THE INFLUENCE OF THE IGNITION SOURCE ENERGY ON THE EXPERIMENTAL VALUES OF SOME HALONS' INERTING CONCENTRATIONS

Yaroslav A. Lisochkin and Vladimir I. Poznyak
Federal state unitary enterprise
Russian Scientific Center "APPLIED CHEMISTRY"
Dobrolubov Ave. 14, St. Petersburg, 197198 Russia
Phone: (812) 238-92-11, E-mail: office@cisp.spb.ru
and
Evgeniy G. Belevtcev and Larisa N. Kunina
OZON Ltd.
Dobrolubov Ave. 14, St. Petersburg, 197198 Russia
Phone/fax: (812) 325-13-73, E-mail: ozonkln@mail.ru

ABSTRACT

Resulting from the test in closed space (10l) the experimental values for inerting concentrations of some halons ($C_2F_4Br_2$, CF_3Br, and C_2F_5H) were determined for a stoichiometric methane/air mixture and depending on the energy of the ignition source. Fuse wire and pyrotechnical composition were used for the ignition sources. The ignition source energy varied in the range 2-420 J. On the grounds of the results one may conclude that to find the true value of a halon inerting concentration, i.e. the value independent of the applied source, it is necessary to use a source with energy exceeding 100 J. for $C_2F_4Br_2$ or C_2F_5H, and 400 J. for CF_3Br. The application of lower energy sources for the mixture ignition leads to underestimated values; the effect is due not to inerting of the mixture but to the growth of the ignition energy when halons are added. It is especially evident for C_2F_4Br and CF_3Br that display inhibiting effect.

INTRODUCTION

Nowadays the critical parameters of flame propagation, listed below, are usually determined experimentally and applied in actual practice of implosion protection:

- Concentration limits of flame propagation,
- Inerting concentration,
- Critical diameter of flame propagation,
- Minimal ignition energy.

The approach to the concentration limits from the zone of inflammation is accompanied with increase of the minimal ignition energy. When defining inflammation zone boundary by experiment without preliminary data on the minimal ignition energy, the ignition limit may happen to be found instead of the inflammation limit. It possibly provides an explanation to the influence of the ignition source on the experimentally determined value of CF_3Br inerting concentration [1].

The objective of this work is to demonstrate this potent effect of the ignition source energy on the results of the determination of halon inerting concentration with an example of a stoichiometric methane/air mixture.

EQUIPMENT

The experiments were carried out in a spherical 10-litre autoclave. The autoclave was provided with a hatch for inspection and cleaning, sockets for installation of pressure transducers, thermocouple and ignitor and a thermostating jacket. With the appropriate valves, the autoclave was inserted to a pressure relief system. The autoclave used the vacuum line, and systems feeding air, gases and vapours to prepare the mixtures.

The mixtures of prescribed composition were prepared directly in the autoclave taking into account the partial pressures of the components. The partial pressures of both methane and halon were being controlled in the process of charging with the "Sapphire" device, the error of the measurement being no more than 0,5 mm Hg. The tests were carried out at room temperature, and the total pressure of the components during the tests was atmospheric. An electrically heated Nichrome spiral was applied to reduce the components mixing time by means of convection. The time of the components' complete mixing was defined through chemical analysis. The process of deflagration was registered by DD10 fast-response gauge (the eigenfrecuency of its membrane oscillations exceeded 10 kHz), IVP-2 electron transducer, and S8-17 electron-beam oscillograph. At the same time, the data on changing pressure in the autoclave were sent to PC for further processing. An open-junction thermocouple was installed at the top of the autoclave. The thermocouple signal was registered simultaneously with the pressure indications by the electron-beam oscillograph.

IGNITOR

Two different types of ignitors were used in the experiments: fuse wire and pyrotechnical composition ones.

