

# Analysis of Corrosion in the Soil and under the Effect of Lost Currents

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**Abstract:** This article analyzes the occurrence, origin and correction of corrosion of metal structures buried in the soil (for example: metal pipes, semi-buried columns, railway relays, etc.). Various substances in the soil, bacteria, environmental influences, temperature and similar factors cause corrosion in the metal buried in the soil. Corrosion in metal structures can cause the metal to corrode. To prevent this condition or to protect the metal from corrosion, the prevention of corrosion by means of protection has been analyzed.

**Keywords:** Metal, corrosion, soil, anode, cathode, structure, temperature, substance, steel, electrochemical, reaction, oxygen, chemical, erosion, current.

Metal structures buried (or partially buried) in the ground are subject to electrochemical corrosion under the influence of soil. The main factors that lead to this are:

Composition and concentration of solutes in the soil; soil moisture and structure;

1. description of air absorption into the soil;
2. the presence of bacteria in the soil;
3. specific resistance and temperature of the soil;
4. soil particle interactions, etc.

Figure 1 below shows a graph of the corrosion rate as a function of soil granularity. As soil granularity increases, corrosion rate values also increase.

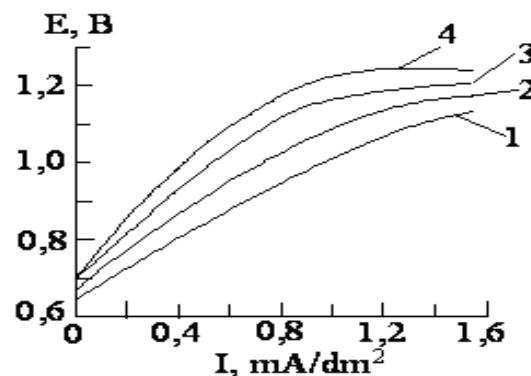


Figure 1. Dependence of corrosion rate on soil grain size (cm). 1-0.01; 2-0.1; 3-0.5; 4-1.

The composition and concentration of solutes in the soil determine the electrolyte properties of the soil. The rate of corrosion is strong when the **pH** of the soil is low and decreases with increasing values (Fig. 2, a).

Corrosion of metal surfaces added to the soil occurs in galvanic corrosion element appearances. Corrosion microelements are formed due to the unevenness of the surface structure of steel products, various oxide and mirror additives, differences in the physical and chemical composition of the soil.

The corrosive microelement forms  $\text{Fe}^{++}$  ions at the electrodes at the electrodes,  $\text{N}_2$  ions at the anode at the hydrogen polarity and  $\text{ON}$ -ions at the oxygen polarity. It also leads to the formation of anode and cathode particles on the metal surface under the influence of different soil composition and oxygen supply.

One of the indicators of soil corrosion activity in relation to steels is the presence of  $\text{Cl}$  and  $\text{SO}_4$  ions in their composition (more than 0.1% together). In this case, the formation of thin layers of protection is difficult.

Strong corrosion is observed at soil moisture  $\text{W} = 30\%$ , while the corrosion rate decreases at  $\text{W} > 30\%$  as oxygen dissolves rapidly.

As a result of air absorption into the soil, the corrosion process is accelerated. Air permeability depends on soil structure (sandy, loamy, etc.).

As microorganisms and their wastes change the chemical composition of the environment and increase the rate of electrochemical reactions, they accelerate the corrosion of underground devices and lead to biological corrosion.

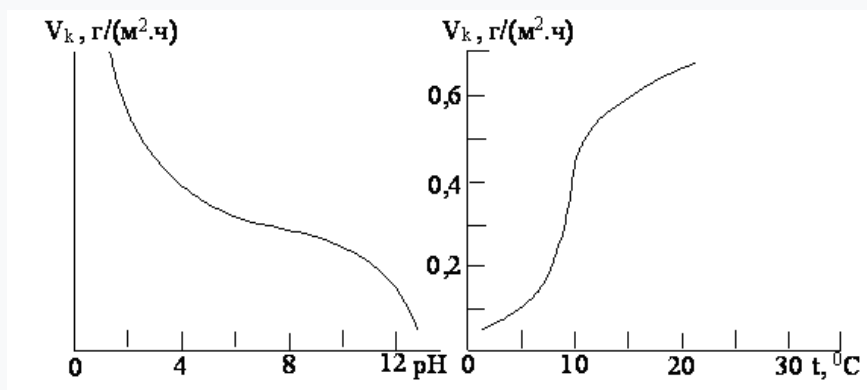


Figure 2. Corrosion rate depends on soil **pH** (a) and temperature (b).

