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Two- and Three-Dimensional

Detonation Wave Interactions

with a Copper Plate

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Edited by Kyle Thorn

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Two- and Three-Dimensional

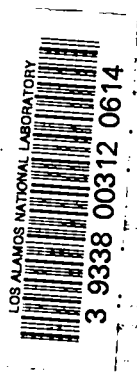# Detonation Wave Interactions

with a Copper Plate

Charles L. Mader
James D. Kershner

TWO- AND THREE-DIMENSIONAL DETONATION WAVE INTERACTIONS WITH A COPPER PLATE

by

Charles L. Mader and James D. Kershner

ABSTRACT

The effect of multipoint initiation of an explosive on the motion of a thin metal plate is investigated in two- and three-dimensional geometry.

I. INTRODUCTION

The flow resulting from laterally colliding, diverging cylindrical detonation waves in PBX 9404 was studied experimentally and theoretically by Mader and Venable.[1] The experimental observations were reproduced numerically using the Forest Fire heterogeneous shock initiation burn[2] in the two-dimensional finite-difference Lagrangian hydrodynamic code (2DL).[2]

The three-dimensional Eulerian reactive hydro-dynamic code (3DE), described in Ref. 3, was used to model numerically the interaction of three spherically diverging detonation waves. The formation of regular and Mach shock reflections in three-dimensional geometry was described. The 3DE code was used to model the initiation of a propagating detonation in the insensitive explosive PBX 9502 by triple-shock-wave interaction from three initiators.[4]

In this report we describe the interactions of two cylindrically diverging detonations and four spherically diverging detonations with thin metal plates.

II. CYLINDRICALLY DIVERGING DETONATION WAVES

Reference 1 shows that the radiographic studies of laterally colliding, diverging cylindrical detonation waves

in PBX 9404 could be reproduced numerically using the 2DL code with the heterogeneous shock initiation model called Forest Fire.[2]

Using the numerical technique, we studied the effect of the resulting wave on the motion of a thin copper plate. The system studied was a 0.4-cm copper plate driven by 6.2 cm of PBX 9404 initiated by two line generators located 5.08 cm apart.

The calculated isobar profiles are shown in Fig. 1. A series of shocks and rarefactions travel back and forth in the metal plate, resulting in a very irregular free-surface profile. The leading free surface of the plate initially is located above the detonators and later changes to above the detonation wave interaction located midway between the detonators. Because the usual system of multipoint initiation of explosives is three dimensional, we extended our study to four detonators.

III. FOUR SPHERICALLY DIVERGING DETONATION WAVES

The geometry studied using the three-dimensional reactive hydrodynamic code 3DE[3] consisted of four detonator cubes of 4 by 4 by 4 cells placed in a cube of PBX 9404 with continuum boundaries on its sides. The cells were cubes with 0.1-cm. sides. The initiator cubes were placed in the corners of the PBX 9404 with their

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cell centers located 1.8 cm apart. The detonator cubes initially were decomposed PBX 9404 with a 3.0-g/cm³ initial density and a 0.05-Mbar-cm³/g energy.

The cube was 24 by 24 cells wide (x-, y-coordinates) by 34 cells high (z-coordinate). On the z-coordinate, there were layers of 2 cells 9404, 4 cells 9404 initiator, 22 cells 9404, 2 cells copper, and 4 cells air. Figure 2 shows the problem. The time step was 0.02 μs until the detonation wave neared the copper (cycle 144), and then it was decreased to 0.01 μs for the rest of the calculation. The problem required 2 hours of CRAY computer time to run 432 cycles.

The pressure contours are shown in Fig. 3 for a cross section run through cell 13 in the x-direction (through the center between the detonators). Figure 4 shows the pressure contours for a cross section run through cell 30 in the z-direction (located initially at the copper surface).

The quadruple point Mach stem has a pressure about 100 kbar higher than that of the surrounding explosive. It is located behind the leading detonation wave surface (which is above the detonators) when it interacts with the copper plate. The copper plate is shocked and reflects a strong shock wave back into the detonation products. A series of shock and rarefaction waves, similar to the two-dimensional case described in Sec. II, travel back and forth in the metal plate resulting in a very complicated free-surface profile.

Again, the leading free surface of the plate initially is located above the detonators but at later times changes to between detonators.

IV. CONCLUSIONS

The effect of multipoint initiation of an explosive on the motion of a thin metal plate has been numerically investigated. The location of the leading free surface changes from above the detonators to above the detonation wave interaction centers. The relative position of the detonators and the run distance of the detonations after they interact and before they shock the metal plate are important parameters in determining the magnitude of the plate free-surface perturbation.

REFERENCES

1. Charles L. Mader and Douglas Venable, "Mach Stems Formed by Colliding Cylindrical Detonation Waves," Los Alamos Scientific Laboratory report LA-7869 (September 1979).

2. Charles L. Mader, *Numerical Modeling of Detonations* (University of California Press, Berkeley, California, 1979).

3. Charles L. Mader and James D. Kershner, "Three-Dimensional Eulerian Calculations of Triple-Initiated PBX 9404," Los Alamos Scientific Laboratory report LA-8206 (September 1980).

