ROCHELLE SALT AS A DIELECTRIC

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Abstract

Both saturation and hysteresis appear in Braun tube oscillograms made at various temperatures with a condenser whose dielectric consists of Rochelle salt slabs cut perpendicular to the a-axis. The dielectric constant for such slabs may reach a value of 18,000. Curves are also given, showing the variation in mechanical and electrical saturation with temperature. These correspond in only a general way to the piezoelectric constant's variation with temperature. Certain marked peculiarities are noted in the resulting mechanical deformation when Rochelle salt is excited with alternating potentials. Clear Rochelle salt half-crystals have been produced up to forty-five centimeters in length.

THE remarkable physical properties of Rochelle salt, the most piezoelectric active of all crystalline substances, have been reported by other authors.[1] Comparatively small plates and few crystals were used in their determinations.

Work at this laboratory has been carried on for a number of years on Rochelle salt with a view towards commercialization. It has, therefore, been necessary to produce large clear crystals in quantity. Clear, flawless half-crystals are grown up to 45 cm in length and 2 kg in weight.

The dielectric strength and insulation value of plates from such crystals is very high. Many hundreds of plates (mostly perpendicular to the a-axis of the crystal) have been produced and their electrical properties measured. Thus a Rochelle salt plate 4.75 mm thick shows a dielectric constant of 18,000 when tested at 15°C at 60 volts 60 cycles alternating current. The highest previously reported value which has come to the attention of the authors is about 1380.[2] An air condenser of area and capacity equal to that of the crystal plate would have a plate separation of only 0.00475 mm, if 1380 be taken as the crystal dielectric constant; and 0.000262 mm (0.0001″) if 18,000 be taken. It is thus evident that a comparatively thin layer of cement or dehydrated Rochelle salt between the body of the crystal and the foil electrode will introduce a very large error in the determination of the dielectric constant. Any adhesive such as balsam in xylol, Japan Gold size, or beeswax dissolved in benzol with a small addition of rosin, may be used in dilute solution for atttaching the foil. It is important, subsequently, to

[1] Frayne, Phys. Rev. **21**, 348 (1923); Isley, Phys. Rev. **24**, 569 (1924); Laurey and Morgan, J. Am. Chem. Soc. **46**, 2192–6, (1924); Pockels, Encyklopadie der Math. Wiss. Vol. 5, Part 2; Valasek, Phys. Rev. **17**, 475 (1921); **19**, 478 (1922); **20**, 639 (1922) and **24**, 560 (1924). Voigt, Lehrbuch der Kristallphysik, Chap. 8, Leipsig (1910).

[2] Valasek, Phys. Rev. **19**, 488 (1922).

rub down the foil very thoroughly to bring it as close to the crystal surface as possible.

A series of Braun tube oscillograms was obtained. For this purpose, and for all other results reported in this paper, a crystal plate was employed measuring about 8.5×5.5×0.5 cm, cut with its plane perpendicular to the

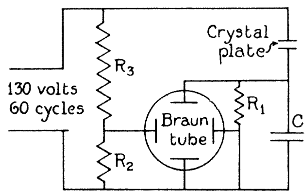
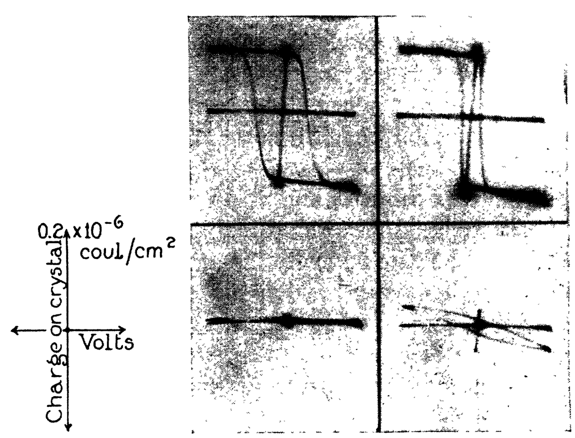


Fig. 1. Schematic connection of Braun tube. Capacity of crystal plate 0.004 to 0.2 Mf; of C 0.7 Mf. $R_1=0.45$ megohms; $R_2=3180$ ohms; $R_3=31800$ ohms.

a-axis, and its long edges parallel to the c-axis. All measurements and oscillograms were carried out with 60 cycle current from the power lines. All vertical deflections are on the same scale as in Fig. 2.

