The comet is now as bright as it is expected to become according to computation, and moreover is rapidly moving southwards, so that it will soon be beyond the reach of observers in these latitudes. During the week it passes from a position near the 6th mag. star 17 Capricorni to the vicinity of the 4th mag. red star A Capricorni.

STELLAR AND NEBULAR SPECTRA WITH CONCAVE GRATING.—In the earlier part of 1898 Messrs. Poor and Mitchell described the results of their attempts to photograph stellar spectra with a Rowland concave grating (*Astro-Physical Journal*, 8, p. 157). The grating used was a small one, having a ruled surface of only 1 × 2 inches with 15,000 lines to the inch, the radius of curvature being about 1 metre. Later a special grating was made with a ruled surface 2 × $5\frac{3}{4}$ inches, having 7219 lines to the inch. The radius of curvature of this was also 1 metre. The instrument was mounted on the 9·3-inch Hasting's refractor as guiding telescope, and the results obtained were very promising, although the observatory is on the *sixth* floor of the Physical Laboratory at Baltimore. In November 1898, however, by the kindness of Prof. Hale, it became possible for Mr. Mitchell to mount the grating on the 12-inch Brashear refractor of the Yerkes Observatory (*Astro-Physical Journal*, x. pp. 29-39, 1899). It will be remembered that the grating is used "*direct*," the concave surface bringing the diffracted beam from the star to focus on the plate, and that a considerable advantage obtains in that the spectra obtained are *normal*. The grating was so oriented that the lines were parallel to the equator, so that irregularities in the driving-clock should have no effect on the definition. The astigmatism alone not being sufficient to give the spectrum sufficient width, this was effected by allowing the star to trail in right ascension. Photographs of the spectra of a large number of stars have been thus obtained, with exposures varying from 5 to 60 minutes. These are given in a table in the article. Of special interest is the fact that these photographs show the ultra-violet region remarkably well, as is to be understood when it is remembered that the light has to traverse neither lenses, prism trains nor slit. The photograph of Sirius showed about 75 lines between Hβ and Hγ, and in the ultra-violet 21 lines of the series due to hydrogen were measured.

In February two very interesting photographs of the spectrum of the Orion nebula were obtained with exposures of about 200 minutes. Just as with an objective prism, these spectra consist of a series of images of the nebula, the measures of corresponding regions of which give the wave-lengths of the various lines they represent.

With the grating used, the length of the photographic region in the first order was about $1\frac{1}{4}$ inches, using Seed's gilt edge plates. In the second order the distance from Hβ to Hγ was 0·6 inch, and from Hβ in the first order to Hβ in the second was 2·8 inches. The photographic plate used, 1 × 5 inches, thus included both spectra, and their duplicate measurement afforded a definite control over the wave-lengths determined.

Attention is directed to the fact that the spectra being *normal*, absolute measurements of wave-length, and therefore of motion in line of sight, may be determined when larger instruments of this kind are available. A grating with ruled surface 10 × 15 inches would probably be fully equal in performance to any spectroscopes in present use.

THE REASON FOR THE HISSING OF THE ELECTRIC ARC.[1]

II.

AND now we come to the most important of all the changes that take place when the arc begins to hiss, viz. the alteration in the shape of the *positive* carbon.

During the course of his 1889 experiments, Luggin (*Wien Sitzungsberichte*, 1889, vol. xcviii. p. 1192) observed that the arc hissed when the crater filled the whole of the end of the positive carbon. He was thus the first to call attention to the fact that there was a direct connection between hissing and the relation between the area of the crater and the cross-section of the tip of the positive carbon. My own observations in 1893 led to a conclusion somewhat similar to Luggin's, but yet differing in an important particular. It seemed to me that, with hissing arcs, the crater always *more* than covered the end of the positive carbon—that it overflowed, as it were, along the side. How far this is true will be seen from an examination of Figs. 4, 5, 6 and 7, which show the shaping of the carbons under various conditions with silent and hissing arcs. These figures have all been made from tracings of the images of actual normal arcs, burning between carbons of various sizes, and they were carefully chosen with special reference to the shaping of the positive carbons. For, with normal arcs, the shape of the end of a positive carbon, even taken quite apart from that of the negative carbon and of the vaporous arc itself, is capable of revealing almost the whole of the conditions under which the arc was burning when it was formed. It is possible, for instance, with a normal arc, to tell, from a mere drawing of the outline of the positive carbon and of its crater, whether the arc with which it was formed had been open or enclosed, short or long, silent or hissing, burning with a large or with a small current for the size of the carbon.

