

NEW TYPES, HALOGEN LESS, ECO-SAFE FIRE-EXTINGUISHING POWDERS AND FOAM-SUSPENSIONS

Lali Gurchumelia¹, Murman Tsarakhov¹, Felix Bejanov², Lasha Tkemaladze², Olga Chudakova²

¹TSU Rafael Agladze Institute of Inorganic Chemistry and Electrochemistry,
11, Mindeli str., Tbilisi, 0186, Georgia

²G. Tsulukidze Mining Institute of the Ministry of Education and Sciences of Georgia,
7, Mindeli str., Tbilisi, 0186, Georgia

Abstract

The aim of the presented investigation is the elaboration of non-halogen, eco-safe, high-efficient, inexpensive and universal fire- extinguishing powders on the basis of local mineral raw materials, which will have good compatibility with water and foams. Thus, foam-suspensions elaborated on the basis of the received powders, will have higher extinguishing ability than water, foams or powders taken separately. Such powders prepared by mechanical treatment and blending of raw materials do not require modification with expensive, halogeninclusive hydrofobizators. On the one hand it simplifies technological process of production of powder and on the other hand decreases prices of powder. The received powders are characterized with high performance characteristics, as well as, high fire-extinguishing ability. Therefore they can be successfully used at extinguishing of all classes of fires in underground and aboveground objects, as well as, in complex with water and foams for extinguishing of large scale fires – forest fires.

Key words: non-halogen, eco-safe, fire-extinguishing powders, foam-suspensions, performance properties, fire extinguishing ability

1. INTRODUCTION

Fires are unsolved problems of world civilization. Within the recent years an amount of fires have increased progressively, which in definite measure is associated with a realization of terrorist actions. No less dangerous are the cases of population choking and poisoning by fire, which is caused, mainly, by combustion products as well as by toxicity of using safety precautions. Unfortunately, the statistics confirms, that traditional safety precautions, for the present, are sufficiently expensive, neither eco-safe nor universal and less efficient. Therefore, the world faces the problem of fire localization, suppression and development of such safety precautions, which will provide inhibition of burning of matter in the zone of inflammation and decrease of toxic materials emission. The use of eco-safe fire-extinguishing means, occur topical among the mentioned measures, and powder ones are admitted to be most efficient fire- extinguishers as unique means against any type of fires (Takashi et al. 2005, Baratov & Vogman 1982, Schreiberg & Porret 1985). It is known, that at present fire-extinguishing powders of serial production represents the fine dispersed mineral salts with different additives, which decrease tendency of consolidation and caking of powder. In serial production powders halogen containing, organic hydrophobizators are mainly used as such additives. Thus, most of them are halogen containing and do not satisfy the contemporary demands, in the first place with the view of effective, non-toxic and universal use. It is unambiguously stated that when halogen gets into atmosphere it causes the disturbance of ozone layer (Schreiberg & Porret, 1985, Baratov et al, 2002).

Therefore, at present one of the most important problem is the elaboration of non-halogen, non-toxic, eco-safe fire- extinguishing powders. It also should be mentioned, that fire- extinguishing powders are characterized with less heat capacity, low permeability and wetting effect compared to water and foams, that's why at extinguishing large scale fires they cannot wholly solve the problem of new ignition caused with inflammation of flickering focuses in open space (Baratov et al. 2002, Potapova 2003). With consideration of the above said it follows, that for extinguishing of large scale fires, particularly - forest fires, use of just fire- extinguishing powders is less effective.

The aim of the presented investigation is the elaboration of non-halogen, eco-safe, high-efficient, universal fire-extinguishing powders on the basis of local mineral raw materials of silicate origin and production of highly effective foam-suspensions based on such powders, the use of which will have higher extinguishing ability than water, foams or powders taken separately. The received fire-extinguishing powders will be used at extinguishing of all classes of fires, as well as, in complex with water and foams for extinguishing of large scale fires – forest fires.

