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Three-Dimensional Modeling of Triple-Wave Initiation of Insensitive Explosives

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ABSTRACT

The initiation of propagating detonation in the insensitive explosive PBX 9502 (95/5 TATB/Kel-F at 1.894 g/cm^3) by triple-shock-wave interaction from three initiators has been modeled using the three-dimensional, reactive, Eulerian hydrodynamic code, 3DE. The Forest Fire burn model of heterogeneous explosive shock initiation was used to model the explosive decomposition.

I. INTRODUCTION

The initiation of propagating, diverging detonation is usually accomplished by small conventional initiators. As the explosive to be initiated becomes more shock insensitive, the initiators must have larger diameters (~2.5 cm) to be effective, or some other method must be used to achieve the required high pressures of adequate duration. High pressures are achieved if two or more shock waves interact to form regular or Mach shock reflections. We will investigate propagating detonation initiation in the insensitive high explosive PBX 9502 (95/5 TATB/Kel-F at 1.894 g/cm^3) by the double- and triple-wave interaction of shock waves formed by initiators that are too weak to initiate propagating detonation individually.

Using multiple shock-wave interactions to initiate propagating detonation in explosives was studied experimentally by Goforth.[1] Mach and regular shock reflections in aluminum were studied experimentally by Al'tshuler et al.[2] and reproduced numerically by Mader.[3] The Mach and regular reflections of detonation waves have been studied experimentally by Gardner and Wackerle,[4] by Lambourn and Wright,[5] and by Venable.[6] Two laterally colliding, divergent detonation waves in PBX 9404 were examined radiographically and reproduced numerically by Mader and Venable[6] using the two-dimensional Lagrangian hydrodynamic code 2DL.[7] Mach stem formation and growth was described.

Three interacting, spherically diverging detonation waves were modeled by Mader and Kershner[8] using the three-dimensional Eulerian hydrodynamic code 3DE and the shock-initiation burn model called Forest Fire.[7] The formation of regular and Mach shock reflections, which resulted from the interaction of three detonation waves, was described.

Propagating detonation initiation of insensitive explosives (PBX 9502 and X0219) by hemispherical initiators was studied experimentally and modeled numerically (Ref. 9). Large regions of partially decomposed explosive were observed to occur even when large initiators were used to initiate propagating detonation in insensitive explosives.

We will investigate the initiation of insensitive explosives by multiple shock-wave interactions.

II. NUMERICAL MODELING

The three-dimensional Eulerian hydrodynamic computer code, 3DE,[8] was used to model numerically the interaction of shock waves in PBX 9502 formed by

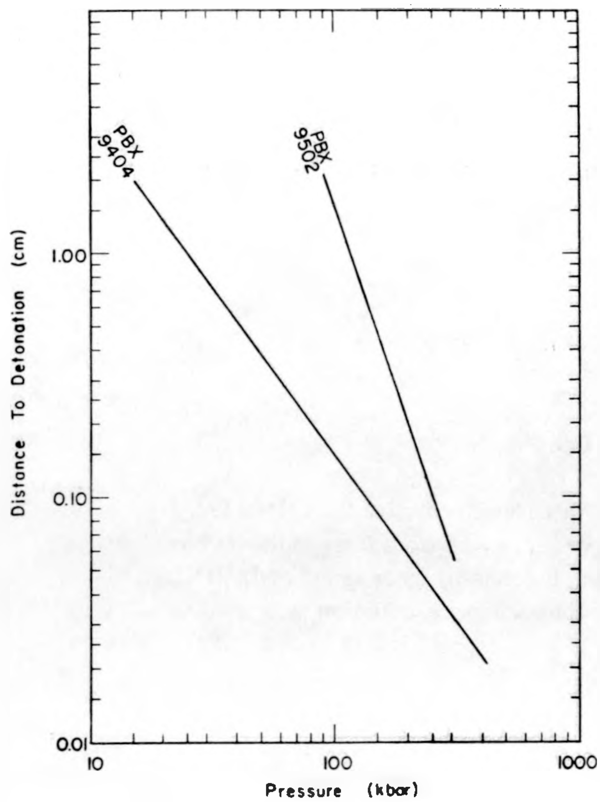

Fig. 1.
The Pop plot or run-to-detonation distance as a shock pressure function.

