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ADIABATIC EXPANSION OF HIGH EXPLOSIVE DETONATION PRODUCTS

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Abstract

A relatively simple pressure, volume, energy (PVE) equation of state has been developed to describe the adiabatic expansion of detonation products. Specific equations for ten explosives have been determined using detonation velocity and pressure data and results from metal acceleration experiments. The thermodynamic and hydrodynamic requirements placed upon this equation of state are discussed and a comparison of calculation and experimental results are presented.

Introduction

Numerous equations of state[1,2,3] have been proposed for describing the adiabatic expansion of detonation products. However, when these equations are used in hydrodynamic calculations, they do not accurately predict the performance of an explosive.

To remedy this, Wilkins[4] developed an equation based primarily on spherical, metal expansion experiments. His equation, when used in hydrodynamic calculations, accurately predicts results for experimental geometries emphasizing the early stages of detonation product expansion. We have extended his work using results from cylindrical, metal expansion experiments to develop an equation of state which can also be used for geometries involving large expansion of the detonation products.

Section I of this report discusses the form of the equation and describes the procedure used to evaluate the constants.

Section II discusses the experiments and the hydrodynamic calculations used in their interpretation.

Appendixes A-D contain a complete tabulation of the experimental and calculational results.

Section I. The Equation of State

A. FORM OF THE EQUATION

The equation of state used here is empirical. Its development follows an earlier equation proposed by Jones and Miller[5] and an equation developed by Wilkins.[4] Therefore we refer to it as the Jones-Wilkins-Lee (JWL) equation.

Jones:

$$P = Ae^{-R\cdot V} - B + C \cdot T \qquad \text{(I.1)}$$

Wilkins:

$$P = \frac{\mathcal{a}}{V^Q} + B\left(1 - \frac{\omega}{R \cdot V}\right) e^{-R\cdot V} + \frac{\omega E}{V}$$

$$P(\Delta) = \frac{a}{V^Q} + Be^{-RV} + \frac{C}{V^{\omega+1}} \qquad \text{(I.2)}$$

where

$$\mathcal{a} = a \frac{(Q - 1)}{(Q - 1 - \omega)}$$

JWL:

$$P = A\left(1 - \frac{\omega}{R_1 \cdot V}\right) e^{-R_1 \cdot V} + B\left(1 - \frac{\omega}{R_2 \cdot V}\right) e^{-R_2 \cdot V} + \frac{\omega E}{V}$$

$$P(\Delta) = Ae^{-R_1 \cdot V} + Be^{-R_2 \cdot V} + \frac{C}{V^{\omega+1}} \qquad \text{(I.3)}$$

V stands for the relative volume $\frac{v}{v_0}$ following the convention used in hydrodynamic codes. However, substitution of V_{sp} (specific volume) $\cdot\ \rho_0$ (loading density) for V will convert these expressions to specific volume. The pressures are given in megabars (Mbar) and adiabat is abbreviated as Δ.

Contributions of the various terms in Eq. (I.3) to the pressure are shown in Fig. 1.

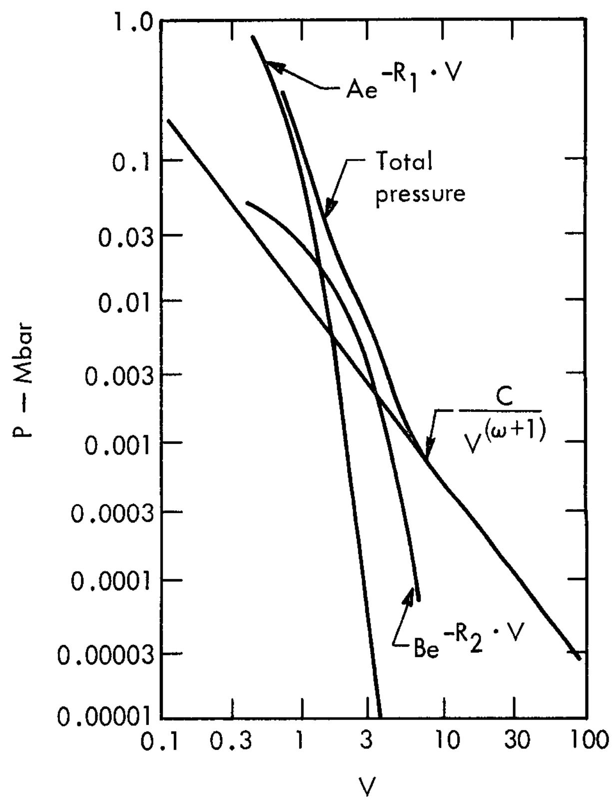


Fig. 1. Contribution of various terms in JWL equation of state to total adiabat pressure for Composition B, Grade A.

B. THERMODYNAMIC-HYDRODYNAMIC CRITERIA

Parameters in the equations are chosen to satisfy the following conditions: 1) the measured Chapman-Jouguet (C-J) state, 2) the measured expansion behavior in the cylinder test, 3) thermodynamic limitations at large expansions, and 4) hydrodynamic continuity.

The measured C-J conditions are directly entered into the equations. The cylinder test expansion behavior is entered by a repetitive trial and error procedure using two-dimensional hydrodynamic calculations. This procedure is described in Section II.

The form of the JWL equation allows us to impose two sensible thermodynamic limitations at large expansions. Firstly, we fix the total available energy, E_0(Mbar cc/cc), at a value consistent with the available chemical energy. This energy is obtained either from detonation calorimetry[6,7] or RUBY[8] calculations.*

Calorimetric E_0's and the JWL values are given in Table I. The calorimetric values are based on H_2O (gas) since it is doubtful whether water vapor can condense to the liquid state in the time it takes for the high explosive gases to expand initially. Moreover, for most HEs, the entropy associated with the C-J adiabat is higher than for the two phase region; thus water will not condense during the adiabatic expansion.

Secondly, in the JWL equation, the profile of the expansion at large values of V is dominated by the value of ω. Since the value of $\Gamma \equiv -\left(\frac{\partial \ln P}{\partial \ln V}\right)_S$ should approach $\frac{C_p}{C_v}$ at large expansion, and since $\Gamma = \omega + 1$ for $V > 10$, we arbitrarily limit the choice of ω to $0.20 < \omega < 0.40$, which is consistent with the heat capacities of the gaseous products for the explosives discussed in this report.

Proper hydrodynamic continuity is assured if P is everywhere a monotonically decreasing function of the relative volume. This is the same as requiring Γ to be greater than zero and continuous, a condition which cannot be predetermined by limitations on the selection of

*RUBY, C-J-adiabat composition at a relative volume of 10 is used to calculate the available chemical energy.

Table I. Comparison of E_0 used in JWL calculations and detonation calorimetric results.

Explosive	Composition[a,b]	E_0 (Mbar cc/cc) JWL	E_0 (Mbar cc/cc) Detonation calorimetry
HMX		0.105	0.109
Nitromethane (NM)		0.051	0.050
PETN		0.101	0.101
TNT		0.07	0.070
Comp B, Grade A	RDX, TNT (64/36)	0.085	0.081
Cyclotol	RDX, TNT (77/23)	0.092	–
PBX 9011	HMX, Estane (90/10)	0.089	–
PBX 9404	HMX, NC, CEF (94/3/3)	0.102	0.098
LX-04-1	HMX, Viton (85/15)	0.095	0.097
LX-07-0	HMX, Viton (90/10)	0.096	–

[a]Abbreviations are NC = Nitrocellulose, CEF = Tris β-chloroethyl phosphate.

[b]Numbers are approximate weight percent.

coefficients, but must be checked for each specific equation. In practice, it has turned out that $R_1 \cong 4$ and $R_1 \cong 1$, and that the value of Γ has always been greater than 1 for the explosives we have investigated. Near the C-J point the high pressure behavior is dominated by the coefficient R_1 as can be seen in Fig. 1. Even for compressions near 2 ($V \cong 0.5$), Γ is still greater than 2.

At very large compressions, the pressure behavior would be dominated by ω. This is probably an incorrect description, but is well outside of the range of pressures normally encountered in experiments on explosives.

C. METHOD FOR DETERMINING COEFFICIENTS

To use Eq. I.3, six constants must be determined. The linear coefficients A, B, and C are determined from E_0, D, P_{CJ} and ρ_0 once a guess is made for the nonlinear coefficients R_1, R_2, and ω. A hydrodynamic calculation is then carried out and the results are compared with experiment.

A procedure based on calculated energy change (E_0 - E) along the adiabat was evolved which minimizes the number of guesses required to obtain agreement with experiment. To a first approximation, the energy delivered to a metal shell at a given expansion is proportional to E_0 - E evaluated from

$$E - E_0 = \frac{A}{R_1} e^{-R_1 V} + \frac{B}{R_2} e^{-R_2 V} + \frac{C}{\omega V^{\omega}} - E_0 \qquad (I.4)$$

for a volume of the detonation products characteristic for a given expansion. If the initial guess for R_1, R_2 and ω used in the hydrodynamic calculation resulted in a metal kinetic energy 10% too high, for example, a new guess for which E - E_0 at the same V is 10% less would give agreement with experiment.

A computer code was used to calculate E - E_0 for systematic variations in R_1, R_2, and ω and to then compare the values with the E - E_0 values calculated using the initial guess. An adiabat that varied from the initial guess by the same amount that the initial guess varied from experiment was then used in the next hydrodynamic calculation. Resultant agreement with experiment was usually within 1%. If not, the procedure was repeated.

Final values for R_1, R_2, and ω give calculated wall velocities within 1% of the experimental wall velocities. The detailed comparisons of calculation and experimental results are given in Appendixes A and B.

D. RESULTS

JWL equation-of-state coefficients have been determined for ten high explosives. (See Table II.) For some of the explosives listed we have given two or three sets of coefficients. The best set is labeled ΔA. The other sets are given for comparisons which will be referred to later in this report.

Where P_{CJ} has not been measured, we have made an estimate assuming that $2.7 < \Gamma_{CJ} < 2.8$. A simple multiple of 10 kbar, causing Γ to fall in this range, was chosen as the C-J pressure. These values are noted by an asterisk (*).

Table III gives a list of coefficients for Wilkins' equation applied to LX-04-1 and

Table II. JWL parameters.

	HMX^a	NM ΔA	NM ΔB	PETN ΔA	TNT	Comp B, Grade A	Cyclotol	PBX 9011	PBX 9404 ΔA	PBX 9404 ΔB	LX-04-1 ΔA	LX-04-1 ΔB	LX-04-1 ΔC	LX-07-0
A	7.7828	2.0925	1.3527	7.9653	3.71213	5.24229	6.03414	6.34717	8.5445	6.72023	8.4984	6.11834	5.94143	6.8674
B	0.07071428	0.056895	0.030284	0.19241	0.032306	0.076783	0.0992357	0.079982	0.20493	0.206750	0.15277	0.076672	0.050039	0.0790406
C	0.006430	0.0077042	0.0064342	0.006651	0.0104527	0.010818	0.010753	0.007270	0.00754	0.0086631	0.011585	0.0068637	0.0094875	0.0114438
R_1	4.2	4.4	0.6	4.8	4.15	4.2	4.7	4.2	4.6	4.25	4.65	4.07	4.0	4.2
R_2	1.0	1.2	1.0	1.2	0.95	1.10	1.1	1.0	1.35	1.45	1.30	1.00	0.9	1.0
ω	0.3	0.3	0.275	0.25	0.30	0.34	0.35	0.3	0.25	0.25	0.35	0.25	0.3	0.4
E_0 (Mbar cc/cc)	0.105	0.051	0.051	0.101	0.07	0.085	0.092	0.089	0.102	0.102	0.095	0.095	0.095	0.096
ρ_0 (g/cc)	1.891	1.128	1.128	1.77	1.63	1.717	1.754	1.77	1.84	1.84	1.865	1.865	1.865	1.865
P_{CJ} (Mbar)	0.42[a]	0.125[10]	0.140[9]	0.32[11]	0.21[12]	0.295[12]	0.32[12]	0.34[a]	0.37[11]	0.390[4]	0.34[11]	0.36[4]	0.36[4]	0.37[a]
Γ_{CJ}	2.7405	2.5386	2.1875	2.812	2.727	2.706	2.7307	2.7611	2.85	2.658	2.9355	2.69	2.69	2.7627
D (cm/μsec)	0.911	0.6287	0.6287	0.83[11]	0.693	0.798	0.825	0.85	0.88	0.88	0.847	0.847	0.846	0.864

[a]P_{CJ} assumed from $P = \frac{\rho D^2}{\Gamma + 1}$; $2.7 < \Gamma_{CJ} > 2.8$.

Table III. Coefficients for Wilkins and Γ-law equation.

	PBX 9404	LX-04-1	Comp B Γ-law	Comp B Simulated BKW	Comp B Simulated LJD
a	0.004563	0.008335	—	0.02771	0.059937
α	0.005266	0.009435	0.126	0.04645	0.09270
B	6.572	5.943	—	0.01191	0.3427
C	0.032	0.029	—	0.08085	0.03515
Q	4.0	4.0	2.706	3.785	3.43
R	4.0	4.0	—	0.6486	3.054
ω	0.35	0.40	—	1.1235	0.8588
E_0 (Mbar cc/cc)	0.1343	0.1126	0.0865	0.0903	0.0836
ρ_0 (g/cc)	1.84	1.865	1.717	1.717	1.714
P_{CJ} (Mbar)	0.39	0.36	0.295	0.280	0.259
V_{CJ}	0.7266	0.7316	0.7302	0.749	0.763
D (cm/μsec)	0.880	0.848	0.798	0.807	0.799

PBX 9404. In the course of our work the BKW and LJD adiabats for Comp B were simulated[13] with Wilkins' equation of state to fit them into a format suitable for input into the HEMP Code.[14] These coefficients are also listed in Table III along with the Γ-law coefficients.

By plotting $\Gamma = -\left(\frac{\partial \ln P}{\partial \ln V}\right)_S$ versus V for the Comp B adiabat, the JWL equation is compared graphically in Figs. 2a, b, c, with the BKW,[15] LJD,[2] and Γ-law[3] equations of state. For LX-04-1 and PBX 9404 both the JWL and Wilkins' Γ-behavior are plotted in Figs. 3a, b, c, d. (For the remaining HE's, Γ vs V plots are given in Appendix D.)

All the Γ versus V curves have characteristic double maxima. If one treats the high density gaseous detonation products as having some of the properties of a

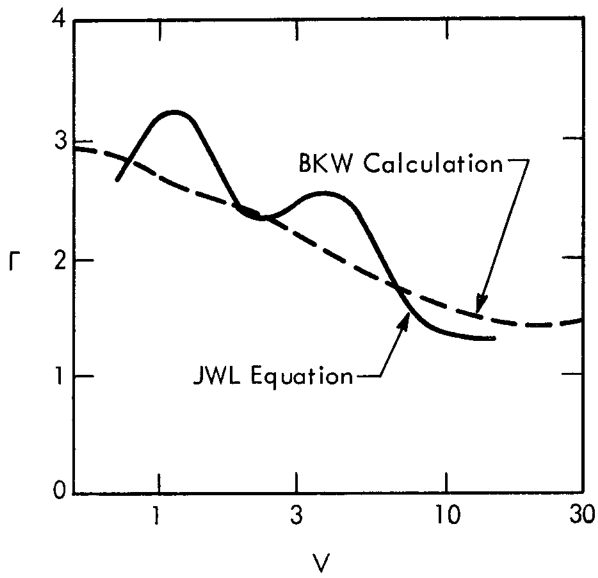


Fig. 2a. Comparison of Γ calculated from the JWL equation and the BKW equation for Composition B, Grade A.

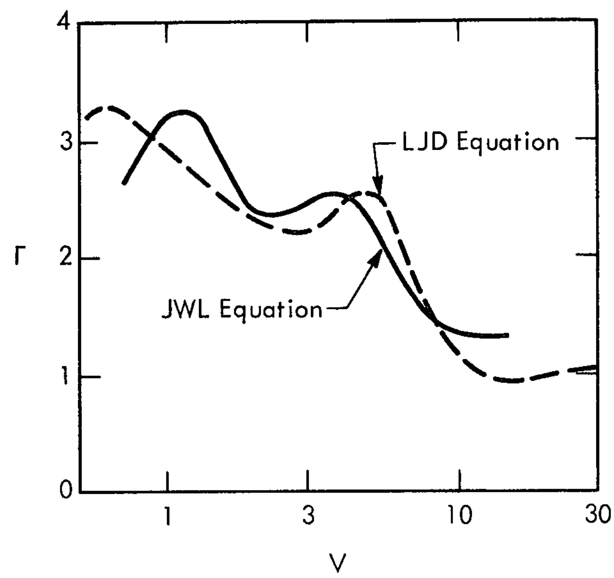


Fig. 2b. Comparison of Γ calculated from the JWL equation and the LJD equation for Composition B, Grade A.

