TABLE II. Smoothed shock parameter data for Lucite.

Shock velocity (m/sec)	Shock pressure (kilobars)	Shock velocity (m/sec)	Shock pressure (kilobars)
3350	20	5410	100
3820	30	5560	110
4160	40	5700	120
4430	50	5840	130
4670	60	5960	140
4880	70	6100	150
5070	80	6210	160
5250	90	6330	170

curves of Fig. 4 and Table I, the pressure in the detonation wave or incident wave p_i calculated through application of Eq. (1) (the impedance mismatch equation), and finally p_i/p_2^* or the ratio of the measured pressure to the calculated Chapman–Jouguet value of the detonation pressure.

Table IV presents similar data for nonideal explosives (i.e., $D/D^* < 1.0$). Also listed in this table are the ratios $(D/D^*)^2$ which should be equal to p_i/p_2^* if the measured pressure is the Chapman–Jouguet pressure, but much lower (about half) if the measured pressure is the "spike pressure." The results show that the measured pressure is definitely the Chapman–Jouguet pressure and that there is no evidence for an over-pressure of the type required by the Zeldovich–von Neumann model.

Figure 7 presents results for special explosive X in 5 cm (d) and composition B in 4.3 cm (d) for which the charge length was varied from 1 to 6 cm to determine if a pressure-buildup effect existed in explosives of very short reaction zone lengths or in explosives with no appreciable detonation velocity transient. These charges were all boostered with identical 1.27×2.54 cm pressed RDX boosters. With such short charges, however, difficulty was encountered in measuring the initial velocity of the shock wave in water because of a rapid

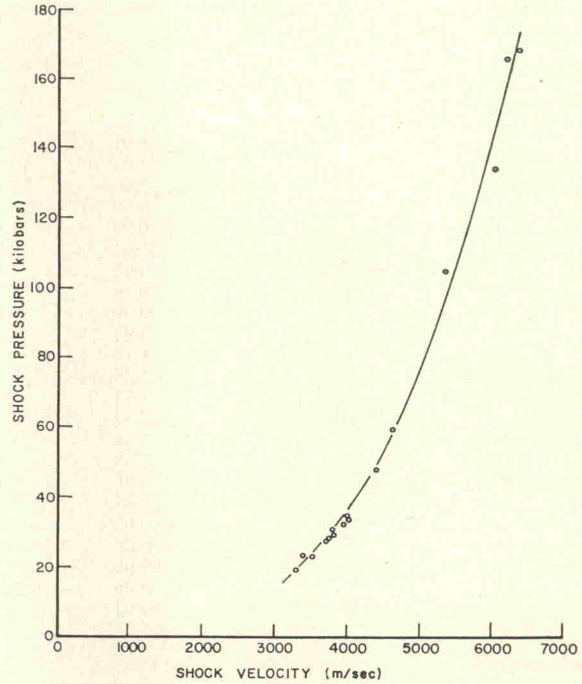

FIG. 6. Experimental shock velocity vs pressure data for Lucite.

attenuation in velocity of the shock in the aquarium. The plot of the results indicates in spite of the observed scatter, a small pickup in detonation pressure as the charge length was increased. Whether or not the detonation velocity increased slightly over this region in order to produce the pressure pickup could not be determined.

Data for the commercial blasting agents were reported by Bauer and Cook.[14] Their results are given both for unconfined charges and charges confined in 0.95-cm thick or 2.44-cm-thick steel tubing. They found that the detonation velocity and pressure of the low density AN/fuel oil mix was very sensitive to confine-

TABLE III. Measured peak pressures in detonation waves of ideal explosives ($D/D^* = 1$).

Explosive	No. of shots	Density (g/cc)	Diameter (cm)	Velocity D (km/sec)	p_t[a] (kbars)	p_i[b] (kbars)	p_i/p_2^*[c]
RDX	4	1.21	2.53	6.48	105	134	0.97
	1	1.18	3.77	6.75	89	118	0.91
	1	1.21	4.40	6.67	94	123	0.90
	3	1.18	5.05	6.74	108	135	1.04
	1	1.10	6.30	6.40	94	112	0.98
	1	1.13	7.62	6.62	97	119	0.98
80/20 RDX/salt	1	1.32	2.53	5.79	85	110	0.85
	1	1.30	4.40	6.20	87	115	0.98
	1	1.28	5.00	6.20	92	119	1.01
TNT (−48+65 mesh)	2	0.86	3.80	4.50	51	50	0.98
	4	0.98	5.05	4.56	52	51	0.95
	2	0.84	7.62	4.46	52	49	1.00
(−6+8 mesh)	1	0.97	16.1	4.88	60	63	1.00
(−4+6 mesh)	2	0.99	25.3	5.01	64	68	1.01
HBX−1	1	1.75	5.0	7.16	116	190	1.0

[a] p_t = initial pressure of shock wave in water.
[b] p_i = pressure at detonation wavefront.
[c] * — designates ideal or hydrodynamic value (calculated from hydrodynamic theory). *Note:* The average deviation (correcting for density) for p_t and p_i was ±6.1%.

TABLE IV. Experimental peak pressures in detonation waves of nonideal explosives ($D/D^* < 1.0$).

