Microsecond Observations of the Dynamic Response of Explosives to Very High Rates of Loading

PAPER I—6

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An explosive sensitivity test has been devised wherein specimens of explosives of the order of a pound in weight are squeezed between an explosive-driven plate and a massive anvil. By using the Beckman & Whitley Model 189 Framing Camera, it is possible to observe the movement of the driving plate, the propagation of the nonreactive shock in the explosive sample, the deformation of the explosive as a result of its being squeezed, and in some cases the onset and propagation of an explosive reaction. Conditions within the explosive, such as pressure, density change and particle velocity, are readily computed from the photographs.

Experimental Technique

An explosives sensitivity test has been devised wherein cylindrical specimens of explosive of the order of a pound in weight are squeezed between a moving plate and a massive anvil. The experimental technique is illustrated in Fig. 1. The metal driving plate is accelerated by means of the plane-wave initiation of a low-density charge of explosive in such a manner as to compress uniformly the explosive test specimen. The motions of the plate and the lines of a reference grid stencilled on the specimen are observed by means of the Beckman & Whitley Model 189 Framing Camera.

Typical Records

By varying the mass of the driving plate, the quantity of driving-plate charge used and the size of the explosive specimen, it is possible to observe the behavior of the explosive over a wide range of impulsive loading conditions. At low-impact loading, no explosive reaction occurs. Figure 2 is such an example. The framing camera record shows the dynamic compression of an unconfined specimen of a military explosive, cast Composition B, 3 in. in diameter by 3 in. high. The time between frames in Fig. 2 is 4 μsec. The deformation of the specimen appears as a gradual "mushrooming" of the cylinder as time passes. The changes in distance between stripes, originally 0.25 in. apart on the specimen, as one proceeds from frame to frame can be used as a measure of changes in density with time. The nonreactive shock wave traveling through the specimen appears as a progressive brightening of the surface of the sample. From dimensional and appearance changes in the specimen in the sequence of Fig. 2, and from the conservation of energy equations for a shock wave, the nonreactive shock velocity and pressure within the specimen are readily calculated.

At high loading, the shock transmitted through the driving plate is of sufficient intensity to initiate an explosive reaction. Some typical records which show high-order detonations resulting from impact are seen in Figs. 3, 4 and 5.

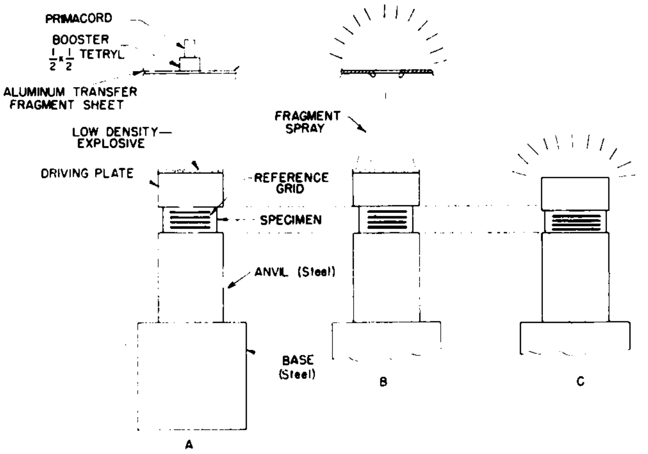

Fig. 1. Test arrangement.

