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EXPLOSIVE DESENSITIZATION BY PRESHOCKING

by

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Shock initiation of heterogeneous explosives proceeds by the process of shock interaction at density discontinuities such as voids which produces local hot spots that decompose and add their energy to the flow. The released energy strengthens the shock so that, when it interacts with additional inhomogeneities, higher temperature hot spots are formed and more of the explosive is decomposed. The shock wave grows stronger and stronger, releasing more and more energy until propagating detonation occurs. The process has been numerically modeled using the technique called Forest Fire. It describes the decomposition rates as a function of the shock pressure (the Pop plot) and the reactive and nonreactive Hugoniot.

It has been observed that preshocking a heterogeneous explosive with a shock pressure too low to cause propagating detonation in the time of interest can cause a propagating detonation in unshocked explosive to fail to continue propagating when the detonation front arrives at the previously shocked explosive. The resulting explosive desensitization has been modeled using a Forest Fire decomposition rate that is determined only by the initial shock pressure of the first shock wave passing through the explosive. This model has been used to reproduce the experimentally observed explosive desensitization of TATR (triaminotrinitrobenzene) explosives previously shocked by short duration 80-kilobar pulses.

I. INTRODUCTION

Heterogeneous explosives, such as PBX 9404 or Composition B, show a different behavior than homogeneous explosives, such as nitromethane or liquid TNT, when propagating along confining surfaces. A heterogeneous explosive can turn sharp corners and propagate outward, and depending upon its sensitivity, it may show either very little or much curvature when propagating along a metal surface. The mechanism of initiation for heterogeneous explosives is different than the Arrhenius kinetic model found adequate for homogeneous explosives. Heterogeneous explosives are initiated and may propagate by the process of shock interaction with density discontinuities such as voids. These interactions result in hot regions that decompose and give increasing pressures that cause more and hotter decomposing regions. Some heterogeneous explosives may require hot spots even for the propagation of the detonation wave.

A model, called Forest Fire¹ after its originator, Charles Forest, has been developed for describing the decomposition rates as a function of the experimentally measured distance of run to detonation vs shock pressure (the Pop plot named after its originator A. Popolato) and the reactive and non-reactive Hugoniot. The model can be used to describe the decomposition from shocks formed either by external drivers or by internal pressure gradients formed by the propagation of a burning front.

The similarity among overlapping portions of the experimentally measured shock distance and time coordinated from experiments having different shock pressures observed for RDX/Exon, 9404, TNT, and TATB supports the assumption that the explosive will pass through the same pressure, distance, and decomposition states at the shock front regardless of the initial conditions. This "single curve build-up assumption" assumes that a reactive shock wave grows to detonation along a unique line in distance, time, and state space. Applying the single-curve build-up assumption to the Pop plots gives the interpretation that the Pop plots are direct descriptions of the shock front.

The HOM equation of state described in Ref. 2 was used to calculate the Hugoniot for partially reacted explosive, the undecomposed explosive, and the detonation products. The Pop plots for 9404 (94/3/3 HMX/Nitrocellulose/CEF at 1.844 g/cc), Composition B (64/36 RDX/TNT at 1.713 g/cc), 9502 (95/5 Triaminotrinitrobenzene/Kel-F at 1.894 g/cc), and Baratol (76/24 Barium Nitrate/TNT at 2.61 g/cc) are shown in Fig. 1. The Forest Fire rates are shown in Fig. 2.

II. EXPERIMENTAL STUDIES

Dick³ performed a PHERMEX radiographic study of detonation waves in 9502 and in Baratol proceeding up a 6.5- by 15.0-cm block of the explosive that is being preshocked by a 0.635-cm steel plate moving 0.09 cm/ μ s. The radiograph for the 9502 explosive is shown in Fig. 3 and for Baratol is shown in Fig. 4. The preshocked 9502 explosive quenches the detonation wave as it propagates into the block of explosive. The preshocked Baratol explosive builds up to a propagating detonation after approximately 1 cm of the run. The two Baratol detonations then interact to form a Mach stem.

III. NUMERICAL CALCULATIONS

The experimental geometries were numerically modeled using a reactive hydrodynamic computer code, 2DL, that solves the Navier-Stokes equations using the finite-difference techniques described in Ref. 2. The Forest Fire rate was used to describe the explosive decomposition rate. For explosives that have been previously shocked, Craig⁴ has experimentally observed that the distance of run to detonation for several multiple shocked explosives is determined primarily by the distance after a second shock has overtaken the lower pressure shock wave (the preshock). To approximate this experimental observation, we programmed the calculation to use Forest Fire rates determined by the first shock wave or the rates determined by any subsequent release waves that result in lower pressures and lower decomposition rates.

While this is an adequate model for some explosives in certain pressure ranges, one would need the experimentally determined Pop plot for multiple

shocked explosives to adequately describe all the possible degrees of preshock explosive desensitization.

Using the two-dimensional reactive Lagrangian code, 2DL,² with the Forest Fire rate determined by the magnitude of the first shock, we have calculated the experimental systems and compared the calculations with the PHERMEX radiographs.

The calculated density profiles for 9502 are shown in Fig. 5. The pressure and mass fraction of undecomposed explosive profiles are shown in Fig. 6.

If the desensitization by preshocking is not included, one obtains the computed results shown in Fig. 7 which do not agree with the experimental observations.

The calculated density profiles for Baratol are shown in Fig. 8, along with the radiographic profiles shown in Fig. 4. The pressure and mass fraction of decomposed explosive are shown in Fig. 9.