Take, for example, Fig. 4 (see p. 285, July 20), and note the difference in the shape of the positive carbon with a current of 3·5 amperes, as in (*a*), and with one of 34 amperes, as in (*b*). In the first case the tip of the positive carbon is rounded, so that the crater lies in its smallest cross-section; in the second, the tip would be practically cylindrical for some distance, but that the

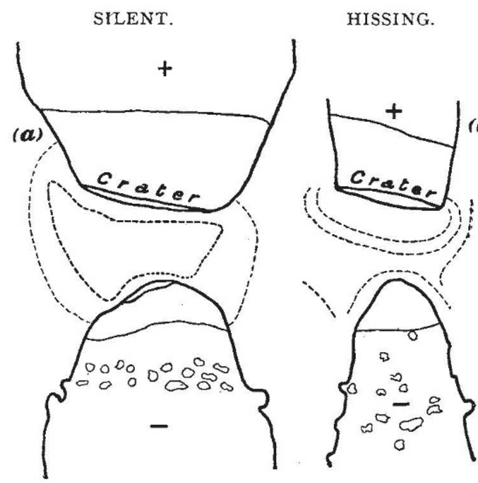

FIG. 7.—Carbons:—(*a*) Positive, 18 mm. Cored. Negative, 15 mm. Solid. (*b*) Positive, 9 mm. Cored. Negative, 8 mm. Solid. Length of Arc, 5 mm. Current, 25 amperes.

crater has burnt away a part of the cylinder, making the tip look as if it had been sheared off obliquely. Comparing now the tips of the positive carbons when the arc is silent and when it is hissing in all the four figures, 4, 5, 6, 7, we find the same difference. With all the silent arcs the tip is more or less rounded, and the crater lies in its smallest cross-section, and consequently is less in area than any but the smallest cross-section. With all the hissing arcs, on the other hand, the tip of the positive carbon is practically cylindrical for a short distance at least, or would be but that it is sheared away by the crater; consequently the area of the crater is *greater* than the smallest cross-section of the tip, or, indeed, than the cross-section of the tip for some little distance along its length.

We have now arrived at the real, the *crucial*, distinction between a silent and a hissing arc. When the crater occupies the *end* of the positive carbon only, the arc is *silent*; when it not only covers the end, but also extends up the *side*, the arc *hisses*. Hence, the arc must be at the *hissing point* when the smallest increase in the area of the crater will make it begin to cover the *side* of the positive carbon, and this can only be when the tip of that carbon has very nearly the same cross-section for some little distance from its end—in other words, when its sides are nearly vertical.

I shall now proceed to show that the extension of the crater up the side of the positive carbon is not the *effect* but the *cause* of hissing; that, in fact, *hissing is produced by the crater be-*

[1] Based on a paper read before the Institution of Electrical Engineers by Mrs. W. E. Ayrton. (Continued from page 286.)

coming too large to occupy the end only of the positive carbon, and therefore extending up its side.

Simple as is this explanation of a very complicated series of phenomena, it is the true one; but before proceeding to demonstrate its truth it will be interesting to see how the laws for the largest silent currents with normal arcs, which have already been obtained from the electrical measurements on pp. 283, 284, may be deduced on the above hypothesis from Figs. 6 and 7.

In Fig. 6 (p. 285) we have a series of four normal arcs of the same length burning between solid carbons of the same diameter; but in (*a*) the current is 6 amperes, in (*b*) 12, in (*c*) 20, and in (*d*) 30 amperes. The bluntness of the tip of the positive carbon may be measured by the obtuseness of the angle A B C. In (*a*) the tip is very blunt, and the area of the crater is certainly less than any but its smallest cross-section; therefore the arc is certainly silent. In (*b*) the tip is less blunt, but the arc is still evidently silent; in (*c*) the angle A B C is much more nearly a right angle, and it is plain that a very small increase in the area of the crater would cause it to burn up the side of the tip; therefore the arc is near the hissing point. In (*d*) the angle A B C is practically a right angle, the tip of the positive carbon is cylindrical, and the crater has evidently burnt partly up its side. Thus with a normal arc, keeping the length of the arc constant and gradually increasing the current, must bring us to a hissing point.

