# On Certain Thermoelectric Effects of Stress in Iron.

By

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Since the discovery made by Thomson that the thermoelectric properties of wires of certain metals were altered by tension, the subject has been studied experimentally by various scientific men. Of these we may mention more particularly Le Roux, von Tunzelman, Cohn, and Ewing. The work done by Cohn and Ewing is of special importance ; and the latter's investigation for iron is the most complete that has been carried out. Reference will be made to their results hereafter. It is sufficient at present to point out one respect in which the work of these experimenters lacks completeness. In all, the method of experiment consisted in studying the effects of stress upon the thermoelectric properties of a wire, whose junctions with the other essential wire of the circuit were kept at steady temperatures. The variations of stress were, in the best experiments, carried through a cycle ; and at different successive stages the thermoelectric current was measured on a suitable galvanometer. The observed changes in the electromotive force might be due to either of two quite different effects ; and the experimental methods adopted could give no criterion by which to draw the correct conclusion. The nature of the problem is most simply expressed in terms of the language of the thermoelectric diagram. In this diagram the thermoelectric relations of the different metals are represented by lines (usually straight) in such a manner that the electromotive force existing in any circuit of two metals is equal to the area included between the appropriate metal lines and the two lines drawn perpendicular to the temperature axis and through the points representing the temperatures of the two junctions. The question propounded above is then this. What change does stress applied to a given metal produce upon the *position* of the line in the thermoelectric diagram ? Does it translate it as a whole up or down ; does it rotate it as a whole about some definite point ; or does it effect a combination of these so that the line is deformed as well as shifted ? In other words does stress change the Thomson Effect in a wire, or does it simply change the Peltier Effect with reference to an unaffected second wire ?

Now it is quite clear that the only way to answer this problem is to arrange an apparatus in which the electromotive forces due to *different* differences of temperature can be measured *simultaneously* on a wire under given conditions of stress. This could be accomplished only by having the gradient of temperature along the wire both steady and gradual. Junctions could then be made at several points along the wire ; and the electromotive forces due to the several circuits so obtainable could be easily measured and compared, once the temperatures were steady. The simplest way of realizing these conditions seemed to be to stretch the wire inside a metal tube, and then to heat the metal tube as in the Forbes Experiment on the conduction of heat along bars.

For ease in manipulation the tube, which was of iron, was made in two semi-cylindrical parts. The upper part or lid fitted accurately upon the lower part which rested horizontally on sharp edged supports. The lower part was somewhat longer than the upper part, the extra length being a solid cylindrical piece of iron which during the experiment was sustained at a bright red heat in a charcoal furnace. To render the fitting secure a ridge cut out longitudinally on each plane surface of the semi-cylindrical lid fitted into a groove cut out on the opposing surface of the lower part. At suitable intervals along this lower part small radial notches were cut. These became holes when the lid was set in position, and through them wires were led from the interior of the tube. The wire to be used was stretched along the axial line of the tube; and it and all the various junction wires were arranged and adjusted before the lid was laid in position. Each junction was a junction of three wires—( 1 ) the axial wire to be tested, ( 2 ) a thin wire of the same material, ( 3 ) a thin wire of some other metal. The two last formed what we shall call the Thermometric Circuit. Its indications served to measure the temperature of the junction. The circuit, formed by the axial wire and the thin wire of the same material, was the essential element in the experiment. We shall call it the Thermoelectric Circuit.

The tension was applied by means of a screw at the extremity of the wire, which projected some distance from the open end of the tube; and was measured on a spring dynamometer set in line. To prevent currents of air circulating in the tube, the open cold end was plugged with cotton wool, and the side holes, through which the thin wires came, were filled up with asbestos. The hot end of the tube was closed naturally by the vertical face of the solid cylindrical portion already mentioned. The end of the wire was clamped to this face.

The current were measured on a high resistance double coiled galvanometer, which was carefully gauged after every single day's experiment.

