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TWO DIMENSIONAL FLOW OF DETONATIONS PROCEEDING PERPENDICULAR TO CONFINED AND UNCONFINED SURFACES

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Plane wave initiated detonation waves proceeding perpendicular to confined surfaces exhibit very little wave curvature and a complicated flow pattern behind the wave. Experimental measurements of the detonation wave arrival across the surface of a charge of Composition B or 9404 explosive show that there is remarkably little curvature present even after the plane wave initiated cylindrical explosive charge has run many charge diameters. Radiographic studies of the density profile of a detonation wave proceeding up a confined or unconfined slab of explosive indicate very little wave front curvature and a complicated rarefaction wave profile.

A numerical study was performed using the reactive, Lagrangian, two-dimensional hydrodynamic code called 2DL. The complicated observed behavior of a detonation wave proceeding perpendicular to a confined or unconfined surface can be approximated if the detonation wave front is programmed to keep a constant velocity regardless of any side effects. The actual process is probably one of failure, reignition and resulting overdriven detontation occuring repeatedly near the explosive surface.

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ABSTRACT

Plane-wave-initiated detonation waves proceeding perpendicular to a confined or unconfined surface exhibit very little wave curvature and a complicated flow pattern behind the wave. Numerical studies of this process have been performed using two dimensional Lagrangian code, 2DL, to solve the reactive hydrodynamics.

I. INTRODUCTION

The detonation wave proceeding perpendicular to a surface that is either a free surface or confined by some high density material presents a challenge to the theorist.

Experimental measurements by Craig, Davis and Campbell[1] of the detonation wave arrival across the surface of a charge have shown for many years that there is remarkably little curvature present even after a large plane wave initiated cylindrical explosive charge has run many charge diameters.

The Los Alamos Scientific Laboratory radiographic facility, PHERMEX[2], has been used to study the density profile of a detonation wave proceeding up a large block of explosive both with free surfaces and confined by various metal plates. For many explosives such as 9404 and Composition B, the detonation wave proceeds almost as if it is a plane wave and exhibits very little curvature. Much greater curvature has been observed for Baratol, nitroguanidine and triaminotrinitro benzene (TATB). This paper examines the experimental data and determines if a numerical model can be developed to describe the data.

II. EXPERIMENTAL DATA

Venable and Boyd[3] showed radiographs of the detonation wave resulting from a 10-cm cube of Composition B explosive initiated by a plane wave generator. Radiographs of the unconfined explosive, explosive confined by 0.638-cm-thick slabs of Lucite, and explosive with embedded tantalum foils were presented. Rivard et al.[4] discussed the flow behind the detonation waves and Davis and

Venable[5] discussed various interpretations of the rarefaction wave observed in the radiographs. In all cases, the detonation wave had very little, if any, curvature at the front.

Many other radiographic studies have confirmed these earlier observations.

In Figure 1 a radiograph is shown of a 10.16 cm cube of Composition B initiated by a plane wave lens and confined by 2.54-cm-thick-plates of aluminum. Figure 2 shows the same system with tantalum foils embedded in the explosive. Figure 3 is a sketch of the prominent features of the radiograph showing the aluminum shock wave and rarefaction from the free surface. Also shown is a remarkably flat detonation front and a small displacement of the foils across it, followed by a large decrease in density originating near the front of the wave as it intersects the metal plate and a large displacement of the foils. A very complicated flow is indicated, and lacking any attractive alternatives, we decided to study the problem with the numerical reactive hydrodynamic codes.

III. THE NUMERICAL STUDY

The numerical study was performed using the reactive, Lagrangian hydrodynamic code 2DL.[6] The present version of the code was coded by D. Simmonds.

Resolved chemical reaction zone studies have been described in reference 7 of the interaction of a supported slab detonation wave in nitromethane passing into a box of nitromethane and into a slab of nitromethane with a void on one side. The side rarefaction travelled into the detonation wave at the experimentally observed velocity and a curved detonation front resulted. The failure wave is observed to travel into the front getting narrower as it progresses. This wave extinguishes detonation at its front, but reignition occurs at the rear and catches up with the wave. The catch up probably results in an overdriven wave which then decays, and the process repeats itself. This apparently results in the average velocity remaining almost the same as the undisturbed detonation wave velocity. Something similar probably occurs in heterogeneous explosives but complicated by the partial decomposition of the shocked but not detonated explosive near the surface.

The numerical calculation of this flow for a sufficiently long time and with sufficient resolution to resolve the reaction zone is presently not economically feasible.

If the usual unresolved explosive burn techniques such as the C-J volume burn[8] or temperature dependent burn[8] are used, one obtains the expected detonation wave curvature as shown in Figure 4.

If a programmed explosive burn is used to keep a constant velocity, plane detonation front regardless of any side effects one can obtain flow that resembles that observed experimentally. The sharp shock burn technique[9] was used and the results are shown in Figure 5 for Composition B and Figure 6 for 9404.

The complicated flow behind the detonation wave results in a density profile remarkably similar to that observed experimentally. In particular the first rarefaction fan is present and so is the density discontinuity near the plate.

A comparison of the calculated and experimental behavior of the metal plate is shown in Figure 7.

IV. CONCLUSION

The complicated observed behavior of a detonation wave proceeding perpendicular to a confined or unconfined surface can be approximated numerically if the detonation wave front is programmed properly. The detonation products near the interface exhibit a complicated flow pattern that is probably not described in detail by any such crude calculation. It would appear unlikely that one could infer anything reliable about the steady state properties of the explosive from the observed behavior of a metal plate or tube confining the explosive without a realistic numerical description of the observed highly complicated flow pattern.

