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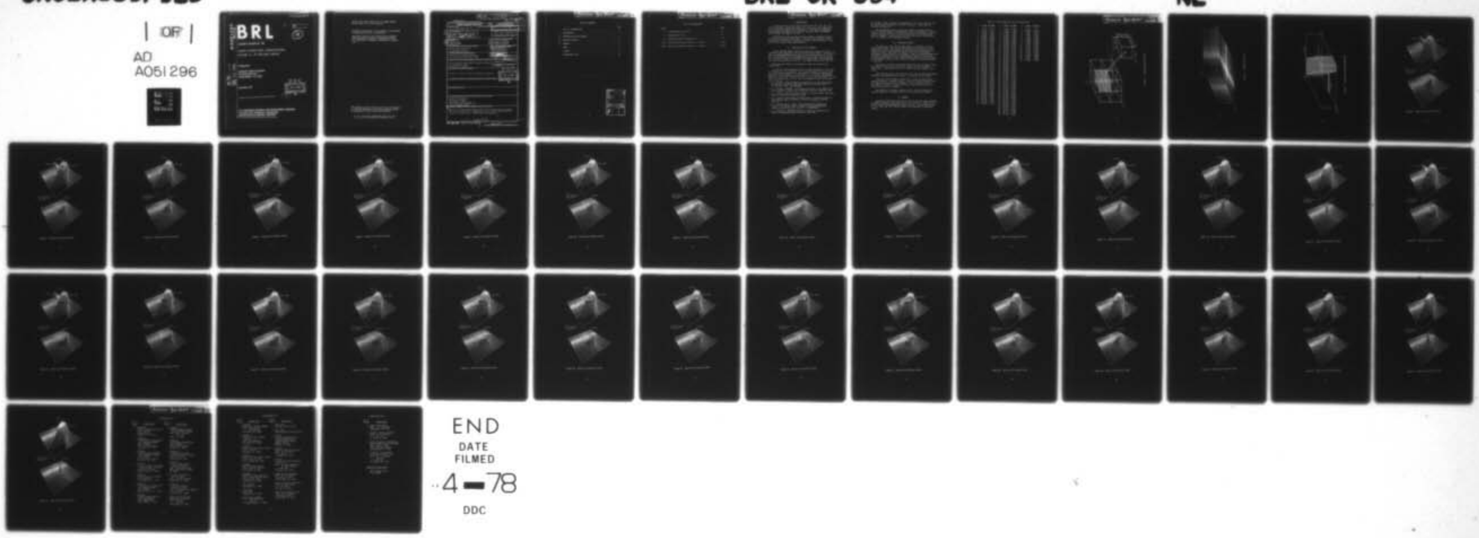

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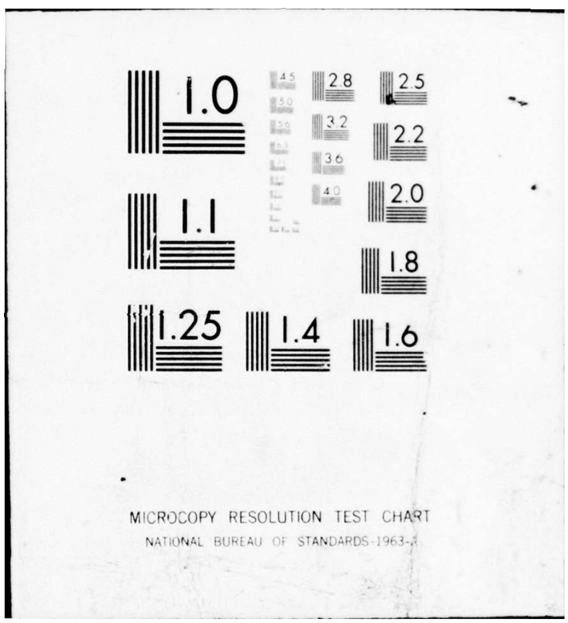
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CONTRACT REPORT NO. 354

THREE-DIMENSIONAL COMPUTATIONS, VOLUME II: 45° OBLIQUE IMPACT

Prepared by

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November 1977

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USA BALLISTIC RESEARCH LABORATORY
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Numerical calculations were made in 1975 of four oblique impact problems: 30°, 45°, 60°, and 77.5°. A graphical display of the results of the 45° impact of a copper jet on a steel target are presented.

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TABLE OF CONTENTS

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LIST OF ILLUSTRATIONS

I. INTRODUCTION

A series of four oblique impact computations (30°, 45°, 60°, and 77.5°) involving a copper jet impacting a steel plate were completed in 1975 for the Ballistic Research Laboratory.[1] This work was performed using TRIDORF[2] and DORF[3,4] and ancillary programs CUBIT[3] and ADJUST[4] under Contract No. DAAD05-75-C-0738.

The effort for 1976 has been directed towards a graphical display of the data from these computations. The four oblique impacts in the series will be presented in sequential volumes[5] with the results of the 45° obliquity impact being reported here.

II. DESCRIPTION OF THE PROBLEM

The 45° oblique impact computation involved a copper jet with a 0.7086-mm radius impacting on a 12.7-mm thick steel target. The obliquity angle is measured between the normal to the target and the axis of the jet. Since TRIDORF uses a rectangular grid, the copper jet was treated as a bar with a square cross section of 1.256-mm width, thus preserving the cross-sectional area of the jet. The impact velocity was 7.55 km/s.

The Tillotson[6] form of the equation of state was used for the computations.

A view of a three-dimensional grid is shown in Figure 1. Each cell is identified by the coordinates (I,J,K), which number the cells in the x,y,z-directions, respectively. The overall size of the computational grid was $x = 39.256$ mm by $y = 40.270$ mm by $z = 17.539$ mm. The maximum number of cells in the x-direction was I = 42, in the y-direction, J = 48, and in the z-direction, K = 18. The total number of cells in the grid

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1. W. E. Johnson, "Three-Dimensional Computations on Penetrator-Target Interactions," Ballistic Research Laboratory Contractor Report No. 338, May 1977. (AD #A041058)

2. W. E. Johnson, "TRIDORF - A Two-Material Version of the TRIOIL Code with Strength," Computer Code Consultants, CCC-976, September 1976.

3. W. E. Johnson, "Code Correlation Study," Air Force Weapons Laboratory Report No. AFWL-TR-70-144, April 1971.

4. W. E. Johnson, "Development and Application of Computer Programs to Hypervelocity Impact," Systems, Science and Software, 3SR-749, July 1971.

5. W. E. Johnson and V. Kucher, "Three-Dimensional Computations, Volume I: 30° Oblique Impact", Ballistic Research Laboratory Contractor Report No. 344, July 1977. (AD #A043295)

6. J. H. Tillotson, "Metallic Equations of State for Hypervelocity Impact," Gulf General Atomic, GA-3216, July 1962.

was 36,288. Table I presents the dimensions of the cells, DX, DY, and DZ, and the grid coordinates as shown in Figure 1. These data are displayed in Figure 2.

The xy-plane was used as a plane of symmetry through the bar in order to keep the number of computational cells at a minimum. Since the width of the bar was four cells, the bar was two cells wide from the plane of symmetry. Figure 3 shows the penetrator-target configuration as it is located in the computational grid.

III. GRAPHICAL RESULTS

The numerical output of the computations is presented as density and pressure fields. The density and pressure are plotted on a two-dimensional spatial plane having the coordinates corresponding to the centers of cells. The fields are plotted such that a cell-number coordinate is held constant. For example, K may be constant meaning that the density or pressure is being presented for the cells between two z-planes bounding the K-cells. These bounding planes will be indicated in each figure. Figures 2 and 3 should be useful for orienting oneself in the grid.

The density scale for the density field plots can be realized from the initial density of the jet and the target, 8.9 and 7.8 Mg/m^3, respectively. The density scale is the same in all the density field plots.

The pressure scale is not the same in all the pressure field plots; therefore, the maximum pressure, Pmax, is indicated on each figure.

The first set of figures, Figures 4-17, shows the density and pressure fields at a constant time of 2.85 μs for various K-slabs which are numbered from the plane of symmetry. The jet appears distinct only when K = 1 and K = 2 since, initially, the jet was two cells in width from the plane of symmetry.

The second set of figures, Figures 18-33, shows the density and pressure fields at a constant time of 3.59 μs for various K-slabs.

IV. SUMMARY

Numerical computations were made in 1975 of oblique impact problems. A graphical display of the results of the 45° impact of a copper jet on a steel target are presented for future analysis. The results for the 30°, 45°, 60°, and 77.5° oblique impacts are presented in sequential volumes.

Table I. Grid Coordinates and Cell Dimensions

I	x (mm)	DX (mm)	J	y (mm)	DY (mm)	K	z (mm)	DZ (mm)
1	4.730	4.730	1	6.990	6.990	1	0.314	0.314
2	6.847	2.117	2	8.790	1.800	2	0.628	0.314
3	8.541	1.694	3	10.390	1.000	3	0.942	0.314
4	9.896	1.355	4	11.790	1.400	4	1.256	0.314
5	10.980	1.084	5	12.990	1.200	5	1.601	0.345
6	11.965	0.985	6	13.990	1.000	6	1.981	0.380
7	12.861	0.896	7	14.790	0.800	7	2.399	0.418
8	13.675	0.814	8	15.390	0.600	8	2.859	0.460
9	14.415	0.740	9	15.890	0.500	9	3.365	0.506
10	15.088	0.673	10	16.290	0.400	10	3.921	0.556
11	15.707	0.619	11	16.604	0.314	11	4.540	0.619
12	16.263	0.556	12	16.918	0.314	12	5.213	0.673
13	16.769	0.506	13	17.232	0.314	13	5.953	0.740
14	17.229	0.460	14	17.546	0.314	14	6.767	0.814
15	17.647	0.418	15	17.860	0.314	15	7.663	0.896
16	18.027	0.380	16	18.174	0.314	16	8.648	0.985
17	18.372	0.345	17	18.488	0.314	17	9.732	1.084
18	18.686	0.314	18	18.802	0.314	18	17.539	7.807
19	19.000	0.314	19	19.116	0.314			
20	19.314	0.314	20	19.430	0.314			
21	19.628	0.314	21	19.744	0.314			
22	19.942	0.314	22	20.058	0.314			
23	20.256	0.314	23	20.372	0.314			
24	20.570	0.314	24	20.686	0.314			
25	20.884	0.314	25	21.000	0.314			
26	21.229	0.345	26	21.314	0.314			
27	21.609	0.380	27	21.628	0.314			
28	22.027	0.418	28	21.973	0.345			
29	22.487	0.469	29	22.353	0.380			
30	22.993	0.506	30	22.771	0.418			
31	23.549	0.556	31	23.231	0.460			
32	24.168	0.619	32	23.737	0.506			
33	24.841	0.673	33	24.293	0.556			
34	25.581	0.740	34	24.912	0.619			
35	26.395	0.814	35	25.585	0.673			
36	27.291	0.896	36	26.325	0.740			
37	28.276	0.985	37	27.139	0.814			
38	29.360	1.084	38	28.035	0.896			
39	30.715	1.355	39	29.020	0.985			
40	32.409	1.694	40	30.104	1.084			
41	34.526	2.117	41	31.459	1.355			
42	39.256	4.730	42	33.153	1.694			
			43	35.270	2.117			
			44	37.700	2.500			
			45	40.270	2.500			
			46	42.770	2.500			
			47	45.270	2.500			
			48	47.770	2.500			