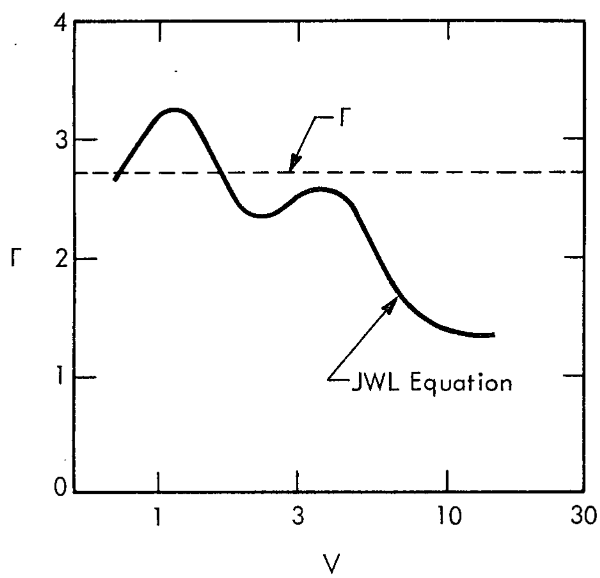


Fig. 2c. Comparison of Γ calculated from the JWL equation and the Γ-law for Composition B, Grade A.

solid lattice,[5,2] the Γ versus V curve should exhibit a maximum near a volume corresponding to the equilibrium lattice distance. This is simply because the lattice pressure, which can be a major part of the total pressure, falls to zero as the compressed lattice expands approaching the equilibrium distance. The logarithmic derivative of the lattice pressure alone will exhibit a singularity at $P_{lattice} = 0$, since

$$\Gamma_{lattice} = -\frac{V}{P}\left(\frac{\partial P}{\partial V}\right)_S.$$

Therefore, results from lattice plus thermal pressure derivatives will exhibit a maximum for the usual intermolecular potential descriptions such as 6-12, exponential 6 or modified Morse.

The locations of the first or high density maxima shown in this report are at gas densities somewhat higher than one would expect from the equilibrium distances derived from the condensed phases of the product gases. It is suggested that the proper equilibrium distances to use may be those for high pressure allotropic forms of the condensed phase. As an example, water exists as ice VII at 21 kbar and has a density of 1.56 g/cc.

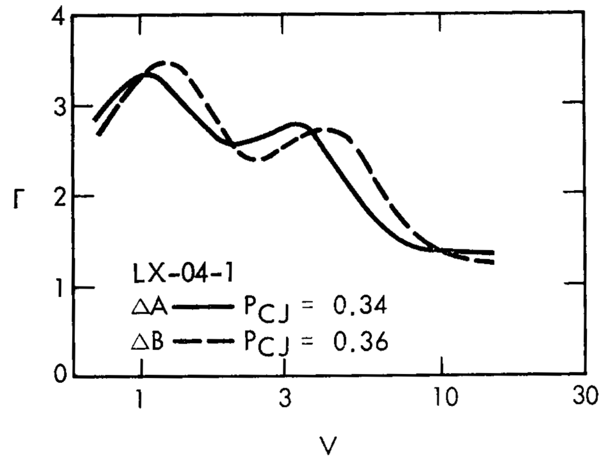


Fig. 3a. Comparison of JWL Γ calculations for LX-04-1 adiabats ΔA and ΔB.

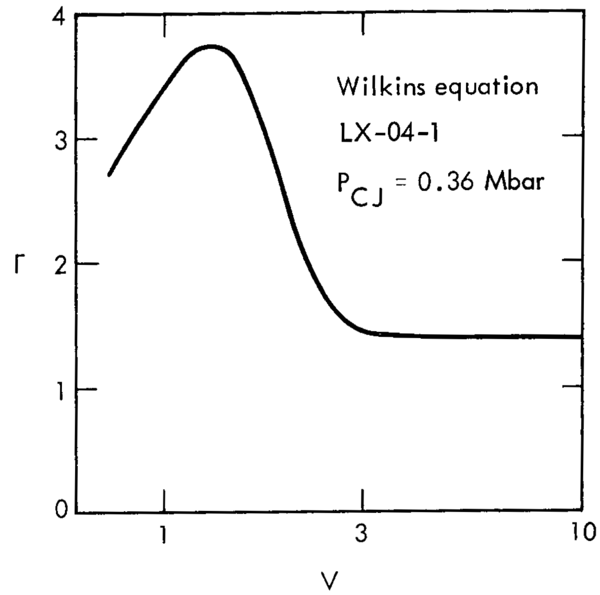


Fig. 3b. Γ for LX-04-1, Wilkins equation.

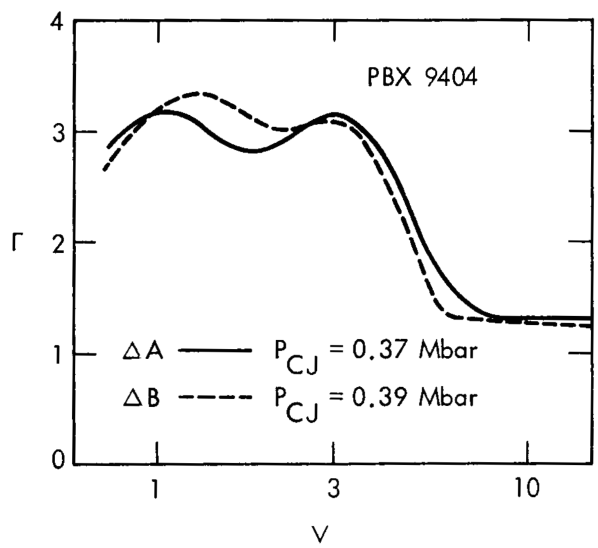


Fig. 3c. Comparison of JWL Γ calculations for PBX 9404 adiabats ΔA and ΔB.

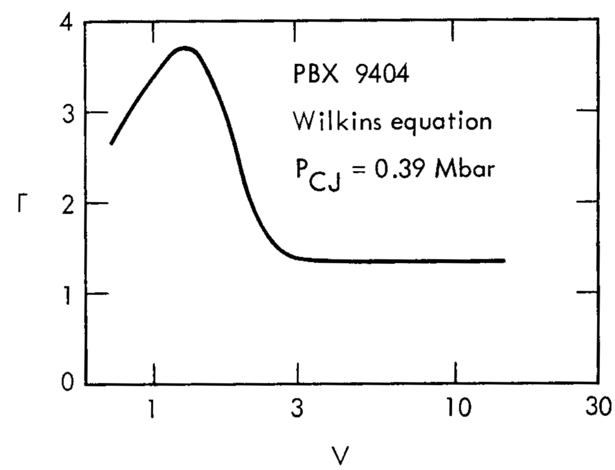


Fig. 3d. Γ for PBX 9404, Wilkins equation.

We cannot explain the second (low density maximum) but have observed that it falls roughly at the critical density of the gases produced by CHNO explosives. It is very difficult to investigate this possible correlation quantitatively since there are no simple, reliable descriptions of fluid behavior near the critical density.

E. DENSITY DEPENDENCE

The JWL equation contains the assumption that the Gruneisen parameter (G) is constant* whereas it is a function of E and V in the most general description.

*It is possible to make the JWL equation consistent with the measured dependence of D on ρ by removing the constraint on G, i.e., allow G = G(V) or G = G(E, V), as described in UCRL-70809.

With the single additional assumption that $E_0' = E_0 \cdot \rho_0'/\rho_0$ one can calculate the C-J state and adiabatic expansion for various values of ρ_0' in a range within ±10% of ρ_0. The only coefficient which changes is C. However, the usual procedure is to use a measured value of D' and the original value of Γ to specify the C-J state and determine new values for A, B, and C. Original values for R_1, R_2, and ω, are retained and E_0' is determined as above. Using P_{CJ}' from

$$P_{CJ}' = \frac{\rho_0' D'^2}{\Gamma + 1} \tag{I.5}$$

and

$$V_{CJ} = V_{CJ}' = \Gamma/(\Gamma + 1), \tag{I.6}$$

the determination requires the solution of the following set of three linear equations for A', B', and C'.

$$P_{CJ}' = A' e^{-R_1 \cdot V_{CJ}} + B' e^{-R_2 \cdot V_{CJ}} + \frac{C'}{V_{CJ}^{(\omega+1)}} \tag{I.7}$$

$$-E_0 = -E_{CJ}' + \frac{1}{2} P_{CJ}'(1 - V_{CJ}) \tag{I.8}$$

where

$$E_{CJ}' = \frac{A'}{R_1} e^{-R_1 \cdot V_{CJ}} + \frac{B'}{R_2} e^{-R_2 \cdot V_{CJ}} + \frac{\left(\frac{C'}{\omega}\right)}{V_{CJ}^{\omega}}$$

and

$$\Gamma_{CJ} = \frac{V_{CJ}}{1 - V_{CJ}} = -\frac{V_{CJ}}{P_{CJ}'} \left[\left(\frac{\partial P}{\partial V}\right)_S\right]_{CJ} \tag{I.9}$$

where

$$\left[\left(\frac{\partial P}{\partial V}\right)_S\right]_{CJ} = -R_1 \cdot A' e^{-R_1 \cdot V_{CJ}} - R_2 \cdot B' e^{-R_2 \cdot V_{CJ}} - (\omega + 1) \frac{C'}{V_{CJ}^{(\omega+2)}}$$

F. USES AND LIMITATIONS

The principal value of the JWL equation of state lies in its ability to give an accurate description of the C-J adiabat. The coefficients we have determined for a JWL equation should be considered a condensed summary of measured C-J adiabat expansion pressures for the high explosives listed. Only to a first approximation are they a description of the equation of state of the high explosive product gases at points removed from that adiabat (i.e., points which are reached by experiments at other than the listed loading density or by reshocking the detonation products).

However, since the JWL equation satisfies the criteria in Section IIB, the uncertainty involved in using this description over a limited range outside of the fitted experiments is, hopefully, minimized. Furthermore, since these criteria are satisfied, *this equation of state should not* only be useful as an "engineering" equation to be used in various calculations for the high explosives listed here, but should also serve as a description of the thermodynamic behavior of the expanding gases.

The lack of temperature information limits the kind of thermodynamic information one can deduce directly, but the properties of the equation allow it to be used either in a test of proposed P, V, T equations, or in the construction of a P, V, T equation.

We have observed that the nonlinear coefficients R_1, R_2 and ω do not vary appreciably from one explosive to another and have applied this information to generate equations of state for CHNO explosives where hydrodynamic measurements were lacking. However, we caution against using such a procedure for other classes of high explosives.

Section II. Experiments and Hydrodynamic Calculations

Experimental accuracy and the validity of our calculation procedures determine how well the adiabats listed in Section I actually do represent the behavior of the detonation products. In this section, we describe the standard tests and, in addition, give results from tests and calculations designed to investigate stability, scaling, and the effect of metal yield strength.

A. EXPERIMENTAL CONFIGURATIONS FOR MEASUREMENT OF ADIABATIC EXPANSIONS

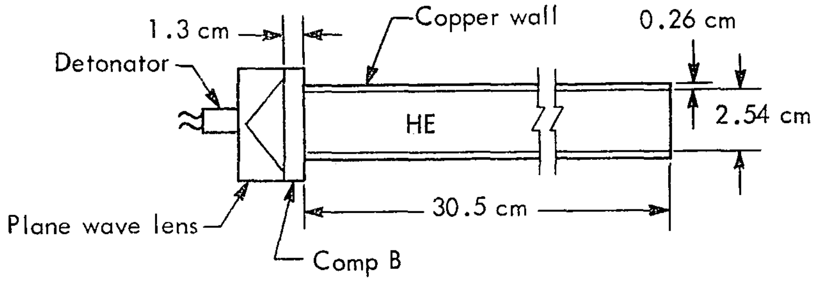
In order to describe the adiabatic expansion of the detonation products it is necessary to obtain experimental data for the initial point (assumed to be the Chapman-Jouguet point) and for points during the subsequent expansion. The C-J pressure and detonation velocity experiments characterizing the initial point have been described elsewhere.[12] The cylinder and sphere tests used to characterize the expansion behavior are described below.

The standard cylinder test geometry used for these experiments is shown in Fig. 4. It is similar to the test configurations used in earlier work.[16,17] The radial motion of the cylinder wall is recorded by a streak camera using shadowgraph techniques. The viewing slit is 20 cm from the booster explosive. The record is read on a precision comparator which punches the coordinate data directly onto IBM cards. A computer code then uses these data to calculate radial wall velocities at specified values of $R - R_0$. Experimental reproducibility is within 0.5% for radius-time data, and 1% for wall velocity, provided the tube surface is electropolished or chemically cleaned. Detonation velocities are measured by placing pin switches 23 cm apart on the surface of the tube.

The effect of explosive diameter on cylinder test results has been investigated. One-in., 2-in. and 4-in. diam, scaled experiments have been carried out for PBX 9404 and TNT. Also, 1-in. and 2-in. diam, scaled experiments were done with Comp B. The results (Tables IVa-IVc) scale hydrodynamically within experimental error. Therefore, for the explosives tested, the standard 1-in. diam test closely approximates infinite diameter behavior. This conclusion is not true for explosives with long reaction zones. In particular, recent experiments with perchlorate-containing explosives indicate diameter effects even with 2-in. diam charges.

The change in cylinder wall velocity as a function of position along the cylinder was also investigated. Data for LX-04-1 in the standard copper cylinder are presented in Fig. 5. For $R - R_0 < 2.5$ cm, radius-time behavior is independent of axial position if $L/D \geq 4.5$. (In the standard test, measurements are made at an L/D of 8.)

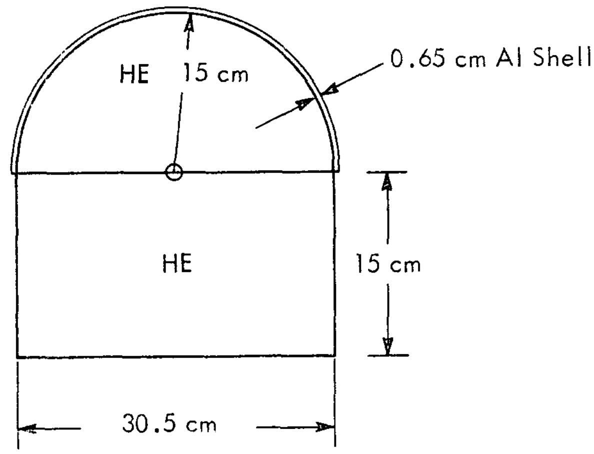
The arrangement for the spherical charge experiments[4] is also shown in Fig. 4. It consists of a hemisphere of HE inside a close fitting hemispherical aluminum shell, the other half of the sphere being simulated by a cylinder of the same HE. The charge is initiated at the center with a spherically divergent



Cylinder: OFHC Copper, ASTM-B-187, density = 8.93 g/cc, i.d. = 2.55 cm, o.d. = 3.07 cm, wall = 0.26 cm, length = 30.5 cm

Explosive: o.d. = 2.54 cm, length = 30.5 cm

Initiator: SE-1 detonator, Tetryl pellet, P-22 plane wave lens, 1.27 cm thick Comp B booster



Hemispherical shell: Aluminum, ASTM-6061-T6 i.r. = 15 cm, density = 2.70 g/cc, o.r. = 15.65 cm, wall = 0.65 cm.

Explosive: Hemisphere, o.r. = 15 cm, cylinder mate, o.d. = 30.5 cm, length = 15 cm.

Initiator: SE-3, spherically divergent "point" detonator.

Fig. 4. Standard experimental test geometries.

detonator. Photography and data reduction were the same as for the cylinder tests. To obtain good film records, it was necessary to have a polished finish on the metal, to illuminate the sphere with a parallel light beam, and to enclose the experiment in a vacuum chamber.

The compilation of results for both the standard cylinder test and the sphere test is to be found in Appendixes A and B.

B. HYDRODYNAMIC CALCULATIONS

The hydrodynamic codes KO[13] and HEMP,[14] were used to determine the

Table IVa. Cylinder test data for 1-in., 2-in., and 4-in. scaled PBX 9404.

$R - R_0$ (cm)	2.54 cm diam PBX 9404 0.2606 cm copper wall — t/1 at $(R - R_0)/1$ (μsec)	5.08 cm diam PBX 9404 0.521 cm copper wall — t/2 at $(R - R_0)/2$ (μsec)	10.17 cm diam PBX 9404 1.04 cm copper wall — t/4 at $(R - R_0)/4$ (μsec)
0.05	0.57	0.53	0.59
0.1	1.11	1.05	1.12
0.15	1.49	1.48	1.51
0.2	1.87	1.89	1.90
0.25	2.25	2.26	2.26
0.3	2.60	2.62	2.62
0.35	2.96	2.96	2.96
0.4	3.27	3.30	3.30
0.5	3.93	3.94	3.94
0.6	4.56	4.57	4.57
0.7	5.18	5.18	5.19
0.8	5.79	5.79	5.79
0.9	6.39	6.39	6.39
1.0	6.98	6.98	6.98
1.1	7.57	7.57	7.56
1.2	8.15	8.14	8.12
1.3	8.73	8.71	8.72
1.4	9.30	9.28	9.30
1.5	9.87	9.82	9.86
1.6	10.44	10.40	10.43
1.7	11.00	10.96	10.99
1.8	11.57	11.51	11.54
1.9	12.13	12.06	12.10
2.0	12.68	12.62	12.65
2.2	13.79	13.71	13.74
2.4	14.90		14.83
2.6	15.99		15.91
2.8	17.09		
3.0	18.17		

Table IVb. Cylinder test data for 1-in., 2-in., and 4-in. scaled TNT.