ACKNOWLEDGMENTS

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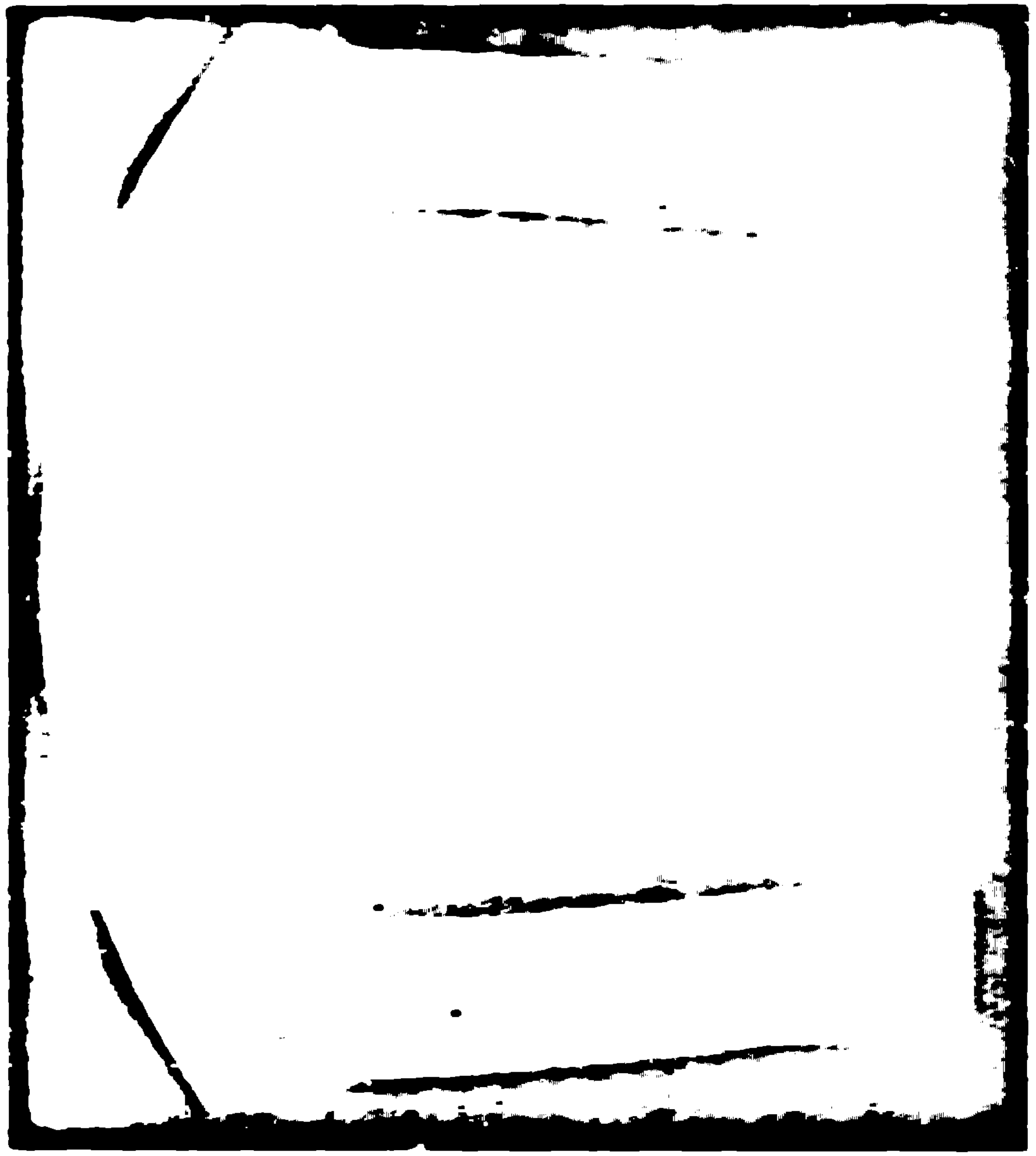
Fig. 1 The static and dynamic radiograph of a 10.16 cm cube of Composition B explosive initiated by a plane wave lens and confined by 2.54-cm-thick plates of aluminum.



[illegible]

