Integration of electric and magnetic fields near wells

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Abstract
The authors propose the method for studying electric and magnetic fields near oil and gas well. The determination of the electrical parameters of the soil near well allows choosing the optimal method of electrical protection. This is especially relevant in the presence of a “black insert” extending from a well. The results of the study and the adoption of an appropriate technical solution allow extending the period of trouble-free operation at the “black insert” section. The pipeline condition is monitored by pipeline magnetometry.

1. Introduction
The so-called metal-plastic pipelines (MPP) are installed on infield pipelines, in particular, from the well to the collection point. The pipes for them are made by connecting metal pipes 9-11 m long into a string 27-33 m long. Then the strings are covered from the inside, from the ends, from the outside with an anti-corrosion plastic coating at the factory. The strings are connected to the pipeline using corrosion-resistant couplings. However, the section between a well and a pipeline with the existing technology is connected with a piece of pipe less than 27 - 33 m in length. This piece of pipe is selected with the appropriate diameter and corrosion protection is installed on it in the field. The following situation is created. MPP serve 15 - 17 years, while the insert (it is called “black”) lasts 5 - 6 years and corrosive destruction occurs on it, which leads to the outflow of oil into the surrounding space.

In order to prevent corrosion damage of “black inserts”, a discrete method of testing “black inserts” by the method of electrical profiling is proposed. The method will allow condition-based servicing of “black inserts”.

The positive effect of the use of this method is a significant reduction in ruptures in the areas of “black inserts”.

2. Materials and methods
During the research the authors used a generator, a microvoltmeter, two catheads with a wire of 500 m each, four rods from the ERA-track, a shielded wire for connecting a microvoltmeter (one set) and connecting wires.

The electrical parameters of ground wires and devices for equalizing electrical potentials are completely determined by their dimensions and the electrical structure of the earth, i.e. distribution of resistivity in the upper layers of the earth crust, within which the spreading of currents is observed.
The source is considered a point source if the distance is 5 times or more greater than the immersion depth of the electrode. A and B are supply electrodes from the power source E and M and N are receiving electrodes.

Four-pole testing device. In this device the supply and potential electrodes are on the same straight line at a finite distance from each other.

\[ \Delta U = J_M - J_N = \frac{1}{2\pi AM} - \frac{1}{2\pi BM} = \frac{1}{2\pi AN} + \frac{1}{2\pi BN} = \frac{1}{2\pi} \left( \frac{1}{AM} - \frac{1}{BN} \right) \]

where \( \Delta U \), \( B \) – difference of potential; \( J_M, J_N \), \( B \) – potentials in points M, N; \( AM, BM, AN, BN \), m – distance between electrodes; \( \rho \), Om\cdot m – specific electric resistance.

Thus,

\[ \rho = \Delta U \cdot \frac{2\pi}{\frac{1}{AM} - \frac{1}{BM} - \frac{1}{AN} + \frac{1}{BN}} \]

The K coefficient for this device will be:

\[ K = \frac{2\pi}{\frac{1}{AM} - \frac{1}{BM} - \frac{1}{AN} + \frac{1}{BN}} \]

The formula for K is universal, it is valid for all considered electrical profiling devices.

3. Results
On the site, the electrodes M, N, A, B are buried and connected to the equipment in accordance with the diagram. Electrode B is connected to the generator with a 500 m long conductor wound on a special cathead, which is included in the ERA-track set. An operator disconnects a conductor from the cathead (i.e., the end of the cathead) while unwinding the wire while moving electrode B, or attaches it to the cathead during measurements. The team consists of 3-5 people, the third member of the team moves electrode B.

In order to obtain various fixed distances, the r track along which electrode B is moved is preliminarily marked with pegs in accordance with the following series of recommended distances: 0.5; 0.7; 1; 2; 3; 4; 5; 7; 10; 20; 30; 40; 50; 70; 100; 200; 400; 500 m. On each peg, the value of r is written in pencil. The marking is made on a wire connected to an electrode B moving along the track. For this
purpose, marks are made on the wire previously unwound for the entire length of the wire at distances recommended in a series of \( r \) values. This method saves time and reduces the number of employees.

A cathead with a marked wire, the end of which is connected to the generator socket, is moved along the track along with electrode B. As the wire is unwound, the marks will appear on it indicating the need to deepen electrode B.

Soil and ground present a complex natural environment, the features of which must be taken into account when considering the corrosion processes occurring in it.

Each type of soil has its own critical moisture value at which corrosion losses reach their maximum.

At low soil moisture, ohmic losses are high, which complicates the course of electrochemical processes.

Soil mineralization can vary widely, which also affects the rate of corrosion.

The air permeability of the soil is of great importance. The obstruction of oxygen access reduces the rate of corrosion.

In addition to uniform corrosion, underground metal structures (including “black inserts”) are subject to pitting and stress corrosion cracking.

Underground corrosion can be intensified by microorganisms.

Soil corrosion can proceed at different rates depending on the composition of the soil. One and the same metal can be used in some areas and quickly corrode in others.

