

LIGHT EMISSION DURING SHOCK INITIATION
OF LIQUID EXPLOSIVES.

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Summary.

A fast photo multiplier and oscilloscope have been used to study the rapid phenomena of transmission of detonation in liquid explosives through a barrier of 0.25 mm thick plastic film in 30 mm cylindrical charges.

The spectral distribution of the light and temperature variation in the re-initiation process have been studied, as well as the influence of donor charge detonation pressure.

All explosives investigated, which included NG, EGDN, and NM, as well as mixtures between two of these and also solutions in either of these of RDX, PETN, TNT, DNT, MNT, toluene, and metanol, were found to have a common pattern of behaviour. This pattern was found to change with the initiating pressure level. Immediate re-initiation (within less than 5 nsec) occurred at shock pressures high above their own detonation pressure. Delayed initiation with shock catch-up and overshoot occurred at lower pressure. At the lowest pressures investigated, a previously unknown pattern similar to that common in pressed, inhomogeneous explosives was observed.

Differences between different explosives in their chemical reactivity appear to have only a small effect on the delay time before detonation occurs in initiation with intense shock from a given donor system. The shock compression temperature, which increases rapidly with decreasing shock impedance, appears to be the decisive factor.

The report is a summary of a paper given at the Second Symposium on Chemical Problems connected with the Stability of Explosives, Tyninge, Sweden, May 25th-27th 1970, arranged by Sektionen för Detonik och Förbrännin

Introduction.

We have been studying homogeneous, liquid explosives at very high rates of reaction. We are then dealing with reactions at initial temperatures well over 1000°K , pressures over 100 kbar and reaction induction times or half lives down into the nanosecond range. These are the states occurring in the borderland between detonation and high intensity shock wave initiation.

We will be describing briefly the experimental method and some experiments aimed at estimating detonation temperatures. We will then summarize an initiation behaviour that is common to a great number of explosives. Finally, we will describe how a change in initial density or shock impedance brings about a change in shock temperature which usually is overwhelmingly large compared to other factors that influence the rate of reaction.

Experimental.

Figure 1 shows the charge arrangement. Through the black PVC barrier of thickness 0.25 mm a high amplitude shock wave is sent into the receptor charge. The light emitted in the receptor is recorded by a high speed photo multiplier oscilloscope recording assembly. This has been described in a previous publication (Persson et.al 1966).

Figure 2 shows typical records for NM in both donor and receptor at different barrier thicknesses. The time-scale is 50 nanosecond per cm. The shock wave enters the receptor earlier, but no light is emitted until the reaction gets under way after an induction period. Figure 3 shows the details of this in an x-t plot. The shock wave moves into the receptor driven by the barrier-receptor interface.

The initiation of liquid explosives as shown in figures 2 and 3 has been described in detail by Campbell et.al (1961).

Temperature estimate from spectral distribution.

Figure 4 shows records where narrow band interference filters were used to get a spectral distribution of the light. We see that the plateau is most developed at long wave-lengths. The evaluation of a number of such records is shown in figure 5.

Figure 6 shows the plateau light level and the peak over-drive level plotted relative to the steady detonation level. The latter is assumed to be black body radiation at 3800°K .

Response of different explosives to same input shock.

Figure 7 shows the three explosives NG, EGDN, and NM (total emission). NM has the longest, EGDN the shortest delay. The amplitude differences 1:0.82:0.11 show in an exaggerated way that NG has the highest and NM the lowest temperature; exaggerated because the SII phosphor of the photo-multiplier cathode is most sensitive at the short wave length foot of the emission curve. In fact, the real differences are not more than 500°K .

Response of one explosive to different input shocks.

Figure 8 shows the range of light emission behaviour common to all the explosives investigated. With a considerable degree of over-drive, we get an initiation delay too short to measure here with the present equipment, which means below 5 nanosec. At the low input shock amplitudes we see a gradual increase in light different from the normal plateau process. We believe that this type of initiation process is similar in nature to that in inhomogeneous explosives.

Table 1 and figure 9 shows a plot of delay times measured from records such as those in figure 8, plotted versus donor detonation pressure.

In order to get immediate reaction, we need donor C-J pressures roughly twice those of the receptor C-J pressure.

Table 2 shows various calculated shock temperatures at different shock pressures in nitromethane. Judging from the previous figure (9) we thus need temperatures above 2500°K to start reaction immediately.

Effects of additives.

Figure 10 shows the effect of adding various percentages of methanol to NG. Initiation delay clearly decreases with increasing percentage of additive. This is interesting because methanol is often used to desensitize NG.

Table 3 shows the effect on initiation delay of the series of additives we have used with NG as a base. The density of the additive appears decisive.

Adding a low density material generally decreases the shock impedance of the explosive. This will result in a higher shock temperature for a given donor system.

The higher the shock temperature, the shorter the initiation delay.

The list of additives in table 3 represents a collection of various

compounds, thought to have widely different desensitizing properties when added to NG. We find no correlation between such chemical desensitizing effects encountered in slow decomposition experiments and the changes in initiation delay observed in the present experiments.

