culating the height of that. I made several observations of the position of the central line of the arch. I might specify that at 9.25 it was at R.A. 20h. 42m., Decl. + 33½°, and R.A. 0h. 43m., Decl. + 33°, and it moved very slowly.

Is it not time some systematic effort was made to calculate the heights of auroras? A good many observations have been made on this point, showing great variation in height; and yet, beyond the conclusion that it seems probable they may be seen at lower elevations nearer the magnetic pole than elsewhere, we know nothing as to whether they vary in height with the place, the time, or the nature of the auroras. Now is the time, seeing that auroras appear to be becoming more numerous than they have been for many years past. T. W. BACKHOUSE.

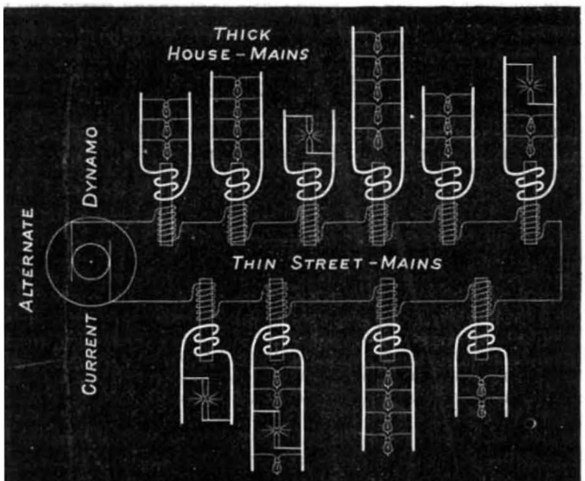
West Hendon House, Sunderland, October 5.

SOME NOTES ON THE FRANKFORT INTERNATIONAL ELECTRICAL EXHIBITION.[1]

III.

From One Hundred to Twenty Thousand Volts.

THE incandescent lamp having, by 1885, reached a fair degree of perfection, it appeared that the one need still remaining, in connection with the distribution of the electric light over a large area, would be supplied by the use of transformers. For a transformer with many convolutions of fine insulated wire on one coil, and a few convolutions of thick insulated wire on the other, would transform a large pressure and small current into a small pressure and large current; hence, if such a transformer were placed in each house, it would be possible to light up even a scattered district by a comparatively fine wire from a central station, whereas previously it had seemed



TRANSFORMERS IN SERIES
GAULARD AND GIBBS' ORIGINAL ARRANGEMENT.
FIG. 2

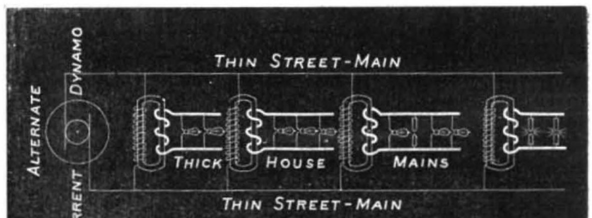
that it would be necessary to use copper conductors many square inches in cross-section to light many houses even when at no great distance from one another.

Hence, in the autumn of 1885 we find Messrs. Gaulard and Gibbs making preparations at the Grosvenor Gallery, Bond Street, for establishing there the pioneer central station for London.

But the method they adopted was that of placing the transformers in series, as seen in Fig. 2, and this system has the great disadvantage that the brightness of the electric lamps in a house cannot be kept automatically constant when other lamps in the same house are turned on or off. There are, of course, two conditions to be fulfilled in electric lighting: one, that turning on or off lamps in one house shall not affect the brightness of the lamps in any other house; the other, that turning on or off lamps in one room shall not affect the brightness of the lamps in any other room of the same house. With transformers in series, the first condition is satisfied by keeping the alternating current which passes through the fine wire or *primary coil* of the transformer perfectly constant; but this does not render the potential difference between the wires from the *secondary circuit*, or house mains, independent of the current in this secondary circuit—that is, independent of the number of lamps turned on in the house. Consequently, the series arrangement of transformers adopted by Messrs. Gaulard and Gibbs, while rendering the lamps in one house independent of those in another, did not attain the same result for lamps in different rooms of the same house.

