TECHNICAL DIAGNOSTICS AND NDT

DIAGNOSTICS OF CORROSION STATE OF INNER SURFACE OF MAIN OIL PIPELINE

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The paper gives the results of laboratory studies on development of theoretical fundamentals and procedural approach to inspection and monitoring of inner corrosion of oil pipelines and tanks. Flow chart of diagnostics of corrosion state of inner surface of oil pipeline is presented. Primary transducers were developed for inspection of oil pipeline inner surface.

Keywords: *welded oil pipeline, inner corrosion, diagnostics, corrosion rate, potential, primary transducers*

Corrosion of metals in non-electrolytes, i.e. in non-electrically conducting flow media (in oil, oil products and other organic compounds), is very dangerous for oil-transport and storage systems.

Oil is a mixture of different hydrocarbons with non-hydrocarbon components (alcohols, phenols, sulfur compounds, oxygen etc.). Pure oil products are non-electrically conducting and, therefore, electrochemical corrosion is impossible in them. However, corroding agents (water and oxygen) are always present in oil products in the amount sufficient for causing corrosion on inner surface of oil pipeline during their running. Corrosion of a bottom part of the pipeline occurs due to presence of settled water, containing dissolved salts and acids in it.

Sections on relief depressions with pipe turns (curved pieces) as well as mechanical and corrosion defects of erection welds pose particular danger for the oil pipeline due to accumulation of moisture and salts in them accelerating the processes of local corrosion dozen and hundred times. A biological factor is activated under such conditions. Changing of a nature of corrosion process is also most probably: for example, oxygen depolarization can transfer into hydrogen due to pH level change inside the defect.

Corrosion of the oil pipelines is unavoidable process as follows from mentioned above. However, knowledge of mechanism of corrosion and procedures for

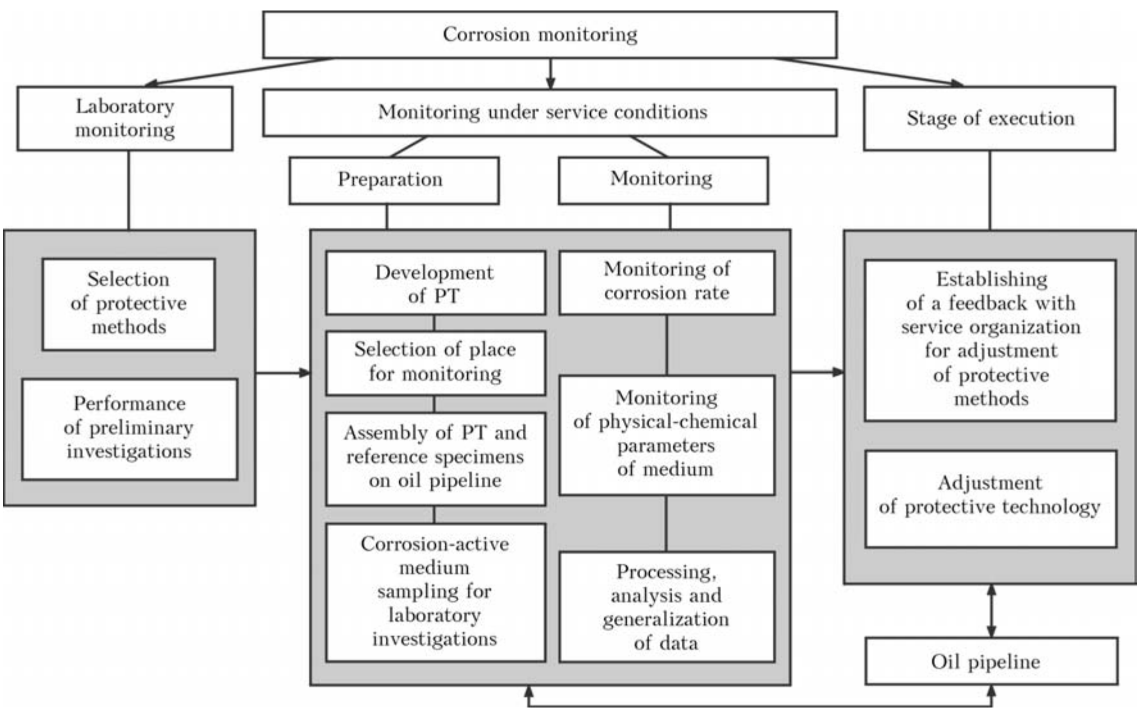

Figure 1. Flow chart of diagnostics of corrosion state of inner surface of oil pipeline