We conclude that the major parameter determining the effect on shock initiation delay of an additive is its capacity to increase or decrease the density of the explosive. For almost all the additives investigated, the resulting change in shock temperature level dominates over the chemical desensitizing

References.

- Campbell, A.W., Davis, W.C., and Travis, J.R. "Shock initiation of detonation in liquid explosives" *Phys. Fluids* 4, 498(1961).
- Persson, P.A., Andersson B., and Ståhl, S.O, "A technique for detailed, time-resolved radiation measurements in the reaction zone of condensed explosives. Proc. 4th NOL Symp. on Detonation. Silver Spring, Maryland, 1965. Office of Naval Research ACR-126 (1966).
- Persson, P.A. and Sjölin, T. "Light emission during initiation of liquid explosives". Swedish Detonic Research Foundation Report DS 1969.
- Persson, P.A. and Sjölin, T. "Light emission during initiation of liquid explosives". Preprints, 5th Symposium (International) on Detonation, Pasadena, California 1970. Office of Naval Research DR-163 (1970).

Table I.

VARIATION OF INITIATION DELAY WITH
DONOR DETONATION PRESSURE.

BARRIER: 0.25 mm PVC

DONOR CHARGE			DELAY	
COMPOSITION	DETONATION PRESSURE	kbar	NM nsec	NG nsec
59/41 HMX/NG	330		<5	20
60/40 HMX/TNT	315		<5	50
NG	266		<5	100
42/58 NG/NM	175		20	400
NM	127		100	300
96/4 NM/MNT	≈ 110		400	-

Table 2.

ESTIMATED SHOCK TEMPERATURES
IN NITROMETHANE

Shock Pressure Kbar	Temperature °K
0	273
69	981
85	1200
92	1300
108	1545
126	<u>1617</u>
144	2115
164	2435
208	3164
257	3992
337	5427

Table 3.

EFFECT OF ADDITIVES ON NG INITIATION
DELAY

ADDITIVE	DENSITY AT 18°C g/cm ³	DELAY
Metanol	0.793	decreases
Toluene	0.89	"
NM	1.13	"
MNT	1.16	"
DNT	1.28	" or increases ^{x/}
EGON	1.48	decreases
NG	1.60	-
TNT	1.64	increases or no change ^{x/}
PETN	1.67	increases
RDX	1.80	increases

^{x/}

Depending on donor charge pressure

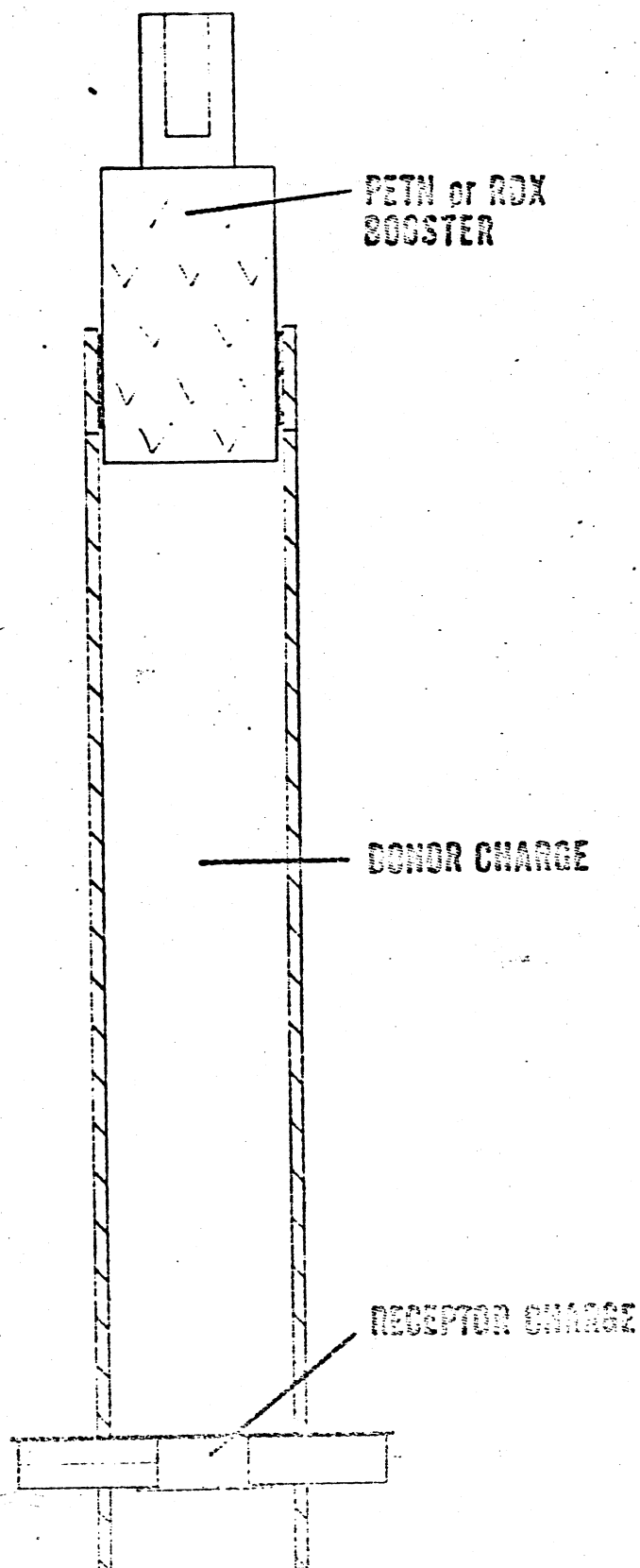
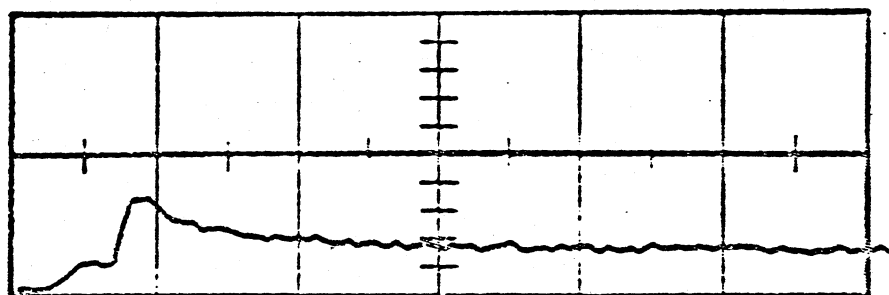
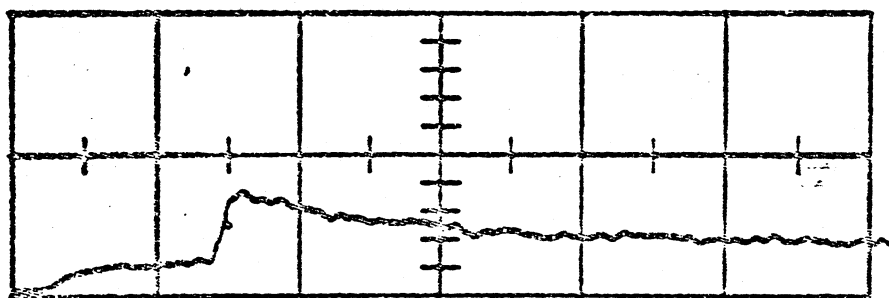


