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THE EXPANDED LARGE SCALE GAP TEST

BY T. P. LIDDIARD D. PRICE

RESEARCH AND TECHNOLOGY DEPARTMENT

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NAVAL SURFACE WEAPONS CENTER

Dahlgren, Virginia 22448-5000 • Silver Spring, Maryland 20903-5000

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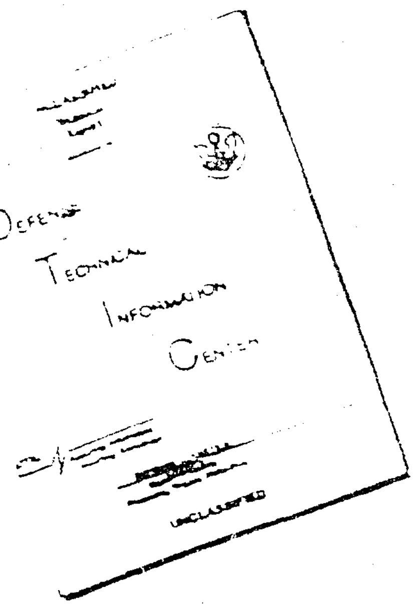

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A gap test with an acceptor diameter and length that are double those of a standard large scale gap test has been developed. A tentative gap-sensitivity relationship between the standard large scale test, normally used ~~at NSWC~~, and the new, expanded size has been obtained. A number of explosive/diluent mixtures were fired in the usual large-scale size to determine the mixtures to be used in the expanded size test. So far, three mixtures have been selected and fired. These were: TATB 40 (% weight)/Teflon 60; TATB 94/Kel-F 6; and TATB 93/HMX 2/Teflon 5. The 50% gap thicknesses in the standard test were 14, 18, and 25 mm, respectively. In the expanded test, the corresponding gap thicknesses were 37.5, 43, and 61 mm.

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FOREWORD

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We gratefully acknowledge the painstaking work of E. Kayser (R16) in making the numerous analyses of the explosive mixtures used in this investigation. Also, we wish to express our appreciation to the personnel of R11 in preparing the acceptor charges and to all those in R12 and R13 who were involved in assembling and firing the charges. Our thanks, too, to J. W. Watt and E. R. Lemar for their part in ordering and obtaining the many non-explosive parts needed for the tests.

Approved by:

KURT F. MUELLER, Head
Energetic Materials Division

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INTRODUCTION

The increased use of very shock insensitive high explosives has produced a need for larger test systems than are normally used for determining gap sensitivities. Relatively little work has been done using acceptor diameters that are larger than 40 or 50 mm. The acceptor diameters in the usual tests are not large enough to give reliable results for the explosives that have large detonation-failure diameters. It follows, then, that the acceptor diameter of the gap test should be substantially larger than the equivalent failure diameter of the acceptor material. If it is otherwise, the gap-test results could be misleading.

The objective of this work is to study a new gap test, designed for relatively shock insensitive explosives, by relating its test results to those of a current standardized test. In particular, we wish to establish the relationship between card gap sensitivities in two sizes, the standard NOL (NSWC) Large Scale Gap Test (LSGT) and the new test, the Expanded Large Scale Gap Test (ELSGT). The LSGT, Figure 1, is fully described in Reference 1 and its calibration in Reference 2. Figure 2 compares it to the ELSGT in which all dimensions of the acceptor system are twice those of the LSGT and those of the donor are nearly twice (1.875).* The witness plate thickness was scaled by 2, but its area was not because of handling problems. The test value is that gap thickness at which the acceptor detonates with a 0.5 probability. This value is called the 50% gap, or the gap sensitivity.

In planning the ELSGT program, four compositions were to be selected for investigation. The four compositions would be shot in both the LSGT and ELSGT sizes. Two of the compositions would have 50% gap values that are greater than 70 cards in the LSGT and two would have gap values below 70 cards. (The thickness of one card is 0.254 mm). Presumably, the range of gap thickness would be near 120 cards maximum and 30 cards minimum.

*The best choice of available molds offered by the manufacturer.

DATA FOR SELECTION OF EXPLOSIVE MIXTURES

During the course of the investigation, fifteen different explosive mixtures were prepared and fired. (Two of the mixtures were nearly identical, differing only slightly in HMX content.) Except for the mixtures chosen for the ELSGT series, small batches were prepared, usually sufficient for four LSGT charges. Several mixtures were prepared but discarded because of compaction or mixing difficulties. The explosive and inert components used in the investigation are listed in Table 1, along with their theoretical maximum densities (TMD's). The proportions, by weight, of the mixtures actually used are listed in Table 2, together with their TMD's and mean experimental densities. The percentages of the components contained in the various mixtures were obtained by analysis at NSWC by E. Kayser (R16). The percentages listed in Table 2 are the mean values of several samples taken at random from various regions throughout a given mixture.

RDX/WAX (OR TEFLON) MIXTURES

The first mixtures to be fired were combinations of RDX and carnauba wax. These two components were chosen because of their low cost and because they were readily available. At the time, our hope was that one base explosive could be used to obtain some, if not all, of the four explosive mixtures needed to complete the investigation. The RDX/wax results were disappointing. As indicated in Table 3, the 50% gap thickness for RDX 48/wax 52 lies somewhere between 200 and 250 cards (51-64 mm). The mixture was much too sensitive to be used in this investigation. The gap sensitivity of RDX 22/wax 78 is seen in Table 3 to be greater than 100 cards (25 mm). Thus, charges composed of RDX/wax must contain very large proportions of wax in order to fall in the desired sensitivity range. A very high wax content leads to charges of low density; the low density and the relatively small amount of explosive contained in the charges produce fairly low detonation pressures. In turn, the low stresses developed in witness plates fail to punch out holes that are typical of a go. The density problem was solved by replacing wax with Teflon 7C powder. However, RDX diluted with 70% Teflon was still very sensitive to shock compression, lying between 220 and 250 cards (56-64 mm). This result prompted us to seek a much less sensitive explosive for a base material.

INSENSITIVE EXPLOSIVES IN LSGT LITERATURE

A number of explosives other than those listed in Table 2 were considered for use in this study largely on the basis of published LSGT results. On looking over the explosives listed in Reference 1, it is seen that the critical gap thickness of relatively few fall in the range of interest. The most promising explosives obtained from the list are given in Table 4, along with the loading densities, %TMD's, and critical gap thicknesses in cards.

All of those listed in the table, except TATB, were rejected for one reason or another as indicated below.

Ammonium perchlorate (AP) and its wax mixtures have large critical diameters which lead to detonation failure at zero gap in the LSGT at densities considerably below the TMD values, i.e., 80-90% TMD. Nitroguanidine (NQ) shows similar behavior, approaching failure at a little above 90% TMD. It is evident that small differences in the loading densities of these explosives, at somewhat less than their failure densities, result in large differences in critical gaps. Also, the relatively low densities of AP and NQ charges would probably result in detonation pressures that are too low to punch out reasonably clear-cut holes in witness plates.

In regard to cast dinitrobenzene (DNB) and TNT, it is difficult to obtain uniform charges using these explosives. Although isostatically pressed charges usually are very uniform in density and in distribution of voids, they are much more shock sensitive than are the corresponding cast charges. Another negative aspect of DNB and TNT is that they are apt to develop metastable detonation velocities that could confuse LSGT results unless special instrumentation is used, e.g., detonation velocity probes.

As to pressed dinitrotoluene (DNT), it was unavailable in fine-grain powder from commercial sources. In order to produce reasonably small-grain material, the DNT would have had to be recrystallized. This process would have added considerably to the cost of preparing charges and to the time taken for their preparation.

It is quite possible that certain blends of the explosives listed in Table 4, with or without binders or diluents, might have had test values within the range of interest. However, the search for such formulations lies well beyond the scope of this investigation. The foregoing considerations and the RDX results led us to the investigation of TATB as a base material. Although TATB is relatively expensive, its gap sensitivity, at fairly high density, lies near the middle of the range of interest.

THE TATB/KEL-F MIXTURE

One source of TATB was immediately available to us in compacted, composite form. The material, containing Kel-F, had been in storage at NSWC for a number of years. Before that, it had been recovered in chunks from a warhead which failed to detonate, or burn, in a test conducted at Eglin AFB. Since no other information was available concerning this material, a percentage weight analysis was made at NSWC. As listed in Table 2, the analysis showed that it contained 93.7 ± 0.3% TATB and 6.3 ± 0.3% Kel-F. The material could very well have been nominally PBX 9502 (TATB 95/Kel-F 5) or LX-17-0 (TATB 92.5/Kel-F 7.5).

TATB/TEFLON MIXTURES

The threshold gap thickness of five TATB/Teflon mixtures in the LSGT were obtained; the Teflon content ranged from 10 to 64%. The results, listed in Table 3, are shown in Figure 3 as a plot of 50% gap versus %Teflon. Although

TATB is a very insensitive explosive, it is seen that at least 60% Teflon is required to achieve a threshold of 50 cards. It is evident from the trend in the data that the negative slope of the curve in Figure 3 becomes quite steep as the %Teflon value at zero gap is approached. It is likely, therefore, that a TATB/Teflon mixture approaching a sensitivity of 30 cards, or perhaps 40 cards, would not give very reproducible results. To prepare uniform mixtures with critical gaps much below 50 cards, the blending of the components would have to be held to very close tolerance of their proportions.

