CORROSION TESTS OF COMMUNICATION CABLES IN SOLONCHAK SOILS

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The authors describe a method of long-term tests of underground communication cables of various designs and present results of year-long observations.

Published data on the corrosion resistance in soil of aluminum and its alloys and on the aging of the insulating covers of aluminum cable casings mainly pertain to sand-clay and peat bog soils [1, 2]. Previous investigations [3-5] indicated considerable aggressiveness of solonchak soils with respect to various protective coatings; steel, aluminum, and lead.

We investigated the protective properties of coatings and the corrosion behavior of metals used for casings and jackets of cables in solonchak soils.

As we see from the results of a chemical analysis (Table 1) the investigated soil is distinguished by a high content of chlorides and sulfates. For a dry residue of more than 1.5% the index of aggressiveness (after Negreev) is quite high, more than 5. The resistivity, less than 5 Ω·m, also indicates a high aggressiveness of the soil.

During the summer, when processes of evaporation predominate, the quantity of chlorides and sulfate is maximum in the upper horizons. The water content drops to 8%. During the cold and humid season of the year the chlorides are washed out of the upper horizons and are dissolved in the ground waters.

The depth of the ground waters at the test site was 1.5-2 m. Observations over a period of ten years showed that the water content of the soil at a depth of 2 m is, for all practical purposes, no longer subjected to seasonal changes, but at a depth of 1 m depends on the season of the year. Daily temperature fluctuations are observed to a depth of 1.5 m. At a depth of 2 m the temperature during the year varies by 5-8°, and at a depth of 1 m by as much as 10-30°.

This article presents the results of testing specimens of cables not acted upon by extraneous currents.

The method involves checking the quality and integrity of the insulation by the change of its resistance in time and by measurements of the electrode potentials of the investigated metals relative to the ground with an insulating coating and without it. We tested 252 specimens arranged in two trenches. Five designs

*Deceased.

TABLE 1*

Depth	Ion content, %							Total, %	Dry residue, %	pH	Water content, %	ρ, Ω·m	Temperature, °C
	SO_4^{2-}	Cl^-	HCO_3^-	CO_3^-	Ca^{2+}	Mg^{2+}	Na^+						
At surface	0,65	0,65	0,08	—	0,055	0,08	0,52	1,98	1,55	6,6	12,9		17,3
1 m	0,15	0,49	0,013	Trace	0,05	0,0045	0,26	1,0	1,36	7,0	25,0	1,1	11,6
2 m	0,055	0,94	0,024	0,027	0,035	0,069	0,51	1,66	1,84	7,5	36,0	1,3	7,2

* The samples were taken at four points over the length of the trench.

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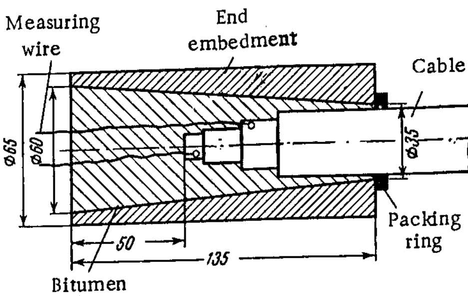

Fig. 1. End embedment.

of the protective covers of aluminum casings of communication cables were studied.

Designs 1 and 2 were of the tape type on cables MKSB, and designs 3, 4, and 5 were of the hose type.

The first design of the cover was made in conformity with GOST 7006-62 and consisted of the following concentric layers applied successively on the aluminum casing: bituminous compound (BN-III), two tapes of polyvinylchloride plastic (PVC) wrapped with an overlap of at least 20%, one tape of fortified bituminized paper or impregnated sulfate paper, bitumen compound, impregnated cable paper, bitumen compound, steel band jacket, bitumen compound, and coating to prevent adhesion of the cable coils.

The second design differed from the first by the bitumen compound, which consisted of 85% bitumen VN-IV and 15% polydiene.

Design 3: bitumen compound, two PVC tapes with an overlap of at least 20%, PVC hose of thickness 1.5-2.5 mm, bituminized cable paper (four layers), steel band jacket, jute.

Design 4: bitumen compound, two PVC tapes with an overlap of at least 20%, PVC hose of thickness 1.5-2.5 mm, bituminized cable paper in four layers, steel band jacket, PVC hose of thickness 2.0-5.0 mm.

