THE MODIFICATION OF THE CHARACTERISTICS OF THE CONDENSED FIRE EXTINGUISHING AEROSOL DURING ITS DISTRIBUTION TROUGH THE PIPELINES

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INTRODUCTION

The aerosol tools for fire suppression developed in Russia during last decade now are widely used for fire protection of different facilities and buildings under different conditions. The pyrotechnically generated fire extinguishing aerosol, being safe to ozone layer, is much cheaper than the gaseous agents, non-toxic and very effective in extinction of class A2 and B fires. But there are some serious disadvantages in using of aerosol means for fire suppression. The aerosol, being generated pyrotechnically, is very hot, so its temperature varies from 1500 ^{0}C to 800 ^{0}C. There are new models of generators of fire extinguishing aerosol (GEA) designed especially for producing low-temperature aerosol with temperature about 600 ^{0}C – 200 ^{0}C. Anyway, such temperatures are dangerous for some combustible materials and explosive atmospheres, so the application of the GEA for fire protection of explosive-hazardous facilities is restricted.

One of the ways of making the aerosol fire suppression tools safe for explosive atmospheres and combustible materials is to distribute the aerosol to protected enclosure by means of pipework. It reduces the temperature of aerosol and at the same time allows arranging one set of GEA to protect several enclosures.

Experimental investigation of the modification of extinguishing and physical characteristics of condensed aerosol during its transportation through the pipelines of different size, shape and material was the goal of the presented work.

EXPERIMENTAL

Experiments were conducted in a laboratory on especially designed experimental set-up (see the Figure 1). The experimental set-up consisted of a model enclosure with the volume of 0.11 cubic meters (0.4*0.4*0.7 meters), made of a transparent plastic. The model enclosure had several openings, which could be closed or opened to change the enclosure integrity. Three types of aerosol-forming compositions were used to produce the condensed aerosol (SBK-2, STK-2MD and STK-5-1). The samples of compound had different oxidizer/fuel proportion α (α(SBK-2)=0.46, α(STK-2MD)=0.44 and α(STK-5-1)=1.00) and temperature of combustion T (T(SBK-2)=1300° C, T(STK-2MD)=950° C and T(STK-5-1)=1200° C). During the experiments the samples were burned in the combustion chamber of the model GEA with the internal diameter d=25 mm without cooling. The pans with gasoline and PMMA samples were used as the model fires.

Condensed aerosol produced in the model GEA was transported to the model enclosure trough the pipes of metal and fiberglass with varied parameters: a) rectilinear pipes with smooth internal surface; b) rectilinear pipes with varied internal roughness and c) pipes bent by varied angles with smooth internal surface. In some experiments there was inert gas discharged into the pipe during the discharge of the aerosol.

Such experimental set was designed to obtain the following data:

1. $C_{eAFC}=f(L_p, D_p, \Delta, \alpha, C_{ig})$
2. $T_e=f(C_{AFC}, C_{ig}, L_p, D_p, \Delta, \alpha)$
3. $\tau_e=f(C_{eAFC}, I_{eAFC}, T_{CA}, L_p, D_p, \Delta, \alpha)$
4. $I_{eAFC}=f(N_e, T_{CA})$

Whereas:
N_e – the integrity of the enclosure (the total area of enclosure boundaries divided by the total area of the openings), dimensionless;
C_{AFC} – the specific extinction quantity of AFC, gAFC/m^{3}of enclosure;
C_{ig} - the effective quantity of the inert gas, g/m^3;
L_p – the length of the pipe, m;
D_p – the internal diameter of the pipe, m;
Δ - the roughness of the internal surface of the pipe, µm;
T_{CA} – temperature of the condensed aerosol at the pipeline discharge outlet °C;
T_e – ambient temperature of the enclosure °C;
τ_e – extinxtion time, seconds;
C_{eAFC} – the specific extinction quantity of AFC (gAFC/m^{3}of_enclosure);
I_{eAFC} – aerosol discharge rate, gram/cubic meter×second.

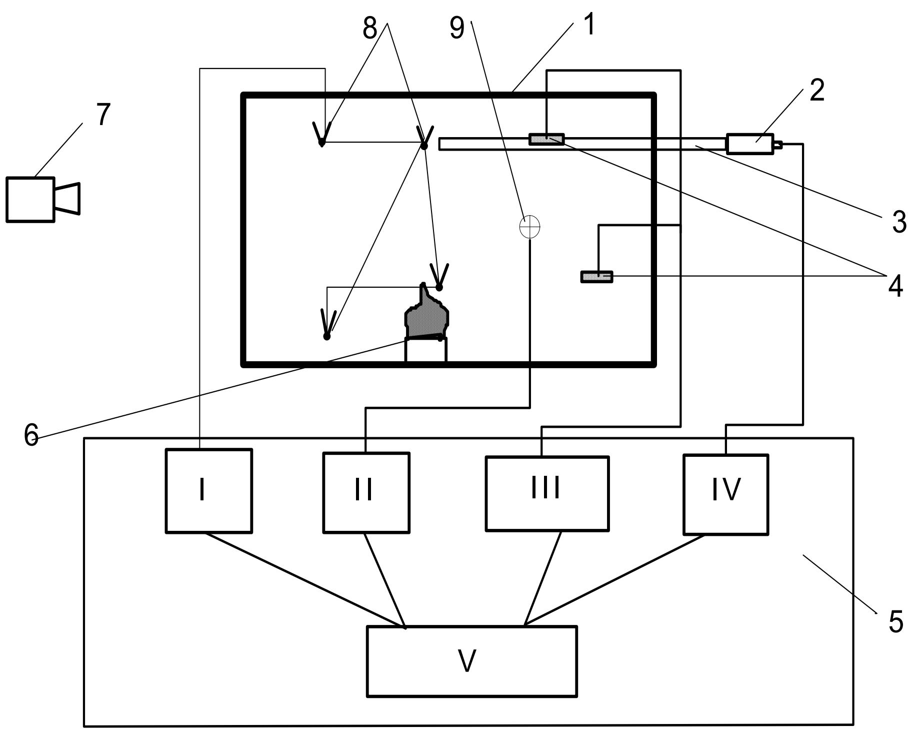

Figure. 1. The scheme of the experimental set-up.

