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DEVELOPMENT OF THE CONTINUOUS WIRE METHOD PROGRESS REPORT IV. COMPARISON WITH OPTICAL MEASUREMENTS OF DETONATION PROPERTIES

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DEVELOPMENT OF THE CONTINUOUS WIRE METHOD PROGRESS REPORT IV. COMPARISON WITH OPTICAL MEASUREMENTS OF DETONATION PROPERTIES

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J. P. Toscano, A. R. Clairmont Jr., I. Jaffe, & D. Price

ABSTRACT: Measurements made with the continuous wire method are compared to those obtained optically of shock-to-detonation transitions in cast Comp B. The electronic and optical results are equivalent in detonation velocity measurements as they are for other explosives. For the transitional phenomena (e.g., delay time and run-length) the electronic method is much less precise than the optical. Hence the continuous wire method is not adequate for making such measurements in cast Comp B.

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The work reported here was carried out under the task MAT 03L 000/ R011 01 01 Prob 059, Transition from Deflagration to Detonation. This report is the fourth on the development work designed to make the continuous wire method useful in studying the shock-to-detonation transition of high explosives. Earlier work was reported in NOLTRs 63-136, 66-21, and 67-10.

E. F. SCHREITER
Captain, USN
Commander

Albert Lightbody
ALBERT LIGHTBODY
By direction

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DEVELOPMENT OF THE CONTINUOUS WIRE METHOD PROGRESS REPORT IV. COMPARISON WITH OPTICAL MEASUREMENTS OF DETONATION PROPERTIES

INTRODUCTION

This is the fourth report on application of the continuous wire method to studying shock-to-detonation transitions. This method uses three embedded wires which are parallel to the charge axis; two are copper and the third a Moleculoy resistance wire. The wires form two constant current circuits, the Cu-Cu and the Moleculoy-Cu, as diagrammed in the previous report.[1] As a detonation reaction sweeps down the charge, the length and corresponding resistance of the Moleculoy wire remaining in the circuit decrease. In principle, the position of the detonation front as a function of time can be obtained from the oscilloscope record of resistance vs time.

The purpose of the present work was to compare continuous wire measurements with those obtained optically on the same charge. Cast Comp B was used throughout this study as a typical high explosive.

EXPERIMENTAL

All charges were of Comp B (60/40/1, RDX/TNT/Wax). They were cast, as previously described,[2] about three wires held under tension in a cylindrical mold. A No. 32 Cu ground wire runs along the axis and is parallelled on either side by another Cu wire and by the Moleculoy resistance wire. The shot design, experimental procedure, and electronic circuitry were identical with those of the previous work.[1] In addition, a 70 mm smear camera was used, at a writing speed of 4 mm/μsec, to follow the shock-to-detonation phenomena which appeared on the surface of the cylindrical charge. The camera slit was focused on the charge surface, parallel to the longitudinal axis, and viewed the entire length of the charge. An argon bomb was used to illuminate the initiating shock prior to detonation; the detonation could be followed by self luminosity.

After X-ray examination, the satisfactory charges were machined to 3.81 cm diam x 15.25 cm length. Charge density was 1.71-1.72 g/cc. The initiating shock was provided by two standard tetryl pellets (5.08 cm diam x 2.54 cm long, ρ_o = 1.51 g/cc) followed by a gap of 0 to 37.4 mm of polymethyl methacrylate (PMMA) and cellulose acetate sheeting; the gap material also had a diameter of 5.08 cm. The calibration for this standard donor/gap system is given in Ref (3).

Fig. 1 shows typical electronic records for Shot 13. All electronic records were processed by the semi-automatic procedure fully described previously.[2] Fig. 2 shows the smear camera record from the same charge (Smear Camera Record 297). The detonation velocity was obtained by fitting the x-t data to a hyperbolic function as described in Ref (4).

DISCUSSION OF RESULTS

Measurement of Detonation Velocity

The continuous wire method was originally designed to measure detonation velocity (D). Although this measurement is of only secondary interest in transitional studies, a comparison of the results from optical and electronic measurements is of value for other studies. Table 1 contains the velocity results from: (a) the Differential record, (b) the Moleculoy-Cu circuit record, and (c) the smear camera record. They are all essentially the same, although the differential records give results that are, on the average, 1% lower than the other two records. The maximum difference, which occurs only once, is 3%. We can conclude that the continuous wire method will give detonation velocity measurements in Comp B equivalent to those from optical methods.

