Boundary Disturbances in High Explosive Shock Tubes

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ABSTRACT

High Velocity disturbances are observed to propagate in advance of the plane shock front along the walls of a high-explosive-operated shock tube. Experiments were performed which indicate that the disturbance proceeds at a constant velocity relative to the shock front, and carries a considerable amount of energy as evidenced by its ability to penetrate metal plates. The velocity of a similar disturbance observed along a rod placed on the axis of the shock tube normal to the plane shock front was essentially independent of the rod material and diameter. This phenomenon was observed when shock tubes were filled with argon or chlorine but was absent when air or helium was used.

Boundary Disturbances in High Explosive Shock Tubes

It is well known that a shock front proceeding down a shock tube will develop into a plane front soon after its initial formation. For very strong shocks, such as might be developed in a shock tube which uses an explosive charge instead of a bursting diaphragm, conditions may be altered. Violent disturbances have been observed to proceed down the walls of the tube well in advance of the shock front.

A number of experiments was conducted in an effort to determine the properties of this disturbance. They were performed with slight modification in two basic types of setup. The first, which will be referred to as a type I experiment is shown in this slide (slide 1) which shows a front or camera view of the expendable experimental assembly. The cardboard tube on the left will be referred to as the experimental tube. It is 8" in diameter and is glued to a 2" x 8" x 8" block of composition B explosive which is detonated by a high explosive plane wave generator. The latter is a combination of fast and slow explosives that converts a point detonation into a plane detonation wave. The front of the experimental tube is sealed by a 1 mil dural or copper foil upon which a polar coordinate system has been inked. The description of a given experiment will include the length of the tube, the gas which it contains, and any foreign object (such as an axial wire) to be introduced. The purpose of this type of experiment is to study the surface of the foil as it interacts with the strong gas shock generated in the tube by the high explosive. These results are interpreted to determine the properties of the gas shock. The foil study is made by photographing its surface with a 25 lens framing camera using light from highly shocked argon.

SLIDE 1 -5-

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The camera view of the second or type II basic experiment shown in this slide (slide 2) is used to photograph a side view of the gas shock and disturbance. As such it supplements the experiment just described which indirectly views the surface of the shock. The 2" thick composition B block and plane wave generator are used as before. The cardboard tube, however, is replaced by a rectangular box constructed of 1/8" sheet Lucite. This box has a 5" x 5" inner cross section and is 16" long. No flash is used; light is supplied by the radiation from the shocked gas.

