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On a differential resistance thermometer

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experiment was rather indefinite; it scarcely did more than tell us—here is the possibility of a chemical process, here electricity can be produced. But which kind, how much, to what potential, remained indefinite. I have not found in all the papers which have been written for the defence of the chemical theory a clear explanation why zinc opposed to copper in liquids, where zinc really is oxidized and dissolved, becomes negative, and why in air and other gases it becomes positive, if the same cause (*viz.* oxidation) is at work.”

To the chemical *strain* theory, held by me, none of this remark is in the least applicable. This theory *does not say* that zinc opposed to copper in a liquid is negative. It says that, changing the surrounding medium from air to acid-water, makes scarcely any difference; and that accordingly connecting zinc and copper by a drop of water leaves them with the same respective potentials as they had before. The strain of oxygen-atoms towards a metal exists whether in air or water, but it can produce no effect in either case until at some point the oxygen be swept away by contact with another metal. Then instantly the chemical forces are able to do work, and to produce, if in air or other dielectric, the Volta-effect; if in acid or other electrolyte, the voltaic current. The metallic contact equalizes the potential of the two metals in the one case; in the other it perpetually *fails* to equalize their potential. The equalization of an otherwise disturbed potential is its only effect.

And no indefiniteness exists as to either the kind or amount of the Volta-effect as so produced, for I have shown fully that a Volta-effect can be calculated in absolute measure for any pair of clean metals immersed in any medium, from purely thermo-chemical data; but whether this effect is the real one or not is at present a matter of opinion.

These so-calculated effects undoubtedly agree in some cases with experimentally observed ones; but whether they all so agree, and, if not, the extent to which they are erroneous, are matters mainly for future experiment to decide; and upon such agreement or disagreement between calculation and experiment my theory definitely stands or falls.

XLVI. *Intelligence and Miscellaneous Articles.*

ON A DIFFERENTIAL RESISTANCE THERMOMETER.

BY T. C. MENDENHALL.

THE determination or registration of the temperature at a distant or not easily accessible point is so extremely desirable that many methods for accomplishing this end have been proposed, and

to some extent made use of during the past fifty years. Naturally enough electricity has been utilized in some way or other in the majority of these systems of telethermometry.

The requirements of the problem seem to be that the device or instrument used at the point, the temperature of which is to be ascertained, shall be of the greatest possible simplicity of construction, involving little or no motion in its parts, so that the liability to "get out of order" shall be reduced to the minimum; and that at the observing or registering station, the necessary appliances shall possess a maximum of durability and simplicity—so that a minimum of time and skill will be demanded in making the observations. The whole system must be certain in its indications and correct within a reasonable limit.

The first of these conditions is apparently sufficiently well satisfied by the thermo-electric-junction, which has probably been more extensively made use of than any other form of electric thermometer. It renders necessary, however, the use of a comparatively delicate galvanometer, and as the electromotive force of a single couple is small (it is difficult to use more than one in general practice) the results are subject to considerable errors arising from unknown or neglected sources of electromotive force. This source of error becomes more important as the range of temperature measured becomes smaller, although it may be almost entirely avoided by care and skill on the part of the operator. The well-known resistance method of Siemens satisfies the same condition very perfectly, and is certainly capable of giving good results when skilfully applied, at least throughout moderate ranges.

The desire to possess some form of electric thermometer which might be utilized in the study of certain problems connected with meteorology, especially the observation of soil and earth temperature, and the use of which would not demand greater skill than that of the ordinary meteorological observer, led to the device and construction of the instrument to be described, which may be called a "differential resistance thermometer." It consists essentially of a mercurial thermometer, not unlike ordinary forms, except that the bulb is greatly enlarged so that the stem may have a diameter of something like a millimetre, and still leave the scale tolerably "open." In one of the instruments already made 1°C. corresponds to about 5 millim. of the scale. Running down through the stem is a fine platinum wire about $\cdot 08$ millim. in diameter. The lower end may be secured in the bulb so that it is kept straight in the bore of the stem, and at the lower end a heavier wire is sealed in the glass, so that metallic contact can be made with this wire both at the upper end and through the mercury at the lower. It is evident that the resistance between these two points will depend largely (but not entirely) on the length of the platinum wire which is above the mercury in the tube, and this will depend on the temperature to which it is exposed. When this temperature rises the resistance is decreased by an amount equal to the difference between that of the platinum wire which disappears and that of

the mercury which takes its place—less the increase in the resistance of the wire and mercury due to increase of temperature.

Let l = length of platinum wire exposed at 0° .

s = resistance per unit length (= length of 1°) of wire.

g = resistance per unit length (= length of 1°) of mercury.

k = temperature coefficient of platinum.

h = temperature coefficient of mercury.

R_0 = total resistance at 0° .

R_t = resistance (including all) at t° .

Then

$$R_t = R_0 - \{s(1 - kl) - g\}t - (ks - gh)t^2. \quad \dots \quad (1)$$

This equation is not quite rigorous, but the approximation is very close. It is of the form

$$R_t = R_0 - Bt - Ct^2. \quad \dots \quad (2)$$

The simplest and best way of dealing with it is to determine the constants of the equation (2) by a series of observations making use of the method of least squares. From the result the resistance for any degree of temperature may be calculated, or, better, a curve can be constructed from which the temperature corresponding to any resistance can easily be read.

The advantage of this method over the use of a simple resistance coil is that the change in resistance accompanying a given change in temperature is much greater, and in fact it may be made as great as one desires. As a result the telephone may be substituted for the galvanometer in the resistance measurements, thus greatly simplifying the apparatus as well as increasing the rapidity with which observations may be made; or, if preferred, a much less sensitive galvanometer may be used. It also possesses the very great advantage of allowing an increase of delicacy as the range of temperature decreases. For earth temperatures this is very desirable, and it will easily be seen that thermometers of this kind can be constructed for a few degrees of range with which, by comparatively rude processes, the measurements may be correct within a very small fraction of a degree. For use in earth temperature measurements the thermometer will be enclosed in a strong brass tube for protection, and the connection with the point of observation made by means of a cable of heavy copper wire. The cable will of course form a part of R_0 in equation (2); but as it is a constant, the substitution of one cable for another, if necessary, will affect the position and not the form of the calibration curve. Its resistance must be small, relatively, and the influence of temperature upon it may be neglected.

With this device a temperature observation may be taken in less than a minute, no time being consumed in the preparation of liquids of known temperature at the observing station, as in the use of the thermo-junction or the resistance coil.—Silliman's *American Journal*, August 1885.