Design 5: bitumen compound, two PVC tapes with an overlap of at least 20%, PVC hose of thickness 1.5-2.5 mm.

At the same time we investigated jackets and aluminum and lead casings with the insulating covers removed. The working length of the specimens with the insulating covers was 50 cm, and of specimens with the insulation removed, 65 cm. The cable specimens were laid across the trenches horizontally.

To determine the effect of laying depth on corrosion resistance of the metals (Al, Pb, Fe) used for the casings and jackets of the cables, their specimens (three rectangular plates each with a working surface of 75 cm^2) were laid at a depth down to 2 m at intervals of 0.25 m.

The specimens with the insulation removed and the plates were inspected, degreased, dried, and weighed before laying.

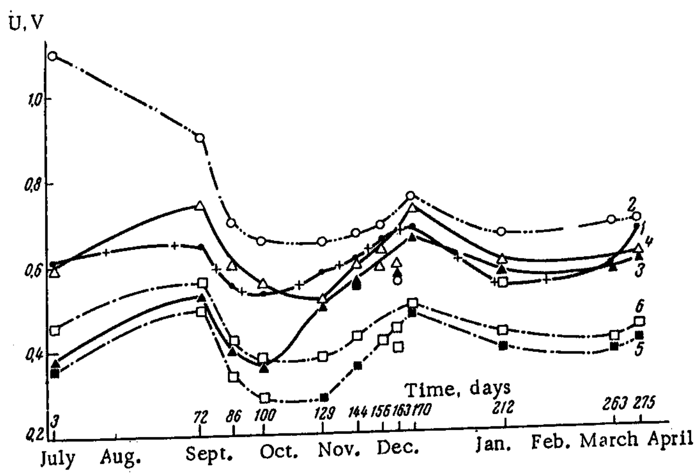

Fig. 2. Change of potentials of specimens in time. 1, 2) Al; 3, 4) steel; 5, 6) Pb; 1, 3, 5) laying depth 1 m; 2, 4, 6) laying depth 2 m.

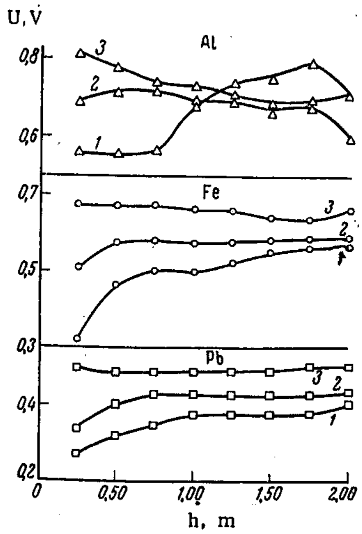

Fig. 3. Potentials of specimens in relation to laying depth and time. 1) Initial potentials; 2) after 1 month; 3) after 3 months (Curves 3 were recorded after downpours).

Measuring wires were attached to the aluminum casing and jacket of the cables with the protective coatings and to the metal casings of the insulation-free cable specimens. The connection sites and the ends of the specimens were insulated by a special method which eliminated their effect on the measurement results. The ends were insulated by a PVC adhesive tape in four layers with an overlap of the loops of up to 30%. Then special branched polyethylene end embedments were placed on them (Fig. 1), into which bituminous mastic was poured. The potentials were measured relative to a copper sulfate reference-electrode by a voltmeter with an imput resistance of 300 kΩ per 1 V of the scale.

One of the main criteria of the condition of insulation is its intermediate resistance. For cables with PVC covers the insulation resistance is appreciably greater than the resistance to the flow of currents, hence for solonchak soils we can consider that the intermediate resistance is equal to the insulation resistance.

The insulation resistance was monitored with respect to the leakage current from the insulated specimens. We measured the currents in circuits: investigated specimen (aluminum casing, jacket), dc source, and special ground connection, the measurements being made between the aluminum casing and ground connection, between the jacket and ground connection, and between the aluminum casing and jacket. *

The special ground connection was made in the form of three 2-inch pipes, each 2.5 m long. The pipes were driven into the ground to a depth of 2 m and welded together by a 16-mm iron bar. The resistance of the ground electrode was 0.45 Ω. The ground electrode was located at a distance of 20 m from the specimens.

Before measuring the current we determined the potentials of the aluminum casing and jacket of the cable.

