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INFLUENCE OF ELECTRICAL FIELDS ON SHOCK OF DETONATION TRANSITION

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ABSTRACT

The prediction that one should be able to influence detonations in condensed explosives as well as gaseous ones by means of axial electric fields is here studied by means of the deflagration to detonation transition (DDT) in a modified card gap (or SPHF plate) test by observing the influence of an applied field on the distance S_2 into the receptor where the DDT occurs. This distance S_2 for Composition B was shown to be appreciably influenced by an applied electrical field.

The magnitude of the effect in 2" diameter cast Composition B (donor and receptor) and nearly a 5 cm lucite SPHF plate was about 0.15mm/KV/cm, a positive to negative potential increasing the distance S_2 and a negative to positive one decreasing S_2 (unless the DDT occurs too close to an electrode).

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INTRODUCTION

Malinovskii[1] first showed that the detonation velocity could be affected in gaseous explosives, especially those detonating near threshold conditions, by the application of strong electrical fields. Malinovskii and Lavrov[2] concluded that negative charges actively propagate detonation waves in gases. They were able to quench detonations completely in the 80/20 air/acetylene mixture by strong electrical fields. Bone, Frazer and Wheeler[3] confirmed Malinovskii's results in the $2CO/O_2$ mixture and found that the detonation velocity was influenced slightly by a strong magnetic field. They also found an influence on the velocity of detonation in this gaseous explosive by electrical fields, velocities increasing under the positive to negative field and decreasing under the reverse field.

Attempts in this laboratory a decade ago to influence the detonation velocity of solid explosives by strong electrical and magnetic fields, however, were without success. On the other hand, while confirming our observations regarding the propagation of detonation, Gibson, Summers and Scott[4] showed that strong axial electrical fields (20 KV/cm) influenced the velocity of the shock to detonation transition (SDT) in a modified card gap test. They found in one test that a negative to positive field of 20 KV/cm increased slightly the initial shock velocity and the detonation velocity at the end of their charge. However, they found no effect for a reverse field in one test.

The situation in gaseous detonations is readily explained by an observation of Lewis[5] that flames under an applied electrical field are always bent toward the negative electrode, ionization occurs in flames and the positive ions produced by ionization move toward the cathode and the free electrons toward the anode. However, because the momentum of ions is great compared with free electrons in such an experiment, the mass motion of the gas is increased in the direction of the cathode and decreased in the opposite direction. The observed ionization in gaseous detonation waves is sufficient to account for a similar effect of electrical fields on mass motion in the detonation of gases as observed[6].

It was realized by Bone, et. al. that electrical and magnetic fields have their greatest influence on detonation under threshold detonation conditions, e.g., in the spinning detonation. When detonation occurs at the threshold of propagation any tendency to decrease the particle velocity would tend to cause failure. It might likewise be supposed that in the formation of a detonation wave by the deflagration to detonation transition or DDT (sometimes also referred to as the shock to detonation transition or SDT) anything which can influence the mass motion of the reaction medium would have a strong influence on the DDT especially near threshold conditions for this transition to occur. The 50/50 point in the card gap test represents a threshold condition in the DDT. Therefore, it should be possible to influence it by applied electrical and magnetic fields.

This report presents the results of studies of the influence of an applied axial electrical field on the distance into the charge S_2 at which the transition to detonation occurs in a modified card gap test.

EXPERIMENTAL

The familiar SPHF method for the DDT[7] was used in this investigation modified to permit the use of an applied field (Figure 1). Both the donor and receptor charges consisted of Composition B and the SPHF plate was lucite. However, since Composition B sometimes shows some variability from one lot to the next, in order to obtain good reproducibility the donors and acceptors in any one series of tests were all poured from the same lot of Composition B or from a given batch of ingredients (TNT, RDX, and wax) as the case may be. The donor charges were all 5 cm in diameter and 20.3 cm long. The electrical potential was applied at two grids which were cast into the explosive when it was poured. The grids were hand woven with 1.0 cm openings (Figure 2). The grid wire was bare copper, 28 gauge. The first grid was located 2 cm and the second grid was located 8 cm from the (receptor) explosive-attenuator interface. The grids were placed parallel to each other in a plane normal to the axis of the acceptor charge as illustrated in Figures 1 and 3. The grids were woven on a peg board and then placed between sections of a cardboard mold that had been cut to the proper lengths on a lathe (Figure 3).