1 – the model enclosure; 2 – generator of the fire extinguishing aerosol (GEA); 3 – the aerosol-transporting pipeline; 4 – pressure gauges; 5 – the control and measurement system (I - potentiometers; II - gas-analyzer, microscope; III - tensimeters; IV – the GEA starting device; V – power supply); 6 – the model fire; 7 - video recorder; 8 - thermocouple; 9 – sampler

RESULTS AND DISCUSSION

First of all an experiments showing the specific extinction quantity of AFC for model fires were conducted. In these experiments samples of aerosol-forming compounds were burned in the model GEA mounted in the model enclosure. Obtained data concerning the specific extinction quantity of AFC for all tested aerosol-forming compounds are stipulated in the Table 1.

Table 1.The extinguishing effective quantity of the condensed aerosol produced by the aerosol-forming compounds SBK-2, STK-2MD and STK-5-1 burning in the model GEA inside of the model enclosure.

Type of fuel	The extinguishing effective quantity, g/m^3		
	SBK-2	STK-2MD	STK-5-1
Gasoline	37	38	51
butanole	38	40	59
PMMA	35	36	57
Wood	39	44	65

Besides that, dependencies of the ambient temperature on the aerosol concentration were obtained for two types of the aerosol-forming composition which have different temperatures of combustion (SBK-2≅1300 °C and STK-2MD≅950 °C). The data are shown on the Figure 2. The ambient temperature in the enclosure is gained during the discharge in proportion to the aerosol concentration. The precise value of the ambient temperature depends on the combustion temperature of the aerosol-forming composition, the discharge rate and the enclosure integrity.

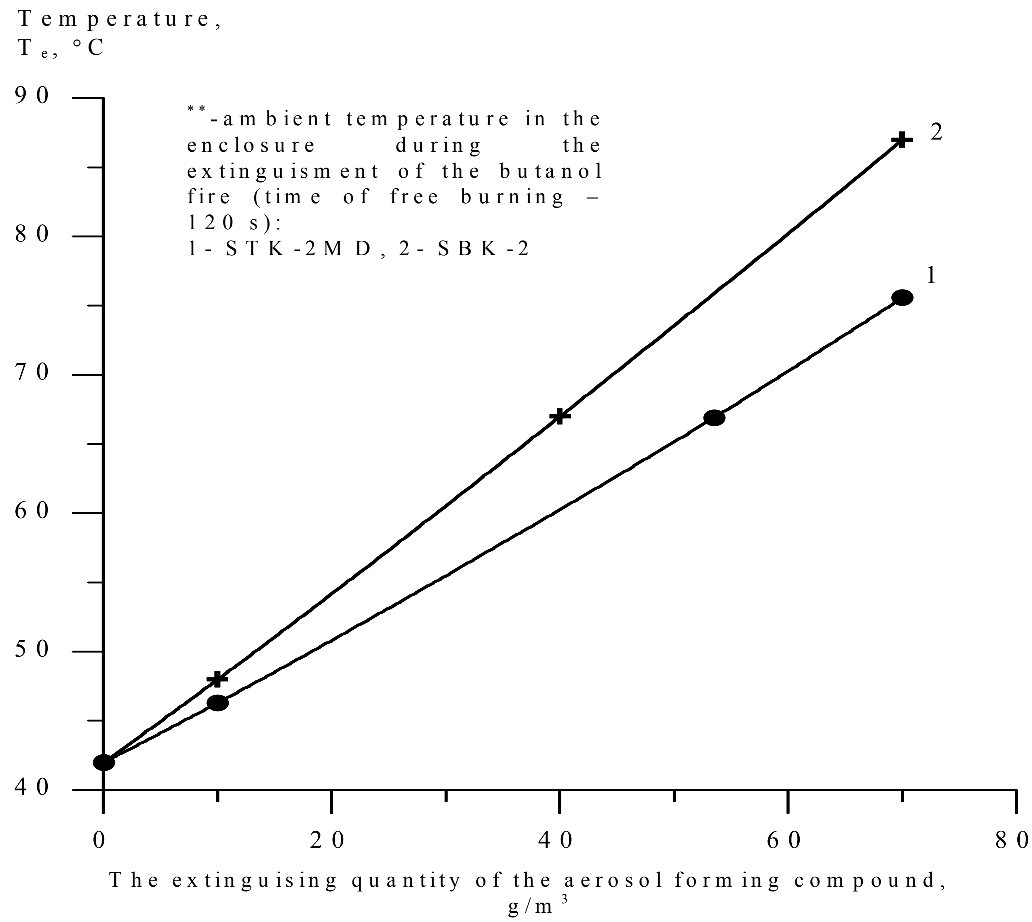

Figure 2.Dependance of the ambient temperature in the protected enclosure on the extinguishing quantity of the aerosol-forming compound during the extinguishment of the butanol fire by means of aerosol-forming compounds SBK-2 and STK-2MD

So for SBK (T_c= 1300 °C) the ambient temperature rises up to 32÷35 °C when C_{AFC}=50 g/m^3; up to 64÷70 °C when C_{AFC}=100 g/m^3; and for STK-2MD (T_c=950 °C) the ambient temperature rises up to 22÷25 °C when C_{AFC}=40 g/m^3; up to 45÷50 °C when C_{AFC} = 100 g/m^3 and so on. You can see that during the extinction of a fire by means of "hot" aerosols an ambient temperature in a protected enclosure can rise to a level dangerous for personnel or equipment.

The transportation of the aerosol through the pipelines allows reducing of the temperature of the aerosol to a safety level by using the pipelines with certain parameters. The dependencies of the aerosol temperature on the pipe length are shown on the Figure 3 and 5. The "hot" aerosol-forming compounds, SBK-2 and STK-5-1, with different oxidizer/fuel proportion α, were used to obtain the data. The transportation of such "hot" aerosols through the pipelines has reduced their temperatures significantly. For the pipes with length of 0.8 m and more and internal diameter of 12÷110 mm the temperature of the aerosol had dropped from 1300 °C to less than 380÷800 °C for SBK and from 1200 °C to less than 200÷250 °C for STK-5-1.