This brings me to the reason for the great importance of distinguishing between arcs that are normal and those that are not. For although, with normal arcs of any given length, hissing only starts when the current is *greater* than it can be with any silent arc of the same length, with a *non*-normal arc of 2 mm. I have been able to produce hissing with a current of 11 amperes, and to have a silent arc burning with a current of 28 amperes, the same carbons being used in each case.

The reason of this is obvious. When the arc is normal, the carbon ends and crater have a perfectly definite size and shape corresponding with each current and length of arc, and changes in these are made slowly, so as to allow time for the carbons to assume their proper form in each case. If, however, the current be *suddenly* much increased, when, say, the carbons have previously been very pointed, then the area of the crater may increase so rapidly that it will extend up the side of the carbon and cause hissing, even although the carbons would have shaped themselves so that there would have been room for the crater to remain at the end of the carbon if the change had been made more gradually.

Suppose, for instance, the end of the positive carbon were filed to a long fine point, then a very small current would make a crater large enough to extend up the side of the point, and produce a hissing arc. If, on the contrary, the end were filed flat, so as to have as large a cross-section as possible, quite a considerable current could flow silently even with a short arc, for in that case it would require the current to be very great for the crater to be large enough to fill up the whole of the end of the positive carbon.

Next, I have shown elsewhere (*The Electrician*, 1895, vol. xxxiv. p. 614) that, with a constant current, the end of the positive carbon becomes rounder and blunter, and occupies a larger portion of the entire cross-section of the carbon rod, the more the carbons are separated. Hence the longer the arc the greater must be the area of the crater, and consequently the greater must be the current, before the crater extends up the side of the positive carbon. Consequently, the longer the arc the greater is the largest silent current.

Thirdly, it follows that when the current and the length of the arc have been increased to such an extent that the round, blunt tip of the positive carbon occupies the whole cross-section of the carbon rod itself, no further increase in the size of the crater is possible without a part of it extending up the side of the carbon. Hence the largest silent current for a positive carbon of a particular diameter cannot exceed a particular value, however long the arc may be made. And lastly, similar reasoning, used in conjunction with Fig. 7, tells us that the thicker the positive carbon the greater must be the largest current that can flow silently with a particular length of arc, which was one of the results deduced from the curves in Figs. 2 and 3.

Thus the fact that hissing occurs when the crater covers more than the end surface of the positive carbon and extends up its side, combined with our knowledge of the way in which the positive carbon shapes itself in practice, is sufficient to enable us to deduce *all* the laws given on pp. 283, 284 which govern the largest current that will flow silently with the *normal* arc under given conditions.

We come now to the question, why should the arc hiss when the crater burns up the side of the positive carbon—what happens then that has not happened previously?

In pondering over this question, the possibility occurred to me that as long as the crater occupied only the *end* surface of the positive carbon it might be protected from direct contact with the air by the carbon vapour surrounding it, but that, when the crater overlapped the side, the air could penetrate to it immediately, thus causing a part at least of its surface to *burn* instead of volatilising. Many circumstances at once seemed to combine to show that this was the true explanation. The dancing circles I observed, and Mr. Trotter's stroboscopic images, how were they caused but by draughts getting into the arc? Then the humming noise, which sounds like the wind blowing through a crack, was not this probably caused by the air rushing through a slight breach in the crater, already getting near to the critical size? This air pouring in faster and faster as the breach widened would cause the arc to rotate faster and faster, sometimes in one direction, sometimes in another, according as the draught was blown from one side or the other. Then, finally, the air would actually reach the crater, burn in contact with it, and the P.D. would fall and the arc would hiss.

In the open arc, whether silent or hissing, the outer envelope of the vaporous portion is always bright green. With the hissing arc the light issuing from the *crater* is also bright green or greenish blue. What so likely as that the two green lights should have a common origin, viz. the combination of carbon with air? For the outer green light is seen just at the junction of the carbons and carbon vapour with the air, and the inner one only appears when air can get direct to the crater.