4. Charles L. Mader and James D. Kershner, "Three-Dimensional Modeling of Triple-Wave Initiation of Insensitive Explosives," Los Alamos National Laboratory report LA-8655 (February 1981).
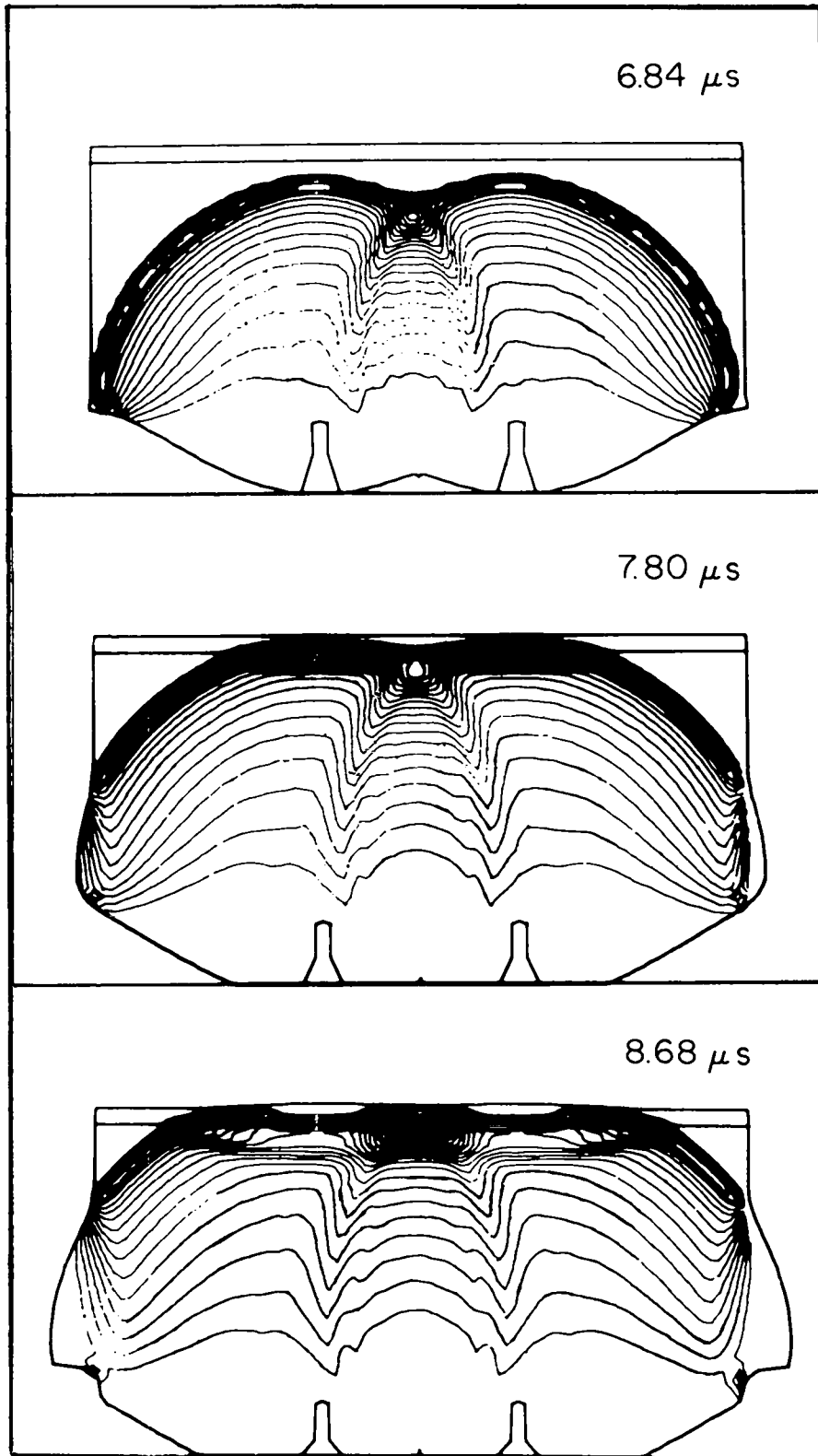
Fig. 1. Calculated isobar contours with a 20-kbar contour interval are shown for two cylindrical diverging detonations initially 5.0 cm apart, interacting with a 0.4-cm copper plate after 6.2 cm of run.
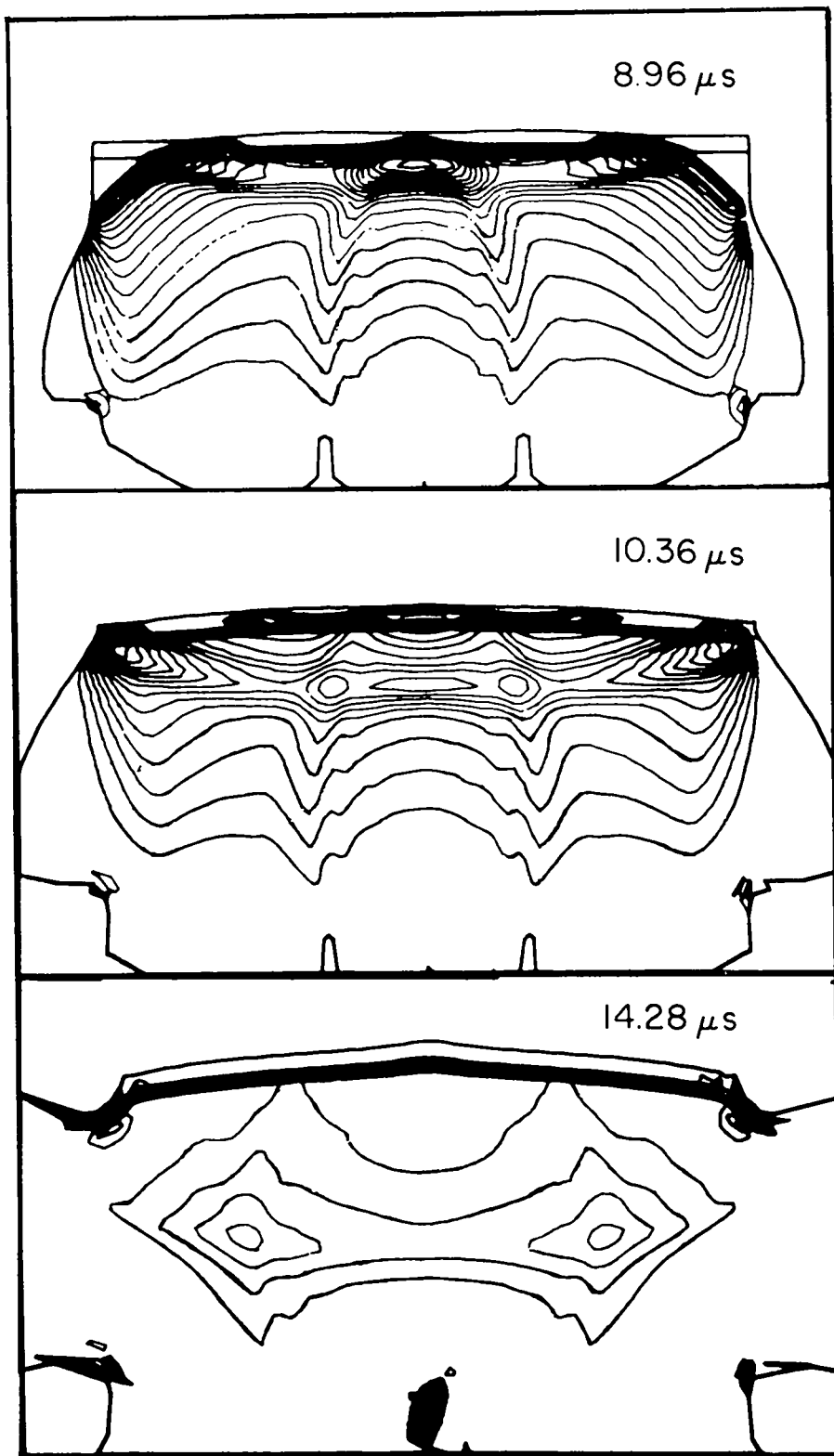
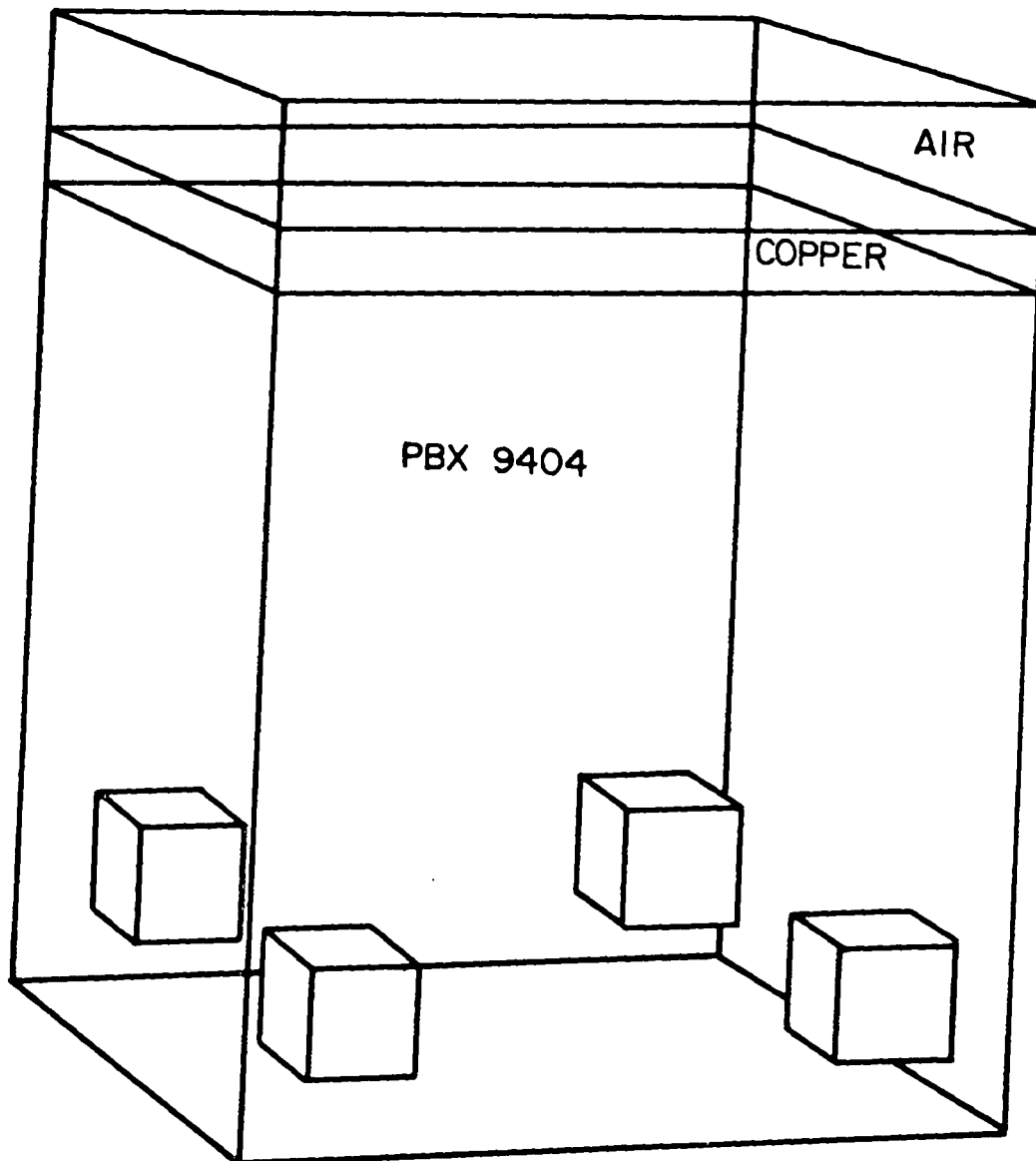8.96 μs