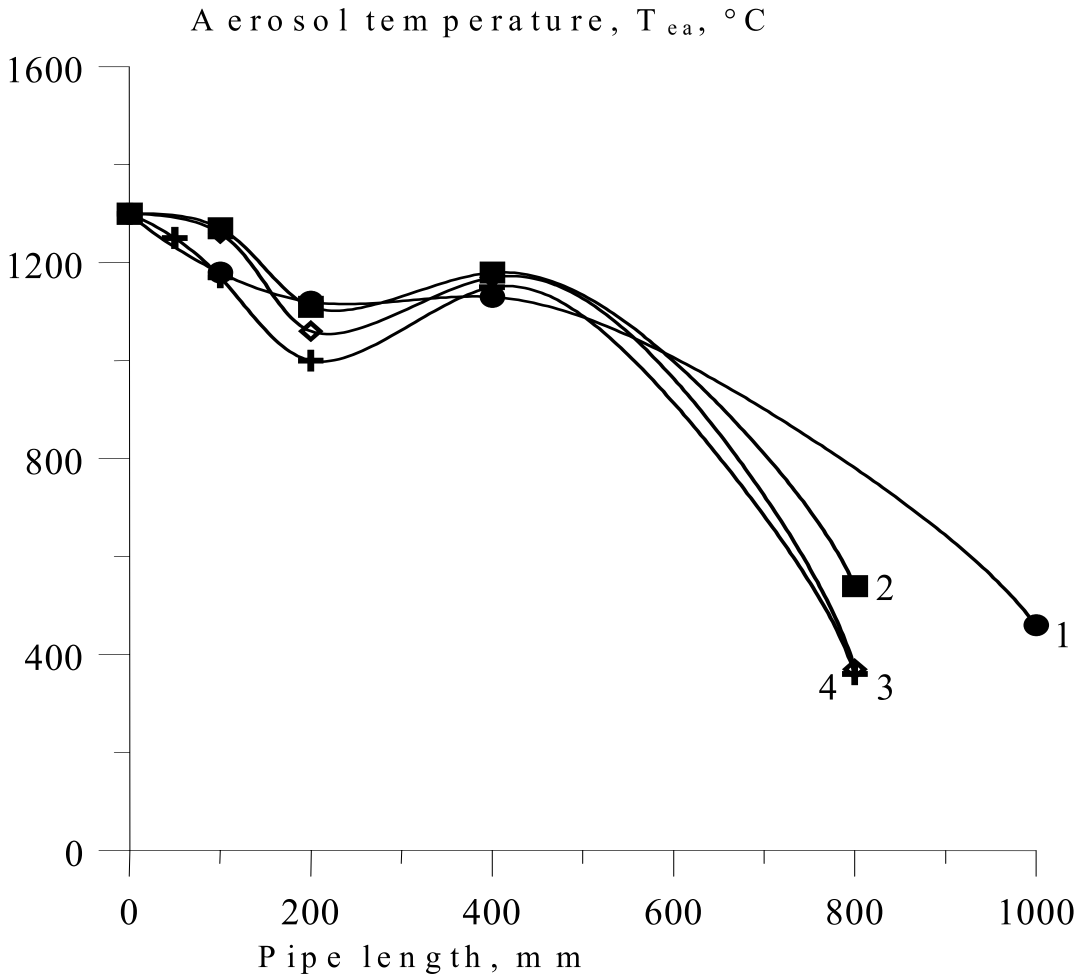

Figure 3. Dependence of the aerosol temperature on the pipe length for SBK-2
1 - Dp = 12 mm; 2 - Dp. = 25 mm;3 - Dp. = 50 mm; 4 - Dp. = 110 mm

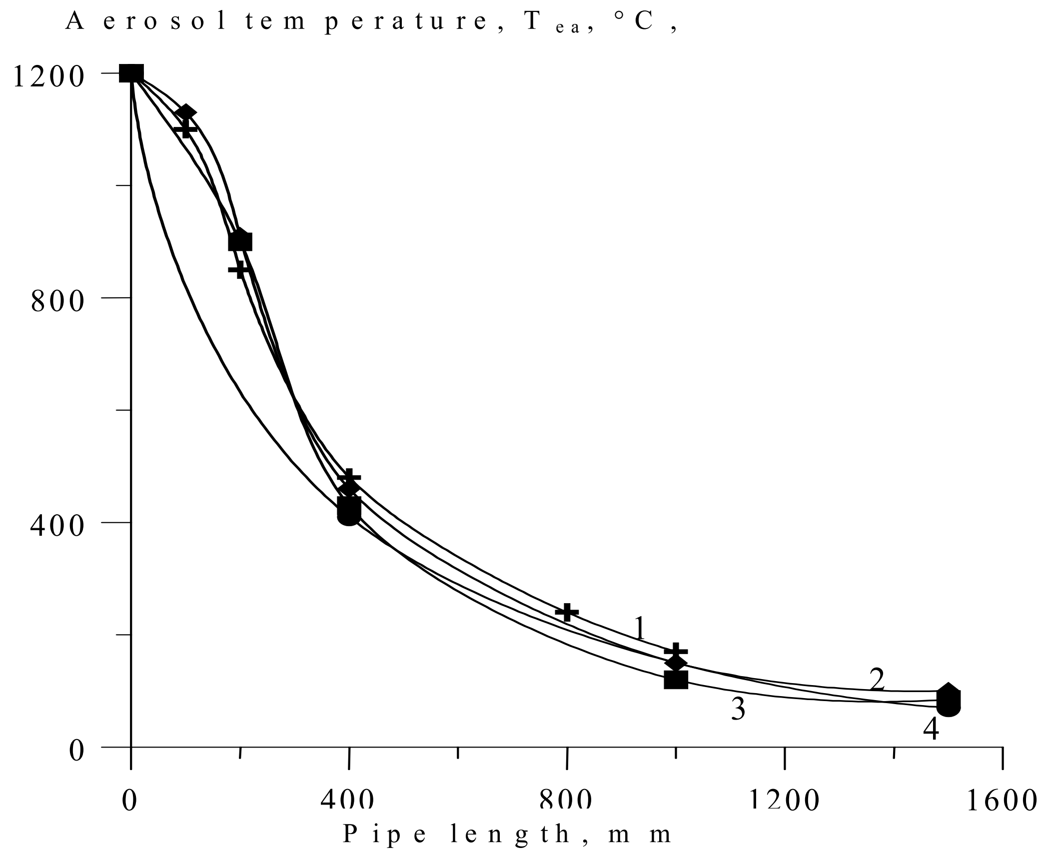

Figure 4. Dependence of the aerosol temperature on the pipe length for STK 5-1.
1 - Dp = 12 mm; 2 - Dp. = 25 mm;3 - Dp. = 50 mm; 4 - Dp. = 110 mm

