commercial, left Beilul last April to explore the source of the Gualima. Four days distance from that town they were attacked and slain by the natives. Signor Giulietti was well known for the difficult journey he accomplished from Zeila Hazar. He was asked by the Geographical Society to explore the interior of the west coast of the Red Sea. At first a journey to Lake Aussa was contemplated, but obstacles arising, the plan was changed for an expedition into the Assab Gallas country.

AT the meeting of the Geographical Society on Monday last Capt. W. J. Gill, R.E., read some extracts from a long account of his explorations in Western Szechuen, which has lately been sent home by Mr. E. Colborne Baber, now Chinese Secretary of H.M. Legation at Peking. The extracts chosen dealt chiefly with the amusing side of Mr. Baber's journey, but the paper, nevertheless, contains abundance of solid information respecting the extreme west of China, and, as Lord Aberdare stated in his anniversary address, is considered by competent judges to be a noteworthy contribution to our knowledge of Asiatic geography. The most valuable part of the extracts read is probably that respecting the almost unknown Lolo country, in the neighbourhood of Ning-yüan-fu. Mr. Baber sent home copies of some pages of a Lolo manuscript, no specimen of which, we believe, has ever been seen in Europe before. These have been submitted to the well-known scholar, M. Terrien de la Couperie, who gave the meeting a brief account of the results of his examination of them. Mr. Baber's paper will be published by the Society, together with the valuable cartographical matter which accompanied it.

M. AND MADAME UJFALVY were to leave Simla for Kashmir, *viâ* Kangra, on June 6. From Kashmir they hope to penetrate into Thibet and Central Asia.

THE death is announced of Mr. Andrew Wilson, author of a well-known book of travel in the Himalayas, "The Abode of Snow."

SOLAR PHYSICS—CONNEXION BETWEEN SOLAR AND TERRESTRIAL PHENOMENA[1]

II.

IN my last Lecture I alluded to the complicated periodicity which sun-spots exhibit. It is right here to quote the remark of Prof. Stokes, that until we have applied to solar phenomena a sufficiently rigid analysis we are not certain that this apparent periodicity will bear all the marks of a true periodicity. It cannot however be denied that solar phenomena are roughly periodical, and this apparent periodicity has influenced observers in their attempts to search for a cause. There have been two schools of speculators in this interesting region, consisting of those who imagine a cause within the sun, and of those who imagine one without. The former *may* be right, but apparently they cannot advance our knowledge much. We know very little of the interior of the sun, and no one has yet ventured on any hypothesis regarding the *modus operandi* by which these strangely complicated and roughly periodical surface phenomena may be supposed to be produced by the internal action of the sun itself.

Those who maintain the hypothesis of an internal cause are apparently driven to it by the *à priori* unlikelihood of any cause operating from without. No doubt we have around the sun bodies, the motions of which are strictly periodical, such as planets, comets, and meteors, but they are relatively so small and so distant, that it seems difficult to regard them as capable of producing such vast phenomena as sun-spots.

There is however this difference between the two hypotheses —those who assert internal action cannot convert their views into a working hypothesis. On the other hand, those who look to external sources can take the most prominent planets, for instance, and endeavour to ascertain whether as a matter of fact the behaviour of the sun with regard to spots is apparently influenced by the relative positions of these. Attempts of this nature have been made by Wolf, Fritz, Loomis, Messrs. De La Rue, Stewart, and Loewy, and others. These attempts have been of two kinds. In the first place observers have tried whether there appear to be solar periods exactly coinciding with certain well-known planetary periods. By this means the following results have been obtained by the Kew observers (Messrs. De La Rue, Stewart, and Loewy):—

(1) An apparent maximum and minimum of spot energy approximately corresponding in time to the perihelion and aphelion of Mercury.

(2) An apparent maximum and minimum of spot energy approximately corresponding in time to the conjunction and opposition of Mercury and Jupiter.

(3) An apparent maximum and minimum of spot energy approximately corresponding in time to the conjunction and opposition of Venus and Jupiter.

(4) An apparent maximum and minimum of spot energy approximately corresponding in time to the conjunction and opposition of Venus and Mercury.

