DESCRIPTION OF DIAGRAMS.

The continuous lines represent the curves of the variations in level of the brain surface produced by pressure and otherwise. The dotted lines represent the height of the blood pressure.

The times in which compression and recoil are measured are noted above the diagrams in seconds. The enumeration of seconds always commences afresh at the point at which the weight is removed.

Fig. 3. 50 grams applied for 1 minute. This diagram shows typically the characters of the excursion and recoil.

Fig. 4. 50 grams applied for 1 minute. Between experiments *a* and *b* the brain was allowed to entirely recover its volume, and the animal was then bled to the extent of 150 c.c. This procedure caused a fall of the brain surface to 3·4.

Fig. 5. Shows a typical curve when 50 grams are applied for 4 seconds only.

Fig. 6. The curves as far as * show the concurrent variations of brain surface and blood pressure under the influence of amyl nitrite. At * experiment *a* was performed. Between experiments *a* and *b* the effect of the amyl nitrite was allowed to wear off completely. 20 grams was the weight employed.

Fig. 7. (*a*) was an experiment upon the normal brain.
(*b*) was performed after administration of amyl nitrite. Weight = 50 grams.

Fig. 8. (*a*) performed with a cannula in one superior cerebral vein.
(*b*) performed with the opposite superior cerebral also blocked. Weight = 50 grams.

Fig. 9. (*a*) performed on the normal brain.
(*b*) performed with both external and both internal jugulars clamped. Weight = 50 grams.

Fig. 10. 50 grams applied for 6 minutes. Etherisation diminished at * with a consequent rise of blood pressure.

Fig. 11. 50 grams applied for 30 seconds to a brain which had undergone considerable previous compression. Etherisation diminished at *. Trachea clamped at ⊙.

"On the Temperature of the Carbons of the Electric Arc; with a Note on the Temperature of the Sun. Experiments made at Daramona, Streete, Co. Westmeath." By W. E. Wilson, M.R.I.A., and P. L. Gray, B.Sc., A.R.C.S. Communicated by G. Johnstone Stoney, F.R.S. Received November 14,—Read November 22, 1894.

The temperature of the positive pole of the electric arc, which is now generally believed to be the boiling point of carbon, is usually taken, on the authority of Violle,* as approximately equal to 3500° C. Violle's method of determining it was as follows:—The carbons of the arc were placed horizontally, and the positive pole was so arranged

* Violle, 'Jour. de Phys.,' 3rd Series, vol. 2, 1893, p. 545.

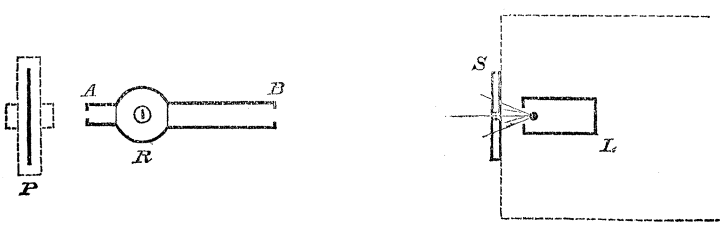
that pieces of its substance could be detached while the arc was passing; these white-hot pieces fell into a calorimeter, and from the amount of heat given up, the temperature was calculated, assuming the specific heat of carbon at this point to have its theoretical value. The method does not seem at first sight a very reliable one, and Violle states that the result is only to be regarded as an approximation.

The method adopted by the authors of this paper is exactly the same as that which they employed last year in their "Experimental Investigations on the Effective Temperature of the Sun,"* in the account of which full descriptions of the apparatus used, &c., are given.

A Brockie-Pell arc lamp was employed in the experiments, the current being obtained from a dynamo worked by a gas engine. It would have been preferable for some reasons to have worked the arc off the 26 Epstein accumulators which we had at our disposal, but the current from these was used in heating the platinum strip, and we did not wish to run the cells off too quickly. Platinoid resistances were inserted in circuit with the arc until it burnt steadily.

