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JWL EQUATION OF STATE COEFFICIENTS FOR HIGH EXPLOSIVES

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January 16, 1973

Prepared for U. S. Atomic Energy Commission under contract no. W-7405-Eng-48

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Introduction

The compilation of equations of state for high explosives now includes some 38 entries. Additions and revisions have recently introduced errors in the listings. To avoid transcribing errors, we have computerized the list and will issue computer updates periodically.

Previous lists should be discarded. If you are maintaining equation of state files for hydrodynamic codes and would like IBM card records of our lists, we will be happy to send you a copy of our card deck. We have noted those entries where changes or corrections have been made. Of special note for this update are the corrections to PBX-9404 and LX-04 from the most recent memo, dated August 23, 1972.

HIGH EXPLOSIVE EQUATION OF STATE DESCRIPTION

The Jones-Wilkins-Lee (JWL) equation of state has been used to accurately describe the pressure-volume-energy behavior of the detonation products of explosives in metal acceleration applications. The equation is:

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

The equation for P as a function of V at constant entropy, i.e., the isentrope, is

$$P_s = Ae^{-R_1 V} + Be^{-R_2 V} + CV^{-(\omega + 1)}$$

where:

V = (volume of detonation products)/(volume undetonated explosive)

P = pressure in megabars

E = energy in Mb cc/cc

A limited number of explosives have been subjected to a rigorous comparison in which coefficients are determined by matching the equation with experimental C-J conditions, calorimetric data, and expansion behavior -- generally cylinder test data.[1,2,3] These explosives are listed in the Table attached without additional notation. It has proven very useful to estimate coefficients for explosives for which a limited amount of data is available. For these explosives the estimated parameters are noted. The best estimates are for those explosives for which cylinder test data is available. We have estimated P_{cj} in many instances by assuming $2.7 < \Gamma < 2.8$. In cases where data was extremely limited we have made estimates from Ruby calculations for P_{cj}, D, and E_o and estimated R_1, R_2 and ω.

[1] J. W. Kury, H. C. Hornig, E. L. Lee, J. L. McDonnel, D. L. Ornellas, M. Finger, F. M. Strange, M. L. Wilkins, "Metal Acceleration by Chemical Explosives", Fourth Symposium on Detonation, p. 3, Office of Naval Research (1965).

[2] E. L. Lee, H. C. Hornig and J. W. Kury, UCRL-50422, May 2, 1968, "Adiabatic Expansion of High Explosive Detonation Products".

[3] E. L. Lee and H. C. Hornig, "Equation of State of Detonation Product Gases", Twelfth Symposium (International) on Combustion, p. 493 (1969).

