Instability of detonation waves in mixtures of tetranitromethane with methanol and nitrobenzene

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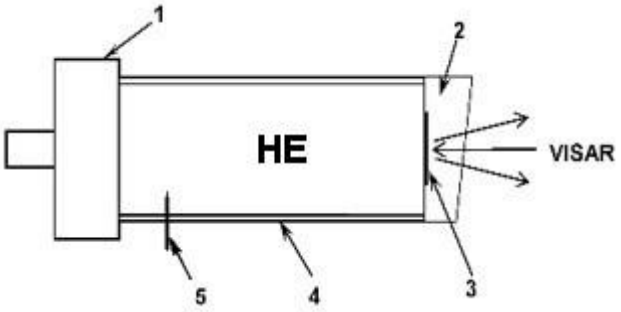
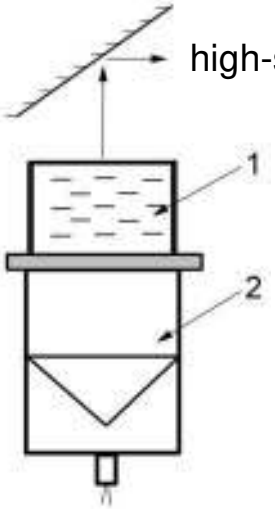
CONTENT:

- Instability of one-dimensional detonation waves (cellular instability);
- Instability of the explosive/shell boundary (reaction disruption waves);
- Instability under shock-wave initiation of detonation;
- Reproducibility of detonation parameters in the vicinity of stoichiometric diluent concentration

Experimental methods of explosive detonation research



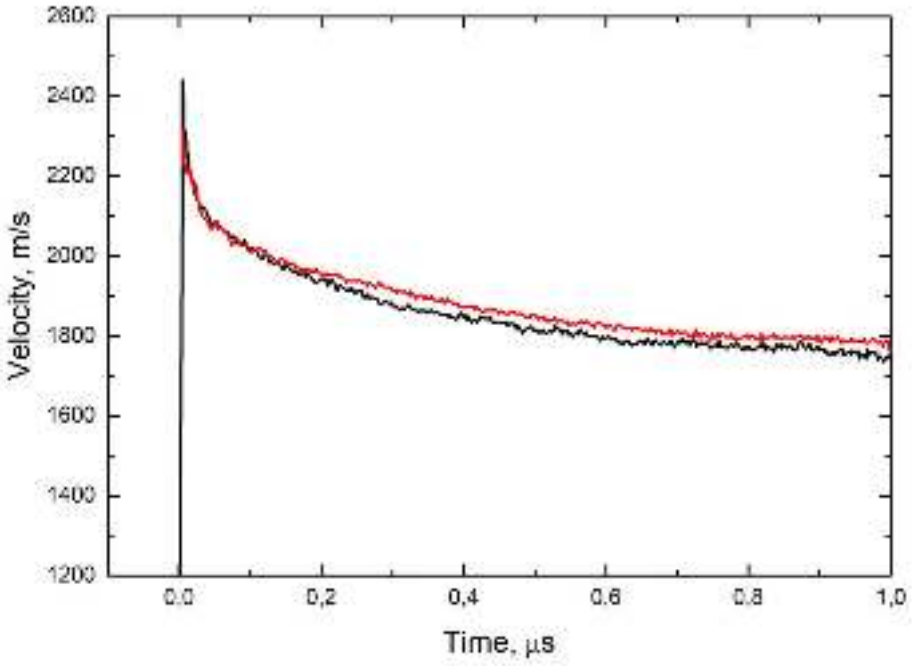
8-channel laser interferometer VISAR



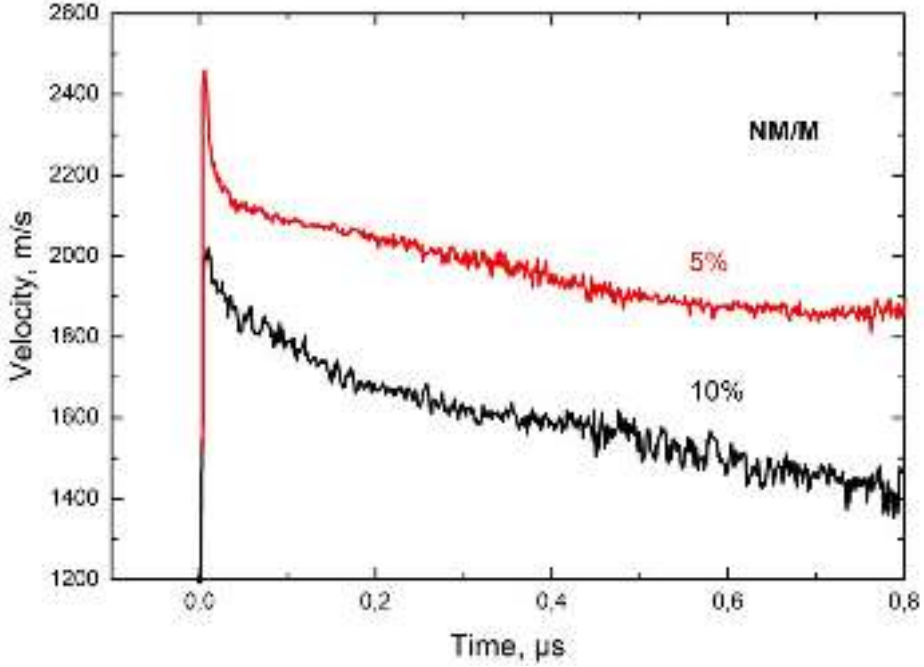
1 - TNM/diluent;
2 – initiating explosive.

- **NANOGATE-22/16 High-Speed Camera;**
- **High-speed streak camera**

Cellular instability: velocity profiles in mixtures of NM with diluents

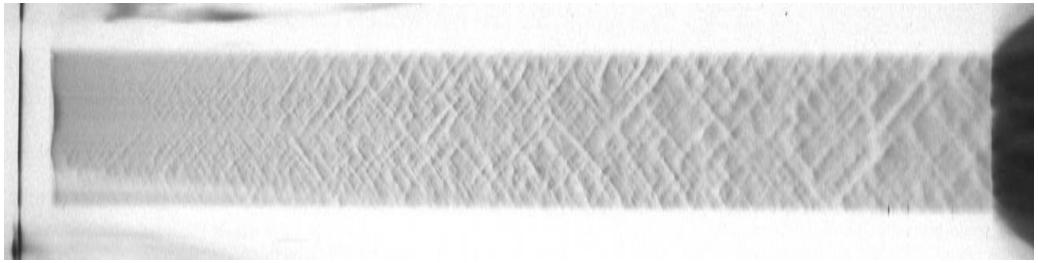


Velocity profiles at the NM/water boundary

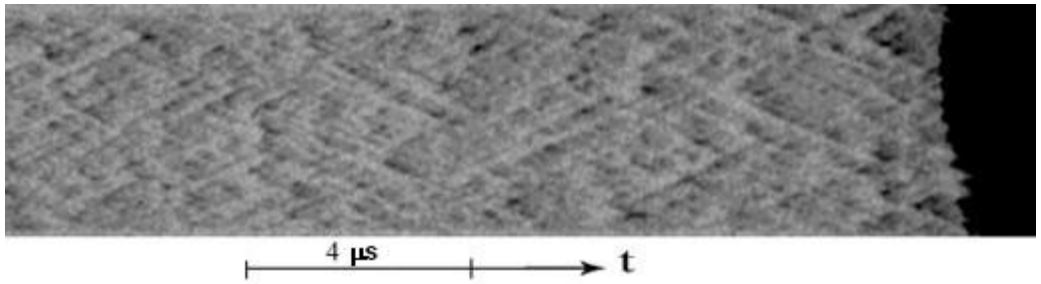


Velocity profiles of the mixture NM/M at the water boundary

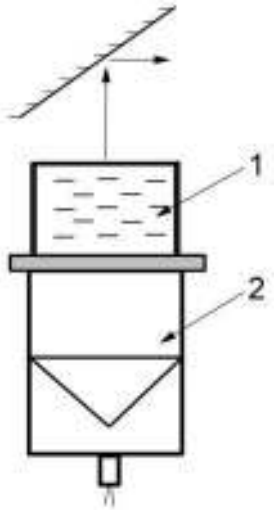
Cellular instability: mixtures of nitromethane with diluents



