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CONTACT PHOTOGRAPHY OF IMPACT EXPLOSIONS

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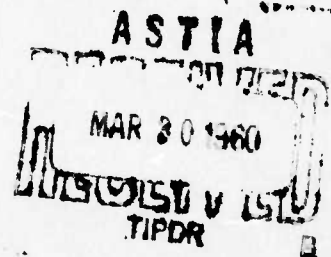
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U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

NAVORD Report 6767

CONTACT PHOTOGRAPHY OF IMPACT EXPLOSIONS

by

Joseph Wenograd

Approved by: DARRELL V. SICKMAN, Chief
Organic Chemistry Division

ABSTRACT: The extent and geometry of the propagation of explosions under the conditions of impact have been studied by exposing a photographic film to the light from an impact explosion. Impact explosions have been found to propagate by at least three mechanisms: fast burning, slow burning and detonation.

By means of experiments with artificial centers of initiation, it has been shown that the extent of propagation of an impact explosion is essentially independent of the drop height.

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U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, SILVER SPRING, MARYLAND

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This report describes the development of a novel technique for observing the effects of a dropped weight on a sample of explosive. At least three distinct modes by which explosions may propagate have been noted. This knowledge is necessary to a better understanding of the impact sensitivity of explosives. The work was performed under Task 301-664/43020/01, a continuing program for the study of the desensitization of explosives.

JOHN A. QUENSE'
Captain, USN
Acting Commander

Albert Lightbody
ALBERT LIGHTBODY
By direction

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CONTACT PHOTOGRAPHY OF IMPACT EXPLOSIONS

I. INTRODUCTION

Under the violent and complex stresses to which explosives are subjected in impact tests, it is believed that hot spots are formed which may develop into impact explosions⁽¹⁾. Several mechanisms by which these hot spots may be formed have been suggested⁽¹⁾ and the idea that impact explosions stem from them is well established. The process by which these hot spots grow and the nature of the rapid chemical consumption of the explosive which is called the explosion are not nearly so well understood. It has been shown that these explosions are quite different from detonations in terms of reaction products, velocity, and tool damage. The extent and geometry of the propagation of explosions under the conditions of impact, as these factors relate to the sensitivity of explosives, have apparently not been studied.

A photographic method whereby a photographic film is placed in virtual contact with an impact explosion has been used to investigate these phenomena. By this technique the total light from the explosion is recorded and an accurate picture of the extent and site of explosion is obtained. Contact photographic methods have been applied before by Eirich⁽²⁾ in experiments designed to elucidate the nature of impact explosions. The principal emphasis of this work was, however, placed on explosions of liquids. The present work, although less general in scope, is directed toward the study of explosions in solid samples.

II. EXPERIMENTAL

A standard ERL impact machine⁽³⁾ (NOL No. 2) was used in all of these experiments. It was equipped with type 12 tools⁽³⁾ and a 2.5 kg weight. The room was made light-tight and was illuminated by a safe-light equipped with a Kodak Wratten No. 7 filter. Two-inch-square pieces of Kodak infrared sensitive sheet film were placed on the anvil of the impact machine with the emulsion side up. Infrared sensitive film was selected partly because of its wide spectral sensitivity and partly because it permitted use of a safe-light. The film was shielded from blast and burning effects by the use of

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pieces of 0.002-inch thick transparent sheet mica. The explosive samples, usually about 50 mg, were placed upon the mica and the striker rested on the explosive. The weight was dropped on the striker as is customary.

The films were developed ten minutes in Kodak Microdol developer. The explosion records shown in this report are positives of the films obtained by these methods. The dark areas represent light given off by the explosion. The records are magnified approximately twofold.

The standard impact test has been rather drastically modified by the experimental setup employed here. Thus, the presence of the film and the mica serve to cushion the blow received by the explosive. Moreover, since the mica is softer than the grit in the sandpaper customarily used, the formation of hot spots is probably impeded. The result of these factors is a change in the scale of impact sensitivities associated with various explosives.

The explosives were standard production samples used without further purification. Small quantities of sensitive materials were introduced to some samples of high explosive to seed the reaction. Pentaerythritol tetranitrate, (PETN), crystals were grown by slow evaporation of acetone solutions. The PETN came out as single crystals and those weighing about 2 mg were used. Diazodinitrophenol, DDNP, crystals were prepared the same way. Clusters of platelets weighing about 2 mg were used. The lead azide pellets were obtained by pressing 5 mg of dextrinated lead azide to a pressure of 25,000 psi.

