CONF-7805125--1

LA-UR-78-2279

MASTER

TITLE: DEVELOPMENT OF A LARGE ELECTRICALLY DRIVEN FLYER SYSTEM FOR EXPLOSIVE INITIATION STUDIES

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SUBMITTED TO: PROCEEDINGS OF THE JOINT FRENCH, GERMAN, UNITED STATES "PHYSICS OF EXPLOSIVES," MEETING HELD AT LOS ALAMOS, NM, MAY 9-11, 1978.

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UNITED STATES
ENERGY RESEARCH AND
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CONTRACT W-7405-ENG. 36

Development of a Large Electrically Driven Flyer System for Explosive Initiation Studies

by

W. L. Seitz, S. C. Schmidt, and Jerry Wackerle

ABSTRACT

An experimental study to develop an electrically driven flyer system for explosive initiation studies is described. Both pulsed laser stereophotography and streak camera studies have been used to determine a foil/land/flyer geometry that will give sufficiently planar flyers for quantitative explosive initiation studies. A shot assembly with explosive wedges 6.4-mm diam and 20° to 30° angles has been designed to study run distances to detonation from 0.5 mm to 2.0 mm. Preliminary results are given for 1.8-g/cm^3 superfine TATB.

I. INTRODUCTION

There is considerable interest in insensitive explosives for use in detonators as well as other weapon components because of the safety factor they provide. However, at present very little initiation data exist for these insensitive explosives especially in the millimeter to submillimeter distance to detonation range. For more sensitive explosives, experiments by Gittings[1] on PBX-9404, Wackerle, et al.[2] on PBX-9404, Trott and Jung[3] on Comp-B and PBX-9404 and de Longueville, et al.[4] on several explosives, have demonstrated that shock duration can significantly influence initiation behavior. The "prompt" initiation behavior of insensitive explosives must also be characterized, both from an engineering point of view and to assist in obtaining a better basic understanding of the initiation process.

To study these insensitive explosives we have chosen 1.80-g/cm^3 superfine TATB as a test explosive, and the explosive wedge as a technique to observe these short distances to detonation. We have chosen the electrically driven flyer system to initiate the explosive. Electrically driven flyer systems have been shown by Weingart, et al.[5,6] to have the capability of driving flyers with sufficient velocity to initiate insensitive explosives.

Electrically driven flyer systems have the advantage that experiments can be performed in an ordinary laboratory, with electrical and optical diagnostic equipment positioned very close to the explosive sample confined in a "boom box". The thin shocks generated are also similar to the shocks present in an ordinary detonator design. However, they have the disadvantages that flat and reproducible flyers are difficult to obtain and that generation of thick shocks is difficult.

II. EXPERIMENTAL AND RESULTS

The experimental arrangement for the explosive wedge assembly is shown in Fig. 1. The explosive wedge is glued into a Lucite holder and positioned at the end of a Lexan barrel. The flyer is accelerated down the barrel by the exploding foil, and generates a high pressure shock wave in the explosive wedge upon impact. Flyer tilts and impact times are determined from light pulses observed when the flyer impacts the Lucite holder around the explosive wedge. Breakout of the shock or detonation wave from the explosive wedge surface is observed with a rotating mirror streak camera by illuminating the wedge surface with a small (<3 g explosive) explosively driven argon flash. The camera optical axis and flash are positioned to give specular reflection from the explosive surface into the camera.

Explosive wedges are hand ground from the central portion of pressed pellets 6.4-mm diameter by 6.4-mm long and with densities of 1.801 ± 0.002 g/cm^3. Wedge angles of nominally 20° and 30° have been used. Wedge toe thicknesses of 50 μm have been obtained with special care and toe thicknesses of 100 μm have been easily obtained. A six millimeter scale is shown on several of the figures to show dimensional sizes in comparison with the wedge size.

Figure 2 shows our present capacitor discharge system, which consists of a 56-μF capacitor bank that can be charged to 20 kV. The capacitor bank is discharged through the foil/cable system by means of a field distortion switch.[7] The foil is vaporized by joule heating and the resulting high pressure, ionized gas accelerates the flyer down the barrel. A streak camera with a crossed slit arrangement, shown in Fig. 3, is used to observe flyer planarity both parallel and perpendicular to the current and also to determine flyer velocity. One-half of the slit is projected through a lens system to give the slit image parallel to the current. The other half of the slit is brought out through turning mirrors and passed through a lens dove prism arrangement to allow the slit to be rotated and positioned to give a slit image perpendicular to the current.

Figure 4 shows streak camera records for three foil thicknesses. Several foil configurations were tried in an attempt to obtain flat and reproducible flyers; however, the foil configuration shown in this figure has given the most planar and reproducible flyers. The foil is fabricated by laminating a thin aluminum sheet to an epoxy fiberglass substrate and photoetching the aluminum to leave a 14.3-mm square foil. The three streak records show the effect of foil thickness on planarity for slits both parallel (right streak in each frame) and perpendicular (left streak in each frame) to the current. The offsets in each trace are the result of grooves machined in the Lucite impact block for velocity determinations. As is evident, the planarity is normally better parallel to the current than it is perpendicular to the current. It can also be seen that flyer planarity is best for the 25-μm foil, only slightly worse for the 51-μm foil, but that the flyer is torn apart for the 76-μm foil.

Flyer velocities as a function of foil thickness are shown in Fig. 5. Flyer velocity is seen to be greatest for the 51-μm foil even though the 25-μm foil gave the best planarity. Therefore, we have used 51-μm foils for most of our shots because of the greater velocity even though some sacrifice in planarity was made.

In observing a number of streak camera records for different foils, we found that imperfections observed in foil burst correlate with imperfections in flyer planarity. Figure 6 is a streak camera record of a foil/flyer configuration for which the foil was known to have a scratch at the point where the early light appears in the right-hand streak record. The flyer is seen to impact the Lucite block early in this region above the scratch. In fact, asimultaneity of the light onset across the foil is noted to be directly associated with flyer aplanarity.

A number of pulsed laser stereo photographs of exploding foils have also been taken using the experimental arrangement shown in Fig. 7.[8] A pulsed laser beam is focused on the exploding foil. Scattered laser light from the foil is then collected by the camera lenses and focused on the film planes. Narrow bandpass filters are used between the lenses and the film planes to filter out self-light generated by foil ionization and air shock. For these large foils a further reduction of the self-light was necessary in order to obtain good photographs. This was accomplished by firing the foils in a butane atmosphere.

Figure 8 shows a single frame of the stereo pair at four different times. The times given are referenced to the time of peak voltage developed across the foil. Early burst is seen to occur along the ends of the foil as shown by the black vapor clouds in the first two frames. Early vaporization is also seen to occur along the edges of the foil. At the later times the central foil portions appear to be bursting rather uniformly; however, there is some nonuniformity still seen around the foil edges. This would suggest that if the foil dimensions were large compared to the barrel diameter that flatter flyers could probably be obtained. However, as has been shown in previous empirical studies,[9] increasing the foil dimensions to achieve this improvement would result in a decreased flyer velocity.