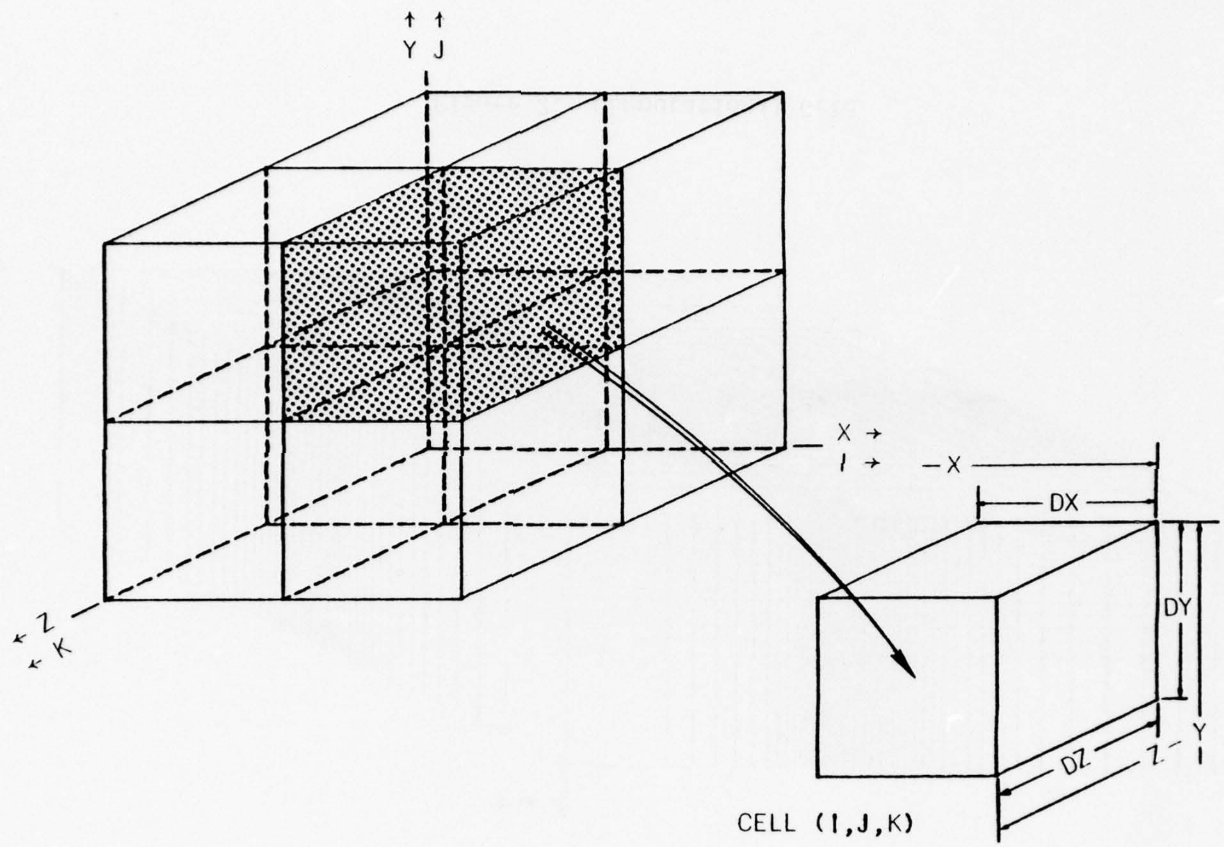


Figure 1. A Three-Dimensional Grid

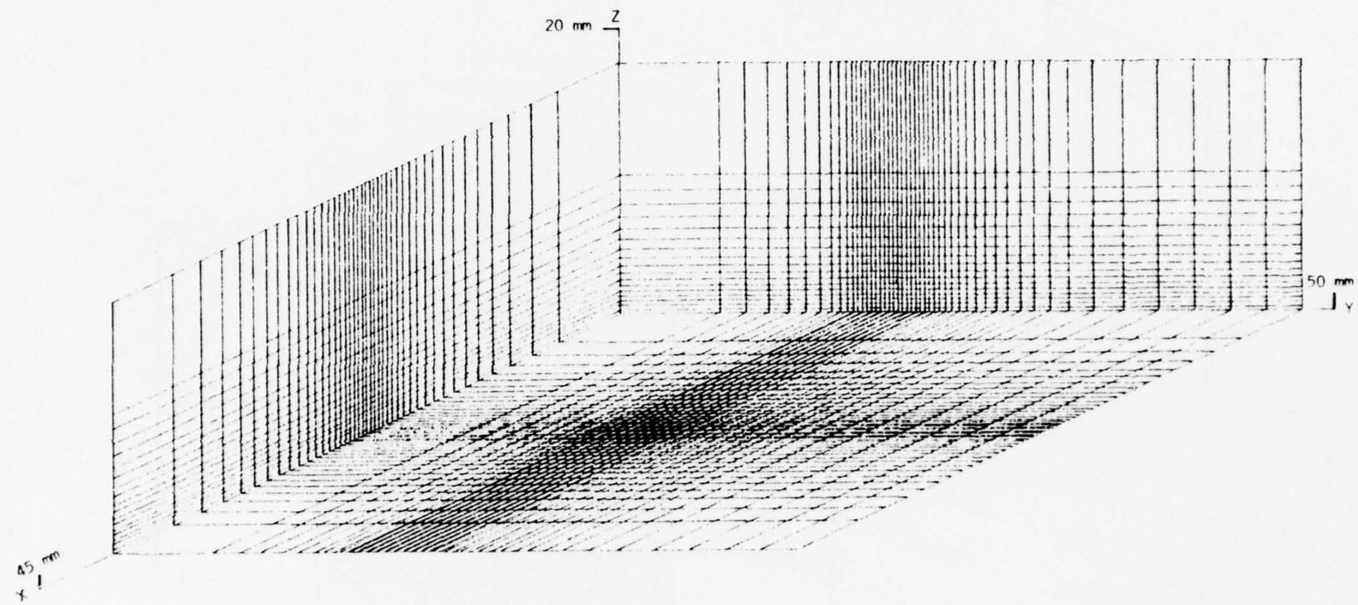


Figure 2. Computational Grid

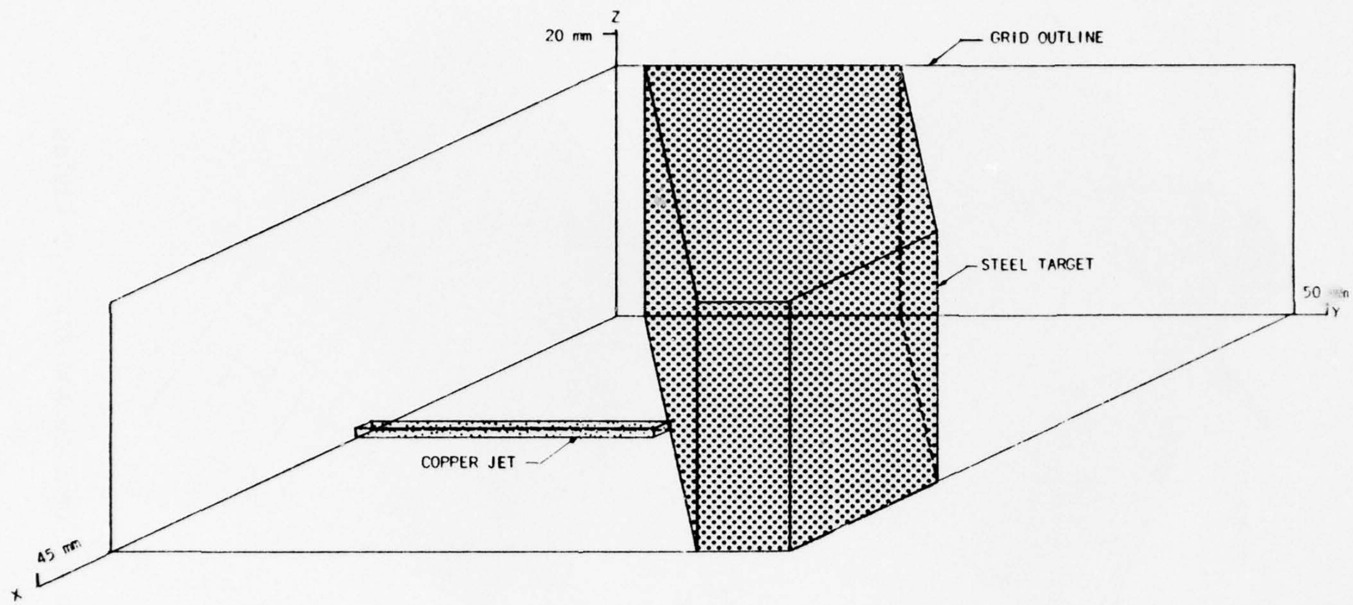


Figure 3. Penetrator-Target Configuration

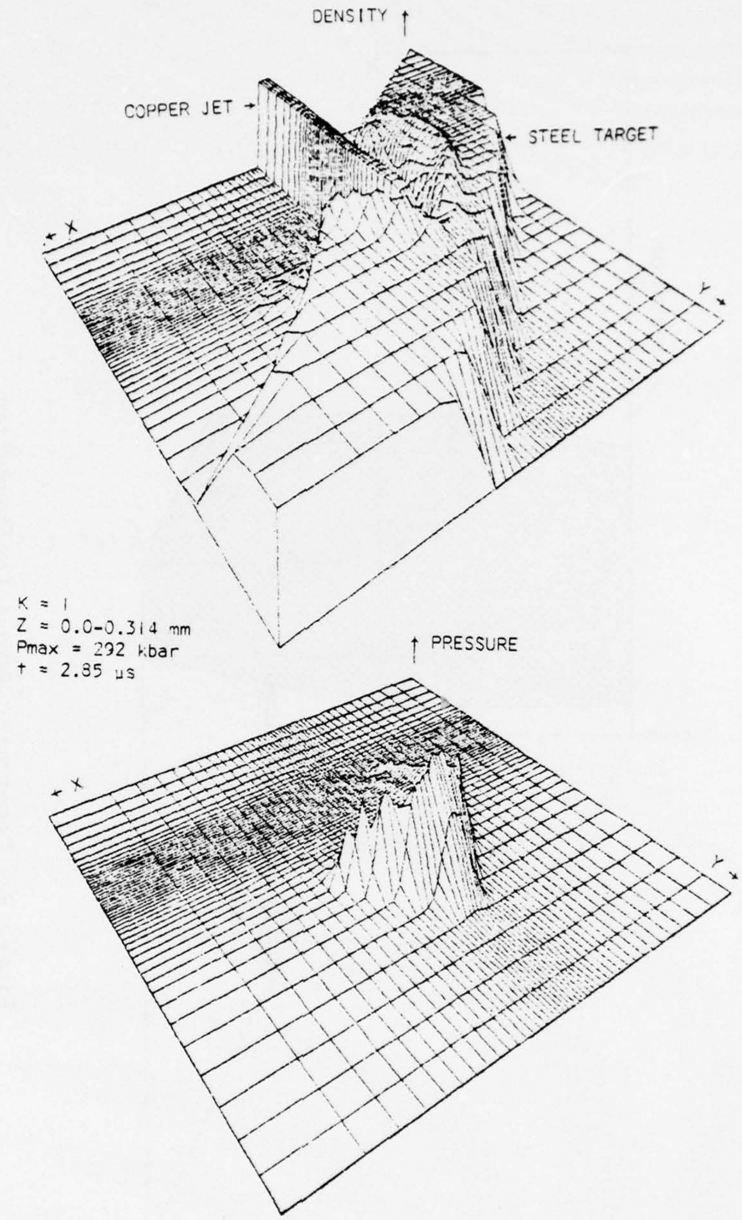
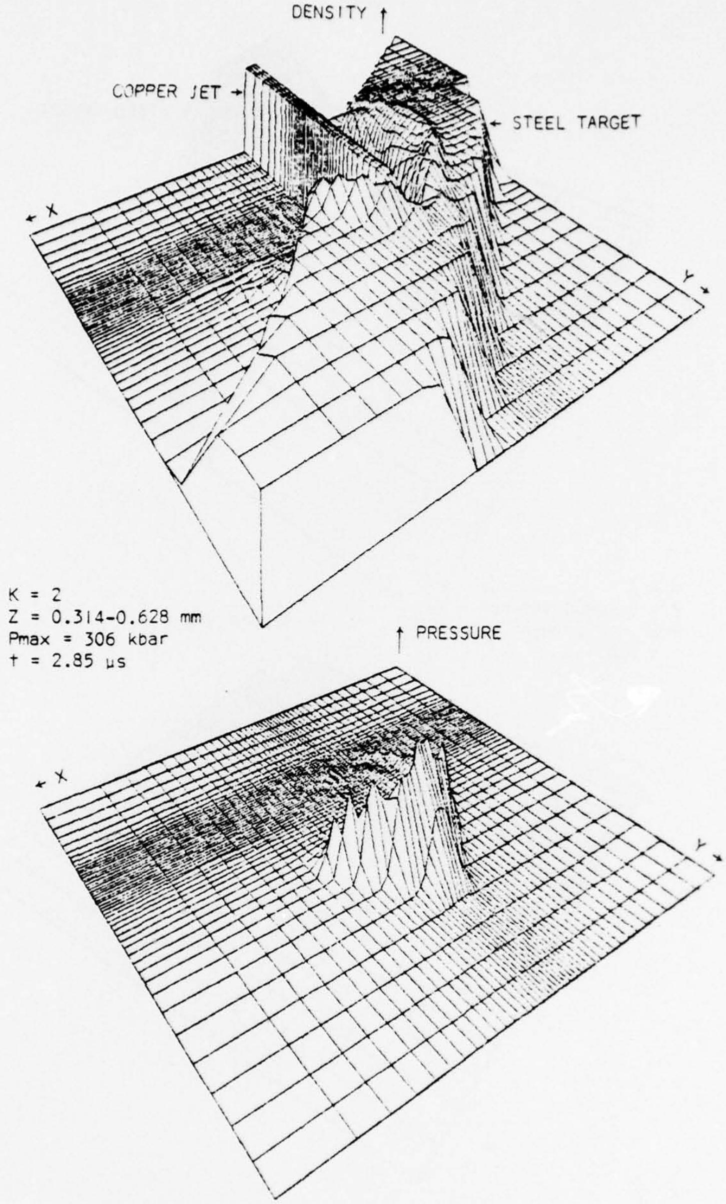


Figure 4. Density and Pressure Fields



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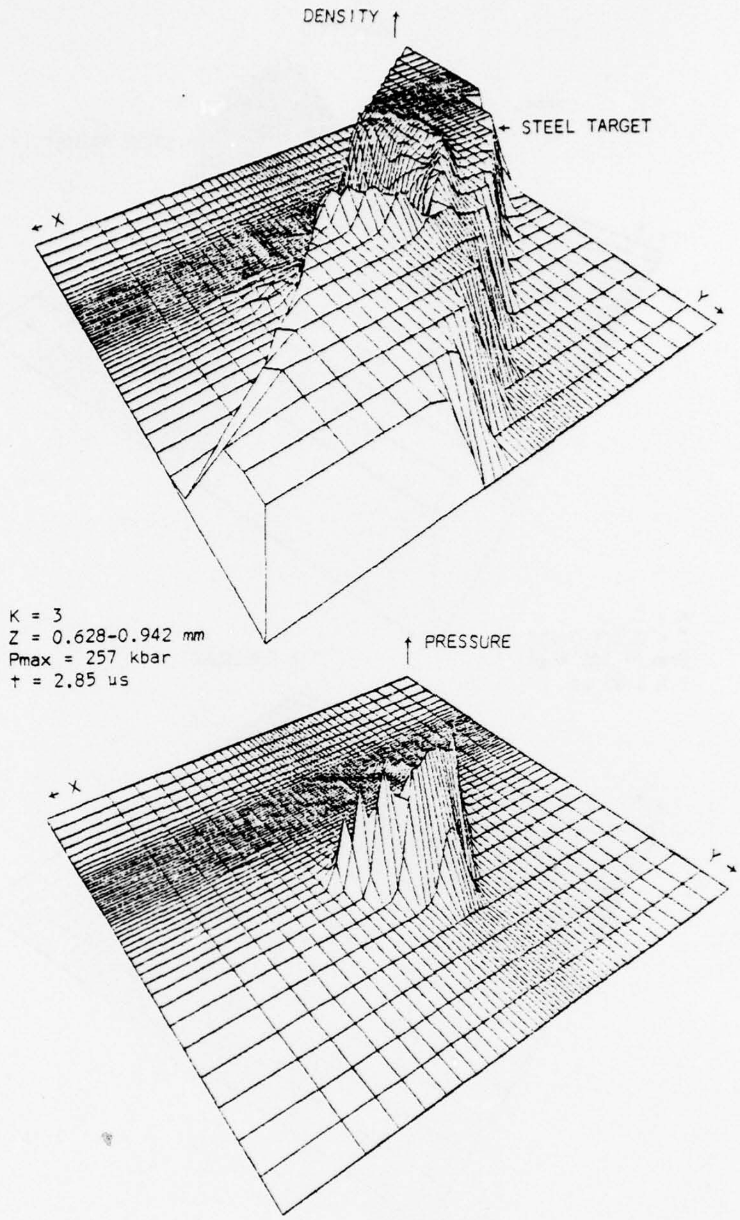

