IMPULSE SPRAY FIRE-EXTINGUISHING SYSTEM

Korobeinichev O.P., Shmakov A.G., Tereshchenko A.G.
shmakov@kinetics.nsc.ru
Institute of Chemical Kinetics and Combustion,
Siberian Branch Russian Academy of Sciences,
Institutskaya st. 3, Novosibirsk, 630090 Russia

Abstract

To extinguish local fires of hydrocarbon fuels and fires in gas wells, an impulse spray fire-extinguishing system (ISFES) may be used. With its help, the fire-extinguishing agent is delivered to the fire zone as a cloud of finely disperse aerosol by operating gas, which may be nitrogen, argon or carbon dioxide. As such fire-extinguishing agents, phosphorus-or metal-containing compounds are suggested, selected by the results of laboratory and extended field studies.

As a model object, diffusion laminar propane flame, stabilized over a Bunsen burner was used in the study. As flame suppressant, fine powder of $K_4[Fe(CN)_6]$ was used. The model ISFES contained four working cylinders used as throwers for the powder and mounted at the equal distance from the burner. A cylinder consists of a working chamber, one of the ends of which is covered with a slit polyester membrane and a device for slitting the membrane with an electromagnetic drive. CO_2 was delivered to the working chamber to reach the pressure of 3-15 atm. A charge of the fire suppressant agent (50-100 mg), placed between two thin paper membranes, was located at the end of the cylinder close to the burner. To enable the ISFES, an electric impulse was given simultaneously to all the four magnets of the membrane slitters, resulting in the release of the working gas with extinguishing powder in the direction of the burner.

The results obtained have shown the efficiency of extinguishing model diffusion propane-air flame to increase with addition of potassium ferrocyanide $K_4[Fe(CN)_6]$ powder in CO_2 flow.

Minimum extinguishing concentration of $K_4[Fe(CN)_6]$ powder when used in the ISFES is evaluated to be about 50 g/m^3, which exceeds the previously measured value of the minimum extinguishing concentration in extinguishing heptane-air diffusion flame with aerosol of the water solution of $K_4[Fe(CN)_6]$ by approximately an order of magnitude.

Introduction

Application of pulse fire extinguishing systems is a promising trend for fighting local fires. Similar systems of different modifications have been developed in Russia over the past decade. The most impressive machine based on the pulse principle is a multi-barrel installation mounted on the full-track tank chassis, ensuring high maneuverability and passability when working under extreme conditions.

The prototype of "Impulse-1" installation had 40 barrels mounted on the T-55 tank chassis and was manufactured in 1990. It was followed by the "Impulse – Storm” installation on the basis of 50 barrels of the T-62 tank chassis. The machine produces a powerful fire-extinguishing gaseous flux containing sprayed fire-extinguishing powder or liquid formulation. At the same time, without additional preparation, the machine allows flexible control of the speed, the kinetic energy flux, the range of exposure (up to 100-120 m), and the frontage (from 0.5 to 3.5 m). In real fire situations, it is of great importance to have a possibility of multiple, combined and highly effective impact on the fire source, using a variety of finely dispersed extinguishing agents, as it allows the most fierce fires to be extinguished, re-ignition to be eliminated and combustible materials to be separated from the ignition sources [1].

An installation for suppressant delivery through atomizers located around the jet of burning gas at high-pressure gas pipelines is described in [2]. A method of extinguishing burning oil gushers by discharging the fire extinguishing jet into them at supersonic speeds is described in [3]. The extinguishing jet is obtained using a solid-propellant gas generator with a special nozzle. When used for a large gusher area, the aerosol jet is directed uniformly at the gusher mouth, at least from four sides. The high extinguishing capacity of the jet agent allows the 3 sec pulse discharge of the jet. Ensuring separation of the combustion front from non-inflamed fuel and removal of the flame from the wellhead is an important issue in this case. To ensure a rapid extinguishing effect, a method of “air vortex rings” was proposed in [4] to extinguish gas and oil well fires of practically any possible power. This method is used in extinguishing oil plumes by directing an air vortex ring filled with sprayed fire-extinguishing powder at the plume.