The pyrotechnical composition was prepared on the basis of mixture of fine-dispersed powders of BaO_2 (88.5% by mass), Al (8.85% by mass) and acetylcellulose binder (2.65% by mass). The composition was preformed in tablets of various masses. Combustion of the composition was initiated by means of the electrically heated Nichrome wire. Copper wire (0.1 mm in diameter, 6 mm in length) was used in our "fuse wire" tests; it was burned out with direct voltage (270V) provided with capacitors of various capacities. The energy fed to the gas mixture was evaluated by a pressure rise in the autoclave when the pyrotechnical composition or the fuse wire was initiated in the air in the absence of methane (Fig. 1 and 2).

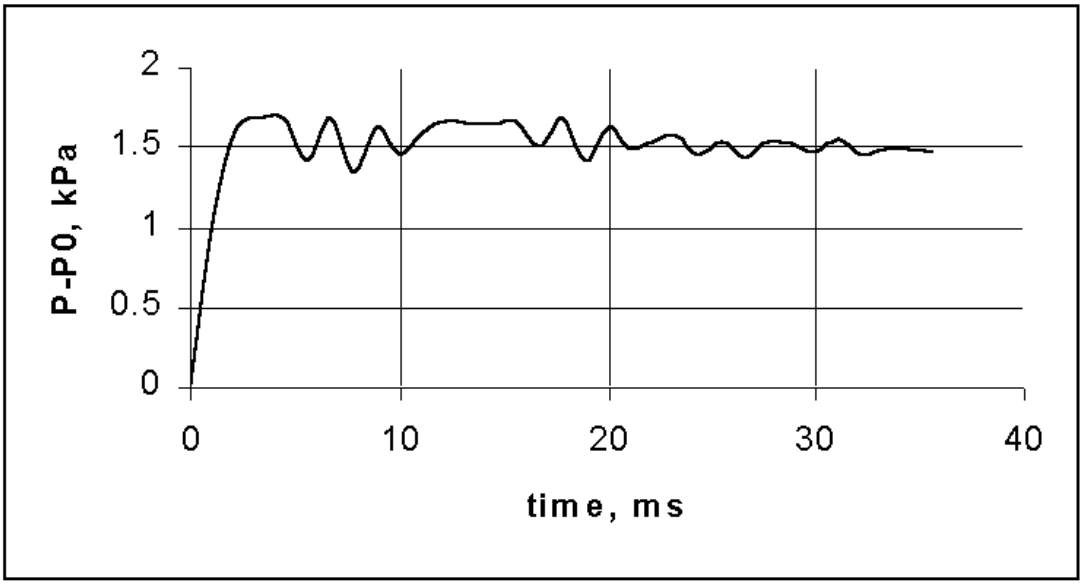

Figure 1. Pressure variation in the autoclave after starting of the "fuse wire"-type ignitor in the air (capacity of the capacitor 4080 mF, initial voltage of the capacitor 270 V, final voltage 75 V)

