Dielectric Losses in Rocksalt

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The phase angle of pure dry rocksalt, measured through the range of 1 to 1000 kilocycles, is found to be less than 0.0001. Moisture increases the power factor greatly, especially at the lower frequencies. Traces of surface contamination with certain organic substances may cause rocksalt to have marked apparent dipole properties. The power factor is not measurably affected by prolonged exposure to either intense x-rays or cathode rays.

JOFFÉ[1] states that the conductivity of rocksalt is not markedly increased by x-rays. This fact is consistent with the theory that x-rays displace electrons from the negative chlorine ions, neutralizing the positive sodium ion. It seemed possible that there might be many ions not completely neutralized and yet modified so as to be more loosely bound than in the neutral state. Under alternating fields, the vibration of these ions would be modified, and, thus, the dielectric losses would be changed. Therefore, it was decided to measure the losses at high frequency both before and after coloration with x-rays and cathode rays.

Apparatus

The apparatus was the same as that used by H. H. Race[2] in studying the dielectric properties of an insulating oil. The frequency range used for this study was from 1 to 1000 kilocycles. The standard variable capacitor was a General Radio precision instrument which had been reinsulated with fused quartz. Its power factor, as roughly computed from the dimensions of the plates and of the fused quartz, was of the order of 0.00001.

Preparation and Mounting of Samples

Thin slabs of rocksalt were cut by using a tightly stretched, moistened string about two feet long. A thread tightly wound with fine wire, such as is used in many high resistances, was found to make a very smooth cut. A natural cleavage face of a large block of rocksalt was first ground smooth with fine carborundrum powder and saturated salt solution. To remove traces of the powder, the surface was rubbed over the damp portion of a tightly stretched cloth and then quickly rubbed dry. The polished surface was painted over with paraffin dissolved in toluol. A slice about 2 mm thick was cut off and the polished, paraffined surface melted onto a piece of plate glass. Such a thin layer of rocksalt is easily bent and much care has to be taken in pressing out the paraffin from under it. The second surface was then ground down and polished and the rocksalt sheet removed. The back surface was washed with very pure toluol, gently cleaned with smoothing powder and polished again.

The rocksalt layer was mounted as follows (See Fig. 1): A steel dish A was filled with clean

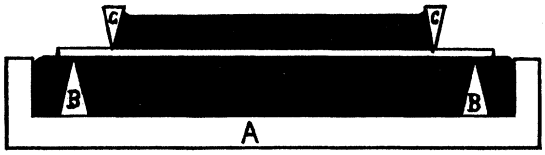

FIG. 1. Condenser mounting.

mercury. An amalgamated brass ring B, which was the same height as the dish, was immersed in the mercury. The rocksalt sheet was slid slowly onto the mercury surface so as to entrap no air bubbles. A smaller brass ring C was laid upon the rocksalt and was filled with mercury. Contacts were made with the two pools of mercury by amalgamated copper wires.

Procedure and Results

The results of the first test will be described because they show the astonishing effect of certain surface impurities. The surfaces of the

[1] Joffé, *The Physics of Crystals*, McGraw-Hill.
[2] H. H. Race, Phys. Rev. 37, 430–466 (1931).

first sample inadvertently became contaminated with oil. The oil was removed with C.P. benzene and the sample mounted. Tests then showed a remarkably pronounced dipole effect, the power factor being below 0.0005 at 10 and 1000 kilocycles but rising to a sharp peak value of 0.003 at about 190 kilocycles. Later measurements showed that the peak was completely spurious and that it was caused by either slight traces of the oil or the residue from the C.P. benzene. The same sample, after having both surfaces repolished showed no peak at all.

An attempt to use electrodes formed by a carbon paint proved unsatisfactory even though all ingredients were left in a desiccator several days to free them from moisture. The power losses proved to be abnormally high.