TATB/TEFLON/HMX MIXTURES

In Table 3, it is seen that TATB mixtures containing only Teflon or Kel-F binders have 50% gaps that are less than 80 cards. Because of this, HMX was added to TATB/Teflon mixtures to increase the 50% gap to above 80 cards. The 50% gap sensitivity as a function of %HMX added to TATB, with several percent binder, is given in Figure 4. It is seen that large positive slopes are obtained from the curve at small percentages of HMX. (The steep slope was also found in LANL gap test values of TATB/HMX mixtures.[3]) Thus, to obtain a test value of about 100 cards, it is necessary to add only 2% HMX to the TATB/Teflon. However, the mixture must be very uniform throughout since a 0.1% change in a 2% HMX mixture produces approximately a one-card change in the 50% gap value.

THE ELSGT/LSGT CHARGES

Three mixtures were chosen for the ELSGT/LSGT comparison study. These three were: TATB 94/Kel-F 6, TATB 40/Teflon 60, and TATB 93/HMX 2/Teflon 5. (Note, the percentages, by weight, given in Table 2 to one decimal place, are rounded off in Table 3.) As previously stated, the TATB/Kel-F mixture was obtained already compacted. The TATB contained in the other two mixtures was from both old and new stock. As given in Table 1, the surface areas of the two TATB powders were the same within the error of analysis. The new TATB stock was marked as being Class 1 and, very likely, the old stock also was Class 1. The HMX, designated as Class 5 (formerly Class E), was in the form of extremely fine powder; see Table 1. The Teflon 7C material was composed of very fine crystals. The TMD of this polymeric material, assumed to be entirely crystalline, is 2.305 g/cm^3. (When sintered, the crystalline structure changes to an amorphous state, drastically lowering the TMD.)

BLENDING, PRESSING, AND MACHINING

The mixtures were prepared in 7-kg (15-lb) batches. In each batch, about 20 liters of water were added to the explosive and Teflon powders. The slurry was stirred for four hours by a high-speed, lightning mixer. Then, the slurried mixture was decanted and dried. Samples were taken at random throughout each of several of the batches prepared first. If acceptable after analyses were made, the batches were set aside for the final blending of all 6-8 batches making up one composition. Unfortunately, some of the batches had to be slurried and stirred again. This was the case especially with the 2% HMX mixture where extreme uniformity of mixing was required. After six batches of the TATB 40/Teflon 60 mixture were prepared (eight for TATB 93/HMX 2/Teflon 5), they were tumble-blended together for one or two hours in a 208-liter (55-gal) drum. The drum had fins attached to the inside surface to facilitate blending and also a Teflon coating to reduce the adhesion of powder. Finally, an analysis was made of samples taken at random throughout the combined batches of each composition.

The isostatic pressing and the machining of TATB/Teflon mixture were carried out at NSWC by R11 personnel. Densities exceeding 95% TMD were attained without heating the hydraulic medium (water 95/soluble oil 5) in the press. THe reasonably high densities were reached by three applications of pressure: the first at 700 kg/cm^2 (10,000 psi), held for 5 minutes; the second at 1400 kg/cm^2, held for 10 minutes; and the third at 2100 kg/cm^2, held for 15 minutes. Prior to pressing, the air pressure in the rubber boot containing the explosive mixture was reduced to ~50 mm of Hg. When removed from the press, the pressing usually was very uneven over its surface. A wad of cotton, located at the plugged end of the boot, decreased the mold capacity. As a consequence of this and of the rough surface to be smoothed by machining, there was a considerable loss of material. To obtain a sufficient number of charges, the machining scraps were recovered and re-pressed. Especially in the case of the compacted TATB 94/Kel 6, there was a considerable amount of waste produced in machining the chunks of explosive to the desired sizes.

ELSGT/LSGT ACCEPTOR ASSEMBLIES

All of the LSGT acceptors were in one, 140 mm (5.50 inch) long piece and were made up entirely of the original pressed material, except for four TATB/Kel-F acceptors composed of re-pressed material. The ELSGT acceptors containing Teflon were made up of two 140 mm long sections since the pressings removed from the boot were too short to obtain the desired length of 279 mm. All of the sections made up of original pressings were placed next to the PMMA in the complete acceptor assembly. The sections formed from re-pressed machinings were placed farthest from the gap in order to have the least effect on any build-up of detonation. It is reasonable to expect that if a build-up occurred at the 50% gap thickness, it would have done so by the time the reaction wave traveled half-way down the acceptor. It is possible that build-up distances exceeding one-half the acceptor length can occur. It is doubtful, though, that any significant change in the 50% gap value would be obtained if a slightly more sensitive, or insensitive, explosive medium were traversed in the last portion of the acceptor. (A series of LSGT shots of re-pressed TATB/Teflon was fired to determine any change in gap sensitivity that might occur due to the use of re-worked material. It is seen in Series 4, Table 3 that the originally pressed material had a 50% gap of 67-73 cards, whereas the re-pressed material had a 50% gap of 62-64 cards; Series 5, Table 3. Although a measurable difference in sensitivity appears to exist on the basis of four shots, the difference is not very much, thus supporting our use of the re-pressed explosive in the far end of the acceptor in the ELSGT study.)

The ELSGT, TATB/Kel-F acceptors were made up of two or three cylindrical sections. The length of those machined from the original compacted material depended on the size and shape of available chunks of explosive. Results of the ELSGT appear in Table 5. In all of the acceptors in the TATB 40/Teflon 60 ELSGT series, No. 2 in Table 5, at least the upper half of the acceptor was composed of the original pressed material. Only two of the TATB/HMX/Teflon acceptors contained re-pressed material. As in the case of all the other assemblies involving machining scraps, the re-pressed section was placed farthest from the gap.

COMPLETE TEST ASSEMBLIES

Both of the ELSGT and LSGT donor charges were composed of prilled, 50/50 pentolite. The charges, pressed to a density of 1.56 ± 0.01 g/cm^3, were obtained from Chemtronics, Inc., Swannanoa, North Carolina. Nominally, the LSGT donors were 50.8 mm (2.00 inches) in diameter by 50.8 mm thick, consisting of two equal sections. The ELSGT donors were 95.3 mm (3.75 inches) in diameter and 95.3 mm thick, also consisting of two equally thick sections.

In the ELSGT shots, only J-2 blasting caps were used to set off the donors. In the LSGT shots, both J-2 caps and RP-80 detonators were used. The RP-80 is preferred over the J-2 from a safety standpoint since it is an exploding bridgewire detonator containing PETN rather than a primary explosive. However, its high voltage pulse requirement makes it less convenient to use in the field. (Although not necessary for use in the LSGT, the RP-80 is extremely reproducible in firing time. Therefore, it is used as an initiator in most of our other experimental work requiring close synchronization to cameras and electronic equipment.) On the basis of this work, there appears to be no significant difference in the results obtained by J-2 and RP-80 detonators.

The main gap components were cut from 50.8 mm diameter (LSGT) and 95.3 mm diameter (ELSGT), cast polymethyl methacrylate (PMMA) rod stock, 1.185 g/cm^3. The gaps were made up of combinations of various component thicknesses. For both the LSGT and ELSGT, the available gap-component thicknesses were 50.8, 25.4, 12.7, 6.35, and 2.54 mm. The 50.8 mm thickness was not needed in the LSGT shots. When necessary, circular layers of 0.25 mm or 0.51 mm thick cellulose acetate were added to build the gap up to the desired thickness. The acetate substitute for PMMA has been determined to have a negligible effect on LSGT results.[4] However, no more acetate layers than necessary were used in the gap.

The ELSGT and LSGT acceptors were machined to a diameter that was just small enough to enable them to slide into their confining tubes of cold-drawn, mild steel. In some cases, though, chilling the acceptor was necessary to permit a slip fit into the tubes. The tubes were cut from seamless tubing; the ends were machined to ± 0.25 mm of the desired length. Nominally, for the LSGT the tubes were 140 mm (5.50 inches) long, 36.5 mm (1.435 inches) inner diameter and 47.6 mm (1.875 inches) outer diameter. For the 279 mm (11.00 inch) long, ELSGT tube, the inner and outer diameters were 73.2 mm (2.880 inches) and 95.3 mm (3.75 inches), respectively. Hence, the ELSGT acceptor confinement, as well as the acceptor, was scaled by a factor of two.

The dimensions of the cold-rolled, mild-steel, LSGT witness plates were nominally 152 x 152 x 9.5 mm (6.00 x 6.00 x 0.375 inches). For the ELSGT witness plates, they were 203 x 203 x 19.1 mm (8.00 x 8.00 x 0.75 inches). These witness plates were scaled in thickness, but not in width. The acceptor was air-spaced 1.6 mm (LSGT) and 3.2 mm (ELSGT) from the witness plate in the test set-up. The witness plate was placed over a container of water, but not in direct contact with the water, to reduce irrelevant damage and make recovery of the plate easier.

TEST FIRING AND RESULTS

All of the standard tests (LSGT) were conducted within firing chambers at NSWC, White Oak. The charges were fired inside a steel cylinder, made from a 16 inch gun barrel, to protect the chamber walls. The ELSGT charges were fired at the open-air site used by NSWC, Fort A. P. Hill, Bowling Green, Virginia. As circumstances warranted, a modified version of the Bruceton up-and-down technique was followed for determining the 50% gap thickness. In the modified procedure described in Reference 1, twelve charges are usually required to establish a 50% gap thickness adequately; actually, twelve or thirteen charges were fired in the three LSGT series for comparison with the ELSGT series of this investigation.

