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PLASTIC BINDERS FOR HEAT RESISTANT EXPLOSIVES (U)

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PLASTIC BINDERS FOR HEAT RESISTANT EXPLOSIVES (U)

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ABSTRACT: A number of commercially available thermosetting and thermoplastic resins were evaluated as bonding agents for DATB - a new high temperature resistant explosive. Because of the practical difficulties involved in making large plastic bonded explosive (PBX) charges with thermosetting binders on conventional presses, the major emphasis was placed on thermoplastic binders. It was found that 5% binder was the minimum amount consistent with acceptable PBX physical properties and minimum dilution of explosive energy. Three, high temperature stable thermoplastic binders were selected as giving the best overall PBX properties of all the polymers evaluated. These were a polycarbonate (Lexan), polyvinylidene fluoride (Kynar) and polytetrafluoroethylene (Teflon). Teflon had the best properties of the three and is recommended as a high temperature binder for DATB.

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The work described in this report is part of a continuing search for improved high explosive systems applicable to guided missile warheads. Special consideration was given to the need to withstand a higher thermal environment, a need which has become increasingly evident in missiles carried by and launched from high performance aircraft.

The work has been supported by two tasks. Some portions of the work, which were of general applicability, were done as applied research under the Study of Explosives Properties, Task No. RUME-3E 012/212 1/F008 10 004 (and its predecessor task, Explosives Applied Research). Other laboratory work, and scaled up effort referred to in the report, was done under the development of the EX-38 warhead for the SPARROW III missile, Task No. RM37 23003/2121/WO2O AO 003

This data should be useful to engineers designing missile warheads which can make effective use of the explosive diaminotrinitrobenzene (DATB). It can also be used for preliminary studies of plastic bonded systems using other high temperature stable explosives of moderate output. In cases where an explosive other than DATB is to be used, however, no plastic binder discussed herein can be designated as definitely feasible until its compatibility and bonding characteristics have been determined for the particular explosive desired.

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Captain, USN
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Albert Lightbody
ALBERT LIGHTBODY
By direction

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INTRODUCTION

The increasing use of high speed missiles and the resulting problems of aerodynamic heating effects on the warhead explosive has given impetus to the development of new explosives that are thermally stable at high temperatures. 1,3-Diamino-2,4,6-trinitrobenzene (DATB) is a new explosive developed by the U.S. Naval Ordnance Laboratory which has the desirable properties of exceptional heat resistance and low sensitivity to impact, Table 1.

DATB is formed into a charge by a plastic bonding technique which is used to obtain good physical properties for those explosive compositions which cannot be conveniently cast or press loaded by themselves. In order to fully exploit the excellent thermal properties of DATB one should use a binder as heat resistant as the explosive. But as a practical matter, the binder need only be thermally stable up to the maximum temperature the missile warhead encounters in use.

The plastic binder used in a plastic bonded explosive (PBX) composition usually has a dual function - as a bonding agent and as a desensitizer for the explosive. Since DATB is very insensitive to shock, the use of binders to further desensitize the explosive was not a primary consideration although the addition of inert binders did desensitize the explosive to some extent. The common plastic binders acted as inert diluents when added to the explosive and reduced the amount of available energy. Therefore, it was desirable to use the lowest amount of binder consistent with the minimum acceptable physical properties. A number of tests with PBXs containing 1-10% of various binders indicated that this minimum amount of binder was about 5% of the total composition.

Because of the difficulties experienced in pressing PBXs containing thermosetting plastic binders into large charges, most of the emphasis was placed on thermoplastic binders. The results of our screening program indicated that the best thermoplastic binder for our particular application was polytetrafluoroethylene (Teflon). The primary object of this work was to screen a large number of potential binders and no attempt was made to evaluate completely all the binders considered. While this report is primarily concerned with the search for a suitable binder for DATB and the application of this DATB/PBX to air-to-air missile warheads, the explosive systems reported are not necessarily limited to this application.

DISCUSSION

The objective of this project was to find binders which in combination with DATB would yield PBXs with the following desirable properties:

Heat Resistance

The pressed PBX charge should be thermally stable and retain a considerable portion of its physical properties at the maximum temperature the warhead encounters in service use.

Compatibility

There should be no chemical interaction between the binder and the explosive at the maximum temperature encountered by the warhead. Plastics and curing agents which react with explosives are to be avoided. In this category are highly basic materials such as amine curing agents many of which are incompatible with nitro groups. Table 2 lists the vacuum stabilities, reference (7), which are a measure of compatibility, of a number of DATB-binder combinations.

Density of Pressed PBX

The PBX should be capable of being pressed to 98% of TMD (theoretical maximum density) at a maximum temperature of about 120°C, a pressure of 20,000 psi and a vacuum of about 1 mm. Densities greater than 98% TMD reduce the ease and reliability of initiation. Although a pressure of 30,000 psi was used to press small experimental charges, the same results were achieved on large charges with a pressure of 20,000 psi. As shown in Table 3, the final density of some PBX charges could be ....proved by allowing them to cool under pressure. This is impractical with large charges so that high densities must be achieved with hot-ejected charges.