Complaints, therefore, became general. Various unsuccessful devices were tried to remedy this evil, when an application was received from Mr. Sebastian Ziani de Ferranti to be allowed to try a transformer which he had designed. The application was accepted, for Mr. Ferranti, although quite young, was already known as having constructed an ingenious alternate-current dynamo, and in February 1886 the charge of the Grosvenor Gallery central station passed over into Mr. Ferranti's hands.

The new engineer recommended that the system of placing the transformers in series should be totally discarded, and that a parallel arrangement should be adopted



TRANSFORMERS IN PARALLEL
ARRANGEMENT NOW ADOPTED
FIG 3.

in its place, as in Fig. 3, because a well-made transformer had this important property—that if the potential difference at the terminals of the primary coil were kept constant, the potential difference between the terminals of the secondary coil would also remain nearly constant whatever were the current passing through this circuit; so that if the pressure between the street mains were always kept the same, the brightness of the lamps would hardly be affected either by turning on or off lamps in the same or in any other house.

Placing the transformers in parallel, however, would necessitate working at a low pressure, said the press, and would rob the transformer system of all its value, for "it is surely not proposed for one moment to work a parallel system where the primary has a difference of potential of 2000 volts." However, that is exactly what Mr. Ferranti not only proposed to do, but what he actually carried out on a large scale, so that his mains by 1888 stretched from Regent's Park to the Thames, and from Chancery Lane to Hyde Park, supplying current to some 20,000 glow-lamps. The Board of Trade had made regulations, about 200 volts being the maximum pressure permitted in a house; Parliament had passed the Electric Lighting Act of 1882, containing clauses rendering the development of the electric lighting industry well nigh commercially impossible; but Mr. Ferranti overcame all these legalities by bridging his mains from house-top to house-top, instead

[1] Continued from p. 524.

of putting them under the streets and himself under the control of the authorities.

But every corner at the Bond Street central station had soon to be utilized; a dynamo weighing tons had on one occasion to be lifted into position over a steam-engine necessarily kept always running to maintain a constant supply of current to the houses. New customers were added daily to the list, more and more current had to be generated nightly, in the face of engineering difficulties, and in the teeth of injunctions against smoke, injunctions against dust, and injunctions against noise.

A fresh start became imperative, so it was decided to build at Deptford, 6 miles away from Bond Street, a vast generating station, which should be the largest in the world, and to use the Grosvenor Gallery, and probably fresh sites to be obtained in town, merely as transforming stations. In the mains between Deptford and London it was decided to employ 10,000 volts, to be reduced to 2400 in London, and the power then distributed by the existing overhead mains, and again reduced to 100 volts on entering the houses, as before.

The scheme was a far-reaching one; permission was asked from the Board of Trade by the London Electric Supply Corporation, the outcome of the original Grosvenor Gallery Syndicate, to run wires along 27 railways and through 30 parishes; two dynamos, each to furnish 1250 horse-power at 10,000 volts, were built with special engines to drive them, as seen in Fig. 4, and a cable laid to London. But on starting the dynamos, when they were completed, it was found that the insulation of the cable would not stand 10,000 nor even 5000 volts; and for a time power was supplied direct from Deptford to the houses in London, one transformation at the houses themselves being alone effected.