$R - R_0$ (cm)	2.54 cm diam TNT 0.2606 cm copper wall — t/1 at $(R - R_0)/1$ (μsec)	5.08 cm diam TNT 0.521 cm copper wall — t/2 at $(R - R_0)/2$ (μsec)	10.17 cm diam TNT 1.04 cm copper wall — t/4 at $(R - R_0)/4$ (μsec)
0			
0.1	1.545	(1.52)	1.62
0.2	2.64	2.69	2.78
0.3	3.615	3.67	3.72
0.4	4.53	4.56	4.61
0.5	5.41	5.42	5.48
0.6	6.25	6.26	6.31
0.7	7.06	7.08	7.12
0.8	7.85	7.88	7.92
0.9	8.63	8.65	8.70
1.0	9.41	9.42	9.47
1.1	10.18	10.17	10.23
1.2	10.94	10.91	10.98
1.3	11.69	11.65	11.72
1.4	12.44	12.38	12.45
1.5	13.17	13.11	13.18
1.6	13.90	13.83	13.90
1.7	14.62	14.56	14.62
1.8	15.34	15.28	15.34
1.9	16.05	16.00	16.05
2.0	16.76		16.76
2.1	17.47		17.46
2.2	18.18		18.16

Table IVc. Cylinder test data for 1-in., and 2-in. scaled Comp B, Grade A.

$R - R_0$ (cm)	2.54 cm diam Comp B 0.2606 cm copper wall — t/1 at $(R - R_0)/1$ (μsec)	5.08 cm diam Comp B 0.521 cm copper wall — t/2 at $(R - R_0)/2$ (μsec)
0.2	2.17	2.15
0.3	3.00	3.00
0.4	3.77	3.78
0.5	4.51	4.51
0.6	5.22	5.21
0.7	5.91	5.90
0.8	6.59	6.59
0.9	7.26	7.26
1.0	7.92	7.92
1.1	8.57	8.57
1.2	9.22	9.21
1.3	9.86	9.85
1.4	10.50	10.48
1.5	11.13	11.11
1.6	11.75	11.73
1.7	12.37	12.35
1.8	12.99	12.97
1.9	13.60	13.59
2.0	14.22	14.20
2.1	14.83	14.81
2.2	15.43	15.41
2.3	16.04	16.02

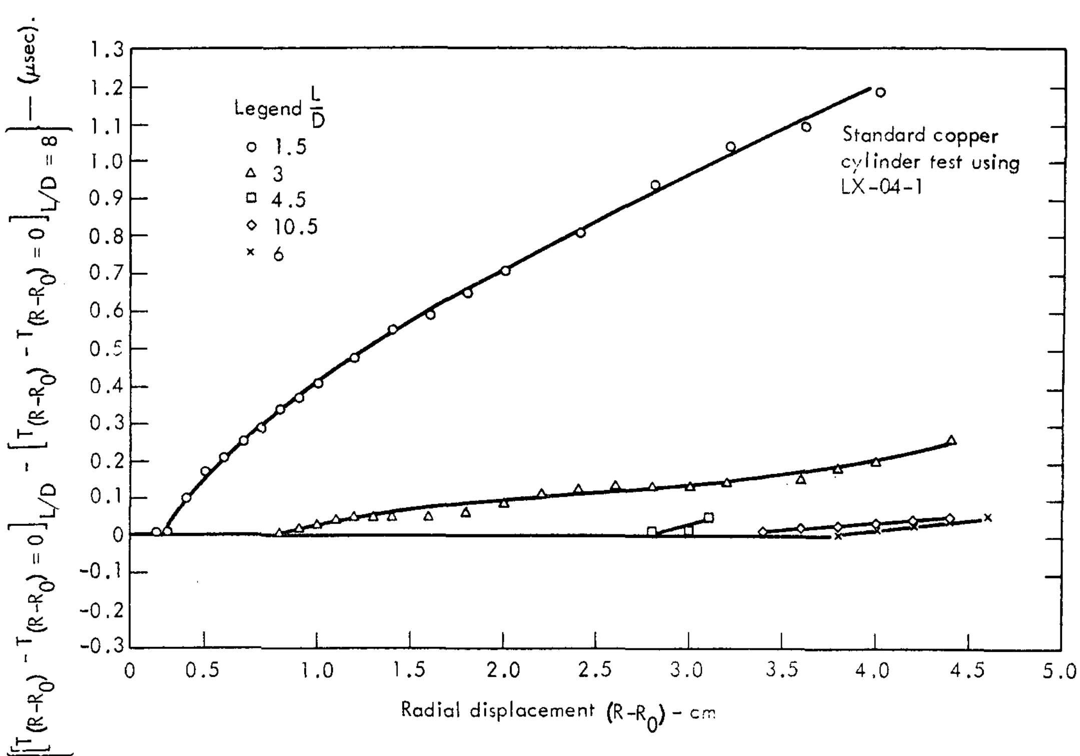


Fig. 5. Change of wall arrival times as a function of position on the cylinder.

detonation product equations of state from the sphere and cylinder experiments by a method of successive approximations. The accuracy of the results depend directly on the accuracy of these Lagrangian codes. Both codes have been tested by comparing results with those from an identical geometry calculated by the method of characteristics; metal motion histories agreed within 0.2% (see Ref. 19).

The zoning used in the HEMP calculations is shown in Fig. 6. The position along the cylinder at which steady state conditions are achieved is influenced by the total number of zones. With the zoning shown, steady state was achieved

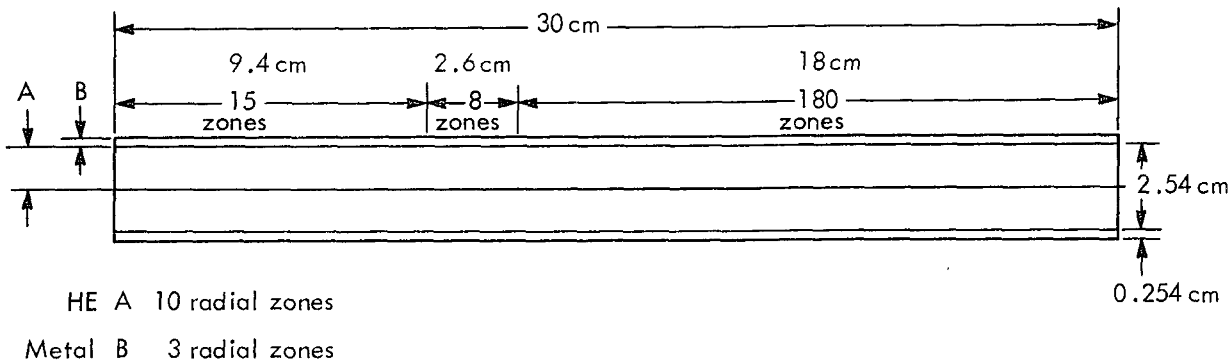


Fig. 6. Zoning for HEMP code calculation for cylinder test.

Table V. Comparisons of cylinder test calculations at various axial positions and cylinder test experimental results at 17.8 cm (7 in.) for Comp B, Grade A.

$(R - R_0)$ (cm)	$t_{std\ exp.}$ (μsec)	t_{calc}(μsec)								
		x = 16	x = 17	x = 18	x = 19	x = 20	x = 21	x = 22	x = 23	x = 24
0	0									
0.150	1.710	1.731	1.737	1.740	1.740	1.741	1.742	1.742	1.742	1.743
0.200	2.180	2.171	2.175	2.177	2.176	2.176	2.178	2.178	2.178	2.179
0.250	2.590	2.605	2.606	2.608	2.607	2.607	2.608	2.608	2.608	2.609
0.300	2.990	3.017	3.018	3.018	3.018	3.018	3.018	3.018	3.018	3.018
0.400	3.780	3.782	3.779	3.778	3.777	3.777	3.776	3.776	3.776	3.776
0.500	4.520	4.525	4.520	4.517	4.517	4.516	4.515	4.515	4.515	4.515
0.600	5.220	5.255	5.245	5.238	5.238	5.236	5.234	5.233	5.233	5.232
0.700	5.910	5.947	5.934	5.927	5.929	5.928	5.924	5.923	5.923	5.921
0.800	6.590	6.629	6.614	6.606	6.611	6.610	6.605	6.604	6.604	6.602
0.900	7.260	7.304	7.286	7.276	7.280	7.276	7.272	7.268	7.269	7.266
1.000	7.920	7.969	7.949	7.939	7.939	7.933	7.929	7.924	7.926	7.923
1.100	8.570	8.625	8.603	8.593	8.590	8.582	8.579	8.573	8.574	8.571
1.200	9.220	9.274	9.250	9.240	9.233	9.226	9.223	9.217	9.217	9.211
1.300	9.860	9.916	9.890	9.880	9.870	9.863	9.861	9.856	9.853	9.846
1.400	10.500	10.554	10.526	10.515	10.503	10.496	10.494	10.490	10.485	10.476
1.500	11.130	11.187	11.158	11.147	11.131	11.125	11.124	11.121	11.113	11.102
1.600	11.750	11.817	11.786	11.775	11.757	11.750	11.751	11.750	11.738	11.725
1.700	12.370	12.444	12.412	12.401	12.379	12.374	12.375	12.375	12.361	12.345
1.800	13.000	13.069	13.035	13.023	12.998	12.994	12.997	12.999	12.988	12.962
1.900	13.600	13.690	13.655	13.642	13.616	13.611	13.615	13.618	13.597	13.577
2.000	14.220	14.311	14.274	14.257	14.233	14.225	14.229	14.230	14.211	14.193
2.200	15.430	15.546	15.505	15.480	15.464	15.445	15.451	15.448	15.434	15.420
2.400	16.640	16.775	16.730	16.696	16.689	16.658	16.665	16.658	16.650	16.641
2.500	17.240	17.387	17.341	17.301	17.301	17.261	17.269	17.261	17.256	17.251
2.600	17.840	17.998	17.950	17.906	17.912	17.863	17.873	17.861	17.861	17.859
2.800	19.040	19.217	19.166	19.110	19.131	19.065	19.075	19.060		
3.000	20.230	20.429	20.374	20.321	20.324	20.266	20.271	20.263		

(within experimental error) 20 cm from the initiated end of the cylinder. Table V and Fig. 7 compare experimental results for Comp B at 20 cm and the calculated expansion history as a function of axial position. The calculation reaches steady state at a somewhat larger L/D than indicated by the experiments discussed in the previous section. This is consistent with the fact that the plane wave lens and booster are omitted in the calculation.

In generating the adiabats given in this report care was taken that both the experimental and calculation results were representative of the steady state region.

The sensitivity of the calculated wall motion to changes in adiabatic pressures was also investigated. Table VI presents results for LX-04-1 calculated using two different adiabats, ΔA and ΔC. Table VII and Fig. 8 show the pressure differences for these two adiabats. The resultant effect on radius-time history is also shown. The difference in results is approximately the experimental uncertainty in the cylinder test and indicates a sensitivity to pressure changes of at least 1% in the major volume region of interest.

At volumes <1.0 the accuracy depends on how well one knows the C-J pressure. Since, however, an increase in C-J pressure, with D and ρ_0 held constant, merely moves the C-J point to a smaller volume the resultant displacement from the original adiabat is small. This is a consequence of the conservation relations, since the Rayleigh line, Hugoniot, and isentrope are tangent at the C-J point. As an example, calculations for nitromethane show that changing the C-J pressure from 140 to 125 kbars and then matching cylinder experiments results in adiabats with less than a 5 kbar change in pressures at any given volume (see Table VIII and Fig. 9).

C. EXPERIMENTS IN NONSTANDARD GEOMETRIES

A rigorous test of the equation of state of an explosive, the hydrodynamic

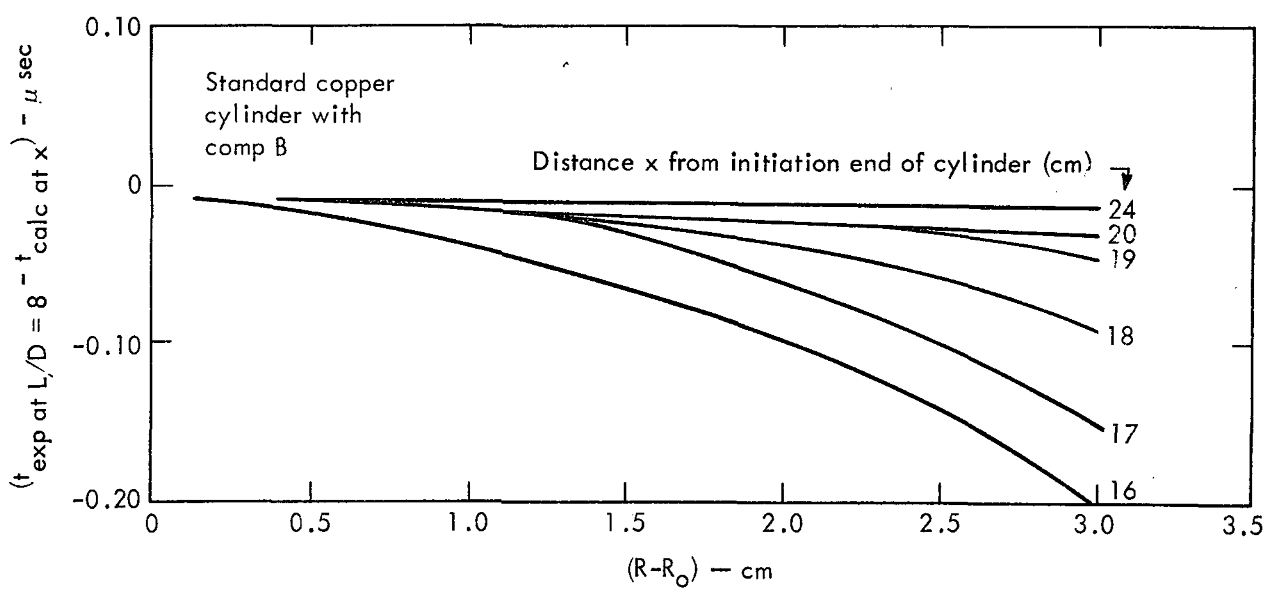


Fig. 7. Approach to steady solution for Composition B, Grade A.

Table VI. Comparison of experimental and calculated cylinder test results for LX-04-1 adiabats ΔB and ΔC.

$R - R_0$ (cm)	R (cm)	t(exp) (μsec)	ΔC: t(calc) (μsec)	ΔC: t(exp) - t(calc) (μsec)	ΔB: t(calc) (μsec)	ΔB: t(exp) - t(calc) (μsec)
0.150	1.680	1.550	1.553	0.007	1.570	-0.020
0.200	1.730	1.980	1.962	0.018	1.974	0.006
0.250	1.780	2.360	2.355	0.005	2.363	-0.003
0.300	1.830	2.740	2.729	-0.009	2.736	0.004
0.400	1.930	3.450	3.458	-0.038	3.458	-0.008
0.500	2.030	4.120	4.152	-0.052	4.137	-0.017
0.600	2.130	4.790	4.825	-0.035	4.804	-0.014
0.700	2.230	5.410	5.482	-0.052	5.457	-0.047
0.800	2.330	6.050	6.121	-0.051	6.087	-0.037
0.900	2.430	6.680	6.752	-0.062	6.711	-0.031
1.000	2.530	7.300	7.378	-0.068	7.329	-0.029
1.100	2.630	7.910	7.997	-0.067	7.941	-0.031
1.200	2.730	8.520	8.610	-0.070	8.547	-0.027
1.300	2.830	9.120	9.218	-0.068	9.149	-0.029
1.400	2.930	9.720	9.820	-0.070	9.747	-0.027
1.500	3.030	10.320	10.419	-0.069	10.342	-0.022
1.600	3.130	10.910	11.015	-0.075	10.934	-0.024
1.700	3.230	11.500	11.607	-0.077	11.525	-0.025
1.800	3.330	12.090	12.198	-0.088	12.113	-0.023
1.900	3.430	12.670	12.786	-0.086	12.699	-0.029
2.000	3.530	13.250	13.372	-0.092	13.281	-0.031
2.200	3.730	14.410	14.539	-0.099	14.439	-0.029
2.400	3.930	15.560	15.702	-0.112	15.592	-0.032
2.500	4.030	16.140	16.281	-0.121	16.166	-0.026

Table VII. Comparison of pressure, energy, and Γ for LX-04-1 adiabats ΔB and ΔC.

