THE EFFECT OF THE FORM IN WHICH MOISTURE IS BOUND ON THE ELECTROPHYSICAL PROPERTIES OF CHASOV – YARSK CLAY

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We present the results from an experimental study of the permittivity and the loss tangent of Chasov–Yarsk clay as functions of the moisture content and wavelengths. We describe the installation used to study the changes in capacitance during the course of drying the material.

There is considerable interest in investigating the electrophysical properties of moistened Chasov–Yarsk clay as a typical colloidal capillary-porous material in connection with a study of the mechanisms of dehydration and drying, as well as for the development of electrical methods of determining the moisture content of disperse systems.

To calculate the power P of the energy scattered in the material as it is heated in a high-frequency electric field E

$$P = 5.55E^2f\varepsilon' \operatorname{tg}\delta \cdot 10^{-7} \text{ w},$$

we must know the magnitude of the permittivity ε' and the loss tangent $\tan\delta$ of the material with a specific moisture content w at various frequencies f.

This clay was cleansed of mechanical impurities by sedimentation in distilled water; it was dried, ground in a porcelain mortar, and passed through a sieve with a mesh of d = 0.25 mm. The prepared specimens were dried for 12 h 120°C. The moisure content of the dried specimen was assumed to be zero.

The water-retention properties of the Chasov-Yarsk clay have been studied rather well by various mutually independent methods [1]. We performed a control check on the water-retention properties of this clay, using such methods as the heats of wetting [2], the Dumanskii indicator [3] involving the use of an ITR-1 interferometer, sorption and desorption isotherms, and thermograms of isothermal drying [4, 5]. All of the tests were carried out at 25°C. The experimental data are given in the table and agree with the literature data of [1, 3].

The electrophysical properties Chasov-Yarsk clay, in connection with the moisture content, were studied in a wavelength range from 6000 to 3 m with Q-meters, in accordance with an earlier developed method [6].

Figure 1a shows the experimental data in the form of curves for the functions $\varepsilon'(w)$ and $\tan\delta(w)$ for wavelengths of 6000, 400, 40, and 20 m.

In the region of moisture contents corresponding to monomolecular adsorption, we find an approximately linear relationship between the permittivity and the moisture content. For large moisture contents we subsequently note a substantial increase in the permittivity, which is all the more pronounced for the longer waves. The latter circumstance indicates the dispersion of the system's permittivity.

With low water contents the magnitude of $\tan\delta$ for all wavelengths increases markedly; we then note a linear relationship between $\tan\delta$ and w. For λ = 6000 m when w ≈ 3.5% we find a transition from the linear segment to a steeper slope for the function $\tan\delta(w)$. This is apparently associated with the fact that for small wavelengths relaxation polarization is characteristic for the molecules of the subsequent adsorption layers of water which are not as strongly bound as the monomolecular layer.

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TABLE 1. Differential Water-Retention Properties of Chasov-Yarsk Clay

Moisture of monomolecular lager, %		Bound moisture, %			Maximum hygroscopic moisture, %	
from BET equation	from drying thermograms	from indicator method	from heat of wetting	from drying thermograms	from sorption isotherms	from drying thermograms
2,6	3,5	6,6	7,0	7,0	18,0	17,0

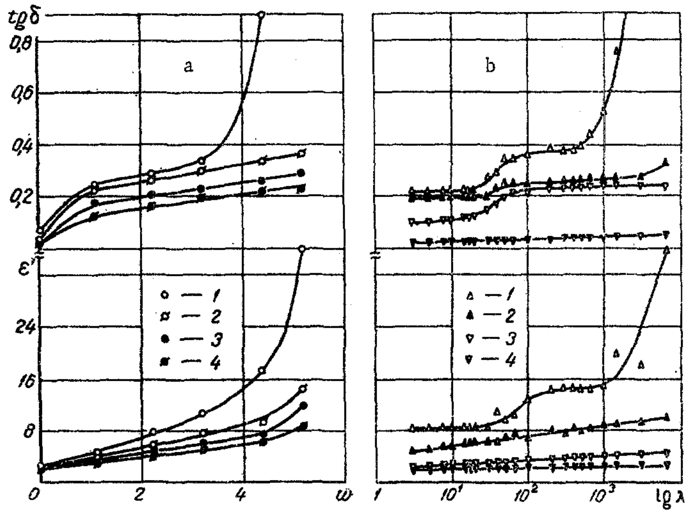

Fig. 1. Electrophysical properties of Chasov-Yarsk clay as a function of moisture content, % for various wavelengths (a) and as a function of the wavelength for various moisture contents (b); a: 1) λ = 6000 m; 2) 400; 3) 40; 4) 20; b: 1) w = 5.2%; 2) 3.2; 3) 1.1; 4) 0.