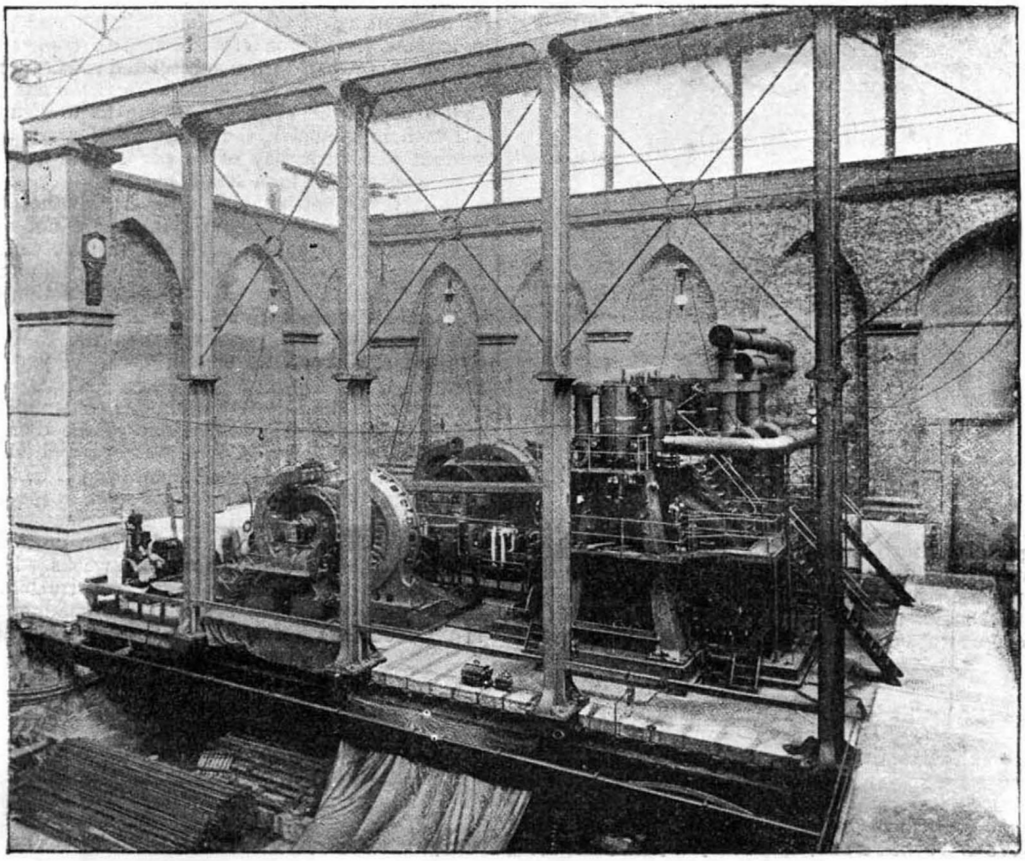


Fig. 4.—Two 1250 horse-power dynamos (opened for inspection) at Deptford.

Fig 5.—Longitudinal section of the Ferranti main. A, inner copper tube; B, outer copper tube; D, iron protecting tube; waxed paper insulation shaded black.

Then Mr. Ferranti carried out his original intention of constructing the main of two concentric copper tubes, to serve respectively as the going and return conductor. The inner copper tube, 20 feet long, seen in section, A,

Fig. 5, has brown paper soaked in ozokerit rolled round it to a thickness of about five-eighths of an inch. Outside this is slipped a larger copper tube, B, Fig. 5, and the whole is drawn through a taper die under great pressure, which has the effect of forcibly compressing the paper and consolidating the mass. Next, more brown paper

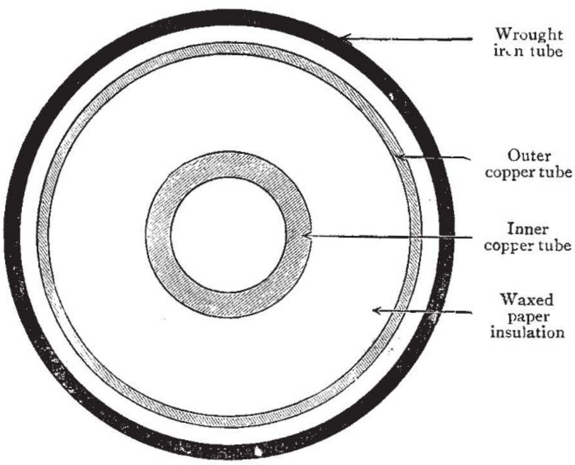


Fig. 6.—Cross-section of the Ferranti main; full size.

soaked in melted ozokerit is rolled on, to a thickness of one-eighth of an inch, and the whole slipped loosely into an iron tube, D, Fig. 5, which protects the cable subsequently from mechanical injury. To fill up any air spaces that may have been left between the iron and the outer copper tubes, the 20-feet section is placed over a