A glass bottom was taped to the mold and molten Composition B was then poured into the mold. After cooling the mold was removed to expose the bare explosive. Three foot, 28 gauge copper wire extensions were connected to the grids which in turn were connected to the coaxial high voltage supply cable.

The shock attenuator or SPHF filter was constructed of laminated sections of lucite plastic. Each attenuator was milled to produce parallel faces at $\pm$ 0.003 cm tolerance in total thickness S_1. Milling to these tolerances was found to be quite essential in order to produce uniform initial shock pressures. The donor was initiated at the bottom by a No. 6 electric blasting cap inserted into a small, uniform Tetryl booster which in turn was attached to the Composition B donor. The position of the initiation of detonation (S_2) was recorded both by high speed framing and high speed streak photography. The framing camera was operated at 4,000 revolutions per second which gave an exposure of 0.96 frames/μsec. Flash bomb front lighting was used to illuminate the receptor charge. A static image was used as reference to determine the initial position of the attenuator-receptor interface. Photographs were taken with high speed ecktachrome color film - ASA 160, Royal X Pan film - ASA 1600 and high speed infrared ASA 80.

Streak camera photography was used to supply the actual quantitative S_1 versus S_2 data because it permitted easier and more accurate data reduction. Moreover, self illumination is quite adequate in streak photography thus eliminating the need of light bombs. The reference position was established in the manner illustrated in Figure 4 a-c. In this method lines spaced 1 cm apart were inked (black india ink) on a clear cellulose acetate sheet which was then taped loosely to the surface of the acceptor. The reference lines registered 1, 2, 3, etc. centimeter distances from the attenuator-acceptor interface. NaCl was poured between the charge surface and the acetate sheet. This was done to increase the intensity of the illumination from the detonation as it reached the surface of the acceptor charge. The camera was operated at its maximum speed of 700 RPS, at F-11 and the film was Kodak Tri-X Aerecon ASA 200 and Kodak infrared ASA 80.

A number of the tests were carried out using simultaneous recording of the sequence with high speed framing and streak cameras. (Figure 5).

Tests were first conducted to determine the effect of the grids on S_2

with no applied potential. Since the primary goal was to determine the influence of the applied potential, it was sufficient that the transition point remain constant at zero applied potential recognizing, of course, that the grid inserts themselves had an appreciable influence on S_2 as compared with a similar assembly that did not contain grids. (Accurate and reproducible construction of grids was therefore essential in this study.)

RESULTS AND INTERPRETATIONS

The experimental results obtained (using Composition B throughout) are presented in Table I. They show clearly that in this explosive axial electrical fields influence appreciably the distance S_2, the distance into the receptor charge where the DDT or SDT occurs. Under the negative to positive electrical potential in the direction of propagation of the shock wave in the receptor the value of S_2 increased with increasing potential (at a rate of from 0.03 to 0.15 cm/KV). Note that the receptor failed in two cases and the DDT occurred at the considerable distance of 65 mm in a third case when the applied potential was +28 KV.

On the other hand a positive to a negative field usually decreased S_2 (or increased the DDT sensitivity) except in one case where S_1 was least and where S_2 was thus probably influenced unduly by the position of the first grid.

Table II summarizes the results of this study in terms of the ratio. $\overline{\Delta S_2/\Delta E}$, the average increase in distance with applied potential data being tabulated in two ranges: (1) between zero and E_{max} designated ($0 \rightarrow E_{max}$) and (2) between E_{min} and E_{max} designated ($E_{min} \rightarrow E_{max}$).
At the smallest value of S_1 (45.7 mm) the ratio $\Delta S_2/\Delta E$ was only about 0.3 mm/KV ignoring the one shot at E_{min} = -29 KV. At all larger values of S_1 this ratio ranged from 0.7 to 1.5 with an average of about 1.0 mm/KV.

The results of this study confirm the prediction that the DDT, a threshold condition associated with detonation, may be appreciably influenced by an applied axial electrical field. A positive to negative field tends to increase and extend the distance into the receptor where the DDT occurs and a negative to positive field tends to reduce this distance. This is in agreement with the expected influence of known ionization conditions in the detonation reaction zone and their development in the DDT[6]. Thus a positive to negative field tends to retard detonation and a negative to positive one to promote detonation. The mechanism of this effect is simply that the mass motion of an incompletely ionized gas under an electrical field is the same as in a flame, namely in the direction of the cathode. Increased mass motion induced by an electrical field in the direction of propagation of detonation should assist detonation whereas decreased mass motion in this direction should retard it. Since this is a relatively small incremental impulse effect compared with the total impulse of a detonation wave, it becomes important and measurable only under threshold conditions, as in the deflagration to detonation transition, or at very low densities (gaseous detonations).