Transitional Phenomena, Optical Records

The phenomena of interest in the shock-to-detonation transition are total delay time (τ), run length (X_ℓ), and time of chemical reaction prior to the onset of detonation. Of these, the smear camera records can give a measure of X_ℓ and an estimate of τ. From other transitional studies, it is assumed that detonation is

TABLE 1

CONTINUOUS WIRE AND SMEAR CAMERA MEASUREMENTS
OF DETONATION VELOCITY IN CAST COMP B

Shot No.		Detonation Velocity, mm/μsec		
Electronic	Camera	Electronic		Optical
		Diff.*	Mol.**	
5	44	7.83	8.05	8.00
1	29	7.87	8.20	8.08
15	299	7.92	--	8.00
2	34	8.14	8.07	8.10
16	300	7.94	8.10	8.07
6	45	8.05	8.14	8.17
3	36	8.09	8.11	8.16
7	46	8.17	8.12	8.08
14	298	7.94	8.05	8.11
13	297	8.02	8.01	8.01
4	37	7.96	8.26	8.23
8	47	8.30	8.21	8.13

* From Differential record.

** From Moleculoy-Cu record.

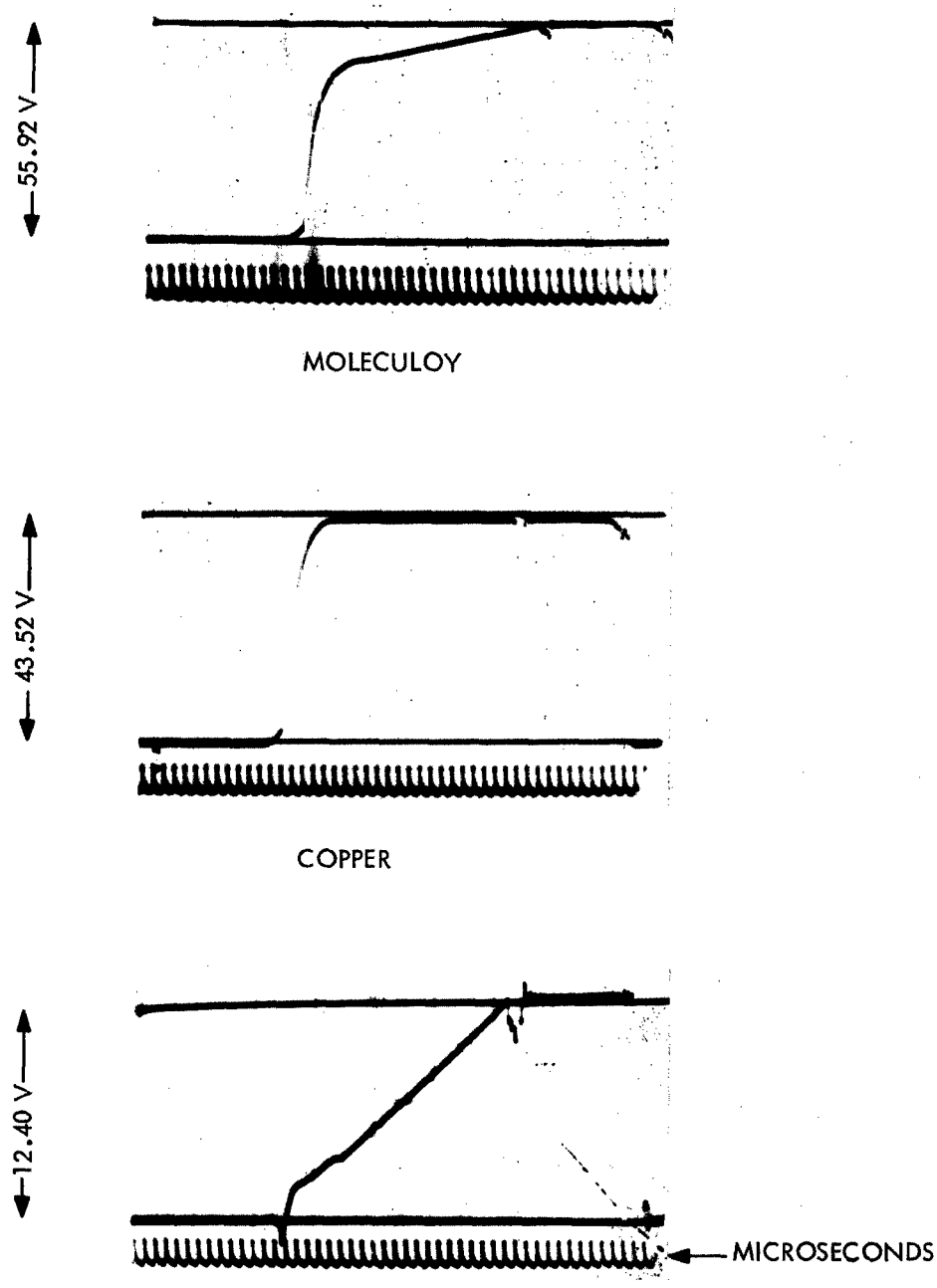

FIG. 1 ELECTRONIC RECORDS FOR SHOT 13 (GAP THICKNESS 145 CARDS)