In this study, the basic principles of the above methods are proposed to be used for extinguishing local hydrocarbon fuel fires and fires at gas wells. To simulate fighting the flame generated by the described combustion sources, as well as to explore the features of chemically active fire suppressants and inhibitor application, a impulse spray fire extinguishing system (ISFES) was developed.

Experimental

Delivery of fire suppressant to the combustion zone is effected as a fine aerosol jet produced by a hydrodynamic shot from several throwers arranged around the combustion source. It is assumed that such a system, deployed around the combustion source, will effectively and almost instantly put out the fire. Working gas (such as nitrogen, argon, carbon dioxide) kept compressed in cylinders or produced by combustion of solid-propellant gas-generating compositions, is used to release the fire suppressant from the ISFES and to deliver it to the combustion source. After release of gases from the system, a ballistic wave of low intensity is formed, which also affects the flame, moves it away, disperses and sprays the fire suppressant, which is delivered to the combustion source as an aerosol cloud. In this case, the following processes take place: 1) Evaporation (and / or thermal decomposition) of the flame suppressant particles lowers the flame temperature. 2) Inert gas displaces air oxygen from the combustion source. 3) Chemically active inhibitor reacts with the main carriers of chain reactions (free atoms and radicals) and reduces the number of active centers in the flame zone, terminating the chain branching and thus extinguishing the flame. It is assumed that the combination of all the above factors, including selection of effective fire suppressants, will allow methods of optimal suppression of various types of fires to be developed, including fires at gas wells and oil spills. The authors have previously investigated the efficiency of extinguishing hydrocarbon flames using various phosphorus-, fluorine-containing and metal-organic compounds [5,6]. The results of the laboratory experiments of extinguishing diffusion n-heptane/air flame have shown the water solutions of complex potassium compounds - $K_4[Fe(CN)6]$ (potassium ferrocyanide) and $K_3[Fe(CN)_6]$ (potassium ferricyanide) to be the most effective flame suppressants, with minimum mass flame extinguishing concentration of $K_4[Fe(CN)_6]$ being 6-7 g/m^3. Subsequent large-scale experiments in extinguishing model ground forest fires and class 0.5A fires (burning stacked lumber) with aerosol of the water solution of $K_3[Fe(CN)_6]$ showed that, using the proposed flame suppressants, it is possible to effectively suppress both flame and smoulder [7]. This, it can be stated that $K_4[Fe(CN)_6]$ и $K_3[Fe(CN)_6]$ both as aerosols of their water solutions and as finely dispersed powders, are effective flame suppressants.

The purpose of this study is to determine the conditions under which hydrocarbon diffusion flame gets extinguished with powders of chemically active flame suppressants, which are discharged with pulse aerosol fire extinguishing systems.

As a model object, diffusion laminar propane flame, stabilized over a Bunsen burner with a diameter of 60 mm, with propane flowing into the air at the rate of 3 cm/sec, was used in the study. As flame suppressant, finely dispersed (particle size 2-4 μm) powder of potassium ferrocyanide $K_4[Fe(CN)_6]$ was used. The model ISFES contained four working cylinders used as throwers for the powder and mounted on the corners of a square at the equal distance from the burner. A cylinder consists of a working chamber, one of the ends of which is covered with a slit polyester membrane and a device for slitting the membrane with an electromagnetic drive. Carbone dioxide (CO_2) was delivered to the working chamber to reach the pressure of 3-15 atm. A charge of the fire suppressant agent (50-100 mg), placed between two thin paper membranes, was located at the end of the cylinder close to the burner. To enable the ISFES, an electric impulse was given simultaneously to all the four magnets of the membrane slitters, resulting in the release of the working gas with extinguishing powder in the direction of the burner. The experiments were conducted outdoors. The experiment results were videotaped. As a result of the tests, parameters of the fire extinguishing impulse – the minimum fire suppressant charge and pressure in the working chamber of the cylinder, at which the model fire source was extinguished, were obtained. Fig. 1 shows a photograph of a ISFES. Fig. 2 shows a photograph of a thrower.