The preshocked Baratol explosive builds up to a propagating detonation after 1 cm of run. The two Baratol detonation waves interact to form a Mach stem.

IV. CONCLUSIONS

The failure of a propagating detonation in unshocked explosive to continue to propagate when it interacts with explosive that has been previously shocked has been studied experimentally using radiographic techniques and has been numerically modeled.

The formation of a Mach stem by perpendicularly interacting Baratol detonation waves has been numerically modeled using the Forest Fire model for describing shock decomposition of heterogeneous explosives.

REFERENCES

1. Charles L. Mader, "Two-Dimensional Homogeneous and Heterogeneous Detonation Wave Propagation," Sixth International Symposium on Detonation, AGR-221, 404 (1976).
2. Charles L. Mader, Numerical Modeling of Detonations, University of California Press, Berkeley (1979).
3. Richard Dick, private communication.
4. Bobby G. Craig, private communication.

FIGURE CAPTIONS

1. Pop plots for 9404, Composition B, 9502, and Baratol.
2. The Forest Fire rates for 9404, Composition B, 9502, and Baratol.
3. A 9502 detonation wave interacting with preshocked 9502. The shock was formed by a steel driver shown on the right side of the radiograph.
4. A Baratol detonation interacting with a detonation wave resulting from build-up from a shock formed by a steel driver shown on the left side of the radiograph.
5. The constant density profiles for a detonation wave in 9502 interacting with explosive that has been previously shocked to about 80 kbars. The decomposition rate is determined by the first shock wave. The isopycnic interval is 0.01 cc/g. The PHERMEX radiographic profiles are shown.
6. The constant pressure and mass fraction profiles for the system shown in Fig. 5 at 5.0 and 9.2 μ s are shown. The isobar interval is 20 kbar and the mass fraction interval is 0.1.
7. The constant density profiles for a detonation wave in 9502 interacting with explosive that has been shocked to about 80 kbar. The decomposition rate is determined by the local pressure. The detonation wave propagates through the shocked explosive.
8. The constant density profiles for a detonation wave in Baratol interacting with explosive that has been shocked strongly enough to result in a second propagating detonation wave.
9. The constant pressure and mass fraction profiles for the system shown in Fig. 8.

