Stevenson Macadam, *The Sanitary Aspects of Cooking and Heating by Coal Gas* (1892)

Stevenson Macadam,[1] *The Sanitary Aspects of Cooking and Heating by Coal Gas* (London: Walter King for the Research and Investigation Committee of the North British Association of Gas Managers, 1892).

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ON THE SANITARY ASPECTS OF COOKING AND HEATING BY COAL GAS.

The subject of the employment of coal gas in the cooking of food and for the heating of houses is one of great importance, and much has already been done to determine the power of gas to do the work. Specially in the Jury Report of the Exhibition[2] held by the Philosophical Society of Glasgow in 1880, two elaborate and instructive reports are given, one of which is on cooking by gas, and the other on heating by gas. The sanitary aspects of the question, however, have not received so much attention as they deserve; and, indeed, beyond a few skirmishes for and against flues, and bearing upon atmospheric pollution, little has been said. But whilst the sanitary aspects of heating by gas may be practically confined to the atmosphere, yet, in regard to cooking by gas, more detailed inquiry requires to be made as to the nature of the gaseous products evolved during the combustion of the coal gas, the effect of such on the meat undergoing the process of cooking, the wholesomeness of the cooked meat in retaining all its proper juices and elements, and in evolving all the vapours of a noxious nature produced during the cooking, as well as in the meat not absorbing noxious or deleterious elements, and in the keeping power and digestibility of the cooked material.

In approaching this subject, I resolved at the outset to devote special attention to proper cooking heats and their attainment in various stoves and to study the nature of the spent gases and the means provided for their escape. In order not to go over ground already well trodden, I took the Glasgow trials as the starting-point and resolved to experiment mainly with the three cooking-stoves which the Jury had placed first in the Glasgow Exhibition, and which had obtained certificates of merit, being the highest awards. These were Waddell and Main's (Glasgow) 'Universal Domestic', Wilson's (Leeds) 'Eclipse' Gas Kitchener,[3] and Wright's (Birmingham) Gas Cooker No. 492. On application to these firms, they at once agreed to place at my disposal stoves of the same size and pattern as those used in Glasgow, in order to enable me to experiment upon them in any way I might consider desirable. Many trials were made with these stoves, alike as to the necessary consumption of gas, the cooking temperature obtained in the ovens, and the nature of the spent gases. The results obtained may be summarized as follows:– /

Waddell and Main's 'Universal Domestic,' No. 3. – This stove stands 31 inches in height, has a top cooking space of 18¼ in. by 17 in., and an oven space of 18 in. by 14 in. and 14 in., being fully 2 cubic feet. The oven is lined with fire-brick both on the sides and the top; there are three boiling-rings on the top, and there is also a reflecting-ring within the top of the oven. Perforated fire-clay slabs are placed between the meat and pastry or bread. The fire-brick lining of the oven serves as an excellent non-conductor, and retains the heat within the oven. The interior of the oven is heated by a series of burners with small side jets which consume the gas with a white flame, as in ordinary house combustion; whilst the rings on the top of the stove are on the Bunsen principle,[4] and burn the gas with a blue non-luminous flame. Two of these upper / rings are used for heating pots or kettles; whilst the third is intended for grilling by deflection when covered with a plate, or for ordinary boiling purposes when the deflector is removed.

When using the oven alone, I found, with a consumption of gas ranging between 11.50 to 11.70 cubic feet per hour, that a cooking temperature of 340° Fahr.[5] was reached in 10 to 15 minutes; and that, keeping up the same quantity of gas, the temperature of 400° was obtained in an hour, which thereafter increased to nearly 500°.[6] As a temperature of 310° to 340° Fahr. is amply sufficient for the cooking of meat, such as joints, I made other trials which showed that after the oven had been heated to 340° Fahr. it could be retained at that temperature by an expenditure of 5.7 cubic feet of gas per hour. It therefore follows that, commencing to heat up the oven to roasting-point by using 12 cubic feet of gas per hour, you may in about 15 minutes reduce the consumption of gas to 6 cubic feet per hour, and still retain the proper heat for cooking a joint of meat. As the meat is well done in two hours, it follows that with a consumption of 14 cubic feet of gas the cooking of the joint may be accomplished. Moreover, pastry or a meat pie may be cooked at the same time within the same oven, and with no further expenditure of gas, except from the use of the browning ring within the top of the oven for 15 to 20 minutes at the close, so that a supply of gas decidedly under 20 cubic feet will amply suffice for the full cooking of joint and pastry, or joint and meat pie, or the whole contents of the oven. There remains the top cooking, where the vegetables – including soups, potatoes, &c. – are boiled. The upper rings consume about 12 cubic feet per hour; and 20 cubic feet in all would more than amply suffice for all possible contingencies, including even reasonable waste. It would thus appear that 40 cubic of gas would cover the cooking of a full dinner in an ordinary middle-class household;[7] and taking the price of the gas as 4s. 2d. per 1000 cubic feet, we have 2d. as the cost of the fuel required from first to last in the operation – being 1d. worth of gas for the two hours' work of the oven, and 1d. worth of gas for the boiling processes on the top of the oven. /

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The proportions of gas and cost given for these three first-class gas cooking-stoves have been reckoned on the assumption that roasts were required to be cooked every day; but if a less pretentious dinner be only prepared on alternate days, dispensing probably with much of the oven or top cooking appliances, the quantity of gas consumed and cost of fuel would necessarily be less, and in the majority of middle-class houses it would probably be found that, for stewing, grilling, and boiling operations on these alternate days, about 20 cubic feet, or 1d. worth of gas, would suffice for the preparation of the dinner. So that for the sum of 3d. the dinner for two days would be cooked. In the preparation of breakfast, the employment of the upper rings for the making of porridge, boiling of the kettle, cooking of fish, ham, or a chop, the making of toast, the boiling of eggs, &c., would certainly not consume more than 10 cubic feet of gas in any of the three stoves already referred to; so that, for an expenditure / of ½d. in gas, a substantial family breakfast would be laid upon the table. A similar sum would amply cover the whole expenditure in gas fuel for all the heating operations required for tea and supper.

The foregoing experimental results have reference to stoves sufficiently large for the daily wants of middle-class families; but, where less cooking is required, smaller-sized stoves may be used. The various 'little cookers' and 'bachelor' stoves will suffice to do all the cooking for a plain breakfast, dinner, or tea, at an expenditure in gas of 6 to 10 cubic feet per hour, or about 1d. per day. When consuming 6 cubic feet per hour, these little stoves in 10 minutes get up a temperature in the brander[8] of from 330° to 430° Fahr., according as the brander is placed farther from or nearer to the gas-jets.

The above remarks apply to the use of the gas-stoves at temperatures within the proper range for cooking purposes. By increasing the consumption of gas in the larger stoves, it is easy to obtain a heat which goes up to 500° and even to 600° Fahr.; but such high temperatures are no more desirable in gas heating-stoves than in ordinary coal heating-ranges. /

The sanitary aspects of cooking by gas must depend greatly upon the nature of the gases and vapours produced during the combustion of the coal gas, and which impinge upon the meat. These gases or vapours are mainly carbonic acid, water vapour, and sulphurous acid, accompanied, when the gas is improperly burned, by traces of carbonic oxide, acetylene, and other oily hydrocarbons.[9] The carbonic acid is formed in large quantities, ranging from 80 to 90 per cent. of the volume of the gas consumed. In special experiments on the Edinburgh gas, I found that 100 volumes of the coal gas yielded from 85 to 90 volumes of carbonic acid; so that in round numbers we may regard the gas as evolving during combustion about its own volume of carbonic acid. Taking the specific gravity of the coal gas as 500, and that of carbonic acid as 1529 (air = 1000), a cubic foot of the coal gas will weigh 268 grains, whilst the cubic foot of carbonic acid will weigh 821 grains.[10] This amount of carbonic acid can also be obtained by the combustion of 224 grains of carbon, of 298 grains of coal, from 1½ hours' consumption of a tallow candle, and from a small house-jet of coal gas. The water vapour is also produced in large quantity during the combustion of the coal gas, and special experiments on the Edinburgh gas showed that one cubic foot of the gas yielded from 1.4 to 1.5 cubic feet of vapour. The sulphurous acid gas is always formed during the burning of the coal gas, but the quantity is small. In 100 cubic feet of gas, we may take 10 grains of sulphur as an average proportion; so that 1 cubic foot of gas will contain 0.1 grain of sulphur. During combustion the sulphur burns into double its weight of sulphurous acid gas, so that the cubic foot of coal gas weighing 268 grains will yield 0.2 grain of sulphurous acid gas, or 1-1340th of the weight of the coal gas. The proportion of sulphur in ordinary coal may be reckoned as 0.5 in 100 parts, or 1-200th of the weight of the coal, yielding during burning 1.0 of sulphurous acid, or 1-100th of the weight of the coal, being fully thirteen times the quantity of sulphurous acid gas evolved during the combustion of coal as compared with coal gas, weight for weight.

