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Two-Dimensional Homogeneous and Heterogeneous Detonation Wave Propagation

by

Charles L. Mader
Charles A. Forest

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87545

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TWO-DIMENSIONAL HOMOGENEOUS AND HETEROGENEOUS

DETONATION WAVE PROPAGATION

by

Charles L. Mader and Charles A. Forest

ABSTRACT

The process of detonation propagation of homogeneous explosives along surfaces may be described using resolved reaction zones, Arrhenius rate laws, and two-dimensional reactive hydrodynamic calculations. The wave curvature increases with increasing reaction zone thickness.

The process of detonation propagation and failure of heterogeneous explosives along surfaces and around corners may be described if the decomposition that occurs by shock interactions with density discontinuities is described by a burn rate determined from the experimentally measured distance of run to detonation as a function of shock pressure, the reactive and nonreactive Hugoniot, and the assumption that the reaction rate derived near the front can be applied throughout the flow.

I. INTRODUCTION

The time-dependent behavior of detonations with resolved reaction zones in condensed homogeneous explosives has been described[1,2] using an Arrhenius rate law. In Ref. 1, a nitromethane detonation failure, resulting from a side rarefaction cooling the explosive inside its reaction zone, was calculated and the experimentally observed rarefaction velocity was numerically reproduced. Here we extend the study to nitromethane detonations proceeding perpendicular to various metal surfaces and examine wave curvature and failure as a function of reaction zone thickness.

Experimental observations[3] of detonation waves in heterogeneous explosives proceeding perpendicular to metal plates showed very little wave curvature after a large plane-wave-initiated cylindrical explosive charge had run several charge diameters. An empirical model with an unresolved explosive reaction zone and programmed to maintain a constant velocity, plane detonation front reproduced the experimental observations. Because the basic mechanism of heterogeneous shock initiation is shock interaction at density discontinuities producing local hot spots that decompose and add their energy to the flow, models such as the heterogeneous sharp shock partial reaction burn model[4] have been developed to model the flow. These models, however, could not be used to solve two-dimensional reactive flows because they did not respond realistically to local state variables. For this study we used a new model, Forest Fire, to describe the hot spot reaction rate in the bulk of the heterogeneous explosive to detonations proceeding perpendicular to metal plates, to detonations turning corners, and to detonations proceeding along free surfaces for shock sensitive and insensitive explosives.

II. HOMOGENEOUS DETONATIONS

Reference 1 shows that the nitromethane reaction zone is ~2500 Å long and that it is probably pulsating about the steady-state values if the usual activation energies (E) and frequency factors (Z) are appropriate. It is impossible to make calculations with such small reaction zones being resolved for systems that are the size usually studied experimentally. We can study the effect the size of the reaction zone has on the flow by increasing the frequency factor to scale up the size of the reaction zone. We can also eliminate the pulsating nature of the reaction zone by using an activation energy that results in a steady, nonpulsating flow. As shown in Ref. 1, 30-kcal/mole activation energy results in steady flow, and by varying the frequency factor, we can have reaction zones of various thicknesses. However, because such scaling results in unrealistically large reaction zones, care is required when extrapolating the calculated results to real experiments.

Experimental measurements[3] of the detonation wave arrival of nitromethane across the surface of a charge have shown that there is remarkably little curvature even after the wave has run many charge diameters in a large plane-wave-initiated cylindrical charge. In our first study we investigated how a resolved reaction zone in nitromethane proceeds perpendicular to a copper surface. Figure 1 shows that the larger reaction zone resulted in an increased wave curvature. We performed the calculations using the 2DL reactive hydrodynamic code[5] with a 0.01-cm-square mesh. The equation-of-state parameters used for nitromethane are described in Ref. 6, and those used for copper aluminum and Plexiglas are described in Ref. 7. The detonation wave was started using the same steady-state piston described in Ref. 5. The absolute pressure value is plotted in each figure. The slight discontinuity at the nitromethane-copper interface is from the different amounts of artificial viscosity in the two materials.

Because the detonation wave curvature decreases with decreasing reaction zone thickness, it is not surprising that nitromethane, with its very thin reaction zone, shows very little wave curvature. The reason for this result appears to be that although the head of the rarefaction goes into the reaction zone at the same speed regardless of the reaction zone thickness, the wave curvature depends on how much the confining surface or wall moves out during passage of the reaction zone. Because lower density walls permit more outward motion than higher density walls, the lower density walls result in more curved fronts. Shortening the reaction zone keeps the wall from moving outward as much during transit, which results in less shock curvature. The problem's two critical parameters are the rarefaction speed and the reaction zone length.

Figure 2 shows that the increased divergence resulting from cylindrical geometry permits the outward moving surface to be more effective in increasing the wave curvature. The effect of changing the density of the confining wall is shown in Fig. 3, where the detonation wave proceeds along a copper and then an aluminum wall. Compared with the copper wall in Fig. 1, the curvature increases and the reaction zone becomes thicker as the reaction proceeds along the aluminum wall. These results qualitatively agree with the experimental observations.

Campbell, Malin, and Holland[8] observed that thin metal foils were as effective as thick cylinders of the same metal at confining the nitromethane detonation wave. In Fig. 4 the thickness of the confining copper wall is decreased, but the shock front and reaction zone profile is the same as in Fig. 1. Other calculations showed that the reaction zone must be thick enough for the rarefaction from the outer copper surface to return to the nitromethane-copper interface before passage of the reaction zone for the reaction zone and wave curvature to be affected by the thickness of the confining metal.

The effect of small grooves in confining brass plates upon the nitromethane detonation wave was studied by P. A. Persson and coworkers.[9] Two of their smear camera traces are shown in Fig. 5. They observed that the depth of the hole determines whether the failure wave arrives at the center of the explosive and that the width of the hole determines the width of the failure wave. Although the actual scale of the experiment and of the reaction zone are too different to be described in one numerical experiment with resolved reaction zones, we can study the main features of the flow. Figure 6 shows that the arrival of the reaction zone at the hole results in a thickening and cooling of the reaction zone until the shock reflects off the top surface of the groove, which results in additional reaction. The reaction zone then proceeds slowly to catch up with the shock front. A greater groove width results in reflected pressures and temperatures being lower, whereas greater groove height results in a thicker reaction zone. As described in Ref. 10, the experimental light is the thermal radiation from the hot explosive. Only near the end of the reaction zone is the material hot enough to produce enough recordable light. The emitted light is absorbed in the partially reacted explosive ahead of it. When the reaction zone is thick enough, no light is recorded. The discontinuity in the light intensity corresponds to a sharp change in the distance from the shock front to the region hot enough to produce recordable light. This complicated behavior makes it difficult to compare the smear camera traces with the calculated results; however, the qualitative features of the flow are apparently well described by the numerical model.

In another interesting experiment, Davis[11] studied the propagation of a nitromethane detonation into an expanding geometry. His smear camera traces (Fig. 7) show a nitromethane detonation proceeding between copper walls initially 1.27 cm apart and funneling out at 15 to 10°. It is surprising that the small angles can result in failure of the detonation wave to propagate. Calculated profiles for the 10° copper funnel are shown in Fig. 8, where the reaction zone thickens and a failure wave, observed experimentally, forms in the calculation. The Arrhenius kinetic model gives a qualitative description of the process of a homogeneous detonation propagating along surfaces. However, it is not possible to give a quantitative description of failure diameter and wave curvature because the reaction zone and experimental scale are not realistically modeled in the numerical calculation.

The detonation wave curvature increases with increasing reaction zone thickness. A thin metal cylinder may prevent detonation failure if the reaction zone is thin enough for the rarefaction from the outside metal surface to arrive in the detonation products after passage of the reaction zone. The observed failure and reignition of nitromethane detonation by holes in confining surfaces can be reproduced qualitatively by the Arrhenius kinetic model.

III. HETEROGENEOUS DETONATIONS

Heterogeneous explosives, such as PBX 9404 or Composition B, show a different behavior than homogeneous explosives 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.

Because previous modeling of heterogeneous shock initiation of explosives has proved useful only for certain applications,[4] we developed Forest Fire to model the bulk decomposition of a heterogeneous explosive. Forest Fire, described in Appendix A, may be used to reproduce the explosive behavior in many one- and two-dimensional situations where data are available. Forest Fire gives the rate of explosive decomposition as a function of local pressure, or any other state variable, in the explosive. In this section we describe the results of applying the Forest Fire description of heterogeneous explosive detonation propagation to detonation propagation along surfaces and around corners.

We used the Los Alamos Scientific Laboratory (LASL) radiographic facility, PHERMEX,[12] to study detonation wave profiles in heterogeneous explosives as they proceed up metal surfaces.[3,12] PHERMEX was also used to study the profiles when a detonation wave in Composition B or X-0219 turns a corner.[13,14]

As described in Ref. 3, a radiographic study was made of a 10.16-cm cube of Composition B, with and without tantalum foils, initiated by a plane wave lens confined by 2.54-cm-thick aluminum plates. The radiographs show a remarkably flat detonation front followed by a large decrease in density originating near the front of the wave as it intersects the metal plate.

A numerical calculation using Arrhenius kinetics results in considerable curvature of the detonating wave if realistic kinetic parameters are used. The Forest Fire model of heterogeneous shock initiation results in a calculated flow that resembles that observed experimentally (Fig. 9). This result suggests that the observed detonation behavior is a consequence of the heterogeneous shock initiation processes. Therefore, the more insensitive explosives should give greater wave curvature and have larger failure diameters. Explosives initiated and burned with a heterogeneous shock initiation model, such as Forest Fire, do not show scaling behavior; therefore, failure depends upon the pressure magnitude and how long it can be maintained. The Forest Fire model results agree with experimental observations for many explosives.

Venable[13] performed a radiographic study of a Baratol plane-wave-initiated Composition B slab detonation proceeding perpendicular to an aluminum block and up a 45° wedge (Fig. 10) and around a 90° block (Fig. 11). Calculations using the Forest Fire model reproduced the radiographic features shown in Figs. 12 and 13. However, this was not a very significant test of the Forest Fire model because the Chapman-Jouguet (C-J) volume burn technique[15] or programmed burn technique of burning explosives[16] can give similar profiles to those observed experimentally. An Arrhenius burn with a resolved reaction zone will not give detonation wave behavior such as observed experimentally.

Dick[14] performed a radiographic study of a detonation wave proceeding up a block of a very insensitive TATB-based explosive, X-0219, and its failure to propagate completely around a corner. Dick's experimental profiles and the calculated profiles using the Forest Fire model are shown in Fig. 14. The agreement shown is encouraging. However, the amount of explosive that remains undecomposed after passage of the shock wave depends primarily upon the curvature of the detonation wave before it turns the corner. If the wave is sufficiently curved, the detonation proceeds like a diverging detonation wave and little or no explosive remains undecomposed. If the wave is flat, or nearly so, when it arrives at the corner, then much more partially decomposed explosive will remain after shock passage. Because the actual experiment was performed with air in the corner, the Lagrangian calculation that required some low-density material in the corner (we used Plexiglas) underestimates the amount of explosive that remains undecomposed. An aluminum corner results in very little undecomposed explosive, and a lower density material slightly increases the amount of undecomposed explosive.

To study this system in a more realistic geometry, we used the Eulerian code 2DE[17] because it can handle large distortion problems such as an explosive-air interface. The calculated results using the Forest Fire burn are shown in Fig. 15. Again, the results depend upon the detonation wave profile before it reaches the corner. An interesting aspect of the calculational study was that if the wave was started out flat, the explosive region near the explosive-air interface remained partially decomposed and the detonation wave never completely burned across the front until the wave became sufficiently curved at the front and near the interface. The failure process of a heterogeneous explosive must be a complicated interaction of the effective reaction zone thickness (presumably dependent upon the void and resulting hot spot size and decomposition rate), which determines how flat the wave should be and the curvature required for decomposition to occur near the surface of the charge. Because details of the hot spot reaction zone are missing from our calculation and model, much work remains to be done before realistic calculations of failure radius can be achieved.

Tanaka and Hikita[18] are now attempting to model charge radius effects using large Arrhenius-type reaction zones.

Calculations were performed using the Forest Fire burn in 2DL for 0.7- and 1.3-cm-radius cylinders of X-0219 confined by Plexiglas and for half-thickness slabs of 1.3 and 2.6 cm. The thinner charges developed greater curvature and the 0.7-cm-radius cylinder failed to propagate. Calculations were also performed using the Forest Fire burn in the 2DE code for 0.65- and 1.3-cm-radius cylinders of X-0219 confined by air. The 0.65-cm-radius cylinder failed to propagate as shown in Fig. 16. The experimentally determined failure radius is 0.75 cm. Similar calculations were performed for 9404, Composition B, and X-0290. Results are compared with experimental failure radius in Table I. The calculated results depend upon the initiation method and the burn resolution. These results suggest that the dominant feature of failure in heterogeneous explosives is the same hot spot decomposition reaction that determines the shock initiation behavior.

IV. CONCLUSIONS

The process of detonation initiation and propagation of homogeneous explosives along surfaces may be qualitatively described using Arrhenius kinetics. However, because the reaction zone scale is orders of magnitude smaller than the scale of the experiments of interest, quantitative calculations are difficult to

TABLE I

EXPERIMENTAL AND CALCULATED FAILURE RADII

Explosive	Experimental Failure Radius (cm)	Calculated Results
X-0219	0.75 ± 0.05	1.3 propagated 0.7 failed
X-0290	0.45 ± 0.05	0.5 propagated 0.3 failed
Comp B	0.214 ± 0.03	0.3 propagated 0.2 failed
9404	0.06 ± 0.01	0.1 propagated 0.05 failed

achieve. The ability of thin metal cylinders to prevent detonation failure in nitromethane and the observed failure and reignition of nitromethane by changes in confinement geometry may be qualitatively reproduced by numerical reactive fluid dynamics with Arrhenius kinetics.

Detonation initiation and propagation of heterogeneous explosives cannot be described adequately using Arrhenius kinetics. The Forest Fire model can describe the decomposition that occurs from hot spots formed by shock interactions with density discontinuities in heterogeneous explosives and can also describe the passage of heterogeneous detonation waves around corners and along surfaces. Failure or propagation of a heterogeneous detonation wave depends upon the interrelated effects of the wave curvature and the shock sensitivity of the explosive. Some of the basic differences have been established between homogeneous and heterogeneous explosive propagation and failure.

ACKNOWLEDGMENTS

We gratefully acknowledge the assistance and contributions of William C. Davis, John Bdzil, Wildon Fickett, Bobby G. Craig, Douglas Venable, Richard Dick, and Elizabeth Marshall, LASL; Jim Kennedy, Sandia Corporation; and Per Anders Persson, Swedish Detonic Research Foundation.

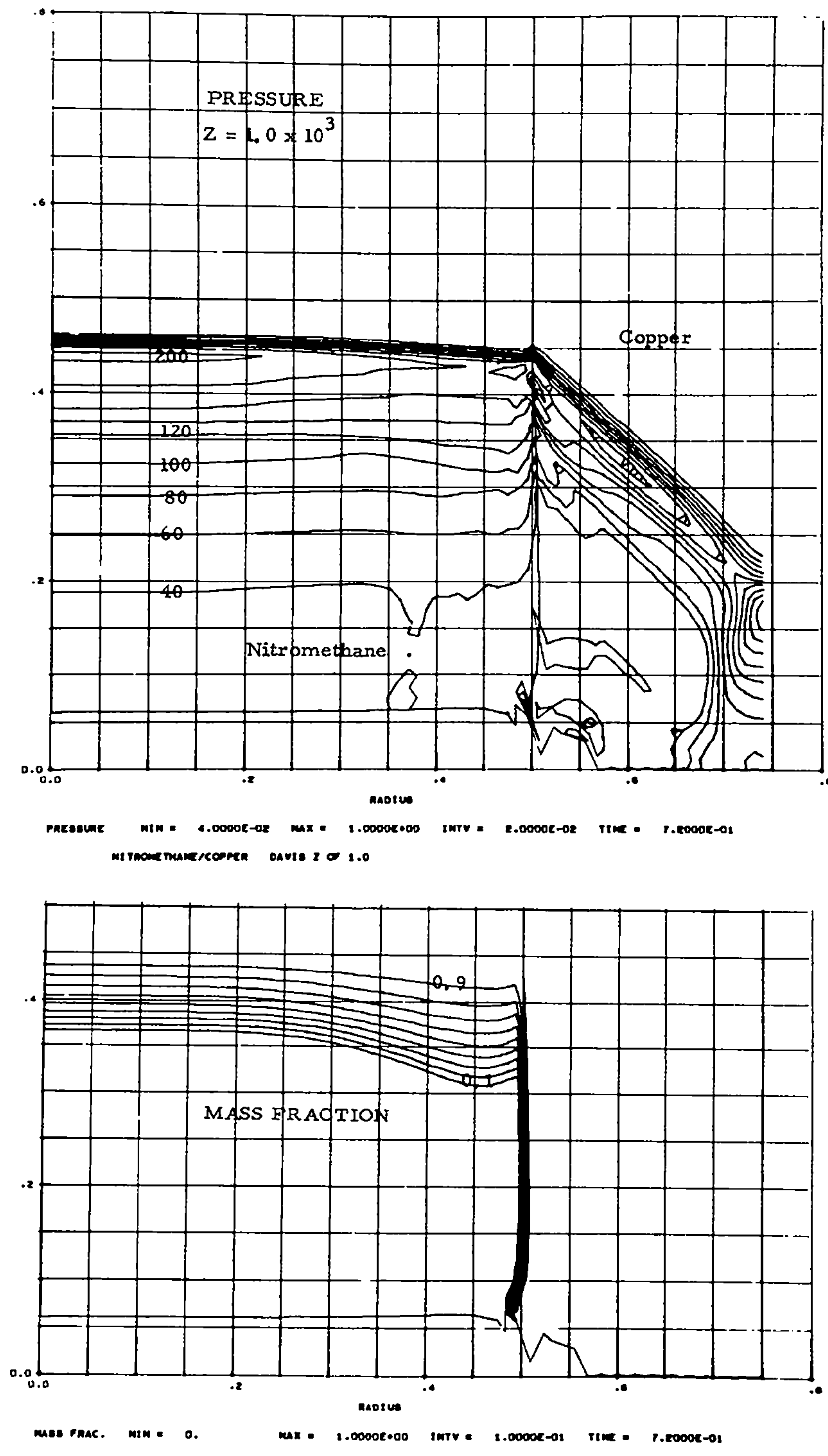
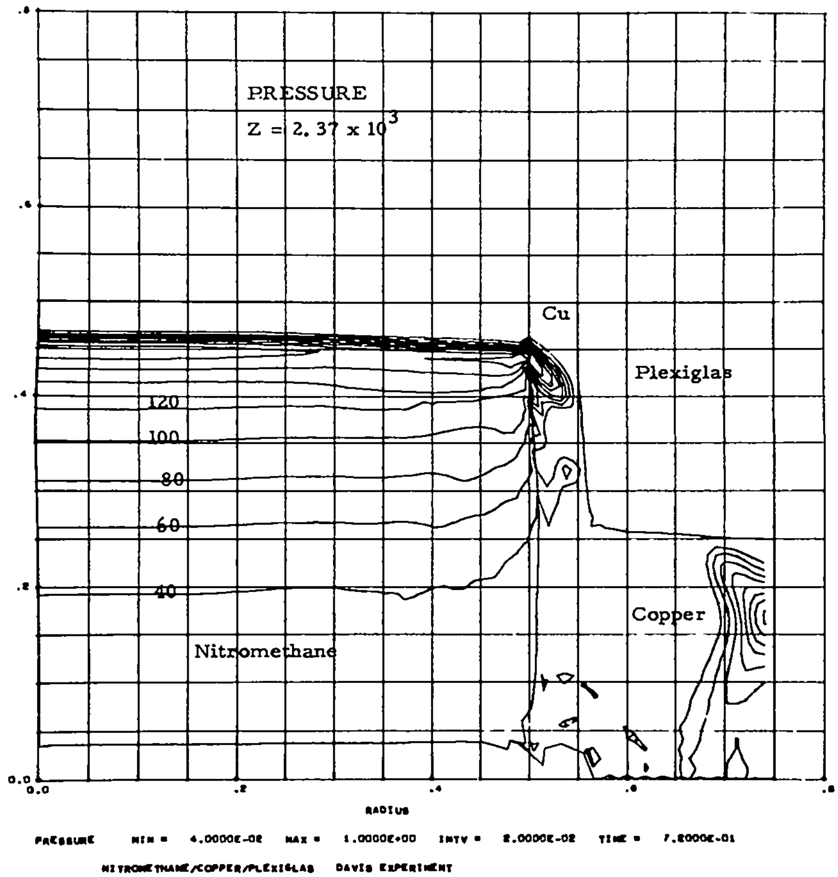


Fig. 1.
Resolved nitromethane zone of various thicknesses proceeding perpendicular to a copper plate. The nitromethane activation energy was 30 kcal/mole. The pressure profiles are given at 20-kbar intervals, and the mass fraction of undecomposed explosive interval is 0.1. $Z = 1.0 \times 10^3$, 2.37×10^3, and 6.0×10^3.


PRESSURE
Z = 2.37 x 10^3
Cu
Plexiglas
120
100
80
60
40
Copper
Nitromethane
0.0
.2
.4
.6
.8
RADIUS
PRESSURE MIN = 4.0000E-02 MAX = 1.0000E+00 INTV = 2.0000E-02 TIME = 7.2000E-01
NITROMETHANE/COPPER/PLEXIGLAS DAVIS EXPERIMENT

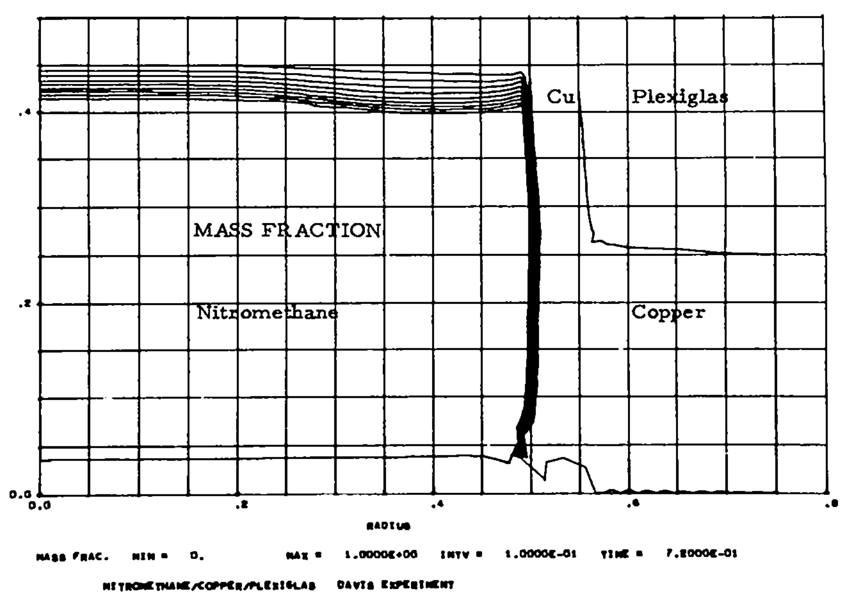

Cu
Plexiglas
MASS FRACTION
Nitromethane
Copper
0.0
.2
.4
.6
.8
RADIUS
MASS FRAC. MIN = 0. MAX = 1.0000E+00 INTV = 1.0000E-01 TIME = 7.2000E-01
NITROMETHANE/COPPER/PLEXIGLAS DAVIS EXPERIMENT

Fig. 1. (cont)

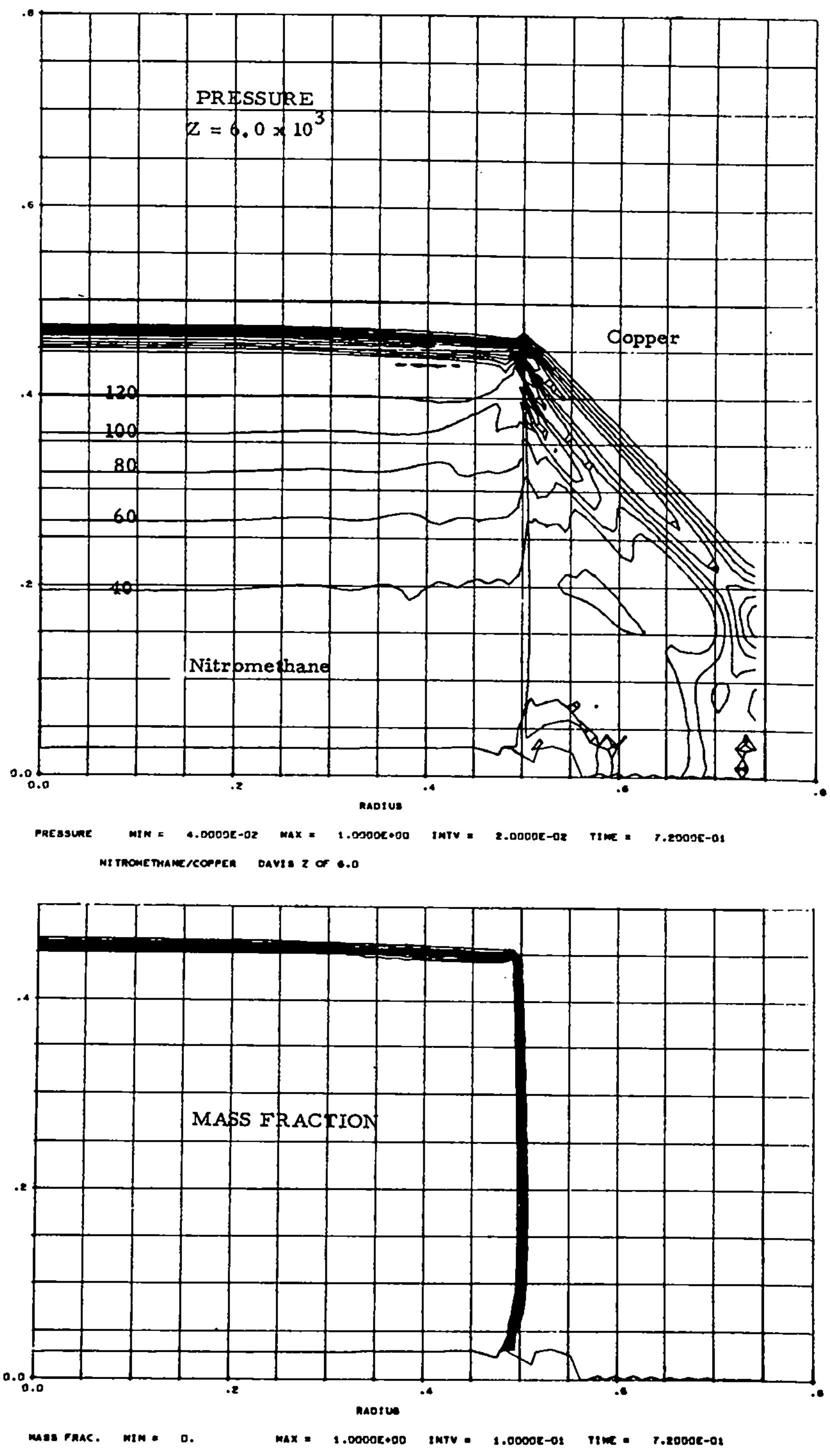

PRESSURE
Z = 6.0 x 10^3
Copper
120
100
80
60
40
Nitromethane
RADIUS
PRESSURE MIN = 4.0000E-02 MAX = 1.0000E+00 INTV = 2.0000E-02 TIME = 7.2000E-01
NITROMETHANE/COPPER DAVIS Z OF 6.0
MASS FRACTION
RADIUS
MASS FRAC. MIN = 0. MAX = 1.0000E+00 INTV = 1.0000E-01 TIME = 7.2000E-01
NITROMETHANE/COPPER DAVIS Z OF 6.0

Fig. 1. (cont)

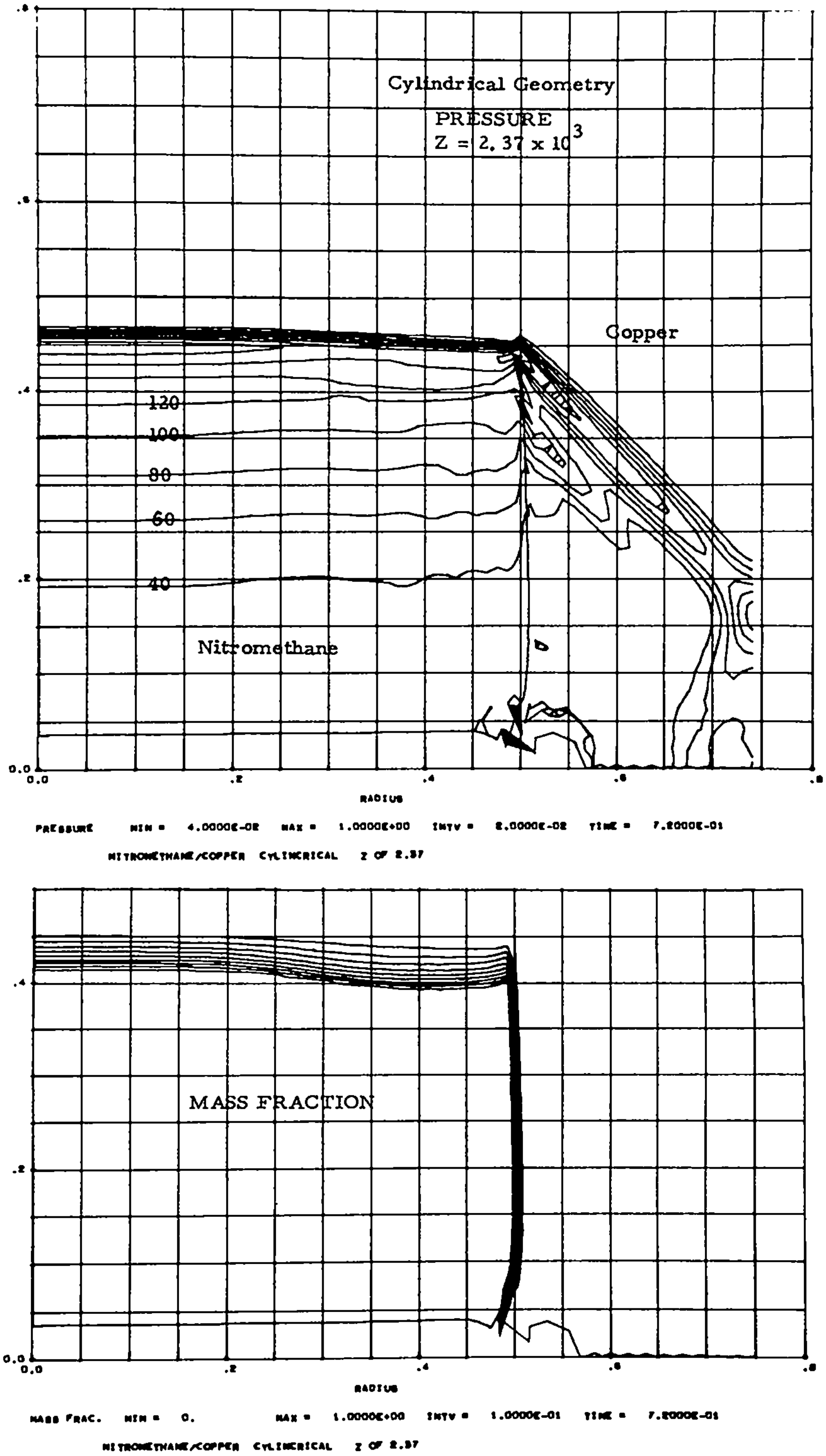


Fig. 2.
Resolved nitromethane zone proceeding perpendicular to a copper cylinder. $Z = 2.37 \times 10^3$; $E = 30$.

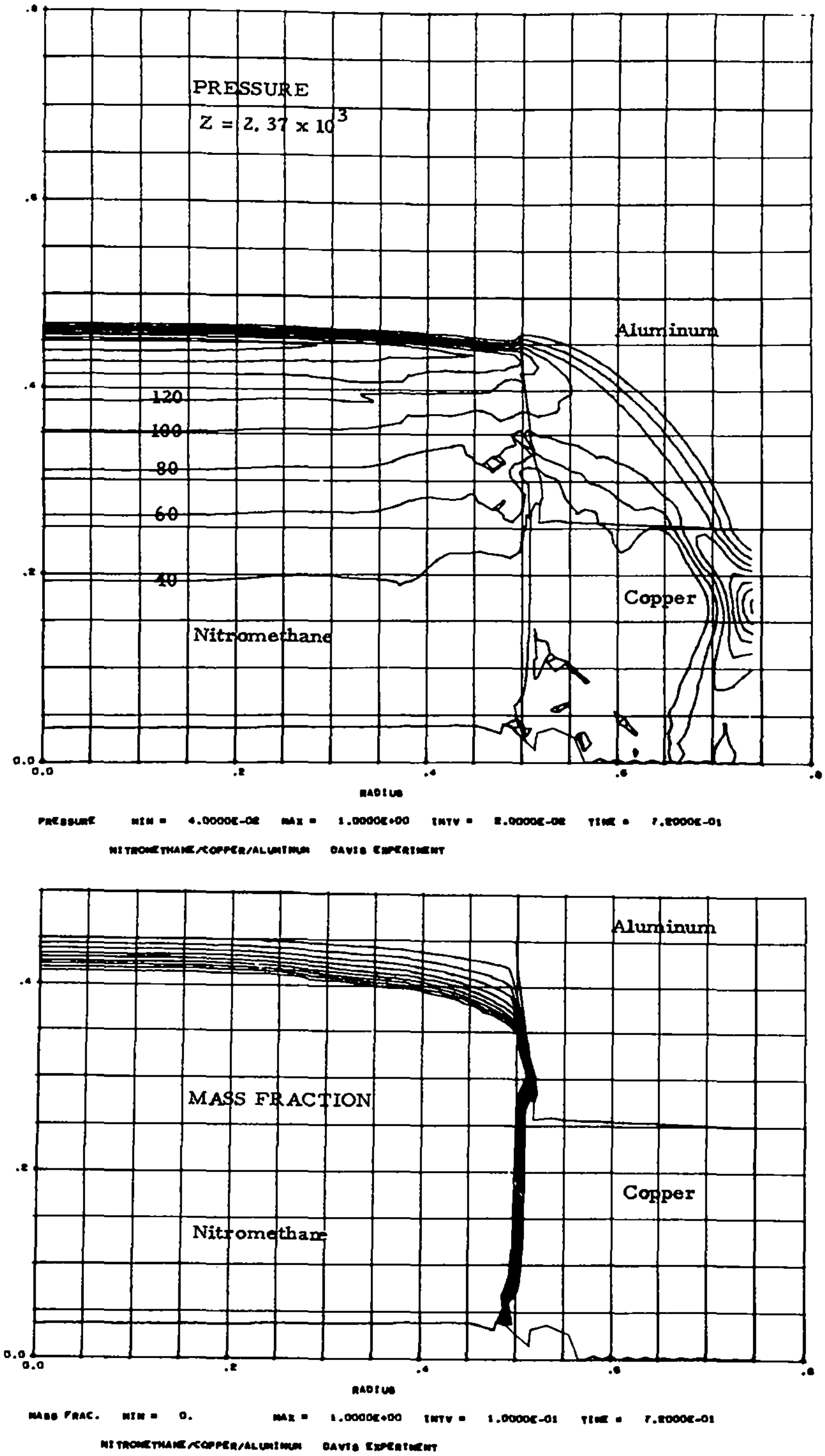


Fig. 3.
Resolved nitromethane zone proceeding perpendicular to a copper and then an aluminum wall. $Z = 2.37 \times 10^3$; $E = 30$.

