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NO. 380

ANOMALIES OF BLAST WAVES  
FROM CHEMICAL EXPLOSIONS (U)

by

J.M. Dewey and A.M. Patterson

PROJECT NO. 16-01-27

May 1971



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Presented to the meeting of the Division of Fluid Dynamics,  
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ABSTRACT

Five types of anomalies have been observed in the blast waves from explosions of solid chemical charges varying in size from less than one gram to 500 tons. The anomalies are in the form of (a) luminous and (b) non-luminous precursor jets from the fireball which move ahead of the main shock; (c) non-luminous surface precursor jets which move along the ground surface and contain surface material; (d) shock front perturbations which do not contain foreign material, and (e) fireball perturbations which distort the shock front. All of these anomalies are of sufficient magnitude to have a significant effect on measurements, and other studies, of blast waves. The properties of all the anomalies are illustrated by photographs, together with data from other measurements. Explanations of some of the anomalies will be postulated. The luminous and non-luminous precursor jets appear to be associated with non-uniform detonation of the charge, resulting in high density regions within the fireball. The increased inertia of these regions cause them to move out ahead of the contact surface and the shock front, as these surfaces decelerate due to the three dimensional expansion of the wave. Some of the other anomalies appear to be associated with air-coupled ground surface waves, which outrun the decelerating shock front.

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INTRODUCTION

In 1964, a 500-ton TNT hemispherical charge was detonated in Canada. High speed photographs of the resulting blast wave showed a number of anomalies, in the form of precursors, which significantly affected many of the measurements which were being made (Dewey, 1965). As a result, a joint American-British-Canadian working group studied the photographic records, together with other measurements, of a large number of chemical explosions. From this study it has been concluded that such anomalies are very common, and in fact, an explosion for which they do not occur might itself be classified as an anomaly.

The phenomena that we shall describe have been observed for explosions ranging in size from less than 1 gm to 500 tons, for a variety of explosives which have been cast, built of cast blocks, pressed, and made from prill with a binding oil. Such phenomena have not been observed for gaseous explosions; but this may be due to the fact that very few such explosions have been studied. Five types of anomaly have been identified. These will be described and the possible causes discussed.

OBSERVATIONS

Figure 1 is a shadowgraph of a clean blast wave from a solid chemical explosive showing no anomalies. The irregular shape of the fire ball arises from the method of construction of the charge and this shape is extremely reproducible from one explosion to another (Patterson & Dewey, 1970). A charge built from cast blocks is shown in Figure 2.

Figure 3 shows (lower left side) the first type of anomaly, which we call a luminous precursor jet. The fire ball begins to expand in a normal manner but at a late stage in its development, at about the time the shock front can first be seen separating from the contact surface, the luminous jet leaves the fire ball and moves out ahead of the shock front. This luminous jet can be seen in more detail in Figure 4. It produces a bow shock which

may reflect from the ground surface and form a mach stem. In movie films of the phenomenon it appears that the jet shoots out from the fire ball through the shock front, but this is an optical illusion, as measurements show that the jet is never accelerating but decelerates less rapidly than the main shock front and the fire ball. This is illustrated in Figure 5 where the position of the leading edge of two such jets is plotted in the x-t plane and compared with the shock front trajectory. At times the jets may separate completely from the fire ball as shown in Figure 6. The detailed structure of the jet can be seen in Figure 7, a close-up photograph. This illustrates that the leading edge of the jet is non-luminous and that the wake has an annular structure. This structure is more clearly illustrated in Figure 4, in which individual shocks from the annuli can be seen.

The second type of anomaly we call a non-luminous precursor jet and is illustrated in Figure 8. Some non-luminous precursor jets subsequently become luminous and visa versa. We therefore believe that these two phenomena are in fact similar, probably differing only in temperature.

It is suggested that these phenomena arise because part of the charge material has incompletely detonated, resulting in a high density region within the detonation products. This high density material will initially lag the surrounding outward rushing detonation products, but because of its greater inertia will decelerate less rapidly than the majority of the detonation products and the shock front itself. It is known that the detonation products from TNT are oxygen deficient and will continue to burn for long periods in the presence of atmospheric oxygen (Dewey, 1964). This undoubtedly accounts for the luminous nature of some of the jets.

For surface burst charges these jets usually occur at a small angle of elevation above the ground surface, occasionally at an elevation of about  $45^{\circ}$  and sometimes vertically above the charge.

The third type of anomaly is a non-luminous surface precursor containing surface material and is illustrated in Figures 9 and 10. These precursors run along the ground surface and are associated with radial roads and compacted areas. They contain large amounts of surface dust and although they may outrun and distort the main shock front they do not normally have a bow shock. It is suggested that this phenomenon is a result of an air-coupled ground surface wave which feeds energy back into the air ahead of the main shock. This phenomenon has been observed on a small scale by Mawbey and Rowe (1966) as illustrated in Figure 11.

The fourth type of anomaly consists of shock front perturbations which do not appear to contain surface material or to be a result of fire ball protrusions. Two such anomalies are illustrated in the lower part of Figure 9. These normally occur close to the ground surface and may again be the result of air-coupled waves over non-dusty ground such as a paved surface.

The fifth type of anomaly is illustrated in the upper right hand part of Figure 3 and consists of shock front perturbations which are clearly associated with fire ball protrusions. These protrusions may be weak luminous precursor jets or some similar fire ball irregularities.

Figure 12 is an aerial photograph showing all five types of anomaly

occurring on one explosion (Patterson, 1969).

In conclusion we believe that anomalies of the first, second and fifth types are in fact a feature to be expected from solid chemical explosives and despite great care in building the charges it has not been possible to eliminate these effects. In fact some of the charges which have been built with great care to avoid these anomalies have in fact produced more than an average number of them (Figure 12).

Anomalies of the third and fourth type appear to be a feature of surface burst explosions of high initial pressures.

It is suggested that all of these anomalies may be avoided by the use of gaseous explosives because of the homogeneous nature of the gas itself, and the low initial loading on the ground surface. A detailed description of these phenomena has been reported by Patterson, et al (1970).