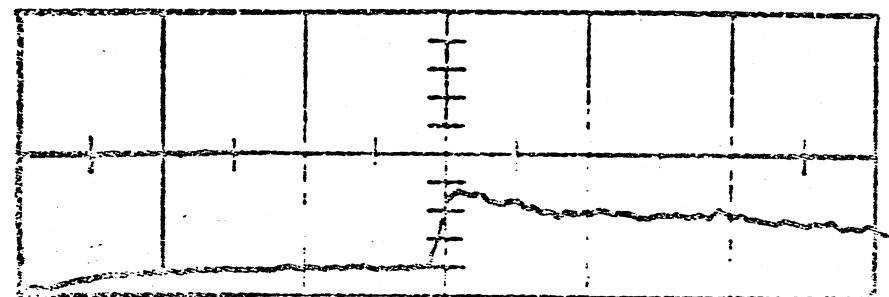
Figure 1. Charge arrangement.



0.14 mm

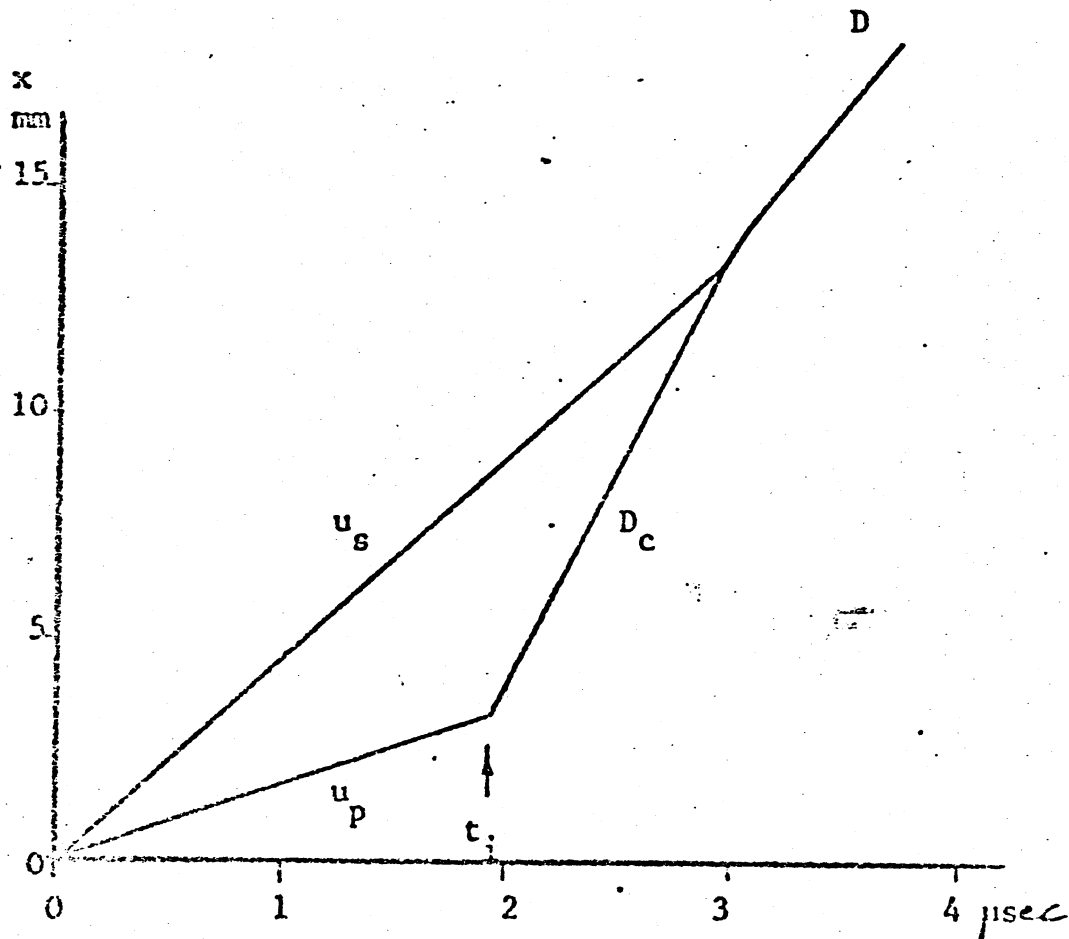


0.25 mm



0.75 mm

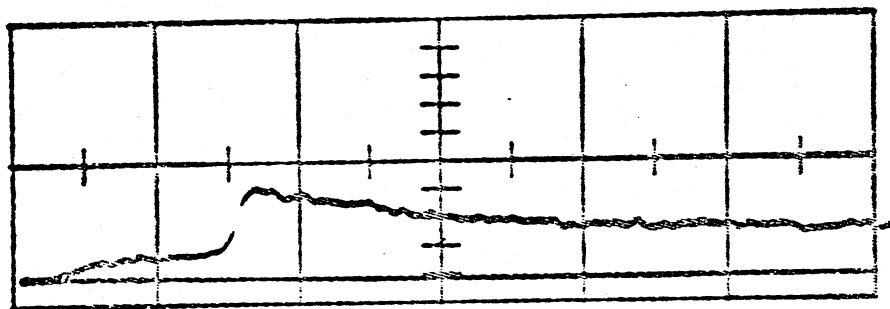
Figure 2. Light emission from initiation of NM through PVC barriers of different thicknesses. Sweep speed 50 nsec/cm.



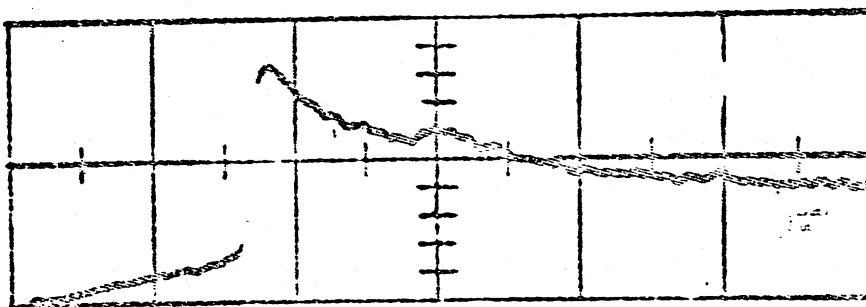