Again, why does the arc always hiss when it is first struck? Is it not because a certain amount of air must always cling to both carbons when they are cold, so that when the crater is first made its surface must combine with this air?

The cloud that draws in round the crater when hissing begins would be a dulness caused by the air cooling the part of the crater with which it first came into contact, the bright spots being at the part where the crater and air were actually burning together. In fact everything seemed to point to the direct contact of crater and air as being the cause of hissing and its attendant phenomena.

One easy and obvious method of testing this theory immediately presented itself. If air were the cause, exclude the air, and there would be no sudden diminution of the P.D. between the carbons, however great a current might be used. Accordingly I tried maintaining arcs of different lengths in an enclosed vessel, and increasing the current up to some 40 amperes. *No* sudden diminution of the P.D. could be observed with any of the currents or lengths of arc employed, although when the same carbons were used to produce *open* arcs, the sudden diminution of 10 volts in the P.D. between the carbons occurred with a current as low as 14 amperes for a 1 mm. arc.

It was, of course, impossible, in these experiments, to avail myself of an ordinary enclosed arc lamp, such as is used for street lighting, since a current of only some 5 or 8 amperes is all that is used with such a lamp, whereas to test my theory it was necessary to employ currents up to 40 amperes. Accordingly I constructed little electric furnaces of different kinds, one of which is shown in Fig. 8.

Some curves connecting the P.D. between the carbons with the current when the arc was completely enclosed in the crucible (Fig. 8) are given in Fig. 9. The carbons were similar to those used with the open arc experiments (Fig. 1, p. 282), being solid, the positive 11 mm. and the negative 9 mm. in diameter. As this crucible—the first one made—had no window, the length of the arc could not be kept quite constant, but the distance by which the carbons were separated was noted at the beginning of the experiment, and they were then allowed to burn away, without being moved, till the end, when the distance the positive carbon had to be moved in order to bring it tightly against the negative was noted. Measured in this way, the length of the arc was 1·5 mm. at the beginning and 2 mm. at the end of the experiment. The current was started at 6 amperes, and gradually increased to 39 amperes; then as gradually diminished to 6 amperes again, increased to 36 amperes, and diminished to 5 amperes, when the arc was extinguished. The

P.D. between the carbons for a given current seems to have increased as the length of time during which the arc had been burning increased; this was undoubtedly partly due to the lengthening of the arc, but was probably also partly due to the whole of the air in the pot having been gradually burnt up or driven out through the slag wool and the asbestos ring by the pressure of the carbon vapour.

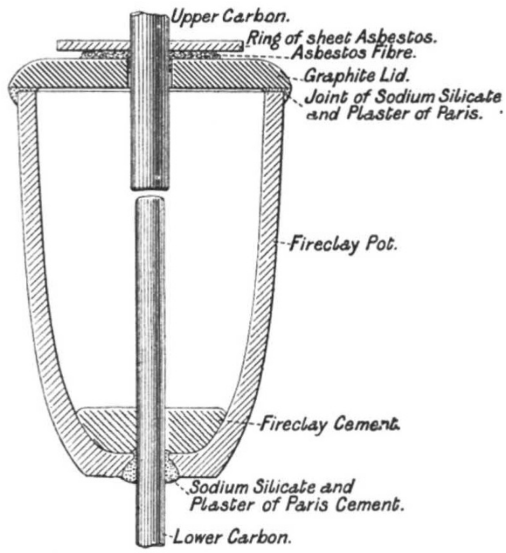

FIG. 8.

Many other sets of curves were obtained, but all with the same result, viz. that when once the crucible had been freed from air, no sudden diminution in the P.D. could be observed on increasing the current far beyond the value at which this diminution occurred on lifting up the lid and allowing the air to have access to the arc.