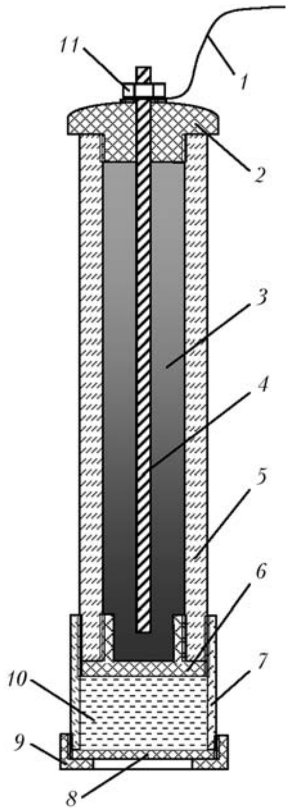

Figure 2. PT scheme for measuring potential of inner surface of oil pipelines and tanks: *1* — lead; *2* — cover; *3* — saturated solution $CuSO_4$; *4* — copper bar; *5* — casing; *6* — porous plug; *7* — additional reservoir; *8* — nanomembrane; *9* — clamping nut; *10* — saturated solution KCl; *11* — nut

its evaluation allows influencing the corrosion process, providing in this way a trouble-free operation of the pipelines for a long time. The development of an accurate procedural approach to measurement and evaluation of a rate of inner corrosion of the pipelines is necessary for their safe and reliable service [1–3]. Present paper is devoted to study of this problem.

Flow chart of diagnostics of corrosion state of inner surface of oil pipeline was developed for investigation and monitoring. In accordance with it three stages of diagnostics carrying out are proposed — laboratory monitoring, monitoring under service conditions and stage of execution. It should be noted that indicated flow chart describes a general working plan and can be adjusted depending on aim of diagnostics and available testing equipment.

Two types of primary transducers (PT) for measurement of potential (Figure 2) and corrosion rate (double- (Figure 3) and single electrode) were developed for monitoring of inner corrosion of the oil pipelines and tanks.

Laboratory investigations of medium corrosivity are an important stage of corrosion monitoring. A water-holding layer (WHL) which is applied on the surface of PT was developed for increasing accuracy of measurement of corrosion rate in oil medium. The additives, promoting absorption and retaining of moisture, were additionally introduced in the WHL. It was experimentally determined that the WHL with

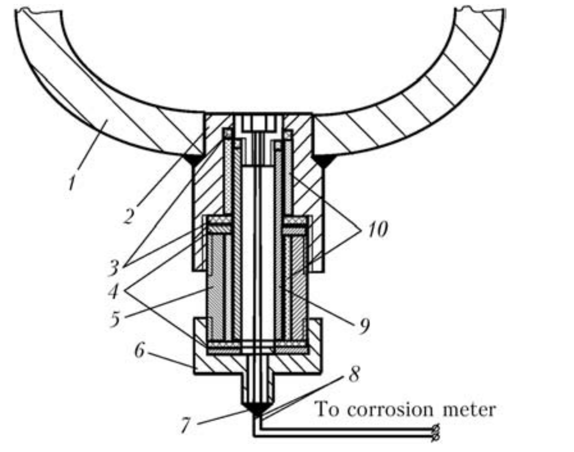

Figure 3. Scheme of double electrode PT for measuring corrosion rate mounted on the oil pipeline: *1* — pipeline; *2* — mounting fitting; *3* — seal washer; *4* — metal washer; *5* — clamping nut; *6* — cover; *7* — sealing material; *8* — leads; *9* — pipe-rod; *10* — sealing bush

10 % LiCl additive is optimum for investigations under field conditions.

Efficiency of PT with WHL was approved by means of measurement of corrosion rate for 17G1S steel in oil-water emulsion of different composition and water-free oil. Experiment results (Figure 4) showed that the developed PT with modernized WHL allows determining a value of corrosion rate at all investigated concentrations of water in oil-water emulsion. Obtained result is very important since simple PTs show, as a rule, zero values in measurements of corrosion rate in oil. 17G1S pipe steel corrosion rates were measured by two methods in the samples of oil (Nos.1–5) and water (No.6).