Space-time representation of the shock initiation of nitromethane.

$p = 81 \text{ kbar}$; $u_p = 1.60$, $u_s = 4.50$, $D_c = 10.0 \text{ km/s}$,
 $D = 6.29 \text{ km/s}$

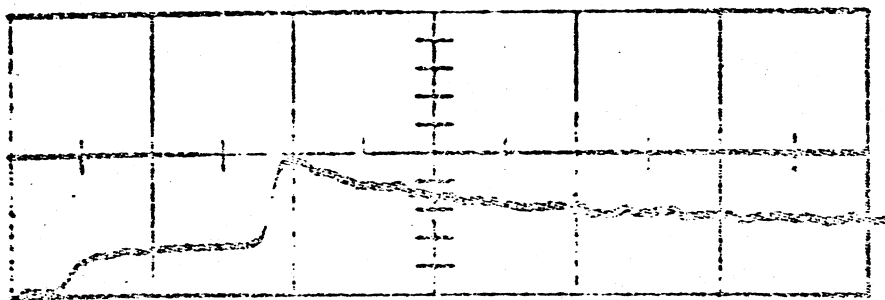
Figure 3. Space-time representation of the shock initiation of nitromethane.
 $p = 81 \text{ kbar}$; $u_p = 1.60$, $u_s = 4.50$, $D_c = 10.0 \text{ km/s}$, $D = 6.29 \text{ km/s}$.



