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Two-Dimensional Detonations

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Charles L. Mader

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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 the 2DL code to solve the reactive hydrodynamics.

I. INTRODUCTION

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

Craig, Davis, and Campbell's experimental measurements[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 with both free surfaces and surfaces confined by various metal plates. For many explosives such as 9404 and Composition B, the detonation wave proceeds almost as if it were a plane wave and exhibits very little curvature. Much greater curvature has been observed for Baratol, nitroguanidine, and triaminotrinitrobenzene (TATB). This report examines the experimental data to determine whether a numerical model can be developed to describe them.

II. EXPERIMENTAL DATA

Venable and Boyd[3] have shown radiographs of the detonation wave resulting from a 10-cm cube of Composition B explosive initiated by a plane-wave generator. Radiographs of unconfined explosive, explosive confined by 0.635-cm-thick slabs of Lucite, and explosive with embedded tantalum foils have been presented. Rivard et al.[4] have discussed the flow behind the detonation waves, and Davis and Venable[5] have discussed various interpretations of the rarefaction wave observed in the radiographs. In all cases, the observed detonation wave had very little, if any, curvature at the front. Many other radiographic studies have confirmed these earlier observations.

Figure 1 shows 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 radiographs 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 using the numerical reactive-hydrodynamic codes.

III. THE NUMERICAL STUDY

The numerical study was performed using the reactive, Lagrangian hydrodynamic code, 2DL.[6] The

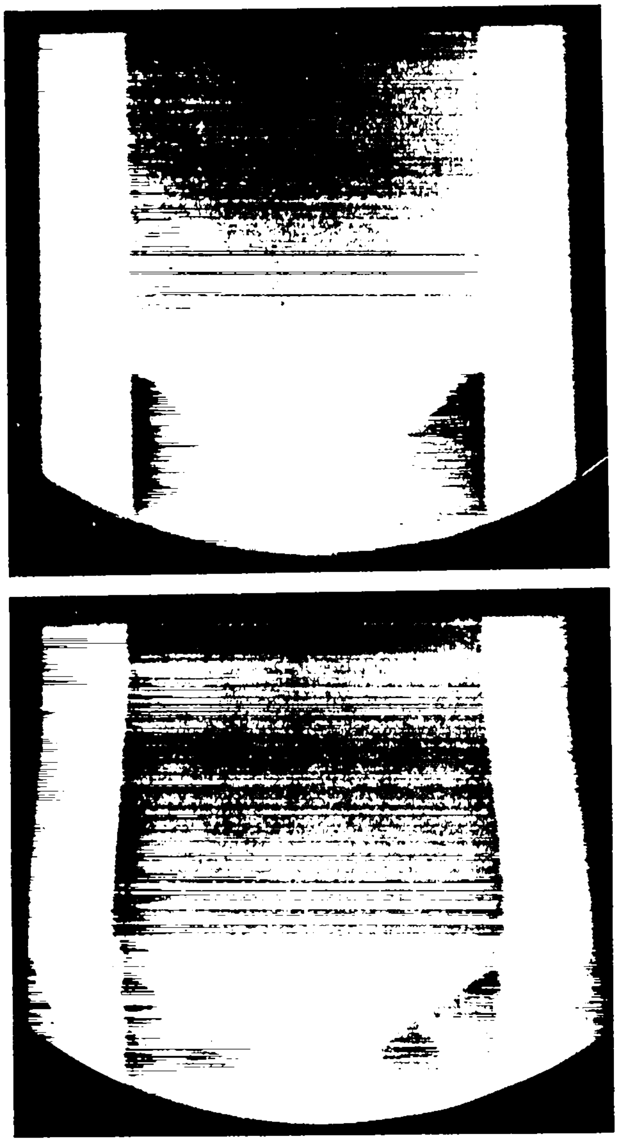

Fig. 1. Static and dynamic radiographs of a 10.16-cm cube of Composition B explosive initiated by a plane-wave lens and confined by 2.54-cm-thick plates of aluminum.