A typical streak record with a corresponding analysis for an explosive wedge shot is shown in Fig. 9. The cutoff of the light reflected into the camera from the explosive surface occurs as the shock or detonation wave breaks out. Straight lines appear to fit the data for both the buildup to detonation and the region after detonation, indicating more or less constant shock velocities in both regions.

We have fired three explosive shots for each of the two different flyer configurations listed in Table I. The overtake time given for each configuration is the calculated time for the lead rarefaction (from the plastic-aluminum interface) to overtake the shock front in the high explosive. Experimental distance and time to detonation and derived Hugoniot data for individual shots are given in Table I, along with averages and standard deviations for the nominally identical shots. It should be noted that the buildup process is not fully supported since the calculated rarefaction overtake time is less than the measured time to detonation.

The Hugoniot data and distance to detonation are also shown in Figs. 10 and 11 respectively. Hugoniot and distance to detonation data obtained by John Ramsay[10] for 1.806-g/cm^3 standard grind TATB with explosive plane wave booster systems are also given in Figs. 10 and 11. For comparison three distance to detonation vs pressure points obtained by Jackson, et al.[6] for 1.81-g/cm^3

TABLE I. Distance and time to detonation, and Hugoniot data for superfine TATB obtained with short duration shocks generated by electrically driven flyers in explosive wedges. The superfine TATB wedges were ground from pellets with a density of 1.801 ± 0.002 g/cc.

	Flyer Velocity (mm/μs)	Overtake Time (μs)	Pressure (GPa)	Shock Velocity (mm/μs)	Particle Velocity (mm/μs)	Distance to Detonation (mm)	Time to Detonation (μs)
Flyer A	2.62 ± .08	0.170	16.7	5.5	1.69	1.66	.292
	"	"	18.4	6.4	1.61	1.89	.265
	"	"	17.1	5.7	1.67	1.76	.293
Average of above three			17.4 ± 0.9	5.8 ± 0.4	1.66 ± 0.04	1.77 ± 0.12	0.283 ± .016
Flyer B	3.26 ± 0.05	0.074	22.7	6.1	2.05	1.04	.218
	"	"	22.4	6.0	2.07	1.28	.227
	"	"	23.7	6.6	2.01	1.36	.222
Average of above three			22.9 ± 0.7	6.2 ± 0.3	2.04 ± 0.03	1.23 ± 0.17	0.222 ± 0.005

Flyer A: 0.12 mm Mylar/0.33 mm Mylar/0.26 mm Al

Flyer B: 0.076 mm Kapton/0.33 mm Mylar/0.13 mm Al

92.5% TATB/7.5% Kel-F are also shown in Fig. 11. Expressions for the shock velocity vs particle velocity and the distance to detonation vs pressure were obtained for the combination of both the superfine and standard grind TATB. The shock-particle velocity expression should be valid since both sets of data were taken for the same void fraction, and the difference in particle size should not be important for this relation. However, the distance to detonation is known to be a function of both particle size and input shock duration.

Previously cited short-shock experiments in PBX-9404,[1-3] Composition-B[3,4] RDX[4] and TNT[4] all have shown increased run distances to detonation as flyer thickness is decreased. Lindstrom's initiation study on porous tetryl[11] and the observations of Howe, et al.[12] on granular TNT have shown that decreasing particle size results in decreased distance to detonation at a given input shock strength. If these two effects occur in TATB then, relative to Ramsay's sustained-shock observations on standard grind explosive, our short-duration shock input would be expected to give longer distances and our superfine material shorter distances to detonation. Therefore, the linear relation between distance to detonation vs pressure for the combined TATB data may result from two compensating effects.

III. CONCLUSIONS

We have obtained useful Hugoniot and initiation data for 1.801-g/cm^3 superfine TATB. We have also demonstrated that the technique of using electrically driven flyers to initiate small insensitive explosive wedges to obtain initiation data is feasible for millimeter distances to detonation.

We are also convinced that if we had chosen one of the more sensitive explosives such as PBX-9404 or PETN as a test explosive that we could study submillimeter distances to detonation, and we plan to study these explosives in the near future.

We have found that some change in geometry is required to give the greater flyer velocities necessary to study submillimeter distances to detonation in 1.8-g/cm^3 superfine TATB. It is not presently known as to how short a distance to detonation can actually be attained for insensitive explosives regardless of flyer velocity.

ACKNOWLEDGMENTS

The authors thank R. L. Mowrer and H. L. Stacy for their expertise, patience, and assistance during all aspects of this work. They also thank Bill Hicks for the assistance in design and fabrication of the foil assemblies, and gratefully appreciate the help of Beverly Clifford with the preparation of the manuscript.

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FIGURE CAPTIONS

Fig. 1. Experimental arrangement for explosive wedge.

Fig. 2. Present capacitor discharge unit.

Fig. 3. Crossed slit arrangement.

Fig. 4. Streak records for three foil thicknesses.

Fig. 5. Flyer velocity vs foil thickness.

Fig. 6. Streak record showing effect of foil imperfection on flyer.

Fig. 7. Experimental arrangement for pulsed laser stereo photography.

Fig. 8. Single frames of pulsed laser stereo pair for four times.

Fig. 9. A typical streak record with corresponding analysis for explosive wedge shot.

Fig. 10. Unreacted Hugoniot data for 1.801 g/cm^3 superfine TATB and for 1.806-g/cm^3 standard grind TATB.

Fig. 11. Comparison of distance to detonation vs pressure for 1.801-g/cm^3 superfine TATB and 1.806-g/cm^3 standard grind TATB. Three points for 1.81-g/cm^3 92.5% TATB/7.5% Kel-F are also shown.