In the ELSGT Series No. 1, twelve TATB 94/Kel-F 6 shots were fired. However, in the ELSGT Series No. 2, only nine TATB 40/Teflon 60 shots were fired. This number of shots was the result of the loss of more material than expected in the machining operation and in the recovery of machining scraps. In the ELSGT Series No. 3, involving TATB 93/HMX 2/Teflon 5, the 50% gap thickness was determined in ten shots. In that series, the four remaining 140 mm long acceptor sections were held for a possible conversion to four LSGT acceptors. (More LSGT charges of TATB 93/HMX 2/Teflon 5 may be fired in the future, if and when the opportunity arises, to reduce the spread in the LSGT 50% gap value.) The worst charges, such as those with the highest or lowest densities, the largest re-pressed sections, or the most flaws, were fired first. Thus, the best charges were fired toward the end of the series where the greatest reproducibility was required.

LSGT WITNESS PLATE DAMAGE

When detonation occurred in the LSGT series, a hole was punched through the plate and the steel tube was broken up into small, high-velocity fragments. The LSGT plates cracked in many cases and a few broke up. When failure occurred, only a minor dent or bend was produced in the plate and damage to the tube ranged from flaring at the PMMA end to a break-up of the tube into several large pieces.

The front and rear views of a recovered LSGT witness plate, indicating a <u>go</u> with a cleanly punched-out hole, are shown in Figure 5. Front (top in the figure) and back contours were obtained from the plates, over the middle and parallel to an edge. An example of a typical cross-section, constructed from front and rear contours, is shown in Figure 6. Also shown is the bend of a non-perforated plate, traced from corner to corner along an outer edge. A similar bend existed at the middle.

Eight of the thirteen witness plates recovered from the LSGT, TATB 94/Kel-F 6 series indicate a <u>go</u>; all eight plates showed cleanly formed holes.

Seven of the plates showed little or no cracking, but the remaining plate was almost broken in two pieces. That plate probably struck a surrounding steel surface or it may have been defective.

The holes punched through the plates in the TATB 93/HMX 2/Teflon 5 series were not quite as clean as they were in the TATB 94/Kel-F 6 series. In addition, cracking occurred in all eight of the holed plates; three of the plates were broken into two or three pieces. In the TATB 40/Teflon 60 series, two of the plates were shattered into 6-7 pieces, as in Figure 7; one broke in half; and the remaining three sustained no cracks of any importance. The holes in all of the plates were somewhat jagged around the inside perimeter, as in Figure 8.

As seen in Table 6, the largest witness-plate holes were produced in the TATB 93/HMX 2/Teflon 5 series. They were slightly larger than the holes produced in the TATB 94/Kel-F 6 series; i.e., Dimension A = 56 ± 1 mm, as compared to 54 ± 1 mm. This is not surprising since a small amount of HMX can contribute significantly to the stress produced in the witness plate. In the TATB 40/Teflon 60 series, holes were only 43 ± 2 mm in diameter. This, too, is not surprising since the high dilution of TATB with Teflon greatly reduces the stress produced in the plate.

Note that the most reproducible measurements of Dimensions C and D occurred in the TATB 94/Kel-F 6 series. The relatively poor reproducibility of the C and D measurements in the TATB 93/HMX 2/Teflon 5 series may be due to slight variations in HMX content. (Figure 4 shows that at low %HMX, a small change in HMX content produces a relatively large change in 50% gap thickness. A similar sensitivity to HMX variation may exist for detonation pressure.) As one might expect, the reproducibility of C and D in the TATB 40/Teflon 60 series was not nearly as good as it was in the TATB 94/Kel-F 6 series due to the high dilution of the TATB.

In regard to the witness plates for which no detonation occurred, depth of bend measurements were made at the center and at the edge. For any particular plate, the depth of bend along an edge (Dimension D) was essentially the same as the depth taken at the center (Dimension E) from a straight-edge placed across the plate, parallel to an edge. All measurements made on any one plate, four at the edges and two at the center, showed negligible variation. The depth of bend measurements are given along with the hole measurements in Table 6. For all of the no-go plates in the three LSGT series of shots, corresponding to the three ELSGT series of shots, the mean depth of bend at the edge was 0.5 ± 0.3 mm (standard deviation of the mean). At the center, it was 0.6 ± 0.5 mm. The least amount of bending occurred in the TATB 94/Kel-F 6 series, being 0.2 ± 0.1 mm at both the edge and the center. In the TATB 93/HMX 2/Teflon 5 series, the depth of bend was 0.6 ± 0.4 mm at the edge and 0.8 ± 0.5 mm at the center. In the TATB 40/Teflon 60 series, it was 0.7 ± 0.2 mm and 0.8 ± 0.5 mm, respectively.

No definite correlation between the depth of bend and the vigor of sub-detonation reaction was detected. However, one shot (No. LS-62) showed a 4 mm deep dent at the center and a bend of 1.6 mm at the edge. The dent was superposed on the general bend of the plate. In addition, a gas-flow pattern was left in the region of the dent. This was the only plate showing such a result. It is apparent that detonation was nearly attained in this instance.

LSGT TUBE DAMAGE - STRENGTH OF REACTION

In general, the condition of the recovered steel tube, or its fragments, is more indicative of the vigor of chemical reaction than is the depth of bend. Obviously, the sub-detonation reaction is much less vigorous when the tube is flared and cracked, as in Figure 9, than it is when the tube is broken into pieces, as in Figure 10. Where available, an estimate of the degree of chemical reaction developed in the acceptor was obained from the recovered tube, or its fragments. Six estimated levels of reaction, along with a corresponding description of tube damage, are listed at the bottom of Table 3. The shots producing these results are identified by the superscript letters, a through f, placed at the right end of NO GO in the RESULT column. Unfortunately, in all of the no-go shots included in Series 10, 11, 12, and 13, the tubes, or tube fragments, were not recovered and set aside after each shot, although the witness plates were. As a consequence, it is impossible to estimate the strength of any sub-detonation reactions that occurred. Those shots are identified by the superscript, g, in Table 3.

One might think that by knowing the degree of reaction produced at a given gap thickness, one could find the 50% gap value more readily than if a strictly go, no-go criterion were used. However, it appears that, in practice, the variation in results obtained from shot to shot, at a given gap thickness, is large enough to eliminate this possibility. In spite of this, the information obtained from the no-go plates and tubes is included here for possible interest to others engaged in similar investigations.

Although considerable variation occurred in plate and tube damage within the three principal LSGT series of shots, there were no cases in which the occurrence of detonation was really questionable; either an obvious go occurred or it did not.

ELSGT WITNESS PLATE DAMAGE

When detonation occurred in the three ELSGT series, the plates were broken into 2 - 7 pieces, usually into 4 or 5 unequal pieces. The cleanest, punched-out holes were obtained in the TATB 94/Kel-F 6 series. An example is shown in Figure 11. In the TATB 93/HMX 2/Teflon 5 series, the holes were not so well formed. In the TATB 40/Teflon 60 series, some steel remained attached at several places around the bottom of the hole, as shown in Figure 12. In the latter series, the damage to the plate was essentially the same for the 135 card gap as it was for the gaps in the 50% gap thickness range (145-150). Thus, there is no doubt that detonation occurred in the highly diluted TATB in spite of the uneven punch out. With some explosives, such as the low-density RDX 22/wax 78 mixture, LSGT Series No. 2, a deep dent was produced in the plate, along with cracking and spalling, rather than a punched-out hole. Undoubtedly, detonation occurred in that series, but it produced insufficient stresses for punching out a hole. (With explosives, such as DNB and TNT, a more refined means of detonation detection probably would have to be used, e.g., probes in the acceptor to measure detonation velocity.)

The hole diameters were obtained from the ELSGT plates by holding the broken sections together while making measurements. Although the fragments did not fit exactly in most cases, the gaps left between fragments were small (±1 mm) and measurements could be made with only a minor correction for the gaps. The ELSGT results, given below those shown for the LSGT plates in Table 6, show that the Dimensions A and B scale and are twice the values listed for the LSGT plates. Dimensions C, D, and E were not measured since the plates were shattered but they would not be expected to scale in any case because of unscaled plate dimensions. From an examination of the plate fragments, it was seen that, in general, more bending of the plates occurred in the TATB 40/Teflon 60 and TATB 93/HMX 2/Teflon 5 series than occurred in the TATB 94/Kel-F 6 series. This result is qualitatively the same as that obtained for the three corresponding LSGT series of shots.

The 16 recovered ELSGT witness plates, for which no detonation occurred, showed a consistent amount of bending. The depth of bend along an edge was 1.5 ± 0.3 mm and 1.9 ± 0.4 mm across the middle, parallel to an edge. The greatest amount of bending occurred in the TATB 94/Kel-F 6 series with a mean depth of 1.7 ± 0.2 mm along the edge and 2.1 ± 0.4 mm at the center. The depth for the TATB 93/HMX 2/Teflon 5 series was 1.4 ± 0.2 mm at the edge and 1.7 ± 0.2 mm at the center. For the TATB 40/Teflon 60 series, it was 1.4 ± 0.3 mm and 1.8 ± 0.5 mm, respectively. In any case, the differences in the depth of bend do not appear to be very significant. As in the LSGT series of shots, more can be learned concerning the degree of reaction by examining the recovered steel tube or its fragments.