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TABLE I. Distance S_2 into Receptor for DDT vs Applied Potential (Composition B Donor and Receptor - d = 5.04 cm, SPHF - lucite)

S_1(mm)	Composition B Lot No.	No. of Shots	Applied Potential (KV)*	S_2(mm)
45.7	5	3	0	29.3 ± 0.9
45.7	5	1	+10	32
45.7	5	1	+15	33
45.7	5	1	+20	38
45.7	5	1	+25	37
45.7	5	1	-25	25
45.7	5	1	-29	31
47.04	1	4	0	32.4 ± 0.2
47.04	1	2	+10	39.5 ± 3.5
47.04	1	1	+15	43
47.04	1	1	+10	55
47.4	1	1	+28	Failed
47.4	1	1	-10	32
47.4	1	1	-15	31
48.4	4	4	0	47.2 ± 2.1
48.4	4	1	+8	48
48.4	4	1	+10	51
48.4	4	1	+15	52
48.4	4	1	+20	62
48.4	4	1	-12	42
48.4	4	1	-25	31
48.4	4	1	-28	28
49.3	2	2	0	27 ± 2.0
49.3	2	1	+10	35
49.3	2	1	+20	42
49.3	2	1	+26	45
49.3	2	1	+28	68
51.0	3	1	0	25
51.0	3	1	+14	36
51.0	3	1	+27	50
51.0	3	1	+28	Failed

*Positive value means positive to negative potential (voltage gradient is the value given divided by 6 - electrodes 6 cm apart). Negative values mean negative to positive potential.

TABLE II. Variation of S_2 with applied potential E as a function (barrier thickness S_1 (near sensitiveness limit S_1*)

S_1 (mm)	E (max) (KV)	E (min) (KV)	S_2 (E_{max}) (mm)	S_2(0) (mm)	S_2(E_{min}) (mm)	$\Delta S_2/\Delta E$ (mm/KV) (0→E_{max})	(mm/KV) (E_{min}→E_{max})
45.7	+25	-25 (-29)	37	29.3	25 (31)	0.3[illegible]	0.28 (0.14)
47.04	+28 (+28)	-15	55 (Failed)	32.4	31	1.25	0.73
48.4	+20	-28	62	47.2	28	0.74	0.71
49.3	+28		68	27		1.47	
51.0	+27 +28		50 (Failed)	25		0.93	