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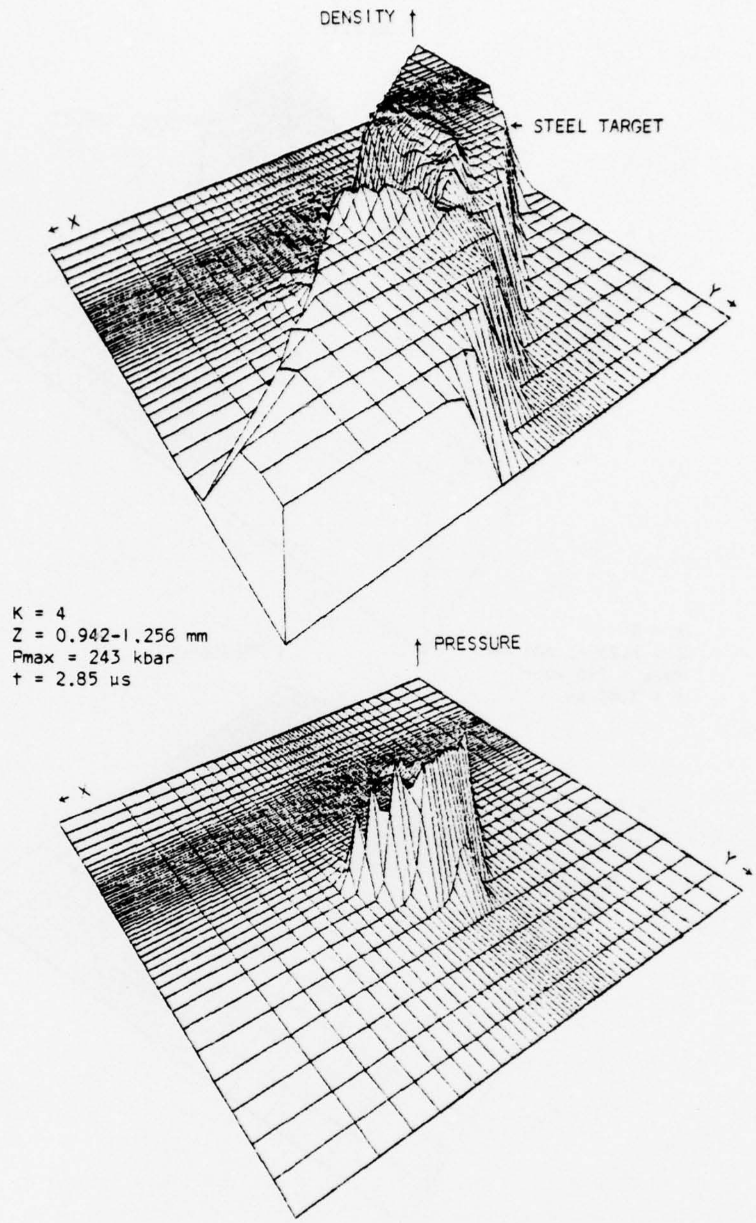

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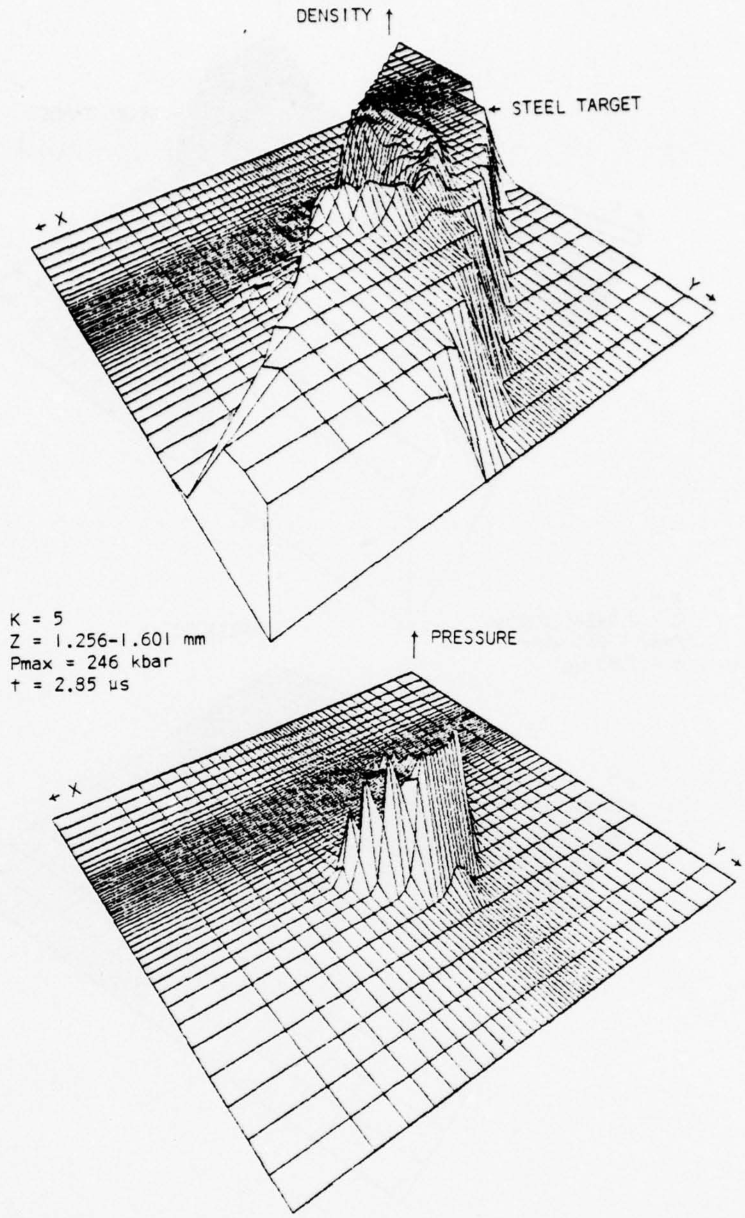

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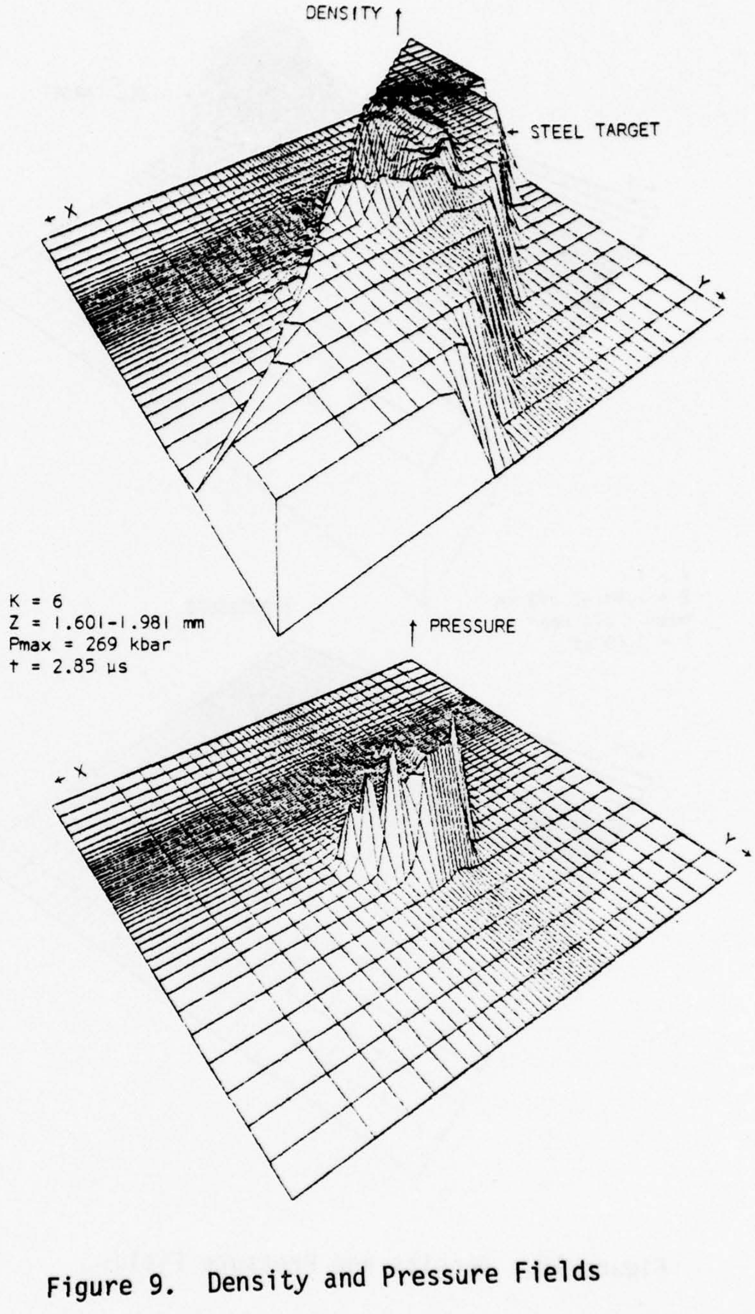

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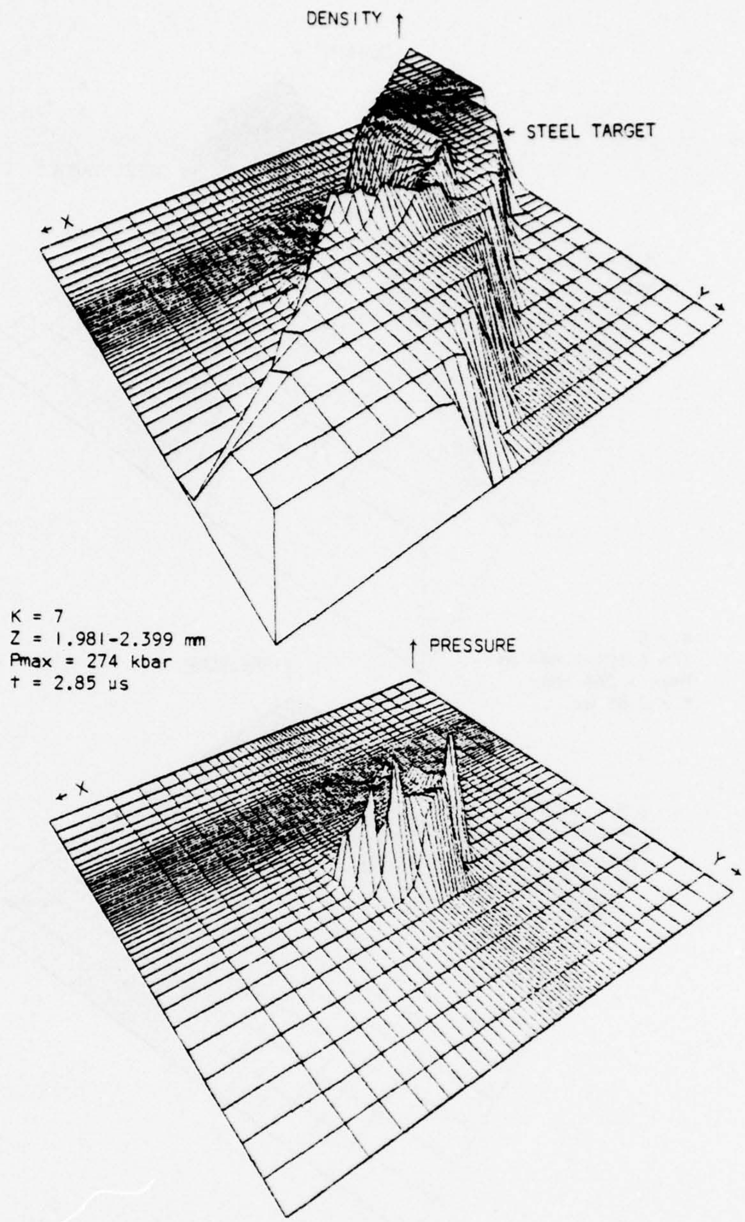