10.36 μs

14.28 μs

Fig. 1. (cont)

4

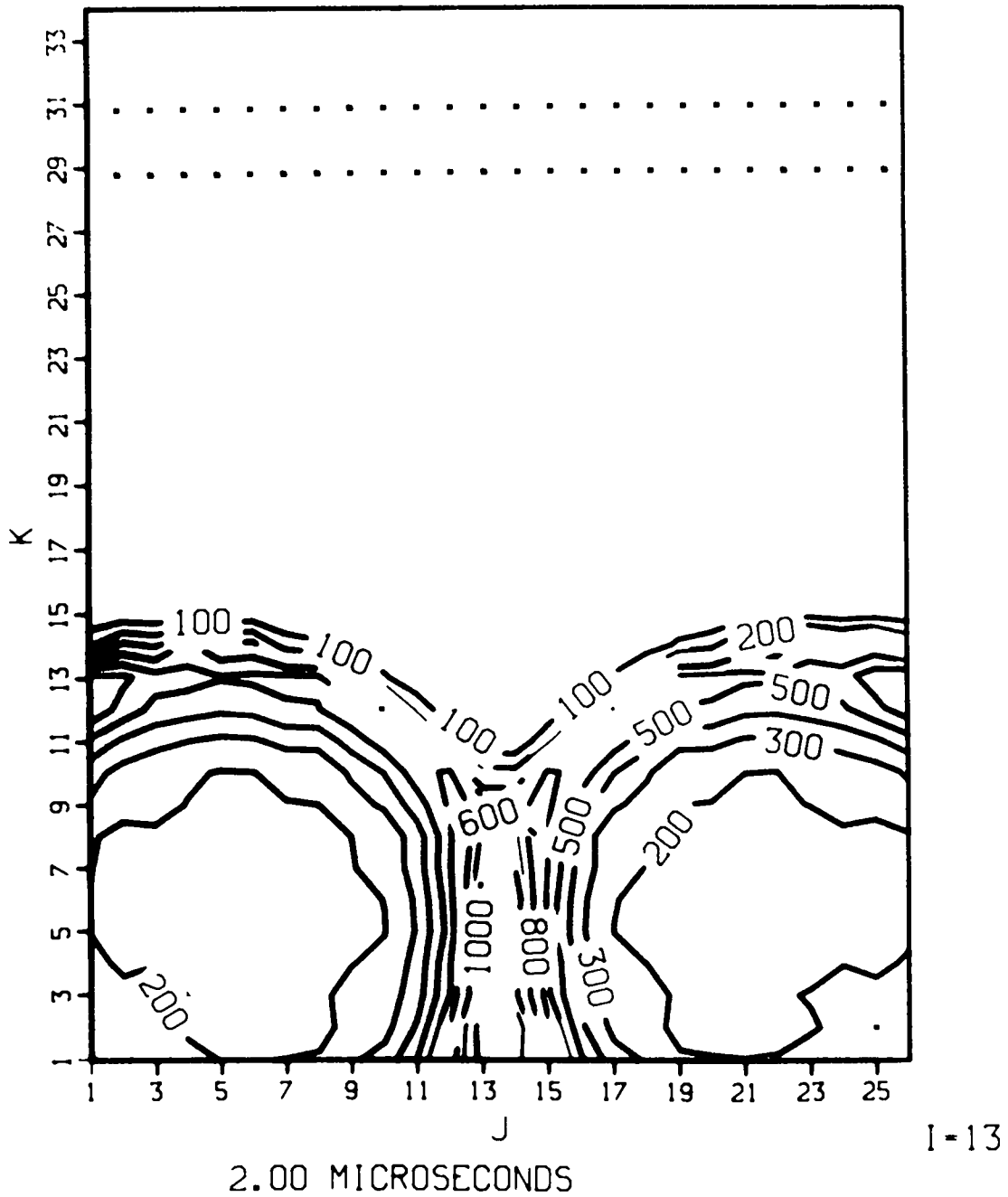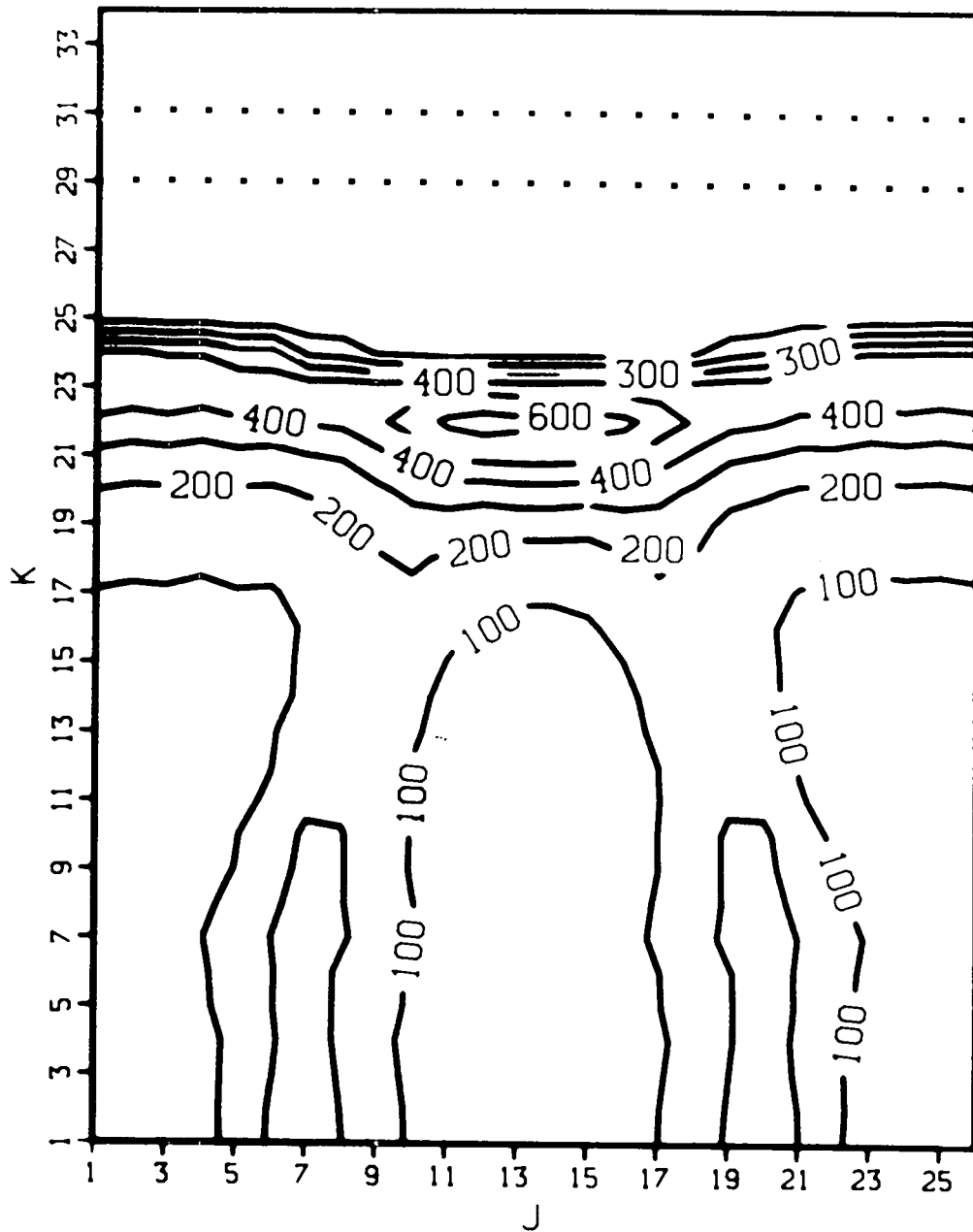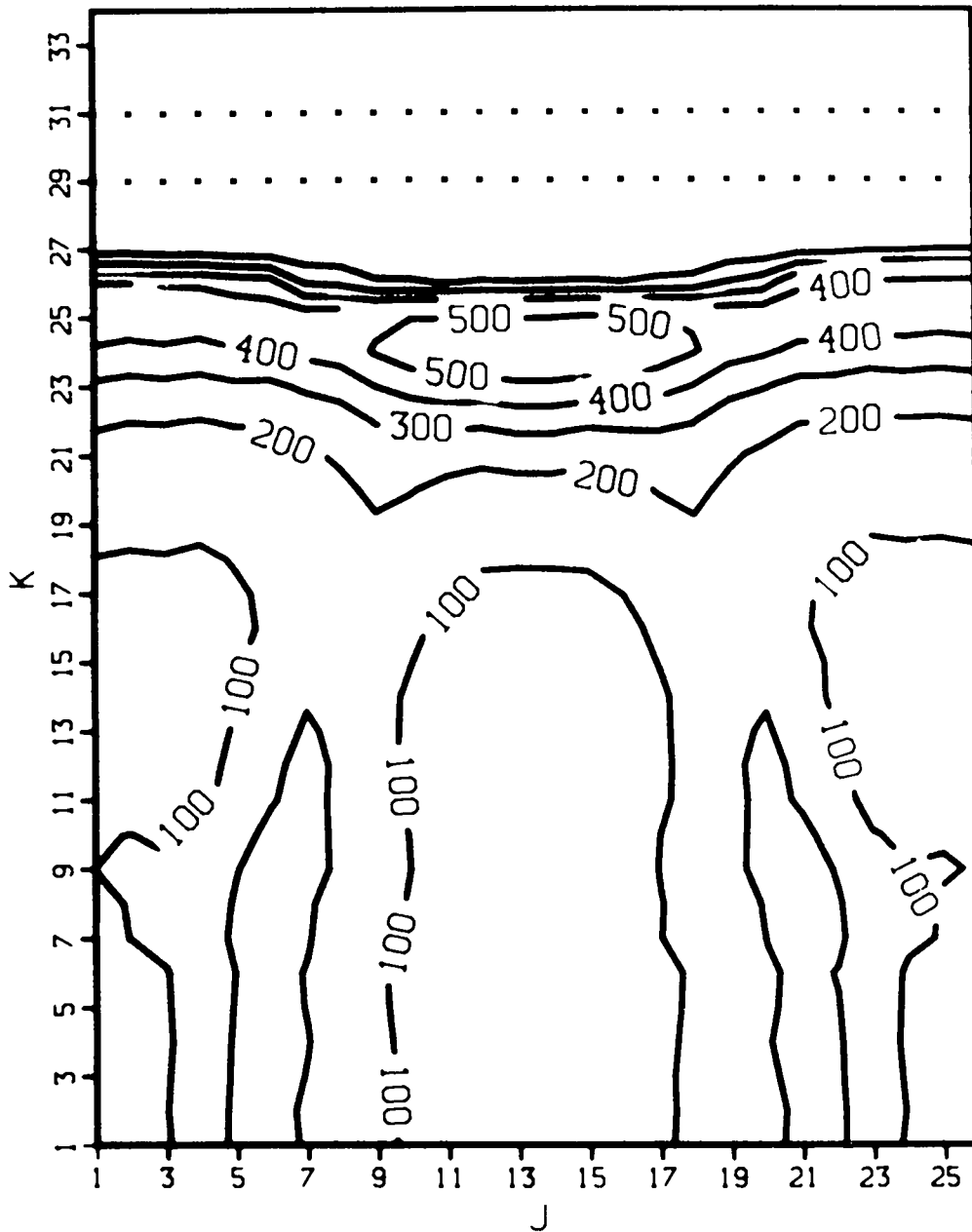Fig. 2. A sketch of the problem with the four detonators in PBX 9404 and a copper plate.