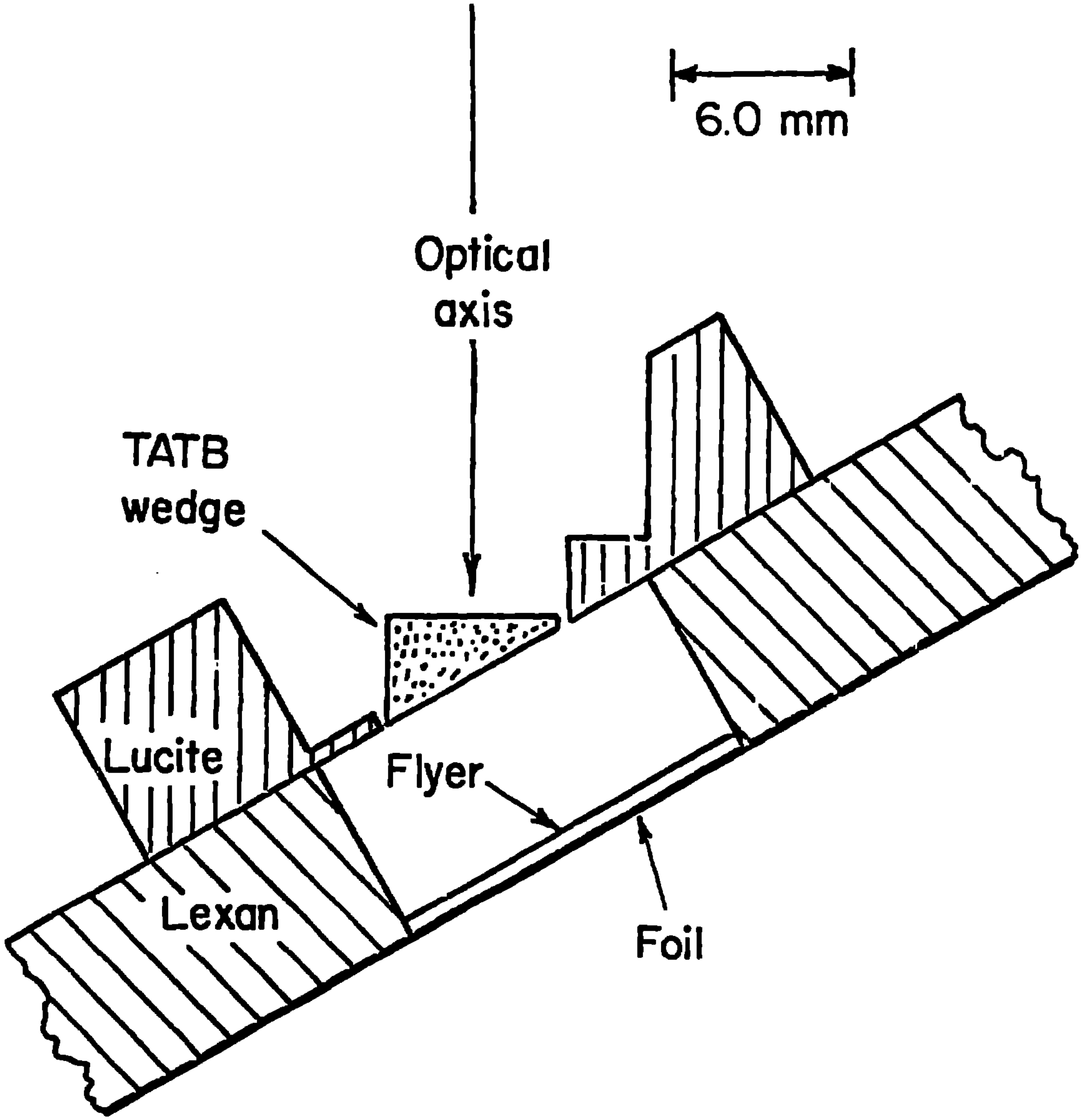


Fig. 1

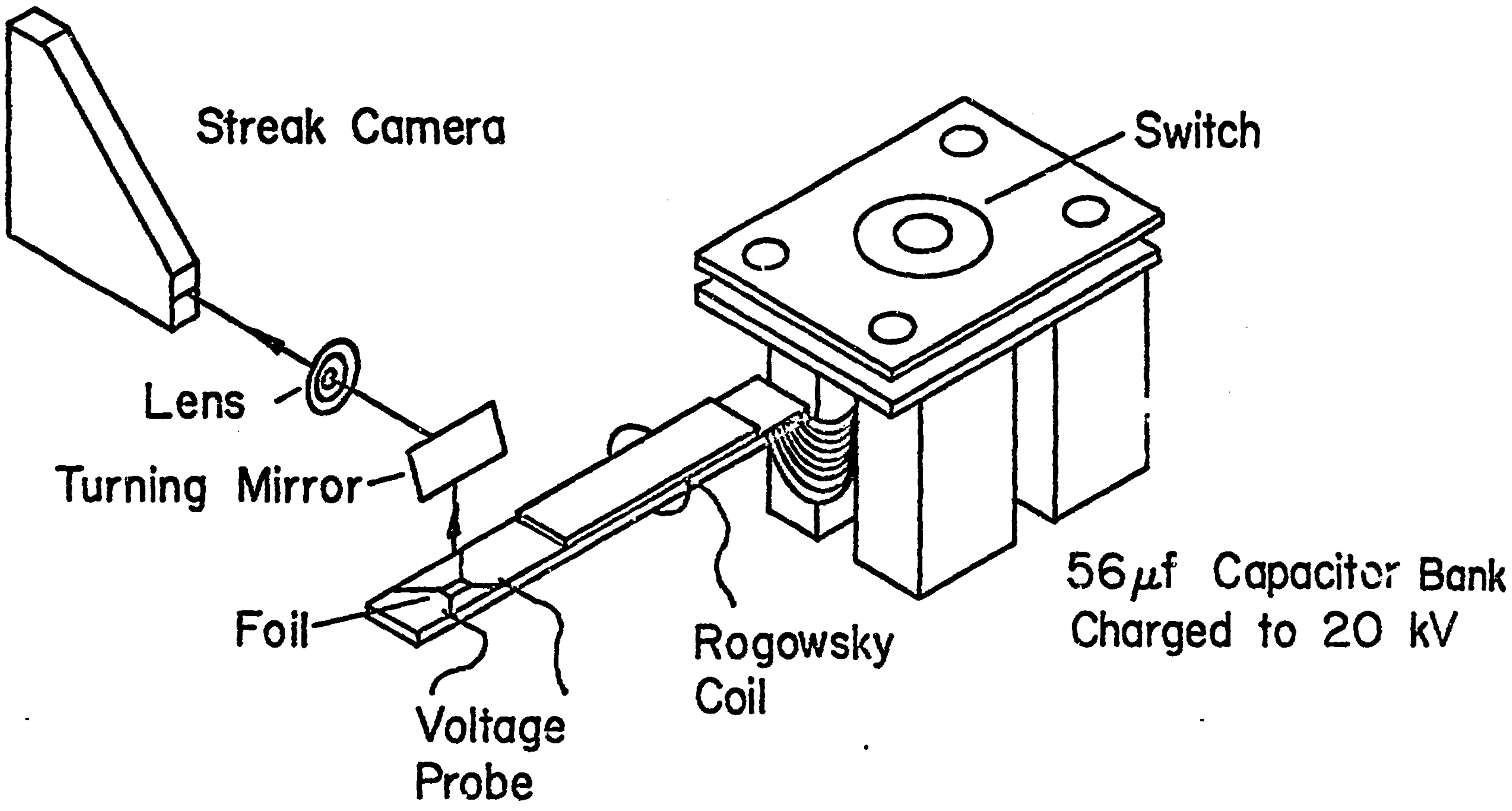

Streak Camera
Switch
Lens
Turning Mirror
Foil
Voltage Probe
Rogowsky Coil
56μf Capacitor Bank Charged to 20 kV

