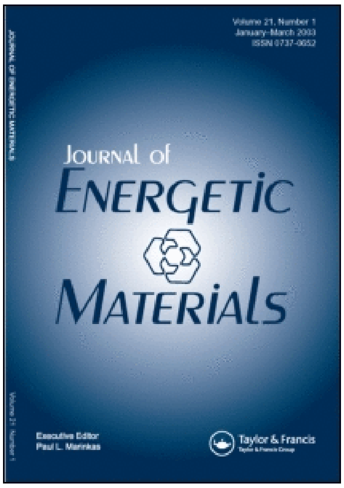

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# Pressed booster compositions prepared by coating RDX using polymer dispersions

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# PRESSED BOOSTER COMPOSITIONS PREPARED BY COATING RDX USING POLYMER DISPERSIONS

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## ABSTRACT

The viability of preparing booster compositions from RDX and commercially available aqueous polyurethane, acrylic and ethylene-vinyl acetate dispersions has been assessed. These dispersions were coagulated in hot aqueous slurries of RDX by electrolyte addition and the use of thermal coagulation aids. When polymer coating of the RDX crystals occurred the precipitated polymer particles were deposited across the surfaces of the crystals. These coatings were often porous; however when softer polymers were used, coalescence occurred and more uniform coatings were obtained. Compositions containing these softer polymers were less sensitive to initiation by shock and impact. The flow properties of these compositions were usually improved by applying an additional coating of zinc stearate. The impact sensitiveness, shock sensitivity and cookoff behaviour of a number of candidate booster compositions have been assessed and suitable compositions have been identified.

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# INTRODUCTION

Polymer bonded explosive (PBX) compositions for pressed booster charges are usually prepared by the slurry technique[1]. This involves heating a vigorously agitated aqueous slurry of the high explosive mixed with an immiscible solution of the polymer in organic solvent. Removal of the solvent by distillation causes the polymer to precipitate out onto the explosive as a coating, and ultimately agglomerates of coated crystals, called moulding powders, are formed. This process has two disadvantages, since it requires special processing equipment designed for distillation and it introduces flammable and/or toxic solvents into explosive processing plants.

These problems are avoided if the solutions of polymer are replaced by aqueous polymer dispersions and moulding powder formation is effected by coagulation of the polymer dispersion in the aqueous explosive slurry. However there have been very few studies of this alternative technique and the compositions that have been prepared have not been well characterised. Wright[2] prepared explosive moulding powders using several different classes of aqueous polymer dispersions, including a polyacrylate. The recommended procedure involved the use of coagulants, including an electrolyte solution and acetic acid, but also required subsequent addition of a water immiscible solvent to digest the binder, followed by distillation of the organic solvent. Deisenroth[3] avoided the use of solvents and coagulated aqueous polyurethane dispersions using a thermal coagulation aid, polyvinyl methyl ether, or phenol-formaldehyde resins as coagulants to prepare moulding powders.

This paper reports on the viability of preparing RDX-based booster compositions by a coagulation technique using aqueous polyurethane, acrylic and ethylene-vinyl acetate (EVA) dispersions. In this study particular emphasis has been placed on effecting a good coating of the explosive crystals by the binder, since this helps moderate the impact sensitiveness[4], shock sensitivity[5] and cookoff response[6] of nitramine-based compositions. These properties have been determined for selected compositions prepared using dispersions, and are compared with results obtained for tetryl and an insensitive booster composition.

## EXPERIMENTAL

### Materials

RDX Grade A Class 1 (recrystallized) was used in all experiments. The aqueous polymer dispersions examined were all commercially available. A total of eleven polyurethane, nine acrylic and four EVA dispersions were examined; these are listed in Table 1. Dioctyl phthalate (DOP, CSR Chemicals) and Reofos 65 (a triaryl phosphate ester, Ciba-Geigy) were used as plasticizers in some compositions. In some experiments, Cartafix U Liquid (Sandoz) and Basensol DS 2171 (BASF), proprietary thermal coagulation aids, were used to lower the temperature required for coagulation of the dispersions. Sodium stearate used was laboratory reagent grade. All inorganic salts used were laboratory reagent or analytical reagent grades. Distilled water was used in all preparations.