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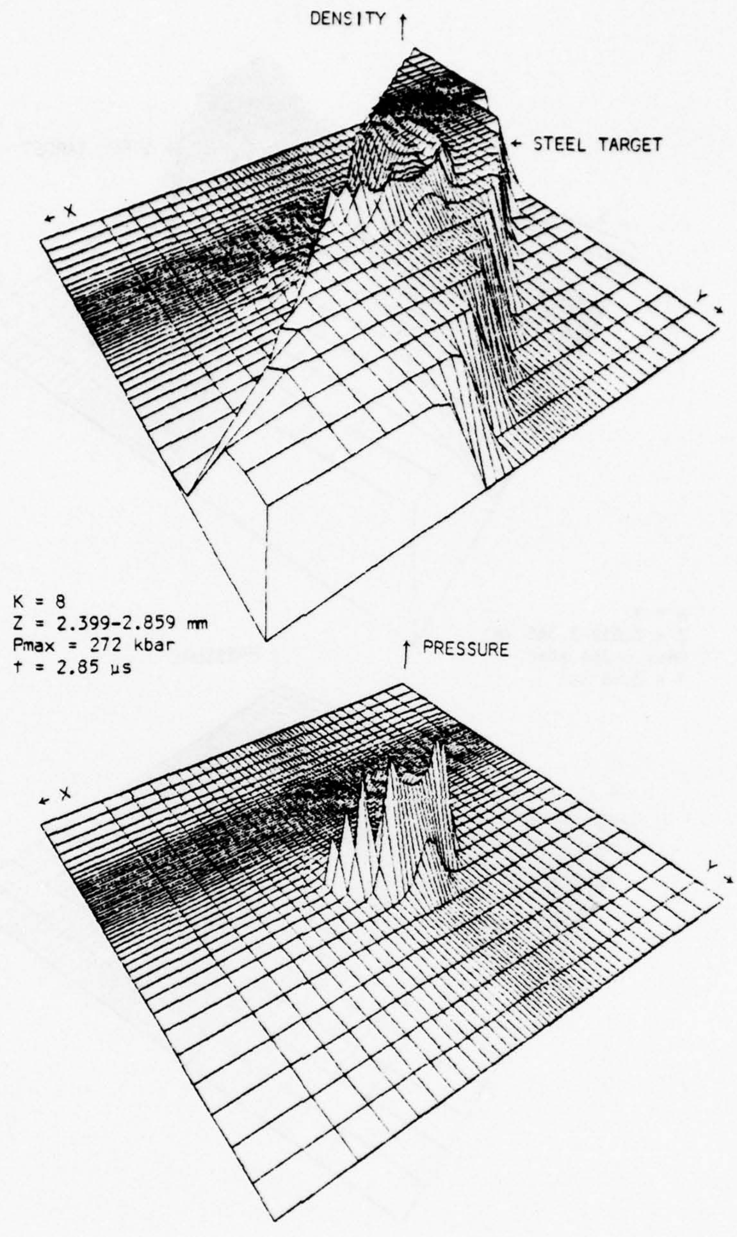
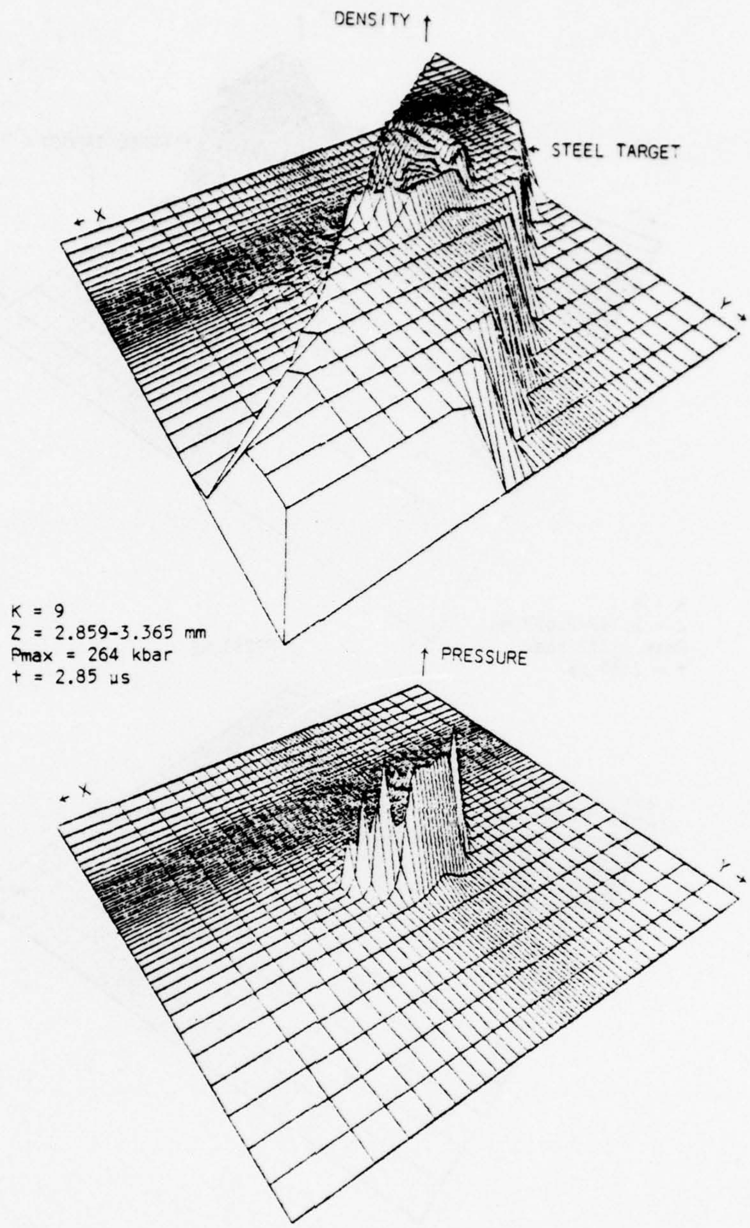


Figure 11. Density and Pressure Fields



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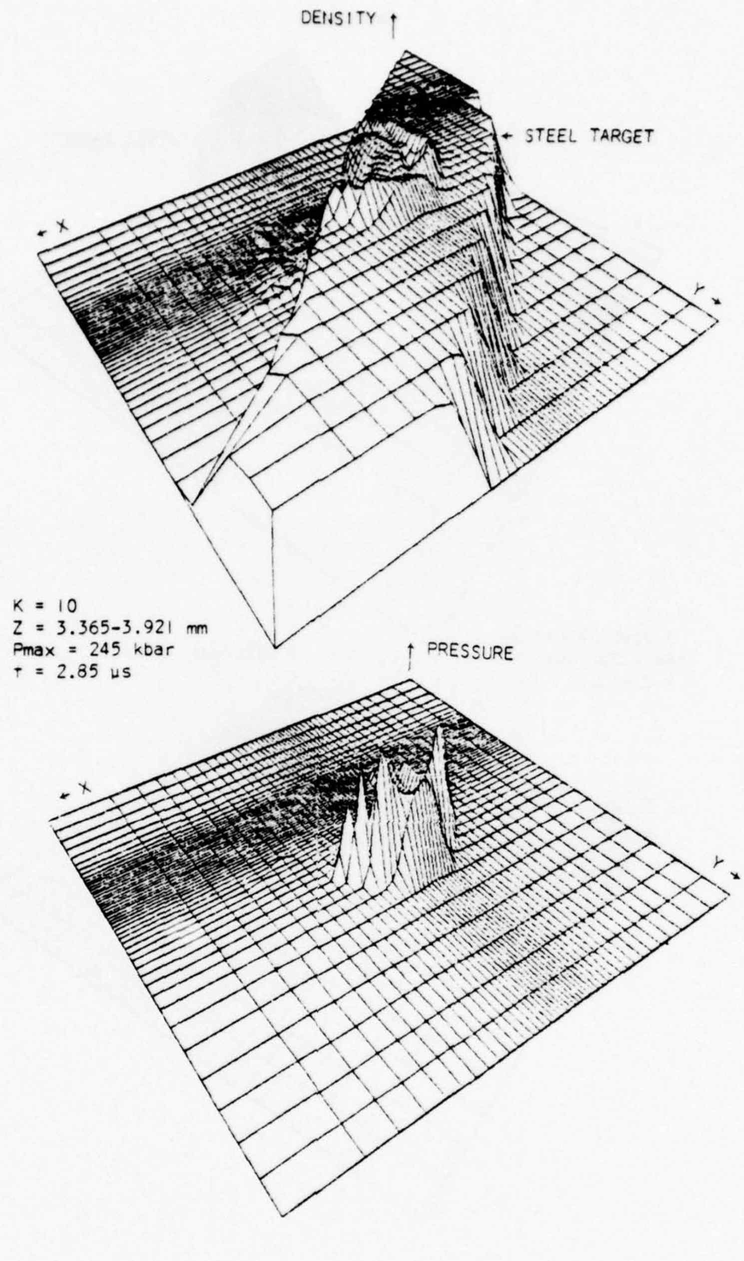

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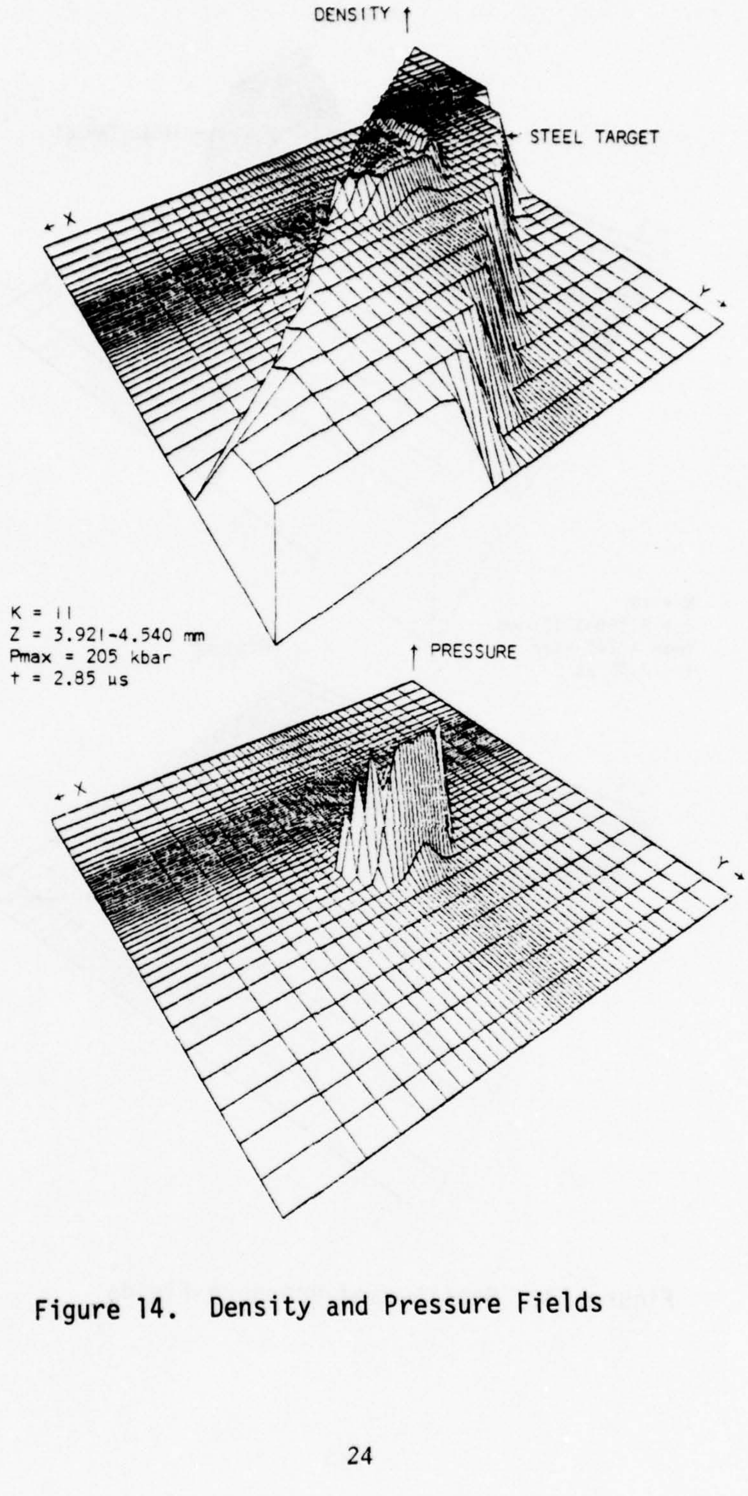

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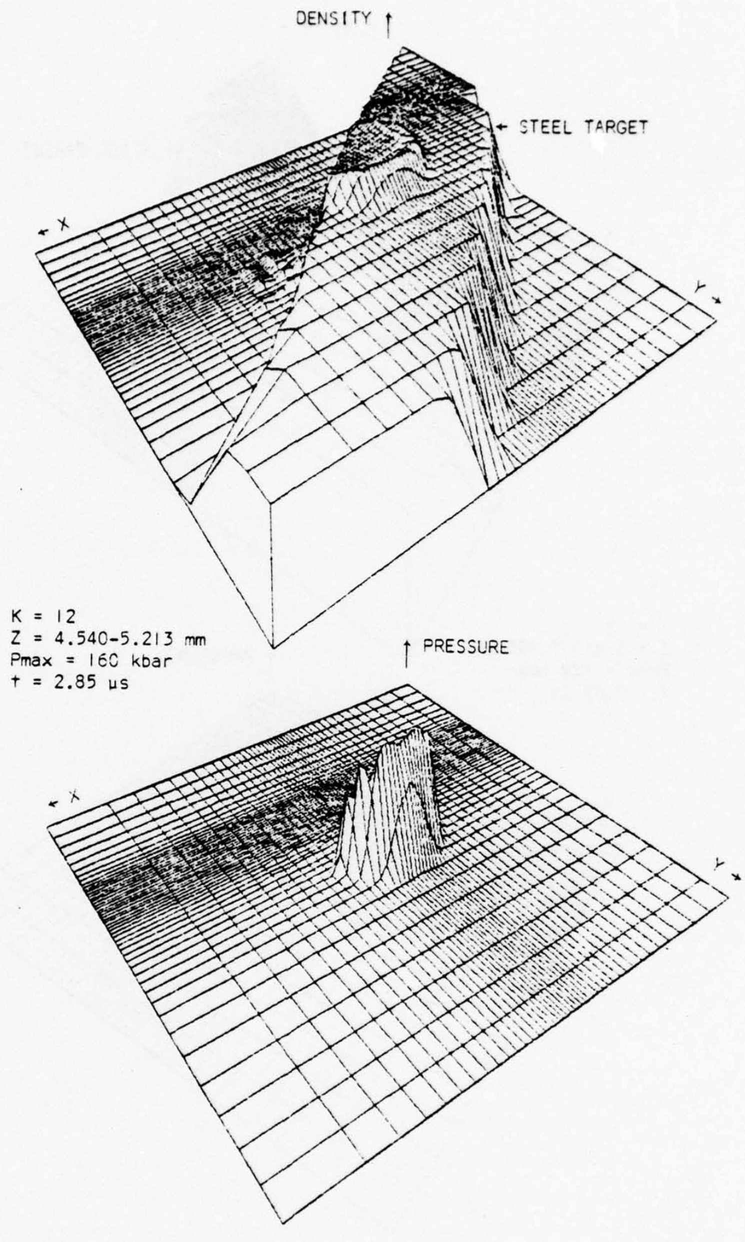

