCTION PROCESSING STILL

OSX-REMIX – Technical Approach

- New, readily available, energetic ingredient to replace some or all RDX.
  - 3-nitrotriazol-5-one (NTO) has shown promise as next-generation ingredient in IM formulations.
    - Comparable energy to RDX, decreased sensitivity.
    - Water solubility proves challenging in aqueous slurry system.
  - 1,3,5-triamino-2,4,6-trinitrobenzene (TATB) is comparable to RDX in energy output, and shows high stability to thermal, shock, and impact/friction stimulus.
    - High cost.
    - Perfectly suited for aqueous slurry-coating manufacturing process.
    - Available in two particle sizes (5µm, 40µm).



NTO



TATB

OSX-REMIX – Modification of Current C-4 Formulation

Modification	Moldability (physical feel)	NOL LSGT (50% card gap)
None – Standard C-4 for baseline		150 – 160 cards
Premix RDX with DOA portion of binder	Identical to Standard	No improvement
Coarse : Fine 2:1	More firm, harder to mold	No improvement
Replace Fine RDX with CL5 HMX	Slightly tougher than Standard C-4	No improvement
Replace Fine RDX with 2.8um FEM RDX	Significantly less moldable	No improvement

- Samples for LSGT were prepared by mechanically pressing bulk C-4 to a density of 1.55 – 1.65 g/cc. Four pellets of equivalent mass / density filled each tube.
- Insensitive candidates were tested at 135 cards (two shots).
  - 10% decrease in sensitivity deemed significant enough for further testing.

OSX-REMIX – New Energetic Components

Modification	Moldability (physical feel)	NOL LSGT (50% card gap)
None – Standard C-4 for baseline		150 – 160 cards
Replace Fine RDX with 5µm TATB	Very poor compared to Standard	No improvement
Replace Fine RDX with 40µm TATB	Comparable to Standard	142.5 cards

- 40µm TATB replacing the standard CL5 RDX shows some promise in reducing shock sensitivity.
- Plate Dent testing shows comparable blast performance (96% of standard C-4).
- Examination of LSGT plates tells different story.

OSX-REMIX – New Energetic Components

OSX-REMIX – Summary and Conclusions

- As proof of concept, an extrudable, moldable formulation with enhanced IM properties was conceived and manufactured at laboratory scale.
  - Modification to nitramine used or coarse / fine ratio did not show significant changes to shock sensitivity.
  - 40µm TATB replaces CL5 RDX in standard Composition C-4 formulation, but provides an inferior general purpose demolition explosive.
    - High cost TATB.
    - Poor metal-cutting properties.
  - Standard aqueous slurry coating process precludes the use of more economical energetic candidates of interest.

OSX-APEX - Background

- Composition C-4 is a legacy explosive formulation with decades of use.
  - 90.5% RDX.
    - Specific ratio of coarse to fine RDX.
  - 9.5% plastic binder.
    - High molecular weight polyisobutylene (PIB).
    - Dioctyladipate (DOA).
    - Lightweight motor oil (Oil).
- Composition C-4 is mainly used for demolition purposes.
  - M112 Demolition Charge.
  - M183 Demo Kit.
  - MICLIC.
  - M18A1 Claymore Mine.

M18A1 Claymore

OSX-APEX - Background

- Composition C-4 is extruded to generate the M112 Block.
  - M112 blocks should be moldable / pliable.
  - Blocks have shown poor physical characteristics after long-term storage.
    - Dry, crumbly feel.
    - Onsite rework with additional plasticizer (motor oil) necessary, time-consuming, and potentially hazardous.

OSX-APEX – Program Objectives

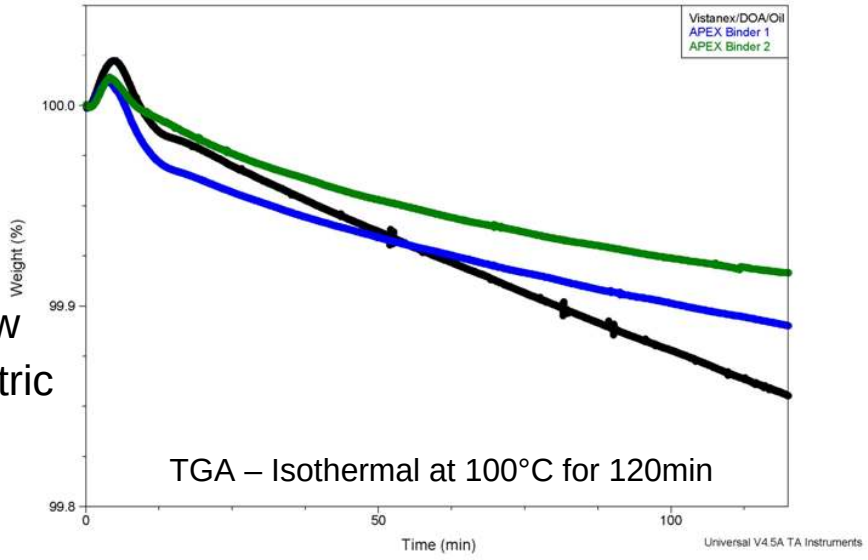
- Explore and formulate an extrudable demolition explosive comparable to Composition C-4.
  - Equivalent energy output and blast effect.
  - Comparable physical properties and moldability.
- Enhance long-term storage issues with an alternate binder.
  - Accelerated aging trial.
  - Intrinsic viscosity.
- Produce large-scale manufactured quantities of an acceptable material for M112 production and trials.