TABLE 1. Aqueous Polymer Dispersions Examined

| Material | Manufacturer |
|---|---|
| *Polyurethane* | |
| Witcobond 231, 232, 234, 240, 740 | Baxenden Chemical Co. Ltd. |
| Q-thane QW-4020 | Quinn |
| Helastic WC-6534, WC-6913, X-961 | Wilmington Chemical Corp. |
| Bayderm Finish 80 UD; Impranil DLH | Bayer |
| *Acrylic* | |
| Acronal 230 D, 250 D, 627, S 704 | BASF |
| Diofan A 880 S | BASF |
| Rhoplex HA-12, HA-24, P-376, B-1139 | Rohm and Haas |
| *EVA* | |
| Mowilith DM 105, DM 120[a], DM 130 | Hoechst |
| Vinnapas EV 2 | Wacker |

[a] Vinyl chloride also present in this copolymer.

## Preparation of RDX/Polymer/Additive Compositions

The methods for preparing all compositions are variations on the general approach described below. If plasticizers were used, these were stirred with the dispersions for a minimum of 24 hours prior to preparation of the compositions. The various booster compositions prepared and the specific experimental conditions are listed in Table 2.

TABLE 2. Experimental Conditions for the Preparation of RDX/Polymer/Additive Compositions

| Composition | Dispersion Concn. (% w/w) | Thermal Coagulation Aid (g) | Addition of Aqueous Electrolyte Solution: Type (% w/w) | Addition of Aqueous Electrolyte Solution: Quantity Added | Addition of Aqueous Electrolyte Solution: Time Taken (min) | Addition of Aqueous Electrolyte Solution: Temp (°C) | Heating for Thermal Coagn.: Time (min) | Heating for Thermal Coagn.: Temp (°C) | Zinc Stearate Coating Conditions: mL of $ZnSO_4$ Soln. (2% w/w) | Zinc Stearate Coating Conditions: Addition Time (min) | Zinc Stearate Coating Conditions: Temp (°C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RDX/Impranil DLH/ZnSt<br>100:2:1 | 40 | | NaCl<br>(20) | 400 mL | 90 | 82 | - | - | 150 | 90 | 82 |
| RDX/Impranil DLH/ZnSt<br>100:2:2 | 40 | - | - | - | - | - | - | - | 50<br>(4%) | 90 | 82 |
| RDX/Helastic WC-6913/ZnSt<br>100:2:1 | 40 | - | - | - | - | - | - | - | 120 | 90 | 82 |
| RDX/Acronal 230 D/Reofos 65/ZnSt<br>95:4:0.4:1 | 50 | Cartafix U<br>(3.22) | $CaCl_2$<br>(25) | 300 g | 80 | 70 | 50 | 95 | 200 | 70 | 80 |
| RDX/Acronal 250 D/DOP<br>95:5:0.5 | 50 | Cartafix U<br>(3.22) | $Al_2(SO_4)_3$<br>(25) | 300 mL | 95 | 70 | 50 | 95 | - | - | - |
| RDX/Rhoplex HA-24/ZnSt<br>95:4:1 | 44.5 | - | $Al_2(SO_4)_3$<br>(25) | 66 g | 25 | 90 | - | - | 200 | 80 | 90 |
| RDX/Mowilith DM 120/ZnSt[a]<br>95:4:1 | 50 | Basensol DS 2171<br>(3.22) | $Al_2(SO_4)_3$<br>(25) | 300 g | 100 | 70 | 30 | 95 | 300 | 100 | 80 |
| RDX/Vinnapas EV 2/ZnSt[b]<br>95:3.5:1.5 | 50 | - | $Na_2SO_4$<br>(20) | 475 mL | 60 | 75 | - | - | 200 | 20 | 90 |

[a] Maintained at 95 °C for 20 min after addition of zinc sulphate solution.

[b] Dispersion diluted with water (90 mL) prior to addition.