Table 1 shows the results of the tests of impulse extinguishing of diffusion propane flame in air. P is excessive pressure in the cylinder. The tests have shown that, with the pressure in the working cylinder of ISFES being 5 atm, the flow rate of CO_2 with inhibitor in the burner zone was about 20 m/sec. As seen from the data shown in Table 1, addition of powder to the flow of CO_2 released from the ISFES considerably improves the efficiency of flame suppression. It can also be seen that extinguishing diffusion propane flame with the powder of $K_4[Fe(CN)_6]$ and with the ISFES (over 50% successful tests) occurs with fire suppressant

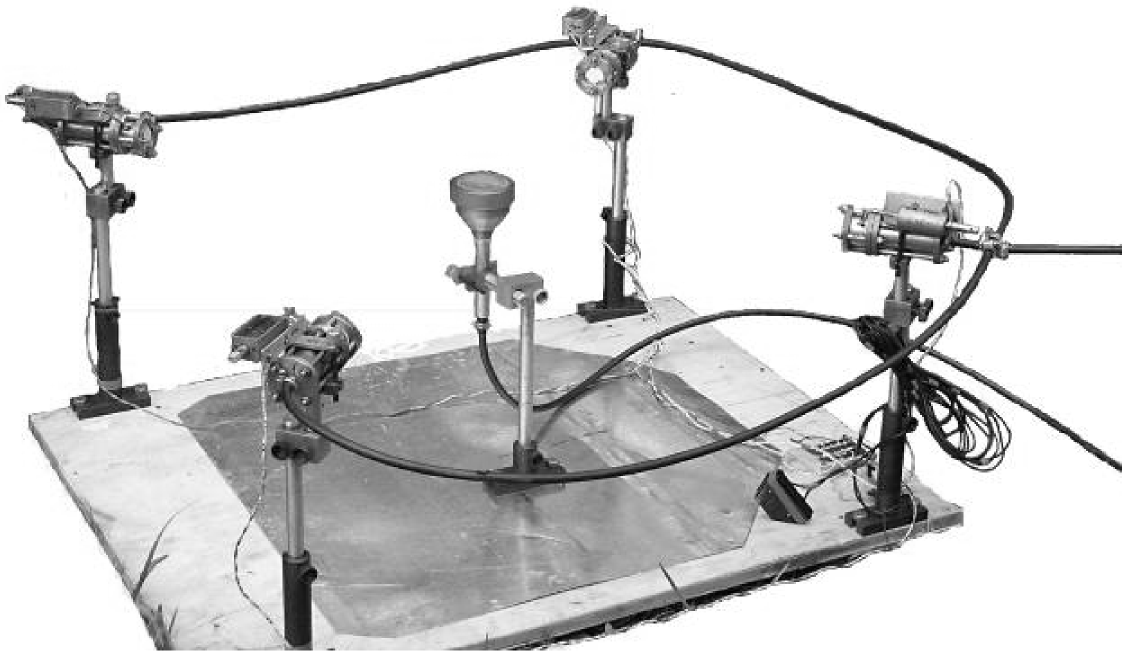

Figure 1. A photograph of a impulse spray fire extinguishing system (ISFES).