During the year, changes in temperature lead to different temperature differences everywhere in the underground structure, creating a potential difference, and as a result, the corrosion process is accelerated (Fig. 2, b). Soil moisture and salts in it change the specific resistance of the soil and can increase the rate of corrosion by forming micro corrosion pairs.

Insulation coatings, cathode or tread protections are used to protect underground structures from corrosion.

DC electrified railways, trams and subways in cities, and DC transmission lines are a source of stray currents because they operate on a wire-to-ground system. In underground metal structures, the corrosion process is accelerated as a result of the difference between the potentials of the current lost in the ground and the “metal device-environment” potentials.

The presence of anode and variable parts in underground pipes and steel tanks is particularly dangerous for corrosion.

Underground devices (eg pipes) have anode protection, insulation coatings, cathode protection, vice-rector protection and electro drainage is protected from corrosion by the use

of protections. The application of this or that method is selected taking into account the technical and economic indicators.

Electrochemical corrosion is a heterogeneous electrochemical reaction that involves processes in aqueous solutions, wet gases, salts and alkaline solutions, and the formation of an electric current as a result of the interaction of the metal with the environment.

Electrochemical corrosion occurs in different forms depending on the conditions under which it occurs, the properties of the environment and other types.

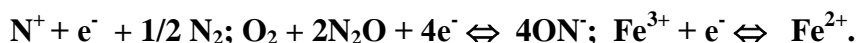
Electrochemical corrosion is the most common type of corrosion, in which two independent anode and cathode parts are formed on the surface of a metal and its alloys by the action of an external medium through an electrochemical mechanism.

In the case of electrically conductive properties in the environment, the reactions that occur on metal surfaces are based on the laws of electrochemical kinetics, ie, oxidation is considered an anode process, and reduction is considered a cathode process.

The anodic process in electrochemical corrosion is the dissolution of metal ions and the retention of electrons on the metal surface:



In the cathodic process, the excess electrons combine with the atoms or molecules of the solution to recover:



An electric current is generated between the anode and the cathode. In the anode parts, electrons pass from the anode to the cathode and metal ions to the solution, i.e. the anode melts (Figure 3). Also, the accumulation of metals with different electrode potentials (Fig. 3, b), under the influence of moisture and aqueous solutions on the metal surface (Fig. 3, c), as well as between residues or hydroxides on the metal surface and the metal (Fig. 3, g.) electrochemical corrosion processes occur.

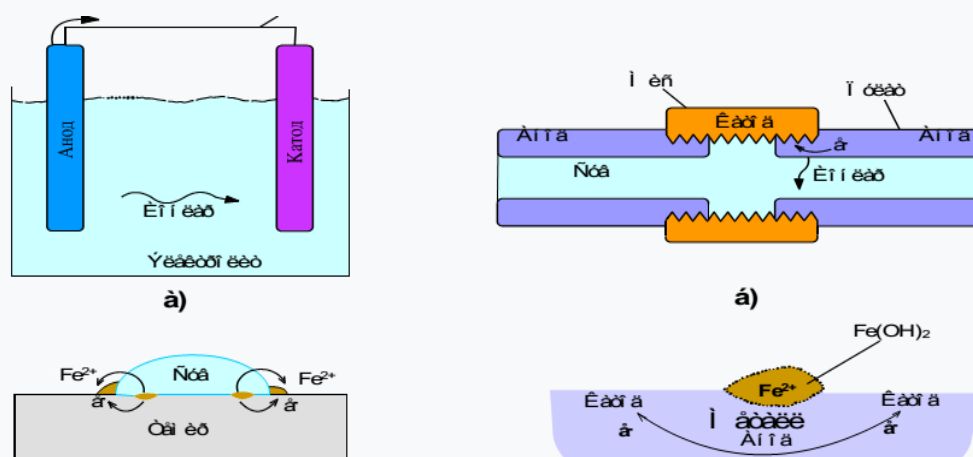


Figure 3. Schemes of electrochemical corrosion processes.

formation of anode and cathode processes in a-solution; b – formation of galvanic pairs at the junction of different materials; v - electrochemical heterogeneous repetitions on the surfaces of water (electrolyte) and iron, as well as air; g is the formation of galvanic pairs under the action of metal and its surface hydroxide.

In addition to the corrosive environment, factors such as internal stresses on the metal surface (Fig. 4, a), uneven distribution of energies over the volume of grains in the metal structure

(Fig. 4, a), and temperature also affect the rate and characteristics of electrochemical corrosion processes.