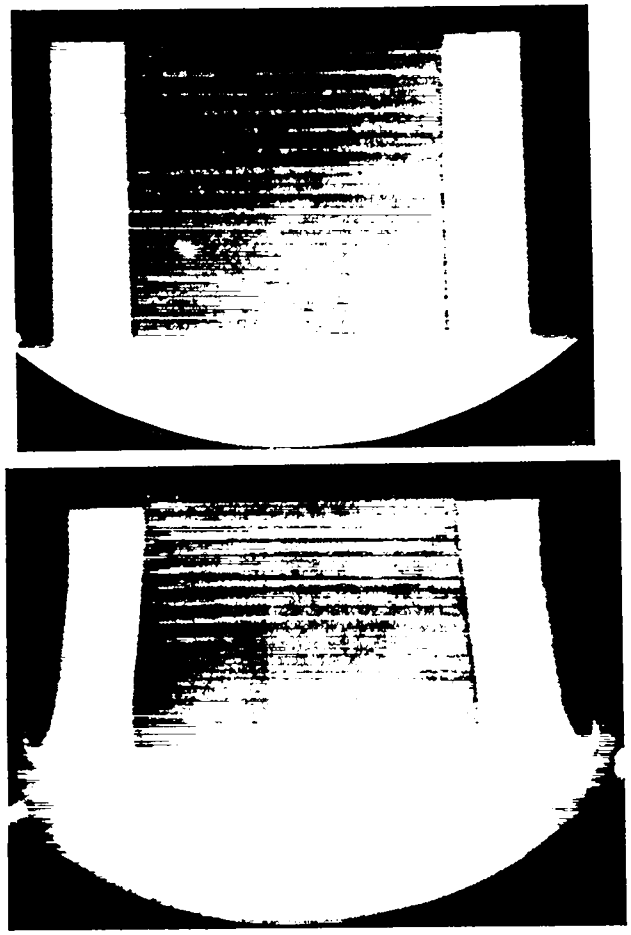

Fig. 2. Static and dynamic radiographs of the same system as that in Fig. 1 with the addition of 0.00125-cm-thick tantalum foils spaced every 0.635 cm.

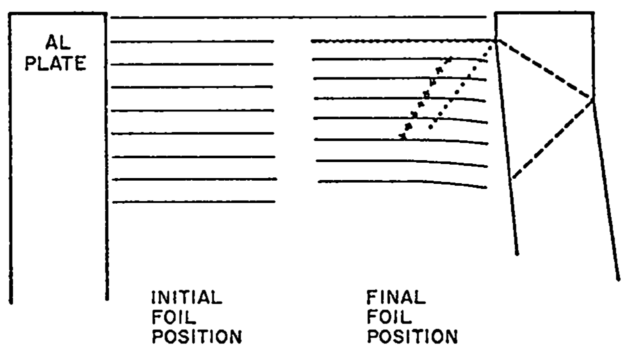

Fig. 3. Prominent features of the radiographs shown in Fig. 2. The initial and final foil positions, the detonation front, the aluminum shock wave and rarefaction, the position of the aluminum plate, and approximate positions of the rarefactions in the detonation products are shown.

present version was coded by Simmonds; it is being developed further by Fickett and Jacobson.

Resolved chemical reaction-zone studies 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 have been described.[7] The side rarefaction travelled into the detonation wave at the experimentally observed velocity, and a curved detonation front resulted. The failure wave travels 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 catchup probably results in an overdriven wave that then decays, and the process repeats itself. This apparently causes the average velocity to remain almost the same as the undisturbed detonation-wave velocity. Something similar probably occurs in heterogeneous explosives but is complicated by the partial decomposition of the shocked, but not detonated, explosive near the surface. The numerical calculation of this flow for a long enough time and with sufficient resolution to resolve the reaction zone is presently not economically feasible.