OSX-APEX – Technical Approach

- Current binder is 9.5% of Composition C-4.
  - 25% of binder is a high molecular weight polyisobutylene rubber.
  - 75% of binder is a combination of dioctyladipate (DOA) and lightweight motor oil.
    - Both low molecular weight liquids at ambient.
    - DOA has historic tendency to leech and exude from certain premixes.
  - Large disparity between molecular weights (viscosities) of polymer and plasticizer may have resulted in these components not complementing one another.
    - Nonuniformity of coating during manufacturing process.
    - Segregation during drying, tagging, packaging.
    - Ultimately poor aging characteristics due to exudation and leeching.
- Replace standard binder with a set of components with similar chemistry and viscosity.
  - Better match.
  - Treat binder as a “system”, allowing for ease of modification for unique applications.

OSX-APEX – Technical Approach

- Polyisobutylene is well-suited for moldable, extrudable explosive formulation.
  - Physical properties.
  - Available in a wide range of molecular weights.
- Complementary component sought for the high molecular weight PIB.
  - Liquid PIB oligomers available in a range of viscosities.
  - Oligomeric constituents should provide increased stability to leeching and exudation.
  - Heavily utilized in cosmetic and personal care industries.
  - Comparable in price to DOA and motor oil.
- Initial investigation gave promising results.
  - Easily dropped in to current slurry coating manufacturing process.
  - Current analytical regime performs well in new system.
  - Blends of PIB polymers and oligomers show good thermal stability via Thermal Gravimetric Analysis (TGA).