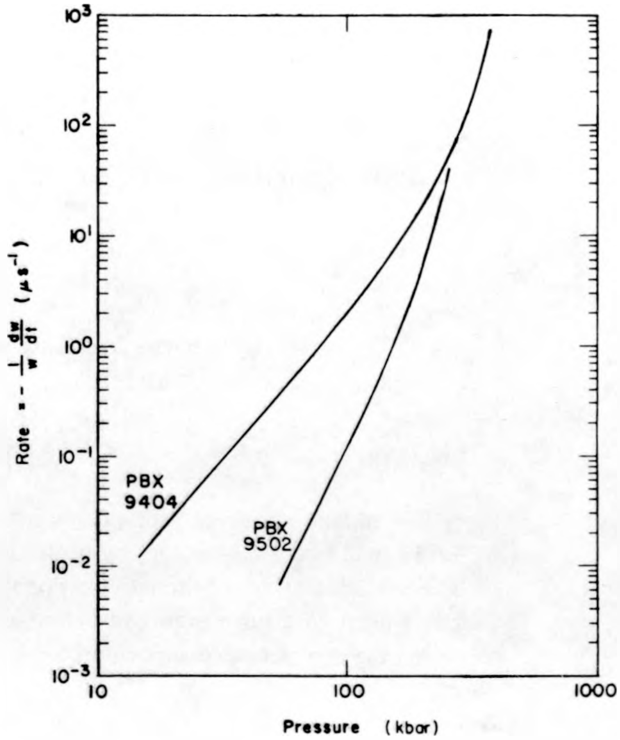

Fig. 2.
The Forest Fire decomposition rates as a shock pressure function.

initiators that are too small to initiate propagating detonation. The calculations were performed on the CRAY computer. The Forest Fire[7] model of heterogeneous explosive shock initiation was used to describe the explosive burn. The HOM[7] equation-of-state constants and Forest Fire constants for PBX 9502 are given in Chap. 4 of Ref. 7, and the Pop plot and Forest Fire rates are shown in Figs. 1 and 2.

The geometry studied is shown in Fig. 3. Two or three initiator cubes of 7 by 7 by 7 cells are placed symmetrically in a PBX 9502 cube with continuum boundaries on its sides. The initiator cube centers were 1.6 cm apart and 1.09 cm from the cube bottoms. The indices i, j, and k designate the position of the x-, y-, and z-coordinates. The total cube height is k of 31, i is 29, and j is 25. The initiator cubes were initially decomposed PBX 9502 with a 2.5-g/cm^3 initial density, which has an initial pressure of 245 kbar. This sends a diverging ~100-kbar shock into the surrounding PBX 9502. The computational cell size used was 0.114 cm, and the time step was 0.022 μs. The computer time for the 22 475 cells was about 50 minutes for 150 cycles.

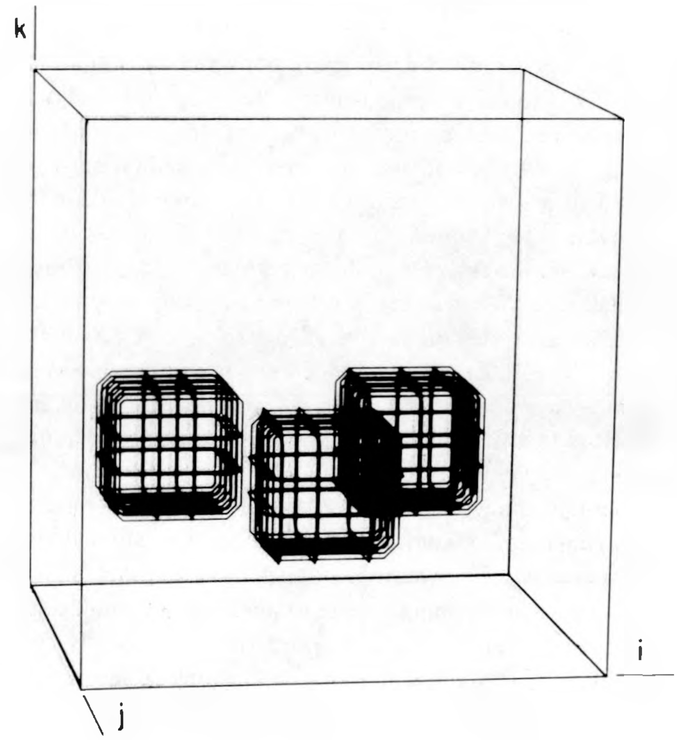

Fig. 3.
A PBX 9502 cube with three embedded rectangular initiators.