Fig. 3. The isobar cross section for cell layer 13 in the x-direction. The isobar interval is 100 kbar. The copper-explosive and copper-air mixed cells are shown with a heavy dot.
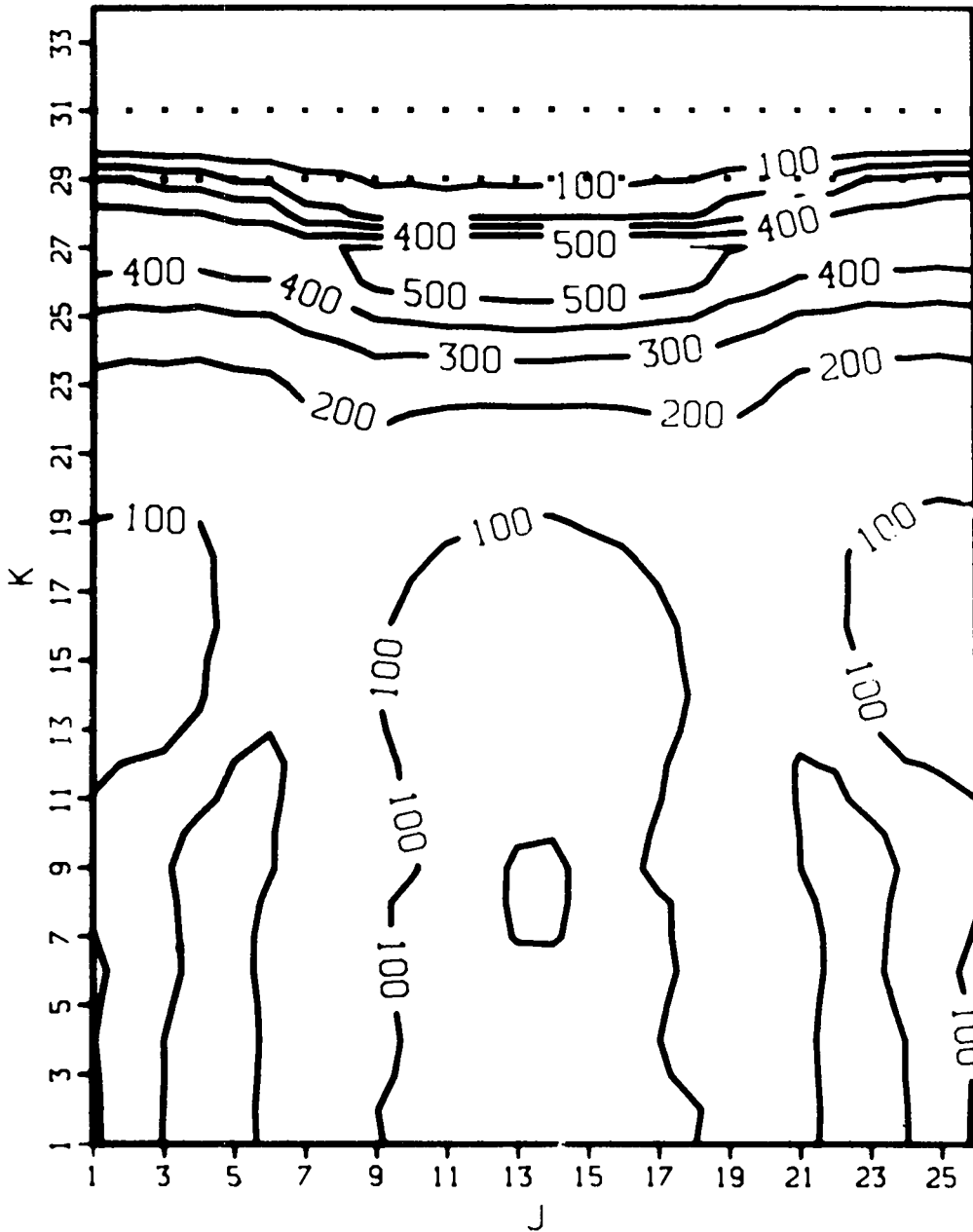
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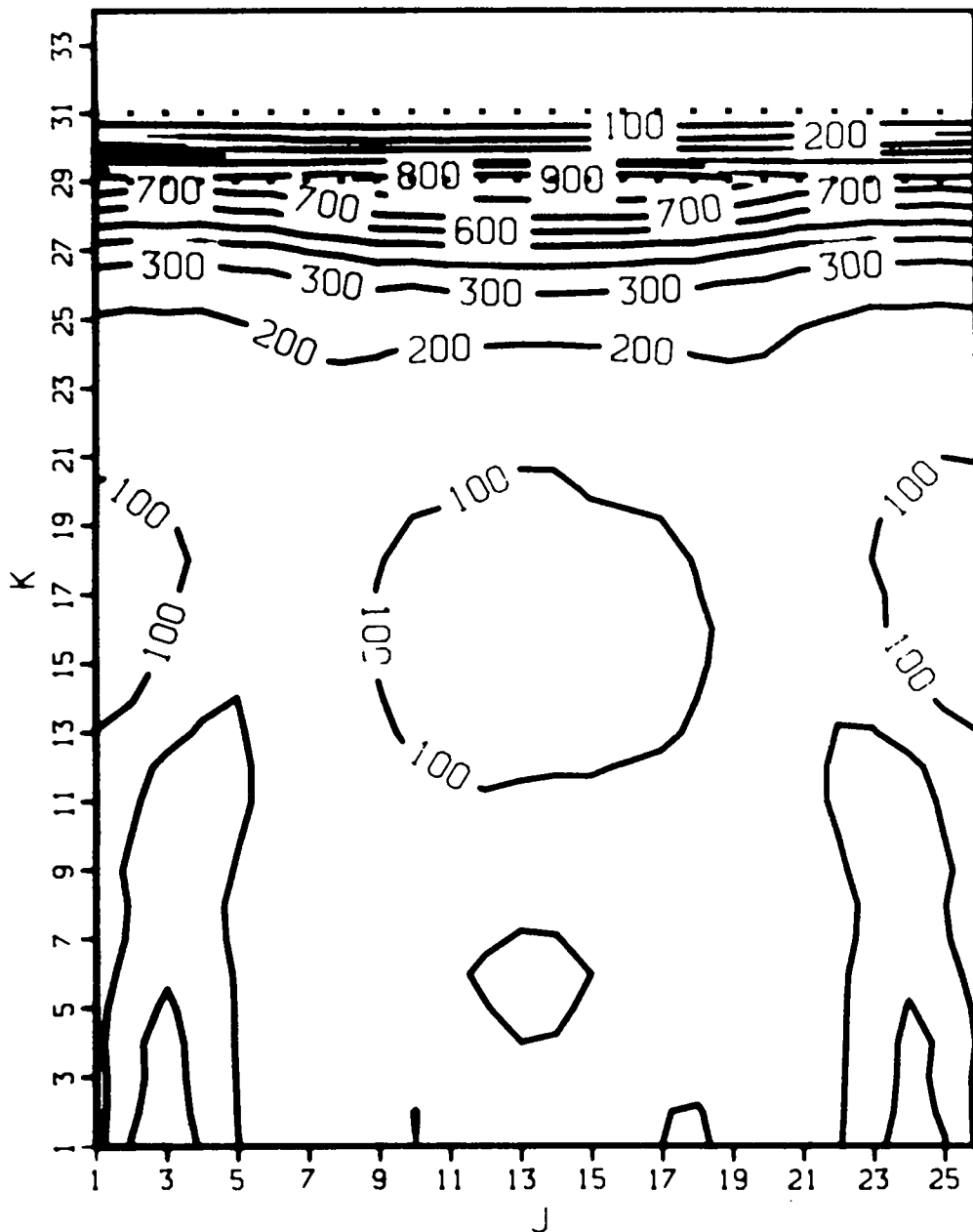
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Fig. 3. (cont)
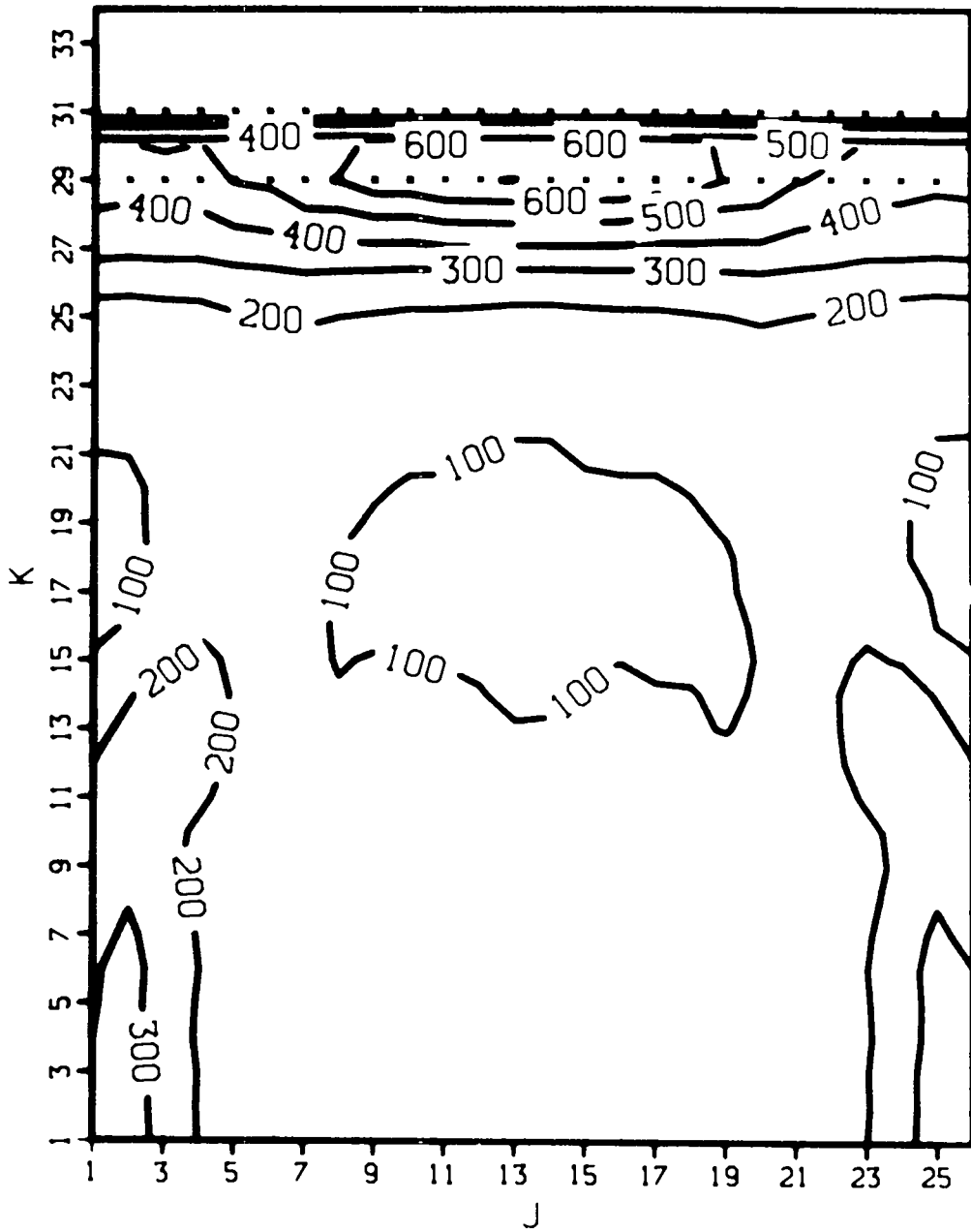
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3.45 MICROSECONDS