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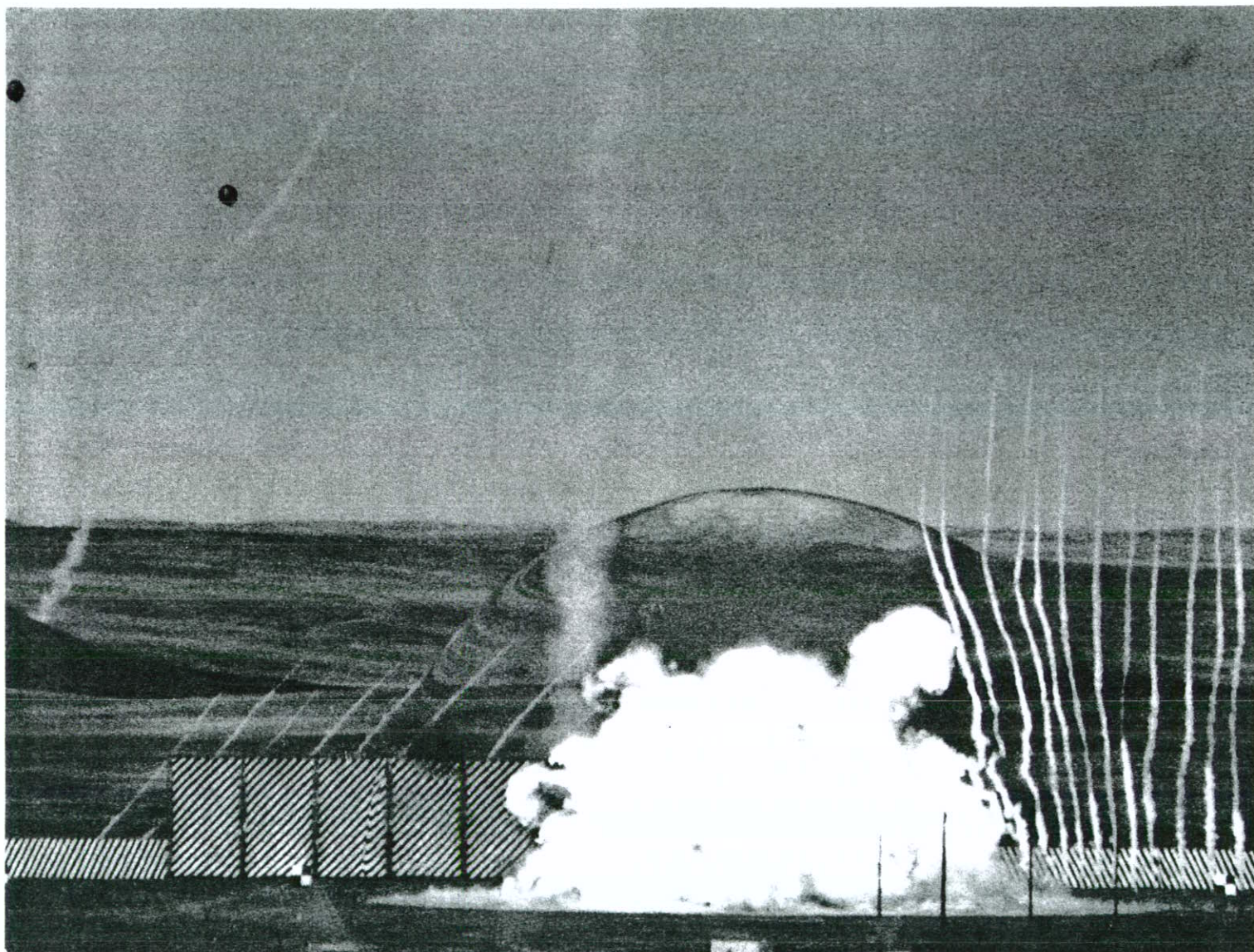


FIGURE 1. VIEW OF SHOCK WAVE FROM 5 TON HEMISPHERE GROUND BURST.