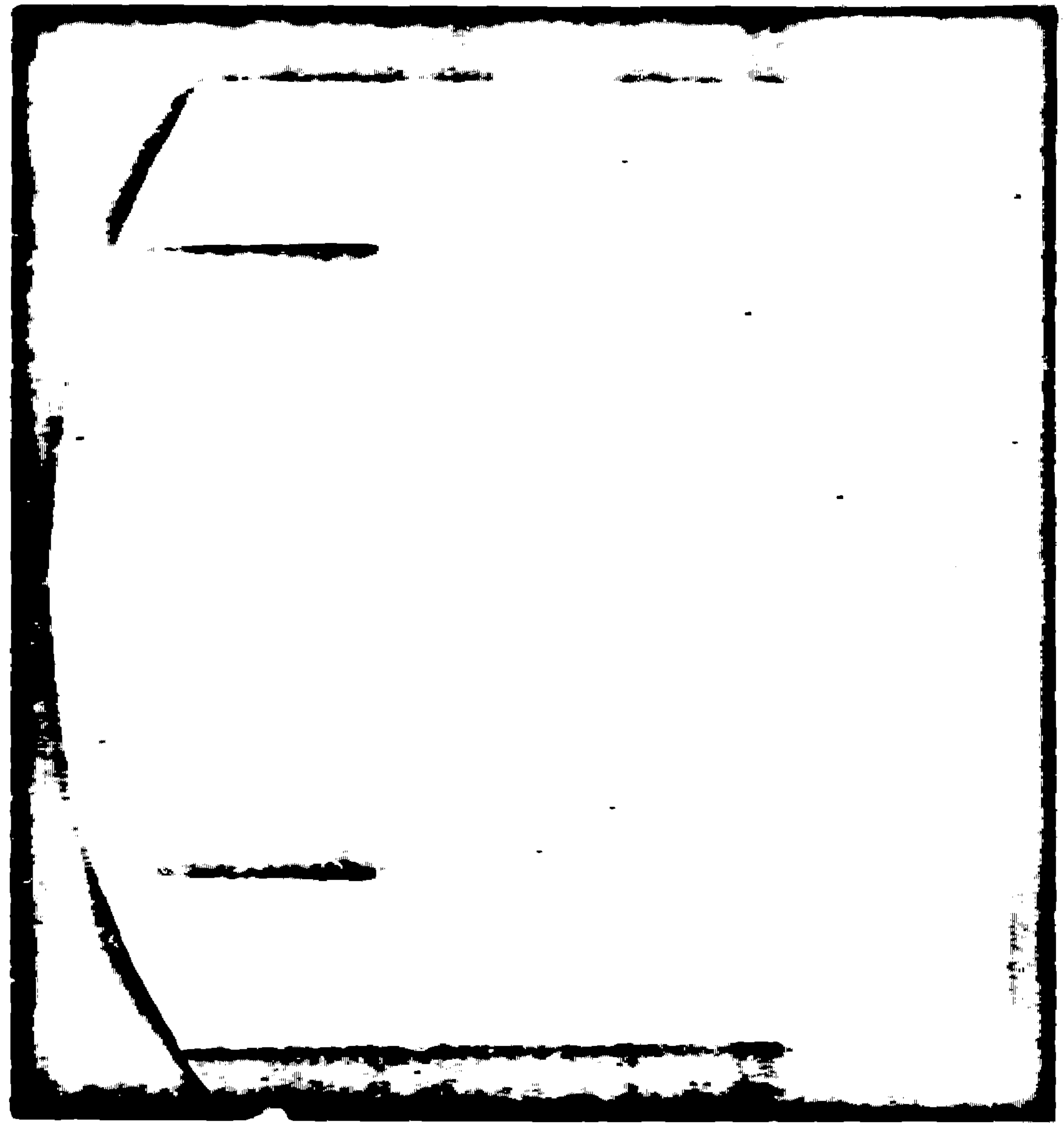


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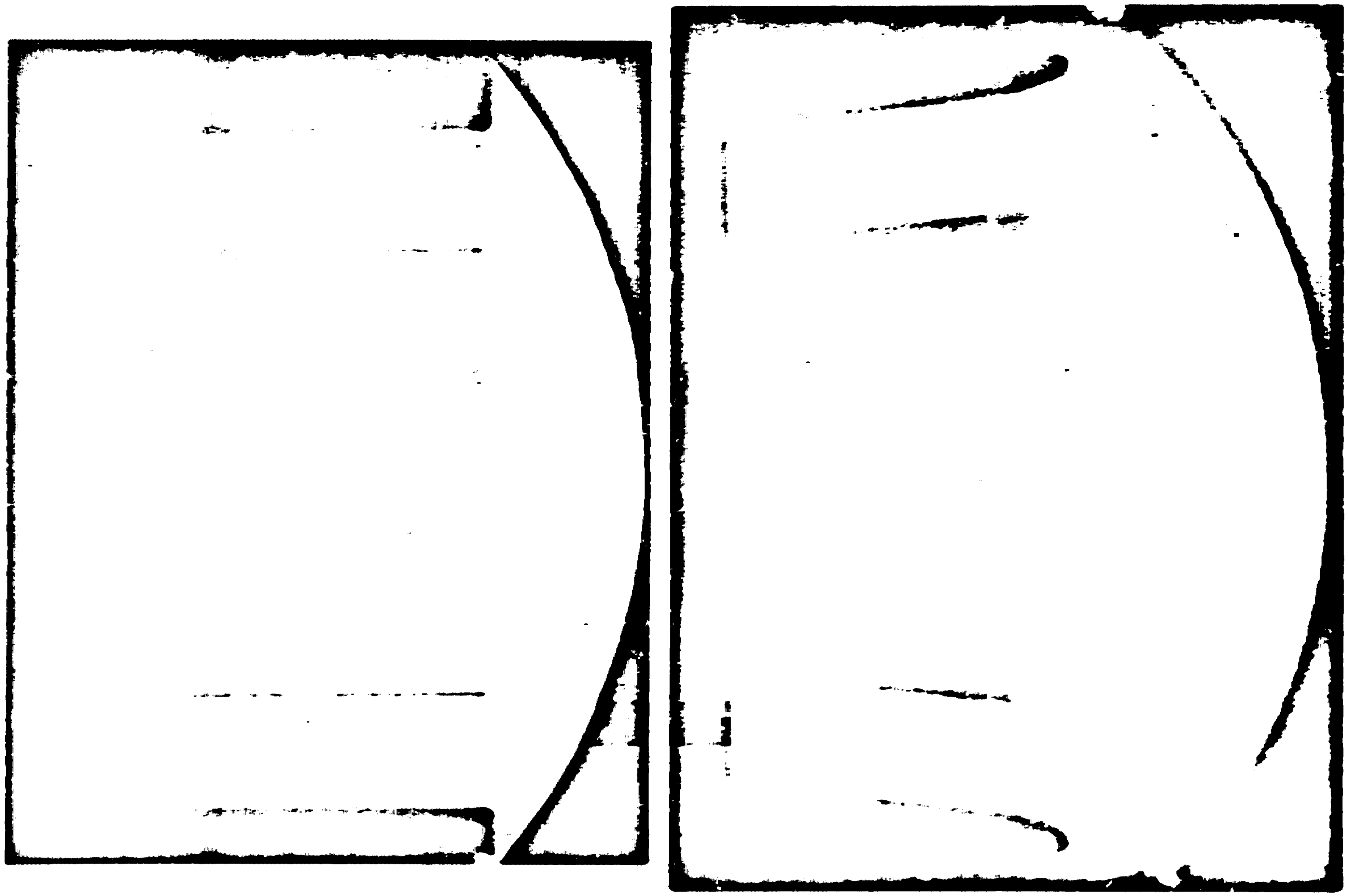
Fig. 2 The static and dynamic radiograph of the same system as Fig. 1 with the addition of 0.00125-cm-thick tantalum foils spaced every 0.635 cm.