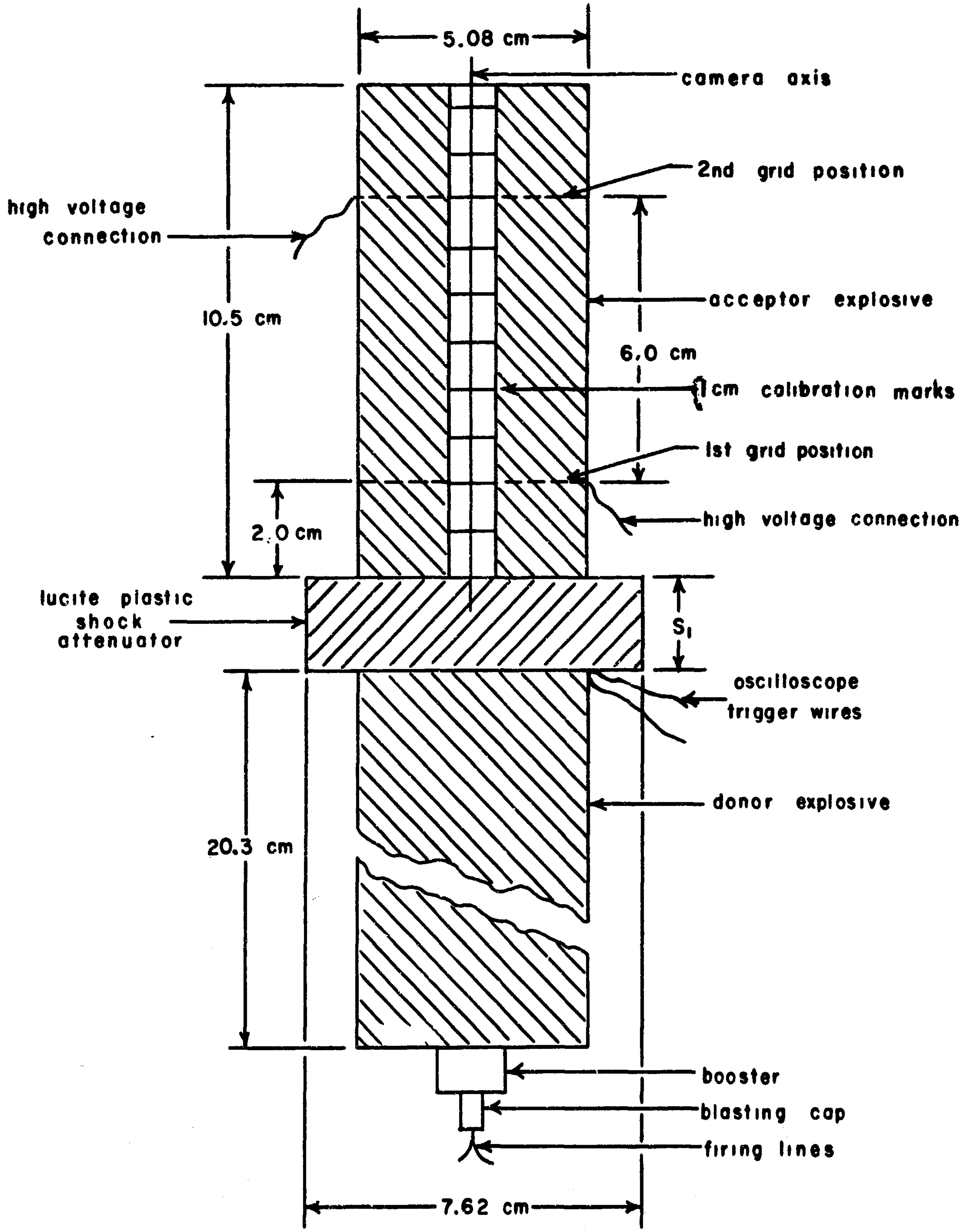

FIGURE 1 . . Detail of set up to determine the effect of Electric Potential on the value of S_2.

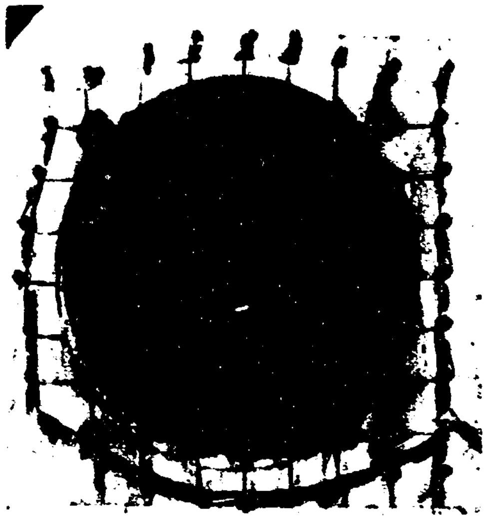

FIGURE 2. Pegboard construction of grids.

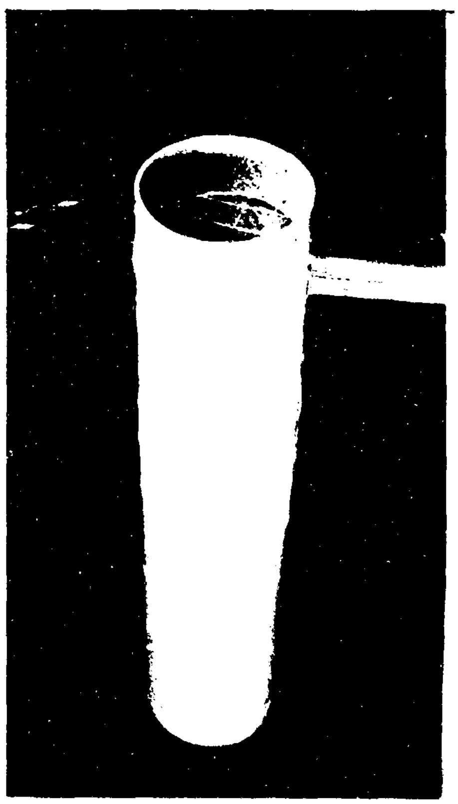

FIGURE 3. Cardboard mailing tube mold for explosive acceptor showing installation of grids before pouring.