Explosive	No. of shots	Density (g/cc)	Diameter (cm)	Velocity D (km/sec)	p_t (kbars)	p_i (kbars)	$(D/D^*)^2$	p_i/p_2^*
TNT (−4+6 mesh)	1	1.00	7.62	4.41	43	46	0.77	0.69
	2	1.01	10.0	4.65	67	61	0.85	0.87
	1	1.01	12.35	5.00	63	69	0.92	0.90
	1	1.00	15.9	4.80	65	66	0.92	0.88
	4	0.99	20.3	5.01	54	59	1.01	0.97
(−6+8 mesh)	2	0.99	7.62	4.51	55	57	0.81	0.84
	2	1.01	10.0	4.82	62	66	0.91	0.93
(−8+10 mesh)	2	0.95	5.0	3.73	41	40	0.60	0.64
	3	0.99	7.62	4.67	56	58	0.81	0.87
	2	0.99	10.0	4.80	61	64	0.92	0.94
(−48+65 mesh)	2	0.84	2.53	3.86	49	44	0.72	0.89
RDX	1	1.10	1.25	5.83	75	89	0.83	0.78
65/35 baratol	1	2.35	5.0	5.15	62	116	0.85	0.74
50/50 cast amatol[a]	1	1.53	4.8	5.55	72	102	0.74	0.75
	1	1.53	7.6	6.04	85	121	0.94	0.89
50/50 amatol[b]	1	1.58	4.8	5.72	84	120	0.76	0.84
	1	1.58	7.62	6.23	100	145	0.89	1.0
50/50 AN/TNT[c]	3	0.97	2.54	2.95	25	24	0.37	0.35
	3	0.97	3.81	3.64	38	37	0.54	0.55
	5	0.98	5.04	4.08	48	48	0.66	0.67
	7	0.96	10.0	4.57	61	62	0.86	0.91
	6	0.96	15.2	4.76	67	67	0.95	1.00
	2	0.96	20.4	4.80	67	68	0.96	1.00
	4	0.94	25.4	4.88	69	69	1.0	1.08

[a] 35 mesh AN. [b] 65 mesh AN. [c] Mechanical mixture.

ment. In 11.7 cm (d) unconfined charges the detonation velocity was only 2.77 km/sec which corresponded to a D/D^* ratio of only 0.66 while with 0.95 cm steel confinement in the same diameter the detonation velocity was 3.93 km/sec corresponding to a D/D^* ratio of 0.94. The series of coarse TNT or composition B "slurries" were much less sensitive to confinement probably because their detonation pressures were much higher.

DISCUSSION OF RESULTS

In comparing the measured values for pressure in the explosive, that is, pressures of the incident waves p_i obtained by the aquarium technique, one will note that in every case where the detonation wave propagated at ideal velocity p_i agreed (with an average deviation of $\pm 6.1\%$) with the Chapman–Jouguet pressure p_2^*, i.e., to the detonation pressure calculated from thermohydrodynamic theory. In most of the loose packed explosives the impedance match between the explosive and water was very good. Therefore, calculations of pressure in the incident medium in terms of pressure in the transmission medium, through applications of the shock impedance mismatch equation, should be quite reliable at least in these cases.

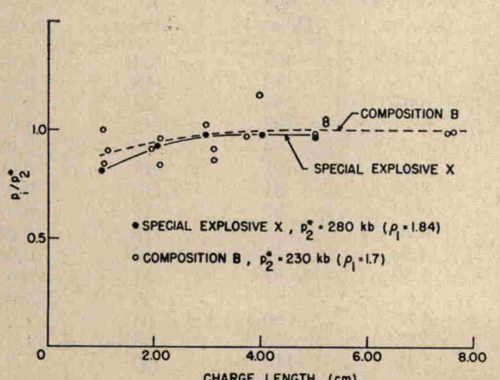

FIG. 7. Pressure of the detonation wave as a function of charge length for 5-cm-diam special explosive X and 4.8-cm-diam composition B boostered with 1.27×2.54-cm pressed RDX.

Since the C–J pressure of the detonation wave is given by the relation $p \doteq \rho_1 DW$ in nonideal detonations the Chapman–Jouguet pressure should be given approximately by the relation

$$p_2 = (D/D^*)^2 p_2^*, \tag{4}$$

where asterisks signify ideal values, p_2^* being the ideal detonation pressure. Equation (4) makes use of the approximation that W/D depends only on ρ_1 and not on D/D^* which is well justified by the generality of the covolume-specific volume $[\alpha(v)]$ curve for high explosives.[16] This is consistent also with a frequently used approximation that $W/D = 0.25$ for condensed explosive. Comparisons of $(D/D^*)^2$ with p/p_2^* given in Tables III and IV indeed show striking agreement. Judging from reproducibility of results it is estimated that the measured pressures for nonideal explosives was at least as accurate as for the ideal ones, the average deviation of results from the mean being about $\pm 5\%$. This is consistent also with the average deviations of the ratios p_i/p_2^* and $(D/D^*)^2$.

Important information regarding the pressure or particle velocity profiles of detonation waves are also apparent from this study. According to the Zeldovich–von Neumann concept, which is based upon transport