Thermal Cycling Resistance

The binder should possess some degree of flexibility to enable the PBX to withstand volume changes without cracking.

Since the missile warhead in flight is subjected to a sudden thermal shock, it was desirable to determine the effect of rapid temperature change on the various PBXs. No attempt was made to simulate the exact temperature profiles of the warhead but instead a NOL thermal cycling test was used. In this test a cylinder of PBX was cycled at ambient humidity from -54°C to + 71°C (-65°F to + 160°F) by placing the charge in a 71°C oven for 4 hours, transferring immediately to a -54°C cold chest for 4 hours and finally placing the charge back in the oven overnight to complete one full cycle.

The charges were not conditioned nor was an attempt made to relieve pressing stresses except that the charges were allowed to remain at ambient temperature and humidity for several days before cycling. The charges were inspected visually and radiographically before and after cycling. All charges were free of cracks before the test. In addition, the physical dimensions and density of each charge were measured before and after cycling.

Another important difference between the test conditions and actual conditions was that a bare charge was used while a metal casing surrounds the actual warhead explosive. Since the test was probably more severe than the actual conditions the fact that a particular PBX failed the test does not necessarily mean it would crack in the warhead during flight. The test did indicate the relative effectiveness of the various binders to enable the PBX to withstand volume changes due to thermal expansion without cracking.

This was an extremely severe test which none of the standard military explosives containing TNT (Comp B, HBXs) will withstand for even one cycle without developing many large cracks. Table 4 lists the results of the thermal shock tests on the more promising PBXs.

Strength

The pressed PBX charge should be strong enough to withstand the handling involved in manufacture and assembly of the warhead. PBX cylinders 2.54 cm x 1.27 cm diameter (1" x 1/2") were tested for compressive strength on a universal tester. Densities of the sample were taken before the test which was performed at ambient temperature at a crosshead speed of 0.13 cm/min. (0.05 in/min.). This test subjects the charge to a combination of stresses and is seldom of direct significance for thermoplastic materials. It is useful as a comparative test. Table 5 gives the compressive strength of a number of PBXs.

Machinability

The charges should be machinable to a tolerance of 0.0025 cm (± .001 inch) since many PBXs are machined into various shapes. The use of a coolant on the cutting tool may be desirable, although it can be dispensed with in the case of heat resistant and insensitive explosives like DATB. For charges of pure DATB and DATB-PBXs in which the binder did not encapsulate the explosive crystals, the coolant roughened the surface and tended to reduce the strength of the charge.

Ease of Fabrication

The PBX should be amenable to handling and fabrication by existing techniques and equipment. In order to utilize to fullest advantage the few available presses for the pressing of large billets it is desirable to have PBXs that require short pressing cycles. PBX molding powders which require short dwell times and allow the pressed billet to be ejected hot shorten the press cycle.

The various binders were screened by comparing their properties to the desirable properties enumerated above. The sample charges were pressed at 120°C and 30,000 psi and were 1.27 cm in diameter unless otherwise noted. All the charges were pressed under a vacuum of one mm.

BINDERS, TYPES AND PROPERTIES

Thermosetting Binders

At the inception of this program, emphasis was put on the physical strength properties, flexibility and thermal resistance of the binder. Therefore, a number of thermosetting resins were evaluated as binders because, as a class, these resins when cured at moderate temperatures are then capable of resisting much higher temperatures. The thermosets also possess higher physical strength properties than the thermoplastics.

(a) Epoxy Resins

Glycidyl ether-type epoxy resins have many desirable properties. These include:

(1) No volatile product formed when the polymer is cross-linked or cured.

(2) Little shrinkage during cure.

(3) Chemical inertness.

(4) Toughness and shock-resistance.

(5) Adhesion almost without equal among organic resins.

(6) Simplicity of formulation and ease of handling.

(7) Moderate to great heat resistance.

Commercial epoxy resins have several shortcomings as PBX binders. Rapid curing agents such as amines are incompatible with DATB. Acid curing agents, which are compatible with explosives, are not only slow curing but require relatively high curing temperatures. Commercial epoxies cured with either anhydrides or amines are too hard and brittle and the addition of plasticizers degrade the thermal properties of the resin. The newer di-epoxide resins are more reactive with acid curing agents but the cured materials lack flexibility.

In order to achieve more flexibility without significantly lowering the thermal stability, a long chain epoxy curing agent (called Adduct B) was synthesized. This was an acid-terminated half-ester made from 2 moles of pyromellitic dianhydride (PMDA) and one mole of a long chain polypropylene glycol. When epoxies were cured with this PMDA-glycol adduct it resulted in very flexible binders with good, high temperature properties which cured quickly at moderate temperatures.