Fig. 2

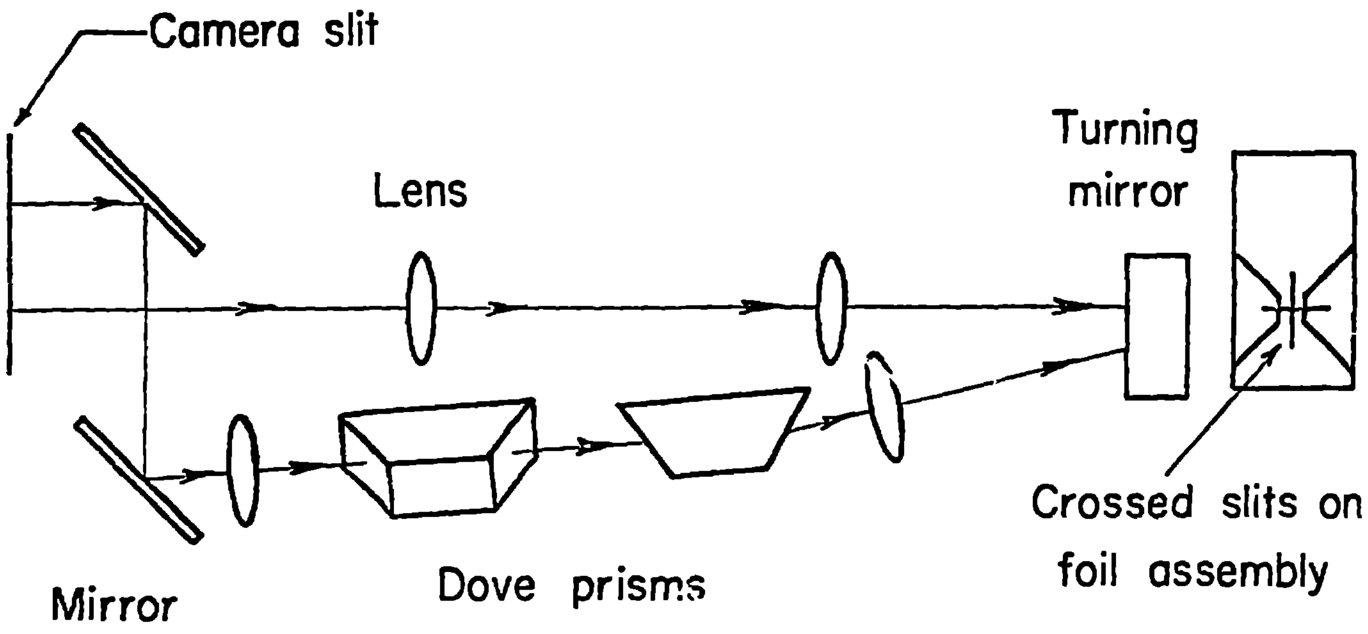
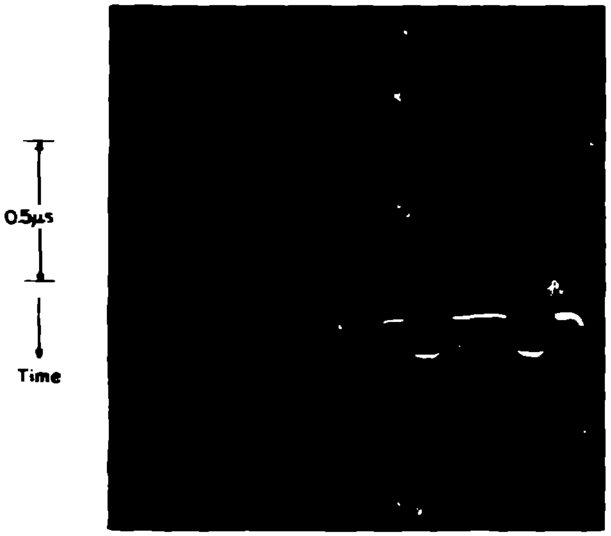
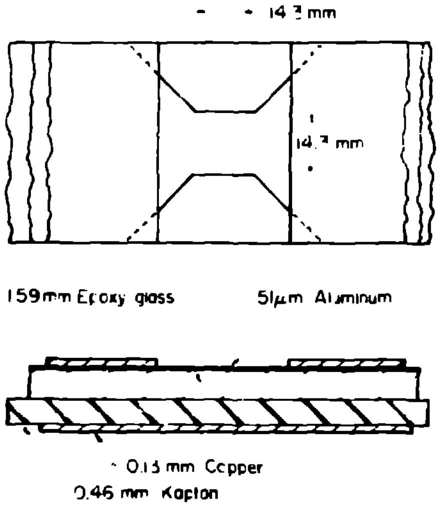
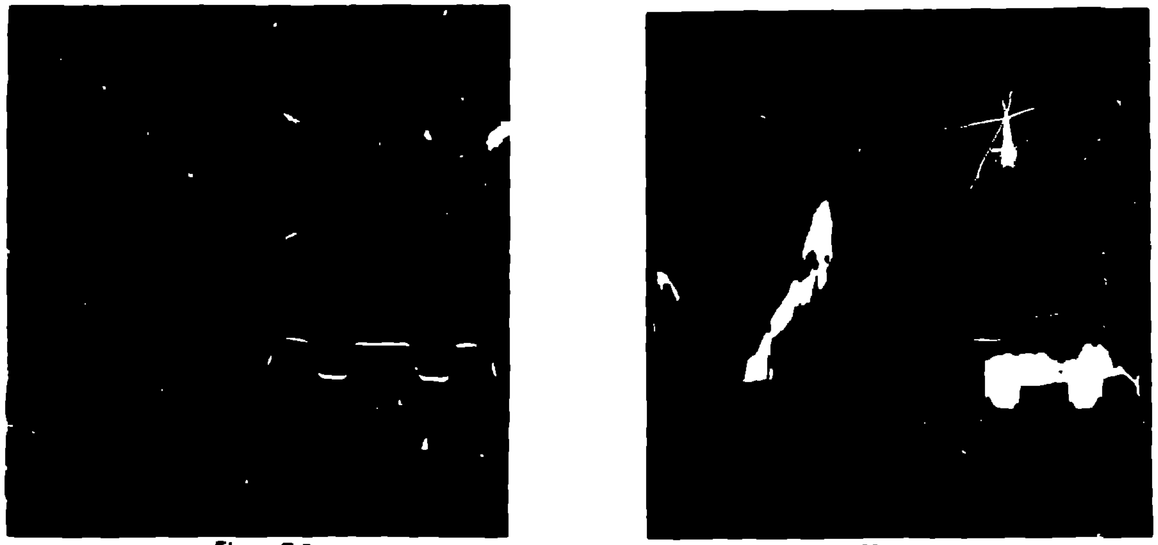

Camera slit
Turning mirror
Lens
Crossed slits on foil assembly
Mirror
Dove prisms