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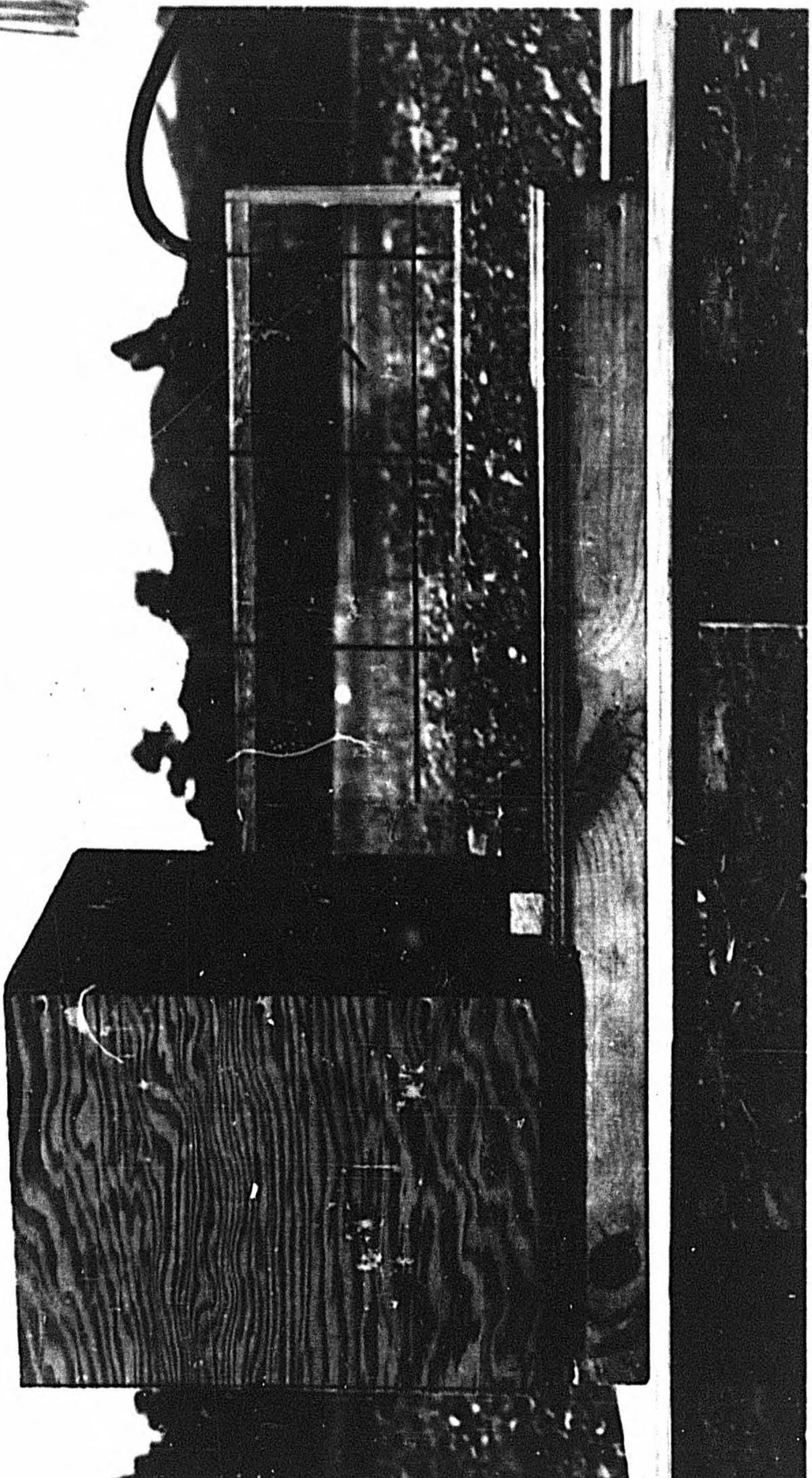

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The first three experiments were of type I, and used different lengths of argon-filled experimental tubing: 8", 16", and 24". The slide (slide 3) shows three pictures spaced at 0.9 microsecond intervals taken from the record of the 8" shot. The top picture shows the peripheral disturbance surrounding the otherwise undisturbed dural foil. The middle picture shows the uniform deterioration of the foil upon arrival of the plane shock front. Note that the peripheral disturbance is confined to a ring approximately 1.3" wide. The bottom picture shows the complete deterioration of the foil by the shock front. The dark vertical line which persists on this picture is a vertical reference wire placed 1" from the surface of the foil.

The average velocity of the peripheral disturbance in the 8" tube was approximately 9.7 mm/μsec. The velocity of the plane shock was 7.8 mm/μsec. The velocities in the longer tubes indicated slight decelerations of both the plane wave and the peripheral disturbance.

Similar experiments were performed in which the argon was replaced by air, helium, and chlorine. The chlorine experiment gave a photographic record similar to one shown in this slide. No boundary disturbance was associated with the air or helium.

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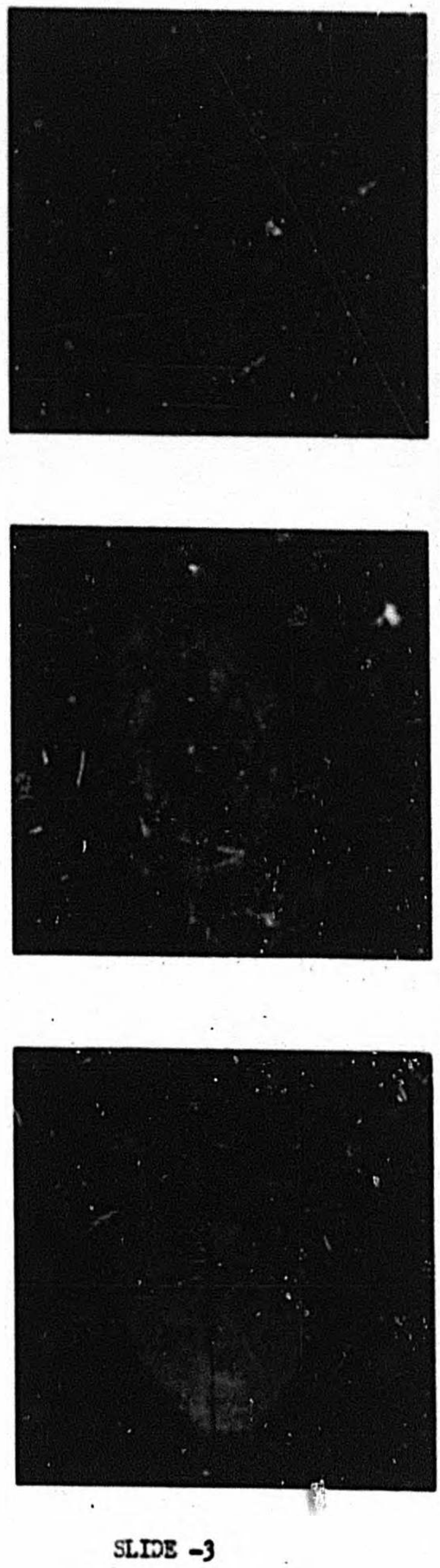