Raw materials: zeolite, clay shale and perlite we selected according to their high operating properties and due to the factors indicating the reduction of burning processes. This is enabled with chemical and thermo-gravimetric analysis. Such raw materials mainly are silicate origin and contain alkali and alkaline-earth metal carbonates, bicarbonates, silicates, oxalates, also Fe, Al and alkali metal hydroxides and crystallization water. On the basis of thermo-gravimetric analysis it is stated, that at their intensive heating incombustible gases, water steam and metal oxides are separated. Released incombustible gases and water steam in flame zone are functioning as phlegmatizer and in surface zone are causing the formation of risen layer. The latter, protective film of metal oxides, risen and coke layer create “fire-limiting” effect. This is indicating to the fact, that they are characterized by high inhibition properties (Gurchumelia et al. 2008).

The extinguishing powders not only should effectively extinguish fire, but they should maintain their performance properties and the negative change of these properties decreases powder effectiveness. The most important performance characteristics are: tendency to consolidation and caking, moisture adsorption, dispersity, powder flow and storage duration. The least desirable performance property is tendency to consolidation and caking, which complicates and conclusively cancels the fire-extinguishing ability of the powder. The main reason, which caused consolidation and caking, is a humidity and temperature of medium. The powder absorbs moisture from air, that is to say, solid particles are dissolved in condensates water and the saturated solution of the solid phase is formed. By further increase of humidity the solution becomes supersaturated and at the contact surfaces of supersaturated and saturated particles the crystallization out of solid phase takes place. Formation of phase contacts is possible only in the conditions of new coagulation. An average hardness of elementary contacts of individual particles depends on the hardness of powder structure (packing and consolidation and caking,) which, for its part, is dependent on particles dispersity, settling and compaction degree. It is established, that the tendency to consolidation and caking increases with increasing dispersity (Gurchumelia et al. 2008, Tsitsishvili et al. 1985).

Proceeding from the above said, that the effectiveness of powder depends on their inhibition properties and on their performance characteristics as well.

2. EXPERIMENTAL PROCEDURE

Fire-extinguishing powders, we prepared by mechanical treatment (grinding and drying at 70⁰-100⁰C) and mixing of raw materials: zeolite, perlite, clay-shale and ammophos, which does not require the modification with expensive halogeninclusive hydrofobizative additives. On the one hand it simplifies technological process of production of powder and on the other hand decreases prices of powder. Such powders have good compatibility with water and foams. The addition of surface active substances into powder suspensions decreases water surface tension, increases permeability and causes powder flotation, which will enable to spray powder together with foam. Thus, foam-suspensions we prepared by mechanical blending of waters, obtained fire-extinguishing powders and surface active substances.

2.1. Performance properties

In order to study performance properties of powders and foam-suspensions laboratory standard methods (Fire Extinguishing Powders of General Purpose 1998, Gurchumelia et al. 2009) are used: caking capacity, moisture adsorption, dispersity, powder flow, storage duration, foam order and foam state. The least desirable operation property of powder is caking capacity, which affects the extinguishing ability of powder.

- powder dispersivity, x (%) - granulometric composition, mass concentration of powder remains left on the sieve

$$x = \frac{m_1}{m}$$

where: m_1 - mass of powder remains on the sieve, kg; m - total mass of remains, kg.

- powder fluidity, Q (kg/s) - powder mass consumption in time necessary for its dispersion from test fire extinguisher

$$Q = \frac{m - m_\tau}{\tau}$$

where: m - mass of extinguisher before testing, kg; m_τ - mass of extinguisher after testing, kg.

- moisture content and tendency to humidity, W (%) - the ratio of moist absorbed with powder to powder mass

$$W = \frac{m_1 - m}{m} \cdot 100$$

where: m_1 - mass of powder remains after moisting, kg; m - total mass of remains, kg.

- tendency to consolidation and caking, C (%) - caked mass ratio to powder mass:

$$C = \frac{m_c}{m}$$

where: m_c - mass of formed cakes, kg; m - powder mass, kg.

- storage duration - the duration of powder storage in the conditions, established by normative documents, during of which the powder operating properties and flow is content;

- foam order - C (%) ratio of the received foam volume - V_f to initial volume of foaming agent water solution V .

$$C = (V_f/V) \cdot 100$$

- foam state, time when 50% of foam volume is deteriorated or time when 50% of liquid phase is separated.