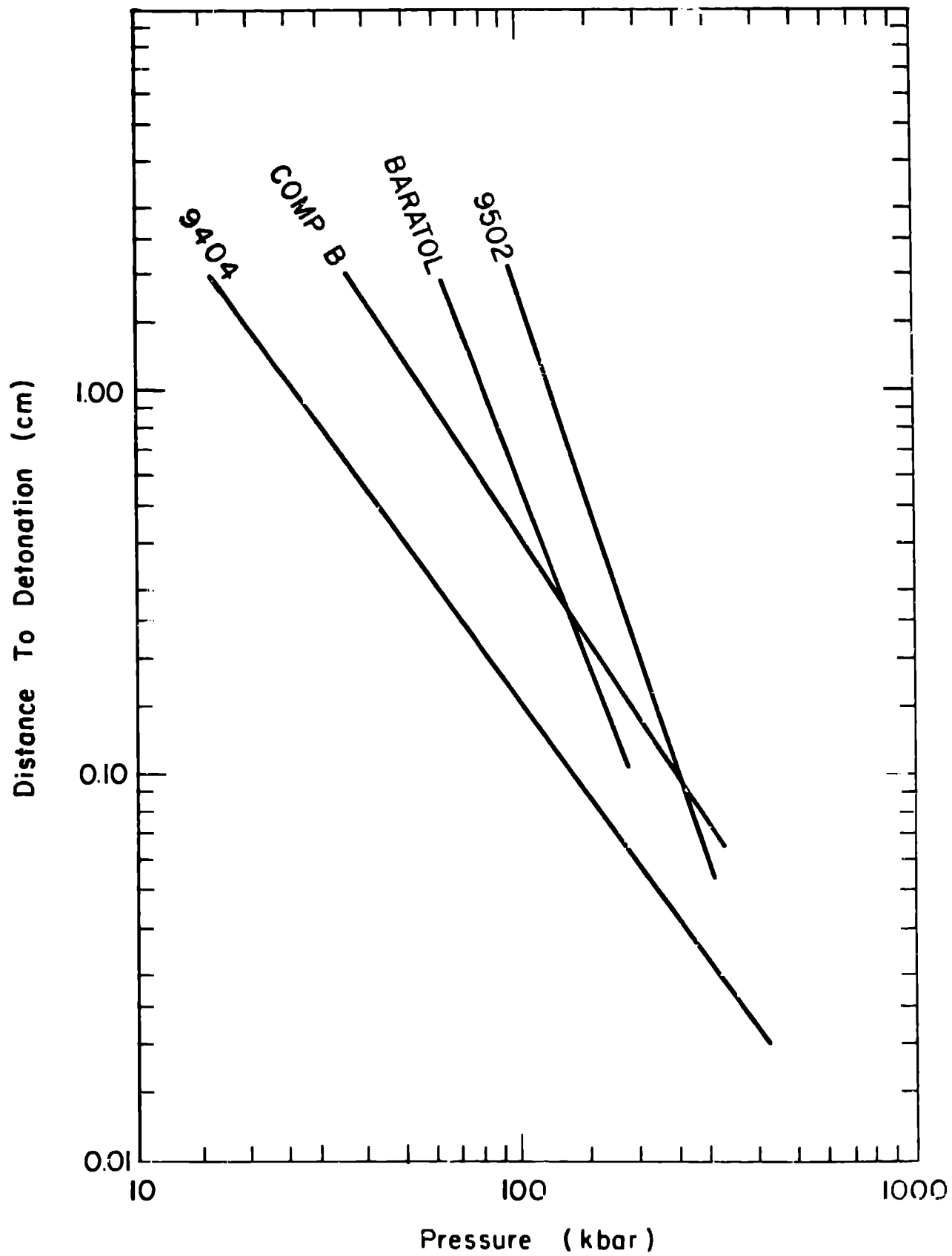


FIGURE 1

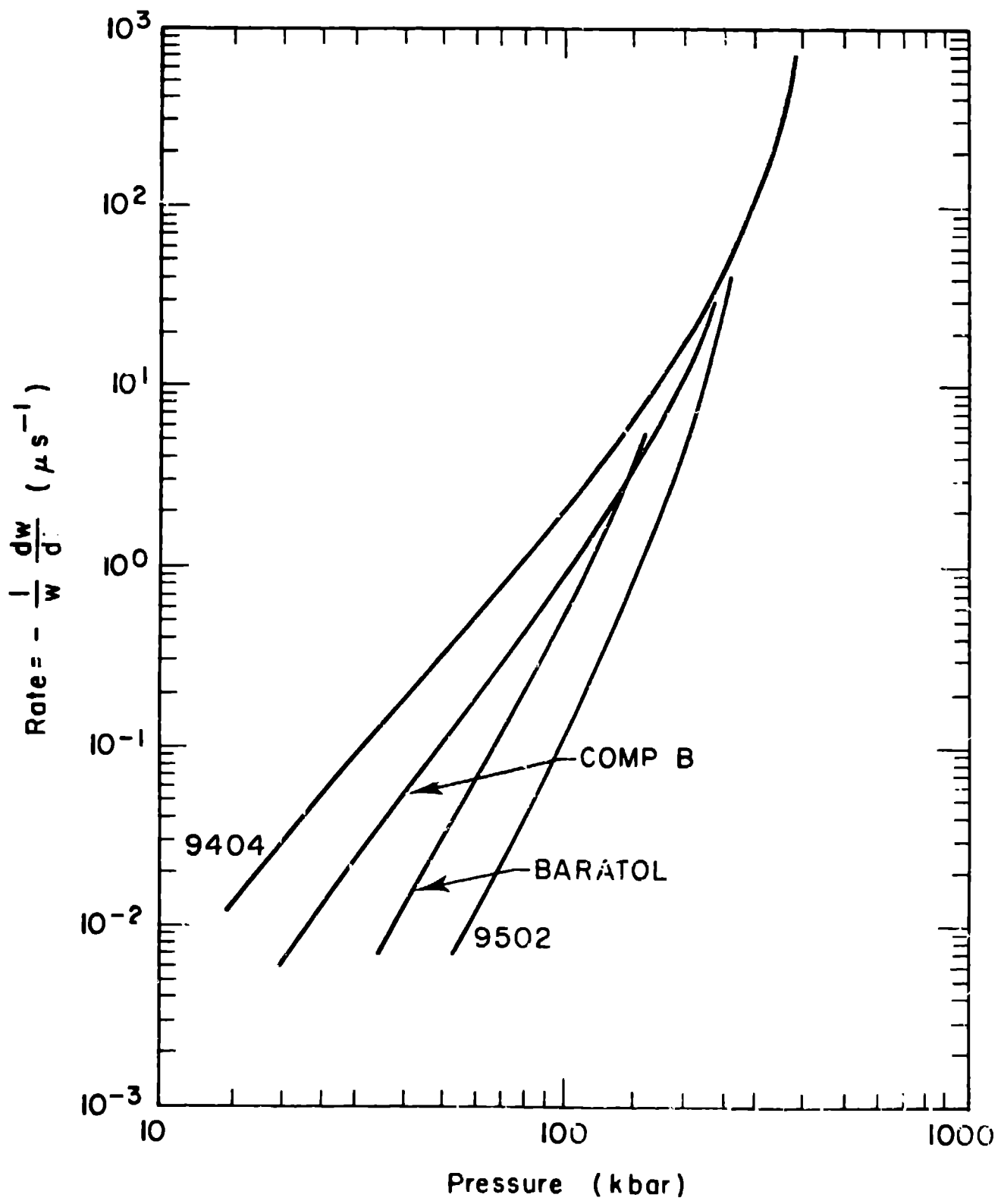