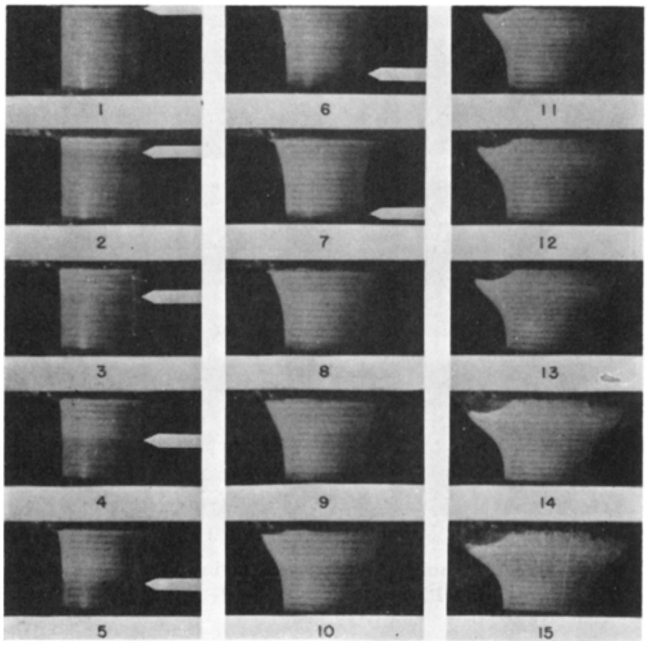

Fig. 2. Framing camera sequence showing deformations under impact of a cast Composition B cylinder, 4 μsec between frames. Arrows indicate shock front.

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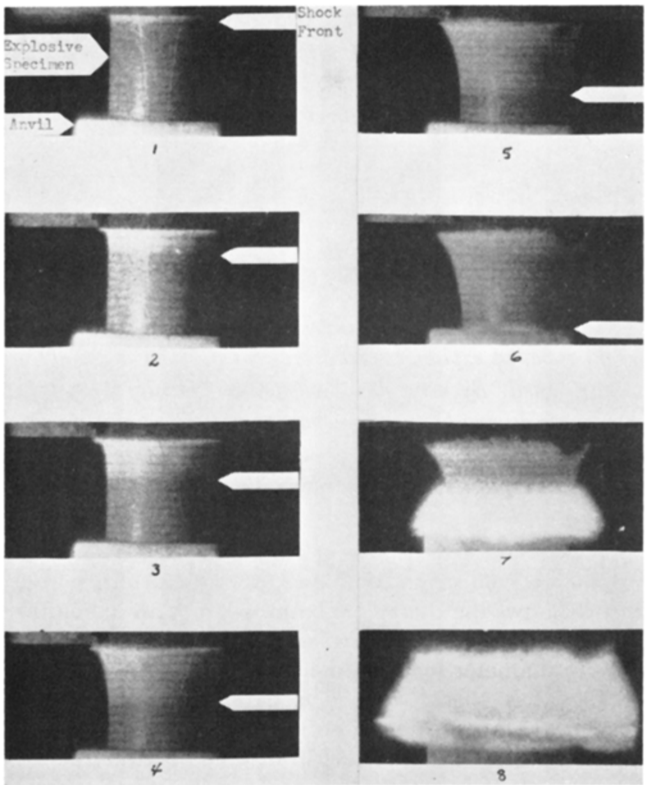

Fig. 3. Framing camera sequence showing impact initiation of an unconfined Composition B cylinder, 3 in. in diameter by 3 in. high, 4 μsec between frames.

Figure 3 presents selected frames, taken 4 μsec apart, of the compression and initiation of an unconfined cylinder of Composition B, 3 in. in diameter by 3 in. high. The time between impact and initiation is about 26 μsec. A high-order detonation of the explosive appears to have started along the bottom surface of the specimen, as is evidenced by the bright line at the bottom of Frame 6, indicating the inception of the reaction at the explosive-anvil interface. The shape of the detonation profile as seen in Frames 7 and 8 also shows that the detonation starts at the bottom of the explosive and moves upward into the previously shocked specimen.

Figure 4, showing selected frames 1 μsec apart, is another example which depicts the inception and growth of a detonation. In this case, the center of the reaction appears to begin at a point in the lower left hand corner of Frame 4, 12.5 μsec after impact, and progresses across and upward. The explosive specimen was 9404 PBX, 2.5 in. in diameter by 2.34 in. high.