TOTAL

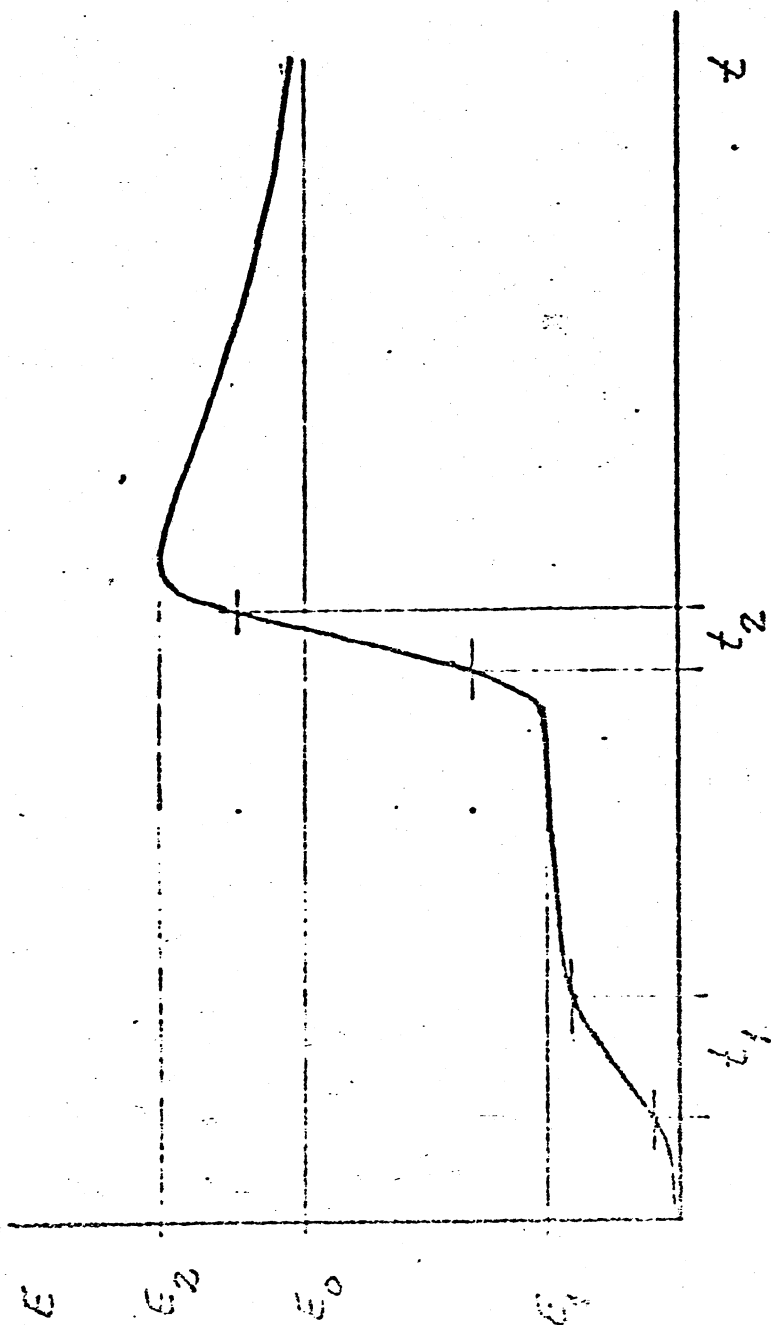


4000 Å



6330 Å

Figure 4. Total light emission and emission through narrow-band filters at 4000 Å and 6330 Å. Amplitudes are not comparable. Sweep speed 50 nsec/cm.



$$t_1 : 0.2E_1 \leftrightarrow 0.8E_1$$

$$t_2 : E_1 + 0.2(E_2 - E_1) \leftrightarrow E_1 + 0.8(E_2 - E_1)$$

Figure 5. Definition of rise-times and amplitudes in spectral distribution experiments.