FIGURE 2

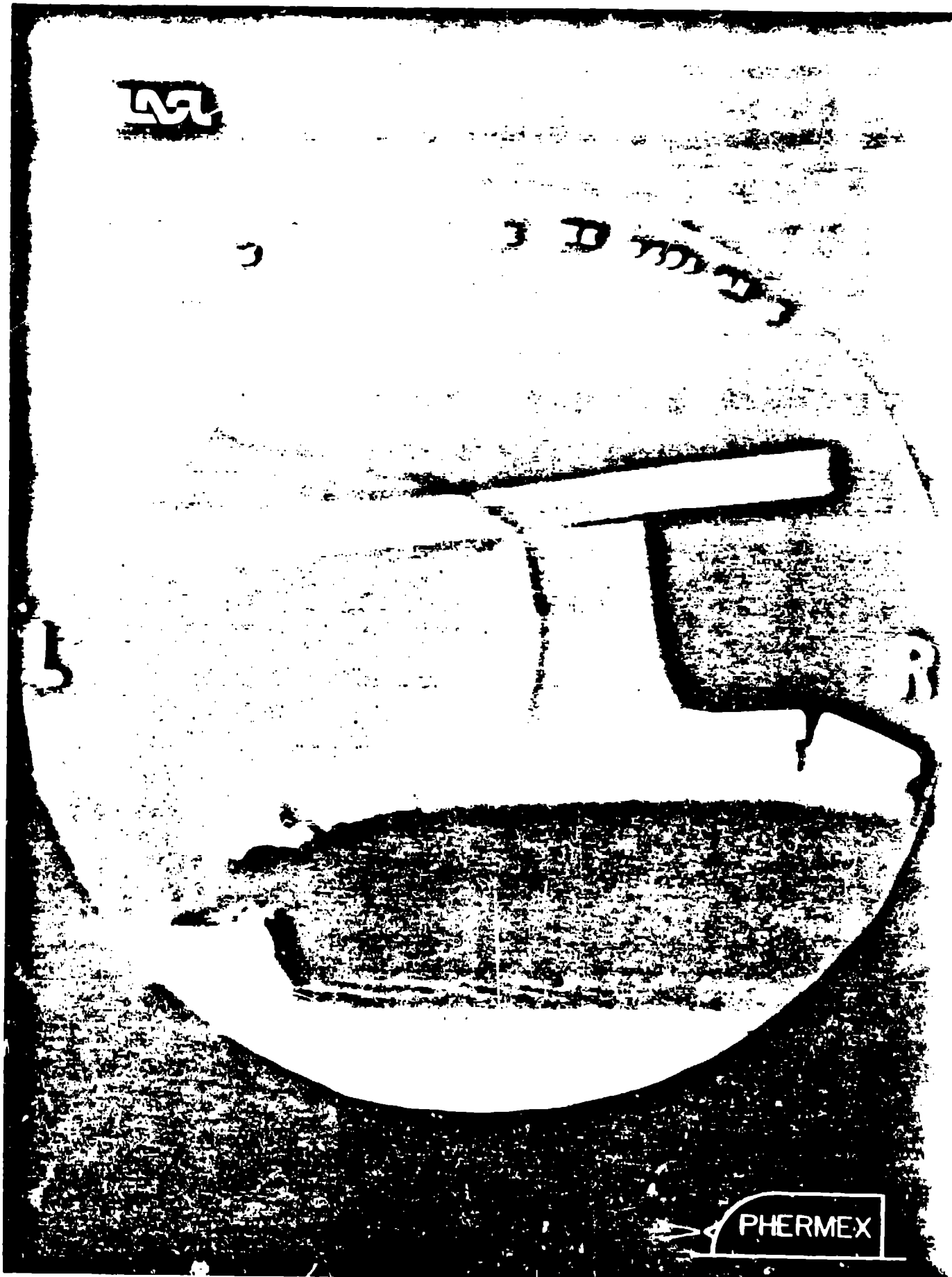


FIGURE 3

