Letters to the Editor

Some Electrical Properties of Water and Ice

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THE problem of the electrical properties of water and ice is of paramount importance in the study of atmospheric electricity, particularly with regard to storm formation, since it is directly due to the interaction of droplets of water and crystals of ice in the cloud that the storm process develops. In this connection, we undertook a series of experiments for the investigation of the properties of water and ice.

1. When ice was reduced to small particles with a saw or scraped with a metallic scraper, and particularly by glass, the small ice chips falling into the container of an electrometer displayed a positive charge. At ice temperatures within the limits of -12° to -18° C, a positive charge from the ice particles appeared on the receptor surface of the electrometer of an order of magnitude of 10^{-9} coulombs per gm of ice particles as a result of this scraping. When glass was used for scraping, a somewhat greater charge developed than when metal was used, but of the very same order of magnitude. When the temperature of the ice was lowered with the aid of a cooling mixture to -55° C, a positive charge appeared on the receptor surface of the electrometer, as a result of the scraping, which was an order of magnitude greater than in the foregoing case. (It is a noteworthy fact that during this procedure, after only 30 scrapings of glass on ice, the receptor surface of the electrometer charged up from the particles of ice to a potential having an order of magnitude of 2000 V). However, upon further reduction of the temperature of the ice to -190° C with the aid of liquid air, the ice became brittle and instead of forming ice dust during scraping cracked off along its planes of juncture. The charge of the chips during this process was also positive, but approximately 300 times smaller than at a temperature of -55° C.

The scraping of the ice in all these experiments took place in the open air at temperatures of the order of -10° / -18° C, and also immediately after carrying the cooled ice from the refrigerator or from the open air into a laboratory with an air temperature of 18° C. In the experiments described, two forms of ice were utilized: ice which had formed in the open air during the freezing of water at the edges of roofs, and ice artificially prepared from distilled water in the laboratory. The character of the electrification of the ice chips did not vary essentially during the process.

2. For the characteristic curves of the electrical properties of ice it is important also to have some idea of its polarization, which we studied in a cylindrical specimen having a radius of 1 cm and a height of 3.5 cm. This specimen of ice was connected into a dc circuit in series with a resistor having a value of the order of 10^6 ohms for a period of approximately 1 hour, and its polarity was noted by reading an electrometer which was hooked up in the circuit between the specimen and the resistor. Computation of the emf of polarization was carried out according to the formula

$$P = u - u_{\text{э}t}(u - u_{\text{э}})/u_{\text{э}},$$

where u is the difference in potential between the terminals of the current source, and u_e and u_{et} are the potentials to ground established by means of the electrometer at the start and at the conclusion of measurement after time t. The results of measurement of the emf of polarization for two temperatures are shown in Fig. 1. The relative error of

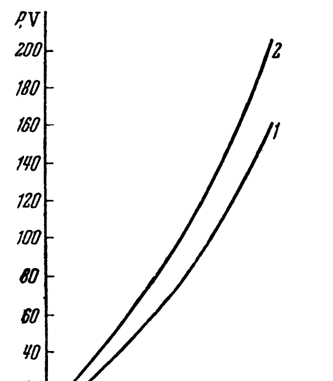

FIG. 1. Dependence of the emf polarization of ice P on the intensity of the applied field E. *1* – at 10°C *2* – at 18°C.

these measurements did not exceed 15%. In order to prevent oxidation of the electrodes between which the ice was compressed from having any effect on the measurements, the electrodes were tinned, and their condition was checked during every measurement. The ice was obtained from distilled water and together with the electrodes frozen to the ice remained in a thermostat where the necessary temperature was maintained constant with the aid of a cooling mixture.

3. The mutual electrical properties of water and ice are characterized by the contact difference in potentials between them.[1] Measurement of the contact difference in potentials was undertaken by us in the open air and was carried out at air temperatures within the limits of -8 to 12° C. The radiator-type collector was positioned at a height of approximately 0.5 cm above the surface of the water or ice and was connected to the electrometer. The water or ice in the glass container under the collector was grounded. First, water which had previously been cooled to approximately +4° C was placed under the collector, and the electrometer was read at a time 2-4 minutes after activating the test setup, when the needle had attained a fixed position. After this, in order to prevent the formation on the collector of a deposit of water or frost and to accelerate freezing, air was blown through the space between the water and the collector at a speed of 2.5 m/sec by means of a fan.

In order to clarify the possible effect of the blowing of air over the water on the results of the measurement, control experiments were carried out for measuring the contact difference in potentials with and without the blower, and these demonstrated that the blower had no effect on the results of measurement. When the water surface had become covered with a solid layer of ice, the blower was turned off and the stable reading of the electrometer was once again recorded. The difference in the readings of the electrometer represents the contact difference in potentials between water and ice. In all the experiments described we used distilled water and the ice obtained from the latter. The freezing of the water under the conditions of our experiments took place over a period of 8 to 16 minutes. The average of the 20 measurements carried out by means of the indicated setup results in a value of 0.15 V with amplitudinal values of 0.2 and 0.1 V for the contact difference in potentials between water and ice. As a check, a series of experiments was carried out replacing the water under the collector with prepared ice, and vice versa. The results obtained were identical with the foregoing.