Fig. 3



25 µm Foil

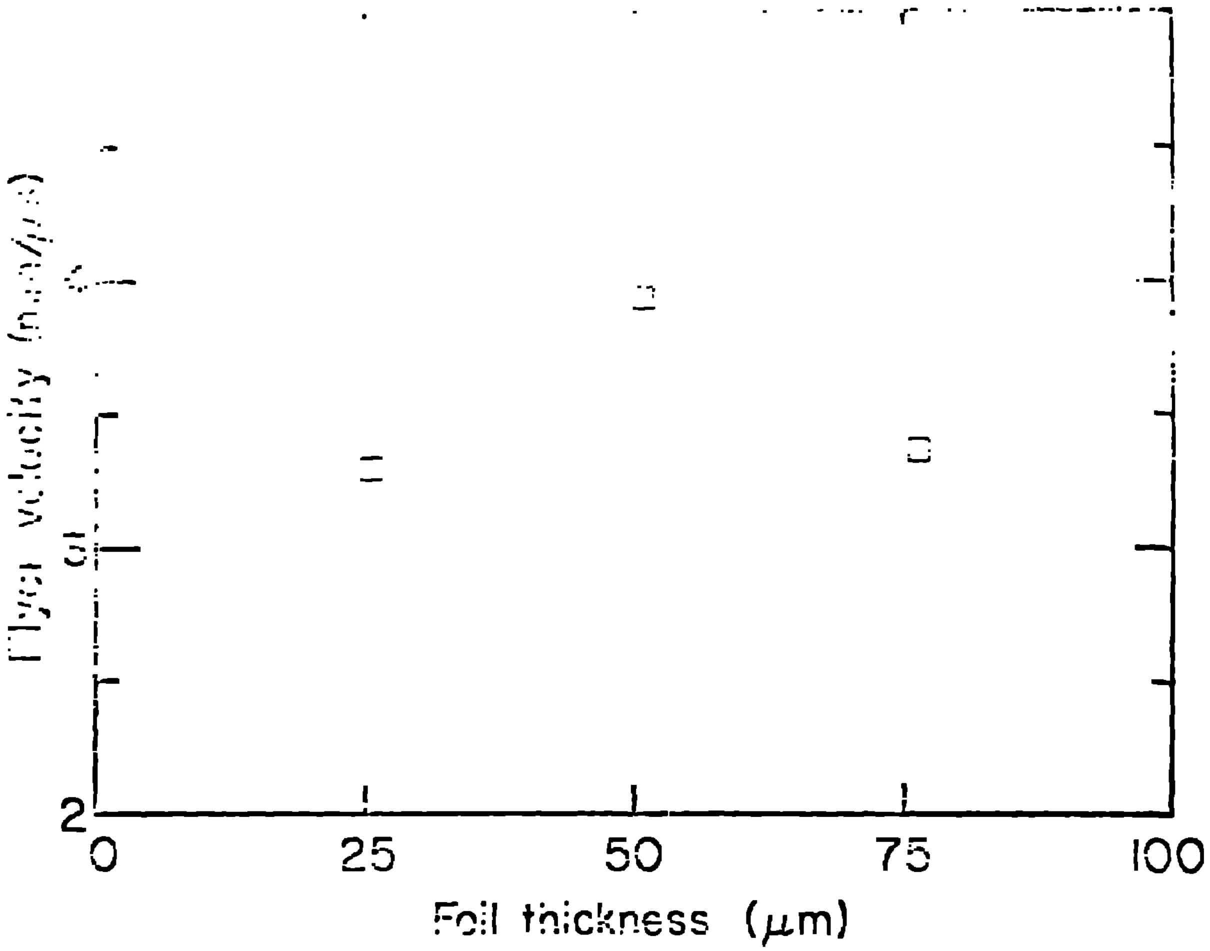




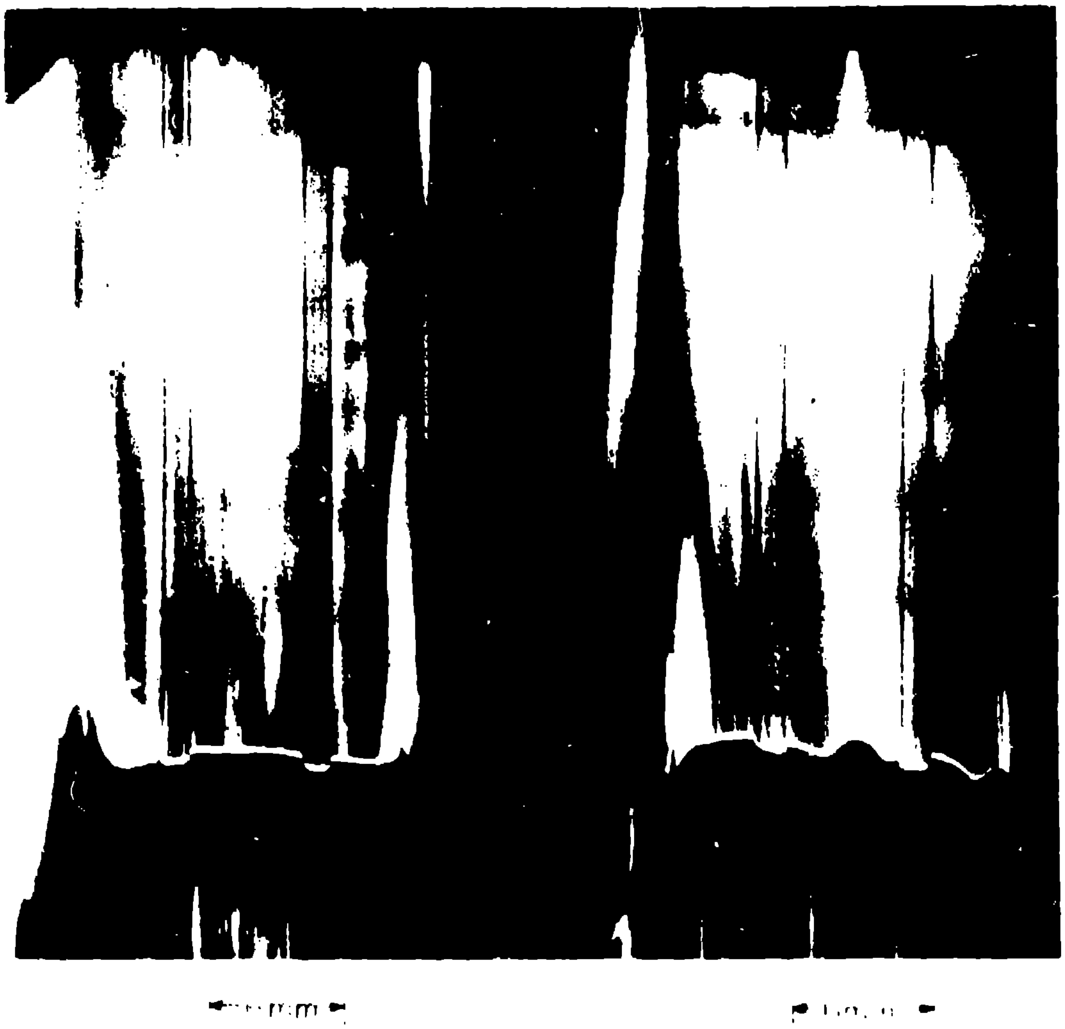
51 µm Foil

76 µm Foil

Fig. 4


Flyer velocity (mm/μs)
2
3
4
0
25
50
75
100
Foil thickness (μm)