It is observed that "rich in fuel" aerosol-forming composition (SBK is a good example) have some disadvantages:

- condensed aerosol formed by such a composition has some combustible ingredients, which are capable to burn in air after discharge, even if being cooled during the transportation; it can cause rise of the ambient temperature;
- the deceleration of the oxidation of the components of such aerosol during its transportation causes evolving of some toxic ingredients in the protected enclosure.

The aerosols produced by burning of AFC's with stoichiometric oxidizer/fuel proportion ($\alpha \cong 1.00$) are the most suitable for the pipe transportation purpose.

On the other hand, reduction of the aerosol temperature by means of transportation of aerosol through the pipelines causes the reduction of its extinguishing efficiency too. It happens because of coagulation of the aerosol particles, reduction of their total surface area and absorption of the particles on the pipe internal surface. The experimentally obtained dependencies of specific extinction quantity of AFC (gAFC/m^{3}of_enclosure) extinguishing concentration of the aerosol on the pipe length for pipes with internal diameter of 12÷110 mm are shown on the Figure 5 and 6. When using pipelines of more than 0.8 m length the extinguishing concentration increases: for SBK- composition in 2.5-3.5 times; for STK-5-1-

composition in 2-3 times. The extinguishing efficiency is as much reduced as pipe internal diameter is; the minimum was obtained for the transportation of the aerosol, produced in the model GEA with diameter of 25 mm through the pipelines with internal diameter of 50 and 100 mm.

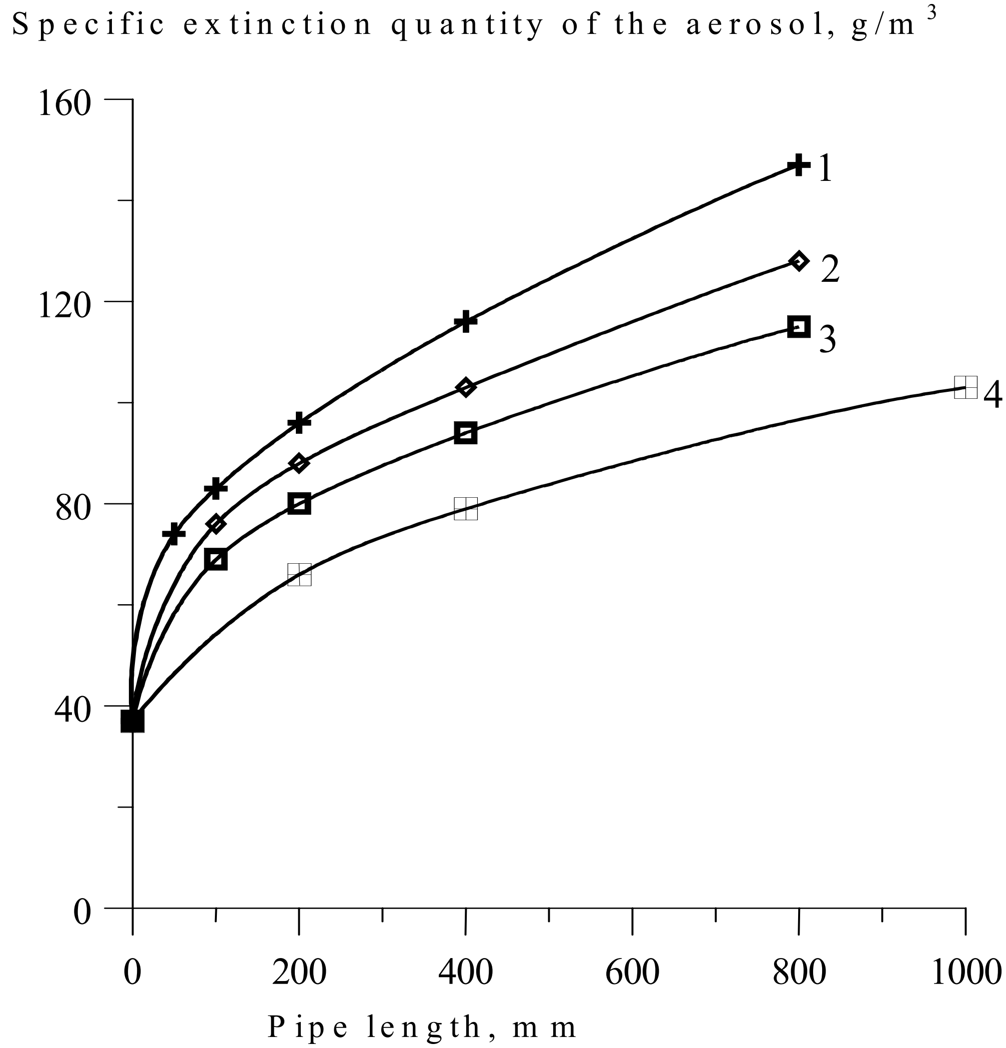

Figure 5 Dependence of the specific extinction quantity of AFC on the pipe length during the extinction of the gasoline model fire (for SBK-2):
1 – D p. = 12 mm; 2 - D p. = 25 mm; 3 - D p. = 50 mm; 4 - D p. = 110 mm