V	$P_{\Delta C}$ (Mbar)	$P_{\Delta B}$ (Mbar)	$P_{\Delta C} - P_{\Delta B}$ (Mbar)	$\frac{E_{\Delta C} - E_{\Delta B}}{E_{\Delta B}}$	$\Gamma_{\Delta C}$	$\Gamma_{\Delta B}$
7.2900E-01	3.6200E-01	3.6200E-01	-1.3039E-07	3.6455E-06	2.6900	2.6900
7.0000E-01	4.0303E-01	4.0306E-01	-2.6278E-05	-1.1771E-06	2.6004	2.6035
7.5000E-01	3.3507E-01	3.3509E-01	-1.1839E-05	6.3375E-06	2.7533	2.7507
8.0000E-01	2.7922E-01	2.7934E-01	-1.1490E-04	1.1572E-04	2.8974	2.8880
8.5000E-01	2.3329E-01	2.3357E-01	-2.8569E-04	9.4434E-04	3.0315	3.0138
9.0000E-01	1.9548E-01	1.9597E-01	-4.8883E-04	1.0986E-02	3.1543	3.1271
9.5000E-01	1.6434E-01	1.6504E-01	-6.9981E-04	-1.0191E-02	3.2644	3.2265
1.0000E 00	1.3865E-01	1.3956E-01	-9.0227E-04	-7.4630E-03	3.3604	3.3108
1.1000E 00	9.9920E-02	1.0116E-01	-1.2447E-03	-8.2158E-03	3.5054	3.4307
1.2000E 00	7.3375E-02	7.4854E-02	-1.4788E-03	-1.0125E-02	3.5814	3.4821
1.3000E 00	5.5052E-02	5.6657E-02	-1.6042E-03	-1.2305E-02	3.5853	3.4664
1.4000E 00	4.2290E-02	4.3927E-02	-1.6365E-03	-1.4516E-02	3.5205	3.3917
1.5000E 00	3.3300E-02	3.4897E-02	-1.5968E-03	-1.6634E-02	3.3981	3.2722
1.6000E 00	2.6877E-02	2.8383E-02	-1.5054E-03	-1.8584E-02	3.2350	3.1259
1.8000E 00	1.8757E-02	1.9993E-02	-1.2358E-03	-2.1829E-02	2.8642	2.8225
2.0000E 00	1.4118E-02	1.5047E-02	-9.2899E-04	-2.4135E-02	2.5389	2.5843
2.2500E 00	1.0644E-02	1.1217E-02	-5.7283E-04	-2.5817E-02	2.2803	2.4252
2.5000E 00	8.4267E-03	8.7102E-03	-2.8351E-04	-2.6442E-02	2.1731	2.3921
2.7500E 00	6.8576E-03	6.9240E-03	-6.6358E-05	-2.6310E-02	2.1620	2.4329
3.0000E 00	5.6739E-03	5.5862E-03	8.7753E-05	-2.5672E-02	2.1986	2.5056
4.0000E 00	2.9328E-03	2.6182E-03	3.1461E-04	-2.1111E-02	2.3756	2.7280
5.0000E 00	1.7267E-03	1.4346E-03	2.9208E-04	-1.6480E-02	2.3303	2.6005
6.0000E 00	1.1498E-03	9.2097E-04	2.2878E-04	-1.2864E-02	2.1059	2.2302
7.0000E 00	8.4789E-04	6.7273E-04	1.7516E-04	-1.0164E-02	1.8419	1.8476
8.0000E 00	6.7288E-04	5.3587E-04	1.3702E-04	-8.1175E-03	1.6276	1.5740
1.0000E 01	4.8168E-04	3.8946E-04	9.2220E-05	-5.2090E-03	1.3987	1.3282
1.5000E 01	2.8076E-04	2.3253E-04	4.8227E-05	-1.0368E-03	1.3030	1.2514

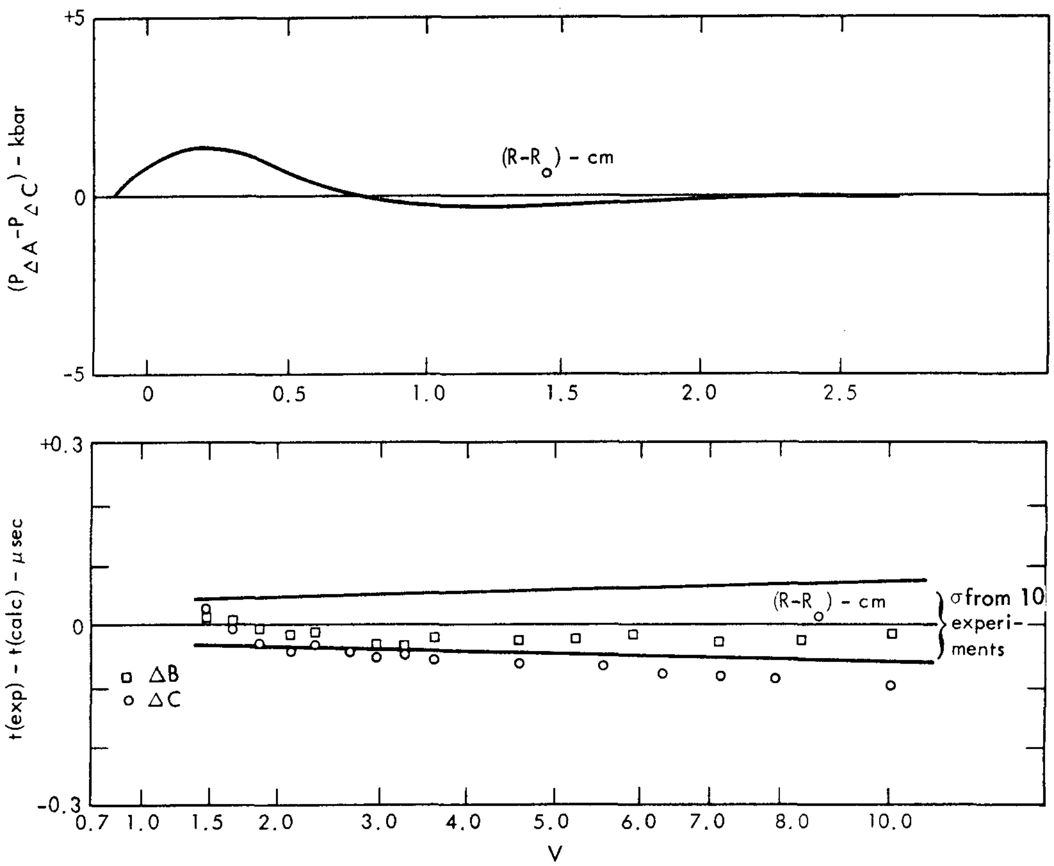


Fig. 8. Comparison of pressure history and cylinder wall motion for LX-04-1 adiabats ΔB and ΔC.

Table VIII. Pressure, energy and Γ for NM adiabats ΔA and ΔB.

NM adiabat ΔA				NM adiabat ΔB			
V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ	V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
6.8670E-01	1.3981E-01	7.2901E-02	2.1886	7.1740E-01	1.2500E-01	6.8662E-02	2.5386
7.0000E-01	1.3402E-01	7.1080E-02	2.2234	7.0000E-01	1.3298E-01	7.0906E-02	2.5023
7.5000E-01	1.1446E-01	6.4882E-02	2.3501	7.5000E-01	1.1151E-01	6.4812E-02	2.6013
8.0000E-01	9.7970E-02	5.9583E-02	2.4700	8.0000E-01	9.4018E-02	5.9689E-02	2.6837
8.5000E-01	8.4059E-02	5.5043E-02	2.5821	8.5000E-01	7.9738E-02	5.5357E-02	2.7489
9.0000E-01	7.2309E-02	5.1142E-02	2.6857	9.0000E-01	6.8046E-02	5.1672E-02	2.7969
9.5000E-01	6.2375E-02	4.7781E-02	2.7801	9.5000E-01	5.8444E-02	4.8518E-02	2.8277
1.0000E 00	5.3967E-02	4.4879E-02	2.8645	1.0000E 00	5.0531E-02	4.5800E-02	2.8421
1.1000E 00	4.0798E-02	4.0176E-02	3.0007	1.1000E 00	3.8551E-02	4.1383E-02	2.9272
1.2000E 00	3.1291E-02	3.6598E-02	3.0903	1.2000E 00	3.0214E-02	3.7969E-02	2.7661
1.3000E 00	2.4387E-02	3.3832E-02	3.1316	1.3000E 00	2.4296E-02	3.5260E-02	2.6764
1.4000E 00	1.9334E-02	3.1659E-02	3.1260	1.4000E 00	1.9998E-02	3.3056E-02	2.5756
1.5000E 00	1.5605E-02	2.9921E-02	3.0785	1.5000E 00	1.6799E-02	3.1224E-02	2.4780
1.6000E 00	1.2825E-02	2.8506E-02	2.9968	1.6000E 00	1.4356E-02	2.9671E-02	2.3932
1.8000E 00	9.1240E-03	2.6344E-02	2.7704	1.8000E 00	1.0910E-02	2.7170E-02	2.2786
2.0000E 00	6.9024E-03	2.4759E-02	2.5244	2.0000E 00	8.6057E-03	2.5232E-02	2.2346
2.2500E 00	5.2079E-03	2.3263E-02	2.2674	2.2500E 00	6.6133E-03	2.3345E-02	2.2460
2.5000E 00	4.1409E-03	2.2104E-02	2.0954	2.5000E 00	5.2086E-03	2.1877E-02	2.2896
2.7500E 00	3.4088E-03	2.1165E-02	1.9952	2.7500E 00	4.1783E-03	2.0710E-02	2.3345
3.0000E 00	2.8730E-03	2.0383E-02	1.9405	3.0000E 00	3.4055E-03	1.9766E-02	2.3635
4.0000E 00	1.6685E-03	1.8201E-02	1.8373	4.0000E 00	1.7390E-03	1.7333E-02	2.2428
5.0000E 00	1.1233E-03	1.6836E-02	1.6966	5.0000E 00	1.0918E-03	1.5963E-02	1.9071
6.0000E 00	8.3556E-04	1.5871E-02	1.5489	6.0000E 00	7.9259E-04	1.5038E-02	1.6162
7.0000E 00	6.6389E-04	1.5127E-02	1.4398	7.0000E 00	6.2669E-04	1.4335E-02	1.4449
8.0000E 00	5.5040E-04	1.4524E-02	1.3729	8.0000E 00	5.1992E-04	1.3765E-02	1.3615
1.0000E 01	4.0814E-04	1.3578E-02	1.3173	1.0000E 01	3.8647E-04	1.2871E-02	1.3097
1.5000E 01	2.4046E-04	1.2023E-02	1.3003	1.5000E 01	2.2793E-04	1.1397E-02	1.3001

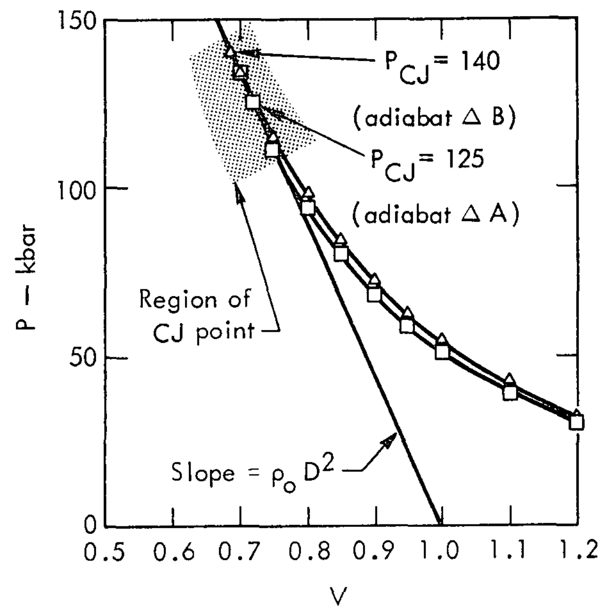


Fig. 9. Comparison of adiabats (Δ) for NM for different values of Chapman-Jouguet pressure.

calculations and the experimental accuracy is to see how well one can calculate experiments with varying ratios of metal to explosive. The data in Table IX compares a calculation using the PBX 9404 adiabat generated from standard cylinder test results with an experiment using a copper cylinder 1/4 as heavy as the standard. (To simplify fabrication of the copper shells 2 in. diam explosive charges were used.) Calculated thin wall arrival times are ~1 to 2% too slow. This discrepancy can be removed by assigning a yield strength of ~10 kbars for copper instead of the normally-used 3 kbars. (The effect of copper yield strength on cylinder motion is illustrated in Fig. 10.) We feel a value of ~10 kbars for the yield strength of copper under high strain rates is not unreasonable. Additional support for an explanation based on yield strength lies in the observation that results from mass-scaled steel and copper cylinder tests show, as one would expect, that steels possess higher yield strength than copper (Fig. 11).

Since the effect is relatively small, we have not attempted to adjust further the adiabat coefficients using a higher yield strength of copper. Moreover, since most hydrodynamic calculations involve containment by materials with moderate yield strengths, any inaccuracy would tend to cancel out.

Table IX. PBX 9404 cylinder test data and calculation for 1/4 standard copper thickness geometry.

5.08 cm diam PBX 9404
0.125 cm copper wall

$R - R_0$ (cm)	$\frac{R}{2}$ (cm)	$\frac{t_{exp}}{2}$ (μsec)	$t_{(calc)}$[a] (μsec)	Δt (μsec)
0.00	1.340	0.0		
0.050	1.390	0.397	0.399	-0.002
0.100	1.440	0.683	0.651	0.032
0.150	1.490	0.920	0.903	0.017
0.200	1.540	1.150	1.141	0.009
0.250	1.590	1.362	1.560	0.002
0.300	1.640	1.570	1.569	0.001
0.350	1.690	1.765	1.771	-0.006
0.400	1.740	1.955	1.968	-0.013
0.450	1.790	2.140	2.161	-0.021
0.500	1.840	2.330	2.350	-0.020
0.600	1.940	2.697	2.721	-0.024
0.700	2.040	3.053	3.084	-0.031
0.800	2.140	3.404	3.441	-0.037
0.900	2.240	3.750	3.793	-0.043
1.000	2.340	4.091	4.141	-0.050
1.100	2.440	4.428	4.486	-0.058
1.200	2.540	4.761	4.830	-0.069
1.300	2.640	5.092	5.172	-0.080
1.400	2.740	5.421	5.510	-0.089
1.500	2.840	5.749	5.846	-0.097
1.600	2.940	6.075	6.181	-0.106
1.700	3.040	6.399	6.514	-0.115
1.800	3.140	6.723	6.845	-0.122
1.900	3.240	7.045	7.178	-0.133
2.000	3.340	7.365	7.513	-0.148

[a] JWL adiabat ΔA was used for the calculation.

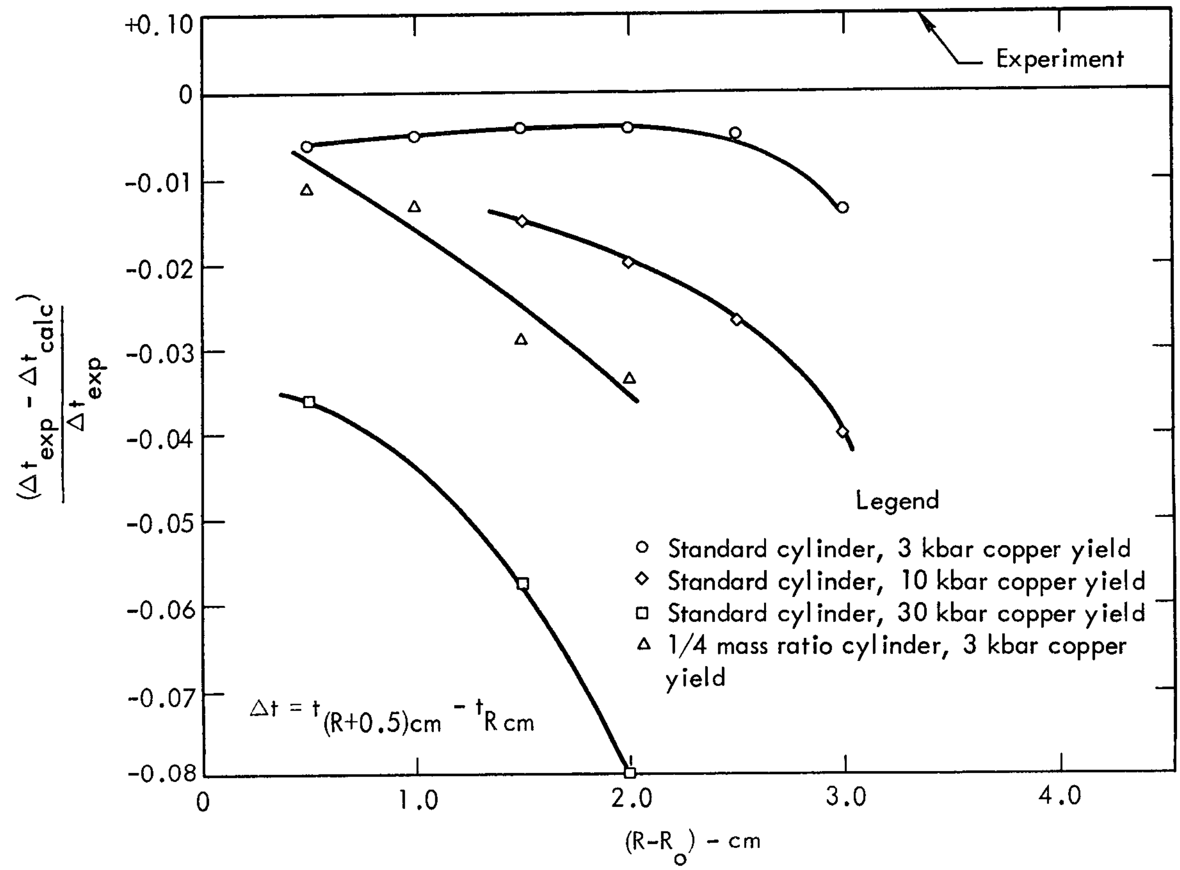


Fig. 10. Effect of wall strength on calculated cylinder test results.