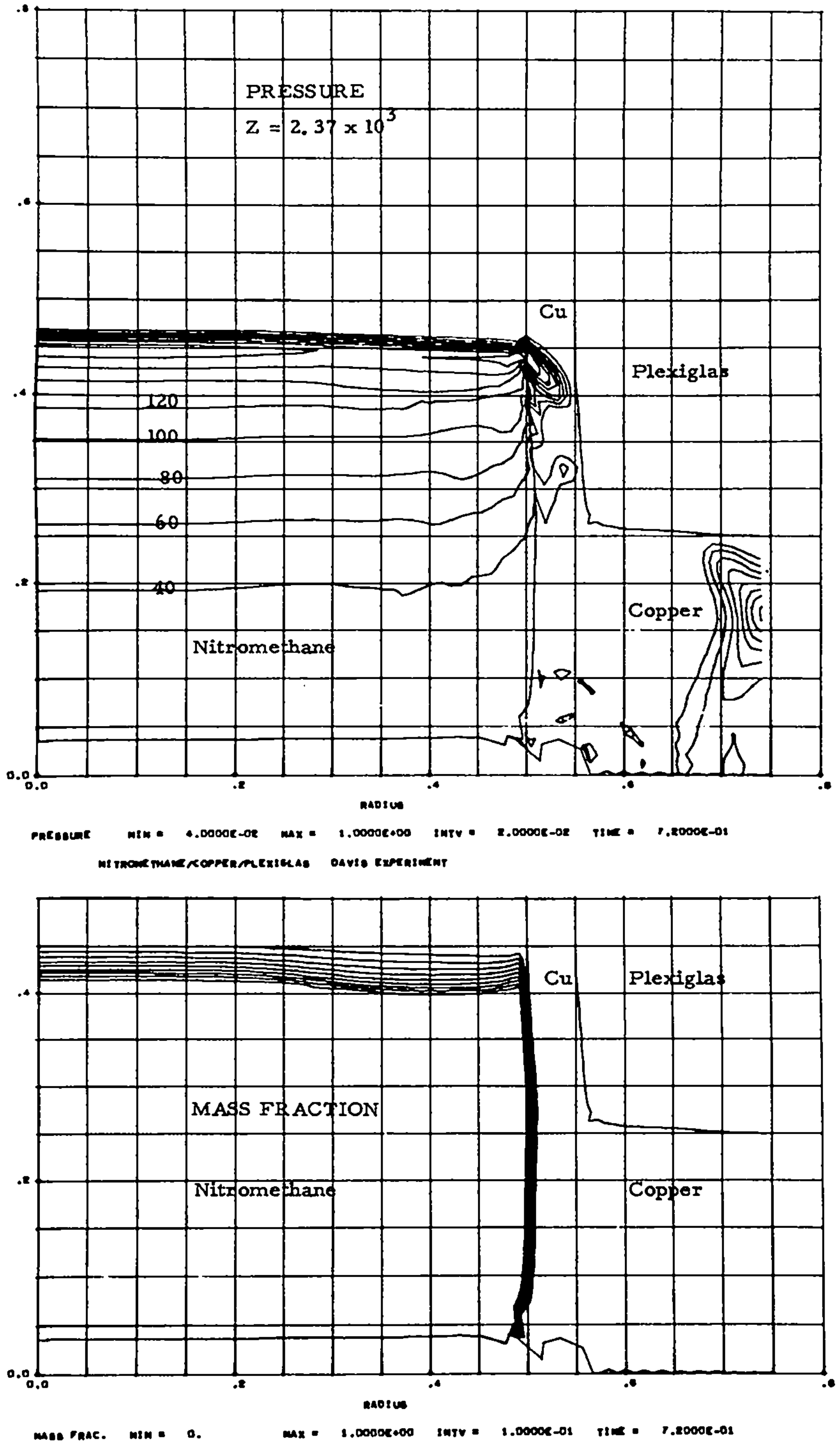
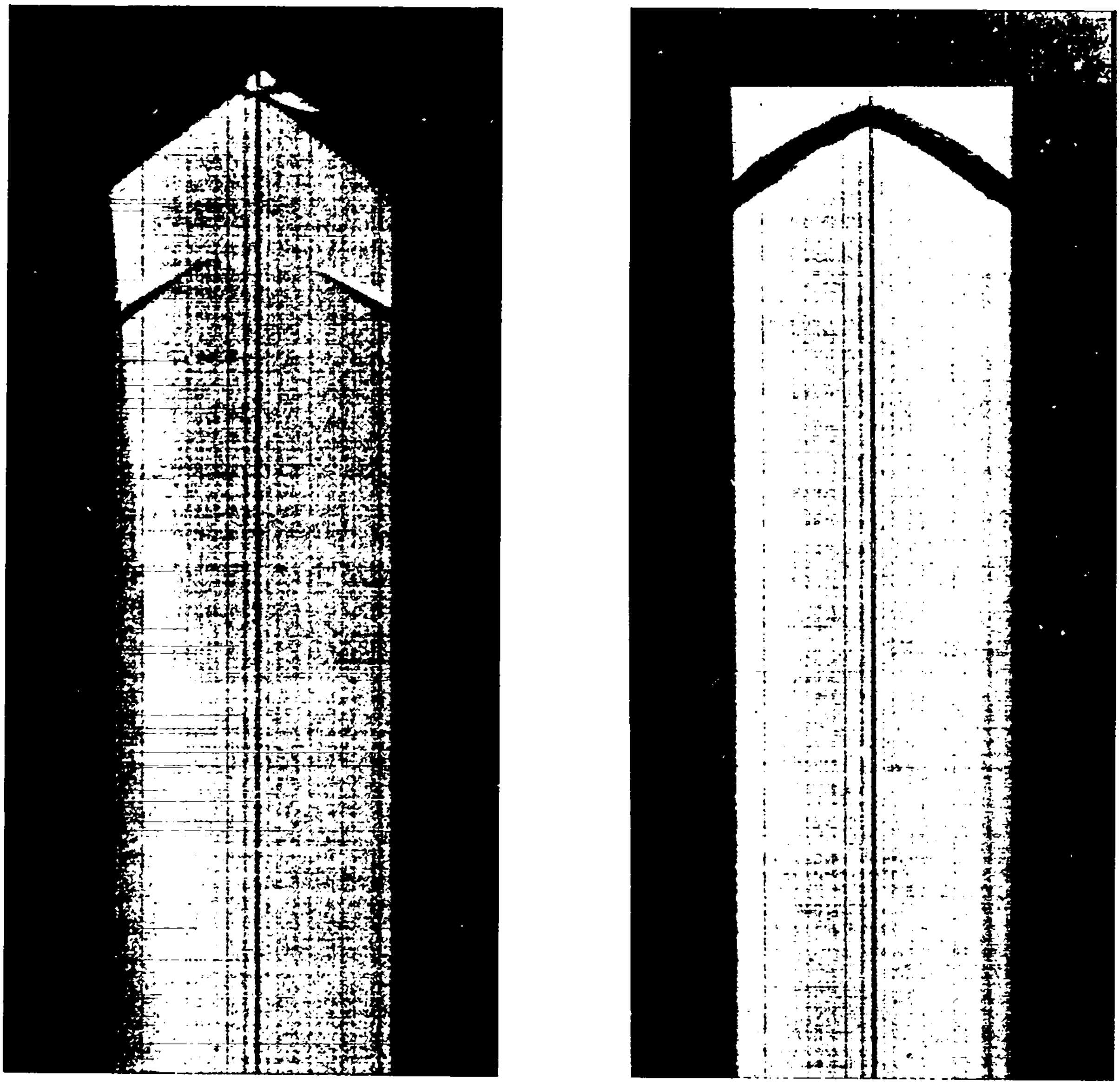


Fig. 4.
Resolved nitromethane reaction zone proceeding perpendicular to a copper plate that becomes about as thin as the reaction zone thickness. $Z = 2.37 \times 10^3$; $E = 30$.



(a) (b)

Fig. 5.
Persson's smear camera traces of a detonation wave proceeding between two brass plates 1 cm apart. The groove in (a) is 0.04 cm deep by 0.075 cm high; that in (b) is 0.075 cm deep by 0.15 cm high.

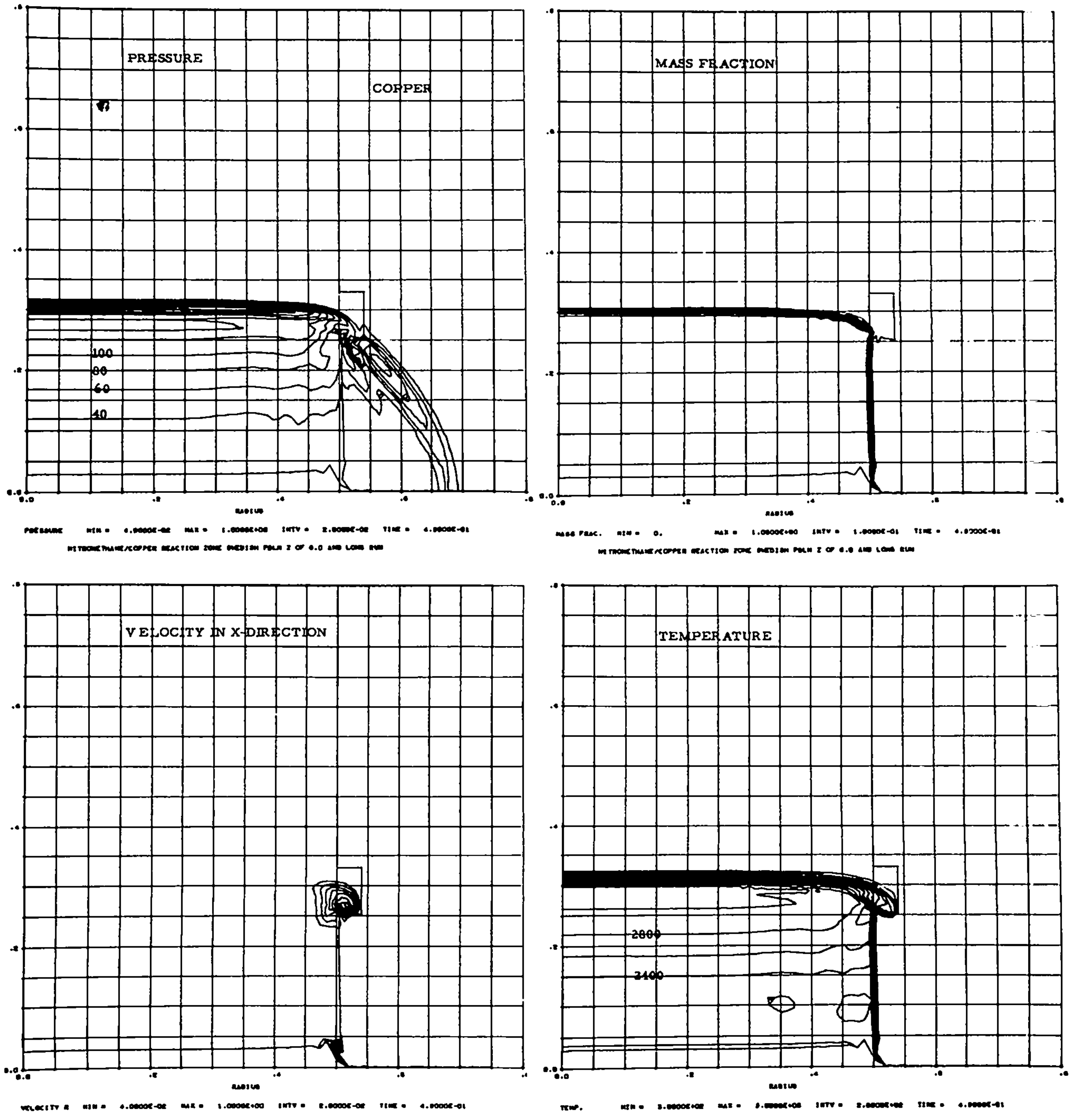


Fig. 6.
Nitromethane reaction zone with a 30-kcal/mole activation energy and a 6.0×10^3 frequency factor interacting with a 0.04- by 0.08-cm groove. The temperature interval is 200° and the velocity interval is 0.02 cm/μs.

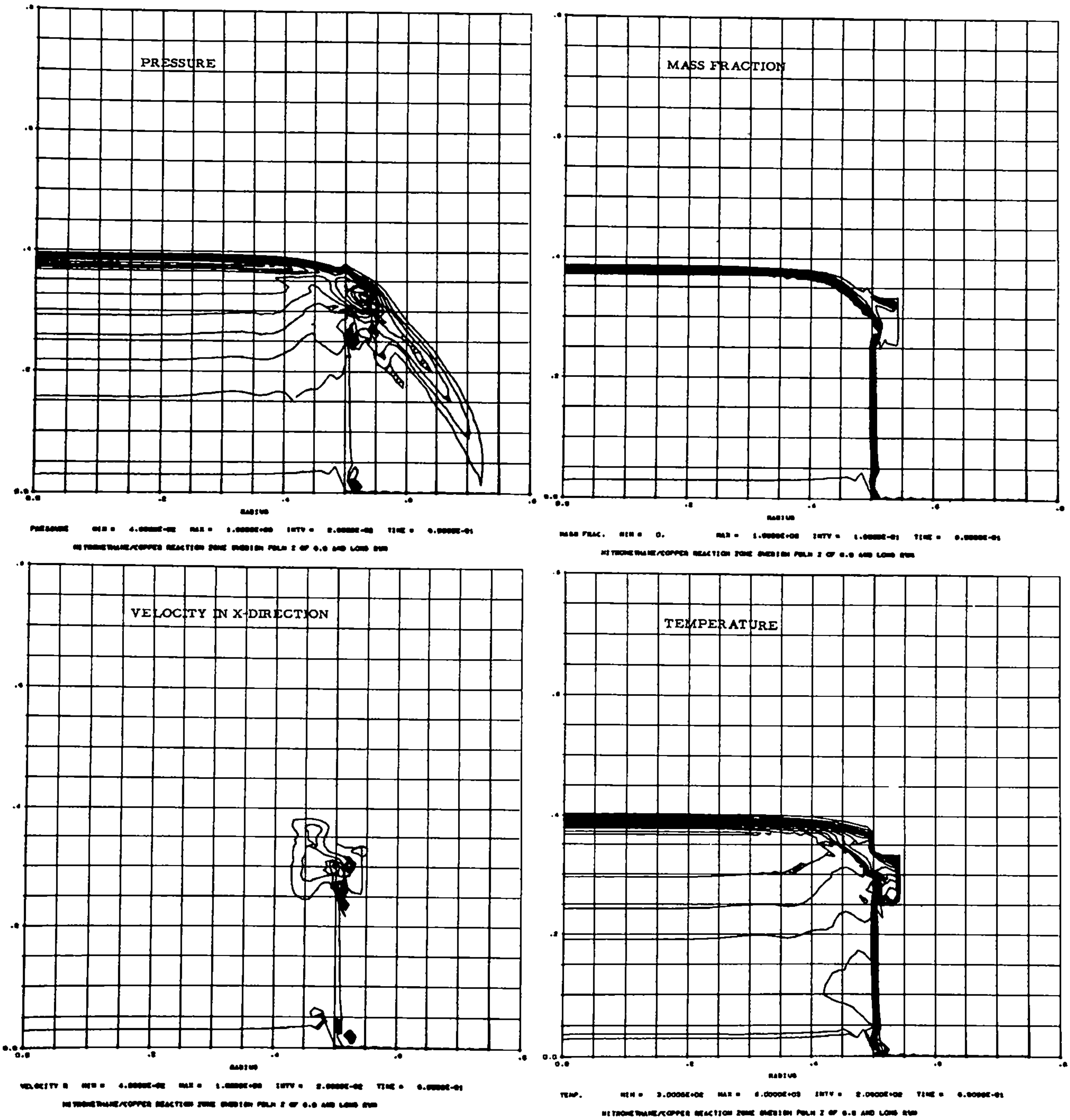

PRESSURE
MASS FRACTION
VELOCITY IN X-DIRECTION
TEMPERATURE

Fig. 6. (cont)

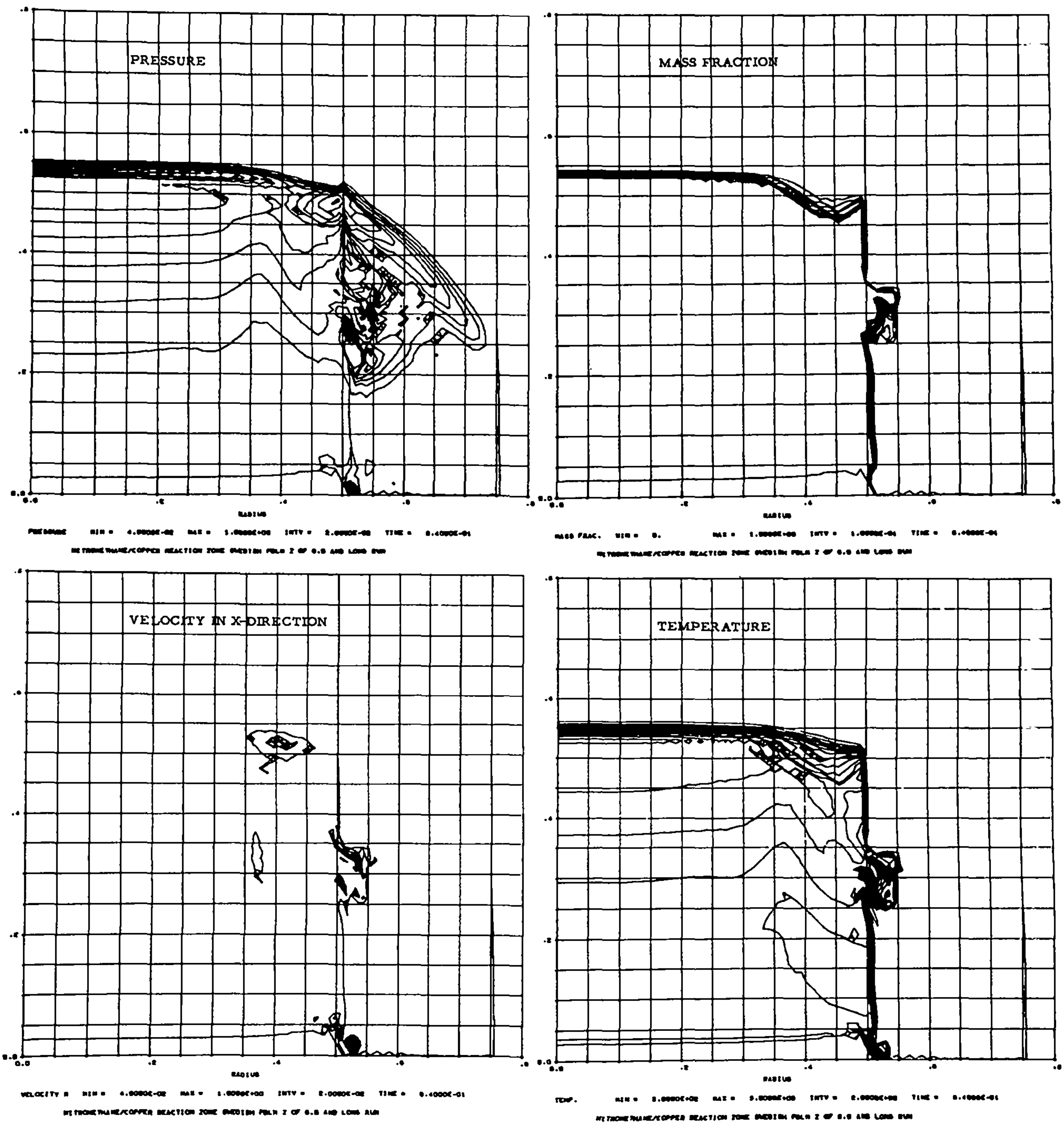

PRESSURE
MASS FRACTION
VELOCITY IN X-DIRECTION
TEMPERATURE

Fig. 6. (cont)

Fig. 7.
Davis's smear camera traces of a nitromethane detonation proceeding between copper walls initially 1.27 cm apart and funneling out at 15 to 10°. The 10° wall shows numerous failures and reignitions; the 15° wall results in detonation wave failure.

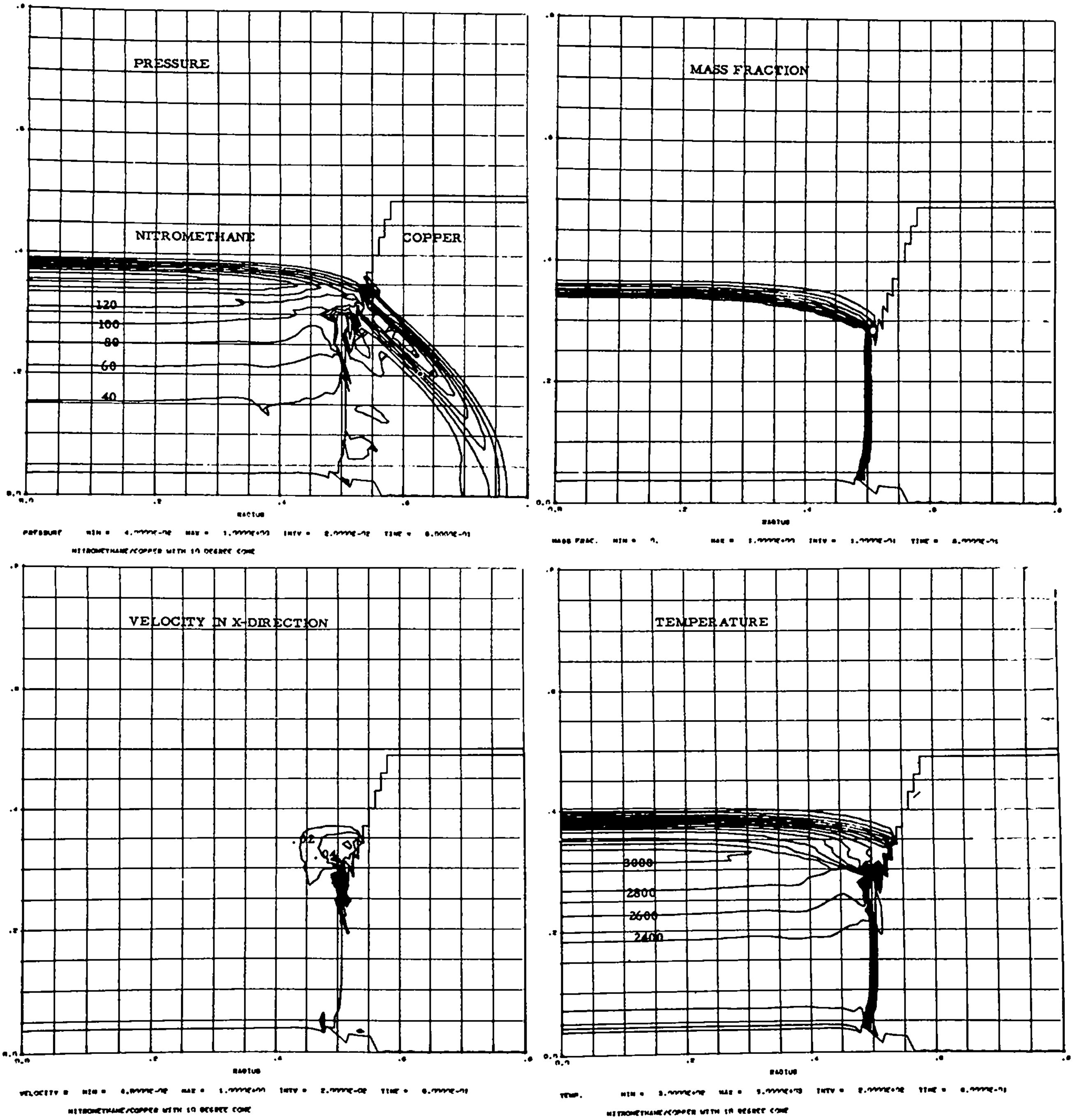


Fig. 8.
Resolved nitromethane detonation wave proceeding up a 10° copper funnel. The Z of 2.37×10^3 may be compared with Fig. 1.

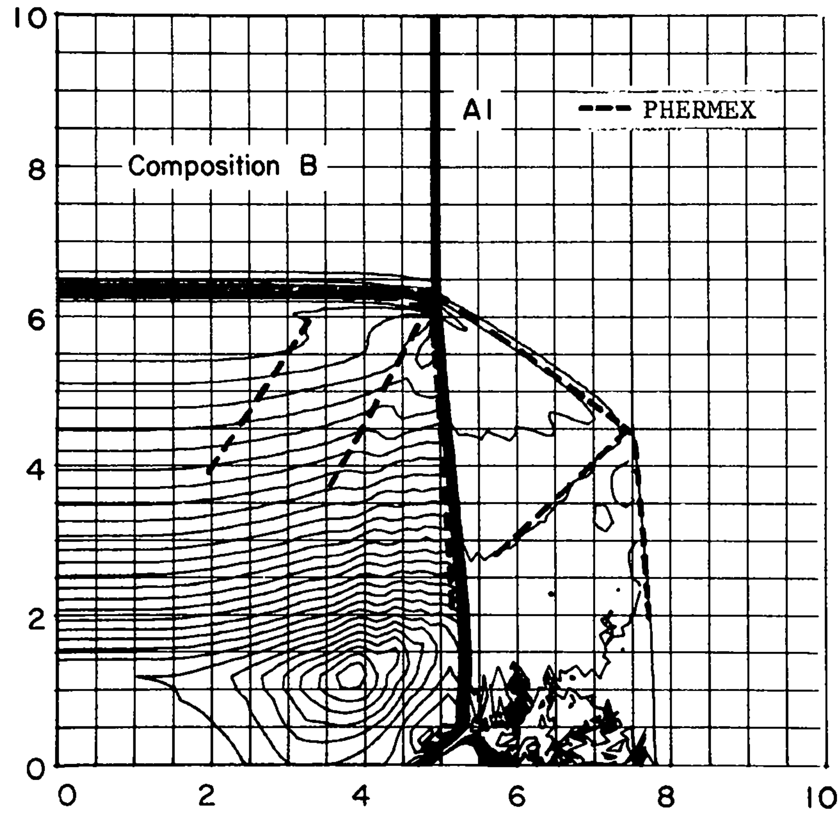


Fig. 9.
Constant density profiles at 8 μs for a 5-cm half-thickness slab of Composition B detonation by the Forest Fire model proceeding perpendicular to a 2.5-cm-thick aluminum plate. The prominent features of a radiograph of the flow are shown by dashed lines.

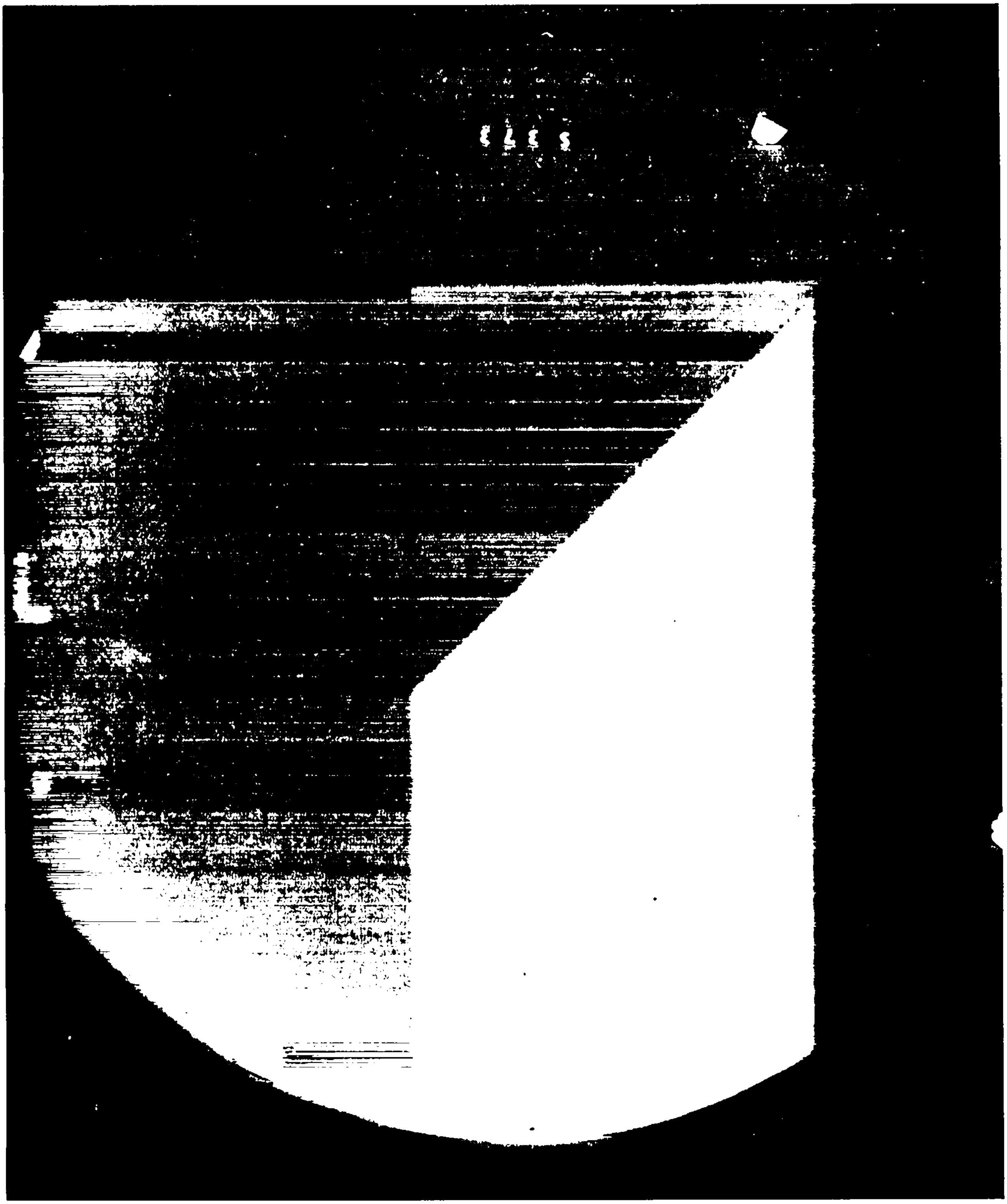


Fig. 10.
PHERMEX radiographs of a Composition B detonation wave proceeding up a 45° aluminum wedge.

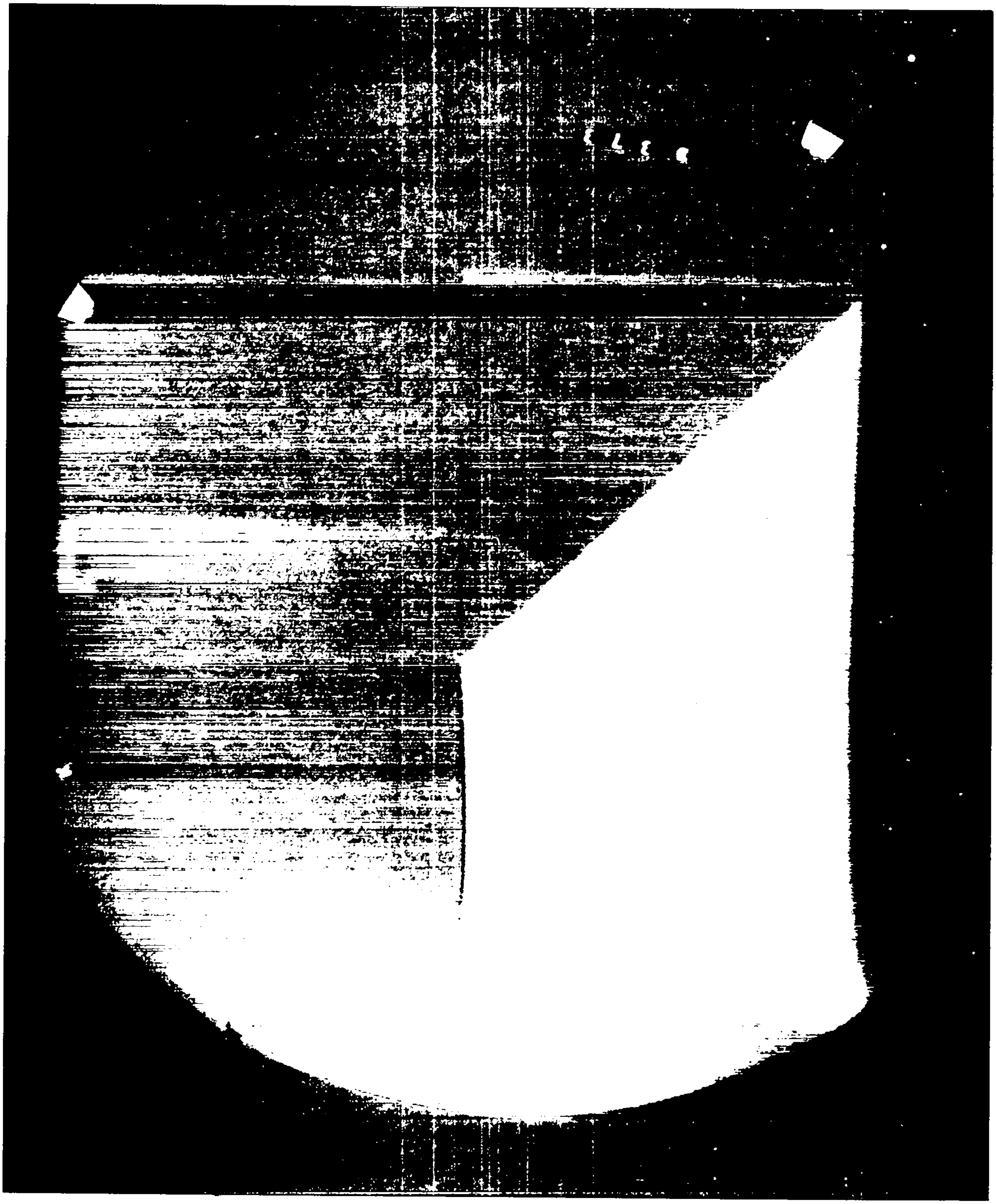


Fig. 10. (cont)

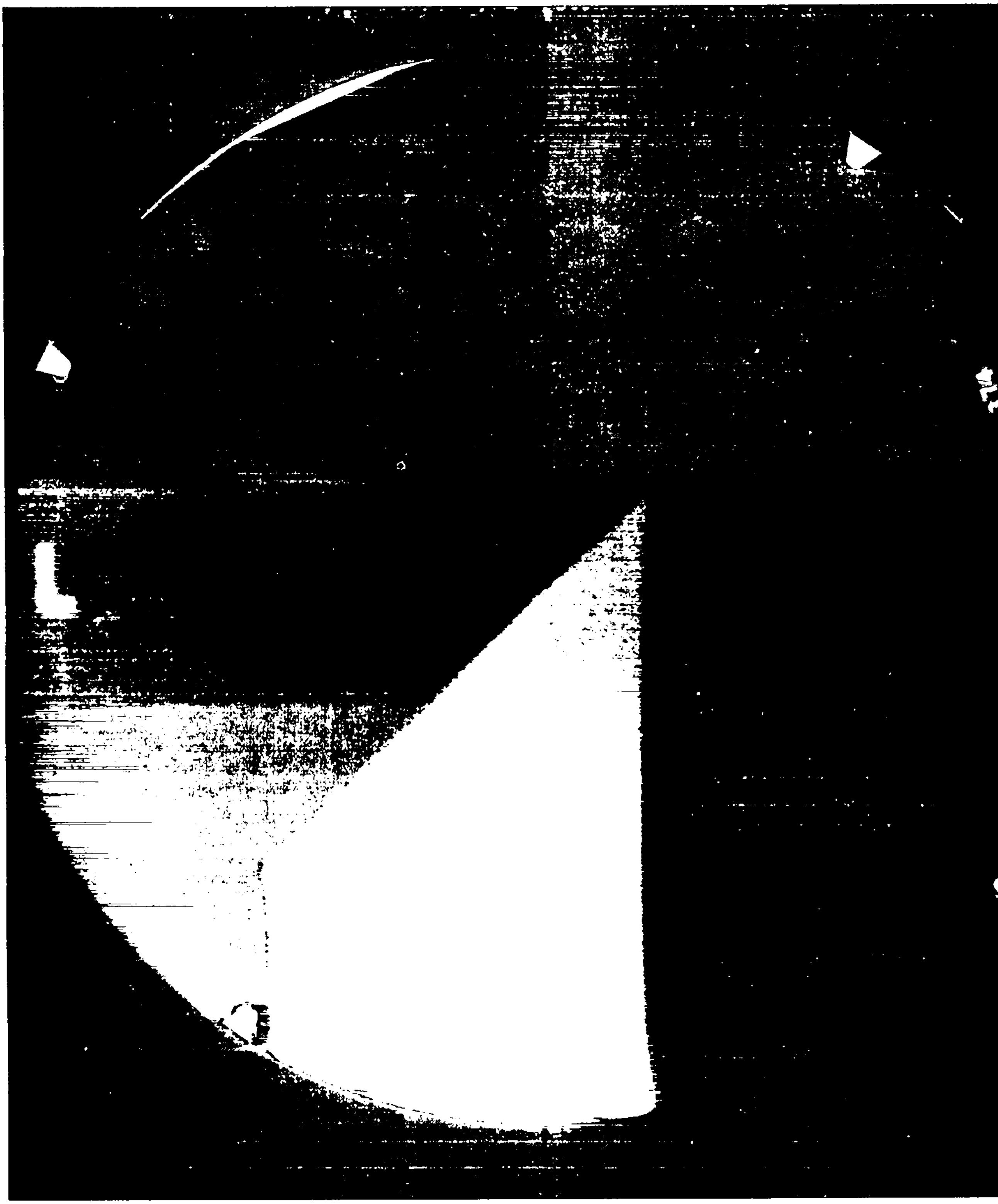


Fig. 10. (cont)

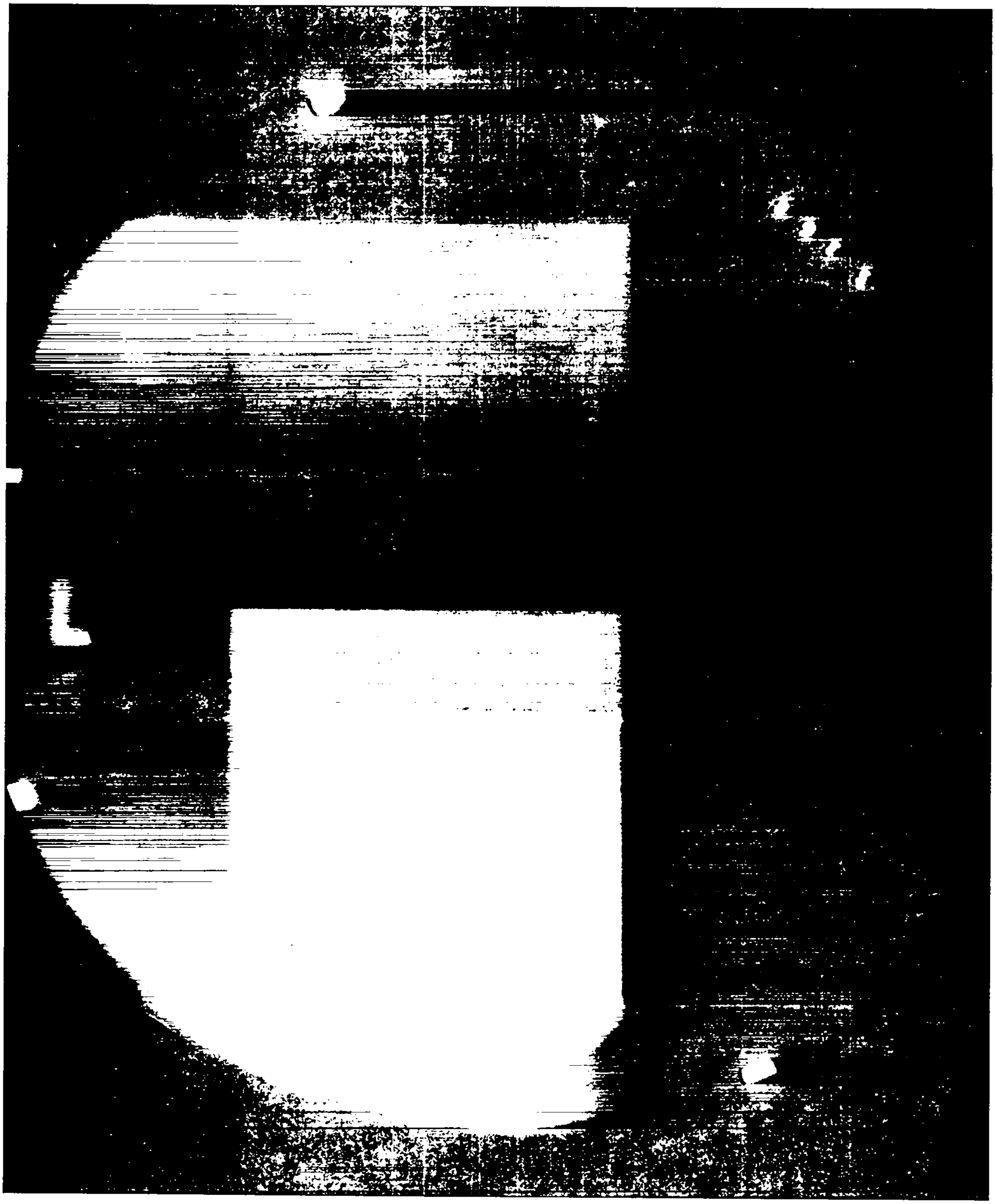


Fig. 11.
PHERMEX radiographs of a Composition B detonation wave proceeding up a 90° aluminum block.