Marlow Figure 2

Fig. 3. Prominent features of the radiograph shown in Fig. 2. The initial and final foil positions, the detonation front, the aluminum shock wave and rarefaction, the position of the aluminum plate and approximate positions of the rarefactions in the detonation products are shown.

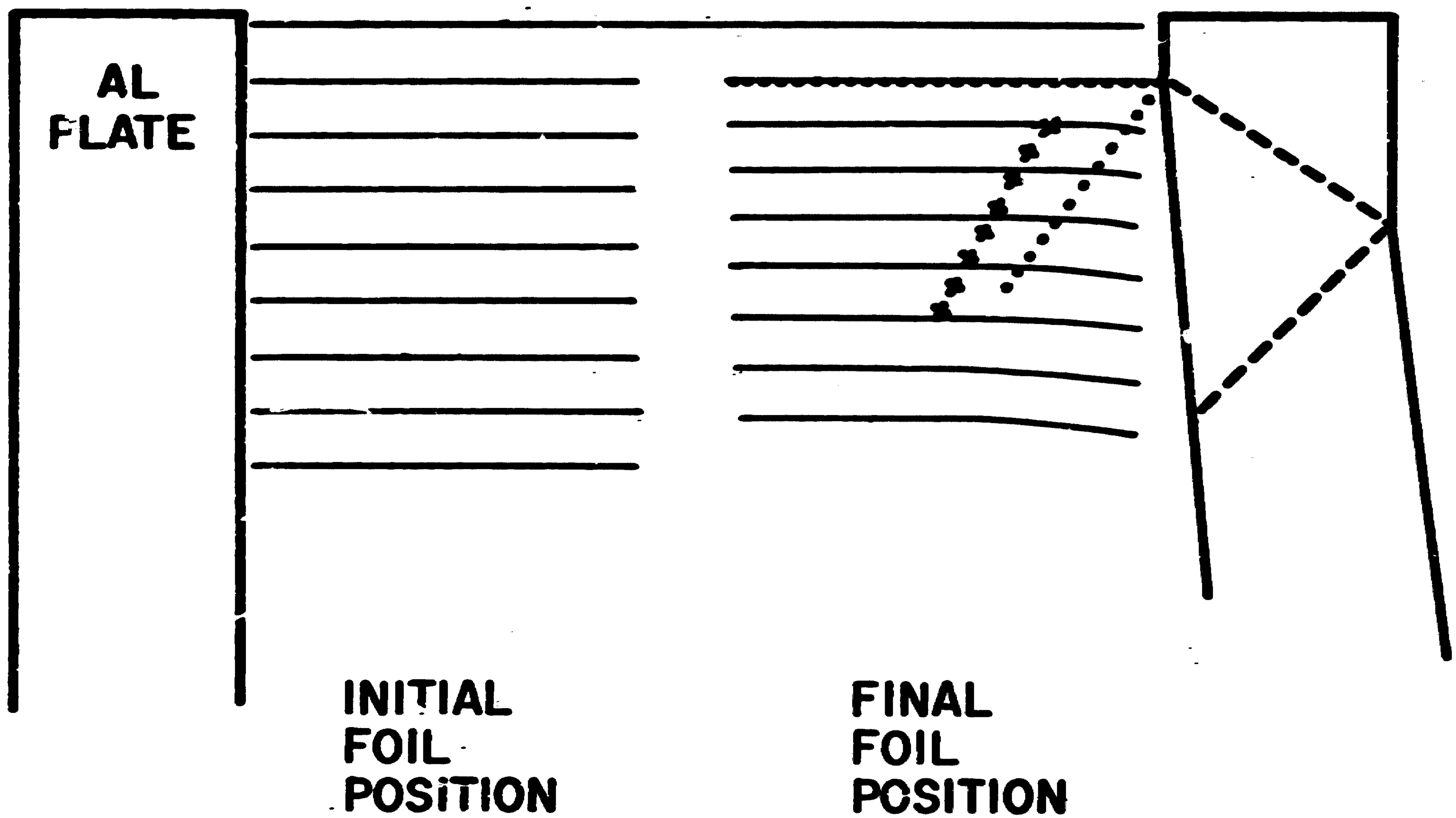

AL
FLATE
INITIAL
FOIL
POSITION
FINAL
FOIL
POSITION

Fig. 4. The isopycnic, isobar, mass fraction and cell corner plots for the detonation of a slab of Composition B confined by an aluminum plate. The C-J volume burn technique was used. The isopycnic interval is 0.03 gm/cc, the isobar interval is 0.05 Mbars and the mass fraction interval is 0.1.