[illegible]


mm

[illegible]

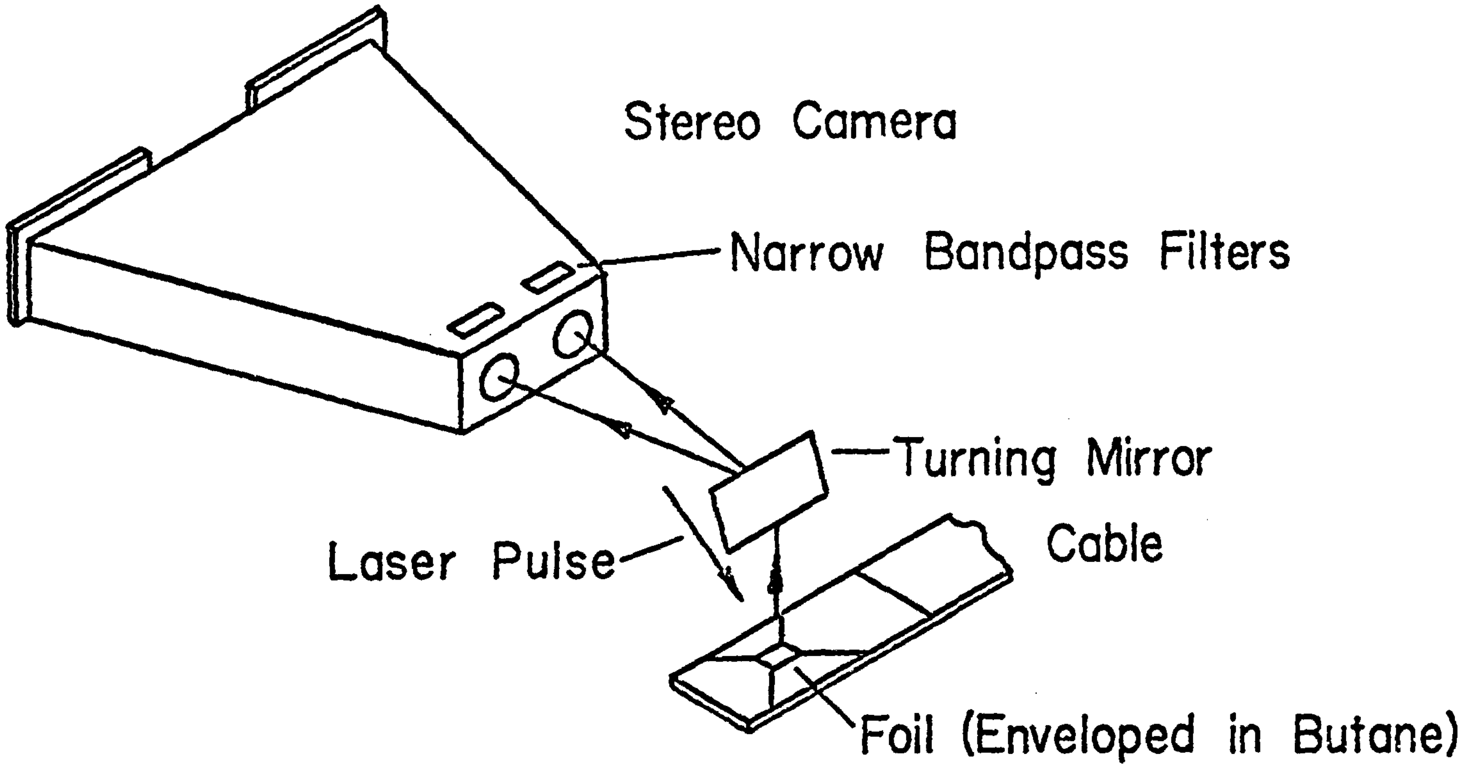
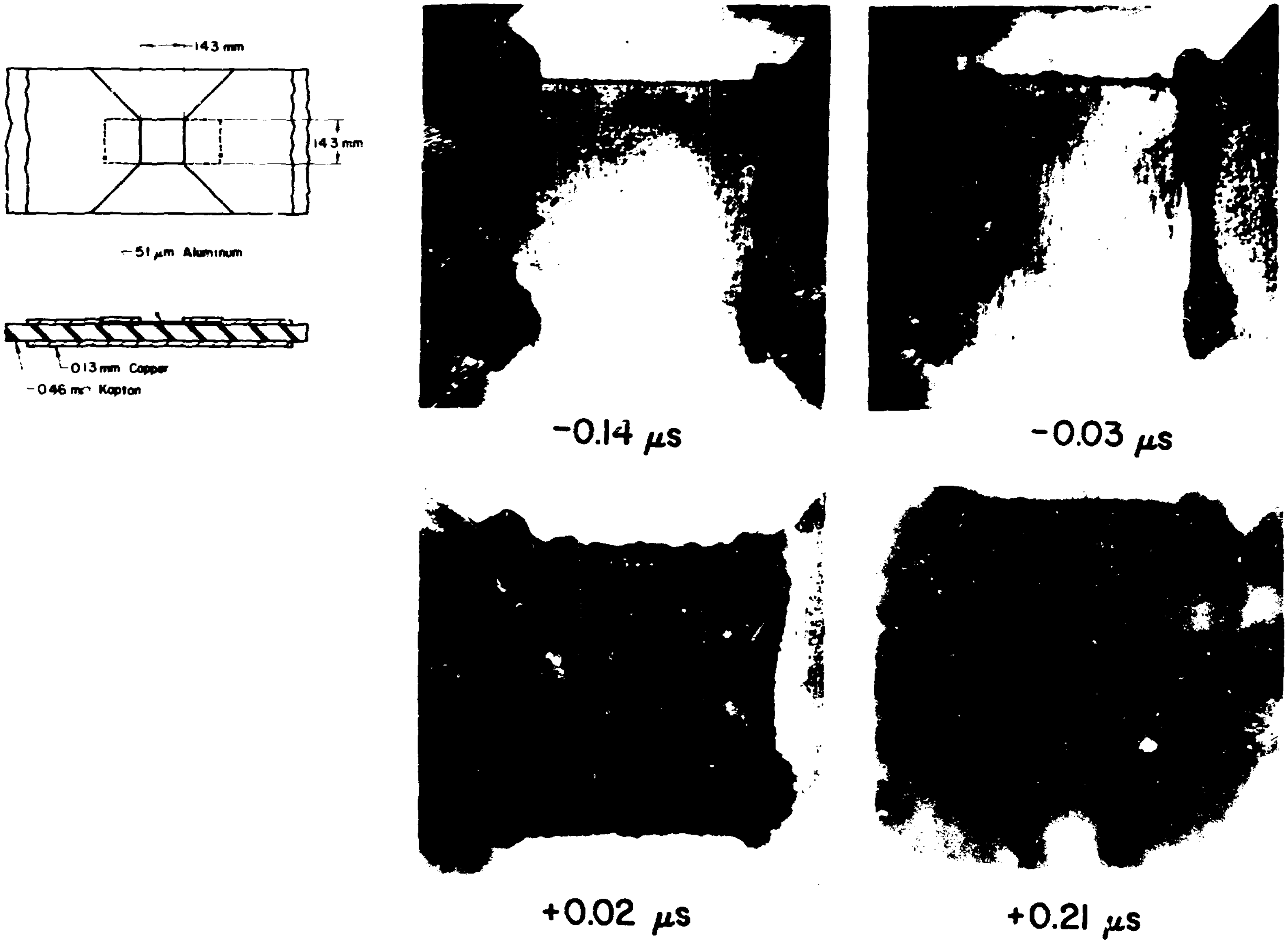