SLIDE -3

The second set of experiments was of type II. The purpose was to photograph a side view of the phenomenon described in the previous experiments. The 5" x 5" x 16" Lucite box was filled with argon. The disturbance was permitted to form over the initial 10" of propagation; the remaining 6" of the run was photographed. Three frames from the record, ordered in time from top to bottom at 2.7 μsec intervals, are shown in this slide (slide 4). The black arrow was marked on the side of the box to indicate the direction of propagation. The black lines forming a rectangle are 4 wires attached for scale and, with the arrow, also serve to establish relative motion of the phenomenon. The horizontal and vertical distances between the wires are 4" and 3", respectively. Several data pertinent to the plane shock front and the peripheral disturbance can be measured from the record. Consider first the shock front. It is most easily identified in the middle picture as the luminous vertical line at the base of the arrow. The relative velocity of this front determined from 12 consecutive frames was 7.5 mm/μsec. The thickness of the luminous front, even as viewed from its side, is less than 3 mm. A measure of the angle defined by the edge of the Lucite box and the luminous boundary of the peripheral disturbance was established on 8 frames as 11°.5 ± 1°.5

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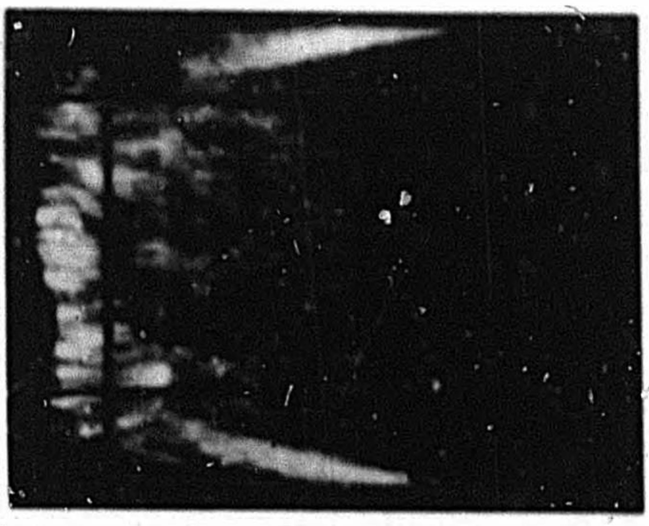

