

THE PREDICTION OF THE REACTION OF AN EXPLOSIVE
SYSTEM IN A FIRE ENVIRONMENT.
COATED RDX SYSTEMS FOR PRESSED EXPLOSIVES.

Carl M. Anderson and Jack M. Pakulak, Jr.
Naval Weapons Center
China Lake, California

ABSTRACT

A means has been found to predict the behavior of an explosive in response to rapid heating as in a fire. The prediction is empirical and is limited at this time to coated RDX systems used for pressed explosives. The prediction is based upon the quality of the coating present on the RDX crystals. A complete, adherent coating is correlated with a mild reaction to rapid heating while a poor to nonexistent coating is correlated with violent explosions and detonations. Assessment of the quality of the coating is made by a scanning electron microscopic (SEM) examination of the interior surfaces of the molding powder. It is suggested that the SEM can be used to guide an explosive development program and as a quality control for explosives production.

INTRODUCTION

This paper deals with a different kind of compatibility than is usually associated with that word. Compatibility, in general, has referred to a chemical compatibility for the continued coexistence of substances in a mixture or in contact. The tightening of safety requirements for shipping, storing, and using munitions has added the factor of the response to heating as in a fire resulting from accidents, fuel spills, collisions, etc., from intentional initiation or from any other source. Heating, of course, is going to aggravate any chemical incompatibility and instability by increasing reaction rates. Our concern has been the prevention of a disastrous reaction once initiation has occurred; that is, the deflagration to detonation transition, DDT, should be stopped. This can be done, at least in the RDX systems considered here, by forming a continuous, adherent coating on the surface of the RDX crystals of a wide range of waxy substances. One could call this a physical or surface compatibility. Further, an observation of the quality of the coating on the molding powder allows one to make a

prediction as to the violence of the reaction that will occur on thermal initiation of the final pressed product. Although not fully documented yet, there are indications that the good coating that produces a mild reaction to thermal initiation also minimizes the reaction to impact, friction, and electrostatic initiation.

BACKGROUND

The behavior of propellants and explosives in response to rapid heating, as would be seen by munitions in a fire, is of major importance for the safety of personnel and equipment. The serious aircraft carrier accidents that produced a loss of hundreds of lives and extensive ship damage were the result of bombs and other munitions detonating in aircraft fuel fires. These aircraft carrier events have led to an extensive program of investigation⁽¹⁾ to minimize the damage in future accidents by developing systems to reduce the severity of the response of propellants and explosives to rapid heating. Any useful prediction of this response would have an obvious application in the development and employment of these systems.

Previously, all of the predictions of munitions response to fire have been based on experience with a particular explosive system and on computer modeling of the heat transferred through the munition case into the explosive. There are a number of one and two dimensional computation procedures that have been worked out to describe the heat fluxes and to predict the temperatures produced in the explosive in a fire.⁽²⁾ In all of the computations, the exothermic decomposition of the explosive or propellant is treated as an additional heat source that leads to a runaway reaction when the chemical reaction kinetics are included. The time and temperature at which the runaway reaction occurs is predicted, but in no case can the violence of the reaction be described. Most of the computations do agree fairly well with the experimental time-temperature data produced in a shell, bomb, or warhead in a fire. The runaway reaction of the explosive/propellant in the real world ranges from a mild burning or deflagration through explosions of varying violence to a true detonation. Detonations and explosions are to be avoided by whatever means can be found.

Detonations and explosions can be minimized for main-charge explosives by the judicious use of external insulation and interior liners, especially liners with an out-gassing system to pressurize and open the weapon case.⁽³⁾ Certain PBX systems, such as PBXC-116/117 (I), using neither liner nor exterior coating, respond to a fuel fire by opening the case and burning or deflagrating even under heavy confinement.⁽⁴⁾ With main-charge reaction minimization systems in place and functioning, there have been occasions with all-up weapons in which a detonation occurred late in the main-charge burnout.⁽⁵⁾ This effect was traced to the booster explosive's having finally gotten warm enough to react violently. Upon investigation, it was found that all of our currently available booster explosives react to heat by detonating. The effort to find a cause and a remedy for this booster behavior, the subject of this report, has led to a means of predicting the response of certain explosives to rapid heating.

Current booster explosives are either tetryl or RDX/wax systems. With the cessation of production of tetryl and the

nonavailability of Class A waxes, new, pressable explosive compositions are needed. In the search for a wax substitute, a copolymer of ethylene and vinylacetate (EVA) was found to have properties approximating those of a Class A wax. At a concentration equivalent to Composition A-3, EVA/RDX did not explode when heated as in a fire, this in contrast to Composition A-3 which does explode. An examination of the surfaces of the explosive in the form of molding powder in the scanning electron microscope (SEM) showed that the EVA had formed a uniform, adherent coating on the RDX while the RDX/wax A-3 had formed a coating of flakes of wax. Following this lead, other booster explosives were examined. All showed poor to nonexistent coatings. With further experience, a correlation was made between the quality of the coating and the behavior on rapid heating. This empirical correlation was then extended to the successful prediction of the kind of reaction produced in a fire environment.

This prediction of thermal response is the first successful prediction of DDT that has been accomplished. The prediction is empirical and is limited to RDX/coating systems at this time, but does represent a major breakthrough in explosives technology. SEM pictures of the molding powder can be used for a quality control procedure and for guidance in the development of new, safer explosive systems for pressed main charges and booster explosives. The extension of this prediction technique to castable systems appears feasible and will be further investigated.

PROGRAM GOAL

One goal of this and other programs in the area of explosives development is defined by MIL-STD-1648⁽⁶⁾ which describes the reactions that occur in munitions in a fire. The standard requires that all Navy munitions shall not react at all before five minutes in a fire and that the reaction, at no time, will be more than a deflagration. A mild explosion, throwing pieces no more than fifteen meters (50 feet), is acceptable. Booster and main charge explosives are included in this requirement. It is considered possible that a violent explosion in a booster assembly with a small shock wave, but with many hot, high velocity fragments, could initiate the main charge.

EXPERIMENTAL

The SEM was used to obtain pictures of the interior surfaces of the explosive molding powder. The SEM was used because its unusual depth of focus allows an investigation of irregular surfaces oriented at various angles and depths. Eight to sixteen photographs were made at various magnifications of two or more areas on the interior surfaces of broken molding powder pellets of each sample. All of the SEM pictures used in this report were produced by Rowland McNeil, Naval Weapons Center, Code 5515, on the various instruments in this region. The techniques of sample preparation, instrument operation, and selection of areas to photograph are given in NWC Technical Publication 5897 by R. A. McNeil.

The assessment of the quality of the coating was made on a purely empirical basis looking for such things as bare, uncoated crystals of explosive, sharp edges, nonadherent, crumbly or even crystalline coating material, etc. The choice of areas to photograph in the SEM was made using these same criteria. An arbitrary scale of four units was used to assign a value to the assessment ranging from 1 for a poor to nonexistent coating to 4 for a complete, adherent coating.

The small scale cook-off bomb (SCB) test was used to determine the response of the explosives to a fire environment. The test was devised as a small scale test to reproduce the heating effects seen by an explosive or propellant in bombs, munitions, and missiles in an aircraft fuel fire.⁽⁷⁾ Heating rates can be reproduced in the SCB as high as three degrees Celsius per second that can be seen by a thermally unprotected bomb to as low as 0.2 degrees Celsius per second as seen by a booster explosive deep inside the main charge in a large warhead. Ten years of experience and hundreds of tests run in the SCB have amply confirmed the direct correlation of the SCB results with the response of explosives and propellants in munitions.