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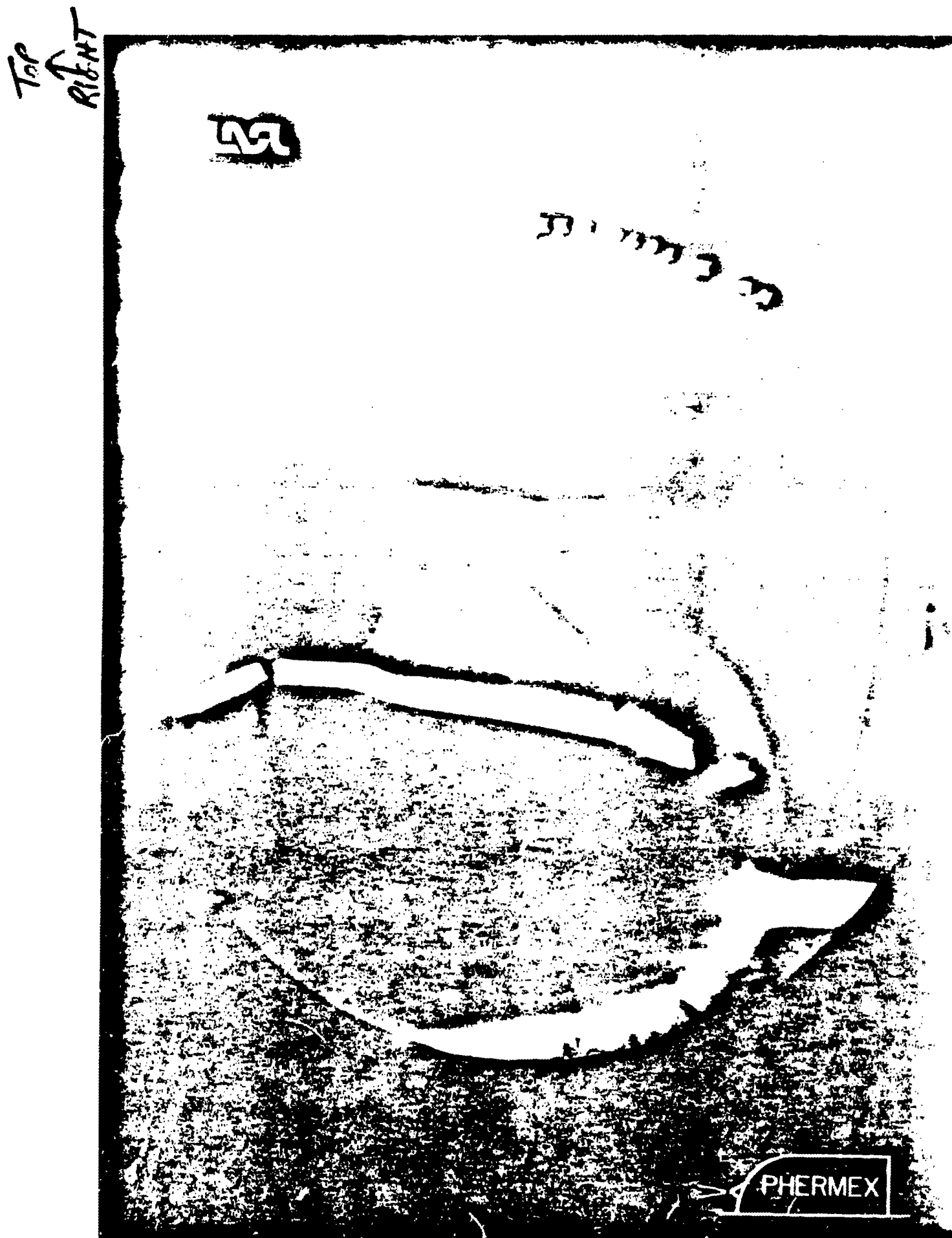