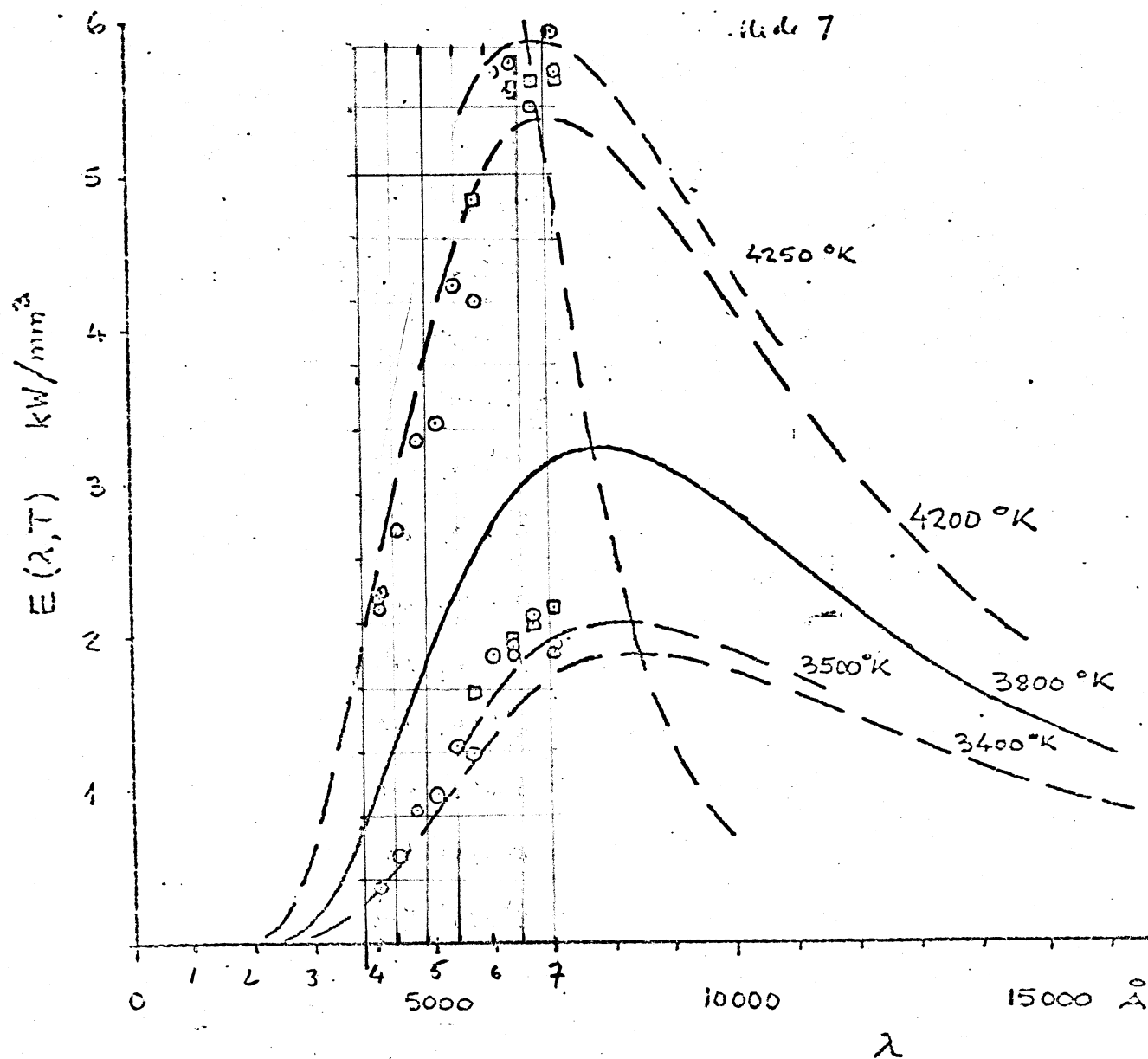


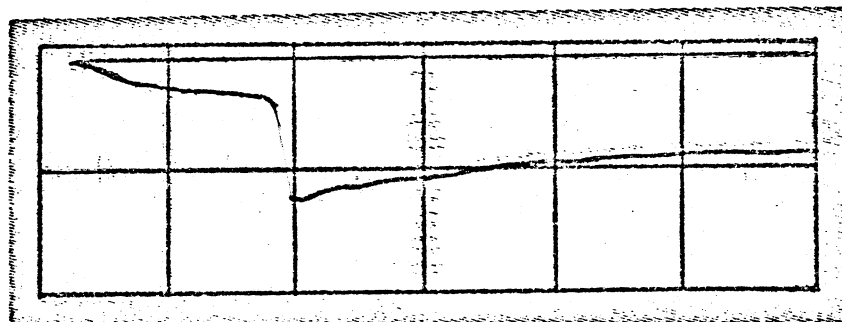
Figure 6. Spectral distribution of light emission during initiation of NM by a NM donor and different thicknesses of PVC barriers. Upper set of points, peak amplitude, and lower set of points, amplitude of pre-compressed detonation; both relative to steady state level, assumed to be at a temperature of 3800°K (full line).