III. RESULTS

Figure 1 is typical of explosions occurring in samples of granular PETN. The explosion seems to have started at the center from which the striations emanate and continue to the boundaries of the explosive layer. The white areas in the darkened region represent places where the emulsion has been blasted away. Figure 2 shows an explosion of an RDX sample. There is less evidence here that initiation has started from a single center.

Figure 3 shows the explosion of a tetryl sample. The feathery nature of the outline of the luminous region is taken to indicate that the reaction spreads in a slow and complex manner.

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The explosion of a 5 mg pellet of lead azide gave the result shown in Figure 4. This pellet is believed to have detonated. The film is punctured in the central area where the pellet was originally situated. The emulsion has been blasted away in the area immediately surrounding the puncture. The parts of the hardened steel anvil and striker which were adjacent to the pellet were scored and had to be discarded. Figure 5 is typical of the records obtained by firing small amounts of crystalline PETN or DDNP. The crystal is apparently crushed and spread out before the explosion occurs.

The preceding five shots were all caused by drops from heights sufficient to cause either tripping of the noisemeter or consumption of all the explosive.

Under the modified test conditions employed here it was not possible to get TNT to explode completely enough to trip the noisemeter. Figure 6, however, shows the result of striking a TNT sample. In this case most of the explosive remained undisturbed and the well-initiated explosion seems to have died out. A similar example is shown in Figure 7.

By introducing an artificial center of initiation, it is possible to initiate reactions in an explosive material by drops from heights too low to cause initiation. Such centers consist of small compact masses of sensitive material prepared as described.

Figure 8 shows an explosion in a sample of RDX initiated by crystalline DDNP. It bears certain similarities to Figure 2. Tetryl will sometimes explode when initiated by sensitive crystalline materials. Figure 9 shows such an explosion initiated by a PETN crystal. The figure bears striking similarities to Figure 3. The indentations in the area of luminosity indicate that the explosion has failed to propagate to these regions. Indeed, upon inspection of the mica and striker, unconsumed explosive was found in this region.

The explosion shown in Figure 10 was most interesting. In this case a circle containing about 50 mg of tetryl was spread on the mica. A 5 mg lead azide pellet was placed in the center standing on its edge. Striking the sample caused an extremely loud explosion which was far louder than the reports commonly heard in impact machine operations. The tools were badly damaged, and as can be seen, more than half of the film was blown away. The arc of blasted emulsion represents the edge of the tools. The reaction encountered here is almost certainly some sort of detonation. As in Figure 4, the blackening continues past the edge of the tools.

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Even TNT can be exploded through the use of artificial centers of initiation. The shot in Figure 11 was initiated by a few mg of fine lead azide. Although the noisemeter indicated a fire, a considerable amount of unconsumed explosive remained.

In many cases the introduction of artificial centers of initiation resulted in only partial consumption of the explosive. Figure 12 shows the partial consumption of an RDX sample upon initiation with a DDNP crystal. A partial in a tetryl sample initiated similarly is shown in Figure 13.

Several TNT samples gave partials when activated by initiation centers. Figures 14 and 15 are TNT samples initiated by PETN crystals. Figure 15 is most interesting in that there appears to be a small center of initiation which propagates in some non-luminous fashion, building to an explosive reaction in about 5 mm.

Figure 16 shows the light pattern obtained when the weight struck a sample of TNT with a PETN initiation center. Examination of the mica showed that the PETN had disappeared, leaving a void in the crushed TNT, corresponding in shape and size to the pattern in Figure 16. It is interesting to note that the PETN could have exploded, giving off light, while giving no evidence of having affected the TNT.

IV. DISCUSSION AND CONCLUSIONS

It is possible to consider the propagation of impact explosions as a separate phenomenon from the actual initiation. It has been shown that such explosions can be initiated with similar results either from centers produced by striking a pure material or from artificial centers produced by the initiation of more sensitive explosives. The nature of the propagations, as seen from the photographs, are such that they may be classified under at least three categories.

Examples of the first and most frequent mode of propagation can be seen in Figures 1, 2, 8, and 11. This mode will be referred to as a fast burning reaction. It is characterized by a rather regular pattern with striations emanating from one or a few points which may be centers of initiation. The striations may be traced out by rapidly moving, reacting particles of explosive. In all cases the luminosity terminates at the boundary of the tools indicating that the reaction is quenched by a release of pressure. All the high explosives used in this study exhibit this type of reaction under some conditions.

