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Development of Innovative Multilayer Materials for Gas-Tight Suits*

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Abstract

The paper notes a crucial role of personal protective equipment (PPE) of skin integument during work with hazardous substances and liquidation of emergency at industry and transport enterprises. Earlier, two- and three-layer materials were used in the country and abroad to manufacture PPE of the isolating type. Currently, the leading companies manufacturing these means overseas for emergency PPE developed new four- and five-layer materials. These suits are present in the Russian market of PPE, however, their cost is quite high. For the first time in the country, the KazKhimNII JSC developed innovative multilayer LTL-1-2 material and its elastomer-based analogues. The universality of protective properties is due to the selection of elastomers with different properties, specially developed formulations, and preparation method of composite materials. By protective properties, new isolating matters are not inferior to the best foreign materials of the highest level of protection. The developed innovative multilayer materials are designed to manufacture multifunctional isolating suits for personnel of industrial enterprises, objects of the Roscosmos State Corporation, and emergency response teams.

Keywords: insulating materials, operating and protection characteristics, multifunctional insulating suits

INTRODUCTION

The chemical security issue in Russia is quite relevant. During operative response at enterprises or transport, it is crucial to prevent the distribution of hazardous chemical substances, as they may result in serious damage to personnel and population health, property damage, and environmental pollution. In this regard, the role of personal protective equipment (PPE), including those of skin integument as the most available and simultaneously relatively efficient health maintenance measure for workers is fairly high.

Personnel of rescue units and enterprise workers require reliable means of individual protection of respiratory organs and skin integument. Herewith, there should be respected the basic principle, in other words, protection level should correspond to hazard degree. This point is quite important, as there are facts that PPE for workers are mainly realised according to the principle of minimum cost for employers. Herewith, protection is often inadequate towards object prognosis hazard, as the actual level used by PPE of skin integument does not fully meet the requirements imposed.

The basis of any PPE of skin integument is a protective material, from which it is manufactured. To produce PPE of skin integument of the isolating type, there widely

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used materials obtained by application of polymer coatings on the fabric base. Earlier, in Russia and overseas, mainly two- and three-layer materials were applied onto the fabric base from two sides. Herewith, polymer compositions based on butyl rubber (BR) or its mixture with triple ethylene propylene rubber (EPR) were often utilised. The wide use of BR is explained by its very low gas permeability, which is quite crucial for materials used for PPE of skin integument. At the same time, traditional protective materials based on BR do not ensure the universality of protective properties (not resistant to open flame, radiation, strongly swell when exposed to aliphatic hydrocarbons, mineral oils).

Based on the available information, we have made a conclusion that currently, the leading foreign companies on manufacturing PPE of skin integument of the isolating type (Drager, MSA AUER, Trelleborg, *etc.*) [1–3] use new multilayer materials (4–5 layers) for their suits, best by protective properties (costumes of the highest level of protection). These suits are present at the Russian market of PPE of skin integument, however, they are very costly.

DEVELOPMENT OF THE MULTI-LAYER MATERIAL LTL-1-2 AND ITS MODIFICATIONS

The KazKhimNII JSC developed for the first time in the country and brought to serial production innovative LTL-1-2 material. A patent for an invention on a preparation method of a multilayer insulating material with a wide range of protective properties confirms technical solution novelty [4]. Figure 1 gives the structure of multilayer LTL-1-2 material.

Rubber coatings of the first two layers differ by composition, however, they have the same basis that is a mixture of chlorosulphonated polyethylene (CSPE) and polychloropropene (PCP) [5].

Protective isolating LTL-1-2 material was obtained by sequential application of coatings based on mixtures of CSPE + PCP and PCP + CSPE (formulations 1 and 2, respectively) through a solution onto the outer face of the lightened isolating material (250–300 g/m^2) with a single-side or a two-side coating based on BR, BR with EPR using

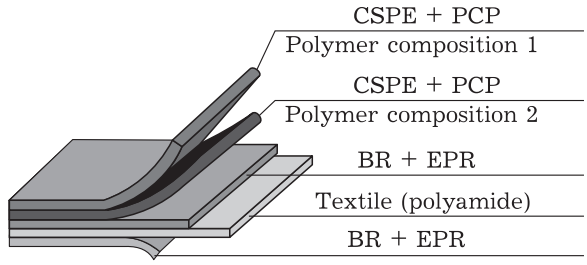

Fig. 1. Structure of multilayer LTL-1-2 material.

a glue-coating machine such as a spreader. Adhesion of the applied coating to the butyl layer (abrasion resistance of over 1000 cycles) is ensured by formula 1 [4, 10]. The presence of a flake barrier pigment in formulation 2 gives a number of valuable properties, such as increased chemical resistance, resistance to open flame and heat flows towards composite materials.