The general plan of experimenting was simple enough. After the tube and contained wire had attained a steady condition as regards temperature, a series of readings of the different thermoelectric and thermometric currents were taken as rapidly as possible, with a sufficient number of repetitions of the same to yield a good mean for each individual circuit. This operation was carried through for a series of ascending and descending values of tension. The small value of the current in the thermoelectric circuit as compared with that in the thermometric required that only a small shunted portion of the latter should be taken through the galvanometer. This necessitated a somewhat complicated arrangement of resistances and commutators, which however it is unnecessary to describe.

In the earlier experiments the thermometric circuits were of copper and iron, and the thermoelectric of iron and iron. By using copper and iron, we expected to be able to get good measurements of the true temperature values of the junctions ; and this because of the existence of a neutral point at an easily attainable temperature. It was found, however, that the uncertainties of reduction from the parabolic temperature scale of experiment to the linear scale of accepted use far outweighed the advantages of having an observed neutral point as a guide. Accordingly after many experiments had been made the Copper Iron thermometric junction was abandoned in favour of a German-silver Iron junction. As is well known, the electromotive force of this pair of metals varies in an approximately linear manner with temperature up to a dull red heat. The graphical comparison of the thermoelectric with the thermometric currents will not in this case differ greatly *in appearance* from what would be the case if an accurate absolute scale of temperature were used instead. Ultimately, of course, the thermometric readings were reduced to the ordinary temperature scale by calculation from the results of direct experiment.

It was determined to experiment first with iron wire. Previous workers had all found that the thermoelectric effects of stress were much more pronounced in this metal than in others. It seemed natural therefore to begin with it. Should the experiments prove promising, it was intended to pursue the enquiry in regard to copper, nickel, platinum, etc. A few experiments were indeed tried with copper and nickel wires ; but in the latter its viscosity under the influence of sustained stress produced a gradual decay in the value of the stress, applied as it was by a tightened screw. It was obvious that a steady stress could be applied only by means of a load acting by its weight ; and for this the apparatus was not readily adjustable.

Several modifications in the mode of experimenting were repeatedly tried before results of a satisfactory character were obtained. In certain experiments with the iron wire, thermoelectric changes of very small amount were obtained by simply varying the *tension* without having established the temperature gradient. This thermoelectric effect increased with the tension. The direction of the current was opposite to the direction of all the currents obtained when the gradient of temperature existed along the wire. In other words, the current was such as might have resulted from a slight heating of the wire where it was gripped by the dynamometer clamp. The probable explanation of this effect is that the part of the stretched wire which lay outside the tube was a little warmer than the part inside the tube. Such a slight gradient of temperature might easily ensue under the influence of the air as it grew warmer with the advance of day, the more massive tube changing more slowly in temperature. If this is the true explanation, the effect will have no existence in the real experiment, in which a steady temperature gradient is to be sustained. In any case, however, these initial currents, as they might be termed, were much smaller than the currents subsequently obtained.

After the best method of experimenting had been by long trial decided upon, the character of the experimental part of the research was in itself very tedious; and since months of preliminary and otherwise futile labour had already been spent it seemed best to postpone a continuation of the experiments till some future date. So far there have been no opportunities for renewing the attack, other work fully engrossing our time.

We are now prepared to discuss the results of the final set of experiments with iron wire.

The dimensions of the tube bar were as follows:

| | | |
|---|---|---|
| Total length of bar... ... ... ... ... | 102 | cm. |
| ,, ,, tubular part ... ... ... | 90 | ,, |
| External diameter of ,, ,, ... ... ... | 4.4 | ,, |
| Internal ,, ,, ,, ,, ... ... ... | 2.2 | ,, |

The diameter of the iron wire used was 1.2 mm. It projected about a foot beyond the cold open end of the tube and was attached to a spring dynamometer measuring pounds-weight. The dynamometer was fixed to a screw working in a fixed nut; and by this means the tension could be increased or diminished as desired.

In the final set of experiments each applied stress acted for at least one whole day before the thermoelectric observations were begun. The wire was left for this interval at the ordinary temperature of the air.

The solid end of the cylinder was then heated to bright redness in a charcoal furnace; and after 2 hours' heating the temperature gradient became fairly steady, as indicated by the thermometric currents on the galvanometer.

There were five pairs of junctions, ten in all—five thermoelectric and five thermometric. The positions of these junctions along the iron wire were so arranged that the temperatures of two successive positions differed by 40°–60° C. The pairs of junctions were distinguished by number, No. I. being the hottest and No. V. the coldest.