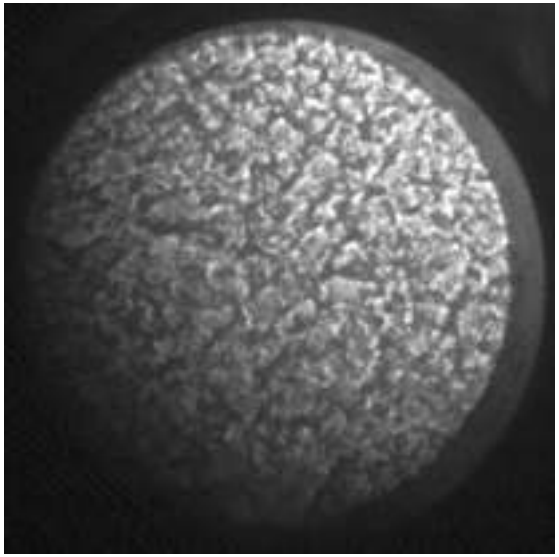
High-speed streak camera. The glow of the detonation front in the mixture of NM/NB 66/34.



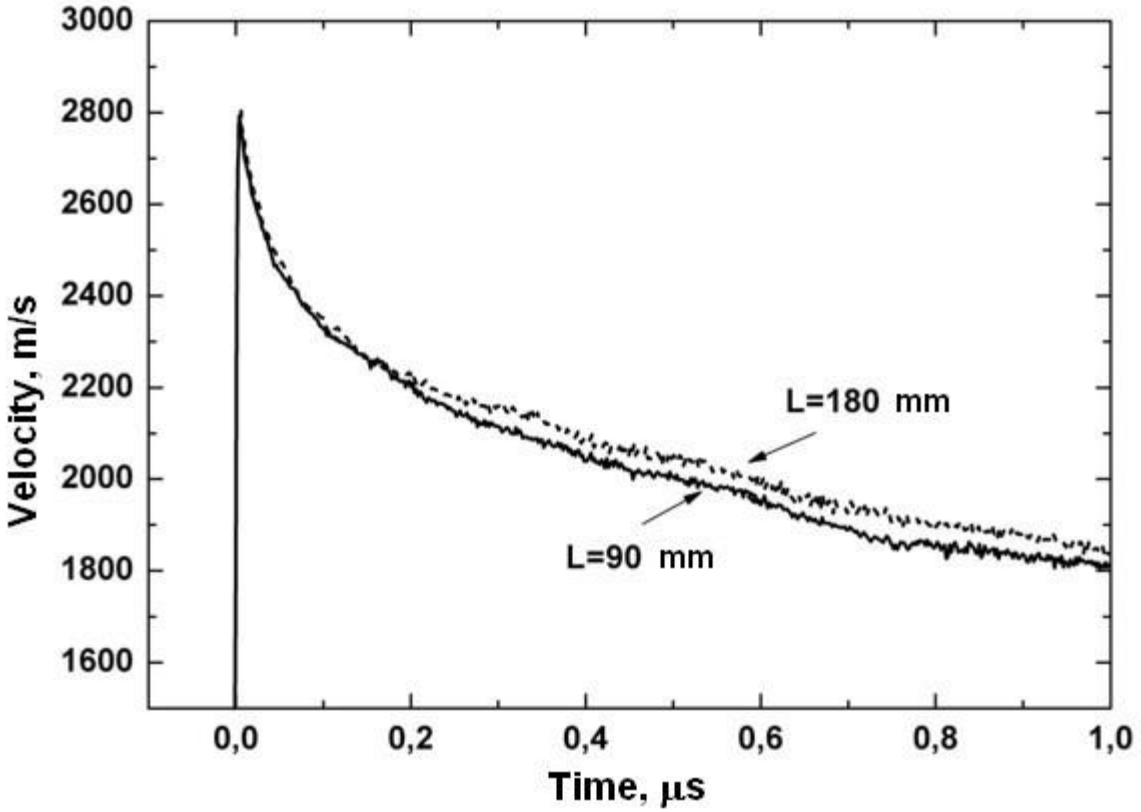
High-speed streak camera. The glow of the detonation front in the mixture of NM/M 65/35.



NANOGATE-22/16 High-Speed Camera. The glow of the detonation front in the mixture of NM/A 80/20.



Cellular instability: velocity profiles in TNM $C(NO_2)_4$

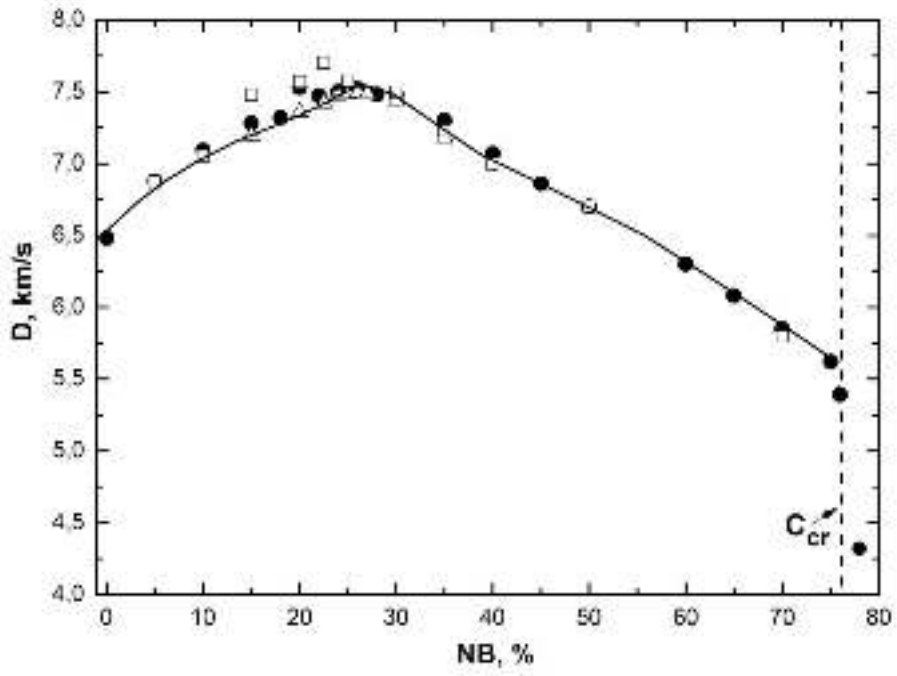


The velocity of the TNM – water boundary with a diameter of the polyethylene shell of 20 mm and a different length of charge.

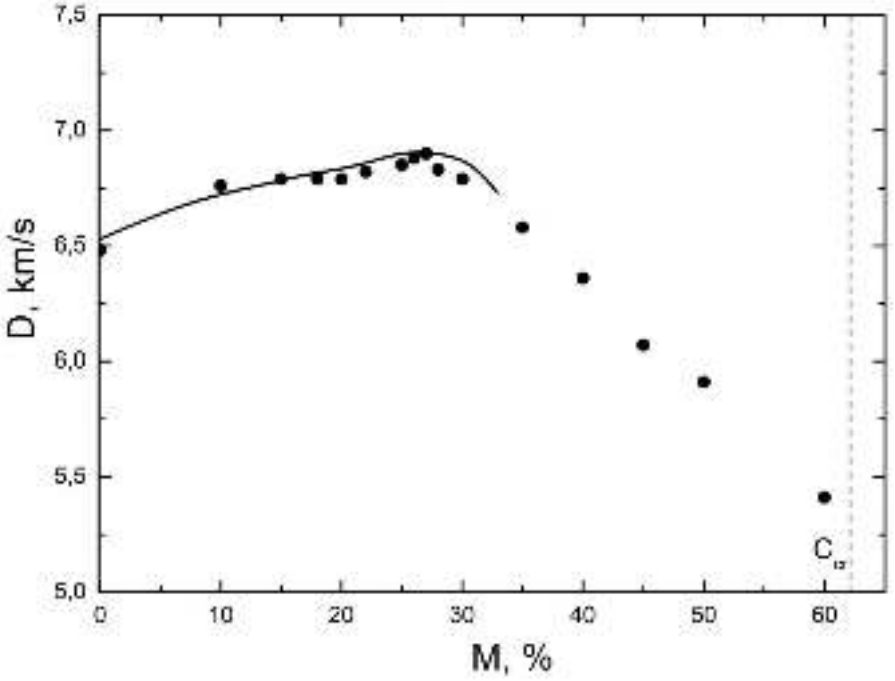
Reaction time:
τ= 150-200 нс;

C-J parameters:
D = 6.48 km/s
u_{CJ}= 1.55 ± 0.03 km/s;
P_{CJ} = 16.5 ± 0.3 GPa.