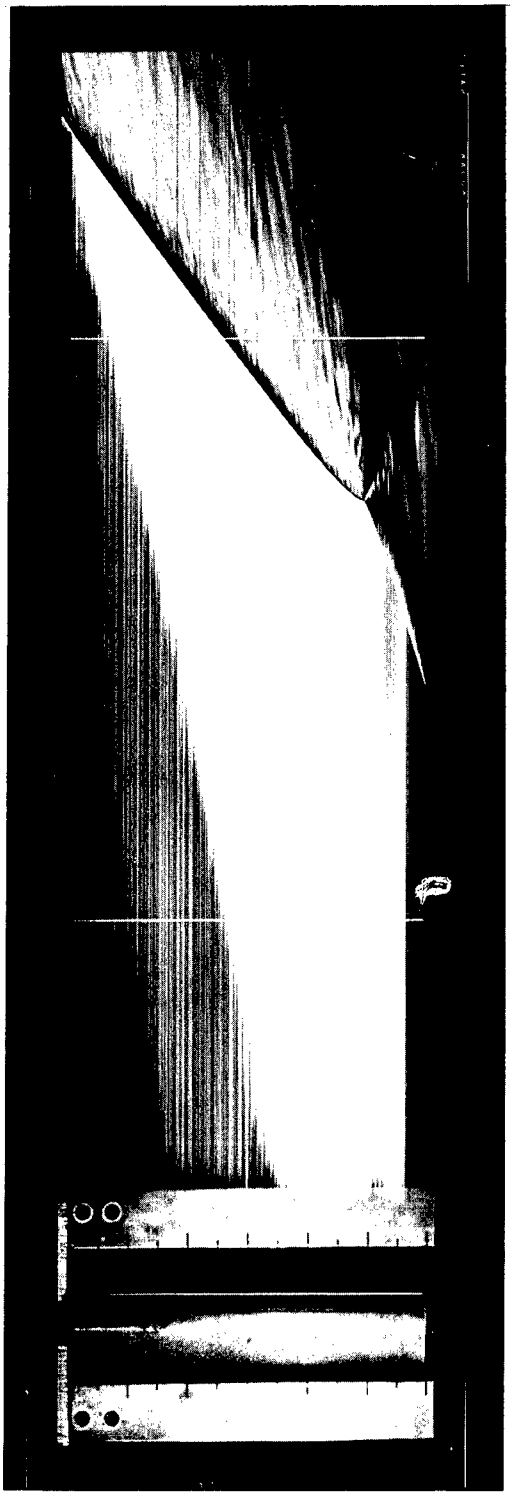

FIG. 2 OPTICAL RECORD OF SHOCK-TO-DETONATION TRANSITION FOR SHOT 13 (GAP THICKNESS 145 CARDS)

initiated on the axis of the charge and then spreads in a hemispherical front. Hence the point of its break-out on the charge surface is at a distance X_ℓ from the point of entry of the initiating shock. This point is located at the intersection of the trace of the predetonation shock and the detonation wave (See Fig. 2). From the X_ℓ value and the writing speed of the camera, an approximate delay time τ_a can be obtained. It is actually the predetonation time on the surface of the charge, but because of the curved surface of the initiating shock and the time required for detonation to spread from the charge axis to the charge surface, we cannot relate it exactly to the delay time on the axis of the charge.

The data X_ℓ, τ_a from the smear camera records are listed in Table 2 and plotted in Fig. 3. The curve τ_a vs X_ℓ is smooth, apparently linear, and extrapolates to $\tau_a = -0.6$ μsec at $X_\ell = 0$. This suggests that the true delay time is near $(\tau_a + 0.6)$. Fig. 4 displays the data, initiating shock pressure P_e vs X_ℓ; again the curve is smooth and shows the trends established by other transitional studies. The log-log plots of P_e vs X_ℓ and of excess delay time* vs X_ℓ are linear as is the case with other good transitional data. In other words, the smear camera records provide precise and consistent X_ℓ, τ data.

The camera records do not, however, give any information about the time of predetonation reaction. Typically they show only a smoothly accelerating shock with most of the acceleration occurring just before detonation breaks out. In Fig. 2 the initial shock velocity is 3.00 mm/μsec and the velocity has reached 3.70 mm/μsec when the shock trace is obscured by the detonation break-out at X_ℓ.