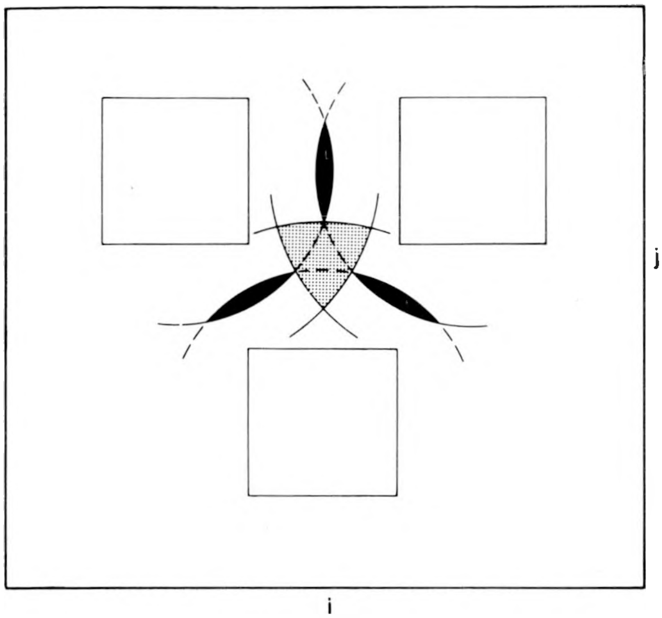

Fig. 4.
The expected double- and triple-shock-wave interactions from three initiators. The dashed lines and dark regions show the double-wave interaction. The solid lines and dotted regions show the triple-wave interaction.

The expected wave interactions are sketched in Fig. 4. The sketch shows the waves, just after double-wave interaction, as dashed lines, and the dark region shows the double-wave interactions. The solid lines and dotted regions show the waves after triple-wave interaction.

The pressures from the diverging double-wave interaction in inert PBX 9502 are about 200 kbar, and those from the triple-wave interaction are about 300 kbar.

The calculated three-dimensional pressure and mass fraction contours for two initiators are shown in Fig. 5 and for three initiators in Fig. 6. The isobar and mass fraction cross sections for layer j of 9 (across the detonator centers) are shown for two initiators in Fig. 7 at 1.34 μs, in Fig. 8 at 1.78 μs, and in Fig. 9 at 2.66 μs. The isobar and mass fraction cross sections for layer j of 11 (across the edge of the detonators) for three initiators are shown in Fig. 10 at 1.78 μs, in Fig. 11 at 3.10 μs, and in Fig. 12 at 4.42 μs.

Although two initiators cause double-wave interaction that results in considerable decomposition, propagating detonation does not result.

Three initiators fail to initiate propagating detonation at the double-wave interaction points but do at the triple-wave interaction region. The higher triple-wave interaction pressure results in a shorter run to detonation. The detonation can be maintained long enough to become a propagating, diverging detonation.

III. CONCLUSIONS

The three-dimensional Eulerian hydrodynamic computer code, 3DE, has been used to examine the interaction of two and three shock waves from initiators in PBX 9502. The dynamics of initiating propagating detonation in an insensitive explosive by multiple shock-wave interactions has been modeled numerically.