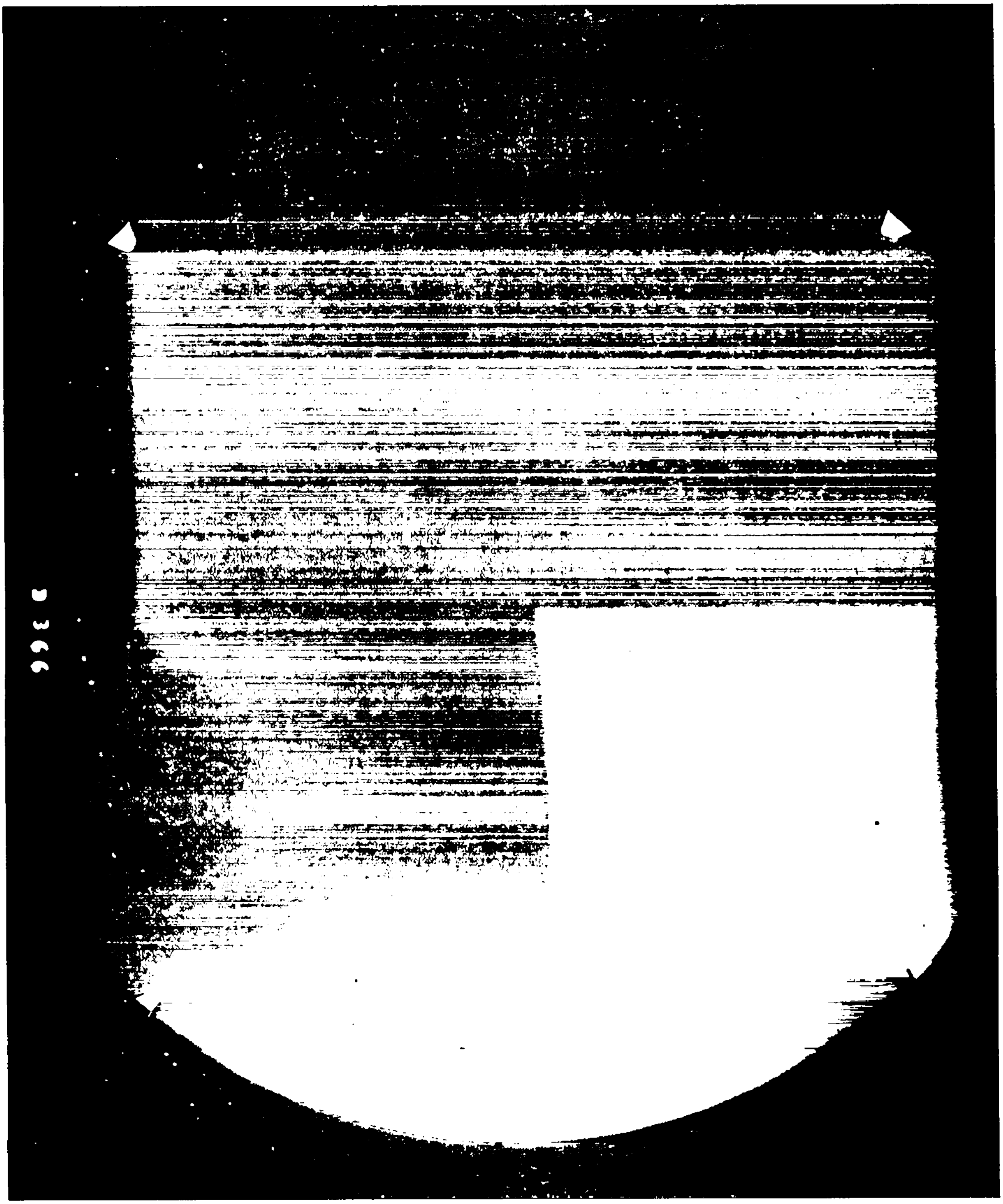


Fig. 11. (cont)

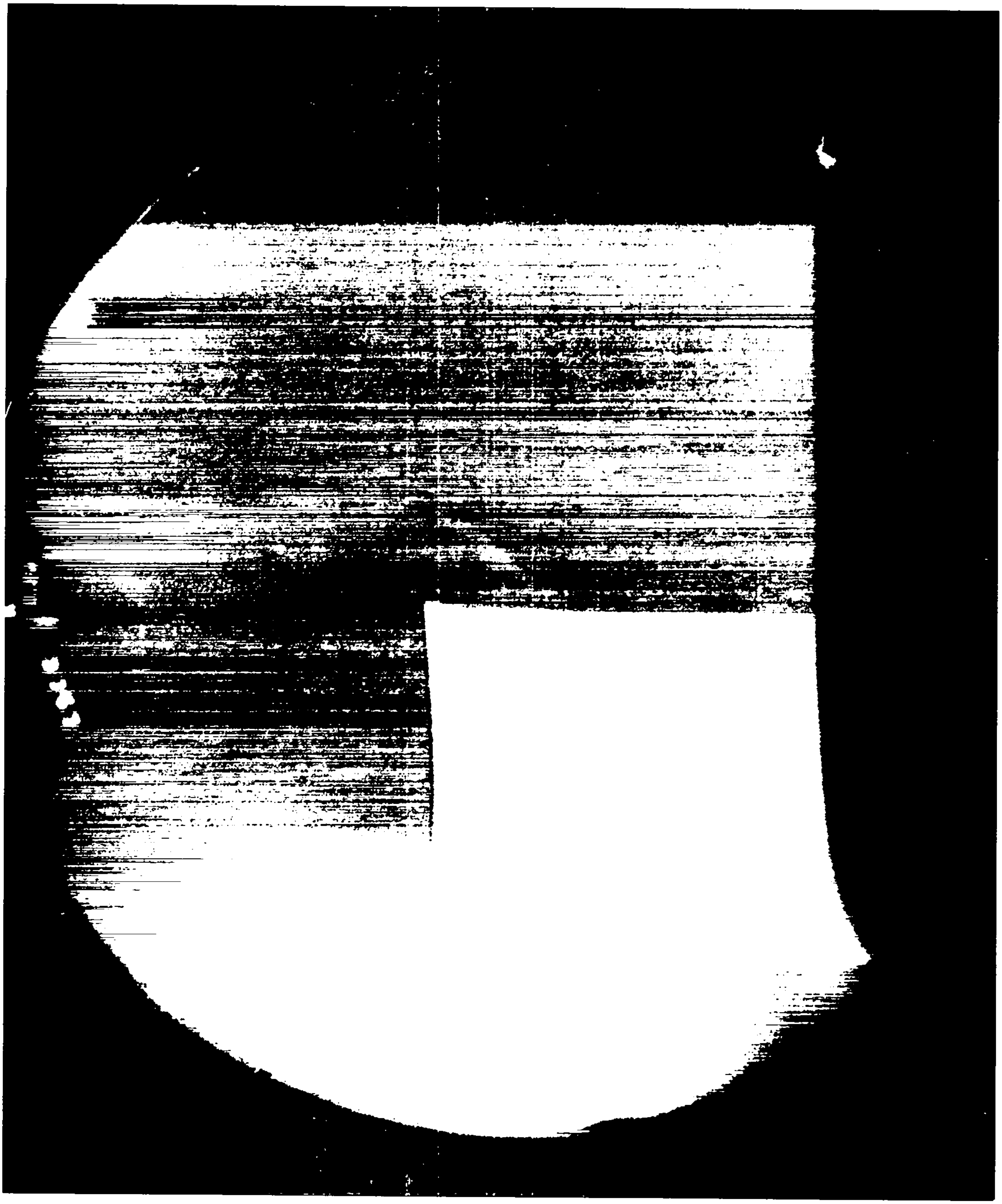


Fig. 11. (cont)

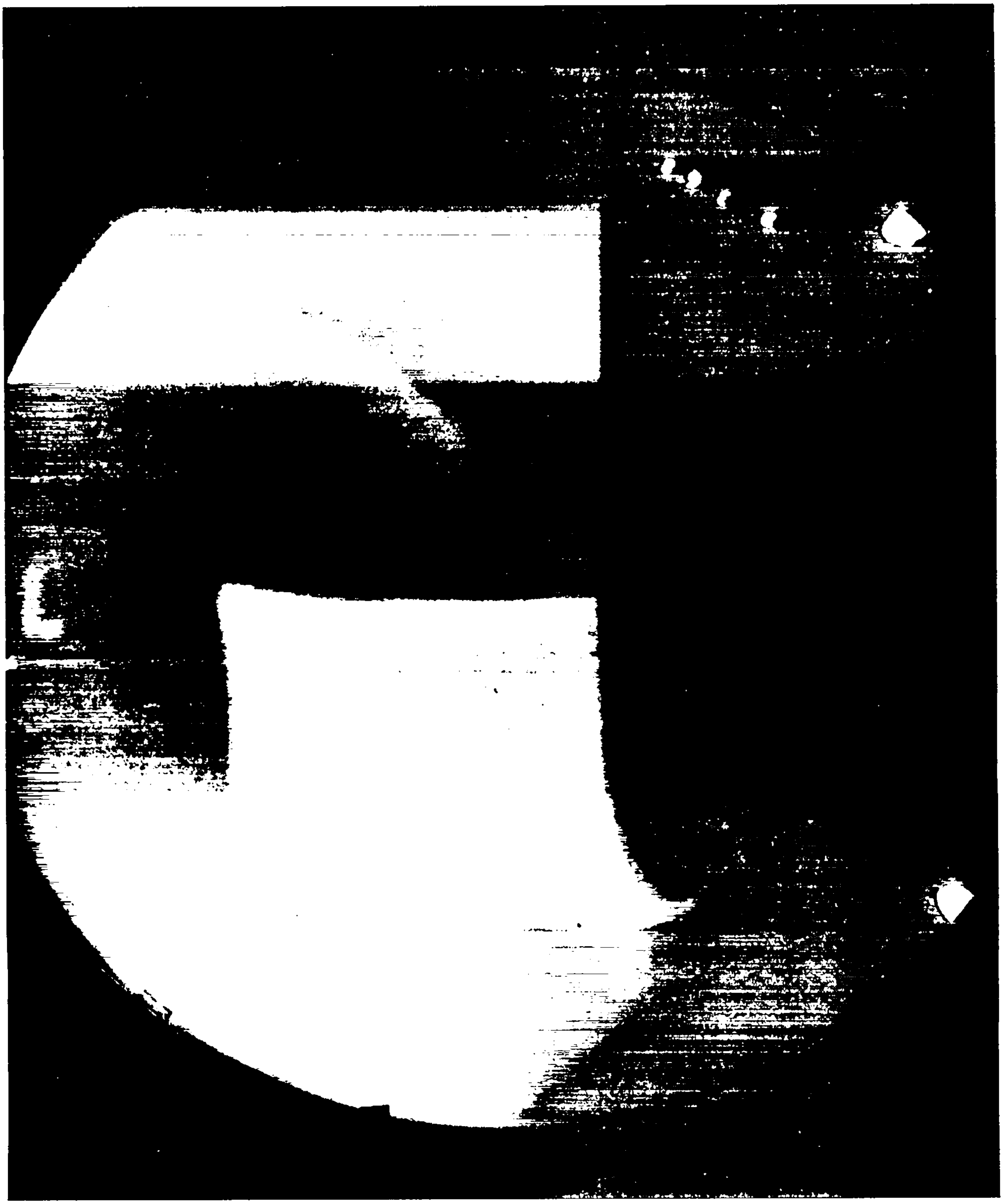


Fig. 11. (cont)

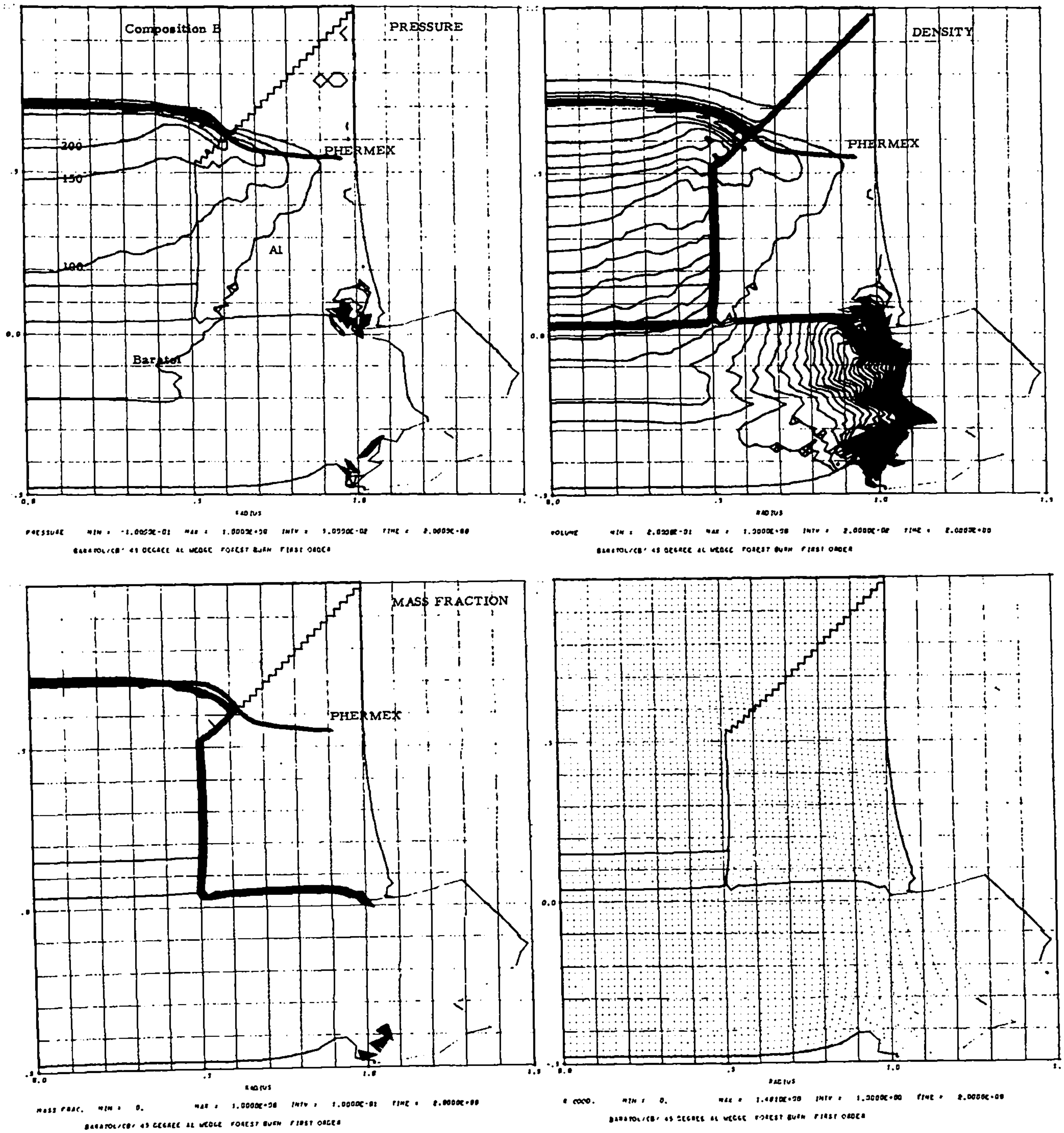


Fig. 12.
Calculated profiles of a Composition B Forest Fire detonation proceeding up a 45° aluminum wedge. The pressure profile interval is 50 kbar, the density profile is 0.02 cm^3/g, the mass fraction interval is 0.1, and the last figure is the mesh used in the calculation. PHERMEX profiles from Fig. 10 are shown.

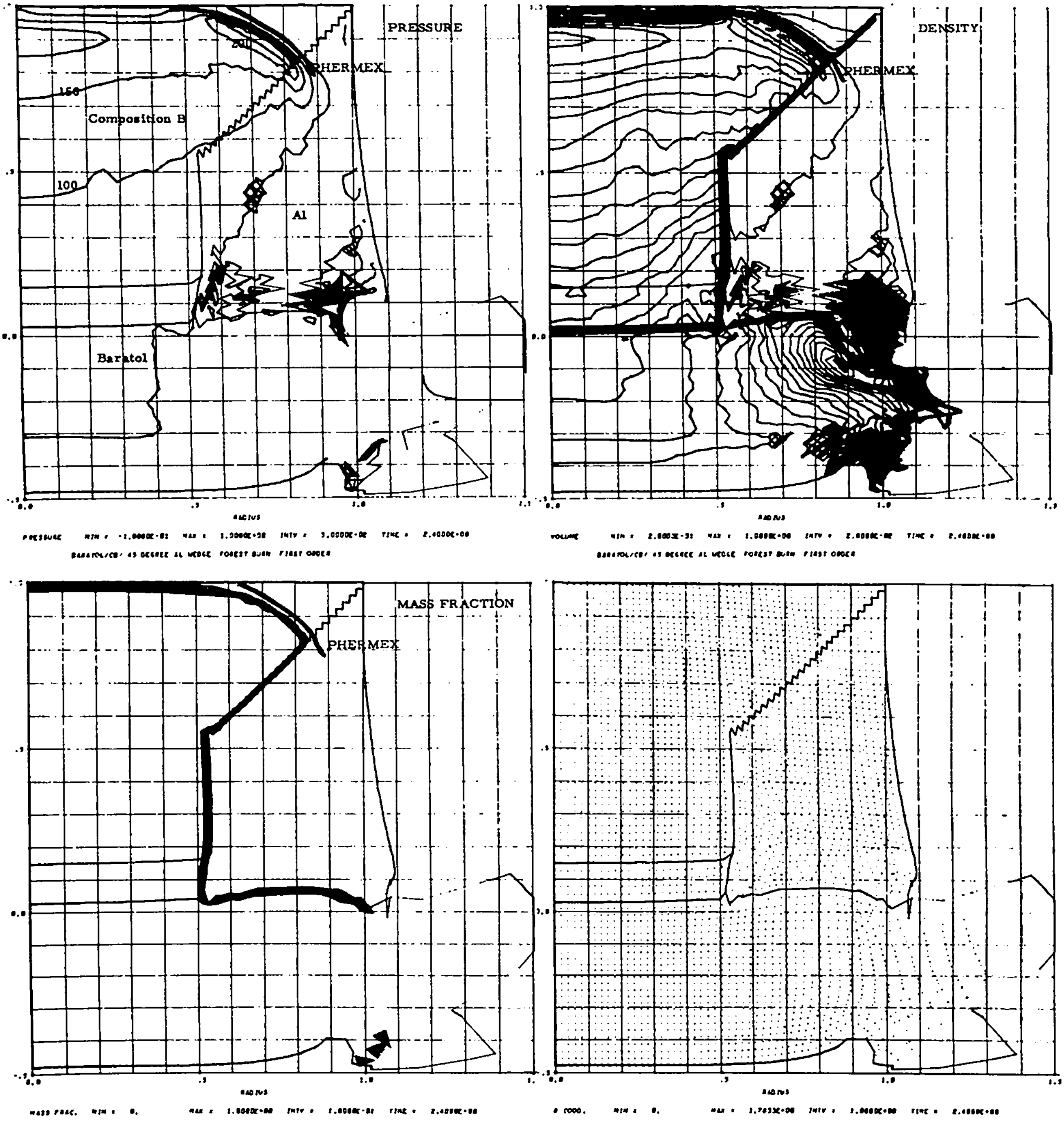

PRESSURE
200
PHERMEX
150
Composition B
100
Al
Baratol
DENSITY
PHERMEX
MASS FRACTION
PHERMEX

Fig. 12. (cont)

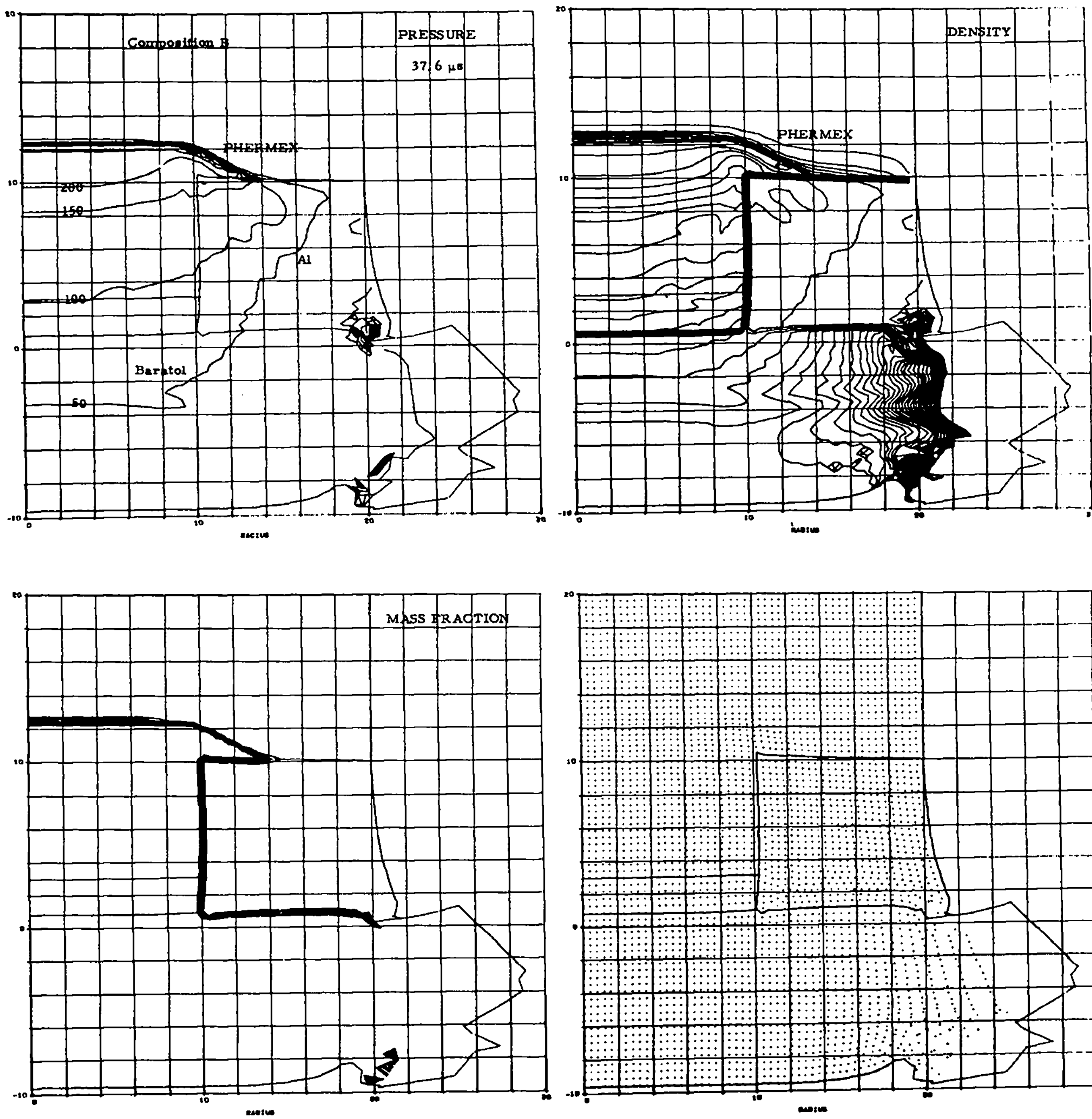


Fig. 13.
Calculated profiles of a Composition B Forest Fire detonation proceeding up a 90° aluminum block. PHERMEX profiles from Fig. 11 are shown.

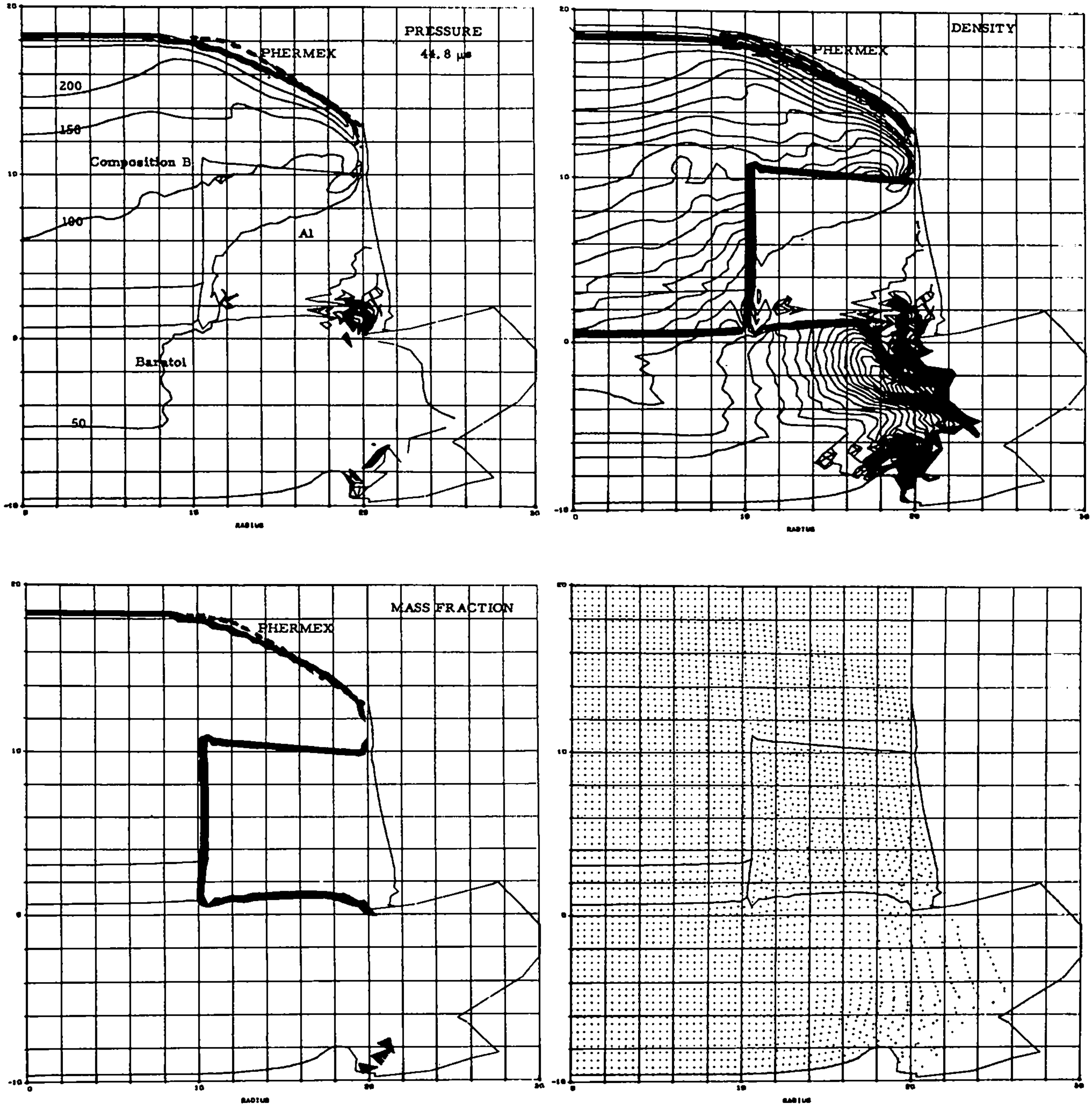

PRESSURE
44.8 μs
PHERMEX
200
150
Composition B
100
Al
Baratol
50
DENSITY
PHERMEX
MASS FRACTION
PHERMEX

Fig. 13. (cont)

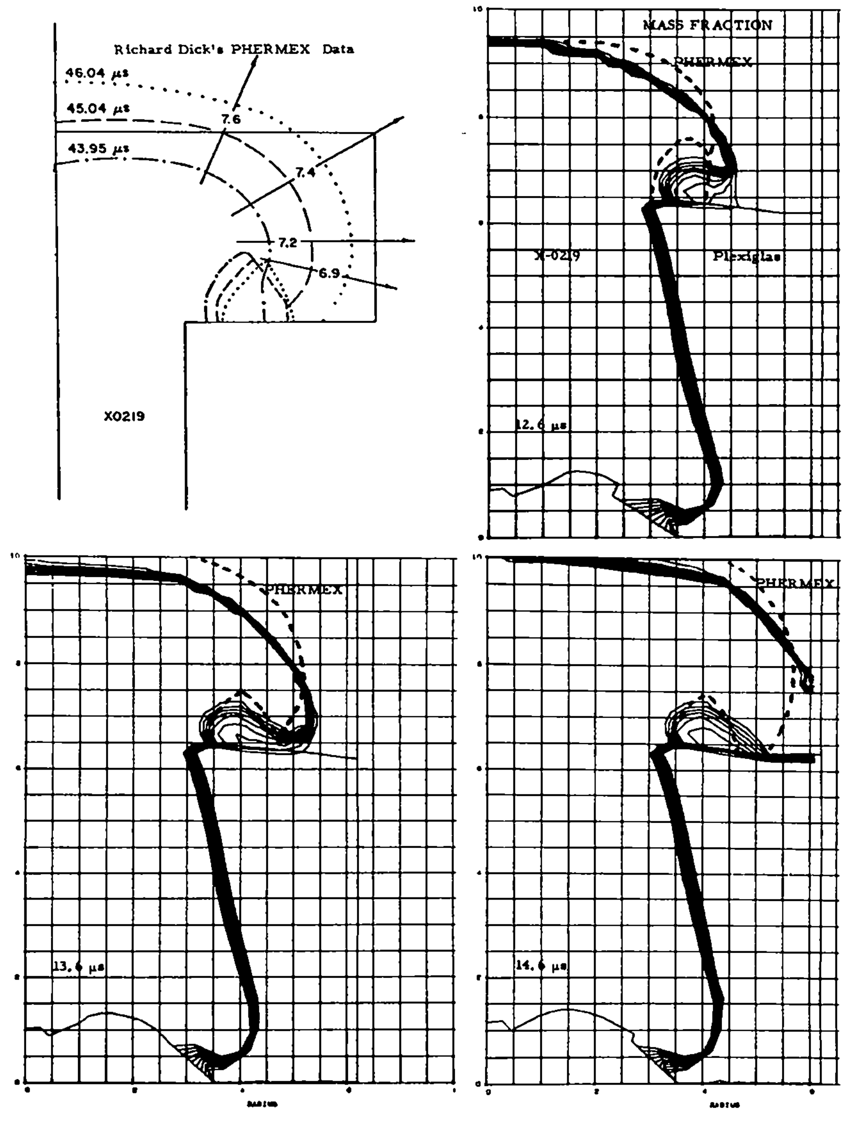


Fig. 14.
Radiographic and calculated 2DL profiles of a detonation wave propagating around a corner of X-0219. The corner was filled with air in the experiment and with Plexiglas in the calculation.

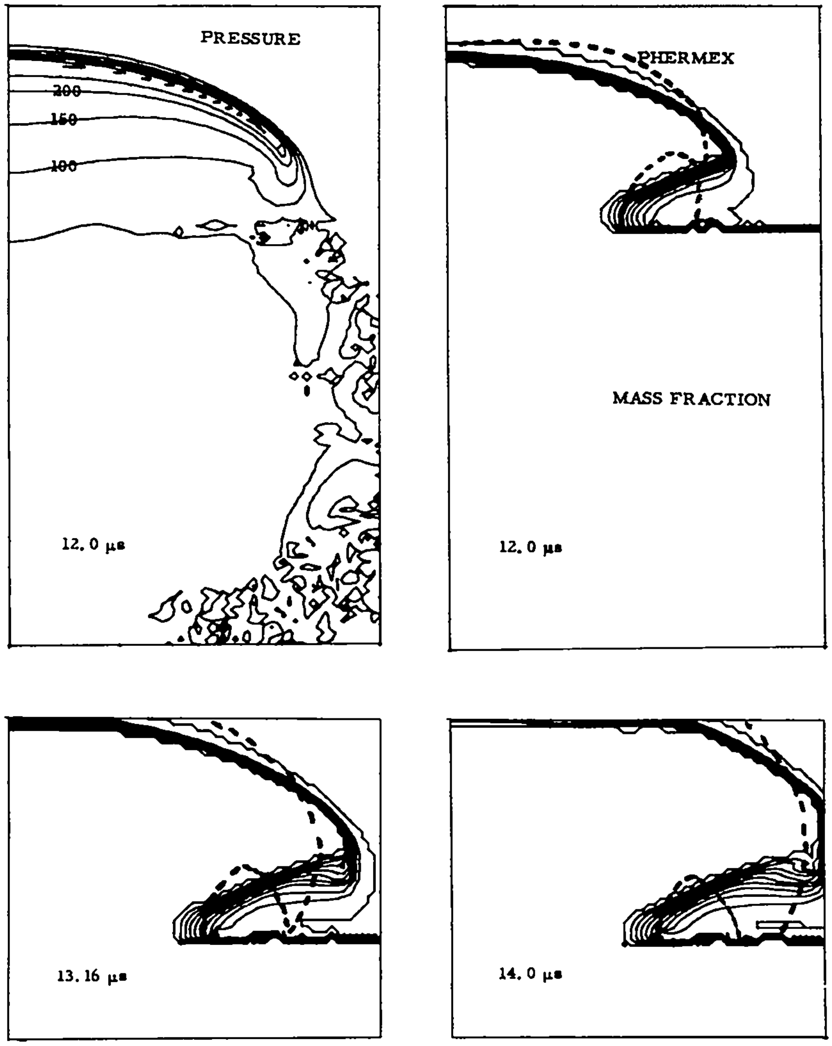


Fig. 15.
Calculated Eulerian 2DE code profiles of a detonation wave propagating around a corner of X-0219 where the corner is filled with air.

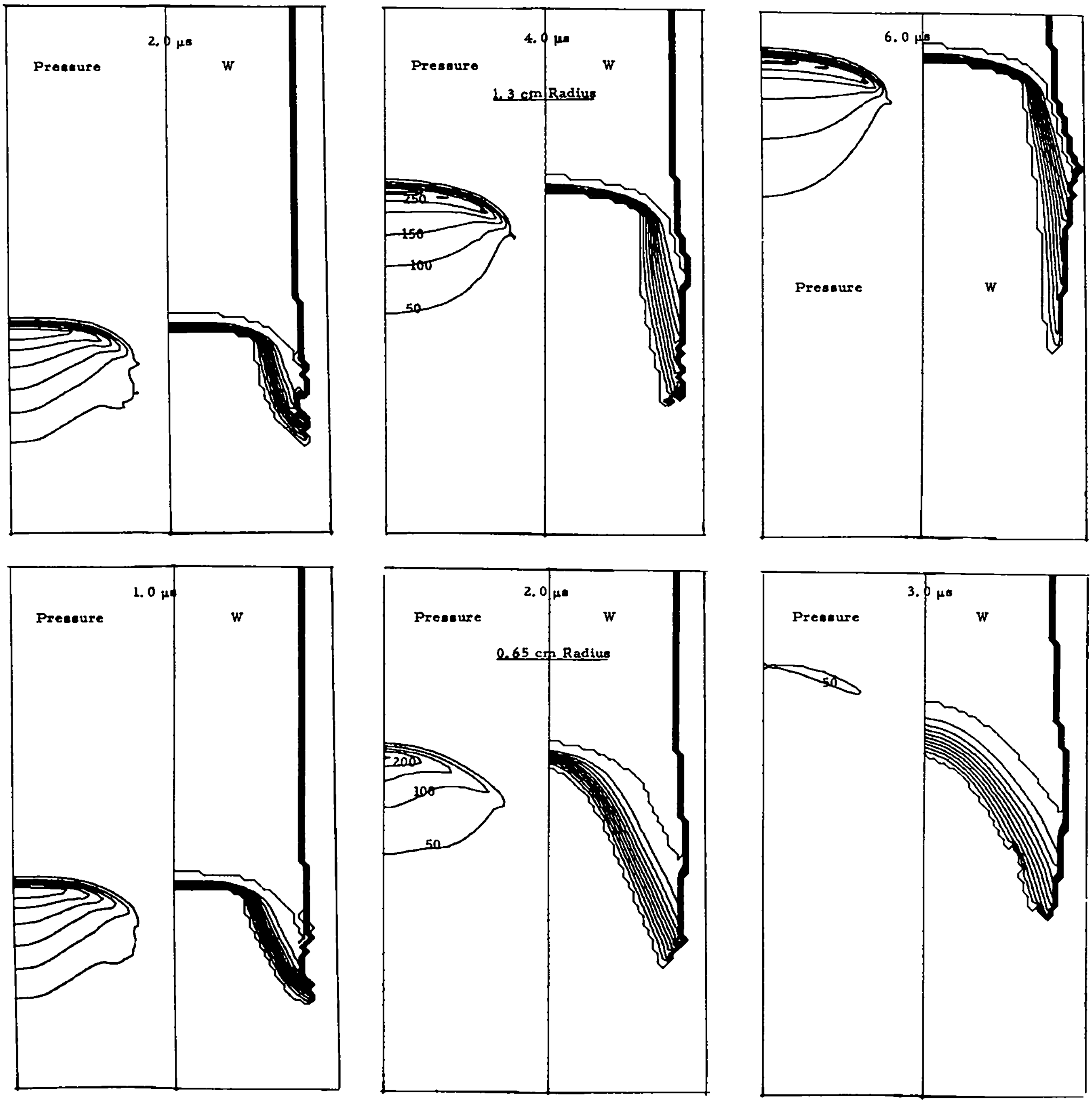


Fig. 16.
Pressure and mass fraction profiles for a 0.65- and a 1.3-cm-radius cylinder of X-0219 calculated using the 2DE code with the Forest Fire burn model.

APPENDIX A

A MODEL FOR SHOCK INITIATION OF HETEROGENEOUS EXPLOSIVES

Our goal is to determine, for a particular explosive, a burn rate that is a function of the local state and that is also consistent with the shock initiation experiments.

The experiments of interest are those that enable direct solution of the time behavior of the shock-pressure wave as the shock builds to detonation. Such information forms a data line in space for the fluid flow equations. With some simple assumptions the flow equations can be solved in the neighborhood of the data line, and consequently, the reaction rate consistent with the time behavior of the shock-pressure wave can be solved.

Some experiments that give direct information about the shock-pressure front are:

A. Distance to detonation as a function of initial shock pressure

$$\ell n(\text{run}) = \alpha_1 + \alpha_2 \, \ell n(P-P_o) \quad ,$$

where run = distance to detonation,
α_1, α_2, and P_0 are constants, P_0 is usually 0, and
P = pressure.