Using the usual unresolved explosive-burn techniques such as the C-J volume burn[8] or temperature-dependent burn,[8] one obtains the expected detonation-wave curvature as shown in Fig. 4. Using a programmed explosive burn to keep a constant-velocity, plane detonation front regardless of any side effects, one can obtain flow that resembles that observed experimentally. We used the sharp-shock burn technique[9] and show the results for Composition B in Fig. 5 and those for 9404 in Fig. 6. 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. The calculated and experimental behavior of the metal plate is shown in Fig. 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 probably is not described in detail by any such crude calculation. It seems 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.

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REFERENCES

1. B. G. Craig, W. C. Davis, and W. Campbell, LASL Group GMX-8 internal monthly reports.
2. D. Venable, "PHERMEX," Physics Today 17, 19 (1964).
3. D. Venable and T. Boyd, "PHERMEX Applications to Studies of Detonation Waves and Shock Waves," Fourth Symposium (International) on Detonation, p. 639 (1965).
4. W. C. Rivard, D. Venable, W. Fickett, and W. C. Davis, "Flash X-Ray Observations of Marked Mass Points in Explosive Products," Fifth Symposium (International) on Detonation, p.1 (1970).
5. W. C. Davis and Douglas Venable, "Pressure Measurements for Composition B-3," Fifth Symposium (International) on Detonation, p. 9 (1970).
6. Charles L. Mader, "The Two-Dimensional Hydrodynamic Hot Spot, Volume III," Los Alamos Scientific Laboratory report LA-3450 (1966).
7. Charles L. Mader, "The Two-Dimensional Hydrodynamic Hot Spot, Volume IV," Los Alamos Scientific Laboratory report LA-3771 (1967).
8. Charles L. Mader and William R. Gage, "FORTRAN SIN-a One-Dimensional Hydrodynamic Code for Problems which Include Chemical Reactions, Elastic-Plastic Flow, Spalling, and Phase Transitions," Los Alamos Scientific Laboratory report LA-3720 (1967).
9. Charles L. Mader, "An Empirical Model of Heterogeneous Shock Initiation of the Explosive 9404," Los Alamos Scientific Laboratory report LA-4475 (1970).