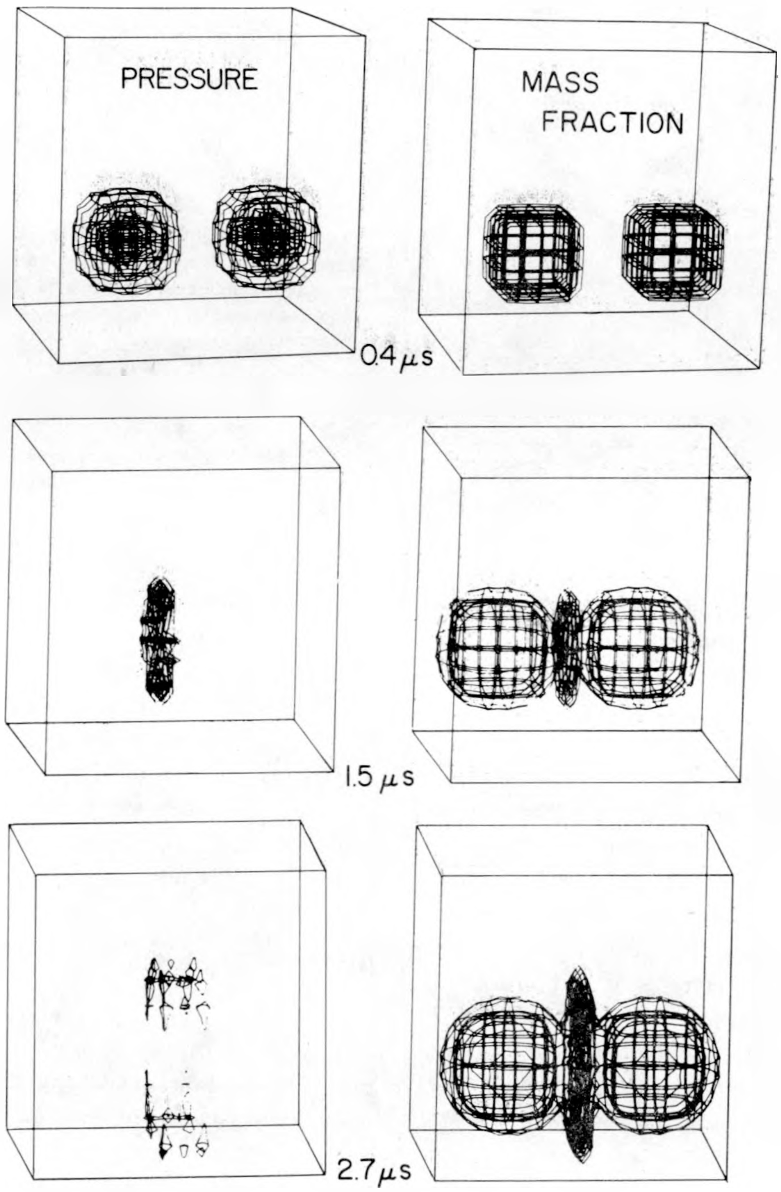

Fig. 5.

The calculated three-dimensional pressure and mass fraction contours for two initiators in PBX 9502. The pressure contours are shown for 200, 150, and 100 kbar at 0.4, 1.5, and 2.7 μs. The mass fraction contours are 0.8 and 0.5.

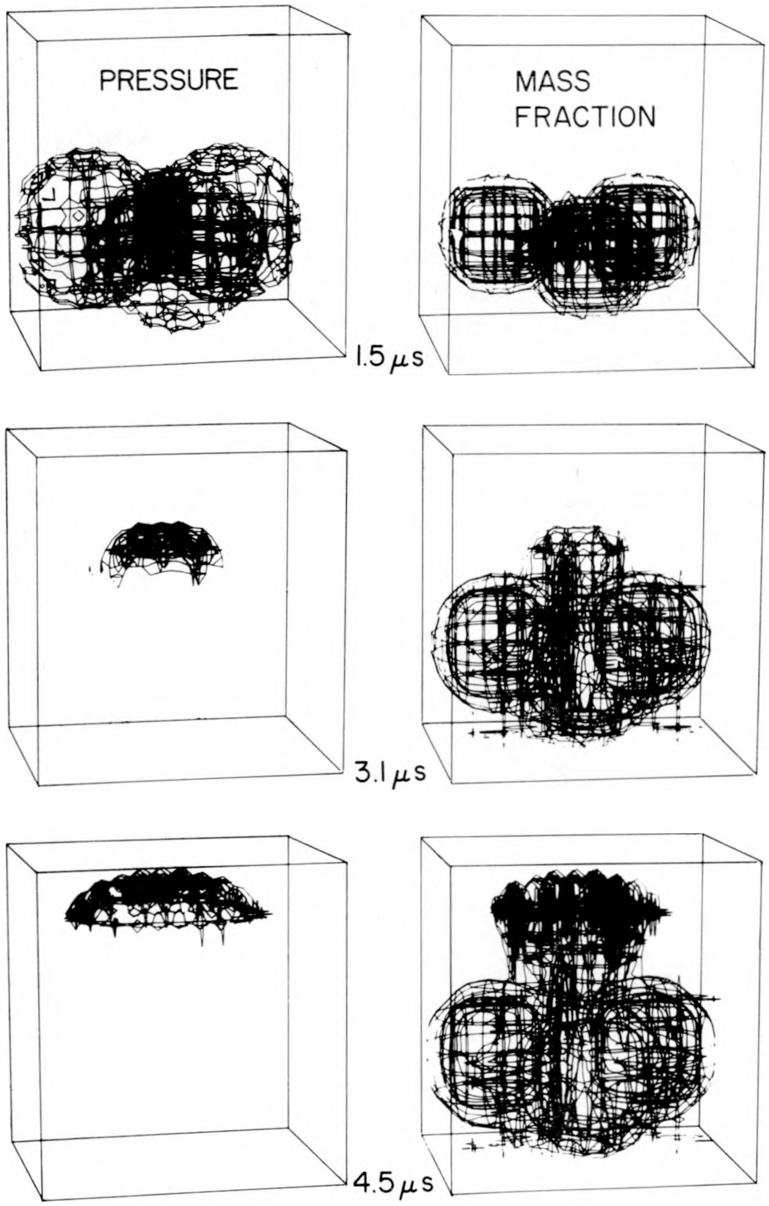

Fig. 6.
The calculated three-dimensional pressure and mass fraction contours for three initiators in PBX 9502. The pressure contours are shown for 200, 150, and 100 kbar at 1.5, 3.1, and 4.5 μs. The mass fraction contours are 0.8 and 0.5.