This relation is called the "Pop plot."

B. Shock velocity as a function of particle velocity

$$U_s = C + S \, U_p \quad ,$$

where U_s = shock velocity,
U_p = particle velocity, and
C and S are constants from fits to experimental data.

These relations, together with the shock jump relations, define the state space line for the shock front.

C. If pressure as a function of time is reported at various mass points, these data can be used to estimate pressure gradients behind the shock and a time-pressure history at a single point.

The single-curve build-up principle[19] is the assumption that a reactive shock wave grows to detonation along a unique line in distance, time, and state space. Experiments have often shown this relation to be plausible to the accuracy of the experiments. Applying the single-curve build-up principle to Pop plots gives the interpretation that the Pop plots are direct descriptions of the shock front.

Figure A-1 shows the Pop plots for 9404, Composition B (60/40 RDX/TNT), X-0290 (95/5 TATB/Kel F), and X-0219 (90/10 TATB/Kel F). The HOM equation of state[15] uses the BKW[20] equation of state for the detonation products and the experimentally determined unreacted Hugoniot to determine the partially reacted Hugoniots. The Hugoniots for 9404, together with Ramsey's[21] partially reacted Hugoniot, are plotted in Fig. A-2. The equations of state are identical to those used in Ref. 4. The partially reacted Hugoniots for each explosive are shown in Fig. A-3. The equation-of-state constants, Pop plot constants, and Forest Fire burn functions are listed in Appendix B. The derivation of the Forest Fire burn and a computer code listing used to calculate the function are given in Appendix C.

Figure A-4 shows the decomposition rate calculated, using the Forest Fire model, as a function of pressure. Forest Fire was incorporated in the SIN code,[15] and the rate was programmed as a function of pressure [$\ell n(\text{rate}) = A + BP + CP^2 \ldots XP^n$]. The rate was set to zero if the pressure was less than the minimum pressure used in the fit, and the burn was completed if the pressure was greater than C-J pressure. If W was less than 0.05 it was set equal to zero. Pressure and mass fraction profiles for 2 cm of 9404 initially shocked to 22.5 kbars are shown in Fig. A-5. The calculations closely reproduce the experimentally observed shock front profiles. We must compare the results of these profiles throughout the explosive to determine if the calculated state values are valid behind the shock front.

Craig and Marshall[22] ran a series of experiments shocking various thicknesses of 9404 to various pressures and measuring the time histories of the velocity of free surfaces of Lucite plates in contact with the explosive. The equations of state used are described in Ref. 4.

The calculated and experimental velocity vs time profiles for a 63-kbar shock and for 30-kbar shocks initiating 9404 are shown in Figs. A-6 and A-7, respectively. The calculated and experimental initial free-surface velocity profiles for various thicknesses of 9404 in contact with a 0.508-cm Lucite plate are shown in Fig. A-8. Figure A-9 shows the velocity for various thicknesses of Lucite plates in contact with 0.254 cm of 9404 initially shocked to 63 kbars by an aluminum driver.

Calculations were also made to determine the model's response to driver pulse width. Gittings[23] reported the excess transit time for 9404 shocked by 0.0127- to 0.040-cm-thick aluminum foils traveling 0.14 to 0.20 cm/μs. The calculated and experimental results are summarized in Table A-I.

Kennedy[24] and Trott and Jung[25] have studied the effect of driver pulse width on the initiation of 9404 at lower shock pressures. The calculated and Trott and Jung[25] experimental results are summarized in Table A-II.

Forest Fire can be used to describe the effect of pulse width upon detonation propagation or failure in the pressure range covered by Gitting's experiments of 135 to 85 kbars and Trott and Jung's experiments to 35 kbars. Figure A-10 shows the calculated pressure and mass fraction of 9404 shocked to 50 and 40 kbars by a 0.1-cm-thick aluminum plate going 0.1 and 0.08 cm/μs. The 50-kbar shock grows and detonation occurs at 0.390 cm in 0.83 μs. A long-duration pulse would result in detonation at 0.386 cm in 0.736 μs.

Trott and Jung[25] also report the effect of driver pulse width for Composition B. The calculated and experimental results are summarized in Table A-III.

Forest Fire can reproduce some of the observed quantitative behavior of the shock initiation of 9404 and Composition B. Forest Fire becomes less realistic

TABLE A-I

CALCULATED AND EXPERIMENTAL RESULTS[23] FOR 9404

Foil Velocity (cm/μs)	Experimental Failure Thickness (cm)	Forest Fire Calculational Thickness (cm)
0.20 (~135 kbars)	0.01 → 0.015	0.0127 failed 0.0190 marginal 0.0254 detonated
0.16	0.019 → 0.025	0.019 failed 0.0254 marginal 0.0381 detonated
0.14 (~85 kbars)	0.025 → 0.035	0.0254 failed 0.0381 detonated

at very low pressures. More refinements will be required to describe the detailed shock initiation behavior upon the passage of multiple shocks through an explosive or any process that changes the Pop plot behavior.

Forest Fire is being successfully applied to other explosives such as PETN and certain shock-sensitive propellants. The results of these studies will be published later.

TABLE A-II

CALCULATED AND EXPERIMENTAL RESULTS[25] FOR 9404

Driver Thickness (cm)	Experimental Driver Failure Velocity (cm/μs)	Forest Fire Calculational Driver Velocity Results (cm)
0.16	0.065 - 0.075 (~35 kbars)	0.06 failed 0.08 marginal
0.102	0.078 - 0.095 (~50 kbars)	0.08 failed 0.10 detonated
0.04	0.11 - 0.12 (~65 kbars)	0.10 failed 0.12 marginal 0.13 detonated

TABLE A-III

CALCULATED AND EXPERIMENTAL RESULTS FOR COMPOSITION B

Driver Thickness (cm)	Experimental Driver Failure Velocity (cm/μs)	Forest Fire Calculational Driver Velocity Results (cm)
0.318	0.09 → 0.11 (~50 kbar)	0.08 marginal 0.10 detonated
0.102	0.11 → 0.12 (~60 kbar)	0.10 failed 0.12 marginal 0.13 detonated
0.04	0.15 → 0.16 (~85 kbar)	0.16 failed 0.17 marginal

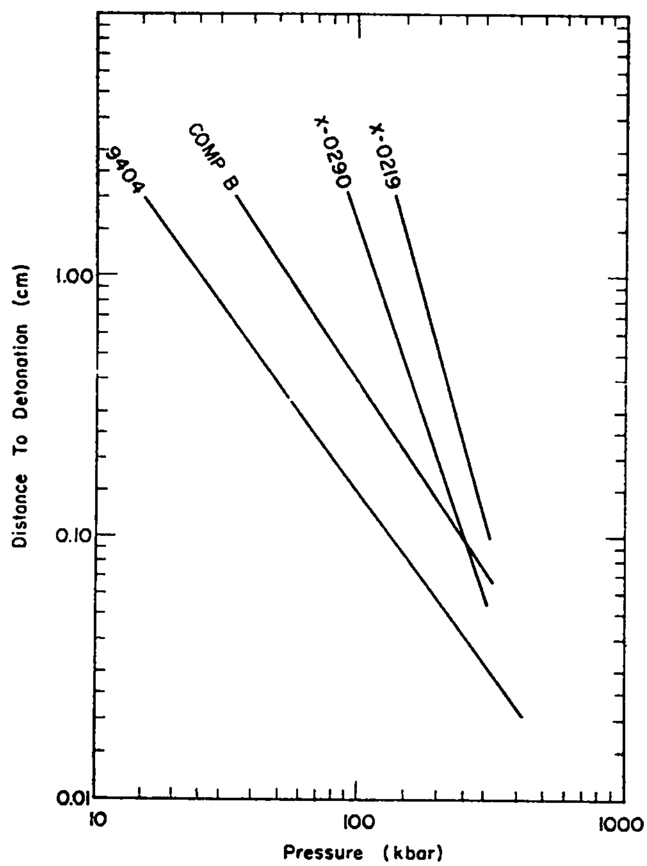


Fig. A-1.
Pop plots for X-0219, X-0290, Composition B, and 9404.

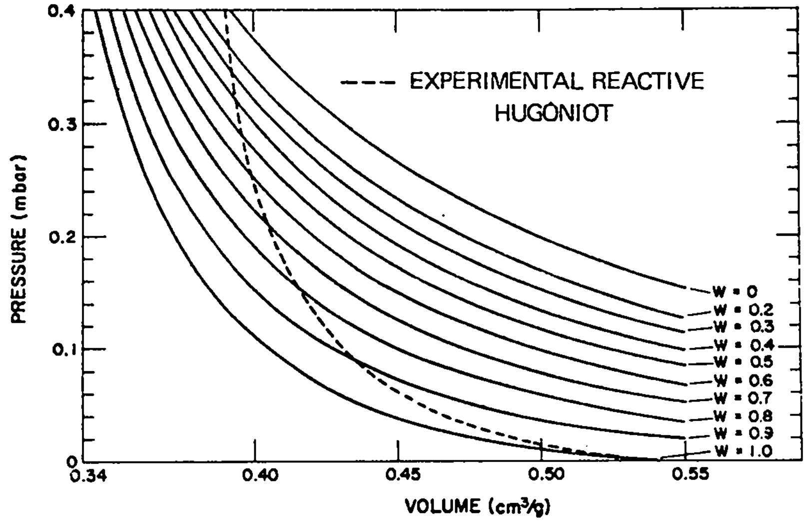


Fig. A-2.
HOM 9404 partially reacted Hugoniots and Ramsey's experimental reactive Hugoniot.

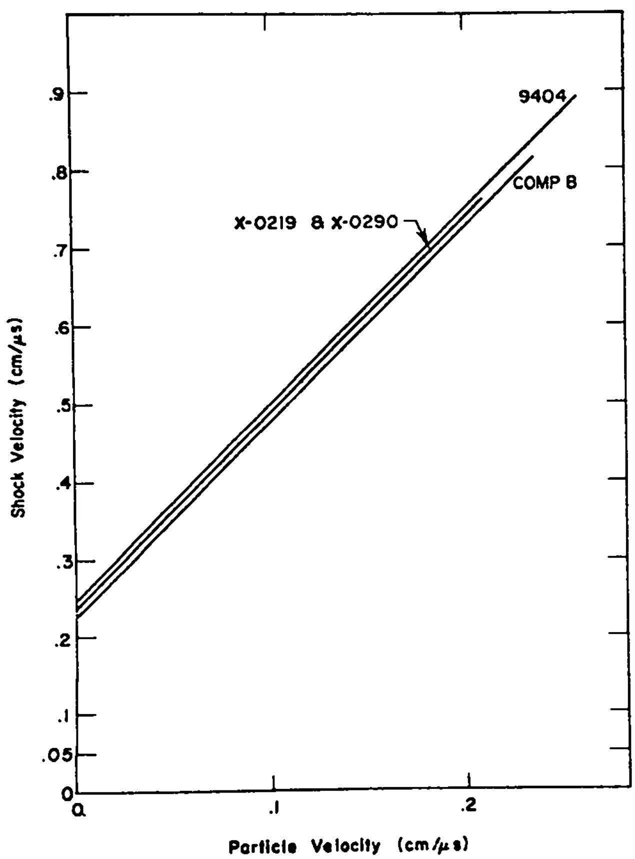


Fig. A-3.
Reactive Hugoniots.

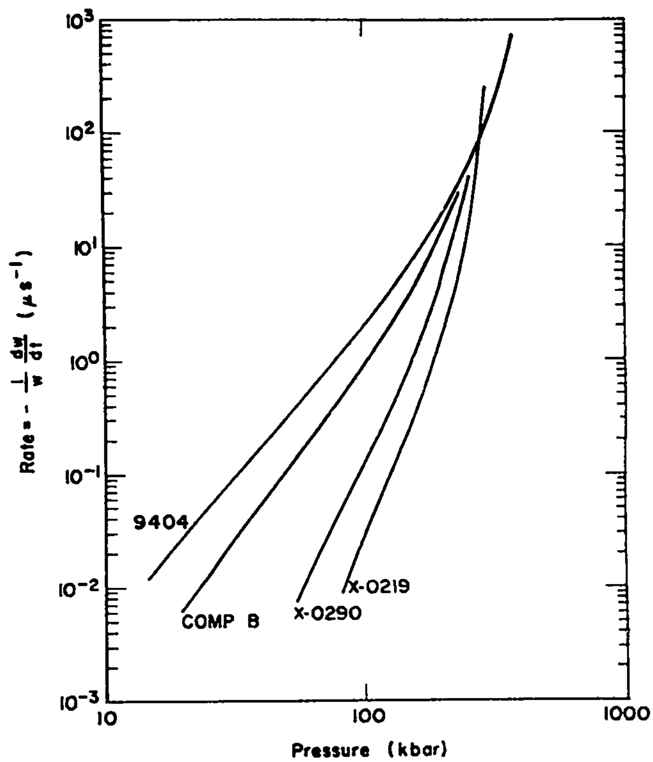


Fig. A-4.
Forest Fire rate vs pressure.

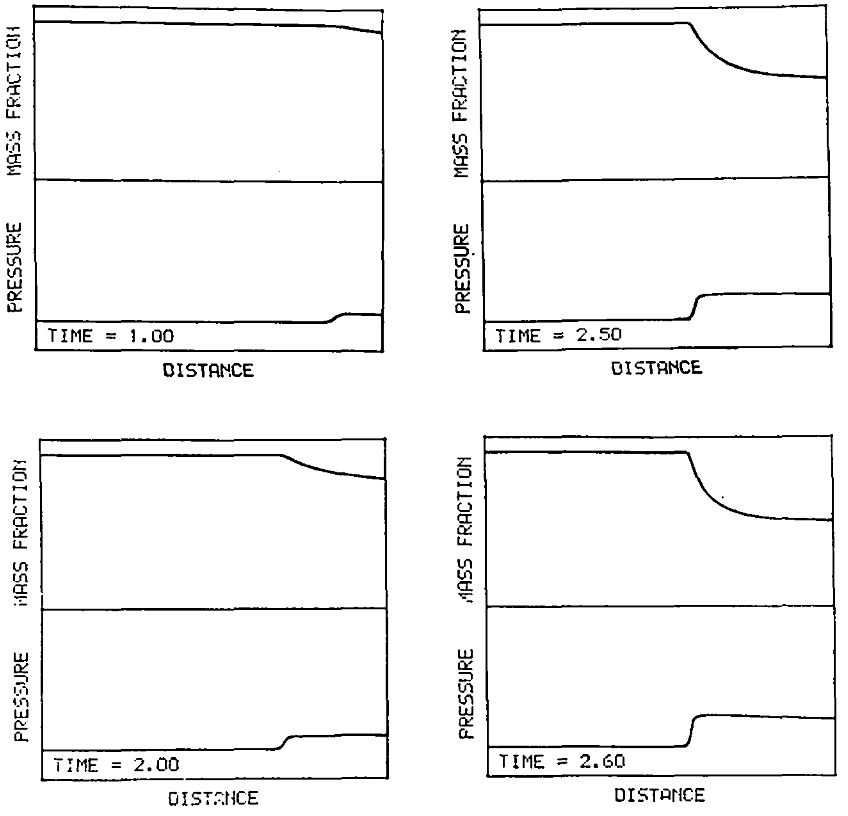


Fig. A-5.
Pressure and mass fraction profiles for 2 cm of 9404 initially shocked to 22.5 kbars. The pressure scale is from -100 to 400 kbars and the mass fraction scale is from 0 to 1.1.

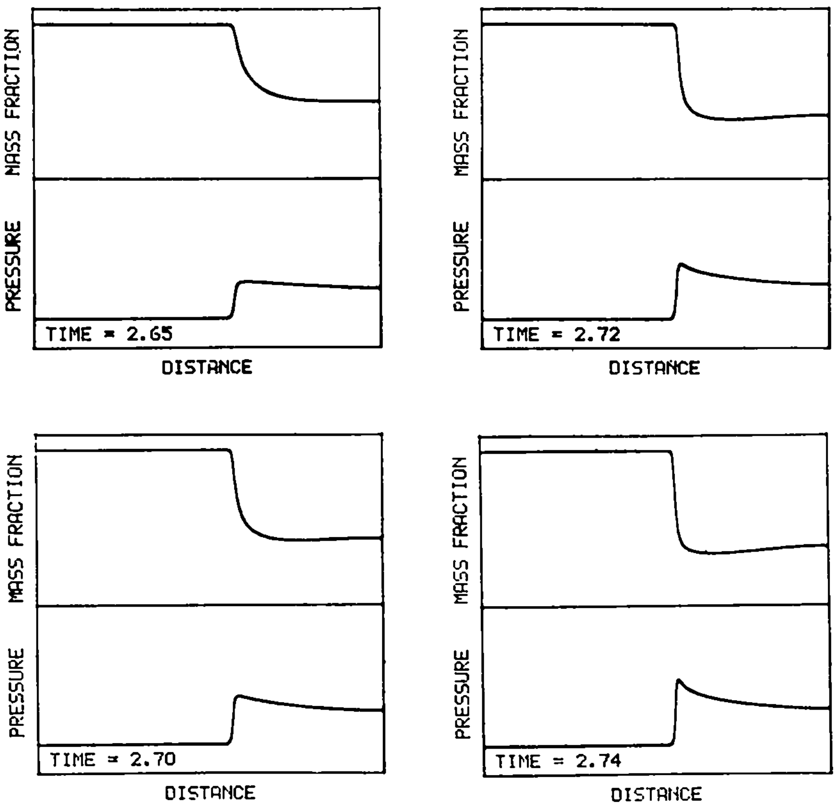


Fig. A-5. (cont)

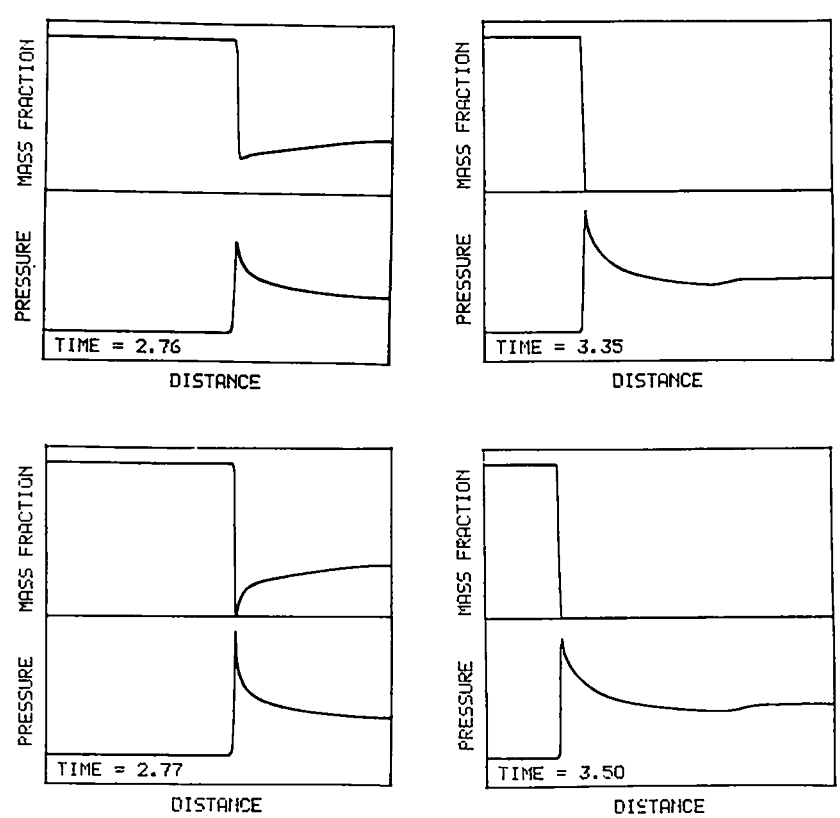


Fig. A-5. (cont)

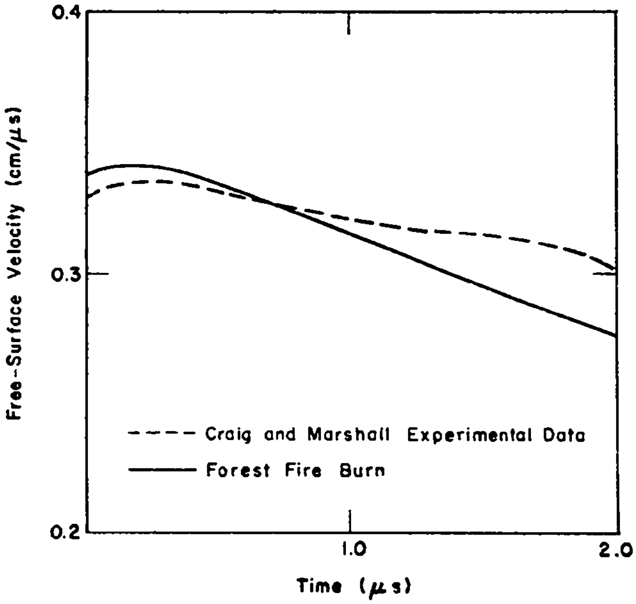


Fig. A-6.
Free-surface velocity of a 0.5-cm-thick Plexiglas plate in contact with 0.254 cm of 9404 initially shocked to 63 kbars.

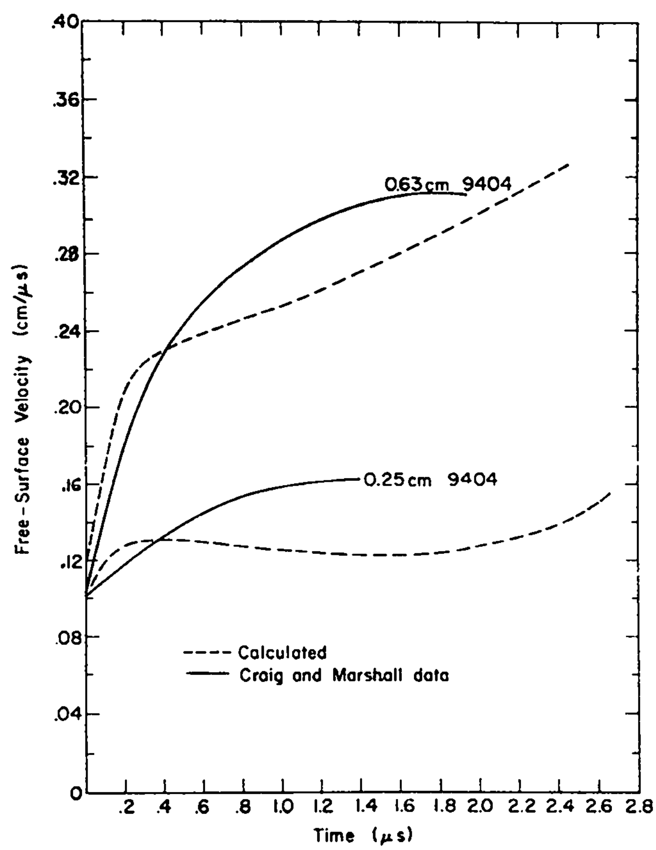


Fig. A-7.
Free-surface velocity of 0.20-cm-thick Plexiglas plates in contact with 0.25- and 0.63-cm-thick pieces of 9404 initially shocked to 30 kbars.

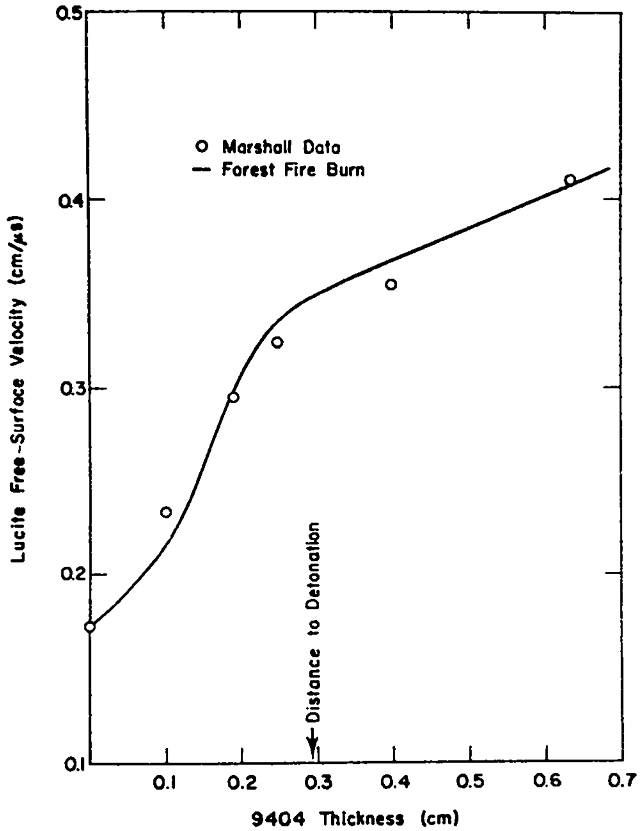


Fig. A-8.
Initial free-surface velocity of a 0.508-cm Lucite plate in contact with various thicknesses of 9404 initially driven by an aluminum plate to 63 kbars.

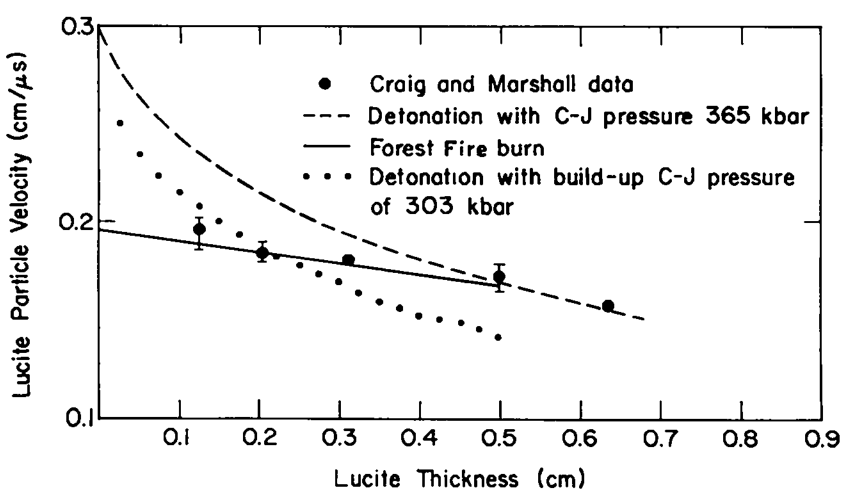


Fig. A-9.
Initial free-surface velocity of various thicknesses of Lucite plates in contact with 0.254 cm of 9404 initially shocked to 63 kbars by an aluminum driver.

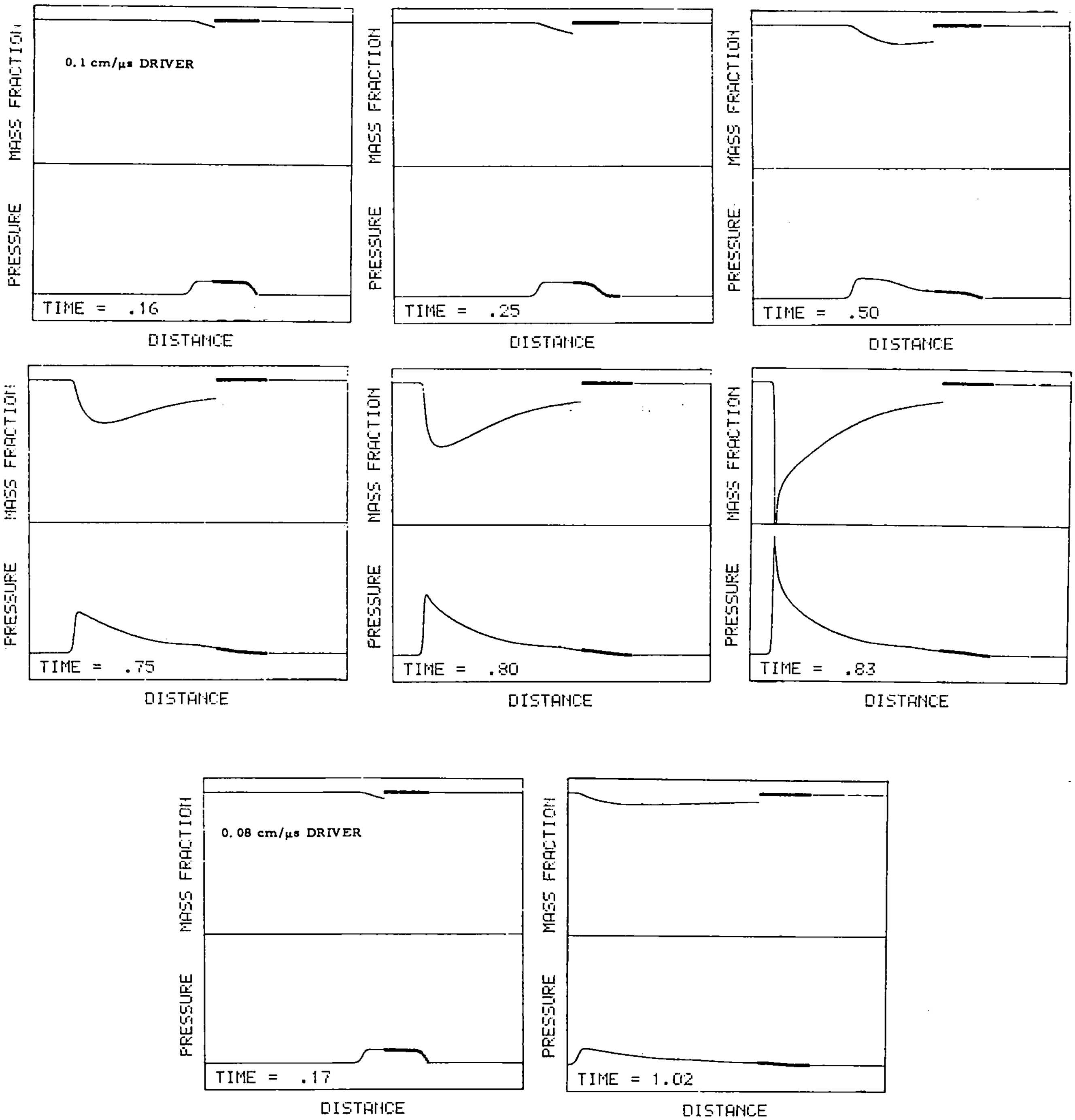


Fig. A-10.
Pressure and mass fraction profiles for 0.4 cm of 9404 initially driven by a 0.1-cm-thick aluminum plate going 0.1 and 0.08 cm/μs. The pressure and mass fraction scales are identical to those of Fig. A-5.

APPENDIX B

FOREST FIRE RATES

Forest Fire results for 9404, Composition B, X-0290, and X-0219 are presented in Tables B-I — B-IV. The coefficients to the log rate as a function of pressure were used in the calculations described in this report. The other constants are given below.

The nomenclature and units in Tables B-I — B-V and C-I — C-IV are

RUN = distance to detonation (cm)

P = shock front pressure (mbars)

V = shock front volume (cm^3/g)

U P = shock front particle velocity (cm/μs)

U S = shock front velocity (cm/μs)

W = mass fraction of undecomposed explosive

RATE = $-\frac{1}{W}\frac{dW}{dt}$, where t is time in μs

TEMPERATURE = HOM temperature in °K of mixture of detonation products and undecomposed explosive

TIME = time to detonation (μs)

	9404	Comp B	X-0290	X-0219
ρ_0 (g/cm^3)	1.844	1.715	1.894	1.914
Min P(kbar)	15	20	55	85
C-J pressure (kbar)	363	284	285	281

TABLE B-I

```
PBX 9404     PCJ = 0.363 MBAR                                                                      RHO = 1.84400

POP PLOT, LN(RUN) = A1 + A2*LN(P-A3),  A1 = -5.040996E+00  A2 = -1.365368E+00  A3 = -0.

REACTION HUGONIOT,  US = C + S*UP,      C =  2.460000E-01   S =  2.530000E+00

CJ DETONATION VELOCITY =  8.880000E-01

HOM EQUATION OF STATE CONSTANTS
UNREACTED EXPLOSIVE
 2.42300000000E-01 1.88300000000E+00 1.00000000000E-02-0.
-0.               -9.04187222042E+00-7.13185252435E+01-1.25204979360E+02
-9.20424177603E+01-2.21893825727E+01 6.75000000000E-01 4.00000000000E-01
 5.42299349241E-01 5.00000000000E-05 0.                -0.
 3.00000000000E+02 1.00000000000E-06-0.                -0.
-0.               -0.               -0.
DETONATION PRODUCTS
-3.53906259964E+00-2.57737590393E+00 2.60075423332E-01 1.39083578508E-02
-1.13963024075E-02-1.61913041133E+00 5.21518534192E-01 6.77506594107E-02
 4.26524264691E-03 1.04679999902E-04 7.36422919790E+00-4.93658222389E-01
 2.92353060961E-02 3.30277402219E-02-1.14532498206E-02 5.00000000000E-01
 1.00000000000E-01


PBX 9404     PCJ = 0.363 MBAR                                                                      RHO = 1.84400
LN(RATE) = C(1) + C(2)*P + ... + C(M+1)*(P**M)
C(I=1,14) =  -8.3979132644E+00  4.0524452315E+02 -1.2887959724E+04  2.9889932207E+05 -4.7962436917E+06
              5.4017707404E+07 -4.3377143285E+08  2.5068548091E+09 -1.0433258901E+10  3.0950369616E+10
             -6.3781135352E+10  8.6704208069E+10 -6.9876089170E+10  2.5277953727E+10
MAXIMUM RELATIVE ERROR AT    8.000000E-02 =      3.462491E-02
```

PBX 9404 PCJ = 0.363 MBAR RHO = 1.84400
POP PLOT, LN(RUN) = A1 + A2*LN(P-A3), A1 = -5.040996E+00 A2 = -1.365368E+00 A3 = -0.
REACTION HUGONIOT, US = C + S*UP, C = 2.460000E-01 S = 2.530000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE	TIME
2.00000	.01500	.49697	.02607	.31197	.99248	1.2016E-02	352.34864	5.46666
1.62040	.01750	.49230	.02958	.32084	.99038	1.7952E-02	363.44553	4.26596
1.35034	.02000	.48807	.03293	.32932	.98813	2.5424E-02	375.03754	3.43466
1.14974	.02250	.48420	.03616	.33747	.98575	3.4570E-02	387.07103	2.83266
.99569	.02500	.48065	.03926	.34533	.98327	4.5525E-02	399.49584	2.38123
.87420	.02750	.47736	.04226	.35291	.98068	5.8423E-02	412.26638	2.03309
.77627	.03000	.47432	.04516	.36025	.97800	7.3385E-02	425.34184	1.75838
.69591	.03250	.47148	.04797	.36738	.97525	9.0563E-02	438.68600	1.53741
.62894	.03500	.46883	.05071	.37430	.97242	1.1008E-01	452.26685	1.35678
.57239	.03750	.46634	.05337	.38103	.96952	1.3206E-01	466.06824	1.20703
.52411	.04000	.46400	.05597	.38759	.96656	1.5665E-01	480.03825	1.08138
.48248	.04250	.46178	.05850	.39400	.96355	1.8398E-01	494.17062	.97481
.44626	.04500	.45969	.06097	.40025	.96049	2.1418E-01	508.44591	.88359
.41450	.04750	.45771	.06339	.40637	.95738	2.4741E-01	522.84694	.80484
.38646	.05000	.45582	.06576	.41236	.95422	2.8379E-01	537.35853	.73634
.36156	.05250	.45403	.06807	.41823	.95102	3.2347E-01	551.96725	.67636
.33931	.05500	.45232	.07035	.42398	.94778	3.6660E-01	566.66117	.62352
.31933	.05750	.45069	.07258	.42963	.94450	4.1332E-01	581.42881	.57669
.30130	.06000	.44912	.07477	.43517	.94118	4.6379E-01	596.26266	.53500
.28496	.06250	.44762	.07692	.44062	.93782	5.1817E-01	611.15335	.49769
.27011	.06500	.44619	.07904	.44597	.93443	5.7660E-01	626.09338	.46417
.25654	.06750	.44481	.08112	.45124	.93101	6.3926E-01	641.07607	.43393
.24411	.07000	.44348	.08317	.45642	.92756	7.0632E-01	656.09544	.40654
.23269	.07250	.44220	.08519	.46153	.92407	7.7794E-01	671.14611	.38166
.22217	.07500	.44097	.08718	.46656	.92055	8.5429E-01	686.22321	.35898
.21244	.07750	.43978	.08914	.47151	.91700	9.3557E-01	701.32253	.33824
.20343	.08000	.43864	.09107	.47640	.91343	1.0243E+00	716.44011	.31922
.19506	.08250	.43753	.09297	.48122	.90981	1.1134E+00	731.58918	.30174
.18727	.08500	.43645	.09485	.48597	.90618	1.2106E+00	746.72972	.28563
.18000	.08750	.43542	.09671	.49067	.90251	1.3134E+00	761.87952	.27075
.17321	.09000	.43441	.09854	.49530	.89882	1.4222E+00	777.03589	.25697
.16685	.09250	.43344	.10035	.49988	.89510	1.5371E+00	792.19639	.24419
.16088	.09500	.43249	.10214	.50441	.89135	1.6583E+00	807.35881	.23231
.15528	.09750	.43157	.10390	.50888	.88758	1.7861E+00	822.52114	.22124
.15000	.10000	.43068	.10565	.51330	.88378	1.9207E+00	837.68156	.21092
.14503	.10250	.42981	.10738	.51767	.87995	2.0623E+00	852.83841	.20127
.14033	.10500	.42897	.10909	.52199	.87609	2.2112E+00	867.99019	.19224
.13590	.10750	.42815	.11078	.52626	.87220	2.3676E+00	883.13552	.18377
.13170	.11000	.42735	.11245	.53049	.86829	2.5319E+00	898.27315	.17583
.12772	.11250	.42657	.11410	.53468	.86435	2.7042E+00	913.40191	.16835
.12394	.11500	.42581	.11574	.53883	.86038	2.8849E+00	928.52077	.16132
.12035	.11750	.42507	.11736	.54293	.85638	3.0742E+00	943.62875	.15469
.11694	.12000	.42435	.11897	.54699	.85236	3.2726E+00	958.72497	.14843
.11370	.12250	.42365	.12056	.55102	.84830	3.4802E+00	973.80860	.14252
.11060	.12500	.42296	.12214	.55501	.84422	3.6974E+00	988.87888	.13692
.10765	.12750	.42229	.12370	.55896	.84011	3.9245E+00	1003.93512	.13162
.10484	.13000	.42163	.12525	.56288	.83598	4.1619E+00	1018.97666	.12660
.10215	.13250	.42099	.12678	.56676	.83181	4.4100E+00	1034.00290	.12184
.09957	.13500	.42036	.12830	.57061	.82761	4.6692E+00	1049.01319	.11731
.09711	.13750	.41975	.12981	.57442	.82339	4.9397E+00	1064.00717	.11301