The general arrangement of the apparatus is shown diagrammatically in Fig. 1.

FIG. 1.



P is the platinum-strip radiator (our modification of Joly's meldometer), the dotted line representing the water-jacket which is placed over the strip. R is the radio-micrometer; A and B are tubes through which radiation can pass to fall on the receiving surfaces within. The diameter of the aperture at A is accurately known; as also is its distance from the receiving-surface, so that the apparent area of platinum, as seen from the latter, may be calculated.

L is the lamp, which is placed inside a wooden box, lined internally with tin-plate, both wood and metal being pierced with small holes opposite to the arc.

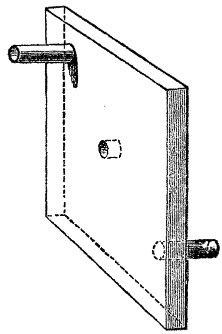
A screen, S, hangs in front of the box, and contains a small, carefully-measured hole, which can be adjusted until the brightest (or any) part of the glowing carbons shines directly into the tube B.

* Wilson and Gray, 'Phil. Trans.,' A, vol. 185, 1894, p. 361.

The size of the hole in the screen S, and its distance from the radio-micrometer, then give the apparent area of bright carbon as seen from the latter.

The screen S is made of copper, and is really a flat box (Fig. 2)

Fig. 2.



provided with an inlet and an outlet tube, so that a continual stream of water from the ordinary house supply could be kept running through it—a precaution necessary from its proximity to the arc. In the experiments, a plentiful stream was kept running through this box, and thence on to the water-jacket round the radiator, the supply being sufficient to prevent any perceptible heating of the screen.

A small hole cut in the side of the wooden box enabled us, with the aid of mirrors, to use a pencil of the light of the arc for reflection from the mirror of the radio-micrometer, thus obviating the necessity of a lime-light, or other bright source, while an incandescent lamp-filament provided us with an extremely sharp band of light on the scale of the radiator. (A larger and better mirror had been affixed to this since its use in our work on the solar temperature, and this mirror, with an incandescent lamp, gives a band of light with edges so sharp on the "temperature scale," that it could, if necessary, be read to the tenth of a millimetre, which is beyond our ordinary requirements.)

The theory of the method is very simple; essentially it is the same as that which applies to the estimation of the effective temperature of the sun, without the complications arising from atmospheric absorption, &c.

In the case of the sun, we can only hope to find (at least at present) the *effective* temperature, as we know little of the radiating power of the photospheric substances, but in the case of the carbons of the arc,

we may assume that we are dealing with a "black" surface of approximately unit emissive power.

Let then

T_1 = absolute temperature of bare platinum-strip at balancing point,

e = ratio of emissive power of a black surface to that of the bare metallic surface at this temperature,

A = ratio of the area subtended by the platinum to that subtended by the glowing carbon, at the receiving surface of the radio-micrometer,

and $q = f(\mathrm{T})$ be the "law of radiation" for a black surface, where q = quantity of radiation as a function of the absolute temperature T_1 of the radiating surface.

Then the radiation from the carbon is A/e times the intensity of that from a black surface at a temperature T_1.

If the radiation from the platinum at the temperature T_1 be put $= q_p$,

then $$q_p = f(T_1).$$

Then the radiation from the carbon

$$= \frac{\mathrm{A}}{e} \cdot q_p = \frac{\mathrm{A}}{e} \cdot f(T_1).$$

And if T_2 = required temperature of the carbon

$$\frac{\mathrm{A}}{e} \cdot f(T_1) = f(T_2),$$

whence T_2 may be obtained, when we know (1) the law of radiation, (2) the ratio of the emissive powers of bare and blacked platinum.

We go on to discuss these two points together, as the experiments on the first give us information on the second.

The Law of Radiation and the Ratio of the Emissive Powers.

