SOUND WAVES FROM EXPLOSIONS.

JOHN E. SMITH, Franklin College.*

The sound waves coming from an explosion should reveal much concerning the nature of the explosion. Sound waves from other sources have been successfully photographed and in the study of explosives, photography is often employed. The present work is a report of the use of spark photography for this purpose, particular attention being paid to the resulting sound waves and other disturbances whose effects are revealed by the sensitive plate.

Mallard and Le Chatelier[1] traced the progress of a flame in a horizontal tube by the light effect upon sensitized paper which was made to move vertically. Oettingen and Gemet[2] used a rotating mirror and photographic camera for recording the stages in the development of an explosion. For a like purpose Dixon[3] used a camera with films attached to a revolving drum.

Photographs taken by any of these or similar methods show only those parts of the disturbance which are self-luminous and are the cumulative result of a longer exposure than is desirable for instantaneous results. Under proper conditions an electric spark has an intense luminous effect which lasts less than one millionth of a second. It has been used successfully in the photography of falling drops[4], insects in flight[5], projectiles in flight[6] and in various experiments with sound waves[7 8 9]. In Bulletin No. 23 of the National Research Council, Foley suggested that the method used in sound wave photography be applied to the study of explosives. Using this method, Dutcher[10] has made an extensive study of explosions in certain gases. The present paper presents some results of a study of solid explosives.

General Principle of the Method. The electric spark as an illuminant has been found most useful in the production of silhouette work. All the photographs shown in this paper are of this type. Following the

* This work was done in the Physics Laboratory at Indiana University. The author wishes to express his gratitude to Dr. Foley for his assistance, suggestions and criticisms.

1 Mallard and Le Chatelier, Annales des Mines, Vol. 4, 1883.

2 Oettingen and Gemet, "Ueber Knallgasexplosion," Annalen der Physik und Chemie, Vol. 33, 1888, p. 586.

3 Dixon, Philosophical Transactions of the Royal Society, Vol. 200, 1903, p. 316.

4 Cranz and Glatzel, Sc. Am. Suppl. Feb. 1, 1913.

5 Bull, Sc. Am., Nov. 26, 1910.

6 Cranz and Külp, Zeitschrift fur das Gesamte Scheissund Springstoffwesen. Translated in Sc. Am. Suppl., March 27, 1915.

7 Hyde, Sc. Am., Aug. 26, 1915. Wood, Phil. Mag., Vol. 48, 1889, p. 218. M. Toepler, Ann. d. Physik. Vol. 27, 1908, p. 1043.

8 Foley and Souder, Phys. Rev., Vol. 35, 1912, p. 373.

9 Foley, Phys. Review, Vol. 14, 1919, p. 143. Phys. Rev., Vol. 20, 1922, p. 505. Phys. Rev., Vol. 16, 1920, p. 449.

10 Dutcher, Phys. Rev., Vol. 15, 1920, p. 228.

plan used by Foley and Souder[5], in photographing sound waves, all lenses and reflectors were omitted from the set-up and the point source of light cast the shadow of the exploding body with its accompanying sound waves directly on the photographic plate. In a series of explosions the time interval between the explosion and exposure was varied and the resulting photographs gave a fairly complete life history of the explosion.

Arrangement of the Apparatus. Three Leyden jars of one gallon size were used on each side of the large induction machine, and twelve of the same kind in the light gap circuit. For the sake of safety it was necessary to devise a method of carrying the charge of explosive to a point between the platinum terminals of the gap after all adjustments of speed, capacity and inductance had been made. For this purpose a rubber stopper was mounted on a block of wood moving between two guides located just under and at right angles to the sound gap.

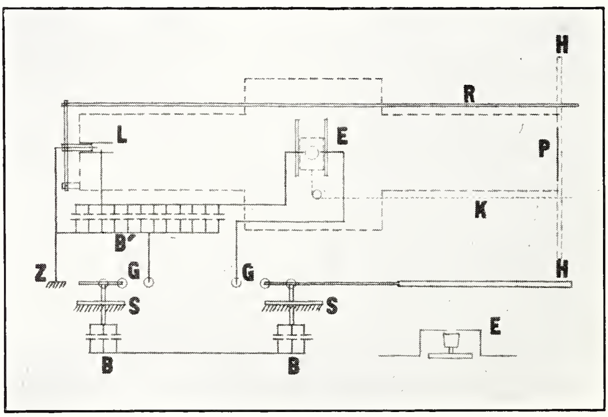

Fig. 1. Diagrammatic horizontal section of apparatus.