RDX (300 g) and water (300 g) were stirred mechanically for 15 min and the dispersion (containing plasticizer if required) was added. The thermal coagulation aid (if required) was added, then the slurry was stirred for a further 15 min, the temperature was raised and the electrolyte solution added at a constant rate over the stated time. This was usually followed by further heating at a high temperature to complete thermal coagulation. The mixture was then cooled to 20°C and the collected product was washed with water (minimum of 2.5 L). If an additional coating of zinc stearate was required, the material was maintained in a damp state after washing and was then stirred with distilled water (180 mL) in the mixing vessel and heated to 80-90°C. A hot aqueous solution of sodium stearate (6% w/w) was added (51 mL was used when the final composition was required to contain 1% zinc stearate). After 15 min an aqueous solution of zinc sulphate (2% w/w) was added at a constant rate over the stated addition time. The mixture was then cooled to 20°C and the composition was collected, washed thoroughly with water (minimum of 4 L) and dried at the pump. Drying was then completed by maintaining the composition at 60°C under vacuum over silica gel for several hours.

## Scanning Electron Microscopy

A Cambridge Instruments Model S250 Mk II scanning electron microscope with a tungsten electron gun was used to obtain the micrographs. The instrument was operated at 15-21kV in the secondary electron mode and a tilt angle of 30 degrees was generally used. The samples were mounted using PVA adhesive and were sputter coated with a conducting film of gold. Coating efficiencies were determined qualitatively after a thorough examination of the sample and several representative micrographs.

## Rotter Impact Sensitiveness: Figure of Insensitiveness (F of I)

A Rotter Apparatus[7] fitted with a 5 kg weight was used to determine the impact sensitiveness of the compositions. The test samples each weighed approximately 30 mg and the results were obtained by conducting a minimum of 25 trials in accordance with the Bruceton procedure. The F of I values quoted, derived from the height for 50% initiation probability, are standardized against RDX Grade F, F of I = 80, and are rounded to the nearest five units. The average gas volumes for positive results are also quoted.

## Shock Sensitivity: Small Scale Gap Test

Shock sensitivity data was obtained using the MRL small scale gap test (SSGT)[8]. The donor used was a UK Mk 3 exploding bridge wire detonator attenuated by brass shim. The acceptor was two 12.7 mm diameter x 12.7 mm height cold pressed cylinders of the explosive under study. A detonation was confirmed using a mild steel witness block. The results were obtained from 20-30 firings using the Bruceton staircase method and are quoted in mm of brass shim for a 50% detonation probability, together with the standard deviation.

## Vacuum Thermal Stability Test

Standard Australian procedures[9] were followed in performing this test. The results quoted are the average volume (mL) of gas evolved at 120°C over

40 h for duplicate 5 g samples. Tests were performed on RDX/binder (95:5) or (100:5) compositions and RDX/additive (95:5) physical mixtures.

### Cookoff Test

The cookoff behaviour of the compositions was assessed using the Super Small-scale Cookoff Bomb (SSCB)[10,11]. The SSCB uses an explosive sample 16 mm diameter and 64 mm long, with a total mass of approximately 20 g, consisting of four pressed pellets. All compositions were pressed to 90% theoretical maximum density (TMD) for testing. Duplicate tests were conducted on all samples at a fast heating rate (approximately 1 °C/s), and compositions which showed mild responses were subjected to further tests at a slow (approximately 0.1 °C/s) heating rate. The results presented describe the type of cookoff response obtained.

## RESULTS AND DISCUSSION

### Screening of a Range of RDX/Polymer (95:5) Compositions

Most of the dispersions examined in this study are anionic in nature. They can be coagulated by the addition of either acid or electrolyte, however the latter procedure was routinely used after initial studies showed that this resulted in better polymer coating of the RDX crystals. In a typical procedure, an aqueous slurry of RDX and the added aqueous dispersion were stirred and heated, then sufficient electrolyte to completely coagulate the dispersion was slowly added. In difficult cases coagulation was enhanced by using electrolytes containing anions of higher valency (eg. $Ca^{2+}$ cf. $Na^{+}$, Schulze-Hardy rule[12]), and occasionally polymeric thermal coagulation aids[13] were also added. In preliminary experiments some compositions were prepared using only thermal coagulation aids (no electrolyte), but these were found to have inferior coating efficiencies. Coagulation of all dispersions was enhanced when higher temperatures were used, but for some dispersions it was necessary to operate at reduced temperatures to prevent agglomeration during processing.