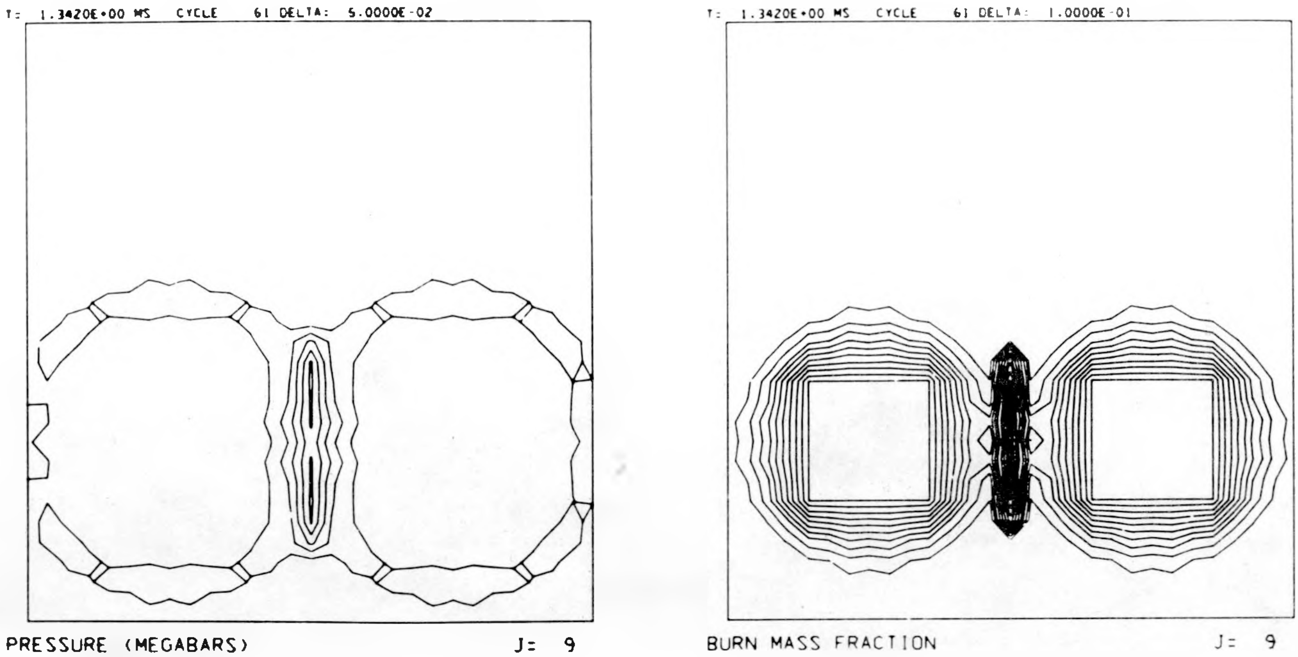

Fig. 7.
The isobar and mass fraction cross sections for layer j of 9 are shown for two initiators at 1.34 μs. The isobar interval is 50 kbar. The mass fraction interval is 0.1.