The other products of combustion of coal gas, such as carbonic oxide, acetylene, and other oily hydrocarbons, are only formed during the imperfect combustion of the gas, as when burners do not properly fit their sockets, or the lights strike back and burn more or less smoky. In none of my trials with the gas cooking-stoves, where the gas was properly attended to, were any of these products observable in the spent gases. Undoubtedly, were the gas consumed imperfectly, acetylene would specially be produced, and would tend to taint the meat; but such can as readily be avoided, with reasonable care, as the smoking of food from an imperfectly lighted coal fire in an ordinary coal cooking-range.

In any stove and with any system of burners the ventilation of the stove must be kept up, so as to ensure that the products of combustion and the gases and vapours evolved from the meat during the cooking are carried away. A deficiency of ventilation may lead to the imperfect combustion of the gas, and even to the partial extinguishment of the lights and the tainting of the meat; but, at the same time, there must not be too much ventilation, for such would conduce to the lowering of the temperature in the oven, and to the drying up of the meat during the progress of the cooking. / The three stoves specially experimented upon by me were fully equipped with ventilating pipes.

The cooking of meat in the gas-stoves yields a large return of cooked meat than in the ordinary coal-ranges. The loss in ordinary cooking with an open fire or in a coal-fire oven – under the best circumstances of having water in the pan underneath, and repeated basting of the joint or *gigot* – is about 40 per cent.; while in meat cooked in gas-stoves the loss is only about 25 per cent. To a large extent the difference of 15 per cent. is due to the meat being constantly surrounded by an aqueous vapour or watery atmosphere derived in great part from the water produced during the combustion of the gas itself; there being about 1½ cubic feet of water vapour formed during the burning of every cubic foot of gas. The influence upon the meat of this atmosphere saturated with moisture, will be not only to keep the meat more moist, but to hinder the escape and evaporation of the juices of the meat, and to retain the osmazome[11] or flavouring matter, so that the meat, when properly done, will be found to be more juicy and more palatable, and yet free from those alkaloidal bodies produced during the confined cooking of meat, and which are more or less hurtful and even poisonous. As the gas-cooked meat is more juicy, it will be more easily digested; but it will be less liable to keep, owing to its being more moist and juicy. Dry meat undoubtedly keeps longer than moist and juicy meat, and if the dryness is carried out till little moisture is left and the meat is hardened, the material can be kept for months without tending to give way, but such dried and hardened meat is more difficult of digestion. The more juicy and tasty gas-cooked meat is a step in the right direction; for we cook to eat, and we eat to digest, so as to impart ready and immediate strength to the animal frame.

The best cooking-stove is one which an ordinary domestic can least fail to keep in order, and where the gas-jets are least likely to go wrong and lead to the imperfect combustion of the gas. In ordinary cooking, the Bunsen jets are more liable to strike back and burn imperfectly, leading to the formation of acetylene and other oily hydrocarbon compounds; whilst the common lighting jets, in their various forms, are least liable to get out of order. Moreover, the Bunsen arrangements are more difficult to light; there being a tendency for explosions to take place, and the lights to be blown out, and when once the Bunsen jets get clogged up with grease they are also more difficult to clean out.

A good gas cooking-stove should be easily heated, easily regulated, and easily worked. All of these conditions were practically obtained in the three stoves under special trial; but I am bound to say that they are more thoroughly obtained in Waddell and Main's stove than in the others, on the following grounds:—(1) That the fire-clay lining, being an excellent non-conductor, retains the heat within the stove without exposing iron to rust. (2) That the jets of gas may be turned down to the smallest lights without striking back or burning imperfectly. (3) That the stove door may be opened and shut without risk of extinguishing the lights or rapidly cooling down the stove.

In the use of a gas cooking-stove the ventilating flue from the stove should be carried into an ordinary chimney, and it will be better that the whole stove should be placed within an ordinary / fireplace, so that the gases produced during the combustion of the upper gas-jets may be carried out of the room. In my opinion the best arrangement would be to place the gas-stove within the ordinary open fireplace without any special building or damper fittings, and to carry the flue from the gas-stove oven only about 3 feet high in the open chimney. The result will be that the short flue will ventilate the oven into the chimney, and at the same time cause a draught which will facilitate the gases from the upper cooking-rings being also carried up the chimney.

A word about the sanitary aspect of heating-stoves. These should never be placed in any room or part of a house without being connected with flues to carry away the spent gases. The statement that no noxious gases are evolved because no smell is observable is quite erroneous. No doubt the gases given off from a heating-stove are the same as those yielded by an ordinary gas-jet in a room, and the inference is sometimes drawn that the heating-stove is no more hurtful than the lighting-jet; but the gas-stove and the gas-bracket are not placed under the same circumstances. When the light-bracket is burning during the long sittings of the winter months, our fires are keeping the rooms well ventilated; and though the common fires may be off during the summer, yet that is the period when our light-bracket is burning during only a few hours, and window ventilation is indulged in. Even when gaslight is kept burning all night in sick-rooms, it is generally lowered, and the ventilation is often aided by a fire in the room. The use of the gas-stove in any room, without proper ventilation, is dangerous, and the spent stove gases should invariably be carried into a chimney. No doubt the stove might be placed in the room without any connection with the chimney, and the room itself be ventilated; but this constant renewal of the air would be a wasteful expenditure of heat, and it would be much more economical to use the connection with the chimney vent. The constant heating of an apartment by a gas-stove would be rather expensive as compared with coal; but where, as in an evening, for an hour or two, it is desired to have a room heated in a ready and serviceable manner, the gas will beat the coal, alike for facility of doing duty and for strict economy.

The wholesomeness of the meat cooked in the gas-stoves must be regarded as beyond doubt. The mere impinging of the spent gases produced during the combustion of the coal gas upon the meat, in the process of cooking, cannot lead to the impregnation of the meat with any noxious matter. These spent gases and vapours are simply carbonic acid and water vapour, with minute proportions of sulphurous acid, and are the same as those evolved from a common coal fire used for grilling a chop or steak, and such have never been challenged as being unhealthy because the spent gases from the coal fire impinged upon them. Indeed, from the quantity of coal consumed in an ordinary coal cooking fire, the proportions or carbonic acid and sulphurous acid evolved therefrom must be many times greater than the amounts yielded by the gas cooking range; and hence the coal-cooked grilled meat should be more influenced by the spent gases than the gas-cooked meat. Moreover, during the process of cooking, the meat is always exuding vapour from itself, and hence is not liable to absorb other vapours which may surround it; so that, independently of the relatively inert / nature of the spent gases, the meat is prevented from absorbing such, were they even noxious. As the best practical proof of the wholesome nature of the meat cooked by gas, and of the absolute want of taint about such, I may further state that for several years I have been officially connected with a large establishment where all the principal joints and dishes, including pastry, are cooked in a gas-range, and I have invariably found the meat, &c., to be thoroughly well done, to be exceedingly good to the taste, and decidedly wholesome. In fact, no better cooked meat and pastry could be prepared, and be more palatable and acceptable.

For cooking purposes, I am confident that gas is not only serviceable but is also economical, besides being cleanly and handy. The attention required by an ordinary coal-range is mainly occupied in the firing or heating operations, and not in the actual cooking process. Either the fire must be kept in night and day for service at only limited periods, or, if allowed to go out, preliminary processes of lighting up with paper and sticks and coal must be gone through for some time before the fire-range is available for service. On the other hand, the gas-stove and cooker is ever ready for work, and the mere turning of a cock and lighting of the gas at once places the gas-range in serviceable order for cooking purposes. Moreover, the coal fire or range is difficult to regulate – at times too hot, at times too cold – but the gas fire or range can, in a moment, be raised or lowered in heating power by the mere opening or closing of the stopcock; and, still further, the coal-range becomes clogged with ash *débris*, which must be removed now and again, leading to much dust and annoyance, while in the gas-range there are no residual products or ashes to remove.