The boundaries of the nonidentical increase in the functions $\varepsilon'(w)$ and $\tan\delta(w)$ for large wavelengths are situated approximately at the point at which we have the transition from the monomolecular layer of the moisture of the polymolecular adsorption.

The dielectric properties of the moistened clay were measured in Q-meters at moisture contents not exceeding that of the bound water, since for greater values of w the conductivity of the system made up of the Chasov-Yarsk clay and water increases markedly, thus leading to a great increase in the experimental error.

Figure 1b shows the experimental data for the functions $\varepsilon'(\log\lambda)$ and $\tan\delta(\log\lambda)$ for several moisture contents. For moisture contents smaller than the quantity of moisture for monomolecular adsorption the curve of the function $\varepsilon'(\log\lambda)$ is in the form of a straight line with a slight slope.

For greater moisture contents for the region of polymolecular adsorption, the permittivity of the system exhibits dispersion.

There is dispersion in the $\tan\delta$ of the system for the entire region of bound water, and the greater the moisture content, the stronger the dispersion. The fact that long-wave dispersion shifts in the direction of shorter wavelengths with an increase in the moisture content of the system is evidently associated with the change in the mobility of the following adsorbed water molecules.

There is considerable interest in studying the kinetics of the process of convection drying for disperse material on the basis of the change in their electrophysical properties during the drying process.

To investigate the kinetics of the relationship between the moisture content and the capacitance of the cuvette which contains the specimen of Chasov-Yarsk clay during the process of convection drying, we set up a device by means of which we were able automatically to record the change in the capacitance, which is

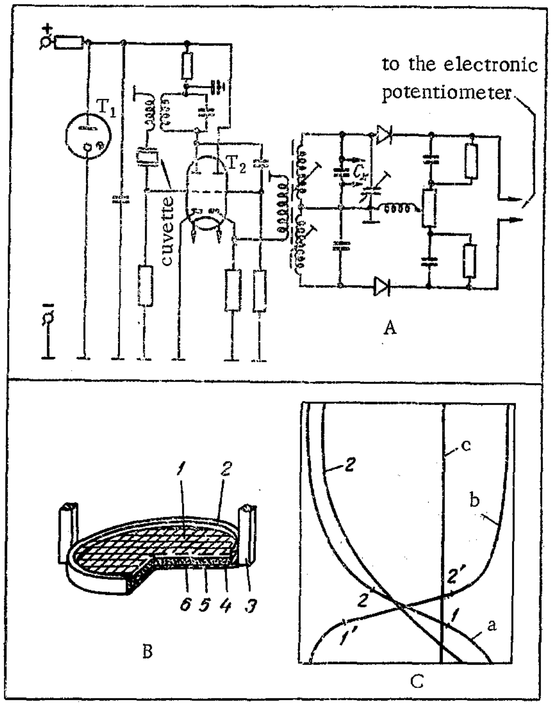

Fig. 2. Basic diagram of the unit by means of which we record the variations in the capacity of themeasuring capacitor (A), in the capacitance of the cuvette capacitor (B), and in the experimental data on the drying of Chasov-Yarsk clay (C); a) thermogram; b) curve for the change in capacitance; c) constancy of the air temperature; d) curve showing the loss in weight [d is not indicated in the figure].

proportional to the ε' of the material, simultaneously recording the drying thermograms and the drying curve. Thus, the kinetics of the change in the capacitance of the material can be directly associated with the sequence of removing moisture found in various forms.