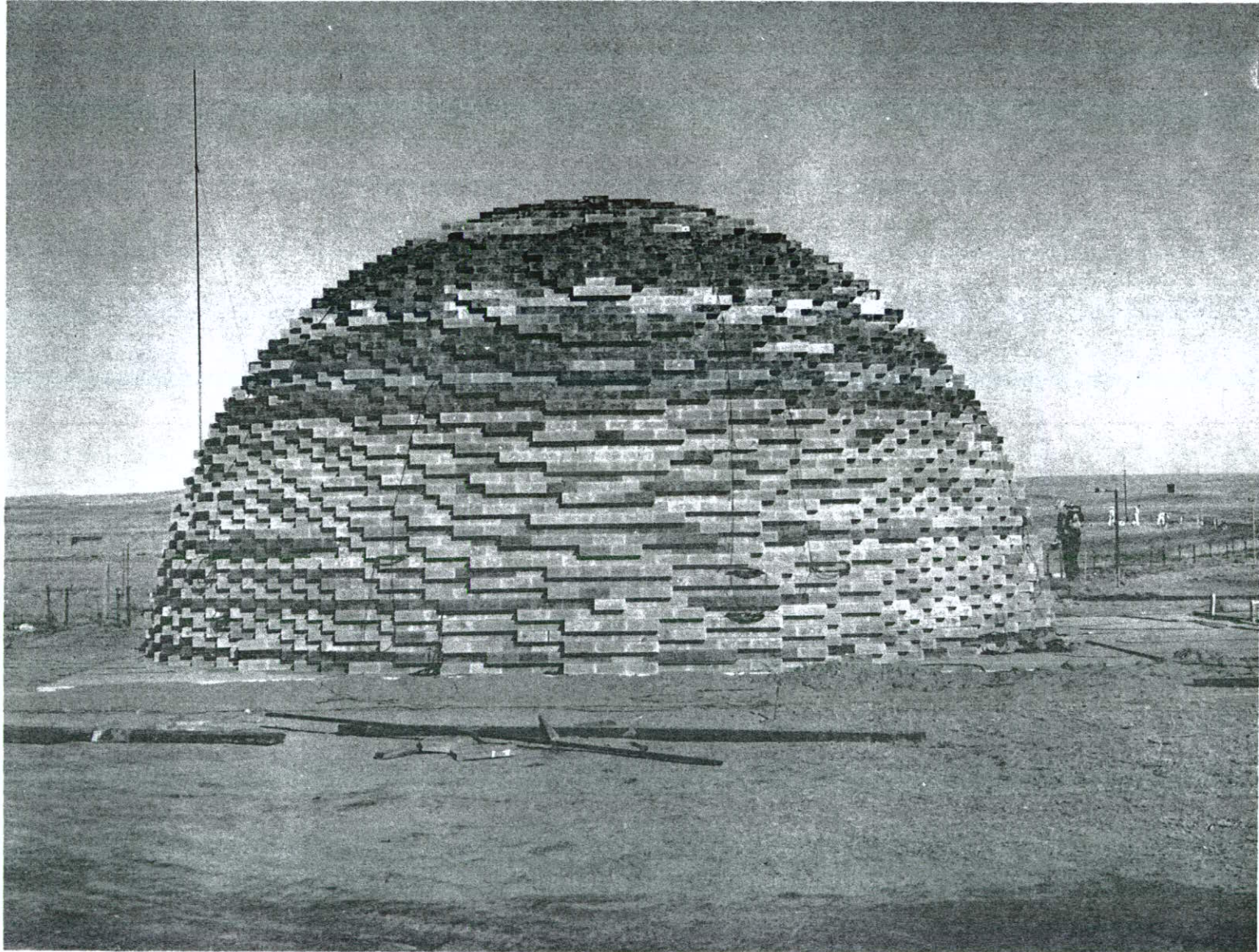


FIGURE 2. PHOTOGRAPH OF 500 TON CHARGE.

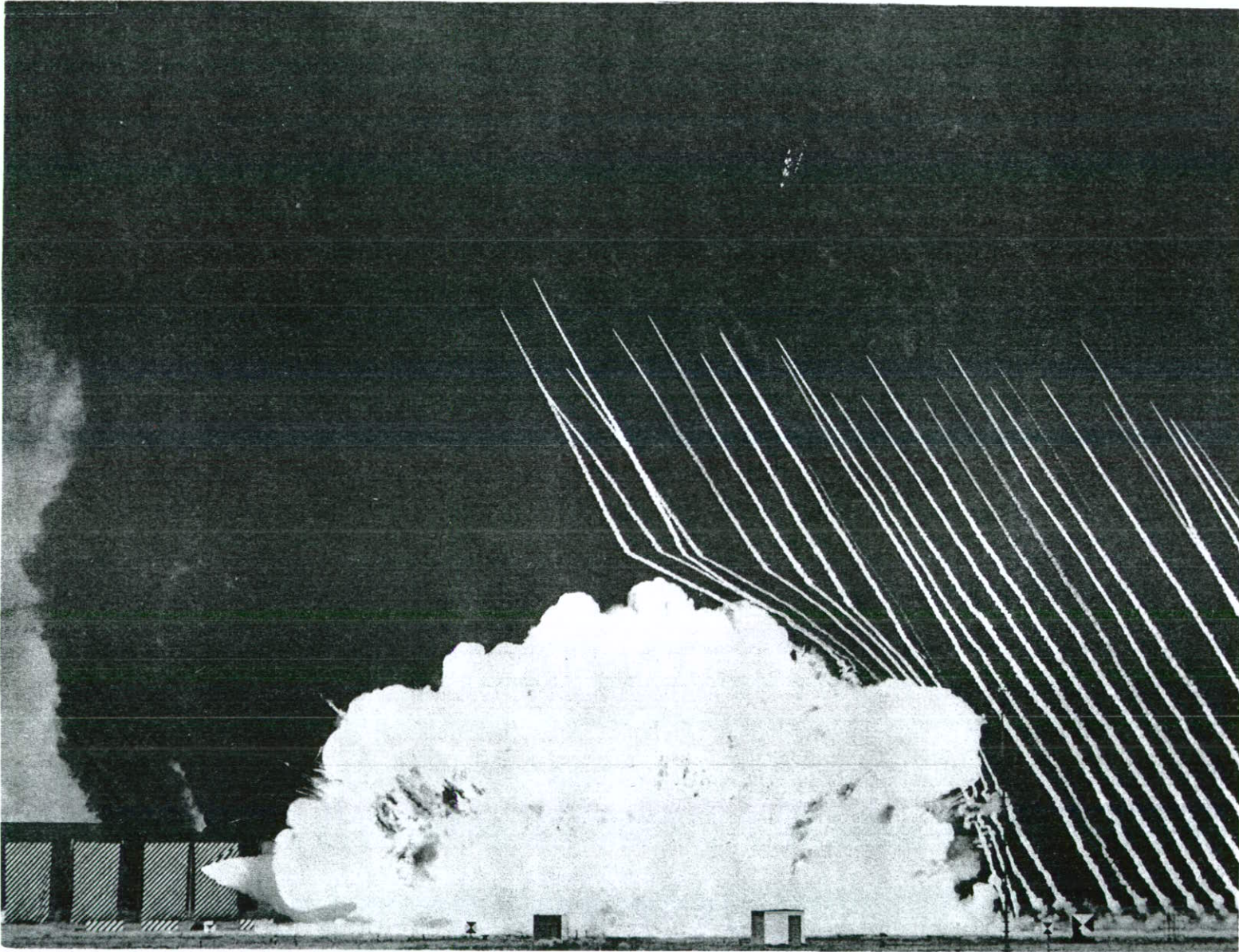


FIGURE 3. FRAME 5 FROM MITCHELL CAMERA SHOWING LUMINOUS JET AND  
FIREBALL PERTURBATION - DISTANT PLAIN EVENT 3  
(FE 567/3)