Independently of the more cleanly and handy nature of gas heating-stoves over coal heating-ranges, there is the practical question of the relative cost of fuel. I have already given the detailed statements based upon experimental data, proving that any of our best gas-ranges may be thoroughly worked for all the necessary cooking connected with an ordinary middle-class family at an expense in gas not exceeding 4d. per day, and where more moderate roasting operations are carried on, on alternate days, for about 3d. a day. Taking the larger of these figures as representing use and probable waste, we have to contrast such with the cost of coal. Now I have determined, in two coal cooking-ranges connected with moderate-sized middle-class houses, that the amount of coal used in ordinary working, including actual cooking and keeping the fire in during the intervals, runs from ½ cwt. to 1 cwt. per day; and taking the average price of coal as laid down in house cellars as 16s. per ton, the cost of the coal used in the coal cooking-ranges would be from 8d. to 16d. per day, or an average of 1s. per day. Taking even the lower figure of 8d. per day, which is rather within the mark, we find that the cost of the fuel for a serviceable coal cooking-range is twice that of a gas cooking-range. Of course, the coal-range is always more or less on duty, whether required or not; whilst the gas-range is only on duty when absolutely required, but is always ready for work at a moment's notice. I admit that the coal-range also heats the kitchen, and probably also heats water in a boiler at the same time, and some allowance must be made for these extras, in the way, either of having a supplemental heating fire in winter or employing extra / gas for such purposes; as, indeed, has been done in some gas-stoves. But, taking everything into consideration, I am of opinion that gas cooking will beat coal cooking in cost of material, as well as in facilities of doing work; in cleanliness; and in efficiency.

Another and very important element in the question of economy is the respective yield of cooked meat from the coal and gas ranges, which in the case of the coal range is 60 per cent. of the raw material and of the gas-range 75 per cent.; which practically means this – that a joint or *gigot* weighing 10 lbs. as purchased from the butcher will come out of the coal-range in a cooked condition weighing 6 lbs., and out of the gas-range weighing 7½ lbs., being a difference of 1½ lbs. in favour of the gas-range. Now, granting that a part of this difference or saving is due to the retention of more water vapour in the meat, there can be no doubt that in the other part it is due to the meat juices being more thoroughly kept in the gas-cooked meat. The practical dietetic result is that the latter cuts out better and goes farther, in the proportion of 25 per cent. more, than the coal-cooked meat. Taking this excess of cooked meat alone into consideration, the saving is far more than ample to cover the whole cost of gas fuel, allowance for cost of stove, and even attendance thereon.

In smaller houses, where the little cooker and bachelor stove is sufficient, especially in summer, when no heating fire is required, the economy in using the gas-stoves must be very great. For an expenditure of 1d. in gas, the whole cooking can be accomplished for the day with comparatively no trouble in lighting the fire, carrying coals, and removing ashes. When required, the gas can be instantly lighted, and the stove is practically in use in a minute. When the cooking is done, the gas is turned off, and the expense instantly stopped. If the kettle requires to be kept hot, the water may simmer away for hours with a minute jet of gas, and the temperature be instantly raised when boiling water is wanted – no preliminary expenditure in sticks or lighters, and no delay or time wasted. Moreover, no smoky chimneys, no soot falling into pots, no cleaning up of fire-places, and no ash-dust diffused throughout the room. Sooty hands, blackened faces, and tarnished dresses reduced to a minimum.

Finally, my experiments on the gas-stoves have thoroughly satisfied me that Scotch gas or cannel gas,[12] as now supplied in Scotland, can be used with efficiency in the heating of gas-ranges, and that there is no necessity to reduce the quality of lighting gas to suit any supposed standard for heating gas. Economy, however, may necessitate that as coals of high-class quality fail or get scarce, we may require to use coals of lower-class quality; and if such be advisable for lighting purposes, then no harm will ensue for heating operations. The primary use of gas is for lighting, and I have every confidence that cooking will adapt itself to the lighting necessity of the time. /

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‘Electricity and the Electric Telegraph’, *Cornhill Magazine* (1860)

‘Electricity and the Electric Telegraph’, *Cornhill Magazine*, 2:7 (July 1860), pp. 61–73.

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Before entering on the question of the application of electricity to telegraphy, a brief recapitulation of the great physical facts on which every attempt of the kind has been based will render the subject more intelligible to the uninitiated. Frictional, or, as it is commonly termed, *statical* electricity, evolved by rubbing glass or kindred substances, is possessed of the property of attracting light substances, such as shreds of paper or pith balls. It also emits sparks, either in the process of evolution, or in its accumulated state, as in the discharge of Leyden jars.[1] Voltaic electricity, evolved by chemical change, chemical combination, and the contact of two dissimilar metals, causes a magnetic needle to deviate from its natural position; it confers magnetism on soft iron; and it also possesses the power of decomposing numerous chemical combinations in solution. Magneto-electricity, evolved by the approximation[2] of a bar of magnetized steel to a coil of wire, followed by its sudden withdrawal, produces effects precisely similar to those of voltaic electricity.

The question of the invention of the electric telegraph has long been a sorely vexed one. The honour has been claimed for America, for England, and for nearly every country on the continent. The scientific world is doubtless divided in its opinions as to the practicability of those early inventions which were worked by means of frictional electricity. But a series of experiments instituted in 1816, showed that the obstacles which had so frequently baffled preceding inventors, were partly of a pecuniary nature, and were not therefore absolutely insurmountable. The question, thus extricated from a labyrinth of prejudice, of conflicting claims, and of still more conflicting opinions, might therefore assume somewhat of the following historical development. One hundred and seven years ago, there appeared in the *Scots' Magazine* a remarkable letter dated from Renfrew, and headed, 'An Expeditious Method for Conveying Intelligence.'[3] Premising that electricity is transmissible through a short wire without any apparent diminution of intensity, the writer shows how, in his opinion, it may be turned to practical account. Extend wires, equal in number to the letters of the alphabet, between two distant places; support them at intervals on glass fixed to solid bodies; let each wire terminate in a ball; place beneath each ball, a shred of paper on which the corresponding letter of the alphabet has been printed. Bring the further end of the first wire into contact with an excited glass tube,[4] and the paper 'A' will instantly rise / to the first ball, in virtue of the principle of attraction. Thus the whole alphabet may be represented. A series of electrical bells, decreasing in tone from 'A' to 'Z,' may be employed instead of the paper. Possible objections are anticipated and met, by showing how the wires may be insulated throughout.

Such was the first electric telegraph invented in 1753; an instrument theoretically accurate in every detail, although rendered impracticable for any considerable distance by its cumbrous arrangement of wires. But the genius which was capable of contriving, was, no doubt, equal to the task of improving. Little is known of the inventor, beyond the fact that an elderly Scotch lady remembered a 'very clever man' of obscure position, named Charles Marshall, who could make 'lichtnin'[5] write an' speak;' and who could 'licht a room wi' coal-reek' (*Anglice*[6] – coal-smoke). However humble the sphere in which he moved, Marshall was clearly a man of no ordinary intellect. Mark the significance of his words, – '*An Expeditious Method for Conveying Intelligence!*' At a time when the very alphabet of the science was unformed, he saw what had not only escaped the acute intellect of Franklin, but what had evidently never been dreamt of by men who inherited the thrones of Newton, of Halley, and of Boyle. In describing the intellectual aspects of that half-century, which not only saw Reid and Smith, Hume and Robertson,[7] in the zenith of their fame, but gave birth to Burns, to Scott, and to Carlyle, some future Macaulay may adorn his 'pictured page' by stories of humble Scotchmen, who gave to civilization the steam-engine, the steam-ship, the electric telegraph, and the gas with which we light our houses and our streets.

In the year 1774, Le Sage, a Frenchman, resident in Geneva,[8] who has been hitherto recognized by many as the originator of electric communication, submitted a plan to Frederick of Prussia, which differed so slightly from that which we have just described, that an account of it might seem a *rifacimento9* of the letter of Charles Marshall. The next we read of, that of M. Lomond, appeared in 1787, and consisted of only one wire; the signals being indicated by the attraction and repulsion of pith balls. Arthur Young – who explains the *modus operandi* in his *Travels* – describes the inventor as a 'very ingenious and inventive mechanic.' 'As the length of the wire makes no difference in the effect,' says the clever and vivacious advocate of *la grande culture, 'a correspondence might be carried on at any distance.'*[10] Other projects followed, in some of which the active principle was that of the discharge of Leyden jars; the first suggestion of which was made so early as 1767, by a professor of natural philosophy in Rome, named Bozolus, and not by Cavallo,[11] as has been hitherto supposed. Each and all of those attempts may, however, be justly regarded as experiments, as it was not until 1816 that their practicability for a distance of eight or ten miles was satisfactorily demonstrated by Mr. Ronalds, of Hammersmith;[12] who, by the provision of perfect insulation, overcame, to some extent, the difficulties which had so frequently baffled his predecessors. About that period, however, the superiority of / Voltaic electricity over that of friction for such purposes became apparent. The former is regular, controllable, and easily held in its legitimate channel, whilst the latter is unsteady, and remarkable for its high tension, escaping easily from its conductors.