Transitional Phenomenon, Electronic Records

In contrast to the optical records, the electronic ones do provide some information on the time of chemical reaction prior to the onset of detonation. Such transitional reactions would be

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* Excess delay time is $(\tau_a + 0.6) - X_\ell D^{-1}$

TABLE 2

OPTICAL AND ELECTRONIC MEASUREMENTS OF
RUN LENGTH AND DELAY TIME IN CAST COMP B

Gap No. card	Shock Pressure* kbar	Optical Results X_t mm	Optical Results τ_a µsec	Electronic Results Δt** µsec (Rise time ~ 0.8 µsec)	Electronic Results X_t mm	Electronic Results τ µsec	Shot Nos. Electronic	Shot Nos. Camera
0	--	--	--	--	--	--	10	--
0	--	--	--	--	--	--	5	44
1	--	--	--	--	--	--	1	29
40	107.0	~0	~0	0.4	5.4	2.0	15	299
75	75.3	6.44	1.43	1.8	7.2	2.7	2	34
90	66.8	9.34	2.32	1.4	10.4	3.0	16	300
100	62.1	10.49	2.51	1.9	14.3	3.5	6	45
125	49.7	17.57	4.64	--	18.9	5.1	3	36
140	42.9	25.60	7.15	5.5	21.4	7.0	7	46
140	42.9	22.23	6.11	4.9	32.4	7.0	14	298
145	40.7	26.16	7.24	6.0	28.4	7.3	13	297
150	37.9	46.60	12.89	11.5	46.9	13.6	4	37
151	37.7	42.07	11.23	--	46.7	12.8	8	47
151	37.7	No detonation		--			--	32

* This is initial amplitude of shock entering the Comp B acceptor. It was calculated from shock pressure at end of the gap[3] and Hugoniot data for Comp B.[5]

** Time at which Cu record reaches zero volt line minus time at which Cu record first shows rise from imposed negative voltage (~ -40V).