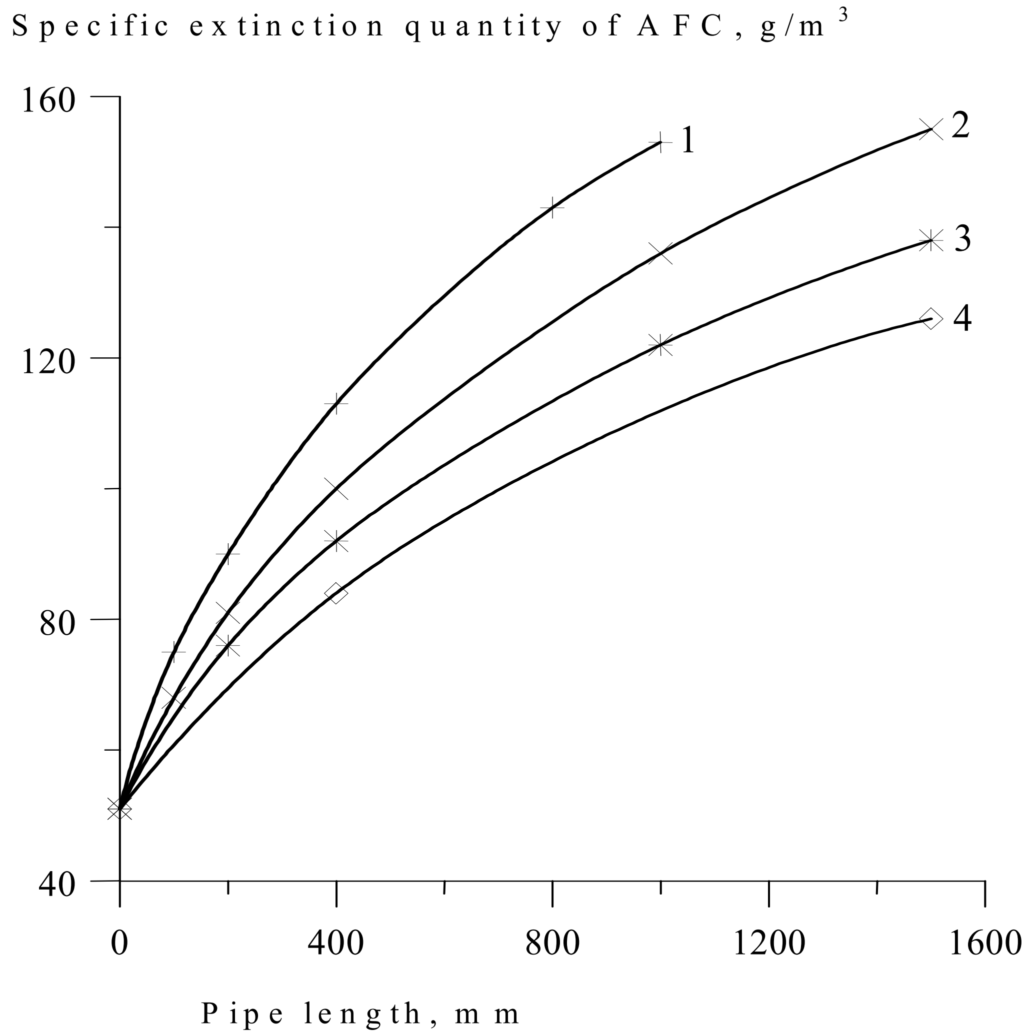

Figure 6 Dependence of the specific extinction quantity of AFC on the pipe length. during the extinction of the gasoline model fire (for STK-5-1):
1 – D p. = 12 mm; 2 - D p. = 25 mm; 3 - D p. = 50 mm; 4 - D p. = 110 mm

The increased roughness of the internal surface of the pipe causes the reduction of the extinguishing efficiency of the aerosol too (see the Figure 7).