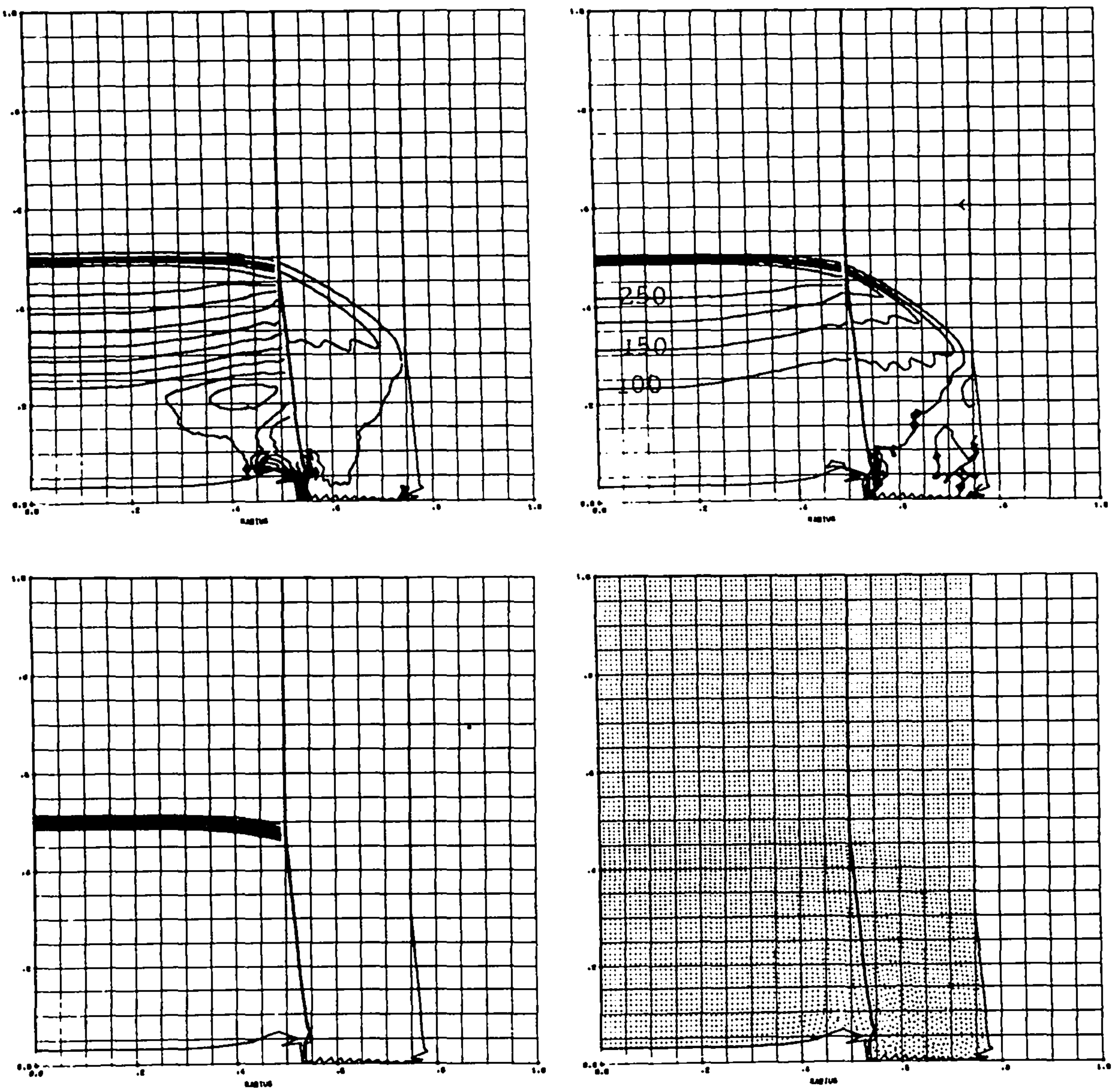

Fig. 4. The isopycnic, isobar, mass fraction, and cell-corner plots for the detonation of a slab of Composition B confined by an aluminum plate. The C-J volume burn technique was used. The isopycnic interval is 0.03 g/cm^3, the isobar interval is 0.05 mbar, and the mass-fraction interval is 0.1.