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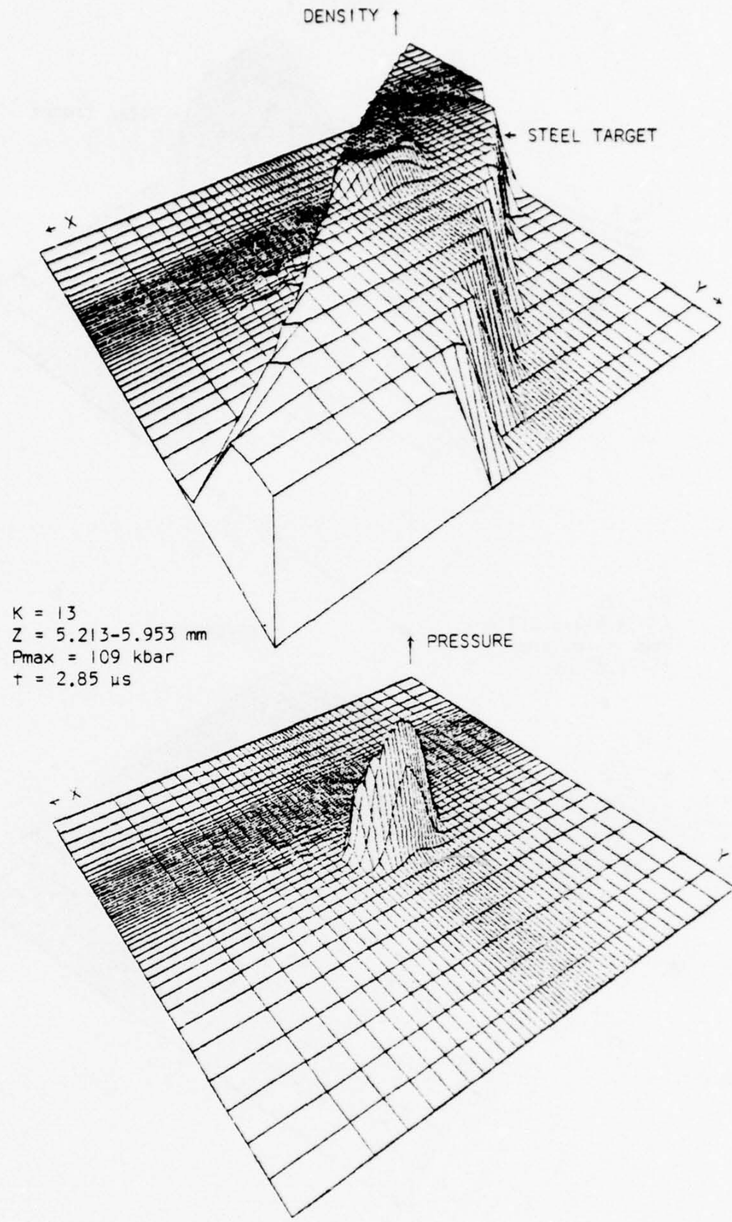

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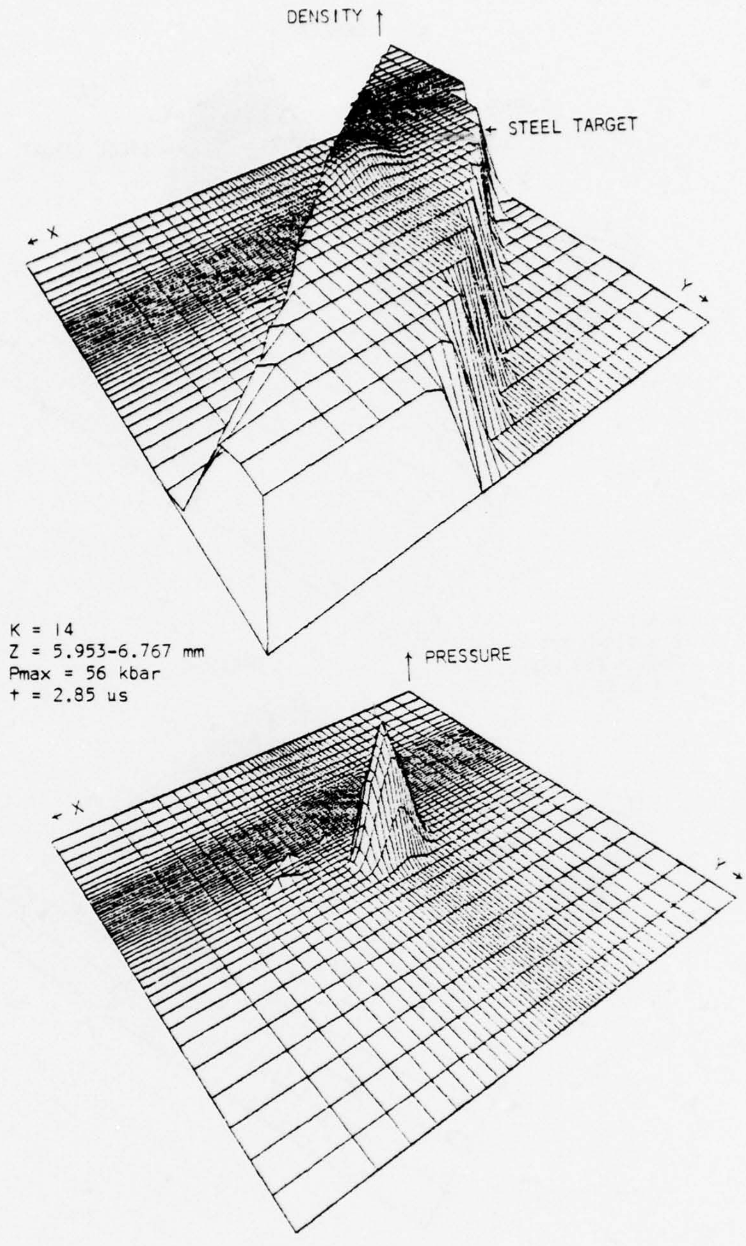

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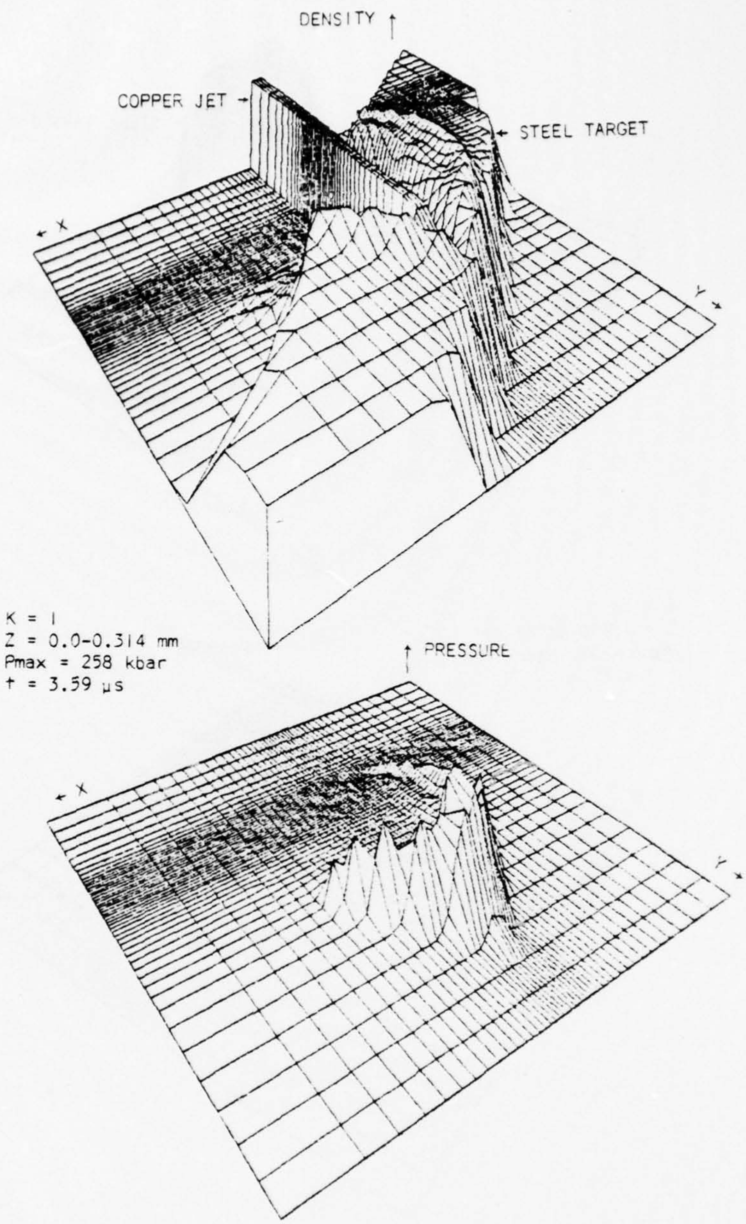

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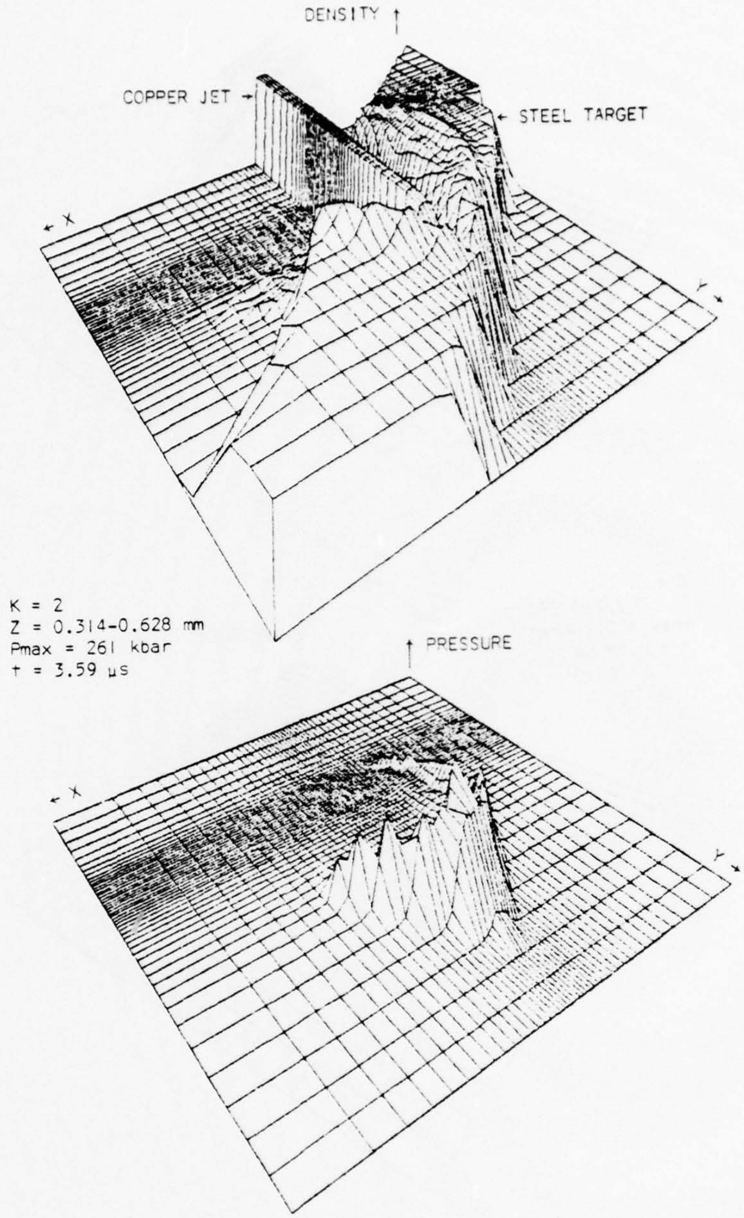