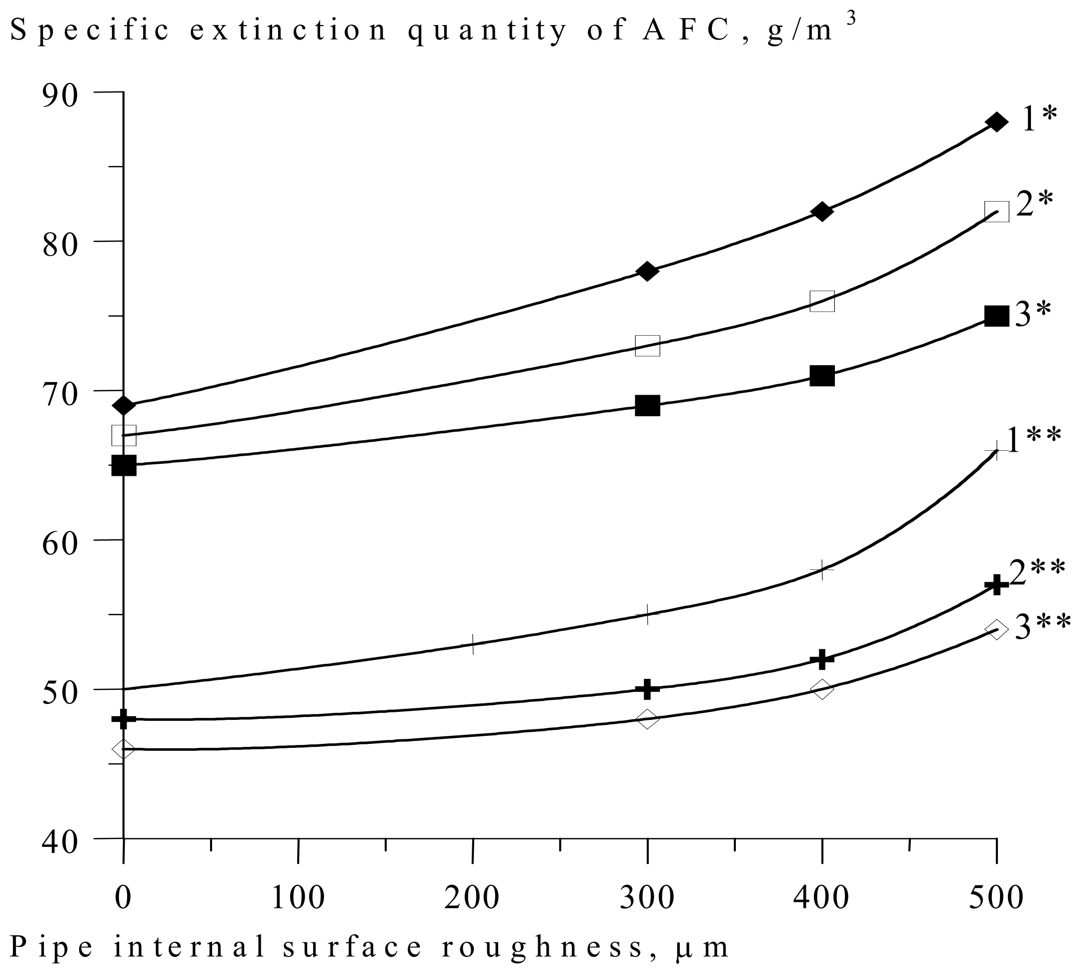

Figure 7. Dependence of the specific extinction quantity of AFC on the pipe internal surface roughness (for pipes with length of 100 mm) during extinction of the gasoline model fire:- * - SBK-2; ** - STK-5-1; 1*, 1- D p.= 12 mm; 2*, 2**- D p. = 25 mm; 3*, 3** - Dp.=50 mm**

The roughness of the internal surface of the pipe (the pipe length is less than 0.8 m) with Δ less than 300 microns reduces the extinguishing efficiency for not more than 10÷12%.

The pipe bend also reduces the aerosol temperature and the extinguishing efficiency (see the Figure 8 and 9). When the bend angle of the 400 mm long pipe is increased from 30° to 90°, the temperature of the aerosol is reduced for 20÷30%.

The other factors that have substantial influence on aerosol extinguishing efficiency (besides the aerosol temperature) are the enclosure integrity and the rate of discharge [1-3].

Till now the experimental and calculation data used for developing of the national standards regarding an aerosol means for fire suppression were obtained for the "hot" condensed aerosols. But the fire extinguishing efficiency of condensed aerosols and the conditions necessary for successful fire extinction depend on the aerosol temperature to a great extent. Cooled condensed aerosol is much more suitable instead “hot” aerosol, for fire suppression in non-tight enclosures. Cooled aerosol isn’t likely to go out of the enclosure through the leakage's, unlike “hot” aerosol, so the total reliability of the aerosol mean for fire suppression increases [3]. Experimental results concerning the extinguishing of the model fires of gasoline and PMMA in the enclosure with varied integrity by condensed aerosol, produced by burning the STK-5-1 composition and transported through the 400 mm long metal pipe with internal diameter of 50 mm are shown on the Figure 10.

We can resume that the cooling of the aerosol during its transportation through the pipelines causes the reduction of its extinguishing efficiency more or less. The discharge of an inert gas, for example, carbon dioxide, through the pipeline simultaneously with the aerosol discharge can be used to compensate that reduction of the efficiency (see the Figure 11). It causes the dilution of the condensed aerosol, which prevents coagulation of its particles, and reduces the temperature of the aerosol and the ambient temperature in the protected enclosure [3-4,6].

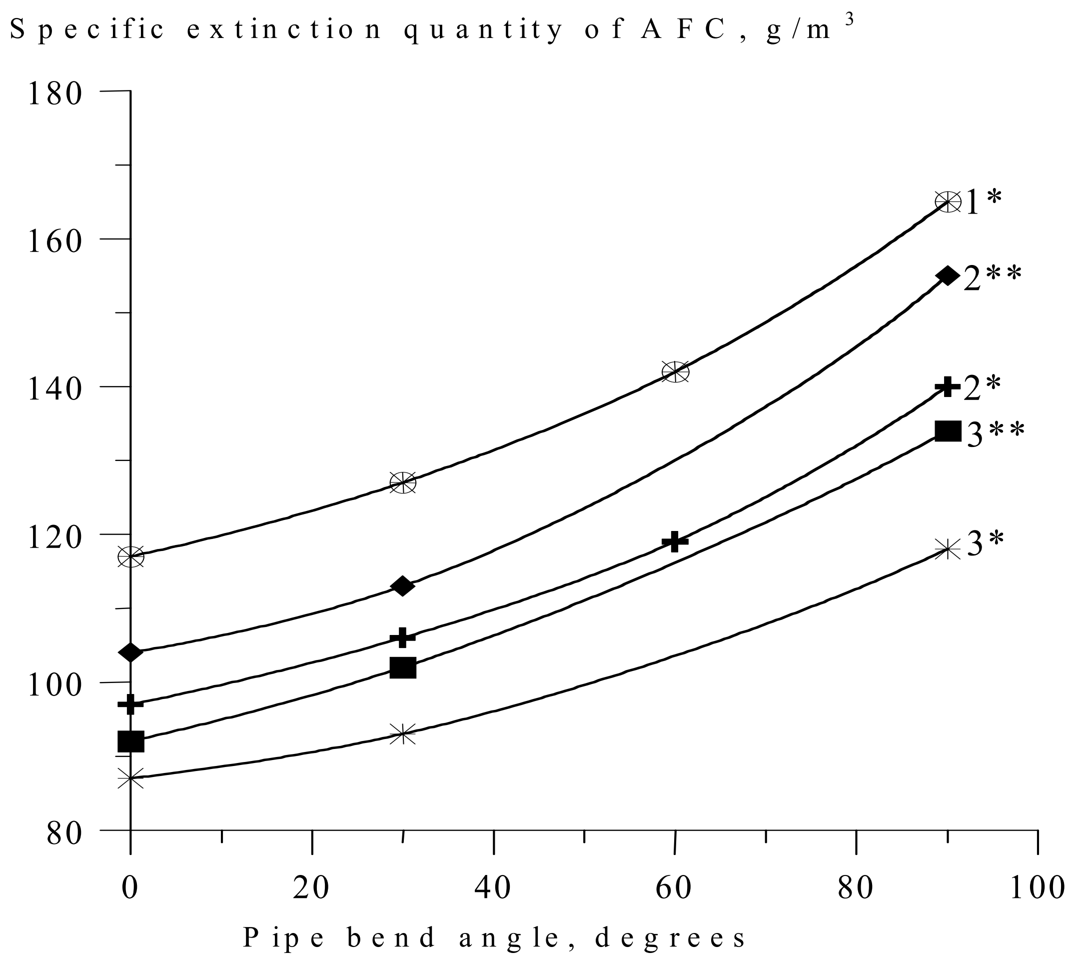

Figure 8. Dependence of specific extintion quantity of AFC (* - SBK-2; ** - STK-5-1) on the pipe bend angle for pipes with length of 400 mm.
1*- D p. =12 mm ;2*, 2- D p =25 mm; 3*, 3** - D p. = 50 mm**