Mr. De La Rue and his colleagues make the following remarks upon these results:—

"There appears to be a certain amount of likeness between the march of the numbers in the four periods which we have investigated, but we desire to record this rather as a result brought out by a certain specified method of treating the material at our disposal, than as a fact from which we are at present prepared to draw conclusions. As the investigation of these and similar phenomena proceeds it may be hoped that much light will be thrown upon the causes of sun-spot periodicity."

I may here mention that within the last month I have, in conjunction with Mr. Dodgson, applied a method of detecting unknown inequalities with the view of seeing whether there are any indications of an unknown inequality in sun-spots having a period near that of Mercury, and I find there are indications of such an inequality having a period which does not differ from that of Mercury by more than about three-hundredths of a day. Besides the four periods above mentioned the Kew observers have, they think, detected evidence of a periodicity in the behaviour of spots with regard to increase or diminution depending apparently on the positions of the two nearer planets, Mercury and Venus. The law appears to be, that as a portion of the sun's surface is carried by rotation nearer to one of these two influential planets, there is a tendency for spots to become less and disappear, while on the other hand when it is carried away from the neighbourhood of one of these planets there is a tendency for spots to break out and increase.

The Kew observers regard this latter species of evidence as being well worthy of a more exhaustive discussion when the sun-spot records are more complete. I have already mentioned that the chief difficulty in attributing solar outbreaks to configurations of the planets is the comparative smallness and great distance of these bodies, so that when we reflect on the enormous amount of energy displayed in a sun-spot we cannot but have great difficulty in supposing that such vast phenomena can be caused by a planet like Venus, for instance, that is never as near to the sun as she is to the earth. But this difficulty depends very much on what we mean by the word "cause." If we mean that the planets cause sun-spots in the way in which the blow of a cannon-ball or the explosion of a shell causes a rent in a fortification, the hypothesis is certainly absurd. But if we only mean that the planets act the part of the man who pulls the trigger of the gun, the hypothesis may be unproved, but it is no longer absurd. For we have reason to believe that there may be great delicacy of construction in the sun's atmosphere, in virtue of which a small cause of this kind may produce a very great effect.

We may therefore believe it possible that planets may act in this way on the sun—the energy displayed in a spot being however not derived from the planets, but from the sun itself, just as the energy of a cannon-ball is not derived from the man who pulls the trigger, but from the explosion in the gun.

All this is chiefly historical, and it leads to a very interesting query. If there is such an action of a planet on the sun, must not this have a reaction? If the earth influences the sun, must not the sun simultaneously influence the earth? Perhaps so; nevertheless it is not an influence of this kind which I shall now bring before you. The sun is periodically stirred up—no matter how—and being stirred up there is an increase in the light and heat which are radiated to the earth. This affects the meteorology of the earth, and also its magnetism, after a method which, if we do not fully understand it now, we may ultimately expect to comprehend. It is this kind of influence, and not an occult action, of which I shall now bring the evidence before you

[1] Lecture in the Course on Solar Physics at South Kensington; delivered by Prof. Balfour Stewart, F.R.S., April 27. Continued from p. 117.

And first of all let me speak of the sun's influence on the magnetism of the earth.

Suppose that the chief observatories of the world have each a vault, and that in this vault a magnetic needle is delicately suspended. We may imagine the sun to be shut out altogether, the only light being that of a lamp which enables us to record, either photographically or otherwise, on a magnified scale any small oscillations of the needle. The vault may be supposed to be sufficiently deep down to be practically uninfluenced by the heat of the sun, so that it will exhibit no difference in temperature between noon and midnight. Finally there must be no iron or steel about the place, or anything which might affect the needle. Now under these circumstances you would naturally imagine that the needle would be perfectly stationary, always pointing in the same direction. Such, however, is not the case—it does not move very greatly, but nevertheless it does move, and its position depends on the hour of the day, or, in other words, upon the sun. The sun cannot heat the chamber in the least, nevertheless it can influence the magnet, and we might even tell in a rough way the hour of the day by noting the position of the needle. In this country the needle attains one extreme in its daily progress about five or six in the morning, and the other about one or two in the afternoon, and the difference in position of these two extremes is called the diurnal range of magnetic declination. Here then we have a magnetical phenomenon which depends upon the sun, and which does not take place simultaneously at the various observatories of the earth, inasmuch as the sun travels from east to west, so that when it is six in the morning at one place it may be midnight at another.