In our paper already quoted we have given a series of experiments on the radiation from bare platinum at temperatures up to 1600° C. approximately, and we have shown that a simple fourth-power law expresses the results very closely, so that for these experiments the "law of radiation" is $q = a(\mathrm{T}^4 - T_0^4)$, where T = absolute temperature of radiating surface, T_0 = temperature of surrounding medium, a = a constant, and q = radiation in arbitrary units. At high temperatures T_0^4 becomes unimportant, and the expression simplifies still further to $q = a\mathrm{T}^4$.

Experiments on a blackened surface are difficult to carry out at

anything beyond moderately low temperatures; we therefore assumed in our former work that the form of the law was the same for a blackened as for a bright surface, there being good grounds, both theoretical and experimental, for such a belief. Further investigations, however, indicate that this assumption is not correct, as will be seen from the experiments detailed below.

A series of experiments on the radiation from bare platinum was made first, exactly in the same way as those described in our work of last year, that is to say, the radiation from the platinum at different temperatures was allowed to fall on a radio-micrometer of the ordinary form, the sensibility of which was reduced sufficiently to give a readable deflection at the highest temperature used, the deflection as given by the scale-readings being then taken as proportional to radiation. This proportionality has been shown before to be strictly true for deflections up to and greater than those obtained in these experiments.

The platinum-strip was next blackened on one side with black oxide of copper, which was ground very fine, mixed up with methylated spirit, and laid on with a camel's-hair brush; this, when the liquid had dried off, gave a very good, even, dead-black surface, the emissive power of which may be taken as approximately equal to that of an ideal black surface.

Lampblack, of course, is useless for these experiments, since it burns off at something under 500° C.; it could only be used if the radiator could be placed in a vacuum, or in an atmosphere having no action on the carbon, for which purpose we are having apparatus specially constructed.

At about 900° C. the black oxide of copper begins to suffer a change; its surface becomes somewhat shiny, and an alloy is formed with the platinum; this puts a limit to the temperature at which the radiation may be taken as that of a "black" surface. Our first strip was spoiled in discovering this limiting temperature; the second strip (after calibration, &c., and radiation experiments with the metal bare) was covered on both sides and examined during the progress of the experiments, which was stopped as soon as the black surface showed any signs of change of physical condition; these were not only apparent to the eye, but were also immediately indicated by a variability of temperature, due to the alteration of emissive power, as the reduction of the oxide crept over the surface of the strip.

Platinum-black would have no advantages in this connection over the copper-oxide, as it reverts to the metallic condition at very nearly the same temperature as that at which the oxide changes in the way mentioned above.

The two series of experiments gave the figures in the following tables:—

The 1st column gives the absolute temperature of the platinum.
„ 2nd „ „ deflection on the scale of the radio-micrometer in millimetres. These numbers then represent radiation in arbitrary units.
„ 3rd „ „ radiation calculated by a formula to be discussed immediately.
„ 4th „ „ differences between the observed and calculated radiation.

Table I.—Radiation of Bare Platinum.

Abs. temp.	Radiation observed.	Radiation calculated.	Obsd.—calc.
637°	7·0	10·2	−3·0
771	17·5	18·8	−1·3
804	22·5	22·5	−0·0
883	33·0	32·4	+0·6
896	36·5	35·5	+1·0
979	52·7	51·5	+1·2
1008	59·2	58·2	+1·0
1033	65·0	64·4	+0·6
1044	68·0	67·3	+0·7
1049	68·5	78·7	−0·2
1133	94·5	94·5	0·0
1155	99·5	102·3	−2·8

Table II.—Radiation from Blacked Platinum.

Abs. temp.	Radiation observed.	Radiation calculated.	Obsd.—calc.
683°	67	67	0
798	115	115	0
893	166	168	−2
933	193	195	−2
957	218	213	+5
975	235	227	+8
1024	269	268	+1
1058	304	299	+5
1075	314	316	−2
1107	349	349	0

The same results are shown graphically in fig. 3, in which the curve is drawn from the formula through points denoted thus ⊙, while the experimental points are denoted thus ⊡.