The SCB fixture, Figures 1 and 2, consists of a stainless steel vessel, 6.35 cm inside diameter and 12.7 cm long, with 3 mm walls. The container is fitted with a 10 ohm

Nichrome ribbon heater wound on a mica insulator and covered with thermal insulation. A plate type thermocouple, Figure 3, is spot welded to the center of the inside wall. The mild steel cover contains a Neoprene or Teflon gasket seal, feedthroughs for the interior thermocouples, and a pressure take off. The 10 cm square, 1.27 cm thick steel plates at top and bottom (the top plate has two 2 cm holes to accommodate the cover attachments) serve both as a clamp to hold the vessel together and as witness plates to define the reaction that occurs.

SCB PROCEDURE

The prepared SCB unit, heater wound and insulated and wall thermocouple installed, is loaded with about 1 kilogram of explosive by direct casting or by insertion of a pressed and machined billet as appropriate. If a liner is required, the liner is formed in place using a mandrel of the proper size for the thickness needed; a second plate type thermocouple is placed in the explosive-liner interface. After carefully attaching and isolating the interior thermocouple leads to the feedthroughs, the unit is assembled. The cap is firmly screwed down onto the gasket; the thermocouple leads checked for continuity and short circuits; the unit clamped between the top and bottom plates; and the pressure tubing installed. The firing bay at NWC for this size of charge, about 1 kilogram, is a 1.5 meter diameter armour steel cylinder, 3 meters long with 9 cm walls. The cylinder, lying horizontal, is closed at one end with a concrete and earth backed sheet piling wall. During a test, the open end is blocked with sandbags. (A detonation reaction inside will move the sandbags as much as 5 meters.) Thermocouple and pressure transducer outputs are recorded on fast pen-drag recorders. The heating rate is controlled with a Honeywell recorder-controller. After a final check, the short on the heater circuit is opened and the test started. Heating is continued until a reaction occurs.

After a reaction has occurred, the fragments of the SCB are collected, examined, and photographed to assess and record the kind of reaction that had taken place. The millivolt-time records are reduced to time-temperature and time-pressure and plotted. A typical plot of the reduced data is shown in Figure 4.

RESULTS

Four levels of reaction intensity are definable by the number and condition of the SCB fragments collected after the reaction. The first level is a detonation resulting in many stressed fragments, often discolored by heat and deformed by collisions with the firing bay walls, and a dented, often punctured, base plate. A violent explosion at the next identifiable level of reaction results in a number of stressed fragments distorted by high velocity collisions with the walls of the firing bay as in a detonation but with little or no deformation of the base plate. The next level, a mild explosion, results in a few large fragments ejected and no deformation of the base plate. The mildest reaction, a deflagration, results in the SCB split open with no fragments thrown out. The noise, the dust cloud, and the conditions in the firing bay produced by the reaction are useful

indicators of the reaction violence, but the size and shape of the fragments and the condition of the witness plates are the defining elements in the description of the reaction that occurred.

All of the experiments run for this study are listed in Table 1. In the table, the various runs on a single explosive are listed as a group, while the SCB number gives the actual sequence in which the tests were run. As indicated in Table 1, predictions were made, for all runs after SCB 148, for the violence of the reaction that would occur. The predictions were made from an assessment of the coating on the explosive from the SEM pictures of the molding powder. It is of interest to note that the SEM photographs of the broken surfaces of the final pressed pellets lack any real character and do not provide enough information for a

TABLE 1. Correlation of Surface Coating With Reaction Violence on Rapid Heating in the SCB.

SCB no.	Figure no.	Sample	Coating quality ^a	Heating rate, °C/s ^b	Time to reaction, min/s	Reaction ^c	
107	5	A-3, RDX/Wax	3		1/33	Explosion I	
148		A-3	3	0.52	6/45	Detonation	
147		A-3	3	0.10	31/19	Explosion II	
144	6	A-5, RDX/Wax	1		1/19	Detonation	
145		A-5	1	0.23	14/1	Detonation	
108	7	CH-6	1		1/26	Detonation	
146		CH-6	1	0.21	12/56	Detonation	
106	8	RDX/EVA, A-3 (C ₆ H ₆)	4		1/33	Deflagration	
151	9	RDX/EVA, A-3 (THF)	3		1/37	Explosion I ^d	
178		PBXC-13, (THF), HS-51253	2	0.5	8/32	Detonation ^d	
179	10	PBXC-13, (THF), HS-51353	2	0.2	31/32	Explosion II ^d	
123		RDX/EVA, 95/5 (C ₆ H ₆)	2		1/29	Explosion I	
128		RDX/EVA, 95/5 (C ₆ H ₆)	2	0.2	15/15	Explosion I	
134		RDX/EVA, 95/5 (THF)	2		1/28	Explosion II	
135		RDX/EVA, 95/5 (THF)	2		1/37	Detonation	
149		RDX/EVA, 95/5 (THF)	3		1/37	Explosion II ^d	
150		RDX/EVA, 95/5 (THF)	2		1/38	Explosion II ^d	
122		12	RDX/EVA, A-5 (C ₆ H ₆)	3		1/31	Explosion II
162			RDX/EHA-VP, A-3	3		1/24	Explosion I ^d
137		14	RDX/EHA-VP, 95/5	2		1/19	Detonation
136	RDX/EHA-VP, 95/5		2		1/26	Explosion II	
163	RDX/EHA-VP, 95/5		2		1/37	Detonation ^d	
138	HMX/EHA-VP, 95/5		1		2/00	Explosion II	
139	HMX/EHA-VP, 95/5		1		1/26	Explosion I	
140	HMX/EHA-VP, 95/5		1	0.21	16/47	Detonation	
164	RDX/Estane, 95/5		3		1/37	Explosion I ^d	
165	RDX/Estane, 95/5		3	0.2	14/38	Detonation ^d	
182	13		Comp A/PE, NSWC	2		1/54	Explosion II ^d
183			Comp A/PE, NSWC	2	0.2	18/38	Detonation ^d

^a Coating quality on a 4-point scale: 1-poor, to 4-excellent.

^b Unless a figure is entered, the heating rate was between 2.5-3.0°C per second.

^c SCB cook-off reaction on a 4-point scale, of Detonation, Explosion II, Explosion I, and Deflagration.

^d Predicted from quality of surface coating.

useful assessment or prediction. In addition, there is surprisingly little migration of the coating material even in hot pressing.

The photographs of explosive surfaces and the corresponding SCB fragments included in this report are representative of the many that were made in the course of this study. With eight to sixteen or more scanning electron photomicrographs made for each sample at various locations and magnifications, the quality of the coating is relatively easy to assess but the selection of examples for this report was difficult.

Composition A-3 is a current G. P. bomb main charge booster explosive that is also used in certain shells. Figure 5a, one of the early SEM scans, shows the wax to be present on the surfaces of the molding powder as flakes. The internal surfaces were not examined. This fairly good wax coating correlates with a mild explosion as shown in Figure 5b.

Composition A-5 is a current fuze-booster explosive used principally for Army applications. At this low additive level, any continuous coating would be difficult to obtain so that Figure 6a shows many bare crystals with occasional flakes of wax. The detonation of SCB 144, Figure 6b, was the result obtained on rapid heating.