During the succeeding twenty years several inventions appeared, some of which were failures, whilst others were more or less successful on a limited scale. Still, grave doubts existed, even in the minds of some distinguished philosophers, as to the practicability of such schemes for great distances, until Professor Wheatstone[13] asserted, in 1834, that the velocity of electricity exceeded 280,000 miles in a second. Three years later, he, in conjunction with Mr. Cooke, patented an invention which, in one sense, deserves to be recognized in the same light as the first steam-engine of Watt; and which, after having undergone numerous improvements, ultimately assumed the form of that 'double-needle' instrument so common in this country. On the night of the 25th of June, 1837, this famous invention was subjected to trial in the presence of several distinguished men; – prominent among whom was the late Robert Stephenson. Wires stretching from Euston Square to Camden Town were connected with the instruments. At the one end stood the able and energetic Mr. Cooke, at the other his coadjutor, Professor Wheatstone. The experiment was successful. 'Never,' says one of the inventors, 'never did I feel such a tumultuous sensation before, as, when all alone in the still room, I heard the needles click; and as I spelled the words, I felt all the magnitude of the invention, now proved to be practicable beyond cavil or dispute.'[14]

Another instrument, most extensively employed, is the recording one, invented in the autumn of 1837, by Professor Morse.[15] In a letter addressed to the Secretary of the Treasury of the United States, written in September of that year, the inventor says:– 'About five years ago, on my voyage home from Europe, the electric experiment of Franklin upon a wire some four miles in length was casually recalled to my mind in a conversation with one of the passengers, in which experiment it was ascertained that the electricity travelled through the whole circuit in a time apparently instantaneous. It immediately occurred to me, that if the presence of electricity could be made visible in any part of this circuit, it would not be difficult to construct a system of signs, by which intelligence could be instantaneously transmitted. From the pressure of unavoidable duties, I was compelled to postpone my experiments, and was not able to test the whole plan, until within a few weeks. The result has realized my most sanguine expectations.'

In the following year Mr. Edward Davy[16] patented an electro-chemical recording instrument, which formed the basis of the 'printing' one of Bain, an obscure clockmaker from Watten in the 'far north,'[17] whose ingenuity gave a powerful impetus to the art of telegraphy in the earlier stages of its progress.

As the 'needle' instrument of Cooke and Wheatstone, the electromagnetic one of Morse, and the electro-chemical one of Bain, form the / grand types of the telegraphic system, and are more extensively used than any other, we shall proceed to explain the relation of their component parts – the battery, the instrument, and the conductor, – with their respective modes of operation.

A battery, in its simplest and most intelligible form, consists of three elements, namely, – two plates of dissimilar metals, such as zinc and copper, and a solution of sulphuric acid and water. The moment the plates are metallically united, electricity is generated. Originating, we shall say, at the zinc, it traverses the wire, then proceeding down the copper, passes through the solution to the point whence it started. An unbroken 'circuit' is thus formed, consisting of the zinc, the uniting wire, the copper, and the solution. Break the continuity of that circuit by snapping the wire, and no current can possibly be generated. Electricians have long differed in opinion as to the origin of the fluid.[18] Volta[19] had triumphantly shown that the mere contact of two dissimilar metals developed it, and his opinion still finds numerous advocates on the continent. The 'contact theory' was combated, however, so early as 1792, by Fabroni,[20] who, in a paper communicated to the Florentine Academy, attributed the fluid to chemical change. According to this theory, which has obtained universal assent in this country, it is the result of the union of the zinc with the oxygen of the water; the quantity of electricity being dependent on the amount of zinc oxydized. Thus chemical combination and chemical decomposition alike contribute to its generation.

To recur to our illustration. Make your uniting wire a hundred miles in length, instead of a few inches: the result, in rapidity of operation, and indeed in every respect, will be similar, save in the proportionate diminution of intensity, consequent on the greater length. Extend a wire from the zinc to a distance of one hundred miles, bury its further end in the ground, connect the copper by a short wire to the ground also, and the result will still be similar – a circumstance which obviates the necessity of 'return' wires for electric telegraphs. Two theories, perhaps equally plausible, and equally consistent with certain recognized laws, have been propounded to account for this interesting phenomenon. The one implies that the current is a foreign element – something superadded to the wire, and that it must therefore be discharged into the *earth* – the great reservoir of superabundant electricity. The advocates of the other theory maintain that the fluid, starting from the zinc, traverses the long wire, and returns through the intervening ground to the copper plate. Should the question be asked, 'Why should a current transmitted from Edinburgh to London not go elsewhere, rather than return to the precise point whence it started?' the answer given is, that the ground between the two places forms one half of the circuit – being equivalent to a 'return' wire. A current cannot be generated in any battery unless an absolutely unbroken circuit exists – unless we provide a way, however roundabout, whereby the fluid evolved at one pole may return to the other. The battery has been in this case not inaptly / compared to a loaded gun; the completion of the circuit being equivalent to the fall of the trigger. A single pair of plates produces too feeble a current for telegraphic purposes, however, and it is found necessary to multiply the number by arranging a series of zinc and copper alternately in a trough. The combined force thus obtained may be said to be proportioned to the increase in number.

The needle instrument, which is now in operation over probably 25,000 miles of wire in England and Scotland alone, is based on the principle of the deviation of a magnetic needle when subjected to electric influence. If the one end of a telegraphic wire, stretching from Edinburgh, and having its other extremity buried in the *earth* in London, be connected with the *zinc* pole of a battery which has its *copper* one in metallic contact with the ground, a current, originating at the zinc, will flow along the wire to London, plunge there into the ground, and return through the intervening earth between the two cities to the copper. If while this current is flowing, a magnetic needle be placed in close proximity to the wire at any point between the two places, it will swing round from its natural position, and place itself at right angles; thus, instead of pointing northwards, it will point, say, towards the west. Now if we reverse the connections of the battery in Edinburgh, by putting the wire into contact with the copper end, whilst the zinc is connected to the ground, the magnetic needle would still place itself at right angles to the wire; but in this case it would swing round to an opposite direction, and point eastwards. If a Schwiegger's Multiplier, as described by Moigno,[21] be interposed at London, *so that the current will flow round its convolutions before entering the ground*, the magnetic needle placed inside will deviate from its vertical position, say to the *right;* and if the battery connections be reversed in Edinburgh as formerly, it will change to the *left*.

Such an arrangement would be to all intents and purposes an electric telegraph. Any person in Edinburgh, having control over the battery, might transmit at will a series of preconcerted signals, consisting of movements to the right and to the left, intelligible to some one in London. Now if both cities are provided with batteries and with Schwiegger's Multipliers, it is obvious that the communication could be made reciprocal, so that Edinburgh could not only speak to London, but *vice versâ*. Multipliers might also be placed in circuit at any point between the two places, so that correspondence might be carried on simultaneously between twenty different towns – the essential condition being the provision of an unbroken metallic channel throughout the whole length, however numerous the *détours* from the main line of wire. The instruments generally require two wires, and contain two multipliers at the back of the dial. The indicating needle in front of the dial is fixed on the same axis as the magnetic one enveloped in the multiplier, so that the deviations of the one correspond with those of the other. The handles are simply mechanical expedients for bringing the battery power into play; for making and breaking the circuit; or for reversing the direction of the current – in short, for / performing with rapidity and precision what we previously supposed was done by the hand. It is obvious, therefore, that if Edinburgh *sends* a message to London, his handles are moved, but if the *receives* one, his needles alone are influenced.

The alphabet is formed partly by simple, partly by complex deviations. Take the *left*-hand needle:– Two movements to the left indicate A; three, B; once right and left, C; once left and right, D; once right, E; twice, F; three times, G. The following eight letters are formed by the simple movement of the *right*-hand needle, whilst the remaining portion of the alphabet is represented by *combined* movements. The rate of transmission varies greatly, being dependent not merely on the experience of the telegraphist, but on his education and quickness of comprehension. An intelligent operator would find no difficulty in reading forty words per minute, whilst an illiterate railway signalman would find *two* sufficient for *his* comprehension in an equal space of time. This instrument possesses some undoubted advantages over others, but experience has shown that for long lines, one or other of those recording instruments, which remain to be explained, are preferable.

The 'printing' telegraph of Morse, so extensively used throughout America, and which is rapidly superseding every other form on the continent, is based on the principle of electro-magnetism. We have shown how the magnetic virtue can be conferred on a piece of soft iron, or removed at will. If a steel 'pricker' or style attached to the armature of an electro-magnet, having its two horns upwards, be so arranged that a ribbon of paper may pass immediately *above* it, it is obvious that when a current is passed round the magnet, the armature will be attracted, and the 'pricker' will scratch the paper. Now, suppose you are in London, and that by simply depressing a key, like that of a pianoforte, you could cause a current from a battery to flow along a wire to Edinburgh, so that it would pass round the wire of an electro-magnet placed there, – it is obvious that you would cause the armature to be attracted, and the paper, if any, to be scratched. Depress the key for an instant, and you leave a small scratch, resembling that of a pinpoint; depress it a little longer, and a longer scratch is left. You have here the exact *modus operandi*. A ribbon of paper is unwound by mechanism, and during this process a series of dots and dashes are scratched on it, which are translated by the telegraphist. The alphabet, as given in a recent work, runs as follows:

A	B	C	D	E	F	G	H	I	
•—	—•••	—•—•	—••	•	••—•	— —•	••••	••	&c.