SPECIMENS WITH INSULATION REMOVED

The initial potentials measured a day after laying the specimens were determined mainly by the concentration of chlorides in the soil electrolyte, water content, and aeration of the soil. For most specimens a shift of the potential in time, at first to the negative side, and then in the opposite direction, was characteristic. The first can be explained by an increase of the area of the anode sections due to destruction of the primary oxide film by chlorine ions; the second, by the accumulation on the metal surface of secondary poorly soluble products, which create an obstacle for the diffusion of the aggressive components of the medium. A positive shift of the potential was observed also when there was an increase of accessibility of oxygen to the metal surface.

The time varying parameters of the soil (water content, concentration and composition of salts, temperature, and aeration) during the first months of the tests had a substantial effect on the electrode potential

* A constant voltage (2 V) was applied to the specimens only during the measurement period.

TABLE 2. Leakage Currents and Potentials of Insulated Specimens of Communication Cables

Design of cover	Leakage current, mA								Potential, V							
	after 1 day				after 12 months				after 1 day				after 12 months			
	jacket		aluminum		jacket		aluminum		jacket		aluminum		jacket		aluminum	
	1m	2m	1m	2m	1m	2m	1m	2m	1m	2m	1m	2m	1m	2m	1m	2m
1	0,25	5	0	0	116	110	0,8	0,8	−0,34	−0,54	—	—	−0,53	−0,54	−0,63	−0,66
2	0,4	9	0	0	114	119	0,35	0,25	−0,36	−0,50	—	—	−0,6	−0,64	−0,62	−0,70
3	0,6	0,4	0	0	210	380	0,002	0,002	−0,38	−0,58	—	—	−0,64	−0,66	−0,69	−0,84
4	0	0	0	0	0	0	0	0	—	—	—	—	—	—	—	—
5	—	—	0	0	—	—	0	0	—	—	—	—	—	—	—	—

(Fig. 2). Later this was less substantial. This can be related with gradual separation of the metal from the soil by a layer of corrosion products. The exception was aluminum, for which corrosion proceeded by the film-pore mechanism, and the changes of the electrode potential are probably related mainly with the nonuniformity of the conditions on the specimen's surface.

The maximum difference of steady potentials at a depth of 1 and 2 m was observed at the beginning, and was 400, 240, and 115 mV respectively for aluminium, steel, and lead.

Additional measurements on plate specimens (Fig. 3) showed that, in relation to the external factors (rain, temperature, salt content, and aeration), the potentials of the metals markedly vary in the case of steel and lead when laid to a depth of 0.75 m and in the case of aluminum, to 1.25 m.

The potentials of the aluminum specimens were identical a day after laying to a depth of 0.75 m, but with a further increase of depth the potentials sharply shifted to the side of more negative values. The most pronounced change of potential of steel occurred in the upper horizon; for lead the potential depended little on laying depth.

INSULATED SPECIMENS

As we see from Table 2, leakage currents from the aluminum casing of the cable after year-long tests were maximum for cables of designs 1 and 2. The same is almost true for design 3, despite the fact that it has a hose insulation between the aluminum casing and the jacket. A plant defect in the hose was found when the specimens were opened. During the year leakage currents were not detected in the cables with hose insulation of designs 4 and 5. In most cases the potentials of the casing were more negative than those of the jacket, so that in the presence of an electrical contact between them the aluminum would be the anode. The laying depth had little effect on the change of resistance of the coating. After penetration of the soil electrolyte to the casing and jacket in cables with tape insulation, the potentials, as in the case of the insulated specimens, were more negative at a depth of 2 m than at 1 m.

CONCLUSIONS

1. Field tests of five variants of protective covers of cables for a year in solonchak soil showed the advantages of hose-type covers (designs 4 and 5) over tape coverings.

2. The laying depth substantially affects the corrosion condition of uninsulated metal specimens, but does not affect the changes of the basic parameters of the investigated insulations. With an increase of depth the seasonal variations of temperature, water content, aeration, and other soil parameters have a lesser effect.

3. The steady potentials of the metals vary during the year less in the lower horizons than in the upper ones. The difference of the steady potentials of the specimens of investigated metals, which were at different depths, decreases with time, lessening the danger of corrosion due to the action of macrocorrosion elements.

4. When the insulation is disturbed and the soil electrolyte penetrates to the jacket and aluminum casing, a galvanic couple can form if there are contacts between them, in which case the aluminum is the anode.

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