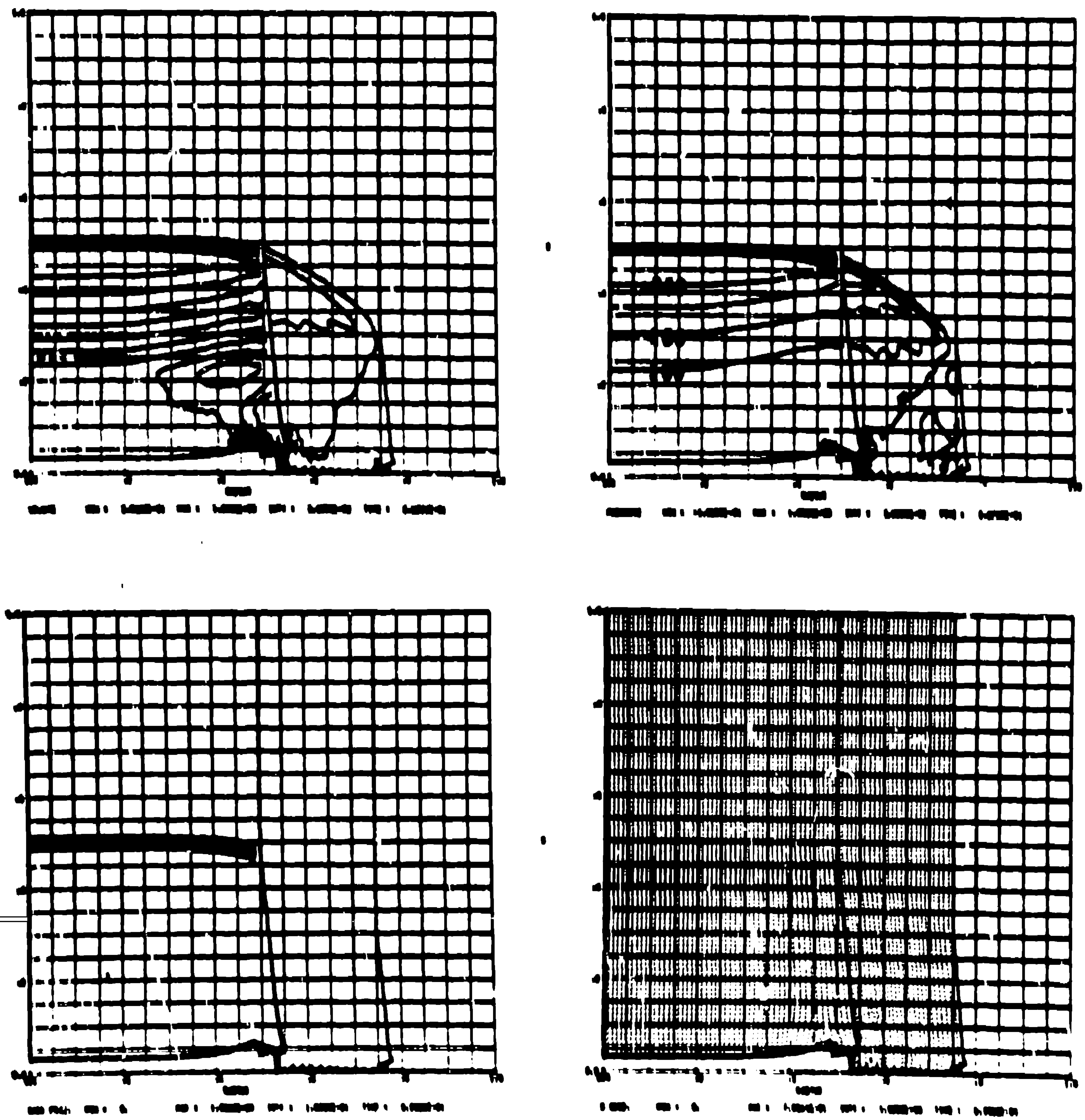


Fig. 5. The isopycnic, isobar, mass fraction and cell corner plots for the detonation of a slab of Composition B confined by an aluminum plate. The sharp shock burn technique was used. The isopycnic interval is 0.03 gm/cc, the isobar interval is 0.05 mbars and mass fraction interval is 0.1.