The next thing to do was to try if an open arc could be made to hiss and the P.D. to diminish suddenly by blowing air at the crater, when the current was so small that the crater remained well at the end of the positive carbon—in fact, to bring the air in contact with the crater artificially when a much smaller current was flowing than would usually produce hissing. I first tried inserting a carbon tube in the arc, and blowing through it, but this almost invariably blew the arc out. Then Mr. Phillips, one of Prof. Ayrton's assistants at the Central Technical College, suggested using a tubular positive carbon and blowing the air down it. This plan answered admirably, for when a current of 10 amperes was flowing with an arc of about 3 mm., so that the arc was quite silent, each puff of air blown down through the positive carbon was followed by a hiss and the characteristic diminution of the P.D. between the carbons. With a current of 6 amperes, however, I could get no hiss, but simply blew the arc out each time, probably because, with such a small current, the arc was cooled sufficiently to be extinguished before the action could take place.

Oxygen was next tried, still with the open arc, and again each puff produced a hiss and diminution of the P.D., the latter being exactly the same in amount as when air was used, namely, about 10 volts. As my idea was that the diminution of the P.D. was due to the chemical combination of air with carbon at the temperature of the crater, the fact of oxygen producing the same diminution as air seemed to show that nitrogen would produce no effect, and that all the effect produced by air was due to the oxygen in it. Accordingly I tried blowing nitrogen down the positive carbon of an open arc, and found that *no* change in the P.D. followed if the nitrogen was blown through gently, but that, beyond a certain pressure, the arc was blown to one side, and thus lengthened, so that the P.D. *rose* as it always does when the arc is lengthened, and, if the pressure continued, the arc went out.

This experiment proved two things—firstly, that it is the *oxygen* in the air that causes the diminution in the P.D. with hissing; secondly, that this diminution is not due to cooling, for nitrogen would cool the arc as effectually as oxygen or air.

To make assurance doubly sure on this point, carbon dioxide was blown down the tubular positive carbon, with the same result as when nitrogen was used, viz. no change was produced in the P.D. between the carbons unless the pressure of the gaseous stream were large enough to blow the arc on one side, and then an increase and not a diminution in the P.D. was observed.

If, however, the current was *very near* the value that made an open arc of the particular length used start hissing, blowing either nitrogen or carbon dioxide through the positive carbon sometimes started hissing; but this was due, *not* to any direct action of the stream of gas on the carbon, but to the arc being deflected by the gaseous stream and burning obliquely up the side of the carbon, and thus allowing the air to come into contact with the crater. The proof of this was that this diminution in the P.D. had the same value as if air had been employed, and that the hissing did not cease when the stream of nitrogen or of carbon dioxide was stopped.

This was not the case with hydrogen, however. When that gas was blown down the positive carbon in the open air, the arc would start hissing, if the current were large enough, *and stop hissing the moment the hydrogen was shut off.* Not-only this, but the diminution in the P.D. had a different value from

ARC ENCLOSED IN CRUCIBLE.