Because the bent metal structure is under the influence of compressive stresses on the inside and tensile stresses on the outside, the metal parts under the action of the stresses act as the anode and the non-stressed parts as the cathode. Therefore, corrosion processes on the surface of metal parts exposed to stresses under the influence of the external environment are accelerated.

The diversity of energy levels in the metal structure also leads to the occurrence of cathodic reactions at the anode and grain center at the grain boundary in their structure (Fig. 4, b).

Uneven distribution of oxygen in the environment on metal surfaces (Fig. 4, a), the use of different types of intermediate materials in the joints (Fig. 4, c) also cause local electrochemical corrosion in the form of spots on the bonding surfaces.

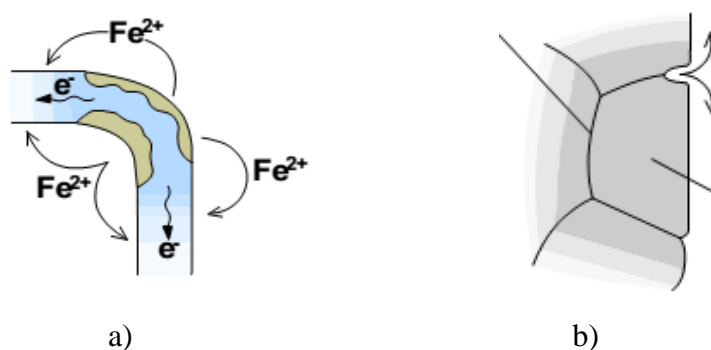


Figure 4. Diagram of electrochemical corrosion as a result of different internal stresses (a) and uneven distribution of energy in grains of metal structure (b).

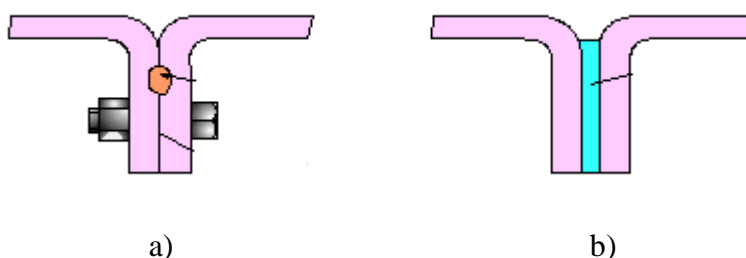


Figure 5. Electrochemical corrosion schemes that occur as a result of uneven distribution of ambient oxygen in compounds (a) and the use of intermediates (b).

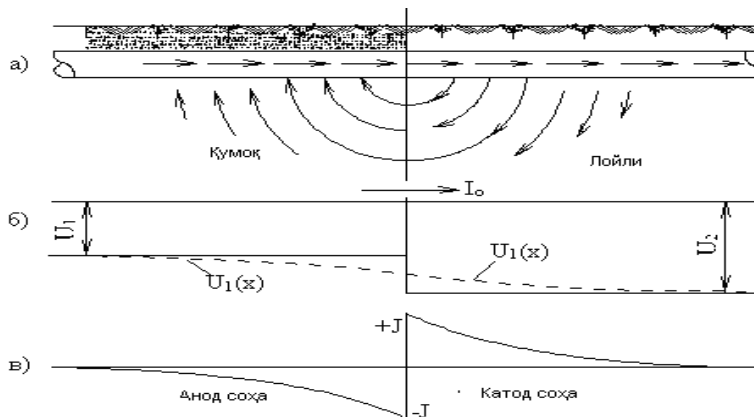


Figure 6. Formation of corrosive macropairs in the underground pipeline.

a - pipe scheme; b is the change in the pipe-soil potential difference; v is the change in corrosion current density along the pipe.

The change in corrosion current density in underground pipes is directed towards the part with high humidity, and the rate of electrochemical corrosion increases with increasing potential difference.

The characteristics, kinetics and mechanisms of corrosion decay change under the influence of external factors. In any case, corrosion products are formed only in the anode parts.

According to the description of corrosion damage and the conditions of its formation, it is divided into general (complete), local and selective corrosion.

Changes in soil composition along the length of the buried pipe have a significant effect on the corrosion rate. For example, if there are sand and clay soils along the length of the pipe, then electrons will move from the surface of the pipe in the muddy part to the sandy part. As a result, anode and cathode fields are formed and the rate of corrosion increases. Metals (materials) decompose at different speeds depending on the aggressive properties of the surrounding environment. The main cause of this decay is due to the chemical or electrochemical interaction of the metal surface with the external environment. Therefore, corrosion processes are divided into chemical and electrochemical corrosion according to the mechanism of reactions that occur on the metal surface.