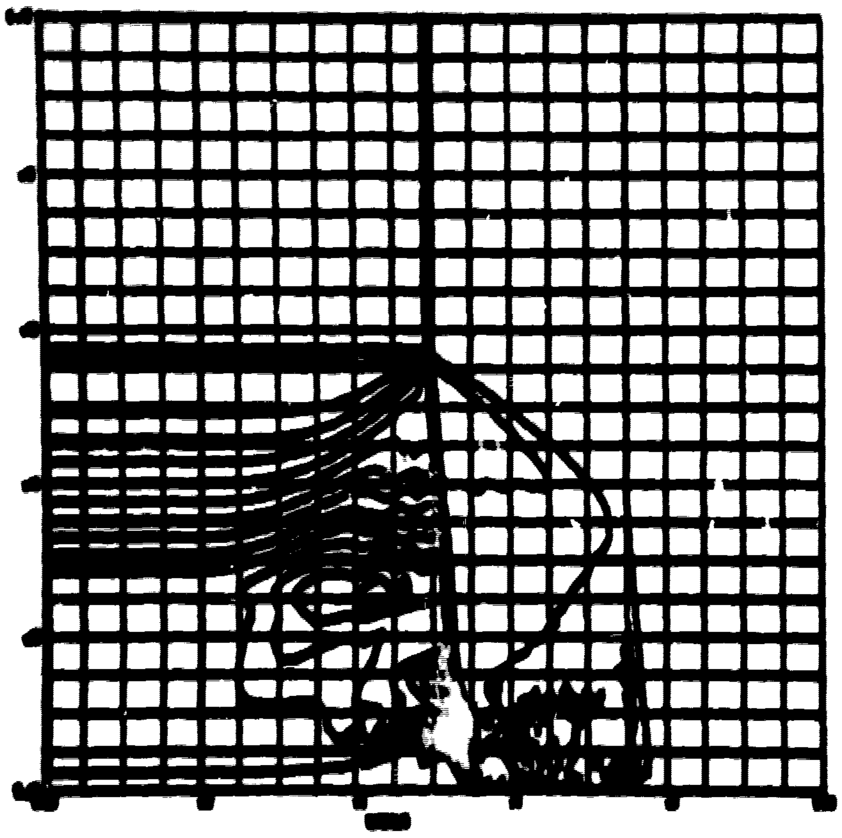
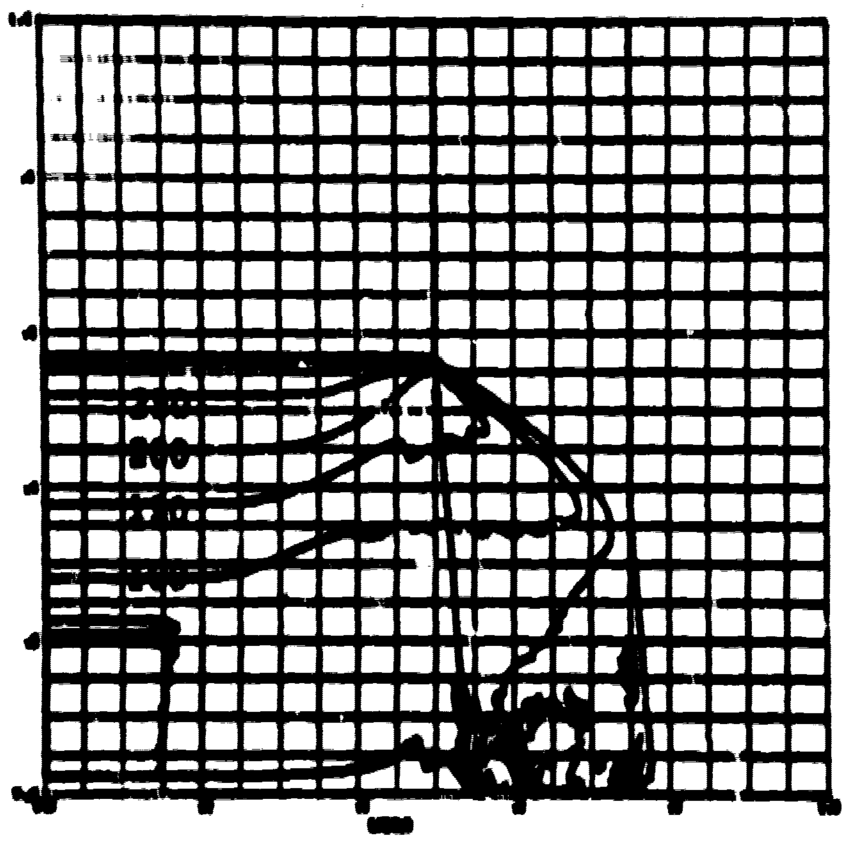