Fig. 3. (cont)

3.70 MICROSECONDS

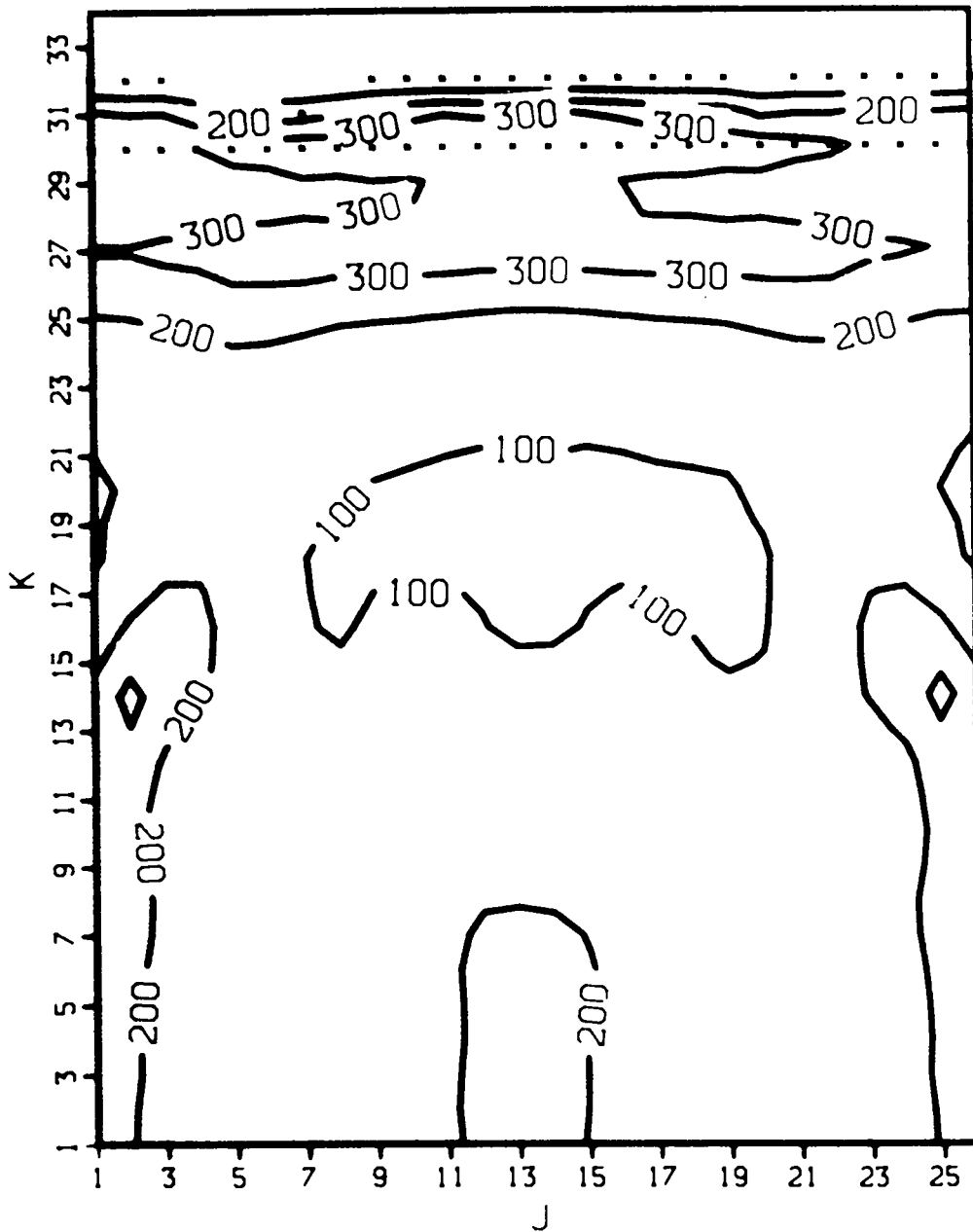I = 13

Fig. 3. (cont)