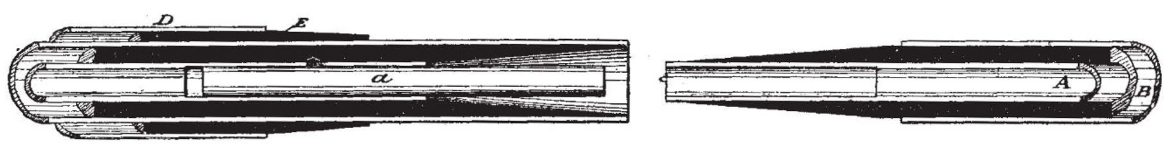


Fig. 7.—Ends of two pieces of main, tapered ready for jointing. *a*, copper rod to make electric connection between inner copper tubes; E, waxed paper coned like a pencil.

fire, and melted wax pumped in between the two through a tube inserted in a hole drilled in the middle of the iron tube.

Fig. 6 shows a cross-section of the finished main full size, and as the sectional area of the metal in each of the copper tubes is about a quarter of a square inch, the main can transmit about 2000 horse-power at 10,000 volts.

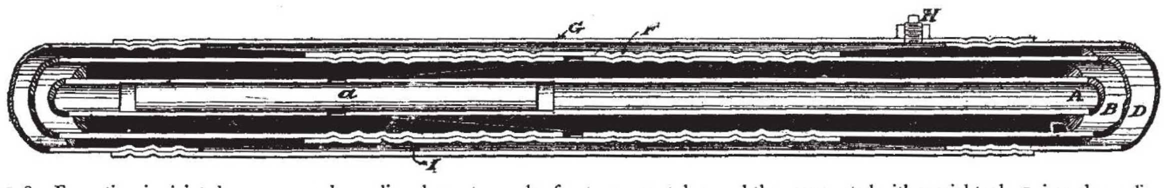


Fig. 8.—Ferranti main, jointed. F, copper sleeve slipped over two ends of outer copper tubes, and then corrugated with special tool; G, iron sleeve slipped over two ends of iron tubes, and corrugated with special tool; H, screw-hole to run in melted wax, I.

The main being constructed in lengths of only 20 feet, some 1500 joints have had to be made in 6 miles of main, or 6500 joints altogether in the five mains which have been laid from London to Deptford. These joints have been made without solder, in the way shown in Figs. 7 and 8, pressure alone between the copper tubes having been relied on to maintain good contact.

The object of using concentric tubes is twofold—first, as the outer copper tube is kept practically at the potential of the earth, it is impossible to get a severe shock unless the inner tube is touched, and this, of course, can only be done by first cutting through the outer; second, the effective increase of the resistance and of the self-induction which occurs with rapidly alternating currents in consequence of the mutual action of the currents in different parts of the conductor on one another is much less for a given cross-section of copper with concentric tubes than with two insulated rods placed side by side. For example, Sir William Thomson has calculated that if copper be employed in the form of a solid rod, 1·2 inch in diameter, the resistance for an alternating current of a frequency of 80 per second will be 31 per cent. greater than for a steady current.

It is very questionable, however, whether these advantages of using concentric tubes are not more than compensated for by the large electrostatic capacity that such a cable possesses. For, as is now fully recognized, the combination of capacity and self-induction can by a species of resonance cause the difference of potential in the circuit to be far greater than the E.M.F. of the dynamo itself, and in certain cases very dangerously greater.

As soon as the Deptford main was constructed to stand 10,000 volts, it was found that one of the dynamos seen in Fig. 4 broke down at this pressure, and therefore for many months the current was sent from Deptford at only 5000 volts; next, the transformer room at the Grosvenor Gallery was burnt down through carelessness, some £8000 worth of transformers destroyed, and a portion of London left in darkness for two or three weeks. New transformers were hastily, too hastily, constructed, and the current was turned on again at the commencement of last December; but after a few days the transformers were, one after another, short-circuited by the electric current sparking from the primary coil to the iron core of the transformers, and all the houses on the London Electric Supply Corporation's system again left in darkness during the nearly perpetual night of a densely foggy winter. The Metropolitan Electric Supply Company—which also distributes an alternating current by means of transformers, but from several central stations in the heart of London itself, and therefore requiring to use only 1000 volts and a single transformation—came to the rescue in certain districts, but in others the householders had to be left to their fate, as it would have been far too expensive to run special mains from the Metropolitan Company's stations merely as a temporary expedient.