Cellular instability: detonation velocity in TNM/NB and TNM/M

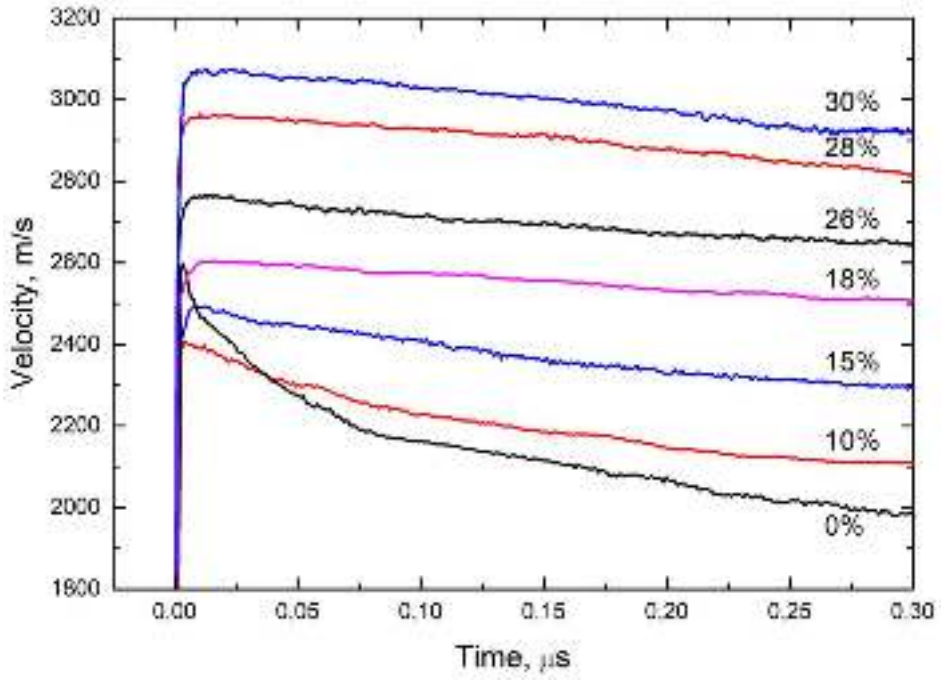


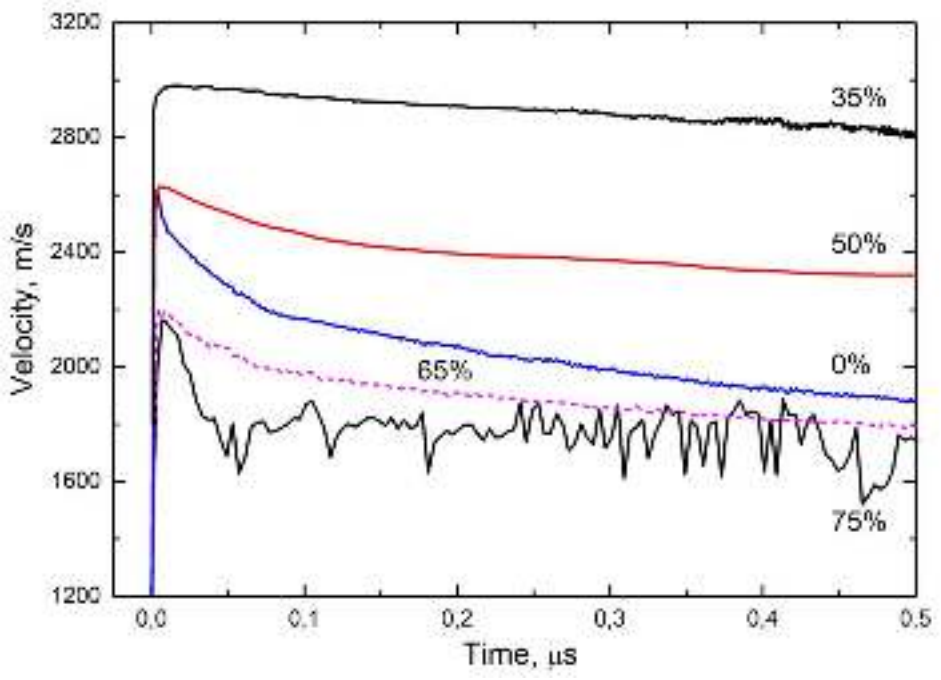
The dependence of detonation velocity for the mixture of TNM /NB on the concentration of NB. Stoichiometric concentration is 76.85/23.15



The dependence of detonation velocity for the mixture of TNM/M on the concentration of M. Stoichiometric concentration is 75.4/24.6

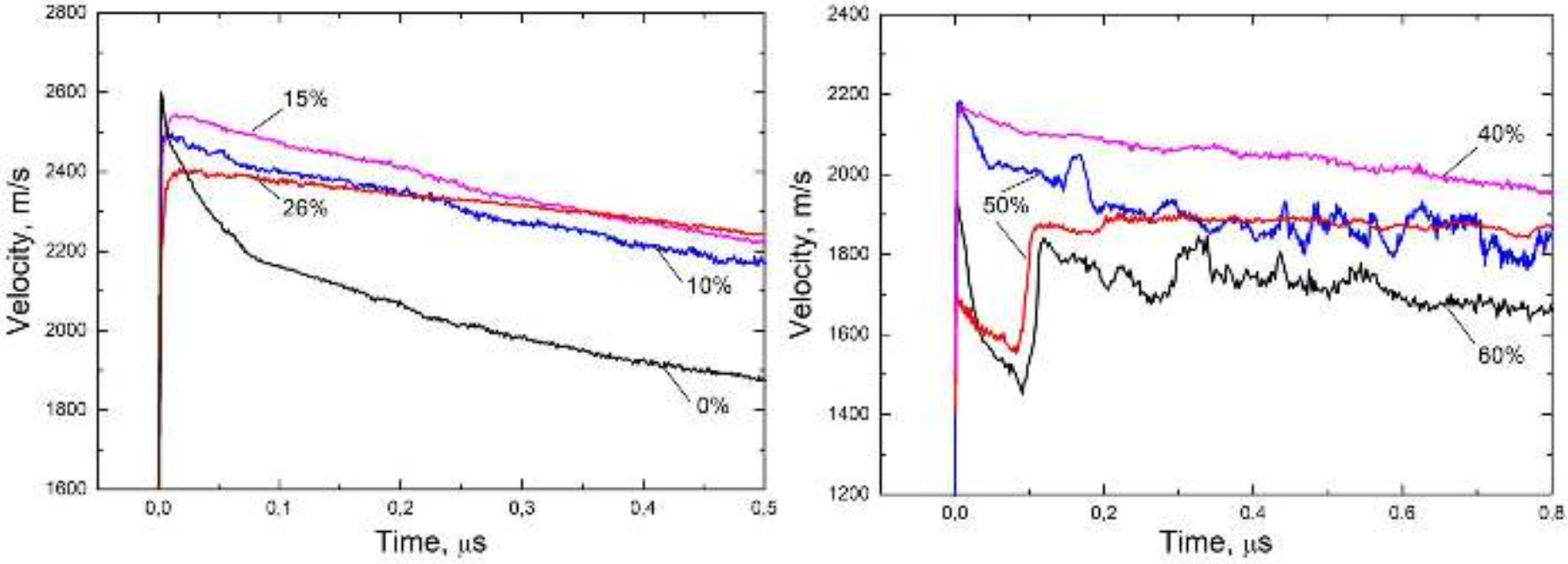
Cellular instability: velocity profiles in the mixture TNM/NB





