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DEVELOPMENT OF COMPOSITE MATERIALS FOR CORROSION PROTECTION OF MAIN GAS AND OIL PIPELINES WITH INCREASED CHEMICAL ADHESION

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Abstract: At present, during new construction of trunk oil pipelines, as well as during re-insulation of existing pipelines for their anti-corrosion protection, various insulation materials and protective coating designs are used, ranging from bituminous-mastic trace application to multilayer polymer coatings of factory application. But with all the variety of protective coatings available, it is practically impossible to make a choice in favor of only one universal coating that would meet all requirements and provide effective corrosion protection of pipelines under various construction and operating conditions. The results of the experiments showed the obtaining of high-quality bituminous composition, which is not inferior to the requirements of standards. On the basis of physical and mechanical studies proved the possibility of obtaining a competitive bitumen composition that meets the requirements of standards.

Keywords: corrosion, corrosion protection methods, gas condensate wells, neutral wells, oil production industry, destruction of tanks, poker technology, operation, production string, tubing, hydrogen sulfide corrosion, carbon dioxide corrosion.

Introduction. The choice of insulation materials and optimal protective coating systems is determined by many factors, but in general it is obvious that the highest performance is achieved by factory applied protective coatings of pipes, connecting parts and shut-off valves of pipelines. Only in stationary factory or base conditions it is possible to ensure high quality of pipe surface preparation (cleaning, technological heating to the required temperature) and application of protective coatings with the use of technologies, equipment and materials that cannot be used in the route method of pipeline insulation.

Corrosion damage of machine parts and mechanisms, gas and oil equipment during storage and application reduces reliability of operation and shortens their service life, corrosion products and protective materials removed from metal surfaces get into the environment and pollute it. Therefore, in all developed countries, the problems of protection of machinery against corrosion and environmental protection have been and remain relevant [1].

One of the most common methods of corrosion protection is coating the surface of metals with paint and varnish materials. If the protective coating on the metal has sufficient thickness or is sufficiently resistant to water and oxygen, it protects the metal from corrosion due to the mechanical barrier [2].

In this connection, there is a necessity to develop new composite materials on the basis of local raw materials and production wastes, allowing to reduce corrosiveness of main gas and oil pipelines.

Results of the study and their analysis. To date, during the construction of trunk oil pipelines polymer tape and bitumen-mastic coatings of trace application are practically not used. These types of protective coatings are used only during repair and re-insulation of oil pipelines. New construction of trunk pipelines is carried out using pipes, shaped connecting parts and pipeline gate valves with factory-applied coatings based on modern polymeric materials. In route conditions only isolation of the welded joints zone of pipelines by coatings based on heat shrinkable polymer tapes is carried out. Structurally such protective coating applied on liquid two-component epoxy primer is similar to the factory polyethylene coating and has rather high protective operational properties [3].

It should be noted that in the last 7-8 years the general level of corrosion protection of pipelines has significantly increased due to the introduction of new technologies, high-quality insulation materials, wide use of pipes and fittings with factory coatings in the construction of pipelines. it can also be stated that modern protective coatings, provided the requirements for construction and laying of pipelines are met, can ensure their accident-free (due to corrosion) operation for the entire period of operation (40-50 years and more)[4].

We have tested dozens of types of various protective coatings for pipelines and accumulated considerable experience in their practical application. The technology of factory insulation of pipes and pipeline elements has been mastered at a number of enterprises and continues to be implemented at high rates. The actual task is not only the development of new requirements for protective coatings, but also the revision of existing standards, making changes and additions to them, introduction of new test methods.

External coatings used for anticorrosion protection of pipelines should meet certain technical requirements. At present the use of external coatings for corrosion protection of trunk and field pipelines is regulated by the Russian standard GOST R 51164-98 "Trunk Steel Pipelines. General requirements for corrosion protection".

We have tested dozens of types of various protective coatings for pipelines and accumulated considerable experience in their practical application. The technology of factory insulation of pipes and pipeline elements has been mastered at a number of domestic enterprises and continues to be implemented at high rates. The actual task is not only the development of new requirements for protective coatings, but also the revision of existing standards, making changes and additions to them, introduction of new test methods[5].

It should also be emphasized that from the moment of development of industry standards, from the establishment of reasonable, strict, but at the same time feasible technical requirements for coatings, the general improvement of the quality of corrosion protection of pipelines begins. Let's consider the main types of modern coatings currently used for corrosion protection of main oil pipelines [6].