The observations were made in the following order. First, the five thermometric currents were measured in rapid succession from I. to V., each current being measured first in the one and then in the other direction through the galvanometer. [This was an invariable rule in the measurement of all currents, the total range from the direct to the reverse reading giving twice the true deflection.] Then followed a similar set of readings of the five thermoelectric currents; then a second set of the thermometric; and so on until 4 sets of the thermometric currents with 3 interpolated sets of the thermoelectric currents had been completed. Exactly similar sets of observations were made for the series of tensions representing total loads of 0, 5, 10, 15, 20, 24 and 0 pounds. Reduced to kilogram-weight per square millimetre, these tensions are a little greater than 0, 2, 4, 6, 8, 9·6, and 0 respectively.

In Table I, the observations are given in full for the five pairs of junctions; T standing for the thermometric junctions whose indications form an arbitrary temperature scale, and E for the thermoelectric junctions whose electromotive forces are the real subjects of investigation. The tension, the temperature of the cold junctions, and the factor for reducing the deflections to electromagnetic units of electromotive force, are given in the space to the left of the tabulated numbers.

# Table I.

Scale-readings of the Galvanometer-deflections of the E. M. F. of Iron-Copper junctions (T), and of Iron-Iron junctions (E) in the five Places.

| | I | | II | | III | | IV | | V | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T | E | T | E | T | E | T | E | T | E |
| Tension 0 | 170 | | 134 | | 100.7 | | 75.15 | | 50.55 | |
| Cold temp. 15°.9–17° | | 140.75 | | 109.5 | | 87.3 | | 69 | | 49.2 |
| Galv. Factor 147.5 | 174.5 | | 138 | | 104.15 | | 78 | | 53.65 | |
| 14th Oct. 1889 | | 141 | | 111 | | 89.75 | | 72.25 | | 52.2 |
| | 174 | | 137.7 | | 104.2 | | 78.5 | | 54.25 | |
| | | 141 | | 111 | | 90 | | 72.75 | | 53.5 |
| | 173.5 | | 137.5 | | 104 | | 78.4 | | 54.5 | |
| | 158.5 | | 123.4 | | 91.5 | | 67.5 | | 44.5 | |
| Tension 5 | | 136.75 | | 101.3 | | 79 | | 61.7 | | 42.2 |
| Cold temp. 14°.4–15°.5 | 159.9 | | 125.5 | | 94.15 | | 70.5 | | 47.5 | |
| Galv. Factor 143 | | 137.25 | | 103.25 | | 81.75 | | 65.3 | | 46.5 |
| Tension applied | 160.7 | | 126.75 | | 95.75 | | 72.25 | | 49.3 | |
| 11.30 a. m. Oct. 14th | | 139.75 | | 105.25 | | 83.75 | | 68 | | 48.75 |
| to 1 p. m. Oct. 15th | 163.75 | | 129.25 | | 97.8 | | 73.7 | | 50.5 | |
| | 160.9 | | 125.75 | | 94.5 | | 70.5 | | 47.95 | |
| Tension 10 | | 142.2 | | 105.6 | | 84.9 | | 67.95 | | 46.5 |
| Cold temp. 16°–17°.2 | 161.25 | | 126.75 | | 95.7 | | 72.15 | | 49.65 | |
| Galv. Factor 143.3 | | 140.5 | | 104.5 | | 84.5 | | 68.95 | | 47.8 |
| Tension applied | 159.2 | | 125.5 | | 94.85 | | 71.5 | | 49.6 | |
| 7 a. m. Oct. 17th to | | 136.5 | | 101.95 | | 82.6 | | 68.2 | | 47.9 |
| 9 a. m. Oct. 18th | 155.5 | | 122.75 | | 93.25 | | 70.8 | | 49.25 | |
| | 163.25 | | 126.55 | | 93 | | 68 | | 44 | |
| Tension 15 | | 144.1 | | 105 | | 81.5 | | 62.25 | | 39.7 |
| Cold temp. 13°.8–15°.2 | 172.2 | | 134.75 | | 100.75 | | 75 | | 50.25 | |
| Galv. Factor 143 65 | | 143.75 | | 107.05 | | 85.3 | | 68.5 | | 44.75 |
| Tension applied | 171.5 | | 135.5 | | 102.5 | | 77.15 | | 52.9 | |
| 11 a. m. Oct. 18th to | | 145.15 | | 108.3 | | 86.5 | | 70.4 | | 47.2 |
| 9 a.m. Oct. 19th | 174.5 | | 138.5 | | 105.25 | | 79.1 | | 54.5 | |