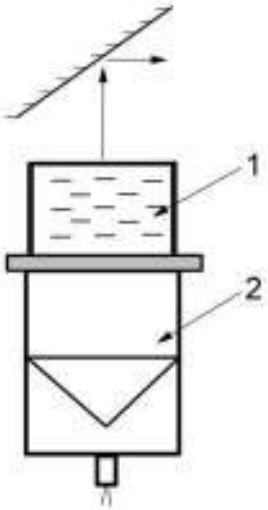
Velocity profiles of the TNM/NB mixture at the boundary with water at different concentrations of nitrobenzene

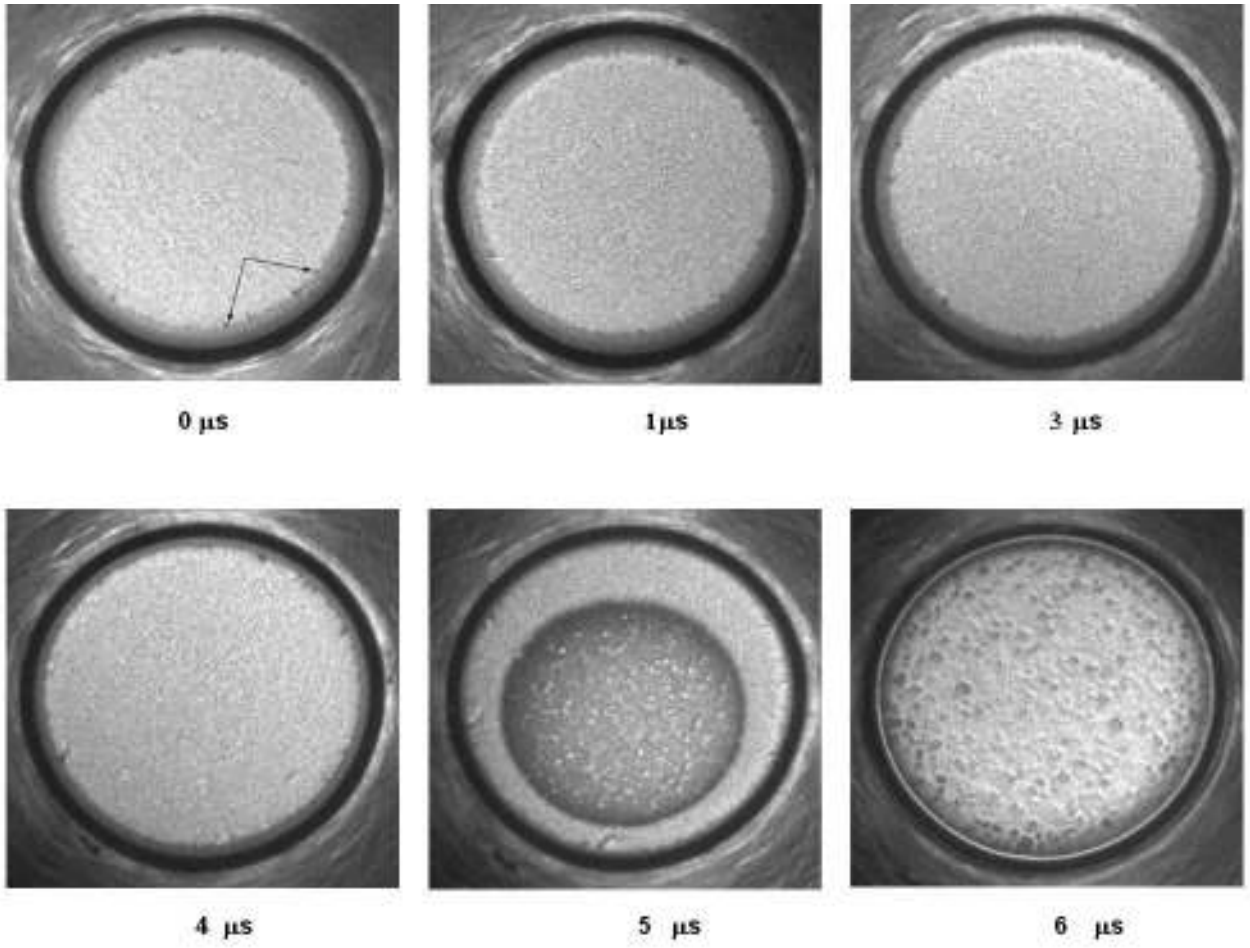
Cellular instability: velocity profiles in the mixture TNM/M



Velocity profiles of the mixture TNM/M at the boundary with water at different concentrations of methanol

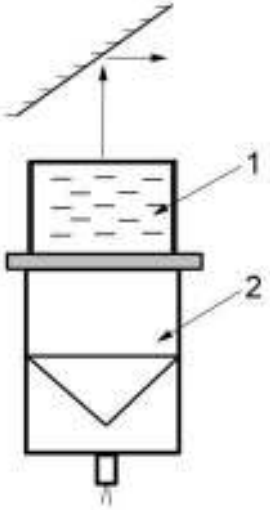
Cellular instability: the mixture TNM/M 50/50



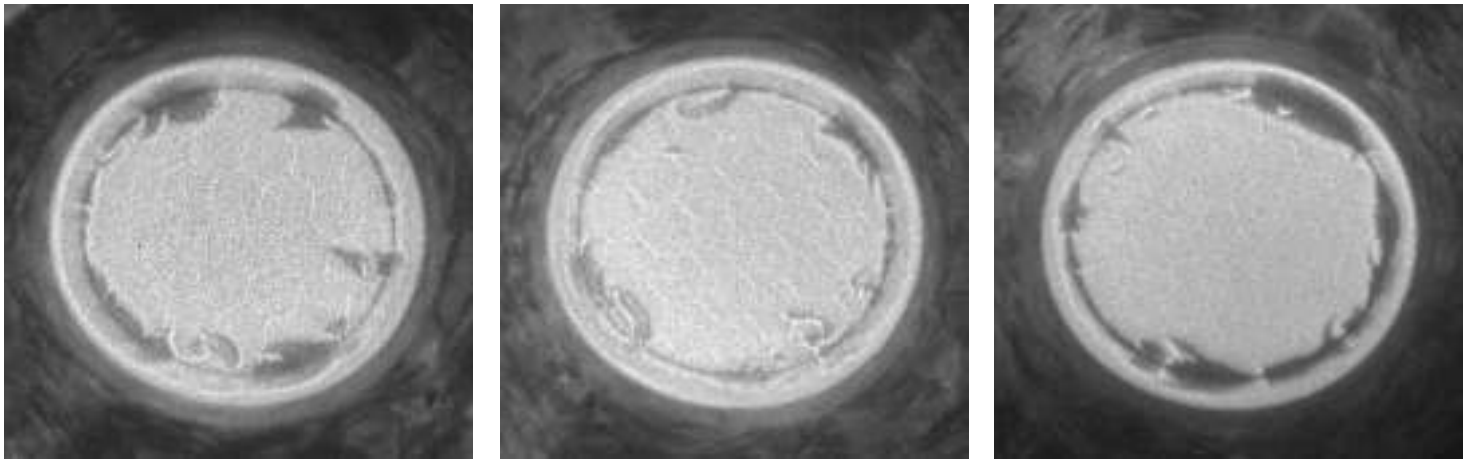


NANOGATE-22/16 High-Speed Camera. The glow of the detonation front in the mixture of TNM/M 50/50.