Innovative multilayer LTL-1-2 material ensures a high level of protection from the impact of the main groups of hazardous organic and inorganic substances: gases of chlorine, ammonia, hydrogen chloride, sulphur dioxide, liquid aggressive substances (40 % NaOH solution, 96 % H_2SO_4, HF, *etc.*), oxidative compounds (nitrogen tetroxide), toxic substances (hydrazine, heptyl , *etc.*, referring to I–II hazard classes). Herewith, it is worth noting high chemical resistance of the new material that does not burn or smoulder if exposed to open flame (on the front side) for 10 s and over. Material flame-resistance increases in about two times during storage (3–4 months), as established.

This material is regarded as basic; preparation of different modifications is probable on its ground. The development of antistatic materials for emergency suits remains a crucial issue; in this regard, the goal was to develop matter with high antistatic properties. Until recently, none of the protective materials used for manufacturing emergency suits of domestic and foreign manufacture has had antistatic properties. In this regard, the existing emergency costumes are periodically poured with water during their use by rescuers in flammable and explosive areas.

Using the developed method of obtaining universal multilayer materials and new ingredients (fillers) in formulations 1 and 2, we obtained new innovative ZIM-A-1-2 material

that had good antistatic properties and a high level of protection from an open flame (the horizontal arrangement of the burners and vertically-oriented samples (GOST R 12.4.200–99)).

Work is continuing on the modification of LTL-1-2 material. On its basis, six-layer LTL-3 material was also developed. Along with a flake-like barrier pigment, the latter contains elastoplast film layer. This allowed substantially increasing flame resistance of the multilayer material.

COMPARATIVE CHARACTERISTICS OF THE DEVELOPED INNOVATIVE MATERIALS AND THEIR FOREIGN ANALOGUES

Table 1 gives general technical characteristics of the innovative multilayer LTL-1-2, ZIM-A-1-2, LTL-3, and the best Himex, D-mex, and Vautex Elite materials.

Table 2 presents the comparison of these materials according to their protective properties.

Based on the data of Tables 1 and 2, one can conclude that LTL-1-2 and LTL-3 materials not only are inferior to foreign analogues by protective properties from the listed chemical substances but are also superior to them by a number of indicators (lower surface density, rigidity, higher abrasion resistance, chemical stability (when exposed to heptyl), resistance to open flame). The ZIM-A-1-2 material has better antistatic properties and the highest resistance to open flame.

THE USE OF THE INNOVATIVE MATERIAL LTL-1-2 FOR ROSCOSMOS STATE CORPORATION AND NATIONAL GUARD

Multifunctional gas-tight suits of the highest level of protection, such as a chemical insulating suit of KICH-4TN space suit type (type 1a, Fig. 2, *a*), an open chemical insulating suit of KICH -4LN form-fitting type (type 1b, see Fig. 2, *b*), KZV-1 protective ventilated suit (type 1c, see Fig. 2, *c*), as well as a suit for protection against KIZ-2 liquid chemical reagents (type 3, see Fig. 2, *d*), were developed based on LTL-1-2 material for Roscosmos State Corporation objects. These suits are already known in the PPE market both in Russia and CIS countries. A new version of protective ventilation KZV-2 suit has been developed. It meets customer requirements (ensures protection against concentrated HF, organic compounds). The Rosatom State Corporation also showed interest in the new material. Moreover, manipulator covers have been produced for FSUE FSPC “Protsenko PA “Start”.