## Table I. *(Continued.)*

| | I | | II | | III | | IV | | V | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T | E | T | E | T | E | T | E | T | E |
| | 170.8 | | 134.5 | | 101.5 | | 76.85 | | 52.8 | |
| Tension 20 | | 150.25 | | 114.5 | | 92.75 | | 76.75 | | 54.5 |
| Cold temp. 17°.3–18°.5 | 171.75 | | 135.35 | | 102.5 | | 77.45 | | 53.7 | |
| Galv. Factor 143.5 | | 152 | | 116.5 | | 94.75 | | 79.65 | | 56.75 |
| Tension applied | 171.2 | | 135 | | 102.5 | | 77.5 | | 53.75 | |
| 9 a. m. Oct. 21st to | | 151.75 | | 116.75 | | 95.25 | | 80.4 | | 57.95 |
| 10 a. m. Oct. 22nd | 169.25 | | 134 | | 102 | | 77 | | 53.45 | |
| | 161.65 | | 126 | | 93.1 | | 69 | | 45.5 | |
| Tension 25–22.5 | | 145.75 | | 107.5 | | 82.95 | | 64 | | 41.7 |
| Cold temp. 14°.8–16°.1 | 171 | | 133.75 | | 100.15 | | 74.7 | | 50.4 | |
| Galv. Factor ? | | 148.5 | | 112 | | 89 | | 71 | | 48 |
| Tention applied | 173.5 | | 136.75 | | 103 | | 77.25 | | 52.75 | |
| 10 a. m. Oct. 23rd to | | 146.95 | | 111.7 | | 90.5 | | 74.3 | | 51.8 |
| 2 p. m. Oct. 24th | 168.7 | | 133.3 | | 102 | | 76.65 | | 52.75 | |
| | 164.1 | | 127.95 | | 95.3 | | 71.25 | | 46.25 | |
| Tension 0 | | 143 | | 108.7 | | 85.5 | | 63.3 | | 45 |
| Cold temp. 16°3–17°.9 | 171 | | 134.5 | | 101 | | 76.25 | | 50.7 | |
| Galv. Factor 138.7 | | 144.95 | | 111.75 | | 89 | | 67.55 | | 49.05 |
| Tension released | 173.7 | | 137.5 | | 104 | | 79.05 | | 53.15 | |
| 11 a. m. Oct. 25th to | | 145 | | 112.25 | | 90.3 | | 69.5 | | 50.8 |
| 10 a. m. Oct. 31st | 173 | | 137.25 | | 104.5 | | 79.55 | | 54.5 | |

It may now be assumed that the mean of any set of four numbers for T will correspond to the mean of the set of three numbers for the E of the same junction-pair. These means are then to be reduced to temperature in the one case, to electromotive force in the other. For the reduction to temperature independent experiments were made to determine the constants of the iron german-silver circuits ; and in the final reduction full account was taken of the slight variations in the value of the cold junction temperature. The results of the reduction are embodied in Table II., all the cold junction temperatures being reduced to 13°.5 C.