Explosive CH-6 is a current Navy fuze-booster used in many warheads and bombs. Again, at a low additive level, any complete coating of the RDX crystals would be difficult. Figure 7a, shows a fair external coating but the interior shows the additive mixture as discrete flakes and crystals. The result obtained in the SCB fast cook-off was a detonation, Figure 7b.

The preparation of RDX/EVA, as a Comp. A-3 substitute, was the initiation point of this study. The very mild deflagration, Figure 8b, of this material relative to Comp. A-3 and its other properties of a reasonable impact sensitivity with a good abrasion resistance, led to the investigation of why or how. The SEM, Figure 8a, pictures showed a good coating all over the molding powder particles. This was the first indication that surfaces might be involved in

the reaction in response to rapid heating.

Figure 9a is a scanning electron micrograph of an RDX/EVA Comp. A-3 analogue prepared using a different solvent system. As can be seen in the figure, when tetrahydrofuran (THF) was substituted for the benzene of the previous preparation, the coating material was not attached to the crystal surfaces. The bare crystals in, and unattached to, a matrix of EVA, a grade 3 or less coating, led to the prediction of a fairly strong explosion, Figure 9b.

Figures 10 and 11 are a pair of RDX/EVA preparations using the same two solvent systems at the 95/5 level. A complete coating at this level is difficult but the difference in adherence of the EVA to the RDX between the two is apparent. This difference shows in the SCB fragments produced in that Figure 11b, from the THF preparation, shows the more violent reaction. Another THF preparation of 95/5 RDX/EVA detonated, SCB 135, Table I.

RDX/EVA, prepared as a substitute for Comp. A-5 from a benzene solution of EVA, showed a reaction of the same order of violence as Comp. A-5. A comparison of Figure 12, RDX/EVA, A-5 and Figure 6, Comp. A-5 RDX/Wax, shows that the EVA holds the RDX together in pellets while the wax flakes do not. This difference may account for the lesser violence of the explosion of the RDX/EVA relative to the detonation of A-5.

The electron photomicrographs and SCB results with Comp. A/PE, are given in Figure 13. Comp. A/PE was prepared by NSWC, White Oak, as a replacement for Comp. A-3, using polyethylene to coat the RDX crystals. Figure 13a shows the coating to be porous and discontinuous which led to the prediction of the explosion of considerable violence obtained, Figure 13b. The discontinuous nature of the coating is evident in the many exceedingly bright areas in the photomicrographs that are the result of the rapid charging of the surfaces in the scanning electron beam even though the sample had been metallized to prevent charge deposition.

Figure 14 of RDX/Estane 5703, 95/5, is to be compared

with Figure 10, a comparable RDX/EVA. The coating appears to be fairly good but not particularly adherent to itself or to the larger RDX crystals. The SCB result was a medium violent explosion considerably stronger than the comparable RDX/EVA, Figure 10b.

In all of the above systems, extending the time to reaction with a lower heating rate produced an SCB result one or two orders more violent than the fast heating rate. Thus a system that simply exploded on fast heating, 70 to 100 seconds, usually detonated when 6 to 20 minutes were used to reach the runaway reaction temperature.

DISCUSSION

The four-point assignment of coating quality cannot be too discriminatory since the entire range of a poor or no coating (1) to a complete, adherent coating (4) is so broad. The assessment of the coating quality depends upon the skill of the SEM operator in choosing the areas to photograph and the judgment of the project chemist in making the quality assignment. Also, the definition of the SCB reaction is somewhat subjective in the middle, explosion, regions. The least and most violent reactions, deflagration and detonation, are easily defined as the one or two piece remainder of the deflagration and the dented or punched base plate of the detonation. Explosions cover the entire range of fragmentation between these extremes and are arbitrarily divided into two classes, Explosion I, mild, and Explosion II, violent, depending primarily on the number (size) and condition of the fragments with no clear dividing line between them. Correlation of the quality of the coating and the SCB reaction is well illustrated in Table 1 and the figures chosen to illustrate typical effects. The twenty examples, SCB numbers less than 149, with 10 materials, established a correlation which was then used to predict correctly the reactions obtained in all of the eleven subsequent tests.

The validity of the small-scale bomb test has been thoroughly demonstrated by correlation with fuel fire tests on warheads, bombs, etc., dating from the conception of the test in 1967 and the establishment of the SCB in its current

form as a routine test in 1971. The SCB numbers date from the inception of a test register in September of 1971. The correlation of the SCB, at about 1 kilogram of explosive, with the subsequent behavior of larger munitions such as bombs, warheads, shells and mines, has been excellent. Thus single or two-sample tests can be used with considerable confidence. A detonation in the SCB indicates an unsafe material and a practical certainty of a disastrous reaction in a weapon. A deflagration in the SCB does not preclude the chance of a detonation in a heavily cased weapon, but does indicate a good probability of a reasonably mild reaction.

The predictions were made on a purely empirical basis of the appearance of the coating on the surface of the RDX crystals. From this and other studies, there is some indication that a partial solubility, or at least a softening of the RDX surface, promotes the formation of an adherent coating. Figures 8 and 9 are SEM photomicrographs of two RDX/EVA preparations. One, Figure 8, was prepared by adding a benzene-ethyl acetate solution of the EVA polymer to slurry of RDX in water containing some ethyl acetate. The other, Figure 9, was prepared by adding a solution of EVA in THF to a water slurry of RDX. The principal difference between these preparations is the fact that THF is very soluble in water while benzene is but slightly soluble. This difference in solubility could control the rate at which the EVA is precipitated such that, with THF, the EVA is rapidly thrown out into the suspension and eventually collects on the RDX producing the nonadherent coating shown in Figure 9a. The corresponding SCB test results, Figures 8b and 9b, clearly show the difference produced by this change in technique of preparation.

Included in this series of SEM surface evaluations and SCB tests are two other coating systems that were submitted for SCB tests during the RDX/EVA study. Figures 13a and 13b show the coating and the SCB results with Comp. A/PE, a proposed substitute for Comp. A-3 prepared by NSWS, White Oak. Comp. A/PE is a polyethylene coated RDX. The coating appears to be granular, porous, and nonadherent and a violent SCB reaction was obtained as predicted. The other system, RDX/Estane 5703, 95/5, shows a fair coating, Figure 14a, and the predicted explosion in the SCB test,

Figure 14b. Estane 5703 was listed simply as a urethane crosslinked rubber binder in this explosive system. This extension of the prediction of the expected reaction of the explosive to rapid heating to other systems is the real breakthrough reported here. The observations and reactions with Comp. A/PE and RDX/Estane indicate that, in the current forms, neither should be an acceptable explosive for Navy use. It is entirely possible that some other method could be found to prepare Comp. A/PE that would produce a good coating and a useful explosive. That is, a waxy, low molecular weight, polyethylene ought to be a good substitute for Class A wax. It may be worth looking for a way to use this material. There is some indication that the procedure of SEM examination of explosives surfaces can be extended to cast main charge PBX systems. This will be the subject of a future report.