Finally, in March of this year, current was again turned on from Deptford, at the pressure originally proposed, viz. 10,000 volts. It was not, however, supplied from the dynamos illustrated in Fig. 4; but, instead, Messrs. Deprez and Carpentier's plan of transforming up and transforming down again, illustrated in Fig. 1, p. 522, was employed. For, by this time, two dynamos, formerly at the Grosvenor Gallery, each of 600 horse-power, had been taken to Deptford and erected there, as seen in Fig. 9; new steam-engines, more powerful than those formerly employed at the Grosvenor Gallery, having been constructed to drive them.

These dynamos generate the current at 2400 volts, then, by means of transformers at Deptford, this is raised to 10,000 volts. On the power arriving in London, the pressure is transformed down again to 2400 volts, and at the houses there is a further transformation of this 2400 volts to 100 volts. There are, therefore, no less than three transformations of pressure between the dynamo terminals at Deptford and the lamps in the houses in London.

Regarded as a gigantic experiment in electrical engineering, the Deptford scheme has achieved a gallant victory, for, with a buoyancy that no disaster could crush, and with the determination of a Napoleon to conquer every mechanical and electrical obstacle in the way, Mr. Ferranti has step by step succeeded in distributing current to quite distant parts of London at a pressure which in 1885 was regarded as quite impracticable, and for the last seven months he has been sending the power to London at a pressure which, even at the end of last year, was deemed simply visionary.

But as a commercial undertaking the Deptford transmission is a dreary failure, since what is the advantage of transmitting the current 6 miles that is in any way commensurate with the capital already expended? When power can be obtained very cheaply, from a rapid river for example, it may be highly remunerative to transport it in some such way as is now being done between Lauffen and Frankfort. But can power be obtained so much more cheaply at Deptford than in London to make it worth while transmitting it over 6 miles? Land undoubtedly costs much less down the river than in the heart of London, coal can be very easily brought to a generating station on the banks of the Thames, and the water might perhaps be employed to work condensing steam-engines; but such economies can only compensate for a fraction of the yearly interest on the capital expended on the Deptford scheme. Indeed, even if the station at Deptford had been built with rigid economy, and only large enough for the present demand, it is questionable whether the loss of power in three transformations of the pressure would not eat up much of the saving that could be effected by having the generating station quite out of London.