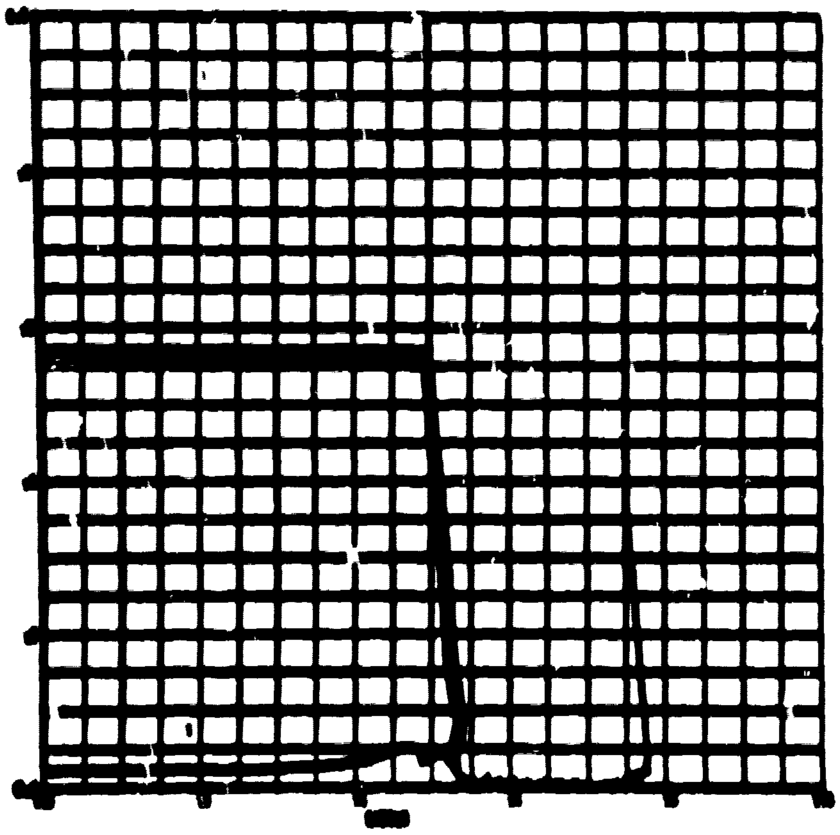
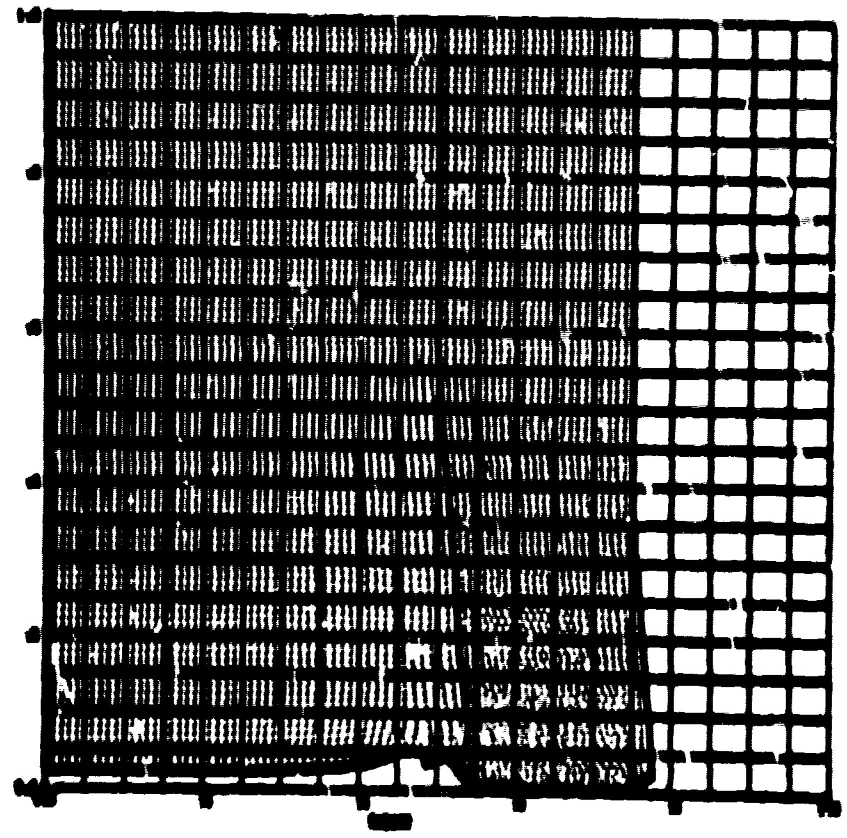