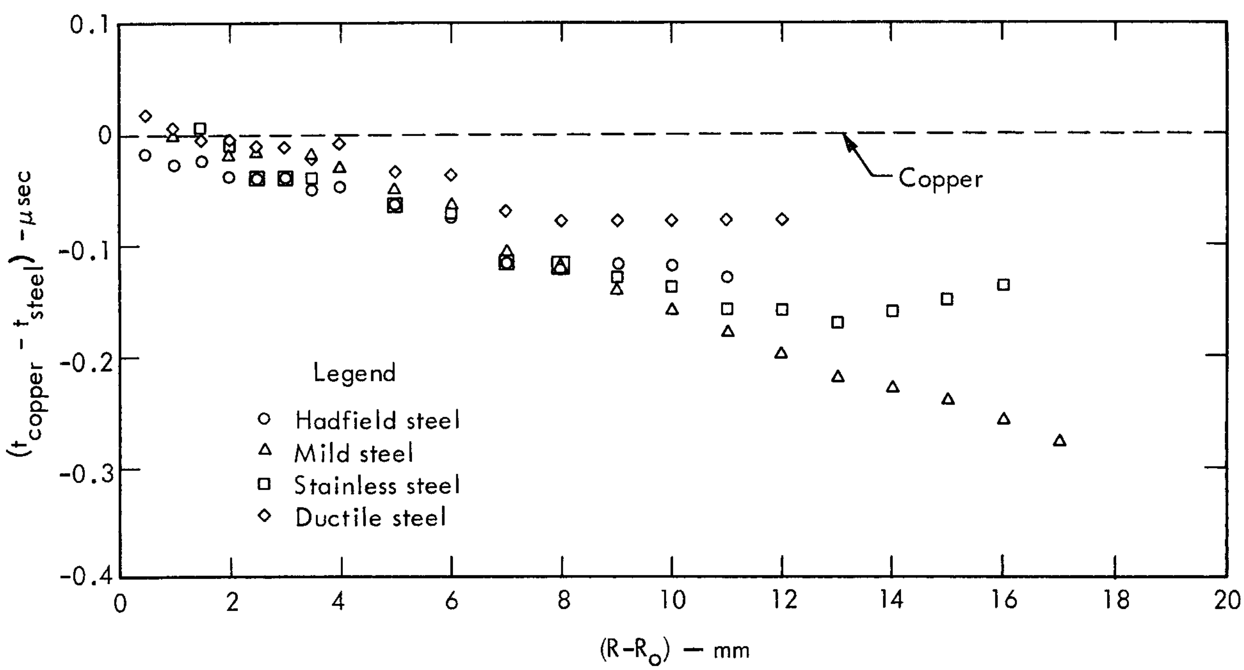


Fig. 11. Arrival time comparison for experiments using copper and various steel cylinders, LX-04-1, 1 in.

Anticipated future improvements in data for metals and in the code treatment of the yield characteristics of metals will place such refinements on much firmer ground.

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Appendix A

Comparisons Between Calculated and Experimental Results for Cylinder Tests

R - R_0 (cm)	R (cm)	$t_{(exp)}$ (μsec)	$t_{(calc)}$ (μsec)	$t_{(exp)} - t_{(calc)}$ (μsec)	$t_{(exp)}$ (μsec)	$t_{(calc)}$ (μsec)	$t_{(exp)} - t_{(calc)}$ (μsec)	$t_{(exp)}$ (μsec)	$t_{(calc)}$ (μsec)	$t_{(exp)} - t_{(calc)}$ (μsec)
		HMX			NM adiabat ΔA			NM adiabat ΔB		
0	1.530	0	0	0	0	0	0	0	0	0
0.050	1.580	0.520	0.475	0.045	1.200	1.182	0.018	1.200	1.290	-0.090
0.100	1.630	1.000	0.941	0.059	2.020	1.981	0.039	2.020	2.033	-0.033
0.150	1.690	1.390	1.395	-0.005	2.720	2.715	0.005	2.720	2.740	-0.020
0.200	1.730	1.790	1.791	-0.001	3.350	3.330	0.020	3.350	3.350	0.000
0.250	1.780	2.160	2.147	0.013	3.950	3.932	0.018	3.950	3.917	0.033
0.300	1.830	2.490	2.487	0.003	4.500	4.505	-0.005	4.500	4.477	0.023
0.400	1.930	3.130	3.141	-0.011	5.560	5.566	-0.006	5.560	5.521	0.039
0.500	2.030	3.750	3.780	-0.030	6.550	6.579	-0.029	6.550	6.525	0.025
0.600	2.130	4.350	4.388	-0.038	7.520	7.547	-0.027	7.520	7.504	0.016
0.700	2.230	4.940	4.974	-0.034	8.460	8.493	-0.033	8.460	8.452	0.008
0.800	2.330	5.520	5.556	-0.036	9.370	9.411	-0.041	9.370	9.374	-0.004
0.900	2.430	6.090	6.132	-0.042	10.260	10.307	-0.047	10.260	10.277	-0.017
1.000	2.530	6.660	6.702	-0.042	11.140	11.187	-0.047	11.140	11.166	-0.026
1.100	2.630	7.220	7.264	-0.044	12.000	12.055	-0.055	12.000	12.045	-0.045
1.200	2.730	7.770	7.821	-0.051	12.860	12.913	-0.053	12.860	12.914	-0.054
1.300	2.830	8.320	8.372	-0.052	13.720	13.763	-0.043	13.720	13.777	-0.057
1.400	2.930	8.870	8.919	-0.049	14.570	14.607	-0.037	14.570	14.632	-0.062
1.500	3.030	9.410	9.462	-0.052	15.420	15.444	-0.024	15.420	15.481	-0.061
1.600	3.130	9.950	10.002	-0.052	16.260	16.276	-0.016	16.260	16.325	-0.065
1.700	3.230	10.490	10.540	-0.050	17.090	17.102	-0.012	17.090	17.163	-0.073
1.800	3.330	11.030	11.076	-0.046	17.910	17.925	-0.015			
1.900	3.430	11.570	11.612	-0.042	18.730	18.744	-0.014			
2.000	3.530	12.100	12.147	-0.047	19.540	19.561	-0.021			
2.200	3.730	13.170	13.213	-0.043	21.170	21.186	-0.016			
2.400	3.930	14.230	14.276	-0.046	22.780	22.802	-0.022			
2.500	4.030	14.750	14.886	-0.056	23.580	23.607	-0.027			
		PETN			TNT			Comp B, Grade A JWL		
0	1.530	0	0	0	0	0	0	0	0	0
0.050	1.580	0.640	0.545	0.095	0.920	0.824	0.096	0.700	0.629	0.071
0.100	1.630	1.160	1.110	0.050	1.550	1.551	-0.001	1.270	1.233	0.037
0.150	1.680	1.570	1.589	-0.019	2.130	2.105	0.025	1.710	1.735	-0.025
0.200	1.730	1.990	1.987	0.003	2.640	2.653	-0.013	2.110	2.171	-0.061
0.250	1.780	2.360	2.382	-0.022	3.150	3.161	-0.011	2.590	2.601	-0.011
0.300	1.830	2.740	2.758	-0.018	3.620	3.630	-0.010	2.990	3.011	-0.021
0.400	1.930	3.430	3.447	-0.017	4.530	4.554	-0.024	3.780	3.769	0.011
0.500	2.030	4.100	4.112	-0.012	5.410	5.424	-0.014	4.520	4.508	0.012
0.600	2.130	4.730	4.760	-0.030	6.250	6.270	-0.020	5.220	5.226	-0.006
0.700	2.230	5.350	5.380	-0.030	7.060	7.088	-0.028	5.910	5.916	-0.006
0.800	2.330	5.970	5.988	-0.018	7.850	7.884	-0.034	6.590	6.597	-0.007
0.900	2.430	6.570	6.590	-0.020	8.630	8.668	-0.038	7.260	7.261	-0.001
1.000	2.530	7.180	7.186	-0.006	9.410	9.441	-0.031	7.920	7.917	0.003
1.100	2.630	7.770	7.776	-0.006	10.180	10.204	-0.024	8.570	8.566	0.004
1.200	2.730	8.360	8.359	0.001	10.940	10.958	-0.018	9.220	9.210	0.010
1.300	2.830	8.950	8.937	0.013	11.690	11.706	-0.016	9.860	9.849	0.011
1.400	2.930	9.530	9.510	0.020	12.440	12.448	-0.008	10.500	10.483	0.017
1.500	3.030	10.100	10.081	0.019	13.170	13.186	-0.016	11.130	11.114	0.016
1.600	3.130	10.670	10.649	0.021	13.900	13.920	-0.020	11.750	11.743	0.007
1.700	3.230	11.240	11.214	0.026	14.620	14.650	-0.030	12.370	12.368	0.002
1.800	3.330	11.810	11.777	0.033	15.340	15.376	-0.036	13.000	12.992	0.008
1.900	3.430	12.370	12.339	0.031	16.050	16.100	-0.050	13.600	13.611	-0.011
2.000	3.530	12.930	12.898	0.032	16.750	16.819	-0.069	14.220	14.223	-0.003
2.200	3.730	14.050	14.013	0.037	18.180	18.252	-0.072	15.430	15.441	-0.011
2.400	3.930	15.160	15.123	0.037	19.590	19.677	-0.087	16.640	16.651	-0.011
2.500	4.030	15.710	15.677	0.033	20.250	20.387	-0.137	17.840	17.854	-0.014
2.600	4.130							19.040	19.053	-0.013
2.800	4.330							20.230	20.256	-0.026
3.000	4.530							21.420	-29.319	50.739
3.200	4.730							22.600	-29.319	51.919

$R - R_0$ (cm)	R (cm)	$t_{(exp)}$ (μsec)	$t_{(calc)}$ (μsec)	$t_{(exp)} - t_{(calc)}$ (μsec)	$t_{(exp)}$ (μsec)	$t_{(calc)}$ (μsec)	$t_{(exp)} - t_{(calc)}$ (μsec)	$t_{(exp)}$ (μsec)	$t_{(calc)}$ (μsec)	$t_{(exp)} - t_{(calc)}$ (μsec)
		Comp B, Grade A BKW adiabat			Comp B, Grade A LJD adiabat			Comp B, Grade A Γ-law adiabat		
0		0	0	0		0	0		0	0
0.200	1.730	2.11	2.10	0.01		2.25	-0.14		2.05	0.06
0.400	1.930	3.78	3.62	0.16		3.84	-0.06		3.50	0.28
0.600	2.130	5.22	4.93	0.29		5.23	-0.01		4.79	0.43
0.800	2.330	6.59	6.20	0.39		6.56	0.03		6.03	0.56
1.000	2.530	7.92	7.43	0.49		7.83	0.09		7.21	0.71
1.200	2.730	9.22	8.62	0.60		9.09	0.13		8.38	0.84
1.400	2.930	10.50	9.78	0.72		10.30	0.20		9.53	0.97
1.600	3.130	11.75	10.93	0.82		11.50	0.23		10.67	1.08
1.800	3.330	13.00	12.07	0.93		12.68	0.32		11.78	1.22
2.000	3.530	14.22	13.19	0.97					12.91	1.31
2.200	3.730	15.43							14.02	1.41
2.400	3.930	15.74							15.13	1.51
2.500	4.030									
		Cyclotol			PBX 9011			LX 07-0		
0	1.530	0	0	0	0	0	0	0	0	0
0.050	1.580	0.650	0.550	0.100	0.640	0.570	0.070	0.570	0.491	0.079
0.100	1.630	1.190	1.120	0.070	1.180	1.119	0.061	1.090	1.007	0.083
0.150	1.680	1.630	1.620	0.010	1.620	1.620	-0.000	1.480	1.493	-0.013
0.200	1.730	2.040	2.035	0.005	2.030	2.032	-0.002	1.870	1.895	-0.025
0.250	1.780	2.430	2.443	-0.013	2.420	2.434	-0.014	2.270	2.279	-0.009
0.300	1.830	2.820	2.833	-0.013	2.800	2.816	-0.016	2.640	2.644	-0.004
0.400	1.930	3.530	3.563	-0.033	3.530	3.554	-0.024	3.340	3.353	-0.013
0.500	2.030	4.230	4.258	-0.028	4.230	4.245	-0.015	4.000	4.022	-0.022
0.600	2.130	4.900	4.944	-0.044	4.900	4.929	-0.029	4.640	4.676	-0.036
0.700	2.230	5.550	5.603	-0.053	5.560	5.590	-0.030	5.270	5.311	-0.041
0.800	2.330	6.200	6.243	-0.043	6.210	6.231	-0.021	5.890	5.927	-0.037
0.900	2.430	6.840	6.877	-0.037	6.850	6.865	-0.015	6.500	6.536	-0.036
1.000	2.530	7.470	7.504	-0.034	7.480	7.493	-0.013	7.110	7.139	-0.029
1.100	2.630	8.090	8.123	-0.033	8.110	8.114	-0.004	7.700	7.735	-0.039
1.200	2.730	8.710	8.736	-0.026	8.730	8.728	0.002	8.300	8.326	-0.026
1.300	2.830	9.320	9.343	-0.023	9.340	9.337	0.003	8.890	8.910	-0.020
1.400	2.930	9.920	9.944	-0.024	9.950	9.942	0.008	9.470	9.491	-0.021
1.500	3.030	10.530	10.543	-0.013	10.560	10.544	0.016	10.050	10.067	-0.017
1.600	3.130	11.130	11.138	-0.008	11.160	11.143	0.017	10.630	10.640	-0.010
1.700	3.230	11.720	11.731	-0.011	11.760	11.740	0.020	11.200	11.211	-0.011
1.800	3.330	12.310	12.322	-0.012	12.350	12.335	0.015	11.770	11.779	-0.009
1.900	3.430	12.900	12.910	-0.010	12.950	12.928	0.022	12.330	12.346	-0.018
2.000	3.530	13.490	13.496	-0.006	13.540	13.521	0.019	12.900	12.913	-0.013
2.200	3.730	14.660	14.662	-0.002	14.710	14.704	0.006	14.020	14.045	-0.025
2.400	3.930	15.820	15.823	-0.003	15.870	15.884	-0.014	15.140	15.172	-0.032
2.500	4.030	16.390	16.402	-0.012	16.450	16.473	-0.023	15.690	15.735	-0.045