ELSGT TUBE DAMAGE - STRENGTH OF REACTION

The condition of the recovered ELSGT tubes, or tube fragments, and an estimate of the level of reaction in the acceptor is given in Table 5. Four levels of reaction are indicated by the letters, a, b, c, and d, defined at the bottom of the table. In eight of the sixteen no-go shots, the gap end of the tube was flared but not cracked; examples are shown in Figure 13. Most of the explosive remained intact with little, if any, chemical reaction occurring. The eight shots producing these results are identified by the superscript a after NO-GO in the RESULT column. Level a was found in all five of the TATB 93/HMX 2/Teflon 5 shots; in two of the five TATB 94/Kel-F 6 shots; and in only one of the six TATB 40/Teflon 60 shots. In two of the TATB 94/Kel-F 6 no-go shots, the tube was both flared and cracked. Some reaction occurred, but much of the explosive remained intact. The two shots with their results are identified by the superscript b in the table. In four of the TATB 40/ Teflon 60 shots, the tube was petaled, Figure 14, or petaled with some parts broken off. The reaction in these shots, identified by superscript c, was moderate with some explosive left unburned. Only two shots, identified by superscript d, showed violent reaction. One was in the TATB 94/Kel-F 6 series and the other was in the TATB 40/Teflon 60 series. At this level of reaction, the tube is violently broken into several fragments. In spite of the violence of reaction, the plates showed only minor bending.

ELSGT AND LSGT 50% GAP THICKNESSES

The results of the LSGT firings are given in Table 3 under Series Nos. 4, 10, 14, and 15. (Series Nos. 14 and 15 are combined since the difference between the two mixtures is very small.) The results of the ELSGT firings are given in Table 5. The apparent difference in the results shown for TATB 94/ Kel-F 6, Series No. 4, Table 3, i.e., 67-68 cards using RP-80 detonators and 70-73 cards using the J-2 blasting caps, probably is due to density variations. In particular, the charges in Shot Nos. LS-09 and LS-26, having gap values of 70 and 68 cards, were of significantly higher density than the mean density of all the charges in the series. Therefore, the acceptor in either or both of these shots might have detonated if the density had been nearer the mean. Both J-2 and RP-80 detonators also were used in LSGT Series No. 10. As seen in Table 3, no effect on the 50% gap value is apparent. However, the experiments were not designed to compare the two detonators; a valid comparison of the RP-80 and the J-2 would require more extensive testing.

A comparison of the ELSGT and LSGT 50% gap thicknesses, in cards, is given in Table 7, along with the mean density of the acceptor charges for each series. Also included in the table are the LSGT and ELSGT 50% gap thicknesses for the cast Atex, a proprietary explosive developed by Aerojet Tactical Systems Company.[5] The ELSGT gap value has been adjusted for diameter. The actual 50% gap value was obtained by the TERA Group of the New Mexico Institute of Mining and Technology using 88.9 mm (3.50 inch) diameter by 88.9 mm thick donors, rather than the 95.3 mm (3.75 inch) diameter by 95.3 mm thick donors used in this investigation. A simple correction factor was used, i.e., the ratio, 3.75/3.50, times the gap value obtained in the smaller, 88.9 mm diameter size. (This factor should equal the ratio of the C-J reaction zone times for the two different sized donors as well as the ratio of their lengths. Thus, it takes account of the longer duration of the loading by the larger donor.)

The ELSGT 50% gap thickness as a function of the corresponding LSGT 50% gap thickness is plotted in Figure 15 for the four compositions given in Table 7. A straight line can be drawn through the lower three data points of Figure 15. In fact, within experimental error, a straight line can be drawn through all four points. Moreover, previous work[6] has suggested that the relationship would be linear. Nevertheless, a curved line has been drawn as the more general approximate relationship. It may well be changed with better values of the two extreme data points. In particular, one cannot rule out the possibilities that another explosive may have the same LSGT value as Atex and yet have a different ELSGT value, and that the correction factor may not check out experimentally.

DISCUSSION AND CONCLUSIONS

The summary data for comparing the two gap tests, given in Table 7, are plotted in Figure 15. The resulting figure is an approximate equivalence curve. The curve looks reasonable, but two points are less well determined than the others: they are the first and last, i.e., the ELSGT value for ATEX and the LSGT value for the three-component mixture. In the former case, we have corrected for a donor of smaller diameter without quantitative justification for the correction we used. In the latter case, an examination of the individual shots shows that the LSGT value is not as well established for this composition as it is for the others.

Additional work that should be done to establish the equivalence curve more soundly is:

1. Confirm or improve the location of the lowest point (Atex data);

2. Obtain better LSGT value for highest point;

3. Obtain an even higher point on the curve to confirm the location of the upper point and upper curve slope; and

4. When a well established curve is obtained, test it with very different high explosive compositions.

Item 4 is included because chemically similar compositions will lie on a curve in many correlations of explosive properties, but very different compositions will not conform to that curve.

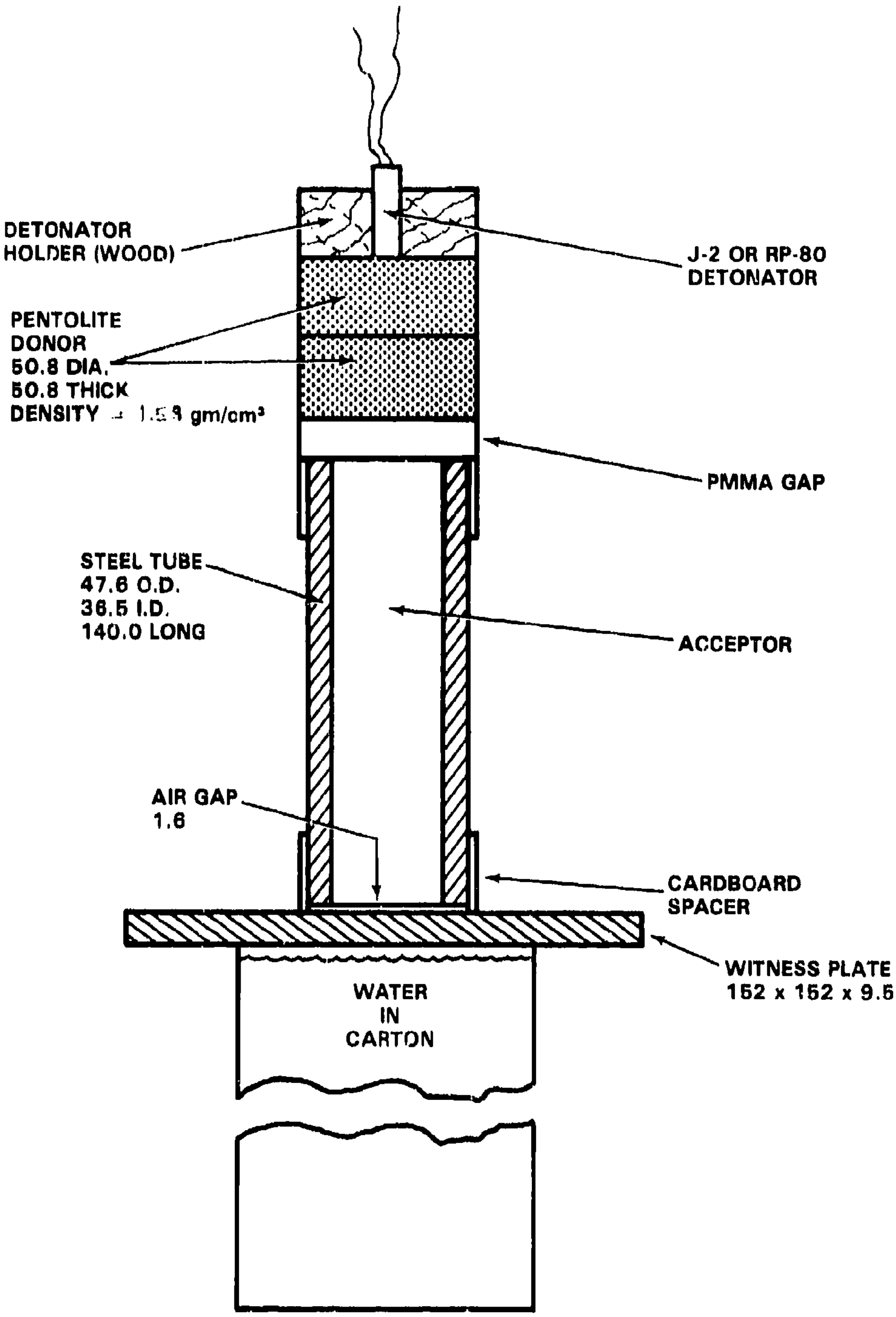


FIGURE 1. LARGE SCALE GAP TEST ASSEMBLY (DIMENSIONS IN mm)