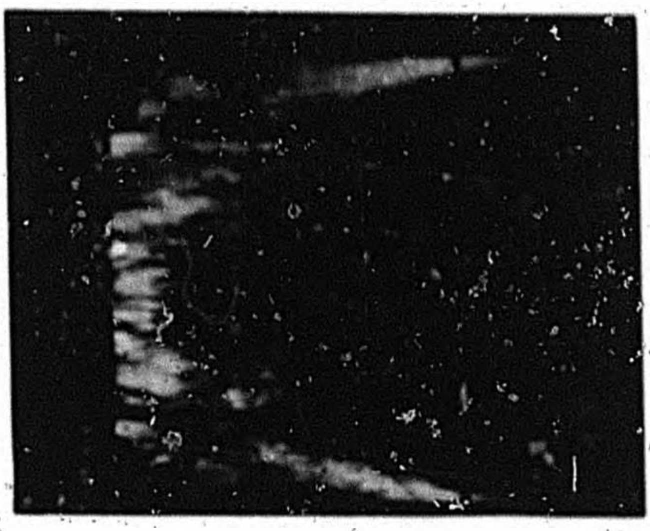

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It was natural to suppose that the type of disturbance apparently supported by the cardboard experimental tube would be intensified by using a wire placed on the axis of a 16" long, argon-filled tube. This slide (slide 5) demonstrates the results of such an experiment. The wire was a tinned 1/16" diameter copper bus wire. One end was glued to the center of the Comp B block. The other end extended through and well beyond the surface of the foil. The four pictures in the slide were chosen to show the development of the disturbance. The first picture (upper left) shows the foil approximately 1 microsecond following initial interaction with the disturbance due to the wire. Note that the peripheral disturbance has not yet appeared. The second picture (upper right), exposed 6.3 microseconds later, shows both the wire disturbance and peripheral disturbance well developed. An interval of 5.4 microseconds separates the second and third (lower left) pictures. The third was exposed just as the foil surface was struck by the plane shock. The fourth follows 0.9 microseconds later and shows the complete deterioration of the foil. The average velocities of the wire disturbance, peripheral disturbance, and plane shock, were determined as 10.3 mm/μsec, 9.7 mm/μsec, and 7.7 mm/μsec, respectively.

A series of similar experiments indicated the axial disturbance to be moderately independent of the central rod diameter and composition. For these experiments the tinned copper wire shown in this slide was replaced by a 1/8" birch dowel and by a 1/8" diameter standard thread brass rod. The diameter of the tinned wires was varied to as small as 10 mils. The average velocity for the axial disturbance for all experiments fell within a range between 10.3 and 11.3 mm/μsec.

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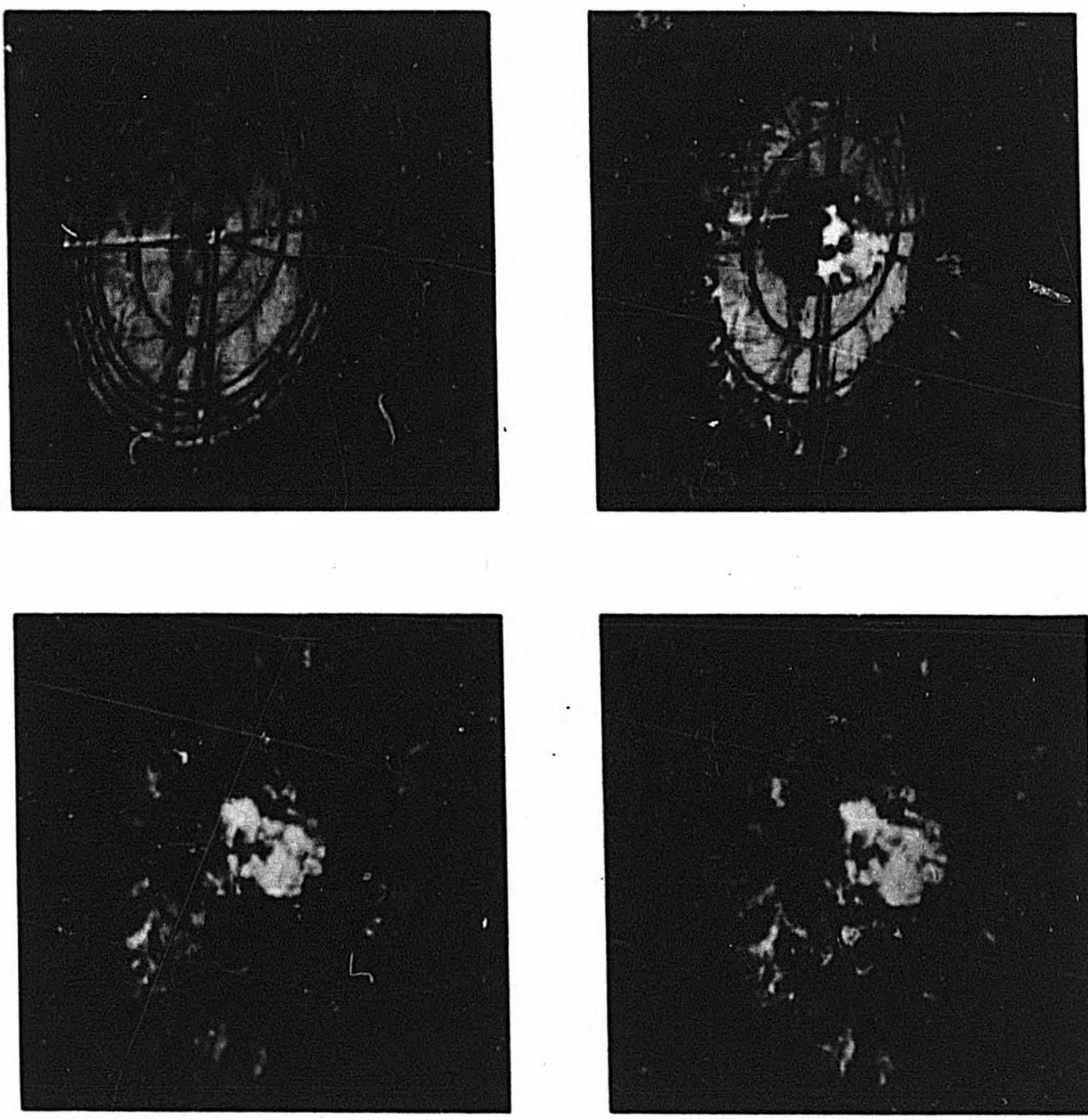