TGA – Isothermal at 100°C for 120min

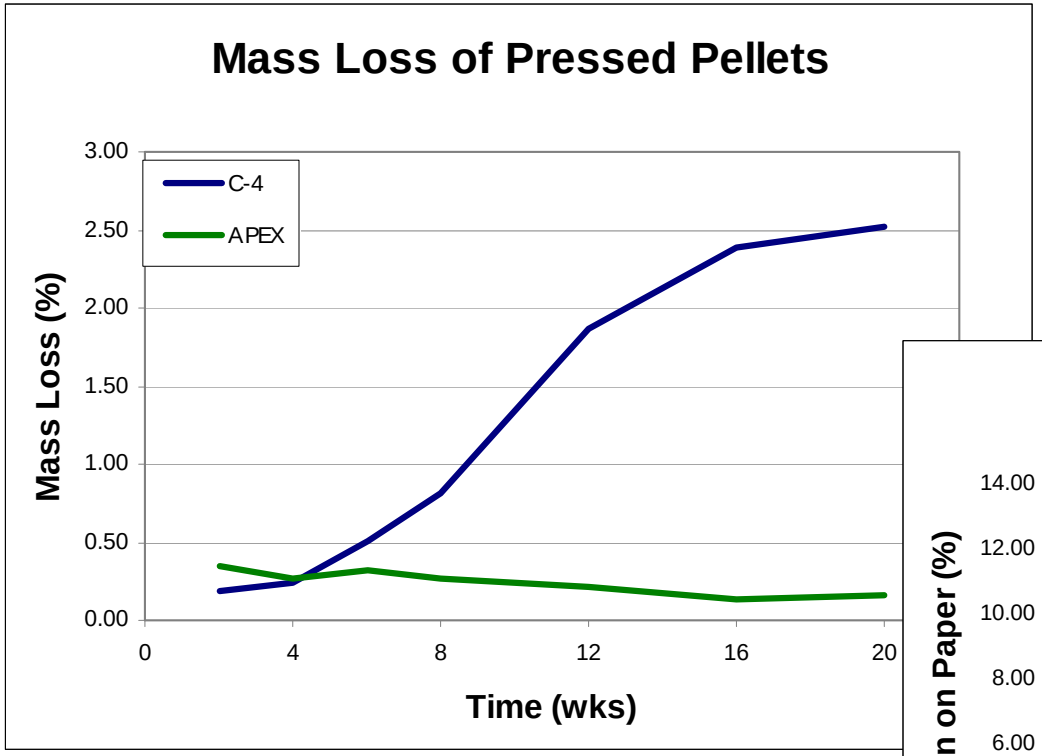
OSX-APEX – Formulation and Evaluation

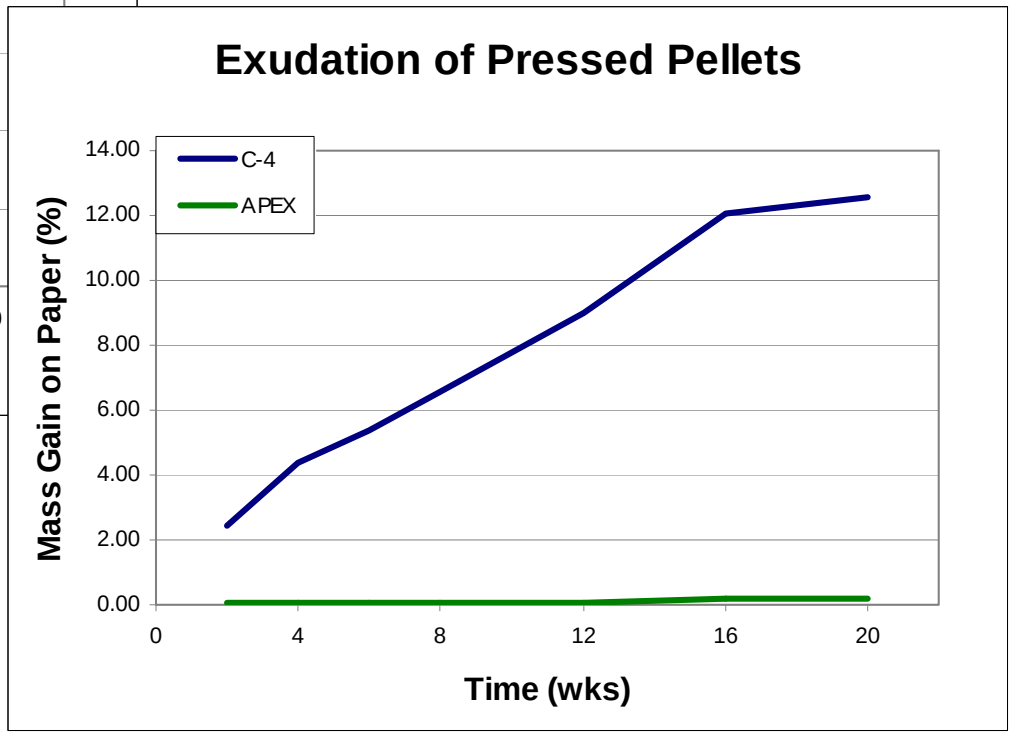
- Several binder system candidates were formulated at laboratory scale for evaluation.
  - Particle size distribution of energetic input is same as standard Composition C-4.
  - APEX binder systems easily dropped in to standard slurry coating process.
  - Lab scale manufacture of standard binder C-4 performed as baseline for comparison.
- All analytical testing, as well as qualitative “look and feel” tests show that alternate binder systems are comparable to legacy Composition C-4.