PBX 9404   PCJ = 0.363 MBAR   RHO = 1.84400
POP PLOT, LN(RUN) = A1 + A2*LN(P-A3), A1 = -5.040996E+00 A2 = -1.365368E+00 A3 = -0.
REACTION HUGONIOT, US = C + S*UP,   C = 2.460000E-01   S = 2.530000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE	TIME
.09475	.14000	.41915	.13131	.57820	.81912	5.2418E+00	1079.00617	.10891
.09249	.14250	.41856	.13279	.58196	.81483	5.5144E+00	1093.96110	.10501
.09032	.14500	.41798	.13426	.58568	.81052	5.8220E+00	1108.89917	.10129
.08823	.14750	.41742	.13572	.58937	.80617	6.1427E+00	1123.81974	.09775
.08623	.15000	.41687	.13717	.59303	.80180	6.4770E+00	1138.72228	.09436
.08431	.15250	.41633	.13860	.59667	.79739	6.8254E+00	1153.60631	.09113
.08246	.15500	.41579	.14003	.60028	.79295	7.1884E+00	1168.47138	.08803
.08067	.15750	.41527	.14144	.60386	.78847	7.5665E+00	1183.31706	.08507
.07896	.16000	.41476	.14285	.60741	.78397	7.9602E+00	1198.14293	.08224
.07730	.16250	.41426	.14424	.61094	.77943	8.3702E+00	1212.94862	.07953
.07571	.16500	.41377	.14563	.61444	.77486	8.7971E+00	1227.73374	.07692
.07417	.16750	.41329	.14700	.61792	.77025	9.2414E+00	1242.49795	.07443
.07268	.17000	.41281	.14837	.62137	.76561	9.7038E+00	1257.24089	.07203
.07125	.17250	.41235	.14972	.62480	.76093	1.0185E+01	1271.96223	.06973
.06986	.17500	.41189	.15107	.62820	.75622	1.0686E+01	1286.66164	.06751
.06852	.17750	.41144	.15241	.63159	.75147	1.1207E+01	1301.33882	.06539
.06723	.18000	.41100	.15373	.63495	.74669	1.1749E+01	1315.99336	.06334
.06597	.18250	.41056	.15505	.63829	.74187	1.2313E+01	1330.62518	.06137
.06476	.18500	.41014	.15637	.64161	.73700	1.2950E+01	1345.25304	.05947
.06358	.18750	.40972	.15767	.64490	.73211	1.3485E+01	1359.82407	.05764
.06244	.19000	.40930	.15896	.64818	.72718	1.4125E+01	1374.37542	.05588
.06134	.19250	.40890	.16025	.65143	.72222	1.4790E+01	1388.90610	.05418
.06027	.19500	.40850	.16153	.65467	.71721	1.5482E+01	1403.41523	.05254
.05923	.19750	.40810	.16280	.65789	.71216	1.6200E+01	1417.90199	.05096
.05822	.20000	.40771	.16406	.66108	.70706	1.6947E+01	1432.36558	.04943
.05724	.20250	.40733	.16532	.66426	.70193	1.7723E+01	1446.80520	.04795
.05629	.20500	.40696	.16657	.66742	.69675	1.8529E+01	1461.22012	.04652
.05537	.20750	.40659	.16781	.67056	.69153	1.9366E+01	1475.60962	.04514
.05447	.21000	.40622	.16904	.67368	.68626	2.0237E+01	1489.97302	.04381
.05360	.21250	.40586	.17027	.67679	.68095	2.1141E+01	1504.30971	.04251
.05275	.21500	.40551	.17149	.67988	.67560	2.1954E+01	1518.61908	.04126
.05192	.21750	.40516	.17271	.68295	.67020	2.3059E+01	1532.90063	.04005
.05112	.22000	.40482	.17391	.68600	.66475	2.4076E+01	1547.15386	.03887
.05033	.22250	.40448	.17512	.68904	.65926	2.5134E+01	1561.37834	.03774
.04957	.22500	.40414	.17631	.69206	.65373	2.6235E+01	1575.57373	.03663
.04883	.22750	.40381	.17750	.69507	.64814	2.7381E+01	1589.73971	.03556
.04811	.23000	.40349	.17868	.69806	.64251	2.8574E+01	1603.87605	.03452
.04740	.23250	.40317	.17986	.70103	.63683	2.9819E+01	1617.98258	.03352
.04671	.23500	.40285	.18102	.70399	.63109	3.1116E+01	1632.05921	.03254
.04604	.23750	.40254	.18219	.70694	.62531	3.2470E+01	1646.10590	.03159
.04539	.24000	.40223	.18335	.70987	.61947	3.3884E+01	1660.12271	.03067
.04475	.24250	.40193	.18450	.71278	.61358	3.5362E+01	1674.10977	.02977
.04413	.24500	.40163	.18565	.71568	.60763	3.6908E+01	1688.06729	.02890
.04352	.24750	.40133	.18679	.71857	.60162	3.8528E+01	1701.99558	.02805
.04293	.25000	.40104	.18792	.72144	.59555	4.0226E+01	1715.89540	.02723
.04235	.25250	.40075	.18905	.72430	.58946	4.1873E+01	1729.73167	.02643
.04178	.25500	.40047	.19018	.72715	.58329	4.3684E+01	1743.55518	.02565
.04123	.25750	.40019	.19130	.72998	.57706	4.5575E+01	1757.34477	.02489
.04069	.26000	.39991	.19241	.73280	.57077	4.7548E+01	1771.09996	.02415
.04016	.26250	.39963	.19352	.73560	.56442	4.9610E+01	1784.82023	.02343

PBX 9404   PCJ = 0.363 MBAR   RHO = 1.84400

POP PLOT, LN(RUN) = A1 + A2*LN(P-A3), A1 = -5.040996E+00 A2 = -1.365368E+00 A3 = -0.

REACTION HUGONIOT, US = C + S*UP, C = 2.460000E-01 S = 2.530000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE	TIME
.03965	.26500	.39936	.19462	.73840	.55800	5.1764E+01	1798.50504	.02273
.03914	.26750	.39909	.19572	.74118	.55153	5.4015E+01	1812.15383	.02204
.03865	.27000	.39883	.19682	.74395	.54499	5.6368E+01	1825.76601	.02138
.03816	.27250	.39857	.19791	.74670	.53839	5.8829E+01	1839.34096	.02073
.03769	.27500	.39831	.19899	.74945	.53172	6.1404E+01	1852.87807	.02010
.03723	.27750	.39805	.20007	.75218	.52498	6.4098E+01	1866.37664	.01948
.03678	.28000	.39780	.20115	.75490	.51817	6.6918E+01	1879.83599	.01888
.03633	.28250	.39755	.20222	.75761	.51130	6.9871E+01	1893.25537	.01829
.03590	.28500	.39731	.20328	.76030	.50436	7.2963E+01	1906.63401	.01772
.03547	.28750	.39706	.20434	.76299	.49734	7.6202E+01	1919.97108	.01716
.03505	.29000	.39682	.20540	.76566	.49021	7.9748E+01	1933.29306	.01662
.03465	.29250	.39658	.20645	.76832	.48304	8.3356E+01	1946.55250	.01609
.03425	.29500	.39634	.20750	.77098	.47579	8.7150E+01	1959.76957	.01557
.03385	.29750	.39611	.20854	.77362	.46847	9.1142E+01	1972.94362	.01506
.03347	.30000	.39588	.20958	.77625	.46106	9.5347E+01	1986.07395	.01456
.03309	.30250	.39565	.21062	.77887	.45357	9.9779E+01	1999.15989	.01408
.03272	.30500	.39543	.21165	.78148	.44601	1.0445E+02	2012.20071	.01360
.03236	.30750	.39520	.21268	.78408	.43835	1.0939E+02	2025.19572	.01314
.03200	.31000	.39498	.21370	.78667	.43061	1.1461E+02	2038.14417	.01269
.03165	.31250	.39476	.21472	.78925	.42278	1.2012E+02	2051.04532	.01224
.03131	.31500	.39454	.21574	.79182	.41487	1.2597E+02	2063.89843	.01181
.03098	.31750	.39433	.21675	.79438	.40686	1.3216E+02	2076.70272	.01139
.03065	.32000	.39412	.21776	.79692	.39876	1.3874E+02	2089.45750	.01097
.03032	.32250	.39391	.21876	.79946	.39056	1.4573E+02	2102.16176	.01057
.03000	.32500	.39370	.21976	.80200	.38227	1.5317E+02	2114.81494	.01017
.02969	.32750	.39349	.22076	.80452	.37387	1.6110E+02	2127.41616	.00978
.02939	.33000	.39329	.22175	.80703	.36538	1.6957E+02	2139.96463	.00940
.02908	.33250	.39309	.22274	.80953	.35678	1.7863E+02	2152.45956	.00903
.02879	.33500	.39289	.22373	.81202	.34808	1.8833E+02	2164.90014	.00866
.02850	.33750	.39269	.22471	.81451	.33927	1.9875E+02	2177.28559	.00830
.02821	.34000	.39249	.22569	.81698	.33039	2.0941E+02	2189.59539	.00795
.02793	.34250	.39230	.22666	.81945	.32137	2.2153E+02	2201.86269	.00761
.02765	.34500	.39211	.22763	.82191	.31223	2.3443E+02	2214.07119	.00727
.02738	.34750	.39192	.22860	.82436	.30298	2.4838E+02	2226.21987	.00694
.02712	.35000	.39173	.22957	.82680	.29361	2.6350E+02	2238.30770	.00662
.02685	.35250	.39154	.23053	.82923	.28412	2.7993E+02	2250.33360	.00630
.02660	.35500	.39135	.23149	.83166	.27450	2.9784E+02	2262.29652	.00599
.02634	.35750	.39117	.23244	.83407	.26476	3.1743E+02	2274.19533	.00569
.02609	.36000	.39099	.23339	.83648	.25489	3.3892E+02	2286.02892	.00539
.02585	.36250	.39081	.23434	.83888	.24489	3.6261E+02	2297.79615	.00510
.02561	.36500	.39063	.23529	.84127	.23475	3.8882E+02	2309.49584	.00481
.02537	.36750	.39045	.23623	.84366	.22448	4.1795E+02	2321.12682	.00453
.02514	.37000	.39028	.23717	.84603	.21406	4.5051E+02	2332.68788	.00425
.02491	.37250	.39010	.23810	.84840	.20350	4.8711E+02	2344.17780	.00398
.02468	.37500	.38993	.23904	.85076	.19279	5.2853E+02	2355.59536	.00371
.02446	.37750	.38976	.23997	.85311	.18193	5.7576E+02	2366.93931	.00345
.02424	.38000	.38959	.24089	.85546	.17092	6.3007E+02	2378.20841	.00320
.02402	.38250	.38942	.24182	.85780	.15974	6.9314E+02	2389.40141	.00294
.02381	.38500	.38926	.24274	.86013	.14840	7.6662E+02	2400.51709	.00270
.02360	.38750	.38909	.24366	.86245	.13695	8.5273E+02	2411.53765	.00245

RHO = 1.84400

PBX 9404 PCJ = 0.363 MBAR

POP PLOT, LN(RUN) = A1 + A2*LN(P-A3), A1 = -5.040996E+00 A2 = -1.365368E+00 A3 = -0.

REACTION HUGONIOT, US = C + S*UP, C = 2.460000E-01 S = 2.530000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE	TIME
.02339	.39000	.38893	.24457	.86477	.12529	9.5798E+02	2422.48936	.00221
.02319	.39250	.38876	.24548	.86707	.11346	1.0873E+03	2433.35857	.00198
.02299	.39500	.38860	.24639	.86938	.10145	1.2498E+03	2444.14362	.00175
.02279	.39750	.38844	.24730	.87167	.08925	1.4601E+03	2454.84291	.00152
.02260	.40000	.38829	.24820	.87396	.07687	1.7424E+03	2465.45479	.00130

TABLE B-II

```
COMP B      PCJ = 0.284                                                                  RHO = 1.71500

POP PLOT, LN(RUN) = A1 + A2*LN(P-A3),  A1 = -4.384168E+00  A2 = -1.501545E+00  A3 = -0.

REACTION HUGONIOT,  US = C + S*UP,      C =  2.310000E-01   S =  2.500000E+00

CJ DETONATION VELOCITY =  8.084000E-01

HOM EQUATION OF STATE CONSTANTS
UNREACTED EXPLOSIVE
 2.31000000000E-01 1.83000000000E+00 1.00000000000E-02-0.
-0.                -8.86750780814E+00-7.97357471516E+01-1.59428975952E+02
-1.35411036759E+02-3.91274655950E+01 1.50000000000E+00 2.59000000000E-01
 5.83090379009E-01 5.00000000000E-05-0.                -0.
 3.00000000000E+02-0.                -0.                -0.
 0.                -0.                -0.
DETONATION PRODUCTS
-3.52584878974E+00-2.33429189056E+00 5.97267325606E-01 3.04510424546E-03
-1.75226403100E-01-1.56087684485E+00 5.33121475935E-01 8.06310874142E-02
 3.33816891056E-03-6.84399991171E-04 7.50278058550E+00-4.41209000835E-01
 1.51292636188E-01 6.77883292739E-02-2.42403364371E-02 5.00000000000E-01
 1.00000000000E-01


COMP B      PCJ = 0.284                                                                  RHO = 1.71500
LN(RATE) = C(1) + C(2)*P + ... + C(M+1)*(P**M)
C(I=1,14) =  -1.0354580437E+01  4.7342744951E+02 -1.6753704228E+04  4.4756746438E+05 -8.4931471542E+06
              1.1555934358E+08 -1.1402565157E+09  8.2065910931E+09 -4.2986627008E+10  1.6183793696E+11
             -4.2605817430E+11  7.4376767275E+11 -7.7289848996E+11  3.6167775705E+11
MAXIMUM RELATIVE ERROR AT    2.125000E-01 =     6.290758E-03
```

COMP B PCJ = 0.284 RHO = 1.71500

POP PLOT, LN(RUN) = A1 + A2*LN(P-A3), A1 = -4.384168E+00 A2 = -1.501545E+00 A3 = -0.

REACTION HUGONIOT, US = C + S*UP, C = 2.310000E-01 S = 2.500000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE	TIME
4.43670	.02000	.51736	.03626	.32164	.98958	6.3454E-03	400.66634	11.63320
3.71751	.02250	.51297	.03972	.33030	.98727	8.8952E-03	418.41861	9.42554
3.17355	.02500	.50896	.04305	.33862	.98483	1.2038E-02	436.95789	7.79832
2.75038	.02750	.50528	.04626	.34664	.98226	1.5837E-02	456.20833	6.56271
2.41352	.03000	.50188	.04936	.35440	.97959	2.0352E-02	476.07009	5.60133
2.14020	.03250	.49873	.05236	.36191	.97682	2.5658E-02	496.48991	4.83793
1.91482	.03500	.49579	.05528	.36919	.97395	3.1820E-02	517.40807	4.22120
1.72638	.03750	.49304	.05811	.37628	.97099	3.8911E-02	538.77184	3.71551
1.56693	.04000	.49046	.06087	.38317	.96795	4.7002E-02	560.53451	3.29551
1.43059	.04250	.48804	.06356	.38990	.96483	5.6172E-02	582.65458	2.94272
1.31293	.04500	.48575	.06618	.39646	.96163	6.6498E-02	605.09506	2.64340
1.21055	.04750	.48359	.06875	.40287	.95836	7.8062E-02	627.82286	2.38720
1.12082	.05000	.48154	.07126	.40914	.95501	9.0948E-02	650.80826	2.16615
1.04164	.05250	.47959	.07371	.41528	.95159	1.0525E-01	674.02446	1.97404
.97136	.05500	.47774	.07612	.42130	.94811	1.2105E-01	697.44721	1.80601
.90865	.05750	.47597	.07848	.42720	.94456	1.3844E-01	721.05452	1.65816
.85240	.06000	.47428	.08080	.43300	.94094	1.5753E-01	744.82632	1.52736
.80172	.06250	.47267	.08307	.43868	.93725	1.7841E-01	768.76375	1.41107
.75586	.06500	.47113	.08531	.44427	.93350	2.0120E-01	792.80728	1.30720
.71422	.06750	.46964	.08751	.44977	.92969	2.2602E-01	816.96535	1.21403
.67627	.07000	.46822	.08967	.45518	.92581	2.5296E-01	841.22356	1.13014
.64155	.07250	.46685	.09180	.46050	.92187	2.8215E-01	865.56860	1.05432
.60971	.07500	.46554	.09390	.46574	.91787	3.1373E-01	889.98810	.98556
.58042	.07750	.46427	.09596	.47091	.91380	3.4781E-01	914.47058	.92301
.55340	.08000	.46304	.09800	.47600	.90967	3.8453E-01	939.00530	.86594
.52841	.08250	.46186	.10001	.48102	.90548	4.2405E-01	963.58224	.81371
.50525	.08500	.46072	.10199	.48597	.90123	4.6649E-01	988.19200	.76580
.48373	.08750	.45962	.10394	.49085	.89691	5.1203E-01	1012.82573	.72174
.46369	.09000	.45855	.10587	.49568	.89253	5.6083E-01	1037.47509	.68112
.44500	.09250	.45751	.10778	.50044	.88809	6.1304E-01	1062.13224	.64359
.42754	.09500	.45651	.10966	.50515	.88358	6.6886E-01	1086.78971	.60885
.41118	.09750	.45554	.11152	.50979	.87900	7.2846E-01	1111.44044	.57662
.39584	.10000	.45459	.11336	.51439	.87436	7.9203E-01	1136.07773	.54667
.38144	.10250	.45368	.11517	.51893	.86966	8.5979E-01	1160.69517	.51878
.36788	.10500	.45279	.11697	.52342	.86488	9.3195E-01	1185.28556	.49277
.35511	.10750	.45192	.11875	.52787	.86005	1.0087E+00	1209.84534	.46847
.34306	.11000	.45108	.12050	.53226	.85514	1.0903E+00	1234.36776	.44574
.33168	.11250	.45026	.12224	.53661	.85016	1.1771E+00	1258.84744	.42444
.32091	.11500	.44946	.12397	.54092	.84512	1.2691E+00	1283.28010	.40445
.31071	.11750	.44868	.12567	.54518	.84000	1.3668E+00	1307.65802	.38567
.30104	.12000	.44792	.12736	.54940	.83481	1.4700E+00	1332.00878	.36801
.29187	.12250	.44718	.12903	.55358	.82955	1.5798E+00	1356.26238	.35136
.28315	.12500	.44646	.13069	.55772	.82422	1.6962E+00	1380.45028	.33567
.27485	.12750	.44575	.13233	.56182	.81882	1.8194E+00	1404.56786	.32085
.26695	.13000	.44506	.13395	.56588	.81334	1.9497E+00	1428.61085	.30684
.25943	.13250	.44439	.13556	.56991	.80779	2.0877E+00	1452.57510	.29359
.25225	.13500	.44373	.13716	.57390	.80216	2.2336E+00	1476.45656	.28103
.24539	.13750	.44309	.13874	.57786	.79645	2.3878E+00	1500.25134	.26913
.23884	.14000	.44246	.14031	.58179	.79066	2.5508E+00	1523.95561	.25783
.23258	.14250	.44185	.14187	.58568	.78480	2.7231E+00	1547.56568	.24710

COMP B PCJ = 0.284 RHO = 1.71500
POP PLOT, LN(RUN) = A1 + A2*LN(P-A3), A1 = -4.384168E+00 A2 = -1.501545E+00 A3 = -0.
REACTION HUGONIOT, US = C + S*UP, C = 2.310000E-01 S = 2.500000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE	TIME
.22658	.14500	.44124	.14341	.58954	.77885	2.9050E+00	1571.07794	.23690
.22084	.14750	.44065	.14495	.59336	.77281	3.0972E+00	1594.48886	.22719
.21534	.15000	.44008	.14647	.59716	.76670	3.3001E+00	1617.79501	.21794
.21006	.15250	.43951	.14797	.60093	.76050	3.5144E+00	1640.99302	.20913
.20499	.15500	.43896	.14947	.60467	.75421	3.7405E+00	1664.07960	.20073
.20012	.15750	.43841	.15095	.60838	.74783	3.9792E+00	1687.05155	.19270
.19545	.16000	.43788	.15243	.61206	.74136	4.2312E+00	1709.90570	.18504
.19095	.16250	.43736	.15389	.61572	.73481	4.4971E+00	1732.63898	.17771
.18662	.16500	.43684	.15534	.61935	.72816	4.7777E+00	1755.24835	.17070
.18246	.16750	.43634	.15678	.62295	.72142	5.0739E+00	1777.73085	.16400
.17844	.17000	.43585	.15821	.62653	.71458	5.3865E+00	1800.08354	.15757
.17457	.17250	.43536	.15963	.63009	.70764	5.7634E+00	1822.30340	.15141
.17084	.17500	.43489	.16105	.63361	.70059	6.0597E+00	1844.41200	.14551
.16724	.17750	.43442	.16245	.63712	.69346	6.4281E+00	1866.34972	.13984
.16377	.18000	.43396	.16384	.64060	.68623	6.8171E+00	1888.14877	.13440
.16041	.18250	.43351	.16522	.64406	.67889	7.2278E+00	1909.80602	.12917
.15716	.18500	.43306	.16660	.64750	.67144	7.6614E+00	1931.31846	.12415
.15403	.18750	.43263	.16796	.65091	.66389	8.1193E+00	1952.68316	.11932
.15100	.19000	.43220	.16932	.65430	.65623	8.6031E+00	1973.89724	.11467
.14806	.19250	.43178	.17067	.65767	.64845	9.1143E+00	1994.95792	.11020
.14522	.19500	.43136	.17201	.66102	.64056	9.6546E+00	2015.86245	.10589
.14247	.19750	.43095	.17334	.66435	.63255	1.0226E+01	2036.60819	.10174
.13980	.20000	.43055	.17467	.66766	.62443	1.0885E+01	2057.19256	.09773
.13722	.20250	.43015	.17598	.67095	.61619	1.1470E+01	2077.61308	.09387
.13471	.20500	.42976	.17729	.67423	.60782	1.2147E+01	2097.86734	.09015
.13228	.20750	.42938	.17859	.67748	.59933	1.2865E+01	2117.95302	.08655
.12993	.21000	.42900	.17988	.68071	.59071	1.3626E+01	2137.86791	.08308
.12764	.21250	.42863	.18117	.68393	.58198	1.4703E+01	2157.59979	.07973
.12542	.21500	.42826	.18245	.68712	.57309	1.5291E+01	2177.17688	.07649
.12326	.21750	.42790	.18372	.69030	.56407	1.6203E+01	2196.56700	.07335
.12116	.22000	.42755	.18498	.69346	.55492	1.7173E+01	2215.77840	.07032
.11912	.22250	.42720	.18624	.69661	.54563	1.8207E+01	2234.80938	.06739
.11714	.22500	.42685	.18749	.69973	.53619	1.9309E+01	2253.65831	.06455
.11521	.22750	.42651	.18874	.70284	.52660	2.0487E+01	2272.32370	.06180
.11334	.23000	.42617	.18998	.70594	.51687	2.1746E+01	2290.80415	.05914
.11151	.23250	.42584	.19121	.70902	.50702	2.3038E+01	2309.06026	.05656
.10974	.23500	.42552	.19243	.71208	.49699	2.4460E+01	2327.15003	.05406
.10801	.23750	.42519	.19365	.71513	.48681	2.5982E+01	2345.04547	.05164
.10632	.24000	.42488	.19486	.71816	.47646	2.7613E+01	2362.74561	.04929
.10468	.24250	.42456	.19607	.72117	.46595	2.9363E+01	2380.24828	.04700
.10308	.24500	.42425	.19727	.72417	.45527	3.1244E+01	2397.55162	.04479
.10152	.24750	.42395	.19846	.72716	.44442	3.3268E+01	2414.65380	.04264
.10000	.25000	.42365	.19965	.73013	.43339	3.5451E+01	2431.55303	.04055
.09852	.25250	.42335	.20084	.73309	.42219	3.7808E+01	2448.24754	.03853
.09707	.25500	.42305	.20201	.73603	.41081	4.0359E+01	2464.73557	.03656
.09566	.25750	.42276	.20318	.73896	.39924	4.3126E+01	2481.01538	.03464
.09428	.26000	.42248	.20435	.74188	.38749	4.6132E+01	2497.08525	.03278
.09294	.26250	.42219	.20551	.74478	.37554	4.9408E+01	2512.94349	.03097
.09162	.26500	.42191	.20667	.74767	.36339	5.2985E+01	2528.58840	.02921
.09034	.26750	.42164	.20782	.75054	.35105	5.6904E+01	2544.01831	.02750

COMP B PCJ = 0.284 RHO = 1.71500
POP PLOT, LN(RUN) = A1 + A2*LN(P-A3), A1 = -4.384168E+00 A2 = -1.501545E+00 A3 = -0.
REACTION HUGONIOT, US = C + S*UP, C = 2.310000E-01 S = 2.500000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE	TIME
.08909	.27000	.42137	.20896	.75341	.33850	6.1208E+01	2559.23153	.02584
.08786	.27250	.42110	.21010	.75626	.32567	6.6112E+01	2574.25452	.02421
.08667	.27500	.42083	.21124	.75910	.31268	7.1427E+01	2589.03751	.02263
.08550	.27750	.42057	.21237	.76192	.29946	7.7348E+01	2603.60080	.02110
.08435	.28000	.42031	.21349	.76473	.28602	8.3979E+01	2617.94302	.01960
.08323	.28250	.42005	.21461	.76753	.27235	9.1446E+01	2632.06290	.01814
.08214	.28500	.41980	.21573	.77032	.25844	9.9908E+01	2645.95921	.01671
.08107	.28750	.41954	.21684	.77310	.24428	1.0957E+02	2659.63077	.01533
.08002	.29000	.41930	.21795	.77586	.22988	1.2068E+02	2673.07641	.01398
.07900	.29250	.41905	.21905	.77862	.21521	1.3359E+02	2686.29505	.01266
.07799	.29500	.41881	.22014	.78136	.20029	1.4876E+02	2699.28563	.01137
.07701	.29750	.41857	.22124	.78409	.18510	1.6680E+02	2712.04714	.01012
.07605	.30000	.41833	.22232	.78681	.16963	1.8859E+02	2724.57861	.00889
.07511	.30250	.41810	.22341	.78952	.15387	2.1540E+02	2736.87915	.00770
.07419	.30500	.41786	.22449	.79222	.13783	2.4916E+02	2748.94790	.00653
.07328	.30750	.41763	.22556	.79490	.12148	2.9290E+02	2760.78405	.00539
.07240	.31000	.41741	.22663	.79758	.10482	3.5173E+02	2772.38685	.00428
.07153	.31250	.41718	.22770	.80025	.08785	4.3449E+02	2783.75558	.00319
.07068	.31500	.41696	.22876	.80290	.07066	5.5874E+02	2794.87717	.00213

TABLE B-III

```
X0290        PCJ = 0.285                                                                 RHO = 1.89400

POP PLOT, LN(RUN) = A1 + A2*LN(P-A3),  A1 = -6.347114E+00  A2 = -2.917511E+00  A3 = -0.

REACTION HUGONIOT,  US = C + S*UP,      C =  2.400000E-01   S =  2.500000E+00

CJ DETONATION VELOCITY =  7.707000E-01

HOM EQUATION OF STATE CONSTANTS
UNREACTED EXPLOSIVE
 2.40000000000E-01 2.05000000000E+00 0.                0.
 0.               -2.30141685560E+01-1.36319013778E+02-2.35068216661E+02
-1.71049590983E+02-4.22635505569E+01 1.50000000000E+00 3.00000000000E-01
 5.27983100541E-01 5.00000000000E-05-0.               -0.
 3.00000000000E+02 0.               -0.               -0.
-0.               -0.               -0.
DETONATION PRODUCTS
-3.87828541159E+00-2.69032297231E+00 2.22074184951E-01 7.42482128000E-02
-3.42819430727E-02-1.58889615377E+00 5.34895448385E-01 9.42824251124E-02
 8.25643459824E-03 2.89357822582E-04 7.06740292649E+00-5.67003244430E-01
 5.17941586095E-02 9.84863946395E-03-1.09218419748E-02 5.00000000000E-01
 1.00000000000E-01


X0290        PCJ = 0.285                                                                 RHO = 1.89400
LN(RATE) = C(1) + C(2)*P + ... + C(M+1)*(P**M)
C(I=1,15) =   1.6223658470E+02 -1.9660891926E+04  1.0170082035E+06 -3.1181988011E+07  6.3734890585E+08
             -9.2043883492F+09  9.6978690159E+10 -7.5817519329E+11  4.4248348854E+12 -1.9206772744E+13
              6.1110150327E+13 -1.3836158944E+14  2.1097494446E+14 -1.9413888714E+14  8.1425481008E+13
MAXIMUM RELATIVE ERROR AT    1.575000F-01 =      1.359446E-02
SEJ
```

X0290 PCJ = 0.285 RHO = 1.89400

POP PLOT, LN(RUN) = A1 + A2*LN(P-A3), A1 = -6.347114E+00 A2 = -2.917511E+00 A3 = -0.

REACTION HUGONIOT, US = C + S*UP, C = 2.400000E-01 S = 2.500000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE	TIME
9.49364	.05250	.44062	.06772	.40931	.96839	5.8999E-03	492.44427	20.86183
8.28875	.05500	.43894	.06998	.41495	.96604	7.2314E-03	505.11963	17.93768
7.28058	.05750	.43733	.07220	.42050	.96363	8.7891E-03	517.96687	15.52375
6.43044	.06000	.43579	.07437	.42594	.96116	1.0601E-02	530.98558	13.51463
5.70843	.06250	.43431	.07651	.43128	.95864	1.2696E-02	544.16574	11.82983
5.09122	.06500	.43290	.07862	.43654	.95606	1.5108E-02	557.49817	10.40718
4.56040	.06750	.43154	.08068	.44171	.95344	1.7870E-02	570.97452	9.19819
4.10131	.07000	.43023	.08272	.44680	.95075	2.1021E-02	584.58710	8.16466
3.70220	.07250	.42898	.08472	.45181	.94801	2.4602E-02	598.32887	7.27627
3.35355	.07500	.42776	.08670	.45674	.94522	2.8655E-02	612.19333	6.50869
3.04760	.07750	.42659	.08864	.46161	.94237	3.3228E-02	626.17450	5.84232
2.77799	.08000	.42546	.09056	.46641	.93947	3.8371E-02	640.26687	5.26121
2.53946	.08250	.42437	.09245	.47114	.93650	4.4138E-02	654.46531	4.75231
2.32764	.08500	.42332	.09432	.47580	.93349	5.0587E-02	668.76508	4.30490
2.13888	.08750	.42230	.09616	.48041	.93041	5.7781E-02	683.16177	3.91006
1.97012	.09000	.42131	.09798	.48496	.92728	6.5786E-02	697.65128	3.56040
1.81876	.09250	.42035	.09978	.48945	.92408	7.4673E-02	712.22977	3.24972
1.68262	.09500	.41942	.10156	.49389	.92083	8.4520E-02	726.89367	2.97280
1.55982	.09750	.41851	.10331	.49828	.91751	9.5407E-02	741.63961	2.72523
1.44875	.10000	.41763	.10505	.50262	.91414	1.0742E-01	756.46446	2.50329
1.34805	.10250	.41678	.10676	.50691	.91069	1.2066E-01	771.36526	2.30378
1.25653	.10500	.41595	.10846	.51115	.90719	1.3522E-01	786.33921	2.12397
1.17317	.10750	.41514	.11014	.51534	.90362	1.5121E-01	801.38370	1.96153
1.09706	.11000	.41436	.11180	.51949	.89998	1.6913E-01	816.49624	1.81443
1.02744	.11250	.41359	.11344	.52360	.89627	1.8792F-01	831.68987	1.68094
.96362	.11500	.41285	.11507	.52767	.89249	2.0892E-01	846.92896	1.55952
.90502	.11750	.41212	.11668	.53170	.88864	2.3187E-01	862.22978	1.44888
.85110	.12000	.41141	.11827	.53569	.88472	2.5690E-01	877.59026	1.34785
.80141	.12250	.41072	.11985	.53964	.88073	2.8419E-01	893.00843	1.25542
.75554	.12500	.41004	.12142	.54355	.87666	3.1390E-01	908.48242	1.17072
.71313	.12750	.40938	.12297	.54743	.87251	3.4622E-01	924.01044	1.09297
.67385	.13000	.40873	.12451	.55127	.86828	3.8136E-01	939.59077	1.02146
.63742	.13250	.40810	.12603	.55508	.86397	4.1951E-01	955.22175	.95561
.60359	.13500	.40749	.12754	.55886	.85957	4.6091E-01	970.90182	.89487
.57213	.13750	.40688	.12904	.56260	.85509	5.0581E-01	986.62945	.83876
.54283	.14000	.40629	.13052	.56631	.85051	5.5446F-01	1002.40316	.78685
.51551	.14250	.40571	.13200	.56999	.84585	6.0715E-01	1018.22154	.73876
.49001	.14500	.40515	.13346	.57365	.84109	6.6419E-01	1034.08322	.69415
.46617	.14750	.40459	.13491	.57727	.83624	7.2589E-01	1049.98687	.65273
.44386	.15000	.40405	.13634	.58086	.83129	7.9261E-01	1065.93119	.61420
.42296	.15250	.40352	.13777	.58443	.82623	8.6473E-01	1081.91494	.57834
.40337	.15500	.40300	.13919	.58797	.82107	9.4265E-01	1097.93689	.54490
.38497	.15750	.40248	.14059	.59148	.81580	1.0268E+00	1113.99584	.51371
.36768	.16000	.40198	.14199	.59497	.81042	1.1177E+00	1130.09004	.48457
.35142	.16250	.40149	.14337	.59843	.80493	1.2158E+00	1146.21956	.45731
.33611	.16500	.40101	.14475	.60186	.79932	1.3217E+00	1162.38265	.43180
.32168	.16750	.40053	.14611	.60528	.79358	1.4360E+00	1178.57872	.40790
.30808	.17000	.40006	.14747	.60866	.78770	1.5583E+00	1194.82756	.38548
.29523	.17250	.39961	.14881	.61203	.78172	1.6914E+00	1211.07899	.36443
.28309	.17500	.39916	.15015	.61537	.77559	1.8351E+00	1227.36094	.34465

X0290 PCJ = 0.285 RHO = 1.89400
POP PLOT, LN(RUN) = A1 + A2*LN(P-A3), A1 = -6.347114E+00 A2 = -2.917511E+00 A3 = -0.
REACTION HUGONIOT, US = C + S*UP, C = 2.400000E-01 S = 2.500000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE	TIME
.27162	.17750	.39872	.15148	.61869	.76933	1.9900E+00	1243.67210	.32605
.26076	.18000	.39828	.15280	.62199	.76293	2.1573E+00	1260.01127	.30855
.25047	.18250	.39785	.15411	.62526	.75638	2.3377E+00	1276.37731	.29205
.24072	.18500	.39743	.15541	.62852	.74967	2.5324E+00	1292.76908	.27650
.23148	.18750	.39702	.15670	.63175	.74281	2.7426E+00	1309.18543	.26183
.22270	.19000	.39661	.15799	.63497	.73578	2.9696E+00	1325.62526	.24798
.21437	.19250	.39622	.15926	.63816	.72858	3.2147E+00	1342.08745	.23489
.20645	.19500	.39582	.16053	.64134	.72120	3.4795E+00	1358.57091	.22251
.19892	.19750	.39544	.16180	.64449	.71365	3.7657E+00	1375.07457	.21079
.19175	.20000	.39505	.16305	.64763	.70590	4.0752E+00	1391.59733	.19970
.18493	.20250	.39468	.16430	.65075	.69793	4.4305E+00	1408.15879	.18918
.17842	.20500	.39431	.16554	.65385	.68984	4.8137E+00	1424.66982	.17921
.17222	.20750	.39395	.16677	.65693	.68145	5.1653E+00	1441.26979	.16975
.16631	.21000	.39359	.16800	.65999	.67290	5.5291E+00	1457.82778	.16077
.16066	.21250	.39324	.16922	.66304	.66404	6.1028E+00	1474.47725	.15224
.15528	.21500	.39289	.17043	.66607	.65501	6.5550E+00	1491.07649	.14413
.15013	.21750	.39254	.17163	.66908	.64571	7.1005E+00	1507.70385	.13641
.14520	.22000	.39221	.17283	.67208	.63616	7.6943E+00	1524.34207	.12907
.14049	.22250	.39187	.17402	.67506	.62634	8.3414E+00	1540.99016	.12208
.13599	.22500	.39155	.17521	.67802	.61623	9.0475E+00	1557.64716	.11542
.13167	.22750	.39122	.17639	.68097	.60583	9.8191E+00	1574.31208	.10907
.12754	.23000	.39090	.17756	.68391	.59512	1.0664E+01	1590.98395	.10302
.12358	.23250	.39059	.17873	.68682	.58410	1.1590E+01	1607.66184	.09724
.11978	.23500	.39028	.17989	.68973	.57273	1.2607E+01	1624.34478	.09172
.11614	.23750	.38997	.18105	.69262	.56101	1.3727E+01	1641.03184	.08645
.11265	.24000	.38967	.18220	.69549	.54893	1.4962E+01	1657.72210	.08142
.10929	.24250	.38937	.18334	.69835	.53652	1.6295E+01	1674.37411	.07660
.10607	.24500	.38908	.18448	.70120	.52366	1.7797E+01	1691.05472	.07200
.10298	.24750	.38878	.18561	.70403	.51038	1.9466E+01	1707.73266	.06759
.10000	.25000	.38850	.18674	.70685	.49665	2.1324E+01	1724.40657	.06338
.09714	.25250	.38821	.18786	.70965	.48246	2.3401E+01	1741.07500	.05934
.09439	.25500	.38793	.18898	.71244	.46778	2.5730E+01	1757.73651	.05547
.09174	.25750	.38766	.19009	.71522	.45258	2.8354E+01	1774.38957	.05175
.08919	.26000	.38738	.19119	.71799	.43684	3.1322E+01	1791.03263	.04820
.08673	.26250	.38712	.19230	.72074	.42053	3.4698E+01	1807.66409	.04478
.08437	.26500	.38685	.19339	.72348	.40360	3.8560E+01	1824.28228	.04151
.08209	.26750	.38659	.19448	.72621	.38604	4.3006E+01	1840.88548	.03836
.07989	.27000	.38633	.19557	.72892	.36780	4.8163E+01	1857.47191	.03534
.07777	.27250	.38607	.19665	.73163	.34885	5.4196E+01	1874.03973	.03244
.07572	.27500	.38581	.19773	.73432	.32913	6.1323E+01	1890.58751	.02965
.07375	.27750	.38556	.19880	.73700	.30861	6.9840E+01	1907.11234	.02697
.07185	.28000	.38532	.19987	.73967	.28723	8.0160E+01	1923.61256	.02439
.07001	.28250	.38507	.20093	.74232	.26493	9.2871E+01	1940.08600	.02190
.06823	.28500	.38483	.20199	.74497	.24166	1.0884E+02	1956.53041	.01952
.06651	.28750	.38459	.20304	.74760	.21736	1.2943E+02	1972.94340	.01721
.06485	.29000	.38435	.20409	.75023	.19195	1.5684E+02	1989.32250	.01500
.06325	.29250	.38412	.20514	.75284	.16535	1.9493E+02	2005.66511	.01287
.06170	.29500	.38388	.20618	.75544	.13748	2.5115E+02	2021.96850	.01081
.06020	.29750	.38366	.20721	.75803	.10825	3.4229E+02	2038.22978	.00883
.05875	.30000	.38343	.20825	.76061	.07736	5.1490E+02	2054.49698	.00691

TABLE B-IV

```
X0219        PCJ = 0.281                                                                          RHO = 1.91400

POP PLOT, LN(RUN) = A1 + A2*LN(P-A3),   A1 = -6.448715E+00   A2 = -3.540121E+00   A3 = -0.

REACTION HUGONIOT,   US = C + S*UP,        C =  2.400000E-01    S =  2.500000E+00

CJ DETONATION VELOCITY =   7.638000E-01

HOM EQUATION OF STATE CONSTANTS
UNREACTED EXPLOSIVE
 2.40000000000E-01 2.05000000000E+00 1.00000000000E-02-0.
-0.               -2.41732675010E+01-1.39872107139E+02-2.37879021477E+02
-1.70729283235E+02-4.16327143692E+01 1.50000000000E+00 3.00000000000E-01
 5.22466039700E-01 5.00000000000E-05-0.                -0.
 3.00000000000E+02-0.               -0.                -0.
 0.               -0.               -0.
DETONATION PRODUCTS
-3.91838765932E+00-2.71643821597E+00 2.05342343130E-01 6.61105468088E-02
-3.91459626339E-02-1.60416980796E+00 5.15253186395E-01 8.70181482233E-02
 7.11483581354E-03 2.31252628821E-04 6.98197293179E+00-6.22066979658E-01
 5.02599390363E-02 1.38984795152E-02-2.09898554653E-02 5.00000000000E-01
 1.00000000000E-01



X0219        PCJ = 0.281                                                                          RHO = 1.91400
LN(RATE) = C(1) + C(2)*P + ... + C(M+1)*(P**M)
C(I=1,12) =   1.4075505136E+03 -9.8714282915E+04  3.0649779677E+06 -5.5916067561E+07  6.6670458079E+08
             -5.4576765803E+09  3.1312974566E+10 -1.2597622279E+11  3.4845587692E+11 -6.3145764386E+11
              6.7508144963E+11 -3.2273266347E+11
MAXIMUM RELATIVE ERROR AT    2.950000E-01 =     5.033449E-02
```

X0219 PCJ = 0.281 RHO = 1.91400

POP PLOT, LN(RUN) = A1 + A2*LN(P-A3), A1 = -6.448715E+00 A2 = -3.540121E+00 A3 = -0.

