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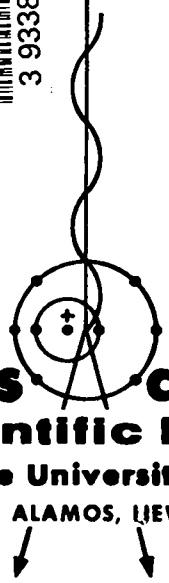
X-0242:
A High-Energy Plastic-Bonded Explosive



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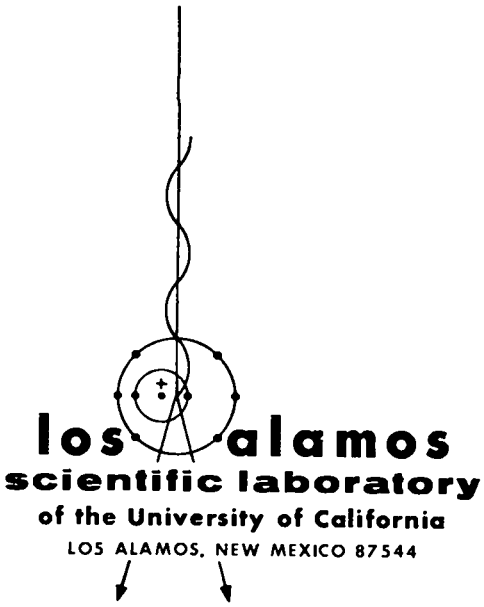

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by

T. M. Benziger

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ABSTRACT

The properties of X-0242, a new high-energy plastic-bonded explosive intended as a replacement for 9404, are presented. Comparisons demonstrate that it equals 9404 in energy, but is significantly better with respect to handling safety and thermal stability.

I. INTRODUCTION

In replacing a long-established explosive such as 9404, any new PBX must demonstrate significant advantages. Because practical considerations preclude any significant change in energy, the improvements must be made in areas where the accepted explosive has recognized service limitations. In the case of 9404, reservations have always existed on its handling safety and, recently, on its thermal stability in the high-temperature environments associated with some applications.

In attempting improvements in these areas, the high energy of 9404 must be maintained. With HMX as the major energy source, and a certain binder level needed for physical strength, any substitute explosive can be expected to include about 95% HMX. In addition, the binder must contribute some energy.

Within these restrictions, numerous attempts have been made by others to develop a suitable binder system for a high-energy PBX. Recent examples include compositions with a halogenated binder (LX-10), a DNPA/FEFO binder (LX-09), and a DNPA/CEF binder (X-0234). All three compositions meet the energy and thermal stability requirements; however, they also appear unduly sensitive in the skid test, which is probably our most reliable method of evaluating the hazard associated with the handling of large consolidated charges. In contrast, the X-0242 explosive system described here appears to overcome this difficulty and to meet the goals of equal energy and higher thermal stability.

II. FORMULATION STUDIES

The development of X-0242 stems from observations made on the unusual insensitivity promoted by Estane (a B. F. Goodrich Co. thermoplastic, polyurethane elastomer) in 9011 (90/10 - HMX/Estane). Other plastic-bonded explosives having the same HMX content are appreciably more sensitive in large-scale sensitivity tests, such as the skid and Susan tests.

Our first attempt to exploit this rather singular desensitizing effect was made six years ago with the development of X-0210 [94/3/3 - HMX/Estane/bis(2,2-dinitropropyl)formal]. This material was superior to 9404 in skid tests and thermal stability. Because its explosive energy in cylinder tests was somewhat lower than that of 9404, interest was not generated in this system, and further work on it was deferred.

When the work was resumed, we recognized that the HMX content would have to be increased to about 95% to meet the energy requirement. We also decided to replace the formal with DNPAF.* This mixture is a more compatible plasticizer for Estane than the formal. It contributes some energy to the formulation, but does not share the thermal instability

*Eutectic mixture of the formal and acetal of 2,2-dinitropropanol.

associated with nitrate esters such as nitrocellulose.

The plastic/plasticizer ratio in the binder was determined in a purely qualitative fashion. With mixture compatibility and the retention of elastomeric properties used as limits, the highest possible loading of plasticizer, as determined by visual observation at temperatures of 0 and 60°C, was adopted. The properties of the resulting formulation are summarized in Tables I, II, and III.

TABLE I

PROPERTIES

	X-0242	9404
Composition (wt %)		
HMX	95	94
Estane	2.5	
DNPAF	2.5	
NC		3
CEF		3
Theoretical density (g/cm^3)	1.855	1.866
Typical density (g/cm^3)	1.843	1.844
Cylinder-test comparison at 5 mm	0.995	1.000
Cylinder-test comparison at 19 mm	1.022	1.000
Plate-dent comparison (P_{CJ})	1.011	1.000
ρD^2 comparison (P_{CJ})	1.008	1.000
Detonation velocity (m/s)	8826	8782
Vacuum stability (ml/g-120°C/48 h)	0.8	3.5
DTA Exotherm (°C)	240	180
Impact sensitivity (cm, 12/12B)	44/80	42/47
Small-scale gap (inch of brass)	0.060	0.097
Minimum priming (mg Extex)	67	24
Spark sensitivity (joules - 3-mil Pb foil)	0.88	0.53