Instability of the explosive/shell boundary: NM



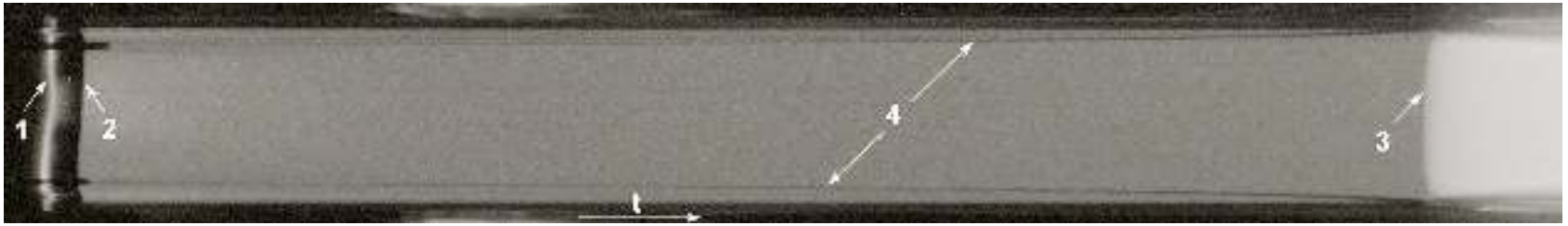
High-speed streak camera. The glow of the detonation front in NM.



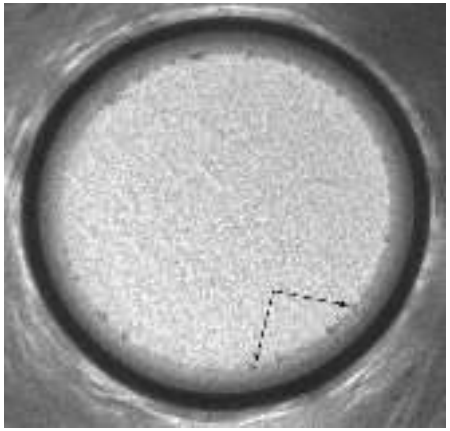
0 μs 1 μs 3 μs

NANOGATE-22/16 High-Speed Camera. The glow of the detonation front in NM

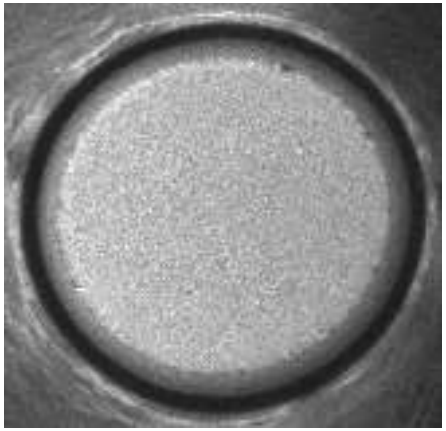
Instability of the explosive/shell boundary: TNM/M



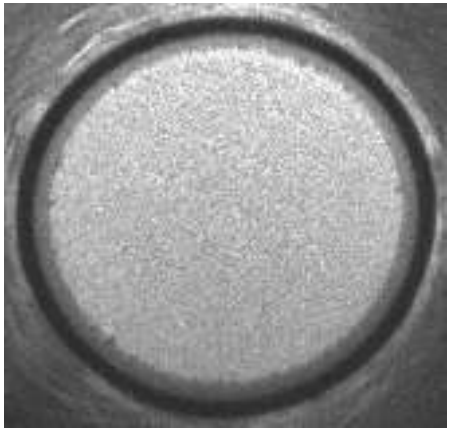
High-speed streak camera. The glow of the detonation front in the mixture TNM/M 60/40.



0 μs



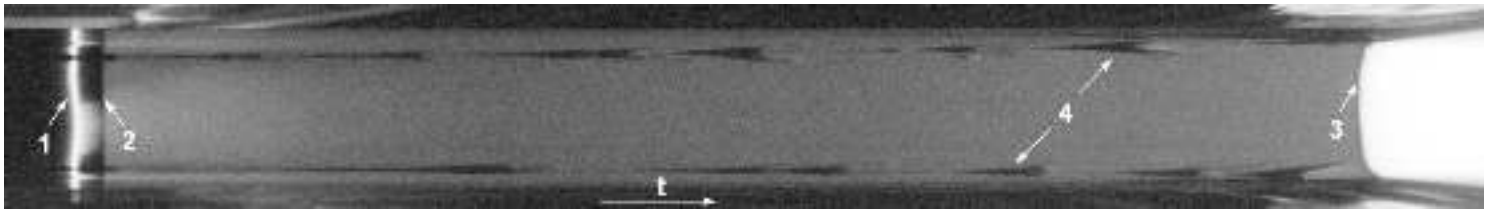
1 μs



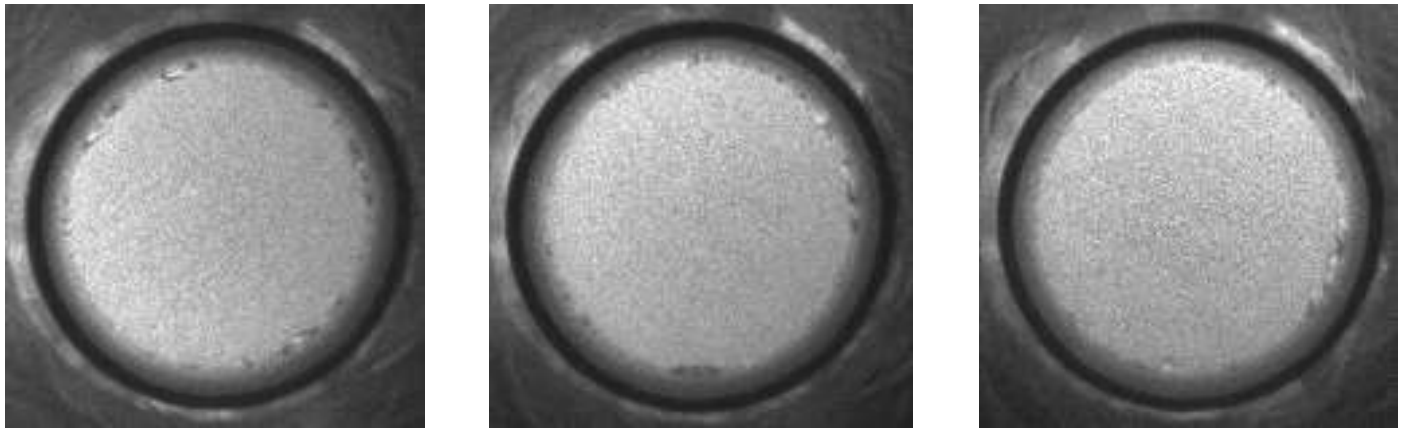
3 μs

NANOGATE-22/16 High-Speed Camera. The glow of the detonation front in the mixture TNM/M 50/50

Instability of the explosive/shell boundary: TNM/NB



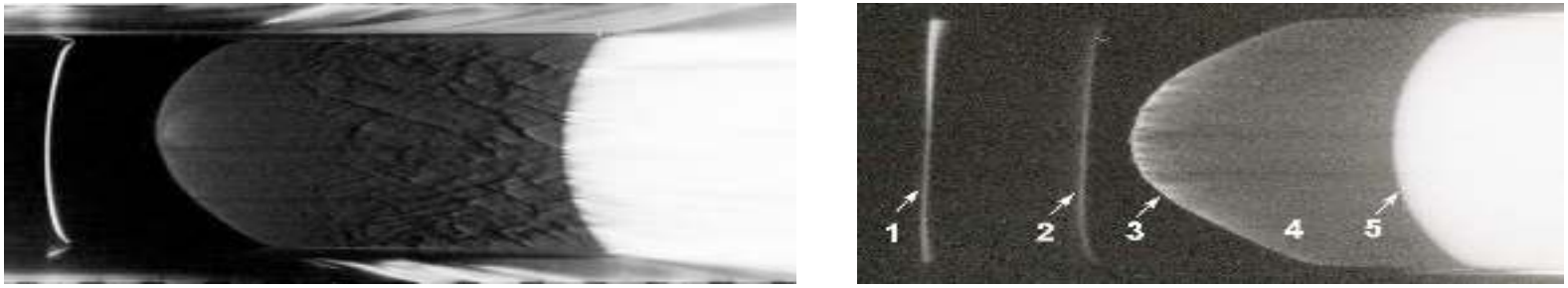
High-speed streak camera. The glow of the detonation front in the mixture TNM/NB 35/65