OSX-APEX – Accelerated Aging

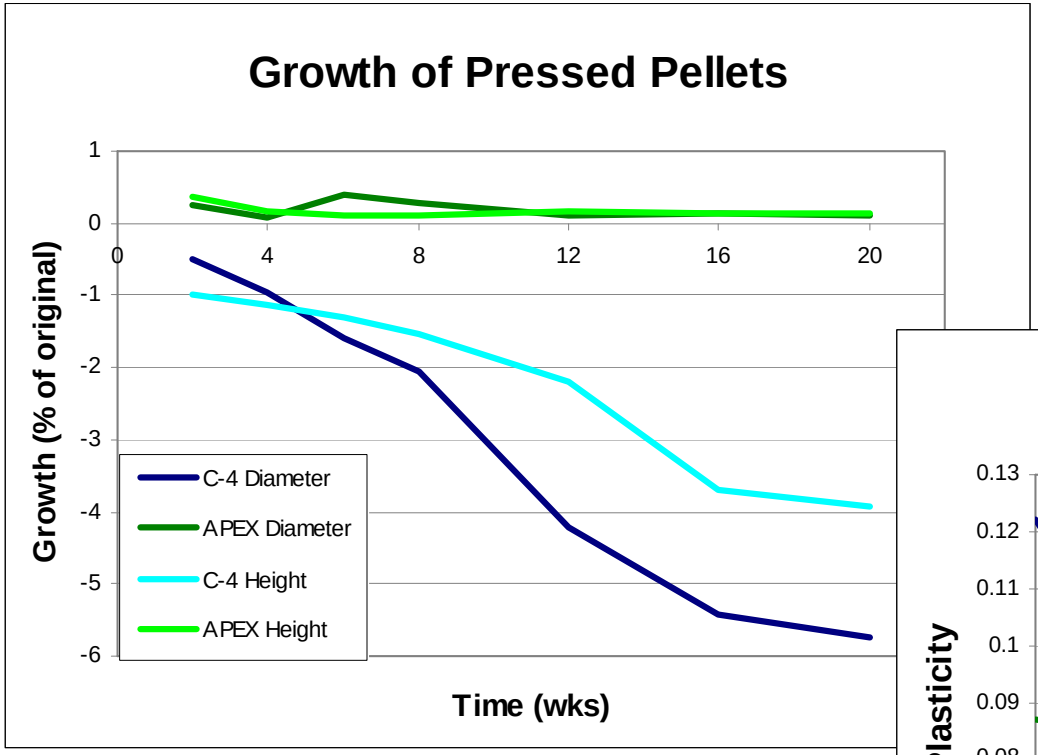
- After initial laboratory investigation and testing was completed, accelerated aging trials were initiated.
- Standard binder C-4 and OSX-APEX were prepared using identical input RDX batches and octane source (3 lb. scale for both).
- Aging performed at 75°C on bulk material and mechanically pressed pellets.
  - Composition and plasticity and “feel” of bulk material.
  - Growth, exudation, and mass loss of pressed pellets.