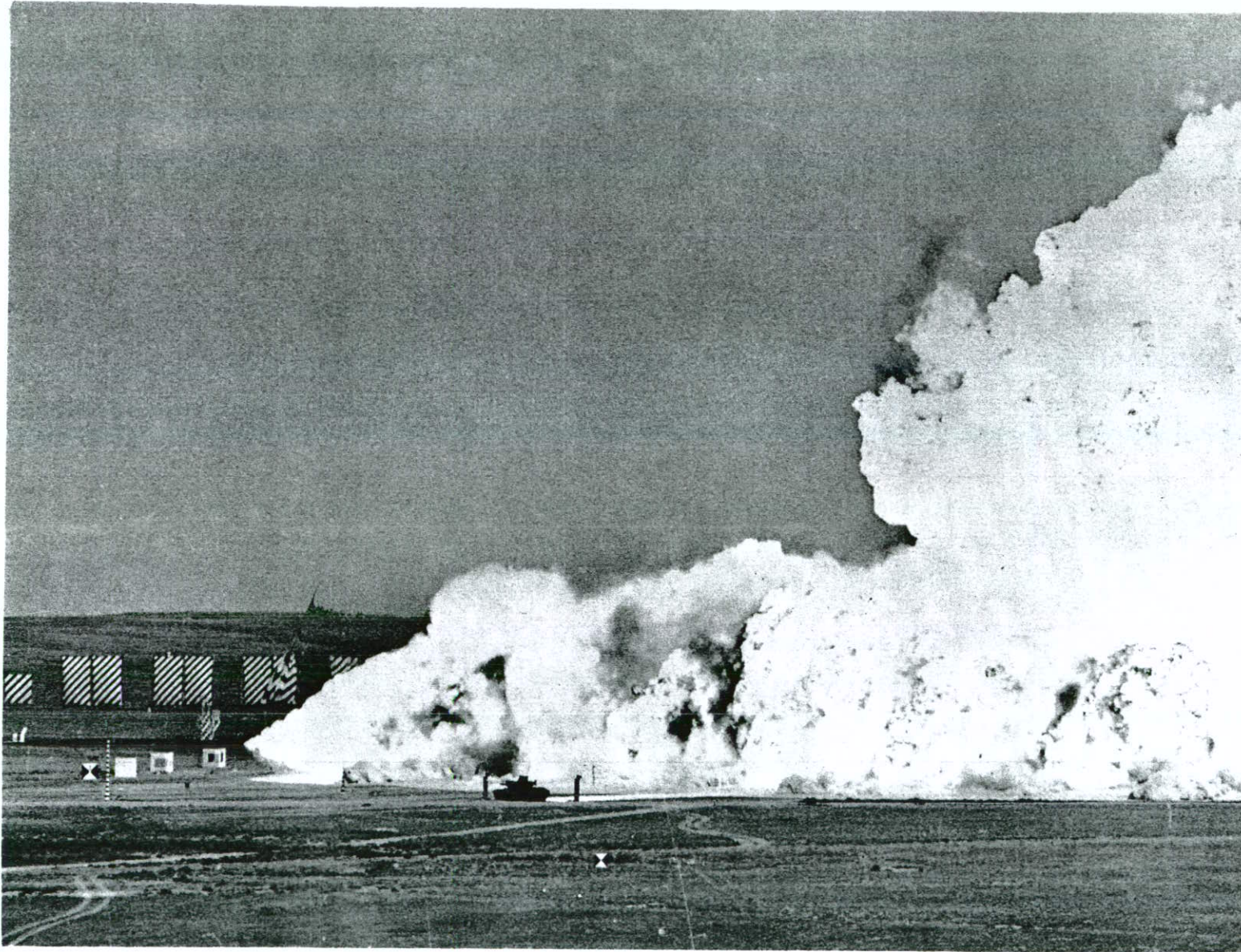


FIGURE 4. PHOTOGRAPH OF MULTIPLE SHOCKS IN THE BOW-MAIN SHOCK  
INTERACTION REGION FROM MAIN CAMERA POSITION.  
Z + 0.2 SEC APPROX. - PRAIRIE FLAT.

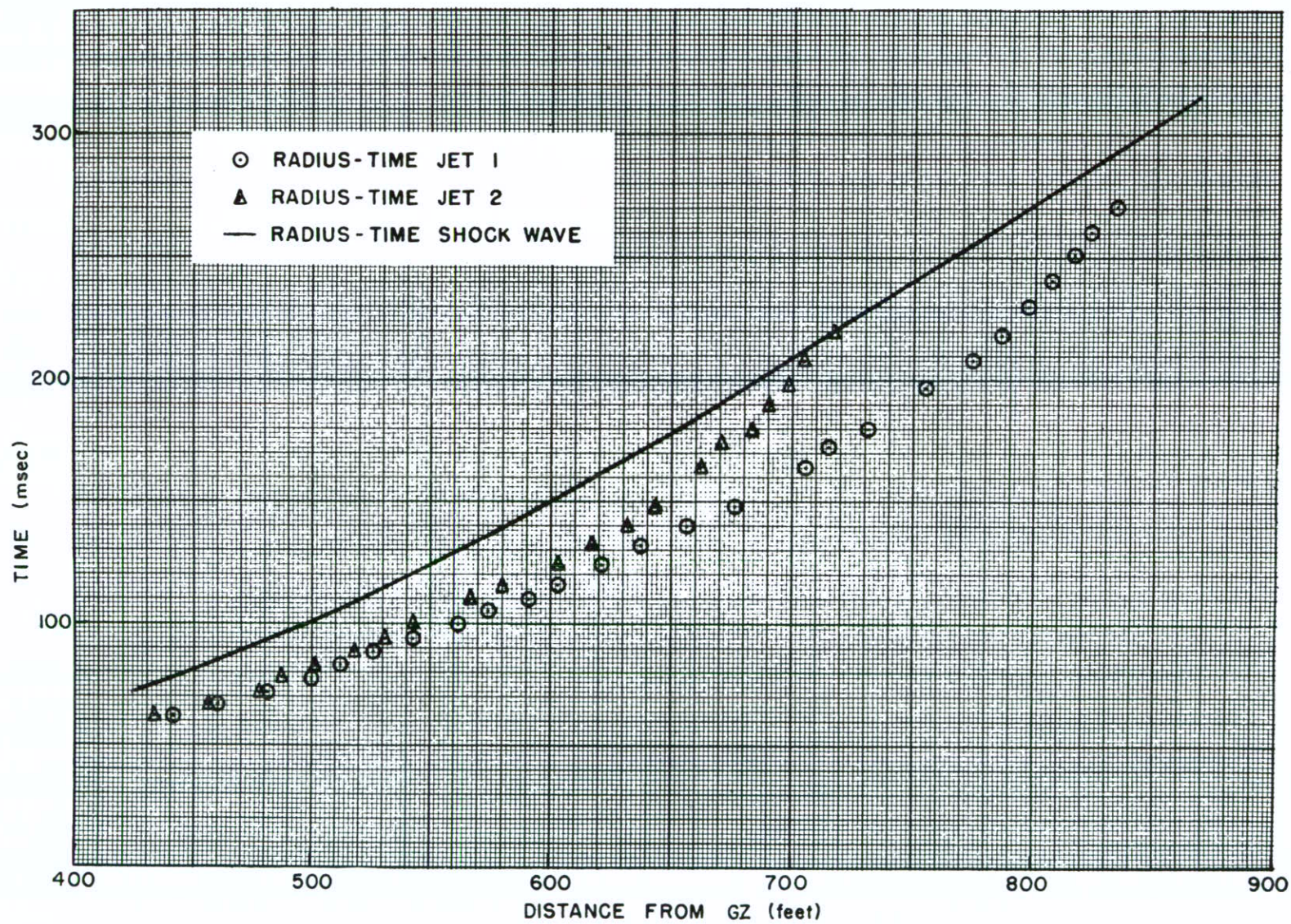


FIGURE 5. RADIUS-TIME PLOTS FOR TWO LUMINOUS PRECURSOR JETS OBSERVED ON 500 TON TNT TRIAL.