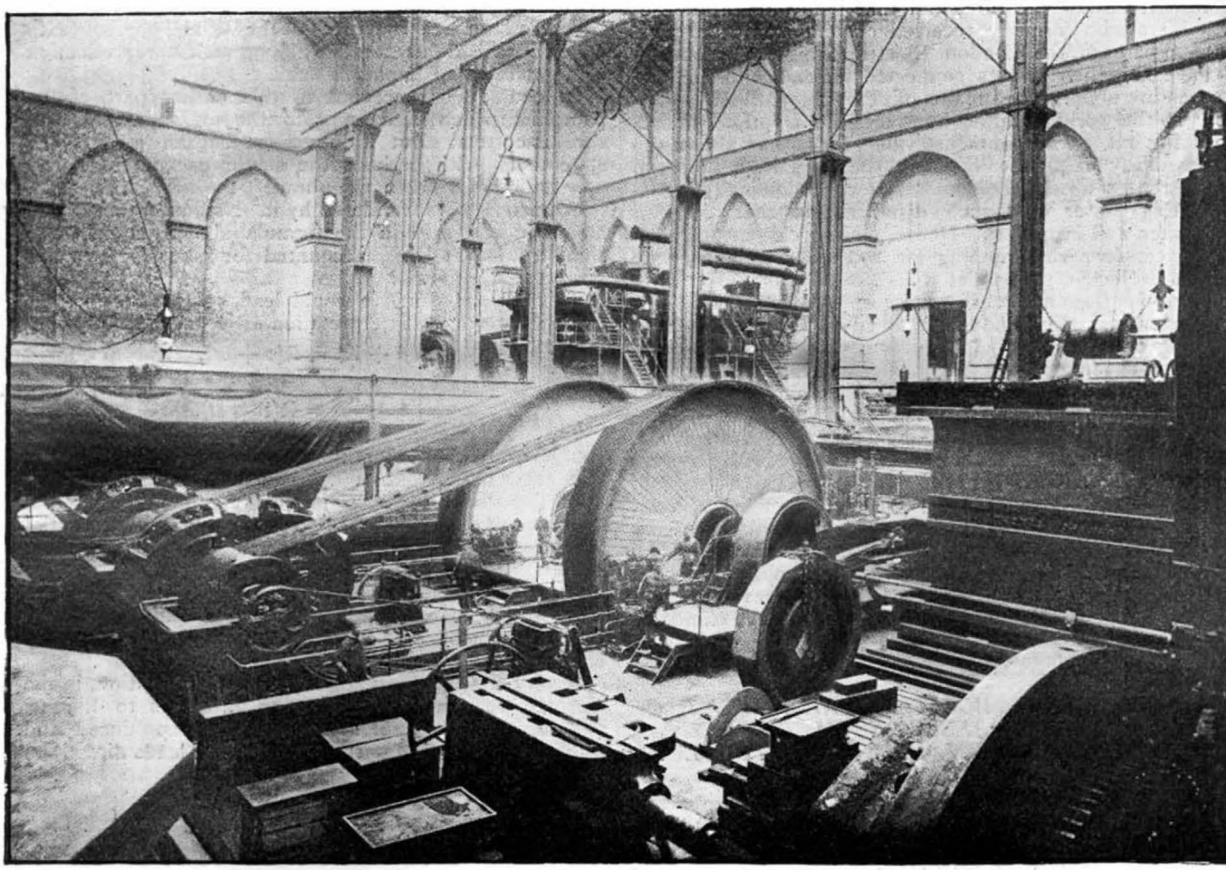


FIG. 9.—Two of the Grosvenor Gallery dynamos re erected at Deptford and driven by new steam-engines. Two 1250 horse-power dynamos at the back.

As it is, however, the London Electric Supply Company have been so engrossed with the electric lighting of London in the *future*, that they have practically ignored the present wants of the householder; the vast building at Deptford has been constructed to carry a second story of boilers and engines, when it is very doubtful if even the present story can be wholly utilized for a long time to come; rows of boilers and furnaces were erected some two or three years ago to supply steam to drive dynamos which are not yet made; tens of thousands of pounds have been expended on machinery to be employed in constructing two ten-thousand horse-power dynamos, and the armature of one of them, 43 feet in diameter, has had to be left abandoned only half finished, because there is neither money nor present need for such a dynamo at Deptford.

And while all these provisions for the future electric lighting of London on a vast scale were slowly proceeding, the present customers were left sometimes for hours, sometimes for days, and occasionally even for weeks in darkness: what wonder is it, then, that all over London there have have been growing up central stations supplying a direct current at low pressure, and that many of the householders who formerly received current from the overhead wires of the London Electric Supply Corporation have had their houses connected instead with the low-pressure underground mains of other companies?

To the world at large, however, the Deptford undertaking has been of immense value, for it has shown the possibility of practically using the very high potential differences absolutely necessary for economically transmitting power over such distances as that between Lauffen and Frankfort. Hence, maintaining 20,000 volts between *bare* wires running for 109 miles along the side of the Neckar railway, at a height of only 16 feet from the ground, sounds much less startling now than did Mr. Ferranti's proposal made and acted on five years ago to bring only one-tenth of this pressure, by means of india-rubber covered conductors, into locked transformer rooms built of brick in the basement of the houses supplied with current from the Grosvenor Gallery.

In fact, the results that have been attained through Mr. Ferranti's undaunted courage, and the well-filled purses of his friends, have led people to look on a pressure of 20,000 volts as they regard a velocity of 70 miles an hour, so that to day, in order to prevent boys climbing up any one of the 3000 ordinary telegraph poles which carry the wires from Lauffen to Frankfort, it is thought sufficient to merely paint a skull and cross-bones on every post as an indication of the deadly fate that awaits the climber.[1]

(*To be continued.*)

ON VAN DER WAALS'S TREATMENT OF LAPLACE'S PRESSURE IN THE VIRIAL EQUATION: IN ANSWER TO LORD RAYLEIGH.