The curve for bare platinum was taken first, and a simple fourth-power law tried on it; this was found to agree very closely with the observed results throughout the range of the experiments, except at

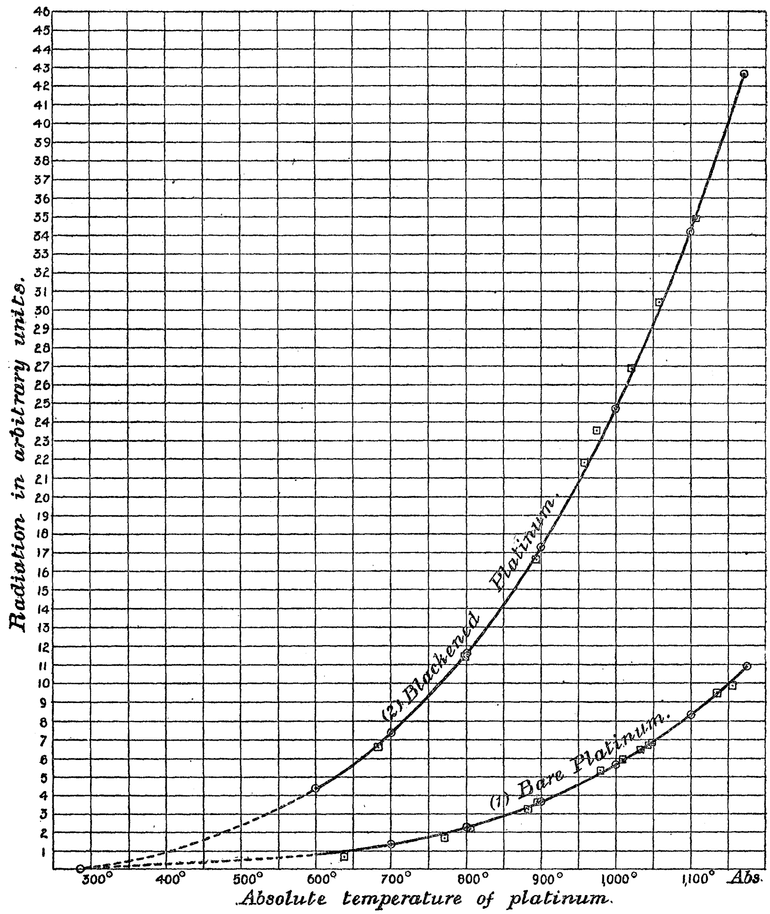


FIG. 3.—Curve showing the relation of radiation to temperature in the case of (1) bare platinum, (2) blacked platinum.

the lowest temperatures, thus confirming our work of last year, *but in the case of the blacked platinum the curve is much less steep than that given by a fourth-power law.* In fact, after several trials it was found that the exponent 3·4, in the expression $q = a\mathrm{T}^x$ followed the curve fairly well, but that a formula of the form

$$q = a(\mathrm{T}^3 - \mathrm{T}_0^3) + b(\mathrm{T}^4 - \mathrm{T}_0^4),$$

would fit both curves, the values of a and b being obtained from the respective experiments in the two cases.

In this expression, as before, q represents quantity of radiation, T the absolute temperature of the radiating surface, T_0 the

temperature of its surroundings, while a and b are constants determined in any case from two experimental points at some distance apart. When these have been calculated, the expression may be simplified by writing $aT_0^3 + bT_0^4 =$ a third constant, c say, so that we have

$$q = aT^3 + bT^4 - c,$$

c being very small and unimportant when any but very low values of T are concerned.

The curves (fig. 3) and figures (Table I and Table II) already given were obtained from expressions of this form; for bare platinum the constants were calculated from

$$\left.\begin{array}{ll} T = 804^\circ \text{ abs.,} & q = 22{\cdot}5 \\ T = 1133 \quad ,, & q = 94{\cdot}5 \end{array}\right\}$$

and

from this, the values obtained are

$$\log a_1 = \bar{9}{\cdot}92855$$
$$\log b_1 = \bar{1}\bar{1}{\cdot}81280$$

a being, however, $-$, and b $+$.