The PBX molding powder was made by mixing the explosive with a solution of resin and curing agent and then driving off the solvent at 50°C. The molding powder was heated to 120°C in an oven, placed in a 120°C mold and cured at 20,000 psi for 30 minutes. This resulted in excellent PBXs of 98% TMD. Table 6 gives a summary of the major types of thermosetting resins screened and a qualitative assessment of each type based on a number of duplicate samples.

(b) Phenolic Resins

Phenolic resins have the following advantages when used in PBXs.

(1) Cure time and temperatures are moderate.

(2) PBXs have high strength and high density.

(3) Some phenolics act as stabilizers for DATB at elevated temperatures.

(4) The cured resin is stable at elevated temperatures.

These resins also have some disadvantages. Water is formed as a by-product when the resin is cured and the cured resin is brittle. A phenolic resin was successfully plasticized with Formvar (Polyvinyl formal) but as shown in Table 7, the thermal properties of the plasticized resin were degraded.

(c) Thermosetting Fluoroelastomers

Viton and Kel-F fluoroelastomers have some attractive binder properties. When properly cured they are elastic and have good, high temperature properties. Unfortunately, PBXs made with these binders had poor physical strength, were difficult to cure at moderate temperatures and produced charges of low density. In addition, the recommended curing agents, amines and peroxides, are incompatible with many explosives.

(d) Silicone Resins and Rubbers

These materials have the desirable binder property of heat resistance and silicone rubbers are elastic. However, the silicone polymers did not make good explosive binders. Final densities of the PBXs were low and it was difficult to process these materials under the standard pressing conditions of 120°C, 30,000 psi and 1 mm vacuum.

Processing Large PBX Charges

Although no great difficulties were experienced in making PBXs on a small laboratory scale with many of these thermosetting resins, a great deal of trouble developed when an attempt was made to press large charges with these binders on conventional pressing equipment.

The major trouble was the difficulty of preheating the PBX molding powder in conventional ovens. It was found that the low thermal conductivity of the molding powder required such long heating times that there was a real possibility of curing the binder before the molding powder was placed in the die and pressed. A stop gap solution was to place the cold molding powder in a heated die and heat the molding powder under pressure. This procedure produced good billets of high density but, due to the time required to heat the explosive to cure temperature, it meant that each press could only produce about two charges per day. Another possible solution was to preheat the molding powder below the curing temperature of the binder and press for a short period of time. The partially cured billet was then post-cured in an oven. This produced fair charges of lower density. Table 8 compares charges made by this procedure with those cured under pressure.

Other means of preheating the molding powder were considered. Rapid high-frequency or dielectric heating might possibly solve the heating problem but introduces safety problems.

Thermoplastic Binders

A number of thermoplastic binders were evaluated in an effort to find a binder more amenable to large scale production of PBXs. It was found that in many instances it is not necessary to heat thermoplastics to their softening point in order to utilize them as PBX binders. High density charges possessing good physical properties were made with thermoplastic binders at pressing temperatures well below their softening point.

Table 9 lists a number of thermoplastic resins that were evaluated as PBX binders. The binders that passed most of the screening tests listed in the Discussion, and gave evidence of making superior PBXs, are treated in greater detail below. Table 10 summarizes the properties of the three binders recommended as having the best overall properties for DATB-PBXs.

(a) Nylon

Nylon binders for various explosives have been studied very extensively at the Naval Ordnance Test Station, China Lake, California, reference (9). The Nylon used is an alcohol-soluble type designated Zytel 63 by du Pont.

The binder is applied to the explosive by slurrying the DATB in an alcohol solution of the Nylon. Water is then added to precipitate the Nylon out of solution completely coating the DATB (under ideal conditions).

Nylon PBXs are easily machined and have good physical strength properties. Large, 7 inch diameter charges of DATB/Nylon (94/6) have been produced for the SPARROW III missile warhead.

There are a number of disadvantages to the use of Nylon. The heat resistance of the material is only fair. Nylon (Zytel 63) starts to soften below 100°C and at 120°C has lost a major portion of its strength.

Nylon PBXs are quite brittle. The thermal cycling tests show that they are no better than pure DATB is this respect. Both failed after two complete cycles when tested in the form of 4.13 cm x 4.13 cm cylindrical charges.

(b) Kel-F

Kel-F is a trade name given to a series of heat resistant chlorotrifluoroethylene polymers. Two of these polymers, Kel-F 820 and Kel-F 300, were evaluated.

Kel-F 820 is acetone soluble and was applied to the DATB by the procedure outlined in part 2 of the experimental section. PBXs made with this material could not be pressed to high density and relaxation caused pressed pellets to lose density with time.

Kel-F 300 is an insoluble resin. It was applied to the DATB by dry blending powdered Kel-F with the explosive. This material could be pressed to high densities at 140°C and 30,000 psi. Work done by the National Bureau of Standards indicated that the resin has a glass transition at 45°C, reference (8). It was felt that this transition might cause trouble when the PBX was put through the thermal cycling test. For this reason the evaluation was discontinued.