SLIDE-5

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Two type 1 experiments were performed to demonstrate the energy of an axial disturbance. The setup was prepared with a 1/16" diameter wire extending along the 16" axis of the experimental tube. For the first experiment a 3" diameter 0.040" thick dural plate was centrally attached to the one mil dural foil. The two pictures shown in this slide (slide 6) were taken from this record. The left picture shows the dural plate framed by the 4" diameter coordinate circle. In this picture the existence of both axial and peripheral disturbance is evident. (Approximately 4 microseconds later, the axial disturbance tore through the dural plate.) The right picture was exposed 9.0 microseconds following the first picture. It shows the axial disturbance well developed on the front surface of the plate. This picture was exposed just as the plane shock struck the foil.

A second experiment was performed in which the dural plate thickness was increased to 0.127". Although the axial disturbance was unable to penetrate this target, it was able to force the plate into a dish shape, the center extending beyond the edges by 0.08".

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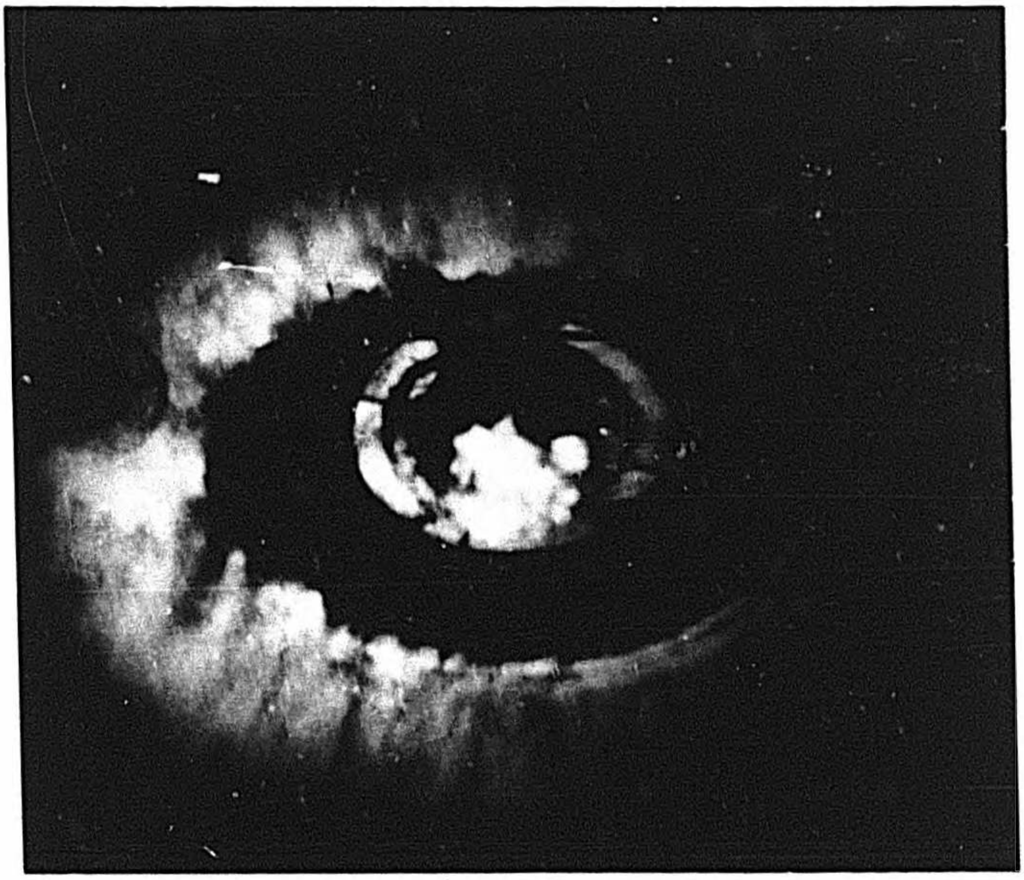