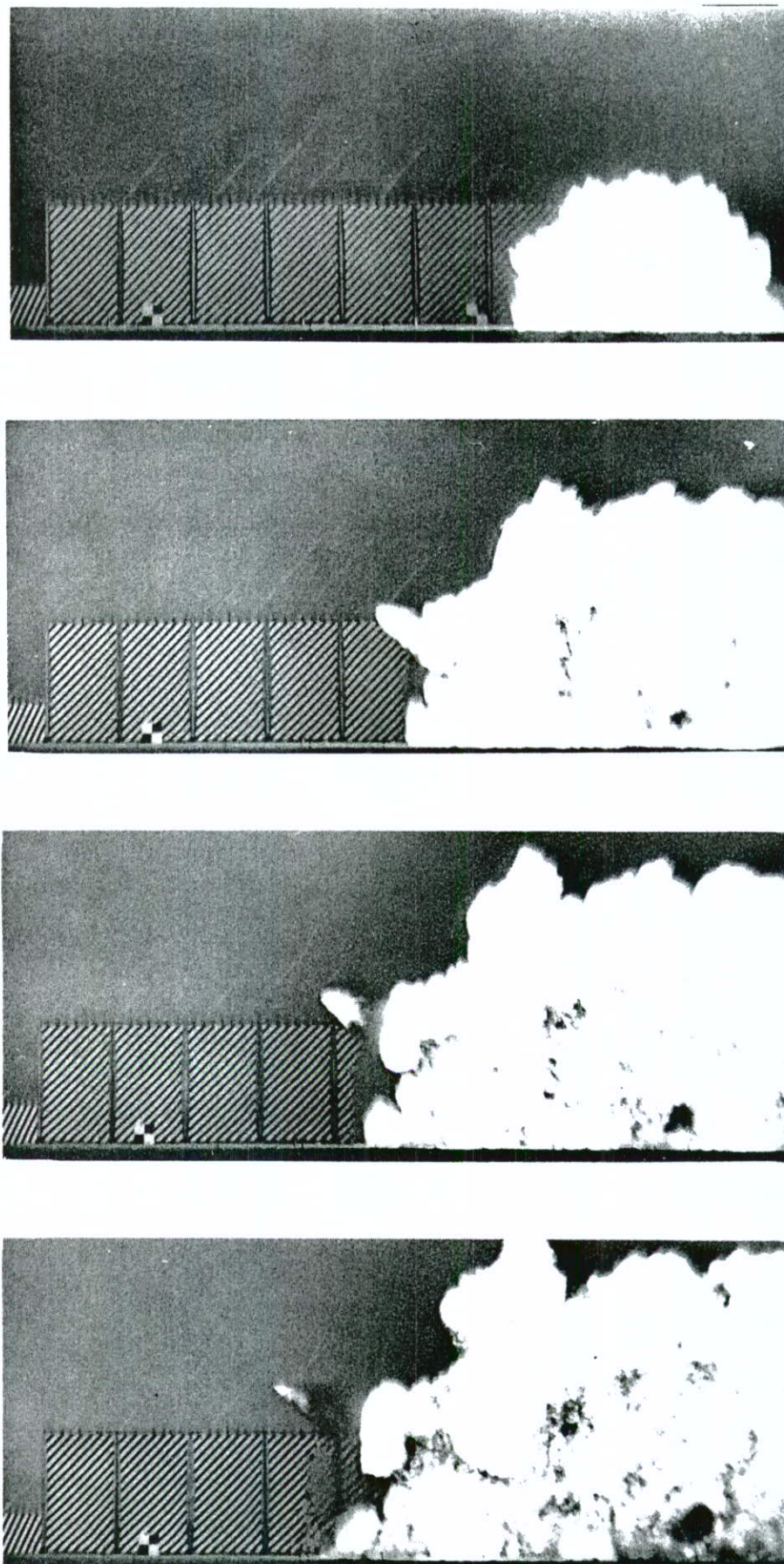


FIGURE 6. FRAMES FROM WF5 CAMERA SHOWING LUMINOUS PRECURSOR JET AND PERTURBATIONS ON FIREBALL - FE 521/1

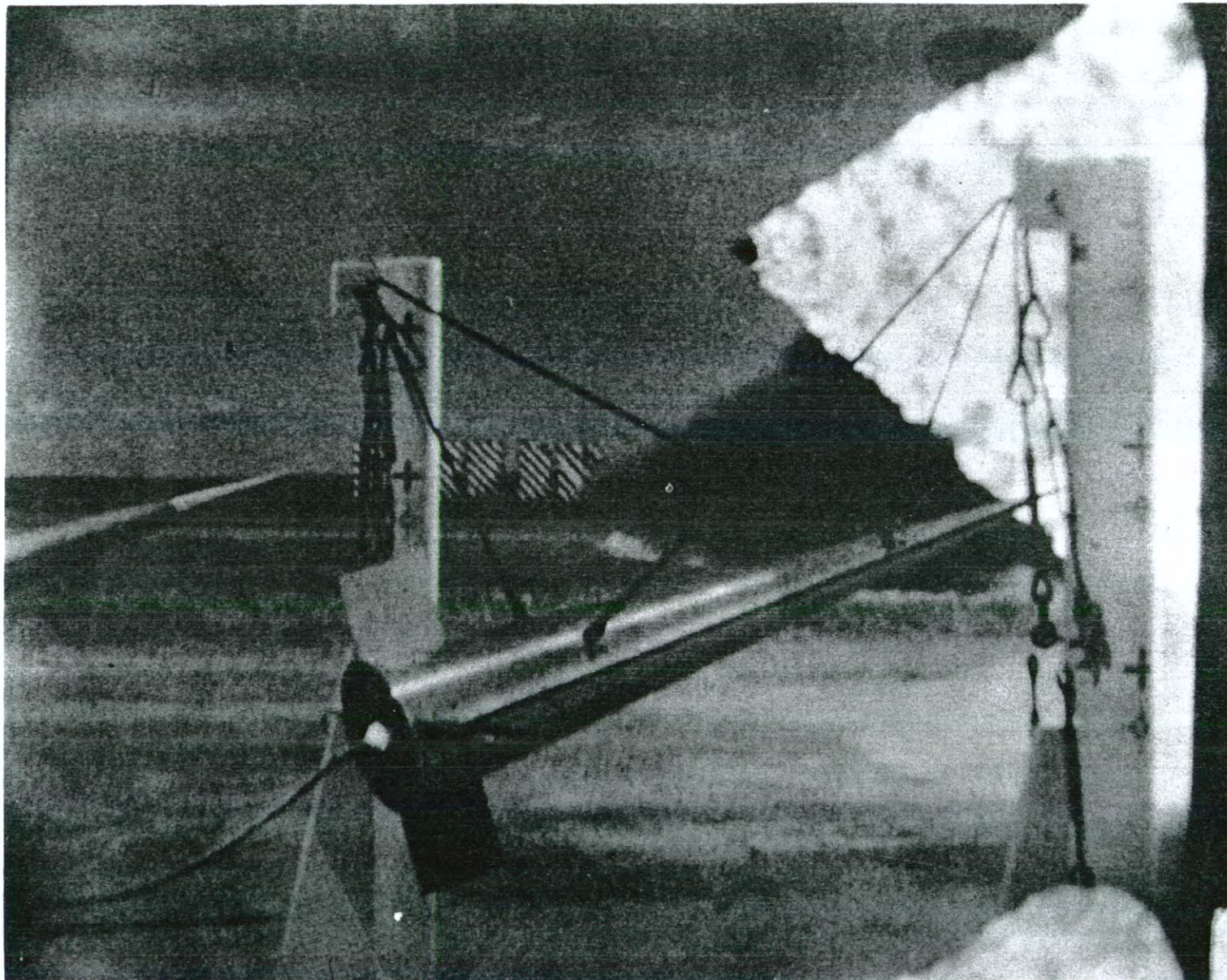


FIGURE 7. CLOSE-UP OF LUMINOUS JET SHOWING THE NON-LUMINOUS TIP AND ANNULAR STRUCTURE.

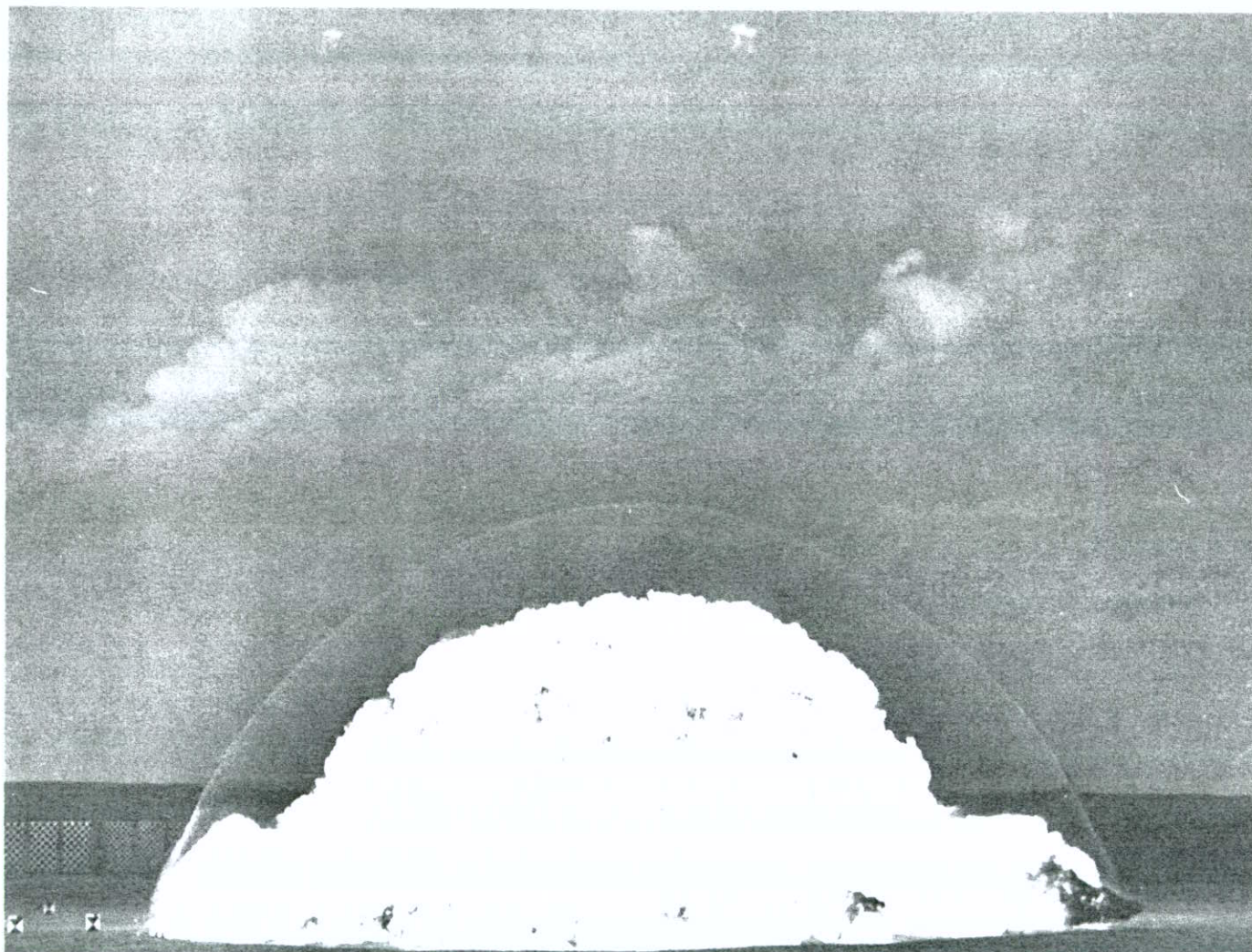


FIGURE 8. FRAME FROM MITCHELL CAMERA SITED IN MAIN CAMERA POSITION  
Z + .05 SEC APPROX.- HORIZONTAL FIELD OF VIEW: 850 FT APPROX.  
(FE 567/6)

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FIGURE 9. AERIAL PHOTOGRAPH OF 500 TON EXPLOSION (SNOWBALL) SHOWING TYPE 3 PRECURSORS, UPPER RIGHT AND TYPE 4 PRECURSOR, LOWER RIGHT.