EXPLOSIVE

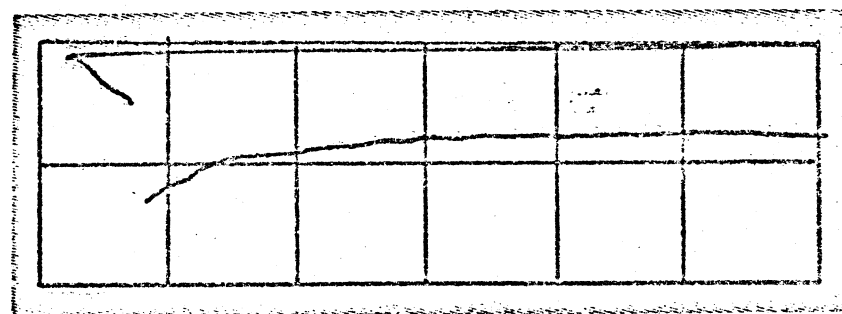
DONOR CHARGE

42/58 NG/NM

NG



EGDN



NM

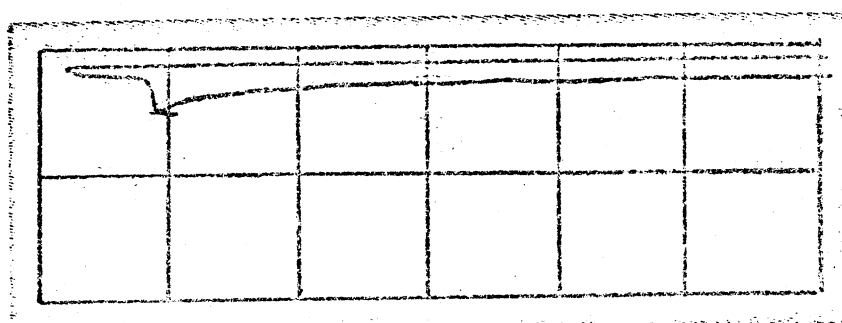
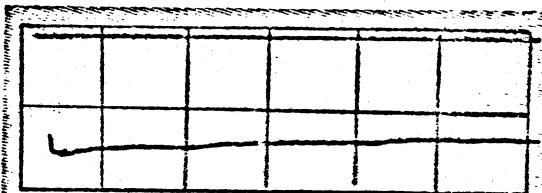


Figure 7. Comparison between different pure explosives. Donor charge 42/58 NG/NM. Sweep speed 50 nsec/cm. Comparable amplitudes. Barrier: 0.25 mm PVC.

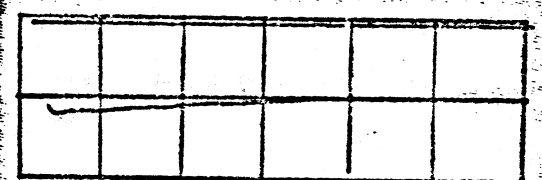
DONOR CHARGE

RECEPTOR CHARGE NM

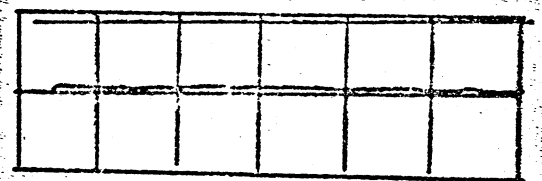
59/41 HMX/NG



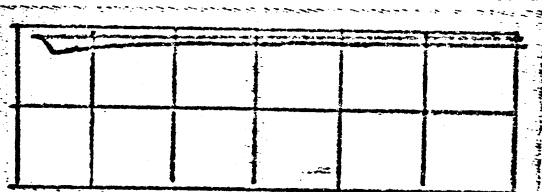
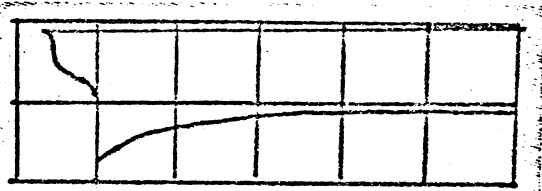
60/40 HMX/TNT



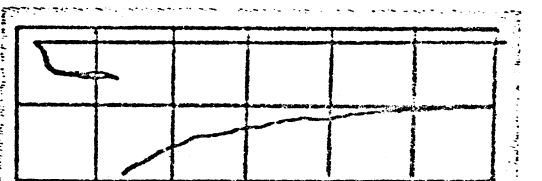
NG



42/58 NG/NM

NM

96/4 NM/MNT



35/5 NM/MNT

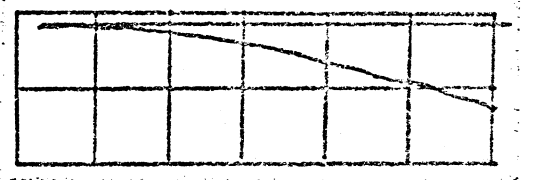


Figure 8. Light emission from initiation of NM with different donors. Barrier: 0.25 mm PVC. Sweep speed 200 nsec/cm. Amplitudes comparable except 42/58 NG/NM record.