Stereo Camera
Narrow Bandpass Filters
Turning Mirror
Laser Pulse
Cable
Foil (Enveloped in Butane)

Fig. 7



−0.14 µs

−0.03 µs

+0.02 µs

+0.21 µs

Fig. 8

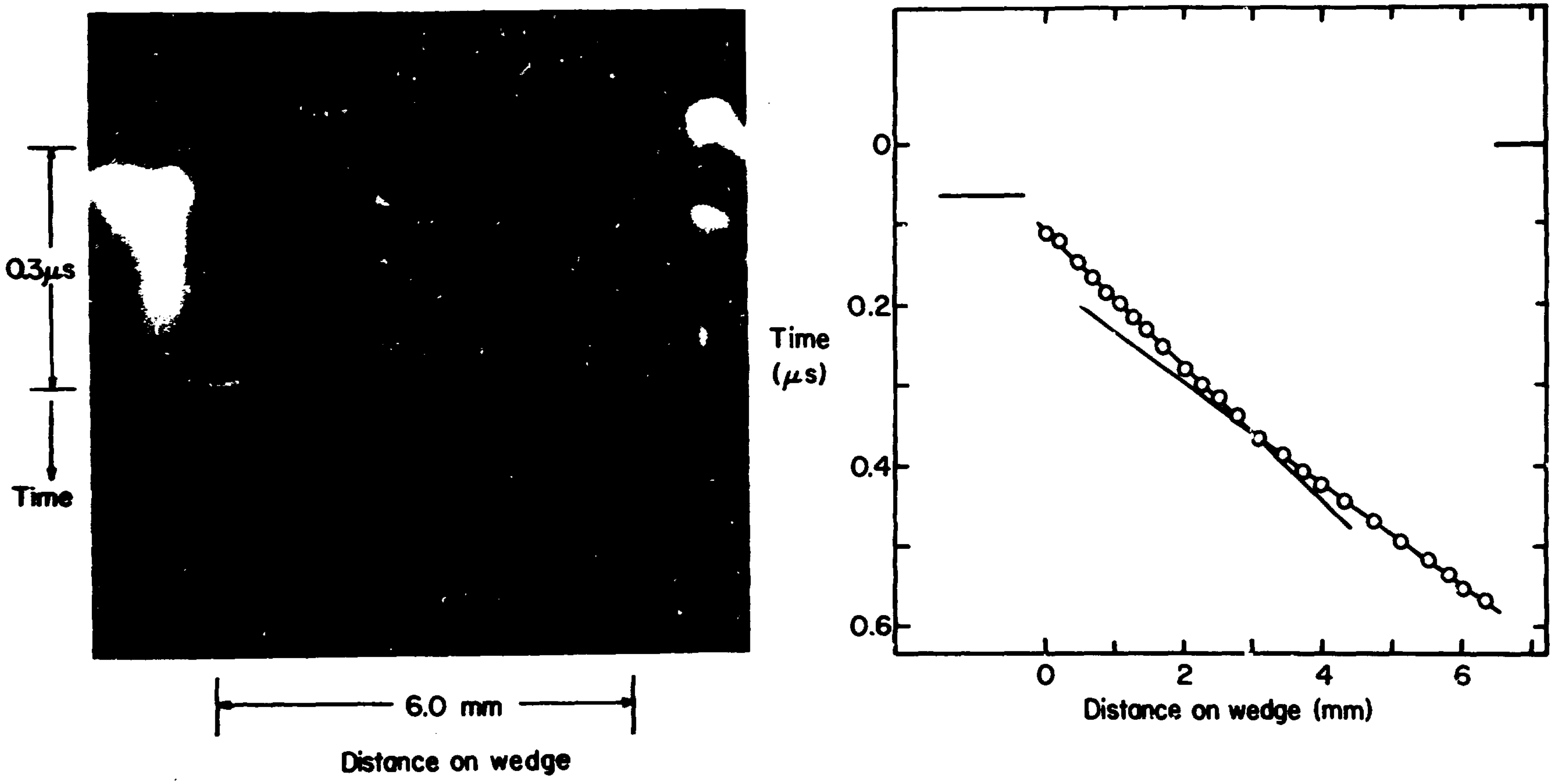

0.3μs
Time
6.0 mm
Distance on wedge
0
0.2
0.4
0.6
Time (μs)
0
2
4
6
Distance on wedge (mm)