Test data of performance factors are given in Table 1.

Test results show, that zeolites are characterized with low tendency to consolidation and caking but with high capacity of moisture absorption, which considerably decreases at admixture of clay shales and perlites. Thus, zeolite-containing composite powders are characterized with low capacity of moisture absorption, as well as, caking ability.

Foam-suspensions production on the bases of obtained composite powders (zeolites, perlites and clay-shales) modified with the phosphorous ammonium salts (ammophos) are characterized by high performance properties: foam order - 200% and foam state – 18-20 sec.

#	Materials	Powder dispersity	Specific surface areas, S (cm ² /kg)	Powder fluidity, Q (kg /s)	Moisture content and tendency to humidity, W%	Tendency to consolidation and caking, C%
1	Clay shale	# 0.1	7270	—	0.18	50
		# 0.1-0.2	5530	0.17	0.18	7.5
		# 0.2-0.3	5100	0.17	1.22	1.02
2	Zeolite	# 0.1	5530	—	4.62	20
		# 0.1-0.2	4640	0.16	4.23	0.6
		# 0.2-0.3	4280	0.16	2.31	0.0
3	Perlite	# 0.1	2540	—	0.83	18
		# 0.1-0.2	1295	0.14	0.53	0.1
		# 0.2-0.3	1093	0.14	0.11	0, 01
4	Zeolite + Clay shale + Perlite	# 0.2-0.3	-	— 0.14 0.14	0.02	0.002
5	Zeolite + Clay shale + Perlite + Amophos	# 0.2-0.3	-	— 0.14 0.14	0.024	0.02

Table 1. Performance properties

We determined the specific surface area of the powders with different dispersity and established the dependence of powder caking on specific surface area (Table 1 and Fig. 1). Powder disparity we determine by granulometric methods. In order to define specific surface area air-penetrating method device ADP -3 is used.

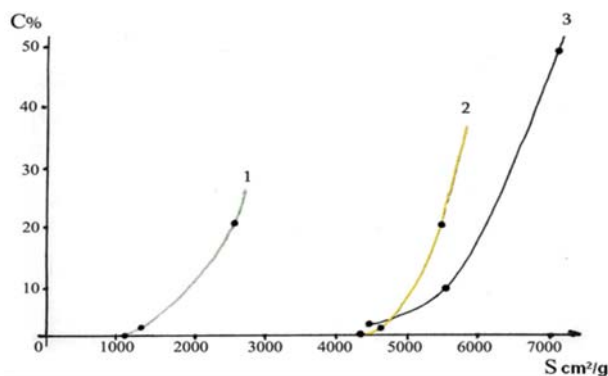


Fig. 1. The relation of powder caking and specific surface areas

1 – Zeolite; 2 – Perlite; 3 – Clay shale

The analysis of experimental data shows, that the caking capacity of high-dispersive powders sharply increases with increasing dispersity, while the caking capacity of lower-dispersive powders

insignificantly changes with changing dispersity. For example, when powder dispersity $< 100 \mu$ the caking capacity is 35–45%, while dispersity is within 100–200 μ caking capacity rapidly decreases to 0,2 – 0,4% and when dispersity - 200–300 μ caking capacity drops to 0%.

On the basis of investigations powder dispersity were selected - up to 250 μ .

2.2. Fire extinguishing ability

With consideration of standard conditions of development of different type fires the fire- extinguishing ability of powders is determined with experimental (polygon) method, which consider extinguishing of different class standard fires with the help of fire- extinguishing constructions and enable to determine: minimum quantity of powder which is consumed for fire- extinguishing or minimum consumption per unit area (G); minimum mass concentration (Cn) and time of fire- extinguishing (τ).

We determine fire-extinguishing ability of powders for the A (wood) and B (oil) class standard fires. Fire-extinguishing ability of foam-suspensions we determine by preliminary experiments for the wood. Experimental results of fire-extinguishing ability are given in Table 2.