## Table II.

E. M. F. between stretched and unaffected Iron wires, at various Tensions and Temperatures.

| Tension | Cold Temp. | Hot Temp. | E. M. F. in Microvolts | Tension | Cold Temp. | Hot Temp. | E. M. F. in Microvolts |
|---|---|---|---|---|---|---|---|
| 0 | 13°.5 | 267°.9 | 562 | 6 | 13°.5 | 269°.4 | 589 |
| | | 211°.7 | 437 | | | 211°.0 | 436 |
| | | 159°.4 | 352 | | | 157°.5 | 344 |
| | | 119°.7 | 282 | | | 160°.6 | 274 |
| | | 82°.0 | 205 | | | 77°.5 | 179 |
| 2 | 13°.5 | 255°.0 | 562 | 8 | 13°.5 | 272°.4 | 617 |
| | | 199°.8 | 421 | | | 215°.3 | 473 |
| | | 149°.6 | 333 | | | 163°.1 | 385 |
| | | 111°.5 | 265 | | | 123°.3 | 322 |
| | | 74°.7 | 187 | | | 85°.2 | 230 |
| 4 | 13°.5 | 254°.2 | 570 | 9.6 | 13°.5 | 278°.9 | 624 |
| | | 199°.8 | 424 | | | 218°.7 | 468 |
| | | 150°.9 | 343 | | | 164°.2 | 366 |
| | | 113°.4 | 279 | | | 122°.2 | 296 |
| | | 78°.1 | 193 | | | 86°.7 | 200 |
| | | | | 0 | 13°.5 | 281°.0 | 605 |
| | | | | | | 221°.3 | 466 |
| | | | | | | 166°.7 | 371 |
| | | | | | | 125°.9 | 281 |
| | | | | | | 84°.3 | 203 |

The headings of the columns sufficiently explain themselves. The tensions are expressed in kilogram-weight per square millimetre. The highest tension attained corresponds to a load of 11.3

kilos. acting along the wire. It will be noticed that there is a slight diminution in this highest tension as the experiment progressed, doubtless due to the yielding of the highly heated part of the wire. This yielding occurred at all the tensions if the experiment were begun soon after the tension was applied. For this reason, each new tension was allowed to act at least for a whole day before the thermoelectric experiment was begun. Also just before the taking of the observations the dynamometer was carefully looked to, and the tension was raised to the desired value if any slight fall had occurred. Of course, once the experiment itself was entered upon the wire was not touched until the whole series of observations had been completed. To go to higher tensions than those here recorded was not practicable because of the diminished tenacity of the wire at its hottest parts. Not a few experiments were spoiled by the breaking of the wire at or near the highest tension attempted.

For each tension we have determinations of electromotive forces at five different temperatures. Some of the results are shown in Figure I., Plate XXXIX. To prevent confusion of figure, only three are shown—the initial and final for no tension, and the fifth for tension 8. Of particular interest in the manner in which the initial and final curves cut each other at a temperature of about 150° or 160° C. In interpreting this result, we must know the thermoelectric relation of the two kinds of iron used in forming the junctions. In the language of the thermoelectric diagram, in which the german-silver line lies below the iron line, the iron forming the small wires had its line also below the line of the iron that was or was to be strained. In other words, the current always flowed from the unaffected wire to the strained or to be strained through the hot junction. Now from Fig. I., we see that the effect of the stress is to increase the currents for all temperatures. The wire under the stress 8 has therefore the same relation to the unstrained wire which this latter has to the small unaffected wire. The stress, so to speak, displaces the line upwards on the diagram. The current is accordingly from the unstrained to the strained iron through the hot junction. On the stress being removed, the wire is left permanently strained, or, as we shall for brevity call it, after-strained. And we see that for temperatures below 155°± the current is from the afterstrained to the unstrained through the hot junction ; but that above 155° the current passes in the other direction. This would mean that the diagram lines for the unstrained and after-strained wires intersect each other indicating a neutral temperature at a temperature of 85° or thereabouts. The directions of the currents as given above show that the diagram line for the after strained wire is inclined at a less angle to the lead line. Hence the (negative) Thomson Effect in this particular iron wire is numerically decreased after the application and withdrawal of longitudinal tension.