3.95 MICROSECONDS
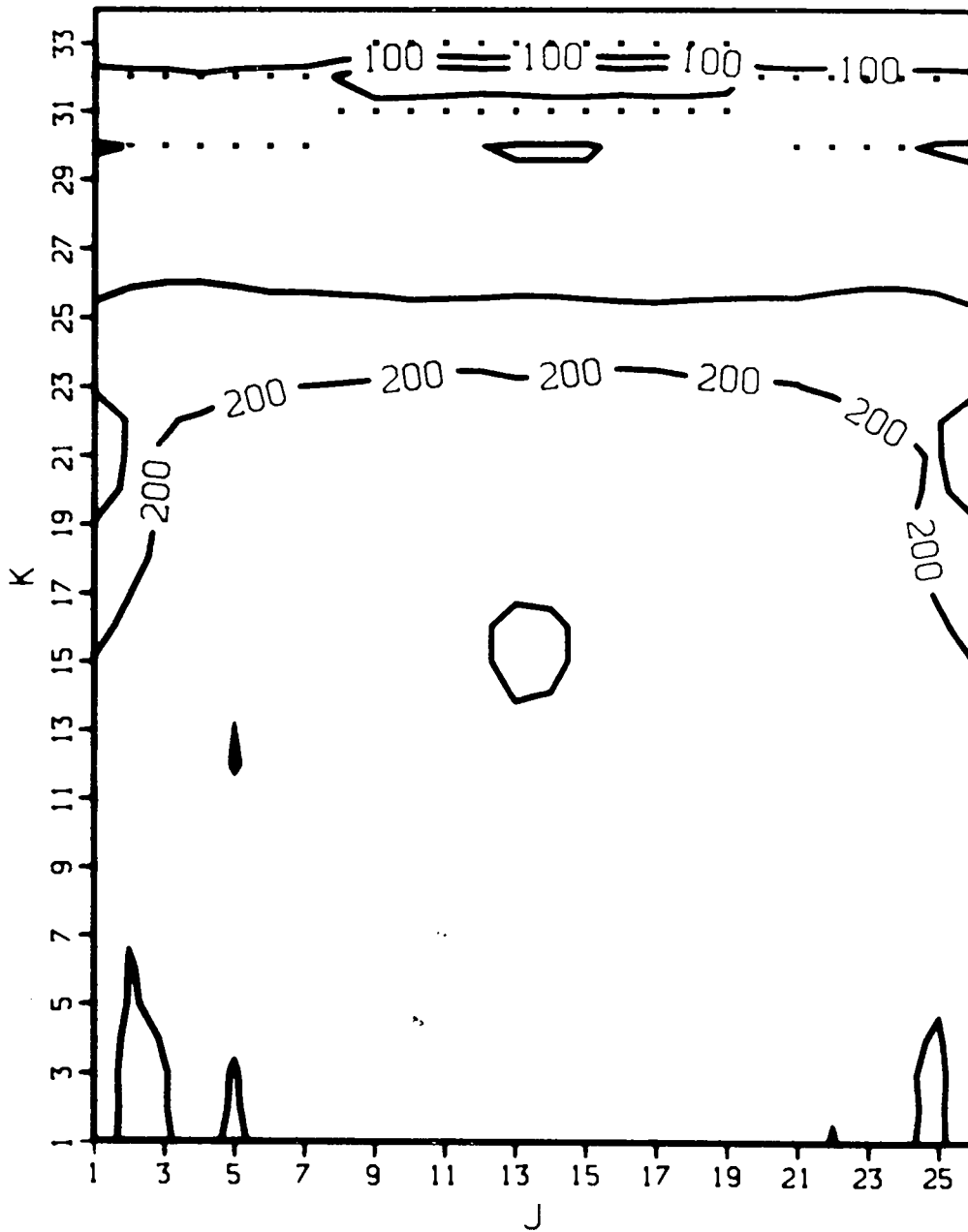
Fig. 3. (cont)

4.20 MICROSECONDS

Fig. 3. (cont)