In addition to the above-mentioned isolating suits based on innovative LTL-1-2 material that are designed for personnel of industrial enterprises, Roscosmos State Corporation objects, emergency response teams, the KazKhimNII JSC developed a special protective suit for the personnel of National Guard troops of the Russian Federation. Apart from indicators

ТАБЛИЦА 1

Общие характеристики и огнезащитные свойства многослойных материалов

Indicators	Materials					
	LTL-1-2	ZIM-A-1-2	LTL-3	Himex	D-mex	Vautex Elite
Surface density, g/m^2	465	480	443	748	494	577
Resistance to abrasion, 1000 cycles	There are no upper layer strips			There are upper layer strips		
Stiffness, N	0.08	0.05	0.035	0.32	0.10	0.11
Resistance to open flame, no less than, s	14 (25)*	60	30	30	40	30
	No residual combustion and smoldering. Spot burnouts of the surface layer			No residual combustion and smoldering.	No residual combustion and smoldering.	No residual combustion and smoldering.
				Increased swelling area, burnout of surface layers, charring	Charring and destruction of upper layer	Increased swelling area, partial burnout to the third layer

*Test results after 3–4 months of storage.

TABLE 2

Comparative characteristics of multilayer materials

Indicators	Materials					
	LTL-1-2	ZIM-A-1-2	LTL-3	Himex	D-mex	Vautex Elite
Time of protective action on gaseous substances, min not less than:						
– chlorine ((3010±60) mg/L)	600	600	600	540	540	540
– ammonia ((71±30) mg/L)	600	600	600	540	540	540
– hydrogen chloride ((1520±40) mg/L)	600	600	600	540	540	540
– sulphur dioxide ((1450±40) mg/L)	600	600	600	540	540	540
Time of protective action on liquid substances, min, no less than:						
– alkali (NaOH, 40 %);	240	240	240	240	240	240
– inorganic mineral acids (H_2SO_4 96 %, HF 40 %);	240	240	240	240	240	240
– animal, vegetable fats and oils (CJR-1), lubricants (motor oil), gas condensate, kerosene, toluene	180	180	180	180	180	180
Time of protective action on KRT (the infection density of 1 L/m^2, on a cycle 1 : 10 : 180), no less than, min:						
– aggressive oxidizing compounds (N_2O_4);	180 (no delaminations)	180 (no delaminations)	180 (no delaminations)	180 (delamination of the upper layer)	180 (no delaminations)	180 (delamination of the upper layer)
– hydrazine and its derivatives (heptyl)	180 (no delaminations)	180 (no delaminations)	180 (no delaminations)	180 (no delaminations)	180 (no delaminations)	180 (no delaminations)
Surface resistivity*, Ω	$1.1 \cdot 10^{14}$	$1.0 \cdot 10^6$–$3.0 \cdot 10^8$	$1.2 \cdot 10^{14}$	$5.3 \cdot 10^{14}$	$8.1 \cdot 10^{13}$	$5.4 \cdot 10^{14}$

* Data for the front side.

presented in Tables 1 and 2, in the technical assignment for special protective units, there have been laid the requirements for protective properties. The demands include those from burning mixtures (at least 10 s over the summer uniforms, 20 s – over winter clothing); from the effects of heat flux with a density of 25 kcal/cm^2 (not less than 20 and 25 s – over summer and winter clothing, respectively).

Figure 2, *e* gives a technical appearance of a special protective suit, *i.e.* overalls with a hood combined with the PMK-S gas mask and saddle pants. A special protective suit should replace an L-1 suit that has found wide applications due to its low cost, however, this costume already does not meet the modern requirements towards protective suits of this type.

The LTL-1-2 five-layer material allows ensuring compliance with all the requirements imposed on a special protective suit, as demonstrated by test results.

CONCLUSION

Considering the carried out research, we have made a conclusion that protective multifunctional suits of different colour

Fig. 2. Gas-tight suits: KICH-4TN (*a*), KICH-4LN (*b*), KZV-1 (*c*); a suit for protection KIZ-2 (*d*), and special protective suit (*e*).

schemes can be made on the basis of innovative multilayer materials, in particular, LTL-1-2, in the interest of consumers of personal protective equipment (PPE) of skin integument. New multilayer domestic materials and isolating suits based thereon allow dealing with the issue of import substitution that is currently relevant.

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