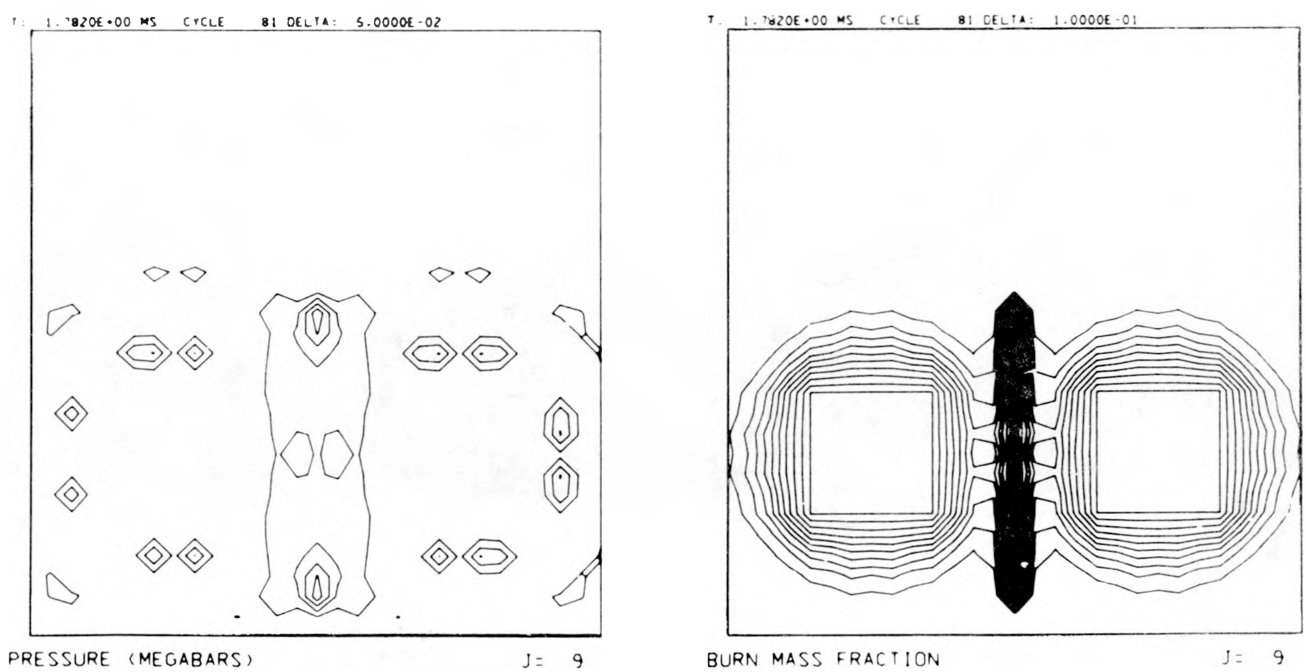

Fig. 8.
The isobar and mass fraction cross sections for layer j of 9 are shown for two initiators at 1.78 μs. The isobar interval is 50 kbar. The mass fraction interval is 0.1.

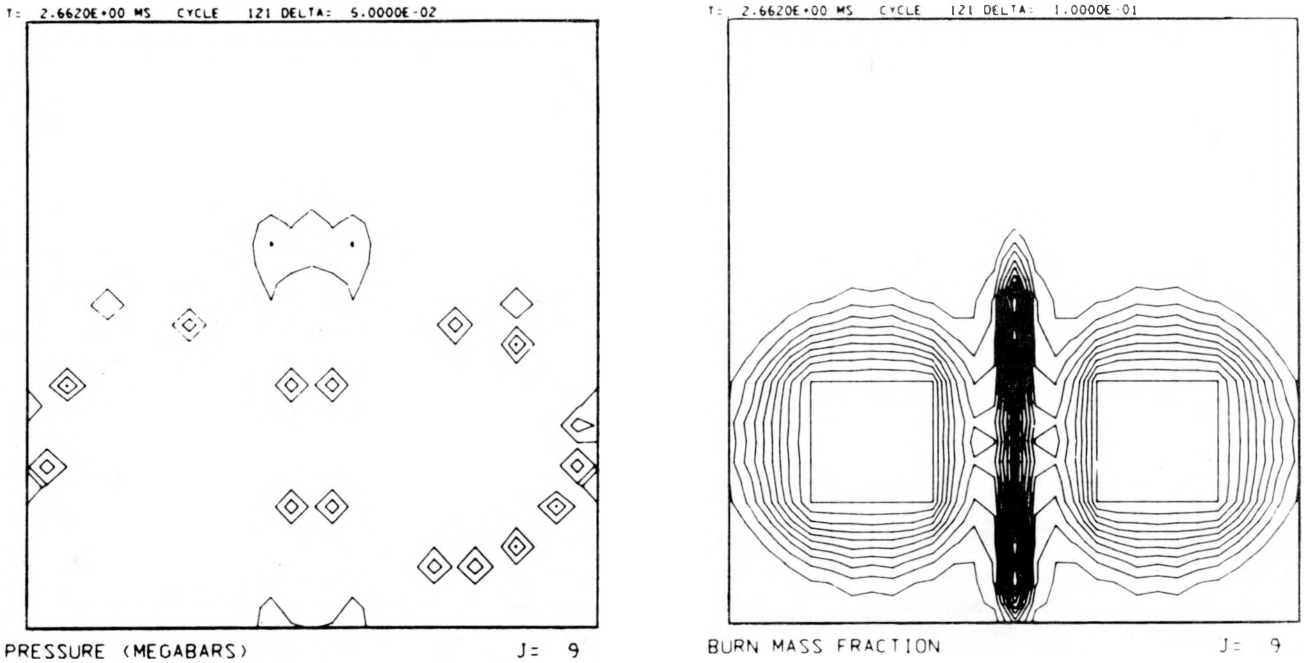

Fig. 9.
The isobar and mass fraction cross sections for layer j of 9 are shown for two initiators at 2.66 μs. The isobar interval is 50 kbar. The mass fraction interval is 0.1.