(c) Teflon

Teflon is a trade name given by du Pont to a polymer of tetrafluoroethylene. Teflon molding powders are somewhat gummy and difficult to dry blend. A dispersion of Teflon in water was found to be ideally suited for application to the explosive. The explosive was simply mixed in water and the dispersion added. Acetone was then added to coagulate the dispersion and the slurry was filtered and dried to produce the molding powder. Since the Teflon was never in solution it did not coat the explosive crystals but was present in the molding powder in the form of small discrete particles.

The addition of 0.5% of 0.32 cm length Dacron fiber seemed to improve the final pressed density of the PBX.

Teflon PBXs with Dacron fiber can withstand 5+ cycles in the thermal shock test from -54°C to +71°C. The compressive strength of the Teflon PBXs ranged from about 5 to 10,000 psi. Teflon does not melt but forms a deformable gel at temperatures above 325°C.

The use of high density binders, like Teflon, may confer an extra dividend. Since most warheads are volume loaded, a warhead containing DATB/Teflon (94/6) (by weight) would contain about 5% more DATB than a DATB/Nylon (94/6) warhead if both were pressed to 98% TMD.

Teflon is recommended as the preferred high temperature binder for DATB since the PBX made with this polymer had the best balance of properties.

(d) Kynar

Kynar is a polyvinylidene fluoride thermoplastic developed by the Pennsalt Chemical Co. This binder was applied to the explosive by mixing the DATB in an acetone solution of the plastic and then adding water to precipitate the plastic out of solution onto the explosive.

PBXs made with this resin were pressed to high densities (98% TMD) at 120°C and 30,000 psi. The PBX charge was ejected at 120°C without lowering the final density. It was found that the machinability of the charge was greatly improved by the addition of 0.5% Dacron fiber.

PBXs made with Kynar withstood 3 cycles before developing cracks in the thermal shock test. The compressive strength of Kynar PBXs was about 10.000 psi. The polymer melts at 170°C.

(e) Lexan

Lexan is a polycarbonate polymer developed by the General Electric Co.

PBXs of high density (98 + TMD) were achieved at 120°C and 30,000 psi with 5% of this thermoplastic binder. These charges were machinable. Lexan has a high melting point of 268°C and is considerably lower in cost than the fluorinated polymers.

EXPERIMENTAL

The first step in screening a new plastic binder for DATB was to investigate methods of applying the binder to the explosive.

1. If the binder was insoluble in water but soluble in an organic water-miscible solvent then:

   (a) The DATB was suspended in water and the plastic solution added to the slurry, where the polymer precipitated. Or:

   (b) The DATB was suspended in the polymer solution and water was added to precipitate the polymer onto the DATB.

2. If the polymer solvent was immiscible in water, the DATB was suspended in water and the polymer solution was slowly added while heat was applied to drive off the volatile solvent. The objective was to coat or encapsulate the DATB crystals with plastic binder.

3. If the polymer was soluble in water the DATB was mixed in an organic solution of the polymer while heat was applied to drive off the solvent. This procedure can be conveniently carried out in a jacketed sigma-blade mixer so that the explosive will be constantly mixed and evenly coated while the solvent is being driven off.

4. Polymers which are insoluble in organic solvents are most conveniently incorporated in the PBX in finely divided form. Dispersions or fine powders can be combined with the explosive by mixing them in water and then filtering and drying. Dry blending of fine polymer powders with DATB was possible in some cases.

The above procedures were adequate for screening small batches of PBX. For large production of PBXs the use of water emulsions or dispersions should be investigated since this would reduce or eliminate the use of organic solvents.

Preparation of PBX Molding Powder

Procedure for DATB/Kynar/Dacron Fiber

DATB	1380 gm	92%
Kynar resin	112.5 gm	7.5%
Dacron fiber (1/4" 3 denier)	7.5 gm	0.5%
Acetone	7,000 ml	
Distilled water	12,000 ml	

a) Dissolve the resin in acetone under reflux.

b) With vigorous stirring, add the DATB and fiber to the resin solution and stir for 10 minutes.

c) Add the water and stir for 10 minutes more.

d) Filter and wash with water.

e) Dry molding powder at 80°C for 4-6 hours.

Procedure for DATB/Teflon 30/Dacron Fiber

DATB	1425 gm	95%
Teflon 30 (60% solids)	112.5 gm	4.5%
Dacron fiber (0.32 cm, 3 denier)	7.5 gm	0.5%
Distilled water	4500 ml	
Acetone	3600 ml	

a) Add DATB and fiber to the water and stir vigorously for 5 minutes.

b) Add Teflon dispersion and stir for 5 minutes.

c) Add acetone and stir for 10 minutes.

d) Filter and wash with water.

e) Dry at 80°C for 4-6 hours in vacuum oven.

Procedure for DATB/Lexan

DATB	470 gm	94%
Lexan	30 gm	6%
Methylene chloride	600 ml	
Distilled water	2400 ml	

a) The Lexan is dissolved in methylene chloride under reflux.

b) The DATB is added to the water which has been heated to 50°C and the slurry is stirred vigorously.

c) The solution of Lexan is added slowly to the stirred slurry and the stirring continued until the solvent has been driven off.

d) The molding powder is filtered, washed with water and dried for 4-6 hours at 80°C in a vacuum oven.