One theory to account for the effect of the quality of the surface coating on the response of RDX to rapid heating involves the fact that a certain "run-up" distance is required from the point of initiation for the formation of a detonation wave. Anything that could break up or disperse this growing wave would then serve to prevent or limit the formation of the supported shock wave that is a detonation. Apparently contact or close approach is needed between RDX crystals to provide a run-up path. Thus a good, complete and adherent coating provides this dispersive barrier and prevents contact between crystals of the explosive with the result that a deflagration-to-detonation, DDT, does not occur. Energy absorbing materials such as those containing heavy halogens, sulfate, or nitro (non-explosive) groups should also be effective by removing energy and limiting the formation of the detonation wave. On the other hand, the use of these materials is to be avoided since they also absorb energy from the desired detonation wave established by the fuze/booster initiation. Waxy substances simply behave as inert diluents in the detonation shock wave and still serve as dispersers in the run-up to DDT region.

The successful prediction of the reaction of a pressed explosive to rapid heating by means of a scanning electron microscopic examination of the molding powder suggests that this procedure could be used for quality control in the

production of these systems. The SEM could also be used as a guide in a development program in the formulation of new, safer explosives. The example used here, showing the result of changing the solvent system in the development of the RDX/EVA explosive, is indicative of the guidance and quality control potential of the procedure.

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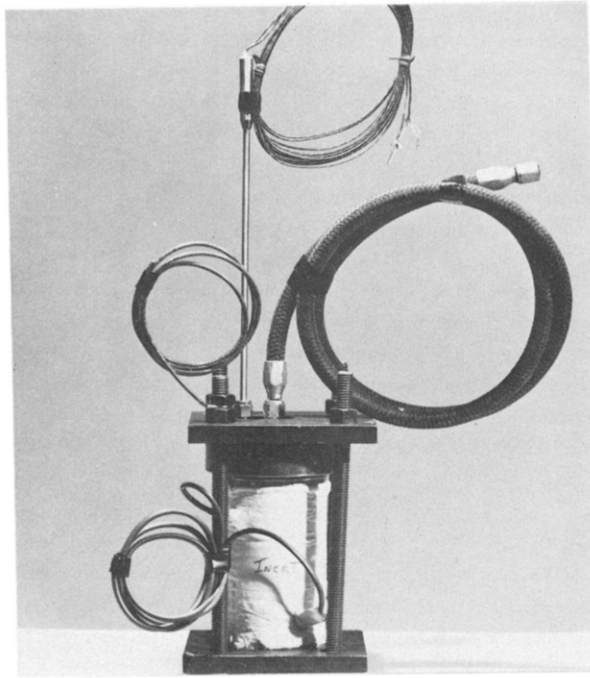


FIGURE 1. SCB TEST FIXTURE.

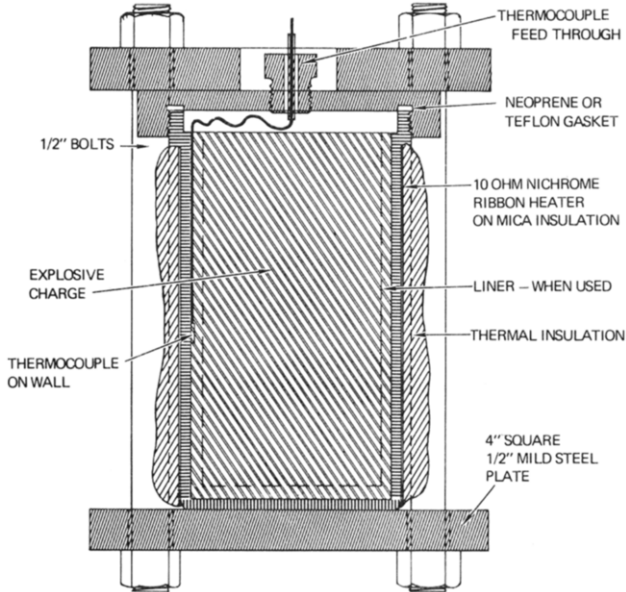


FIGURE 2. CROSS SECTION SKETCH OF SCB.

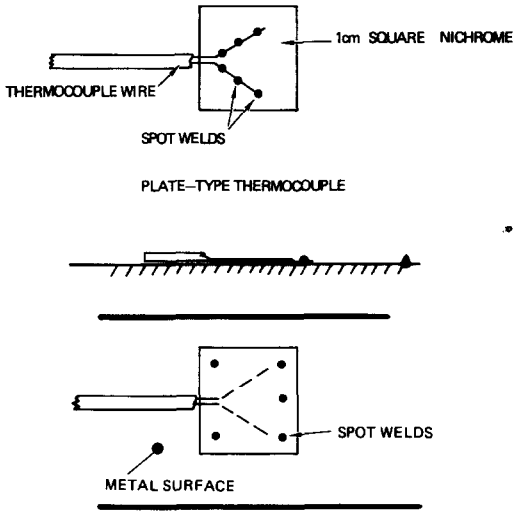


FIGURE 3. APPLICATION OF PLATE TYPE THERMOCOUPLE.

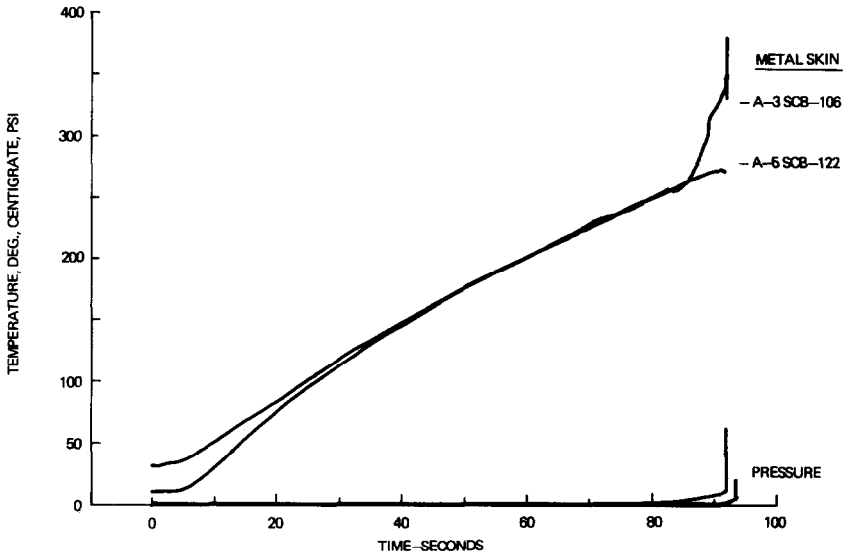


FIGURE 4. SCB FAST COOK-OFF RDX/EVA SYSTEM.

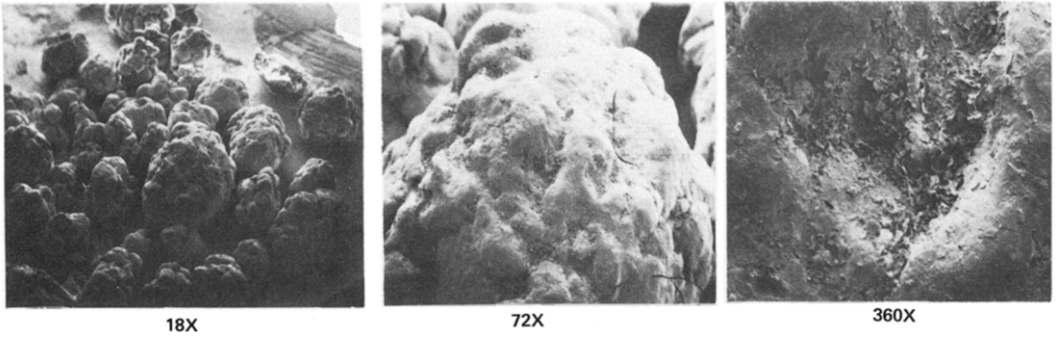


FIGURE 5a. MOLDING POWDER COMP A-3. NOTE: ORIGINALS 9 X 9 CM.