Corrosion processes can be classified as follows:

- a) according to the mechanisms of reactions of the metal surface with the external environment: chemical and electrochemical corrosion;
- b) by type of corrosive environment: atmospheric, gaseous, electrolytes, electrolytes, sea, soil, under the influence of stray currents and biological corrosion;
- c) under the influence of mechanical stresses: under the influence of tensile and alternating stresses, friction, pressure, etc .;
- d) according to the geometric characteristics of corrosion erosion: corrosion on the surface and inside of the metal.

Chemical corrosion is the process by which a metal interacts chemically with an aggressive environment. In chemical corrosion, chemical heterogeneous reactions of liquid or gaseous media with the metal surface occur, resulting in no electric current. Corrosion is observed on the metal surface under the influence of dry gases and vapors, liquid electrolytes (oil and its products, alcohols, mineral oils, organic compounds). Chemical corrosion results in the formation of chemical compounds as corrosion products.

Electrochemical corrosion is a heterogeneous electrochemical reaction that involves processes in aqueous solutions, wet gases, salts and alkaline solutions, and the formation of an electric current as a result of the interaction of the metal with the environment. Electrochemical corrosion can be classified according to the conditions under which it occurs, the properties of the medium and other types.

According to the types of aggressive environments, corrosion processes are divided into atmospheric, gaseous, liquid, soil, under the influence of stray currents, and biological corrosion.

Depending on the conditions of occurrence, there are corrosion processes in the contact (at the junction of different metals), in the gap (in the space between the two metals) and under the influence of voltage.

The characteristics, kinetics and mechanisms of corrosion decay change under the influence of external factors.

Corrosion products are formed only at the anode parts. The following types of corrosion processes occur by electrochemical mechanisms:

- a) corrosion in electrolytes;
- b) soil corrosion;
- c) electrocorrosion.

According to the description of corrosion damage and the conditions of its formation, it is divided into general (complete), local and selective corrosion.

In general corrosion, corrosion products cover all parts of the metal surface in a flat or uneven manner. (Figure 7).

Local corrosion occurs in the form of spots, granules, spots and scattered on the subsurface layer of metal surfaces (Fig. 8).

Selective corrosion is divided into component-selective and structural-selective types and occurs in crystalline and serrated forms. (Figure 9).

In general corrosion, corrosion products cover all parts of the metal surface in a flat or uneven manner. Corrosion on metal surfaces is divided into flat and uneven corrosion depending on the depth of erosion. General corrosion is a less dangerous type of corrosion, in which case the corroded part loses very little of its strength properties (up to 5%).

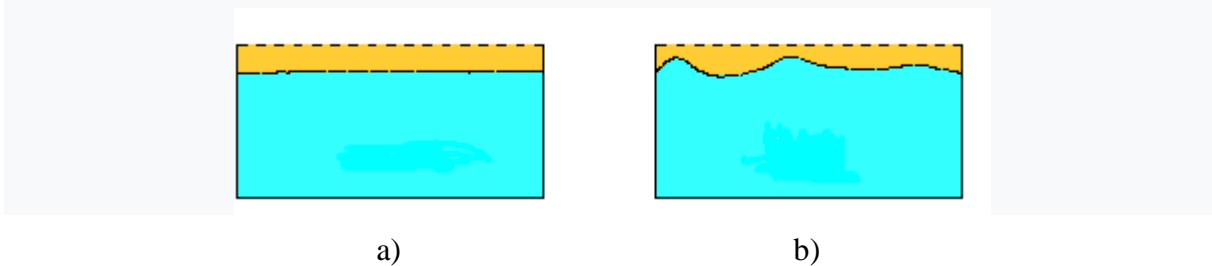


Figure 7 General or complete types of corrosion. a - flat; b - uneven.

Local corrosion erodes individual parts of metal surfaces. Decomposition does not occur at the same rate. Local corrosion occurs in the form of spots, wounds, spots, longitudinal, subcutaneous, fibrous, and scattered on individual parts and layers of the surface (Figure 7).