Curves, representative of all the experiments whose results are given in Table II., were carefully drawn by free hand on a large scale ; and from these the electromotive forces corresponding to particular temperatures were picked out. A more pretensious process of interpolation could hardly have been more accurate under the circumstances ; for the curves, though smooth, have all a distinctly sinuous form, which it would be difficult if not impossible to represent by an equation of degree lower than the fourth. The electromotive forces corresponding to convenient temperatures, picked out as just described by inspection of the curves, will be found tabulated in Table III. ; and in Table IV. the result of subtracting each number in the zero tension column from all the others in the same row is shown :

## Table III.

E. M. F. between the stretched and unaffected Iron Wires, at chosen Temperatures and at various Tensions.

| Hot Temp. | Tension 0 | Tension 2 | Tension 4 | Tension 6 | Tension 8 | Tension 9.6 | Tension 0 |
|---|---|---|---|---|---|---|---|
| 100° | 242 | 242 | 249 | 240 | 270 | 243 | 231 |
| 120° | 283 | 282 | 294 | 282 | 316 | 294 | 270 |
| 150° | 338 | 333 | 342 | 333 | 366 | 342 | 335 |
| 180° | 387 | 384 | 392 | 381 | 410 | 391 | 396 |
| 200° | 419 | 423 | 425 | 416 | 445 | 424 | 430 |
| 230° | 470 | 494 | 500 | 478 | 506 | 491 | 485 |
| 250° | 515 | 548 | 557 | 531 | 556 | 544 | 529 |

## Table IV.

E. M. F. between the unstretched and stretched Iron Wires at chosen Temperatures and at various Tensions.

| Hot Temp. | Tension 0 | Tension 2 | Tension 4 | Tension 6 | Tension 8 | Tension 9.6 | Tension 0 |
|---|---|---|---|---|---|---|---|
| 100° | 0 | 0 | 7 | −2 | 28 | 1 | −11 |
| 120° | 0 | −1 | 11 | −1 | 33 | 11 | −13 |
| 150° | 0 | −5 | 4 | −5 | 28 | 4 | −3 |
| 180° | 0 | −3 | 5 | −6 | 23 | 4 | +9 |
| 200° | 0 | +4 | 6 | −3 | 26 | 5 | 11 |
| 230° | 0 | 24 | 30 | +8 | 36 | 21 | 15 |
| 250° | 0 | 33 | 42 | 16 | 41 | 29 | 14 |

In the last Table we see, almost at a glance, the progress of things as the tension increased. The graphs of Figure II. are obtained by plotting the electromotive forces corresponding to one temperature in terms of tensions. These should correspond in general features to the curves obtained by Cohn and Ewing. In a very general they do so; but they are much more irregular. This perhaps is not surprising if we bear in mind the fact that each graph is made up out of as many different days' experiments as there are points. If we leave out of consideration the experiment for tension 6, the remaining points on each graph arrange themselves in a fairly regular manner. There does not, however, seem to be any sufficient reason for omitting this experiment. For the peculiar deviations of all the points belonging to it cannot be easily explained as due to any errors in reduction either to temperature or to electromotive force. The same peculiarity appears if we use the unreduced thermometric readings in drawing the curves. On the other hand, the galvanometer constant was almost exactly the same day after day (as may be seen from Table I), excepting for the two last series of experiments at the highest tension and the final zero.

In drawing our conclusions we must however bear in mind the smallness of the quantities tabulated in Table IV. The probable errors of observation are of the order of the smaller quantities given in that Table; so that it would be out of the question to attach any importance to values less than 5.

Nevertheless, we are able to recognize in the graphs figured a certain ordered succession of changes; and there can be no doubt as to the significance of the values for the after-strained wire. Here we have a result apparently new to the subject; we are not aware that the possibility of such an effect has even been hinted at by previous workers. We have already expressed the nature of this result by saying that the Thomson Effect in an iron wire undergoes a permanent change after the longitudinal tension has been applied and removed. If $e$ is the electromotive force between the after-strained and unstrained wire, reckoned positive when the current flows from the after-strained to the unstrained through the hot junction, we may represent the values in the last column of Table IV. by the linear expression

$$e = + 34 - 0.21\ t$$

where $t$ is the temperature in Centigrade degrees, and the unit is 1 microvolt. The deviation of this straight line from the curve drawn through the points is well within the errors of observation. It would be unsafe to sttach any importance to the suggestion of two vertices in the tabulated numbers, indicating two neutral points, one above and one below 160° C. ($e = 0$).