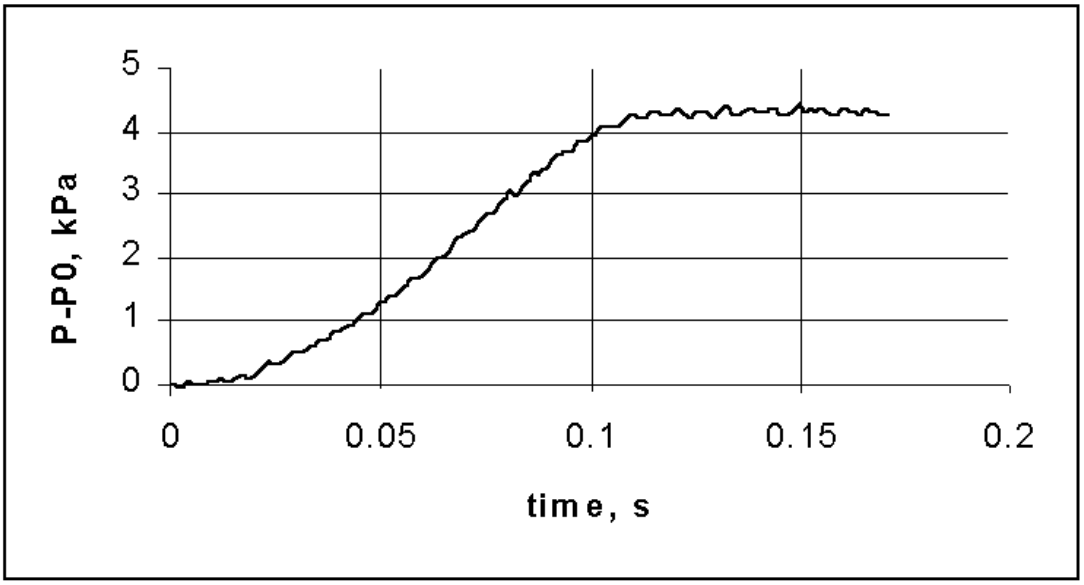

Figure 2. Pressure variation in the autoclave after starting of the " pyrotechnical composition"-type ignitor (mass 0,123 g)

The energy of the ignition source of was calculated according to the formula:

$$\mathbf{q} = \frac{\mathbf{\Delta PV}}{\mathbf{k-1}}, \qquad (1)$$

here ΔP is the maximal pressure increment after initiating of the ignitor, V is volume of the autoclave,

$\mathbf{k} = \frac{\mathbf{c_p}}{\mathbf{c_v}}$ is the ratio of the air heat capacity at constant pressure to that at constant volume.

Simple mean value for the source energy in the set of 5 experiments with fuse wire was 2, 12, 37 J, and that for the pyrotechnical composition was 72, 120, 240, 420 J.

The maximal deviation for source energy within a control set of tests with the same type of the source never exceeded 30%. The ignitor was installed at 30 mm from the autoclave bottom near to its axis of symmetry.

RESULTS

The experimental value of the halon inerting concentration was determined in a series of tests with ignitors of the same type with varied concentration of halon in the methane/air stoichiometric mixture. CF_3Br, $C_2F_4Br_2$ and C_2F_5H were used for inerts. For each set of tests the variation in halon concentration was 1%.

The tests, where the maximal pressure buildup did not exceed 0,1 MPa, were considered as suppression of ignition. This criterion exceeded much the value of 1 psa as recommended in ASTM E 918. It was used here because the mixtures diluted with a halon burn very slowly. Time of ascend for the burning site initiated with the source of ignition in the autoclave was 0.4 s (Fig 3).

The pressure increase over this period was not large enough to come to the conclusion that deflagration had started. The mixture was considered as explosive if the pressure growth continued longer than 0.4 s, i.e. when the pressure growth was being observed after the contact between the burning site and the chamber cold wall and, obviously, after flame propagation downward. In those tests the acceleration of pressure growth in the process of the burning site emergence was registered along with considerable growth of the maximal pressure increase (Fig. 3).