In the next place, we have abrupt magnetical changes analogous to the well-known abrupt meteorological changes, and bearing the appropriate name of magnetic storms.

A magnetic storm is not a mere local outbreak, but is felt simultaneously at all the various points of the earth's surface. The various needles in the various vaults of which we have now been speaking will all be affected at the same moment of time, and will be found to be oscillating backwards and forwards in a disturbed state. It thus appears that diurnal ranges and magnetic storms are two distinct phenomena.

To begin with diurnal declination ranges. These have, as their very name implies, a connexion with the hour of the day, and hence with the position of the sun. Again, in middle latitudes declination ranges are greatest in summer when the sun is most powerful, and least in winter. Lamont was the first to observe the signs of a long period inequality in the yearly means of the Munich diurnal declination ranges, and in 1852 Sir Edward Sabine succeeded in showing that this inequality followed that of sun-spots previously discovered by Schwabe, maximum ranges corresponding to years of maximum sun-spots, and minimum ranges to years of minimum sun-spots. In the same year Dr. Wolf and M. Gautier independently remarked the same coincidence.

But there is more than a mere general correspondence between these two phenomena, for it is believed that all inequalities of sun-spots, whether of long or short period, are accompanied by corresponding changes of declination range, a large range invariably accompanying a large number of spots. Perhaps I ought to say a large range following a large outbreak of spots, for the solar phenomenon leads the way and the magnetic change follows after it at a greater or less interval of time. I may add, likewise, that we have some evidence which leads us to suspect that particular states of declination range, like particular states of weather, have a motion from west to east, the magnetical weather moving faster than the meteorological. From a preliminary investigation which I have made, I even think there may ultimately be a possibility of forecasting meteorological weather by means of magnetic weather five or six days before. It will be noticed, that as far as declination range is concerned, we have no evidence of a direct magnetic action of the sun upon the earth, but we have, on the other hand, evidence that the magnetic effect, like the meteorological, lags behind the cause in such a way that we are inclined to attribute the magnetic as well as the meteorological phenomena to the heating effect of the sun's rays.

Let us next take magnetic storms. These, as we have seen, affect the various stations simultaneously, so that the magnetism of the earth appears to change as a whole, and in this respect they are very different from the ordinary diurnal oscillations of the needle. Nevertheless, equally with declination ranges, magnetic storms appear to depend on the state of the sun. In 1852 Sir Edward Sabine showed that in those years when there are most sun-spots there are most magnetic storms, while, on the other hand, years of minimum sun-spots correspond to a minimum number of such storms. The late John Allan Broun, an eminent magnetician, has given reasons for believing that the greater magnetic disturbances are apparently due to actions proceeding from particular meridians of the sun; this when verified will be a fact of the greatest importance.

Again, Prof. Loomis of America, from a discussion of 135 cases of magnetic disturbance, concludes that great disturbances of the earth's magnetism are accompanied by unusual disturbances of the sun's surface on the very day of the magnetic storm. It might at first sight be thought from this last observation that a magnetic storm is due to some direct magnetic influence propagated from the sun to the earth, and accompanying a rapid development of spots, the influence being thus very different from that which may be supposed to cause variations in the magnetic range. But I do not see that this result follows from Prof. Loomis' observations. There is, I think, evidence that the earth before a magnetic storm is in a critical magnetic state—out of relation to its surroundings—and hence a sudden solar outburst may be the immediate occasion of its starting off. But I fail to see any evidence that the influence received from the sun on such occasions is different in kind to that which affects magnetic ranges. For we know that magnetic storms occur most frequently about the equinoxes, or at those times when the sun is crossing the equator. Now were a magnetic storm produced by a magnetic influence immediately proceeding from the sun, it would be difficult to understand why there should be any marked reference in magnetic storms to certain months of the year.

When the magnetism of the earth is in a disturbed state this may of course be rendered visible by means of the oscillations of a delicately suspended magnetic needle. Nevertheless there are associated phenomena of a very conspicuous character which vividly impress us with the reality of the occurrence. One of these is the aurora—displays of which invariably accompany considerable magnetic storms, on which occasions they may be witnessed over a large portion of the globe.