FIGURE 4a. Checking alignment and exposure of apparatus used to test the effect of S_2 versus electric fields.

FIGURE 4b. Front or camera view of apparatus showing booster, attenuater and receptor.

FIGURE 4c. Back view looking toward periscopes located on top of the instrument shelter.

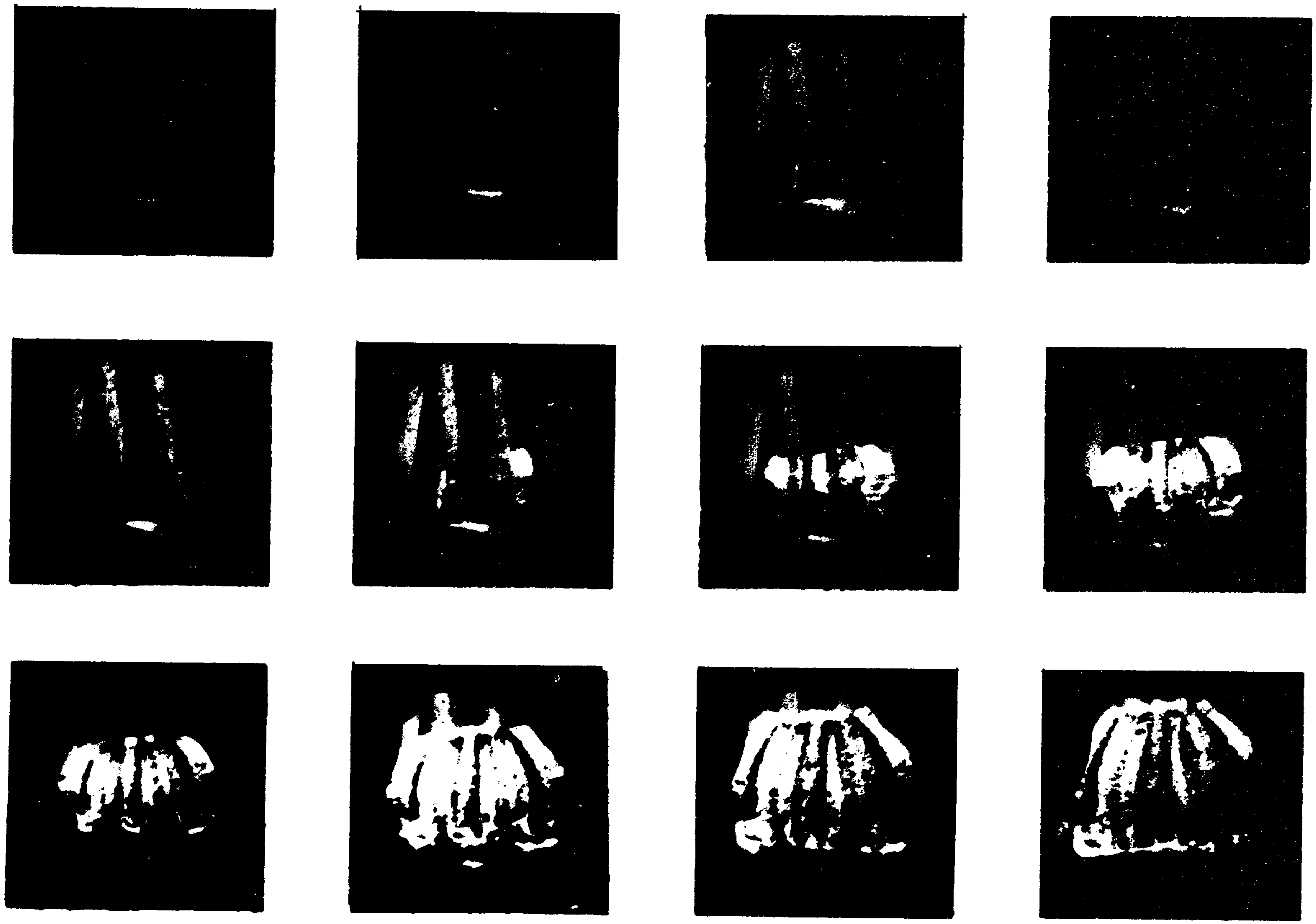

FIGURE 5. Framing camera record of DDT along scaled Composition B charge.