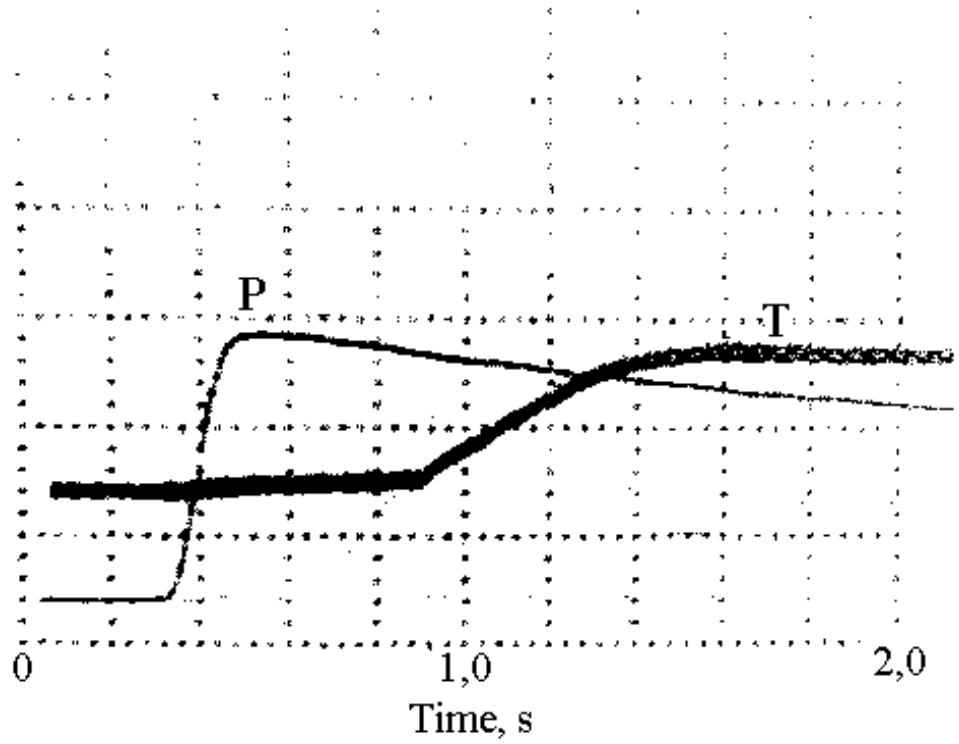

Figure 3. Data of pressure sensor and thermocouple located at the top of the autoclave after starting of the pyrotechnical composition ignition (photo was made from the screen of the electronic oscillograph)

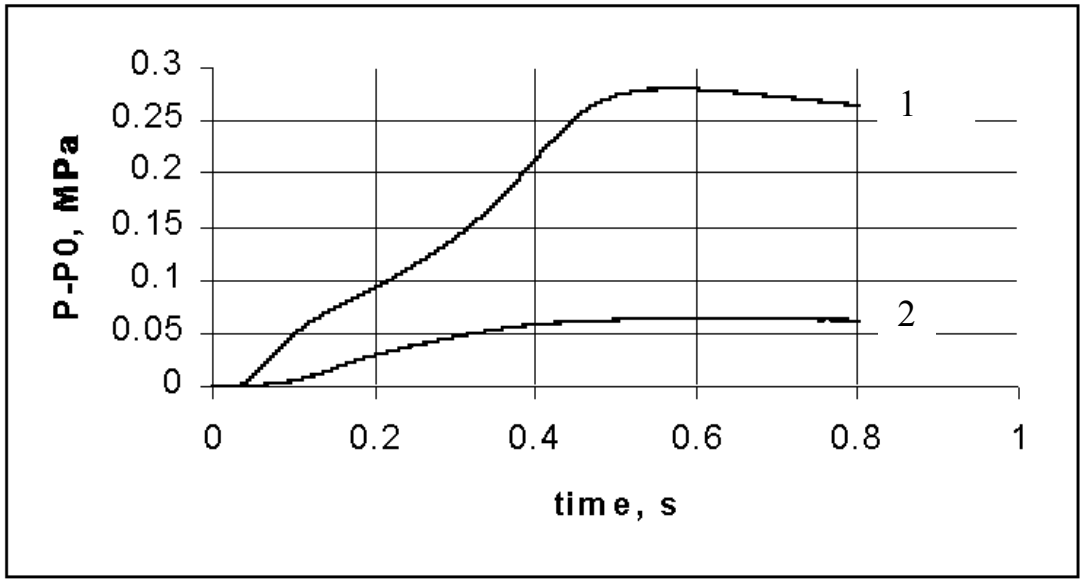

Figure 4. Oscillogram of pressure variation in the autoclave after starting of the ignitor in stoichiometric methane/air mixture with the addition of halon CF_3Br (1 corresponds to 20% vol., as 2 to 22% vol.), ignitor is pyrotechnical composition, mass 0,39 g, Eign = 420 J

The test results are shown in Fig. 5,6,7.