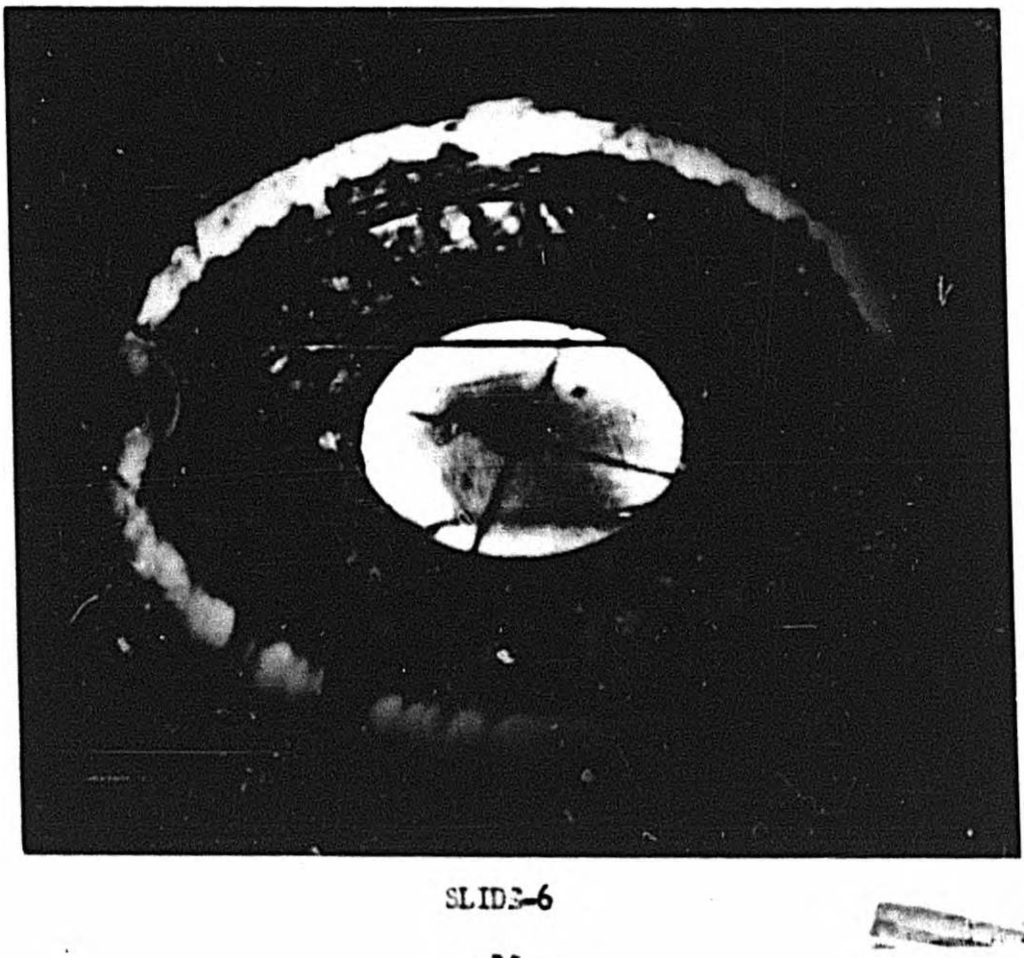

SLIDE-6

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This slide (slide 7) shows 20 frames spaced at 0.9 microsecond intervals from a type II experiment in which a wire extended only 10" from the high explosive along the axis of the Lucite box. It shows how the axial disturbance is suppressed when the supporting boundary is removed. The velocity of the unsupported disturbance is 6.3 mm/μsec over the time of this record. It is being overtaken by the shock front which moves at approximately 7.4 mm/μsec.