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A second mode of propagation which is considered a slow burning is exemplified by Figures 3, 7, and 9. This type of propagation is characterized by a feathery pattern which ends at the boundary of the tools. The nature of these patterns suggests multiple initiation and surface grain burning. Slow burnings seem to be quite characteristic for explosions of tetryl under the conditions used in the Naval Ordnance Laboratory test. Some explosions of TNT also seem to propagate by this mode of reaction.

A third mode of propagation is represented by Figures 4 and 10. Because of the violence of the reactions and the amount of damage caused, these reactions must be regarded as detonations.

These detonations are characterized by a scoring of the impact tools and a blackening of the film beyond the area of high pressure. Both detonations started in lead azide, a material which is known to detonate in thin layers. The tetryl of Figure 10 must have picked up the detonation, as the reaction had far more violence than can be attributed to the detonation of 5 mg of lead azide.

Whether a given shot in an impact sensitivity test is an explosion or a failure is decided by a microphone-actuated noisemeter. This technique was adopted to circumvent reliance on the highly subjective human ear as a criterion of a fire. It has long been recognized, however, that in many shots there is a consumption of the explosive which is either insufficiently extensive or violent to register as an explosion. Such shots, in the course of which there is either audible, visible, or olfactory evidence for reaction, are regarded as partials. The method used here represents a most sensitive technique for detecting such partials, since the existence of regions with sufficient luminosity to expose the film is a positive evidence for chemical reaction. Moreover, this technique permits a consideration of the extent and geometry of such partials.

Partial explosions such as illustrated in Figures 7, 9, 12, 13, and 15 do not appear to spread well laterally. Instead they spread, apparently by the rapid burning mode, to the tool periphery consuming only a narrow segment of the explosive. These photographs illustrate the directional nature of partials. Holden⁽⁴⁾ has considered the effect of partial explosions and their directionality on the efficiency of the microphone actuated noisemeter.

The use of artificial centers of initiation has permitted a consideration of the effect of increasing drop height on the propagation of impact explosions. Ten tetryl samples seeded with DDNP crystals were struck from heights varying from twenty to sixty cm. In eight cases this resulted in initiation of the DDNP and partial consumption of the tetryl. Tetryl alone gave no reaction at drops less than 100 cm. There was little or no noticeable difference in the extent of propagation at the higher drop heights. Eight TNT samples seeded with DDNP and struck from heights varying between 25-150 cm which behaved similarly; although pure TNT showed no reaction at all in drops from less than 200 cm.

It is thus possible to conclude that the ability of an impact explosion to propagate is fairly independent of the drop height. It would appear, then, that the differences in sensitivity among explosives results from differences in their tendency to form centers of initiation under impact conditions.

V. ACKNOWLEDGEMENT

The author wishes to acknowledge the assistance of Mrs. Sarah F. Duck in carrying out the necessary experiments.

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Table I.

Key to Figures

<u>Figure</u>	<u>Bulk Explosive</u>	<u>Initiation Center</u>	<u>Height for 2 kg Weight cm.</u>	<u>Noisemeter Decision</u>
1	PETN	--	16	FIRE
2	RDX	--	40	FIRE
3	Tetryl	--	150	FIRE
4	Lead azide pellet	--	20	FIRE
5	PETN crystal	--	20	FIRE
6	TNT	--	100	FAILURE
7	TNT	--	320	FAILURE
8	RDX	DDNP	25	FIRE
9	RDX	PETN	30	FIRE
10	Tetryl	Lead Azide	20	FIRE
11	TNT	Lead Azide	100	FIRE
12	RDX	DDNP	20	FAILURE
13	Tetryl	DDNP	30	FAILURE
14	TNT	PETN	60	FIRE
15	TNT	PETN	175	FAILURE
16	TNT	PETN	100	FAILURE

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3. H. D. Mallory, Navord Report 4236, "The Development of Impact Sensitivity Tests at the Explosives Research Laboratory, Bruceton, Pa. During the Years 1941-45," 16 March 1956
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FIG. 1



FIG. 2



FIG. 3



FIG. 4

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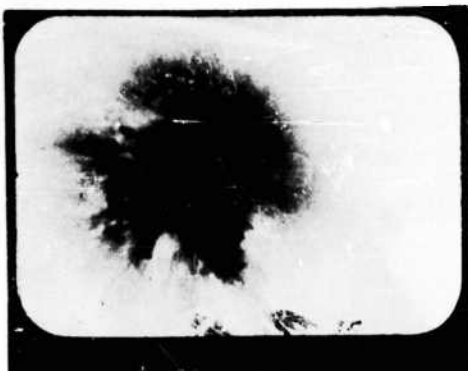