$R - R_0$ (cm)	R (cm)	$t_{(exp)}$ (μsec)	$t_{(calc)}$ (μsec)	$t_{(exp)} - t_{(calc)}$ (μsec)	$t_{(exp)}$ (μsec)	$t_{(calc)}$ (μsec)	$t_{(exp)} - t_{(calc)}$ (μsec)	$t_{(exp)}$ (μsec)	$t_{(calc)}$ (μsec)	$t_{(exp)} - t_{(calc)}$ (μsec)
		PBX 9404 adiabat ΔA			PBX 9404 adiabat ΔB			PBX 9404 Wilkins adiabat		
0	1.530	0	0	0	0	0	0	0	0	0
0.050	1.580	0.570	0.546	0.024	0.570	0.493	0.077	0.570	0.466	0.104
0.100	1.630	1.100	1.036	0.064	1.100	1.005	0.095	1.100	0.962	0.138
0.150	1.680	1.480	1.501	-0.021	1.480	1.485	-0.005	1.480	1.441	0.039
0.200	1.730	1.870	1.890	-0.020	1.870	1.879	-0.009	1.870	1.857	0.013
0.250	1.780	2.240	2.256	-0.016	2.240	2.255	-0.015	2.240	2.238	0.002
0.300	1.830	2.600	2.606	-0.006	2.600	2.613	-0.013	2.600	2.598	0.002
0.400	1.930	3.270	3.284	-0.014	3.270	3.306	-0.036	3.270	3.302	-0.032
0.500	2.030	3.930	3.935	-0.005	3.930	3.954	-0.024	3.930	3.994	-0.064
0.600	2.130	4.560	4.566	-0.006	4.560	4.593	-0.033	4.560	4.652	-0.092
0.700	2.230	5.180	5.181	-0.001	5.180	5.217	-0.037	5.180	5.289	-0.109
0.800	2.330	5.790	5.791	-0.001	5.790	5.821	-0.031	5.790	5.919	-0.129
0.900	2.430	6.390	6.395	-0.005	6.390	6.420	-0.030	6.390	6.540	-0.150
1.000	2.530	6.980	6.990	-0.010	6.980	7.013	-0.033	6.980	7.139	-0.159
1.100	2.630	7.570	7.579	-0.009	7.570	7.600	-0.030	7.570	7.731	-0.161
1.200	2.730	8.150	8.162	-0.012	8.150	8.182	-0.032	8.150	8.318	-0.168
1.300	2.830	8.730	8.739	-0.009	8.730	8.760	-0.030	8.730	8.898	-0.168
1.400	2.930	9.300	9.313	-0.013	9.300	9.334	-0.034	9.300	9.472	-0.172
1.500	3.030	9.870	9.883	-0.013	9.870	9.905	-0.035	9.870	10.040	-0.170
1.600	3.130	10.440	10.451	-0.011	10.440	10.474	-0.034	10.440	10.602	-0.162
1.700	3.230	11.000	11.017	-0.017	11.000	11.040	-0.040	11.000	11.158	-0.158
1.800	3.330	11.560	11.579	-0.019	11.560	11.605	-0.045	11.560	11.710	-0.150
1.900	3.430	12.130	12.143	-0.013	12.130	12.168	-0.038	12.130	12.258	-0.128
2.000	3.530	12.680	12.709	-0.029	12.680	12.731	-0.051	12.680	12.801	-0.121
2.100	3.630				13.240	13.292	-0.052	13.240	13.340	-0.100
2.200	3.730	13.790	13.838	-0.048	13.790	13.851	-0.061	13.790	13.877	-0.097
2.300	3.830				14.350	14.410	-0.060	14.350	14.410	-0.060
2.400	3.930	14.350	14.401	-0.051	14.900	14.968	-0.068	14.900	14.941	-0.041
2.500	4.030	14.900	14.963	-0.063	15.450	15.525	-0.075	15.450	15.470	-0.020
		LX 04-1 adiabat ΔA			LX 04-1 adiabat ΔB			LX 04-1 Wilkins adiabat		
0	1.530	0	0	0	0	0	0	0	0	0
0.050	1.580	0.600	0.513	0.087	0.600	0.552	0.048	0.600	0.494	0.106
0.100	1.630	1.130	1.063	0.067	1.130	1.079	0.051	1.130	1.025	0.105
0.150	1.680	1.550	1.561	-0.011	1.550	1.569	-0.019	1.550	1.527	0.023
0.200	1.730	1.980	1.969	0.011	1.980	1.974	0.006	1.980	1.948	0.032
0.250	1.780	2.360	2.367	-0.007	2.360	2.363	-0.003	2.360	2.348	0.012
0.300	1.830	2.740	2.746	-0.006	2.740	2.735	0.005	2.740	2.726	0.014
0.400	1.930	3.450	3.469	-0.019	3.450	3.458	-0.008	3.450	3.469	-0.019
0.500	2.030	4.120	4.149	-0.029	4.120	4.138	-0.018	4.120	4.128	-0.068
0.600	2.130	4.790	4.821	-0.031	4.790	4.806	-0.016	4.790	4.870	-0.030
0.700	2.230	5.410	5.472	-0.062	5.410	5.457	-0.047	5.410	5.536	-0.126
0.800	2.330	6.050	6.106	-0.056	6.050	6.090	-0.040	6.050	6.196	-0.146
0.900	2.430	6.680	6.733	-0.053	6.680	6.716	-0.036	6.680	6.847	-0.157
1.000	2.530	7.300	7.351	-0.051	7.300	7.335	-0.035	7.300	7.487	-0.187
1.100	2.630	7.910	7.962	-0.052	7.910	7.947	-0.037	7.910	8.112	-0.202
1.200	2.730	8.520	8.567	-0.047	8.520	8.552	-0.032	8.520	8.729	-0.209
1.300	2.830	9.120	9.166	-0.046	9.120	9.151	-0.031	9.120	9.339	-0.219
1.400	2.930	9.720	9.761	-0.041	9.720	9.746	-0.026	9.720	9.942	-0.222
1.500	3.030	10.320	10.352	-0.032	10.320	10.337	-0.017	10.320	10.539	-0.219
1.600	3.130	10.910	10.941	-0.031	10.910	10.925	-0.015	10.910	11.130	-0.220
1.700	3.230	11.500	11.526	-0.026	11.500	11.511	-0.011	11.500	11.717	-0.217
1.800	3.330	12.090	12.110	-0.020	12.090	12.093	-0.003	12.090	12.300	-0.210
1.900	3.430	12.670	12.681	-0.021	12.670	12.676	-0.006	12.670	12.879	-0.209
2.000	3.530	13.250	13.271	-0.021	13.250	13.259	-0.009	13.250	13.453	-0.203
2.100	3.630				14.410	14.419	-0.009			
2.200	3.730	14.410	14.425	-0.015	15.560	15.576	-0.016	14.410	14.594	-0.184
2.300	3.830				16.140	16.154	-0.014			
2.400	3.930	15.560	15.573	-0.013				15.560	15.724	-0.154
2.500	4.030	16.140	16.145	-0.005				16.140	16.285	-0.145

Appendix B

Comparisons Between Calculated and Experimental Results for Sphere Tests

			Comp B, Grade A							
			JWL adiabat		BKW adiabat		LJD adiabat		Γ-law adiabat	
$R - R_0$ (cm)	R (cm)	$t_{(exp)}$ (μsec)	$t_{(calc)}$ (μsec)	$t_{(exp)} - t_{(calc)}$ (μsec)	$t_{(calc)}$ (μsec)	$t_{(exp)} - t_{(calc)}$ (μsec)	$t_{(calc)}$ (μsec)	$t_{(exp)} - t_{(calc)}$ (μsec)	$t_{(calc)}$ (μsec)	$t_{(exp)} - t_{(calc)}$ (μsec)
0	15.875	0	0	0	0	0	0	0	0	0
0.5	16.375	1.98	2.03	-0.05	2.04	-0.06	2.20	-0.22	2.00	-0.02
1.0	16.875	3.87	3.75	0.12	3.69	0.18	4.00	-0.13	3.59	0.28
1.5	17.375	5.48	5.37	0.11	5.25	0.23	5.64	-0.16	5.09	0.39
2.0	17.875	7.08	6.95	0.13	6.76	0.32	7.22	-0.14	6.57	0.49
2.5	18.375	8.59	8.50	0.09	8.24	0.35	8.76	-0.17	8.00	0.59
3.0	18.875	10.10	10.01	0.09	9.68	0.42	10.27	-0.17	9.39	0.71
3.5	19.375	11.57	–	–	11.09	0.48	11.75	-0.18	10.74	0.83

			PBX 9404					
			JWL adiabat ΔA		JWL adiabat ΔB		Wilkins adiabat	
$R - R_0$ (cm)	R (cm)	$t_{(exp)}$ (μsec)	$t_{(calc)}$ (μsec)	$t_{(exp)} - t_{(calc)}$ (μsec)	$t_{(calc)}$ (μsec)	$t_{(exp)} - t_{(calc)}$ (μsec)	$t_{(calc)}$ (μsec)	$t_{(exp)} - t_{(calc)}$ (μsec)
0	15.875	0	0	0	0	0	0	0
0.5	16.375	1.48	1.56	-0.25	1.65	-0.17	1.51	-0.20
1.0	16.875	3.12	3.28	-0.16	3.17	-0.05	3.23	-0.12
1.5	17.375	4.63	4.79	-0.14	4.65	-0.02	4.77	-0.14
2.0	17.875	6.01	6.24	-0.20	6.06	-0.05	6.22	-0.21
2.5	18.375	7.35	7.63	-0.23	7.41	-0.06	7.60	-0.25
3.0	18.875	8.69	8.99	-0.23	8.74	-0.05	8.96	-0.27
4.0	19.875	11.39	11.68	-0.20	11.41	-0.02	11.64	-0.25
5.0	20.875	14.00	14.34	-0.23	14.03	-0.03	14.26	-0.26
6.0	21.875	16.55	16.97	-0.27	16.63	-0.08	16.82	-0.27
7.0	22.875	19.07	19.60	-0.36	19.20	-0.13	19.34	-0.27

			LX 04-1					
			JWL adiabat ΔA		JWL adiabat ΔB		Wilkins adiabat	
$R - R_0$ (cm)	R (cm)	$t_{(exp)}$ (μsec)	$t_{(calc)}$ (μsec)	$t_{(exp)} - t_{(calc)}$ (μsec)	$t_{(calc)}$ (μsec)	$t_{(exp)} - t_{(calc)}$ (μsec)	$t_{(calc)}$ (μsec)	$t_{(exp)} - t_{(calc)}$ (μsec)
0	15.875	0	0	0	0	0	0	0
0.5	16.375	1.55	1.82	-0.27	1.78	-0.23	1.67	-0.12
1.0	16.875	3.22	3.50	-0.28	3.38	-0.16	3.42	-0.20
1.5	17.375	4.80	5.00	-0.20			4.95	-0.15
2.0	17.875	6.38	6.53	-0.15	6.41	-0.03	6.46	-0.08
2.5	18.375	7.85					7.95	-0.10
3.0	18.875	9.27	9.54	-0.27	9.25	0.02	9.46	-0.19
4.0	19.875	12.04	12.26	-0.22	12.01	0.03	12.18	-0.14
5.0	20.875	14.80	15.04	-0.24	14.74	0.06	14.94	-0.14
6.0	21.875	17.51	15.80	-0.29	17.45	0.06	17.64	-0.13
7.0	22.875	20.24	20.51	-0.27	20.15	0.09	20.30	-0.06

Appendix C

Summary of Pressure, Volume, and Energy Dependence for Adiabatic Expansion of Detonation Products

We have found it useful to list the pressures, relative volumes and energies associated with the adiabatic expansions in order to make comparisons with other descriptions and to assess the effect of various portions of the adiabat on expansion behavior.

V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
HMX			
7.33060E-01	4.20000E-01	1.61057E-01	2.74616
7.00000E-01	4.75693E-01	1.75843E-01	2.65037
7.50000E-01	3.94247E-01	1.54163E-01	2.79332
8.00000E-01	3.27816E-01	1.36168E-01	2.92427
8.50000E-01	2.73574E-01	1.21179E-01	3.04180
9.00000E-01	2.29230E-01	1.08646E-01	3.14453
9.50000E-01	1.92927E-01	9.81220E-02	3.23122
1.00000E 00	1.63160E-01	8.92443E-02	3.30080
1.10000E 00	1.18576E-01	7.53017E-02	3.38597
1.20000E 00	8.82238E-02	6.50574E-02	3.39877
1.30000E 00	6.73248E-02	5.73436E-02	3.34555
1.40000E 00	5.27301E-02	5.13835E-02	3.24015
1.50000E 00	4.23613E-02	4.66575E-02	3.10149
1.60000E 00	3.48445E-02	4.28166E-02	2.94975
1.80000E 00	2.50312E-02	3.69184E-02	2.67303
2.00000E 00	1.90844E-02	3.25512E-02	2.49111
2.25000E 00	1.43193E-02	2.84192E-02	2.40926
2.50000E 00	1.10981E-02	2.52652E-02	2.44319
2.75000E 00	8.75582E-03	2.27978E-02	2.53947
3.00000E 00	6.98411E-03	2.08401E-02	2.66079
4.00000E 00	3.05358E-03	1.61355E-02	3.06375
5.00000E 00	1.52662E-03	1.39601E-02	3.07658
6.00000E 00	8.95807E-04	1.27928E-02	2.71477
7.00000E 00	6.11649E-04	1.20564E-02	2.22444
8.00000E 00	4.67280E-04	1.15241E-02	1.82325
1.00000E 01	3.27253E-04	1.07487E-02	1.43130
1.50000E 01	1.90299E-04	9.51331E-03	1.30240

V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
NM adiabat ΔA			
6.8627E-01	1.4000E-01	7.2961E-02	2.1875
7.0000E-01	1.3402E-01	7.1080E-02	2.2234
7.5000E-01	1.1446E-01	6.4882E-02	2.3501
8.0000E-01	9.7970E-02	5.9583E-02	2.4699
8.5000E-01	8.4059E-02	5.5043E-02	2.5821
9.0000E-01	7.2309E-02	5.1142E-02	2.6857
9.5000E-01	6.2375E-02	4.7781E-02	2.7801
1.0000E 00	5.3967E-02	4.4879E-02	2.8645
1.1000E 00	4.0798E-02	4.0176E-02	3.0007
1.2000E 00	3.1291E-02	3.6598E-02	3.0903
1.3000E 00	2.4387E-02	3.3832E-02	3.1316
1.4000E 00	1.9334E-02	3.1659E-02	3.1260
1.5000E 00	1.5605E-02	2.9921E-02	3.0785
1.6000E 00	1.2825E-02	2.8506E-02	2.9968
1.8000E 00	9.1241E-03	2.6344E-02	2.7704
2.0000E 00	6.9024E-03	2.4759E-02	2.5243
2.2500E 00	5.2079E-03	2.3263E-02	2.2674
2.5000E 00	4.1409E-03	2.2104E-02	2.0954
2.7500E 00	3.4088E-03	2.1165E-02	1.9952
3.0000E 00	2.8730E-03	2.0383E-02	1.9406
4.0000E 00	1.6685E-03	1.8201E-02	1.8773
5.0000E 00	1.1233E-03	1.6836E-02	1.6966
6.0000E 00	8.3556E-04	1.5871E-02	1.5489
7.0000E 00	6.6389E-04	1.5127E-02	1.4398
8.0000E 00	5.5840E-04	1.4524E-02	1.3729
1.0000E 01	4.0814E-04	1.3578E-02	1.3173
1.5000E 01	2.4046E-04	1.2023E-02	1.3003

V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
NM adiabat ΔB			
7.1740E-01	1.2500E-01	6.8662E-02	2.5386
7.0000E-01	1.3298E-01	7.0906E-02	2.5023
7.5000E-01	1.1151E-01	6.4812E-02	2.6013
8.0000E-01	9.4018E-02	5.9689E-02	2.6837
8.5000E-01	7.9738E-02	5.5357E-02	2.7489
9.0000E-01	6.8046E-02	5.1672E-02	2.7969
9.5000E-01	5.8444E-02	4.8518E-02	2.8277
1.0000E 00	5.0531E-02	4.5800E-02	2.8421
1.1000E 00	3.8551E-02	4.1383E-02	2.8272
1.2000E 00	3.0214E-02	3.7969E-02	2.7661
1.3000E 00	2.4296E-02	3.5260E-02	2.6764
1.4000E 00	1.9998E-02	3.3056E-02	2.5756
1.5000E 00	1.6799E-02	3.1224E-02	2.4780
1.6000E 00	1.4356E-02	2.9671E-02	2.3932
1.8000E 00	1.0910E-02	2.7170E-02	2.2786
2.0000E 00	8.6057E-03	2.5232E-02	2.2346
2.2500E 00	6.6133E-03	2.3345E-02	2.2460
2.5000E 00	5.2086E-03	2.1877E-02	2.2896
8.7500E 00	4.1783E-03	2.0710E-02	2.3345
3.0000E 00	3.4055E-03	1.9766E-02	2.3635
4.0000E 00	1.7390E-03	1.7333E-02	2.2428
5.0000E 00	1.0918E-03	1.5963E-02	1.9071
6.0000E 00	7.9259E-04	1.5038E-02	1.6162
7.0000E 00	6.2669E-04	1.4335E-02	1.4449
8.0000E 00	5.1992E-04	1.3765E-02	1.3615
1.0000E 01	3.8647E-04	1.2871E-02	1.3097
1.5000E 01	2.2793E-04	1.1397E-02	1.3001

V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
PETN			
7.37700E-01	3.20000E-01	1.42968E-01	2.81243
7.00000E-01	3.70132E-01	1.55950E-01	2.73524
7.50000E-01	3.05401E-01	1.39123E-01	2.83507
8.00000E-01	2.53668E-01	1.25194E-01	2.91380
8.50000E-01	2.12206E-01	1.13585E-01	2.97083
9.00000E-01	1.78868E-01	1.03838E-01	3.00617
9.50000E-01	1.51962E-01	9.55912E-02	3.02061
1.00000E 00	1.30157E-01	8.85570E-02	3.01567
1.10000E 00	9.78670E-02	7.72633E-02	2.95708
1.20000E 00	7.59830E-02	6.86392E-02	2.85380
1.30000E 00	6.07553E-03	6.18463E-02	2.73193
1.40000E 00	4.98385E-02	5.63454E-02	2.61419
1.50000E 00	4.17589E-02	5.17847E-02	2.51623
1.60000E 00	3.55848E-02	4.79305E-02	2.44604
1.80000E 00	2.67890E-02	4.17552E-02	2.39244
2.00000E 00	2.07912E-02	3.70313E-02	2.43214
2.25000E 00	1.55073E-02	3.25336E-02	2.55918
2.50000E 00	1.17444E-02	2.91523E-02	2.72222
2.75000E 00	8.98970E-03	2.65779E-02	2.88792
3.00000E 00	6.94649E-03	2.45984E-02	3.03697
4.00000E 00	2.75936E-03	2.01330E-02	3.28744
5.00000E 00	1.36657E-03	1.81901E-02	2.90777
6.00000E 00	8.51978E-04	1.71196E-02	2.25322
9.60000E 00	3.95537E-04	1.51168E-02	1.29961
1.16000E 01	3.10880E-04	1.44169E-02	1.25706
1.44000E 01	2.37127E-04	1.36582E-02	1.25041
2.20000E 01	1.39603E-04	1.22851E-02	1.25000