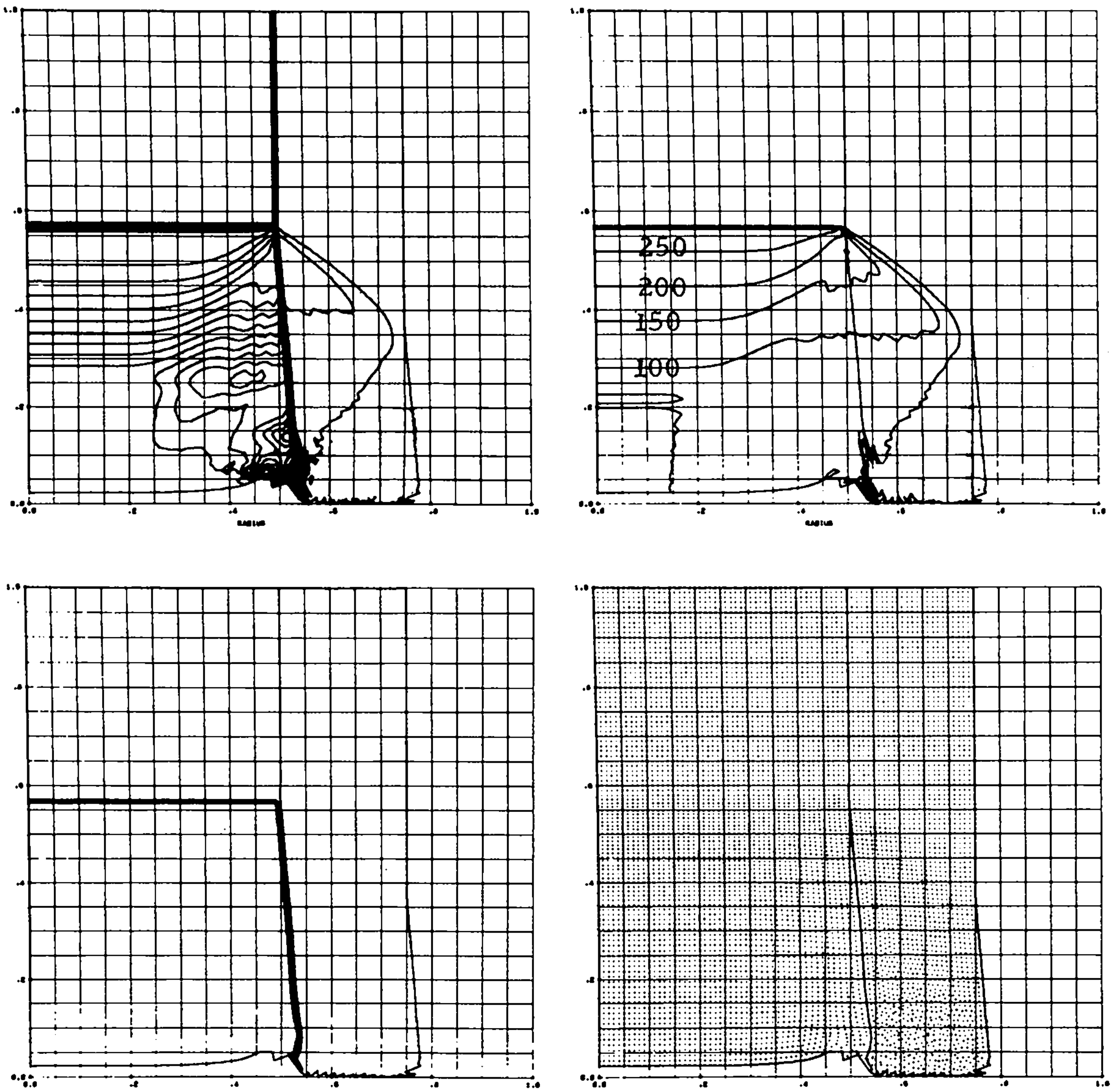

Fig. 5. The isopycnic, isobar, mass fraction, and cell-corner plots for the detonation of a slab of Composition B confined by an aluminum plate. The sharp-shock burn technique was used. The isopycnic interval is 0.03 g/cm^3, the isobar interval is 0.05 mbar, and the mass-fraction interval is 0.1.