Fig. 9

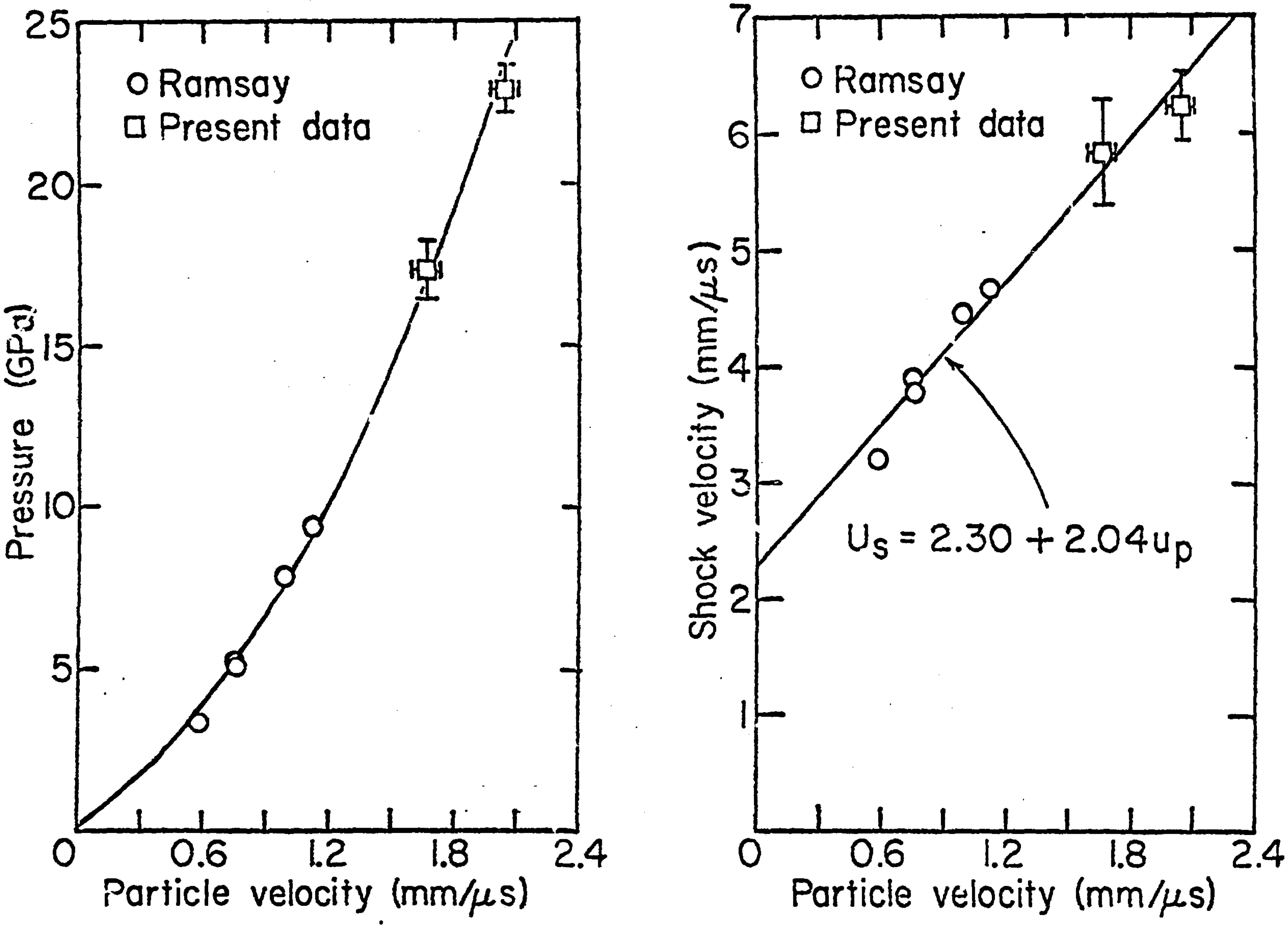
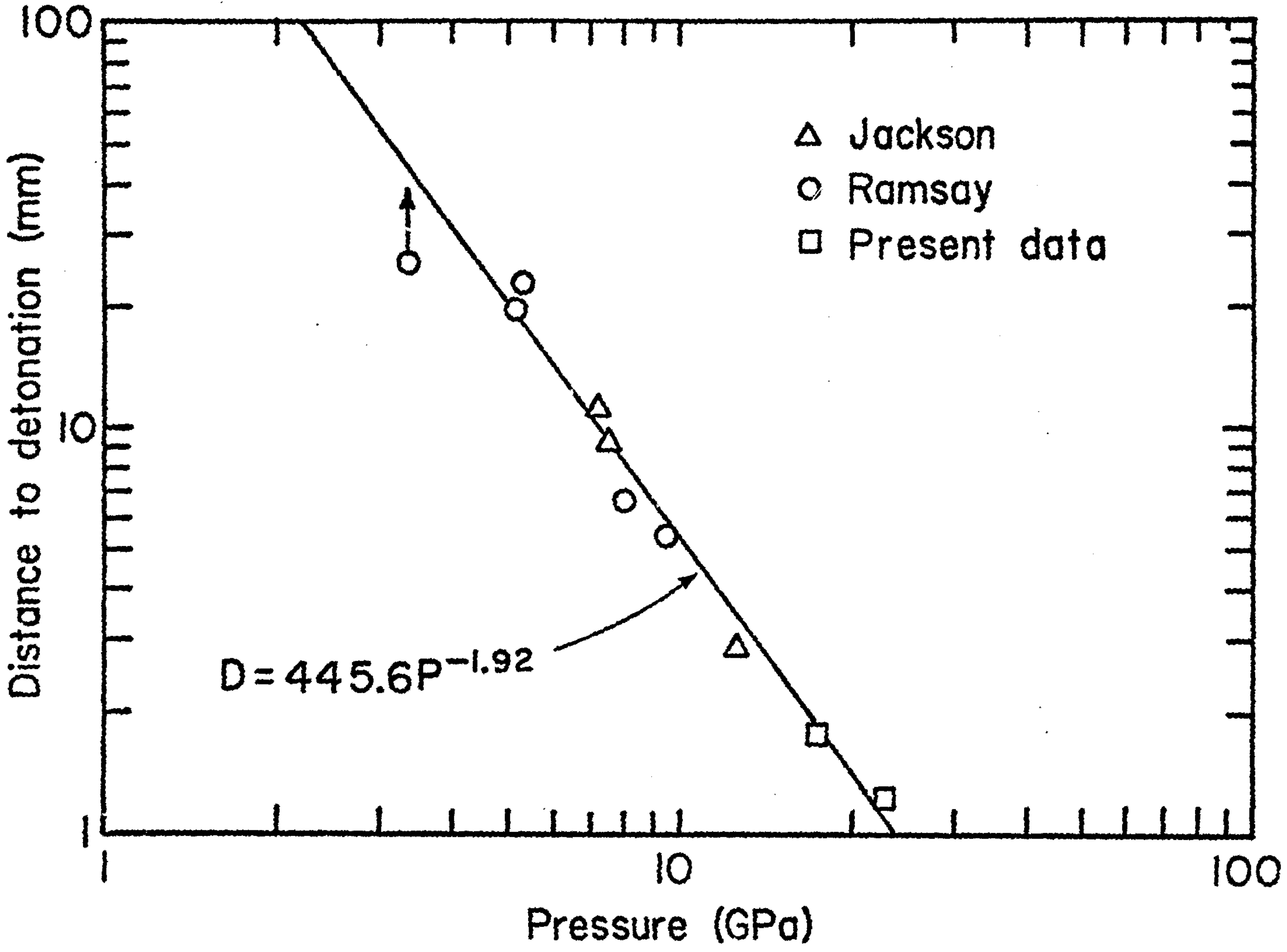

○ Ramsay
□ Present data
Pressure (GPa)
25
20
15
10
5
0
0.6
1.2
1.8
2.4
Particle velocity (mm/μs)
○ Ramsay
□ Present data
Shock velocity (mm/μs)
7
6
5
4
3
2
1
0
0.6
1.2
1.8
2.4
Particle velocity (mm/μs)
$U_s = 2.30 + 2.04u_p$

Fig. 10



100
10
1
1
10
100
Distance to detonation (mm)
Pressure (GPa)
△ Jackson
○ Ramsay
□ Present data
$D = 445.6P^{-1.92}$

Fig. 11