V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
TNT			
7.31690E-01	2.10000E-01	9.81726E-02	2.72703
7.00000E-01	2.36467E-01	1.05238E-01	2.63482
7.50000E-01	1.96188E-01	9.44555E-02	2.77832
8.00000E-01	1.63283E-01	8.54964E-02	2.91030
8.50000E-01	1.36375E-01	7.80274E-02	3.02925
9.00000E-01	1.14346E-01	7.17776E-02	3.13370
9.50000E-01	9.62892E-02	6.65266E-02	3.22222
1.00000E 00	8.14662E-02	6.20949E-02	3.29356
1.10000E 00	5.92391E-02	5.51313E-02	3.38092
1.20000E 00	4.40963E-02	5.00123E-02	3.39203
1.30000E 00	3.36777E-02	4.61554E-02	3.33074
1.40000E 00	2.64203E-02	4.31719E-02	3.20908
1.50000E 00	2.12877E-02	4.08009E-02	3.04550
1.60000E 00	1.75913E-02	3.88668E-02	2.86119
1.80000E 00	1.28269E-02	3.58699E-02	2.50443
2.00000E 00	9.99956E-03	3.36092E-02	2.23573
2.25000E 00	7.77975E-03	3.14079E-02	2.04792
2.50000E 00	6.29692E-03	2.96592E-02	1.97992
2.75000E 00	5.21675E-03	2.82264E-02	1.97575
3.00000E 00	4.38918E-03	2.70299E-02	1.99686
4.00000E 00	2.44698E-03	2.37481E-02	2.03980
5.00000E 00	1.56943E-03	2.17931E-02	1.91445
6.00000E 00	1.12582E-03	2.04683E-02	1.72246
7.00000E 00	8.74718E-04	1.94787E-02	1.55569
8.00000E 00	7.16349E-04	1.86885E-02	1.44219
1.00000E 01	5.26293E-04	1.74650E-02	1.33768
1.50000E 01	3.09270E-04	1.54625E-02	1.30088

V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
Comp B, Grade A LJD adiabat			
0.763	2.5920E-01	1.2565E-01	3.2190
0.623	5.0000E-01	1.7630E-01	3.2338
0.729	3.0000E-01	1.3507E-01	3.2395
0.828	2.0000E-01	1.1095E-01	3.1669
0.907	1.5000E-01	9.7160E-02	3.0902
1.037	1.0000E-02	8.1230E-02	2.9637
1.174	7.0000E-02	6.9850E-02	2.8452
1.325	5.0000E-02	6.0940E-02	2.7300
1.608	3.0000E-02	4.9990E-02	2.5528
1.892	2.0000E-02	4.3000E-02	2.4203
2.136	1.5000E-02	3.8790E-02	2.3335
2.553	1.0000E-02	3.3700E-02	2.2212
3.004	7.0000E-03	2.9830E-02	2.2061
3.506	5.0000E-03	2.6780E-02	2.2472
4.367	3.0000E-03	2.3370E-02	2.4599
5.135	2.0000E-03	2.1450E-02	2.5466
5.754	1.5000E-03	2.0370E-02	2.4987
6.826	1.0000E-03	1.9050E-02	2.2179
8.170	7.0000E-04	1.7940E-02	1.7411
10.292	5.0000E-04	1.6690E-02	1.2241
16.814	3.0000E-04	1.4220E-02	9.9740
46.570	1.0000E-04	9.3000E-03	1.1370
137.800	1.0000E-05	2.0000E-03	1.1860

V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
Comp B, Grade A JWL adiabat			
0.730	2.9500E-01	1.2480E-01	2.7064
0.650	3.9873E-01	1.5239E-01	2.4730
0.700	3.3014E-01	1.3422E-01	2.6218
0.800	2.2853E-01	1.0663E-01	2.8854
0.850	1.9120E-01	9.6172E-02	2.9977
0.900	1.6063E-01	8.7401E-02	3.0952
0.950	1.3557E-01	8.0017E-02	3.1769
1.000	1.1499E-01	7.3770E-02	3.2419
1.100	8.4069E-02	6.3916E-02	3.3198
1.200	6.2922E-02	5.6632E-02	3.3291
1.300	4.8285E-02	5.1116E-02	3.2769
1.400	3.8004E-02	4.6831E-02	3.1769
1.500	3.0656E-02	4.3418E-02	3.0466
1.600	2.5298E-02	4.0633E-02	2.9044
1.800	1.8253E-02	3.6342E-02	2.6422
2.000	1.3960E-02	3.3152E-02	2.4603
2.250	1.0524E-02	3.0123E-02	2.3548
2.500	8.2218E-03	2.7797E-02	2.3426
2.750	6.5679E-03	2.5859E-02	2.3751
3.000	5.3317E-03	2.4479E-02	2.4184
4.000	2.6310E-03	2.0716E-02	2.4380
5.000	1.5656E-03	1.8694E-02	2.1739
6.000	1.0849E-03	1.7397E-02	1.8464
7.000	8.3223E-04	1.6450E-02	1.6057
8.000	6.7838E-04	1.5700E-02	1.4673
10.000	4.9576E-04	1.4545E-02	1.3650
15.000	2.8720E-04	1.2670E-02	1.3403

V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
Comp B, Grade A Γ-law adiabat			
0.730	2.9496E-01	1.2625E-01	2.7060
0.650	4.0411E-01	1.5397E-01	2.7060
0.700	3.3068E-01	1.3568E-01	2.7060
0.800	2.3040E-01	1.0904E-01	2.7060
0.850	1.9554E-01	9.7426E-02	2.7060
0.900	1.6752E-01	8.8374E-02	2.7060
0.950	1.4472E-01	8.0587E-02	2.7060
1.000	1.2596E-01	7.3835E-02	2.7060
1.100	9.7327E-02	6.2755E-02	2.7060
1.200	7.6909E-02	5.4098E-02	2.7060
1.300	6.1932E-02	4.7193E-02	2.7060
1.400	5.0678E-02	4.1588E-02	2.7060
1.500	4.2047E-02	3.6970E-02	2.7060
1.600	3.5310E-02	3.3116E-02	2.7060
1.800	2.5673E-02	2.7088E-02	2.7060
2.000	1.9304E-02	2.2631E-02	2.7060
2.250	1.4036E-02	1.8511E-02	2.7060
2.500	1.0554E-02	1.5466E-02	2.7060
2.750	8.1547E-03	1.3145E-02	2.7060
3.000	6.4440E-03	1.1332E-02	2.7060
4.000	2.9585E-03	6.9366E-03	2.7060
5.000	1.6174E-03	4.7405E-03	2.7060
6.000	9.8757E-04	3.4733E-03	2.7060
7.000	6.5074E-04	2.6701E-03	2.7060
8.000	4.5340E-04	2.1261E-03	2.7060
10.000	2.4788E-04	1.4530E-03	2.7060
15.000	8.2745E-05	7.2753E-04	2.7060

V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
Comp B, Grade A BKW adiabat			
7.4623E-01	2.8443E-01	1.3359E-01	2.8600
8.4271E-01	1.9910E-01	1.1060E-01	2.8290
9.5308E-01	1.3937E-01	9.2192E-02	2.7850
1.0806E 00	9.7561E-02	7.7304E-02	2.7360
1.2295E 00	6.8293E-02	6.5185E-02	2.6800
1.4043E 00	4.7805E-02	5.5164E-02	2.6200
1.6114E 00	3.3463E-02	4.6951E-02	2.5500
1.8588E 00	2.3424E-02	3.9944E-02	2.4760
2.1561E 00	1.6397E-02	3.4119E-02	2.3960
2.5158E 00	1.1478E-02	2.9184E-02	2.3100
2.9542E 00	8.0345E-03	2.4975E-02	2.2200
3.4921E 00	5.6242E-03	2.1362E-02	2.1300
4.1566E 00	3.9369E-03	1.8237E-02	2.0350
4.9838E 00	2.7558E-03	1.5515E-02	1.9380
6.0218E 00	1.9291E-03	1.3125E-02	1.8400
7.3354E 00	1.3504E-03	1.1009E-02	1.7500
9.0114E 00	9.4526E-04	9.1194E-03	1.6600
1.1167E 01	6.6168E-04	7.4186E-03	1.5900
1.3961E 01	4.6318E-04	5.8763E-03	1.5270
1.7606E 01	3.2422E-04	4.4685E-03	1.4850
2.2382E 01	2.2696E-04	3.1771E-03	1.4700
2.8666E 01	1.5887E-04	1.9880E-03	1.4800
3.6949E 01	1.1121E-04	8.9080E-04	1.5500

V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
Cyclotol			
7.3195E-01	3.2000E-01	1.3489E-01	2.7306
7.0000E-01	3.6078E-01	1.4575E-01	2.6446
7.5000E-01	2.9924E-01	1.2930E-01	2.7768
8.0000E-01	2.4918E-01	1.1563E-01	2.8952
8.5000E-01	2.0840E-01	1.0423E-01	2.9984
9.0000E-01	1.7513E-01	9.4669E-02	3.0852
9.5000E-01	1.4794E-01	8.6615E-02	3.1548
1.0000E 00	1.2566E-01	7.9794E-02	3.2064
1.1000E 00	9.2307E-02	6.9003E-02	3.2553
1.2000E 00	6.9563E-02	6.0981E-02	3.2362
1.3000E 00	5.3832E-02	5.4858E-02	3.1605
1.4000E 00	4.2763E-02	5.0060E-02	3.0456
1.5000E 00	3.4816E-02	4.6202E-02	2.9113
1.6000E 00	2.8978E-02	4.3027E-02	2.7755
1.8000E 00	2.1190E-02	3.8077E-02	2.5490
2.0000E 00	1.6325E-02	3.4359E-02	2.4159
2.2500E 00	1.2329E-02	3.0812E-02	2.3681
2.5000E 00	9.5945E-03	2.8091E-02	2.4025
2.7500E 00	7.6072E-03	2.5953E-02	2.4718
3.0000E 00	6.1154E-03	2.4247E-02	2.5456
4.0000E 00	2.8734E-03	2.0020E-02	2.6444
5.0000E 00	1.6300E-03	1.7860E-02	2.3826
6.0000E 00	1.0923E-03	1.6533E-02	1.9989
7.0000E 00	8.2235E-04	1.5589E-02	1.6970
8.0000E 00	6.6414E-04	1.4852E-02	1.5178
1.0000E 00	4.8198E-04	1.3725E-02	1.3852
1.5000E 00	2.7786E-04	1.1908E-02	1.3504

V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
PBX 9011			
7.3412E-01	3.4000E-01	1.3420E-01	2.7611
7.0000E-01	3.8687E-01	1.4658E-01	2.6610
7.5000E-01	3.2054E-01	1.2896E-01	2.8059
8.0000E-01	2.6613E-01	1.1434E-01	2.9391
8.5000E-01	2.2188E-01	1.0218E-01	3.0590
9.0000E-01	1.8572E-01	9.2020E-02	3.1644
9.5000E-01	1.5612E-01	8.3499E-02	3.2538
1.0000E 00	1.3187E-01	7.6319E-02	3.3261
1.1000E 00	9.5584E-02	6.5064E-02	3.4165
1.2000E 00	7.0916E-02	5.6817E-02	3.4331
1.3000E 00	5.3965E-02	5.0625E-02	3.3812
1.4000E 00	4.2157E-02	4.5854E-02	3.2740
1.5000E 00	3.3793E-02	4.2079E-02	3.1301
1.6000E 00	2.7752E-02	3.9018E-02	2.9702
1.8000E 00	1.9913E-02	3.4324E-02	2.6713
2.0000E 00	1.5204E-02	3.0848E-02	2.4649
2.2500E 00	1.1463E-02	2.7549E-02	2.3538
2.5000E 00	8.9492E-03	2.5016E-02	2.3600
2.7500E 00	7.1259E-03	2.3018E-02	2.4284
3.0000E 00	5.7464E-03	2.1416E-02	2.5201
4.0000E 00	2.6644E-03	1.7453E-02	2.7864
5.0000E 00	1.4361E-03	1.5492E-02	2.6885
6.0000E 00	9.0610E-04	1.4355E-02	2.3284
7.0000E 00	6.5224E-04	1.3590E-02	1.9374
8.0000E 00	5.1382E-04	1.3013E-02	1.6499
1.0000E 01	3.6800E-04	1.2149E-02	1.3858
1.5000E 01	2.1511E-04	1.0754E-02	1.3016

V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
PBX 9404 adiabat ΔA			
7.2660E-01	3.9000E-01	1.5531E-01	2.6576
7.0000E-01	4.3006E-01	1.6621E-01	2.5851
7.5000E-01	3.5814E-01	1.4657E-01	2.7189
8.0000E-01	2.9931E-01	1.3018E-01	2.8415
8.5000E-01	2.5110E-01	1.1646E-01	2.9520
9.0000E-01	2.1151E-01	1.0492E-01	3.4096
9.5000E-01	1.7894E-01	9.5190E-02	3.1339
1.0000E 00	1.5209E-01	8.6935E-02	3.2046
1.1000E 00	1.1149E-01	7.3883E-02	3.3051
1.2000E 00	8.3418E-02	6.4223E-02	3.4541
1.3000E 00	6.3748E-02	5.6921E-02	3.3590
1.4000E 00	4.9744E-02	5.1285E-02	3.3304
1.5000E 00	3.9596E-02	4.6845E-02	3.2806
1.6000E 00	3.2100E-02	4.3278E-02	3.2213
1.8000E 00	2.2112E-02	3.7944E-02	3.1110
2.0000E 00	1.5995E-02	3.4180E-02	3.0433
2.2500E 00	1.1196E-02	3.0829E-02	3.0239
2.5000E 00	8.1331E-03	2.8439E-02	3.0472
2.7500E 00	6.0746E-03	2.6679E-02	3.0749
3.0000E 00	4.6467E-03	2.5350E-02	3.0785
4.0000E 00	1.9933E-03	2.2305E-02	2.6810
5.0000E 00	1.1812E-03	2.0788E-02	1.9959
6.0000E 00	8.5799E-04	1.9789E-02	1.5491
7.0000E 00	6.8729E-04	1.9023E-02	1.3546
8.0000E 00	5.7669E-04	1.8395E-02	1.2840
1.0000E 01	4.3499E-04	1.7396E-02	1.2532
1.5000E 01	2.6198E-04	1.5719E-02	1.2500

PBX 9404 adiabat ΔB

V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
7.4033E-01	3.7000E-01	1.5004E-01	2.8510
7.0000E-01	4.3282E-01	1.6619E-01	2.7477
7.5000E-01	3.5651E-01	1.4653E-01	2.8743
8.0000E-01	2.9508E-01	1.3029E-01	2.9847
8.5000E-01	2.4552E-01	1.1682E-01	3.0780
9.0000E-01	2.0546E-01	1.0558E-01	3.1534
9.5000E-01	1.7297E-01	9.6149E-02	3.2105
1.0000E 00	1.4655E-01	8.8184E-02	3.2495
1.1000E 00	1.0733E-01	7.5620E-02	3.2763
1.2000E 00	8.0786E-02	6.6298E-02	3.2449
1.3000E 00	6.2473E-02	5.9190E-02	3.1724
1.4000E 00	4.9550E-02	5.3625E-02	3.0786
1.5000E 00	4.0202E-02	4.9161E-02	2.9816
1.6000E 00	3.3259E-02	4.5505E-02	2.8953
1.8000E 00	2.3824E-02	3.9874E-02	2.7828
2.0000E 00	1.7806E-02	3.5751E-02	2.7570
2.2500E 00	1.2837E-02	3.1965E-02	2.8122
2.5000E 00	9.4937E-03	2.9199E-02	2.9124
2.7500E 00	7.1601E-03	2.7133E-02	3.0144
3.0000E 00	5.4887E-03	2.5564E-02	3.0912
4.0000E 00	2.2586E-03	2.2012E-02	2.9513
5.0000E 00	1.2484E-03	2.0347E-02	2.3071
6.0000E 00	8.6516E-04	1.9317E-02	1.7425
7.0000E 00	6.7836E-04	1.8554E-02	1.4449
8.0000E 00	5.6461E-04	1.7937E-02	1.3207
1.0000E 01	4.2430E-04	1.6961E-02	1.2581
1.5000E 01	2.5543E-04	1.5326E-02	1.2500

PBX 9404 Wilkins adiabat

V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
7.2660E-01	3.9002E-01	1.8753E-01	2.6577
7.0000E-01	4.2992E-01	1.9848E-01	2.5653
7.5000E-01	3.5806E-01	1.7883E-01	2.7370
8.0000E-01	2.9853E-01	1.6247E-01	2.8982
8.5000E-01	2.4929E-01	1.4880E-01	3.0485
9.0000E-01	2.0859E-01	1.3739E-01	3.1870
9.5000E-01	1.7497E-01	1.2783E-01	3.3126
1.0000E 00	1.4721E-01	1.1980E-01	3.4239
1.1000E 00	1.0530E-01	1.0731E-01	3.5984
1.2000E 00	7.6613E-02	9.8302E-02	3.6994
1.3000E 00	5.6902E-02	9.1687E-02	3.7188
1.4000E 00	4.3276E-02	8.6719E-02	3.6543
1.5000E 00	3.3781E-02	8.2895E-02	3.5134
1.6000E 00	2.7096E-02	7.9870E-02	3.3079
1.8000E 00	1.8887E-02	7.5359E-02	2.8807
2.0000E 00	1.4435E-02	7.2069E-02	2.3064
2.2500E 00	1.1317E-02	6.8888E-02	1.8510
2.5000E 00	9.4543E-03	6.6389E-02	1.5859
2.7500E 00	8.1862E-03	6.4112E-02	1.4502
3.0000E 00	7.2383E-03	6.2189E-02	1.3861
4.0000E 00	4.9051E-03	5.6254E-02	1.3413
5.0000E 00	3.6354E-03	5.2039E-02	1.3440
6.0000E 00	2.8447E-03	4.8827E-02	1.3463
7.0000E 00	2.3113E-03	4.6265E-02	1.3475
8.0000E 00	1.9306E-03	4.4154E-02	1.3483
1.0000E 01	1.4289E-03	4.0838E-02	1.3490
1.5000E 01	8.2675E-04	3.5436E-02	1.3497