A cord was attached for drawing the charge into place. A diagrammatic horizontal section of the apparatus used is shown in figure 1. The block, guides and platinum terminals are at E in the center of the figure and the cord K is indicated by the dotted line. The block, stopper and terminals are shown in the detail at the lower right. S and S are the brushes on the induction machine, B and B—the batteries of Leyden jars on the machine, B′—the battery of Leyden jars in the secondary circuit, G and G—the gaps on the machine, Z—a ground connection, L—the light gap, R—the rod controlling the length of L, P—the photographic plate, and HH—the slide for holding the plate holder.

Operation of the Apparatus. The operator starts the induction machine which furnishes the electric charge, draws the block with the rubber stopper back from the spark terminals, places the charge of explosive on the rubber stopper and takes his position in line with the ground glass where the exposure is to be made. He then causes the spark to pass at regular intervals and observes the sound waves coming from the gap where the explosion is to occur. He adjusts the speed of the machine and the length of gap until the waves indicate a proper

Fig. 2.

Fig. 3.

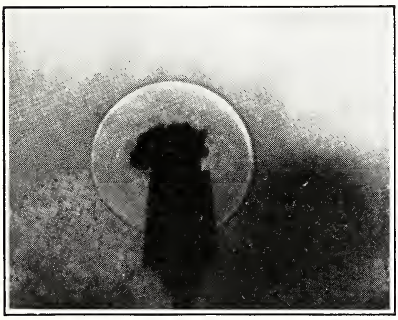

Fig. 4.

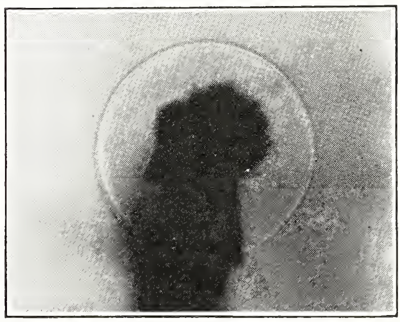

Fig. 5.

Fig. 6.

Fig. 7.

Figs. 2-7. Photographs showing successive stages of an explosion when unconfined lead styphnate was fired by an electric spark.

time interval and uniform operation. He then quickly places the unexposed plate in position, pulls the cord which draws the charge into place and causes the spark to pass which fires the charge and makes the exposure.

Discussion of Photographs. Figures 2 to 7 were selected from a large number as typical of the results obtained when unconfined lead styphnate was fired by an electric spark. To produce these photographs charges about 0.7 cm. in diameter were placed in a shallow cup cut in the upper end of the stopper which served as a firing base. The stopper is clearly outlined in each of the photographs. The ignition spark gap with the wires leading to it are not visible since they are directly in line with the charge and the support respectively.

Figure 2 was taken soon after the ignition spark had passed. A disturbance was created by the spark itself, but it is evident that the explosion has started, for the small dark dome on top of the stopper is larger than the charge. Figures 3, 4, 5, and 6 show well defined sound waves resulting from the electric spark and also the manner in which an explosion advances. In figures 6 and 7 there is evidence that all parts of the charge are not fired simultaneously. The wave pattern at the edge of the shadow indicates great numbers of explosion centers. In some cases as in figure 6, there is sufficient symmetry in the disturbance that the explosion has produced to cause a fairly even wave front. This appeared in a number of photographs. In figure 7 a number of extraordinary outbreaks are evident, as the dark shadow shows several ragged extended portions. It is also evident that the mass of air to the right has suffered a violent distortion.

Conclusions. 1. This method of instantaneous photography provides a means of studying the development of an explosion in solids. In contrast to work previously done in this field, it is independent of the illumination furnished by the explosion, it shows what is occurring at any particular instant of time rather than the cumulative result over an interval of time, and at the one instant it shows more than other methods, for it reveals changes in the density of the gases due to any cause whatever.

2. The sound waves from the igniting spark and from the explosion proper provide a general time reference in the study.

3. The number and character of the sound waves emanating from the explosion show something of the manner and order in which the parts of the charge explode.

4. Any unusual displacement of the body of air is indicated by the distortion of the sound waves.

5. As the method is perfectly general it may be applied to other explosives.