MY DEAR LORD RAYLEIGH,—As you are aware, I did not see your letter of September 7 (NATURE, 24/9/91) till a fortnight after its date; and my reply has been further delayed for a week in consequence of the closing of Edinburgh University Library at this season. Even now I can refer only to the German version of Van der Waals's pamphlet.

Partly on account of its unfamiliar language, but more especially on account of a very definite unfavourable opinion expressed by Clerk-Maxwell (NATURE, 15/10/74) I did not attempt to read the pamphlet when it appeared; and it was not till 1888 that, in consequence of some hints from Dr. H. Du Bois, I hastily perused it in its German form.

The passage which you quote from my paper (where, by the way, the printers have unfortunately put *resistance* for *resilience*) is certainly not a very accurate description of Van der Waals's method, but it represents faithfully the difficulties which I felt on first reading the pamphlet. I said that Van der Waals's "justification of the introduction of the term a/v^2 into an account already closed, as it were, escapes me." And I am not surprised that it did so. For the statement of Clerk-Maxwell had prepared me to look for error; and when, at the end of Chap. VI., I met with the formula

$$p(v-b) = R(1+at),$$

which, a couple of pages later (nothing but general reasoning intervening), somehow developed itself into

$$\left(p+\frac{a}{v^2}\right)(v-b) = R(1+at),$$

I naturally concluded that this was the matter adverted to. I spoke of the first of these equations as a "closed account," because of the process by which b had been introduced. To this point I must presently recur.

I had not examined with any particular care the opening chapters, to which your letter chiefly refers; probably having supposed them to contain nothing beyond a statement and proof of the Virial Theorem (with which I was already familiar) along with a reproduction of a good deal of Laplace's work.

Of course your account of this earlier part of the pamphlet (which I have now, for the first time, read with care) is correct. But I do not see that any part of my statements (with perhaps the single exception of the now italicized word in the phrase "the *whole* procedure is erroneous") is invalidated by it. No doubt, the sudden appearance of a/v^2 in the formula above quoted is, to some extent at least, accounted for; but is the term correctly introduced?

The formula you give would lead, on Van der Waals's principles as to the interpretation of $\frac{1}{3}\Sigma(mV^2)$, to

$$v(p+K) = R(1+at),$$

or

$$v\left(p+\frac{a}{v^2}\right) = R(1+at).$$

But how can the factor $(v-b)/v$, which Van der Waals introduces on the left in consequence of the finite diameters of the particles, be justifiably applied to the term in K as well as to that in p? Yet to apply it so is essential to Van der Waals's theory; for without it the resulting equation will not give a cubic in v, and cannot therefore be applied to the isothermals for which it is required. And, in any case, it could scarcely be said that the K term, after being manipulated in this manner, is, in any strict sense, "extracted from the term $\Sigma(Rr)$."

A very strange thing appears, in this connection, in the German version. A result, due it seems to Lorentz (which, in ignorance of his work, I had reproduced and published in the first part of my paper), leads directly to the equation

$$pv = R(1+at)\left(1+\frac{b}{v}\right);$$

which is then put in the confessedly approximate form

$$p(v-b) = R(1+at).$$

Of this it is remarked:—"was genau mit dem obigen Resultate [that obtained by the use of the factor $(v-b)/v$] übereinstimmt." It is obvious that, when we have to divide both sides by $v-b$, we ought to restore the proper factor on the right; and thus that the equation ought to take the final form

$$p+\frac{a}{v^2} = R(1+at)\,\frac{v+b}{v^2},$$

instead of the more convenient form

$$p+\frac{a}{v^2} = \frac{R(1+at)}{v-b},$$

in which Van der Waals employs it. But then it would not give the required cubic in v!

I think that the mere fact of Van der Waals's saying (in a passage which is evidently applicable to his own

[1] We have to thank the *Electrician* and the *Electrical Review* for some of the illustrations used in this article.