The possibility of metal corrosion in the soil is determined by the electrical conductivity (determined by the nature and concentration of water-soluble salts) and the acidity of the soil.

Thus, the electrical profiling method can be used to monitor black inserts.

Reliable and safe operation of pipelines largely depends on the operability of the linear part of the pipeline.

The defects of a pipe, as a structural element of a pipeline, include mechanical damage and deformation of pipes of insulating coatings that occur at different stages (during transportation, installation and operation of pipelines), as well as technological elements of the structure (fasteners, etc.).

The main factor that leads to the decrease in the reliability of straight sections of the pipeline is corrosion damage of the outer surfaces of pipelines due to insulation failure and erosion damage due to intergranular corrosion.

The research results are devoted to the study of the magnetic field in the near-pipe space, which provide information about the state of the pipe.

Ferromagnetism, observed at the macroscopic level, by its very nature is a quantum mechanical phenomenon. Therefore, in order to describe such magnetic materials, it is necessary to formulate a heuristic model that takes into account interactions of this type. Using this model, it is possible to describe in the language of physics of continuous media the interactions between the lattice continuum - an information carrier - and magnetization field. Magnetization field effect is associated with the spin continuum through the concept of the gyromagnetic. Indeed, since the magnetic moment of the atom and the spin are connected with each individual particle in a quantum-mechanical way and the electrons make the predominant contribution to the magnetic moment of the atom, it is more convenient to call the continuum the electron spin continuum continuously expressing the discrete distribution of individual spins in a real ferromagnetic body.

Thus, field equations that describe the continuum of the lattice are needed — the equations of motion of mechanics, as well as equations that describe the electron spin continuum. For example, this can be done using elastic materials. Such attempts have been made and they are known in the literature [1 - 2].

One of the factors leading to the decrease in the reliability of pipelines is corrosion damage to the outer surfaces of pipelines due to insulation failure and erosion damage to the inner surfaces of pipelines due to intergranular corrosion and hydrodynamic shocks of the transported product, leading to a loss of
metal in the pipe wall. Under certain conditions, two damage to pipelines, contributing to a decrease in the thickness of the pipeline walls, can lead to cracking and metal rupture.

It is known that a defect on a pipe is a stress concentrator. The stresses of this kind on a ferromagnetic material lead to additional magnetization in the area of the defect, as it is shown in Figure 2.

![Figure 2. 3D image of magnetic field variations](image)

4. Conclusion
In order to increase the efficiency of defect detection in underground pipelines by the non-contact method, the authors propose a method that includes measuring the characteristics of the magnetic field above the pipeline during the movement of the sensor along the pipeline. The magnitude of the magnetic induction is measured at points located from each other at a distance of 0.25-0.5 m. Then a graph is drawn of the dependence of the magnitude of magnetic induction on the coordinates of the pipeline. Next, the average values of magnitude of magnetic induction for the selected area are found and then the values of the standard deviations are determined. The areas where the values of magnetic field induction are equal or exceed twice the value of the standard deviations are distinguished. The areas highlighted on the graph are determined on the ground. These areas are excavated and visual-measuring control is carried out using ultrasonic thickness gauges or eddy current flaw detectors. The average values of the magnetic induction values are determined for a section with a length of not more than 250 m.

The essence of the technology will be clear from the following description and graphic material. Figure 3 shows the change in the value of the magnetic induction along the pipeline. The method is implemented as follows.

The magnetic induction is measured at points separated from each other at a distance of 0.25-0.5 m on the ground along the pipeline. A magnetometer is used for measurements. As a rule, the location of the pipeline on the ground is known. In the absence of such information, the magnetometer is used as a locator and the position of the pipeline on the ground is preliminarily determined. As an example Figure 3 shows the result of a magnetic survey of the pipeline. At the 10th station an anomaly was found that exceeds the average value plus two standard deviations, which is evidence of a defect on the pipe. They excavated the pipe and found a defect.

The proposed method for defect detection is non-contact; the continuity of the pipeline walls is non-destructive. It does not require excavation when measuring and reduces labor costs for performing measurements. It has the prospects for a high level of automation, allows documenting the measurement results, building a database on the basis of which a system for the assessment of the continuity of the pipeline walls can be built. The method is applicable both for “black” pipes, and for metal-polymer pipes.
buried in the ground at a depth of up to 3 meters. A more detailed discussion of the research results can be found in the works [3 - 6]. The research results presented in the article allow concluding that the study of stray magnetic fields near underground pipelines makes it possible to detect and classify defects both on the pipe body and on welded seams, as well as to find places of destruction of corrosion protection on in-field pipelines. The information obtained in this way allows the pipeline to be serviced in the most efficient way.

Figure 3. Magnetometric diagnostics diagram: 1, 3 - unacceptable defects, grinding and diagnostics are required (flaw detection, thickness measurement); 2 - acceptable defect (in the initial stage); 4 - the defect is close to critical, grinding is required

Thus [7-10], the integration of methods of electrical profiling and magnetic survey allows controlling the technical condition of the “black insert” and thereby ensuring its reliable operation.

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