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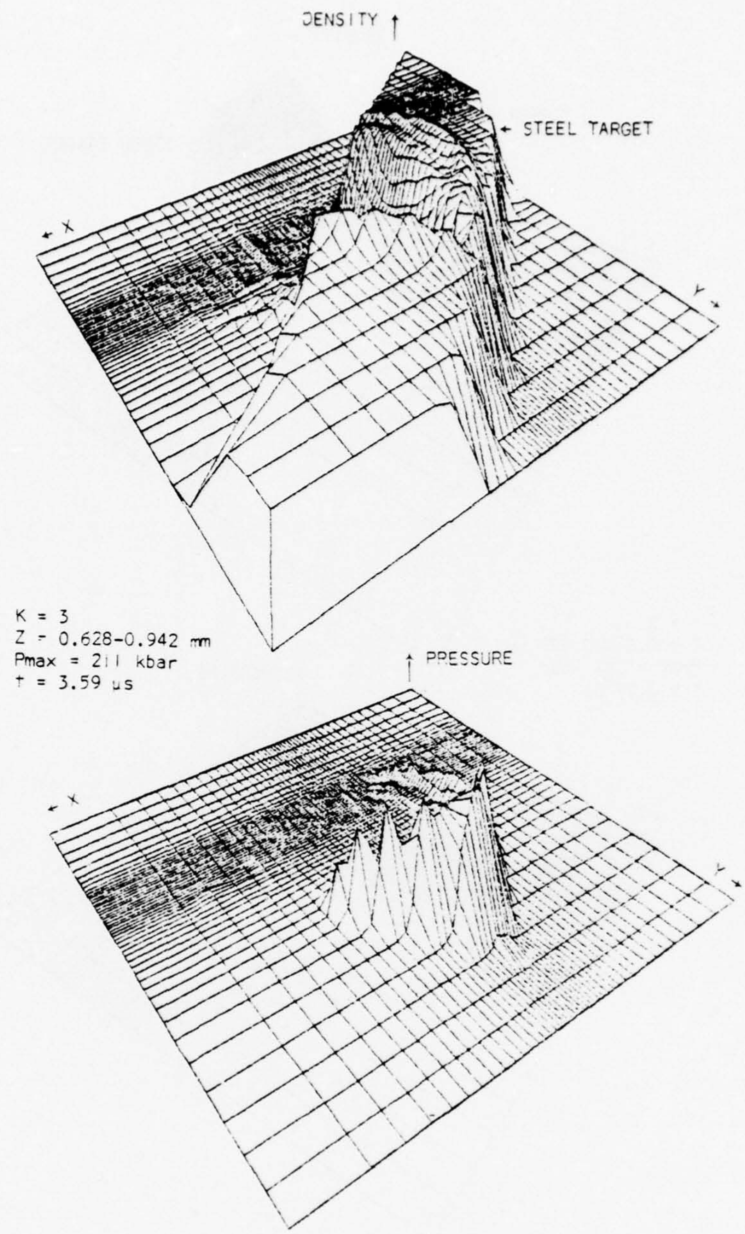

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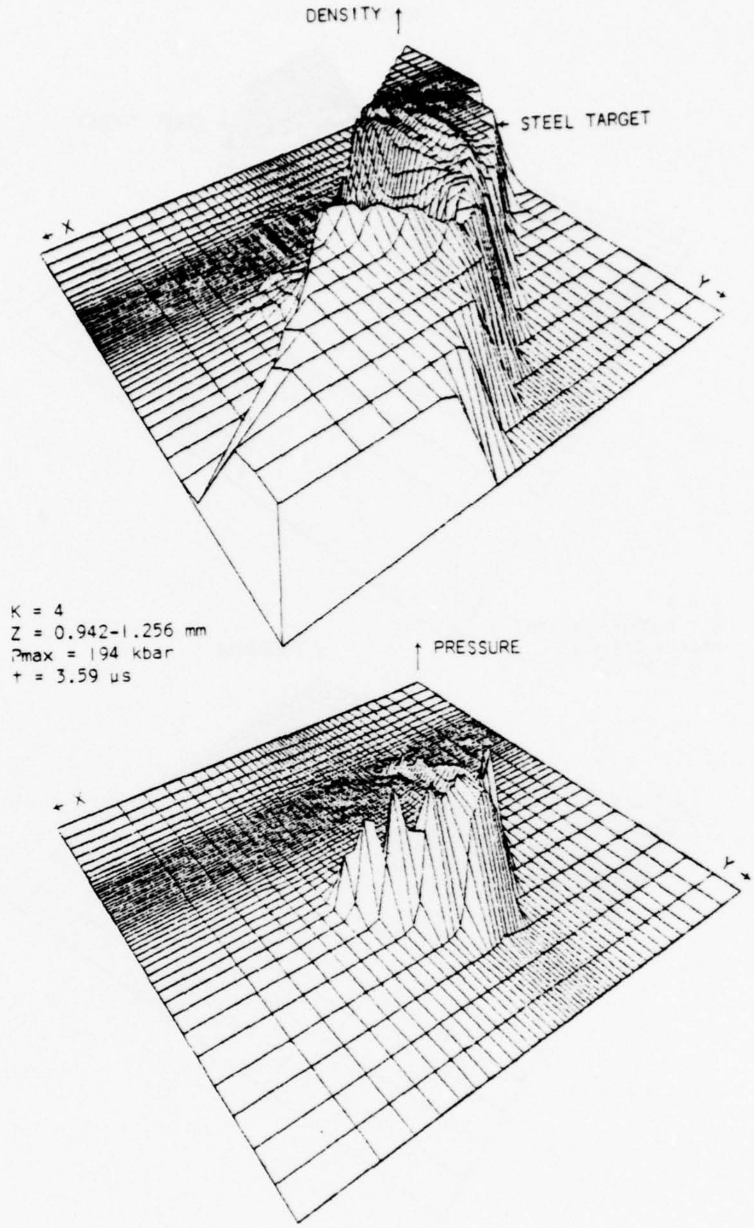

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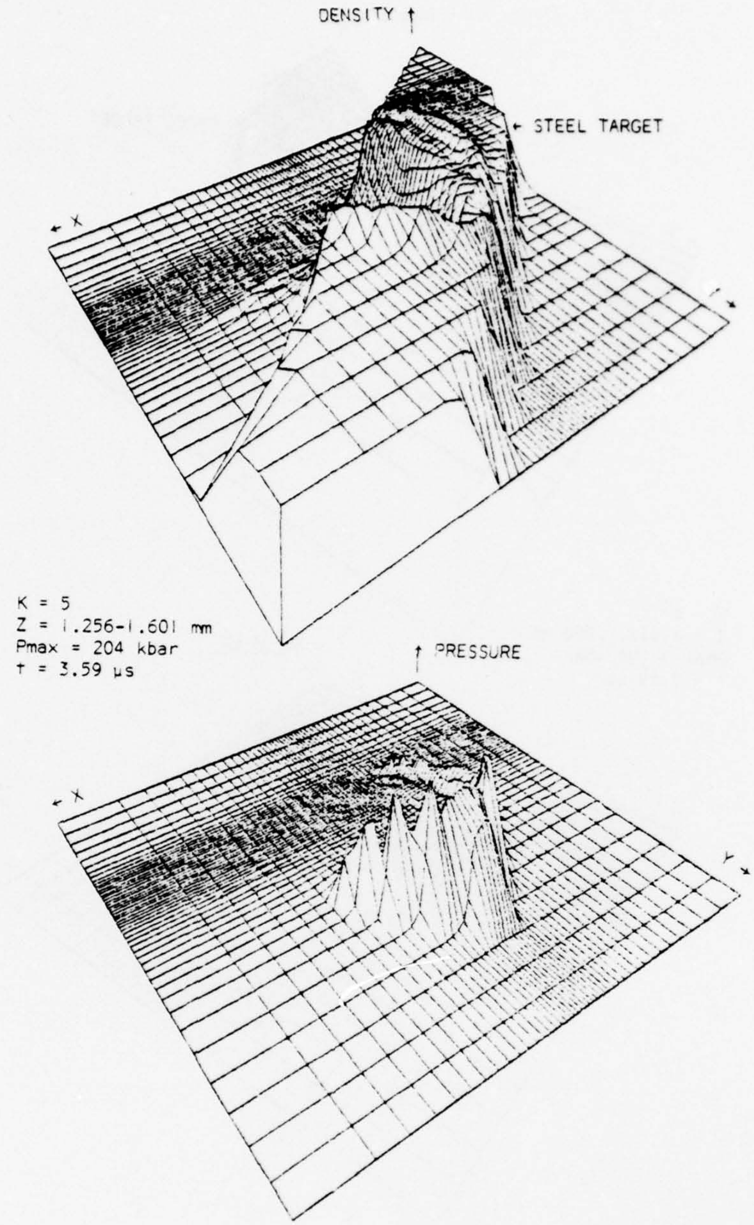

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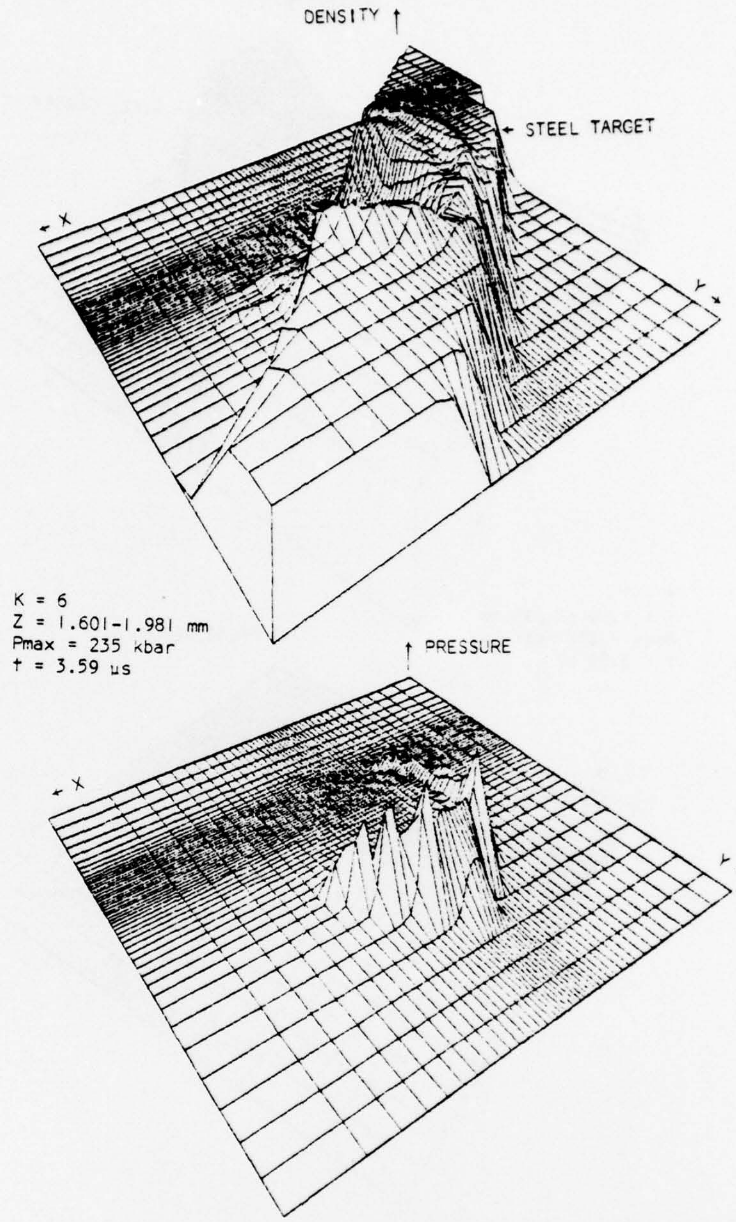

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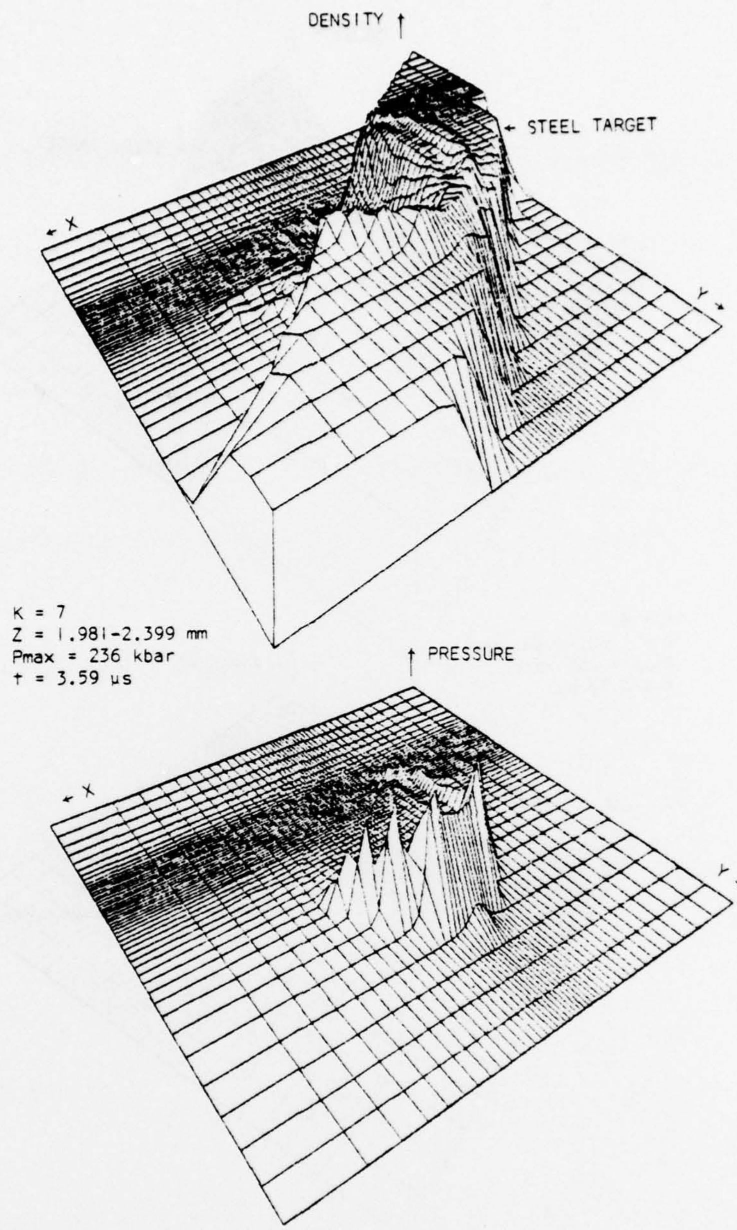