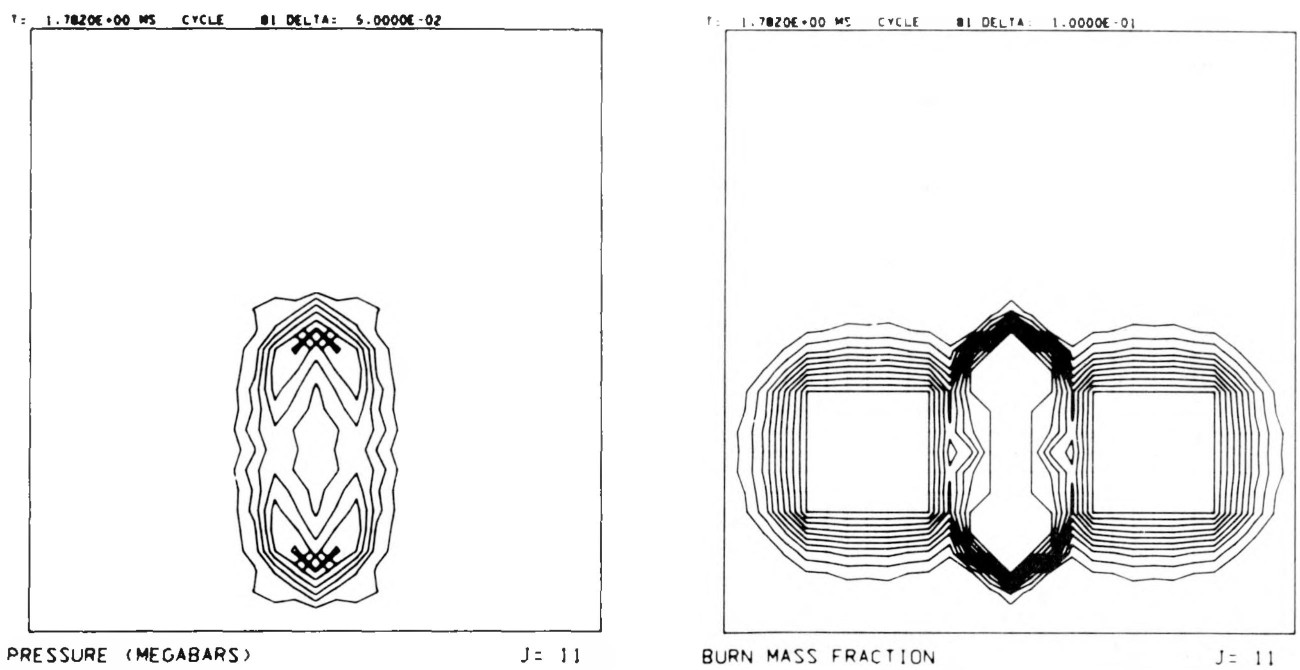

Fig. 10.
The isobar and mass fraction cross sections for layer j of 11 are shown for three initiators at 1.78 μs. The isobar interval is 50 kbar. The mass fraction interval is 0.1.