Procedure for Pressing DATB/PBX

The following procedure was used for pressing experimental 1.27 cm (0.5 inch) diameter charges. Some modifications will be necessary in order to press larger charges. The major change will involve the preheating of the molding powder before it is loaded into the die.

a) The cold molding powder was poured into the heated die and 1 mm vacuum applied for 10 minutes.

b) A pressure of 5,000 psi was applied until the die and molding powder reached the pressing temperature of 120°C.

c) A pressure of 20-30,000 psi was applied for 10 minutes.

d) The pressure was released and the pellet ejected from the hot die.

CONCLUSIONS

1. A wide variety of commercial thermosetting and thermoplastic resins can be used to convert DATB into a PBX. PBXs made with thermoplastics were easier to process on a large scale with conventional techniques and presses.

2. Five percent by weight of binder was the minimum amount consistent with acceptable PBX physical properties and minimum dilution of explosive energy.

3. Some phenolic resins acted to reduce the amount of gas evolved by DATB at elevated temperatures.

4. Some plastic binders helped the PBX charges to resist cracking when thermally shocked from -54°C to +71°C for several cycles.

5. PBX pressed charges which were allowed to cool under pressure had higher densities in most cases.

6. Pure DATB and many DATB/PBX charges were machinable to close tolerances. The machinability and pressed density of some PBXs could be improved by the addition of 0.5% Dacron fiber.

7. The three thermoplastic binders which resulted in DATB/PBXs with good overall properties were polycarbonate, polyvinylidene fluoride and polytetrafluoroethylene.

8. Polytetrafluoroethylene had the best overall properties and is recommended as a high temperature binder for DATB.

RECOMMENDATIONS FOR FUTURE WORK

As the need for larger PBX warheads increase there is a resulting increase in fabrication costs and difficulties. The point has been reached where research in the following areas are needed:

1. Castable explosives using both conventional and energetic liquid thermosettling binders.

2. Pressed PBX explosives using liquid thermosetting binders and low (1-5000 psi) pressures to achieve high density charges.

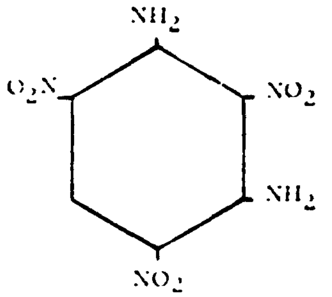
ACKNOWLEDGMENT

The authors wish to recognize the assistance of Mr. George L. Swann in carrying out this work.

TABLE 1

PROPERTIES OF DATB

1,3-Diamino-2,4,6-trinitrobenzene



$C_6H_5N_5O_6$

M. W. 243

Melting Point, reference (1)	286°C
Crystal Density, reference (2)	1.837 gm/cc
Impact Sensitivity, reference (3)	>320 cm (Explosive D = 250 cm)
Gap Sensitivity, reference (4)	less sensitive than cast TNT
Vacuum Thermal Stability, reference (1)	1.5% decomposition/hr at 260°C
Cook-Off Temperature, reference (5)	8 minutes at 320°C
Detonation Velocity (density =1.80), reference (3)	7600 m/sec
Failure Diameter, reference (3)	0.53 cm
Polymorphic Transition, reference (1)	217°C (Form II, density = 1.815)
Coefficient of Linear Expansion, reference (6)	47×10^{-6} cm/cm/°C
Solubility	Insoluble in water and most organic solvents. Soluble in (gamma) butyrolactone, dimethylsulfoxide and concentrated sulfuric acid

TABLE 2

VACUUM STABILITY DATA
(DATB with Various Binders)

Binder or Binder and Catalyst	% by wgt.	Test Temp. (°C)	cc gas/gm DATB/hr
DATB (control)	100	260	7.0 (avg.)
DATB (control)	100	204	<0.1 (avg.)
Epoxy Resins			
Epon 1001/HET	2.5/2.5	260	7.7
Epon 1001/BF_3-Amine	4.8/0.2	260	20.0
Epon 1001/Adduct B	2.3/2.7	260	11.8
Epon 1001/Adduct B	2.3/2.7	204	0.1
Epon 1007/HET	2.5/2.5	260	10.0
Epon 1001/Epon 1007/Adduct B/ BF_3-Amine	1.9/0.4/ 2.6/0.1	260	24 (avg.)
Epon 1001/Epon 1007/Adduct B	1.9/0.4/ 2.6	260	13.8
Epon 1001/Epon 1007/Adduct B	1.9/0.4/ 2.6	204	0.3
Epon 1310/DDS	4/1	260	20.7
Epon 1310/BF_3-Amine	4.95/0.05	260	12.4
Epon 1310/HET	2.5/2.5	260	12.6
Epon 1310/Syl-Kem 90/PMDA	2.5/1/2	260	11.3
Epon 1310/Dichloromaleic Anhydride	3.5/1.5	260	17.7
Epoxide 206/Maleic Anhydride	2.5/2.5	204	0.3
Stycast 2741/Stycast 15	3/2	260	12.1
Phenolic Resins			
BRL-2741	6	260	8.0 (avg.)
BRL-2741	6	204	<0.1
BLL-3085*	6	260	1.2 (avg.)*
Plaskon V-204*	6	260	4.4*
CTL 91-LD	5	260	6.8