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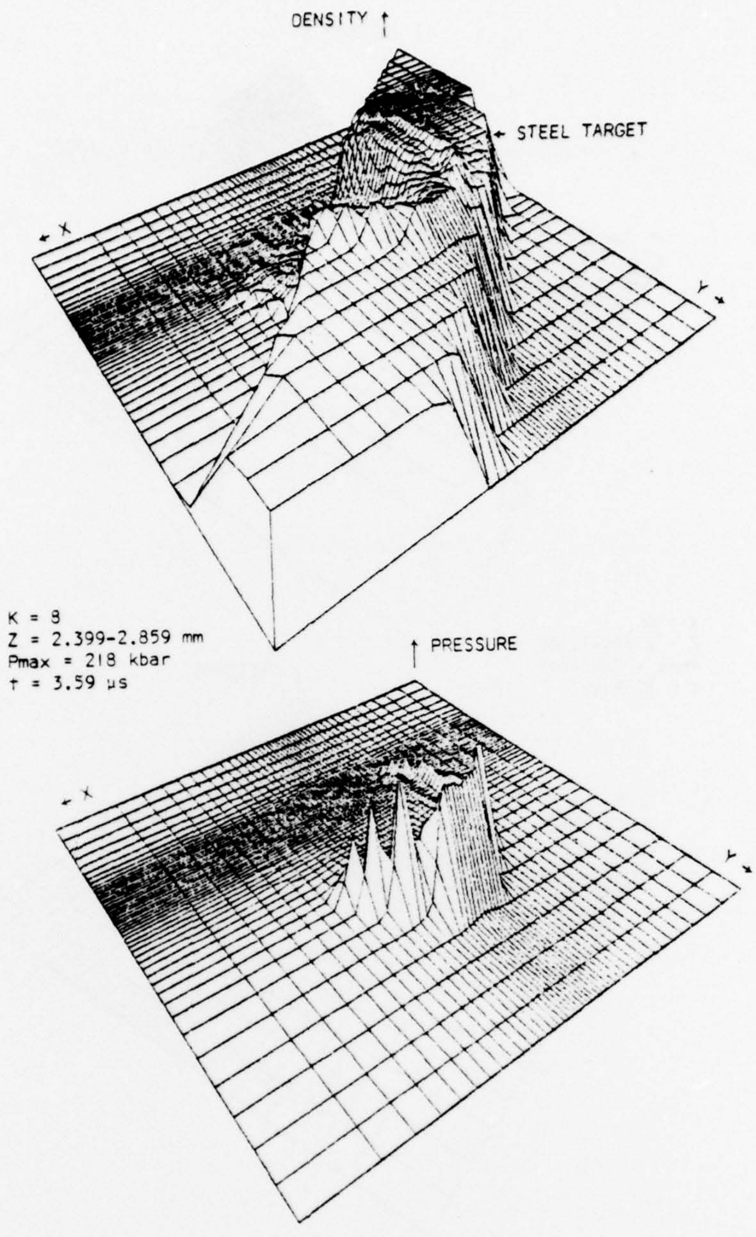

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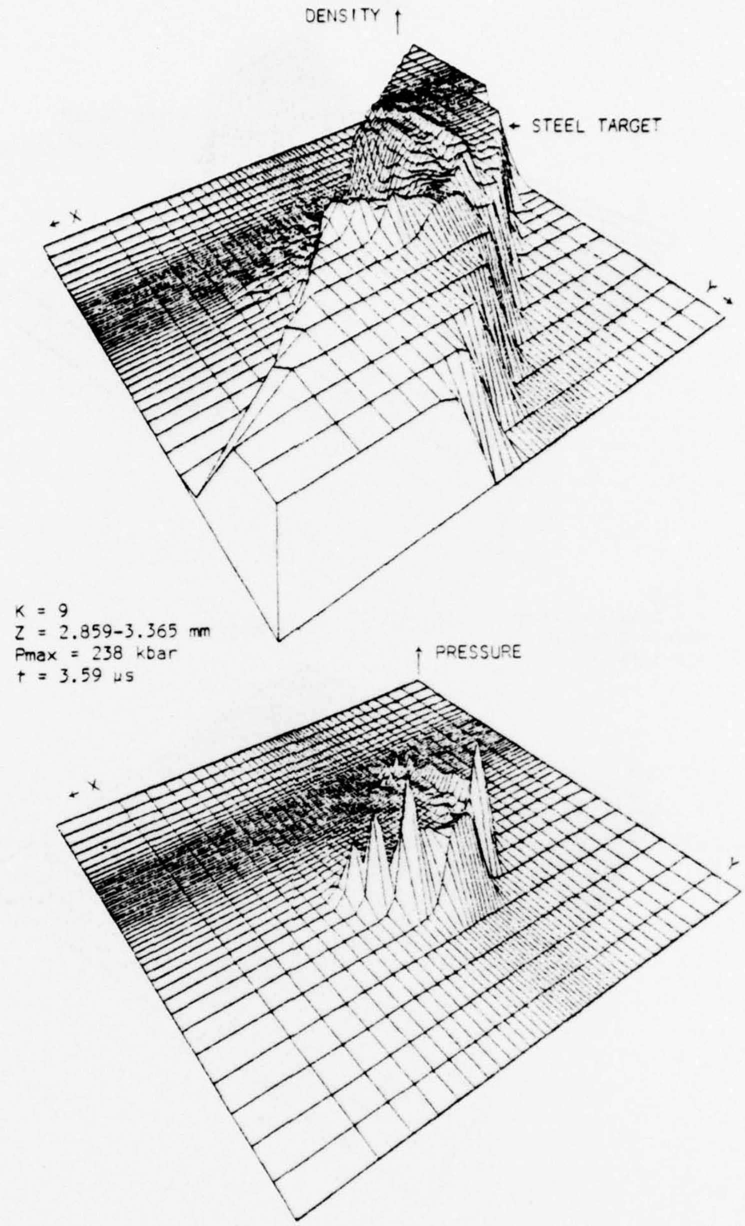

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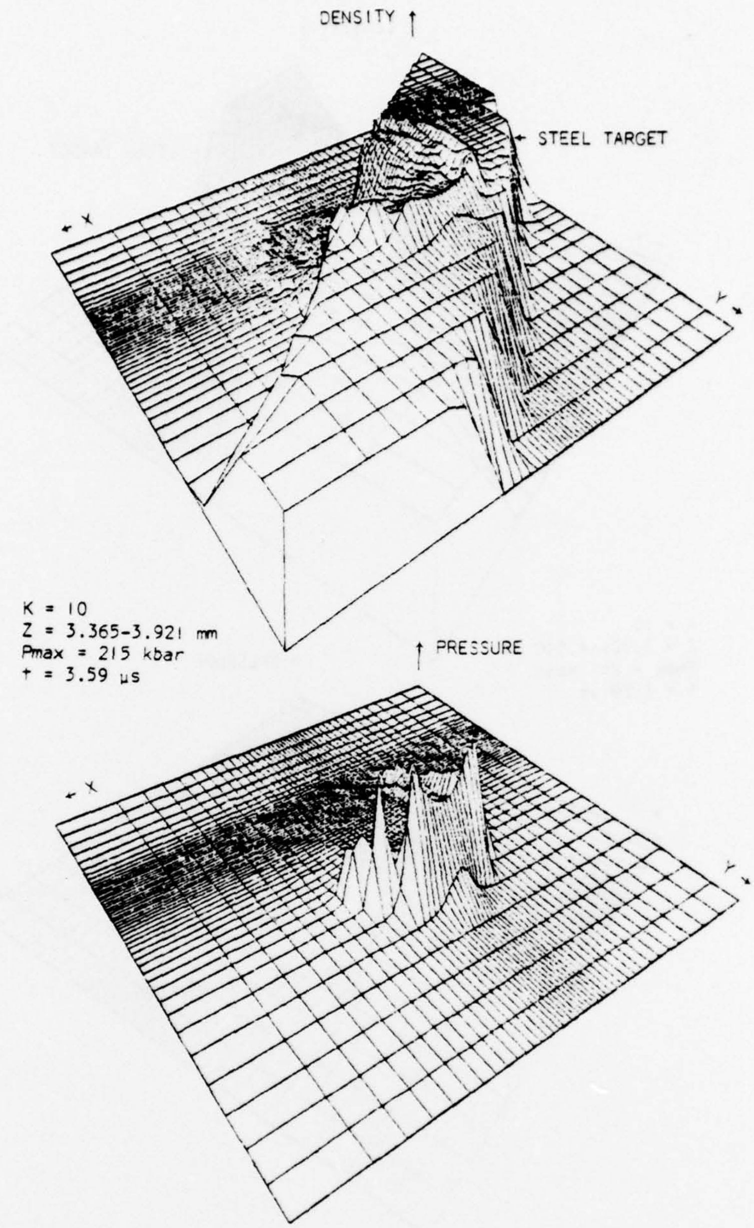

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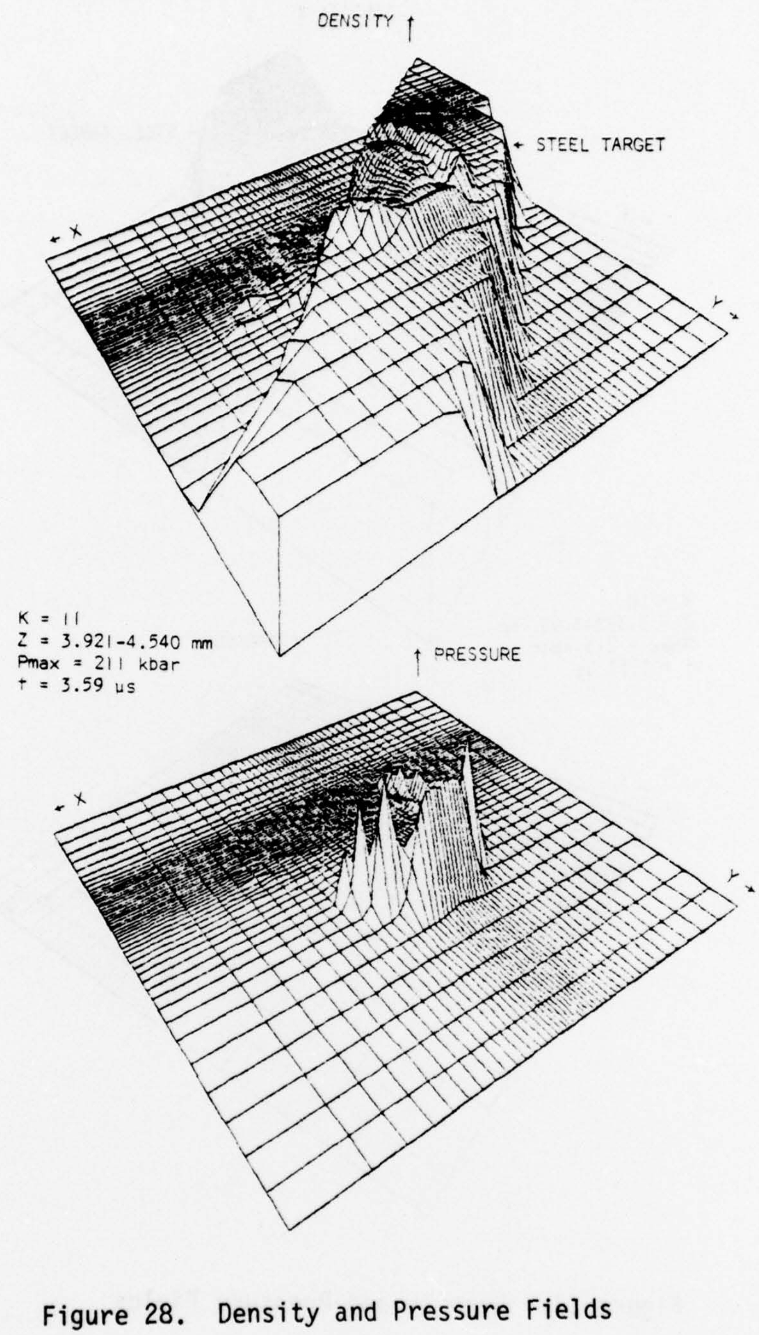