Figure 5 shows the impact and subsequent initiation of a similar cylinder of the explosive 9404 PBX. The time between frames is 1 μsec. In this case, the shock intensity was of sufficient strength to initiate detonation before it reached the face of the anvil. The detonation is first observed in Frame 7, and appears to have started at about 1.6 in. from the top of the specimen. The reaction occurs 10.5 μsec after impact, and propagates both in the forward and the reverse direction.

Photographic Techniques

The event is illuminated by means of an argon-filled explosive flashlight. A detailed description of this light source appears in another paper given at this Congress.* Figure 6 shows the light source in relationship to the experimental setup. The long horizontal cylinder on the left is the light source. This figure also shows the explosive specimen located within the test fixture. The primary function of the test fixture is to shield the field of view of the impacted specimen from the smoke and fragments associated with the initiation of the driving-plate charge.

The Beckman & Whitley Model 189 Camera control used in these experiments emits a single triggering pulse

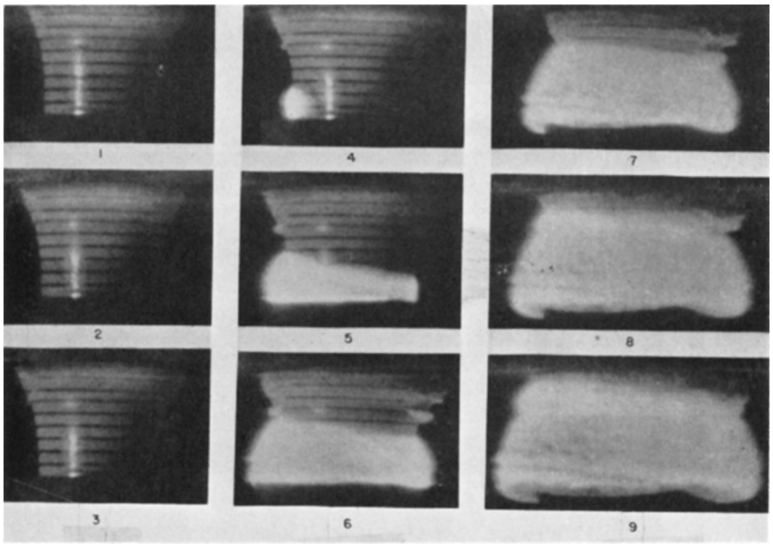

Fig. 4. Framing camera sequence showing the inception and growth of a detonation in 9404 PBX, 1 μsec between frames.

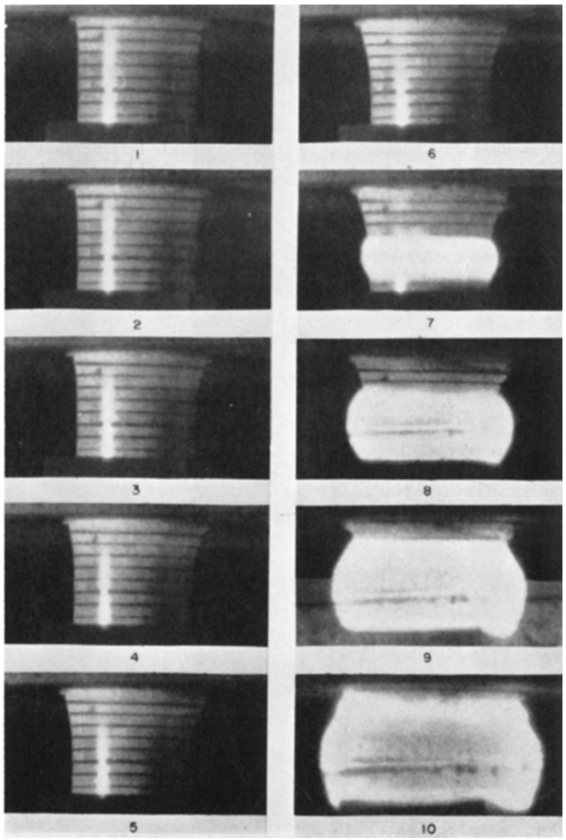

Fig. 5. Framing camera sequence showing forward and reverse propagation of a detonation in 9404 PBX, 1 μsec between frames.