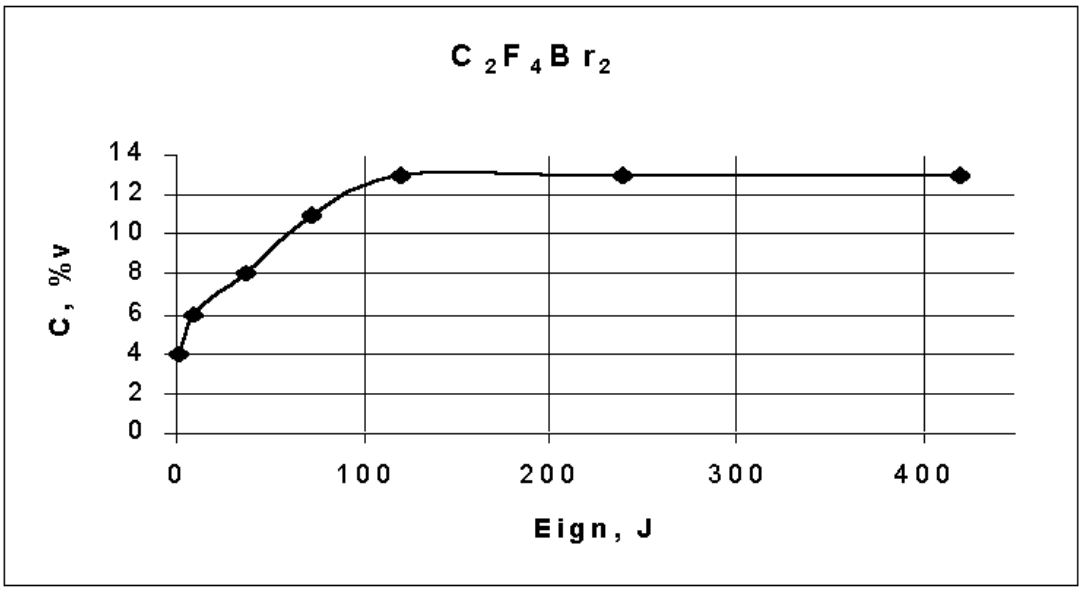

Figure 5. Dependence of experimentally defined $C_2F_4Br_2$ inerting concentration value on the ignitor energy

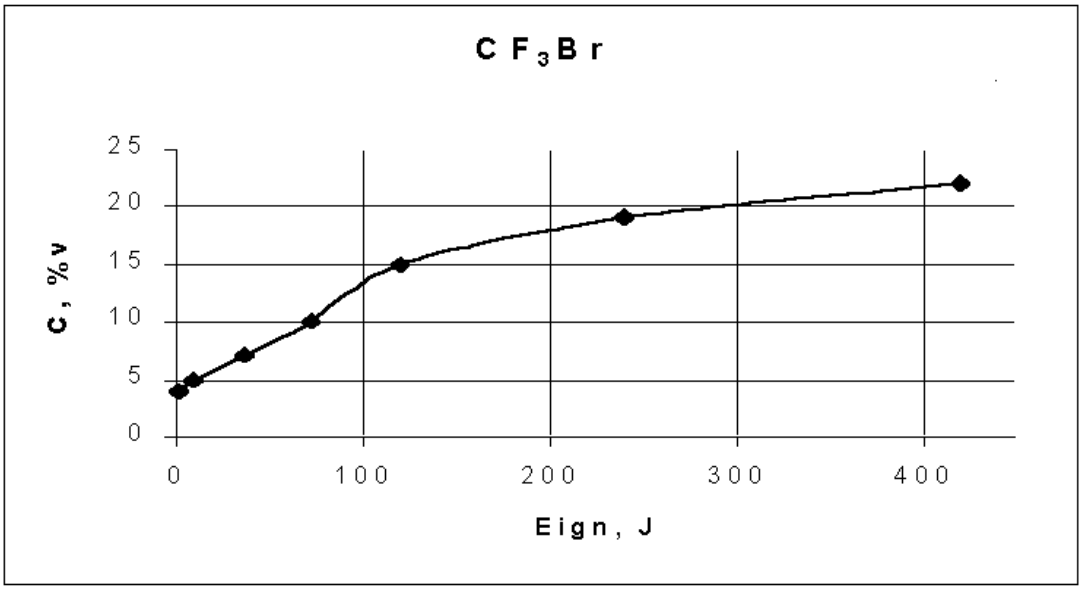

Figure 6. Dependence of experimentally defined CF_3Br inerting concentration value on the ignitor energy