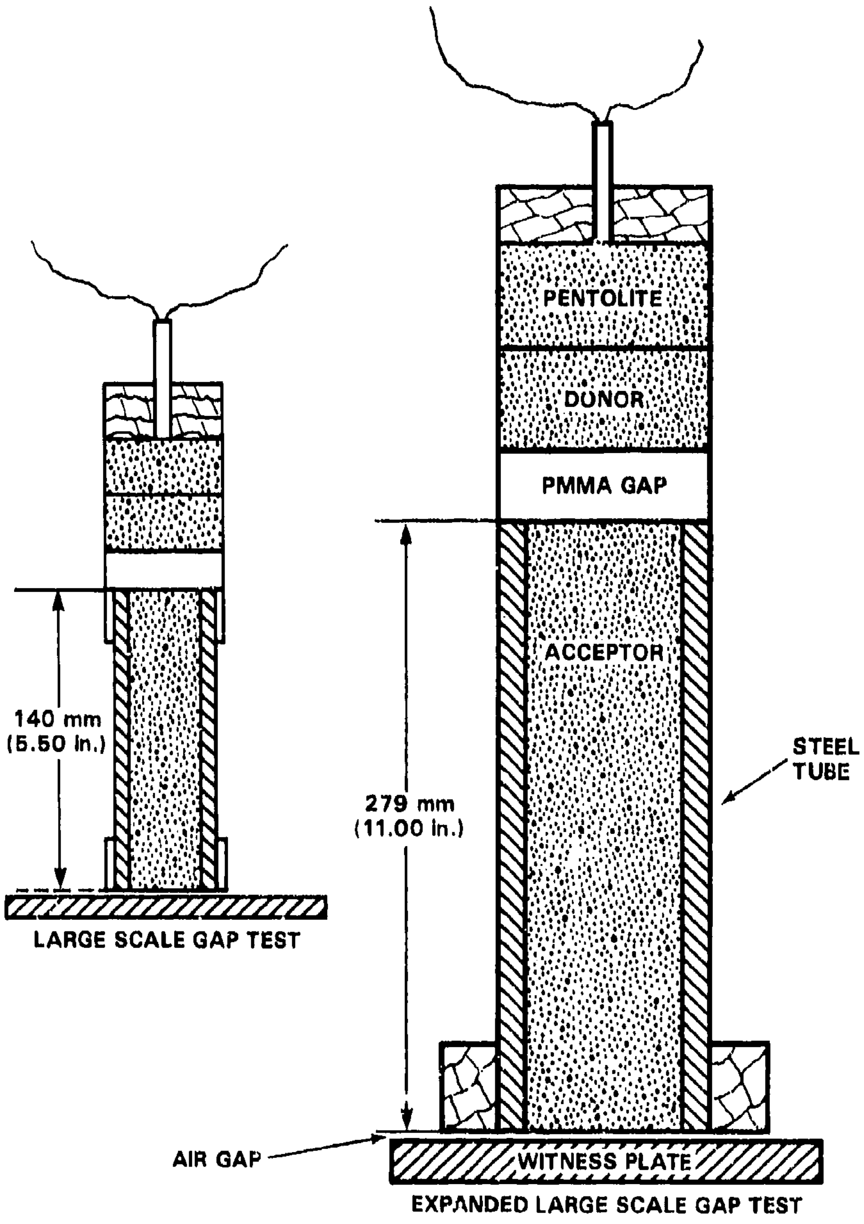


FIGURE 2. COMPARISON OF LSGT AND ELSGT ASSEMBLIES

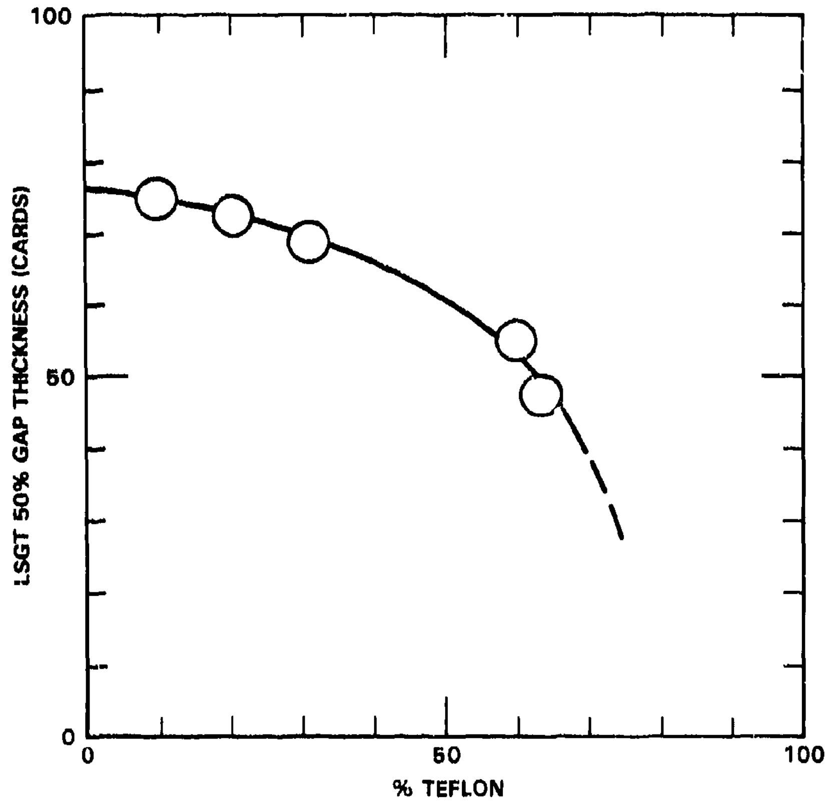


FIGURE 3. THE 50% GAP THICKNESS VERSUS % TEFLON FOR SEVERAL TATB/TEFLON MIXTURES

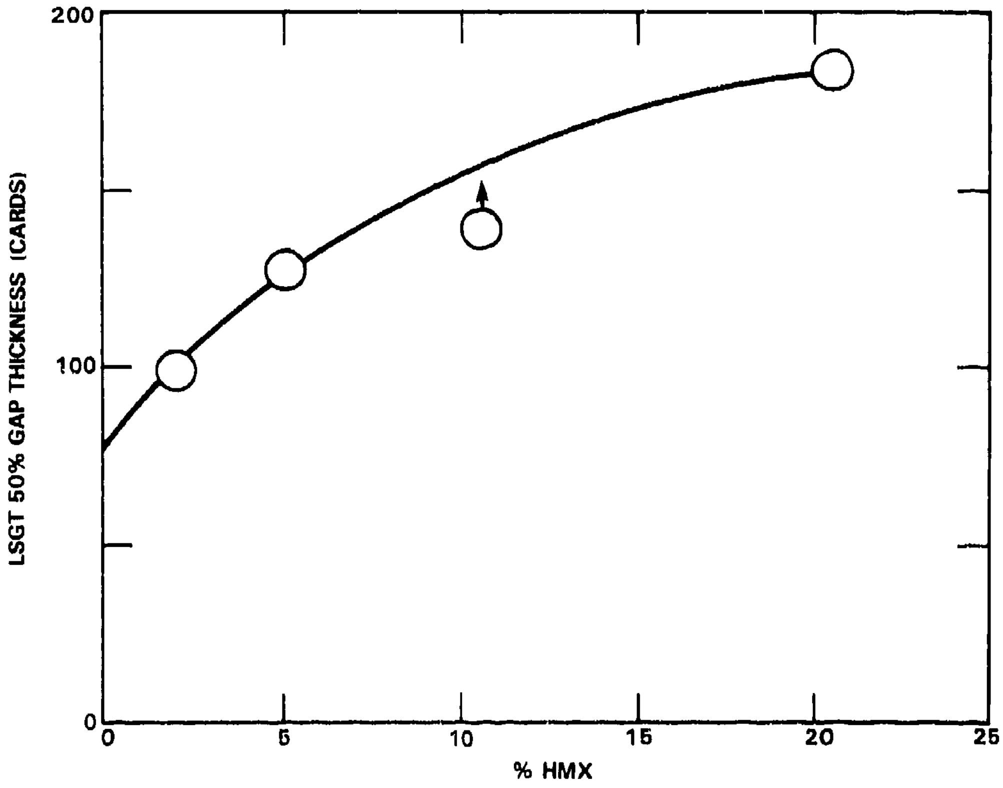
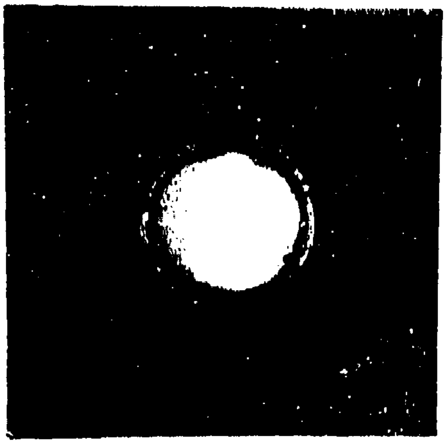
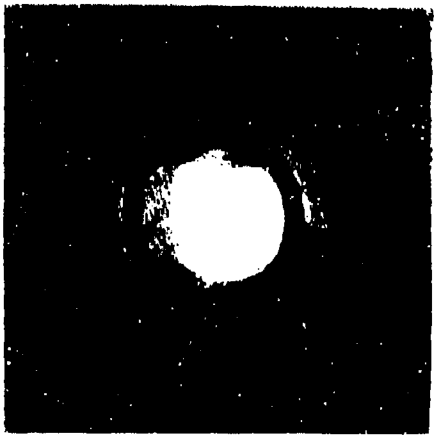