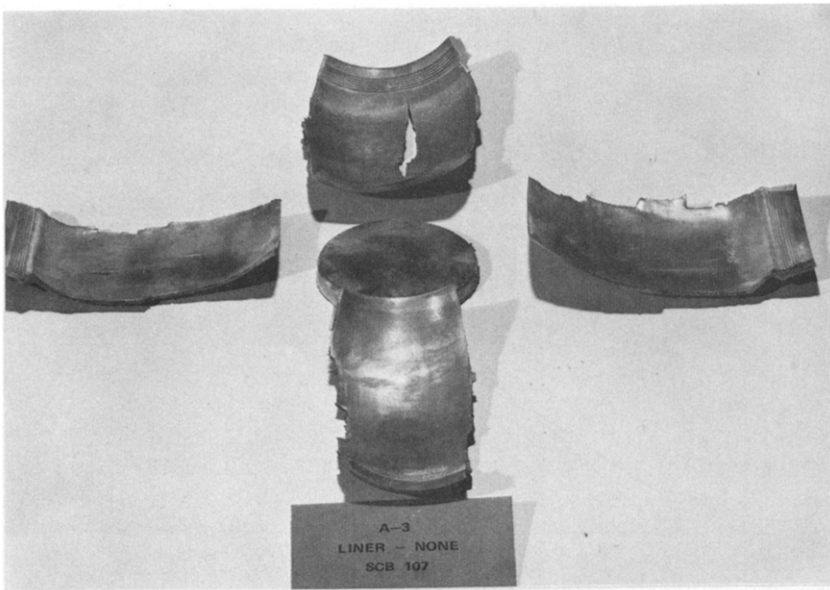


FIGURE 5b. MOLDING POWDER COMP A-3 MILD EXPLOSION.



18X



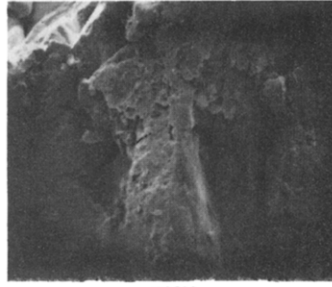
76X



120X



600X



720X

FIGURE 6a. MOLDING POWDER COMP A-5. NOTE: ORIGINALS 9 X 9 CM.

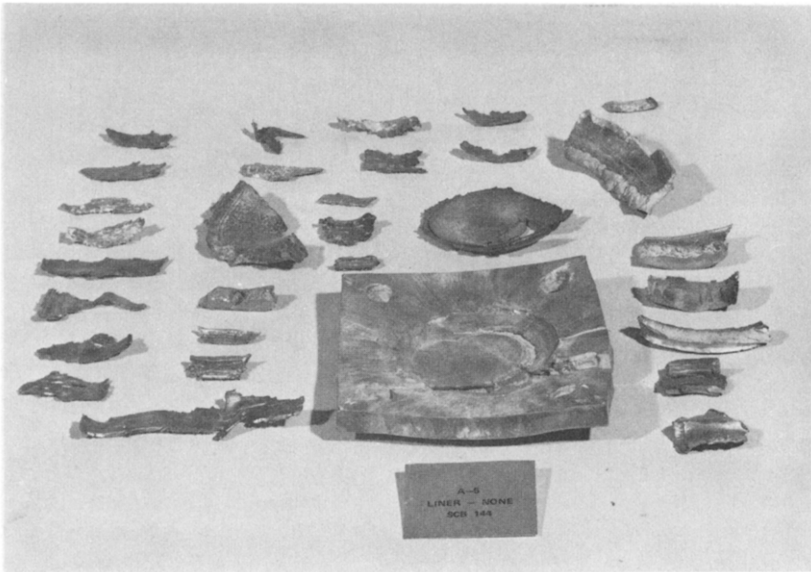


FIGURE 6b. MOLDING POWDER COMP A-5. DETONATION RESULT OF RAPID HEATING.

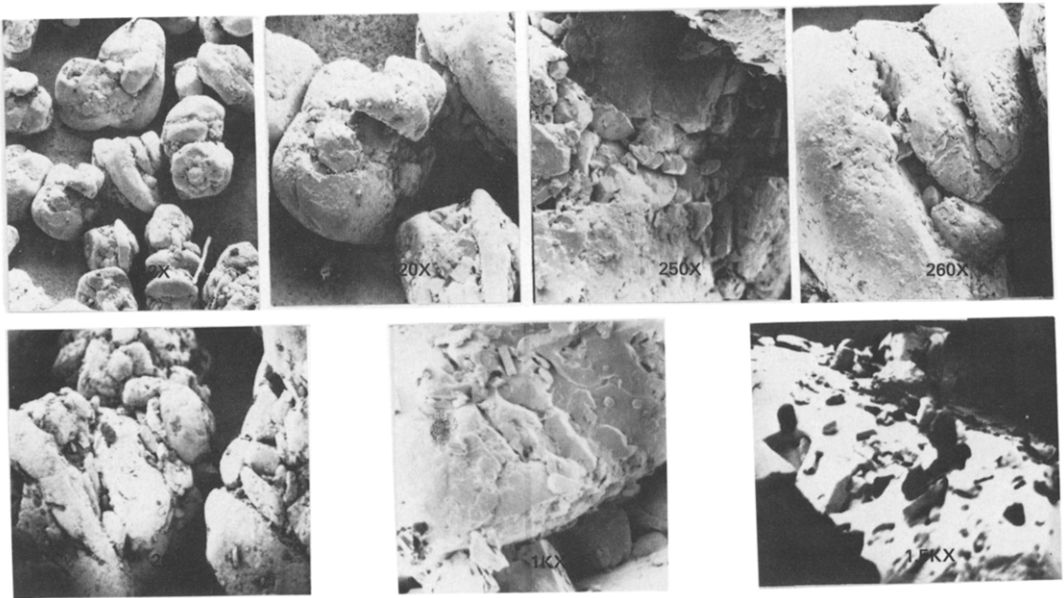


FIGURE 7a. MOLDING POWDER CH-6. NOTE: ORIGINALS 9 X 10 CM.