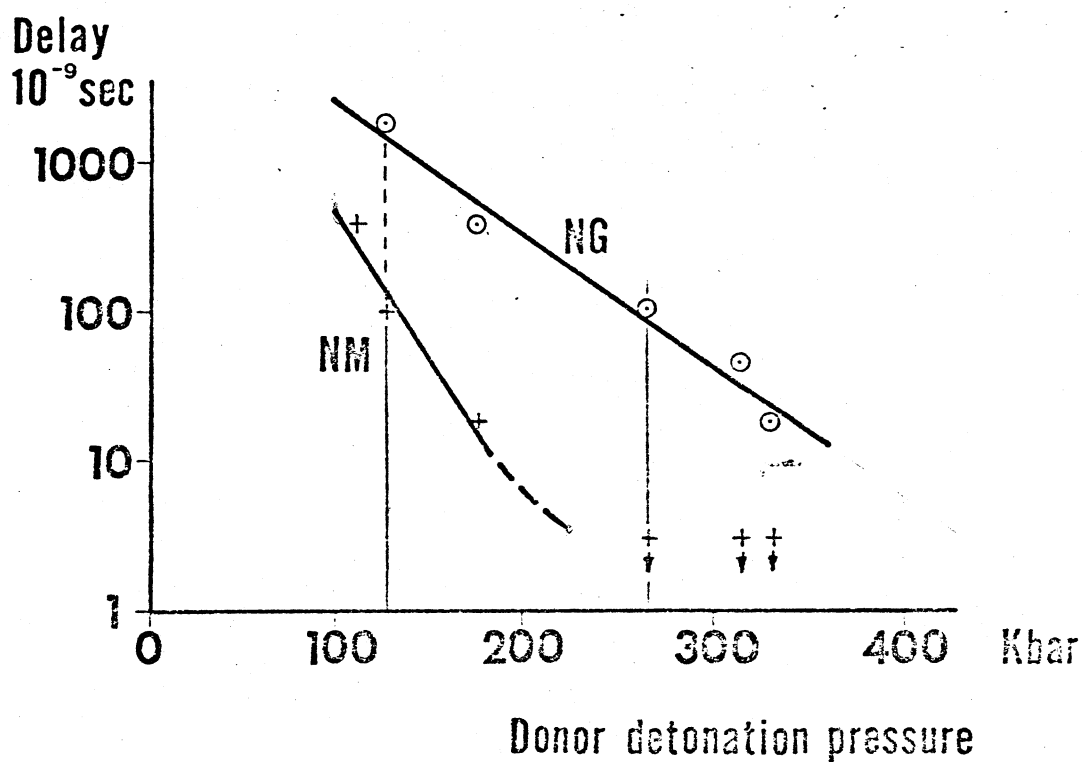


Figure 9. Initiation delay of NM and NG behind 0.25 mm PVC barrier as a function of the detonation pressure of the donor explosive,

RECEPTOR CHARGE
% metanol in NG

DONOR CHARGE
42/58 NG/NM

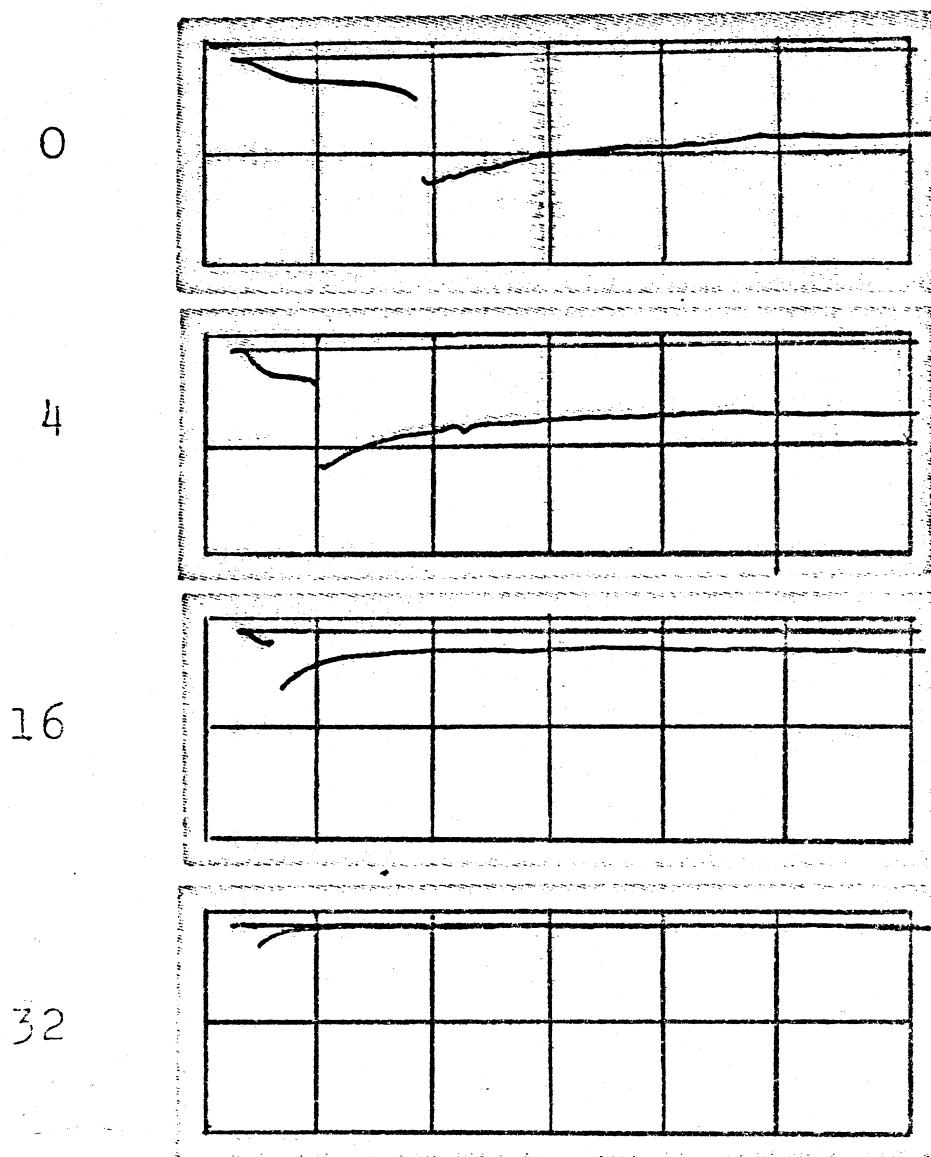


Figure 10. Effects of metanol added to NG. Sweep speed 50 nsec/cm. Comparable amplitudes.