Moulding powders with approximately 5 percent polymer that were prepared by this method showed a range of properties; some were free flowing powders but those prepared from soft polymers had a tendency to form clumps during the drying process. This problem was most severe with the RDX/Vinnapas EV 2 composition which was not characterised because of its poor flow properties. However a free flowing composition RDX/Vinnapas EV 2/zinc stearate (95:4:1) was prepared by washing the polymer-coated RDX to remove electrolyte and applying a zinc stearate coating in a second coating operation.

As part of the screening process the impact sensitiveness of these compositions was determined. Most were as sensitive or slightly more sensitive to impact than the original uncoated RDX Grade A (F of I = 80). Results for the most promising compositions are included in Table 3. In general those polymers which desensitized RDX were comparatively soft. The impact sensitiveness of RDX/polymer compositions will be influenced by the fracture, physical and thermal properties of the polymers[14] and by differences in polymer coating efficiencies[4].

TABLE 3. Impact Sensitiveness of RDX/Polymer and RDX/Polymer/Additive Compositions

| Composition and Class of Binder Used | | F of I[a] | Gas Evolution[b] (mL) |
|---|---|---|---|
| *Polyurethane* | | | |
| RDX/Impranil DLH | 100:5 | 130 | 15 |
| RDX/Helastic WC-6913 | 100:5 | 95 | 16 |
| *Acrylic* | | | |
| RDX/Acronal 230 D | 95:5 | 70 | 15 |
| RDX/Acronal 250 D | 95:5 | 80 | 17 |
| RDX/Rhoplex HA-24 | 95:5 | 95 | 13 |
| *EVA* | | | |
| RDX/Mowilith DM 120 | 95:5 | 90 | 14 |
| RDX/Vinnapas EV 2/ZnSt | 95:4:1 | 115 | 15 |
| *For Comparison* | | | |
| RDX/ZnSt | 100:2 | 120 | 17 |
| RDX/Impranil DLH[c] | 100:5 | 70 | 12 |
| RDX/Acronal 230 D/Reofos 65 | 95:5:0.5 | 100 | 14 |
| RDX/Acronal 250 D/DOP | 95:5:0.5 | 85 | 13 |

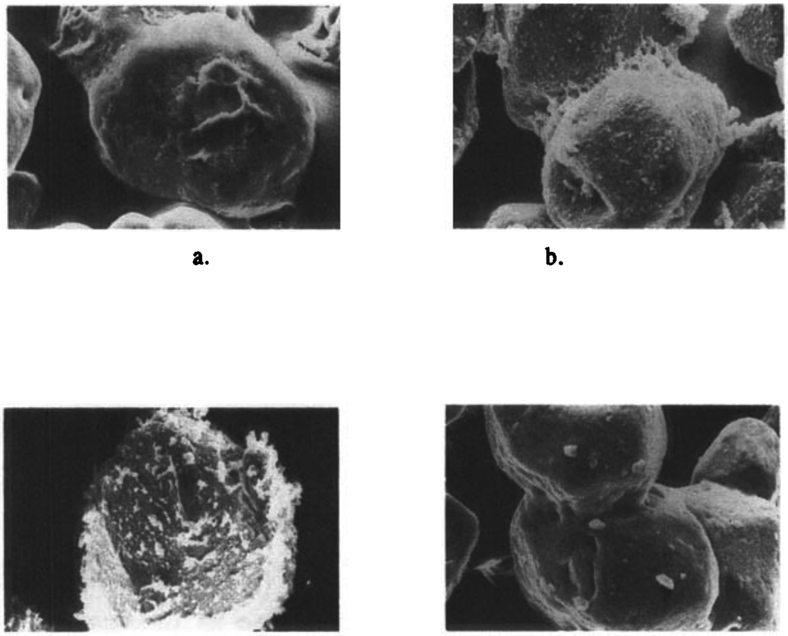
[a] Relative to RDX Grade F = 80.

[b] Evolved gas volume indicates the degree of propagation.

[c] A physical mixture of a sieve cut of RDX Grade A (250 - 300 μm), F of I = 75, with fine (<106 μm) particles of polymer.