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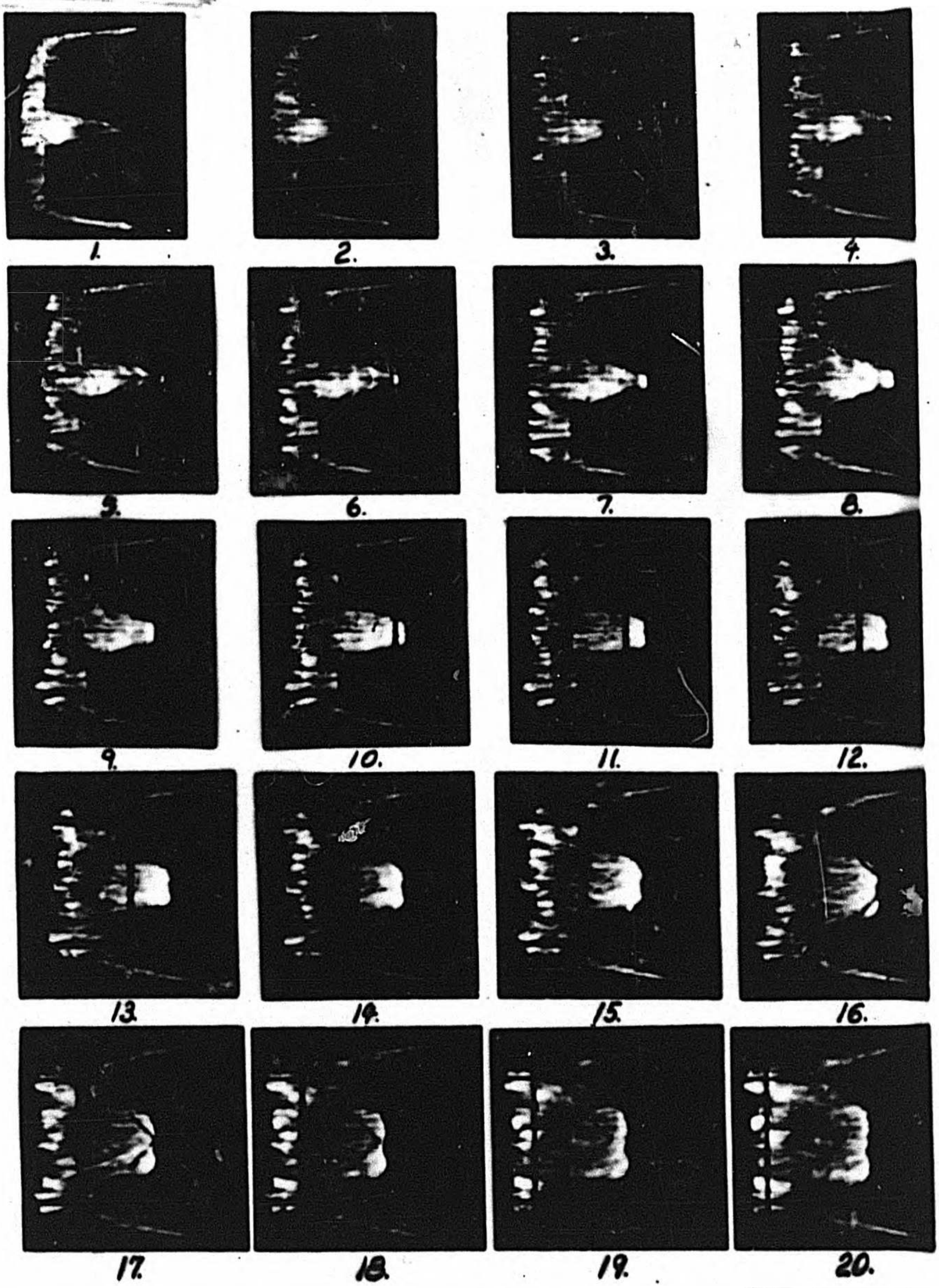

SLIDE 7

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This slide (slide 8) shows 6 frames, spaced at 2.7 micro-second intervals, of a type II experiment performed to study the formation of an axial disturbance. For this experiment the wire extended axially along the front 8" of the box, i.e. the initial 6" of propagation was undisturbed by the wire. The first three pictures of this slide shows the undisturbed plane shock front approaching the axial wire. The following pictures show the development of the disturbance. The head of the disturbance decelerates from 15 mm/μsec to 10.5 mm/μsec.