T_0 was always about 288 (*i.e.*, the temperature of the room was 15° C.), and in this case, c comes out $= 0{\cdot}24$ (*i.e.*, 0·24 mm. on the scale of the radio-micrometer), which is practically negligible.

For blacked platinum the constants were calculated from the experimental points

$$\left.\begin{array}{ll} T = 683^\circ \text{ abs.,} & q = 67{\cdot}0 \\ T = 1107 \quad ,, & q = 349{\cdot}0 \end{array}\right\}$$

whence we obtain

$$\log a_2 = \bar{7}{\cdot}22166$$
$$\log b_2 = \bar{1}\bar{1}{\cdot}92915,$$

both a and b being $+$, while $c = 4{\cdot}6$, so that for calculating the radiation, in our arbitrary units, at any temperature, we have

$$q = a_2T^3 + b_2T^4 - 4{\cdot}6 \text{ for blacked platinum,}$$

and

$$q = a_1T^3 + b_1T^4 - 0{\cdot}2 \text{ for bare platinum,}$$

the constants being those given above for blacked and bare platinum respectively.

From the two radiation curves, for bare and blacked platinum respectively, we may obtain the relative values of the emissive powers at different temperatures. That the ratio is not constant has been known for some time;* the table given below will show the nature and extent of the variation.

* Schleiermacher, 'Wied. Ann.,' vol. 26, 1885, p. 287. Also Wilson and Gray's paper already quoted, p. 380, in which several references will be found, relating to experiments on this point, and the law of radiation, &c.

The radiation is calculated from the formulæ given on p. 31, for temperatures 600°, 700° .... 1200° abs.; the fourth column gives the ratio black/bare.

Table III.—Ratio of Emissive Powers of Black and Bare Platinum.

Abs. temp.	Radiation of black platinum.	Radiation of bare platinum.	Ratio.
600°	42·4	6·4	6·62
700	73·0	12·5	5·84
800	116·1	22·0	5·28
900	173·2	36·2	4·78
1000	247·0	56·3	4·39
1100	341·5	83·6	4·09
1200	459·4	119·9	3·83

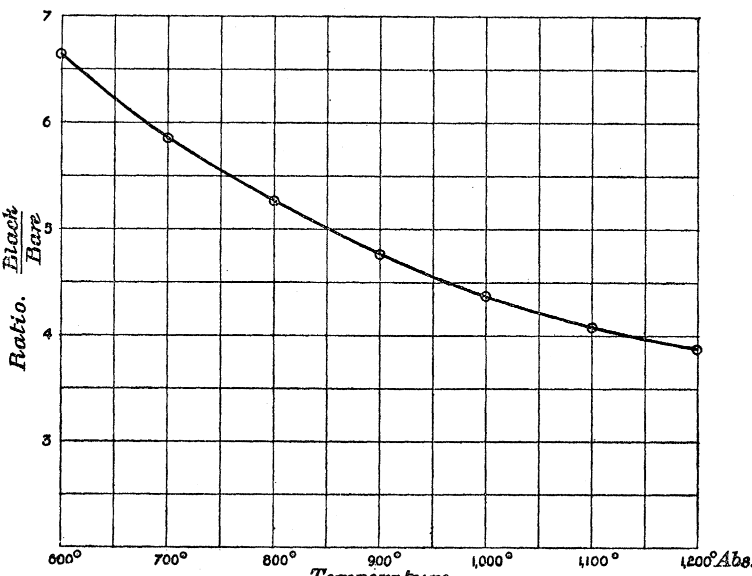


Fig. 4.—Curve showing the ratio of the emissive powers of blacked and bare platinum at different temperatures.

The curve (fig. 4) shows the same results graphically.