FIGURE 4. THE 50% GAP THICKNESS VERSUS % HMX FOR SEVERAL TATB/HMX/ 5% TEFLON MIXTURES



FRONT



REAR

LS-34

FIGURE 5. FRONT AND REAR VIEWS OF A LSGT WITNESS PLATE WITH A CLEANLY PUNCHED-OUT HOLE

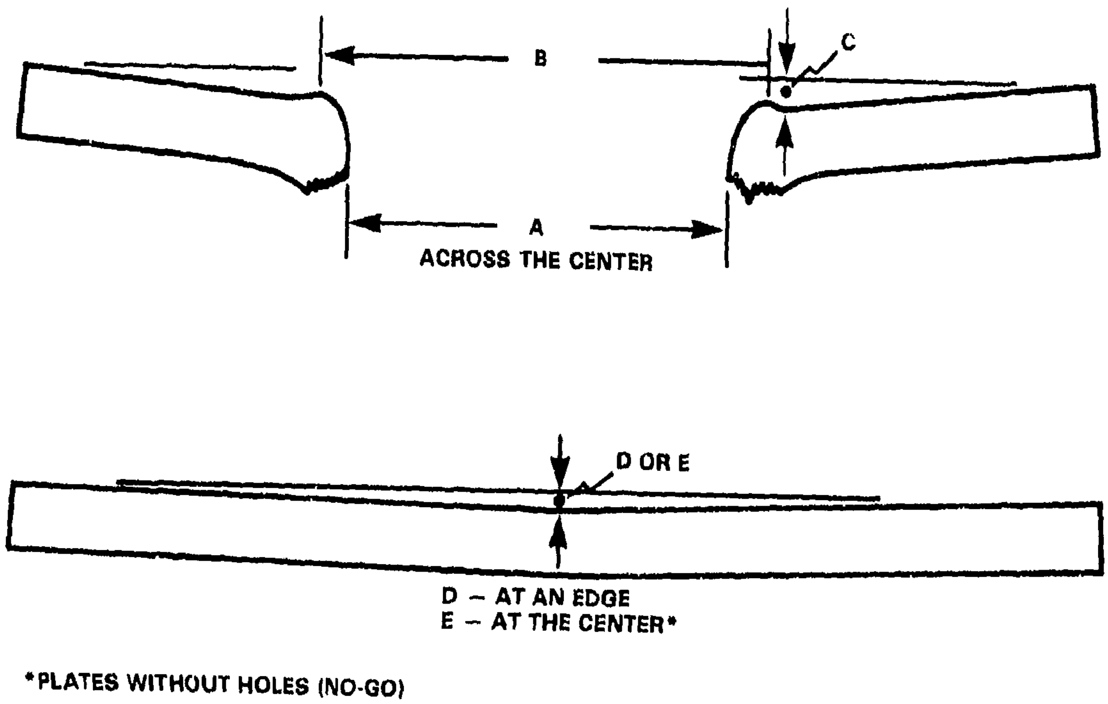
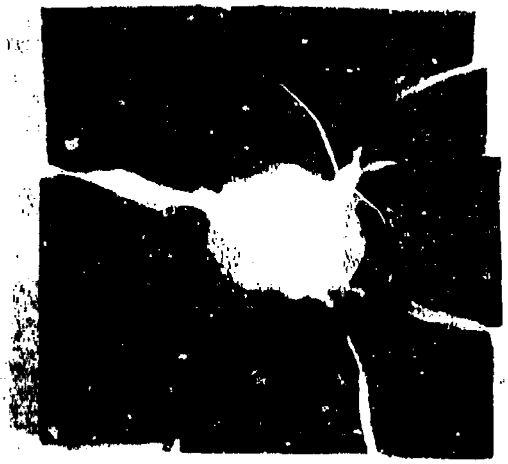
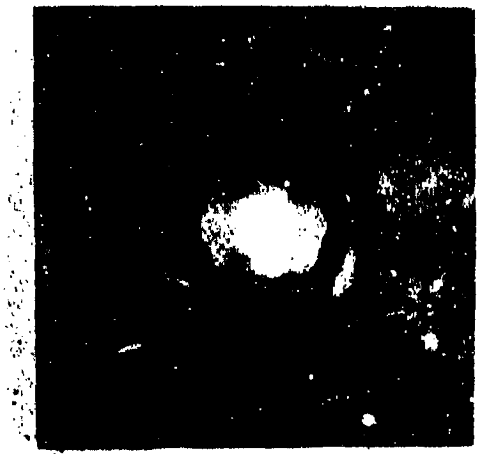


FIGURE 6. PROFILES TAKEN FROM TYPICALLY DAMAGED LSGT WITNESS PLATES



LS-54

FIGURE 7. WITNESS PLATE FRAGMENTS RECOVERED FROM A DETONATING LSGT ACCEPTOR OF TATB 40/TEFLON 60



LS-60

FIGURE 8. REAR VIEW OF AN LSGT WITNESS PLATE WITH A RAGGED HOLE FORMED BY THE DETONATION OF A TATB 40/TEFLON 60 ACCEPTOR

LS-14

FIGURE 9. A FLARED AND SPLIT TUBE RECOVERED FROM A WEAKLY REACTING LSGT ACCEPTOR OF TATB 94/KEL-F 6 (REACTION LEVEL b, TABLE 3)

LS-17

FIGURE 10. TUBE FRAGMENTS RECOVERED FROM A VIGOROUS REACTION IN AN LSGT ACCEPTOR OF TATB 94/KEL-F 6 (REACTION LEVEL e, TABLE 3)

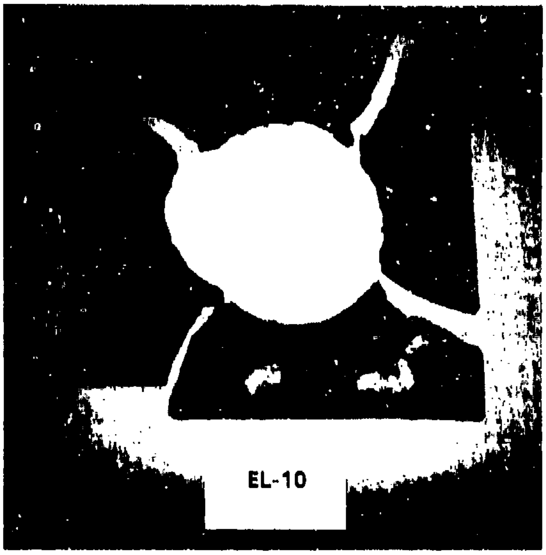


FIGURE 11. PLATE FRAGMENTS FROM A DETONATING ELSGT ACCEPTOR OF TATB 94/KEL-F 6 SHOWING THAT A FAIRLY CLEAN HOLE WAS PUNCHED OUT BEFORE BREAK-UP

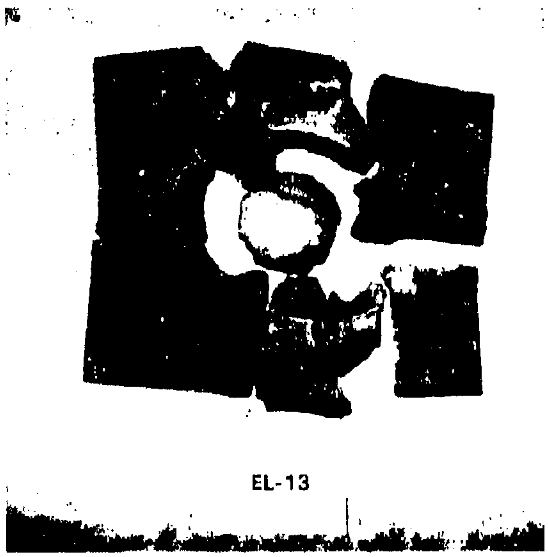


FIGURE 12. PLATE FRAGMENTS FROM A DETONATING ELSGT ACCEPTOR OF TATB 40/TEFLON 60 SHOWING INCOMPLETE DETACHMENT OF STEEL AROUND THE REAR PERIMETER OF THE HOLE

FIGURE 13. RECOVERED ELSGT TUBES SHOWING THAT LITTLE IF ANY CHEMICAL REACTION OCCURRED (REACTION LEVEL a, TABLE 5)

FIGURE 14. A PETALED TUBE RECOVERED FROM A MODERATELY REACTING ACCEPTOR OF TATB 40/TEFLON 60 (REACTION LEVEL c, TABLE 5)