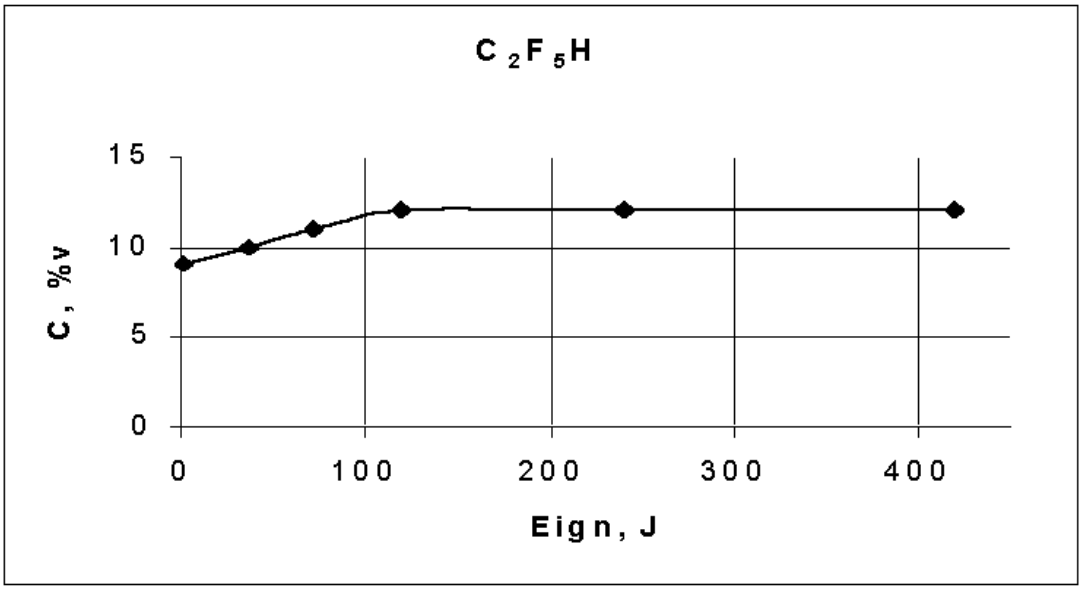

Figure 7. Dependence of experimentally defined C_2F_5H inerting concentration value on the ignitor energy

CONCLUSIONS

Concentration limits of flame propagation (including the inerting concentration) are the principal properties of the reagents' mixture that do not depend on the experiment parameters. The influence of the power of the source of ignition on the inflammation limits of methane/air /halon mixtures may only be due to the increase in the ignition energy that occurs when halon is added to methane/air mixture. This assumption is in excellent agreement with the inhibiting effect of halons on the normal flame propagation rate and, appropriately, on the ignition energy. For bromine-containing halons the inhibiting effect is larger and that is why there is such a difference between the curves for C_2F_4Br, CF_3Br and C_2F_5H. Reduction of the normal combustion rate, without decrease in adiabatic temperature of the flame front, has impact on the value of the critical diameter, ignition energy and diffuse flame stability conditions, but it cannot suppress deflagration. In the final analysis the inerting concentration is defined by the diluter heat capacity and from this standpoint the fluorocarbons do not seem to be promising agents to suppress deflagration in closed space. They ignite spontaneously when mixed with air at high temperature, i.e. they enter exothermal reactions with oxygen, thus affecting their efficiency when mixed with excess of air [2]. Under certain conditions, the reactions of halon oxidation may lead to the halon deflagration, when the halon is mixed with air in the absence of any other combustible component [3].

The problem of flame extinguishing at decrease of the normal flame propagation rate due to convective heat losses was beyond the scope of this work [4]. The final conclusion about the hazards of those slowly burning mixtures can be made after tests in large volumes and using ignitors of higher power.

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