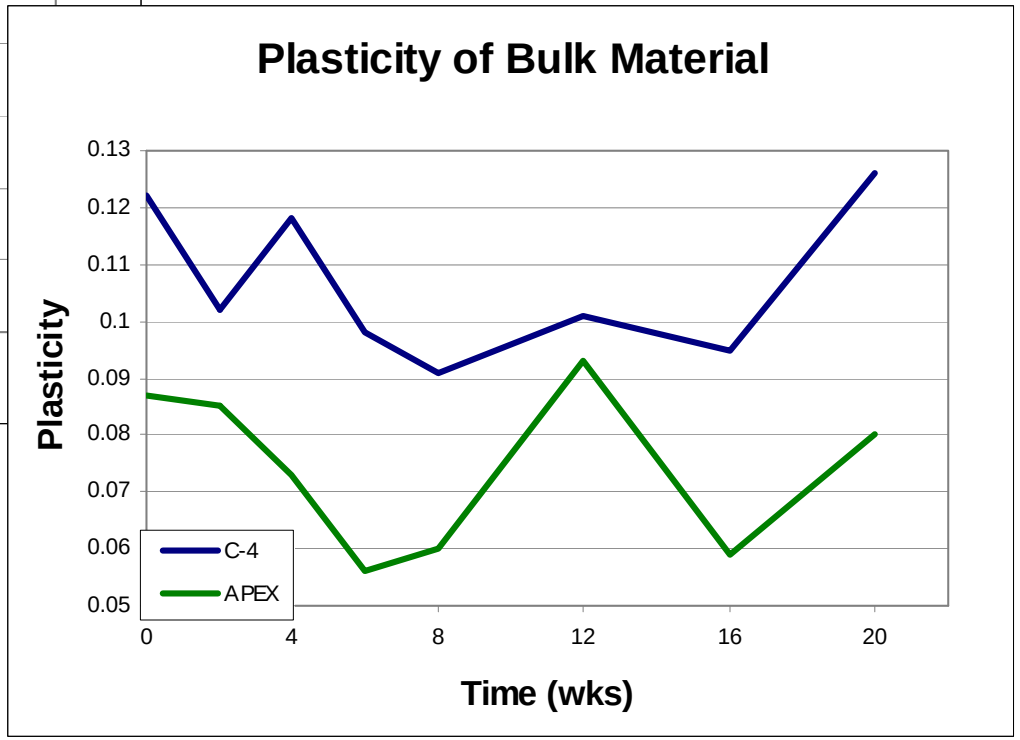
OSX-APEX – Accelerated Aging





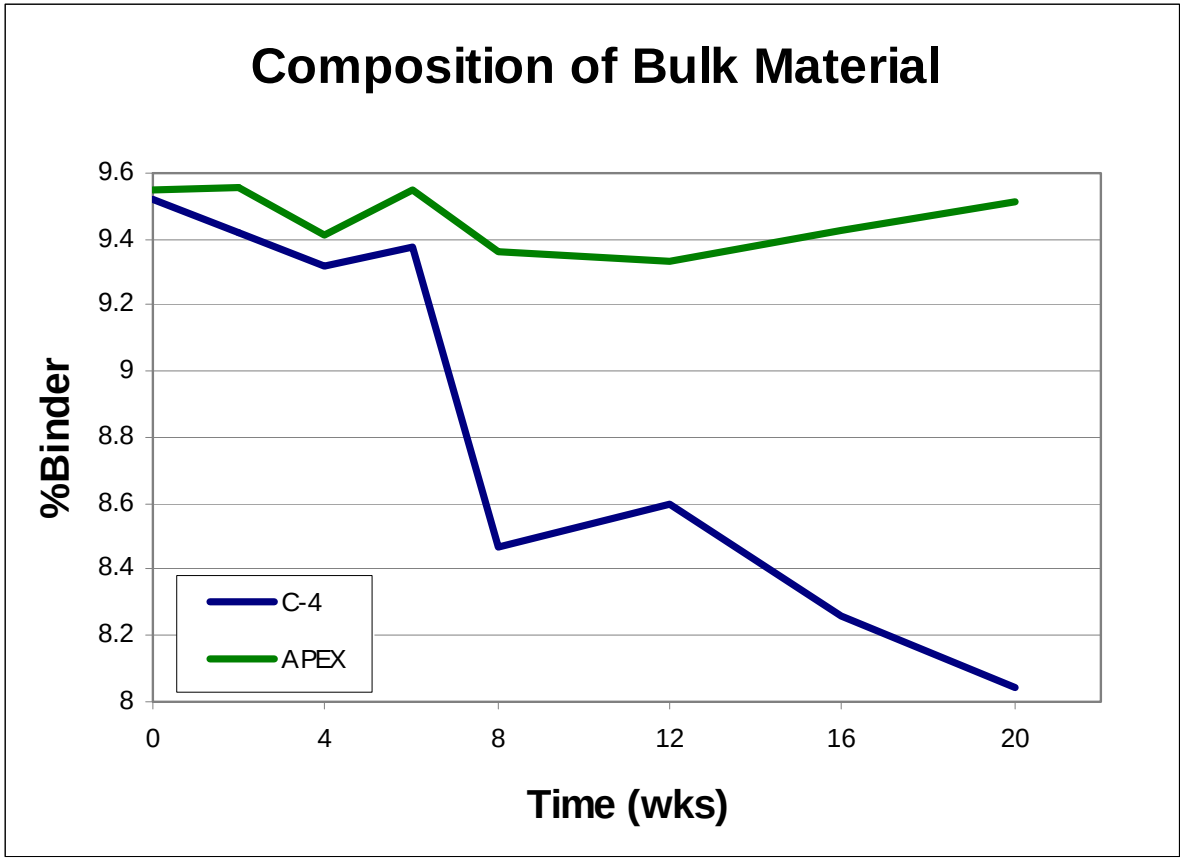
OSX-APEX – Accelerated Aging





OSX-APEX – Accelerated Aging

- Accelerated aging trial shows OSX-APEX fares very well in comparison to Composition C-4.
- APEX is significantly more stable to growth / shrinkage.
- APEX has virtually no exudation issues; Paper under standard Composition C-4 is literally wet with DOA / Oil plasticizer.
- APEX's mass and composition are very stable over time; C-4 loses over 15% of its binder over 20 weeks.
- Significant differences in material "feel".
  - Comp C-4 becomes grainy, soft, and crumbly over time.
  - APEX retains good physical characteristics at 20 weeks.
  - Plasticity data inconclusive, as it contradicts the "feel" test.



Conclusions and Future Endeavors

- OSX-APEX has been developed as an alternate extrudable demolition explosive.
  - Comparable physical properties as newly manufactured Composition C-4.
  - Superior physical characteristics after accelerated aging trial.
  - By developing a binder “system”, individual applications may have unique formulation tailored for use.
- Future endeavors include further evaluation of physical parameters.
  - Simulation of actual production environment.
    - Lab-scale drying kettle.
    - Lab-scale conical mixer.
  - Intrinsic viscosity via capillary rheometry.
- Verify OSX-APEX sensitivity and performance properties.
- Large scale manufacture of OSX-APEX.
  - M112 Charge Demolition Block configuration.

Questions?