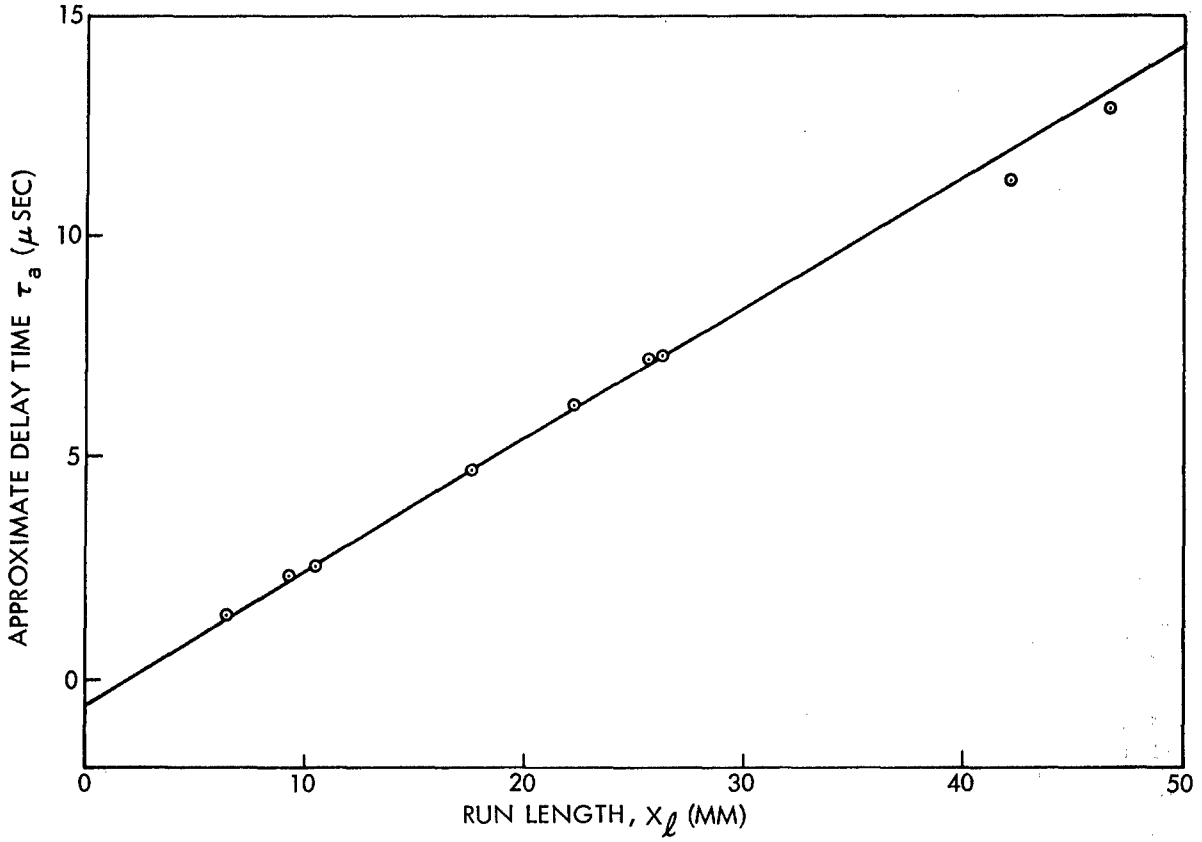

FIG. 3 τ_a VS X_ℓ FROM SMEAR CAMERA MEASUREMENTS IN CAST COMP B

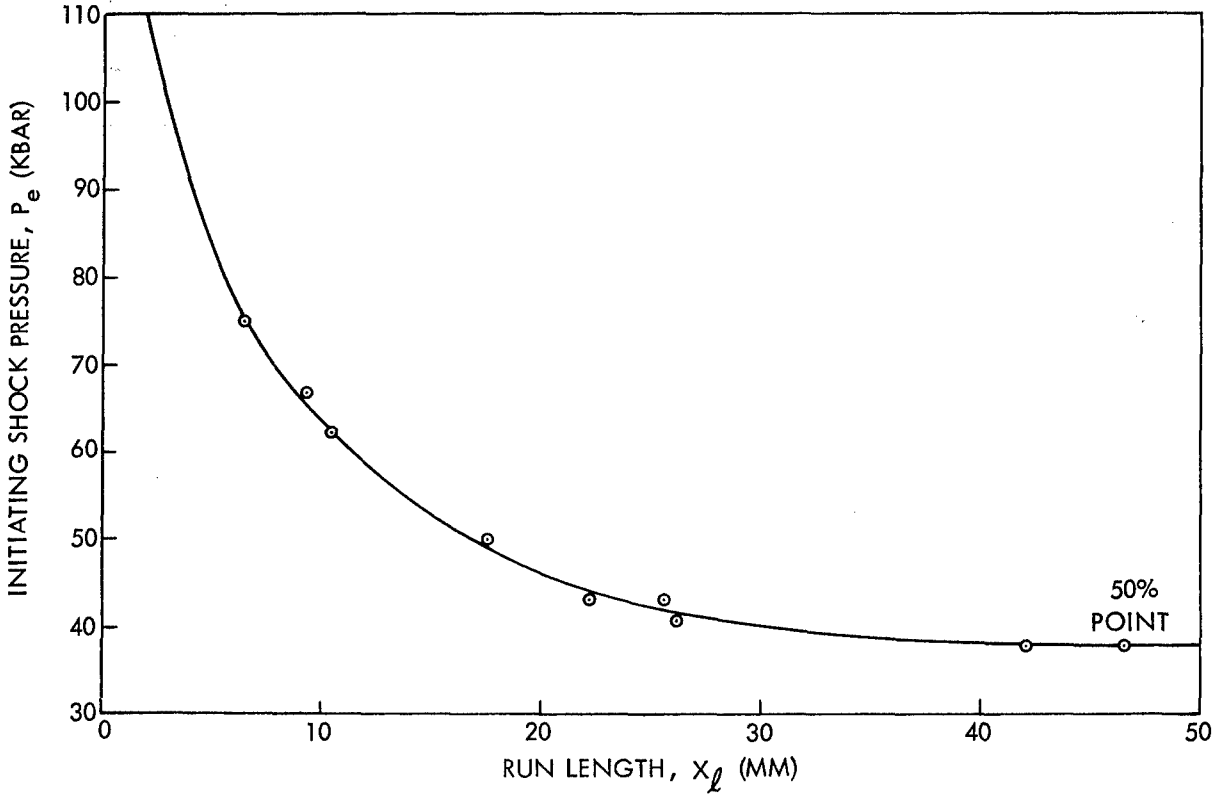

FIG. 4 P_e VS X_ℓ FROM SMEAR CAMERA MEASUREMENTS IN CAST COMP B

indicated by electrical conductance of their products and this conductance should be measured by the Cu-Cu(ground) circuit. In the case of DINA,[1] the pre-detonation conductance could not be observed*; consequently it was possible to use the time at which this circuit registered zero resistance as the moment at which detonation began. For Comp B, the situation is very different. As the data of Table 2 show, at moderate initiating pressures, this interval was ~ 1.5 μsec, and it increased to 11.5 μsec as the initiating pressure approached its minimum value (50% point). DINA has a zero oxygen balance to CO whereas Comp B has one of -10%. In thermal decomposition at the hot spots, the products should not be very different, but the free carbon from Comp B would probably increase the conductance of the products above that to be expected from the DINA products (carbon free). Although this factor may account for part of the difference in this measurement, it does not seem likely to account for a 10-fold difference in the duration of the transitional reactions. We suggest that the major difference lies in the rate of growth to detonation from burning in the ignition areas. This rate seems high for DINA and relatively lower for Comp B. Of course, DINA requires that the accelerated burning generate a pressure of only about 15 kbar whereas Comp B requires about 38 kbar to achieve detonation. Even at the same burning rate, Comp B would therefore require a longer time to achieve detonation.