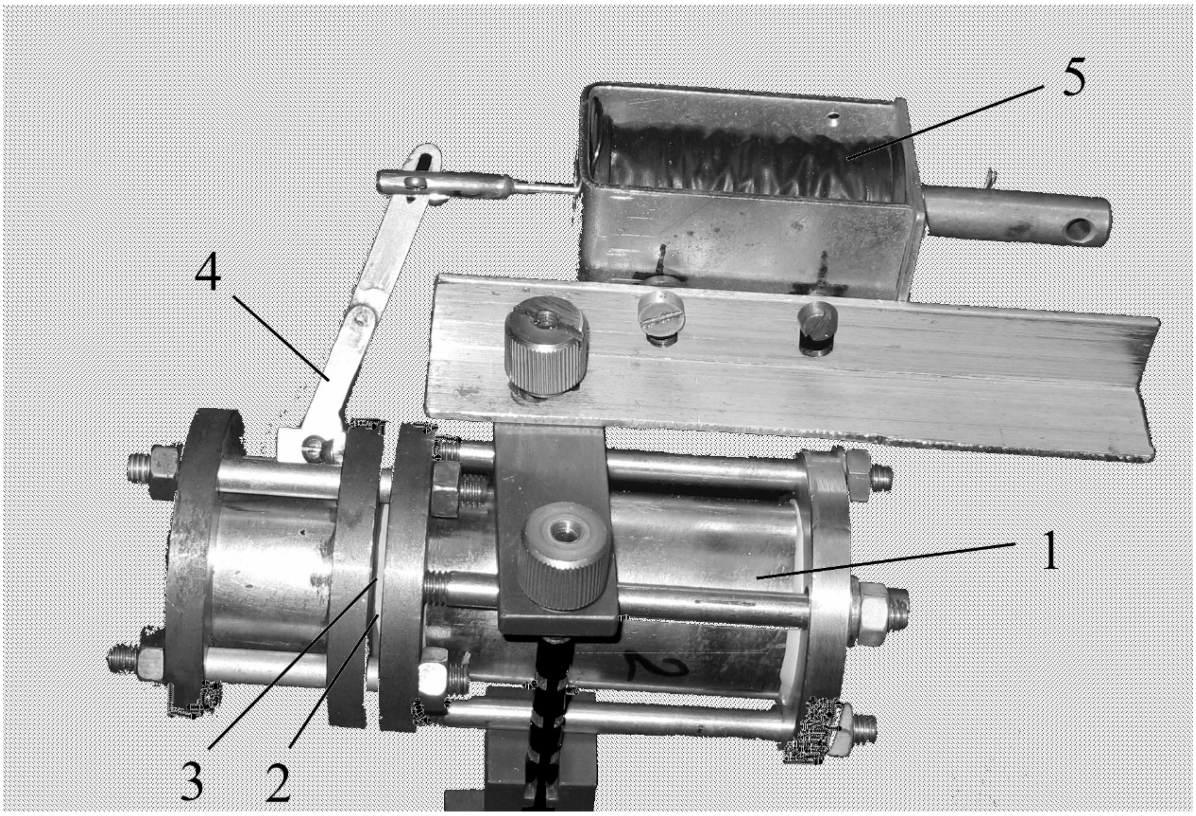

Figure 2. A photograph of a cylinder for discharging the extinguishing mixture
1- a high-pressure chamber, 2 – a polyester membrane, 3 – extinguishing powder placed between paper sheets, 4 – a lever activating a cutter for slitting the membrane, 5 – an electric magnet.

Table 1. The results of the tests of impulse extinguishing of diffusion propane flame in air. P is excessive pressure in the cylinder.

Test №	P, atm	Weight, mg	Fire suppressant mass concentration, g/m^3	Fire suppression	Test №	P, atm	Weight, mg	Fire suppressant mass concentration, g/m^3	Fire suppression
1	8	0	0	+	9	4	35	16	-
2	4	0	0	-	10	4	50	24	-
3	4	0	0	-	11	4	50	24	-
4	5	0	0	-	12	4.2	100	48	+
5	6	0	0	+	13	4	100	48	+
6	4	500	240	+	14	4	100	48	-
7	4	50	24	+	15	4	100	48	+
8	4	20	9.6	-	16	4	100	48	-