Relative coating efficiencies appeared to have the most pronounced effect on impact sensitiveness and were qualitatively assessed using scanning electron microscopy (SEM). Representative micrographs of some of these compositions and RDX Grade A crystals as shown in Figures 1 and 2. The least sensitive composition (F of I = 130) contained Impranil DLH, and examination of this composition showed that the RDX crystals were well coated with a film of polymer containing fine polymer agglomerates; disruption of this film of polymer is visible at the leading edge of the coated crystal shown (Figure 1b cf. 1a). The low impact sensitiveness must be attributed to the good polymer coating because a physical mixture of fine particles of this polymer with RDX is more sensitive to impact (F of I = 70) than RDX. The RDX/Vinnapas EV 2/zinc stearate (95:4:1) composition also gave a high F of I value (115) and SEM examination of a Vinnapas EV 2 coating, prior to addition of the zinc stearate, showed that the polymer was deposited in a uniform film over the crystals to give an excellent coating (Figure 1c). In this case the high F of I value can be attributed to both coating effects and the desensitizing effect of zinc stearate. An RDX/zinc stearate (100:2) composition has an F of I value of 120, and when zinc stearate is applied in a second step it is deposited in small flakes over the coated crystal surface (see Fig 1d cf. 1b illustrating this effect when Impranil DLH is the polymer).

The compositions prepared from Rhoplex HA-24 and Mowilith DM 120 (Fs of I = 95 and 90) were significantly less sensitive than RDX, but in these cases the polymer coatings were not uniform (Figures 2a and 2b). The polymers were deposited in clumps across the crystal surfaces. Although there was evidence of coalescence of the precipitate, some areas of exposed RDX crystal were clearly visible. The Helastic WC-6913 polymer gave a similar coating and was also less sensitive to impact (F of I = 95) than RDX.



a. b.

c. d.

FIGURE 1

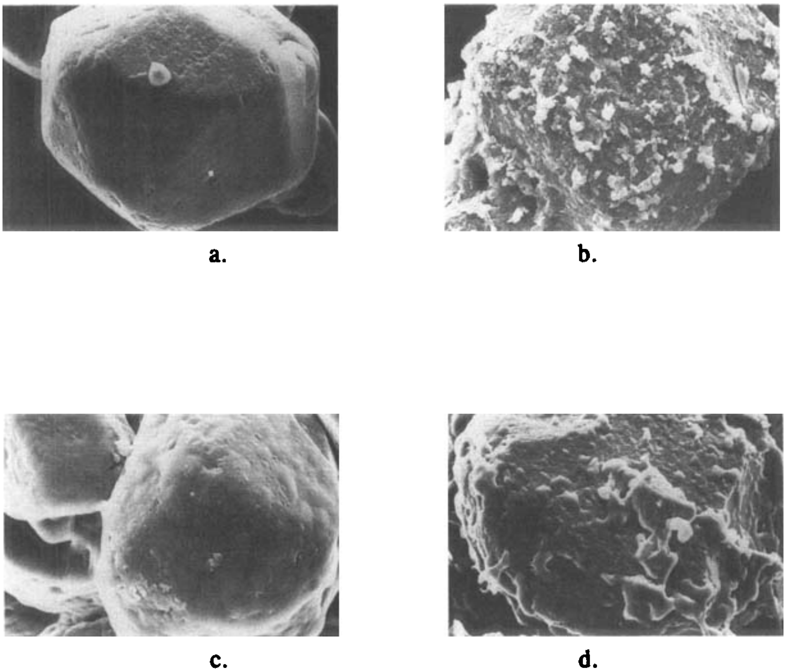
Scanning electron micrographs of RDX and various RDX-based compositions.

(a) RDX Grade A Class 1 recrystallized - x 300.

(b) RDX/Impranil DLH (100:2) - x 250. Crystals coated with polymer film containing fine agglomerates.

(c) RDX/Vinnapas EV 2 (98:2) - x 450. Crystals are well coated with polymer.

(d) RDX/Impranil DLH/ZnSt (100:2:1) - x 250. The zinc stearate, applied in a second step, is well distributed on the polymer-coated crystal.



a. b.

c. d.

FIGURE 2

Scanning electron micrographs of various RDX-based compositions.