REACTION HUGONIOT, US = C + S*UP, C = 2.400000E-01 S = 2.500000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE	TIME
9.75765	.08500	.41926	.09366	.47415	.93252	1.0089E-02	657.22629	18.61415
8.80599	.08750	.41825	.09549	.47873	.92941	1.1732E-02	671.10324	16.61652
7.97015	.09000	.41727	.09730	.48326	.92624	1.3591E-02	685.06487	14.87862
7.23339	.09250	.41632	.09909	.48772	.92301	1.5689E-02	699.10743	13.36092
6.58174	.09500	.41540	.10085	.49214	.91972	1.8052E-02	713.22741	12.03071
6.00350	.09750	.41450	.10260	.49650	.91638	2.0705E-02	727.42153	10.86084
5.48883	.10000	.41363	.10432	.50081	.91296	2.3679E-02	741.68670	9.82863
5.02940	.10250	.41279	.10603	.50507	.90949	2.7004E-02	756.02004	8.91507
4.61814	.10500	.41196	.10772	.50929	.90595	3.0714E-02	770.41880	8.10414
4.24903	.10750	.41116	.10939	.51346	.90235	3.4847E-02	784.88041	7.38230
3.91692	.11000	.41038	.11104	.51759	.89868	3.9442E-02	799.40244	6.73803
3.61738	.11250	.40963	.11267	.52168	.89493	4.4533E-02	813.99763	6.16154
3.34659	.11500	.40889	.11429	.52572	.89112	5.0184E-02	828.63112	5.64444
3.10125	.11750	.40816	.11589	.52972	.88724	5.6436E-02	843.31881	5.17952
2.87851	.12000	.40746	.11748	.53369	.88329	6.3343E-02	858.05867	4.76059
2.67588	.12250	.40677	.11905	.53762	.87926	7.0964E-02	872.84877	4.38228
2.49119	.12500	.40610	.12060	.54151	.87516	7.9362E-02	887.68725	4.03995
2.32253	.12750	.40545	.12215	.54537	.87098	8.8605E-02	902.57233	3.72958
2.16824	.13000	.40481	.12367	.54919	.86672	9.8767E-02	917.50233	3.44764
2.02685	.13250	.40418	.12519	.55297	.86238	1.0993E-01	932.47560	3.19106
1.89707	.13500	.40357	.12669	.55673	.85795	1.2217E-01	947.49057	2.95715
1.77775	.13750	.40297	.12818	.56045	.85344	1.3559E-01	962.54572	2.74354
1.66790	.14000	.40239	.12966	.56414	.84883	1.5028E-01	977.63959	2.54816
1.56659	.14250	.40181	.13112	.56780	.84414	1.6636E-01	992.77075	2.36917
1.47305	.14500	.40125	.13257	.57144	.83935	1.8395E-01	1007.93783	2.20494
1.38655	.14750	.40070	.13402	.57504	.83447	2.0316E-01	1023.13949	2.05403
1.30646	.15000	.40016	.13544	.57861	.82949	2.2413E-01	1038.37441	1.91518
1.23220	.15250	.39964	.13686	.58216	.82441	2.4702E-01	1053.64133	1.78723
1.16328	.15500	.39912	.13827	.58568	.81922	2.7198E-01	1068.93844	1.66919
1.09921	.15750	.39861	.13967	.58917	.81392	2.9919E-01	1084.26567	1.56013
1.03961	.16000	.39811	.14106	.59264	.80851	3.2884E-01	1099.62123	1.45925
.98409	.16250	.39762	.14243	.59608	.80299	3.6112E-01	1115.00395	1.36583
.93231	.16500	.39714	.14380	.59950	.79735	3.9628E-01	1130.41313	1.27922
.88398	.16750	.39667	.14516	.60289	.79159	4.3454E-01	1145.84667	1.19882
.83881	.17000	.39621	.14650	.60626	.78568	4.7586E-01	1161.32402	1.12411
.79656	.17250	.39576	.14784	.60961	.77967	5.2117E-01	1176.79840	1.05461
.75700	.17500	.39531	.14917	.61293	.77352	5.7046E-01	1192.29548	.98989
.71993	.17750	.39487	.15049	.61623	.76723	6.2407E-01	1207.81387	.92956
.68515	.18000	.39444	.15180	.61951	.76080	6.8236E-01	1223.35232	.87327
.65250	.18250	.39402	.15311	.62277	.75422	7.4574E-01	1238.90963	.82070
.62181	.18500	.39360	.15440	.62600	.74749	8.1466E-01	1254.48455	.77156
.59296	.18750	.39319	.15569	.62922	.74060	8.8961E-01	1270.07589	.72558
.56579	.19000	.39279	.15697	.63242	.73354	9.7113E-01	1285.68244	.68252
.54021	.19250	.39239	.15824	.63559	.72631	1.0598E+00	1301.30299	.64217
.51609	.19500	.39200	.15950	.63875	.71891	1.1563E+00	1316.93637	.60431
.49333	.19750	.39162	.16076	.64189	.71132	1.2613E+00	1332.58137	.56877
.47184	.20000	.39124	.16200	.64501	.70355	1.3756E+00	1348.23668	.53537
.45154	.20250	.39087	.16324	.64811	.69557	1.4888E+00	1363.90364	.50397
.43235	.20500	.39050	.16448	.65119	.68739	1.6359E+00	1379.57438	.47443
.41419	.20750	.39014	.16570	.65426	.67900	1.7839E+00	1395.25412	.44661

X0219 PCJ = 0.281 RHO = 1.91400

POP PLOT, LN(RUN) = A1 + A2*LN(P-A3), A1 = -6.448715E+00 A2 = -3.540121E+00 A3 = -0.

REACTION HUGONIOT, US = C + S*UP, C = 2.400000E-01 S = 2.500000F+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE	TIME
.39699	.21000	.38979	.16692	.65730	.67042	1.9551F+00	1410.91686	.42039
.38071	.21250	.38944	.16813	.66033	.66155	2.0998E+00	1426.62974	.39566
.36526	.21500	.38909	.16934	.66335	.65247	2.3144E+00	1442.32323	.37233
.35062	.21750	.38875	.17054	.66634	.64314	2.5252F+00	1458.01901	.35030
.33671	.22000	.38842	.17173	.66932	.63355	2.7560E+00	1473.71587	.32948
.32351	.22250	.38809	.17292	.67229	.62368	3.0091E+00	1489.41266	.30980
.31096	.22500	.38776	.17409	.67524	.61354	3.2869E+00	1505.10822	.29118
.29904	.22750	.38744	.17527	.67817	.60310	3.5922E+00	1520.80138	.27355
.28769	.23000	.38712	.17643	.68109	.59235	3.9283E+00	1536.49097	.25685
.27688	.23250	.38681	.17760	.68399	.58127	4.2989E+00	1552.17583	.24102
.26660	.23500	.38650	.17875	.68688	.56985	4.7084E+00	1567.85479	.22601
.25679	.23750	.38620	.17990	.68975	.55808	5.1617F+00	1583.52668	.21177
.24745	.24000	.38590	.18104	.69261	.54600	5.6488E+00	1599.15754	.19825
.23854	.24250	.38560	.18218	.69545	.53349	6.2081E+00	1614.80041	.18541
.23003	.24500	.38531	.18331	.69828	.52057	6.8256E+00	1630.42988	.17320
.22191	.24750	.38502	.18444	.70110	.50722	7.5149E+00	1646.04431	.16160
.21415	.25000	.38473	.18556	.70390	.49343	8.2866E+00	1661.64200	.15055
.20674	.25250	.38445	.18668	.70669	.47916	9.1535E+00	1677.22122	.14004
.19965	.25500	.38418	.18779	.70947	.46440	1.0131F+01	1692.78015	.13004
.19288	.25750	.38390	.18889	.71223	.44912	1.1237E+01	1708.31692	.12050
.18639	.26000	.38363	.18999	.71498	.43328	1.2495E+01	1723.82961	.11141
.18018	.26250	.38336	.19109	.71772	.41687	1.3933E+01	1739.31620	.10275
.17424	.26500	.38310	.19218	.72044	.39984	1.5587E+01	1754.77464	.09448
.16854	.26750	.38284	.19326	.72316	.38216	1.7500E+01	1770.20275	.08658
.16308	.27000	.38258	.19434	.72586	.36379	1.9731E+01	1785.59831	.07905
.15784	.27250	.38232	.19542	.72855	.34470	2.2355E+01	1800.95897	.07185
.15282	.27500	.38207	.19649	.73122	.32483	2.5472E+01	1816.28276	.06497
.14800	.27750	.38182	.19756	.73389	.30415	2.9219E+01	1831.56633	.05839
.14338	.28000	.38158	.19862	.73654	.28259	3.3787E+01	1846.80742	.05210
.13894	.28250	.38133	.19967	.73919	.26010	3.9452E+01	1862.00326	.04608
.13467	.28500	.38109	.20073	.74182	.23662	4.6625E+01	1877.15097	.04032
.13057	.28750	.38085	.20178	.74444	.21209	5.5951E+01	1892.24751	.03480
.12663	.29000	.38062	.20282	.74705	.18642	6.8496E+01	1907.28972	.02952
.12284	.29250	.38039	.20386	.74965	.15954	8.6165E+01	1922.27425	.02445
.11919	.29500	.38016	.20489	.75223	.13137	1.6286E+02	1937.19761	.01960
.11569	.29750	.37993	.20592	.75481	.10160	1.5748E+02	1952.10301	.01494
.11231	.30000	.37970	.20695	.75738	.07048	2.4498E+02	1966.90355	.01047

APPENDIX C

EQUATIONS AND COMPUTER LISTING USED TO COMPUTE

FOREST FIRE RATES

Where the explosive burn is fast enough to affect the reactive shock motion, single curve build-up is assumed to apply and the Pop plot is interpreted to give a relationship between pressure and distance for the shock front. Using a reactive Hugoniot for the reactive shock, complete solution may be obtained for the state variables and their time derivatives at the shock front as shown in Ref. 4.

More information is needed to obtain a burn rate function that is consistent with the Pop plot and the reactive Hugoniot data line. The assumption that the pressure gradient at the front is zero was found to be adequate for many purposes. Tables C-I — C-IV show burn rates calculated at various points behind the shock for a growing square wave. The "RUN" entry, which marks the wave position, is the initial distance of the mass point from the detonation point. For example, in each sublist at constant pressure the smallest "RUN" marks the shock front. Tables C-I — C-IV show that the rate varies some, but not drastically, at various points in the wave. Therefore, the assumption that the pressure gradient at the front is zero is about equal to assuming a growing square wave if the rate derived at the front is used throughout the flow. When the shock front approaches the detonation state, the growing square wave is inappropriate and the Forest Fire model ceases to approximate a square wave.

The following equations present a general derivation of the Forest Fire model. The derivation is then restricted to the growing square wave used in Tables C-I — C-IV. It is also restricted to zero pressure gradient at the front to calculate the explosive rates described in Appendix B. The code listing given at the end of this Appendix was written in FORTRAN IV for the CDC-7600 computer. This code was used to calculate the explosive rates in Appendix B.

Nomenclature

P = pressure

U_s = shock velocity

U = particle velocity

V = specific volume

ρ = density

I = internal energy

W = mass fraction

x = distance

t = time

Notation: The Lagrangian "mass coordinates" are

$$\frac{\partial}{\partial m} = \frac{1}{\rho}\frac{\partial}{\partial x}$$

and

$$\frac{\partial}{\partial \tau} = \frac{\partial}{\partial t} + u\frac{\partial}{\partial x} .$$

The fluid flow equations are

$$U_\tau = -P_m \ ,$$

$$V_\tau = U_m \ ,$$

and

$$I_\tau = -P \cdot V_\tau \ .$$

The solution of burn rates is consistent with growing reactive shock. Solve for

$$P, V, I$$

and

$$P_\tau, V_\tau, I_\tau \ .$$

Then solve for W and W_τ from

$$P = H(V, I, W)$$

and

$$P_\tau = H_V V_\tau + H_I I_\tau + H_w W_\tau \ .$$

Notation: Let $\hat{P}$, $\hat{V}$, $\hat{I}$, and $\hat{U}$ be shock front functions.

Let $m_s(\ )$ = mass position of the shock so that $m_s(o) = 0$.

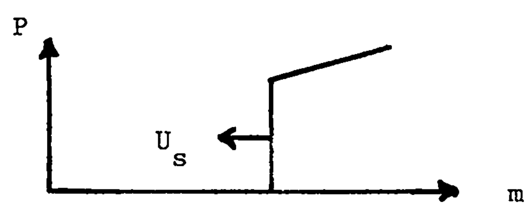
Let $t_s(m)$ = time of shock arrival at mass point m.

Note: $$\frac{d\ m_s(\tau)}{d\tau} = \rho_o\ U_s(\tau)$$

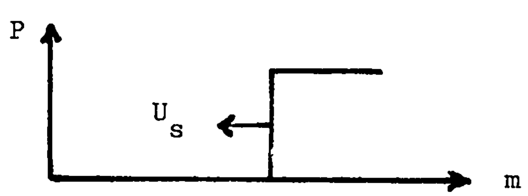
and $$\frac{d\ t_s(m)}{dm} = \frac{1}{\rho_o\ U_s(m)} \quad .$$

Assumption: Let $\frac{\partial P}{\partial m} \equiv P_m = f(\tau)$.

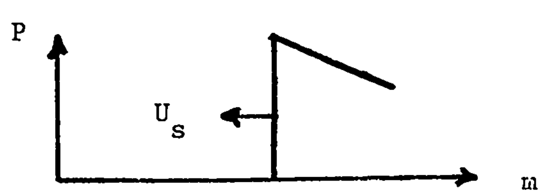
Then the shock-pressure wave looks like



or



or



.

The solution of flow equations is

$$P(m,\tau) = \hat{P}\Big(m_s(\tau)\Big) + P_m(\tau)\Big(m - m_s(\tau)\Big) ,$$

$$P_\tau(m,\tau) = \left(\frac{d\hat{P}}{dm} - P_m(\tau)\right) \frac{dm_s(\tau)}{d\tau} + \frac{dP_m(\tau)}{d\tau}\Big(m - m_s(\tau)\Big) ,$$

$$U(m,\tau) = \hat{U}(m) - \int_{t_s(m)}^{\tau} P_m(t')\, dt' ,$$

$$U_m(m,\tau) = \frac{d\hat{U}}{dm} + P_m\Big(t_s(m)\Big) \frac{dt_s(m)}{dm} \qquad \begin{bmatrix}\text{a function}\\ \text{of m only}\end{bmatrix} ,$$

$$V(m,\tau) = \hat{V}(m) + U_m(m) \int_{t_s(m)}^{\tau} dt' ,$$

$$I(m,\tau) = \hat{I}(m) - U_m(m) \int_{t_s(m)}^{\tau} P(m,t')\, dt' ,$$

$$V_\tau = U_m(m) ,$$

and

$$I_\tau = -P(m,\tau) \cdot U_m(m) .$$

The reactive shock Hugoniot and shock jump relations are

$$U_s = c + S\hat{U} ,$$

$$\hat{P} = \rho_o U_s \hat{U} ,$$

$$\hat{V} = V_o \Big(U_s - \hat{U}\Big)/U_s ,$$

and

$$\hat{I} = \hat{U}^2/2 .$$

Then,

$$\hat{U} = -\left(-c + \left[c^2 + 4V_o S \hat{P}\right]^{\frac{1}{2}}\right)/2S \quad ,$$

$$U_s = -\left(c + \left[c^2 + 4V_o S \hat{P}\right]^{\frac{1}{2}}\right)/2 \quad ,$$

$$d\hat{P} = \rho_o \left(S\hat{U} + U_s\right) d\hat{U} \quad .$$

The Pop plot is

$$\ell n(\text{run}) = \alpha_1 + \alpha_2 \, \ell n \left(\hat{P} - P_o\right)$$

$$\frac{dP}{d\ \text{run}} = \frac{\left(\hat{P} - P_o\right)}{\alpha_2 \ \text{run}\ (\hat{P})} \quad .$$

Then,

$$\frac{d\hat{P}}{dm} = \frac{V_o \left(\hat{P} - P_o\right)}{\alpha_2 \ \text{run}(\hat{P})}$$

and

$$\frac{d\hat{U}}{dm} = \frac{1}{\rho_o \left(S\hat{U} + U_s\right)} \ \frac{d\hat{P}}{dm} \quad .$$

The solution for t_s is

$$\frac{d\,t_s}{d\,run} = \frac{1}{\left(\frac{d\,run}{dt_s}\right)}$$

Thus integrate

$$\frac{dt_s}{d\,run} = \frac{-2}{c+\left[c^2 + 4V_o S\left(e^{-\alpha_1/\alpha_2} run^{1/\alpha_2} + P_o\right)\right]^{\frac{1}{2}}}$$

with initial conditions

$$t_s(o) = 0 \quad .$$

Remember that $m_s = \rho_o$ run .

Special integral evaluations are given for $\hat{P}_m \equiv 0$. Here $\hat{P}$ may be used as the independent variable $dt' = d\hat{P}/(d\hat{P}/dt)$. Thus,

$$(*) \qquad \int_{t_s(m)}^{\tau} dt' = \int_{\hat{P}(m)}^{\hat{P}(\tau)} \frac{-\alpha_2\,run(P)}{U_s(P)\;(P-P_o)}\,dP$$

and

$$\int_{t_s(m)}^{\tau} \dot{P}(t')\,dt' = \int_{\hat{P}(m)}^{\hat{P}(\tau)} \frac{-P\,\alpha_2\,run(P)}{U_s(P)\;(P-P_o)}\,dP \quad ,$$

where

$$\frac{run(P)}{U_s(P)} = \frac{2\,\exp\left[\alpha_1 + \alpha_2\,\ell n\left(P-P_o\right)\right]}{C + \left[C^2 + 4V_o\;S\;P\right]^{1/2}} \quad .$$

The integral (*) can also be used to calculate the time to detonation, t_{DET}, if the upper limit is set to P_{DET}, where

$$P_{DET} = \rho_o D_{CJ} (D_{CJ} - C)/S$$

and

$$D_{CJ} = \text{C-J detonation velocity}$$

Restriction of the square wave solution ($\hat{P}m_{\hat{}} = 0$) to the shock front only gives further simplification. In summary, using $\hat{P}$ as the independent variable,

$$\ell n(\text{run}) = \alpha_1 + \alpha_2 \, \ell n(\hat{P} - P_o) \quad ,$$

$$\hat{U} = \left[-C + (C^2 + 4V_o \, S \, \hat{P})^{1/2}\right]/(2S) \quad ,$$

$$U_s = C + S\hat{U} \quad ,$$

$$V = V_o \, (U_s - \hat{U})/U_s \quad ,$$

and

$$I = \hat{U}^2/2 \quad .$$

W is solved from $\hat{P} = H(V,I,W)$,

$$P_\tau = (P - P_o)U_s/(\alpha_2 \, \text{run}) \quad ,$$

$$U_m = \frac{-V_o^2 \, (\hat{P} - P_o)}{\alpha_2 \cdot \text{run} \cdot (U_s + S\hat{U})} \quad ,$$

$$V_\tau = U_m \quad ,$$

and

$$I_\tau = -P \, V_\tau \quad .$$

Finally, we solve for W_τ from

$$P_\tau = H_V \cdot V_\tau + H_I \cdot I_\tau + Hw\, W_\tau \quad .$$

Temperature is calculated as an additional output of the HOM equation of state.

TABLE C-I

PBX 9404 PCJ = 0.363 MBAR RHO = 1.8440

POP PLOT, LN(R) = A + B*LN(P), A = -5.040996E+00 B = -1.365368E+00

REACTION HUGONIOT, US = C + S*UP, C = 2.460000E-01 S = 2.530000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE
2.00000	.01500	.49697	.02607	.31197	.99248	1.2016E-02	352.34864
2.20000	.01500	.50139	.02461	.30826	.98643	1.1513E-02	372.08939
2.40000	.01500	.50501	.02333	.30503	.98154	1.1125E-02	388.21313
2.60000	.01500	.50804	.02221	.30220	.97751	1.0816E-02	401.63889
2.80000	.01500	.51060	.02122	.29968	.97412	1.0572E-02	412.99791
3.00000	.01500	.51279	.02032	.29742	.97125	1.0374E-02	422.73805
.99569	.02500	.48065	.03926	.34533	.98327	4.5525E-02	399.49584
1.09526	.02500	.48608	.03718	.34006	.97335	4.3925E-02	428.72565
1.19483	.02500	.49057	.03536	.33547	.96529	4.2703E-02	452.82587
1.29440	.02500	.49434	.03376	.33141	.95859	4.1748E-02	473.08033
1.39397	.02500	.49756	.03233	.32779	.95295	4.0989E-02	490.37218
1.49354	.02500	.50034	.03104	.32454	.94812	4.0378E-02	505.32972
.62894	.03500	.46883	.05071	.37430	.97242	1.1008E-01	452.26685
.69183	.03500	.47485	.04813	.36777	.95888	1.0685E-01	488.51048
.75472	.03500	.47984	.04587	.36205	.94783	1.0441E-01	518.57058
.81762	.03500	.48406	.04387	.35700	.93863	1.0252E-01	543.99477
.88051	.03500	.48767	.04209	.35248	.93085	1.0104E-01	565.83618
.94340	.03500	.49080	.04048	.34841	.92417	9.9876E-02	584.84324
.44626	.04500	.45969	.06097	.40025	.96049	2.1418E-01	508.44591
.49088	.04500	.46609	.05796	.39264	.94351	2.0909E-01	549.87602
.53551	.04500	.47141	.05532	.38597	.92962	2.0527E-01	584.43009
.58013	.04500	.47591	.05299	.38005	.91802	2.0238E-01	613.80287
.62476	.04500	.47978	.05089	.37476	.90819	2.0016E-01	639.16064
.66938	.04500	.48314	.04901	.37000	.89974	1.9846E-01	661.33466
.33931	.05500	.45232	.07035	.42398	.94778	3.6660E-01	566.66045
.37324	.05500	.45898	.06696	.41541	.92747	3.5978E-01	611.93135
.40717	.05500	.46453	.06398	.40788	.91082	3.5481E-01	649.85478
.44110	.05500	.46923	.06135	.40120	.89690	3.5116E-01	682.23058
.47503	.05500	.47327	.05898	.39523	.88509	3.4850E-01	710.29777
.50896	.05500	.47679	.05685	.38984	.87491	3.4640E-01	734.97015
.27011	.06500	.44619	.07904	.44597	.93443	5.7660E-01	626.09370
.29712	.06500	.45304	.07531	.43652	.91087	5.6882E-01	674.12018
.32413	.06500	.45875	.07203	.42823	.89152	5.6510E-01	714.54379
.35114	.06500	.46359	.06911	.42086	.87535	5.5966E-01	749.15578
.37815	.06500	.46776	.06651	.41426	.86160	5.5734E-01	779.27922
.40516	.06500	.47139	.06415	.40830	.84975	5.5595E-01	805.82610
.22217	.07500	.44097	.08718	.46656	.92055	8.5429E-01	686.22360
.24438	.07500	.44796	.08312	.45630	.89378	8.4695E-01	736.13463
.26660	.07500	.45379	.07956	.44730	.87180	8.4280E-01	778.25888
.28882	.07500	.45874	.07640	.43929	.85340	8.4067E-01	814.50376
.31103	.07500	.46301	.07357	.43212	.83774	8.4002E-01	846.16098
.33325	.07500	.46673	.07100	.42564	.82424	8.4044E-01	874.15436

PBX 9404 PCJ = 0.363 MBAR RHO = 1.8440

POP PLOT, LN(R) = A + B*LN(P), A = -5.040096E+00 B = -1.365368E+00

REACTION HUGONIOT, US = C + S*UP, C = 2.460000E-01 S = 2.530000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE
.18727	.08500	.43645	.09485	.48597	.90618	1.2106E+00	746.73005
.20599	.08500	.44356	.09050	.47498	.87625	1.2069E+00	797.73859
.22472	.08500	.44948	.08668	.46530	.85165	1.2064E+00	840.98702
.24345	.08500	.45451	.08328	.45671	.83104	1.2081E+00	878.33880
.26217	.08500	.45885	.08024	.44900	.81349	1.2114E+00	911.07793
.28090	.08500	.46264	.07749	.44204	.79835	1.2158E+00	940.12446
.16088	.09500	.43249	.10214	.50441	.89135	1.6583E+00	807.35911
.17697	.09500	.43968	.09751	.49271	.85827	1.6622E+00	858.85671
.19306	.09500	.44568	.09344	.48241	.83106	1.6694E+00	902.69982
.20915	.09500	.45077	.08983	.47326	.80825	1.6786E+00	940.70963
.22523	.09500	.45517	.08658	.46506	.78881	1.6881E+00	974.17355
.24132	.09500	.45900	.08365	.45764	.77205	1.7005E+00	1003.91987
.14033	.10500	.42897	.10909	.52199	.87609	2.2112E+00	867.99048
.15437	.10500	.43623	.10420	.50962	.83984	2.2288E+00	919.42239
.16840	.10500	.44229	.09990	.49874	.81003	2.2493E+00	963.40141
.18243	.10500	.44743	.09607	.48907	.78501	2.2705E+00	1001.69856
.19647	.10500	.45187	.09264	.48039	.76372	2.2946E+00	1035.48710
.21050	.10500	.45574	.08954	.47254	.74532	2.3189E+00	1065.67593
.12394	.11500	.42581	.11574	.53883	.86038	2.8849E+00	928.52104
.13634	.11500	.43313	.11061	.52583	.82097	2.9247E+00	979.40109
.14873	.11500	.43923	.10608	.51439	.78852	2.9656E+00	1023.12860
.16112	.11500	.44442	.10206	.50422	.76132	3.0096E+00	1061.33306
.17352	.11500	.44889	.09845	.49509	.73813	3.0535E+00	1095.20537
.18591	.11500	.45280	.09519	.48683	.71810	3.0970E+00	1125.57214
.11060	.12500	.42296	.12214	.55501	.84422	3.6974E+00	988.87914
.12167	.12500	.43032	.11676	.54141	.80161	3.7695E+00	1038.79478
.13273	.12500	.43647	.11203	.52944	.76654	3.8458E+00	1081.87465
.14379	.12500	.44168	.10782	.51879	.73711	3.9212E+00	1119.72410
.15485	.12500	.44619	.10404	.50923	.71203	3.9954E+00	1153.41635
.16591	.12500	.45012	.10062	.50058	.69036	4.0685E+00	1183.73307
.09957	.13500	.42036	.12830	.57061	.82761	4.6692E+00	1049.01350
.10953	.13500	.42776	.12270	.55643	.78178	4.7923E+00	1097.54941
.11949	.13500	.43394	.11777	.54395	.74404	4.9164E+00	1139.70656
.12944	.13500	.43919	.11338	.53284	.71237	5.0383E+00	1176.92861
.13940	.13500	.44371	.10943	.52287	.68537	5.1580E+00	1210.21112
.14936	.13500	.44766	.10587	.51385	.66205	5.2880E+00	1240.26077
.09032	.14500	.41798	.13426	.58568	.81052	5.8220E+00	1108.89939
.09935	.14500	.42542	.12844	.57095	.76142	6.0189E+00	1155.70593
.10838	.14500	.43162	.12331	.55798	.72098	6.2490E+00	1196.64994
.11741	.14500	.43689	.11875	.54643	.68704	6.4016E+00	1233.00481
.12644	.14500	.44143	.11465	.53606	.65810	6.5997E+00	1265.67895
.13547	.14500	.44540	.11094	.52668	.63309	6.7689E+00	1295.31643

PBX 9404 PCJ = 0.363 MBAR RHO = 1.8440
POP PLOT, LN(R) = A + B*LN(P), A = -5.040996E+00 B = -1.365368E+00
REACTION HUGONIOT, US = C + S*UP, C = 2.460000E-01 S = 2.530000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE
.08246	.15500	.41579	.14003	.60028	.79295	7.1884E+00	1168.47157
.09070	.15500	.42326	.13400	.58501	.74053	7.4838E+00	1213.26086
.09895	.15500	.42948	.12868	.57156	.69734	7.7745E+00	1252.73303
.10719	.15500	.43477	.12395	.55959	.66109	8.1206E+00	1288.00999
.11544	.15500	.43932	.11970	.54884	.63018	8.3406E+00	1319.87889
.12368	.15500	.44331	.11586	.53912	.60345	8.6051E+00	1348.95790
.07571	.16500	.41377	.14563	.61444	.77486	8.7971E+00	1227.73389
.08328	.16500	.42126	.13939	.59866	.71907	9.2812E+00	1270.18790
.09085	.16500	.42750	.13389	.58475	.67308	9.6665E+00	1307.96916
.09842	.16500	.43280	.12900	.57237	.63445	1.0076E+01	1342.01403
.10599	.16500	.43737	.12461	.56125	.60155	1.0481E+01	1372.89905
.11356	.16500	.44136	.12063	.55119	.57308	1.0937E+01	1401.25068
.06986	.17500	.41189	.15107	.62820	.75622	1.0686E+01	1286.66175
.07685	.17500	.41939	.14463	.61192	.69696	1.1301E+01	1326.57006
.08384	.17500	.42565	.13896	.59757	.64812	1.1920E+01	1362.44128
.09082	.17500	.43097	.13391	.58480	.60714	1.2515E+01	1394.97455
.09781	.17500	.43555	.12938	.57332	.57218	1.3128E+01	1424.76438
.10480	.17500	.43955	.12527	.56293	.54196	1.3725E+01	1452.22968
.06476	.18500	.41014	.15637	.64161	.73700	1.2950E+01	1345.25338
.07124	.18500	.41766	.14974	.62483	.67423	1.3774E+01	1382.32285
.07771	.18500	.42393	.14390	.61006	.62247	1.4623E+01	1416.07923
.08419	.18500	.42925	.13869	.59690	.57901	1.5359E+01	1447.03138
.09066	.18500	.43384	.13402	.58507	.54199	1.6371E+01	1475.54264
.09714	.18500	.43785	.12979	.57437	.50998	1.7512E+01	1501.99657
.06027	.19500	.40850	.16153	.65467	.71721	1.5482E+01	1403.41521
.06629	.19500	.41603	.15471	.63743	.65078	1.6689E+01	1437.49671
.07232	.19500	.42232	.14871	.62223	.59606	1.7914E+01	1468.93577
.07835	.19500	.42765	.14336	.60870	.55011	1.9134E+01	1498.10296
.08438	.19500	.43224	.13855	.59654	.51094	2.0351E+01	1525.24027
.09040	.19500	.43626	.13420	.58553	.47703	2.1661E+01	1550.67815
.05629	.20500	.40696	.16657	.66742	.69675	1.8529E+01	1461.22001
.06192	.20500	.41451	.15957	.64971	.62662	2.0153E+01	1492.04395
.06755	.20500	.42080	.15340	.63411	.56883	2.1849E+01	1521.03017
.07318	.20500	.42614	.14791	.62021	.52032	2.3566E+01	1548.28530
.07881	.20500	.43074	.14297	.60773	.47890	2.5385E+01	1573.98262
.08444	.20500	.43476	.13851	.59642	.44311	2.7240E+01	1598.20216
.05275	.21500	.40551	.17149	.67988	.67560	2.1954E+01	1518.61890
.05802	.21500	.41307	.16432	.66172	.60167	2.4316E+01	1545.98519
.06330	.21500	.41937	.15799	.64572	.54073	2.6626E+01	1572.35879
.06857	.21500	.42472	.15236	.63147	.48954	2.9084E+01	1597.61108
.07384	.21500	.42932	.14730	.61866	.44588	3.1660E+01	1621.69452
.07912	.21500	.43334	.14272	.60707	.40810	3.3601E+01	1644.66315

TABLE C-II

CONF B   PCJ = 0.284   RHO = 1.7150

POP PLOT,   LN(R) = A + B*LN(P),   A = -4.384168E+00   B = -1.501545E+00

REACTION HUGONIOT,   US = C + S*UP,   C = 2.312000E-01   S = 2.500000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE
4.43670	.02000	.51736	.03626	.32164	.98958	6.3454E-03	400.66634
4.88037	.02000	.52268	.03450	.31725	.98288	6.1176E-03	430.35075
5.32404	.02000	.52709	.03296	.31339	.97742	5.9409E-03	454.59395
5.76771	.02000	.53082	.03159	.30998	.97289	5.8046E-03	474.81595
6.21138	.02000	.53401	.03037	.30692	.96906	5.6960E-03	491.97653
6.65505	.02000	.53677	.02927	.30417	.96579	5.6084E-03	506.74867
2.41352	.03000	.50188	.04936	.35440	.97959	2.0352E-02	476.07010
2.65487	.03000	.50790	.04708	.34870	.96933	1.9763E-02	516.14336
2.89622	.03000	.51291	.04508	.34369	.96093	1.9315E-02	548.97410
3.13758	.03000	.51717	.04330	.33924	.95392	1.8967E-02	576.46154
3.37893	.03000	.52082	.04170	.33526	.94798	1.8693E-02	599.88299
3.62028	.03000	.52400	.04026	.33166	.94288	1.8475E-02	620.13102
1.56693	.04000	.49046	.06087	.38317	.96795	4.7002E-02	560.53451
1.72362	.04000	.49690	.05816	.37639	.95414	4.5995E-02	608.47218
1.88032	.04000	.50227	.05577	.37042	.94278	4.5240E-02	647.82870
2.03701	.04000	.50683	.05364	.36510	.93328	4.4667E-02	680.86477
2.19370	.04000	.51077	.05173	.36033	.92520	4.4229E-02	709.09488
2.35040	.04000	.51420	.05001	.35602	.91825	4.3894E-02	733.57439
1.12082	.05000	.48154	.07126	.40914	.95501	9.0948E-02	650.80826
1.23290	.05000	.48824	.26816	.40141	.93759	8.9673E-02	704.70880
1.34498	.05000	.49385	.06544	.39459	.92323	8.8762E-02	749.02661
1.45706	.05000	.49862	.06301	.38852	.91117	8.8336E-02	786.33559
1.56915	.05000	.50273	.06083	.38307	.90091	8.7646E-02	818.25126
1.68123	.05000	.50633	.05885	.37814	.89205	8.7346E-02	845.99336
.85240	.06000	.47428	.08080	.43300	.94094	1.5753E-01	744.82632
.93763	.06000	.48118	.07736	.42441	.91982	1.5647E-01	803.15128
1.02287	.06000	.48695	.07433	.41684	.90238	1.5586E-01	851.14588
1.10811	.06000	.49185	.07164	.41009	.88772	1.5558E-01	891.57654
1.19335	.06000	.49609	.06921	.40402	.87521	1.5553E-01	926.26796
1.27859	.06000	.49980	.06701	.39853	.86439	1.5564E-01	956.48409
.67627	.07000	.46822	.08967	.45518	.92581	2.5296E-01	841.22286
.74389	.07000	.47525	.08592	.44581	.90091	2.5316E-01	902.59360
.81152	.07000	.48114	.08262	.43755	.88030	2.5379E-01	953.16861
.87915	.07000	.48614	.07967	.43018	.86294	2.5472E-01	995.83657
.94677	.07000	.49047	.07702	.42355	.84810	2.5586E-01	1032.50913
1.01440	.07000	.49426	.07462	.41755	.83525	2.5714E-01	1064.50910
.55340	.08000	.46304	.09800	.47600	.90967	3.8453E-01	939.00506
.60874	.08000	.47018	.09396	.46591	.88086	3.8773E-01	1002.25576
.66408	.08000	.47615	.09040	.45700	.85698	3.9121E-01	1054.43398
.71942	.08000	.48123	.08722	.44906	.83683	3.9485E-01	1098.51491
.77476	.08000	.48562	.08437	.44192	.81959	3.9858E-01	1136.46437
.83010	.08000	.48947	.08178	.43544	.80465	4.0235E-01	1169.63630