Material	Seat of fire				Time of fire extinguishing, τ (s)	Minimum consumption per unit area, G (kg/m ²)	Minimum mass concentration, Cn (kg/m ³)
	Class of fire	Length of seat of fire, L (m)	Area of extinguishing, S (m ²)	Volume of fuel, V (l)			
Clay shale	A	0.5	0.9	-	18	4.1	8.2
	B	-	0.25	4	12		7
Zeolite (Clinoptilolite)	A	0.5	0.9	-	15	2.6	5.2
	B	-	0.25	4	8		4.8
Perlite	A	0.5	0.9	-	10	2.2	4.4
	B	-	0.25	4	8		4.0
Zeolite + Clay shale + Perlite	A	0.5	0.9	-	10	1.8	3.6
	B	-	0.25	4	7		2.0
Zeolite + Clay shale + Perlite + Amophos	A	0.5	0.9		8	1.4	2.5
	B	-	0.25		6		1.1
Foam suspension	A	0.5	0.9		5	-	-
	B	-	-		-		-

Table 2. Fire-extinguishing ability

Test results show, that composite powders (zeolites, perlites and clay-shales) are characterized with higher fire extinguishing ability than zeolites, perlites and clay shales taken separately and admixture of zeolite-containing composite powders with phosphorous ammonium salts, considerably increases fire extinguishing capacity.

Preliminary experiments of foam-suspensions produced on the bases of composite powders (zeolites, perlites and clay-shales) modified with the phosphorous ammonium salts confirm, that they are characterized by higher fire-extinguishing ability than obtained powders.

3. RESULTS AND DISCUSSION

Experimental results on performance properties of zeolites, clay shales and perlites confirm that zeolites are characterized with lower caking ability, but higher moisture capacity compared to perlites and clay shales, while, composite powders produced for admixture zeolites, perlites and clay shales are characterized with low moisture capacity, as well as, caking ability. This is indicating of the fact, that zeolite in composite powders play the role of hydrophobizators. Proceeding from the above said, zeolite-containing composite powders does not require the modification with expensive halogeninclusive hydrofobizative additives, which is reflected in the low cost price of powders. Therefore, we can surmise, that the introduction of phosphorus ammonium salts in zeolite-containing composite powders, which are highly hygroscopic, but characterized inhibition effect of burning products, does not cause significant changes of operating properties, but considerably increases fire-extinguishing capacity.

For the increases of efficiency of powder optimal dispersity (up to 250 μ) were selected in such way, that caking capacity be minimal, powder feed must be convenient (high-disperse powder direct feeding into ignition place creates many problems) and particle measures should be suitable for their rapid heating and destruction, that is to say a homogeneous action of combustion products on the flame as well as a heterogeneous inhibition of combustion process must take place. Homogenous effect means heating, evaporation and destruction of powder particles, when there happens emission of incombustible gases and metal oxides performing burning processes inhibition. But it is known, that if powder particles dimensions exceed 50 μ than, such particles have no time to be heated to ignition temperature, therefore homogeneous mechanism of extinguishing is less effective and heterogeneous mechanism has leading role, which means heterogeneous removal of reaction active centers (atoms and radicals) on the surface of solid particles of the powder.

Experimental results on fire-extinguishing ability of powder confirm, that composite fire-extinguishing powders based on zeolites, perlites, clay shales and ammophos on flame zone perform homogenous as well as heterogenous inhibition of combustion process and in surface zone they form protective layer, which hinders heat transfer to combustive material and excludes direct contact of combustive material with air. Hence, they are characterized by high fire-extinguishing effect.

From the all above-mentioned one can suggest, that obtained fire-extinguishing powders are non-halogen, eco-safe, highly effective and far cheaper than imported analogues. Thus, they can be successfully used at extinguishing of all classes of fires in underground and aboveground objects, within large temperature range or, in such low temperatures where CO₂, water and chladones could not be used.

As it is known phosphorous ammonium salts are heterogenic inhibitors well dissoluble in water. In case of suspension production on the bases of composite powders modified with the mentioned minerals water inhibition increase is expected, i.e., the inhibition effect of chemical reactions going on in flame zone is increase. At the same time the diluting effect of burning gases and water heat capacity is increase.