Fig. 6. The isopycnic, isobar, mass fraction and cell corners plots for the detonation of a slab of 9404 confined by an aluminum plate. The sharp shock burn technique was used. The isopycnic interval is 0.02 gm/cc, the isobar interval is 0.05 mbars and mass fraction interval is 0.1.

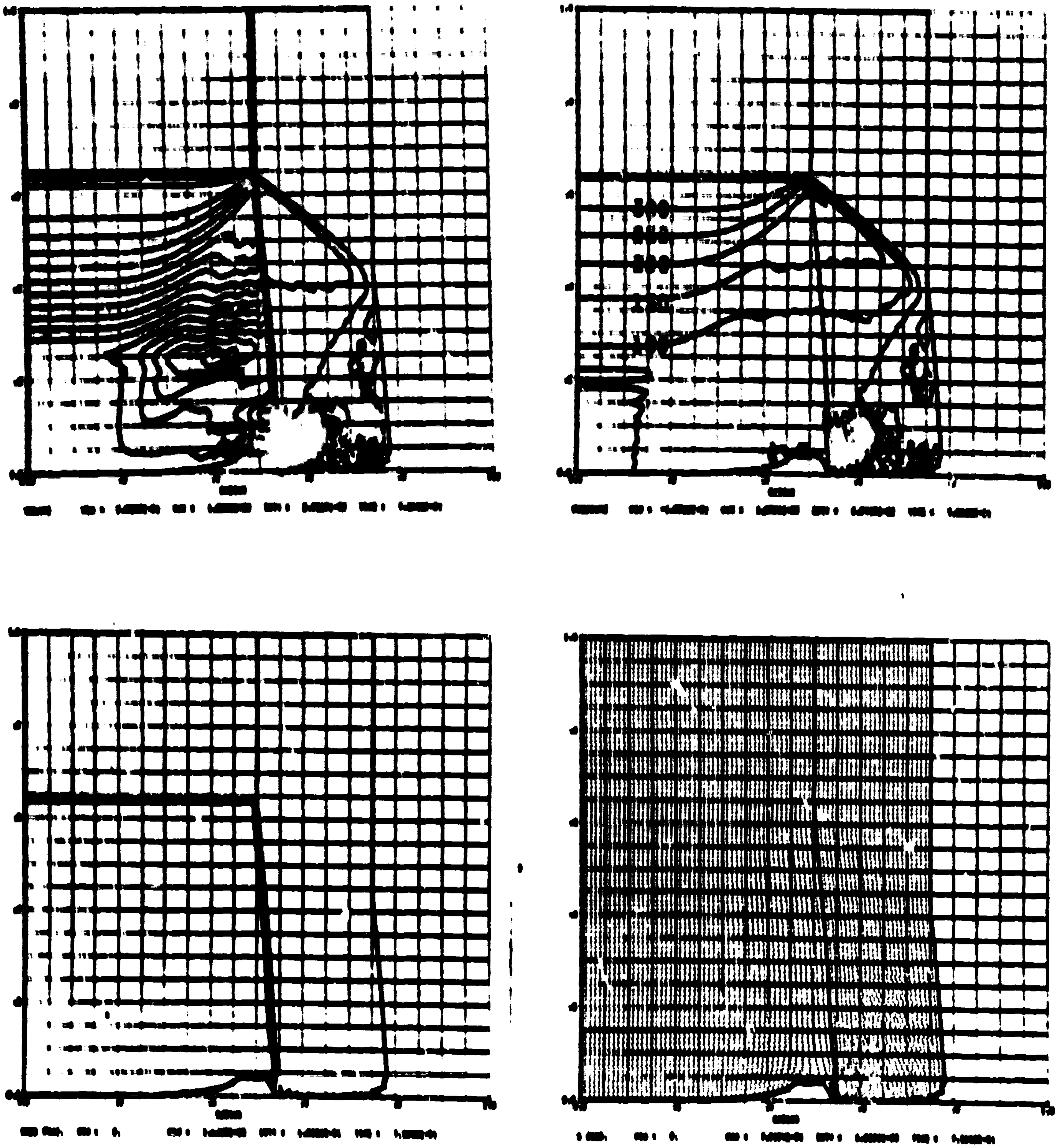
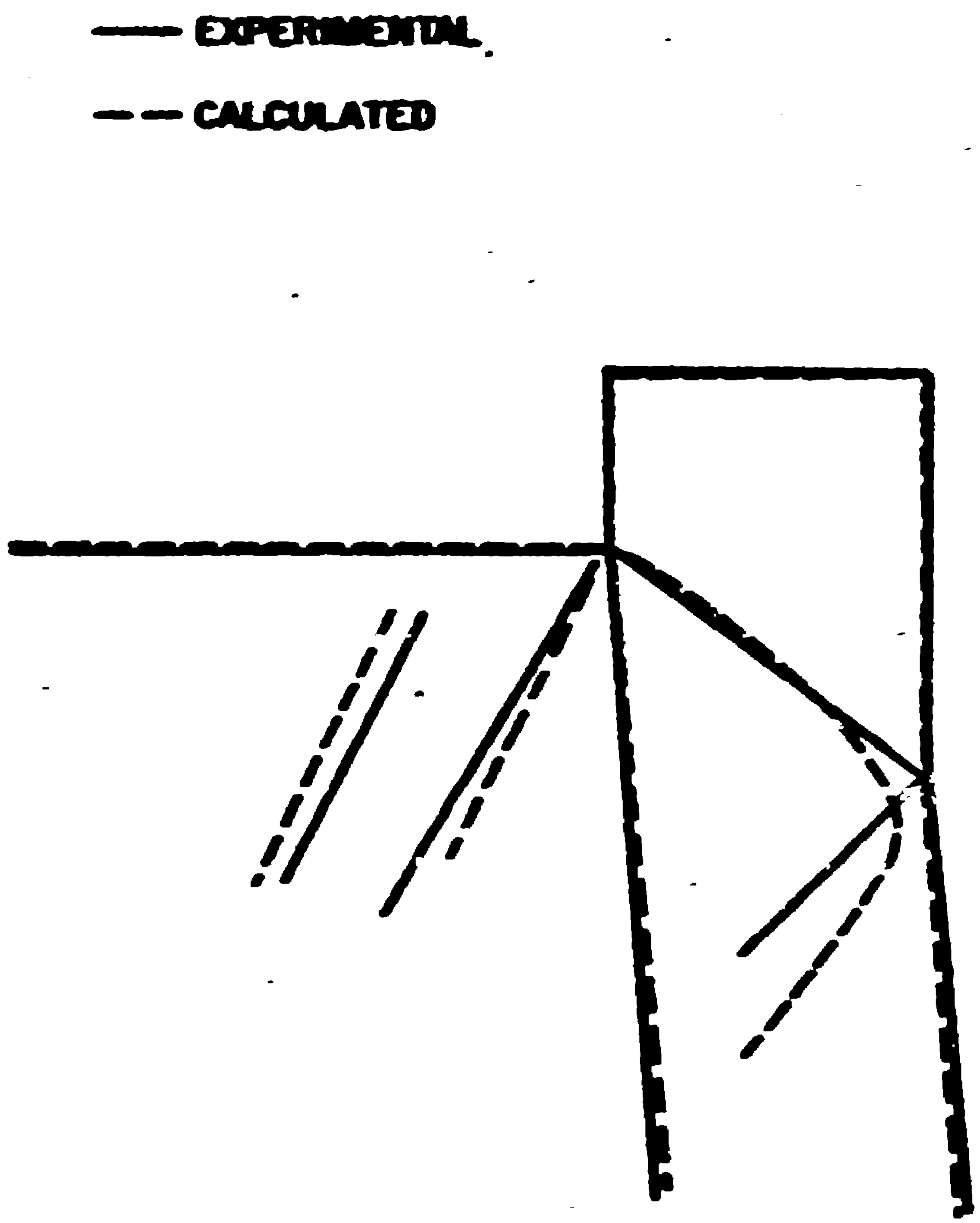


Fig. 7. A sketch of the prominent features of the radiograph shown in Fig. 2 and the calculation shown in Fig. 5.



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