Equal measured volumes of oil and distilled water were mixed with the help of a magnetic stirrer at 300 rpm rate during 30 min and left to complete breakdown according to the first procedure. Water-soluble aggressive oil agents which are the reason of pipe wall corrosion transfer in a water phase and remain in it. The water phase was separated from oil with the help of funnel after breakdown of oil-water emulsion. The corrosion rate of 17G1S steel was measured on three

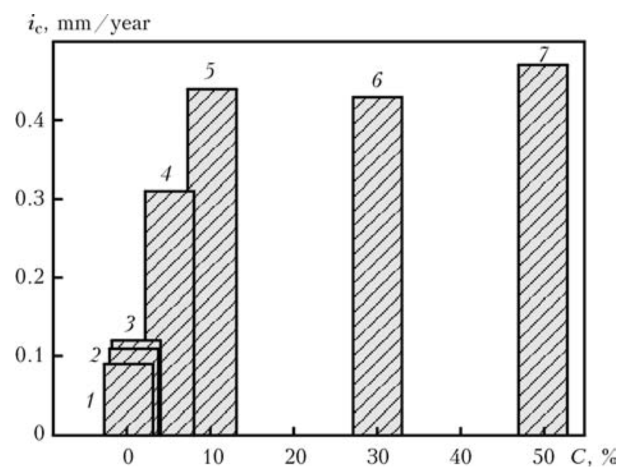

Figure 4. Changing of corrosion rate i_c of 17G1S steel depending on content *C* of 3 % NaCl in oil-water emulsion, %: *1* — 0; *2* — 0.5; *3* — 1; *4* — 5; *5* — 10; *6* — 30; *7* — 50

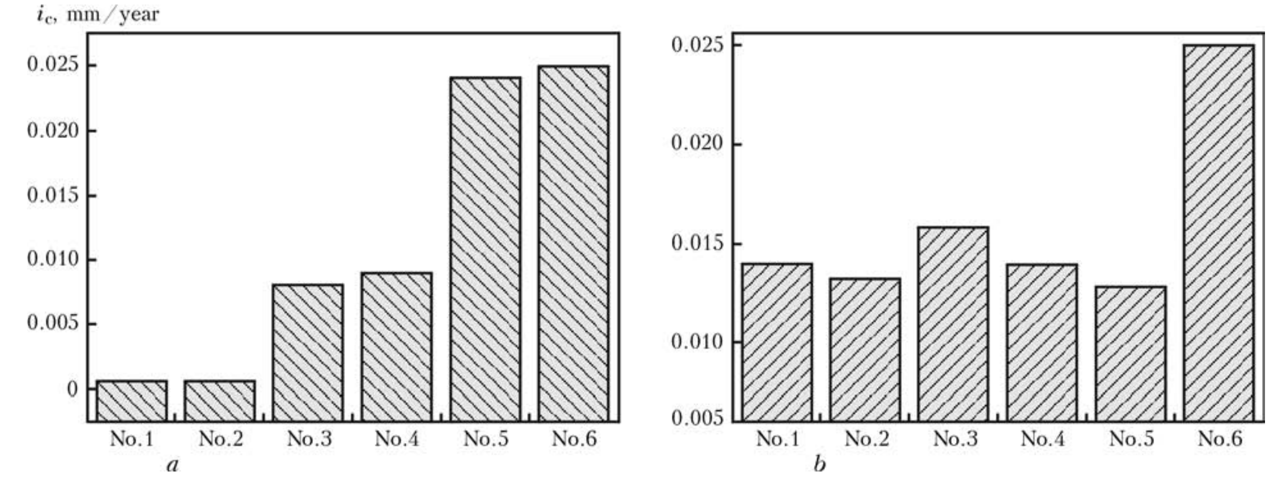

Figure 5. Results of corrosion rate measurement of 17G1S pipe steel in oil samples (Nos. 1–5) and water (No.6) obtained according to the first (*a*) and second (*b*) procedures

parallel PT in the water phase saturated with corrosion-active components. Obtained results were compared with the results of electrochemical investigations of 17G1S steel in distilled water. Emulsions made from samples 1 and 2 did not breakdown, therefore, it was impossible to determine water content in them. The measurements were carried out directly in the oil-water emulsion. Using a method of polarization resistance it was determined that the corrosion rate in these samples made 0.00063 and 0.00059 mm/year, respectively (Figure 5, *a*). It is obvious that obtained results of corrosion rate measurement were not entirely correct.