Another of these is the earth currents which on such occasions affect all telegraphic lines connected with the earth. These earth currents are automatically registered at Greenwich by the Astronomer Royal, and their peculiarity is that during magnetic storms they are very violent, passing rapidly and frequently backwards and forwards between positive and negative.

We come now to the meteorological effects produced by the variable state of the sun's surface. More than ten years ago Mr. Baxendell of Manchester pointed out that the convection currents of the earth were apparently altered by the state of the sun's surface, and since that time this peculiar connexion between the sun and the earth has been investigated on an extensive scale by observers in various portions of the globe. Dr. Charles Meldrum of the Mauritius Observatory was one of the first pioneers in this important branch of inquiry. In 1872 he showed that the rainfalls at Mauritius, Adelaide, and Brisbane were greater generally in years of maximum than in years of minimum sun-spots. Shortly afterwards Mr. Lockyer showed that the same law held for the rainfalls at the Cape of Good Hope and Madras. Dr. Meldrum afterwards took twenty-two European observatories, and found that the law held in nineteen out of the twenty-two. It would however appear from the observations of Governor Rawson that at Barbadoes, and perhaps other places, the maximum rainfall does not coincide with the maximum sun-spot years. As locality has a very great influence upon rainfall, it might be supposed that by measuring the recorded depths of water in large rivers and lakes we should be able to integrate the rainfall over a large area, and thus avoid irregularities due to local influence. This too has been attempted. In 1873 Gustav Wex examined the recorded depths of water in the Elbe, Rhine, Oder, Danube, and Vistula for the six sun-spot periods from 1800 to 1867, and came to the conclusion that the years in which the maximum amount of water appeared in these rivers were years of maximum sun-spots, while the minimum amounts of water occurred during the years of minimum sun-spots.

In 1874 Mr. G. M. Dawson, in America, analysing the fluctuations of the great lakes, came to a similar conclusion. This leads me to a very practical and important part of the subject. In countries such as ours we often suffer from excessive rainfall, and are rarely incommoded by excessive heat; but in hot countries such as India a deficient rainfall means a dearth, or even a famine

This has been brought prominently before us of late years by Dr. Hunter, Director-General of Statistics in India, who has shown that famines are most frequent at Madras about the years of minimum sun-spots—years which were likewise associated with a diminished rainfall.

In summing up the rainfall evidence we ought to bear in mind that the direction as well as the intensity of the earth's convection currents is no doubt altered by solar variability. And if we at the same time reflect how very local rainfall is, we cannot expect that the same rule regarding it should hold for all the various stations of the earth's surface. But on the whole there appears to me to be evidence that we have most rainfall during most sun-spots. Of course we know little or nothing of variations in the rainfall at sea.

I have already mentioned that the magnetic storms of the earth are most frequent during years of maximum sun-spots, and the very same thing may be said of wind-storms. Dr. Meldrum has found that there are more cyclones in the Indian Ocean in years when there are most sun-spots, and fewest cyclones in years when there are fewest sun-spots. M. Poëy has proved a similar coincidence between the hurricanes of the West Indies and the years of maximum sun-spots, and I believe that a similar conclusion has been arrived at with regard to the typhoons of the Chinese seas.

In 1877 Mr. Henry Jeula of Lloyds and Dr. Hunter found that the percentage of casualties on the registered vessels of the United Kingdom was $17\frac{1}{2}$ per cent. greater during the maximum two years than during the minimum two years in the common sun-spot cycle.

We may therefore imagine that the wind as well as the rain of the earth is most violent during years of maximum sun-spots.

We come now to the pressure of the air. If there were no sun the pressure of the air would ultimately distribute itself equally where it is now unequal. This inequality is no doubt caused by the sun, and we should expect it to be most pronounced when the sun has most power. It is also different in summer and winter. In summer we generally find a low barometer in the centres of great continents, and a high barometer over the sea; while during winter we have the converse of this, or a high barometer over continents and a low barometer at sea. I think it likely that the true relation between the variations of sun-spots and of barometric pressure will ultimately be discovered by means of the admirable weather-maps of the United States; meanwhile, however, especially in India, something has already been done in this direction.