It will be observed that this alphabet, which reminds us of the celebrated *A* and *B* cypher of Lord Bacon,[22] is based on two primary characters. The instrument could produce only a long line, or a series of dots, and the result is a character unsurpassed in the history of cryptography for its simplicity and ingenuity. Another interesting circumstance in connection with this alphabet is its universality. Being as intelligible to the continental / telegraphist as to the English one, a message in English may be rendered with the greatest accuracy in St. Petersburg, although the Russian operator may know no language but his own.

The 'printing' instrument of Bain, in use on some English lines, is based on that principle of electro-chemical decomposition which Sir Humphry Davy[23] and Ritter[24] so successfully elucidated. If a piece of paper, dipped in an acidulated solution of yellow prussiate of potash, be brought into connection with the *zinc* end of a battery, a steel point conveying a current from the *copper* end will leave a deep blue mark, so long as the circuit is complete. A ribbon of paper so saturated, and resembling a roll of cotton tape, is unwound by mechanism, whilst the alphabet is also formed by dots and dashes. The *modus operandi* of this instrument resembles that of Morse so closely, that the only essential difference lies in the fact of the paper being chemically prepared.

A valuable adjunct to the last two machines deserves special mention. We allude to the 'Relay.' A current may be too weak to influence a large magnet, or to decompose a chemical solution *directly*, yet it may be adequate to the task of influencing a small magnet, or a needle, in such a way as to bring fresh *local* battery power into play sufficient for the required purpose. Contrivances of this kind, termed 'relays,' are also peculiarly valuable on long lines. A battery in London may be incapable of producing intelligible signals in Copenhagen, but it may possess sufficient power to work a 'relay' placed in Hamburg, and so arranged that, bringing fresh power into operation, it repeats with the utmost accuracy the signals transmitted from London; re-impelling the message to Copenhagen as rapidly and correctly as if the London current had traversed the whole length, and thus performing efficiently by mechanical means what would otherwise be inefficiently done by the human hand.

Other kinds of instruments might be deemed worthy of a detailed description, such as those in which the letters are printed in Roman capitals, or represented by an indicator revolving on a circular dial; but as they are seldom used, being peculiarly liable to derangement – and more remarkable for ingenuity than for utility – we shall content ourselves with a simple statement of the fact, that in such cases, the object is attained by the liberation of mechanism through the influence of an electro-magnet: much in the same manner, indeed, as those bells which, occasionally appended to the 'needle' instrument, we often hear ringing at railway stations.

The wire, stretched on poles, which conveys the current to its destination, is generally made of iron which has been previously subjected to the process termed *galvanization*, by being raised to a high temperature and drawn through a bath of melted zinc. The sole object of this amalgamation is the prevention of oxidation, or rust. In such cases, however, the bare wire must be supported by *insulators*, made of earthenware, porcelain, or glass; which, in virtue of their non-conductibility, serve to keep the fluid to its legitimate channel, – the great object of insulation being the prevention of any escape to the ground, through / moisture or other causes. Underground wires, and those which are stretched in damp tunnels, are generally made of copper, invested with one or two coatings of gutta percha.[25]

Another interesting branch of our subject is that of submarine telegraphy. Although, from an early period, it was obvious to those who were conversant with electrical science that an insulated wire could convey a current under water as easily as on the land, still it was not until the introduction of gutta percha as an element in the construction of telegraphs, that subaqueous communication was recognized as *un fait accompli*. A perfect non-conductor, and apparently possessed of the requisite homogeneous, plastic, and pliant properties, no substance seemed better adapted for such purposes, and in the first great trial to which it was subjected in September 1850 between France and England, the result was highly satisfactory. As the feeble experimental rope submerged on that occasion snapped, however, within a few days, submarine communication may be said to date only from October 1851, when a strong one was successfully deposited. In manufacturing a cable, the conducting medium – generally a copper wire – receives three distinct coatings of gutta percha, with a view to the prevention of leakage; it is then surrounded by one or two coatings of hemp or tow soaked in pitch, and is finally surrounded by a sheathing of galvanized iron wires, twisted longitudinally, so that it may acquire the requisite strength, protection, and flexibility.

The failure of the last effort to establish trans-Atlantic communication may be attributed to certain mechanical and engineering defects, which are not likely to operate in any future attempt. Difficulties of a much more serious nature remain, however, to be encountered. Long submarine cables are found to be practically elongated Leyden jars. The conducting wire is analogous to the internal coating, the outer metallic sheathing to the external one. The wire must, therefore, be regularly discharged of the superfluous fluid before it can be used for its legitimate purpose. It has also been found that long lines running parallel to the equator, are peculiarly susceptible of the disturbing influences of induced currents of terrestrial magnetism. Judging from such circumstances, and the results of recent experiment, we think that it would be scarcely possible to transmit more than three or four brief messages per hour by one wire to Newfoundland. There can be no doubt, however, as to the ultimate success of the Atlantic scheme, in a mechanical and engineering point of view, if the necessary conditions are scrupulously fulfilled.

In endeavouring to explain our subject, we have been influenced by a desire to illustrate essential principles rather than subsidiary details. The modifications of the battery are endless, but the fundamental principle of chemical decomposition and chemical affinity is in every case the same. The instrument may assume forms which appear widely different from those which we have selected as types, but each and all will generally be found to be based on one or other of those great physical laws which we have endeavoured to illustrate. /

It is unnecessary to enter into any details as to the manifold purposes to which the electric telegraph is now applied. Already it has become an indispensable agent of civilized society – materially influencing the political, social, and commercial relations of every country in Europe. And from whatever point of view we regard it, we cannot but feel convinced that science, in this her most brilliant achievement, has placed in our hands an instrument which adds another link to that chain of causes which is slowly, silently, and imperceptibly bridging over the chasms which separate nation from nation and race from race; and whose influence on the future of civilization it is impossible to estimate. Its frail tendrils have not only penetrated into every corner of Europe – into remote lands whose religious systems and social institutions exist now as they existed at a time when our ancestors were mere barbarians, but it conveys its own significant lesson to the Indian in his wigwam, to the Hottentot in his kraal,[26] and to the Arab in the desert.

In conclusion: What is electricity? Science has hitherto failed to answer the question satisfactorily. Some hold that it is a *state* or *condition of matter;* others, that it is an independent substance, an impalpable, imponderable, and highly elastic fluid. The nomenclature of the science is, therefore grounded, in some measure, on hypothesis. *Fluid, current, positive, negative*, are simply the convenient terms of convenient theories. We talk of electricity 'traversing a wire;' but an opinion has long been gaining ground that it merely influences the molecular arrangement of the conductor: that, instead of propagating itself by a series of pulsations, it simply causes every component particle to assume certain electrical conditions. We talk of 'positive' and 'negative,' as if there were two distinct currents, one of which is more powerful than the other; whilst in reality this dual force is co-existent, co-active, and mutually dependent, just as if there were only one which, under certain conditions, is capable of producing diametrically opposite results. This uncertainty is by no means confined to electrical science.

We produce light and heat; we throw a stone into the air with an absolute conviction that it will fall to the ground. There are laws of light and of heat, and there is a law of gravitation. But a law implies something – a force, an agency; and what are those forces or agencies? We talk proudly of 'man's dominion over nature,' of 'scanning the heavens,' of 'taming the lightning,' but we can see little beyond the shows of things. The shadow is there, but the substance eludes our grasp. Like the physiognomist, we may indeed decipher something of Nature from the aspect of her countenance, but we cannot see the workings of her inmost heart. The greatest philosopher among us is still, as in the days of Newton, like a child standing on the seashore. The illimitable ocean lies outstretched before him. Now and then she casts a pearl at his feet. But her richest treasures lie far down in those unfathomable depths which mortal hand can never reach, and mortal eye can never pierce. /

‘Electricity as a Light-Producer’, *Chambers Journal* (1877)

‘Electricity as a Light-Producer’, *Chambers Journal*, 721 (20 October 1877), pp. 667–9.

ELECTRICITY AS A LIGHT-PRODUCER.

It has long been the opinion of scientific people that in electricity we have a power the development of which is only at present in its infancy. The marvellous details of our telegraphic system constantly remind us that there is a mysterious fluid round about us which can to a certain extent be made subservient and obedient to the will of man. This familiarity with that which would a few centuries ago have been stigmatised as the outcome of sorcery, has led the ignorant to place a blind belief in its powers. The subtle fluid has in fact taken the place of the necromancer’s wand, and is believed by many to be capable of anything or everything. The electrician is thus credited with much that does not of right belong to his domain, and the wildest speculations are occasionally indulged in as to what next he will do for us. That electricity will prove of far more extended use than the present state of knowledge allows, we all have vague anticipations, and among these is the reasonable hope that it will some day supersede coal-gas as a means of artificial illumination. We propose, by a brief review of the present position of electrical research, to point out how far such a hope is justified by facts.