0 μs 1 μs 2 μs

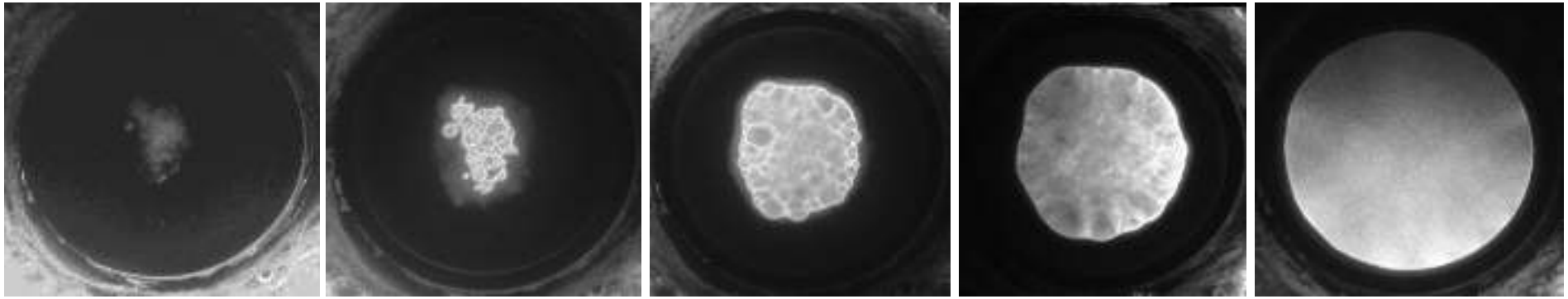
NANOGATE-22/16 High-Speed Camera. The glow of the detonation front in the mixture TNM/NB 35/65

Instability under shock-wave initiation of detonation: TNM



a *b*

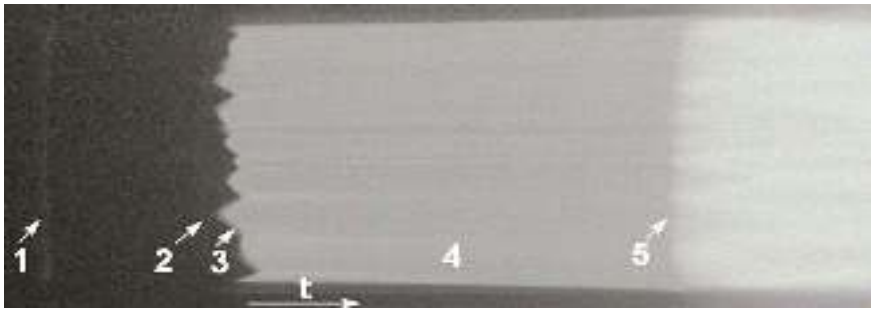
High-speed streak camera. *a* – TNM/M 40/60; *b* – *TNM: 1 –the exit of detonation wave from the active explosive charge to the PMMA screen, 2 – the input of the shock wave to the TNM, 3 – the detonation front, 4 – the detonation region, 5 – the exit of detonation wave to a free surface.*



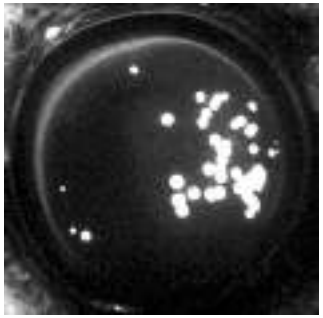
t

NANOGATE-22/16 High-Speed Camera. The glow of the detonation front for TNM. The interval between frames is 0.3 microseconds

Instability under shock-wave initiation of detonation: TNM/NB

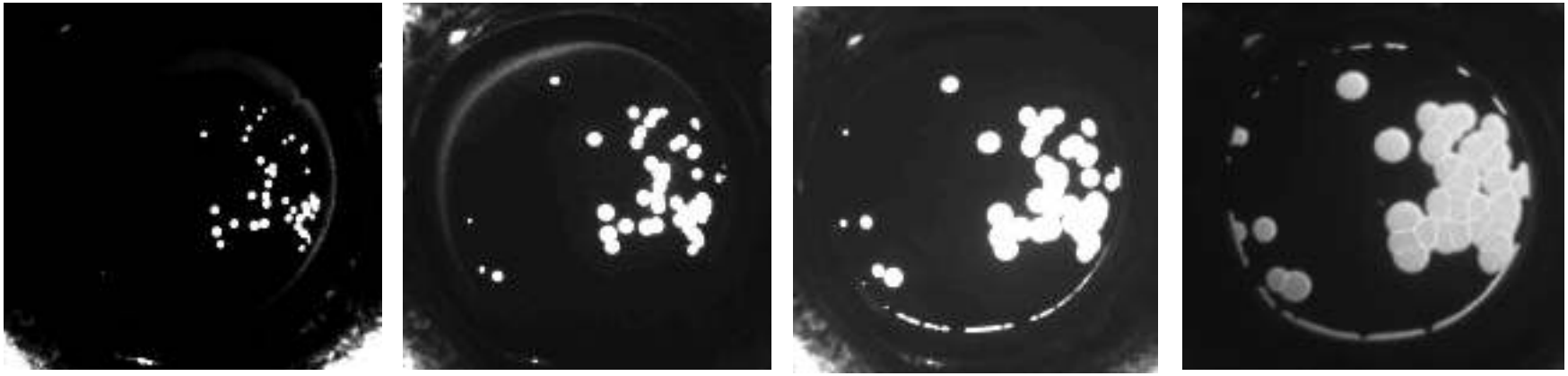


a



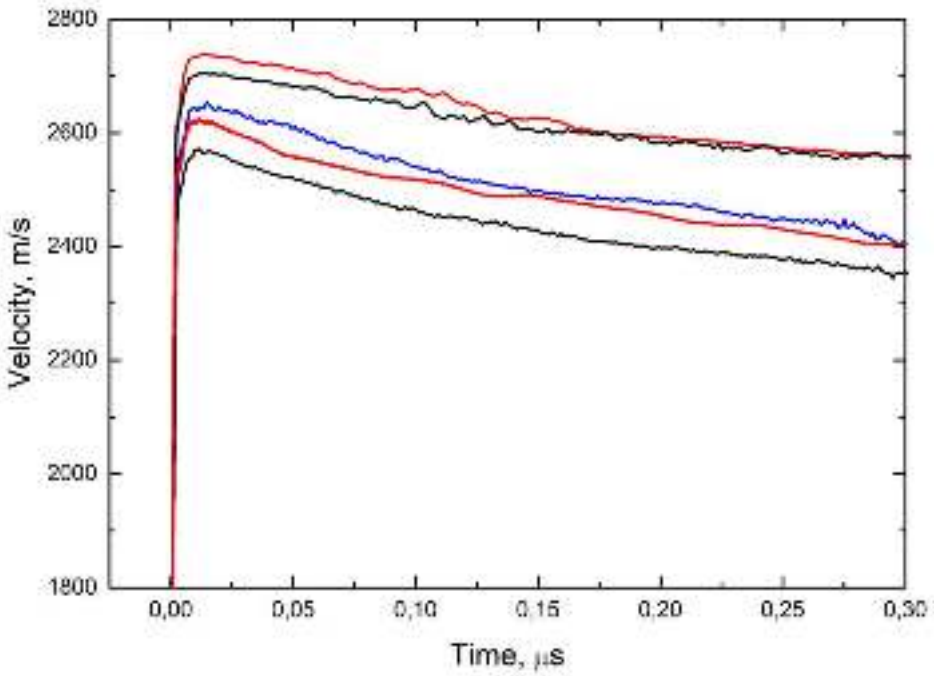
b

High-speed streak camera (*a*). TNM/NB 85/15: ***1 –the exit of detonation wave from the active explosive charge to the screen, 2 – the input of the shock wave to the TNM/NB, 3 – the detonation front, 4 – the detonation region, 5 – the exit of detonation wave to a free surface.***