(a) RDX/Rhoplex HA-24 (95:5) - x 200. Precipitated polymer deposited in clumps with some evidence of coalescence.

(b) RDX/Mowilith DM 120 (95:5) - x 200. Precipitated polymer particles have coalesced to give a fair coating.

(c) RDX/Acronal 230 D (95:5) - x 200. The deposited polymer particles form a porous, open mat coating.

(d) RDX/Acronal 230 D/Reofos 65 (95:5:0.5) - x 200. The precipitated polymer has formed a more uniform film, giving a good coating.

Coating efficiencies in the remaining more sensitive compositions varied. In some cases it appeared that only mixtures of polymer and explosive were obtained, and in other cases fine and coarse precipitated polymer particles were deposited across the crystal surfaces to form a porous, open mat coating. A porous coating was observed for the RDX/Acronal 230 D (95:5) composition (Figure 2c) but incorporation of Reofos 65 plasticizer into the polymer caused coalescence of the precipitated polymer to give a more uniform coating (Figure 2d) and raised the F of I value from 70 to 100.

The affinities of the coagulated polymers for the surface of the RDX crystals varied markedly for the range of dispersions studied. Interactions of colloidal particles and surfaces under similar conditions have been considered in numerous studies of heterocoagulation[15]. Presumably studies of this type, involving measurements of zeta potentials, would explain why only some polymers are deposited on the crystal surface. If polymers are precipitated onto the crystal surface it appears that those with the lowest film formation temperatures are most likely to give a uniform coating.

Vacuum thermal stability tests were performed on the promising RDX/polymer compositions and some RDX/plasticizer physical mixtures. The results for these tests conducted at 120°C are shown in Table 4. The normal pass/fail criterion for compatibility with RDX in this test is that the gas evolution should not exceed 5 ml over 40 hours[16]. All the tests gave low evolved gas volumes, indicating that these polymers and plasticizers have acceptable compatibility with RDX.

TABLE 4. Vacuum Thermal Stability Test Results for RDX/Polymer Compositions and RDX/Plasticizer Physical Mixtures

| Composition and Class of Binder Used | | Average Gas Evolved (mL), after 40 hours at 120°C |
|---|---|---|
| *Polyurethane* | | |
| RDX/Impranil DLH | 100:5 | 0.89 |
| RDX/Helastic WC-6913 | 100:5 | 1.27 |
| *Acrylic* | | |
| RDX/Acronal 230 D | 95:5 | 0.41 |
| RDX/Acronal 250 D | 95:5 | 0.98 |
| RDX/Rhoplex HA-24 | 95:5 | 0.20 |
| *EVA* | | |
| RDX/Mowilith DM 120 | 95:5 | 0.70 |
| RDX/Vinnapas EV 2/ZnSt | 95:4:1 | 0.10 |
| *For Comparison* | | |
| RDX Grade A | | 0.6 |
| RDX/DOP[a] | 95:5 | 0.0 |
| RDX/Reofos 65[a] | 95:5 | 0.05 |

[a] Physical mixtures

## Candidate Booster Compositions

To obtain acceptable booster compositions the most promising compositions were formulated to give moulding powders which were free flowing. This usually involved incorporation of zinc stearate in a separate process, however in two cases this was incorporated with the polymer in a one step method. The results quoted in this section were obtained for booster compositions prepared on a larger scale by the general method outlined in the Experimental Section and detailed in Table 2.

Rotter impact sensitiveness data for eight formulations, and comparative data for other booster compositions, are shown in Table 5. Five of the formulations were no more sensitive to impact than granular Tetryl (ie Fs of I $\geqslant$ 110). The two compositions that contained the plasticized acrylate binders were the most sensitive; their impact sensitiveness was comparable to that of PBXW-7 Type II (RDX/TATB/Viton A 35:60:5) which is a US insensitive booster