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* Jack Gershon and R. H. Stresau, "Explosive flashlight: a new development in an explosive light source," published in these *Proceedings*.

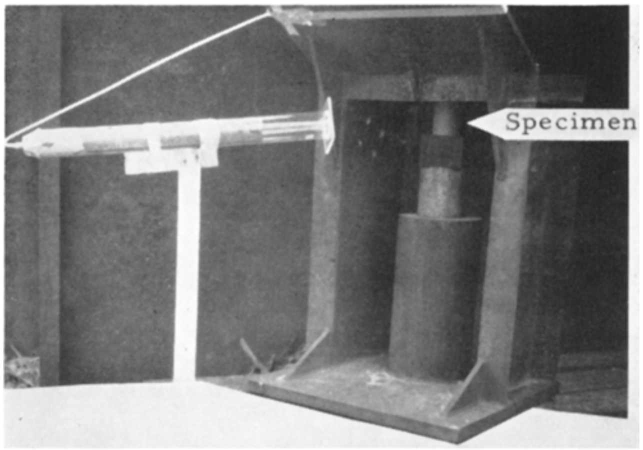

Fig. 6. Experimental arrangement showing argon light source in relation to specimen.

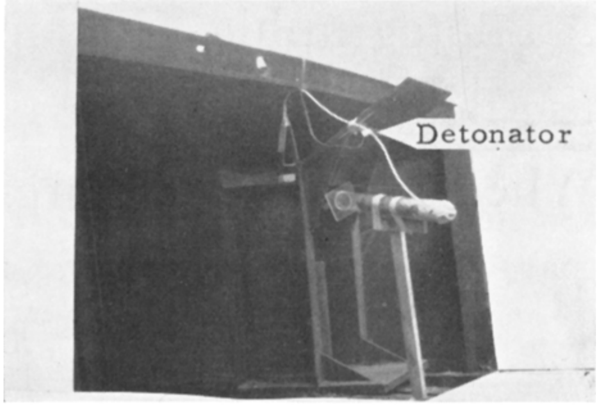

Fig. 7. Position of detonator along the primacord which connects the charges.

which may be used to synchronize the event to be photographed with the position of the rotating mirror of the camera. In the experiments discussed herein, it was necessary to synchronize both the firing of the explosive light source and the driving-plate charge with the active period of the camera. This was accomplished by the use of a single detonator which was appropriately located along a length of primacord connecting these two charges (Fig. 7). The triggering pulse itself is not of sufficient magnitude to initiate a wire bridge detonator at an accurately predetermined time, but this pulse was used to trigger a strong pulse from a firing supply. A U.S. Army Electric Detonator, M-36-Al, was found to fire reproducibly with a delay of 20 μsec when initiated by a firing pulse of a few hundred volts. The detonator subsequently transmits detonation in both directions along the primacord. The arrival of detonation at the explosive booster which actuates the light source and at the explosive booster which actuates the initiation system for the driving-plate charge is accurately timed by use of predetermined lengths of primacord on either side of the detonator.

Based on animations of the 25 frames of the original 35mm film, 16mm motion pictures were made for numerous experiments. Each frame is usually reproduced ten times; however, for better dynamic viewing of the event, as few as two repetitions of each frame have been used. One of the advantages of animations of these high-speed events is illustrated by Fig. 5. When the animations of this event were viewed, it was possible to observe a nonreactive shock wave propagating through the specimen. This is not noticeable in the single-frame prints of Fig. 5.

Kodak Tri-X Film was used for all the black-and-white photography. The best results were obtained by developing the film for 25 min in Microdol Developer. Daylight Super Anscochrome film was used for color photography. The color film was force-developed using an Ansco processing kit. Satisfactory results were obtained by developing 36 min in the first developer and 24 min in the color developer.

Conclusions

The use of high-speed photographic observations has proved to be a valuable aid in the study of the behavior of high explosives at high rates of loading.

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