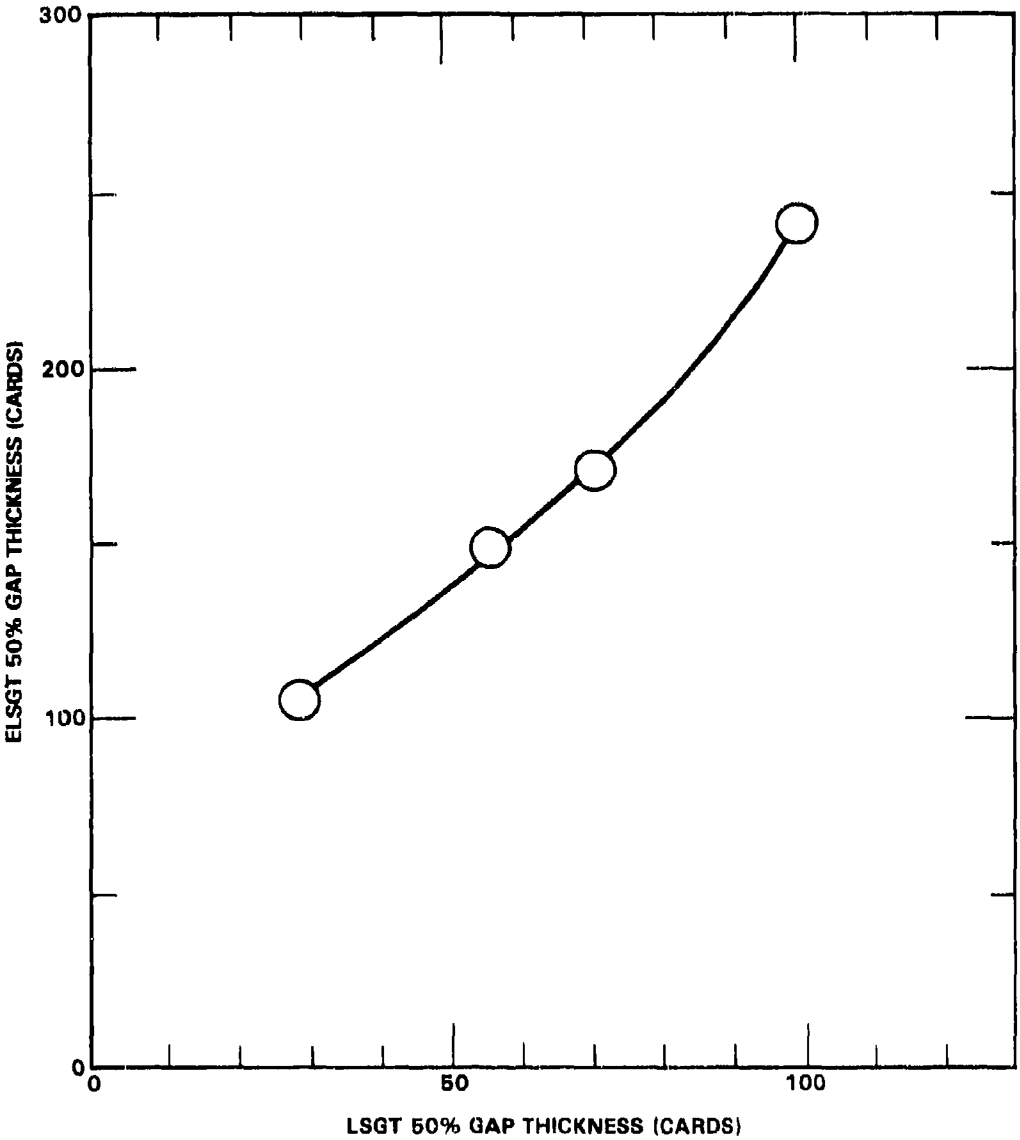


FIGURE 15. THE ELSGT 50% GAP THICKNESS VERSUS THE LSGT THICKNESS

TABLE 1. EXPLOSIVE AND INERT COMPONENTS OF THE ACCEPTORS USED IN THIS STUDY

MATERIAL	TMD (g/cm^3)
TATB[a] (X989, OLD STOCK)[b]	1.938
TATB[a] (X1029, NEW STOCK)[c]	1.938
RDX[d] (X985)	1.802
HMX[e] (X933)	1.905
WAX, CARNAUBA NO. 1 REFINED YELLOW[f]	0.990-1.002
KEL-F[g] (3M COMPANY)	2.02 (NOM)
TEFLON 7C, CRYSTALLINE POWDER[h]	2.305

[a]SURFACE AREA ANALYSES BY E. KAYSER, R16, NSWC:
X989 = 0.63 ± 0.06 m^2/g
X1029 = 0.61 ± 0.06

[b]PARTICLE SIZE DISTRIBUTION UNKNOWN; PROBABLY LIKE X1029

[c]CLASS 1 TATB (MEETS LANL SPEC 12Y-188025): 15-35% THRU 20 μ SIEVE, 60% MAX THRU 45 μ

[d]CLASS 2 RDX (FORMERLY CLASS B): 99 ± 1% THRU 500 μ (25 MESH, U.S. STND SIEVE), 95 ± 5% THRU 297 μ (50 MESH), 65 ± 15% THRU 149 μ (100 MESH), 33 ± 13% THRU 74 μ (200 MESH)

[e]CLASS 5 HMX (FORMERLY CLASS E): 98% MIN THRU 44 μ (325 MESH)

[f]OBTAINED FROM FRANK B. ROSS CO., JERSEY CITY, NEW JERSEY

[g]PROBABLY KEL-F 800; TATB/KEL-F OBTAINED IN COMPACTED MIXTURE; HISTORY OF MANUFACTURE UNKNOWN

[h]A FLUOROCARBON RESIN FROM E. I. DUPONT, WILMINGTON, DELAWARE

TABLE 2. EXPLOSIVE MIXTURES USED IN THE EXPANDED LARGE SCALE GAP TEST STUDY

	COMPOSITION (% BY WEIGHT)[a]						DENSITY (g/cm^3)	
	TATB	RDX	HMX	WAX	KEL-F	TEFLON	TMD	EXP
1.	--	48.2	--	51.8	--	--	1.270	1.218
2.	--	22.4	--	77.6	--	--	1.107	1.061
3.	--	30.0	--	--	--	70.0	2.127	2.031
4.	93.7	--	--	--	6.3	--	1.943	1.887
5.[b]	93.7	--	--	--	6.3	--	1.943	1.879
6.	90.0	--	--	--	--	10.0	1.969	1.880
7.	79.2	--	--	--	--	20.8	2.004	1.925
8.	68.7	--	--	--	--	31.3	2.040	1.959
9.	36.4	--	--	--	--	63.6	2.156	2.092
10.	39.6	--	--	--	--	60.4	2.144	2.087
11.	75.8	--	19.5	--	--	4.7	1.946	1.854
12.	85.5	--	10.1	--	--	4.4	1.948	1.865
13.	90.2	--	5.0	--	--	4.8	1.951	1.874
14.	92.7	--	2.3	--	--	5.0	1.953	1.871
15.	93.1	--	1.9	--	--	5.0	1.953	1.870

[a]ANALYSES BY E. KAYSER, R16, NSWC

[b]PRESSED FROM MACHINING SCRAPS OF NO. 4

TABLE 3. LARGE SCALE GAP TEST DATA

COMPOSITION	SHOT NO.	DENSITY (g/cm^3)	GAP (CARDS)	RESULTS	50% GAP (CARDS)
1. RDX 48/WAX 52 95.9% TMD	LS-01	1.221	0	GO	
REQUEST NO. (RN) 6476	-02	1.215	70	GO	
RP-80 DETONATOR	-03	1.215	140	GO	200-250
	-04	1.217	200	GO	
	-05	1.220	250	NO GO[a]	
2. RDX 22/WAX 78 95.8% TMD	LS-06	1.063	70	GO	
RN 6540	-07	1.060	100	GO	>100
RP-80 DETONATOR	-08	1.060	50	GO	
3. RDX 30/TEFLON 70 95.5% TMD	LS-21	2.030	100	GO	
RN 6595	-22	2.040	200	GO	220-250
RP-80 DETONATOR	-23	2.028	220	GO	
	-24	2.025	250	NO GO[a]	
4. TATB 94/KEL-F 6 97.1 TMD	LS-09	1.896	70	NO GO[a]	
RN 6582 & 6588	-10	1.896	40	GO	
	-11	1.895	55	GO	
	-12	1.895	63	GO	
RP-80 DETONATOR	-25	1.881	66	GO	67-68
	-26	1.898	68	NO GO?	
	-27	1.884	67	GO	
	-28	1.894	67	NO GO?	
	-29	1.886	68	GO	

TABLE 3. LARGE SCALE GAP TEST DATA (CONTINUED)

COMPOSITION	SHOT NO.	DENSITY (g/cm^3)	GAP (CARDS)	RESULTS	50% GAP (CARDS)
4. TATB 94/KEL-F 6 (CONT)	-30	1.891	70	GO	
	-31	1.886	75	NO GO[e]	
J-2 DETONATOR					70-73
	-32	1.887	70	GO	
	-33	1.886	73	NO GO[e]	
5. TATB 94/KEL-F 6	LS-17	1.881	70	NO GO[e]	
96.7% TMD					
RN 6588 (MACHINING SCRAPS)	-18	1.877	65	NO GO[f]	62-64
RP-80 DETONATOR	-19	1.878	62	GO	
	-20	1.879	64	NO GO[f]	
6. TATB 90/TEFLON 10	LS-13	1.884	68	GO	
95.5% TMD					
RN 6583	-14	1.878	100	NO GO[b]	
					70-80
RP-80 DETONATOR	-15	1.874	70	GO	
	-16	1.885	80	NO GO[f]	
7. TATB 79/TEFLON 21	LS-34	1.928	70	GO	
96.1% TMD					
RN 6616 A	-35	1.925	80	NO GO[e]	
					73-75
J-2 DETONATOR	-36	1.924	75	NO GO[e]	
	-37	1.923	73	GO	
8. TATB 69/TEFLON 31	LS-38	1.959	70	NO GO[f]	
96.0% TMD					
RN 6616 B	-39	1.960	60	GO	
					68-70
J-2 DETONATOR	-40	1.955	65	GO	
	-41	1.960	68	GO	
9. TATB 36/TEFLON 64	LS-42	2.094	60	NO GO[e]	
97.0% TMD					
RN 6793	-43	2.093	50	NO GO[f]	
					45-50
J-2 DETONATOR	-44	2.091	40	GO	
	-45	2.090	45	GO	

TABLE 3. LARGE SCALE GAP TEST DATA (CONTINUED)

COMPOSITION	SHOT NO.	DENSITY (g/cm^3)	GAP (CARDS)	RESULTS	50% GAP (CARDS)
10. TATB 40/TEFLON 60 97.3% TMD	LS-54	2.090	40	GO	
RN 6847	-55	2.082	50	GO	
J-2 DETONATOR	-56	2.089	60	NO GO[g]	
	-57	2.086	55	GO	
	-58	2.089	58	NO GO[g]	
	-59	2.086	56	NO GO[g]	55-57
	-64	2.087	55	GO	
	-65	2.087	56	NO GO[g]	
	-60	2.088	55	GO	
	-61	2.088	56	NO GO[g]	
RP-80 DETONATOR	-62	2.086	55	NO GO[h]	55-56
	-63	2.087	54	GO	
11. TATB 75/HMX 20/TEFLON 5 95.3% TMD	LS-50	1.852	200	NO GO[g]	
RN 6870	-51	1.854	160	GO	
	-52	1.855	180	GO	180-190
	-53	1.854	190	NO GO[g]	
12. TATB 86/HMX 10/TEFLON 4 95.7% TMD	LS-46	1.865	100	GO	
RN 6871	-47	1.864	120	GO	
J-2 DETONATOR	-48	1.864	130	GO	>140
	-49	1.867	140	GO	
13. TATB 90/HMX 5/TEFLON 5 96.1% TMD	LS-66	1.874	120	GO	
RN 6904 A	-67	1.871	140	NO GO[g]	
J-2 DETONATOR	-68	1.875	130	NO GO[g]	125-130
	-69	1.874	125	GO	