Tests on second procedure were also carried out in this connection. Before measurements PT surface was covered with WHL. The instantaneous rate of corrosion was measured in the oil samples in as-received condition (Figure 5, *b*). It follows from data obtained that application of PT with WHL allows increasing accuracy of measurement of corrosion rate in the oil medium, providing efficiency of PT for a long time and measuring corrosion rate locally in the place of moisture accumulation more accurately.

Selection of place for monitoring is one of the most important stage of preparation to monitoring under service conditions. Scanning of inner surface of oil pipeline with the help of PT for potential measurement (see Figure 2) can be carried out for selection of the place where the monitoring of inner surface of oil pipeline is planned to be done. In our opinion, it is reasonable to consider a method of introduction of PT for potential measurement on the pipe inspection gear (PIG). Modular structure of inspection PIGs of Rosen type allows joining several technologies for in-tube monitoring in one PIG. In this connection, the module for potential measurements can be used in combination with such technologies as record of data about the oil pipeline (about temperature, pressure and other physical parameters), determination of intrinsic geometry of oil pipeline, identification of transversally and longitudinally oriented defects, detection of cracks and other defects of welds.

We propose you to examine a procedure of investigation of inner surface of oil pipeline on a laboratory bench which is to be a pipe section with a weld having artificial defects. Defects geometry is so that water and corrosion products can be accumulated in them.

Clamping cell with cover was screwed to the pipe section. In order to carry out the measurements inside the weld, the cover is freely moved along the cell and fastening hole of the PT for measuring potential or corrosion rate. Weld defects were filled with water and damped flux which was used as a water and salt-holding layer. The cell was oil-filled. The results of potential measurements are shown in Figure 6. It was determined that the potential was equal zero in the points of oil pipeline surface free from moisture and its value varied from −0.5 to −0.6 V in the artificial defects.

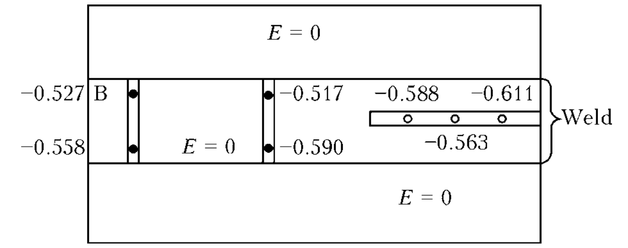

Figure 6. Results of E potential measurements on the laboratory bench: ○, ● — defect, respectively, filled with used welding flux saturated with 3 % NaCl solution and distilled water

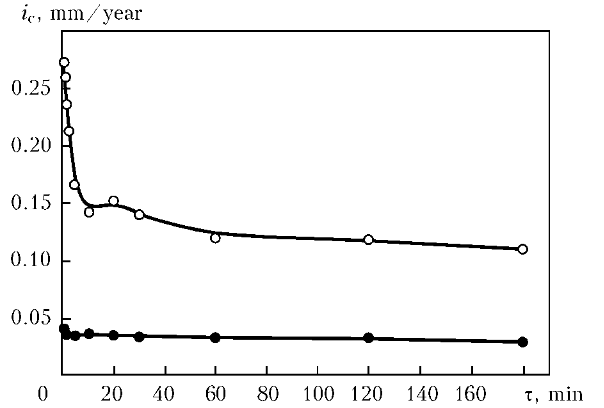

Figure 7. Dynamics of corrosion rate measurement in defects of the weld on the laboratory bench (○, ● — see Figure 6)

Measurement results of corrosion rate, mm/year, on test coils Nos. 1–3 of OTS «Luganskaya» obtained by different methods

Place of analysis in a coil	Massmetry method	Polarization resistance method
No.1		
Top	0.00081	0.010
Middle	0	
Bottom	0.00080	
No.2		
Top	0.00081	0.011
Middle	0	
Bottom	0.00240	
No.3		
Top	0.00321	0.020
Middle	0.00078	
Bottom	0.00240	