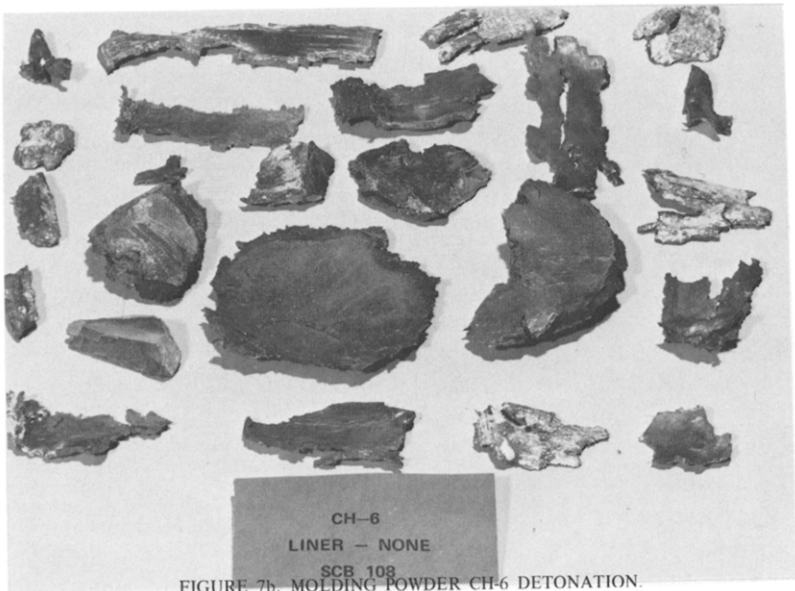


FIGURE 7b. MOLDING POWDER CH-6 DETONATION.

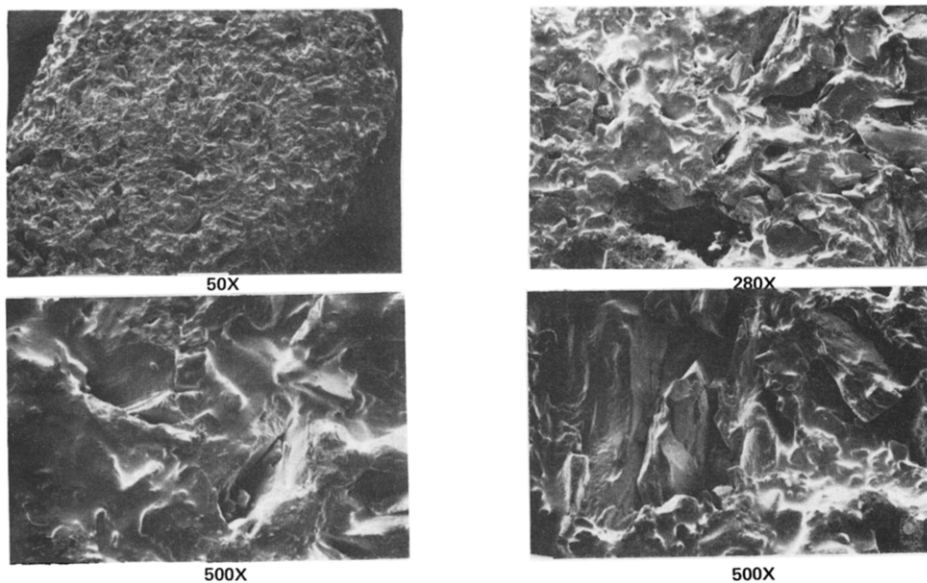


FIGURE 8a. MOLDING POWDER SECTION RDX/EVA A-3 (C₆H₆). NOTE: ORIGINALS 8 X 9 CM.



FIGURE 8b. MOLDING POWDER SECTION RDX/EVA A-3 (C₆H₆) DEFLAGRATION.

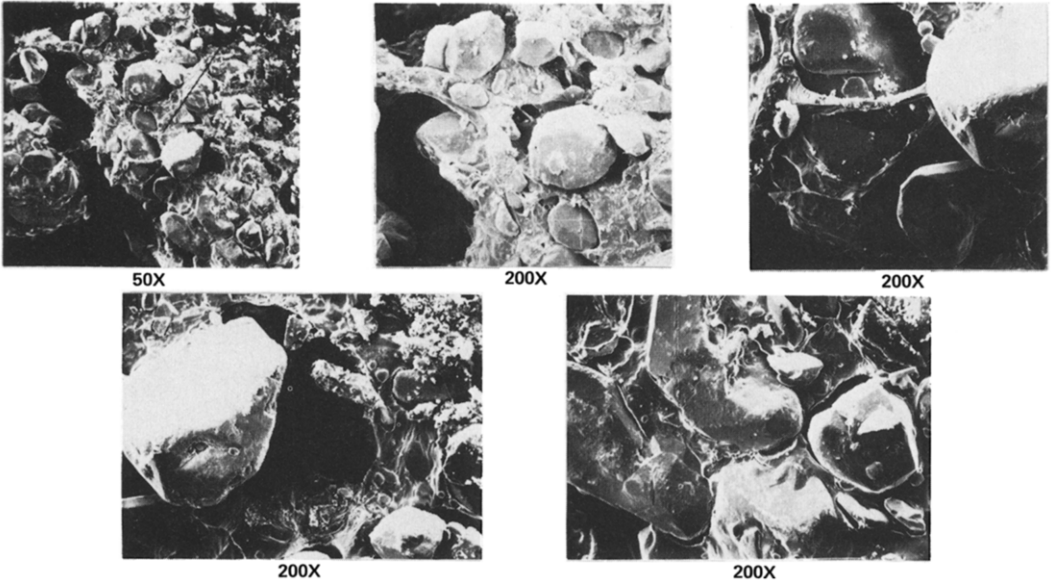


FIGURE 9a. MOLDING POWDER SECTION RDX/EVA, A-3 (THF). NOTE: ORIGINALS 9 X 10 CM.

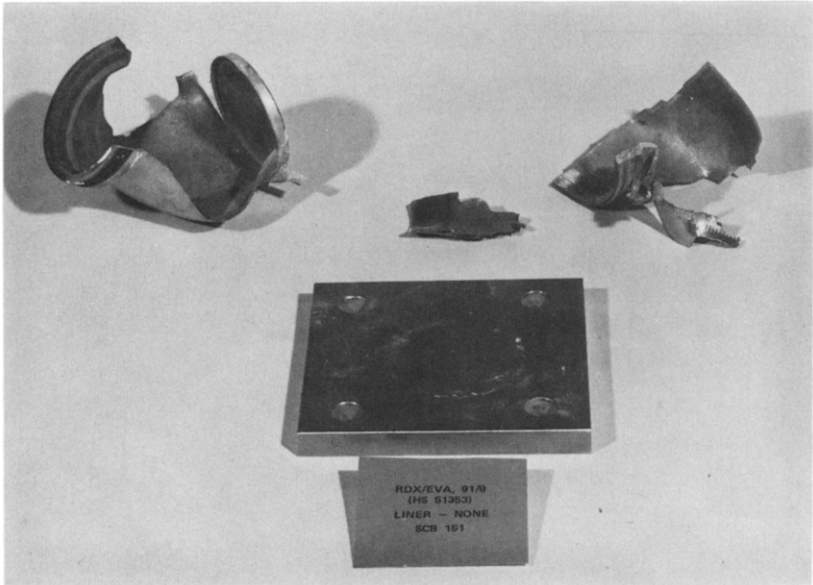
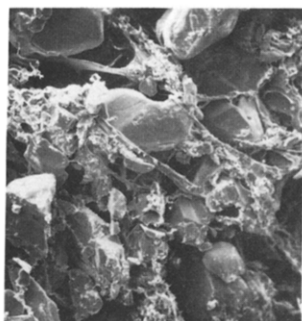


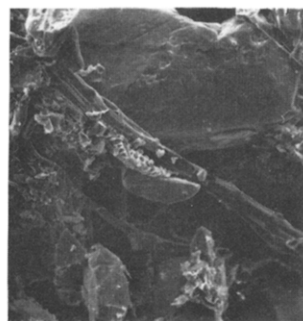
FIGURE 9b. MOLDING POWDER SECTION RDX/EVA, A-3 (THF) EXPLOSION.