EQUATION OF STATE PARAMETERS FOR SOME EXPLOSIVES

NAME	COMPOSITION	WT PER CENT	C. J. PARAMETERS: P MBAR	C. J. PARAMETERS: D CM PER MICSEC	C. J. PARAMETERS: E0 MB-CC/CC	C. J. PARAMETERS: RHO GM/CC	C. J. PARAMETERS: GAMMA	JWL EQUATION OF STATE COEFFICIENTS: A	JWL EQUATION OF STATE COEFFICIENTS: B	JWL EQUATION OF STATE COEFFICIENTS: C	JWL EQUATION OF STATE COEFFICIENTS: R1	JWL EQUATION OF STATE COEFFICIENTS: R2	JWL EQUATION OF STATE COEFFICIENTS: W
‡ BTF	BENZO-TRIFURANE	100.0	0.360*	0.848	0.1150	1.859	2.717	8.407	0.14960	0.01368	4.60	1.20	0.30
COMP B GRADE A	RDX TNT	64.0 36.0	0.295	0.798	0.0850	1.717	2.706	5.242	0.07678	0.01082	4.20	1.10	0.34
CYCLOTOL	RDX TNT	77.0 23.0	0.320	0.825	0.0920*	1.754	2.731	6.034	0.09924	0.01075	4.30	1.10	0.35
DIPAM**	DIAMINOHEXNITRO BIPHENYL	100.0	0.180*	0.670	0.0620*	1.550	2.842	4.254	0.08007	0.01175	4.70	1.30	0.39
EL-506A**	PETN CH2	85.0 15.0	0.205*	0.720	0.0700*	1.480	2.752	3.738	0.03647	0.01138	4.20	1.10	0.30
EL-506C**	PETN NC CH2	63.0 8.0 29.0	0.195*	0.700	0.0620*	1.480	2.719	3.490	0.04524	0.00854	4.10	1.20	0.30
HNS**	HEXANITRO-STILBENE	100.0	0.175*	0.660	0.0600*	1.540	2.885	4.469	0.08358	0.01010	4.80	1.30	0.39
HMX		100.0	0.420*	0.911	0.1050	1.891	2.740	7.783	0.07071	0.00643	4.20	1.00	0.30
HMX-TNT INERT	EDC-11	100.0	0.311	0.821	0.0890*	1.776	2.850	7.008	0.12116	0.00493	4.50	1.10	0.30
‡ HMX INERT	EDC-24	100.0	0.335	0.873	0.1020	1.783	3.050	9.433	0.08805	0.01123	4.70	0.90	0.35
LX-01**	TNM NM INP	33.3 52.0 14.7	0.155	0.684	0.0610*	1.230	2.711	3.110	0.04761	0.01039	4.50	1.00	0.35
‡ LX-04-1	HMX VITON	85.0 15.0	0.340	0.847	0.0950	1.865	2.936	8.498	0.15277	0.01159	4.65	1.30	0.35
‡ LX-07	HMX VITON	90.0 10.0	0.355	0.864	0.1000*	1.865	2.921	8.710	0.13896	0.00891	4.60	1.15	0.30
LX-09	HMX DNPA FEFO	93.0 4.6 2.4	0.373	0.884	0.1050*	1.838	2.851	8.684	0.18711	0.00729	4.60	1.25	0.25

* ESTIMATED QUANTITIES ** CYLINDER TEST DATA NOT AVAILABLE

‡ REVISED DATA

EQUATION OF STATE PARAMETERS FOR SOME EXPLOSIVES

NAME	COMPOSITION	WT PER CENT	C. J. PARAMETERS					JWL EQUATION OF STATE COEFFICIENTS					
			P MBAR	D CM PER MICSEC	E0 MB-CC/CC	RHO GM/CC	GAMMA	A	B	C	R1	R2	W
LX-10	HMX VITON	95.0 5.0	0.375	0.882	0.1040*	1.860	2.861	8.802	0.17437	0.00809	4.60	1.20	0.30
LX-11	HMX VITON	80.0 20.0	0.330	0.832	0.0900*	1.875	2.930	7.791	0.10668	0.00885	4.50	1.15	0.30
NM		100.0	0.125	0.628	0.0510	1.128	2.538	2.092	0.05689	0.00770	4.40	1.20	0.30
OCTOL	HMX TNT	78.0 22.0	0.342	0.848	0.0960*	1.821	2.830	7.486	0.13380	0.01167	4.50	1.20	0.38
PBX 9010	RDX KEL F	90.0 10.0	0.340	0.839	0.0900	1.787	2.700	5.814	0.06801	0.00234	4.10	1.00	0.35
‡ PBX 9011	HMX ESTANE	90.0 10.0	0.340	0.850	0.0890*	1.777	2.776	6.347	0.07998	0.00727	4.20	1.00	0.30
‡ PBX 9404-3	HMX NC CEF	94.0 3.0 3.0	0.370	0.880	0.1020	1.840	2.850	8.545	0.20493	0.00754	4.60	1.35	0.25
‡ PETN		100.0	0.335	0.830	0.1010	1.770	2.640	6.170	0.16926	0.00699	4.40	1.20	0.25
‡ PETN		100.0	0.220	0.745	0.0856*	1.500	2.788	6.253	0.23290	0.01152	5.25	1.60	0.28
PETN		100.0	0.140	0.654	0.0719*	1.260	2.831	5.731	0.20160	0.01267	6.00	1.80	0.28
PETN**		100.0	0.062	0.517	0.0502*	0.880	2.668	3.486	0.11288	0.00941	7.00	2.00	0.24
‡ PENTOLITE	TNT PETN	50.0 50.0	0.250*	0.747	0.0800	1.670	2.727	4.911	0.09061	0.00876	4.40	1.10	0.30
RX-01-AE	NM SIO2 GUAR	87.0 10.0 3.0	0.125*	0.611	0.0450*	1.210	2.614	2.111	0.04754	0.00795	4.30	1.30	0.34
RX-08-DR	HMX EDNP SIO2	76.0 22.0 2.0	0.290*	0.796	0.0800*	1.711	2.736	5.267	0.06823	0.00991	4.20	1.05	0.36
RX-04-DS	HMX AL VITON	80.0 10.0 10.0	0.340*	0.852	0.1050*	1.865	2.981	9.073	0.10400	0.01473	4.70	1.00	0.40