The Cu circuit records for shock-to-detonation transition in DINA were sharp and easily read.[1] They provided a time for the onset of detonation which approximated the beginning of the straight line portions of both the Differential and the Moleculoy records. This is not the case for Comp B. Here the Cu record trace frequently approaches the zero volt line asymptotically so that an end point (beginning of detonation) is difficult to select. Moreover,

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* If present, its duration was less than 0.5 μsec. In two charges, an interval of about 1 μsec was observed.

the time so chosen does not seem to coincide with the beginning of detonation on the other two records. Consequently in the present work, the time of detonation onset was selected as that most consistent with all three records; a triple plot of voltage vs time was examined for each charge and particular weight was given to a time which appeared to be at the beginning of the straight line portion of both the Moleculoy and the Differential records. This procedure did not give satisfactory results for DINA, and, as will be shown, does not give acceptable results for Comp B either.

The values X_ℓ and τ obtained from the continuous wire records are also listed in Table 2, and plotted τ vs X_ℓ in Fig. 5. Here the scatter is so great that a straight line ending at the origin is used. Within the same large scatter, P_e vs X_ℓ shows the usual trend (Fig. 6). But comparison of Figs. 3 and 4 with Figs. 5 and 6 readily shows the inadequacy of the electronic measurements. Although, as Fig. 7 shows, they are undoubtedly correlated with the optical results, they are too imprecise to be used for quantitative work. We conclude that the continuous wire method is inadequate for measuring X_ℓ and τ in shock-to-detonation transitions of Comp B.

Because the Moleculoy and Cu circuits are not independent,[1] a few shots were made to compare the results from the Moleculoy records of charges containing two wires with those of the three wire charges. Some of these results are shown in Table 3. The two wire system appears to give larger values (ca. 0.5 μsec in τ and 5-8 mm in X_ℓ), but these changes are no larger than errors that can be made in reading the records of a single shot or, indeed, of the maximum scatter of Fig. 5. It is not certain therefore whether the two wire system gives different results from those of the three wire system. Neither is satisfactory for measurements of transitional phenomena in Comp B.

CONCLUSIONS

The continuous wire method measures the detonation velocity of Comp B as precisely as does an optical method. It is, however, much too imprecise to measure run length or delay time in the shock-to-