TABLE 2 (cont'd)

VACUUM STABILITY DATA
(DATB with Various Binders)

[illegible]	% by wgt.	Test Temp. (°C)	cc gas/gm DATB/hr.
[illegible]			
[illegible]	5	260	7.6
[illegible]	5	204	<0.1
[illegible]	5	204	<0.1
[illegible]	4.2/0.6/ 0.1/0.1	260	30.0
[illegible]	4.2/0.5 .1/0.1	204	1.5
[illegible] cobalt [illegible]/ MEK Peroxide	4.5/0.25/ 0.25	204	0.7
Kel-F [illegible]	[illegible]	260	3.7*
Kel-F [illegible]	5	204	0.15
[illegible]	5	204	0.12
E[illegible]	5	204	0.15
Z[illegible]	5	204	0.4
Teflon [illegible]	7	204	0.9
FM-[illegible]	5	260	13.1
FM-[illegible]	5	204	<0.1
Raybond 31001	5	260	14.2
Raybond 31001	5	204	<0.1
Raybond 34029	5	260	14.5
Raybond 34029	5	204	<0.1
Kynar	5	204	0.5

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*Resins stabilized explosive in samples that evolved less than 7.0 cc gas/gm/hr. at 260°C

Test samples were prepared by pressing PBX into a pellet at 120°C at 35,000 psi and then crushing pellet into powder.

One determination was made on each composition unless otherwise noted.

TABLE 3

EJECTION TEMPERATURE VS. DENSITY

Composition	TMD	Ejection Temp. (°C)	Final Density
DATB/Zytel 63 (94/6)	1.76	120	1.69
		95	1.72
DATB/Zytel 63/Nylon fiber (95/4.5/0.5)	1.77	120	1.71
		90	1.74
DATB/Teflon 30 (93/7)	1.85	120	1.80
		90	1.80
DATB/Lexan (95/5)	1.78	120	1.72
		90	1.73

All the above charges were 2.54 cm x 1.27 cm diameter and the data is based on at least 6 samples/composition.

TABLE 4

RESULTS OF THERMAL CYCLING TESTS

Composition	Nominal Charge Size (cm)	Density (Initial)	% TMD	Density (Final)	% TMD	No. of[1] Cycles	Results
DATB	5x5	1.79	98	---	---	2	Cracked in two on 3rd cycle.
DATB	5x5	1.80	98	---	---	2	Cracked in two on 3rd cycle.
DATB/Teflon 30 (95/5)	4x4	1.73	94	1.714	93	4	3 cracks on 5th cycle.
DATB/Teflon 30 (95/5)	4x4	1.75	95	1.74	94	4	2 small cracks on 5th cycle.
DATB/Teflon 30 (93/7)	4x4	1.71	92	1.69	91	5	Unchanged.
DATB/Teflon 30 (93/7)	4x4	1.72	93	1.70	92	5	Unchanged.
DATB/Teflon 30/ Dacron (92/7.5/0.5)	4x4	1.79	97	1.77	96	4	1 small crack on 5th cycle.
DATB/Teflon 30/ Dacron (92/7.5/0.5)	4x4	1.81	98	1.79	97	5	Unchanged.
DATB/Zytel 63 (95/5)	4x4	1.66	94	1.65	93	1	Cracked in two on 2nd cycle.
DATB/Zytel 63 (95/5)	4x4	1.73	98	1.71	96	1	Horizontal crack on 2nd cycle.
DATB/Zytel 63 (95/5)	4x4	1.76	99	1.74	98	2	Horizontal crack on 3rd cycle.
DATB/BRL-2741 (95/5)	4x4	1.77	98	1.76	93	2	Cracked in two on 3rd cycle.

TABLE 4 (cont'd)

RESULTS OF THERMAL CYCLING TESTS

Composition	Nominal Charge Size (cm)	Density (Initial)	% TMD	Density (Final)	% TMD	No. of[1] Cycles	Results
DATB/BRL-2741 (95/5)	4x4	1.78	99	1.77	98	3	Cracked in two on 4th cycle.
DATB/Epox B (95/5)	5x5	1.75	98	1.69	95	7	Unchanged.
DATB/Epox B (95/5)	5x5	1.75	98	1.69	95	7	Unchanged.
DATB/Kynar/Dacron (95/4.5/0.5)	5x5	1.75	96	1.74	96	3	1 small crack on 4th cycle.
DATB/Kynar/Dacron (95/4.5/0.5)	5x5	1.75	96	1.74	96	3	1 small crack on 4th cycle.
DATB/Kynar/Dacron (92/7.5/0.5)	5x5	1.77	97	1.76	97	3	1 small crack on 4th cycle.
DATB/Kynar/Dacron (92/7.5/0.5)	5x5	1.77	97	1.76	97	3	1 small crack on 4th cycle.