If we regard the distribution of isobaric lines, that is to say of lines of equal barometric pressure, we shall find that the Indo-Malayan region is one which for the mean of the year has a barometric pressure probably below the average. Now during years of powerful solar action we might imagine that this peculiarity would be increased. But this is precisely what all the Indian observers have found for years with most sun-spots.

On the other hand Western Siberia in the winter season has a pressure decidedly above the average, and we should therefore imagine that during years of powerful solar action the winter pressure would be particularly high. This again is the state of things that Mr. Blanford has found in his discussion of the Russian stations to correspond with years of most sun-spots.

It therefore appears to me that the barometric evidence as far as it goes is favourable to the belief that years of maximum sun-spots are years of greatest solar power.

I come now to consider the question of temperature. Mr. Baxendell was the first to conclude that the distribution of temperature under different winds, like that of barometric pressure, is very sensibly influenced by the changes which take place in solar activity. In 1870 Prof. Piazzi Smyth published the results of observations made from 1837 to 1869 with thermometers sunk in the rock at the Royal Observatory, Edinburgh. He concluded from these that a heat wave occurs about every eleven years, its maximum slightly lagging behind the minimum of the sun-spot cycle. In 1871 Mr. E. J. Stone examined the temperature observations recorded during thirty years at the Cape of Good Hope, and came to the conclusion that the same cause which leads to an access of mean annual temperature at the Cape leads equally to a dissipation of sun-spots. Dr. W. Köppen in 1873 discussed at great length the connexion between sun-spots and terrestrial temperature, and found that in the tropics the maximum temperature occurs fully a year before the year of minimum sun-spots: while in the zones beyond the tropics it occurs two years after the minimum. The regularity and magnitude of the temperature wave is most strongly marked in the tropics.

The temperature evidence now given appears at first sight to be antagonistic to that derived from the other elements, both of magnetism and meteorology, and to lead us to conclude that the sun heats us most when there are fewest spots on its surface. This conclusion will not, however, be strengthened if we discuss the subject with greater minuteness. Scientifically, we may regard the earth as an engine, of which the sun is the furnace, the equatorial regions the boiler, and the polar regions the condenser. Now this engine works in the following manner. Hot air and vapour are carried along the upper regions of the atmosphere from the equator to the poles by means of the anti-trade winds, while in return the cold polar air is carried along the surface of the earth from the poles to the equator, forming what is known as the trade winds. Now whenever the sun's heat is most powerful, both trades and anti-trades should, I imagine, be most powerful likewise. But we live in the trades rather than in the anti-trades—in the surface currents, and not in the upper currents of the earth's atmosphere. When the sun is most powerful, therefore, is it not possible that we might have a particularly strong and cold polar current blowing about us? The same thing would happen in the case of a furnace-fire—the stronger the fire the more powerful the hot draught up the chimney—the more powerful also the cold draught from without along the floor of the room. It might thus follow that a man standing in the furnace room near the door might be chilled rather than heated when the furnace itself was roaring loudest. In fact temperature is a phenomenon due to many causes. Thus a low temperature may be due

(1) To a deficiency in solar power.
(2) To a clouded sky.
(3) To cold rain.
(4) To cold winds.
(5) To cold water and ice.
(6) To cold produced by evaporation.
(7) To cold produced by radiation.

Now Mr. Blanford, the Indian observer, has recently shown that a low temperature of the air and soil is accompanied in the stations which he has examined by a copious rainfall and by a large number of clouds. If therefore we regard a high rainfall as the concomitant of many sun-spots, we must not be surprised if this is sometimes accompanied with a low temperature, nor hastily conclude from this lowering of temperature that the sun is less rather than more powerful. Considerations of this nature have induced me to think that the true connexion between sun-spots and terrestrial temperature is more likely to be discovered by a study of short-period inequalities of sun-spots than by that of the eleven-year period in which there is time enough to change the whole convection system of the earth. I have accordingly discussed at some length two prominent sun-spot inequalities of short periods (about twenty-four days), and endeavoured to see in what way they affect the terrestrial temperature. From this it appears that a rapid increase of sun-spots is followed in a day or two by an increase of the diurnal temperature range at Toronto. Now an increase of diurnal temperature range surely denotes an increase of solar energy, and we are thus led to associate an increase of solar heat with a large development of spots.