Epoxy, polypropylene and polyethylene protective coatings are most often used as factory pipe coatings during construction of gas and oil trunk pipelines. In the USA, Canada, Great Britain and a number of other countries the most popular are factory epoxy pipe coatings with a thickness of 350-400 microns. Pipe coatings based on powder epoxy paints have high adhesion to steel, resistance to cathodic peeling, increased (up to

80-100°C) heat resistance [7]. At the same time, the low impact strength of epoxy coatings, especially at subzero temperatures, largely limits the scope of their application. This is the reason why the factory insulation of pipes with epoxy powder coatings, which was first introduced at the Volzhsky Pipe Plant more than 20 years ago, has not been widely used in our country. Epoxy coatings could not compete with factory polyethylene pipe coatings [8].

In foreign practice in recent years more and more preference is given to two-layer epoxy pipe coatings. Such coatings, consisting of inner insulating and outer protective layer with total thickness of 750-1000 microns, have high resistance to abrasive wear, abrasion, have increased impact strength, which practically does not change at ambient temperatures from + 40°C to - 40°C [9].

Single-layer factory epoxy coatings are recommended for construction of oil pipelines up to and including 530 mm in diameter, and two-layer epoxy coatings are recommended for construction of pipelines up to and including 820 mm in diameter. It is most preferable to use this type of protective coating for insulation of pile supports, for construction of pipeline sections by trenchless laying method, for anticorrosion protection of "hot" (up to 80-100°C) sections of pipelines, as well as for anticorrosion coating of pipes with heat-insulating polyurethane foam coating. One of the most promising external coatings of pipelines is undoubtedly factory polypropylene coatings.

Figure1. Types of anti-corrosion coatings for main pipes

Many methods are known to combat corrosion. Of these, several main groups can be distinguished. The first group of protection is applied at the stage of metal production during its metallurgical and mechanical processing. The general theory of alloying is based on three main factors that characterize the effectiveness of the corrosion element [8].

The corrosion rate can be reduced or prevented altogether by creating alloys that form a layer of corrosion products with high protective properties on their surface under the action of aggressive medium. Alloying of structural steels with copper-zinc and aluminum contributes to the increase of protective properties of the surface layer and eliminates the possibility of internal stresses in it [9].

The most universal way to protect metals from corrosion is the application of both metallic and non-metallic coatings on the metal surface.

The main purpose of the protective coating is, on the one hand, to create a barrier layer that prevents the penetration of corrosive medium to the metal surface, and on the other hand, to limit or completely prevent the formation of a new phase of corrosion products at the metal-coating interface. The material of the protective coating, first of all, should have high chemical stability, weak permeability to water, gases, chlorine vapor, sulfate, etc., good to the metal, mechanical strength and stability of the structure.

We have investigated physical, chemical and technological properties of the developed anticorrosive materials.

On the surface of the building material during a certain time and at a given pressure did not occur any changes, that is, on the surface of the sample did not appear water, hence the material is considered to have withstood the test, quality assessments of the developed composite anticorrosive material are shown in Table 1.

Table 1. Quality of the developed composite anticorrosive material

Name of indicators	Composite anticorrosive material
Appearance	Homogeneous liquid of black color
Drying time, at 20°C	5 minutes
Adhesion strength, MPa	0,2
Thickness of one layer, mm	1,0
Consumption per one layer, kg/m ^{2}	1,7-2,0
Water absorption within 24 h% by weight	0,11
Water resistance during 72 h at pressure not less than 0,001 MPa	Resists
Softening point, °C, not lower than	80
Loss of mass when material is heated (Q), %	0,24
Density at 200C, g/cm ^{3}	0,94 г/см^3
Mass fraction of non-volatile substances, %, not less than	60
Flexibility on a bar with radius 5,0±0,2 mm at temperature 5^{0}C (GOST 26589-94)	No cracks
Warranty storage period	18 months

Table 2. Protective effect of the developed anticorrosive coating at salt-acid corrosion on "D" grade steel.

Anticorrosive material	HCl concentration, %	Corrosion rate, g/m^2 h	Degree of protection, %
	23	32,4601	90

In order to determine the optimal values of the obtained research results, a full factor experiment was conducted [10]. Table 3 shows the values of the input factors.