TABLE III

PHYSICAL PROPERTIES

	X-0242	9404
Compression Tests		
Ultimate strength (psi)		
0°F	2180	4859
75°F	1062	2479
165°F	628	658
Modulus (10^5 psi)		
0°F	3.4	9.9
75°F	1.4	2.9
165°F	1.0	1.2
Creep (%, 100 psi/24 h)		
140°F	0.82	0.48
165°F	1.10	----
Tensile Tests		
Ultimate strength (psi)		
-65°F	913	533
75°F	248	482
165°F	129	97

III. EXPLOSIVE PERFORMANCE

The three comparisons appearing in Table I - cylinder test, plate dent, and ρD^2 ratios - all demonstrate that X-0242 equals 9404 in energy. These results also confirm previous BKW calculations made by C. Mader, Los Alamos Scientific Laboratory (private communication).

IV. HANDLING SAFETY

In evaluating this factor, skid tests (45°, sandpaper targets) were used. Two formulations

TABLE II

SKID-TEST RESULTS - 45°, SANDPAPER TARGETS

X-0242 (0.5 wt % Calcium Stearate)

Drop Height (ft)	Result
64	E E
32	E E N E N
16	N E N N
8	N

50% height - 25 ft

Overpressure - 0.7 psi (av)

X-0242

Drop Height (ft)	Result
64	E
32	N E E E E
16	N N N N

50% height - 26 ft

Overpressure - not measured, but E's judged to be of same magnitude as with calcium stearated version.

were examined, standard X-0242 and the same stock coated with 0.5 wt % of a pressing lubricant, calcium stearate. The results are presented in Table II.

The handling safety of X-0242 as measured by this test (H_{50} of 26 ft and overpressure of about 0.7 psi) appears to be exceptional for a high-energy PBX. Other materials in this energy class are markedly more sensitive and hazardous. For example, 9404 has an H_{50} of 4 ft and an overpressure of 8 psi.

The explosive X-0242 and its earlier version, X-0210, as well as the parent explosive, 9011, all exhibit an unusual insensitivity that can only be attributed to the common binder ingredient, Estane. Why this material acts in this way is not known, and an investigation of this effect appears warranted.

V. THERMAL STABILITY

Extensive studies have been made by R. Rogers, Los Alamos Scientific Laboratory, on the kinetics of decomposition of energetic binder systems (private communication). In all of his work the 9404 system, NC/CEF, appears considerably less stable than the X-0242 binder, Estane/DNPAF. The X-0242 binder does not decompose autocatalytically as does NC/CEF and degrades at a much lower rate, as shown in the following table.

ESTIMATED TIME FOR 3% DECOMPOSITION

°C	Estane/DNPAF	NC/CEF + DPA
50	8.7×10^4 yr	0.34 yr
75	4.7×10^2 yr	3.7 days
100	5.1 yr	4.3 h
120	0.2 yr	0.5 h

DTA and vacuum stability results, given in Table I, also demonstrate the greater thermal stability of X-0242 as compared with 9404.

VI. STRENGTH COMPARISONS

Strength comparisons of X-0242 and 9404 are given in Table III. The X-0242 appears somewhat weaker than 9404, but in compression its properties are less dependent on temperature than are those of 9404.

EE/mj:79(50)

VII. MANUFACTURE AND FABRICATION

X-0242 may be produced easily by using the slurry process as shown in Table IV, which gives typical instructions for pilot-plant manufacture. The toluene additive is used to control the particle size. It acts as a transient plasticizer and maintains a sufficient tack in the binder during the forming stage to allow the production of particles of the desired size.

The conditions used in preparing pressed samples were 20,000 psi at 100°C. With three intensifications, over 99% of theoretical density was attained.

TABLE IV

PREPARATION OF X-0242

Desired Composition: 95/2.5/2.5 - HMX/Estane/DNPAF

Formulation

HMX: 23.25 lb coarse, Hol 701-37, GHBC-1-A
10.00 lb fine, Hol 934-1, 5101-1

33.25 lb total in 20 gal of water

Lacquer: 397 g Estane 5703, F-1
443 g DNPAF,* 79A-67

840 g total in 4.7 liters DCE (1,2-dichloroethane)

Additive: 600 ml of toluene

Procedure

The HMX/H_2O slurry is heated to 60°C.
The toluene is added to the slurry.
The lacquer (at 50°C) is added to the slurry.
The dispersion is heated to 85°C.
The dispersion is cooled to 50°C and filtered.
The powder is dried at 60°C in a forced draft oven.

*The DNPAF weight is increased by a factor of 0.115 to correct for loss of impurities and water solubility.

Notes

1. The lacquer is prepared by soaking the Estane in DCE overnight, adding the eutectic, and heating and agitating the solution.
2. Pressings have been made at 100°C/20,000 psi (3X).

VIII. SUMMARY

The properties of X-0242 demonstrate that it has significant advantages over 9404. It is equivalent to 9404 in energy, but it possesses greater temperature stability and significantly better handling safety.

ACKNOWLEDGMENTS

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