Corrosion products accumulate in the places, where the values of pipe wall potential obtained with the help of PT for potential measurements differ from zero, and dangerous corrosion situation appear. At that, more detailed control of inner corrosion in dynamics is necessary. Setting of PT for corrosion rate measurements (single and double electrode) is reasonable in such places. Type of PT for corrosion rate measurements and arrangement of its mounting depend on peculiarities and geometries of dangerous area. The rate of corrosion in time was determined for different defects on the laboratory bench, where presence of moisture was found with the help of PT for potential measurements. As a result of investigations carried out it was determined that corrosion took place in the defects with moisture accumulation, and sample surface did not fall under corrosion failure (Figure 7) in the places situated in the immediate proximity to them. Local corrosion was most intensive under the flux layer in defects of weld that was evidenced by more negative potential values and higher corrosion rates.

Test coils of OJSC «Ukrtransnafta» were used for approval of developed procedure and PT for corrosion rate measurements on inner wall of oil pipeline. Three coils were installed on OTS «Luganskaya». Coil 1 was filled with pure oil, 2 — oil with inhibitor (2 % solution of inhibitor TAL-25-13R in oil), coil 3 was empty (simulation of pipe cleaned from oil).

Reference specimens for massmetric measurements were situated in the test coils. PTs were mounted in the bottom part of coils so that their working surface became a part of inner surface of oil pipeline (Figure 8). Such PT positioning in particular is necessary for objective representation of corrosion state of inner wall of oil pipeline. It is seen from the results of corrosion rate measurements, given in the Table, that corrosion rate in the bottom part of test coils made, mm/year: coil 1 — 0.0008; 2, 3 — 0.0024. Using the method of polarization resistance the following values of corrosion rate were obtained, mm/year: coil 1 — 0.01; 2 — 0.011; 3 — 0.02.

It can be concluded that data obtained with the help of the method of polarization resistance are most reliable based on investigation results. In series the reference specimens, which were situated in the bottom part of test coil, had normal positioning to the bottom surface of oil pipeline. At that water did not accumulate on the specimen surface, flowed down from it and accumulated on the coil bottom.

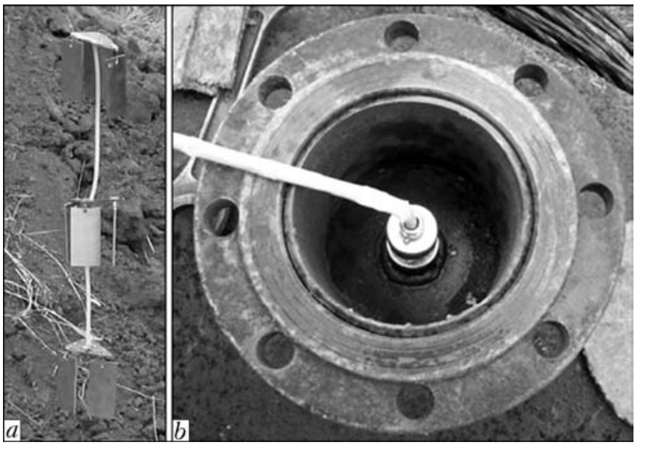

Figure 8. Series of reference specimens (*a*) and appearance of PT for measurement of rate of oil pipeline inner corrosion (*b*)

It was provided for by PT location that its working surface is the part of inner surface of oil pipeline where moisture was accumulated. Therefore, corrosion pattern on the PT surface is more close to real one. This explains spread in data about corrosion rate, obtained by methods of polarization resistance and massmetry. Besides, the corrosion rate has the highest values at the first moment of contact of metal surface with the corrosion medium and it significantly slows down in time. The approval of PT for measurement of rate of inner corrosion, carried out on three test coils of OJSC «Ukrtransnafta», confirmed their working capacity.

Thus, the structural scheme of diagnostics of corrosion state of inner surface of main oil pipelines was developed. Organization and maintenance of a feedback between the oil pipeline and service organization is an important condition for monitoring that allows effectively adjusting technology and method of oil pipeline protection. The values of corrosion rate at any concentrations of water in oil-water emulsion as well as water-free oil can be determined using PT with modernized WHL. It was determined that the local corrosion has most intensive development under the flux layer in the defects of weld. Working capacity of developed PT for determination of corrosion rate of inner wall of oil pipeline was shown by the approval, carried out on test coils of OJSC «Ukrtransnafta».

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