COMP P PCJ = 0.284 RHO = 1.7150
POP PLOT, LN(R) = A + B*LN(P), A = -4.384168E+00 B = -1.501545E+00
REACTION HUGONIOT, US = C + S*UP, C = 2.310000E-01 S = 2.500000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE
.46369	.09000	.45855	.10587	.49568	.89253	5.6083E-01	1037.47506
.51076	.09000	.46576	.10157	.48491	.85967	5.6982E-01	1101.52929
.55643	.09000	.47180	.09776	.47541	.83240	5.7874E-01	1154.42700
.60280	.09000	.47694	.09437	.46693	.80938	5.8751E-01	1199.17907
.64917	.09000	.48138	.09132	.45930	.78964	5.9591E-01	1237.80110
.69554	.09000	.48527	.08855	.45238	.77253	6.0440E-01	1271.58181
.39584	.10000	.45459	.11336	.51439	.87436	7.9203E-01	1136.07773
.43543	.10000	.46187	.10880	.50299	.83731	8.1107E-01	1199.94805
.47501	.10000	.46796	.10477	.49292	.80653	8.2912E-01	1252.79087
.51460	.10000	.47314	.10117	.48393	.78053	8.4694E-01	1297.52455
.55418	.10000	.47762	.09794	.47585	.75824	8.6411E-01	1336.17282
.59377	.10000	.48154	.09500	.46851	.73888	8.8069E-01	1370.08366
.34306	.11000	.45108	.12050	.53226	.85514	1.0903E+00	1234.36866
.37737	.11000	.45840	.11570	.52026	.81374	1.1253E+00	1297.16855
.41167	.11000	.46453	.11146	.50965	.77934	1.1593E+00	1349.13526
.44598	.11000	.46975	.10767	.50019	.75026	1.1917E+00	1393.25952
.48029	.11000	.47426	.10427	.49166	.72530	1.2229E+00	1431.45619
.51459	.11000	.47820	.10117	.48393	.70363	1.2530E+00	1465.03610
.30104	.12000	.44792	.12736	.54940	.83481	1.4700E+00	1332.00966
.33115	.12000	.45529	.12233	.53682	.78892	1.5308E+00	1392.81865
.36125	.12000	.46145	.11788	.52570	.75076	1.5890E+00	1443.28552
.39136	.12000	.46669	.11391	.51578	.71849	1.6448E+00	1486.23088
.42146	.12000	.47122	.11034	.50684	.69078	1.6985E+00	1523.49376
.45157	.12000	.47518	.10710	.49874	.66671	1.7489E+00	1556.33984
.26695	.13000	.44506	.13395	.56588	.81334	1.9498E+00	1428.61099
.29365	.13000	.45246	.12870	.55275	.76278	2.0488E+00	1486.69879
.32034	.13000	.45865	.12406	.54115	.72072	2.1440E+00	1535.03441
.34704	.13000	.46391	.11992	.53079	.68513	2.2331E+00	1576.32246
.37373	.13000	.46846	.11618	.52146	.65461	2.3246E+00	1612.17467
.40043	.13000	.47244	.11280	.51299	.62807	2.4123E+00	1643.89461
.23884	.14000	.44246	.14031	.58179	.79066	2.5508E+00	1523.95535
.26272	.14000	.44989	.13485	.56813	.73524	2.7064E+00	1578.58619
.28661	.14000	.45609	.13002	.55605	.68914	2.8541E+00	1624.25044
.31049	.14000	.46137	.12571	.54527	.65017	3.0048E+00	1663.29515
.33438	.14000	.46593	.12182	.53556	.61670	3.1503E+00	1697.43692
.35826	.14000	.46993	.11830	.52675	.58761	3.2916E+00	1727.71857
.21534	.15000	.44008	.14647	.59716	.76670	3.3001E+00	1617.79534
.23687	.15000	.44752	.14080	.58299	.70624	3.5381E+00	1668.28915
.25840	.15000	.45375	.13579	.57047	.65597	3.7722E+00	1710.68323
.27994	.15000	.45904	.13131	.55928	.61346	4.0493E+00	1747.18911
.30147	.15000	.46361	.12728	.54921	.57697	4.2358E+00	1779.22847
.32300	.15000	.46761	.12363	.54006	.54525	4.4660E+00	1807.76716

COMP B PCJ = 0.284 RHO = 1.7150

POP PLOT, LN(R) = A + B*LN(P), A = -4.384168E+00 B = -1.501545E+00

REACTION HUGONIOT, US = C + S*UP, C = 2.310000E-01 S = 2.500000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE
.19545	.16000	.43788	.15243	.61206	.74136	4.2312E+00	1709.90594
.21499	.16000	.44535	.14656	.59740	.67567	4.5866E+00	1755.64746
.23454	.16000	.45158	.14138	.58444	.62108	4.9484E+00	1794.33294
.25408	.16000	.45689	.13675	.57287	.57492	5.3093E+00	1827.88530
.27363	.16000	.46147	.13258	.56244	.53531	5.6782E+00	1857.52463
.29317	.16000	.46547	.12879	.55297	.50089	6.0435E+00	1884.06518
.17844	.17000	.43585	.15821	.62653	.71458	5.3865E+00	1800.08371
.19629	.17000	.44333	.15216	.61140	.64345	5.9170E+00	1840.48927
.21413	.17000	.44958	.14681	.59801	.58438	6.4609E+00	1875.06370
.23197	.17000	.45489	.14202	.58606	.53445	7.0262E+00	1905.34463
.24982	.17000	.45948	.13772	.57529	.49163	7.5981E+00	1932.30152
.26766	.17000	.46349	.13380	.56551	.45442	8.1933E+00	1956.63915
.16377	.18000	.43396	.16384	.64060	.68623	6.8171E+00	1888.14889
.18014	.18000	.44145	.15760	.62500	.60946	7.6010E+00	1922.71043
.19652	.18000	.44771	.15208	.61121	.54575	8.4251E+00	1952.79538
.21289	.18000	.45303	.14716	.59889	.49194	9.2894E+00	1979.50610
.22927	.18000	.45762	.14271	.58779	.44579	1.0207E+01	2003.58237
.24565	.18000	.46163	.13868	.57771	.40573	1.1173E+01	2025.51289
.15100	.19000	.43220	.16932	.65430	.65623	8.6031E+00	1973.89732
.16610	.19000	.43970	.16290	.63826	.57360	9.7867E+00	2002.15832
.18119	.19000	.44597	.15723	.62407	.50507	1.0988E+01	2027.45345
.19629	.19000	.45129	.15216	.61139	.44724	1.2340E+01	2050.37367
.21139	.19000	.45589	.14759	.59996	.39769	1.3811E+01	2071.36022
.22649	.19000	.45990	.14344	.58959	.35461	1.5468E+01	2090.81241
.13980	.20000	.43055	.17467	.66766	.62443	1.0885E+01	2057.19260
.15378	.20000	.43806	.16807	.65118	.53569	1.2516E+01	2078.79810
.16776	.20000	.44433	.16224	.63660	.46220	1.4394E+01	2098.99218
.18174	.20000	.44966	.15703	.62358	.40023	1.6525E+01	2117.91520
.19572	.20000	.45426	.15234	.61184	.34709	1.9007E+01	2135.74319
.20970	.20000	.45828	.14808	.60119	.30098	2.1872E+01	2152.52339
.12993	.21000	.42900	.17988	.68071	.59071	1.3626E+01	2137.86793
.14292	.21000	.43652	.17312	.66380	.49564	1.6095E+01	2152.44432
.15591	.21000	.44280	.16714	.64885	.41699	1.8998E+01	2167.35883
.16890	.21000	.44813	.16179	.63549	.35068	2.2496E+01	2182.18809
.18190	.21000	.45273	.15698	.62344	.29390	2.6761E+01	2196.68257
.19489	.21000	.45675	.15260	.61251	.24462	3.2118E+01	2210.75515
.12116	.22000	.42755	.18498	.69346	.55492	1.7173E+01	2215.77841
.13328	.22000	.43508	.17806	.67614	.45327	2.0837E+01	2223.06127
.14539	.22000	.44135	.17193	.66082	.36925	2.5425E+01	2232.54337
.15751	.22000	.44669	.16645	.64713	.29848	3.1322E+01	2243.13820
.16963	.22000	.45129	.16151	.63479	.23791	3.9222E+01	2254.26394
.18174	.22000	.45531	.15703	.62358	.18542	5.0196E+01	2265.52826

TABLE C-III

X0290 PCJ = 0.285 RHO = 1.8940

POP PLOT, LN(P) = A + B*LN(P), A = -6.347114E+00 B = -2.917511E+00

REACTION HUGONIOT, US = C + S*UP, C = 2.400000E-01 S = 2.500000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE
9.49364	.05250	.44062	.06772	.40931	.96839	5.8999E-03	492.44427
10.44300	.05250	.44371	.06617	.40543	.95781	5.7128E-03	513.77132
11.39237	.05250	.44632	.06478	.40196	.94890	5.5627E-03	531.71011
12.34173	.05250	.44858	.06353	.39882	.94126	5.4406E-03	547.09047
13.29109	.05250	.45056	.06238	.39595	.93463	5.3400E-03	560.48058
14.24046	.05250	.45230	.06133	.39332	.92880	5.2563E-03	572.28761
5.70843	.06250	.43431	.07651	.43128	.95864	1.2696E-02	544.16574
6.27927	.06250	.43749	.07480	.42699	.94591	1.2341E-02	567.27023
6.85012	.06250	.44018	.07326	.42315	.93518	1.2057E-02	586.69686
7.42096	.06250	.44251	.07187	.41967	.92599	1.1827E-02	603.34469
7.99180	.06250	.44454	.07060	.41650	.91800	1.1638E-02	617.83519
8.56265	.06250	.44634	.06943	.41359	.91098	1.1482E-02	630.61251
3.70220	.07250	.42898	.08472	.45181	.94801	2.4602E-02	598.32887
4.07242	.07250	.43222	.08286	.44714	.93306	2.4008E-02	622.80652
4.44264	.07250	.43497	.08118	.44295	.92045	2.3537E-02	643.36664
4.81286	.07250	.43735	.07967	.43917	.90964	2.3158E-02	660.97325
5.18308	.07250	.43942	.07828	.43571	.90025	2.2849E-02	676.29243
5.55330	.07250	.44126	.07702	.43254	.89199	2.2597E-02	689.79835
2.53946	.08250	.42437	.09245	.47114	.93650	4.4138E-02	654.46531
2.79340	.08250	.42767	.09045	.46612	.91923	4.3252E-02	679.95979
3.04735	.08250	.43047	.08865	.46161	.90466	4.2555E-02	701.34574
3.30129	.08250	.43288	.08701	.45754	.89217	4.2002E-02	719.64507
3.55524	.08250	.43499	.08553	.45382	.88132	4.1560E-02	735.55991
3.80919	.08250	.43685	.08416	.45040	.87177	4.1205E-02	749.58662
1.81876	.09250	.42035	.09978	.48945	.92408	7.4673E-02	712.22977
2.00064	.09250	.42369	.09764	.48410	.90438	7.3494E-02	738.42675
2.18252	.09250	.42652	.09572	.47930	.88776	7.2585E-02	760.37185
2.36439	.09250	.42896	.09398	.47496	.87351	7.1882E-02	779.13185
2.54627	.09250	.43109	.09240	.47099	.86112	7.1314E-02	795.45879
2.72815	.09250	.43297	.09094	.46735	.85023	7.0898E-02	809.81954
1.34805	.10250	.41678	.10676	.50691	.91070	1.2066E-01	771.36461
1.48286	.10250	.42015	.10450	.50124	.88844	1.1930E-01	797.98532
1.61767	.10250	.42301	.10247	.49616	.86966	1.1828E-01	820.26809
1.75247	.10250	.42548	.10063	.49156	.85357	1.1756E-01	839.27829
1.88728	.10250	.42763	.09895	.48737	.83958	1.1705E-01	855.78989
2.02208	.10250	.42953	.09740	.48351	.82728	1.1671E-01	870.33286
1.02744	.11250	.41359	.11344	.52360	.89627	1.8792E-01	831.68955
1.13018	.11250	.41699	.11106	.51765	.87133	1.8674E-01	858.47836
1.23293	.11250	.41987	.10892	.51230	.85029	1.8599E-01	880.84919
1.33567	.11250	.42235	.10698	.50746	.83225	1.8558E-01	899.93380
1.43842	.11250	.42452	.10522	.50304	.81657	1.8542E-01	916.49740
1.54116	.11250	.42643	.10359	.49898	.80278	1.8545E-01	931.07912

X0290 PCJ = 0.285 RHO = 1.8940

POP PLOT, LN(R) = A + B*LN(P), A = -6.347114E+00 B = -2.917511E+00

REACTION HUGONIOT, US = C + S*UP, C = 2.400000E-01 S = 2.500000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE
.80141	.12250	.41072	.11985	.53964	.88073	2.8419E-01	893.00830
.88155	.12250	.41414	.11736	.53340	.85294	2.8392E-01	919.74647
.96170	.12250	.41704	.11512	.52780	.82950	2.8414E-01	942.03711
1.04184	.12250	.41953	.11309	.52273	.80940	2.8471E-01	961.02954
1.12198	.12250	.42171	.11124	.51810	.79193	2.8555E-01	977.50051
1.20212	.12250	.42363	.10954	.51385	.77657	2.8659E-01	991.99318
.63742	.13250	.40810	.12603	.55508	.86397	4.1951E-01	955.22174
.70117	.13250	.41154	.12343	.54857	.83315	4.2157E-01	981.70303
.76491	.13250	.41445	.12109	.54273	.80716	4.2409E-01	1003.73912
.82865	.13250	.41696	.11897	.53744	.78487	4.2693E-01	1022.49109
.89239	.13250	.41915	.11704	.53261	.76550	4.3000E-01	1038.73909
.95614	.13250	.42108	.11527	.52817	.74846	4.3287E-01	1053.04739
.51551	.14250	.40571	.13200	.56999	.84585	6.0715E-01	1018.22153
.56706	.14250	.40917	.12929	.56323	.81181	6.1407E-01	1044.25739
.61861	.14250	.41209	.12686	.55715	.78309	6.2130E-01	1065.88104
.67016	.14250	.41461	.12466	.55165	.75846	6.2823E-01	1084.27879
.72172	.14250	.41680	.12265	.54662	.73708	6.3601E-01	1100.17168
.77327	.14250	.41874	.12080	.54201	.71828	6.4374E-01	1114.15017
.42296	.15250	.40352	.13777	.58443	.82623	8.6473E-01	1081.91480
.46526	.15250	.40698	.13496	.57741	.78873	8.8083E-01	1107.33238
.50756	.15250	.40992	.13244	.57111	.75709	8.9646E-01	1128.41304
.54985	.15250	.41244	.13016	.56540	.72999	9.1284E-01	1146.28133
.59215	.15250	.41464	.12808	.56019	.70643	9.2890E-01	1161.74471
.63444	.15250	.41659	.12616	.55540	.68573	9.4464E-01	1175.33177
.35142	.16250	.40149	.14337	.59843	.80493	1.2158E+00	1146.21968
.38656	.16250	.40497	.14047	.59117	.76370	1.2478E+00	1170.87208
.42170	.16250	.40791	.13786	.58465	.72895	1.2803E+00	1191.24159
.45685	.16250	.41044	.13550	.57874	.69916	1.3121E+00	1208.51364
.49199	.16250	.41265	.13334	.57335	.67328	1.3432E+00	1223.44215
.52713	.16250	.41459	.13136	.56840	.65053	1.3737E+00	1236.55004
.29523	.17250	.39961	.14881	.61203	.78171	1.6914E+00	1211.07945
.32475	.17250	.40329	.14581	.60454	.73650	1.7531E+00	1234.78017
.35428	.17250	.40604	.14312	.59781	.69836	1.8135E+00	1254.35334
.38380	.17250	.40858	.14068	.59171	.66568	1.8726E+00	1270.92060
.41332	.17250	.41079	.13846	.58614	.63729	1.9308E+00	1285.22606
.44284	.17250	.41274	.13641	.58103	.61234	1.9887E+00	1297.78615
.25047	.18250	.39785	.15411	.62526	.75638	2.3377E+00	1276.37767
.27552	.18250	.40135	.15102	.61754	.70680	2.4476E+00	1299.03085
.30056	.18250	.40430	.14824	.61061	.66500	2.5559E+00	1317.69071
.32561	.18250	.40684	.14573	.60433	.62918	2.6634E+00	1333.46243
.35066	.18250	.40906	.14344	.59859	.59807	2.7715E+00	1347.08065
.37571	.18250	.41101	.14133	.59332	.57075	2.8744E+00	1359.00759

X0290 PCJ = 0.285 RHO = 1.8940
POP PLOT, LN(R) = A + B*LN(P), A = -6.347114E+00 B = -2.917511E+00
REACTION HUGONIOT, US = C + S*UP, C = 2.400000E-01 S = 2.500000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE
.21437	.19250	.39622	.15926	.63816	.72858	3.2147E+00	1342.08770
.23581	.19250	.39972	.15609	.63022	.67426	3.4056E+00	1363.56058
.25724	.19250	.40268	.15324	.62309	.62846	3.5973E+00	1381.20737
.27868	.19250	.40522	.15065	.61663	.58922	3.7923E+00	1396.11779
.30012	.19250	.40744	.14829	.61073	.55518	3.9801E+00	1408.94189
.32156	.19250	.40939	.14612	.60531	.52526	4.1722E+00	1420.20561
.18493	.20250	.39468	.16430	.65075	.69793	4.4305E+00	1408.15881
.20342	.20250	.39819	.16104	.64259	.63844	4.7383E+00	1428.31273
.22191	.20250	.40115	.15811	.63527	.58826	5.0773E+00	1444.87017
.24040	.20250	.40370	.15545	.62863	.54532	5.4131E+00	1458.79928
.25890	.20250	.40591	.15303	.62257	.50803	5.7606E+00	1470.81504
.27739	.20250	.40787	.15080	.61700	.47527	6.1148E+00	1481.35157
.16066	.21250	.39324	.16922	.66304	.66404	6.1028E+00	1474.47670
.17673	.21250	.39675	.16587	.65467	.59882	6.6177E+00	1493.23824
.19280	.21250	.39972	.16286	.64716	.54386	7.1998E+00	1508.58778
.20886	.21250	.40226	.16014	.64035	.49680	7.8119E+00	1521.51917
.22493	.21250	.40448	.15766	.63414	.45595	8.4516E+00	1532.65472
.24100	.21250	.40644	.15537	.62843	.42008	9.1197E+00	1542.41453
.14049	.22250	.39187	.17402	.67506	.62634	8.3414E+00	1540.99019
.15454	.22250	.39539	.17060	.66649	.55478	9.3042E+00	1558.25690
.16859	.22250	.39836	.16752	.65879	.49449	1.0344E+01	1572.35713
.18264	.22250	.40091	.16473	.65182	.44289	1.1469E+01	1584.21686
.19669	.22250	.40313	.16218	.64545	.39811	1.2686E+01	1594.42043
.21074	.22250	.40509	.15984	.63960	.35874	1.4037E+01	1603.40848
.12358	.23250	.39059	.17873	.68682	.58410	1.1590E+01	1607.66183
.13594	.23250	.39411	.17522	.67806	.50550	1.3264E+01	1623.33024
.14830	.23250	.39708	.17207	.67018	.43928	1.5164E+01	1636.10876
.16066	.23250	.39963	.16922	.66304	.38263	1.7319E+01	1646.84247
.17301	.23250	.40185	.16661	.65653	.33341	1.9827E+01	1656.12180
.18537	.23250	.40381	.16422	.65054	.29022	2.2729E+01	1664.25637
.10929	.24250	.38937	.18334	.69835	.53652	1.6295E+01	1674.37410
.12022	.24250	.39289	.17975	.68939	.44998	1.9319E+01	1688.38485
.13115	.24250	.39587	.17653	.68134	.37712	2.2958E+01	1699.78263
.14208	.24250	.39842	.17362	.67404	.31473	2.7463E+01	1709.38925
.15301	.24250	.40064	.17095	.66738	.26061	3.3129E+01	1717.66363
.16394	.24250	.40260	.16850	.66126	.21311	4.0502E+01	1724.94358
.09714	.25250	.38821	.18786	.70965	.48246	2.3401E+01	1741.07503
.10685	.25250	.39174	.18420	.70050	.38696	2.9112E+01	1753.34774
.11657	.25250	.39472	.18091	.69228	.30661	3.6677E+01	1763.30863
.12628	.25250	.39727	.17793	.68482	.23772	4.7392E+01	1771.75492
.13599	.25250	.39949	.17521	.67802	.17803	6.3355E+01	1779.02285
.14571	.25250	.40145	.17271	.67176	.12563	8.9946E+01	1785.43636

TABLE C-IV

X0219 PCJ = 0.281 RHO = 1.9140

POP PLOT, LN(R) = A + B*LN(P), A = -6.448715E+00 B = -3.540121E+00

REACTION HUGONIOT, US = C + S*UP, C = 2.400000E-01 S = 2.500000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE
9.75765	.08500	.41926	.09366	.47415	.93252	1.0089E-02	657.22629
10.73341	.08500	.42196	.09199	.46996	.91750	9.8430E-03	677.08086
11.70918	.08500	.42426	.09048	.46619	.90478	9.6451E-03	693.77218
12.68494	.08500	.42624	.08911	.46277	.89384	9.4842E-03	708.07757
13.66071	.08500	.42798	.08786	.45964	.88430	9.3521E-03	720.53152
14.63647	.08500	.42951	.08671	.45676	.87588	9.2427E-03	731.51762
6.58174	.09500	.41540	.10085	.49214	.91972	1.8052E-02	713.22741
7.23992	.09500	.41813	.09907	.48768	.90265	1.7676E-02	733.40858
7.89809	.09500	.42045	.09747	.48367	.88820	1.7376E-02	750.34719
8.55626	.09500	.42245	.09601	.48003	.87576	1.7135E-02	764.84690
9.21444	.09500	.42421	.09468	.47670	.86490	1.6934E-02	777.48013
9.87261	.09500	.42576	.09345	.47363	.85534	1.6774E-02	788.59519
4.61814	.10500	.41196	.10772	.50929	.90595	3.0714E-02	770.41834
5.07995	.10500	.41472	.10583	.50458	.88672	3.0272E-02	790.69770
5.54177	.10500	.41706	.10414	.50035	.87043	2.9777E-02	807.70371
6.00358	.10500	.41909	.10260	.49650	.85643	2.9455E-02	822.22622
6.46539	.10500	.42086	.10119	.49298	.84422	2.9198E-02	834.84796
6.92721	.10500	.42242	.09989	.48974	.83346	2.8995E-02	845.96859
3.34659	.11500	.40889	.11429	.52572	.89112	5.0184E-02	828.63091
3.68124	.11500	.41166	.11231	.52077	.86962	4.9542E-02	848.79804
4.01590	.11500	.41402	.11053	.51632	.85142	4.9054E-02	865.66684
4.35056	.11500	.41606	.10891	.51227	.83576	4.8683E-02	880.06928
4.68522	.11500	.41784	.10743	.50857	.82211	4.8402E-02	892.57438
5.01988	.11500	.41942	.10607	.50517	.81008	4.8193E-02	903.58455
2.49119	.12500	.40610	.12060	.54151	.87516	7.9362E-02	887.68718
2.74031	.12500	.40890	.11853	.53633	.85126	7.8708E-02	907.56348
2.98943	.12500	.41127	.11667	.53167	.83102	7.8248E-02	924.15679
3.23854	.12500	.41332	.11498	.52744	.81361	7.7937E-02	938.30481
3.48766	.12500	.41511	.11343	.52357	.79843	7.7740E-02	950.57637
3.73678	.12500	.41669	.11200	.52000	.78506	7.7633E-02	961.37308
1.89707	.13500	.40357	.12669	.55673	.85795	1.2217E-01	947.49057
2.08677	.13500	.40638	.12453	.55133	.83149	1.2177E-01	966.90683
2.27648	.13500	.40877	.12259	.54647	.80908	1.2160E-01	983.08392
2.46619	.13500	.41082	.12082	.54206	.78982	1.2160E-01	996.85634
2.65589	.13500	.41262	.11921	.53802	.77302	1.2173E-01	1008.79001
2.84560	.13500	.41421	.11772	.53431	.75820	1.2183E-01	1019.30897
1.47305	.14500	.40125	.13257	.57144	.83935	1.8395E-01	1007.93779
1.62035	.14500	.40407	.13033	.56583	.81016	1.8436E-01	1026.74001
1.76766	.14500	.40647	.12831	.56078	.78545	1.8501E-01	1042.37269
1.91496	.14500	.40853	.12648	.55619	.76418	1.8566E-01	1055.68564
2.06227	.14500	.41034	.12480	.55200	.74568	1.8668E-01	1067.17259
2.20957	.14500	.41193	.12325	.54813	.72936	1.8778E-01	1077.27086

X0219 PCJ = 0.201 RHO = 1.9140
POP PLOT, LN(R) = A + B*LN(P), A = -6.448715E+00 B = -3.540121E+00
REACTION HUGONIOT, US = C + S*UP, C = 2.400000E-01 S = 2.500000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE
1.16328	.15500	.39912	.13827	.58568	.81922	2.7198E-01	1068.93881
1.27960	.15500	.40195	.13595	.57987	.78710	2.7426E-01	1086.98623
1.39593	.15500	.40435	.13385	.57463	.75991	2.7659E-01	1101.97174
1.51226	.15500	.40642	.13195	.56988	.73655	2.7930E-01	1114.66922
1.62859	.15500	.40823	.13021	.56553	.71619	2.8207E-01	1125.65338
1.74491	.15500	.40983	.12861	.56153	.69824	2.8487E-01	1135.30015
.93231	.16500	.39714	.14380	.59950	.79735	3.9628E-01	1130.41263
1.02554	.16500	.39998	.14140	.59349	.76208	4.0218E-01	1147.58612
1.11877	.16500	.40239	.13923	.58808	.73225	4.0849E-01	1161.78441
1.21200	.16500	.40447	.13727	.58317	.70660	4.1477E-01	1173.82256
1.30523	.16500	.40628	.13547	.57867	.68428	4.2144E-01	1184.19837
1.39846	.16500	.40788	.13381	.57453	.66456	4.2718E-01	1193.34561
.75700	.17500	.39531	.14917	.61293	.77352	5.7046E-01	1192.29586
.83270	.17500	.39816	.14669	.60673	.73487	5.8394E-01	1208.44705
.90840	.17500	.40057	.14446	.60115	.70217	5.9722E-01	1221.79262
.98410	.17500	.40265	.14243	.59608	.67405	6.1029E-01	1233.08568
1.05980	.17500	.40447	.14058	.59144	.64958	6.2287E-01	1242.80860
1.13550	.17500	.40607	.13887	.58716	.62798	6.3604E-01	1251.37490
.62181	.18500	.39360	.15440	.62600	.74749	8.1466E-01	1254.48484
.68399	.18500	.39646	.15185	.61962	.70515	8.4123E-01	1269.53362
.74617	.18500	.39887	.14955	.61387	.66932	8.6736E-01	1281.93410
.80836	.18500	.40096	.14746	.60865	.63854	8.9322E-01	1292.41017
.87054	.18500	.40277	.14555	.60387	.61172	9.1904E-01	1301.44561
.93272	.18500	.40438	.14379	.59947	.58808	9.4502E-01	1309.37694
.51609	.19500	.39200	.15950	.63875	.71891	1.1563E+00	1316.93657
.56769	.19500	.39486	.15688	.63219	.67254	1.2063E+00	1330.77775
.61930	.19500	.39728	.15451	.62628	.63332	1.2560E+00	1342.15510
.67091	.19500	.39937	.15236	.62091	.59961	1.3061E+00	1351.76121
.72252	.19500	.40119	.15040	.61599	.57028	1.3539E+00	1360.01833
.77413	.19500	.40279	.14859	.61147	.54443	1.4024E+00	1367.26217
.43235	.20500	.39050	.16448	.65119	.68739	1.6359E+00	1379.57450
.47558	.20500	.39337	.16178	.64445	.63662	1.7277E+00	1392.11631
.51882	.20500	.39579	.15935	.63838	.59366	1.8212E+00	1402.41169
.56205	.20500	.39788	.15715	.63287	.55679	1.9121E+00	1411.06393
.60529	.20500	.39970	.15513	.62782	.52467	2.0050E+00	1418.52260
.64852	.20500	.40131	.15327	.62318	.49638	2.0982E+00	1425.05765
.36526	.21500	.38909	.16934	.66335	.65247	2.3144E+00	1442.32329
.40179	.21500	.39196	.16658	.65644	.59682	2.4820E+00	1453.49153
.43832	.21500	.39439	.16409	.65022	.54979	2.6502E+00	1462.61417
.47484	.21500	.39648	.16182	.64456	.50938	2.8239E+00	1470.29803
.51137	.21500	.39830	.15976	.63939	.47420	3.0016E+00	1476.91041
.54790	.21500	.39991	.15785	.63462	.44324	3.1832E+00	1482.70392