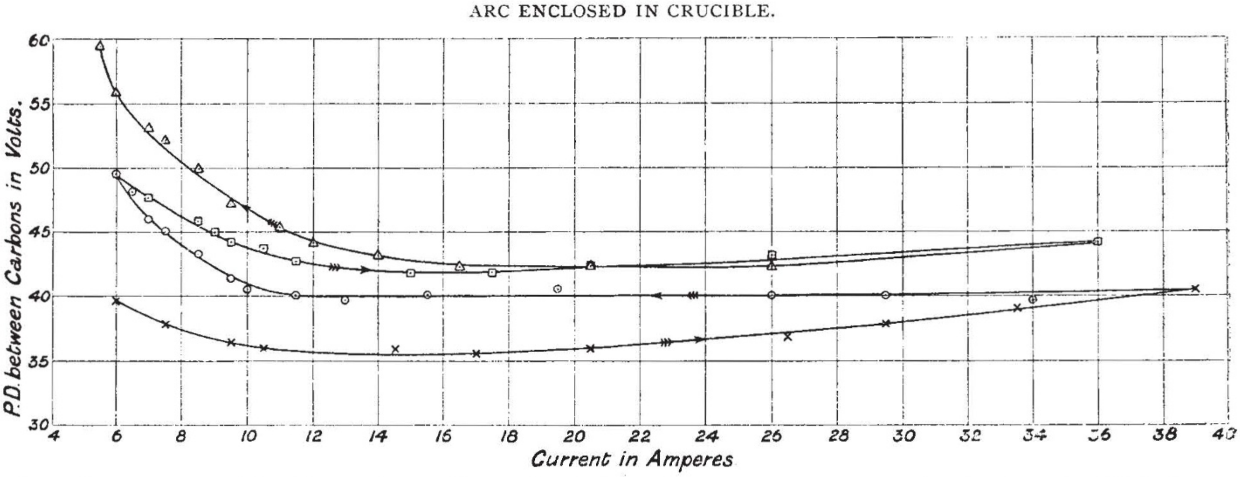

FIG. 9.—Curves connecting P.D. and Current for nearly Constant Length of Arc of 1·5 mm. to 2 mm. The arrows show the direction in which the Current was varied. Carbons:—Positive, 11 mm. Solid; Negative, 9 mm. Solid.

that produced by air, being only about 6·6 volts, or about $3\frac{1}{2}$ volts lower than when the hissing was caused by air alone.

In order to exclude all possibility of doubt as to the effect of the various gases, I repeated the experiments with the arc entirely enclosed in one of the fire-clay crucibles, so that the only gases that could reach the crater were those blown down the tubular positive carbon. The current was distinctly below the hissing point, being only 10 or 11 amperes, and the arc was from 2 mm. to 3 mm. long.

The results were exactly the same as with the open arc, except in the case of hydrogen. For air and oxygen produced hissing and a sudden diminution of the P.D., and nitrogen and carbon dioxide had no such effect, even when the current was very much increased. But whereas, as has been previously stated, hydrogen produced a distinct hissing of its own when blown down the positive carbon in the *open air*, it produced *none* when used in the same way with the arc *enclosed* in the crucible.

To prove that, in order to produce the sudden diminution of P.D under discussion, it was necessary for the active gas to actually *touch* the crater, a tubular *negative* carbon was used, and each gas was blown up through it in turn, gently enough not to force the gas directly against the crater.

In *no* case was there any sudden diminution of the P.D., whatever gas was employed, and whether the arc was open or enclosed. On the contrary, there was generally a small increase, probably due to the lengthening of the arc by its being blown on one side. If oxygen or air were blown *very hard* up the negative carbon, they would either produce hissing, or blow the arc out, or both; for in that case some of the gas got to the crater uncombined with the carbon vapour, and acted exactly as if it had been blown down the tubular positive carbon.

The case, then, stands thus:

(1) When the arc begins to hiss in the ordinary way, the P.D. between the carbons diminishes by about 10 volts.

(2) If the air is excluded from the arc, this diminution of the P.D. does not take place, even when the current is nearly three times as great as would cause hissing in the air.

(3) If, however, while the air is excluded, puffs of air are sent against the crater, the diminution of the P.D. *does* occur, even with currents much *smaller* than would cause hissing in the air.

(4) If, instead of air, *oxygen* is sent against the crater, the P.D. is diminished to exactly the same extent as when air is used.

(5) If, on the other hand, *nitrogen* is sent against the crater, *no* diminution of the P.D. is observable.

(6) If air or oxygen is gently blown through the *negative* carbon, so that it cannot get direct to the crater, *no* diminution of the P.D. follows.

Thus there can be no shadow of doubt that *the sudden diminution of P.D. that accompanies the hissing of the open arc is due to the oxygen in the air getting directly at the crater and combining with the carbon at its surface.*

It only remains to show how the actual hissing *sound* may be produced by the burning of the surface of the crater. The moment this burning begins, a cloud of gas, formed of the products of combustion, must spread over the crater, protecting it momentarily from the action of the air as effectually as the carbon vapour had hitherto done. When this gas is dispersed, the air will again come in contact with the crater, a fresh cloud will form, and the whole action will start *de novo*. Thus a series of rushes and stoppages of the air will take place, setting up an irregular vibration of just the kind to cause a hissing noise. Not only this, however, but since the crater must cease to burn each time that it is protected by the gas, the diminution of P.D. must also cease to exist, since its cause is removed, and the P.D. will therefore rise momentarily. Thus an oscillation of the P.D. between the carbons, and, consequently, of the *electric* current, must be created, corresponding with the oscillation of the *air* current.