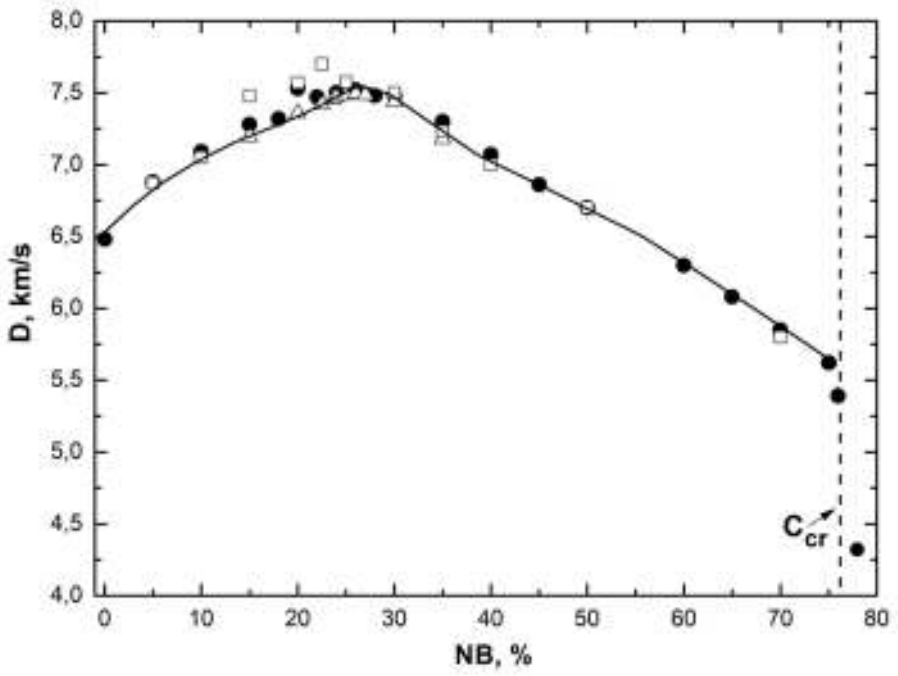


NANOGATE-22/16 High-Speed Camera. The glow of the detonation front for TNM/NB. The interval between frames is 0.1 microseconds

Reproducibility of detonation parameters in the vicinity of stoichiometric diluent concentration



Velocity profiles of the mixtureTNM/NB 76/24 at the boundary with water.
Stoichiometric concentration is 76.85/23.15



The dependence of detonation velocity for the mixture of TNM /NB on the concentration of NB.
△ - [1] □ - [2] ● - [3]

1. - Zotov E.V. Electric-spark initiation of liquid high explosives. – Sarov, RFNC-VNIIEF, 2004;

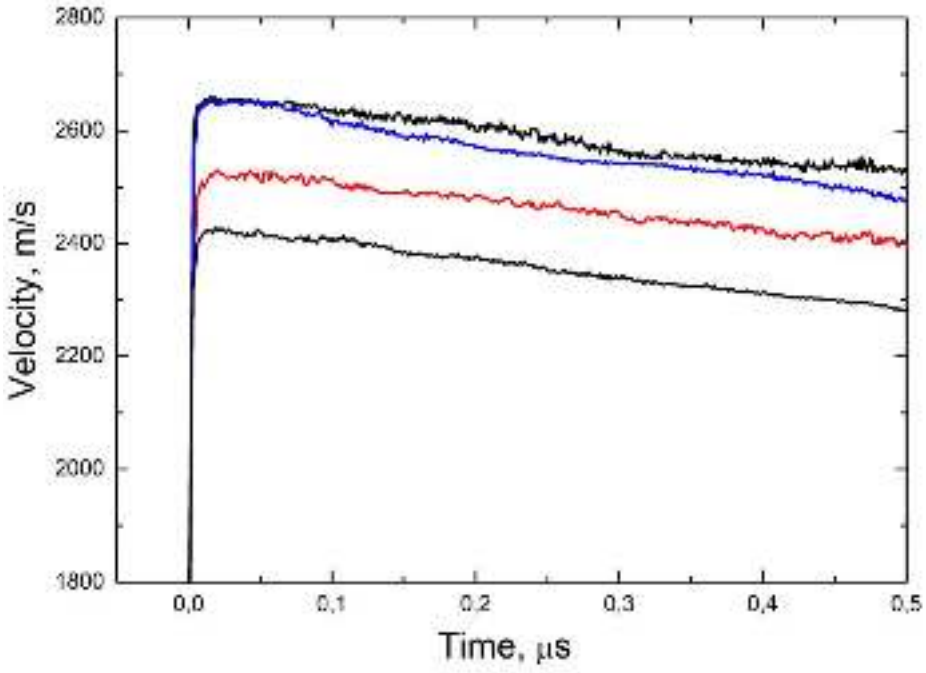
2. - Roth, J. F. // Z Gesamte Schiess-Sprengstoffweste, 1941, N *36*, P. 4-28;

3. - A.V. Utkin, V. M. Mochalova, A. M. Astakhov, V. E. Rykova, and S. A. Koldunov. // Combustion, Explosion, and Shock Waves, 2020, Vol. 56, No. 5, pp.556-565;

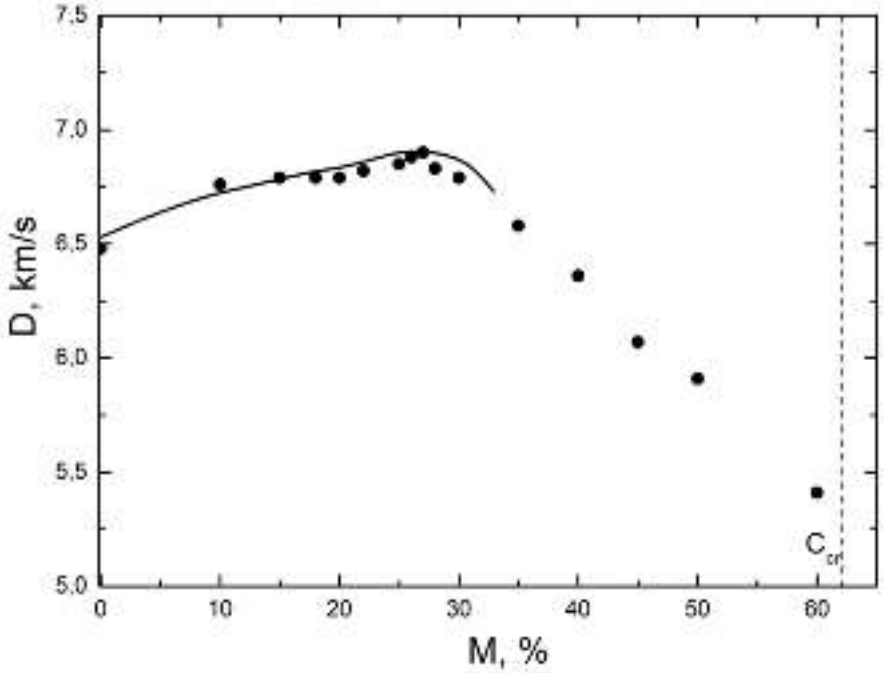
4. - Apin A. Ya., Voskoboinikov I.M., Sosnov G.S. // J. of Appl. Mechanics and Technical Physics, 1963, N 5, pp.115-117;

5. - Fedorov A.V., Mikhaylov A.L., Men'shikh A.V., Nazarov D.V., Finyushin S.A., Davydov V.A. // Journal of Energetic Materials, 2010, V. 28(S1), pp. 205-215.

Reproducibility of detonation parameters in the vicinity of stoichiometric diluent concentration

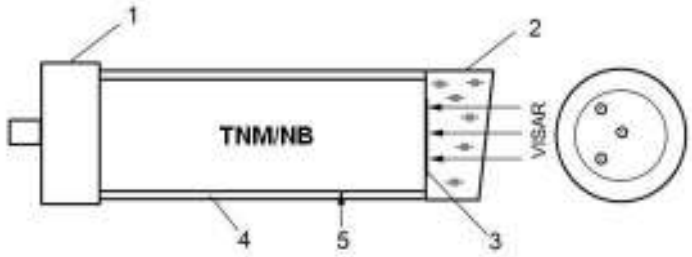


Velocity profiles of the mixtureTNM/M 85/15 at the boundary with water.