* ESTIMATED QUANTITIES

** CYLINDER TEST DATA NOT AVAILABLE

‡ REVISED DATA

EQUATION OF STATE PARAMETERS FOR SOME EXPLOSIVES

			C. J. PARAMETERS					J W L EQUATION OF STATE COEFFICIENTS					
NAME	COMPOSITION	WT PER CENT	P MBAR	D CM PER MICSEC	E0 MB-CC/CC	RHO GM/CC	GAMMA	A	B	C	R1	R2	W
RX-06-AF	HMX	73.0	0.270*	0.780	0.0760*	1.658	2.736	5.030	0.09065	0.00781	4.30	1.10	0.35
	EDNP	25.0											
	MDNP	1.0											
	SIO2	1.0											
‡ RX-08-AC	HMX	68.0	0.340*	0.844	0.0980*	1.794	2.758	6.527	0.09678	0.01235	4.30	1.10	0.35
	FEFO	30.0											
	SIO2	2.0											
‡ RX-08-BV	HMX	74.0	0.360*	0.860	0.1000*	1.810	2.719	6.699	0.12901	0.01145	4.30	1.20	0.30
	FEFO	24.7											
	CAB-O-SIL	1.3											
RX-08-DW	HMX	76.0	0.290*	0.856	0.1000*	1.845	2.758	7.145	0.15885	0.01059	4.40	1.30	0.32
	EDNP	22.0											
	SIO2	2.0											
RX-23-AA	HN	79.0	0.280*	0.858	0.0630	1.420	2.732	5.086	0.09463	0.00370	4.20	1.20	0.35
	N2H4	21.0											
RX-23-AB	HN	70.0	0.190*	0.748	0.0410	1.380	3.064	4.657	0.03661	0.00433	4.40	1.20	0.40
	N2H4	5.9											
	H2O	24.1											
RX-23-AC	HN	30.0	0.175*	0.787	0.0390	1.130	2.998	4.445	0.08146	0.00350	4.60	1.40	0.40
	N2H4	70.0											
TETRYL**	TETRYL	100.0	0.285	0.791	0.0820	1.730	2.798	5.868	0.10671	0.00774	4.40	1.20	0.28
TNT		100.0	0.210	0.693	0.0600	1.630	2.727	3.738	0.03747	0.00734	4.15	0.90	0.35
X-0219	TATB	90.0	0.260*	0.753	0.0680*	1.920	3.190	8.268	0.08479	0.00831	4.80	1.20	0.35
	KEL-F	10.0											
XTX-8003	PETN	80.0	0.170	0.735	0.0660*	1.540	3.894	27.140	0.17930	0.01202	7.00	1.60	0.35
	SYLGARD	20.0											

* ESTIMATED QUANTITIES   ** CYLINDER TEST DATA NOT AVAILABLE

‡ REVISED DATA

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