PIEZO ELECTRICITY OF ROCHELLE SALT CRYSTALS.

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(*A note descriptive of a demonstration given before* The Faraday Society, *on Wednesday, June* 22, 1921.)

During the past few years an English electrical engineer, Mr. A. McLean Nicolson, has been at work in the Research Laboratory of the American Telegraph and Telephone Co., New York City, on piezo-electric effects of Rochelle salt crystals. He has obtained remarkable results which the writer has seen, and through the kindness of the Company in lending apparatus is now able to demonstrate the effects in England. An investigation is now going on to see if they can be applied to ordinary telephones. It may be that the crystals can be used for mastoid deafness by being placed in the cavity behind the ear left by the operation.

In 1703 some Dutch jewellers accidentally discovered that tourmaline exhibited curious electrical effects. When pressure is applied at opposite ends of a tourmaline crystal, electrification is induced on the surface of the crystal, and it is most marked at the ends, which become positively and negatively electrified.

The effect may be regarded as due to the crystal molecules being *stratified askew to the line of pressure*, and the resultant molecular motion of the skew crystal surfaces resulting from pressure, is the cause of the electrification. It is, therefore, necessary only to use such crystals as possess *skew symmetry* with regard to a line of stress.

The word piezo-electric is now used to describe the effect and it is derived from the Greek word "piezein" signifying "to press". It relates to crystals which when subjected to change of stress, become electrically polarised, and which will also dilate or vibrate when electric charges are applied to them. About two-thirds of the crystals that are known, are capable of displaying piezo-electrical effects.

Quartz and Rochelle salt are piezo-electrically active for the reason that they are also optically active, which is because of their structural asymmetry.

In asymmetric crystals the same mechanism which operates on polarised light to rotate the plane of polarisation also causes a liberation of electricity when the crystal is elastically deformed, or a dilatation when electric potential is applied. This mechanism is found only in hemihedral or hemimorphous crystals possessing an asymmetric arrangement of *atoms* in the organic molecule such as the tartrates, sugar, camphor, etc., or an asymmetric arrangement of the mineral *molecules* such as quartz, tourmaline, boracite, etc.

H. and P. Curie proved that it was due directly to stresses, or changes in the applied stresses, and not merely to temperature changes. Amongst many minerals and organic crystals investigated by them, crystals of Rochelle salt were found to have the largest piezo-electric constant.

Mr. A. McLean Nicolson commenced his research in 1917 and he found that certain prepared Rochelle salt crystals are susceptible of considerable piezo-electric activity. For example he has obtained potentials as high as 500 volts, alternating currents measurable through a thermocouple, and has produced crystal tones audible at a distance of several hundred feet.

Rochelle salt is sodium potassium tartrate having the formula—

$$NaKC_4H_4O_6 . 4H_2O.$$

The crystal is grown from nuclei or seed crystals immersed in a saturated solution of the salt by the application of a temperature gradient to the solution, and the nucleus may be suspended by a clean thread, or laid on a glass plate. The cooling is purposely hurried and in a few hours the seed crystal increases from a few grams weight to several hundred grams, according to the volume and density of liquor. An average crystal weighs 100 grams and measures 65 mm. × 65 mm. × 25 mm. and several are shown in Fig. 1.

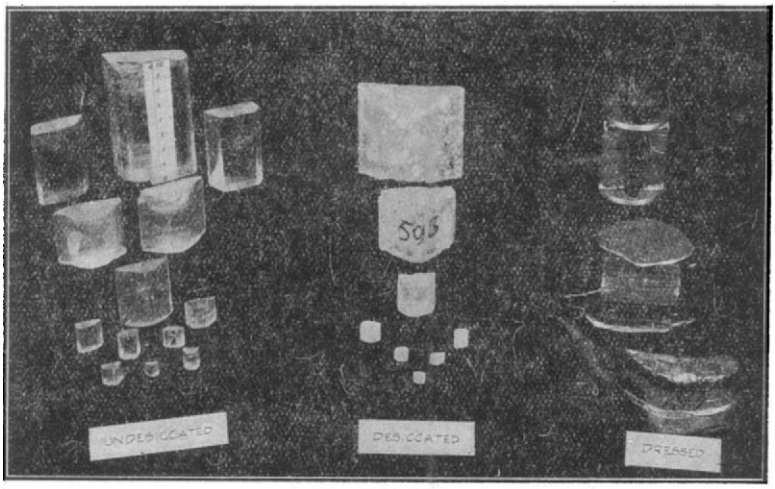

FIG. 1.—Rochelle salt crystals grown by Mr. A. McLean Nicolson.