Sir Humphry Davy[1] was the first to discover that when the terminal wires of a powerful electric battery were furnished with carbon-points and brought into such a position that they almost touched, the space between them became bridged over with a dazzling arc of light. The excessive cost of producing this light (owing to the rapid consumption of the metal-plates and acids which together form the battery-power) rendered it for a long time almost inapplicable to any other purpose than that of lecture-room demonstration. But it was evident to all that a means of illumination so nearly approaching in its intensity the light of the sun, would, if practicable, be of immense value to society at large. Apart from its cost, there were many other hindrances to its ready adoption. The incandescent carbon-points – which we may here remark are cut from a hard form of gas-coke – were found to waste away unequally. Some plan had therefore to be hit upon of not only replacing them at certain intervals, but also, in view of this inequality of consumption, of preserving their relative distance the one from the other; otherwise the light they gave became intermittent and irregular. These difficulties were met by employing clock-work as a regulator, and more recently by a train of wheelwork and magnets set in motion by the current itself. These arrangements naturally led to complications, which required the constant supervision of skilled operators, and the coveted light was necessarily confined to uses of a special nature where the question of cost and trouble was unimportant.

The use of the battery for the electric light has for some years been almost entirely superseded by the magneto-electric machine. The construction of this machine is based upon Faraday's discovery,[2] that when a piece of soft iron inclosed in a coil of metal wire is caused to pass by the poles of a magnet, an electric current is produced in the wire. The common form of this machine consists of a number of such iron cores so arranged upon a revolving cylinder that in continual succession they fly past a number of stationary horse-shoe magnets placed in a frame round its circumference. By a piece of mechanism called a commutator, the various small streams of electricity thus induced are collected together into one powerful current. This invention forms one of the most advanced steps in the history of the electric light. But although it produces electricity without the consumption of metal involved in the battery system, another element of cost comes into view in the expense of the steam-power necessary to work it; besides which the original outlay is considerable.

In the year 1853 a Company was formed at Paris for producing (by the aid of some large magneto-electric machines) gas for combustion, by the decomposition of water. The Company failed to produce gas, and what was perhaps more to the annoyance of the subscribers, they failed also to shew any dividends, and the expensive machines were voted impostors. However, an Englishman, Mr Holms,[3] succeeded in turning them to better account, and eventually produced by their aid a light of great power. Mr Wilde of Manchester[4] was another worker in the same field; and improved machines were soon introduced to public notice by both gentlemen. A few years after, the South Foreland and Dungeness lighthouses were provided with experimental lights. (The first-named headland had previously been furnished with an oxyhydrogen or lime light,[5] a source of illumination which is also open to the same objections of requiring constant attention and renewal.)

It is a matter of surprise to most visitors to the South Foreland lighthouse to find that a small factory and staff of men are necessary to keep the electric apparatus in working order. The extent of the establishment is partly explained by the fact that, in case of a breakdown of any part of the apparatus, everything is kept in duplicate. Hence there are two ten horse-power steam-engines, and a double set of magneto-electric machines, although only half that number are in actual use at one time. The old oil-lamps are also kept ready, in view of the improbable event of both sets of electrical apparatus going wrong.

Although lighthouses were the first places to which electrical illumination was applied, there are many other purposes for which that species of light is invaluable. One of the chief of these is its use in submarine operations. Unlike other lights, being quite independent of atmospheric air or any kind of gas for its support, and merely requiring an attachment of a couple of gutta-percha-covered wires[6] for its connection with the source of electricity (which may be at a considerable distance from the place of combustion), it is specially applicable to the use of divers. The importance of a means of brilliantly lighting the work of those engaged in clearing wreck or laying the foundations of subaqueous structures cannot be over-estimated. There is another service too in which we may hope some day to see it commonly employed: we mean as a source of light to our miners. For this purpose, the burner could be placed in a thick glass globe hermetically closed;[7] / in fact the globe might even be exhausted of air, for experiments prove that the light is in several respects improved when burnt in a vacuum! The danger of fire-damp explosion would by this means be almost altogether obviated; for unless the glass were broken (and abundant means suggest themselves for protecting it), no communication could be made between the light and the gas-laden air of the mine. As a means of night-signalling, the electric light can also be profitably applied. This can be done by an alphabet of flashes of varying duration; the readiness with which the light can be extinguished and rekindled by the mere touch of a wire, rendering it peculiarly adapted for such a purpose; while the distance at which it can be seen is perhaps only limited by the convexity of the earth. Several of Her Majesty's ships are now being fitted with the electric light, which is to serve both for signalling purposes, and as a precautionary measure against the attack of torpedo-boats. For military field operations a brilliant light is often useful; and an electrical apparatus is in actual use by one of the belligerents in the present war.[8] In this case, the light is doubtless worked by an electric battery, as a steam-engine is hardly a convenient addition to the impedimenta of a moving column.

Having called our readers' attention to the several special public uses for which the electric light is available, we may now consider how far it can serve us for the more common wants of every-day life. In its crude state as we have described it, governed by such a touchy thing as clock-work, it could not possibly compete with gas for ordinary purposes. But one or two improvements have within the last few months been made, which have led many to hope that the day is not far distant when the light will become common in our streets, if not in our houses.

These improvements are two in number. The one is a plan whereby the electric current can be subdivided so as to serve a number of different lights, and the other is an improvement in the arrangement of the burner. The first-mentioned invention seems most certainly to bring the system more on a par with gas-lighting, only that wires take the place of pipes. But the second offers features of a more novel character. The carbons, instead of being placed point to point, one above the other, as in the old system, are put side by side and made into a kind of candle. The carbons therefore represent a double wick; while the portion of the candle usually made of tallow is made of kaolin, a form of white clay used in the manufacture of porcelain. The points are thus kept at a fixed distance apart; and as they burn, they vitrify the kaolin between them, which both checks their waste and adds, by its incandescence, to the light produced. The old difficulty of keeping the carbons apart by the aid of clock-work, therefore disappears. The invention of this 'electric candle' is due to a Russian engineer, M. Jablochkoff.[9] Another plan which is also credited to the same inventor is that of doing away with the carbon-points altogether, and substituting for them a thin plate of kaolin. The light produced is said to be softer, steadier, and more constant than that obtained by any previous method. Successful experiments with M. Jablochkoff's invention both in France and England have shewn it to be readily applicable to many purposes. It was lately tried at the West India Docks, London, where its power of illuminating large areas for the purpose (among others) of unloading ships by night, was fully demonstrated. Moreover, its portability is such that it can be carried into the depths of a ship's hold. We may mention as a result of these experiments, that the various gas companies' shares have been depreciated to a considerable extent.

Meanwhile, improvements in the magneto-electric machine have not been wanting; Siemens[10] in England and Gramme[11] in France have succeeded in obtaining intense currents from machines far less bulky than those of the old pattern. But still steam-power is required to set them in motion, and until this is obviated, we cannot expect that the electric light can become really available for more general use. The inventors claim that their method of illumination is, for the amount of light obtained, far cheaper than any other known, pleading that one burner is equal to one hundred gas-lights. But we must remember that for ordinary purposes this amount of light is far beyond our needs. In factories where steam-power is already available, and where the light would supersede a large number of gas-burners, it can of course be employed with profit. Indeed we learn that at several large workshops in different parts of France the light is in actual use with the best results. Some of the railway stations both there and in Belgium are also making arrangements for its immediate adoption.

The problem, however, which has now to be solved is, whether the light can be made available for domestic purposes. We fear that the necessary motive-power presents an insuperable objection; for although, as we have explained, one engine will feed a certain number of lights, it will bear no comparison in this respect with the capabilities of a small gas-holder. Besides which, a man would have far more difficulty and expense in starting a steam-engine in his back-garden than he would have (as is commonly done in country districts) in founding a small gas-factory for the supply of his premises. Without losing sight of the benefits which coal-gas has given us, we may hope that it is not the last and best kind of artificial illumination open to us. It blackens our ceilings and walls; it spoils our books and pictures, besides robbing our dwellings of oxygen, and giving us instead a close and unhealthy atmosphere. The combustion of electricity is on the other hand, as we have already shewn, *independent of any supply of air*; and instead of vitiating the atmosphere, it adds to it a supply of that sea-side luxury ozone, which may truly be said to be 'recommended by the faculty.'[12] Besides these advantages, it can be used without any sensible rise of temperature. Another great advantage which its use secures is its actinic[13] qualities, which would enable artists and all whose work depends upon a correct appreciation of colours, to be independent of daylight.