FIG. 5

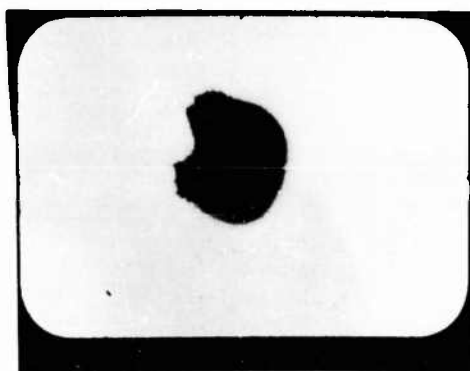


FIG. 6



FIG. 7



FIG. 8



FIG. 9



FIG. 10

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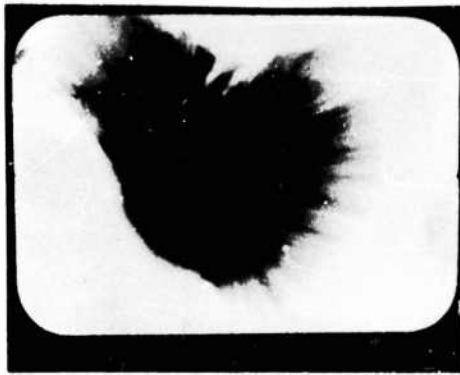


FIG. 11

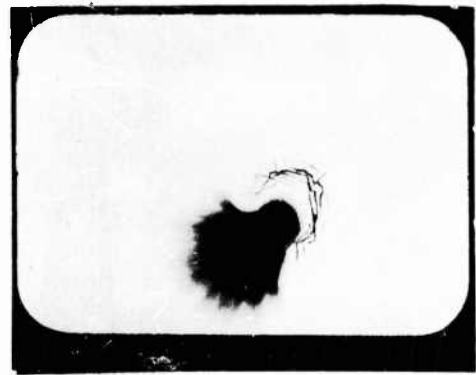


FIG. 12

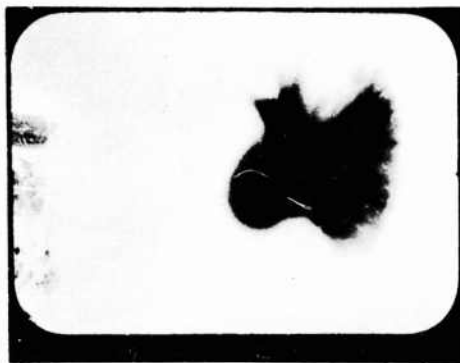


FIG. 13

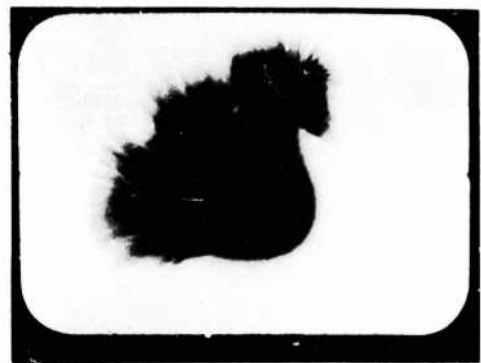


FIG. 14

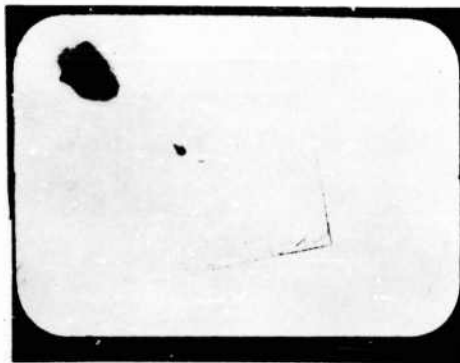


FIG. 15

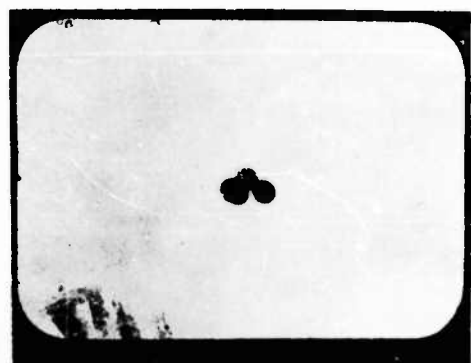


FIG. 16