Defence Science Journal, Vol 49, No 3, July 1999, pp. 269-273

Explosive Materials Combustion by Heated Wires

I.V. Kondakov, B.G. Loboiko and V.A. Pestrechikhin

Russian Federal Nuclear Centre, 456 770, *Snezhinsk Chelyabinsk Region, Russia.*

ABSTRACT

The knowledge of ignition parameters of explosive materials (EM) presents both the definite scientific interest for developing the ignition kinetics models and the practical interest from the point of view of their danger assessment. The present investigations, as opposed to the known technique for EMs ignition temperature determination, have been performed by using the model explosive material samples of high density which have been produced on the basis of HMX and TATB. Applying the technique of firing ballistic powders by a heated wire[1], the EM ignition temperature depending on the time (rate) of heating has been investigated. The technique makes it possible to calculate heat pulses and heat flows leading to ignition. By decreasing the heat flow, the time for the EM heating up to ignition increases and temperature falls thereby approaching the critical value, characterising the danger limit under accidents associated with heating. The ignition of EM based on HMX and TATB takes place in a different manner. With the EM on the basis of HMX and with great heat flows, the ignition beginning from the surface in the form of flash is typical but when achieving the critical parameters, the heated layer flash takes place that increases the probability of the explosion realisation. EM based on TATB always ignite in the form of combustion from the surface, independent of the heat flow that points to the higher extent of its safety. These data correlate well with the higher parameters of its ignition.

1. INTRODUCTION

Explosive materials (EM) tests for sensitivity to thermal stimuli, as a rule, are performed on bulk materials. Determination is made for the temperature of flash under certain time delay (5; 30 s) in standard conditions of heating in a test tube. The present investigations were performed on EM containing HMX (sample 1) and TATB (sample 2). Using the technique of ballistic powders ignition by hot wire[1], investigations have been made on the parameters and the characteristics of EM combustion depending on time (rate) of heating. It permitted not only recording of the temperature but also calculating thermal pulses and average thermal flows leading of EM ignition. The knowledge about parameters of EM combustion is important to develop models of ignition kinetics.

2. EXPERIMENTAL SETUP

Investigations were performed on cylindrical EM samples in experimental node for the determination of the combustion parameters (Fig. 1). Between the two EM samples (40 mm diameter, 20 mm and 10 mm height), of nickel wire (0.25 mm in diameter) was placed, and the samples were tightened by flanges on pins. At the initial heating, the wire was introduced into the sample at the cost of EM softening and the elastic properties of rubber insert due to which the gap between the EM samples was closed. The wire, being both heating element and temperature gauge, permits to record temperature and also calculates the thermal parameters at the initiation of EM

Received 18 March 1997, revised 12 March 1998

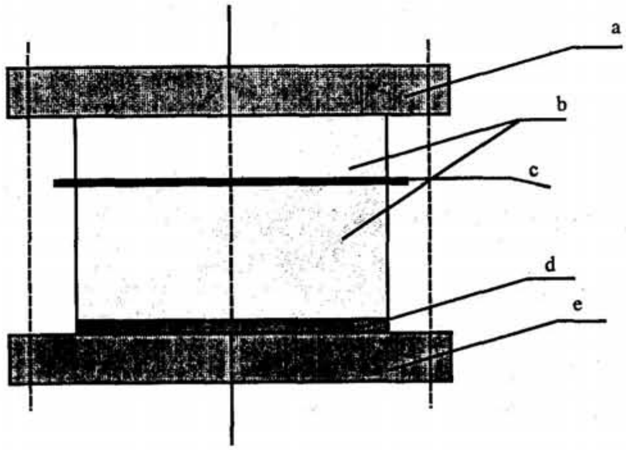

Figure 1. Experimental node to investigate EM combustion parameters, (a) upper flange, (b) HE sample, (c) heated wire, (d) rubber insertion, and (e) lower flange.

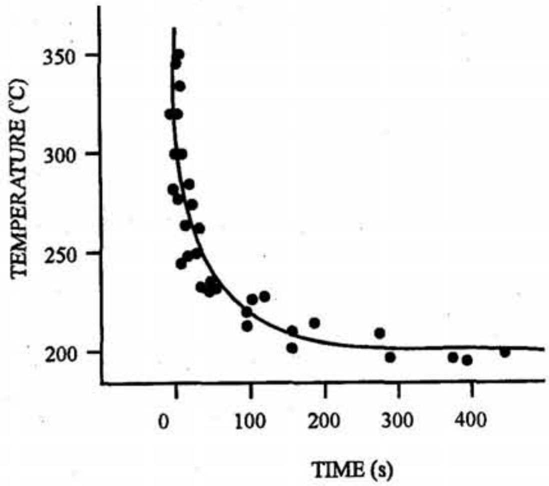

Figure 2. Dependence of combustion temperature on heating time for sample 1.

combustion. During experiment, voltage was supplied to the wire to keep the current constant during the experiment. Depending on resistance which was calibrated as a function of temperature, $R = f(\mathrm{T})$, the voltage on the wire was measured. Subsequently, the value of R was calculated and the EM ignition temperature was determined. The rate of heating changed from one experiment to another by the value of supplied current. The more was the current value, the less was the time of heating necessary to achieve temperature of combustion and the higher was the temperature.