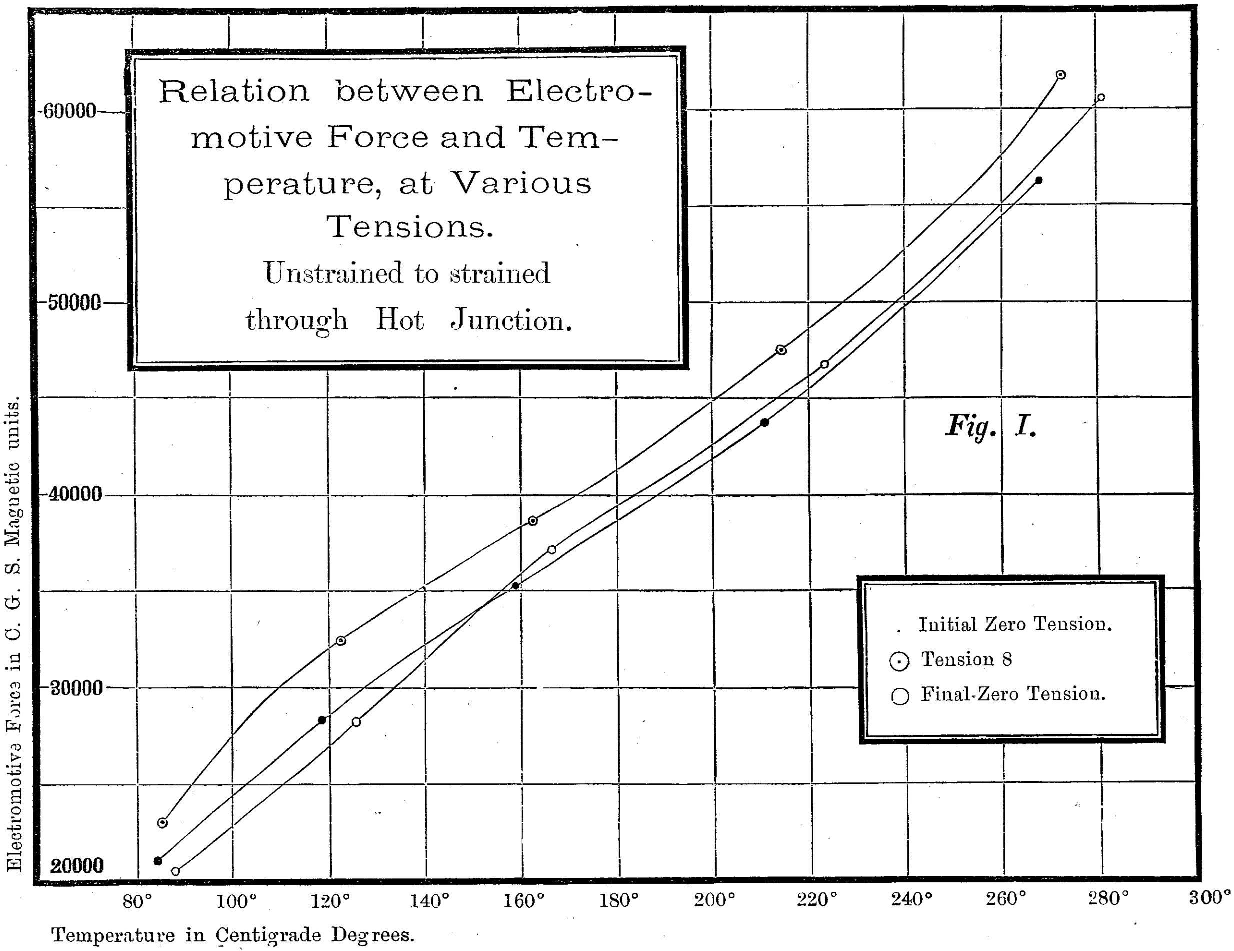
Thomson, Cohn, Ewing, and other investigators have worked with temperatures lower than the highest we used ; so that it is not possible to make a thorough comparison between these earlier results and ours. Where a satisfactory comparison can be made there is complete agreement. For example in Ewing's first set of experiments, the after-strained wire came out *positive* to the unstrained wire with the hot junction at 100°C. Our result is $e = + 13$.