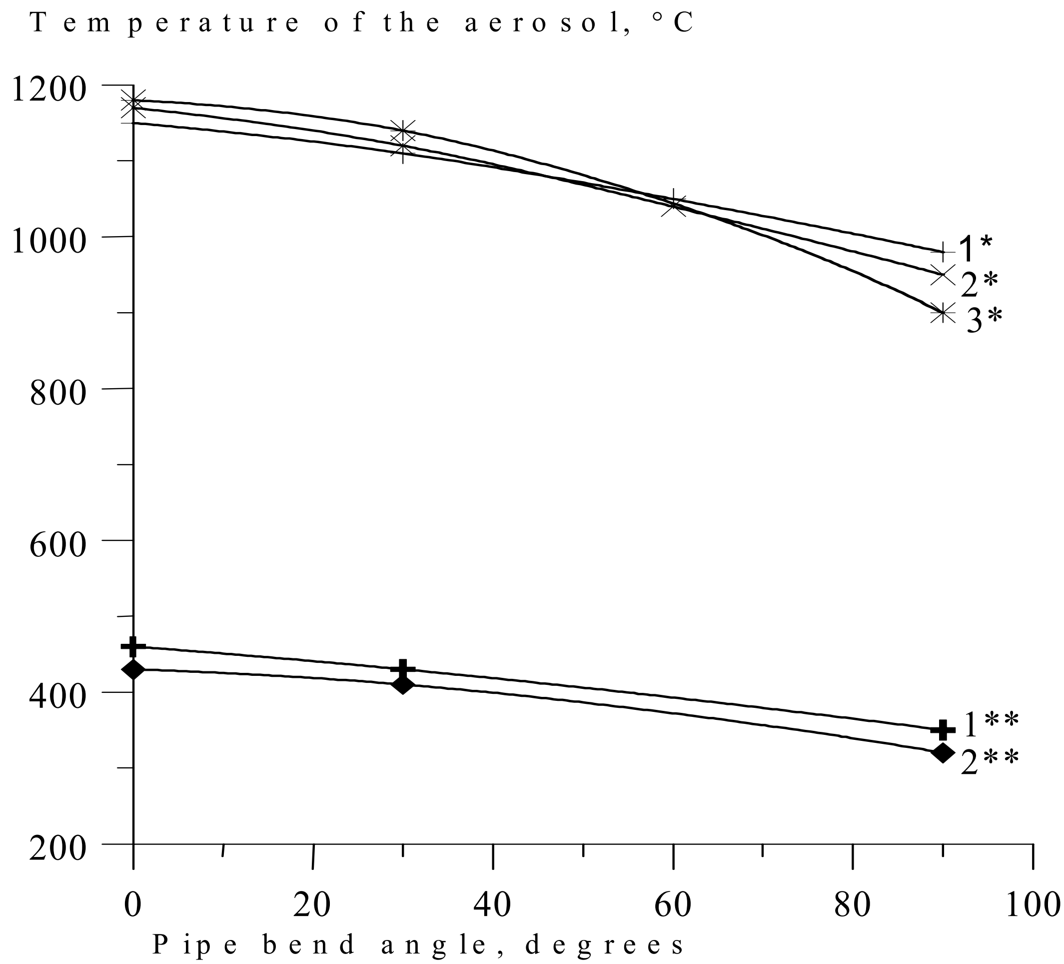

Figure 9. Dependence of temperature of condensed aerosol (* - SBK-2; ** - STK-5-1 on the pipe bend angle for pipes with length of 400 mm.
1*- D p. =12 mm ;2*, 2- D p =25 mm; 3*, 3** - D p. = 50 mm**