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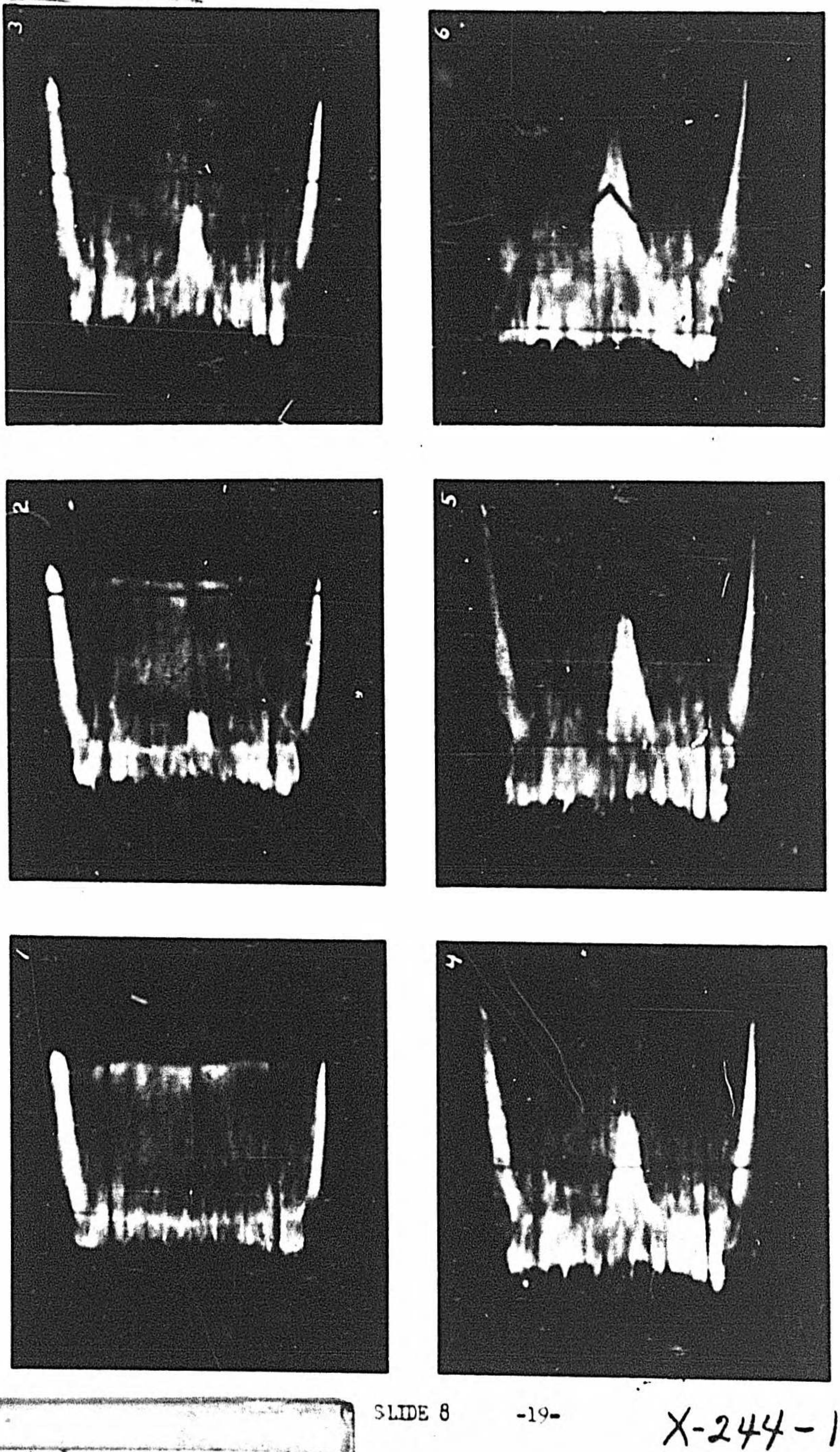

SLIDE 8

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