50X



200X



500X

FIGURE 10a. MOLDING POWDER SECTION RDX/EVA 95/5 (C_6H_6). NOTE: ORIGINALS 9 X 10 CM.



FIGURE 10b. MOLDING POWDER SECTION RDX/EVA 95/5 (C_6H_6) REACTION.

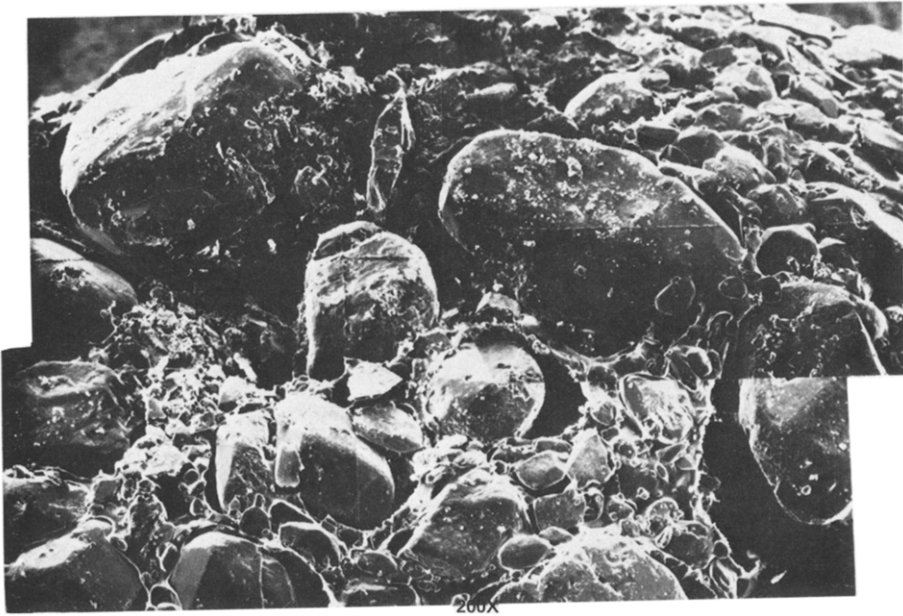


FIGURE 11a. MOLDING POWDER SECTION RDX/EVA, 95/5 (THF). NOTE: ORIGINALS 9 X 10 CM.

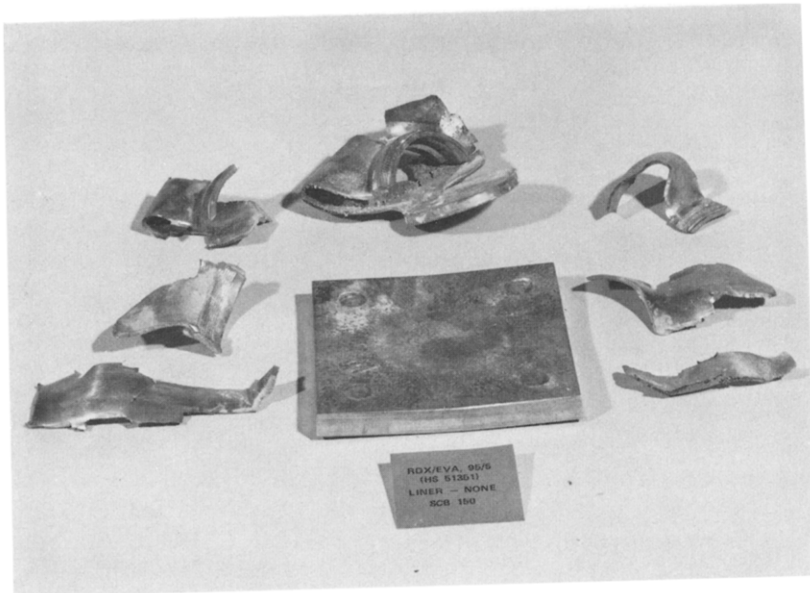


FIGURE 11b. MOLDING POWDER SECTION RDX/EVA, 95/5 (THF) REACTION.

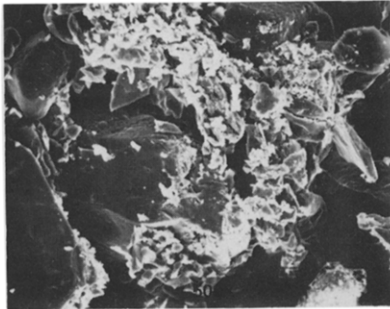
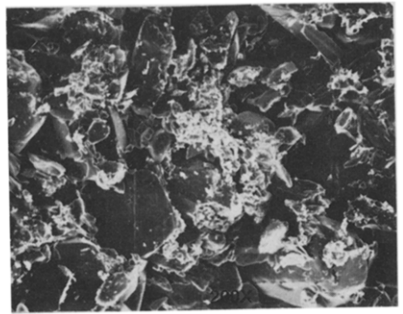
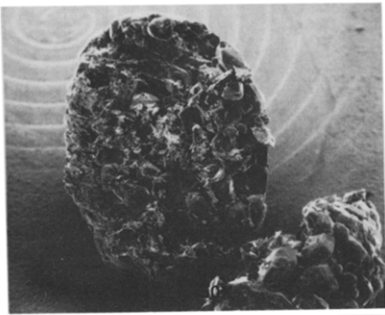


FIGURE 12a. MOLDING POWDER SECTION RDX/EVA A-5. NOTE: ORIGINALS 8 X 9 CM.

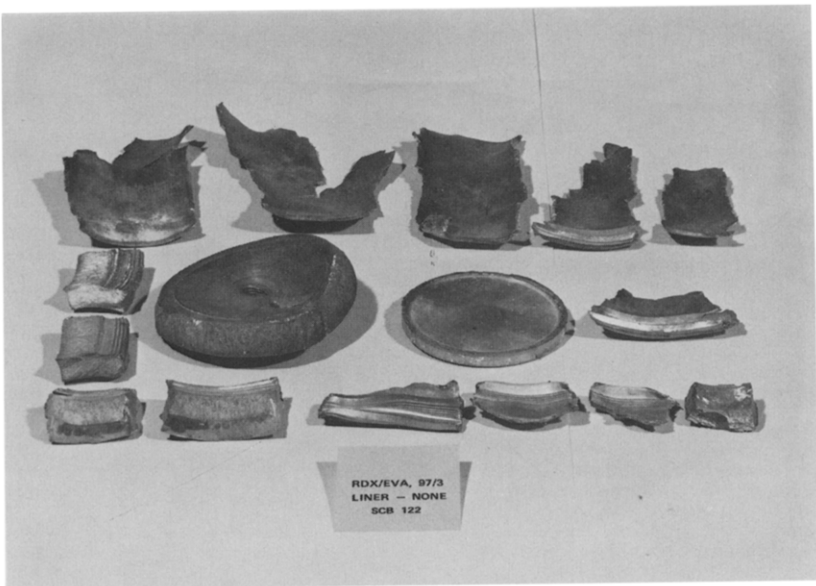


FIGURE 12b. MOLDING POWDER SECTION RDX/EVA A-5 EXPLOSION.