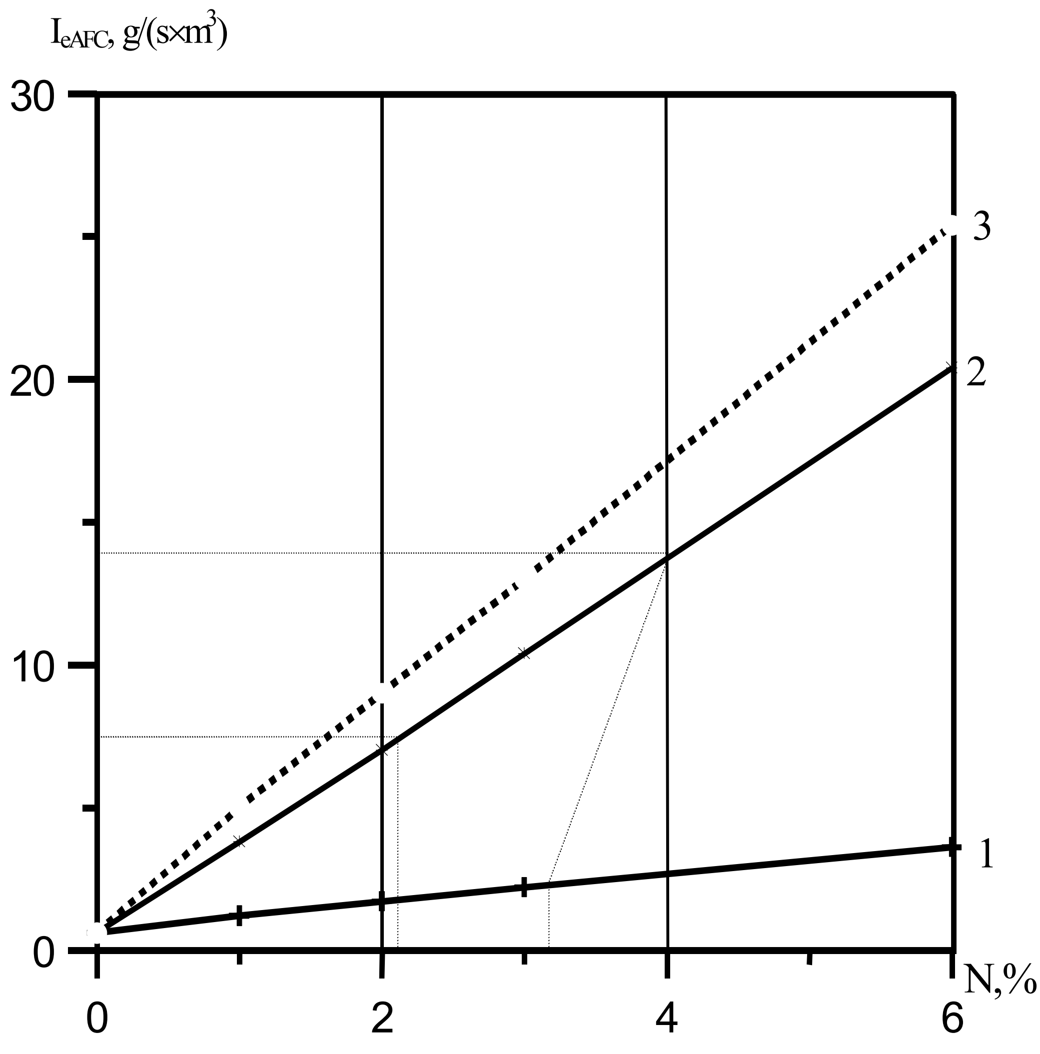

Figure 10. Dependence of the nessesary for extinction disharge rate of the cooled aerosol (I_{eAFC}) on the integrity of the model enclosure (N) and the placement of leakage's: 1 – leakage's are placed in the lower part of the enclosure; 2 - leakage's are placed both in the lower and in the higher parts of the enclosure (total leakage area of the higher part divided by the total leakage area of the lower part is less than 1); 3 - leakage's are placed both in the lower and in the higher parts of the enclosure (total leakage area of the higher part divided by the total leakage area of the lower part is less than 1)

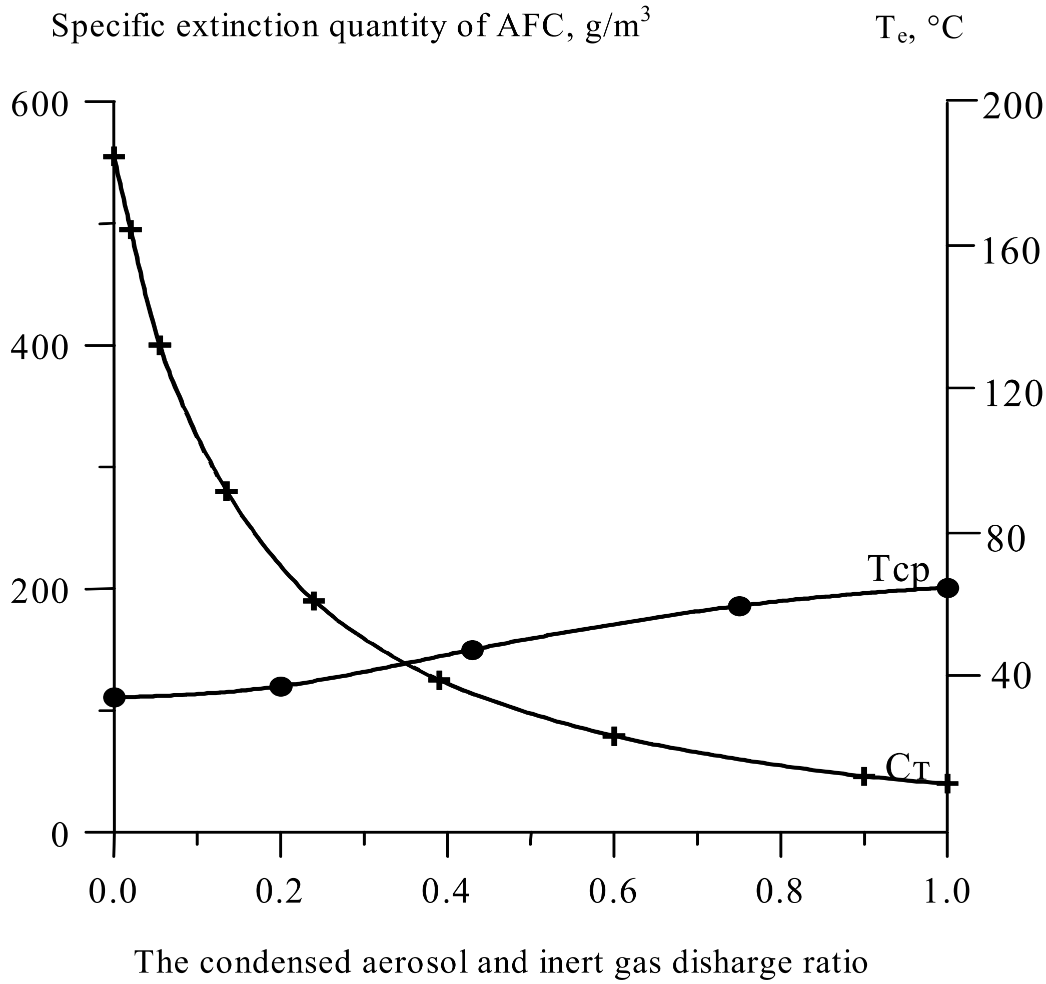

Figure 11. Dependence of specific extinction quantity of SBK-2 and ambient temperature via enclosure on the condensed aerosol and inert gas (CO_2) disharge ratio. Condensed aerosol and inert gas were transported trough the pipeline with 1,4 m and diameter 50 mm)

CONCLUSIONS

The dependencies of the most important (from the practical point of view) characteristics of condensed aerosols (such as temperature and extinguishing efficiency) on the parameters of the pipelines by which it is being transported can be regarded as a result of presented work. The obtained data were used to improve Russian national standards regarding an application of an aerosol means for fire suppression [9-10].

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