A second sample 5 cm × 5 cm × 1.5 mm was prepared, making a condenser of 67.8 $\mu\mu$f capacity. The surfaces were more highly polished, and the material was more optically clear. The power factor was measured at several frequencies and found to be low and constant. In order to see what effect might be caused by surface moisture, the top electrode was removed and a film of moisture was formed by breathing near it. The electrode was quickly put into place. The power factor was then almost too large to measure and was variable. Measurements were soon stopped when the high-frequency current arced through a crack which had developed in the crystal.

Final measurements were taken on a specially large and pure crystal. The block of rocksalt, 4.5×6×7 cm, was obtained from Ward's Natural Science Establishment. It had been sawed out practically parallel to the natural cleavage planes. It was remarkably transparent and throughout the whole sample had no visible flaw. A plate was cut from the 6×7 face and the polished sheet was 0.9 mm thick. This large surface allowed larger electrodes to be used and produced a condenser of 125.1 $\mu\mu$f capacity. With this increased capacity the accuracy of measurement of the power factor was much improved. The sample was left in a desiccator over night and its power losses measured the next day. It was then colored amber by a 40-minute exposure to x-rays. The sample was about 12 inches from the target of the tube. The potential was 200 kilovolts and the current through the tube was 30 m.a. The sample was again left overnight in the desiccator. The desiccator was placed in a light-tight box so that no fading of the coloration would take place. The upper curve in Fig. 2 shows that the values of the power loss before and after exposure to x-rays are identical. The sample was then given a further exposure to x-rays for two hours. It then had a deep-amber color which, in such a thin layer, represented an intense coloration. It was placed in the desiccator in the dark and, as it happened, was left for four days before measurements could be taken. The power factor was then so low that it could not be measured. There was less loss in the sample than in the quartz-insulated standard condenser. Thus the power factor was of the order of 0.0001 or less. If x-radiation had produced any effect, it would have been such as to increase the conductivity and increase the power losses. Therefore, the decided decrease which occurred must have been due entirely to the complete drying which the sample had undergone. To test that point, the sample was left exposed to the humidity of the room (in August) for a day, and then, although it was not noticeably faded, the power factor had increased to nearly the same values as before the coloration.

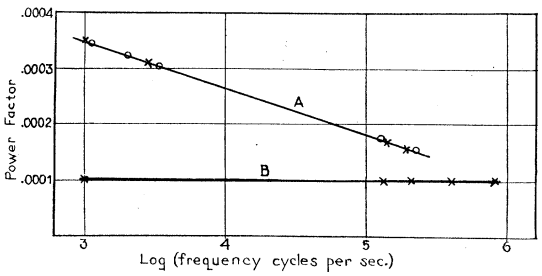

FIG. 2. Curve A: the power factor of rocksalt before and after exposure to x-rays; sample dried twelve hours. Curve B: the power factor of intensely colored rocksalt after four days of drying.

In order to see if extreme coloration could cause power loss, each surface was exposed 113 seconds to cathode rays from a Coolidge tube. The potential across the tube was 250 kilovolts and the current through the tube was 11 m.a. The sample was about one inch from the metal window of the tube. Both surfaces were colored a blackish brown. This coloration was essentially a surface phenomena. After desiccation for two days the

power factor at 1000 cycles was found to be about 0.1 and was slightly variable. Careful cleaning of the edges of the sample to remove the surface conduction around the edges reduced the power factor to 0.032. The surface coloration was then thoroughly scraped from both sides of the sample for a distance of about five millimeters from all the edges. The sample was then desiccated for two days and one week respectively. The power factor at the end of the week was smaller than at the end of two days and was again less than 0.0001.

Conclusions

Throughout the range of frequency from 10^3 to 10^6 cycles per second and at room temperature: (1) The power factor of pure and thoroughly dried rocksalt is certainly less than 0.0001 and is probably of the order of 0.00001. (2) Slight traces of certain impurities on the surfaces of rocksalt may raise the power factor remarkably at certain frequencies. (3) The effect of moisture on the surface is to increase the power factor considerably, relatively more at low frequencies. (4) Neither intense coloration of rocksalt throughout its body by x-rays nor intense surface coloration by cathode rays appreciably affects the power factor.

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