It will be seen at once that the ratio diminishes as the temperature increases, but less and less rapidly. The observations agree fairly well with the old experiments generally described in the text-books —experiments made at 100° C. and thereabouts—in which the ratio

is given as from 10 to 12. They differ slightly from Schleiermacher's series, the ratio in his being a little lower than in ours at the same temperature.

There is a fair agreement with Rossetti's result at high temperatures; he obtained 2·9 at about 1500° C., which is very little lower than the value which would be reached by a theoretical continuation of our curve (fig. 4).

The tendency of the curve appears to be to approach a constant value of about 3, but it is impossible to dogmatise on this point, from the physical limitations of the inquiry. The fact that the ratio *does* diminish shows that the physical nature of one or both of the surfaces is different at different temperatures; probably it is the bare platinum which changes, and it is possible that the constant value of the ratio is just attained at the melting-point of the metal. Experiments with a molten surface would be interesting, but very difficult to carry out.

The Balancing Experiments.

We may now pass on to the "balance experiments," from which the temperature of the carbons of the arc may be calculated. The principle of the method has already been described in the earlier part of the paper.

When the arc was shining on the top receiving-surface of the radio-micrometer, and the incandescent platinum on the lower, the position is denoted as Position A, the reverse, by Position B.

The angle subtended by the area of incandescent platinum, in both cases, was 5°·301.

The diameter of the hole in the screen (fig. 2), through which the radiation of the arc passed, was 0·337 cm. In position B, its distance from the receiving surface was 57·0 cm.; in position A it was 58·2 cm., giving angular apertures of 0·339° and 0·332° respectively. The screen was close enough to the arc to make it certain that the hole was completely filled with the brightest part of the crater of the + pole. The hole was sufficiently small to form a rough "pin-hole" image of the carbons, by means of which it could be seen during an experiment that the brightest part of the + pole was shining directly into the tube of the radio-micrometer, and so on to the receiving surface.

In position B, the ratio of the areas of platinum and carbon, as seen from the receiving-surface, was

$$(5{\cdot}301/0{\cdot}339)^2 = 245,$$

and in position A, the ratio was

$$(5{\cdot}301/0{\cdot}332)^2 = 255.$$

The following are the temperatures at which the radiation from the bare platinum balanced that from the hottest part of the + pole:—

Position B.		Position A.	
	715° C.		862° C.
	717		930
	737		924
	720		922
	732		902
	722		933
	722		985
			945
Mean =	724° C. = 997° abs.	Mean =	925° C. = 1198° abs.

The results in position A are not so concordant as those in position B, but the arc was not quite so steady; the first low reading (862°) was probably taken when the growth of condensed carbon on the −pole was partly shading the receiving surface from the heat of the crater, while the high reading (985° C.) probably corresponds to one of those sudden "bursts" of high temperature which we have frequently observed to take place, although we cannot offer any explanation of them.

The current in the above experiments was about 14 ampères; a few observations were subsequently made with less resistance in circuit, and a current of about 25 ampères; the temperature then appeared to be a little higher than with the smaller current, but the arc in this case was so unsteady as to prevent the observations being made very carefully.

[Later experiments with a higher voltage (110 volts) and a current varying from 10 to 40 ampères indicate an exact equality of temperature, which confirms the usually-accepted view.—April 8th, 1895.]

Working out the results of the two positions separately, we have, for the ratio of emissive powers, at

$$997° \text{ abs.}, \frac{\text{black}}{\text{bare}} = 4{\cdot}4.$$

$$1198 \quad ,, \quad ,, \quad 3{\cdot}85.$$

From the formula (p. 31), for blacked platinum,

$$q = a\mathrm{T}^3 + b\mathrm{T}^4 - 4{\cdot}56,$$

we have for position B, $q = 244{\cdot}48$,

and for ,, A, $q = 456{\cdot}87$.