I have thus brought before you a quantity of evidence, chiefly indirect, tending to prove that the sun's rays are most powerful when there are most spots. But you will naturally ask why I have not given you any direct evidence on this point. Is it not possible, you ask, to measure the direct heating effect of the sun's rays, so as to decide the question without further circumlocution? Now, strange to say, this has not been done.

We call an instrument that measures the sun's direct influence an actinometer, and I will now briefly allude to two such instruments, one for measuring the chemical effect of the sun's rays devised by Dr. Roscoe, and another for measuring the heating effect of the sun's rays, devised by myself. (The lecturer here described the mode of action of these actinometers.)

But the use of such instruments is rather a problem of the future than of the past. Hitherto it cannot be said that we have determined by actual observation whether the sun's rays are more powerful or less powerful at times of maximum sun-spots. I may, however, quote the actinometrical observations made in India at Mussooree and Dehra by Mr. J. B. N. Hennessey as confirming, so far as the evidence goes, the hypothesis of greater solar energy at maximum than at minimum epochs.

My trust is that for the future India will throw great light upon the problem we are now discussing. We have a distinguished meteorologist, General Strachey, as member of the Council of India, we have General Walker and the trigonometrical survey staff, and we have Mr. Blandford and the various meteorological and magnetic observers of India, and I am glad to think that neither solar nor actinometric observations are likely to be forgotten.

Let me now briefly recapitulate the conclusions we have come to

In my first lecture I endeavoured to bring before you theoretical grounds for imagining that the sun is most powerful when there are most spots on its surface.

This has been supported by the evidence of a meteorological nature derived from these observations of rainfall, wind, barometric pressure, and temperature which have now been discussed, and likewise from such actinometric observations as have been made in Mussorree and Dehra. With regard to magnetical observations, we have the fact that diurnal declination ranges are largest in times of maximum sun-spots, and that on such occasions we have likewise a great number of magnetic storms, accompanied with earth currents and displays of the aurora. In fine we have most magnetic activity when there are most spots. There may perhaps be some doubt as to the exact method by which solar phenomena affect the magnetism of the earth, but we have already hypotheses from two distinguished physicists, the late Prof. Faraday and Prof. Stokes, while others have likewise been engaged in similar speculations.

Thus we may hope that eventually the truth will be attained. Meanwhile however we may conclude that the earth is most active both meteorologically and magnetically when there are most spots on the sun's surface. And if this be so, who will say that this is not a problem of great practical as well as of great theoretical importance?

ON GAS SUPPLY BOTH FOR HEATING AND ILLUMINATING PURPOSES[1]

WHEN, within the memory of living men, the gas-burner took the place of the time-honoured oil-lamp, the improvement, both as regards the brilliancy of the light and the convenience of the user, was so great that the ultimate condition of perfection appeared to have been reached. Nothing apparently remained for the engineer to effect but improvements in the details of the works and apparatus, so that this great boon of modern times might be utilised to the largest extent. It is only in recent years that much attention has been bestowed upon the utilisation of by-products, with a view of cheapening the cost of production of the gas, and that the consumer has become alive to the importance of having a gas of high illuminating power and free from nauseous constituents, such as bisulphide of carbon, thus providing a gentle stimulant for steady progress on the part of the gas-works manager.

This condition of steadiness and comfort has been somewhat rudely shaken by the introduction within the last year or two of the electric light, which, owing to its greater brilliancy and cheapness, threatens to do for gas what gas did for oil half a century before. The lighting of the City of London and of many public halls and works furnishes indisputable proof that the electric light is not an imaginary, but a real and formidable competitor to gas as an illuminant, and it is indeed time for gas engineers and managers to look seriously to their position with regard to this new rival; to decide whether to meet it as a foe, and contest its progress inch by inch, or to accept at once the new condition of things, conceding the ground that cannot reasonably be maintained, and to look about in search of such compensating fields as may be discovered for a continuation or extension of their labours.