(1) Number of cycles charge withstood before cracking. Total number of cycles for those charges that did not crack.

TABLE 5

COMPRESSIVE STRENGTH DATA
(DATB with Various Binders)

Binder (%)	Density (gm/cc)	Average Comp. Strength (psi)
DATB (pure)	1.80	7950
DATB	1.814	9950
BLL-3085 (5)	1.788	9300
BLL-3085/TCP (4.2/1.8)	1.716	7400
BRL-2741 (5)	1.736	9725
BRL-2741	1.776	10500
Stycast 2662/Catalyst 14 (4/1)	1.641	5050
Stycast 2741/Catalyst 15 (3/2)	1.732	8150
Plaskon V-204 (6)	1.71	5950
Kynar (5)	1.79	9790
Kynar/Dacron (4.5/0.5)	1.78	10020
Lexan (5)	1.72	10760
Lexan (6)	1.74	12670
Teflon 30 (5)	1.80	6980
Teflon 30 (7)	1.81	5620
Teflon 30/Dacron (4.5/0.5)	1.79	10360
Zytel 63 (5)	1.74	8450

Test samples were 2.54 cm high x 1.27 cm diameter.
Test performed at ambient temperature and crosshead speed of 0.13 cm/min.

TABLE 6

SUMMARY OF THERMOSETTING BINDERS EVALUATED
DATB/Binder (95/5)

Binder	%	Pressed Density	Machinability	Remarks
Epoxies				
Epon 1007/HET	2.4/1.6	High	Fair	Hard and brittle
Epon 1310/DDS	4/1	High	Fair	Hard and brittle
Epon 1310/DDSAA	2.5/2.5	High	Good	Tough
Epon 1001/Epon 1007/ Adduct B	2/0.4/ 2.6	High	Excellent	Flexible
Phenolics				
BRL-2741	5	High	Fair	Brittle
BRL-2741/Formvar 12/85	3.5/1.5	High	Good	Flexible
BRL-3085/TCP	3/2	High	Good	Flexible
Silicones				
Silastic RTV 501/ Catalyst A	4.9/0.1	Low	---	Short pot life
DC-2106/Catalyst XY15	4.9/0.1	Low	---	Difficult to cure below 120°C
Polyesters				
Laminac 4232/Benzoyl peroxide	4.9/0.1	Low	Poor	Brittle
AR-2076/DAIP/TBP	4.4/0.45/ 0.15	Low	Poor	Brittle
Fluorinated Elastomers				
Viton A/Mg O/Benzoyl peroxide	4.3/0.6/ 0.1	Low	Fair	Flexible, poor cure
Kel-F 3700/Dyphos/ Benzoyl peroxide/ Zn O	4.1/0.4/ 0.1/0.4	Low	Fair	Poor cure

TABLE 7

THERMAL PROPERTIES OF A PLASTICIZED PHENOLIC RESIN

Composition	% Formvar	Wt. Loss, % (after 2 hrs. at 230°C)
BRL-2741/Formvar	0	2.1
"	20	10.5
"	30	13.7
"	40	15.7
"	50	19.3

Above compositions were given a normal cure before testing. Two determinations were made for each composition.

TABLE 8

DENSITY OF POST-CURED PBX CHARGES

Composition	Normal Cure(1) ρ (gm/cc)	Post-Cured(2) ρ (gm/cc)
DATB/Epon 1001/HET (94/3/3)	1.77	1.69
DATB/Epon 1001/HET (94/3/3)	1.78	1.71
DATB/CTL-37-9X (94/6)	1.75	1.73
DATB/Epon 1310/DDS (95/1.25/3.75)	1.75	1.73

---

(1) Pressed at 120°C for 2 hrs. at 35,000 psi.

(2) Pressed at 100°C for 10 min. at 35,000 psi. Post-cured at 130°C for 2 hrs. at ambient pressure.

Two determinations were made for each composition.

TABLE 9

SUMMARY OF THERMOPLASTIC BINDERS EVALUATED
DATB/Binder (95/5)

Binder	Pressed Density	Machinability	Remarks
Delrin	Poor	Poor	Insoluble in common solvents. Powdered resin poor binder.
Exon 461	High	Good	Tough and strong; heat resistance low.
Kel-F Dispersion	High	Good	Tough
Kel-F 820	Low	Poor	
Kynar	High	Good	Tough; moderate heat resistance.
Lexan	High	Good	Tough; high heat resistance.
Penton	Poor	Poor	Insoluble in common solvents. Powdered resin poor binder.
Teflon 7	---	---	Could not be dry blended with DATB.
Teflon 30	High	Excellent	Tough; high heat resistance.
Teflon TE 9500 (FEP)	High	Excellent	Tough; high heat resistance.
Zytel 63	High	Excellent	Tough; low heat resistance.