Experimental dependence of temperature on heating time are given in Figs 2 and 3. The plots show that the temperature of combustion of sample 2, in time interval under study, gradually decreases from 350 °C up to 330 °C. Sample 1 has more complicated dependence of ignition temperature on time under great thermal flows, i.e., under small heating time (< 30 s), one observes sharp drop from 350 °C to 230 °C and under small thermal flows, i.e., under the time more than 30 s, the decrease is smooth up to the critical value of about 200 °C.

Using formulae[1], calculations were made for full pulse of ignition (Q_{EM}), and average thermal flow ($\dot{q}$). Q_{EM} without regard for the heat used for wire heating, was determined by the formula:

$$Q_{EM} = I^2 R_{in}\left(\tau_h + \int_0^{\tau_h} \frac{\Delta R}{R_{in}} d\tau\right) - Q_w, J$$

where

I	Current of heating (A)
IR_{in}	Initial wire resistance (Ohm)
ΔR	Change of resistance depending on the temperature over time τ (Ohm)
τ_h	Time of heating (s)
Q_w	Heat used to heat the wire
J	Full pulse of ignition.

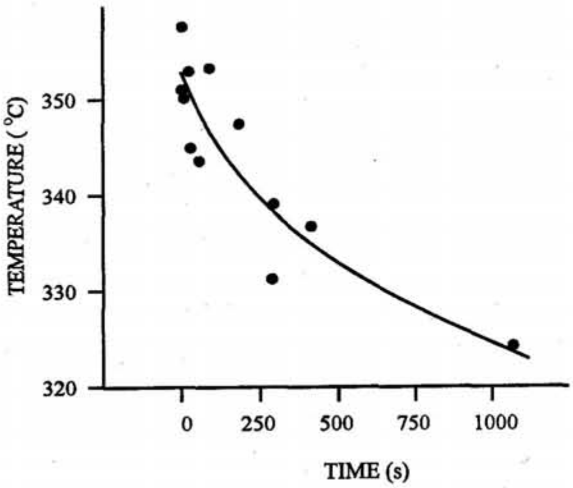

Figure 3. Dependence of combustion temperature on heating time for sample 2.

The value of $\dot{q}$ was calculated by the following formula:

$$\dot{q} = \frac{Q_{EM}}{\tau_h S}, \frac{W}{m^2}$$

where

	$S = \pi d.1$
m^2	Wire surface
d	Wire diameter
l	Wire length

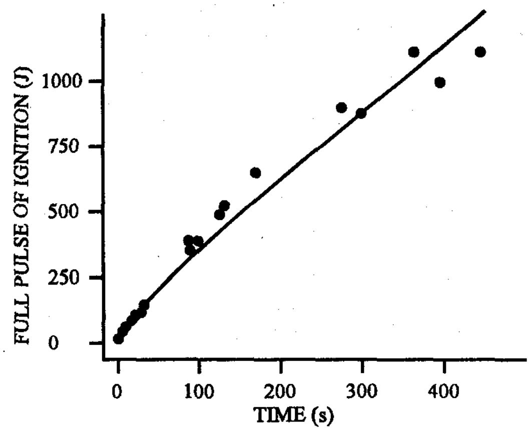

Figure 4. Dependence of full pulse of ignition on the time of heating for sample 1.

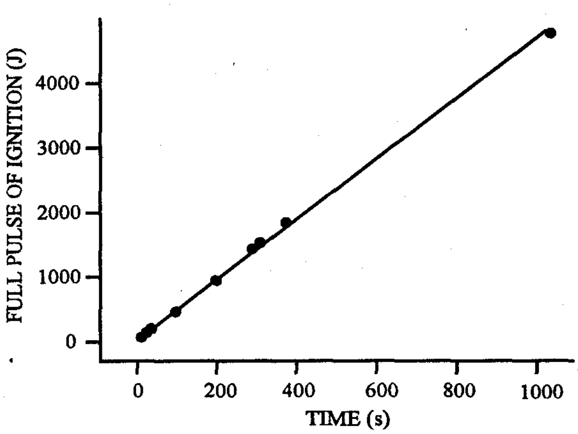

Figure 5. Dependence of full pulse of ignition on the time of heating for sample 2.