For my own part I present myself before you both as a rival and as a friend; as a rival, because I am one of the promoters of electric illumination, and as a friend, because I have advocated and extended the use of gas for heating purposes during the last twenty years, and am by no means disposed to relinquish my advocacy of gas both as an illuminating and as a heating agent. Speaking as a gas engineer, I should be rather disposed to regard the electric light as a welcome incentive to fresh exertion, confidently anticipating achievements by the use of gas which would probably have been long postponed under the continued *regime* of a monopoly. Already we observe, both in our thoroughfares and in our apartments, gas-burners producing a brighter and more powerful light than was to be seen previously; and although gas will have to yield to the electric light the illumination of our lighthouses, halls, and great thoroughfares, it will be in a position, I believe, to hold its own as a domestic illuminant, owing to its great convenience of usage, and to the facility with which it can be subdivided and regulated. The loss which it is likely to sustain in large appliances as an illuminant would be more than compensated by its use as a heating agent, to which the attention of both the producer and the consumer has latterly been largely directed.

[1] Paper read before the British Association of Gas Managers at Birmingham, June 14, by C. W. Siemens, D.C.L., F.R.S., Civil Engineer.

Having in the development of the regenerative gas-furnace had exceptional opportunities of recognising the many advantages of gaseous over solid fuel, I ventured, as early as 1863, to propose to the Town Council of Birmingham the establishment of works for the distribution of heating gas throughout the town, and it has occurred to me to take this opportunity (when the gas managers of Great Britain hold their annual meeting at the very place of my early proposal) to place before them the idea that then guided me, and to suggest a plan of operation for its realisation which at the present day will not, I venture to hope, be regarded by them as Utopian. The proposal of 1863 consisted in the establishment of separate mains for the distribution of heating gas, to be produced in vertical retorts, that might be shortly described as Appold's coke oven heated by means of "producer" gas and "regenerators." The heat of the retorts was to be increased beyond the ordinary limit in order to produce a coke suitable for locomotive and other purposes; and the gas produced being possessed of less illuminating but of the same heating power, and being, with a view to cheapness, less thoroughly purified than ordinary retort gas, was to be distributed through the town as a heating agent, to be applied to the small boilers and furnaces of the numerous little factories peculiar to the district, as well as for domestic purposes. The Corporation applied for an Act of Parliament, but did not succeed in obtaining it, owing to the opposition of the existing gas companies, who pledged themselves to carry out such an undertaking if found feasible by them. I am ready to admit that at the time in question the success of the undertaking would have involved considerable practical difficulty, but I feel confident that the modified plan which it is my present object to bring before you would reduce those difficulties to a minimum, and open out on the other hand a new field of vast proportions for the enterprise and energy of those interested in gas-works, and of great benefit to the public.

The gas-retort would be the same as at present, and the only change I would advocate in the benches is the use of the regenerative gas-furnace. This was first successfully introduced by me at the Paris Gas-works in 1863, and has since found favour with the managers of gas-works abroad and in this country. The advantages that have been proved in favour of this mode of heating are economy of fuel, greater durability of retorts, owing to the more perfect distribution of heat, the introduction of an additional retort in each bed in the position previously occupied by the fire-grate, and above all, a more rapid distillation of the coal, resulting in charges of four hours each, whereas six hours are necessary under the ordinary mode of firing. The additional suggestion I have now to make consists in providing over each bench of retorts two collecting pipes, the one being set aside for illuminating, and the other for a separate service of heating gas. I shall be able to prove to you from unimpeachable evidence that the gas coming from a retort varies very greatly in its character during progressive periods of the charge; that during the first quarter of an hour after closing the retort, the gas given off consists principally of marsh gas (CH_4) and other occluded gases and vapours, which are of little or no use for illuminating purposes; from the end of the first quarter of an hour, for a period of two hours, rich hydrocarbons, such as acetylene (C_2H_2) and olefiant gas (C_2H_4) are given off; whereas the gases passing away after this consist for the most part again of marsh gas possessing low illuminating power.

M. Ellissen, the late chief of the experimental department of the Paris Gas-works, and actual President of the French Society of Gas Engineers, has favoured me with the result of a most interesting series of experiments, which he carried out in connection with the late M. Regnault, the eminent physicist, some years ago, the object of the experiments being to discover the proper period of time to be allowed for each charge.

The results of these experiments are given in a diagram showing in a striking manner that although the average illu-