FIGURE 4

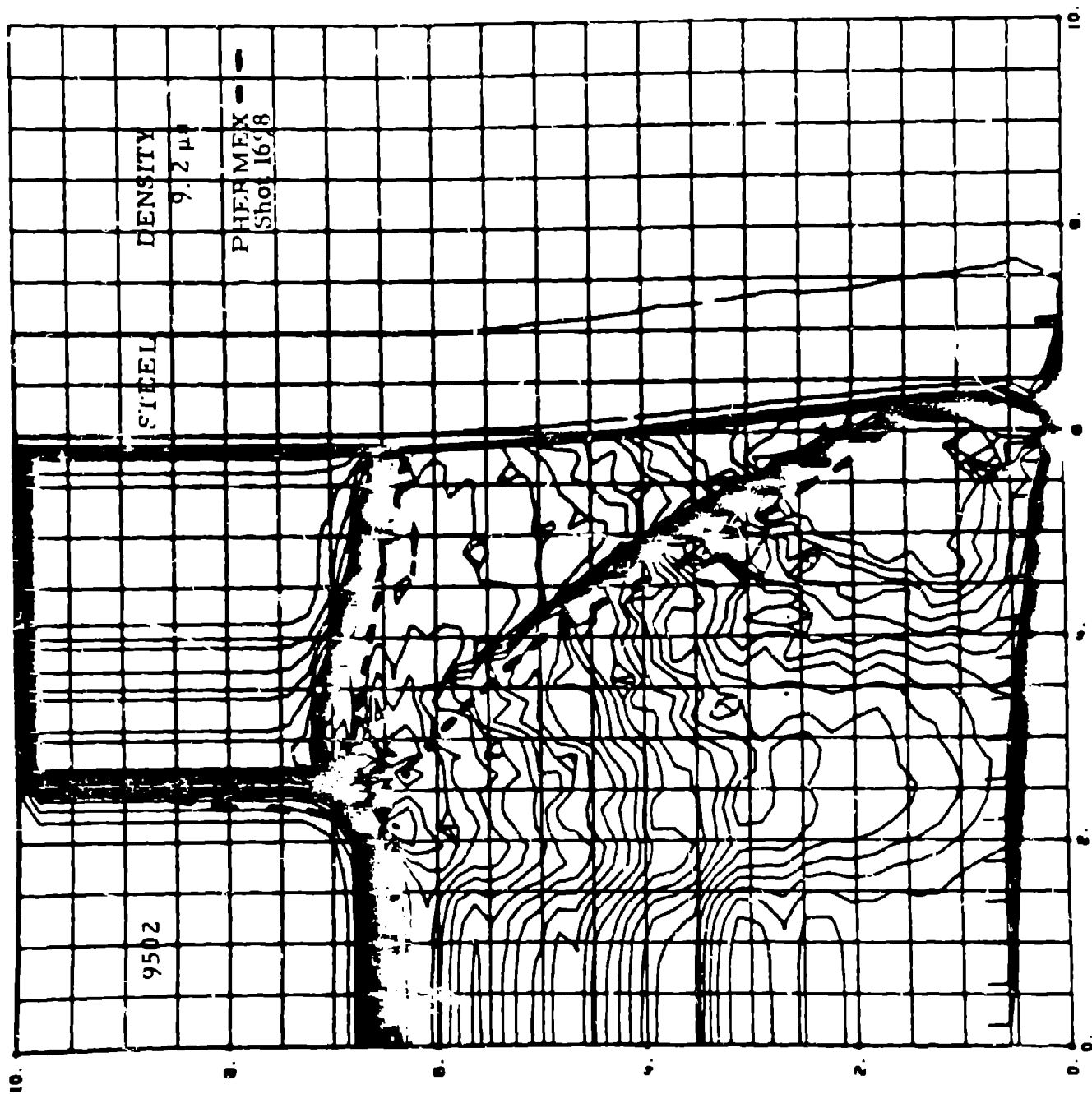


FIGURE 5

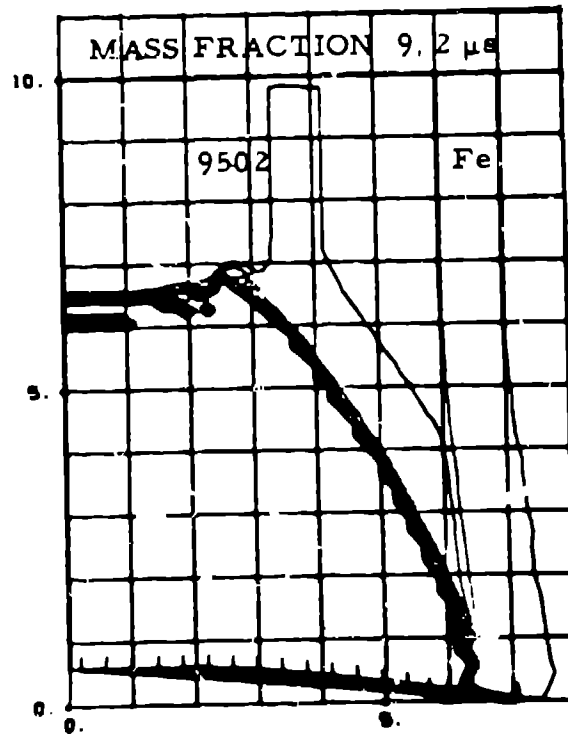
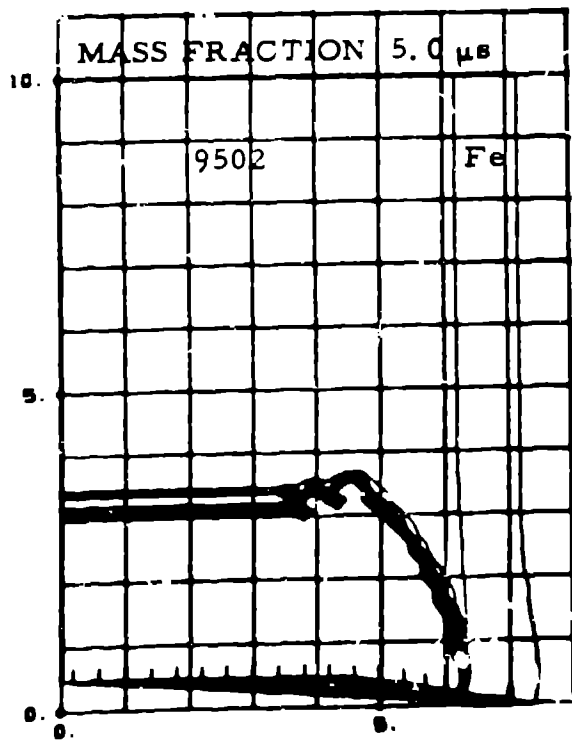
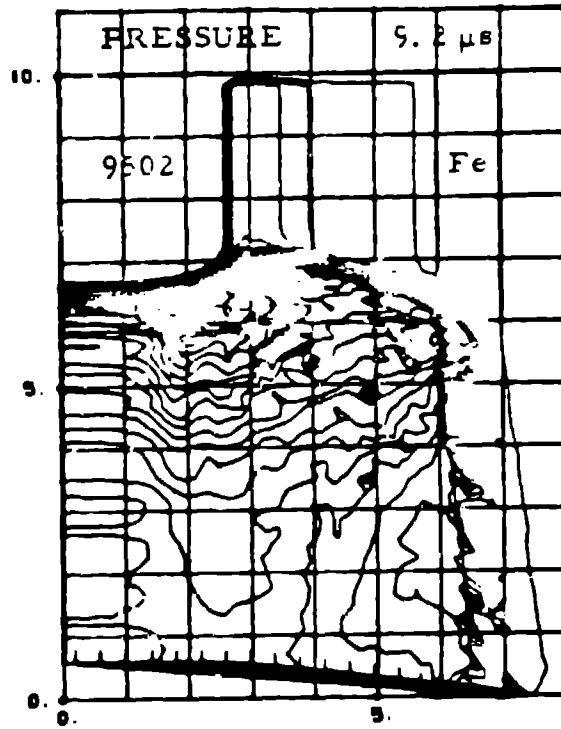
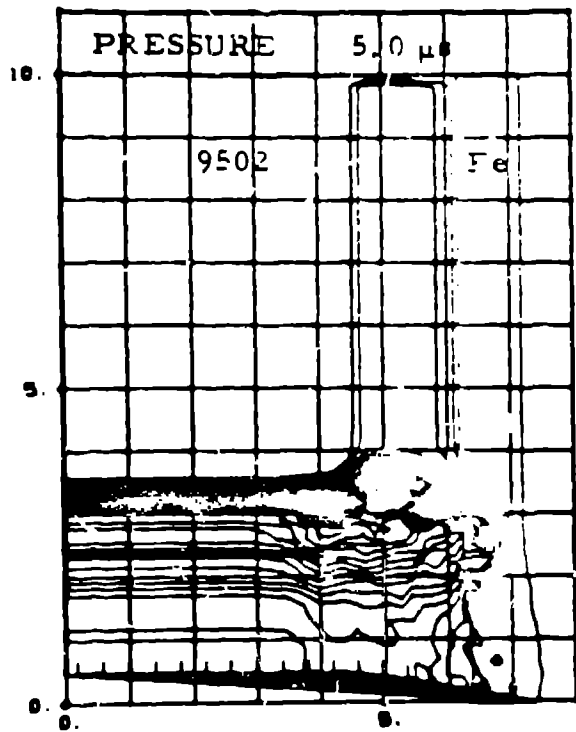