TABLE 5. Impact Sensitiveness of RDX/Polymer/Additive and Other Booster Compositions

| Composition and Class of Binder Used | | F of I[a] | Gas Evolution[b] (mL) |
|---|---|---|---|
| *Polyurethane* | | | |
| RDX/Impranil DLH/ZnSt | 100:2:1 | 125 | 15 |
| RDX/Impranil DLH/ZnSt[c] | 100:2:2 | 115 | 16 |
| RDX/Helastic WC-6913/ZnSt[c] | 100:2:1 | 110 | 15 |
| *Acrylic* | | | |
| RDX/Acronal 230 D/Reofos 65/ZnSt | 95:4:0.4:1 | 90 | 12 |
| RDX/Acronal 250 D/DOP | 95:5:0.5 | 85 | 15 |
| RDX/Rhoplex HA-24/ZnSt | 95:4:1 | 110 | 11 |
| *EVA* | | | |
| RDX/Mowilith DM 120/ZnSt | 95:4:1 | 105 | 11 |
| RDX/Vinnapas EV 2/ZnSt | 95:3.5:1.5 | 125 | 13 |
| *Other Booster Compositions* | | | |
| Tetryl, granular[17] | | 110 | 16 |
| RDX/Viton A[18] | 95:5 | 65 | 14 |
| PBXW-7 Type II[19] | | 90 | 4 |

[a] Relative to RDX Grade F = 80.

[b] Evolved gas volume indicates the degree of propagation.

[c] Prepared by the one step coating process described in the text.

composition. The Viton A binder used in PBXW-7 Type II gave an RDX/polymer (95:5) composition which was much more sensitive to impact (F of I = 65) than the formulations developed in this study.

All the candidate booster compositions were cold pressed to 90% TMD to prepare pellets for shock sensitivity and cookoff testing. The compositions containing the plasticized acrylate polymers gave poor pellets; those containing Acronal 230 D were quite crumbly while those containing Acronal 250 D grew considerably on storage and showed signs of plasticizer migration.

The shock sensitivity results for all the candidate booster compositions are compared with data for other booster compositions in Table 6. All the compositions are less shock sensitive than granular tetryl and more shock sensitive than PBXW-7 Type II. The compositions containing the plasticized acrylic polymers and Helastic WC-6913 have comparatively high $M_{50\%}$ values ranging from 2.65 to 2.59 mm while the remaining compositions have similar (2.27 to 2.17 mm) lower $M_{50\%}$ values. In general the polymers that coated the RDX crystals well gave pressed compositions with comparatively low shock sensitivity.

## Cookoff Behaviour of Compositions Containing Acrylate and EVA Polymers

The results of SSCB tests on the booster compositions containing acrylate and EVA binders are shown in Table 7, together with results for tetryl, RDX/Viton A (95:5) and PBXW-7 Type II for comparison. Fast heating rate tests were performed on all compositions, and usually only those compositions that gave mild reactions were then tested at the slow heating rate.

TABLE 6. Shock Sensitivity (SSGT) of RDX/Polymer/Additive and Other Booster Compositions Pressed to 90%TMD (Nominal)

| Composition and Class of Binder Used | | Density (%TMD) | Shock Sensitivity[a] | |
|---|---|---|---|---|
| | | | $M_{50\%}$ | Std.Dev. |
| *Polyurethane* | | | | |
| RDX/Impranil DLH/ZnSt | 100:2:1 | 90.04 | 2.27 | 0.021 |
| RDX/Impranil DLH/ZnSt[b] | 100:2:2 | 90.08 | 2.27 | 0.030 |
| RDX/Helastic WC-6913/ZnSt[b] | 100:2:1 | 90.09 | 2.59 | 0.020 |
| *Acrylic* | | | | |
| RDX/Acronal 230 D/Reofos 65/ZnSt | 95:4:0.4:1 | 90.03 | 2.63 | 0.039 |
| RDX/Acronal 250 D/DOP | 95:5:0.5 | 90.06 | 2.65 | 0.052 |
| RDX/Rhoplex HA-24/ZnSt | 95:4:1 | 90.00 | 2.17 | 0.021 |
| *EVA* | | | | |
| RDX/Mowilith DM 120/ZnSt | 95:4:1 | 90.02 | 2.18 | 0.032 |
| RDX/Vinnapas EV 2/ZnSt | 95:3.5:1.5 | 90.00 | 2.17 | 0.028 |
| *Other Booster Compositions* | | | | |
| Tetryl, granular[17] | | 90.0 | 3.26 | 0.026 |
| PBXW-7 Type II[19] | | 90.0 | 1.42 | 0.015 |

[a] All figures are in mm of brass shim.