I-13

4.45 MICROSECONDS

Fig. 3. (cont)
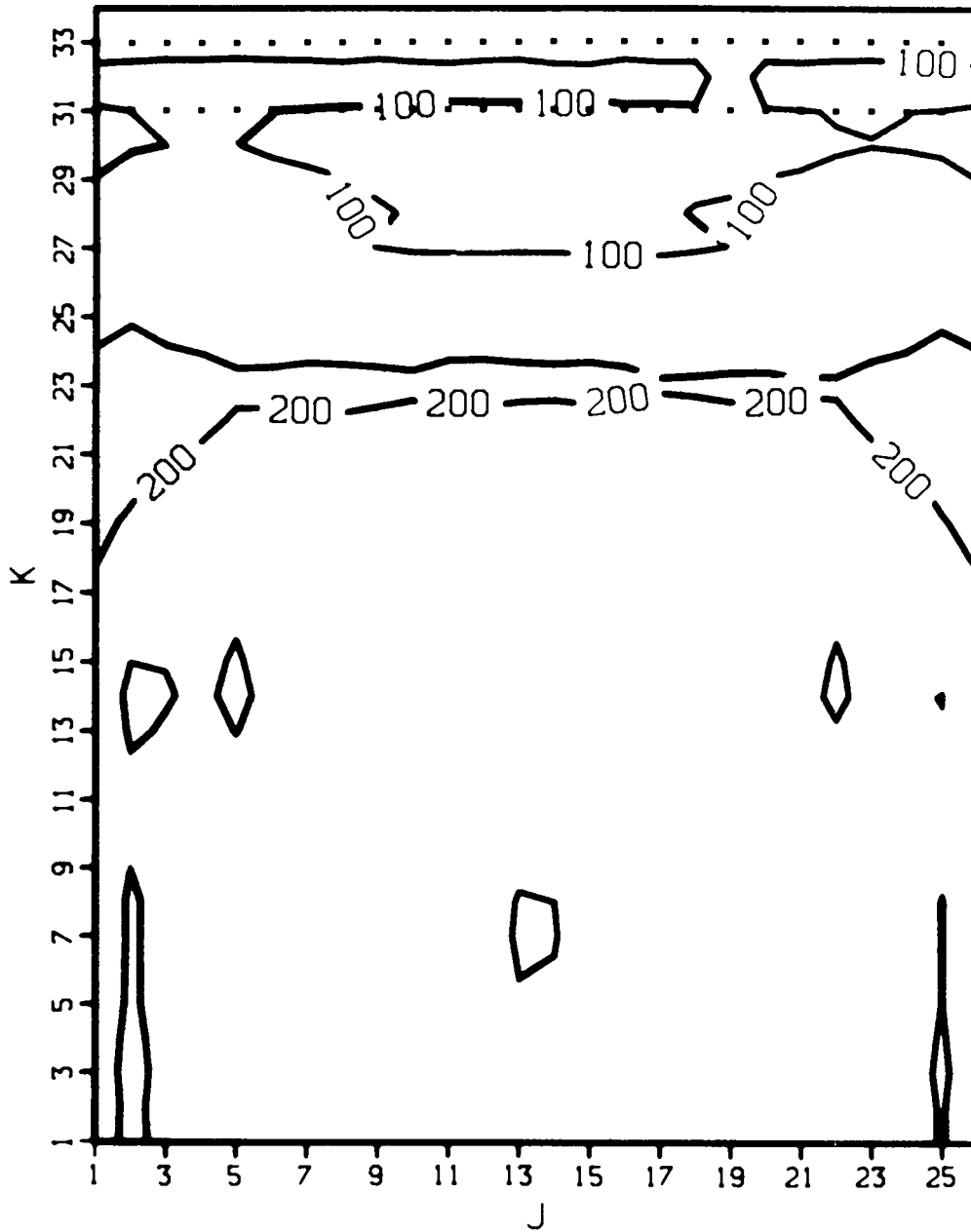
I-13

12

4.95 MICROSECONDS

I=13

Fig. 3. (cont)
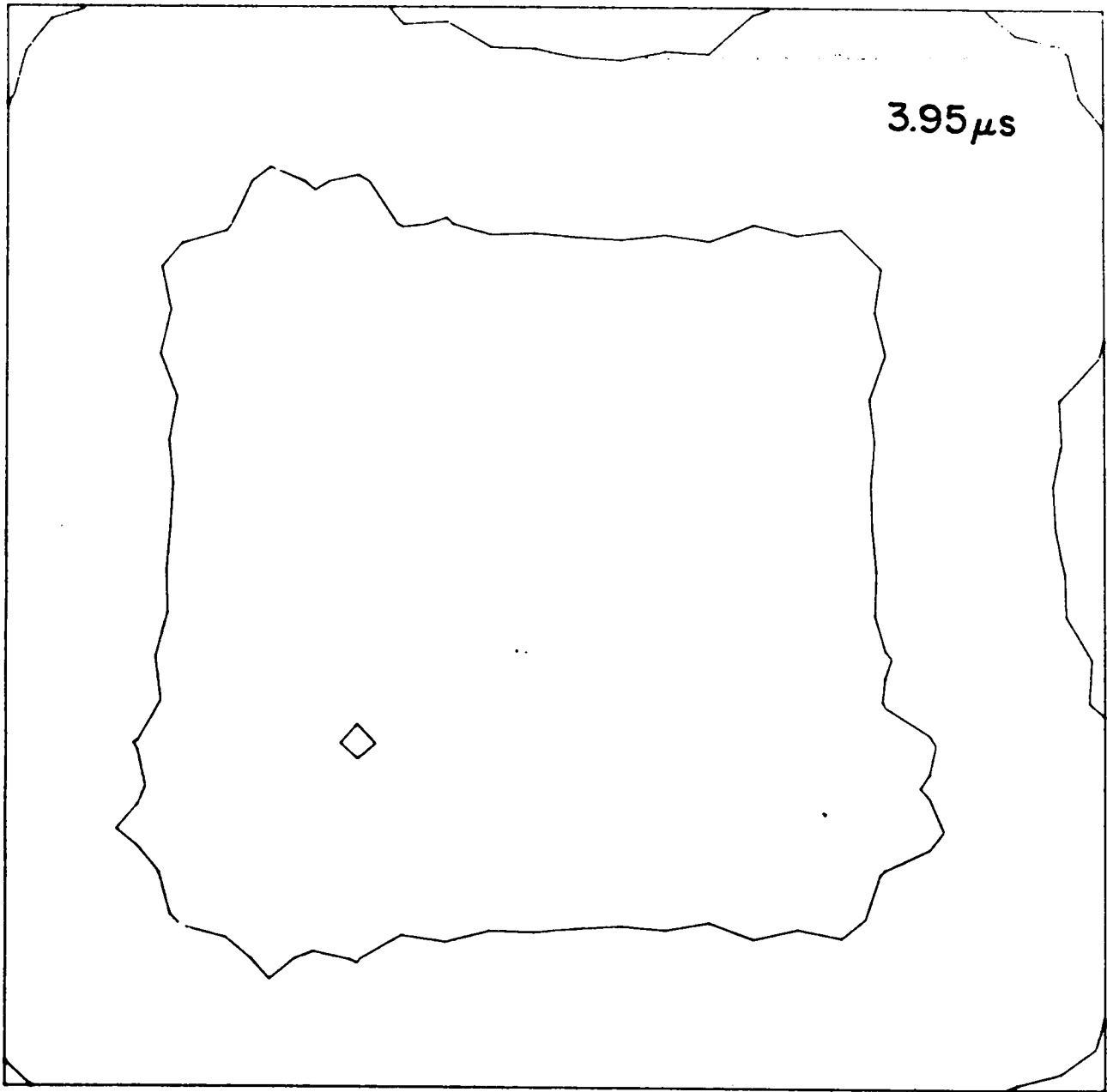
5.20 MICROSECONDS

Fig. 3. (cont)

I-13
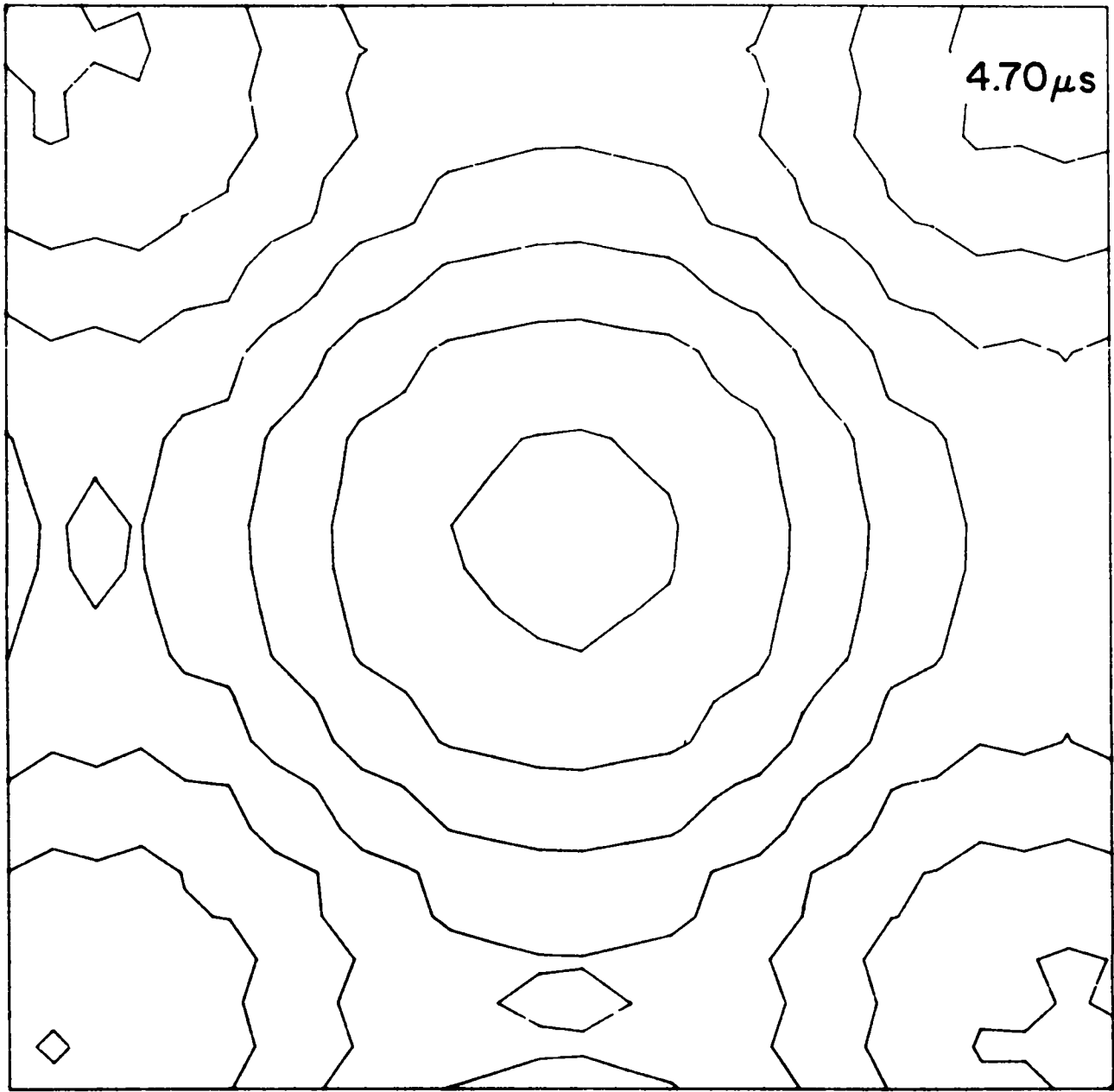
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PRESSURE (MEGABARS)   K= 30

Fig. 4. Isobar cross sections for cell layer 30 in the z-direction, initially located at the copper surface. The isobar interval is 50 kbar.

4.70μs

PRESSURE (MEGABARS)   K= 30

Fig. 4. (cont)

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