The dependence of Q_{EM} on the time of EM heating is given in Figs 4 and 5. Dependence of $\dot{q}$ is given in Figs 6 and 7.

3. RESULTS

It is necessary to note that for sample 1, the type of ignition depending on time of heating was different. When the time of heating was <30 s, there was ignition from the surface with subsequent

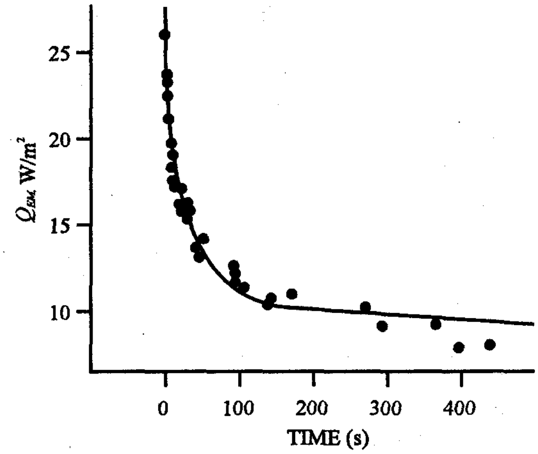

Figure 6. Dependence of thermal flow under sample 1 ignition on the time of heating.

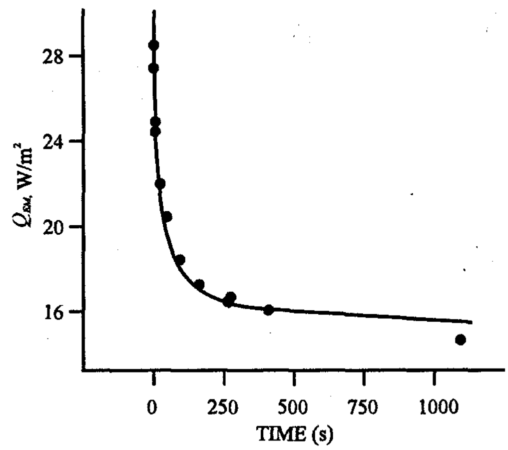

Figure 7. Dependence of thermal flow under sample 2 ignition on the time of heating.

sample destruction and EM burning ceasing. Under the condition of sample enclosure, burning could turn into explosion. The character of sample 2 ignition was the same for all regimes of heating in the range of study and took place in the form of combustion with subsequent slow burning out of heated layer and EM bursning ceasing.

The analyses of dependence, $T = f(\tau)$ and $\dot{q} = f(\tau)$ show that with EM heating time increase (up to the moment of ignition), parameters T and $\dot{q}$ decrease and approach to critical values. These values are typical of each EM, and if these are lower, then there is no ignition. Critical parameters of ignition for EM are shown in Table 1.

Table 1. Critical parameters of ignition

Types of EM	Critical temperature of ignition (°C)	Full pulse of ignition, (J)	Average thermal flow (W/m^2)	Ignition characteristics
Sample 1	200	116,5	9,52	Flash
Sample 2	330	2019,7	16,15	Ignition

4. CONCLUSIONS

By investigating the ignition of EM samples by means of local heating from the wire, the parameters of EM ignition for different rates of heating were obtained. It revealed that there is a dependence between the ignition temperature and the thermal flow; the lower the thermal flow, the lower is the ignition temperature, but there are critical values for which there is no ignition, if they are lower.

Sample 1 has sharper dependence than sample 2. When the ignition temperature approaches critical in sample 1, ignition takes place in the form of a flash that increases the probability of explosion.

For sample 2, combustion in all cases takes place in the form of combustion from the surface. Its combustion parameters (temperature and thermal flow) are much higher than that of sample 1. This indicates that charges out of TATB-containing EM are more fireproof than charges out of HMX-containing EM.

REFERENCE

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Contributors

Dr IV Kondakov did his graduation from Kazan Chemical-Technological Institute in 1964. He has been a staff member of VNIITF since 1965. Presently, he is a working at the Russian Federal Nuclear Centre—Research Institute of Technical Physics, Russia as Division Dy. Chief Engineer. His area of specialisation is industrial engineering.

Dr BG Loboiko did his graduation from Moscow Physics Engineering Institute, in 1960. He has been a staff member of VNIITF since 1961. Presently, he is working at the Russian Federal Nuclear Centre—Research Institute of Technical Physics as Dy. Chief Engineer. He is the recipient of *USSR State Prize* (1983) and *Scientist of the Russian Federation* (1998).

Dr VA Pestrechikhin did his graduation from Ural Polytechnical Institute in 1979. He has been a staff member of VNIITF since 1972. Presently, he is working at the Russian Federal Nuclear Centre—Research Institute of Physics.