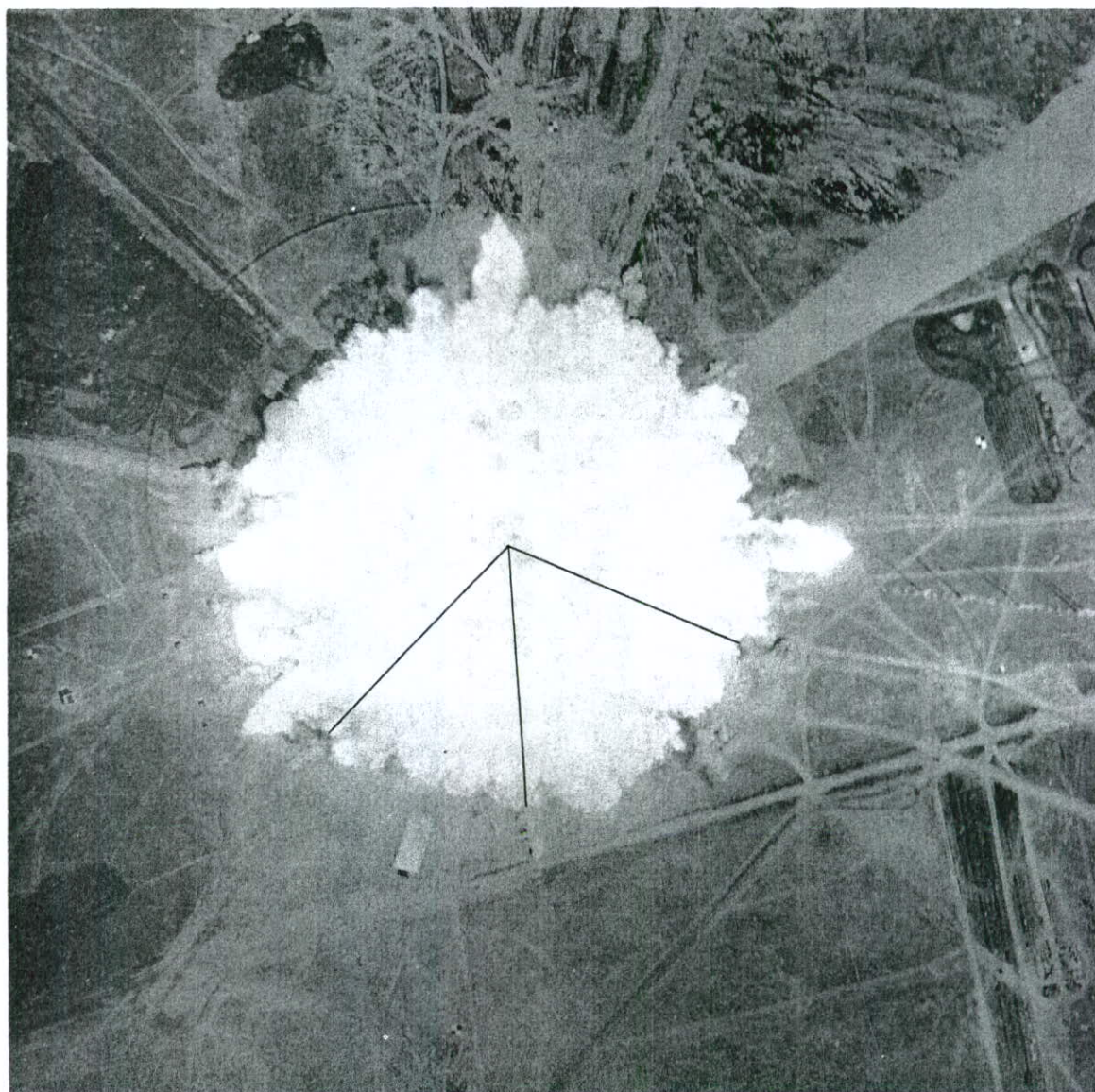


FIGURE 10. AERIAL VIEW SHOWING NON-RADIAL FLOW OF  
3 NON-LUMINOUS JETS - PRAIRIE FLAT.