Therefore we have a radiation from the +pole of the arc, in our arbitrary units, corresponding to

$$244{\cdot}48 \times \frac{245}{4{\cdot}4} = 13613 \text{ in position B,}$$

and to

$$456{\cdot}87 \times \frac{255}{3{\cdot}83} = 30420 \text{ in position A.}$$

The geometrical mean of these two numbers,

$$\sqrt{13613 \times 30420} = 20350,$$

is the true radiation in our arbitrary units. To find the corresponding temperature, we must substitute this value in the equation on p. 31, *i.e.*,

$$20350 = a\mathrm{T}^3 + b\mathrm{T}^4 - 5.$$

This is most easily solved by trial, T coming out as 3520°.

To this about 100° must be added, owing to the curvature of the radiation curve (for full reason, see Wilson and Gray's paper already quoted, p. 387), giving approximately

3600° abs., or 3300° C.

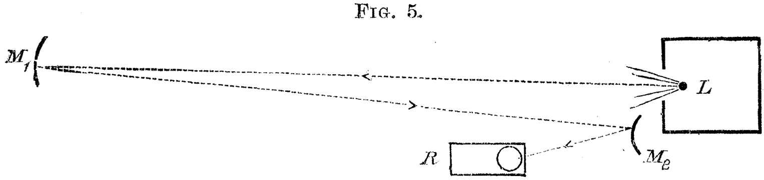
as the temperature of the hottest part of the +pole of the electric arc, a result surprisingly near Violle's estimate, 3500° C.

The Comparative Radiation from Different Parts of the Arc.

After the above experiments had been finished, an attempt was made to obtain comparative values of the radiation, and hence the temperatures, of different parts of the carbons of the arc. For this purpose, a radio-micrometer of the ordinary form was employed, on to the receiving-surface of which radiation could fall through a large pin-hole.

An image of the carbons was then formed by an arrangement shown diagrammatically in the figure (fig. 5), in which L is the arc

FIG. 5.



lamp, inside a lantern with the condenser removed, M_1 is a concave mirror, M_2 a convex mirror, both silver-on-glass, and R is the radio-

micrometer. The reason for not forming a direct image with a lens was the varying transparency of glass for radiation at different temperatures; the mirrors also enabled us to "dilute" the heat considerably, and so obtain convenient direct deflections on the radio-micrometer scale.

The sketch (fig. 6) shows approximately the shape of the image formed, on a scale about two-thirds full size.

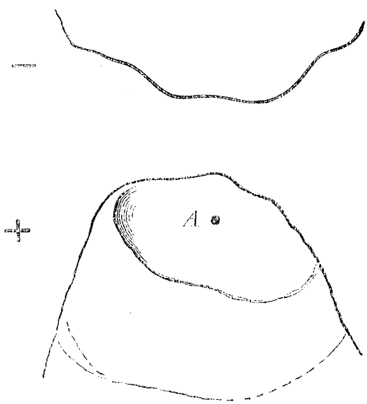


Fig. 6.—Image of the carbons from a tracing. A represents the size of the aperture by which radiation reached the receiving-surface.

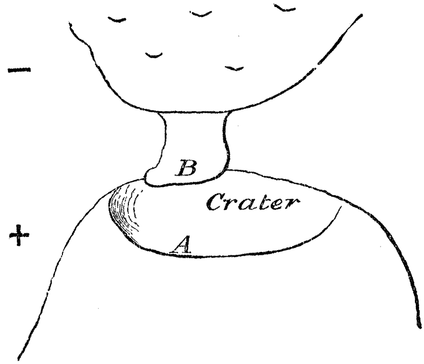
The mirror, M_2, being provided with adjusting screws, it was easy to bring any part of the image, either of the carbons or the pale violet glow of the arc itself, on to the small aperture, the deflection on the scale of the radio-micrometer then giving readings proportional to the radiation from the chosen point.