In conclusion, we may say that, beyond the special uses for the electric light which we have enumerated, and for which it has by experience been found practicable, we see no likelihood of its more general adoption until two requisites are discovered. The one is a substance that will, without wasting away and requiring constant renewal, act as an incandescent burner; and the / other is a cheap and ready method of obtaining the electric fluid. For the former we know not where to look, for even the hardest diamond disappears under contact with the electric poles. But with regard to the latter, we cannot help thinking how, many years ago, Franklin[14] succeeded by the aid of a kite-string in drawing electricity from the clouds. Is it too much to hope that other philosophers may discover some means not only of obtaining the luminous fluid from the same source, but of storing it up for the benefit of all?

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Macadam, *The Sanitary Aspects of Cooking and Heating by Coal Gas*

1. *Stevenson Macadam*: Dr Stevenson Macadam (*c.* 1830–1901) was the author of a successful textbook, *Practical Chemistry* (London and Edinburgh: William and Robert Chambers, 1865), with further editions in 1866, 1867, 1869, 1871 and 1883 and of a school textbook, *The Chemistry of Common Things* (London, Edinburgh and New York: T. Nelson and Sons, 1866). He declared himself to be a lecturer at the Medical School, Surgeon's Hall and at the School of Arts in Edinburgh, a Fellow of the Royal Society of Edinburgh and a Fellow of the Chemical Society in these publications; in this, later, publication he also refers to himself as a Consulting Analytical Chemist and a Fellow of the Institute of Chemistry.
2. *the Exhibition*: The Glasgow Gas Exhibition, opened on 28 September 1880.
3. *Kitchener*: 'A cooking-range fitted with various appliances such as ovens, plate-warmers, water-heaters, etc.' (*OED*, which gives the first usage in this sense as 1851).
4. *the Bunsen principle*: Robert Wilhelm Eberhard Bunsen (1811–99), professor of chemistry at Marburg, Breslau and finally, from 1852, Heidelberg universities. Invented the magnesium light, widely used in photography, in 1860. With Gustav Kirchhoff (1824–87) pioneered the study of the emission spectra of heated elements. The Bunsen burner uses the principle of a blowpipe, mixing large quantities of air with the gas before ignition to produce a smokeless flame of low luminosity but high heating power.
5. *340° Fahr.*: 340° Fahrenheit, or about 170° Celsius or gas mark 4, a 'moderate' or 'medium' oven.
6. *400°... 500°*: 400° F. is about 200° Celsius or gas mark 6, a 'moderately hot' oven; 500° F. is about 260° Celsius and is off the temperature scale of modern ovens which goes up to 475° F. or 246° Celsius, gas mark 9 ('very hot').
7. *an ordinary middle-class household*: The 1881 *Census of Scotland* shows Macadam's household (himself, his wife and three teenage or adult children) to have been attended by three live-in servants, a relatively large number for a household of this size and composition. It seems likely that his assumptions of what an 'ordinary' middle-class household was like were coloured by his own comfortable circumstances.
8. *brander*: A gridiron (*OED*) presumably so-called because it imparts marks like the branding marks on livestock to meat cooked upon it.
9. *carbonic acid ... oily hydrocarbons*: Carbonic acid is carbon dioxide, $CO2$. Sulphurous acid has the molecular formula $H2SO3$. Carbonic oxide is carbon monoxide, CO. Acetylene is the explosive producer of bright light, first produced on a commercial scale in 1895, with molecular formula $C2H2$.
10. *268 grains ... 821 grains*: There are 7,000 grains (gr) in 1 lb avoirdupois. A grain is now defined as exactly 64.79891 mg in the International System of Units. So 268 gr is about 0.6 of an ounce or about 17 g; 821 gr is about 1.9 oz or about 53 g.
11. *osmazome*: 'A name formerly given to that substance or mixture of substances soluble in water and alcohol which gives meat its flavour and smell; (more generally) meat juice or extract' (*OED*).
12. *cannel gas*: Gas obtained from cannel coal. See note 3 to *Practical Economy*, above.

'Electricity and the Electric Telegraph', *Cornhill Magazine*

1. *Leyden* jars: Devices that appear to store static electricity.

2. *approximation*: The action of bringing close; literally, as here, as well as figuratively (*OED*).
3. *An Expeditious Method for Conveying Intelligence*: C. M., 'To the Author of the Scots Magazine', *Scots Magazine* 15 (February 1753), pp. 73–4. For 'C. M.,' see the text, below.
4. *excited glass tube*: A Leyden jar.
5. *'lichtnin'*: lightning.
6. Anglice: Latin: 'in English'.
7. *Reid and Smith, Hume and Robertson*: Thomas Reid (1710–96), natural and moral philosopher; the author of an *Inquiry into the Human Mind, on the Principles of Common Sense* (Dublin: Printed for Alexander Ewing, 1764) which contested the theory of ideas propagated by Descartes, Locke, and Malebranche. Adam Smith (bapt. 1723 d. 1790), the philosopher and political economist. David Hume (1711–76), the philosopher and historian. William Robertson (1721–93), a Scottish historian now largely forgotten but in his time thought to be the equal of Hume and Gibbon (*ODNB*).
8. *a Frenchman, resident in Geneva*: Georges-Louis Le Sage (1724–1803), a physicist and mathematician, was born and died in Geneva and is sometimes accounted a Swiss; his parents were French. He is now mainly remembered for his theory of gravitation.
9. rifacimento: Italian; a reworking.
10. *at any distance*: Arthur Young, *Travels, During the Years 1787, 1788, and 1789. Undertaken More Particularly with a View of Ascertaining the Cultivation, Wealth, Resources, and National Prosperity, of the Kingdom of France* (Bury St Edmund's: printed by J. Rackham; for W. Richardson, Royal-Exchange, London, 1792), p. 65. A fuller quotation seems worthwhile. Young is in Paris and writes:

    > In the evening to Mons. Lomond, a very ingenious and inventive mechanic, who has made an improvement of the jenny for spinning cotton. Common machines are said to make too hard a thread for certain fabrics, but this forms is loose and spongy. In electricity he has made a remarkable discovery: you write two or three words on a paper; he takes it with him into a room, and turns a machine inclosed in a cylindrical case, at the top of which is an electrometer, a small fine pith ball; a wire connects with a similar cylinder and electrometer in a distant apartment; and his wife, by remarking the corresponding motions of the ball, writes down the words they indicate: from which it appears that he has formed an alphabet of motions. As the length of the wire makes no difference in the effect, a correspondence might be carried on at any distance: within and without a besieged town, for instance; or for a purpose much more worthy, and a thousand times more harmless, between two lovers prohibited or prevented from any better connection. Whatever the use may be, the invention is beautiful. Mons. Lomond has many other curious machines, all the entire work of his own hands: mechanical invention seems in him a natural propensity. In the evening to the *Comedie Française*.

11. *Cavallo*: Tiberius, or Tiberio, Cavallo (1749–1809) born in Naples but came to England in 1771 and stayed in England for the rest of his life. Published *A Complete Treatise on Electricity in Theory and Practice: With Original Experiments* (London: Printed for Edward and Charles Dilly, 1777); elected a Fellow of the Royal Society in 1779 (*ODNB*).
12. *Mr. Ronalds of Hammersmith*: Sir Francis Ronalds (1788–1873) inventor, meteorologist and bibliographer. In 1823 he published his *Description of an Electric Telegraph and of*

*some other Electrical Apparatus (*London: Printed for R. Hunter, 1823). As a boy Charles Wheatstone saw his experiments. Knighted 1870 (*ODNB*).