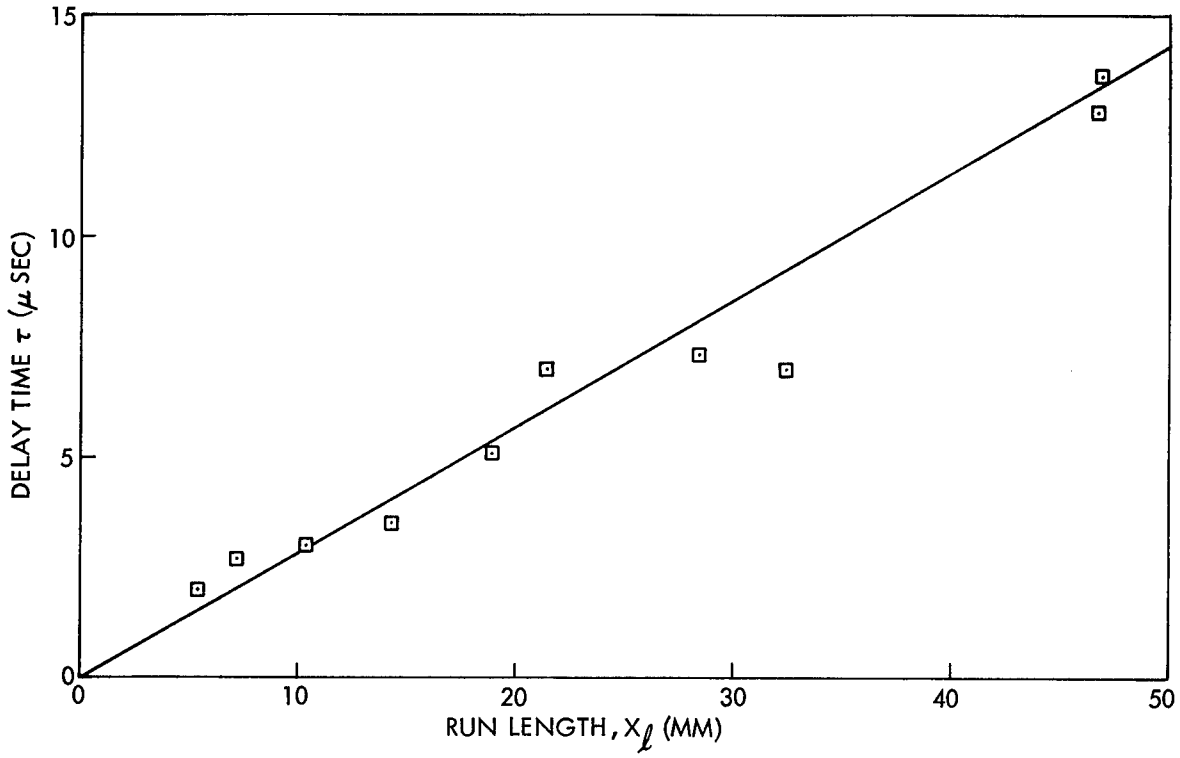

FIG. 5 τ VS X_ℓ FROM CONTINUOUS WIRE MEASUREMENTS IN COMP B

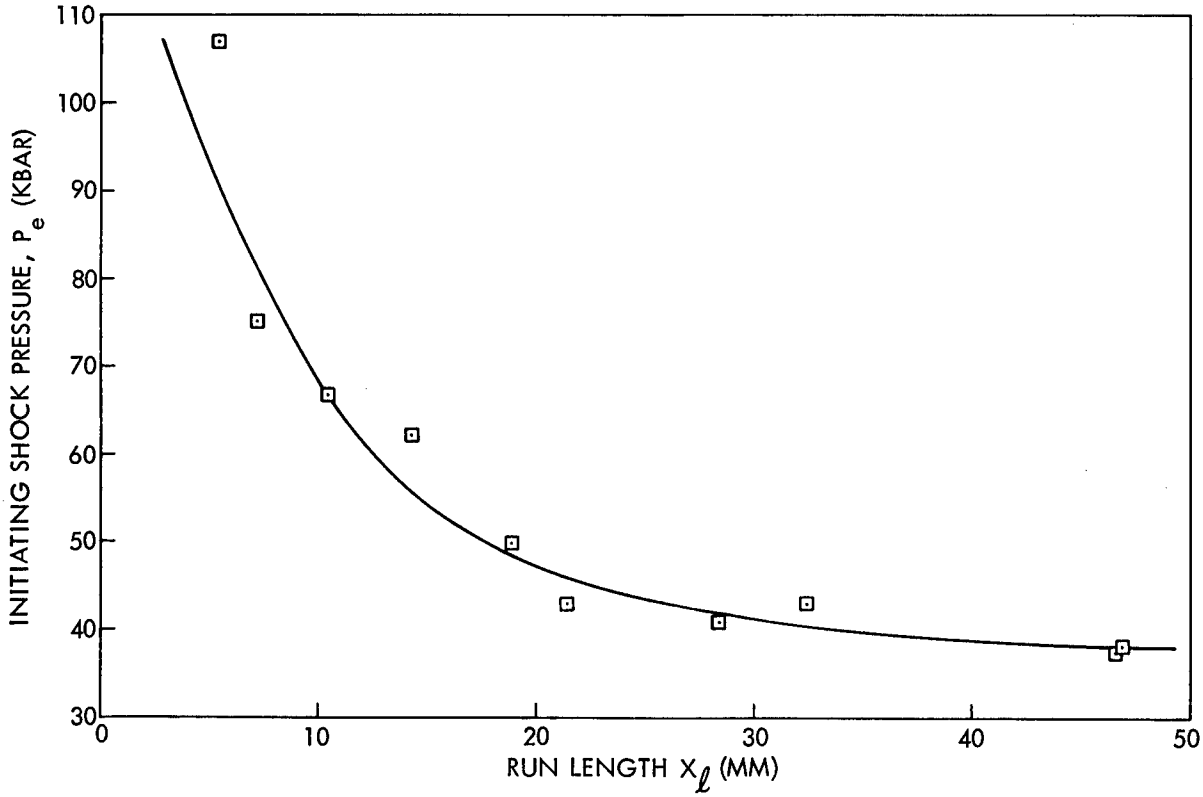

FIG. 6 P_e VS X_ℓ FROM CONTINUOUS WIRE MEASUREMENTS IN CAST COMP B

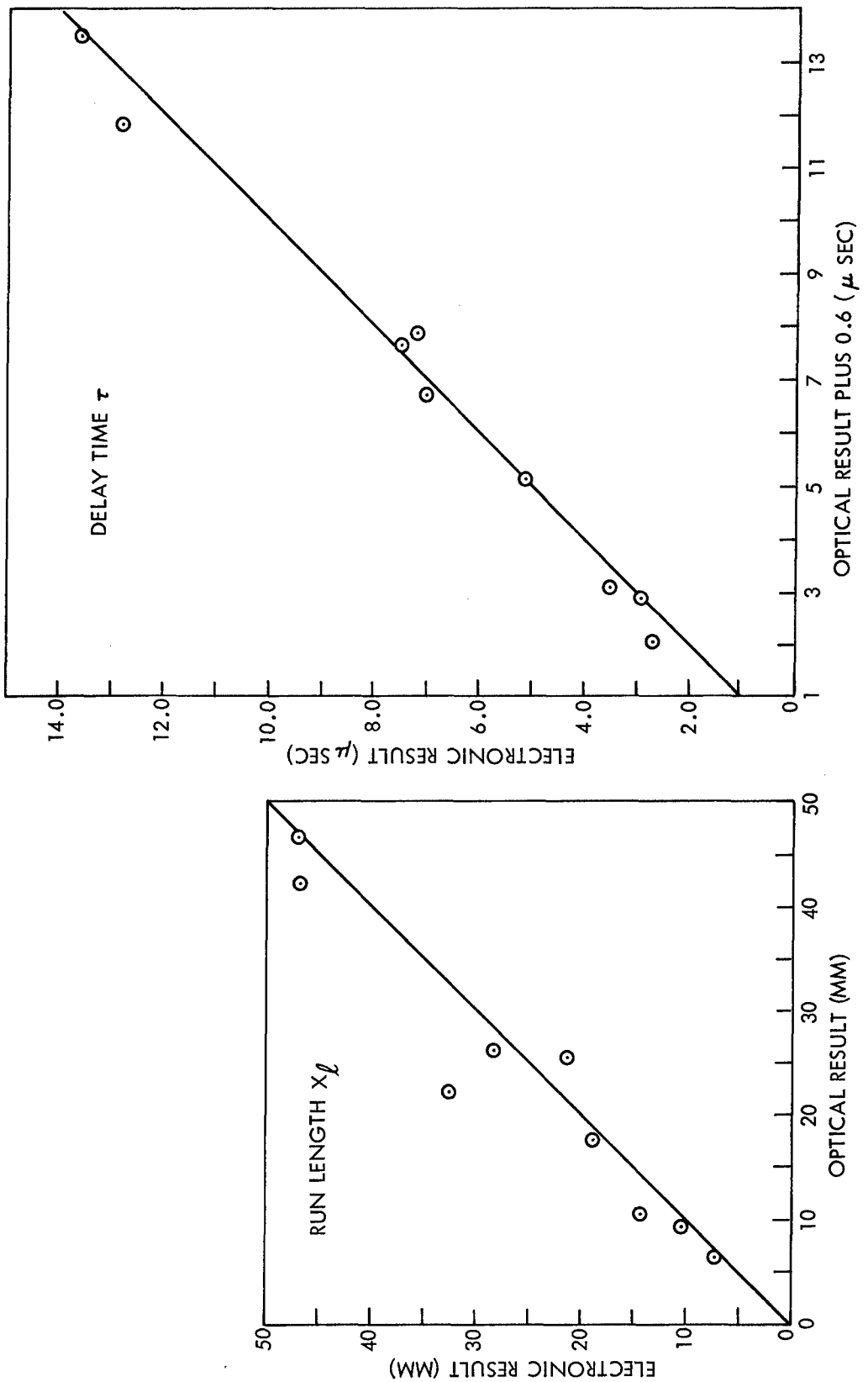

FIG. 7 ELECTRONIC VS OPTICAL MEASUREMENTS IN CAST COMP B

TABLE 3

MEASUREMENTS IN TWO AND THREE WIRE CHARGES OF COMP B

Shot No. Electronic	Shot No. Camera	Gap No. cards	No. wires in Charge	Electronic Results τ μsec	Electronic Results X_ℓ* mm	Optical Results X_ℓ mm	Optical Results τ_a μsec
6	45	100	3	3.6	12.5	10.5	2.5
17	301	100	3	3.6	13.4	11.9	**
18	302	100	2	4.1	20.4	11.7	**
3	36	125	3	5.1	17.4	17.6	4.6
11	295	125	2	5.7	22.4	16.5	**
12	296	125	2	5.5	25.4	16.8	**

* Read from Moleculoy records; results in Table 2 read from Differential records.

** Record of detonation (self-luminosity) only.

detonation transitions of this explosive. Its inadequacy here probably results from the slow growth to detonation in Comp B as compared to the relatively fast growth in DINA where its measurements seemed more satisfactory.

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2. Explosives - Detonation
3. Detonations - Velocity
I. Title
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III. Project

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