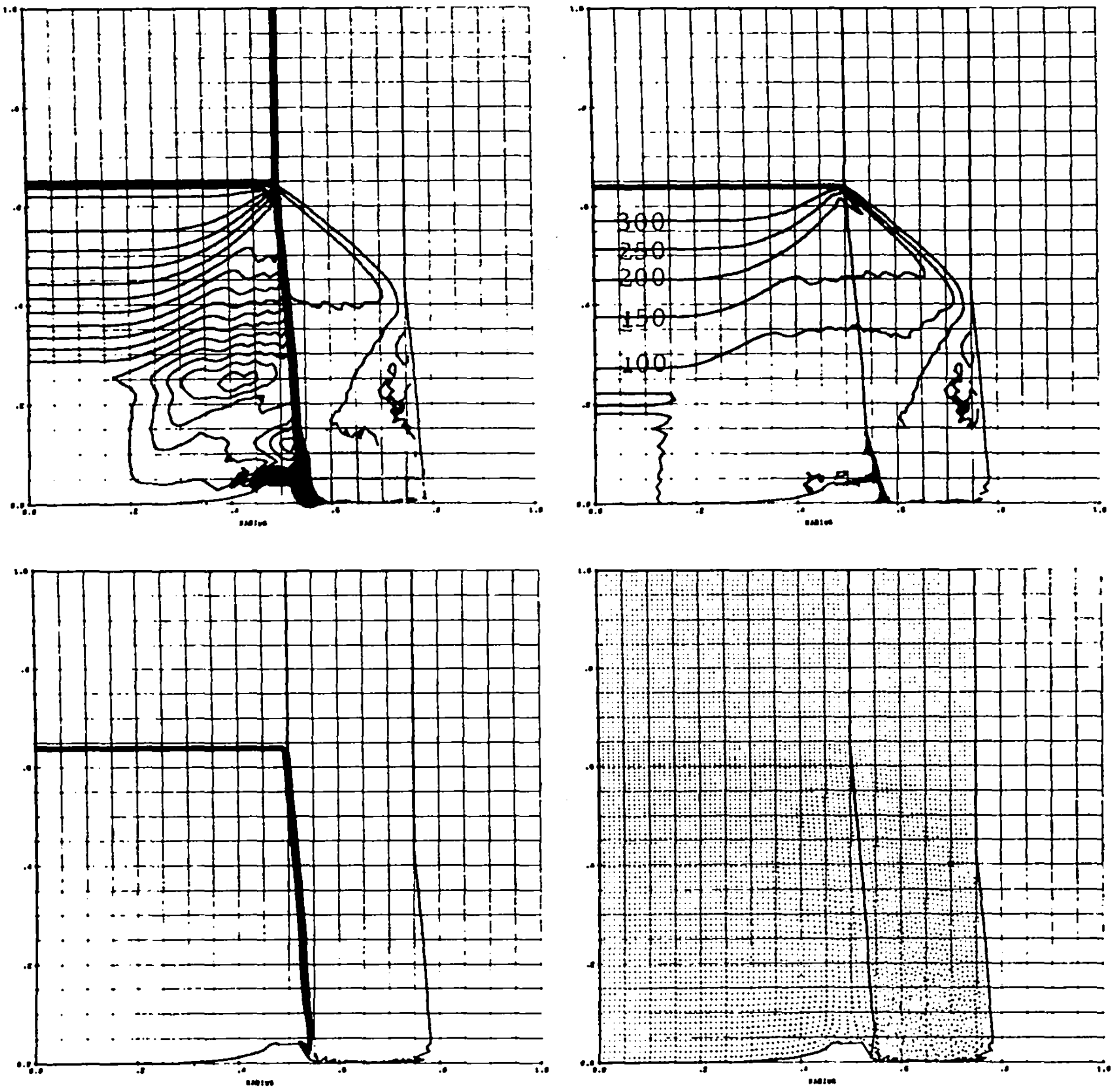

Fig. 6. The isopycnic, isobar, mass fraction, and cell-corner plots for the detonation of a slab of 9404 confined by an aluminum plate. The sharp-shock burn technique was used. The isopycnic interval is 0.02 g/cm^3, the isobar interval is 0.05 mbar, and the mass-fraction interval is 0.1.

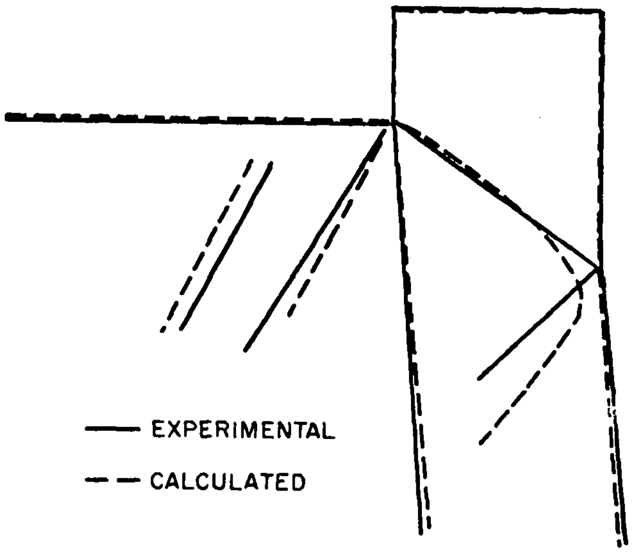

Fig. 7. Prominent features of the radiograph shown in Fig. 2 and the calculation shown in Fig. 5.

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