Fig. 1 shows the connections employed with the Braun tube for obtaining crystal oscillograms. At the left is a resistance acting as a voltage divider. To the right is the crystal plate under test, connected in series with a con-

Free



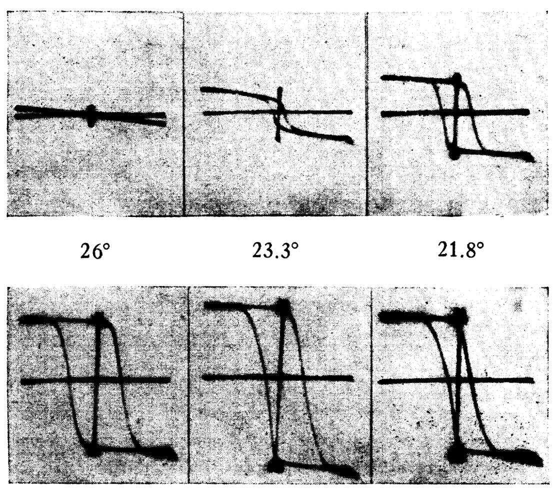
387 v. per cm 1161 v. per cm
Restrained

Fig. 2. Oscillograms of crystal plate, free and restrained. Temperature 15° C; frequency 60 cycles per sec.

denser giving voltages proportional to the charge on the crystal. The resulting oscillograms, such as shown in Fig. 2, have ordinates proportional to crystal charge and abscissae proportional to applied voltage.

Fig. 2 shows comparative oscillograms of a plate when entirely free, and of the same plate restrained by cementing it between two thick aluminum plates, thus very largely precluding mechanical motion due to piezo-activity. The left-hand vertical pair is for 387 peak volts per cm; the right-hand vertical pair is for 1161 peak volts per cm. The upper pair is unrestrained; the lower pair is restrained. Dielectric constants calculated from these oscillograms show exceedingly interesting and suggestive values: from the left-hand oscillogram (restrained plate) about 430; from the left-hand oscillogram (free plate) in the saturated range about 330; from the same oscillogram for a complete cycle, excluding saturation range 10,500; and for maximum instantaneous value not less than 200,000.

Such enormous values of the dielectric constant in connection with less efficient foiling of the crystal plates, may account in part for the previously observed storage battery effect. Supplementary tests indicate that little



26° 23.3° 21.8°

15° 0° −8°

Fig. 3. Hysteresis and saturation of Rochelle salt plate II. Potential gradient in dielectric 387 (peak) volts per cm; frequency 60 cycles per sec.

change in the value of the dielectric constant is to be looked for as a result of improvement in foiling. In these supplementary tests, electrodes of saturated Rochelle salt solution were used and results did not differ significantly from those obtained from a carefully foiled plate. Moreover these large values of the dielectric constant of Rochelle salt have been observed in many hundreds of plates of various dimensions from many different crystals. Determination of the dielectric constant was usually made by applying 112 volts of 60 cycles alternating potential to the free crystal plate and noting the resulting current. In addition, circuit resonance and condenser substitution methods served to check this first method, all three giving results in substantial agreement.

Fig. 3 comprises a series of comparative oscillograms made from the same crystal plate at different temperatures as indicated. Proceeding from top left to bottom right it is evident that as the temperature is decreased both the voltages and charges required for saturation greatly increase. So also do the areas of the hysteresis loop. Here again the method of applying the foil electrodes to the crystal is of great importance as the shape and area of the loop will vary somewhat with this factor.

All of the oscillograms were made with the greatest care. A second crystal plate gave results identical with the first. Two other plates of the same dimensions as before but with their long edges cut at 45° to the c-axis, showed no essential differences in the derived oscillograms. Though no special humidity precautions were observed, the resistance of the plates, at 100 volts constant potential, never fell below many megohms.