X0219 PCJ = 0.281 RHO = 1.9140

POP PLOT, LN(R) = A + B*LN(P), A = -6.448715E+00 B = -3.540121E+00

REACTION HUGONIOT, US = C + S*UP, C = 2.400000E-01 S = 2.500000E+00

RUN	P	V	UP	US	W	RATE	TEMPERATURE
.31096	.22500	.38776	.17409	.67524	.61354	3.2869E+00	1505.10823
.34206	.22500	.39063	.17126	.66816	.55251	3.5864E+00	1514.81109
.37316	.22500	.39306	.16872	.66179	.50092	3.9019E+00	1522.73629
.40425	.22500	.39515	.16640	.65600	.45661	4.2335E+00	1529.39970
.43535	.22500	.39698	.16428	.65070	.41805	4.5820E+00	1535.13211
.46645	.22500	.39858	.16233	.64582	.38413	4.9480E+00	1540.15260
.26660	.23500	.38650	.17875	.68688	.56985	4.7084E+00	1567.85478
.29326	.23500	.38938	.17586	.67964	.50282	5.2532E+00	1576.02541
.31992	.23500	.39181	.17325	.67312	.44615	5.8533E+00	1582.69979
.34658	.23500	.39390	.17088	.66720	.39749	6.5092E+00	1588.30755
.37324	.23500	.39572	.16871	.66177	.35518	7.2270E+00	1593.12744
.39989	.23500	.39733	.16671	.65678	.31783	8.0446E+00	1597.42229
.23003	.24500	.38531	.18331	.69828	.52057	6.8256E+00	1630.42988
.25303	.24500	.38819	.18035	.69089	.44672	7.8621E+00	1637.04433
.27604	.24500	.39062	.17769	.68422	.38434	9.0554E+00	1642.42978
.29904	.24500	.39271	.17527	.67817	.33081	1.0440E+01	1646.94892
.32204	.24500	.39454	.17305	.67263	.28412	1.2114E+01	1650.91522
.34505	.24500	.39614	.17101	.66752	.24309	1.4105E+01	1654.38810
.19965	.25500	.38418	.18779	.70947	.46440	1.0131E+01	1692.78020
.21962	.25500	.38706	.18477	.70191	.38286	1.2185E+01	1697.77619
.23958	.25500	.38949	.18204	.69511	.31401	1.4753E+01	1701.83947
.25955	.25500	.39158	.17957	.68893	.25480	1.8129E+01	1705.32673
.27952	.25500	.39341	.17731	.68327	.20334	2.2652E+01	1708.34000
.29948	.25500	.39501	.17522	.67806	.15806	2.9088E+01	1711.02414
.17424	.26500	.38310	.19218	.72044	.39984	1.5587E+01	1754.77480
.19166	.26500	.38598	.18910	.71274	.30949	2.0031E+01	1758.11592
.20908	.26500	.38842	.18632	.70580	.23310	2.6541E+01	1760.89672
.22651	.26500	.39051	.18380	.69949	.16757	3.6863E+01	1763.26842
.24393	.26500	.39233	.18149	.69372	.11056	5.5840E+01	1765.36729
.26135	.26500	.39394	.17936	.68840	.06039	1.0228E+02	1767.27199
.15282	.27500	.38207	.19649	.73122	.32483	2.5472E+01	1816.28267
.16811	.27500	.38496	.19335	.72337	.22420	3.6931E+01	1817.98213
.18339	.27500	.38739	.19052	.71629	.13922	5.9451E+01	1819.42666
.19867	.27500	.38949	.18794	.70986	.06628	1.2504E+02	1820.72006
.13467	.28500	.38109	.20073	.74182	.23662	4.6625E+01	1877.15081
.14814	.28500	.38398	.19753	.73381	.12393	8.9442E+01	1877.20041
.16161	.28500	.38642	.19464	.72661	.02881	3.8087E+02	1877.34143
.11919	.29500	.38016	.20489	.75223	.13137	1.6286E+02	1937.19734

```
      PROGRAM FFIRE( INP, OUT, PUN)
C  CHARLES A FOREST, JAN 1976
C
C
C  CODE CONTROL INPUT, THE FIRST TWO CARDS
C-----------------------------------------------------------------------
C  JPUN(I=1,4),JDBUG = INTEGER FLAGS,  FORMAT(12I6)
C      JPUN(1).NE.0,  PUNCH COEFFICIENTS,  W = POLYNOMIAL( U )
C      JPUN(2).NE.0,  PUNCH COEFFICIENTS,  LN(RATE)=POLYNOMIAL(LN(TEMP))
C      JPUN(3).NE.0,  PUNCH COEFFICIENTS,  W = POLYNOMIAL( P )
C      JPUN(4).NE.0,  PUNCH COEFFICIENTS,  LN(RATE) = POLYNOMIAL( P )
C      JDBUG.NE.0,  TURN ON ERROR EXIT PRINT IN DIFFHOM AND SOLVEWT
C-----------------------------------------------------------------------
C  PSTART,DELP,PSTOP = PRESSURE GRID CONTROL,  FORMAT(6F12.6)
C      PSTART = MINIUM PRESSURE TO TRY IN RATE CALCULATION
C      PDELP = PRESSURE INCREMENT
C      PSTOP = MAXIMUM PRESSURE FOR RATE CALCULATION
C-----------------------------------------------------------------------
C  END OF CODE CONTROL INPUT
C
C
C  INPUT FOR EACH EXPLOSIVE MATERIAL
C-----------------------------------------------------------------------
C  LABEL(I=1,8) = HOLLERITH DESCRIPTION, FORMAT(8A10)
C-----------------------------------------------------------------------
C  HUG(I=1,4) = COEFFICIENTS FOR (US,UP) RELATION,  FORMAT(6F12,6)
C      US = HUG(1)+HUG(2)*UP   IF P.GE.PHSW
C      US = HUG(3)+HUG(4)*UP   IF P.LT.PHSW
C      PHSW IS CALCULATED BY THE CODE FROM THE HUG(I=1,4) INPUT
C-----------------------------------------------------------------------
C  POP(I=1,3) = COEFF. FOR (DIST.,PRESS.) RELATION, FORMAT(6F12.4)
C      LN(DISTANCE TO DETONATION) = POP(1)+POP(2)*LN(P-POP(3))
C-----------------------------------------------------------------------
C  RHO,USCJ = INITIAL DENSITY,DETONATION VELOCITY, FORMAT(6F12.6)
C-----------------------------------------------------------------------
C  SX(I=1,23) = HOM EOS CONSTANTS FOR SOLID EXPLOSIVE, FORMAT(4E18.11)
C-----------------------------------------------------------------------
C  GX(I=1,17) = HOM CONSTANTS FOR DETONATION PROUDCTS, FORMAT(4E18.11)
C-----------------------------------------------------------------------
C  END OF INPUT FOR EACH EXPLOSIVE MATERIAL
C
C
C  JOB TERMINATION CARD, FOLLOWS LAST MATERIAL
C-----------------------------------------------------------------------
C  END PUNCHED IN COLUMNS 1-3 CAUSES NORMAL EXIT ,  FORMAT(A10)
C-----------------------------------------------------------------------
C  END OF INPUT DECK
C
C
C
      EXTERNAL DTDPF
C
      DIMENSION JPUN(4)
      COMMON / DBUG / JDBUG
C
C         COMMON BLOCK FOR COEFFICIENTS TO HOM EQUATION OF STATE
      COMMON /HOMC / SX(23), GX(17)
```

```
C          SX = C,S,VSW,C1,S1,F,G,H,I,J,GAMMA,CV,V0,ALPHA,SPA,USP,
C                T0,P0,2*Y0/3,MU,PLAP,SPALL P,MINV
C          GX = A,B,C,D,E,K,L,M,N,O,Q,R,S,T,U,CV,Z
C
C          ARRAYS FOR SHOCK FRONT CALCULATION
      COMMON /SHOCK/ RHO, V0, POP(3), HUG(4), PHSW, LABEL(8), VV(10),
     1  DHOM(3)
C          ARRAYS FOR SAVING SOLUTION POINTS
      DIMENSION UX(500), PX(500), VX(500), TX(500), WX(500), RX(500)
C          ARRAYS FOR LEAST SQUARES ROUTINE
      DIMENSION XX(300), XXX(300), YY(300), YYY(300), WGHT(300),
     A  YYP(300), DELY(300), COEF(30), SB(30), TT(30), CC(30), SC(30),
     A  A(30,30), ST(30), BB(30)
C
      DATA RUNMX / 10. /
      DATA DEL / 0.002 /
C
C          READ CODE CONTROL CARDS
      READ 9003, (JPUN(I),I=1,4),JDBUG
      READ 9000, PSTART, DELP, PSTOP
C
C           PRINT OPTIONS SELECTED
      DO 110 I=1,4
      IF(JPUN(I) .EQ. 0) GO TO 110
      PRINT 9106
      PRINT 9124
      IF(I .EQ. 1) PRINT 9111
      IF(I .EQ. 2) PRINT 9112
      IF(I .EQ. 3) PRINT 9113
      IF(I .EQ. 4) PRINT 9114
      PRINT 9106
  110 CONTINUE
      IF(JDBUG .GT. 0) PRINT 9120, JDBUG
      PRINT 9106
      PRINT 9115, PSTART, DELP, PSTOP
      PRINT 9106
C
C          BEGIN MAIN MATERIAL LOOP
 1000 CONTINUE
      READ 9001, (LABEL(I),I=1,8)
C
C          NORMAL EXIT
      IF(LABEL(1) .EQ. 3HEND ) RETURN
C
      READ 9000, (HUG(I),I=1,4)
      READ 9000, (POP(I),I=1,3)
      READ 9000, RHO, USCJ
C          READ HOM EOS CONSTANTS
      READ 9002, (SX(I),I=1,23)
      READ 9002, (GX(I),I=1,17)
C
C
C          LOOK AT HUGONIOT CONSTANTS, ARE THERE MORE THAN ONE PAIR (C,S)
      PHSW = -1.
      IF(ABS(HUG(3))+ABS(HUG(4)) .EQ. 0.) GO TO 1020
C          SOLVE FOR INTERSECTION OF HUGONIOTS
C          US = HUG(1) + HUG(2)*UP FOR P GREATER THAN PHSW
```

```
C          US = HUG(3) + HUG(4)*UP FOR P LESS THAN PHSW
      U = (HUG(3)-HUG(1))/(HUG(2)-HUG(4))
      US = HUG(1) + HUG(2)*U
      PHSW = RHO*US*U
 1020 CONTINUE
C
C
C          PRINT HEADER PAGE
      PRINT 9103, (LABEL(I),I=1,8) , RHO
      PRINT 9106
      PRINT 9104, (POP(I),I=1,3)
      PRINT 9106
      PRINT 9105, (HUG(I),I=1,2)
      IF(PHSW .GT. 0.) PRINT 9117, PHSW, HUG(3), HUG(4)
      PRINT 9106
      PRINT 9118, USCJ
      PRINT 9106
      PRINT 9107
      PRINT 9108, (SX(I),I=1,23)
      PRINT 9109, (GX(I),I=1,17)
      PRINT 9106
C
      P = PSTART
      PMX = PSTOP
      V0 = 1./RHO
      NPT = 0
      LINE = 0
      W = .96
      HTEST = 10.*DEL
      IF(P .LT. POP(3)) P = POP(3) + DELP
C
C          CALC. PRESSURE ON REACTIVE HUGONIOT FOR CJ DETONATION VELOCITY
      PUSCJ = RHO*USCJ*(USCJ-HUG(1))/HUG(2)
      IF(PMX .GT. PUSCJ) PMX = PUSCJ
C
C          BEGIN PRESSURE LOOP
 1100 CONTINUE
C
C          SET REACTION HUGONIOT CONSTANTS
      KK = 1
      IF(P .LT. PHSW) KK = 3
      HUG1 = HUG(KK)
      HUG2 = HUG(KK+1)
      CA1 = HUG1**2
      CA2 = 4.*V0*HUG2
C
C          P GIVEN AT THE SHOCK FRONT
C          RUN = DISTANCE TO DETONATION
      RUN = EXP( POP(1)+POP(2)*ALOG(P-POP(3)) )
      IF(RUN .LE. RUNMX) GO TO 1110
 1105 CONTINUE
      P = P + DELP
      W = .96
      GO TO 1100
C
 1110 CONTINUE
C          CALC. V, U, US, W ON THE REACTIVE HUGONIOT
```

```
      SQ = SQRT(CA1 + CA2*P)
      U = ( -HUG1+SQ )/( 2.*HUG2 )
      US = HUG1 + HUG2*U
      V = VØ*(US-U)/US
      E = .5*U*U
C
C        CALC. TIME TO DETONATION (TDET)
      TDET = SIMPSN( DTDPF, P, PUSCJ, 1.ØE-Ø7)
C
C        CALC. TOTAL DERIVATIVES AT SHOCK FRONT
      PDOT = -(P-POP(3))*US/(POP(2)*RUN)
      UDOT = VØ*PDOT/SQ
      VDOT = -HUG1*VØ*UDOT/(US**2)
      EDOT = U*UDOT
C
C    ASSUME FLAT PRESSURE WAVE,    PX = Ø.
C        THEN
      DP = PDOT
      DUDX = UDOT/(US-U)
      DV = V*DUDX
      DE = -P*DV
C
C        CHECK FOR CLOSENESS TO NONREACTIVE HUGONIOT
C        JHUG=Ø,  ON OR CLOSE TO NONREACTIVE HUGONIOT
C        JHUG=1,  AWAY FROM NONREACTIVE HUGONIOT
      KK = 1
      IF(V .LE. SX(3)) KK = 4
      UPH = SQRT(P*(VØ-V))
      USH = SX(KK) + SX(KK+1)*UPH
      PH = RHO*USH*UPH
      VH = VØ*(USH-UPH)/USH
      JHUG = Ø
      IF(ABS(V-VH)/V + ABS(P-PH)/P .GT. HTEST) JHUG = 1
C
C        SOLVE FOR W AND T
      CALL SOLVEWT( P, V, E, W, T, JHUG)
      IF(W .GT. Ø.) GO TO 115Ø
      IF(NPT .EQ. Ø) GO TO 11Ø5
      GO TO 2ØØØ

 115Ø CONTINUE
C        CALC. DERIVATIVES OF HOM EOS WITH RESPECT TO V, E, AND W
      VV(1) = V
      VV(2) = E
      VV(3) = W
      VV(4) = P
      CALL DIFFHOM( VV, DHOM, DEL, JHUG)
      IF(VV(4).LT.Ø. .AND. NPT.EQ.Ø) GO TO 11Ø5
      IF(VV(4).LT.Ø.) GO TO 2ØØØ
C
C        CALC. DW FROM TOTAL DERIVATIVE OF EOS ALONG THE PARTICAL PATH
C        DP = DHOM(1)*DV + DHOM(2)*DE + DHOM(3)*DW
      DW = (DP - DHOM(1)*DV - DHOM(2)*DE)/DHOM(3)
C
      RATE = -DW/W
C
C      SAVE VALUES
```

```
      NPT = NPT + 1
      UX(NPT) = U
      PX(NPT) = P
      VX(NPT) = V
      TX(NPT) = T
      WX(NPT) = W
      RX(NPT) = RATE
C
C        PRINT
      LINE = LINE+1
      IF(MOD(LINE,50) .NE. 1) GO TO 1810
      PRINT 9103, (LABEL(I),I=1,8), RHO
      PRINT 9104, (POP(I),I=1,3)
      PRINT 9105, (HUG(I),I=1,2)
      IF(PHSW .GT. 0.) PRINT 9117, PHSW, HUG(3), HUG(4)
      PRINT 9106
      PRINT 9100
      PRINT 9106
 1810 CONTINUE
      PRINT 9101, RUN, P, V, U, US, W, RATE, T, TDET
 1950 CONTINUE
      P = P + DELP
      IF(P .GT. PMX) GO TO 2000
      GO TO 1100
C        END PRESSURE LOOP
C
 2000 CONTINUE
C        GENERATE POLYNOMIAL FITS FOR W AND RATE
C
      PRINT 9106
      DO 2300 NFIT=1,4
      GO TO (2010,2020,2030,2040) NFIT
C
 2010 CONTINUE
C        FIT,  W = FCN(U)
      XXX(1) = XX(1) = 0.
      YYY(1) = YY(1) = 1.
      WGHT(1) = .1*FLOAT(NPT)
      NP = NPT + 1
      DO 2012 I=2,NP
      XXX(I) = XX(I) = UX(I-1)
      YYY(I) = YY(I) = WX(I-1)
      WGHT(I) = 1.
 2012 CONTINUE
      GO TO 2100
C
 2020 CONTINUE
C        FIT,  LOG(RATE) = FCN( T )
      NP = NPT
      DO 2022 I=1,NP
      XXX(I) = XX(I) = ALOG(TX(I))
      YYY(I) = YY(I) = ALOG(RX(I))
      WGHT(I) = 1.
 2022 CONTINUE
      GO TO 2100
C
 2030 CONTINUE
```

```
C        FIT,   W = FCN(P)
      XXX(1) = XX(1) = 0.
      YYY(1) = YY(1) = 1.
      WGHT(1) = .1*FLOAT(NPT)
      NP = NPT + 1
      DO 2032 I=2,NP
      XXX(I) = XX(I) = PX(I-1)
      YYY(I) = YY(I) = WX(I-1)
      WGHT(I) = 1.
 2032 CONTINUE
      GO TO 2100
C
 2040 CONTINUE
C        FIT,  LOG(RATE) = FCN(P)
      NP = NPT
      DO 2042 I=1,NP
      XXX(I) = XX(I) = PX(I)
      YYY(I) = YY(I) = ALOG(RX(I))
      WGHT(I) = 1.
 2042 CONTINUE
      GO TO 2100
C
 2100 CONTINUE
      MID = 0
      ERRMX = 1.0E+300
      KM = 14
      M = NP
 2110 CONTINUE
      CALL PFTS(M,KM,1,0,0,0,1,MID,KDEG,SIGMA,XX,YY,WGHT,YYP,DELY,BB,SB,
     A          TT,ST,CC,SC,A)
      MID = 1
      NX = KDEG + 1
      CALL LSQERR( NP, XXX, YYY, NX, BB, XERR, ERR)
      IF(ERR .GE. ERRMX) GO TO 2118
      NN = NX
      XXMX = XERR
      ERRMX = ERR
      DO 2115 I=1,NN
      COEF(I) = BB(I)
 2115 CONTINUE
 2118 CONTINUE
      IF(NX .GT. KM) GO TO 2120
      GO TO 2110
 2120 CONTINUE
      PRINT 9106
C
      IF(JPUN(NFIT) .EQ. 0) GO TO 2190
C        PUNCH SELECTED POLYNOMIAL COEFFICIENTS
      PUNCH 9119, (LABEL(I),I=1,7),RHO
      IF(NFIT .EQ. 1) PUNCH 9111
      IF(NFIT .EQ. 2) PUNCH 9112
      IF(NFIT .EQ. 3) PUNCH 9113
      IF(NFIT .EQ. 4) PUNCH 9114
      PUNCH 9003, NN
      PUNCH 9002, (COEF(I),I=1,NN)
 2190 CONTINUE
C
```

```
      GO TO (2200, 2225, 2250,2275) NFIT
C
 2200 CONTINUE
C         FIT,  W = FCN(U)
      PRINT 9103, (LABEL(I),I=1,8), RHO
      PRINT 9111
      PRINT 9110, NN, (COFF(I),I=1,NN)
      PRINT 9116, XXMX, ERRMX
      GO TO 2300
C
 2225 CONTINUE
C         FIT,  LOG(RATE) = FCN( T )
C         CALCULATE FIT AT EACH TEMPERATURE
C         LOG(RATE) = POLY( LOG(TEMP) )
      DO 2235 J=1,NP
      RATE = EXP( POLYNL(XX(J),NN,COEF) )
      D = (RX(J)-RATE)/RX(J)
      IF(MOD(J,50) .NE. 1) GO TO 2230
      PRINT 9103, (LABEL(I),I=1,8), RHO
      PRINT 9112
      PRINT 9110, NN, (COEF(I),I=1,NN)
      PRINT 9106
      PRINT 9123
      PRINT 9106
 2230 CONTINUE
      PRINT 9122, TX(J),RX(J),RATE,D
 2235 CONTINUE
      GO TO 2300
C
 2250 CONTINUE
C         FIT,  W = FCN(P)
      PRINT 9103, (LABEL(I),I=1,8), RHO
      PRINT 9113
      PRINT 9110, NN, (COEF(I),I=1,NN)
      PRINT 9116, XXMX, ERRMX
      GO TO 2300
C
 2275 CONTINUE
C         FIT,  LOG(RATE) = FCN(P)
C         CALCULATE FIT AT EACH PRESSURE
      DO 2285 J=1,NP
      RATE = EXP( POLYNL(XX(J),NN,COEF) )
      D = (RX(J) - RATE)/RX(J)
      IF(MOD(J,50) .NE. 1) GO TO 2280
      PRINT 9103, (LABEL(I),I=1,8), RHO
      PRINT 9114
      PRINT 9110, NN, (COEF(I),I=1,NN)
      PRINT 9106
      PRINT 9121
      PRINT 9106
 2280 CONTINUE
      PRINT 9122, PX(J),RX(J),RATE,D
 2285 CONTINUE
      GO TO 2300
C
 2300 CONTINUE
C         END PLOYNOMIAL FIT LOOP
```

```
C
      GO TO 1000
C        END MAIN MATERIAL LOOP
C
C        FORMATS
C        INPUT FORMATS
 9000 FORMAT( 6F12.6 )
 9001 FORMAT( 8A10 )
 9002 FORMAT( 4E18.11)
 9003 FORMAT(12I6)
C        OUTPUT FORMATS
 9100 FORMAT(7X,3HRUN,9X,1HP,11X,1HV,11X,2HUP,10X,2HUS,10X,1HW,11X,
     A  4HRATE,7X,11HTEMPERATURE,6X,4HTIME )
 9101 FORMAT( 6F12.5, 1PE16.4, 0P, 2F12.5)
 9103 FORMAT(1H1,8A10,5X,5HRHO =,F8.5)
 9104 FORMAT(1X,43HPOP PLOT, LN(RUN) = A1 + A2*LN(P-A3),  A1 =,1PE14.6,
     A  2X,4HA2 =,1PE14.6,2X,4HA3 =,1PE14.6)
 9105 FORMAT(1X,43HREACTION HUGONIOT,  US = C + S*UP,      C =,1PE14.6,
     A  2X,4H S =,1PE14.6)
 9106 FORMAT(1H )
 9107 FORMAT(1X,31HHOM EQUATION OF STATE CONSTANTS )
 9108 FORMAT(1X,19HUNREACTED EXPLOSIVE / (1X,1P4E18.11))
 9109 FORMAT(1X,19HDETONATION PRODUCTS / (1X,1P4E18.11))
 9110 FORMAT(1X,6HC(I=1, ,I2,4H) = ,1P5E18.10/(13X,1P5E18.10))
 9111 FORMAT(1X,39HW = C(1) + C(2)*U + ... + C(M+1)*(U**M) )
 9112 FORMAT(1X,46HLN(RATE) = C(1) + C(2)*T + ... + C(M+1)*(T**M) ,
     A  5X,20HT = LOG(TEMPERATURE) )
 9113 FORMAT(1X,39HW = C(1) + C(2)*P + ... + C(M+1)*(P**M) )
 9114 FORMAT(1X,46HLN(RATE) = C(1) + C(2)*P + ... + C(M+1)*(P**M) )
 9115 FORMAT(1X,8HPSTART =,1PE14.6,2X,6HDELP =,E14.6,2X,7HPSTOP =,E14.6)
 9116 FORMAT(1X,25HMAXIMUM RELATIVE ERROR AT,1PE16.6,3H = ,1PE16.6)
 9117 FORMAT(4X,20H AND IF P LESS THAN ,F8.5,5X,4HC = ,1PE16.6,
     A  5X,4HS = ,1PE16.6)
 9118 FORMAT(1X,24HCJ DETONATION VELOCITY =,1PE14.6)
 9119 FORMAT(6A10,A7,2X,4HRHO=,F7.4)
 9120 FORMAT(1X,23HDBUG PRINTS ON, JDBUG =,I6)
 9121 FORMAT(7X,8HPRESSURE,8X,4HRATE,12X,3HFIT,13X,10HREL. ERROR )
 9122 FORMAT(1X,1P4E16.6)
 9123 FORMAT(6X,11HTEMPERATURE,6X,4HRATE,12X,3HFIT,13X,10HREL. ERROR )
 9124 FORMAT(1X,34HPUNCHED OUTPUT FOR COEFFICIENTS OF  )
      END
```

```
      FUNCTION DTDPF( P)
C        SET INDEX FOR HUGONIOT CONSTANTS
      COMMON /SHOCK/ RHO, V0, POP(3), HUG(4), PHSW, LABEL(8), VV(10),
     1  OHOM(3)
      KK = 1
      IF(P .LT. PHSW) KK = 3
C
      US = .5*( HUG(KK) + SQRT(HUG(KK)**2 + 4.*V0*HUG(KK+1)*P) )
      RUN = EXP( POP(1)+POP(2)*ALOG(P-POP(3)) )
```

```
C
      DTDPF = -RUN*POP(2)/( US*(P-POP(3)) )
      RETURN
      END
```

```
      FUNCTION POLYNL( X, NC, C)
      DIMENSION C(1)
C        POLYNL = SUM( C(N)*(X**(N-1)) ),N=1,NC
C
      NCM = NC-1
      S = C(NC)
      DO 10 N=1,NCM
      S = S*X + C(NC-N)
   10 CONTINUE
      POLYNL = S
      RETURN
      END
```

```
      SUBROUTINE DIFFHOM( VV, DHOM, DEL, JHUG)
C           VV(1) = V          VV(2) = E          VV(3) = W
C           VV(4) = P
C         DHOM(1) = DP/DV   DHOM(2) = DP/DE   DHOM(3) = DP/DW
C
      COMMON / HOMC / SX(23), GX(17)
      COMMON / DBUG / JDBUG
C
      DIMENSION VV(1), DHOM(1)
      P0 = VV(4)
      DO 100 N=1,3
      VSAVE = VV(N)
      IF(JHUG .EQ. 1) GO TO 40
C        CASE(JHUG=0, ON OR NEAR NONREACTIVE HUGONIOT)
      GO TO ( 70, 65, 60) N
C
   40 CONTINUE
C        CASE(JHUG=1, OFF NONREACTIVE HUGONIOT)
      GO TO (65, 65, 55) N
C
   55 CONTINUE
C        SUBCASES FOR DIFFERENCES WITH RESPECT TO W
      IF(VSAVE .LT. .05) GO TO 70
      IF(VSAVE .GT. .98) GO TO 60
      GO TO 65
C
   60 CONTINUE
```

```
C          DIFFERENCE TO SMALLER ARGUMENTS
      VA = VSAVE*(1. - DEL)
      VB = VSAVE*(1. - 2.*DEL)
      GO TO 80
   65 CONTINUE
C          CENTRAL DIFFERENCE
      VA = VSAVE*(1. - DEL)
      VB = VSAVE*(1. + DEL)
      GO TO 80
   70 CONTINUE
C          DIFFERENCE TO BIGGER ARGUMENTS
      VA = VSAVE*(1. + DEL)
      VB = VSAVE*(1. + 2.*DEL)
      GO TO 80
C
   80 CONTINUE
      VV(N) = VA
      CALL HOM  ( VV, SX, GX, IND)
      IF(IND .EQ. -3) GO TO 200
      P1 = VV(4)
      VV(N) = VB
      CALL HOM  (VV,SX,GX,IND)
      IF(IND .EQ. -3) GO TO 200
      P2 = VV(4)
      A = (VB - VSAVE)/(VA - VSAVE)
      DHOM(N) = ( (P1-P0)*A - (P2-P0)/A )/( VB - VA )
      VV(N) = VSAVE
  100 CONTINUE
C          NORMAL EXIT
      RETURN
  200 CONTINUE
C          ERROR EXIT
      VV(4) = -1.
      IF(JDBUG .EQ. 0) RETURN
      PRINT 9000
      PRINT 9001, (VV(I),I=1,10)
      RETURN
 9001 FORMAT(1X,*VV*/ (1P5E18.8) )
 9000 FORMAT(1X*ERROR EXIT, SUBROUTINE DIFFHOM*)
      END
```

```
      SUBROUTINE SOLVEWT( P, V, E, W, T, JHUG)
      DIMENSION TX(10), VV(10)
      COMMON / HOMC / SX(23), GX(17)
      COMMON / DBUG / JDBUG
C
      IF(JHUG .EQ. 1) GO TO 50 .
C          CASE(JHUG=0,  ON OR NEAR NONREACTIVE HUGONIOT)
      VV(1) = V
      VV(2) = E
      VV(3) = 1.
```

```
      CALL HOM  ( VV, SX, GX, IND)
      IF(IND .EQ. -3) GO TO 200
      W = 1.
      T = VV(5)
      RETURN
C
   50 CONTINUE
C           CASE(JHUG=1,  AWAY FROM NONREACTIVE HUGONIOT)
      DP = 0.
      TX(1) = W
      TX(2) = .98
      TX(3) = 1.0E-07
      TX(10) = 0.
      VV(1) = V
      VV(2) = E
C
  100 CONTINUE
      CALL LFB( W, DP, TX)
      IF(TX(10)) 200, 120, 110
  110 CONTINUE
      IF(W .GT. 1.) W = .99
      VV(3) = W
      CALL HOM  ( VV, SX, GX, IND)
      IF(IND .EQ. -3) GO TO 200
      DP = P - VV(4)
      T = VV(5)
      GO TO 100
  120 CONTINUE
C           NORMAL EXIT
      RETURN
  200 CONTINUE
C           ERROR EXIT
      W = -1.
      IF(JDBUG .EQ. 0) RETURN
      PRINT 9002
      PRINT 9000, (TX(I),I=1,10)
      PRINT 9001, (VV(I),I=1,10)
      RETURN
 9000 FORMAT(1X,*TX*/ (1P5E18.8) )
 9001 FORMAT(1X,*VV*/ (1P5E18.8) )
 9002 FORMAT(1X,*ERROR EXIT, SUBROUTINE SOLVETW*)
      END
```

```
      SUBROUTINE LSQERR( NPT, XX, YY, NC, C, XMX, ERRMX)
      DIMENSION XX(NPT), YY(NPT), C(NC)
      ERRMX = 0.
      XMX = XX(1)
      NCP = NC + 1
      DO 10 J=1,NPT
      X = XX(J)
      Y = YY(J)
```

```
      S = 0.
      DO 4 N=1,NC
      S = S*X + C(NCP-N)
    4 CONTINUE
      ERR = ABS(Y - S)
      IF(ABS(Y) .GT. 0.) ERR = ERR/ABS(Y)
      IF(ERR .LT. ERRMX) GO TO 10
      XMX = X
      ERRMX = ERR
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE HOM (V,S,G,IND)
C
C     HOM CALCULATES THE EQUATION OF STATE FOR A SOLID, GAS, OR
C     SOLID-GAS MIXTURE.
C
C     THE PARAMETERS ARE
C     V     AN ARRAY OF DIMENSION 5
C           V(1)     SPECIFIC VOLUME      INPUT
C           V(2)     INTERNAL ENERGY      INPUT
C           V(3)     MASS FRACTION        INPUT
C           V(4)     -ABS(DP/DX)          INPUT
C           IF V(4) IS .GE.0  NO SPALLING CALCULATION IS DONE FOR A PURE
C           SOLID
C           V(4)     PRESSURE             OUTPUT
C           V(5)     TEMPERATURE          OUTPUT
C     S     AN ARRAY OF DIMENSION 18 CONTAINING THE PARAMETERS FOR THE
C           SOLID EQUATION OF STATE
C           S(1)     C
C           S(2)     S
C           S(3)     VSW   VOLUME TO SWITCH TO SECOND US,UP FIT
C           S(4)     C1
C           S(5)     S1
C           S(6)     F
C           S(7)     G
C           S(8)     H
C           S(9)     I
C           S(10)    J
C           S(11)    GAMMA
C           S(12)    CV
C           S(13)    V0   INITIAL VOLUME
C           S(14)    ALPHA
C           S(15)    SPALL A
C           S(16)    ULTIMATE SPALL PRESSURE
C           S(17)    T0    INITIAL TEMPERATURE
C           S(18)    P0     INITIAL PRESSURE
C     S(22) IS SPALL INTERFACE PRESSURE
C     S(23) IS MIN V FOR TWO PHASE FE EQUATION OF STATE
C     G     AN ARRAY OF DIMENSION 17 CONTAINING THE PARAMETERS FOR THE
```

```
C             GAS EQUATION OF STATE
C             G(1)     A
C             G(2)     B
C             G(3)     C
C             G(4)     D
C             G(5)     E
C             G(6)     K
C             G(7)     L
C             G(8)     M
C             G(9)     N
C             G(10)    O
C             G(11)    Q
C             G(12)    R
C             G(13)    S
C             G(14)    T
C             G(15)    U
C             G(16)    CV
C             G(17)    Z
C        IND     OUTPUT INDICATOR
C             SET TO 0 FOR NORMAL EXIT
C             SET TO 1 FOR SPALLED SOLID
C             SET TO -1 FOR HOM ERROR IN ITERATION
C      IND  INPUT INDICATOR FOR SHARP SHOCK BURN AND IS EQUAL TO 3
C        WILL GIVE HUGONIOT PRESSURE AND ENERGY FOR INPUT V AND W = 0
         DIMENSION V(5),S(23),G(17),VIT(10)
         DATA GASW /0.02/
         DATA SOLW /.999/
         DATA SPMIN/5.0E-3/
         DATA VGSS /.9/
         DATA VIT(3) /1.E-5/
         DATA VIT(10) /0./
         IF(IND.EQ.3) GO TO 2
         IND=0
       2 IF (V(3).GT.SOLW) GO TO 10
         IF (V(3).LT.GASW) GO TO 110
         GO TO 210
C     EQUATION OF STATE FOR SOLID ONLY
      10 IF (V(1).GT.S(13)) GO TO 50
C        FOR TWO PHASE FE TYPE EQUATION OF STATE
         IF(V(1).GT.S(3)) GO TO 11
         IF(V(1).LT.S(23)) GO TO 45
         V(1)=S(23)
         GO TO 45
      11 C1=S(1)
         S1=S(2)
      20 VOMV=S(13)-V(1)
         HP=((C1/(S(13)-S1*VOMV))**2)*VOMV
         HE = (HP-S(18))*VOMV*0.5
         V(4)=HP+(V(2)-HE)*S(11)/V(1)
C        IF NO HEAT CAPACITY SKIP TEMP CALCULATION
         IF (S(12)) 21,22,21
      21 ALNV=ALOG(V(1))
         V(5)=(V(2)-HE)*23890./S(12)+EXP(S(6)+ALNV*(S(7)+ALNV*(S(8)+ALNV*
        1(S(9)+ALNV*S(10)))))
      22 RETURN
C        SWITCH TO SECOND US,UP FIT
      45 C1=S(4)
```

```
      S1=S(5)
      GO TO 20
C     SPALLING SOLID EQUATION OF STATE
   50 DPDX=V(4)
C     IF ALPHA IS ZERO SET P=P0 AND DO NOT SPALL
      IF (S(14)) 51,51,52
   51 V(4)=S(18)
      V(5)=S(17)
      RETURN
   52 V(4)=(S(11)*(V(2)+(1.-V(1)/S(13))*S(12)*1.39528394E-5/S(14)))/V(1)
      V(5)=V(2)*23890./S(12)+S(17)
      IF (DPDX.GE.0.) RETURN
C     IF SPA LESS THAN / 0.0001 DO NOT SPALL
      IF (S(15) .LT.0.0001)    RETURN
      T=S(15)*SQRT(-DPDX)
      SPLP=-T
      IF (T.GT.S(16)) SPLP=-S(16)
      IF (T.LT.SPMIN) SPLP=-SPMIN
      IF (V(4).GT.SPLP) RETURN
      V(4)=S(22)
C     SET IND FOR SPALLED SOLID
      IND=1
      RETURN
C  EQUATION OF STATE FOR GAS ONLY
  110 ALNV=ALOG(V(1))
      ALNPI=G(1)+ALNV*(G(2)+ALNV*(G(3)+ALNV*(G(4)+ALNV*G(5))))
      ALNII=G(6)+ALNPI*(G(7)+ALNPI*(G(8)+ALNPI*(G(9)+ALNPI*G(10))))
      ALNTI=G(11)+ALNV*(G(12)+ALNV*(G(13)+ALNV*(G(14)+ALNV*G(15))))
      EI=EXP(ALNII)-G(17)
C     SHARP SHOCK BURN
      IF(IND.EQ.3) GO TO 111
      V(4)=EXP(ALNPI)+(EI-V(2))/V(1)*(G(12)+ALNV*(G(13)+G(13)+ALNV*(
     13.*G(14)+ALNV*4.*G(15))))
      V(5)=EXP(ALNTI)+(V(2)-EI)*23890./G(16)
      RETURN
C     SHARP SHOCK BURN
 111  SIP = EXP(ALNPI)
      V(4) = SIP
      DO 112 IX = 1,6
      V(2) = 0.5*V(4)*(S(13) - V(1))
      V(4) = SIP + (EI-V(2))/V(1)*(G(12)+ALNV*(G(13) +G(13)+ALNV*(
     13.*G(14)+ALNV*4.*G(15))))
 112  CONTINUE
      RETURN
C  EQUATION OF STATE FOR MIXTURE OF SOLID AND GAS
  210 OMW=1.-V(3)
      OMWR=1./OMW
      IF (V(1).LT.S(13)) GO TO 230
      WR=1./V(3)
      VIT(1)=(V(1)-V(3)*S(13)*VGSS)*OMWR
      VIT(2)=1.002
C     IBR=1 FOR ITERATION ON VG
      IBR=1
  215 CALL LFB (X,F,VIT)
      IF (VIT(10)) 900,260,220
  220 IF (X.LE.0.) GO TO 225
      VG=X
```

```
      VS=(V(1)-OMW*VG)*WR
      IF (VS.LE.0.) GO TO 225
      IF (VS.GT.S(13)) VS=S(13)
      GO TO 250
C     SET VS=VG=VOLUME WHEN GET IN TROUBLE
  225 VS=V(1)
      VG=V(1)
      X=V(1)
      GO TO 250
  230 VIT(1)=V(1)
      VIT(2)=.999
C     IBR=2 FOR ITERATION ON VS
      IBR=2
  235 CALL LFB (X,F,VIT)
      IF (VIT(10)) 900,260,240
  240 IF (X.LE.0.) GO TO 225
      IF (X.GT.S(13)) X=S(13)
      VS=X
      VG=(V(1)-V(3)*VS)*OMWR
      IF (VG.LE.0.) GO TO 225
C     CALCULATE TEMPERATURE/PRESSURE DIFFERENCE FOR MIXTURE ITERATION
  250 VOMV=S(13)-VS
      HP=((S(1)/(S(13)-S(2)*VOMV))**2)*VOMV
      HE = (HP-S(18))*VOMV*0.5
      ALNV=ALOG(VS)
      HT=EXP(S(6)+ALNV*(S(7)+ALNV*(S(8)+ALNV*(S(9)+ALNV*S(10)))))
      ALNV=ALOG(VG)
      ALNPI=G(1)+ALNV*(G(2)+ALNV*(G(3)+ALNV*(G(4)+ALNV*G(5))))
      EI=EXP(G(6)+ALNPI*(G(7)+ALNPI*(G(8)+ALNPI*(G(9)+ALNPI*G(10)))))-
     1G(17)
      PI=EXP(ALNPI)
      TI=EXP(G(11)+ALNV*(G(12)+ALNV*(G(13)+ALNV*(G(14)+ALNV*G(15)))))
      BETER=-(G(12)+ALNV*(G(13)+G(13)+ALNV*(3.*G(14)+4.*ALNV*G(15))))
      TEMP=-G(16)*BETER/VG
      TEMP1=S(11)*S(12)/VS
      F=-(HT*TEMP1+TI*TEMP)*4.18585182E-5
      TEMP=TEMP+TEMP1
      VSTO=(S(12)-G(16))*V(3)+G(16)
      F=((OMW*G(16)*TI+V(3)*S(12)*HT)*4.18585182E-5+(EI-HE)*V(3)-EI+
     1V(2))*TEMP/VSTO+F-PI+HP
      GO TO (215,235),IBR
C     HAVE FOUND A SOLUTION FOR THE MIXTURE
C     GET THE TEMPERATURE AND PRESSURE
  260 VARST=((((TI-HT)*G(16)*4.18585182E-5+V(2)*OMWR-EI)*S(12)+HE*G(16))
     1*OMW/VSTO)-HE
      V(4)=HP+VARST*S(11)/VS
      V(5)=HT+VARST*23890./S(12)
      RETURN
C     ERROR IN HOM ITERATION      SET IND TO -1
  900 IND=-1
      RETURN
      END
```

```
      SUBROUTINE LFB (XP,FP,TX)

C        TX(1)       INITIAL GUESS
C        TX(2)       RATIO TO GET SECOND POINT
C        TX(3)       ZERO DEFINITION
C        TX(10)      COUNT OF NUMBER OF ITERATIONS
C                    SET TO ZERO ON SOLUTION
C                    SET TO NEGATIVE OF COUNT ON ERROR
C        FP          =FUNCTION(XP)
C        WHEN A SOLUTION IS FOUND, XP IS THE ROOT
C
C        ERROR EXITS OCCUR FOR
C                 1. TOO MANY ITERATIONS, .GT.CNTMAX
C                 2. TWO SUCESSIVE XP S OR FP S ARE EQUAL
      DIMENSION TX(10)
      DATA CNTMAX /1000./
      IF (TX(10).LE.0.) GO TO 1
      TX(10)=TX(10)+1.
      IF (TX(10)-3.) 2,3,4
C   ENTRY FIRST TIME THROUGH
    1 TX(10)=1.
      IF (TX(1).EQ.0.) TX(1) = 1.
      XP=TX(1)
C   GO GET F(XP)
      RETURN
C   ENTRY SECOND TIME THROUGH
    2 TX(9)=FP
      TX(8)=XP
      TX(5)=FP
      IF (ABS(FP).LT.TX(3)) GO TO 18
      XP=TX(1)*TX(2)
C   GO GET F(XP)
      RETURN
C   ENTRY THIRD TIME THROUGH
    3 TX(5)=FP
      TX(6)=XP
      TX(7)=FP
      IF (ABS(FP).LT.TX(3)) GO TO 18
      XP=TX(6)-TX(7)*(TX(6)-TX(8))/(TX(7)-TX(9))
C   GO GET F(XP)
      RETURN
C   ENTRY FOR FOURTH AND SUCEEDING TIMES THROUGH
    4 IF (TX(10).GT.CNTMAX) GO TO 99
      TX(4)=XP
      TX(5)=FP
      T=TX(4)-TX(6)
      IF (T.EQ.0.) GO TO 99
      IF (ABS(FP).LT.TX(3)) GO TO 18
      R=TX(5)-TX(7)
      IF (R.EQ.0.) GO TO 99
      XP=TX(4)-TX(5)*(T/R)
      IF (TX(5)*TX(7).LT.0.) GO TO 11
      IF (TX(5)*TX(9).GE.0.) GO TO 11
      IF (XP.GT.TX(4)) GO TO 6
      IF (XP.GT.TX(8)) GO TO 10
    8 XP=TX(4)-TX(5)*(TX(4)-TX(8))/(TX(5)-TX(9))
```

```
   10 TX(7)=TX(5)
      TX(6)=TX(4)
C  GO GET F(XP)
      RETURN
    6 IF (XP.GT.TX(8)) GO TO 8
      GO TO 10
   11 TX(9)=TX(7)
      TX(8)=TX(6)
      GO TO 10
C  HAVE FOUND A SOLUTION
   18 TX(10)=0.
      TX(1)=XP
      TX(4)=XP
      RETURN
C  AN ERROR HAS OCCURED
C  SET COUNT NEGATIVE AND EXIT
   99 TX(10)=-TX(10)
      RETURN
      END
```

```
      FUNCTION SIMPSN(ARG,Y1,Y2,FERR)
C     SIMPSN INTEGRATION ROUTINE WRITTEN AS FORTRAN IV FUNCTION J.SMITH
      DIMENSION F2T(20),FMT(20),F3T(20),F4T(20),FBT(20),
     1DXT(20),X1T(20),X2T(20),ART(20),EPST(20),ES2T(20),
     2ES3T(20),LEG(20),SUM1(20),SUM2(20)
C     INITIAL SET-UP
      A=Y1
      EPS=FERR
      B=Y2
      DA=B-A
      FA=ARG(A)
      FM=4.*ARG((A+B)*.5)
      FB=ARG(B)
      AREA=1.0
      EST=1.0
      L=1
C     BEGIN SIMPSON
    1 DX=DA/3.
      X1=A+DX
      X2=X1+DX
      F1=4.*ARG(A+.5*DX)
      F2=ARG(X1)
      F3=ARG(X2)
      F4=4.*ARG(A+2.5*DX)
      DX6=DX/6.
      EST1=(FA+F1+F2)*DX6
      EST2=(F2+FM+F3)*DX6
      EST3=(F3+F4+FB)*DX6
      AREA=AREA-ABS(EST)+ABS(EST1)+ABS(EST2)+ABS(EST3)
      SUM=EST1+EST2+EST3
C     TEST FOR CONVERGENCE
```

```
      IF(ABS(EST-SUM)-EPS*AREA)2,2,3
    2 IF(EST-1.0)6,3,6
    3 IF(L-20)5,6,6
    5 L=L+1
      LEG(L)=3
C     STORE PARAMETERS FOR SIMPSON II AND III
      F2T(L)=F2
      FMT(L)=FM
      F3T(L)=F3
      F4T(L)=F4
      FBT(L)=FB
      DXT(L)=DX
      X1T(L)=X1
      X2T(L)=X2
      ART(L)=AREA
      EPST(L)=EPS/1.7
      ES2T(L)=EST2
      ES3T(L)=EST3
C     RETURN TO SIMPSON I
      DA=DX
      FM=F1
      FB=F2
      EST=EST1
      EPS=EPST(L)
      GO TO 1
    6 IF(LEG(L)-2)9,8,7
    7 SUM1(L)=SUM
      LEG(L)=2
C     RETURN TO SIMPSON II
      A=X1T(L)
      DA=DXT(L)
      FA=F2T(L)
      FM=FMT(L)
      FB=F3T(L)
      AREA=ART(L)
      EST=ES2T(L)
      EPS=EPST(L)
      GO TO 1
    8 SUM2(L)=SUM
      LEG(L)=1
C     RETURN TO SIMPSON III
      A=X2T(L)
      DA=DXT(L)
      FA=F3T(L)
      FM=F4T(L)
      FB=FBT(L)
      AREA=ART(L)
      EST=ES3T(L)
      EPS=EPST(L)
      GO TO 1
    9 SUM=SUM1(L)+SUM2(L)+SUM
      L=L-1
      IF(L-1)11,11,6
   11 SIMPSN = SUM
      RETURN
      END
```

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