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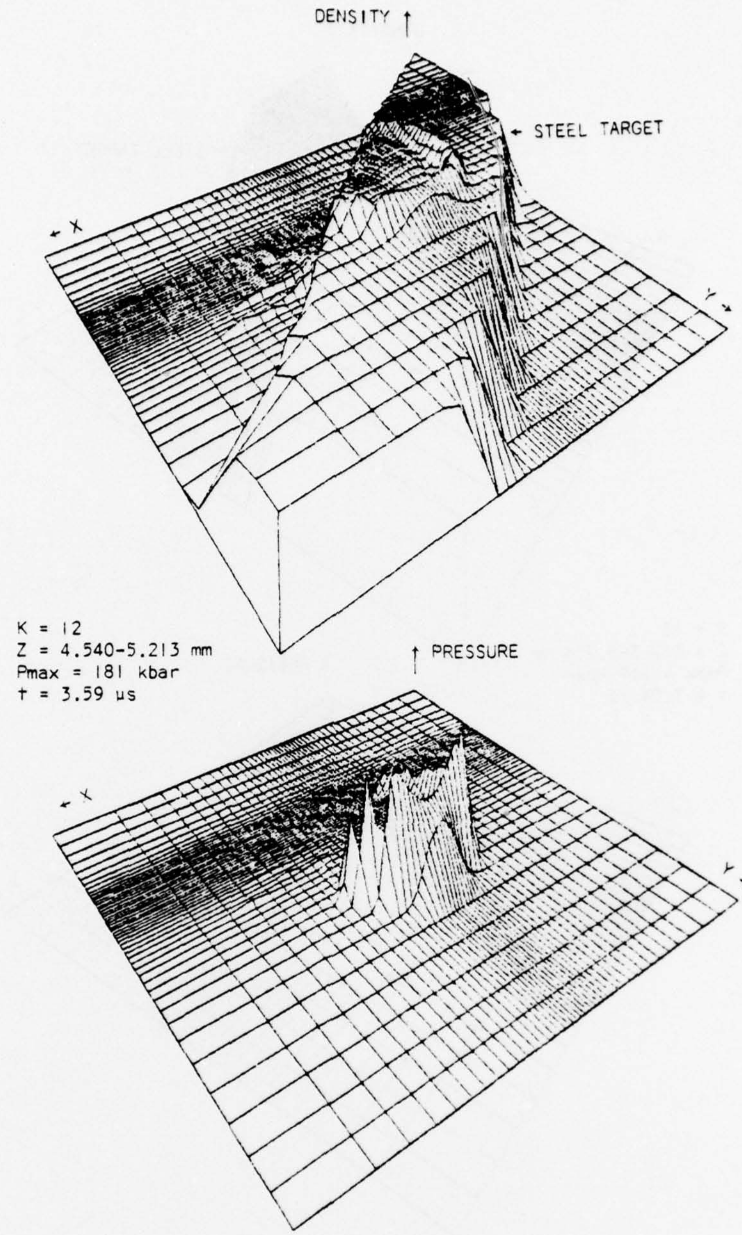

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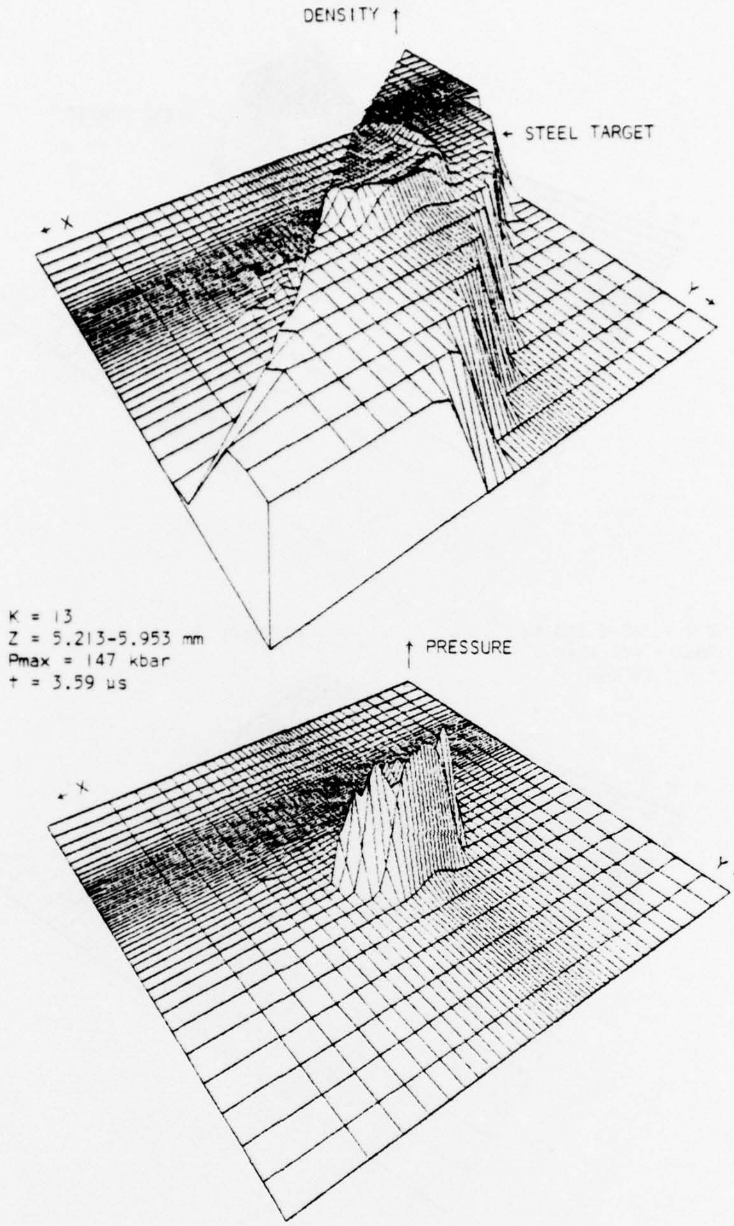

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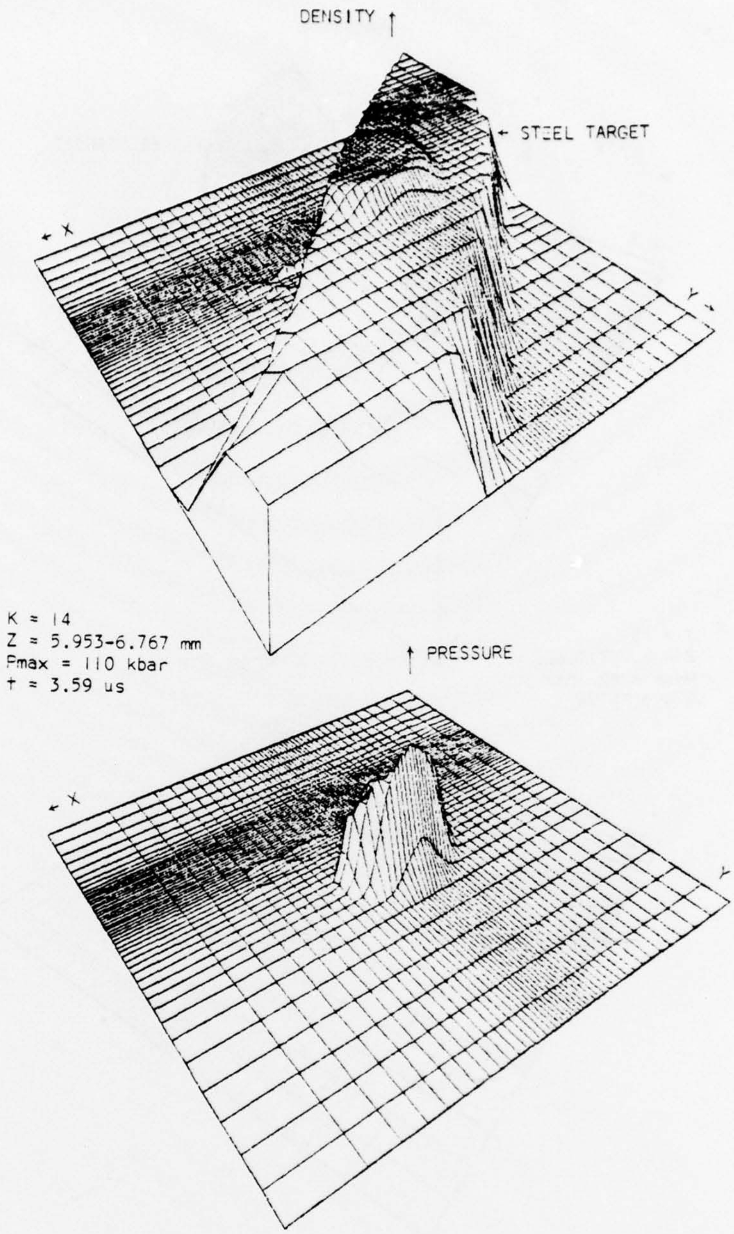

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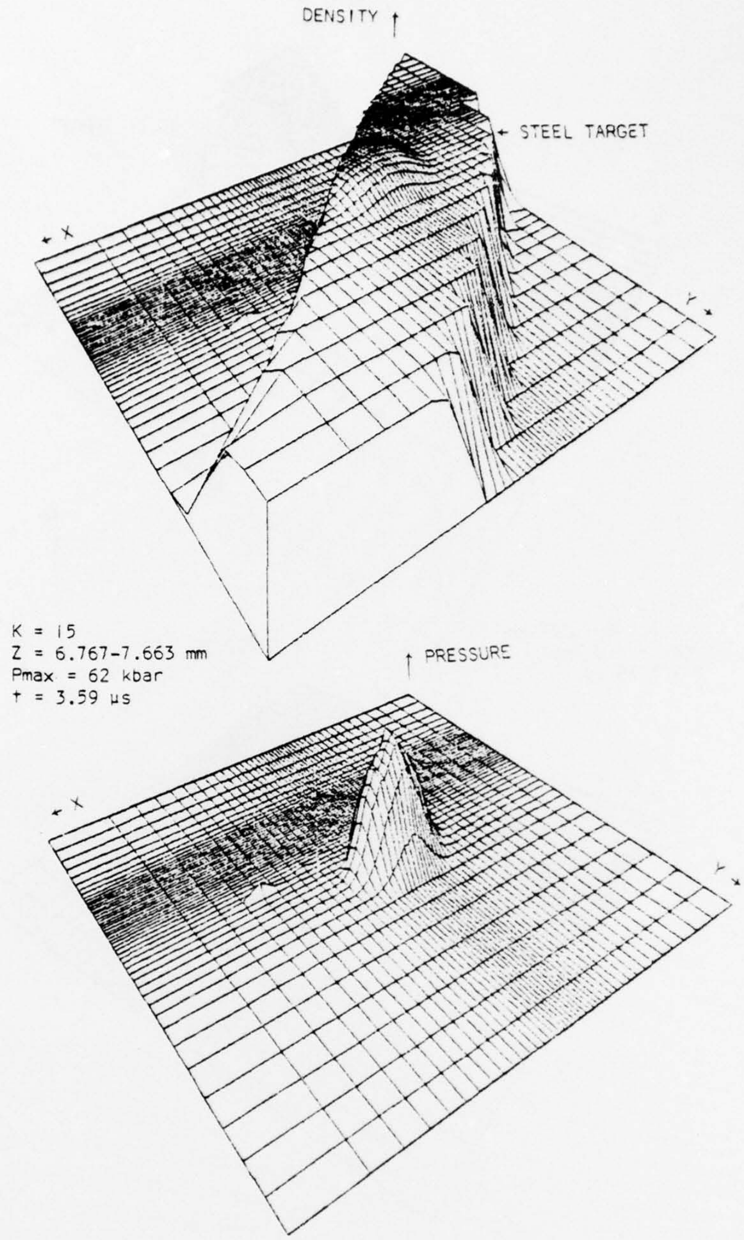

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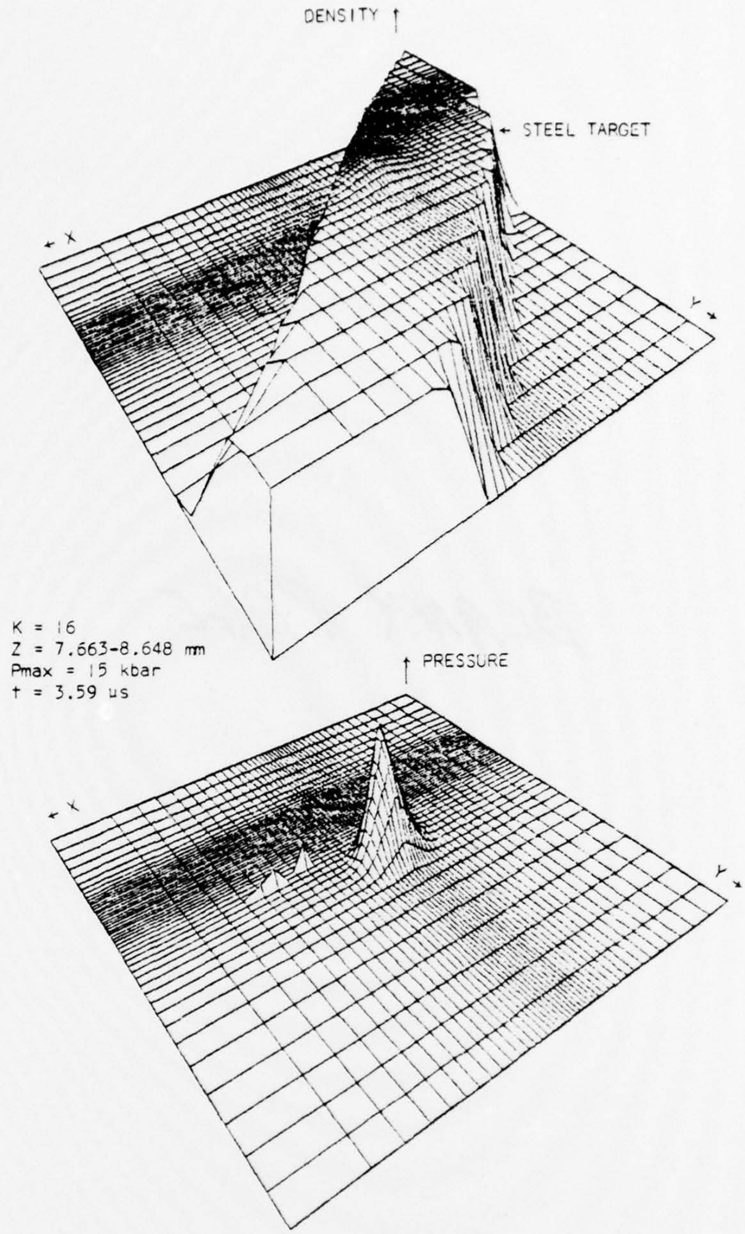

Figure 33. Density and Pressure Fields

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