FIGURE 6

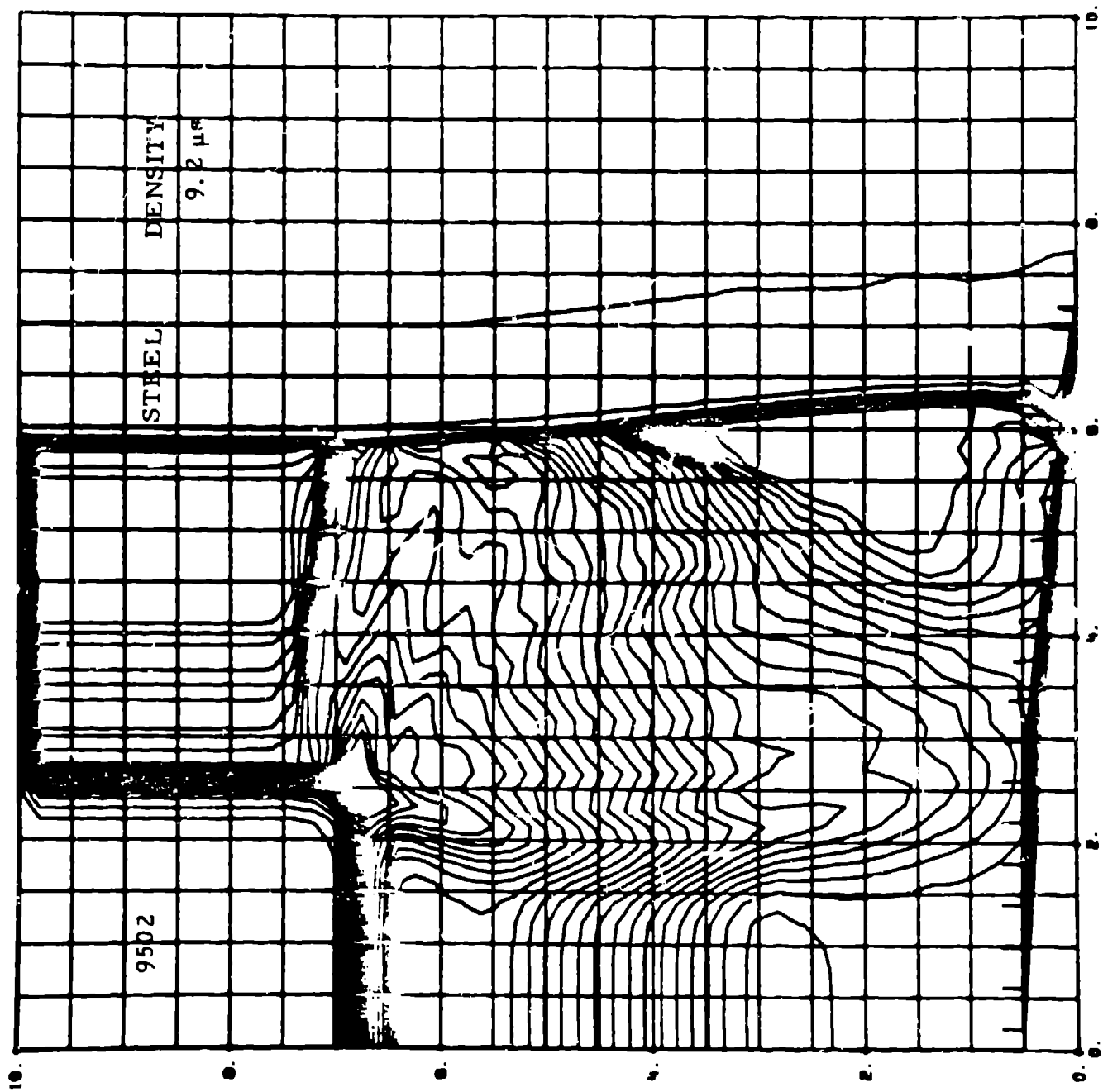


FIGURE 7

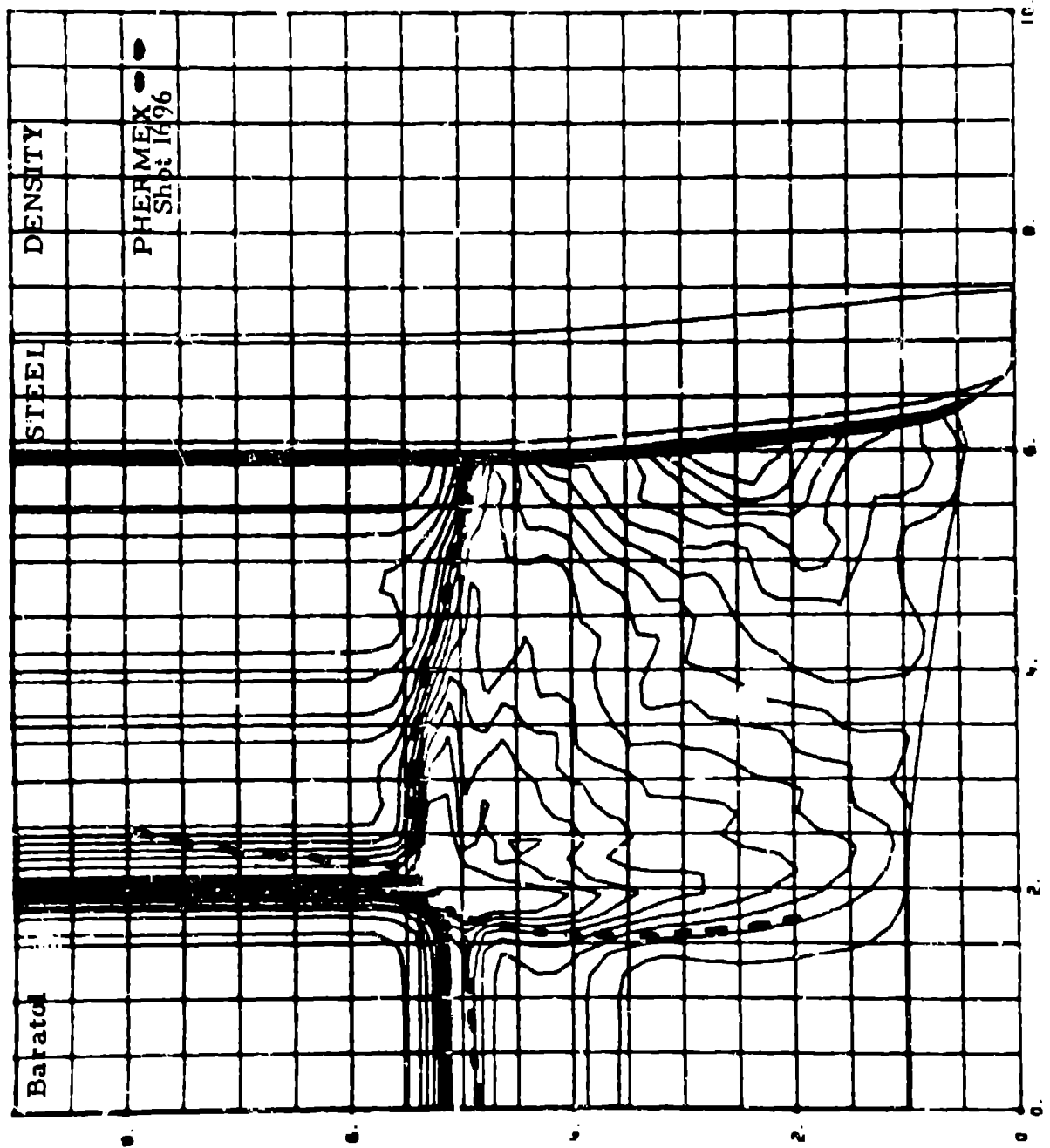