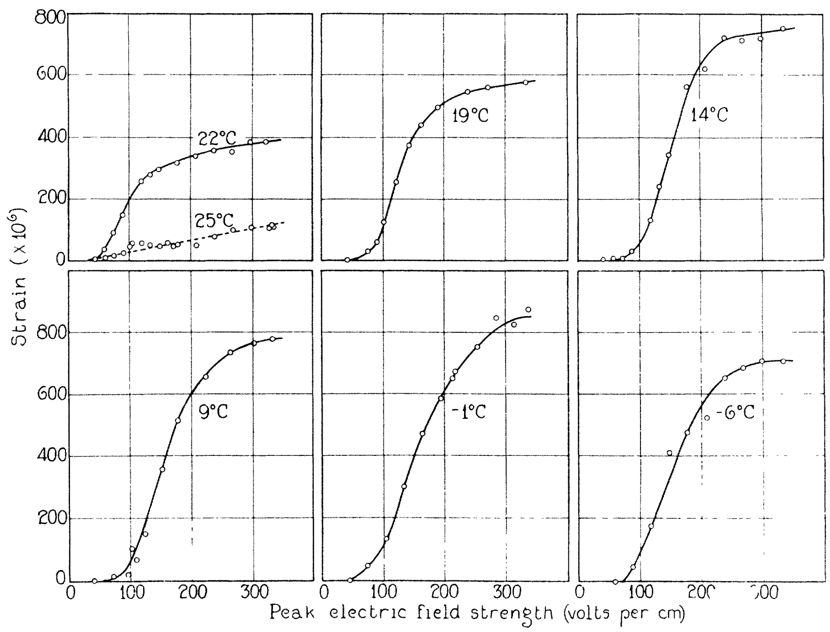


Fig. 4. Temperature variation of saturation effect and piezoelectric constant.

If a standard plate—its long edge being cut parallel to c-axis—is electrified with an alternating potential, it will be deformed and such deformation can be observed and measured conveniently with a microscope. For the results shown in Fig. 4, one short edge of the plate was cemented to a large lead block and various values of 60 cycle potential were applied to the electrodes. The alternating motion produced under these conditions lies in the plane of the plate and is perpendicular to the c-axis. The relation between total deformation and electrification is shown for various temperatures.

Saturation is again in evidence and saturation values again increase greatly with decrease in temperature. Keeping close pace with it is the voltage required to produce saturation. But it is very noteworthy that considerable voltage must be applied before the crystal shows appreciable deformation.

Fig. 5 shows the close relationship existing at different temperatures between: 1st, volts per cm required for mechanical saturation; 2nd, the energy loss per cubic centimeter per cycle; 3rd, the charge per cubic centimeter required for electrical saturation. Though not shown in this figure, these curves are followed closely by those of the voltage required for electrical saturation and of the deformation at mechanical saturation. No determina-

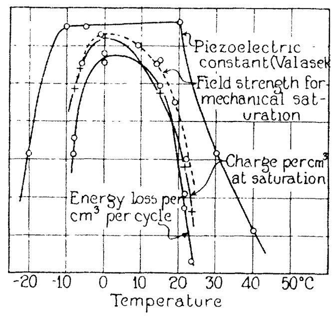


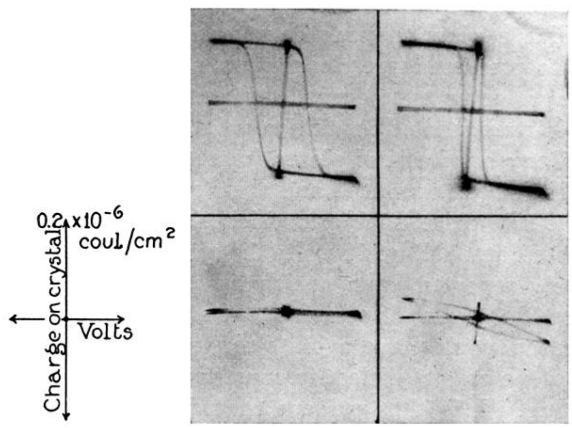
Fig. 5. Properties of Rochelle salt at various temperatures.

tions of the piezoelectric constant were made, but Valasek's[3] most recent curve of the temperature variation of the piezo-electric constant is included for the sake of comparing temperature variation of this property with those of the others.

It has been the great privilege of the authors to carry on this work begun under the very able leadership of the late Charles F. Brush, Jr.

[3] Valasek, Science Vol. LXV No. 1679, p. 235 (1927).

Free



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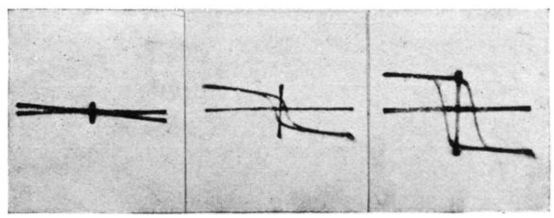
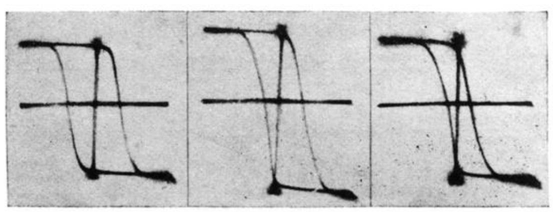


26°   23.3°   21.8°



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