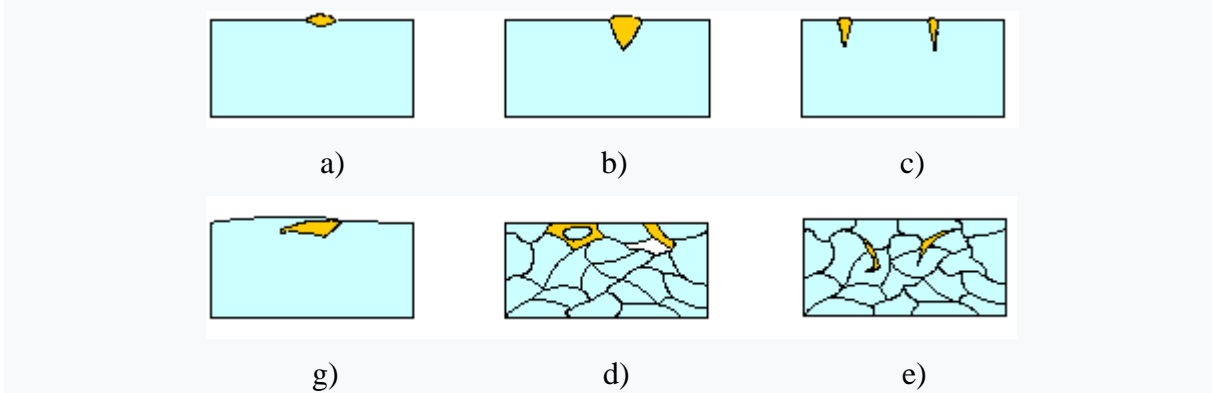


Figure 8. Local corrosion patterns: a-dog; b- traumatic; v - pitting (dotted); g - surface; d - longitudinal; e - ipsimon.

Steel and other alloys are prone to selective corrosion because they consist of several solid

alloy structures.

Selective corrosion alloys are divided into selective-structural (Fig. 9, a) when they consist of several structures and component-selective when they consist of several components (Fig. 10, b).

Examples of structural selective corrosion are, for example, ferrite (anode) and cementite (cathode) (Fig. 9, a), and component-selective corrosion is exemplified by brass leaching processes (Fig. 9, b).

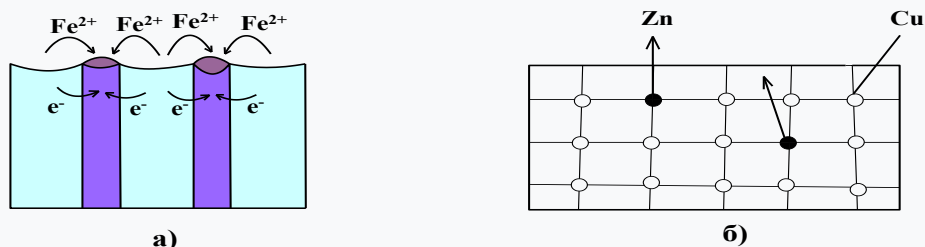


Figure 9 Selective types of corrosion: a - structure-selection; b - component selection corrosion.

One of the most dangerous types of local corrosion is intercrystalline corrosion. In intercrystalline corrosion, the corrosion process increases in depth along the boundaries where the grains are less stable without erosion. In this case, corrosion occurs along the grain boundary or under the action of stresses in the form of grooves along the grains (Fig. 10).

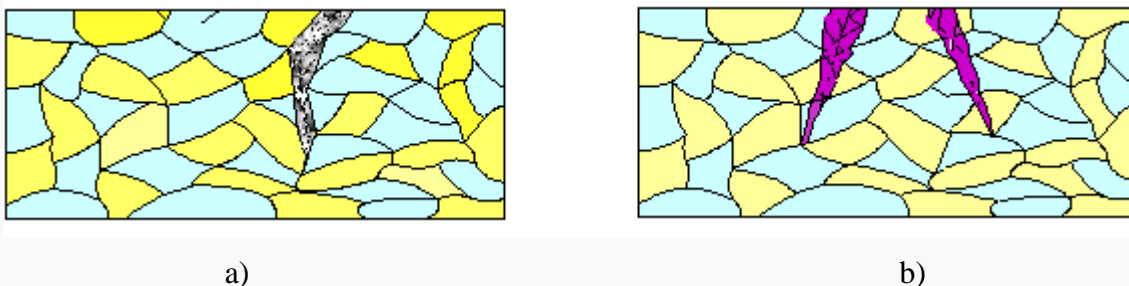


Figure 10. Intercrystalline corrosion: a - at the grain boundary and b - along the grains.

Local corrosion is more dangerous than general corrosion. The walls of equipment (pipes, tanks, etc.) can drastically reduce the strength properties or lead to damage to the bar and damage to the tightness of the equipment.

Under the influence of aggressive environments and external or residual stresses - corrosion cracking, corrosion fatigue under the influence of alternating stresses.

In corrosive environments, the phenomenon of erosion of metal surfaces as a result of the interaction of the surfaces of parts or the combined action of friction is called corrosion - erosion. Corrosive erosion occurs in the form of frictional corrosion and fretting-corrosion.

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