These oscillations of both air and electric currents do actually exist with the hissing arc. The first I have proved by means of a fine asbestos fibre fastened at one end to the hole in the crucible (Fig 8) through which the positive carbon moved. The asbestos ring was raised, and the space between the carbon and the crucible was left clear, and was made large enough to allow the free end of the short fibre to stretch out horizontally between the two. When the arc was silent, the fibre scarcely moved, but the moment hissing started it set up a vigorous vibration, instead of being sucked into the crucible as it would have been if there had been a steady inward current of air.

Messrs. Frith and Rodgers (*Phil. Mag.*, 1896, p. 420) showed, in 1896, that the *electric* current was oscillatory with the hissing arc, and Messrs. Duddell and Marchant (*Journ. Inst. Elec. Engs.*, vol. xxviii. p. 84) in the account of their beautiful experiments with the oscillograph, have given actual curves of the P.D. and current with the direct current hissing arc, showing distinctly the oscillations in both.

Thus the direct contact of the oxygen of the air with the crater of the positive carbon is capable of producing, not only the diminution of the P.D. between the carbons of the arc, which is the most striking accompaniment of hissing, but also every other important manifestation connected with it, including the sound itself.

HERTHA AYRTON.

THE INTERNATIONAL CONFERENCE ON HYBRIDISATION AND CROSS-BREEDING.

In this country where the application of biological principles to the industries which they underlie is left as a rule to private enterprise or the half-hearted interest of County Councils, any means whereby the scientific worker is shown to be useful to the practical man is a help towards a better state of things.

For this reason alone the Conference on Hybridisation suggested by Mr. W. Bateson, and held on July 11 and 12, under the auspices of the Royal Horticultural Society, may have more importance in the future than Prof. Henslow claimed for it in the present. The more immediate results that will accrue are those which the Society foresaw must arise if the attempt to call forth papers, remarks and exhibits dealing with hybridisation was at all successful. Two days were not many to devote to the meeting, and it is a matter of surprise that such an amount of work was done in the time. When, however, the whole of the contributions, whether read or unread at the conference, are published in the form of an illustrated report, the Royal Horticultural Society should be more than satisfied.

Nevertheless the question of hybridisation is so large, as Mr. Engleheart said in the discussion, that "whole sets of subjects" (graft hybrids, for instance) could not even be touched upon, and the suggestion made in several quarters, but by the American delegates in particular, that a supplementary conference be held in another country should be taken up seriously.

Before discussing the chief points of the meetings it may be of interest to give a list of the speakers and their subjects.

Tuesday, July 11, in the Society's Gardens at Chiswick:—

(1) Maxwell T. Masters, F.R.S., Introductory remarks as Chairman.

(2) W. Bateson, F.R.S., "Hybridisation and Cross breeding as a Method of Scientific Investigation."

(3) A. de la Devansaye, "Hybrid Anthuriums."

(4) Prof. Hugo de Vries, "Hybridisation as a means of Pangenetic Infection."

(5) The Rev. Prof. Henslow, "Hybridisation and its Failures."

(6) C. C. Hurst, "Experiments in Hybridisation and Cross-breeding."

Wednesday, July 12, at the Town Hall, Westminster.

(1) The Rev. Prof. Henslow, Introductory remarks as Chairman.

(2) Herbert J. Webber, "Work of the United States Department of Agriculture in Plant Hybridisation."

(3) Dr. J. H. Wilson, "The Structure of certain New Hybrids (*Passiflora*, *Albuca*, *Begonia*, &c.)"

(4) R. Allen, "Hybridisation viewed from the Standpoint of Systematic Botany."

(5) Henry de Vilmorin, "Hybrid Poppies."

(N.B.—Nos. 2 and 3 were illustrated by means of lantern slides, and No. 5 by large water-colour drawings.)

(6) Discussion; Prof. Henslow, Mr. Burbidge, Rev. G. H. Engleheart, Mr. George Paul, Mr. Bunyard, Dr. Masters, Mr. Willet Hays, and Mr. W. Cuthbertson.

The United States was represented by Mr. Herbert Webber, of the Department of Agriculture, his colleague Mr. Swingle, and Mr. Willet Hayes; France by MM. de la Devansaye