Magnified to this extent, however, the arc was never steady enough to allow a detailed "mapping-out" of the carbon surfaces with regard to temperature. Even when the light is apparently steady to the eye, the violet arc itself often shifts its position, while the − pole continually alters in shape from the carbon deposited on it, which causes a bulbous excrescence, somewhat as shown in fig. 7, to form gradually.

When this is the case, the arc naturally strikes across from some such position as A to B; B then becomes, as might be expected, much hotter than any other part of the −pole.

As an example of the kind of difference existing between the two poles, the following figures may be given; they correspond to the hottest obtainable point in the crater of the +pole, and to the hottest point on the −pole, before any excrecence has had time to grow.

Fig. 7.



The numbers are scale divisions on the scale of the radio-micrometer, and therefore represent the radiation in arbitrary units :—

+ pole. Radiation 60·2 and 67·1
Mean = 63·7
− pole. Radiation = 21·8,

so that the radiation from the hottest part of the + pole was about three times as great as that from the hottest part of the − pole.

Taking the temperature of the former as 3300° C., this would give a temperature of about 2350° C. for the latter.

In a case where a "blob" had formed on the − pole, as in fig. 7, the following readings were obtained :—

+ pole. Radiation 57·0, 56·0, 56·6, and 55·5
Mean = 56·3
− pole. Radiation of hottest part = 38·3.

Again, taking 3300° C. for the former, this gives about 2700° C. for the latter, or 350° C. higher than that of the − pole just after the arc is started.

We may say, then, that if the temperature of the crater is about 3300° C., that of the − carbon is ordinarily about 2400° C. in its hotter parts.

As for the temperature of the arc itself, we can say nothing. Allowing the pale violet glow between the poles to fall on the aperture of the radio-micrometer, we obtained deflections of from 1 to 2 per cent. of those obtained when the hottest part of the crater was used, which seems to indicate a comparatively high radiative power for the hot gases which lie between the carbon poles.

Note on the Effective Temperature of the Sun.

In the authors' work on this subject, radiation experiments were made with bare platinum, at temperatures up to 1600° C. approximately, and it was assumed that a formula of the same form as expressed these results would also hold for a blacked surface, while the ratio of the emissive powers at high temperatures was taken on Rossetti's authority as about 2·9.

The new work, given above, appears to show that the curve for the black surface does not, however, follow a simple fourth-power law so closely as does that for the bare platinum, and that, taking the law as given on p. 31 of the present paper, a correction must be made to the result obtained by the earlier work.

The approximate value of this correction may be obtained by taking the figures given as a typical case on p. 386 of last year's paper, and applying the new law to them.

In this case, the corrected ratio (*i.e.*, the ratio corrected for atmospheric absorption, and for loss by reflection from the glass of the heliostat) of the apparent areas of the bare platinum and the sun was approximately 1295 : 1, and balance was obtained with the platinum at a temperature of 1514° Abs.

Now by the formula on p. 31, the radiation of bare platinum at this temperature

$$= a \,.\, 1514^3 + b \,.\, 1514^4 - 0{\cdot}27 = 311{\cdot}77$$

a and b having the values given on p. 31.

The radiation from the sun therefore

$$= 1295 \times 311{\cdot}77 = 403{,}450.$$

To find the effective temperature of the sun, we have, therefore, to solve the equation

$$403{,}450 + 4{\cdot}6 = a\mathrm{T}^3 + b\mathrm{T}^4,$$

where a and b now have the values corresponding to the curve for the black surface. This gives T = 7800° Abs., approximately, instead of 7000°, as given by the older method of working.

That is to say, supposing the new formula to be correct, our estimate of the solar temperature would have to be increased by something like 800°.

If, however, the ratio of the emissive powers approaches a constant value, as the figures and curves on p. 32 make possible, the expression for the curve of the black surface would be somewhat altered, in such a direction as to reduce the correction, so that we may say finally that, taking Ångström's estimate of the atmospheric absorption, which gave in our former work an effective solar temperature of 7400° C., its more probable value would now be not very far from 8000° C.

FIG. 2.