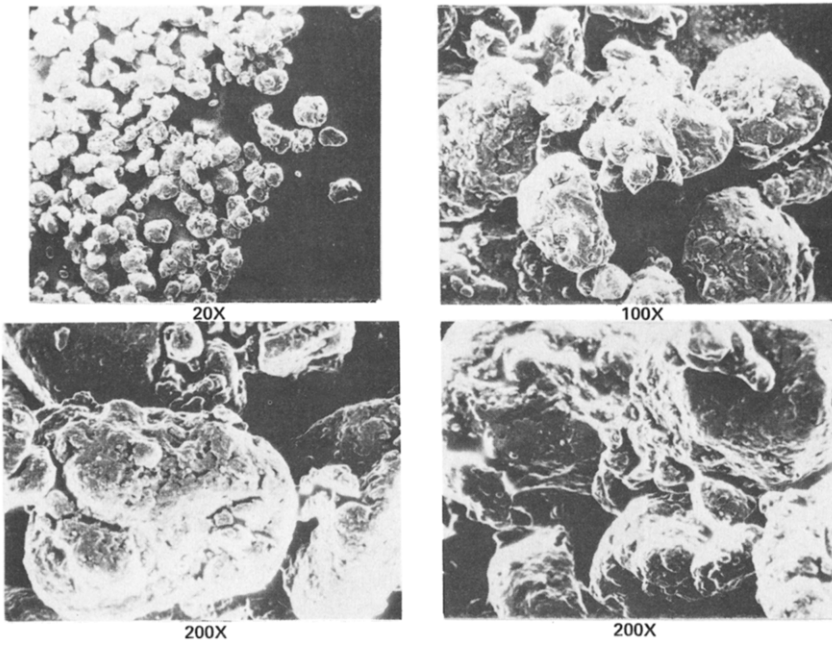


FIGURE 13a. MOLDING POWDER SECTION COMP A/PE. NOTE: ORIGINALS 9 X 10 CM.

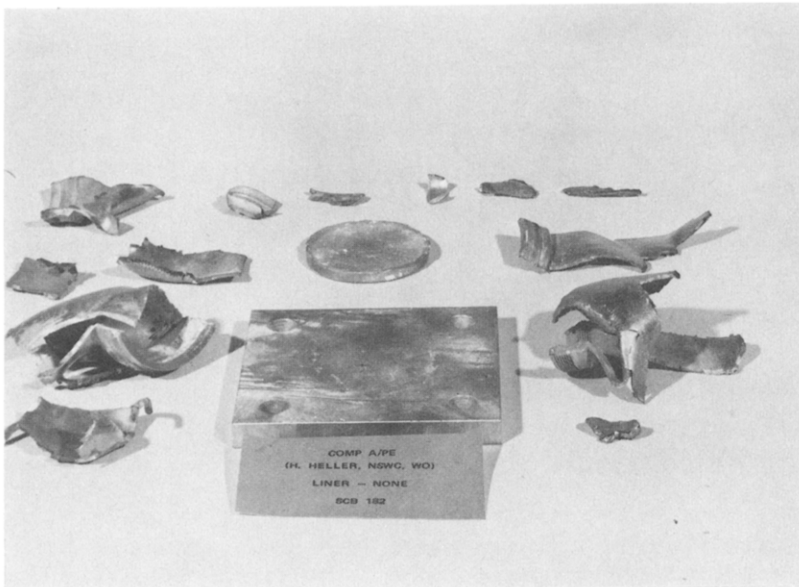


FIGURE 13b. MOLDING POWDER SECTION COMP A/PE EXPLOSION.

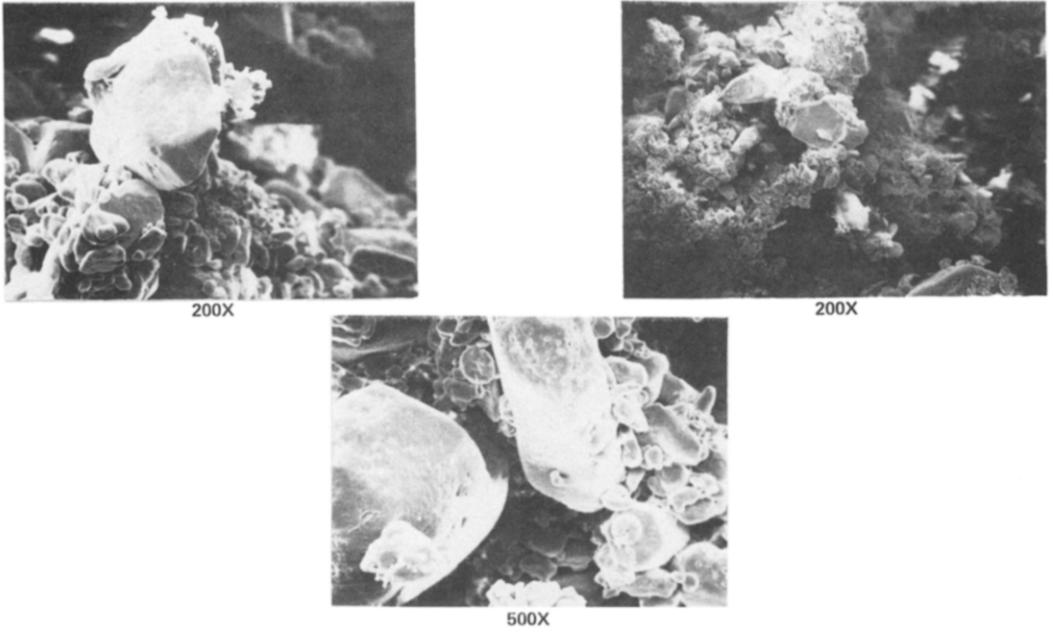


FIGURE 14a. MOLDING POWDER SECTION RDX/ESTANE 5703 95/5. NOTE: ORIGINALS 9 X 10 CM.

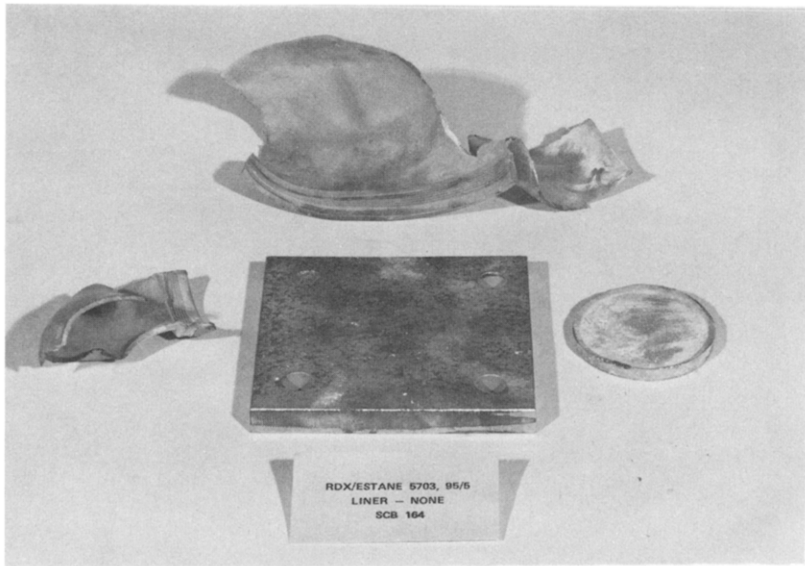


FIGURE 14b. MOLDING POWDER SECTION RDX/ESTANE 5703 95/5 EXPLOSION.