In his later series of experiments Professor Ewing was concerned wholly with the thermoelectric behaviour of iron wire under the combined influence of stress and magnetization. He kept his hot junction at a temperature of 160°C ; and it will be noticed that the after-strained wire comes out *negative* to the unstrained wire. Since however no observation is recorded for an unmagnetized wire, and since Professor Ewing himself seems disposed to regard this negative character as due to the magnetization, it is impossible to make a satisfactory comparison. The values of the electromotive forces given by him are of the same order of quantity as that just given.

Our experiments indicate a maximum current as occurring about the tension of 8, which corresponds to a load of between 9 and 10 kilos —a result in fair agreement with some of Professor Ewing's.

The general conclusion that may be deduced is that the effect of tension on the thermoelectric position of an iron wire is a complex function of the temperature. Not only does the line on the thermoelectric diagram suffer displacement up or down but it also suffers rotation. In other words the Peltier Effect and Thomson Effect are both changed.

These results can only be regarded as preliminary. They are sufficient to show that the method is workable, and they have a distinct value in themselves. It would be advisable to repeat and extend the experiments with a much more massive iron tube than that here used. A smaller gradient of temperature would be thereby obtained, and it would not be necessary to keep the one end of the wire at a very high temperature. By such a modification, much higher tensions might be applied.


Relation between Electromotive Force and Temperature, at Various Tensions.
Unstrained to strained through Hot Junction.
Fig. I.
. Initial Zero Tension.
⊙ Tension 8
○ Final-Zero Tension.
Electromotive Force in C. G. S. Magnetic units.
60000
50000
40000
30000
20000
80° 100° 120° 140° 160° 180° 200° 220° 240° 260° 280° 300°
Temperature in Centigrade Degrees.

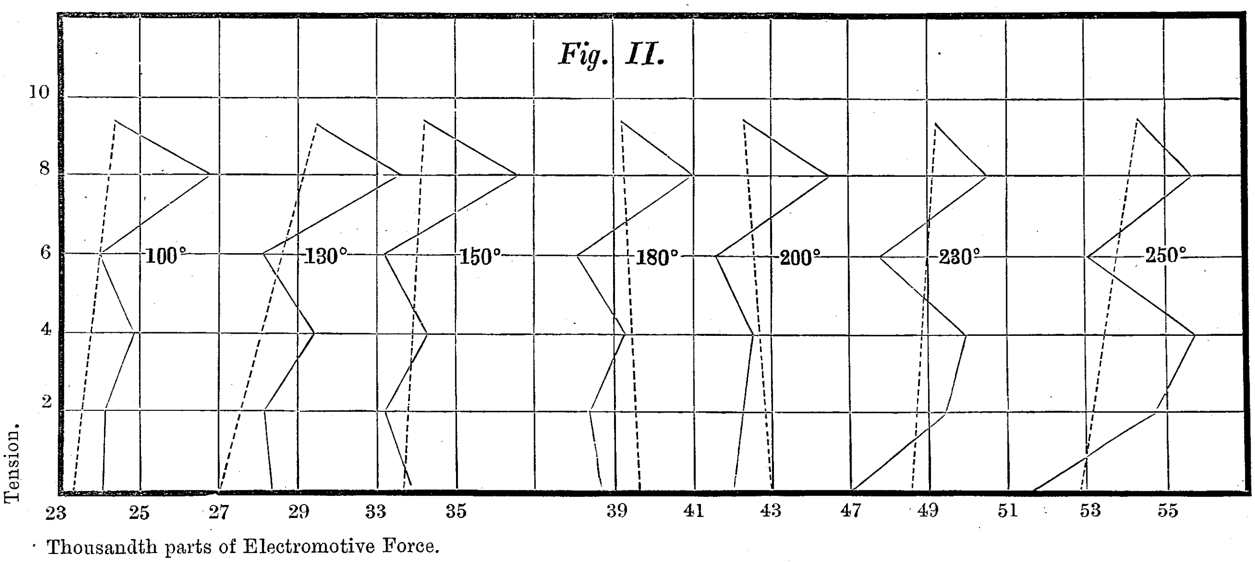


Fig. II.
Tension.
10
8
6
4
2
100°
130°
150°
180°
200°
230°
250°
23 25 27 29 33 35 39 41 43 47 49 51 53 55
Thousandth parts of Electromotive Force.