[b] Prepared by the one step coating process described in the text.

The composition containing plasticized Acronal 230 D gave detonations at the fast heating rate. The composition containing plasticized Acronal 250 D gave mild explosions at the fast heating rate and a detonation at the slow heating rate. Both compositions containing the EVA copolymers (Mowilith DM 120 and Vinnapas EV 2) gave widely varying responses at the fast heating rate, ranging from burning through to detonation, while both compositions gave detonations at the slow heating rate. The reason for the variable responses at the fast heating

TABLE 7. Cookoff Test (SSCB) Results for Several RDX/Polymer/Additive and Other Booster Compositions Pressed to 90% TMD

| | Cookoff Response | |
|---|---|---|
| Composition and Class of Binder Used | Fast Heating | Slow Heating |
| *Acrylic* | | |
| RDX/Acronal 230 D/Reofos 65/ZnSt | Detonation | Not determined |
| 95:4:0.4:1 | Detonation | |
| RDX/Acronal 250 D/DOP | Mild explosion | Detonation |
| 95:5:0.5 | Mild explosion | |
| RDX/Rhoplex HA-24/ZnSt | Mild explosion | Mild explosion[a] |
| 95:4:1 | Deflagration[a] | Violent explosion |
| *EVA* | | |
| RDX/Mowilith DM 120/ZnSt | Burning[a,b] | Detonation |
| 95:4:1 | Detonation | |
| | Deflagration[a] | |
| RDX/Vinnapas EV 2/ZnSt | Burning[a,b] | Detonation |
| 95:3.5:1.5 | Detonation | |
| | Deflagration[a] | |
| *Other Booster Compositions* | | |
| Tetryl[11] | Detonation | |
| RDX/Viton A[18] 95:5 | Detonation | Detonation |
| PBXW-7 Type II[11] | Burning[a,b] | Deflagration[a] |

[a] Traces of explosive on parts after test.

[b] Appreciable amounts (>2 g) of unconsumed explosive recovered after test.

rate is unclear; generally good agreement is obtained between replicate tests at a given heating rate[10,11]. The composition containing Rhoplex HA-24 gave the best results; a deflagration and mild explosion were observed at the fast heating rate, and explosions, varying from mild to extremely violent, were obtained at the slow heating rate. There is no obvious correlation between the relative coating efficiencies of the various polymers and the observed cookoff response, indicating other factors are having a more pronounced effect on the cookoff response for this series of compositions.

Two of the booster compositions consistently gave milder responses than tetryl or RDX/Viton A (95:5) at the fast heating rate, and the one containing Rhoplex HA-24 also showed a reduction in cookoff response at the slow heating rate. The cookoff responses of this composition were not as mild as those of PBXW-7 Type II; however this was not unexpected since PBXW-7 Type II contains 60% of an insensitive explosive, TATB, to moderate the cookoff response[20].

## CONCLUSIONS

Explosive moulding powders suitable for use in fuze booster applications can be prepared by adding certain commercially available aqueous polymer dispersions to aqueous RDX slurries and coagulating the dispersions. In favourable cases the precipitated polymer particles are deposited across the surfaces of the crystals and undergo some coalescence to give more uniform coatings. The best coatings were obtained when soft polymers were used, and compositions containing these polymers have comparatively low impact sensitiveness. The poor flow properties of these compositions were improved by applying a zinc stearate coating, usually in a second coating operation; this made processing the moulding powders more complex and diminished the advantages of using polymer dispersions in the preparation of moulding powders.

The polymers selected for candidate booster compositions exhibited satisfactory thermal stability and compatibility with RDX. Results of further testing indicated that several of the candidate compositions may be suitable for use in boosters. All had shock sensitivities intermediate between those of tetryl and a US insensitive booster composition PBXW-7 Type II. Five of the compositions were no more sensitive to impact than granular tetryl and seven were no more sensitive than PBXW-7 Type II. Some of the binder systems identified in this study substantially moderated the cookoff response of RDX, and one composition, RDX/Rhoplex HA-24/zinc stearate (95:4:1), did not detonate at the slow heating rate.

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