4. Electrification during the exhaust of a droplet-steam jet from a nozzle has been known since the time of Faraday. A similar phenomenon was later observed in the exhaust into the atmosphere of compressed gases through a nozzle. However, in this case, as Drozdov[2] notes, the electrification is observed only under conditions of contamination of the gas flow by a liquid or particles of a solid aerosol. In order to obtain the characteristic curves of this phenomenon supplementing those already known, we carried out the measurements which are described below. Steam was produced in a steam boiler where the pressure could be raised to 6 atm. Filling of the steam boiler was done with ordinary tap water. In all the experiments the output of steam was accomplished over a period of 4 sec through a nozzle with a diameter of 0.5 cm, and during the course of the experiments the boiler was grounded. The pressure drop in the boiler during steam output amounted to 1-2 atm, if the initial pressure of steam at the beginning of output was within the limits of 3-6 atm; the drop was 0.5 atm at an initial steam pressure of less than 3 atm. In the experiments conducted, the potential gradient with respect to ground was recorded immediately after the cessation of steam output with the aid of a radio-thorium collector used in conjunction with an electrometer. The results are given in Fig. 2 for various steam pressures and for various distances from the nozzle. As can be seen from Fig. 2, with an increase

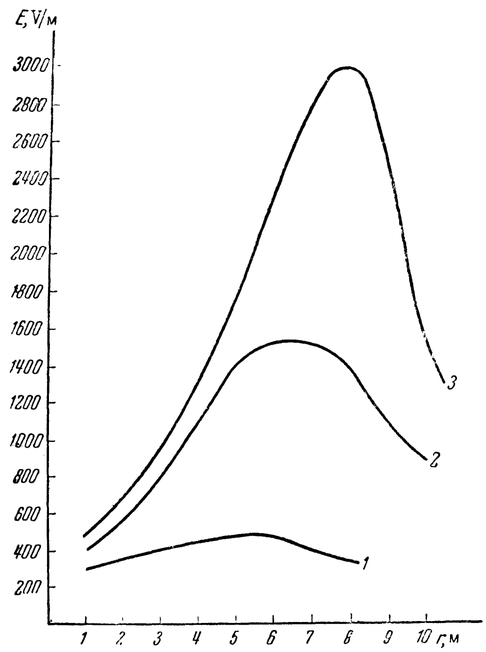

FIG. 2 Dependence of Potential gradient E of the space charge with respect to ground on the distance r from the nozzle along the axis of flow at the pressures: *1* – 1 atm. *2* – 2 atm. *3* – 6 atm.

in pressure, the zone of maximum potential gradient moves away from the nozzle along the axis of droplet-steam flow. At fixed distances from the nozzle, the greater the pressure of steam in the boiler before exhaust, the greater is the potential gradient which occurs. Also noteworthy is the fact that the electrification of the air takes place not only along the axis of flow, but also in a direction perpendicular to this axis, and the higher the pressure in the boiler the stronger this effect. During the exhaust of compressed air from a compressor within the limits of 1 to 6 atm no electrification at all was observed. The error in the measurement of the potential gradient in all cases did not exceed 50 V. The sign of the charge which the droplet-steam jet transmitted to the air was positive in all the measurements. The measurements were carried out in a room having the dimensions 12 x 6 x 2.75 m^3 at a height of 1 m from the surface of the stone floor. Water pipes were used for grounding. The velocity of the droplet-steam flow was measured by an anemometer at various distances from the nozzle and at different pressures, while all the measurements were carried out along the axis of symmetry of the flow. The results of measurement of the velocity of flow are presented in Fig. 3.

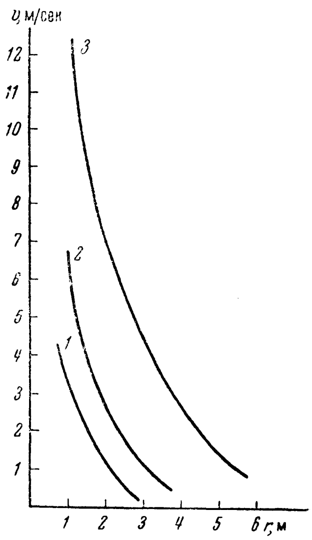

FIG. 3. Dependence of the velocity of flow v on the distance r from the nozzle along the axis of flow at steam pressures within the boiler of: *1* – 1 atm. *2* – 2 atm. *3* – 6 atm.

The electrical properties of water and ice which we investigated provide supplementary materials for the understanding of phenomena connected with the process of development of storms.

[1]V. I. Arabadzhi, Dokl. Akad. Nauk SSSR 60, 811 (1948).

[2]N. G. Drozdov. *Statistical Electricity in Industry*, Energoizdat, Moscow-Leningrad, 1949.

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The Question of the Formation of a Cellular Structure in a Layer of Fog or Smoke

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IN the literature, cases of the formation of a cellular structure in the layers of a liquid or a gas are described by an unsteady state, for example by heating underneath and by cooling from above.[1,2]

In addition, cases are described of the formation of a cellular structure in two-phase systems (for example in spermaceti, which contains a suspended aluminum powder,[3] in a layer of smoke, which is introduced into a chamber which is heated from below and cooled from above).[4,5] As cause of formation of a cellular layer in a two-phase system (similarly for one-phase) it is acceptable to assume a convection, determined by the difference of temperature between the lower and upper boundaries of the layer. However, as observations carried out by us show, the formation of a cellular structure in a layer of fog is possible in conditions when the gas is cooled from below and heated from above or when in general a temperature gradient is absent. The horizontally situated layer of fog of variable thickness is easily obtained in a diffusion-condensation chamber by means of a gaseous discharge. Cylindrical and rectangular chambers were employed with a bottom which is cooled and with glazed walls, differing little from the one described earlier.[6]

The chamber was filled with air or argon. A surface of ethyl alcohol gave rise to a vapor which is collected in a tube which is placed near the top. For the creation of a continuous process of diffusion near the walls at the bottom of the chamber a porous membrane was inserted which is moistened with alcohol. Under the action of the capillary force the alcohol, being at the bottom, was raised through the membrane to the top and thereupon, having evaporated, diffused downwards. Other sources of the vapor were absent in this case.

In the presence of a gaseous discharge between