FIGURE 8

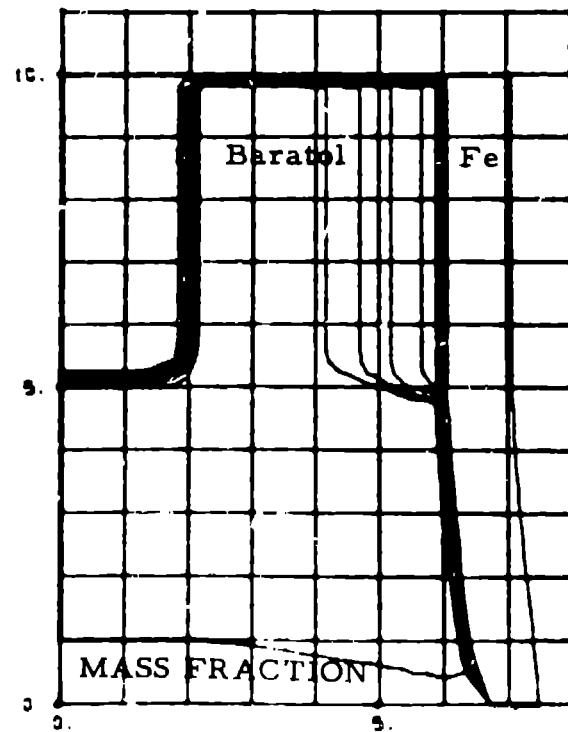
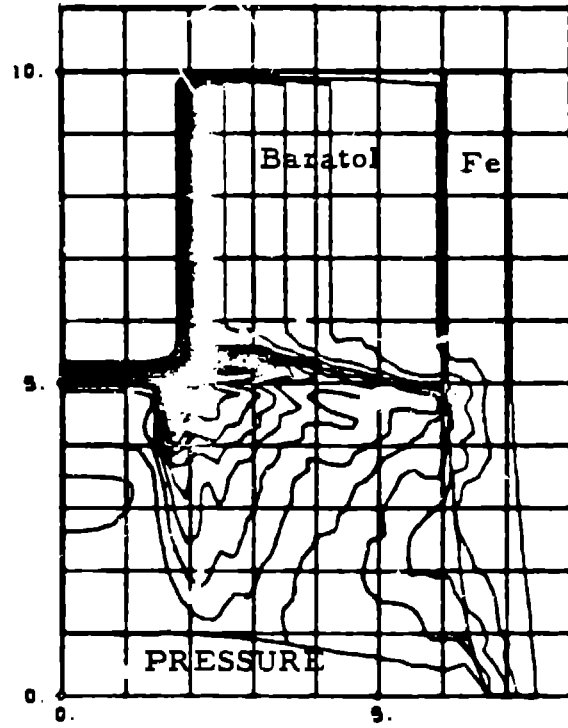


FIGURE 9