13. *Professor Wheatstone*: Sir Charles Wheatstone (1802–75). In 1834 appointed Professor of Experimental Philosophy at King's College, London, where he began experiments to determine the speed of electric currents in copper wire, obtaining a result of 288,000 miles per hour in comparison with the modern estimate of about 186,000 m.p.h. From these experiments he moved on, in conjunction with William Fothergill Cooke (1806–79), the 'Mr. Cooke' of the text, to the construction of a practical telegraph, patented by Cooke and Wheatstone jointly in 1837 (*ODNB*).
14. *'Never...dispute'*: The words were Wheatstone's and were quoted by John Munro (1849–1930) in his *Heroes of the Telegraph* (London: The Religious Tract Society, 1891).
15. *Professor Morse*: Samuel Finley Breese Morse (1791–1872), the US inventor of the single-wire telegraph and the Morse Code. He conceived the former invention in 1832, built an experimental version in 1835 and a practical system in 1844 but did not apply for a patent until 1849.
16. *Mr. Edward Davy*: Edward Davy (1806–85), chemist. He invented a telegraph system using a relay system in which the electric current was augmented by batteries at intervals along the route thus compensating for the normal attenuation of the current with distance. He published his *Outline of a New Plan of Telegraphic Communication in 1836.*
17. *Bain ... 'far north'*: Alexander Bain (1810–77) clockmaker. The son of a crofter. He invented an electric clock patented in 1841, and an experimental 'printing telegraph', patented in 1843 and now sometimes regarded as a precursor to the facsimile machine. The 'chemical telegraph' mentioned in the text's next sentence used the electric current of the telegraph message to make marks on a moving paper tape soaked in a mixture of ammonium nitrate and potassium ferrocyanide. The paper turned blue when a current passed through it. Watten, Bain's birthplace, is a village in Caithness between Wick and Thurso in the far north of Scotland (*ODNB*).
18. *fluid*: Electricity.
19. *Volta*: Count Alessandro Giuseppe Antonio Anastasio Volta (1745–1827) the Italian physicist who, in 1800, invented the electric battery.
20. *Fabroni*: or more usually Fabbroni: Giovanni Valentino Mattia Fabbroni (1752–1822) an Italian naturalist and chemist. One of the earliest to suggest that electrical phenomena had a chemical origin.
21. *Schwiegger's Multiplier ... Moigno*: the name is variously spelled as Schwieger. Schweiger and Schweigger. Moigno is the Abbé Moigno, François-Napoléon-Marie Moigno (1804–84) a French Jesuit physicist and science popularizer. He published a *Traité de Télégraphie Électrique, Renfermant son Histoire, sa Théorie et la Description des Appareils avec les Deux Mémoires de M. Wheatstone sur la Vitesse et la Détermination des Courants d'Électricité, et un Mémoire Inédit d'Ampère sur la Théorie Electro-chimique* (Paris: A. Franck, 1849).
22. A *and* B *cipher of Lord Bacon*: Francis Bacon, first Viscount Saint Albans (1561–1626), the philosopher and politician. His *A* and *B* cypher was partly a method of steganography (a method of hiding a message rather than translating it into a code). The method was in two stages. In the first stage each letter of the plaintext was transformed into a combination of five As or Bs. For example 'a' was transformed to 'AAAAA', 'b' to 'AAAAB', etc. This yields a coded text. In the second stage an innocuous text of the same length as the coded text is found or composed. Each letter of the innocuous text is then transformed one way if it corresponds to an 'A' in the coded text, another way if it corresponds to a 'B';

for example, the transformation might be into upper case for 'A' and lower case for 'B', or Arial font for 'A' and Times New Roman for 'B', etc.

23. *Sir Humphry Davy*: Sir Humphry Davy (1778–1829), the chemist and inventor of the miner's safety lamp. See Volume 2 (pp. 357–9).
24. *Ritter*: Johann Wilhelm Ritter (1776–1810), a German scientist particularly interested in Galvanism.
25. *gutta percha*: Gutta-percha is rubber. It was distinguished by the Victorians from caoutchouc, also known as India-rubber, derived from the south American *Hevea brasiliensis* and other trees. 'Caoutchouc' is thought to derive from a Carib word, 'Cahuchu'. 'Gutta-percha' was derived from trees of the order *Sapotaceæ* native to south-east Asia; the name is Malay in origin.
26. *Hottentot in his kraal*: 'Hottentot' is now regarded as a derogatory term, the people once referred to as such being the Khoikhoi, or Khoi, sometimes spelled Khoekhoe, of south west Africa. A 'kraal' is a village.

'Electricity as a Light-Producer', *Chambers Journal*

1. *Sir Humphry Davy*: Sir Humphry Davy (1778–1829), the chemist and inventor of the miner's safety lamp. See Volume 2, pp. 357–9.
2. *Faraday's discovery*: Michael Faraday (1791–1867), the scientist. The discovery noted here was made by Faraday in 1821; he termed it the phenomenon of electromagnetic rotation and it is the principle behind the electric motor. In 1831 he discovered the principle of electromagnetic induction which led to the development of the magneto which is what is described here; the dynamo, which uses electro magnets rather than the permanent magnets of the magneto, was a later development (*ODNB*).
3. *Mr Holms*: Probably Frederick Hale Holme, Holm or, more usually, Holmes (*c.* 1811–after 1881), a chemist who patented an electric arc light in 1846. Examples were installed in the South Foreland Lighthouse near Dover in 1858; one is preserved in the Science Museum, South Kensington, London. From the early 1860s he is often referred to as 'Professor Holmes' but the title did not necessarily indicate a university appointment at this time and no academic appointment has been traced.
4. *Mr Wilde of Manchester*: Not identified. His machine caused a sensation at the Royal Society Soirée in 1863 one reporter writing

> Justice to this memorable *soirée* we must fail to do; for although we had hoped to have fortified ourselves for our evening duties by an attendance at Mr. Wilde's trial experiments during the day the fascinations of the marvelous flood of light that poured away from the machine so unceasingly and so gloriously was as irresistible in its influence upon ourselves as it was upon the crowd of illustrious men who honoured the president, General Sabine, with their presence. Never have we seen such excitement among men naturally so stately and reserved.
>
> 'The Royal Society Soirée', *The Standard* [London], 4 March 1867, p. 6.

He was also mentioned in a letter to the *Pall Mall Gazette* in 1866 by John Tyndall of the Royal Institution: 'Mr. Wilde, of Manchester, has recently devised an electro-magnetic machine of far greater power than either that of Mr. Holmes or that of M. Berlioz [of Paris]. I have witnessed the splendid performance of Mr. Wilde's machine, which, if it stand the test of continuous working, will supersede all others' (*Pall Mall Gazette*, 21 December 1866).

5. *lime light*: Current usage is almost entirely metaphorical. This, the literal meaning, refers to 'light produced by a blowpipe-flame directed against a block of pure, compressed quicklime. The lime … becomes brilliantly incandescent.' The candle-power of the light depended on the flame and its fuel. Combinations of oxygen, coal-gas, benzoline and hydrogen were used, often under pressure. The most powerful in use by the end of the nineteenth century used warm oxygen saturated with benzoline giving a light of up to 1,350 candles (*Chambers Encyclopædia*, s.v. Lime-light).
6. *gutta-percha-covered wires*: See note 26 to 'Electricity and the Electric Telegraph', above.
7. *thick glass globe hermetically closed*: The author here clearly anticipates the invention of the incandescent lightbulb usually credited to Joseph Swan and Thomas Edison and patented in 1879–80. However, the idea had occurred to many and had been demonstrated by James Bowman Lindsay in 1835, Warren de la Rue in 1840 and a number of others subsequently.
8. *the present war*: The Russo–Turkish War of 1877–8.
9. *M. Jablochkoff*: Pavel Nikolayevich Yablochkov (1847–94). His 'electric candle' or 'Yablochkov candle', was a form of arc lamp. Yablochkov developed a lighting system complete with dynamos in Paris. In October 1877, the same month the present text was published, the system was used for the first time, to illuminate the Halle Marengo of the Magasins du Louvre in Paris.
10. *Siemens*: Sir (Charles) William Siemens (1823–83), the renowned electrical engineer and metallurgist. His elder brother, Werner, who co-founded the firm Siemens and Halske in Berlin in 1847 had invented a way of insulating telegraph wires with gutta-percha, making the submarine telegraph possible. William invented a 'self-exciting' electric dynamo in which the current for the electromagnets was generated by the dynamo itself, this dispensing with the necessity for permanent magnets. A naturalized British subject from 1859; knighted 1883 (*ODNB*).
11. *Gramme*: Zénobe Théophile Gramme (1826–1901) was a Belgian electrical engineer who invented the 'Gramme machine', a dynamo capable of generating significantly higher voltages than those previously possible. It was the first electrical motor to be successful industrially.
12. *'recommended by the faculty'*: That is the faculty of medicine; doctors.
13. *actinic*: Used of light to mean having the power to cause chemical changes (*OED*); possibly misused here to mean an absence of effect in perception on the colour of objects.
14. *Franklin*: Benjamin Franklin. See note 11 to 'On Warming and Ventilating'. He proposed this, his most famous, experiment in 1750 and he may or may not have carried it out in 1752. It was designed to show that lightning and electricity were identical. It led directly to the invention of lightning conductors to protect buildings from lightning strikes.

'The Prime Minister on Electricity', *Saturday Review*

1. *Mr. Gladstone … very clearly*: The author is alluding to Gladstone's writings on Homer (*Studies on Homer and the Homeric Age*, 3 vols (Oxford: Oxford University Press, 1858)), formerly largely ignored by his biographers but treated seriously by both Richard Shannon, in *Gladstone*, 2 vols (1982: London: Allen Lane, 1999) and H. C. G. Matthew in *Gladstone*, 2 vols (Oxford: Clarendon Press, 1986 and 1995). It is fully considered by David W. Bebbington, *The Mind of Gladstone: Religion, Homer, and Politics* (Oxford: Oxford University Press, 2004).