The additional introduction of surface active substances into suspensions decrease water surface tension and increase permeability, at the same time cause powder flotation which is enable to spray powder together with foam.

Therefore foam-suspensions, elaborated on the basis of the received powders have higher cooling effect and permeability compared to powders, while differing from water and foam they make homogenous, as well as, heterogeneous inhibition of burning process. Thus they have higher extinguishing ability than water, foams or powders taken separately. Since, they can be successfully used for extinguishing of large scale fires – forest fires.

At the same time, as it is well known, zeolites, and ammophos represents combined fertilizers, which decreases acidity of soil, regulates interchange of P, K and N - ions in the soil, cultivates microorganisms and promotes their growth, which in turn are indicators of soil productivity (Tsitsishvili et al. 1985). Proceeding from the above said, we can predict, that the obtained composite

powders and foam-suspensions not only effectively extinguish fires, but they can also decrease concentration toxic gases in medium and prevent the probability of their penetration in the soil.

CONCLUSION

- Received fire-extinguishing powders are made by mechanical treatment and mixing of local mineral raw materials of silicate origin, which does not require modification with expensive, halogen-containing hydrofobizative additives, thus they are non-halogen, eco-safe, highly effective and far cheaper than imported analogues.
- They are characterized of good compatibility with water and foams. Thus, foam-suspensions elaborated on the basis of the received powders, have higher cooling effect and permeability compared to powders, while differing from water and foam they make homogeneous, as well as, heterogeneous inhibition of burning process. Therefore, they have higher extinguishing ability than water or powders taken separately.
- From the all above-mentioned one can suggest, that the fire-extinguishing powders of our preparation may be effectively used for extinguishing of all classes of fires in underground and aboveground objects, within large temperature range, as well as at such low temperatures when CO₂, water and foam cannot be used and in complex with water and foams for extinguishing of large scale fires – forest fires.

REFERENCES

- Baratov, A and Vogman, L (1982), 'Fire extinguishing powder compositions', Moscow: Stroyizdat.
- Baratov, A, Kopylov, N & Timofeev, E 2002, 'About Substitution for Ozone-Depleting Agents for Fire Extinguishing', *Proceedings of the 12th Halon Options Technical Working Conference*, eds. R.G Gann & P.A. Reneke, NIST SP 984: Gaithersburg, MD, pp. 1-12.
- 'Fire Extinguishing Powders of General Purpose' 1998. Testing methods, Normative Documents, ГИИБ 170-98, Russia.
- Gurchumelia, L, Bejanov, F, Baliashvili, G & Sarjveladze, N 2008, 'Development of Novel Composite Fire-extinguishing Powders on the Basis of Mineral Raw Materials', *Modelling, monitoring and management of Forest Fires*, Wit Press publishes leading books in Science and Technology, Toledo, Spain, pp.61-71 <<http://library.witpress.com/pages/PaperInfo.asp?PaperID=19595>>
- Gurchumelia, L, Bezarashvili, G, Chikhradze, N and Chudakova O 2009, 'Investigation of performance properties of novel composite fire-extinguishing powders based on mineral raw materials. Materials Characterisation., New Forest, UK: Wit Press publishes leading books in Science and Technology, pp.337-347 <<http://library.witpress.com/pages/PaperInfo.asp?PaperID=20159>>
- Potapova T 2003, 'Forest Fires', *Info Pravo – Recommendations for detection and extinguishing of forest fires* (YTB), V Mire Nauki, №3.
- Schreiberg G & Porret P 1985, 'Fire-extinguishing Means', Moscow.
- Takahashi, F, Linteris, G & Katta, V 2005, 'Physical and Chemical Aspects of Cup-Burner Flame Extinguishment', *Halon Options Technical Working Conference, 15th Proceedings*, Next Generation Fire Suppression Technology Program, May 24-26, 2005, Albuquerque, NM, pp. 1-10.
- Tsitsishvili G, Andronikashvili T & Kirov G 1985, 'Natural zeolite', Moscow: Chemistry.