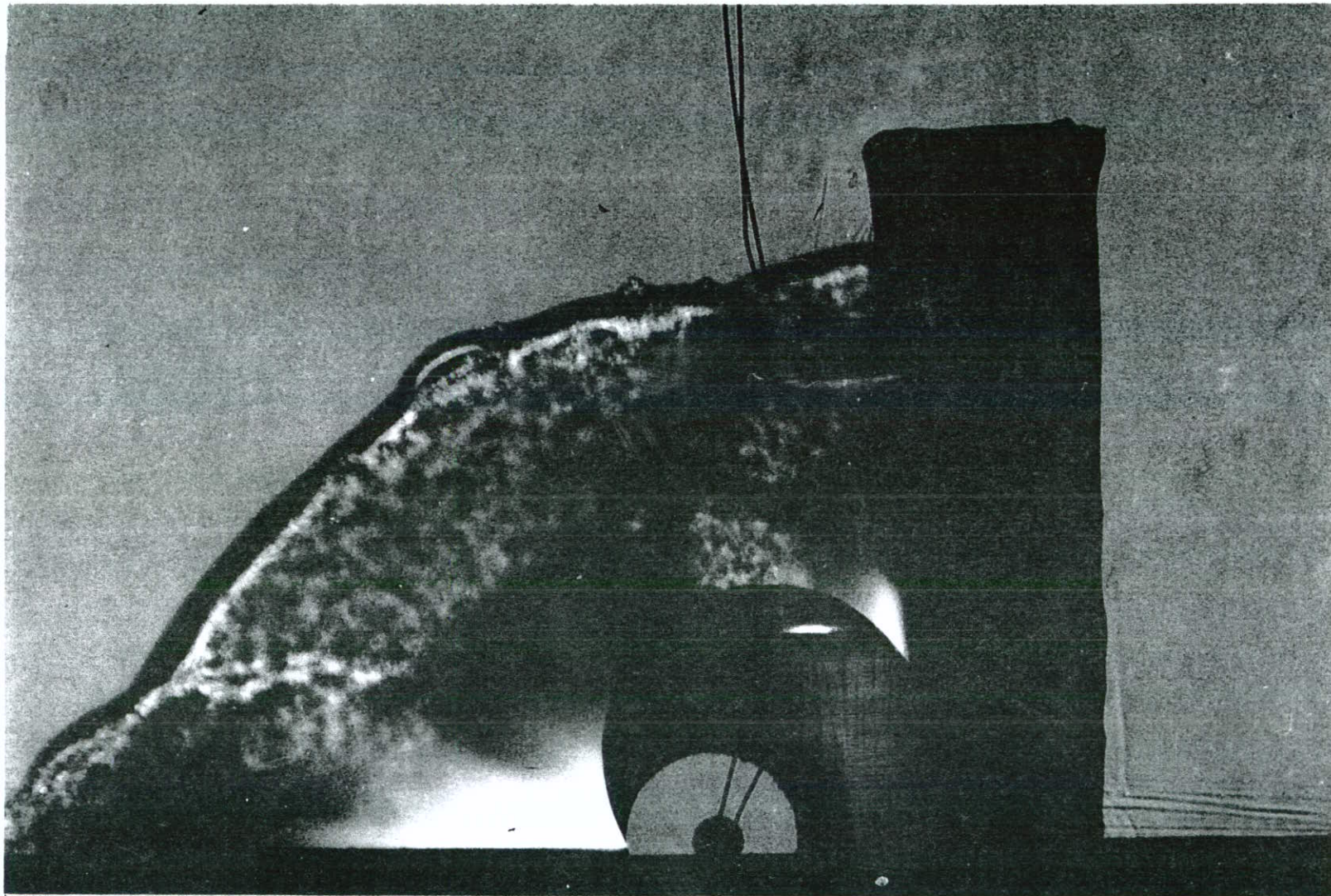


FIGURE 11. 0.25g CHARGE DETONATED ON A STEEL PLATE, SHOWING  
PRECURSOR PHENOMENA.

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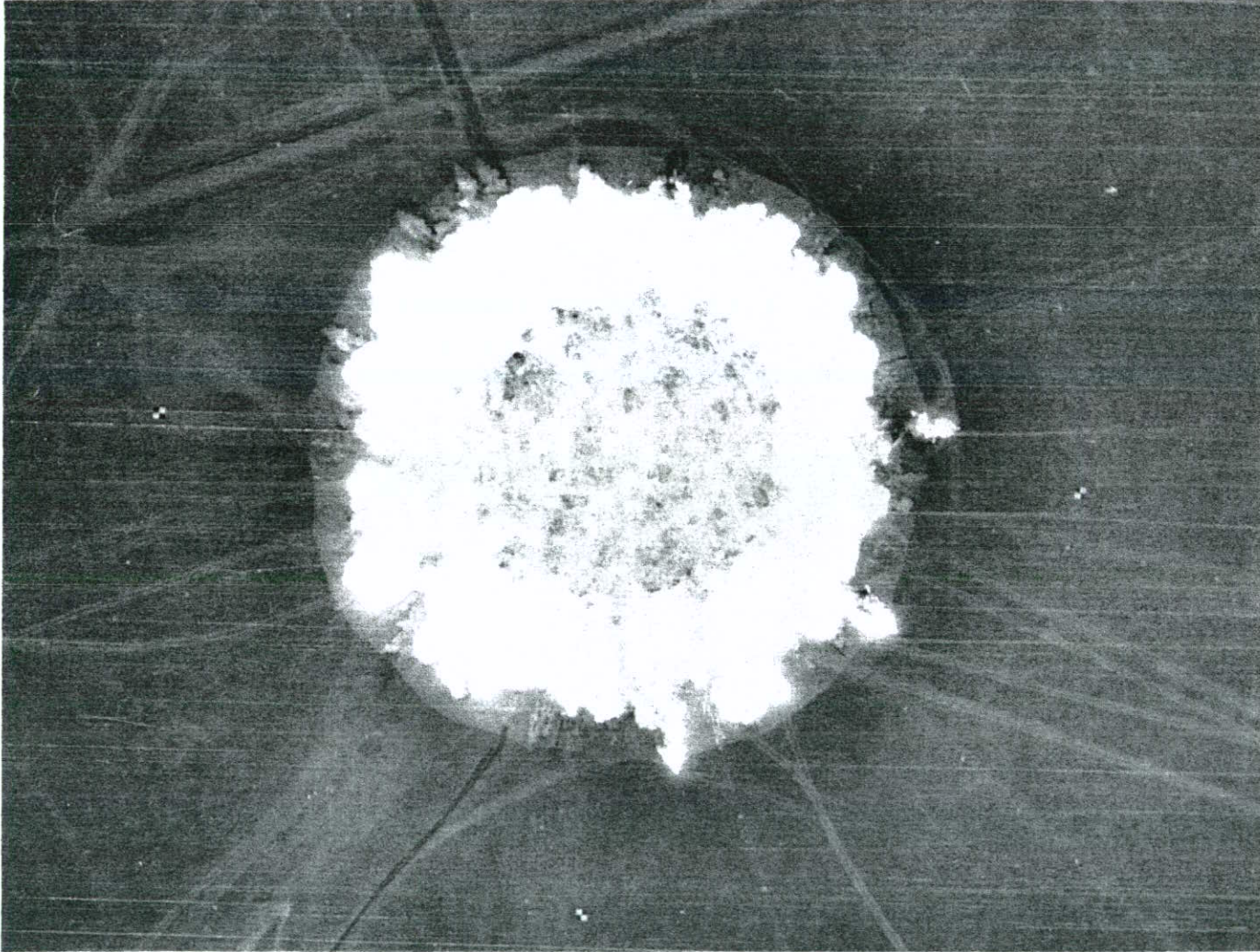


FIGURE 12. FRAME FROM AERIAL HULCHER CAMERA - Z + 0.2 SEC APPROX.  
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## KEY WORDS

1. Anomalies - Blast Wave
2. Precursor Jets
3. Perturbations - Shock Front
4. Perturbations - Fireball

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