This installation provides the experimental basis for the thermogram method of isothermal drying [4, 5] with a cuvette in the form of a measuring capacitor. To record the changes in capacitance, we set up a special unit (Fig. 2A). This unit operates on the principle of a frequency discriminator [7], to one of whose arms a measuring capacitor is connected. The arms of the discriminator are tuned to the fundamental frequency of 776 kHz of a hf generator. The selected measurement frequency is determined from preliminary measurements of the permittivity of the test material on a Q-meter and is the optimum frequency for this surface.

The zero output of the discriminator to which a measuring capacitor is connected is set by means of a trimmer which is connected into the pickup loop.

To maintain a sufficiently high Q factor for the discriminator loop with a measuring capacitor during the drying process, the latter is provided with an air space between the material and the upper plate.

The cuvette is a round flat capacitor (Fig. 2B). To remove the moisture being evaporated from the material, the upper plate of this capacitor is made in the form of a thin copper grid 1 whose rigidity is ensured by attaching triangles of copper rods by means of soldering.

The constant separation of 2.5 mm between the plates is maintained by an ebonite ring 2 which is grooved to leave room for the copper grid. The lower plate and the ebonite ring are attached to an ebonite bracket 3 which is attached, at the top, to a small-button bantam glass tube. In this manner the cuvette-capacitor is connected to the automatic balance and the thin copper conductors (d = 0.06 mm) do not affect the weighing procedure.

The measuring capacitor is connected by means of a coaxial lead to the unit which records changes in capacitance. The geometric capacitance of the capacitor is 5.5 pF and that of the coaxial lead is 12 pF, whereas the limit value for the capacitance of the measuring capacitor which contains the moisture specimen being tested is 60 pF.

The measuring capacitor is protected in the thermostat from external electromagnetic fields by the thin copper grid which is reliably grounded.

The lower plate 4 of the capacitor is made of tinplated pure-copper foil 0.03 mm in thickness and 44 mm in diameter; it is attached to the ebonite ring. A flat resistance thermometer 5 (a copper wire 0.06 mm in diameter and a resistance of 75 Ω at 20°C) is attached at the bottom of the plate, and this thermometer is covered over with a mica plate that is 0.03 mm thick, and this is then covered with the copper foil 6.

It should be noted that the given cuvette-capacitor provides for reliable recording of the change in the capacitance of the material only when the material does not shrink during drying in the specified moisture-content interval. This method of investigating the relationship between the permitivity and the moisture content during the drying process can be for Chasov–Yarsk clay in the region of moisture contents that does not exceed the maximum hygroscopic content [8].

Prior to the test the clay was put into the cuvette-capacitor and moistioned in an exsiccator with distilled water, until the maximum hygroscopic moisture content was attained.

An hour before the start of the test, the measuring unit was switched on to bring it into a steady-state operational regime.

The cuvette-capacitor is attached to the unit as quickly as possible and the zero setting of the frequency discriminator is set. The variations in capacitance, the drying thermograms, the constancy of the air temperature, and the loss of weight in the drying of the specimen are recorded on the tape of the automatic EPP-09/M2 electronic potentiometer (Fig. 2C).

Projecting the critical points of the thermogram (1, 2), which correspond to the various forms in which the adsorbed moisture is bound in the material, onto the drying curve, we determine the moisture content of the material at these points. As we can see from Fig. 3C, the critical points of the thermogram correspond to the critical points on the curve for the change in capacitance. This circumstance confirms the dependence of the permittivity for the Chasov-Yarsk clay on the forms of moisture bonding to the material.

The capacitance varies in the following manner during the drying process. As the moisture of a given bonding form is removed, the capacitance of the system diminishes in virtually linear fashion, and this is evidently associated with the presence in these moisture-content regions of only certain types of polariza- for the system. On transition across the boundary between the various forms of moisture bonding we find a pronounced change in capacitance, and this is apparently a result of other types of polarization taking effect.

Thus the investigation of the electrophysical properties of moist Chasov-Yarsk clay shows that they are dependent on the forms in which the moisture is bound to the material. This experimental fact must necessarily be taken into consideration in designing and calibrating electrical moisture meters intended for colloidal capillary-porous materials. By studying the kinetics of the change in the permittivity of moist colloidal capillary-porous materials we can derive valuable information on the nature of the kinetics and the dynamics of the process of convection drying.

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