TABLE 10

PROPERTIES OF BEST PBX SYSTEMS EVALUATED

	DATB-PBX with 5%		
Properties	Teflon	Kynar	Lexan
Melting point of binder (°C)	325(1)	170	268
Pressed density (% TMD)	98	98	98
Machinability	Excellent	Excellent	Good
Compatibility of binder with DATB	Excellent	Excellent	Excellent
Thermal cycling resistance (no. of cycles from -54°C to +71°C with no cracking)	5+	3	--(2)
Compressive strength (average) (psi)	7000	9800	10800

---

(1) Amorphous gel above this temperature.

(2) Not tested.

GLOSSARY

THERMOSETTING RESINS

1. Epoxy Resins

Epon 828 Epon 1001 Epon 1007 Epon 1310 Epon X-71 Epon X-81	Glycidyl ether epoxies - Shell Chemical Co.
EP-206	Vinyl cyclohexene dioxide - Carbide Chemical Co.
Stycast 2340 Stycast 2662 Stycast 2741	Flexiblized epoxy resins - Emerson and Cummings, Inc.
Epox B	Epon 1001 + Epon 1007, cured with Adduct B - NOL
ST-847	Silicone/Epoxy co-polymer - Allied Chemical Co.

2. Epoxy Curing Agents

HET	HET anhydride or chlorendic anhydride - Hooker Chemical Co.
DDS	Diaminodiphenylsulfone - Merck and Co.
DDSAA	Dodecenylsuccinic anhydride - Allied Chemical Co.
PMDA	Pyromellitic dianhydride - du Pont
Adduct B	Acid terminated ester of PMDA and polypropylene glycol - NOL

GLOSSARY (cont'd)

THERMOSETTING RESINS

BF_3-Amines	BF_3 complexed with various amines - Allied Chemical Co.
Stycast 14 Stycast 15	Amine curing agents - Emerson and Cummings, Inc.

3. Epoxy Flexiblizers

Syl-Kem 90	Difunctional epoxy-silicone - Dow-Corning Corp.
Cardolite	Reactive flexiblizer - Minn. Mining and Mfg. Co.
Lancast A	Reactive flexiblizer - Ciba Co.

4. Phenolic Resins

BRL-2741 BRP-5661 BRP-6661 BRP-5095 BLL-3085	Heat reactive phenolics - Bakelite Co.
Plaskon V-204	Heat reactive phenolic -
Plaskon A-150	Heat reactive phenolic - Allied Chemical Co.
ST-847	Silicone-phenolic resin -
CTL 91-LD CTL 37-9X	High temperature phenolic - Central Test Lab.
Ray-Bond R-84029	Modified phenolic - Raybestos-Manhattan Inc.
Ray-Bond R-81001	Rubber-phenolic -

GLOSSARY (cont'd)

THERMOSETTING RESINS

5. Phenolic Plasticizers

Formvar 12/85	Polyvinyl formal - Shawinigan Resins Corp.
Versamide 125	Polyamide resin - General Mills
TCP	Tricresyl phosphate

6. Silicone Resins

DC-2106	Silicone resin	Dow-Corning Corp.
DC-5071	Silicone resin	
Silastic RTV-501	Silicone rubber	
SE-76	Silicone rubber gum - General Electric	

7. Fluorinated Elastomers

Viton A	Copolymer of hexafluoropropylene and vinylidene fluoride - du Pont
Kel-F5500	Copolymer of chlorotrifluoroethylene and vinylidene fluoride - Minn. Mining and Mfg. Co.
Kel-F3700	

8. Thermoplastic Resins

Delrin	Acetal resin - du Pont
Exon 461	Vinyl chloride/vinylidene fluoride copolymer-Firestone Plastics Co.
Kel-F Dispersion No. N-1	Polytrifluorochloroethylene dispersion - Minn. Mining and Mfg. Co.
Kel-F 820	Copolymer of trifluorochloroethylene and vinylidene fluoride - Minn. Mining and Mfg. Co.
Kynar	Polyvinylidene fluoride - Pennsalt Chem. Co.
Lexan	Polycarbonate - General Electric Co.
Penton	Chlorinated polyether - Hercules Powder Co.
Teflon 7	Tetrafluoroethylene powder - du Pont
Teflon 30	Teflon dispersion - du Pont
Teflon (FEP)	Dispersion, copolymer of tetrafluoroethylene and hexafluoropropene - du Pont
Zytel 63	Alcohol - soluble nylon - du Pont

GLOSSARY (cont'd)

THERMOSETTING RESINS

9. Miscellaneous

Dacron fiber	Polyester fiber - du Pont
Dyphos	Dibasic lead phosphite

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3. Binders, Plastic
4. Diamino-trinitro benzene
5. PBX
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III. Rich, Richard D. jt. author
IV. Project
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