LX-04-1 adiabat ΔA

V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
7.2900E-01	3.6200E-01	1.4405E-01	2.6900
7.0000E-01	4.0306E-01	1.5513E-01	2.6035
7.5000E-01	3.3509E-01	1.3674E-01	2.7505
8.0000E-01	2.7934E-01	1.2142E-01	2.8880
8.5000E-01	2.3357E-01	1.0864E-01	3.0138
9.0000E-01	1.9597E-01	9.7928E-02	3.1271
9.5000E-01	1.6504E-01	8.8927E-02	3.2265
1.0000E 00	1.3956E-01	8.1333E-02	3.3108
1.1000E 00	1.0116E-01	6.9419E-02	3.4307
1.2000E 00	7.4854E-02	6.0700E-02	3.4821
1.3000E 00	5.6657E-02	5.4179E-02	3.4664
1.4000E 00	4.3927E-02	4.9187E-02	3.3917
1.5000E 00	3.4897E-02	4.5271E-02	3.2722
1.6000E 00	2.8383E-02	4.2124E-02	3.1259
1.8000E 00	1.9993E-02	3.7366E-02	2.8225
2.0000E 00	1.5047E-02	3.3902E-02	2.5843
2.2500E 00	1.1217E-02	3.0657E-02	2.4252
2.5000E 00	8.7102E-03	2.8185E-02	2.3921
2.7500E 00	6.9240E-03	2.6242E-02	2.4329
3.0000E 00	5.5862E-03	2.4686E-02	2.5056
4.0000E 00	2.6182E-03	2.0818E-02	2.7280
5.0000E 00	1.4346E-03	1.8877E-02	2.6005
6.0000E 00	9.2098E-04	1.7732E-02	2.2302
7.0000E 00	6.7274E-04	1.6949E-02	1.8476
8.0000E 00	5.3587E-04	1.6351E-02	1.5740
1.0000E 01	3.8946E-04	1.5443E-02	1.3282

LX-04-1 adiabat ΔB

V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
7.4590E-01	3.4000E-01	1.3820E-01	2.9355
7.0000E-01	4.0812E-01	1.5531E-01	2.8142
7.5000E-01	3.3456E-01	1.3681E-01	2.9456
8.0000E-01	2.7560E-01	1.2161E-01	3.0603
8.5000E-01	2.2825E-01	1.0906E-01	3.1568
9.0000E-01	1.9013E-01	9.8635E-02	3.2340
9.5000E-01	1.5937E-01	8.9925E-02	3.2913
1.0000E 00	1.3448E-01	8.2600E-02	3.3286
1.1000E 00	9.7786E-02	7.1112E-02	3.3451
1.2000E 00	7.3220E-02	6.2642E-02	3.2943
1.3000E 00	5.6457E-02	5.6210E-02	3.1945
1.4000E 00	4.4757E-02	5.1183E-02	3.0683
1.5000E 00	3.6382E-02	4.7148E-02	2.9369
1.6000E 00	3.0218E-02	4.3833E-02	2.8169
1.8000E 00	2.1924E-02	3.8688E-02	2.6450
2.0000E 00	1.6668E-02	3.4864E-02	2.5715
2.2500E 00	1.2318E-02	3.1279E-02	2.5780
2.5000E 00	9.3619E-03	2.8591E-02	2.6355
2.7500E 00	7.2602E-03	2.6527E-02	2.6991
3.0000E 00	5.7286E-03	2.4914E-02	2.7428
4.0000E 00	2.6256E-03	2.1023E-02	2.5862
5.0000E 00	1.5488E-03	1.9021E-02	2.1137
6.0000E 00	1.0939E-03	1.7727E-02	1.7191
7.0000E 00	8.5460E-04	1.6764E-02	1.5047
8.0000E 00	7.0403E-04	1.5989E-02	1.4098
1.0000E 01	5.1782E-04	1.4785E-02	1.3578
1.5000E 01	2.9934E-04	1.2829E-02	1.3500

LX-04-1 adiabat ΔC

V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
7.2900E-01	3.6200E-01	1.4405E-01	2.6900
7.0000E-01	4.0303E-01	1.5513E-01	2.6004
7.5000E-01	3.3507E-01	1.3674E-01	2.7533
8.0000E-01	2.7922E-01	1.2142E-01	2.8974
8.5000E-01	2.3329E-01	1.0865E-01	3.0315
9.0000E-01	1.9548E-01	9.7960E-02	3.1543
9.5000E-01	1.6434E-01	8.8989E-02	3.2644
1.0000E 00	1.3865E-01	8.1435E-02	3.3604
1.1000E 00	9.9920E-02	6.9629E-02	3.5054
1.2000E 00	7.3375E-02	6.1047E-02	3.5814
1.3000E 00	5.5052E-02	5.4681E-02	3.5853
1.4000E 00	4.2290E-02	4.9852E-02	3.5205
1.5000E 00	3.3300E-02	4.6098E-02	3.3981
1.6000E 00	2.6877E-02	4.3107E-02	3.2350
1.8000E 00	1.8757E-02	3.8624E-02	2.8642
2.0000E 00	1.4118E-02	3.5376E-02	2.5389
2.2500E 00	1.0644E-02	3.2318E-02	2.2803
2.5000E 00	8.4267E-03	2.9952E-02	2.1731
2.7500E 00	6.8576E-03	2.8051E-02	2.1620
3.0000E 00	5.6739E-03	2.6491E-02	2.1986
4.0000E 00	2.9328E-03	2.2384E-02	2.3756
5.0000E 00	1.7267E-03	2.0131E-02	2.3303
6.0000E 00	1.1498E-03	1.8726E-02	2.1059
7.0000E 00	8.4789E-04	1.7742E-02	1.8419
8.0000E 00	6.7288E-04	1.6989E-02	1.6276
1.0000E 01	4.8168E-04	1.5857E-02	1.3987
1.5000E 01	2.8076E-04	1.4035E-02	1.3030

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V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
7.2900E-01	3.6350E-01	1.6185E-01	2.7174
7.0000E-01	4.0512E-01	1.7299E-01	2.6228
7.5000E-01	3.3619E-01	1.5451E-01	2.7844
8.0000E-01	2.7951E-01	1.3916E-01	2.9380
8.5000E-01	2.3288E-01	1.2639E-01	3.0826
9.0000E-01	1.9451E-01	1.1574E-01	3.2170
9.5000E-01	1.6291E-01	1.0683E-01	3.3397
1.0000E 00	1.3687E-01	9.9355E-02	3.4494
1.1000E 00	9.7670E-02	8.7753E-02	3.6236
1.2000E 00	7.0900E-02	7.9408E-02	3.7285
1.3000E 00	5.2522E-02	7.3294E-02	3.7554
1.4000E 00	3.9821E-02	6.8716E-02	3.7016
1.5000E 00	3.0970E-02	6.5202E-02	3.5721
1.6000E 00	2.4738E-02	6.2435E-02	3.3804
1.8000E 00	1.7073E-02	5.8336E-02	2.8933
2.0000E 00	1.2916E-02	5.5376E-02	2.4065
2.2500E 00	1.0009E-02	5.2546E-02	1.9470
2.5000E 00	8.2813E-03	5.0276E-02	1.6723
2.7500E 00	7.1148E-03	4.8359E-02	1.5277
3.0000E 00	6.2505E-03	4.6693E-02	1.4569
4.0000E 00	4.1589E-03	4.1616E-02	1.3999
5.0000E 00	3.0438E-03	3.8064E-02	1.3987
6.0000E 00	2.3585E-03	3.5388E-02	1.3992
7.0000E 00	1.9009E-03	3.3272E-02	1.3994
8.0000E 00	1.5769E-03	3.1542E-02	1.3996
1.0000E 01	1.1539E-03	2.8849E-02	1.3998
1.5000E 01	6.5411E-04	2.4530E-02	1.3999

V	Pressure (Mbar)	Energy (Mbar cc/cc)	Γ
		LX-07-0	
7.3423E-01	3.7000E-01	1.4517E-01	2.7627
7.0000E-01	4.2116E-01	1.5869E-01	2.6623
7.5000E-01	3.4874E-01	1.3950E-01	2.8071
8.0000E-01	2.8970E-01	1.2359E-01	2.9403
8.5000E-01	2.4151E-01	1.1035E-01	3.8604
9.0000E-01	2.0213E-01	9.9294E-02	3.1660
9.5000E-01	1.6991E-01	9.0020E-02	3.2556
1.0000E 00	1.4350E-01	8.2206E-02	3.3283
1.1000E 00	1.0399E-01	6.9960E-02	3.4193
1.2000E 00	7.7130E-02	6.0989E-02	3.4364
1.3000E 00	5.8618E-02	5.4255E-02	3.3844
1.4000E 00	4.5829E-02	4.9068E-02	3.2762
1.5000E 00	3.6734E-02	4.4965E-02	3.1302
1.6000E 00	3.0110E-01	4.1637E-02	2.9668
1.8000E 00	2.1668E-02	3.6532E-02	2.6581
2.0000E 00	1.6572E-02	3.2747E-02	2.4392
2.2500E 00	1.2548E-02	2.9144E-02	2.3110
2.5000E 00	9.8500E-03	2.6364E-02	2.2993
2.7500E 00	7.8956E-03	2.4157E-02	2.3490
3.0000E 00	6.4165E-03	2.2377E-02	2.4217
4.0000E 00	3.0912E-03	1.7880E-02	2.6194
5.0000E 00	1.7349E-03	1.5561E-02	2.5052
6.0000E 00	1.1274E-03	1.4168E-02	2.1994
7.0000E 00	8.2272E-04	1.3208E-02	1.8906
8.0000E 00	6.4917E-04	1.2480E-02	1.6696
1.0000E 01	4.5917E-04	1.1393E-02	1.4672
1.5000E 01	2.5828E-04	9.6844E-03	1.4013

Appendix D

Γ Versus Volume Behavior for JWL Adiabat

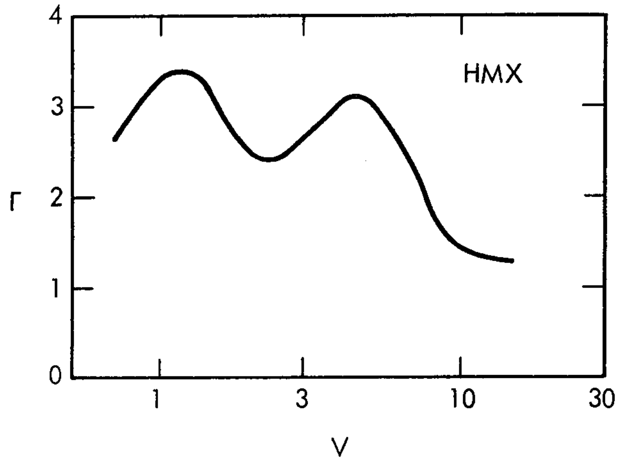

Fig. D-1. Γ vs relative volume (V) for HMX for the JWL equation of state.

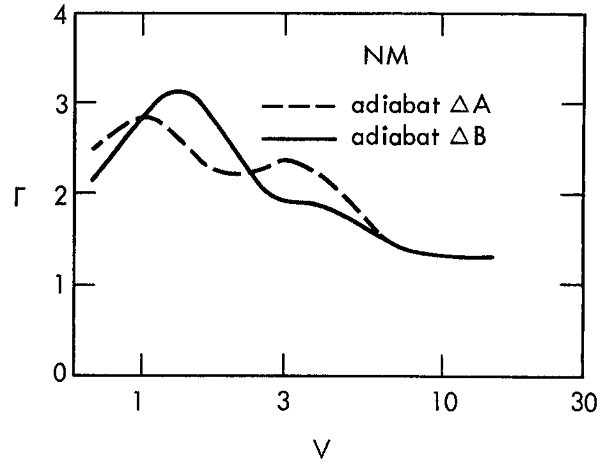

Fig. D-2. Γ vs relative volume (V) for NM for the JWL equation of state.

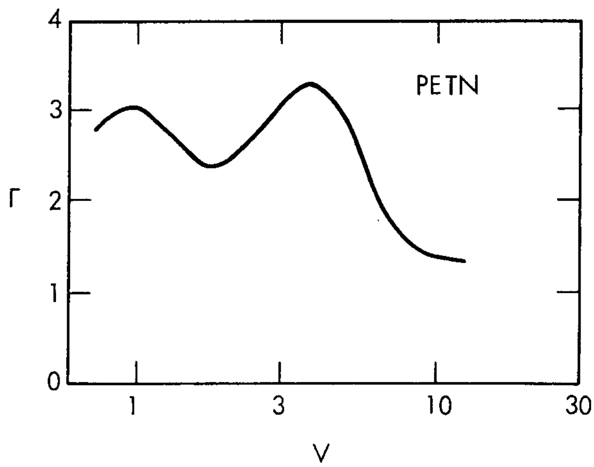

Fig. D-3. Γ vs relative volume (V) for PETN for the JWL equation of state.

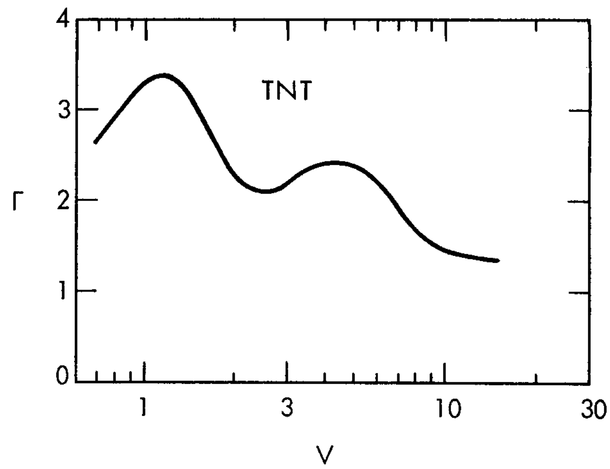

Fig. D-4. Γ vs relative volume (V) for TNT for the JWL equation of state.

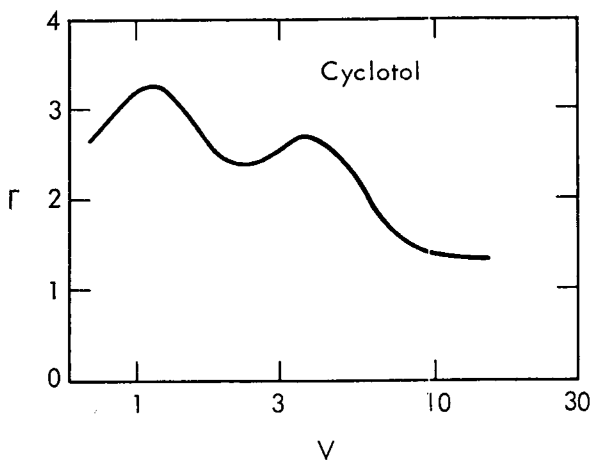

Fig. D-5. Γ vs relative volume (V) for Cyclotol for the JWL equation of state.

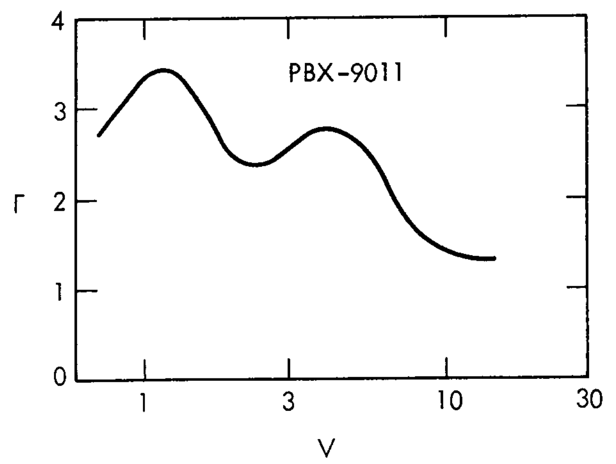

Fig. D-6. Γ vs relative volume (V) for PBX-9011 for the JWL equation of state.

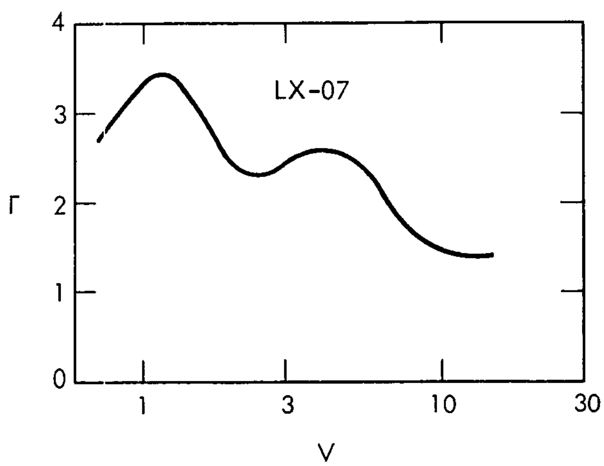

Fig. D-7. Γ vs relative volume (V) for LX-07 for the JWL equation of state.

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