Crystals thus rapidly grown develop internal stresses producing strain regions, and at each end of the seed-nucleus and on its axis, pyramids are formed which mineralogists term "hour-glass" marking. The phenomenon is probably due to shearing strains set up by relatively greater contractions of the outer-crystal envelope during cooling; at any rate the more rapid the growth the better the "hour-glass" effect. It is well shown in Fig. 2. Mr. Nicolson finds that the best shape for the crystals is with one side slightly concave and the other side more convex.

The electrical performance of the crystal suggests that the crystal molecules throughout the pyramidal regions during growth, are subject to forces which turn them, in planes containing the principal axis, through a right angle. The poles are at right angles to each other and the pyramids are electrically positive when the rest of the crystal structure is negative and *vice versa*.

Mr. Nicolson has found that the effect is very pronounced when the crystal is dried in alcohol and baked in an oven. He first treats the crystal

in 90 per cent. alcohol for 24 hours, and in 100 per cent. alcohol for about 4 hours, and then bakes it at 40° C. for several days. This treatment reduces the weight 3 per cent. Ageing and compression also improve the crystal. If baked at too high a temperature the crystal becomes paralysed and only recovers slowly.

Analysis of the direction of applied stresses to the sensitive regions has shown that, for the *composite*, i.e. "hour-glass" marked structure, a twisting couple about the principal axis excites the greatest electrification of the crystal electrodes.

For experimental purposes the crystal is varnished and waxed tinfoil electrodes are pressed on it. It is then placed between two aluminium discs held together by small steel springs, attached by eye-rivets to the lower plate. Thumb screws are provided to tighten the springs to the requisite amount after the crystal has been inserted.

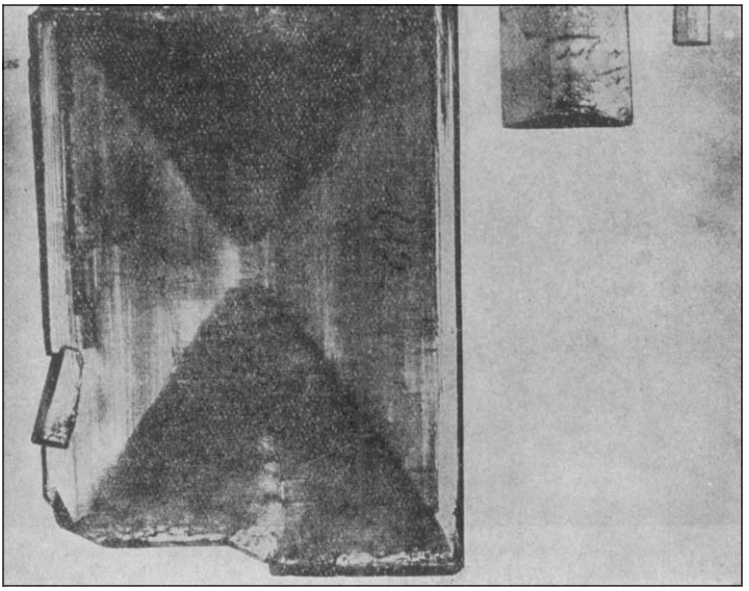

FIG. 2.—Rochelle salt crystal showing the "hour-glass" effect due to quick growth.

Any part of the metal structure will readily convey jars and vibrations to the crystal, for example if the crystal transmitter be laid on a large sheet of paper and receivers are applied to the electrodes, it is quite easy to hear gentle rubbing of the paper or the tick of a watch, transmitted along the paper to the crystal.

A crystal used on a phonograph record will generate several volts, with sufficient power to operate a large number of telephone receivers. As many as 200 receivers of 12,000 ohms impedance each have been operated from one crystal. To operate effectively, the crystal applied to the phonograph is subjected to torsional vibrations, and by means of the usual needle the vibrations are imparted to the aluminium plate under the crystal.