TABLE 3. LARGE SCALE GAP TEST DATA (CONTINUED)

COMPOSITION	SHOT NO.	DENSITY (g/cm^3)	GAP (CARDS)	RESULTS	50% GAP (CARDS)
14. TATB 93/HMX 2/TEFLON 5 95.8% TMD	LS-70	1.873	110	NO GO[b]	
RN 6904 B	-71	1.871	100	GO	100-102
J-2 DETONATOR	-72	1.871	105	NO GO[d]	
	-73	1.869	102	NO GO[c]	
15. TATB 93/HMX 2/TEFLON 5 95.8% TMD	LS-74	1.875	100	NO GO[d]	
RN 6904 C	-75	1.869	90	GO	
J-2 DETONATOR	-76	1.873	95	NO GO[d]	
	-77	1.869	93	GO	
	-78	1.872	94	GO	95-100
	-79	1.870	95	GO	
	-80	1.871	97	GO	
	-81	1.870	99	GO	
	-82	1.871	100	GO	

[a]NO CHEMICAL REACTION; TUBE FLARED SOMEWHAT; MOST OF HE INTACT

[b]LITTLE, IF ANY, REACTION; TUBE FLARED AND CRACKED OPEN; MUCH OF HE INTACT

[c]SOME REACTION; TUBE FLARED AND SPLIT OPEN WITH 0-2 FRAGMENTS; SOME HE LEFT

[d]MODERATE REACTION; TUBE PETALED AND SPLIT WIDE OPEN; A LITTLE HE SCATTERED AROUND

[e]MODERATE TO VIOLENT REACTION; TUBE BROKEN INTO 3-6 PIECES; LITTLE, IF ANY, HE LEFT

[f]VIOLENT REACTION; TUBE BROKEN INTO 8-15 PIECES; NO HE RECOVERED

[g]TUBE CONDITION NOT KNOWN; FRAGMENTS RECOVERED AFTER SEVERAL SHOTS WERE MADE; MOST OF THE TUBES FRAGMENTED. (THE WITNESS PLATES, HOWEVER, WERE RECOVERED AFTER EACH SHOT.)

[h]DENT IN CENTER OF WITNESS PLATE ALONG WITH FLOW PATTERN

TABLE 4. EXPLOSIVES WITH 50% GAPS BELOW 120 CARDS (TAKEN FROM APPENDIX C OF REFERENCE 1. ALL CHARGES WERE ISOSTATICALLY PRESSED EXCEPT WHERE NOTED.)

EXPLOSIVE	TMD g/cm^3	EXP DENS (g/cm^3)	%TMD	GAP (CARDS)
AMMONIUM PERCHLORATE (AP)	1.95	1.56[a]	80.1	87
		1.57	80.6	80
		1.57	80.4	71
		1.58	81.1	93
DINITROBENZENE (DNB), CAST	1.566	1.51	96.4	32
DINITROTOLUENE (DNT) 350 μm	1.521	1.49	98.1	85
150 μm		1.50	98.9	24
NITROGUANIDINE (NQ)	1.78	1.61[b]	90.6	47
		1.63[c]	91.4	35
		1.64[b]	92.1	32
		1.64[b]	92.1	36
NQ/NaCl (90/10)	1.81	1.70	93.8	27
TATB	1.938	1.83	94.2	78
TNT, CAST[d]	1.654	1.62	98.1	108

[a]HYDRAULIC PRESSED

[b]HIGH BULK DENSITY

[c]LOW BULK DENSITY

[d]ONLY ONE CAST TNT LISTED FELL BELOW 120 CARDS

TABLE 5. EXPANDED LARGE SCALE GAP TEST DATA

COMPOSITION	STUB NO.	DENSITY (g/cm^3)	GAP (CARDS)	RESULT	50% GAP (CARDS)
1. TATB 94/KEL-F 6 97.1% TMD	EL-01	1.879	125	GO	
RN 6588	-02	1.891	225	NO GO[a]	
J-2 DETONATOR	-03	1.884	175	NO GO[b]	
	-04	1.888	150	GO	
	-05	1.886	163	GO	
	-06	1.886	169	NO GO[d]	169-172
	-07	1.887	167	GO	
	-08	1.887	168	GO	
	-09	1.887	169	GO	
	-10	1.886	170	GO	
	-11	1.887	172	NO GO[b]	
	-12	1.886	172	NO GO[a]	
2. TATB 40/TEFLON 60 97.3% TMD	EL-13	2.088	135	GO	
RN 6847	-14	2.076	150	GO	
J-2 DETONATOR	-15	2.082	160	NO GO[a]	
	-16	2.088	155	NO GO[c]	
	-17	2.082	153	NO GO[d]	145-150
	-18	2.083	151	NO GO[c]	
	-19	2.087	149	NO GO[c]	
	-20	2.088	145	GO	
	-21	2.087	148	NO GO[c]	

TABLE 5. EXPANDED LARGE SCALE GAP TEST DATA (CONTINUED)

COMPOSITION	SHOT NO.	DENSITY (g/cm^3)	GAP (CARDS)	RESULT	50% GAP (CARDS)
3. TATB 93/HMX 2/TEFLON 5 95.8% TMD	EL-22	1.873	200	GO	
RN 6904 C	-23	1.868	240	GO	
J-2 DETONATOR	-24	1.873	260	NO GO[a]	
	-25	1.870	250	NO GO[a]	
	-26	1.874	245	NO GO[a]	238-242
	-27	1.868	242	NO GO[a]	
	-28	1.871	240	NO GO[a]	
	-29	1.869	236	GO	
	-30	1.873	238	GO	
	-31	1.869	239	GO	

[a]LITTLE, IF ANY, CHEMICAL REACTION; STEEL TUBE FLARED; MOST OF THE HE INTACT

[b]SOME REACTION; TUBE FLARED AND CRACKED; MUCH OF THE HE INTACT

[c]MODERATE REACTION; TUBE PETALED; SOME HE LEFT

[d]VIOLENT REACTION; TUBE FRAGMENTED; HE FAIRLY WELL CONSUMED

TABLE 6. MEASUREMENT OF DAMAGE TO WITNESS PLATES

COMPOSITION	DIAMETER OF DEPTH OF BEND (mm) A	B	C	D	E
LSGT PLATES					
TATB 93/HMX 2/TEFLON 5	56±1	62±1	6.7±2.0	4.2±0.8	-
NO GO	-	-	-	0.6±0.4	0.8±0.5
TATB 94/KEL-F 6	54±1	63±1	3.8±0.4	2.7±0.4	-
NO GO	-	-	-	0.2±0.1	0.2±0.1
TATB 40/TEFLON 60	43±2	49±2	5.4±0.8	2.1±0.7	-
NO GO	-	-	-	0.7±0.2	0.8±0.5
ELSGT PLATES					
TATB 93/HMX 2/TEFLON 5	115±2	125±3	-	-	-
NO GO	-	-	-	1.4±0.2	1.7±0.2
TATB 94/KEL-F 6	112±2	124±3	-	-	-
NO GO	-	-	-	1.7±0.2	2.1±0.4
TATB 40/TEFLON 60	86*	94	-	-	-
NO GO	-	-	-	1.4±0.3	1.8±0.5

*ONLY ONE PLATE MEASURABLE IN THIS SERIES

TABLE 7. COMPARISON OF ELSGT AND LSGT DATA

COMPOSITION	MEAN DENS (g/cm³)		50% GAP (CARDS)[a]	
	LSGT	ELSGT	LSGT	ELSGT
TATB 93/HMX 2/TEFLON 5	1.871	1.868	95-102	238-242
TATB 94/KEL-F 6	1.890	1.886	70-73	169-172
TATB 40/TEFLON 60	2.087	2.085	55-57	145-150
ATEX[b]	1.49	1.49	29-30	(102-107)[c]

[a]TESTS RUN WITH J-2 DETONATORS ONLY

[b]A CASTABLE COMPOSITE EXPLOSIVE DEVELOPED BY AEROJET TACTICAL SYSTEMS COMPANY

[c]ADJUSTED FROM THE 95-100 CARD, 50% GAP ACTUALLY OBTAINED

REFERENCES

1. Price, D.; Clairmont, A. R., Jr.; and Erkman, J. O., The NOL Large Scale Gap Test. III. Compilation of Unclassified Data and Supplementary Information for Interpretation of Results, NOLTR 74-40, Mar 1974.

2. Erkman, J. O.; Edwards, D. J.; Clairmont, A. R., Jr.; and Price, D., Calibration of the NOL Large Scale Gap Test; Hugoniot Data for Polymethyl Methacrylate, NOLTR 73-15, Apr 1973.

3. Campbell, A. W.; Flaugh, H. L.; Popolato, A.; and Ramsay, J. B., "Customized Explosives Based on Plastic-Bonded Mixtures of TATB and HMX," Proceedings of the 7th Symposium (Int.) on Detonation, NSWC MP 82-334, 1981, pp. 566-574.

4. Jaffe, I.; Beauregard, R. L.; and Amster, A. B., The Attenuation of Shock in Lucite, NavOrd 6876, May 1960.

5. Barry, J. W. and Zimmerman, G. A., "Atex - A Castable Insensitive High Explosive," Minutes of the Twenty-First Explosive Safety Seminar, Vol. 1, 1984, pp. 249-258.

6. Price, D., "Gap Tests and How They Grow," Minutes of 22nd Explosive Safety Seminar, DDESB, Vol. 1, 1986, pp. 365-380.

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