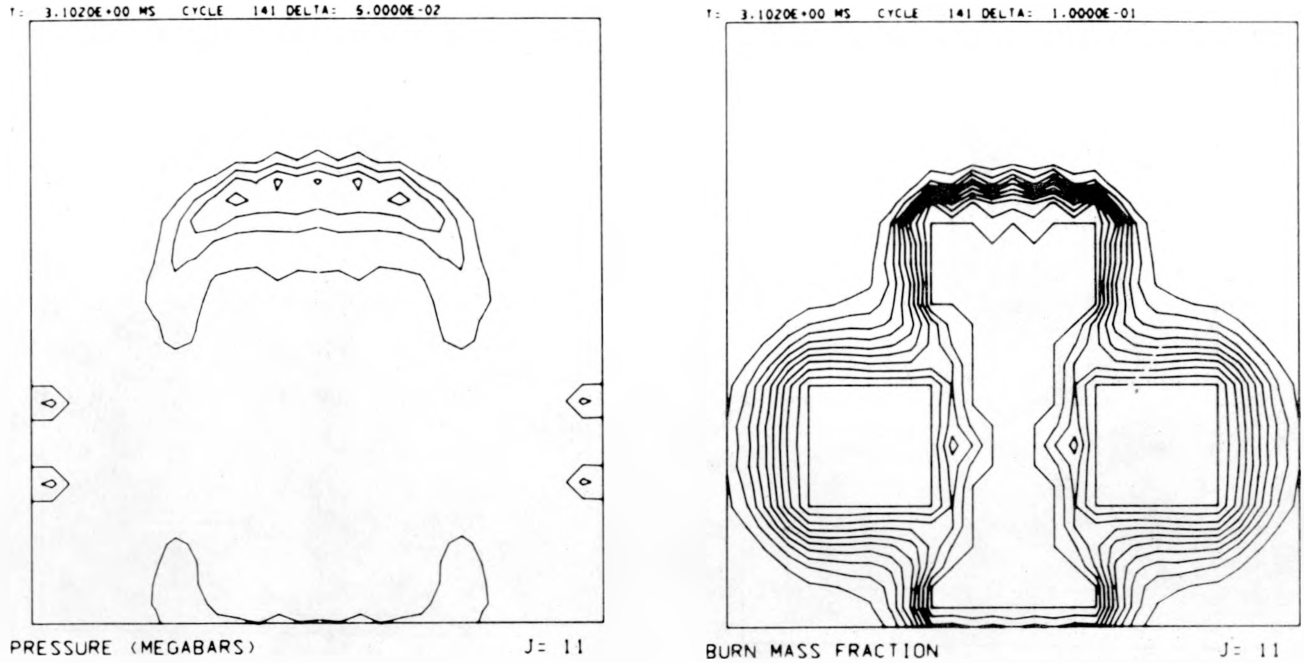

Fig. 11.
The isobar and mass fraction cross sections for layer j of 11 are shown for three initiators at 3.10 μs. The isobar interval is 50 kbar. The mass fraction interval is 0.1.

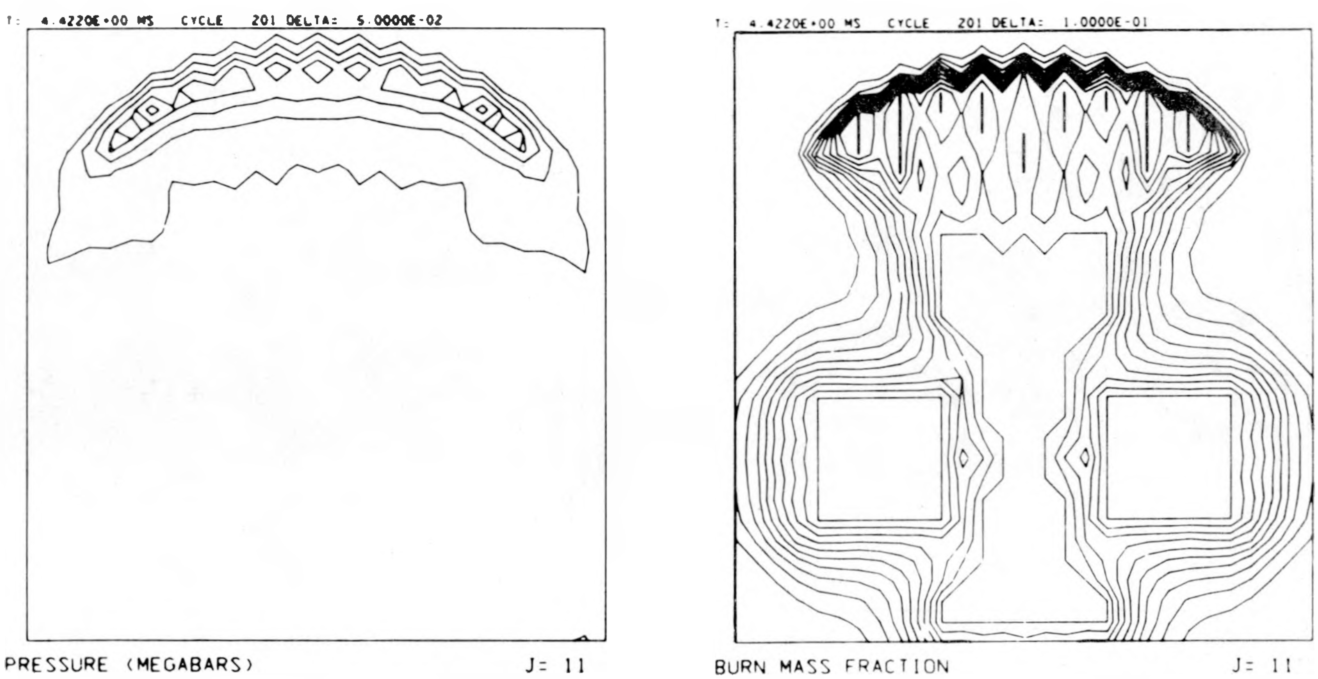

Fig. 12.
The isobar and mass fraction cross sections for layer j of 11 are shown for three initiators at 4.42 μs. The isobar interval is 50 kbar. The mass fraction interval is 0.1.

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