mass concentration exceeding 50 g/m^3. This value exceeds the values of the minimum extinguishing concentration for aerosol of the solution $K_4[Fe(CN)_6]$, determined previously in the laboratory conditions [5,6] by nearly an order of magnitude. One of the possible causes of such divergence of data may be spatial inhomogenuity of the flow generated by the ISFES in the burner zone. This can be seen from the results of test № 7, in which concentration was 24 g/m3 when flame was successfully extinguished, while in tests №14 and №16, in which concentration was twice as much - 48 g/m^3, flame was not extinguished. The second cause is the properties of the fire suppressant particles. It is to be mentioned that dry fine powder of $K_4[Fe(CN)_6]$ was used in the study as fire suppressant, while in study [5,6] the aerosol of the solution $K_4[Fe(CN)_6]$ was used for the purpose. This factor is likely to pay an essential role but this requires further study.

Conclusions

An experimental installation has been developed to study extinguishing of diffusion propane-air flame with a pulse aerosol fire extinguishing system using chemically active fire suppressants.

The results obtained have shown the efficiency of extinguishing model diffusion propane-air flame to increase with addition of potassium ferrocyanide $K_4[Fe(CN)_6]$ powder (particle diameter 2-4 μm) in CO_2 flow.

Minimum extinguishing concentration of $K_4[Fe(CN)_6]$ powder when used in the ISFES is evaluated to be about 50 g/m^3, which exceeds the previously measured value of the minimum extinguishing concentration in extinguishing heptane-air diffusion flame with aerosol of the water solution of $K_4[Fe(CN)_6]$ by approximately an order of magnitude.

References

[1] Impulse-Storm Multi-Barrel Installation, http://rus.impulse-storm.com/storm/effect/

[2] Glotov, G.F., “An Assembly for Extinguishing the Flame of the Combustible Gas Jet”. Patent of the Russian Federation No. 2059794. Central Aerohydrodynamics Institute Named after professor N.E. Zhukovsky.

[3] Zhegrov, E.F., Doronichev, A.I., Ivankov, L.D., Milehin, Yu.M., “The Method of Extinguishing Plumes at Gas, Oil and Gas-Oil Wells, an Assembly for its Implementation and an Extinguishing System”. 1999. Patent of the Russian Federation No. 2143544. Federal Center for Double-use Technologies “Soyuz”.

[4] Akhmetov, D.G., Lugovtsov, B.A., and Tarasov, V.F., “Extinguishing gas and oil well fires by means of vortex rings”, *Combustion, Explosion and Shock Waves*, 16(5): 490-494 (1980).

[5] Korobeinichev, O.P., Shmakov, A.G., Shvartsberg, V. M., Yakimov, S.A., “Study of Fire Suppression Effectiveness of Organophosphorus Compounds and Compositions on their Base”, *Proceedings of Halon Options Technical Working Conferences (HOTWC - 2005),* NIST SP 984-3, Gaithersburg, MD, USA, (CD version) (2005) http://www.bfrl.nist.gov/866/HOTWC/HOTWC2006/pubs/R0501570.pdf

[6] Shmakov, A.G., Korobeinichev, O.P., Shvartsberg, V.M., Yakimov, S.A., Knyazkov, D.A., Komarov, V.F., and Sakovich, G.V., "Testing ogranophosphorus, organofluorine, and metal-containing compounds and solid-propellant gas-generating compositions doped with phosphorus-containing additives as effective fire suppressants", *Combustion, Explosion and Shock Waves*, 42(6): 678-687 (2006)

[7] Korobeinichev, O.P., Shmakov, A.G., Chernov, A.A., Bol’shova, T.A., Shvartsberg, V.M., Kutsenogii, K.P., and Makarov, V.I., “Fire Suppression by Aerosols of Aqueous Solutions of Salts”, *Combustion, Explosion, and Shock Waves*, 46(1): 16–20 (2010)