A given force produces the greater piezo effect when it is applied in such a way as to twist the crystal about its principal axis, and conversely, an applied electrical force produces the maximum response in the form of

twisting motion. To make maximum use of this torsional effect, Mr. Nicolson applies a cylindrical paper diaphragm around the receiving crystal, and attaches it by means of rings to the compressor plates which hold the crystal, as shown in Fig. 3. By turning one of the rings round the compressor plate the cylindrical diaphragm itself becomes twisted into diagonal corrugations stretched tightly across the crystal poles. The diaphragm is made of a strong light material like bond paper. Singing against the diaphragm, near resonance, will generate about 20 micro-amperes of current or produce 15 volts on open circuit and a clap of the hand near the transmitter will excite trains of oscillations.

With the aid of a vacuum tube amplifier, very good transmission of

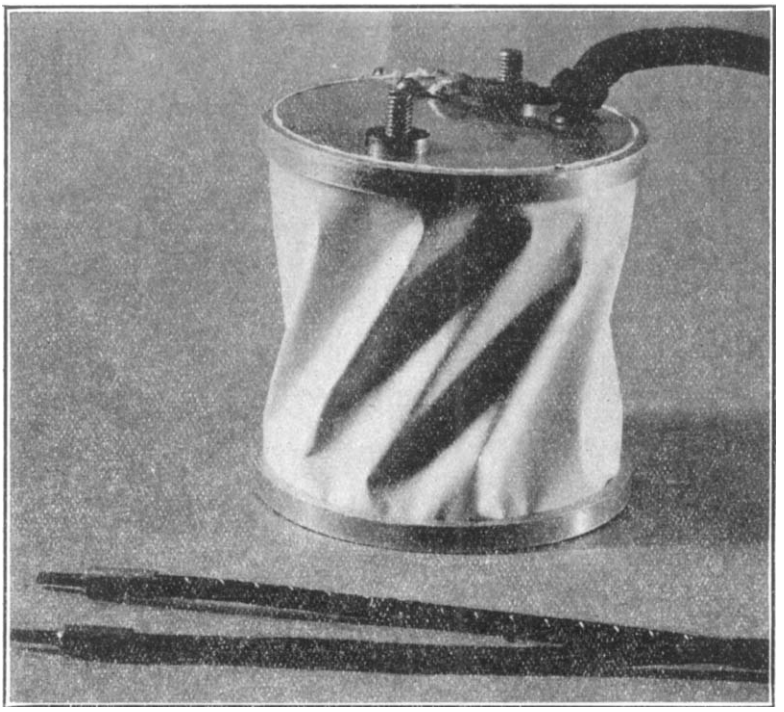

FIG. 3.—Receiver having a corrugated diaphragm to give the torsional effect.

speech and music may be obtained by using piezo crystals at both ends of a long line as the sole transmitting and receiving apparatus.

It has been noticed that the crystals improve with time, particularly soon after they are made. Drying out is probably one cause of this improvement and also realignment or recrystallisation of disturbed portions of the crystal molecules. After several months' use, the crystals reach a very steady operating condition in which their activity is permanent.

A microphone is more sensitive than the crystal transmitter, because the microphone with its associated local battery gives out more energy than it receives and hence constitutes an amplifier. The crystal translates only that portion of the energy applied to it which affects its mechanically sensitive regions.

Fig. 4 shows the amplifier circuit used in connection with Rochelle salt

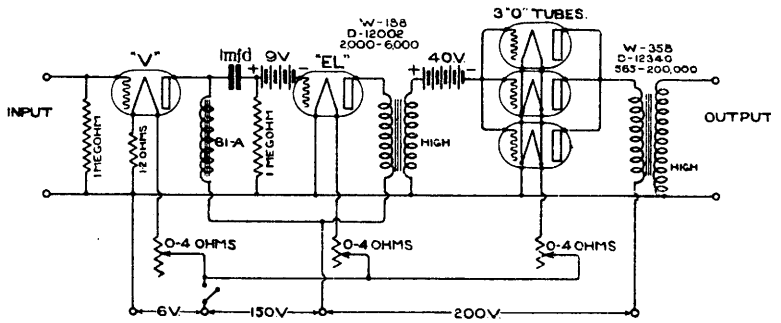

FIG. 4.

crystals in the Research Laboratories of the American Telephone and Telegraph Company and Western Electric Company.