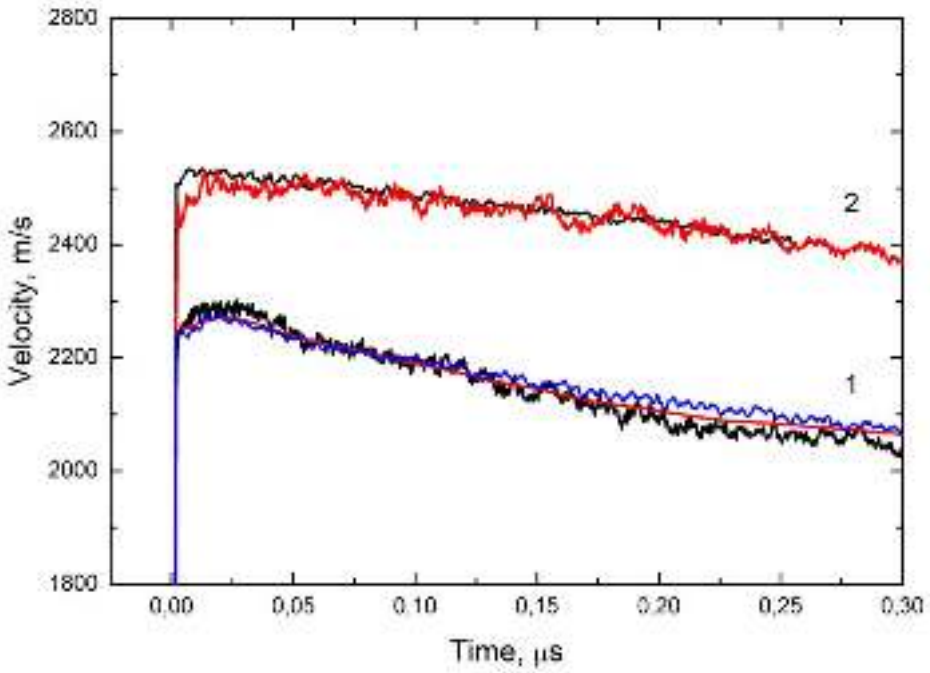


The dependence of detonation velocity for the mixture of TNM/M on the concentration of M. Stoichiometric concentration is 75.4/24.6

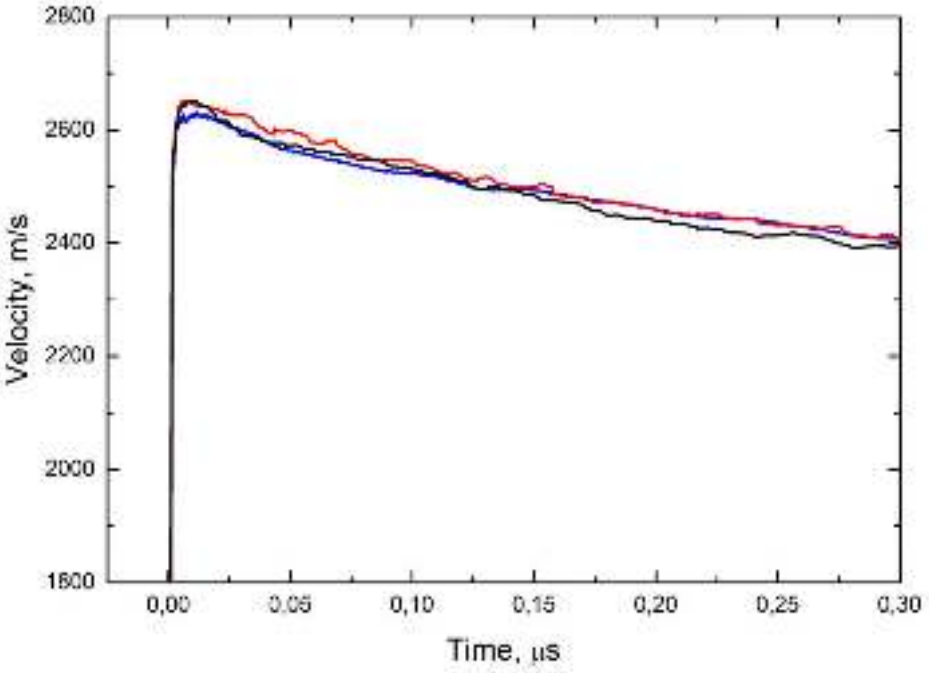
Reproducibility of detonation parameters in the vicinity of stoichiometric diluent concentration



1 – plane shock wave generator; 2 – water window;
3 – aluminum foil; 4 – shell; 5 – sensor



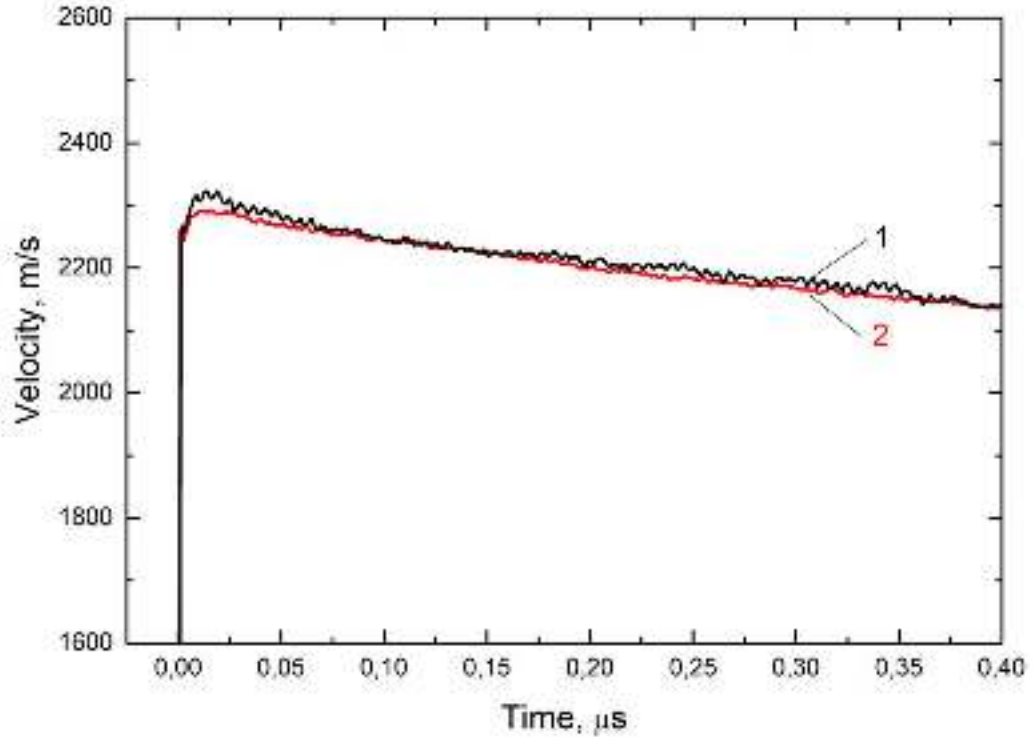
Velocity profiles at the boundary of the mixture TNM/M 85/15 with water. In each of the two experiments (1 and 2), the registration was carried out on the charge axis and at a distance from the center equal to half the charge radius.



Velocity profiles at the boundary of the mixture TNM/NB 76/24 with water. The velocity was recorded on the charge axis and at a distance from the center equal to half of the charge radius.

Reproducibility of detonation parameters in the vicinity of stoichiometric diluent concentration

The scheme of the experiment when registering velocity profiles in two sections of the studied explosive.



Velocity profiles at the boundary of the mixture TNM/M 85/15 with water in two different sections of the explosive

CONCLUSIONS

- **One-dimensional detonation waves in explosives based on TNM are stable with respect to small perturbations. Cellular instability is observed when approaching the limit concentration of an inert diluent.**
- **The simultaneous existence of a cellular structure of the detonation front and instability of the explosive/shell boundary is not necessary. In the mixture of TNM/NB 35/65, reaction disruption waves are observed in the absence of cellular instability.**
- **Shock-wave initiation of detonation of TNM and its mixtures with inert diluents in the vicinity of stoichiometry is focal.**
- **The lack of reproducibility of wave profiles in mixtures of TNM with nitrobenzene and methanol in the vicinity of stoichiometry is not associated with longitudinal or transverse instability of the flow and is due to the kinetics of chemical reactions.**