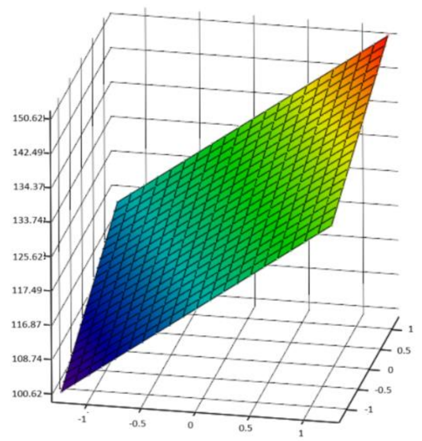
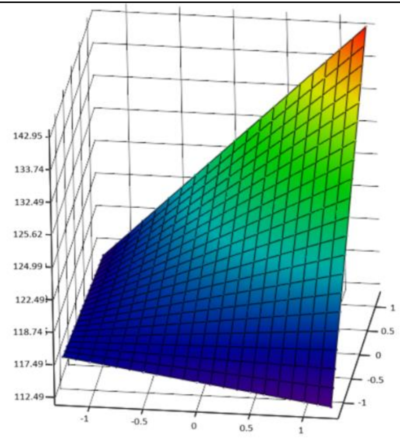
Table 3. Input factors

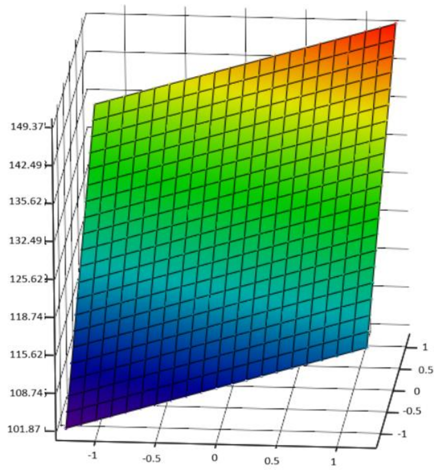
o/n	Factors	Designation	levels of variation			variation
			-1	0	+1	
1	Corrosion rate, g/m² h	X_1	30	35	40	5
2	HCl concentration, %	X_2	15	25	35	10
3	Drying time, min	X_3	10	13	16	3

The experimental results and variances of the output parameter are presented in Table 4.

Table 4. Planning matrix.

o/n	X_1	X_2	X_3	Y_1
1	75	80	10	95
2	95	80	10	105
3	75	120	10	130
4	95	120	10	140
5	75	80	16	110
6	95	80	16	125
7	75	120	16	140
8	95	120	16	160
9	85	100	13	125
10	85	100	13	126
11	85	100	13	125

	
$y = 125,62 + 16,875 * x_2 + 8,125 * x_3$ *(x_1=0)*	$y = 125,62 + 6,875 * x_1 + 8,125 * x_3 + 1,875 * x_1 * x_3$ *(x_2=0)*
Corrosion rate $x_1 = 28 \div 36$, drying time $x_3 = 10 \div 20$ $x_2 = 0$	HCl concentration $x_2 = 21 \div 25$, drying time $x_3 = 10 \div 20$ $x_1 = 0$



$y = 125{,}62 + 6{,}875 * x_1 + 16{,}875 * x_2$ *(x_3=0)*

Corrosion rate $x_1 = 28 \div 36$, HCl concentration $x_2 = 21 \div 25$, $x_3 = 0$

Thus, as a result of the full factor experiment it is established that the efficiency of corrosion protection has high indicators at corrosion rate equal to 32 (g/m^2-h), the percentage of HCl concentration 23% and the drying time of anticorrosion composition 15 minutes. Based on the results of the experiment it can be concluded that the identified optimal parameters allow to develop an effective and resource-saving formulation of anticorrosion coating. The obtained results will be used to select the optimal concentration that effectively protects oil and gas pipelines from corrosion.

Conclusion. The developed composite anticorrosive material is considered to have passed the test if there are no signs of swelling, displacement of the cover layer and excessive elongation on the surface of the sample. Indeed, the results of the experiments showed the obtaining of a high-quality bituminous composition, not inferior to the requirements of standards. On the basis of physical and mechanical studies proved the possibility of obtaining a competitive bitumen composition that meets the requirements of standards.

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